## DESCRIPTION

The RZC2013 is a monolithic synchronous buck regulator. The device integrates two 130mR MOSFETs, and provides 2A of continuous load current over a wide input voltage of 4.75V to 27V. Current mode control provides fast transient response and cycle-by-cycle current limit.

An adjustable soft-start prevents inrush current at turn-on, and in shutdown mode the supply current drops to 1µA.

This device, available in SOP-8 and ESOP-8 package, provides a very compact solution with minimal external components.

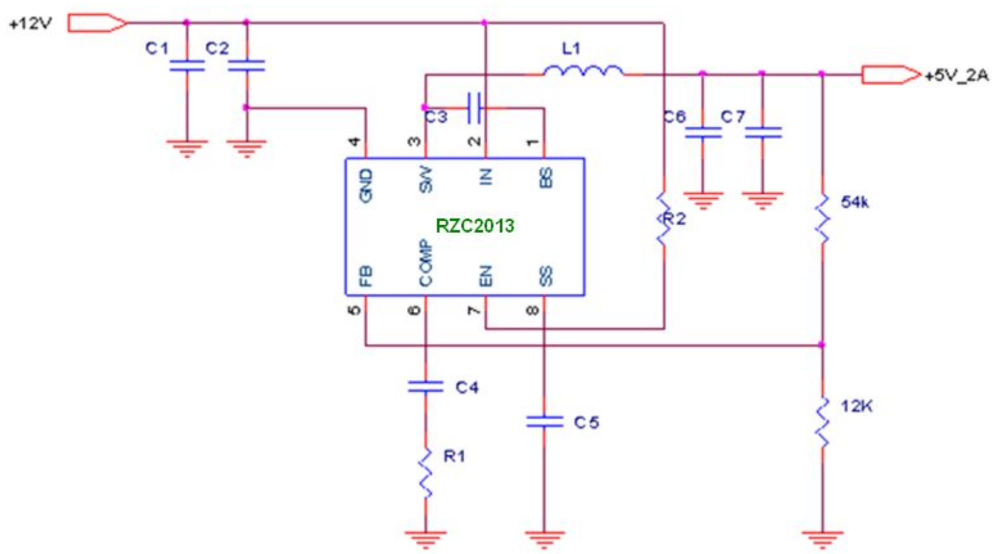
## APPLICATIONS

- Distributed Power Systems
- Networking Systems
- FPGA, DSP, ASIC Power Supplies
- Green Electronics/ Appliances
- Notebook Computers

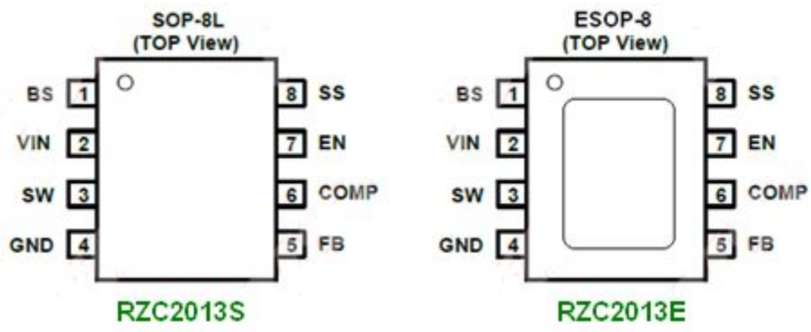
## FEATURES

- 2A Output Current
- Wide 4.75V to 27V Operating Voltage
- Integrated 130mΩ Power MOSFET Switches
- Output Adjustable from 0.925V to $0.8V_{IN}$
- Up to 93% Efficiency
- Programmable Soft-Start
- Stable with Low ESR Ceramic Output Capacitors
- Fixed 340kHz Frequency
- Cycle-by-Cycle Over Current Protection
- Input Under Voltage Lockout
- SOP-8 and ESOP-8 Package

## TYPICAL APPLICATION



## PACKAGE REFERENCE




Note: S:SOP-8;E:ESOP-8;

