

NCP81109F

Product Preview

Single-Phase Voltage Regulator with SVID Interface for Computing Applications

High Switching Frequency, High Efficiency, Integrated Power MOSFETs

The NCP81109F, a single-phase synchronous buck regulator, integrates power MOSFETs to provide a high-efficiency and compact-footprint power management solution for new generation computing CPUs. The device is able to deliver up to 14 A TDC output current on an adjustable output with SVID interface. Operating in high switching frequency up to 1.2 MHz allows employing small size inductors and capacitors while maintaining high efficiency due to integrated solution with high performance power MOSFETs. Current-mode RPM control with feedforward from both input power supply and output voltage ensures stable operation over wide operation condition. The NCP81109F is in a QFN48 6 x 6 mm package.

Features

- Meets Intel® Server Specifications
- 5 V to 20 V Input Voltage Range
- 1.0 V/1.5 V Fixed Boot Voltage
- Adjustable Output Voltage with SVID Interface
- Integrated Gate Driver and Power MOSFETs
- Up to 14 A TDC Output Current
- 500 kHz ~ 1.2 MHz Switching Frequency
- Current-Mode RPM Control
- Programmable SVID Address and ICCMax
- Programmable DVID Feed-Forward to Support Fast DVID
- Feedforward Operation for Input Supply Voltage and Output Voltage
- Output Over-Voltage and Under-Voltage Protections
- External Current Limitation Programming with Inductor Current Sense
- QFN48, 6 x 6 mm, 0.4 mm Pitch Package
- This is a Pb-Free Device

Typical Applications

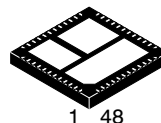
- Server Applications

This document contains information on a product under development. ON Semiconductor reserves the right to change or discontinue this product without notice.



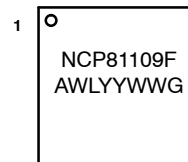
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QFN48
CASE 485CJ

MARKING DIAGRAM



NCP81109F = Specific Device Code
A = Assembly Location
WL = Wafer Lot
YY = Year
WW = Work Week
G = Pb-Free Package

ORDERING INFORMATION

| Device | Package | Shipping† |
|----------------|--------------------|-----------------------|
| NCP81109FMNTXG | QFN48 (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.

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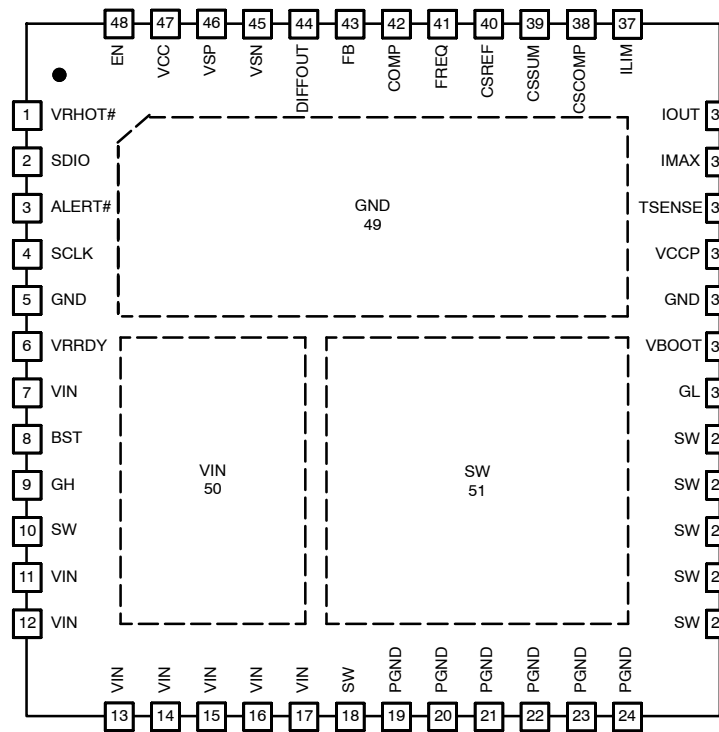


Figure 1. Pin Configuration
(Top View)

