

8+2 Phase Output Controller with SVID Interface for Desktop Computer CPU Applications

ASP2100, ASP2100R

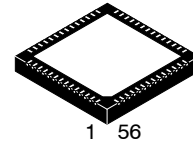
The ASP2100 and ASP2100R are dual rail, eight plus two phase buck solutions optimized for Intel®'s IMVP9.1 Rev0.9 and Rev0.95 CPU's respectively. The multi-phase rail control system is based on Dual-Edge pulse-width modulation (PWM) combined with DCR current sensing or smart power stage current sensing. These features provide an ultra-fast initial response to dynamic load events and reduced system cost. The ASP2100 has an ultra-low offset current monitor amplifier with programmable offset compensation for high accuracy current monitoring.

Features

- Vin Range 4.5 V to 21 V
- Startup into Pre-Charged Loads While Avoiding False OVP
- Digital Soft Start Ramp
- Adjustable V_{BOOT}
- High Impedance Differential Amplifier for Accurate Output Voltage Sensing
- Dual VID Table Support to be Compatible with IMVP9.1
- Support for High Current Extensions
- Auto Phase Shedding
- Dynamic Reference Injection
- Programmable Output Voltage Slew Rates
- Dynamic VID Feed-Forward
- Differential Current Sense Amplifiers for Each Phase
- Programmable Adaptive Voltage Positioning (AVP)
- Current Mode Dual Edge Modulation for Fastest Initial Response to Transient Loading
- High Performance Operational Error Amplifier
- Accurate Total Summing Current Amplifier
- Thermal Monitor
- Adjustable Switching Frequency Range
- Digitally Stabilized Switching Frequency
- Ultrasonic Operation
- Support Acoustic Noise Mitigation Function
- PSYS Input Monitor (SVID address 0x0D)
- Support for VCCIN_AUX IMON Input
- Meets Intel's IMVP9.1 Specifications
- I²C Control Interface

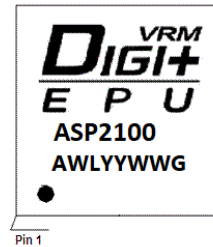
Typical Applications

- Desktop Computers



QFN56
CASE 485BT

MARKING DIAGRAMS



| | |
|----|-----------------|
| A | = Assembly Site |
| WL | = Wafer Lot |
| YY | = Year |
| WW | = Work Week |
| G | = Pb-Free |

ORDERING INFORMATION

| Device | Package | Shipping [†] |
|---------------|--------------------|-----------------------|
| ASP2100MNTXG | QFN56 (Pb-Free) | 2500 / Tape & Reel |
| ASP2100RMNTXG | QFN56 (Pb-Free) | 2500 / Tape & Reel |

[†]For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

ASP2100, ASP2100R

BLOCK DIAGRAM

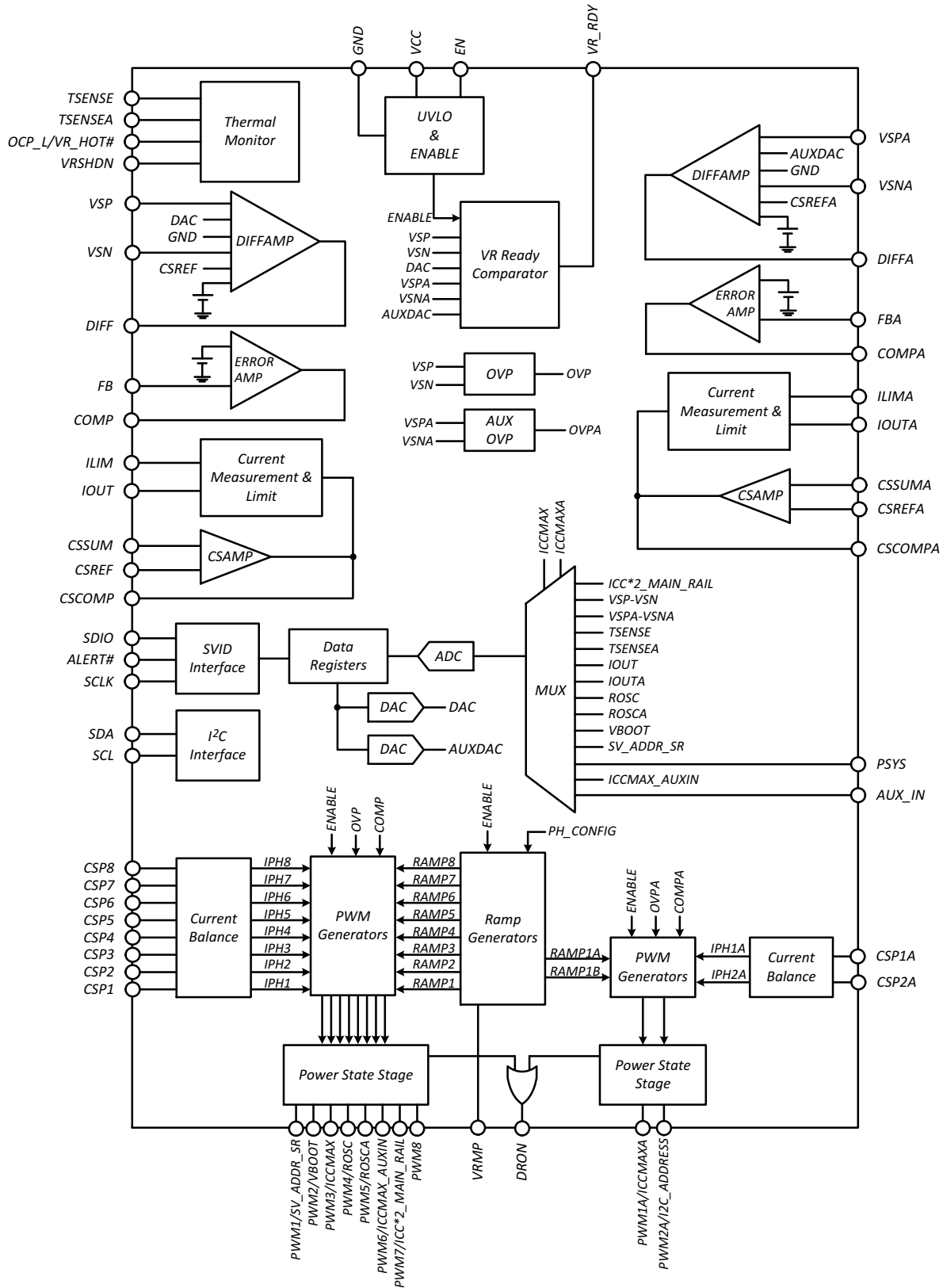


Figure 1. Internal Block Diagram

ASP2100, ASP2100R

APPLICATION INFORMATION

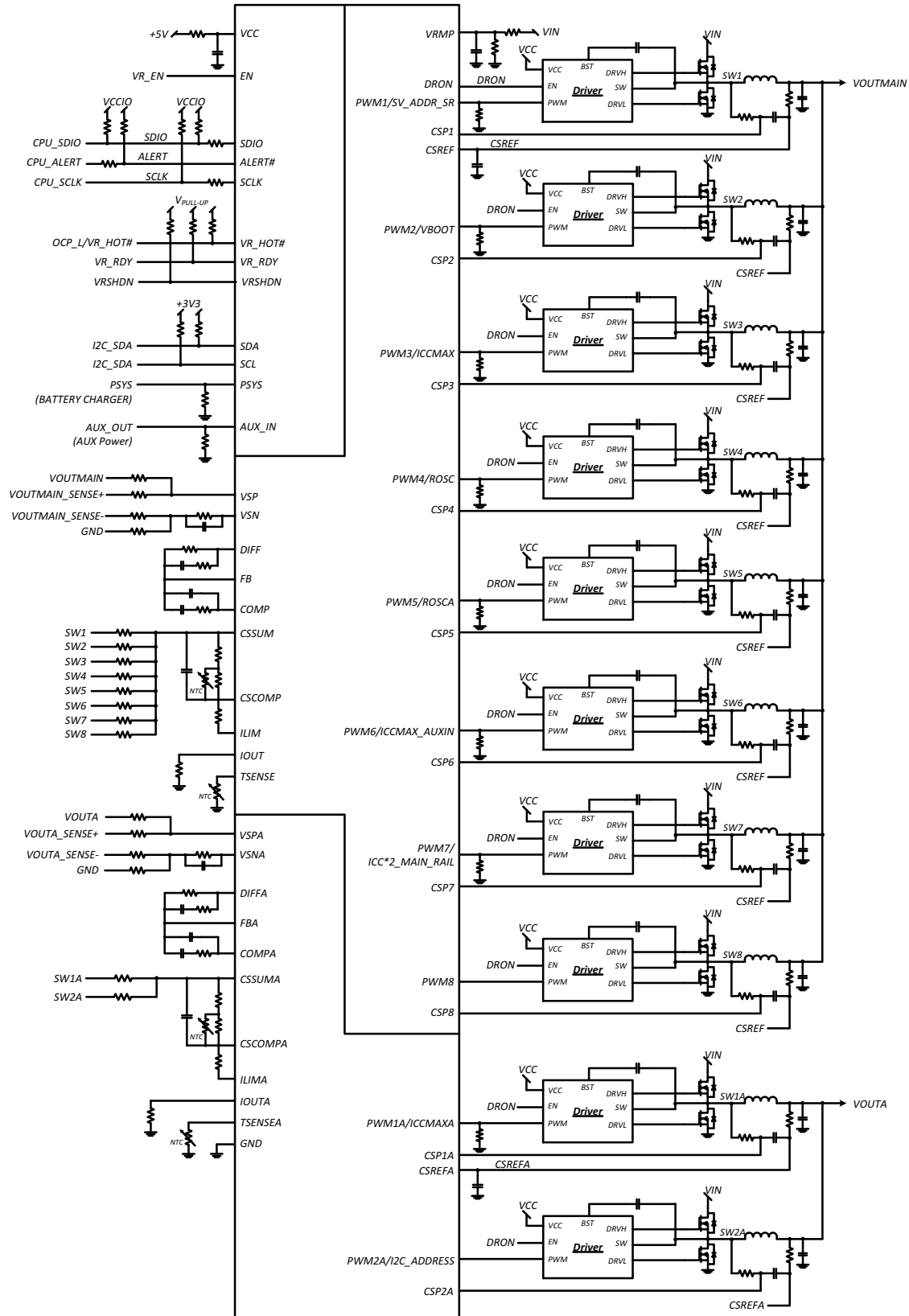


Figure 2. Typical Application Circuit

ASP2100, ASP2100R

PIN ASSIGNMENT

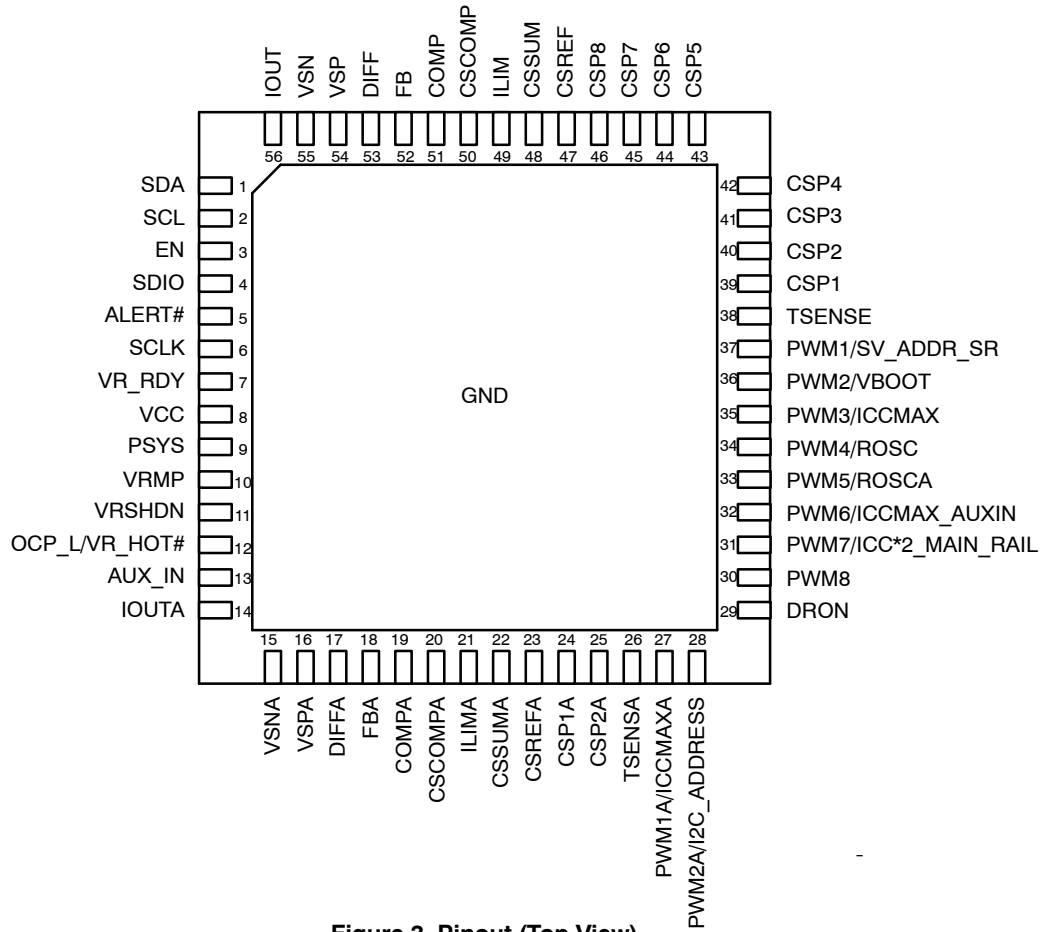


Figure 3. Pinout (Top View)

PIN FUNCTION DESCRIPTION

| Pin No. | Pin Name | Description |
|---------|---------------|--|
| 1 | SDA | I ² C bus serial data interface |
| 2 | SCL | I ² C bus clock |
| 3 | EN | Enable. High enables both rails |
| 4 | SDIO | Serial VID data interface |
| 5 | ALERT# | Serial VID ALERT# |
| 6 | SCLK | Serial VID clock |
| 7 | VR_RDY | VR_RDY indicates both rails are ready to accept SVID commands |
| 8 | VCC | Power for the internal control circuits. A decoupling capacitor is connected from this pin to ground |
| 9 | PSYS | System power signal input. A resistor to ground scales this signal |
| 10 | VRMP | Feed-forward input of Vin for the ramp-slope compensation. The current fed into this pin is used to control the ramp of the PWM slopes |
| 11 | VRSHDN | VRSHDN output, pulled and latched low until power off if VR temp reaches programmed level |
| 12 | OCP_L/VR_HOT# | OD output. Indicates high VR temperature, or OCP_L threshold crossed. OCP_L need to enable by I ² C |
| 13 | AUX_IN | AUX IMON Input on 0x0Dh SVID domain. A resistor to ground scales this signal. |
| 14 | IOUTA | Total output current monitor |
| 15 | VSNA | Differential output voltage negative sense for regulator 2 |
| 16 | VSPA | Differential output voltage positive sense for regulator 2 |

ASP2100, ASP2100R

PIN FUNCTION DESCRIPTION (continued)

| Pin No. | Pin Name | Description |
|---------|--------------------------|---|
| 17 | DIFFA | Output of the regulator 2 differential remote sense amplifier |
| 18 | FBA | Error amplifier voltage feedback for regulator 2 |
| 19 | COMPA | Output of the error amplifier and the inverting inputs of the PWM comparators for regulator 2 |
| 20 | CSCOMPA | Output of total-current-sense amplifier for regulator 2 |
| 21 | ILIMA | Over-current threshold setting – programmed with a resistor to CSCOMPA for regulator 2 |
| 22 | CSSUMA | Inverting input of total-current-sense amplifier for regulator 2 |
| 23 | CSREFA | Total-current-sense amplifier reference voltage input for regulator 2 |
| 24 | CSP1A | Non-inverting input to current-balance amplifier for Phase 1 of regulator 2 |
| 25 | CSP2A | Non-inverting input to current-balance amplifier for Phase 2 of regulator 2 |
| 26 | TSENSEA | Temperature sense input for regulator 2 |
| 27 | PWM1A/ICCMAXA | PWM1 output for regulator 2. Pulldown on this pin programs ICCMAX for regulator 2 during startup |
| 28 | PWM2A/ I2C_ADDRESS | PWM2 output for regulator 2. Pulldown on this pin programs I ² C address during startup |
| 29 | DRON | External FET driver enable for discrete driver or ONSem DrMOS |
| 30 | PWM8 | PWM8 output for regulator 1. |
| 31 | PWM7/ ICC*2_MAIN_RAIL | PWM7 output for regulator 1/Pulldown resistor on this pin can be used to enable ICC*2_MAIN_RAIL function. |
| 32 | PWM6/ ICCMAX_AUXIN | PWM6 output for regulator 1/Pulldown resistor on this pin programs ICCMAX for the AUX_IN monitoring rail |
| 33 | PWM5/ROSCA | PWM5 output for regulator 1/Pulldown on this pin programs RoscA value for regulator 2 |
| 34 | PWM4/ROSC | PWM4 output for regulator 1/Pulldown on this pin programs Rosc value for regulator 1 |
| 35 | PWM3/ICCMAX | PWM3 output for regulator 1/Pulldown on this pin programs ICCMAX for regulator 1 during startup |
| 36 | PWM2/VBOOT | PWM2 output for regulator 1/Pin-program for regulator 1 and regulator 2 Vboot |
| 37 | PWM1/ SV_ADDR_SR | ASP2100: PWM1 output for regulator 1/Pulldown on this pin configures SVID address and slew rate. ASP2100R: PWM1 output for regulator 1 / Pulldown on this pin configures SVID address, slew rate and VR_Hot control for Fast V-Mode. |
| 38 | TSENSE | Temperature sense input for regulator 1 |
| 39 | CSP1 | Differential current sense positive for Phase 1 of regulator 1 |
| 40 | CSP2 | Differential current sense positive for Phase 2 of regulator 1 |
| 41 | CSP3 | Differential current sense positive for Phase 3 of regulator 1 |
| 42 | CSP4 | Differential current sense positive for Phase 4 of regulator 1 |
| 43 | CSP5 | Differential current sense positive for Phase 5 of regulator 1 |
| 44 | CSP6 | Differential current sense positive for Phase 6 of regulator 1 |
| 45 | CSP7 | Differential current sense positive for Phase 7 of regulator 1 |
| 46 | CSP8 | Differential current sense positive for Phase 8 of regulator 1 |
| 47 | CSREF | Total-current-sense amplifier reference voltage input for regulator 1 |
| 48 | CSSUM | Inverting input of total-current-sense amplifier for regulator 1 |
| 49 | ILIM | Over-current threshold setting – programmed with a resistor to CSCOMP for regulator 1 |
| 50 | CSCOMP | Output of total-current-sense amplifier for regulator 1 |
| 51 | COMP | Output of the error amplifier and the inverting inputs of the PWM comparators for regulator 1 |
| 52 | FB | Error amplifier voltage feedback for regulator 1 |
| 53 | DIFF | Output of the regulator 1 differential remote sense amplifier |
| 54 | VSP | Differential output voltage sense positive for regulator 1 |
| 55 | VSN | Differential output voltage sense negative for regulator 1 |
| 56 | IOUT | Total output current monitor for regulator 1 |
| | Flag | GND |

1. “Regulator 1” is referred to as “Main” rail throughout the datasheet. “Main” is the primary rail with the highest phase count.
2. “Regulator 2” is referred to as “A” rail throughout the datasheet.

