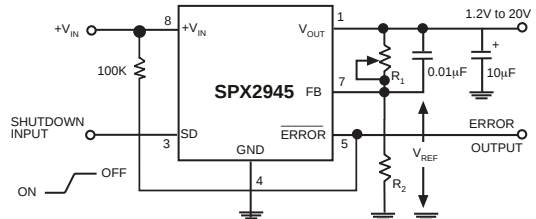


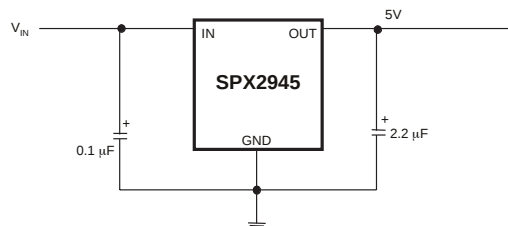
## 400mA Low Dropout Voltage Regulator with Shutdown

### FEATURES

- Output 3.3V, 5.0V at 400mA Output
- Very Low Quiescent Current, 100 $\mu$ A
- Low Dropout Voltage, 420mV at 400mA
- Extremely Tight Load and Line Regulation
- Very Low Temperature Coefficient
- Current & Thermal Limiting
- Error Flag Warns Of Output Dropout
- Logic-Controlled Electronic Shutdown
- Output Programmable From 1.24V to 20V (for SO-8)



*Adjustable Regulator*



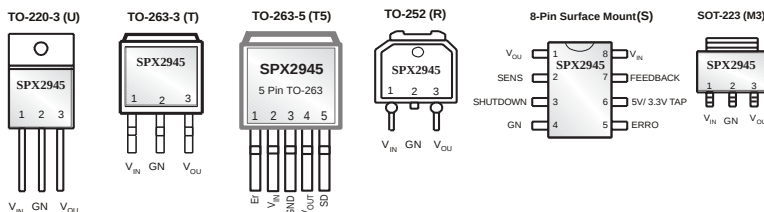
*5V Regulator Circuit*

### DESCRIPTION

The SPX2945 is a low power voltage regulator. This device is an excellent choice for use in battery-powered applications such as cordless telephones, radio control systems, and portable computers. The SPX2945 features very low quiescent current (100 $\mu$ A Typ.) and very low dropout voltage. This includes a tight initial tolerance of 1% max and very low output temperature coefficient, making the SPX2945 useful as a low-power voltage reference.

The error flag output feature is used as power-on reset for warning of a low output voltage, due to a falling voltage input of batteries. Another feature is the logic-compatible shutdown input which enables the regulator to be switched on and off. The SPX2945 is offered in 3-pin TO-220 package, SO-8 (same pin out as SPX2951), SOT-223, surface mount 3-Pin TO-252, 3-Pin TO-263 packages and 5-Pin TO-263.

The regulator output voltage (of the 8-pin SO-8) may be pin-strapped for a 3.3V and 5.0V or programmed from 1.24V to 20V with an external pair of resistors. Look for SPX2951 for 150mA and SPX2954 for 250mA applications.



## ABSOLUTE MAXIMUM RATINGS

Power Dissipation ..... Internally Limited  
 Lead Temp. (Soldering, 5 Seconds) ..... 260°C  
 Storage Temperature Range ..... -65°C to +150°C  
 Operating Junction Temperature Range ..... -40°C to +125°C  
 Input Supply Voltage ..... -20V to +26V

Feedback Input Voltage ..... -1.5V to +26V  
 Shutdown Input Voltage ..... -0.3V to +26V  
 Error Comparator Output ..... -0.3V to +26V  
 ESD Rating ..... 2kV Min

## ELECTRICAL CHARACTERISTICS

Electrical characteristics at  $V_{IN} = V_O + 1V$ ,  $I_O = 1mA$ ,  $C_{OUT} = 2.2\mu F$ ,  $T_A = 25^\circ C$ , unless otherwise specified. The ♦ denotes the specifications which apply over full operating temperature range -40°C to +85°C, unless noted.

