

# NCP5378

## Single Phase Synchronous Buck Controller with Integrated Gate Drivers and Programmable DAC

The NCP5378 is a single chip solution which combines differential voltage sensing, differential phase current sensing, adaptive voltage positioning, and on board gate drivers to provide accurately regulated power for Intel processors. This controller IC maintains the same features as the multi-phase product family, but reduces the output to a single-phase, for lower current systems. Low power mode operation combined with inductor current sensing reduces system cost by providing the fastest initial response to dynamic load events.

The gate drive adaptive non overlap and power saving operation circuit can provide a low switching loss and high efficiency solution for notebook and desktop systems. A high performance operational error amplifier is provided to simplify compensation of the system. Dynamic Reference Injection further simplifies loop compensation by eliminating the need to compromise between closed-loop transient response and Dynamic VID performance.

### Features

- Meets Intel's VR11.1 Specifications
- High Performance Operational Error Amplifier
- Internal Soft Start
- Dynamic Reference Injection (Patent #US07057381)
- DAC Range from 0.5 V to 1.6 V
- $\pm 0.5\%$  DAC Voltage Accuracy from 1.0 V to 1.6 V
- True Differential Remote Voltage Sensing Amplifier
- "Lossless" Differential Inductor Current Sensing
- Adaptive Voltage Positioning (AVP)
- Latched Over Voltage Protection (OVP)
- Guaranteed Startup into Pre-Charged Loads
- Threshold Sensitive Enable Pin for VTT Sensing
- Power Good Output with Internal Delays
- Thermally Compensated Current Monitoring
- Thermal Shutdown Protection
- Adaptive-Non-Overlap Gate Drive Circuit
- Integrated MOSFET Drivers
- Automatic Power-saving Modes Maximize Efficiency during Light Load Operation
- 32-lead QFN
- This is a Pb-Free Device

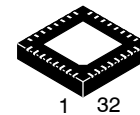
### Applications

- Desktop Power Supplies for Next-generation Intel Chipsets



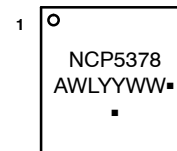
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QFN32  
CASE 488AM

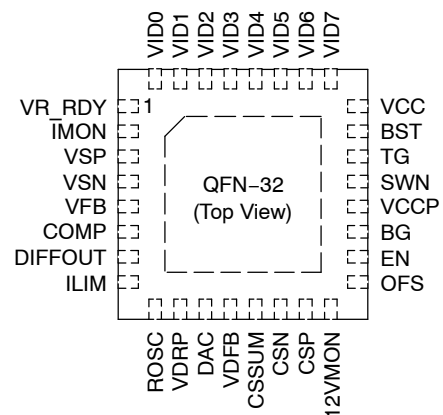
### MARKING DIAGRAM



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

(Note: Microdot may be in either location)

### PIN CONNECTIONS



### ORDERING INFORMATION

| Device       | Package         | Shipping†        |
|--------------|-----------------|------------------|
| NCP5378MNR2G | QFN32 (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 Specifications Brochure, BRD8011/D.

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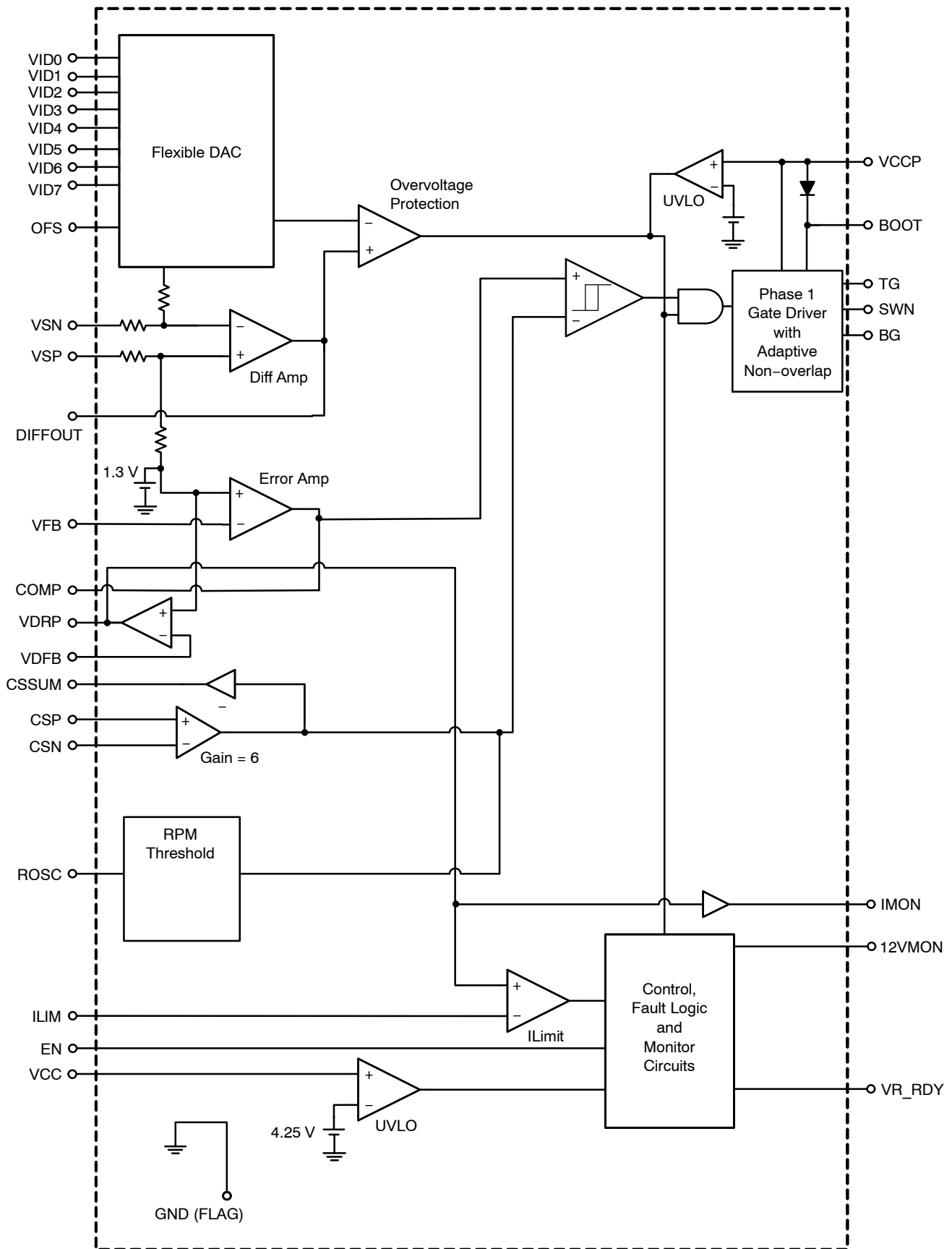


Figure 1. Functional Block Diagram

# NCP5378

**Table 1. PIN DESCRIPTIONS**

| Pin No.     | Symbol  | Description   |
|-------------|---------|---|
| 1           | VR_RDY  | Open collector output. High indicates that the output is regulating   |
| 2           | IMON    | 0 to 1 Volt analog signal proportional to the output load current. VSN referenced Clamped to 1.1 Vmax   |
| 3           | VSP     | Non-inverting input to the internal differential remote sense amplifier   |
| 4           | VSN     | Inverting input to the internal differential remote sense amplifier   |
| 5           | VFB     | Compensation amplifier voltage feedback   |
| 6           | COMP    | Output of the compensation amplifier  |
| 7           | DIFFOUT | Output of the differential remote sense amplifier   |
| 8           | ILIM    | Over current shutdown threshold setting. $ILIM = VDRP - 1.3\text{ V}$ . Resistor divide ROSC to set threshold   |
| 9           | ROSC    | A resistance from this pin to ground programs the oscillator frequency according to $f_{SW} = 1 / (ROSC \bullet 100\text{ pF})$ . This pin supplies a trimmed output voltage of 2.00 V. |
| 10          | VDRP    | Voltage output signal proportional to current used for current limit and output voltage droop   |
| 11          | DAC     | DAC output used to provide feed forward for dynamic VID   |
| 12          | VDFB    | Droop Amplifier Voltage Feedback  |
| 13          | CSSUM   | Inverted Sum of the Differential Current Sense inputs.  |
| 14          | CSN     | Inverting input to current sense amplifier  |
| 15          | CSP     | Non-inverting input to current sense amplifier  |
| 16          | 12VMON  | Monitor a 12 V input through a resistor divider   |
| 17          | OFS     | External Offset   |
| 18          | EN      | Threshold sensitive input. High = startup, Low = shutdown.  |
| 19          | BG      | Low side gate drive   |
| 20          | VCCP    | Power VCC for gate drivers with UVLO monitor  |
| 21          | SWN     | Switch Node   |
| 22          | TG      | High side gate drive  |
| 23          | BST     | Upper MOSFET floating BSTstrap supply for driver  |
| 24          | VCC     | Power for the internal control circuits with UVLO monitor   |
| 25          | VID7    | Voltage ID DAC input  |
| 26          | VID6    | Voltage ID DAC input  |
| 27          | VID5    | Voltage ID DAC input  |
| 28          | VID4    | Voltage ID DAC input  |
| 29          | VID3    | Voltage ID DAC input  |
| 30          | VID2    | Voltage ID DAC input  |
| 31          | VID1    | Voltage ID DAC input  |
| 32          | VID0    | Voltage ID DAC input  |
| 33/<br>FLAG | GND     | Power supply return (QFN Flag)  |