ASP2100, ASP2100R

MAXIMUM RATINGS (Note 3)

| Pin Symbol | V _{MAX} | V _{MIN} | I _{SOURCE} | I _{SINK} |
|-----------------|------------------|------------------|---------------------|-------------------|
| COMP, COMPA | VCC + 0.3 V | −0.3 V | 2 mA | 2 mA |
| CSCOMP, CSCOMPA | VCC + 0.3 V | −0.3 V | 2 mA | 2 mA |
| PWMX | VCC + 0.3 V | −0.3 V | – | 1 mA |
| VSN, VSNA | GND + 0.3 V | GND − 0.3 V | 1 mA | 2 mA |
| DIFF, DIFFA | VCC + 0.3 V | −0.3 V | 2 mA | 2 mA |
| VR_RDY | VCC + 0.3 V | −0.3 V | 2 mA | – |
| VCC | 6.0 V | −0.3 V | – | – |
| VRMP | VCC + 0.3 V | −0.3 V | – | – |
| SCLK, SDIO | 3.6 V | −0.3 V | – | – |
| All Other Pins | VCC + 0.3 V | −0.3 V | – | – |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

3. All signals referenced to GND unless noted otherwise

ESD CAPABILITY

| Description | Symbol | Typ | Unit |
|---|--------|-------|------|
| ESD Capability, Human Body Model (Note 4) | ESDHBM | 2,000 | V |
| ESD Capability, Charged Device Model (Note 4) | ESDCDM | 750 | V |

4. This device series incorporates ESD protection and is tested by the following methods:

ESD Human Body Model tested per AEC-Q100-002 (EIA/JESD22-A114)

ESD Charge Device Model tested per AEC-Q100-011 (EIA/JESD22-C101)

Latch-up Current Maximum Rating: ≤ 200 mA per JEDEC standard: JESD78.

RECOMMENDED OPERATING CONDITIONS

| Description | Symbol | Min | Max | Unit |
|---|----------------|------|------|------|
| VCC Voltage Range | VCC | 4.75 | 5.25 | V |
| Operating Junction Temperature Range (Note 5) | T _J | −10 | 125 | °C |
| Operating Ambient Temperature Range | T _A | −10 | 100 | °C |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

5. JEDEC JESD 51-7 with 0 LFM.

THERMAL CHARACTERISTICS

| Description | Symbol | Value | Unit |
|--|----------------------|-------------|------|
| Thermal Characteristic QFN Package | R _{JA} | 65 | °C/W |
| Maximum Storage Temperature Range | T _{STG} | −40 to +150 | °C |
| Soldering Temperature | | 260 | °C |
| Junction-to-Ambient, Thermal Resistance (Note 6) | θ _{JA} | 30 | °C/W |
| Junction-to-Case (Top), Thermal Resistance (Note 6) | θ _{JC(TOP)} | 18 | °C/W |
| Junction-to-Board Heat Spreader, Thermal Resistance (Note 6) | θ _{JB} | 1.0 | °C/W |
| Junction-to-Case (Top), Measurement Reference (Note 6) | Ψ _{J-CT} | 1.1 | °C/W |
| Moisture Sensitivity Level QFN Package | MSL | 1 | |

6. JEDEC JESD 51-7 with 0 LFM

ASP2100, ASP2100R

ELECTRICAL CHARACTERISTICS ($-10^{\circ}\text{C} < T_A < 100^{\circ}\text{C}$; $4.75\text{ V} < V_{CC} < 5.25\text{ V}$; $C_{VCC} = 0.1\text{ }\mu\text{F}$ unless otherwise noted)

| Parameter | Test Conditions | Min | Typ | Max | Unit |
|-----------|-----------------|-----|-----|-----|------|
|-----------|-----------------|-----|-----|-----|------|

BIAS SUPPLY

| | | | | | |
|-------------------|---------------------|------|-----|------|---------------|
| VCC Voltage Range | | 4.75 | – | 5.25 | V |
| Quiescent Current | PS0 | – | 31 | – | mA |
| | PS1 | – | 26 | – | mA |
| | PS2 | – | 21 | – | mA |
| | PS3 | – | 17 | – | mA |
| | PS4 | – | – | 79 | μA |
| | Enable Low | – | – | 64 | μA |
| UVLO Threshold | VCC Rising | – | – | 4.5 | V |
| | VCC Falling | 4.1 | – | – | V |
| | VCC UVLO Hysteresis | – | 100 | – | mV |

VRMP

| | | | | | |
|------------------|---|-------|---|-------|---|
| VIN Supply Range | VRMP range prior to external voltage divider resistor network with 1/12 ratio | 4.5 | – | 21 | V |
| UVLO Threshold | VRMP Rising | – | – | 0.355 | V |
| | VRMP Falling | 0.250 | – | – | V |

ENABLE INPUT

| | | | | | |
|-----------------|--------------------|-----|---|-----|---|
| Upper Threshold | Activation Level | 0.8 | – | – | V |
| Lower Threshold | Deactivation Level | – | – | 0.3 | V |

PHASE DETECTION

| | | | | | |
|---------------------------|--|----------------|-----|---|----|
| CSP Pin Threshold Voltage | | $V_{CC} - 0.4$ | – | – | V |
| Phase Detect Timer | | – | 1.5 | – | ms |

IMVP9.1 DAC (PROTOCOL 0EH)

| | | | | | |
|-------------------------|---|------|---|-----|----|
| System Voltage Accuracy | $0\text{ V} < \text{DAC} < 0.495\text{ V}$ (25°C only) | –10 | – | 10 | mV |
| | $0.5\text{ V} < \text{DAC} < 0.745\text{ V}$ (25°C only) | –8 | – | 8 | mV |
| | $0.75\text{ V} < \text{DAC}$ (25°C only) | –0.5 | – | 0.5 | % |

DAC SLEW RATE

| | | | | | |
|----------------------|-----------------------------------|---|----------|---|-------------------------|
| Soft Start Slew Rate | | – | 1/4 fast | – | $\text{mV}/\mu\text{s}$ |
| Slew Rate Slow | | – | 1/4 fast | – | $\text{mV}/\mu\text{s}$ |
| Slew Rate Fast | Resistor Selectable (See Table 4) | – | >10 | – | $\text{mV}/\mu\text{s}$ |
| VOFS Slew Rate | | – | 1/4 fast | – | $\text{mV}/\mu\text{s}$ |

DRON

| | | | | | |
|---------------------|---------------|---|---|-----|---|
| Output High Voltage | Sourcing 1 mA | 3 | – | – | V |
| Output Low Voltage | Sinking 1 mA | – | – | 0.1 | V |

TSENSE

| | | | | | |
|---------------------|---------------------|-------|-----|-------|---------------|
| TSENSE Bias Current | | 115.5 | 120 | 124.5 | μA |
| Alert# | Assert Threshold | – | 486 | – | mV |
| | De-Assert Threshold | – | 548 | – | mV |
| VR_HOT | Assert Threshold | – | 448 | – | mV |
| | De-Assert Threshold | – | 511 | – | mV |
| VRSHDN | Assert Threshold | – | 185 | – | mV |

VR_RDY OUTPUT

| | | | | | |
|------------------|-------------------------------|---|-----|-----|----|
| VR_RDY Rise Time | 1 k Ω pull-up to 3.3 V | – | 110 | 150 | ns |
| VR_RDY Fall Time | CTOT = 45 pF | – | 20 | 150 | ns |

ASP2100, ASP2100R

ELECTRICAL CHARACTERISTICS ($-10^{\circ}\text{C} < T_A < 100^{\circ}\text{C}$; $4.75\text{ V} < V_{CC} < 5.25\text{ V}$; $C_{VCC} = 0.1\text{ }\mu\text{F}$ unless otherwise noted) (continued)

| Parameter | Test Conditions | Min | Typ | Max | Unit |
|---------------------------|------------------------------|-----|-----|-----|------|
| VR_RDY Output Voltage Low | $I_{VR_RDY} = -4\text{ mA}$ | – | – | 0.3 | V |

SVID (SDIO and SCLK)

| | | | | | |
|---------------------------|--------------|------|---|------|----------|
| SVID Voltage Low Level | VIL (Note 7) | – | – | 0.45 | V |
| SVID Voltage High Level | VIH (Note 7) | 0.65 | – | – | V |
| SVID Pull Down Resistance | (Note 8) | – | 4 | – | Ω |
| SDIO Output Low Voltage | VOL | – | – | 0.3 | V |
| SVID Clock to Data Delay | TCO (Note 8) | – | – | 12 | ns |
| SVID Setup Time | (Note 8) | 7 | – | – | ns |
| SVID Hold Time | (Note 8) | 14 | – | – | ns |
| Input Capacitance | (Note 8) | – | 5 | – | pF |

ALERT#

| | | | | | |
|------------------|--|---|---|-----|---|
| VOL (Output Low) | | – | – | 0.3 | V |
|------------------|--|---|---|-----|---|

OVP AND UVP

| | | | | | |
|--|--|------|------|------|---------------|
| Absolute Over Voltage Threshold | 10 mV DAC step During Soft Start – CSREF Rising | 3.3 | 3.44 | 3.6 | V |
| | 5 mV DAC step During Soft Start – CSREF Rising | 2.4 | 2.5 | 2.6 | V |
| Over Voltage Threshold Above DAC | VSP–VSN–VID Rising | 350 | 400 | 475 | mV |
| Over Voltage Delay | VSP–VSN Rising to PWM Low | | 50 | | ns |
| Under Voltage Threshold Below DAC–DROOP (VUVM) | VSP–VSN–VID Falling | –440 | –400 | –360 | mV |
| Under Voltage Delay | | – | 5 | – | μs |

PWM OUTPUT

| | | | | | |
|---------------------|----------------------------|----------------|-----|-----|---|
| Output High Voltage | Sourcing 500 μA | $V_{CC} - 0.2$ | – | – | V |
| Output Mid Voltage | No Load, Power State 2 | 1.7 | 1.8 | 1.9 | V |
| Output Low Voltage | Sinking 500 μA | – | – | 0.7 | V |

DIFFERENTIAL AMPLIFIER

| | | | | | |
|---------------------|--------------------------------|-----|------|-----|-----|
| Input Bias Current | VSP = 1.3 V | 200 | – | 500 | nA |
| –3 dB Bandwidth | CL = 20 pF, RL = 10 k Ω | – | 22.5 | – | MHz |
| Closed Loop DC Gain | VSP – VSN = 0.5 V to 1.3 V | – | 1 | – | V/V |

ERROR AMPLIFIER

| | | | | | |
|--------------------|---|------|----|-----|------------------|
| Input Bias Current | Input = 1.3 V | –400 | – | 400 | nA |
| DC Gain | CL = 20 pF, RL = 10 k Ω | – | 80 | – | dB |
| –3 dB Bandwidth | CL = 20 pF, RL = 10 k Ω | – | 20 | – | MHz |
| Slew Rate | $\Delta V_{in} = 100\text{ mV}$, $G = -10\text{ V/V}$, $\Delta V_{out} = 1.5\text{ V to }2.5\text{ V}$, CL = 20 pF, RL = 10 k Ω | – | 5 | – | V/ μs |

OVER-CURRENT PROTECTION (ILIM)

| | | | | | |
|---|--|----|------|----|---------------|
| ILim Threshold Current Immediately, OCP_LVRHOT# Asserts | ICL0 – PS0 Operation | 8 | 9 | 10 | μA |
| | ICL1 – PS1, PS2, PS3 Operation (Note 9) | – | 9/N | – | μA |
| ILim Threshold Current (Delayed OCP shutdown) | ICLM0 – PS0 Operation | 11 | 13 | 15 | μA |
| | ICLM1 – PS1, PS2, PS3 Operation (Note 9) | – | 13/N | – | μA |
| Shutdown Delay | Immediate | – | 650 | – | ns |
| | Delayed | – | 20 | – | μs |

ASP2100, ASP2100R

ELECTRICAL CHARACTERISTICS (−10°C < T_A < 100°C; 4.75 V < V_{CC} < 5.25 V; C_{VCC} = 0.1 μF unless otherwise noted) (continued)

| Parameter | Test Conditions | Min | Typ | Max | Unit |
|-----------|-----------------|-----|-----|-----|------|
|-----------|-----------------|-----|-----|-----|------|

IOOUT OUTPUT

| | | | | | |
|--------------|--|-----|----|------|-----|
| Current Gain | IOOUT/ILIM (RLIM = 20 kΩ, RIOUT = 5 kΩ, Vout = 0.8 V, 1.25 V, 1.52 V) | 9.5 | 10 | 10.5 | A/A |
|--------------|--|-----|----|------|-----|

PWM GENERATOR

| | | | | | |
|-------------------------|--|---|------|---|----|
| PWM Minimum Pulse Width | | – | 40 | – | ns |
| 0% Duty Cycle | Comp Voltage for PWM Held Low | – | 1.3 | – | V |
| 100% Duty Cycle | Comp Voltage for PWM Held High VIN at 4.5 V | – | 1.75 | – | V |
| | Comp Voltage for PWM Held High VIN at 21 V | – | 3.4 | – | |

CURRENT SUMMING AMPLIFIER (CSAMP)

| | | | | | |
|--------------------------------|--|------|----|-----|-----|
| Offset Voltage | | –500 | – | 500 | μV |
| Input Bias Current | CSSUM = CSREF = 1.0 V | –10 | – | 10 | μA |
| Open Loop Gain | | – | 80 | – | dB |
| Open Loop Unity Gain Bandwidth | C _L = 20 pF to GND, R _L = 10 kΩ to GND | – | 10 | – | MHz |

CURRENT BALANCE AMPLIFIER

| | | | | | |
|---------------------------------------|---------------|------|---|-----|----|
| Differential Mode Input Voltage Range | CSREF = 1.2 V | –100 | – | 100 | mV |
|---------------------------------------|---------------|------|---|-----|----|

PSYS

| | | | | | |
|--------------------------|--|---|-----------|---|---|
| Full Scale Input Voltage | | – | 2.5 | – | V |
| Disable Threshold | | – | VCC – 0.4 | – | V |

I²C (SDA AND SCL)

| | | | | | |
|---------------------------------------|---|----------------------------|-----|----------------------------|-----|
| High Input Voltage (V _{IH}) | V _{TT_I2C} is the I ² C (SDA & SCL) Termination Voltage, 1.71 V ≤ V _{TT_I2C} ≤ 5.25 V (Note 10) | 0.65 * V _{TT_I2C} | – | – | V |
| Low Input Voltage (V _{IL}) | | – | – | 0.35 * V _{TT_I2C} | V |
| Hysteresis | (Note 10) | – | 120 | – | mV |
| Output Low Voltage | I _{PULLUP} = 3 mA | – | – | 0.4 | V |
| Input Current | | –10 | – | – | μA |
| Input Capacitance | SDA and SCL | – | 5 | – | pF |
| Clock Frequency | | – | – | 400 | kHz |
| SCL Falling Edge to SDA Valid Timing | (Note 8) | – | – | 1 | μs |

7. Tested at 25°C / 5 V VCC only.

8. Guaranteed by characterization, not production tested.

9. N is the phase configuration number in PS0.

10. Guaranteed by design, not production tested.

Start Up

Following the rise of VCC above the UVLO threshold, externally programmed configuration data is collected, and all PWM outputs are set to Mid-level to prepare the gate drivers of the power stages for activation. When the controller is enabled, DRON is asserted (high) to activate the external gate drivers. A digital counter steps the DAC up

from zero to the target boot voltage based on the Soft Start Slew Rate in the spec table. As the DAC ramps, the PWM outputs of each rail will change from Mid-level to high when the first PWM pulse for that rail is produced. When the controller is disabled, the PWM signals return to Mid-level. The VR_RDY signal is asserted when the controller is ready to accept the first SVID command.

