# NCV8508

# 5.0 V, 250 mA LDO with Watchdog and $\overline{\text{RESET}}$

The NCV8508 is a precision micropower Low Dropout (LDO) voltage regulator. The part contains many of the required operational requirements for powering microprocessors. Its robustness makes it suitable for severe automotive environments. In addition to being a good fit for the automotive environment, the NCV8508 is ideal for use in battery operated, microprocessor controlled equipment because of its extremely low quiescent current.

**Features**

- Output Voltage: 5.0 V
- ±3.0% Output Voltage
- $I_{OUT}$ Up to 250 mA
- Quiescent Current Independent of Load
- Micropower Compatible Control Functions:
  - Wakeup
  - Watchdog
  - $\overline{\text{RESET}}$
- Low Quiescent Current (100 μA typ)
- Protection Features:
  - Thermal Shutdown
  - Short Circuit
  - 45 V Operation
- Internally Fused Leads in SO−16L Package
- NCV Prefix for Automotive and Other Applications Requiring Site and Control Changes
- Pb−Free Package is Available*

*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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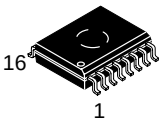
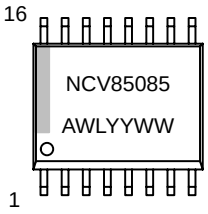
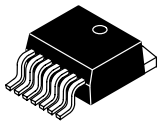
http://onsemi.com

**MARKING DIAGRAMS**

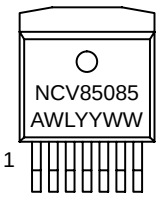



**SO−16L**
**DW SUFFIX**
**CASE 751G**



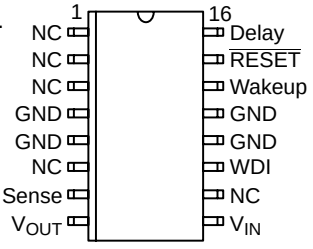
**$D^2PAK$−7**
**DPS SUFFIX**
**CASE 936AB**



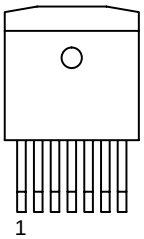

A = Assembly Location
WL = Wafer Lot
YY = Year
WW = Work Week

**PIN CONNECTIONS**

**SO−16L**



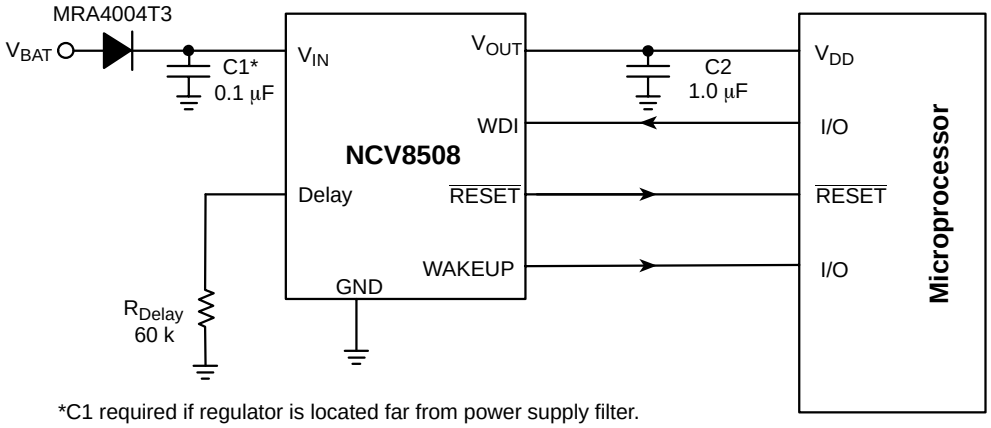

**$D^2PAK$−7**




Tab = GND
Lead 1. $V_{OUT}$
2. $V_{IN}$
3. WDI
4. GND
5. Wakeup
6. $\overline{\text{RESET}}$
7. Delay

**ORDERING INFORMATION**

See detailed ordering and shipping information in the package dimensions section on page 10 of this data sheet.




*C1 required if regulator is located far from power supply filter.

**Figure 1. Application Circuit**

**MAXIMUM RATINGS**

| Rating | | Value | Unit |
|---|---|---|---|
| Input Voltage, $V_{IN}$ | | −0.3 to 45 | V |
| Output Voltage, $V_{OUT}$ | | −0.3 to 18 | V |
| ESD Susceptibility: | Human Body Model<br>Machine Model | 2.0<br>200 | kV<br>V |
| Logic Inputs/Outputs ($\overline{\text{RESET}}$, WDI, Wakeup) | | −0.3 to +7.0 | V |
| Operating Junction Temperature, $T_J$ | | −40 to150 | °C |
| Storage Temperature Range, $T_S$ | | −55 to +150 | °C |
| Package Thermal Resistance, SO−16L: | Junction−to−Case, $R_{\theta JC}$<br>Junction−to−Ambient, $R_{\theta JA}$ | 18<br>80 | °C/W<br>°C/W |
| Package Thermal Resistance, $D^2PAK$, 7−Lead: | Junction−to−Case, $R_{\theta JC}$<br>Junction−to−Ambient, $R_{\theta JA}$ | 4.0<br>10 to 50 (Note 2) | °C/W<br>°C/W |
| Lead Temperature Soldering: | Reflow: (SMD styles only) (Note 1) | 240 peak (Note 3) | °C |

Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.

1. 60 second maximum above 183°C.
2. Depending on thermal properties of substrate $R_{\theta JA} = R_{\theta JC} + R_{\theta JCA}$.
3. −5°C/+0°C allowable conditions.