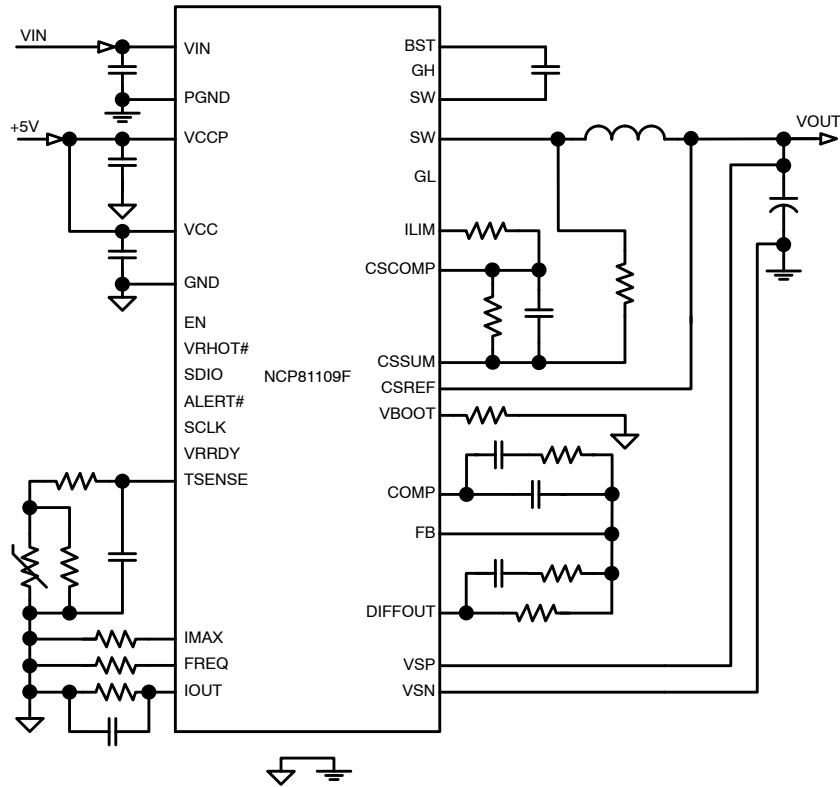


Figure 2. Typical Application Circuit

NCP81109F

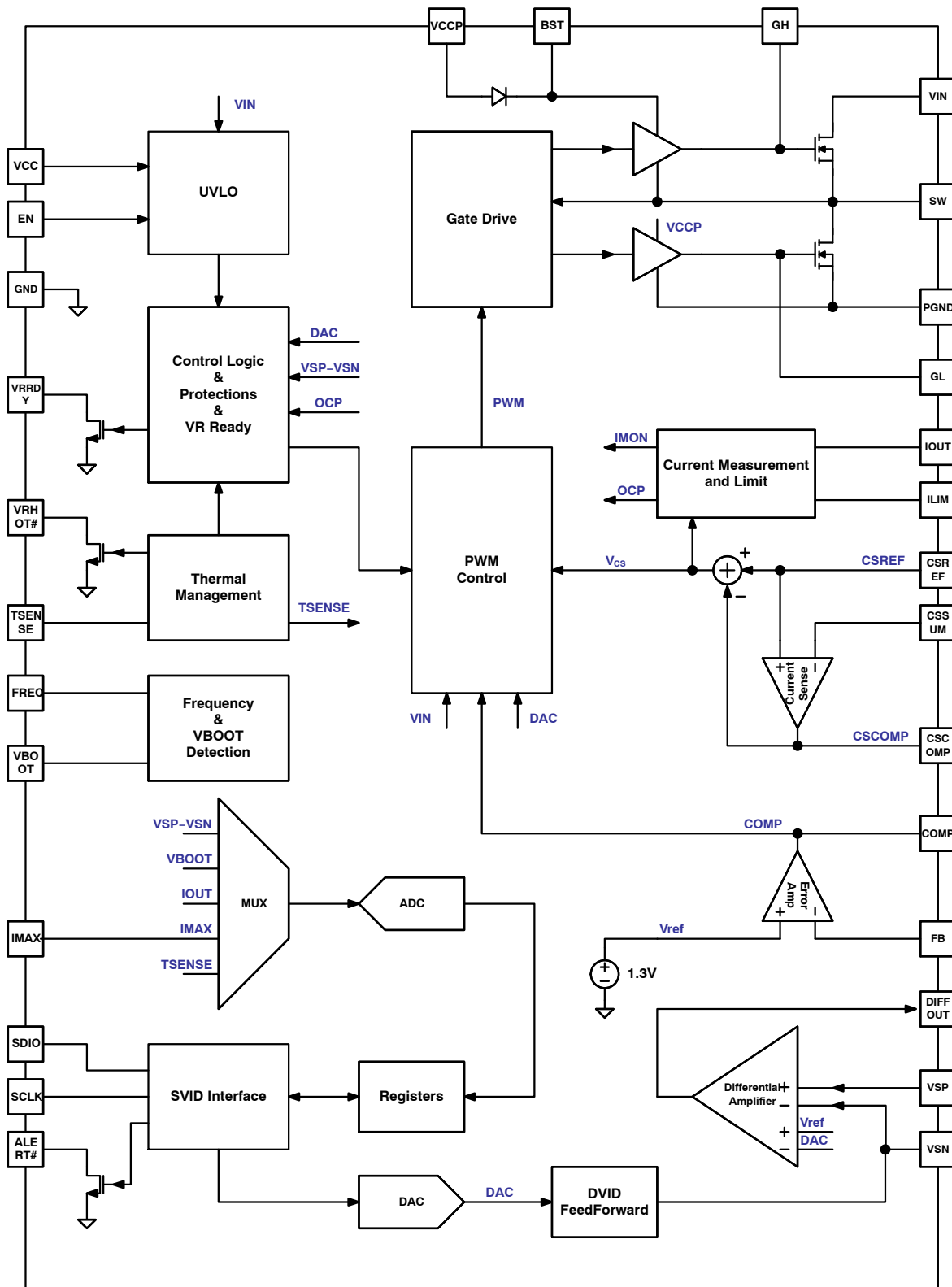


Figure 3. Functional Block Diagram

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PIN DESCRIPTION

| Pin | Name | Type | Description |
|---------------|---------|---------------------|---|
| 1 | VRHOT# | Logic Output | VR HOT. Logic low output represents over temperature. |
| 2 | SDIO | Logic Bidirectional | Serial Data IO Port. Data port of SVID interface. |
| 3 | ALERT# | Logic Output | ALERT. Open-drain output. Provides a logic low valid alert signal of SVID interface. |
| 4 | SCLK | Logic Input | Serial Clock. Clock input of SVID interface. |
| 5, 32, 49 | GND | Analog Ground | Analog Ground. Ground of internal control circuits. Must be connected to the system ground. |
| 6 | VRRDY | Logic Output | Voltage Regulator Ready. Open-drain output. Provides a logic high valid power good output signal, indicating the regulator's output is in regulation window. |
| 7, 11-17, 50 | VIN | Power Input | Power Supply Input. These pins are the power supply input pins of the device, which are connected to drain of internal high-side power MOSFET. 22 μ F or more ceramic capacitors must bypass this input to power ground. The capacitors should be placed as close as possible to these pins. |
| 8 | BST | Power Bidirectional | Bootstrap. Provides bootstrap voltage for the high-side gate driver. A 0.1 μ F ~ 1 μ F ceramic capacitor is required from this pin to SW (pin 10). A 1 – 2 Ω resistor may be employed in series with the BST cap to reduce switching noise and ringing when needed. |
| 9 | GH | Analog Output | Gate of High-Side MOSFET. Directly connected with the gate of the high-side power MOSFET. |
| 10 | SW | Power Return | Switching Node. Provides a return path for integrated high-side gate driver. It is internally connected to source of high-side MOSFET. |
| 18, 25-29, 51 | SW | Power Output | Switch Node. Pins to be connected to an external inductor. These pins are interconnection between internal high-side MOSFET and low-side MOSFET. |
| 19-24 | PGND | Power Ground | Power Ground. These pins are the power supply ground pins of the device, which are connected to source of internal low-side power MOSFET. Must be connected to the system ground. |
| 30 | GL | Analog Output | Gate of Low-Side MOSFET. Directly connected with the gate of the low-side power MOSFET. |
| 31 | VBOOT | Analog Input | Boot-Up Voltage. A resistor from this pin to ground programs SVID address. |
| 33 | VCCP | Analog Power | Voltage Supply of Gate Driver. Power supply input pin of internal gate driver. A 4.7 μ F or larger ceramic capacitor bypasses this input to ground. This capacitor should be placed as close as possible to this pin. |
| 34 | TSENSE | Analog | Temperature Sense. An external temperature sense network is connected to this pin. |
| 35 | IMAX | Analog Input | Current Maximum. A resistor from this pin to ground programs IMAX. |
| 36 | IOUT | Analog Output | OUT Current Monitor. Provides output signal representing output current by connecting a resistor from this pin to ground. Shorting this pin to ground disables IMON function. |
| 37 | ILIM | Analog Output | Limit of Current. A resistor from this pin to CSCOMP programs over-current threshold with inductor current sense. |
| 38 | CSCOMP | Analog Output | Current Sense COMP. Output pin of current sense amplifier. |
| 39 | CSSUM | Analog Input | Current Sense SUM. Inverting input of current sense amplifier. |
| 40 | CSREF | Analog Input | Current Sense Reference. Non-Inverting input of current sense amplifier. |
| 41 | FREQ | Analog Input | Frequency. A resistor from this pin to ground programs switching frequency. |
| 42 | COMP | Analog | Compensation. Output pin of error amplifier. |
| 43 | FB | Analog Input | Feedback. Inverting input to error amplifier. |
| 44 | DIFFOUT | Analog Output | Differential Amplifier Output. Output pin of differential voltage sense amplifier. |
| 45 | VSN | Analog Input | Voltage Sense Negative Input. Inverting input of differential voltage sense amplifier. It is also used for DVID feed forward function with an external resistor. |
| 46 | VSP | Analog Input | Voltage Sense Positive Input. Non-inverting input of differential voltage sense amplifier. |

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PIN DESCRIPTION

| Pin | Name | Type | Description |
|-----|------|--------------|---|
| 47 | VCC | Analog Power | Voltage Supply of Controller. Power supply input pin of control circuits. A 1 μ F or larger ceramic capacitor bypasses this input to ground. This capacitor should be placed as close as possible to this pin. |
| 48 | EN | Logic Input | Enable. Logic high enables the device and logic low makes the device in standby mode. |

MAXIMUM RATINGS

| Rating | Symbol | Value | | Unit |
|---|-------------------|----------------------|-------------------|----------------|
| | | Min | Max | |
| Power Supply Voltage to PGND | V_{VIN} | | 30 | V |
| Switch Node to PGND | V_{SW} | | 30 | V |
| Analog Supply Voltage to GND | V_{CC}, V_{CCP} | -0.3 | 6.5 | V |
| BST to PGND | BST_PGND | -0.3 | 33 38 (<50 ns) | V |
| BST to SW | BST_SW | -0.3 | 6.5 | V |
| GH to SW | GH | -0.3 -2 (<200 ns) | BST+0.3 | V |
| GL to GND | GL | -0.3 -2 (<200 ns) | VCCP+0.3 | V |
| VSN to GND | VSN | -0.3 | 0.3 | V |
| IOUT | IOUT | -0.3 | 2.5 | V |
| PGND to GND | PGND | -0.3 | 0.3 | V |
| Other Pins | | -0.3 | VCC+0.3 | V |
| Latch up Current: (Note 1) All pins, except digital pins Digital pins | I_{LU} | -100 -10 | 100 10 | mA |
| Operating Junction Temperature Range | T_J | -10 | 125 | $^{\circ}$ C |
| Operating Ambient Temperature Range | T_A | -10 | 100 | $^{\circ}$ C |
| Storage Temperature Range | T_{STG} | -40 | 150 | $^{\circ}$ C |
| Thermal Resistance Junction to Board (Note 2) | $R_{\theta JB}$ | 8.2 | | $^{\circ}$ C/W |
| Thermal Resistance Junction to Ambient (Note 2) | $R_{\theta JA}$ | 21.8 | | $^{\circ}$ C/W |
| Power Dissipation at $T_A = 25^{\circ}$ C (Note 3) | P_D | 4.59 | | W |
| Moisture Sensitivity Level (Note 4) | MSL | 3 | | - |

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.

1. Latch up Current per JEDEC standard: JESD78 class II.
2. The thermal resistance values are dependent of the internal losses split between devices and the PCB heat dissipation. This data is based on a typical operation condition with a 4-layer FR-4 PCB board, which has two, 1-ounce copper internal power and ground planes and 2-ounce copper traces on top and bottom layers with approximately 80% copper coverage. No airflow and no heat sink applied (reference EIA/JEDEC 51.7). It also does not account for other heat sources that may be present on the PCB next to the device in question (such as inductors, resistors etc.)
3. The maximum power dissipation (P_D) is dependent on input voltage, output voltage, output current, external components selected, and PCB layout. The reference data is obtained based on $T_{JMAX} = 125^{\circ}$ C and $R_{\theta JA} = 21.8^{\circ}$ C/W.
4. Moisture Sensitivity Level (MSL): 3 per IPC/JEDEC standard: J-STD-020D.1.

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ELECTRICAL CHARACTERISTICS ($V_{IN} = 12\text{ V}$, $V_{CC} = V_{CCP} = 5\text{ V}$, $V_{OUT} = 1.0\text{ V}$, typical values are referenced to $T_J = 25^\circ\text{C}$, Min and Max values are referenced to T_J from -10°C to 100°C , unless otherwise noted.)

| Characteristics | Test Conditions | Symbol | Min | Typ | Max | Unit |
|-----------------|-----------------|--------|-----|-----|-----|------|
|-----------------|-----------------|--------|-----|-----|-----|------|

SUPPLY VOLTAGE

| | | | | | | |
|--------------------------------|----------|-----------|------|----|------|---|
| Supply Voltage V_{IN} Range | (Note 5) | V_{IN} | | 12 | | V |
| Supply Voltage V_{CC} Range | (Note 5) | V_{CC} | 4.75 | 5 | 5.25 | V |
| Supply Voltage V_{CCP} Range | (Note 5) | V_{CCP} | 4.75 | 5 | 5.25 | V |

SUPPLY VOLTAGE MONITOR

| | | | | | | |
|---------------|-------------------|-------------|-----|------|-----|----|
| V_{IN} UVLO | Falling Threshold | V_{INUV-} | 3.0 | 3.25 | 3.5 | V |
| | Hysteresis | V_{INHYS} | | 650 | – | mV |
| V_{CC} UVLO | Falling Threshold | V_{CCUV-} | 3.8 | 4.08 | – | V |
| | Rising Threshold | V_{CCUV+} | – | 4.34 | 4.5 | V |
| | Hysteresis | V_{CCHYS} | – | 260 | – | mV |

SUPPLY CURRENT

| | | | | | | |
|---|---------------------------------|-------------|---|-----|------|---------------|
| V_{IN} Quiescent Supply Current (Power MOSFETs) | EN high, no load, PS0,1,2 Modes | I_Q | – | 1.5 | 3 | mA |
| | EN high, no load, PS3 Mode | | – | 1.5 | 3 | mA |
| | EN high, PS4 Mode (Note 6) | | – | – | 1 | μA |
| V_{IN} Shutdown Current | EN low (Note 6) | I_{SD} | – | – | 1 | μA |
| V_{CC} Quiescent Supply Current (Controller) | EN high, no load, PS0,1,2 Modes | I_{QCC} | – | 8.0 | 12 | mA |
| | EN high, no load, PS3 Mode | | – | 7.5 | 12 | mA |
| | EN high, PS4 Mode (Note 6) | | – | 170 | 194 | μA |
| V_{CC} Shutdown Current | EN low (Note 6) | I_{SDCC} | – | – | 90 | μA |
| V_{CCP} Quiescent Supply Current (Gate Driver) | EN high, no load, PS0,1,2 Modes | I_{QCCP} | – | 0.7 | 1.25 | mA |
| | EN high, no load, PS3 Mode | | – | 0.7 | 1.25 | mA |
| | EN high, PS4 Mode | | – | – | 2 | μA |
| V_{CCP} Shutdown Current | EN low | I_{SDCCP} | – | – | 2 | μA |

