

## LMP8358 Zero-Drift, Programmable Instrumentation Amplifier with Diagnostics

Check for Samples: [LMP8358](#)

### FEATURES

Typical Values Unless Otherwise Noted,  $T_A = 25^\circ\text{C}$

- **Supply Voltage** 2.7V to 5.5V
- **Supply Current** 1.8 mA
- **Max Gain Error** 0.15%
- **Max Gain Drift** 16 ppm/ $^\circ\text{C}$
- **Min CMRR** 110 dB
- **Max Offset Voltage** 10  $\mu\text{V}$
- **Max Offset Voltage Drift** 50 nV/ $^\circ\text{C}$
- **GBW (Gain = 10)** 8 MHz
- **Max Non-Linearity** 100 ppm
- **Operating Temperature Range**  $-40^\circ\text{C}$  to  $125^\circ\text{C}$
- **Input Fault Detection**
- **SPI or Pin Configurable Modes**
- **EMIRR at 1.8GHz** 92 dB
- **14-Pin SOIC and 14-Pin TSSOP Package**

### APPLICATIONS

- **Bridge Sensor Amplifier**
- **Thermopile Amplifier**
- **Portable Instrumentation**
- **Medical Instrumentation**
- **Precision Low-side Current Sensing**

### DESCRIPTION

The LMP8358 is a precision programmable-gain instrumentation amplifier in TI's LMP™ precision amplifier family. Its gain can be programmed to 10, 20, 50, 100, 200, 500, or 1000 through an SPI-compatible serial interface or through a parallel interface. Alternatively, its gain can be set to an arbitrary value using two external resistors. The LMP8358 uses patented techniques to measure and continuously correct its input offset voltage, eliminating offset drift over time and temperature and the effect of 1/f noise. Its ground-sensing CMOS input features a high CMRR and low input bias currents. It is capable of sensing differential input voltages in a common-mode range that extends from 100mV below the negative supply to 1.4V below the positive supply, making it an ideal solution for interfacing with ground-referenced sensors, supply-referenced sensor bridges, and any other application requiring precision and long-term stability. Additionally, the LMP8358 includes fault detection circuitry to detect open and shorted inputs and deteriorating connections to the signal source. Other features that make the LMP8358 a versatile solution for many applications are its rail-to-rail output, low input voltage noise and high gain-bandwidth product.



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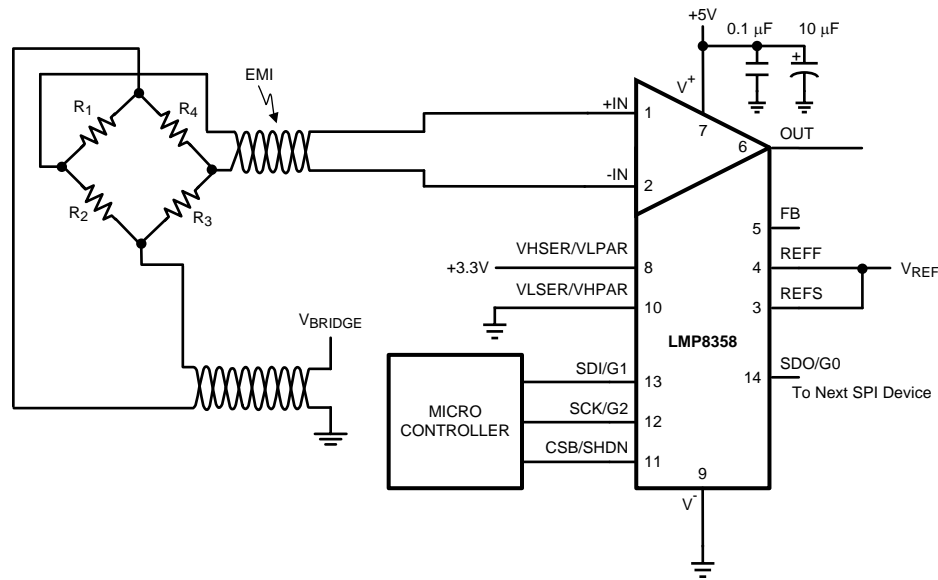
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## Typical Application



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## Absolute Maximum Ratings <sup>(1)(2)</sup>

|  |                  |  |
|--|------------------|--|
| ESD Tolerance <sup>(3)</sup>   | Human Body Model | 2kV  |
|  | Machine Model    | 200V                                       |
|  | Charge Device    | 1kV  |
| V <sub>IN</sub> Differential (V <sub>+IN</sub> - V <sub>-IN</sub> )  |                  | V <sub>S</sub>                             |
| Output Short Circuit Duration <sup>(4)</sup>   |                  |  |
| Any pin relative to V <sup>-</sup>   |                  | 6V, -0.3V                                  |
| +IN, -IN, OUT Pins   |                  | V <sup>+</sup> +0.3V, V <sup>-</sup> -0.3V |
| +IN, -IN Pins  |                  | ±10 mA                                     |
| Storage Temperature Range  |                  | -65°C to 150°C                             |
| Junction Temperature <sup>(5)</sup>  |                  | 150°C                                      |
| For soldering specifications: see product folder at <a href="http://www.ti.com">www.ti.com</a> and <a href="http://www.ti.com/lit/SNOA549">http://www.ti.com/lit/SNOA549</a> . |                  |  |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but for which specific performance is not ensured. For ensured specifications and the test conditions, see Electrical Characteristics.
- (2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.
- (3) Human Body Model, applicable std. MIL-STD-883, Method 3015.7. Machine Model, applicable std. JESD22-A115-A (ESD MM std. of JEDEC). Field-Induced Charge-Device Model, applicable std. JESD22-C101-C (ESD FICDM std. of JEDEC).
- (4) The short circuit test is a momentary test which applies to both single-supply and split-supply operation. Continuous short circuit operation at elevated ambient temperature can exceed the maximum allowable junction temperature of 150°C.
- (5) The maximum power dissipation is a function of T<sub>J(MAX)</sub>, θ<sub>JA</sub>. The maximum allowable power dissipation at any ambient temperature is P<sub>D</sub> = (T<sub>J(MAX)</sub> - T<sub>A</sub>) / θ<sub>JA</sub>. All numbers apply for packages soldered directly onto a PC Board.

## Operating Ratings <sup>(1)</sup>

|   |                |         |
|---|----------------|---------|
| Temperature Range   | –40°C to 125°C |         |
| Supply Voltage ( $V_S = V^+ - V^-$ )                        | 2.7V to 5.5V   |         |
| $V_{IN}$ Differential ( $V_{+IN} - V_{-IN}$ )               | ±100mV         |         |
| Package Thermal Resistance ( $\theta_{JA}$ <sup>(2)</sup> ) | 14-Pin SOIC    | 145°C/W |
|   | 14-Pin TSSOP   | 135°C/W |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but for which specific performance is not ensured. For ensured specifications and the test conditions, see Electrical Characteristics.
- (2) The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $\theta_{JA}$ . The maximum allowable power dissipation at any ambient temperature is  $P_D = (T_{J(MAX)} - T_A) / \theta_{JA}$ . All numbers apply for packages soldered directly onto a PC Board.

## 3.3V Electrical Characteristics

Unless otherwise specified, all limits are ensured for  $T_A = 25^\circ\text{C}$ .  $V^+ = 3.3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{REF} = V^+/2$ ,  $V_{CM} = V^+/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{REF}$ ,  $C_L = 10\text{ pF}$ ; Serial Control Register: G[2:0] = 110b (Gain = 1000x), COMP[2:0] = 000b, MUX[1:0] = 00b, POL, SHDN, FILT, PIN = 0b, CUR[2:0] = 000b. **Boldface** limits apply at the temperature extremes.

| Symbol      | Parameter   | Conditions  | Min <sup>(1)</sup> | Typ <sup>(2)</sup> | Max <sup>(1)</sup> | Units                                |
|-------------|---|---|--------------------|--------------------|--------------------|--------------------------------------|
| $V_{OS}$    | Input Offset Voltage                                  | $V_{CM} = V^+/2$  |                    | 1                  | 10<br><b>15</b>    | $\mu\text{V}$                        |
|             |   | $V_{CM} = 0\text{V}$  |                    | 1                  | 10<br><b>15</b>    |                                      |
| $TCV_{OS}$  | Input Offset Voltage Temperature Drift <sup>(3)</sup> | $V_{CM} = V^+/2$  |                    |                    | 50                 | $\text{nV}/^\circ\text{C}$           |
|             |   | $V_{CM} = 0\text{V}$  |                    |                    | 50                 |                                      |
| CMRR        | Common Mode Rejection Ratio                           | $V^- - 0.1\text{V} \leq V_{CM} \leq V^+ - 1.4\text{V}$        | 110<br><b>105</b>  | 139                |                    | dB                                   |
| CMVR        | Common Mode Voltage Range                             | $CMRR \geq 110\text{ dB}$                                     | <b>–0.1</b>        |                    | <b>1.9</b>         | V                                    |
| $V_{REFRR}$ | $V_{REF}$ Rejection Ratio                             | $V^- + 0.1\text{V} \leq V_{REF} \leq V^+ - 1.4\text{V}$       | 110<br><b>105</b>  | 145                |                    | dB                                   |
| PSRR        | Power supply Rejection Ratio                          | $2.7\text{V} \leq V^+ \leq 5.5\text{V}$                       | 112<br><b>105</b>  | 138                |                    | dB                                   |
| EMIRR       | Electro Magnetic Interference Rejection Ratio         | +IN / –IN, $V_{RF} = 100\text{ mV}_P$ , $f = 900\text{ MHz}$  |                    | 83                 |                    | dB                                   |
|             |   | +IN / –IN, $V_{RF} = 100\text{ mV}_P$ , $f = 1800\text{ MHz}$ |                    | 93                 |                    |                                      |
| $Z_{INDM}$  | Differential Input Impedance                          |   |                    | 50  1              |                    | $\text{M}\Omega \parallel \text{pF}$ |
| $Z_{INCM}$  | Common Mode Input Impedance                           |   |                    | 50  1              |                    | $\text{M}\Omega \parallel \text{pF}$ |
| $V_{INDM}$  | Differential Mode Input Voltage                       |   |                    |                    | ±100               | mV                                   |
| $I_B$       | Input Bias Current                                    |   |                    | 0.006              | 1.2<br><b>2</b>    | nA                                   |
| $I_{OS}$    | Input Offset Current                                  |   |                    | 0.1                | 112                | pA                                   |
| $e_n$       | Input Voltage Noise Density                           | Gain = 10, $f = 1\text{ kHz}$                                 |                    | 27                 |                    | $\text{nV}/\sqrt{\text{Hz}}$         |
|             |   | Gain = 20, $f = 1\text{ kHz}$                                 |                    | 31                 |                    |                                      |
|             |   | Gain = 50, $f = 1\text{ kHz}$                                 |                    | 28                 |                    |                                      |
|             |   | Gain = 100, $f = 1\text{ kHz}$                                |                    | 27                 |                    |                                      |
|             |   | Gain = 200, $f = 1\text{ kHz}$                                |                    | 28                 |                    |                                      |
|             |   | Gain = 500, $f = 1\text{ kHz}$                                |                    | 28                 |                    |                                      |
|             |   | Gain = 1000, $f = 1\text{ kHz}$                               |                    | 27                 |                    |                                      |
|             |   | Gain = External, $f = 1\text{ kHz}$                           |                    | 27                 |                    |                                      |

- (1) All limits are specified by testing or statistical analysis.
- (2) Typical Values indicate the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.
- (3) The offset voltage average drift is determined by dividing the value of  $V_{OS}$  at the temperature extremes by the total temperature change.

### 3.3V Electrical Characteristics (continued)

Unless otherwise specified, all limits are ensured for  $T_A = 25^\circ\text{C}$ .  $V^+ = 3.3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{REF}} = V^+/2$ ,  $V_{\text{CM}} = V^+/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{\text{REF}}$ ,  $C_L = 10\text{ pF}$ ; Serial Control Register: G[2:0] = 110b (Gain = 1000x), COMP[2:0] = 000b, MUX[1:0] = 00b, POL, SHDN, FILT, PIN = 0b, CUR[2:0] = 000b. **Boldface** limits apply at the temperature extremes.

| Symbol | Parameter                          | Conditions   | Min <sup>(1)</sup> | Typ <sup>(2)</sup> | Max <sup>(1)</sup>  | Units                        |
|--------|------------------------------------|--|--------------------|--------------------|---------------------|------------------------------|
| $e_n$  | Input Voltage Noise                | Gain = 10, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.9                |                     | $\mu\text{V}_{\text{PP}}$    |
|        |                                    | Gain = 20, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.6                |                     |                              |
|        |                                    | Gain = 50, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.6                |                     |                              |
|        |                                    | Gain = 100, $0.1\text{ Hz} < f < 10\text{ Hz}$   |                    | 0.7                |                     |                              |
|        |                                    | Gain = 200, $0.1\text{ Hz} < f < 10\text{ Hz}$   |                    | 0.6                |                     |                              |
|        |                                    | Gain = 500, $0.1\text{ Hz} < f < 10\text{ Hz}$   |                    | 0.6                |                     |                              |
|        |                                    | Gain = 1000, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.6                |                     |                              |
|        |                                    | Gain = External, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.6                |                     |                              |
| $I_n$  | Input Current Noise Density        | Gain = 100, $f = 1\text{ kHz}$   |                    | 0.5                |                     | $\text{pA}/\sqrt{\text{Hz}}$ |
| $G_E$  | Gain Error                         | Gain = 10, 20, 50, 100, 200, 500<br>$V_{\text{OUT}} = V_{\text{REF}} + 1\text{V}$ and $V_{\text{OUT}} = V_{\text{REF}} - 1\text{V}$                  |                    | 0.03               | 0.1<br><b>0.15</b>  | %                            |
| $G_E$  | Gain Error                         | Gain = 1000<br>$V_{\text{OUT}} = V_{\text{REF}} + 1\text{V}$ and $V_{\text{OUT}} = V_{\text{REF}} - 1\text{V}$                                       |                    | 0.03               | 0.15<br><b>0.25</b> | %                            |
| $G_E$  | Gain Error Contribution from Chip  | $V_{\text{OUT}} = V_{\text{REF}} + 1\text{V}$ and $V_{\text{OUT}} = V_{\text{REF}} - 1\text{V}$  |                    | 0.03               |                     | %                            |
|        | Gain Error Temperature Coefficient | For all gain settings (internal and external),<br>$V_{\text{OUT}} = V_{\text{REF}} + 1\text{V}$ and<br>$V_{\text{OUT}} = V_{\text{REF}} - 1\text{V}$ |                    | 3                  | 16                  | $\text{ppm}/^\circ\text{C}$  |
| NL     | Non-Linearity                      |  |                    | 3.3                | 100                 | ppm                          |
| GBW    | Gain Bandwidth                     | COMP[2:0] = 000b, Gain > 10  |                    | 8                  |                     | MHz                          |
|        |                                    | COMP[2:0] = 001b, Gain > 30  |                    | 24                 |                     |                              |
|        |                                    | COMP[2:0] = 010b, Gain > 200   |                    | 80                 |                     |                              |
|        |                                    | COMP[2:0] = 011b, Gain > 300   |                    | 240                |                     |                              |
|        |                                    | COMP[2:0] = 1xxb, Gain > 1   |                    | 0.8                |                     |                              |
| BW     | -3 dB Bandwidth                    | Gain = 10, COMP[2:0] = 000b  |                    | 900                |                     | kHz                          |
|        |                                    | Gain = 10, COMP[2:0] = 1xxb  |                    | 70                 |                     |                              |
|        |                                    | Gain = 20, COMP[2:0] = 000b  |                    | 400                |                     |                              |
|        |                                    | Gain = 20, COMP[2:0] = 1xxb  |                    | 37                 |                     |                              |
|        |                                    | Gain = 50, COMP[2:0] = 001b  |                    | 490                |                     |                              |
|        |                                    | Gain = 50, COMP[2:0] = 1xxb  |                    | 16                 |                     |                              |
|        |                                    | Gain = 100, COMP[2:0] = 010b   |                    | 680                |                     |                              |
|        |                                    | Gain = 100, COMP[2:0] = 1xxb   |                    | 8                  |                     |                              |
|        |                                    | Gain = 200, COMP[2:0] = 010b   |                    | 195                |                     |                              |
|        |                                    | Gain = 200, COMP[2:0] = 1xxb   |                    | 4                  |                     |                              |
|        |                                    | Gain = 500, COMP[2:0] = 011b   |                    | 130                |                     |                              |
|        |                                    | Gain = 500, COMP[2:0] = 1xxb   |                    | 1.5                |                     |                              |
|        |                                    | Gain = 1000, COMP[2:0] = 011b  |                    | 89                 |                     |                              |
|        |                                    | Gain = 1000, COMP[2:0] = 1xxb  |                    | 0.8                |                     |                              |
| SR     | Slew Rate <sup>(4)</sup>           | COMP[2:0] = 000b, 10% to 90% of Step,<br>$V_{\text{OUT}} = 2\text{ V}_{\text{PP}}$   |                    | 1.6                |                     | $\text{V}/\mu\text{s}$       |
|        |                                    | COMP[2:0] = 001b, 10% to 90% of Step,<br>$V_{\text{OUT}} = 2\text{ V}_{\text{PP}}$   |                    | 3.8                |                     |                              |
|        |                                    | COMP[2:0] = 010b, 10% to 90% of Step,<br>$V_{\text{OUT}} = 2\text{ V}_{\text{PP}}$   |                    | 6.5                |                     |                              |
|        |                                    | COMP[2:0] = 011b, 10% to 90% of Step,<br>$V_{\text{OUT}} = 2\text{ V}_{\text{PP}}$   |                    | 9.3                |                     |                              |
|        |                                    | COMP[2:0] = 1xxb, 10% to 90% of Step,<br>$V_{\text{OUT}} = 2\text{ V}_{\text{PP}}$   |                    | 0.17               |                     |                              |

(4) Slew rate is the average of the rising and falling slew rates.

