

## CURRENT MODE PWM CONTROLLER

### DESCRIPTION

The SG1846 family of control ICs provides all of the necessary features to implement fixed frequency, current mode control schemes while maintaining a minimum external parts count. The superior performance of this technique can be measured in improved line regulation, enhanced load response characteristics, and a simpler, easier-to-design control loop. Topological advantages include inherent pulse-by-pulse current limiting capability, automatic symmetry correction for push-pull converters, and the ability to parallel "power modules" while maintaining equal current sharing.

Protection circuitry includes built-in under-voltage lockout and programmable current limit in addition to soft start capability. A shutdown function is also available which can initiate either a complete shutdown with automatic restart or latch the supply off.

Other features include fully latched operation, double pulse suppression, deadtime adjust capability, and a  $\pm 1\%$  trimmed bandgap reference.

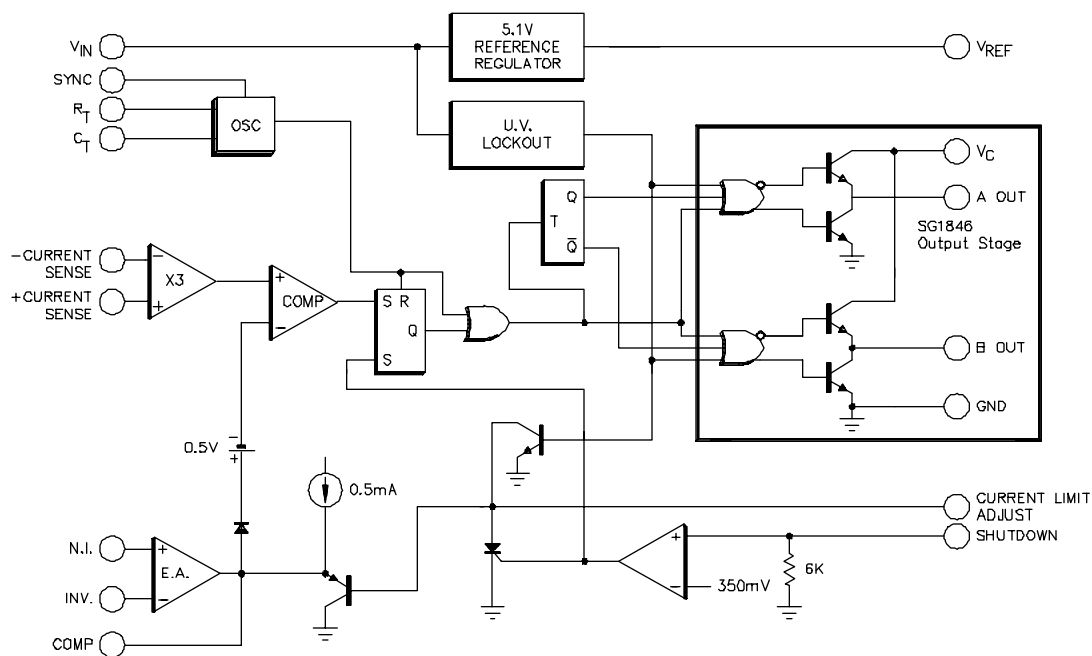
### FEATURES

- Automatic feed forward compensation
- Programmable pulse by pulse current limiting
- Automatic symmetry correction in push-pull configuration
- Enhanced load response characteristics
- Parallel operation capability for modular power systems
- Differential current sense amplifier with wide common mode range
- Double pulse suppression
- 200mA totem-pole outputs
- $\pm 1\%$  bandgap reference
- Under-voltage lockout
- Soft-start capability
- Shutdown capability
- 500KHz operation

### HIGH RELIABILITY FEATURES - SG1846

- ◆ Available to MIL-STD - 883
- ◆ Radiation data available
- ◆ LMI level "S" processing available

### BLOCK DIAGRAM



**ABSOLUTE MAXIMUM RATINGS** (Note 1 and 2)

|                                           |                           |
|-------------------------------------------|---------------------------|
| Supply Voltage (+V <sub>IN</sub> )        | 40V                       |
| Collector Supply Voltage(V <sub>C</sub> ) | 40V                       |
| Analog Inputs (Pins 3, 4, 5, 6, & 16)     | -0.3V to +V <sub>IN</sub> |
| Logic Input                               | -0.3V to 5.5V             |
| Source/Sink Load current (continuous)     | 200mA                     |
| Source/Sink Load Current (peak, 200ns)    | 500mA                     |
| Reference Load Current                    | 30mA                      |
| Soft Start Sink Current                   | 50mA                      |

Note 1. Values beyond which damage may occur.

Note 2. Pin numbers refer to ceramic J package.

|                                                           |                |
|-----------------------------------------------------------|----------------|
| Sync Output Current                                       | 5mA            |
| Error Amplifier Output Current                            | 5mA            |
| Oscillator Charging current (Pin 9)                       | 5mA            |
| Operating Junction Temperature                            |                |
| Hermetic (J, L, F Packages)                               | 150°C          |
| Plastic (N, DW Package)                                   | 150°C          |
| Storage Temperature Range                                 | -65°C to 150°C |
| Lead Temperature (Soldering, 10 Seconds)                  | 300°C          |
| RoHS Peak Package Solder Reflow Temp. (40 sec. max. exp.) | 260° (+0, -5)  |

**THERMAL DATA****J Package:**

|                                                       |        |
|-------------------------------------------------------|--------|
| Thermal Resistance-Junction to Case, $\theta_{JC}$    | 30°C/W |
| Thermal Resistance-Junction to Ambient, $\theta_{JA}$ | 80°C/W |

**N Package:**

|                                                       |        |
|-------------------------------------------------------|--------|
| Thermal Resistance-Junction to Case, $\theta_{JC}$    | 40°C/W |
| Thermal Resistance-Junction to Ambient, $\theta_{JA}$ | 65°C/W |

**DW Package:**

|                                                       |        |
|-------------------------------------------------------|--------|
| Thermal Resistance-Junction to Case, $\theta_{JC}$    | 40°C/W |
| Thermal Resistance-Junction to Ambient, $\theta_{JA}$ | 95°C/W |

**F Package:**

|                                                       |         |
|-------------------------------------------------------|---------|
| Thermal Resistance-Junction to Case, $\theta_{JC}$    | 70°C/W  |
| Thermal Resistance-Junction to Ambient, $\theta_{JA}$ | 115°C/W |

**L Package:**

|                                                       |         |
|-------------------------------------------------------|---------|
| Thermal Resistance-Junction to Case, $\theta_{JC}$    | 35°C/W  |
| Thermal Resistance-Junction to Ambient, $\theta_{JA}$ | 120°C/W |

Note A. Junction Temperature Calculation:  $T_J = T_A + (P_D \times \theta_{JA})$ .