OUTPUT VOLTAGE

| | | | | | | |
|----------------------|----------|-----------|---|---|-----|---|
| Output Voltage Range | (Note 5) | V_{OUT} | 0 | – | 2.3 | V |
|----------------------|----------|-----------|---|---|-----|---|

REGULATION ACCURACY

| | | | | | | |
|-------------------------|---|--|-----|--|----|----|
| System Voltage Accuracy | $0.5\text{ V} < \text{DAC} < 1.52\text{ V}$ | | –8 | | 8 | mV |
| | $0.25\text{ V} < \text{DAC} < 0.495\text{ V}$ | | –10 | | 10 | mV |

DVID

| | | | | | | |
|----------------------|---------|------|--|--|--|-------------------|
| Fast Slew Rate | Default | FSR | | 14 | | mV/ μs |
| Soft Start Slew Rate | | SSSR | | FSR/4 | | mV/ μs |
| Slow Slew Rate | | SSR | | FSR/2 FSR/4 (default) FSR/8 FSR/16 | | mV/ μs |

DIFFERENTIAL VOLTAGE-SENSE AMPLIFIER

| | | | | | | |
|-------------------------|---|------------------------|-------------|-----|-----------|---------------------|
| DC Gain | $V_{SP} - V_{SN} = 0.5\text{ V to } 2.3\text{ V}$ | GAIN_DVA | | 1.0 | | V/V |
| –3 dB Gain Bandwidth | $CL = 20\text{ pF to GND}$, $RL = 10\text{ k}\Omega$ to GND (Note 5) | BW_DVA | | 10 | | MHz |
| VSP Input Voltage Range | (Note 5) | VSP | –0.3 | – | 3.0 | V |
| VSN Input Voltage Range | (Note 5) | VSN | –0.3 | – | 0.3 | V |
| Input Bias Current | $V_{SP}, CSREF = 1.3\text{ V}$ | I_{VSP} I_{VSN} | –15 –100 | | 15 100 | μA nA |

5. Guaranteed by design, not tested in production.

6. $T_J = 25^\circ\text{C}$.

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| Characteristics | Test Conditions | Symbol | Min | Typ | Max | Unit |
|-----------------|-----------------|--------|-----|-----|-----|------|
|-----------------|-----------------|--------|-----|-----|-----|------|

DIFFERENTIAL CURRENT-SENSE AMPLIFIER

| | | | | | | |
|----------------------|--|----------------------------|-------------|----|-----------|---------------------|
| DC Gain | (Note 5) | GAIN_DCA | | 80 | | dB |
| -3dB Gain Bandwidth | $CL = 20\text{ pF}$ to GND, $RL = 10\text{ k}\Omega$ to GND (Note 5) | BW_DCA | | 10 | | MHz |
| Input Offset Voltage | | V_{OS_CS} | -300 | - | 300 | μV |
| Input Bias Current | $CSSUM = CSREF = 1.2\text{ V}$ | I_{CSSUM} I_{CSREF} | -7.5 -10 | | 7.5 10 | nA μA |

ERROR AMPLIFIER

| | | | | | | |
|----------------------|--|---------------|------|-----|-----|------------------------|
| DC Gain | $CL = 20\text{ pF}$ to GND, $RL = 10\text{ k}\Omega$ to GND (Note 5) | GAIN_EA | | 80 | | dB |
| Unity Gain Bandwidth | $CL = 20\text{ pF}$ to GND, $RL = 10\text{ k}\Omega$ to GND (Note 5) | BW_EA | | 20 | | MHz |
| Slew Rate | $\Delta V_{in} = 100\text{ mV}$, $G = -10\text{ V/V}$, $\Delta V_{out} = 1.5\text{ V} - 2.5\text{ V}$, $CL = 20\text{ pF}$ to GND, $RL = 10\text{ k}\Omega$ to GND (Note 5) | SR_EA | | 25 | | $\text{V}/\mu\text{s}$ |
| Output Voltage Swing | $I_{source_EA} = 2\text{ mA}$ | V_{max_EA} | 3.5 | - | - | V |
| | $I_{sink_EA} = 2\text{ mA}$ | V_{min_EA} | - | - | 1 | V |
| FB Voltage | | V_{FB} | | 1.3 | | V |
| Input Bias Current | $V_{FB} = 1.3\text{ V}$ | I_{FB} | -1.5 | | 1.5 | μA |

SWITCHING FREQUENCY

| | | | | | | |
|---|----------|-------|------|-----|------|-----|
| Normal Operation Frequency (Programmed by a resistor at FREQ pin) | (Note 5) | FSW | 500 | | 1200 | kHz |
| FREQ Output Voltage | | VFREQ | 1.95 | 2.0 | 2.05 | V |

CONTROL LOGIC

| | | | | | | |
|---------------------------|--|----------|-----|-----|-----|---------------|
| ENABLE Input High Voltage | | VEN_H | 0.8 | - | - | V |
| ENABLE Input Low Voltage | | VEN_L | - | - | 0.3 | V |
| ENABLE Input Hysteresis | | VEN_HYS | - | 300 | - | mV |
| ENABLE Input Bias Current | | IEN_BIAS | - | | 1.0 | μA |

SCLK, SDIO

| | | | | | | |
|---|---|-----------|------|------|------|---------------|
| Input High Voltage | | V_{IH} | 0.65 | | | V |
| Input Low Voltage | | V_{IL} | | | 0.45 | V |
| Input Threshold Hysteresis | | V_{HYS} | | 50 | | mV |
| Output High Voltage | (Note 5) | V_{OH} | | 1.05 | | V |
| Output Low Voltage | SDIO | V_{OL} | | | 0.3 | V |
| Buffer On Resistance (data line, ALERT#, and VR_HOT#) | | R_{ON} | 3.0 | | 13 | Ω |
| Input Leakage Current | Pin voltage between 0 and 1.05 V | | -100 | | 100 | μA |
| Input Capacitance | Die capacitance only (Note 5) | | | | 4.0 | pF |
| VR Clock to Data Delay | Time between SCLK rising edge and valid SDIO level (Note 5) | T_{co} | 4 | | 8.3 | ns |
| Setup Time | Time before SCLK falling (sampling) edge that SDIO level must be valid (Note 5) | T_{su} | 7 | | | ns |

5. Guaranteed by design, not tested in production.

6. $T_J = 25^\circ\text{C}$.

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| Characteristics | Test Conditions | Symbol | Min | Typ | Max | Unit |
|-----------------|-----------------|--------|-----|-----|-----|------|
|-----------------|-----------------|--------|-----|-----|-----|------|

SCLK, SDIO

| | | | | | | |
|-----------|---|------|----|--|--|----|
| Hold Time | Time after SCLK falling edge that the SDIO level remains valid (Note 5) | Thld | 14 | | | ns |
|-----------|---|------|----|--|--|----|

ALERT#

| | | | | | | |
|------------------------|---------------------------------------|--|------|---|-----|---------------|
| Output Low Voltage | $I_{_ALERT\#} = -4\text{ mA}$ | | - | - | 0.3 | V |
| Output Leakage Current | High Impedance State, ALERT # = 3.3 V | | -1.0 | - | 1.0 | μA |

VR_HOT#

| | | | | | | |
|------------------------|--------------------------------------|--|------|---|-----|---------------|
| Output Low Voltage | $I_{_VRHOT\#} = -4\text{ mA}$ | | - | - | 0.3 | V |
| Output Leakage Current | High Impedance State, VRHOT# = 3.3 V | | -1.0 | - | 1.0 | μA |

TSENSE

| | | | | | | |
|-----------------------------|-----------------------------|--|-----|-----|-----|---------------|
| Alert# Assert Threshold | | | | 491 | | mV |
| Alert# De-assert Threshold | | | | 513 | | mV |
| VR_HOT# Assert Threshold | | | | 472 | | mV |
| VR_HOT# De-assert Threshold | | | | 494 | | mV |
| TSENSE Bias Current | $V_{TSENSE} = 0.4\text{ V}$ | | 115 | 120 | 125 | μA |

VBOOT

| | | | | | | |
|-----------------|--------------------------|--|--|----|--|---------------|
| Sensing Current | $V_{VBOOT} = \text{GND}$ | | | 10 | | μA |
|-----------------|--------------------------|--|--|----|--|---------------|

IMAX

| | | | | | | |
|-----------------|-------------------------|--|--|----|--|---------------|
| Sensing Current | $V_{IMAX} = \text{GND}$ | | | 10 | | μA |
|-----------------|-------------------------|--|--|----|--|---------------|

ADC

| | | | | | | |
|---------------------------------|-------|--|----|---------|-----|---------------|
| Voltage Range | | | 0 | | 2.0 | V |
| Total Unadjusted Error (TUE) | | | -1 | | 1 | % |
| Differential Nonlinearity (DNL) | 8-bit | | | | 1 | LSB |
| Power Supply Sensitivity | | | | ± 1 | | % |
| Conversion Time | | | | 30 | | μs |
| Round Robin | | | | 90 | | μs |

VR_READY (VRRDY Output)

| | | | | | | |
|----------------------------|--|-------|------|-----|-----|---------------|
| Rise Time | External 1 k Ω pull-up to 3.3 V, CTOT = 45 pF, $\Delta V_o = 10\%$ to 90% | | | 100 | | ns |
| Fall Time | External 1 k Ω pull-up to 3.3 V, CTOT = 45 pF, $\Delta V_o = 90\%$ to 10% | | | 10 | | ns |
| Output Voltage at Power-Up | Pulled up to 5 V via 2 k Ω | | - | - | 1.0 | V |
| VR_READY Delay (Rising) | DAC = Target to VR_READY | | | 50 | | μs |
| VR_READY Delay (Falling) | From OCP or OVP | | | 5 | | μs |
| VRRDY Pin Low Voltage | Voltage at VRRDY pin with 4 mA sink current | VPG_L | - | - | 0.3 | V |
| VRRDY Pin Leakage Current | VRRDY = 5 V | PG_LK | -1.0 | - | 1.0 | μA |

OVER VOLTAGE PROTECTION

| | | | | | | |
|---|--|--|-----|-----|-----|---|
| Absolute Over Voltage Threshold During Soft-Start | | | 2.8 | 2.9 | 3.0 | V |
|---|--|--|-----|-----|-----|---|

