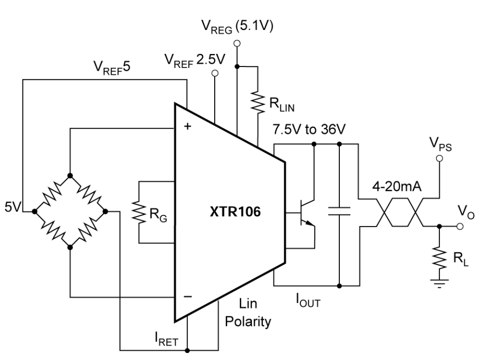
XTR106 4mA-to-20mA Current Transmitter With Bridge Excitation and Linearization

1 Features

- Low total unadjusted error
- 2.5V, 5V bridge excitation references
- 5.1V regulator output
- Low span drift: ±25ppm/°C maximum
- Low offset drift: 0.25μV/°C
- High PSR: 110dB minimum
- High CMR: 86dB minimum
- Wide supply range: 7.5V to 36V
- 14-pin DIP and SOIC package options

2 Applications

- Field transmitter and sensor
- Factory automation
- Compatible with HART modem
- Pressure and temperature bridge transmitters
- Industrial process control
- SCADA remote data acquisition
- Weighing systems
- Strain gauge transmitters
- Accelerometers



Bridge Nonlinearity Correction Schematic Using the XTR106

3 Description

The XTR106 is a monolithic 4mA to 20mA, two-wire current transmitter designed for cost-optimized bridge sensor applications. This device 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 V_{REG} 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.

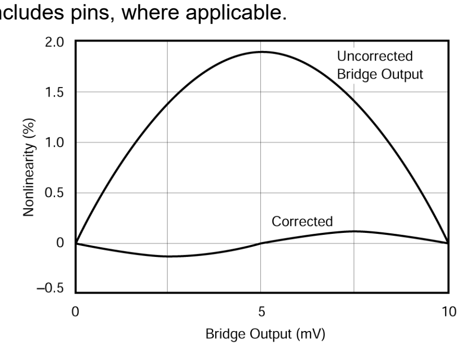
Linearization circuitry provides second-order correction to the transfer function by controlling bridge excitation voltage. The device provides up to a 20:1 improvement in nonlinearity, even with cost-optimized transducers.

The XTR106 is available in 14-pin plastic DIP and 14-pin SOIC surface-mount packages, and is specified for the –40°C to +85°C temperature range. The device operates from –40°C to +125°C.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
XTR106	D (SOIC, 14)	8.65mm × 6mm
	N (PDIP, 14)	19.3mm × 9.4mm

(1) For all available packages, see Section 10.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



XTR106 Bridge Nonlinearity Correction

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4 Pin Configuration and Functions

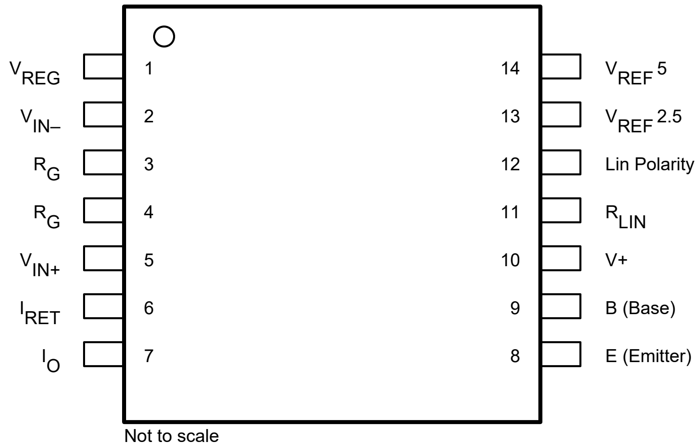


Figure 4-1. D Package, 14-Pin SOIC, and N Package, 14-Pin PDIP (Top View)

Table 4-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
B (Base)	9	Output	Base connection for external transistor
E (Emitter)	8	Input	Emitter connection for external transistor
I_O	7	Output	Regulated 4mA to 20mA current loop output
I_{RET}	6	Input	*Local ground* return pin for V_{REG}, $V_{REF}5$, and $V_{REF}2.5$
Lin Polarity	12	Input	Linearity correction circuit polarity setting. Connect to I_{RET} to correct for positive nonlinearity, or connect to V_{REG} to correct for negative nonlinearity or if not using the linearity correction feature
R_G	3, 4	—	Input stage gain setting pins. The resistance R_G between pins 3 and 4 sets the gain of the voltage-to-current transfer function
R_{LIN}	11	—	Linearity correction resistor pin. The resistance R_{LIN} between pins 1 and 11 sets the corrective factor of the linearity correction circuit
V+	10	Power	Loop power supply
V_{IN-}	2	Input	Negative (inverting) differential voltage input
V_{IN+}	5	Input	Positive (noninverting) differential voltage input
$V_{REF}5$	14	Output	5V reference voltage output
$V_{REF}2.5$	13	Output	2.5V reference voltage output
V_{REG}	1	Output	5.1V regulator voltage output

5 Specifications

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[(1)]

		MIN	MAX	UNIT
V+	Power supply (referenced to IO pin)		40	V
	Input voltage, V_{IN+} or $V_{IN–}$ (referenced to IRET pin)	0	V+	V
	Output current limit		Continuous	
T_A	Operating temperature	–40	125	°C
T_J	Junction temperature		165	°C
T_{stg}	Storage temperature	–55	125	°C
	Lead temperature (soldering, 10s)		300	°C

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime

5.2 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V+	Power supply (referenced to the I_O pin)	7.5	24	36	V
T_A	Specified temperature	−40		85	°C

5.3 Thermal Information

THERMAL METRICS[(1)]		XTR106		UNIT
		D (SOIC)	N (PDIP)	
		14 PINS		
$R_{θJA}$	Junction-to-ambient thermal resistance	86.8	51.8	°C/W
$R_{θJC(top)}$	Junction-to-case (top) thermal resistance	46.9	29.4	°C/W
$R_{θJB}$	Junction-to-board thermal resistance	46.0	24.2	°C/W
$Ψ_{JT}$	Junction-to-top characterization parameter	9.6	7.8	°C/W
$Ψ_{JB}$	Junction-to-board characterization parameter	45.6	23.7	°C/W
$R_{θJC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC package thermal metrics* application note.

5.4 Electrical Characteristics

at T_A = +25°C, V+ = 24V, and TIP29C external transistor (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNITS
OUTPUT							
I_O	Output current equation				$I_O = V_{IN} \cdot (40/R_G)$ + 4mA, V_{in} in Volts, R_G in Ω		A
	Output current, specified range			4		20	mA
I_{OVER}	Overscale limit			24	28	30	mA
I_{UNDER}	Underscale limit	I_{REG} = 0, I_{REF} = 0		1	1.6	2.2	mA
		I_{REF} + I_{REG} = 2.5mA		2.9	3.4	4	
ZERO OUTPUT(1) **(V_{IN} = 0V, R_G = ∞)**							
I_{ZERO}	Zero output				4		mA
	Initial error	XTR106P, XTR106U			±5	±25	μA
		XTR106PA, XTR106UA			±5	±50	
	vs temperature	T_A = −40°C to +85°C			±0.07	±0.9	μA/°C
	vs supply voltage, V+	V+ = 7.5V to 36V			0.04	0.2	μA/V
	vs common-mode voltage (CMRR)	V_{CM} = 1.1V to 3.5V(5)			0.02		μA/V
	vs V_{REG} (I_O)				0.8		μA/mA
i_n	Noise: 0.1Hz to 10Hz				0.035		μAp-p
SPAN							
S	Span equation (transconductance)				S = 40/R_G		A/V
	Untrimmed error	Full scale (V_{IN}) = 50mV	XTR106P, XTR106U		±0.05	±0.2	%
			XTR106PA, XTR106UA		±0.05	±0.4	
	vs temperature (2)	T_A = −40°C to +85°C			±3	±25	ppm/°C
	Nonlinearity: ideal input(3)	Full scale (V_{IN}) = 50mV			±0.001	±0.01	%
INPUT(4)							
V_{OS}	Offset voltage	V_{CM} = 2.5V	XTR106P, XTR106U		±50	±100	μV
			XTR106PA, XTR106UA		±50	±250	
	vs temperature	T_A = −40°C to +85°C	XTR106P, XTR106U		±0.25	±1.5	μV/°C
			XTR106PA, XTR106UA		±0.25	±3	
	vs supply voltage, V+	V+ = 7.5V to 36V			±0.1	±3	μV/V
CMRR	vs common-mode voltage, RTI	V_{CM} = 1.1V to 3.5V(5)	XTR106P, XTR106U		±10	±50	μV/V
			XTR106PA, XTR106UA		±10	±100	
V_{CM}	Common-mode range(5)			1.1		3.5	V
I_B	Input bias current	XTR106P, XTR106U			5	25	nA
		XTR106PA, XTR106UA			5	50	
	vs temperature	T_A = −40°C to +85°C			20		pA/°C
I_{OS}	Input offset current	XTR106P, XTR106U			±0.2	±3	nA
		XTR106PA, XTR106UA			±0.2	±10	
	vs temperature	T_A = −40°C to +85°C			5		pA/°C
Z_{IN}	Impedance: differential				0.1 || 1		GΩ || pF
	Common-mode				5 || 10		GΩ || pF
V_n	Noise: 0.1Hz to 10Hz				0.6		μVp-p

5.4 Electrical Characteristics (continued)

at T_A = +25°C, V+ = 24V, and TIP29C external transistor (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNITS
VOLTAGE REFERENCES[5] **(Lin Polarity Connected to V_{REG}, R_{LIN} = 0)**							
V_{REF}2.5	Initial: 2.5V reference				2.5		V
V_{REF}5	5V reference				5		V
	Accuracy	V_{REF} = 2.5V or 5V	XTR106P, XTR106U		±0.05	±0.25	%
			XTR106PA, XTR106UA		±0.05	±0.5	
	vs temperature[6]	T_A = −40°C to +85°C	XTR106P, XTR106U		±20	±35	ppm/°C
			XTR106PA, XTR106UA		±20	±75	
	vs supply voltage, V+	V+ = 7.5V to 36V			±5	±20	ppm/V
	vs load	I_{REF} = 0mA to 2.5mA			60		ppm/mA
	Noise: 0.1Hz to 10Hz				10		µVp-p
V_{REG} [5]							
	V_{REG}				5.1		V
	Accuracy				±0.02	±0.1	V
	vs temperature	T_A = −40°C to +85°C			±0.5		mV/°C
	vs supply voltage, V+	V+ = 7.5V to 36V			1		mV/V
I_{REG}	Output current				See Typical Curves		mA
	Output impedance	I_{REG} = 0mA to 2.5mA			80		Ω
LINEARIZATION[7]							
R_{LIN}	R_{LIN} (external) equation				RLIN = KLIN • (4B/(1−2B)), K_{LIN} in Ω, B is nonlinearity relative to V_{FS}		Ω
K_{LIN}	K_{LIN} linearization factor	V_{REF} = 5V			6.645		kΩ
		V_{REF} = 2.5V			9.905		kΩ
	Accuracy				±1	±5	%
	vs Temperature	T_A = −40°C to +85°C			±50	±100	ppm/°C
B	Maximum correctable sensor nonlinearity	V_{REF} = 5V			±5		% of V_{FS}
		V_{REF} = 2.5V			−2.5, +5		% of V_{FS}

(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_{RET} pin.
(6) Calculated using the box method: $(MAX_{(–40°C\ to\ 85°C)} – MIN_{(–40°C\ to\ 85°C)}) / MIN_{(–40°C\ to\ 85°C)} / (85°C – (–40°C))$.
(7) See also Section 6.3.1. V_{FS} = full-scale V_{IN}.

