



# XTR110

## PRECISION VOLTAGE-TO-CURRENT CONVERTER/TRANSMITTER

### FEATURES

- 4mA TO 20mA TRANSMITTER
- SELECTABLE INPUT/OUTPUT RANGES:  
0V to +5V, 0V to +10V Inputs  
0mA to 20mA, 5mA to 25mA Outputs  
Other Ranges
- 0.005% MAX NONLINEARITY, 14 BIT
- PRECISION +10V REFERENCE OUTPUT
- SINGLE SUPPLY OPERATION
- WIDE SUPPLY RANGE: 13.5V to 40V

### APPLICATIONS

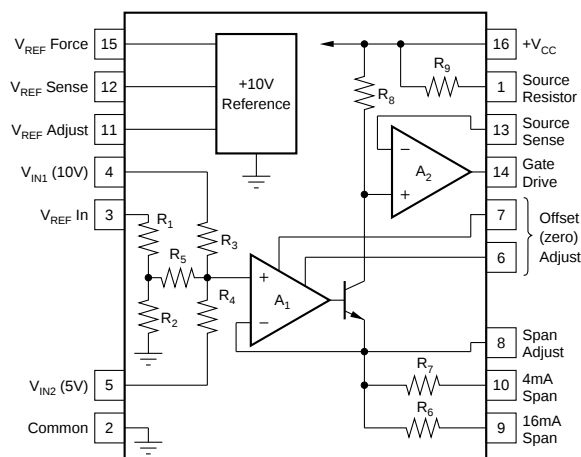
- INDUSTRIAL PROCESS CONTROL
- PRESSURE/TEMPERATURE TRANSMITTERS
- CURRENT-MODE BRIDGE EXCITATION
- GROUNDED TRANSDUCER CIRCUITS
- CURRENT SOURCE REFERENCE FOR DATA ACQUISITION
- PROGRAMMABLE CURRENT SOURCE FOR TEST EQUIPMENT
- POWER PLANT/ENERGY SYSTEM MONITORING

### DESCRIPTION

The XTR110 is a precision voltage-to-current converter designed for analog signal transmission. It accepts inputs of 0 to 5V or 0 to 10V and can be connected for outputs of 4 to 20mA, 0 to 20mA, 5 to 25mA and many other commonly used ranges.

A precision on-chip metal film resistor network provides input scaling and current offsetting. An internal 10V voltage reference can be used to drive external circuitry.

The XTR110 is available in 16-pin plastic DIP, ceramic DIP and SOL-16 surface-mount packages. Commercial and industrial temperature range models are available.



# SPECIFICATIONS

## ELECTRICAL

At  $T_A = +25^\circ\text{C}$  and  $V_{CC} = +24\text{V}$  and  $R_L = 250\Omega^{**}$ , unless otherwise specified.

| PARAMETER                    | CONDITIONS                            | XTR110AG, KP, KU |                                                                  |        | XTR110BG |        |        | UNITS                       |
|------------------------------|---------------------------------------|------------------|------------------------------------------------------------------|--------|----------|--------|--------|-----------------------------|
|                              |                                       | MIN              | TYP                                                              | MAX    | MIN      | TYP    | MAX    |                             |
| <b>TRANSMITTER</b>           |                                       |                  |                                                                  |        |          |        |        |                             |
| Transfer Function            |                                       |                  | $I_O = 10 [(V_{REF}/16) + (V_{IN1}/4) + (V_{IN2}/2)] / R_{SPAN}$ |        |          |        |        |                             |
| Input Range: $V_{IN1}^{(5)}$ | Specified Performance                 | 0                |                                                                  | +10    | *        |        | *      | V                           |
| $V_{IN2}$                    | Specified Performance                 | 0                |                                                                  | +5     | *        |        | *      | V                           |
| Current, $I_O$               | Specified Performance <sup>(1)</sup>  | 4                |                                                                  | 20     | *        |        | *      | mA                          |
|                              | Derated Performance <sup>(1)</sup>    | 0                |                                                                  | 40     | *        |        | *      | mA                          |
| Nonlinearity                 | 16mA/20mA Span <sup>(2)</sup>         |                  | 0.01                                                             | 0.025  |          | 0.002  | 0.005  | % of Span                   |
| Offset Current, $I_{OS}$     | $I_O = 4\text{mA}^{(1)}$              |                  |                                                                  |        |          |        |        |                             |
| Initial                      | (1)                                   |                  | 0.2                                                              | 0.4    |          | 0.02   | 0.1    | % of Span                   |
| vs Temperature               | (1)                                   |                  | 0.0003                                                           | 0.005  |          | *      | 0.003  | % of Span/ $^\circ\text{C}$ |
| vs Supply, $V_{CC}$          | (1)                                   |                  | 0.0005                                                           | 0.005  |          | *      | *      | % of Span/V                 |
| Span Error                   | $I_O = 20\text{mA}$                   |                  |                                                                  |        |          |        |        |                             |
| Initial                      | (1)                                   |                  | 0.3                                                              | 0.6    |          | 0.05   | 0.2    | % of Span                   |
| vs Temperature               | (1)                                   |                  | 0.0025                                                           | 0.005  |          | 0.0009 | 0.003  | % of Span/ $^\circ\text{C}$ |
| vs Supply, $V_{CC}$          | (1)                                   |                  | 0.003                                                            | 0.005  |          | *      | *      | % of Span/V                 |
| Output Resistance            | From Drain of FET ( $Q_{EXT}^{(3)}$ ) |                  | $10 \times 10^9$                                                 |        |          | *      |        | $\Omega$                    |
| Input Resistance             | $V_{IN1}$                             |                  | 27                                                               |        |          | *      |        | k $\Omega$                  |
|                              | $V_{IN2}$                             |                  | 22                                                               |        |          | *      |        | k $\Omega$                  |
|                              | $V_{REF}$ In                          |                  | 19                                                               |        |          | *      |        | k $\Omega$                  |
| Dynamic Response             |                                       |                  |                                                                  |        |          |        |        |                             |
| Settling Time                | To 0.1% of Span                       |                  | 15                                                               |        |          | *      |        | $\mu\text{s}$               |
|                              | To 0.01% of Span                      |                  | 20                                                               |        |          | *      |        | $\mu\text{s}$               |
| Slew Rate                    |                                       |                  | 1.3                                                              |        |          | *      |        | mA/ $\mu\text{s}$           |
| <b>VOLTAGE REFERENCE</b>     |                                       |                  |                                                                  |        |          |        |        |                             |
| Output Voltage               |                                       | +9.95            | +10                                                              | +10.05 | +9.98    | *      | +10.02 | V                           |
| vs Temperature               |                                       |                  | 35                                                               | 50     |          | 15     | 30     | ppm/ $^\circ\text{C}$       |
| vs Supply, $V_{CC}$          | Line Regulation                       |                  | 0.0002                                                           | 0.005  |          | *      | *      | %/V                         |
| vs Output Current            | Load Regulation                       |                  | 0.0005                                                           | 0.01   |          | *      | *      | %/mA                        |
| vs Time                      |                                       |                  | 100                                                              |        |          | *      |        | ppm/1k hrs                  |
| Trim Range                   |                                       | -0.100           |                                                                  | +0.25  | *        |        | *      | V                           |
| Output Current               | Specified Performance                 | 10               |                                                                  |        | *        |        |        | mA                          |
| <b>POWER SUPPLY</b>          |                                       |                  |                                                                  |        |          |        |        |                             |
| Input Voltage, $V_{CC}$      |                                       | +13.5            |                                                                  | +40    | *        |        | *      | V                           |
| Quiescent Current            | Excluding $I_O$                       |                  | 3                                                                | 4.5    |          | *      | *      | mA                          |
| <b>TEMPERATURE RANGE</b>     |                                       |                  |                                                                  |        |          |        |        |                             |
| Specification: AG, BG        |                                       | -40              |                                                                  | +85    | *        |        | *      | $^\circ\text{C}$            |
| KP, KU                       |                                       | 0                |                                                                  | +70    |          |        |        | $^\circ\text{C}$            |
| Operating: AG, BG            |                                       | -55              |                                                                  | +125   | *        |        | *      | $^\circ\text{C}$            |
| KP, KU                       |                                       | -25              |                                                                  | +85    |          |        |        | $^\circ\text{C}$            |

