FEATURES

- LOW TOTAL UNADJUSTED ERROR
- 2.5V, 5V BRIDGE EXCITATION REFERENCE
- 5.1V REGULATOR OUTPUT
- LOW SPAN DRIFT: ±25ppm/°C max
- LOW OFFSET DRIFT: 0.25µV/°C
- HIGH PSR: 110dB min
- HIGH CMR: 86dB min
- WIDE SUPPLY RANGE: 7.5V to 36V
- 14-PIN DIP AND SO-14 SURFACE-MOUNT

APPLICATIONS

- PRESSURE BRIDGE TRANSMITTERS
- STRAIN GAGE TRANSMITTERS
- TEMPERATURE BRIDGE TRANSMITTERS
- INDUSTRIAL PROCESS CONTROL
- SCADA REMOTE DATA ACQUISITION
- REMOTE TRANSDUCERS
- WEIGHING SYSTEMS
- ACCELEROMETERS

DESCRIPTION

The XTR106 is a low cost, monolithic 4-20mA, two-wire current transmitter designed for bridge sensors. It provides complete bridge excitation (2.5V or 5V reference), instrumentation amplifier, sensor linearization, and current output circuitry. Current for powering additional external input circuitry is available from the VREG pin.

The instrumentation amplifier can be used over a wide range of gain, accommodating a variety of input signal types and sensors. Total unadjusted error of the complete current transmitter, including the linearized bridge, is low enough to permit use without adjustment in many applications. The XTR106 operates on loop power supply voltages down to 7.5V.

Linearization circuitry provides second-order correction to the transfer function by controlling bridge excitation voltage. It provides up to a 20:1 improvement in nonlinearity, even with low cost transducers.

The XTR106 is available in 14-pin plastic DIP and SO-14 surface-mount packages and is specified for the –40°C to +85°C temperature range. Operation is from –55°C to +125°C.
## SPECIFICATIONS

At $T_A = +25\, ^\circ\text{C}$, $V_\text{+} = 24\, \text{V}$, and TIP29C external transistor, unless otherwise noted.

### OUTPUT
- **Output Current Equation** $I_O$ = $V_{\text{FS}} \cdot (40/R_G) + 4\, \text{mA}$, $V_{\text{FS}}$ in Volts, $R_G$ in $\Omega$
- **Output Current, Specified Range** $I_O$ = 4 to 20 mA
- **Over-Scale Limit** $I_{\text{OVER}}$ = 24 to 30 mA
- **Under-Scale Limit** $I_{\text{UNDER}}$ = 1 to 2.2 mA

### ZERO OUTPUT
- **Initial Error** $I_{\text{ZERO}}$ = 4 to ±25 mA
- **vs Temperature** $T_A = -40\, ^\circ\text{C}$ to $+85\, ^\circ\text{C}$
- **vs Supply Voltage, $V_+$** $V_+ = 7.5\, \text{V}$ to $36\, \text{V}$
- **vs Common-Mode Voltage** $V_{\text{CM}} = 1.1\, \text{V}$ to $3.5\, \text{V}$
- **vs $V_{\text{REG}}$ ($I_O$)** 0.8 mA

### SPAN
- **Span Equation (Transconductance)** $S = 40/R_G$
- **Untrimmed Error Full Scale ($V_{\text{IN}}$)** $= 50\, \text{mV}$
- **Nonlinearity: Ideal Input** $B$ is nonlinearity relative to $V_{\text{FS}}$

### INPUT
- **Offset Voltage** $V_{\text{OS}}$
  - **vs Temperature** $T_A = -40\, ^\circ\text{C}$ to $+85\, ^\circ\text{C}$
  - **vs Supply Voltage, $V_+$** $V_+ = 7.5\, \text{V}$ to $36\, \text{V}$
  - **vs Common-Mode Voltage** $V_{\text{CM}} = 1.1\, \text{V}$ to $3.5\, \text{V}$
  - **Common-Mode Range** $V_{\text{CM}}$
  - **Common-Mode Range ($B$)** $= 1.1$ to $3.5$
  - **Input Bias Current** $I_B$
  - **vs Temperature** $T_A = -40\, ^\circ\text{C}$ to $+85\, ^\circ\text{C}$
  - **Input Offset Current** $I_{\text{OS}}$
  - **vs Temperature** $T_A = -40\, ^\circ\text{C}$ to $+85\, ^\circ\text{C}$
  - **Impedance: Differential** $Z_{\text{IN}}$
  - **Impedance: Common-Mode** $Z_{\text{CM}}$