| PARAMETER                                      | CONDITIONS<br>(Note 2)                                                     | MIN            | TYP                    | MAX                                         |                              | UNITS             |
|------------------------------------------------|----------------------------------------------------------------------------|----------------|------------------------|---------------------------------------------|------------------------------|-------------------|
| <b>3.3V Version</b>                            |                                                                            |                |                        |                                             |                              |                   |
| Output Voltage                                 | $1mA \leq I_L \leq 400mA$                                                  | 3.267<br>3.217 | 3.3<br>3.3             | 3.333<br>3.382                              | ♦                            | V                 |
| <b>5.0V Version</b>                            |                                                                            |                |                        |                                             |                              |                   |
| Output Voltage                                 | $1mA \leq I_L \leq 400mA$                                                  | 4.950<br>4.880 | 5.0<br>5.0             | 5.050<br>5.120                              | ♦                            | V                 |
| <b>All Voltage Options</b>                     |                                                                            |                |                        |                                             |                              |                   |
| Output Voltage<br>Temperature Coefficient      | (Note1)                                                                    | 20             |                        | 100                                         | ♦                            | ppm/°C            |
| Line Regulation (Note 3)                       | $6V \leq V_{IN} \leq 20V$ (Note 4)                                         |                | 1.5                    | 20                                          | ♦                            | mV                |
| Load Regulation (Note 3)                       | $I_L = 1$ to 400mA                                                         |                | 6                      | 20<br>30                                    | ♦                            | mV                |
| Dropout Voltage (Note5)                        | $I_L = 1mA$<br><br>$I_L = 400mA$                                           |                | 60<br><br>360          | 100<br>150<br>450<br>700                    | ♦<br><br>♦                   | mV                |
| Ground Current                                 | $I_L = 1mA$<br><br>$I_L = 150mA$<br><br>$I_L = 300mA$<br><br>$I_L = 400mA$ |                | 100<br><br>2<br>4<br>8 | 200<br>300<br>4<br>6<br>8<br>12<br>15<br>25 | ♦<br><br>♦<br><br>♦<br><br>♦ | μA<br><br>mA      |
| Current Limit                                  | $V_{OUT} = 0$                                                              |                | 330                    | 800                                         | ♦                            | mA                |
| Thermal Regulation                             |                                                                            |                | 0.05                   | 0.2                                         |                              | %/W               |
| Output Noise, 10Hz to 100kHz,<br>$I_L = 100mA$ | $C_L = 2.2\mu F$<br>$C_L = 33\mu F$                                        |                | 400<br>260             |                                             |                              | μV <sub>RMS</sub> |
| PSRR at 100KHz<br>$I_L = 100mA$                | $C_L = 10\mu F$                                                            |                | 31                     |                                             |                              | dB                |
| <b>Adjustable 8 Pin Version only</b>           |                                                                            |                |                        |                                             |                              |                   |
| Reference Voltage                              |                                                                            | 1.210          | 1.235                  | 1.260                                       |                              | V                 |
| Reference Voltage                              | Over Temperature                                                           | 1.185          |                        | 1.285                                       |                              | V                 |
| Feedback Pin Bias Current                      |                                                                            |                | 20                     | 40<br>60                                    | ♦                            | nA                |
| Reference Voltage Temp.<br>Coefficient         |                                                                            |                | 20                     |                                             |                              | ppm/°C            |

## ELECTRICAL CHARACTERISTICS: Continued

Electrical characteristics at  $V_{IN} = V_O + 1V$ ,  $I_O = 1mA$ ,  $C_{OUT} = 2.2\mu F$ ,  $T_A = 25^\circ C$ , unless otherwise specified. ♦ applies over the full operating temperature range.

| PARAMETER                                            | CONDITIONS<br>(Note 2)                     | MIN      | TYP           | MAX                     | ♦               | UNITS   |
|------------------------------------------------------|--------------------------------------------|----------|---------------|-------------------------|-----------------|---------|
| Feedback Pin Bias Current<br>Temperature Coefficient |                                            |          | 0.1           |                         |                 | nA/°C   |
| Output Leakage Current                               | $V_{OH}=20V$                               |          | 0.01          | 1<br>2                  | ♦               | $\mu A$ |
| Output Low Voltage                                   | $V_{IN}=4.5V$<br>$I_{OL}=400\mu A$         |          | 150           | 250<br>400              | ♦               | mV      |
| Upper Threshold Voltage                              | (Note 6)                                   | 40<br>25 | 60            |                         |                 | mV      |
| Lower Threshold Voltage                              | (Note 6)                                   |          | 75            | 95<br>140               | ♦               | mV      |
| Hysteresis                                           | (Note 6)                                   |          | 15            |                         |                 | mV      |
| Input Logic Voltage                                  | Low (Regulator ON)<br>High (Regulator OFF) |          | 1.3           | 0.7<br>2.0              | ♦<br>♦          | V       |
| Shutdown Pin Input Current                           | $V_S=2.4V$<br><br>$V_S=26V$                |          | 30<br><br>450 | 50<br>100<br>600<br>750 | ♦<br><br>♦<br>♦ | $\mu A$ |
| Regulator Output Current<br>in Shutdown              | (Note 7)                                   | 10<br>20 | 3             |                         | ♦               | $\mu A$ |

**Note 1:** Output or reference voltage temperature coefficients defined as the worst case voltage change divided by the total temperature range.

**Note 2:** Unless otherwise specified all limits are guaranteed for  $T_J = 25^\circ C$ ,  $V_{IN} = 6V$ ,  $I_L = 1mA$  and  $C_L = 2.2\mu F$ . Additional conditions for the 8-pin versions are feedback tied to 5V/3.3V tap and output tied to output sense ( $V_{OUT} = 5V$ ) and  $V_{SHUTDOWN} \leq 0.8V$ .

