NKK

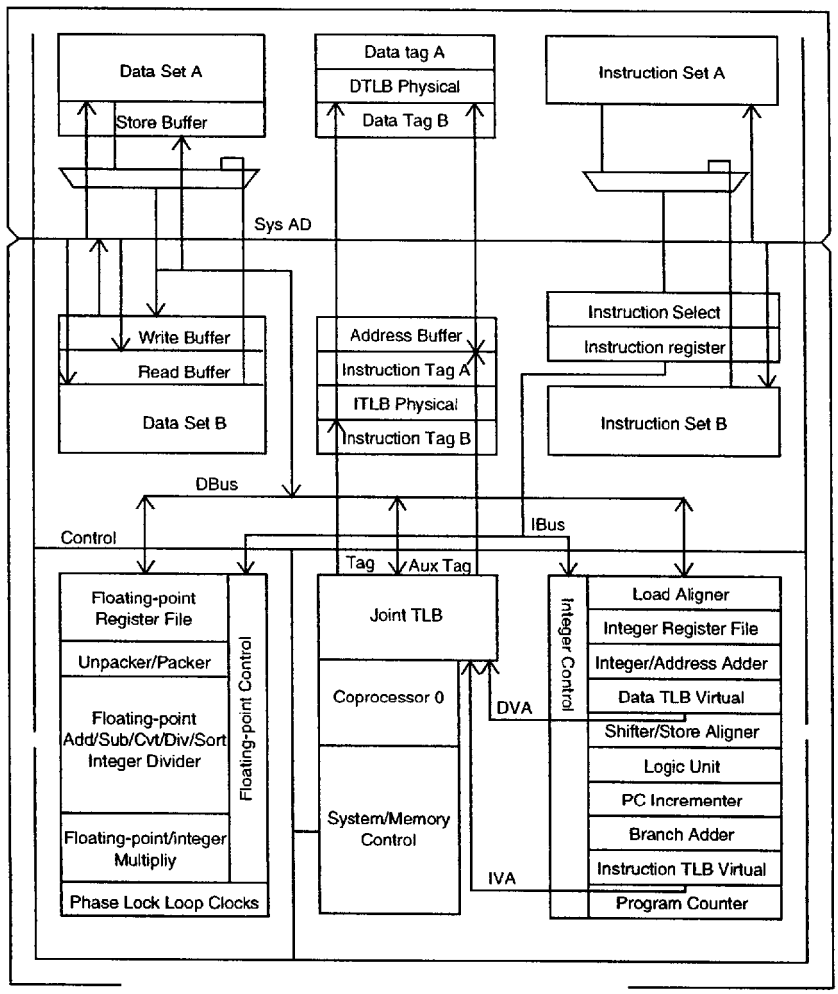
FOURTH GENERATION 64bit RISC Microprocessor

NR4700

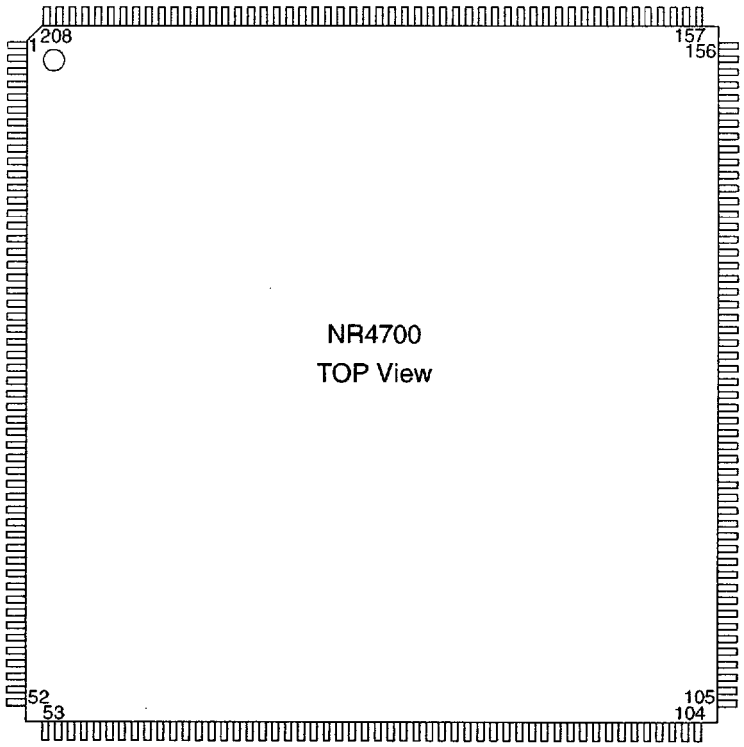
■ FEATURES:

- True 64-bit microprocessor
  - 64-bit integer operations
  - 64-bit floating-point operations
  - 64-bit registers
  - 64-bit virtual address space
- High-performance microprocessor
  - 150 peak MIPS at 150MHz
  - 75 peak MFLOPS/s at 150MHz
  - 110 SPECint92 at 150MHz
  - Two-way set associative caches
- Improved FPA multiply performance
  - 1 mul, 1 add every 4 clock cycles
- High level of integration
  - 64-bit integer CPU
  - 64-bit floating-point unit
  - 16KB instruction cache; 16KB data cache
  - Flexible-MMU with large TLB
- Low-power operation
  - 3.3V power supply
  - 24mW/MHz internal power dissipation (3.6W @ 150MHz, 3.3V)
  - Standby mode reduces internal power
- Standard operating system support includes :
  - Microsoft® Windows NT™
  - UNISOFT Unix™ System V.4
- Fully software and pin-compatible with NR4600 Processor
- Available in NR4600 pin-compatible 179-pin PGA or 208-pin MQUAD
- 50MHz, 67MHz, 75MHz input frequency with mode bit dependent output clock frequency
  - On chip clock doubler for 150MHz pipeline
- 64GB physical address space
- Processor family for a wide variety of applications
  - Desktop workstations and PCs
  - Deskside or departmental servers
  - High-performance embedded applications (e.g. color printers, multi-media and internetworking)
  - Notebooks

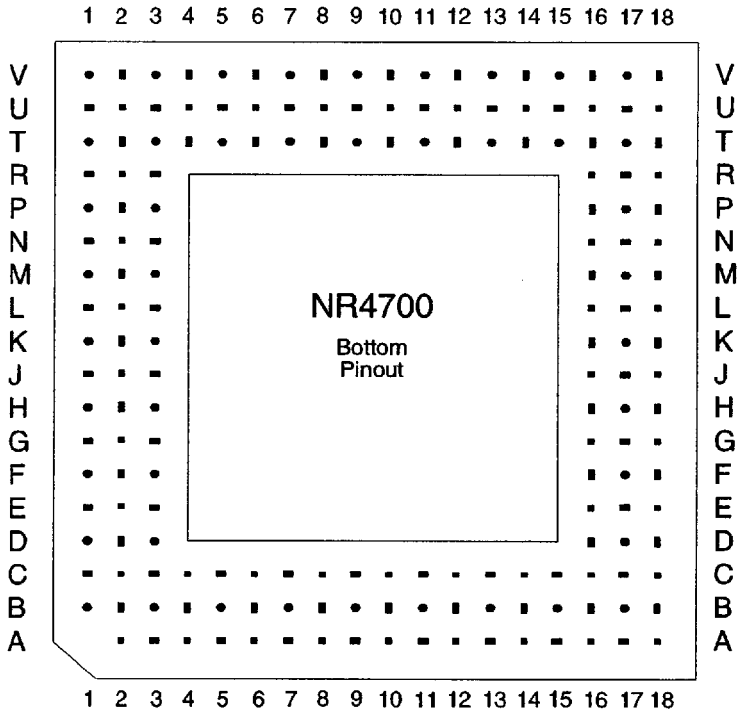
■ Block diagram



PHYSICAL SPECIFICATIONS -MQUAD



PHYSICAL SPECIFICATIONS - PGA



NR4700 MQUAD package pin-out

Pin	Function	Pin	Function	Pin	Function	Pin	Function
1	N.C.	53	N.C.	105	N.C.	157	N.C.
2	N.C.	54	N.C.	106	N.C.	158	N.C.
3	Vss	55	SysCmd2	107	N.C.	159	RClock0
4	Vcc	56	SysAD36	108	N.C.	160	RClock1
5	SysAD45	57	SysAD4	109	Vcc	161	SyncOut
6	SysAD13	58	SysCmd1	110	Vss	162	SysAD30
7	Fault	59	Vss	111	SysAD21	163	Vcc
8	SysAD44	60	Vcc	112	SysAD53	164	Vss
9	Vss	61	SysAD35	113	RdRdy	165	SysAD62
10	Vcc	62	SysAD3	114	ModeIn	166	MasterOut
11	SysAD12	63	SysCmd0	115	SysAD22	167	SysAD31
12	SysCmdP	64	SysAD34	116	SysAD54	168	SysAD63
13	SysAD43	65	Vss	117	Vcc	169	Vcc
14	SysAD11	66	Vcc	118	Vss	170	Vss
15	Vss	67	N.C.	119	Release	171	VCCOK
16	Vcc	68	N.C.	120	SysAD23	172	SysADC3
17	SysCmd8	69	SysAD2	121	SysAD55	173	SysADC7
18	SysAD42	70	Int5	122	NMI	174	Vcc
19	SysAD10	71	SysAD33	123	Vcc	175	Vss
20	SysCmd7	72	SysAD1	124	Vss	176	N.C.
21	Vss	73	Vss	125	SysADC2	177	N.C.
22	Vcc	74	Vcc	126	SysADC6	178	N.C.
23	SysAD41	75	Int4	127	Vcc	179	N.C.
24	SysAD9	76	SysAD32	128	SysAD24	180	N.C.
25	SysCmd6	77	SysAD0	129	Vcc	181	VccP
26	SysAD40	78	Int3	130	Vss	182	VssP
27	N.C.	79	Vss	131	SysAD56	183	N.C.
28	N.C.	80	Vcc	132	N.C.	184	N.C.
29	Vss	81	Int2	133	SysAD25	185	MasterClock
30	Vcc	82	SysAD16	134	SysAD57	186	Vcc
31	SysAD8	83	SysAD48	135	Vcc	187	Vss
32	SysCmd5	84	Int1	136	Vss	188	SyncIn
33	SysADC4	85	Vss	137	IOOut	189	Vcc
34	SysADC0	86	Vcc	138	SysAD26	190	Vss
35	Vss	87	SysAD17	139	SysAD58	191	JTCK
36	Vcc	88	SysAD49	140	IOIn	192	SysADC5
37	SysCmd4	89	Int0	141	Vcc	193	SysADC1
38	SysAD39	90	SysAD18	142	Vss	194	JTDI
39	SysAD7	91	Vss	143	SysAD27	195	Vcc
40	SysCmd3	92	Vcc	144	SysAD59	196	Vss
41	Vss	93	SysAD50	145	ColdReset	197	SysAD47
42	Vcc	94	ValidIn	146	SysAD28	198	SysAD15
43	SysAD38	95	SysAD19	147	Vcc	199	JTD0
44	SysAD6	96	SysAD51	148	Vss	200	SysAD46
45	ModeClock	97	Vss	149	SysAD60	201	Vcc
46	WrRdy	98	Vcc	150	Reset	202	Vss
47	SysAD37	99	ValidOut	151	SysAD29	203	SysAD14
48	SysAD5	100	SysAD20	152	SysAD61	204	JTMS
49	Vss	101	SysAD52	153	Vcc	205	TClock1
50	Vcc	102	ExtRqst	154	Vss	206	TClock0
51	N.C.	103	N.C.	155	N.C.	207	N.C.
52	N.C.	104	N.C.	156	N.C.	208	N.C.