### VOLTAGE REFERENCES
- **VREF2.5**
  - **Value** 2.5 V
  - **Accuracy** ±0.25 V
  - **vs Temperature** $T_A = -40\, ^\circ\text{C}$ to $+85\, ^\circ\text{C}$
  - **vs Supply Voltage, $V_+$** $V_+ = 7.5\, \text{V}$ to $36\, \text{V}$
  - **vs Load** $I_{\text{REF}}$
  - **Noise: 0.1Hz to 10Hz**

### LINEARIZATION
- **$R_{\text{LIN}}$ (external) Equation** $R_{\text{LIN}}$
  - **$K_{\text{LIN}}$ Linearization Factor** $K_{\text{LIN}}$
  - **Accuracy** ±1 %
  - **Max Correctable Sensor Nonlinearity** $B$

### POWER SUPPLY
- **$V_+$**
  - **Specified Voltage Range** +7.5 V to +36 V

### TEMPERATURE RANGE
- **Specification**
- **Operating**
- **Storage**
- **Thermal Resistance** $\theta_{JA}$
  - **14-Pin DIP**
  - **SO-14 Surface Mount**

### NOTES:
1. Describes accuracy of the 4mA low-scale offset current. Does not include input amplifier effects. Can be trimmed to zero.
2. Does not include initial error or TCR of gain-setting resistor, $R_G$.
3. Increasing the full-scale input range improves nonlinearity.
4. Does not include Zero Output initial error.
5. Voltage measured with respect to $I_{\text{REF}}$ pin. (6) See “Linearization” text for detailed explanation. $V_{\text{REG}} = $ full-scale $V_{\text{FS}}$.
PIN CONFIGURATION

Top View

<table>
<thead>
<tr>
<th>Top View</th>
<th>DIP and SOIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>VREG</td>
<td>1</td>
</tr>
<tr>
<td>VIN</td>
<td>2</td>
</tr>
<tr>
<td>RO</td>
<td>3</td>
</tr>
<tr>
<td>RO</td>
<td>4</td>
</tr>
<tr>
<td>VIN+</td>
<td>5</td>
</tr>
<tr>
<td>IRET</td>
<td>6</td>
</tr>
<tr>
<td>IO</td>
<td>7</td>
</tr>
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<td>8</td>
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<tr>
<td></td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>14</td>
</tr>
</tbody>
</table>

VREG: Power Supply, V+ (referenced to IO pin) .......................................... 40V
VIN: Input Voltage, VVI (referenced to IRET pin) .................................. 0V to V+
RO: Lin Polarity
VIN+: V+ B (Base)
IRET: E (Emitter)

PACKAGE/ORDERING INFORMATION

For the most current package and ordering information, see the Package Option Addendum at the end of this data sheet.

ABSOLUTE MAXIMUM RATINGS(1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply, V+ (referenced to IO pin)</td>
<td>40V</td>
</tr>
<tr>
<td>Input Voltage, VIN, VVIN (referenced to IRET pin)</td>
<td>0V to V+</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>-55°C to +125°C</td>
</tr>
<tr>
<td>Lead Temperature (soldering, 10s)</td>
<td>+300°C</td>
</tr>
<tr>
<td>Output Current Limit</td>
<td>Continuous</td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>+165°C</td>
</tr>
</tbody>
</table>

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.
**FUNCTIONAL DIAGRAM**

- **REF Amp**: Bandgap
- **Lin Amp**: Current Direction Switch
- **V REF 5**: Reference Voltage
- **V REF 2.5**: Reference Voltage
- **V IN**: Input Voltage
- **R G**: Resistors
- **I = 100µA + V IN**: Current Expression
- **IO = 4mA + V IN * (40 / R G)**: Output Current Expression
- **100µA**: Current Source
- **5.1V**: Supply Voltage

Diagram shows the functional relationships and connections between various components, including amplifiers, reference voltages, and current sources.
TYPICAL PERFORMANCE CURVES

At $T_A = +25^\circ C$, $V_+ = 24V$, unless otherwise noted.