5. Guaranteed by design, not tested in production.
6. $T_J = 25^\circ\text{C}$.

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ELECTRICAL CHARACTERISTICS ($V_{IN} = 12\text{ V}$, $V_{CC} = V_{CCP} = 5\text{ V}$, $V_{OUT} = 1.0\text{ V}$, typical values are referenced to $T_J = 25^\circ\text{C}$, Min and Max values are referenced to T_J from -10°C to 100°C , unless otherwise noted.)

| Characteristics | Test Conditions | Symbol | Min | Typ | Max | Unit |
|-----------------|-----------------|--------|-----|-----|-----|------|
|-----------------|-----------------|--------|-----|-----|-----|------|

OVER VOLTAGE PROTECTION

| | | | | | | |
|----------------------------------|----------------------|--|-----|-----|-----|----|
| Over Voltage Threshold Above DAC | VSP rising | | 350 | 400 | 425 | mV |
| Over Voltage Delay | VSP rising to GH low | | | 50 | | ns |

UNDER VOLTAGE PROTECTION

| | | | | | | |
|-----------------------------------|-------------|--|-----|-----|-----|---------------|
| Under Voltage Threshold Below DAC | VSP falling | | 250 | 300 | 350 | mV |
| Under-voltage Delay | | | | 5 | | μs |

OVER CURRENT PROTECTION

| | | | | | | |
|---|--|-------------------|------|------|------|---------------|
| ILIM Threshold Current (OCP shutdown after 50 μs delay) | | I_{LIMTH_SLOW} | 9.0 | 10.0 | 11.0 | μA |
| ILIM Threshold Current (immediate OCP shutdown) | | I_{LIMTH_FAST} | 13.5 | 15.0 | 16.5 | μA |

IOUT OUTPUT

| | | | | | | |
|-------------------------------|---|--|------|-----|------|---------------|
| Current Gain | ($I_{OUTCURRENT}$) / ($I_{LIMCURRENT}$); $R_{ILIM} = 20\text{ k}\Omega$; $R_{IOUT} = 5.0\text{ k}\Omega$; DAC = 0.8 V, 1.25 V, 1.52 V | | 9.5 | 10 | 10.5 | A/A |
| Input Referred Offset Voltage | $I_{LIM} - CSREF$ | | -2.0 | - | 2.0 | mV |
| Output Source Current | I_{LIM} sink current = 80 μA | | | 800 | | μA |

HIGH-SIDE MOSFET

| | | | | | | |
|-------------------------------|---|-------------|---|-----|---|------------------|
| Drain-to-Source ON Resistance | $V_{GS} = 4.5\text{ V}$, $I_D = 10\text{ A}$ | R_{ON_H} | - | 8.0 | - | $\text{m}\Omega$ |
|-------------------------------|---|-------------|---|-----|---|------------------|

LOW-SIDE MOSFET

| | | | | | | |
|-------------------------------|---|-------------|---|-----|---|------------------|
| Drain-to-Source ON Resistance | $V_{GS} = 4.5\text{ V}$, $I_D = 10\text{ A}$ | R_{ON_L} | - | 4.0 | - | $\text{m}\Omega$ |
|-------------------------------|---|-------------|---|-----|---|------------------|

HIGH-SIDE GATE DRIVE

| | | | | | | |
|-------------------------------|---------------------------------|---------------|---|-----|-----|----------|
| Pull-High Drive ON Resistance | $V_{BST} - V_{SW} = 5\text{ V}$ | R_{DRV_HH} | - | 1.2 | 2.8 | Ω |
| Pull-Low Drive ON Resistance | $V_{BST} - V_{SW} = 5\text{ V}$ | R_{DRV_HL} | - | 0.8 | 2.0 | Ω |
| GH Propagation Delay Time | From GL falling to GH rising | T_{GH_d} | | 15 | | ns |

LOW-SIDE GATE DRIVE

| | | | | | | |
|-------------------------------|-----------------------------------|---------------|---|-----|------|----------|
| Pull-High Drive ON Resistance | $V_{CCP} - V_{PGND} = 5\text{ V}$ | R_{DRV_LH} | - | 0.9 | 2.8 | Ω |
| Pull-Low Drive ON Resistance | $V_{CCP} - V_{PGND} = 5\text{ V}$ | R_{DRV_LL} | - | 0.4 | 1.25 | Ω |
| GL Propagation Delay Time | From GH falling to GL rising | T_{GL_d} | | 10 | | ns |

SW to PGND RESISTANCE

| | | | | | | |
|---------------------------------|----------|----------|---|------|---|------------------|
| SW to PGND Pull-Down Resistance | (Note 5) | R_{SW} | - | 1.88 | - | $\text{k}\Omega$ |
|---------------------------------|----------|----------|---|------|---|------------------|

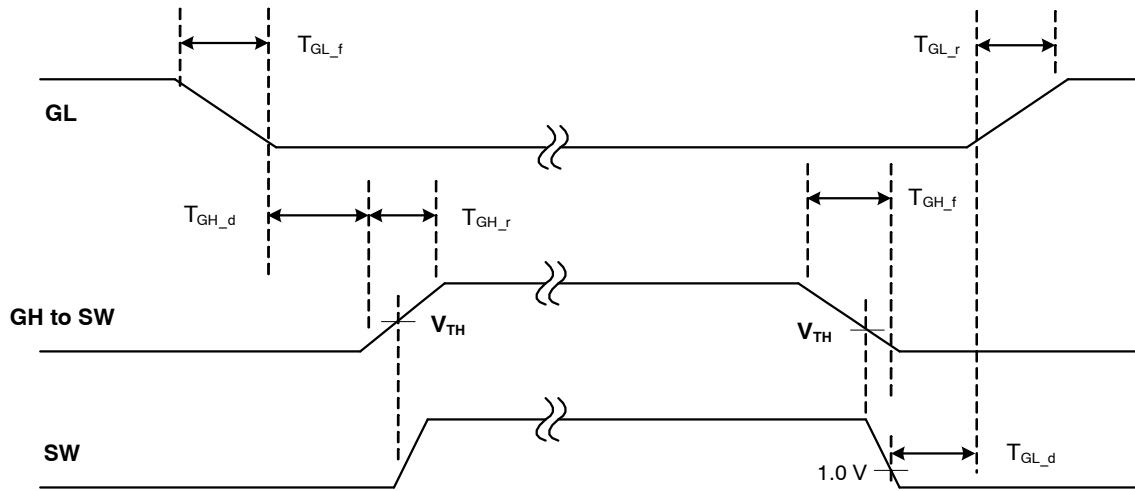
BOOTSTRAP RECTIFIER SWITCH

| | | | | | | |
|---------------|-------------------------------------|---------------|---|----|----|----------|
| On Resistance | $EN = L$ or $EN = H$ and $DRVL = H$ | R_{on_BST} | 5 | 13 | 20 | Ω |
|---------------|-------------------------------------|---------------|---|----|----|----------|

5. Guaranteed by design, not tested in production.

6. $T_J = 25^\circ\text{C}$.

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NOTE: Timing is referenced to the 90% and 10% points, unless otherwise noted.

Figure 4. Timing Diagram of Gate Drivers

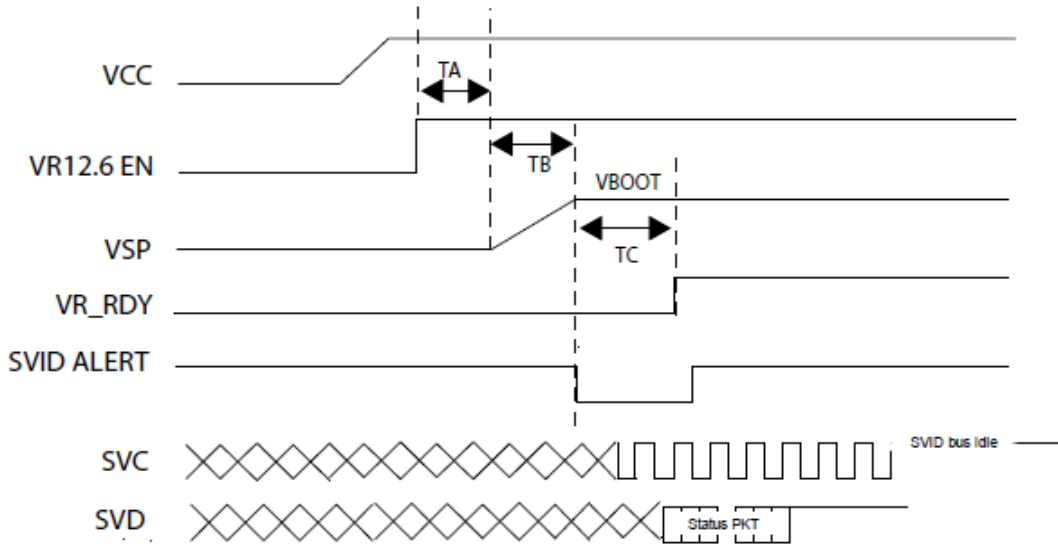


Figure 5. Timing Diagram of Start Up

Table 1. START-UP AND ENABLE TIMINGS

| Symbol | Description | Values | | | Note |
|--------|---|----------------------|-----|-----------|--|
| | | Min | Typ | Max | |
| TA | Non-zero Vboot Case: start of Vboot ramp Zero Vboot Case: Controller ready accept SVID command | | | 2.5 ms | Complete all internal analog and digital configurations and reset protocols during TA. May be disclosed to CPU through register 2Dh. |
| TB | Vboot ramp time | Depends on Slew rate | | | When Vboot > 0 V, the VR is to slew at the default Slow rate of FAST/4 |
| TC | Completion of Vboot ramp or initial SetVID ramp to assertion of associated VR_READY | 0 μ s | | 6 μ s | |