## PIN FUNCTIONS

| PIN NO. | Name | Description |
|---|---|---|
| 1 | BS | High-Side Gate Drive Boost Input. BS supplies the drive for the high-side N-Channel MOSFET switch. Connect a 0.01µF or greater capacitor from SW to BS to power the high side switch. |
| 2 | IN | Power Input. Drive IN with a 4.75V to 27V power source. Bypass IN to GND with a suitably large capacitor to eliminate noise on the input to the IC. |
| 3 | SW | Power Switching Output. SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load. |
| 4 | GND | Ground. |
| 5 | FB | Feedback Input. FB senses the output voltage to regulate that voltage. Drive FB with a resistive voltage divider from the output voltage. The feedback threshold is 0.925V. |
| 6 | COMP | Compensation Node. COMP is used to compensate the regulation control loop. Connect a series RC network from COMP to GND to compensate the regulation control loop. In some cases, an additional capacitor from COMP to GND is required. |
| 7 | EN | Enable Input. EN is a digital input that turns the regulator on or off. Drive EN high to turn on the regulator, drive it low to turn it off. Pull up with 100kΩ resistor for automatic startup. |
| 8 | SS | Soft-Start Control Input. SS controls the soft start period. Connect a capacitor from SS to GND to set the soft-start period. A 0.1µF capacitor sets the soft-start period to 15ms. To disable the soft-start feature, SS unconnected the Capacitor. |