Note B. The above numbers for  $\theta_{JC}$  are maximums for the limiting thermal resistance of the package in a standard mounting configuration. The  $\theta_{JA}$  numbers are meant to be guidelines for the thermal performance of the device/pc-board system. All of the above assume no ambient airflow.

**RECOMMENDED OPERATING CONDITIONS** (Note 3)

|                                         |                |
|-----------------------------------------|----------------|
| Supply Voltage Range                    | 8V to 40V      |
| Collector Supply Voltage Range          | 4.5V to 40V    |
| Source/Sink Output Current (continuous) | 100mA          |
| Source/Sink Output Current (peak 200ns) | 200mA          |
| Reference Load Current                  | 0 to 10mA      |
| Oscillator Frequency Range              | 1KHz to 500KHz |

|                                               |                              |
|-----------------------------------------------|------------------------------|
| Oscillator Timing Resistor (R <sub>T</sub> )  | 2K $\Omega$ to 100K $\Omega$ |
| Oscillator Timing Capacitor (C <sub>T</sub> ) | 1000 pF to 0.1 $\mu$ F       |
| Operating Ambient Temperature Range           |                              |
| SG1846                                        | -55°C to 125°C               |
| SG2846                                        | -25°C to 85°C                |
| SG3846                                        | 0°C to 70°C                  |

Note 3. Range over which the device is functional.

**ELECTRICAL CHARACTERISTICS**

(Unless otherwise specified, these specifications apply over the operating ambient temperatures for SG1846/SG1847 with -55°C  $\leq$  T<sub>A</sub>  $\leq$  125°C, SG2846 with -25°C  $\leq$  T<sub>A</sub>  $\leq$  85°C, SG3846 with 0°C  $\leq$  T<sub>A</sub>  $\leq$  70°C, +V<sub>IN</sub> = 15V. Low duty cycle pulse testing techniques are used which maintains junction and case temperatures equal to the ambient temperature.)

| Parameter                       | Test Conditions                             | SG1846<br>SG2846 |      |      | SG3846 |      |      | Units |
|---------------------------------|---------------------------------------------|------------------|------|------|--------|------|------|-------|
|                                 |                                             | Min.             | Typ. | Max. | Min.   | Typ. | Max. |       |
| Reference Section               |                                             |                  |      |      |        |      |      |       |
| Output Voltage                  | T <sub>J</sub> = 25°C, I <sub>O</sub> = 1mA | 5.05             | 5.10 | 5.15 | 5.00   | 5.10 | 5.20 | V     |
| Line Regulation                 | V <sub>IN</sub> = 8V to 40V                 |                  | 5    | 20   |        | 5    | 20   | mV    |
| Load Regulation                 | I <sub>L</sub> = 1mA to 10mA                |                  | 3    | 15   |        | 3    | 15   | mV    |
| Temperature Stability (Note 4)  |                                             |                  | 0.4  |      |        | 0.4  |      | mV/°C |
| Total Output Variation (Note 4) | Line, Load and Temperature                  | 5.00             |      | 5.20 | 4.95   |      | 5.25 | V     |
| Output Noise Voltage (Note 4)   | 10Hz ≤ f ≤ 10KHz. T <sub>J</sub> = 25°C     |                  | 100  |      |        | 100  |      | μV    |
| Long Term Stability (Note 4)    | T <sub>J</sub> = 125°C, 1000Hrs.            |                  | 5    |      |        | 5    |      | mV    |
| Short Circuit Output Current    | V <sub>REF</sub> = 0V                       | -10              | -45  |      | -10    | -45  |      | mA    |