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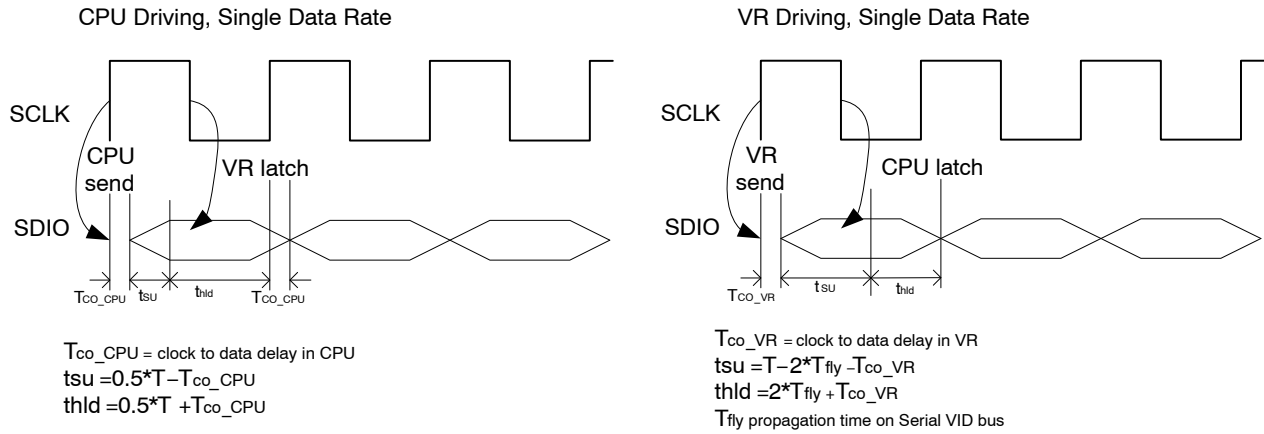


Figure 6. Timing Diagram of SVID

Table 2. STATE TRUTH TABLE

| STATE | VR_RDY Pin | Error AMP Comp Pin | OVP & UVP | Method of Reset |
|---|--|--------------------|-------------------|-----------------|
| POR 0 < VCC < UVLO | N/A | N/A | N/A | |
| Disabled EN < threshold UVLO > threshold | Low | Low | Disabled | |
| Start up Delay & Calibration EN > threshold UVLO > threshold | Low | Low | Disabled | |
| Soft Start EN > threshold UVLO > threshold | Low | Operational | Active / No latch | |
| Normal Operation EN > threshold UVLO > threshold | High | Operational | Active / Latching | N/A |
| Over Voltage | Low | N/A | DAC + 400 mV | |
| Over Current | Low | Operational | Last DAC Code | |
| VID Code = 00h | Low: if Reg34h:bit0 = 0; High: if Reg34h:bit0 = 1 | Clamped at 0.9 V | Disabled | |

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Table 3. VR12 VID CODES

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | Voltage (V) | HEX |
|------|------|------|------|------|------|------|------|-------------|-----|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | OFF | 00 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.25000 | 01 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.25500 | 02 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0.26000 | 03 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0.26500 | 04 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.27000 | 05 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0.27500 | 06 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0.28000 | 07 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0.28500 | 08 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0.29000 | 09 |
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0.29500 | 0A |
| 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0.30000 | 0B |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0.30500 | 0C |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0.31000 | 0D |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0.31500 | 0E |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0.32000 | 0F |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.32500 | 10 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.33000 | 11 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0.33500 | 12 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0.34000 | 13 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0.34500 | 14 |
| 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0.35000 | 15 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0.35500 | 16 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0.36000 | 17 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0.36500 | 18 |
| 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0.37000 | 19 |
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0.37500 | 1A |
| 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0.38000 | 1B |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0.38500 | 1C |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0.39000 | 1D |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0.39500 | 1E |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0.40000 | 1F |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.40500 | 20 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0.41000 | 21 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0.41500 | 22 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0.42000 | 23 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0.42500 | 24 |
| 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0.43000 | 25 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0.43500 | 26 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0.44000 | 27 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0.44500 | 28 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0.45000 | 29 |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0.45500 | 2A |
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0.46000 | 2B |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0.46500 | 2C |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0.47000 | 2D |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0.47500 | 2E |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0.48000 | 2F |

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Table 3. VR12 VID CODES

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | Voltage (V) | HEX |
|------|------|------|------|------|------|------|------|-------------|-----|
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0.48500 | 30 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0.49000 | 31 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0.49500 | 32 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0.50000 | 33 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0.50500 | 34 |
| 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0.51000 | 35 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0.51500 | 36 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0.52000 | 37 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0.52500 | 38 |
| 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0.53000 | 39 |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0.53500 | 3A |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0.54000 | 3B |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0.54500 | 3C |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0.55000 | 3D |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0.55500 | 3E |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0.56000 | 3F |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.56500 | 40 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0.57000 | 41 |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0.57500 | 42 |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0.58000 | 43 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0.58500 | 44 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0.59000 | 45 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0.59500 | 46 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0.60000 | 47 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0.60500 | 48 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0.61000 | 49 |
| 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0.61500 | 4A |
| 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0.62000 | 4B |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0.62500 | 4C |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0.63000 | 4D |
| 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0.63500 | 4E |
| 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0.64000 | 4F |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0.64500 | 50 |
| 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0.65000 | 51 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0.65500 | 52 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0.66000 | 53 |
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0.66500 | 54 |
| 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0.67000 | 55 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0.67500 | 56 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0.68000 | 57 |
| 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0.68500 | 58 |
| 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0.69000 | 59 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0.69500 | 5A |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0.70000 | 5B |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0.70500 | 5C |
| 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0.71000 | 5D |
| 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0.71500 | 5E |
| 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0.72000 | 5F |

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Table 3. VR12 VID CODES

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | Voltage (V) | HEX |
|------|------|------|------|------|------|------|------|-------------|-----|
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0.72500 | 60 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0.73000 | 61 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0.73500 | 62 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0.74000 | 63 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0.74500 | 64 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0.75000 | 65 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0.75500 | 66 |
| 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0.76000 | 67 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0.76500 | 68 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0.77000 | 69 |
| 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0.77500 | 6A |
| 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0.78000 | 6B |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0.78500 | 6C |
| 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0.79000 | 6D |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0.79500 | 6E |
| 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0.80000 | 6F |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0.80500 | 70 |
| 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0.81000 | 71 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0.81500 | 72 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0.82000 | 73 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0.82500 | 74 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0.83000 | 75 |
| 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0.83500 | 76 |
| 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0.84000 | 77 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0.84500 | 78 |
| 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0.85000 | 79 |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0.85500 | 7A |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0.86000 | 7B |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0.86500 | 7C |
| 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0.87000 | 7D |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0.87500 | 7E |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0.88000 | 7F |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.88500 | 80 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.89000 | 81 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0.89500 | 82 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0.90000 | 83 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0.90500 | 84 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.91000 | 85 |
| 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0.91500 | 86 |
| 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0.92000 | 87 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0.92500 | 88 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0.93000 | 89 |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0.93500 | 8A |
| 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0.94000 | 8B |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0.94500 | 8C |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0.95000 | 8D |
| 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0.95500 | 8E |
| 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0.96000 | 8F |

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Table 3. VR12 VID CODES

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | Voltage (V) | HEX |
|------|------|------|------|------|------|------|------|-------------|-----|
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0.96500 | 90 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0.97000 | 91 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0.97500 | 92 |
| 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0.98000 | 93 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0.98500 | 94 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0.99000 | 95 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0.99500 | 96 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1.00000 | 97 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1.00500 | 98 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1.01000 | 99 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1.01500 | 9A |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1.02000 | 9B |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1.02500 | 9C |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1.03000 | 9D |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1.03500 | 9E |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1.04000 | 9F |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1.04500 | A0 |
| 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1.05000 | A1 |
| 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1.05500 | A2 |
| 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1.06000 | A3 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1.06500 | A4 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1.07000 | A5 |
| 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1.07500 | A6 |
| 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1.08000 | A7 |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1.08500 | A8 |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1.09000 | A9 |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1.09500 | AA |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1.10000 | AB |
| 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1.10500 | AC |
| 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1.11000 | AD |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1.11500 | AE |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1.12000 | AF |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1.12500 | B0 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1.13000 | B1 |
| 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1.13500 | B2 |
| 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1.14000 | B3 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1.14500 | B4 |
| 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1.15000 | B5 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1.15500 | B6 |
| 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1.16000 | B7 |
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1.16500 | B8 |
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1.17000 | B9 |
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1.17500 | BA |
| 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1.18000 | BB |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1.18500 | BC |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1.19000 | BD |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1.19500 | BE |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1.20000 | BF |

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Table 3. VR12 VID CODES

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | Voltage (V) | HEX |
|------|------|------|------|------|------|------|------|-------------|-----|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1.20500 | C0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1.21000 | C1 |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1.21500 | C2 |
| 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1.22000 | C3 |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1.22500 | C4 |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1.23000 | C5 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1.23500 | C6 |
| 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1.24000 | C7 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1.24500 | C8 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1.25000 | C9 |
| 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1.25500 | CA |
| 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1.26000 | CB |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1.26500 | CC |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1.27000 | CD |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1.27500 | CE |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1.28000 | CF |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1.28500 | D0 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1.29000 | D1 |
| 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1.29500 | D2 |
| 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1.30000 | D3 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1.30500 | D4 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1.31000 | D5 |
| 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1.31500 | D6 |
| 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1.32000 | D7 |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1.32500 | D8 |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1.33000 | D9 |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1.33500 | DA |
| 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1.34000 | DB |
| 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1.34500 | DC |
| 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1.35000 | DD |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1.35500 | DE |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1.36000 | DF |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1.36500 | E0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1.37000 | E1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 1.37500 | E2 |
| 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1.38000 | E3 |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1.38500 | E4 |
| 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1.39000 | E5 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1.39500 | E6 |
| 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1.40000 | E7 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1.40500 | E8 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1.41000 | E9 |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1.41500 | EA |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1.42000 | EB |
| 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1.42500 | EC |
| 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1.43000 | ED |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1.43500 | EE |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1.44000 | EF |

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Table 3. VR12 VID CODES

| VID7 | VID6 | VID5 | VID4 | VID3 | VID2 | VID1 | VID0 | Voltage (V) | HEX |
|------|------|------|------|------|------|------|------|-------------|-----|
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1.44500 | F0 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1.45000 | F1 |
| 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1.45500 | F2 |
| 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1.46000 | F3 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1.46500 | F4 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1.47000 | F5 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1.47500 | F6 |
| 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1.48000 | F7 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1.48500 | F8 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1.49000 | F9 |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1.49500 | FA |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1.50000 | FB |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1.50500 | FC |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1.51000 | FD |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1.51500 | FE |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.52000 | FF |