5.5 Typical Characteristics

at T_A = +25°C, V+ = 24V (unless otherwise noted)

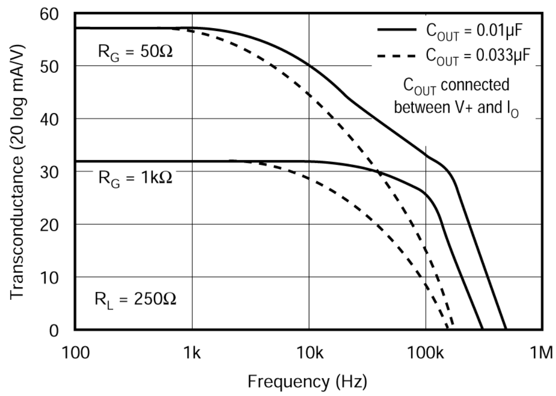


Figure 5-1. Transconductance vs Frequency

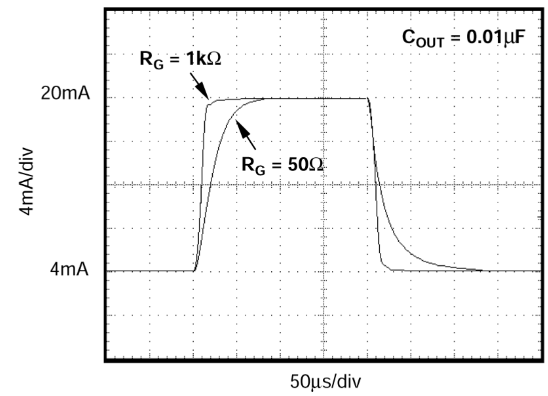


Figure 5-2. Step Response

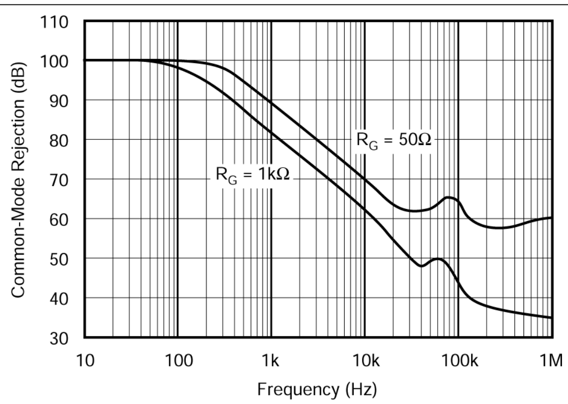


Figure 5-3. Common-Mode Rejection vs Frequency

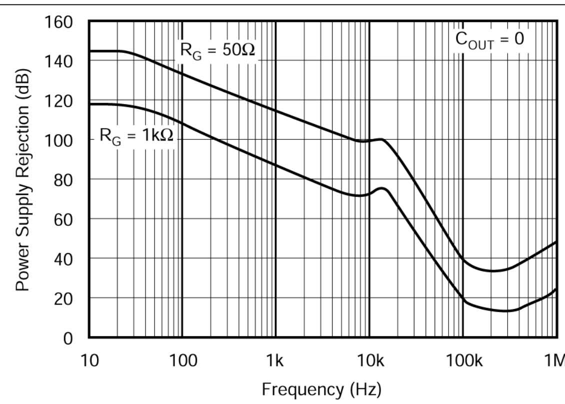


Figure 5-4. Power Supply Rejection vs Frequency

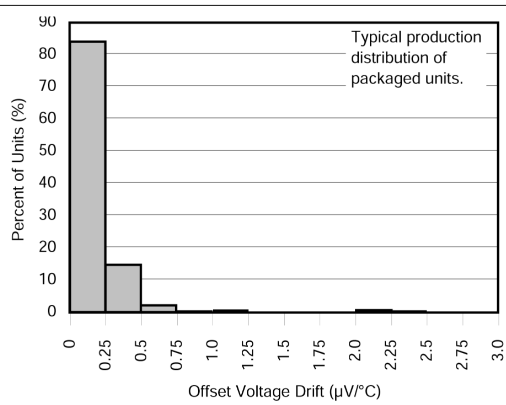


Figure 5-5. Input Offset Voltage Drift Production Distribution

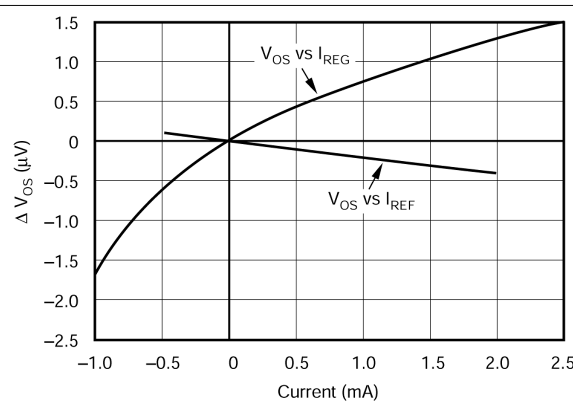


Figure 5-6. Input Offset Voltage Change vs V_{REG} And V_{REF} Currents

5.5 Typical Characteristics (continued)

at T_A = +25°C, V+ = 24V (unless otherwise noted)

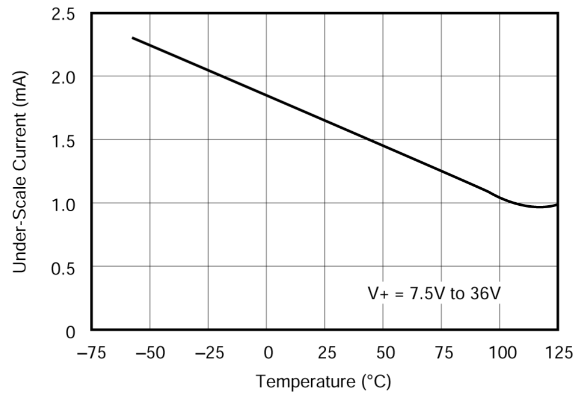


Figure 5-7. Underscale Current vs Temperature

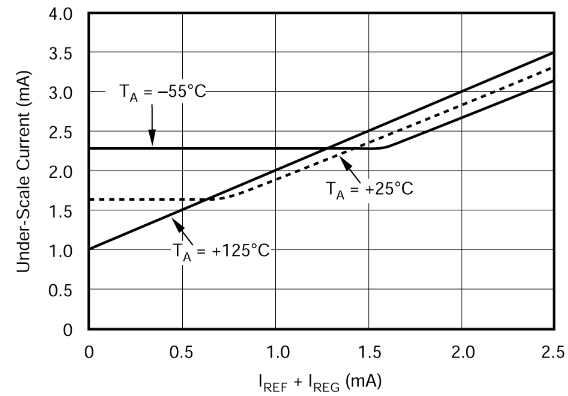


Figure 5-8. Underscale Current vs I_{REF} + I_{REG}

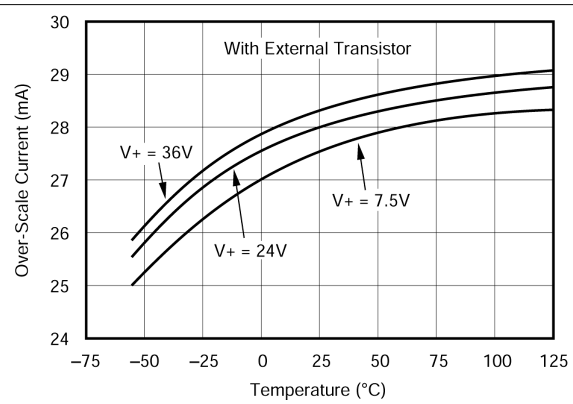


Figure 5-9. Overscale Current vs Temperature

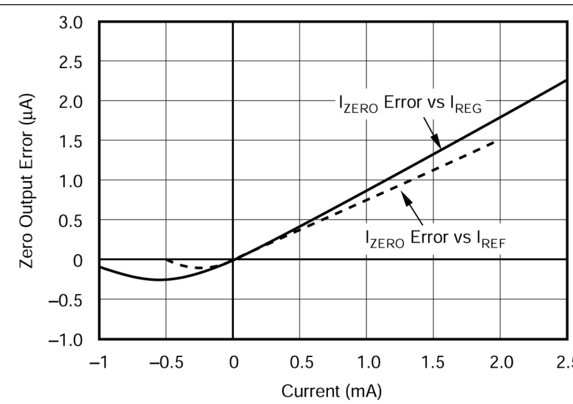


Figure 5-10. Zero Output Error vs V_{REF} and V_{REG} Currents

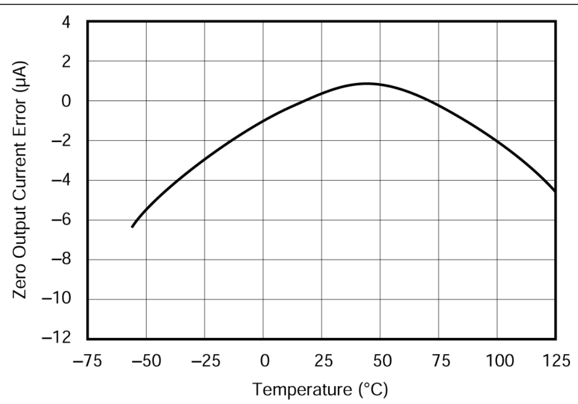


Figure 5-11. Zero Output Current Error vs Temperature

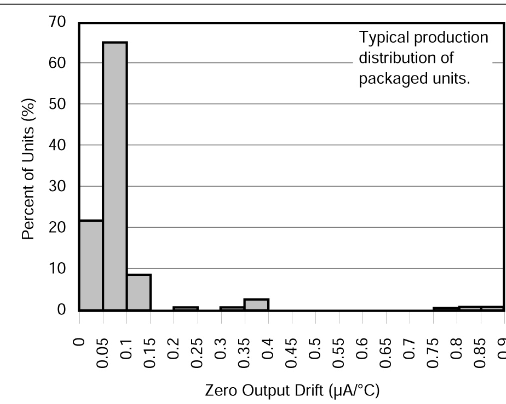


Figure 5-12. Zero Output Drift Production Distribution

5.5 Typical Characteristics (continued)

at T_A = +25°C, V+ = 24V (unless otherwise noted)