**ELECTRICAL CHARACTERISTICS** ($-40°C \le T_J \le 125°C$; $6.0\ V \le V_{IN} \le 28\ V$, $100\ \mu A \le I_{OUT} \le 150\ mA$, $C_2 = 1.0\ \mu F$, $R_{Delay} = 60\ k$; unless otherwise specified.)

| Characteristic | Test Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| **OUTPUT** | | | | | |
| Output Voltage | – | 4.85 | 5.00 | 5.15 | V |
| Dropout Voltage ($V_{IN} - V_{OUT}$) | $I_{OUT}$ = 150 mA. Note 4 | – | 450 | 900 | mV |
| Load Regulation | $V_{IN}$ = 14 V, 100 μA ≤ $I_{OUT}$ ≤ 150 mA | – | 5.0 | 30 | mV |
| Line Regulation | 6.0 V ≤ $V_{IN}$ ≤ 28 V, $I_{OUT}$ = 5.0 mA | – | 5.0 | 50 | mV |
| Current Limit | – | 250 | 400 | – | mA |
| Thermal Shutdown | Guaranteed by Design | 150 | 180 | 210 | °C |
| Quiescent Current | $V_{IN}$ = 12 V, $I_{OUT}$ = 150 mA, (see Figure 6) | – | 100 | 150 | μA |
| **$\overline{\text{RESET}}$** | | | | | |
| Threshold | – | 4.50 | 4.65 | 4.80 | V |
| Output Low | $R_{LOAD}$ = 10 k to $V_{OUT}$, $V_{OUT}$ ≥ 1.0 V<br>$R_{LOAD}$ = 5.1 k to $V_{OUT}$, $V_{OUT}$ ≥ 1.0 V | – | 0.2<br>0.4 | 0.4<br>0.8 | V |
| Output High | $R_{LOAD}$ = 10 k to GND<br>$R_{LOAD}$ = 5.1 k to GND | $V_{OUT}$ − 0.5<br>$V_{OUT}$ − 1.0 | $V_{OUT}$ − 0.25<br>$V_{OUT}$ − 0.5 | – | V |
| Delay Time | $V_{IN}$ = 14 V, $R_{Delay}$ = 60 k, $I_{OUT}$ = 5.0 mA<br>$V_{IN}$ = 14 V, $R_{Delay}$ = 120 k, $I_{OUT}$ = 5.0 mA | 2.0<br>– | 3.0<br>6.0 | 4.0<br>– | ms<br>ms |
| **WATCHDOG INPUT** | | | | | |
| Threshold High | – | 70 | – | – | %$V_{OUT}$ |
| Threshold Low | – | – | – | 30 | %$V_{OUT}$ |
| Hysteresis | – | – | 100 | – | mV |
| Input Current | WDI = 6.0 V | – | 0.1 | +10 | μA |
| Pulse Width | 50% WDI falling edge to<br>50% WDI rising edge and<br>50% WDI rising edge to<br>50% WDI falling edge, (see Figure 5) | 5.0 | – | – | μs |
| **WAKEUP OUTPUT** ($V_{IN}$ = 14 V, $I_{OUT}$ = 5.0 mA) | | | | | |
| Wakeup Period | See Figures 4 and 5, $R_{DELAY}$ = 60 k<br>See Figures 4 and 5, $R_{DELAY}$ = 120 k | 18<br>– | 25<br>50 | 32<br>– | ms<br>ms |
| Wakeup Duty Cycle Nominal | See Figure 3 | 45 | 50 | 55 | % |
| $\overline{\text{RESET}}$ HIGH to<br>Wakeup Rising Delay Time | $R_{DELAY}$ = 60 k<br>50% $\overline{\text{RESET}}$ rising edge to<br>50% Wakeup edge, $R_{DELAY}$ = 120 k<br>(see Figures 3 and 4) | 9.0<br>– | 12.5<br>25 | 16<br>– | ms<br>ms |
| Wakeup Response to<br>Watchdog Input | 50% WDI falling edge to<br>50% Wakeup falling edge | – | 0.1 | 5.0 | μs |
| Wakeup Response to $\overline{\text{RESET}}$ | 50% $\overline{\text{RESET}}$ falling edge to<br>50% Wakeup falling edge.<br>$V_{OUT}$ = 5.0 V→ 4.5 V | – | 0.1 | 5.0 | μs |
| Output Low | $R_{LOAD}$ = 10 k to $V_{OUT}$, $V_{OUT}$ ≥ 1.0 V<br>$R_{LOAD}$ = 5.1 k to $V_{OUT}$, $V_{OUT}$ ≥ 1.0 V | – | 0.2<br>0.4 | 0.4<br>0.8 | V |
| Output High | $R_{LOAD}$ = 10 k to GND<br>$R_{LOAD}$ = 5.1 k to GND | $V_{OUT}$ − 0.5<br>$V_{OUT}$ − 1.0 | $V_{OUT}$ − 0.25<br>$V_{OUT}$ − 0.5 | – | V |
| **DELAY** | | | | | |
| Output Voltage | $I_{DELAY}$ = 50 μA. Note 5 | – | 1.25 | – | V |

4. Measured when the output voltage has dropped 100 mV from the nominal value. (see Figure 12)
5. Current drain on the Delay pin directly affects the Delay Time, Wakeup Period, and the $\overline{\text{RESET}}$ to Wakeup Delay Time.

**PACKAGE PIN DESCRIPTION**

| PACKAGE PIN # | | PIN SYMBOL | FUNCTION |
|---|---|---|---|
| $D^2PAK-7$ | SO−16L | | |
| 1 | 8 | $V_{OUT}$ | Regulated output voltage ± 3.0%. |
| 2 | 9 | $V_{IN}$ | Supply Voltage to the IC. |
| 3 | 11 | WDI | CMOS compatible input lead. The Watchdog function monitors the falling edge of the incoming signal. |
| 4 | 4, 5, 12, 13 | GND | Ground connection. |
| 5 | 14 | Wakeup | CMOS compatible output consisting of a continuously generated signal used to “wake up” the microprocessor from sleep mode. |
| 6 | 15 | $\overline{\text{RESET}}$ | CMOS compatible output lead $\overline{\text{RESET}}$ goes low whenever $V_{OUT}$ drops by more than 7.0% from nominal, or during the absence of a correct Watchdog signal. |
| 7 | 16 | Delay | Buffered bandgap voltage used to create timing current for $\overline{\text{RESET}}$ and Wakeup from $R_{Delay}$. |
| − | 1−3, 6, 10 | NC | No Connection. |
| − | 7 | Sense | Kelvin connection which allows remote sensing of the output voltage for improved regulation. Connect to $V_{OUT}$ if remote sensing is not required. |