TIMING DIAGRAMS

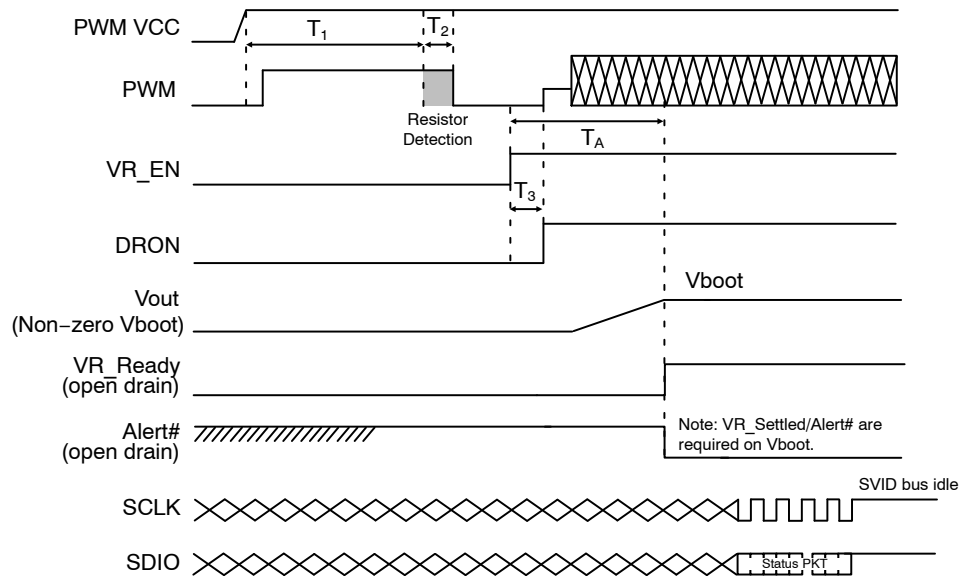


Figure 4. IMVP9.1 Start-Up Timing Diagram
(With PWM resistor detection and DRON)

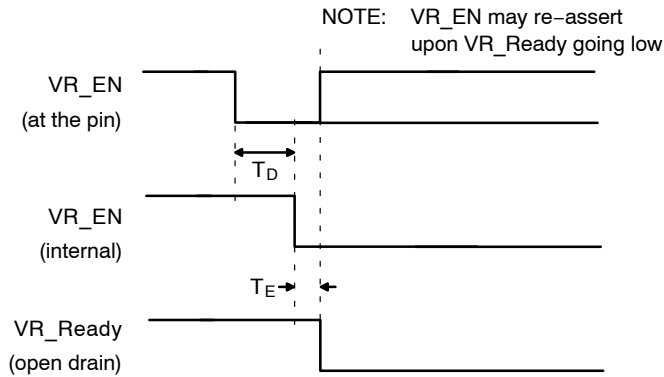


Figure 5. Shut-Down Timing Diagram

Table 1. START-UP AND SHUT-DOWN TIMING

| | Description | Min | Typ | Max | Unit |
|----|--|-----|-----|-----|------|
| TA | VR_EN to VR_Ready. Controller ready to accept SVID command | – | – | 2.5 | ms |
| TD | External de-assertion of VR_EN to the internal recognition of VR_EN de-assertion (glitch filter) | 0 | – | 1 | μs |
| TE | VR_EN internal de-assertion to VR_Ready de-assertion | – | – | 500 | ns |
| T1 | VCC rise over UVLO to configured resistor detection begin | – | 1.5 | – | ms |
| T2 | Configured resistor detection time | – | 100 | – | μs |
| T3 | VR_EN to DRON | – | 117 | – | μs |

DEVICE CONFIGURATION

Phase and Rail Configuration

During start-up, the number of operational phases of the multiphase rail is determined by the internal circuitry monitoring the CSP inputs. If a reduced phase count is required, the appropriate CSP pins should be externally pulled to VCC with a resistor during startup. Also, whether or not the PSYS function is active and responds to an address call on the SVID bus is determined by the internal circuitry monitoring the PSYS input. Tying the PSYS input to VCC will cause the PSYS rail to not respond to any calls to address 0Dh on the SVID bus.

Basic Configuration

The controller has four basic configuration features. On power up a 10 μ A current is sourced from these pins through a resistor connected to this pin and the resulting voltage is measured. The following features will be programmed:

- SVID Address
- Slew Rate
- V_{BOOT}
- Output Voltage Step

SVID address and slew rate options are shown in Table 4.

V_{BOOT} and output voltage step options are shown in Table 6.

ASP2100R Fast V-Mode

VR_HOT assertion for Fast V-Mode on/off selection as shown in Table 5. Fast V-Mode is only supported on the ASP2100R.

Switching Frequency

Switching frequencies between 180 kHz and 1.17 MHz are programmed on power up with pulldown resistors on the Rosc and RoscA pins. Switching frequency options are shown in Table 9. The Main Rail follows the configuration number in PS0. The A rail follows 1-phase switching frequency setting.

ICCMAX

The SVID interface provides the platform ICCMAX values for each rail, at register 21h. Resistors to ground on the PWM3/ICCMAX, PWM1A/ICCMAXA and PWM6/ICCMAX_AUXIN pins program these registers. On power up, 10 μ A is sourced from these pins to generate voltages on the program resistors. The values of the registers are set by the equation below. The resistor values should be no less than 10 k Ω .

$$ICCMAX_{21h} = \frac{R \times 10 \mu A \times 255}{2.5 V} \quad (\text{eq. 1})$$

ICCMAX Additional Capability

IMVP9.1 adds an option to extend the current range of the main rail by scaling the LSB size of register ICCMAX_{21h} by 2^{ICCMAX_ADD50h[1:0]} amps (See Table 2). On the ASP2100 and ASP2100R, these register bits can be configured to 2 A per bit by enabling ICC*2_MAIN_RAIL mode. See Table 6 for details on how to enable this mode.

Table 2. ICCMAX CAPABILITY SCALING

| ICCMAX_ADD50h[4:0] | | ICC Scaling | Power Scaling |
|--------------------|---------------|----------------|---------------|
| Power [4:2] | Current [1:0] | | |
| 010 | 00 | 1 A / bit | 4 W / bit |
| 011 | 01 | 2 A / bit | 8 W / bit |

When ICC*2_MAIN_RAIL mode is enabled, the bits ICCMAX_ADD50h[1:0] are set to 01b to indicate a scaling of 2 A per bit. This scaling applies to both the ICCMAX_{21h} and the IOUT_H15h SVID registers. The bits ICCMAX_ADD50h[4:2] are also set to 011b to indicate that the POUT_H18h register value is scaled to 8 W per bit. See SVID register ICCMAX_ADD50h description in Table 19 for more details. Table 3 shows the rail configurations when ICC*2_MAIN_RAIL mode is enabled or disabled.

Table 3. RAIL SETTINGS FOR ICC*2_MAIN_RAIL MODE

| | | ICC*2_MAIN_RAIL | |
|-----------|---|-----------------|---------|
| | | Disabled | Enabled |
| Main Rail | ICCMAX _{21h} LSB Size | 1 A | 2 A |
| | IOUT _{15h} LSB Size | 1 A | 2 A |
| | POUT _{18h} LSB Size | 4 W | 8 W |
| | HIGHPOWER_ICCMAX_ADD _{50h} [1:0] | 00 | 01 |
| | HIGHPOWER_ICCMAX_ADD _{50h} [4:2] | 010 | 011 |
| | Default Loadline Weighting | 50% | 100% |
| A Rail | ICCMAX _{21h} LSB Size | 1 A | |
| | IOUT _{15h} LSB Size | 1 A | |
| | POUT _{18h} LSB Size | 4 W | |
| | HIGHPOWER_ICCMAX_ADD _{50h} [1:0] | 00 | |
| | HIGHPOWER_ICCMAX_ADD _{50h} [4:2] | 010 | |
| | Default Loadline Weighting | 50% | |
| VCCIN_AUX | ICCMAX _{21h} LSB Size | 1 A | |
| | IOUT _{15h} LSB Size | 1 A | |
| | POUT _{18h} LSB Size | 4 W | |
| | HIGHPOWER_ICCMAX_ADD _{50h} [1:0] | 00 | |
| | HIGHPOWER_ICCMAX_ADD _{50h} [4:2] | 010 | |

Ultrasonic Mode

The switching frequency of a rail in DCM will decrease at very light loads. Ultrasonic Mode forces the switching frequency to stay above the audible range.

CCM/DCM Operation

In PS0, all rails operate in Continuous Conduction Mode (CCM) which uses the dual-edge control methodology. However, if PS0 is configured as one-phase instead of multi-phase, the control methodology changes to RPM operation. RPM has great transient performance in one-phase CCM operation. The RPM frequency average DC value is targeted to be similar to the PS0 Dual Edge frequency. However, the switching frequency of RPM depends on input voltage, output voltage, load current, inductor value, and output capacitor value.

In PS2 and PS3, all rails will operate in either Continuous Conduction Mode (CCM) or discontinuous Conduction Mode (DCM) depending on load current in order to prevent loss of efficiency from negative inductor current.

Table 4. ASP2100 SVID ADDRESS AND SLEW RATE

| Resistor (kΩ) | SR (mV/μs) | Main Rail SVID Address | A Rail SVID Address |
|---------------|------------|------------------------|---------------------|
| 10 | 10 | 00 | 01 |
| 14 | 30 | 00 | 01 |
| 18.7 | 48 | 00 | 01 |
| 24.3 | 10 | 01 | 00 |
| 30.9 | 30 | 01 | 00 |
| 38.3 | 48 | 01 | 00 |
| 47.5 | 10 | 00 | 02 |
| 59 | 30 | 00 | 02 |
| 71.5 | 48 | 00 | 02 |
| 86.6 | 10 | 01 | 02 |
| 105 | 30 | 01 | 02 |
| 127 | 48 | 01 | 02 |

Table 5. ASP2100R SVID ADDRESS, SLEW RATE AND FAST V-MODE

| Resistor (k Ω) | SR (mV/ μ s) | Main Rail SVID Address | A Rail SVID Address | VR_HOT Assertion Fast V-Mode |
|------------------------|------------------|------------------------|---------------------|------------------------------|
| 10 | 10 | 0 | 1 | ON |
| 14 | 30 | 0 | 1 | ON |
| 18.7 | 48 | 0 | 1 | ON |
| 24.3 | 10 | 0 | 1 | OFF |
| 30.9 | 30 | 0 | 1 | OFF |
| 38.3 | 48 | 0 | 1 | OFF |
| 47.5 | 10 | 0 | 2 | ON |
| 59 | 30 | 0 | 2 | ON |
| 71.5 | 48 | 0 | 2 | ON |
| 86.6 | 10 | 0 | 2 | OFF |
| 105 | 30 | 0 | 2 | OFF |
| 127 | 48 | 0 | 2 | OFF |

Table 6. V_{BOOT} AND OUTPUT VOLTAGE STEP

| Resistor (k Ω) | V _{BOOT} (V) Main Rail | V _{BOOT} (V) A Rail | Output Voltage Step |
|------------------------|---------------------------------|------------------------------|--|
| 10 | 0 V | 0 V | Both rails 5 mV/step |
| 14 | 0 V | 1.05 V | |
| 18.7 | 1.05 V | 0 V | |
| 24.3 | 1.05 V | 1.05 V | |
| 30.9 | 0 V | 0 V | Both rails 10 mV/step |
| 38.3 | 0 V | 1.8 V | |
| 47.5 | 1.8 V | 0 V | |
| 59 | 1.8 V | 1.8 V | |
| 71.5 | 0 V | 0 V | Main rail 5 mV/step. A rail 10 mV/step. |
| 86.6 | 0 V | 1.8 V | |
| 105 | 1.05 V | 0 V | |
| 127 | 1.05 V | 1.8 V | |
| 154 | 0 V | 0 V | Main rail 10 mV/step. A rail 5 mV/step. |
| 187 | 1.8 V | 0 V | |
| 221 | 0 V | 1.05 V | |
| 280 | 1.8 V | 1.05 V | |

Table 7. POWER STATES

| SVID Power State | Typical Operating Mode |
|------------------|---------------------------|
| PS0 | Multiphase rail dual edge |
| PS1 | One-phase CCM RPM |
| PS2 | One-phase DCM RPM |
| PS3 | One-phase DCM RPM |
| PS4 | Standby |

PSYS

The PSYS pin is an analog input to the VR controller. PSYS is a system input power monitor that facilitates the monitoring of the total platform system power. The system power is sensed at the platform charging device, the VR controller facilitates reporting back current and through the SVID interface at address 0Dh.

AUX_IN

The AUX_IMON current monitor input is a means of measuring the VCCIN_AUX platform VR output current using the IMVP9.1 ADC. This input is used to digitize the VCCIN_AUX output current information, which is sent to the IMVP9.1 PWM controller as an analog current mode signal proportional to the VCCIN_AUX output current. The signal is converted to a voltage at the IMVP9.1 controller input pin by a termination resistor, located at the controller. A resistor with high input impedance should be selected to avoid loading effects on the signal. The AUX Current reading is scaled by ICCMAX_AUXIN and can be read back on Register 0x15 of Rail 0x0D of the controller SVID bus.

Programming Pin

This is a multifunction select pin used to set the operation of multiple features and the combination of these features enabled/disabled. Items programmed on this pin are ICC*2_MAIN_RAIL which allows the user to select if the ICCMAX and IOUT reporting for the main rail is a 1 A or 2 A LSB step size. When off, the resolution is 1 A per LSB. When on, the resolution is set to 2 A per LSB which allows reporting of over 255 A on the main rail only.

Auto phase shedding can be enabled in PS0 mode in order to minimize power dissipation. Auto phase shedding is determined by the I²C settings described in the Phase Shedding (Enable by I²C) section and the I²C register maps.

The other options include spread spectrum and acoustic noise solution. These programming pin functions must be enabled by the resistor setting shown in Table 8 before they can be enabled/disabled in I²C.

ASP2100, ASP2100R

Table 8. PIN OF ICC*2_MAIN_RAIL CONFIGURATION

| Resistor (kΩ) | ICC*2 Main Rail | Acoustic Noise Solution | Spread Spectrum | Auto Phase Shedding |
|---------------|-----------------|-------------------------|-----------------|---------------------|
| 10 | OFF | OFF | OFF | OFF |
| 14 | OFF | OFF | OFF | ON |
| 18.7 | OFF | OFF | ON | OFF |
| 24.3 | OFF | OFF | ON | ON |
| 30.9 | OFF | ON | OFF | OFF |
| 38.3 | OFF | ON | OFF | ON |
| 47.5 | OFF | ON | ON | OFF |
| 59 | OFF | ON | ON | ON |
| 71.5 | ON | OFF | OFF | OFF |
| 86.6 | ON | OFF | OFF | ON |
| 105 | ON | OFF | ON | OFF |
| 127 | ON | OFF | ON | ON |
| 154 | ON | ON | OFF | OFF |
| 187 | ON | ON | OFF | ON |
| 221 | ON | ON | ON | OFF |
| 280 | ON | ON | ON | ON |

Table 9. SWITCHING FREQUENCY

| Control by I ² C (Hex) | ROSC / ROSCA Control by Pin Resistor (kΩ) | Switching Frequency (kHz) (PS0 Number of Phases) | | |
|-----------------------------------|---|--|---------|---------|
| | | 1 Phase~6 Phase | 7 Phase | 8 Phase |
| 0000 | 10 | 180 | 180 | 180 |
| 0001 | 14 | 225 | 215 | 210 |
| 0010 | 18.7 | 270 | 250 | 240 |
| 0011 | 24.3 | 315 | 285 | 270 |
| 0100 | 30.9 | 360 | 320 | 300 |
| 0101 | 38.3 | 405 | 355 | 330 |
| 0110 | 47.5 | 450 | 390 | 360 |
| 0111 | 59 | 495 | 425 | 390 |
| 1000 | 71.5 | 540 | 460 | 420 |
| 1001 | 86.6 | 630 | 495 | 450 |
| 1010 | 105 | 720 | 530 | 480 |
| 1011 | 127 | 810 | 600 | 510 |
| 1100 | 154 | 900 | 700 | 540 |
| 1101 | 187 | 990 | 800 | 600 |
| 1110 | 221 | 1080 | 900 | 700 |
| 1111 | 280 | 1170 | 1000 | 800 |

THEORY OF OPERATION

Input Voltage Feed-Forward (VRMP Pin)

Ramp generator circuits are provided for the dual-edge modulator. The ramp generators implement input voltage feed-forward control by varying the ramp slopes proportional to the VRMP pin voltage. The VRMP pin also has a UVLO function, which is active only after the controller is enabled. The VRMP pin is high impedance input when the controller is disabled. For multi-phase operation, the dual-edge PWM ramp amplitude is changed according to the following:

$$VRMP_{PP} = 0.1 \times V_{VRMP} \quad (\text{eq. 2})$$

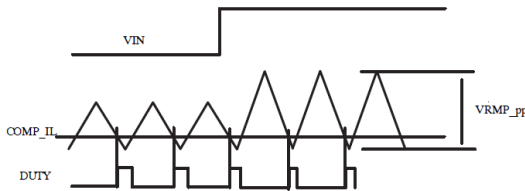


Figure 6. Ramp Feed Forward

An external voltage divider is required on this VRMP pin in order to scale the voltage seen on the VRMP pin the voltage divider on the pin needs to be setup to maintain a ratio of 1/12. Typical resistor values may include 1 M Ω R_{up} / 90.9 k Ω R_{down} or 1.1 M Ω R_{up} / 100 k Ω R_{down} . UVLO on VRMP is inactive in PS4 power state and PS3 when a VID to 0 V is received.