NCP81109F

Table 4. SUPPORTED REGISTERS

| Index | Name | Description | Access | Default |
|-------|-----------------------------------|--|--------|---------|
| 00h | Vendor ID | Uniquely identifies the VR vendor. The vendor ID assigned by Intel to ON Semiconductor is 0x1Ah | R | 1Ah |
| 01h | Product ID | Uniquely identifies the VR product. The VR vendor assigns this number. | R | 19h |
| 02h | Product Revision | Uniquely identifies the revision or stepping of the VR control IC. The VR vendor assigns this data. | R | 00h |
| 03h | Date code ID | | R | 00h |
| 05h | Protocol ID | Identifies the SVID Protocol the controller supports | R | 01h |
| 06h | Capability | <p>Informs the Master of the controller's Capabilities, 1 = supported, 0 = not supported</p> <p>Bit 7 = Iout_format. Bit 7 = 0 when 1A = 1LSB of Reg 15h. Bit 7 = 1 when Reg 15 FFh = Icc_Max. Default = 1</p> <p>Bit 6 = ADC Measurement of Temp Supported = 1</p> <p>Bit 5 = ADC Measurement of Pin Supported = 0</p> <p>Bit 4 = ADC Measurement of Vin Supported = 0</p> <p>Bit 3 = ADC Measurement of Iin Supported = 0</p> <p>Bit 2 = ADC Measurement of Pout Supported = 1</p> <p>Bit 1 = ADC Measurement of Vout Supported = 1</p> <p>Bit 0 = ADC Measurement of Iout Supported = 1</p> | R | D7h |
| 10h | Status_1 | Data register read after ALERT# signal is asserted. Conveying the status of the VR. | R | 00h |
| 11h | Status_2 | Data register showing optional status_2 data. | R | 00h |
| 12h | Temp zone | Data register showing temperature zones the system is operating in | R | 00h |
| 15h | I_out | 8 bit binary word ADC of current. This register reads 0xFF when the IOUT(A) pin voltage is 2 V. The IOUT(A) voltage should be scaled with an external resistor to ground such that a load equal to Icc_Max generates a 2 V signal. | R | 01h |
| 16h | V_out | 8 bit binary ADC of output voltage between VSP and VSN. LSB size is 8 mV | R | 01h |
| 17h | VR_Temp | 8 bit binary word ADC of voltage. Binary format in deg C, IE 100C = 64h. A value of 00h indicates this function is not supported | R | 01h |
| 18h | P_out | 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 |
| 1Ch | Status 2 Last read | 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 | 00h |
| 21h | Icc_Max | Data register containing the Icc_Max. 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 | 00h |
| 22h | Temp_Max | Data register containing the max temperature and the level VR_hot asserts. This value defaults to 100°C and programmable over the SVID Interface | R/W | 64h |
| 24h | SR_fast | Slew Rate for SetVID_fast commands. Binary format in mV/μs. | R | 32h |
| 25h | SR_slow | Slew Rate for SetVID_slow commands. It is 4X slower than the SR_fast rate. Binary format in mV/μs | R | 0Ch |
| 26h | Vboot | The NCP81109F ramps to Vboot and holds at Vboot until it receives a new SVID SetVID command to move to a different voltage. Default value = 0 V. | R | 00h |
| 2Ah | SR_Slow selector | <p>Fast_SR/2</p> <p>Fast_SR/4: default</p> <p>Fast_SR/8</p> <p>Fast_SR/16</p> | R/W | 02h |
| 2Bh | PS4 exit latency | 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 | 00h |
| 2Ch | PS3 exit latency | 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 | 00h |
| 2Dh | EN to Ready for SVID command (TA) | Reflects the latency from enable assertion to the VR controller being ready to accept SVID commands. | R | 00h |

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Table 4. SUPPORTED REGISTERS

| Index | Name | Description | Access | Default |
|-------|----------------|--|--------|---------|
| 30h | Vout_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. VR 12 VID format. | RW | B5h |
| 31h | VID setting | Data register containing currently programmed VID voltage. VID data format. | RW | 00h |
| 32h | Pwr State | Register containing the current programmed power state. | RW | 00h |
| 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 2s complement. 00h = no margin 01h = +1 VID step 02h = +2 VID steps FFh = -1 VID step FEh = -2 VID steps. | RW | 00h |
| 34h | MultiVR Config | | | |

NCP81109F

DETAILED DESCRIPTION

General

The NCP81109F, a single-phase synchronous buck regulator, integrates power MOSFETs to provide a high-efficiency and compact-footprint power management solution for new generation computing CPUs. The device is able to deliver up to 14 A TDC output current on an adjustable output with SVID interface. Operating in high switching frequency up to 1.2 MHz allows employing small size inductors and capacitors while maintaining high

efficiency due to integrated solution with high performance power MOSFETs. Current-mode RPM control with feedforward from both input power supply and output voltage ensures stable operation over wide operation condition.

Operation Modes

The NCP81109F implements PS0, PS1, PS2, PS3, and PS4 power operation modes as shown in Table 5.

Table 5. POWER STATUS AND OPERATION MODES

| Power Status | Operation Mode |
|--------------|--|
| PS0 | Forced CCM mode – normal mode |
| PS1 | Forced CCM mode – low power mode |
| PS2 | Auto CCM/DCM mode – very low power mode |
| PS3 | Auto CCM/DCM mode – ultra low power mode |
| PS4 | Vout = 0, SVID active only |

Current-Mode RPM Operation

The NCP81109F operates with the current-mode Ramp-Pulse-Modulation (RPM) scheme in PS0/1/2/3 operation modes. In forced CCM mode, the inductor current is always continuous and the device operates in quasi-fixed switching frequency, which has a typical value programmed by users through a resistor at pin FREQ. In auto CCM/DCM mode, the inductor current is continuous and the device operates in quasi-fixed switching frequency in medium and heavy load range, while the inductor current becomes discontinuous and the device automatically operates in PFM mode with an adaptive fixed on time and variable switching frequency in light load range.

Serial VID interface (SVID)

The NCP81109F supports Intel serial VID interface. It communicates with the microprocessor through three wires (SCLK, SDIO, ALERT#). SCLK, SDIO and ALERT# should be pulled high to CPU I/O voltage VTT (which is typically 1.0 to 1.1 V) using 55 Ω Resistors. The SVID bus will operate at a max frequency of 43 MHz. For NCP81109F, VID code change rate is controlled by the SVID interface with three options as shown in Table 6. All the supported registers are shown in Table 4.

Table 6. REGISTERS FOR VID CODE CHANGE RATE

| Option | SVID Command Code | Feature | Register Address (Indicating the slew rate of VID code change) |
|--------------|-------------------|--|---|
| SetVID_Fast | 01h | selectable slew rate | 24h |
| SetVID_Slow | 02h | Fast_SR/2 Fast_SR/4: default Fast_SR/8 Fast_SR/16 | 25h |
| SetVID_Decay | 03h | No control, VID code down | N/A |

NCP81109F

Start Up Sequence

A timing diagram of start-up sequence is shown in Figure 5, and timing parameters are shown in Table 1.

pin to GND, which programs SVID address as well. Both values are set on power up and cannot be changed after the initial power up sequence is complete.

Boot Voltage and SVID Address

Table 7 shows two boot voltage options of 1.0 V and 1.5 V programmed by an external 1% resistor Rvboot from Vboot

Table 7. BOOT VOLTAGE AND SVID ADDRESS CONFIGURATION

| Rvboot (Ω) | Vboot Pin Voltage (mV) | | | Address | Vboot (V) |
|------------------------|------------------------|------|------|---------|--------------|
| | Min | Typ | Max | | |
| 0 | 0 | 0 | 102 | 0x0 | 1.0 |
| 14.0k | 102 | 140 | 180 | 0x1 | 1.0 |
| 22.1k | 180 | 219 | 258 | 0x2 | 1.0 |
| 30.1k | 258 | 301 | 344 | 0x3 | 1.0 |
| 39.2k | 344 | 391 | 438 | 0x4 | 1.0 |
| 48.7k | 438 | 484 | 531 | 0x5 | 1.0 |
| 57.6k | 531 | 578 | 625 | 0x6 | 1.0 |
| 68.1k | 625 | 676 | 727 | 0x7 | 1.0 |
| 78.7k | 727 | 781 | 836 | 0x8 | 1.0 |
| 88.7k | 836 | 894 | 953 | 0x0 | 1.5 |
| 100k | 953 | 1007 | 1062 | 0x1 | 1.5 |
| 113k | 1062 | 1125 | 1188 | 0x2 | 1.5 |
| 124k | 1188 | 1250 | 1312 | 0x3 | 1.5 |
| 137k | 1312 | 1378 | 1445 | 0x4 | 1.5 |
| 150k | 1445 | 1511 | 1578 | 0x5 | 1.5 |
| 165k | 1578 | 1648 | 1719 | 0x6 | 1.5 |
| 178k | 1719 | 1789 | 1859 | 0x7 | 1.5 |
| 196k | 1859 | 1950 | - | 0x8 | 1.5 |

Switching Frequency

Switching frequency is programmed by a resistor R_{FREQ} to ground at the FREQ pin. The typical frequency range is from 500 kHz to 1.2 MHz. The FREQ pin provides approximately 2 V out and the source current is mirrored into the internal ramp generator. The switching frequency can be found in Figure 7 with a given R_{FREQ}. The frequency

shown in Figure 7 is under condition of 10 A output current at VID = 1 V. The frequency has a variation over VID voltage and loading current, which maintains similar output ripple voltage over different operation condition. Figure 8 shows frequency variations over the VID voltage range.