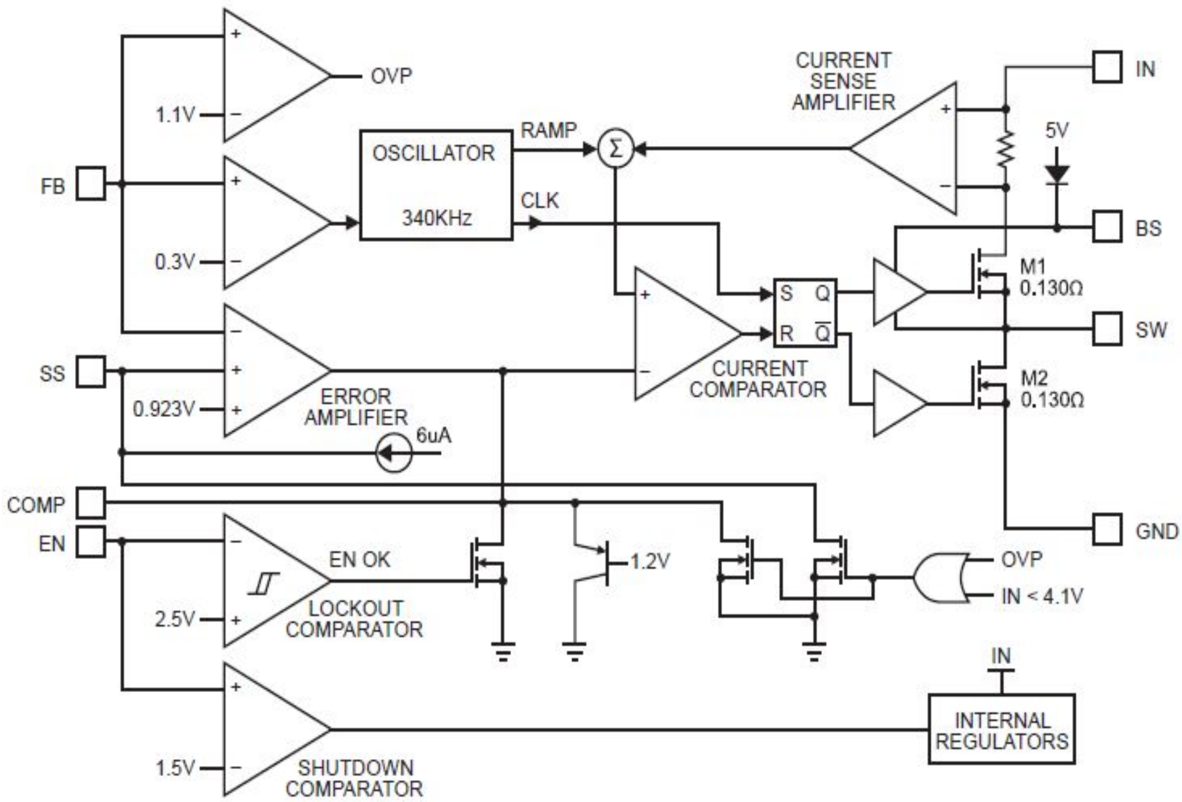
## ABSOLUTE MAXIMUM RATINGS

Supply Voltage $V_{IN}$ ........................................ -0.3V to +30V
Switch Node Voltage $V_{SW}$ ........................................ 30V
Boost Voltage $V_{BS}$ ........................................ $V_{SW}$–0.3V to $V_{SW}$ + 6V
All Other Pins........................................ -0.3V to +6V
Junction Temperature ........................................ +150°C
Lead Temperature ........................................ +260°C/10s
Storage Temperature ........................................ –55°C to + 150°C

## Recommended Operating Conditions

Input Voltage ($V_{IN}$) ........................................ 4.75V to 27V
Output Voltage ($V_{SW}$) ........................................ 0.925 to 20V
Operating Temperature........................................ –20°C to +85°C

## Functional Block Diagram



## ELECTRICAL CHARACTERISTICS

($V_{IN}$ = 12V, $T_A$ = +25°C, unless otherwise noted.)

| Parameter | Symbol | Condition | MIN | TYP | MAX | Units |
|---|---|---|---|---|---|---|
| Shutdown Supply Current | $I_{SD}$ | $V_{EN} \leq 0.3V$ | | 0.3 | 3.0 | uA |
| Supply Current | $I_Q$ | $V_{EN} \geq 2.6V$, $V_{FB}$ = 1.0V | | 1.3 | 1.5 | mA |
| Feedback Voltage | $V_{FB}$ | $4.75V \leq V_{IN} \leq 27V$ | 0.900 | 0.925 | 0.950 | V |
| Feedback Overvoltage Threshold | $V_{FB\_OVP}$ | | | 1.1 | | V |
| Error Amplifier Voltage | $A_{EA}$ | | | 480 | | V/V |
| Error Amplifier Transconductance | $G_{EA}$ | $\Delta I_C = \pm 10\mu A$ | | 800 | | uA/V |
| High-Side Switch On Resistance | $R_{DS(ON)-1}$ | | | 130 | | mΩ |
| Low-Side Switch On Resistance | $R_{DS(ON)-2}$ | | | 130 | | mΩ |
| High-Side Switch Leakage Current | | $V_{EN}$ = 0V, $V_{SW}$ = 0V | | | 10 | uA |
| Upper Switch Current Limit | | Minimum Duty Cycle | 2.4 | 3.4 | -- | A |
| Lower Switch Current Limit | | From Drain to Source | | 1.1 | | A |
| COMP to Current Sense Transconductance | $G_{CS}$ | | | 3.5 | | A/V |
| Oscillation Frequency | $F_{osc1}$ | | 300 | 340 | 380 | Khz |
| Short Circuit Oscillation Frequency | $F_{osc2}$ | $V_{FB}$ = 0V | | 100 | | Khz |
| Maximum Duty Cycle | $D_{MAX}$ | $V_{FB}$ = 1.0V | | 90 | | % |
| EN Shutdown Threshold Voltage | | $V_{EN}$ Rising | 1.1 | 1.5 | 2.0 | V |
| EN Shutdown Threshold Voltage Hysteresis | | | | 200 | | mV |
| EN Lockout Threshold Voltage | | | 2.2 | 2.5 | 2.7 | V |
| EN Lockout Hysterisis | | | | 200 | | mV |
| Input Under Voltage Lockout Threshold | | $V_{IN}$ Rising | 3.80 | 4.20 | 4.40 | V |
| Input Under Voltage Lockout Threshold Hysteresis | | | | 200 | | mV |
| Soft-Start Current | | $V_{SS}$ = 0V | | 6 | | uA |
| Soft-Start Period | | $C_{SS}$ = 0.1μF | | 15 | | mS |
| Thermal Shutdown(1) | | | | 160 | | °C |

Note1: Guaranteed by design, not tested.

# OPERATION FUNCTIONAL DESCRIPTION

The RZC2013 is a synchronous rectified, current-mode, step-down regulator. It regulates input voltages from 4.5V to 27V down to an output voltage as low as 0.925V, and supplies up to 2A of load current.