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## ABSOLUTE MAXIMUM RATINGS

| Rating | Symbol | Value | Unit |
|--------|--------|-------|------|
|--------|--------|-------|------|

### ELECTRICAL INFORMATION

|   |                     |  |    |
|---|---------------------|--|----|
| Controller Power Supply Voltages to GND       | $V_{CC}$            | -0.3, 7  | V  |
| Driver Power Supply Voltages to GND           | $V_{CCP}$           | -0.3, 15   | V  |
| High-Side Gate Driver Supplies: BST to SWN    | $V_{BST} - V_{SWN}$ | 40 V wrt/GND<br>40 V $\leq$ 50 ns wrt/GND<br>-0.3, 15 wrt/SWN                  | V  |
| High-Side FET Gate Driver Voltages: TG to SWN | $V_{TG} - V_{SWN}$  | BOOT + 0.3 V<br>35 V $\leq$ 50 ns wrt/GND<br>-0.3, 15 wrt/SWN<br>-5 V (200 ns) | V  |
| Switch Node: SWN                              | $V_{SWN}$           | 35<br>40 V $\leq$ 50 ns wrt/GND<br>-5 VDC<br>-10 V (200 ns)                    | V  |
| Low-Side Gate Drive: BG                       | $V_{BG} - AGND$     | $V_{CC} + 0.3$ V<br>-5 V (200 ns)  | V  |
| Logic Inputs                                  | $V_{LOGIC}$         | -0.3, 6  | V  |
| GND   | $V_{GND}$           | 0  | V  |
| V-  |                     | GND $\pm$ 300  | mV |
| I <sub>mon</sub> Out                          | $V_{IMON}$          | 1.1  | V  |
| All Other Pins                                |                     | -0.3, 5.5  | V  |

### THERMAL INFORMATION

|  |                 |             |      |
|--|-----------------|-------------|------|
| Thermal Characteristic<br>QFN Package (Note 1) | $R_{\theta JA}$ | 32.6        | °C/W |
| Operating Junction Temperature Range (Note 2)  | $T_J$           | 0 to 125    | °C   |
| Operating Ambient Temperature Range            | $T_{AMB}$       | 0 to +70    | °C   |
| Maximum Storage Temperature Range              | $T_{STG}$       | -55 to +150 | °C   |
| Moisture Sensitivity Level<br>QFN Package      | MSL             | 1           |      |

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

\*All signals referenced to GND unless noted otherwise.

\*The maximum package power dissipation must be observed.

1. JESD 51-5 (1S2P Direct-Attach Method) with 0 LFM
2. Operation at -40°C to 0°C guaranteed by design, not production tested.

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## ELECTRICAL CHARACTERISTICS

0°C < T<sub>A</sub> < 70°C; 0°C < T<sub>J</sub> < 125°C; 4.75 < V<sub>CC</sub> < 5.25 V; All DAC Codes; C<sub>VCC</sub> = 0.1 μF unless otherwise noted.

| Parameter                      | Test Conditions  | Min  | Typ | Max | Unit |
|--------------------------------|--|------|-----|-----|------|
| <b>ERROR AMPLIFIER</b>         |  |      |     |     |      |
| Input Bias Current             |  | -200 | -   | 200 | nA   |
| Open Loop DC Gain              | C <sub>L</sub> = 60 pF to GND,<br>R <sub>L</sub> = 10 kΩ to GND  | -    | 100 | -   | dB   |
| Open Loop Unity Gain Bandwidth | C <sub>L</sub> = 60 pF to GND,<br>R <sub>L</sub> = 10 kΩ to GND  | -    | 18  | -   | MHz  |
| Open Loop Phase Margin         | C <sub>L</sub> = 60 pF to GND,<br>R <sub>L</sub> = 10 kΩ to GND  | -    | 70  | -   | °    |
| Slew Rate                      | ΔV <sub>in</sub> = 100 mV, G = -10V/V,<br>ΔV <sub>out</sub> = 1.5 V - 2.5 V,<br>C <sub>L</sub> = 60 pF to GND,<br>DC Load = ±125 μA to GND | -    | 10  | -   | V/μs |
| Maximum Output Voltage         | 10 mV of Overdrive,<br>I <sub>SOURCE</sub> = 2.0 mA  | 3.0  | -   | -   | V    |
| Minimum Output Voltage         | 10 mV of Overdrive,<br>I <sub>SINK</sub> = 500 μA  | -    | -   | 75  | mV   |
| Output Source Current          | 10 mV of Overdrive,<br>V <sub>out</sub> = 3.5 V  | 1.5  | 2.0 | -   | mA   |
| Output Sink Current            | 10 mV of Overdrive,<br>V <sub>out</sub> = 0.1 V  | 0.65 | 1.0 | -   | mA   |

## DIFFERENTIAL SUMMING AMPLIFIER

|  |   |          |              |             |     |
|--|---|----------|--------------|-------------|-----|
| V+ Input Pull down Resistance              | DRVON = low<br>DRVON = high                                     | -<br>-   | 0.6<br>6.0   | -<br>-      | kΩ  |
| V+ Input Bias Voltage                      | DRVON = low<br>DRVON = high                                     | -<br>0.8 | 0.05<br>0.88 | 0.1<br>0.95 | V   |
| Input Voltage Range (Note 3)               |   | -0.3     | -            | 3.0         | V   |
| -3 dB Bandwidth                            | C <sub>L</sub> = 80 pF to GND,<br>R <sub>L</sub> = 10 kΩ to GND | -        | 15           | -           | MHz |
| Closed Loop DC gain VS to Diffout (Note 3) | VS+ to VS- = 0.5 V to 1.6 V                                     | 0.98     | 1.0          | 1.02        | V/V |
| Maximum Output Voltage                     | 10 mV of Overdrive,<br>I <sub>SOURCE</sub> = 2 mA               | 3.0      | -            | -           | V   |
| Minimum Output Voltage                     | 10 mV of Overdrive,<br>I <sub>SINK</sub> = 1 mA                 | -        | -            | 0.5         | V   |
| Output Source Current                      | 10 mV of Overdrive,<br>V <sub>out</sub> = 3 V                   | 1.5      | 2.0          | -           | mA  |
| Output Sink Current                        | 10 mV of Overdrive,<br>V <sub>out</sub> = 0.2 V                 | 1.0      | 1.5          | -           | mA  |

## INTERNAL OFFSET VOLTAGE

|   |  |    |   |    |    |
|---|--|----|---|----|----|
| Offset Voltage to the (+) Pin of the Error Amp & the VDRP Pin |  | -2 | 0 | +2 | mV |
|---|--|----|---|----|----|

## VDROOP AMPLIFIER

|                                |   |      |     |     |     |
|--------------------------------|---|------|-----|-----|-----|
| Input Bias Current             |   | -200 | -   | 200 | nA  |
| Inverting Voltage Range        |   | 0    | 1.3 | 3.0 | V   |
| Open Loop DC Gain              | C <sub>L</sub> = 20 pF to GND including ESD<br>R <sub>L</sub> = 1 kΩ to GND | -    | 100 | -   | dB  |
| Open Loop Unity Gain Bandwidth | C <sub>L</sub> = 20 pF to GND including ESD<br>R <sub>L</sub> = 1 kΩ to GND | -    | 18  | -   | MHz |

3. Guaranteed by design.

4. For propagation delays, "tpdh" refers to the specified signal going high "tpdl" refers to it going low. Reference Gate Timing Diagram.

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## ELECTRICAL CHARACTERISTICS

0°C < T<sub>A</sub> < 70°C; 0°C < T<sub>J</sub> < 125°C; 4.75 < V<sub>CC</sub> < 5.25 V; All DAC Codes; C<sub>VCC</sub> = 0.1 μF unless otherwise noted.

