Simple, Low-Cost 4 mA to 20 mA Pressure Transmitter

Technical Note

INTRODUCTION

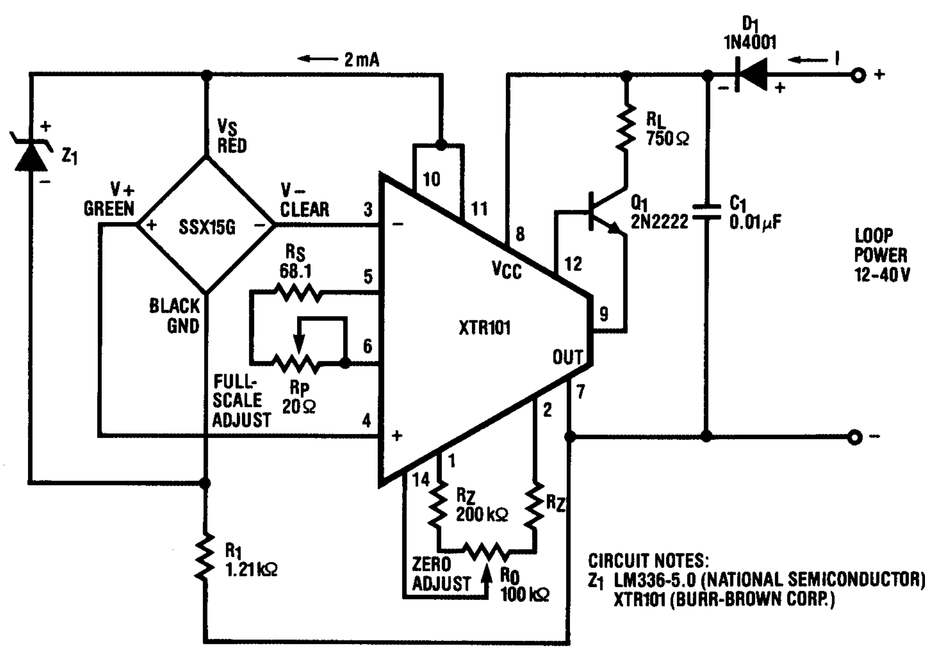
The two wire 4 mA to 20 mA transmission loop is one of the most popular output signals for pressure sensing devices in industrial applications. The use of current as a transmission signal provides a low impedance transmission path which is less susceptible to induced noise pickup. This also eliminates the concern of IR drop along the line, which makes the signal relatively independent of line resistance and line length. Best of all, there is no ambiguity between a zero pressure reading and an open circuit because at least 4mA of current is always flowing through the circuit.

The main disadvantage of 4 mA to 20 mA pressure transmitters has been their high costs which have continued even though low-cost semiconductor pressure sensors are available. However, now by using a new low cost precision integrated circuit sensor in combination with a single IC, a simple low-cost pressure transmitter can be realized. SenSym's new SCX or SSX series sensors can be used with the XTR101 (Burr Brown Corporation) to make a high accuracy, reliable, pressure transmitter. The temperature compensator SCX or SSX sensor utilizes hybrid technology and laser trimmed resistors to achieve zero offsets of less than ±1 mV and span calibrations within 1 % FSO. The XTR101 is a monolithic device especially designed to convert the low-level signal from a sensor to the desired current output. It features dual matched 1mA current sources as well as full scale adjustment nodes. This application note will discuss how to construct a simple and low-cost 4 mA to 20 mA transmitter using the sensor and XTR101.

CIRCUIT DESCRIPTION

By using the built-in features of the SCX sensor and the XTR101, a simple pressure transmitter can be made as shown in Figure 1. The XTR101 will provide two one milliamp current sources for sensor excitation if the bias voltage between the V_{CC} and OUT pins is between 12 Vdc and 40 Vdc. The SCX is a constant voltage device, and driving the sensor with constant current will increase its output errors over temperature. Therefore, a 5.0 Vdc reference is placed in parallel with the sensor to maintain a constant sensor voltage. The SCX sensor has a nominal input impedance of 4 kOhm, thus requiring 1.25 mA with a 5 Vdc sensor supply. This circuit leaves 750 µA to bias the voltage reference which is within the operating range of the LM336-5.0.

Figure 1
A 30 ft. Tank Level Transmitter



On the XTR101, the common-mode voltage of the signal inputs (pins 3 and 4) from the sensor must be between 4 Vdc and 6 Vdc above the voltage at the OUT pin (pin 7). This requirement can be easily satisfied by inserting a 1.21 kOhm resistor in series with the sensor. This connection raises the common-mode voltage of the sensor outputs to 4.9 Vdc above the negative supply. The 2.4 Vdc is in addition, to the normal common-mode voltage of the sensor output of 2.5 Vdc from the outputs being one-half of the 5 Vdc sensor supply voltage. These connections enable the sensor outputs to be typically 4.9 Vdc higher than pin 7 and near the middle of the common-mode input range of the XTR101.