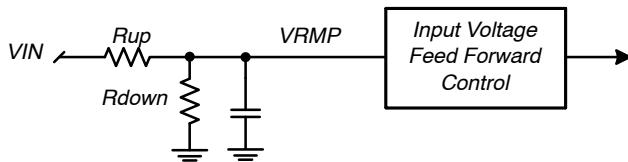


Figure 7. Ramp Feed Forward Circuit

Differential Current Feedback Amplifiers

Each phase of the rail has a low offset, differential amplifier to sense the current of that phase in order to balance current. The CSREF and CSPx pins are high impedance inputs, but it is recommended that any external filter resistor RCSN does not exceed 10 k Ω to avoid offset due to leakage current.

It is also recommended that the voltage sense element be no less than 0.5 m Ω for best current balance.

The external filter RCSN_x and CCSN_x time constant should match the inductor L/DCR time constant, but fine tuning of this time constant is generally not required. Phase

current signals are summed with the COMP or ramp signals at their respective PWM comparator inputs in order to balance phase currents via a current mode control approach.

$$RCSN_x = \frac{L_{PHASE}}{CCSN_x \times DCR} \quad (\text{eq. 3})$$

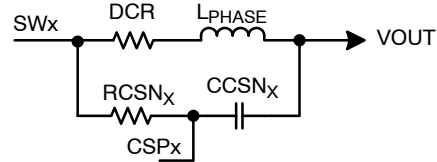


Figure 8. Per Phase Current Sense Network

Total Current Sense Amplifier

The multiphase rail uses a patented approach to sum the phase currents into a single, temperature compensated, total current signal. This signal is then used to generate the output voltage droop, total current limit, and the output current monitoring functions. The RREF_x resistors average the voltages at the output terminals of the inductors to create a low impedance reference voltage at CSREF. The RPH_x resistors sum currents from the switch nodes to the virtual CSREF potential created at the CSSUM pin by the amplifier. The total current signal is the difference between the CSCOMP and CSREF voltages.

The amplifier filters, and amplifies, the voltage across the inductors in order to extract only the voltage across the inductor series resistances (DCR). An NTC thermistor (Rth) in the feedback network placed near the Phase 1 inductor senses the inductor temperature, and compensates both the DC gain and the filter time constant for the change in DCR with temperature. The Phase 1 inductor is chosen for the thermistor location so that the temperature of the inductor providing current in the PS1 power mode.

The DC gain equation for the DC total current signal is:

$$V_{CSCOMP} - V_{CSREF} = - \frac{R_{CS1} \times R_{th}}{R_{CS2} + \frac{R_{CS1} \times R_{th}}{R_{CS1} + R_{th}}} \times DCR \times I_{OUT} \quad (\text{eq. 4})$$

Set the DC gain by adjusting the value of the Rph resistors in order to make the ratio of total current signal to output current equal the desired loadline. The values of Rcs1 and Rcs2 are set based on the effect of temperature on both the thermistor and inductor, and may need to be adjusted to eliminate output voltage temperature drift with the final product enclosure and cooling.

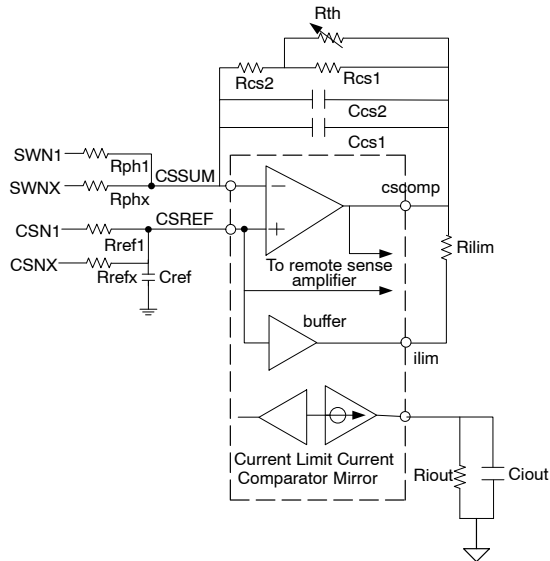


Figure 9. Total Current Sense Amplifier

The pole frequency of the CSCOMP filter should be set equal to the zero of the output inductor. This causes the total current signal to contain only the component of inductor voltage caused by the DCR voltage, and therefore to be proportional to inductor current. Connecting Ccs2 in parallel with Ccs1 allows fine tuning of the pole frequency using commonly available capacitor values. It is best to perform fine tuning during transient testing.

$$F_Z = \frac{DCR_{25^\circ C}}{2\pi \times L_{Phase}} \quad (\text{eq. 5})$$

$$F_P = \frac{1}{2\pi \times \left(R_{CS2} + \frac{R_{CS1} \times R_{th}}{R_{CS1} + R_{th}} \right) \times (C_{CS1} + C_{CS2})} \quad (\text{eq. 6})$$

This signal then goes through a standard error compensation network and into the inverting input of the error amplifier.

The value of the CREF capacitor (in nF) on the CSREF pin should be:

$$C_{ref} = \frac{0.02 \times R_{ph}}{R_{ref}} \quad (\text{eq. 7})$$

High Performance Voltage Error Amplifier

The Remote Sense Amplifier output feeds a Type III compensation network formed by the Error Amplifier and external tuning components. The non-inverting input of the error amplifier is connected to the same reference voltage used to bias the Remote Sense Amplifier output.

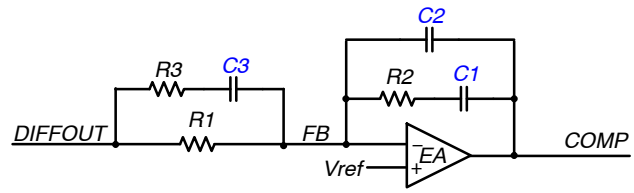


Figure 10. Error Amplifier

Loadline Programming (V_{DROOP})

An output loadline is a power supply characteristic wherein the regulated (DC) output voltage decreases proportional to load current. This characteristic can reduce the output capacitance required to maintain output voltage within limits during load transients faster than those to which the regulation loop can respond.

A load line is produced by adding a signal proportional to output load current (V_{DROOP}) to the output voltage feedback signal – thereby satisfying the voltage regulator at an output voltage reduced proportional to load current. The load line is programmed by setting the gain of the Total Current Sense Amplifier such that the total current signal is equal to the desired output voltage droop.

$$V_{DROOP} = \frac{R_{CS2} + \frac{R_{CS1} \times R_{th}}{R_{CS1} + R_{th}}}{R_{ph}} \times DCR \times I_{OUT} \times \text{weighting} \quad (\text{eq. 8})$$

Where the default weighting is 50% for A rail and Main rail when ICC*2_MAIN_RAIL = OFF and is 100% for Mail Rail when ICC*2_MAIN_RAIL = ON

Rail Remote Sense Amplifier

A high performance high input impedance true differential amplifier is provided to accurately sense regulator output voltage. The VSP and VSN inputs should be connected to the regulator's output voltage sense points. The remote sense amplifier takes the difference of the output voltage with the DAC voltage and adds the droop voltage.

$$V_{DIFFOUT} = (V_{VSP} - V_{VSN}) + (1.3 \text{ V} - V_{DAC}) + (V_{DROOP} - V_{CSREF}) \quad (\text{eq. 9})$$

Programming the Current Limit

The current limit thresholds are programmed with a resistor between the ILIM and CSCOMP pins for the main rail and ILIMA and CSCOMPA for the A-rail. For simplicity, only the main rail operation will be described. Refer to Table 10 for equivalent A-Rail parameters.

The multiphase rail generates a replica of the CSREF pin voltage at the ILIM pin, and compares the ILIM pin current

to ICL0 and ICLM0 (ICL1 and ICLM1 in PS1, PS2 and PS3). When enabled by setting I²C register 0x1E[0]=1, if the ILIM pin current exceeds ICL0 (ICL1 for PS1, PS2, and PS3), the controller asserts OCP_L/VRHOT# immediately, but does not shut down. If the ILIM pin current exceeds

ICLM0 (ICLM1 for PS1, PS2 and PS3), the rail latches off after a programmable delay (0x1B[7:5]). Set the value of the current limit resistor RILIM according to Equation 10 for the desired output current limit.

Table 10. OCP SETUP, CONTROL AND MONITORING

| Description | Main Rail | A-Rail |
|--|----------------|------------------|
| R _{ILIM} resistor connection | CSCOMP to ILIM | CSCOMPA to ILIMA |
| OCP_L Current (PS0) [Default = 9 μA] | ICL0 | ICL0A |
| OCP_L Current (PS1, PS2, PS3) [Default = 1.125 μA] | ICL1 | ICL1A |
| Total OCP Enable | 0x1D[3] | 0x39[3] |
| OCP_L OCP Ratio I2C Register, [Default = 90%] | 0x19[3:1] | 0x37[3:1] |
| OCP_L Hysteresis Ratio Bit, ['0' = 10%, '1' = 20%] | 0x19[0] | 0x37[0] |
| OCP_L Enable Bits, ['0' = OFF, '1' = ON] | 0x1E[0] | 0x3A[0] |
| OCP Current (PS0) [Default = 13 μA] | ICLM0 | ICLM0A |
| OCP Current (PS1, PS2, PS3) [Default = 1.625 μA] | ICLM1 | ICLM1A |
| OCP Ratio I ² C Register, [Default = 130%] | 0x19[7:4] | 0x37[7:4] |
| Total OCP Delay, [Default = 20 μs] | 0x1B[7:5] | |
| Total OCP Single Phase threshold, ['0' = 100%, '1' = 200%] | 0x22[5] | 0x3B[5] |
| Total OCP Indicator | 0x18[7] | 0x36[5] |

The OCP_RATIO can be independently set for both the immediate (OCP_L) limit and the delayed OCP limit by modifying the respective I²C 0x19[3:1] and 0x19[7:4] bit fields.

$$R_{ILIM} = \frac{R_{CS2} + \frac{R_{CS1} \times R_{TH}}{R_{CS1} + R_{TH}}}{R_{PH}} \times \frac{DCR \times I_{LIM}}{10\mu A \times OCP_RATIO} \quad (\text{eq. 10})$$

This equation sets the current limit when all phases are active. When the number of active phases is reduced, either by auto phase shedding or by entering the PS1, PS2, or PS3 power states, the OCP current limit is reduced according to Equation 11.

$$I_{LIM\ ACTIVE} = I_{LIM} \times \frac{\text{Active Phases}}{\text{Total Phase Count}} \quad (\text{eq. 11})$$

For example:

OCP is set to 240 A on the 8 phase rail. If only a single phase is active, then the OCP limit automatically scales to 240 A x 1/8 = 30 A. If 4 phases are active, then the OCP limit is 120 A.

Programming IOUT

The IOUT pin sources a current proportional to the ILIM current. The voltage on the IOUT pin is monitored by the internal A/D converter and should be scaled with an external resistor to ground such that a load equal to ICCMAX generates a 2.5 V signal on IOUT.

$$R_{IOUT} = \frac{2.5\text{ V} \times R_{LIMIT}}{10 \times \frac{R_{CS2} + \frac{R_{CS1} \times R_{TH}}{R_{CS1} + R_{TH}}}{R_{PH}} \times DCR \times ICCMAX} \quad (\text{eq. 12})$$

Programming DAC Feed-Forward Filter

The multiphase rail outputs a pulse of current from the VSN pin upon each increment of the internal DAC following a DVID UP command. This current is scaled with the load line setting from registers 0x0D and 0x0E for the main rail and 0x2E for the A rail.

A parallel RC network inserted into the path from VSN to the output voltage return sense point, VSS_SENSE, causes these current pulses to temporarily decrease the voltage between VSP and VSN. This causes the output voltage during DVID to be regulated slightly higher, to compensate for the response of the DROOP function to the current flowing into the charging output capacitors. In the following equations, COUT is the total output capacitance of the system.

It is recommended that the highest load line weighting for the highest desired load line be used. This allows the DAC feed-forward current to optimally scale with the load line weight adjustments.

$$C_{FF} = 2.2\text{ nF} \quad (\text{eq. 13})$$

$$R_{FF} = C_{out} \times LL/C_{FF} \quad (\text{eq. 14})$$

ASP2100, ASP2100R

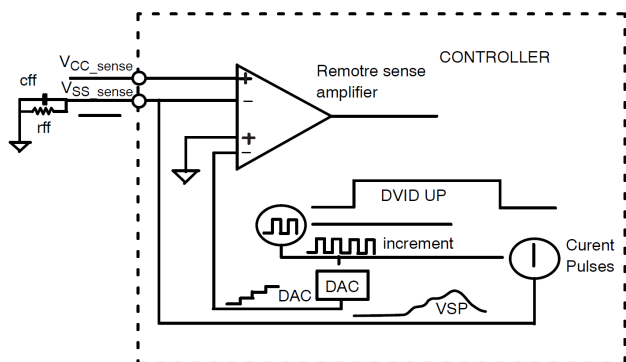


Figure 11. DAC Feed Forward

TSENSE Network

A temperature sense input is provided for each rail. A precision 120 μ A current is sourced from the TSENSE & TSENSEA pins to generate a voltage on the temperature sense networks. The voltages on the temperature sense inputs are sampled by the internal A/D converter and compared to the threshold registers. A 100k NTC such as the Murata NCU18WF104F6SRB should be used and connected as shown in Figure 12. R_{COMP1} & R_{COMP2} are used to linearise the network response over the temperature range from 25°C to 106°C. Recommended values are 300 Ω and 13.7 k Ω respectively when the NCU18WF104F6SRB is used. A 100 nF filter cap, located near the controller, should also be used.

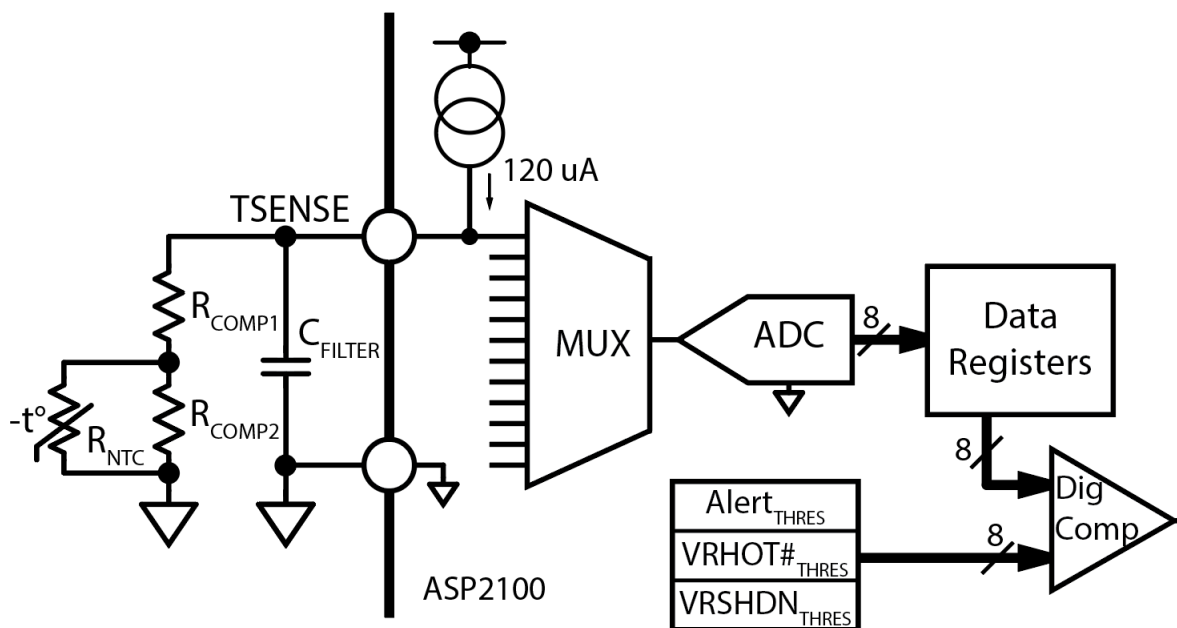


Figure 12. TSENSE Network

The Alert, VRHOT# and VRSHDN thresholds can be programmed over I²C for the Main and A-rails using the following registers.