**TYPICAL PERFORMANCE CURVES**

**TRANSCONDUCTANCE vs FREQUENCY**

- $R_G = 50\Omega$
- $C_{OUT} = 0.01\mu F$
- $C_{OUT} = 0.033\mu F$

**COMMON-MODE REJECTION vs FREQUENCY**

- $R_G = 1k\Omega$
- $C_{OUT} = 0.01\mu F$

**POWER SUPPLY REJECTION vs FREQUENCY**

- $R_G = 1k\Omega$
- $R_G = 50\Omega$

**STEP RESPONSE**

- $R_G = 1k\Omega$
- $C_{OUT} = 0.01\mu F$

**INPUT OFFSET VOLTAGE DRIFT PRODUCTION DISTRIBUTION**

- Typical production distribution of packaged units.

**INPUT OFFSET VOLTAGE CHANGE vs $V_{\text{REG}}$ and $V_{\text{REF}}$ CURRENTS**

- $V_{\text{OS}}$ vs $I_{\text{REG}}$
- $V_{\text{OS}}$ vs $I_{\text{REF}}$
TYPICAL PERFORMANCE CURVES (CONT)

At $T_A = +25^\circ C, V_+ = 24V$, unless otherwise noted.

- **UNDER-SCALE CURRENT vs TEMPERATURE**
  - $V_+ = 7.5V$ to 36V
  - Temperature ($^\circ C$)

- **OVER-SCALE CURRENT vs TEMPERATURE**
  - $V_+ = 36V$
  - $V_+ = 24V$
  - Temperature ($^\circ C$)

- **ZERO OUTPUT CURRENT ERROR vs TEMPERATURE**
  - Temperature ($^\circ C$)

- **ZERO OUTPUT DRIFT PRODUCTION DISTRIBUTION**
  - Typical production distribution of packaged units.

- **UNDER-SCALE CURRENT vs $I_{REF} + I_{REG}$**
  - $T_A = -55^\circ C$
  - $T_A = +25^\circ C$
  - $T_A = +125^\circ C$

- **ZERO OUTPUT ERROR vs $I_{REF}$ and $I_{REG}$ CURRENTS**
  - Zero Output Error ($\mu A$)
  - Current (mA)

- **ZERO OUTPUT ERROR vs $V_{REF}$ and $V_{REG}$ CURRENTS**
  - Zero Output Error ($\mu A$)

- **OVER-SCALE CURRENT vs TEMPERATURE**
  - $V_+ = 7.5V$
  - $V_+ = 36V$
  - Temperature ($^\circ C$)
TYPICAL PERFORMANCE CURVES (CONT)

At $T_A = +25^\circ C$, $V_+ = 24V$, unless otherwise noted.

INPUT VOLTAGE, INPUT CURRENT, and ZERO OUTPUT CURRENT NOISE DENSITY vs FREQUENCY

REFERENCE TRANSIENT RESPONSE

$V_{REF} = 5V$

REFERENCE AC LINE REJECTION vs FREQUENCY

$V_{REF} = 2.5$

$V_{REF} = 5V$

$T_A = +25^\circ C$, $-55^\circ C$

$T_A = +125^\circ C$

$T_A = +125^\circ C$

$T_A = +25^\circ C$, $-55^\circ C$

$T_A = +125^\circ C$

$T_A = +25^\circ C$, $-55^\circ C$

$T_A = +125^\circ C$

$T_A = +25^\circ C$, $-55^\circ C$

$T_A = +125^\circ C$

$T_A = +25^\circ C$, $-55^\circ C$

$T_A = +125^\circ C$

$T_A = +25^\circ C$, $-55^\circ C$

$T_A = +125^\circ C$

$T_A = +25^\circ C$, $-55^\circ C$

$T_A = +125^\circ C$
TYPICAL PERFORMANCE CURVES (CONT)

At $T_A = +25^\circ C; V_+ = 24V$, unless otherwise noted.

REFERENCE VOLTAGE DRIFT PRODUCTION DISTRIBUTION

REFERENCE VOLTAGE DEVIATION vs TEMPERATURE

Typical production distribution of packaged units.