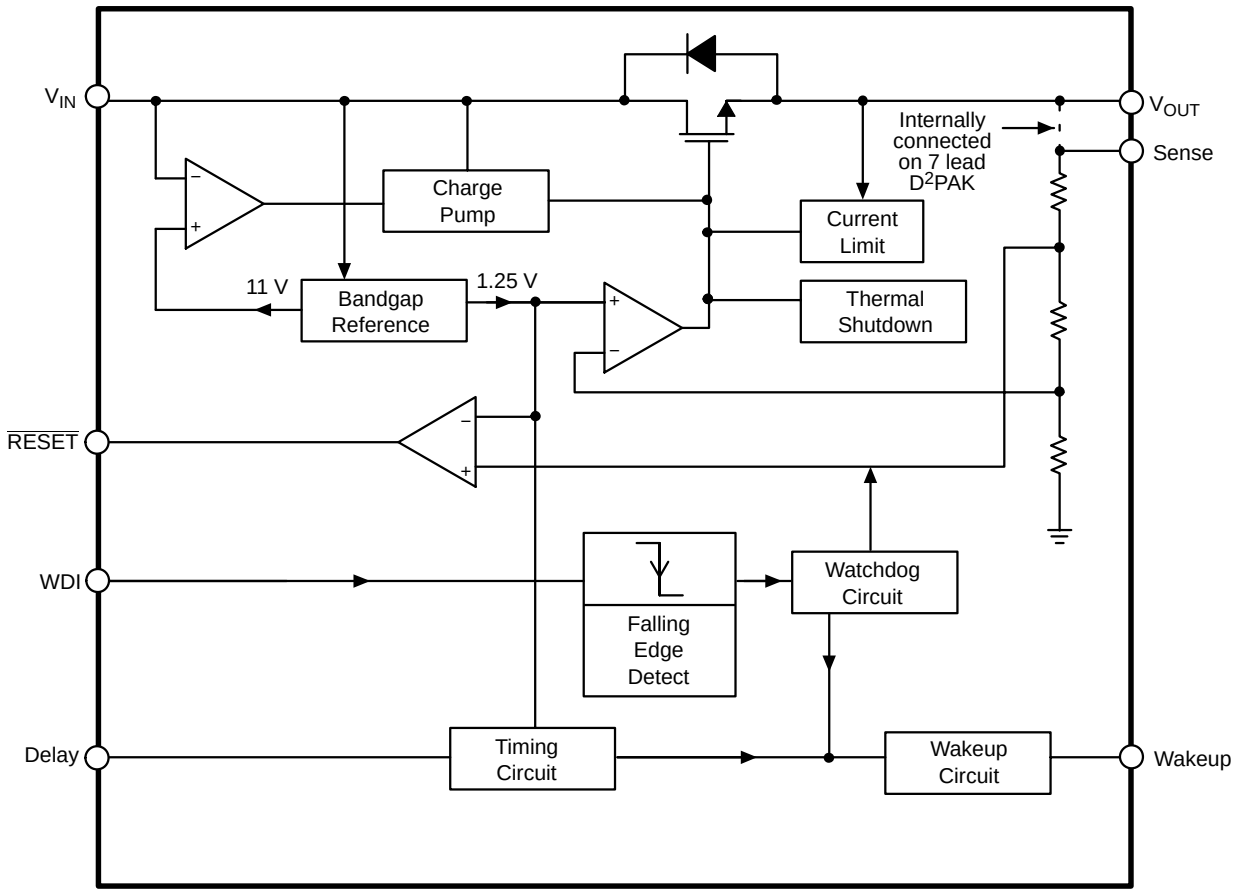



**Figure 2. Block Diagram**

## TIMING DIAGRAMS

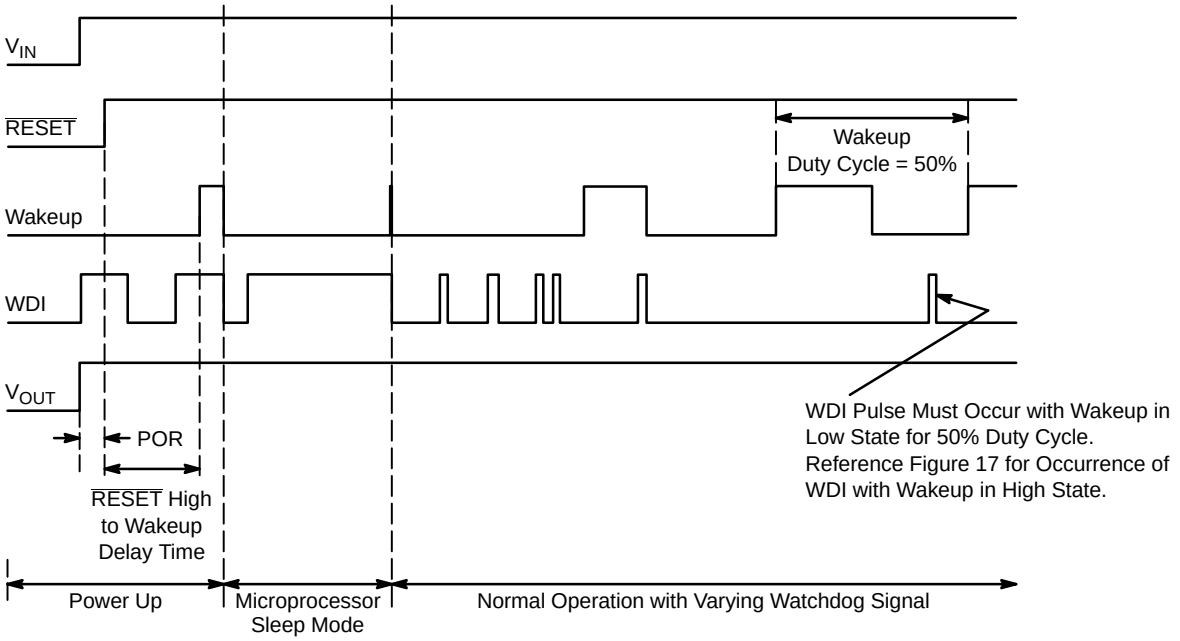



**Figure 3. Power Up, Sleep Mode and Normal Operation**

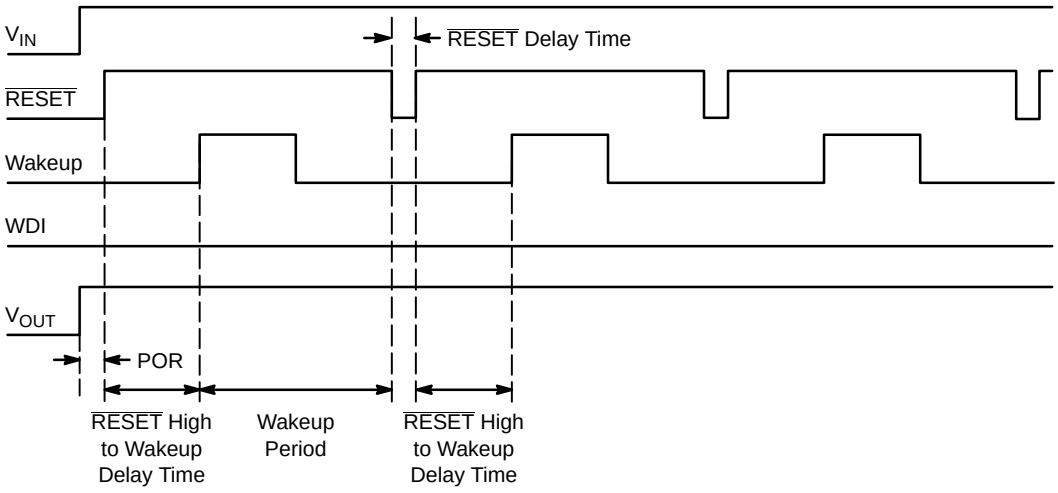



**Figure 4. Error Condition: Watchdog Remains Low and a $\overline{RESET}$ Is Issued**

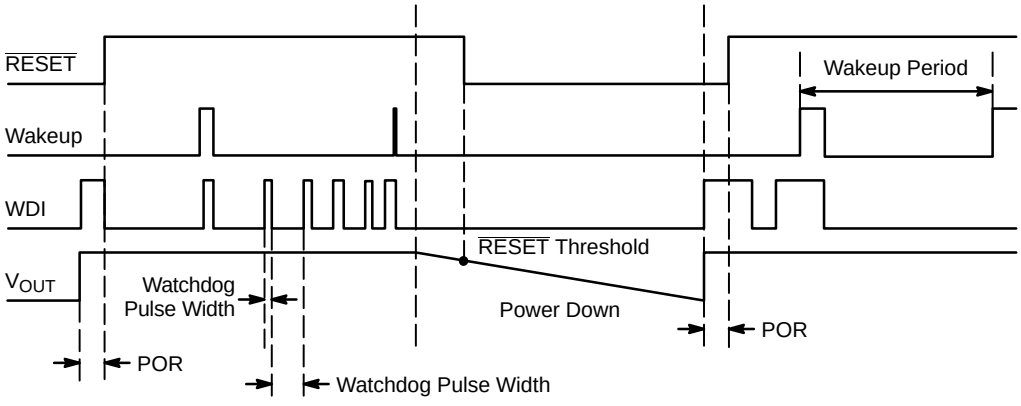



**Figure 5. Power Down and Restart Sequence**

## TYPICAL PERFORMANCE CHARACTERISTICS

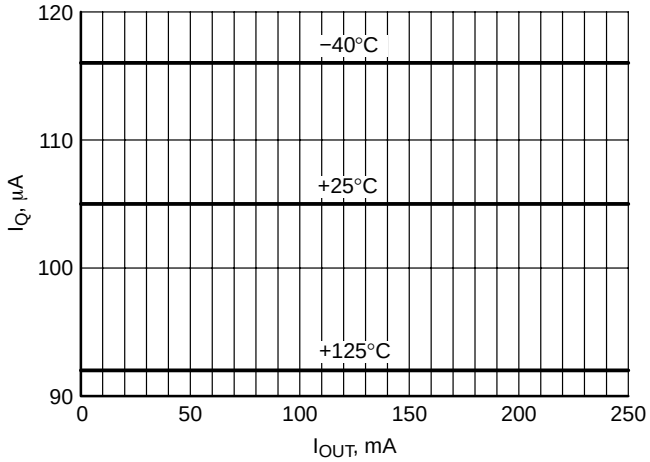



**Figure 6. Quiescent Current vs Output Current**

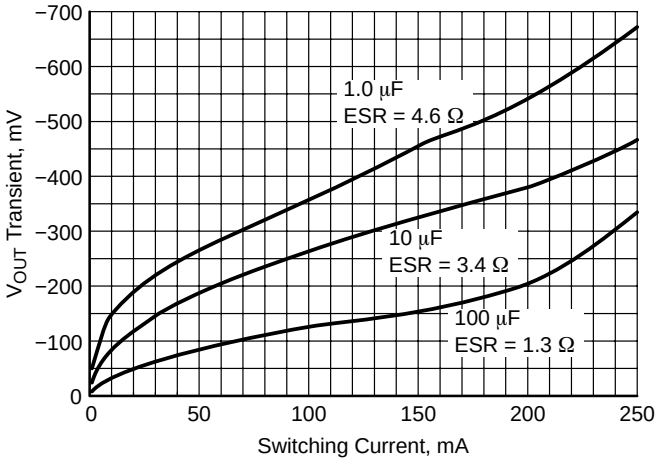



**Figure 7. Load Transient Response**

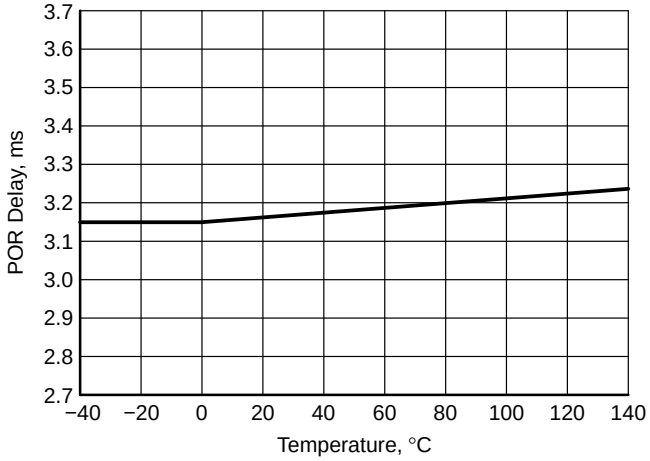



**Figure 8. POR Delay vs Temp, $R_{DELAY}$ = 60 kΩ**

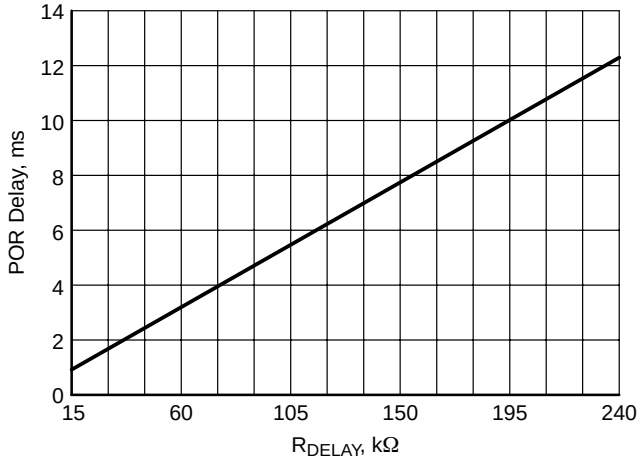



**Figure 9. POR Delay vs $R_{DELAY}$**

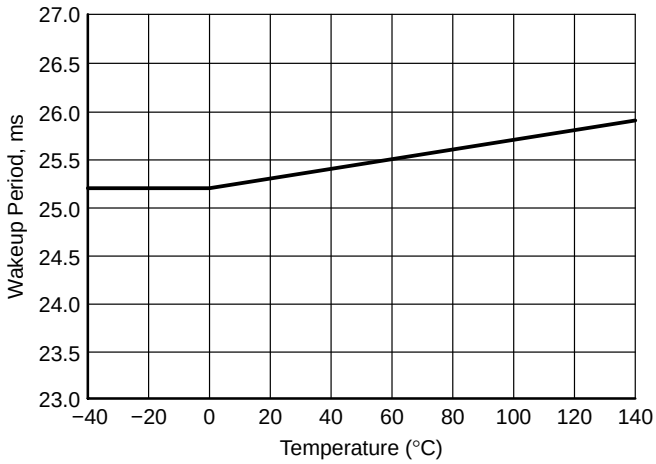



**Figure 10. Wakeup Period vs Temp, $R_{DELAY}$ = 60 kΩ**

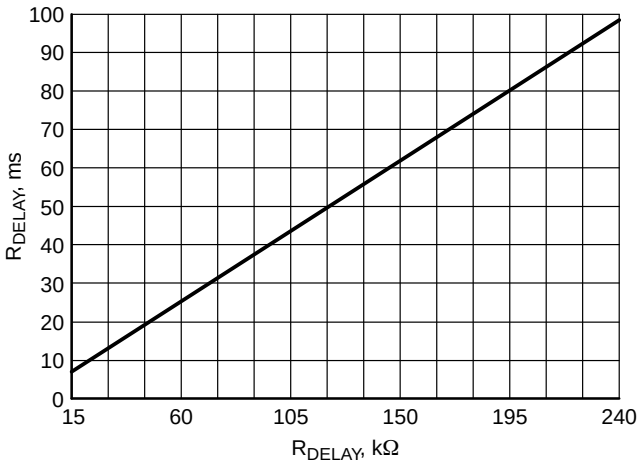



**Figure 11. Wakeup Period vs $R_{DELAY}$**

## TYPICAL PERFORMANCE CHARACTERISTICS

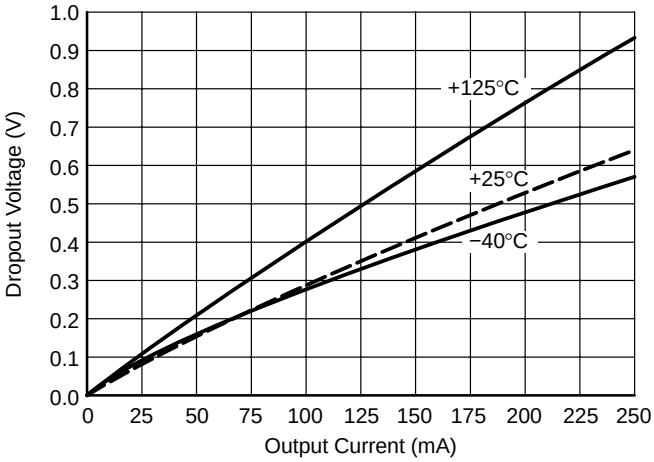



**Figure 12. Dropout Voltage vs Output Current**

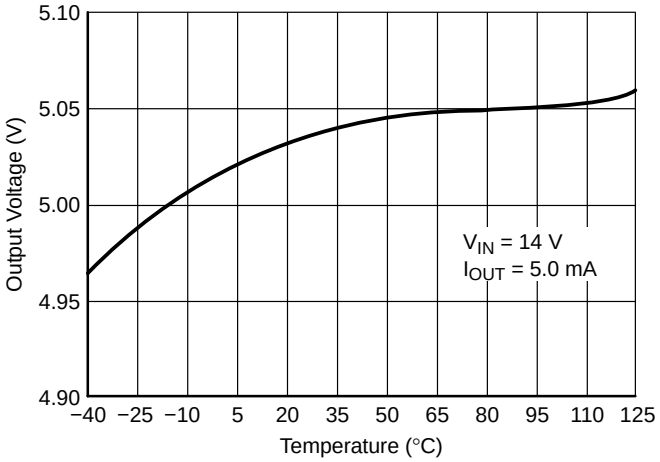



**Figure 13. Output Voltage vs Temperature**

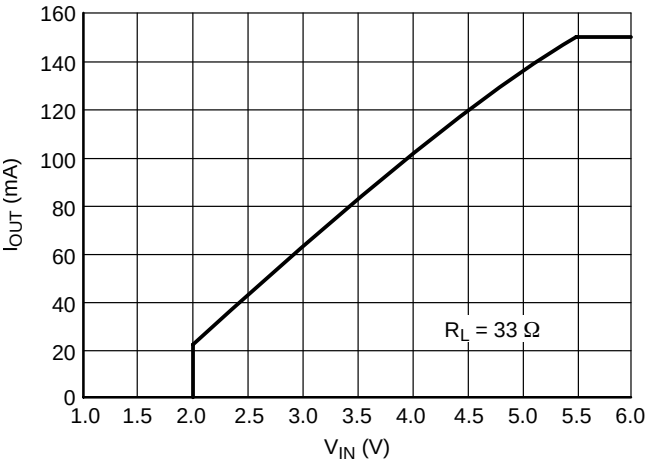



**Figure 14. Output Current vs Input Voltage**

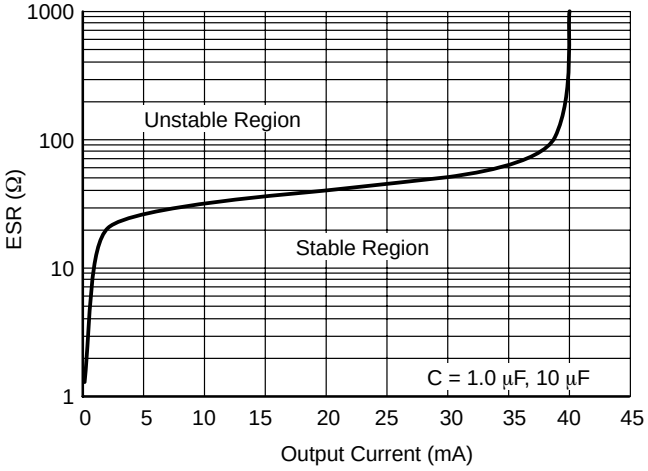