### 3.3V Electrical Characteristics (continued)

Unless otherwise specified, all limits are ensured for  $T_A = 25^\circ\text{C}$ .  $V^+ = 3.3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{REF}} = V^+/2$ ,  $V_{\text{CM}} = V^+/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{\text{REF}}$ ,  $C_L = 10\text{ pF}$ ; Serial Control Register: G[2:0] = 110b (Gain = 1000x), COMP[2:0] = 000b, MUX[1:0] = 00b, POL, SHDN, FILT, PIN = 0b, CUR[2:0] = 000b. **Boldface** limits apply at the temperature extremes.

| Symbol              | Parameter                             | Conditions  | Min <sup>(1)</sup> | Typ <sup>(2)</sup> | Max <sup>(1)</sup> | Units               |
|---------------------|---------------------------------------|---|--------------------|--------------------|--------------------|---------------------|
| $t_s$               | 0.01% Settling Time                   | 2 V Step, $C_L = 10\text{ pF}$ , COMP[2:0] = 011b                 |                    | 4                  |                    | $\mu\text{s}$       |
| $V_{\text{OUT}}$    | Output Voltage Swing High             | $R_L = 2\text{ k}\Omega$ to $V^+/2$                               |                    |                    | 32<br><b>40</b>    | mV from top rail    |
|                     |                                       | $R_L = 10\text{ k}\Omega$ to $V^+/2$                              |                    |                    | 12<br><b>17</b>    |                     |
|                     |                                       | $R_L > 1\text{ M}\Omega$ to $V^+/2$                               |                    |                    | 7<br><b>12</b>     |                     |
|                     | Output Voltage Swing Low              | $R_L = 2\text{ k}\Omega$ to $V^+/2$                               |                    |                    | 28<br><b>38</b>    | mV from bottom rail |
|                     |                                       | $R_L = 10\text{ k}\Omega$ to $V^+/2$                              |                    |                    | 12<br><b>17</b>    |                     |
|                     |                                       | $R_L > 1\text{ M}\Omega$ to $V^+/2$                               |                    |                    | 8<br><b>13</b>     |                     |
| $I_{\text{OUT}}$    | Output Current Sourcing               | $V_{\text{OUT}}$ tied to $V^+/2$                                  | 21<br><b>15</b>    | 28                 |                    | mA                  |
|                     | Output Current Sinking                | $V_{\text{OUT}}$ tied to $V^+/2$                                  | 32<br><b>25</b>    | 37                 |                    |                     |
| $I_S$               | Supply Current                        | Fault detection off, $V_{\text{IN DIFF}} = 0\text{V}$             |                    | 1.8                | 2.1                | mA                  |
|                     |                                       | Fault detection on, $V_{\text{IN DIFF}} = 0\text{V}$              |                    | 1.9                | 2.2                | mA                  |
|                     |                                       | in Shutdown   |                    | 0.014              | 1                  | $\mu\text{A}$       |
| $T_{\text{SD\_ON}}$ | Turn-on time from Shutdown            |   |                    | 85                 |                    | $\mu\text{s}$       |
| $\text{PSE}$        | Prescaler Error (Offset + Gain Error) | $V_{\text{CM}} = V^+/2$   |                    | 5                  | 15                 | mV                  |
|                     | Prescaler Gain Factor                 |   |                    | 0.02               |                    | V/V                 |
| $I_{\text{TEST}}$   | Fault Detection: Test Current         | Setting 1 (CUR[2:0] = 001b), $V_{\text{CM}} < V^+ - 1.15\text{V}$ |                    | 10                 |                    | nA                  |
|                     |                                       | Setting 2 (CUR[2:0] = 010b), $V_{\text{CM}} < V^+ - 1.15\text{V}$ |                    | 100                |                    | nA                  |
|                     |                                       | Setting 3 (CUR[2:0] = 011b), $V_{\text{CM}} < V^+ - 1.15\text{V}$ |                    | 1                  |                    | $\mu\text{A}$       |
|                     |                                       | Setting 4 (CUR[2:0] = 100b), $V_{\text{CM}} < V^+ - 1.15\text{V}$ |                    | 10                 |                    | $\mu\text{A}$       |
|                     |                                       | Setting 5 (CUR[2:0] = 101b), $V_{\text{CM}} < V^+ - 1.15\text{V}$ |                    | 100                |                    | $\mu\text{A}$       |

### 5.0V Electrical Characteristics

Unless otherwise specified, all limits are ensured for  $T_A = 25^\circ\text{C}$ .  $V^+ = 5.0\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{REF}} = V^+/2$ ,  $V_{\text{CM}} = V^+/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{\text{REF}}$ ,  $C_L = 10\text{ pF}$ ; Serial Control Register: G[2:0] = 110b (Gain = 1000x), COMP[2:0] = 000b, MUX[1:0] = 00b, POL, SHDN, FILT, PIN = 0b, CUR[2:0] = 000b. **Boldface** limits apply at the temperature extremes.

| Symbol                   | Parameter   | Conditions                  | Min <sup>(1)</sup> | Typ <sup>(2)</sup> | Max <sup>(1)</sup> | Units                |
|--------------------------|---|-----------------------------|--------------------|--------------------|--------------------|----------------------|
| $V_{\text{OS}}$          | Input Offset Voltage                                  | $V_{\text{CM}} = V^+/2$     |                    | 0.9                | 10<br><b>15</b>    | $\mu\text{V}$        |
|                          |   | $V_{\text{CM}} = 0\text{V}$ |                    | 0.9                | 10<br><b>15</b>    |                      |
| $\text{TCV}_{\text{OS}}$ | Input Offset Voltage Temperature Drift <sup>(3)</sup> | $V_{\text{CM}} = V^+/2$     |                    |                    | 50                 | nV/ $^\circ\text{C}$ |
|                          |   | $V_{\text{CM}} = 0\text{V}$ |                    |                    | 50                 |                      |

(1) All limits are specified by testing or statistical analysis.

(2) Typical Values indicate the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.

(3) The offset voltage average drift is determined by dividing the value of  $V_{\text{OS}}$  at the temperature extremes by the total temperature change.

## 5.0V Electrical Characteristics (continued)

Unless otherwise specified, all limits are ensured for  $T_A = 25^\circ\text{C}$ .  $V^+ = 5.0\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{REF}} = V^+/2$ ,  $V_{\text{CM}} = V^+/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{\text{REF}}$ ,  $C_L = 10\text{ pF}$ ; Serial Control Register: G[2:0] = 110b (Gain = 1000x), COMP[2:0] = 000b, MUX[1:0] = 00b, POL, SHDN, FILT, PIN = 0b, CUR[2:0] = 000b. **Boldface** limits apply at the temperature extremes.

| Symbol             | Parameter                                     | Conditions   | Min <sup>(1)</sup> | Typ <sup>(2)</sup> | Max <sup>(1)</sup>  | Units                     |
|--------------------|---|--|--------------------|--------------------|---------------------|---------------------------|
| CMRR               | Common Mode Rejection Ratio                   | $V^- - 0.1\text{V} \leq V_{\text{CM}} \leq V^+ - 1.4\text{V}$  | 116<br><b>105</b>  | 142                |                     | dB                        |
| $V_{\text{REFRR}}$ | $V_{\text{REF}}$ Rejection Ratio              | $V^- + 0.1\text{V} \leq V_{\text{REF}} \leq V^+ - 1.4\text{V}$   | 115<br><b>105</b>  | 150                |                     | dB                        |
| CMVR               | Common Mode Voltage Range                     | CMRR $\geq 115\text{ dB}$  | <b>-0.1</b>        |                    | <b>3.6</b>          | V                         |
| PSRR               | Power supply Rejection Ratio                  | $2.7\text{V} \leq V^+ \leq 5.5\text{V}$  | 112<br><b>105</b>  | 138                |                     | dB                        |
| EMIRR              | Electro Magnetic Interference Rejection Ratio | +IN / -IN, $V_{\text{RF}} = 100\text{ mV}_P$ , $f = 900\text{ MHz}$  |                    | 83                 |                     | dB                        |
|                    |   | +IN / -IN, $V_{\text{RF}} = 100\text{ mV}_P$ , $f = 1800\text{ MHz}$   |                    | 93                 |                     |                           |
| $Z_{\text{INDM}}$  | Differential Input Impedance                  |  |                    | 50  1              |                     | M $\Omega$    pF          |
| $Z_{\text{INCM}}$  | Common Mode Input Impedance                   |  |                    | 50  1              |                     | M $\Omega$    pF          |
| $V_{\text{INDM}}$  | Differential Mode Input Voltage               |  |                    |                    | $\pm 100$           | mV                        |
| $I_B$              | Input Bias Current                            |  |                    | 0.006              | 1.2<br><b>2</b>     | nA                        |
| $I_{\text{OS}}$    | Input Offset Current                          |  |                    | 0.2                | 113                 | pA                        |
| $e_n$              | Input Voltage Noise Density                   | Gain = 10, $f = 1\text{ kHz}$  |                    | 25                 |                     | nV/ $\sqrt{\text{Hz}}$    |
|                    |   | Gain = 20, $f = 1\text{ kHz}$  |                    | 28                 |                     |                           |
|                    |   | Gain = 50, $f = 1\text{ kHz}$  |                    | 26                 |                     |                           |
|                    |   | Gain = 100, $f = 1\text{ kHz}$   |                    | 25                 |                     |                           |
|                    |   | Gain = 200, $f = 1\text{ kHz}$   |                    | 28                 |                     |                           |
|                    |   | Gain = 500, $f = 1\text{ kHz}$   |                    | 26                 |                     |                           |
|                    |   | Gain = 1000, $f = 1\text{ kHz}$  |                    | 25                 |                     |                           |
|                    |   | Gain = External, $f = 1\text{ kHz}$  |                    | 25                 |                     |                           |
| $e_n$              | Input Voltage Noise                           | Gain = 10, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.7                |                     | $\mu\text{V}_{\text{PP}}$ |
|                    |   | Gain = 20, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.7                |                     |                           |
|                    |   | Gain = 50, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.5                |                     |                           |
|                    |   | Gain = 100, $0.1\text{ Hz} < f < 10\text{ Hz}$   |                    | 0.6                |                     |                           |
|                    |   | Gain = 200, $0.1\text{ Hz} < f < 10\text{ Hz}$   |                    | 0.6                |                     |                           |
|                    |   | Gain = 500, $0.1\text{ Hz} < f < 10\text{ Hz}$   |                    | 0.5                |                     |                           |
|                    |   | Gain = 1000, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.6                |                     |                           |
|                    |   | Gain = External, $0.1\text{ Hz} < f < 10\text{ Hz}$  |                    | 0.6                |                     |                           |
| $I_n$              | Input Current Noise Density                   | Gain = 100, $f = 1\text{ kHz}$   |                    | 0.5                |                     | pA/ $\sqrt{\text{Hz}}$    |
| $G_E$              | Gain Error                                    | Gain = 10, 20, 50, 100, 200, 500<br>$V_{\text{OUT}} = V_{\text{REF}} + 1\text{V}$ and $V_{\text{OUT}} = V_{\text{REF}} - 1\text{V}$                  |                    | 0.03               | 0.1<br><b>0.15</b>  | %                         |
| $G_E$              | Gain Error                                    | Gain = 1000<br>$V_{\text{OUT}} = V_{\text{REF}} + 1\text{V}$ and $V_{\text{OUT}} = V_{\text{REF}} - 1\text{V}$                                       |                    | 0.03               | 0.15<br><b>0.25</b> | %                         |
| $G_E$              | Gain Error Contribution from chip             | $V_{\text{OUT}} = V_{\text{REF}} + 1\text{V}$ and $V_{\text{OUT}} = V_{\text{REF}} - 1\text{V}$  |                    | 0.03               |                     | %                         |
|                    | Gain Error Temperature Coefficient            | For all gain settings (internal and external),<br>$V_{\text{OUT}} = V_{\text{REF}} + 1\text{V}$ and<br>$V_{\text{OUT}} = V_{\text{REF}} - 1\text{V}$ |                    | 3                  | 16                  | ppm/ $^\circ\text{C}$     |
| NL                 | Non-Linearity                                 |  |                    | 3                  | 100                 | ppm                       |
| GBW                | Gain Bandwidth                                | COMP[2:0] = 000b, Gain > 10  |                    | 8                  |                     | MHz                       |
|                    |   | COMP[2:0] = 001b, Gain > 100   |                    | 24                 |                     |                           |
|                    |   | COMP[2:0] = 010b, Gain > 200   |                    | 80                 |                     |                           |
|                    |   | COMP[2:0] = 011b, Gain > 500   |                    | 240                |                     |                           |
|                    |   | COMP[2:0] = 1xxb,<br>Gain $\Rightarrow 1$  |                    | 0.8                |                     |                           |

## 5.0V Electrical Characteristics (continued)

Unless otherwise specified, all limits are ensured for  $T_A = 25^\circ\text{C}$ .  $V^+ = 5.0\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{REF}} = V^+/2$ ,  $V_{\text{CM}} = V^+/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{\text{REF}}$ ,  $C_L = 10\text{ pF}$ ; Serial Control Register: G[2:0] = 110b (Gain = 1000x), COMP[2:0] = 000b, MUX[1:0] = 00b, POL, SHDN, FILT, PIN = 0b, CUR[2:0] = 000b. **Boldface** limits apply at the temperature extremes.

