

Intel[®] G31 / P31 Express Chipset

Datasheet

— *For the Intel[®] 82G31 Graphics and Memory Controller Hub (GMCH) and the Intel[®] 82P31 Memory Controller Hub (MCH)*

July 2007



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Contents

1	Introduction	15
1.1	Terminology	18
1.2	Reference Documents	20
1.3	(G)MCH Overview.....	21
1.3.1	Host Interface.....	21
1.3.2	System Memory Interface.....	22
1.3.3	Direct Media Interface (DMI).....	23
1.3.4	PCI Express* Interface.....	23
1.3.5	Graphics Features (Intel® 82G31 GMCH Only)	24
1.3.6	SDVO and Analog Display Features (Intel® 82G31 GMCH Only)	24
1.3.7	(G)MCH Clocking.....	25
1.3.8	Power Management	26
1.3.9	Thermal Sensor	26
2	Signal Description	27
2.1	Host Interface Signals.....	28
2.2	System Memory (DDR2) Interface Signals.....	31
2.2.1	System Memory Channel A Interface Signals.....	31
2.2.2	System Memory Channel B Interface Signals.....	32
2.2.3	DDR2 DRAM Reference and Compensation Signals	33
2.3	PCI Express* Interface Signals	33
2.4	Analog Display Signals (Intel® 82G31 GMCH Only)	34
2.5	Clocks, Reset, and Miscellaneous	35
2.6	Direct Media Interface.....	36
2.7	Serial DVO Interface (Intel® 82G31 GMCH Only)	36
2.7.1	SDVO/PCI Express* Signal Mapping	38
2.8	Power and Ground.....	39
3	System Address Map	41
3.1	Legacy Address Range	44
3.1.1	DOS Range (0h – 9_FFFFh).....	45
3.1.2	Legacy Video Area (A_0000h-B_FFFFh)	45
3.1.3	Expansion Area (C_0000h-D_FFFFh)	46
3.1.4	Extended System BIOS Area (E_0000h-E_FFFFh).....	47
3.1.5	System BIOS Area (F_0000h-F_FFFFh)	47
3.1.6	PAM Memory Area Details.....	47
3.2	Main Memory Address Range (1MB – TOLUD)	48
3.2.1	ISA Hole (15 MB-16 MB)	49
3.2.2	TSEG.....	49
3.2.3	Pre-allocated Memory	49
3.3	PCI Memory Address Range (TOLUD – 4 GB)	50
3.3.1	APIC Configuration Space (FEC0_0000h–FECF_FFFFh)	51
3.3.2	HSEG (FEDA_0000h–FEDB_FFFFh).....	52
3.3.3	FSB Interrupt Memory Space (FEE0_0000–FEEF_FFFF)	52
3.3.4	High BIOS Area.....	52



3.4	Main Memory Address Space (4 GB to TOUUD)	52
3.4.1	Memory Re-claim Background	53
3.4.2	Memory Reclaiming	53
3.5	PCI Express* Configuration Address Space.....	53
3.6	PCI Express* Graphics Attach (PEG).....	54
3.7	Graphics Memory Address Ranges (Intel® 82G31 GMCH Only)	55
3.8	System Management Mode (SMM)	55
3.8.1	SMM Space Definition	56
3.8.2	SMM Space Restrictions.....	56
3.8.3	SMM Space Combinations.....	57
3.8.4	SMM Control Combinations	57
3.8.5	SMM Space Decode and Transaction Handling.....	57
3.8.6	Processor WB Transaction to an Enabled SMM Address Space	57
3.8.7	SMM Access Through GTT TLB (Intel® 82G31 GMCH Only)	58
3.9	Memory Shadowing	58
3.10	I/O Address Space.....	59
3.10.1	PCI Express* I/O Address Mapping	59
3.11	(G)MCH Decode Rules and Cross-Bridge Address Mapping	60
3.11.1	Legacy VGA and I/O Range Decode Rules	60
4	(G)MCH Register Description	61
4.1	Register Terminology	62
4.2	Configuration Process and Registers.....	64
4.2.1	Platform Configuration Structure	64
4.3	Configuration Mechanisms	65
4.3.1	Standard PCI Configuration Mechanism	65
4.3.2	PCI Express* Enhanced Configuration Mechanism	65
4.4	Routing Configuration Accesses	67
4.4.1	Internal Device Configuration Accesses.....	68
4.4.2	Bridge Related Configuration Accesses.....	68
4.5	I/O Mapped Registers	69
4.5.1	CONFIG_ADDRESS—Configuration Address Register	69
4.5.2	CONFIG_DATA—Configuration Data Register	71
5	DRAM Controller Registers (D0:F0).....	73
5.1	DRAM Controller (D0:F0).....	73
5.1.1	VID—Vendor Identification.....	75
5.1.2	DID—Device Identification	75
5.1.3	PCICMD—PCI Command	76
5.1.4	PCISTS—PCI Status.....	77
5.1.5	RID—Revision Identification	78
5.1.6	CC—Class Code.....	79
5.1.7	MLT—Master Latency Timer	79
5.1.8	HDR—Header Type	80
5.1.9	SVID—Subsystem Vendor Identification.....	80
5.1.10	SID—Subsystem Identification	80
5.1.11	CAPPTR—Capabilities Pointer	81
5.1.12	PXPEPBAR—PCI Express* Egress Port Base Address	81
5.1.13	MCHBAR—(G)MCH Memory Mapped Register Range Base	82
5.1.14	GGC—GMCH Graphics Control Register (Intel® 82G31 GMCH Only)	82
5.1.15	DEVEN—Device Enable.....	84
5.1.16	PCIEXBAR—PCI Express* Register Range Base Address	86
5.1.17	DMIBAR—Root Complex Register Range Base Address	88



5.1.18	PAM0—Programmable Attribute Map 0.....	89
5.1.19	PAM1—Programmable Attribute Map 1.....	91
5.1.20	PAM2—Programmable Attribute Map 2.....	92
5.1.21	PAM3—Programmable Attribute Map 3.....	93
5.1.22	PAM4—Programmable Attribute Map 4.....	94
5.1.23	PAM5—Programmable Attribute Map 5.....	95
5.1.24	PAM6—Programmable Attribute Map 6.....	96
5.1.25	LAC—Legacy Access Control.....	97
5.1.26	REMAPBASE—Remap Base Address Register.....	98
5.1.27	REMAPLIMIT—Remap Limit Address Register.....	98
5.1.28	SMRAM—System Management RAM Control.....	99
5.1.29	ESMRAMC—Extended System Management RAM Control.....	100
5.1.30	TOM—Top of Memory.....	101
5.1.31	TOUUD—Top of Upper Usable Dram.....	102
5.1.32	GBSM—Graphics Base of Stolen Memory.....	103
5.1.33	BGSM—Base of GTT stolen Memory.....	104
5.1.34	TSEGMB—TSEG Memory Base.....	104
5.1.35	TOLUD—Top of Low Usable DRAM.....	105
5.1.36	ERRSTS—Error Status.....	106
5.1.37	ERRCMD—Error Command.....	108
5.1.38	SMICMD—SMI Command.....	109
5.1.39	SKPD—Scratchpad Data.....	109
5.1.40	CAPID0—Capability Identifier.....	110
5.2	MCHBAR.....	114
5.2.1	CHDECMISC—Channel Decode Miscellaneous.....	116
5.2.2	C0DRB0—Channel 0 DRAM Rank Boundary Address 0.....	117
5.2.3	C0CYCTRKPCHG—Channel 0 CYCTRK PCHG.....	118
5.2.4	C0CYCTRKACT—Channel 0 CYCTRK ACT.....	119
5.2.5	C0CYCTRKWR—Channel 0 CYCTRK WR.....	120
5.2.6	C0CYCTRKRD—Channel 0 CYCTRK READ.....	121
5.2.7	C0CYCTRKREFR—Channel 0 CYCTRK REFR.....	121
5.2.8	C0CKECTRL—Channel 0 CKE Control.....	122
5.2.9	C0REFRCTRL—Channel 0 DRAM Refresh Control.....	123
5.2.10	C0ODTCTRL—Channel 0 ODT Control.....	124
5.2.11	C1DRB0—Channel 1 DRAM Rank Boundary Address 0.....	125
5.2.12	C1DRB1—Channel 1 DRAM Rank Boundary Address 1.....	125
5.2.13	C1DRB2—Channel 1 DRAM Rank Boundary Address 2.....	126
5.2.14	C1DRB3—Channel 1 DRAM Rank Boundary Address 3.....	126
5.2.15	C1DRA01—Channel 1 DRAM Rank 0,1 Attributes.....	127
5.2.16	C1DRA23—Channel 1 DRAM Rank 2,3 Attributes.....	127
5.2.17	C1CYCTRKPCHG—Channel 1 CYCTRK PCHG.....	128
5.2.18	C1CYCTRKACT—Channel 1 CYCTRK ACT.....	129
5.2.19	C1CYCTRKWR—Channel 1 CYCTRK WR.....	130
5.2.20	C1CYCTRKRD—Channel 1 CYCTRK READ.....	131
5.2.21	C1CKECTRL—Channel 1 CKE Control.....	132
5.2.22	C1REFRCTRL—Channel 1 DRAM Refresh Control.....	133
5.2.23	C1ODTCTRL—Channel 1 ODT Control.....	135
5.2.24	EPC0DRB1—EP Channel 0 DRAM Rank Boundary Address 1.....	136
5.2.25	EPC0DRB2—EP Channel 0 DRAM Rank Boundary Address 2.....	136
5.2.26	EPC0DRB3—EP Channel 0 DRAM Rank Boundary Address 3.....	136
5.2.27	EPC0DRA01—EP Channel 0 DRAM Rank 0,1 Attribute.....	137
5.2.28	EPC0DRA23—EP Channel 0 DRAM Rank 2,3 Attribute.....	137
5.2.29	EPDCYCTRKWRTPRE—EPD CYCTRK WRT PRE.....	138
5.2.30	EPDCYCTRKWRTACT—EPD CYCTRK WRT ACT.....	138
5.2.31	EPDCYCTRKWRTWR—EPD CYCTRK WRT WR.....	139



5.2.32	EPDCYCTRKWTRD—EPD CYCTRK WRT READ	140
5.2.33	EPDCKECONFIGREG—EPD CKE Related Configuration Register	141
5.2.34	EPDREFCONFIG—EP DRAM Refresh Configuration	143
5.2.35	TSC1—Thermal Sensor Control 1	145
5.2.36	TSC2—Thermal Sensor Control 2	146
5.2.37	TSS—Thermal Sensor Status	148
5.2.38	TSTTP—Thermal Sensor Temperature Trip Point	149
5.2.39	TCO—Thermal Calibration Offset	150
5.2.40	THERM1—Hardware Throttle Control	151
5.2.41	TIS—Thermal Interrupt Status	152
5.2.42	TSMICMD—Thermal SMI Command	154
5.2.43	PMSTS—Power Management Status	155
5.3	EPBAR	156
5.3.1	EPESD—EP Element Self Description	156
5.3.2	EPLE1D—EP Link Entry 1 Description	157
5.3.3	EPLE1A—EP Link Entry 1 Address	157
5.3.4	EPLE2D—EP Link Entry 2 Description	158
5.3.5	EPLE2A—EP Link Entry 2 Address	159
6	PCI Express* Registers (D1:F0)	161
6.1	PCI Express* Configuration Register Details (D1:F0)	164
6.1.1	VID1—Vendor Identification	164
6.1.2	DID1—Device Identification	164
6.1.3	PCICMD1—PCI Command	165
6.1.4	PCISTS1—PCI Status	167
6.1.5	RID1—Revision Identification	168
6.1.6	CC1—Class Code	168
6.1.7	CL1—Cache Line Size	169
6.1.8	HDR1—Header Type	169
6.1.9	PBUSN1—Primary Bus Number	169
6.1.10	SBUSN1—Secondary Bus Number	170
6.1.11	SUBUSN1—Subordinate Bus Number	170
6.1.12	IOBASE1—I/O Base Address	171
6.1.13	IOLIMIT1—I/O Limit Address	171
6.1.14	SSTS1—Secondary Status	172
6.1.15	MBASE1—Memory Base Address	173
6.1.16	MLIMIT1—Memory Limit Address	174
6.1.17	PMBASE1—Prefetchable Memory Base Address	175
6.1.18	PMLIMIT1—Prefetchable Memory Limit Address	176
6.1.19	PMBASEU1—Prefetchable Memory Base Address	177
6.1.20	PMLIMITU1—Prefetchable Memory Limit Address	178
6.1.21	CAPPTR1—Capabilities Pointer	179
6.1.22	INTRLINE1—Interrupt Line	179
6.1.23	INTRPIN1—Interrupt Pin	179
6.1.24	BCTRL1—Bridge Control	180
6.1.25	PM_CAPID1—Power Management Capabilities	182
6.1.26	PM_CS1—Power Management Control/Status	183
6.1.27	SS_CAPID—Subsystem ID and Vendor ID Capabilities	184
6.1.28	SS—Subsystem ID and Subsystem Vendor ID	184
6.1.29	MSI_CAPID—Message Signaled Interrupts Capability ID	185
6.1.30	MC—Message Control	185
6.1.31	MA—Message Address	186
6.1.32	MD—Message Data	186
6.1.33	PEG_CAPL—PCI Express*-G Capability List	187
6.1.34	PEG_CAP—PCI Express*-G Capabilities	187



6.1.35	DCAP—Device Capabilities	188
6.1.36	DCTL—Device Control	189
6.1.37	DSTS—Device Status	190
6.1.38	LCAP—Link Capabilities	191
6.1.39	LCTL—Link Control	193
6.1.40	LSTS—Link Status	195
6.1.41	SLOTCAP—Slot Capabilities	196
6.1.42	SLOTCTL—Slot Control	197
6.1.43	SLOTSTS—Slot Status	200
6.1.44	RCTL—Root Control	201
6.1.45	RSTS—Root Status	202
6.1.46	PEGLC—PCI Express*-G Legacy Control	203
6.1.47	VCECH—Virtual Channel Enhanced Capability Header	204
6.1.48	PVCCAP1—Port VC Capability Register 1	204
6.1.49	PVCCAP2—Port VC Capability Register 2	205
6.1.50	PVCCCTL—Port VC Control	205
6.1.51	VC0RCAP—VC0 Resource Capability	206
6.1.52	VC0RCTL—VC0 Resource Control	207
6.1.53	VC0RSTS—VC0 Resource Status	208
6.1.54	RCLDECH—Root Complex Link Declaration Enhanced	209
6.1.55	ESD—Element Self Description	209
6.1.56	LE1D—Link Entry 1 Description	210
6.1.57	LE1A—Link Entry 1 Address	210
6.1.58	PEGSSTS—PCI Express*-G Sequence Status	211
7	Direct Memory Interface (DMI) Registers	213
7.1	Direct Memory Interface (DMI) Configuration Register Details	214
7.1.1	DMIVCECH—DMI Virtual Channel Enhanced Capability	214
7.1.2	DMIPVCCAP1—DMI Port VC Capability Register 1	215
7.1.3	DMIPVCCAP2—DMI Port VC Capability Register 2	215
7.1.4	DMIPVCCTL—DMI Port VC Control	216
7.1.5	DMIVC0RCAP—DMI VC0 Resource Capability	216
7.1.6	DMIVC0RCTL0—DMI VC0 Resource Control	217
7.1.7	DMIVC0RSTS—DMI VC0 Resource Status	218
7.1.8	DMIVC1RCAP—DMI VC1 Resource Capability	218
7.1.9	DMIVC1RCTL1—DMI VC1 Resource Control	219
7.1.10	DMIVC1RSTS—DMI VC1 Resource Status	220
7.1.11	DMILCAP—DMI Link Capabilities	220
7.1.12	DMILCTL—DMI Link Control	221
7.1.13	DMILSTS—DMI Link Status	222
8	Integrated Graphics Registers (D2:F0,F1) (Intel® 82G31 GMCH Only)	223
8.1	Integrated Graphics Register Details (D2:F0)	223
8.1.1	VID2—Vendor Identification	224
8.1.2	DID—Device Identification	225
8.1.3	PCICMD2—PCI Command	225
8.1.4	PCISTS2—PCI Status	227
8.1.5	RID2—Revision Identification	228
8.1.6	CC—Class Code	228
8.1.7	CLS—Cache Line Size	229
8.1.8	MLT2—Master Latency Timer	229
8.1.9	HDR2—Header Type	230
8.1.10	GMADR—Graphics Memory Range Address	230
8.1.11	IOBAR—I/O Base Address	231
8.1.12	SVID2—Subsystem Vendor Identification	231



8.1.13	SID2—Subsystem Identification	232
8.1.14	ROMADR—Video BIOS ROM Base Address	232
8.1.15	CAPPOINT—Capabilities Pointer	233
8.1.16	INTRLINE—Interrupt Line	233
8.1.17	INTRPIN—Interrupt Pin	233
8.1.18	MINGNT—Minimum Grant	234
8.1.19	MAXLAT—Maximum Latency	234
8.1.20	CAPID0—Capability Identifier	235
8.1.21	MGGC—GMCH Graphics Control Register	236
8.1.22	DEVEN—Device Enable	238
8.1.23	SSRW—Software Scratch Read Write	239
8.1.24	BSM—Base of Stolen Memory	239
8.1.25	HSRW—Hardware Scratch Read Write	239
8.1.26	MC—Message Control	240
8.1.27	MA—Message Address	241
8.1.28	MD—Message Data	241
8.1.29	GDRST—Graphics Debug Reset	242
8.1.30	PMCAPID—Power Management Capabilities ID	243
8.1.31	PMCAP—Power Management Capabilities	243
8.1.32	PMCS—Power Management Control/Status	244
8.1.33	SWSMI—Software SMI	245
8.2	IGD Configuration Register Details (D2:F1)	246
8.2.1	VID2—Vendor Identification	248
8.2.2	DID2—Device Identification	248
8.2.3	PCICMD2—PCI Command	249
8.2.4	PCISTS2—PCI Status	250
8.2.5	RID2—Revision Identification	251
8.2.6	CC—Class Code Register	251
8.2.7	CLS—Cache Line Size	252
8.2.8	MLT2—Master Latency Timer	252
8.2.9	HDR2—Header Type	253
8.2.10	MMADR—Memory Mapped Range Address	253
8.2.11	SVID2—Subsystem Vendor Identification	254
8.2.12	SID2—Subsystem Identification	254
8.2.13	ROMADR—Video BIOS ROM Base Address	255
8.2.14	CAPPOINT—Capabilities Pointer	255
8.2.15	MINGNT—Minimum Grant	256
8.2.16	MAXLAT—Maximum Latency	256
8.2.17	CAPID0—Mirror of Dev0 Capability Identifier	256
8.2.18	MGGC—Mirror of Dev 0 GMCH Graphics Control Register	257
8.2.19	DEVEN—Device Enable	259
8.2.20	SSRW—Mirror of Fun 0 Software Scratch Read Write	260
8.2.21	BSM—Mirror of Func0 Base of Stolen Memory	260
8.2.22	HSRW—Mirror of Dev2 Func0 Hardware Scratch Read Write	261
8.2.23	GDRST—Mirror of Dev2 Func0 Graphics Reset	261
8.2.24	PMCAPID—Mirror of Fun 0 Power Management Capabilities ID	262
8.2.25	PMCAP—Mirror of Fun 0 Power Management Capabilities	263
8.2.26	PMCS—Power Management Control/Status	264
8.2.27	SWSMI—Mirror of Func0 Software SMI	265
9	Functional Description	267
9.1	Host Interface	267
9.1.1	FSB IOQ Depth	267
9.1.2	FSB OOQ Depth	267
9.1.3	FSB GTL+ Termination	267



	9.1.4	FSB Dynamic Bus Inversion	267
	9.1.5	APIC Cluster Mode Support	268
9.2		System Memory Controller.....	268
	9.2.1	System Memory Organization Modes	268
	9.2.2	System Memory Technology Supported	270
9.3		PCI Express*	271
	9.3.1	Intel® Serial Digital Video Output (sDVO) (Intel® 82G31 GMCH Only)	272
9.4		Integrated Graphics Controller (Intel® 82G31 GMCH Only)	276
	9.4.1	3D Graphics Pipeline	276
9.5		Display Interfaces (Intel® 82G31 GMCH Only)	278
	9.5.1	Analog Display Port Characteristics	279
	9.5.2	Digital Display Interface	280
	9.5.3	Multiple Display Configurations.....	283
9.6		Power Management	283
9.7		Thermal Sensor.....	284
	9.7.1	PCI Device 0, Function 0	284
	9.7.2	MCHBAR Thermal Sensor Registers	284
9.8		Clocking.....	285
10		Electrical Characteristics	287
	10.1	Absolute Minimum and Maximum Ratings	287
	10.1.1	Current Consumption	289
	10.2	Signal Groups	291
	10.3	Buffer Supply and DC Characteristics	294
	10.3.1	I/O Buffer Supply Voltages	294
	10.3.2	General DC Characteristics	296
	10.4	R, G, B / CRT DAC Display DC Characteristics (Intel® 82G31 GMCH Only)...	300
11		Ballout and Package Information	301
	11.1	Ballout.....	301
	11.2	Package Information.....	316
12		Testability.....	317
	12.1	XOR Test Mode Initialization	317
	12.2	XOR Chain Definition	319
	12.3	XOR Chains	320



Figures

Figure 1-1. Intel® G31 Express Chipset System Block Diagram Example	16
Figure 1-2. Intel® P31 Express Chipset System Block Diagram Example	17
Figure 3-1. System Address Ranges.....	43
Figure 3-2. DOS Legacy Address Range.....	44
Figure 3-3. Main Memory Address Range.....	48
Figure 3-4. PCI Memory Address Range.....	51
Figure 4-1. Memory Map to PCI Express* Device Configuration Space.....	66
Figure 4-2. GMCH Configuration Cycle Flow Chart.....	67
Figure 9-1. sDVO Conceptual Block Diagram	273
Figure 9-2. Concurrent sDVO / PCI Express* Non-Reversed Configurations.....	275
Figure 9-3. Concurrent sDVO / PCI Express* Reversed Configurations	275
Figure 9-4. Integrated 3D Graphics Pipeline	277
Figure 9-5. Intel® G31/P31 Express Chipset System Clock Diagram	286
Figure 11-1. (G)MCH Ballout Diagram (Top View Left – Columns 43–30)	302
Figure 11-2. (G)MCH Ballout Diagram (Top View Middle – Columns 29–15)	303
Figure 11-3. (G)MCH Ballout Diagram (Top View Right – Columns 14–0).....	304
Figure 11-6. (G)MCH Package Drawing.....	316
Figure 12-1. XOR Test Mode Initialization Cycles	317



Tables

Table 3-1. Expansion Area Memory Segments	46
Table 3-2. Extended System BIOS Area Memory Segments	47
Table 3-3. System BIOS Area Memory Segments.....	47
Table 3-4. Pre-allocated Memory Example for 64 MB DRAM, 1 MB VGA, 1 MB GTT stolen and 1 MB TSEG	49
Table 3-5. Pre-Allocated Memory Example for 64-MB DRAM, 1-MB VGA and 1-MB TSEG.....	56
Table 3-6. SMM Space Table.....	57
Table 5-1. DRAM Controller Register Address Map (D0:F0).....	73
Table 5-2. MCHBAR Register Address Map	114
Table 5-3. EPBAR Register Address Map	156
Table 6-1. PCI Express* Register Address Map (Device 1, Function 0).....	161
Table 7-1. DMI Register Address Map.....	213
Table 8-1. Integrated Graphics Device Register Address Map (Device 2, Function 0)	223
Table 8-2. Integrated Graphics Device Register Address Map (D2:F1)	246
Table 9-1. Sample System Memory Dual Channel Symmetric Organization Mode with Intel® Flex Memory Mode Enabled.....	269
Table 9-2. Sample System Memory Dual Channel Asymmetric Organization Mode with Intel® Flex Memory Mode Disabled	269
Table 9-3. Supported DIMM Module Configurations	270
Table 9-4. Concurrent sDVO / PCI Express* Configuration Strap Controls.....	274
Table 10-1. Absolute Minimum and Maximum Ratings	287
Table 10-2. Current Consumption in S0	289
Table 10-4. Signal Groups.....	291
Table 10-5. I/O Buffer Supply Voltage.....	295
Table 10-6. DC Characteristics	296
Table 10-7. R, G, B / CRT DAC Display DC Characteristics: Functional Operating Range (VCCA_DAC = 3.3 V ± 5%)	300
Table 11-1. (G)MCH Ballout Sorted by Signal Name	305
Table 12-1. XOR Chain 14 functionality	318
Table 12-2. XOR Chain Outputs.....	319
Table 12-3. XOR Chain 0.....	320
Table 12-4. XOR Chain 1.....	321
Table 12-5. XOR Chain 2.....	321
Table 12-6. XOR Chain 3.....	322
Table 12-7. XOR Chain 4.....	322
Table 12-8. XOR Chain 5.....	322
Table 12-9. XOR Chain 6.....	323
Table 12-10. XOR Chain 8	324
Table 12-11. XOR Chain 9	325
Table 12-12. XOR Chain 10	325
Table 12-13. XOR Chain 12	326
Table 12-14. XOR Chain 13	326
Table 12-15. XOR Chain 14	326



Revision History

Revision Number	Description	Revision Date
-001	Initial release	July 2007

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Intel® 82G31 / 82P31 (G)MCH

Features

- Processor/Host Interface (FSB)
 - Supports Intel® Core™2 Duo desktop processors and Intel® Core™2 Quad processors
 - 800/1067 MT/s (200/266 MHz) FSB
 - Hyper-Threading Technology (HT Technology)
 - FSB Dynamic Bus Inversion (DBI)
 - 36-bit host bus addressing
 - 12-deep In-Order Queue
 - 1-deep Defer Queue
 - GTL+ bus driver with integrated GTL termination resistors
 - Supports cache Line Size of 64 bytes
- System Memory Interface
 - One or two channels (each channel consisting of 64 data lines)
 - Single or Dual Channel memory organization
 - DDR2-800/667 frequencies
 - Unbuffered, non-ECC DIMMs only
 - Supports 1-Gb, 512-Mb DDR2 technologies for x8 and x16 devices
 - 4 GB maximum memory
- Direct Media Interface (DMI)
 - Chip-to-chip connection interface to Intel ICH7
 - 2 GB/s point-to-point DMI to ICH9 (1 GB/s each direction)
 - 100 MHz reference clock (shared with PCI Express graphics attach)
 - 32-bit downstream addressing
 - Messaging and Error Handling
- PCI Express* Interface
 - One x16 PCI Express port
 - Compatible with the *PCI Express Base Specification, Revision 1.1*
 - Raw bit rate on data pins of 2.5 Gb/s resulting in a real bandwidth per pair of 250 MB/s
- Integrated Graphics Device (82G31 GMCH only)
 - Core frequency of 400 MHz
 - 1.6 GP/s pixel rate
 - High-Quality 3D Setup and Render Engine
 - High-Quality Texture Engine
 - 3D Graphics Rendering Enhancements
 - 2D Graphics
 - Video Overlay
 - Multiple Overlay Functionality
- Analog Display (82G31 GMCH only)
 - 350 MHz Integrated 24-bit RAMDAC
 - Up to 2048x1536 @ 75 Hz refresh
 - Hardware Color Cursor Support
 - DDC2B Compliant Interface
- Digital Display (82G31 GMCH only)
 - SDVO ports in single mode supported
 - 225 MHz dot clock on each 12-bit interface
 - Flat panels up to 1920x1200 @ 60 Hz or digital CRT/HDTV at 1400x1050 @ 85Hz
 - Dual independent display options with digital display
 - Multiplexed digital display channels (supported with ADD2 Card).
 - Supports TMDS transmitters or TV-Out encoders
 - ADD2/MEC card uses PCI Express graphics x16 connector
 - Two channels multiplexed with PCI Express* Graphics port
 - Supports Hot-Plug and Display
- Thermal Sensor
 - Catastrophic Trip Point support
 - Hot Trip Point support for SMI generation
- Power Management
 - PC99 suspend to DRAM support ("STR", mapped to ACPI state S3)
 - ACPI Revision 2.0 compatible power management
 - Supports processor states: C0, C1, C2
 - Supports System states: S0, S1, S3, and S5
 - Supports processor Thermal Management 2
- Package
 - FC-BGA. 34 mm × 34 mm. The 1226 balls are located in a non-grid pattern





1 Introduction

The Intel® G31/P31 Express Chipset is designed for use with Intel® Core™2 Duo desktop processor and Intel® Core™2 Quad processor based platforms. The chipsets each contain two components: GMCH (or MCH) for the host bridge and I/O Controller Hub 7 (ICH7) for the I/O subsystem. The 82G31 GMCH is part of the Intel® G31 Express Chipset. The 82P31 MCH is part of the Intel® P31 Express chipset. The ICH7 is the seventh generation I/O Controller Hub and provides a multitude of I/O related functions. Figure 1-1 and Figure 1-2 show examples system block diagrams for the Intel® G31 and P31 Express Chipsets.

This document is the datasheet for the Intel® 82G31 Graphics and Memory Controller Hub (GMCH) and Intel® 82P31 Memory Controller Hub (MCH). Topics covered include; signal description, system memory map, PCI register description, a description of the (G)MCH interfaces and major functional units, electrical characteristics, ballout definitions, and package characteristics.

The primary difference between the Intel® 82G31 GMCH and 82P31 MCH is that the 82G31 GMCH has an integrated graphics device (IGD) plus the associated display interfaces. The 82P31 does not contain an IGD and the associated interfaces.

Note: Unless otherwise specified, the information in this document applies to the Intel® 82G31 Graphics and Memory Controller Hub (GMCH) and Intel® 82P31 Memory Controller Hub (MCH).

Note: The term (G)MCH refers to the 82G31 GMCH and 82P31 MCH.

Note: Unless otherwise specified, ICH7 refers to the Intel® 82801GB ICH7, Intel® 82801GR ICH7R, and Intel® 82801GDH ICH7DH I/O Controller Hub 7 components.

Figure 1-1. Intel® G31 Express Chipset System Block Diagram Example

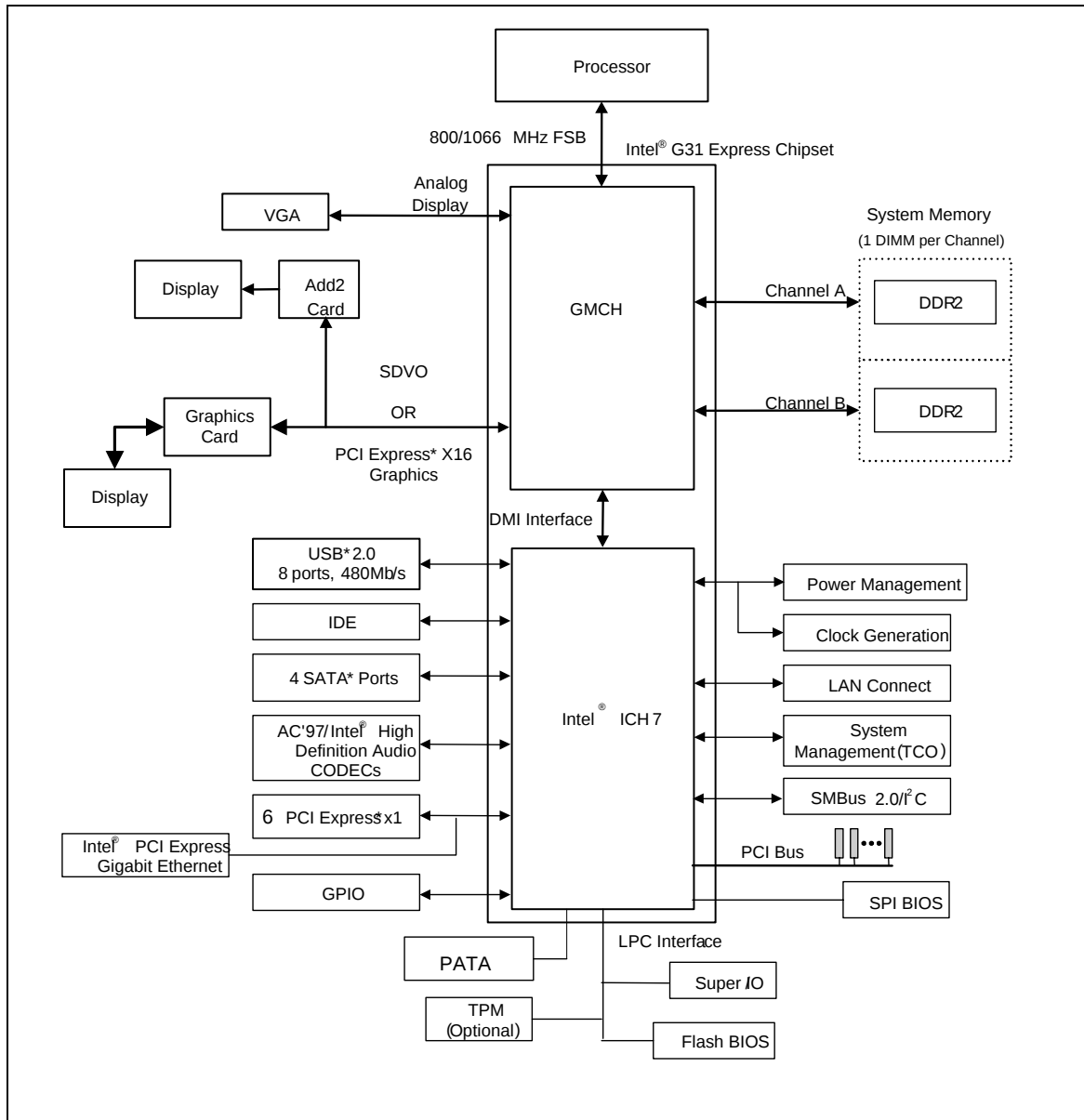
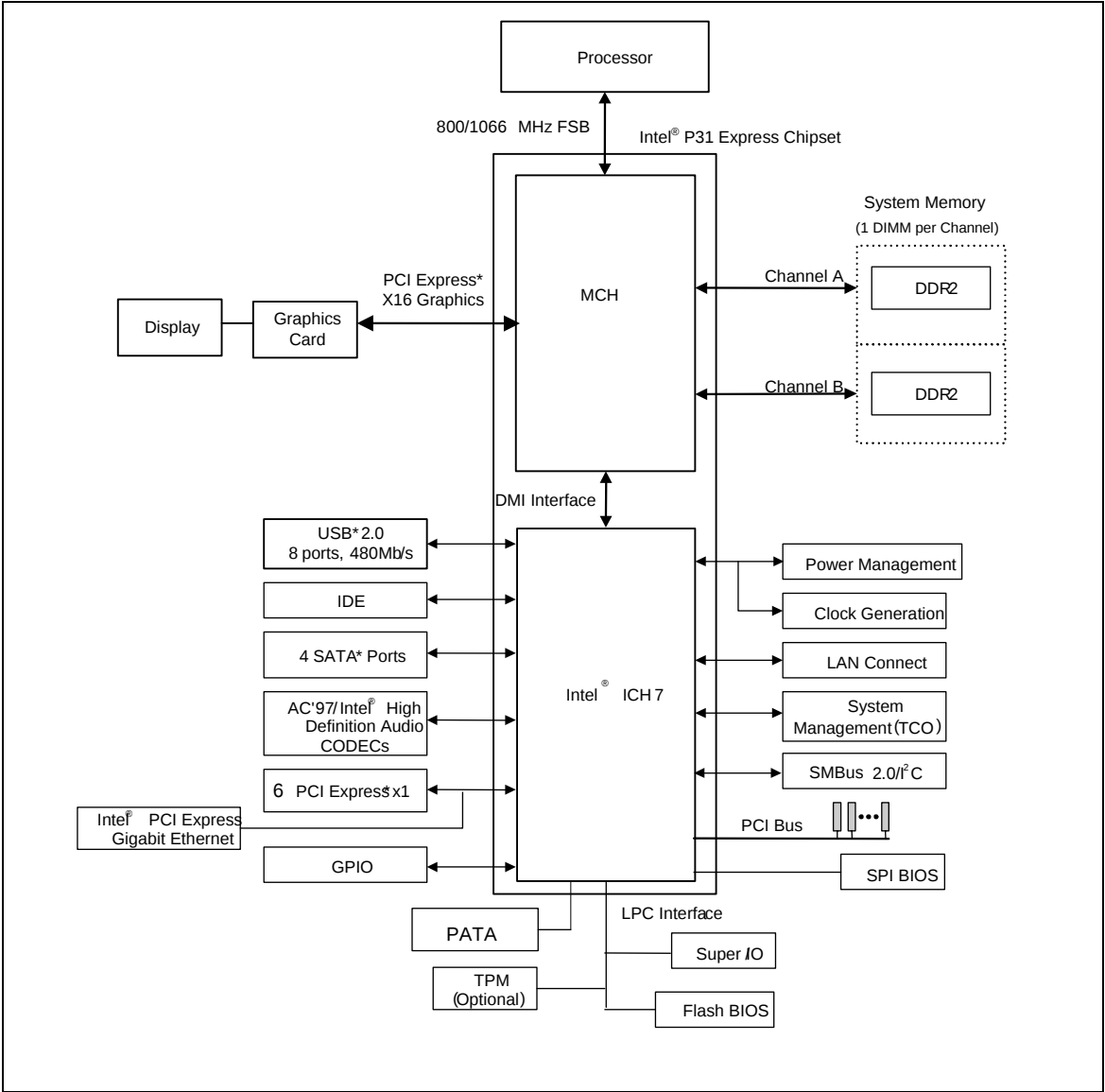




Figure 1-2. Intel® P31 Express Chipset System Block Diagram Example





1.1 Terminology

Term	Description
ADD Card	Advanced Digital Display Card. Provides digital display options for an Intel Graphics Controller that supports ADD cards (have DVOs multiplexed with AGP interface). Keyed like an AGP 4x card and plugs into an AGP connector. Will not work with an Intel Graphics Controller that implements Intel® SDVO.
ADD2 Card	Advanced Digital Display Card – 2 nd Generation. Provides digital display options for an Intel graphics controller that supports ADD2 cards. Plugs into an x16 PCI Express* connector but utilizes the multiplexed SDVO interface. Will not work with an Intel Graphics Controller that supports Intel® DVO and ADD cards.
Chipset / Root – Complex	Used in this specification to refer to one or more hardware components that connect processor complexes to the I/O and memory subsystems. The chipset may include a variety of integrated devices.
Core	The internal base logic in the (G)MCH
CPU	Refers to the processors.
CRT	Cathode Ray Tube
DBI	Dynamic Bus Inversion
DDR2	A second generation Double Data Rate SDRAM memory technology
DMI	(G)MCH-Intel® ICH7 Direct Media Interface
DVI	Digital Video Interface. Specification that defines the connector and interface for digital displays.
DVMT	Dynamic Video Memory Technology
FSB	Front Side Bus, synonymous with Host or processor bus
Full Reset	Full reset is when PWROK is deasserted. Warm reset is when both RSTIN# and PWROK are asserted.
GMCH	Graphics Memory Controller Hub component that contains the processor interface, DRAM controller, display interfaces, integrated graphics device, and x16 PCI Express port (typically the external graphics interface). It communicates with the I/O controller hub (Intel® ICH7) over the DMI interconnect.
HAW	Host Address Width. This refers to the maximum host physical address that can be accessed by a given processor / root-complex implementation. The host BIOS typically reports the host system address map.
Host	This term is used synonymously with processor
HPA	Host Physical Address
IGD	Internal Graphics Device
Intel® ICH7	Seventh generation I/O Controller Hub component that contains additional functionality compared to previous Intel® ICHs. The Intel® I/O Controller Hub 7 component contains the primary PCI interface, LPC interface, USB2, SATA, ATA-100 and other I/O functions. It communicates with the (G)MCH over a proprietary interconnect called DMI. For this (G)MCH, the term Intel® ICH refers to Intel® ICH7.



Term	Description
INTx	An interrupt request signal where X stands for interrupts A, B, C and D
IOQ	In Order Queue
MCH	Memory Controller Hub component that contains the processor interface, DRAM controller, and x16 PCI Express port (typically the external graphics interface). It communicates with the I/O controller hub (Intel® ICH7) over the DMI interconnect.
Media Expansion Card (MEC)	Media Expansion Card –. Provides digital display options for an Intel Graphics Controller that supports MEC cards. Plugs into an x16 PCI Express connector but utilizes the multiplexed SDVO interface. Adds Video In capabilities to platform. Will not work with an Intel Graphics Controller that supports DVO and ADD cards. Will function as an ADD2 card in an ADD2 supported system, but Video In capabilities will not work.
MSI	Message Signaled Interrupt. A transaction conveying interrupt information to the receiving agent through the same path that normally carries read and write commands.®
OOQ	Out of Order Queuing
PCI Express*	A high-speed serial interface whose configuration is software compatible with the legacy PCI specifications.
Primary PCI	The physical PCI bus that is driven directly by the Intel® ICH7 component. Communication between Primary PCI and the (G)MCH occurs over DMI. Note that the Primary PCI bus is not PCI Bus 0 from a configuration standpoint.
Rank	A unit of DRAM corresponding to eight x8 SDRAM devices in parallel or four x16 SDRAM devices in parallel, ignoring ECC. These devices are usually, but not always, mounted on a single side of a DIMM.
SCI	System Control Interrupt. Used in ACPI protocol.
sDVO	Serial Digital Video Out (sDVO). Digital display channel that serially transmits digital display data to an external sDVO device. The sDVO device accepts this serialized format and then translates the data into the appropriate display format (i.e., TMDS, LVDS, and TV-Out). This interface is not electrically compatible with the previous digital display channel - DVO. For 82G31 GMCH, it will be multiplexed on a portion of the x16 graphics PCI Express interface.
sDVO Device	Third party codec that utilizes sDVO as an input. May have a variety of output formats, including DVI, LVDS, HDMI, TV-out, etc.
SERR	System Error. An indication that an unrecoverable error has occurred on an I/O bus.
SMI	System Management Interrupt. Used to indicate any of several system conditions such as thermal sensor events, throttling activated, access to System Management RAM, chassis open, or other system state related activity.
TMDS	Transition Minimized Differential Signaling. Signaling interface from Silicon Image that is used in DVI and HDMI.
UMA	Unified Memory Architecture used for system memory.. Typically used by IGD or ME functionality.
VCO	Voltage Controlled Oscillator



1.2 Reference Documents

Document Name	Location
<i>Intel® G31/P31 Express Chipset Specification Update</i>	http://www.intel.com/design/chipsets/specupdt/317496.htm
<i>Intel® G31/P31 Express Chipset Thermal and Mechanical Design Guide.</i>	http://www.intel.com/design/chipsets/designex/317497.htm
<i>Intel® Core™ 2 Duo Processor and Intel® Pentium® Dual Core Processor Thermal and Mechanical Design Guide</i>	http://www.intel.com/design/processor/designex/317804.htm
<i>Intel® I/O Controller Hub 7 (ICH7) Family Thermal Mechanical Design Guide.</i>	http://developer.intel.com//design/chipsets/designex/307015.htm
<i>Intel® I/O Controller Hub 7 (ICH7) Family Datasheet</i>	http://developer.intel.com//design/chipsets/datashts/307013.htm
<i>Designing for Energy Efficiency White Paper</i>	www.intel.com/design/chipsets/applnnts/316970.htm
<i>Intel® P35/G33 Express Chipset Memory Technology and Configuration Guide White Paper</i>	www.intel.com/design/chipsets/applnnts/316971.htm
<i>Advanced Configuration and Power Interface Specification, Version 2.0</i>	http://www.acpi.info/
<i>Advanced Configuration and Power Interface Specification, Version 1.0b</i>	http://www.acpi.info/
<i>The PCI Local Bus Specification, Version 2.3</i>	http://www.pcisig.com/specifications
<i>PCI Express* Specification, Version 1.1</i>	http://www.pcisig.com/specifications



1.3 (G)MCH Overview

The Intel® 82G31 GMCH and 82P31 MCH are designed for use with the Intel® Core™2 Duo processors and Intel® Core™2 Quad processors in desktop platforms. The role of a (G)MCH in a system is to manage the flow of information between its four interfaces: the processor interface, the system memory interface, the external graphics interface, and the I/O controller through DMI interface. This includes arbitrating between the four interfaces when each initiates transactions. The (G)MCH supports one or two channels of DDR2 SDRAM. It also supports the PCI Express based external graphics attach. The Intel® G31/P31 platform supports the seventh generation I/O Controller Hub (Intel® ICH7).

1.3.1 Host Interface

The (G)MCH can use a single LGA775 socket processor. The (G)MCH supports a FSB frequency of 800/1066 MHz. Host-initiated I/O cycles are decoded to PCI Express, DMI, or the (G)MCH configuration space. Host-initiated memory cycles are decoded to PCI Express, DMI or system memory. PCI Express device accesses to non-cacheable system memory are not snooped on the host bus. Memory accesses initiated from PCI Express using PCI semantics and from DMI to system SDRAM will be snooped on the host bus.

Capabilities of the Host Interface include:

- Supports Intel Core™2 Duo processors and Intel® Core™2 Quad processors
- Supports Front Side Bus (FSB) at the following Frequency Ranges:
 - 800/1066 (200/266MHz)
- Supports FSB Dynamic Bus Inversion (DBI)
- Supports 36-bit host bus addressing, allowing the processor to access the entire 64 GB of the host address space.
- Has a 12-deep In-Order Queue to support up to twelve outstanding pipelined address requests on the host bus
- Has a 1-deep Defer Queue
- Uses GTL+ bus driver with integrated GTL termination resistors
- Supports a Cache Line Size of 64 bytes



1.3.2 System Memory Interface

The (G)MCH integrates a system memory DDR2 controller with two, 64-bit wide interfaces. The buffers support SSTL_1.8 (Stub Series Terminated Logic for 1.8 V) signal interfaces. The memory controller interface is fully configurable through a set of control registers.

Capabilities of the system memory interface include:

- Directly supports one or two channels of DDR2 memory with a maximum of one DIMM per channel
- Supports single and dual channel memory organization modes
- Supports a data burst length of eight for all memory organization modes
- Supports memory data transfer rates of 667 and 800 MHz for DDR2
- I/O Voltage of 1.8 V for DDR2
- Supports only un-buffered non-ECC DDR2 DIMMs
- Supports maximum memory bandwidth of 6.4 GB/s in single-channel or dual-channel asymmetric mode, or 12.8 GB/s in dual-channel symmetric mode assuming DDR2 800MHz
- Supports 512 Mb and 1 Gb DDR2 DRAM technologies for x8 and x16 devices
- Using 512 Mb device technologies, the smallest memory capacity possible is 256 MB, assuming Single Channel Mode with a single x16 single sided un-buffered non-ECC DIMM memory configuration
- Using 1 Gb device technologies, the largest memory capacity possible is 4 GB, assuming Dual Channel Mode with two x8 double sided un-buffered non-ECC DIMM memory configuration
- Supports up to 16 simultaneous open pages per channel (assuming 2 ranks of 8 bank devices)
- Supports opportunistic refresh scheme
- Supports Partial Writes to memory using Data Mask (DM) signals
- Supports a memory thermal management scheme to selectively manage reads and/or writes. Memory thermal management can be triggered either by on-die thermal sensor, or by preset limits. Management limits are determined by weighted sum of various commands that are scheduled on the memory interface



1.3.3 Direct Media Interface (DMI)

Direct Media Interface (DMI) is the chip-to-chip connection between the (G)MCH and ICH7. This high-speed interface integrates advanced priority-based servicing allowing for concurrent traffic and true isochronous transfer capabilities. Base functionality is completely software transparent permitting current and legacy software to operate normally.

To provide for true isochronous transfers and configurable Quality of Service (QoS) transactions, the ICH7 supports two virtual channels on DMI: VC0 and VC1. These two channels provide a fixed arbitration scheme where VC1 is always the highest priority. VC0 is the default conduit of traffic for DMI and is always enabled. VC1 must be specifically enabled and configured at both ends of the DMI link (i.e., the ICH7 and (G)MCH).

- A chip-to-chip connection interface to Intel ICH7
- 2 GB/s point-to-point DMI to ICH7 (1 GB/s each direction)
- 100 MHz reference clock (shared with PCI Express Graphics Attach)
- 32-bit downstream addressing
- APIC and MSI interrupt messaging support. Will send Intel-defined "End Of Interrupt" broadcast message when initiated by the processor.
- Message Signaled Interrupt (MSI) messages
- SMI, SCI and SERR error indication

1.3.4 PCI Express* Interface

The (G)MCH contains one 16-lane (x16) PCI Express port intended for an external PCI Express graphics card. The PCI Express port is compliant to the *PCI Express* Base Specification* revision 1.1. The x16 port operates at a frequency of 2.5 GB/s on each lane while employing 8b/10b encoding, and supports a maximum theoretical bandwidth of 40 GB/s in each direction. The 82G31 GMCH multiplexes a PCI Express interface with the Intel® sDVO ports.

- One, 16-lane PCI Express port intended for graphics attach, compatible to the PCI Express* Base Specification revision 1.1.
- PCI Express frequency of 1.25 GHz resulting in 2.5 GB/s each direction per lane.
- Raw bit-rate on the data pins of 2.5 GB/s, resulting in a real bandwidth per pair of 250 MB/s given the 8b/10b encoding used to transmit data across this interface
- Maximum theoretical realized bandwidth on the interface of 4 GB/s in each direction simultaneously, for an aggregate of 8 GB/s when x16.
- PCI Express* Graphics Extended Configuration Space. The first 256 bytes of configuration space alias directly to the PCI Compatibility configuration space. The remaining portion of the fixed 4 KB block of memory-mapped space above that (starting at 100h) is known as extended configuration space.
- PCI Express Enhanced Addressing Mechanism. Accessing the device configuration space in a flat memory mapped fashion.



- Automatic discovery, negotiation, and training of link out of reset
- Supports traditional PCI style traffic (asynchronous snooped, PCI ordering)
- Supports traditional AGP style traffic (asynchronous non-snooped, PCI Express-relaxed ordering)
- Hierarchical PCI-compliant configuration mechanism for downstream devices (i.e., normal PCI 2.3 Configuration space as a PCI-to-PCI bridge)
- Supports “static” lane numbering reversal. This method of lane reversal is controlled by a Hardware Reset strap, and reverses both the receivers and transmitters for all lanes (e.g., TX[15]->TX[0], RX[15]->RX[0]). This method is transparent to all external devices and is different than lane reversal as defined in the PCI Express Specification. In particular, link initialization is not affected by static lane reversal.

1.3.5 Graphics Features (Intel® 82G31 GMCH Only)

The GMCH provides an integrated graphics device (IGD) delivering cost competitive 3D, 2D and video capabilities. The GMCH contains an extensive set of instructions for 3D operations, 2D operations, motion compensation, overlay, and display control. The GMCH's video engines support video conferencing and other video applications. The GMCH uses a UMA configuration with DVMT for graphics memory. The GMCH also has the capability to support external graphics accelerators via the PCI Express Graphics (PEG) port but cannot work concurrently with the integrated graphics device. High bandwidth access to data is provided through the system memory port.

1.3.6 SDVO and Analog Display Features (Intel® 82G31 GMCH Only)

The GMCH provides interfaces to a progressive scan analog monitor and two SDVO ports. For the GMCH, the SDVO ports are multiplexed with PCI Express x16 graphics port signals. The GMCH supports two multiplexed SDVO ports that each drive pixel clocks up to 225 MHz. The SDVO ports can each support a single-channel SDVO device. If both ports are active in single-channel mode, they can have different display timing and data.

The digital display channels are capable of driving a variety of SDVO devices (e.g., TMDS, TV-Out). Note that SDVO only works with the Integrated Graphics Device (IGD). The GMCH is capable of driving an Advanced Digital Display (ADD2) card or Media Expansion Card. The Media Expansion Card adds video-in capabilities. The GMCH is compliant with DVI Specification 1.0. When combined with a DVI compliant external device and connector, the GMCH has a high-speed interface to a digital display (e.g., flat panel or digital CRT).

The GMCH is compliant with HDMI specification 1.1. When combined with a HDMI compliant external device and connector, the external HDMI device can support standard, enhanced, or high-definition video, plus multi-channel digital audio on a single cable.



Capabilities of the SDVO and Analog Display interfaces include:

- SDVO Support
 - SDVO ports in either single modes supported
 - 3x3 Built In full panel scalar
 - 180 degree Hardware screen rotation
 - Multiplexed Digital Display Channels (Supported with ADD2/MEC)
 - Two channels multiplexed with PCI Express* Graphics port
 - 200 MHz dot clock on each 12-bit interface
 - Supports flat panels up to 1920 x 1200 @ 60 Hz or digital CRT/HDTV at 1400 x 1050 @ 85 Hz
 - Supports Hot-Plug and Display
 - Supports TMDS transmitters or TV-out encoders
 - ADD2/Media Expansion card utilizes PCI Express Graphics x16 connector
- Analog Display Support
 - 350 MHz Integrated 24-bit RAMDAC
 - Up to 2048x1536 @ 75 Hz refresh
 - Hardware Color Cursor Support
 - DDC2B Compliant Interface
- Dual Independent Display options with digital display

1.3.7 (G)MCH Clocking

- Differential Host clock of 200/266 MHz (HCLKP/HCLKN). Supports transfer rates of 800/1066 MT/s.
- Memory clocks of 333 and 400 MHz generated from (G)MCH PLLs that use the Host clock as a reference.
- The PCI Express* PLL of 100MHz Serial Reference Clock (GCLKP/GCLKN) generates the PCI Express core clock of 250 MHz
- Display timings are generated from display PLLs that use a 96MHz differential non-spread spectrum clock as a reference. Display PLLs can also use the SDVO_TVCLKIN[+/-] from an SDVO device as a reference.
- All of the above clocks are capable of tolerating Spread Spectrum clocking.
- Host, Memory, and PCI Express Graphics PLLs and all associated internal clocks are disabled until PWROK is asserted.



1.3.8 Power Management

(G)MCH Power Management support includes:

- PC99 suspend to DRAM support ("STR", mapped to ACPI state S3)
- SMRAM space remapping to A0000h (128 KB)
- Supports extended SMRAM space above 256 MB, additional 1 MB TSEG from the Base of graphics stolen memory (BSM) when enabled, and cacheable (cacheability controlled by processor)
- ACPI Rev 1.0b compatible power management
- Supports processor states: C0, C1, and C2
- Supports System states: S0, S1, S3 and S5
- Supports processor Thermal Management 2 (TM2)

1.3.9 Thermal Sensor

(G)MCH Thermal Sensor support includes:

- Catastrophic Trip Point support for emergency clock gating for the (G)MCH at 115 °C
- Hot Trip Point support for SMI generation between 85 °C and 105 °C

§



2 Signal Description

This chapter provides a detailed description of (G)MCH signals. The signals are arranged in functional groups according to their associated interface.

The following notations are used to describe the signal type:

Signal Type	Description
PCI Express*	PCI Express interface signals. These signals are compatible with PCI Express 1.1 Signaling Environment AC Specifications and are AC coupled. The buffers are not 3.3 V tolerant. Differential voltage spec = $(D+ - D-) * 2 = 1.2V_{max}$. Single-ended maximum = 1.25 V. Single-ended minimum = 0 V.
DMI	Direct Media Interface signals. These signals are compatible with PCI Express 1.1 Signaling Environment AC Specifications, but are DC coupled. The buffers are not 3.3 V tolerant. Differential voltage spec = $(D+ - D-) * 2 = 1.2V_{max}$. Single-ended maximum = 1.25 V. Single-ended minimum = 0 V.
CMOS	CMOS buffers. 1.5 V tolerant.
COD	CMOS Open Drain buffers. 3.3 V tolerant.
HVCMOS	High Voltage CMOS buffers. 3.3 V tolerant.
HVIN	High Voltage CMOS input-only buffers. 3.3 V tolerant.
SSTL_1.8	Stub Series Termination Logic. These are 1.8 V output capable buffers. 1.8 V tolerant.
A	Analog reference or output. May be used as a threshold voltage or for buffer compensation.
GTL+	Gunning Transceiver Logic signaling technology. Implements a voltage level as defined by VTT of 1.2V.



2.1 Host Interface Signals

Note: Unless otherwise noted, the voltage level for all signals in this interface is tied to the termination voltage of the Host Bus (Vtt).

Signal Name	Type	Description
HADS#	I/O GTL+	Address Strobe: The processor bus owner asserts HADS# to indicate the first of two cycles of a request phase. The (G)MCH can assert this signal for snoop cycles and interrupt messages.
HBNR#	I/O GTL+	Block Next Request: Used to block the current request bus owner from issuing new requests. This signal is used to dynamically control the processor bus pipeline depth.
HBPRI#	O GTL+	Priority Agent Bus Request: The (G)MCH is the only Priority Agent on the processor bus. It asserts this signal to obtain the ownership of the address bus. This signal has priority over symmetric bus requests and will cause the current symmetric owner to stop issuing new transactions unless the HLOCK# signal was asserted.
HBREQ0#	I/O GTL+	Bus Request 0: The (G)MCH pulls the processor's bus HBREQ0# signal low during HCPURST#. The processor samples this signal on the active-to-inactive transition of HCPURST#. The minimum setup time for this signal is 4 HCLKs. The minimum hold time is 2 clocks and the maximum hold time is 20 HCLKs. HBREQ0# should be tristated after the hold time requirement has been satisfied.
HCPURST#	O GTL+	CPU Reset: The HCPURST# pin is an output from the (G)MCH. The (G)MCH asserts HCPURST# while RSTIN# is asserted and for approximately 1 ms after RSTIN# is de-asserted. The HCPURST# allows the processors to begin execution in a known state. Note that the Intel® ICH7 must provide processor frequency select strap set-up and hold times around HCPURST#. This requires strict synchronization between (G)MCH HCPURST# de-assertion and the ICH7 driving the straps.
HDBSY#	I/O GTL+	Data Bus Busy: Used by the data bus owner to hold the data bus for transfers requiring more than one cycle.
HDEFER#	O GTL+	Defer: Signals that the (G)MCH will terminate the transaction currently being snooped with either a deferred response or with a retry response.



Signal Name	Type	Description															
HDINV[3:0] #	I/O GTL +	Dynamic Bus Inversion: Driven along with the HD[63:0] # signals. Indicates if the associated signals are inverted or not. HDINV[3:0] # are asserted such that the number of data bits driven electrically low (low voltage) within the corresponding 16 bit group never exceeds 8. HDINV[x] # Data Bits HDINV[3] # HD[63:48] # HDINV[2] # HD[47:32] # HDINV[1] # HD[31:16] # HDINV[0] # HD[15:0] #															
HA[35:3] #	I/O GTL +	Host Address Bus: HA[35:3] # connect to the processor address bus. During processor cycles, the HA[35:3] # are inputs. The (G)MCH drives HA[35:3] # during snoop cycles on behalf of DMI and PCI Express* Graphics initiators. HA[35:3] # are transferred at 2x rate.															
HADSTB[1:0] #	I/O GTL +	Host Address Strobe: The source synchronous strobes used to transfer HA[35:3] # and HREQ[4:0] at the 2x transfer rate.															
HD[63:0] #	I/O GTL +	Host Data: These signals are connected to the processor data bus. Data on HD[63:0] is transferred at 4x rate. Note that the data signals may be inverted on the processor bus, depending on the HDINV[3:0] # signals.															
HDSTBP[3:0] # HDSTBN[3:0] #	I/O GTL +	Differential Host Data Strobes: The differential source synchronous strobes used to transfer HD[63:0] # and HDINV[3:0] # at 4x transfer rate. Named this way because they are not level sensitive. Data is captured on the falling edge of both strobes. Hence, they are pseudo-differential, and not true differential. <table><tr><th>Strobes</th><th>Bits</th><th>Data</th></tr><tr><td>HDSTBP[3] #, HDSTBN[3] #</td><td>HDINV[3] #</td><td>HD[63:48] #</td></tr><tr><td>HDSTBP[2] #, HDSTBN[2] #</td><td>HDINV[2] #</td><td>HD[47:32] #</td></tr><tr><td>HDSTBP[1] #, HDSTBN[1] #</td><td>HDINV[1] #</td><td>HD[31:16] #</td></tr><tr><td>HDSTBP[0] #, HDSTBN[0] #</td><td>HDINV[0] #</td><td>HD[15:0] #</td></tr></table>	Strobes	Bits	Data	HDSTBP[3] #, HDSTBN[3] #	HDINV[3] #	HD[63:48] #	HDSTBP[2] #, HDSTBN[2] #	HDINV[2] #	HD[47:32] #	HDSTBP[1] #, HDSTBN[1] #	HDINV[1] #	HD[31:16] #	HDSTBP[0] #, HDSTBN[0] #	HDINV[0] #	HD[15:0] #
Strobes	Bits	Data															
HDSTBP[3] #, HDSTBN[3] #	HDINV[3] #	HD[63:48] #															
HDSTBP[2] #, HDSTBN[2] #	HDINV[2] #	HD[47:32] #															
HDSTBP[1] #, HDSTBN[1] #	HDINV[1] #	HD[31:16] #															
HDSTBP[0] #, HDSTBN[0] #	HDINV[0] #	HD[15:0] #															
HHIT #	I/O GTL +	Hit: Indicates that a caching agent holds an unmodified version of the requested line. Also, driven in conjunction with HHITM # by the target to extend the snoop window.															
HHITM #	I/O GTL +	Hit Modified: Indicates that a caching agent holds a modified version of the requested line and that this agent assumes responsibility for providing the line. Also, driven in conjunction with HHIT # to extend the snoop window.															



Signal Name	Type	Description																		
HTRDY#	O GTL+	Host Target Ready: Indicates that the target of the processor transaction is able to enter the data transfer phase.																		
HRS[2:0]#	O GTL+	Response Signals: Indicates type of response according to the table <table><tr><th>Encoding</th><th>Response Type</th></tr><tr><td>000</td><td>Idle state</td></tr><tr><td>001</td><td>Retry response</td></tr><tr><td>010</td><td>Deferred response</td></tr><tr><td>011</td><td>Reserved(not driven by (G)MCH)</td></tr><tr><td>100</td><td>Hard Failure(not driven by (G)MCH)</td></tr><tr><td>101</td><td>No data response</td></tr><tr><td>110</td><td>Implicit Writeback</td></tr><tr><td>111</td><td>Normal data response</td></tr></table>	Encoding	Response Type	000	Idle state	001	Retry response	010	Deferred response	011	Reserved(not driven by (G)MCH)	100	Hard Failure(not driven by (G)MCH)	101	No data response	110	Implicit Writeback	111	Normal data response
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100	Hard Failure(not driven by (G)MCH)																			
101	No data response																			
110	Implicit Writeback																			
111	Normal data response																			
BSEL[2:0]	I CMOS	Bus Speed Select: At the de-assertion of RSTIN#, the value sampled on these pins determines the expected frequency of the bus.																		
HRCOMP	I/O CMOS	Host RCOMP: Used to calibrate the Host GTL+ I/O buffers. This signal is powered by the Host Interface termination rail (Vtt).																		
HSCOMP	I/O CMOS	Slew Rate Compensation: Compensation for the Host Interface																		
HSCOMP#	I/O A	Slew Rate Compensation: Compensation for the Host Interface for falling edges																		
HSWING	I A	Host Voltage Swing: This signal provides the reference voltage used by FSB RCOMP circuits. HSWING is used for the signals handled by HRCOMP.																		
HDVREF	I A	Host Reference Voltage: Voltage input for the Data signals of the Host GTL interface.																		
HACCVREF	I A	Host Reference Voltage: Voltage input for the Address signals of the Host GTL interface.																		



2.2 System Memory (DDR2) Interface Signals

2.2.1 System Memory Channel A Interface Signals

Signal Name	Type	Description
SCLK_A[2:0]	O SSTL-1.8	SDRAM Differential Clock: (3 per DIMM), SCLK_A and its complement, SCLK_A# make a differential clock pair output. The crossing of the positive edge of SCLK_A and the negative edge of its complement SCLK_A# are used to sample the command and control signals on the SDRAM.
SCLK_A[2:0]#	O SSTL-1.8	SDRAM Complementary Differential Clock: (3 per DIMM) These are the complementary differential DDR2 Clock signals.
SCS_A[1:0]#	O SSTL-1.8	Chip Select: (1 per Rank) These signals select particular SDRAM components during the active state. There is one Chip Select for each SDRAM rank.
SMA_A[14:0]	O SSTL-1.8	Memory Address: These signals are used to provide the multiplexed row and column address to the SDRAM.
SBS_A[2:0]	O SSTL-1.8	Bank Select: These signals define which banks are selected within each SDRAM rank. DDR2: 1-Gb technology uses 8 banks.
SRAS_A#	O SSTL-1.8	Row Address Strobe: Used with SCAS_A# and SWE_A# (along with SCS_A#) to define the SDRAM commands.
SCAS_A#	O SSTL-1.8	Column Address Strobe: Used with SRAS_A# and SWE_A# (along with SCS_A#) to define the SDRAM commands.
SWE_A#	O SSTL-1.8	Write Enable: Used with SCAS_A# and SRAS_A# (along with SCS_A#) to define the SDRAM commands.
SDQ_A[63:0]	I/O SSTL-1.8	Data Lines: SDQ_A signals interface to the SDRAM data bus.
SDM_A[7:0]	O SSTL-1.8	Data Mask: When activated during writes, the corresponding data groups in the SDRAM are masked. There is one SDM_A bit for every data byte lane.
SDQS_A[7:0]	I/O SSTL-1.8	Data Strobes: For DDR2, SDQS_A, and its complement SDQS_A# make up a differential strobe pair. The data is captured at the crossing point of SDQS_A and its complement SDQS_A# during read and write transactions.
SDQS_A[7:0]#	I/O SSTL-1.8	Data Strobe Complements: These are the complementary DDR2 strobe signals.
SCKE_A[1:0]	O SSTL-1.8	Clock Enable: (1 per Rank) SCKE_A is used to initialize the SDRAMs during power-up, to power-down SDRAM ranks, and to place all SDRAM ranks into and out of self-refresh during Suspend-to-RAM.
SODT_A[1:0]	O SSTL-1.8	On Die Termination: Active On-die Termination Control signals for DDR2 devices.



2.2.2 System Memory Channel B Interface Signals

Signal Name	Type	Description
SCLK_B[2:0]	O SSTL-1.8	SDRAM Differential Clock: (3 per DIMM) SCLK_B and its complement, SCLK_B#, make a differential clock pair output. The crossing of the positive edge of SCLK_B and the negative edge of its complement SCLK_B# are used to sample the command and control signals on the SDRAM.
SCLK_B[2:0]#	O SSTL-1.8	SDRAM Complementary Differential Clock: (3 per DIMM) These are the complementary differential DDR2 Clock signals.
SCS_B[1:0]#	O SSTL-1.8	Chip Select: (1 per Rank) These signals select particular SDRAM components during the active state. There is one Chip Select for each SDRAM rank
SMA_B[14:0]	O SSTL-1.8	Memory Address: These signals are used to provide the multiplexed row and column address to the SDRAM.
SBS_B[2:0]	O SSTL-1.8	Bank Select: These signals define which banks are selected within each SDRAM rank DDR2: 1-Gb technology uses 8 banks.
SRAS_B#	O SSTL-1.8	Row Address Strobe: Used with SCAS_B# and SWE_B# (along with SCS_B#) to define the SDRAM commands
SCAS_B#	O SSTL-1.8	Column Address Strobe: Used with SRAS_B# and SWE_B# (along with SCS_B#) to define the SDRAM commands.
SWE_B#	O SSTL-1.8	Write Enable: Used with SCAS_B# and SRAS_B# (along with SCS_B#) to define the SDRAM commands.
SDQ_B[63:0]	I/O SSTL-1.8	Data Lines: SDQ_B signals interface to the SDRAM data bus.
SDM_B[7:0]	O SSTL-1.8	Data Mask: When activated during writes, the corresponding data groups in the SDRAM are masked. There is one SBDM for every data byte lane.
SDQS_B[7:0]	I/O SSTL-1.8	Data Strobes: For DDR2, SDQS_B, and its complement ,SDQS_B#, make up a differential strobe pair. The data is captured at the crossing point of SDQS_B and its complement SDQS_B# during read and write transactions.
SDQS_B[7:0]#	I/O SSTL-1.8	Data Strobe Complements: These are the complementary DDR2 strobe signals.
SCKE_B[1:0]	O SSTL-1.8	Clock Enable: (1 per Rank) SCKE_B is used to initialize the SDRAMs during power-up, to power-down SDRAM ranks, and to place all SDRAM ranks into and out of self-refresh during Suspend-to-RAM.
SODT_B[1:0]	O SSTL-1.8	On Die Termination: Active On-die Termination Control signals for DDR2 devices.



2.2.3 DDR2 DRAM Reference and Compensation Signals

Signal Name	Type	Description
SRCOMP[3:0]	I A	System Memory RCOMP
SVREF	I A	SDRAM Reference Voltage: Reference voltage input for DQ, DQS, and DQS# input signals.
SMRCOMPVOL	I A	System Memory RCOMP reference
SMRCOMPVOH	I A	System Memory RCOMP reference

2.3 PCI Express* Interface Signals

Signal Name	Type	Description
EXP_RXN[15:0] EXP_RXP[15:0]	I PCI EXPRESS*	PCI Express* Receive Differential Pair (RX)
EXP_TXN[15:0] EXP_TXP[15:0]	O PCI EXPRESS*	PCI Express* Graphics Transmit Differential Pair (TX)
EXP_COMPO	I A	PCI Express* Graphics Output Current Compensation
EXP_COMPI	I A	PCI Express* Graphics Input Current Compensation



2.4 Analog Display Signals (Intel® 82G31 GMCH Only)

Signal Name	Type	Description
RED	O A	RED Analog Video Output: This signal is a CRT Analog video output from the internal color palette DAC. The DAC is designed for a 37.5 ohm routing impedance, but the terminating resistor to ground will be 75 ohms (e.g., 75 ohm resistor on the board, in parallel with a 75 ohm CRT load).
RED#	O A	RED# Analog Output: This signal is an analog video output from the internal color palette DAC. It should be shorted to the ground plane.
GREEN	O A	GREEN Analog Video Output: This signal is a CRT Analog video output from the internal color palette DAC. The DAC is designed for a 37.5 ohm routing impedance, but the terminating resistor to ground will be 75 ohms (e.g., 75 ohm resistor on the board, in parallel with a 75 ohm CRT load).
GREEN#	O A	GREEN# Analog Output: This signal is an analog video output from the internal color palette DAC. It should be shorted to the ground plane.
BLUE	O A	BLUE Analog Video Output: This signal is a CRT Analog video output from the internal color palette DAC. The DAC is designed for a 37.5 ohm routing impedance, but the terminating resistor to ground will be 75 ohms (e.g., 75 ohm resistor on the board, in parallel with a 75 ohm CRT load).
BLUE#	O A	BLUE# Analog Output: This signal is an analog video output from the internal color palette DAC. It should be shorted to the ground plane.
REFSET	O A	Resistor Set: Set point resistor for the internal color palette DAC. A 255 ohm 1% resistor is required between REFSET and motherboard ground.
HSYNC	O 3.3V CMOS	CRT Horizontal Synchronization: This signal is used as the horizontal sync (polarity is programmable) or "sync interval", 3.3 V output
VSNC	O 3.3V CMOS	CRT Vertical Synchronization: This signal is used as the vertical sync (polarity is programmable) 3.3V output.
DDC_CLK	I/O 3.3V CMOS	Monitor Control Clock
DDC_DATA	I/O 3.3V CMOS	Monitor Control Data



2.5 Clocks, Reset, and Miscellaneous

Signal Name	Type	Description
HCLKP HCLKN	I HCSL	Differential Host Clock In: These pins receive a differential host clock from the external clock synthesizer. This clock is used by all of the (G)MCH logic that is in the Host clock domain. Memory domain clocks are also derived from this source.
GCLKP GCLKN	I HCSL	Differential PCI Express* Graphics Clock In: These pins receive a differential 100 MHz Serial Reference clock from the external clock synthesizer. This clock is used to generate the clocks necessary for the support of PCI Express.
DREFCLKN DREFCLKP	I HCSL	Display PLL Differential Clock In
RSTIN#	I HVIN	Reset In: When asserted, this signal will asynchronously reset the (G)MCH logic. This signal is connected to the PCIRST# output of the Intel® ICH7. All PCI Express Graphics Attach output signals will also tri-state compliant to <i>PCI Express* Specification Rev 1.1</i> . This input should have a Schmitt trigger to avoid spurious resets. This signal is required to be 3.3V tolerant.
EXP_SLR	I CMOS	PCI Express* Static Lane Reversal/Form Factor Selection: (G)MCH's PCI Express lane numbers are reversed to differentiate BTX and ATX form factors 0 = (G)MCH PCI Express lane numbers are reversed (BTX) 1 = Normal operation (ATX)
BSEL2 BSEL1 BSEL0	I HCSL	Bus Speed Select: At the assertion of PWROK, the value sampled on these pins determines the expected frequency of the bus. These pins must also be routed to probe points or to the XDP connector when applicable
EXP_EN	I GTL+	Concurrent PCI Express Port Enable: Concurrent SDVO and PCI Express 0 = Only SDVO or PCI Express is operational. 1 = Both SDVO and PCI Express are operating simultaneously via the PCI Express port. NOTE: For the 82P31 MCH, this signal should be connected to ground.
PWROK	I/O SSTL	Power OK: When asserted, PWROK is an indication to the (G)MCH that core power has been stable for at least 10 us.
ICH_SYNC#	O HVC MOS	Maintains synchronization between (G)MCH and ICH



Signal Name	Type	Description		
ALLZTEST/ XORTEST	I/O GTL+	XORTEST	ALLZTEST	Description
		0	0	Intel Reserved
		0	1	XOR Chain. Used for Chipset Bed of Nails testing to execute XOR Chain Test
		1	0	All pins tristated. Used for chipset testing
		1	1	Normal
TEST[2:0]	I/O A	In Circuit Test: These pins should be connected to test points on the motherboard. They are internally shorted to the package ground and can be used to determine if the corner balls on the (G)MCH are correctly soldered down to the motherboard. These pins should NOT connect to ground on the motherboard. If TEST[2:0] are not going to be used, they should be left as no connects.		