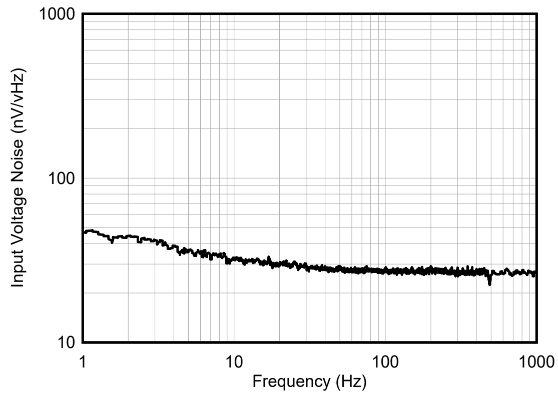


Figure 5-13. Input Voltage Noise Density vs Frequency

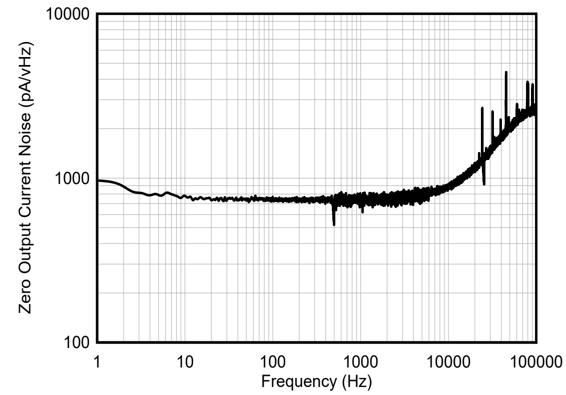


Figure 5-14. Zero Output Current Noise Density vs Frequency

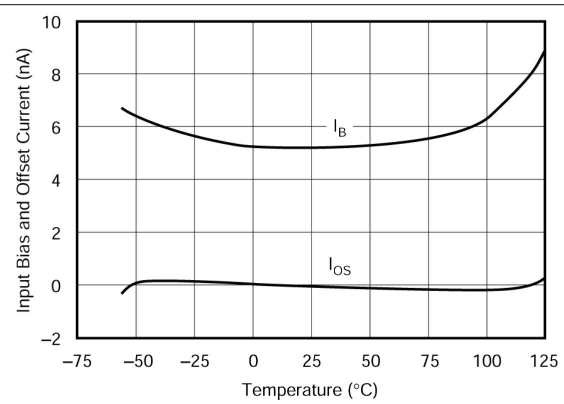


Figure 5-15. Input Bias and Offset Current vs Temperature

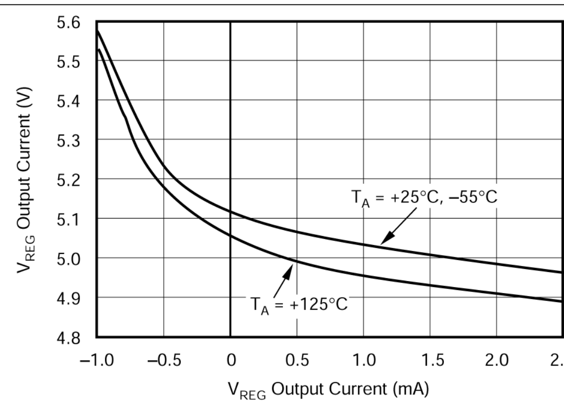


Figure 5-16. V_{REG} Output Voltage vs V_{REG} Output Current

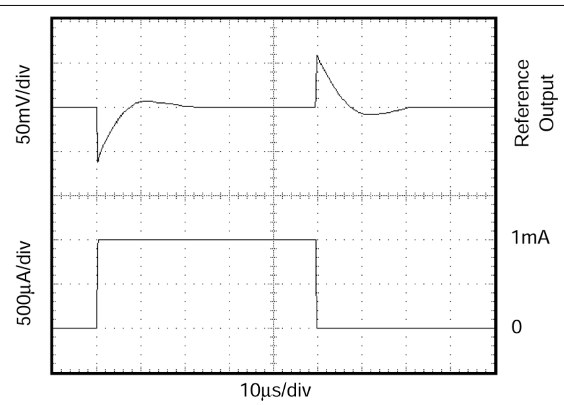


Figure 5-17. V_{REF}5 Reference Transient Response

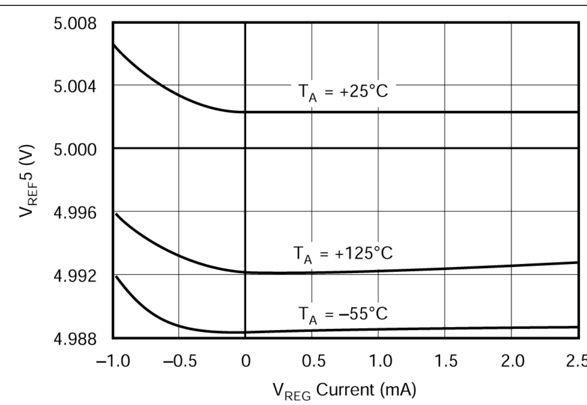


Figure 5-18. V_{REF}5 vs V_{REG} Output Current

5.5 Typical Characteristics (continued)

at T_A = +25°C, V+ = 24V (unless otherwise noted)

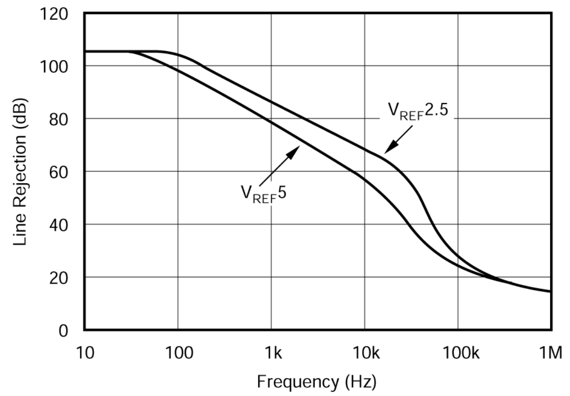


Figure 5-19. Reference AC Line Rejection vs Frequency

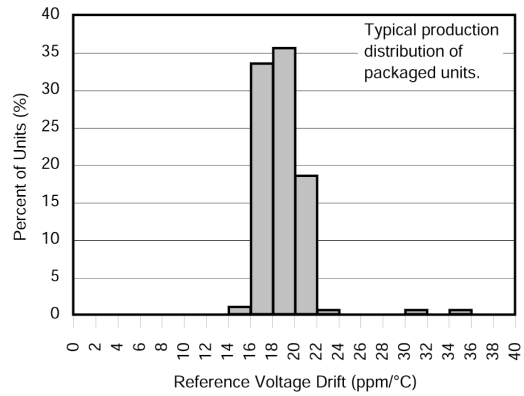


Figure 5-20. Reference Voltage Drift Production Distribution

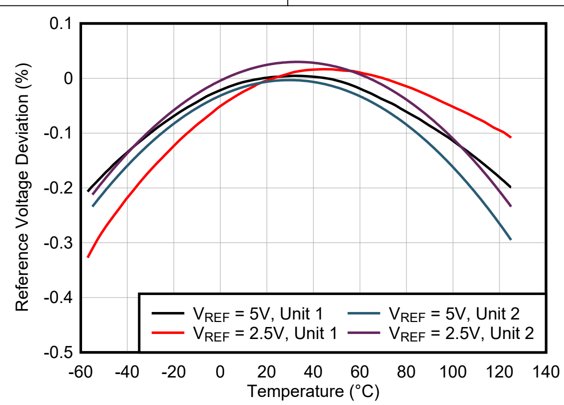


Figure 5-21. Reference Voltage Deviation vs Temperature

6 Detailed Description

6.1 Overview

The XTR106 is a monolithic 4mA-to-20mA, 2-wire current transmitter with a differential voltage input. Figure 6-1 shows the simplified schematic of the XTR106. The loop power supply, V+, provides power for all circuitry. The output loop current is modulated by the XTR106 and is typically measured as a voltage across a series load resistor (R_L).

The instrumentation amplifier input of the XTR106 measures the voltage difference between the noninverting and inverting inputs. This difference is then gained up according to the value of R_G, and expressed as a regulated current output.

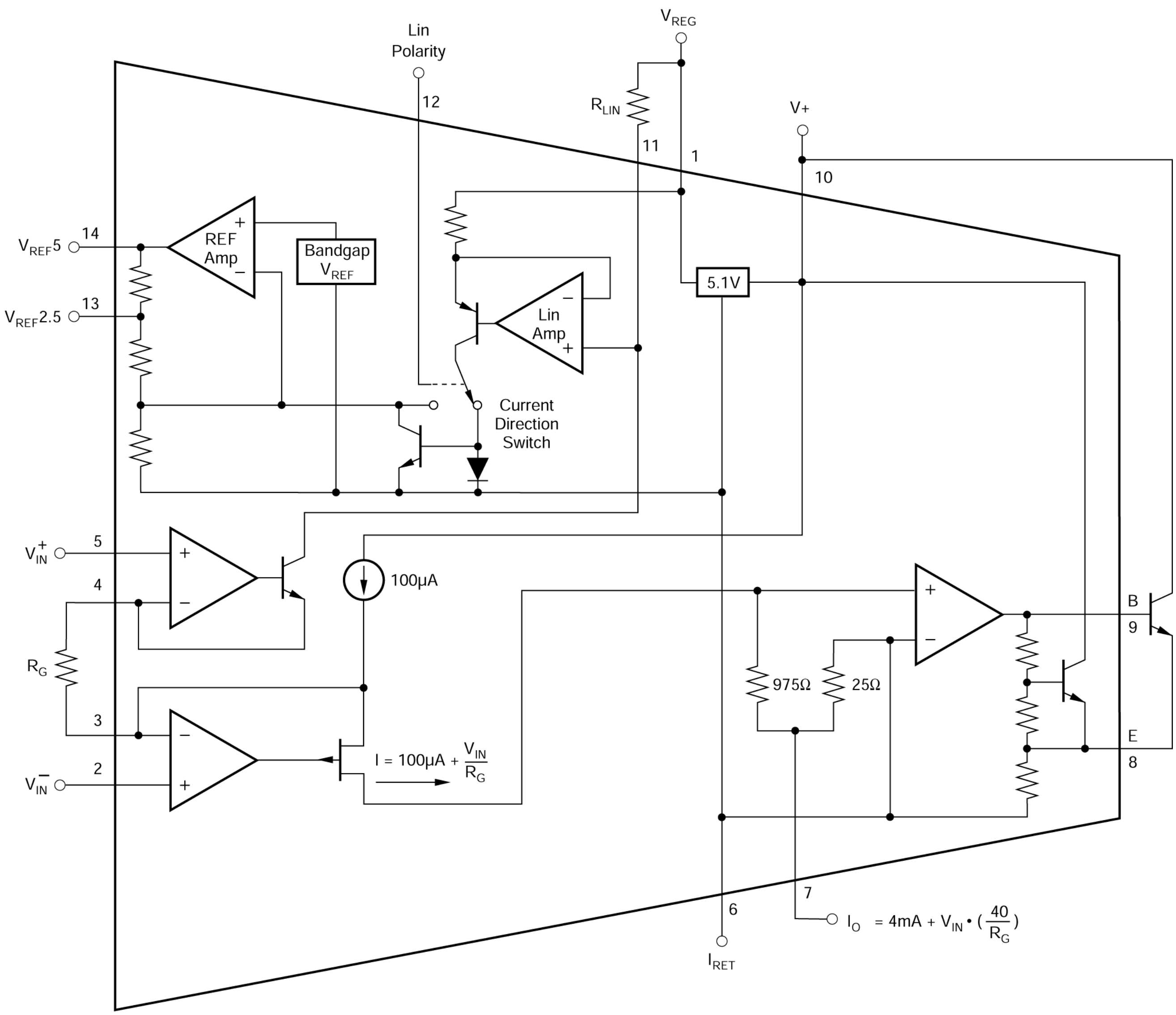
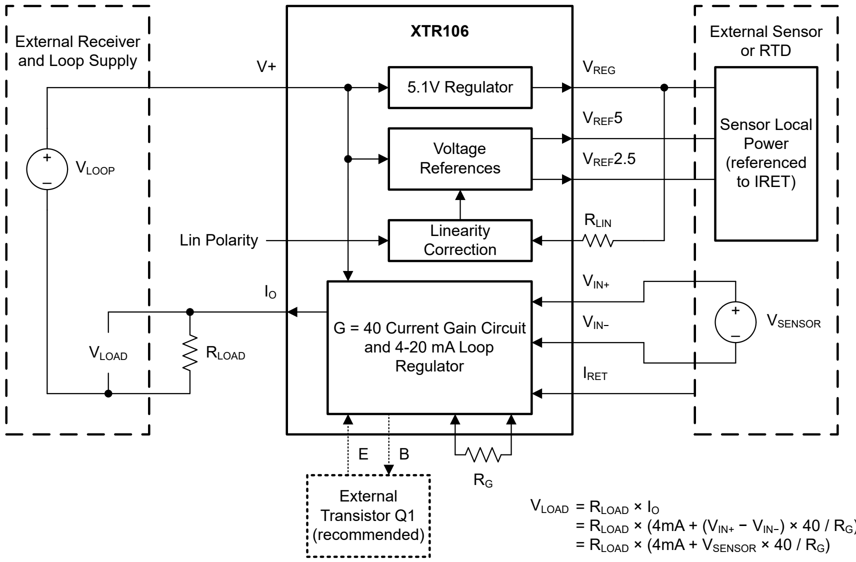


Figure 6-1. Simplified Schematic

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 Linearization

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

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 configuration can be tailored to correct for bridge sensor nonlinearity.