| Symbol              | Parameter                             | Conditions   | Min <sup>(1)</sup> | Typ <sup>(2)</sup> | Max <sup>(1)</sup> | Units               |
|---------------------|---------------------------------------|--|--------------------|--------------------|--------------------|---------------------|
| BW                  | –3 dB Bandwidth                       | Gain = 10, COMP[2:0] = 000b  |                    | 930                |                    | kHz                 |
|                     |                                       | Gain = 10, COMP[2:0] = 1xxb  |                    | 74                 |                    |                     |
|                     |                                       | Gain = 20, COMP[2:0] = 000b  |                    | 385                |                    |                     |
|                     |                                       | Gain = 20, COMP[2:0] = 1xxb  |                    | 37                 |                    |                     |
|                     |                                       | Gain = 50, COMP[2:0] = 001b  |                    | 460                |                    |                     |
|                     |                                       | Gain = 50, COMP[2:0] = 1xxb  |                    | 16                 |                    |                     |
|                     |                                       | Gain = 100, COMP[2:0] = 010b   |                    | 640                |                    |                     |
|                     |                                       | Gain = 100, COMP[2:0] = 1xxb   |                    | 8                  |                    |                     |
|                     |                                       | Gain = 200, COMP[2:0] = 010b   |                    | 195                |                    |                     |
|                     |                                       | Gain = 200, COMP[2:0] = 1xxb   |                    | 4                  |                    |                     |
|                     |                                       | Gain = 500, COMP[2:0] = 011b   |                    | 130                |                    |                     |
|                     |                                       | Gain = 500, COMP[2:0] = 1xxb   |                    | 1.5                |                    |                     |
|                     |                                       | Gain = 1000, COMP[2:0] = 011b  |                    | 89                 |                    |                     |
|                     |                                       | Gain = 1000, COMP[2:0] = 1xxb  |                    | 0.8                |                    |                     |
| SR                  | Slew Rate <sup>(4)</sup>              | COMP[2:0] = 000b, 10% to 90% of Step, $V_{\text{OUT}} = 2 V_{\text{PP}}$ |                    | 1.7                |                    | V/ $\mu\text{s}$    |
|                     |                                       | COMP[2:0] = 001b, 10% to 90% of Step, $V_{\text{OUT}} = 2 V_{\text{PP}}$ |                    | 5.0                |                    |                     |
|                     |                                       | COMP[2:0] = 010b, 10% to 90% of Step, $V_{\text{OUT}} = 2 V_{\text{PP}}$ |                    | 9.0                |                    |                     |
|                     |                                       | COMP[2:0] = 011b, 10% to 90% of Step, $V_{\text{OUT}} = 2 V_{\text{PP}}$ |                    | 11.0               |                    |                     |
|                     |                                       | COMP[2:0] = 1xxb, 10% to 90% of Step, $V_{\text{OUT}} = 2 V_{\text{PP}}$ |                    | 0.16               |                    |                     |
| $t_s$               | 0.01% Settling Time                   | 2 V Step, $C_L = 10\text{ pF}$ , COMP[2:0] = 011b                        |                    | 4                  |                    | $\mu\text{s}$       |
| $V_{\text{OUT}}$    | Output Voltage Swing High             | $R_L = 2\text{ k}\Omega$ to $V^+/2$                                      |                    |                    | 52<br><b>62</b>    | mV from top rail    |
|                     |                                       | $R_L = 10\text{ k}\Omega$ to $V^+/2$                                     |                    |                    | 22<br><b>30</b>    |                     |
|                     |                                       | $R_L > 1\text{ M}\Omega$ to $V^+/2$                                      |                    |                    | 12<br><b>17</b>    |                     |
|                     | Output Voltage Swing Low              | $R_L = 2\text{ k}\Omega$ to $V^+/2$                                      |                    |                    | 42<br><b>55</b>    | mV from bottom rail |
|                     |                                       | $R_L = 10\text{ k}\Omega$ to $V^+/2$                                     |                    |                    | 16<br><b>22</b>    |                     |
|                     |                                       | $R_L > 1\text{ M}\Omega$ to $V^+/2$                                      |                    |                    | 12<br><b>17</b>    |                     |
| $I_{\text{OUT}}$    | Output Current Sourcing               | $V_{\text{OUT}}$ tied to $V^+/2$   | 23<br><b>16</b>    | 31                 |                    | mA                  |
|                     | Output Current Sinking                | $V_{\text{OUT}}$ tied to $V^+/2$   | 34<br><b>30</b>    | 41                 |                    |                     |
| $I_S$               | Supply Current                        | Fault detection off, $V_{\text{IN DIFF}} = 0\text{V}$                    |                    | 1.8                | 2.1                | mA                  |
|                     |                                       | Fault detection on, $V_{\text{IN DIFF}} = 0\text{V}$                     |                    | 1.9                | 2.2                | mA                  |
|                     |                                       | in Shutdown  |                    | 0.006              | 1                  | $\mu\text{A}$       |
| $T_{\text{SD\_ON}}$ | Turn-on time from Shutdown            |  |                    | 85                 |                    | $\mu\text{s}$       |
| $\text{PSE}$        | Prescaler Error (Offset + Gain Error) | $V_{\text{CM}} = V^+/2$  |                    | 5                  | 8                  | mV                  |
|                     | Prescaler Gain Factor                 |  |                    | 0.02               |                    | V/V                 |

(4) Slew rate is the average of the rising and falling slew rates.

### 5.0V Electrical Characteristics (continued)

Unless otherwise specified, all limits are ensured for  $T_A = 25^\circ\text{C}$ .  $V^+ = 5.0\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{REF}} = V^+/2$ ,  $V_{\text{CM}} = V^+/2$ ,  $R_L = 10\text{ k}\Omega$  to  $V_{\text{REF}}$ ,  $C_L = 10\text{ pF}$ ; Serial Control Register:  $G[2:0] = 110\text{b}$  (Gain = 1000x),  $\text{COMP}[2:0] = 000\text{b}$ ,  $\text{MUX}[1:0] = 00\text{b}$ ,  $\text{POL}$ ,  $\text{SHDN}$ ,  $\text{FILT}$ ,  $\text{PIN} = 0\text{b}$ ,  $\text{CUR}[2:0] = 000\text{b}$ . **Boldface** limits apply at the temperature extremes.

| Symbol            | Parameter                     | Conditions  | Min <sup>(1)</sup> | Typ <sup>(2)</sup> | Max <sup>(1)</sup> | Units |
|-------------------|-------------------------------|---|--------------------|--------------------|--------------------|-------|
| I <sub>TEST</sub> | Fault Detection: Test Current | Setting 1 (CUR[2:0] = 001b), V <sub>CM</sub> < V <sup>+</sup> - 2.25V |                    | 10                 |                    | nA    |
|                   |                               | Setting 2 (CUR[2:0] = 010b), V <sub>CM</sub> < V <sup>+</sup> - 2.25V |                    | 100                |                    | nA    |
|                   |                               | Setting 3 (CUR[2:0] = 011b), V <sub>CM</sub> < V <sup>+</sup> - 2.25V |                    | 1                  |                    | μA    |
|                   |                               | Setting 4 (CUR[2:0] = 100b), V <sub>CM</sub> < V <sup>+</sup> - 2.25V |                    | 10                 |                    | μA    |
|                   |                               | Setting 5 (CUR[2:0] = 101b), V <sub>CM</sub> < V <sup>+</sup> - 2.25V |                    | 100                |                    | μA    |

### Electrical Characteristics (Serial Interface)

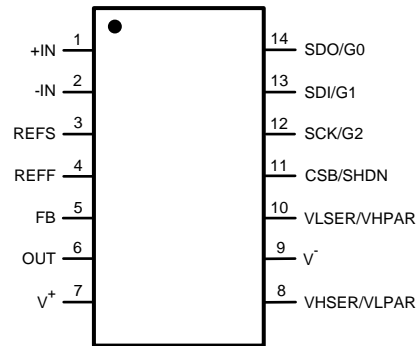
Unless otherwise specified, all limits ensured for  $T_A = 25^\circ\text{C}$ ,  $V^+ - V^- \geq 2.7\text{V}$ ,  $V^+ \geq \text{VHSER/VLPA}$ ,  $V^- \leq \text{VLSER/VHPA}$ ,  $V_D = (\text{VHSER/VLPA}) - (\text{VLSER/VHPA}) \geq 2.5\text{V}$ .

| Symbol                         | Parameter                                     | Conditions  | Min <sup>(1)</sup>    | Typ <sup>(2)</sup> | Max <sup>(1)</sup>   | Units |
|--------------------------------|---|---|-----------------------|--------------------|----------------------|-------|
| V <sub>IL</sub>                | Input Logic Low Threshold                     |   |                       |                    | 0.3 × V <sub>D</sub> | V     |
| V <sub>IH</sub>                | Input Logic High Threshold                    |   | 0.7 × V <sub>D</sub>  |                    |                      | V     |
| V <sub>OL</sub>                | Output Logic Low Threshold                    | I <sub>SDO</sub> = 2mA  |                       |                    | 0.2                  | V     |
| V <sub>OH</sub>                | Output Logic High Threshold                   | I <sub>SDO</sub> = 2mA  | V <sub>D</sub> – 0.2V |                    |                      |       |
| I <sub>SDO</sub>               | Output Source Current, SDO                    | V <sub>D</sub> = 3.3V or 5.0V,<br>CSB = 0V, V <sub>OH</sub> = V <sup>+</sup> – 0.7V | –2                    |                    |                      | mA    |
|                                | Output Sink Current, SDO                      | V <sub>D</sub> = 3.3V or 5.0V,<br>CSB = 0V, V <sub>OL</sub> = 1.0V                  | 2                     |                    |                      |       |
| I <sub>OZ</sub>                | Output Tri-state Leakage Current, SDO         | V <sub>D</sub> = 3.3V or 5.0V,<br>CSB = V <sub>D</sub> = 3.3V or 5V                 |                       |                    | ±1                   | μA    |
| t <sub>1</sub>                 | High Period, SCK                              | (3)   | 100                   |                    |                      | ns    |
| t <sub>2</sub>                 | Low Period, SCK                               | (3)   | 100                   |                    |                      | ns    |
| t <sub>3</sub>                 | Set Up Time, CSB to SCK                       | (3)   | 50                    |                    |                      | ns    |
| t <sub>4</sub>                 | Set Up Time, SDI to SCK                       | (3)   | 30                    |                    |                      | ns    |
| t <sub>5</sub>                 | Hold Time, SCK to SDI                         | (3)   | 10                    |                    |                      | ns    |
| t <sub>6</sub>                 | Prop. Delay, SCK to SDO                       | (3)   |                       |                    | 60                   | ns    |
| t <sub>7</sub>                 | Hold Time, SCK Transition to CSB Rising Edge  | (3)   | 50                    |                    |                      | ns    |
| t <sub>8</sub>                 | CSB Inactive                                  | (3)   | 50                    |                    |                      | ns    |
| t <sub>9</sub>                 | Prop. Delay, CSB to SDO Active                | (3)   |                       |                    | 50                   | ns    |
| t <sub>10</sub>                | Prop. Delay, CSB to SDO Inactive              | (3)   |                       |                    | 50                   | ns    |
| t <sub>11</sub>                | Hold Time, SCK Transition to CSB Falling Edge | (3)   | 10                    |                    |                      | ns    |
| t <sub>r</sub> /t <sub>f</sub> | Signal Rise and Fall Times                    | (3)   | 1.5                   |                    | 5                    | ns    |

- (1) All limits are specified by testing or statistical analysis.
- (2) Typical Values indicate the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not ensured on shipped production material.
- (3) Load for these tests is shown in the Timing Diagram Test Circuit.



## Connection Diagram

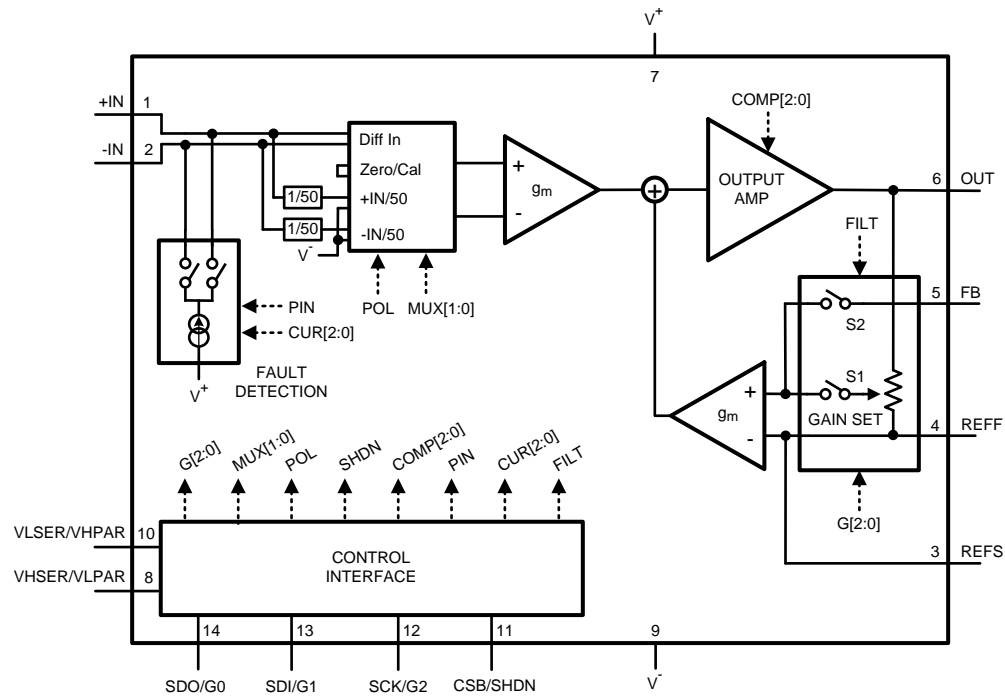


**Figure 1. 14-Pin SOIC/ 14-Pin TSSOP  
Top View**

## Pin Descriptions

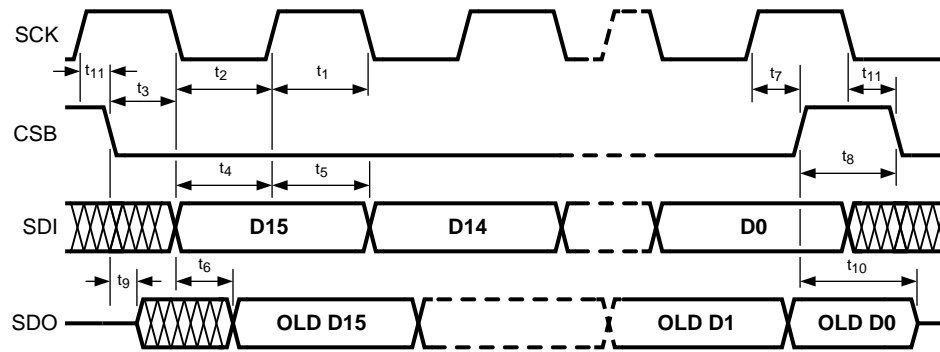
| Pin Name       | Communication Mode |                        |
|----------------|--------------------|------------------------|
|                | Serial             | Parallel               |
| +IN            | Positive Input     |                        |
| -IN            | Negative Input     |                        |
| REFS           | Reference Sense    |                        |
| REFF           | Reference Force    |                        |
| FB             | Feedback           |                        |
| OUT            | Output             |                        |
| V <sup>+</sup> | Positive Supply    |                        |
| VHSER/VLPAR    | Set High           | Set Low                |
| V <sup>-</sup> | Negative Supply    |                        |
| VLSEr/VHPAR    | Set Low            | Set High               |
| CSB/SHDN       | Chip Select        | Shutdown (Active High) |
| SCK/G2         | Serial Clock       | Gain (MSB)             |
| SDI/G1         | Serial Data In     | Gain                   |
| SDO/G0         | Serial Data Out    | Gain (LSB)             |