\* Specifications same as AG/KP grades. \*\* Specifications apply to the range of  $R_L$  shown in Typical Performance Curves.

NOTES: (1) Including internal reference. (2) Span is the change in output current resulting from a full-scale change in input voltage. (3) Within compliance range limited by  $(+V_{CC} - 2V) + V_{DS}$  required for linear operation of the FET. (4) For  $V_{REF}$  adjustment circuit see Figure 3. (5) For extended  $I_{REF}$  drive circuit see Figure 4. (5) Unit may be damaged. See section, "Input Voltage Range".

## ABSOLUTE MAXIMUM RATINGS

|                                                           |                                             |
|-----------------------------------------------------------|---------------------------------------------|
| Power Supply, $+V_{CC}$ .....                             | 40V                                         |
| Input Voltage, $V_{IN1}$ , $V_{IN2}$ , $V_{REF}$ In ..... | $+V_{CC}$                                   |
| See text regarding safe negative input voltage range.     |                                             |
| Storage Temperature Range: A, B .....                     | $-55^\circ\text{C}$ to $+125^\circ\text{C}$ |
| K, U .....                                                | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |
| Lead Temperature                                          |                                             |
| (soldering, 10s) G, P .....                               | $300^\circ\text{C}$                         |
| (wave soldering, 3s) U .....                              | $260^\circ\text{C}$                         |
| Output Short-Circuit Duration, Gate Drive                 |                                             |
| and $V_{REF}$ Force .....                                 | Continuous to common and $+V_{CC}$          |
| Output Current Using Internal $50\Omega$ Resistor .....   | 40mA                                        |



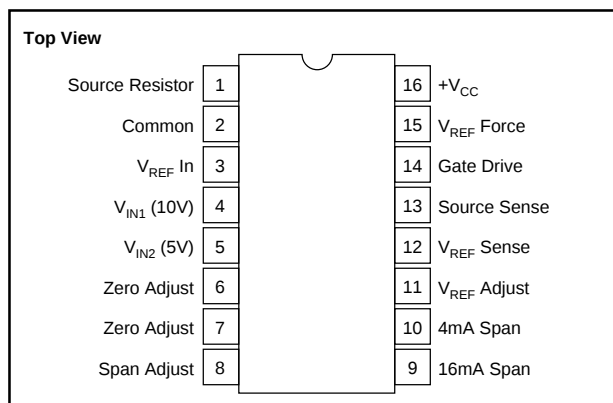
## ELECTROSTATIC DISCHARGE SENSITIVITY

Any integral circuit can be damaged by ESD. Burr-Brown 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 published specifications.