Reference Voltage Deviation (%)$V_{REF} = 5V$$V_{REF} = 2.5V$

Temperature (°C)
APPLICATIONS INFORMATION

Figure 1 shows the basic connection diagram for the XTR106. The loop power supply, V_{PS}, provides power for all circuitry. Output loop current is measured as a voltage across the series load resistor, R_L. A 0.01 \mu F to 0.03 \mu F supply bypass capacitor connected between V+ and I_O is recommended. For applications where fault and/or overload conditions might saturate the inputs, a 0.03 \mu F capacitor is recommended.

A 2.5V or 5V reference is available to excite a bridge sensor. For 5V excitation, pin 14 (V_{REF5}) should be connected to the bridge as shown in Figure 1. For 2.5V excitation, connect pin 13 (V_{REF2.5}) to pin 14 as shown in Figure 3b. The output terminals of the bridge are connected to the instrumentation amplifier inputs, V_{IN} and V_{IN}. A 0.01 \mu F capacitor is shown connected between the inputs and is recommended for high impedance bridges (> 10k\Omega). The resistor R_G sets the gain of the instrumentation amplifier as required by the full-scale bridge voltage, V_{FS}.

Lin Polarity and R_{LIN} provide second-order linearization correction to the bridge, achieving up to a 20:1 improvement in linearity. Connections to Lin Polarity (pin 12) determine the polarity of nonlinearity correction and should be connected either to I_{RET} or V_{REG}. Lin Polarity should be connected to V_{REG} even if linearity correction is not desired. R_{LIN} is chosen according to the equation in Figure 1 and is dependent on K_{LIN} (linearization constant) and the bridge’s nonlinearity relative to V_{FS} (see “Linearization” section).

The transfer function for the complete current transmitter is:

\[ I_O = 4mA + V_{IN} \cdot \left( \frac{40}{R_G} \right) \]  

\[ V_{IN} \text{ in Volts, } R_G \text{ in Ohms} \]

where V_{IN} is the differential input voltage. As evident from the transfer function, if no R_G is used (R_G = \infty), the gain is zero and the output is simply the XTR106’s zero current. A negative input voltage, V_{IN}, will cause the output current to be less than 4mA. Increasingly negative V_{IN} will cause the output current to limit at approximately 1.6mA. If current is being sourced from the reference and/or V_{REG}, the current limit value may increase.

Increasingly positive input voltage (greater than the full-scale input, V_{FS}) will produce increasing output current according to the transfer function, up to the output current limit of approximately 28mA. Refer to the Typical Performance Curve, “Over-Scale Current vs Temperature.”

The I_{RET} pin is the return path for all current from the references and V_{REG}. I_{RET} also serves as a local ground and is the reference point for V_{REG} and the on-board voltage references. The I_{RET} pin allows any current used in external circuitry to be sensed by the XTR106 and to be included in the output current without causing error. The input voltage range of the XTR106 is referred to this pin.

NOTES:

(1) Connect Lin Polarity (pin 12) to I_{RET} (pin 6) to correct for positive bridge nonlinearity or connect to V_{REG} (pin 1) for negative bridge nonlinearity. The R_{LIN} pin and Lin Polarity pin must be connected to V_{REG} if linearity correction is not desired. Refer to “Linearization” section and Figure 3.

(2) Recommended for bridge impedances > 10k\Omega

(3) \[ R_{LIN} = \left| K_{LIN} \cdot \frac{4B}{1 - 2B} \right| \]  

(K_{LIN} in \Omega)

(4) \[ R_G = \left( \frac{V_{FS}}{400 \mu A} \right) \cdot \frac{1 + 2B}{1 - 2B} \]  

(V_{FS} in V)

\[ K_{IN} = 9.905k\Omega \text{ for 2.5V reference} \]

\[ K_{IN} = 6.645k\Omega \text{ for 5V reference} \]

B is the bridge nonlinearity relative to V_{FS}

V_{FS} is the full-scale input voltage

(5) R_1 and R_2 form bridge trim circuit to compensate for the initial accuracy of the bridge. See “Bridge Balance” text.

FIGURE 1. Basic Bridge Measurement Circuit with Linearization.
EXTERNAL TRANSISTOR

External pass transistor, Q1, conducts the majority of the signal-dependent 4-20mA loop current. Using an external transistor isolates the majority of the power dissipation from the precision input and reference circuitry of the XTR106, maintaining excellent accuracy.