## Block Diagram

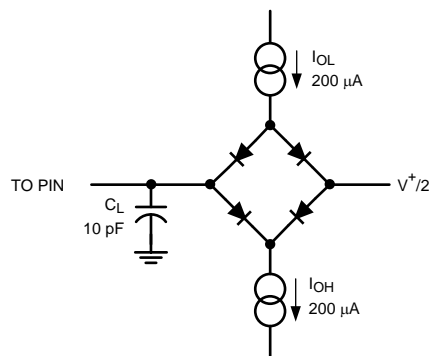


**Figure 2. 14-Pin SOIC/ 14-Pin TSSOP**

## Timing Diagrams



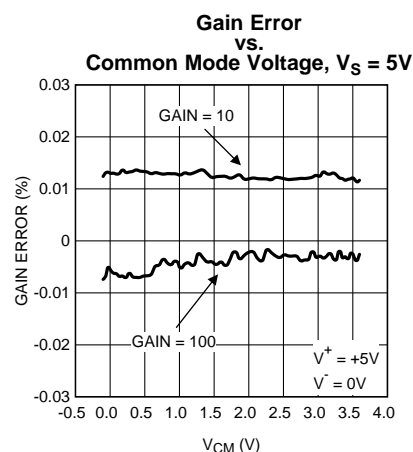
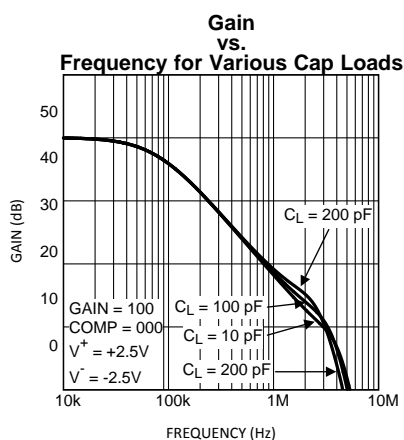
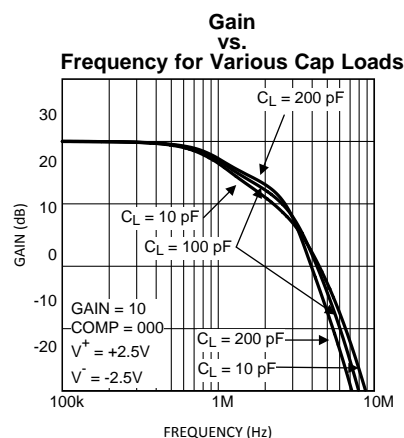
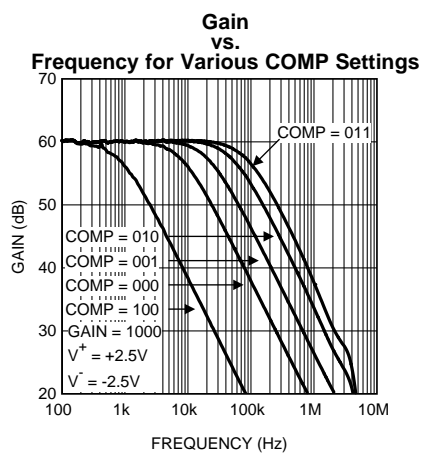
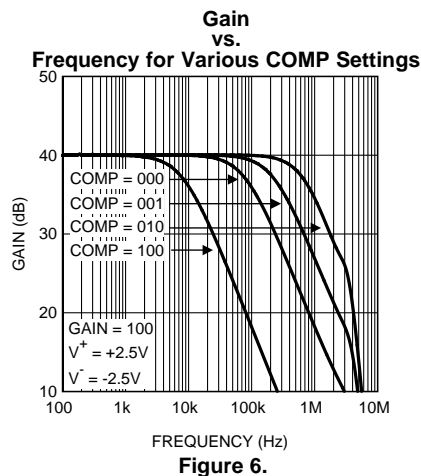
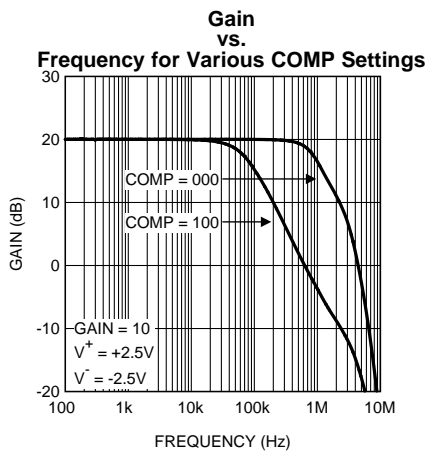
**Figure 3. SPI Timing Diagram**



**Figure 4. Timing Diagram Test Circuit**

## Typical Performance Characteristics

$V^+ = 3.3V$  and  $T_A = 25^\circ C$  unless otherwise noted.



## Typical Performance Characteristics (continued)

$V^+ = 3.3V$  and  $T_A = 25^\circ C$  unless otherwise noted.

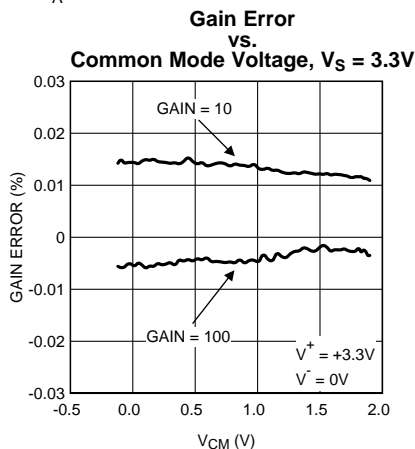


Figure 11.

### Gain Error Distribution, Gain = 10, $V_S = 3.3V$

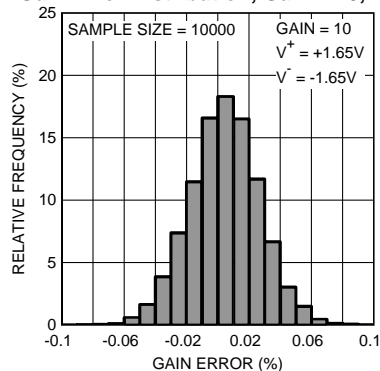


Figure 12.

### Gain Error Distribution, Gain = 100, $V_S = 3.3V$

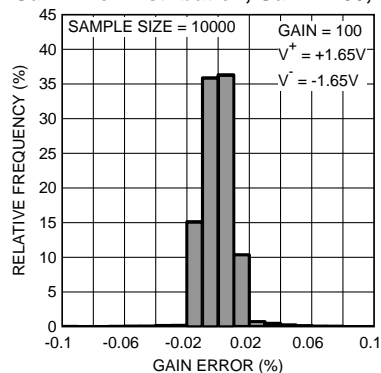


Figure 13.

### Gain Error Distribution, Gain = 1000, $V_S = 3.3V$

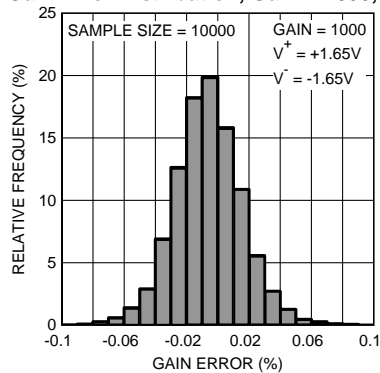


Figure 14.

### $V_{OS}$ Distribution, $V_S = 3.3V$

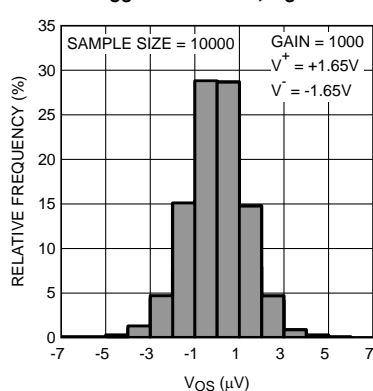


Figure 15.

### $V_{OS}$ Distribution, $V_S = 5.0V$

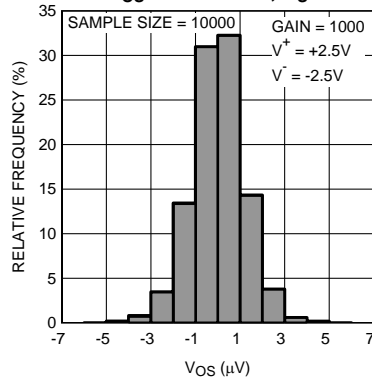
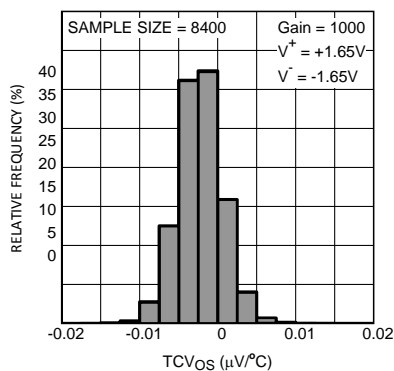


Figure 16.

## Typical Performance Characteristics (continued)

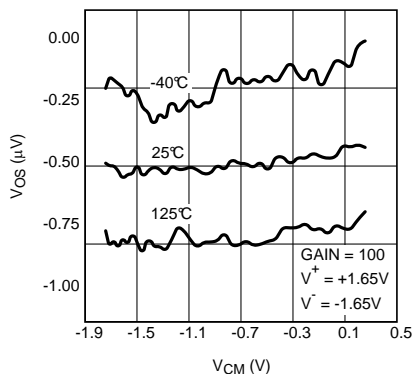
$V^+ = 3.3\text{V}$  and  $T_A = 25^\circ\text{C}$  unless otherwise noted.

**TCV<sub>OS</sub> Distribution,  $V_S = 3.3\text{V}$**

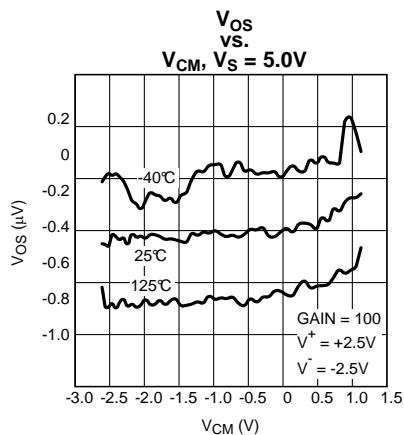


**Figure 17.**

**$V_{OS}$   
vs.  
 $V_{CM}$ ,  $V_S = 3.3\text{V}$**

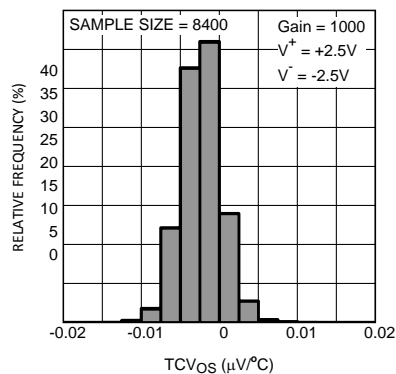


**Figure 19.**



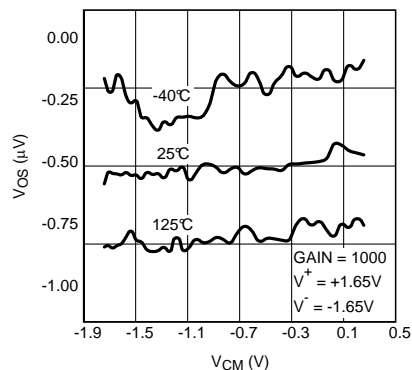
**Figure 21.**

**TCV<sub>OS</sub> Distribution,  $V_S = 5\text{V}$**

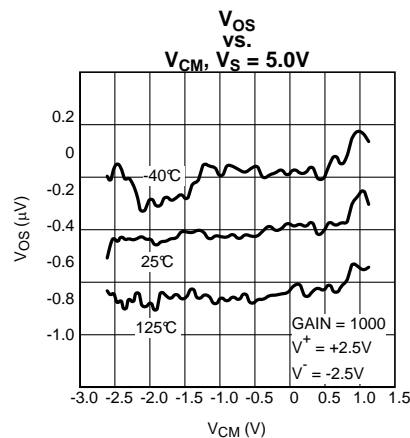


**Figure 18.**

**$V_{OS}$   
vs.  
 $V_{CM}$ ,  $V_S = 3.3\text{V}$**



**Figure 20.**



**Figure 22.**

## Typical Performance Characteristics (continued)

$V^+ = 3.3\text{V}$  and  $T_A = 25^\circ\text{C}$  unless otherwise noted.

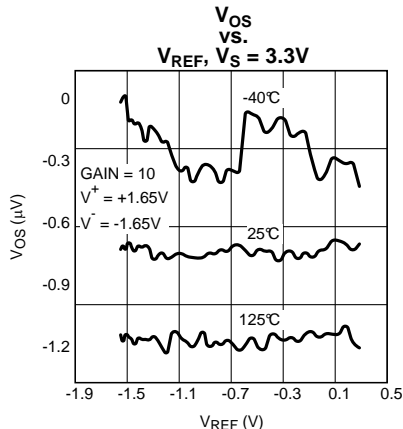


Figure 23.

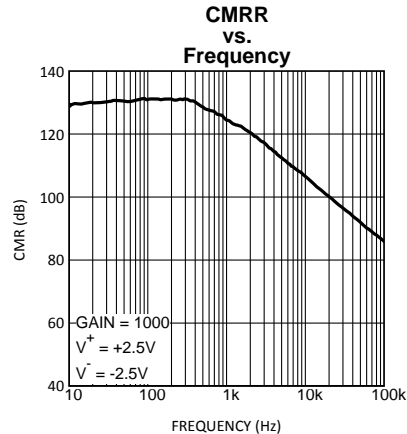


Figure 24.

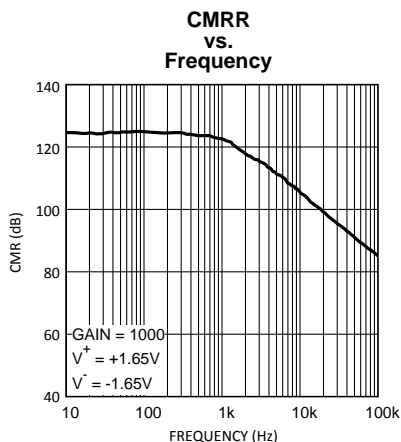


Figure 25.

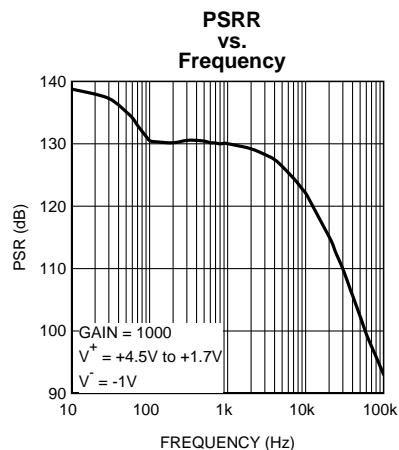


Figure 26.

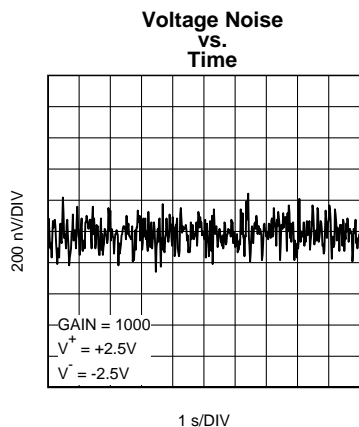


Figure 27.