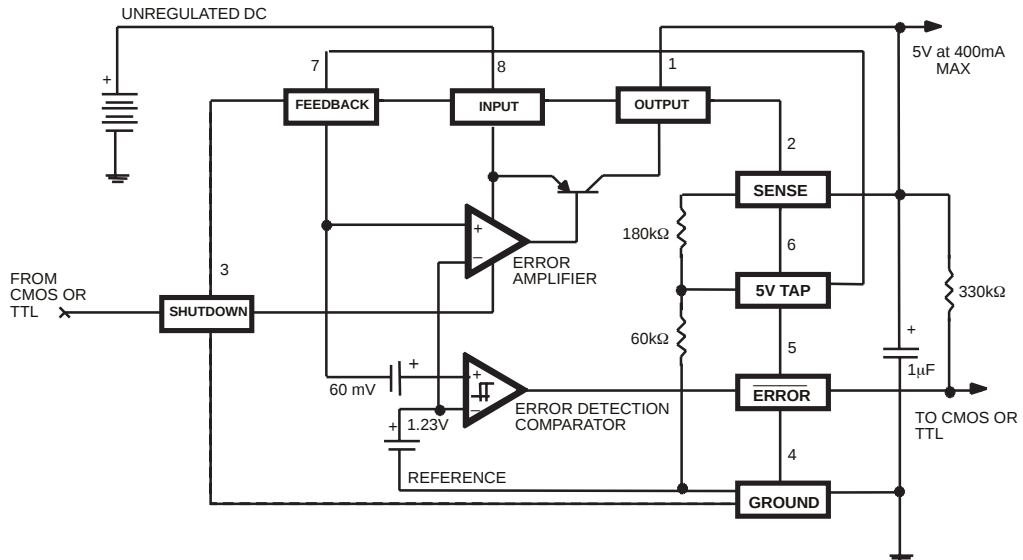
**Note 3:** Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

**Note 4:** Line regulation for the SPX2945 is tested at  $150^\circ C$  for  $I_L = 1mA$ . For  $T_J = 125^\circ C$ , line regulation is guaranteed by design.

**Note 5:** Dropout voltage is defined as the input to output differential at which the output voltage drops 100 mV below its nominal value measured at 1V differential at very low values of programmed output voltage, the minimum input supply voltage of 2V ( 2.3V over temperature) must be taken into account.

**Note 6:** Comparator thresholds are expressed in terms of a voltage differential at the feedback terminal below the nominal reference voltage measured at 6V input. To express these thresholds in terms of output voltage change, multiply by the error amplifier gain  $= V_{OUT}/V_{REF} = (R1 + R2)/R2$ . For example, at a programmed output voltage of 5V, the Error output is guaranteed to go low when the output drops by  $95mV \times 5V/1.235 = 384mV$ . Thresholds remain constant as a percent of  $V_{OUT}$  as  $V_{OUT}$  is varied, with the dropout warning occurring at typically 5% below nominal, 7.5% guaranteed.

**Note 7:**  $V_{SHUTDOWN} \geq 2V$ ,  $V_{IN} \leq 26V$ ,  $V_{OUT} = 0$ , Feedback pin tied to 5V/3.3V Tap.



## APPLICATION INFORMATION

### External Capacitors

The stability of the SPX2945 requires a 2.2μF or greater capacitor between output and ground. Oscillation could occur without this capacitor. Most types of tantalum or aluminum electrolytic works fine here. For operations of below -25°C solid tantalum is recommended since the many aluminum types have electrolytes that freeze at about -30°C. The ESR of about 5Ω or less and resonant frequency above 500kHz are the most important parameters in the value of the capacitor. The capacitor value can be increased without limit.

At lower values of output current, less output capacitance is required for stability. For the currents below 10mA the value of the capacitor can be reduced to 0.5μF and 0.15μF for 1mA. More output capacitance needed for the 8-pin version at voltages below 5V since it runs the error amplifier at lower gain. At worst case 4.7μF or greater must be used for the condition of 250mA load at 1.23V output.

The SPX2945, unlike other low dropout regulators will remain stable and in regulation with no load in addition to the internal voltage divider. This feature is especially important in applications like CMOS RAM keep-alive.

If there is more than 10 inches of wire between the input and the AC filter capacitor, or if a battery is used as the input, then a 0.1μF tantalum or aluminum electrolytic capacitor should be placed from the input to the ground.

Instability can occur if there is stray capacitance to the SPX2945 feedback terminal (pin 7). This could cause more problems when using a higher value of external resistors to set the output voltage.

This problem can be fixed by adding a 100pF capacitor between output and feedback and increasing the output capacitor to at least 3.3μF.

## Error Detection Comparator Output

The Comparator produces a logic low output whenever the SPX2945 output falls out of regulation by more than around 5%. This is around 60mV offset divided by the 1.235 reference voltage. This trip level remains 5% below normal regardless of the programmed output voltage of the regulator. Figure 1 shows the timing diagram depicting the ERROR signal and the regulator output voltage as the SPX2945 input is ramped up and down. The ERROR signal becomes low at around 1.3V input, and goes high around 5V input (input voltage at which  $V_{OUT} = 4.75$ ). Since the SPX2945's dropout voltage is load dependent, the input voltage trip point (around 5V) will vary with the load current. The output voltage trip point (approx. 4.75V) does not vary with load.