Either positive or negative bridge nonlinearity errors can be compensated by proper connection of the Lin Polarity pin. To correct for positive bridge nonlinearity (upward bowing), connect Lin Polarity (pin 12) to I_{RET} (pin 6); see also Figure 6-2. This correction 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); see also Figure 6-3. This correction causes V_{REF} to decrease with bridge output. The Lin Polarity pin is a high-impedance node.

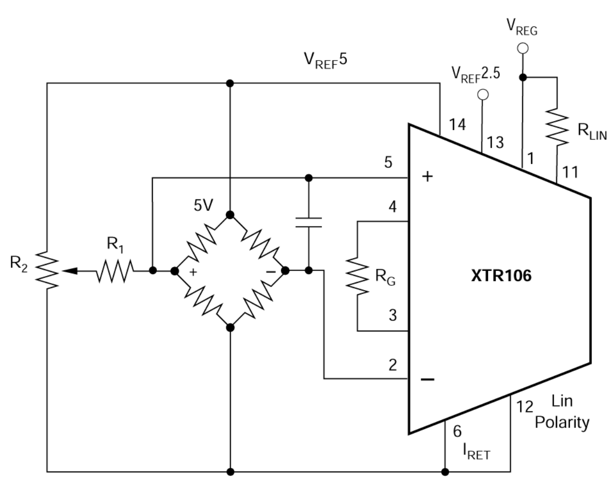


Figure 6-2. Connection for Positive Bridge Nonlinearity, V_{REF} = 5V

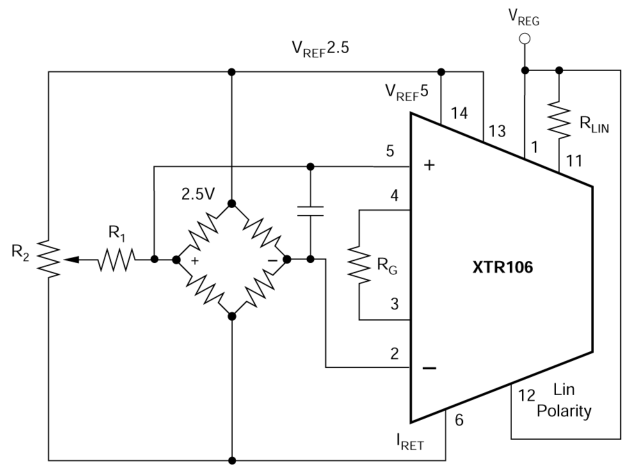


Figure 6-3. Connection for Negative Bridge Nonlinearity, V_{REF} = 2.5V

If no linearity correction is desired, connect both the R_{LIN} and Lin Polarity pins to V_{REG} (see also Figure 6-4). This connection results in a constant reference voltage independent of input signal.

Note

Do not leave the R_{LIN} or Lin Polarity pins open or connected to another potential.

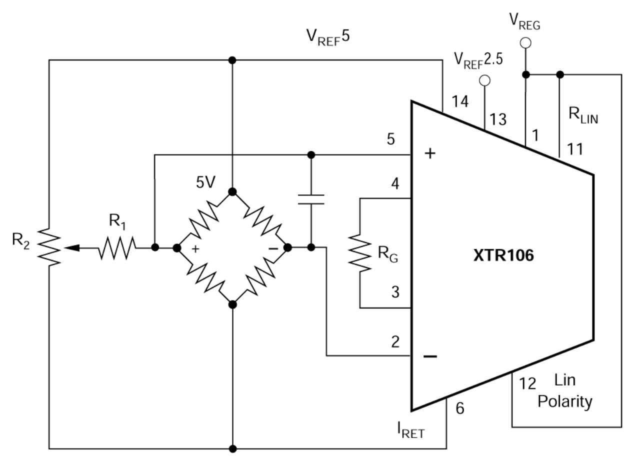


Figure 6-4. Connection if No Linearity Correction is Desired, V_{REF} = 5V

R_{LIN} is the external linearization resistor and is connected between pin 11 and pin 1 (V_{REG}); see also Figure 6-2 and Figure 6-3. To determine the value of R_{LIN}, the nonlinearity of the bridge sensor with constant excitation voltage must be known. The XTR106 linearity circuitry can only compensate for the parabolic-shaped portions of a sensor nonlinearity. Optimized correction occurs when maximum deviation from linear output occurs at midscale (see Figure 7-3 and Figure 7-4). Sensors with nonlinearity curves similar to that shown in Figure 7-3 and Figure 7-4, but not peaking exactly at midscale can be substantially improved.

A sensor with an S-shaped nonlinearity curve (equal positive and negative nonlinearity) cannot be improved with the XTR106 correction circuitry. The value of R_{LIN} is chosen according to Equation 1. R_{LIN} depends on a linearization factor, K_{LIN}, which differs for the 2.5V reference and 5V reference. The sensor nonlinearity term, B (relative to full scale), is positive or negative depending on the direction of the bow.

Linearization resistor:

$$R_{LIN} = \left|K_{LIN} \times \frac{4B}{1 - 2B}\right| \tag{1}$$

where:

- K_{LIN} is the linearization factor (in Ω)
- K_{LIN} is 9905Ω for the 2.5V reference
- K_{LIN} is 6645Ω for the 5V reference
- B is the sensor nonlinearity relative to V_{FS} (for –2.5% nonlinearity, B = –0.025)
- V_{FS} is the full-scale bridge output without linearization (in V)

A maximum ±5% nonlinearity 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 6-5 can be used for bridges with unknown bridge nonlinearity polarity.

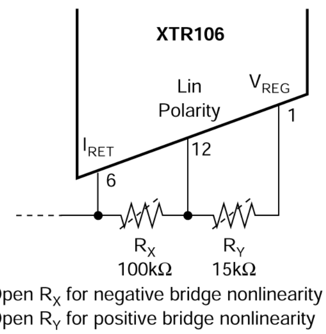


Figure 6-5. Onboard Resistor Circuit for Unknown Bridge Nonlinearity Polarity

Gain is affected by the varying excitation voltage used to correct bridge nonlinearity. The corrected value of the gain resistor is calculated from Equation 2.

Gain-set resistor:

$$R_G = \frac{V_{FS}}{400\mu A} \times \frac{1 + 2B}{1 - 2B} \tag{2}$$

where:

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

When using linearity correction, keep the sensor output common-mode voltage within the XTR106 allowable input range of 1.1V to 3.5V. Equation 3 can be used to calculate the XTR106 new excitation voltage. The common-mode voltage of the bridge output is simply half this value if no common-mode resistor is used (see also the examples in Figure 6-2 and Figure 6-3). Exceeding the common-mode range can yield unpredictable results.

Adjusted excitation voltage at full-scale output:

$$V_{REF\ (Adj)} = V_{REF\ (Initial)} \times \frac{1 + 2B}{1 - 2B} \tag{3}$$

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 Equation 1 and Equation 2. A second calibration measurement is then taken to adjust R_G to account for the offsets and mismatches in the linearization.

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.

For 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} = 9905Ω

$$R_{LIN} = \left| \frac{(9905\Omega)(4)(-0.025)}{1-(2)(-0.025)} \right| = 943\Omega \tag{4}$$

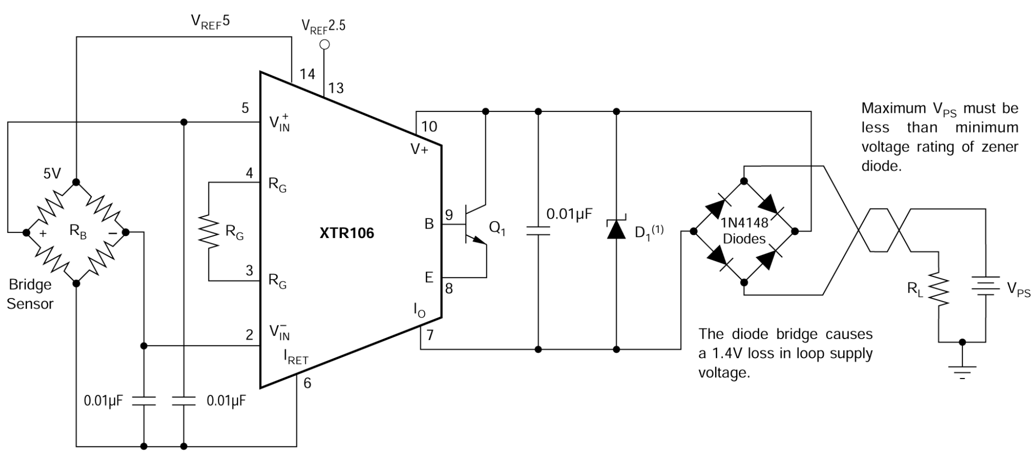
$$R_G = \frac{0.05V}{400\mu A} \times \frac{1+(2)(-0.025)}{1-(2)(-0.025)} = 113\Omega \tag{5}$$

$$V_{CM} = \frac{V_{REF\,(Adj)}}{2} = \frac{1}{2} \times 2.5V \times \frac{1+(2)(-0.025)}{1-(2)(-0.025)} = 1.13V \tag{6}$$

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

6.3.2 Reverse-Voltage Protection

The XTR106 low compliance rating (7.5V) permits the use of various voltage protection methods without compromising operating range. Figure 6-6 shows a diode bridge circuit which allows normal operation even when the voltage connection lines are reversed. The bridge causes a two diode drop (approximately 1.4V) loss in loop-supply voltage. This results in a compliance voltage of approximately 9V—satisfactory for most applications. If a 1.4V drop in loop supply is too much, a diode can be inserted in series with the loop supply voltage and the V+ pin, as shown in Figure 7-6. This protects against reverse output connection lines with only a 0.7V loss in loop-supply voltage.



(1) 36V Zener diode, such as 1N4753A or P6KE39A. Use lower-voltage Zener diodes with loop power-supply voltages < 30V for increased protection.

Figure 6-6. Reverse-Voltage Operation and Overvoltage Surge Protection

6.3.3 Overvoltage Surge Protection

Remote connections to current transmitters are sometimes subjected to voltage surges. Limit the maximum surge voltage applied to the XTR106 to the lowest practical value. 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 maintains proper transmitter operation at normal loop voltages, yet provides an appropriate level of protection against voltage surges. The XTR106 is specified to an absolute maximum loop voltage of 40V.

Most surge protection Zener diodes have a diode characteristic in the forward direction that conducts excessive current, possibly damaging receiving-side circuitry, if the loop connections are reversed. If a surge protection diode is used, use a series diode or diode bridge for protection against reversed connections.

6.4 Device Functional Modes

The device has one mode of operation that applies when operated within the *Recommended Operating Conditions*.

7 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

7.1 Application Information

Figure 7-1 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 0.01μF to 0.03μF supply bypass capacitor connected between V+ and I_O is recommended. For applications where fault, overload conditions, or both can saturate the inputs, a 0.03μF capacitor is recommended.