NR4700 PGA pin-out

Function	Pin
$\overline{\text{ColdReset}}$	T14
$\overline{\text{ExtRqst}}$	U2
$\overline{\text{Fault}}$	B16
Reserved O (NC)	U10
Reserved I (Vcc)	T9
IOIn	T13
IOOut	U12
$\overline{\text{Int0}}$	N2
$\overline{\text{Int1}}$	L3
$\overline{\text{Int2}}$	K3
$\overline{\text{Int3}}$	J3
$\overline{\text{Int4}}$	H3
$\overline{\text{Int5}}$	F2
JTCK	H17
JTDI	G16
JTDO	F16
JTMS	E16
MasterClock	J17
MasterOut	P17
ModeClock	B4
ModeIn	U4
$\overline{\text{NMI}}$	U7
RClock0	T17
RClock1	R16
$\overline{\text{RdRdy}}$	T5
$\overline{\text{Release}}$	V5
$\overline{\text{Reset}}$	U16
SyncIn	J16
SyncOut	P16

Function	Pin
SysAD0	J2
SysAD1	G2
SysAD2	E1
SysAD3	E3
SysAD4	C2
SysAD5	C4
SysAD6	B5
SysAD7	B6
SysAD8	B9
SysAD9	B11
SysAD10	C12
SysAD11	B14
SysAD12	B15
SysAD13	C16
SysAD14	D17
SysAD15	E18
SysAD16	K2
SysAD17	M2
SysAD18	P1
SysAD19	P3
SysAD20	T2
SysAD21	T4
SysAD22	U5
SysAD23	U6
SysAD24	U9
SysAD25	U11
SysAD26	T12
SysAD27	U14
SysAD28	U15
SysAD29	T16

Function	Pin
SysAD30	R17
SysAD31	M16
SysAD32	H2
SysAD33	G3
SysAD34	F3
SysAD35	D2
SysAD36	C3
SysAD37	B3
SysAD38	C6
SysAD39	C7
SysAD40	C10
SysAD41	C11
SysAD42	B13
SysAD43	A15
SysAD44	C15
SysAD45	B17
SysAD46	E17
SysAD47	F17
SysAD48	L2
SysAD49	M3
SysAD50	N3
SysAD51	R2
SysAD52	T3
SysAD53	U3
SysAD54	T6
SysAD55	T7
SysAD56	T10
SysAD57	T11
SysAD58	U13
SysAD59	V15

Function	Pin
SysAD60	T15
SysAD61	U17
SysAD62	N16
SysAD63	N17
SysADC0	C8
SysADC1	G17
SysADC2	T8
SysADC3	L16
SysADC4	B8
SysADC5	H16
SysADC6	U8
SysADC7	L17
SysCmd0	E2
SysCmd1	D3
SysCmd2	B2
SysCmd3	A5
SysCmd4	B7
SysCmd5	C9
SysCmd6	B10
SysCmd7	B12
SysCmd8	C13
SysCmdP	C14
TClock0	C17
TClock1	D16
VCCOK	M17
$\overline{\text{ValidIn}}$	P2
$\overline{\text{ValidOut}}$	R3
$\overline{\text{WrRdy}}$	C5
VccP	K17
VssP	K16

Function	Pin
Vcc	A2
Vcc	A4
Vcc	A9
Vcc	A11
Vcc	A13
Vcc	A16
Vcc	B18
Vcc	C1
Vcc	D18
Vcc	F1
Vcc	G18
Vcc	H1
Vcc	J18
Vcc	K1
Vcc	L18
Vcc	M1
Vcc	N18
Vcc	R1
Vcc	T18
Vcc	U1
Vcc	V3
Vcc	V6
Vcc	V8
Vcc	V10
Vcc	V12
Vcc	V14
Vcc	V17
Vss	A3
Vss	A6
Vss	A8

Function	Pin
Vss	A10
Vss	A12
Vss	A14
Vss	A17
Vss	A18
Vss	B1
Vss	C18
Vss	D1
Vss	F18
Vss	G1
Vss	H18
Vss	J1
Vss	K18
Vss	L1
Vss	M18
Vss	N1
Vss	P18
Vss	R18
Vss	T1
Vss	U18
Vss	V1
Vss	V2
Vss	V4
Vss	V7
Vss	V9
Vss	V11
Vss	V13
Vss	V16
Vss	V18
reserved (NC)	A7

PIN DESCRIPTION

The following is a list of interface, interrupt, and miscellaneous pins available on the NR4700.

Pin Name	Type	description
System interface		
$\overline{\text{ExtRqst}}$	Input	External request Signals that the system interface needs to submit an external request.
$\overline{\text{Release}}$	Output	Release interface Signals that the processor is releasing the system interface to slave state.
$\overline{\text{RdRdy}}$	Input	Read Ready Signals that an external agent can now accept a processor read.
$\overline{\text{WrRdy}}$	Input	Write Ready Signals that an external agent can now accept a processor write request.
$\overline{\text{ValidIn}}$	Input	Valid Input Signals that an external agent is now driving a valid address or data on the SysAD bus and a valid command or data identifier on the SysCmd bus.
$\overline{\text{ValidOut}}$	Output	Valid output Signals that the processor is now driving a valid address or data on the SysAD bus and a valid command or data identifier on the SysCmd bus.
SysAD (63..0)	Input/ Output	System address/data bus A 64-bit address and data bus for communication between the processor and an external agent.
SysADC (7..0)	Input/ Output	System address/data check bus An 8-bit bus containing parity check bits for the SysAD bus during data cycles.
SysCmd (8..0)	Input/ Output	System command/data identifier bus A 9-bit bus for command and data identifier transmission between the processor and an external agent.
SysCmdP	Input/ Output	Reserved for system command/data identifier bus parity For the NR4700 unused on input and zero on output.
Clock/control interface		
MasterClock	Input	Master clock Master clock input at the processor operating frequency.
MasterOut	Output	Master clock out Master clock output aligned with MasterClock.
RClock (1:0)	Output	Receive clocks Two identical receive clocks at the system interface frequency.
TClock (1:0)	Output	Transmit clocks. Two identical transmit clocks at the system interface frequency.
IOOut	Output	Reserved for future output Always HIGH.
IOIn	Input	Reserved for future input Should be driven high.
SyncOut	Output	Synchronization clock out Synchronization clock output. Must be connected to SyncIn through an interconnect that models the interconnect between MasterOut, TClock, RClock, and the external agent.

Pin Name	Type	description
SyncIn	Input	Synchronization clock in Synchronization clock input. See SyncOut.
$\overline{\text{Fault}}$	Output	Fault Always HIGH.
VccP	Input	Quiet Vcc For PLL Quiet Vcc for the internal phase locked loop.
VssP	Input	Quiet Vss for PLL Quiet Vss for the internal phase locked loop.
Interrupt interface		
$\overline{\text{Int}}$ (5..0)	Input	Interrupt Six general processor interrupts, bit-wise ORed with bits 5:0 of the interrupt register.
$\overline{\text{NMI}}$	Input	Non-maskable interrupt Non-maskable interrupt, ORed with 6 of the interrupt register.
JTAG interface		
JTDI	Input	JTAG data in JTAG serial data in.
JTCK	Input	JTAG clock input JTAG serial clock input.
JTDO	Output	JTAG data out JTAG serial data out.
JTMS	Input	JTAG command JTAG command signal, signals that the incoming serial data is command data.
Clock/control interface		
VCCOK	Input	VCC is OK When asserted, this signal indicates to the R4700 that the 3.3V power supply has been above 3.0V for more than 100 milliseconds and will remain stable. The assertion of VCCOk initiates the reading of the boot-time mode control serial stream.
$\overline{\text{ColdReset}}$	Input	Cold reset This signal must be asserted for a power on rest or a cold reset. The clocks SClock, TClock, and RClock begin to cycle and are synchronized with the de-assertion edge of ColdReset. ColdReset must be de-asserted synchronously with MasterOut.
$\overline{\text{Reset}}$	Input	Reset This signal must be asserted for any reset sequence. It may be asserted synchronously or asynchronously for a cold reset, or synchronously to initiate a warm reset. Reset must be de-asserted synchronously with MasterOut.
ModeClock	Output	Boot mode clock Serial boot-mode data clock output at the system clock frequency divided by two hundred and fifty six.
ModeIn	Input	Boot mode data in Serial boot-mode data input.

■ DESCRIPTION:

The NKK NR4700 High-Performance 64-bit RISC Microprocessor is a follow-on to the NR4600, and is fully compatible with it. The NR4700 has improved FPA multiply operations.