**Figure 15. Output Capacitor ESR**

## DEFINITION OF TERMS

**Dropout Voltage:** The input−output voltage differential at which the circuit ceases to regulate against further reduction in input voltage. Measured when the output voltage has dropped 100 mV from the nominal value obtained at 14 V input, dropout voltage is dependent upon load current and junction temperature.

**Input Voltage:** The DC voltage applied to the input terminals with respect to ground.

**Line Regulation:** The change in output voltage for a change in the input voltage. The measurement is made under conditions of low dissipation or by using pulse techniques such that the average chip temperature is not significantly affected.

**Load Regulation:** The change in output voltage for a change in load current at constant chip temperature.

**Quiescent Current:** The part of the positive input current that does not contribute to the positive load current. The regulator ground lead current.

**Ripple Rejection:** The ratio of the peak−to−peak input ripple voltage to the peak−to−peak output ripple voltage.

**Current Limit:** Peak current that can be delivered to the output.

## DETAILED OPERATING DESCRIPTION

The NCV8508 is a precision micropower voltage regulator with very low quiescent current (100 μA typical at 250 mA load). A typical dropout voltage is 450 mV at 150 mA. Microprocessor control logic includes Watchdog, Wakeup and $\overline{\text{RESET}}$. This unique combination of extremely low quiescent current and full microprocessor control makes the NCV8508 ideal for use in battery operated, microprocessor controlled equipment in addition to being a good fit in the automotive environment.