Since the external transistor is inside a feedback loop its characteristics are not critical. Requirements are: \( V_{CEO} = 45\,\text{V} \) min, \( \beta = 40 \) min and \( P_D = 800\,\text{mW} \). Power dissipation requirements may be lower if the loop power supply voltage is less than 36V. Some possible choices for Q1 are listed in Figure 1.

The XTR106 can be operated without an external pass transistor. Accuracy, however, will be somewhat degraded due to the internal power dissipation. Operation without Q1 is not recommended for extended temperature ranges. A resistor \( R = 3.3k\,\Omega \) connected between the \( I_{RET} \) pin and the E (emitter) pin may be needed for operation below 0°C without Q1 to guarantee the full 20mA full-scale output, especially with V+ near 7.5V.

The low operating voltage (7.5V) of the XTR106 allows operation directly from personal computer power supplies (12V ±5%). When used with the RCV420 Current Loop Receiver (Figure 8), load resistor voltage drop is limited to 3V.

BRIDGE BALANCE

Figure 1 shows a bridge trim circuit \( (R_1, R_2) \). This adjustment can be used to compensate for the initial accuracy of the bridge and/or to trim the offset voltage of the XTR106. The values of \( R_1 \) and \( R_2 \) depend on the impedance of the bridge, and the trim range required. This trim circuit places an additional load on the \( V_{REF} \) output. Be sure the additional load on \( V_{REF} \) does not affect zero output. See the Typical Performance Curve, “Under-Scale Current vs \( V_{REF} + I_{REG} \)” The effective load of the trim circuit is nearly equal to \( R_2 \). An approximate value for \( R_1 \) can be calculated:

\[
R_1 = \frac{5V \cdot R_B}{4 \cdot V_{TRIM}}
\]

where, \( R_B \) is the resistance of the bridge.

\( V_{TRIM} \) is the desired ±voltage trim range (in V).

Make \( R_2 \) equal or lower in value to \( R_1 \).

LINEARIZATION

Many bridge sensors are inherently nonlinear. With the addition of one external resistor, it is possible to compensate for parabolic nonlinearity resulting in up to 20:1 improvement over an uncompensated bridge output.

Linearity correction is accomplished by varying the bridge excitation voltage. Signal-dependent variation of the bridge excitation voltage adds a second-order term to the overall transfer function (including the bridge). This can be tailored to correct for bridge sensor nonlinearity.

Either positive or negative bridge non-linearity errors can be compensated by proper connection of the Lin Polarity pin. To correct for positive bridge nonlinearity (upward bowing), Lin Polarity (pin 12) should be connected to \( I_{RET} \) (pin 6) as shown in Figure 3a. This causes \( V_{REF} \) to increase with bridge output which compensates for a positive bow in the bridge response. To correct negative nonlinearity (downward bowing), connect Lin Polarity to \( V_{REG} \) (pin 1) as shown in Figure 3b. This causes \( V_{REF} \) to decrease with bridge output. The Lin Polarity pin is a high impedance node.

If no linearity correction is desired, both the \( R_{LIN} \) and Lin Polarity pins should be connected to \( V_{REG} \) (Figure 3c). This results in a constant reference voltage independent of input signal. \( R_{LIN} \) or Lin Polarity pins should not be left open or connected to another potential.

\( R_{LIN} \) is the external linearization resistor and is connected between pin 11 and pin 1 (\( V_{REG} \)) as shown in Figures 3a and 3b. To determine the value of \( R_{LIN} \) the nonlinearity of the bridge sensor with constant excitation voltage must be known. The XTR106’s linearity circuitry can only compensate for the parabolic-shaped portions of a sensor’s nonlinearity. Optimum correction occurs when maximum deviation from linear output occurs at mid-scale (see Figure 4). Sensors with nonlinearity curves similar to that shown in

![FIGURE 2. Operation without External Transistor.](image-url)
Figure 4, but not peaking exactly at mid-scale can be substantially improved. A sensor with a “S-shaped” nonlinearity curve (equal positive and negative nonlinearity) cannot be improved with the XTR106’s correction circuitry. The value of $R_{LIN}$ is chosen according to Equation 4 shown in Figure 3. $R_{LIN}$ is dependent on a linearization factor, $K_{LIN}$, which differs for the 2.5V reference and 5V reference. The sensor’s nonlinearity term, $B$ (relative to full scale), is positive or negative depending on the direction of the bow.