Table 11. TSENSE and TSENSEA I²C REGISTERS

| Threshold | Main Rail | A-Rail | Default Value |
|-----------|-----------|-----------|---------------|
| Alert | 0x59[7:4] | 0x59[3:0] | 0x03 |
| VRHOT# | 0x22[3:0] | 0x3B[3:0] | 0x04 |
| VRSHDN | 0x20[7:4] | 0x21[7:4] | 0x07 |

The typical threshold values are shown in Table 12. The temperature values are related to the ideal response given in Equation 15.

$$T_{TH} = \left(1 - \frac{V_{TH}}{1.8V}\right) \times 140^{\circ}C \quad (\text{eq. 15})$$

Table 12. TSENSE & TSENSEA THRESHOLD VOLTAGES

| Register Value | | VRSHDN | | VRHOT#/Alert | | | |
|----------------|------|------------------------------|------------------------|------------------------------|------------------------|--------------------------------|------------------------|
| Dec | Hex | V _{THASSET} [mV] | Temp [°C] (Note 11) | V _{THASSET} [mV] | Temp [°C] (Note 11) | V _{THDEASSET} [mV] | Temp [°C] (Note 11) |
| 0 | 0x00 | 365 | 112 | 603 | 93 | 666 | 88 |
| 1 | 0x01 | 340 | 114 | 564 | 96 | 627 | 91 |
| 2 | 0x02 | 315 | 116 | 526 | 99 | 589 | 94 |
| 3 | 0x03 | 290 | 118 | 487 | 102 | 548 | 97 |
| 4 | 0x04 | 260 | 120 | 448 | 105 | 511 | 100 |
| 5 | 0x05 | 235 | 122 | 408 | 108 | 471 | 103 |
| 6 | 0x06 | 210 | 124 | 368 | 111 | 433 | 106 |
| 7 | 0x07 | 185 | 126 | 329 | 114 | 394 | 109 |
| 8 | 0x08 | 159 | 128 | 292 | 117 | 355 | 112 |
| 9 | 0x09 | 129 | 130 | 251 | 120 | 316 | 115 |
| 10 | 0x0A | 105 | 132 | 214 | 123 | 277 | 118 |
| 11 | 0x0B | 80 | 134 | 175 | 126 | 238 | 121 |
| 12 | 0x0C | 54 | 136 | 135 | 129 | 199 | 125 |
| 13 | 0x0D | 24 | 138 | 97 | 132 | 160 | 128 |
| 14 | 0x0E | 2 | 140 | 57 | 136 | 121 | 131 |
| 15 | 0x0F | | | | | | |

11. Temperatures shown relate to an ideal temperature characteristic.

$$T_{TRIP} = \left(1 - \frac{V_{TH}}{1.8V}\right) \times 140^{\circ}\text{C}$$

These values match the recommended threshold values for temperatures up to 106°C to within $\pm 3^{\circ}\text{C}$. For temperatures above 106°C, the NTC, R_{COMP1}, R_{COMP2}, and I²C threshold values must be adjusted to achieve the desired trip point using Equation 16.

$$V_{TH} = \left(R_{COMP1} + \frac{R_{COMP2} \times R_{NTC}}{R_{COMP2} + R_{NTC}}\right) \times 120 \mu\text{A} \quad (\text{eq. 16})$$

Where R_{NTC} is the NTC resistance at the desired temperature.

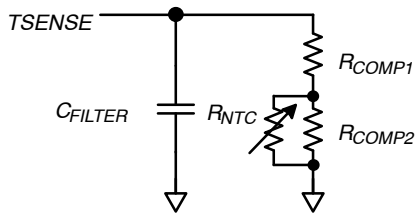


Figure 13. TSENSE Network

PWM Comparators

The noninverting input of each comparator (one for each phase) is connected to the summation of the error amplifier output (COMP) and each phase current (I_L x DCR x Phase Balance Gain Factor). The inverting input is connected to the triangle ramp voltage of that phase. The output of the comparator generates the PWM output. During steady state PS0 operation, the main rail PWM pulses are centered on the valley of the triangle ramp waveforms and both edges of the PWM signals are modulated. During a transient event, the duty cycle can increase rapidly as the error amp signal increases with respect to the ramps, to provide a highly linear and proportional response to the step load.

ASP2100, ASP2100R

I²C Address

In addition to the SVID interface between the CPU and VR, the controller also supports communication via I²C over the I²C. The I²C interface consists of SDA and SCL. Communication over I²C can occur once VCC is ready (even prior to enabling the controller), however, you should wait a minimum of 5 ms after VCC is ready before communicating. I²C address can be configured through hardware pin.

Output Voltage Offset (VOFS)

According to Intel definition, output voltage offset can be implemented through SVID. I²C also provides flexibility to change VOFS. There are four possibilities to change output voltage offset. For the default setting, VOFS is controlled by SVID. It can also be controlled by I²C register and ignored SVID setting. When phase shedding feature enable, VOFS can also be adjusted depend on output load.

Table 13. I²C SLAVE ADDRESS CONFIGURATION

| Resistor (k Ω) | Device I ² C Slave Address |
|------------------------|---------------------------------------|
| 10 | 20h |
| 14 | 21h |
| 18.7 | 22h |
| 24.3 | 23h |
| 30.9 | 24h |
| 38.3 | 25h |
| 47.5 | 26h |
| 59 | 27h |
| 71.5 | 28h |
| 86.6 | 29h |
| 105 | 2Ah |
| 127 | 2Bh |
| 154 | 2Ch |
| 187 | 2Dh |
| 221 | 2Eh |
| 280 | 2Fh |

Phase Shedding (Enable by I²C)

The phase shedding feature can be implemented by I²C. The main rail it supports three adjustable current threshold, VM0~VM2. And four current stage, LCS0~LCS3, can set each phase number, offset voltage, load-line, and switching frequency. The A rail supports one adjustable current threshold, VM0. Two current stages, LCS0 and LCS1, can also separate their phase number, offset voltage, load-line, and switching frequency.

Phase shedding is enabled when the programming pin (see Table 8), the Power State Control bit and the Auto Phase Function Control bit are all enabled. For the main rail, the Power Stage Control bit is 0x1D[5] and the Auto Phase Function Control bit is 0x1E[4]. For the A rail, the Power Stage Control bit is 0x39[5] and the Auto Phase Function Control bit is 0x3A[4].

Table 14. OUTPUT VOLTAGE OFFSET (VOFS) OF MAIN RAIL

| VOFS of Main Rail | | 0x1D[4] OFS Control | |
|----------------------------------|-------------|--|--|
| | | 0 (Follow SVID) | 1 (Ignore SVID) |
| 0x1E[5] I ² C VOFS | 0 (Disable) | SVID 0x33 | I ² C 0x27 |
| | 1 (Enable) | SVID 0x33 + I ² C 0x07~0x0A (Depend on phase shedding setting) | I ² C 0x27 + I ² C 0x07~0x0A (Depend on phase shedding setting) |

Table 15. OUTPUT VOLTAGE OFFSET (VOFS) OF A RAIL

| VOFS of A Rail | | 0x39[4] OFS Control | |
|----------------------------------|-------------|--|--|
| | | 0 (Follow SVID) | 1 (Ignore SVID) |
| 0x3A[5] I ² C VOFS | 0 (Disable) | SVID 0x33 | I ² C 0x40 |
| | 1 (Enable) | SVID 0x33 + I ² C 0x2B~0x2C (Depend on phase shedding setting) | I ² C 0x40 + I ² C 0x2B~0x2C (Depend on phase shedding setting) |

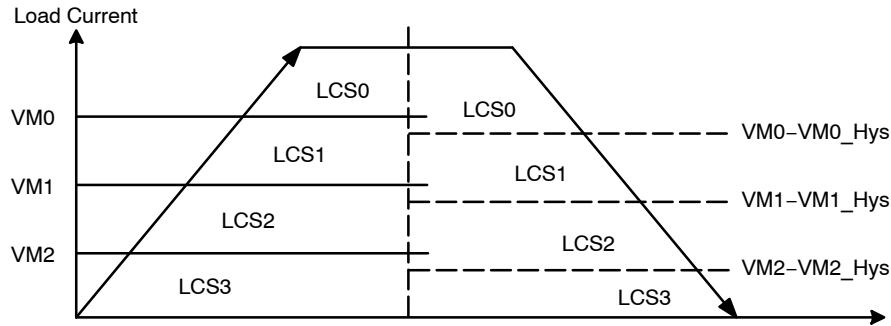


Figure 14. Phase Shedding for Main Rail

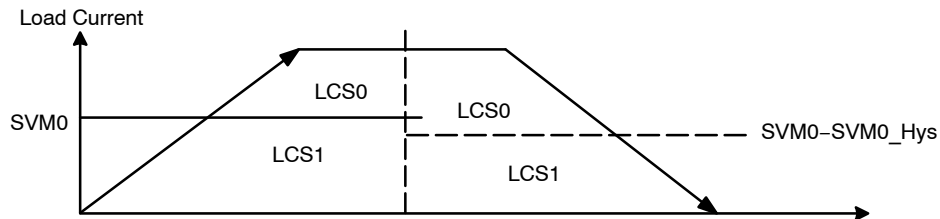


Figure 15. Phase Shedding for A Rail

ASP2100, ASP2100R

Table 16. PHASE CONFIGURATION

| Phase Configuration | Programming Pin in CSPx | Unused Pin |
|---------------------|--|--|
| 8 + 2 | All CSP pins are connected normally | No unused Pin |
| 7 + 2 | CSP1 to CSP7 and CSP1A to CSP2A pins connected normally. CSP8 connected to VCC through a 2 kΩ resistor. | Float PWM8. |
| 6 + 2 | CSP1 to CSP6 and CSP1A to CSP2A pins connected normally. CSP7 connected to VCC through a 2 kΩ resistor. | Float PWM8 and CSP8. Use PWM7 for programming ICC*2_MAIN_RAIL only. |
| 5 + 2 | CSP1 to CSP5 and CSP1A to CSP2A pins connected normally. CSP6 connected to VCC through a 2 kΩ resistor. | Float PWM8, CSP7, and CSP8. Use PWM7 for programming ICC*2_MAIN_RAIL only. Use PWM6 for programming ICCMAX_AUXIN only. |
| 4 + 2 | CSP1 to CSP4 and CSP1A to CSP2A pins connected normally. CSP5 connected to VCC through a 2 kΩ resistor. | Float PWM8, CSP6, CSP7, and CSP8. Use PWM7 for programming ICC*2_MAIN_RAIL only. Use PWM6 for programming ICCMAX_AUXIN only. Use PWM5 for programming ROSCA only. |
| 3 + 2 | CSP1 to CSP3 and CSP1A to CSP2A pins connected normally. CSP4 connected to VCC through a 2 kΩ resistor. | Float PWM8, CSP5, CSP6, CSP7, and CSP8. Use PWM7 for programming ICC*2_MAIN_RAIL only. Use PWM6 for programming ICCMAX_AUXIN only. Use PWM5 for programming ROSCA only. Use PWM4 for programming ROSC only. |
| 2 + 2 | CSP1 to CSP2 and CSP1A to CSP2A pins connected normally. CSP3 connected to VCC through a 2 kΩ resistor. | Float PWM8, CSP4, CSP5, CSP6, CSP7, and CSP8. Use PWM7 for programming ICC*2_MAIN_RAIL only. Use PWM6 for programming ICCMAX_AUXIN only. Use PWM5 for programming ROSCA only. Use PWM4 for programming ROSC only. Use PWM3 for programming ICCMAX only. |
| 8 + 1 | CSP1 to CSP8 and CSP1A pins connected normally. CSP2A connected to VCC through a 2 kΩ resistor. | Use PWM2A for programming I2C_ADDRESS only. |
| 8 + 0 | CSP1 to CSP8 pins connected normally. CSP1A connected to VCC through a 2 kΩ resistor. | Float PWM1A and CSP2A. Use PWM2A for programming I2C_ADDRESS only. |

Table 17. PHASE SHEDDING CONFIGURATION

| Main Rail Phase Configuration in PS0 | Main Rail Phase Configuration when Phase Shedding Enable (I ² C 0x06, IICP0~IICP3) | | | |
|--------------------------------------|---|------|------|------|
| | “00” | “01” | “10” | “11” |
| 8 | 8 | 4 | 2 | 1 |
| 7 | 7 | 4 | 2 | 1 |
| 6 | 6 | 4 | 2 | 1 |
| 5 | 5 | 3 | 2 | 1 |
| 4 | 4 | 3 | 2 | 1 |

FAULT PROTECTION

Over Current Protection (OCP)

A programmable total phase current limit is provided which shuts down the controller when a programmable timer expires. See section "Programming the Current Limit" on page 16 for more details on this feature. To recover from an OCP fault, the EN pin or VCC voltage must be cycled low.

Input Under-voltage Lockouts (UVLO)

The VR monitors the 5 V VCC supply as well as the VRMP pin voltage. Hysteresis is incorporated within these monitors.

Output Under Voltage Monitor

The multiphase phase rail output voltage is monitored for under voltage at the output of the differential amplifier. If the multiphase-phase rail output falls more than VUVM2 below the DAC-DROOP voltage, the UVM comparator will trip – sending the VR_RDY signal low.

Output Over Voltage Protection

The multiphase phase output voltage is monitored for OVP at the VSP pin. During normal operation, if an output voltage exceeds the DAC voltage by VOVP, the VR_RDY flag goes low, and the DAC voltage of the overvoltage rail will be slowly ramped down to 0 V to avoid producing a negative output voltage. At the same time, the PWM outputs of the overvoltage rail are sent low. The PWM output will pulse to mid-level during the DAC ramp down period if the output decreases below the DAC + OVP threshold as DAC decreases. When the DAC gets to zero, the PWMs will be held low, and the VR will stay in this mode until the VCC voltage or EN is toggled.

Absolute OVP

During start up, the OVP threshold is set to the absolute over voltage threshold. This allows the controller to start up without false triggering OVP.

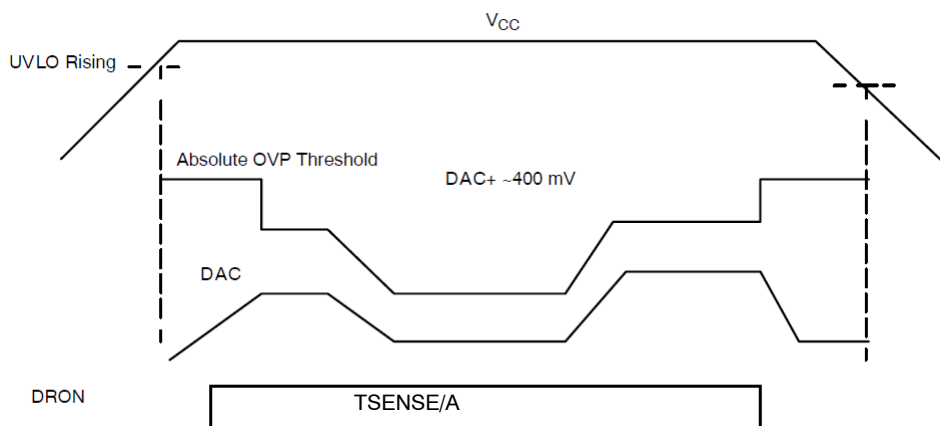


Figure 16. OVP Threshold Behavior

ASP2100, ASP2100R

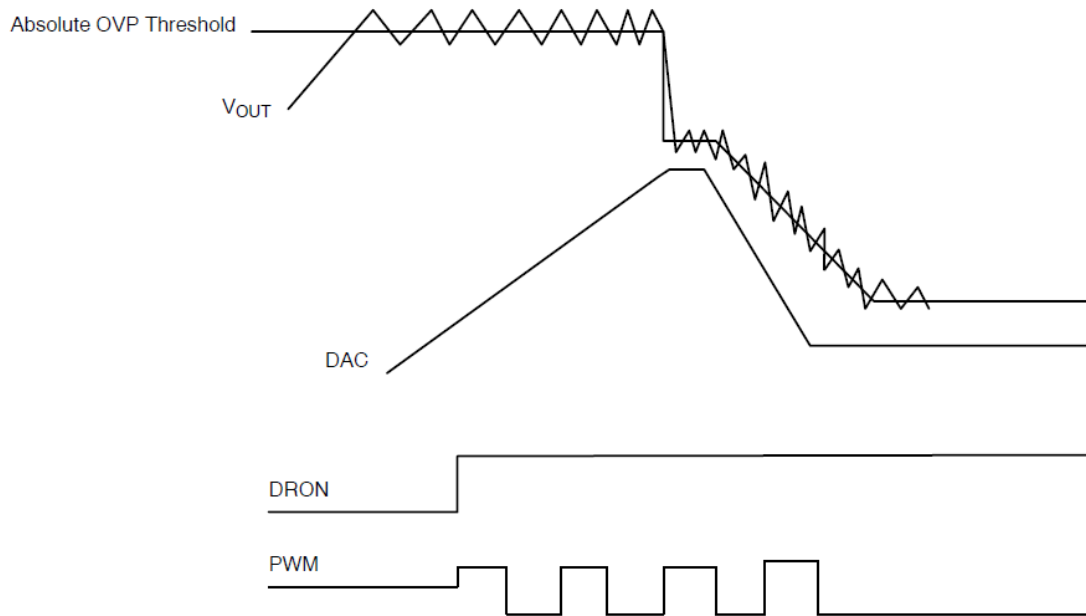


Figure 17. OVP Behavior at Start-up

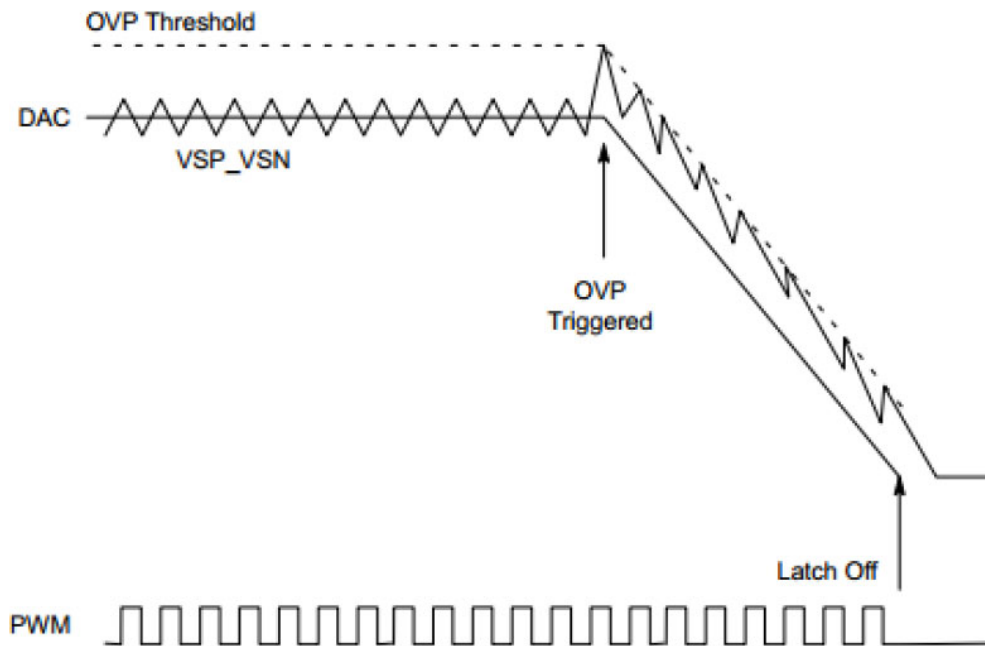


Figure 18. OVP During Normal Operation Mode

ASP2100, ASP2100R

Serial VID Interface (SVID)