The RZC2013 uses current-mode control to regulate the output voltage. The output voltage is measured at FB through a resistive voltage divider and amplified through the internal trans-conductance error amplifier. The voltage at the COMP pin is compared to the switch current measured internally to control the output voltage.

The converter uses internal N-Channel MOSFET switches to step-down the input voltage to the regulated output voltage. Since the high side MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between SW and BS is needed to drive the high side gate. The boost capacitor is charged from the internal 5V rail when SW is low.

When the RZC2013 FB pin exceeds 20% of the nominal regulation voltage of 0.925V, theover voltage comparator is tripped and the COMP pin and the SS pin are discharged to GND, forcing the high-side switch off.

# APPLICATIONS INFORMATION

## COMPONENT SELECTION

### Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin.The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = \frac{R_2}{R_1 + R_2} \times V_{OUT}$$

Where $V_{FB}$ is the feedback voltage and $V_{OUT}$ is the output voltage.Thus the output voltage is:

$$V_{OUT} = \frac{R_1 + R_2}{R_2} \times 0.925$$

### Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. A good rule for determining the inductance to use is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

$$L=\frac{V_{OUT}}{F_S\times\Delta I_L}\times(1-D);D=\frac{V_{OUT}}{V_{IN}}\quad;$$

Where $V_{OUT}$ is the output voltage, $V_{IN}$ is the input voltage, $F_S$ is the switching frequency, and $\Delta I_L$ is the peak-to-peak inductor ripple current.
Choose an inductor that will not saturate under the maximum inductor peak current. The peak inductor current can be calculated by:

$$I_{LP}=I_{LOAD}+\frac{V_{OUT}}{2\times F_S\times L}\times(1-D);$$

Where $I_{LOAD}$ is the load current.
The choice of which style inductor to use mainly depends on the price vs. Size Requirements and any EMI requirements.

**Optional Schottky Diode**

During the transition between high-side switch and low-side switch, the body diode of the low side power MOSFET conducts the inductor current. The forward voltage of this body diode is high. An optional Schottky diode may be paralleled between the SW pin and GND pin to improve overall efficiency.Table 1 lists Schottky diode and their manufacturers.

TABLE 1--Diode Selection Guide

| VIN max | Part Number | Voltage/Current Rating |
|---|---|---|
| <20V | B130 | 30V,1A |
| <20V | SK13 | 30V.1A |
| >20V | B140 | 40V,1A |
| >20V | SK14 | 30V,1A |

**Input Capacitor**

The input capacitor needs to be carefully selected to maintain sufficiently low ripple at the supply input of the converter.A low ESR electrolytic capacitor is highly recommended.Since large current flows in and out of this capacitor during switching,its ESR also affects efficiency.
The input capacitance needs to be higher than 100uF.The RMS ripple current rating needs to be higher than 50% of the output current.The input capacitor should be placed close to the VIN and GND pins of the RZC2013,with the shortest traces possible.The input capacitor can be placed a little bit away if a small parallel 0.1uF ceramic capacitor is placed right next to the RZC2013.
When VIN above 15V,pure ceramic $C_{IN}$ is not recommended,This is because the ESR of a ceramic cap is often too small,pure ceramic $C_{IN}$ will work with the parasite inductance of the input trace and forms a Vin resonant tank.When Vin is hot plug in/out.this resonant tank will boost the Vin spike to a very high voltage and damage the RZC2013.

**Output Capacitor**

The output capacitor also needs to have a low ESR to keep low output ripple voltage .In the case of ceramic output ceramic output capacitors,RESR is very small and does not contribute to the ripple.Therefore,a lower capacitance value can be used for ceramic capacitors.In the case of tantalum or electrolytic capacitors,the ripple is dominated by RESR multiplied by the ripple current.In that case,the output capacitor is chosen to have sufficiently low ESR.

For ceramic output capacitors,typically choose two capacitors of about 22uF.For tantalum or electrolytic capacitors,choose a capacitor with less than 50mΩ ESR.