SPAN ADJUSTMENT

The XTR101 provides a full-scale adjust by connecting a resistor between pins 5 and 6. The gain resistor can be easily calculated from the following equation.

$$R_T = \frac{\frac{40}{16\text{ mA}}}{\text{Span}} - 0.016$$

Where: R_T is in ohms, and span is the sensor output at full-scale minus the offset voltage in millivolts. To allow for calibration of the full-scale output, R_T consists of a fixed-value resistor(R_S)and an adjustment pot(R_P).

ZERO ADJUSTMENT

The transmitter can be adjusted for offset errors by using a pot (R_0) and two resistors (R_Z) connected to the XTR101. This adjustment comes in contact with the internal instrumentation amplifier, and for every 100 µV of adjustment the transmitter will drift an additional ±0.3 µV/°C. Therefore, it is recommended that low offset devices be used to minimize possible transmitter errors. Although this adjustment method induces a slight error into the transmitter, an offset adjustment connected directly to the sensor output is likely to induce larger temperature errors by causing an imbalance in the sensor resistors and compensation networks.

OTHER CONSIDERATIONS

Transmitter accuracy is increased by using an external transistor to reduce the heat dissipated by the XTR101. The transistor is connected in parallel with an internal transistor where the load current will be shared. A 750 watt (¼ watt to ½ watt) resistor in series with the collector is recommended for systems that have a power supply greater than 24 Vdc.

Lead lengths on the circuit board should be kept as short as possible to reduce noise and parasitic resistance. It is especially important to minimize the lead lengths for the high impedance signal input and the offset adjustment nodes on the converter.
By placing a 0.01 µF capacitor and a diode near the XTR101 package, the circuit is protected from voltage transients and reverse polarity of the power supply.

DESIGN EXAMPLES

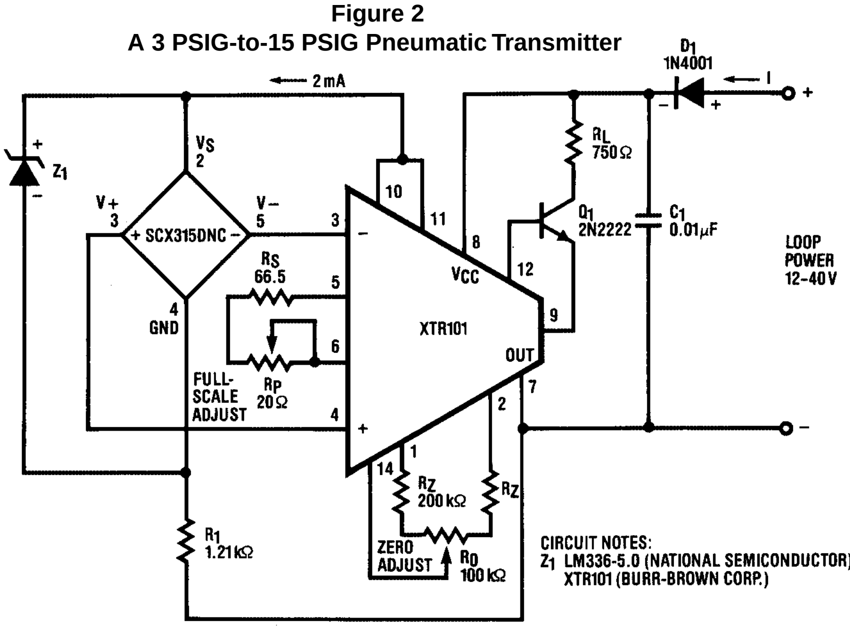
Example 1: A 30 Ft. Tank Level Indicator

A 30 ft process tank holds a solution with a specific gravity of 0.95. A pressure sensor is located near the bottom of tank to monitor the solution height. The pressure at the bottom of the full tank can be calculated as follows:

$$P_{(fs)} = \frac{(0.95)\ 30\text{ ft} \times 12\text{ in/ft}}{27.68\text{ in/psi}}$$

$$P_{(fs)} = 12.36\text{ psi}$$

Figure 2
A 3 PSIG-to-15 PSIG Pneumatic Transmitter



The SSX15G is used for this application for the convenience of a threaded mount and stainless steel isolation. From the SSX15G datasheet, the device will have an output of 90 mV at 15 psi with a 12 Vdc power supply. The SSX15G is ratiometric, so with a 12.36 psi input and a 5 Vdc supply, the sensor will output 30.9 mV. The gain resistor can be found by using the gain equation where R_T is calculated to equal 79.7 Ohm. To allow a five percent span adjustment range, let R_S equal a 68.1 Ohm resistor and R_P a 20 Ohm pot. A zero adjustment of ±280 µA is provided by letting R_Z equal 200 kOhm and R_O equal a 100 kOhm pot. The completed circuit is shown in Figure 1.