The Serial VID Interface (SVID Interface) is a 3 wire digital interface used to transfer power management information between the CPU (Master) and the VR controller (Slave). The 3 wires are clock (SCLK), data (SDIO) and ALERT#. The SCLK is unidirectional and

generated by the master. The SDIO is bi-directional, used for transferring data from the microprocessor to the VR controller and from the VR controller to the CPU. The ALERT# is an open drain output from the VR controller to signal to the master that the Status Register should be read.

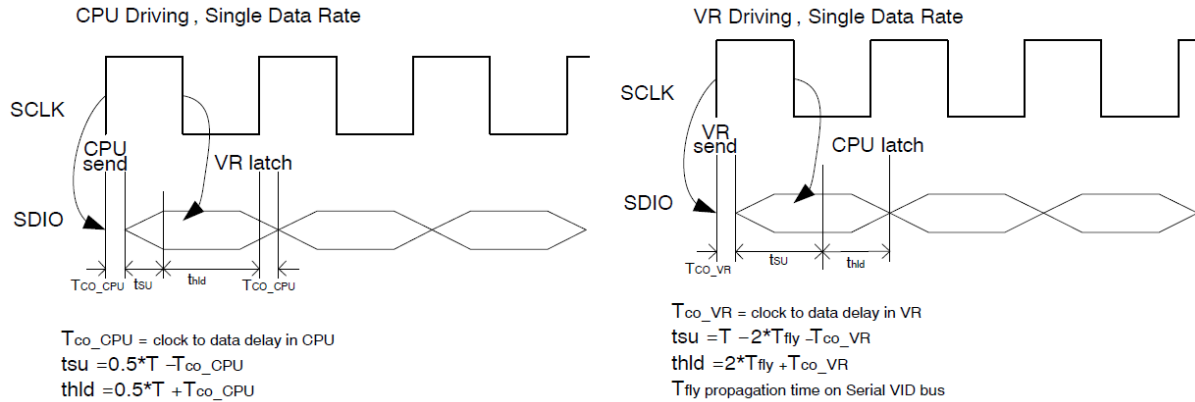


Figure 19. SVID Timing Diagram

Table 18. SLEW RATE

| Option | SVID Command Code | Feature Description | Register Address (Indicating the Slew Rate of VID Code Change) |
|--------------|-------------------|---|--|
| SetVID_Fast | 01h | 10 mV/ μ s, 30 mV/ μ s, or 48 mV/ μ s VID code change slew rate | 24h |
| SetVID_Slow | 02h | = 1/4 of SetVID_Fast VID code change slew rate | 25h |
| SetVID_Decay | 03h | No control, VID code down | N/A |

ASP2100, ASP2100R

Table 19. I²C REGISTERS FOR MAIN RAIL

| Reg Addr | Register Name | Description | Access | Default |
|----------|--|---|--------|---------|
| 0x01 | VM0[7:0] | Current threshold for LCS0 (highest current state) Resolution = (ICCMAX/255) A/bit | R/W | 00h |
| 0x02 | VM1[7:0] | Current threshold for LCS1 Resolution = (ICCMAX/255) A/bit | R/W | 00h |
| 0x03 | VM2[7:0] | Current threshold for LCS2 Resolution = (ICCMAX/255) A/bit | R/W | 00h |
| 0x04 | VM0_HYST[5:3] VM1_HYST[2:0] | Bit[5:3]: Set VM0 Hysteresis, 8 steps VM0 Hys = (ICCMAX/100) x (2 + [5:3]) Bit[2:0]: Set VM1 Hysteresis, 8 steps VM1 Hys = (ICCMAX/100) x (2 + [2:0]) | R/W | 00h |
| 0x05 | VM2_HYST[5:3] SVM0_Hys_Arail[2:0] | Bit[5:3]: Set VM2 Hysteresis, 8 steps VM2 Hys = (ICCMAX/100) x (2 + [5:3]) Bit[2:0]: Set SVM0 Hysteresis, 8 steps SVM0 Hys = (ICCMAX/100) x (2 + [2:0]) | R/W | 00h |
| 0x06 | IICP3[7:6] IICP2[5:4] IICP1[3:2] IICP0[1:0] | <i>Number of phases active in each I²C state</i> Phase count while in I ² C defined states Bit[7:6]: phases on in LCS3 Bit[5:4]: phases on in LCS2 Bit[3:2]: phases on in LCS1 Bit[1:0]: phases on in LCS0 00: 8 phases, 01: 4 phases, 10: 2 phases, 11: 1 phase 2 phases operate by PWM1 and PWM2. Note: 0x1D[5] & 0x1E[4] must be set to enable auto-phase shedding. | R/W | 00h |
| 0x07 | VOFS0[7:0] | <i>Voltage Offset Adjustment</i> (Note 12) Offsets for I ² C states LCS0 – LCS3 (5 mV/step). VOFS is 2's compliment, Bit 7 is sign bit. Voltage change slew rate is SLOW. Note: 0x1E[5] must be set to enable the voltage offset function | R/W | 00h |
| 0x08 | VOFS1[7:0] | | R/W | 00h |
| 0x09 | VOFS2[7:0] | | R/W | 00h |
| 0x0A | VOFS3[7:0] | | R/W | 00h |
| 0x0B | IICF0[7:4] IICF1[3:0] | IICF0[7:4] = LCS0 operating frequency IICF1[3:0] = LCS1 operating frequency IICF2[7:4] = LCS2 operating frequency IICF3[3:0] = LCS3 operating frequency Refer to switching frequency configuration settings in Table 9. Note: 0x52[6] must be set to enable I ² C frequency control | R/W | 00h |
| 0x0C | IICF2[7:4] IICF3[3:0] | | R/W | 00h |
| 0x0D | IICLL0[7:4] IICLL1[3:0] | DC Load Line weighting in each I ² C state LCS0 – LCS3 If ICC*2_MAIN_RAIL = OFF Range is 0% – 93.75% in 6.25% steps. (Default is 50%) If ICC*2_MAIN_RAIL = ON Range is 0% – 187.25% in 12.5% steps. (Default is 100%) Note: 0x1E[2] must be set to enable DC loadline adjustment | R/W | 88h |
| 0x0E | IICLL2[7:4] IICLL3[3:0] | | R/W | 88h |
| 0x0F | CB_EN[7] PH1_IGAIN[6:4] PH2_IGAIN[2:0] | <i>Current Balance Gain</i> Adjustment CB_EN[7] = Enable/Disable current balance feature. Enable = 0 (Default), Disable = 1 PH1_IGAIN[6:4] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% PH2_IGAIN[2:0] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% | R/W | 44h |
| 0x10 | PH3_IGAIN[6:4] PH4_IGAIN[2:0] | <i>Current Balance Gain</i> PH3_IGAIN[6:4] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% PH4_IGAIN[2:0] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% | R/W | 44h |

ASP2100, ASP2100R

Table 19. I²C REGISTERS FOR MAIN RAIL

| Reg Addr | Register Name | Description | Access | Default |
|----------|--|---|--------|---------|
| 0x11 | PH5_IGAIN[6:4] PH6_IGAIN[2:0] | <i>Current Balance Gain</i> PH5_IGAIN[6:4] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% PH6_IGAIN[2:0] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% | R/W | 44h |
| 0x12 | PH7_IGAIN[6:4] PH8_IGAIN[2:0] | <i>Current Balance Gain</i> PH7_IGAIN[6:4] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% PH8_IGAIN[2:0] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% | R/W | 44h |
| 0x14 | LCHVID[7:0] | Latch VID register – default = 1.1 V (ABh) Refer to IMVP9.1 SVID table. VDAC control by LCHVID when 0x1D[6] = “1” | R/W | ABh |
| 0x15 | IOUT[7:0] | 8 bit ADC reading. Reads FFh when IOUT = ICCMAX | RO | – |
| 0x16 | VOUT_MSB[7:0] | Main Rail Voltage Reading, 8-bit MSB If 0x1E[6] = “0”, VOUT = VDAC, 5mV/step If 0x1E[6] = “1”, VOUT = Sense Voltage, 3.9 mV/step Note: Read this register before reading VOUT_LSB (0x17). | RO | – |
| 0x17 | VOUT_LSB[1:0] | Main Rail Voltage Reading, 2-bit LSB If 0x1E[6] = “0”, VOUT = VDAC, 5 mV/step If 0x1E[6] = “1”, VOUT = Sense Voltage, 3.9 mV/step. Note: Read VOUT_MSB (0x16) before reading this register. | RO | – |
| 0x18 | Protection Indicator[7:0] | <i>Protection Enable/Disable Indicator</i> Bit[7]: OCP Indicator 0 = Not Active; 1 = Active Bit[6]: Per phase OCP Indicator 0 = Not Active; 1 = Active Bit[5]: OVP Indicator 0 = Not Active; 1 = Active Bit[4]: UVP Indicator 0 = Not Active; 1 = Active Bit[3:0]: Per phase OCP indicator if Bit[6] = 1 phase 1 = 0001; phase 2 = 0010; phase 3 = 0011; phase 4 = 0100; phase 5 = 0101; phase 6 = 0110; phase 7 = 0111; phase 8 = 1000; reserved = 1xxx | RO | – |
| 0x19 | Total OCP[7:4] OCP_L[3:1] OCP_L Hys[0] | <i>Total OCP threshold, OCP_L flag assertion level and hysteresis setting</i> OCP[7:4]: Total Current OCP Ratio of ILIM (Over Current Protection) 0000: 50%; 0001: 60%; 0010: 70%; 0011: 80%; 0100: 90%; 0101: 100%; 0110: 110%; 0111: 120%; 1000: 130%(Default); 1001: 140%; 1010: 150%; 1011: 160%; 1100: 170%; 1101: 180%; 1110: 190%; 1111: 200% OCP_L[3:1]: OCP_L Ratio of ILIM (Over Current Protection) 000: 65%; 001: 70%; 010: 75%; 011: 80%; 100: 85%; 101: 90%(Default); 110: 95%; 111: 100% OCP_L Hys[0]: OCP_L Hysteresis Ratio of ILIM (Over Current Protection) 0: 10% (Default); 1: 20% Note: 0x1D[3] must be set to enable Total OCP threshold I ² C setting | R/W | 8Ah |

ASP2100, ASP2100R

Table 19. I²C REGISTERS FOR MAIN RAIL

| Reg Addr | Register Name | Description | Access | Default |
|----------|---|---|--------|---------|
| 0x1A | IMONOVr[7:6] OC[5:4] UV[3:2] OV[1:0] | IMONOVr[7]: Overwrite SVID 0x15h (IMON) "1" = Enable; "0" = Disable IMONOVr[6]: Overwrite SVID 0x15h (IMON) "1" = 1/2; "0" = 1/4 OCP[5:4]: Per Phase OCP 00 = 400 mV; 01 = 500 mV (Default); 10 = 600 mV; 11 = 700 mV The lowest threshold for each phase is 400mV/amp gain. The default gain is 6 so this corresponds to 83 mV across CSPx/CSREF. Bit[3:2]: UVP Setting 00 = 400 mV (default); 01 = 500 mV; 10 = 600 mV; 11 = 700 mV Bit[1:0]: OVP Setting 00 = 400 mV (default); 01 = 500 mV; 10 = 600 mV; 11 = 700 mV | R/W | 50h |
| 0x1B | OCP_delay[7:0] | <i>OCP Delay Setting – Main & A share the same setting</i> OCP_delay[7:5]: Total OCP delay 000 = 5 μ s; 001 = 10 μ s; 010 = 15 μ s; 011 = 20 μ s (Default); 100 = 25 μ s; 101 = 30 μ s; 110 = 35 μ s; 111 = 40 μ s OCP_delay[4:2]: Per Phase OCP delay 000 = 2 μ s; 001 = 4 μ s; 010 = 6 μ s (Default); 011 = 8 μ s; 100 = 10 μ s; 101 = 12 μ s; 110 = 14 μ s; 111 = 16 μ s OCP_delay[1:0]: RESERVED | R/W | 68h |
| 0x1C | VR_SR[3:0] SVR_SR[7:4] | DVID slew rate. Range is from 8 mV/ μ s to 48 mV/ μ s. 0x0~0x5, 8 mV/ μ s~18 mV/ μ s, 2 mV/ μ s per step 0x6~0xF, 21 mV/ μ s~48 mV/ μ s, 3 mV/ μ s per step Note: 0x1D[7] must be set to enable I ² C slew rate control using this register | R/W | 33h |
| 0x1D | Misc1[7:0] | Bit[7]: Slew Rate Control 0 = Select from pin 1 = Select from register Bit[6]: VDAC Control 0 = SVID 0x31 VDAC follow SVID 1 = SVID 0x31 VDAC ignore SVID. VDAC control by LCHVID Bit[5]: PWR State Control 0 = SVID 0x32 PWR state follow SVID 1 = SVID 0x32 PWR state ignore SVID. Phase control by I ² C Bit[4]: OFS control 0 = SVID 0x33 Offset follow SVID 1 = SVID 0x33 Offset ignore SVID. Offset control by I ² C (Note 12) Bit[3]: Total OCP Control 0 = Disable Total OCP function (OCPL# = H) 1 = Enable Total OCP function Bit[2]: Per-phase OCP Control 0 = Disable Per-phase OCP function 1 = Enable Per-phase OCP function Bit[1]: OVP Control 0 = Disable OVP function (VR_OVP# = H) 1 = Enable OVP function Bit[0]: UVP Control 0 = Disable UVP function 1 = Enable UVP function | R/W | 0Fh |
| 0x1E | Misc2[7:0] | Bit[7]: Spread Spectrum (Note 13) "0" to disable; "1" to enable Bit[6]: VOUT Voltage value select "0" for SVID register; "1" actual A/D Bit[5]: Output voltage offset control (Note 12) "0" to disable; "1" to enable Bit[4]: Auto phase function control (Note 13) "0" disable; "1" to enable If Bit[4] is 0, follow IICP0 if 1D[5] = 1; or follow SVID PS if 1D[5] = 0. This bit with function after 0x1D[5] = "1" Bit[3]: DCM enable when in 1 phase "0" always CCM; "1" DCM Bit[2]: Loadline enable "0" disables LL; "1" enables Bit[1]: USM/PSM selection when in DCM "0" enable PSM (pulse skip mode); "1" enables USM (ultrasonic mode) Bit[0]: OCP_L enable control "0" to disable; "1" to enable | R/W | 9Ch |