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## PIN CONFIGURATION



## PACKAGE INFORMATION

| MODEL    | PACKAGE              | PACKAGE DRAWING NUMBER <sup>(1)</sup> |
|----------|----------------------|---------------------------------------|
| XTR110AG | 16-Pin Ceramic DIP   | 109                                   |
| XTR110BG | 16-Pin Ceramic DIP   | 109                                   |
| XTR110KP | 16-Pin Plastic DIP   | 180                                   |
| XTR110KU | SOL-16 Surface-Mount | 211                                   |

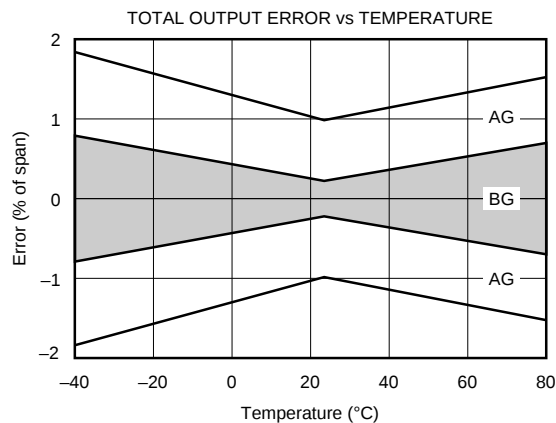
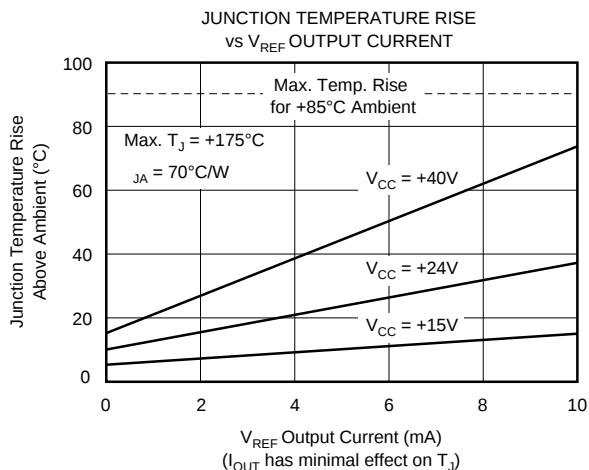
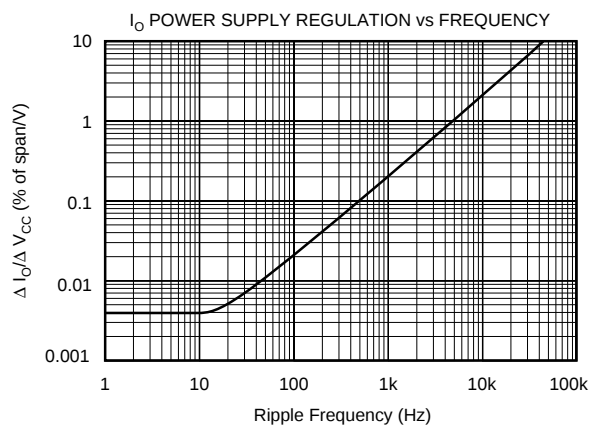
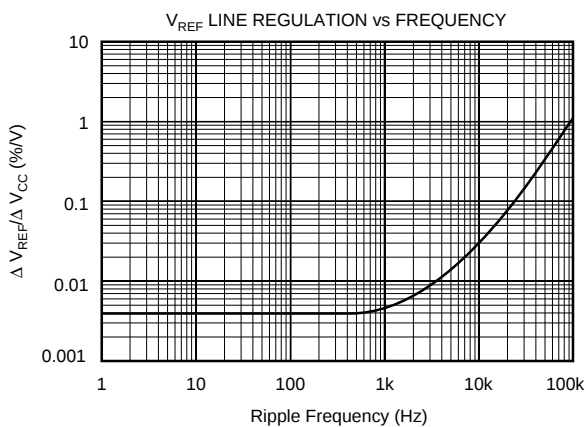
NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book.

## ORDERING INFORMATION

| MODEL    | PACKAGE              | TEMPERATURE RANGE |
|----------|----------------------|-------------------|
| XTR110AG | 16-Pin Ceramic DIP   | -40°C to +85°C    |
| XTR110BG | 16-Pin Ceramic DIP   | -40°C to +85°C    |
| XTR110KP | 16-Pin Plastic DIP   | 0°C to +70°C      |
| XTR110KU | SOL-16 Surface-Mount | 0°C to +70°C      |

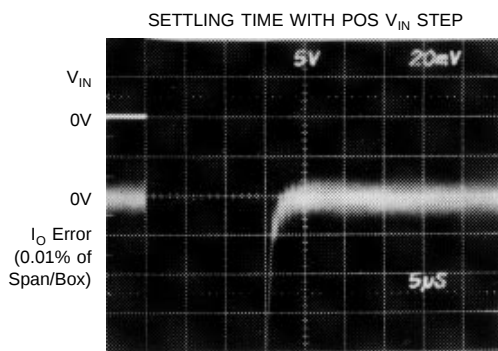
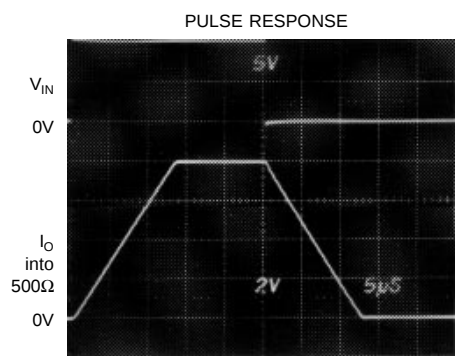
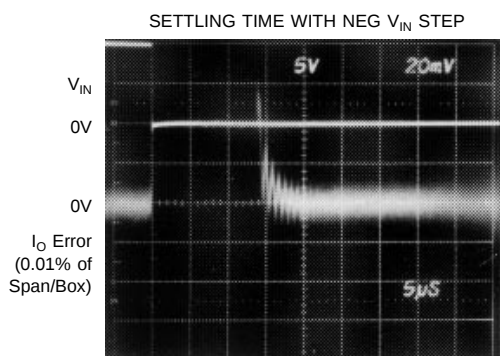
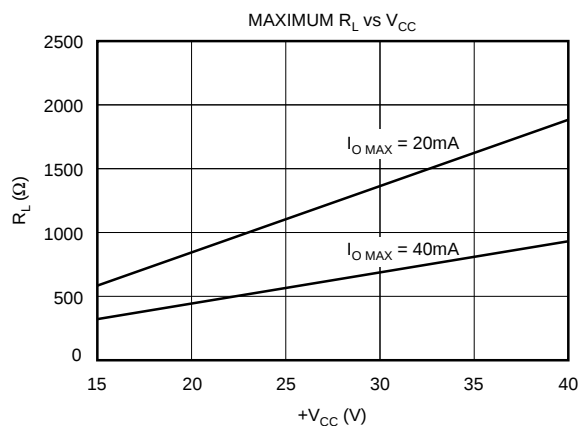
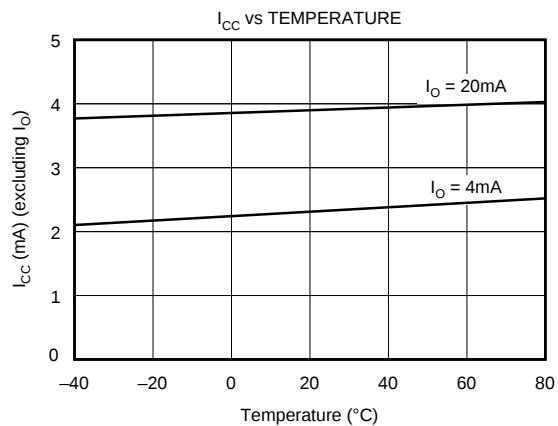
## TYPICAL PERFORMANCE CURVES