**ELECTRICAL CHARACTERISTICS** (continued)

| Parameter                                                       | Test Conditions                                               | SG1846<br>SG2846 |      |                     | SG3846 |      |                     | Units |
|-----------------------------------------------------------------|---------------------------------------------------------------|------------------|------|---------------------|--------|------|---------------------|-------|
|                                                                 |                                                               | Min.             | Typ. | Max.                | Min.   | Typ. | Max.                |       |
| Oscillator Section (Note 9)                                     |                                                               |                  |      |                     |        |      |                     |       |
| Initial Accuracy                                                | T <sub>j</sub> = 25°C                                         | 39               | 43   | 47                  | 39     | 43   | 47                  | KHz   |
| Voltage Stability                                               | V <sub>IN</sub> = 8V to 40V                                   |                  | 1    | 2                   |        | 1    | 2                   | %     |
| Temperature Stability (Note 4)                                  | Over Operating Range                                          |                  | 1    |                     |        | 1    |                     | %     |
| Sync Output High Level                                          |                                                               | 3.9              | 4.35 |                     | 3.9    | 4.35 |                     | V     |
| Sync Output Low Level                                           |                                                               |                  | 2.3  | 2.5                 |        | 2.3  | 2.5                 | V     |
| Sync Input High Level                                           | Pin 8 = 0V                                                    | 3.9              |      |                     | 3.9    |      |                     | V     |
| Sync Input Low Level                                            | Pin 8 = 0V                                                    |                  |      | 2.5                 |        |      | 2.5                 | V     |
| Sync Input Current                                              | Sync Voltage = 5.25V, Pin 8 = 0V                              |                  | 1.2  | 1.5                 |        | 1.2  | 1.5                 | mA    |
| Error Amp Section                                               |                                                               |                  |      |                     |        |      |                     |       |
| Input Offset Voltage                                            |                                                               |                  | 0.5  | 5                   |        | 0.5  | 10                  | mV    |
| Input Bias Current                                              |                                                               |                  | -0.6 | -1                  |        | -0.6 | -2                  | µA    |
| Input Offset Current                                            |                                                               |                  | 40   | 250                 |        | 40   | 250                 | nA    |
| Common Mode Range                                               | V <sub>IN</sub> = 8V to 40V                                   | 0                |      | V <sub>IN</sub> -2V | 0      |      | V <sub>IN</sub> -2V | V     |
| Open Loop Voltage Gain                                          | V <sub>O</sub> = 1.2V to 3V, V <sub>CM</sub> = 2V             | 80               | 105  |                     | 80     | 105  |                     | dB    |
| Unity Gain Bandwidth (Note 4)                                   | T <sub>j</sub> = 25°C                                         | 0.7              | 1.0  |                     | 0.7    | 1.0  |                     | MHz   |
| CMRR                                                            | V <sub>CM</sub> = 0V to 38V, V <sub>IN</sub> = 40V            | 75               | 100  |                     | 75     | 100  |                     | dB    |
| PSRR                                                            | V <sub>IN</sub> = 8V to 40V                                   | 80               | 105  |                     | 80     | 105  |                     | dB    |
| Output Sink Current                                             | V <sub>ID</sub> = - 15mV to -5V, V <sub>PIN 7</sub> = 1.2V    | 2                | 6    |                     | 2      | 6    |                     | mA    |
| Output Source Current                                           | V <sub>ID</sub> = 15mV to 5V, V <sub>PIN 7</sub> = 2.5V       | -0.4             | -0.5 |                     | -0.4   | -0.5 |                     | mA    |
| High Level Output Voltage                                       | R <sub>L</sub> = 15KΩ (Pin 7)                                 | 4.3              | 4.6  |                     | 4.3    | 4.6  |                     | V     |
| Low Level Output Voltage                                        | R <sub>L</sub> = 15KΩ (Pin 7)                                 |                  | 0.7  | 1                   |        | 0.7  | 1                   | V     |
| Current Sense Amplifier Section                                 |                                                               |                  |      |                     |        |      |                     |       |
| Amplifier Gain (Notes 5 & 6)                                    | V <sub>PIN 3</sub> = 0V, Pin 1 Open                           | 2.5              | 2.75 | 3.0                 | 2.5    | 2.75 | 3.0                 | V     |
| Maximum Differential (Note 6)                                   | Pin 1 Open R <sub>L</sub> = 15KΩ (Pin 7)                      |                  |      |                     |        |      |                     |       |
| Input Signal (V <sub>PIN 4</sub> - V <sub>PIN 3</sub> )(Note 5) |                                                               | 1.1              | 1.2  |                     | 1.1    | 1.2  |                     | V     |
| Input Offset Voltage (Note 5)                                   | V <sub>PIN 1</sub> = 0.5V, Pin 7 Open                         |                  | 5    | 25                  |        | 5    | 25                  | mV    |
| CMRR                                                            | V <sub>CM</sub> = 1V to 12V                                   | 60               | 83   |                     | 60     | 83   |                     | dB    |
| PSRR                                                            | V <sub>IN</sub> = 8V to 40V                                   | 60               | 84   |                     | 60     | 84   |                     | dB    |
| Input Bias Current (Note 5)                                     | V <sub>PIN 1</sub> = 0.5V, Pin 7 Open                         |                  | -2.5 | -10                 |        | -2.5 | -10                 | µA    |
| Input Offset Current (Note 5)                                   | V <sub>PIN 1</sub> = 0.5V, Pin 7 Open                         |                  | 0.08 | 1                   |        | 0.08 | 1                   | µA    |
| Input Common Mode Range                                         |                                                               | 0                |      | V <sub>IN</sub> -3  | 0      |      | V <sub>IN</sub> -3  | V     |
| Delay to Outputs (Note 4)                                       | T <sub>j</sub> = 25°C                                         |                  | 200  | 500                 |        | 200  | 500                 | ns    |
| Current Limit Adjust Section                                    |                                                               |                  |      |                     |        |      |                     |       |
| Current Limit Offset Voltage(Note 5)                            | V <sub>PIN 3</sub> = 0, V <sub>PIN 4</sub> = 0V, Pin 7 Open   | 0.45             | 0.5  | 0.55                | 0.45   | 0.5  | 0.55                | V     |
| Input Bias Current                                              | V <sub>PIN 5</sub> = V <sub>REF</sub> V <sub>PIN 6</sub> = 0V |                  | -10  | -30                 |        | -10  | -30                 | µA    |
| Shutdown Terminal Section                                       |                                                               |                  |      |                     |        |      |                     |       |
| Threshold Voltage                                               |                                                               | 250              | 350  | 400                 | 250    | 350  | 400                 | mV    |
| Input Voltage Range                                             |                                                               | 0                |      | V <sub>IN</sub>     | 0      |      | V <sub>IN</sub>     | V     |
| Minimum Latching Current                                        |                                                               |                  |      |                     |        |      |                     |       |
| (I <sub>PIN 1</sub> ) (Note 7)                                  |                                                               | 3.0              | 1.5  |                     | 3.0    | 1.5  |                     | mA    |
| Maximum Non-Latching Current                                    |                                                               |                  |      |                     |        |      |                     |       |
| (I <sub>PIN 1</sub> ) (Note 8)                                  |                                                               |                  | 1.5  | 0.8                 |        | 1.5  | 0.8                 | mA    |
| Delay to Outputs (Note 4)                                       | T <sub>j</sub> = 25°C                                         |                  | 300  | 600                 |        | 300  | 600                 | ns    |
| Output Section                                                  |                                                               |                  |      |                     |        |      |                     |       |
| Collector Emitter Voltage                                       |                                                               | 40               |      |                     | 40     |      |                     | V     |
| Collector Leakage Current                                       | V <sub>C</sub> = 40V                                          |                  |      | 200                 |        |      | 200                 | µA    |
| Output Low Level                                                | I <sub>SINK</sub> = 20mA                                      |                  | 0.1  | 0.4                 |        | 0.1  | 0.4                 | V     |
|                                                                 | I <sub>SINK</sub> = 100mA                                     |                  | 0.4  | 2.1                 |        | 0.4  | 2.1                 | V     |
| Output High Level                                               | I <sub>SOURCE</sub> = 20mA                                    | 13               | 13.5 |                     | 13     | 13.5 |                     | V     |
|                                                                 | I <sub>SOURCE</sub> = 100mA                                   | 12               | 13.5 |                     | 12     | 13.5 |                     | V     |
| Rise Time (Note 4)                                              | C <sub>L</sub> = 1nF, T <sub>j</sub> = 25°C                   |                  | 50   | 300                 |        | 50   | 300                 | ns    |
| Fall Time (Note 4)                                              | C <sub>L</sub> = 1nF, T <sub>j</sub> = 25°C                   |                  | 50   | 300                 |        | 50   | 300                 | ns    |

## ELECTRICAL CHARACTERISTICS (continued)

| Parameter                     | Test Conditions | SG1846<br>SG2846 |      |      | SG3846 |      |      | Units |
|-------------------------------|-----------------|------------------|------|------|--------|------|------|-------|
|                               |                 | Min.             | Typ. | Max. | Min.   | Typ. | Max. |       |
| Under-Voltage Lockout Section |                 |                  |      |      |        |      |      |       |
| Start-Up Threshold            |                 |                  | 7.7  | 8.0  |        | 7.7  | 8.0  | V     |
| Threshold Hysteresis          |                 |                  | 0.75 |      |        | 0.75 |      | V     |
| Total Standby Current         |                 |                  |      |      |        |      |      |       |
| Supply Current                |                 |                  | 17   | 21   |        | 17   | 21   | mA    |

Note 4. These parameters although guaranteed over the recommended operating conditions, are not tested in production.