ASP2100, ASP2100R

Table 19. I²C REGISTERS FOR MAIN RAIL

| Reg Addr | Register Name | Description | Access | Default |
|----------|---|--|--------|---------|
| 0x1F | WD[7:5] | Watchdog timer, (Note: I ² C watchdog timer expires, all I ² C registers return to default settings.) Bit[7]: 1 = Enable; 0 = Disable Bit[6]: Reset I ² C registers to default values (except for register 0x1F, this is independent of the watchdog timer). Bit[5]: Timer 0 = 800 ms; 1 = 1600 ms | R/W | 00h |
| 0x20 | VRSHDN_TH[7:4] | Bit[7:4]: Main Rail VRSHDN Threshold Setting. See Table 12 for threshold values Bit[3:0]: Reserved | R/W | 70h |
| 0x22 | VRSHDN_BH[7] VRSHDN_EN[6] OCPH[5] VRHOT_ALERT_EN[4] TEMP_VRHOT#[3:0] | <i>Select Behavior of VRSHDN</i> Bit[7]: OTP behavior selection 0 = VRSHDN# go low only; 1 = controller shutdown only Bit[6]: OTP function enable/disable 0 = Disable; 1 = Enable Bit[5]: Total OCP threshold control when single phase operation. 0 = Default; 1 = Double Bit[4]: VRHOT# "0" = Enable; "1" = Disable Note: when VR_HOT is disabled ALERT will not assert and the Temp Status bit (SVID reg 0x10 bit) is not set. Bit[3:0]: VRHOT# Threshold See Table 12 for threshold values | R/W | 04h |
| 0x26 | IMON_OFS[7:0] | IMON offset 2's compliment value (positive and negative adjustment) | R/W | 00h |
| 0x27 | DVID_OFS[7:0] | DVID offset function (2's compliment, 5 mV step) Note: 0x1D[4] must be set to "1" to enable this function (Note 12) | R/W | 00h |
| 0x41 | VBOOT_ENABLE[7] VBOOT_VOLTAGE[6:0] | Bit[7]: VBOOT Operation '0' => VBOOT follows H/W resistor setting. (See Table 6) '1' => VBOOT follows I ² C setting. Bits[6:0] VBOOT voltage setting '0' => VBOOT = 0 V 'N', where $1 \leq N \leq 127$ => $VBOOT = 300 \text{ mv} + VDAC_STEP \times (2N - 11)$ VDAC_STEP is the output voltage step size as shown in Table 6. | R/W | 00h |
| 0x43 | TM[7:0] | <i>I²C Thermal Monitor Value Reading.</i> Temperature reports in degree celsius (°C). To get accurate temperature, specific Tsense network is required. Place one NTC and one normal resistor in parallel. NTC uses 100 kΩ under 25°C and B25/50 approximates 4250. Use 13.5 kΩ for parallel resistor and 0.3 kΩ for series resistor. | RO | – |
| 0x52 | ROSC_OFFSET_CTRL[7:0] | Bit[7]: Reserved Bit[6]: Control setting function (ROSC) "0" = Disable (follow H/W resistor setting) "1" = Enable (follow I ² C setting) Bit[5]: ICC*2_MAIN_RAIL setting "0" = Disable "1" = Enable Bit[3]: Reserved Bit[2]: Control setting function (ROSCA) "0" = Disable (follow H/W resistor setting) "1" = Enable (follow I ² C setting) Bit[1:0]: Reserved | R/W | 0x20 |
| 0x55 | AC_NOISE_SLOPE[5:4] AC_NOISE_MULTI_LOPE[3] AC_NOISE_SR[2:1] AC_NOISE_EN[0] | Bit[7:6]: Reserved Bit[5:4]: Acoustic noise set point to change DVID down slope "00" = Every 4 VID Steps for VID Down "01" = Every 8 VID Steps for VID Down "10" = Every 16 VID Steps for VID Down "11" = Every 32 VID Steps for VID Down Bit[3]: Acoustic noise multi slope on DVID Down "0" = Disable (Default); "1" = Enable Bit[2:1]: Acoustic noise slew rate control "00" = 1/2 (Default); "01" = 1/4; "10" = 1/8; "11" = 1/16 Bit[0]: Acoustic noise mode enable "0" = Disable; "1" = Enable (Note 13) | R/W | 01h |

Table 19. I²C REGISTERS FOR MAIN RAIL

| Reg Addr | Register Name | Description | Access | Default |
|----------|--|--|--------|---------|
| 0x56 | BST_CAP_LOW_TIME[5:4] BST_CAP_ON_DVID[3] BST_CAP_TIME[2] BST_CAP_PULSED[1] BST_CAP_EN[0] | Bit[7:6]: Reserved Bit[5:4]: Boost cap low time. "00" = 400 ns, "01" = 200 ns, "10" = 800 ns, "11" = 600 ns Bit[3]: Boost cap in parallel with DVID on VID up from low power state "0" = Disable; "1" = Enable Bit[2]: Shorter Boost Cap Refresh "0" = when ps_exit_timer Eh; "1" = when ps_exit_timer 7h Bit[1]: Boost cap low PS exit "0" = Continuous Boosting when Phases are off "1" = Boost Cap Refresh at PS Exit only Bit[0]: Boost Cap Mode Enable "0" = Disable "1" = Enable | R/W | 0Bh |
| 0x59 | TEMP_ALERT#[7:4] STEMP_ALERT#[3:0] | Bit[s7:4]: Thermal Alert Threshold for Main Rail Bits[3:0] Thermal Alert Threshold for A-Rail See Table 12 for threshold values | R/W | 33h |
| 0x5A | ACTIVE_PHASE[7:0] | Real time active phase indicator for Main rail. "1" = Active Bit[7]: Phase8 active indicator Bit[6]: Phase7 active indicator Bit[5]: Phase6 active indicator Bit[4]: Phase5 active indicator Bit[3]: Phase4 active indicator Bit[2]: Phase3 active indicator Bit[1]: Phase2 active indicator Bit[0]: Phase1 active indicator | RO | – |

12. Offset should only be changed or enabled/disabled when the controller is operating in PS0 mode.

13. This functionality will only be available if it is also enabled using the pin function resistor (See Table 8).

ASP2100, ASP2100R

Table 20. I²C REGISTERS FOR A RAIL

| Reg Addr | Register Name | Description | Access | Default |
|----------|---|---|--------|---------|
| 0x05 | VM2_HYST[5:3] SVM0_Hys_Arail[2:0] | Bit[5:3]: Set VM2 Hysteresis, 8 steps VM2 Hys = (ICCMAX/100) x (2 + [5:3]) Bit[2:0]: Set SVM0 Hysteresis, 8 steps SVM0 Hys = (ICCMAX/100) x (2 + [2:0]) | R/W | 00h |
| 0x1C | VR_SR[3:0] SVR_SR[7:4] | DVID slew rate. Range is from 8 mV/μs to 48 mV/μs. 0x0~0x5, 8 mV/μs~18 mV/μs, 2 mV/μs per step 0x6~0xF, 21 mV/μs~48 mV/μs, 3 mV/μs per step Note: 0x1D[7] must be set to enable I ² C slew rate control using this register | R/W | 33h |
| 0x21 | SVRSHDN_TH[7:4] | Bit[7:4]: A Rail VRSHDN Threshold Setting. See Table 12 for threshold values Bit[3:0]: Reserved | R/W | 70h |
| 0x29 | SVM0[7:0] | Current Threshold for SLCS0 (SVM0) Resolution = (ICCMAX / 255) A/bit | R/W | 00h |
| 0x2A | SIICP1[1] SIICP0[0] | <i>Number of phases active in each I²C state</i> Phase count while in I ² C defined states Bit[7:2]: Reserved Bit[1]: phases on in SLCS1 Bit[0]: phases on in SLCS0 "0": 2 phases, "1": 1 phase | R/W | 02h |
| 0x2B | SVOFS0[7:0] | <i>Voltage Offset Adjustment</i> (Note 15) Offsets for I ² C states SLCS0 – SLCS1 (5 mV/step). SVOFS is 2's compliment, Bit 7 is sign bit. | R/W | 00h |
| 0x2C | SVOFS1[7:0] | Voltage change slew rate is SLOW. Note: 0x39[4] must be set to enable offset function. | R/W | 00h |
| 0x2D | SIICF0[7:4] SIICF1[3:0] | SIICF0[7:4] = SLCS0 operating frequency SIICF1[3:0] = SLCS1 operating frequency Refer to switching frequency configuration settings in Table 9. Note: 0x52[2] must be set to enable I ² C frequency control | R/W | 00h |
| 0x2E | SIICLL0[7:4] SIICLL1[3:0] | DC Load Line Weighting LL adjustment in each I ² C state SLCS0 – SLCS1 0% – 93.75%, 6.25% steps Default = 50% of externally programmed LL Note: 0x3A[2] must be set to enable DC loadline adjustment | R/W | 88h |
| 0x2F | SCB_EN[7] SPH1_IGAIN[6:4] SPH2_IGAIN[2:0] | Adjustment SCB_EN [7] = Enable/Disable current balance feature. Enable = 0 (Default), Disable = 1 <i>Current Balance Gain</i> SPH1_IGAIN[6:4] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% SPH2_IGAIN[2:0] 000 = 50%; 001 = 62.5%; 010 = 75%; 011 = 87.5%; 100 = 100%; 101 = 112.5%; 110 = 125%; 111 = 137.5% | R/W | 44h |
| 0x32 | SLCHVID[7:0] | Latch VID register – default = 1.1 V (Abh) Refer to IMVP9.1 SVID table. VDAC control by LCHVID when 0x39[6] = "1" | R/W | ABh |
| 0x33 | SIOUT[7:0] | 8 bit ADC reading. Reads FFh when IOUTA = ICCMAXA | RO | – |
| 0x34 | SVOUT_MSB[7:0] | A Rail Voltage Reading, 8-bit MSB If 0x3A[6] = "0", VOUT = VDAC, 5 mV/step If 0x3A[6] = "1", VOUT = Sense Voltage, 3.9 mV/step Note: Read this register before reading SVOUT_LSB (0x35). | RO | – |
| 0x35 | SVOUT_LSB[1:0] | A Rail Voltage Reading, 2-bit LSB If 0x3A[6] = "0", VOUT = VDAC, 5 mV/step If 0x3A[6] = "1", VOUT = Sense Voltage, 3.9 mV/step Note: Read SVOUT_MSB (0x34) before reading this register. | RO | – |

ASP2100, ASP2100R

Table 20. I²C REGISTERS FOR A RAIL (continued)

| Reg Addr | Register Name | Description | Access | Default |
|----------|---|--|--------|---------|
| 0x36 | Sprotection Indicator[5:0] | <i>Protection Enable/Disable Indicator</i> Bit[5]: OCP Indicator 0 = Not Active; 1 = Active Bit[4]: Per phase OCP Indicator 0 = Not Active; 1 = Active Bit[3]: OVP Indicator 0 = Not Active; 1 = Active Bit[2]: UVP Indicator 0 = Not Active; 1 = Active Bit[1:0]: Per phase OCP indicator if Bit[4] = 1 phase 1 = 01; phase 2 = 10; No fault = 00 | RO | – |
| 0x37 | STotal OCP[7:4] SOCP_L[3:1] SOCP_L Hys[0] | <i>Total OCP threshold, OCP_L flag assertion level and hysteresis setting</i> SOCP[7:4]: Total Current OCP Ratio of ILIM (Over Current Protection) 0000: 50%; 0001: 60%; 0010: 70%; 0011: 80%; 0100: 90%; 0101: 100%; 0110: 110%; 0111: 120%; 1000: 130%(Default); 1001: 140%; 1010: 150%; 1011: 160%; 1100: 170%; 1101: 180%; 1110: 190%; 1111: 200% SOCP_L[3:1]: OCP_L Ratio of ILIM (Over Current Protection) 000: 65%; 001: 70%; 010: 75%; 011: 80%; 100: 85%; 101: 90%(Default); 110: 95%; 111: 100% SOCP_L Hys[0]: OCP_L Hysteresis Ratio of ILIM (Over Current Protection) 0: 10% (Default); 1: 20% Note: 0x39[3] must be set to enable Total Current OCP function. | R/W | 8Ah |
| 0x38 | SIMONOVr[7:6] SOC[5:4] SUV[3:2] SOV[1:0] | SIMONOVr[7]: Overwrite SVID 0x15h (IMON) “1” = Enable; “0” = Disable SIMONOVr[6]: Overwrite SVID 0x15h (IMON) “1” = 1/2; “0” = 1/4 SOC[5:4]: Per Phase OCP 00 = 400 mV; 01 = 500 mV (Default); 10 = 600 mV; 11 = 700 mV The lowest threshold for each phase is 400mV/amp gain. The default gain is 6 so this corresponds to 83 mV across CSPxA/CSREFA. Bit[3:2]: UVP Setting 00 = 400 mV (default); 01 = 500 mV; 10 = 600 mV; 11 = 700 mV Bit[1:0]: OVP Setting 00 = 400 mV (default); 01 = 500 mV; 10 = 600 mV; 11 = 700 mV | R/W | 50h |
| 0x39 | SMisc1[7:0] | Bit[7]: Slew Rate Control 0 = Select from pin 1 = Select from register Bit[6]: VDAC Control 0 = SVID 0x31 VDAC follow SVID 1 = SVID 0x31 VDAC ignore SVID. VDAC control by SLCHVID Bit[5]: PWR State Control 0 = SVID 0x32 PWR state follow SVID 1 = SVID 0x32 PWR state ignore SVID. Phase control by I ² C Bit[4]: OFS control (Note 15) 0 = SVID 0x33 Offset follow SVID 1 = SVID 0x33 Offset ignore SVID. Offset control by I ² C Bit[3]: Total OCP Control 0 = Disable Total OCP function (OCPL# = H) 1 = Enable Total OCP function Bit[2]: Per-phase OCP Control 0 = Disable Per-phase OCP function 1 = Enable Per-phase OCP function Bit[1]: OVP Control 0 = Disable OVP function (VR_OVP# = H) 1 = Enable OVP function Bit[0]: UVP Control 0 = Disable UVP function 1 = Enable UVP function | R/W | 0Fh |

ASP2100, ASP2100R

Table 20. I²C REGISTERS FOR A RAIL (continued)

| Reg Addr | Register Name | Description | Access | Default |
|----------|---|---|--------|---------|
| 0x3A | SMisc2[7:0] | Bit[7]: Spread Spectrum (Note 14) "0" to disable; "1" to enable Bit[6]: SVOUT Voltage value select "0" for SVID register; "1" actual A/D Bit[5]: Output voltage offset control (Note 15) "0" to disable; "1" to enable Bit[4]: Auto phase function control (Note 14) "0" disable; "1" to enable If Bit[4] is 0, follow SIICP0 if 39[5] = 1; or follow SVID PS if 39[5] = 0. This bit with function after 0x39[5] = "1" Bit[3]: DCM enable when in 1 phase "0" always CCM; "1" DCM Bit[2]: Loadline enable "0" disables LL; "1" enables (default) Bit[1]: USM/PSM selection when in DCM "0" enable PSM (pulse skip mode); "1" enables USM (ultrasonic mode) Bit[0]: OCP_L# enable control "0" to disable; "1" to enable | R/W | 9Ch |
| 0x3B | SVRSHDN_BH[7] SVRSHDN_EN[6] SOCPH[5] SVRHOT_ALERT_EN[4] STEMP_VRHOT#[3:0] | <i>Select Behavior of VRSHDN</i> Bit[7]: OTP behavior selection 0 = VRSHDN# go low only; 1 = controller shutdown only Bit[6]: OTP function enable/disable 0 = Disable; 1 = Enable Bit[5]: Total OCP threshold control when single phase operation. 0 = Default; 1 = Double Bit[4]: VRHOT# "0" = Enable; "1" = Disable Note: when VR_HOT is disabled ALERT will not assert and the Temp Status bit (SVID reg 0x10 bit) is not set. Bit[3:0]: VRHOT. Threshold See Table 12 for threshold values | R/W | 04h |
| 0x3F | SIMON_OFS[7:0] | IMON offset [7:0] (can be positive or negative) SVID IMON Offset: 0x15 ± Bit[7:0] I ² C IMON Offset: 0x33 ± Bit[7:0] | R/W | 00h |
| 0x40 | SDVID_OFS[7:0] | DVID offset function (2's compliment, 5 mv step) Enable this register after 0x39[4] = "1" (Note 15) | R/W | 00h |
| 0x42 | SVBOOT_ENABLE[7] SVBOOT_VOLTAGE[6:0] | Bit[7]: VBOOT Operation '0' => VBOOT follows H/W resistor setting as per table 6. '1' => VBOOT follows I ² C setting. Bits[6:0] VBOOT voltage setting = 0 => VBOOT = 0 V = N, where 1 ≤ N ≤ 127 => VBOOT = 300 mV + VDAC_STEP X (2N - 11) VDAC_STEP is the output voltage step size as shown in Table 6. | R/W | 00h |
| 0x44 | STM[7:0] | <i>I²C Thermal Monitor Value Reading.</i> Temperature reports in degree celsius (°C). To get accurate temperature, specific Tsense network is required. Place one NTC and one normal resistor in parallel. NTC uses 100 kΩ under 25°C and B25/50 approximates 4250. Use 13.5 kΩ for parallel resistor and 0.3 kΩ for series resistor. | RO | – |
| 0x57 | SAC_NOISE_SLOPE[5:4] SAC_NOISE_MULTI_LOPE[3] SAC_NOISE_SR[2:1] SAC_NOISE_EN[0] | Bit[7:6]: Reserved Bit[5:4]: Acoustic noise set point to change DVID down slope "00" = Every 4 VID Steps for VID Down "01" = Every 8 VID Steps for VID Down "10" = Every 16 VID Steps for VID Down "11" = Every 32 VID Steps for VID Down Bit[3]: Acoustic noise multi slope on DVID Down "0" = Disable (Default); "1" = Enable Bit[2:1]: Acoustic noise slew rate control "00" = 1/2 (Default); "01" = 1/4; "10" = 1/8; "11" = 1/16 Bit[0]: Acoustic noise mode enable "0" = Disable; "1" = Enable (Note 14) | R/W | 01h |