The NR4700 supports a wide variety of processor-based applications, from 32-bit WindowsNT™ desktop or notebook systems through high-performance, 64-bit systems. Compatible with the NR4600/R4000PC family for both hardware and software, the NR4700 will serve in many of the same applications, but, in addition supports faster floating point computation, thus improving its performance in graphics-oriented applications. It does not provide integrated secondary cache and multiprocessor support as found in the R4000SC and R4000MC, but an external secondary cache can lastly be designed around it. The large on-chip two-way set associative caches make this unnecessary in many systems.

The NR4700 brings R4400SC performance levels to the R4000PC package, while at the same time providing lower cost and lower power. It does this by providing larger on-chip caches that are two-way set associative, fewer pipeline stalls, and early restart for data cache misses. It also improves the performance of floating point multiply operations and allows 1 multiply and 1 add every 4 clock cycles. The result is 110 SPECint92 and > 90 SPECfp92 (exact figures are system-dependent).

The NR4700 provides complete upward application-software compatibility with the NR3000 family of microprocessors as well as the NR4600 microprocessor. Microsoft® Windows NT™ and UNISOFT Unix™ V.4 operating systems insure the availability of thousands of applications programs, geared to provide a complete solution to a large number of processing needs. An array of development tools facilitates the rapid development of NR4700-based systems, enabling a wide variety of customers to take advantage of the MIPS Open Architecture philosophy.

Together with NR4600/R4000 family, the NR4700 provides a compatible, timely, and necessary evolution path from 32-bit to true, 64-bit computing. The design objectives of the R4000 clearly mandated this evolution path; the result is a true 64-bit processor fully compatible with 32-bit operating systems and applications.

The 64-bit computing and addressing capability of the NR4700 enables a wide variety of capabilities previously limited by a smaller address space. For example, the large address space allows operating systems with extensive file mapping; direct access to large files can occur without explicit I/O calls. Applications such as large CAD databases, multi-media, and high-quality images storage and retrieval all directly benefit from the enlarged address space.

This data sheet provides an overview of the features and architecture of the NR4700 CPU. A more detailed description of the processor is available in the "NR4600/NR4700 User's Manual", to be available from NKK. Further information on development support, applications notes, and complementary products are also available for your local NKK sales representative.

HARDWARE OVERVIEW

The NR4700 family brings a high-level of integration designed for high-performance computing. The key elements of the NR4700 are briefly described below. A more detailed description of each of these subsystems will be available in the User's Manual.

Figure 1. CPU Registers

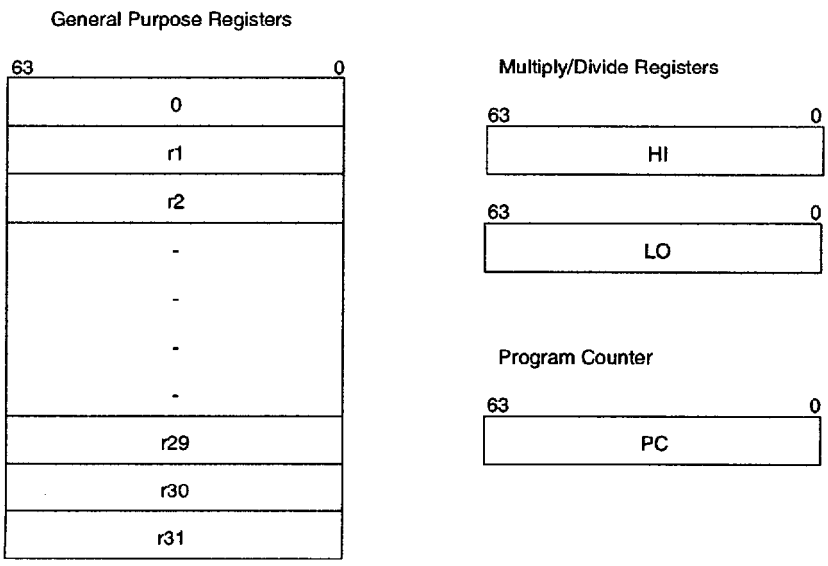
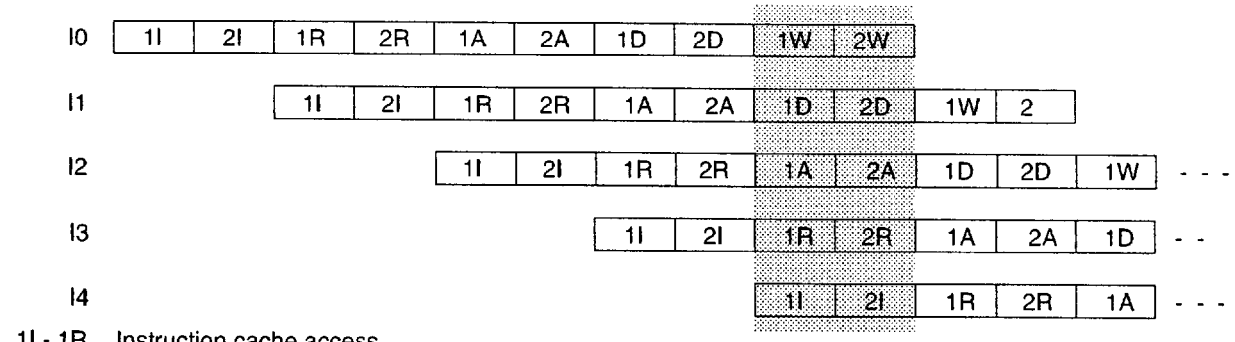


Figure 2. NR4700 Pipeline



1I - 1R	Instruction cache access
2I	Instruction virtual to physical address translation in ITLB
2A -2D	Data cache access and load align
1D	Data virtual to physical address translation in DTLB
1D - 2D	Virtual to physical address translation in JTLB
2R	Register file read
2R	Bypass calculation
2R	Instruction decode
2R	Branch address calculation
1A	Issue or slip decision
1A - 2A	Integer add, logical, shift
1A	Data virtual address calculation
2A	Store align
1A	Branch decision
2W	Register file write

■ Pipeline

The NR4700 uses a 5-stage pipeline similar to the NR3000. The simplicity of this pipeline allows the NR4700 to be lower cost and lower power than super-scalar or super-pipelined processors. Unlike the NR3000, the NR4700 does virtual-to-physical translation in parallel with cache access. This allows the NR4700 to operate at over three times the frequency of the NR3000 and to support a larger TLB for address translation.

Compared to the 8-stage R4000 pipeline, the NR4700 is more efficient (requires fewer stalls).

Figure 2 shows the NR4700 pipeline.

■ Integer Execution Engine

The NR4700 implements the MIPS Instruction Set architecture, and thus is fully upward compatible with applications running on the earlier generation parts. The NR4700 includes the same additions to the instruction set as found in the R400 family microprocessor, targeted at improving performance and capability while maintaining binary compatibility with earlier processors. The extensions result in better code density, greater multi-processing support, improved performance for commonly used code sequences in operating system kernels, and faster execution of floating-point intensive applications. All resource dependencies are made transparent to the programmer, insuring transportability among implementations of the MIPS instruction set architecture.

In addition to the instruction extensions detailed above, new instructions defined in the NR4600 that take advantage of the 64-bit architecture of the processor are also incorporated into the NR4700. The NR4700 is fully software compatible with the NR4600. When operating as a 32-bit processor, the NR4700 will take an exception on these new instructions.

The MIPS integer unit implements a load/store architecture with single cycle ALU operations (logical, shift, add, sub) and autonomous multiply/divide unit. The register resources include: 32 general-purpose orthogonal integer registers, the HI/LO result registers for the integer multiply /divide unit, and the program counter. In addition, the on-chip floating-point co-processor adds 32 floating-point registers, and a floating-point control/status register.

■ Register File

The NR4700 has 32 general-purpose registers.These registers are used for scalar integer operations and address calculation. The register file consists of two read ports and one write port, and is fully bypassed to minimize operation latency in the pipeline.

■ ALU

The NR4700 ALU consists of the integer adder and logic unit. The adder performs address calculations in addition to arithmetic operations, and the logic unit performs all logical and shift operations. Each of these units is highly optimized and can perform an operation in a single pipeline cycle.

■ Integer Multiply/Divide

The NR4700 uses the floating-point unit to perform integer multiply and divide. The results of the operation are placed in the *HI* and *LO* registers. The values can then be transferred to the general purpose register file using the MFHI/MFLO instructions. Table 1 below shows the number of processor internal cycles required between an integer multiply or divide and a subsequent MFHI or MFLO operation, in order that no interlock or stall occurs. The NR4700 performs an integer multiply faster than the NR4600 by 2 clock cycles. However, it takes the same number of clock cycles for integer division.

	32-bit	64-bit
MULT	8	10
DIV	42	74

Table 1: Integer multiply/divide cycles

■ Floating-Point Co-Processor

The NR4700 incorporates an entire floating-point co-processor on chip, including a floating-point register file and execution units. The floating-point co-processor forms a "seamless" interface with the integer unit, decoding and executing instructions in parallel with the integer unit. The floating point co-processor of the NR4700 has improved the floating multiply operations compared to the NR4600. This improves the peak MFLOPS to be equal to half of the pipeline clock rate.

■ Floating-Point Units

The NR4700 floating-point execution units supports single and double precision arithmetic, as specified in the IEEE Standard 754. The execution unit is broken into a separate multiply unit and a combined add/convert/divide /square root unit. Overlap of multiplies and add/subtract is supported. The multiplier is partially pipelined, allowing a new multiply to begin every 4 cycles.

As in the R4000, the NR4700 maintains fully precise floating-point exceptions while allowing both overlapped and pipelined operations. Precise exceptions are extremely important in mission-critical environments and highly desirable for debugging in any environment.

The floating-point unit's operation set includes floating-point add, subtract, multiply, divide, square root, conversion between fixed-point and floating-point format, conversion among floating-point formats, and floating-point compare.

Operation	Single Precision	Double Precision
ADD	4	4
SUB	4	4
MUL	5	6
DIV	32	61
SQRT	31	60
CMP	3	3
FIX	4	4
FLOAT	6	6
ABS	1	1
MOV	1	1
NEG	1	1
LWC1, LDC1	2	2
SWC1, SDC1	1	1

Table 2: Floating-Point Cycles

These operations comply with the IEEE Standard 754. The floating point unit improves the multiply compared to the NR4600 by performing a single precision multiply in 4 clock cycles and a double precision multiply in 5 clock cycles.