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

### VDROOP AMPLIFIER

|                        |   |     |    |     |      |
|------------------------|---|-----|----|-----|------|
| Open Loop Phase Margin | C <sub>L</sub> = 20 pF to GND including ESD<br>R <sub>L</sub> = 1 kΩ to GND | –   | 70 | –   | °    |
| Slew Rate              | C <sub>L</sub> = 20 pF to GND including ESD<br>R <sub>L</sub> = 1 kΩ to GND | –   | 10 | –   | V/μs |
| Maximum Output Voltage | 10 mV of Overdrive, I <sub>SOURCE</sub> = 4.0 mA                            | 3.0 | –  | –   | V    |
| Minimum Output Voltage | 10 mV of Overdrive, I <sub>SINK</sub> = 1.0 mA                              | –   | –  | 1.0 | V    |
| Output Source Current  | 10 mV of Overdrive, V <sub>out</sub> = 3.0 V                                | 4.0 | –  | –   | mA   |
| Output Sink Current    | 10 mV of Overdrive, V <sub>out</sub> = 1.0 V                                | 1.0 | –  | –   | mA   |

### CSSUM AMPLIFIER

|   |   |     |    |     |     |
|---|---|-----|----|-----|-----|
| Current Sense Input to V <sub>DRP</sub> –3 dB Bandwidth | C <sub>L</sub> = 10 pF to GND,<br>R <sub>L</sub> = 10 kΩ to GND | –   | 12 | –   | MHz |
| Current Summing Amp Output Offset Voltage               | CSP – CSN = 0, CSP = 1.1 V                                      | –16 | –  | +5  | mV  |
| Maximum CSSUM Output Voltage                            | CSP – CSN = –0.2 V<br>(all phases) I <sub>SOURCE</sub> = 1 mA   | 3.0 | –  | –   | V   |
| Minimum CSSUM Output Voltage                            | CSP – CSN = 0.7 V<br>(all phases) I <sub>SINK</sub> = 1 mA      | –   | –  | 0.3 | V   |
| Output Source Current                                   | V <sub>out</sub> = 3.0 V  | 1.0 | –  | –   | mA  |
| Output Sink Current                                     | V <sub>out</sub> = 0.3 V  | 4.0 | –  | –   | mA  |

### CURRENT SENSE AMPLIFIERS

|  |                         |        |      |        |     |
|--|-------------------------|--------|------|--------|-----|
| Input Bias Current                         | CSP = CSN = 1.4 V       | –50    | –    | 50     | nA  |
| Common Mode Input Voltage Range            |                         | –0.3   | –    | 2.0    | V   |
| Differential Mode Input Voltage Range      |                         | –120   | –    | 120    | mV  |
| Current Sharing Offset CSP to CSN (Note 3) | all VIOS                | –2     | –    | 2      | mV  |
| Current Sense Input to CSSUM Gain          | 0 V < CSP – CSN < 0.1 V | –3.834 | –3.7 | –3.574 | V/V |

### IMON

|   |  |       |     |      |     |
|---|--|-------|-----|------|-----|
| V <sub>DRP</sub> to IMON Gain                           | 1.325 V > V <sub>DRP</sub> > 1.75 V                              | 1.965 | –   | 2.02 | V/V |
| Current Sense Input to V <sub>DRP</sub> –3 dB Bandwidth | C <sub>L</sub> = 30 pF to GND,<br>R <sub>L</sub> = 100 kΩ to GND | –     | 4.0 | –    | MHz |
| Output Referred Offset Voltage                          | V <sub>DRP</sub> = 1.5 V, I <sub>SOURCE</sub> = 0 mA             | 0     | 23  | 50   | mV  |
| Minimum Output Voltage                                  | V <sub>DRP</sub> = 1.3 V, I <sub>SINK</sub> = 25 μA              | –     | –   | 0.1  | V   |
| Maximum Output Voltage                                  | I <sub>out</sub> = 300 μA  | 1.0   | –   | –    | V   |
| Output Sink Current                                     | V <sub>out</sub> = 0.3 V   | 175   | –   | –    | μA  |
| Maximum Clamp Voltage                                   | IMON – VSN V <sub>DRP</sub> = HIGH<br>R <sub>LOAD</sub> = Open   | 1.1   | –   | 1.2  | V   |

### RPM THRESHOLD

|                         |   |      |       |      |      |
|-------------------------|---|------|-------|------|------|
| Ramp Slope (Note 3)     | R <sub>OSC</sub> = 69.8 kΩ, DAC = 1.1 V |      | 0.175 |      | V/μs |
| R <sub>OSC</sub> Output |   | 1.93 | 2.00  | 2.05 | V    |

### VR\_RDY (Power Good) OUTPUT

|                                  |   |   |     |     |    |
|----------------------------------|---|---|-----|-----|----|
| VR_RDY Output Saturation Voltage | I <sub>PGD</sub> = 5 mA   | – | –   | 0.4 | V  |
| VR_RDY Rise Time                 | External pull-up of 1 kΩ to 1.25 V,<br>C <sub>TOT</sub> = 45 pF, ΔVo = 10% to 90% | – | 100 | 250 | ns |

3. Guaranteed by design.

4. For propagation delays, “tpdh” refers to the specified signal going high “tpdl” refers to it going low. Reference Gate Timing Diagram.

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## ELECTRICAL CHARACTERISTICS

0°C < T<sub>A</sub> < 70°C; 0°C < T<sub>J</sub> < 125°C; 4.75 < V<sub>CC</sub> < 5.25 V; All DAC Codes; C<sub>VCC</sub> = 0.1 μF unless otherwise noted.

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

### VR\_RDY (Power Good) OUTPUT

|  |   |     |     |     |                   |
|--|---|-----|-----|-----|-------------------|
| VR_RDY Output Voltage at Power-up      | VR_RDY pulled up to 5 V via 2 kΩ,<br>t <sub>R(VCC)</sub> ≤ 3 × t <sub>R(5V)</sub><br>100 μs ≤ t <sub>R(VCC)</sub> ≤ 20 ms | –   | –   | 1.0 | V                 |
| VR_RDY High – Output Leakage Current   | VR_RDY = 5.5 V via 1 K  | –   | –   | 0.1 | μA                |
| VR_RDY Upper Threshold Voltage (INTEL) | VCore Increasing, DAC = 1.3 V   | –   | 300 | 250 | mV<br>(below DAC) |
| VR_RDY Lower Threshold Voltage (INTEL) | VCore Decreasing, DAC = 1.3 V   | 390 | 350 | 300 | mV<br>(below DAC) |
| VR_RDY Rising Delay                    | VCore Increasing  | –   | 250 | –   | ns                |
| VR_RDY Falling Delay                   | VCore Decreasing  | –   | 5.0 | –   | ns                |

### DIGITAL SOFT-START

|                             |                            |     |     |     |    |
|-----------------------------|----------------------------|-----|-----|-----|----|
| Soft-Start Ramp Time        | DAC = 0 to DAC = 1.1 V     | 1.0 | –   | 1.3 | ms |
| VR11 V <sub>boot</sub> time | Not used in Legacy Startup | 400 | 500 | 600 | μs |

### VR11

|   |  |      |     |     |    |
|---|--|------|-----|-----|----|
| VID Threshold   |  | 450  | 600 | 770 | mV |
| VR11 Input Bias Current                                   |  | –100 | –   | 100 | nA |
| Delay Before Latching VID Change (VID Deskewing) (Note 3) | Measured from the Edge of the 1st VID Change | 200  | –   | 300 | ns |

### ENABLE INPUT

|                                   |   |     |     |     |    |
|-----------------------------------|---|-----|-----|-----|----|
| Enable High Input Leakage Current | Pull-up to 1.3 V  | –   | –   | 200 | nA |
| VR11.1 Threshold                  |   | 450 | 600 | 770 | mV |
| Enable Delay Time                 | Measure time from Enable transitioning HI to when SS begins | –   | 3.5 | –   | ms |

### CURRENT LIMIT

|                                |   |      |      |      |     |
|--------------------------------|---|------|------|------|-----|
| ILIM to VDRP Gain              |   | 0.97 | 1.00 | 1.03 | V/V |
| ILIM Pin Input Bias Current    |   | –    | 0.1  | 1.0  | μA  |
| ILIM Pin Working Voltage Range |   | 0.1  | –    | 2.0  | V   |
| ILIM Accuracy                  | Measured with respect to the ILIM setting | –25  | –    | 25   | mV  |
| Delay                          |   | –    | –    | 120  | ns  |

### OVERVOLTAGE PROTECTION

|                             |  |          |          |          |    |
|-----------------------------|--|----------|----------|----------|----|
| VR11 Over Voltage Threshold |  | VID+ 180 | VID+ 205 | VID+ 230 | mV |
| Delay                       |  | –        | –        | 100      | ns |

### UNDERVOLTAGE PROTECTION

|                                      |  |     |      |     |    |
|--------------------------------------|--|-----|------|-----|----|
| V <sub>CC</sub> UVLO Start Threshold |  | 4.0 | 4.25 | 4.5 | V  |
| V <sub>CC</sub> UVLO Stop Threshold  |  | 3.8 | 4.05 | 4.3 | V  |
| V <sub>CC</sub> UVLO Hysteresis      |  | 150 | 200  | –   | mV |