The error comparator has an open-collector output, which requires an external pull-up resistor. Depending on the system requirements the resistor may be returned to 5V output or other supply voltage. In determining the value of this resistor, note that the output is rated to sink 400 $\mu$ A; this value adds to battery drain in a low battery condition. Suggested values range from 100K to 1M $\Omega$ . If the output is unused this resistor is not required.

## Programming the Output Voltage of SPX2945

The SPX2945 may be pin-strapped for 5V or 3.3V using its internal voltage divider by tying Pin 1 (output) to Pin 2 (sense) and Pin 7 (feedback) to Pin 6 (5V/3.3V Tap).

Also, it may be programmed for any output voltage between its 1.235V reference and its 20V maximum rating. As seen in Figure 2, an external pair of resistors is required.

Refer to the below equation for the programming of the output voltage::

$$V_{OUT} = V_{REF} \times (1 + R_1/R_2) + I_{FB}R_1$$

The  $V_{REF}$  is 1.235 and  $I_{FB}$  is the feedback bias current, nominally -20nA. The minimum recommended load current of 1  $\mu$ A forces an upper limit of 1.2 M $\Omega$  on value of  $R_2$ . If no load is presented the  $I_{FB}$  produces an error of typically

2% in  $V_{OUT}$ , which may be eliminated at room temperature by trimming  $R_1$ . To improve the accuracy choose the value of  $R_2 = 100k$ ; this reduces the error by 0.17% and increases the resistor program current by 12 $\mu$ A. Since the SPX2945 typically draws 60  $\mu$ A at no load with Pin 2 open-circuited this is a small price to pay.

## Reducing Output Noise

It may be an advantage to reduce the AC noise present at the output. One way is to reduce the regulator bandwidth by increasing the size of the output capacitor. This is the only way that noise can be reduced on the 3 lead SPX2945 but is relatively inefficient, as increasing the capacitor from 1 $\mu$ F to 220 $\mu$ F only decreases the noise from 430 $\mu$ V to 160 $\mu$ V Vrms for a 100kHz bandwidth at 5V output. Noise could also be reduced fourfold by a bypass capacitor across  $R_1$ , since it reduces the high frequency gain from 4 to unity. Pick

$$C_{BYPASS} \approx 1 / 2\pi R_1 \times 200 \text{ Hz}$$

or choose 0.01 $\mu$ F. When doing this, the output capacitor must be increased to 3.3 $\mu$ F to maintain stability. These changes reduce the output noise from 430 $\mu$ V to 100 $\mu$ V Vrms for a 100kHz bandwidth at 5V output. With the bypass capacitor added, noise no longer scales with output voltage so that improvements are more dramatic at higher output voltages.