Table 2 gives the latencies of some of the floating-point instructions in internal processor cycles. Note that multiplies are pipelined, so that a new multiply can be initiated every 4 pipeline cycles.

■ Floating-Point General Register File

The floating-point register file is made up of thirty-two 64-bit registers. With the LDC1 and SDC1 instructions the floating-point unit can take advantage of the 64-bit wide data cache and issue a co-processor load or store double-word instruction in every cycle.

The floating-point control register space contains two registers; one for determining configuration and revision information for the coprocessor and one for control and status information. These are primarily involved with diagnostic software, exception handling, state saving and re-storing, and control of rounding modes.

■ System Control Co-processor (CP0)

The system control co-processor in the MIPS architecture is responsible for the virtual memory sub-system, the exception control system, and the diagnostic capability of the processor. In the MIPS architecture, the system control co-processor (and thus the kernel software) is implementation dependent. The NR4700 CP0 is identical to that of the R4000PC same as the NR4600, except that the WatchLo

and WatchHi registers are no longer present and the index CACHE ops use an extra address bit to select one of the two sets (the R4000 caches are direct mapped, instead of two-way set associative).

The Memory management unit controls the virtual memory system page mapping. It consists of an instruction address translation buffer (the ITLB), a data address translation buffer (the DTLB), a joint TLB (the JTLB), and co-processor registers used for the virtual memory mapping sub-system.

■ System Control Co-Processor Registers

The NR4700 incorporates all system control co-processor (CP0) registers on-chip. These registers provide the path through which the virtual memory system's page mapping is examined and changed, exceptions are handled, and operating modes are controlled (kernel vs. user mode, interrupts enabled or disabled, cache features). In addition, The NR4700 includes registers to implement a real-time cycle counting facility, to aid in cache diagnostic testing, and to assist in data error detection. Figure 3 on shows the CP0 registers.

■ Virtual to Physical Address Mapping

The NR4700 provides three modes of virtual addressing:

- user mode
- supervisor mode
- kernel mode

This mechanism is available to system software to provide a secure environment for user processes. Bits in a status register determine which virtual addressing mode is used. In the user mode, the NR4700 provides a single, uniform virtual address space of 256GB (2GB for 32-bit address mode).

When operating in the kernel mode, four distinct virtual address spaces, totalling 1024GB (4GB in 32-bit address mode), are simultaneously available and are differentiated by the high-order bits of the virtual address.

The NR4700 processor also supports a supervisor mode in which the virtual address space is 256.5GB (2.5GB in 32-bit address mode), divided into three regions based on the high-order bits of the virtual address.

Figure 4 shows the address space layout for 32-bit virtual address operation.

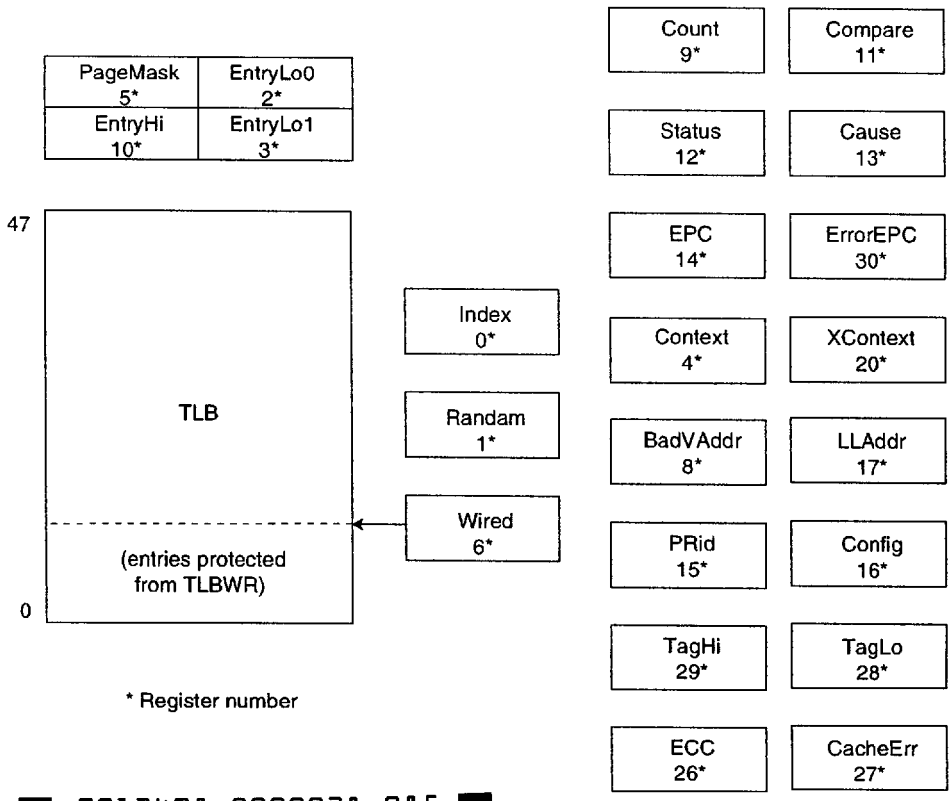
When the NR4700 is configured for 64-bit virtual address, the virtual address space layout is an upward compatible extension of the 32-bit virtual address space layout.

■ Joint TLB

For fast virtual-to-physical address decoding, the NR4700 uses a large, fully associative TLB which maps 96 Virtual pages to their corresponding physical address. The TLB is organized as 48 pairs of even-odd entries, and maps a virtual address and address space identifier into the large, 64GB physical address space.

Two mechanisms are provided to assist in controlling the amount of mapped space, and the replacement characteristics of various memory regions. First, the page

FIGURE 3. THE NR4700 CP0 REGISTER



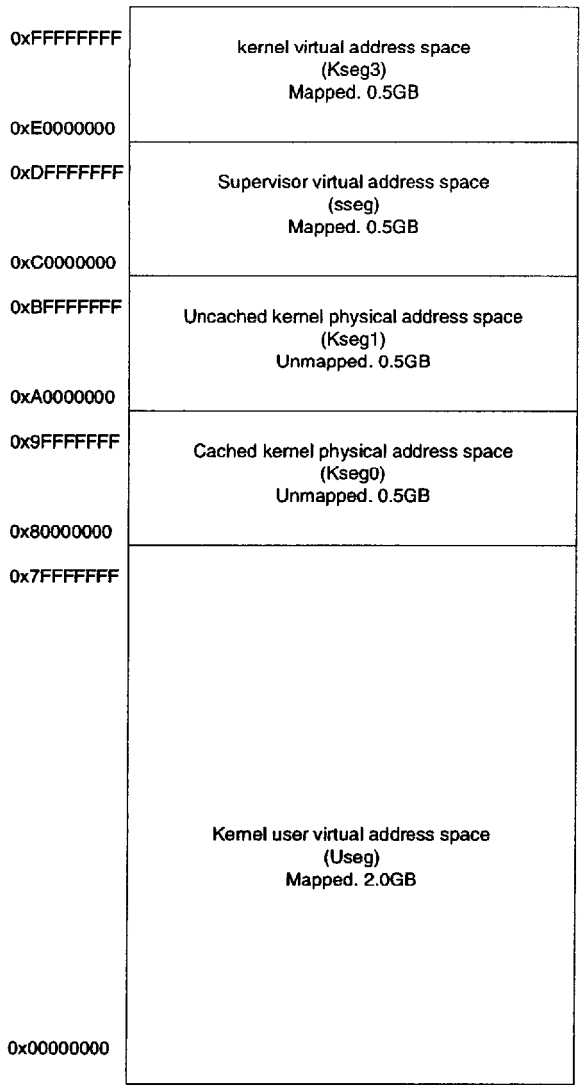
* Register number

size can be configured, on a per-entry basis, to map a page size of 4KB to 16MB (in multiplies of 4). A CP0 register is loaded with the page size of a mapping, and that size is entered into the TLB when a new entry is written. Thus, operating systems can provide special purpose maps; for example, a typical frame buffer can be memory mapped using only one TLB entry.

The second mechanism controls the replacement algorithm when a TLB miss occurs. The NR4700 provides a random replacement algorithm to select a TLB entry to be written with a new mapping; however, the processor provides a mechanism whereby a system specific number of mappings can be locked into the TLB, and thus avoid being randomly replaced. This facilities the design of real-time systems, by allowing deterministic access to critical soft-ware.

The joint TLB also contains information to control the cache coherency protocol for each page. Specifically, each page has attribute bits to determine whether the coherency algorithm is: uncached, non-coherent write-back, non-coherent write-through write-allocate, non-coherent write-through no write-allocate.Non-coherent write-back is typically used for both code and data on the NR4700, the write-through modes support more efficient frame buffer accesses than the R4000 family; cache coherency is not supported however.

Figure 4. Kernel Mode Virtual Addressing (32-bit mode)



■ Instruction TLB

The NR4700 also incorporates a 2-entry instruction TLB. Each entry maps a 4KB page. The instruction TLB improves performance by allowing instruction address translation to occur in parallel with data address translation. When a miss occurs on an instruction address translation, the least-recently used ITLB is filled from the JTLB. The operation of the ITLB invisible to the user.

■ Data TLB

The NR4700 also incorporates a 4-entry data TLB. Each entry maps a 4KB page. The data TLB improves performance by allowing data address translation to occur in parallel with data address translation. When a miss occurs on an data address translation, the DTLB is filled from the JTLB. The DTLB refill is pseudo-LRU: the least recently used entry of the least recently used half is filled. The operation of the DTLB is invisible to the user.

Furthermore, the large 2-way set-associative caches increase emulation performance of DOS and Windows 3.1™ applications when running under WindowsNT™.

■ Cache Memory

In order to keep the NR4700's high-performance pipeline full and operating efficiently, the NR4700 incorporates on-chip instruction and data caches that can be accessed in a single processor cycle. Each cache has its own 64-bit data path and can be accessed in parallel. The cache sub-system provides the integer and floating-point units with an aggregate bandwidth of 2.4GB per second at a pipeline clock frequency of 150MHz. The cache sub-system is the same as for the NR4600.

■ Instruction Cache

The NR4700 incorporates a two-way set associative on-chip instruction cache. This virtually indexed, physically tagged cache is 16KB in size and is protected with word parity.