### 12VMON UVLO

|                         |                       |     |      |     |   |
|-------------------------|-----------------------|-----|------|-----|---|
| 12VMON (High Threshold) | V <sub>CC</sub> Valid | –   | 0.77 | 0.8 | V |
| 12VMON (Low Threshold)  | V <sub>CC</sub> Valid | 0.4 | 0.68 | –   | V |

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| Parameter  | Test Conditions   | Min  | Typ  | Max  | Unit  |
|--|---|------|------|------|-------|
| <b>DAC OUTPUT</b>  |   |      |      |      |       |
| Output Source Current  | V <sub>out</sub> = 1.6 V  | 0    | –    | 5.0  | mA    |
| Output Sink Current  | V <sub>out</sub> = 0.3 V  | 5.0  | –    | 16   | mA    |
| <b>VID INPUTS</b>  |   |      |      |      |       |
| Threshold  |   | 450  | 600  | 770  | mV    |
| VR11 Mode Leakage  |   | –100 | –    | 100  | nA    |
| Delay before Latching VID Change (VID Deskewing) (Note 3)                        | Measured from the edge of the 1 <sup>st</sup> VID change            | 200  | –    | 300  | ns    |
| <b>DIGITAL DAC SLEW RATE LIMITER</b>   |   |      |      |      |       |
| Slew Rate Limit  |   | 12.5 | –    | 16   | mV/μs |
| Soft-Start Slew Rate   |   | –    | 0.84 | –    | mV/μs |
| <b>INPUT SUPPLY CURRENT</b>  |   |      |      |      |       |
| V <sub>CC</sub> Quiescent Current  | EN Low, No PWM  | 10   | –    | 30   | mA    |
| <b>V<sub>CCP</sub> SUPPLY VOLTAGE</b>  |   |      |      |      |       |
| V <sub>CCP</sub> UVLO Start Threshold  |   | 8.2  | 9.0  | 9.5  | V     |
| V <sub>CCP</sub> UVLO Stop Threshold   |   | 7.2  | 8.0  | 8.5  | V     |
| V <sub>CCP</sub> UVLO Hysteresis   |   | 1.0  | –    | –    | V     |
| V <sub>CCP</sub> POR   | Voltage at which the Driver OVP becomes active                      | 3.0  | 3.2  | –    |       |
| <b>BOOST PIN UVLO</b>  |   |      |      |      |       |
| BOOST UVLO Start Threshold (Note 3)  |   | 3.15 |      | 4.15 | V     |
| BOOST UVLO Stop Threshold (Note 3)   |   | 3.0  |      | 3.85 | V     |
| BOOST UVLO Hysteresis (Note 3)   |   | 50   | 200  | –    | mV    |
| <b>STARTUP HIGH SIDE SHORT TRIP (Active only during 1<sup>st</sup> power on)</b> |   |      |      |      |       |
| V <sub>swx</sub> Output Overvoltage Trip Threshold at Startup                    | Power Startup time, V <sub>CC</sub> > 9 V                           | 1.7  | –    | 2.03 | V     |
| <b>HIGH SIDE DRIVER</b>  |   |      |      |      |       |
| R <sub>H_TG</sub> Output Resistance, Sourcing                                    | V <sub>BST</sub> – V <sub>SW</sub> = 12 V                           | –    | 1.8  | –    | Ω     |
| R <sub>H_TG</sub> Output Resistance, Sinking                                     | V <sub>BST</sub> – V <sub>SW</sub> = 12 V                           | –    | 1.0  | –    |       |
| T <sub>rDRVH</sub> Transition Time   | C <sub>LOAD</sub> = 3 nF, V <sub>BST</sub> – V <sub>SW</sub> = 12 V | –    | 25   | –    | ns    |
| T <sub>fDRVH</sub> Transition Time   | C <sub>LOAD</sub> = 3 nF, V <sub>BST</sub> – V <sub>SW</sub> = 12 V | –    | 20   | –    | ns    |
| T <sub>pdHDRVH</sub> Propagation Delay (Note 4)                                  | Driving High, C <sub>LOAD</sub> = 3.3 nF, V <sub>CCP</sub> = 12 V   | –    | 15   | –    | ns    |
| <b>LOW SIDE DRIVER</b>   |   |      |      |      |       |
| R <sub>H_BG</sub> Output Resistance, Sourcing                                    | SW = GND  | –    | 1.6  | –    | Ω     |
| R <sub>L_BG</sub> Output Resistance, Sinking                                     | SW = V <sub>CC</sub>  | –    | 1.0  | –    | Ω     |
| T <sub>rDRVL</sub> Transition Time   | C <sub>LOAD</sub> = 3 nF  | –    | 20   | –    | ns    |
| T <sub>fDRVL</sub> Transition Time   | C <sub>LOAD</sub> = 3 nF  | –    | 20   | –    | ns    |
| T <sub>pdHDRVL</sub> Propagation Delay (Note 4)                                  | Driving High, C <sub>LOAD</sub> = 3.3 nF, V <sub>CCP</sub> = 12 V   | –    | 20   | –    | ns    |
| V <sub>NCDT</sub> Negative Current Detector Threshold (Note 3)                   |   | –    | –4.0 | –    | mV    |

3. Guaranteed by design.

4. For propagation delays, “tpdh” refers to the specified signal going high “tpdl” refers to it going low. Reference Gate Timing Diagram.



# NCP5378

## ELECTRICAL CHARACTERISTICS

0°C < T<sub>A</sub> < 70°C; 0°C < T<sub>J</sub> < 125°C; 4.75 < V<sub>CC</sub> < 5.25 V; All DAC Codes; C<sub>VCC</sub> = 0.1 μF unless otherwise noted.

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

### THERMAL SHUTDOWN

|   |  |     |     |   |    |
|---|--|-----|-----|---|----|
| Tsd Thermal Shutdown (Note 3)               |  | 150 | 170 | – | °C |
| Tsdhys Thermal Shutdown Hysteresis (Note 3) |  | –   | 20  | – | °C |

### VRM 11 DAC

|                         |                     |   |   |      |    |
|-------------------------|---------------------|---|---|------|----|
| System Voltage Accuracy | 1.0 V < DAC < 1.6 V | – | – | ±0.5 | %  |
|                         | 0.8 V < DAC < 1.0 V | – | – | ±5.0 | mV |
|                         | 0.5 V < DAC < 0.8 V | – | – | ±8.0 | mV |

3. Guaranteed by design.

4. For propagation delays, “tpdh” refers to the specified signal going high “tpdl” refers to it going low. Reference Gate Timing Diagram.

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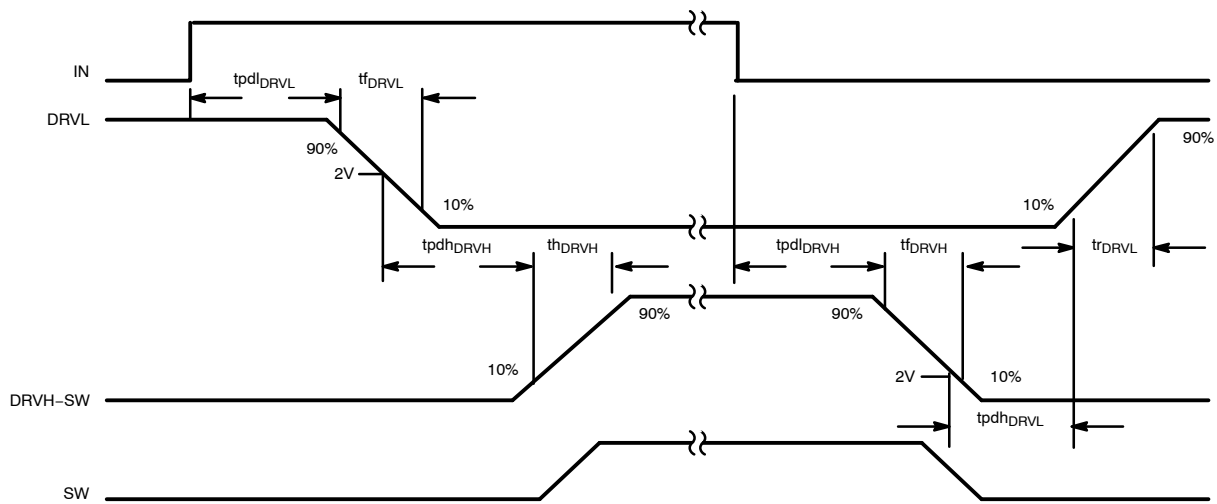


Figure 2. Timing Diagram

## FUNCTIONAL DESCRIPTIONS

### General

The NCP5378 is a ramp-pulse-modulated (RPM) controller designed with necessary features for CPU applications. The IC consists of the following blocks: Precision Flexible DAC, Differential Remote Voltage Sense Amplifier, High Performance Voltage Error Amplifier, Differential Current Feedback Amplifier, precision programmable DAC and PWM Comparator with Hysteresis. The controller also supports power saving operation at light load. Protection features include: Undervoltage Lockout, Soft Start, Over Current Protection, Over Voltage Protection, and Power Good Monitor.