2.6 Direct Media Interface

Signal Name	Type	Description
DMI_RXP_3:0 DMI_RXN_3:0	I DMI	Direct Media Interface: Receive differential pair (RX). MCH-ICH serial interface input.
DMI_TXP_3:0 DMI_TXN_3:0	O DMI	Direct Media Interface: Transmit differential pair (TX). MCH-ICH serial interface output.

2.7 Serial DVO Interface (Intel® 82G31 GMCH Only)

All but two of the pins in this section are multiplexed with the PCI Express interface. sDVO is mapped to lanes 0-7 or lanes 15-8 of the PEG port depending on the PCI Express Static Lane Reversal and sDVO/PCI Express Coexistence straps. The lower 8 lanes are used when **both** straps are either asserted or not asserted. Otherwise, the upper 8 lanes are used.

Signal Name	Type	Description
SDVOB_CLKN	O PCIE	Serial Digital Video Channel B Clock Complement
SDVOB_CLKP	O PCIE	Serial Digital Video Channel B Clock
SDVOB_RED#	O PCIE	Serial Digital Video Channel C Red Complement



Signal Name	Type	Description
SDVOB_RED	O PCIE	Serial Digital Video Channel C Red
SDVOB_GREEN#	O PCIE	Serial Digital Video Channel B Green Complement
SDVOBGREEN	O PCIE	Serial Digital Video Channel B Green
SDVOB_BLUE#	O PCIE	Serial Digital Video Channel B Blue Complement
SDVOB_BLUE	O PCIE	Serial Digital Video Channel B Blue
SDVOC_RED#	O PCIE	Serial Digital Video Channel C Red Complement
SDVOC_RED	O PCIE	Serial Digital Video Channel C Red Channel B Alpha
SDVOC_GREEN#	O PCIE	Serial Digital Video Channel C Green Complement
SDVOC_GREEN	O PCIE	Serial Digital Video Channel C Green
SDVOC_BLUE#	O PCIE	Serial Digital Video Channel C Blue Complement
SDVOC_BLUE	O PCIE	Serial Digital Video Channel C Blue
SDVOC_CLKN	O PCIE	Serial Digital Video Channel C Clock Complement
SDVOC_CLKP	O PCIE	Serial Digital Video Channel C Clock
SDVO_TVCLKIN#	I PCIE	Serial Digital Video TVOUT Synchronization Clock Complement
SDVO_TVCLKIN	I PCIE	Serial Digital Video TVOUT Synchronization Clock
SDVOB_INT#	I PCIE	Serial Digital Video Input Interrupt Complement
SDVOB_INT	I PCIE	Serial Digital Video Input Interrupt



Signal Name	Type	Description
SDVOC_INT#	I PCIE	Serial Digital Video Input Interrupt Complement
SDVOC_INT	I PCIE	Serial Digital Video Input Interrupt
SDVO_FLDSTALL#	I PCIE	Serial Digital Video Field Stall Complement.
SDVO_FLDSTALL	I PCIE	Serial Digital Video Field Stall
SDVO_CTRLCLK	I/O COD	Serial Digital Video Device Control Clock
SDVO_CTRLDATA	I/O COD	Serial Digital Video Device Control Data

2.7.1 SDVO / PCI Express* Signal Mapping

sDVO Signal	Configuration-wise Mapping			
	sDVO Only – Normal	sDVO Only – Reversed	Concurrent sDVO and PCI Express* – Normal	Concurrent sDVO and PCI Express* – Reversed
SDVOB_RED#	EXP_TXN0	EXP_TXN15	EXP_TXN15	EXP_TXN0
SDVOB_RED	EXP_TXP0	EXP_TXP15	EXP_TXP15	EXP_TXP0
SDVOB_GREEN#	EXP_TXN1	EXP_TXN14	EXP_TXN14	EXP_TXN1
SDVOB_GREEN	EXP_TXP1	EXP_TXP14	EXP_TXP14	EXP_TXP1
SDVOB_BLUE#	EXP_TXN2	EXP_TXN13	EXP_TXN13	EXP_TXN2
SDVOB_BLUE	EXP_TXP2	EXP_TXP13	EXP_TXP13	EXP_TXP2
SDVOB_CLKN	EXP_TXN3	EXP_TXN12	EXP_TXN12	EXP_TXN3
SDVOB_CLKP	EXP_TXP3	EXP_TXP12	EXP_TXP12	EXP_TXP3
SDVOC_RED#	EXP_TXN4	EXP_TXN11	EXP_TXN11	EXP_TXN4
SDVOC_RED	EXP_TXP4	EXP_TXP11	EXP_TXP11	EXP_TXP4
SDVOC_GREEN#	EXP_TXN5	EXP_TXN10	EXP_TXN10	EXP_TXN5
SDVOC_GREEN	EXP_TXP5	EXP_TXP10	EXP_TXP10	EXP_TXP5
SDVOC_BLUE#	EXP_TXN6	EXP_TXN9	EXP_TXN9	EXP_TXN6
SDVOC_BLUE	EXP_TXP6	EXP_TXP9	EXP_TXP9	EXP_TXP6
SDVOC_CLKN	EXP_TXN7	EXP_TXN8	EXP_TXN8	EXP_TXN7
SDVOC_CLKP	EXP_TXP7	EXP_TXP8	EXP_TXP8	EXP_TXP7



sDVO Signal	Configuration-wise Mapping			
	sDVO Only – Normal	sDVO Only – Reversed	Concurrent sDVO and PCI Express* – Normal	Concurrent sDVO and PCI Express* – Reversed
SDVO_TVCLKIN#	EXP_RXN0	EXP_RXN15	EXP_RXN15	EXP_RXN0
SDVO_TVCLKIN	EXP_RXP0	EXP_RXP15	EXP_RXP15	EXP_RXP0
SDVOB_INT#	EXP_RXN1	EXP_RXN14	EXP_RXN14	EXP_RXN1
SDVOB_INT	EXP_RXP1	EXP_RXP14	EXP_RXP14	EXP_RXP1
SDVOC_INT#	EXP_RXN5	EXP_RXN10	EXP_RXN10	EXP_RXN5
SDVOC_INT	EXP_RXP5	EXP_RXP10	EXP_RXP10	EXP_RXP5
SDVO_FLDSTALL#	EXP_RXN2	EXP_RXN13	EXP_RXN13	EXP_RXN2
SDVO_FLDSTALL	EXP_RXP2	EXP_RXP13	EXP_RXP13	EXP_RXP2

2.8 Power and Ground

Name	Voltage	Description
VCC	1.25 V	Core Power
VTT	1.05V/1.2 V	Processor System Bus Power
VCC_EXP	1.25 V	PCI Express* and DMI Power
VCCSM	1.8V	System Memory Power
VCC_SMCLK	1.8V	System Clock Memory Power
VCC3_3	3.3 V	3.3 V CMOS Power
VCCA_EXP	1.25 V	PCI Express PLL Analog Power
VCCA_DPLLA	1.25 V	Display PLL A Analog Power
VCCA_DPLLB	1.25 V	Display PLL B Analog Power
VCCA_HPLL	1.25 V	Host PLL Analog Power
VCCA_MPLL	1.25 V	System Memory PLL Analog Power
VCCA_DAC	3.3 V	Display DAC Analog Power
VCCD_CRT	1.5/1.8 V	Display Digital Supply Power
VSS	0 V	Ground





3 System Address Map

The (G)MCH supports 64 GB (36 bit) of host address space and 64 KB+3 of addressable I/O space. There is a programmable memory address space under the 1 MB region which is divided into regions which can be individually controlled with programmable attributes such as Disable, Read/Write, Write Only, or Read Only. Attribute programming is described in the Register Description section. This section focuses on how the memory space is partitioned and what the separate memory regions are used for. I/O address space has simpler mapping and is explained near the end of this section.

Note: Address mapping information for the Integrated Graphics Device applies to the 82G31 GMCH only. The 82P31 MCH does not have an IGD.

The (G)MCH supports PEG port upper pre-fetchable base/limit registers. This allows the PEG unit to claim IO accesses above 36 bit, complying with the PCI Express Specification. Addressing of greater than 4 GB is allowed on either the DMI Interface or PCI Express interface. The (G)MCH supports a maximum of 4 GB of DRAM. No DRAM memory will be accessible above 4 GB.

When running in internal graphics mode, writes to GMADR range linear range are supported. Write accesses to linear regions are supported from DMI only. Write accesses to tileX and tileY regions (defined via fence registers) are not supported from DMI or the PEG port. GMADR read accesses are not supported from either DMI or PEG.

In the following sections, it is assumed that all of the compatibility memory ranges reside on the DMI Interface. The exception to this rule is VGA ranges, which may be mapped to PCI-Express, DMI, or to the internal graphics device (IGD). In the absence of more specific references, cycle descriptions referencing PCI should be interpreted as the DMI Interface/PCI, while cycle descriptions referencing PCI Express or IGD are related to the PCI Express bus or the internal graphics device respectively. The (G)MCH does not remap APIC or any other memory spaces above TOLUD (Top of Low Usable DRAM). The TOLUD register is set to the appropriate value by BIOS. The reclaim base/reclaim limit registers remap logical accesses bound for addresses above 4 GB onto physical addresses that fall within DRAM.



The Address Map includes a number of programmable ranges:

- 1. Device 0
 - PXPEPBAR – Express port registers. Necessary for setting up VC1 as an isochronous channel using time based weighted round robin arbitration. (4 KB window)
 - MCHBAR – Memory mapped range for internal (G)MCH registers. For example, memory buffer register controls. (16 KB window)
 - PCIEXBAR – Flat memory-mapped address spaced to access device configuration registers. This mechanism can be used to access PCI configuration space (0–FFh) and Extended configuration space (100h–FFFh) for PCI Express devices. This enhanced configuration access mechanism is defined in the PCI Express specification. (64 MB, 128 MB, or 256 MB window).
 - DMIBAR – This window is used to access registers associated with the Direct Media Interface (DMI) register memory range. (4 KB window)
 - GGCGMS (82G31 GMCH only) – GMCH graphics control register, Graphics Mode Select. Used to select the amount of main memory that is pre-allocated to support the internal graphics device in VGA (non-linear) and Native (linear) modes. (0-256 MB options).
 - GGCGGMS (82G31 GMCH only) – GMCH graphics control register, GTT Graphics Memory Size. GGCGGMS is used to select the amount of main memory that is pre-allocated to support the Internal Graphics Translation Table. (0-2 MB options).
- Device 1
 - MBASE1/MLIMIT1 – PCI Express port non-prefetchable memory access window.
 - PMBASE1/PMLIMIT1 – PCI Express port prefetchable memory access window.
 - PMUBASE/PMULIMIT – PCI Express port upper prefetchable memory access window
 - IOBASE1/IOLIMIT1 – PCI Express port IO access window.
- Device 2, Function 0 (82G31 GMCH only)
 - MMADR – IGD registers and internal graphics instruction port. (512 KB window)
 - IOBAR – IO access window for internal graphics. Though this window address/data register pair, using I/O semantics, the IGD and internal graphics instruction port registers can be accessed. Note, this allows accessing the same registers as MMADR. In addition, the IOBAR can be used to issue writes to the GTTADR table.
 - GMADR – Internal graphics translation window. (128 MB, 256 MB or 512 MB window).
 - GTTADR – Internal graphics translation table location. (1 MB window). Note that the Base of GTT stolen Memory register (Device 0 A8) indicates the physical address base which is 1 MB aligned.
- Device 2, Function 1 (82G31 GMCH only)
 - MMADR – Function 1 IGD registers and internal graphics instruction port. (512 KB window)

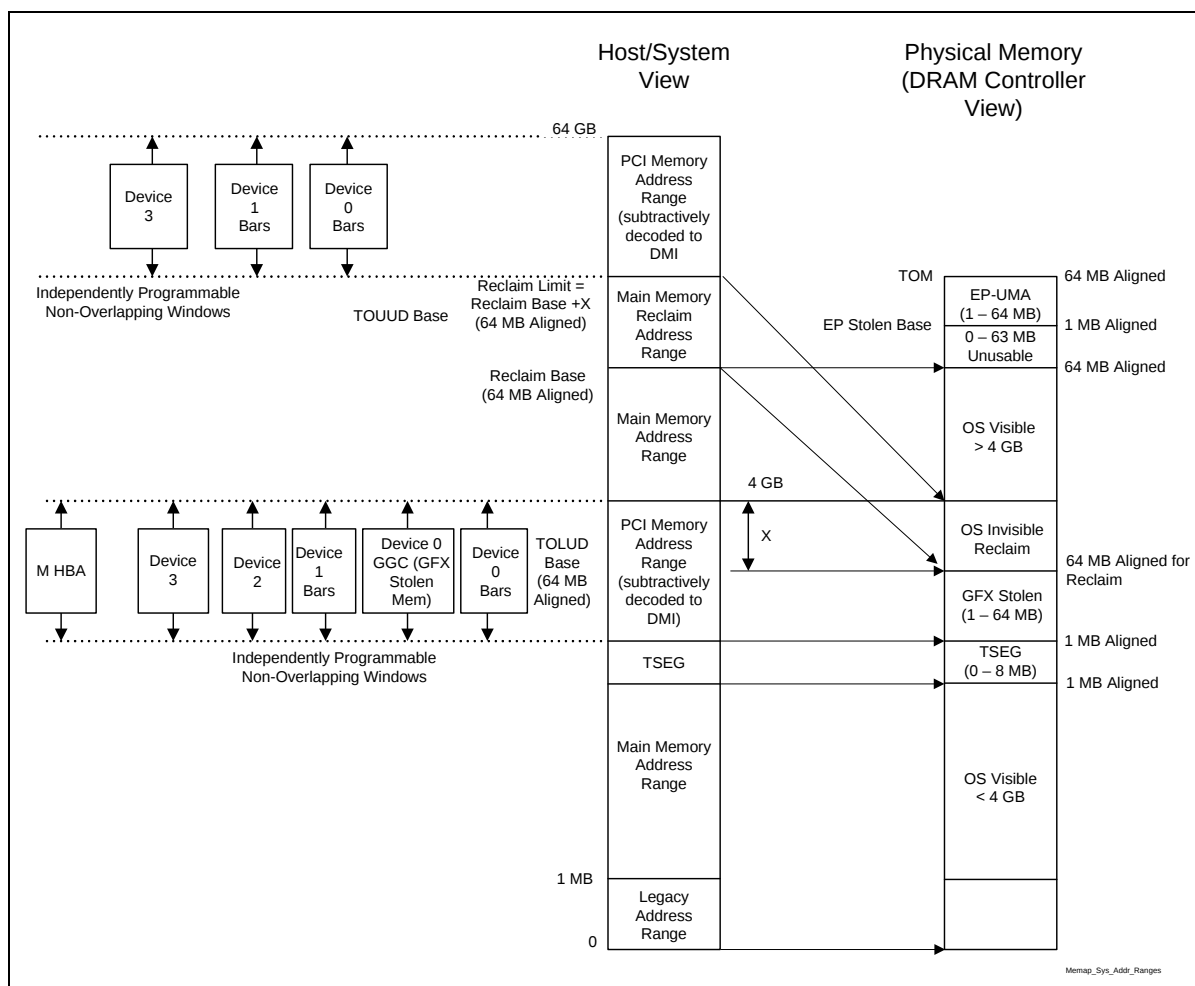


The rules for the above programmable ranges are:

1. ALL of these ranges MUST be unique and NON-OVERLAPPING. It is the BIOS or system designers' responsibility to limit memory population so that adequate PCI, PCI Express, High BIOS, PCI Express Memory Mapped space, and APIC memory space can be allocated.
2. There are NO Hardware Interlocks to prevent problems in the case of overlapping ranges.
3. Accesses to overlapped ranges may produce indeterminate results.
4. The only peer-to-peer cycles allowed below the top of Low Usable memory (register TOLUD) are DMI Interface to PCI Express VGA range writes. Note that peer to peer cycles to the Internal Graphics VGA range are not supported.

Figure 3-1 represents the system memory address map in a simplified form.

Figure 3-1. System Address Ranges



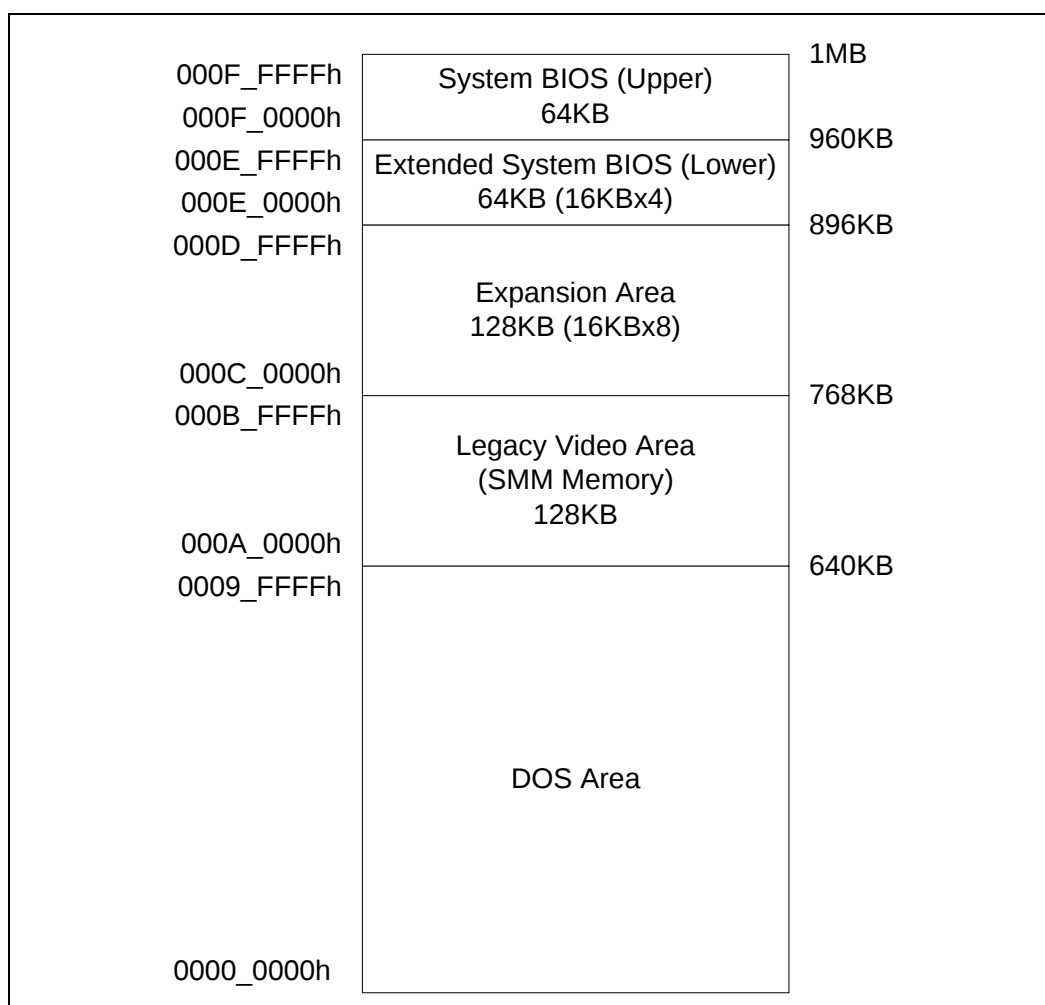


3.1 Legacy Address Range

This area is divided into the following address regions:

- 0 – 640 KB – DOS Area
- 640 – 768 KB – Legacy Video Buffer Area
- 768 – 896 KB in 16 KB sections (total of 8 sections) – Expansion Area
- 896 – 960 KB in 16 KB sections (total of 4 sections) – Extended System BIOS Area
- 960 KB – 1 MB Memory – System BIOS Area

Figure 3-2. DOS Legacy Address Range





3.1.1 DOS Range (0h – 9_FFFFh)

The DOS area is 640 KB (0000_0000h – 0009_FFFFh) in size and is always mapped to the main memory controlled by the (G)MCH.

3.1.2 Legacy Video Area (A_0000h-B_FFFFh)

The legacy 128KB VGA memory range, frame buffer, (000A_0000h – 000B_FFFFh) can be mapped to IGD (Device 2), to PCI Express (Device 1), and/or to the DMI Interface. The appropriate mapping depends on which devices are enabled and the programming of the VGA steering bits. Based on the VGA steering bits, priority for VGA mapping is constant. The (G)MCH always decodes internally mapped devices first. Internal to the (G)MCH, decode precedence is always given to IGD. The (G)MCH always positively decodes internally mapped devices, namely the IGD (82G31 GMCH only) and PCI-Express. Subsequent decoding of regions mapped to PCI Express or the DMI Interface depends on the Legacy VGA configuration bits (VGA Enable & MDAP). This region is also the default for SMM space.

Compatible SMRAM Address Range (A_0000h-B_FFFFh)

When compatible SMM space is enabled, SMM-mode processor accesses to this range are routed to physical system DRAM at 000A 0000h – 000B FFFFh. Non-SMM-mode processor accesses to this range are considered to be to the Video Buffer Area as described above. PCI Express and DMI originated cycles to enabled SMM space are not allowed and are considered to be to the Video Buffer Area, if IGD on the 82G31 GMCH is not enabled as the VGA device. PCI Express and DMI initiated cycles are attempted as Peer cycles, and will master abort on PCI if no external VGA device claims them.

Monochrome Adapter (MDA) Range (B_0000h-B_7FFFh)

Legacy support requires the ability to have a second graphics controller (monochrome) in the system. Accesses in the standard VGA range are forwarded to IGD, PCI Express, or the DMI Interface (depending on configuration bits). Since the monochrome adapter may be mapped to anyone of these devices, the (G)MCH must decode cycles in the MDA range (000B_0000h - 000B_7FFFh) and forward either to IGD, PCI Express, or the DMI Interface. This capability is controlled by a VGA steering bits and the legacy configuration bit (MDAP bit). In addition to the memory range B0000h to B7FFFh, the (G)MCH decodes IO cycles at 3B4h, 3B5h, 3B8h, 3B9h, 3BAh and 3BFh and forwards them to the either IGD, PCI-Express, and/or the DMI Interface.

PEG 16-bit VGA Decode

The *PCI to PCI Bridge Architecture Specification Revision 1.2*, it is required that 16-bit VGA decode be a feature.



3.1.3 Expansion Area (C_0000h-D_FFFFh)

This 128 KB ISA Expansion region (000C_0000h – 000D_FFFFh) is divided into eight 16 KB segments. Each segment can be assigned one of four Read/Write states: read-only, write-only, read/write, or disabled. Typically, these blocks are mapped through (G)MCH and are subtractive decoded to ISA space. Memory that is disabled is not remapped.

Non-snooped accesses from PCI Express or DMI to this region are always sent to DRAM.

Table 3-1. Expansion Area Memory Segments

Memory Segments	Attributes	Comments
0C0000h – 0C3FFFh	WE RE	Add-on BIOS
0C4000h – 0C7FFFh	WE RE	Add-on BIOS
0C8000h – 0CBFFFh	WE RE	Add-on BIOS
0CC000h – 0CFFFFh	WE RE	Add-on BIOS
0D0000h – 0D3FFFh	WE RE	Add-on BIOS
0D4000h – 0D7FFFh	WE RE	Add-on BIOS
0D8000h – 0DBFFFh	WE RE	Add-on BIOS
0DC000h – 0DFFFFh	WE RE	Add-on BIOS



3.1.4 Extended System BIOS Area (E_0000h-E_FFFFh)

This 64 KB area (000E_0000h – 000E_FFFFh) is divided into four 16 KB segments. Each segment can be assigned independent read and write attributes so it can be mapped either to main DRAM or to DMI Interface. Typically, this area is used for RAM or ROM. Memory segments that are disabled are not remapped elsewhere.

Non-snooped accesses from PCI Express or DMI to this region are always sent to DRAM.

Table 3-2. Extended System BIOS Area Memory Segments

Memory Segments	Attributes	Comments
0E0000h – 0E3FFFh	WE RE	BIOS Extension
0E4000h – 0E7FFFh	WE RE	BIOS Extension
0E8000h – 0EBFFFh	WE RE	BIOS Extension
0EC000h – 0EFFFFh	WE RE	BIOS Extension

3.1.5 System BIOS Area (F_0000h-F_FFFFh)

This area is a single 64 KB segment (000F_0000h – 000F_FFFFh). This segment can be assigned read and write attributes. It is by default (after reset) Read/Write disabled and cycles are forwarded to DMI Interface. By manipulating the Read/Write attributes, the (G)MCH can “shadow” BIOS into the main DRAM. When disabled, this segment is not remapped.

Non-snooped accesses from PCI Express or DMI to this region are always sent to DRAM.

Table 3-3. System BIOS Area Memory Segments

Memory Segments	Attributes	Comments
0F0000h – 0FFFFFFh	WE RE	BIOS Area

3.1.6 PAM Memory Area Details

The 13 sections from 768 KB to 1 MB comprise what is also known as the PAM Memory Area.

The (G)MCH does not handle IWB (Implicit Write-Back) cycles targeting DMI. Since all memory residing on DMI should be set as non-cacheable, there will normally not be IWB cycles targeting DMI. However, DMI becomes the default target for processor and DMI originated accesses to disabled segments of the PAM region. If the MTRRs covering the PAM regions are set to WB or RD it is possible to get IWB cycles targeting DMI. This may occur for processor originated cycles and for DMI originated cycles to disabled PAM regions.



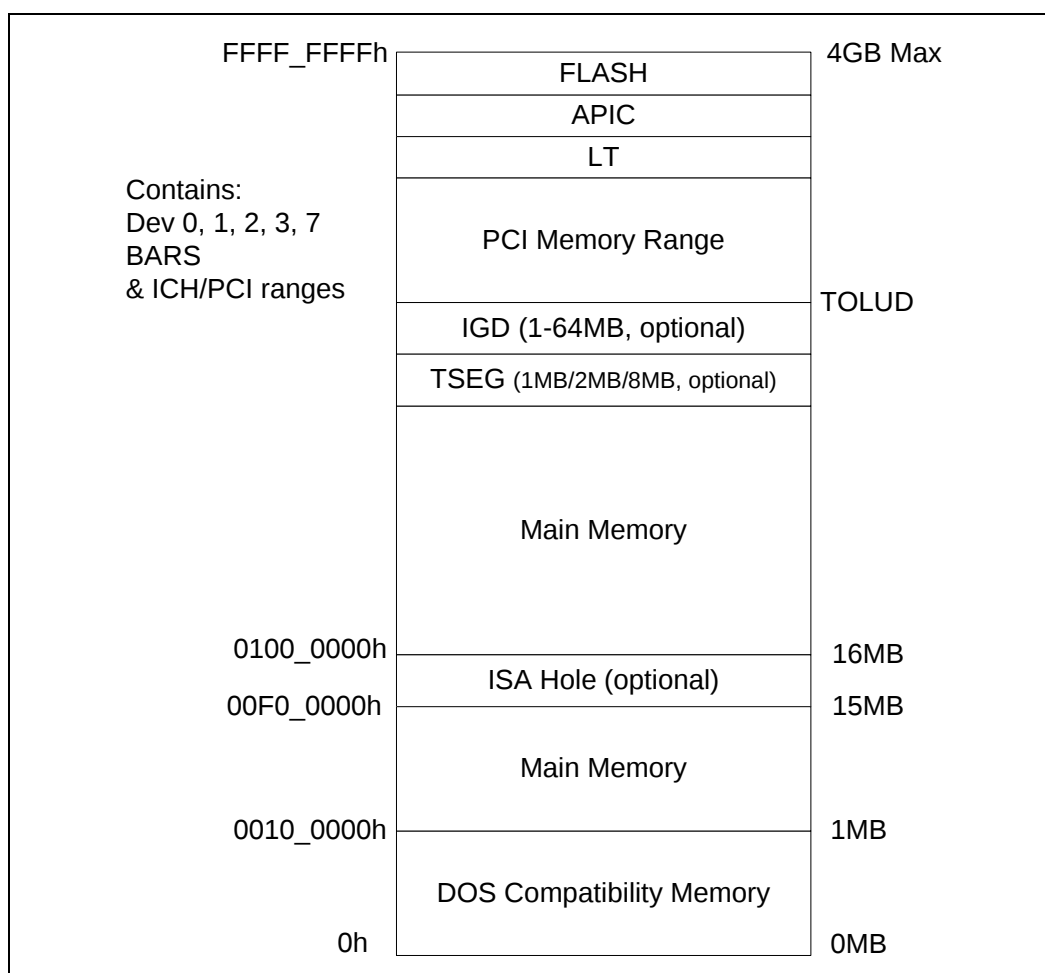
For example, say that a particular PAM region is set for “Read Disabled” and the MTRR associated with this region is set to WB. A DMI master generates a memory read targeting the PAM region. A snoop is generated on the FSB and the result is an IWB. Since the PAM region is “Read Disabled” the default target for the Memory Read becomes DMI. The IWB associated with this cycle will cause the (G)MCH to hang.

Non-snooped accesses from PCI Express or DMI to this region are always sent to DRAM.

3.2 Main Memory Address Range (1MB – TOLUD)

This address range extends from 1 MB to the top of Low Usable physical memory that is permitted to be accessible by the (G)MCH (as programmed in the TOLUD register). All accesses to addresses within this range will be forwarded by the (G)MCH to the DRAM unless it falls into the optional TSEG, optional ISA Hole, or optional IGD stolen VGA memory.

Figure 3-3. Main Memory Address Range





3.2.1 ISA Hole (15 MB-16 MB)

A hole can be created at 15 MB–16 MB as controlled by the fixed hole enable in Device 0 space. Accesses within this hole are forwarded to the DMI Interface. The range of physical DRAM memory disabled by opening the hole is not remapped to the top of the memory – that physical DRAM space is not accessible. This 15 MB–16 MB hole is an optionally enabled ISA hole.

Video accelerators originally used this hole. It is also used by validation and customer SV teams for some of their test cards. That is why it is being supported. There is no inherent BIOS request for the 15 MB–16 MB window.

3.2.2 TSEG

TSEG is optionally 1 MB, 2 MB, or 8 MB in size. TSEG is below IGD stolen memory, which is at the top of Low Usable physical memory (TOLUD). SMM-mode processor accesses to enabled TSEG access the physical DRAM at the same address. Non-processor originated accesses are not allowed to SMM space. PCI Express, DMI, and Internal Graphics originated cycle to enabled SMM space are handled as invalid cycle type with reads and writes to location 0 and byte enables turned off for writes. When the extended SMRAM space is enabled, processor accesses to the TSEG range without SMM attribute or without WB attribute are also forwarded to memory as invalid accesses. Non-SMM-mode Write Back cycles that target TSEG space are completed to DRAM for cache coherency. When SMM is enabled, the maximum amount of memory available to the system is equal to the amount of physical DRAM minus the value in the TSEG register which is fixed at 1 MB, 2 MB or 8 MB.

3.2.3 Pre-allocated Memory

Voids of physical addresses that are not accessible as general system memory and reside within system memory address range (< TOLUD) are created for SMM-mode, legacy VGA graphics compatibility, and graphics GTT stolen memory. **It is the responsibility of BIOS to properly initialize these regions.** Table 3-4 details the location and attributes of the regions. Enabling/Disabling these ranges are described in the (G)MCH Control Register Device 0 (GCC).

Table 3-4. Pre-allocated Memory Example for 64 MB DRAM, 1 MB VGA, 1 MB GTT stolen and 1 MB TSEG

Memory Segments	Attributes	Comments
0000_0000h – 03CF_FFFFh	R/W	Available System Memory 61 MB
03D0_0000h – 03DF_FFFFh	SMM Mode Only - Processor Reads	TSEG Address Range and Pre-allocated Memory
03E0_0000h – 03EF_FFFFh	R/W	Pre-allocated Graphics VGA memory. 1MB (or 4/8/16/32/64/128/256 MB) when IGD is enabled.
03F0_0000h – 03FF_FFFFh	R/W	Pre-allocated Graphics GTT stolen memory. 1 MB (or 2 MB) when IGD is enabled.

NOTES:

- References to IDG and graphics STOLEN memory is only for the 82G31 GMCH.



3.3 PCI Memory Address Range (TOLUD – 4 GB)

This address range, from the top of low usable DRAM (TOLUD) to 4 GB is normally mapped to the DMI Interface.

Device 0 exceptions are:

- Addresses decoded to the Express port registers (PXPEPBAR)
- Addresses decoded to the memory mapped range for internal (G)MCH registers (MCHBAR)
- Addresses decoded to the flat memory-mapped address spaced to access device configuration registers (PCIEXBAR)
- Addresses decoded to the registers associated with the Direct Media Interface (DMI) register memory range. (DMIBAR)

With PCI Express port, there are two exceptions to this rule:

- Addresses decoded to the PCI Express Memory Window defined by the MBASE1, MLIMIT1, registers are mapped to PCI Express.
- Addresses decoded to the PCI Express prefetchable Memory Window defined by the PMBASE1, PMLIMIT1, registers are mapped to PCI Express.

In integrated graphics configurations, there are exceptions to this rule:

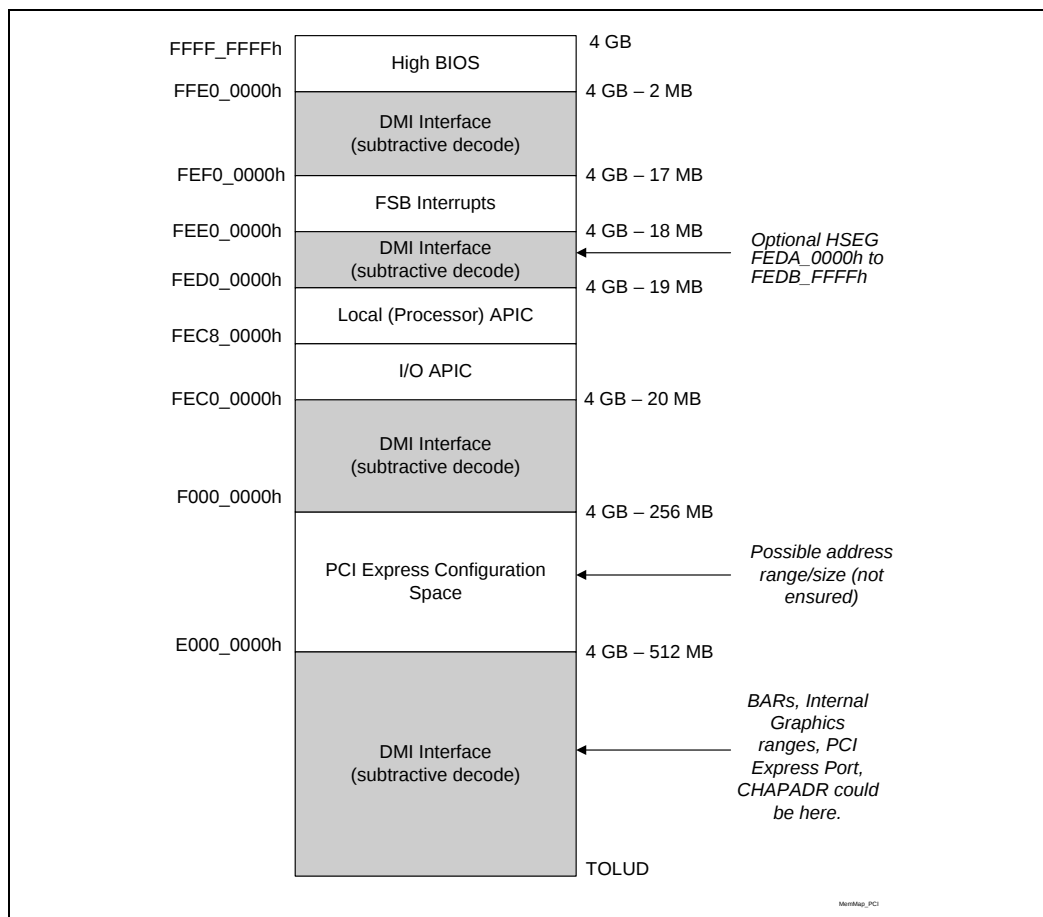
- Addresses decoded to the IGD registers and internal graphics instruction port (Function 0 MMADR, Function 1 MMADR)
- Addresses decode to the internal graphics translation window (GMADR)
- Addresses decode to the Internal graphics translation table (GTTADR)

Some of the MMIO Bars may be mapped to this range or to the range above TOLUD.

There are sub-ranges within the PCI Memory address range defined as APIC Configuration Space, FSB Interrupt Space, and High BIOS Address Range. The exceptions listed above for internal graphics and the PCI Express ports **MUST NOT** overlap with these ranges.



Figure 3-4. PCI Memory Address Range



3.3.1 APIC Configuration Space (FEC0_0000h–FECF_FFFFh)

This range is reserved for APIC configuration space. The I/O APIC(s) usually reside in the ICH portion of the chip-set, but may also exist as stand-alone components like PXH.

The IOAPIC spaces are used to communicate with IOAPIC interrupt controllers that may be populated in the system. Since it is difficult to relocate an interrupt controller using plug-and-play software, fixed address decode regions have been allocated for them. Processor accesses to the default IOAPIC region (FEC0_0000h to FEC7_FFFFh) are always forwarded to DMI.

The (G)MCH optionally supports additional I/O APICs behind the PCI Express “Graphics” port. When enabled via the PCI Express Configuration register (Device 1 Offset 200h), the PCI Express port will positively decode a subset of the APIC configuration space – specifically FEC8_0000h thru FECF_FFFFh. Memory request to this range would then be forwarded to the PCI Express port. This mode is intended for the entry Workstation/Server SKU of the (G)MCH, and would be disabled in typical Desktop systems. When disabled, any access within entire APIC Configuration space (FEC0_0000h to FECF_FFFFh) is forwarded to DMI.



3.3.2 HSEG (FEDA_0000h–FEDB_FFFFh)

This optional segment from FEDA_0000h to FEDB_FFFFh provides a remapping window to SMM Memory. It is sometimes called the High SMM memory space. SMM-mode processor accesses to the optionally enabled HSEG are remapped to 000A_0000h – 000B_FFFFh. Non-SMM-mode processor accesses to enabled HSEG are considered invalid and are terminated immediately on the FSB. The exceptions to this rule are Non-SMM-mode Write Back cycles which are remapped to SMM space to maintain cache coherency. PCI Express and DMI originated cycles to enabled SMM space are not allowed. Physical DRAM behind the HSEG transaction address is not remapped and is not accessible. All cacheline writes with WB attribute or Implicit write backs to the HSEG range are completed to DRAM like an SMM cycle.

3.3.3 FSB Interrupt Memory Space (FEE0_0000–FEEF_FFFF)

The FSB Interrupt space is the address used to deliver interrupts to the FSB. Any device on PCI Express or DMI may issue a Memory Write to 0FEEh_xxxxh. The (G)MCH will forward this Memory Write along with the data to the FSB as an Interrupt Message Transaction. The (G)MCH terminates the FSB transaction by providing the response and asserting HTRDYB. This Memory Write cycle does not go to DRAM.

3.3.4 High BIOS Area

The top 2 MB (FFE0_0000h – FFFF_FFFFh) of the PCI Memory Address Range is reserved for System BIOS (High BIOS), extended BIOS for PCI devices, and the A20 alias of the system BIOS. The processor begins execution from the High BIOS after reset. This region is mapped to DMI Interface so that the upper subset of this region aliases to 16 MB–256 KB range. The actual address space required for the BIOS is less than 2 MB but the minimum processor MTRR range for this region is 2 MB so that full 2 MB must be considered.

3.4 Main Memory Address Space (4 GB to TOUTD)

The (G)MCH supports 36 bit addressing. The maximum main memory size supported is 4 GB total DRAM memory. A hole between TOLUD and 4 GB occurs when main memory size approaches 4 GB or larger. As a result, TOM, and TOUTD registers and RECLAIMBASE/RECLAIMLIMIT registers become relevant.

The new reclaim configuration registers exist to reclaim lost main memory space. The greater than 32 bit reclaim handling will be handled similar to other (G)MCHs. Upstream read and write accesses above 36-bit addressing will be treated as invalid cycles by PEG and DMI.

Top of Memory

The “Top of Memory” (TOM) register reflects the total amount of populated physical memory. This is NOT necessarily the highest main memory address (holes may exist in main memory address map due to addresses allocated for memory mapped I/O above TOM).



The Top of Upper Usable Dram (TOUUD) register reflects the total amount of addressable DRAM. If reclaim is enabled, then it will reflect the reclaim limit. TOLUD register is restricted to 4 GB memory (A[31:20]). When reclaim is enabled, TOLUD must be 64 MB aligned, but when reclaim is disabled, TOLUD can be 1 MB aligned.

C1DRB3 cannot be used directly to determine the effective size of memory as the values programmed in the DRBs depend on the memory mode (stacked, interleaved). The Reclaim Base/Limit registers also can not be used because reclaim can be disabled. The C0DRB3 register is used for memory channel identification (channel 0 vs. channel 1) in the case of stacked memory.

3.4.1 Memory Re-claim Background

The following are examples of Memory Mapped IO devices are typically located below 4 GB:

- High BIOS
- HSEG
- TSEG
- Graphics stolen
- GTT stolen
- XAPIC
- Local APIC
- FSB Interrupts
- Mbase/Mlimit
- Memory Mapped IO space that supports only 32 B addressing

The (G)MCH provides the capability to re-claim the physical memory overlapped by the Memory Mapped IO logical address space. The (G)MCH re-maps physical memory from the Top of Low Memory (TOLUD) boundary up to the 4 GB boundary to an equivalent sized logical address range.

3.4.2 Memory Reclaiming

An incoming address (referred to as a logical address) is checked to see if it falls in the memory re-map window. The bottom of the re-map window is defined by the value in the RECLAIMBASE register. The top of the re-map window is defined by the value in the RECLAIMLIMIT register. An address that falls within this window is reclaimed to the physical memory starting at the address defined by the TOLUD register. The TOLUD register must be 64 MB aligned when RECLAIM is enabled, but can be 1 MB aligned when reclaim is disabled.

3.5 PCI Express* Configuration Address Space

There is a device 0 register, PCIEXBAR, which defines the base address for the configuration space associated with all devices and functions that are potentially a part of the PCI Express root complex hierarchy. The size of this range is programmable because the Intel G31/P31 Express chipset BIOS must assign this address range such that it will not conflict with any other address ranges.

See the configuration portion of this document for more details.



3.6 PCI Express* Graphics Attach (PEG)

The (G)MCH can be programmed to direct memory accesses to the PCI Express interface when addresses are within either of two ranges specified via registers in (G)MCH's Device 1 configuration space.

- The first range is controlled via the Memory Base Register (MBASE) and Memory Limit Register (MLIMIT) registers.
- The second range is controlled via the Pre-fetchable Memory Base (PMBASE) and Pre-fetchable Memory Limit (PMLIMIT) registers.

Conceptually, address decoding for each range follows the same basic concept. The top 12 bits of the respective Memory Base and Memory Limit registers correspond to address bits A[31:20] of a memory address. For the purpose of address decoding, the (G)MCH assumes that address bits A[19:0] of the memory base are zero and that address bits A[19:0] of the memory limit address are FFFFh. This forces each memory address range to be aligned to 1 MB boundary and to have a size granularity of 1 MB.

The (G)MCH positively decodes memory accesses to PCI Express memory address space as defined by the following equations:

$$\text{Memory_Base_Address} \leq \text{Address} \leq \text{Memory_Limit_Address}$$

$$\text{Prefetchable_Memory_Base_Address} \leq \text{Address} \leq \text{Prefetchable_Memory_Limit_Address}$$

The window size is programmed by the plug-and-play configuration software. The window size depends on the size of memory claimed by the PCI Express device. Normally these ranges will reside above the Top-of-Low Usable-DRAM and below High BIOS and APIC address ranges. They MUST reside above the top of low memory (TOLUD) if they reside below 4 GB and MUST reside above top of upper memory (TOUUD) if they reside above 4 GB or they will steal physical DRAM memory space.

It is essential to support a separate Pre-fetchable range in order to apply USWC attribute (from the processor point of view) to that range. The USWC attribute is used by the processor for write combining.

Note that the (G)MCH Device 1 memory range registers described above are used to allocate memory address space for any PCI Express devices sitting on PCI Express that require such a window.

The PCICMD1 register can override the routing of memory accesses to PCI Express. In other words, the memory access enable bit must be set in the device 1 PCICMD1 register to enable the memory base/limit and pre-fetchable base/limit windows.

For the Intel® G31/P31 Express Chipset, the upper PMUBASE1/PMULIMIT1 registers have been implemented for PCI Express Specification compliance. The G31/P31 Express Chipset locates MMIO space above 4 GB using these registers.



3.7 Graphics Memory Address Ranges (Intel® 82G31 GMCH Only)

The (G)MCH can be programmed to direct memory accesses to IGD when addresses are within any of three ranges specified via registers in the (G)MCH's Device 2 configuration space.

- The Memory Map Base Register (MMADR) is used to access graphics control registers.
- The Graphics Memory Aperture Base Register (GMADR) is used to access graphics memory allocated via the graphics translation table.
- The Graphics Translation Table Base Register (GTTADR) is used to access the translation table.

These ranges can reside above the Top-of-Low-DRAM and below High BIOS and APIC address ranges. They **MUST** reside above the top of memory (TOLUD) and below 4 GB so they do not steal any physical DRAM memory space.

GMADR is a Prefetchable range in order to apply USWC attribute (from the processor point of view) to that range. The USWC attribute is used by the processor for write combining.

3.8 System Management Mode (SMM)

System Management Mode uses main memory for System Management RAM (SMM RAM). The (G)MCH supports: Compatible SMRAM (C_SMRAM), High Segment (HSEG), and Top of Memory Segment (TSEG). System Management RAM space provides a memory area that is available for the SMI handlers and code and data storage. This memory resource is normally hidden from the operating system so that the processor has immediate access to this memory space upon entry to SMM. (G)MCH provides three SMRAM options:

- Below 1 MB option that supports compatible SMI handlers.
- Above 1 MB option that allows new SMI handlers to execute with write-back cacheable SMRAM.
- Optional TSEG area of 1 MB, 2 MB, or 8 MB in size. The TSEG area lies below IGD stolen memory.

The above 1 MB solutions require changes to compatible SMRAM handlers code to properly execute above 1 MB.

Note: DMI Interface and PCI Express masters are not allowed to access the SMM space.



3.8.1 SMM Space Definition

SMM space is defined by its **addressed** SMM space and its DRAM SMM space. The addressed SMM space is defined as the range of bus addresses used by the processor to access SMM space. DRAM SMM space is defined as the range of physical DRAM memory locations containing the SMM code. SMM space can be accessed at one of three transaction address ranges: Compatible, High and TSEG. The Compatible and TSEG SMM space is not remapped and therefore the addressed and DRAM SMM space is the same address range. Since the High SMM space is remapped the addressed and DRAM SMM space is a different address range. Note that the High DRAM space is the same as the Compatible Transaction Address space. Table 3-5 describes three unique address ranges.

Table 3-5. Pre-Allocated Memory Example for 64-MB DRAM, 1-MB VGA and 1-MB TSEG

SMM Space Enabled	Transaction Address Space	DRAM Space (DRAM)
Compatible	000A_0000h to 000B_FFFFh	000A_0000h to 000B_FFFFh
High	FEDA_0000h to FEDB_FFFFh	000A_0000h to 000B_FFFFh
TSEG	(TOLUD-STOLEN-TSEG) to TOLUD-STOLEN	(TOLUD-STOLEN-TSEG) to TOLUD-STOLEN

NOTES:

1. STOLEN memory is only for the 82G31 GMCH.

3.8.2 SMM Space Restrictions

If any of the following conditions are violated the results of SMM accesses are unpredictable and may cause the system to hang:

- The Compatible SMM space **must not** be set-up as cacheable.
- High or TSEG SMM transaction address space **must not** overlap address space assigned to system DRAM, or to any "PCI" devices (including DMI Interface, PCI-Express, and graphics devices). This is a BIOS responsibility.
- Both D_OPEN and D_CLOSE **must not** be set to 1 at the same time.
- When TSEG SMM space is enabled, the TSEG space **must not** be reported to the OS as available DRAM. This is a BIOS responsibility.
- Any address translated through the GMADR TLB must not target DRAM from A_0000-F_FFFFh.



3.8.3 SMM Space Combinations

When High SMM is enabled (G_SMFRAME=1 and H_SMRAM_EN=1) the Compatible SMM space is effectively disabled. Processor originated accesses to the Compatible SMM space are forwarded to PCI Express if VGAEN=1 (also depends on MDAP), otherwise they are forwarded to the DMI Interface. PCI Express and DMI Interface originated accesses are **never** allowed to access SMM space.

Table 3-6. SMM Space Table

Global Enable G_SMFRAME	High Enable H_SMRAM_EN	TSEG Enable TSEG_EN	Compatible (C) Range	High (H) Range	TSEG (T) Range
0	X	X	Disable	Disable	Disable
1	0	0	Enable	Disable	Disable
1	0	1	Enable	Disable	Enable
1	1	0	Disabled	Enable	Disable
1	1	1	Disabled	Enable	Enable

3.8.4 SMM Control Combinations

The G_SMFRAME bit provides a global enable for all SMM memory. The D_OPEN bit allows software to write to the SMM ranges without being in SMM mode. BIOS software can use this bit to initialize SMM code at power-up. The D_LCK bit limits the SMM range access to only SMM mode accesses. The D_CLS bit causes SMM (both CSEG and TSEG) data accesses to be forwarded to the DMI Interface or PCI Express. The SMM software can use this bit to write to video memory while running SMM code out of DRAM.

3.8.5 SMM Space Decode and Transaction Handling

Only the processor is allowed to access SMM space. PCI Express and DMI Interface originated transactions are not allowed to SMM space.

3.8.6 Processor WB Transaction to an Enabled SMM Address Space

Processor Writeback transactions (REQa[1]# = 0) to enabled SMM Address Space must be written to the associated SMM DRAM even though D_OPEN=0 and the transaction is not performed in SMM mode. This ensures SMM space cache coherency when cacheable extended SMM space is used.



3.8.7 SMM Access Through GTT TLB (Intel® 82G31 GMCH Only)

Accesses through GTT TLB address translation to enabled SMM DRAM space are not allowed. Writes will be routed to Memory address 000C_0000h with byte enables de-asserted and reads will be routed to Memory address 000C_0000h. If a GTT TLB translated address hits enabled SMM DRAM space, an error is recorded.

PCI Express and DMI Interface originated accesses are **never** allowed to access SMM space directly or through the GTT TLB address translation. If a GTT TLB translated address hits enabled SMM DRAM space, an error is recorded.

PCI Express and DMI Interface write accesses through GMADR range will be snooped. Assesses to GMADR linear range (defined via fence registers) are supported. PCI Express and DMI Interface tileY and tileX writes to GMADR are not supported. If, when translated, the resulting physical address is to enabled SMM DRAM space, the request will be remapped to address 000C_0000h with de-asserted byte enables.

PCI Express and DMI Interface read accesses to the GMADR range are not supported; therefore, there are no address translation concerns. PCI Express and DMI Interface reads to GMADR will be remapped to address 000C_0000h. The read will complete with UR (unsupported request) completion status.

GTT fetches are always decoded (at fetch time) to ensure not in SMM (actually, anything above base of TSEG or 640 KB – 1 MB). Thus, they will be invalid and go to address 000C_0000h, but that is not specific to PCI Express or DMI; it applies to processor or internal graphics engines. Also, since the GMADR snoop would not be directly to the SMM space, there would not be a writeback to SMM. In fact, the writeback would also be invalid (because it uses the same translation) and go to address 000C_0000h.

3.9 Memory Shadowing

Any block of memory that can be designated as read-only or write-only can be “shadowed” into (G)MCH DRAM memory. Typically this is done to allow ROM code to execute more rapidly out of main DRAM. ROM is used as a read-only during the copy process while DRAM at the same time is designated write-only. After copying, the DRAM is designated read-only so that ROM is shadowed. Processor bus transactions are routed accordingly.



3.10 I/O Address Space

The (G)MCH does not support the existence of any other I/O devices beside itself on the processor bus. The (G)MCH generates either DMI Interface or PCI Express bus cycles for all processor I/O accesses that it does not claim. The (G)MCH contains two internal registers in the processor I/O space: Configuration Address Register (CONFIG_ADDRESS) and the Configuration Data Register (CONFIG_DATA). These locations are used to implement the configuration space access mechanism.

The processor allows 64 K+3 bytes to be addressed within the I/O space. The (G)MCH propagates the processor I/O address without any translation on to the destination bus and therefore provides addressability for 64K+3 byte locations. Note that the upper 3 locations can be accessed only during I/O address wrap-around when processor bus HA16# address signal is asserted. HA16# is asserted on the processor bus when an I/O access is made to 4 bytes from address 0FFFDh, 0FFFEh, or 0FFFFh. HA16# is also asserted when an I/O access is made to 2 bytes from address 0FFFFh.

A set of I/O accesses (other than ones used for configuration space access) are consumed by the internal graphics device if it is enabled. The mechanisms for internal graphics I/O decode and the associated control is explained later.

The I/O accesses (other than ones used for configuration space access) are forwarded normally to the DMI Interface bus unless they fall within the PCI Express I/O address range as defined by the mechanisms explained below. I/O writes are NOT posted. Memory writes to ICH or PCI Express are posted. The PCICMD1 register can disable the routing of I/O cycles to the PCI Express.

The (G)MCH responds to I/O cycles initiated on PCI Express or DMI with an UR status. Upstream I/O cycles and configuration cycles should never occur. If one does occur, the request will route as a read to Memory address 000C_0000h so a completion is naturally generated (whether the original request was a read or write). The transaction will complete with an UR completion status.

For Intel processors, I/O reads that lie within 8-byte boundaries but cross 4-byte boundaries are issued from the processor as 1 transaction. The (G)MCH will break this into 2 separate transactions. I/O writes that lie within 8-byte boundaries but cross 4-byte boundaries are assumed to be split into 2 transactions by the processor.

3.10.1 PCI Express* I/O Address Mapping

The (G)MCH can be programmed to direct non-memory (I/O) accesses to the PCI Express bus interface when processor initiated I/O cycle addresses are within the PCI Express I/O address range. This range is controlled via the I/O Base Address (IOBASE) and I/O Limit Address (IOLIMIT) registers in (G)MCH Device 1 configuration space.

Address decoding for this range is based on the following concept. The top 4 bits of the respective I/O Base and I/O Limit registers correspond to address bits A[15:12] of an I/O address. For the purpose of address decoding, the (G)MCH assumes that lower 12 address bits A[11:0] of the I/O base are zero and that address bits A[11:0] of the I/O limit address are FFFh. This forces the I/O address range alignment to 4 KB boundary and produces a size granularity of 4 KB.



The (G)MCH positively decodes I/O accesses to PCI Express I/O address space as defined by the following equation:

$$\text{I/O_Base_Address} \leq \text{CPU I/O Cycle Address} \leq \text{I/O_Limit_Address}$$

The effective size of the range is programmed by the plug-and-play configuration software and it depends on the size of I/O space claimed by the PCI Express device.

The (G)MCH also forwards accesses to the Legacy VGA I/O ranges according to the settings in the Device 1 configuration registers BCTRL (VGA Enable) and PCICMD1 (IOAE1), unless a second adapter (monochrome) is present on the DMI Interface/PCI (or ISA). The presence of a second graphics adapter is determined by the MDAP configuration bit. When MDAP is set, the (G)MCH will decode legacy monochrome I/O ranges and forward them to the DMI Interface. The I/O ranges decoded for the monochrome adapter are 3B4h, 3B5h, 3B8h, 3B9h, 3Bah and 3BFh.

Note that the (G)MCH Device 1 I/O address range registers defined above are used for all I/O space allocation for any devices requiring such a window on PCI Express.

The PCICMD1 register can disable the routing of I/O cycles to PCI Express.

3.11 (G)MCH Decode Rules and Cross-Bridge Address Mapping

VGAA = 000A_0000 – 000A_FFFF

MDA = 000B_0000 – 000B_7FFF

VGAB = 000B_8000 – 000B_FFFF

MAINMEM = 0100_0000 to TOLUD

HIGHMEM = 4 GB to TOM

RECLAIMMEM = RECLAIMBASE to RECLAIMLIMIT

3.11.1 Legacy VGA and I/O Range Decode Rules

The legacy 128 KB VGA memory range 000A_0000h-000B_FFFFh can be mapped to IGD (Device 2 in 82G31 GMCH), to PCI Express (Device 1), and/or to the DMI Interface depending on the programming of the VGA steering bits. Priority for VGA mapping is constant in that the (G)MCH always decodes internally mapped devices first. Internal to the (G)MCH, decode precedence is always given to IGD. The (G)MCH always positively decodes internally mapped devices, namely the IGD and PCI-Express. Subsequent decoding of regions mapped to PCI Express or the DMI Interface depends on the Legacy VGA configurations bits (VGA Enable and MDAP).

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4 (G)MCH Register Description

The (G)MCH contains two sets of software accessible registers, accessed via the Host processor I/O address space: Control registers and internal configuration registers.

- Control registers are I/O mapped into the processor I/O space, which control access to PCI and PCI Express configuration space (see Section 4.5).
- Internal configuration registers residing within the (G)MCH are partitioned into three logical device register sets (“logical” since they reside within a single physical device). The first register set is dedicated to Host Bridge functionality (i.e., DRAM configuration, other chipset operating parameters and optional features). The second register block is dedicated to Host-PCI Express Bridge functions (controls PCI Express interface configurations and operating parameters). For the 82G31 GMCH, another register block is for the internal graphics functions.

The (G)MCH internal registers (I/O Mapped, Configuration and PCI Express Extended Configuration registers) are accessible by the Host processor. The registers that reside within the lower 256 bytes of each device can be accessed as Byte, Word (16 bit), or DWord (32 bit) quantities, with the exception of CONFIG_ADDRESS, which can only be accessed as a DWord. All multi-byte numeric fields use “little-endian” ordering (i.e., lower addresses contain the least significant parts of the field). Registers which reside in bytes 256 through 4095 of each device may only be accessed using memory mapped transactions in DWord (32 bit) quantities.

Some of the (G)MCH registers described in this section contain reserved bits. These bits are labeled “Reserved”. Software must deal correctly with fields that are reserved. On reads, software must use appropriate masks to extract the defined bits and not rely on reserved bits being any particular value. On writes, software must ensure that the values of reserved bit positions are preserved. That is, the values of reserved bit positions must first be read, merged with the new values for other bit positions and then written back. Note the software does not need to perform read, merge, and write operation for the Configuration Address Register.

In addition to reserved bits within a register, the (G)MCH contains address locations in the configuration space of the Host Bridge entity that are marked either “Reserved” or “Intel Reserved”. The (G)MCH responds to accesses to “Reserved” address locations by completing the host cycle. When a “Reserved” register location is read, a zero value is returned. (“Reserved” registers can be 8-, 16-, or 32 bits in size). Writes to “Reserved” registers have no effect on the (G)MCH. Registers that are marked as “Intel Reserved” must not be modified by system software. Writes to “Intel Reserved” registers may cause system failure. Reads from “Intel Reserved” registers may return a non-zero value.

Upon a Full Reset, the (G)MCH sets its entire set of internal configuration registers to predetermined default states. Some register values at reset are determined by external strapping options. The default state represents the minimum functionality feature set required to successfully bringing up the system. Hence, it does not represent the optimal system configuration. It is the responsibility of the system initialization software (usually BIOS) to properly determine the DRAM configurations, operating parameters and optional system features that are applicable, and to program the (G)MCH registers accordingly.



4.1 Register Terminology

The following table shows the register-related terminology that is used.

Item	Definition
RO	Read Only bit(s). Writes to these bits have no effect. This may be a status bit or a static value.
RO/S	Read Only / Sticky bit(s). Writes to these bits have no effect. These are status bits only. Bits are not returned to their default values by "warm" reset, but will be reset with a cold/complete reset (for PCI Express related bits a cold reset is "Power Good Reset" as defined in the PCI Express spec).
RS/WC	Read Set / Write Clear bit(s). The first time the bit is read with an enabled byte, it returns the value 0, but a side-effect of the read is that the value changes to 1. Any subsequent reads with enabled bytes return a 1 until a 1 is written to the bit. When the bit is read, but the byte is not enabled, the state of the bit does not change, and the value returned is irrelevant, but will match the state of the bit. When a 0 is written to the bit, there is no effect. When a 1 is written to the bit, its value becomes 0, until the next byte-enabled read. When the bit is written, but the byte is not enabled, there is no effect.
R/W	Read / Write bit(s). These bits can be read and written by software. Hardware may only change the state of this bit by reset.
R/WC	Read / Write Clear bit(s). These bits can be read. Internal events may set this bit. A software write of '1' clears (sets to '0') the corresponding bit(s) and a write of '0' has no effect.
R/WC/L	Read / Write Clear / Lockable bit(s). These bits can be read. Internal events may set this bit. A software write of '1' clears (sets to '0') the corresponding bit(s) and a write of '0' has no effect. Additionally there is a Key bit (which is marked R/W/K or R/W/L/K) that, when set, prohibits this bit field from being writeable (bit field becomes Read Only).
R/WC/S	Read / Write Clear / Sticky bit(s). These bits can be read. Internal events may set this bit. A software write of '1' clears (sets to '0') the corresponding bit(s) and a write of '0' has no effect. Bits are not cleared by "warm" reset, but will be reset with a cold/complete reset (for PCI Express related bits a cold reset is "Power Good Reset" as defined in the PCI Express spec).
R/W/B	Read / Write / Blind bit(s). These bits can be read and written by software. Additionally there is a selector bit which, when set, changes what may be read from these bits. The value written is always stored in a hidden register. When the selector bit indicates that the written value should not be read, some other status is read from this bit. When the selector bit indicates that the written value should be read, the value in the hidden register is read from this bit.
R/W/B/L	Read / Write / Blind / Lockable bit(s). These bits can be read and written by software. Additionally there is a selector bit which, when set, changes what may be read from these bits. The value written is always stored in a hidden register. When the selector bit indicates that the written value should not be read, some other status is read from this bit. When the selector bit indicates that the written value should be read, the value in the hidden register is read from this bit. Additionally there is a Key bit (which is marked R/W/K or R/W/L/K) that, when set, prohibits this bit field from being writeable (bit field becomes Read Only).



Item	Definition
R/W/K	Read / Write / Key bit(s). These bits can be read and written by software. Additionally this bit, when set, prohibits some other bit field(s) from being writeable (bit fields become Read Only).
R/W/L	Read / Write / Lockable bit(s). These bits can be read and written by software. Additionally there is a Key bit (which is marked R/W/K or R/W/L/K) that, when set, prohibits this bit field from being writeable (bit field becomes Read Only).
R/W/L/K	Read / Write / Lockable / Key bit(s). These bits can be read and written by software. Additionally this bit is a Key bit that, when set, prohibits this bit field and/or some other specified bit fields from being writeable (bit fields become Read Only).
R/W/S	Read / Write / Sticky bit(s). These bits can be read and written by software. Bits are not cleared by "warm" reset, but will be reset with a cold/complete reset (for PCI Express related bits a cold reset is "Power Good Reset" as defined in the PCI Express spec).
R/W/S/B	Read / Write / Sticky / Blind bit(s). These bits can be read and written by software. Additionally there is a selector bit which, when set, changes what may be read from these bits. The value written is always stored in a hidden register. When the selector bit indicates that the written value should not be read, some other status is read from this bit. When the selector bit indicates that the written value should be read, the value in the hidden register is read from this bit. Bits are not cleared by "warm" reset, but will be reset with a cold/complete reset (for PCI Express related bits a cold reset is "Power Good Reset" as defined in the PCI Express spec).
R/W/SC	Read / Write / Self Clear bit(s). These bits can be read and written by software. When the bit is '1', hardware may clear the bit to '0' based upon internal events, possibly sooner than any subsequent software read could retrieve a '1'.
R/W/SC/L	Read / Write / Self Clear / Lockable bit(s). These bits can be read and written by software. When the bit is '1', hardware may clear the bit to '0' based upon internal events, possibly sooner than any subsequent software read could retrieve a '1'. Additionally there is a bit (which is marked R/W/K or R/W/L/K) that, when set, prohibits this bit field from being writeable (bit field becomes Read Only).
R/VO	Write Once bit(s). Once written by software, bits with this attribute become Read Only. These bits can only be cleared by a Reset. If there are multiple R/VO fields within a DWORD, they should be written all at once (atomically) to avoid capturing an incorrect value.
W	Write Only. These bits may be written by software, but will always return zeros when read. They are used for write side-effects. Any data written to these registers cannot be retrieved.



4.2 Configuration Process and Registers

4.2.1 Platform Configuration Structure

The DMI physically connects the (G)MCH and the Intel ICH7; so, from a configuration standpoint, the DMI is logically PCI bus 0. As a result, all devices internal to the (G)MCH and the Intel ICH7 appear to be on PCI bus 0.

Note: The ICH7 internal LAN controller does not appear on bus 0 – it appears on the external PCI bus (whose number is configurable).

The system's primary PCI expansion bus is physically attached to the Intel ICH7 and, from a configuration perspective, appears to be a hierarchical PCI bus behind a PCI-to-PCI bridge and therefore has a programmable PCI Bus number. The PCI Express Graphics Attach appears to system software to be a real PCI bus behind a PCI-to-PCI bridge that is a device resident on PCI bus 0.

Note: A physical PCI bus 0 does not exist and that DMI and the internal devices in the (G)MCH and Intel ICH7 logically constitute PCI Bus 0 to configuration software.

The (G)MCH contains three PCI devices within a single physical component. The configuration registers for the three devices are mapped as devices residing on PCI bus 0.

- **Device 0: Host Bridge / DRAM Controller.** Logically this appears as a PCI device residing on PCI bus #0. Device 0 contains the standard PCI header registers, PCI Express base address register, DRAM control (including thermal/throttling control), configuration for the DMI, and other (G)MCH specific registers.
- **Device 1: Host-PCI Express Bridge.** Logically this appears as a "virtual" PCI-to-PCI bridge residing on PCI bus #0 and is compliant with PCI Express Specification rev 1.0. Device 1 contains the standard PCI-to-PCI bridge registers and the standard PCI Express/PCI configuration registers (including the PCI Express memory address mapping). It also contains Isochronous and Virtual Channel controls in the PCI Express extended configuration space.
- **Device 2: Internal Graphics Control (82G31 GMCH only).** Logically, this appears as a PCI device residing on PCI bus 0. Physically, device 2 contains the configuration registers for 3D, 2D, and display functions.



4.3 Configuration Mechanisms

The processor is the originator of configuration cycles so the FSB is the only interface in the platform where these mechanisms are used. Internal to the (G)MCH transactions received through both configuration mechanisms are translated to the same format.

4.3.1 Standard PCI Configuration Mechanism

The following is the mechanism for translating processor I/O bus cycles to configuration cycles.

The PCI specification defines a slot based "configuration space" that allows each device to contain up to 8 functions with each function containing up to 256 8-bit configuration registers. The PCI specification defines two bus cycles to access the PCI configuration space: Configuration Read and Configuration Write. Memory and I/O spaces are supported directly by the processor. Configuration space is supported by a mapping mechanism implemented within the (G)MCH.

The configuration access mechanism makes use of the CONFIG_ADDRESS Register (at I/O address 0CF8h through 0CFBh) and CONFIG_DATA Register (at I/O address 0CFCh through 0CFFh). To reference a configuration register a DW I/O write cycle is used to place a value into CONFIG_ADDRESS that specifies the PCI bus, the device on that bus, the function within the device and a specific configuration register of the device function being accessed. CONFIG_ADDRESS[31] must be 1 to enable a configuration cycle. CONFIG_DATA then becomes a window into the four bytes of configuration space specified by the contents of CONFIG_ADDRESS. Any read or write to CONFIG_DATA will result in the (G)MCH translating the CONFIG_ADDRESS into the appropriate configuration cycle.

The (G)MCH is responsible for translating and routing the processor's I/O accesses to the CONFIG_ADDRESS and CONFIG_DATA registers to internal (G)MCH configuration registers, DMI or PCI Express.

4.3.2 PCI Express* Enhanced Configuration Mechanism

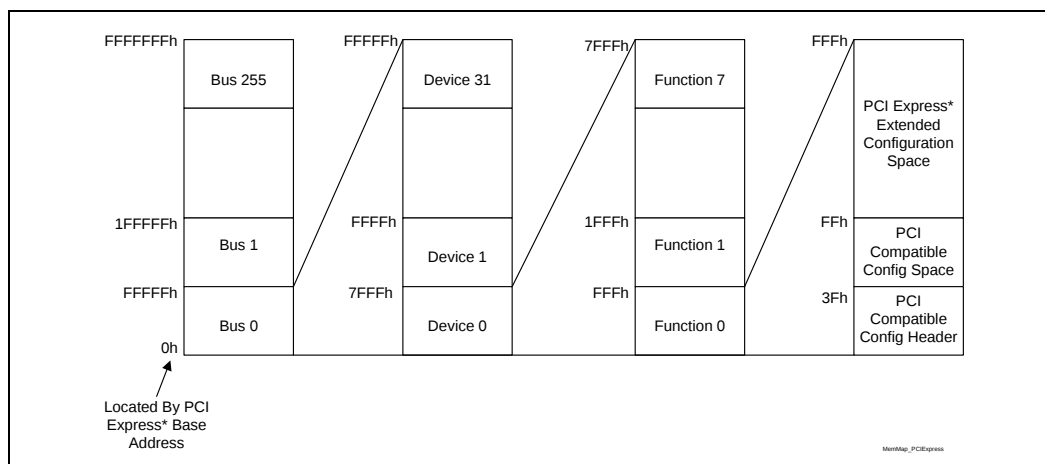
PCI Express extends the configuration space to 4096 bytes per device/function as compared to 256 bytes allowed by PCI Specification Revision 2.3. PCI Express configuration space is divided into a PCI 2.3 compatible region, which consists of the first 256B of a logical device's configuration space and a PCI Express extended region which consists of the remaining configuration space.

The PCI compatible region can be accessed using either the Standard PCI Configuration Mechanism or using the PCI Express Enhanced Configuration Mechanism described in this section. The extended configuration registers may only be accessed using the PCI Express Enhanced Configuration Mechanism. To maintain compatibility with PCI configuration addressing mechanisms, system software must access the extended configuration space using 32-bit operations (32-bit aligned) only. These 32-bit operations include byte enables allowing only appropriate bytes within the DWord to be accessed. Locked transactions to the PCI Express memory mapped configuration address space are not supported. All changes made using either access mechanism are equivalent.