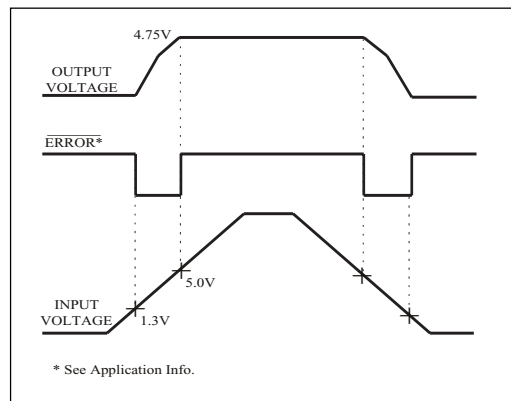
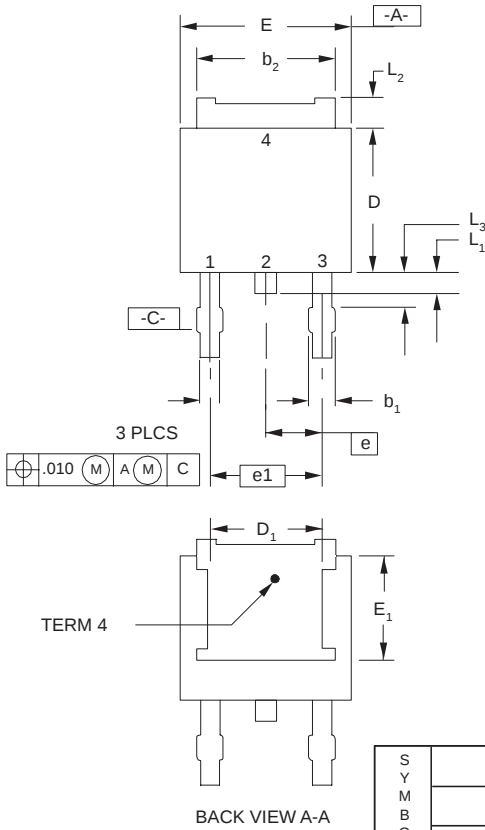
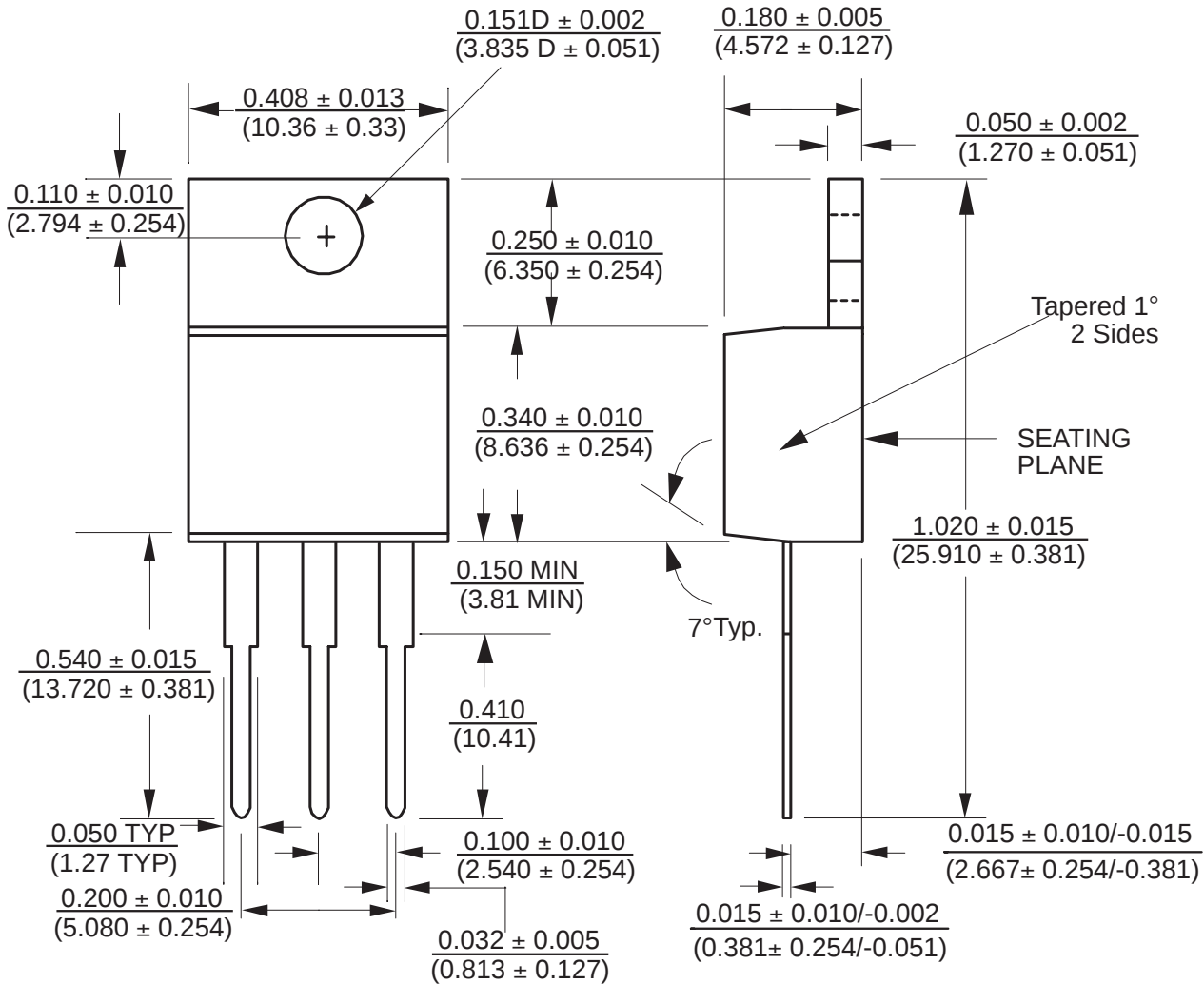