Note 5. Parameter measured at trip point of latch with  $V_{PIN5} = V_{REF}$ ,  $V_{PIN6} = 0V$ .

Note 6. Amplifier gain defined as :  $G = \frac{\Delta V_{PIN7}}{\Delta V_{PIN4}}$ ;  $V_{PIN4} = 0V$  to  $1.0V$

Note 7. Current into Pin 1 guaranteed to latch circuit in shutdown state.  
Note 8. Current into Pin 1 guaranteed not to latch circuit in shutdown state.

Note 9.  $R_T = 10K\Omega$ ,  $C_T = 4.7nF$

## CHARACTERISTIC CURVES

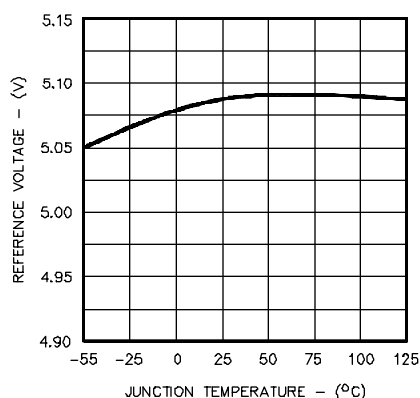


FIGURE 1.  
REFERENCE VOLTAGE VS. TEMPERATURE

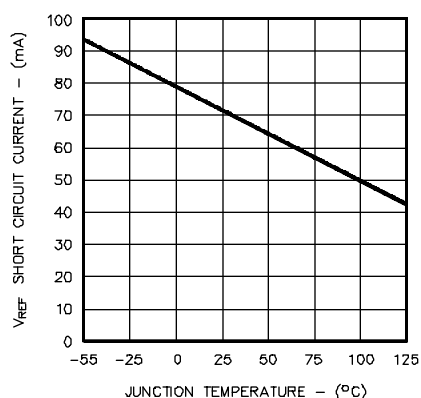


FIGURE 2.  
 $V_{REF}$  SHORT CIRCUIT CURRENT VS. TEMPERATURE

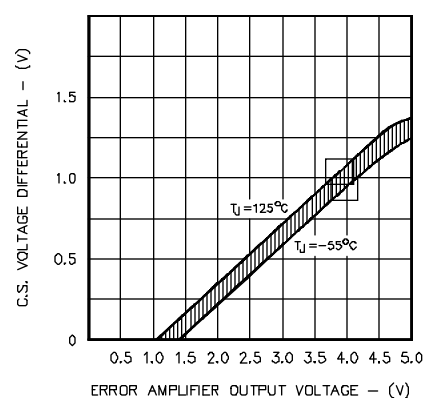


FIGURE 3.  
CURRENT SENSE THRESHOLD  
VS. ERROR AMPLIFIER OUTPUT

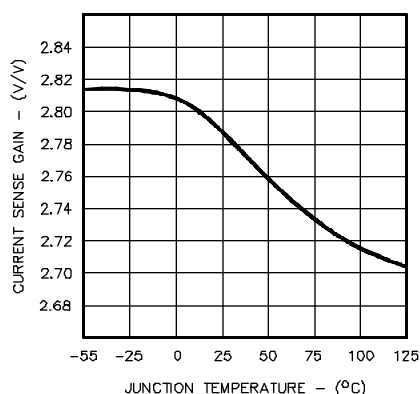


FIGURE 4.  
CURRENT SENSE GAIN VS. TEMPERATURE

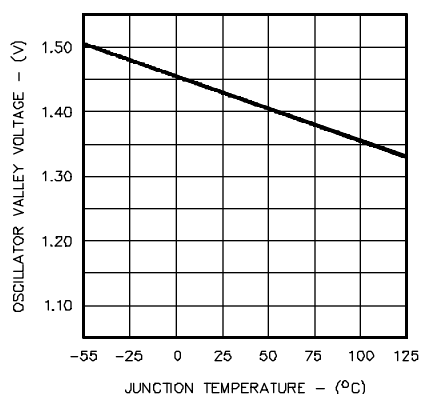


FIGURE 5.  
OSCILLATOR VALLEY VOLTAGE VS. TEMPERATURE

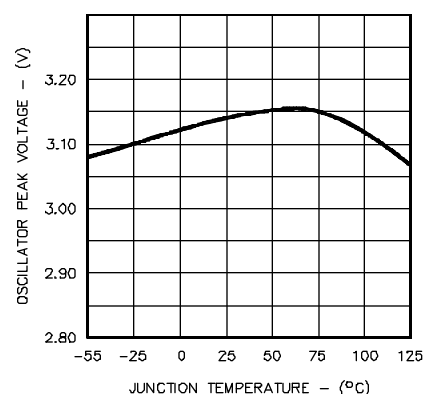


FIGURE 6.  
OSCILLATOR PEAK VOLTAGE VS. TEMPERATURE

## CHARACTERISTIC CURVES (continued)

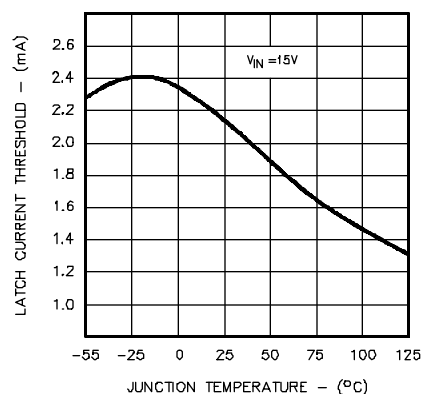


FIGURE 7.  
MINIMUM SCR LATCH CURRENT

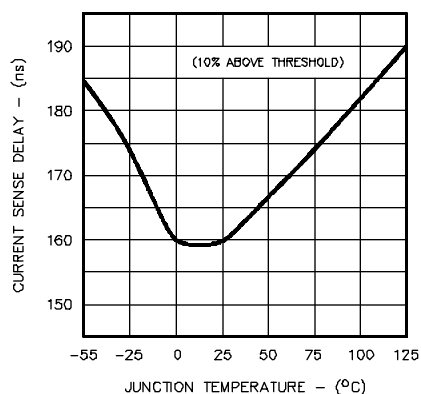


FIGURE 8.  
CURRENT SENSE DELAY VS. TEMPERATURE

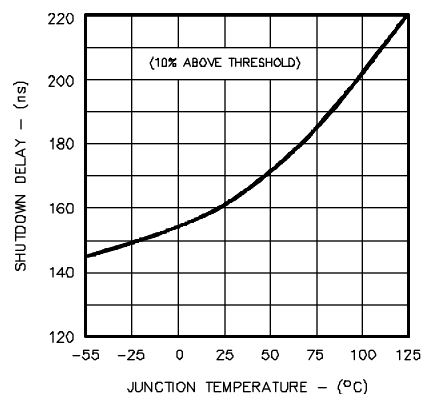


FIGURE 9.  
SHUTDOWN DELAY TO OUTPUT VS. TEMPERATURE

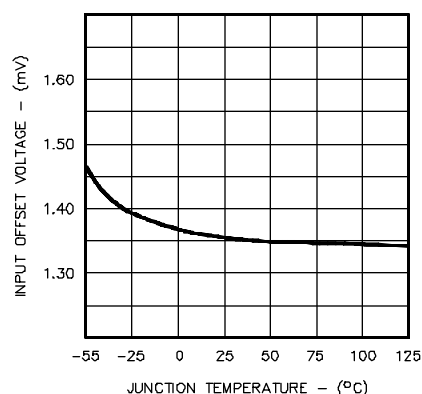


FIGURE 10.  
ERROR AMPLIFIER INPUT OFFSET VOLTAGE  
VS. TEMPERATURE

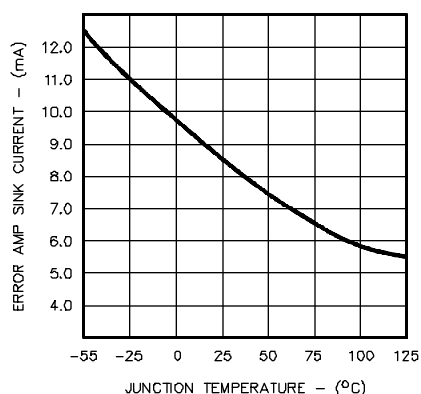


FIGURE 11.  
ERROR AMP SINK CURRENT VS. TEMPERATURE

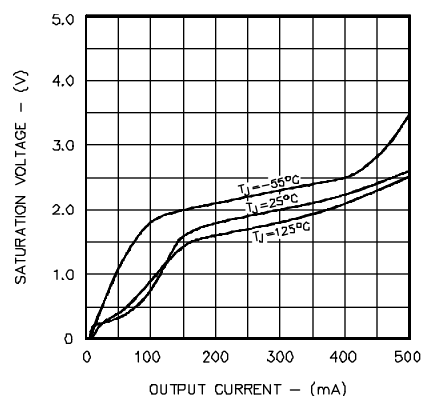


FIGURE 12.  
OUTPUT TRANSISTOR SATURATION VOLTAGE  
VS. OUTPUT CURRENT (SINK TRANSISTOR)

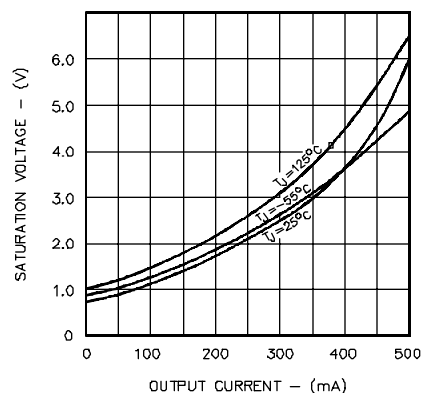


FIGURE 13.  
OUTPUT TRANSISTOR SATURATION VOLTAGE  
VS. OUTPUT CURRENT (SOURCE TRANSISTOR)