A 2.5V or 5V reference is available to excite a bridge sensor. For 5V excitation, connect pin 14 ($V_{REF}5$) to the bridge; see also Figure 7-1. For 2.5V excitation, connect pin 13 ($V_{REF}2.5$) to pin 14; see also Figure 6-3. The output terminals of the bridge are connected to the instrumentation amplifier inputs, V_{IN+} and V_{IN-}. A 0.01μF capacitor is shown connected between the inputs and is recommended for high impedance bridges (> 10kΩ). 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; connect either to I_{RET} or V_{REG}. Connect Lin Polarity to V_{REG} even if linearity correction is not desired. R_{LIN} is chosen according to Equation 7 and depends on K_{LIN} (linearization constant) and the bridge nonlinearity relative to V_{FS} (see Section 6.3.1).

$$R_{LIN} = \left|K_{LIN} \times \frac{4B}{1-2B}\right| \quad (7)$$

where:

- K_{LIN} is in Ω

$$R_G = \left(\frac{V_{FS}}{400\mu A}\right) \times \frac{1+2B}{1-2B} \quad (8)$$

where:

- V_{FS} is in V
- K_{LIN} = 9.905kΩ for 2.5V reference
- K_{LIN} = 6.645kΩ for 5V reference
- B is the bridge nonlinearity relative to V_{FS}
- V_{FS} is the full-scale input voltage

The transfer function for the complete current transmitter is:

$$I_O = 4mA + V_{IN} \times \left(\frac{40}{R_G}\right) \quad (9)$$

Where:

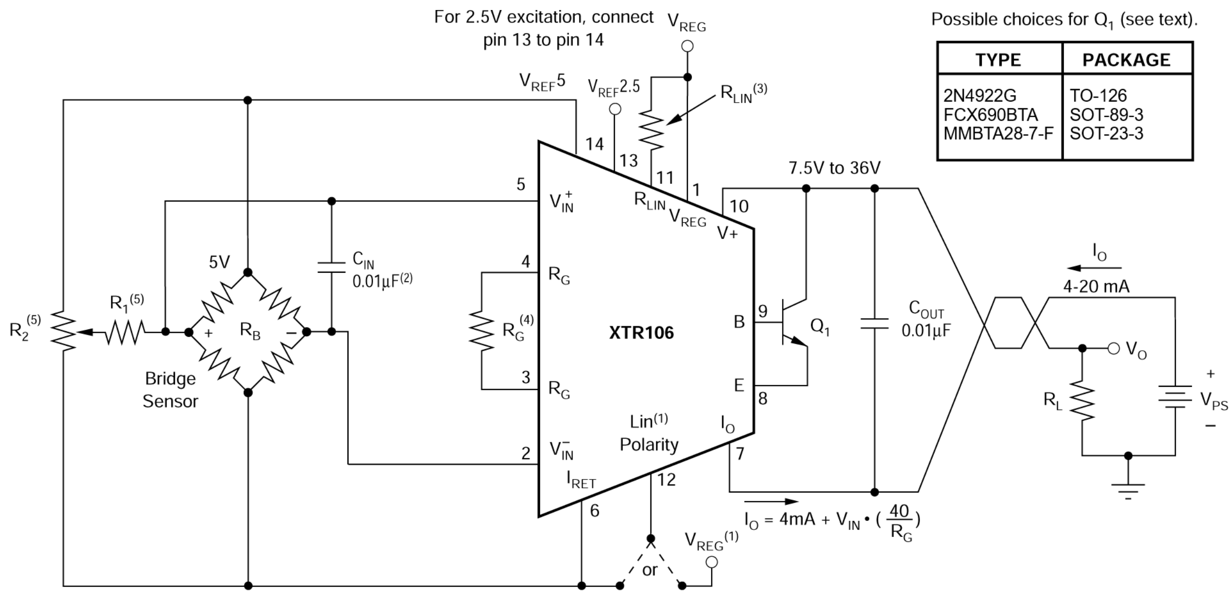
- V_{IN} V_{IN} is the differential input voltage in Volts
- R_G is in Ohms

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 zero current.

A negative input voltage, V_{IN}, causes the output current to be less than 4mA. Increasingly negative V_{IN} causes 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 can increase. See also Figure 5-7 and Figure 5-8.

Increasingly positive input voltage (greater than the full-scale input, V_{FS}) produces increasing output current according to the transfer function, up to the output current limit of approximately 28mA. See also Figure 5-9.

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 onboard 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.



TYPE	PACKAGE
2N4922G	TO-126
FCX690BTA	SOT-89-3
MMBTA28-7-F	SOT-23-3

(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 the *Linerization* section.

(2) Recommended for bridge impedances > 10kΩ.

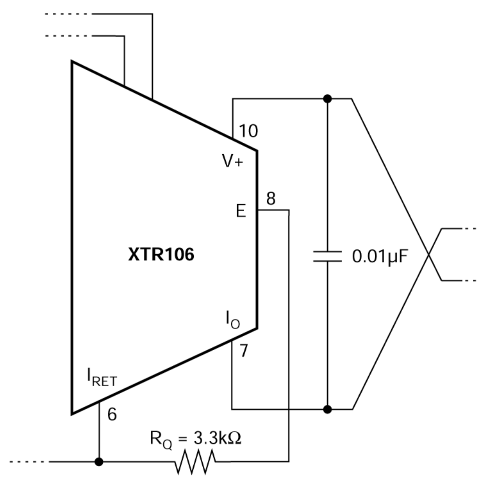
(3) R_1 and R_2 form bridge trim circuit to compensate for the initial accuracy of the bridge. See the *Bridge Balance* text.

Figure 7-1. Basic Bridge Measurement Circuit With Linearization

7.1.1 External Transistor

External pass transistor, Q_1, conducts the majority of the signal-dependent 4mA-to-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.

The external transistor is inside a feedback loop; therefore, the characteristics are not critical. Requirements are: V_{CEO} = 45V min, β = 40 min and P_D = 800mW. Power dissipation requirements can be lower if the loop power supply voltage is less than 36V. Some possible choices for Q_1 are listed in Figure 7-1. The XTR106 can be operated without an external pass transistor. Accuracy, however, is somewhat degraded as a result of the internal power dissipation and subsequent self-heating. Operation without Q_1 is not recommended for extended temperature ranges. A resistor (R = 3.3kΩ) connected between the I_{RET} pin and the E (emitter) pin is advised for operation less than 0°C without Q_1 to maintain the full 20mA full-scale output, especially with V+ near 7.5V.



(1) For operation without external transistor, connect a 3.3kΩ resistor between pin 6 and pin 8. See text for discussion of performance.

Figure 7-2. Operation Without an External Transistor

7.1.2 Loop Power Supply

The voltage applied to the XTR106, V+, is measured with respect to the I_O connection, pin 7. V+ can range from 7.5V to 36V. The loop-supply voltage, V_{PS}, differs from the voltage applied to the XTR106 according to the voltage drop on the current sensing resistor, R_L (plus any other voltage drop in the line).

If a low loop-supply voltage is used, R_L (including the loop wiring resistance) must be made a relatively low value so that V+ remains 7.5V or greater for the maximum loop current of 20mA:

$$R_{L\,MAX} = \left(\frac{(V+) - 7.5V}{20mA}\right) - R_{WIRING} \quad (10)$$

For loop currents up to 30mA, design for V+ equal or greater than 7.5V to allow for out-of-range input conditions. V+ must be at least 8V if 5V sensor excitation is used and if correcting for bridge nonlinearity greater than +3%.

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 7-6), load resistor voltage drop is limited to 3V.

7.1.3 Bridge Balance

Figure 7-1 shows a bridge trim circuit (R_1, R_2). This adjustment can be used to compensate for the initial accuracy of the bridge, to trim the offset voltage of the XTR106, or both. 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 Figure 5-8. The effective load of the trim circuit is nearly equal to R_2. An approximate value for R_1 can be calculated:

$$R_1 \approx \frac{5V \times R_B}{4 \times V_{TRIM}} \quad (11)$$

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.

7.1.4 Underscale Current

The total current being drawn from the V_{REF} and V_{REG} voltage sources, as well as temperature, affect the XTR106 underscale current value (see Figure 5-8). Consider this when choosing the bridge resistance and excitation voltage, especially for transducers operating over a wide temperature range (see Figure 5-7).

7.1.5 Low-Impedance Bridges

The XTR106 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 ≤ 2.5mA (Figure 7-5). Add resistance 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 can be needed to reduce offset voltage and drift.

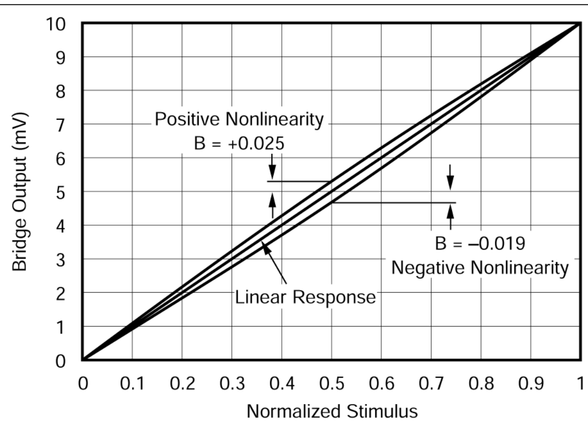


Figure 7-3. Bridge Transducer Transfer Function with Parabolic Nonlinearity

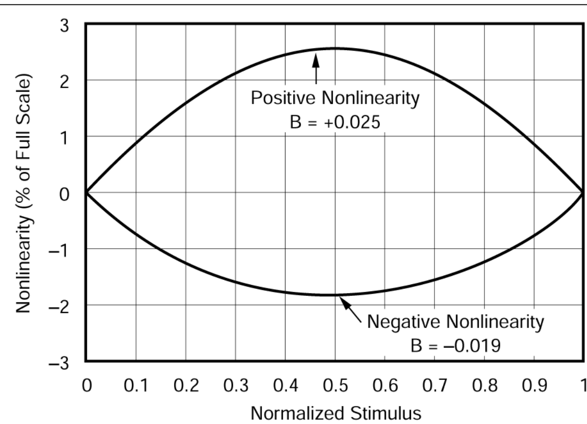
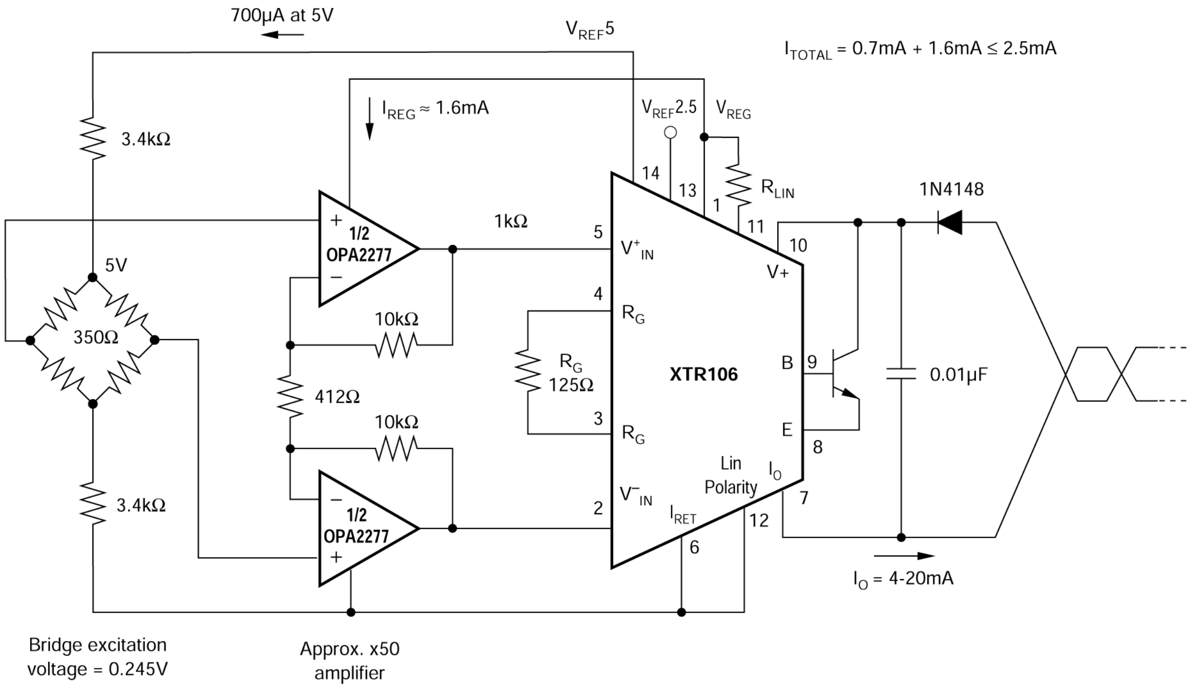


Figure 7-4. Nonlinearity vs Stimulus



(1) Shown connected to correct positive bridge nonlinearity. For negative bridge nonlinearity, see Figure 6-3.