### VID Inputs

VID0–VID7 control the target regulation voltage during normal operation. In VR11 mode the VID capture is enabled at the end of the  $V_{BST}$  waiting period. If the VID is valid the DAC counter will track to it. If an invalid VID occurs it will be ignored for 10  $\mu$ s before the controller shuts down.

### Remote Sense Amplifier

A high performance differential amplifier is provided to accurately sense the output voltage of the regulator. The noninverting input should be connected to the regulator's output voltage. The inverting input should be connected to the return line of the regulator. Both connection points are intended to be at a remote point so that the most accurate reading of the output voltage can be obtained. The amplifier is configured in a very unique way. First, the gain of the amplifier is internally set to unity. Second, both the inverting and noninverting inputs of the amplifier are summing nodes. The inverting input sums the output voltage return voltage with the DAC voltage. The noninverting input sums the

remote output voltage with a 1.3 V reference. The resulting voltage at the output of the remote sense amplifier is:

$$V_{\text{Diffout}} = V_{\text{out}} + 1.3 \text{ V} - V_{\text{dac}} - V_{\text{outreturn}}$$

This signal then goes through a standard compensation circuit and into the inverting input of the error amplifier. The noninverting input of the error amplifier is also connected to the 1.3 V reference. The 1.3 V reference then is subtracted out and the error signal at the comp pin of the error amplifier is as normally expected:

$$V_{\text{comp}} = V_{\text{dac}} - V_{\text{out}}$$

The noninverting input of the remote sense amplifier is pulled low through a small current sink during a fault condition to prevent accidental charging of the regulator output.

### High Performance Voltage Error Amplifier

A high performance voltage error amplifier is provided. The error amplifier's inverting input and its output (the compensation pin) are both pinned out. A standard type 3 compensation circuit is used to compensate the system. This involves a 3 pole, 2 zero compensation network. The system output current during a transient can slew as fast as 500 A/ $\mu$ s. The high frequency output impedance of the system may be as low as 0.5 milli-ohm. The PWM will need to go from a low duty cycle to full duty cycle within 100 ns. In order to respond to this magnitude of change, the output of the error amplifier must slew at a rate of at least 5 V/ $\mu$ s. The error amplifier output voltage needs to be able to slew from steady state to below 1.0 V or above 2.5 V. The error amplifier also needs to be very fast. The output of the error amplifier needs to respond within 50 ns to any perturbation on the input.

The comp pin will be pulled to ground in a fault condition and should not jump up when the fault cleared.

#### Differential Current Feedback Amplifier

A differential amplifier are provided to sense the output current of each phase.

The current sense amplifier senses the current through its corresponding phase. A voltage is generated across a current sense element such as an inductor or sense resistor. The sense voltage will be very low. The sense element will normally be between 0.5 m $\Omega$  and 1.5 m $\Omega$ . It is possible to sense both negative and positive going current. It is further possible that the differential sense signal is below 0 V. The output of these amplifiers shall not invert if the common mode range is exceeded.

The gain of this amplifier is fixed and is noninverting. The output of the amplifier is used to control 3 functions. First, the output controls the adaptive voltage positioning, where the output voltage is actively controlled according to the output current. Second, the output signal is fed to the current limit circuit. Finally, the phase current is connected to the PWM comparator. The offset voltage difference from amplifier to amplifier and the error in bias current from amplifier to amplifier need to be minimized. The offset and bias current design needs to be able to eliminate differences from amplifier to amplifier.

#### Switching Frequency in RPM Mode

When the NCP5378 operates in RPM mode, its switching frequency is controlled by the ripple voltage on the COMP pin. Each time the COMP pin voltage exceeds the RPM pin voltage threshold level determined by the VID voltage and the external resistor connected between RPM and ground, an internal ramp signal is started and TG is driven high. The slew rate of the internal ramp is programmed by the current entering the ROSC pin. When the internal ramp signal intercepts the COMP voltage, the TG pin is reset low. In continuous current mode, the switching frequency of RPM operation is almost constant. While in discontinuous current conduction mode, the switching frequency is reduced as a function of the load current.

#### Soft Start

Soft start is implemented internally. A digital counter steps the DAC up from zero to the target voltage based on the predetermined rate in the spec table.

The VR11 mode ramps DAC to 1.1 V, pauses for 500  $\mu$ s, reads the DAC setting, then ramps to the final DAC setting.

#### Digital Slew Rate Limiter / Soft Start Block

The slew rate limiter and the soft-start block are to be implemented with a digital up/down counter controlled by an oscillator that can be synchronized to VID line changes. During soft start the DAC will ramp at the softstart rate, after soft start is complete the ramp rate will follow the Intel rate depending on the mode. In normal operation the design must keep up with the Intel spec of 1 DAC step every 1.25  $\mu$ s.

The DAC must be implemented down as close to zero as possible (less than 20 mV out the DAC Buffer) in order to avoid the output voltage jumping up at the beginning of the ramp.

Preferably when DAC = 0 the buffer to the RS amp should deliver less than 20 mV. The digital DAC offset should be introduced prior to the digital compare.

### Protection Features

#### Undervoltage Lockouts

An undervoltage circuit senses the input  $V_{CC}$  and  $V_{CCP}$  of the controller and driver voltage rail. During power up the input voltage to the controller is monitored. The PWM outputs and the soft start circuit are disabled until the input voltage exceeds the threshold voltage of the comparator. Hysteresis is incorporated within the comparator.

The PWM signals will control the gate status when  $V_{CC}$  threshold is exceeded. If  $V_{CC}$  decreases below the stop threshold, the output gate will be forced low until input voltage  $V_{CC}$  rises above the startup threshold.

#### Overcurrent Latch

A programmable overcurrent latch is incorporated within the IC. The oscillator pin provides the reference voltage for this pin. A resistor divider from this pin generates the reference voltage. The latch is set when the current information exceeds the programmed voltage. To recover the part must be reset by the EN pin or by cycling  $V_{CC}$ .

The outputs will remain disabled until the  $V_{CC}$  voltage or EN is removed and reapplied.

#### UVLO Monitor

If the output voltage falls greater than 300 mV below the DAC voltage the UVLO comparator will trip sending the VR\_RDY signal low.

#### Overvoltage Protection

The output voltage is monitored at the input of the differential amplifier. During normal operation, if the output voltage exceeds the DAC voltage by 180 mV (OR 350 mV if OFS is active), the VR\_RDY flag goes low, the high side gate drivers are all brought low, and the low side gate drivers are all brought high until the voltage falls below the OVP threshold. If the over voltage trip 8 times the output voltage will shut down. The OVP will not shut down the controller if it occurs during soft-start. This is to allow the controller to pull the output down to the DAC voltage and start up into a pre-charged output.

#### VCCP Power ON Reset OVP

The VCCP power on reset OVP feature is used to protect the CPU during startup. When VCCP is higher than 3.2 V, the gate driver will monitor the switching node SW pin. If SWN pin higher than 1.9 V, the bottom gate will be forced to high for discharge of the output capacitor. This works best if the 5 V standby is diode OR'ed into VCCP with the 12 V rail. The

fault mode will be latched unless VCCP is reduced below the UVLO threshold.

## Power Saving Mode

The device maintains a RPM operation in power saving mode. The 12VMON input will be used for two purposes: feedforward input supply information for RPM mode and secondary power input voltage UVLO.

## Adaptive Non-overlap

The non-overlap dead time control is used to avoid shoot through damage to the power MOSFETs. When the PWM signal pull high, BG will go low after a propagation delay, the controller monitors the switching node (SWN) pin voltage and the gate voltage of the MOSFET to know the status of the MOSFET. When the low side MOSFET status is off an internal timer will delay turn on of the high-side MOSFET. When the PWM pull low, gate TG will go low after the propagation delay (tpdIDRVH). The time to turn off the high side MOSFET is depending on the total gate charge of the high-side MOSFET. A timer will be triggered once the high side MOSFET is turn off to delay the turn on the low-side MOSFET.

## Externally Programmable Offset

The OFS pin provides a means to program a DC current for generating an offset voltage across the resistor, R<sub>FB</sub> between FB and V<sub>DIFF</sub>. The offset current is generated via an external resistor and precision internal voltage references. For positive offset connect a resistor to GND.

For negative offset connect a resistor to V<sub>CC</sub>. The nominal no-load offset on NCP5378 is -19 mV.