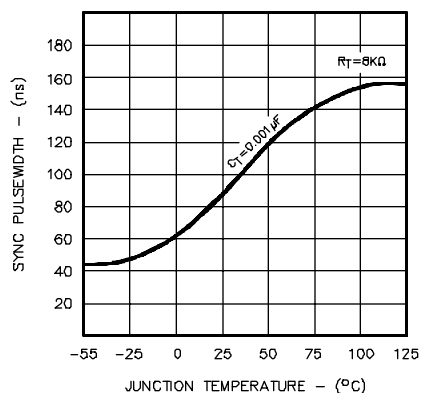


FIGURE 14.  
SYNC PULSEWIDTH VS. TEMPERATURE

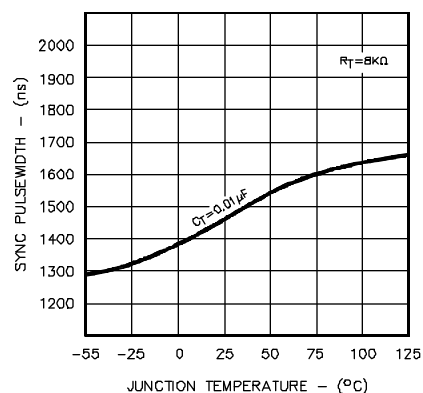


FIGURE 15.  
SYNC PULSEWIDTH VS. TEMPERATURE

# CHARACTERISTIC CURVES (continued)

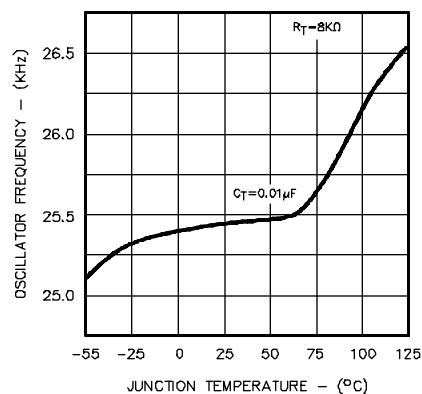


FIGURE 16.  
OSCILLATOR FREQUENCY VS. TEMPERATURE

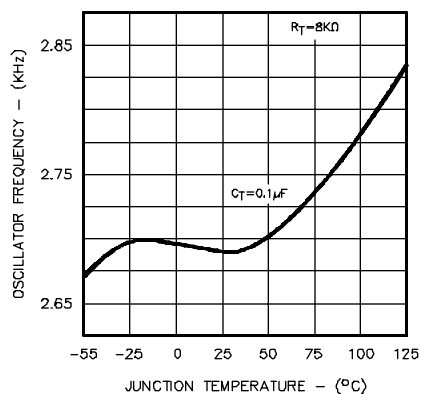


FIGURE 17.  
OSCILLATOR FREQUENCY VS. TEMPERATURE

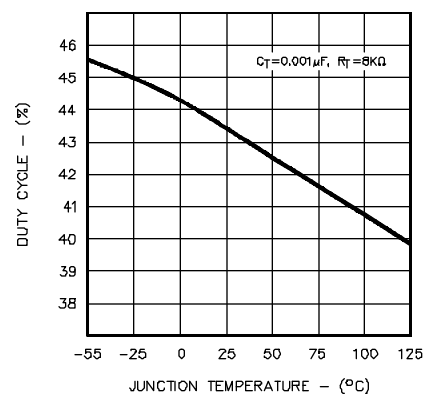


FIGURE 18.  
DUTY CYCLE VS. TEMPERATURE

## APPLICATION INFORMATION

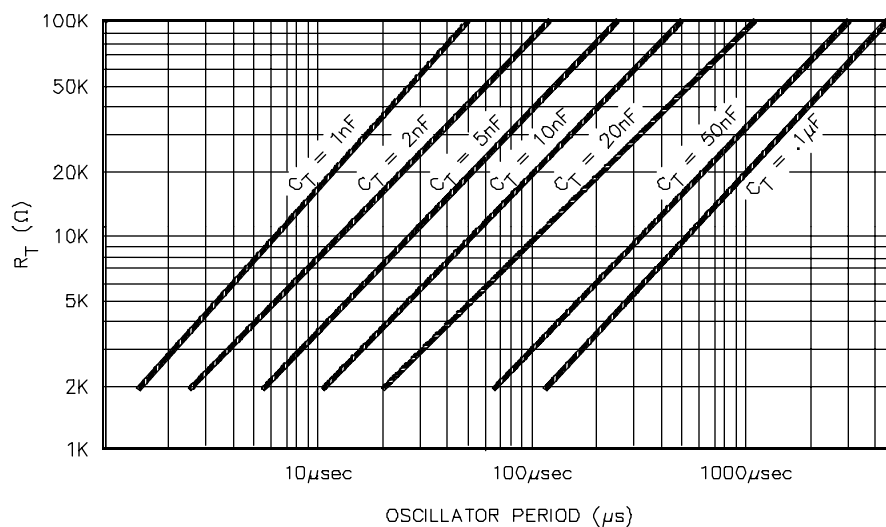


FIGURE 19- OSCILLATOR FREQUENCY CURVES

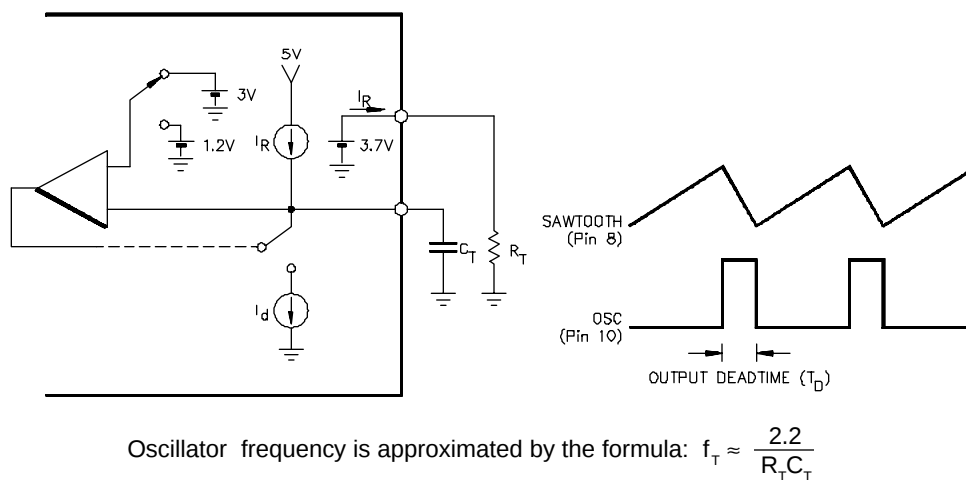


FIGURE 20 - OSCILLATOR CIRCUIT

# APPLICATION INFORMATION (continued)

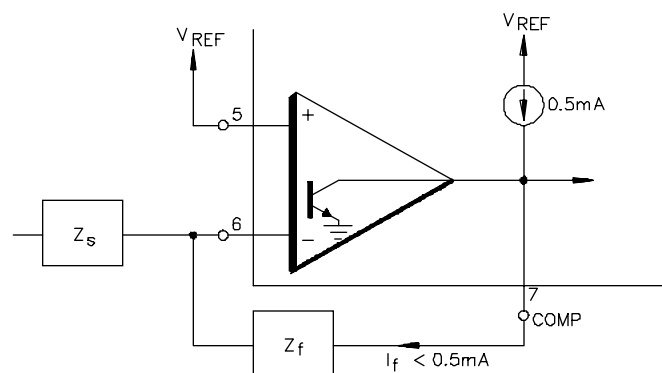


FIGURE 21 - ERROR AMP OUTPUT CONFIGURATION  
(Error amplifier can source up to 0.5mA)

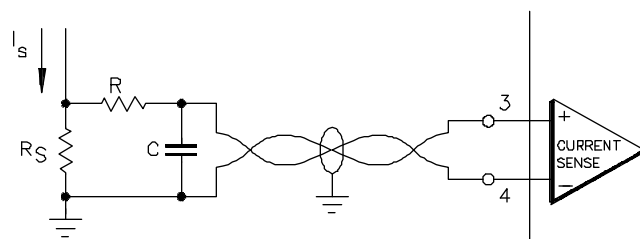


FIGURE 22 - CURRENT SENSE AMP CONNECTIONS

A small RC filter may be required in some applications to reduce switch transients. Differential input allows remote, noise free switching.