The NCV8508 Wakeup function brings the microprocessor out of Sleep mode. The microprocessor in turn, signals its Wakeup status back to the NCV8508 by issuing a Watchdog signal.

The Watchdog logic function monitors an input signal (WDI) from the microprocessor. The NCV8508 responds to the falling edge of the Watchdog signal which it expects at least once during each Wakeup period. When the correct Watchdog signal is received, a falling edge is issued on the Wakeup signal line.

$\overline{\text{RESET}}$ is independent of $V_{IN}$ and operates correctly to an output voltage as low as 1.0 V. A signal is issued in any of three situations. During power up the $\overline{\text{RESET}}$ is held low until the output voltage is in regulation. During operation if the output voltage shifts below the regulation limits, the $\overline{\text{RESET}}$ toggles low and remains low until proper output voltage regulation is restored. And finally, a $\overline{\text{RESET}}$ signal is issued if the regulator does not receive a Watchdog signal within the Wakeup period.

The $\overline{\text{RESET}}$ pulse width, Wakeup signal frequency, and Wakeup delay time are all set by one external resistor, $R_{Delay}$.

The Delay pin is a buffered bandgap voltage (1.25 V). It can be used as a reference for an external tracking regulator as shown in Figure 16.

The regulator is protected against short circuit and thermal runaway conditions. The device runs through 45 volt transients, making it suitable for use in automotive environments.

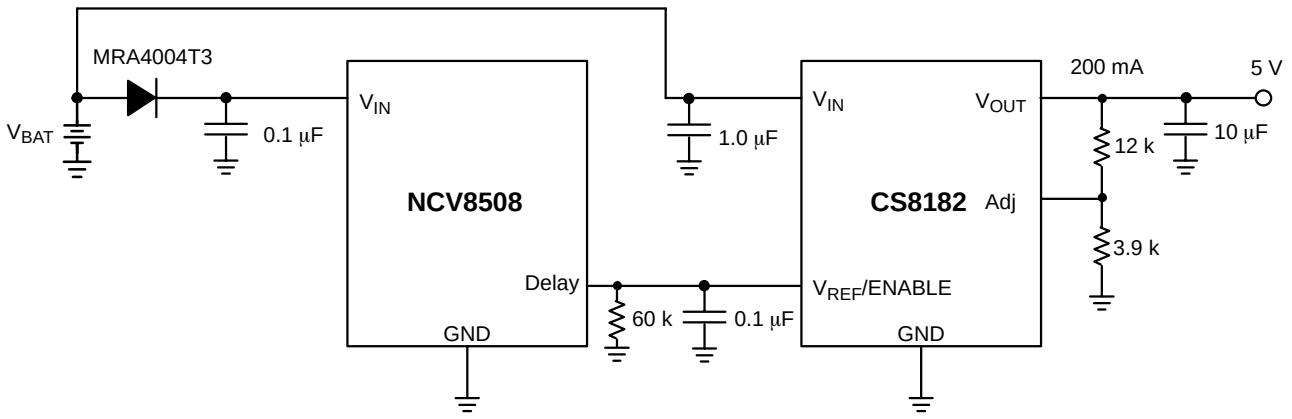



**Figure 16. Application Circuit**

## CIRCUIT DESCRIPTION

### Functional Description

To reduce the drain on the battery a system can go into a low current consumption mode when ever its not performing a main routine. The Wakeup signal is generated continuously and is used to interrupt a microcontroller that is in sleep mode. The nominal output is a 5.0 volt square wave (voltage generated from $V_{OUT}$) with a duty cycle of 50% at a frequency that is determined by a timing resistor, $R_{Delay}$.

When the microprocessor receives a rising edge from the Wakeup output, it must issue a Watchdog pulse and check its inputs to decide if it should resume normal operations or remain in the sleep mode.

The first falling edge of the Watchdog signal causes the Wakeup to go low within 2.0 μs (typ) and remain low until the next Wakeup cycle (see Figure 17). Other Watchdog pulses received within the same cycle are ignored (Figure 3).

During power up, $\overline{\text{RESET}}$ is held low until the output voltage is in regulation. During operation, if the output voltage shifts below the regulation limits, the $\overline{\text{RESET}}$ toggles low and remains low until proper output voltage regulation is restored. After the $\overline{\text{RESET}}$ delay, $\overline{\text{RESET}}$ returns high.

