

## DC MOTOR PULSE WIDTH MODULATOR

### DESCRIPTION

The SG1731 is a pulse width modulator circuit designed specifically for DC motor control. It provides a bi-directional pulse train output in response to the magnitude and polarity of an analog error signal input. The device is useful as the control element in motor-driven servo systems for precision positioning and speed control, as well as in audio modulators and amplifiers using carrier frequencies to 350 KHz.

The circuit contains a triangle waveform oscillator, a wideband operational amplifier for error voltage generation, a summing/scaling network for level-shifting the triangle waveform, externally programmable PWM comparators and dual  $\pm 100\text{mA}$ ,  $\pm 22\text{V}$  totem pole drivers with commutation diodes for full bridge output. A SHUTDOWN terminal forces the drivers into a floating high-impedance state when driven LOW. Supply voltage to the control circuitry and to the output drivers may be from either dual positive and negative supplies, or single-ended.

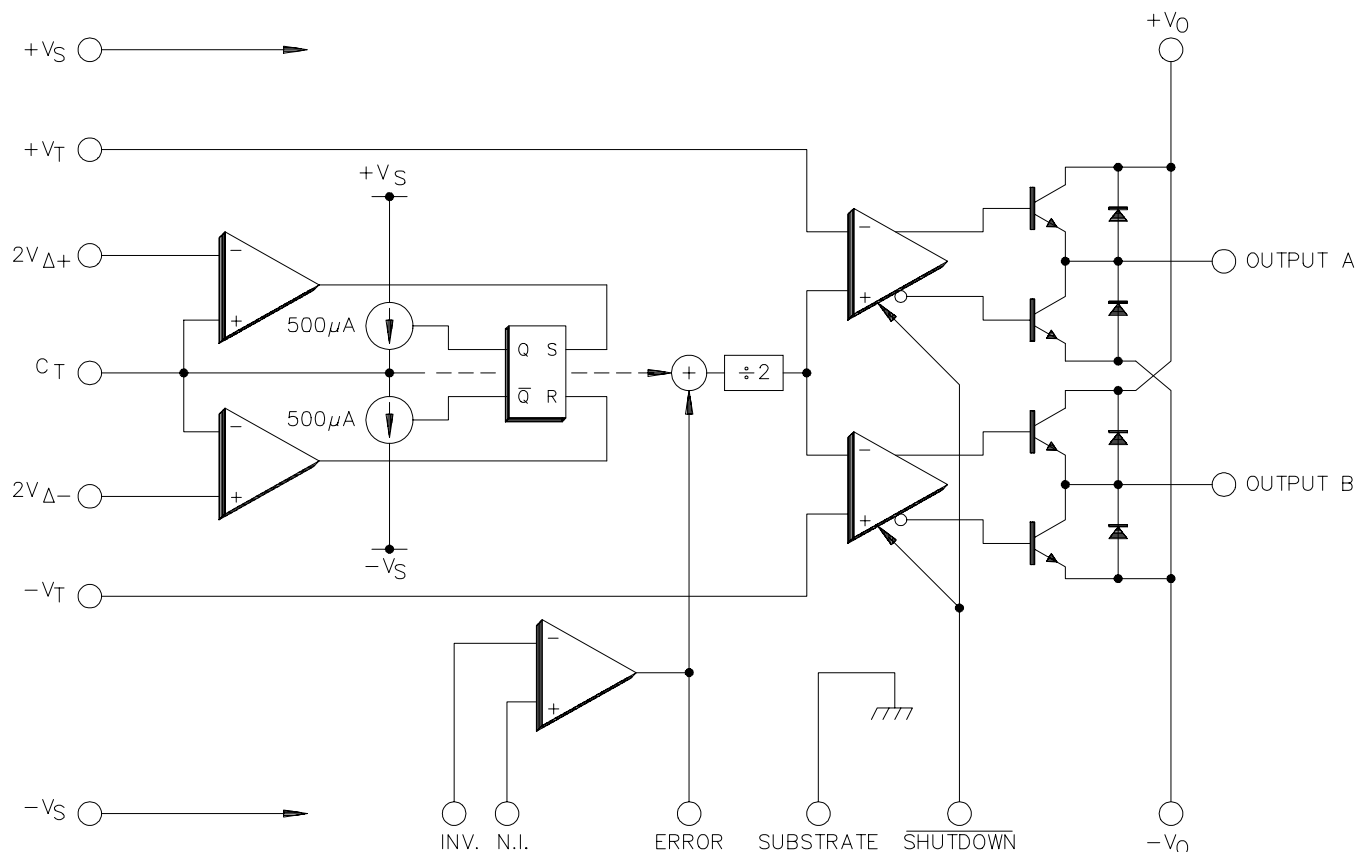
### FEATURES

- $\pm 3.5\text{V}$  to  $\pm 15\text{V}$  control supply
- $\pm 2.5\text{V}$  to  $\pm 22\text{V}$  driver supply
- Dual 100mA source/sink output drivers
- 5KHz to 350KHz oscillator range
- High slew rate error amplifier
- Adjustable deadband operation
- Digital SHUTDOWN input

### HIGH RELIABILITY FEATURES - SG1731

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

### BLOCK DIAGRAM



## ABSOLUTE MAXIMUM RATINGS (Note1)

Supply Voltage ( $\pm V_S$ ) .....  $\pm 18V$   
 Analog Inputs .....  $\pm V_S$   
 Digital Inputs (SHUTDOWN) .....  $-V_S - 0.3V$  to  $-V_S + 18V$   
 Output Driver Supply Voltage ( $\pm V_O$ ) .....  $\pm 25V$   