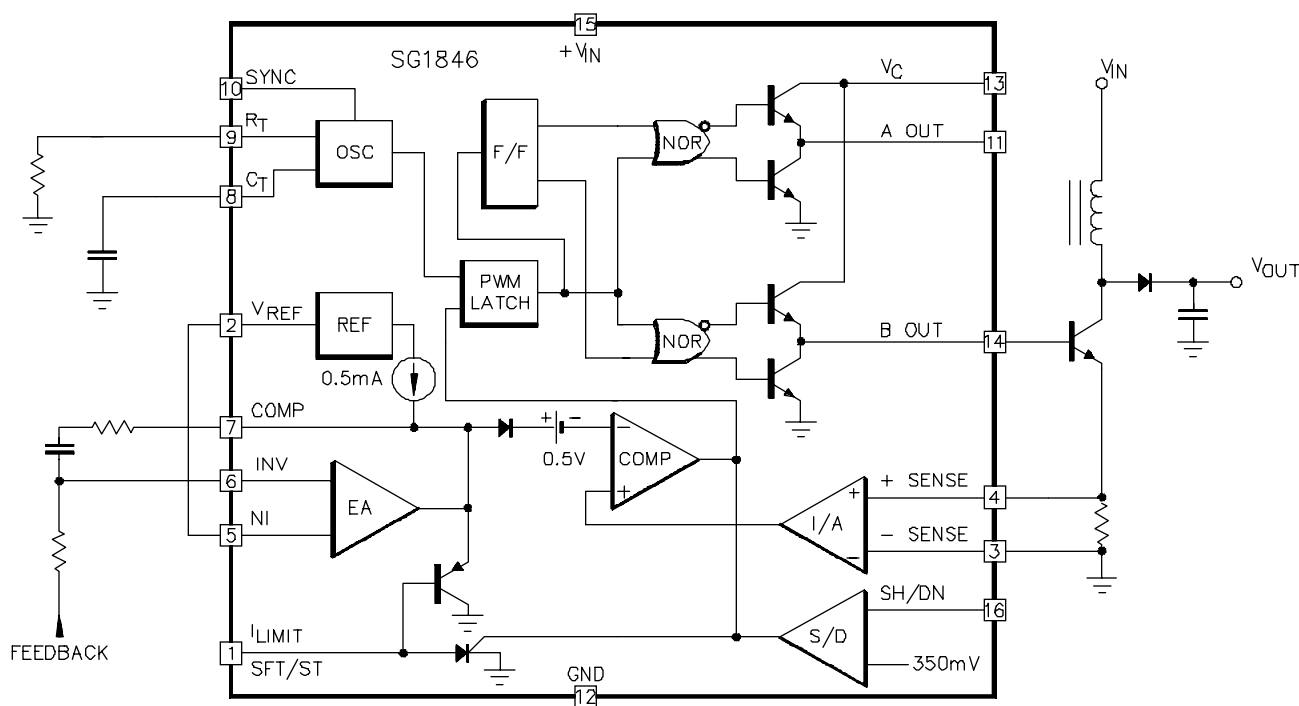


FIGURE 23 - SINGLE ENDED BOOST CONFIGURATION

## APPLICATIONS INFORMATION (continued)

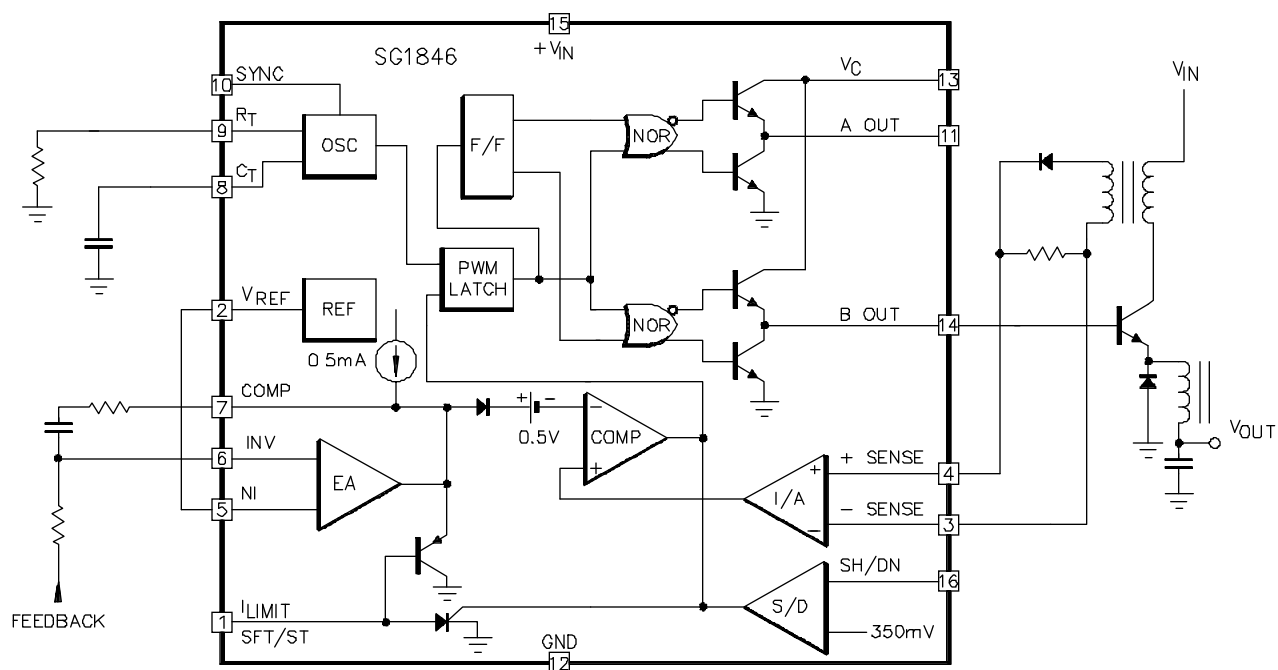