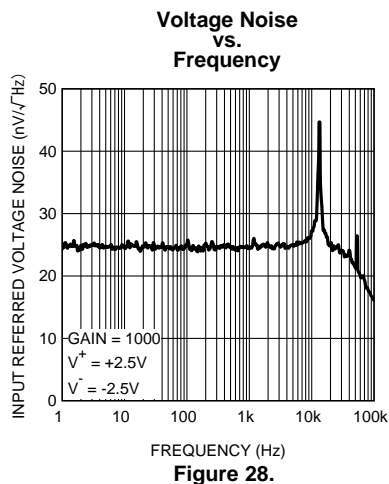


Figure 28.

## Typical Performance Characteristics (continued)

$V^+ = 3.3\text{V}$  and  $T_A = 25^\circ\text{C}$  unless otherwise noted.

Small Signal Step Response for Various COMP Settings

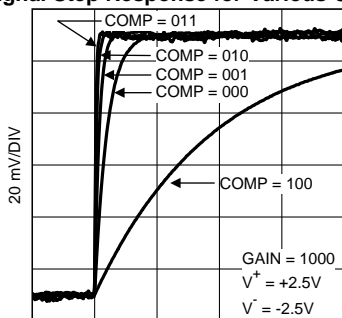


Figure 29.

Small Signal Step Response for Various COMP Settings

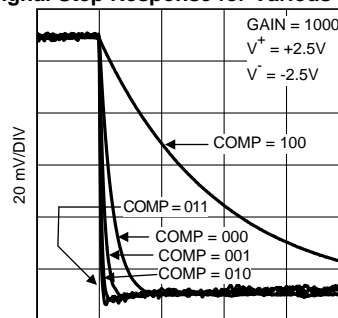


Figure 30.

Large Signal Step Response for Various COMP Settings

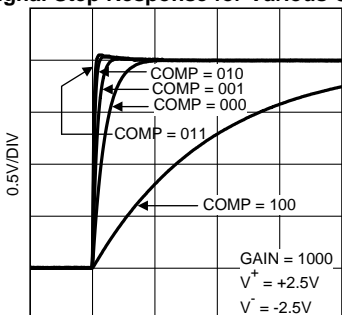


Figure 31.

Large Signal Step Response for Various COMP Settings

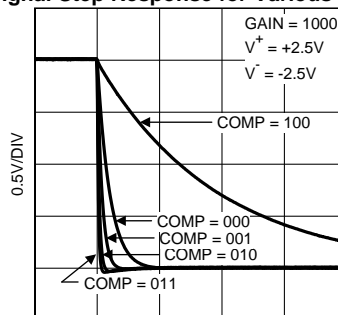


Figure 32.

Positive Overshoot  
vs.  
 $C_{LOAD}$

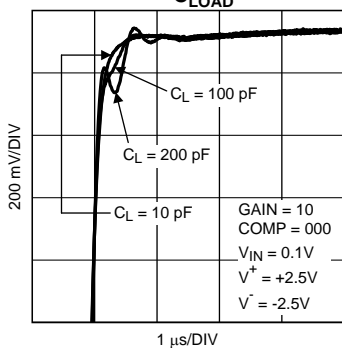


Figure 33.

Supply Current  
vs.  
Supply Voltage

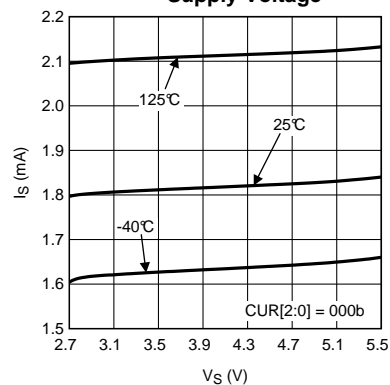


Figure 34.



## Typical Performance Characteristics (continued)

$V^+ = 3.3\text{V}$  and  $T_A = 25^\circ\text{C}$  unless otherwise noted.

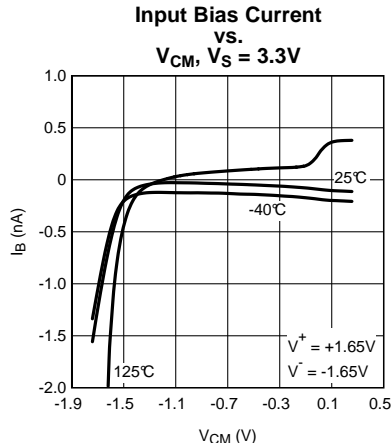


Figure 35.

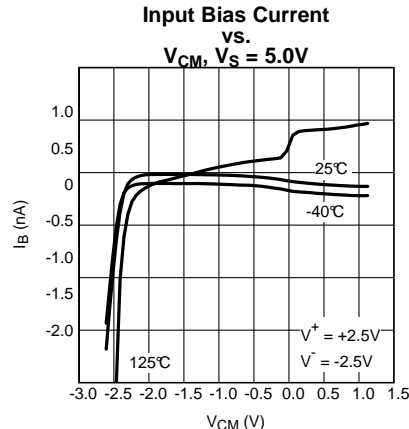


Figure 36.

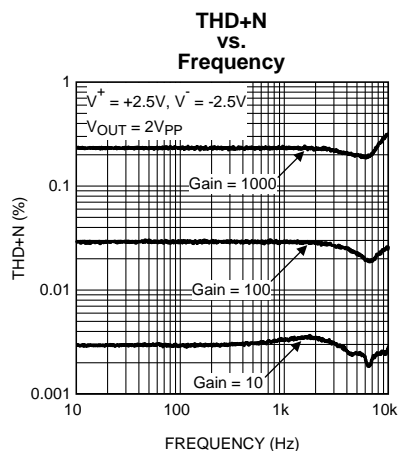


Figure 37.

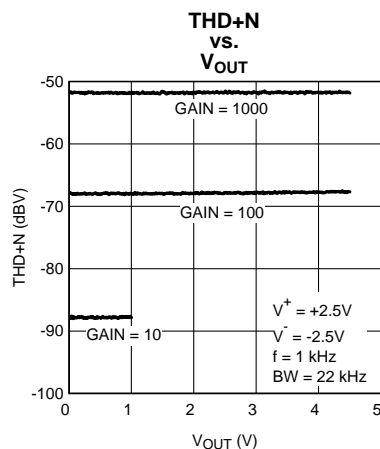


Figure 38.

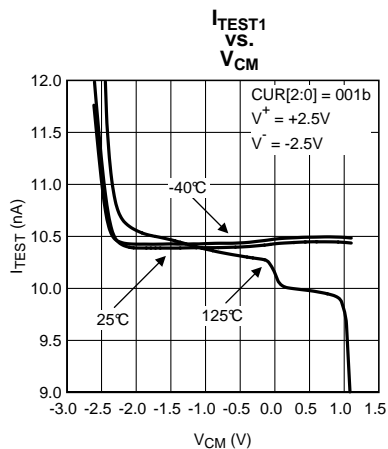


Figure 39.

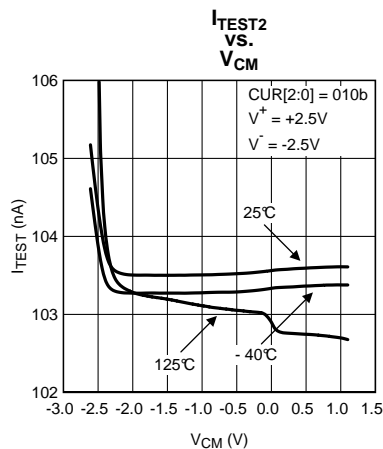


Figure 40.

## Typical Performance Characteristics (continued)

$V^+ = 3.3\text{V}$  and  $T_A = 25^\circ\text{C}$  unless otherwise noted.

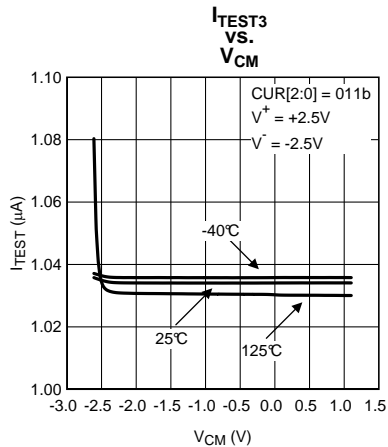


Figure 41.

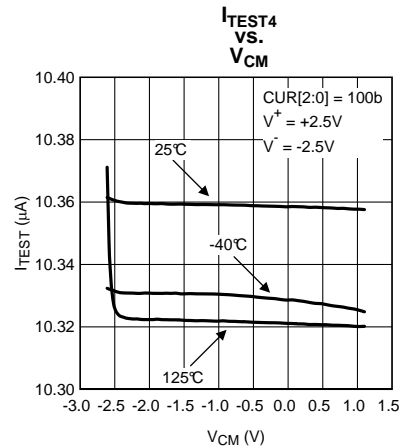


Figure 42.

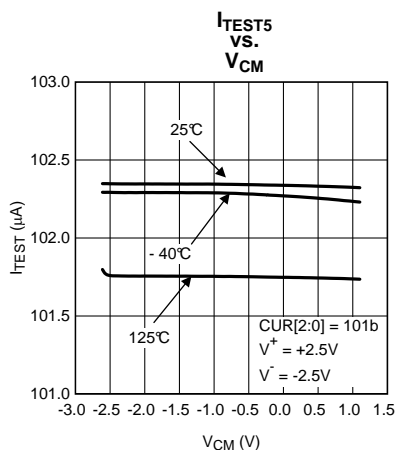


Figure 43.

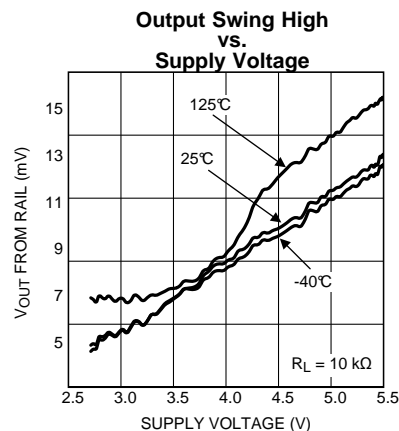


Figure 44.

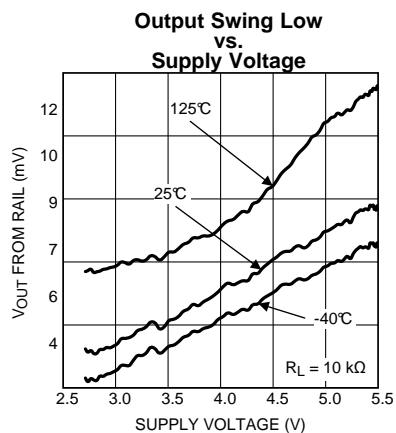


Figure 45.

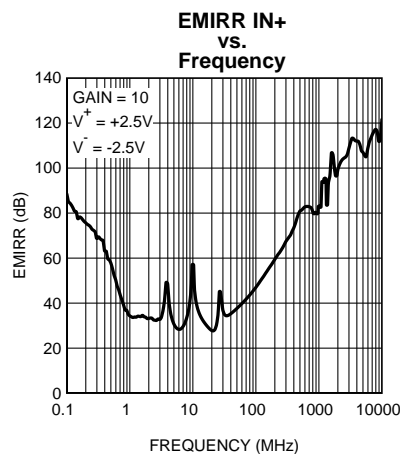


Figure 46.

## APPLICATION INFORMATION

### INTRODUCTION

The LMP8358 is a precision programmable gain instrumentation amplifier. Its gain can be programmed to 10, 20, 50, 100, 200, 500 or 1000 through an SPI-compatible serial interface or through a parallel interface. Alternatively, its gain can be set to an arbitrary value using external resistors. Note that at low gains the dynamic range is limited by the maximum input differential voltage of  $\pm 100\text{mV}$ . The LMP8358 uses patented techniques to measure and continuously correct its input offset voltage, eliminating offset drift over time and temperature, and the effect of  $1/f$  noise. Its ground sensing CMOS input features a high CMRR and low input bias currents. It is capable of sensing differential input voltages in a common-mode range that extends from 100 mV below the negative supply to 1.4V below the positive supply, making it an ideal solution for interfacing with ground-referenced sensors, supply-referenced sensor bridges, and any other application requiring precision and long term stability. Additionally, the LMP8358 includes fault detection circuitry, so open and shorted inputs can be detected, as well a deteriorating connection to the signal source. Other features that make the LMP8358 a versatile solution for many applications are: its rail-to-rail output, low input voltage noise and high gain-bandwidth product.

### TRANSIENT RESPONSE TO FAST INPUTS

The LMP8358 is a current-feedback instrumentation amplifier that consists of two auto-zeroed input stages. These two input stages are operated in a ping-pong fashion: as one stage is auto-zeroed the other stage provides the path between the input pins and the output. The auto-zeroing decreases offset, offset drift, and  $1/f$  noise while the ping-pong architecture provides a continuous path between the input and the output. As with all devices that use auto-zeroing, care must be taken with the signal frequency used with the device. On-chip continuous auto-zero correction circuitry eliminates the  $1/f$  noise and significantly reduces the offset voltage and offset voltage drift; all of which are very low-frequency events. For slow-changing sensor signals, below 2kHz, this correction is transparent. Higher-frequency signals as well as fast changing edges will show a settling and ramping time lasting about  $1\mu\text{s}$ . Like all auto-zeroing devices, if the input frequency is above the auto-zero frequency, aliasing will occur. This can occur both at the auto-zeroing frequency of about 12kHz and the ping-pong frequency of about 50kHz. If needed, a low-pass filter should be placed on the output of the LMP8358 to filter out this disturbance.

### COMMUNICATION WITH THE PART AND REGISTER DESCRIPTION

The LMP8358 supports a serial and a parallel digital interface mode as shown in [Figure 47](#) and [Figure 48](#).

**Parallel user mode** Gain is set using G0, G1 and G2 pins. The shutdown mode can be activated by asserting SHDN. Fault detection features are unavailable.

**Serial user mode** The part is SPI-programmable through SDI, SCK, SDO and CSB. All features are available.

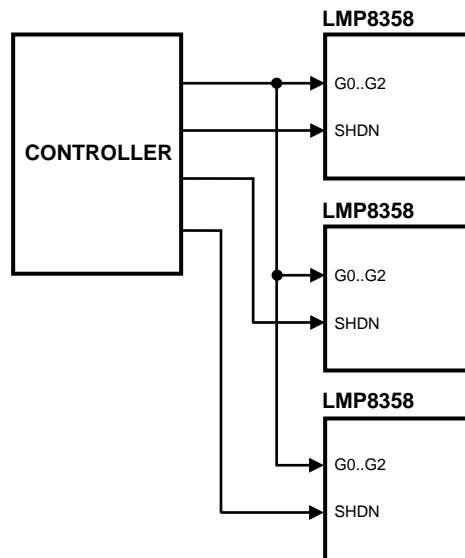


Figure 47. (A) Communication with LMP8358 in Parallel Mode

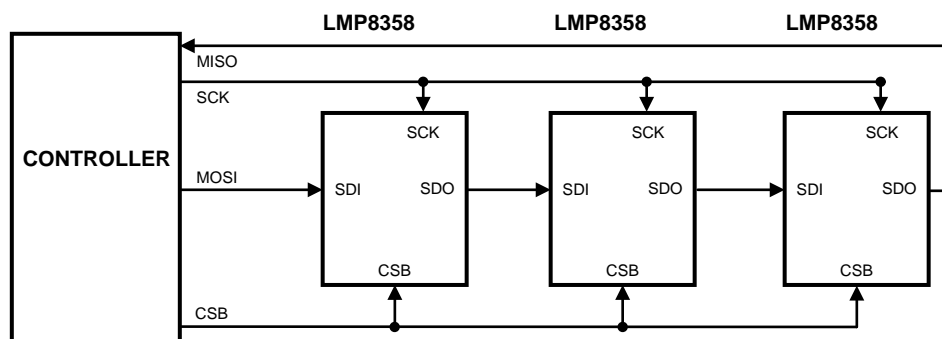


Figure 48. (B) Communication with LMP8358 in Serial Mode

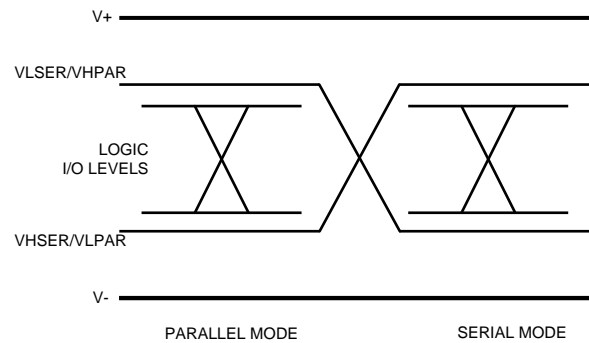
### Communication Mode Selection

The interface mode is determined by the two interface level pins VLSEr/VHPAR and VHSEr/VLPAR.