 Source/Sink Output Current (continuous) ..... 200mA  
 Source/Sink Output Current (peak, 500ns) ..... 400mA

Note 1. Values beyond which damage may occur.

Output Driver Diode Current (continuous) ..... 200mA  
 Output Driver Diode Current (peak, 500ns) ..... 400mA  
 Operating Junction Temperature  
   Hermetic (J - Package) ..... 150°C  
   Plastic (N - 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°C (+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

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 2)

Supply Voltage Range ( $\pm V_S$ ) .....  $\pm 3.5V$  to  $\pm 15V$   
 Error Amp Common-Mode Range .....  $-V_S + 3V$  to  $V_S - 3V$   
 Output Driver Supply Voltage Range .....  $\pm 2.5V$  to  $\pm 22V$   
 Source/Sink Output Current (continuous) ..... 100mA  
 Source/Sink Output Current (peak, 500ns) ..... 200mA  
 Output Driver Diode Current (continuous) ..... 100mA  
 Output Driver Diode Current (peak, 500ns) ..... 200mA

Oscillator Frequency Range ..... 10Hz to 350KHz  
 Oscillator Voltage (Peak-to-Peak) ..... 1V to 10V  
 Oscillator Timing Capacitor ( $C_T$ ) ..... 200pF to 2.5 $\mu$ F  
 Operating Ambient Temperature Range  
   SG1731 ..... -55°C to 125°C  
   SG2731 ..... -25°C to 85°C  
   SG3731 ..... 0°C to 70°C

Note 2. Range over which the device is functional and parameter limits are guaranteed.

## ELECTRICAL CHARACTERISTICS

(Unless otherwise specified, these specifications apply over the operating ambient temperatures for SG1731 with -55°C  $\leq T_A \leq$  125°C, SG2731 with -25°C  $\leq T_A \leq$  85°C, SG3731 with 0°C  $\leq T_A \leq$  70°C,  $V_S = \pm 15V$ , and  $V_O = \pm 22V$ . Low duty cycle pulse testing techniques are used which maintains junction and case temperatures equal to the ambient temperature.)