FIGURE 24 - BUCK CONVERTER WITH CURRENT SENSE WINDING

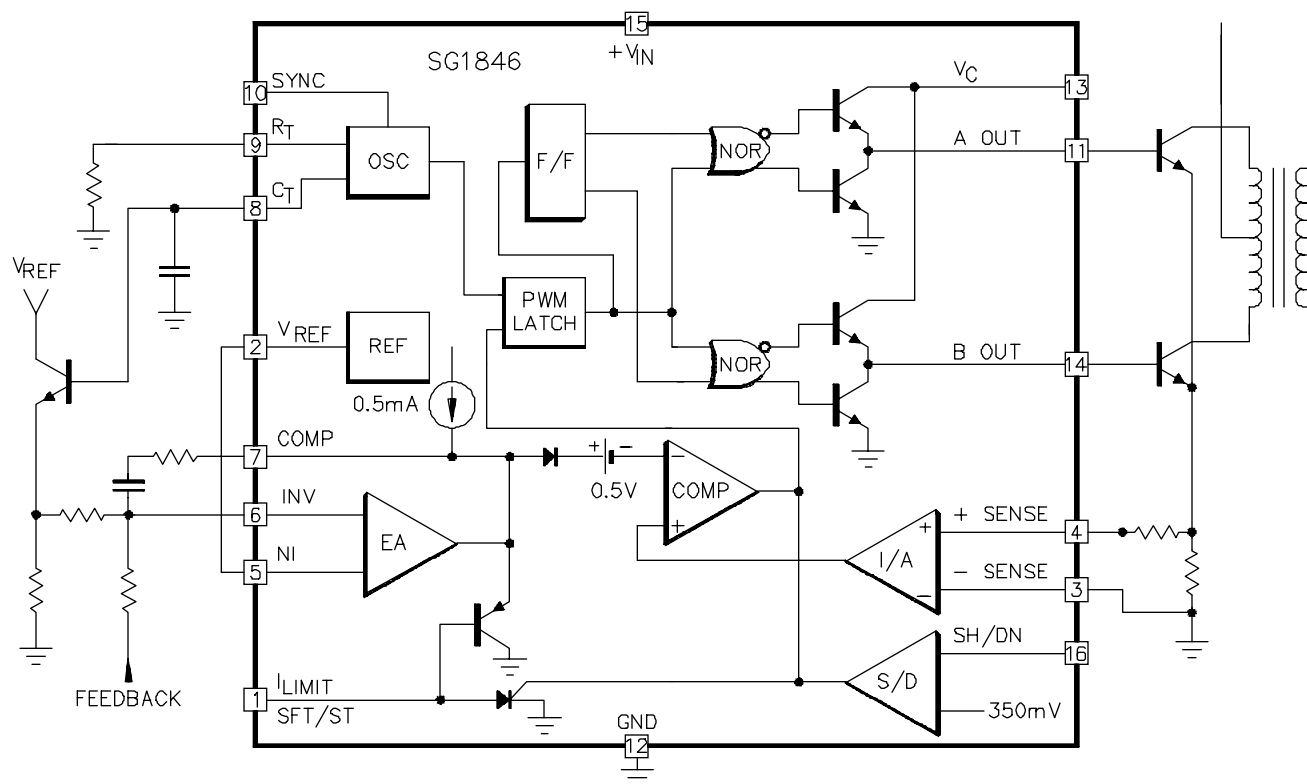
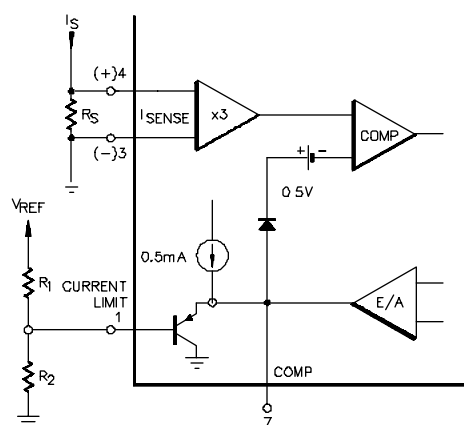


