

RCV420

Precision 4mA to 20mA CURRENT LOOP RECEIVER

FEATURES

- COMPLETE 4-20mA TO 0-5V CONVERSION
- INTERNAL SENSE RESISTORS
- PRECISION 10V REFERENCE
- BUILT-IN LEVEL-SHIFTING
- $\pm 40\text{V}$ COMMON-MODE INPUT RANGE
- 0.1% OVERALL CONVERSION ACCURACY
- HIGH NOISE IMMUNITY: 86dB CMR

APPLICATIONS

- PROCESS CONTROL
- INDUSTRIAL CONTROL
- FACTORY AUTOMATION
- DATA ACQUISITION
- SCADA
- RTUs
- ESD
- MACHINE MONITORING

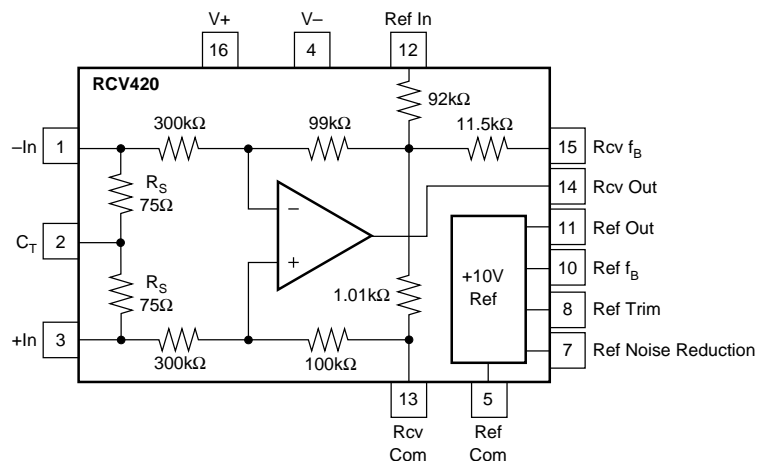
DESCRIPTION

The RCV420 is a precision current-loop receiver designed to convert a 4–20mA input signal into a 0–5V output signal. As a monolithic circuit, it offers high reliability at low cost. The circuit consists of a premium grade operational amplifier, an on-chip precision resistor network, and a precision 10V reference. The RCV420 features 0.1% overall conversion accuracy, 86dB CMR, and $\pm 40\text{V}$ common-mode input range.

The circuit introduces only a 1.5V drop at full scale, which is useful in loops containing extra instrument burdens or in intrinsically safe applications where

transmitter compliance voltage is at a premium. The 10V reference provides a precise 10V output with a typical drift of 5ppm/ $^{\circ}\text{C}$.

The RCV420 is completely self-contained and offers a highly versatile function. No adjustments are needed for gain, offset, or CMR. This provides three important advantages over discrete, board-level designs: 1) lower initial design cost, 2) lower manufacturing cost, and 3) easy, cost-effective field repair of a precision circuit.



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SPECIFICATIONS

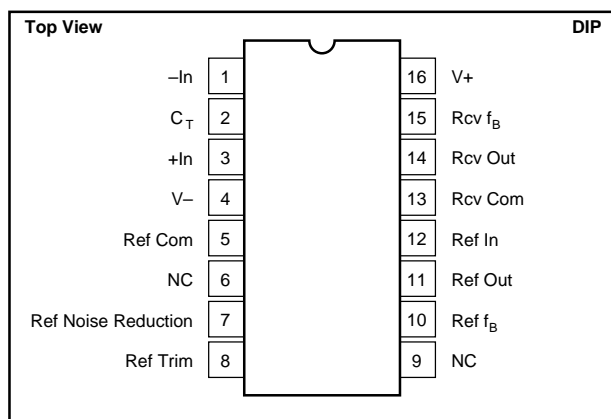
ELECTRICAL

At T = +25°C and V_S = ±15V, unless otherwise noted.

CHARACTERISTICS	RCV420KP, JP			UNITS
	MIN	TYP	MAX	
GAIN Initial Error Error—JP Grade vs Temp Nonlinearity ⁽¹⁾		0.3125 0.05 15 0.0002	0.15 0.25 0.002	V/mA % of span % of span ppm/°C % of span
OUTPUT Rated Voltage (I _O = +10mA, -5mA) Rated Current (E _O = 10V) Impedance (Differential) Current Limit (To Common) Capacitive Load (Stable Operation)	10 +10, -5	12 0.01 +49, -13 1000		V mA Ω mA pF
INPUT Sense Resistance Input Impedance (Common-Mode) Common-Mode Voltage CMR ⁽²⁾ vs Temp (DC) (T _A = T _{MIN} to T _{MAX}) AC 60Hz	74.25 70	75 200 80 76 80	75.75 ±40	Ω kΩ V dB dB dB
OFFSET VOLTAGE (RTO)⁽³⁾ Initial vs Temp vs Supply (±11.4V to ±18V) vs Time	74	10 90 200	1	mV μV/°C dB μV/mo
ZERO ERROR⁽⁴⁾ Initial Initial—JP Grade vs Temp		0.025 10	0.075 0.15	% of span % of span ppm of span/°C
OUTPUT NOISE VOLTAGE f _B = 0.1Hz to 10Hz f _O = 10kHz		50 800		μVp-p nV/√Hz
DYNAMIC RESPONSE Gain Bandwidth Full Power Bandwidth Slew Rate Settling Time (0.01%)		150 30 1.5 10		kHz kHz V/μs μs
VOLTAGE REFERENCE Initial Trim Range ⁽⁵⁾ vs Temp vs Supply (±11.4V to ±18V) vs Output Current (I _O = 0 to +10mA) vs Time Noise (0.1Hz to 10Hz) Output Current	9.99 +10, -2	±4 5 0.0002 0.0002 15 5	10.01	V % ppm/°C %/V %/mA ppm/kHz μVp-p mA
POWER SUPPLY Rated Voltage Range ⁽⁶⁾ Quiescent Current (V _O = 0V)	-5, +11.4	±15 3	±18 4	V V mA
TEMPERATURE RANGE Specification Operation Storage Thermal Resistance, θ _{JA}	0 -25 -40	80	+70 +85 +85	°C °C °C °C/W