ASP2100, ASP2100R

Table 20. I²C REGISTERS FOR A RAIL (continued)

| Reg Addr | Register Name | Description | Access | Default |
|----------|---|--|--------|---------|
| 0x58 | SBST_CAP_LOW_TIME[5:4] SBST_CAP_ON_DVID[3] SBST_CAP_TIME[2] SBST_CAP_PULSED[1] SBST_CAP_EN[0] | Bit[7:6]: Reserved Bit[5:4]: Boost cap low time. "00" = 400 ns, "01" = 200 ns, "10" = 800 ns, "11" = 600 ns Bit[3]: Boost cap in parallel with DVID on VID up from low power state "0" = Disable (Default); "1" = Enable Bit[2]: Shorter Boost Cap Refresh "0" = when ps_exit_timer Eh; "1" = when ps_exit_timer 7h Bit[1]: Boost cap low PS exit "0" = Continuous Boosting when Phases are off "1" = Boost Cap Refresh at PS Exit only Bit[0]: Boost Cap Mode Enable "0" = Disable "1" = Enable | R/W | 0Bh |
| 0x59 | TEMP_ALERT#[7:4] STEMP_ALERT#[3:0] | Bit[7:4]: Thermal Alert Threshold for Main Rail Bit[3:0]: Thermal Alert Threshold for A-Rail See Table 12 for threshold values | R/W | 33h |
| 0x5B | SACTIVE_PHASE[1:0] | Real time active phase indicator for A Rail. "1" = Active Bit[1]: Phase2 active indicator Bit[0]: Phase1 active indicator | R0 | – |

14. This functionality will only be available if it is also enabled using the pin function resistor (See Table 8).

15. Offset should only be changed or enabled/disabled when the controller is operating in PS0 mode.

Table 21. GENERAL REGISTERS

| Reg Addr | Register Name | Description | Access | ASP2100 | ASP2100R |
|----------|---------------|-------------|--------|---------|----------|
| 0x48 | Version ID | | RO | 01h | |
| 0xB2 | Chip ID | | RO | 50h | 70h |

ASP2100, ASP2100R

Table 22. SVID REGISTER MAP

| Index | Register Name | Description | Access | Default 00h | PSYS 0Dh |
|-------|---------------|--|--------|-------------------------------|-------------------------------|
| 00h | VENDOR_ID | Uniquely identifies the VR vendor. The vendor ID assigned by Intel to onsemi is 1Ah. | R | 1Ah | 1Ah |
| 01h | PROD_ID | Uniquely identifies the VR product. The VR vendor assigns this number. | R | ASP2100: 50h ASP2100R: 70h | ASP2100: 50h ASP2100R: 70h |
| 02h | PROD_REV | Uniquely identifies the revision or stepping of the VR control IC. The VR vendor assigns this data. | R | 01h | 01h |
| 05h | PROTOCOL_ID | Identifies the SVID Protocol the controller supports | R | 0Eh | 0Eh |
| 06h | CAPABILITY | <i>Inform the Master of the controller's Capabilities</i> "1" = supported, "0" = not supported Bit[7]: Output Current reported as a fraction of IC-CMAX. Default = "1" Bit[6]: ADC Measurement of Temp Supported. Default = "1" Bit[5]: ADC Measurement of Pin Supported. Default = "0" Bit[4]: ADC Measurement of Vin Supported. Default = "1" Bit[3]: ADC Measurement of Iin Supported. Default = "0" Bit[2]: ADC Measurement of Pout Supported. Default = "1" Bit[1]: ADC Measurement of Vout Supported. Default = "1" Bit[0]: ADC Measurement of Iout Supported. Default = "1" | R | D7h | N/A |
| 10h | STATUS1 | Data register read after the ALERT# signal is asserted. Conveying the status of the VR. Bit[7]: Read status Bit[6:4]: Reserved Bit[3]: VID 30mV above target Bit[2]: ICCMAX status Bit[1]: Temp status Bit[0]: VR settled status | R | – | N/A |
| 11h | STATUS2 | Data register showing optional status_2 data. Bit[7:3]: Reserved Bit[2]: Cycle to cycle current limit Bit[1]: Data frame fault Bit[0]: Parity fault | R | – | N/A |
| 12h | TEMPERATURE | Data register showing temperature zones the system is operating in. | R | – | N/A |
| 14h | LASTREAD | Contains last read value read by GET command. | R | 00h | N/A |
| 15h | IOUT_H | 8 bit binary word ADC of current. This register reads 0xFF when the output current is at Icc_Max. | R | 01h | 01h |
| 16h | VOUT_H | 8 bit binary word ADC of output voltage, measured between VSP and VSN. LSB size is 15.625 mV. | R | 01h | N/A |
| 17h | VR_TEMP | 8 bit binary word ADC of voltage. Binary format in deg C, IE 100°C = 64h. A value of 00h indicates this function is not supported. To get accurate temperature, specific Tsense network is required. Place one NTC and one normal resistor in parallel. NTC uses 100 kΩ under 25°C and B25/50 approximates 4250. Use 13.5 kΩ for parallel resistor and 0.3 kΩ for series resistor. | R | 01h | N/A |
| 18h | POUT_H | 8 bit binary word representative of output power. The output voltage is multiplied by the output current value and the result is stored in this register. A value of 00h indicates this function is not supported. | R | 01h | N/A |

ASP2100, ASP2100R

Table 22. SVID REGISTER MAP (continued)

| Index | Register Name | Description | Access | Default 00h | PSYS 0Dh |
|-------|------------------|--|--------|-------------|----------|
| 1Ah | VIN_H | 8 bit binary word ADC of voltage. Input voltage is "1Ah / 255 * 2.5 *12", unit is Volt. | R | 01h | N/A |
| 1Bh | PIN_H | Required for Input Power Domain Address 0Dh. | R | N/A | 00h |
| 1Ch | STATUS2_LASTREAD | When the status 2 register is read its contents are copied into this register. The format is the same as the Status 2 Register. | R | – | N/A |
| 1Fh | I_C2CL | Cycle-to-cycle current limit level. | R/W | 00h | N/A |
| 21h | ICC_MAX | Data register containing the Icc_Max the platform supports. The value is measured on the ICCMAX pin on power up and placed in this register. From that point on the register is read only. | R | – | – |
| 22h | TEMP_MAX | Data register containing the max temperature the platform supports and the level (No Suggestions) asserts. This value defaults to 106°C and programmable over the SVID Interface | R | 6Ah | N/A |
| 24h | SR_FAST | Slew Rate for SetVID_fast commands. Binary format in mV/μs. | R | By setting | N/A |
| 25h | SR_SLOW | Slew Rate for SetVID_slow commands. It is 16, 8, 4 or 2 times slower than the SR_fast rate. Binary format in mV/μs. FAST/4 is default for IMVP9.1. | R | 1/4 Fast | N/A |
| 26h | VBOOT | The VBOOT is resistor programmed at startup. The controller will ramp to VBOOT and hold at VBOOT until it receives a new SVID SetVID command to move to a different voltage. | R | By setting | N/A |
| 2Ah | SLOW_SR_SEL_HC | Fast_SR/2 (Default), Fast_SR/4, Fast_SR/8, Fast_SR/16 | R/W | 02h | N/A |
| 2Bh | PS4_EXIT_LAT | Reflects the latency of exiting PS4 state. The exit latency is defined as the time duration, in μs, from the ACK of the SETVID Slow/Fast command to the output voltage beginning to ramp. | R | 7Bh | N/A |
| 2Ch | PS3_EXIT_LAT | Reflects the latency of exiting PS3 state. The exit latency is defined as the time duration, in μs, from the ACK of the SETVID/SetPS command until the controller is capable of supplying max current of the command PS state. | R | 55h | N/A |
| 2Dh | EN_SVID_RDY_T | Reflects the latency from enable assertion to the VR controller being ready to accept SVID commands. | R | CAh | N/A |
| 30h | VID_MAX | Programmed by master and sets the maximum VID the VR will support. If a higher VID code is received, the VR should respond with "not supported" acknowledge. IMVP9.1 VID format. | R/W | FFh | N/A |
| 31h | VID_SETTING | Data register containing currently programmed VID voltage. VID data format. | R | – | N/A |
| 32h | PWR_STATE | Register containing the current programmed power state. | R | – | N/A |
| 33h | OFFSET | Sets offset in VID steps added to the VID setting for voltage margining. Bit 7 is sign bit, 0 = positive margin, 1 = negative margin. Remaining 7 BITS are #. VID steps for margin 2 s complement 00h = no margin 01h = +1 VID step 02h = +2 VID steps FFh = -1 VID step FEh = -2 VID steps | R/W | 00h | N/A |

ASP2100, ASP2100R

Table 22. SVID REGISTER MAP (continued)

| Index | Register Name | Description | Access | Default 00h | PSYS 0Dh |
|-------|----------------|---|--------|-------------|----------|
| 34h | MULTI_VR_CFG | Bit mapped data register that configures multiple VRs behavior on the same bus and can be programmed to reset behavior of VR_Ready under 0.0 V VID command. | R/W | 01h | 00h |
| 35h | MAIN_ADDR_PTR | Write address pointer for main address space. | R | – | N/A |
| 49h | PSYS_DBC_CLR | Sets the duration of the Deassert Debounce applied to the PSYS critical comparator. This value is encoded in the Mantissa and Exponent format. Bits [7:4] contains Mantissa and [3:0] contains the Exponent. | R/W | N/A | 00h |
| 4Ah | PSYS_CR_LVL_H | Sets the threshold level of the PSYS critical comparator, while PSYS is higher than this threshold the VR_HOT signal is asserted. Must be scaled to the same voltage level as PSYS ADC. Delay from PSYS exceeding threshold to VR_HOT# assertion is dependent on register 0x4F debounce time. | R/W | N/A | 00h |
| 4Bh | PSYS_W2_LVL_H | Sets the threshold level of the PSYS warning 2 comparator. Must be scaled to the same voltage level as PSYS ADC | R/W | N/A | 00h |
| 4Ch | PSYS_W1_LVL_H | Sets the threshold level of the PSYS warning 1 comparator. Must be scaled to the same voltage level as PSYS ADC | R/W | N/A | 00h |
| 4Dh | PSYS_WARN2_CNT | This counter accumulates the duration of time that the PSYS input is above the warning 2 level set by register 0x4B. This register is only cleared on each read or when the threshold level in 0x4B is changed. This register does not roll over when it reaches 0xFF. Data is held while in PS4. This value is encoded in the Mantissa and Exponent format. Bits [7:4] contains Mantissa and [3:0] contains the Exponent. | R | N/A | – |
| 4Eh | PSYS_WARN1_CNT | This counter accumulates the duration of time that the PSYS input is above the warning 1 level set by register 0x4C. This register is only cleared on each read or when the threshold level in 0x4C is changed. This register does not roll over when it reaches 0xFF. Data is held while in PS4. This value is encoded in the Mantissa and Exponent format. Bits [7:4] contains Mantissa and [3:0] contains the Exponent. | R | N/A | – |
| 4Fh | PSYS_DBC_SET | Sets the duration of the Assert Debounce applied to the PSYS critical comparator. This value is encoded in the Mantissa and Exponent format. Bits [7:4] contains Mantissa and [3:0] contains the Exponent. | R/W | N/A | 00h |
| 50h | ICCMAX_ADD | ICCMAX additional capability Bit[7:2]: Optional if not supported reads 0's Bit[1:0]: "00" indicates 1A/bit scaling, "01" indicates 2A/bit scaling | R | By setting | N/A |
| 5Ch | C2CL_EVENT_CNT | Cycle-to-cycle current limit triggered event counter. | R | – | N/A |

ASP2100, ASP2100R

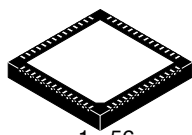
Table 23. IVMP9.1 VID COMMAND

| VID Code (Hex) | Setting Voltage (V) (5 mV/Step) | Setting Voltage (V) (10 mV/Step) |
|----------------|------------------------------------|-------------------------------------|
| 00h | 0 | 0 |
| 01h | 0.250 | 0.200 |
| 02h | 0.255 | 0.210 |
| 03h | 0.260 | 0.220 |
| 04h | 0.265 | 0.230 |
| 05h | 0.270 | 0.240 |
| ... | ... | ... |
| A1h | 1.050 | 1.800 |
| ... | ... | ... |
| FBh | 1.500 | 2.700 |
| FCh | 1.505 | 2.710 |
| FDh | 1.510 | 2.720 |
| FEh | 1.515 | 2.730 |
| FFh | 1.520 | 2.740 |

MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS

ON Semiconductor®

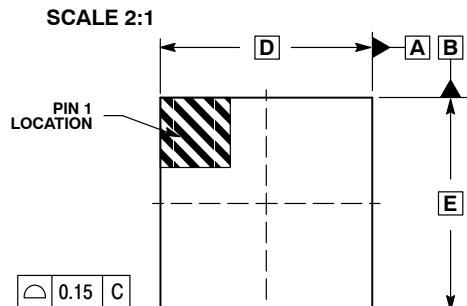
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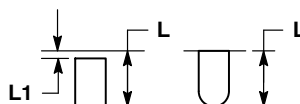
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SCALE 2:1

QFN56 7x7, 0.4P
CASE 485BT
ISSUE A

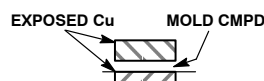
DATE 02 DEC 2014



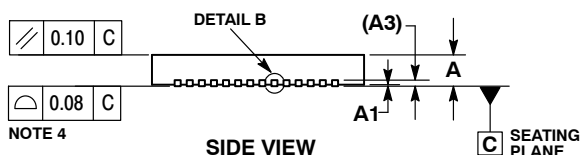
TOP VIEW



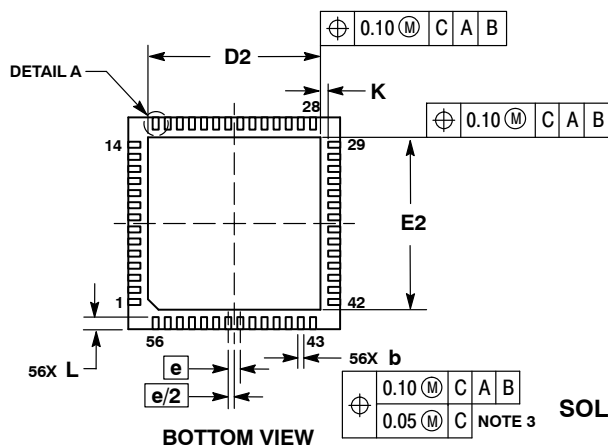
DETAIL A
ALTERNATE TERMINAL
CONSTRUCTIONS



DETAIL B
ALTERNATE
CONSTRUCTIONS



SIDE VIEW



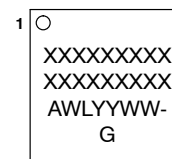
BOTTOM VIEW

NOTES:

1. DIMENSIONS AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO THE PLATED TERMINAL AND IS MEASURED ABETWEEN 0.15 AND 0.25 MM FROM TERMINAL TIP.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.
5. FOR DEVICE OPN CONTAINING W OPTION, DETAILS A AND B, ALTERNATE CONSTRUCTION PERTAINING TO THE L1 DIMENSION, ARE NOT APPLICABLE.

| MILLIMETERS | | |
|-------------|------|------|
| DIM | MIN | MAX |
| A | 0.80 | 1.00 |
| A1 | 0.00 | 0.05 |
| A3 | 0.20 | REF |
| b | 0.15 | 0.25 |
| D | 7.00 | BSC |
| D2 | 5.60 | 5.80 |
| E | 7.00 | BSC |
| E2 | 5.60 | 5.80 |
| e | 0.40 | BSC |
| K | 0.25 | REF |
| L | 0.30 | 0.50 |
| L1 | 0.05 | 0.15 |

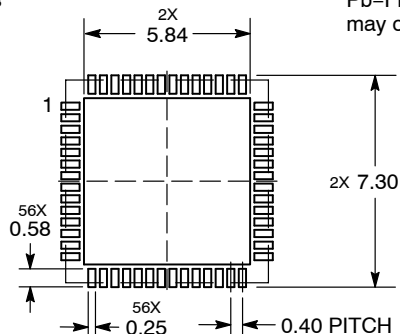
GENERIC MARKING DIAGRAM*



A = Assembly Location
WL = Wafer Lot
YY = Year
WW = Work Week
G = Pb-Free Package

*This information is generic. Please refer to device data sheet for actual part marking.
Pb-Free indicator, "G" or microdot "▪", may or may not be present.

RECOMMENDED SOLDERING FOOTPRINT*



DIMENSIONS: MILLIMETERS

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

| | | |
|------------------|------------------|---|
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| DESCRIPTION: | QFN56 7X7, 0.40P | PAGE 1 OF 1 |

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