To set the no-load offset please use the equations below:

For Negative Offset connect R<sub>OFS</sub> to V<sub>CC</sub>

$$R_{OFS} = \frac{(V_{CC} - 2.0) \cdot R_{FB}}{V_{OFFSET}}$$

For Positive Offset connect R<sub>OFS</sub> to GND

$$R_{OFS} = \frac{0.3 \times R_{FB}}{V_{OFFSET}}$$

For example to get 0 mV no-load offset; (since the part has a nominal of -19mV)

$$R_{OFS} = \frac{0.3 \times R_{FB}}{19 \text{ mV}}$$

## Layout Guidelines

Layout is very important thing for design a DC-DC converter. The strap capacitor and Vin capacitor are most critical items, it should be placed as close as to the controller IC. Another item is using a GND plane. Ground plane can provide a good return path for gate drives for reducing the ground noise. Therefore GND pin should be directly connected to the ground plane and close to the low-side MOSFET source pin. Also, the gate drive trace should be considered. The gate drives has a high di/dt when switching, therefore a minimized gate drives trace can reduce the di/dv, raise and fall time for reduce the switching loss.

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**Table 2. VRM11 VID Codes**

| VID7<br>800 mV | VID6<br>400 mV | VID5<br>200 mV | VID4<br>100 mV | VID3<br>50 mV | VID2<br>25 mV | VID1<br>12.5 mV | VID0<br>6.25 mV | Voltage<br>(V) | HEX |
|----------------|----------------|----------------|----------------|---------------|---------------|-----------------|-----------------|----------------|-----|
| 0              | 0              | 0              | 0              | 0             | 0             | 0               | 0               |                | 00  |
| 0              | 0              | 0              | 0              | 0             | 0             | 0               | 1               |                | 01  |
| 0              | 0              | 0              | 0              | 0             | 0             | 1               | 0               | 1.60000        | 02  |
| 0              | 0              | 0              | 0              | 0             | 0             | 1               | 1               | 1.59375        | 03  |
| 0              | 0              | 0              | 0              | 0             | 1             | 0               | 0               | 1.58750        | 04  |
| 0              | 0              | 0              | 0              | 0             | 1             | 0               | 1               | 1.58125        | 05  |
| 0              | 0              | 0              | 0              | 0             | 1             | 1               | 0               | 1.57500        | 06  |
| 0              | 0              | 0              | 0              | 0             | 1             | 1               | 1               | 1.56875        | 07  |
| 0              | 0              | 0              | 0              | 1             | 0             | 0               | 0               | 1.56250        | 08  |
| 0              | 0              | 0              | 0              | 1             | 0             | 0               | 1               | 1.55625        | 09  |
| 0              | 0              | 0              | 0              | 1             | 0             | 1               | 0               | 1.55000        | 0A  |
| 0              | 0              | 0              | 0              | 1             | 0             | 1               | 1               | 1.54375        | 0B  |
| 0              | 0              | 0              | 0              | 1             | 1             | 0               | 0               | 1.53750        | 0C  |
| 0              | 0              | 0              | 0              | 1             | 1             | 0               | 1               | 1.53125        | 0D  |
| 0              | 0              | 0              | 0              | 1             | 1             | 1               | 0               | 1.52500        | 0E  |
| 0              | 0              | 0              | 0              | 1             | 1             | 1               | 1               | 1.51875        | 0F  |
| 0              | 0              | 0              | 1              | 0             | 0             | 0               | 0               | 1.51250        | 10  |
| 0              | 0              | 0              | 1              | 0             | 0             | 0               | 1               | 1.50625        | 11  |
| 0              | 0              | 0              | 1              | 0             | 0             | 1               | 0               | 1.50000        | 12  |
| 0              | 0              | 0              | 1              | 0             | 0             | 1               | 1               | 1.49375        | 13  |
| 0              | 0              | 0              | 1              | 0             | 1             | 0               | 0               | 1.48750        | 14  |
| 0              | 0              | 0              | 1              | 0             | 1             | 0               | 1               | 1.48125        | 15  |
| 0              | 0              | 0              | 1              | 0             | 1             | 1               | 0               | 1.47500        | 16  |
| 0              | 0              | 0              | 1              | 0             | 1             | 1               | 1               | 1.46875        | 17  |
| 0              | 0              | 0              | 1              | 1             | 0             | 0               | 0               | 1.46250        | 18  |
| 0              | 0              | 0              | 1              | 1             | 0             | 0               | 1               | 1.45625        | 19  |
| 0              | 0              | 0              | 1              | 1             | 0             | 1               | 0               | 1.45000        | 1A  |
| 0              | 0              | 0              | 1              | 1             | 0             | 1               | 1               | 1.44375        | 1B  |
| 0              | 0              | 0              | 1              | 1             | 1             | 0               | 0               | 1.43750        | 1C  |
| 0              | 0              | 0              | 1              | 1             | 1             | 0               | 1               | 1.43125        | 1D  |
| 0              | 0              | 0              | 1              | 1             | 1             | 1               | 0               | 1.42500        | 1E  |
| 0              | 0              | 0              | 1              | 1             | 1             | 1               | 1               | 1.41875        | 1F  |
| 0              | 0              | 1              | 0              | 0             | 0             | 0               | 0               | 1.41250        | 20  |
| 0              | 0              | 1              | 0              | 0             | 0             | 0               | 1               | 1.40625        | 21  |
| 0              | 0              | 1              | 0              | 0             | 0             | 1               | 0               | 1.40000        | 22  |
| 0              | 0              | 1              | 0              | 0             | 0             | 1               | 1               | 1.39375        | 23  |
| 0              | 0              | 1              | 0              | 0             | 1             | 0               | 0               | 1.38750        | 24  |
| 0              | 0              | 1              | 0              | 0             | 1             | 0               | 1               | 1.38125        | 25  |
| 0              | 0              | 1              | 0              | 0             | 1             | 1               | 0               | 1.37500        | 26  |
| 0              | 0              | 1              | 0              | 0             | 1             | 1               | 1               | 1.36875        | 27  |
| 0              | 0              | 1              | 0              | 1             | 0             | 0               | 0               | 1.36250        | 28  |
| 0              | 0              | 1              | 0              | 1             | 0             | 0               | 1               | 1.35625        | 29  |
| 0              | 0              | 1              | 0              | 1             | 0             | 1               | 0               | 1.35000        | 2A  |

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**Table 2. VRM11 VID Codes**

| VID7<br>800 mV | VID6<br>400 mV | VID5<br>200 mV | VID4<br>100 mV | VID3<br>50 mV | VID2<br>25 mV | VID1<br>12.5 mV | VID0<br>6.25 mV | Voltage<br>(V) | HEX |
|----------------|----------------|----------------|----------------|---------------|---------------|-----------------|-----------------|----------------|-----|
| 0              | 0              | 1              | 0              | 1             | 0             | 1               | 1               | 1.34375        | 2B  |
| 0              | 0              | 1              | 0              | 1             | 1             | 0               | 0               | 1.33750        | 2C  |
| 0              | 0              | 1              | 0              | 1             | 1             | 0               | 1               | 1.33125        | 2D  |
| 0              | 0              | 1              | 0              | 1             | 1             | 1               | 0               | 1.32500        | 2E  |
| 0              | 0              | 1              | 0              | 1             | 1             | 1               | 1               | 1.31875        | 2F  |
| 0              | 0              | 1              | 1              | 0             | 0             | 0               | 0               | 1.31250        | 30  |
| 0              | 0              | 1              | 1              | 0             | 0             | 0               | 1               | 1.30625        | 31  |
| 0              | 0              | 1              | 1              | 0             | 0             | 1               | 0               | 1.30000        | 32  |
| 0              | 0              | 1              | 1              | 0             | 0             | 1               | 1               | 1.29375        | 33  |
| 0              | 0              | 1              | 1              | 0             | 1             | 0               | 0               | 1.28750        | 34  |
| 0              | 0              | 1              | 1              | 0             | 1             | 0               | 1               | 1.28125        | 35  |
| 0              | 0              | 1              | 1              | 0             | 1             | 1               | 0               | 1.27500        | 36  |
| 0              | 0              | 1              | 1              | 0             | 1             | 1               | 1               | 1.26875        | 37  |
| 0              | 0              | 1              | 1              | 1             | 0             | 0               | 0               | 1.26250        | 38  |
| 0              | 0              | 1              | 1              | 1             | 0             | 0               | 1               | 1.25625        | 39  |
| 0              | 0              | 1              | 1              | 1             | 0             | 1               | 0               | 1.25000        | 3A  |
| 0              | 0              | 1              | 1              | 1             | 0             | 1               | 1               | 1.24375        | 3B  |
| 0              | 0              | 1              | 1              | 1             | 1             | 0               | 0               | 1.23750        | 3C  |
| 0              | 0              | 1              | 1              | 1             | 1             | 0               | 1               | 1.23125        | 3D  |
| 0              | 0              | 1              | 1              | 1             | 1             | 1               | 0               | 1.22500        | 3E  |
| 0              | 0              | 1              | 1              | 1             | 1             | 1               | 1               | 1.21875        | 3F  |
| 0              | 1              | 0              | 0              | 0             | 0             | 0               | 0               | 1.21250        | 40  |
| 0              | 1              | 0              | 0              | 0             | 0             | 0               | 1               | 1.20625        | 41  |
| 0              | 1              | 0              | 0              | 0             | 0             | 1               | 0               | 1.20000        | 42  |
| 0              | 1              | 0              | 0              | 0             | 0             | 1               | 1               | 1.19375        | 43  |
| 0              | 1              | 0              | 0              | 0             | 1             | 0               | 0               | 1.18750        | 44  |
| 0              | 1              | 0              | 0              | 0             | 1             | 0               | 1               | 1.18125        | 45  |
| 0              | 1              | 0              | 0              | 0             | 1             | 1               | 0               | 1.17500        | 46  |
| 0              | 1              | 0              | 0              | 0             | 1             | 1               | 1               | 1.16875        | 47  |
| 0              | 1              | 0              | 0              | 1             | 0             | 0               | 0               | 1.16250        | 48  |
| 0              | 1              | 0              | 0              | 1             | 0             | 0               | 1               | 1.15625        | 49  |
| 0              | 1              | 0              | 0              | 1             | 0             | 1               | 0               | 1.15000        | 4A  |
| 0              | 1              | 0              | 0              | 1             | 0             | 1               | 1               | 1.14375        | 4B  |
| 0              | 1              | 0              | 0              | 1             | 1             | 0               | 0               | 1.13750        | 4C  |
| 0              | 1              | 0              | 0              | 1             | 1             | 0               | 1               | 1.13125        | 4D  |
| 0              | 1              | 0              | 0              | 1             | 1             | 1               | 0               | 1.12500        | 4E  |
| 0              | 1              | 0              | 0              | 1             | 1             | 1               | 1               | 1.11875        | 4F  |
| 0              | 1              | 0              | 1              | 0             | 0             | 0               | 0               | 1.11250        | 50  |
| 0              | 1              | 0              | 1              | 0             | 0             | 0               | 1               | 1.10625        | 51  |
| 0              | 1              | 0              | 1              | 0             | 0             | 1               | 0               | 1.10000        | 52  |
| 0              | 1              | 0              | 1              | 0             | 0             | 1               | 1               | 1.09375        | 53  |
| 0              | 1              | 0              | 1              | 0             | 1             | 0               | 0               | 1.08750        | 54  |
| 0              | 1              | 0              | 1              | 0             | 1             | 0               | 1               | 1.08125        | 55  |