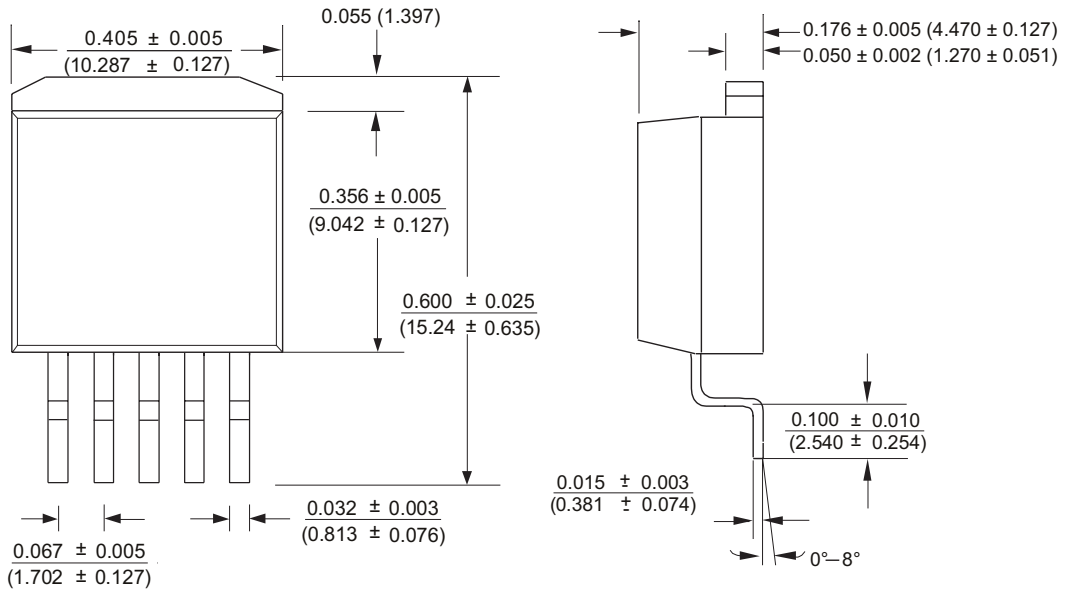
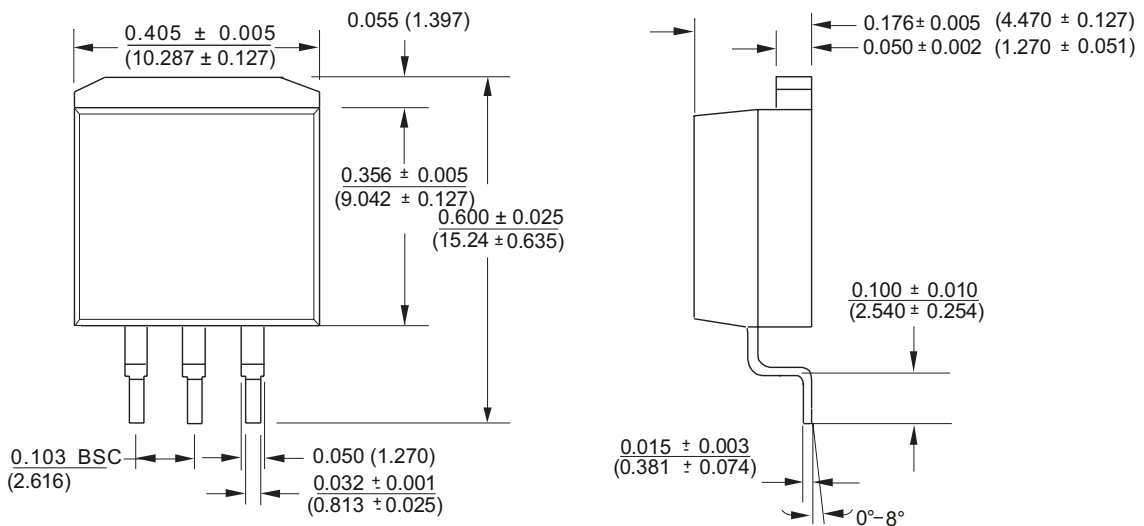
Figure 1. ERROR Output Timing

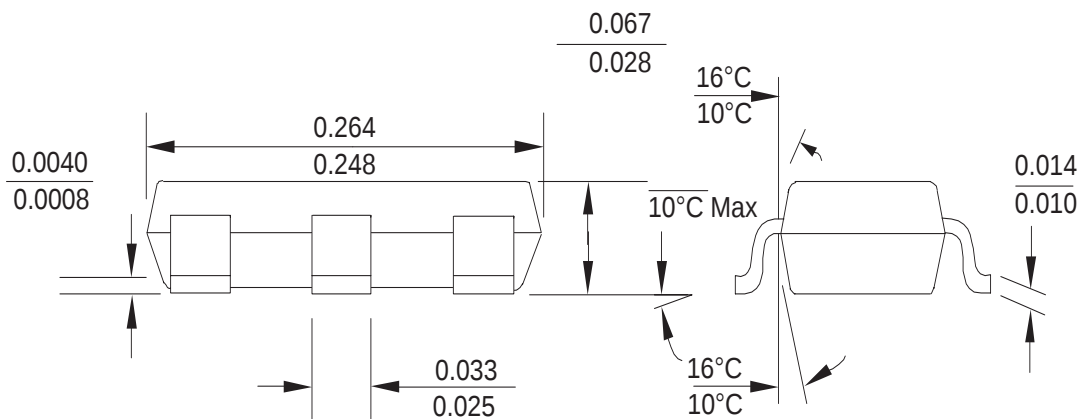
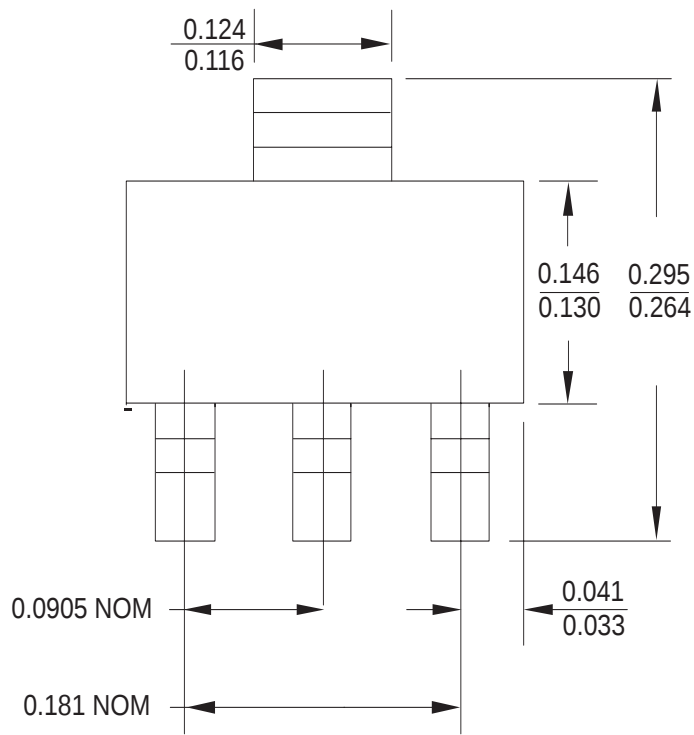