$T_A = +25^\circ\text{C}$ ,  $V_{CC} = 24\text{VDC}$ ,  $R_L = 250\Omega$ , unless otherwise noted.



# TYPICAL PERFORMANCE CURVES (CONT)

$T_A = +25^\circ\text{C}$ ,  $V_{CC} = 24\text{VDC}$ ,  $R_L = 250\Omega$ , unless otherwise noted.



## APPLICATIONS INFORMATION

Figure 1 shows the basic connections required for 0 to 10V input and 4 to 20mA output. Other input voltage and output current ranges require changes in connections of pins 3, 4, 5, 9 and 10 as shown in the table of Figure 1.

The complete transfer function of the XTR110 is:

$$I_O = \frac{10 \left[ \frac{(V_{REF IN})}{16} + \frac{(V_{IN1})}{4} + \frac{(V_{IN2})}{2} \right]}{R_{SPAN}} \quad (1)$$

$R_{SPAN}$  is the internal  $50\Omega$  resistor,  $R_9$ , when connected as shown in Figure 1. An external  $R_{SPAN}$  can be connected for different output current ranges as described later.

### EXTERNAL TRANSISTOR

An external pass transistor,  $Q_{EXT}$ , is required as shown in Figure 1. This transistor conducts the output signal current. A P-channel MOSFET transistor is recommended. It must have a voltage rating equal or greater than the maximum power supply voltage. Various recommended types are shown in Table I.

| MANUFACTURER            | PART NO. | BV <sub>DSS</sub> <sup>(1)</sup> | BV <sub>GS</sub> <sup>(1)</sup> | PACKAGE |
|-------------------------|----------|----------------------------------|---------------------------------|---------|
| Ferranti                | ZVP1304A | 40V                              | 20V                             | TO-92   |
|                         | ZVP1304B | 40V                              | 20V                             | TO-39   |
|                         | ZVP1306A | 60V                              | 20V                             | TO-92   |
|                         | ZVP1306B | 60V                              | 20V                             | TO-39   |
| International Rectifier | IRF9513  | 60V                              | 20V                             | TO-220  |
| Motorola                | MTP8P08  | 80V                              | 20V                             | TO-220  |
| RCA                     | RFL1P08  | 80V                              | 20V                             | TO-39   |
|                         | RFT2P08  | 80V                              | 20V                             | TO-220  |
| Siliconix (preferred)   | VP0300B  | 30V                              | 40V                             | TO-39   |
|                         | VP0300L  | 30V                              | 40V                             | TO-92   |
|                         | VP0300M  | 30V                              | 40V                             | TO-237  |
|                         | VP0808B  | 80V                              | 40V                             | TO-39   |
|                         | VP0808L  | 80V                              | 40V                             | TO-92   |
|                         | VP0808M  | 80V                              | 40V                             | TO-237  |
| Supertex                | VP1304N2 | 40V                              | 20V                             | TO-220  |
|                         | VP1304N3 | 40V                              | 20V                             | TO-92   |
|                         | VP1306N2 | 60V                              | 20V                             | TO-220  |
|                         | VP1306N3 | 60V                              | 20V                             | TO-92   |

NOTE: (1) BV<sub>DSS</sub>—Drain-source breakdown voltage. BV<sub>GS</sub>—Gate-source breakdown voltage.

TABLE I. Available P-Channel MOSFETs.