Because the cache is virtually indexed, the virtual-to-physical address translation occurs in parallel with the cache access, thus further increasing performance by allowing these two operations to occur simultaneously. The tag holds a 24-bit physical address and valid bit, and is parity protected.

The instruction cache is 64-bit wide, and can be refilled or accessed in a single processor cycle. Instruction fetches require only 32 bits per cycle, for a peak instruction bandwidth of 600MB/sec at 150MHz. Sequential accesses take

advantage of the 64-bit fetch to reduce power dissipation, and cache miss refill writes 64 bits-per-cycle to minimize the cache miss penalty. The line size is eight instructions (32 bytes) to maximize performance.

■ Data Cache

For fast, single cycle data access, the NR4700 includes a 16KB on-chip data cache that is two-way set associative with a fixed 32-byte (eight words) line size.

The data cache is protected with byte parity and its tag is protected with a single parity bit. It is virtually indexed and physically tagged to allow simultaneous address translation and data cache access.

The normal write policy is write-back, which means that a store to a cache line does not immediately cause memory to be updated. This increases system performance by reducing bus traffic and eliminating the bottleneck of waiting for each store operation to finish before issuing a subsequent memory operation. Software can however select write-through on a per-page basis when it is appropriate, such as for frame buffers.

Associated with the Data cache is the store buffer. When the NR4700 executes a Store instruction, this single-entry buffer gets written with the store data while the tag comparison is performed. If the tag matches, then the data is written into the Data Cache in the next cycle that the Data cache is not accessed (the next non-load cycle). The store buffer allows the NR4700 to execute a store every processor cycle and to perform back-to-back stores without penalty.

■ Write buffer

Writes to external memory, whether cache miss write-backs or stores to uncached or write-through addresses, use the on-chip write buffer. The write buffer holds up to four 64-bit address and 64-bit data pairs. The entire buffer is used for a data cache write-back and allows the processor to proceed in parallel with memory update. For uncached and write-through stores, the write buffer significantly increases performance over the R4000 family of processors.

■ System Interface

The NR4700 supports a 64-bit system interface that is compatible with the R4000PC system interface. This interface operates from two clocks provided by the NR4700, TClock [1:0] and RClock [1:0], at some division of the internal clock.

The interface consists of a 64-bit Address/Data bus with 8 check bits and a 9-bit command bus protected with parity. In addition, there are 8 handshake signals and 6 interrupt inputs. the interface has a simple timing specification and is capable of transferring data between the processor and memory at a peak rate of 600MB/sec at 150MHz.

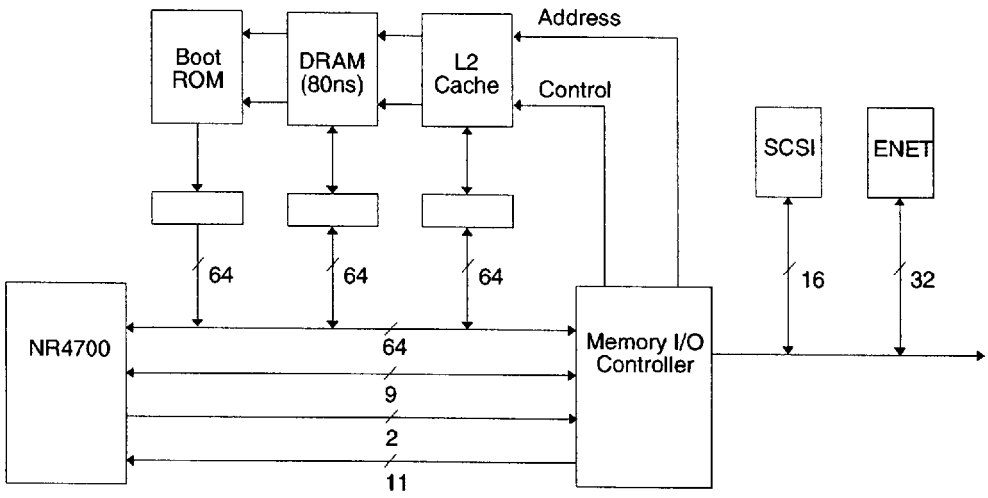
Figure 5 shows a typical system using the NR4700. In this example two banks of DRAMs are used to supply and accept data with a DDxxDD data pattern.

■ System Address/Data Bus

The 64-bit System Address Data (SysAD) bus is used to transfer addresses and data between the NR4700 and the rest of the system. It is protected with an 8-bit parity check bus, SysADC.

The system interface is configurable to allow easier interfacing to memory and I/O systems of varying frequencies.The data rate and the bus frequency at which the NR4700 transmits data to the system interface are programmable via boot time mode control bits. Also, the rate at which the processor receives data is fully controlled by the external device. Therefore, either a low cost interface requiring no read or write buffering or a faster, high performance interface can be designed to communicate with

Figure 5. Typical Desktop System Block Diagram



the NR4700. Again, the system designer has the flexibility to make these price/performance trade-offs.

■ System Command Bus

The NR4700 interface has a 9-bit System Command (SysCmd) bus. The command bus indicates whether the SysAD bus carries an address or data. If the SysAD carries an address, then the SysCmd bus also indicates what type of transaction is to take place (for example, a read or write). If the SysAD carries data, then the SysCmd bus also gives information about the data (for example, this is the last data word transmitted, or the cache state of this data line is clean exclusive). The SysCmd bus is bidirectional to support both processor requests and external requests to the NR4700. Processor requests are initiated by the NR4700 and responded to by an external device. External requests are issued by an external device and require the NR4700 to respond.

The NR4700 supports one to eight byte and block transfers on the SysAD bus. In the case of a sub-double-word transfer, the low-order 3 address bits gives the byte address of the transfer, and the sysCmd bus indicates the number of bytes being transferred.

■ Handshake Signals

There are six handshake signals on the system interface. Two of these, $\overline{\text{RdRdy}}$ and $\overline{\text{WrRdy}}$ are used by an external device to indicate to the NR4700 whether it can accept a new read or write transaction. The NR4700 samples these signals before de-asserting the address on read and write requests.

$\overline{\text{ExtRqst}}$ and $\overline{\text{Release}}$ are used to transfer control of the SysAD and SysCmd buses between the processor and an external device. When an external device needs to control the interface, it asserts $\overline{\text{ExtRqst}}$. The NR4700 responds by asserting $\overline{\text{Release}}$ to release the system interface to slave state.

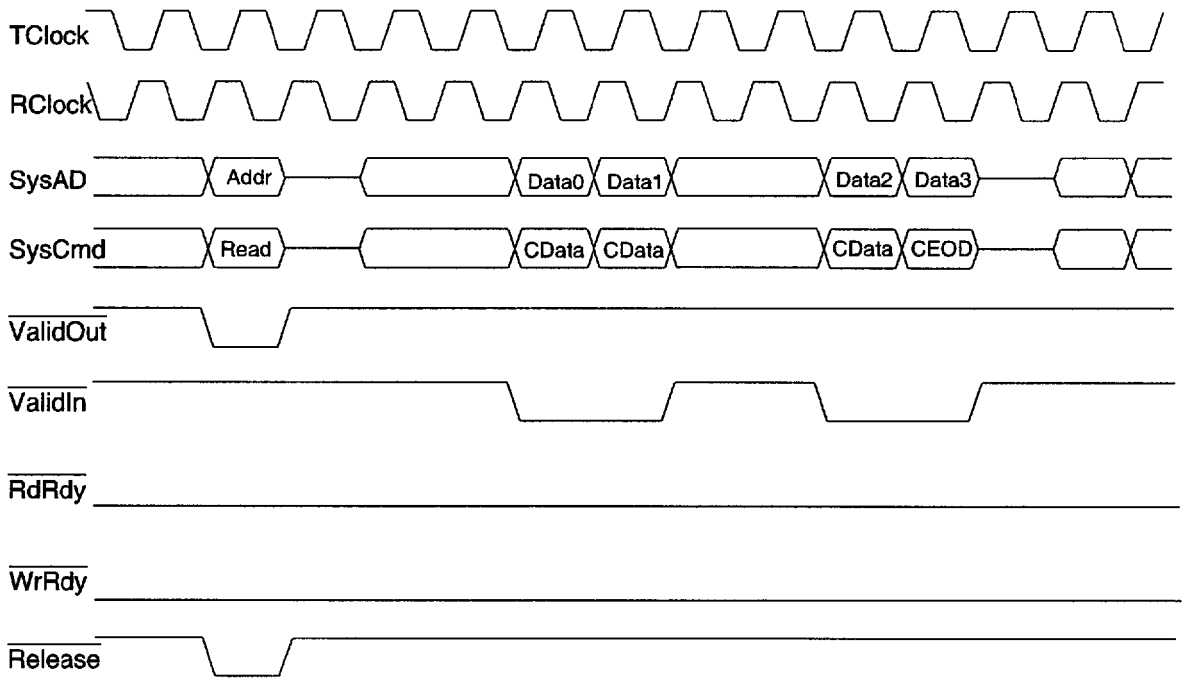
$\overline{\text{ValidOut}}$ and $\overline{\text{ValidIn}}$ are used by the NR4700 and the external device respectively to indicate that there is a valid command or data on the SysAD and SysCmd buses. The NR4700 asserts $\overline{\text{Validout}}$ when it is driving these buses with a valid command or data, and the external device drives $\overline{\text{ValidIn}}$ when it has control of the buses and is driving a valid command or data.

■ Non-overlapping System Interface

The NR4700 uses a non-overlapping system interface, compatible with the NR4600. This means that only one processor request may be outstanding at a time and that the request must be serviced by an external device before the NR4700 issues another request. The NR4700 can issue read and write requests to an external device, and an external device can issue read and write requests to the NR4700.

For processor read transaction the NR4700 asserts $\overline{\text{ValidOut}}$ and simultaneously drives the address and read command on the SysAD and SysCmd buses. If the system interface has $\overline{\text{RdRdy}}$ asserted, then the processor tri-states its drivers and release the system interface to slave state by

Figure 6. Processor Block read



asserting $\overline{\text{Release}}$. The external device can then begin sending the data to the NR4700.