**NOTES**

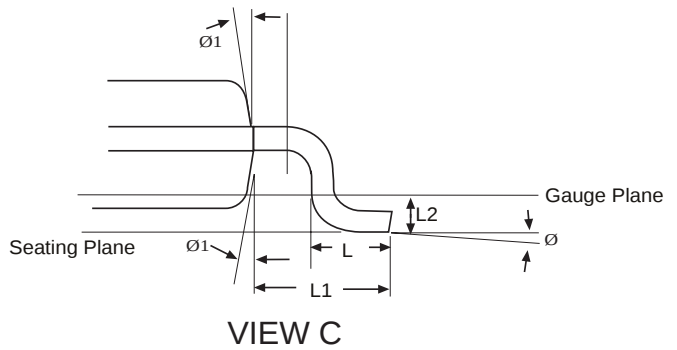
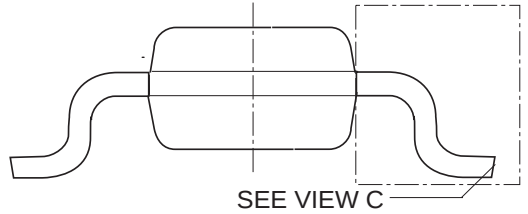
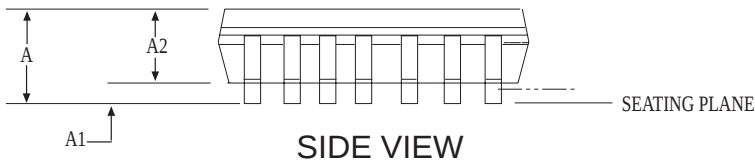
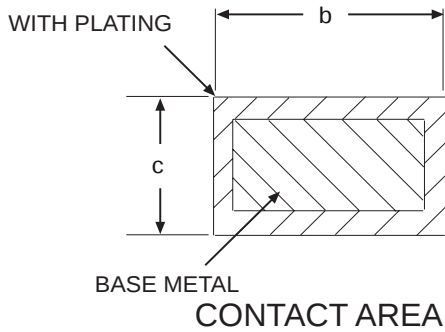
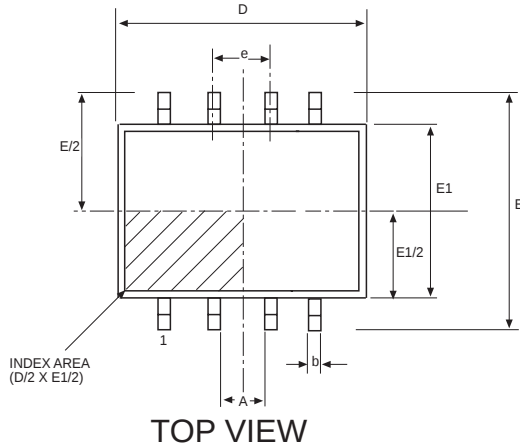
1. Refer To Applicable Symbol List.
2. Dimensions And Tolerancing Per Ansi Y14.5m - 1982.
3. Lead Dimension Uncontrolled in L<sub>3</sub>
4. Tab Contour Optional Within Dim. b<sub>2</sub> & L<sub>2</sub> And E<sub>1</sub> & D<sub>1</sub>
5. D<sub>1</sub> & E<sub>1</sub> Establishes A Minimum Mounting Surface for Terminal 4.
6. L is the Termal Length for Soldering.
7. Controlling Dimension: Inch
8. 2 Mils Suggested For Postive Contact At Mounting.