**VLSEr/VHPAR < VHSEr/VLPAR** Serial Interface. VLSEr = Logic low level, VHSEr = Logic high level.

**VLSEr/VHPAR > VHSEr/VLPAR** Parallel interface. VLPAR = Logic low level, VHPAR = Logic high level.

The levels applied to the VLSEr/VHPAR and VHSEr/VLPAR pins should be between the  $V^+$  and  $V^-$  levels as shown in [Figure 49](#).



**Figure 49. Communication Mode Selection.**

### PARALLEL CONTROL INTERFACE MODE

The LMP8358 is put into Parallel Mode by setting VLSEr/VHPAR > VHSEr/VLPAR. The register in the LMP8358 does not control the settings of the LMP8358 in this mode. Gain and shutdown are set by placing a high or low logic level on pins 11 (SHDN), 12 (G2), 13 (G1), and 14 (G0), as shown in [Table 1](#) and [Table 2](#). The logic high and low levels are defined by the voltages on the VLSEr/VHPAR and VHSEr/VLPAR pins. See the [START UP AND POWER ON RESET](#) section for power on requirements when using the parallel mode.

**Table 1. Function of Digital IO Pins, Parallel Mode**

| Pin Name | Description            |
|----------|------------------------|
| G0       | Gain setting (LSB)     |
| G1       | Gain setting           |
| G2       | Gain setting (MSB)     |
| SHDN     | Shutdown (Active High) |
| VHPAR    | Positive logic level   |
| VLPAR    | Negative logic level   |

**Table 2. Pin Levels for Setting Gain, Parallel Mode**

| G2 | G1 | G0 | Gain Setting           | Bandwidth | Compensation Setting (Automatically Set) |
|----|----|----|------------------------|-----------|--|
| 0  | 0  | 0  | 10x (power-up default) | 930 kHz   | 000b                                     |
| 0  | 0  | 1  | 20x                    | 385 kHz   | 000b                                     |
| 0  | 1  | 0  | 50x                    | 460 kHz   | 001b                                     |
| 0  | 1  | 1  | 100x                   | 640 kHz   | 010b                                     |
| 1  | 0  | 0  | 200x                   | 195 kHz   | 010b                                     |
| 1  | 0  | 1  | 500x                   | 130 kHz   | 011b                                     |
| 1  | 1  | 0  | 1000x                  | 89 kHz    | 011b                                     |
| 1  | 1  | 1  | User defined           | 800 kHz   | 1xxb                                     |

### SERIAL CONTROL INTERFACE MODE

The LMP8358 is put into Serial Mode by setting VLSEr/VHPAR < VHSEr/VLPAR. In the Serial Mode the LMP8358 can be programmed by using pins 11 – 14 as shown in [Table 3](#) and the SPI Timing Diagram. The LMP8358 contains a 16 bit register which controls the performance of the part. These bits can be changed using the Serial Mode of communication. The register of the LMP8358 is shown in [Table 4](#). Immediately after power on the register should be written with the value needed for the application. See the [START UP AND POWER ON RESET](#) section.

**Table 3. Function of Digital IO Pins, Serial Mode**

| Pin Name | Description          |
|----------|----------------------|
| SDO      | Serial Data Out      |
| SDI      | Serial Data In       |
| SCK      | Serial Clock         |
| CSB      | Chip Select          |
| VL SER   | Negative Logic level |
| VH SER   | Positive Logic Level |

**Table 4. LMP8358 Register Description, Serial Mode**

| Bit No | Name  | Description                           |
|--------|-------|---------------------------------------|
| 0      | G0    | Gain setting (LSB)                    |
| 1      | G1    | Gain setting                          |
| 2      | G2    | Gain setting (MSB)                    |
| 3      | COMP0 | Frequency compensation setting (LSB)  |
| 4      | COMP1 | Frequency compensation setting        |
| 5      | COMP2 | Frequency compensation setting (MSB)  |
| 6      | MUX0  | Input multiplexer selection (LSB)     |
| 7      | MUX1  | Input multiplexer selection (MSB)     |
| 8      | POL   | Input polarity switch                 |
| 9      | SHDN  | Shutdown Enable                       |
| 10     | FILT  | Enable filtering using external cap   |
| 11     | PIN   | Fault detection pin selection         |
| 12     | CUR0  | Fault detection current setting (LSB) |
| 13     | CUR1  | Fault detection current setting       |
| 14     | CUR2  | Fault detection current setting (MSB) |
| 15     | N/A   | Unused, set to 0                      |

### Serial Control Interface Operation

The LMP8358 gain, bandwidth compensation, shutdown, input options, and fault detection are controlled by an on board programmable register. Data to be written into the control register is first loaded into the LMP8358 via the serial interface. The serial interface employs an 16-bit double-buffered register for glitch-free transitions between settings. Data is loaded through the serial data input, SDI. Data passing through the shift register is output through the serial data output, SDO. The serial clock, SCK controls the serial loading process. All sixteen data bits are required to correctly program the amplifier. The falling edge of CSB enables the shift register to receive data. The SCK signal must be high during the falling and rising edge of CSB. Each data bit is clocked into the shift register on the rising edge of SCK. Data is transferred from the shift register to the holding register on the rising edge of CSB. Operation is shown in the SPI Timing Diagram.

The serial control pins can be connected in one of two ways when two or more LMP8358s are used in an application.

### Star Configuration

The configuration shown in [Figure 50](#) can be used if each LMP8358 will always have the same value in each register. After the microcontroller writes, all registers will have the same value. Using multiple CSB lines as shown in [Figure 51](#) allows different values to be written into each register.

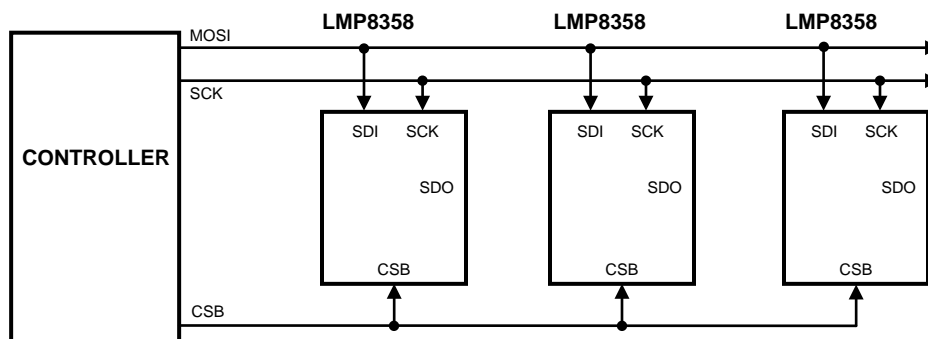


Figure 50. Star Configuration for Writing the Same Value Into Each Register

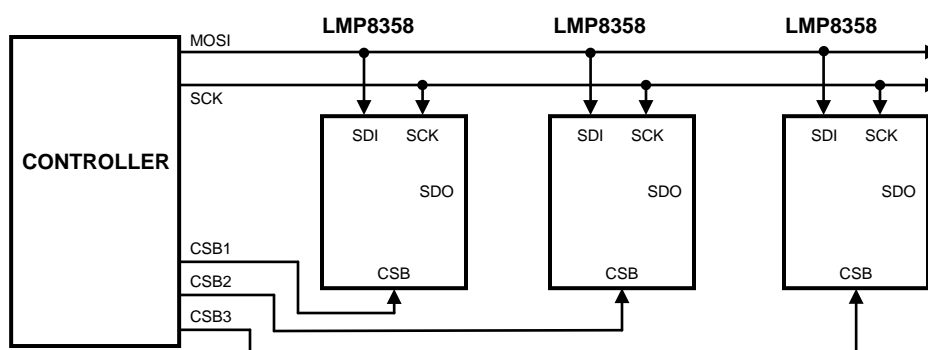


Figure 51. Star Configuration for Writing Different Values Into Each Register

### Daisy Chain Configuration

This configuration can be used to program the same or different values in the register of each LMP8358. The connections are shown in Figure 52. In this configuration the SDO pin of each LMP8358 is connected to the SDI pin of the following LMP8358.

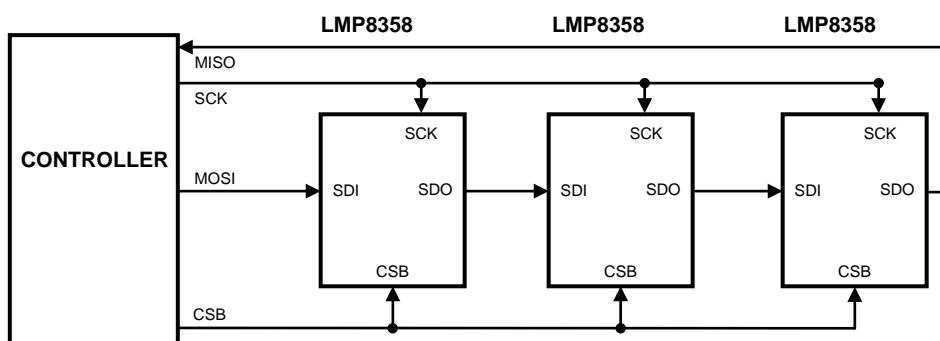


Figure 52. Daisy Chain Configuration

The following two examples show how the registers are written in the Daisy Chain Configuration.

Table 5. If all three LMP8358s need a gain of 100 with a compensation level of 010. (0000 0000 0001 0011)

|          | Register of LMP8358 #1 | Register of LMP8358 #2 | Register of LMP8358 #3 | Notes                  |
|----------|------------------------|------------------------|------------------------|------------------------|
| Power on | 0000 0000 0000 0000    | 0000 0000 0000 0000    | 0000 0000 0000 0000    | Default power on state |

**Table 5. If all three LMP8358s need a gain of 100 with a compensation level of 010. (0000 0000 0001 0011) (continued)**

|                                 |                     |                     |                     |   |
|---------------------------------|---------------------|---------------------|---------------------|---|
| After first two bytes are sent  | 0000 0000 0001 0011 | 0000 0000 0000 0000 | 0000 0000 0000 0000 | The data in the register of LMP8358 #1 is shifted into the register of LMP8358 #2, the data in the register of LMP8358 #2 is shifted into the register of LMP8358 #3. |
| After second two bytes are sent | 0000 0000 0001 0011 | 0000 0000 0001 0011 | 0000 0000 0000 0000 |   |
| After third two bytes are sent  | 0000 0000 0001 0011 | 0000 0000 0001 0011 | 0000 0000 0001 0011 |   |

**Table 6. If LMP8358 #1 needs a gain of 20 (0000 0000 0000 0001), LMP8358 #2 needs a gain of 1000 with a compensation level of 011 (0000 0000 0001 1110), and LMP8358 #3 needs a gain of 100 with a compensation level of 010 (0000 0000 0001 0011).**

|                                 | Register of LMP8358 #1 | Register of LMP8358 #2 | Register of LMP8358 #3 | Notes   |
|---------------------------------|------------------------|------------------------|------------------------|---|
| Power on                        | 0000 0000 0000 0000    | 0000 0000 0000 0000    | 0000 0000 0000 0000    | Default power on state  |
| After first two bytes are sent  | 0000 0000 0001 0011    | 0000 0000 0000 0000    | 0000 0000 0000 0000    | The data in the register of LMP8358 #1 is shifted into the register of LMP8358 #2, the data in the register of LMP8358 #2 is shifted into the register of LMP8358 #3. |
| After second two bytes are sent | 0000 0000 0001 1110    | 0000 0000 0001 0011    | 0000 0000 0000 0000    |   |
| After third two bytes are sent  | 0000 0000 0000 0001    | 0000 0000 0001 1110    | 0000 0000 0001 0011    |   |

## LMP8358 SETTINGS

### Gain (Serial, Parallel)

When the LMP8358 is in Parallel Mode the gain can be set by applying a high or low level to pins 12 (G2), 13 (G1), and 14 (G0), as shown in [Table 2](#). The Frequency Compensation bits are automatically set as shown in [Table 2](#) to optimize the bandwidth. In Serial Mode the gain is determined by setting G[2:0] as shown in [Table 7](#) and the bandwidth can be changed using the Frequency Compensation bits in the register.

**Table 7. Gain Setting (Register bits 2:0)**

| G2 | G1 | G0 | Gain Setting           |
|----|----|----|------------------------|
| 0  | 0  | 0  | 10x (power-up default) |
| 0  | 0  | 1  | 20x                    |
| 0  | 1  | 0  | 50x                    |
| 0  | 1  | 1  | 100x                   |
| 1  | 0  | 0  | 200x                   |
| 1  | 0  | 1  | 500x                   |
| 1  | 1  | 0  | 1000x                  |
| 1  | 1  | 1  | User Defined           |

When G[2:0] = 000b to 110b switch S1 is closed and switch S2 is open as shown in the Block Diagram.

When G[2:0] = 111b in either serial or parallel mode switch S1 is open and S2 is closed and the LMP8358 gain is set by external resistors as shown in [Figure 53](#). The gain is:

$$\text{GAIN} = 1 + (Z1/Z2) \quad (1)$$

When the gain is set by external resistors and COMP[2:0] = 1xxb, a capacitor can be used to implement a noise reduction low pass filter. See the [Filter and External Filter Capacitor \(Serial\)](#) section. R1 and C<sub>FILTER</sub> are placed between the OUT and FB pins. R2 is placed between the FB and REFS pins.



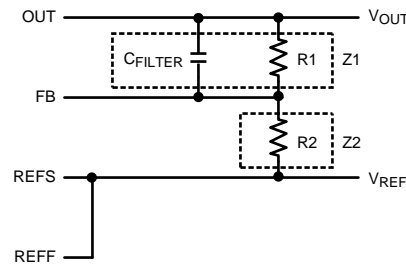


Figure 53. External Gain Set Resistors and Filter Capacitor

### Frequency Compensation (Serial)

The gain-bandwidth compensation is set to one of five levels under program control. The amount of compensation can be decreased to maximize the available bandwidth as the gain of the amplifier is increased. The compensation level is selected by setting bits COMP[2:0] of the control register with 000b, 001b, 010b, 011b, or 1xxb. Table 8 shows the bandwidths achieved at the selectable gain and compensation settings. Note that for gains 10X and 20X, the recommended compensation setting is 000b. For the gain setting 50X, compensation settings may be 000b and 001b. Gain settings 100X and 200X may use the three bandwidth compensation settings 000b, 001b, and 010b. At gains of 500X and 1000X, all bandwidth compensation ranges may be used. Note that for lower gains, it is possible to under compensate the amplifier into instability.