Figure 7-5. 350Ω Bridge With x50 Preamplifier

7.1.6 Other Sensor Types

The XTR106 can be used with a wide variety of inputs. The 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 I_{RET}. The linearization feature of the XTR106 can be used with any sensor whose output is ratiometric with an excitation voltage.

7.1.7 Radio Frequency Interference

The long wire lengths of current loops invite radio frequency (RF) interference. RF interference can be rectified by the sensitive input circuitry of the XTR106 causing errors. These errors 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 can 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. Figure 6-6 shows to connect these bypass capacitors to the I_{RET} pin. Although the dc voltage at the I_{RET} pin is not equal to 0V (at the loop supply, V_{PS}) this circuit point can be considered the transmitter ground. The 0.01µF capacitor connected between V+ and I_O can help minimize output interference.

7.1.8 Error Analysis

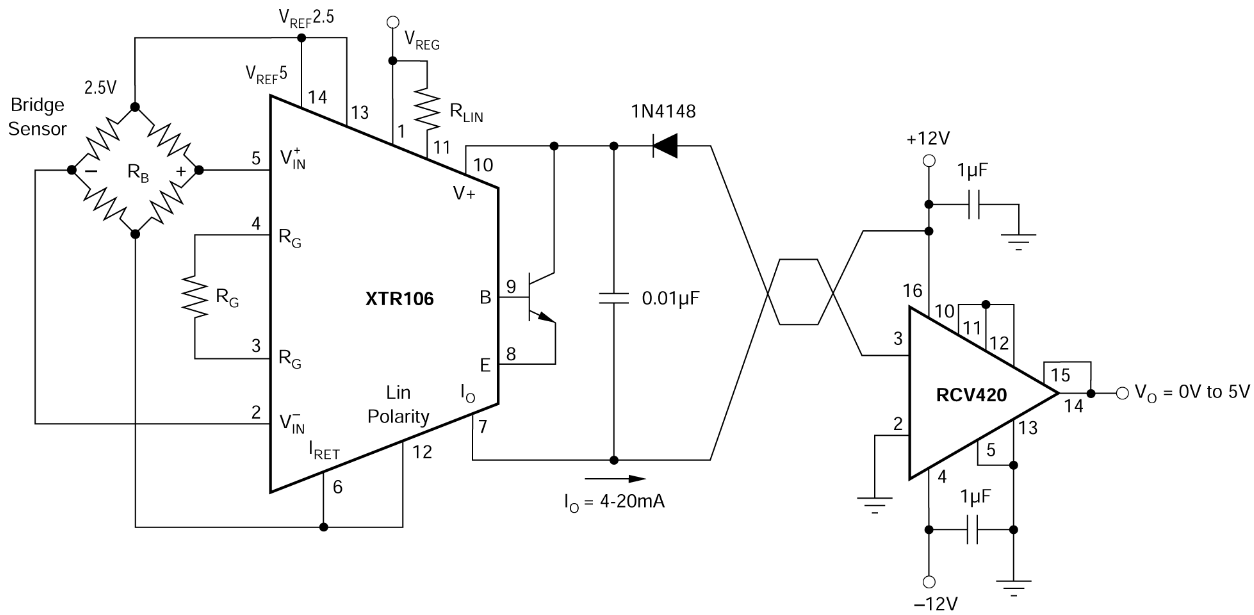
Table 7-1 shows how to calculate the effect various error sources have on circuit accuracy. A sample error calculation for a typical bridge sensor measurement circuit (5kΩ bridge, V_{REF} = 5V, V_{FS} = 50mV) is provided. The results reveal the XTR106 excellent accuracy, in this case 1.2% unadjusted. Adjusting gain and offset errors improves circuit accuracy to 0.33%. These are worst-case errors; maximum values were used in the calculations and all errors were assumed to be positive (additive). The XTR106 achieves performance that is difficult to obtain with discrete circuitry and requires less board space.

Table 7-1. Error Calculation

SAMPLE ERROR CALCULATION(1)				
Bridge Impedance (R_B) 5kΩ		**Full Scale Input (V_{FS}) 50mV**		
Ambient Temperature Range (ΔT_A) 20°C		**Excitation Voltage (V_{REF}) 5V**		
Supply Voltage Change (ΔV+) 5V		**Common-Mode Voltage Change (ΔCM) 25mV (= V_{FS}/2)**		
			ERROR (ppm of Full Scale)	
ERROR SOURCE	**SAMPLE ERROR EQUATION**	**ERROR CALCULATION**	**UNADJ**	**ADJUST**
INPUT				
Input offset voltage	$V_{OS}/V_{FS} \cdot 10^6$	$200\mu V/50mV \cdot 10^6$	2000	0
vs common-mode	$CMRR \cdot \Delta CM/V_{FS} \cdot 10^6$	$50\mu V/V \cdot 0.025V/50mV \cdot 10^6$	25	25
vs power supply	$(V_{OS}$ vs $V+) \cdot (\Delta V+)/V_{FS} \cdot 10^6$	$3\mu V/V \cdot 5V/50mV \cdot 10^6$	300	300
Input bias current	$CMRR \cdot I_B \cdot (R_B/2)/V_{FS} \cdot 10^6$	$50\mu V/V \cdot 25nA \cdot 2.5k\Omega/50mV \cdot 10^6$	0.1	0
Input offset current	$I_{OS} \cdot R_B/V_{FS} \cdot 10^6$	$3nA \cdot 5k\Omega/50mV \cdot 10^6$	300	0
		Total Input Error	**2625**	**325**
EXCITATION				
Voltage reference accuracy	V_{REF} Accuracy (%)/100% $\cdot 10^6$	$0.25\%/100\% \cdot 10^6$	2500	0
vs supply	$(V_{REF}$ vs $V+) \cdot (\Delta V+) \cdot (V_{FS}/V_{REF})$	$20ppm/V \cdot 5V\ (50mV/5V)$	1	1
		Total Excitation Error	**2501**	**1**
GAIN				
Span	Span Error (%)/100% $\cdot 10^6$	$0.2\%/100\% \cdot 10^6$	2000	0
Nonlinearity	Nonlinearity (%)/100% $\cdot 10^6$	$0.01\%/100\% \cdot 10^6$	100	100
		Total Gain Error	**2100**	**100**
OUTPUT				
Zero output	$\lvert I_{ZERO} - 4mA \rvert/16000\mu A \cdot 10^6$	$25\mu A/16000\mu A \cdot 10^6$	1563	0
vs supply	$(I_{ZERO}$ vs $V+) \cdot (\Delta V+)/16000\mu A \cdot 10^6$	$0.2\mu A/V \cdot 5V/16000\mu A \cdot 10_6$	62.5	62.5
		Total Output Error	**1626**	**63**
DRIFT (ΔT_A = 20°C)				
Input offset voltage	$Drift \cdot \Delta T_A/(V_{FS}) \cdot 10^6$	$1.5\mu V/°C \cdot 20°C/(50mV) \cdot 10^6$	600	600
Input offset current (typical)	$Drift \cdot \Delta T_A \cdot R_B/(V_{FS}) \cdot 10^6$	$5pA/°C \cdot 20°C \cdot 5k\Omega/(50mV) \cdot 10^6$	10	10
Voltage reference accuracy		$35ppm/°C \cdot 20°C$	700	700
Span		$225ppm/°C \cdot 20°C$	500	500
Zero output	$Drift \cdot \Delta T_A/16000\mu A \cdot 10^6$	$0.9\mu A/°C \cdot 20°C/16000\mu A \cdot 10^6$	1125	1125
		Total Drift Error	**2936**	**2936**
NOISE (0.1Hz to 10Hz, typical)				
Input offset voltage	$V_n(p\text{-}p)/V_{FS} \cdot 10^6$	$0.6\mu V/50mV \cdot 10^6$	12	12
Zero output	I_{ZERO} Noise / $16000\mu A \cdot 10^6$	$0.035\mu A/16000\mu A \cdot 10^6$	2.2	2.2
Thermal R_B noise	$[\sqrt{2} \cdot \sqrt{(R_B/2)/1k\Omega} \cdot 4nV/\sqrt{Hz} \cdot \sqrt{10Hz}]/V_{FS} \cdot 10^6$	$[\sqrt{2} \cdot \sqrt{2.5k\Omega/1k\Omega} \cdot 4nV/\sqrt{Hz} \cdot \sqrt{10Hz}]]/50mV \cdot 10^6$	0.6	0.6
Input current noise	$(i_n \cdot 40.8 \cdot \sqrt{2} \cdot R_B/2)/V_{FS} \cdot 10^6$	$(200fA/\sqrt{Hz} \cdot 40.8 \cdot \sqrt{2} \cdot 2.5k\Omega)/50mV \cdot 10^6$	0.6	0.6
		Total Noise Error	**15**	**15**
		TOTAL ERROR:	**11803**	**3340**
			1.18%	**0.33%**

(1) All errors are minimum and maximum, and referred to input, unless otherwise stated.