The PCI Express Enhanced Configuration Mechanism utilizes a flat memory-mapped address space to access device configuration registers. This address space is reported by the system firmware to the operating system. There is a register, PCIEXBAR, that defines the base address for the block of addresses below 4 GB for the configuration space associated with busses, devices and functions that are potentially a part of the PCI Express root complex hierarchy. In the PCIEXBAR register there exists controls to limit the size of this reserved memory mapped space. 256 MB is the amount of address space required to reserve space for every bus, device, and function that could possibly exist. Options for 128 MB and 64 MB exist in order to free up those addresses for other uses. In these cases the number of busses and all of their associated devices and functions are limited to 128 or 64 busses respectively.

The PCI Express Configuration Transaction Header includes an additional 4 bits (ExtendedRegisterAddress[3:0]) between the Function Number and Register Address fields to provide indexing into the 4 KB of configuration space allocated to each potential device. For PCI Compatible Configuration Requests, the Extended Register Address field must be all zeros.

Figure 4-1. Memory Map to PCI Express* Device Configuration Space



Just the same as with PCI devices, each device is selected based on decoded address information that is provided as a part of the address portion of Configuration Request packets. A PCI Express device will decode all address information fields (bus, device, function and extended address numbers) to provide access to the correct register.

To access this space (steps 1, 2, 3 are done only once by BIOS),

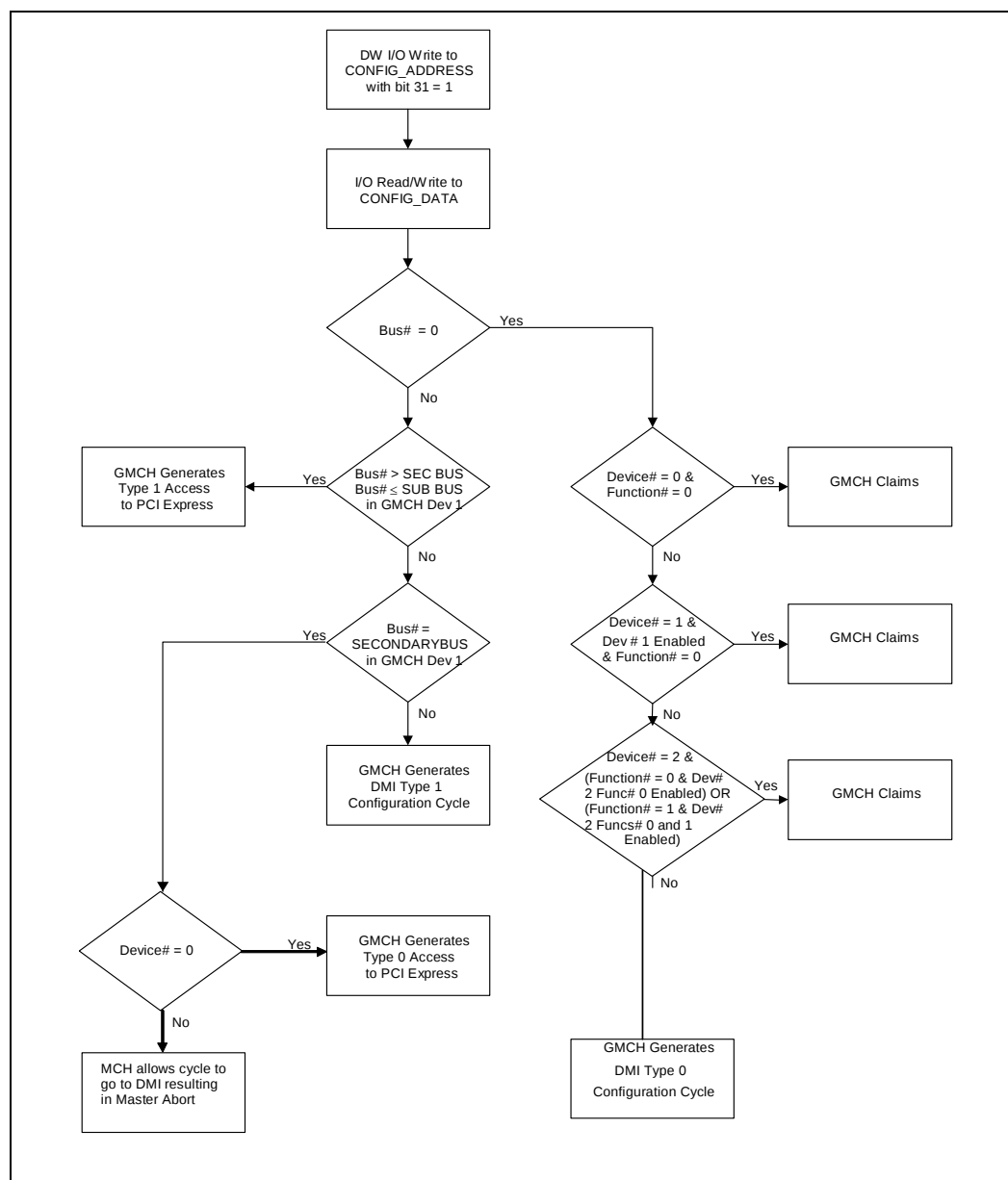
1. use the PCI compatible configuration mechanism to enable the PCI Express enhanced configuration mechanism by writing 1 to bit 0 of the PCIEXBAR register.
2. use the PCI compatible configuration mechanism to write an appropriate PCI Express base address into the PCIEXBAR register
3. calculate the host address of the register you wish to set using (PCI Express base + (bus number * 1 MB) + (device number * 32KB) + (function number * 4 KB) + (1 B * offset within the function) = host address)
4. use a memory write or memory read cycle to the calculated host address to write or read that register.



4.4 Routing Configuration Accesses

The (G)MCH supports two PCI related interfaces: DMI and PCI Express. The (G)MCH is responsible for routing PCI and PCI Express configuration cycles to the appropriate device that is an integrated part of the (G)MCH or to one of these two interfaces. Configuration cycles to the ICH7 internal devices and Primary PCI (including downstream devices) are routed to the ICH7 via DMI. Configuration cycles to both the PCI Express Graphics PCI compatibility configuration space and the PCI Express Graphics extended configuration space are routed to the PCI Express Graphics port device or associated link.

Figure 4-2. GMCH Configuration Cycle Flow Chart





4.4.1 Internal Device Configuration Accesses

The (G)MCH decodes the Bus Number (bits 23:16) and the Device Number fields of the CONFIG_ADDRESS register. If the Bus Number field of CONFIG_ADDRESS is 0 the configuration cycle is targeting a PCI Bus 0 device.

If the targeted PCI Bus #0 device exists in the (G)MCH and is not disabled, the configuration cycle is claimed by the appropriate device.

4.4.2 Bridge Related Configuration Accesses

Configuration accesses on PCI Express or DMI are PCI Express Configuration TLPs.

- Bus Number [7:0] is Header Byte 8 [7:0]
- Device Number [4:0] is Header Byte 9 [7:3]
- Function Number [2:0] is Header Byte 9 [2:0]

And special fields for this type of TLP:

- Extended Register Number [3:0] is Header Byte 10 [3:0]
- Register Number [5:0] is Header Byte 11 [7:2]

See the PCI Express specification for more information on both the PCI 2.3 compatible and PCI Express Enhanced Configuration Mechanism and transaction rules.

4.4.2.1 PCI Express* Configuration Accesses

When the Bus Number of a type 1 Standard PCI Configuration cycle or PCI Express Enhanced Configuration access matches the Device #1 Secondary Bus Number a PCI Express Type 0 Configuration TLP is generated on the PCI Express link targeting the device directly on the opposite side of the link. This should be Device #0 on the bus number assigned to the PCI Express link (likely Bus #1).

The device on other side of link must be Device #0. The (G)MCH will Master Abort any Type 0 Configuration access to a non-zero Device number. If there is to be more than one device on that side of the link there must be a bridge implemented in the downstream device.

When the Bus Number of a type 1 Standard PCI Configuration cycle or PCI Express Enhanced Configuration access is within the claimed range (between the upper bound of the bridge device's Subordinate Bus Number register and the lower bound of the bridge device's Secondary Bus Number register) but doesn't match the Device #1 Secondary Bus Number, a PCI Express Type 1 Configuration TLP is generated on the secondary side of the PCI Express link.

PCI Express Configuration Writes:

- Internally the host interface unit will translate writes to PCI Express extended configuration space to configuration writes on the backbone.
- Writes to extended space are posted on the FSB, but non-posted on the PCI Express or DMI (i.e.. translated to config writes)



4.4.2.2 DMI Configuration Accesses

Accesses to disabled (G)MCH internal devices, bus numbers not claimed by the Host-PCI Express bridge, or PCI Bus #0 devices not part of the (G)MCH will subtractively decode to the ICH7 and consequently be forwarded over the DMI via a PCI Express configuration TLP.

If the Bus Number is zero, the (G)MCH will generate a Type 0 Configuration Cycle TLP on DMI. If the Bus Number is non-zero, and falls outside the range claimed by the Host-PCI Express bridge, the (G)MCH will generate a Type 1 Configuration Cycle TLP on DMI.

The ICH7 routes configurations accesses in a manner similar to the (G)MCH. The ICH7 decodes the configuration TLP and generates a corresponding configuration access. Accesses targeting a device on PCI Bus #0 may be claimed by an internal device. The ICH7 compares the non-zero Bus Number with the Secondary Bus Number and Subordinate Bus Number registers of its P2P bridges to determine if the configuration access is meant for Primary PCI, or some other downstream PCI bus or PCI Express link.

Configuration accesses that are forwarded to the ICH7, but remain unclaimed by any device or bridge will result in a master abort.

4.5 I/O Mapped Registers

The (G)MCH contains two registers that reside in the processor I/O address space – the Configuration Address (CONFIG_ADDRESS) Register and the Configuration Data (CONFIG_DATA) Register. The Configuration Address Register enables/disables the configuration space and determines what portion of configuration space is visible through the Configuration Data window.

4.5.1 CONFIG_ADDRESS—Configuration Address Register

I/O Address:	0CF8h Accessed as a DW
Default Value:	00000000h
Access:	R/W
Size:	32 bits

CONFIG_ADDRESS is a 32-bit register that can be accessed only as a DW. A Byte or Word reference will "pass through" the Configuration Address Register and DMI onto the Primary PCI bus as an I/O cycle. The CONFIG_ADDRESS register contains the Bus Number, Device Number, Function Number, and Register Number for which a subsequent configuration access is intended.

Bit	Access & Default	Description
31	RW 0b	Configuration Enable (CFGE). 0 = Disable 1 = Enable
30:24		Reserved



Bit	Access & Default	Description
23:16	RW 00h	Bus Number. If the Bus Number is programmed to 00h the target of the Configuration Cycle is a PCI Bus 0 agent. If this is the case and the (G)MCH is not the target (i.e., the device number is ≥ 2), then a DMI Type 0 Configuration Cycle is generated. If the Bus Number is non-zero, and does not fall within the ranges enumerated by device 1's Secondary Bus Number or Subordinate Bus Number Register, then a DMI Type 1 Configuration Cycle is generated. If the Bus Number is non-zero and matches the value programmed into the Secondary Bus Number Register of device 1, a Type 0 PCI configuration cycle will be generated on PCI Express-G. If the Bus Number is non-zero, greater than the value in the Secondary Bus Number register of device 1 and less than or equal to the value programmed into the Subordinate Bus Number Register of device 1 a Type 1 PCI configuration cycle will be generated on PCI Express-G. This field is mapped to byte 8 [7:0] of the request header format during PCI Express Configuration cycles and A[23:16] during the DMI Type 1 configuration cycles.
15:11	RW 00h	Device Number. This field selects one agent on the PCI bus selected by the Bus Number. When the Bus Number field is "00" the (G)MCH decodes the Device Number field. The (G)MCH is always Device Number 0 for the Host bridge entity, Device Number 1 for the Host-PCI Express entity. Therefore, when the Bus Number = 0 and the Device Number equals 0, 1, or 2 the internal (G)MCH devices are selected. This field is mapped to byte 6 [7:3] of the request header format during PCI Express Configuration cycles and A [15:11] during the DMI configuration cycles.
10:8	RW 000b	Function Number. This field allows the configuration registers of a particular function in a multi-function device to be accessed. The (G)MCH ignores configuration cycles to its internal devices if the function number is not equal to 0 or 1. This field is mapped to byte 6 [2:0] of the request header format during PCI Express Configuration cycles and A[10:8] during the DMI configuration cycles.
7:2	RW 00h	Register Number. This field selects one register within a particular Bus, Device, and Function as specified by the other fields in the Configuration Address Register. This field is mapped to byte 7 [7:2] of the request header format during PCI Express Configuration cycles and A[7:2] during the DMI Configuration cycles.
1:0		Reserved



4.5.2 CONFIG_DATA—Configuration Data Register

I/O Address: 0CFCh
Default Value: 00000000h
Access: R/W
Size: 32 bits

CONFIG_DATA is a 32-bit read/write window into configuration space. The portion of configuration space that is referenced by CONFIG_DATA is determined by the contents of CONFIG_ADDRESS.

Bit	Access & Default	Description
31:0	R/W 0000 0000 h	Configuration Data Window (CDW) If bit 31 of CONFIG_ADDRESS is 1, any I/O access to the CONFIG_DATA register will produce a configuration transaction using the contents of CONFIG_ADDRESS to determine the bus, device, function, and offset of the register to be accessed.





5 DRAM Controller Registers (D0:F0)

The DRAM Controller registers are in Device 0 (D0), Function 0 (F0).

5.1 DRAM Controller (D0:F0)

Warning: Address locations that are not listed are considered Intel Reserved registers locations. Reads to Reserved registers may return non-zero values. Writes to reserved locations may cause system failures.

All registers that are defined in the PCI 2.3 specification, but are not necessary or implemented in this component are simply not included in this document. The reserved/unimplemented space in the PCI configuration header space is not documented as such in this summary.

Table 5-1. DRAM Controller Register Address Map (D0:F0)

Address Offset	Register Symbol	Register Name	Default Value	Access
00–01h	VID	Vendor Identification	8086h	RO
02–03h	DID	Device Identification	29C0h	RO
04–05h	PCICMD	PCI Command	0006h	RO, RW
06–07h	PCISTS	PCI Status	0090h	RWC, RO
08h	RID	Revision Identification	See register description	RO
09–0Bh	CC	Class Code	060000h	RO
0Dh	MLT	Master Latency Timer	00h	RO
0Eh	HDR	Header Type	00h	RO
2C–2Dh	SVID	Subsystem Vendor Identification	0000h	RWO
2E–2Fh	SID	Subsystem Identification	0000h	RWO
34h	CAPPTR	Capabilities Pointer	E0h	RO
40–47h	PXPEPBAR	PCI Express Port Base Address	0000000000 000000h	RW, RO
48–4Fh	MCHBAR	(G)MCH Memory Mapped Register Range Base	0000000000 000000h	RW, RO
52–53h	GGC	GMCH Graphics Control Register	0030h	RO, RW
54–57h	DEVEN	Device Enable	000003DBh	RO, RW



DRAM Controller Registers (D0:F0)

Address Offset	Register Symbol	Register Name	Default Value	Access
60–67h	PCIEXBAR	PCI Express Register Range Base Address	00000000E000000h	RO, RW/L, RW/L/K
68–6Fh	DMIBAR	Root Complex Register Range Base Address	000000000000000h	RO, RW
90h	PAM0	Programmable Attribute Map 0	00h	RO, RW
91h	PAM1	Programmable Attribute Map 1	00h	RO, RW
92h	PAM2	Programmable Attribute Map 2	00h	RO, RW
93h	PAM3	Programmable Attribute Map 3	00h	RO, RW
94h	PAM4	Programmable Attribute Map 4	00h	RO, RW
95h	PAM5	Programmable Attribute Map 5	00h	RO, RW
96h	PAM6	Programmable Attribute Map 6	00h	RO, RW
97h	LAC	Legacy Access Control	00h	RW/L, RO, RW
98–99h	REMAPBASE	Remap Base Address Register	03FFh	RO, RW
9A–9Bh	REMAPLIMIT	Remap Limit Address Register	0000h	RO, RW
9Dh	SMRAM	System Management RAM Control	02h	RO, RW/L, RW, RW/L/K
9Eh	ESMRAMC	Extended System Management RAM Control	38h	RW/L, RWC, RO
A0–A1h	TOM	Top of Memory	0001h	RO, RW
A2–A3h	TOUUD	Top of Upper Usable Dram	0000h	RW
A4–A7h	GBSM	Graphics Base of Stolen Memory	00000000h	RW/L, RO
A8–ABh	BGSM	Base of GTT stolen Memory	00000000h	RW/L, RO
AC–AFh	TSEGMB	TSEG Memory Base	00000000h	RW/L, RO
B0–B1h	TOLUD	Top of Low Usable DRAM	0010h	RW/L RO
C8–C9h	ERRSTS	Error Status	0000h	RO, RWC/S
CA–CBh	ERRCMD	Error Command	0000h	RO, RW
CC–CDh	SMICMD	SMI Command	0000h	RO, RW
DC–DFh	SKPD	Scratchpad Data	00000000h	RW
E0–EAh	CAPID0	Capability Identifier	0000010000000010B0009h	RO



5.1.1 VID—Vendor Identification

B/D/F/Type: 0/0/0/PCI
 Address Offset: 0–1h
 Default Value: 8086h
 Access: RO
 Size: 16 bits

This register combined with the Device Identification register uniquely identifies any PCI device.

Bit	Access & Default	Description
15:0	RO 8086h	Vendor Identification Number (VID): PCI standard identification for Intel.

5.1.2 DID—Device Identification

B/D/F/Type: 0/0/0/PCI
 Address Offset: 02–03h
 Default Value: See table below
 Access: RO
 Size: 16 bits

This register combined with the Vendor Identification register uniquely identifies any PCI device.

Bit	Access & Default	Description
15:0	RO 29C0h	Device Identification Number (DID): 29C0h = Intel® 82G31/82P31 (G)MCH



5.1.3 PCICMD—PCI Command

B/D/F/Type: 0/0/0/PCI
 Address Offset: 4–5h
 Default Value: 0006h
 Access: RO, RW
 Size: 16 bits

Since (G)MCH Device 0 does not physically reside on PCI_A many of the bits are not implemented.

Bit	Access & Default	Description
15:10	RO 00h	Reserved
9	RO 0b	Fast Back-to-Back Enable (FB2B): This bit controls whether or not the master can do fast back-to-back write. Since device 0 is strictly a target, this bit is not implemented and is hardwired to 0.
8	RW 0b	SERR Enable (SERRE): This bit is a global enable bit for Device 0 SERR messaging. The (G)MCH does not have an SERR signal. The (G)MCH communicates the SERR condition by sending an SERR message over DMI to the ICH. 1 = The (G)MCH is enabled to generate SERR messages over DMI for specific Device 0 error conditions that are individually enabled in the ERRCMD and DMIUEMSK registers. The error status is reported in the ERRSTS, PCISTS, and DMIUEST registers. 0 = The SERR message is not generated by the (G)MCH for Device 0. Note that this bit only controls SERR messaging for the Device 0. Device 1 has its own SERRE bits to control error reporting for error conditions occurring in that device. The control bits are used in a logical OR manner to enable the SERR DMI message mechanism.
7	RO 0b	Address/Data Stepping Enable (ADSTEP): Address/data stepping is not implemented in the (G)MCH, and this bit is hardwired to 0.
6	RW 0b	Parity Error Enable (PERRE): This bit controls whether or not the Master Data Parity Error bit in the PCI Status register can be set. 0 = Master Data Parity Error bit in PCI Status register can NOT be set. 1 = Master Data Parity Error bit in PCI Status register CAN be set.
5	RO 0b	VGA Palette Snoop Enable (VGASNOOP): The (G)MCH does not implement this bit and it is hardwired to a 0.
4	RO 0b	Memory Write and Invalidate Enable (MWIE): The (G)MCH will never issue memory write and invalidate commands. This bit is therefore hardwired to 0.
3	RO 0b	Special Cycle Enable (SCE): The (G)MCH does not implement this bit and it is hardwired to a 0. Writes to this bit position have no effect.
2	RO 1b	Bus Master Enable (BME): The (G)MCH is always enabled as a master on the backbone. This bit is hardwired to a 1.
1	RO 1b	Memory Access Enable (MAE): The (G)MCH always allows access to main memory. This bit is not implemented and is hardwired to 1.
0	RO 0b	I/O Access Enable (IOAE): This bit is not implemented in the (G)MCH and is hardwired to a 0.



5.1.4 PCISTS—PCI Status

B/D/F/Type: 0/0/0/PCI
 Address Offset: 6–7h
 Default Value: 0090h
 Access: RWC, RO
 Size: 16 bits

This status register reports the occurrence of error events on Device 0's PCI interface. Since the (G)MCH Device 0 does not physically reside on PCI_A many of the bits are not implemented.

Bit	Access & Default	Description
15	RWC 0b	Detected Parity Error (DPE): 1 = Device received a Poisoned TLP.
14	RWC 0b	Signaled System Error (SSE): Software clears this bit by writing a 1 to it. 1 = The (G)MCH Device 0 generated a SERR message over DMI for any enabled Device 0 error condition. Device 0 error conditions are enabled in the PCICMD, ERRCMD, and DMIUEMSK registers. Device 0 error flags are read/reset from the PCISTS, ERRSTS, or DMIUEST registers.
13	RWC 0b	Received Master Abort Status (RMAS): Software clears this bit by writing a 1 to it. 1 = (G)MCH generated a DMI request that receives an Unsupported Request completion packet.
12	RWC 0b	Received Target Abort Status (RTAS): Software clears this bit by writing a 1 to it. 1 = (G)MCH generated a DMI request that receives a Completer Abort completion packet.
11	RO 0b	Signaled Target Abort Status (STAS): The (G)MCH will not generate a Target Abort DMI completion packet or Special Cycle. This bit is not implemented in the (G)MCH and is hardwired to a 0.
10:9	RO 00b	DEVSEL Timing (DEVT): These bits are hardwired to "00". Writes to these bit positions have no affect. Device 0 does not physically connect to PCI_A. These bits are set to "00" (fast decode) so that optimum DEVSEL timing for PCI_A is not limited by the (G)MCH.
8	RWC 0b	Master Data Parity Error Detected (DPD): 1 = This bit is set when DMI received a Poisoned completion from the ICH. NOTE: This bit can only be set when the Parity Error Enable bit in the PCI Command register is set.
7	RO 1b	Fast Back-to-Back (FB2B): This bit is hardwired to 1. Device 0 does not physically connect to PCI_A. This bit is set to 1 (indicating fast back-to-back capability) so that the optimum setting for PCI_A is not limited by the (G)MCH.



Bit	Access & Default	Description
6	RO 0b	Reserved
5	RO 0b	66 MHz Capable: Does not apply to PCI Express. Hardwired to 0.
4	RO 1b	Capability List (CLIST): This bit is hardwired to 1 to indicate to the configuration software that this device/function implements a list of new capabilities. A list of new capabilities is accessed via register CAPPTR at configuration address offset 34h. Register CAPPTR contains an offset pointing to the start address within configuration space of this device where the Capability Identification register resides.
3:0	RO 0h	Reserved

5.1.5 RID—Revision Identification

B/D/F/Type: 0/0/0/PCI
Address Offset: 8h
Default Value: See register table below
Access: RO
Size: 8 bits

This register contains the revision number of the (G)MCH Device #0. These bits are read only and writes to this register have no effect.

Bit	Access & Default	Description
7:0	RO 00h	Revision Identification Number (RID): This is an 8-bit value that indicates the revision identification number for the (G)MCH Device 0. Refer to the <i>Intel® G31/P31 Express Chipset Family Specification Update</i> for the value of the Revision ID register.



5.1.6 CC—Class Code

B/D/F/Type: 0/0/0/PCI
 Address Offset: 09–0Bh
 Default Value: 060000h
 Access: RO
 Size: 24 bits

This register identifies the basic function of the device, a more specific sub-class, and a register-specific programming interface.

Bit	Access & Default	Description
23:16	RO 06h	Base Class Code (BCC): This is an 8-bit value that indicates the base class code for the (G)MCH. 06h = Bridge device.
15:8	RO 00h	Sub-Class Code (SUBCC): This is an 8-bit value that indicates the category of Bridge into which the (G)MCH falls. 00h = Host Bridge.
7:0	RO 00h	Programming Interface (PI): This is an 8-bit value that indicates the programming interface of this device. This value does not specify a particular register set layout and provides no practical use for this device.

5.1.7 MLT—Master Latency Timer

B/D/F/Type: 0/0/0/PCI
 Address Offset: 0Dh
 Default Value: 00h
 Access: RO
 Size: 8 bits

Device 0 in the (G)MCH is not a PCI master. Therefore this register is not implemented.

Bit	Access & Default	Description
7:0	RO 00h	Reserved



5.1.8 HDR—Header Type

B/D/F/Type: 0/0/0/PCI
Address Offset: Eh
Default Value: 00h
Access: RO
Size: 8 bits

This register identifies the header layout of the configuration space. No physical register exists at this location.

Bit	Access & Default	Description
7:0	RO 00h	PCI Header (HDR): This field always returns 0 to indicate that the (G)MCH is a single function device with standard header layout. Reads and writes to this location have no effect.

5.1.9 SVID—Subsystem Vendor Identification

B/D/F/Type: 0/0/0/PCI
Address Offset: 2C–2Dh
Default Value: 0000h
Access: RWO
Size: 16 bits

This value is used to identify the vendor of the subsystem.

Bit	Access & Default	Description
15:0	RWO 0000h	Subsystem Vendor ID (SUBVID): This field should be programmed during boot-up to indicate the vendor of the system board. After it has been written once, it becomes read only.

5.1.10 SID—Subsystem Identification

B/D/F/Type: 0/0/0/PCI
Address Offset: 2E–2Fh
Default Value: 0000h
Access: RWO
Size: 16 bits

This value is used to identify a particular subsystem.

Bit	Access & Default	Description
15:0	RWO 0000h	Subsystem ID (SUBID): This field should be programmed during BIOS initialization. After it has been written once, it becomes read only.



5.1.11 CAPPTR—Capabilities Pointer

B/D/F/Type:	0/0/0/PCI
Address Offset:	34h
Default Value:	E0h
Access:	RO
Size:	8 bits

The CAPPTR provides the offset that is the pointer to the location of the first device capability in the capability list.

Bit	Access & Default	Description
7:0	RO E0h	Capabilities Pointer (CAPPTR): Pointer to the offset of the first capability ID register block. In this case the first capability is the product-specific Capability Identifier (CAPID0).

5.1.12 PXPEPBAR—PCI Express* Egress Port Base Address

B/D/F/Type:	0/0/0/PCI
Address Offset:	40–47h
Default Value:	0000000000000000h
Access:	RW, RO
Size:	64 bits

This is the base address for the PCI Express Egress Port MMIO Configuration space. There is no physical memory within this 4 KB window that can be addressed. The 4 KB reserved by this register does not alias to any PCI 2.3 compliant memory mapped space. On reset, the Egress port MMIO configuration space is disabled and must be enabled by writing a 1 to PXPEPBAREN [Dev 0, offset 40h, bit 0]

Bit	Access & Default	Description
63:36	RO 0000000h	Reserved
35:12	RW 000000h	PCI Express Egress Port MMIO Base Address (PXPEPBAR): This field corresponds to bits 35:12 of the base address PCI Express Egress Port MMIO configuration space. BIOS will program this register resulting in a base address for a 4 KB block of contiguous memory address space. This register ensures that a naturally aligned 4 KB space is allocated within the first 64 GB of addressable memory space. System Software uses this base address to program the (G)MCH MMIO register set.
11:1	RO 000h	Reserved
0	RW 0b	PXPEPBAR Enable (PXPEPBAREN): 0 = PXPEPBAR is disabled and does not claim any memory 1 = PXPEPBAR memory mapped accesses are claimed and decoded appropriately



5.1.13 MCHBAR—(G)MCH Memory Mapped Register Range Base

B/D/F/Type: 0/0/0/PCI
Address Offset: 48–4Fh
Default Value: 0000000000000000h
Access: RW, RO
Size: 64 bits

This is the base address for the (G)MCH Memory Mapped Configuration space. There is no physical memory within this 16 KB window that can be addressed. The 16 KB reserved by this register does not alias to any PCI 2.3 compliant memory mapped space. On reset, the (G)MCH MMIO Memory Mapped Configuration space is disabled and must be enabled by writing a 1 to MCHBAREN [Dev 0, offset 48h, bit 0]

Bit	Access & Default	Description
63:36	RO 0000000h	Reserved
35:14	RW 000000h	GMCH Memory Mapped Base Address (MCHBAR): This field corresponds to bits 35:14 of the base address (G)MCH Memory Mapped configuration space. BIOS will program this register resulting in a base address for a 16 KB block of contiguous memory address space. This register ensures that a naturally aligned 16 KB space is allocated. System Software uses this base address to program the (G)MCH Memory Mapped register set.
13:1	RO 0000h	Reserved
0	RW 0b	MCHBAR Enable (MCHBAREN): 0 = MCHBAR is disabled and does not claim any memory 1 = MCHBAR memory mapped accesses are claimed and decoded appropriately

5.1.14 GGC—GMCH Graphics Control Register (Intel® 82G31 GMCH Only)

B/D/F/Type: 0/0/0/PCI
Address Offset: 52–53h
Default Value: 0030h
Access: RO, RW
Size: 16 bits

Bit	Access & Default	Description
15:10	RO 00h	Reserved



Bit	Access & Default	Description
9:8	RW 0h	GTT Graphics Memory Size (GGMS): This field is used to select the amount of main memory that is pre-allocated to support the Internal Graphics Translation Table. The BIOS ensures that memory is pre-allocated only when Internal graphics is enabled. 00 = No memory pre-allocated. GTT cycles (Memory and I/O) are not claimed. 01 = 1 MB of memory pre-allocated for GTT. 10 = Reserved 11 = Reserved Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set.
7:4	RW 0011b	Graphics Mode Select (GMS): This field is used to select the amount of Main Memory that is pre-allocated to support the Internal Graphics device in VGA (non-linear) and Native (linear) modes. The BIOS ensures that memory is pre-allocated only when Internal graphics is enabled. 0000 = No memory pre-allocated. Device 2 (IGD) does not claim VGA cycles (Memory and I/O), and the Sub-Class Code field within Device 2 function 0 Class Code register is 80h. 0001 = DVMT (UMA) mode, 1 MB of memory pre-allocated for frame buffer. 0010 = DVMT (UMA) mode, 4 MB of memory pre-allocated for frame buffer. 0011 = DVMT (UMA) mode, 8 MB of memory pre-allocated for frame buffer. 0100 = DVMT (UMA) mode, 16 MB of memory pre-allocated for frame buffer. 0101 = DVMT (UMA) mode, 32 MB of memory pre-allocated for frame buffer. 0110 = DVMT (UMA) mode, 48 MB of memory pre-allocated for frame buffer. 0111 = DVMT (UMA) mode, 64 MB of memory pre-allocated for frame buffer. 1000 = DVMT (UMA) mode, 128 MB of memory pre-allocated for frame buffer. 1001 = DVMT (UMA) mode, 256 MB of memory pre-allocated for frame buffer. Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set. BIOS Requirement: BIOS must not set this field to 000 if IVD (bit 1 of this register) is 0.
3:2	RO 00b	Reserved



Bit	Access & Default	Description
1	RW 0b	IGD VGA Disable (IVD): 0 = Enable. Device 2 (IGD) claims VGA memory and I/O cycles, the Sub-Class Code within Device 2 Class Code register is 00h. 1 = Disable. Device 2 (IGD) does not claim VGA cycles (Memory and I/O), and the Sub-Class Code field within Device 2 function 0 Class Code register is 80h. BIOS Requirement: BIOS must not set this bit to 0 if the GMS field (bits 6:4 of this register) pre-allocates no memory. This bit MUST be set to 1 if Device 2 is disabled either via a fuse or fuse override (CAPID0[46] = 1) or via a register (DEVEN[3] = 0).
0	RO 0b	Reserved

5.1.15 DEVEN—Device Enable

B/D/F/Type: 0/0/0/PCI
 Address Offset: 54–57h
 Default Value: 000003DBh
 Access: RO, RW
 Size: 32 bits

This register allows for enabling/disabling of PCI devices and functions that are within the (G)MCH.

Bit	Access & Default	Description
31:10	RO 0s	Reserved
9:6	RO 1s	Reserved
5	RO 0b	Reserved
4	RW 1b	82G31 GMCH Internal Graphics Engine Function 1 (D2F1EN): 0 = Bus 0, Device 2, Function 1 is disabled and hidden 1 = Bus 0, Device 2, Function 1 is enabled and visible If Device 2, Function 0 is disabled and hidden, then Device 2, Function 1 is also disabled and hidden independent of the state of this bit. If this component is not capable of Dual Independent Display (CAPID0[78] = 1), then this bit is hardwired to 0b to hide Device 2, Function 1. 82P31 MCH Reserved



Bit	Access & Default	Description
3	RW 1b	82G31 GMCH Internal Graphics Engine Function 0 (D2F0EN): 0 = Bus 0, Device 2, Function 0 is disabled and hidden 1 = Bus 0, Device 2, Function 0 is enabled and visible If this GMCH does not have internal graphics capability (CAPID0[46] = 1), then Device 2, Function 0 is disabled and hidden independent of the state of this bit. 82P31 MCH Reserved
2	RO 0b	Reserved
1	RW 1b	PCI Express Port (D1EN): 0 = Bus 0, Device 1, Function 0 is disabled and hidden. 1 = Bus 0, Device 1, Function 0 is enabled and visible. Default value is determined by the device capabilities (see CAPID0 [44]), SDVO Presence hardware strap and the SDVO/PCIe Concurrent hardware strap. Device 1 is Disabled on Reset if the SDVO Presence strap was sampled high, and the SDVO/PCIe Concurrent strap was sampled low at the last assertion of PWROK, and is enabled by default otherwise. Note: SDVO references are for the 82G31 GMCH only.
0	RO 1b	Host Bridge (D0EN): Bus 0, Device 0, Function 0 may not be disabled and is therefore hardwired to 1.



5.1.16 PCIEXBAR—PCI Express* Register Range Base Address

B/D/F/Type:	0/0/0/PCI
Address Offset:	60–67h
Default Value:	00000000E0000000h
Access:	RO, RW/L, RW/L/K
Size:	64 bits

This is the base address for the PCI Express configuration space. This window of addresses contains the 4 KB of configuration space for each PCI Express device that can potentially be part of the PCI Express Hierarchy associated with the (G)MCH. There is not actual physical memory within this window of up to 256 MB that can be addressed. The actual length is determined by a field in this register. Each PCI Express Hierarchy requires a PCI Express BASE register. The (G)MCH supports one PCI Express hierarchy. The region reserved by this register does not alias to any PCI 2.3 compliant memory mapped space. For example, MCHBAR reserves a 16 KB space and PXPEPBAR reserves a 4 KB space both outside of PCIEXBAR space. They cannot be overlaid on the space reserved by PCIEXBAR for devices 0.

On reset, this register is disabled and must be enabled by writing a 1 to the enable field in this register. This base address shall be assigned on a boundary consistent with the number of buses (defined by the Length field in this register), above TOLUD and still within 64 bit addressable memory space. All other bits not decoded are read only 0. The PCI Express Base Address cannot be less than the maximum address written to the Top of physical memory register (TOLUD). Software must ensure that these ranges do not overlap with known ranges located above TOLUD. Software must ensure that the sum of Length of enhanced configuration region + TOLUD + (other known ranges reserved above TOLUD) is not greater than the 36-bit addressable limit of 64 GB. In general system implementation and number of PCI/PCI Express/PCI-X buses supported in the hierarchy will dictate the length of the region.

Bit	Access & Default	Description
63:36	RO 0000000h	Reserved



Bit	Access & Default	Description
35:28	RW/L 0Eh	PCI Express Base Address (PCIEXBAR): This field corresponds to bits 35:28 of the base address for PCI Express enhanced configuration space. BIOS will program this register resulting in a base address for a contiguous memory address space; size is defined by bits 2:1 of this register. This Base address shall be assigned on a boundary consistent with the number of buses (defined by the Length field in this register) above TOLUD and still within 64-bit addressable memory space. The address bits decoded depend on the length of the region defined by this register. The address used to access the PCI Express configuration space for a specific device can be determined as follows: PCI Express Base Address + Bus Number * 1 MB + Device Number * 32 KB + Function Number * 4 KB The address used to access the PCI Express configuration space for Device 1 in this component would be PCI Express Base Address + 0 * 1 MB + 1 * 32 KB + 0 * 4 KB = PCI Express Base Address + 32 KB. Remember that this address is the beginning of the 4 KB space that contains both the PCI compatible configuration space and the PCI Express extended configuration space.
27	RW/L 0b	128 MB Base Address Mask (128ADMSK): This bit is either part of the PCI Express Base Address (R/W) or part of the Address Mask (RO, read 0b), depending on the value of bits 2:1 in this register.
26	RW/L 0b	64 MB Base Address Mask (64ADMSK): This bit is either part of the PCI Express Base Address (R/W) or part of the Address Mask (RO, read 0b), depending on the value of bits 2:1 in this register.
25:3	RO 000000h	Reserved
2:1	RW/L/K 00b	Length (LENGTH): This Field describes the length of this region. Enhanced Configuration Space Region/Buses Decoded 00 = 256 MB (buses 0–255). Bits 31:28 are decoded in the PCI Express Base Address Field 01 = 128 MB (Buses 0–127). Bits 31:27 are decoded in the PCI Express Base Address Field. 10 = 64 MB (Buses 0–63). Bits 31:26 are decoded in the PCI Express Base Address Field. 11 = Reserved
0	RW/L 0b	PCIEXBAR Enable (PCIEXBAREN): 0 = The PCIEXBAR register is disabled. Memory read and write transactions proceed as if there were no PCIEXBAR register. PCIEXBAR bits 35:26 are R/W with no functionality behind them. 1 = The PCIEXBAR register is enabled. Memory read and write transactions whose address bits 35:26 match PCIEXBAR will be translated to configuration reads and writes within the (G)MCH. These Translated cycles are routed as shown in the table above.



5.1.17 DMIBAR—Root Complex Register Range Base Address

B/D/F/Type:	0/0/0/PCI
Address Offset:	68–6Fh
Default Value:	0000000000000000h
Access:	RO, RW
Size:	64 bits

This is the base address for the Root Complex configuration space. This window of addresses contains the Root Complex Register set for the PCI Express Hierarchy associated with the (G)MCH. There is no physical memory within this 4 KB window that can be addressed. The 4 KB reserved by this register does not alias to any PCI 2.3 compliant memory mapped space. On reset, the Root Complex configuration space is disabled and must be enabled by writing a 1 to DMIBAREN [Dev 0, offset 68h, bit 0].

Bit	Access	Description
63:36	RO 0000000h	Reserved
35:12	RW 000000h	DMI Base Address (DMIBAR): This field corresponds to bits 35:12 of the base address DMI configuration space. BIOS will program this register resulting in a base address for a 4 KB block of contiguous memory address space. This register ensures that a naturally aligned 4 KB space is allocated within the first 64 GB of addressable memory space. System Software uses this base address to program the DMI register set.
11:1	RO 000h	Reserved
0	RW 0b	DMIBAR Enable (DMIBAREN): 0 = DMIBAR is disabled and does not claim any memory 1 = DMIBAR memory mapped accesses are claimed and decoded appropriately



5.1.18 PAM0—Programmable Attribute Map 0

B/D/F/Type:	0/0/0/PCI
Address Offset:	90h
Default Value:	00h
Access:	RO, RW
Size:	8 bits

This register controls the read, write, and shadowing attributes of the BIOS area from 0F0000h–0FFFFFFh. The (G)MCH allows programmable memory attributes on 13 Legacy memory segments of various sizes in the 768 KB to 1 MB address range. Seven Programmable Attribute Map (PAM) Registers are used to support these features. Cacheability of these areas is controlled via the MTRR registers in the P6 processor. Two bits are used to specify memory attributes for each memory segment. These bits apply to both host accesses and PCI initiator accesses to the PAM areas. These attributes are:

RE – Read Enable.	When RE = 1, the processor read accesses to the corresponding memory segment are claimed by the (G)MCH and directed to main memory. Conversely, when RE = 0, the host read accesses are directed to PCI_A.
WE – Write Enable.	When WE = 1, the host write accesses to the corresponding memory segment are claimed by the (G)MCH and directed to main memory. Conversely, when WE = 0, the host write accesses are directed to PCI_A.

The RE and WE attributes permit a memory segment to be Read Only, Write Only, Read/Write, or disabled. For example, if a memory segment has RE = 1 and WE = 0, the segment is Read Only. Each PAM Register controls two regions, typically 16 KB in size.

Note that the (G)MCH may hang if a PCI Express Graphics Attach or DMI originated access to Read Disabled or Write Disabled PAM segments occur (due to a possible IWB to non-DRAM).

For these reasons the following critical restriction is placed on the programming of the PAM regions: At the time that a DMI or PCI Express Graphics Attach accesses to the PAM region may occur, the targeted PAM segment must be programmed to be both readable and writeable.



Bit	Access & Default	Description
7:6	RO 00b	Reserved
5:4	RW 00b	0F0000h–0FFFFFFh Attribute (HIENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0F0000h to 0FFFFFFh. 00 = DRAM Disabled: All accesses are directed to DMI. 01 = Read Only: All reads are sent to DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.
3:0	RO 0h	Reserved



5.1.19 PAM1—Programmable Attribute Map 1

B/D/F/Type: 0/0/0/PCI
 Address Offset: 91h
 Default Value: 00h
 Access: RO, RW
 Size: 8 bits

This register controls the read, write, and shadowing attributes of the BIOS areas from 0C0000h–0C7FFFh.

Bit	Access & Default	Description
7:6	RO 00b	Reserved
5:4	RW 00b	0C4000h–0C7FFFh Attribute (HIENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0C4000 to 0C7FFF. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.
3:2	RO 00b	Reserved
1:0	RW 00b	0C0000h–0C3FFFh Attribute (LOENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0C0000h to 0C3FFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.



5.1.20 PAM2—Programmable Attribute Map 2

B/D/F/Type: 0/0/0/PCI
 Address Offset: 92h
 Default Value: 00h
 Access: RO, RW
 Size: 8 bits

This register controls the read, write, and shadowing attributes of the BIOS areas from 0C8000h–0CFFFFh.

Bit	Access & Default	Description
7:6	RO 00b	Reserved
5:4	RW 00b	0CC000h–0CFFFFh Attribute (HIENABLE): 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.
3:2	RO 00b	Reserved
1:0	RW 00b	0C8000h–0CBFFFh Attribute (LOENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0C8000h to 0CBFFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM..



5.1.21 PAM3—Programmable Attribute Map 3

B/D/F/Type: 0/0/0/PCI
 Address Offset: 93h
 Default Value: 00h
 Access: RO, RW
 Size: 8 bits

This register controls the read, write, and shadowing attributes of the BIOS areas from 0D0000h–0D7FFFh.

Bit	Access & Default	Description
7:6	RO 00b	Reserved
5:4	RW 00b	0D4000h–0D7FFFh Attribute (HIENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0D4000h to 0D7FFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.
3:2	RO 00b	Reserved
1:0	RW 00b	0D0000–0D3FFF Attribute (LOENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0D0000h to 0D3FFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.



5.1.22 PAM4—Programmable Attribute Map 4

B/D/F/Type: 0/0/0/PCI
 Address Offset: 94h
 Default Value: 00h
 Access: RO, RW
 Size: 8 bits

This register controls the read, write, and shadowing attributes of the BIOS areas from 0D8000h–0DFFFFh.

Bit	Access & Default	Description
7:6	RO 00b	Reserved
5:4	RW 00b	0DC000h–0DFFFFh Attribute (HIENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0DC000h to 0DFFFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.
3:2	RO 00b	Reserved
1:0	RW 00b	0D8000h–0DBFFFh Attribute (LOENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0D8000h to 0DBFFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.



5.1.23 PAM5—Programmable Attribute Map 5

B/D/F/Type: 0/0/0/PCI
 Address Offset: 95h
 Default Value: 00h
 Access: RO, RW
 Size: 8 bits

This register controls the read, write, and shadowing attributes of the BIOS areas from 0E0000h–0E7FFFh.

Bit	Access & Default	Description
7:6	RO 00b	Reserved
5:4	RW 00b	0E4000h–0E7FFFh Attribute (HIENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0E4000h to 0E7FFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.
3:2	RO 00b	Reserved
1:0	RW 00b	0E0000h–0E3FFFh Attribute (LOENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0E0000h to 0E3FFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.



5.1.24 PAM6—Programmable Attribute Map 6

B/D/F/Type: 0/0/0/PCI
 Address Offset: 96h
 Default Value: 00h
 Access: RO, RW
 Size: 8 bits

This register controls the read, write, and shadowing attributes of the BIOS areas from 0E8000h–0EFFFFh.

Bit	Access & Default	Description
7:6	RO 00b	Reserved
5:4	RW 00b	0EC000h–0EFFFFh Attribute (HIENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0E4000h to 0E7FFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.
3:2	RO 00b	Reserved
1:0	RW 00b	0E8000h–0EBFFFh Attribute (LOENABLE): This field controls the steering of read and write cycles that address the BIOS area from 0E0000h to 0E3FFFh. 00 = DRAM Disabled: Accesses are directed to DMI. 01 = Read Only: All reads are serviced by DRAM. All writes are forwarded to DMI. 10 = Write Only: All writes are sent to DRAM. Reads are serviced by DMI. 11 = Normal DRAM Operation: All reads and writes are serviced by DRAM.



5.1.25 LAC—Legacy Access Control

B/D/F/Type: 0/0/0/PCI
 Address Offset: 97h
 Default Value: 00h
 Access: RW, RO, RW
 Size: 8 bits

This 8-bit register controls a fixed DRAM hole from 15–16 MB.

Bit	Access & Default	Description															
7	RW 0b	Hole Enable (HEN): This field enables a memory hole in DRAM space. The DRAM that lies "behind" this space is not remapped. 0 = No memory hole. 1 = Memory hole from 15 MB to 16 MB..															
6:1	RO 00000b	Reserved															
0	RW 0b	MDA Present (MDAP): This bit works with the VGA Enable bits in the BCTRL register of Device 1 to control the routing of processor initiated transactions targeting MDA compatible I/O and memory address ranges. This bit should not be set if device 1's VGA Enable bit is not set. If device 1's VGA enable bit is not set, then accesses to IO address range x3BCh–x3BFh are forwarded to DMI. If the VGA enable bit is set and MDA is not present, then accesses to IO address range x3BCh–x3BFh are forwarded to PCI Express if the address is within the corresponding IOBASE and IOLIMIT, otherwise they are forwarded to DMI. MDA resources are defined as the following: Memory: 0B0000h – 0B7FFFh I/O: 3B4h, 3B5h, 3B8h, 3B9h, 3BAh, 3BFh, (including ISA address aliases, A[15:10] are not used in decode) Any I/O reference that includes the I/O locations listed above, or their aliases, will be forwarded to the DMI even if the reference includes I/O locations not listed above. The following table shows the behavior for all combinations of MDA and VGA: <table> <tr> <th>VGAEN</th><th>MDAP</th><th>Description</th></tr> <tr> <td>0</td><td>0</td><td>All References to MDA and VGA space are routed to DMI</td></tr> <tr> <td>0</td><td>1</td><td>Invalid combination</td></tr> <tr> <td>1</td><td>0</td><td>All VGA and MDA references are routed to PCI Express Graphics Attach.</td></tr> <tr> <td>1</td><td>1</td><td>All VGA references are routed to PCI Express Graphics Attach. MDA references are routed to DMI.</td></tr> </table> VGA and MDA memory cycles can only be routed across the PEG when MAE (PCICMD1[1]) is set. VGA and MDA I/O cycles can only be routed across the PEG if IOAE (PCICMD1[0]) is set.	VGAEN	MDAP	Description	0	0	All References to MDA and VGA space are routed to DMI	0	1	Invalid combination	1	0	All VGA and MDA references are routed to PCI Express Graphics Attach.	1	1	All VGA references are routed to PCI Express Graphics Attach. MDA references are routed to DMI.
VGAEN	MDAP	Description															
0	0	All References to MDA and VGA space are routed to DMI															
0	1	Invalid combination															
1	0	All VGA and MDA references are routed to PCI Express Graphics Attach.															
1	1	All VGA references are routed to PCI Express Graphics Attach. MDA references are routed to DMI.															



5.1.26 REMAPBASE—Remap Base Address Register

B/D/F/Type: 0/0/0/PCI
Address Offset: 98–99h
Default Value: 03FFh
Access: RO, RW
Size: 16 bits

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 3FFh	Remap Base Address [35:26] (REMAPBASE): The value in this register defines the lower boundary of the Remap window. The Remap window is inclusive of this address. In the decoder A[25:0] of the Remap Base Address are assumed to be 0s. Thus, the bottom of the defined memory range will be aligned to a 64 MB boundary. When the value in this register is greater than the value programmed into the Remap Limit register, the Remap window is disabled.

5.1.27 REMAPLIMIT—Remap Limit Address Register

B/D/F/Type: 0/0/0/PCI
Address Offset: 9A–9Bh
Default Value: 0000h
Access: RO, RW
Size: 16 bits

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Remap Limit Address [35:26] (REMAPLMT): The value in this register defines the upper boundary of the Remap window. The Remap window is inclusive of this address. In the decoder A[25:0] of the remap limit address are assumed to be Fhs. Thus the top of the defined range will be one less than a 64 MB boundary. When the value in this register is less than the value programmed into the Remap Base register, the Remap window is disabled.



5.1.28 SMRAM—System Management RAM Control

B/D/F/Type: 0/0/0/PCI
 Address Offset: 9Dh
 Default Value: 02h
 Access: RO, RW/L, RW, RW/L/K
 Size: 8 bits

The SMRAMC register controls how accesses to Compatible and Extended SMRAM spaces are treated. The Open, Close, and Lock bits function only when G_SMFRAME bit is set to a 1. Also, the OPEN bit must be reset before the LOCK bit is set.

Bit	Access & Default	Description
7	RO 0b	Reserved
6	RW/L 0b	SMM Space Open (D_OPEN): When D_OPEN=1 and D_LCK=0, the SMM space DRAM is made visible even when SMM decode is not active. This is intended to help BIOS initialize SMM space. Software should ensure that D_OPEN=1 and D_CLS=1 are not set at the same time.
5	RW 0b	SMM Space Closed (D_CLS): When D_CLS = 1 SMM space DRAM is not accessible to data references, even if SMM decode is active. Code references may still access SMM space DRAM. This will allow SMM software to reference through SMM space to update the display even when SMM is mapped over the VGA range. Software should ensure that D_OPEN=1 and D_CLS=1 are not set at the same time.
4	RW/L/K 0b	SMM Space Locked (D_LCK): When D_LCK is set to 1 then D_OPEN is reset to 0 and D_LCK, D_OPEN, C_BASE_SEG, H_SMFRAME_EN, TSEG_SZ and TSEG_EN become read only. D_LCK can be set to 1 via a normal configuration space write but can only be cleared by a Full Reset. The combination of D_LCK and D_OPEN provide convenience with security. The BIOS can use the D_OPEN function to initialize SMM space and then use D_LCK to "lock down" SMM space in the future so that no application software (or BIOS itself) can violate the integrity of SMM space, even if the program has knowledge of the D_OPEN function.
3	RW/L 0b	Global SMRAM Enable (G_SMFRAME): If set to a 1, then Compatible SMRAM functions are enabled, providing 128 KB of DRAM accessible at the A0000h address while in SMM (ADSB with SMM decode). To enable Extended SMRAM function this bit has be set to 1. Refer to the section on SMM for more details. Once D_LCK is set, this bit becomes read only.
2:0	RO 0b	Compatible SMM Space Base Segment (C_BASE_SEG): This field indicates the location of SMM space. SMM DRAM is not remapped. It is simply made visible if the conditions are right to access SMM space, otherwise the access is forwarded to DMI. Since the (G)MCH supports only the SMM space between A0000 and BFFFF, this field is hardwired to 010.



5.1.29 ESMRAMC—Extended System Management RAM Control

B/D/F/Type: 0/0/0/PCI
 Address Offset: 9Eh
 Default Value: 38h
 Access: RW, RWC, RO
 Size: 8 bits

The Extended SMRAM register controls the configuration of Extended SMRAM space. The Extended SMRAM (E_SMRAM) memory provides a write-back cacheable SMRAM memory space that is above 1 MB.

Bit	Access & Default	Description
7	RW 0b	Enable High SMRAM (H_SMFRAME): This bit controls the SMM memory space location (i.e., above 1 MB or below 1 MB) When G_SMFRAME is 1 and H_SMFRAME is set to 1, the high SMRAM memory space is enabled. SMRAM accesses within the range 0FEDA0000h to 0FEDBFFFFh are remapped to DRAM addresses within the range 000A0000h to 000BFFFFh. Once D_LCK has been set, this bit becomes read only.
6	RWC 0b	Invalid SMRAM Access (E_SMERR): This bit is set when processor has accessed the defined memory ranges in Extended SMRAM (High Memory and T-segment) while not in SMM space and with the D-OPEN bit = 0. It is software's responsibility to clear this bit. The software must write a 1 to this bit to clear it.
5	RO 1b	SMRAM Cacheable (SM_CACHE): This bit is forced to 1 by the (G)MCH.
4	RO 1b	L1 Cache Enable for SMRAM (SM_L1): This bit is forced to 1 by the (G)MCH.
3	RO 1b	L2 Cache Enable for SMRAM (SM_L2): This bit is forced to 1 by the (G)MCH.
2:1	RW 00b	TSEG Size (TSEG_SZ): Selects the size of the TSEG memory block if enabled. Memory from the top of DRAM space is partitioned away so that it may only be accessed by the processor interface and only then when the SMM bit is set in the request packet. Non-SMM accesses to this memory region are sent to DMI when the TSEG memory block is enabled. 00 = 1 MB TSEG. (TOLUD – GTT Graphics Memory Size – Graphics Stolen Memory Size – 1 MB) to (TOLUD – GTT Graphics Memory Size – Graphics Stolen Memory Size). 01 = 2 MB TSEG. (TOLUD – GTT Graphics Memory Size – Graphics Stolen Memory Size – 2 MB) to (TOLUD – GTT Graphics Memory Size – Graphics Stolen Memory Size). 10 = 8 MB TSEG. (TOLUD – GTT Graphics Memory Size – Graphics Stolen Memory Size – 8 MB) to (TOLUD – GTT Graphics Memory Size – Graphics Stolen Memory Size). 11 = Reserved. Once D_LCK has been set, these bits becomes read only.



Bit	Access & Default	Description
0	RW 0b	TSEG Enable (T_EN): Enabling of SMRAM memory for Extended SMRAM space only. When G_SMROME = 1 and TSEG_EN = 1, the TSEG is enabled to appear in the appropriate physical address space. Note that once D_LCK is set, this bit becomes read only.

5.1.30 TOM—Top of Memory

B/D/F/Type: 0/0/0/PCI
 Address Offset: A0–A1h
 Default Value: 0001h
 Access: RO, RW
 Size: 16 bits

This Register contains the size of physical memory. BIOS determines the memory size reported to the OS using this Register.

Bit	Access & Default	Description
15:10	RO 00h	Reserved
9:0	RW 001h	Top of Memory (TOM): This register reflects the total amount of populated physical memory. This is NOT necessarily the highest main memory address (holes may exist in main memory address map due to addresses allocated for memory mapped I/O). These bits correspond to address bits 35:26 (64 MB granularity). Bits 25:0 are assumed to be 0.



5.1.31 TOUUD—Top of Upper Usable Dram

B/D/F/Type: 0/0/0/PCI
Address Offset: A2–A3h
Default Value: 0000h
Access: RW
Size: 16 bits

This 16 bit register defines the Top of Upper Usable DRAM.

Configuration software must set this value to TOM minus all EP stolen memory if reclaim is disabled. If reclaim is enabled, this value must be set to (reclaim limit + 1 byte) 64 MB aligned since reclaim limit is 64 MB aligned. Address bits 19:0 are assumed to be 000_0000h for the purposes of address comparison. The Host interface positively decodes an address towards DRAM if the incoming address is less than the value programmed in this register and greater than or equal to 4 GB.

Bit	Access & Default	Description
15:0	RW 0000h	TOUUD (TOUUD): This register contains bits 35:20 of an address one byte above the maximum DRAM memory above 4 GB that is usable by the operating system. Configuration software must set this value to TOM minus all EP stolen memory if reclaim is disabled. If reclaim is enabled, this value must be set to (reclaim limit + 1 byte) 64 MB aligned since reclaim limit is 64 MB aligned. Address bits 19:0 are assumed to be 000_0000h for the purposes of address comparison. The Host interface positively decodes an address towards DRAM if the incoming address is less than the value programmed in this register and greater than 4 GB.



5.1.32 GBSM—Graphics Base of Stolen Memory

B/D/F/Type: 0/0/0/PCI
 Address Offset: A4–A7h
 Default Value: 00000000h
 Access: RW, RO
 Size: 32 bits

This register contains the base address of graphics data stolen DRAM memory. BIOS determines the base of graphics data stolen memory by subtracting the graphics data stolen memory size (PCI Device 0 offset 52h, bits 7:4) from TOLUD (PCI Device 0, offset B0h, bits 15:4).

Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set.

Bit	Access & Default	Description
31:20	RW 000h	Graphics Base of Stolen Memory (GBSM): This register contains bits 31:20 of the base address of stolen DRAM memory. BIOS determines the base of graphics stolen memory by subtracting the graphics stolen memory size (PCI Device 0, offset 52h, bits 6:4) from TOLUD (PCI Device 0, offset B0h, bits 15:04). Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set.
19:0	RO 00000h	Reserved



5.1.33 BGSM—Base of GTT stolen Memory

B/D/F/Type: 0/0/0/PCI
Address Offset: A8–ABh
Default Value: 00000000h
Access: RW/L, RO
Size: 32 bits

This register contains the base address of stolen DRAM memory for the GTT. BIOS determines the base of GTT stolen memory by subtracting the GTT graphics stolen memory size (PCI Device 0 offset 52 bits 9:8) from the graphics stolen memory base (PCI Device 0, offset A4h, bits 31:20).

Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set.

Bit	Access & Default	Description
31:20	RW/L 000h	Graphics Base of Stolen Memory (GBSM): This register contains bits 31:20 of the base address of stolen DRAM memory. BIOS determines the base of graphics stolen memory by subtracting the GTT graphics stolen memory size (PCI Device 0, offset 52h, bits 9:8) from the graphics stolen memory base (PCI Device 0, offset A4h, bits 31:20). Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set.
19:0	RO 00000h	Reserved

5.1.34 TSEGMB—TSEG Memory Base

B/D/F/Type: 0/0/0/PCI
Address Offset: AC–AFh
Default Value: 00000000h
Access: RW/L, RO
Size: 32 bits

This register contains the base address of TSEG DRAM memory. BIOS determines the base of TSEG memory by subtracting the TSEG size (PCI Device 0, offset 9Eh, bits 2:1) from graphics GTT stolen base (PCI Device 0, offset A8h, bits 31:20).

Once D_LCK has been set, these bits becomes read only.

Bit	Access & Default	Description
31:20	RW/L 000h	TSEG Memory base (TSEGMB): This register contains bits 31:20 of the base address of TSEG DRAM memory. BIOS determines the base of TSEG memory by subtracting the TSEG size (PCI Device 0, offset 9Eh, bits 2:1) from graphics GTT stolen base (PCI Device 0, offset A8h, bits 31:20). Once D_LCK has been set, these bits becomes read only.
19:0	RO 00000h	Reserved



5.1.35 TOLUD—Top of Low Usable DRAM

B/D/F/Type:	0/0/0/PCI
Address Offset:	B0–B1h
Default Value:	0010h
Access:	RW, RO
Size:	16 bits

This 16 bit register defines the Top of Low Usable DRAM. TSEG, GTT Graphics Memory and Graphics Stolen Memory are within the DRAM space defined. From the top, (G)MCH optionally claims 1 to 64 MB of DRAM for internal graphics if enabled 1, 2 MB of DRAM for GTT Graphics Stolen Memory (if enabled) and 1, 2, or 8 MB of DRAM for TSEG, if enabled.

Programming Example :

C1DRB3 is set to 4 GB

TSEG is enabled and TSEG size is set to 1 MB

Internal Graphics is enabled and Graphics Mode Select set to 32 MB

GTT Graphics Stolen Memory Size set to 2 MB

BIOS knows the OS requires 1 GB of PCI space.

BIOS also knows the range from FEC0_0000h to FFFF_FFFFh is not usable by the system. This 20MB range at the very top of addressable memory space is lost to APIC.

According to the above equation, TOLUD is originally calculated to:

4 GB = 1_0000_0000h

The system memory requirements are: 4GB (max addressable space) – 1 GB (PCI space) – 35 MB (lost memory) = 3 GB – 35 MB (minimum granularity) = ECB0_0000h

Since ECB0_0000h (PCI and other system requirements) is less than 1_0000_0000h, TOLUD should be programmed to ECBh.



Bit	Access & Default	Description
15:4	RW 001h	Top of Low Usable DRAM (TOLUD): This register contains bits 31:20 of an address one byte above the maximum DRAM memory below 4 GB that is usable by the operating system. Address bits 31:20 programmed to 01h implies a minimum memory size of 1 MB. Configuration software must set this value to the smaller of the following 2 choices: maximum amount memory in the system minus ME stolen memory plus one byte or the minimum address allocated for PCI memory. Address bits 19:0 are assumed to be 0_0000h for the purposes of address comparison. The Host interface positively decodes an address towards DRAM if the incoming address is less than the value programmed in this register. Note that the Top of Low Usable DRAM is the lowest address above both Graphics Stolen memory and TSEG. BIOS determines the base of Graphics Stolen Memory by subtracting the Graphics Stolen Memory Size from TOLUD and further decrements by TSEG size to determine base of TSEG. This register must be 64 MB aligned when reclaim is enabled.
3:0	RO 0000b	Reserved

5.1.36 ERRSTS—Error Status

B/D/F/Type: 0/0/0/PCI
 Address Offset: C8–C9h
 Default Value: 0000h
 Access: RO, RWC/S
 Size: 16 bits

This register is used to report various error conditions via the SERR DMI messaging mechanism. An SERR DMI message is generated on a zero to one transition of any of these flags (if enabled by the ERRCMD and PCICMD registers).

These bits are set regardless of whether or not the SERR is enabled and generated. After the error processing is complete, the error logging mechanism can be unlocked by clearing the appropriate status bit by software writing a 1 to it.

Bit	Access & Default	Description
15	RO 0b	Reserved
14	RWC/S 0b	Isochronous TBWRR Run Behind FIFO Full (ITCV): If set, this bit indicates a VC1 TBWRR is running behind, resulting in the slot timer to stop until the request is able to complete. If this bit is already set, then an interrupt message will not be sent on a new error event.



Bit	Access & Default	Description
13	RWC/S 0b	Isochronous TBWRR Run behind FIFO Put (ITSTV): If set, this bit indicates a VC1 TBWRR request was put into the run behind. This will likely result in a resulting in a contract violation due to the (G)MCH Express port taking too long to service the isochronous request. If this bit is already set, then an interrupt message will not be sent on a new error event.
12	RWC/S 0b	(G)MCH Software Generated Event for SMI (GSGESMI): This indicates the source of the SMI was a Device 2 Software Event.
11	RWC/S 0b	(G)MCH Thermal Sensor Event for SMI / SCI / SERR (GTSE): This bit indicates that a (G)MCH Thermal Sensor trip has occurred and an SMI, SCI or SERR has been generated. The status bit is set only if a message is sent based on Thermal event enables in Error command, SMI command and SCI command registers. A trip point can generate one of SMI, SCI, or SERR interrupts (two or more per event is invalid). Multiple trip points can generate the same interrupt, if software chooses this mode, subsequent trips may be lost. If this bit is already set, then an interrupt message will not be sent on a new thermal sensor event.
10	RO 0b	Reserved
9	RWC/S 0b	LOCK to non-DRAM Memory Flag (LCKF): 1 = (G)MCH has detected a lock operation to memory space that did not map into DRAM.
8	RO 0b	Reserved
7	RWC/S 0b	DRAM Throttle Flag (DTF): 1 = DRAM Throttling condition occurred. 0 = Software has cleared this flag since the most recent throttling event.
6:0	RO 0s	Reserved



5.1.37 ERRCMD—Error Command

B/D/F/Type: 0/0/0/PCI
Address Offset: CA–CBh
Default Value: 0000h
Access: RO, RW
Size: 16 bits

This register controls the (G)MCH responses to various system errors. Since the (G)MCH does not have an SERR# signal, SERR messages are passed from the (G)MCH to the ICH over DMI.

When a bit in this register is set, a SERR message will be generated on DMI whenever the corresponding flag is set in the ERRSTS register. The actual generation of the SERR message is globally enabled for Device #0 via the PCI Command register.

Bit	Access & Default	Description
15:12	RO 0h	Reserved
11	RW 0b	SERR on (G)MCH Thermal Sensor Event (TSESERR): 1 = The (G)MCH generates a DMI SERR special cycle when bit 11 of the ERRSTS is set. The SERR must not be enabled at the same time as the SMI for the same thermal sensor event. 0 = Reporting of this condition via SERR messaging is disabled.
10	RO 0b	Reserved
9	RW 0b	SERR on LOCK to non-DRAM Memory (LCKERR): 1 = The (G)MCH will generate a DMI SERR special cycle whenever a processor lock cycle is detected that does not hit DRAM. 0 = Reporting of this condition via SERR messaging is disabled.
8:7	RW 00b	Reserved
6:0	RO 0s	Reserved



5.1.38 SMICMD—SMI Command

B/D/F/Type: 0/0/0/PCI
 Address Offset: CC-CDh
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

This register enables various errors to generate an SMI DMI special cycle. When an error flag is set in the ERRSTS register, it can generate an SERR, SMI, or SCI DMI special cycle when enabled in the ERRCMD, SMICMD, or SCICMD registers, respectively. Note that one and only one message type can be enabled.

Bit	Access & Default	Description
15:12	RO 0h	Reserved
11	RW 0b	SMI on (G)MCH Thermal Sensor Trip (TSTSMI): 1 = A SMI DMI special cycle is generated by (G)MCH when the thermal sensor trip requires an SMI. A thermal sensor trip point cannot generate more than one special cycle. 0 = Reporting of this condition via SMI messaging is disabled.
10:0	RO 0s	Reserved

5.1.39 SKPD—Scratchpad Data

B/D/F/Type: 0/0/0/PCI
 Address Offset: DC-DFh
 Default Value: 00000000h
 Access: RW
 Size: 32 bits

This register holds 32 writable bits with no functionality behind them. It is for the convenience of BIOS and graphics drivers.

Bit	Access & Default	Description
31:0	RW 00000000h	Scratchpad Data (SKPD): 1 DWord of data storage.



5.1.40 CAPID0—Capability Identifier

B/D/F/Type: 0/0/0/PCI
 Address Offset: E0–EAh
 Default Value: 000001000000000010B0009h
 Access: RO
 Size: 88 bits

Control of bits in this register are only required for customer visible SKU differentiation.

Bit	Access & Default	Description
87:79	RO 0s	Reserved
78	RO 0b	82G31 GMCH Dual Independent Display Disable (DIDD): This bit determines whether the component is capable of Dual Independent Display functionality. This functionality requires both functions (0 and 1) to be visible in the Internal Graphics Device 2. This capability is only meaningful if the component is capable of Internal Graphics. Definitions: • Clone mode – Same Image. Different display timing on each pipe. • Twin mode – Same Image. Same exact display timings. • Extended Desktop mode – Unique images. Different display timings on each pipe. When Device 2 Function 1 is hidden, the second controller and its associated frame buffer are no longer visible to the Operating System. The OS thinks our device has only one display controller and stops supporting Extended Desktop mode. 0 = Capable of Dual Independent Display (independent frame buffers), Extended Desktop mode is supported. 1 = Not capable of Dual Independent Display. Hardwires bit 4 of the Device Enable (DEVEN) register (Device 0 Offset 54h) to '0'. Clone mode and twin mode are still supported (single frame buffer). 82P31 MCH Reserved
77	RO 0b	Dual Channel Disable (DCD): 0 = Dual channel operation allowed 1 = Only single channel operation allowed
76	RO 1b	2 DIMMS per Channel Disable (2DPCD): This bit is 1 indicating support for 1 DIMM per channel.
75:71	RO 0000b	Reserved



Bit	Access & Default	Description
70	RO 0b	Multiprocessor Disable (MD): 0 = (G)MCH capable of Multiple Processors 1 = (G)MCH capable of uni-processor only.
69	RO 0b	FAN Speed Control Disable (FSCD): Not supported.
68:52	RO 0s	Reserved
51	RO 0b	VLD and IDCT Disable (VLDIDCTD): 0 = Enable VLD and IDCT 1 = Disable VLD and IDCT
50:48	RO 0s	Reserved
47	RO 0b	82G31 GMCH 3D Integrated graphics Disable (3DIGD): 0 = 3D Internal Graphics are enabled 1 = 3D Internal Graphics are disabled. VGA still supported 82P31 MCH Reserved
46	RO 0b	82G31 GMCH Internal Graphics Disable (IGD): 0 = There is a graphics engine within this GMCH. Internal Graphics Device (Device 2) is enabled and all of its memory and I/O spaces are accessible. Configuration cycles to Device 2 will be completed within the GMCH. All non-SMM memory and IO accesses to VGA will be handled based on Memory and IO enables of Device 2 and IO registers within Device 2 and VGA Enable of the PCI to PCI bridge control register in Device 1 (If PCI Express graphics attach is supported). A selected amount of Graphics Memory space is pre-allocated from the main memory based on Graphics Mode Select (GMS in the GMCH Control Register). Graphics Memory is pre-allocated above TSEG Memory. 1 = There is no graphics engine within this GMCH. Internal Graphics Device (Device 2) and all of its memory and I/O functions are disabled. Configuration cycle targeted to Device 2 will be passed on to DMI. In addition, all clocks to internal graphics logic are turned off. All non-SMM memory and IO accesses to VGA will be handled based on VGA Enable of the PCI to PCI bridge control register in Device 1. DEVEN [4:3] (Device 0, offset 54h) have no meaning. Device 2 Functions 0 and 1 are disabled and hidden. 82P31 MCH Reserved



Bit	Access & Default	Description
45	RO 0b	PEG Port x16 Disable (PEGX16D): 0 = Capable of x16 PEG Port. 1 = Not Capable of x16 PEG port, instead PEG limited to x8 and below. Causes PEG port to enable and train logical lanes 7:0 only. Logical lanes 15:8 are powered down, and the Max Link Width field of the Link Capability register reports x8 instead of x16. (in the case of lane reversal, lanes 15:8 are active and lanes 7:0 are powered down)
44	RO 0b	PCI Express Port Disable (PEGPD): 0 = There is a PCI Express Port on this (G)MCH. Device 1 and associated memory spaces are accessible. All non-SIMM memory and I/O accesses to VGA will be handled based on VGA Enable of the PCI to PCI bridge control register in Device 1 and VGA settings controlling internal graphics VGA if internal graphics is enabled. 1 = There is no PCI Express Port on this (G)MCH. Device 1 and associated memory and IO spaces are disabled by hardwiring the D1EN field bit 1 of the Device Enable register (DEVEN Dev 0 Offset 54h). In addition, Next_Pointer = 00h, VGA memory and I/O cannot decode to the PCI Express interface. From a Physical Layer perspective, all 16 lanes are powered down and the link does not attempt to train.
43:34	RO 0s	Reserved
33:31	RO 000b	DDR Frequency Capability (DDRFC): This field controls which values may be written to the Memory Frequency Select field 6:4 of the Clocking Configuration registers (MCHBAR Offset C00h). Any attempt to write an unsupported value will be ignored. 000 = (G)MCH capable of "All" memory frequencies 001 = Reserved 010 = Reserved 011 = Reserved 100 = (G)MCH capable of up to DDR2 1067 101 = (G)MCH capable of up to DDR2 800 110 = (G)MCH capable of up to DDR2 667



Bit	Access & Default	Description
30:28	RO 000b	FSB Frequency Capability (FSBFC): This field controls which values are allowed in the FSB Frequency Select Field 2:0 of the Clocking Configuration Register. These values are determined by the BSEL[2:0] frequency straps. Any unsupported strap values will render the (G)MCH System Memory Interface inoperable. 000 = (G)MCH capable of "All" Memory Frequencies 001 = Reserved 010 = Reserved 011 = Reserved 100 = (G)MCH capable of up to FSB 1067 101 = (G)MCH capable of up to FSB 800 110 = (G)MCH capable of up to FSB 667
27:24	RO 1h	CAPID Version (CAPIDV): This field has the value 0001b to identify the first revision of the CAPID register definition.
23:16	RO 0bh	CAPID Length (CAPIDL): This field has the value 0bh to indicate the structure length (11 bytes).
15:8	RO 00h	Next Capability Pointer (NCP): This field is hardwired to 00h indicating the end of the capabilities linked list.
7:0	RO 09h	Capability Identifier (CAP_ID): This field has the value 1001b to identify the CAP_ID assigned by the PCI SIG for vendor dependent capability pointers.