Table 8. Frequency Compensation (Register bits 5:3)

| Gain\COMP [2:0]                  | Bandwidth      |                 |                  |                   |  |
|----------------------------------|----------------|-----------------|------------------|-------------------|--|
|                                  | 000            | 001             | 010              | 011               | 1xx  |
| 10                               | 930 kHz        | n/a             | n/a              | n/a               | 74 kHz                                       |
| 20                               | 385 kHz        | n/a             | n/a              | n/a               | 37 kHz                                       |
| 50                               | 160 kHz        | 460 kHz         | n/a              | n/a               | 16 kHz                                       |
| 100                              | 80 kHz         | 225 kHz         | 640 kHz          | n/a               | 8 kHz  |
| 200                              | 38 kHz         | 95 kHz          | 195 kHz          | n/a               | 4 kHz  |
| 500                              | 16 kHz         | 40 kHz          | 85 kHz           | 130 kHz           | 1.5 kHz                                      |
| 1000                             | 8 kHz          | 22 kHz          | 50 kHz           | 89 kHz            | 0.8 kHz                                      |
| User Defined Gain<br>GBW Product | > 10x<br>8 MHz | > 30x<br>24 MHz | > 100x<br>80 MHz | > 300x<br>240 MHz | > 1x<br>0.8 MHz<br>(For external filter cap) |

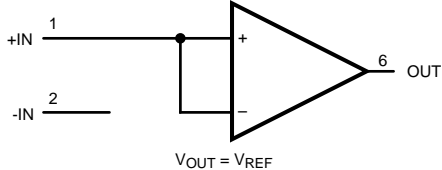
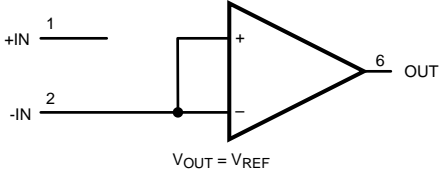
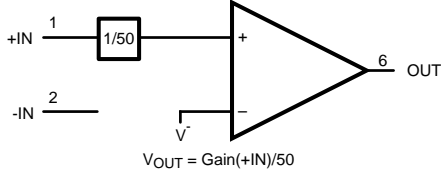
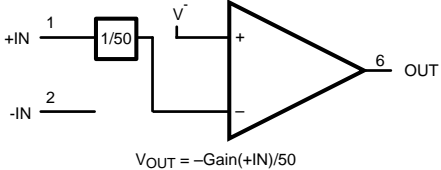
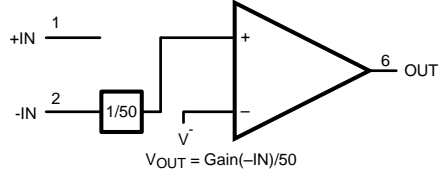
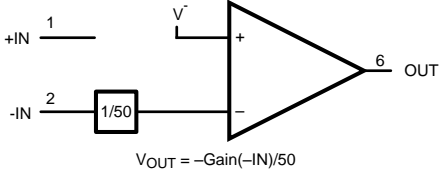
### Input Multiplexer and Polarity Switch (Serial)

The Input Multiplexer Selection bits MUX[1:0] and Polarity bit POL can be used to set the inputs of the LMP8358 to the states shown in Table 9.

Table 9. Input Multiplexer and Polarity (Register bits 8:6)

| MUX1 | MUX0 | Diff Input for POL = 0                                   | Diff Input for POL = 1                                   |
|------|------|--|--|
| 0    | 0    | <p><math>V_{OUT} = \text{Gain}((+IN) - (-IN))</math></p> | <p><math>V_{OUT} = \text{Gain}((-IN) - (+IN))</math></p> |

**Table 9. Input Multiplexer and Polarity (Register bits 8:6) (continued)**

| MUX1 | MUX0 | Diff Input for POL = 0  | Diff Input for POL = 1  |
|------|------|---|---|
| 0    | 1    |  $V_{OUT} = V_{REF}$             |  $V_{OUT} = V_{REF}$              |
| 1    | 0    |  $V_{OUT} = \text{Gain}(+IN)/50$ |  $V_{OUT} = -\text{Gain}(+IN)/50$ |
| 1    | 1    |  $V_{OUT} = \text{Gain}(-IN)/50$ |  $V_{OUT} = -\text{Gain}(-IN)/50$ |

### Polarity Reversal

When MUX[1:0] = 00b and POL = 0b the LMP8358 has the input of a normal instrumentation amplifier. The input for the LMP8358 is defined as  $\text{Gain} \times (V_{+IN} - V_{-IN})$ . When POL = 1b, the input for the LMP8358 is defined as  $\text{Gain} \times (V_{-IN} - V_{+IN})$ . Polarity reversal can be used to do system level calibration, for example, to compensate for thermocouple voltages, residual offset of the LMP8358, or offsets of the sensor or ADC.

### Short Inputs

When MUX[1:0] = 01b and POL = 0b both inputs are connected to the +IN pin of the LMP8358. The -IN pin is left floating. When MUX[1:0] = 01b and POL = 1b both inputs are connected to the -IN pin of the LMP8358. The +IN pin is left floating.

### Compare Input to V-

When MUX[1:0] = 10b or 11b one external input of the LMP8358 is floating. The other external input is divided by 50 as shown in Table 9. The internal instrumentation amplifier input that is not connected to the external pin is connected to V-. With a scale factor of 1/50 this gives an overall gain of 0.2x, 0.4x, 1x, 2x, 4x, 10x, or 20x depending on what the gain is set to with G[2:0] bits as shown in Table 10.

**Table 10. Overall Gain using G[2:0], MUX[1:0] and POL**

| G[2:0] | MUX[1:0]   | Overall System Gain |          |
|--------|------------|---------------------|----------|
|        |            | POL = 0b            | POL = 1b |
| 000b   | 10b or 11b | 0.2                 | -0.2     |
| 001b   | 10b or 11b | 0.4                 | -0.4     |
| 010b   | 10b or 11b | 1                   | -1       |
| 011b   | 10b or 11b | 2                   | -2       |
| 100b   | 10b or 11b | 4                   | -4       |
| 101b   | 10b or 11b | 10                  | -10      |
| 110b   | 10b or 11b | 20                  | -20      |

### Shutdown Enable (Serial, Parallel)

When the SHDN bit of the LMP8358 register is set to 1b the part is put into shutdown mode. It will use less than 1µA in this state.

**Table 11. Shutdown (Register bit 9)**

| SHDN | Mode          |
|------|---------------|
| 0    | Active mode   |
| 1    | Shutdown mode |

### Filter and External Filter Capacitor (Serial)

The FILT bit controls the state of switch S2 shown in the Block Diagram. When G[2:0] = 000b to 110b, switch S2 will be open if FILT = 0b and S2 will be closed if FILT = 1b. When G[2:0] = 111b switch S2 is always closed and does not depend on the value in the FILT bit.

When FILT = 1b and COMP[2:0] = 1xxb the LMP8358 is unity-gain stable and an external filter cap can be applied as shown in [Figure 53](#). The corner filter of the filter is:

$$F_{-3dB} = 1/(2\pi R_{FILTER} C_{FILTER}) \quad (2)$$

R<sub>FILTER</sub> depends on the gain of the part and is shown in [Table 13](#).

**Table 12. Filter (Register bit 10)**

| FILT | Mode                        |
|------|-----------------------------|
| 0    | No external filter cap used |
| 1    | External filter cap used    |

**Table 13. R<sub>FILTER</sub> Value**

| Gain              | R <sub>FILTER</sub> Value |
|-------------------|---------------------------|
| 10                | 18.5 kΩ                   |
| 20                | 112 kΩ                    |
| 50                | 168 kΩ                    |
| 100               | 187 kΩ                    |
| 200               | 1.12 MΩ                   |
| 500               | 1.68 MΩ                   |
| 1000              | 1.87 MΩ                   |
| User-Defined Gain | External Resistor R1      |

The tolerance of the R<sub>FILTER</sub> value for the pre-defined gains is about ±3%. If an external filter cap is not used FILT should be set to 0b to prevent errors related to leakage currents on the FB pin.

### Fault Detection Pin and Current Setting (Serial)

The LMP8358 has an internal current source that can be used to detect faults in the overall system. See the [FAULT DETECTION METHODS](#) Section. When PIN = 0b this current source is connected to the +IN pin. When PIN = 1b the current source is connected to the –IN pin.

**Table 14. Pin Current Source (Register bit 11)**

| PIN | Current source is connected to |
|-----|--------------------------------|
| 0   | +IN pin                        |
| 1   | –IN pin                        |

The Fault Detection Current bit, CUR[2:0] controls the amount of current that sent to the input pin as shown in Table 15.

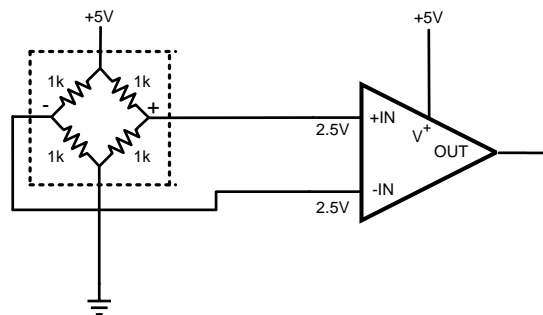
**Table 15. Fault Detection Current Source (Register bits 14:12)**

| CUR2 | CUR1 | CUR0 |                                 |
|------|------|------|---------------------------------|
| 0    | 0    | 0    | disconnected and powered down * |
| 0    | 0    | 1    | 10 nA                           |
| 0    | 1    | 0    | 100 nA                          |
| 0    | 1    | 1    | 1 $\mu$ A                       |
| 1    | 0    | 0    | 10 $\mu$ A                      |
| 1    | 0    | 1    | 100 $\mu$ A                     |
| 1    | 1    | 0    | disconnected, but powered *     |
| 1    | 1    | 1    | Do Not Use                      |

\* Leaving the fault detection current source powered allows it to switch between current levels faster, particularly when supplying currents less than 1  $\mu$ A.

## FAULT DETECTION METHODS

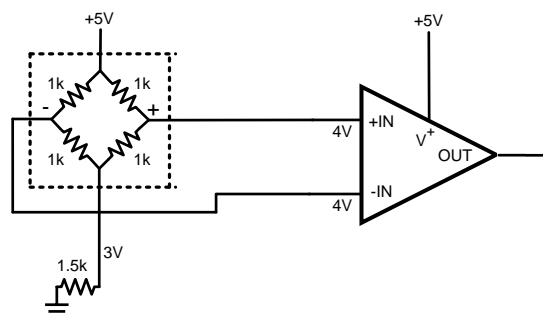
Using the Multiplexer, Polarity, and Current features the end user can detect faults in the system between the sensor and the LMP8358. These examples will use the set up shown in Figure 54 which shows a bridge sensor connected through some cabling to a supply and the LMP8358. The fault detection methods are described below.



**Figure 54. Bridge Connected to the LMP8358 With No Problems**

### Common Mode Out of Range

Figure 55 shows an example of a degraded connection between the bottom of the bridge and ground. This fault is shown by the 1.5 k $\Omega$  resistor placed between the bridge and ground. This will raise the common mode at the inputs of the LMP8358 to 4V, which is out of the CMVR. To determine the common mode voltage at the input pins, use the 1/50 feature by setting MUX[1:0] to 10b to test the +IN pin or to 11b to test the -IN pin, POL to 0b, and G[2:0] to 010b for a gain of 50 (0082x or 00C2x). This will give an overall gain of 1 and the output will read 4V for either MUX setting.



**Figure 55. Degraded Connection Between the Bottom of the Bridge and Ground**

## Open Input

Figure 56 shows an example of an open input fault. To sense this type of fault use the 1/50 feature by setting MUX[1:0] to 10b to test the +IN pin or to 11b to test the -IN pin, POL to 0b, PIN to 1b to test the -IN pin, and G[2:0] to 010b for a gain of 50, and inject 100µA current by setting CUR[2:0] = 101b (5082x or 58C2x). Since the input is open the input pin will be pulled to V+. With an overall gain of 1 the output will read 5V for open input.

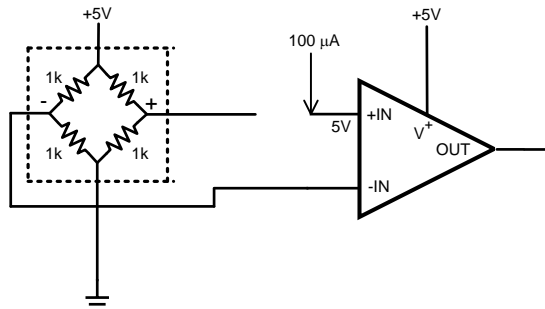


Figure 56. Open Input

## Input Shorted to V+ or V-

Figure 57 shows an example of an input pin shorted to V+ or V-. To sense this fault, use the 1/50 feature by setting MUX[1:0] to 10b to test the +IN pin or to 11b to test the -IN pin, POL to 0b, and G[2:0] to 010b for a gain of 50 (0082x or 00C2x). This will give an overall gain of 1 and the output will read either V+ or V- depending on whether the input pin is shorted to V+ or V-.

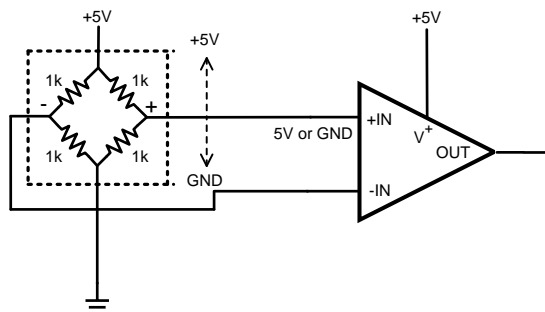


Figure 57. Input Shorted to V+ or V-

## Shorted Inputs

Figure 58 shows the inputs of the LMP8358 shorted. To detect this fault set CUR[2:0] = 101b to inject a 100µA current and set the gain to 10x (5000x). The LMP8358 is set up with normal differential inputs. The output will read about 0.07V because of the voltage drop across the internal ESD resistor, which has a value between 60Ω to 90Ω. If the gain is set to 100x with an injected current of 100µA the output will be about 0.7V.

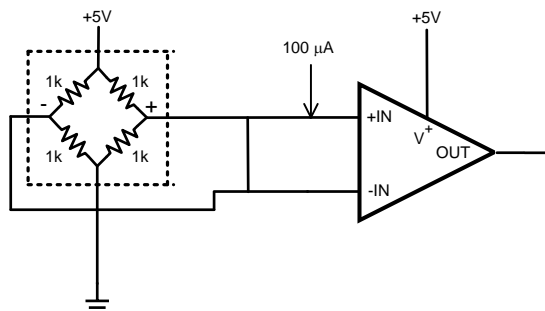


Figure 58. Shorted Inputs

## Degraded Input Line

Figure 59 shows an example of a degraded connection between the bridge and the +IN pin of the LMP8358. This fault is shown by the 1 k $\Omega$  resistor placed between the bridge and the LMP8358. To detect this fault use the 1/50 feature by setting MUX[1:0] to 10b to test the +IN pin, POL to 0b, and G[2:0] to 010b for a gain of 50. This will give an overall gain of 1. Set CUR[2:0] = 101b to inject a 100 $\mu$ A current and read the output voltage (5082x). Next set MUX[1:0] to 11b and PIN to 1b to test the -IN pin as shown in Figure 60 and read the output (58C2x). If the voltages of these two measurements are different a degraded input fault exists.