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**Table 2. VRM11 VID Codes**

| VID7<br>800 mV | VID6<br>400 mV | VID5<br>200 mV | VID4<br>100 mV | VID3<br>50 mV | VID2<br>25 mV | VID1<br>12.5 mV | VID0<br>6.25 mV | Voltage<br>(V) | HEX |
|----------------|----------------|----------------|----------------|---------------|---------------|-----------------|-----------------|----------------|-----|
| 0              | 1              | 0              | 1              | 0             | 1             | 1               | 0               | 1.07500        | 56  |
| 0              | 1              | 0              | 1              | 0             | 1             | 1               | 1               | 1.06875        | 57  |
| 0              | 1              | 0              | 1              | 1             | 0             | 0               | 0               | 1.06250        | 58  |
| 0              | 1              | 0              | 1              | 1             | 0             | 0               | 1               | 1.05625        | 59  |
| 0              | 1              | 0              | 1              | 1             | 0             | 1               | 0               | 1.05000        | 5A  |
| 0              | 1              | 0              | 1              | 1             | 0             | 1               | 1               | 1.04375        | 5B  |
| 0              | 1              | 0              | 1              | 1             | 1             | 0               | 0               | 1.03750        | 5C  |
| 0              | 1              | 0              | 1              | 1             | 1             | 0               | 1               | 1.03125        | 5D  |
| 0              | 1              | 0              | 1              | 1             | 1             | 1               | 0               | 1.02500        | 5E  |
| 0              | 1              | 0              | 1              | 1             | 1             | 1               | 1               | 1.01875        | 5F  |
| 0              | 1              | 1              | 0              | 0             | 0             | 0               | 0               | 1.01250        | 60  |
| 0              | 1              | 1              | 0              | 0             | 0             | 0               | 1               | 1.00625        | 61  |
| 0              | 1              | 1              | 0              | 0             | 0             | 1               | 0               | 1.00000        | 62  |
| 0              | 1              | 1              | 0              | 0             | 0             | 1               | 1               | 0.99375        | 63  |
| 0              | 1              | 1              | 0              | 0             | 1             | 0               | 0               | 0.98750        | 64  |
| 0              | 1              | 1              | 0              | 0             | 1             | 0               | 1               | 0.98125        | 65  |
| 0              | 1              | 1              | 0              | 0             | 1             | 1               | 0               | 0.97500        | 66  |
| 0              | 1              | 1              | 0              | 0             | 1             | 1               | 1               | 0.96875        | 67  |
| 0              | 1              | 1              | 0              | 1             | 0             | 0               | 0               | 0.96250        | 68  |
| 0              | 1              | 1              | 0              | 1             | 0             | 0               | 1               | 0.95625        | 69  |
| 0              | 1              | 1              | 0              | 1             | 0             | 1               | 0               | 0.95000        | 6A  |
| 0              | 1              | 1              | 0              | 1             | 0             | 1               | 1               | 0.94375        | 6B  |
| 0              | 1              | 1              | 0              | 1             | 1             | 0               | 0               | 0.93750        | 6C  |
| 0              | 1              | 1              | 0              | 1             | 1             | 0               | 1               | 0.93125        | 6D  |
| 0              | 1              | 1              | 0              | 1             | 1             | 1               | 0               | 0.92500        | 6E  |
| 0              | 1              | 1              | 0              | 1             | 1             | 1               | 1               | 0.91875        | 6F  |
| 0              | 1              | 1              | 1              | 0             | 0             | 0               | 0               | 0.91250        | 70  |
| 0              | 1              | 1              | 1              | 0             | 0             | 0               | 1               | 0.90625        | 71  |
| 0              | 1              | 1              | 1              | 0             | 0             | 1               | 0               | 0.90000        | 72  |
| 0              | 1              | 1              | 1              | 0             | 0             | 1               | 1               | 0.89375        | 73  |
| 0              | 1              | 1              | 1              | 0             | 1             | 0               | 0               | 0.88750        | 74  |
| 0              | 1              | 1              | 1              | 0             | 1             | 0               | 1               | 0.88125        | 75  |
| 0              | 1              | 1              | 1              | 0             | 1             | 1               | 0               | 0.87500        | 76  |
| 0              | 1              | 1              | 1              | 0             | 1             | 1               | 1               | 0.86875        | 77  |
| 0              | 1              | 1              | 1              | 1             | 0             | 0               | 0               | 0.86250        | 78  |
| 0              | 1              | 1              | 1              | 1             | 0             | 0               | 1               | 0.85625        | 79  |
| 0              | 1              | 1              | 1              | 1             | 0             | 1               | 0               | 0.85000        | 7A  |
| 0              | 1              | 1              | 1              | 1             | 0             | 1               | 1               | 0.84375        | 7B  |
| 0              | 1              | 1              | 1              | 1             | 1             | 0               | 0               | 0.83750        | 7C  |
| 0              | 1              | 1              | 1              | 1             | 1             | 0               | 1               | 0.83125        | 7D  |
| 0              | 1              | 1              | 1              | 1             | 1             | 1               | 0               | 0.82500        | 7E  |
| 0              | 1              | 1              | 1              | 1             | 1             | 1               | 1               | 0.81875        | 7F  |
| 1              | 0              | 0              | 0              | 0             | 0             | 0               | 0               | 0.81250        | 80  |