5.2 MCHBAR

The MCHBAR registers are offset from the MCHBAR base address. Table 5-2 provides an address map of the registers listed by address offset in ascending order. Detailed register bit descriptions follow the table.

Table 5-2. MCHBAR Register Address Map

Address Offset	Register Symbol	Register Name	Default Value	Access
111h	CHDECMISC	Channel Decode Miscellaneous	00h	RW
200–01h	C0DRB0	Channel 0 DRAM Rank Boundary Address 0	0000h	RO, RW
250–251h	C0CYCTRKPCHG	Channel 0 CYCTRK PCHG	0000h	RW, RO
252–255h	C0CYCTRKACT	Channel 0 CYCTRK ACT	00000000h	RW, RO
256–257h	C0CYCTRKWR	Channel 0 CYCTRK WR	0000h	RW
258–25Ah	C0CYCTRKRD	Channel 0 CYCTRK READ	000000h	RW, RO
25B–25Ch	C0CYCTRKREFR	Channel 0 CYCTRK REFR	0000h	RO, RW
260–263h	C0CKECTRL	Channel 0 CKE Control	00000800h	RO, RW, RW
269–26Eh	C0REFRCTRL	Channel 0 DRAM Refresh Control	021830000 C30h	RW, RO
29C–29Fh	C0ODTCTRL	Channel 0 ODT Control	00000000h	RO, RW
600–601h	C1DRB0	Channel 1 DRAM Rank Boundary Address 0	0000h	RW, RO
602–603h	C1DRB1	Channel 1 DRAM Rank Boundary Address 1	0000h	RW, RO
604–605h	C1DRB2	Channel 1 DRAM Rank Boundary Address 2	0000h	RW, RO
606–607h	C1DRB3	Channel 1 DRAM Rank Boundary Address 3	0000h	RW, RO
608–609h	C1DRA01	Channel 1 DRAM Rank 0,1 Attributes	0000h	RW,
60A–60Bh	C1DRA23	Channel 1 DRAM Rank 2,3 Attributes	0000h	RW
650–651h	C1CYCTRKPCHG	Channel 1 CYCTRK PCHG	0000h	RO, RW
652–655h	C1CYCTRKACT	Channel 1 CYCTRK ACT	00000000h	RO, RW
656–657h	C1CYCTRKWR	Channel 1 CYCTRK WR	0000h	RW,
658–65Ah	C1CYCTRKRD	Channel 1 CYCTRK READ	000000h	RO, RW
660–663h	C1CKECTRL	Channel 1 CKE Control	00000800h	RW, RW, RO
669–66Eh	C1REFRCTRL	Channel 1 DRAM Refresh Control	021830000 C30h	RW, RO
69C–69Fh	C1ODTCTRL	Channel 1 ODT Control	00000000h	RO, RW



Address Offset	Register Symbol	Register Name	Default Value	Access
A00– A01h	EPC0DRB0	EP Channel 0 DRAM Rank Boundary Address 0	0000h	RW, RO
A02– A03h	EPC0DRB1	EP Channel 0 DRAM Rank Boundary Address 1	0000h	RO, RW
A04– A05h	EPC0DRB2	EP Channel 0 DRAM Rank Boundary Address 2	0000h	RO, RW
A06– A07h	EPC0DRB3	EP Channel 0 DRAM Rank Boundary Address 3	0000h	RW, RO
A08– A09h	EPC0DRA01	EP Channel 0 DRAM Rank 0,1 Attribute	0000h	RW
A0A– A0Bh	EPC0DRA23	EP Channel 0 DRAM Rank 2,3 Attribute	0000h	RW
A19– A1Ah	EPDCYCTRKWRTPRE	EPD CYCTRK WRT PRE	0000h	RW, RO
A1C– A1Fh	EPDCYCTRKWRTACT	EPD CYCTRK WRT ACT	00000000h	RO, RW
A20– A21h	EPDCYCTRKWRTWR	EPD CYCTRK WRT WR	0000h	RW, RO
A22– A23h	EPDCYCTRKWRTREF	EPD CYCTRK WRT REF	0000h	RO, RW
A24– A26h	EPDCYCTRKWRTRD	EPD CYCTRK WRT READ	000000h	RW
A28– A33h	EPDCKECONFIGREG	EPD CKE related configuration registers	00E0000000h	RW
A30–A33h	EPDREFCONFIG	EP DRAM Refresh Configuration	40000C30h	RO, RW
CD8h	TSC1	Thermal Sensor Control 1	00h	RW/L, RW, RS/WC
CD9h	TSC2	Thermal Sensor Control 2	00h	RW/L, RO
CDAh	TSS	Thermal Sensor Status	00h	RO
CDC–CDFh	TSTTP	Thermal Sensor Temperature Trip Point	00000000h	RO, RW, RW/L
CE2h	TCO	Thermal Calibration Offset	00h	RW/L/K, RW/L
CE4h	THERM1	Hardware Throttle Control	00h	RW/L, RO, RW/L/K
CEA–CEBh	TIS	Thermal Interrupt Status	0000h	RO, RWC
CF1h	TSMICMD	Thermal SMI Command	00h	RO, RW
F14–F17h	PMSTS	Power Management Status	00000000h	RWC/S, RO



5.2.1 CHDECMISC—Channel Decode Miscellaneous

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 111h
 Default Value: 00h
 Access: RW
 Size: 8 bits

This register has Miscellaneous CHDEC/MAGEN configuration bits.

Bit	Access & Default	Description
7	RW 0b	Reserved
6:5	RW 00b	Enhanced Mode Select (ENHMODESEL): 00 = Swap Enabled for Bank Selects and Rank Selects 01 = XOR Enabled for Bank Selects and Rank Selects 10 = Swap Enabled for Bank Selects only 11 = XOR Enabled for Bank Select only
4	RW 0b	Ch2 Enhanced Mode (CH2_ENHMODE): This bit enables Enhanced addressing mode of operation is enabled for Ch 2. 0 = Disable 1 = Enable
3	RW 0b	Ch1 Enhanced Mode (CH1_ENHMODE): This bit enables Enhanced addressing mode of operation is enabled for Ch 1. 0 = Disable 1 = Enable
2	RW 0b	Ch0 Enhanced Mode (CH0_ENHMODE): This bit enables Enhanced addressing mode of operation is enabled for Ch 0. 0 = Disable 1 = Enable
1	RW 0b	Reserved
0	RW 0b	EP Present (EPPRSNT): This bit indicates whether EP UMA is present in the system or not. 0 = Not Present 1 = Present



5.2.2 C0DRB0—Channel 0 DRAM Rank Boundary Address 0

B/D/F/Type:	0/0/0/MCHBAR
Address Offset:	200–201h
Default Value:	0000h
Access:	RW, RO
Size:	16 bits

The DRAM Rank Boundary Registers define the upper boundary address of each DRAM rank with a granularity of 64 MB. Each rank has its own single-word DRB register. These registers are used to determine which chip select will be active for a given address. Channel and rank map:

Ch 0, Rank 0 = 200h
 Ch 0, Rank 1 = 202h
 Ch 1, Rank 0 = 600h
 Ch 1, Rank 1 = 602h

Programming Guide

Non-Stacked Mode

If Channel 0 is empty, all of the C0DRBs are programmed with 00h.

C0DRB0 = Total memory in Ch 0, Rank 0 (in 64 MB increments)
 C0DRB1 = Total memory in Ch 0, Rank 0 + Ch 0, Rank 1 (in 64 MB increments)
 ...

If Channel 1 is empty, all of the C1DRBs are programmed with 00h

C1DRB0 = Total memory in Ch 1, Rank 0 (in 64 MB increments)
 C1DRB1 = Total memory in Ch 1, Rank 0 + Ch 1, Rank 1 (in 64 MB increments)
 ...

Stacked Mode

CODRBs:

Similar to Non-stacked mode.

C1DRB0, C1DRB1 and C1DRB2:

They are also programmed similar to non-stacked mode. Only exception is, the DRBs corresponding to the topmost populated rank and the (unpopulated) higher ranks in Channel 1 must be programmed with the value of the total Channel 1 population plus the value of total Channel 0 population (C0DRB3).

Example: If only ranks 0 and 1 are populated in Ch1 in stacked mode, then

C1DRB0 = Total memory in ch1 rank0 (in 64MB increments)

C1DRB1 = C0DRB3 + Total memory in ch1 rank0 + ch1 rank1 (in 64 MB increments)
 (rank 1 is the topmost populated rank)

C1DRB2 = C1DRB1



C1DRB3 = C1DRB1

C1DRB3:

C1DRB3 = C0DRB3 + Total memory in Channel 1.

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Channel 0 Dram Rank Boundary Address 0 (C0DRBA0): This register defines the DRAM rank boundary for rank0 of Channel 0 (64 MB granularity) = R0 R0 = Total Rank 0 memory size is 64 MB R1 = Total Rank 1 memory size is 64 MB

5.2.3 C0CYCTRKPCHG—Channel 0 CYCTRK PCHG

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 250–251h
 Default Value: 0000h
 Access: RW, RO
 Size: 16 bits

This register provides Channel 0 CYCTRK Precharge.

Bit	Access & Default	Description
15:11	RO 00000b	Reserved
10:6	RW 00000b	Write To PRE Delayed (C0sd_cr_wr_pchg): This field indicates the minimum allowed spacing (in DRAM clocks) between the WRITE and PRE commands to the same rank-bank. This field corresponds to t_{WR} in the DDR Specification.
5:2	RW 0000b	READ To PRE Delayed (C0sd_cr_rd_pchg): This field indicates the minimum allowed spacing (in DRAM clocks) between the READ and PRE commands to the same rank-bank.
1:0	RW 00b	PRE To PRE Delayed (C0sd_cr_pchg_pchg): This field indicates the minimum allowed spacing (in DRAM clocks) between two PRE commands to the same rank.



5.2.4 C0CYCTRKACT—Channel 0 CYCTRK ACT

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 252–255h
 Default Value: 00000000h
 Access: RW, RO
 Size: 32 bits

This register provides Channel 0 CYCTRK Activate.

Bit	Access & Default	Description
31:28	RO 0h	Reserved
27:22	RW 000000b	ACT Window Count (C0sd_cr_act_windowcnt): This field indicates the window duration (in DRAM clocks) during which the controller counts the # of activate commands which are launched to a particular rank. If the number of activate commands launched within this window is greater than 4, then a check is implemented to block launch of further activates to this rank for the rest of the duration of this window.
21	RW 0b	Max ACT Check Disable (C0sd_cr_maxact_dischk): This field disenables the check which ensures that there are no more than four activates to a particular rank in a given window.
20:17	RW 0000b	ACT to ACT Delayed (C0sd_cr_act_act[]): This field indicates the minimum allowed spacing (in DRAM clocks) between two ACT commands to the same rank. This field corresponds to t_{RRD} in the DDR Specification.
16:13	RW 0000b	PRE to ACT Delayed (C0sd_cr_pre_act): This field indicates the minimum allowed spacing (in DRAM clocks) between the PRE and ACT commands to the same rank-bank. This field corresponds to t_{RP} in the DDR Specification.
12:9	RW 0h	ALLPRE to ACT Delay (C0sd0_cr_preall_act): From the launch of a prechargeall command wait for these many # of memory clocks before launching a activate command. This field corresponds to t_{PALL_RP} .
8:0	RW 00000000 0b	REF to ACT Delayed (C0sd_cr_rfsh_act): This configuration register indicates the minimum allowed spacing (in DRAM clocks) between REF and ACT commands to the same rank. This field corresponds to t_{RFC} in the DDR Specification.



5.2.5 C0CYCTRKWR—Channel 0 CYCTRK WR

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: 256–257h
Default Value: 0000h
Access: RW
Size: 16 bits

This register provides Channel 0 CYCTRK WR.

Bit	Access & Default	Description
15:12	RW 0h	ACT To Write Delay (C0sd_cr_act_wr): This field indicates the minimum allowed spacing (in DRAM clocks) between the ACT and WRITE commands to the same rank-bank. This field corresponds to t_{RCD_wr} in the DDR Specification.
11:8	RW 0h	Same Rank Write To Write Delay (C0sd_cr_wrsr_wr): This field indicates the minimum allowed spacing (in DRAM clocks) between two WRITE commands to the same rank.
7:4	RW 0h	Different Rank Write to Write Delay (C0sd_cr_wrdr_wr): This field indicates the minimum allowed spacing (in DRAM clocks) between two WRITE commands to different ranks. This field corresponds to t_{WR_WR} in the DDR Specification.
3:0	RW 0h	READ To WRTE Delay (C0sd_cr_rd_wr): This field indicates the minimum allowed spacing (in DRAM clocks) between the READ and WRITE commands. This field corresponds to t_{RD_WR} .



5.2.6 C0CYCTRKR—Channel 0 CYCTRK READ

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 258–25Ah
 Default Value: 000000h
 Access: RW, RO
 Size: 24 bits

This register provides Channel 0 CYCTRK RD.

Bit	Access & Default	Description
23:21	RO 000b	Reserved
20:17	RW 0h	Min ACT To READ Delay (C0sd_cr_act_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between the ACT and READ commands to the same rank-bank. This field corresponds to t_{RCD_rd} in the DDR Specification.
16:12	RW 00000b	Same Rank Write To READ Delay (C0sd_cr_wrsr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between the WRITE and READ commands to the same rank. This field corresponds to t_{WTR} in the DDR Specification.
11:8	RW 0000b	Different Ranks Write To READ Delay (C0sd_cr_wrdr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between the WRITE and READ commands to different ranks. This field corresponds to t_{WR_RD} in the DDR Specification.
7:4	RW 0000b	Same Rank Read To Read Delay (C0sd_cr_rdsr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between two READ commands to the same rank.
3:0	RW 0000b	Different Ranks Read To Read Delay (C0sd_cr_rddr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between two READ commands to different ranks. This field corresponds to t_{RD_RD} .

5.2.7 C0CYCTRKREFR—Channel 0 CYCTRK REFR

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 25B–25Ch
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

This register provides Channel 0 CYCTRK Refresh.

Bit	Access & Default	Description
15:13	RO 000b	Reserved
12:9	RW 0000b	Same Rank PALL to REF Delay (C0sd_cr_pchgall_rfsh): This field indicates the minimum allowed spacing (in DRAM clocks) between the PRE-ALL and REF commands to the same rank.
8:0	RW 000000000b	Same Rank REF to REF Delay (C0sd_cr_rfsh_rfsh): This field indicates the minimum allowed spacing (in DRAM clocks) between two REF commands to same ranks.



5.2.8 C0CKECTRL—Channel 0 CKE Control

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 260–263h
 Default Value: 00000800h
 Access: RO, RW, RW/L
 Size: 32 bits

This register provides CKE controls for Channel 0

Bit	Access & Default	Description
31:28	RO 0000b	Reserved
27	RW 0b	start the self-refresh exit sequence (sd0_cr_srcstart): This field indicates the request to start the self-refresh exit sequence.
26:24	RW 000b	CKE pulse width requirement in high phase (sd0_cr_cke_pw_hl_safe): This field indicates CKE pulse width requirement in high phase. This field corresponds to t_{CKE} (high) in the DDR Specification.
23:22	RW/L 0b	Reserved
21	RW/L 0b	Rank 1 Population (sd0_cr_rankpop1): 1 = Rank 1 populated 0 = Rank 1 not populated
20	RW/L 0b	Rank 0 Population (sd0_cr_rankpop0): 1 = Rank 0 populated 0 = Rank 0 not populated
19:17	RW 000b	CKE pulse width requirement in low phase (sd0_cr_cke_pw_lh_safe): This field indicates CKE pulse width requirement in low phase. This field corresponds to t_{CKE} (low) in the DDR Specification.
16	RW 0b	Enable CKE toggle for PDN entry/exit (sd0_cr_pdn_enable): This bit indicates that the toggling of CKEs (for PDN entry/exit) is enabled.
15:14	RO 00b	Reserved
13:10	RW 0010b	Minimum Powerdown exit to Non-Read command spacing (sd0_cr_txp): This field indicates the minimum number of clocks to wait following assertion of CKE before issuing a non-read command. 0000–0001 = Reserved 0010–1001 = 2–9clocks 1010–1111 = Reserved
9:1	RW 00000000 0b	Self refresh exit count (sd0_cr_slfrfsh_exit_cnt): This field indicates the Self refresh exit count. (Program to 255). This field corresponds to t_{XSNR}/t_{XSRD} in the DDR Specification.
0	RW 0b	Indicates only 1 DIMM populated (sd0_cr_singledimmpop): This bit, when set, indicates that only 1 DIMM is populated.



5.2.9 COREFRCTRL—Channel 0 DRAM Refresh Control

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 269–26Eh
 Default Value: 021830000C30h
 Access: RW, RO
 Size: 48 bits

This register provides settings to configure the DRAM refresh controller.

Bit	Access & Default	Description								
47:42	RO 00h	Reserved								
41:37	RW 10000b	Direct Rcomp Quiet Window (DIRQUIET): This field indicates the amount of refresh_tick events to wait before the service of rcomp request in non-default mode of independent rank refresh.								
36:32	RW 11000b	Indirect Rcomp Quiet Window (INDIRQUIET): This field indicates the amount of refresh_tick events to wait before the service of rcomp request in non-default mode of independent rank refresh.								
31:27	RW 00110b	Rcomp Wait (RCOMPWAIT): This field indicates the amount of refresh_tick events to wait before the service of rcomp request in non-default mode of independent rank refresh.								
26	RW 0b	Reserved								
25	RW 0b	Refresh Counter Enable (REFCNTEN): This bit is used to enable the refresh counter to count during times that DRAM is not in self-refresh, but refreshes are not enabled. Such a condition may occur due to need to reprogram DIMMs following DRAM controller switch. This bit has no effect when Refresh is enabled (i.e., there is no mode where Refresh is enabled but the counter does not run). Thus, in conjunction with bit 23 REFEN, the modes are: <table><thead><tr><th>REFEN:REFCNTEN</th><th>Description</th></tr></thead><tbody><tr><td>0:0</td><td>Normal refresh disable</td></tr><tr><td>0:1</td><td>Refresh disabled, but counter is accumulating refreshes.</td></tr><tr><td>1:X</td><td>Normal refresh enable</td></tr></tbody></table>	REFEN:REFCNTEN	Description	0:0	Normal refresh disable	0:1	Refresh disabled, but counter is accumulating refreshes.	1:X	Normal refresh enable
REFEN:REFCNTEN	Description									
0:0	Normal refresh disable									
0:1	Refresh disabled, but counter is accumulating refreshes.									
1:X	Normal refresh enable									
24	RW 0b	All Rank Refresh (ALLRKREF): This configuration bit enables (by default) that all the ranks are refreshed in a staggered/atomic fashion. If set, the ranks are refreshed in an independent fashion.								
23	RW 0b	Refresh Enable (REFEN): 0 = Disabled 1 = Enabled								
22	RW 0b	DDR Initialization Done (INITDONE): Indicates that DDR initialization is complete. 0 = Not Done 1 = Done								



Bit	Access & Default	Description
21:20	RW 00b	Reserved
19:18	RW 00b	DRAM Refresh Panic Watermark (REFPANICWM): When the refresh count exceeds this level, a refresh request is launched to the scheduler and the dref_panic flag is set. 00 = 5 01 = 6 10 = 7 11 = 8
17:16	RW 00b	DRAM Refresh High Watermark (REFHIGHWM): When the refresh count exceeds this level, a refresh request is launched to the scheduler and the dref_high flag is set. 00 = 3 01 = 4 10 = 5 11 = 6
15:14	RW 00b	DRAM Refresh Low Watermark (REFLOWWM): When the refresh count exceeds this level, a refresh request is launched to the scheduler and the dref_low flag is set. 00 = 1 01 = 2 10 = 3 11 = 4
13:0	RW 001100001 10000b	Refresh Counter Time Out Value (REFTIMEOUT): Program this field with a value that will provide 7.8 us at the memory clock frequency. At various memory clock frequencies this results in the following values: 667 MHz -> 1450 hex

5.2.10 C0ODTCTRL—Channel 0 ODT Control

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 29C–29Fh
 Default Value: 00000000h
 Access: RO, RW
 Size: 32 bits

This register provides ODT controls.

Bit	Access & Default	Description
31:12	RO 00000h	Reserved
11:0	RW 0s	Reserved



5.2.11 C1DRB0—Channel 1 DRAM Rank Boundary Address 0

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 600–601h
 Default Value: 0000h
 Access: RW, RO
 Size: 16 bits

The operation of this register is detailed in the description for register C0DRB0.

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Channel 1 DRAM Rank Boundary Address 0 (C1DRBA0): See C0DRB0 register. In stacked mode, if this is the topmost populated rank in Channel 1, program this value to be cumulative of Ch0 DRB3.

5.2.12 C1DRB1—Channel 1 DRAM Rank Boundary Address 1

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 602–603h
 Default Value: 0000h
 Access: RW, RO
 Size: 16 bits

The operation of this register is detailed in the description for register C0DRB0.

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Channel 1 DRAM Rank Boundary Address 1 (C1DRBA1): See C0DRB1 register. In stacked mode, if this is the topmost populated rank in Channel 1, program this value to be cumulative of Ch0 DRB3.



5.2.13 C1DRB2—Channel 1 DRAM Rank Boundary Address 2

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: 604–605h
Default Value: 0000h
Access: RW, RO
Size: 16 bits

The operation of this register is detailed in the description for register C0DRB0.

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Channel 1 DRAM Rank Boundary Address 2 (C1DRBA2): See C0DRB2 register. In stacked mode, if this is the topmost populated rank in Channel 1, program this value to be cumulative of Ch0 DRB3.

5.2.14 C1DRB3—Channel 1 DRAM Rank Boundary Address 3

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: 606–607h
Default Value: 0000h
Access: RW, RO
Size: 16 bits

The operation of this register is detailed in the description for register C0DRB0.

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Channel 1 DRAM Rank Boundary Address 3 (C1DRBA3): See C0DRB3 register. In stacked mode, this will be cumulative of Ch0 DRB3.



5.2.15 C1DRA01—Channel 1 DRAM Rank 0,1 Attributes

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 608–609h
 Default Value: 0000h
 Access: RW
 Size: 16 bits

The operation of this register is detailed in the description for register C0DRA01.

Bit	Access & Default	Description
15:8	RW 00h	Channel 1 DRAM Rank-1 Attributes (C1DRA1): See C0DRA1 register.
7:0	RW 00h	Channel 1 DRAM Rank-0 Attributes (C1DRA0): See C0DRA0 register.

5.2.16 C1DRA23—Channel 1 DRAM Rank 2,3 Attributes

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 60A–60Bh
 Default Value: 0000h
 Access: RW
 Size: 16 bits

The operation of this register is detailed in the description for register C0DRA01.

Bit	Access & Default	Description
15:8	RW 00h	Reserved
7:0	RW 00h	Reserved



5.2.17 C1CYCTRPCHG—Channel 1 CYCTRK PCHG

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: 650–651h
Default Value: 0000h
Access: RO, RW
Size: 16 bits

This register provides Channel 1 CYCTRK Precharge.

Bit	Access & Default	Description
15:11	RO 00000b	Reserved
10:6	RW 00000b	Write To PRE Delayed (C1sd_cr_wr_pchg): This field indicates the minimum allowed spacing (in DRAM clocks) between the WRITE and PRE commands to the same rank-bank. This field corresponds to t_{WR} in the DDR Specification.
5:2	RW 0000b	READ To PRE Delayed (C1sd_cr_rd_pchg): This field indicates the minimum allowed spacing (in DRAM clocks) between the READ and PRE commands to the same rank-bank
1:0	RW 00b	PRE To PRE Delayed (C1sd_cr_pchg_pchg): This field indicates the minimum allowed spacing (in DRAM clocks) between two PRE commands to the same rank.



5.2.18 C1CYCTRKACT—Channel 1 CYCTRK ACT

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 652–655h
 Default Value: 00000000h
 Access: RO, RW
 Size: 32 bits

This register provides Channel 1 CYCTRK ACT.

Bit	Access & Default	Description
31:28	RO 0h	Reserved
27:22	RW 000000b	ACT Window Count (C1sd_cr_act_windowcnt): This field indicates the window duration (in DRAM clocks) during which the controller counts the # of activate commands which are launched to a particular rank. If the number of activate commands launched within this window is greater than 4, then a check is implemented to block launch of further activates to this rank for the rest of the duration of this window.
21	RW 0b	Max ACT Check Disable (C1sd_cr_maxact_dischk): This field disenables the check which ensures that there are no more than four activates to a particular rank in a given window.
20:17	RW 0000b	ACT to ACT Delayed (C1sd_cr_act_act[]): This field indicates the minimum allowed spacing (in DRAM clocks) between two ACT commands to the same rank. This field corresponds to t_{RRD} in the DDR Specification.
16:13	RW 0000b	PRE to ACT Delayed (C1sd_cr_pre_act): This field indicates the minimum allowed spacing (in DRAM clocks) between the PRE and ACT commands to the same rank-bank:12:9R/W0000bPRE-ALL to ACT Delayed (C1sd_cr_preall_act): This configuration register indicates the minimum allowed spacing (in DRAM clocks) between the PRE-ALL and ACT commands to the same rank. This field corresponds to t_{RP} in the DDR Specification.
12:9	RW 0h	ALLPRE to ACT Delay (C1sd_cr_preall_act): From the launch of a Prechargeall command wait for these many # of memory clocks before launching a activate command. This field corresponds to t_{PALL_RP} .
8:0	RW 00000000 0b	REF to ACT Delayed (C1sd_cr_rfsh_act): This field indicates the minimum allowed spacing (in DRAM clocks) between REF and ACT commands to the same rank. This field corresponds to t_{RFC} in the DDR Specification.



5.2.19 C1CYCTRKWR—Channel 1 CYCTRK WR

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: 656–657h
Default Value: 0000h
Access: RW
Size: 16 bits

This register provides Channel 1 CYCTRK WR.

Bit	Access & Default	Description
15:12	RW 0h	ACT To Write Delay (C1sd_cr_act_wr): This field indicates the minimum allowed spacing (in DRAM clocks) between the ACT and WRITE commands to the same rank-bank. This field corresponds to t_{RCD_wr} in the DDR Specification.
11:8	RW 0h	Same Rank Write To Write Delayed (C1sd_cr_wrsr_wr): This field indicates the minimum allowed spacing (in DRAM clocks) between two WRITE commands to the same rank.
7:4	RW 0h	Different Rank Write to Write Delay (C1sd_cr_wrdr_wr): This field indicates the minimum allowed spacing (in DRAM clocks) between two WRITE commands to different ranks. This field corresponds to t_{WR_WR} in the DDR Specification.
3:0	RW 0h	READ To WRITE Delay (C1sd_cr_rd_wr): This field indicates the minimum allowed spacing (in DRAM clocks) between the READ and WRITE commands. This field corresponds to t_{RD_WR} .



5.2.20 C1CYCTRKR—Channel 1 CYCTRK READ

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 658–65Ah
 Default Value: 000000h
 Access: RO, RW
 Size: 24 bits

This is the Channel 1 CYCTRK READ register.

Bit	Access & Default	Description
23:21	RO 0h	Reserved
20:17	RW 0h	Min ACT To READ Delayed (C1sd_cr_act_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between the ACT and READ commands to the same rank-bank. This field corresponds to t_{RCD_rd} in the DDR Specification.
16:12	RW 00000b	Same Rank Write To READ Delayed (C1sd_cr_wrsr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between the WRITE and READ commands to the same rank. This field corresponds to t_{WTR} in the DDR Specification.
11:8	RW 0000b	Different Ranks Write To READ Delayed (C1sd_cr_wrdr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between the WRITE and READ commands to different ranks. This field corresponds to t_{WR_RD} in the DDR Specification.
7:4	RW 0000b	Same Rank Read To Read Delayed (C1sd_cr_rdsr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between two READ commands to the same rank.
3:0	RW 0000b	Different Ranks Read To Read Delayed (C1sd_cr_rddr_rd): This configuration register indicates the minimum allowed spacing (in DRAM clocks) between two READ commands to different ranks. This field corresponds to t_{RD_RD} .



5.2.21 C1CKECTRL—Channel 1 CKE Control

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 660–663h
 Default Value: 00000800h
 Access: RW/L, RW, RO
 Size: 32 bits

This register provides Channel 1 CKE Controls.

Bit	Access & Default	Description
31:28	RO 0h	Reserved
27	RW 0b	start the self-refresh exit sequence (sd1_cr_srcstart): This field indicates the request to start the self-refresh exit sequence.
26:24	RW 000b	CKE pulse width requirement in high phase (sd1_cr_cke_pw_hl_safe): This field indicates CKE pulse width requirement in high phase. This field corresponds to t_{CKE} (high) in the DDR Specification.
23:22	RW/L 00b	Reserved
21	RW/L 0b	Rank 1 Population (sd1_cr_rankpop1): 1 = Rank 1 populated 0 = Rank 1 not populated.
20	RW/L 0b	Rank 0 Population (sd1_cr_rankpop0): 1 = Rank 0 populated 0 = Rank 0 not populated
19:17	RW 000b	CKE pulse width requirement in low phase (sd1_cr_cke_pw_lh_safe): This configuration register indicates CKE pulse width requirement in low phase. This field corresponds to t_{CKE} (low) in the DDR Specification.
16	RW 0b	Enable CKE toggle for PDN entry/exit (sd1_cr_pdn_enable): This configuration bit indicates that the toggling of CKEs (for PDN entry/exit) is enabled.
15:14	RO 00b	Reserved



Bit	Access & Default	Description
13:10	RW 0010b	Minimum Powerdown Exit to Non-Read command spacing (sd1_cr_txp): This configuration register indicates the minimum number of clocks to wait following assertion of CKE before issuing a non-read command. 1010–1111 = Reserved. 0010–1001 = 2–9 clocks 0000–0001 = Reserved.
9:1	RW 000000000b	Self refresh exit count (sd1_cr_slfrsh_exit_cnt): This configuration register indicates the Self refresh exit count. (Program to 255). This field corresponds to t_{XSNR}/t_{XSRD} in the DDR Specification.
0	RW 0b	Indicates only 1 DIMM pPopulated (sd1_cr_singledimmpop): This bit indicates that only 1 DIMM is populated.

5.2.22 C1REFRCTRL—Channel 1 DRAM Refresh Control

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 669–66Eh
 Default Value: 021830000C30h
 Access: RW, RO
 Size: 48 bits

This register provides settings to configure the DRAM refresh controller.

Bit	Access & Default	Description
47:42	RO 00h	Reserved
41:37	RW 10000b	Direct Rcomp Quiet Window (DIRQUIET): This configuration setting indicates the amount of refresh_tick events to wait before the service of rcomp request in non-default mode of independent rank refresh.
36:32	RW 11000b	Indirect Rcomp Quiet Window (INDIRQUIET): This configuration setting indicates the amount of refresh_tick events to wait before the service of rcomp request in non-default mode of independent rank refresh.
31:27	RW 00110b	Rcomp Wait (RCOMPWAIT): This configuration setting indicates the amount of refresh_tick events to wait before the service of rcomp request in non-default mode of independent rank refresh.
26	RW 0b	ZQCAL Enable (ZQCALEN): This bit enables the DRAM controller to issue ZQCAL S command periodically. 0 = Disable 1 = Enable



Bit	Access & Default	Description								
25	RW 0b	Refresh Counter Enable (REFCNTEN): This bit is used to enable the refresh counter to count during times that DRAM is not in self-refresh, but refreshes are not enabled. Such a condition may occur due to need to reprogram DIMMs following DRAM controller switch. This bit has no effect when Refresh is enabled (i.e., there is no mode where Refresh is enabled but the counter does not run). Thus, in conjunction with bit 23 REFEN, the modes are: <table><thead><tr><th>REFEN:REFCNTEN</th><th>Description</th></tr></thead><tbody><tr><td>0:0</td><td>Normal refresh disable</td></tr><tr><td>0:1</td><td>Refresh disabled, but counter is accumulating refreshes.</td></tr><tr><td>1:X</td><td>Normal refresh enable</td></tr></tbody></table>	REFEN:REFCNTEN	Description	0:0	Normal refresh disable	0:1	Refresh disabled, but counter is accumulating refreshes.	1:X	Normal refresh enable
REFEN:REFCNTEN	Description									
0:0	Normal refresh disable									
0:1	Refresh disabled, but counter is accumulating refreshes.									
1:X	Normal refresh enable									
24	RW 0b	All Rank Refresh (ALLRKREF): This configuration bit enables (by default) that all the ranks are refreshed in a staggered/atomic fashion. If set, the ranks are refreshed in an independent fashion.								
23	RW 0b	Refresh Enable (REFEN): Refresh is enabled. 0 = Disabled 1 = Enabled								
22	RW 0b	DDR Initialization Done (INITDONE): Indicates that DDR initialization is complete. 0 = Not Done 1 = Done								
21:20	RW 00b	DRAM Refresh Hysteresis (REFHYSTERISIS): Hysteresis level - Useful for dref_high watermark cases. The dref_high flag is set when the dref_high watermark level is exceeded, and is cleared when the refresh count is less than the hysteresis level. This field should be set to a value less than the high watermark level. 00 = 3 01 = 4 10 = 5 11 = 6								
19:18	RW 00b	DRAM Refresh Panic Watermark (REFPANICWM): When the refresh count exceeds this level, a refresh request is launched to the scheduler and the dref_panic flag is set. 00 = 5 01 = 6 10 = 7 11 = 8								
17:16	RW 00b	DRAM Refresh High Watermark (REFHIGHWM): When the refresh count exceeds this level, a refresh request is launched to the scheduler and the dref_high flag is set. 00 = 3 01 = 4 10 = 5 11 = 6								



Bit	Access & Default	Description
15:14	RW 00b	DRAM Refresh Low Watermark (REFLOWWM): When the refresh count exceeds this level, a refresh request is launched to the scheduler and the dref_low flag is set. 00 = 1 01 = 2 10 = 3 11 = 4
13:0	RW 00110000 110000b	Refresh Counter Time Out Value (REFTIMEOUT): Program this field with a value that will provide 7.8 us at the memory clock frequency. At various memory clock frequencies this results in the following values: 266 MHz -> 820 hex 333 MHz -> A28 hex 400 MHz -> C30 hex 533 MHz -> 104B hex 666 MHz -> 1450 hex

5.2.23 C1ODTCTRL—Channel 1 ODT Control

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: 69C–69Fh
 Default Value: 00000000h
 Access: RO, RW
 Size: 32 bits

This register provides ODT controls.

Bit	Access & Default	Description
31:12	RO 00000h	Reserved
11:8	RW 0h	DRAM ODT for Read Commands (sd1_cr_odt_duration_rd): Specifies the duration in MDCLKs to assert DRAM ODT for Read Commands. The Async value should be used when the Dynamic Powerdown bit is set. Else use the Sync value.
7:4	RW 0h	DRAM ODT for Write Commands (sd1_cr_odt_duration_wr): Specifies the duration in MDCLKs to assert DRAM ODT for Write Commands. The Async value should be used when the Dynamic Powerdown bit is set. Else use the Sync value.
3:0	RW 0h	MCH ODT for Read Commands (sd1_cr_mchodt_duration): Specifies the duration in MDCLKs to assert (G)MCH ODT for Read Commands



5.2.24 EPC0DRB1—EP Channel 0 DRAM Rank Boundary Address 1

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: A02–A03h
Default Value: 0000h
Access: RO, RW
Size: 16 bits

See C0DRB0 register.

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Channel 0 Dram Rank Boundary Address 1 (C0DRBA1):

5.2.25 EPC0DRB2—EP Channel 0 DRAM Rank Boundary Address 2

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: A04–A05h
Default Value: 0000h
Access: RO, RW
Size: 16 bits

See C0DRB0 register.

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Channel 0 DRAM Rank Boundary Address 2 (C0DRBA2):

5.2.26 EPC0DRB3—EP Channel 0 DRAM Rank Boundary Address 3

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: A06–A07h
Default Value: 0000h
Access: RW, RO
Size: 16 bits

See C0DRB0 register.

Bit	Access & Default	Description
15:10	RO 000000b	Reserved
9:0	RW 000h	Channel 0 DRAM Rank Boundary Address 3 (C0DRBA3):



5.2.27 EPC0DRA01—EP Channel 0 DRAM Rank 0,1 Attribute

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: A08–A09h
 Default Value: 0000h
 Access: RW
 Size: 16 bits

The DRAM Rank Attribute Registers define the page sizes/number of banks to be used when accessing different ranks. These registers should be left with their default value (all zeros) for any rank that is unpopulated, as determined by the corresponding CxDRB registers. Each byte of information in the CxDRA registers describes the page size of a pair of ranks. Channel and rank map:

Ch0 Rank0, 1: 108h – 109h

Ch1 Rank0, 1: 188h – 189h

Bit	Access & Default	Description
15:8	RW 00h	Channel 0 DRAM Rank-1 Attributes (C0DRA1): This field defines DRAM pagesize/number-of-banks for rank1 for given channel.
7:0	RW 00h	Channel 0 DRAM Rank-0 Attributes (C0DRA0): This field defines DRAM pagesize/number-of-banks for rank0 for given channel.

5.2.28 EPC0DRA23—EP Channel 0 DRAM Rank 2,3 Attribute

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: A0A–A0Bh
 Default Value: 0000h
 Access: RW
 Size: 16 bits

See C0DRA01 register.

Bit	Access & Default	Description
15:0	RW 00h	Reserved



5.2.29 EPDCYCTRKWRTPRE—EPD CYCTRK WRT PRE

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: A19–A1Ah
Default Value: 0000h
Access: RW, RO
Size: 16 bits

This register provides EPD CYCTRK WRT PRE Status.

Bit	Access & Default	Description
15:11	RW 00000b	ACTTo PRE Delayed (C0sd_cr_act_pchg) : This field indicates the minimum allowed spacing (in DRAM clocks) between the ACT and PRE commands to the same rank-bank
10:6	RW 00000b	Write To PRE Delayed (C0sd_cr_wr_pchg) : This field indicates the minimum allowed spacing (in DRAM clocks) between the WRITE and PRE commands to the same rank-bank
5:2	RW 0000b	READ To PRE Delayed (C0sd_cr_rd_pchg) : This field indicates the minimum allowed spacing (in DRAM clocks) between the READ and PRE commands to the same rank-bank
1:0	RO 00b	Reserved

5.2.30 EPDCYCTRKWRTACT—EPD CYCTRK WRT ACT

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: A1C–A1Fh
Default Value: 00000000h
Access: RO, RW
Size: 32 bits

This register provides EPD CYCTRK WRT ACT Status.

Bit	Access & Default	Description
31:21	RO 000h	Reserved
20:17	RW 0000b	ACT to ACT Delayed (C0sd_cr_act_act[]) : This field indicates the minimum allowed spacing (in DRAM clocks) between two ACT commands to the same rank.
16:13	RW 0000b	PRE to ACT Delayed (C0sd_cr_pre_act) : This field indicates the minimum allowed spacing (in DRAM clocks) between the PRE and ACT commands to the same rank-bank:12:9R/W0000bPRE-ALL to ACT Delayed (C0sd_cr_preall_act): This field indicates the minimum allowed spacing (in DRAM clocks) between the PRE-ALL and ACT commands to the same rank.
12:9	RO 0h	Reserved
8:0	RW 00000000 0b	REF to ACT Delayed (C0sd_cr_rfsh_act) : This field indicates the minimum allowed spacing (in DRAM clocks) between REF and ACT commands to the same rank.



5.2.31 EPDCYCTRKWRTWR—EPD CYCTRK WRT WR

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: A20–A21h
 Default Value: 0000h
 Access: RW, RO
 Size: 16 bits

This register provides EPD CYCTRK WRT WR Status.

Bit	Access & Default	Description
15:12	RW 0h	ACT To Write Delay (C0sd_cr_act_wr): This configuration register indicates the minimum allowed spacing (in DRAM clocks) between the ACT and WRITE commands to the same rank-bank.
11:8	RW 0h	Same Rank Write To Write Delayed (C0sd_cr_wrsr_wr): This configuration register indicates the minimum allowed spacing (in DRAM clocks) between two WRITE commands to the same rank.
7:4	RO 0h	Reserved
3:0	RW 0h	Same Rank WRITE to READ Delay (C0sd_cr_rd_wr): This configuration register indicates the minimum allowed spacing (in DRAM clocks) between the WRITE and READ commands to the same rank



5.2.32 EPDCYCTRKWRTRD—EPD CYCTRK WRT READ

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: A24–A26h
 Default Value: 000000h
 Access: RW
 Size: 24 bits
 BIOS Optimal Default: 000h

This register provides EPD CYCTRK WRT RD Status.

Bit	Access & Default	Description
23:23	RO 0h	Reserved
22:20	RW 000b	EPDunit DQS Slave DLL Enable to Read Safe (EPDSDLL2RD): This field provides the setting for Read command safe from the point of enabling the slave DLLs.
19:18	RO 0h	Reserved
17:14	RW 0h	Min ACT To READ Delayed (C0sd_cr_act_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between the ACT and READ commands to the same rank-bank.
13:9	RW 00000b	Same Rank READ to WRITE Delayed (C0sd_cr_wrsr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between the READ and WRITE commands.
8:6	RO 0h	Reserved
5:3	RW 000b	Same Rank Read To Read Delayed (C0sd_cr_rdsr_rd): This field indicates the minimum allowed spacing (in DRAM clocks) between two READ commands to the same rank.
2:0	RO 0h	Reserved



5.2.33 EPDCKECONFIGREG—EPD CKE Related Configuration Register

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: A28–A2Ch
 Default Value: 00E0000000h
 Access: RW
 Size: 40 bits
 BIOS Optimal Default: 0h

This register provides CKE related configuration for EPD.

Bit	Access & Default	Description
39:35	RW 00000b	EPDunit TXPDLL Count (EPDTXPDLL): This field specifies the delay from precharge power down exit to a command that requires the DRAM DLL to be operational. The commands are read/write.
34:32	RW 000b	EPDunit TXP count (EPDCKETXP): This field specifies the timing requirement for Active power down exit or fast exit pre-charge power down exit to any command or slow exit pre-charge power down to Non-DLL (rd/wr/odt) command.
31:29	RW 111b	Mode Select (sd0_cr_sms): This field indicates the mode in which the controller is operating in. 111 = indicates normal mode of operation, else special mode of operation.
28:27	RW 00b	EPDunit EMRS command select. (EPDEMRSEL): EMRS mode to select BANK address. 01 = EMRS 10 = EMRS2 11 = EMRS3
26:24	RW 000b	CKE pulse width requirement in high phase (sd0_cr_cke_pw_hl_safe): This field indicates CKE pulse width requirement in high phase.
23:20	RW 0h	one-hot active rank population (ep_scr_actrank): This field indicates the active rank in a one hot manner
19:17	RW 000b	CKE pulse width requirement in low phase (sd0_cr_cke_pw_lh_safe): This field indicates CKE pulse width requirement in low phase.
16:15	RO 0h	Reserved
14	RW 0b	EPDunit MPR mode (EPDMPR): MPR Read Mode 1 = MPR mode 0 = Normal mode In MPR mode, only read cycles must be issued by Firmware. Page Results are ignored by DCS and just issues the read chip select.



Bit	Access & Default	Description
13	RW 0b	EPDunit Power Down enable for ODT Rank (EPDOAPDEN): Configuration to enable the ODT ranks to dynamically enter power down. 1 = Enable active power down. 0 = Disable active power down.
12	RW 0b	EPDunit Power Down enable for Active Rank (EPDAAPDEN): Configuration to enable the active rank to dynamically enter power down. 1 = Enable active power down. 0 = Disable active power down.
11:10	RO 0h	Reserved
9:1	RW 00000000 0b	Self refresh exit count (sd0_cr_slfrsh_exit_cnt): This field indicates the Self refresh exit count. (Program to 255)
0	RW 0b	indicates only 1 rank enabled (sd0_cr_singledimmpop): This field indicates that only 1 rank is enabled. This bit needs to be set if there is one active rank and no odt ranks, or if there is one active rank and one odt rank and they are the same rank.



5.2.34 EPDREFCONFIG—EP DRAM Refresh Configuration

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: A30–A33h
 Default Value: 40000C30h
 Access: RO, RW
 Size: 32 bits

This register provides settings to configure the EPD refresh controller.

Bit	Access & Default	Description								
31	RO 0b	Reserved								
30:29	RW 10b	EPDunit refresh count addition for self refresh exit. (EPDREF4SR): Configuration indicating the number of additional refreshes that needs to be added to the refresh request count after exiting self refresh. Typical value is to add 2 refreshes. 00 = Add 0 Refreshes 01 = Add 1 Refreshes 10 = Add 2 Refreshes 11 = Add 3 Refreshes Signal name used: ep_scr_refreq_aftersr[1:0]								
28	RW 0b	Refresh Counter Enable (REFCNTEN): This bit is used to enable the refresh counter to count during times that DRAM is not in self-refresh, but refreshes are not enabled. Such a condition may occur due to need to reprogram DIMMs following DRAM controller switch. This bit has no effect when Refresh is enabled (i.e. there is no mode where Refresh is enabled but the counter does not run). Thus, in conjunction with bit 23 REFEN, the modes are: <table><thead><tr><th>REFEN:REFCNTEN</th><th>Description</th></tr></thead><tbody><tr><td>0:0</td><td>Normal refresh disable</td></tr><tr><td>0:1</td><td>Refresh disabled, but counter is accumulating refreshes.</td></tr><tr><td>1:X</td><td>Normal refresh enable</td></tr></tbody></table>	REFEN:REFCNTEN	Description	0:0	Normal refresh disable	0:1	Refresh disabled, but counter is accumulating refreshes.	1:X	Normal refresh enable
REFEN:REFCNTEN	Description									
0:0	Normal refresh disable									
0:1	Refresh disabled, but counter is accumulating refreshes.									
1:X	Normal refresh enable									
27	RW 0b	Refresh Enable (REFEN): 0 = Disabled 1 = Enabled								
26	RW 0b	DDR Initialization Done (INITDONE): Indicates that DDR initialization is complete. 0 = Not Done 1 = Done								



Bit	Access & Default	Description
25:22	RW 0000b	DRAM Refresh Hysterisis (REFHYSTERISIS): Hysterisis level - Useful for dref_high watermark cases. The dref_high flag is set when the dref_high watermark level is exceeded, and is cleared when the refresh count is less than the hysterisis level. This bit should be set to a value less than the high watermark level. 0000 = 0 0001 = 1 1000 = 8
21:18	RW 0000b	DRAM Refresh High Watermark (REFHIGHWM): When the refresh count exceeds this level, a refresh request is launched to the scheduler and the dref_high flag is set. 0000 = 0 0001 = 1 1000 = 8
17:14	RW 0000b	DRAM Refresh Low Watermark (REFLOWWM): When the refresh count exceeds this level, a refresh request is launched to the scheduler and the dref_low flag is set. 0000 = 0 0001 = 1 1000 = 8
13:0	RW 001100001 10000b	Refresh Counter Time Out Value (REFTIMEOUT): Program this field with a value that will provide 7.8 us at the memory clock frequency. At various memory clock frequencies this results in the following values: 266 MHz -> 820 hex 333 MHz -> A28 hex 400 MHz -> C30 hex 533 MHz -> 104B hex 666 MHz -> 1450 hex



5.2.35 TSC1—Thermal Sensor Control 1

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: CD8h
 Default Value: 00h
 Access: RW/L, RW, RS/WC
 Size: 8 bits

This register controls the operation of the thermal sensor. Bit 0 is reset to its default by PLTRST#.

Bit	Access & Default	Description
7	RW/L 0b	Thermal Sensor Enable (TSE): This bit enables power to the thermal sensor. Lockable via TCO bit 7. 0 = Disabled 1 = Enabled
6	RW 0b	Analog Hysteresis Control (AHC): This bit enables the analog hysteresis control to the thermal sensor. When enabled, about 1 degree of hysteresis is applied. This bit should normally be off in thermometer mode since the thermometer mode of the thermal sensor defeats the usefulness of analog hysteresis. 0 = hysteresis disabled 1 = analog hysteresis enabled.
5:2	RW 0000b	Digital Hysteresis Amount (DHA): This bit determines whether no offset, 1 LSB, 2... 15 is used for hysteresis for the trip points. 0000 = digital hysteresis disabled, no offset added to trip temperature 0001 = offset is 1 LSB added to each trip temperature when tripped ... 0110 = ~3.0 °C (Recommended setting) ... 1110 = added to each trip temperature when tripped 1111 = added to each trip temperature when tripped
1	RW/L 0b	Thermal Sensor Comparator Select (TSCS): This bit multiplexes between the two analog comparator outputs. Normally Catastrophic is used. Lockable via TCO bit 7. 0 = Catastrophic 1 = Hot



Bit	Access & Default	Description
0	RS/WC 0b	In Use (IU): Software semaphore bit. After a full (G)MCH RESET, a read to this bit returns a 0. After the first read, subsequent reads will return a 1. A write of a 1 to this bit will reset the next read value to 0. Writing a 0 to this bit has no effect. Software can poll this bit until it reads a 0, and will then own the usage of the thermal sensor. This bit has no other effect on the hardware, and is only used as a semaphore among various independent software threads that may need to use the thermal sensor. Software that reads this register but does not intend to claim exclusive access of the thermal sensor must write a one to this bit if it reads a 0, in order to allow other software threads to claim it. See also THERM3 bit 7 and IUB, which are independent additional semaphore bits.

5.2.36 TSC2—Thermal Sensor Control 2

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: CD9h
 Default Value: 00h
 Access: RW/L, RO
 Size: 8 bits

This register controls the operation of the thermal sensor.

Bit	Access & Default	Description
7:4	RO 0h	Reserved
3:0	RW/L 0h	Thermometer Mode Enable and Rate (TE): If analog thermal sensor mode is not enabled by setting these bits to 0000b, these bits enable the thermometer mode functions and set the Thermometer controller rate. When the Thermometer mode is disabled and TSC1[TSE] =enabled, the analog sensor mode should be fully functional. In the analog sensor mode, the Catastrophic trip is functional, and the Hot trip is functional at the offset below the catastrophic programmed into TSC2[CHO]. The other trip points are not functional in this mode. When Thermometer mode is enabled, all the trip points (Catastrophic, Hot, Aux0) will all operate using the programmed trip points and Thermometer mode rate. Note: When disabling the Thermometer mode while thermometer running, the Thermometer mode controller will finish the current cycle. Note: During boot, all other thermometer mode registers (except



Bit	Access & Default	Description
		lock bits) should be programmed appropriately before enabling the Thermometer Mode. Clock used is the memory command clock (i.e., ep_mcclk). Note: The same legacy thermal sensor design in prior (G)MCHs has been used in this design. However, the thermal sensor logic runs in a memory command clock domain that is ½ the frequency of the memory clock used in prior designs. Hence the period counted for the thermal sensor settling time has doubled for the same settings, compared to prior (G)MCHs. Thus the thermal sensor programming should be updated to maintain the same thermometer rate count as in prior (G)MCHs. Lockable via TCO bit 7. 0000 = Thermometer mode disabled (i.e., analog sensor mode) 0001 = enabled, 512 clock mode 0010 = enabled, 1024 clock mode (normal Thermometer mode operation, for DDR 667/800) provides ~6.14 us settling time @ 167 MHz ep_mcclk (DDR 667) provides ~5.12 us settling time @ 200 MHz ep_mcclk (DDR 800) 0011 = enabled, 1536 clock mode (normal Thermometer mode operation, for DDR 1066) provides ~9.22 us settling time @ 167 MHz ep_mcclk (DDR 667) provides ~7.68 us settling time @ 200 MHz ep_mcclk (DDR 800) 0100 = enabled, 2048 clock mode (normal Thermometer mode operation, for DDR 1333) provides ~15.36 us settling time @ 133 MHz ep_mcclk (DDR 533) provides ~12.29 us settling time @ 167 MHz ep_mcclk (DDR 667) provides ~10.24 us settling time @ 200 MHz ep_mcclk (DDR 800) 0101 = enabled, 3072 clock mode 0110 = enabled, 4096 clock mode 0111 = enabled, 6144 clock mode all other permutations are reserved 1111 = enabled, 4 clock mode (for testing digital logic) NOTE: The settling time for DAC and Thermal Diode is between 2 and 5 us. To meet this requirement the SE value must be programmed to be 5 us or more. Recommendation is to use: "0010" setting for DDR 667/800.



5.2.37 TSS—Thermal Sensor Status

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: CDAh
Default Value: 00h
Access: RO
Size: 8 bits

This read only register provides trip point and other status of the thermal sensor.

Bit	Access & Default	Description
7	RO 0b	Catastrophic Trip Indicator (CTI): 1 = Internal thermal sensor temperature is above the catastrophic setting.
6	RO 0b	Hot Trip Indicator (HTI): 1 = Internal thermal sensor temperature is above the Hot setting.
5	RO 0b	Aux0 Trip Indicator (A0TI): 1 = Internal thermal sensor temperature is above the Aux0 setting.
4	RO 0b	Thermometer Mode Output Valid (TOV): 1 = Thermometer mode is able to converge to a temperature and that the TR register is reporting a reasonable estimate of the thermal sensor temperature. 0 = Thermometer mode is off, or that temperature is out of range, or that the TR register is being looked at before a temperature conversion has had time to complete.
3:2	RO 00b	Reserved
1	RO 0b	Direct Catastrophic Comparator Read (DCCR): This bit reads the output of the Catastrophic comparator directly, without latching via the Thermometer mode circuit. Used for testing.
0	RO 0b	Direct Hot Comparator Read (DHCR): This bit reads the output of the Hot comparator directly, without latching via the Thermometer mode circuit. Used for testing.



5.2.38 TSTTP—Thermal Sensor Temperature Trip Point

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: CDC–CDFh
 Default Value: 00000000h
 Access: RO, RW, RW/L
 Size: 32 bits

This register :

- Sets the target values for the trip points in thermometer mode. See also TST[Direct DAC Connect Test Enable].
- Reports the relative thermal sensor temperature

Bit	Access & Default	Description
31:24	RO 00h	Relative Temperature (RELT): In Thermometer mode, the RELT field of this register report the relative temperature of the thermal sensor. Provides a two's complement value of the thermal sensor relative to the Hot Trip Point. Temperature above the Hot Trip Point will be positive. TR and HTPS can both vary between 0 and 255. But RELT will be clipped between ± 127 to keep it an 8 bit number. See also TSS[Thermometer mode Output Valid] In the Analog mode, the RELT field reports HTPS value.
23:16	RW 00h	Aux0 Trip point setting (A0TPS): Sets the target for the Aux0 trip point.
15:8	RW/L 00h	Hot Trip Point Setting (HTPS): Sets the target value for the Hot trip point. Lockable via TCO bit 7.
7:0	RW/L 00h	Catastrophic Trip Point Setting (CTPS): Sets the target for the Catastrophic trip point. See also TST[Direct DAC Connect Test Enable]. Lockable via TCO bit 7.



5.2.39 TCO—Thermal Calibration Offset

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: CE2h
 Default Value: 00h
 Access: RW/L/K, RW/L
 Size: 8 bits

Bit 7: reset to its default by PLTRST#.

Bit	Access & Default	Description
7	RW/L/K 0b	Lock Bit for Catastrophic (LBC): This bit, when written to a 1, locks the Catastrophic programming interface, including bits 7:0 of this register and bits 15:0 of TSTTP, bits 1,7 of TSC 1, bits 3:0 of TSC 2, bits 4:0 of TSC 3, and bits 0,7 of TST. This bit may only be set to a 0 by a hardware reset (PLTRST#). Writing a 0 to this bit has no effect.
6:0	RW/L 00h	Calibration Offset (CO): This field contains the current calibration offset for the Thermal Sensor DAC inputs. The calibration offset is a twos complement signed number which is added to the temperature counter value to help generate the final value going to the thermal sensor DAC. This field is Read/Write and can be modified by Software unless locked by setting bit 7 of this register. The fuses cannot be programmed via this register. Once this register has been overwritten by software, the values of the TCO fuses can be read using the Therm3 register. Note for TCO operation: While this is a seven-bit field, the 7th bit is sign extended to 9 bits for TCO operation. The range of 00h to 3Fh corresponds to 0 0000 0000 to 0 0011 1111. The range of 41h to 7Fh corresponds to 1 1100 001 (i.e., negative 3Fh) to 1 1111 1111 (i.e., negative 1), respectively.



5.2.40 THERM1—Hardware Throttle Control

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: CE4h
 Default Value: 00h
 Access: RW/L, RO, RW/L/K
 Size: 8 bits

All bits in this register are reset to their defaults by PLTRST#.

Bit	Access & Default	Description
7	RW/L 00h	Internal Thermal Hardware Throttling Enable (ITHTE): This bit is a master enable for internal thermal sensor-based hardware throttling. 0 = Disable. Hardware actions via the internal thermal sensor are disabled. 1 = Enable. Hardware actions via the internal thermal sensor are enabled.
6	RW/L 00h	Internal Thermal Hardware Throttling Type (ITHTT): This policy bit determines what type of hardware throttling will be enacted by the internal thermal sensor when enabled by ITHTE. 0 = (G)MCH throttling 1 = DRAM throttling
5	RO 00h	Reserved
4	RW/L 00h	Throttling Temperature Range Selection (TTRS): This bit determines what temperature ranges will enable throttling. Lockable by bit 0 of this register. See also the throttling registers in MCHBAR configuration space C0GTC and C1GTC [(G)MCH Thermal Sensor Trip Enable] and PEFC [Thermal Sensor Trip Enable] which are used to enable or disable throttling. 0 = Catastrophic only. The Catastrophic thermal temperature range will enable main memory thermal throttling. 1 = Hot and Catastrophic.
3	RW/L 00h	Halt on Catastrophic (HOC): 0 = Continue to toggle clocks when the catastrophic sensor trips. 1 = All clocks are disabled when the catastrophic sensor trips. A system reset is required to bring the system out of a halt from the thermal sensor.
2:1	RO 00b	Reserved
0	RW/L/K 00h	Hardware Throttling Lock Bit (HTL): This bit locks bits 7:0 of this register. 0 = The register bits are unlocked. 1 = The register bits are locked. It may only be set to a 0 by a hardware reset. Writing a 0 to this bit has no effect.



5.2.41 TIS—Thermal Interrupt Status

B/D/F/Type:	0/0/0/MCHBAR
Address Offset:	CEA–CEBh
Default Value:	0000h
Access:	RO, RWC
Size:	16 bits

This register is used to report which specific error condition resulted in the dev. 0 fn. 0 ERRSTS[Thermal Sensor event for SMI/SCI/SERR] or memory mapped IIR Thermal Event. Software can examine the current state of the thermal zones by examining the TSS. Software can distinguish internal or external Trip Event by examining EXTTSCS.

Software must write a 1 to clear the status bits in this register.

Following scenario is possible. An interrupt is initiated on a rising temperature trip, the appropriate DMI cycles are generated, and eventually the software services the interrupt and sees a rising temperature trip as the cause in the status bits for the interrupts. Assume that the software then goes and clears the local interrupt status bit in the TIS register for that trip event. It is possible at this point that a falling temperature trip event occurs before the software has had the time to clear the global interrupts status bit. But since software has already looked at the status register before this event happened, software may not clear the local status flag for this event. Therefore, after the global interrupt is cleared by software, software must look at the instantaneous status in the TSS register.

All bits in this register are reset to their defaults by PLTRST#.

Bit	Access & Default	Description
15:10	RO 00h	Reserved
9	RWC 0b	Was Catastrophic Thermal Sensor Interrupt Event (WCTSIE): 1 = Indicates that a Catastrophic Thermal Sensor trip based on a higher to lower temperature transition thru the trip point 0 = No trip for this event
8	RWC 0b	Was Hot Thermal Sensor Interrupt Event (WHTSIE): 1 = Indicates that a Hot Thermal Sensor trip based on a higher to lower temperature transition thru the trip point 0 = No trip for this event
7	RWC 0b	Was Aux0 Thermal Sensor Interrupt Event (WA0TSIE): 1 = Indicates that an Aux0 Thermal Sensor trip based on a higher to lower temperature transition thru the trip point 0 = No trip for this event Software must write a 1 to clear this status bit.
6:5	RO 00b	Reserved



Bit	Access & Default	Description
4	RWC 0b	Catastrophic Thermal Sensor Interrupt Event (CTSIE): 1 = Indicates that a Catastrophic Thermal Sensor trip event occurred based on a lower to higher temperature transition thru the trip point. 0 = No trip for this event Software must write a 1 to clear this status bit.
3	RWC 0b	Hot Thermal Sensor Interrupt Event (HTSIE): 1 = Indicates that a Hot Thermal Sensor trip event occurred based on a lower to higher temperature transition thru the trip point. 0 = No trip for this event Software must write a 1 to clear this status bit.
2	RWC 0b	Aux0 Thermal Sensor Interrupt Event (A0TSIE): 1 = Indicates that an Aux0 Thermal Sensor trip event occurred based on a lower to higher temperature transition thru the trip point. 0 = No trip for this event Software must write a 1 to clear this status bit.
1:0	RO 00b	Reserved



5.2.42 TSMICMD—Thermal SMI Command

B/D/F/Type: 0/0/0/MCHBAR
Address Offset: CF1h
Default Value: 00h
Access: RO, RW
Size: 8 bits

This register selects specific errors to generate a SMI DMI special cycle, as enabled by the Device 0 SMI Error Command Register [SMI on (G)MCH Thermal Sensor Trip]. The SMI must not be enabled at the same time as the SERR/SCI for the thermal sensor event.

All bits in this register are reset to their defaults by PLTRST#.

Bit	Access & Default	Description
7:3	RO 00h	Reserved
2	RW 0b	SMI on (G)MCH Catastrophic Thermal Sensor Trip (SMGCTST): 1 = Does not mask the generation of an SMI DMI special cycle on a catastrophic thermal sensor trip. 0 = Disable reporting of this condition via SMI messaging.
1	RW 0b	SMI on (G)MCH Hot Thermal Sensor Trip (SMGHTST): 1 = Does not mask the generation of an SMI DMI special cycle on a Hot thermal sensor trip. 0 = Disable reporting of this condition via SMI messaging.
0	RW 0b	SMI on (G)MCH Aux Thermal Sensor Trip (SMGATST): 1 = Does not mask the generation of an SMI DMI special cycle on an Auxiliary thermal sensor trip. 0 = Disable reporting of this condition via SMI messaging.



5.2.43 PMSTS—Power Management Status

B/D/F/Type: 0/0/0/MCHBAR
 Address Offset: F14–F17h
 Default Value: 00000000h
 Access: RWC/S, RO
 Size: 32 bits

This register is Reset by PWROK only.

Bit	Access & Default	Description
31:9	RO 000000h	Reserved
8	RWC/S 0b	Warm Reset Occurred (WRO): Set by the PMunit whenever a Warm Reset is received, and cleared by PWROK=0. 0 = No Warm Reset occurred. 1 = Warm Reset occurred. BIOS Requirement: BIOS can check and clear this bit whenever executing POST code. This way BIOS knows that if the bit is set, then the PMSTS bits [1:0] must also be set, and if not BIOS needs to power-cycle the platform.
7:2	RO 00h	Reserved
1	RWC/S 0b	Channel 1 in Self-Refresh (C1SR): Set by power management hardware after Channel 1 is placed in self refresh as a result of a Power State or a Reset Warn sequence. Cleared by Power management hardware before starting Channel 1 self refresh exit sequence initiated by a power management exit. Cleared by the BIOS by writing a 1 in a warm reset (Reset# asserted while PWROK is asserted) exit sequence. 0 = Channel 1 not ensured to be in self refresh. 1 = Channel 1 in Self Refresh.
0	RWC/S 0b	Channel 0 in Self-Refresh (C0SR): Set by power management hardware after Channel 0 is placed in self refresh as a result of a Power State or a Reset Warn sequence. Cleared by Power management hardware before starting Channel 0 self refresh exit sequence initiated by a power management exit. Cleared by the BIOS by writing a 1 in a warm reset (Reset# asserted while PWROK is asserted) exit sequence. 0 = Channel 0 not ensured to be in self refresh. 1 = Channel 0 in Self Refresh.



5.3 EPBAR

Table 5-3. EPBAR Register Address Map

Address Offset	Symbol	Register Name	Default Value	Access
44–47h	EPESD	EP Element Self Description	00000201h	RO, RWO
50–53h	EPLE1D	EP Link Entry 1 Description	01000000h	RO, RWO
58–5Fh	EPLE1A	EP Link Entry 1 Address	0000000000 000000h	RO, RWO
60–63h	EPLE2D	EP Link Entry 2 Description	02000002h	RO, RWO
68–6Fh	EPLE2A	EP Link Entry 2 Address	0000000000 008000h	RO

5.3.1 EPESD—EP Element Self Description

B/D/F/Type: 0/0/0/PXPEPBAR
Address Offset: 44–47h
Default Value: 00000201h
Access: RO, RWO
Size: 32 bits

This register provides information about the root complex element containing this Link Declaration Capability.

Bit	Access & Default	Description
31:24	RO 00h	Port Number (PN): This field specifies the port number associated with this element with respect to the component that contains this element. A value of 00h indicates to configuration software that this is the default Express port.
23:16	RWO 00h	Component ID (CID): This field indicates identifies the physical component that contains this Root Complex Element. BIOS Requirement: Must be initialized according to guidelines in the <i>PCI Express* Isochronous/Virtual Channel Support Hardware Programming Specification (HPS)</i> .
15:8	RO 0sh	Number of Link Entries (NLE): This field indicates the number of link entries following the Element Self Description. This field reports 2 (one each for PEG and DMI).
7:4	RO 0h	Reserved
3:0	RO 1h	Element Type (ET): This field indicates the type of the Root Complex Element. Value of 1 h represents a port to system memory.



5.3.2 EPLE1D—EP Link Entry 1 Description

B/D/F/Type:	0/0/0/PXPEPBAR
Address Offset:	50–53h
Default Value:	01000000h
Access:	RO, RWO
Size:	32 bits

This register provides the first part of a Link Entry which declares an internal link to another Root Complex Element.

Bit	Access & Default	Description
31:24	RO 01h	Target Port Number (TPN): Specifies the port number associated with the element targeted by this link entry (DMI). The target port number is with respect to the component that contains this element as specified by the target component ID.
23:16	RWO 00h	Target Component ID (TCID): This field indicates the physical or logical component that is targeted by this link entry. BIOS Requirement: Must be initialized according to guidelines in the <i>PCI Express* Isochronous/Virtual Channel Support Hardware Programming Specification (HPS)</i> .
15:2	RO 0000h	Reserved
1	RO 0b	Link Type (LTYP): This field indicates that the link points to memory-mapped space (for RCRB). The link address specifies the 64-bit base address of the target RCRB.
0	RWO 0b	Link Valid (LV): 0 = Link Entry is not valid and will be ignored. 1 = Link Entry specifies a valid link.

5.3.3 EPLE1A—EP Link Entry 1 Address

B/D/F/Type:	0/0/0/PXPEPBAR
Address Offset:	58–5Fh
Default Value:	0000000000000000h
Access:	RO, RWO
Size:	64 bits

This register provides the second part of a Link Entry which declares an internal link to another Root Complex Element.

Bit	Access & Default	Description
63:36	RO 0s	Reserved
35:12	RWO 0s	Link Address (LA): This field contains the memory mapped base address of the RCRB that is the target element (DMI) for this link entry.
11:0	RO 0s	Reserved



5.3.4 EPLE2D—EP Link Entry 2 Description

B/D/F/Type: 0/0/0/PXPEPBAR
 Address Offset: 60–63h
 Default Value: 02000002h
 Access: RO, RWO
 Size: 32 bits

This register provides the first part of a Link Entry which declares an internal link to another Root Complex Element.

Bit	Access & Default	Description
31:24	RO 02h	Target Port Number (TPN): This field specifies the port number associated with the element targeted by this link entry (PEG). The target port number is with respect to the component that contains this element as specified by the target component ID.
23:16	RWO 00h	Target Component ID (TCID): This field indicates the physical or logical component that is targeted by this link entry. A value of 0 is reserved. Component IDs start at 1. This value is a mirror of the value in the Component ID field of all elements in this component. BIOS Requirement: Must be initialized according to guidelines in the <i>PCI Express* Isochronous/Virtual Channel Support Hardware Programming Specification (HPS)</i> .
15:2	RO 0s	Reserved
1	RO 1b	Link Type (LTYP): This field indicates that the link points to configuration space of the integrated device which controls the x16 root port. The link address specifies the configuration address (segment, bus, device, function) of the target root port.
0	RWO 0b	Link Valid (LV): 0 = Link Entry is not valid and will be ignored. 1 = Link Entry specifies a valid link.



5.3.5 EPLE2A—EP Link Entry 2 Address

B/D/F/Type: 0/0/0/PXPEPBAR
 Address Offset: 68–6Fh
 Default Value: 0000000000008000h
 Access: RO
 Size: 64 bits

This register provides the second part of a Link Entry which declares an internal link to another Root Complex Element.

Bit	Access & Default	Description
63:28	RO 0s	Reserved for Configuration Space Base Address (): Not required if root complex has only one configuration space.
27:20	RO 0s	Bus Number (BUSN):
19:15	RO 00001b	Device Number (DEVN): Target for this link is PCI Express x16 port (Device 1).
14:12	RO 000b	Function Number (FUNN):
11:0	RO 0s	Reserved





6 PCI Express* Registers (D1:F0)

Device 1 contains the controls associated with the PCI Express x16 root port that is the intended to attach as the point for external graphics. It also functions as the virtual PCI-to-PCI bridge.

Warning: When reading the PCI Express "conceptual" registers such as this, you may not get a valid value unless the register value is stable.

The *PCI Express* Specification* defines two types of reserved bits.

Reserved and Preserved:

1. Reserved for future RW implementations; software must preserve value read for writes to bits.
2. Reserved and Zero: Reserved for future R/WC/S implementations; software must use 0 for writes to bits.

Unless explicitly documented as Reserved and Zero, all bits marked as reserved are part of the Reserved and Preserved type, which have historically been the typical definition for Reserved.

Note: Most (if not all) control bits in this device cannot be modified unless the link is down. Software is required to first Disable the link, then program the registers, and then re-enable the link (which will cause a full-retrain with the new settings).