Figure 6 shows a processor block read request and the external agent read response. The read latency is 4 cycles ($\overline{\text{ValidOUT}}$ to $\overline{\text{ValidIN}}$), and the response data pattern is DDxxDD. Figure 7 shows a processor block write.

Write Reissue and Pipeline Write

The NR4600 and the NR4700 implement additional write protocols designed to improve performance. This implementation doubles the effective write bandwidth. The write re-issue has a high repeat rate of 2 cycles per write. A write issues if $\overline{\text{WrRdy}}$ is asserted 2 cycles earlier and is still asserted at the issue cycle. If it is not still asserted, the last write re-issues again. Pipelined writes have the same 2 cycle per write repeat rate, but can issue one more write after $\overline{\text{WrRdy}}$ de-asserts. They still follow the issue rule as R4x00 mode for other writes.

■ External requests

The NR4700 responds to requests issued by an external device. The requests can take several forms. An external device may needs to supply data in response to an NR4700 read request or it may need to gain control over the system interface bus to access other resources which may be on that bus. It also may issue requests to the processor, such as a request for the NR4700 to write to the NR4700 interrupt register.

The following is a list of the supported external requests:

- Write
- Null
- Read response

■ Boot Time Options

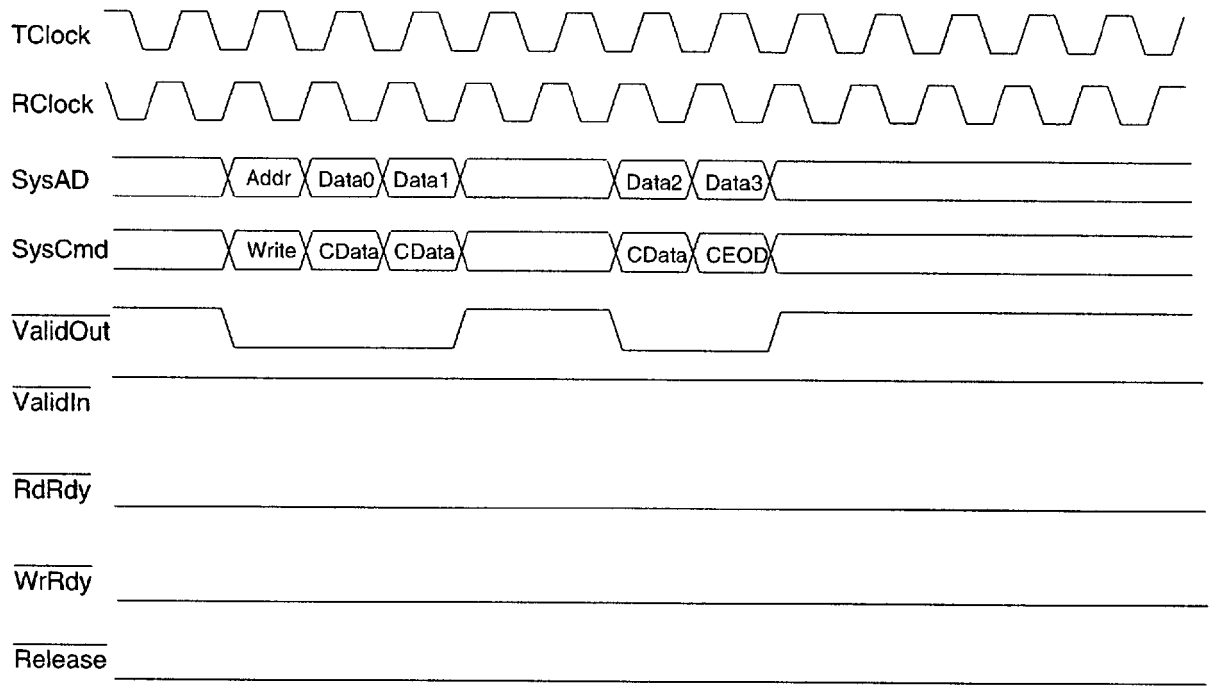
Fundamental operational modes for the processor are initialized by the boot-time mode control interface. The boot-time mode control interface is a serial interface operating at a very low frequency (MasterClock divided by 256). The low-frequency operation allows the initialization information to be kept in a low-cost serial EEPROM; alternatively the twenty-or-so bits could be generated by the system interface ASIC or a simple PAL.

Immediately after the VCCOK Signal is asserted, the processor reads a serial bit stream of 256 bits to initialize all fundamental operational modes. After initialization is complete, the processor continues to drive the serial clock output, but no further initialization bits are read.

■ JTAG Interface

For compatibility with the R4000PC, the NR4700 supports the JTAG interface pins, with the serial input connected to serial output. Boundary scan is not supported.

Figure 7. Processor Block Write



Mode bit	Description
0	reserved (must be zero)
4..1	Write-back data rate 0 → D, 1 → DDx, 2 → DDxx, 3 → DxDx, 4 → DDxxx, 5 → DDxxxx, 6 → DxxDxx, 7 → DDxxxxxx, 8 → DxxxDxxx, 9-15 reserved
7..5	Clock divisor 0 → 2, 1 → 3, 2 → 4, 3 → 5, 4 → 6, 5 → 7, 6 → 8, 7 reserved
8	0 → Little endian, 1 → Big endian,
10..9	00 → R4000 compatible, 01 → reserved, 10 → pipelined write, 11 → write re-issue
11	Disable the timer interrupt on $\overline{Int}$[5] 0 → Enable 1 → Disable
12	reserved (must be zero)
14..13	Output driver strength 10 → 100% strength (fastest), 11 → 83% strength, 00 → 67% strength, 01 → 50% strength (slowest)
15	0 → TClock(0) enabled 1 → TClock(0) disabled
16	0 → TClock(1) enabled 1 → TClock(1) disabled
17	0 → RClock(0) enabled 1 → RClock(0) disabled
18	0 → RClock(1) enabled 1 → RClock(1) disabled
255..19	must be zero

Table 3: Boot time mode stream

■ Boot-Time Modes

The boot-time serial mode stream is defined in Table 3. Bit 0 is the bit presented to the processor when VCCOK is asserted; bit 255 is the last.

■ Power Management

CP0 is also used to control the power management for the NR4700. This is the standby mode and it can be used to reduce the power consumption of the internal core of the CPU. The standby mode is entered by executing the WAIT instruction with the SysAD bus idle and is exited by any interrupt.

Standby Mode Operation

The NR4700 provides a means to reduce the amount of power consumed by the internal core when the CPU would otherwise not be performing any useful operations. This is known as "Standby Mode".

■ Entering Standby Mode

Executing the WAIT instruction enables interrupts and enters Standby mode. When the WAIT instruction finishes the W pipe-stage, if the SysAD bus is currently idle, the internal clocks will shut down, thus freezing the pipeline. The PLL, internal timer, some of the input pin clocks ($\overline{Int}$[5:0], $\overline{NMI}$, $\overline{ExtRqst}$, $\overline{Reset}$, and $\overline{ColdReset}$) and the output clocks (TClock[1:0], RClock[1:0], SyncOut, ModeClock and MasterOut) will continue to run. If the conditions are not correct when the WAIT instruction finishes the W pipe-stage (i.e. the SysAD bus is not idle), the WAIT is treated as a NOP.

Once the CPU is in Standby Mode, any interrupt, including the internally generated timer interrupt, will causes the CPU to exit Standby Mode.

Thermal Conditions

The NR4700 utilizes special packaging techniques to improve the thermal properties of high-speed processors. The NR4700 is packaged using cavity down packaging in a 179-pin PGA package with integral thermal slug, and a 208-lead MQUAD QFP package. These packages effectivity dissipate the power of the CPU, increasing device reliability.

The NR4700 utilizes the MQUAD package (the "MQ" package), which is an all-aluminum package with the die attached to a normal copper lead frame mounted to the aluminum casing. Due to the heat-spreading effect of the aluminum, the package allows for an efficient thermal transfer between the die and the case. The aluminum offers less internal resistance from one end of the package to the other, reducing the temperature gradient across the package and therefore presenting a greater area for convection and conduction to the PCB for a given temperature. Even nominal amounts of airflow will dramatically reduce the junction temperature of the die, resulting in cooler operation. The MQUAD package is pin compatible with the 208-pin PQFP package.

The NR4700 is guaranteed in a case temperature range of 0°to +85°C. The type of package, speed (power) of the device, and airflow conditions affect the equivalent ambient temperature conditions that will meet this specification.

The equivalent allowable ambient temperature, T_A, can be calculated using the thermal resistance from case to ambient (Φ_{CA}) of the given package. The following equation relates ambient and case temperatures:

$$T_A = T_C - P * \Phi_{CA}$$

Where P is the maximum power consumption at hot temperature, calculated by using the maximum I_{CC} specification for the device.

Typical values for Φ_{CA} at various air-flows are shown in Table 4.

	ΦCA					
Airflow (ft/min)	0	200	400	600	800	1000
PGA	16	7	5	3	2.5	2
MQUAD	20	12	9	8	7	6

Table 4:Thermal Resistance (Φ_{CA}) at Various air-flows

Note that the NR4700 implements advanced power management to substantially reduce the average power dissipation of the device. This operation is described in the "NR4600/NR4700 User's Manual".

■ Difference from the R4000PC

Table 5 to 11 highlight some of the differences between the NR4700 and the R4000PC. This list is not exhaustive.