ADJUSTMENT PROCEDURE

(A) Vent the sensor to atmosphere and adjust R_0 so that I_{OUT} equals 4.00 mA.
(B) At a full pressure of 12.36 psi, adjust R_P so that I_{OUT} equals 20.00 mA.
(C) Repeat (A) and (B) as necessary.

Example 2: A 3 psi to 5 psi Pneumatic Transmitter

The SCX315DNC has been especially calibrated for the 3 psi to 15 psi range such that the sensor output at 3 psi is equal to 0 Vdc. Therefore, as shown in Figure 2, no additional components are needed to offset the 3 psi pressure signal as with other pressure devices. This pressure transmitter can still use the same simple adjust procedure as in the first example to measure the 3 psi to 15 psi pressure range used in pneumatic controls. From the SCX315DNC datasheet, the sensor will have an offset of 0 Vdc at 3 psi, and at 15 psi the sensor will output 72 mV with a 12 Vdc supply. The gain resistor can be found by calculating the span with 5 volts of excitation and substituting the output into the gain equation. R_T is calculated to equal 77 Ohm. To allow for a five percent span adjustment let R_S equal a 66.5 Ohm resistor and R_P a 20 Ohm pot. By having R_Z equal 200 kOhm and with R_0 a 100 kOhm pot, the offset current can be adjusted ±280 µA.

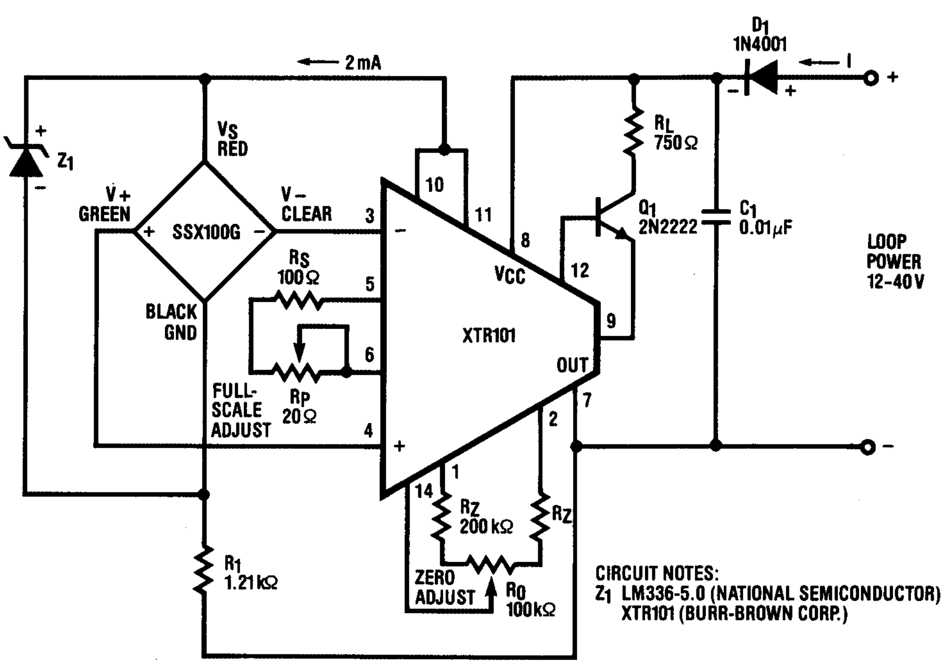
ADJUSTMENT PROCEDURE

(A) Apply 3 psi to the sensor and adjust R_{0s} such that I_{OUT} is equal to 4.00 mA.
(B) Apply 15 psi and adjust R_P until I_{OUT} is equal to 20.00 mA.
(C) Repeat (A)and(B) as necessary.

Example 3: A 0 psi to 100 psi Cooling System

An SSX100G is used to monitor a cooling system that has an operating range of 0 psi to 100 psi. From the SSX100G datasheet, the sensor will output 100 mV with 100 psi applied and a 12 Vdc excitation voltage. With a 5 Vdc excitation, the SSX100G will have a full-scale output of 41.7 mV. R_T can be found by the gain equation to equal 109 Ohm. Allowing for ±5 % adjustment let R_S equal a 100 Ohm resistor and R_P a 20 Ohm pot. By letting R_Z equal a 200 kOhm resistor and R_0 equal a 100 kOhm pot, the offset current can be adjusted by ±200 µA.

Figure 3
A 0 PSIG-to-100 PSIG Cooling System Transmitter



ADJUSTMENT PROCEDURE

(A) Vent the sensor, and adjust R_0 until I_{OUT} equals 4.00 mA.

(B) Apply 100 psig to the sensor, and adjust R_P so that I_{OUT} equals 20.00 mA.

(C) Repeat (A) and (B) if necessary.

CONCLUSION

By combining the SCX or SSX compensated sensors with the XTR101, a simple and low-cost 4 mA to 20 mA pressure transmitter can be designed. This design requires a minimum of additional components and provides a cost effective solution to many industrial pressure sensing applications.

For application assistance, current specifications, or name of the nearest Authorized Distributor, check the Honeywell web site or call:

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