**Compensation Components**

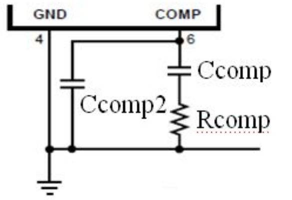



Figure 2. Stability Compensation

The feedback loop of the RZC2013 is stabilized by the components at the COMP pin,as shown in figure 1.The DC loop gain of the system is determined by the following equation:

$$A_{VDC} = G_{COMP} \times A_{VEA} \times \frac{V_{FB}}{I_{OUT}}$$

The dominant pole P1 is due to Ccomp:

$$F_{P1} = \frac{G_{EA}}{2\pi \times C_{COMP} \times A_{VEA}}$$

The second pole P2 is the output pole:

$$F_{P2} = \frac{I_{OUT}}{2\pi \times C_{OUT} \times V_{OUT}}$$

The first zero Z1 is due to Rcomp and Ccomp:

$$F_{Z1} = \frac{1}{2\pi \times C_{COMP} \times R_{COMP}}$$

The system may have another zero of importance, if the output capacitor has a large capacitance and/or a high ESR value. The zero, due to the ESR and capacitance of the output capacitor, is located at:

$$F_{ESR} = \frac{1}{2\pi \times C_{OUT} \times R_{ESR}}$$

And finally ,the third pole is due to Rcomp and Ccomp(if Ccomp2 is used)

$$F_{P3} = \frac{1}{2\pi \times C_{COMP2} \times R_{COMP}}$$

**STEP1.Set the crossover frequency at 1/10 of the switching frequency via Rcomp:**

$$R_{COMP} = \frac{2\pi \times V_{OUT} \times C_{OUT} \times F_{SW}}{10 \times G_{EA} \times C_{COMP} \times V_{FB}}$$

But limit Rcomp to 10KΩ maximum.

**STEP2. Set the zero $f_{Z1}$ at 1/4 of the crossover frequency. If Rcomp is less than 10KΩ,the equation for Ccomp is:**

$$C_{COMP} = \frac{0.637}{R_{COMP} \times F_C}$$

The value unit is F;

**STEP3.If the output capacitor`s ESR is high enough to cause a zero at lower than 4 times the crossover frequency,an additional compensation capacitor Ccomp2 is required.The condition for using Ccomp2 is:**

$$1 \le \pi \times C_{OUT} \times R_{ESR} \times F_S$$

And the proper value for Ccomp2 is:

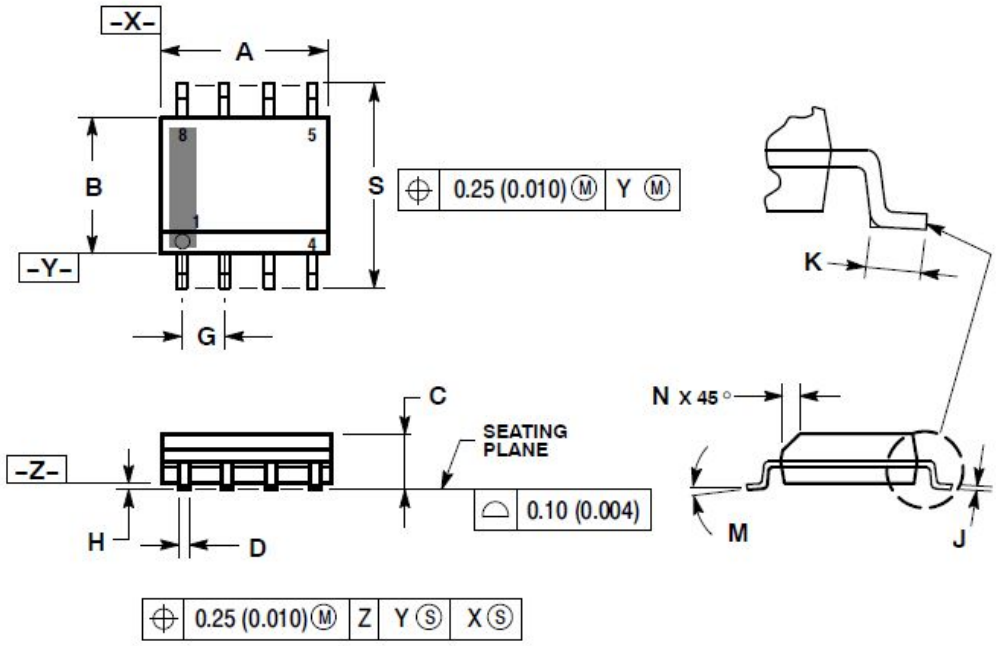
$$C_{COMP2} = \frac{C_{OUT} \times R_{ESR\_OUT}}{R_{COMP}}$$

Though Ccomp2 is unnecessary when the output capacitor has sufficiently low ESR,a small value Ccomp2 such as 100pF may improve stability against PCB layout parasitic effects.