| Parameter                            | Test Conditions                                            | SG1731/2731/3731 |      |      | Units |
|--------------------------------------|------------------------------------------------------------|------------------|------|------|-------|
|                                      |                                                            | Min.             | Typ. | Max. |       |
| Oscillator Section                   |                                                            |                  |      |      |       |
| C <sub>T</sub> Charging Current      | T <sub>A</sub> = 25°C                                      | 450              | 500  | 550  | μA    |
|                                      | T <sub>A</sub> = T <sub>MIN</sub> to T <sub>MAX</sub>      | 400              |      | 600  | μA    |
| 2VΔ± Input Bias Current              | V <sub>CM</sub> = ±5V                                      |                  |      | -20  | μA    |
| Initial Oscillator Frequency         | C <sub>T</sub> = 1000pF, 2VΔ± = ±5V, T <sub>A</sub> = 25°C | 22.5             | 25.0 | 27.5 | KHz   |
| Temperature Stability (Note 3)       | C <sub>T</sub> = 1000pF, 2VΔ± = ±5V                        |                  |      | 10   | %     |
| Error Amplifier Section (Note 5)     |                                                            |                  |      |      |       |
| Input Offset Voltage                 |                                                            |                  |      | 10   | mV    |
| Input Bias Current                   |                                                            |                  |      | 3    | μA    |
| Input Offset Current                 |                                                            |                  |      | 600  | nA    |
| Open Loop Voltage Gain               | R <sub>L</sub> = 2KΩ                                       | 70               |      |      | dB    |
| Output Voltage Swing                 | R <sub>L</sub> = 2KΩ                                       | ±10              |      |      | V     |
| Common-Mode Rejection Ratio          |                                                            | 70               |      |      | dB    |
| Slew Rate (Notes 3 and 4)            | T <sub>A</sub> = 25°C                                      | 5                | 10   |      | V/μs  |
| Unity Gain Bandwidth (Notes 3 and 4) | T <sub>A</sub> = 25°C                                      | 0.7              | 1    |      | MHz   |
| PWM Comparators                      |                                                            |                  |      |      |       |
| Input Bias Current                   | ±V <sub>T</sub> = ±3V                                      |                  |      | 6    | μA    |

## ELECTRICAL CHARACTERISTICS (continued)

| Parameter                           | Test Conditions                 | SG1731/2731/3731 |      |             | Units   |
|-------------------------------------|---------------------------------|------------------|------|-------------|---------|
|                                     |                                 | Min.             | Typ. | Max.        |         |
| <b>SHUTDOWN Section</b>             |                                 |                  |      |             |         |
| Logic Threshold                     | $-V_S = -3.5V \text{ to } -15V$ | $V_S + 0.8$      |      | $V_S + 2.0$ | V       |
| SHUTDOWN HIGH Current               | $V_{SHUTDOWN} = -V_S + 2.4V$    |                  |      | 400         | $\mu A$ |
| SHUTDOWN LOW Current                | $V_{SHUTDOWN} = -V_S$           |                  |      | -1.0        | mA      |
| <b>Output Drivers (Each Output)</b> |                                 |                  |      |             |         |
| HIGH Output Voltage                 | $I_{SOURCE} = 20mA$             | 19.2             |      |             | V       |
|                                     | $I_{SOURCE} = 100mA$            | 19.0             |      |             | V       |
| LOW Output Voltage                  | $I_{SINK} = 20mA$               |                  |      | -19.2       | V       |
|                                     | $I_{SINK} = 100mA$              |                  |      | -19.0       | V       |
| Driver Risettime                    | $C_L = 1000pF$                  |                  |      | 300         | ns      |
| Driver Falltime                     | $C_L = 1000pF$                  |                  |      | 300         | ns      |
| <b>Total Supply Current</b>         |                                 |                  |      |             |         |
| $V_S$ Supply Current                | $V_{SHUTDOWN} = -V_S + 0.8V$    |                  |      | 14          | mA      |
| $V_O$ Supply Current                | $V_{SHUTDOWN} = -V_S + 0.8V$    |                  |      | 6           | mA      |

Note 3. These parameters, although guaranteed, are not tested in production.

Note 5.  $V_{CM} = \pm 12V$ .

Note 4. Unity Gain Inverting 10K $\Omega$  Feedback Resistance.

## APPLICATION INFORMATION

### SUPPLY VOLTAGE

The SG1731 requires a supply voltage for the control circuitry ( $V_S$ ) and for the power output drivers ( $V_O$ ). Each supply may be either balanced positive and negative with respect to ground, or single-ended. The only restrictions are:

1. The voltage between  $+V_S$  and  $-V_S$  must be at least 7.0V; but no more than 44V.
2. The voltage between  $+V_O$  and  $-V_O$  must be at least 5.0V; but no more than 44V.
3.  $+V_O$  must be at least 5V more positive than  $-V_S$ . This eliminates the combination of a single-ended positive control supply with a single-ended negative driver supply.