Table 6-1. PCI Express* Register Address Map (Device 1, Function 0)

Address Offset	Register Symbol	Register Name	Default Value	Access
00–01h	VID1	Vendor Identification	8086h	RO
02–03h	DID1	Device Identification	29C1h	RO
04–05h	PCICMD1	PCI Command	0000h	RO, RW
06–07h	PCISTS1	PCI Status	0010h	RO, RWC
08h	RID1	Revision Identification	See register description	RO
09–0Bh	CC1	Class Code	060400h	RO
0Ch	CL1	Cache Line Size	00h	RW
0Eh	HDR1	Header Type	01h	RO
18h	PBUSN1	Primary Bus Number	00h	RO
19h	SBUSN1	Secondary Bus Number	00h	RW
1Ah	SUBUSN1	Subordinate Bus Number	00h	RW



Address Offset	Register Symbol	Register Name	Default Value	Access
1Ch	IOBASE1	I/O Base Address	F0h	RW, RO
1D	IOLIMIT1	I/O Limit Address	00h	RW, RO
1E–1Fh	SSTS1	Secondary Status	0000h	RWC, RO
20–21h	MBASE1	Memory Base Address	FFF0h	RW, RO
22–23h	MLIMIT1	Memory Limit Address	0000h	RW, RO
24–25h	PMBASE1	Prefetchable Memory Base Address	FFF1h	RW, RO
26–27h	PMLIMIT1	Prefetchable Memory Limit Address	0001h	RW, RO
28–2Bh	PMBASEU1	Prefetchable Memory Base Address	00000000h	RW,
2C–2Fh	PMLIMITU1	Prefetchable Memory Limit Address	00000000h	RW
34h	CAPPTR1	Capabilities Pointer	88h	RO
3Ch	INTRLINE1	Interrupt Line	00h	RW
3Dh	INTRPIN1	Interrupt Pin	01h	RO
3E–3Fh	BCTRL1	Bridge Control	0000h	RO, RW
80–83h	PM_CAPID1	Power Management Capabilities	C8039001h	RO
84–87h	PM_CS1	Power Management Control/Status	00000000h	RO, RW/S, RW
88–8Bh	SS_CAPID	Subsystem ID and Vendor ID Capabilities	0000800Dh	RO
8C–8Fh	SS	Subsystem ID and Subsystem Vendor ID	00008086h	RWO
90–91h	MSI_CAPID	Message Signaled Interrupts Capability ID	A005h	RO
92–93h	MC	Message Control	0000h	RW, RO
94–97h	MA	Message Address	00000000h	RW, RO
98–99h	MD	Message Data	0000h	RW
A0–A1h	PEG_CAPL	PCI Express-G Capability List	0010h	RO
A2–A3h	PEG_CAP	PCI Express-G Capabilities	0141h	RO, RWO
A4–A7h	DCAP	Device Capabilities	00008000h	RO
A8–A9h	DCTL	Device Control	0000h	RO, RW
AA–ABh	DSTS	Device Status	0000h	RO, RWC
AC–AFh	LCAP	Link Capabilities	02014D01h	RO, RWO
B0–B1h	LCTL	Link Control	0000h	RO, RW, RW/SC
B2–B3h	LSTS	Link Status	1001h	RO
B4–B7h	SLOTCAP	Slot Capabilities	00040000h	RWO, RO



Address Offset	Register Symbol	Register Name	Default Value	Access
B8–B9h	SLOTCTL	Slot Control	01C0h	RO, RW
BA–BBh	SLOTSTS	Slot Status	0000h	RO, RWC
BC–BDh	RCTL	Root Control	0000h	RO, RW
C0– C3h	RSTS	Root Status	00000000h	RO, RWC
EC– EFh	PEGLC	PCI Express-G Legacy Control	00000000h	RW, RO
100–103h	VCECH	Virtual Channel Enhanced Capability Header	14010002h	RO
104–107h	PVCCAP1	Port VC Capability Register 1	00000000h	RO
108–10Bh	PVCCAP2	Port VC Capability Register 2	00000000h	RO
10C–10Dh	PVCCTL	Port VC Control	0000h	RO, RW
110–113h	VC0RCAP	VC0 Resource Capability	00000000h	RO
114–117h	VC0RCTL	VC0 Resource Control	800000FFh	RO, RW
11A–11Bh	VC0RSTS	VC0 Resource Status	0002h	RO
140–143h	RCLDECH	Root Complex Link Declaration Enhanced	00010005h	RO
144–147h	ESD	Element Self Description	02000100h	RO, RWO
150–153h	LE1D	Link Entry 1 Description	00000000h	RO, RWO
158–15Fh	LE1A	Link Entry 1 Address	0000000000 000000h	RO, RWO
218–21Fh	PEGSSTS	PCI Express-G Sequence Status	0000000000 000FFFh	RO



6.1 PCI Express* Configuration Register Details (D1:F0)

6.1.1 VID1—Vendor Identification

B/D/F/Type: 0/1/0/PCI
Address Offset: 00–01h
Default Value: 8086h
Access: RO
Size: 16 bits

This register combined with the Device Identification register uniquely identify any PCI device.

Bit	Access & Default	Description
15:0	RO 8086h	Vendor Identification (VID1): PCI standard identification for Intel.

6.1.2 DID1—Device Identification

B/D/F/Type: 0/1/0/PCI
Address Offset: 02–03h
Default Value: 29C1h
Access: RO
Size: 16 bits

This register combined with the Vendor Identification register uniquely identifies any PCI device.

Bit	Access & Default	Description
15:8	RO 29h	Device Identification Number (DID1(UB)): Identifier assigned to the (G)MCH device 1 (virtual PCI-to-PCI bridge, PCI Express Graphics port).
7:4	RO 7h	Device Identification Number (DID1(HW)): Identifier assigned to the (G)MCH device 1 (virtual PCI-to-PCI bridge, PCI Express Graphics port).
3:0	RO 1h	Device Identification Number (DID1(LB)): Identifier assigned to the (G)MCH device 1 (virtual PCI-to-PCI bridge, PCI Express Graphics port).



6.1.3 PCICMD1—PCI Command

B/D/F/Type: 0/1/0/PCI
 Address Offset: 04–05h
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

Bit	Access & Default	Description
15:11	RO 00h	Reserved
10	RW 0b	INTA Assertion Disable (INTAAD): This bit Only affects interrupts generated by the device (PCI INTA from a PME or Hot Plug event) controlled by this command register. It does not affect upstream MSIs, upstream PCI INTA–INTD assert and de-assert messages. 0 = This device is permitted to generate INTA interrupt messages. 1 = This device is prevented from generating interrupt messages. Any INTA emulation interrupts already asserted must be de-asserted when this bit is set.
9	RO 0b	Fast Back-to-Back Enable (FB2B): Not Applicable or Implemented. Hardwired to 0.
8	RW 0b	SERR# Message Enable (SERRE1): Controls Device 1 SERR# messaging. The (G)MCH communicates the SERR# condition by sending an SERR message to the ICH. This bit, when set, enables reporting of non-fatal and fatal errors detected by the device to the Root Complex. Note that errors are reported if enabled either through this bit or through the PCI Express specific bits in the Device Control Register. 0 = The SERR message is generated by the (G)MCH for Device #1 only under conditions enabled individually through the Device Control Register. 1 = The (G)MCH is enabled to generate SERR messages which will be sent to the ICH for specific Device 1 error conditions generated/detected on the primary side of the virtual PCI to PCI bridge (not those received by the secondary side). The status of SERRs generated is reported in the PCISTS1 register.
7	RO 0b	Reserved: Not Applicable or Implemented. Hardwired to 0.
6	RW 0b	Parity Error Response Enable (PERRE): This bit controls whether or not the Master Data Parity Error bit in the PCI Status register can bet set. 0 = Master Data Parity Error bit in PCI Status register can NOT be set. 1 = Master Data Parity Error bit in PCI Status register CAN be set.
5	RO 0b	VGA Palette Snoop (VGAPS): Not Applicable or Implemented. Hardwired to 0.



Bit	Access & Default	Description
4	RO 0b	Memory Write and Invalidate Enable (MWIE): Not Applicable or Implemented. Hardwired to 0.
3	RO 0b	Special Cycle Enable (SCE): Not Applicable or Implemented. Hardwired to 0.
2	RW 0b	Bus Master Enable (BME): This bit controls the ability of the PEG port to forward Memory and IO Read/Write Requests in the upstream direction. This bit does not affect forwarding of Completions from the primary interface to the secondary interface. 0 = This device is prevented from making memory or IO requests to its primary bus. Note that according to PCI Specification, as MSI interrupt messages are in-band memory writes, disabling the bus master enable bit prevents this device from generating MSI interrupt messages or passing them from its secondary bus to its primary bus. Upstream memory writes/reads, IO writes/reads, peer writes/reads, and MSIs will all be treated as invalid cycles. Writes are forwarded to memory address 000C_0000h with byte enables de-asserted. Reads will be forwarded to memory address 000C_0000h and will return Unsupported Request status (or Master abort) in its completion packet. 1 = This device is allowed to issue requests to its primary bus. Completions for previously issued memory read requests on the primary bus will be issued when the data is available.
1	RW 0b	Memory Access Enable (MAE): 0 = All of device 1's memory space is disabled. 1 = Enable the Memory and Pre-fetchable memory address ranges defined in the MBASE1, MLIMIT1, PMBASE1, and PMLIMIT1 registers.
0	RW 0b	IO Access Enable (IOAE): 0 = All of device 1's I/O space is disabled. 1 = Enable the I/O address range defined in the IOBASE1, and IOLIMIT1 registers.



6.1.4 PCISTS1—PCI Status

B/D/F/Type: 0/1/0/PCI
 Address Offset: 06–07h
 Default Value: 0010h
 Access: RO, RWC
 Size: 16 bits

This register reports the occurrence of error conditions associated with primary side of the "virtual" Host-PCI Express bridge embedded within the (G)MCH.

Bit	Access & Default	Description
15	RO 0b	Detected Parity Error (DPE): Not Applicable or Implemented. Hardwired to 0. Parity (generating poisoned TLPs) is not supported on the primary side of this device (error forwarding is not done).
14	RWC 0b	Signaled System Error (SSE): This bit is set when this Device sends an SERR due to detecting an ERR_FATAL or ERR_NONFATAL condition and the SERR Enable bit in the Command register is 1. Both received (if enabled by BCTRL1[1]) and internally detected error messages affect this field.
13	RO 0b	Received Master Abort Status (RMAS): Not Applicable or Implemented. Hardwired to 0. The concept of a master abort does not exist on primary side of this device.
12	RO 0b	Received Target Abort Status (RTAS): Not Applicable or Implemented. Hardwired to 0. The concept of a target abort does not exist on primary side of this device.
11	RO 0b	Signaled Target Abort Status (STAS): Not Applicable or Implemented. Hardwired to 0. The concept of a target abort does not exist on primary side of this device.
10:9	RO	DEVSELB Timing (DEVT): This device is not the subtractively decoded device on bus 0. This bit field is therefore hardwired to 00 to indicate that the device uses the fastest possible decode.
8	RO 0b	Master Data Parity Error (PMDPE): Because the primary side of the PEG's virtual PCI-to-PCI bridge is integrated with the (G)MCH functionality there is no scenario where this bit will get set. Because hardware will never set this bit, it is impossible for software to have an opportunity to clear this bit or otherwise test that it is implemented. The PCI specification defines it as a RWC, but for this implementation an RO definition behaves the same way and will meet all Microsoft testing requirements. This bit can only be set when the Parity Error Enable bit in the PCI Command register is set.
7	RO 0b	Fast Back-to-Back (FB2B): Not Applicable or Implemented. Hardwired to 0.
6	RO 0b	Reserved
5	RO 0b	66 / 60MHz capability (CAP66): Not Applicable or Implemented. Hardwired to 0.



Bit	Access & Default	Description
4	RO 1b	Capabilities List (CAPL): Indicates that a capabilities list is present. Hardwired to 1.
3	RO 0b	INTA Status (INTAS): Indicates that an interrupt message is pending internally to the device. Only PME and Hot Plug sources feed into this status bit (not PCI INTA-INTD assert and de-assert messages). The INTA Assertion Disable bit, PCICMD1[10], has no effect on this bit.
2:0	RO 000b	Reserved

6.1.5 RID1—Revision Identification

B/D/F/Type:	0/1/0/PCI
Address Offset:	08h
Default Value:	See register table below
Access:	RO
Size:	8 bits

This register contains the revision number of the (G)MCH device 1. These bits are read only and writes to this register have no effect.

Bit	Access & Default	Description
7:0	RO 00h	Revision Identification Number (RID1): This is an 8-bit value that indicates the revision identification number for the (G)MCH Device 0. Refer to the <i>Intel® G31/P31 Express Chipset Family Specification Update</i> for the value of the Revision ID register.

6.1.6 CC1—Class Code

B/D/F/Type:	0/1/0/PCI
Address Offset:	09–0Bh
Default Value:	060400h
Access:	RO
Size:	24 bits

This register identifies the basic function of the device, a more specific sub-class, and a register- specific programming interface.

Bit	Access & Default	Description
23:16	RO 06h	Base Class Code (BCC): This field indicates the base class code for this device. This code has the value 06h, indicating a Bridge device.
15:8	RO 04h	Sub-Class Code (SUBCC): This field indicates the sub-class code for this device. The code is 04h indicating a PCI to PCI Bridge.
7:0	RO 00h	Programming Interface (PI): This field indicates the programming interface of this device. This value does not specify a particular register set layout and provides no practical use for this device.



6.1.7 CL1—Cache Line Size

B/D/F/Type: 0/1/0/PCI
 Address Offset: 0Ch
 Default Value: 00h
 Access: RW
 Size: 8 bits

Bit	Access & Default	Description
7:0	RW 00h	Cache Line Size (Scratch pad): Implemented by PCI Express devices as a read-write field for legacy compatibility purposes but has no impact on any PCI Express device functionality.

6.1.8 HDR1—Header Type

B/D/F/Type: 0/1/0/PCI
 Address Offset: 0Eh
 Default Value: 01h
 Access: RO
 Size: 8 bits

This register identifies the header layout of the configuration space. No physical register exists at this location.

Bit	Access & Default	Description
7:0	RO 01h	Header Type Register (HDR): Returns 01 to indicate that this is a single function device with bridge header layout.

6.1.9 PBUSN1—Primary Bus Number

B/D/F/Type: 0/1/0/PCI
 Address Offset: 18h
 Default Value: 00h
 Access: RO
 Size: 8 bits

This register identifies that this "virtual" Host-PCI Express bridge is connected to PCI bus #0.

Bit	Access & Default	Description
7:0	RO 00h	Primary Bus Number (BUSN): Configuration software typically programs this field with the number of the bus on the primary side of the bridge. Since device 1 is an internal device and its primary bus is always 0, these bits are read only and are hardwired to 0.



6.1.10 SBUSN1—Secondary Bus Number

B/D/F/Type: 0/1/0/PCI
Address Offset: 19h
Default Value: 00h
Access: RW
Size: 8 bits

This register identifies the bus number assigned to the second bus side of the "virtual" bridge (i.e., to PCI Express-G). This number is programmed by the PCI configuration software to allow mapping of configuration cycles to PCI Express-G.

Bit	Access & Default	Description
7:0	RW 00h	Secondary Bus Number (BUSN): This field is programmed by configuration software with the bus number assigned to PCI Express.

6.1.11 SUBUSN1—Subordinate Bus Number

B/D/F/Type: 0/1/0/PCI
Address Offset: 1Ah
Default Value: 00h
Access: RW
Size: 8 bits

This register identifies the subordinate bus (if any) that resides at the level below PCI Express-G. This number is programmed by the PCI configuration software to allow mapping of configuration cycles to PCI Express-G.

Bit	Access & Default	Description
7:0	RW 00h	Subordinate Bus Number (BUSN): This register is programmed by configuration software with the number of the highest subordinate bus that lies behind the device #1 bridge. When only a single PCI device resides on the PCI Express segment, this register will contain the same value as the SBUSN1 register.



6.1.12 IOBASE1—I/O Base Address

B/D/F/Type: 0/1/0/PCI
 Address Offset: 1Ch
 Default Value: F0h
 Access: RW, RO
 Size: 8 bits

This register controls the processor to PCI Express-G I/O access routing based on the following formula:

$$\text{IO_BASE} \leq \text{address} \leq \text{IO_LIMIT}$$

Only the upper 4 bits are programmable. For the purpose of address decode, address bits A[11:0] are treated as 0. Thus the bottom of the defined I/O address range will be aligned to a 4 KB boundary.

Bit	Access & Default	Description
7:4	RW Fh	I/O Address Base (IOBASE): This field corresponds to A[15:12] of the I/O addresses passed by bridge 1 to PCI Express.
3:0	RO 0h	Reserved

6.1.13 IOLIMIT1—I/O Limit Address

B/D/F/Type: 0/1/0/PCI
 Address Offset: 1Dh
 Default Value: 00h
 Access: RW, RO
 Size: 8 bits

This register controls the processor to PCI Express-G I/O access routing based on the following formula:

$$\text{IO_BASE} \leq \text{address} \leq \text{IO_LIMIT}$$

Only the upper 4 bits are programmable. For the purpose of address decode, address bits A[11:0] are assumed to be FFFh. Thus, the top of the defined I/O address range will be at the top of a 4 KB aligned address block.

Bit	Access & Default	Description
7:4	RW 0h	I/O Address Limit (IOLIMIT): This field corresponds to A[15:12] of the I/O address limit of device 1. Devices between this upper limit and IOBASE1 will be passed to the PCI Express hierarchy associated with this device.
3:0	RO 0h	Reserved



6.1.14 SSTS1—Secondary Status

B/D/F/Type: 0/1/0/PCI
Address Offset: 1E–1Fh
Default Value: 0000h
Access: RWC, RO
Size: 16 bits

SSTS1 is a 16-bit status register that reports the occurrence of error conditions associated with secondary side (i.e., PCI Express side) of the "virtual" PCI-PCI bridge embedded within (G)MCH.

Bit	Access & Default	Description
15	RWC 0b	Detected Parity Error (DPE): This bit is set by the Secondary Side for a Type 1 Configuration Space header device whenever it receives a Poisoned TLP, regardless of the state of the Parity Error Response Enable bit in the Bridge Control Register.
14	RWC 0b	Received System Error (RSE): This bit is set when the Secondary Side for a Type 1 configuration space header device receives an ERR_FATAL or ERR_NONFATAL.
13	RWC 0b	Received Master Abort (RMA): This bit is set when the Secondary Side for Type 1 Configuration Space Header Device (for requests initiated by the Type 1 Header Device itself) receives a Completion with Unsupported Request Completion Status.
12	RWC 0b	Received Target Abort (RTA): This bit is set when the Secondary Side for Type 1 Configuration Space Header Device (for requests initiated by the Type 1 Header Device itself) receives a Completion with Completer Abort Completion Status.
11	RO 0b	Signaled Target Abort (STA): Not Applicable or Implemented. Hardwired to 0. The (G)MCH does not generate Target Aborts (the (G)MCH will never complete a request using the Completer Abort Completion status).
10:9	RO 00b	DEVSELB Timing (DEVT): Not Applicable or Implemented. Hardwired to 0.
8	RWC 0b	Master Data Parity Error (SMDPE): When set, this bit indicates that the (G)MCH received across the link (upstream) a Read Data Completion Poisoned TLP (EP=1). This bit can only be set when the Parity Error Enable bit in the Bridge Control register is set.
7	RO 0b	Fast Back-to-Back (FB2B): Not Applicable or Implemented. Hardwired to 0.
6	RO 0b	Reserved
5	RO 0b	66 / 60 MHz capability (CAP66): Not Applicable or Implemented. Hardwired to 0.
4:0	RO 00h	Reserved



6.1.15 MBASE1—Memory Base Address

B/D/F/Type:	0/1/0/PCI
Address Offset:	20–21h
Default Value:	FFF0h
Access:	RW, RO
Size:	16 bits

This register controls the processor-to-PCI Express non-prefetchable memory access routing based on the following formula:

$$\text{MEMORY_BASE} \leq \text{address} \leq \text{MEMORY_LIMIT}$$

The upper 12 bits of the register are read/write and correspond to the upper 12 address bits A[31:20] of the 32 bit address. The bottom 4 bits of this register are read-only and return zeroes when read. This register must be initialized by the configuration software. For the purpose of address decode, address bits A[19:0] are assumed to be 0. Thus, the bottom of the defined memory address range will be aligned to a 1 MB boundary.

Bit	Access & Default	Description
15:4	RW FFFh	Memory Address Base (MBASE): This field corresponds to A[31:20] of the lower limit of the memory range that will be passed to PCI Express.
3:0	RO 0h	Reserved



6.1.16 MLIMIT1—Memory Limit Address

B/D/F/Type:	0/1/0/PCI
Address Offset:	22–23h
Default Value:	0000h
Access:	RW, RO
Size:	16 bits

This register controls the processor to PCI Express-G non-prefetchable memory access routing based on the following formula:

$$\text{MEMORY_BASE} \leq \text{address} \leq \text{MEMORY_LIMIT}$$

The upper 12 bits of the register are read/write and correspond to the upper 12 address bits A[31:20] of the 32 bit address. The bottom 4 bits of this register are read-only and return zeroes when read. This register must be initialized by the configuration software. For the purpose of address decode, address bits A[19:0] are assumed to be FFFFh. Thus, the top of the defined memory address range will be at the top of a 1MB aligned memory block. NOTE: Memory range covered by MBASE and MLIMIT registers are used to map non-prefetchable PCI Express address ranges (typically where control/status memory-mapped I/O data structures of the graphics controller will reside) and PMBASE and PMLIMIT are used to map prefetchable address ranges (typically graphics local memory). This segregation allows application of USWC space attribute to be performed in a true plug-and-play manner to the prefetchable address range for improved processor - PCI Express memory access performance.

Note also that configuration software is responsible for programming all address range registers (prefetchable, non-prefetchable) with the values that provide exclusive address ranges i.e. prevent overlap with each other and/or with the ranges covered with the main memory. There is no provision in the (G)MCH hardware to enforce prevention of overlap and operations of the system in the case of overlap are not ensured.

Bit	Access & Default	Description
15:4	RW 000h	Memory Address Limit (MLIMIT): This field corresponds to A[31:20] of the upper limit of the address range passed to PCI Express.
3:0	RO 0h	Reserved



6.1.17 PMBASE1—Prefetchable Memory Base Address

B/D/F/Type: 0/1/0/PCI
 Address Offset: 24–25h
 Default Value: FFF1h
 Access: RW, RO
 Size: 16 bits

This register in conjunction with the corresponding Upper Base Address register controls the processor-to-PCI Express prefetchable memory access routing based on the following formula:

$$\text{PREFETCHABLE_MEMORY_BASE} \leq \text{address} \leq \text{PREFETCHABLE_MEMORY_LIMIT}$$

The upper 12 bits of this register are read/write and correspond to address bits A[31:20] of the 40-bit address. The lower 8 bits of the Upper Base Address register are read/write and correspond to address bits A[39:32] of the 40-bit address. This register must be initialized by the configuration software. For the purpose of address decode, address bits A[19:0] are assumed to be 0. Thus, the bottom of the defined memory address range will be aligned to a 1 MB boundary.

Bit	Access & Default	Description
15:4	RW FFFh	Prefetchable Memory Base Address (MBASE): This field corresponds to A[31:20] of the lower limit of the memory range that will be passed to PCI Express.
3:0	RO 1h	64-bit Address Support: This field indicates that the upper 32 bits of the prefetchable memory region base address are contained in the Prefetchable Memory base Upper Address register at 28h.



6.1.18 PMLIMIT1—Prefetchable Memory Limit Address

B/D/F/Type: 0/1/0/PCI
Address Offset: 26–27h
Default Value: 0001h
Access: RW, RO
Size: 16 bits

This register in conjunction with the corresponding Upper Limit Address register controls the processor-to-PCI Express prefetchable memory access routing based on the following formula:

$$\text{PREFETCHABLE_MEMORY_BASE} \leq \text{address} \leq \text{PREFETCHABLE_MEMORY_LIMIT}$$

The upper 12 bits of this register are read/write and correspond to address bits A[31:20] of the 40-bit address. The lower 8 bits of the Upper Limit Address register are read/write and correspond to address bits A[39:32] of the 40-bit address. This register must be initialized by the configuration software. For the purpose of address decode, address bits A[19:0] are assumed to be FFFFh. Thus, the top of the defined memory address range will be at the top of a 1MB aligned memory block. Note that prefetchable memory range is supported to allow segregation by the configuration software between the memory ranges that must be defined as UC and the ones that can be designated as a USWC (i.e. prefetchable) from the processor perspective.

Bit	Access & Default	Description
15:4	RW 000h	Prefetchable Memory Address Limit (PMLIMIT): This field corresponds to A[31:20] of the upper limit of the address range passed to PCI Express.
3:0	RO 1h	64-bit Address Support: This field indicates that the upper 32 bits of the prefetchable memory region limit address are contained in the Prefetchable Memory Base Limit Address register at 2Ch



6.1.19 PMBASEU1—Prefetchable Memory Base Address

B/D/F/Type: 0/1/0/PCI
 Address Offset: 28–2Bh
 Default Value: 00000000h
 Access: RW
 Size: 32 bits

The functionality associated with this register is present in the PEG design implementation.

This register in conjunction with the corresponding Upper Base Address register controls the processor-to-PCI Express prefetchable memory access routing based on the following formula:

$$\text{PREFETCHABLE_MEMORY_BASE} \leq \text{address} \leq \text{PREFETCHABLE_MEMORY_LIMIT}$$

The upper 12 bits of this register are read/write and correspond to address bits A[31:20] of the 40-bit address. The lower 8 bits of the Upper Base Address register are read/write and correspond to address bits A[39:32] of the 40-bit address. This register must be initialized by the configuration software. For the purpose of address decode, address bits A[19:0] are assumed to be 0. Thus, the bottom of the defined memory address range will be aligned to a 1 MB boundary.

Bit	Access & Default	Description
31:0	RW 00000000h	Prefetchable Memory Base Address (MBASEU): This field corresponds to A[63:32] of the lower limit of the prefetchable memory range that will be passed to PCI Express.



6.1.20 PMLIMITU1—Prefetchable Memory Limit Address

B/D/F/Type: 0/1/0/PCI
Address Offset: 2C–2Fh
Default Value: 00000000h
Access: RW
Size: 32 bits

The functionality associated with this register is present in the PEG design implementation.

This register in conjunction with the corresponding Upper Limit Address register controls the processor-to-PCI Express prefetchable memory access routing based on the following formula:

$$\text{PREFETCHABLE_MEMORY_BASE} \leq \text{address} \leq \text{PREFETCHABLE_MEMORY_LIMIT}$$

The upper 12 bits of this register are read/write and correspond to address bits A[31:20] of the 40-bit address. The lower 8 bits of the Upper Limit Address register are read/write and correspond to address bits A[39:32] of the 40-bit address. This register must be initialized by the configuration software. For the purpose of address decode, address bits A[19:0] are assumed to be FFFFh. Thus, the top of the defined memory address range will be at the top of a 1MB aligned memory block.

Note that prefetchable memory range is supported to allow segregation by the configuration software between the memory ranges that must be defined as UC and the ones that can be designated as a USWC (i.e. prefetchable) from the processor perspective.

Bit	Access & Default	Description
31:0	RW 00000000h	Prefetchable Memory Address Limit (MLIMITU): This field corresponds to A[63:32] of the upper limit of the prefetchable Memory range that will be passed to PCI Express.



6.1.21 CAPPTR1—Capabilities Pointer

B/D/F/Type: 0/1/0/PCI
 Address Offset: 34h
 Default Value: 88h
 Access: RO
 Size: 8 bits

The capabilities pointer provides the address offset to the location of the first entry in this device's linked list of capabilities.

Bit	Access & Default	Description
7:0	RO 88h	First Capability (CAPPTR1): The first capability in the list is the Subsystem ID and Subsystem Vendor ID Capability.

6.1.22 INTRLIN1—Interrupt Line

B/D/F/Type: 0/1/0/PCI
 Address Offset: 3Ch
 Default Value: 00h
 Access: RW
 Size: 8 bits

This register contains interrupt line routing information. The device itself does not use this value, rather it is used by device drivers and operating systems to determine priority and vector information.

Bit	Access & Default	Description
7:0	RW 00h	Interrupt Connection (INTCON): Used to communicate interrupt line routing information.

6.1.23 INTRPIN1—Interrupt Pin

B/D/F/Type: 0/1/0/PCI
 Address Offset: 3Dh
 Default Value: 01h
 Access: RO
 Size: 8 bits

This register specifies which interrupt pin this device uses.

Bit	Access & Default	Description
7:0	RO 01h	Interrupt Pin (INTRPIN): As a single function device, the PCI Express device specifies INTA as its interrupt pin. 01h=INTA.



6.1.24 BCTRL1—Bridge Control

B/D/F/Type: 0/1/0/PCI
Address Offset: 3E–3Fh
Default Value: 0000h
Access: RO, RW
Size: 16 bits

This register provides extensions to the PCICMD1 register that are specific to PCI-to-PCI bridges. The BCTRL provides additional control for the secondary interface (i.e., PCI Express) as well as some bits that affect the overall behavior of the "virtual" Host-PCI Express bridge in the (G)MCH (e.g., VGA compatible address ranges mapping).

Bit	Access & Default	Description
15:12	RO 0h	Reserved
11	RO 0b	Discard Timer SERR# Enable (DTSERRE): Not Applicable or Implemented. Hardwired to 0.
10	RO 0b	Discard Timer Status (DTSTS): Not Applicable or Implemented. Hardwired to 0.
9	RO 0b	Secondary Discard Timer (SDT): Not Applicable or Implemented. Hardwired to 0.
8	RO 0b	Primary Discard Timer (PDT): Not Applicable or Implemented. Hardwired to 0.
7	RO 0b	Fast Back-to-Back Enable (FB2BEN): Not Applicable or Implemented. Hardwired to 0.
6	RW 0b	Secondary Bus Reset (SRESET): Setting this bit triggers a hot reset on the corresponding PCI Express Port. This will force the LTSSM to transition to the Hot Reset state (via Recovery) from L0, L0s, or L1 states.
5	RO 0b	Master Abort Mode (MAMODE): Does not apply to PCI Express. Hardwired to 0.
4	RW 0b	VGA 16-bit Decode (VGA16D): Enables the PCI-to-PCI bridge to provide 16-bit decoding of VGA I/O address precluding the decoding of alias addresses every 1 KB. This bit only has meaning if bit 3 (VGA Enable) of this register is also set to 1, enabling VGA I/O decoding and forwarding by the bridge. 0 = Execute 10-bit address decodes on VGA I/O accesses. 1 = Execute 16-bit address decodes on VGA I/O accesses.
3	RW 0b	VGA Enable (VGAEN): This bit controls the routing of processor initiated transactions targeting VGA compatible I/O and memory address ranges.



Bit	Access & Default	Description
2	RW 0b	ISA Enable (ISAEN): Needed to exclude legacy resource decode to route ISA resources to legacy decode path. This bit modifies the response by the (G)MCH to an I/O access issued by the processor that target ISA I/O addresses. This applies only to I/O addresses that are enabled by the IOBASE and IOLIMIT registers. 0 = All addresses defined by the IOBASE and IOLIMIT for processor I/O transactions will be mapped to PCI Express. 1 = (G)MCH will not forward to PCI Express any I/O transactions addressing the last 768 bytes in each 1 KB block even if the addresses are within the range defined by the IOBASE and IOLIMIT registers.
1	RW 0b	SERR Enable (SERREN): 0 = No forwarding of error messages from secondary side to primary side that could result in an SERR. 1 = ERR_COR, ERR_NONFATAL, and ERR_FATAL messages result in SERR message when individually enabled by the Root Control register.
0	RW 0b	Parity Error Response Enable (PEREN): This bit controls whether or not the Master Data Parity Error bit in the Secondary Status register is set when the (G)MCH receives across the link (upstream) a Read Data Completion Poisoned TLP. 0 = Master Data Parity Error bit in Secondary Status register can NOT be set. 1 = Master Data Parity Error bit in Secondary Status register CAN be set.



6.1.25 PM_CAPID1—Power Management Capabilities

B/D/F/Type: 0/1/0/PCI
 Address Offset: 80–83h
 Default Value: C8039001h
 Access: RO
 Size: 32 bits

Bit	Access & Default	Description
31:27	RO 19h	PME Support (PMES): This field indicates the power states in which this device may indicate PME wake via PCI Express messaging. D0, D3hot & D3cold. This device is not required to do anything to support D3hot & D3cold, it simply must report that those states are supported. Refer to the PCI Power Management 1.1 specification for encoding explanation and other power management details.
26	RO 0b	D2 Power State Support (D2PSS): Hardwired to 0 to indicate that the D2 power management state is NOT supported.
25	RO 0b	D1 Power State Support (D1PSS): Hardwired to 0 to indicate that the D1 power management state is NOT supported.
24:22	RO 000b	Auxiliary Current (AUXC): Hardwired to 0 to indicate that there are no 3.3Vaux auxiliary current requirements.
21	RO 0b	Device Specific Initialization (DSI): Hardwired to 0 to indicate that special initialization of this device is NOT required before generic class device driver is to use it.
20	RO 0b	Auxiliary Power Source (APS): Hardwired to 0.
19	RO 0b	PME Clock (PMECLK): Hardwired to 0 to indicate this device does NOT support PMEB generation.
18:16	RO 011b	PCI PM CAP Version (PCIPMCV): A value of 011b indicates that this function complies with revision 1.2 of the PCI Power Management Interface Specification.
15:8	RO 90h	Pointer to Next Capability (PNC): This contains a pointer to the next item in the capabilities list. If MSICH (CAPL[0] @ 7Fh) is 0, then the next item in the capabilities list is the Message Signaled Interrupts (MSI) capability at 90h
7:0	RO 01h	Capability ID (CID): Value of 01h identifies this linked list item (capability structure) as being for PCI Power Management registers.



6.1.26 PM_CS1—Power Management Control/Status

B/D/F/Type: 0/1/0/PCI
 Address Offset: 84–87h
 Default Value: 00000000h
 Access: RO, RW/S, RW
 Size: 32 bits

Bit	Access & Default	Description
31:16	RO 0000h	Reserved: Not Applicable or Implemented. Hardwired to 0.
15	RO 0b	PME Status (PMESTS): This bit indicates that this device does not support PME# generation from D3cold.
14:13	RO 00b	Data Scale (DSCALE): This field indicates that this device does not support the power management data register.
12:9	RO 0h	Data Select (DSEL): This field indicates that this device does not support the power management data register.
8	RW/S 0b	PME Enable (PMEE): This bit indicates that this device does not generate PMEB assertion from any D-state. 0 = PMEB generation not possible from any D State 1 = PMEB generation enabled from any D State The setting of this bit has no effect on hardware. See PM_CAP[15:11]
7:2	RO 00h	Reserved
1:0	RW 00b	Power State (PS): This field indicates the current power state of this device and can be used to set the device into a new power state. If software attempts to write an unsupported state to this field, write operation must complete normally on the bus, but the data is discarded and no state change occurs. 00 = D0 01 = D1 (Not supported in this device.) 10 = D2 (Not supported in this device.) 11 = D3 Support of D3cold does not require any special action. While in the D3hot state, this device can only act as the target of PCI configuration transactions (for power management control). This device also cannot generate interrupts or respond to MMR cycles in the D3 state. The device must return to the D0 state to be fully-functional. When the Power State is other than D0, the bridge will Master Abort (i.e., not claim) any downstream cycles (with exception of type 0 configuration cycles). Consequently, these unclaimed cycles will go down DMI and come back up as Unsupported Requests, which the (G)MCH logs as Master Aborts in Device 0 PCISTS[13] There is no additional hardware functionality required to support these Power States.



6.1.27 SS_CAPID—Subsystem ID and Vendor ID Capabilities

B/D/F/Type: 0/1/0/PCI
Address Offset: 88–8Bh
Default Value: 0000800Dh
Access: RO
Size: 32 bits

This capability is used to uniquely identify the subsystem where the PCI device resides. Because this device is an integrated part of the system and not an add-in device, it is anticipated that this capability will never be used. However, it is necessary because Microsoft will test for its presence.

Bit	Access & Default	Description
31:16	RO 0000h	Reserved
15:8	RO 80h	Pointer to Next Capability (PNC): This contains a pointer to the next item in the capabilities list which is the PCI Power Management capability.
7:0	RO 0Dh	Capability ID (CID): Value of 0Dh identifies this linked list item (capability structure) as being for SSID/SSVID registers in a PCI-to-PCI Bridge.

6.1.28 SS—Subsystem ID and Subsystem Vendor ID

B/D/F/Type: 0/1/0/PCI
Address Offset: 8C–8Fh
Default Value: 00008086h
Access: RWO
Size: 32 bits

System BIOS can be used as the mechanism for loading the SSID/SVID values. These values must be preserved through power management transitions and a hardware reset.

Bit	Access & Default	Description
31:16	RWO 0000h	Subsystem ID (SSID): This field identifies the particular subsystem and is assigned by the vendor.
15:0	RWO 8086h	Subsystem Vendor ID (SSVID): This field identifies the manufacturer of the subsystem and is the same as the vendor ID which is assigned by the PCI Special Interest Group.



6.1.29 MSI_CAPID—Message Signaled Interrupts Capability ID

B/D/F/Type: 0/1/0/PCI
 Address Offset: 90–91h
 Default Value: A005h
 Access: RO
 Size: 16 bits

When a device supports MSI it can generate an interrupt request to the processor by writing a predefined data item (a message) to a predefined memory address.

Bit	Access & Default	Description
15:8	RO A0h	Pointer to Next Capability (PNC): This field contains a pointer to the next item in the capabilities list which is the PCI Express capability.
7:0	RO 05h	Capability ID (CID): A value of 05h identifies this linked list item (capability structure) as being for MSI registers.

6.1.30 MC—Message Control

B/D/F/Type: 0/1/0/PCI
 Address Offset: 92–93h
 Default Value: 0000h
 Access: RW, RO
 Size: 16 bits

System software can modify bits in this register, but the device is prohibited from doing so.

If the device writes the same message multiple times, only one of those messages is ensured to be serviced. If all of them must be serviced, the device must not generate the same message again until the driver services the earlier one.

Bit	Access & Default	Description
15:8	RO 00h	Reserved
7	RO 0b	64-bit Address Capable (64AC): Hardwired to 0 to indicate that the function does not implement the upper 32 bits of the Message Address register and is incapable of generating a 64-bit memory address.
6:4	RW 000b	Multiple Message Enable (MME): System software programs this field to indicate the actual number of messages allocated to this device. This number will be equal to or less than the number actually requested. The encoding is the same as for the MMC field below.



Bit	Access & Default	Description
3:1	RO 000b	Multiple Message Capable (MMC): System software reads this field to determine the number of messages being requested by this device. 000 = 1 message requested All other encodings are reserved.
0	RW 0b	MSI Enable (MSIEN): This bit controls the ability of this device to generate MSIs. 0 = MSI will not be generated. 1 = MSI will be generated when we receive PME or HotPlug messages. INTA will not be generated and INTA Status (PCISTS1[3]) will not be set.

6.1.31 MA—Message Address

B/D/F/Type: 0/1/0/PCI
Address Offset: 94–97h
Default Value: 00000000h
Access: RW, RO
Size: 32 bits

Bit	Access & Default	Description
31:2	RW 00000000h	Message Address (MA): Used by system software to assign an MSI address to the device. The device handles an MSI by writing the padded contents of the MD register to this address.
1:0	RO 00b	Force DWord Align (FDWA): Hardwired to 0 so that addresses assigned by system software are always aligned on a DWord address boundary.

6.1.32 MD—Message Data

B/D/F/Type: 0/1/0/PCI
Address Offset: 98–99h
Default Value: 0000h
Access: RW
Size: 16 bits

Bit	Access & Default	Description
15:0	RW 0000h	Message Data (MD): Base message data pattern assigned by system software and used to handle an MSI from the device. When the device must generate an interrupt request, it writes a 32-bit value to the memory address specified in the MA register. The upper 16 bits are always set to 0. The lower 16 bits are supplied by this register.



6.1.33 PEG_CAPL—PCI Express*-G Capability List

B/D/F/Type: 0/1/0/PCI
 Address Offset: A0–A1h
 Default Value: 0010h
 Access: RO
 Size: 16 bits

This register enumerates the PCI Express capability structure.

Bit	Access & Default	Description
15:8	RO 00h	Pointer to Next Capability (PNC): This value terminates the capabilities list. The Virtual Channel capability and any other PCI Express specific capabilities that are reported via this mechanism are in a separate capabilities list located entirely within PCI Express Extended Configuration Space.
7:0	RO 10h	Capability ID (CID): This field identifies this linked list item (capability structure) as being for PCI Express registers.

6.1.34 PEG_CAP—PCI Express*-G Capabilities

B/D/F/Type: 0/1/0/PCI
 Address Offset: A2–A3h
 Default Value: 0141h
 Access: RO, RWO
 Size: 16 bits

This register indicates PCI Express device capabilities.

Bit	Access & Default	Description
15:14	RO 00b	Reserved
13:9	RO 00h	Interrupt Message Number (IMN): Not Applicable or Implemented. Hardwired to 0.
8	RWO 1b	Slot Implemented (SI): 0 = The PCI Express Link associated with this port is connected to an integrated component or is disabled. 1 = The PCI Express Link associated with this port is connected to a slot.
7:4	RO 4h	Device/Port Type (DPT): Hardwired to 4h to indicate root port of PCI Express Root Complex.
3:0	RO 1h	PCI Express Capability Version (PCI EXPRESS*CV): Hardwired to 1 as it is the first version.



6.1.35 DCAP—Device Capabilities

B/D/F/Type: 0/1/0/PCI
Address Offset: A4–A7h
Default Value: 00008000h
Access: RO
Size: 32 bits

This register indicates PCI Express device capabilities.

Bit	Access & Default	Description
31:16	RO 0000h	Reserved: Not Applicable or Implemented. Hardwired to 0.
15	RO 1b	Role Based Error Reporting (RBER): This bit indicates that this device implements the functionality defined in the Error Reporting ECN as required by the PCI Express 1.1 specification.
14:6	RO 000h	Reserved: Not Applicable or Implemented. Hardwired to 0.
5	RO 0b	Extended Tag Field Supported (ETFS): Hardwired to indicate support for 5-bit Tags as a Requestor.
4:3	RO 00b	Phantom Functions Supported (PFS): Not Applicable or Implemented. Hardwired to 0.
2:0	RO 000b	Max Payload Size (MPS): Hardwired to indicate 128B max supported payload for Transaction Layer Packets (TLP).



6.1.36 DCTL—Device Control

B/D/F/Type: 0/1/0/PCI
 Address Offset: A8–A9h
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

This register provides control for PCI Express device specific capabilities.

The error reporting enable bits are in reference to errors detected by this device, not error messages received across the link. The reporting of error messages (ERR_CORR, ERR_NONFATAL, ERR_FATAL) received by Root Port is controlled exclusively by Root Port Command Register.

Bit	Access & Default	Description
15:8	RO 000h	Reserved
7:5	RW 000b	Max Payload Size (MPS): 000 = 128B max supported payload for Transaction Layer Packets (TLP). As a receiver, the Device must handle TLPs as large as the set value; as transmitter, the Device must not generate TLPs exceeding the set value. All other encodings are reserved. Hardware will actually ignore this field. It is writeable only to support compliance testing.
4	RO 0b	Reserved: For Enable Relaxed Ordering
3	RW 0b	Unsupported Request Reporting Enable (URRE): When set, allows signaling ERR_NONFATAL, ERR_FATAL, or ERR_CORR to the Root Control register when detecting an unmasked Unsupported Request (UR). An ERR_CORR is signaled when an unmasked Advisory Non-Fatal UR is received. An ERR_FATAL or ERR_NONFATAL is sent to the Root Control register when an uncorrectable non-Advisory UR is received with the severity bit set in the Uncorrectable Error Severity register.
2	RW 0b	Fatal Error Reporting Enable (FERE): When set, enables signaling of ERR_FATAL to the Root Control register due to internally detected errors or error messages received across the link. Other bits also control the full scope of related error reporting.
1	RW 0b	Non-Fatal Error Reporting Enable (NERE): When set, enables signaling of ERR_NONFATAL to the Root Control register due to internally detected errors or error messages received across the link. Other bits also control the full scope of related error reporting.
0	RW 0b	Correctable Error Reporting Enable (CERE): When set, enables signaling of ERR_CORR to the Root Control register due to internally detected errors or error messages received across the link. Other bits also control the full scope of related error reporting.



6.1.37 DSTS—Device Status

B/D/F/Type: 0/1/0/PCI
 Address Offset: AA–ABh
 Default Value: 0000h
 Access: RO, RWC
 Size: 16 bits

This register reflects status corresponding to controls in the Device Control register. The error reporting bits are in reference to errors detected by this device, not errors messages received across the link.

Bit	Access & Default	Description
15:6	RO 000h	Reserved and Zero: For future R/WC/S implementations; software must use 0 for writes to bits.
5	RO 0b	Transactions Pending (TP): 0 = All pending transactions (including completions for any outstanding non-posted requests on any used virtual channel) have been completed. 1 = Device has transaction(s) pending (including completions for any outstanding non-posted requests for all used Traffic Classes).
4	RO 0b	Reserved
3	RWC 0b	Unsupported Request Detected (URD): 0 = Unsupported request Not detected. 1 = Device received an Unsupported Request. Errors are logged in this register regardless of whether error reporting is enabled or not in the Device Control Register. Additionally, the Non-Fatal Error Detected bit or the Fatal Error Detected bit is set according to the setting of the Unsupported Request Error Severity bit. In production systems setting the Fatal Error Detected bit is not an option as support for AER will not be reported.
2	RWC 0b	Fatal Error Detected (FED): 0 = Fatal error Not detected. 1 = Fatal error(s) were detected. Errors are logged in this register regardless of whether error reporting is enabled or not in the Device Control register. When Advanced Error Handling is enabled, errors are logged in this register regardless of the settings of the uncorrectable error mask register.
1	RWC 0b	Non-Fatal Error Detected (NFED): 0 = Non-Fatal error Not detected. 1 = Non-fatal error(s) were detected. Errors are logged in this register regardless of whether error reporting is enabled or not in the Device Control register. When Advanced Error Handling is enabled, errors are logged in this register regardless of the settings of the uncorrectable error mask register.



Bit	Access & Default	Description
0	RWC 0b	Correctable Error Detected (CED): 0 = Correctable error Not detected. 1 = Correctable error(s) were detected. Errors are logged in this register regardless of whether error reporting is enabled or not in the Device Control register. When Advanced Error Handling is enabled, errors are logged in this register regardless of the settings of the correctable error mask register.

6.1.38 LCAP—Link Capabilities

B/D/F/Type: 0/1/0/PCI
 Address Offset: AC-AFh
 Default Value: 02014D01h
 Access: RO, RWO
 Size: 32 bits

This register indicates PCI Express device specific capabilities.

Bit	Access & Default	Description
31:24	RO 02h	Port Number (PN): This field indicates the PCI Express port number for the given PCI Express link. Matches the value in Element Self Description[31:24].
23:21	RO 000b	Reserved
20	RO 0b	Data Link Layer Link Active Reporting Capable (DLLARC): For a Downstream Port, this bit must be set to 1b if the component supports the optional capability of reporting the DL_Active state of the Data Link Control and Management State Machine. For a hot-plug capable Downstream Port (as indicated by the Hot-Plug Capable field of the Slot Capabilities register), this bit must be set to 1b. For Upstream Ports and components that do not support this optional capability, this bit must be hardwired to 0b.
19	RO 0b	Surprise Down Error Reporting Capable (SDERC): For a Downstream Port, this bit must be set to 1b if the component supports the optional capability of detecting and reporting a Surprise Down error condition. For Upstream Ports and components that do not support this optional capability, this bit must be hardwired to 0b.



Bit	Access & Default	Description
18	RO 0b	Clock Power Management (CPM): A value of 1b in this bit indicates that the component tolerates the removal of any reference clock(s) when the link is in the L1 and L2/3 Ready link states. A value of 0b indicates the component does not have this capability and that reference clock(s) must not be removed in these link states. This capability is applicable only in form factors that support “clock request” (CLKREQ#) capability. For a multi-function device, each function indicates its capability independently. Power Management configuration software must only permit reference clock removal if all functions of the multifunction device indicate a 1b in this bit.
17:15	RWO 010b	L1 Exit Latency (L1ELAT): This field indicates the length of time this Port requires to complete the transition from L1 to L0. The value 010 b indicates the range of 2 us to less than 4 us. Both bytes of this register that contain a portion of this field must be written simultaneously in order to prevent an intermediate (and undesired) value from ever existing.
14:12	RO 100b	L0s Exit Latency (L0SELAT): Indicates the length of time this Port requires to complete the transition from L0s to L0. 000 = Less than 64 ns 001 = 64ns to less than 128ns 010 = 128ns to less than 256 ns 011 = 256ns to less than 512 ns 100 = 512ns to less than 1 us 101 = 1 us to less than 2 us 110 = 2 us – 4 us 111 = More than 4 us The actual value of this field depends on the common Clock Configuration bit (LCTL[6]) and the Common and Non-Common clock L0s Exit Latency values in PEGLOSLAT (Offset 22Ch)
11:10	RWO 11b	Active State Link PM Support (ASLPMS): 00 = Reserved 01 = L0s is supported 10 = Reserved 11 = L1 and L0s are supported BIOS Requirement: Desktop chipsets do not support ASPM L1, so BIOS should program this field to 01.
9:4	RO 10h	Max Link Width (MLW): This field indicates the maximum number of lanes supported for this link.
3:0	RO 1h	Max Link Speed (MLS): Hardwired to indicate 2.5 Gb/s.



6.1.39 LCTL—Link Control

B/D/F/Type: 0/1/0/PCI
 Address Offset: B0–B1h
 Default Value: 0000h
 Access: RO, RW, RW/SC
 Size: 16 bits
 BIOS Optimal Default: 0h

This register allows control of PCI Express link.

Bit	Access & Default	Description
15:9	RO 0000000b	Reserved
8	RO 0b	Enable Clock Power Management (ECPM): Applicable only for form factors that support a “Clock Request” (CLKREQ#) mechanism, this enable functions as follows 0 = Disable. Clock power management is disabled and device must hold CLKREQ# signal low (Default) 1 = Enable. Device is permitted to use CLKREQ# signal to power manage link clock according to protocol defined in appropriate form factor specification. Components that do not support Clock Power Management (as indicated by a 0b value in the Clock Power Management bit of the Link Capabilities Register) must hardwire this bit to 0b.
7	RW 0b	Extended Synch (ES): 0 = Standard Fast Training Sequence (FTS). 1 = Forces the transmission of additional ordered sets when exiting the L0s state and when in the Recovery state. This mode provides external devices (e.g., logic analyzers) monitoring the Link time to achieve bit and symbol lock before the link enters L0 and resumes communication. This is a test mode only and may cause other undesired side effects such as buffer overflows or underruns.
6	RW 0b	Common Clock Configuration (CCC): The state of this bit affects the L0s Exit Latency reported in LCAP[14:12] and the N_FTS value advertised during link training. See PEGLOSLAT at offset 22Ch. 0 = This component and the component at the opposite end of this Link are operating with asynchronous reference clock. 1 = This component and the component at the opposite end of this Link are operating with a distributed common reference clock.
5	RW/SC 0b	Retrain Link (RL): This bit always returns 0 when read. This bit is cleared automatically (no need to write a 0). 0 = Normal operation. 1 = Full Link retraining is initiated by directing the Physical Layer LTSSM from L0, L0s, or L1 states to the Recovery state.



Bit	Access & Default	Description
4	RW 0b	Link Disable (LD): Writes to this bit are immediately reflected in the value read from the bit, regardless of actual Link state. 0 = Normal operation 1 = Link is disabled. Forces the LTSSM to transition to the Disabled state (via Recovery) from L0, L0s, or L1 states. Link retraining happens automatically on 0 to 1 transition, just like when coming out of reset.
3	RO 0b	Read Completion Boundary (RCB): Hardwired to 0 to indicate 64 byte.
2	RW 0b	Far-End Digital Loopback (FEDLB):
1:0	RW 00b	Active State PM (ASPM): This field controls the level of active state power management supported on the given link. 00 = Disabled 01 = L0s Entry Supported 10 = Reserved 11 = L0s and L1 Entry Supported



6.1.40 LSTS—Link Status

B/D/F/Type: 0/1/0/PCI
 Address Offset: B2–B3h
 Default Value: 1001h
 Access: RO
 Size: 16 bits

This register indicates PCI Express link status.

Bit	Access & Default	Description
15:14	RO 00b	Reserved and Zero: For future R/WC/S implementations; software must use 0 for writes to bits.
13	RO 0b	Data Link Layer Link Active (Optional) (DLLLA): This bit indicates the status of the Data Link Control and Management State Machine. It returns a 1b to indicate the DL_Active state, 0b otherwise. This bit must be implemented if the corresponding Data Link Layer Active Capability bit is implemented. Otherwise, this bit must be hardwired to 0b.
12	RO 1b	Slot Clock Configuration (SCC): 0 = The device uses an independent clock irrespective of the presence of a reference on the connector. 1 = The device uses the same physical reference clock that the platform provides on the connector.
11	RO 0b	Link Training (LTRN): This bit indicates that the Physical Layer LTSSM is in the Configuration or Recovery state, or that 1b was written to the Retrain Link bit but Link training has not yet begun. Hardware clears this bit when the LTSSM exits the Configuration/Recovery state once Link training is complete.
10	RO 0b	Undefined: The value read from this bit is undefined. In previous versions of this specification, this bit was used to indicate a Link Training Error. System software must ignore the value read from this bit. System software is permitted to write any value to this bit.
9:4	RO 00h	Negotiated Width (NW): Indicates negotiated link width. This field is valid only when the link is in the L0, L0s, or L1 states (after link width negotiation is successfully completed). 00h = Reserved 01h = X1 02h = Reserved 04h = Reserved 08h = Reserved 10h = X16 All other encodings are reserved.
3:0	RO 1h	Negotiated Speed (NS): Indicates negotiated link speed. 1h = 2.5 Gb/s All other encodings are reserved.



6.1.41 SLOTCAP—Slot Capabilities

B/D/F/Type: 0/1/0/PCI
 Address Offset: B4–B7h
 Default Value: 00040000h
 Access: RWO, RO
 Size: 32 bits

PCI Express Slot related registers allow for the support of Hot Plug.

Bit	Access & Default	Description
31:19	RWO 0000h	Physical Slot Number (PSN): Indicates the physical slot number attached to this Port.
18	RWO 1b	No Command Completed Support (NCCS): 1 = This slot does not generate software notification when an issued command is completed by the Hot-Plug Controller. This bit is only permitted to be set to 1b if the hotplug capable port is able to accept writes to all fields of the Slot Control register without delay between successive writes.
17	RO 0b	Reserved for Electromechanical Interlock Present (EIP):
16:15	RWO 00b	Slot Power Limit Scale (SPLS): This field specifies the scale used for the Slot Power Limit Value. 00 = 1.0x 01 = 0.1x 10 = 0.01x 11 = 0.001x If this field is written, the link sends a Set_Slot_Power_Limit message.
14:7	RWO 00h	Slot Power Limit Value (SPLV): In combination with the Slot Power Limit Scale value, specifies the upper limit on power supplied by slot. Power limit (in Watts) is calculated by multiplying the value in this field by the value in the Slot Power Limit Scale field. If this field is written, the link sends a Set_Slot_Power_Limit message.
6	RO 0b	Hot-plug Capable (HPC): 0 = Not Hot-plug capable 1 = Slot is capable of supporting hot-lug operations.
5	RO 0b	Hot-plug Surprise (HPS): 0 = No Hot-plug surprise 1 = An adapter present in this slot might be removed from the system without any prior notification. This is a form factor specific capability. This bit is an indication to the operating system to allow for such removal without impacting continued software operation.



Bit	Access & Default	Description
4	RO 0b	Power Indicator Present (PIP): 0 = No power indicator 1 = A Power Indicator is electrically controlled by the chassis for this slot.
3	RO 0b	Attention Indicator Present (AIP): 0 = No Attention indicator 1 = An Attention Indicator is electrically controlled by the chassis.
2	RO 0b	MRL Sensor Present (MSP): 0 = No MRL sensor 1 = MRL Sensor is implemented on the chassis for this slot.
1	RO 0b	Power Controller Present (PCP): 0 = No power controller 1 = A software programmable Power Controller is implemented for this slot/adaptor (depending on form factor).
0	RO 0b	Attention Button Present (ABP): 0 = No attention button 1 = An Attention Button for this slot is electrically controlled by the chassis.

6.1.42 SLOTCTL—Slot Control

B/D/F/Type: 0/1/0/PCI
 Address Offset: B8–B9h
 Default Value: 01C0h
 Access: RO, RW
 Size: 16 bits

PCI Express Slot related registers allow for the support of Hot Plug.

Bit	Access & Default	Description
15:13	RO 000b	Reserved
12	RO 0b	Data Link Layer State Changed Enable (DLLSCE): If the Data Link Layer Link Active capability is implemented, when set to 1b, this field enables software notification when Data Link Layer Link Active field is changed.
11	RO 0b	Electromechanical Interlock Control (EIC): If an Electromechanical Interlock is implemented, a write of 1b to this field causes the state of the interlock to toggle. A write of 0b to this field has no effect. A read to this register always returns a 0.



Bit	Access & Default	Description
10	RO 0b	Power Controller Control (PCC): If a Power Controller is implemented, this field when written sets the power state of the slot per the defined encodings. Reads of this field must reflect the value from the latest write, even if the corresponding hotplug command is not complete, unless software issues a write without waiting for the previous command to complete in which case the read value is undefined. Depending on the form factor, the power is turned on/off either to the slot or within the adapter. Note that in some cases the power controller may autonomously remove slot power or not respond to a power-up request based on a detected fault condition, independent of the Power Controller Control setting. The defined encodings are: 0 = Power On 1 = Power Off If the Power Controller Implemented field in the Slot Capabilities register is set to 0b, then writes to this field have no effect and the read value of this field is undefined.
9:8	RO 01b	Power Indicator Control (PIC): If a Power Indicator is implemented, writes to this field set the Power Indicator to the written state. Reads of this field must reflect the value from the latest write, even if the corresponding hot-plug command is not complete, unless software issues a write without waiting for the previous command to complete in which case the read value is undefined. 00 = Reserved 01 = On 10 = Blink 11 = Off
7:6	RO 11b	Attention Indicator Control (AIC): If an Attention Indicator is implemented, writes to this field set the Attention Indicator to the written state. Reads of this field must reflect the value from the latest write, even if the corresponding hot-plug command is not complete, unless software issues a write without waiting for the previous command to complete in which case the read value is undefined. If the indicator is electrically controlled by chassis, the indicator is controlled directly by the downstream port through implementation specific mechanisms. 00 = Reserved 01 = On 10 = Blink 11 = Off



Bit	Access & Default	Description
5	RO 0b	Hot-plug Interrupt Enable (HPIE): 0 = Disable 1 = Enables generation of an interrupt on enabled hot-plug events Default value of this field is 0b. If the Hot Plug Capable field in the Slot Capabilities register is set to 0b, this bit is permitted to be read-only with a value of 0b.
4	RO 0b	Command Completed Interrupt Enable (CCI): If Command Completed notification is supported (as indicated by No Command Completed Support field of Slot Capabilities Register), when set to 1b, this bit enables software notification when a hot-plug command is completed by the Hot-Plug Controller. If Command Completed notification is not supported, this bit must be hardwired to 0b.
3	RW 0b	Presence Detect Changed Enable (PDCE): 0 = Disable 1 = Enables software notification on a presence detect changed event.
2	RO 0b	MRL Sensor Changed Enable (MSCE): If the MRL Sensor Present field in the Slot Capabilities register is set to 0b, this bit is permitted to be read-only with a value of 0b. 0 = Disable (default) 1 = Enables software notification on a MRL sensor changed event.
1	RO 0b	Power Fault Detected Enable (PFDE): If Power Fault detection is not supported, this bit is permitted to be read-only with a value of 0b. 0 = Disable (default) 1 = Enables software notification on a power fault event.
0	RO 0b	Attention Button Pressed Enable (ABPE): 0 = Disable (default) 1 = Enables software notification on an attention button pressed event.



6.1.43 SLOTSTS—Slot Status

B/D/F/Type: 0/1/0/PCI
Address Offset: BA–BBh
Default Value: 0000h
Access: RO, RWC
Size: 16 bits

PCI Express Slot related registers allow for the support of Hot Plug.

Bit	Access & Default	Description
15:7	RO 0000000b	Reserved and Zero: For future R/WC/S implementations; software must use 0 for writes to bits.
6	RO 0b	Presence Detect State (PDS): This bit indicates the presence of an adapter in the slot, reflected by the logical "OR" of the Physical Layer in-band presence detect mechanism and, if present, any out-of-band presence detect mechanism defined for the slot's corresponding form factor. Note that the in-band presence detect mechanism requires that power be applied to an adapter for its presence to be detected. Consequently, form factors that require a power controller for hot-plug must implement a physical pin presence detect mechanism. 0 = Slot Empty 1 = Card Present in slot This register must be implemented on all Downstream Ports that implement slots. For Downstream Ports not connected to slots (where the Slot Implemented bit of the PCI Express Capabilities Register is 0b), this bit must return 1b.
5	RO 0b	Reserved
4	RO 0b	Command Completed (CC): If Command Completed notification is supported (as indicated by No Command Completed Support field of Slot Capabilities Register), this bit is set when a hot-plug command has completed and the Hot-Plug Controller is ready to accept a subsequent command. The Command Completed status bit is set as an indication to host software that the Hot-Plug Controller has processed the previous command and is ready to receive the next command; it provides no assurance that the action corresponding to the command is complete. If Command Completed notification is not supported, this bit must be hardwired to 0b.
3	RWC 0b	Detect Changed (PDC): This bit is set when the value reported in Presence Detect State is changed.
2	RO 0b	MRL Sensor Changed (MSC): If an MRL sensor is implemented, this bit is set when a MRL Sensor state change is detected. If an MRL sensor is not implemented, this bit must not be set.



Bit	Access & Default	Description
1	RO 0b	Power Fault Detected (PFD): If a Power Controller that supports power fault detection is implemented, this bit is set when the Power Controller detects a power fault at this slot. Note that, depending on hardware capability, it is possible that a power fault can be detected at any time, independent of the Power Controller Control setting or the occupancy of the slot. If power fault detection is not supported, this bit must not be set.
0	RO 0b	Attention Button Pressed (ABP): If an Attention Button is implemented, this bit is set when the attention button is pressed. If an Attention Button is not supported, this bit must not be set.

6.1.44 RCTL—Root Control

B/D/F/Type: 0/1/0/PCI
 Address Offset: BC–BDh
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

This register allows control of PCI Express Root Complex specific parameters. The system error control bits in this register determine if corresponding SERRs are generated when our device detects an error (reported in this device's Device Status register) or when an error message is received across the link. Reporting of SERR as controlled by these bits takes precedence over the SERR Enable in the PCI Command Register.

Bit	Access & Default	Description
15:4	RO 000h	Reserved
3	RW 0b	PME Interrupt Enable (PMEIE): 0 = No interrupts are generated as a result of receiving PME messages. 1 = Enables interrupt generation upon receipt of a PME message as reflected in the PME Status bit of the Root Status Register. A PME interrupt is also generated if the PME Status bit of the Root Status Register is set when this bit is set from a cleared state.
2	RW 0b	System Error on Fatal Error Enable (SEFEE): This bit controls the Root Complex's response to fatal errors. 0 = No SERR generated on receipt of fatal error. 1 = SERR should be generated if a fatal error is reported by any of the devices in the hierarchy associated with this Root Port, or by the Root Port itself.



Bit	Access & Default	Description
1	RW 0b	System Error on Non-Fatal Uncorrectable Error Enable (SENFUEE): This bit controls the Root Complex's response to non-fatal errors. 0 = No SERR generated on receipt of non-fatal error. 1 = SERR should be generated if a non-fatal error is reported by any of the devices in the hierarchy associated with this Root Port, or by the Root Port itself.
0	RW 0b	System Error on Correctable Error Enable (SECEE): This bit controls the Root Complex's response to correctable errors. 0 = No SERR generated on receipt of correctable error. 1 = SERR should be generated if a correctable error is reported by any of the devices in the hierarchy associated with this Root Port, or by the Root Port itself.

6.1.45 RSTS—Root Status

B/D/F/Type: 0/1/0/PCI
Address Offset: C0–C3h
Default Value: 00000000h
Access: RO, RWC
Size: 32 bits

This register provides information about PCI Express Root Complex specific parameters.

Bit	Access & Default	Description
31:18	RO 0000h	Reserved
17	RO 0b	PME Pending (PMEP): 1 = Another PME is pending when the PME Status bit is set. When the PME Status bit is cleared by software; the PME is delivered by hardware by setting the PME Status bit again and updating the Requestor ID appropriately. The PME pending bit is cleared by hardware if no more PMEs are pending.
16	RWC 0b	PME Status (PMES): 1 = PME was asserted by the requestor ID indicated in the PME Requestor ID field. Subsequent PMEs are kept pending until the status register is cleared by writing a 1 to this field.
15:0	RO 0000h	PME Requestor ID (PMERID): This field indicates the PCI requestor ID of the last PME requestor.



6.1.46 PEGLC—PCI Express*-G Legacy Control

B/D/F/Type: 0/1/0/PCI
 Address Offset: EC–EFh
 Default Value: 00000000h
 Access: RW, RO
 Size: 32 bits

This register controls functionality that is needed by Legacy (non-PCI Express aware) operating systems during run time.

Bit	Access & Default	Description
31:3	RO 00000000h	Reserved
2	RW 0b	PME GPE Enable (PMEGPE): 0 = Do not generate GPE PME message when PME is received. 1 = Generate a GPE PME message when PME is received (Assert_PMEGPE and Deassert_PMEGPE messages on DMI). This enables the (G)MCH to support PMEs on the PEG port under legacy operating systems.
1	RW 0b	Hot-Plug GPE Enable (HPGPE): 0 = Do not generate GPE Hot-Plug message when Hot-Plug event is received. 1 = Generate a GPE Hot-Plug message when Hot-Plug Event is received (Assert_HPGPE and Deassert_HPGPE messages on DMI). This enables the (G)MCH to support Hot-Plug on the PEG port under legacy operating systems.
0	RW 0b	General Message GPE Enable (GENGPE): 0 = Do not forward received GPE assert/de-assert messages. 1 = Forward received GPE assert/de-assert messages. These general GPE message can be received via the PEG port from an external Intel device (i.e., PxH) and will be subsequently forwarded to the ICH (via Assert_GPE and Deassert_GPE messages on DMI). For example, PxH might send this message if a PCI Express device is hot plugged into a PxH downstream port.



6.1.47 VCECH—Virtual Channel Enhanced Capability Header

B/D/F/Type: 0/1/0/MMR
Address Offset: 100–103h
Default Value: 14010002h
Access: RO
Size: 32 bits

This register indicates PCI Express device Virtual Channel capabilities. Extended capability structures for PCI Express devices are located in PCI Express extended configuration space and have different field definitions than standard PCI capability structures.

Bit	Access & Default	Description
31:20	RO 140h	Pointer to Next Capability (PNC): The Link Declaration Capability is the next in the PCI Express extended capabilities list.
19:16	RO 1h	PCI Express Virtual Channel Capability Version (PCI EXPRESS*VCCV): Hardwired to 1 to indicate compliances with the 1.1 version of the PCI Express specification.
15:0	RO 0002h	Extended Capability ID (ECID): Value of 0002 h identifies this linked list item (capability structure) as being for PCI Express Virtual Channel registers.

6.1.48 PVCCAP1—Port VC Capability Register 1

B/D/F/Type: 0/1/0/MMR
Address Offset: 104–107h
Default Value: 00000000h
Access: RO
Size: 32 bits

This register describes the configuration of PCI Express Virtual Channels associated with this port.

Bit	Access & Default	Description
31:7	RO 0000000h	Reserved
6:4	RO 000b	Low Priority Extended VC Count (LPEVCC): This field indicates the number of (extended) Virtual Channels in addition to the default VC belonging to the low-priority VC (LPVC) group that has the lowest priority with respect to other VC resources in a strict-priority VC Arbitration. The value of 0 in this field implies strict VC arbitration.
3	RO 0b	Reserved
2:0	RO 000b	Extended VC Count (EVCC): This field indicates the number of (extended) Virtual Channels in addition to the default VC supported by the device.



6.1.49 PVCCAP2—Port VC Capability Register 2

B/D/F/Type: 0/1/0/MMR
 Address Offset: 108–10Bh
 Default Value: 00000000h
 Access: RO
 Size: 32 bits

This register describes the configuration of PCI Express Virtual Channels associated with this port.

Bit	Access & Default	Description
31:24	RO 00h	VC Arbitration Table Offset (VCATO): This field indicates the location of the VC Arbitration Table. This field contains the zero-based offset of the table in DQWORDS (16 bytes) from the base address of the Virtual Channel Capability Structure. A value of 0 indicates that the table is not present (due to fixed VC priority).
23:0	RO 0s	Reserved

6.1.50 PVCCTL—Port VC Control

B/D/F/Type: 0/1/0/MMR
 Address Offset: 10C–10Dh
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

Bit	Access & Default	Description
15:4	RO 000h	Reserved
3:1	RW 000b	VC Arbitration Select (VCAS): This field will be programmed by software to the only possible value as indicated in the VC Arbitration Capability field. Since there is no other VC supported than the default, this field is reserved.
0	RO 0b	Reserved



6.1.51 VC0RCAP—VC0 Resource Capability

B/D/F/Type: 0/1/0/MMR
Address Offset: 110–113h
Default Value: 00000000h
Access: RO
Size: 32 bits

Bit	Access & Default	Description
31:16	RO 0000h	Reserved
15	RO 0b	Reject Snoop Transactions (RSNPT): 0 = Transactions with or without the No Snoop bit set within the TLP header are allowed on this VC. 1 = Any transaction without the No Snoop bit set within the TLP header will be rejected as an Unsupported Request.
14:0	RO 0000h	Reserved



6.1.52 VC0RCTL—VC0 Resource Control

B/D/F/Type: 0/1/0/MMR
 Address Offset: 114–117h
 Default Value: 800000FFh
 Access: RO, RW
 Size: 32 bits

This register controls the resources associated with PCI Express Virtual Channel 0.

Bit	Access & Default	Description
31	RO 1b	VC0 Enable (VC0E): For VC0, this is hardwired to 1 and read only as VC0 can never be disabled.
30:27	RO 0h	Reserved
26:24	RO 000b	VC0 ID (VC0ID): Assigns a VC ID to the VC resource. For VC0, this is hardwired to 0 and read only.
23:8	RO 0000h	Reserved
7:1	RW 7Fh	TC/VC0 Map (TCVC0M): This field indicates the TCs (Traffic Classes) that are mapped to the VC resource. Bit locations within this field correspond to TC values. For example, when bit 7 is set in this field, TC7 is mapped to this VC resource. When more than one bit in this field is set, it indicates that multiple TCs are mapped to the VC resource. In order to remove one or more TCs from the TC/VC Map of an enabled VC, software must ensure that no new or outstanding transactions with the TC labels are targeted at the given Link.
0	RO 1b	TC0/VC0 Map (TC0VC0M): Traffic Class 0 is always routed to VC0.



6.1.53 VC0RSTS—VC0 Resource Status

B/D/F/Type: 0/1/0/MMR
Address Offset: 11A–11Bh
Default Value: 0002h
Access: RO
Size: 16 bits

This register reports the Virtual Channel specific status.

Bit	Access & Default	Description
15:2	RO 0000h	Reserved
1	RO 1b	VC0 Negotiation Pending (VC0NP): 0 = The VC negotiation is complete. 1 = The VC resource is still in the process of negotiation (initialization or disabling). This bit indicates the status of the process of Flow Control initialization. It is set by default on Reset, as well as whenever the corresponding Virtual Channel is Disabled or the Link is in the DL_Down state. It is cleared when the link successfully exits the FC_INIT2 state. Before using a Virtual Channel, software must check whether the VC Negotiation Pending fields for that Virtual Channel are cleared in both Components on a Link.
0	RO 0b	Reserved



6.1.54 RCLDECH—Root Complex Link Declaration Enhanced

B/D/F/Type: 0/1/0/MMR
 Address Offset: 140–143h
 Default Value: 00010005h
 Access: RO
 Size: 32 bits

This capability declares links from this element (PEG) to other elements of the root complex component to which it belongs. See PCI Express specification for link/topology declaration requirements.

Bit	Access & Default	Description
31:20	RO 000h	Pointer to Next Capability (PNC): This is the last capability in the PCI Express extended capabilities list
19:16	RO 1h	Link Declaration Capability Version (LDCV): Hardwired to 1 to indicate compliances with the 1.1 version of the PCI Express specification.
15:0	RO 0005h	Extended Capability ID (ECID): Value of 0005h identifies this linked list item (capability structure) as being for PCI Express Link Declaration Capability.

6.1.55 ESD—Element Self Description

B/D/F/Type: 0/1/0/MMR
 Address Offset: 144–147h
 Default Value: 02000100h
 Access: RO, RWO
 Size: 32 bits

This register provides information about the root complex element containing this Link Declaration Capability.

Bit	Access & Default	Description
31:24	RO 02h	Port Number (PN): This field specifies the port number associated with this element with respect to the component that contains this element. This port number value is utilized by the Express port of the component to provide arbitration to this Root Complex Element.
23:16	RWO 00h	Component ID (CID): This field identifies the physical component that contains this Root Complex Element.
15:8	RO 01h	Number of Link Entries (NLE): This field indicates the number of link entries following the Element Self Description. This field reports 1 (to Express port only as we don't report any peer-to-peer capabilities in our topology).
7:4	RO 0h	Reserved
3:0	RO 0h	Element Type (ET): This field indicates the type of the Root Complex Element. Value of 0h represents a root port.