FIGURE 25 - PUSH/PULL CONVERTER WITH SLOPE COMPENSATION

## APPLICATIONS INFORMATION (continued)



Peak Current ( $I_S$ ) is determined by the formula:  $I_S = \frac{\frac{R_2 V_{REF}}{R_1 + R_2} - 0.5}{3R_S}$

FIGURE 26 - PULSE BY PULSE CURRENT LIMITING

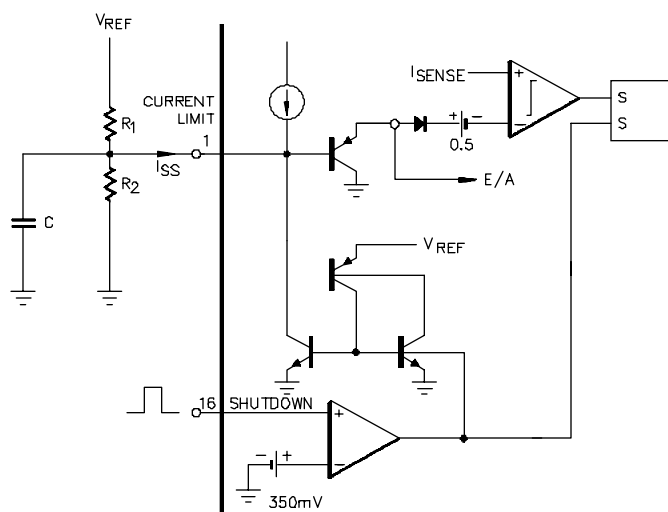
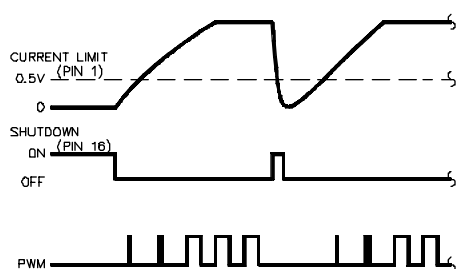


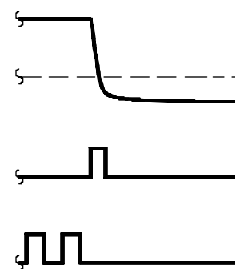
FIGURE 27 - SOFT START AND SHUTDOWN/RESTART FUNCTIONS



$$\frac{V_{REF}}{R_1} < 0.8mA$$

FIGURE 28 - SHUTDOWN WITH AUTO-RESTART

If  $\frac{V_{REF}}{R_1} < 0.8mA$  the shutdown latch will commutate when  $I_{SS} < 0.8mA$  and a restart cycle will be initiated.



$$\frac{V_{REF}}{R_1} > 3mA \text{ (LATCHED OFF)}$$

FIGURE 29 - SHUTDOWN WITHOUT AUTO-RESTART (LATCHED)

If  $\frac{V_{REF}}{R_1} > 3mA$  the device will latch off until power is recycled.

## CONNECTION DIAGRAMS &amp; ORDERING INFORMATION (See Notes Below)

| Package                                                         | Part No.                                                      | Ambient Temperature Range                                                          | Connection Diagram                                                                                                        |
|-----------------------------------------------------------------|---------------------------------------------------------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| 16-PIN CERAMIC DIP<br>J - PACKAGE                               | SG1846J/883B<br>SG1846J/DESC<br>SG1846J<br>SG2846J<br>SG3846J | -55°C to 125°C<br>-55°C to 125°C<br>-55°C to 125°C<br>-25°C to 85°C<br>0°C to 70°C | <p>N Package: RoHS Compliant / Pb-free Transition DC: 0503<br/>N Package: RoHS / Pb-free 100% Matte Tin Lead Finish</p>   |
| 16-PIN PLASTIC DIP<br>N - PACKAGE                               | SG2846N<br>SG3846N                                            | -25°C to 85°C<br>0°C to 70°C                                                       |                                                                                                                           |
| 16-PIN WIDEBODY<br>PLASTIC S.O.I.C<br>DW - PACKAGE              | SG2846DW<br>SG3846DW                                          | -25°C to 85°C<br>0°C to 70°C                                                       | <p>DW Package: RoHS Compliant / Pb-free Transition DC: 0516<br/>DW Package: RoHS / Pb-free 100% Matte Tin Lead Finish</p> |
| 16-PIN CERAMIC<br>FLAT PACK<br>F - PACKAGE (Note 3)             | SG1846F/DESC                                                  | -55°C to 125°C                                                                     |                                                                                                                           |
| 20-PIN CERAMIC<br>LEADLESS CHIP CARRIER<br>L - PACKAGE (Note 3) | SG1846L/883B<br>SG1846L/DESC<br>SG1846L                       | -55°C to 125°C<br>-55°C to 125°C<br>-55°C to 125°C                                 |                                                                                                                           |

Notes: 1. Contact factory for JAN and DESC part availability.  
2. All parts are viewed from the top.  
3. Consult factory for product availability.