### SUBSTRATE CONNECTION

The substrate connection (Pin 10) must always be connected to either  $-V_S$  or  $-V_O$ , whichever is more negative. The substrate must also be well bypassed to ground with a high quality capacitor.

### OSCILLATOR

The triangle oscillator consists of two voltage comparators, a set/reset flip-flop, a bi-directional 500 $\mu A$  current source, and an external timing capacitor  $C_T$ . A positive reference voltage ( $2V_{\Delta+}$ ) applied to Pin 2 determines the positive peak value of the triangle, and a negative reference voltage ( $2V_{\Delta-}$ ) at Pin 7 sets the negative peak value of the triangle waveform.

Since the value of the internal current source is fixed at a nominal  $\pm 500\mu A$ , the oscillator period is a function of the selected peak-to-peak voltage excursion and the value of  $C_T$ . The theoretical expression for the oscillator period is:

$$T_{OSC} = \frac{2C_T dV}{5 \times 10^{-4}} \quad (\text{Eq.1})$$

where  $C_T$  is the timing capacitor in Farads and  $dV$  is  $V_{OSC}$  in Volts peak-to-peak.

As a design aid, the solutions to Equation 1 over the recommended range of  $T_{OSC}$  and  $V_{OSC}$  are given in graphic form in Figure 1. The lower limit on  $T_{OSC}$  is 1.85 $\mu s$ , corresponding to a maximum frequency of 350 KHz. The maximum value of  $V_{OSC}$ , ( $2V_{\Delta+}$ ) - ( $2V_{\Delta-}$ ), is 10V peak-to-peak for linear waveforms.

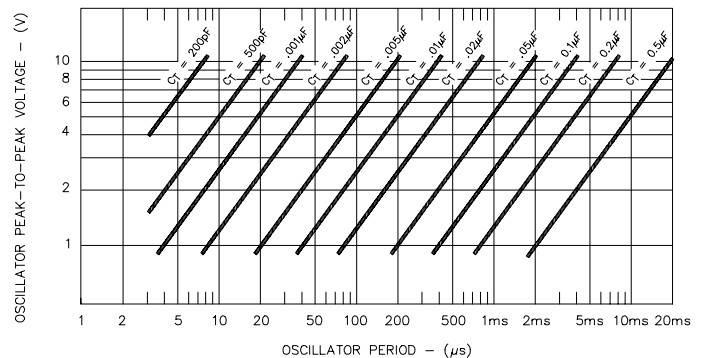


FIGURE 1 - SG1731 OSCILLATOR PERIOD VS.  $V_{OSC}$  AND  $C_T$

### ERROR AMPLIFIER

The error amplifier of the SG1731 is a conventional internally-compensated operational amplifier with low output impedance. All of the usual feedback and frequency compensation techniques may be used to control the closed-loop gain characteristics. The control supply voltage  $\pm V_S$  will determine the input common mode range and output voltage swing; both will extend to within 3V of the  $V_S$  supply.

### PULSE WIDTH MODULATION

Pulse width modulation occurs by comparing the triangle waveform to a fixed upper ( $+V_T$ ) and lower ( $-V_T$ ) threshold voltage. A crossing above the upper threshold causes Output A to switch to the HIGH state, and a crossing below

## APPLICATION INFORMATION (continued)

the lower threshold causes Output B to switch to the HIGH state. If  $\pm V_s$  is less than  $\pm 8V$  then  $\pm V_T$  can be obtained with resistors from  $\pm V_s$ . If  $\pm V_s$  is greater than  $\pm 8V$  use zeners.

Threshold crossings are generated by shifting the triangle waveform up and down with the error voltage (Pin 5). A positive error voltage will result in a pulse width modulated output at Driver A (Pin 13). Similarly, a negative error voltage produces a pulse train at Driver B (Pin 12). Figure 2 illustrates this process for the case where  $V_{\Delta+}$  is greater than  $V_T$ .

It is important to note that the triangle shifting circuit also attenuates the waveform seen at  $C_T$  by a factor of 2. This results in a waveform at the PWM comparators with a positive peak of  $V_{\Delta+}$  and a negative peak of  $V_{\Delta-}$ , and must be taken into account when selecting the values for  $+V_T$  and  $-V_T$ .