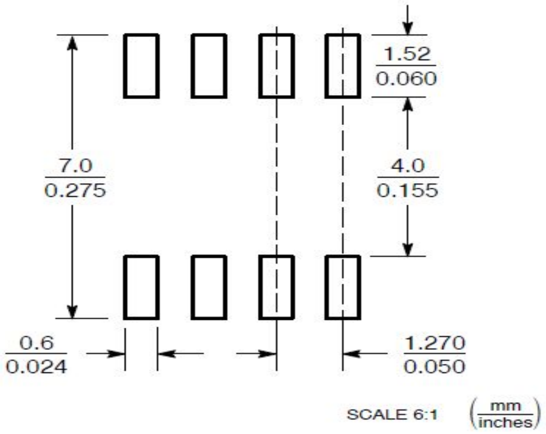
<table>
<tr><th>VIN Range (V)</th><th>VOUT (V)</th><th>COUT (uF)</th><th>Rcomp (kΩ)</th><th>Ccomp (nF)</th><th>Ccomp2 (pF)</th><th>Inductor (uH)</th></tr>
<tr><td>5--15</td><td>1.0</td><td rowspan="6">22uF×2</td><td>3.3</td><td>5.6</td><td rowspan="6">none</td><td>4.7</td></tr>
<tr><td>5--15</td><td>1.2</td><td>3.9</td><td>4.7</td><td>4.7</td></tr>
<tr><td>5--15</td><td>1.8</td><td>5.6</td><td>3.3</td><td rowspan="4">10</td></tr>
<tr><td>5--15</td><td>2.5</td><td>8.2</td><td>2.2</td></tr>
<tr><td>5--15</td><td>3.3</td><td>10</td><td>2</td></tr>
<tr><td>5--15</td><td>5.0</td><td>10</td><td>3.3</td></tr>
<tr><td>5--24</td><td>1.0</td><td rowspan="6">470uF<br>120mΩ</td><td rowspan="6">10</td><td rowspan="6">6.8</td><td rowspan="6">680</td><td rowspan="2">4.7</td></tr>
<tr><td>5--24</td><td>1.2</td></tr>
<tr><td>5--24</td><td>1.8</td><td rowspan="4">10</td></tr>
<tr><td>5--24</td><td>2.5</td></tr>
<tr><td>5--24</td><td>3.3</td></tr>
<tr><td>5--24</td><td>5.0</td></tr>
</table>