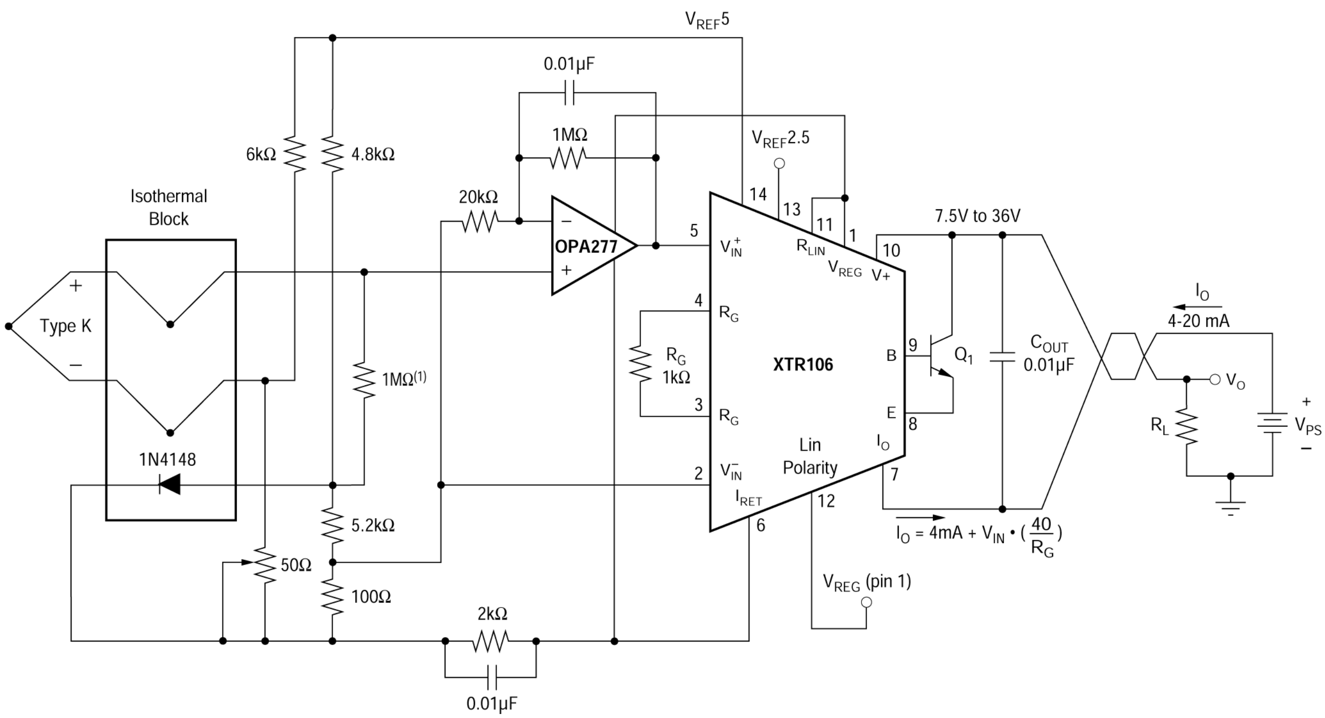
7.2 Typical Applications



(1) Lin Polarity shown connected to correct positive bridge nonlinearity. See Figure 6-3 to correct negative bridge nonlinearity.

(2) See ISO124 data sheet if isolation is needed.

Figure 7-6. ±12V-Powered Transmitter and Receiver Loop



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

(1) For burn-out indication.

(2) See ISO124 data sheet if isolation is needed.

Figure 7-7. Thermocouple Low-Offset, Low-Drift Loop Measurement With Diode Cold-Junction Compensation

7.3 Layout

7.4 Layout Guidelines

The XTR106 is typically used with an external transistor (Q_1) to regulate the power dissipation of the 4mA to 20mA loop. This allows the resulting localized self-heating to be distanced from the precision circuitry of the XTR106 and reduces overtemperature drift errors.

The XTR106 can be used without the Q_1 transistor if the application requirements do not lead to violation of the device *Absolute Maximum Requirements*, such as the maximum junction temperature. Calculate the peak power dissipation and multiply by thermal resistance to approximate the associated junction temperature rise. Minimize overheat conditions for reliable long-term operation.

Place supply bypass capacitors close to the package and make connections with low-impedance conductors. Reduce trace lengths for R_G to minimize coupled environmental noise. If the loop power supply is electrically noisy, implement filtering using decoupling capacitors and small resistors or dampening inductors in series with V+.

8 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

8.1 Documentation Support

8.2 Related Documentation

For related documentation see the following:

- Texas Instruments, *Special Function Amplifiers* Precision Labs video series on Current Loop Transmitters
- Texas Instruments, *Analog Linearization of Resistance Temperature Detectors* technical article
- Texas Instruments, *A Basic Guide to RTD Measurements* application note

8.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

8.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

8.5 Trademarks

TI E2E™ is a trademark of Texas Instruments.
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8.6 Electrostatic Discharge Caution

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.

8.7 Glossary

TI Glossary   This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (November 2003) to Revision B (January 2025) — **Page**

- Updated the numbering format for tables, figures, and cross-references throughout the document................. 1
- Added the *Pin Configuration and Functions*, *Recommended Operating Conditions, Thermal Information, Electrical Characteristics*, *Detailed Description*, *Functional Block Diagram*, *Application and Implementation*, *Typical Applications*, *Device and Documentation Support*, and *Mechanical, Packaging, and Orderable Information* sections...1
- Modified end equipments in *Applications* 1
- Moved operating and storage temperature parameters from *Electrical Characteristics* to *Absolute Maximum Ratings* 4
- Changed minimum operating temperature from −55°C to −40°C in *Absolute Maximum Ratings* 4
- Moved specified temperature and power-supply parameters from *Electrical Characteristics* to *Recommended Operating Conditions* 4

10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
XTR106P	Active	Production	PDIP (N) | 14	25 | TUBE	Yes	Call TI	N/A for Pkg Type	-40 to 85	XTR106P A
XTR106P.A	Active	Production	PDIP (N) | 14	25 | TUBE	Yes	Call TI	N/A for Pkg Type	-40 to 85	XTR106P A
XTR106PA	Active	Production	PDIP (N) | 14	25 | TUBE	Yes	Call TI	N/A for Pkg Type	-	XTR106P A
XTR106PA.A	Active	Production	PDIP (N) | 14	25 | TUBE	Yes	Call TI	N/A for Pkg Type	-40 to 85	XTR106P A
XTR106U/2K5	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	Call TI | Nipdau	Level-3-260C-168 HR	-40 to 85	XTR106U
XTR106U/2K5.A	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	Call TI	Level-3-260C-168 HR	-40 to 85	XTR106U
XTR106U/2K5.B	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	Call TI	Level-3-260C-168 HR	-40 to 85	XTR106U
XTR106UA	Obsolete	Production	SOIC (D) | 14	-	-	Call TI	Call TI	-40 to 85	XTR106U A
XTR106UA/2K5	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	Call TI | Nipdau	Level-3-260C-168 HR	-40 to 85	(XTR106U, XTR106UA) A
XTR106UA/2K5.A	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	Call TI	Level-3-260C-168 HR	-40 to 85	(XTR106U, XTR106UA) A
XTR106UA/2K5.B	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	Call TI	Level-3-260C-168 HR	-40 to 85	(XTR106U, XTR106UA) A

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

[5] **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

[6] **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

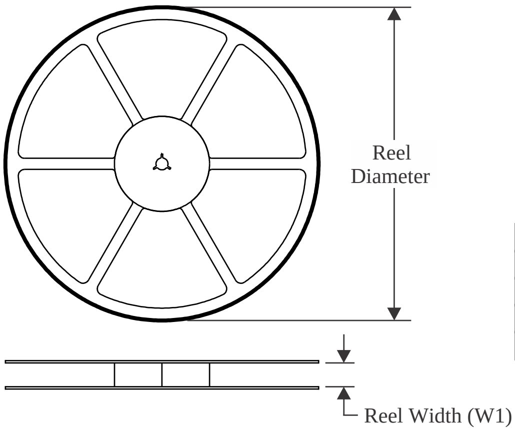
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

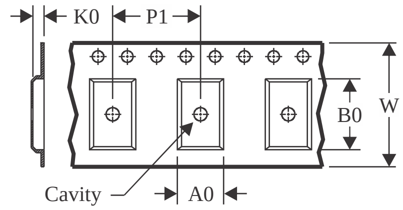
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

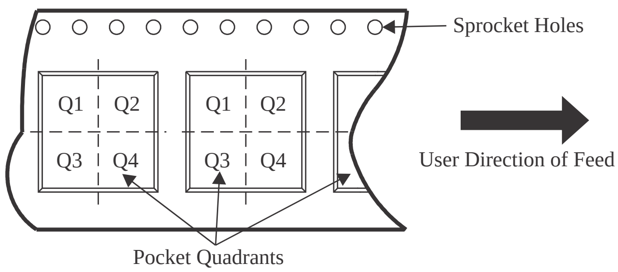


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

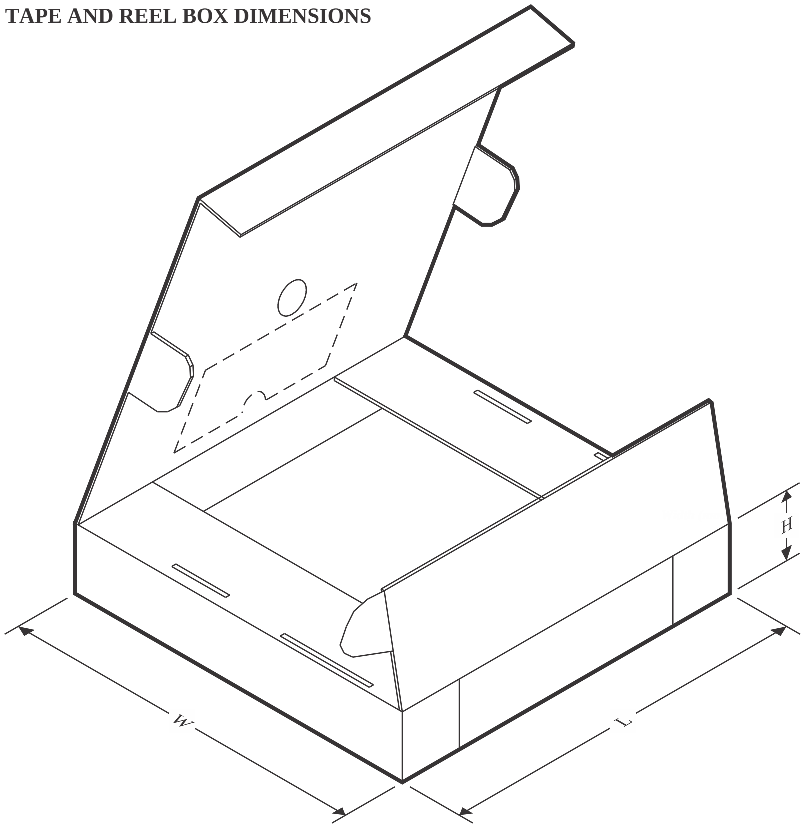
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
XTR106U/2K5	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
XTR106UA/2K5	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1

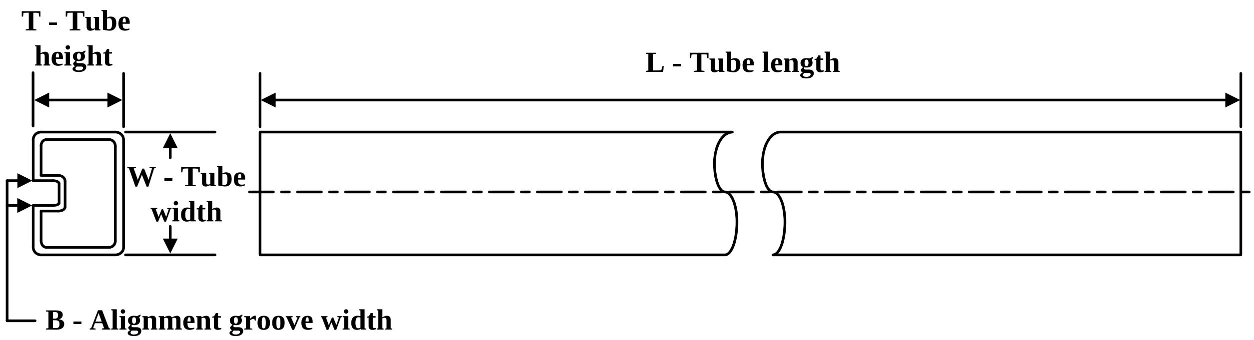
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