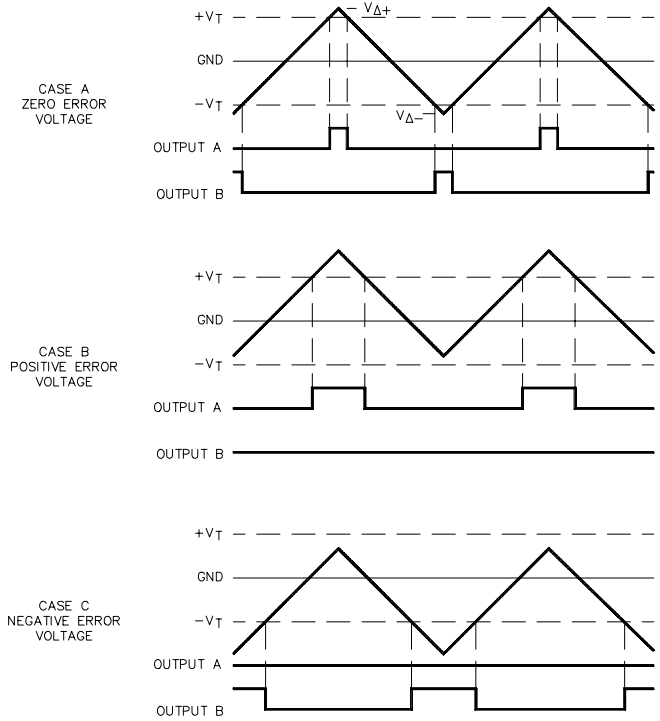


FIGURE 2 - PULSE WIDTH MODULATION WITH NO DEADBAND

## APPLICATION CIRCUITS

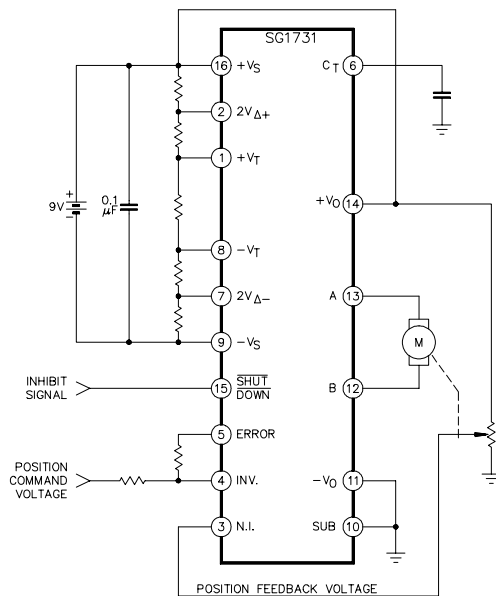


FIGURE 3

In this simple battery-powered position servo, the control supply and driver supply are both single-ended positive with respect to ground.

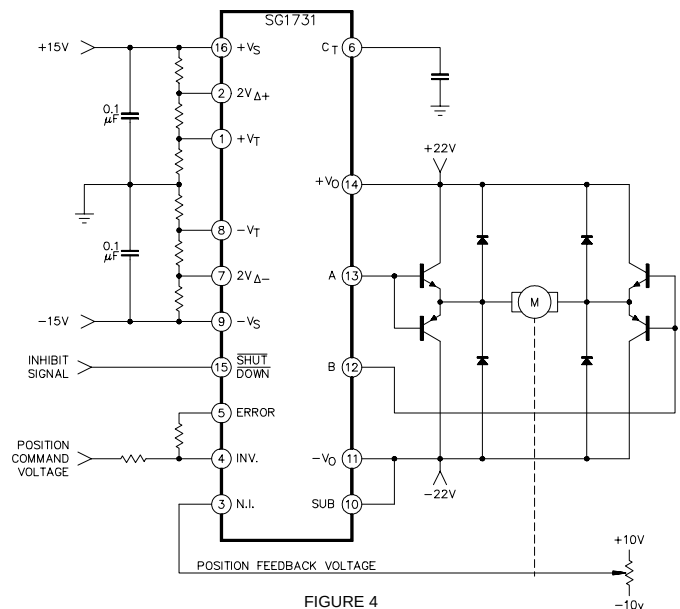


FIGURE 4

A high torque position servo is obtained by buffering the output drivers to obtain higher output current.