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**Table 2. VRM11 VID Codes**

| VID7<br>800 mV | VID6<br>400 mV | VID5<br>200 mV | VID4<br>100 mV | VID3<br>50 mV | VID2<br>25 mV | VID1<br>12.5 mV | VID0<br>6.25 mV | Voltage<br>(V) | HEX |
|----------------|----------------|----------------|----------------|---------------|---------------|-----------------|-----------------|----------------|-----|
| 1              | 0              | 0              | 0              | 0             | 0             | 0               | 1               | 0.80625        | 81  |
| 1              | 0              | 0              | 0              | 0             | 0             | 1               | 0               | 0.80000        | 82  |
| 1              | 0              | 0              | 0              | 0             | 0             | 1               | 1               | 0.79375        | 83  |
| 1              | 0              | 0              | 0              | 0             | 1             | 0               | 0               | 0.78750        | 84  |
| 1              | 0              | 0              | 0              | 0             | 1             | 0               | 1               | 0.78125        | 85  |
| 1              | 0              | 0              | 0              | 0             | 1             | 1               | 0               | 0.77500        | 86  |
| 1              | 0              | 0              | 0              | 0             | 1             | 1               | 1               | 0.76875        | 87  |
| 1              | 0              | 0              | 0              | 1             | 0             | 0               | 0               | 0.76250        | 88  |
| 1              | 0              | 0              | 0              | 1             | 0             | 0               | 1               | 0.75625        | 89  |
| 1              | 0              | 0              | 0              | 1             | 0             | 1               | 0               | 0.75000        | 8A  |
| 1              | 0              | 0              | 0              | 1             | 0             | 1               | 1               | 0.74375        | 8B  |
| 1              | 0              | 0              | 0              | 1             | 1             | 0               | 0               | 0.73750        | 8C  |
| 1              | 0              | 0              | 0              | 1             | 1             | 0               | 1               | 0.73125        | 8D  |
| 1              | 0              | 0              | 0              | 1             | 1             | 1               | 0               | 0.72500        | 8E  |
| 1              | 0              | 0              | 0              | 1             | 1             | 1               | 1               | 0.71875        | 8F  |
| 1              | 0              | 0              | 1              | 0             | 0             | 0               | 0               | 0.71250        | 90  |
| 1              | 0              | 0              | 1              | 0             | 0             | 0               | 1               | 0.70625        | 91  |
| 1              | 0              | 0              | 1              | 0             | 0             | 1               | 0               | 0.70000        | 92  |
| 1              | 0              | 0              | 1              | 0             | 0             | 1               | 1               | 0.69375        | 93  |
| 1              | 0              | 0              | 1              | 0             | 1             | 0               | 0               | 0.68750        | 94  |
| 1              | 0              | 0              | 1              | 0             | 1             | 0               | 1               | 0.68125        | 95  |
| 1              | 0              | 0              | 1              | 0             | 1             | 1               | 0               | 0.67500        | 96  |
| 1              | 0              | 0              | 1              | 0             | 1             | 1               | 1               | 0.66875        | 97  |
| 1              | 0              | 0              | 1              | 1             | 0             | 0               | 0               | 0.66250        | 98  |
| 1              | 0              | 0              | 1              | 1             | 0             | 0               | 1               | 0.65625        | 99  |
| 1              | 0              | 0              | 1              | 1             | 0             | 1               | 0               | 0.65000        | 9A  |
| 1              | 0              | 0              | 1              | 1             | 0             | 1               | 1               | 0.64375        | 9B  |
| 1              | 0              | 0              | 1              | 1             | 1             | 0               | 0               | 0.63750        | 9C  |
| 1              | 0              | 0              | 1              | 1             | 1             | 0               | 1               | 0.63125        | 9D  |
| 1              | 0              | 0              | 1              | 1             | 1             | 1               | 0               | 0.62500        | 9E  |
| 1              | 0              | 0              | 1              | 1             | 1             | 1               | 1               | 0.61875        | 9F  |
| 1              | 0              | 1              | 0              | 0             | 0             | 0               | 0               | 0.61250        | A0  |
| 1              | 0              | 1              | 0              | 0             | 0             | 0               | 1               | 0.60625        | A1  |
| 1              | 0              | 1              | 0              | 0             | 0             | 1               | 0               | 0.60000        | A2  |
| 1              | 0              | 1              | 0              | 0             | 0             | 1               | 1               | 0.59375        | A3  |
| 1              | 0              | 1              | 0              | 0             | 1             | 0               | 0               | 0.58750        | A4  |
| 1              | 0              | 1              | 0              | 0             | 1             | 0               | 1               | 0.58125        | A5  |
| 1              | 0              | 1              | 0              | 0             | 1             | 1               | 0               | 0.57500        | A6  |
| 1              | 0              | 1              | 0              | 0             | 1             | 1               | 1               | 0.56875        | A7  |
| 1              | 0              | 1              | 0              | 1             | 0             | 0               | 0               | 0.56250        | A8  |
| 1              | 0              | 1              | 0              | 1             | 0             | 0               | 1               | 0.55625        | A9  |
| 1              | 0              | 1              | 0              | 1             | 0             | 1               | 0               | 0.55000        | AA  |
| 1              | 0              | 1              | 0              | 1             | 0             | 1               | 1               | 0.54375        | AB  |



# NCP5378

Table 2. VRM11 VID Codes

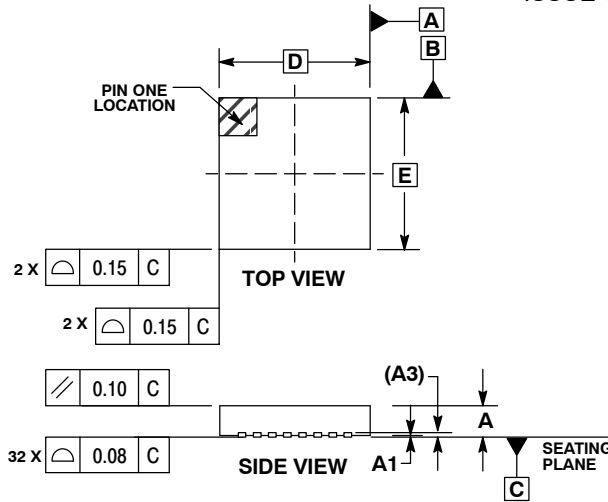
| VID7<br>800 mV | VID6<br>400 mV | VID5<br>200 mV | VID4<br>100 mV | VID3<br>50 mV | VID2<br>25 mV | VID1<br>12.5 mV | VID0<br>6.25 mV | Voltage<br>(V) | HEX |
|----------------|----------------|----------------|----------------|---------------|---------------|-----------------|-----------------|----------------|-----|
| 1              | 0              | 1              | 0              | 1             | 1             | 0               | 0               | 0.53750        | AC  |
| 1              | 0              | 1              | 0              | 1             | 1             | 0               | 1               | 0.53125        | AD  |
| 1              | 0              | 1              | 0              | 1             | 1             | 1               | 0               | 0.52500        | AE  |
| 1              | 0              | 1              | 0              | 1             | 1             | 1               | 1               | 0.51875        | AF  |
| 1              | 0              | 1              | 1              | 0             | 0             | 0               | 0               | 0.51250        | B0  |
| 1              | 0              | 1              | 1              | 0             | 0             | 0               | 1               | 0.50625        | B1  |
| 1              | 0              | 1              | 1              | 0             | 0             | 1               | 0               | 0.50000        | B2  |
| 1              | 1              | 1              | 1              | 1             | 1             | 1               | 0               | OFF            | FE  |
| 1              | 1              | 1              | 1              | 1             | 1             | 1               | 1               | OFF            | FF  |

5. NOTE: Internal DAC voltage is centered 19 mV below the listed voltage for VR11.1.

# NCP5378

## PACKAGE DIMENSIONS

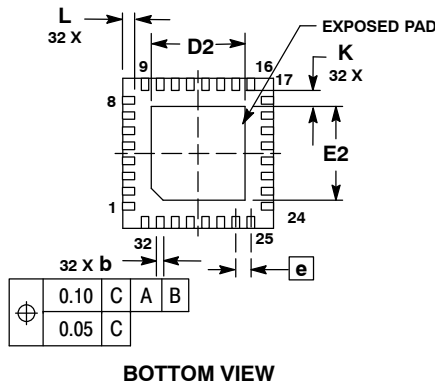
QFN32 5x5, 0.5P  
CASE 488AM-01  
ISSUE O



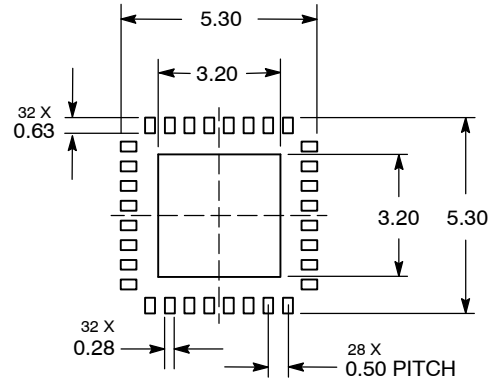
**NOTES:**

1. DIMENSIONS AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.25 AND 0.30 MM TERMINAL.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

| DIM | MILLIMETERS |       |       |
|-----|-------------|-------|-------|
|     | MIN         | NOM   | MAX   |
| A   | 0.800       | 0.900 | 1.000 |
| A1  | 0.000       | 0.025 | 0.050 |
| A3  | 0.200 REF   |       |       |
| b   | 0.180       | 0.250 | 0.300 |
| D   | 5.00 BSC    |       |       |
| D2  | 2.950       | 3.100 | 3.250 |
| E   | 5.00 BSC    |       |       |
| E2  | 2.950       | 3.100 | 3.250 |
| e   | 0.500 BSC   |       |       |
| K   | 0.200       | ---   | ---   |
| L   | 0.300       | 0.400 | 0.500 |



**SOLDERING FOOTPRINT\***



\*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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