The Watchdog circuitry continuously monitors the input Watchdog signal (WDI) from the microprocessor. The absence of a falling edge on the Watchdog input during one Wakeup cycle will cause a $\overline{\text{RESET}}$ pulse to occur at the end of the Wakeup cycle. (see Figure 4).

The Wakeup output is pulled low during a $\overline{\text{RESET}}$ regardless of the cause of the $\overline{\text{RESET}}$. After the $\overline{\text{RESET}}$ returns high, the Wakeup cycle begins again (see Figure 4).

The $\overline{\text{RESET}}$ Delay Time, Wakeup signal frequency and $\overline{\text{RESET}}$ high to Wakeup delay time are all set by one external resistor $R_{Delay}$.

Wakeup Period = $(4.17 \times 10^{-7})R_{Delay}$

$\overline{\text{RESET}}$ Delay Time = $(5.21 \times 10^{-8})R_{Delay}$

$\overline{\text{RESET}}$ HIGH to Wakeup Delay Time = $(2.08 \times 10^{-7})R_{Delay}$

Resistor temperature coefficient and tolerance as well as the tolerance of the NCV8508 must be taken into account in order to get the correct system tolerance for each parameter.

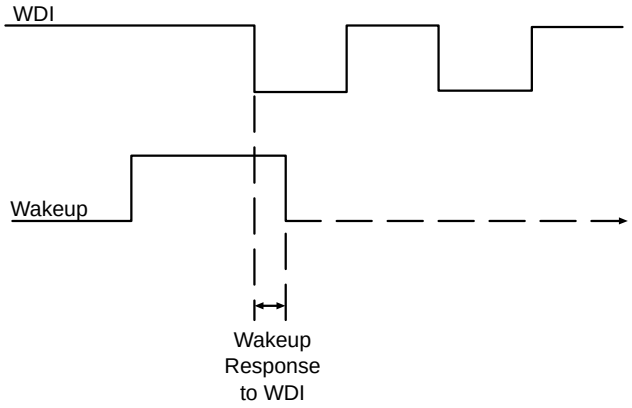



**Figure 17. Wakeup Response to WDI**

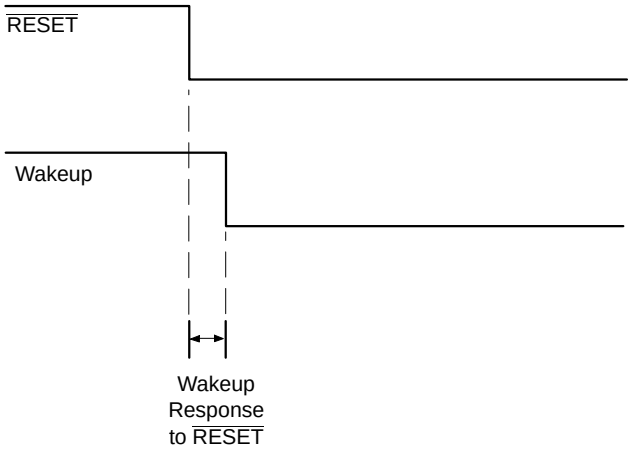



**Figure 18. Wakeup Response to $\overline{\text{RESET}}$ (Low Voltage)**

## APPLICATION NOTES

### Calculating Power Dissipation in a Single Output Linear Regulator

The maximum power dissipation for a single output regulator (Figure 19) is:

$$P_{D(max)} = [V_{IN(max)} - V_{OUT(min)}]I_{OUT(max)} + V_{IN(max)}I_Q \quad (1)$$

where:

$V_{IN(max)}$ is the maximum input voltage,

$V_{OUT(min)}$ is the minimum output voltage,

$I_{OUT(max)}$ is the maximum output current for the application, and

$I_Q$ is the quiescent current the regulator consumes at $I_{OUT(max)}$.

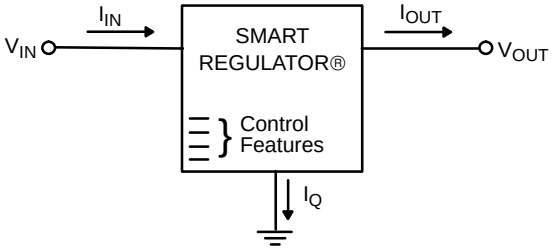



**Figure 19. Single Output Regulator with Key Performance Parameters Labeled**

Once the value of $P_{D(max)}$ is known, the maximum permissible value of $R_{\theta JA}$ can be calculated:

$$R_{\theta JA} = \frac{150^\circ C - T_A}{P_D} \quad (2)$$

The value of $R_{\theta JA}$ can then be compared with those in the package section of the data sheet. Those packages with $R_{\theta JA}$'s less than the calculated value in Equation 2 will keep the die temperature below 150°C.

In some cases, none of the packages will be sufficient to dissipate the heat generated by the IC, and an external heatsink will be required.

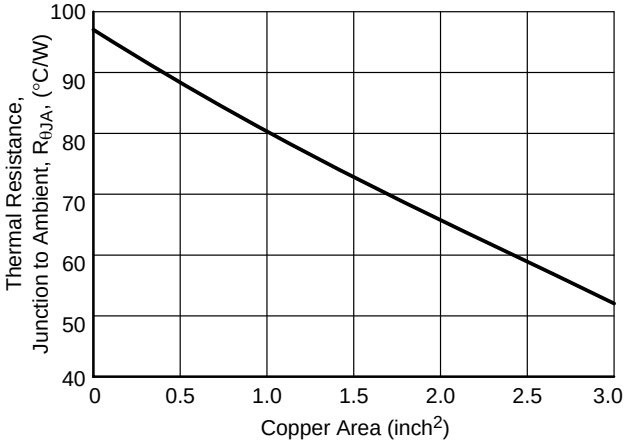



**Figure 20. 16 Lead SOW (4 Leads Fused), θJA as a Function of the Pad Copper Area (2 oz. Cu Thickness), Board Material = 0.0625″ G−10/R−4**

### Heatsinks

A heatsink effectively increases the surface area of the package to improve the flow of heat away from the IC and into the surrounding air.