NCP81109F

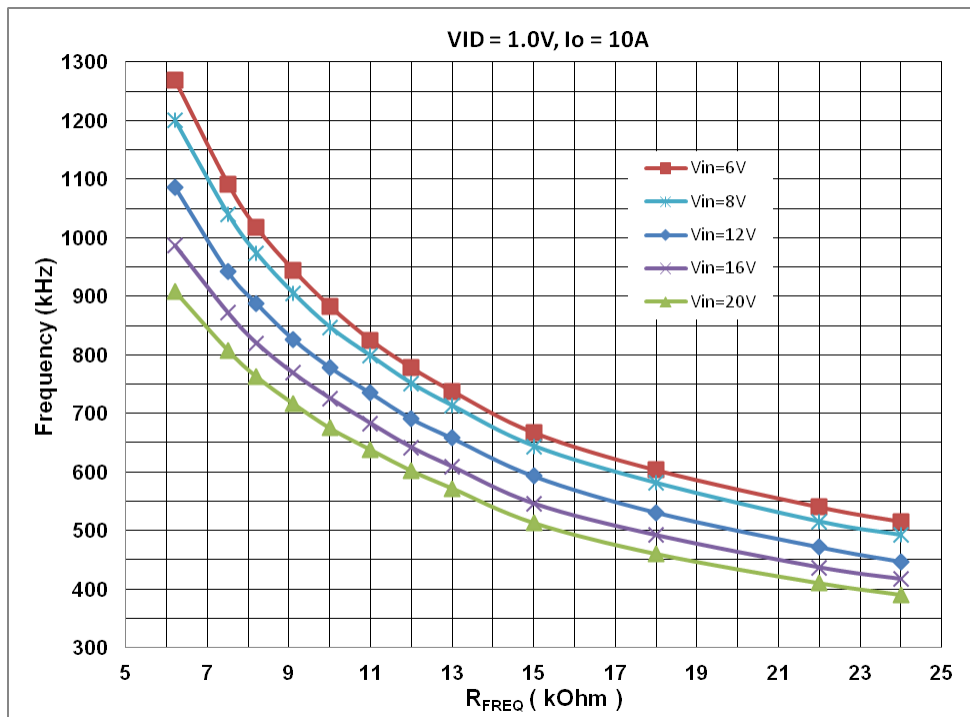


Figure 7. Switching Frequency vs. R_{FREQ}

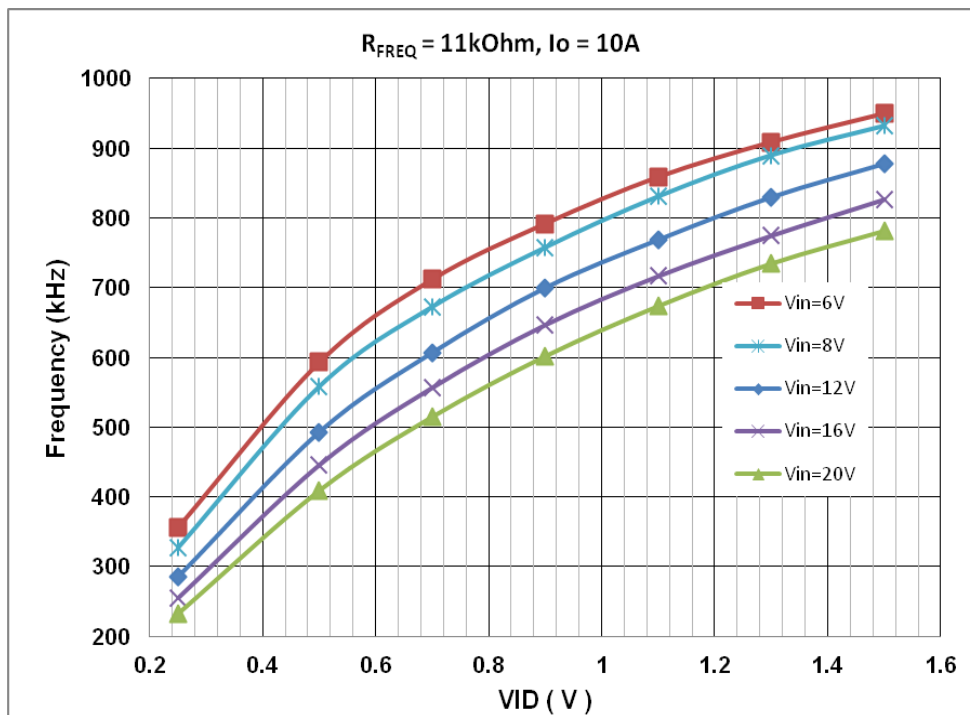


Figure 8. Switching Frequency vs. VID Voltage

Remote Voltage Sense

A high performance differential amplifier is provided to accurately sense the output voltage of the regulator. The VSP and VSN inputs should be connected to the regulator's output voltage sense points. The output (DIFOUT) of the

remote sense amplifier is a sum of the error voltage (between the output VSP-VSN and the DAC) and a 1.3 V DC bias.

$$V_{DIFOUT} = (V_{VSP} - V_{VSN}) + (1.3 \text{ V} - V_{DAC}) \quad (\text{eq. 1})$$

The value of RILIM can be designed using the following equation with a required over current protection threshold ILIM and a known current-sense network.

$$R_{ILIM} = \frac{V_{CS@I_{LIM}}}{10 \mu} = \frac{R_{CS}}{R_{CS3}} \cdot I_{LIM_PK} \cdot DCR \cdot 10^5$$

$$= \frac{R_{CS}}{R_{CS3}} \cdot \left(I_{LIM} + \frac{(V_{IN} - V_{OUT}) \cdot V_{OUT}}{2 \cdot L \cdot F_{SW} \cdot V_{IN}} \right) \cdot DCR \cdot 10^5 \quad (\text{eq. 5})$$

ICC_MAX

The SVID interface conveys the platform ICC_MAX value to the CPU by register 21h. A resistor R_ICC_MAX from the IMAX pin to ground programs this register at the time the part is enabled. A 10 μA current is sourced from this pin to generate a voltage on the program resistor. The value of the register is 1A per LSB and is set by the equation below. The resistor value should be no less than 10 k.

$$ICC_MAX_{21h} = \frac{R_{ICCMAX} \cdot 10 \mu \cdot 64}{2} = R_{ICCMAX} \cdot 3.2 \cdot 10^{-4} \quad (\text{eq. 6})$$

IOUT

The IOUT pin sources a current equal to the ILIM sink current gained by the IOUT Current Gain (10 typ.). The voltage of 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 V signal on IOUT. A pull-up resistor to 5 V VCC can be used to offset the IOUT signal positive if needed.

$$R_{IOUT} = \frac{2}{10 \cdot V_{CS@ICC_MAX}} \cdot R_{ILIM}$$

$$= \frac{1}{5 \cdot \frac{R_{CS}}{R_{CS3}} \cdot ICC_MAX \cdot DCR} \cdot R_{ILIM} \quad (\text{eq. 7})$$

Input UVLO Protection

NCP81109F monitors supply voltages at the VCC pin and the VIN pins in order to provide under voltage protection. If either supply drops below its threshold, the controller will shut down the outputs. Upon recovery of the supplies, the controller reenters its startup sequence, and soft start begins.

Output Under-Voltage Protection

The output voltage is monitored by a dedicated differential amplifier. If the output falls below target by more than “Under Voltage Threshold below DAC–Droop”, the UVL comparator sends the VR_RDY signal low.

Output Over-Voltage Protection

During normal operation the output voltage is monitored at the differential inputs VSP and VSN. If the output voltage exceeds the DAC voltage by “Over Voltage Threshold above DAC”, GH will be forced low, and GL will go high. After the OVP trips, the DAC ramps slowly down to zero to avoid a negative output voltage spike during shutdown. If the DAC+OVP Threshold drops below the output, GL will again go high, and will toggle between low and high as the output voltage follows the DAC+OVP Threshold down. When the DAC gets to zero, the GH will be held low and the GL will remain high. To reset the part, the EN pin must be cycled low. During soft-start, the OVP threshold is set to 2.9 V. This allows the controller to start up without false triggering the OVP.

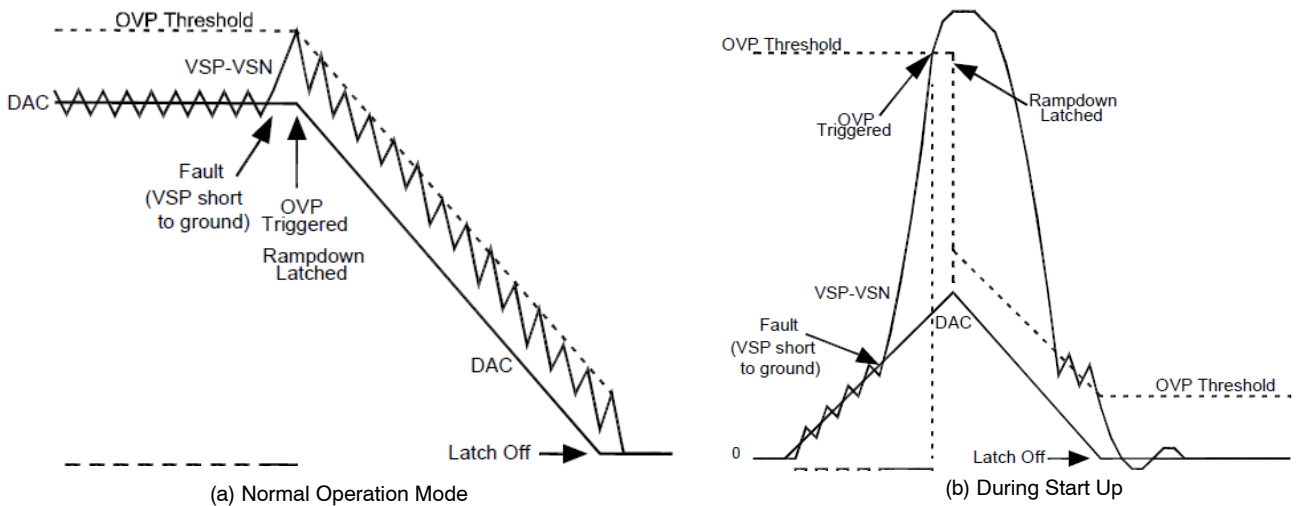


Figure 10. Function of Over Voltage Protection

Temperature Sense and Thermal Alert

The NCP81109F provides an external temperature sense and a thermal alert in normal operation mode. The temperature sense and thermal alert circuit diagram is shown in Figure 11. A precision current I_{TSENSE} is sourced out the output of the TSENSE pin to generate a voltage across the temperature sense network, which consists of a NTC thermistor R_{NTC} (100 k Ω typ.), two resistors R_{COMP1} (0 Ω typ.) and R_{COMP2} (8.2 k Ω typ.), and a filter capacitor C_{Filter} (0.1 μ F typ.). The voltage on the temperature sense input is sampled by the internal A/D converter and then digitally converted to temperature and stored in SVID register 17h. Usually the thermistor is placed close to a hot spot like inductor or NCP81109F itself. A 100k NTC thermistor similar to the Murata NCP15WF104D03RC should be used. The NCP81109F

also monitors the voltage at the TSENSE pin and compares the voltage to internal thresholds and assert ALERT# or VRHOT# once it trips the thresholds. The DC voltage at TSENSE pin can be calculated by

$$V_{TSENSE} = I_{TSENSE} \cdot \left(R_{COMP1} + \frac{R_{COMP2} \cdot R_{NTC_T}}{R_{COMP2} + R_{NTC_T}} \right) \tag{eq. 8}$$

R_{NTC_T} is the resistance of R_{NTC} at an absolute temperature T, which is obtained by

$$R_{NTC_T} = R_{NTC_T0} \cdot \exp \left(B \cdot \left(\frac{1}{T} - \frac{1}{T_0} \right) \right) \tag{eq. 9}$$

where R_{NTC_T0} is a known resistance of R_{NTC} at an absolute temperature T_0 , and B is the B-constant of R_{NTC} .