A maximum ±5% non-linearity can be corrected when the 5V reference is used. Sensor nonlinearity of +5%−2.5% can be corrected with 2.5V excitation. The trim circuit shown in Figure 3d can be used for bridges with unknown bridge nonlinearity polarity.

Gain is affected by the varying excitation voltage used to correct bridge nonlinearity. The corrected value of the gain resistor is calculated from Equation 5 given in Figure 3.

**EQUATIONS**

**Linearization Resistor:**

$$R_{LIN} = \frac{K_{LIN} \cdot 4B}{1-2B} \quad \text{(in } \Omega)$$  \hspace{1cm} (4)

**Gain-Set Resistor:**

$$R_G = \frac{V_{FS}}{400 \mu A} \cdot \frac{1+2B}{1-2B} \quad \text{(in } \Omega)$$  \hspace{1cm} (5)

**Adjusted Excitation Voltage at Full-Scale Output:**

$$V_{REF(Adj)} = V_{REF(Init)} \cdot \frac{1+2B}{1-2B} \quad \text{(in } V)$$  \hspace{1cm} (6)

where, $K_{LIN}$ is the linearization factor (in $\Omega$)

- $K_{LIN} = 9905 \Omega$ for the 2.5V reference
- $K_{LIN} = 6645 \Omega$ for the 5V reference

$B$ is the sensor nonlinearity relative to $V_{FS}$

- For −2.5% nonlinearity, $B = -0.025$
- For +2.5% nonlinearity, $B = +0.025$

$V_{FS}$ is the full-scale bridge output without linearization (in V)

**Example:**

Calculate $R_{LIN}$ and the resulting $R_G$ for a bridge sensor with 2.5% downward bow nonlinearity relative to $V_{FS}$ and determine if the input common-mode range is valid.

$V_{REF} = 2.5V$ and $V_{FS} = 50mV$

For a 2.5% downward bow, $B = -0.025$

(Lin Polarity pin connected to $V_{REG}$)

For $V_{REF} = 2.5V$, $K_{LIN} = 9905 \Omega$

$$R_{LIN} = \frac{(9905 \Omega) \cdot 4(-0.025)}{1-(-2)(-0.025)} = 943 \Omega$$

$$R_G = \frac{0.05V}{400 \mu A} \cdot \frac{1+(-2)(-0.025)}{1-(-2)(-0.025)} = 113 \Omega$$

$$V_{CM} = \frac{V_{REF(Adj)}}{2} = \frac{1}{2} \cdot 2.5 \cdot \frac{1+(-2)(-0.025)}{1-(-2)(-0.025)} = 1.13V$$

which falls within the 1.1V to 3.5V input common-mode range.

**FIGURE 3.** Connections and Equations to Correct Positive and Negative Bridge Nonlinearity.
When using linearity correction, care should be taken to ensure that the sensor’s output common-mode voltage remains within the XTR106’s allowable input range of 1.1V to 3.5V. Equation 6 in Figure 3 can be used to calculate the XTR106’s new excitation voltage. The common-mode voltage of the bridge output is simply half this value if no common-mode resistor is used (refer to the example in Figure 3). Exceeding the common-mode range may yield unpredictable results.

For high precision applications (errors < 1%), a two-step calibration process can be employed. First, the nonlinearity of the sensor bridge is measured with the initial gain resistor and $R_{LIN} = 0$ ($R_{LIN}$ pin connected directly to $V_{REG}$). Using the resulting sensor nonlinearity, $B$, values for $R_G$ and $R_{LIN}$ are calculated using Equations 4 and 5 from Figure 3. A second calibration measurement is then taken to adjust $R_G$ to account for the offsets and mismatches in the linearization.

**UNDER-SCALE CURRENT**

The total current being drawn from the $V_{REF}$ and $V_{REG}$ voltage sources, as well as temperature, affect the XTR106’s under-scale current value (see the Typical Performance Curve, “Under-Scale Current vs $I_{REF} + I_{REG}$”). This should be considered when choosing the bridge resistance and excitation voltage, especially for transducers operating over a wide temperature range (see the Typical Performance Curve, “Under-Scale Current vs Temperature”).