| S<br>Y<br>M<br>B<br>O<br>L | INCHES |       | MM    |        | N<br>O<br>T<br>E |
|----------------------------|--------|-------|-------|--------|------------------|
|                            | MIN.   | MAX   | MIN.  | MAX    |                  |
|                            |        |       |       |        |                  |
| A                          | 0.086  | 0.094 | 2.184 | 2.3876 |                  |
| A1                         | 0.035  | 0.045 | 0.889 | 1.143  |                  |
| b                          | 0.025  | 0.035 | 0.635 | 0.889  |                  |
| b1                         | 0.300  | 0.045 | 7.620 | 1.143  |                  |
| b2                         | 0.205  | 0.215 | 5.207 | 5.461  | 4                |
| c                          | 0.018  | 0.023 | 0.457 | 0.5842 |                  |
| c1                         | 0.018  | 0.023 | 0.457 | 0.5842 |                  |
| D                          | 0.235  | 0.245 | 5.969 | 6.223  |                  |
| D1                         | 0.170  | -     | 4.318 | -      | 4,5              |
| E                          | 0.250  | 0.265 | 6.350 | 6.731  |                  |
| E1                         | 0.170  | -     | 4.318 | -      | 4,5              |
| e                          |        | 0.098 |       | 2.489  |                  |
| e1                         |        | 0.180 |       | 4.572  |                  |
| H                          | 0.370  | 0.410 | 9.398 | 10.414 |                  |
| L                          | 0.020  | -     | 0.508 | -      | 6                |
| L1                         | 0.025  | 0.040 | 0.635 | 1.016  |                  |
| L2                         | 0.035  | 0.050 | 0.889 | 1.270  | 4                |
| L3                         | 0.045  | 0.060 | 1.143 | 1.524  | 3                |




**PACKAGE: 3 PIN TO-263**






| DIMENSIONS<br>Minimum/Maximum<br>(mm) |          | 8 Pin NSOIC<br>(JEDEC MS-012,<br>AA - VARIATION) |      |  |
|---------------------------------------|----------|--------------------------------------------------|------|--|
| COMMON HEIGHT DIMENSION               |          |                                                  |      |  |
| SYMBOL                                | MIN      | NOM                                              | MAX  |  |
| A                                     | 1.35     | -                                                | 1.75 |  |
| A1                                    | 0.10     | -                                                | 0.25 |  |
| A2                                    | 1.25     | -                                                | 1.65 |  |
| b                                     | 0.31     | -                                                | 0.51 |  |
| c                                     | 0.17     | -                                                | 0.25 |  |
| D                                     | 4.90 BSC |                                                  |      |  |
| E                                     | 6.00 BSC |                                                  |      |  |
| E1                                    | 3.90 BSC |                                                  |      |  |
| e                                     | 1.27 BSC |                                                  |      |  |
| L                                     | 0.40     | -                                                | 1.27 |  |
| L1                                    | 1.04 REF |                                                  |      |  |
| L2                                    | 0.25 BSC |                                                  |      |  |
| Ø                                     | 0°       | -                                                | 8°   |  |
| Ø1                                    | 5°       | -                                                | 15°  |  |

## 8 PIN NSOIC

| Ordering No.  | Top Mark            | Accuracy | Output Voltage | Packages      |
|---------------|---------------------|----------|----------------|---------------|
| SPX2945M3-3.3 | 2945M3<br>33YYWW    | 1%       | 3.3V           | 3-Pin SOT-223 |
| SPX2945M3-5.0 | 2945M3<br>50YYWW    | 1%       | 5.0V           | 3-Pin SOT-223 |
| SPX2945S-3.3  | 2945S33<br>33YYWW   | 1%       | 3.3V           | 8-Pin SOIC    |
| SPX2945S-5.0  | SPX2945R<br>50YYWW  | 1%       | 5.0V           | 8-Pin SOIC    |
| SPX2945R-3.3  | SPX2945R<br>504YYWW | 1%       | 3.3V           | 3-Pin TO-252  |
| SPX2945R-5.0  | SPX2945R<br>YYWW    | 1%       | 5.0V           | 3-Pin TO-252  |
| SPX2945T-3.3  | SPX2945T<br>33YYWW  | 1%       | 3.3V           | 3-Pin TO-263  |
| SPX2945T-5.0  | SPX2945T5<br>50YYWW | 1%       | 5.0V           | 3-Pin TO-263  |
| SPX2945T5-3.3 | SPX2945T5<br>33YYWW | 1%       | 3.3V           | 5-Pin TO-263  |
| SPX2945T5-5.0 | SPX2945T<br>50YYWW  | 1%       | 5.0V           | 5-Pin TO-263  |
| SPX2945U-3.3  | SPX2945U<br>33YYWW  | 1%       | 3.3V           | 3-Pin TO-220  |
| SPX2945U-5.0  | SPX2945U<br>50YYWW  | 1%       | 5.0V           | 3-Pin TO-220  |



ANALOG EXCELLENCE

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