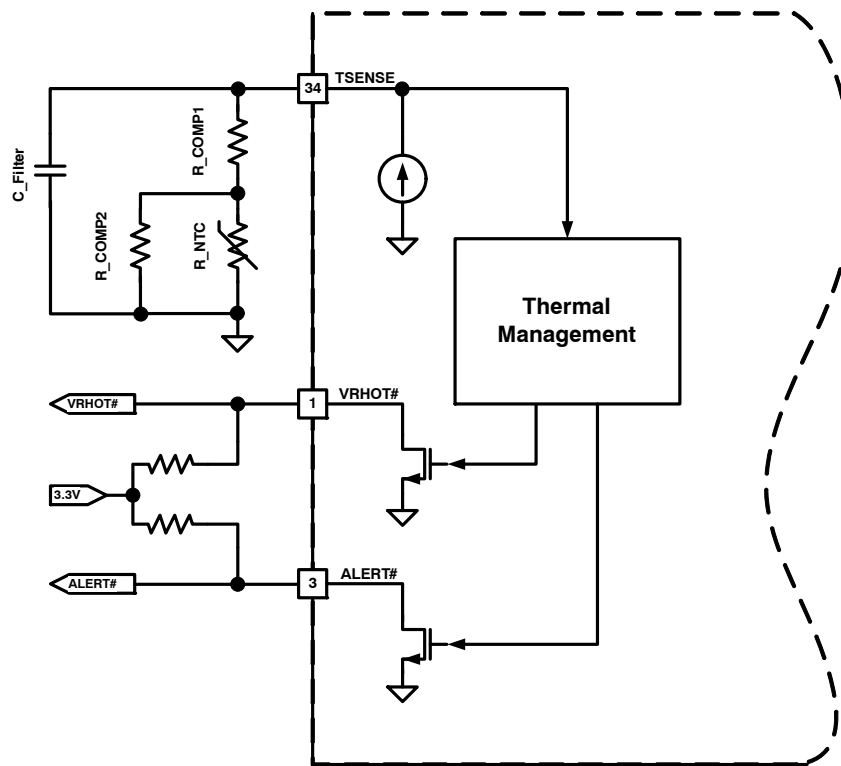


Figure 11. Temperature Sense and Thermal Alert Circuit Diagram

LAYOUT GUIDELINES

Electrical Layout Considerations

Good electrical layout is a key to make sure proper operation, high efficiency, and noise reduction. Electrical layout guidelines are:

- **Power Paths:** Use wide and short traces for power paths (such as VIN, VOUT, SW, and PGND) to reduce parasitic inductance and high-frequency loop area. It is also good for efficiency improvement.
- **Power Supply Decoupling:** The device should be well decoupled by input capacitors and input loop area should be as small as possible to reduce parasitic inductance, input voltage spike, and noise emission. Usually, a small low-ESL MLCC is placed very close to VIN and PGND pins.
- **VCC Decoupling:** Place decoupling caps as close as possible to the controller VCC and VCCP pins. The filter resistor at VCC pin should be not higher than 2.2 Ω to prevent large voltage drop.
- **Switching Node:** SW node should be a copper pour, but compact because it is also a noise source.
- **Bootstrap:** The bootstrap cap and an option resistor need to be very close and directly connected between pin 8 (BST) and pin 10 (SW). No need to externally connect pin 10 to SW node because it has been internally connected to other SW pins.
- **Ground:** It would be good to have separated ground planes for PGND and GND and connect the two planes at one point. Directly connect GND pin to the exposed pad and then connect to GND ground plane through vias.
- **Voltage Sense:** Use Kelvin sense pair and arrange a “quiet” path for the differential output voltage sense.
- **Current Sense:** Careful layout for current sensing is critical for jitter minimization, accurate current

limiting, and IOUT reporting. The filter cap from CSCOMP to CSREF should be close to the controller. The temperature compensating thermistor should be placed as close as possible to the inductor. The wiring path should be kept as short as possible and well away from the switch node.

- **Compensation Network:** The small feedback cap from COMP to FB should be as close to the controller as possible. Keep the FB traces short to minimize their capacitance to ground.
- **SVID Bus:** The Serial VID bus is a high speed data bus and the bus routing should be done to limit noise coupling from the switching node. The signals should be routed with the Alert# line in between the SVID clock and SVID data lines. The SVID lines must be ground referenced and each line’s width and spacing should be such that they have nominal 50 Ω impedance with the board stackup.

Thermal Layout Considerations

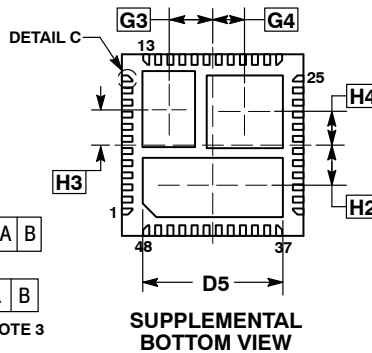
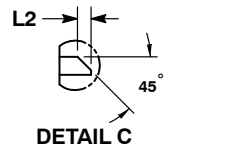
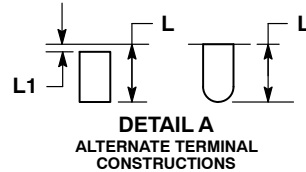
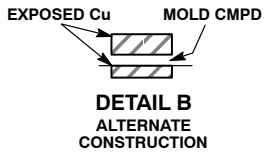
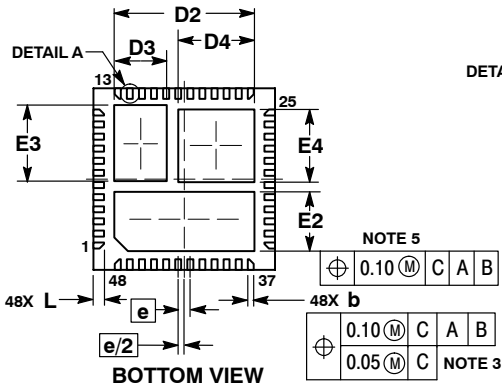
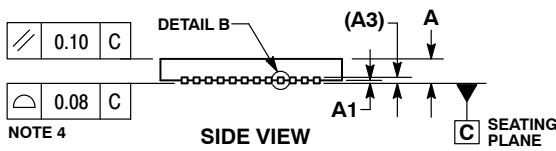
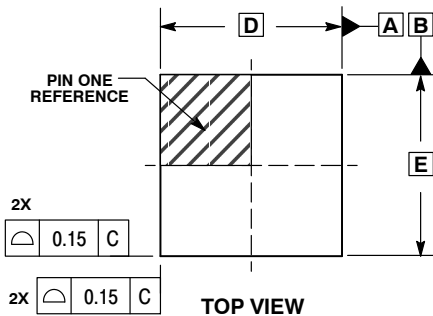
Good thermal layout helps high power dissipation from a small package with reduced temperature rise. Thermal layout guidelines are:

- The exposed pads must be well soldered on the board.
- A four or more layers PCB board with solid ground planes is preferred for better heat dissipation.
- More free vias are welcome to be around IC and underneath the exposed pads to connect the inner ground layers to reduce thermal impedance.
- Use large area copper pour to help thermal conduction and radiation.
- Do not put the inductor to be too close to the IC, thus the heat sources are distributed.

NCP81109F

PACKAGE DIMENSIONS

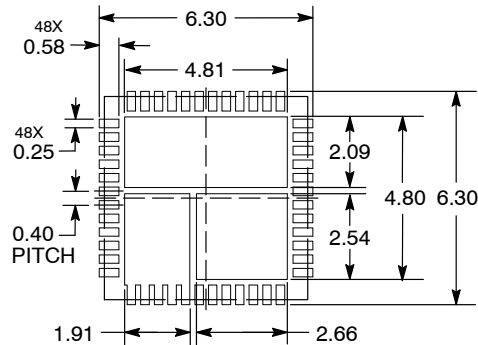
QFN48 6x6, 0.4P
CASE 485CJ
ISSUE A



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
 2. CONTROLLING DIMENSIONS: MILLIMETERS.
 3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30mm FROM TERMINAL TIP
 4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.
 5. POSITIONAL TOLERANCE APPLIES TO ALL THREE EXPOSED PADS IN BOTH X AND Y AXIS.


| MILLIMETERS | | |
|-------------|------|------|
| DIM | MIN | MAX |
| A | 0.80 | 1.00 |
| A1 | --- | 0.05 |
| A3 | 0.20 | REF |
| b | 0.15 | 0.25 |
| D | 6.00 | BSC |
| D2 | 4.53 | 4.73 |
| D3 | 1.64 | 1.84 |
| D4 | 2.42 | 2.62 |
| D5 | 4.58 | 4.78 |
| E | 6.00 | BSC |
| E2 | 1.86 | 2.06 |
| E3 | 2.41 | 2.61 |
| E4 | 2.30 | 2.50 |
| e | 0.40 | BSC |
| G3 | 1.45 | BSC |
| G4 | 1.06 | BSC |
| H2 | 1.40 | BSC |
| H3 | 1.19 | BSC |
| H4 | 1.10 | BSC |
| L | 0.25 | 0.45 |
| L1 | --- | 0.15 |
| L2 | 0.15 | REF |

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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