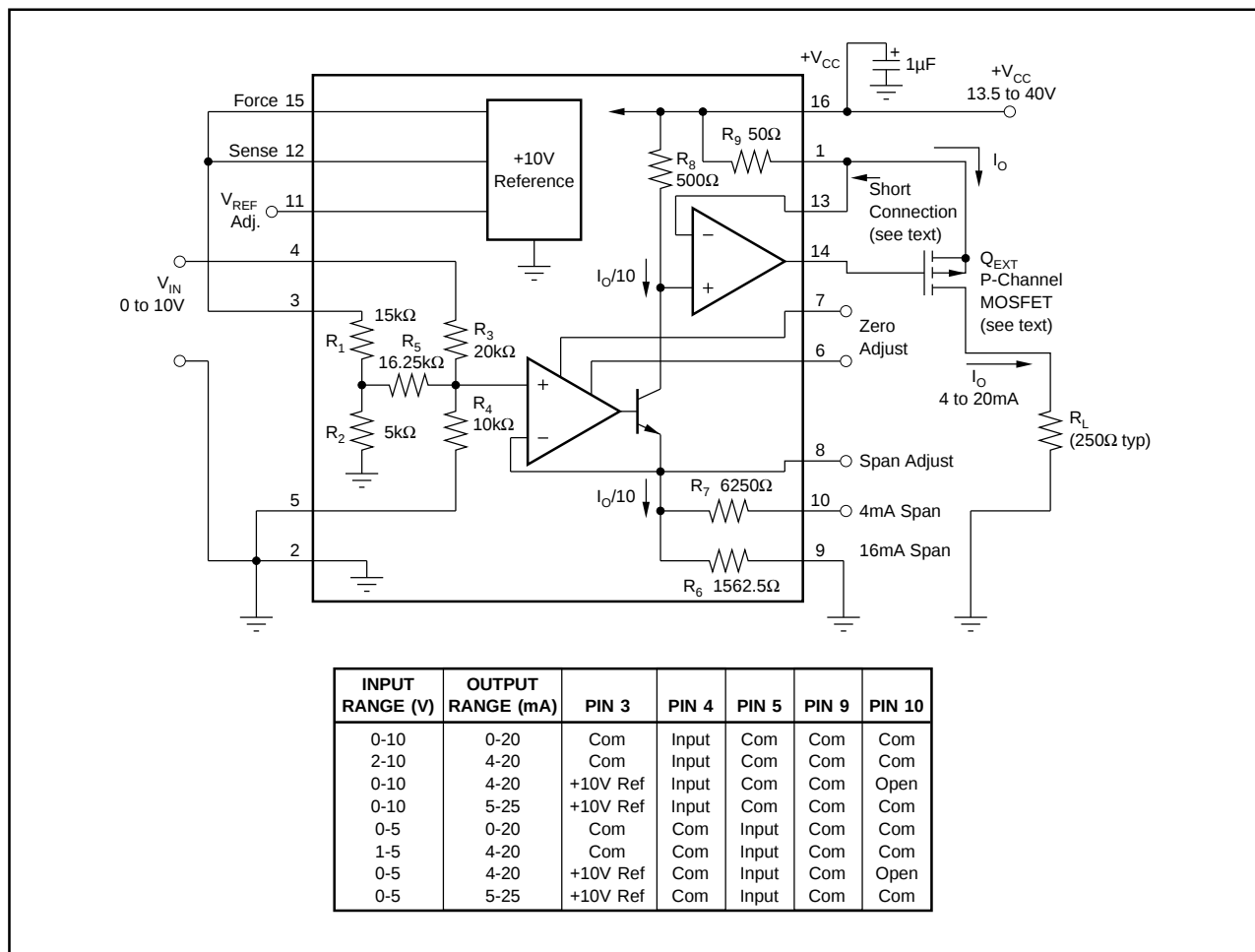


FIGURE 1. Basic Circuit Connection.

If the supply voltage,  $+V_{CC}$ , exceeds the gate-to-source breakdown voltage of  $Q_{EXT}$ , and the output connection (drain of  $Q_{EXT}$ ) is broken,  $Q_{EXT}$  could fail. If the gate-to-source breakdown voltage is lower than  $+V_{CC}$ ,  $Q_{EXT}$  can be protected with a 12V zener diode connected from gate to source.

Two PNP discrete transistors (Darlington-connected) can be used for  $Q_{EXT}$ —see Figure 2. Note that an additional capacitor is required for stability. Integrated Darlington transistors are not recommended because their internal base-emitter resistors cause excessive error.

## TRANSISTOR DISSIPATION

Maximum power dissipation of  $Q_{EXT}$  depends on the power supply voltage and full-scale output current. Assuming that the load resistance is low, the power dissipated by  $Q_{EXT}$  is:

$$P_{MAX} = (+V_{CC}) I_{FS} \quad (2)$$

The transistor type and heat sinking must be chosen according to the maximum power dissipation to prevent overheating. See Table II for general recommendations.

| PACKAGE TYPE | ALLOWABLE POWER DISSIPATION                   |
|--------------|-----------------------------------------------|
| TO-92        | Lowest: Use minimum supply and at +25°C.      |
| TO-237       | Acceptable: Trade-off supply and temperature. |
| TO-39        | Good: Adequate for majority of designs.       |
| TO-220       | Excellent: For prolonged maximum stress.      |
| TO-3         | Use if hermetic package is required.          |

TABLE II. External Transistor Package Type and Dissipation.

## INPUT VOLTAGE RANGE

The internal op amp  $A_1$  can be damaged if its non-inverting input (an internal node) is pulled more than 0.5V below common (0V). This could occur if input pins 3, 4 or 5 were driven with an op amp whose output could swing negative under abnormal conditions. The voltage at the input of  $A_1$  is:

$$V_{A1} = \frac{(V_{REF IN})}{16} + \frac{(V_{IN1})}{4} + \frac{(V_{IN2})}{2} \quad (3)$$

This voltage should not be allowed to go more negative than -0.5V. If necessary, a clamp diode can be connected from the negative-going input to common to clamp the input voltage.

## COMMON (Ground)

Careful attention should be directed toward proper connection of the common (grounds). All commons should be joined at one point as close to pin 2 of the XTR110 as possible. The exception is the  $I_{OUT}$  return. It can be returned to any point where it will not modulate the common at pin 2.

## VOLTAGE REFERENCE

The reference voltage is accurately regulated at pin 12 ( $V_{REF SENSE}$ ). To preserve accuracy, any load including pin

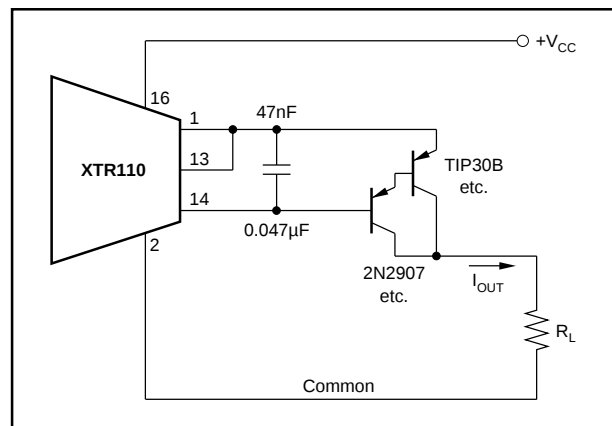


FIGURE 2.  $Q_{EXT}$  Using PNP Transistors.