Table 5: System interface comparison between R4000PC and NR4700

	R4000PC	NR4700
I/O	TTL compatible	LVCMOS (3.3V ± 0.3V)
Package	179-pin ceramic PGA	same and 208-pin MQUAD
JTAG	yes	no (serial out connected directly to serial in ?)
Block transfer sizes	16B or 32B	32B
Sclock divisor	2, 3, or 4	2, 3, 4, 5, 6, 7, 8
Non-block writes	max throughput of 4 sclock cycles	two new system interface protocol options that support 2 sclock cycle throughput (remains 4 in compatibility mode)
Serial configuration	as described in *R4000 User's Guide*	different, as described in Table3
Address bit 63..56 on reads and write	zero	bit 19..12 of virtual address
Uncached and write-through stores	uncached stores stall until sent on system interface	uncached and write-through stores buffered in 4-entry write buffer
SysADC	parity only	same
SysADC for non-data cycles	zero on R4000, parity on R4400	zero
SysCmdP	zero on R4000, parity on R4400	zero
Parity error during write-back	use Cache Error exception	output bad parity
Error bit in data identifier of read responses	Bus Error if error bit set for any double-word	Only check error bit of first double-word; all other error bits ignored
Parity error on read data	Bus Error if parity error in any double-word	bad parity written to cache; take Cache Error exception if bad parity occurs on double-words that the processor is waiting for
Block writes	1-2 null cycles between address and data	0 cycles between address and data
Release after Read Request	variable latency	0 latency
SysAD value for x cycles of write-back data pattern	data bus undefined	data bus maintains last D cycle value
SysAD bus use after last D cycle of write-back	?	unused for trailing x cycles (e.g. DDxxDDxx, not DDxxDD)
Output slew rate	dynamic feedback control	simple CMOS output buffers with 2-bit static strength control
IOOut output	output slew rate control feedback loop output	driven HIGH, do not connect (reserved for future output)
IOIn input	output slew rate control input	should be driven HIGH (reserved for future input)
$\overline{\text{GrpRun}}$ output	do not connect	same (reserved for future output)
$\overline{\text{GrpStall}}$ input	should be connected to Vcc	same (reserved for future input)
$\overline{\text{Fault}}$ output pin	indicates compare mismatch	driven HIGH, do not connect (reserved for future output)

Table 6: Cache comparison between R4000PC and NR4700

	R4000PC	NR4700
Cache Sizes	8KB Instruction cache, 8KB Data cache	16KB Instruction cache, 16KB Data cache
Cache Line sizes	software selectable between 16B and 32B	fixed at 32B
Cache Index	$vAddr1_{2..0}$	same
Cache Tag	$pAddr_{35..12}$	same
Cache Organization	direct mapped	2-way set associative
Data cache write policy	write-allocate and write-back	write-allocate or not based on TLB entry, write-through or not based on TLB entry
Data cache miss	stall, output address, copy dirty data to write-back buffer, refill cache, output write-back data	same, with FIFO to select the set to refill
Data order for block reads	sub-block ordering	same
Data order for block writes	sequential	same
Instruction cache miss restart	restart after all data received and written to cache	same
Data cache miss restart	restart after all data received and written to cache	restart on first double-word, send subsequent double-words to response buffer
Instruction Tag	2-bit cache state	1-bit cache state
Cache miss overhead	5-8? cycles	3 cycles
Instruction cache parity	1 parity bit per 8 data bits	1 parity bit per 32 data bits
Data cache parity	1 parity bit per 8 data bits	same

Table 7: TLB comparison between R4000PC and NR4700

	R4000PC	NR4700
Instruction virtual address translation	2-entry ITLB	same
ITLB miss	1 cycle penalty, refilled from JTLB, LRU replacement	1 cycle on branch, jump, and ERET, 2 cycles otherwise, refilled from JTLB, LRU replacement
Data virtual address translation	done directly in JTLB	4-entry DTLB
DTLB miss	n.a.	1 cycle penalty, refilled from JTLB, pseudo-LRU replacement
JTLB	48 entries of even/odd page pairs, fully associative	same
Page size	4KB, 16KB, ..., 16MB	same
Multiple entry match in JTLB	sets TS in Status and disables TLB until Reset to prevent damage	no damage for multiple match; no detection or shutdown implemented
Virtual address size	VSIZE = 40	same
Physical address size	PSIZE = 36	same

Table 8: Pipeline comparison between R4000PC and NR4700

	R4000PC	NR4700
ALU latency	1 cycle	1 cycle
Load latency	3 cycles	2 cycles
Branch latency	4 cycles (2 cycle penalty for taken branches)	2 cycles (no penalty for taken branches)
Store buffer (not write buffer)	2 double-words	1 double-word
Integer multiply	integer multiply hardware, 1 cycle to issue	done in floating-point multiplier, 4 cycles to issue
Integer divide	done in integer datapath adder, slips until done	done in floating-point adder, 4 cycles to issue
Integer multiply	HI and LO available at the same time	LO available one cycle before HI
Integer divide	HI and LO available at the same time	HI available one cycle before LO
HI and LO hazards	yes, HI and LO written early in pipeline	no, HI and LO written after W
MFHI/MFLO latency	1 cycle	2 cycles
SLLV, SRLV, SRAV	2 cycles to issue	1 cycle to issue
DSLL, DSRL, DSRA, DSLL32, DSRL32, DSRA32, DSLLV, DSRLV, DSRAV	2 cycles to issue	1 cycle to issue

Table 9: Coprocessor 0 comparison between R4000PC and NR4700

	R4000PC	NR4700
WatchLo, WatchHi	implemented	unimplemented
Config	as described in *MIPS R-series Architecture*	subset
Status	as described in *MIPS R-series Architecture*, but RP not functional	no TS or RP
Low-power standby mode	no	WAIT instruction disables internal clock, freezing pipeline and other state; resume on interrupt
MFC0/MTC0 hazard	only hazardous for certain cp0 register combinations	always hazardous - detected and 1-cycle slip inserted
EntryLo0, EntryLo1	as described in *MIPS R-series Architecture*	two new cache algorithms added to C field for non-coherent write-through
TagLo, TagHi, ECC, CacheErr	R4000SC bits implemented but meaningless	Only bits meaningful on R4000PC implemented
TagLo	as described in *MIPS R-series Architecture*	bit 5..3 used for reserved bits $ITAG_{28..25}$, bit 2 used for F bit
Exceptions	as described in *MIPS R-series Architecture* (VCEI and VCED not possible in R4000PC)	VCEI, VCED, and WATCH exceptions not implemented
Index CACHE ops I Fill CACHE op	use $vAddr_{12..4}$ to select line	use $vAddr_{13}$ to select set, $vAddr_{12..5}$ to select line of set
Index Store Tag CACHE op	Status.CE ignored	TagLo.P stored if Status.CE set
PRId	Imp = 0x04	Imp = 0x21

Table 10: Coprocessor 1 comparison between R4000PC and NR4700

	R4000PC	NR4700
Possible exception stall	only for operands that can cause exceptions	some simplifications in detection hardware
Floating-point divide	separate divide unit	done in floating-point adder
Floating-point square root	done in floating-point adder	same
Converts to/from 64-bit integer	uses unimplemented for integer operands/results with more than 53 bits of precision	handles full 64-bit operands and results
Floating-point registers	Status.FR enables all 32 floating-point registers	same
FCR0	imp = 0x05	Imp = 0x20

Table 11: R4000PC Errata comparison with NR4700

R4000PC	R4000PC errata	NR4600
COPz rs field illegal	FPE unimplemented exception for COP1 (incorrect)	reserved instruction exception, as described in *MIPS R-series Architecture*
BCz rt field illegal	FPE unimplemented exception for COP1 (incorrect)	reserved instruction exception, as described in *MIPS R-series Architecture*
Address error check for xkseg	C00000FFFFFFFFFF (incorrect)	C00000FF7FFFFFFF (correct)
PTEBase field of Context and XContext	same bits (incorrect)	same for rev 1.x separate for rev 2.0
TLB vs. XTLB refill vector selection	based on current mode (incorrect)	based on address (correct)

ABSOLUTE MAXIMUM RATINGS(1)

Symbol	Rating	NR4700	
		Commercial	Unit
V_{TERM}	Terminal Voltage with respect to GND	-0.5(2) to +4.6	V
T_C	Operating temperature (Case)	0 to +85	°C
T_{BIAS}	Case temperature Under Bias	-55 to +125	°C
T_{STG}	Storage Temperature	-55 to +125	°C
I_{IN}	DC Input Current	20(3)	mA
I_{OUT}	DC Output Current	50	mA

NOTES:

1. Stresses greater than those listed under ABSOLUTE MAXIMUM RATINGS may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.
2. V_{IN} minimum = -2.0V for pulse width less than 15ns. V_{IN} should not exceed V_{CC} +0.5 Volts.
3. When V_{IN} < 0V or V_{IN} > V_{CC}
4. Not more than one output should be shorted at a time. Duration of the short should not exceed 30 seconds.

RECOMMENDED OPERATION TEMPERATURE AND SUPPLY VOLTAGE

Grade	Temperature	GND	V_{CC}
			NR4700
Commercial	0°C to +85°C(Case)	0V	3.3V ± 5%

DC EIECTRICAL CHARACTERISTICS - COMMERCIAL TEMPERATURE RANGE

(V_{CC} = 3.3V ± 5%, T_{CASE} = 0°C to +85°C)

parameter	NR4700 100MHz		NR4700 133MHz		NR4700 150MHz		Conditions
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
V_{OL}		0.1V		0.1V		0.1V	$\|I_{OUT}\|$ = 20µA
V_{OH}	VCC - 0.1V		VCC - 0.1V		VCC - 0.1V		
V_{OL}		0.4V		0.4V		0.4V	$\|I_{OUT}\|$ = 4mA
V_{OH}	2.4V		2.4V		2.4V		
V_{IL}	-0.5V	$0.2V_{CC}$	-0.5V	$0.2V_{CC}$	-0.5V	$0.2V_{CC}$	
V_{IH}	$0.7V_{CC}$	V_{CC} + 0.5V	$0.7V_{CC}$	V_{CC} + 0.5V	$0.7V_{CC}$	V_{CC} + 0.5V	
V_{OHC}							
V_{ILC}							
C_{IN}		10pF		10pF		10pF	
C_{OUT}		10pF		10pF		10pF	
I/O_{LEAK}		20µA		20µA		20µA	I/ O Leak, VCC=Max.