6.1.56 LE1D—Link Entry 1 Description

B/D/F/Type: 0/1/0/MMR
Address Offset: 150–153h
Default Value: 00000000h
Access: RO, RWO
Size: 32 bits

This register provides the first part of a Link Entry which declares an internal link to another Root Complex Element.

Bit	Access & Default	Description
31:24	RO 00h	Target Port Number (TPN): This field specifies the port number associated with the element targeted by this link entry (Express Port). The target port number is with respect to the component that contains this element as specified by the target component ID.
23:16	RWO 00h	Target Component ID (TCID): This field identifies the physical or logical component that is targeted by this link entry.
15:2	RO 0000h	Reserved
1	RO 0b	Link Type (LTYP): This field indicates that the link points to memory-mapped space (for RCRB). The link address specifies the 64-bit base address of the target RCRB.
0	RWO 0b	Link Valid (LV): 0 = Link Entry is not valid and will be ignored. 1 = Link Entry specifies a valid link.

6.1.57 LE1A—Link Entry 1 Address

B/D/F/Type: 0/1/0/MMR
Address Offset: 158–15Fh
Default Value: 0000000000000000h
Access: RO, RWO
Size: 64 bits

This register provides the second part of a Link Entry which declares an internal link to another Root Complex Element.

Bit	Access & Default	Description
63:32	RO 00000000h	Reserved
31:12	RWO 0000h	Link Address (LA): This field contains the memory-mapped base address of the RCRB that is the target element (Express Port) for this link entry.
11:0	RO 000h	Reserved



6.1.58 PEGSSTS—PCI Express*-G Sequence Status

B/D/F/Type: 0/1/0/MMR
 Address Offset: 218–21Fh
 Default Value: 0000000000000FFFh
 Access: RO
 Size: 64 bits

This register provides PCI Express status reporting that is required by the PCI Express specification.

Bit	Access & Default	Description
63:60	RO 0h	Reserved
59:48	RO 000h	Next Transmit Sequence Number (NTSN): This field indicates the value of the NXT_TRANS_SEQ counter. This counter represents the transmit Sequence number to be applied to the next TLP to be transmitted onto the Link for the first time.
47:44	RO 0h	Reserved
43:32	RO 000h	Next Packet Sequence Number (NPSN): This field indicates the packet sequence number to be applied to the next TLP to be transmitted or re-transmitted onto the Link.
31:28	RO 0h	Reserved
27:16	RO 000h	Next Receive Sequence Number (NRSN): This field is the sequence number associated with the TLP that is expected to be received next.
15:12	RO 0h	Reserved
11:0	RO FFFh	Last Acknowledged Sequence Number (LASN): This field is the sequence number associated with the last acknowledged TLP.

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7 Direct Memory Interface (DMI) Registers

This Root Complex Register Block (RCRB) controls the (G)MCH-ICH9 serial interconnect. The base address of this space is programmed in DMIBAR in D0:F0 configuration space. Table 7-1 provides an address map of the DMI registers listed by address offset in ascending order. Section 7.1 provides register bit descriptions.

Table 7-1. DMI Register Address Map

Address Offset	Register Symbol	Register Name	Default Value	Access
00–03h	DMIVCECH	DMI Virtual Channel Enhanced Capability	04010002h	RO
04–07h	DMIPVCCAP1	DMI Port VC Capability Register 1	00000001h	RWO, RO
08–0Bh	DMIPVCCAP2	DMI Port VC Capability Register 2	00000000h	RO
0C–0Dh	DMIPVCCTL	DMI Port VC Control	0000h	RO, RW
10–13h	DMIVC0RCAP	DMI VC0 Resource Capability	00000001h	RO
14–17h	DMIVC0RCTL0	DMI VC0 Resource Control	800000FFh	RO, RW
1A–1Bh	DMIVC0RSTS	DMI VC0 Resource Status	0002h	RO
1C–1Fh	DMIVC1RCAP	DMI VC1 Resource Capability	00008001h	RO
20–23h	DMIVC1RCTL1	DMI VC1 Resource Control	01000000h	RW, RO
26–27h	DMIVC1RSTS	DMI VC1 Resource Status	0002h	RO
84–87h	DMILCAP	DMI Link Capabilities	00012C41h	RO, RWO
88–89h	DMILCTL	DMI Link Control	0000h	RW, RO
8A–8Bh	DMILSTS	DMI Link Status	0001h	RO



7.1 Direct Memory Interface (DMI) Configuration Register Details

7.1.1 DMIVCECH—DMI Virtual Channel Enhanced Capability

B/D/F/Type: 0/0/0/DMIBAR
Address Offset: 00–03h
Default Value: 04010002h
Access: RO
Size: 32 bits

This register indicates DMI Virtual Channel capabilities.

Bit	Access & Default	Description
31:20	RO 040h	Pointer to Next Capability (PNC): This field contains the offset to the next PCI Express capability structure in the linked list of capabilities (Link Declaration Capability).
19:16	RO 1h	PCI Express* Virtual Channel Capability Version (PCI EXPRESS*VCCV): Hardwired to 1 to indicate compliances with the 1.1 version of the PCI Express specification.
15:0	RO 0002h	Extended Capability ID (ECID): Value of 0002h identifies this linked list item (capability structure) as being for PCI Express Virtual Channel registers.



7.1.2 DMIPVCCAP1—DMI Port VC Capability Register 1

B/D/F/Type: 0/0/0/DMIBAR
 Address Offset: 04–07h
 Default Value: 00000001h
 Access: RWO, RO
 Size: 32 bits

This register describes the configuration of PCI Express Virtual Channels associated with this port.

Bit	Access & Default	Description
31:7	RO 0000000h	Reserved
6:4	RO 000b	Low Priority Extended VC Count (LPEVCC): This field indicates the number of (extended) Virtual Channels in addition to the default VC belonging to the low-priority VC (LPVC) group that has the lowest priority with respect to other VC resources in a strict-priority VC Arbitration. The value of 0 in this field implies strict VC arbitration.
3	RO 0b	Reserved
2:0	RWO 001b	Extended VC Count (EVCC): This field indicates the number of (extended) Virtual Channels in addition to the default VC supported by the device. The Private Virtual Channel is not included in this count.

7.1.3 DMIPVCCAP2—DMI Port VC Capability Register 2

B/D/F/Type: 0/0/0/DMIBAR
 Address Offset: 08–0Bh
 Default Value: 00000000h
 Access: RO
 Size: 32 bits

This register describes the configuration of PCI Express Virtual Channels associated with this port.

Bit	Access & Default	Description
31:0	RO 00000000h	Reserved



7.1.4 DMIPVCCTL—DMI Port VC Control

B/D/F/Type: 0/0/0/DMIBAR
Address Offset: 0C–0Dh
Default Value: 0000h
Access: RO, RW
Size: 16 bits

Bit	Access & Default	Description
15:4	RO 000h	Reserved
3:1	RW 000b	VC Arbitration Select (VCAS): This field will be programmed by software to the only possible value as indicated in the VC Arbitration Capability field. See the PCI express specification for more details.
0	RO 0b	Reserved

7.1.5 DMIVC0RCAP—DMI VC0 Resource Capability

B/D/F/Type: 0/0/0/DMIBAR
Address Offset: 10–13h
Default Value: 00000001h
Access: RO
Size: 32 bits

Bit	Access & Default	Description
31:16	RO 00000h	Reserved
15	RO 0b	Reject Snoop Transactions (REJSNPT): 0 = Transactions with or without the No Snoop bit set within the TLP header are allowed on this VC. 1 = Any transaction without the No Snoop bit set within the TLP header will be rejected as an Unsupported Request.
14:8	RO 00h	Reserved
7:0	RO 01h	Port Arbitration Capability (PAC): Having only bit 0 set indicates that the only supported arbitration scheme for this VC is non-configurable hardware-fixed.



7.1.6 DMIVC0RCTL0—DMI VC0 Resource Control

B/D/F/Type: 0/0/0/DMIBAR
 Address Offset: 14–17h
 Default Value: 800000FFh
 Access: RO, RW
 Size: 32 bits

This register controls the resources associated with PCI Express Virtual Channel 0.

Bit	Access & Default	Description
31	RO 1b	Virtual Channel 0 Enable (VC0E): For VC0 this is hardwired to 1 and read only as VC0 can never be disabled.
30:27	RO 0h	Reserved
26:24	RO 000b	Virtual Channel 0 ID (VC0ID): Assigns a VC ID to the VC resource. For VC0 this is hardwired to 0 and read only.
23:20	RO 0h	Reserved
19:17	RW 000b	Port Arbitration Select (PAS): This field configures the VC resource to provide a particular Port Arbitration service. Valid value for this field is a number corresponding to one of the asserted bits in the Port Arbitration Capability field of the VC resource. Because only bit 0 of that field is asserted. This field will always be programmed to 1.
16:8	RO 000h	Reserved
7:1	RW 7Fh	Traffic Class / Virtual Channel 0 Map (TCVC0M): This field indicates the TCs (Traffic Classes) that are mapped to the VC resource. Bit locations within this field correspond to TC values. For example, when bit 7 is set in this field, TC7 is mapped to this VC resource. When more than one bit in this field is set, it indicates that multiple TCs are mapped to the VC resource. To remove one or more TCs from the TC/VC Map of an enabled VC, software must ensure that no new or outstanding transactions with the TC labels are targeted at the given Link.
0	RO 1b	Traffic Class 0 / Virtual Channel 0 Map (TC0VC0M): Traffic Class 0 is always routed to VC0.



7.1.7 DMIVC0RSTS—DMI VC0 Resource Status

B/D/F/Type: 0/0/0/DMIBAR
Address Offset: 1A–1Bh
Default Value: 0002h
Access: RO
Size: 16 bits

This register reports the Virtual Channel specific status.

Bit	Access & Default	Description
15:2	RO 0000h	Reserved.
1	RO 1b	Virtual Channel 0 Negotiation Pending (VC0NP): This bit indicates the status of the process of Flow Control initialization. It is set by default on Reset, as well as whenever the corresponding Virtual Channel is Disabled or the Link is in the DL_Down state. It is cleared when the link successfully exits the FC_INIT2 state. 0 = The VC negotiation is complete. 1 = The VC resource is still in the process of negotiation (initialization or disabling). BIOS Requirement: Before using a Virtual Channel, software must check whether the VC Negotiation Pending fields for that Virtual Channel are cleared in both Components on a Link.
0	RO 0b	Reserved

7.1.8 DMIVC1RCAP—DMI VC1 Resource Capability

B/D/F/Type: 0/0/0/DMIBAR
Address Offset: 1C–1Fh
Default Value: 00008001h
Access: RO
Size: 32 bits

Bit	Access & Default	Description
31:16	RO 00000h	Reserved
15	RO 1b	Reject Snoop Transactions (REJSNPT): 0 = Transactions with or without the No Snoop bit set within the TLP header are allowed on this VC. 1 = Any transaction without the No Snoop bit set within the TLP header will be rejected as an Unsupported Request.
14:8	RO 00h	Reserved
7:0	RO 01h	Port Arbitration Capability (PAC): Having only bit 0 set indicates that the only supported arbitration scheme for this VC is non-configurable hardware-fixed.



7.1.9 DMIVC1RCTL1—DMI VC1 Resource Control

B/D/F/Type: 0/0/0/DMIBAR
 Address Offset: 20–23h
 Default Value: 01000000h
 Access: RW, RO
 Size: 32 bits

This register controls the resources associated with PCI Express Virtual Channel 1.

Bit	Access & Default	Description
31	RW 0b	Virtual Channel 1 Enable (VC1E): 0 = Virtual Channel is disabled. 1 = Virtual Channel is enabled.
30:27	RO 0h	Reserved
26:24	RW 001b	Virtual Channel 1 ID (VC1ID): This field assigns a VC ID to the VC resource. Assigned value must be non-zero. This field can not be modified when the VC is already enabled.
23:20	RO 0h	Reserved
19:17	RW 000b	Port Arbitration Select (PAS): This field configures the VC resource to provide a particular Port Arbitration service. Valid value for this field is a number corresponding to one of the asserted bits in the Port Arbitration Capability field of the VC resource.
16:8	RO 000h	Reserved
7:1	RW 00h	Traffic Class / Virtual Channel 1 Map (TCVC1M): This field indicates the TCs (Traffic Classes) that are mapped to the VC resource. Bit locations within this field correspond to TC values. For example, when bit 7 is set in this field, TC7 is mapped to this VC resource. When more than one bit in this field is set, it indicates that multiple TCs are mapped to the VC resource. In order to remove one or more TCs from the TC/VC Map of an enabled VC, software must ensure that no new or outstanding transactions with the TC labels are targeted at the given Link.
0	RO 0b	Traffic Class 0 / Virtual Channel 1 Map (TC0VC1M): Traffic Class 0 is always routed to VC0.



7.1.10 DMIVC1RSTS—DMI VC1 Resource Status

B/D/F/Type: 0/0/0/DMIBAR
Address Offset: 26–27h
Default Value: 0002h
Access: RO
Size: 16 bits

This register reports the Virtual Channel specific status.

Bit	Access & Default	Description
15:2	RO 0000h	Reserved
1	RO 1b	Virtual Channel 1 Negotiation Pending (VC1NP): 0 = The VC negotiation is complete. 1 = The VC resource is still in the process of negotiation (initialization or disabling).
0	RO 0b	Reserved

7.1.11 DMILCAP—DMI Link Capabilities

B/D/F/Type: 0/0/0/DMIBAR
Address Offset: 84–87h
Default Value: 00012C41h
Access: RO, RWO
Size: 32 bits

This register indicates DMI specific capabilities.

Bit	Access & Default	Description
31:18	RO 0000h	Reserved
17:15	RWO 010b	L1 Exit Latency (L1SELAT): This field indicates the length of time this Port requires to complete the transition from L1 to L0. 010b = 2 us to less than 4 us.
14:12	RWO 010b	L0s Exit Latency (L0SELAT): This field indicates the length of time this Port requires to complete the transition from L0s to L0. 010 = 128 ns to less than 256 ns
11:10	RO 11b	Active State Link PM Support (ASLPMS): L0s & L1 entry supported.
9:4	RO 04h	Max Link Width (MLW): This field indicates the maximum number of lanes supported for this link.
3:0	RO 1h	Max Link Speed (MLS): Hardwired to indicate 2.5 Gb/s.



7.1.12 DMILCTL—DMI Link Control

B/D/F/Type: 0/0/0/DMIBAR
 Address Offset: 88–89h
 Default Value: 0000h
 Access: RW, RO
 Size: 16 bits

This register allows control of DMI.

Bit	Access & Default	Description
15:8	RO 00h	Reserved
7	RW 0b	Extended Synch (EXTSYNC): 0 = Standard Fast Training Sequence (FTS). 1 = Forces the transmission of additional ordered sets when exiting the L0s state and when in the Recovery state.
6:3	RO 0h	Reserved
2	RW 0b	Far-End Digital Loopback (FEDLB):
1:0	RW 00b	Active State Power Management Support (ASPMS): This field controls the level of active state power management supported on the given link. 00 = Disabled 01 = L0s Entry Supported 10 = Reserved 11 = L0s and L1 Entry Supported



7.1.13 DMILSTS—DMI Link Status

B/D/F/Type: 0/0/0/DMIBAR
Address Offset: 8A–8Bh
Default Value: 0001h
Access: RO
Size: 16 bits

This register indicates DMI status.

Bit	Access & Default	Description
15:10	RO 00h	Reserved and Zero for future R/WC/S implementations. Software must use 0 for writes to these bits.
9:4	RO 00h	Negotiated Width (NWID): This field indicates negotiated link width. This field is valid only when the link is in the L0, L0s, or L1 states (after link width negotiation is successfully completed). 04h = X4 All other encodings are reserved.
3:0	RO 1h	Negotiated Speed (NSPD): This field indicates negotiated link speed. 1h = 2.5 Gb/s All other encodings are reserved.



8 Integrated Graphics Registers (D2:F0,F1) (Intel® 82G31 GMCH Only)

The Integrated Graphics Device (IGD) registers are located in Device 2 (D0), Function 0 (F0) and Function 1 (F1). This chapter provides the descriptions for these registers. Section 8.1 provides the register descriptions for Device 2, Function 0. Section 8.2 provides the register descriptions for Device 2, Function 1.

8.1 Integrated Graphics Register Details (D2:F0)

Device 2, Function 0 contains registers for the internal graphics functions. Table 8-1 lists the PCI configuration registers in order of ascending offset address.

Function 0 can be VGA compatible or not, this is selected through bit 1 of GGC register (Device 0, offset 52h).

Note: The following sections describe Device 2 PCI configuration registers only.

Table 8-1. Integrated Graphics Device Register Address Map (Device 2, Function 0)

Address Offset	Register Symbol	Register Name	Default Value	Access
00–01h	VID2	Vendor Identification	8086h	RO
02–03h	DID	Device Identification	29C2h	RO
04–05h	PCICMD2	PCI Command	0000h	RO, RW
06–07h	PCISTS2	PCI Status	0090h	RO
08h	RID2	Revision Identification	See register description	RO
09–0Bh	CC	Class Code	030000h	RO
0Ch	CLS	Cache Line Size	00h	RO
0Dh	MLT2	Master Latency Timer	00h	RO
0Eh	HDR2	Header Type	80h	RO
10–13h	MMADR	Memory Mapped Range Address	00000000h	RO, RW
2C–2Dh	SVID2	Subsystem Vendor Identification	0000h	RWO
2E–2Fh	SID2	Subsystem Identification	0000h	RWO
30–33h	ROMADR	Video BIOS ROM Base Address	00000000h	RO



Address Offset	Register Symbol	Register Name	Default Value	Access
34h	CAPPOINT	Capabilities Pointer	90h	RO
3Eh	MINGNT	Minimum Grant	00h	RO
3Fh	MAXLAT	Maximum Latency	00h	RO
40–50h	CAPID0	Capability Identifier	00000000 00000001 00000000 10B0009h	RO
52–53h	MGGC	GMCH Graphics Control Register	0030h	RO
54–57h	DEVEN	Device Enable	00003DBh	RO
58–5Bh	SSRW	Software Scratch Read Write	00000000h	RW
5C–5Fh	BSM	Base of Stolen Memory	07800000h	RO
60–61h	HSRW	Hardware Scratch Read Write	0000h	RW
C0h	GDRST	Graphics Debug Reset	00h	RO, RW/L
D0–D1h	PMCAPID	Power Management Capabilities ID	0001h	RWO, RO
D2–D3h	PMCAP	Power Management Capabilities	0022h	RO
D4–D5h	PMCS	Power Management Control/Status	0000h	RO, RW
E0–E1h	SWSMI	Software SMI	0000h	RW
E4–E7h	ASLE	System Display Event Register	00000000h	RW
FC–FFh	ASLS	ASL Storage	00000000h	RW

8.1.1 VID2—Vendor Identification

B/D/F/Type: 0/2/0/PCI
 Address Offset: 00–01h
 Default Value: 8086h
 Access: RO
 Size: 16 bits

This register combined with the Device Identification register uniquely identifies any PCI device.

Bit	Access & Default	Description
15:0	RO 8086h	Vendor Identification Number (VID): PCI standard identification for Intel.



8.1.2 DID—Device Identification

B/D/F/Type: 0/2/0/PCI
 Address Offset: 02–03h
 Default Value: 29C2h
 Access: RO
 Size: 16 bits

This register combined with the Vendor Identification register uniquely identifies any PCI device.

Bit	Access & Default	Description
15:0	RO 29C2h	Device Identification Number (DID): This is a 16 bit value assigned to the GMCH Graphic device.

8.1.3 PCICMD2—PCI Command

B/D/F/Type: 0/2/0/PCI
 Address Offset: 04–05h
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

This 16-bit register provides basic control over the IGD's ability to respond to PCI cycles. The PCICMD Register in the IGD disables the IGD PCI compliant master accesses to main memory.

Bit	Access & Default	Description
15:11	RO 00h	Reserved
10	RW 0b	Interrupt Disable (INTDIS): This bit disables the device from asserting INTx#. 0 = Enable the assertion of this device's INTx# signal. 1 = Disable the assertion of this device's INTx# signal. DO_INTx messages will not be sent to DMI.
9	RO 0b	Fast Back-to-Back (FB2B): Not Implemented. Hardwired to 0.
8	RO 0b	SERR Enable (SERRE): Not Implemented. Hardwired to 0.
7	RO 0b	Address/Data Stepping Enable (ADSTEP): Not Implemented. Hardwired to 0.
6	RO 0b	Parity Error Enable (PERRE): Not Implemented. Hardwired to 0. Since the IGD belongs to the category of devices that does not corrupt programs or data in system memory or hard drives, the IGD ignores any parity error that it detects and continues with normal operation.



Integrated Graphics Registers (D2:F0,F1) (Intel® 82G31 GMCH Only)

Bit	Access & Default	Description
5	RO 0b	Video Palette Snooping (VPS): This bit is hardwired to 0 to disable snooping.
4	RO 0b	Memory Write and Invalidate Enable (MWIE): Hardwired to 0. The IGD does not support memory write and invalidate commands.
3	RO 0b	Special Cycle Enable (SCE): This bit is hardwired to 0. The IGD ignores Special cycles.
2	RW 0b	Bus Master Enable (BME): This bit controls the IGD's response to bus master accesses. 0 = Disable IGD bus mastering. 1 = Enable the IGD to function as a PCI compliant master.
1	RW 0b	Memory Access Enable (MAE): This bit controls the IGD's response to memory space accesses. 0 = Disable. 1 = Enable.
0	RW 0b	I/O Access Enable (IOAE): This bit controls the IGD's response to I/O space accesses. 0 = Disable. 1 = Enable.



8.1.4 PCISTS2—PCI Status

B/D/F/Type: 0/2/0/PCI
 Address Offset: 06–07h
 Default Value: 0090h
 Access: RO
 Size: 16 bits

PCISTS is a 16-bit status register that reports the occurrence of a PCI compliant master abort and PCI compliant target abort. PCISTS also indicates the DEVSEL# timing that has been set by the IGD.

Bit	Access & Default	Description
15	RO 0b	Detected Parity Error (DPE): Since the IGD does not detect parity, this bit is always hardwired to 0.
14	RO 0b	Signaled System Error (SSE): The IGD never asserts SERR#, therefore this bit is hardwired to 0.
13	RO 0b	Received Master Abort Status (RMAS): The IGD never gets a Master Abort, therefore this bit is hardwired to 0.
12	RO 0b	Received Target Abort Status (RTAS): The IGD never gets a Target Abort, therefore this bit is hardwired to 0.
11	RO 0b	Signaled Target Abort Status (STAS): Hardwired to 0. The IGD does not use target abort semantics.
10:9	RO 00b	DEVSEL Timing (DEVT): N/A. These bits are hardwired to "00".
8	RO 0b	Master Data Parity Error Detected (DPD): Since Parity Error Response is hardwired to disabled (and the IGD does not do any parity detection), this bit is hardwired to 0.
7	RO 1b	Fast Back-to-Back (FB2B): Hardwired to 1. The IGD accepts fast back-to-back when the transactions are not to the same agent.
6	RO 0b	User Defined Format (UDF): Hardwired to 0.
5	RO 0b	66 MHz PCI Capable (66C): Hardwired to 0.
4	RO 1b	Capability List (CLIST): This bit is set to 1 to indicate that the register at 34h provides an offset into the function's PCI Configuration Space containing a pointer to the location of the first item in the list.
3	RO 0b	Interrupt Status (INTSTS): This bit reflects the state of the interrupt in the device. Only when the Interrupt Disable bit in the command register is a 0 and this Interrupt Status bit is a 1, will the devices INTx# signal be asserted.
2:0	RO 000b	Reserved



8.1.5 RID2—Revision Identification

B/D/F/Type: 0/2/0/PCI
Address Offset: 08h
Default Value: See register table below
Access: RO
Size: 8 bits

This register contains the revision number for Device #2 Functions 0 and 1.

Bit	Access & Default	Description
7:0	RO 00h	Revision Identification Number (RID): This is an 8-bit value that indicates the revision identification number for the GMCH Device 2. Refer to the <i>Intel® G31/P31 Express Chipset Family Specification Update</i> for the value of the Revision ID register.

8.1.6 CC—Class Code

B/D/F/Type: 0/2/0/PCI
Address Offset: 09–0Bh
Default Value: 030000h
Access: RO
Size: 24 bits

This register contains the device programming interface information related to the Sub-Class Code and Base Class Code definition for the IGD. This register also contains the Base Class Code and the function sub-class in relation to the Base Class Code.

Bit	Access & Default	Description
23:16	RO 03h	Base Class Code (BCC): This is an 8-bit value that indicates the base class code for the GMCH. This code has the value 03h, indicating a Display Controller.
15:8	RO 00h	Sub-Class Code (SUBCC): Value will be determined based on Device 0 GGC register, GMS and IVD fields. 00h = VGA compatible 80h = Non VGA (GMS = "0000" or IVD = "1")
7:0	RO 00h	Programming Interface (PI): 00h = Hardwired as a Display controller.



8.1.7 CLS—Cache Line Size

B/D/F/Type: 0/2/0/PCI
 Address Offset: 0Ch
 Default Value: 00h
 Access: RO
 Size: 8 bits

The IGD does not support this register as a PCI slave.

Bit	Access & Default	Description
7:0	RO 00h	Cache Line Size (CLS): This field is hardwired to 0s. The IGD as a PCI compliant master does not use the Memory Write and Invalidate command and, in general, does not perform operations based on cache line size.

8.1.8 MLT2—Master Latency Timer

B/D/F/Type: 0/2/0/PCI
 Address Offset: 0Dh
 Default Value: 00h
 Access: RO
 Size: 8 bits

The IGD does not support the programmability of the master latency timer because it does not perform bursts.

Bit	Access & Default	Description
7:0	RO 00h	Master Latency Timer Count Value (MLTCV): Hardwired to 0s.



8.1.1.9 HDR2—Header Type

B/D/F/Type: 0/2/0/PCI
Address Offset: 0Eh
Default Value: 80h
Access: RO
Size: 8 bits

This register contains the Header Type of the IGD.

Bit	Access & Default	Description
7	RO 1b	Multi Function Status (MFUNC): Indicates if the device is a Multi-Function Device. The Value of this register is determined by Device #0, offset 54h, DEVEN[4]. If Device 0 DEVEN[4] is set, the MFUNC bit is also set.
6:0	RO 00h	Header Code (H): This is a 7-bit value that indicates the Header Code for the IGD. This code has the value 00h, indicating a type 0 configuration space format.

8.1.1.10 GMADR—Graphics Memory Range Address

B/D/F/Type: 0/2/0/PCI
Address Offset: 18–1Bh
Default Value: 00000008h
Access: RW, RO, RW/L
Size: 32 bits

IGD graphics memory base address is specified in this register.

Bit	Access & Default	Description
31:29	RW 000b	Memory Base Address (MBA): Set by the OS, these bits correspond to address signals 31:29.
28	RW/L 0b	512MB Address Mask (512ADMSK): This Bit is either part of the Memory Base Address (R/W) or part of the Address Mask (RO), depending on the value of MSAC[1:0]. See MSAC (D2:F0, offset 62h) for details.
27	RW/L 0b	256 MB Address Mask (256ADMSK): This bit is either part of the Memory Base Address (R/W) or part of the Address Mask (RO), depending on the value of MSAC[1:0]. See MSAC (D2:F0, offset 62h) for details.
26:4	RO 000000h	Address Mask (ADM): Hardwired to 0s to indicate at least 128 MB address range.
3	RO 1b	Prefetchable Memory (PREFMEM): Hardwired to 1 to enable prefetching.
2:1	RO 00b	Memory Type (MEMTYP): Hardwired to 0 to indicate 32-bit address.
0	RO 0b	Memory / IO Space (MIOS): Hardwired to 0 to indicate memory space.



8.1.11 IOBAR—I/O Base Address

B/D/F/Type:	0/2/0/PCI
Address Offset:	14–17h
Default Value:	00000001h
Access:	RO, RW
Size:	32 bits

This register provides the Base offset of the I/O registers within Device 2. Bits 15:3 are programmable allowing the I/O Base to be located anywhere in 16 bit I/O Address Space. Bits 2:1 are fixed and return zero; bit 0 is hardwired to a one indicating that 8 bytes of I/O space are decoded. Access to the 8Bs of I/O space is allowed in PM state D0 when IO Enable (PCICMD bit 0) set. Access is disallowed in PM states D1–D3 or if I/O Enable is clear or if Device 2 is turned off or if Internal graphics is disabled thru the fuse or fuse override mechanisms.

Note that access to this IO BAR is independent of VGA functionality within Device 2. Also note that this mechanism is available only through function 0 of Device 2 and is not duplicated in function 1.

If accesses to this IO bar is allowed then the GMCH claims all 8, 16 or 32 bit I/O cycles from the processor that falls within the 8B claimed.

Bit	Access & Default	Description
31:16	RO 0000h	Reserved
15:3	RW 0000h	IO Base Address (IOBASE): Set by the OS, these bits correspond to address signals 15:3.
2:1	RO 00b	Memory Type (MEMTYPE): Hardwired to 0s to indicate 32-bit address.
0	RO 1b	Memory/I/O Space (MIOS): Hardwired to 1 to indicate I/O space.

8.1.12 SVID2—Subsystem Vendor Identification

B/D/F/Type:	0/2/0/PCI
Address Offset:	2C–2Dh
Default Value:	0000h
Access:	RWO
Size:	16 bits

Bit	Access & Default	Description
15:0	RWO 0000h	Subsystem Vendor ID (SUBVID): This value is used to identify the vendor of the subsystem. This register should be programmed by BIOS during boot-up. Once written, this register becomes Read Only. This register can only be cleared by a Reset.



8.1.13 SID2—Subsystem Identification

B/D/F/Type: 0/2/0/PCI
Address Offset: 2E–2Fh
Default Value: 0000h
Access: RWO
Size: 16 bits

Bit	Access & Default	Description
15:0	RWO 0000h	Subsystem Identification (SUBID): This value is used to identify a particular subsystem. This field should be programmed by BIOS during boot-up. Once written, this register becomes Read Only. This register can only be cleared by a Reset.

8.1.14 ROMADR—Video BIOS ROM Base Address

B/D/F/Type: 0/2/0/PCI
Address Offset: 30–33h
Default Value: 00000000h
Access: RO
Size: 32 bits

The IGD does not use a separate BIOS ROM, therefore this register is hardwired to 0s.

Bit	Access & Default	Description
31:18	RO 0000h	ROM Base Address (RBA): Hardwired to 0s.
17:11	RO 00h	Address Mask (ADMSK): Hardwired to 0s to indicate 256 KB address range.
10:1	RO 000h	Reserved. Hardwired to 0s.
0	RO 0b	ROM BIOS Enable (RBE): 0 = ROM not accessible.



8.1.15 CAPPOINT—Capabilities Pointer

B/D/F/Type: 0/2/0/PCI
 Address Offset: 34h
 Default Value: 90h
 Access: RO
 Size: 8 bits

Bit	Access & Default	Description
7:0	RO 90h	Capabilities Pointer Value (CPV): This field contains an offset into the function's PCI Configuration Space for the first item in the New Capabilities Linked List, the MSI Capabilities ID registers at address 90h or the Power Management capability at D0h. This value is determined by the configuration in CAPL[0].

8.1.16 INTRLINE—Interrupt Line

B/D/F/Type: 0/2/0/PCI
 Address Offset: 3Ch
 Default Value: 00h
 Access: RW
 Size: 8 bits

Bit	Access & Default	Description
7:0	RW 00h	Interrupt Connection (INTCON): This field is used to communicate interrupt line routing information. POST software writes the routing information into this register as it initializes and configures the system. The value in this register indicates to which input of the system interrupt controller the device's interrupt pin is connected.

8.1.17 INTRPIN—Interrupt Pin

B/D/F/Type: 0/2/0/PCI
 Address Offset: 3Dh
 Default Value: 01h
 Access: RO
 Size: 8 bits

Bit	Access & Default	Description
7:0	RO 01h	Interrupt Pin (INTRPIN): As a single function device, the IGD specifies INTA# as its interrupt pin. 01h = INTA#.



8.1.18 MINGNT—Minimum Grant

B/D/F/Type: 0/2/0/PCI
Address Offset: 3Eh
Default Value: 00h
Access: RO
Size: 8 bits

Bit	Access & Default	Description
7:0	RO 00h	Minimum Grant Value (MGV): The IGD does not burst as a PCI compliant master.

8.1.19 MAXLAT—Maximum Latency

B/D/F/Type: 0/2/0/PCI
Address Offset: 3Fh
Default Value: 00h
Access: RO
Size: 8 bits

Bit	Access & Default	Description
7:0	RO 00h	Maximum Latency Value (MLV): The IGD has no specific requirements for how often it needs to access the PCI bus.



8.1.20 CAPID0—Capability Identifier

B/D/F/Type: 0/2/0/PCI
 Address Offset: 40–50h
 Default Value: 00000000000000000100000000010B0009h
 Access: RO
 Size: 136 bits
 BIOS Optimal Default 000000000000h

This register control of bits in this register are only required for customer visible SKU differentiation.

Bit	Access & Default	Description
135:28	RO 0s	Reserved
27:24	RO 1h	CAPID Version (CAPIDV): This field has the value 0001b to identify the first revision of the CAPID register definition.
23:16	RO 0Bh	CAPID Length (CAPIDL): This field has the value 0bh to indicate the structure length (11 bytes).
15:8	RO 00h	Next Capability Pointer (NCP): This field is hardwired to 00h indicating the end of the capabilities linked list.
7:0	RO 09h	Capability Identifier (CAP_ID): This field has the value 1001b to identify the CAP_ID assigned by the PCI SIG for vendor dependent capability pointers.



8.1.21 MGGC—GMCH Graphics Control Register

B/D/F/Type: 0/2/0/PCI
Address Offset: 52–53h
Default Value: 0030h
Access: RO
Size: 16 bits

Bit	Access & Default	Description
15:10	RO 00h	Reserved
9:8	RO 0h	GTT Graphics Memory Size (GGMS): This field is used to select the amount of Main Memory that is pre-allocated to support the Internal Graphics Translation Table. The BIOS ensures that memory is pre-allocated only when Internal graphics is enabled. 00 = No memory pre-allocated. GTT cycles (Memory and I/O) are not claimed. 01 = No VT mode, 1 MB of memory pre-allocated for GTT. 10 = VT mode, 2 MB of memory pre-allocated for GTT. 11 = Reserved Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set.



Bit	Access & Default	Description
7:4	RO 0011b	Graphics Mode Select (GMS): This field is used to select the amount of Main Memory that is pre-allocated to support the Internal Graphics device in VGA (non-linear) and Native (linear) modes. The BIOS ensures that memory is pre-allocated only when Internal graphics is enabled. 0000 = No memory pre-allocated. Device 2 (IGD) does not claim VGA cycles (Memory and I/O), and the Sub-Class Code field within Device 2 function 0 Class Code register is 80. 0001 = DVMT (UMA) mode, 1 MB of memory pre-allocated for frame buffer. 0010 = DVMT (UMA) mode, 4 MB of memory pre-allocated for frame buffer. 0011 = DVMT (UMA) mode, 8 MB of memory pre-allocated for frame buffer. 0100 = DVMT (UMA) mode, 16 MB of memory pre-allocated for frame buffer. 0101 = DVMT (UMA) mode, 32 MB of memory pre-allocated for frame buffer. 0110 = DVMT (UMA) mode, 48 MB of memory pre-allocated for frame buffer. 0111 = DVMT (UMA) mode, 64 MB of memory pre-allocated for frame buffer. 1000 = DVMT (UMA) mode, 128 MB of memory pre-allocated for frame buffer. 1001 = DVMT (UMA) mode, 256 MB of memory pre-allocated for frame buffer. Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set. BIOS Requirement: BIOS must not set this field to 000 if IVD (bit 1 of this register) is 0.
3:0	RO 0000b	Reserved



8.1.22 DEVEN—Device Enable

B/D/F/Type: 0/2/0/PCI
 Address Offset: 54–57h
 Default Value: 000003DBh
 Access: RO
 Size: 32 bits

This register allows for enabling/disabling of PCI devices and functions that are within the GMCH. The table below the bit definitions describes the behavior of all combinations of transactions to devices controlled by this register.

Bit	Access & Default	Description
31:10	RO 0s	Reserved
9:6	RO 1111b	Reserved
5	RO 0b	Reserved
4	RO 1b	Internal Graphics Engine Function 1 (D2F1EN): 0 = Bus 0, Device 2, Function 1 is disabled and hidden 1 = Bus 0, Device 2, Function 1 is enabled and visible If Device 2, Function 0 is disabled and hidden, then Device 2, Function 1 is also disabled and hidden independent of the state of this bit. If this component is not capable of Dual Independent Display (CAPID0[78] = 1), then this bit is hardwired to 0b to hide Device 2, Function 1.
3	RO 1b	Internal Graphics Engine Function 0 (D2F0EN): 0 = Bus 0, Device 2, Function 0 is disabled and hidden 1 = Bus 0, Device 2, Function 0 is enabled and visible If this GMCH does not have internal graphics capability (CAPID0[46] = 1), then Device 2, Function 0 is disabled and hidden independent of the state of this bit.
2	RO 0b	Reserved
1	RO 1b	PCI Express Port (D1EN): 0 = Bus 0, Device 1, Function 0 is disabled and hidden. 1 = Bus 0, Device 1, Function 0 is enabled and visible. Default value is determined by the device capabilities (see CAPID0 [44]), SDVO Presence hardware strap and the SDVO/PCIe Concurrent hardware strap. Device 1 is Disabled on Reset if the SDVO Presence strap was sampled high, and the SDVO/PCIe Concurrent strap was sampled low at the last assertion of PWROK, and is enabled by default otherwise.
0	RO 1b	Host Bridge (D0EN): Bus 0, Device 0, Function 0 may not be disabled and is therefore hardwired to 1.



8.1.23 SSRW—Software Scratch Read Write

B/D/F/Type: 0/2/0/PCI
 Address Offset: 58–5Bh
 Default Value: 00000000h
 Access: RW
 Size: 32 bits

Bit	Access & Default	Description
31:0	RW 00000000h	Reserved

8.1.24 BSM—Base of Stolen Memory

B/D/F/Type: 0/2/0/PCI
 Address Offset: 5C–5Fh
 Default Value: 07800000h
 Access: RO
 Size: 32 bits

Graphics Stolen Memory and TSEG are within DRAM space defined under TOLUD. From the top of low used DRAM, GMCH claims 1 to 64 MBs of DRAM for internal graphics if enabled.

The base of stolen memory will always be below 4 GB. This is required to prevent aliasing between stolen range and the reclaim region.

Bit	Access & Default	Description
31:20	RO 078h	Base of Stolen Memory (BSM): This field contains bits 31:20 of the base address of stolen DRAM memory. The host interface determines the base of Graphics Stolen memory by subtracting the graphics stolen memory size from TOLUD. See Device 0 TOLUD for more explanation.
19:0	RO 00000h	Reserved

8.1.25 HSRW—Hardware Scratch Read Write

B/D/F/Type: 0/2/0/PCI
 Address Offset: 60–61h
 Default Value: 0000h
 Access: RW
 Size: 16 bits

Bit	Access & Default	Description
15:0	RW 0000h	Reserved



8.1.26 MC—Message Control

B/D/F/Type: 0/2/0/PCI
Address Offset: 92–93h
Default Value: 0000h
Access: RO, RW
Size: 16 bits

System software can modify bits in this register, but the device is prohibited from doing so. If the device writes the same message multiple times, only one of those messages is ensured to be serviced. If all of them must be serviced, the device must not generate the same message again until the driver services the earlier one.

Bit	Access & Default	Description
15:8	RO 00h	Reserved
7	RO 0b	64 Bit Capable (64BCAP): Hardwired to 0 to indicate that the function does not implement the upper 32 bits of the Message address register and is incapable of generating a 64-bit memory address. This may need to change in future implementations when addressable system memory exceeds the 32b / 4 GB limit.
6:4	RW 000b	Multiple Message Enable (MME): System software programs this field to indicate the actual number of messages allocated to this device. This number will be equal to or less than the number actually requested. The encoding is the same as for the MMC field (Bits 3:1).
3:1	RO 000b	Multiple Message Capable (MMC): System Software reads this field to determine the number of messages being requested by this device. 000 = 1 All of the following are reserved in this implementation 001 = 2 010 = 4 011 = 8 100 = 16 101 = 32 110 = Reserved 111 = Reserved
0	RW 0b	MSI Enable (MSIEN): This bit controls the ability of this device to generate MSIs.



8.1.27 MA—Message Address

B/D/F/Type: 0/2/0/PCI
 Address Offset: 94–97h
 Default Value: 00000000h
 Access: RW, RO
 Size: 32 bits

Bit	Access & Default	Description
31:2	RW 00000000h	Message Address (MESSADD): Used by system software to assign an MSI address to the device. The device handles an MSI by writing the padded contents of the MD register to this address.
1:0	RO 00b	Force DWord Align (FDWORD): Hardwired to 0 so that addresses assigned by system software are always aligned on a DWord address boundary.

8.1.28 MD—Message Data

B/D/F/Type: 0/2/0/PCI
 Address Offset: 98–99h
 Default Value: 0000h
 Access: RW
 Size: 16 bits

Bit	Access & Default	Description
15:0	RW 0000h	Message Data (MESSDATA): Base message data pattern assigned by system software and used to handle an MSI from the device. When the device must generate an interrupt request, it writes a 32-bit value to the memory address specified in the MA register. The upper 16 bits are always set to 0. The lower 16 bits are supplied by this register.



8.1.29 GDRST—Graphics Debug Reset

B/D/F/Type: 0/2/0/PCI
Address Offset: C0h
Default Value: 00h
Access: RO, RW
Size: 8 bits

Bit	Access & Default	Description
7:4	RO 0h	Reserved
3:2	RW 00b	Graphics Reset Domain (GRDOM): 00 = Full Graphics Reset will be performed (both render and display clock domain resets asserted) 01 = Reserved (Invalid Programming) 10 = Reserved (Invalid Programming) 11 = Reserved (Invalid Programming)
1	RO 0b	Reserved
0	RW 0b	Graphics Reset Enable (GR): Setting this bit asserts graphics-only reset. The clock domains to be reset are determined by GRDOM. Hardware resets this bit when the reset is complete. Setting this bit without waiting for it to clear, is undefined behavior. Once this bit is set to a 1, all graphics core MMIO registers are returned to power on default state. All Ring buffer pointers are reset, command stream fetches are dropped and ongoing render pipeline processing is halted, state machines and State Variables returned to power on default state. If the Display is reset, all display engines are halted (garbage on screen). VGA memory is not available, Store DWords and interrupts are not assured to be completed. Device 2 I/O registers are not available. When issuing the graphics reset, disable the cursor, display, and overlay engines using the MMIO registers. Wait 1 us. Issue the graphics reset by setting this bit to 1. Device 2 Configuration registers continue to be available while graphics reset is asserted. This bit is hardware auto-clear.



8.1.30 PMCAPID—Power Management Capabilities ID

B/D/F/Type: 0/2/0/PCI
 Address Offset: D0–D1h
 Default Value: 0001h
 Access: RWO, RO
 Size: 16 bits

Bit	Access & Default	Description
15:8	RWO 00h	Next Capability Pointer (NEXT_PTR): This field contains a pointer to the next item in the capabilities list. BIOS is responsible for writing this to the FLR Capability when applicable.
7:0	RO 01h	Capability Identifier (CAP_ID): SIG defines this ID is 01h for power management.

8.1.31 PMCAP—Power Management Capabilities

B/D/F/Type: 0/2/0/PCI
 Address Offset: D2–D3h
 Default Value: 0022h
 Access: RO
 Size: 16 bits

This register is a Mirror of Function 0 with the same read/write attributes. The hardware implements a single physical register common to both functions 0 and 1.

Bit	Access & Default	Description
15:11	RO 00h	PME Support (PMES): This field indicates the power states in which the IGD may assert PME#. Hardwired to 0 to indicate that the IGD does not assert the PME# signal.
10	RO 0b	D2 Support (D2): The D2 power management state is not supported. This bit is hardwired to 0.
9	RO 0b	D1 Support (D1): Hardwired to 0 to indicate that the D1 power management state is not supported.
8:6	RO 000b	Reserved
5	RO 1b	Device Specific Initialization (DSI): Hardwired to 1 to indicate that special initialization of the IGD is required before generic class device driver is to use it.
4	RO 0b	Reserved
3	RO 0b	PME Clock (PMECLK): Hardwired to 0 to indicate IGD does not support PME# generation.
2:0	RO 010b	Version (VER): Hardwired to 010b to indicate that there are 4 bytes of power management registers implemented and that this device complies with revision 1.1 of the PCI Power Management Interface Specification.



8.1.32 PMCS—Power Management Control/Status

B/D/F/Type: 0/2/0/PCI
Address Offset: D4–D5h
Default Value: 0000h
Access: RO, RW
Size: 16 bits

Bit	Access & Default	Description
15	RO 0b	PME Status (PMESTS): This bit is 0 to indicate that IGD does not support PME# generation from D3 (cold).
14:13	RO 00b	Data Scale (DSCALE): The IGD does not support data register. This bit always returns 00 when read, write operations have no effect.
12:9	RO 0h	Data Select (DSEL): The IGD does not support data register. This bit always returns 0h when read, write operations have no effect.
8	RO 0b	PME Enable (PME_EN): This bit is 0 to indicate that PME# assertion from D3 (cold) is disabled.
7:2	RO 00h	Reserved
1:0	RW 00b	Power State (PWRSTAT): This field indicates the current power state of the IGD and can be used to set the IGD into a new power state. If software attempts to write an unsupported state to this field, write operation must complete normally on the bus, but the data is discarded and no state change occurs. On a transition from D3 to D0 the graphics controller is optionally reset to initial values. 00 = D0 (Default) 01 = D1 (Not Supported) 10 = D2 (Not Supported) 11 = D3



8.1.33 SWSMI—Software SMI

B/D/F/Type: 0/2/0/PCI
 Address Offset: E0–E1h
 Default Value: 0000h
 Access: RW
 Size: 16 bits

As long as there is the potential that DVO port legacy drivers exist which expect this register at this address, D2, F0 address E0h–E1h must be reserved for this register.

Bit	Access & Default	Description
15:8	RW 00h	Software Scratch Bits (SWSB):
7:1	RW 00h	Software Flag (SWF): This field is used to indicate caller and SMI function desired, as well as return result.
0	RW 0b	GMCH Software SMI Event (GSSMIE): When Set, this bit will trigger an SMI. Software must write a "0" to clear this bit.



8.2 IGD Configuration Register Details (D2:F1)

The Integrated Graphics Device registers are located in Device 2 (D2), Function 0 (F0) and Function 1 (F1). This section provides the descriptions for the D2:F1 registers. Table 8-2 provides an address map of the D2:F1 registers listed in ascending order by address offset. Detailed bit descriptions follow the table.

Table 8-2. Integrated Graphics Device Register Address Map (D2:F1)

Address Offset	Register Symbol	Register Name	Default Value	Access
00–01h	VID2	Vendor Identification	8086h	RO
02–03h	DID2	Device Identification	29C3h	RO
04–05h	PCICMD2	PCI Command	0000h	RO, RW
06–07h	PCISTS2	PCI Status	0090h	RO
08h	RID2	Revision Identification	See register description	RO
09–0Bh	CC	Class Code Register	038000h	RO
0Ch	CLS	Cache Line Size	00h	RO
0Dh	MLT2	Master Latency Timer	00h	RO
0Eh	HDR2	Header Type	80h	RO
10–13h	MMADR	Memory Mapped Range Address	00000000h	RW, RO
2C–2Dh	SVID2	Subsystem Vendor Identification	0000h	RO
2E–2Fh	SID2	Subsystem Identification	0000h	RO
30–33h	ROMADR	Video BIOS ROM Base Address	00000000h	RO
34h	CAPPOINT	Capabilities Pointer	D0h	RO
3Eh	MINGNT	Minimum Grant	00h	RO
3Fh	MAXLAT	Maximum Latency	00h	RO
40–50h	CAPID0	Mirror of Dev0 Capability Identifier	0000000000 0000000100 000000010 B0009h	RO
52–53h	MGGC	Mirror of Dev 0 GMCH Graphics Control Register	0030h	RO
54–57h	DEVEN	Device Enable	000003DBh	RO
58–5Bh	SSRW	Mirror of Fun 0 Software Scratch Read Write	00000000h	RO
5C–5Fh	BSM	Mirror of Func0 Base of Stolen Memory	07800000h	RO
60–61h	HSRW	Mirror of Dev2 Func0 Hardware Scratch Read Write	0000h	RO



Address Offset	Register Symbol	Register Name	Default Value	Access
62h	MSAC	Mirror of Dev2 Func0 Multi Size Aperture Control	02h	RO
C0h	GDRST	Mirror of Dev2 Func0 Graphics Reset	00h	RO
C1–C3h	MI_GFX_CG_DIS	Mirror of Fun 0 MI Graphics Unit Level Clock Ungating	000000h	RO
C4–C7h	RSVD	Reserved	00000000h	RO
C8h	RSVD	Reserved	00h	RO
CA–CBh	RSVD	Reserved	0000h	RO
CC–CDh	GCDGMBUS	Mirror of Dev2 Func0 Graphics Clock Frequency Register for GMBUS unit	0000h	RO
D0–D1h	PMCAPID	Mirror of Fun 0 Power Management Capabilities ID	0001h	RO
D2–D3h	PMCAP	Mirror of Fun 0 Power Management Capabilities	0022h	RO
D4–D5h	PMCS	Power Management Control/Status	0000h	RO, RW
D8–DBh	RSVD	Reserved	00000000h	RO
E0–E1h	SWSMI	Mirror of Func0 Software SMI	0000h	RO
E4–E7h	ASLE	Mirror of Dev2 Func0 System Display Event Register	00000000h	RO
F0–F3h	GCFG	Mirror of Dev2 Func0 Graphics Clock Frequency and Gating Control	00000000h	RO/P, RO
F4–F7h	RSVD	Mirror of Fun 0 Reserved for LBB-Legacy Backlight Brightness	00000000h	RO
FC–FFh	ASLS	ASL Storage	00000000h	RW



8.2.1 VID2—Vendor Identification

B/D/F/Type: 0/2/1/PCI
Address Offset: 00–01h
Default Value: 8086h
Access: RO
Size: 16 bits

This register, combined with the Device Identification register, uniquely identifies any PCI device.

Bit	Access & Default	Description
15:0	RO 8086h	Vendor Identification Number (VID): PCI standard identification for Intel.

8.2.2 DID2—Device Identification

B/D/F/Type: 0/2/1/PCI
Address Offset: 02–03h
Default Value: 29C3h
Access: RO
Size: 16 bits

This register is unique in Function 1 (the Function 0 DID is separate). This difference in Device ID is necessary for allowing distinct Plug and Play enumeration of function 1 when both function 0 and function 1 have the same class code.

Bit	Access & Default	Description
15:0	RO 29C3h	Device Identification Number (DID): This is a 16 bit value assigned to the GMCH Graphic device Function 1



8.2.3 PCICMD2—PCI Command

B/D/F/Type: 0/2/1/PCI
 Address Offset: 04–05h
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

This 16-bit register provides basic control over the IGD's ability to respond to PCI cycles. The PCICMD Register in the IGD disables the IGD PCI compliant master accesses to main memory.

Bit	Access & Default	Description
15:10	RO 0s	Reserved
9	RO 0b	Fast Back-to-Back (FB2B) : Not Implemented. Hardwired to 0.
8	RO 0b	SERR Enable (SERRE) : Not Implemented. Hardwired to 0.
7	RO 0b	Address/Data Stepping Enable (ADSTEP) : Not Implemented. Hardwired to 0.
6	RO 0b	Parity Error Enable (PERRE) : Not Implemented. Hardwired to 0. Since the IGD belongs to the category of devices that does not corrupt programs or data in system memory or hard drives, the IGD ignores any parity error that it detects and continues with normal operation.
5	RO 0b	VGA Palette Snoop Enable (VGASNOOP) : This bit is hardwired to 0 to disable snooping.
4	RO 0b	Memory Write and Invalidate Enable (MWIE) : Hardwired to 0. The IGD does not support memory write and invalidate commands.
3	RO 0b	Special Cycle Enable (SCE) : This bit is hardwired to 0. The IGD ignores Special cycles.
2	RW 0b	Bus Master Enable (BME) : 0 = Disable IGD bus mastering. 1 = Enable the IGD to function as a PCI compliant master.
1	RW 0b	Memory Access Enable (MAE) : This bit controls the IGD's response to memory space accesses. 0 = Disable. 1 = Enable.
0	RW 0b	I/O Access Enable (IOAE) : This bit controls the IGD's response to I/O space accesses. 0 = Disable. 1 = Enable.



8.2.4 PCISTS2—PCI Status

B/D/F/Type: 0/2/1/PCI
Address Offset: 06–07h
Default Value: 0090h
Access: RO
Size: 16 bits

PCISTS is a 16-bit status register that reports the occurrence of a PCI compliant master abort and PCI compliant target abort. PCISTS also indicates the DEVSEL# timing that has been set by the IGD.

Bit	Access & Default	Description
15	RO 0b	Detected Parity Error (DPE): Since the IGD does not detect parity, this bit is always hardwired to 0.
14	RO 0b	Signaled System Error (SSE): The IGD never asserts SERR#, therefore this bit is hardwired to 0.
13	RO 0b	Received Master Abort Status (RMAS): The IGD never gets a Master Abort, therefore this bit is hardwired to 0.
12	RO 0b	Received Target Abort Status (RTAS): The IGD never gets a Target Abort, therefore this bit is hardwired to 0.
11	RO 0b	Signaled Target Abort Status (STAS): Hardwired to 0. The IGD does not use target abort semantics.
10:9	RO 00b	DEVSEL Timing (DEVT): N/A. These bits are hardwired to "00".
8	RO 0b	Master Data Parity Error Detected (DPD): Since Parity Error Response is hardwired to disabled (and the IGD does not do any parity detection), this bit is hardwired to 0.
7	RO 1b	Fast Back-to-Back (FB2B): Hardwired to 1. The IGD accepts fast back-to-back when the transactions are not to the same agent.
6	RO 0b	User Defined Format (UDF): Hardwired to 0.
5	RO 0b	66 MHz PCI Capable (66C): N/A - Hardwired to 0.
4	RO 1b	Capability List (CLIST): This bit is set to 1 to indicate that the register at 34h provides an offset into the function's PCI Configuration Space containing a pointer to the location of the first item in the list.
3	RO 0b	Interrupt Status (INTSTS): Hardwired to 0.
2:0	RO 000b	Reserved



8.2.5 RID2—Revision Identification

B/D/F/Type:	0/2/1/PCI
Address Offset:	08h
Default Value:	See register table below
Access:	RO
Size:	8 bits

This register contains the revision number for Device 2 Functions 0 and 1.

Bit	Access & Default	Description
7:0	RO 00h	Revision Identification Number (RID): This is an 8-bit value that indicates the revision identification number for the GMCH Device 2. Refer to the <i>Intel® G31/P31 Express Chipset Family Specification Update</i> for the value of the Revision ID register.

8.2.6 CC—Class Code Register

B/D/F/Type:	0/2/1/PCI
Address Offset:	09–0Bh
Default Value:	038000h
Access:	RO
Size:	24 bits

This register contains the device programming interface information related to the Sub-Class Code and Base Class Code definition for the IGD. This register also contains the Base Class Code and the function sub-class in relation to the Base Class Code.

Bit	Access & Default	Description
23:16	RO 03h	Base Class Code (BCC): This is an 8-bit value that indicates the base class code for the GMCH. This code has the value 03h, indicating a Display Controller.
15:8	RO 80h	Sub-Class Code (SUBCC): 80h = Non VGA
7:0	RO 00h	Programming Interface (PI): 00h = Hardwired as a Display controller.



8.2.7 CLS—Cache Line Size

B/D/F/Type: 0/2/1/PCI
Address Offset: 0Ch
Default Value: 00h
Access: RO
Size: 8 bits

The IGD does not support this register as a PCI slave.

Bit	Access & Default	Description
7:0	RO 00h	Cache Line Size (CLS): This field is hardwired to 0s. The IGD as a PCI compliant master does not use the Memory Write and Invalidate command and, in general, does not perform operations based on cache line size.

8.2.8 MLT2—Master Latency Timer

B/D/F/Type: 0/2/1/PCI
Address Offset: Dh
Default Value: 00h
Access: RO
Size: 8 bits

The IGD does not support the programmability of the master latency timer because it does not perform bursts.

Bit	Access & Default	Description
7:0	RO 00h	Master Latency Timer Count Value (MLTCV): Hardwired to 0s.



8.2.9 HDR2—Header Type

B/D/F/Type: 0/2/1/PCI
 Address Offset: 0Eh
 Default Value: 80h
 Access: RO
 Size: 8 bits

This register contains the Header Type of the IGD.

Bit	Access & Default	Description
7	RO 1b	Multi Function Status (MFUNC): Indicates if the device is a Multi-Function Device. The Value of this register is determined by Device 0, offset 54h, DEVEN[4]. If Device 0 DEVEN[4] is set, the MFUNC bit is also set.
6:0	RO 00h	Header Code (H): This is a 7-bit value that indicates the Header Code for the IGD. This code has the value 00h, indicating a type 0 configuration space format.

8.2.10 MMADR—Memory Mapped Range Address

B/D/F/Type: 0/2/1/PCI
 Address Offset: 10–13h
 Default Value: 00000000h
 Access: RW, RO
 Size: 32 bits

This register requests allocation for the IGD registers and instruction ports. The allocation is for 512 KB and the base address is defined by bits 31:19.

Bit	Access & Default	Description
31:19	RW 0000h	Memory Base Address (MBA): Set by the OS, these bits correspond to address signals 31:19.
18:4	RO 0000h	Address Mask (ADMSK): Hardwired to 0s to indicate 512 KB address range.
3	RO 0b	Prefetchable Memory (PREFMEM): Hardwired to 0 to prevent prefetching.
2:1	RO 00b	Memory Type (MEMTYP): Hardwired to 0s to indicate 32-bit address.
0	RO 0b	Memory / IO Space (MIOS): Hardwired to 0 to indicate memory space.



8.2.11 SVID2—Subsystem Vendor Identification

B/D/F/Type: 0/2/1/PCI
Address Offset: 2C–2Dh
Default Value: 0000h
Access: RO
Size: 16 bits

Bit	Access & Default	Description
15:0	RO 0000h	Subsystem Vendor ID (SUBVID): This value is used to identify the vendor of the subsystem. This register should be programmed by BIOS during boot-up. Once written, this register becomes Read Only. This register can only be cleared by a Reset.

8.2.12 SID2—Subsystem Identification

B/D/F/Type: 0/2/1/PCI
Address Offset: 2E–2Fh
Default Value: 0000h
Access: RO
Size: 16 bits

Bit	Access & Default	Description
15:0	RO 0000h	Subsystem Identification (SUBID): This value is used to identify a particular subsystem. This field should be programmed by BIOS during boot-up. Once written, this register becomes Read Only. This register can only be cleared by a Reset.



8.2.13 ROMADR—Video BIOS ROM Base Address

B/D/F/Type: 0/2/1/PCI
 Address Offset: 30–33h
 Default Value: 00000000h
 Access: RO
 Size: 32 bits

The IGD does not use a separate BIOS ROM, therefore this register is hardwired to 0s.

Bit	Access & Default	Description
31:18	RO 0000h	ROM Base Address (RBA): Hardwired to 0s.
17:11	RO 00h	Address Mask (ADMSK): Hardwired to 0s to indicate 256 KB address range.
10:1	RO 000h	Reserved. Hardwired to 0s.
0	RO 0b	ROM BIOS Enable (RBE): 0 = ROM not accessible.

8.2.14 CAPPOINT—Capabilities Pointer

B/D/F/Type: 0/2/1/PCI
 Address Offset: 34h
 Default Value: D0h
 Access: RO
 Size: 8 bits

Bit	Access & Default	Description
7:0	RO D0h	Capabilities Pointer Value (CPV): This field contains an offset into the function's PCI Configuration Space for the first item in the New Capabilities Linked List, the MSI Capabilities ID registers at the Power Management capability at D0h.



8.2.15 MINGNT—Minimum Grant

B/D/F/Type: 0/2/1/PCI
Address Offset: 3Eh
Default Value: 00h
Access: RO
Size: 8 bits

Bit	Access & Default	Description
7:0	RO 00h	Minimum Grant Value (MGV): The IGD does not burst as a PCI compliant master.

8.2.16 MAXLAT—Maximum Latency

B/D/F/Type: 0/2/1/PCI
Address Offset: 3Fh
Default Value: 00h
Access: RO
Size: 8 bits

Bit	Access & Default	Description
7:0	RO 00h	Maximum Latency Value (MLV): The IGD has no specific requirements for how often it needs to access the PCI bus.

8.2.17 CAPID0—Mirror of Dev0 Capability Identifier

B/D/F/Type: 0/2/1/PCI
Address Offset: 40–50h
Default Value: 00000000000000000100000000010B0009h
Access: RO
Size: 136 bits
BIOS Optimal Default: 000000000000h

Control of bits in this register are only required for customer visible component differentiation.

Bit	Access & Default	Description
7:0	RO 09h	Capability Identifier (CAP_ID): This field has the value 1001b to identify the CAP_ID assigned by the PCI SIG for vendor dependent capability pointers.



8.2.18 MGGC—Mirror of Dev 0 GMCH Graphics Control Register

B/D/F/Type: 0/2/1/PCI
 Address Offset: 52–53h
 Default Value: 0030h
 Access: RO
 Size: 16 bits

Bit	Access & Default	Description
15:10	RO 00h	Reserved
9:8	RO 0h	GTT Graphics Memory Size (GGMS): This field is used to select the amount of main memory that is pre-allocated to support the Internal Graphics Translation Table. The BIOS ensures that memory is pre-allocated only when Internal graphics is enabled. 00 = No memory pre-allocated. GTT cycles (Memory and I/O) are not claimed. 01 = No VT mode, 1 MB of memory pre-allocated for GTT. 10 = VT mode, 2 MB of memory pre-allocated for GTT. 11 = reserved Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set.



Integrated Graphics Registers (D2:F0,F1) (Intel® 82G31 GMCH Only)

Bit	Access & Default	Description
7:4	RO 0011b	Graphics Mode Select (GMS) This field is used to select the amount of Main Memory that is pre-allocated to support the Internal Graphics device in VGA (non-linear) and Native (linear) modes. The BIOS ensures that memory is pre-allocated only when Internal graphics is enabled. 0000 = No memory pre-allocated. Device 2 (IGD) does not claim VGA cycles (Memory and I/O), and the Sub-Class Code field within Device 2 function 0 Class Code register is 80h. 0001 = DVMT (UMA) mode, 1 MB of memory pre-allocated for frame buffer. 0010 = DVMT (UMA) mode, 4 MB of memory pre-allocated for frame buffer. 0011 = DVMT (UMA) mode, 8 MB of memory pre-allocated for frame buffer. 0100 = DVMT (UMA) mode, 16 MB of memory pre-allocated for frame buffer. 0101 = DVMT (UMA) mode, 32 MB of memory pre-allocated for frame buffer. 0110 = DVMT (UMA) mode, 48 MB of memory pre-allocated for frame buffer. 0111 = DVMT (UMA) mode, 64 MB of memory pre-allocated for frame buffer. 1000 = DVMT (UMA) mode, 128 MB of memory pre-allocated for frame buffer. 1001 = DVMT (UMA) mode, 256 MB of memory pre-allocated for frame buffer. Note: This register is locked and becomes Read Only when the D_LCK bit in the SMRAM register is set. BIOS Requirement: BIOS must not set this field to 000 if IVD (bit 1 of this register) is 0.
3:2	RO 00b	Reserved
1	RO 0b	IGD VGA Disable (IVD): 0 = Enable. Device 2 (IGD) claims VGA memory and I/O cycles, the Sub-Class Code within Device 2 Class Code register is 00. 1 = Disable. Device 2 (IGD) does not claim VGA cycles (Memory and I/O), and the Sub- Class Code field within Device 2, function 0 Class Code register is 80h. BIOS Requirement: BIOS must not set this bit to 0 if the GMS field (bits 6:4 of this register) pre-allocates no memory. This bit MUST be set to 1 if Device 2 is disabled either via a fuse or fuse override (CAPID0[38] = 1) or via a register (DEVEN[3] = 0).
0	RO 0b	Reserved



8.2.19 DEVEN—Device Enable

B/D/F/Type: 0/2/1/PCI
 Address Offset: 54–57h
 Default Value: 000003DBh
 Access: RO
 Size: 32 bits

This register allows for enabling/disabling of PCI devices and functions that are within the GMCH. The table below the bit definitions describes the behavior of all combinations of transactions to devices controlled by this register.

Bit	Access & Default	Description
31:5	RO 0s	Reserved
4	RO 1b	Internal Graphics Engine Function 1 (D2F1EN): 0 = Bus 0:Device2:Function1 is disabled and hidden 1 = Bus0:Device2:Function1 is enabled and visible If Device2:Function0 is disabled and hidden, then Device2:Function1 is also disabled and hidden independent of the state of this bit. If this component is not capable of Dual Independent Display (CAPID0[78] = 1), then this bit is hardwired to 0b to hide Device2:Function1.
3	RO 1b	Internal Graphics Engine Function 0 (D2F0EN): 0 = Bus0:Device2:Function0 is disabled and hidden 1 = Bus0:Device2:Function0 is enabled and visible If this GMCH does not have internal graphics capability (CAPID0[46] = 1), then Device2:Function0 is disabled and hidden independent of the state of this bit.
2	RO 0b	Reserved
1	RO 1b	PCI Express Port (D1EN): 0 = Bus0:Device1:Function0 is disabled and hidden. 1 = Bus0:Device1:Function0 is enabled and visible. Default value is determined by the device capabilities (see CAPID0 [44]), SDVO Presence hardware strap and the SDVO/PCIe Concurrent hardware strap. Device 1 is Disabled on Reset if the SDVO Presence strap was sampled high, and the SDVO/PCIe Concurrent strap was sampled low at the last assertion of PWROK, and is enabled by default otherwise.
0	RO 1b	Host Bridge (D0EN): Bus 0 Device 0 Function 0 may not be disabled and is therefore hardwired to 1.



8.2.20 SSRW—Mirror of Fun 0 Software Scratch Read Write

B/D/F/Type: 0/2/1/PCI
Address Offset: 58–5Bh
Default Value: 00000000h
Access: RO
Size: 32 bits

Bit	Access & Default	Description
31:0	RO 00000000h	Reserved

8.2.21 BSM—Mirror of Func0 Base of Stolen Memory

B/D/F/Type: 0/2/1/PCI
Address Offset: 5C–5Fh
Default Value: 07800000h
Access: RO
Size: 32 bits

Graphics Stolen Memory and TSEG are within DRAM space defined under TOLUD. From the top of low used DRAM, GMCH claims 1 to 64 MBs of DRAM for internal graphics if enabled.

The base of stolen memory will always be below 4 GB. This is required to prevent aliasing between stolen range and the reclaim region.

Bit	Access & Default	Description
31:20	RO 078h	Base of Stolen Memory (BSM): This register contains bits 31:20 of the base address of stolen DRAM memory. The host interface determines the base of Graphics Stolen memory by subtracting the graphics stolen memory size from TOLUD. See Device 0 TOLUD for more explanation.
19:0	RO 00000h	Reserved



8.2.22 HSRW—Mirror of Dev2 Func0 Hardware Scratch Read Write

B/D/F/Type: 0/2/1/PCI
 Address Offset: 60–61h
 Default Value: 0000h
 Access: RO
 Size: 16 bits

Bit	Access & Default	Description
15:0	RO 0000h	Reserved

8.2.23 GDRST—Mirror of Dev2 Func0 Graphics Reset

B/D/F/Type: 0/2/1/PCI
 Address Offset: C0h
 Default Value: 00h
 Access: RO
 Size: 8 bits

This register is a mirror of the Graphics Reset Register in Device 2.

Bit	Access & Default	Description
7:4	RO 0h	Reserved
3:2	RO 00b	Graphics Reset Domain (GRDOM): 00 = Full Graphics Reset will be performed (both render and display clock domain resets asserted) 01 = Reserved (Invalid Programming) 10 = Reserved (Invalid Programming) 11 = Reserved (Invalid Programming)
1	RO 0b	Reserved



Bit	Access & Default	Description
0	RO 0b	Graphics Reset (GDR): Setting this bit asserts graphics-only reset. The clock domains to be reset are determined by GRDOM. Hardware resets this bit when the reset is complete. Setting this bit without waiting for it to clear, is undefined behavior. Once this bit is set to a 1, all graphics core MMIO registers are returned to power on default state. All Ring buffer pointers are reset, command stream fetches are dropped and ongoing render pipeline processing is halted, state machines and State Variables returned to power on default state. If the Display is reset, all display engines are halted (garbage on screen). VGA memory is not available; Store DWords and interrupts are not ensured to be completed. Device 2 I/O registers are not available. Device 2 Configuration registers continue to be available while Graphics reset is asserted. This bit is hardware auto-clear.

8.2.24 PMCAPID—Mirror of Fun 0 Power Management Capabilities ID

B/D/F/Type: 0/2/1/PCI
Address Offset: D0–D1h
Default Value: 0001h
Access: RO
Size: 16 bits

This register is a mirror of function 0 with the same R/W attributes. The hardware implements a single physical register common to both functions 0 and 1.

Bit	Access & Default	Description
15:8	RO 00h	Next Capability Pointer (NEXT_PTR): This contains a pointer to next item in capabilities list. This is the final capability in the list and must be set to 00h.
7:0	RO 01h	Capability Identifier (CAP_ID): SIG defines this ID is 01h for power management.



8.2.25 PMCAP—Mirror of Fun 0 Power Management Capabilities

B/D/F/Type: 0/2/1/PCI
 Address Offset: D2–D3h
 Default Value: 0022h
 Access: RO
 Size: 16 bits

This register is a Mirror of Function 0 with the same read/write attributes. The hardware implements a single physical register common to both functions 0 and 1.

Bit	Access & Default	Description
15:11	RO 00h	PME Support (PMES): This field indicates the power states in which the IGD may assert PME#. Hardwired to 0 to indicate that the IGD does not assert the PME# signal.
10	RO 0b	D2 Support (D2): The D2 power management state is not supported. This bit is hardwired to 0.
9	RO 0b	D1 Support (D1): Hardwired to 0 to indicate that the D1 power management state is not supported.
8:6	RO 000b	Reserved
5	RO 1b	Device Specific Initialization (DSI): Hardwired to 1 to indicate that special initialization of the IGD is required before generic class device driver is to use it.
4	RO 0b	Reserved
3	RO 0b	PME Clock (PMECLK): Hardwired to 0 to indicate IGD does not support PME# generation.
2:0	RO 010b	Version (VER): Hardwired to 010b to indicate that there are 4 bytes of power management registers implemented and that this device complies with revision 1.1 of the PCI Power Management Interface Specification.



8.2.26 PMCS—Power Management Control/Status

B/D/F/Type: 0/2/1/PCI
 Address Offset: D4–D5h
 Default Value: 0000h
 Access: RO, RW
 Size: 16 bits

Bit	Access & Default	Description
15	RO 0b	PME Status (PMESTS): This bit is 0 to indicate that IGD does not support PME# generation from D3 (cold).
14:13	RO 00b	Data Scale (DSCALE): The IGD does not support data register. This bit always returns 0 when read, write operations have no effect.
12:9	RO 0h	Data Select (DATASEL): The IGD does not support data register. This bit always returns 0 when read, write operations have no effect.
8	RO 0b	PME Enable (PME_EN): This bit is 0 to indicate that PME# assertion from D3 (cold) is disabled.
7:2	RO 00h	Reserved
1:0	RW 00b	Power State (PWRSTAT): This field indicates the current power state of the IGD and can be used to set the IGD into a new power state. If software attempts to write an unsupported state to this field, write operation must complete normally on the bus, but the data is discarded and no state change occurs. On a transition from D3 to D0 the graphics controller is optionally reset to initial values. 00 = D0 (Default) 01 = D1 (Not Supported) 10 = D2 (Not Supported) 11 = D3



8.2.27 SWSMI—Mirror of Func0 Software SMI

B/D/F/Type: 0/2/1/PCI
 Address Offset: E0–E1h
 Default Value: 0000h
 Access: RO
 Size: 16 bits

As long as there is the potential that DVO port legacy drivers exist which expect this register at this address, D2:F0 address E0h–E1h must be reserved for this register.