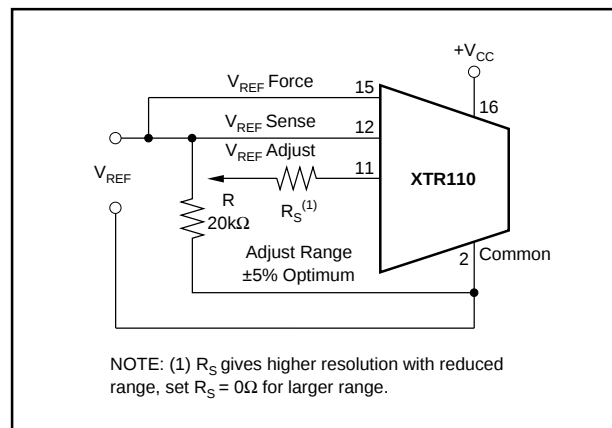


FIGURE 3. Optional Adjustment of Reference Voltage.

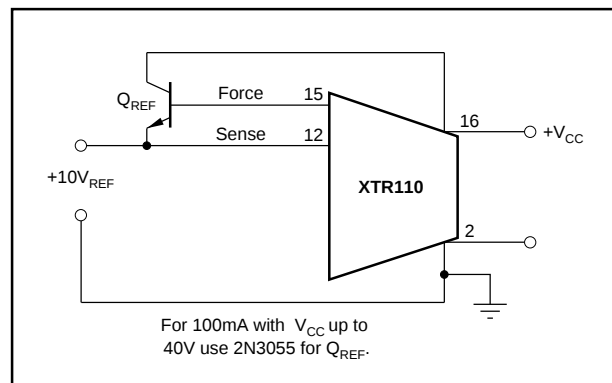


FIGURE 4. Increasing Reference Current Drive.

3 should be connected to this point. The circuit in Figure 3 shows adjustment of the voltage reference.

The current drive capability of the XTR110's internal reference is 10mA. This can be extended if desired by adding an external NPN transistor shown in Figure 4.

## OFFSET (ZERO) ADJUSTMENT

The offset current can be adjusted by using the potentiometer,  $R_1$ , shown in Figure 5. Set the input voltage to zero and then adjust  $R_1$  to give 4mA at the output. For spans starting

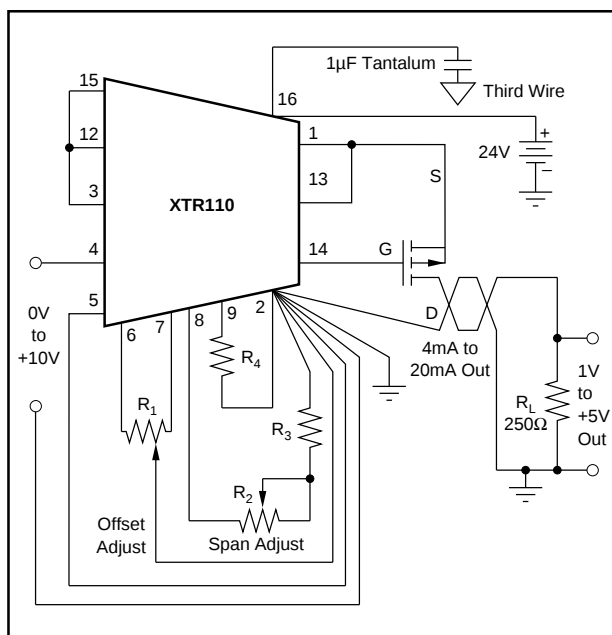


FIGURE 5. Offset and Span Adjustment Circuit for 0V to +10V Input, 4mA to 20mA Output.

at 0mA, the following special procedure is recommended: set the input to a small nonzero value and then adjust  $R_1$  to the proper output current. When the input is zero the output will be zero. Figures 6 and 7 show graphically how offset is adjusted.

## SPAN ADJUSTMENT

The span is adjusted at the full-scale output current using the potentiometer,  $R_2$ , shown in Figure 5. This adjustment is interactive with the offset adjustment, and a few iterations may be necessary. For the circuit shown, set the input voltage to +10V full scale and adjust  $R_2$  to give 20mA full-scale output. Figures 6 and 7 show graphically how span is adjusted.

The values of  $R_2$ ,  $R_3$ , and  $R_4$  for adjusting the span are determined as follows: choose  $R_4$  in series to slightly decrease the span; then choose  $R_2$  and  $R_3$  to increase the span to be adjustable about the center value.

## LOW TEMPERATURE COEFFICIENT OPERATION

Although the precision resistors in the XTR110 track within 1ppm/°C, the output current depends upon the absolute temperature coefficient (TC) of any one of the resistors,  $R_6$ ,  $R_7$ ,  $R_8$ , and  $R_9$ . Since the absolute TC of the output current can have 20ppm/°C, maximum, the TC of the output current can have 20ppm/°C drift. For low TC operation, zero TC resistors can be substituted for either the span resistors ( $R_6$  or  $R_7$ ) or for the source resistor ( $R_9$ ) but not both.