APPLICATION CIRCUITS

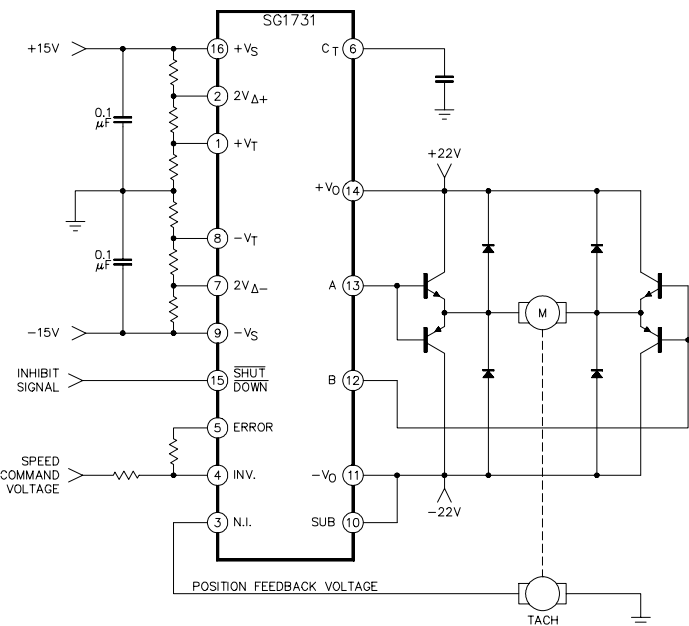


FIGURE 5

Bi-directional speed control results when the feedback voltage transducer is a tachometer.

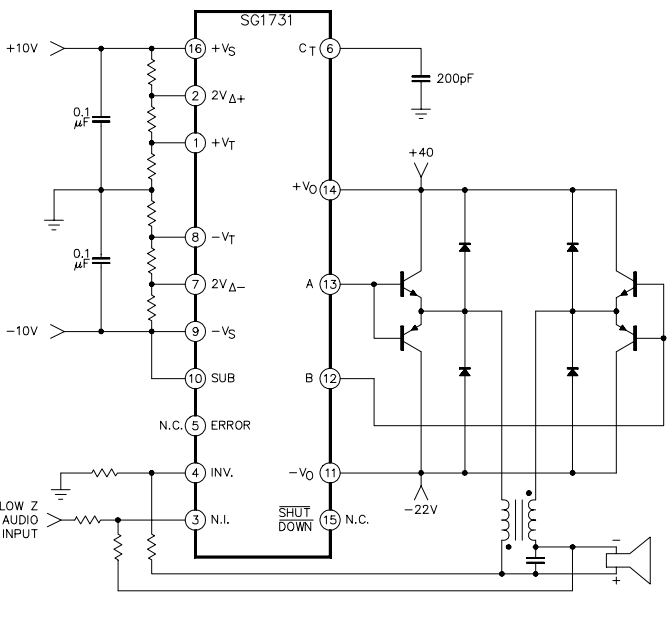


FIGURE 6

The two-quadrant transfer function of the SG1731 is ideal for pulse width modulated audio power amplifiers.

CONNECTION DIAGRAMS & ORDERING INFORMATION (See Note Below)

| Package                           | Part No.                                      | Ambient Temperature Range                                        | Connection Diagram                                          |
|-----------------------------------|-----------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------------|
| 16-PIN CERAMIC DIP<br>J - PACKAGE | SG1731J/883B<br>SG1731J<br>SG2731J<br>SG3731J | -55°C to 125°C<br>-55°C to 125°C<br>-25°C to 85°C<br>0°C to 65°C | <p>N Package: RoHS / Pb-free 100% Matte Tin Lead Finish</p> |
| 16-PIN PLASTIC DIP<br>N - PACKAGE | SG2731N<br>SG3731N                            | -25°C to 85°C<br>0°C to 65°C                                     |                                                             |

Note 1. All packages are viewed from the top.  
Note 2. Contact factory for flatpack and leadless chip carrier availability.