Bit	Access & Default	Description
15:8	RO 00h	Software Scratch Bits (SWSB):
7:1	RO 00h	Software Flag (SWF): This field is used to indicate caller and SMI function desired, as well as return result.
0	RO 0b	GMCH Software SMI Event (GSSMIE): When Set, this bit will trigger an SMI. Software must write a 0 to clear this bit.



Integrated Graphics Registers (D2:F0,F1) (Intel® 82G31 GMCH Only)



9 Functional Description

9.1 Host Interface

The (G)MCH supports the Intel® Core 2 Duo processor. The cache line size is 64 bytes. Source synchronous transfer is used for the address and data signals. The address signals are double pumped and a new address can be generated every other bus clock. At 200/267 MHz bus clock the address signals run at 667 MT/s. The data is quad pumped and an entire 64B cache line can be transferred in two bus clocks. At 200/266 MHz bus clock, the data signals run at 800/1066 MT/s for a maximum bandwidth of 6.4/8.5 GB/s.

9.1.1 FSB IOQ Depth

The Scalable Bus supports up to 12 simultaneous outstanding transactions.

9.1.2 FSB OOQ Depth

The (G)MCH supports only one outstanding deferred transaction on the FSB.

9.1.3 FSB GTL+ Termination

The (G)MCH integrates GTL+ termination resistors on die.

9.1.4 FSB Dynamic Bus Inversion

The (G)MCH supports Dynamic Bus Inversion (DBI) when driving and when receiving data from the processor. DBI limits the number of data signals that are driven to a low voltage on each quad pumped data phase. This decreases the worst-case power consumption of the (G)MCH. HDINV[3:0]# indicate if the corresponding 16 bits of data are inverted on the bus for each quad pumped data phase:

HDINV[3:0]#	Data Bits
HDINV0#	HD[15:0]#
HDINV1#	HD[31:16]#
HDINV2#	HD[47:32]#
HDINV3#	HD[63:48]#

Whenever the processor or the (G)MCH drives data, each 16-bit segment is analyzed. If more than 8 of the 16 signals would normally be driven low on the bus, the



corresponding HDINV# signal will be asserted, and the data will be inverted prior to being driven on the bus. Whenever the processor or the (G)MCH receives data, it monitors HDINV[3:0]# to determine if the corresponding data segment should be inverted.

9.1.5 APIC Cluster Mode Support

APIC Cluster mode support is required for backwards compatibility with existing software, including various operating systems. As one example, beginning with Microsoft Windows 2000, there is a mode (boot.ini) that allows an end user to enable the use of cluster addressing support of the APIC.

- The (G)MCH supports three types of interrupt re-direction:
 - Physical
 - Flat-Logical
 - Clustered-Logical

9.2 System Memory Controller

The system memory controller supports DDR2 protocols with two independent 64 bit wide channels each accessing one DIMM. It supports a maximum of one un-buffered non-ECC DDR2 DIMM per channel.

9.2.1 System Memory Organization Modes

The system memory controller supports three memory organization modes, Single Channel, Dual Channel Symmetric, and Dual Channel Asymmetric.

9.2.1.1 Single Channel Mode

In this mode, all memory cycles are directed to a single channel.

Single channel mode is used when either Channel A or Channel B DIMMs are populated in any order, but not both.

9.2.1.2 Dual Channel Symmetric Mode

This mode provides maximum performance on real applications. Addresses are ping-ponged between the channels after each cache line (64 byte boundary). If there are two requests, and the second request is to an address on the opposite channel from the first, that request can be sent before data from the first request has returned. If two consecutive cache lines are requested, both may be retrieved simultaneously, since they are guaranteed to be on opposite channels.

Dual channel symmetric mode is used when both Channel A and Channel B DIMMs are populated in any order with the total amount of memory in each channel being the same, but the DRAM device technology and width may vary from one channel to the other.



Table 9-1 is a sample dual channel symmetric memory configuration showing the rank organization:

Table 9-1. Sample System Memory Dual Channel Symmetric Organization Mode with Intel® Flex Memory Mode Enabled

	Channel 0 population	Cumulative top address in Channel 0	Channel 1 population	Cumulative top address in Channel 1
Rank 1	512 MB	2048 MB	512 MB	2048 MB
Rank 0	512 MB	1024 MB	512 MB	1024 MB

9.2.1.3 Dual Channel Asymmetric Mode with Intel® Flex Memory Mode Enabled

This mode trades performance for system design flexibility. Unlike the previous mode, addresses start in channel 0 and stay there until the end of the highest rank in channel 0, and then addresses continue from the bottom of channel 1 to the top. Real world applications are unlikely to make requests that alternate between addresses that sit on opposite channels with this memory organization, so in most cases, bandwidth will be limited to that of a single channel.

Dual channel asymmetric mode is used when both Channel A and Channel B DIMMs are populated in any order with the total amount of memory in each channel being different.

Table 9-2 is a sample dual channel asymmetric memory configuration showing the rank organization.

Table 9-2. Sample System Memory Dual Channel Asymmetric Organization Mode with Intel® Flex Memory Mode Disabled

	Channel 0 population	Cumulative top address in Channel 0	Channel 1 population	Cumulative top address in Channel 1
Rank 1	512 MB	1024 MB	512 MB	2304 MB
Rank 0	512 MB	512 MB	512 MB	1792 MB



9.2.2 System Memory Technology Supported

The (G)MCH supports the following DDR2 Data Transfer Rates, DIMM Modules, and DRAM Device Technologies:

- DDR2 Data Transfer Rates: 667 (PC2-5300) , 800 (PC2-6400)
- DDR2 DIMM Modules:
 - Raw Card C - Single Sided x16 un-buffered non-ECC
 - Raw Card D - Single Sided x8 un-buffered non-ECC
 - Raw Card E - Double Sided x8 un-buffered non-ECC
- DDR2 and DRAM Device Technology: 512 MB and 1 GB

Table 9-3. Supported DIMM Module Configurations

Mem. Type	Raw Card Ver.	DIMM Cap.	DRAM Device Tech.	DRAM Org.	# of DRAM Devices	# of Physical Device Ranks	# of Row / Col Address Bits	# of Banks Inside DRAM	Page Size
DDR2 667 and 800	C	256 MB	512 Mb	32M X 16	4	1	13/10	4	8K
		512 MB	1 Gb	64M X 16	4	1	13/10	8	8K
	D	512 MB	512 Mb	64M X 8	8	1	14/10	4	8K
		1 GB	1 Gb	128M X 8	8	1	14/10	8	8K
	E	1 GB	512 Mb	64M X 8	16	2	14/10	4	8K
		2 GB	1 Gb	128M X 8	16	2	14/10	8	8K



9.3 PCI Express*

See Section 1.3 for a list of PCI Express features, and the PCI Express specification for further details.

This (G)MCH is part of a PCI Express root complex. This means it connects a host processor/memory subsystem to a PCI Express hierarchy. The control registers for this functionality are located in device #1 configuration space and two Root Complex Register Blocks (RCRBs). The DMI RCRB contains registers for control of the Intel ICH7 attach ports.

PCI Express* Architecture

The PCI Express architecture is specified in layers. Compatibility with the PCI addressing model (a load-store architecture with a flat address space) is maintained to ensure that all existing applications and drivers operate unchanged. The PCI Express configuration uses standard mechanisms as defined in the PCI Plug-and-Play specification. The initial speed of 1.25 GHz (250 MHz internally) results in 2.5 GB/s/direction which provides a 250 MB/s communications channel in each direction (500 MB/s total) that is close to twice the data rate of classic PCI per lane.

Transaction Layer

The upper layer of the PCI Express architecture is the Transaction Layer. The Transaction Layer's primary responsibility is the assembly and disassembly of Transaction Layer Packets (TLPs). TLPs are used to communicate transactions, such as read and write, as well as certain types of events. The Transaction Layer also manages flow control of TLPs.

Data Link Layer

The middle layer in the PCI Express stack, the Data Link Layer, serves as an intermediate stage between the Transaction Layer and the Physical Layer. Responsibilities of Data Link Layer include link management, error detection, and error correction.

Physical Layer

The Physical Layer includes all circuitry for interface operation, including driver and input buffers, parallel-to-serial and serial-to-parallel conversion, PLL(s), and impedance matching circuitry.



9.3.1 Intel® Serial Digital Video Output (sDVO) (Intel® 82G31 GMCH Only)

The sDVO description is located here because it is multiplexed onto the PCI Express x16 port pins. The Intel® sDVO Port is the second generation of digital video output from compliant Intel® GMCHs. The electrical interface is based on the PCI Express interface, though the protocol and timings are completely unique. Whereas PCI Express runs at a fixed frequency, the frequency of the sDVO interface is dependant upon the active display resolution and timing. The port can be dynamically configured in several modes to support display configurations.

Essentially, an sDVO port will transmit display data in a high speed, serial format across differential AC coupled signals. An sDVO port consists of a sideband differential clock pair and a number of differential data pairs.

9.3.1.1 Intel® sDVO Capabilities

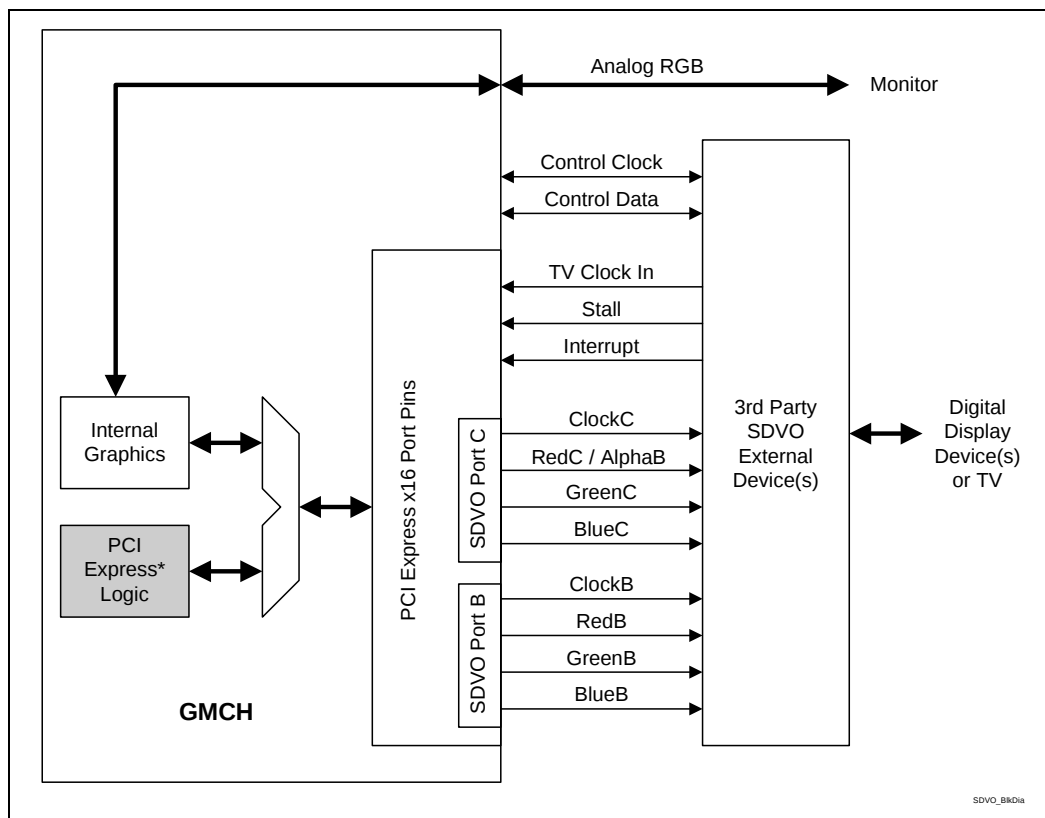
sDVO ports can support a variety of display types including LVDS, DVI, Analog CRT, TV-Out and external CE type devices. The GMCH uses an external sDVO device to translate from sDVO protocol and timings to the desired display format and timings.

The Internal Graphics Controller can have one or two sDVO ports multiplexed on the x16 PCI Express interface. When an external x16 PCI Express graphics accelerator is not in use, an ADD2 card may be plugged into the x16 connector or if a x16 slot is not present, the sDVO(s) may be located 'down' on the motherboard to access the multiplexed sDVO ports and provide a variety of digital display options.

The ADD2/Media Expansion card is designed to fit in a x16 PCI Express connector. The ADD2/Media Expansion card can support one or two devices. If a single channel sDVO device is utilized, it should be attached to the channel B sDVO pins. The ADD2 card can support two separate sDVO devices when the interface is in Dual Independent or Dual Simultaneous Standard modes. The Media Expansion card adds Video in capabilities.

The sDVO port defines a two-wire point-to-point communication path between the sDVO device and GMCH. The sDVO Control Clock and Data provide similar functionality to I²C. However unlike I²C, this interface is intended to be point-to-point (from the GMCH to the sDVO device) and will require the sDVO device to act as a switch and direct traffic from the sDVO Control bus to the appropriate receiver. Additionally, this Control bus will be able to run at faster speeds (up to 1 MHz) than a traditional I²C interface would.

Figure 9-1. sDVO Conceptual Block Diagram



9.3.1.2 Intel® sDVO Modes

The port can be dynamically configured in several modes:

- **Standard.** This mode provides baseline SDVO functionality. It supports Pixel Rates between 25 MP/s and 225 MP/s. It uses three data pairs to transfer RGB data.
- **Dual Standard.** This mode uses Standard data streams across both SDVOB and SDVOC. Both channels can only run in Standard mode (3 data pairs) and each channel supports Pixel Rates between 25 MP/s and 225 MP/s.
 - **Dual Independent Standard.** In Dual Independent Standard mode, each SDVO channel sees a different pixel stream. The data stream across SDVOB is not the same as the data stream across SDVOC.
 - **Dual Simultaneous Standard.** In Dual Simultaneous Standard mode, both SDVO channels see the same pixel stream. The data stream across SDVOB is the same as the data stream across SDVOC. The display timings will be identical, but the transfer timings may not be (i.e., SDVOB clocks and data may not be perfectly aligned with SDVOC clock and data as seen at the SDVO device(s)). Since this mode uses just a single data stream, it uses a single pixel pipeline within the GMCH.



9.3.1.3 PCI Express* and Internal Graphics Simultaneous Operation

9.3.1.3.1 Standard PCI Express* Cards and Internal Graphics

BIOS control of simultaneous operation is needed to ensure the PCI Express is configured appropriately.

9.3.1.3.2 Media Expansion Cards (Concurrent sDVO and PCI Express*)

sDVO lane reversal is supported in the 82G31 GMCH. This functionality allows current sDVO ADD2 cards to work in current ATX and BTX systems instead of requiring a separate card. The GMCH allows sDVO and PCI Express to operate concurrently on the PCI Express Port. The card that plugs into the x16 connector in this case is called a Media Expansion card. It uses 4 or 8 lanes for sDVO and up to 8 lanes of standard PCI Express.

The GMCH only supports PCI Express width when sDVO is present is x1.

This concurrency is supported in reversed and non-reversed configurations. Mirroring / Reversing is always about the axis.

Table 9-4. Concurrent sDVO / PCI Express* Configuration Strap Controls

Configuration #	Description	Slot Reversed Strap	sDVO Present Strap	sDVO/PCI Express* Concurrent Strap
1	PCI Express* not reversed	—	—	—
2	PCI Express* Reversed	Yes	—	—
3	sDVO (ADD2) not reversed	—	Yes	—
4	sDVO (ADD2) Reversed	Yes	Yes	—
5	sDVO & PCI Express* (MEDIA EXPANSION) not reversed	—	Yes	Yes
6	sDVO & PCI Express* (MEDIA EXPANSION) Reversed	Yes	Yes	Yes

Notes:

1. The Configuration #s refer to the following figures (no intentional relation to validation configs).
2. Configuration 4, 5, and 6 (required addition of sDVO/PCI Express* Concurrent Strap).



Figure 9-2. Concurrent sDVO / PCI Express* Non-Reversed Configurations

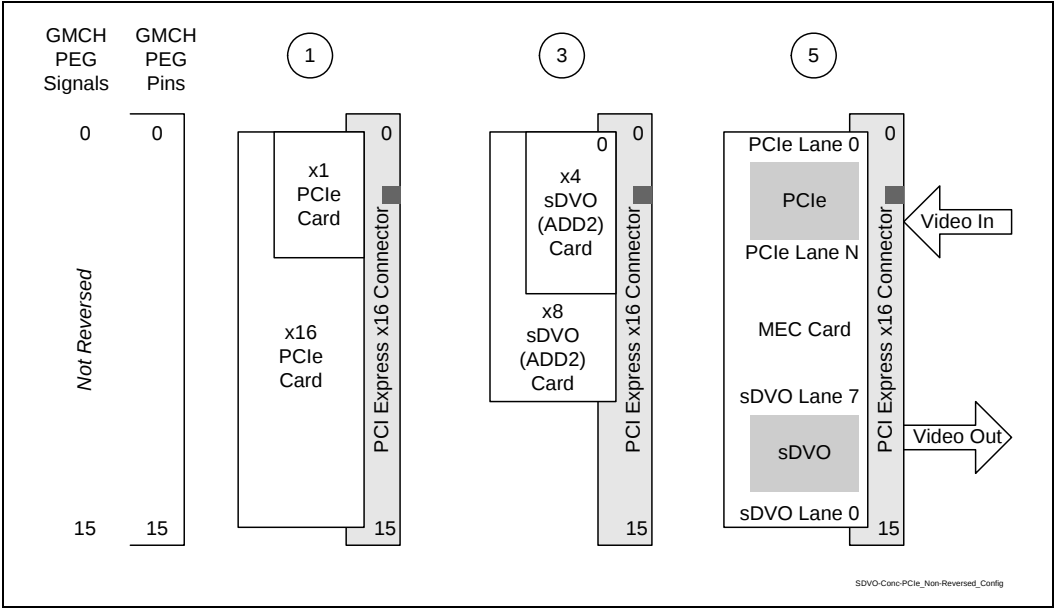
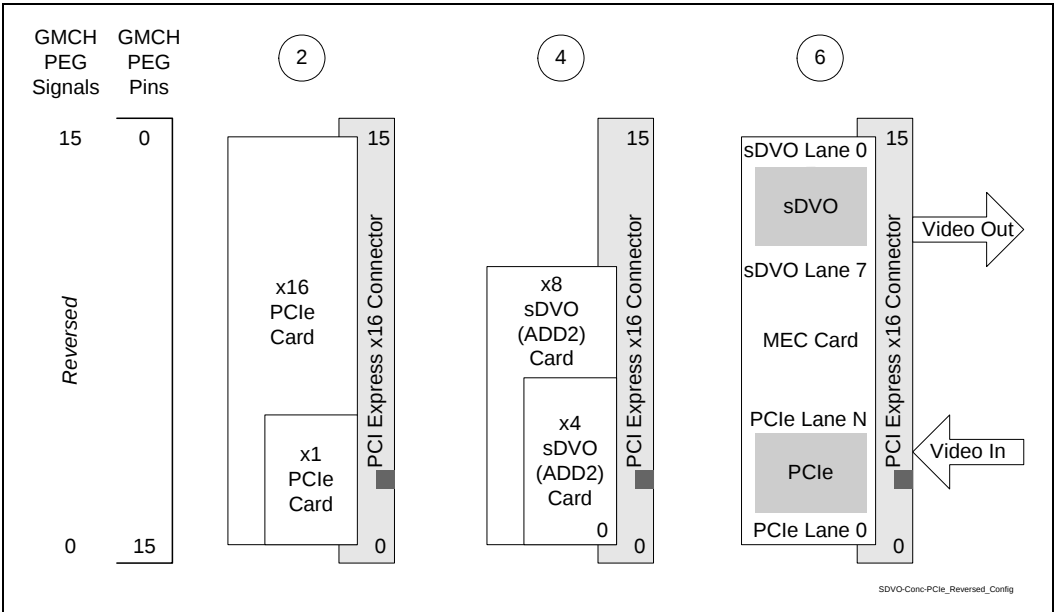


Figure 9-3. Concurrent sDVO / PCI Express* Reversed Configurations





9.4 Integrated Graphics Controller (Intel® 82G31 GMCH Only)

The major components in the Integrated Graphics Device (IGD) are the engines, planes, pipes and ports. The GMCH has a 3D/2D instruction processing unit to control the 3D and 2D engines. The IGD's 3D and 2D engines are fed with data through the memory controller. The output of the engines are surfaces sent to memory that are then retrieved and processed by the GMCH planes.

The GMCH contains a variety of planes, such as display, overlay, cursor and VGA. A plane consists of rectangular shaped image that has characteristics such as source, size, position, method, and format. These planes get attached to source surfaces that are rectangular memory surfaces with a similar set of characteristics. They are also associated with a particular destination pipe.

A pipe consists of a set of combined planes and a timing generator. The GMCH has two independent display pipes, allowing for support of two independent display streams. A port is the destination for the result of the pipe. The GMCH contains three display ports; 1 analog (DAC) and two digital (sDVO ports B and C). The ports will be explained in more detail later in this section.

The entire IGD is fed with data from its memory controller. The GMCH's graphics performance is directly related to the amount of bandwidth available. If the engines are not receiving data fast enough from the memory controller, the rest of the IGD will also be affected.

The rest of this section will focus on explaining the IGD components, their limitations, and dependencies.

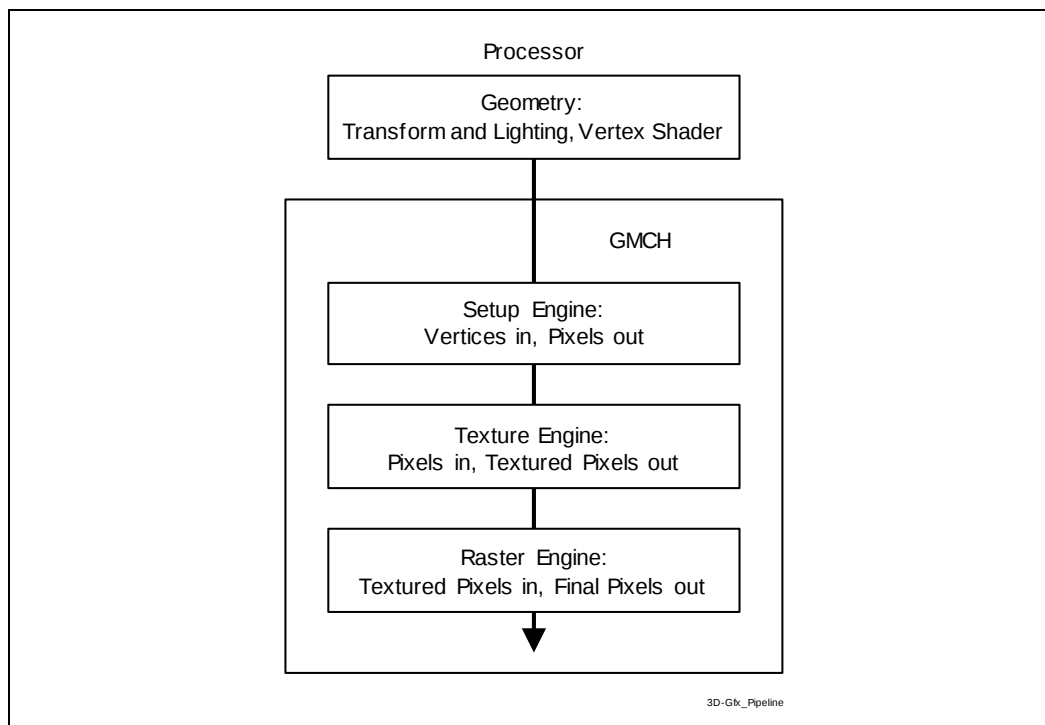
9.4.1 3D Graphics Pipeline

The 82G31 GMCH graphics is the next step in the evolution of integrated graphics. In addition to running the graphics engine at 400 MHz, the GMCH graphics has two pixel pipelines that provide a 1.3 GB/s fill rate that enables an excellent consumer gaming experience.

The 3D graphics pipeline for the GMCH has a deep pipelined architecture in which each stage can simultaneously operate on different primitives or on different portions of the same primitive. The 3D graphics pipeline is divided into four major stages: geometry processing, setup (vertex processing), texture application, and rasterization.

The GMCH graphics is optimized for use with current and future Intel® processors for advance software based transform and lighting techniques (geometry processing) as defined by the Microsoft DirectX* API. The other three stages of 3D processing are handled on the integrated graphics device. The setup stage is responsible for vertex processing; converting vertices to pixels. The texture application stage applies textures to pixels. The rasterization engine takes textured pixels and applies lighting and other environmental affects to produce the final pixel value. From the rasterization stage, the final pixel value is written to the frame buffer in memory so it can be displayed.

Figure 9-4. Integrated 3D Graphics Pipeline



9.4.1.1 3D Engine

The 3D engine on the GMCH has been designed with a deep pipelined architecture, where performance is maximized by allowing each stage of the pipeline to simultaneously operate on different primitives or portions of the same primitive. The GMCH supports Perspective-Correct Texture Mapping, Multitextures, Bump-Mapping, Cubic Environment Maps, Bilinear, Trilinear and Anisotropic MIP mapped filtering, Gouraud shading, Alpha-blending, Vertex and Per Pixel Fog and Z/W Buffering.

The 3D pipeline subsystem performs the 3D rendering acceleration. The main blocks of the pipeline are the setup engine, scan converter, texture pipeline, and raster pipeline. A typical programming sequence would be to send instructions to set the state of the pipeline followed by rendering instructions containing 3D primitive vertex data.

The engines' performance is dependent on the memory bandwidth available. Systems that have more bandwidth available will outperform systems with less bandwidth. The engines' performance is also dependent on the core clock frequency. The higher the frequency, the more data is processed.

9.4.1.2 Texture Engine

The GMCH allows an image, pattern, or video to be placed on the surface of a 3D polygon. The texture processor receives the texture coordinate information from the setup engine and the texture blend information from the scan converter. The texture processor performs texture color or ChromaKey matching, texture filtering (anisotropic, trilinear, and bilinear interpolation), and YUV-to-RGB conversions.



9.4.1.3 Raster Engine

The raster engine is where the color data (such as, fogging, specular RGB, texture map blending, etc.) is processed. The final color of the pixel is calculated and the RGBA value combined with the corresponding components resulting from the texture engine. These textured pixels are modified by the specular and fog parameters. These specular highlighted, fogged, textured pixels are color blended with the existing values in the frame buffer. In parallel, stencil, alpha, and depth buffer tests are conducted that determine whether the frame and depth buffers will be updated with the new pixel values.

9.5 Display Interfaces (Intel® 82G31 GMCH Only)

The GMCH has three display ports, one analog and two digital. Each port can transmit data according to one or more protocols. The digital ports are connected to an external device that converts one protocol to another. Examples of these are TV encoders, external DACs, LVDS transmitters, HDMI transmitters and TMDS transmitters. Each display port has control signals that may be used to control, configure and/or determine the capabilities of an external device.

The GMCH has one dedicated display port, the analog port. sDVO ports B and C are multiplexed with the PCI Express Graphics (PEG) interface and are not available if an external PEG device is in use. When a system utilizes a PEG connector, sDVO ports B and C can be utilized via an ADD2 (Advanced Digital Display 2) or MEC (Media Expansion Card).

- The GMCH's analog port utilizes an integrated 350 MHz RAMDAC that can directly drive a standard progressive scan analog monitor up to a resolution of 2048x1536 pixels with 32-bit color at 75 Hz.
- The GMCH's sDVO ports are each capable of driving a 225 MP pixel rate. Each port is capable of driving a digital display up to 1920x1200 @ 60Hz.

The GMCH is compliant with DVI Specification 1.0. When combined with a DVI compliant external device and connector, the GMCH has a high speed interface to a digital display (e.g., flat panel or digital CRT).

The GMCH is compliant with HDMI Specification 1.1. When combined with a HDMI compliant external device and connector, the external HDMI device can supports standard, enhanced, or high-definition video, plus multi-channel digital audio on a single cable.



9.5.1 Analog Display Port Characteristics

The analog display port provides a RGB signal output along with a HSYNC and VSYNC signal. There is an associated DDC signal pair that is implemented using GPIO pins dedicated to the analog port. The intended target device is for a CRT based monitor with a VGA connector. Display devices such as LCD panels with analog inputs may work satisfactory but no functionality added to the signals to enhance that capability.

Table 9-1. Analog Port Characteristics

Signal	Port Characteristic	Support
RGB	Voltage Range	0.7 V p-p only
	Monitor Sense	Analog Compare
	Analog Copy Protection	No
	Sync on Green	No
	Voltage	2.5 V
	Enable/Disable	Port control
HSYNC	Polarity adjust	VGA or port control
VSYNC	Composite Sync Support	No
	Special Flat Panel Sync	No
	Stereo Sync	No
DDC	Voltage	Externally buffered to 5V
	Control	Through GPIO interface

9.5.1.1 Integrated RAMDAC

The display function contains a RAM-based Digital-to-Analog Converter (RAMDAC) that transforms the digital data from the graphics and video subsystems to analog data for the CRT monitor. GMCH's integrated 350 MHz RAMDAC supports resolutions up to 2048 x 1536 @ 75 Hz. Three 8-bit DACs provide the R, G, and B signals to the monitor.

9.5.1.2 Sync Signals

HSYNC and VSYNC signals are digital and conform to TTL signal levels at the connector. Since these levels cannot be generated internal to the device, external level shifting buffers are required. These signals can be polarity adjusted and individually disabled in one of the two possible states. The sync signals should power up disabled in the high state. No composite sync or special flat panel sync support will be included.



9.5.1.3 VESA/VGA Mode

VESA/VGA mode provides compatibility for pre-existing software that set the display mode using the VGA CRTC registers. Timings are generated based on the VGA register values and the timing generator registers are not used.

9.5.1.4 DDC (Display Data Channel)

DDC is a standard defined by VESA. Its purpose is to allow communication between the host system and display. Both configuration and control information can be exchanged allowing plug- and-play systems to be realized. Support for DDC 1 and 2 is implemented. The GMCH uses the DDC_CLK and DDC_DATA signals to communicate with the analog monitor. The GMCH generates these signals at 2.5 V. External pull-up resistors and level shifting circuitry should be implemented on the board.

The GMCH implements a hardware GMBus controller that can be used to control these signals allowing for transactions speeds up to 400 kHz.

9.5.2 Digital Display Interface

The GMCH has several options for driving digital displays. The GMCH contains two sDVO ports that are multiplexed on the PEG interface. When an external PEG graphics accelerator is not present, the GMCH can use the multiplexed sDVO ports to provide extra digital display options. These additional digital display capabilities may be provided through an ADD2/MEDIA EXPANSION CARD, which is designed to plug in to a PCI Express connector.

9.5.2.1 Multiplexed Digital Display Channels – Intel® sDVOB and Intel® sDVOC

The GMCH has the capability to support digital display devices through two sDVO ports multiplexed with the PEG signals. When an external graphics accelerator is used via the PEG port, these sDVO ports are not available.

The shared sDVO ports each support a pixel clock up to 225 MHz and can support a variety of transmission devices.

SDVOCTRLDATA is an open-drain signal that will act as a strap during reset to tell the GMCH whether the interface is a PCI Express interface or an sDVO interface. When implementing sDVO, either via ADD2 cards or with a down device, a pull-up is placed on this line to signal to the GMCH to run in sDVO mode and for proper GMBus operation.

9.5.2.1.1 ADD2/MEDIA EXPANSION CARD(MEC)

When a G31 Express Chipset platform uses a PEG connector, the multiplexed sDVO ports may be used via an ADD2 or MEC card. The ADD2 card will be designed to fit a standard PCI Express (x16) connector. Please refer to the latest ADD2/MEC EDS and ADD2 or MEC card design kits for more details on ADD2/MEC.



9.5.2.2 TMDS Capabilities

The GMCH is compliant with DVI Specification 1.0. When combined with a DVI compliant external device and connector, the GMCH has a high speed interface to a digital display (e.g., flat panel or digital CRT). The GMCH can drive a flat panel up to 1920x1200 or a dCRT/HDTV up to 1400x1050. Flat Panel is a fixed resolution display. The GMCH supports panel fitting in the transmitter, receiver or an external device, but has no native panel fitting capabilities. The GMCH will however, provide unscaled mode where the display is centered on the panel.

9.5.2.2.1 HDMI Capabilities

The GMCH is compliant with HDMI Specification 1.1. When combined with a HDMI compliant external device and connector, the external HDMI device can support standard, enhanced, or high-definition video, plus multi-channel digital audio on a single cable. The GMCH has a high speed interface to a digital display (e.g., flat panel or digital TV). The GMCH can drive a digital TV up to 1600x1200.

9.5.2.2.2 LVDS Capabilities

The GMCH may use the multiplexed sDVO ports to drive an LVDS transmitter. Flat Panel is a fixed resolution display. The GMCH supports panel fitting in the transmitter, receiver or an external device, but has no native panel fitting capabilities. The GMCH will however, provide unscaled mode where the display is centered on the panel. The GMCH supports scaling in the LVDS transmitter through the sDVO stall input pair.

9.5.2.2.3 TV-IN Capabilities

The GMCH in conjunction with ADD2/MEDIA EXPANSION CARD can function as a TV-Tuner card capable of taking in both analog or HD signals

9.5.2.2.4 TV-Out Capabilities

Although traditional TVs are not digital displays, the GMCH uses a digital display channel to communicate with a TV-Out transmitter. For that reason, the GMCH considers a TV-Output to be a digital display. The GMCH supports NTSC/PAL/SECAM standard definition formats. The GMCH will generate the proper timing for the external encoder. The external encoder is responsible for generation of the proper format signal. Since the multiplexed sDVO interface is a NTSC/PAL/SECAM display on the TV-out port can be configured to be the boot device. It is necessary to ensure that appropriate BIOS support is provided.

The TV-out interface on GMCH allows an external TV encoder device to drive a pixel clock signal on SDVO_TVClk[+/-] that the GMCH uses as a reference frequency. The frequency of this clock is dependent on the output resolution required.



Flicker Filter and Overscan Compensation

The overscan compensation scaling and the flicker filter is done in the external TV encoder chip. Care must be taken to allow for support of TV sets with high performance de-interlacers and progressive scan displays connected to by way of a non-interlaced signal. Timing will be generated with pixel granularity to allow more overscan ratios to be supported.

Analog Content Protection

Analog content protection will be provided through the external encoder using Macrovision 7.01. DVD software must verify the presence of a Macrovision TV encoder before playback continues. Simple attempts to disable the Macrovision operation must be detected.

Connectors

Target TV connectors support includes the CVBS, S-Video, Component, HDMI and SCART connectors. The external TV encoder in use will determine the method of support.

9.5.2.2.5 Control Bus

Communication to SDVO registers and if utilized, ADD2/MEC PROMs and monitor DDCs, are accomplished by using the SDVOCTRLDATA and SDVOCTRLCLK signals through the SDVO device. These signals run up to 1 MHz and connect directly to the SDVO device. The SDVO device is then responsible for routing the DDC and PROM data streams to the appropriate location. Consult SDVO device data sheets for level shifting requirements of these signals.

9.5.2.2.6 Intel® sDVO Modes

The port can be dynamically configured in several modes:

- **Standard.** This mode provides baseline SDVO functionality. It supports pixel rates between 25 MP/s and 225 MP/s. It uses three data pairs to transfer RGB data.
- **Dual Standard.** This mode provides Standard data streams across both SDVOB and SDVOC. Both channels can only run in Standard mode (3 data pairs) and each channel supports Pixel Rates between 25 MP/s and 225 MP/s.
 - **Dual Independent Standard.** In Dual Independent Standard mode, each SDVO channel will transmit a different pixel stream. The data stream across SDVOB will not be the same as the data stream across SDVOC.
 - **Dual Simultaneous Standard.** In Dual Simultaneous Standard mode, both SDVO channels will transmit the same pixel stream. The data stream across SDVOB will be the same as the data stream across SDVOC. The display timings will be identical, but the transfer timings may not be (i.e., SDVOB clocks and data may not be perfectly aligned with SDVOC clock and data as seen at the SDVO device(s)). Since this uses just a single data stream, it uses a single pixel pipeline within the GMCH.



9.5.3 Multiple Display Configurations

Microsoft Windows* 2000, Windows XP and Windows Vista* operating systems supports for multi-monitor display. Since the GMCH has several display ports available for its two pipes, it can support up to two different images on different display devices. Timings and resolutions for these two images may be different. The GMCH supports Dual Display Clone, Dual Display Twin, and Extended Desktop.

Dual Display Clone uses both display pipes to drive the same content, at the same resolution and color depth to two different displays. This configuration allows for different refresh rates on each display.

Dual Display Twin uses one of the display pipes to drive the same content, at the same resolution, color depth, and refresh rates to two different displays.

Extended Desktop uses both display pipes to drive different content, at potentially different resolutions, refresh rates, and color depths to two different displays. This configuration allows for a larger Windows Desktop by utilizing both displays as a work surface.

Note: The (G)MCH is also incapable of operating in parallel with an external PCI Express graphics device. The (G)MCH can, however, work in conjunction with a PCI graphics adapter.

9.6 Power Management

Power Management Feature List:

- ACPI 1.0b support
- ACPI S0, S1, S3 (both Cold and chipset Hot), S5, C0, C1, and C2 states
- Enhanced power management state transitions for increasing time processor spends in low power states
- Internal Graphics Display Device Control D0, D1, D2, D3
- Graphics Adapter States: D0, D3
- PCI Express Link States: L0, L0s, L2/L3 Ready, L3



9.7 Thermal Sensor

There are several registers that need to be configured to support the (G)MCH thermal sensor functionality and SMI# generation. Customers must enable the Catastrophic Trip Point at 115 °C as protection for the (G)MCH. If the Catastrophic Trip Point is crossed, then the (G)MCH will instantly turn off all clocks inside the device. Customers may optionally enable the Hot Trip Point between 85 °C and 105 °C to generate SMI#. Customers will be required to then write their own SMI# handler in BIOS that will speed up the (G)MCH (or system) fan to cool the part.

9.7.1 PCI Device 0, Function 0

The SMICMD register requires that a bit be set to generate an SMI# when the Hot trip point is crossed. The ERRSTS register can be inspected for the SMI alert.

Address Offset	Symbol	Register Name	Default Value	Access
C8–C9h	ERRSTS	Error Status	0000h	RO, RWC/S
CC–CDh	SMICMD	SMI Command	0000h	RO, RW

9.7.2 MCHBAR Thermal Sensor Registers

The Digital Thermometer Configuration Registers reside in the MCHBAR configuration space.

Address Offset	Symbol	Register Name	Default Value	Access
CD8h	TSC1	Thermal Sensor Control 1	00h	RW/L, RW RS/WC,
CD9h	TSC2	Thermal Sensor Control 2	00h	RW/L, RO
CDAh	TSS	Thermal Sensor Status	00h	RO
CDC–CDFh	TSTTP	Thermal Sensor Temperature Trip Point	00000000h	RO, RW, RW/L
CE2h	TCO	Thermal Calibration Offset	00h	RW/L/K, RW/L
CE4h	THERM1	Hardware Protection	00h	RW/L, RO, RW/L/K
CE6h	THERM3	TCO Fuses	00h	RS/WC, RO
CEA–CEBh	TIS	Thermal Interrupt Status	0000h	RO, RWC,
CF1h	TSMICMD	Thermal SMI Command	00h	RO, RW

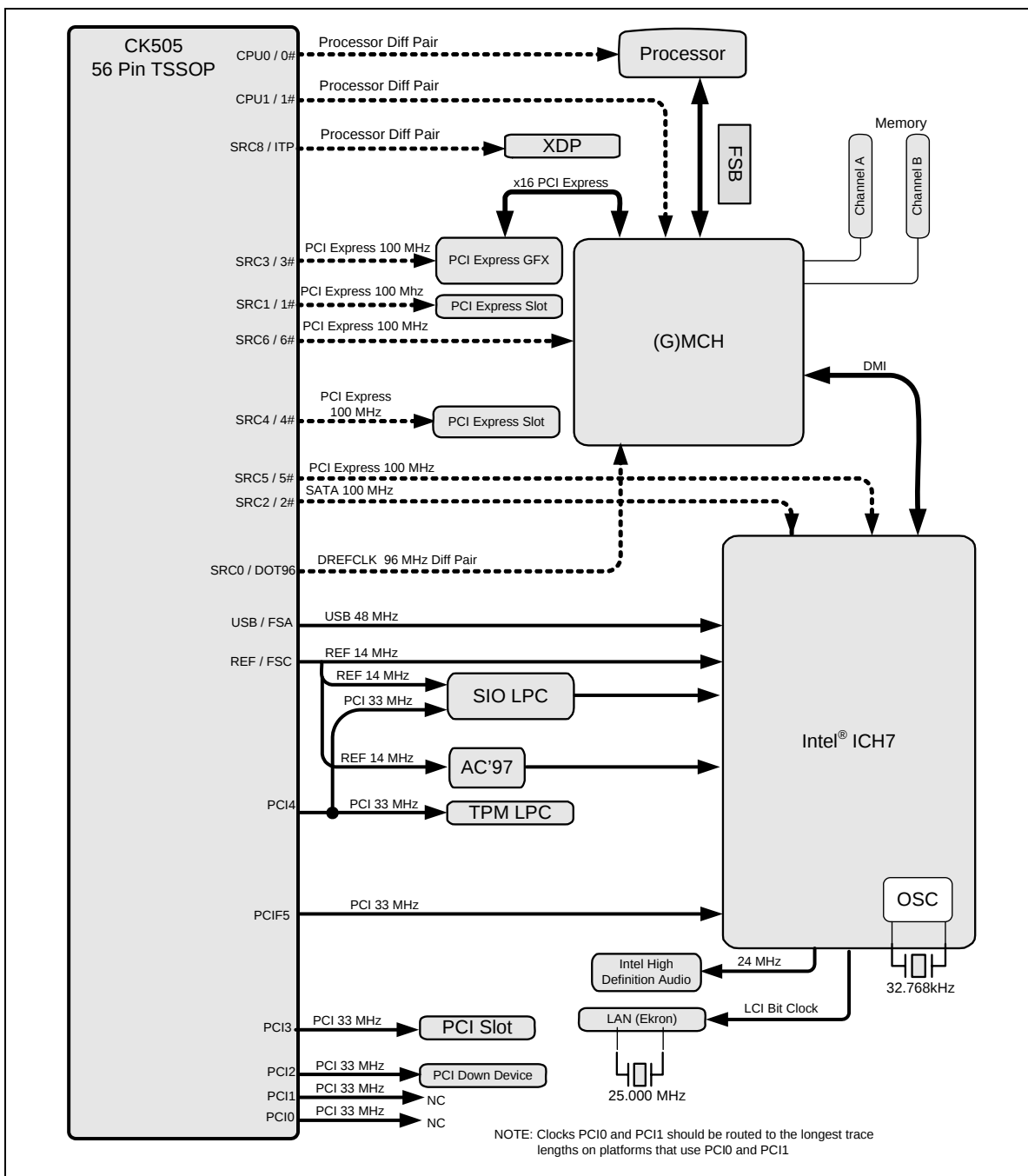


9.8 Clocking

The (G)MCH has a total of 5 PLLs providing many times that many internal clocks. The PLLs are:

- Host PLL – Generates the main core clocks in the host clock domain. Can also be used to generate memory and internal graphics core clocks. Uses the Host clock (H_CLKIN) as a reference.
- Memory I/O PLL - Optionally generates low jitter clocks for memory I/O interface, as opposed to from Host PLL. Uses the Host FSB differential clock (HPL_CLKINP/HPL_CLKINN) as a reference. Low jitter clock source from Memory I/O PLL is required for DDR667 and higher frequencies.
- PCI Express PLL – Generates all PCI Express related clocks, including the Direct Media Interface that connects to the ICH. This PLL uses the 100 MHz clock (G_CLKIN) as a reference.
- Display PLL A – Generates the internal clocks for Display A. Uses D_REFCLKIN as a reference.
- Display PLL B – Generates the internal clocks for Display B. Also uses D_REFCLKIN as a reference.
- CK505 is the Clocking chip is required for the Intel® G31/P31 Express Chipset platform

Figure 9-5. Intel® G31/P31 Express Chipset System Clock Diagram



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10 Electrical Characteristics

This chapter provides the DC characteristics for the 82G31 GMCH and 82P31 MCH.

Note: References to the internal graphics device or associated ports (e.g., SDVO port, analog port) apply to the 82G31 GMCH.

10.1 Absolute Minimum and Maximum Ratings

Table 10-1 specifies the (G)MCH absolute maximum and minimum ratings. Within functional operation limits, functionality and long-term reliability can be expected.

At conditions outside functional operation condition limits, but within absolute maximum and minimum ratings, neither functionality nor long-term reliability can be expected. If a device is returned to conditions within functional operation limits after having been subjected to conditions outside these limits, but within the absolute maximum and minimum ratings, the device may be functional, but with its lifetime degraded depending on exposure to conditions exceeding the functional operation condition limits.

At conditions exceeding absolute maximum and minimum ratings, neither functionality nor long-term reliability can be expected. Moreover, if a device is subjected to these conditions for any length of time its reliability will be severely degraded or not function when returned to conditions within the functional operating condition limits.

Although the (G)MCH contains protective circuitry to resist damage from static electric discharge, precautions should always be taken to avoid high static voltages or electric fields.

Table 10-1. Absolute Minimum and Maximum Ratings

Symbol	Parameter	Min	Max	Unit	Notes
T _{storage}	Storage Temperature	-55	150	°C	1
(G)MCH Core					
VCC	1.25 V Core Supply Voltage with respect to VSS	-0.3	1.375	V	
Host Interface (800/1066 MHz)					
VTT	System Bus Input Voltage with respect to VSS	-0.3	1.32	V	
VCCA_HPLL	1.25 V Host PLL Analog Supply Voltage with respect to VSS	-0.3	1.375	V	
System Memory Interface (DDR2 667/800 MHz)					
VCCSM	1.8 V DDR2 System Memory Supply Voltage with respect to VSS	-0.3	4.0	V	



Symbol	Parameter	Min	Max	Unit	Notes
VCC_SMCLK	1.8 V DDR2 Clock System Memory Supply Voltage with respect to VSS	-0.3	4.0	V	
VCCA_MPLL	1.25 V System Memory PLL Analog Supply Voltage with respect to VSS	-0.3	1.375	V	
PCI Express* / Intel® sDVO / DMI Interface					
VCC_EXP	1.25 V PCI Express* and DMI Supply Voltage with respect to VSS	-0.3	1.375	V	
VCCA_EXP	3.3 V PCI Express* Analog Supply Voltage with respect to VSS	-0.3	3.63	V	
VCCA_EXPPLL	1.25 V PCI Express* PLL Analog Supply Voltage with respect to VSS	-0.3	1.375	V	
R, G, B / CRT DAC Display Interface (8 bit)					
VCCA_DAC	3.3 V Display DAC Analog Supply Voltage with respect to VSS	-0.3	3.63	V	
VCCD_CRT	1.5 V Display DAC Digital Supply Voltage with respect to VSS	-0.3	1.98	V	
VCCDQ_CRT	1.5 V Display DAC Quiet Digital Supply Voltage with respect to VSS	-0.3	1.98	V	
VCCA_DPLLA	1.25 V Display PLL A Analog Supply Voltage with respect to VSS	-0.3	1.375	V	
VCCA_DPLL B	1.25 V Display PLL B Analog Supply Voltage with respect to VSS	-0.3	1.375	V	
Controller Link Interface					
VCC_CL	1.25 V Supply Voltage with respect to VSS	-0.3	1.375	V	
CMOS Interface					
VCC3_3	3.3 V CMOS Supply Voltage with respect to VSS	-0.3	3.63	V	

NOTE:

1. Possible damage to the (G)MCH may occur if the (G)MCH temperature exceeds 150 °C. Intel does not ensure functionality for parts that have exceeded temperatures above 150 °C due to spec violation.



10.1.1 Current Consumption

Table 10-2 shows the current consumption for the (G)MCH in the Advanced Configuration and Power Interface (ACPI) S0 state. I_{cc} max values are determined on a per-interface basis, at the highest frequencies for each interface. Sustained current values or Max current values cannot occur simultaneously on all interfaces. Sustained values are *measured* sustained RMS maximum current consumption and includes leakage estimates. The measurements are made with fast silicon at 96° C T_{case} temperature, at the Max voltage listed in Table 10-4. The Max values are maximum theoretical pre-silicon calculated values. In some cases, the Sustained measured values have exceeded the Max theoretical values.

Table 10-2. Current Consumption in S0

Symbol	Parameter	Signal Names	Sustained	Max	Unit	Notes
I _{VCC}	1.25 V Core Supply Current (Using Integrated Graphics)	VCC (int. graphics)	5.27	7.00	A	1,2
	1.25 V Core Supply Current (Using External Graphics)	VCC (ext. graphics)	2.34	3.18		
I _{VCCSM}	DDR2 System Memory Interface (1.8 V) Supply Current	VCCSM	2.62	3.71	A	1, 2, 3
I _{VCC_SMCLK}	DDR2 System Memory Clock Interface (1.8 V) Supply Current	VCC_SMCLK	180	220	mA	
I _{VCC_EXP}	1.25 V PCI Express* / Intel® SDVO and DMI Supply Current (Using Integrated Graphics)	VCC_EXP (int. graphics)	0.46	1.00	A	2
	1.25 V PCI Express* / Intel® SDVO and DMI Supply Current (Using External Graphics)	VCC_EXP (ext. graphics)	1.43	2.45		
I _{VCC_CL}	1.25 V Controller Supply Current	VCC_CL	2.45	3.88	A	2
I _{VTT}	System Bus Supply Current	VTT	0.52	1	A	1
I _{VCCA_EXP}	3.3 V PCI Express* / Intel® SDVO and DMI Analog Supply Current	VCCA_EXP	39	72	mA	
I _{VCCA_DAC}	3.3 V Display DAC Analog Supply Current	VCCA_DAC	74	78	mA	
I _{VCC3_3}	3.3 V CMOS Supply Current	VCC3_3	0.5	16	mA	
I _{VCCD_CRT}	1.5 V Display Digital Supply Current	VCCD_CRT	20	30	mA	3
I _{VCCDQ_CRT}	1.5 V Display Quiet Digital Supply Current	VCCDQ_CRT	9	11	mA	
I _{VCCA_EXPLL}	1.25 V PCI Express* / Intel® SDVO and DMI PLL Analog Supply Current	VCCA_EXPLL	39	72	mA	
I _{VCCA_HPLL}	1.25 V Host PLL Supply Current	VCCA_HPLL	20	30	mA	



Symbol	Parameter	Signal Names	Sustained	Max	Unit	Notes
I_{VCCA_DPLLA}	1.25 V Display PLL A and PLL B Supply Current	VCCA_DPLLA	49	73	mA	
$I_{VCCA_DPLL B}$	1.25 V Display PLL A and PLL B Supply Current	VCCA_DPLL B	42	70	mA	
I_{VCCA_MPLL}	1.25 V System Memory PLL Analog Supply Current	VCCA_MPLL	115	173	mA	

NOTES:

1. Measurements are for current coming through chipset's supply pins.
2. Rail includes DLLs (and FSB sense amps on VCC).
3. Sustained Measurements are combined because one voltage regulator on the platform supplies both rails on the (G)MCH.



10.2 Signal Groups

The signal description includes the type of buffer used for the particular signal:

PCI Express* / Intel® sDVO	PCI Express interface signals. These signals are compatible with PCI Express 1.1 Signaling Environment AC Specifications and are AC coupled. The buffers are not 3.3 V tolerant. Differential voltage spec = $(D+ - D-) * 2 = 1.2V_{max}$. Single-ended maximum = 1.25 V. Single-ended minimum = 0 V.
DMI	Direct Media Interface signals. These signals are compatible with PCI Express 1.0 Signaling Environment AC Specifications, but are DC coupled. The buffers are not 3.3 V tolerant. Differential voltage spec = $(D+ - D-) * 2 = 1.2V_{max}$. Single-ended maximum = 1.25 V. Single-ended minimum = 0 V.
GTL+	Open Drain GTL+ interface signal. Refer to the GTL+ I/O Specification for complete details.
HCSL	Host Clock Signal Level buffers. Current mode differential pair. Differential typical swing = $(D+ - D-) * 2 = 1.4V$. Single ended input tolerant from -0.35V to 1.2V. Typical crossing voltage 0.35V.
SSTL-1.8	Stub Series Termination Logic. These are 1.8 V output capable buffers. 1.8 V tolerant.
SSTL-1.5	Stub Series Termination Logic. These are 1.5 V output capable buffers. 1.5 V tolerant.
CMOS	CMOS buffers
Analog	Analog reference or output. May be used as a threshold voltage or for buffer compensation.

Table 10-3. Signal Groups

Signal Type	Signals	Notes
Host Interface Signal Groups		
GTL+ Input/Outputs	HADS#, HBNR#, HBREQ0#, HDBSY#, HDRDY#, HDINV[3:0]#, HA[35:3]#, HADSTB[1:0]#, HD[63:0]#, HDSTBP[3:0]#, HDSTBN[3:0]#, HHIT#, HHITM#, HREQ[4:0]#, HLOCK#	
GTL+ Common Clock Outputs	HBPRI#, HCPURST#, HDEFER#, HTRDY#, HRS[2:0]#	
Analog Host I/F Ref & Comp. Signals	HDVREF, HACCREF, HSWING, HRCOMP, HSCOMP, HSCOMP#	
GTL+ Input	BSEL[2:0]	



Signal Type	Signals	Notes
PCI Express* Graphics and Intel® sDVO Interface Signal Groups		
PCI Express* / Intel® sDVO Input	PCI Express* Interface: EXP_RXN[15:0], EXP_RXP[15:0], Intel® sDVO Interface: SDVO_TVCLKIN+, SDVO_TVCLKIN-, SDVOB_INT+, SDVOB_INT-, SDVO_STALL+, SDVO_STALL-, SDVOC_INT+, SDVOC_INT-	1
PCI Express* / Intel® sDVO Output	PCI Express* Interface: EXP_TXN[15:0], EXP_TXP[15:0] Intel® sDVO Interface: SDVOB_RED+, SDVOB_RED-, SDVOB_GREEN+, SDVOB_GREEN-, SDVOB_BLUE+, SDVOB_BLUE-, SDVOB_CLK+, SDVOB_CLK-, SDVOC_RED+/SDVOB_ALPHA+, SDVOC_RED-/SDVOB_ALPHA-, SDVOC_GREEN+, SDVOC_GREEN-, SDVOC_BLUE+, SDVOC_BLUE-, SDVOC_CLK+, SDVOC_CLK-	1
CMOS I/O OD	SDVO_CTRLCLK, SDVO_CTRLDATA	
Analog PCI Express* / Intel® sDVO I/F Compensation Signals	EXP_COMPO, EXP_COMPI	
Direct Media Interface Signal Groups		
DMI Input	DMI_RXN[3:0], DMI_RXP[3:0]	
DMI Output	DMI_TXN[3:0], DMI_TXP[3:0]	
System Memory Interface Signal Groups		
SSTL-1.8 / SSTL-1.5 Input/Output	SDQ_A[63:0], SDQ_B[63:0], SDQS_A[7:0], SDQS_A[7:0]#, SDQS_B[7:0], SDQS_B[7:0]#	
SSTL-1.8 / SSTL-1.5 Output	SDM_A[7:0], SDM_B[7:0], SMA_A[14:0], SMA_B[14:0], SBS_A[2:0], SBS_B[2:0], SRAS_A#, SRAS_B#, SCAS_A#, SCAS_B#, SWE_A#, SWE_B#, SODT_A[3:0], SODT_B[3:0], SCKE_A[3:0], SCKE_B[3:0], SCS_A[3:0]#, SCS_B[3:0]#, SCLK_A[5:0], SCLK_A[5:0]#, SCLK_B[5:0], SCLK_B[5:0]#	
CMOS Input	N/A	
Reference and Comp. Voltages	SRCOMP[3:0], SMVREF, SRCOMP_VOL, SRCOMP_VOH	
Controller Link Signal Groups		
CMOS I/O OD	CL_DATA, CL_CLK	
CMOS Input	CL_RST#, CL_PWROK	
Analog Controller Link Reference Voltage	CL_VREF	



Signal Type	Signals	Notes
R, G, B / CRT DAC Display Signal Groups		
Analog Current Outputs	RED, RED#, GREEN, GREEN#, BLUE, BLUE#	
Analog/Ref DAC Miscellaneous	REFSET	2
CMOS I/O OD	DDC_CLK, DDC_DATA	
HVCMOS Output	HSYNC, VSYNC	
Clocks		
HCSL	HCLKN, HCLKP, DREFCLKP, DREFCLKN, GCLKP, GCLKN	
Reset, and Miscellaneous Signal Groups		
CMOS Input	EXP_EN, EXP_SLR, RSTIN#, PWROK	
CMOS Output	ICH_SYNC#	
Miscellaneous	TEST[2:0]	
I/O Buffer Supply Voltages		
System Bus Input Supply Voltage	VTT	
1.25 V PCI Express* / Intel® sDVO Supply Voltages	VCC_EXP	
3.3 V PCI Express* / Intel® sDVO Analog Supply Voltage	VCCA_EXP	
1.8 V DDR2 Supply Voltage	VCCSM	
1.8 V DDR2 Clock Supply Voltage	VCC_SMCLK	
1.25 V (G)MCH Core Supply Voltage	VCC	
1.25 V Controller Supply Voltage	VCC_CL	
3.3 V CMOS Supply Voltage	VCC3_3	
3.3 V R, G, B / CRT DAC Display Analog Supply Voltage	VCCA_DAC	
1.5 V DAC Digital Supply Voltages	VCCD_CRT, VCCDQ_CRT	
PLL Analog Supply Voltages	VCCA_HPLL, VCCA_EXPLL, VCCA_DPLLA, VCCA_DPLLB, VCCA_MPLL	

NOTES:

1. Refer to Section 2.7 for Intel® sDVO and PCI Express* Pin Mapping.
2. Current Mode Reference pin. DC Specifications not required



10.3 Buffer Supply and DC Characteristics

10.3.1 I/O Buffer Supply Voltages

The I/O buffer supply voltage is measured at the (G)MCH package pins. The tolerances shown in Table 10-4 are inclusive of all noise from DC up to 20 MHz. In the lab, the voltage rails should be measured with a bandwidth limited oscilloscope with a roll off of 3 dB/decade above 20 MHz under all operating conditions.

Table 10-4 indicates which supplies are connected directly to a voltage regulator or to a filtered voltage rail. For voltages that are connected to a filter, they should be measured at the *input* of the filter.

If the recommended platform decoupling guidelines cannot be met, the system designer will have to make tradeoffs between the voltage regulator output DC tolerance and the decoupling performance of the capacitor network to stay within the voltage tolerances listed in Table 10-4.



Table 10-4. I/O Buffer Supply Voltage

Symbol	Parameter	Min	Nom	Max	Unit	Notes
VCCSM	DDR2 I/O Supply Voltage	1.7	1.8	1.9	V	
VCC_SMCLK	DDR2 Clock Supply Voltage	1.7	1.8	1.9	V	2
VCC_EXP	SDVO, PCI Express* Supply Voltage	1.188	1.25	1.313	V	
VCCA_EXP	SDVO, PCI Express* Analog Supply Voltage	3.135	3.3	3.465	V	2
VTT	1.2 V System Bus Input Supply Voltage	1.14	1.2	1.26	V	4
	1.1 V System Bus Input Supply Voltage	1.045	1.1	1.155	V	
VCC	(G)MCH Core Supply Voltage	1.188	1.25	1.313	V	
VCC_CL	Controller Supply Voltage	1.188	1.25	1.313	V	
VCC3_3	CMOS Supply Voltage	3.135	3.3	3.465	V	
VCCA_DAC	Display DAC Analog Supply Voltage	3.135	3.3	3.465	V	3
VCCD_CRT	Display Digital Supply Voltage	1.425	1.5	1.575	V	1
VCCDQ_CRT	Display Quiet Digital Supply Voltage	1.425	1.5	1.575	V	1
VCCA_HPLL, VCCA_EXPPLL, VCCA_DPLLA, VCCA_DPLLB, VCCA_MPLL	Various PLLs' Analog Supply Voltages	1.188	1.25	1.313	V	2

NOTES:

1. The VCCD_CRT and VCCDQ_CRT can also operate at a nominal 1.8 V $\pm 5\%$ input voltage. Only the 1.5 V nominal voltage setting will be validated internally.
2. These rails are filtered from other voltage rails on the platform and should be measured at the *input* of the filter.
3. VCCA_DAC voltage tolerance should only be measured when the DAC is turned ON and at a stable resolution setting. Any noise on the DAC during power on or display resolution changes do not impact the circuit.
4. (G)MCH supports both VTT = 1.2 V nominal and VTT = 1.1 V nominal depending on the identified processor.



10.3.2 General DC Characteristics

Platform Reference Voltages at the top of Table 10-5 are specified at DC only. V_{REF} measurements should be made with respect to the supply voltage. Customers should refer to the Platform Design Guide for proper decoupling of the V_{REF} voltage dividers on the platform.

Table 10-5. DC Characteristics

Symbol	Parameter	Min	Nom	Max	Unit	Notes
Reference Voltages						
FSB_DVREF FSB_ACCVREF	Host Data, Address, and Common Clock Signal Reference Voltages	$0.666 \times V_{TT_FSB} - 2\%$	$0.666 \times V_{TT_FSB}$	$0.666 \times V_{TT_FSB} + 2\%$	V	
FSB_SWING	Host Compensation Reference Voltage	$0.25 \times V_{TT_FSB} - 2\%$	$0.25 \times V_{TT_FSB}$	$0.25 \times V_{TT_FSB} + 2\%$	V	
CL_VREF	Controller Link Reference Voltage	$0.270 \times V_{CC_CL}$	$0.279 \times V_{CC_CL}$	$0.287 \times V_{CC_CL}$	V	
DDR_VREF	DDR2 Reference Voltage	$0.49 \times SMVREF$	$0.50 \times SMVREF$	$0.51 \times SMVREF$	V	
Host Interface						
V_{IL_H}	Host GTL+ Input Low Voltage	-0.10	0	$(0.666 \times V_{TT_FSB}) - 0.1$	V	
V_{IH_H}	Host GTL+ Input High Voltage	$(0.666 \times V_{TT_FSB}) + 0.1$	V_{TT_FSB}	$V_{TT_FSB} + 0.1$	V	
V_{OL_H}	Host GTL+ Output Low Voltage	—	—	$(0.25 \times V_{TT_FSB}) + 0.1$	V	
V_{OH_H}	Host GTL+ Output High Voltage	$V_{TT_FSB} - 0.1$	—	V_{TT_FSB}	V	
I_{OL_H}	Host GTL+ Output Low Current	—	—	$V_{TT_FSBmax} * (1 - 0.25) / R_{ttmin}$	mA	$R_{ttmin} = 47.5 \Omega$
I_{LEAK_H}	Host GTL+ Input Leakage Current	—	—	45	μA	$V_{OL} < V_{pad} < V_{tt_FSB}$
C_{PAD}	Host GTL+ Input Capacitance	2.0	—	2.5	pF	
C_{PCKG}	Host GTL+ Input Capacitance (common clock)	0.90	—	2.5	pF	
DDR2 System Memory Interface						
$V_{IL(DC)}$	DDR2 Input Low Voltage	—	—	$DDR_VREF - 0.125$	V	
$V_{IH(DC)}$	DDR2 Input High Voltage	$DDR_VREF + 0.125$	—	—	V	



Symbol	Parameter	Min	Nom	Max	Unit	Notes
$V_{IL(AC)}$	DDR2 Input Low Voltage	—	—	DDR_VREF – 0.20	V	
$V_{IH(AC)}$	DDR2 Input High Voltage	DDR_VREF + 0.20	—	—	V	
V_{OL}	DDR2 Output Low Voltage	—	—	0.2 * VCC_DDR	V	1
V_{OH}	DDR2 Output High Voltage	0.8 * VCC_DDR	—	—	V	1
I_{Leak}	Input Leakage Current	—	—	±20	μA	4
I_{Leak}	Input Leakage Current	—	—	±550	μA	5
$C_{I/O}$	DQ/DQS/DQSB DDR2 Input/Output Pin Capacitance	1.0	—	4.0	pF	
Input Clocks						
V_{IL}	Input Low Voltage	-0.150	0	—	V	
V_{IH}	Input High Voltage	0.660	0.710	0.850	V	
$V_{CROSS(ABS)}$	Absolute Crossing Voltage	0.300	—	0.550	V	6,7,8
$\Delta V_{CROSS(REL)}$	Range of Crossing Points	—	—	0.140	V	
C_{IN}	Input Capacitance	1	—	3	pF	
SDVO_CTRLDATA, SDVO_CTRLCLK						
V_{IL}	Input Low Voltage	—	—	0.75	V	
V_{IH}	Input High Voltage	1.75	—	—	V	
I_{LEAK}	Input Leakage Current	—	—	± 10	μA	
C_{IN}	Input Capacitance	—	—	10.0	pF	
I_{OL}	Output Low Current (CMOS Outputs)	—	—	7.8	mA	@ 50% swing
I_{OH}	Output High Current (CMOS Outputs)	-1	—	—	mA	@ 50% swing
V_{OL}	Output Low Voltage (CMOS Outputs)	—	—	0.4	V	
V_{OH}	Output High Voltage (CMOS Outputs)	2.25	—	—	V	
CRT_DDC_DATA, CRT_DDC_CLK						
V_{IL}	Input Low Voltage	—	—	0.9	V	
V_{IH}	Input High Voltage	2.1	—	—	V	
I_{LEAK}	Input Leakage Current	—	—	± 10	μA	
C_{IN}	Input Capacitance	—	—	10.0	pF	
I_{OL}	Output Low Current (CMOS Outputs)	—	—	27.0	mA	@ 50% swing



Symbol	Parameter	Min	Nom	Max	Unit	Notes
I_{OH}	Output High Current (CMOS Outputs)	-1	—	—	mA	@ 50% swing
V_{OL}	Output Low Voltage (CMOS Outputs)	—	—	0.4	V	
V_{OH}	Output High Voltage (CMOS Outputs)	2.7	—	—	V	
CL_DATA, CL_CLK						
V_{IL}	Input Low Voltage	—	—	0.277	V	
V_{IH}	Input High Voltage	0.427	—	—	V	
I_{LEAK}	Input Leakage Current	—	—	± 20	μA	
C_{IN}	Input Capacitance	—	—	1.5	pF	
I_{OL}	Output Low Current (CMOS Outputs)	—	—	1.0	mA	@ V_{OL_HI} max
I_{OH}	Output High Current (CMOS Outputs)	6.0	—	—	mA	@ V_{OH_HI} min
V_{OL}	Output Low Voltage (CMOS Outputs)	—	—	0.06	V	
V_{OH}	Output High Voltage (CMOS Outputs)	0.6	—	—	V	
PWROK, CL_PWROK, RSTIN#						
V_{IL}	Input Low Voltage	—	—	0.3	V	
V_{IH}	Input High Voltage	2.7	—	—	V	
I_{LEAK}	Input Leakage Current	—	—	± 1	mA	
C_{IN}	Input Capacitance	—	—	6.0	pF	
CL_RST#						
V_{IL}	Input Low Voltage	—	—	0.13	V	
V_{IH}	Input High Voltage	1.17	—	—	V	
I_{LEAK}	Input Leakage Current	—	—	± 20	μA	
C_{IN}	Input Capacitance	—	—	5.0	pF	
ICH_SYNCB						
I_{OL}	Output Low Current (CMOS Outputs)	—	—	2.0	mA	@ V_{OL_HI} max
I_{OH}	Output High Current (CMOS Outputs)	-2.0	—	—	mA	@ V_{OH_HI} min
V_{OL}	Output Low Voltage (CMOS Outputs)	—	—	0.33	V	
V_{OH}	Output High Voltage (CMOS Outputs)	2.97	—	—	V	



Symbol	Parameter	Min	Nom	Max	Unit	Notes
EXP_SLR, EXP_EN						
V _{IL}	Input Low Voltage	-0.10	0	(0.63 x V _{TT}) - 0.1	V	
V _{IH}	Input High Voltage	(0.63 x V _{TT}) + 0.1	V _{TT}	V _{TT} + 0.1	V	
I _{LEAK}	Input Leakage Current	—	—	20	μA	V _{OL} < V _{pad} < V _{tt}
C _{IN}	Input Capacitance	2		2.5	pF	
CRT_HSYNC, CRT_VSYNC						
I _{OL}	Output Low Current (CMOS Outputs)	—	—	8.0	mA	@V _{OL_HI} max
I _{OH}	Output High Current (CMOS Outputs)	-8.0	—		mA	@V _{OH_HI} min
V _{OL}	Output Low Voltage (CMOS Outputs)	—	—	0.5	V	
V _{OH}	Output High Voltage (CMOS Outputs)	2.4	—		V	

NOTES:

1. Determined with 2x (G)MCH Buffer Strength Settings into a 50 Ω to 0.5xVCC_DDR test load.
2. Specified at the measurement point into a timing and voltage compliance test load as shown in Transmitter compliance eye diagram of PCI Express* specification and measured over any 250 consecutive TX Uls.
3. Specified at the measurement point over any 250 consecutive Uls. The test load shown in Receiver compliance eye diagram of PCI Express* spec should be used as the RX device when taking measurements.
4. Applies to pin to VCC or VSS leakage current for the DDR_A_DQ_63:0 and DDR_B_DQ_63:0 signals.
5. Applies to pin to pin leakage current between DDR_A_DQS_7:0, DDR_A_DQSB_7:0, DDR_B_DQS_7:0, and DDR_B_DQSB_7:0 signals.
6. Crossing voltage defined as instantaneous voltage when rising edge of BCLK0 equals falling edge of BCLK1.
7. V_{Havg} is the statistical average of the V_H measured by the oscilloscope.
8. The crossing point must meet the absolute and relative crossing point specifications simultaneously. Refer to the appropriate processor datasheet for further information.



10.4 R, G, B / CRT DAC Display DC Characteristics (Intel® 82G31 GMCH Only)

**Table 10-6. R, G, B / CRT DAC Display DC Characteristics: Functional Operating Range
(VCCA_DAC = 3.3 V ± 5 %)**

Parameter	Min	Typ	Max	Units	Notes
DAC Resolution	8	—	—	Bits	1
Max Luminance (full-scale)	0.665	0.700	0.77	V	1, 2, 4 (white video level voltage)
Min Luminance	—	0.000	—	V	1, 3, 4 (black video level voltage)
LSB Current	—	73.2	—	μA	4,5
Integral Linearity (INL)	-1.0	—	+1.0	LSB	1,6
Differential Linearity (DNL)	-1.0	—	+1.0	LSB	1,6
Video channel-channel voltage amplitude mismatch	—	—	6	%	7
Monotonicity	Ensured			—	

NOTES:

1. Measured at each R, G, B termination according to the VESA Test Procedure – Evaluation of Analog Display Graphics Subsystems Proposal (Version 1, Draft 4, December 1, 2000).
2. Max steady-state amplitude
3. Min steady-state amplitude
4. Defined for a double 75 Ω termination.
5. Set by external reference resistor value.
6. INL and DNL measured and calculated according to VESA Video Signal Standards.
7. Max full-scale voltage difference among R, G, B outputs (percentage of steady-state full-scale voltage).



11 Ballout and Package Information

This chapter provides the (G)MCH ballout and package information.

11.1 Ballout

The following three figures show the (G)MCH ballout as viewed from the top side of the package. The figures are divided into a left-side view, middle view, and right-side view of the package. Table 11-1 lists the ballout alphabetically by signal name.

Note: Notes for Figure 11-1, Figure 11-2, Figure 11-3, and Table 11-1.

1. Some balls marked as RSVD (Reserved) are used in XOR testing. See Chapter 12 for details.
2. Balls that are listed as NC are No Connects.
3. Analog Display Signals (CRT_RED, CRT_REDB, CRT_GREEN, CRT_GREENB, CRT_BLUE, CRT_BLUEB, CRT_IREF, CRT_HSYNC, CRT_VSYNC, CRT_DDC_CLK, CRT_DDC_DATA) and the SDVO_CTRLCLK and SDVO_CTRLDATA signals are not used on the 82P31 MCH. Contact your Intel field representative for proper termination of the corresponding balls.
4. For the 82G31 GMCH, the PCI Express and SDVO signals are multiplexed. However, only the PCI Express signal name is included in the following ballout figures and table. See Section 2.7 for the PCI Express to SDVO signal name mapping.