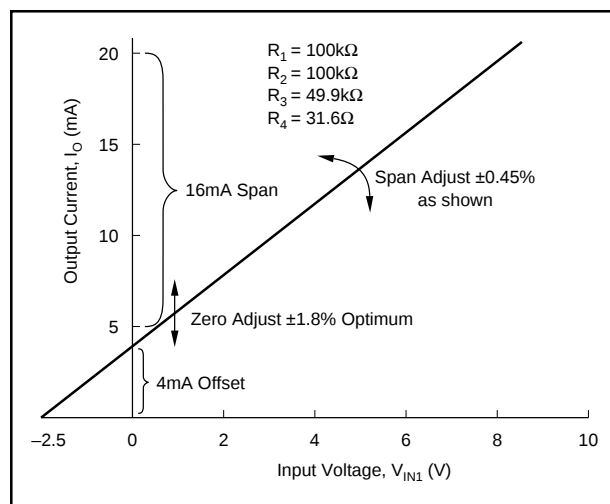


FIGURE 6. Zero and Span of 0V to +10V Input, 4mA to 20mA Output Configuration (see Figure 5).

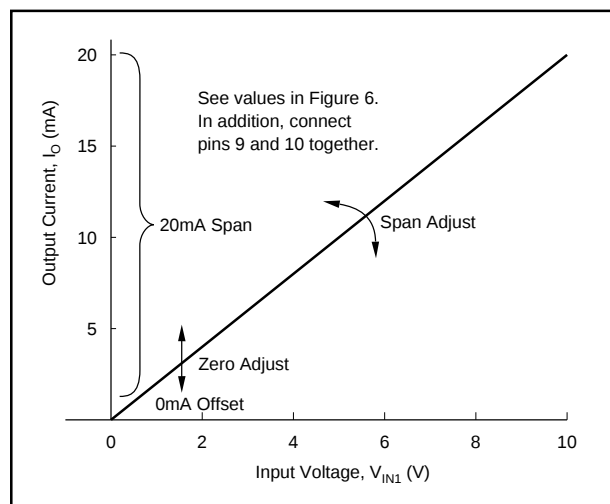


FIGURE 7. Zero and Span of 0V to +10V<sub>IN</sub>, 0mA to 20mA Output Configuration (see Figure 5).

## EXTENDED SPAN

For spans beyond 40mA, the internal 50Ω resistor (R<sub>9</sub>) may be replaced by an external resistor connected between pins 13 and 16.

Its value can be calculated as follows:

$$R_{EXT} = R_9 (\text{Span}_{OLD}/\text{Span}_{NEW})$$

Since the internal thin-film resistors have a 20% absolute value tolerance, measure  $R_9$  before determining the final value of  $R_{EXT}$ . Self-heating of  $R_{EXT}$  can cause nonlinearity. Therefore, choose one with a low TC and adequate power rating. See Figure 10 for application.

## TYPICAL APPLICATIONS

The XTR110 is ideal for a variety of applications requiring high noise immunity current-mode signal transmission. The precision +10V reference can be used to excite bridges and transducers. Selectable ranges make it very useful as a precision programmable current source. The compact design

and low price of the XTR110 allow versatility with a minimum of external components and design engineering expense.

Figures 8 through 10 show typical applications of the XTR110.