■ Power Consumption

parameter		NR4700 100MHz		NR4700 133MHz		NR4700 150MHz		Conditions
		Typical(1)	Maximum	Typical(1)	Maximum	Typical(1)	Maximum	
System Condition:		100/ 25MHz		133/ 33MHz		150/ 38MHz		
I_{CC}	standby		125mA		175mA		200mA	C_L = 0pF(2)
			175mA		225mA		250mA	C_L = 50pF
	active	575mA	875mA	775mA	1150mA	875mA	1300mA	C_L = 0pF, No SysAD activity(2)
		650mA	1100mA	850mA	1370mA	950mA	1520mA	C_L = 50pF R4x00 compatible writes T_C = 25°C
		650mA	1275mA	850mA	1525mA	950mA	1725mA	C_L = 50pF Pipelined writes or Write re-issue, T_C = 25°C(2)

NOTES:

1. Typical integer instruction mix and cache miss rates.
2. Guaranteed by design.

AC ELECTRICAL CHARACTERISTICS - COMMERCIAL TEMPERATURE RANGE

(V_{CC} = 3.3V ± 5% ; TCASE = 0°C to +85°C)

■ Clock Parameters

Parameter	Symbol	Test Conditions	NR4700 100MHz		NR4700 133MHz		NR4700 150MHz		Units
			Min	Max	Min	Max	Min	Max	
MasterClock High	t_{MCHigh}	Transition ≤ 5ns	4		3		3		ns
MasterClock Low	t_{MCLow}	Transition ≤ 5ns	4		3		3		ns
MasterClock Frequency(1)			25	50	25	67	25	75	MHz
MasterClock Period	t_{MCP}		20	40	15	40	13.3	40	ns
Clock Jitter for Master Clock	$t_{JitterIn}$(2)			± 250		± 250		± 250	ps
Clock Jitter for MasterOut, SyncOut, TClock, RClock	$t_{JitterOut}$(2)			± 500		± 500		± 500	ps
MasterClock Rise Time	t_{MCRise}(2)			5		4		3.5	ns
MasterClock Fall Time	t_{MCFall}(2)			5		4		3.5	ns
ModeClock Period	$t_{ModeCKP}$			256* t_{MCP}		256* t_{MCP}		256* t_{MCP}	ns

NOTES:

1. Operation of the NR4700 is only guaranteed with the Phase Lock Loop enabled.
2. Guaranteed by design.

■ System Interface Parameters(1)

Parameter	Symbol	Test Condition	NR4700 100MHz		NR4700 133MHz		NR4700 150MHz		Units
			Min	Max	Min	Max	Min	Max	
Data Output(2)	t_{DM} =Min	$mode_{14..13}$=10 (fastest)	1.0	9	1.0	9	1.0	8	ns
	t_{DO} =Max	$mode_{14..13}$=01 (slowest)	2.0	15	2.0	12	2.0	12	ns
Data Setup	t_{DS}	t_{rise} = 5ns	3.5		3.5		3.5		ns
Data Hold	t_{DH}	t_{fall} = 5ns	1.5		1.5		1.5		ns

NOTES:

1. Timings are measured from 1.5V of the clock to 1.5V of the signal.
2. Capacitive load for all output timings is 50pF.

■ Boot Time Interface Parameters

Parameter	Symbol	Test Condition	NR4700 100MHz		NR4700 133MHz		NR4700 150MHz		Units
			Min	Max	Min	Max	Min	Max	
Mode Data Setup	t_{DS}		3		3		3		Master Clock Cycle
Mode Data Hold	t_{DH}		0		0		0		Master Clock Cycle

■ Capacitive Load Deration

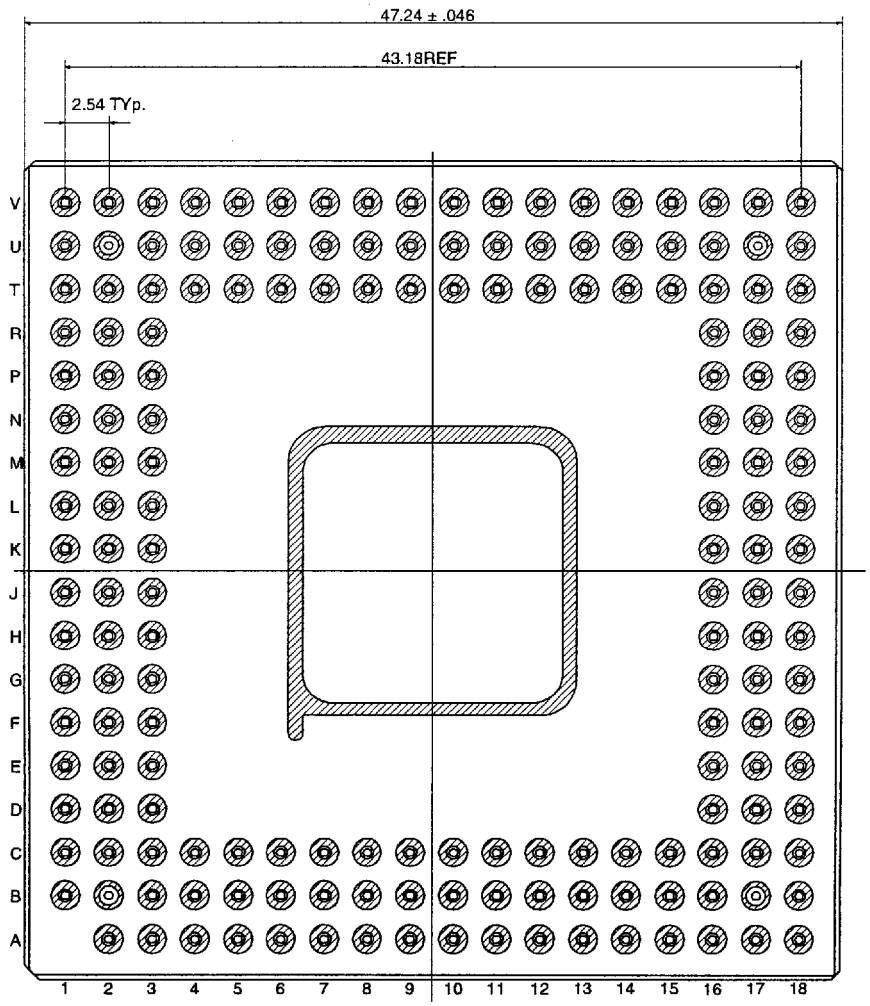
Parameter	Symbol	NR4700 100MHz		NR4700 133MHz		NR4700 150MHz		Units
		Min	Max	Min	Max	Min	Max	
Load Derate	C_{LD}		2		2		2	ns/25pF

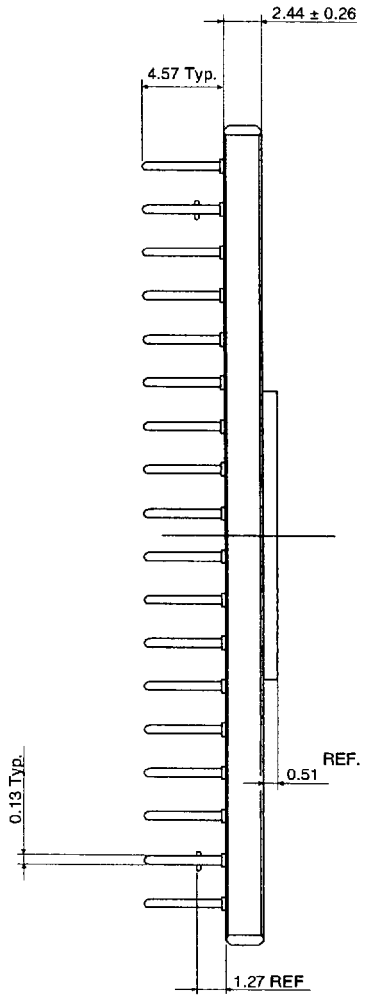
■ Ordering Information

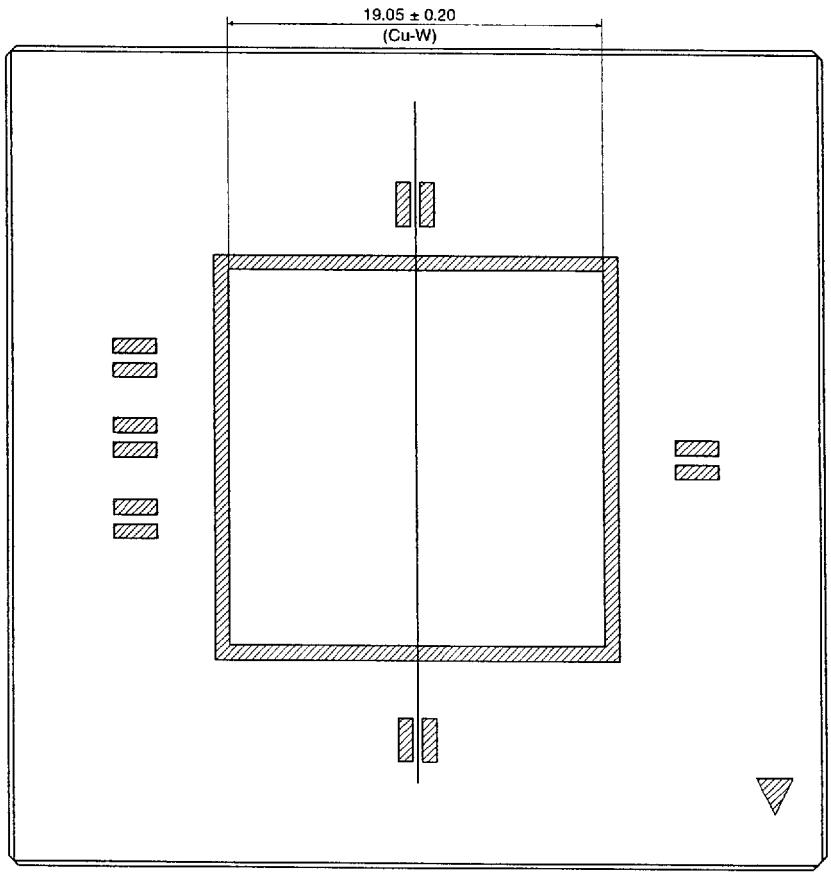
PART No.	Pipeline Clock Frequency (MHz)	Package
NR4700LCG-100	100	179 pin PGA
NR4700LMQ-100	100	208 pin MQUAD
NR4700LCG-133	133	179 pin PGA
NR4700LMQ-133	133	208 pin MQUAD
NR4700LCG-150	150	179 pin PGA
NR4700LMQ-150	150	208 pin MQUAD

■ Package Information

179Pin PGA




2.44 ± 0.26
4.57 Typ.
REF.
0.51
0.13 Typ.
1.27 REF


19.05 ± 0.20
(Cu-W)

208Pin MQUAD