Figure 11-1. (G)MCH Ballout Diagram (Top View Left – Columns 43–30)

	43	42	41	40	39	38	37	36	35	34	33	32	31	30	
BC	TEST0	NC	VSS		VCCSM		VSS			VCCSM		VSS		VCCSM	BC
BB	NC	VCC_SMCLK	VCC_SMCLK	SRCOMP2	VCCSM	RSVD	VCCSM		RSVD	SWE_A#	VCCSM	RSVD	SCS_B1#		BB
BA	VCC_SMCLK	VCC_SMCLK		SRCOMP3	RSVD	SODT_A1			SCS_A1#	RSVD	SBS_A0		SMA_A0	SODT_B1	BA
AY		VCC_SMCLK	VSS	VSS		SMA_A13	SODT_A0		SCAS_A#		SMA_A10	VCCSM	RSVD		AY
AW	VSS	RSVD	VSS		SDQS_B4		SDQ_B32		SCS_A0#		SCLK_A2#	SBS_A1	SCLK_B0#		AW
AV		SDQ_A32	SDQ_A37	SDQ_A36		SDQ_B33	VSS		VSS		SCLK_A2	SCLK_B2	SCLK_B0		AV
AU	SDM_A4	VSS		SDQ_A33	SDQS_B4#	VSS	SDM_B4		SDQ_B36		RSVD	VSS	SCLK_A0		AU
AT											RSVD	SCLK_B2#	VSS		AT
AR		SDQ_A38	SDQS_A4	SDQS_A4#	SDQ_B44	VSS	SDQ_B39		SDQ_B37		VSS	VSS	SCLK_A0#		AR
AP	VSS	SDQ_A34	SDQ_A39									RSVD	RSVD		AP
AN		SDQ_A45	SDQ_A40	SDQ_A44	SDQ_A35	VSS	SDQ_B35	SDQ_B34	SDQ_B38		RSVD	RSVD	VSS		AN
AM	SDM_A5	VSS		VSS	SDQ_A41	SDQ_B41	SDM_B5	VSS	SDQ_B40	SDQ_B45	VSS		RSVD		AM
AL		SDQ_A46	SDQS_A5	SDQS_A5#	SDQ_A47	SDQ_B43	SDQ_B46	VSS	SDQS_B5	SDQS_B5#	VSS	SDQ_B47	RSVD		AL
AK	VSS	SDQ_A42	SDQ_A43											VCC2	AK
AJ		SDQ_A52	SDQ_A53	SDQ_A48	VSS	SDQ_B49	SDQ_B52	VSS	SDQ_B53	SDQ_B42	VSS	RSVD	VCC2	VCC2	AJ
AH	SDQ_A49	VSS													AH
AG		SDQS_A6	SDQS_A6#	SDM_A6	SDM_B6	SDQ_B48	VSS	SDQS_B6#	SDQS_B6	VSS	SDQ_B54	RSVD	VCC2	VCC2	AG
AF	VSS	SDQ_A55	SDQ_A54		SDQ_A50	SDQ_B61	VSS	VSS	SDQ_B50	SDQ_B55	SDQ_B51	RSVD	VCC2	VCC2	AF
AE		SDQ_A60	SDQ_A61	SDQ_A51											AE
AD	SDQ_A57	VSS		SDQ_A56	VSS	SDM_B7	VSS	SDQ_B56	VSS	SDQ_B60	VSS	VCC2	VCC2	VCC2	AD
AC		SDQS_A7	SDQS_A7#	SDM_A7	SDQ_A62	VSS	SDQS_B7#	SDQS_B7	VSS	SDQ_B62	SDQ_B57	VCC2	VCC2	VCC	AC
AB	VSS	SDQ_A63	SDQ_A58												AB
AA		HBREQ0#	HRS1#	SDQ_A59	RSVD	VSS	HA35#	SDQ_B59	VSS	SDQ_B58	SDQ_B63	VCC2	VCC2	VCC2	AA
Y	HHITM#	VSS		HTRDY#	HA34#	HA33#	VSS	HA32#	VSS	HA29#	VSS	VCC2	VCC2	VCC2	Y
W		HBNR#	HDRDY#	HADS#											W
V	VSS	HA30#	HLOCK#		VSS	HA31#	VSS	HA22#	HA28#	VSS	HA27#	VSS	RSVD	VCC2	V
U		HHIT#	HRS0#	HDBSY#	HRS2#	VSS	HA17#	HA24#	VSS	HADSTB1#	HA25#	HCLKN	RSVD	RSVD	U
T	HDEFER#	VSS													T
R		HD4#	HD2#	HD0#	HA21#	HA23#	HA19#	VSS	HA26#	HA14#	VSS	HCLKP	VSS	RSVD	R
P	VSS	HA20#	HD1#											VSS	P
N		HD7#	HD6#	HD3#	HA18#	HA16#	HA12#	VSS	HA15#	HA10#	VSS	HA9#	VSS		N
M	HDSTBN0#	VSS		HDINV0#	HD5#	HA11#	VSS	HA13#	VSS	HADSTB0#	VSS		HD34#		M
L		HD10#	HD8#	HDSTBP0#	HA4#	HREQ2#	HA6#	HA7#	HREQ1#		VSS	VSS			L
K	VSS	HA8#	HD12#									HD29#	HD36#		K
J		HA3#	HD11#	HA5#	HD9#	VSS	HREQ4#		VSS		HDINV1#	VSS	HD32#		J
H											HDSTBN1#	HD30#	VSS		H
G	HREQ3#	VSS		HD13#	HBPR1#	VSS	HD19#		HDSTBP1#		HD25#	VSS	HD37#		G
F		HD15#	HD14#	HREQ0#		HD18#	VSS		VSS		HD27#	HD33#	HD39#		F
E	VSS	HD20#	HD50#		HD21#		HD22#		HD28#		HDINV3#	VSS	HD35#		E
D		HD52#	HD17#	VSS		HDSTBN3#	HD57#		HD54#		HD59#	HD63#	VSS		D
C	VSS	HD16#		HD53#	HD23#	HD56#			HD49#	HD60#	HD48#		HCPURST#	VTT	C
B	NC	NC	HD51#	HD55#	HD24#	HDSTBP3#	VSS		HD61#	HD31#	HD58#	VSS	VSS	VTT	B
A	TEST2	NC	VSS		VSS		HD26#		VSS		HD62#			VTT	A
	43	42	41	40	39	38	37	36	35	34	33	32	31	30	



Figure 11-2. (G)MCH Ballout Diagram (Top View Middle – Columns 29–15)

	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	
BC		VSS		VCCSM		VSS		VCCSM		SCKE_A0		VCCSM		SMA_B3		BC
BB	RSVD	VCCSM	SCS_B0#	VCCSM	SMA_A1	VCCSM	SMA_A8	SMA_A11	SBS_A2	VCCSM	RSVD	VCCSM	SMA_B0	VCCSM	SMA_B6	BB
BA	SODT_B0		SWE_B#	SMA_A2	SMA_A3		SMA_A5	SMA_A9	SMA_A14		RSVD	SBS_B1	SMA_B2		SMA_B5	BA
AY	SMA_B13		RSVD		SMA_A4	SMA_A6	SMA_A7		RSVD	SCKE_A1	SBS_B0		SMA_B1		SMA_B8	AY
AW	SCAS_B#		RSVD	SRAS_B#		VCCSM	SDQ_B29		SMA_A12	VCCSM		SMA_B10	SDQ_B23		SMA_B4	AW
AV	RSVD		VSS	VCCSM		SDQ_B24	VSS		VSS	SDQ_A31		VCCSM	VSS		SDQ_B22	AV
AU	RSVD		SCLK_B1	SDQS_B3#		VSS	SDQ_B28		SDQ_A26	VSS		SDQS_A3#	SDQ_B18		SDQ_B16	AU
AT	VSS		SCLK_B1#	SDQ_B26		SDQS_B3	SDQ_B25		SDQ_A27	SDQS_A3		SDQ_A24	SDQ_B19		VSS	AT
AR	RSVD		VSS	VSS		SDQ_B30	VSS		VSS	VSS		SDQ_A25	VSS		SDQS_B2#	AR
AP	RSVD		SCLK_A1	SDQ_B27		VSS	SDM_B3		RSVD	SDQ_A30		VSS	SDQ_A28		SDQS_B2	AP
AN	VSS		SCLK_A1#	SDQ_B31		VSS	VSS		RSVD	VSS		SDM_A3	SDQ_A29		VSS	AN
AM	VSS		RSVD	RSVD		VSS	VSS		RSVD	VSS		RSTIN#	PWROK		PWROK2	AM
AL	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	AL
AK	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	AK
AJ	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	VCC2		VCC2	AJ
AH																AH
AG	VCC2		VCC2	VCC2	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC		VCC	AG
AF	VCC2		VCC2	VCC	VCC	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VCC		VCC	AF
AE			VCC	VCC	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VSS	VCC			AE
AD	VCC2		VCC	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VCC		VCC	AD
AC	VCC2		VCC	VCC	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VSS	VCC		VCC	AC
AB			VCC	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VCC			AB
AA	VCC2		VCC	VCC	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VSS	VCC		VCC	AA
Y	VCC2		VCC	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VCC		VCC	Y
W			VCC	VCC	VCC	VSS	VCC	VSS	VCC	VSS	VCC	VCC	VCC			W
V	VCC2		VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC		VCC	V
U	VCC2		VCC2	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC		VCC	U
T																T
R	RSVD		VTT	VTT		VTT	VTT		VSS	VCC		VCC	VCC		VCC	R
P	VTT		VTT	VTT		VTT	VTT		VSS	VCC		VSS	VSS		VCC	P
N	VTT		VSS	VTT		VTT	VTT		VSS	NC		RSVD	RSVD		RSVD	N
M	VTT		VSS	HD47#		VTT	VTT		VSS	RSVD		RSVD	VSS		VSS	M
L	VSS		HD42#	HD45#		VTT	VTT		VSS	VSS		RSVD	RSVD		RSVD	L
K	HD38#		HD43#	VSS		VTT	VTT		VSS	ALLZTEST		VSS	RSVD		EXP_RXP1	K
J	HD40#		VSS	HD46#		VTT	VTT		VSS	BSEL1		BSEL2	EXP_EN		EXP_RXN1	J
H	VSS		HDSTBN2#	HD44#		VTT	VTT		VSS	VSS		RSVD	VSS		VSS	H
G	HDINV2#		HDSTBP2#	VTT		VTT	VTT		VSS	BSEL0		RSVD	SDVO_CT_RLCLK		EXP_RXN0	G
F	HD41#		VSS	VTT		VTT	VTT		VSS	XORTEST		VSS	RSVD		EXP_RXP0	F
E	VTT		VTT	VTT		VSS	VTT		VSS	VSS		EXP_SLR	SDVO_CT_RLCLK		VSS	E
D	VTT	VTT	VTT		HSCOMP#	HDVREF	HRCOMP		VSS	BLUE#	GREEN#		VSS	VSS	VSYNC	D
C	VTT		VTT	VSS	HSCOMP		VCCA_HP_LL	VCCA_DP_LL	VCCD_CRT		GREEN	RED#	VCCA_DA_C		HSYNC	C
B	VTT	VTT	VTT	VSS	HSWING	HACCVREF	VSS	VSS	VCCDQ_CRT	BLUE	VSS	RED	VCC3_3	VCCA_DA_C	VCCA_EX_PPLL	B
A		VTT		VSS		VCCA_MP_LL		VCCA_DP_LLA		REFSET		VSS		VCCA_EX_P		A
	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	



Figure 11-3. (G)MCH Ballout Diagram (Top View Right – Columns 14–0)

	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
BC	VCCSM		SBS_B2		VSS			SDQ_A17		VSS		VSS	NC	TEST1	BC
BB	SMA_B9	SMA_B11	VCCSM	RSVD	SDQ_A23	SDQS_A2		VSS	SDQ_A20	SDQ_A10	SDQ_A15	SDQS_A1	RSVD	NC	BB
BA	SMA_B7	SMA_B12		RSVD	SDQ_A22	SDQS_A2#			SDQ_A21	SDQ_A14	SDQS_A1#		SDM_A1	VSS	BA
AY		SMA_B14	SCKE_B0	SDQ_A19		SDM_A2		SDQ_A16	SDQ_A11		VSS	SDQ_A9	SDQ_A8		AY
AW		SDM_B2	SCKE_B1	SDQ_A18		SDM_B1		SDQ_B3			SDQ_B2		SDQ_A12	VSS	AW
AV		SDQ_B17	SDQ_B14	VSS		VSS		VSS	SDQS_B0		SDQ_A7	SDQ_A2	SDQ_A3		AV
AU		SDQ_B20	SDQ_B15	SDQ_B9		SDQ_B13		SDQ_B7	VSS	SDQS_B0#	SDQS_A0		VSS	SDQ_A6	AU
AT		VSS	VSS	SDQ_B8											AT
AR		SDQ_B11	SDQS_B1	SDQ_B12		VSS		SDM_B0	VSS	SDQ_A0	SDQ_A1	SDQS_A0#	SDM_A0		AR
AP		SDQ_B10	SDQS_B1#									SDQ_A4	SDQ_A5	VSS	AP
AN		VSS	VSS	VSS		SDQ_B6	SDQ_B1	SDQ_B0	SDQ_B5	SDQ_B4	VSS	SRCOMP1	SRCOMP0		AN
AM		SDQ_B21		VSS	SMRCOMP VOH	VSS	SMRCOMP VOL	VSS	SVREF	VREF2	VSS		VSS	VSS	AM
AL		VCC2	VCC2	VCC2	VCC2	VCC2	VCC2	VCC2	VCC2	VCC2	VCC2	VCC2	VCC2		AL
AK	VCC2											VCC2	VCC2	VCC2	AK
AJ	VCC2	VCC2	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC		AJ
AH												VCC	VCC	VCC	AH
AG	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC		AG
AF	VCC	VCC	VCC	VCC	VSS	VSS	VSS	VSS	VSS	VSS		VSS	VSS	VSS	AF
AE											VCC_EXP	VCC_EXP	VCC_EXP		AE
AD	VCC	RSVD	RSVD	VCC_EXP	VCC_EXP	VCC_EXP	VCC_EXP	VCC_EXP	VCC_EXP	VCC_EXP	VCC_EXP		VCC_EXP	VCC_EXP	AD
AC	VCC	VCC	EXP_COMP I	EXP_COMP O	VSS	DMI_TXN2	DMI_TXP2	VSS	VCC	VSS	VCC_EXP	VCC_EXP	VCC_EXP		AC
AB												DMI_RXP3	VSS	VSS	AB
AA	VCC	VCC	V_1P25_PL TRST#	RSVD	RSVD	RSVD	VSS	DMI_RXP2	DMI_RXN2	VSS	DMI_RXN3	VCC	DMI_TXN3		AA
Y	VCC	VCC	RSVD	VCC	VSS	DMI_RXN1	DMI_RXP1	VSS	VCC	VSS	DMI_TXN1		DMI_TXP3	VSS	Y
W											DMI_TXP1	VSS	DMI_RXP0		W
V	VCC	VCC	VCC	VSS	VCC	VCC	VSS	DMI_TXP0	DMI_TXN0	VSS		EXP_TXP1 5	VSS	DMI_RXN0	V
U	VCC	VCC	RSVD	RSVD	VCC	VCC	VSS	VSS	VCC	VSS	EXP_TXN1 5	VCC	EXP_TXP1 4		U
T											EXP_TXP1 4		EXP_TXN1 4	VSS	T
R	VCC	RSVD	RSVD	VSS	EXP_RXN1 3	EXP_RXP1 3	VSS	EXP_RXN1 5	EXP_RXP1 5	VSS	EXP_RXN1 4	VSS	EXP_TXP1 3		R
P	VCC											EXP_TXP1 2	VSS	EXP_TXN1 3	P
N		VSS	VCC	VCC	VSS	VCC	VCC	VSS	VCC	VSS	EXP_TXN1 2	VCC	EXP_TXP1 1		N
M		DDC_CLK		VSS	VSS	EXP_RXN1 0	EXP_RXP1 0	VSS	EXP_RXN1 2	EXP_RXP1 2	EXP_RXP1 1		EXP_TXN1 1	VSS	M
L		DDC_DATA	VCC	VSS		EXP_RXP9	EXP_RXN9	VSS	VCC	VSS	EXP_RXN1 1	VSS	EXP_TXP1 0		L
K		VSS	VSS									EXP_TXN9	VSS	EXP_TXN1 0	K
J		ICH_SYNC #	EXP_RXP3	EXP_RXP4		VSS		VSS	VCC	VSS	EXP_TXP9	VCC	VCC		J
H		VSS	EXP_RXN3	EXP_RXN4											H
G		VSS	VSS	VSS		VSS		VSS	EXP_RXP8	EXP_RXN8	EXP_TXN8		VCC	VSS	G
F		RSVD	EXP_RXP2	VCC		VCC		EXP_RXP5	EXP_RXN6		EXP_TXP8	VSS	EXP_TXP7		F
E		VSS	EXP_RXN2	VSS		VSS		EXP_RXN5		EXP_RXP6		VSS	EXP_TXN7	VSS	E
D		DREFCLKN	EXP_TXN0	EXP_TXP0		EXP_TXN2		EXP_TXP4	EXP_TXN4		VCC	VSS	EXP_RXN7		D
C	DREFCLKP	VCC		VSS	EXP_TXP2	VCC			VSS	VSS	VSS		EXP_RXP7	VSS	C
B	VSS	GCLKN	GCLKP	EXP_TXP1	VSS	EXP_TXP3		EXP_TXN3	EXP_TXN5	EXP_TXP5	EXP_TXN6	EXP_TXP6	NC		B
A	RSVD		VSS		EXP_TXN1			VSS		VSS		VSS			A
	14	13	12	11	10	9	8	7	6	5	4	3	2	1	



Table 11-1. (G)MCH Ballout Sorted by Signal Name

Signal Name	Ball #	Signal Name	Ball #	Signal Name	Ball #
ALLZTEST	K20	EXP_RXN9	L8	EXP_TXN14	T2
BLUE	B20	EXP_RXN10	M9	EXP_TXN15	U4
BLUE#	D20	EXP_RXN11	L4	EXP_TXP0	D11
BSEL0	G20	EXP_RXN12	M6	EXP_TXP1	B11
BSEL1	J20	EXP_RXN13	R10	EXP_TXP2	C10
BSEL2	J18	EXP_RXN14	R4	EXP_TXP3	B9
DDC_CLK	M13	EXP_RXN15	R7	EXP_TXP4	D7
DDC_DATA	L13	EXP_RXP0	F15	EXP_TXP5	B5
DMI_RXN0	V1	EXP_RXP1	K15	EXP_TXP6	B3
DMI_RXN1	Y9	EXP_RXP2	F12	EXP_TXP7	F2
DMI_RXN2	AA6	EXP_RXP3	J12	EXP_TXP8	F4
DMI_RXN3	AA4	EXP_RXP4	J11	EXP_TXP9	J4
DMI_RXP0	W2	EXP_RXP5	F7	EXP_TXP10	L2
DMI_RXP1	Y8	EXP_RXP6	E5	EXP_TXP11	N2
DMI_RXP2	AA7	EXP_RXP7	C2	EXP_TXP12	P3
DMI_RXP3	AB3	EXP_RXP8	G6	EXP_TXP13	R2
DMI_TXN0	V6	EXP_RXP9	L9	EXP_TXP14	U2
DMI_TXN1	Y4	EXP_RXP10	M8	EXP_TXP15	V3
DMI_TXN2	AC9	EXP_RXP11	M4	GCLKN	B13
DMI_TXN3	AA2	EXP_RXP12	M5	GCLKP	B12
DMI_TXP0	V7	EXP_RXP13	R9	GREEN	C19
DMI_TXP1	W4	EXP_RXP14	T4	GREEN#	D19
DMI_TXP2	AC8	EXP_RXP15	R6	HA3#	J42
DMI_TXP3	Y2	EXP_SLR	E18	HA4#	L39
DREFCLKN	D13	EXP_TXN0	D12	HA5#	J40
DREFCLKP	C14	EXP_TXN1	A10	HA6#	L37
EXP_COMPI	AC12	EXP_TXN2	D9	HA7#	L36
EXP_COMPO	AC11	EXP_TXN3	B7	HA8#	K42
EXP_EN	J17	EXP_TXN4	D6	HA9#	N32
EXP_RXN0	G15	EXP_TXN5	B6	HA10#	N34
EXP_RXN1	J15	EXP_TXN6	B4	HA11#	M38
EXP_RXN2	E12	EXP_TXN7	E2	HA12#	N37
EXP_RXN3	H12	EXP_TXN8	G4	HA13#	M36
EXP_RXN4	H11	EXP_TXN9	K3	HA14#	R34
EXP_RXN5	E7	EXP_TXN10	K1	HA15#	N35
EXP_RXN6	F6	EXP_TXN11	M2	HA16#	N38
EXP_RXN7	D2	EXP_TXN12	N4	HA17#	U37
EXP_RXN8	G5	EXP_TXN13	P1	HA18#	N39



Signal Name	Ball #	Signal Name	Ball #	Signal Name	Ball #
HA19#	R37	HD12#	K41	HD51#	B41
HA20#	P42	HD13#	G40	HD52#	D42
HA21#	R39	HD14#	F41	HD53#	C40
HA22#	V36	HD15#	F42	HD54#	D35
HA23#	R38	HD16#	C42	HD55#	B40
HA24#	U36	HD17#	D41	HD56#	C38
HA25#	U33	HD18#	F38	HD57#	D37
HA26#	R35	HD19#	G37	HD58#	B33
HA27#	V33	HD20#	E42	HD59#	D33
HA28#	V35	HD21#	E39	HD60#	C34
HA29#	Y34	HD22#	E37	HD61#	B35
HA30#	V42	HD23#	C39	HD62#	A32
HA31#	V38	HD24#	B39	HD63#	D32
HA32#	Y36	HD25#	G33	HDBSY#	U40
HA33#	Y38	HD26#	A37	HDEFER#	T43
HA34#	Y39	HD27#	F33	HDINV0#	M40
HA35#	AA37	HD28#	E35	HDINV1#	J33
HACCVREF	B24	HD29#	K32	HDINV2#	G29
HADS#	W40	HD30#	H32	HDINV3#	E33
HADSTB0#	M34	HD31#	B34	HDRDY#	W41
HADSTB1#	U34	HD32#	J31	HDSTBN0#	M43
HBNR#	W42	HD33#	F32	HDSTBN1#	H33
HBPRI#	G39	HD34#	M31	HDSTBN2#	H27
HBREQ0#	AA42	HD35#	E31	HDSTBN3#	D38
HCLKN	U32	HD36#	K31	HDSTBP0#	L40
HCLKP	R32	HD37#	G31	HDSTBP1#	G35
HCPURST#	C31	HD38#	K29	HDSTBP2#	G27
HD0#	R40	HD39#	F31	HDSTBP3#	B38
HD1#	P41	HD40#	J29	HDVREF	D24
HD2#	R41	HD41#	F29	HHIT#	U42
HD3#	N40	HD42#	L27	HHITM#	Y43
HD4#	R42	HD43#	K27	HLOCK#	V41
HD5#	M39	HD44#	H26	HRCOMP	D23
HD6#	N41	HD45#	L26	HREQ0#	F40
HD7#	N42	HD46#	J26	HREQ1#	L35
HD8#	L41	HD47#	M26	HREQ2#	L38
HD9#	J39	HD48#	C33	HREQ3#	G43
HD10#	L42	HD49#	C35	HREQ4#	J37
HD11#	J41	HD50#	E41	HRS0#	U41



Signal Name	Ball #
HRS1#	AA41
HRS2#	U39
HSCOMP	C25
HSCOMP#	D25
HSWING	B25
HSYNC	C15
HTRDY#	Y40
ICH_SYNC#	J13
NC	BC42
NC	BC2
NC	BB43
NC	BB1
NC	B43
NC	B42
NC	B2
NC	N20
NC	A42
PWROK	AM17
PWROK2	AM15
RED	B18
RED#	C18
REFSET	A20
RSVD	AJ32
RSVD	V31
RSVD	AL31
RSVD	A14
RSVD	F13
RSVD	F17
RSVD	H18
RSVD	K17
RSVD	G18
RSVD	M18
RSVD	L18
RSVD	L15
RSVD	M20
RSVD	N15
RSVD	N18
RSVD	N17
RSVD	L17

Signal Name	Ball #
RSVD	AD12
RSVD	AD13
RSVD	Y12
RSVD	AA9
RSVD	AA10
RSVD	AA11
RSVD	R29
RSVD	R30
RSVD	U30
RSVD	U31
RSVD	R13
RSVD	R12
RSVD	U11
RSVD	U12
RSVD	AA39
RSVD	AP21
RSVD	AW42
RSVD	BB2
RSVD	AF32
RSVD	AG32
RSVD	BB19
RSVD	AM21
RSVD	BB31
RSVD	BB29
RSVD	AY31
RSVD	AY27
RSVD	BA11
RSVD	BB11
RSVD	AP32
RSVD	AW27
RSVD	AR29
RSVD	AN33
RSVD	AV29
RSVD	AU29
RSVD	AM31
RSVD	AN32
RSVD	AN21
RSVD	BA39
RSVD	BB35

Signal Name	Ball #
RSVD	BB38
RSVD	BA34
RSVD	BA19
RSVD	AY21
RSVD	AU33
RSVD	AM27
RSVD	AP31
RSVD	AT33
RSVD	AM26
RSVD	AP29
RSTIN#	AM18
SBS_A0	BA33
SBS_A1	AW32
SBS_A2	BB21
SBS_B0	AY19
SBS_B1	BA18
SBS_B2	BC12
SCAS_A#	AY35
SCAS_B#	AW29
SCKE_A0	BC20
SCKE_A1	AY20
SCKE_B0	AY12
SCKE_B1	AW12
SCLK_A0	AU31
SCLK_A0#	AR31
SCLK_A1	AP27
SCLK_A1#	AN27
SCLK_A2	AV33
SCLK_A2#	AW33
SCLK_B0	AV31
SCLK_B0#	AW31
SCLK_B1	AU27
SCLK_B1#	AT27
SCLK_B2	AV32
SCLK_B2#	AT32
SCS_A0#	AW35
SCS_A1#	BA35
SCS_B0#	BB27
SCS_B1#	BB30



Signal Name	Ball #	Signal Name	Ball #	Signal Name	Ball #
SDM_A0	AR2	SDQ_A23	BB10	SDQ_A62	AC39
SDM_A1	BA2	SDQ_A24	AT18	SDQ_A63	AB42
SDM_A2	AY9	SDQ_A25	AR18	SDQ_B0	AN7
SDM_A3	AN18	SDQ_A26	AU21	SDQ_B1	AN8
SDM_A4	AU43	SDQ_A27	AT21	SDQ_B2	AW5
SDM_A5	AM43	SDQ_A28	AP17	SDQ_B3	AW7
SDM_A6	AG40	SDQ_A29	AN17	SDQ_B4	AN5
SDM_A7	AC40	SDQ_A30	AP20	SDQ_B5	AN6
SDM_B0	AR7	SDQ_A31	AV20	SDQ_B6	AN9
SDM_B1	AW9	SDQ_A32	AV42	SDQ_B7	AU7
SDM_B2	AW13	SDQ_A33	AU40	SDQ_B8	AT11
SDM_B3	AP23	SDQ_A34	AP42	SDQ_B9	AU11
SDM_B4	AU37	SDQ_A35	AN39	SDQ_B10	AP13
SDM_B5	AM37	SDQ_A36	AV40	SDQ_B11	AR13
SDM_B6	AG39	SDQ_A37	AV41	SDQ_B12	AR11
SDM_B7	AD38	SDQ_A38	AR42	SDQ_B13	AU9
SDQ_A0	AR5	SDQ_A39	AP41	SDQ_B14	AV12
SDQ_A1	AR4	SDQ_A40	AN41	SDQ_B15	AU12
SDQ_A2	AV3	SDQ_A41	AM39	SDQ_B16	AU15
SDQ_A3	AV2	SDQ_A42	AK42	SDQ_B17	AV13
SDQ_A4	AP3	SDQ_A43	AK41	SDQ_B18	AU17
SDQ_A5	AP2	SDQ_A44	AN40	SDQ_B19	AT17
SDQ_A6	AU1	SDQ_A45	AN42	SDQ_B20	AU13
SDQ_A7	AV4	SDQ_A46	AL42	SDQ_B21	AM13
SDQ_A8	AY2	SDQ_A47	AL39	SDQ_B22	AV15
SDQ_A9	AY3	SDQ_A48	AJ40	SDQ_B23	AW17
SDQ_A10	BB5	SDQ_A49	AH43	SDQ_B24	AV24
SDQ_A11	AY6	SDQ_A50	AF39	SDQ_B25	AT23
SDQ_A12	AW2	SDQ_A51	AE40	SDQ_B26	AT26
SDQ_A13	AW3	SDQ_A52	AJ42	SDQ_B27	AP26
SDQ_A14	BA5	SDQ_A53	AJ41	SDQ_B28	AU23
SDQ_A15	BB4	SDQ_A54	AF41	SDQ_B29	AW23
SDQ_A16	AY7	SDQ_A55	AF42	SDQ_B30	AR24
SDQ_A17	BC7	SDQ_A56	AD40	SDQ_B31	AN26
SDQ_A18	AW11	SDQ_A57	AD43	SDQ_B32	AW37
SDQ_A19	AY11	SDQ_A58	AB41	SDQ_B33	AV38
SDQ_A20	BB6	SDQ_A59	AA40	SDQ_B34	AN36
SDQ_A21	BA6	SDQ_A60	AE42	SDQ_B35	AN37
SDQ_A22	BA10	SDQ_A61	AE41	SDQ_B36	AU35



Signal Name	Ball #	Signal Name	Ball #	Signal Name	Ball #
SDQ_B37	AR35	SDQS_A6	AG42	SMA_B0	BB17
SDQ_B38	AN35	SDQS_A6#	AG41	SMA_B1	AY17
SDQ_B39	AR37	SDQS_A7	AC42	SMA_B2	BA17
SDQ_B40	AM35	SDQS_A7#	AC41	SMA_B3	BC16
SDQ_B41	AM38	SDQS_B0	AV6	SMA_B4	AW15
SDQ_B42	AJ34	SDQS_B0#	AU5	SMA_B5	BA15
SDQ_B43	AL38	SDQS_B1	AR12	SMA_B6	BB15
SDQ_B44	AR39	SDQS_B1#	AP12	SMA_B7	BA14
SDQ_B45	AM34	SDQS_B2	AP15	SMA_B8	AY15
SDQ_B46	AL37	SDQS_B2#	AR15	SMA_B9	BB14
SDQ_B47	AL32	SDQS_B2#	AR15	SMA_B10	AW18
SDQ_B48	AG38	SDQS_B3	AT24	SMA_B11	BB13
SDQ_B49	AJ38	SDQS_B3#	AU26	SMA_B12	BA13
SDQ_B50	AF35	SDQS_B3#	AU26	SMA_B13	AY29
SDQ_B51	AF33	SDQS_B4	AW39	SMA_B14	AY13
SDQ_B52	AJ37	SDQS_B4#	AU39	SMRCOMPVOH	AM10
SDQ_B53	AJ35	SDQS_B5	AL35	SMRCOMPVOL	AM8
SDQ_B54	AG33	SDQS_B5#	AL34	SODT_A0	AY37
SDQ_B55	AF34	SDQS_B6	AG35	SODT_A1	BA38
SDQ_B56	AD36	SDQS_B6#	AG36	SODT_B0	BA29
SDQ_B57	AC33	SDQS_B7	AC36	SODT_B1	BA30
SDQ_B58	AA34	SDQS_B7#	AC37	SRAS_A#	BB33
SDQ_B59	AA36	SDVO_CTRLCLK	E17	SRAS_B#	AW26
SDQ_B60	AD34	SDVO_CTRLDATA	G17	SRCOMP0	AN2
SDQ_B61	AF38	SMA_A0	BA31	SRCOMP1	AN3
SDQ_B62	AC34	SMA_A1	BB25	SRCOMP2	BB40
SDQ_B63	AA33	SMA_A2	BA26	SRCOMP3	BA40
SDQS_A0	AU4	SMA_A3	BA25	SVREF	AM6
SDQS_A0#	AR3	SMA_A4	AY25	SWE_A#	BB34
SDQS_A1	BB3	SMA_A5	BA23	SWE_B#	BA27
SDQS_A1#	BA4	SMA_A6	AY24	TEST0	BC43
SDQS_A2	BB9	SMA_A7	AY23	TEST1	BC1
SDQS_A2#	BA9	SMA_A8	BB23	TEST2	A43
SDQS_A3	AT20	SMA_A9	BA22	V_1P25_PLTRST#	AA12
SDQS_A3#	AU18	SMA_A10	AY33	VCC	P20
SDQS_A4	AR41	SMA_A11	BB22	VCC	Y11
SDQS_A4#	AR40	SMA_A12	AW21	VCC	AG25
SDQS_A5	AL41	SMA_A13	AY38	VCC	AG24
SDQS_A5#	AL40	SMA_A14	BA21	VCC	AG23



Signal Name	Ball #	Signal Name	Ball #	Signal Name	Ball #
VCC	AG22	VCC	AA27	VCC	U19
VCC	AG21	VCC	AA26	VCC	U18
VCC	AG20	VCC	AA17	VCC	U17
VCC	AG19	VCC	AA15	VCC	U15
VCC	AG18	VCC	AA14	VCC	U14
VCC	AG17	VCC	Y27	VCC	R20
VCC	AG15	VCC	Y26	VCC	R18
VCC	AG14	VCC	Y18	VCC	R17
VCC	AF26	VCC	Y17	VCC	R15
VCC	AF25	VCC	Y15	VCC	R14
VCC	AF24	VCC	Y14	VCC	P15
VCC	AF22	VCC	W27	VCC	P14
VCC	AF20	VCC	W26	VCC	AJ12
VCC	AF18	VCC	W25	VCC	AJ11
VCC	AF17	VCC	W23	VCC	AJ10
VCC	AF15	VCC	W21	VCC	AJ9
VCC	AF14	VCC	W19	VCC	AJ8
VCC	AE27	VCC	W18	VCC	AJ7
VCC	AE26	VCC	W17	VCC	AJ6
VCC	AE25	VCC	V27	VCC	AJ5
VCC	AE23	VCC	V26	VCC	AJ4
VCC	AE21	VCC	V25	VCC	AJ3
VCC	AE19	VCC	V24	VCC	AJ2
VCC	AE17	VCC	V23	VCC	AH4
VCC	AD27	VCC	V22	VCC	AH2
VCC	AD26	VCC	V21	VCC	AH1
VCC	AD18	VCC	V20	VCC	AG13
VCC	AD17	VCC	V19	VCC	AG12
VCC	AD15	VCC	V18	VCC	AG11
VCC	AD14	VCC	V17	VCC	AG10
VCC	AC27	VCC	V15	VCC	AG9
VCC	AC26	VCC	V14	VCC	AG8
VCC	AC17	VCC	U26	VCC	AG7
VCC	AC15	VCC	U25	VCC	AG6
VCC	AC14	VCC	U24	VCC	AG5
VCC	AB27	VCC	U23	VCC	AG4
VCC	AB26	VCC	U22	VCC	AG3
VCC	AB18	VCC	U21	VCC	AG2
VCC	AB17	VCC	U20	VCC	AF13



Signal Name	Ball #
VCC	AF12
VCC	AF11
VCC	AD24
VCC	AD22
VCC	AD20
VCC	AC25
VCC	AC23
VCC	AC21
VCC	AC19
VCC	AC13
VCC	AC6
VCC	AB24
VCC	AB22
VCC	AB20
VCC	AA25
VCC	AA23
VCC	AA21
VCC	AA19
VCC	AA13
VCC	AA3
VCC	Y24
VCC	Y22
VCC	Y20
VCC	Y13
VCC	Y6
VCC	V13
VCC	V12
VCC	V10
VCC	V9
VCC	U13
VCC	U10
VCC	U9
VCC	U6
VCC	U3
VCC	N12
VCC	N11
VCC	N9
VCC	N8
VCC	N6

Signal Name	Ball #
VCC	N3
VCC	L6
VCC	J6
VCC	J3
VCC	J2
VCC	G2
VCC	F11
VCC	F9
VCC	D4
VCC	C13
VCC	C9
VCC	L12
VCC_EXP	AD11
VCC_EXP	AD10
VCC_EXP	AD9
VCC_EXP	AD8
VCC_EXP	AD7
VCC_EXP	AD6
VCC_EXP	AD5
VCC_EXP	AD4
VCC_EXP	AD2
VCC_EXP	AD1
VCC_EXP	AC4
VCC_EXP	AC3
VCC_EXP	AC2
VCC_EXP	AE4
VCC_EXP	AE3
VCC_EXP	AE2
VCC_SMCLK	BB42
VCC_SMCLK	BA43
VCC_SMCLK	BB41
VCC_SMCLK	BA42
VCC_SMCLK	AY42
VCC2	AJ26
VCC2	AJ24
VCC2	AJ23
VCC2	AJ21
VCC2	AJ20
VCC2	AJ18

Signal Name	Ball #
VCC2	AJ17
VCC2	AJ15
VCC2	AJ14
VCC2	AA30
VCC2	AA29
VCC2	Y30
VCC2	Y29
VCC2	V30
VCC2	V29
VCC2	U29
VCC2	U27
VCC2	AL12
VCC2	AL11
VCC2	AL10
VCC2	AL9
VCC2	AL8
VCC2	AL7
VCC2	AL6
VCC2	AL5
VCC2	AL4
VCC2	AL3
VCC2	AL2
VCC2	AK26
VCC2	AK24
VCC2	AK23
VCC2	AK21
VCC2	AK20
VCC2	AK18
VCC2	AK17
VCC2	AK15
VCC2	AK3
VCC2	AK2
VCC2	AK1
VCC2	AJ13
VCC2	AD31
VCC2	AC31
VCC2	AA31
VCC2	Y31
VCC2	Y32



Signal Name	Ball #	Signal Name	Ball #	Signal Name	Ball #
VCC2	AJ30	VCCA_DPLL	C22	VSS	AE22
VCC2	AJ29	VCCA_EXP	A16	VSS	AE20
VCC2	AJ27	VCCA_EXPPLL	B15	VSS	AE18
VCC2	AG30	VCCA_HPLL	C23	VSS	AC18
VCC2	AG29	VCCA_MPLL	A24	VSS	AA18
VCC2	AG27	VCCD_CRT	C21	VSS	W24
VCC2	AG26	VCCDQ_CRT	B21	VSS	W22
VCC2	AF30	VCCSM	BC39	VSS	W20
VCC2	AF29	VCCSM	BC34	VSS	R21
VCC2	AF27	VCCSM	BC30	VSS	E1
VCC2	AD30	VCCSM	BC26	VSS	C43
VCC2	AD29	VCCSM	BC22	VSS	C1
VCC2	AC30	VCCSM	BC18	VSS	A41
VCC2	AC29	VCCSM	BC14	VSS	A5
VCC2	AL26	VCCSM	BB39	VSS	A3
VCC2	AL24	VCCSM	BB37	VSS	BC37
VCC2	AL23	VCCSM	BB32	VSS	BC32
VCC2	AL21	VCCSM	BB28	VSS	BC28
VCC2	AL20	VCCSM	BB26	VSS	BC24
VCC2	AL18	VCCSM	BB24	VSS	BC10
VCC2	AL17	VCCSM	BB20	VSS	BC5
VCC2	AL15	VCCSM	BB18	VSS	BB7
VCC2	AK30	VCCSM	BB16	VSS	AY41
VCC2	AK29	VCCSM	BB12	VSS	AY4
VCC2	AK27	VCCSM	AY32	VSS	AW43
VCC2	AJ31	VCCSM	AW24	VSS	AW41
VCC2	AG31	VCCSM	AW20	VSS	AW1
VCC2	AF31	VCCSM	AV26	VSS	AV37
VCC2	AD32	VCCSM	AV18	VSS	AV35
VCC2	AC32	VREF2	AM5	VSS	AV27
VCC2	AA32	VSS	D16	VSS	AV23
VCC2	AL29	VSS	BC41	VSS	AV21
VCC2	AL27	VSS	BC3	VSS	AV17
VCC2	AL13	VSS	BA1	VSS	AV11
VCC2	AK14	VSS	AY40	VSS	AV9
VCC3_3	B17	VSS	AF23	VSS	AV7
VCCA_DAC	C17	VSS	AF21	VSS	AU42
VCCA_DAC	B16	VSS	AF19	VSS	AU38
VCCA_DPLLA	A22	VSS	AE24	VSS	AU32



Signal Name	Ball #
VSS	AU24
VSS	AU20
VSS	AU6
VSS	AU2
VSS	AT31
VSS	AT29
VSS	AT15
VSS	AT13
VSS	AT12
VSS	AR38
VSS	AR33
VSS	AR32
VSS	AR27
VSS	AR26
VSS	AR23
VSS	AR21
VSS	AR20
VSS	AR17
VSS	AR9
VSS	AR6
VSS	AP43
VSS	AP24
VSS	AP18
VSS	AP1
VSS	AN38
VSS	AN31
VSS	AN29
VSS	AN24
VSS	AN23
VSS	AN20
VSS	AN15
VSS	AN13
VSS	AN12
VSS	AN11
VSS	AN4
VSS	AM42
VSS	AM40
VSS	AM36
VSS	AM33

Signal Name	Ball #
VSS	AM29
VSS	AM24
VSS	AM23
VSS	AM20
VSS	AM11
VSS	AM9
VSS	AM7
VSS	AM4
VSS	AM2
VSS	AM1
VSS	AL36
VSS	AL33
VSS	AK43
VSS	AJ39
VSS	AJ36
VSS	AJ33
VSS	AH42
VSS	AG37
VSS	AG34
VSS	AF43
VSS	AF37
VSS	AF36
VSS	AF10
VSS	AF9
VSS	AF8
VSS	AF7
VSS	AF6
VSS	AF5
VSS	AF3
VSS	AF2
VSS	AF1
VSS	AD42
VSS	AD39
VSS	AD37
VSS	AD35
VSS	AD33
VSS	AD25
VSS	AD23
VSS	AD21

Signal Name	Ball #
VSS	AD19
VSS	AC38
VSS	AC35
VSS	AC24
VSS	AC22
VSS	AC20
VSS	AC10
VSS	AC7
VSS	AC5
VSS	AB43
VSS	AB25
VSS	AB23
VSS	AB21
VSS	AB19
VSS	AB2
VSS	AB1
VSS	AA38
VSS	AA35
VSS	AA24
VSS	AA22
VSS	AA20
VSS	AA8
VSS	AA5
VSS	Y42
VSS	Y37
VSS	Y35
VSS	Y33
VSS	Y25
VSS	Y23
VSS	Y21
VSS	Y19
VSS	Y10
VSS	Y7
VSS	Y5
VSS	Y1
VSS	W3
VSS	V43
VSS	V39
VSS	V37



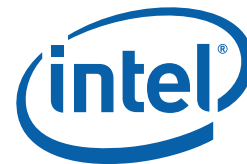
Signal Name	Ball #	Signal Name	Ball #	Signal Name	Ball #
VSS	V34	VSS	M27	VSS	G42
VSS	V32	VSS	M21	VSS	G38
VSS	V11	VSS	M17	VSS	G32
VSS	V8	VSS	M15	VSS	G21
VSS	V5	VSS	M10	VSS	G13
VSS	V2	VSS	M7	VSS	G12
VSS	U38	VSS	M1	VSS	G11
VSS	U35	VSS	L33	VSS	G9
VSS	U8	VSS	L32	VSS	G7
VSS	U7	VSS	L31	VSS	G1
VSS	U5	VSS	L29	VSS	F37
VSS	T42	VSS	L21	VSS	F35
VSS	T1	VSS	L20	VSS	F27
VSS	R36	VSS	L11	VSS	F21
VSS	R33	VSS	L7	VSS	F18
VSS	R31	VSS	L5	VSS	F3
VSS	R11	VSS	L3	VSS	E43
VSS	R8	VSS	K43	VSS	E32
VSS	R5	VSS	K26	VSS	E24
VSS	R3	VSS	K21	VSS	E21
VSS	P43	VSS	K18	VSS	E20
VSS	P30	VSS	K13	VSS	E15
VSS	P21	VSS	K12	VSS	E13
VSS	P18	VSS	K2	VSS	E11
VSS	P17	VSS	J38	VSS	E9
VSS	V32	VSS	J35	VSS	E3
VSS	V11	VSS	J32	VSS	D40
VSS	V8	VSS	J27	VSS	D31
VSS	V5	VSS	J21	VSS	D21
VSS	V2	VSS	J9	VSS	D17
VSS	U38	VSS	J7	VSS	D3
VSS	U35	VSS	J5	VSS	C26
VSS	U8	VSS	H31	VSS	C11
VSS	U7	VSS	H29	VSS	C6
VSS	U5	VSS	H21	VSS	C5
VSS	T42	VSS	H20	VSS	C4
VSS	T1	VSS	H17	VSS	B37
VSS	M35	VSS	H15	VSS	B32
VSS	M33	VSS	H13	VSS	B31



Signal Name	Ball #
VSS	B26
VSS	B23
VSS	B22
VSS	B19
VSS	B14
VSS	B10
VSS	A39
VSS	A34
VSS	A26
VSS	A18
VSS	A12
VSS	A7
VSS	M11
VSYN	D15
VTT	R27
VTT	R26
VTT	R24
VTT	R23
VTT	P29
VTT	P27
VTT	P26

Signal Name	Ball #
VTT	P24
VTT	P23
VTT	N29
VTT	N26
VTT	N24
VTT	N23
VTT	M29
VTT	M24
VTT	M23
VTT	L24
VTT	L23
VTT	K24
VTT	K23
VTT	J24
VTT	J23
VTT	H24
VTT	H23
VTT	G26
VTT	G24
VTT	G23
VTT	F26

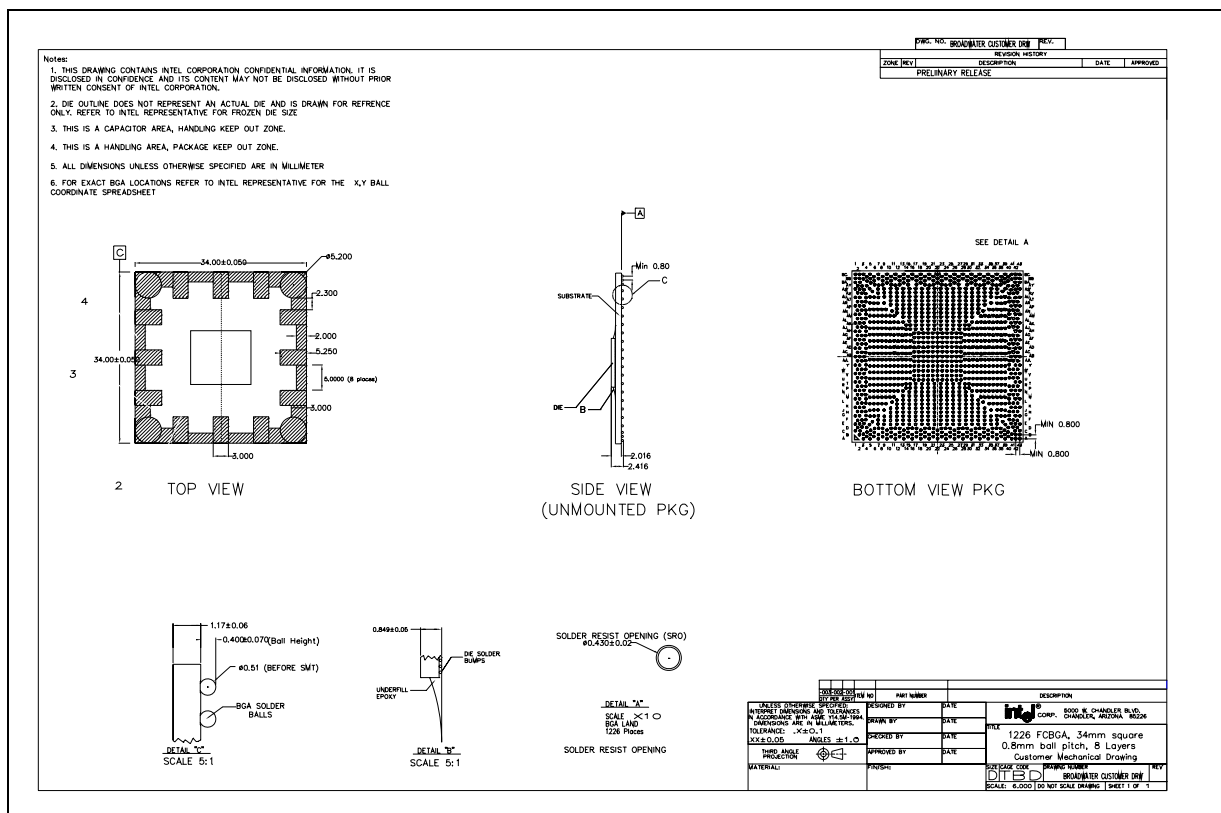
Signal Name	Ball #
VTT	F24
VTT	F23
VTT	E29
VTT	E27
VTT	E26
VTT	E23
VTT	D29
VTT	D28
VTT	D27
VTT	C30
VTT	C29
VTT	C27
VTT	B30
VTT	B29
VTT	B28
VTT	B27
VTT	A30
VTT	A28
XORTEST	F20



11.2 Package Information

For additional information, refer to the *Intel® G31/P31 Express Chipset Thermal and Mechanical Design Guide*.

Figure 11-4. (G)MCH Package Drawing





12 Testability

In the (G)MCH, testability for Automated Test Equipment (ATE) board level testing has been implemented as an XOR chain. An XOR-tree is a chain of XOR gates each with one input pin connected to it which allows for pad to ball to trace connection testing.

The XOR testing methodology is to boot the part using straps to enter XOR mode (A description of the boot process follows). Once in XOR mode, all of the pins of an XOR chain are driven to logic 1. This action will force the output of that XOR chain to either a 1 if the number of the pins making up the chain is even or a 0 if the number of the pins making up the chain is odd.

Once a valid output is detected on the XOR chain output, a walking “0” pattern is moved from one end of the chain to the other. Every time the walking “0” is applied to a pin on the chain, the output will toggle. If the output does not toggle, there is a disconnect somewhere between die, package, and board and the system can be considered a failure.

12.1 XOR Test Mode Initialization

Figure 12-1. XOR Test Mode Initialization Cycles

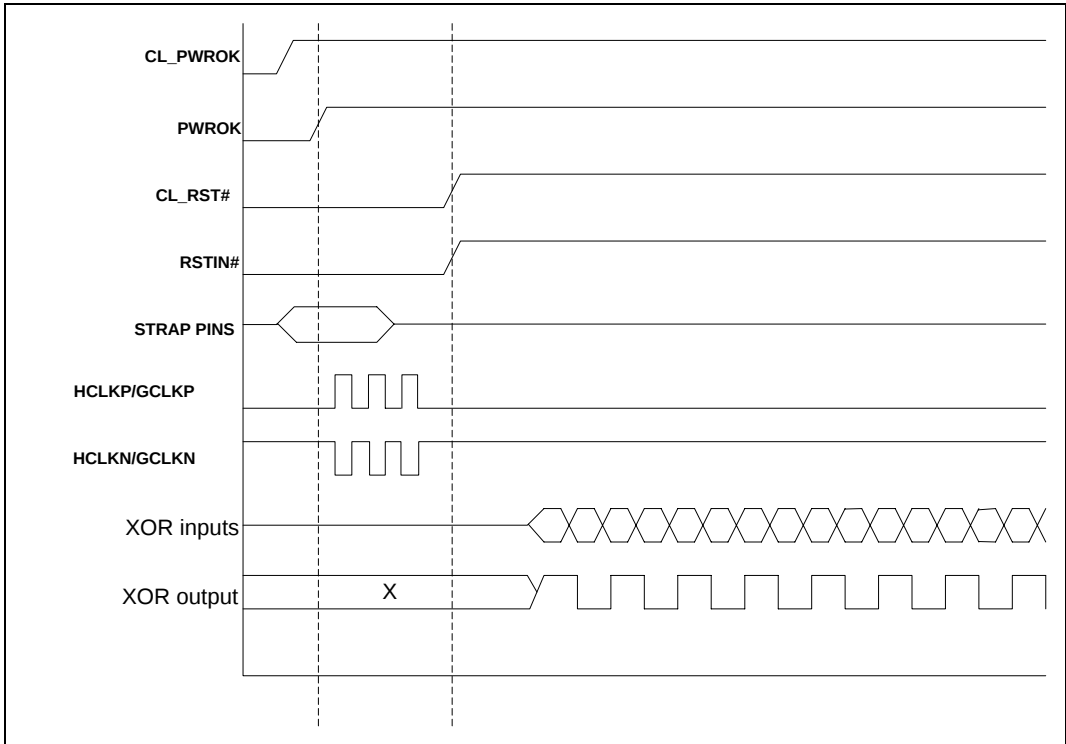


Figure 12-1 shows the wave forms to be able to boot the part into XOR mode. The straps that need to be controlled during this boot process are BSEL[2:0], SDVO_CTRLDATA, EXP_EM, EXP_SLR, and XORTEST.

On Broadwater platforms, all strap values must be driven before PWROK asserts. BSEL0 must be a 1. BSEL[2:1] need to be defined values, but logic value in any order will do. XORTEST must be driven to 0.

If sDVO is present in the design (82G31 GMCH only), SDVO_CTRLDATA must be pulled to logic 1. Depending on if Static Lane Reversal is used and if the sDVO/PCIe Coexistence is selected, EXP_SLR and EXP_EN must be pulled in a valid manner.

Because of the different functionalities of the sDVO/PCIe interface, not all of the pins will be used in all implementations. Due to the need to minimize test points and unnecessary routing, the XOR Chain 14 is dynamic depending on the values of SDVO_CTRLDATA, EXP_SLR, and EXP_EN. See Table 12-1 for what parts of XOR Chain 14 become valid XOR inputs depending on the use of SDVO_CTRLDATA, EXP_SLR, and EXP_EN.

Table 12-1. XOR Chain 14 functionality

SDVO_CTRLDATA	EXP_EN	EXP_SLR	XOR Chain 14
0	1	0	EXP_RXP[15:0] EXP_RXN[15:0] EXP_TXP[15:0] EXP_TXN[15:0]
0	1	1	EXP_RXP[15:0] EXP_RXN[15:0] EXP_TXP[15:0] EXP_TXN[15:0]
1	0	0	EXP_RXP[15:8] EXP_RXN[15:8] EXP_TXP[15:8] EXP_TXN[15:8]
1	0	1	EXP_RXP[7:0] EXP_RXN[7:0] EXP_TXP[7:0] EXP_TXN[7:0]
1	1	0	EXP_RXP[15:0] EXP_RXN[15:0] EXP_TXP[15:0] EXP_TXN[15:0]
1	1	1	EXP_RXP[15:0] EXP_RXN[15:0] EXP_TXP[15:0] EXP_TXN[15:0]



12.2 XOR Chain Definition

The (G)MCH has 15 XOR chains. The XOR chain outputs are driven out on the output pins shown in Table 12-2. During fullwidth testing, XOR chain outputs will be visible on both pins.

Table 12-2. XOR Chain Outputs

XOR Chain	Output Pins	Coordinate Location
xor_out0	ALLZTEST	K20
xor_out1	XORTEST	F20
xor_out2	ICH_SYNC#	J13
xor_out3	RSV	F17
xor_out4	RSV	AA9
xor_out5	RSV	AA10
xor_out6	BSEL1	J20
xor_out7	BSEL2	J18
xor_out8	RSV	AA11
xor_out9	RSV	Y12
xor_out10	EXP_SLR	E18
xor_out11	EXP_EN	J17
xor_out12	MTYPE	G18
xor_out13	RSV	K17
xor_out14	BSEL0	G20

12.3 XOR Chains

The following tables lists the XOR chain.

Table 12-3. XOR Chain 0

Pin Count	Ball #	Signal Name
1	B33	HD58#
2	C35	HD49#
3	B40	HD55#
4	E41	HD50#
5	C40	HD53#
6	B41	HD51#
7	A32	HD62#
8	B35	HD61#
9	C33	HD48#
10	D35	HD54#
11	C38	HD56#
12	D37	HD57#
13	D42	HD52#
14	C34	HD60#
15	D32	HD63#
16	D33	HD59#
17	B34	HD31#
18	A37	HD26#
19	B39	HD24#
20	D41	HD17#
21	C42	HD16#
22	C39	HD23#
23	E37	HD22#
24	E35	HD28#
25	E42	HD20#
26	F38	HD18#
27	E39	HD21#
28	G33	HD25#
29	F33	HD27#

Table 12-3. XOR Chain 0

Pin Count	Ball #	Signal Name
30	G37	HD19#
31	H32	HD30#
32	K32	HD29#
33	F29	HD41#
34	H26	HD44#
35	J26	HD46#
36	G31	HD37#
37	F32	HD33#
38	F31	HD39#
39	E31	HD35#
40	J29	HD40#
41	M26	HD47#
42	L26	HD45#
43	J31	HD32#
44	K27	HD43#
45	L27	HD42#
46	K29	HD38#
47	K31	HD36#
48	M31	HD34#
49	J41	HD11#
50	R42	HD4#
51	F42	HD15#
52	M39	HD5#
53	F41	HD14#
54	G40	HD13#
55	J39	HD9#
56	K41	HD12#
57	N40	HD3#
58	N41	HD6#



Table 12-3. XOR Chain 0

Pin Count	Ball #	Signal Name
59	R41	HD2#
60	L42	HD10#
61	L41	HD8#
62	P41	HD1#
63	N42	HD7#
64	R40	HD0#

Table 12-4. XOR Chain 1

Pin Count	Ball #	Signal Name
1	L37	HA6#
2	N35	HA15#
3	L36	HA7#
4	L39	HA4#
5	M38	HA11#
6	L38	HREQ2#
7	J37	HREQ4#
8	N34	HA10#
9	L35	HREQ1#
10	F40	HREQ0#
11	M34	HADSTB0#
12	M36	HA13#
13	N37	HA12#
14	J40	HA5#
15	K42	HA8#
16	R34	HA14#
17	N32	HA9#
18	N38	HA16#
19	G43	HREQ3#
20	J42	HA3#
21	Y38	HA33#
22	Y34	HA29#

Table 12-4. XOR Chain 1

Pin Count	Ball #	Signal Name
23	V42	HA30#
24	R35	HA26#
25	U36	HA24#
26	U33	HA25#
27	Y39	HA34#
28	V33	HA27#
29	V36	HA22#
30	R38	HA23#
31	U34	HADSTB1#
32	R37	HA19#
33	AA37	HA35#
34	U37	HA17#
35	N39	HA18#
36	V38	HA31#
37	R39	HA21#
38	Y36	HA32#
39	V35	HA28#
40	P42	HA20#

Table 12-5. XOR Chain 2

Pin Count	Ball #	Signal Name
1	G35	HDSTBP1#
2	H33	HDSTBN1#
3	U42	HHIT#
4	Y40	HTRDY#
5	AA41	HRS1#
6	Y43	HHITM#
7	G27	HDSTBP2#
8	H27	HDSTBN2#
9	L40	HDSTBP0#
10	M43	HDSTBN0#

Table 12-5. XOR Chain 2

Pin Count	Ball #	Signal Name
11	V41	HLOCK#
12	W42	HBNR#
13	C31	HCPURST#
14	G39	HBPRI#

Table 12-6. XOR Chain 3

Pin Count	Ball #	Signal Name
1	B38	HDSTBP3#
2	D38	HDSTBN3#
3	E33	HDINV3#
4	J33	HDINV1#
5	U40	HDBSY#
6	U39	HRS2#
7	W41	HDRDY#
8	U41	HRS0#
9	T43	HDEFER#
10	G29	HDINV2#
11	M40	HDINV0#
12	W40	HADS#
13	AA42	HBREQ0#

Table 12-7. XOR Chain 4

Pin Count	Ball #	Signal Name
1	AY37	SODT_A0
2	BA35	SCS_A1#
3	BA38	SODT_A1
4	AY33	SMA_A10
5	AW35	SCS_A0#
6	BA31	SMA_A0
7	AW33	SCLK_A2#

Table 12-7. XOR Chain 4

Pin Count	Ball #	Signal Name
8	AV33	SCLK_A2
9	AU31	SCLK_A0
10	AR31	SCLK_A0#
11	AN27	SCLK_A1#
12	AP27	SCLK_A1
13	BA22	SMA_A9
14	BA26	SMA_A2
15	BA25	SMA_A3
16	AY25	SMA_A4
17	AY23	SMA_A7
18	AY20	SCKE_A1
19	BA23	SMA_A5
20	BB25	SMA_A1
21	BB23	SMA_A8
22	AY24	SMA_A6
23	BC20	SCKE_A0
24	AU18	SDQS_A3#
25	AN18	SDM_A3
26	BA9	SDQS_A2#
27	AY9	SDM_A2
28	BA4	SDQS_A1#
29	BA2	SDM_A1
30	AR3	SDQS_A0#
31	AR2	SDM_A0

Table 12-8. XOR Chain 5

Pin Count	Ball #	Signal Name
1	AC41	SDQS_A7#
2	AC40	SDM_A7
3	AG41	SDQS_A6#
4	AG40	SDM_A6



Table 12-8. XOR Chain 5

Pin Count	Ball #	Signal Name
5	AL40	SDQS_A5#
6	AM43	SDM_A5
7	AR40	SDQS_A4#
8	AU43	SDM_A4
9	AY38	SMA_A13
10	AY35	SCAS_A#
11	AW32	SBS_A1
12	BA33	SBS_A0
13	BB33	SRAS_A#
14	BB34	SWE_A#
15	BB22	SMA_A11
16	BB21	SBS_A2
17	BA21	SMA_A14
18	AW21	SMA_A12

Table 12-9. XOR Chain 6

Pin Count	Ball #	Signal Name
15	AF41	SDQ_A54
16	AJ42	SDQ_A52
17	AJ40	SDQ_A48
18	AF39	SDQ_A50
19	AL41	SDQS_A5
20	AL39	SDQ_A47
21	AN40	SDQ_A44
22	AM39	SDQ_A41
23	AL42	SDQ_A46
24	AN41	SDQ_A40
25	AK42	SDQ_A42
26	AN42	SDQ_A45
27	AK41	SDQ_A43
28	AR41	SDQS_A4
29	AV40	SDQ_A36
30	AV42	SDQ_A32
31	AP41	SDQ_A39
32	AN39	SDQ_A35
33	AU40	SDQ_A33
34	AV41	SDQ_A37
35	AP42	SDQ_A34
36	AR42	SDQ_A38
37	AT20	SDQS_A3
38	AR18	SDQ_A25
39	AU21	SDQ_A26
40	AV20	SDQ_A31
41	AP20	SDQ_A30
42	AT18	SDQ_A24
43	AN17	SDQ_A29
44	AT21	SDQ_A27
45	AP17	SDQ_A28
46	BB9	SDQS_A2
47	AY11	SDQ_A19

Table 12-9. XOR Chain 6

Pin Count	Ball #	Signal Name
1	AC42	SDQS_A7
2	AB41	SDQ_A58
3	AE42	SDQ_A60
4	AD43	SDQ_A57
5	AB42	SDQ_A63
6	AA40	SDQ_A59
7	AC39	SDQ_A62
8	AE41	SDQ_A61
9	AD40	SDQ_A56
10	AG42	SDQS_A6
11	AH43	SDQ_A49
12	AE40	SDQ_A51
13	AJ41	SDQ_A53
14	AF42	SDQ_A55

Table 12-9. XOR Chain 6

Pin Count	Ball #	Signal Name
48	BA10	SDQ_A22
49	AW11	SDQ_A18
50	BC7	SDQ_A17
51	BA6	SDQ_A21
52	BB10	SDQ_A23
53	AY7	SDQ_A16
54	BB6	SDQ_A20
55	BB3	SDQS_A1
56	BB4	SDQ_A15
57	BB5	SDQ_A10
58	AY6	SDQ_A11
59	BA5	SDQ_A14
60	AY2	SDQ_A8
61	AY3	SDQ_A9
62	AW3	SDQ_A13
63	AW2	SDQ_A12
64	AU4	SDQS_A0
65	AV3	SDQ_A2
66	AR4	SDQ_A1
67	AR5	SDQ_A0
68	AP2	SDQ_A5
69	AV4	SDQ_A7
70	AU1	SDQ_A6
71	AP3	SDQ_A4
72	AV2	SDQ_A3

Table 12-10. XOR Chain 8

Pin Count	Ball #	Signal Name
1	AW31	SCLK_B0#
2	AV31	SCLK_B0
3	AT32	SCLK_B2#

Table 12-10. XOR Chain 8

Pin Count	Ball #	Signal Name
4	AU27	SCLK_B1
5	AT27	SCLK_B1#
6	AV32	SCLK_B2
7	BB30	SCS_B1#
8	BA30	SODT_B1
9	BA29	SODT_B0
10	BB27	SCS_B0#
11	AW15	SMA_B4
12	AY17	SMA_B1
13	AY15	SMA_B8
14	BA15	SMA_B5
15	AW18	SMA_B10
16	AW12	SCKE_B1
17	BA14	SMA_B7
18	BA17	SMA_B2
19	AY12	SCKE_B0
20	BB14	SMA_B9
21	BB17	SMA_B0
22	BB15	SMA_B6
23	BC16	SMA_B3
24	AU26	SDQS_B3#
25	AP23	SDM_B3
26	AR15	SDQS_B2#
27	AW13	SDM_B2
28	AP12	SDQS_B1#
29	AW9	SDM_B1
30	AU5	SDQS_B0#
31	AR7	SDM_B0



Table 12-11. XOR Chain 9

Pin Count	Ball #	Signal Name
1	AC37	SDQS_B7#
2	AD38	SDM_B7
3	AG36	SDQS_B6#
4	AG39	SDM_B6
5	AL34	SDQS_B5#
6	AM37	SDM_B5
7	AU39	SDQS_B4#
8	AU37	SDM_B4
9	AY29	SMA_B13
10	AW26	SRAS_B#
11	AW29	SCAS_B#
12	BA27	SWE_B#
13	BA18	SBS_B1
14	AY19	SBS_B0
15	AY13	SMA_B14
16	BC12	SBS_B2
17	BA13	SMA_B12
18	BB13	SMA_B11

Table 12-12. XOR Chain 10

Pin Count	Ball #	Signal Name
1	AC36	SDQS_B7
2	AF38	SDQ_B61
3	AC34	SDQ_B62
4	AA34	SDQ_B58
5	AA33	SDQ_B63
6	AA36	SDQ_B59
7	AD36	SDQ_B56
8	AC33	SDQ_B57
9	AD34	SDQ_B60
10	AG35	SDQS_B6

Table 12-12. XOR Chain 10

Pin Count	Ball #	Signal Name
11	AF34	SDQ_B55
12	AJ38	SDQ_B49
13	AF33	SDQ_B51
14	AJ35	SDQ_B53
15	AG33	SDQ_B54
16	AG38	SDQ_B48
17	AJ37	SDQ_B52
18	AF35	SDQ_B50
19	AL35	SDQS_B5
20	AL38	SDQ_B43
21	AJ34	SDQ_B42
22	AM34	SDQ_B45
23	AL32	SDQ_B47
24	AM38	SDQ_B41
25	AM35	SDQ_B40
26	AL37	SDQ_B46
27	AR39	SDQ_B44
28	AW39	SDQS_B4
29	AV38	SDQ_B33
30	AN35	SDQ_B38
31	AN36	SDQ_B34
32	AR37	SDQ_B39
33	AW37	SDQ_B32
34	AU35	SDQ_B36
35	AN37	SDQ_B35
36	AR35	SDQ_B37
37	AT24	SDQS_B3
38	AP26	SDQ_B27
39	AU23	SDQ_B28
40	AT23	SDQ_B25
41	AV24	SDQ_B24
42	AR24	SDQ_B30
43	AW23	SDQ_B29

Table 12-12. XOR Chain 10

Pin Count	Ball #	Signal Name
44	AT26	SDQ_B26
45	AN26	SDQ_B31
46	AP15	SDQS_B2
47	AM13	SDQ_B21
48	AU15	SDQ_B16
49	AT17	SDQ_B19
50	AU17	SDQ_B18
51	AW17	SDQ_B23
52	AV13	SDQ_B17
53	AV15	SDQ_B22
54	AU13	SDQ_B20
55	AR12	SDQS_B1
56	AR11	SDQ_B12
57	AV12	SDQ_B14
58	AU11	SDQ_B9
59	AU12	SDQ_B15
60	AR13	SDQ_B11
61	AU9	SDQ_B13
62	AP13	SDQ_B10
63	AT11	SDQ_B8
64	AV6	SDQS_B0
65	AU7	SDQ_B7
66	AW7	SDQ_B3
67	AN6	SDQ_B5
68	AW5	SDQ_B2
69	AN9	SDQ_B6
70	AN5	SDQ_B4
71	AN7	SDQ_B0
72	AN8	SDQ_B1

Table 12-13. XOR Chain 12

Pin Count	Ball #	Signal Name
1	G17	SDVO_CTRLDATA
2	E17	SDVO_CTRLCLK
3	L13	DDC_DATA
4	M13	DDC_CLK

Table 12-14. XOR Chain 13

Pin Count	Ball #	Signal Name
1	AA2	DMI_TXN_3
2	Y2	DMI_TXP_3
3	AA4	DMI_RXN_3
4	AB3	DMI_RXP_3
5	AC9	DMI_TXN_2
6	AC8	DMI_TXP_2
7	AA6	DMI_RXN_2
8	AA7	DMI_RXP_2
9	Y4	DMI_TXN_1
10	W4	DMI_TXP_1
11	Y9	DMI_RXN_1
12	Y8	DMI_RXP_1
13	V6	DMI_TXN_0
14	V7	DMI_TXP_0
15	V1	DMI_RXN_0
16	W2	DMI_RXP_0

Table 12-15. XOR Chain 14

Pin Count	Ball #	Signal Name
1	U4	EXP_TXN15
2	V3	EXP_TXP15
3	R7	EXP_RXN15
4	R6	EXP_RXP15



Table 12-15. XOR Chain 14

Pin Count	Ball #	Signal Name
5	T2	EXP_TXN14
6	U2	EXP_TXP14
7	R4	EXP_RXN14
8	T4	EXP_RXP14
9	P1	EXP_TXN13
10	R2	EXP_TXP13
11	R10	EXP_RXN13
12	R9	EXP_RXP13
13	N4	EXP_TXN12
14	P3	EXP_TXP12
15	M6	EXP_RXN12
16	M5	EXP_RXP12
17	M2	EXP_TXN11
18	N2	EXP_TXP11
19	L4	EXP_RXN11
20	M4	EXP_RXP11
21	K1	EXP_TXN10
22	L2	EXP_TXP10
23	M9	EXP_RXN10
24	M8	EXP_RXP10
25	K3	EXP_TXN9
26	J4	EXP_TXP9
27	L8	EXP_RXN9
28	L9	EXP_RXP9
29	G4	EXP_TXN8
30	F4	EXP_TXP8
31	G5	EXP_RXN8
32	G6	EXP_RXP8
33	E2	EXP_TXN7
34	F2	EXP_TXP7
35	D2	EXP_RXN7
36	C2	EXP_RXP7

Table 12-15. XOR Chain 14

Pin Count	Ball #	Signal Name
37	B4	EXP_TXN6
38	B3	EXP_TXP6
39	F6	EXP_RXN6
40	E5	EXP_RXP6
41	B6	EXP_TXN5
42	B5	EXP_TXP5
43	E7	EXP_RXN5
44	F7	EXP_RXP5
45	D6	EXP_TXN4
46	D7	EXP_TXP4
47	H11	EXP_RXN4
48	J11	EXP_RXP4
49	B7	EXP_TXN3
50	B9	EXP_TXP3
51	H12	EXP_RXN3
52	J12	EXP_RXP3
53	D9	EXP_TXN2
54	C10	EXP_TXP2
55	E12	EXP_RXN2
56	F12	EXP_RXP2
57	A10	EXP_TXN1
58	B11	EXP_TXP1
59	J15	EXP_RXN1
60	K15	EXP_RXP1
61	D12	EXP_TXN0
62	D11	EXP_TXP0
63	G15	EXP_RXN0
64	F15	EXP_RXP0