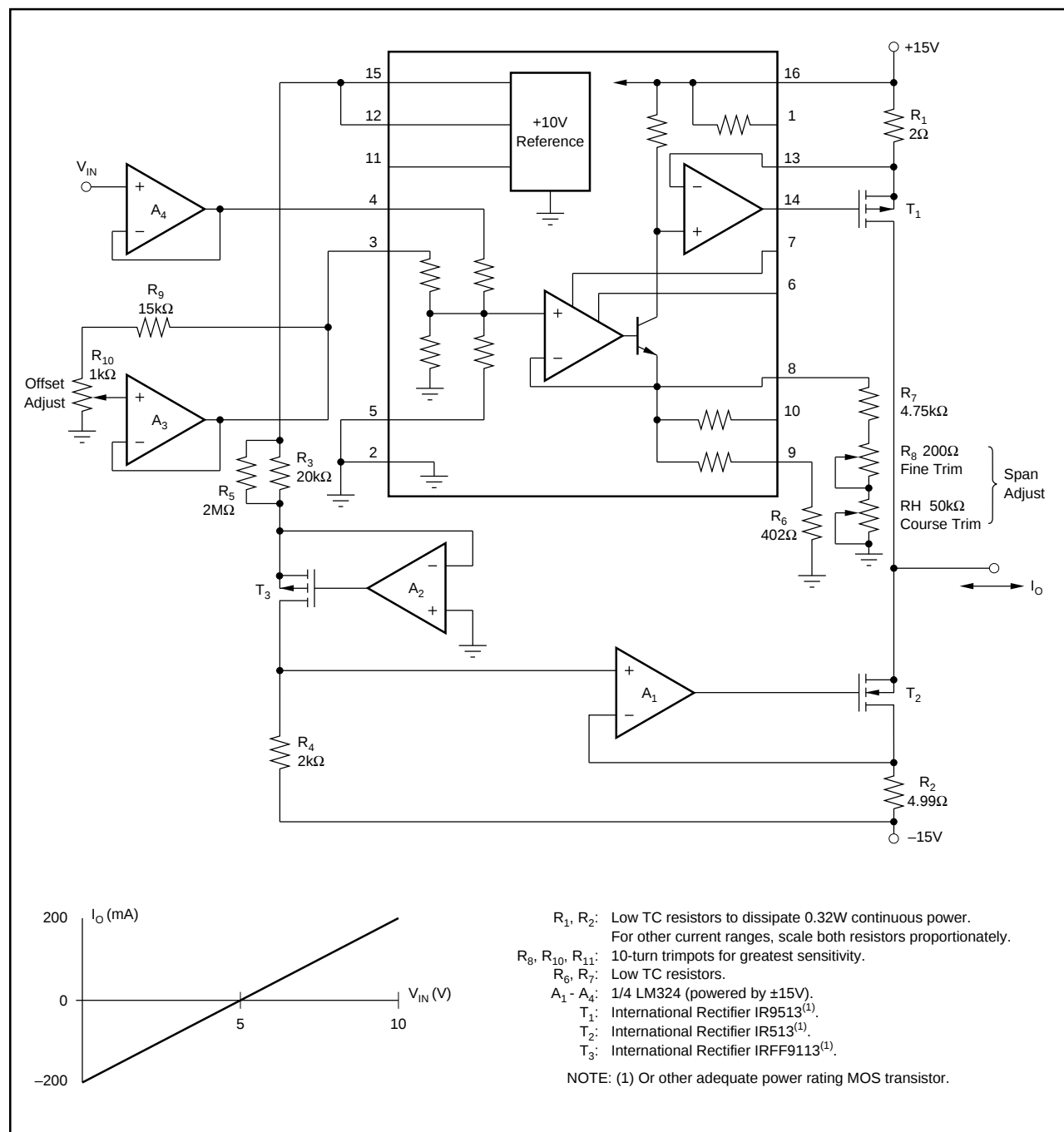


FIGURE 8.  $\pm 200mA$  Current Pump.

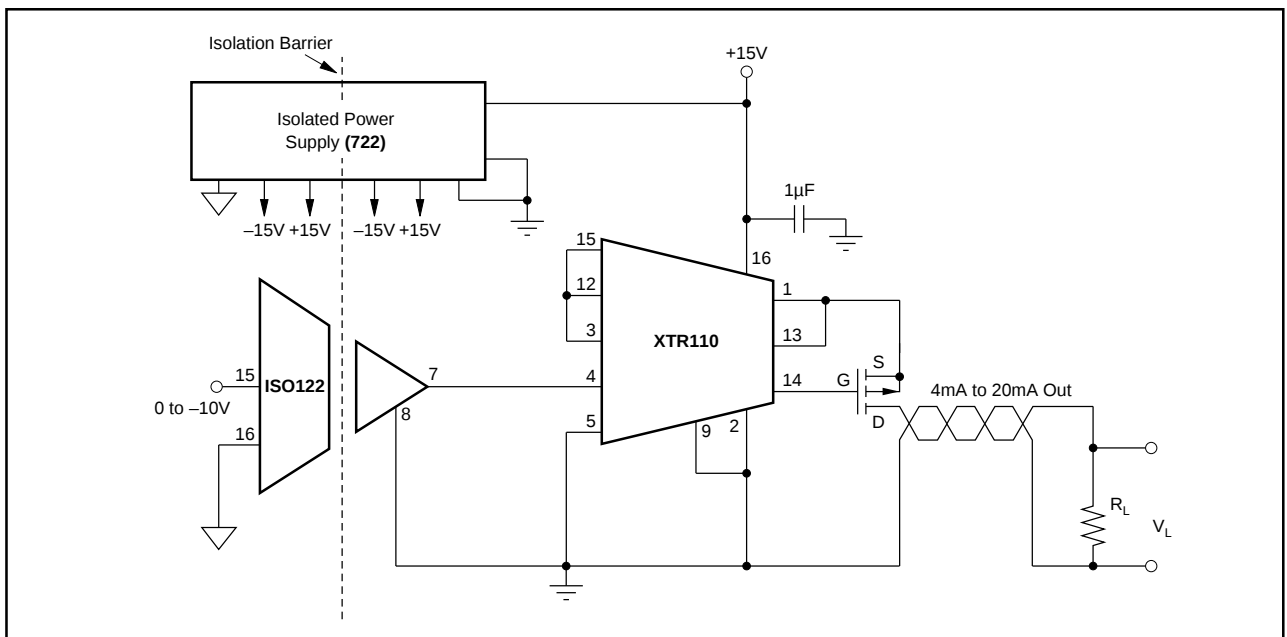


FIGURE 9. Isolated 4mA to 20mA Channel.

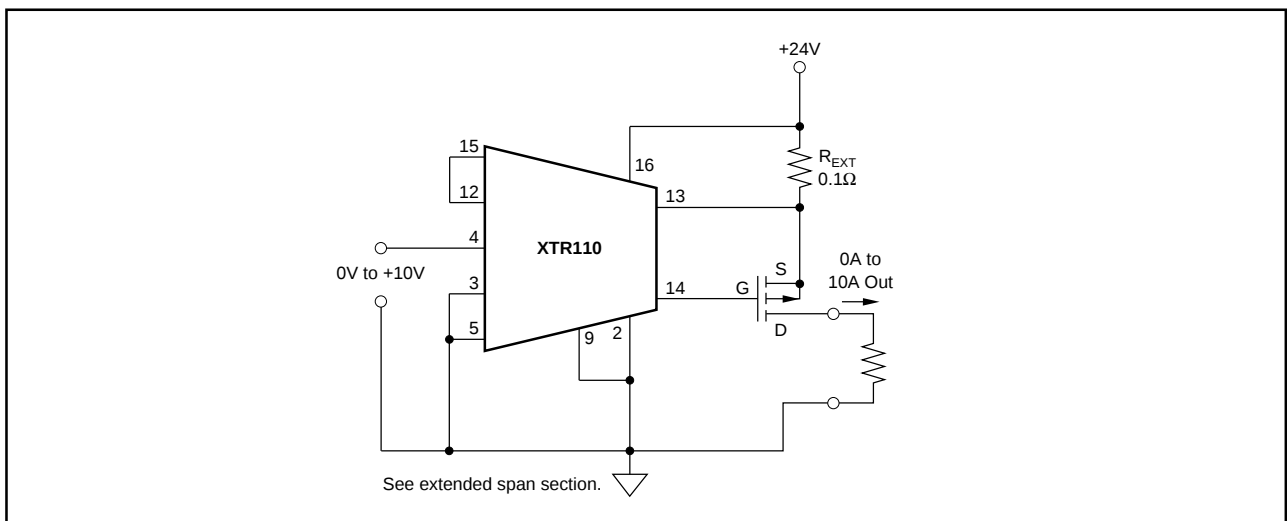


FIGURE 10. 0A to 10A Output Voltage-to-Current Converter.