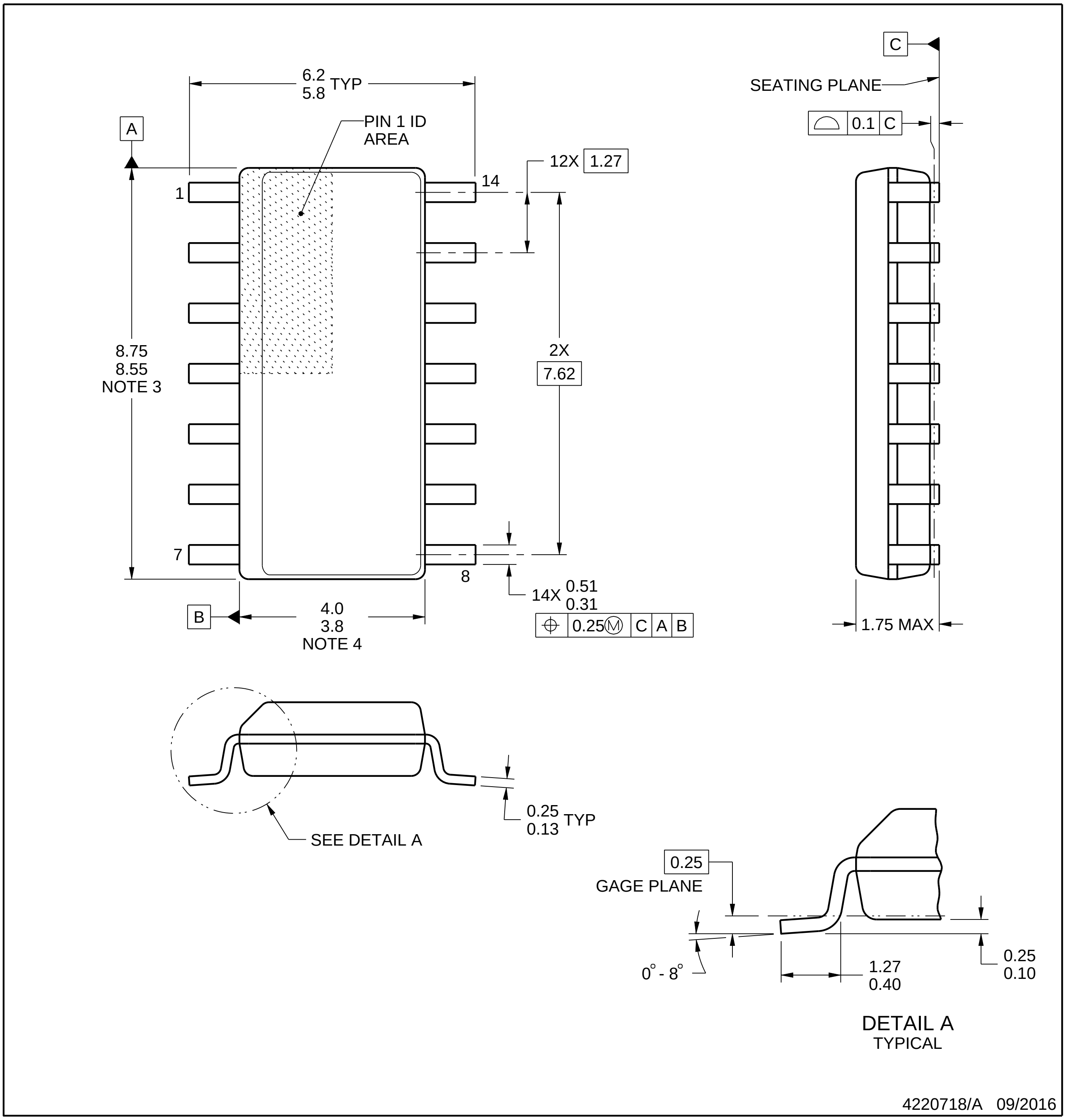
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
XTR106U/2K5	SOIC	D	14	2500	353.0	353.0	32.0
XTR106UA/2K5	SOIC	D	14	2500	353.0	353.0	32.0

TUBE



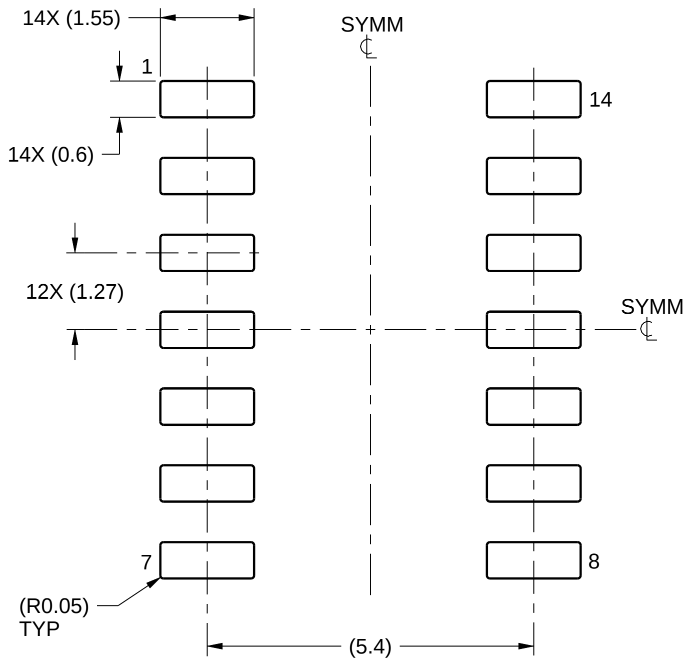
*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
XTR106P	N	PDIP	14	25	506	13.97	11230	4.32
XTR106P.A	N	PDIP	14	25	506	13.97	11230	4.32
XTR106PA	N	PDIP	14	25	506	13.97	11230	4.32
XTR106PA.A	N	PDIP	14	25	506	13.97	11230	4.32

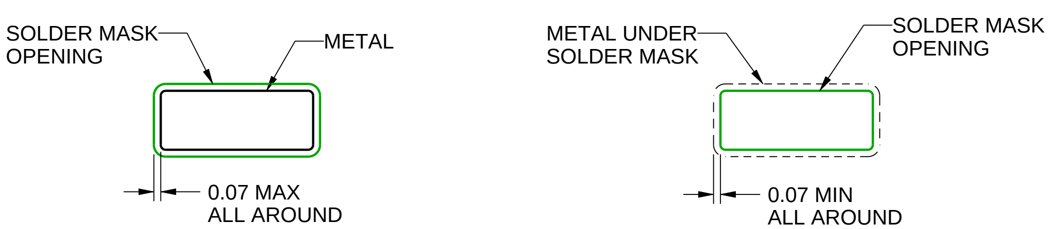


NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
5. Reference JEDEC registration MS-012, variation AB.



LAND PATTERN EXAMPLE
SCALE:8X



NON SOLDER MASK DEFINED

SOLDER MASK DEFINED

SOLDER MASK DETAILS

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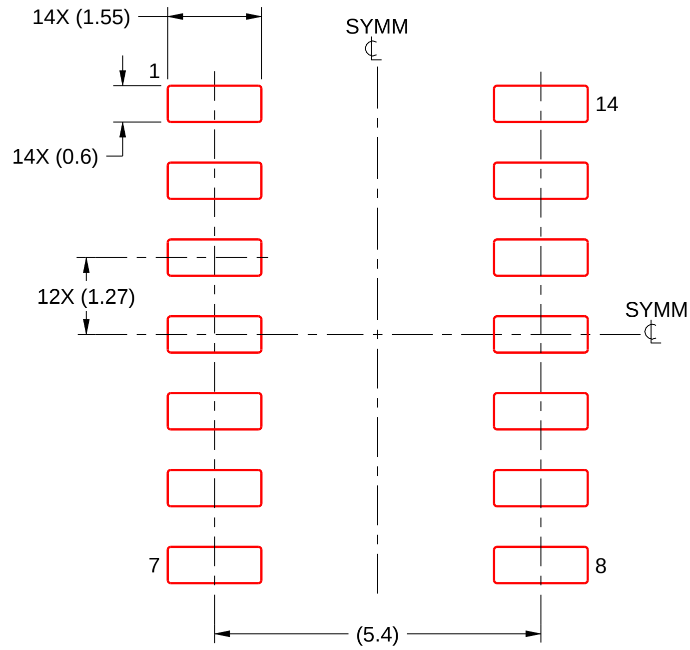
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:8X

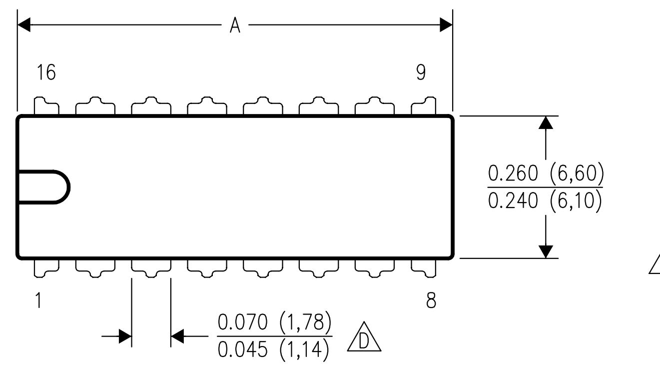
4220718/A 09/2016

NOTES: (continued)

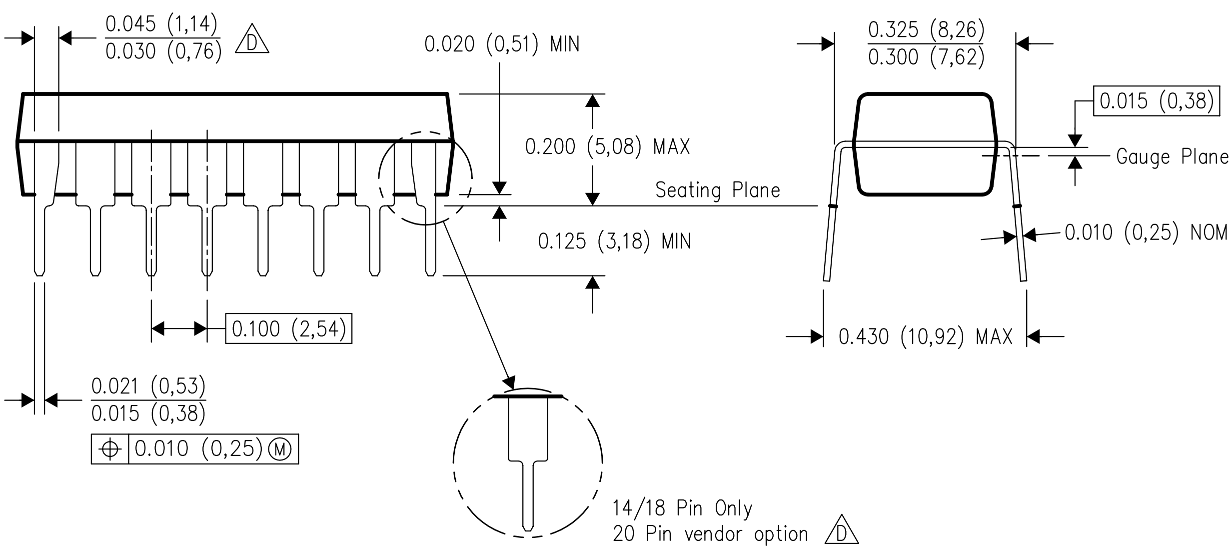
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

N (R–PDIP–T**) PLASTIC DUAL–IN–LINE PACKAGE

16 PINS SHOWN



PINS ** / DIM	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
(C) MS–001 VARIATION	AA	BB	AC	AD



4040049/E 12/2002

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
(C) Falls within JEDEC MS–001, except 18 and 20 pin minimum body length (Dim A).
(D) The 20 pin end lead shoulder width is a vendor option, either half or full width.