Each material in the heat flow path between the IC and the outside environment will have a thermal resistance. Like series electrical resistances, these resistances are summed to determine the value of $R_{\theta JA}$:

$$R_{\theta JA} = R_{\theta JC} + R_{\theta CS} + R_{\theta SA} \quad (3)$$

where:

$R_{\theta JC}$ = the junction−to−case thermal resistance,

$R_{\theta CS}$ = the case−to−heatsink thermal resistance, and

$R_{\theta SA}$ = the heatsink−to−ambient thermal resistance.

$R_{\theta JC}$ appears in the package section of the data sheet. Like $R_{\theta JA}$, it too is a function of package type. $R_{\theta CS}$ and $R_{\theta SA}$ are functions of the package type, heatsink and the interface between them. These values appear in heatsink data sheets of heatsink manufacturers.

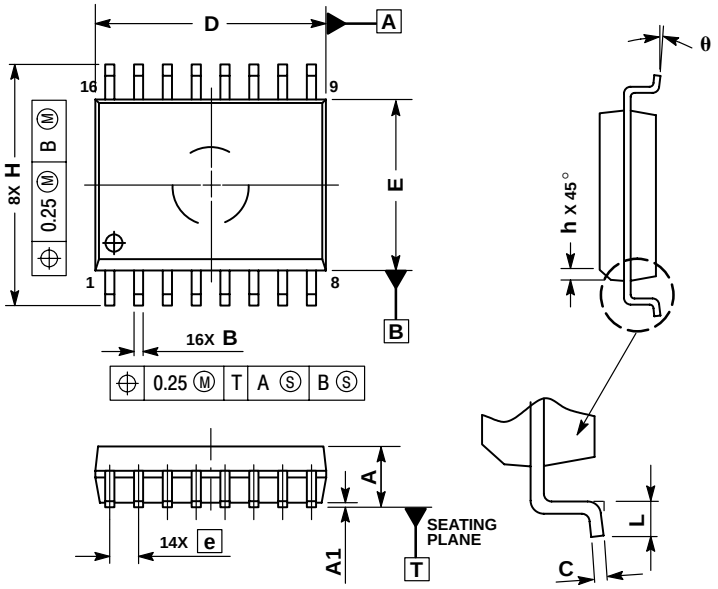
### ORDERING INFORMATION

| Device | Output Voltage | Package | Shipping† |
|---|---|---|---|
| NCV8508DW50 | 5.0 V | SO−16L | 47 Units / Rail |
| NCV8508DW50G | 5.0 V | SO−16L (Pb−Free) | 47 Units / Rail |
| NCV8508DW50R2 | 5.0 V | SO−16L | 1000 / Tape & Reel |
| NCV8508D2T50 | 5.0 V | $D^2$PAK−7 | 50 Units / Rail |
| NCV8508D2T50G | 5.0 V | $D^2$PAK−7 (Pb−Free) | 50 Units / Rail |
| NCV8508D2T50R4 | 5.0 V | $D^2$PAK−7 | 750 / 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.

## PACKAGE DIMENSIONS

**SO−16L**
**DW SUFFIX**
CASE 751G−03
ISSUE C

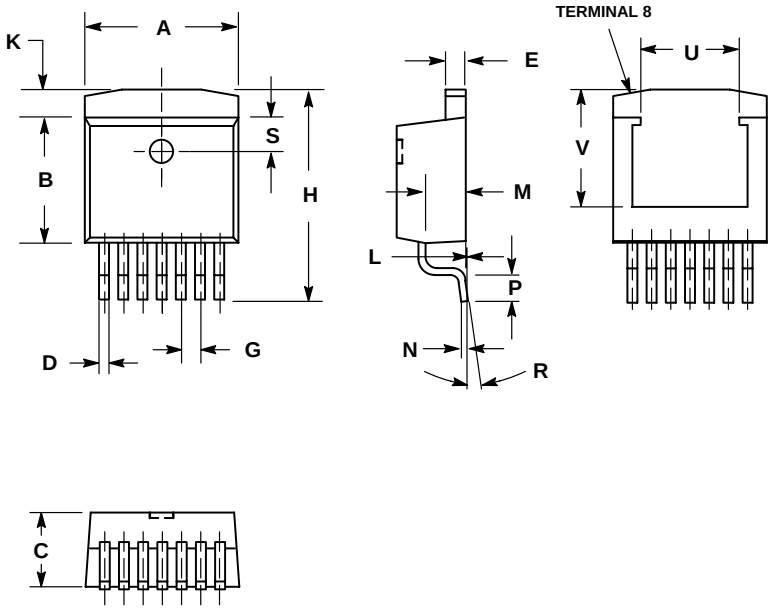



NOTES:
1. DIMENSIONS ARE IN MILLIMETERS.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.
3. DIMENSIONS D AND E DO NOT INLCUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.13 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

| | MILLIMETERS | |
|---|---|---|
| DIM | MIN | MAX |
| A | 2.35 | 2.65 |
| A1 | 0.10 | 0.25 |
| B | 0.35 | 0.49 |
| C | 0.23 | 0.32 |
| D | 10.15 | 10.45 |
| E | 7.40 | 7.60 |
| e | 1.27 BSC | |
| H | 10.05 | 10.55 |
| h | 0.25 | 0.75 |
| L | 0.50 | 0.90 |
| q | 0 ° | 7 ° |

## PACKAGE DIMENSIONS

**D²PAK−7 (SHORT LEAD)**
**DP SUFFIX**
CASE 936AB−01
ISSUE O




NOTES:
1. DIMENSIONS AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 0.396 | 0.406 | 10.05 | 10.31 |
| B | 0.326 | 0.336 | 8.28 | 8.53 |
| C | 0.170 | 0.180 | 4.31 | 4.57 |
| D | 0.026 | 0.036 | 0.66 | 0.91 |
| E | 0.045 | 0.055 | 1.14 | 1.40 |
| G | 0.050 REF | | 1.27 REF | |
| H | 0.539 | 0.579 | 13.69 | 14.71 |
| K | 0.055 | 0.066 | 1.40 | 1.68 |
| L | 0.000 | 0.010 | 0.00 | 0.25 |
| M | 0.100 | 0.110 | 2.54 | 2.79 |
| N | 0.017 | 0.023 | 0.43 | 0.58 |
| P | 0.058 | 0.078 | 1.47 | 1.98 |
| R | 0 ° | 8 ° | 0 ° | 8 ° |
| S | 0.095 | 0.105 | 2.41 | 2.67 |
| U | 0.256 REF | | 6.50 REF | |
| V | 0.305 REF | | 7.75 REF | |



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