## PACKAGE DIMENSIONS:

### SOP-8



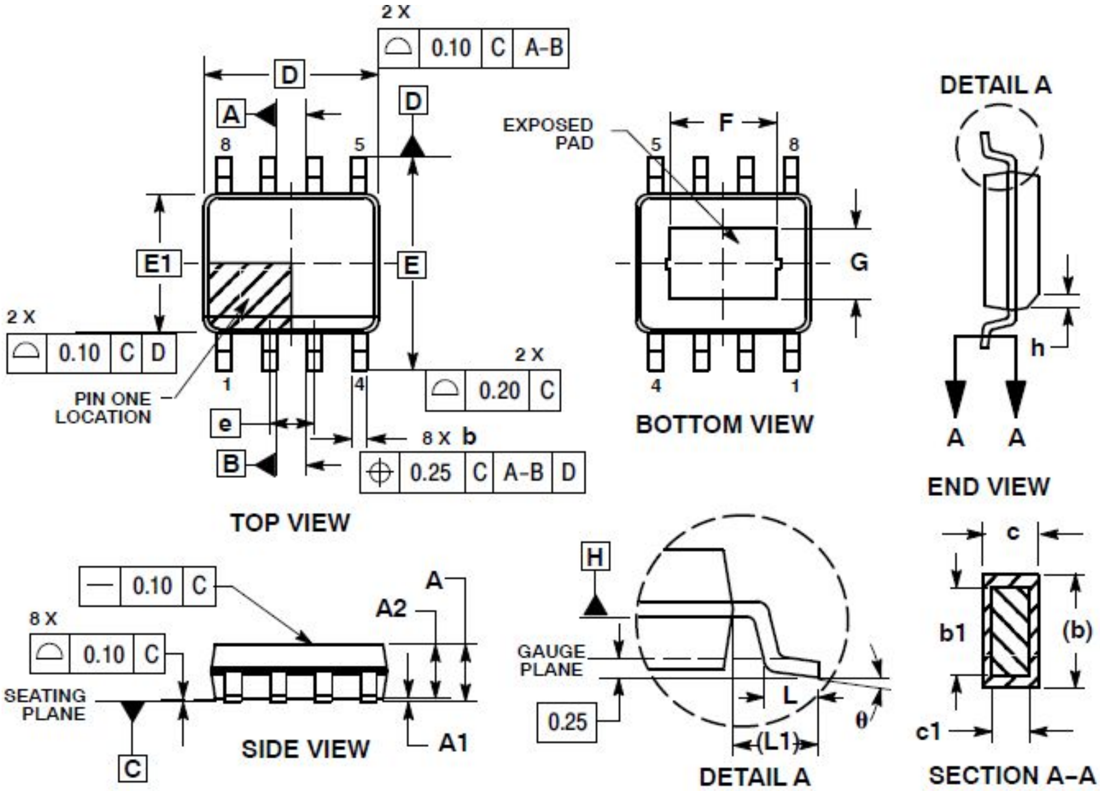

SOLDERING FOOTPRINT*



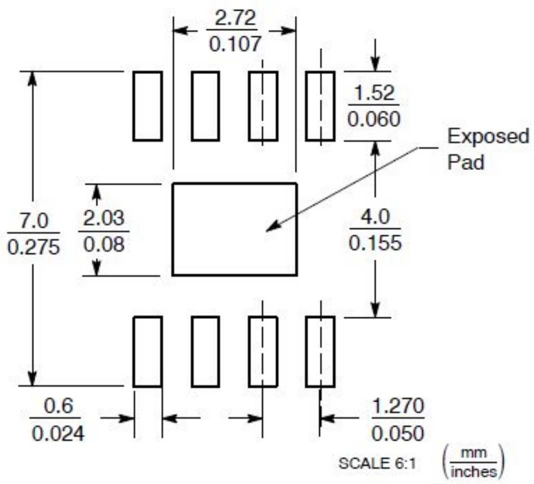

| DIM | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 4.80 | 5.00 | 0.189 | 0.197 |
| B | 3.80 | 4.00 | 0.150 | 0.157 |
| C | 1.35 | 1.75 | 0.053 | 0.069 |
| D | 0.33 | 0.51 | 0.013 | 0.020 |
| G | 1.27 BSC | | 0.050 BSC | |
| H | 0.10 | 0.25 | 0.004 | 0.010 |
| J | 0.19 | 0.25 | 0.007 | 0.010 |
| K | 0.40 | 1.27 | 0.016 | 0.050 |
| M | 0 ° | 8 ° | 0 ° | 8 ° |
| N | 0.25 | 0.50 | 0.010 | 0.020 |
| S | 5.80 | 6.20 | 0.228 | 0.244 |

## PACKAGE DIMENSIONS:

### ESOP-8




SOLDERING FOOTPRINT




| DIM | MILLIMETERS | |
|---|---|---|
| | MIN | MAX |
| A | 1.35 | 1.75 |
| A1 | 0.00 | 0.10 |
| A2 | 1.35 | 1.65 |
| b | 0.31 | 0.51 |
| b1 | 0.28 | 0.48 |
| c | 0.17 | 0.25 |
| c1 | 0.17 | 0.23 |
| 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 | |
| F | 2.24 | 3.20 |
| G | 1.55 | 2.51 |
| h | 0.25 | 0.50 |
| θ | 0 ° | 8 ° |