**LOW IMPEDANCE BRIDGES**

The XTR106’s two available excitation voltages (2.5V and 5V) allow the use of a wide variety of bridge values. Bridge impedances as low as 1kΩ can be used without any additional circuitry. Lower impedance bridges can be used with the XTR106 by adding a series resistance to limit excitation current to $\leq$ 2.5mA (Figure 5). Resistance should be added to control the excitation current.

**FIGURE 4. Parabolic Nonlinearity.**

**FIGURE 5. 350Ω Bridge with x50 Preamplifier.**
to the upper and lower sides of the bridge to keep the bridge output within the 1.1V to 3.5V common-mode input range. Bridge output is reduced so a preamplifier as shown may be needed to reduce offset voltage and drift.

OTHER SENSOR TYPES

The XTR106 can be used with a wide variety of inputs. Its high input impedance instrumentation amplifier is versatile and can be configured for differential input voltages from millivolts to a maximum of 2.4V full scale. The linear range of the inputs is from 1.1V to 3.5V, referenced to the IREF terminal, pin 6. The linearization feature of the XTR106 can be used with any sensor whose output is ratiometric with an excitation voltage.

### TABLE I. Error Calculation.

<table>
<thead>
<tr>
<th>ERROR SOURCE</th>
<th>ERROR EQUATION</th>
<th>ERROR CALCULATION</th>
<th>UNADJ</th>
<th>ADJUST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INPUT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Offset Voltage vs Common-Mode</td>
<td>( \frac{V_{OS}}{V_{FS}} \times 10^6 )</td>
<td>200µV/50mV \times 10^6</td>
<td>2000</td>
<td>0</td>
</tr>
<tr>
<td>vs Power Supply</td>
<td>( \frac{V_{OS}}{V_{+}} + (\Delta V)/V_{FS} \times 10^6 )</td>
<td>50µV/50mV \times 10^6</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>( \frac{l_{IB} \times R_{B}}{V_{FS}} \times 10^6 )</td>
<td>5µA/50mV \times 10^6</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>( \frac{I_{OS} \times R_{B}}{V_{FS}} \times 10^6 )</td>
<td>0.025µA/50mV \times 10^6</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td><strong>EXCITATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Reference Accuracy vs Supply</td>
<td>( \frac{V_{REF} \times (V_{REF} + \Delta V)}{V_{REF}} \times 10^6 )</td>
<td>20ppmV/50mV</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>GAIN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Span</td>
<td>Span Error (%)/100 \times 10^6</td>
<td>0.2%/100 \times 10^6</td>
<td>2000</td>
<td>0</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>Nonlinearity (%)/100 \times 10^6</td>
<td>0.01%/100 \times 10^6</td>
<td>100</td>
<td>100</td>
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<tr>
<td><strong>OUTPUT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero Output vs Supply</td>
<td>( \frac{I_{ZERO} – 4mA}{16000\mu A} \times 10^6 )</td>
<td>25µA/16000µA \times 10^6</td>
<td>1563</td>
<td>0</td>
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<tr>
<td><strong>DRIFT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drift vs Ambient Temperature Range Drift</td>
<td>( \frac{\Delta T_{A}}{V_{FS}} \times 10^6 )</td>
<td>1.5µV/°C \times 20°C</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Thermal Rb Noise</td>
<td>( \frac{\sqrt{2 \times \sqrt{\frac{R_B}{2}}/1000 \times 4nV/\sqrt{Hz} \times \sqrt{10Hz}}}{V_{FS}} \times 10^6 )</td>
<td>0.025µA/16000µA \times 10^6</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Input Current Noise</td>
<td>( \frac{\sqrt{V_{FS} \times (R_{B}/2)} \times \sqrt{4nV/\sqrt{Hz} \times \sqrt{10Hz}}}{V_{FS}} \times 10^6 )</td>
<td>0.6µV/50mV \times 10^6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>NOISE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Offset Voltage</td>
<td>( \frac{V_{n}}{V_{FS}} \times 10^6 )</td>
<td>0.6µV/50mV \times 10^6</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Thermal Rb Noise</td>
<td>( \frac{\sqrt{2 \times \sqrt{\frac{R_B}{2}}/1000 \times 4nV/\sqrt{Hz} \times \sqrt{10Hz}}}{V_{FS}} \times 10^6 )</td>
<td>0.025µA/16000µA \times 10^6</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Input Current Noise</td>
<td>( \frac{\sqrt{V_{FS} \times (R_{B}/2)} \times \sqrt{4nV/\sqrt{Hz} \times \sqrt{10Hz}}}{V_{FS}} \times 10^6 )</td>
<td>0.6µV/50mV \times 10^6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
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</table>