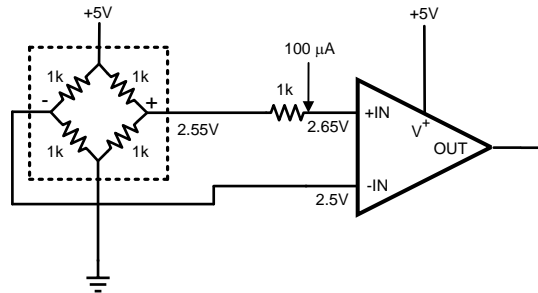


Figure 59. Degraded Input Line, Step 1

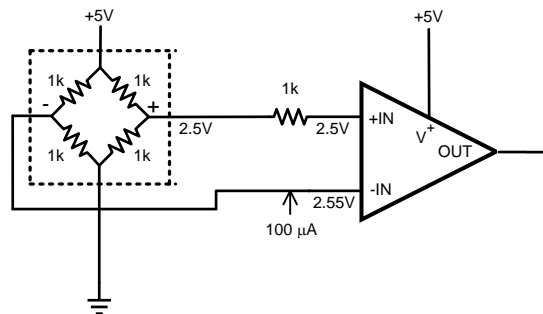


Figure 60. Degraded Input Line, Step 2

## Fault Detection Example

Using the fault detection features of the LMP8358 an end product, such as a scale, can periodically test that no damage has occurred to the system. A routine can be written that could, for example, run on start up, that will step through the fault detection features shown above and compare the output voltage to a table like that shown in Table 16. If the circuit shown in Figure 54 is used the values shown in column 2 of Table 16 would show that the system is working correctly, the values in the columns under the Possible Faults heading would show that there is a potential problem and that operator attention is needed.

Table 16. Fault Detection Matrix

|                  | No Faults        |  | Possible Faults      |                  |                               |                  |                    |
|------------------|------------------|--|----------------------|------------------|-------------------------------|------------------|--------------------|
|                  | V <sub>OUT</sub> | V <sub>OUT</sub>                                   | Possible Cause       | V <sub>OUT</sub> | Possible Cause                | V <sub>OUT</sub> | Possible Cause     |
| LMP8358 Register |                  |  |                      |                  |                               |                  |                    |
| 00 82x           | 2.5V             | V <sub>OUT</sub> < CMVR or V <sub>OUT</sub> > CMVR | Input is out of CMVR | V <sup>+</sup>   | +IN shorted to V <sup>+</sup> | 0V               | +IN shorted to GND |
| 00 C2x           | 2.5V             | V <sub>OUT</sub> < CMVR or V <sub>OUT</sub> > CMVR | Input is out of CMVR | V <sup>+</sup>   | -IN shorted to V <sup>+</sup> | 0V               | -IN shorted to GND |
| 50 00x           | 0.61V            | V <sup>+</sup>                                     | +IN Open             | 0.07V            | Inputs shorted                |                  |                    |
| 50 03x           | 4.97V            | V <sup>+</sup>                                     | -IN                  | 0.7V             | Inputs shorted                |                  |                    |
| 50 82x           | 2.55V            | 2.65V*   | Degraded +IN line    |                  |                               |                  |                    |
| 58 C2x           | 2.55V            | 2.55V*   | Degraded +IN line    |                  |                               |                  |                    |
| 50 82x           | 2.55V            | 2.55V*   | Degraded -IN line    |                  |                               |                  |                    |

**Table 16. Fault Detection Matrix (continued)**

|        |       |        |                   |  |  |  |  |
|--------|-------|--------|-------------------|--|--|--|--|
| 58 C2x | 2.55V | 2.65V* | Degraded -IN line |  |  |  |  |
|--------|-------|--------|-------------------|--|--|--|--|

\* The values shown for a degraded input line will vary depending on the resistance in the line. This table uses the value in [Figure 59](#) and [Figure 60](#), 1kΩ.

## START UP AND POWER ON RESET

During power on, 50μs after  $V^+ - V^- > 1V$  the LMP8358 resets the internal register to 0000x. If the digital supplies and inputs are undefined after the Power On Reset transients could occur which can cause erroneous data to be written over the default values in the register. The following should be done to prevent this from happening:

- Bring all supplies up at the same time. All power supplies, analog and digital, should be brought up together within 40μs so that the supplies are not undefined after the Power On Reset at 50μs. This is easiest done by tying the VHSE/VLPAR and VLSE/VHPPAR pins to the analog supplies. — Parallel Mode
- Immediately after power on, write to the register the value needed for the application. (This is always recommended.) — Serial Mode

## LAYOUT

The LMP8358 is a precision device that contains both analog and digital sections as shown in the Block Diagram. The PCB should be carefully designed to minimize the interaction between the analog and digital sections and to maximize the performance of the part. This should include the following:

0.1μF ceramic capacitors should be placed as close as possible to each supply pin. If a digital supply pin is tied to an analog pin only one 0.1μF capacitor is needed for both pins. A larger 1μF or 10μF capacitor should be located near the part for each supply.

Digital and analog traces should be kept away from each other. Analog and digital traces should not run next to each other, if they do the digital signal can couple onto the analog line. The LMP8358 pinout is set up to simplify layout by not having analog, power, and digital pins mixed together. Pins 1 — 6 are the analog signals, pins 7 — 10 are the power pins, and pins 11 — 14 are the digital signals.

Be aware of the signal and power return paths. The return paths of the analog, digital, and power sections should not cross each other and the return path should be underneath the respective signal or power path. The best PCB layout is if the bottom plane of the PCB is a solid plane.

The REFF and REFS pins are connected to the bottom side of the gain resistors of the LMP8358 as shown in the Block Diagram. Any impedance on these pins will change the specified gain. If the REFF and REFS pins are to be connected to ground they should be tied directly to the ground plane and not through thin traces that can add impedance. If the REFF and REFS pins are to be connected to a voltage, the voltage source must be low impedance. This can be done by adding an op amp, such as the LMP7701, set up in a buffer configuration with the LMP7701 output connected to REFF, the negative input of the op amp connected to REFS, and the desired reference voltage connected to the positive input of the op amp as shown in [Figure 61](#).

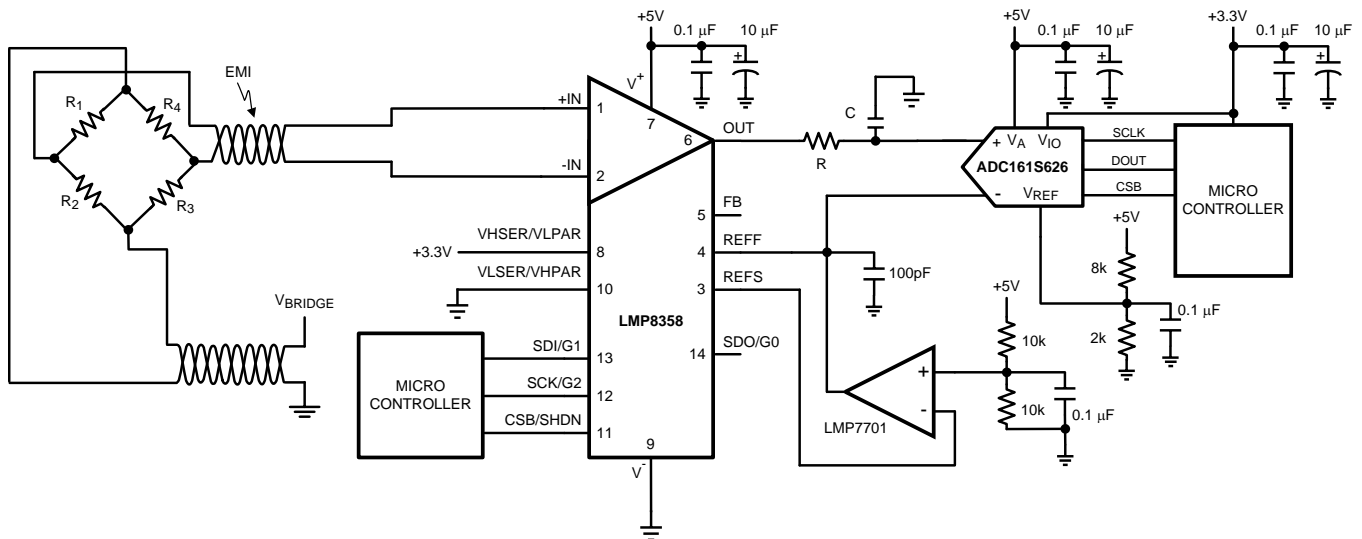
## DIFFERENTIAL BRIDGE SENSOR

Non-amplified differential bridge sensors, which are used in a variety of applications, typically have a very small differential output signal. This small signal needs to be accurately amplified before it can be used by an ADC.

The high DC performance of the LMP8358 makes it a good choice for use with a differential bridge sensor. This performance includes low input offset voltage, low input offset voltage drift, and high CMRR. The on chip EMI rejection filters available on the LMP8358 help remove the EMI interference introduced to the signal as shown in [Figure 61](#) and improves the overall system performance.

The circuit in [Figure 61](#) shows a signal path solution for a typical bridge sensor using the LMP8358. The typical output voltage of a resistive load cell is 2mV/V. If the bridge sensor is using a 5V supply the maximum output voltage will be  $2mV/V \times 5V = 10mV$ . The bridge voltage in this example is the same as the LMP8358 and ADC161S626 supply voltage of +5V. This 10mV signal must be accurately amplified by the LMP8358 to best match the dynamic range of the ADC. This is done by setting the gain of the LMP8358 to 200 which will give an output from the LMP8358 of 2V. To use the complete range of the ADC161S626 the  $V_{REF}$  of the ADC should be set to half of the input or 1V. This is done by the resistor divider on the  $V_{REF}$  pin of the ADC161S626. The

negative input of the ADC and the REFF and REFS pins of the LMP8358 can be set to +2.5V to set the signal at the center of the supply. A resistor divider supplies +2.5V to the positive input of an LMP7701 set up in a buffer configuration. The LMP7701 acts as a low impedance source for the REFF pin. The  $V_{IO}$  and VHSE/VLPAR pins should all be set to the same voltage as the microcontroller, +3.3V in this example. The VLSE/VHPAR pin should be connected to ground. The resistor and capacitor between the LMP8358 and the ADC161S626 serve a dual purpose. The capacitor is a charge reservoir for the sampling capacitor of the ADC. The resistor provides isolation for the LMP8358 from the capacitive load. The values listed in the ADC161S626 datasheet are 180 $\Omega$  for the resistor and the 470pF for the capacitor. These two components also form a low pass filter of about 1.9MHz. If a filter is needed to attenuate disturbance from the internal auto-zeroing at 12kHz and the ping-pong frequency at 50kHz of the LMP8358 these values could be changed to 7870 $\Omega$  and 0.01 $\mu$ F which will make a filter with a corner of about 2kHz.



**Figure 61. Differential Bridge Sensor**



## REVISION HISTORY

| Changes from Revision A (March 2013) to Revision B         | Page               |
|--|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">32</a> |

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish | MSL Peak Temp<br>(3) | Op Temp (°C) | Top-Side Markings<br>(4) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| LMP8358MA/NOPB   | ACTIVE        | SOIC         | D                  | 14   | 55             | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 125   | LMP8358<br>MA            | <a href="#">Samples</a> |
| LMP8358MAX/NOPB  | ACTIVE        | SOIC         | D                  | 14   | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 125   | LMP8358<br>MA            | <a href="#">Samples</a> |
| LMP8358MT/NOPB   | ACTIVE        | TSSOP        | PW                 | 14   | 94             | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 125   | LMP835<br>8MT            | <a href="#">Samples</a> |
| LMP8358MTX/NOPB  | ACTIVE        | TSSOP        | PW                 | 14   | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 125   | LMP835<br>8MT            | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

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(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

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D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



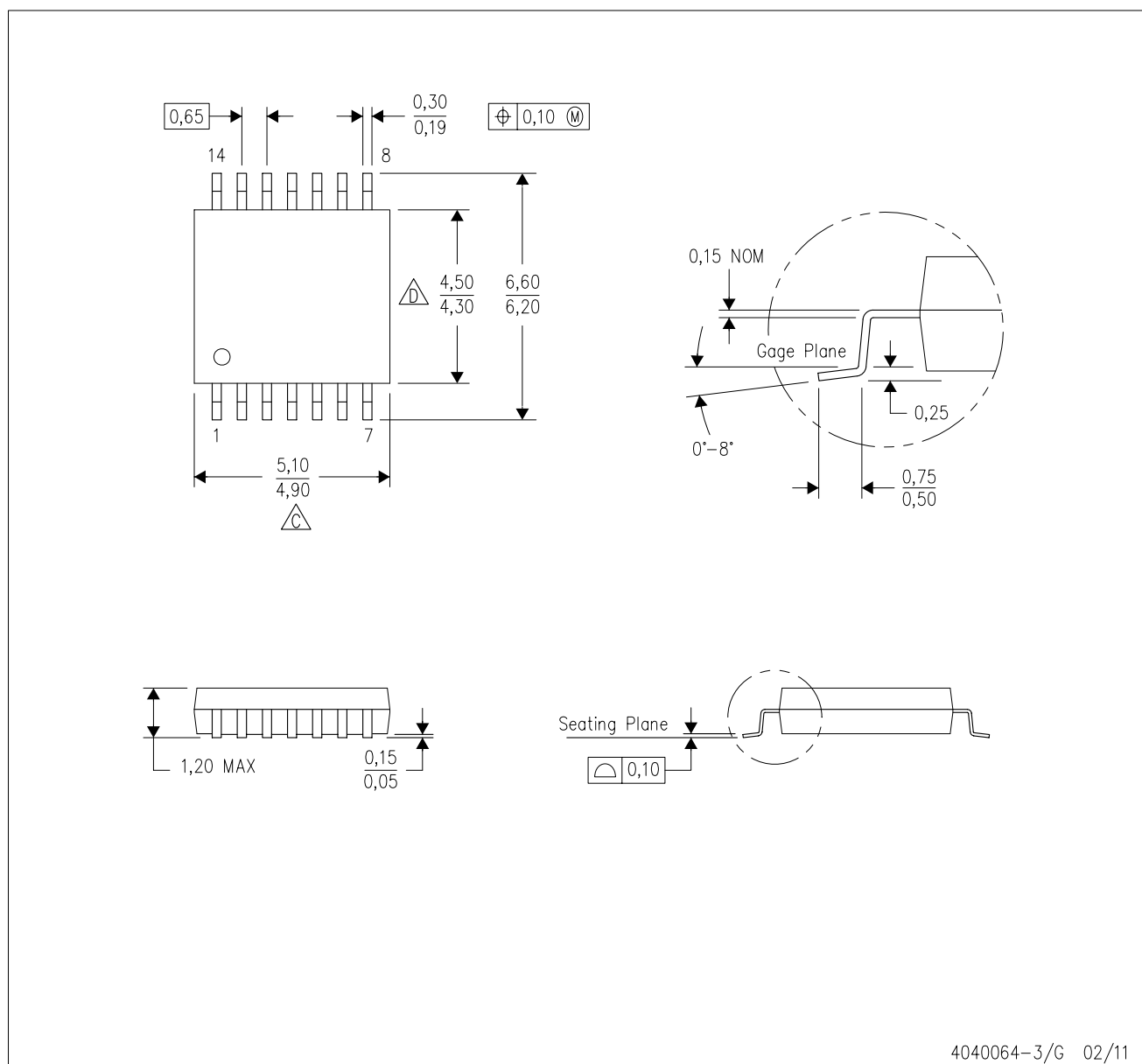
4040047-5/M 06/11

## NOTES:

- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
-  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
-  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
- E. Reference JEDEC MS-012 variation AB.

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



- NOTES:
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  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
  - E. Falls within JEDEC MO-153

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- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- Лицензия ФСБ на осуществление работ с использованием сведений, составляющих государственную тайну;
- Поставка специализированных компонентов (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Aeroflex, Peregrine, Syfer, Eurofarad, Texas Instrument, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

Помимо этого, одним из направлений компании «ЭлектроПласт» является направление «Источники питания». Мы предлагаем Вам помощь Конструкторского отдела:

- Подбор оптимального решения, техническое обоснование при выборе компонента;
- Подбор аналогов;
- Консультации по применению компонента;
- Поставка образцов и прототипов;
- Техническая поддержка проекта;
- Защита от снятия компонента с производства.



#### Как с нами связаться

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