**ERROR ANALYSIS**

Table I shows how to calculate the effect various error sources have on circuit accuracy. A sample error calculation for a typical bridge sensor measurement circuit is shown (5kΩ bridge, \( V_{REF} = 5V \), \( V_{FS} = 50mV \)) is provided. The results reveal the XTR106’s excellent accuracy, in this case 1.2% unadjusted. Adjusting gain and offset errors improves circuit accuracy to 0.33%. Note that these are worst-case errors; guaranteed maximum values were used in the calculations and all errors were assumed to be positive (additive). The XTR106 achieves performance which is difficult to obtain with discrete circuitry and requires less board space.
Most surge protection zener diodes have a diode characteristic in the forward direction that will conduct excessive current, possibly damaging receiving-side circuitry if the loop connections are reversed. If a surge protection diode is used, a series diode or diode bridge should be used for protection against reversed connections.

**RADIO FREQUENCY INTERFERENCE**

The long wire lengths of current loops invite radio frequency interference. RF can be rectified by the sensitive input circuitry of the XTR106 causing errors. This generally appears as an unstable output current that varies with the position of loop supply or input wiring.

If the bridge sensor is remotely located, the interference may enter at the input terminals. For integrated transmitter assemblies with short connection to the sensor, the interference more likely comes from the current loop connections. Bypass capacitors on the input reduce or eliminate this input interference. Connect these bypass capacitors to the I_RET terminal as shown in Figure 6. Although the dc voltage at the I_RET terminal is not equal to 0V (at the loop supply, V_PS) this circuit point can be considered the transmitter’s “ground.”

The 0.01µF capacitor connected between V+ and I_O may help minimize output interference.

**OVER-VOLTAGE SURGE PROTECTION**

Remote connections to current transmitters can sometimes be subjected to voltage surges. It is prudent to limit the maximum surge voltage applied to the XTR106 to as low as practical. Various zener diode and surge clamping diodes are specially designed for this purpose. Select a clamp diode with as low a voltage rating as possible for best protection. For example, a 36V protection diode will assure proper transmitter operation at normal loop voltages, yet will provide an appropriate level of protection against voltage surges. Characterization tests on three production lots showed no damage to the XTR106 with loop supply voltages up to 65V.

![Figure 6. Reverse Voltage Operation and Over-Voltage Surge Protection.](image-url)
FIGURE 7. Thermocouple Low Offset, Low Drift Loop Measurement with Diode Cold-Junction Compensation.

FIGURE 8. ±12V-Powered Transmitter/Receiver Loop.
## PACKAGING INFORMATION

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan</th>
<th>Lead finish/ Ball material</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking</th>
<th>Samples</th>
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<td>PDIP</td>
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<td>-40 to 85</td>
<td>XTR106U</td>
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</table>

(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) RoHS: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
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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) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device 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 Device Marking for that device.
Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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**TAPE AND REEL INFORMATION**

*All dimensions are nominal*

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<th>Device</th>
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<th>SPQ</th>
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<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
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## TAPE AND REEL BOX DIMENSIONS

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<td>35.0</td>
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*All dimensions are nominal*
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.
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
N (R-PDIP-T**)

PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN

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<tr>
<th>Pins</th>
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<td>A MAX</td>
<td>0.775 (19.69)</td>
<td>0.775 (19.69)</td>
<td>0.920 (23.37)</td>
<td>1.060 (26.92)</td>
</tr>
<tr>
<td>A MIN</td>
<td>0.745 (18.92)</td>
<td>0.745 (18.92)</td>
<td>0.850 (21.59)</td>
<td>0.940 (23.88)</td>
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<table>
<thead>
<tr>
<th>Variation</th>
<th>AA</th>
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<tr>
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NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.

 longstanding: Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).
C. The 20 pin end lead shoulder width is a vendor option, either half or full width.
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