NOTES: (1) Nonlinearity is the max peak deviation from best fit straight line. (2) With 0 source impedance on Rcv Com pin. (3) Referred to output with all inputs grounded including Ref In. (4) With 4mA input signal and Voltage Reference connected (includes V_{OS}, Gain Error, and Voltage Reference Errors). (5) External trim slightly affects drift. (6) I_O Ref = 5mA, I_O Rcv = 2mA.

PIN CONFIGURATION



ABSOLUTE MAXIMUM RATINGS⁽¹⁾

Supply	±22V
Input Current, Continuous	40mA
Input Current Momentary, 0.1s	250mA, 1% Duty Cycle
Common-Mode Input Voltage, Continuous	±40V
Lead Temperature (soldering, 10s)	+300°C
Output Short Circuit to Common (Rcv and Ref)	Continuous

NOTE: (1) Stresses above these ratings may cause permanent damage.

PACKAGE INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER ⁽¹⁾
RCV420KP	16-Pin Plastic DIP	180
RCV420JP	16-Pin Plastic DIP	180

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

ORDERING INFORMATION

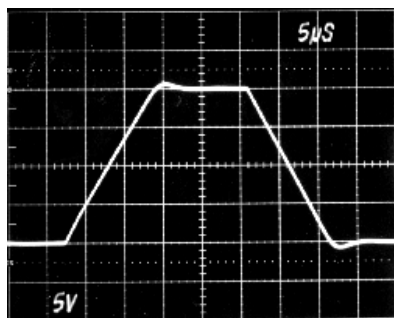
PRODUCT	PERFORMANCE GRADE	PACKAGE
RCV420KP	0°C to +70°C	16-Pin Plastic DIP
RCV420JP	0°C to +70°C	16-Pin Plastic DIP

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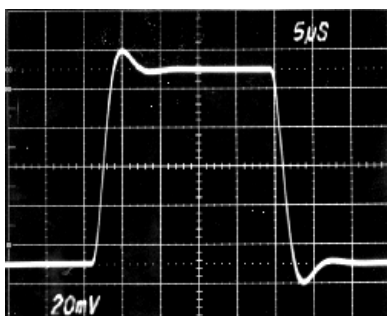
TYPICAL PERFORMANCE CURVES

At $T_A = +25^\circ\text{C}$, $V_S = \pm 15\text{V}$, unless otherwise noted.

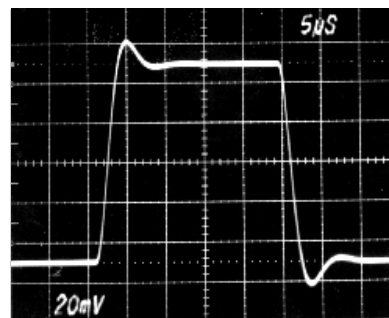
STEP RESPONSE
NO LOAD



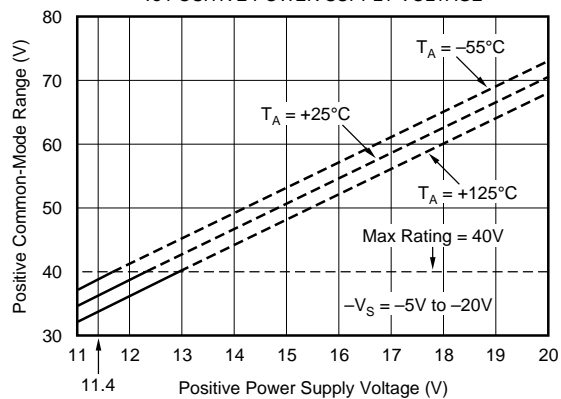
SMALL SIGNAL RESPONSE
NO LOAD



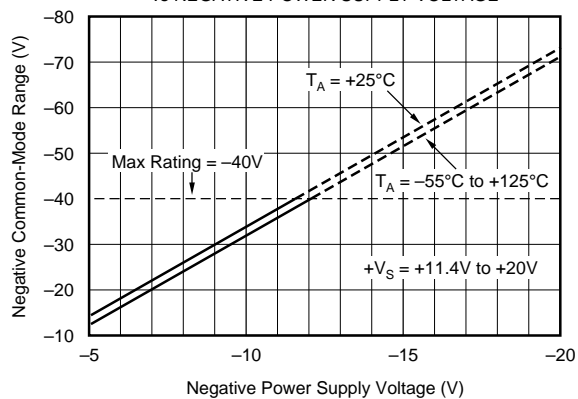
SMALL SIGNAL RESPONSE
 $R_L = \infty$, $C_L = 1000\text{pF}$



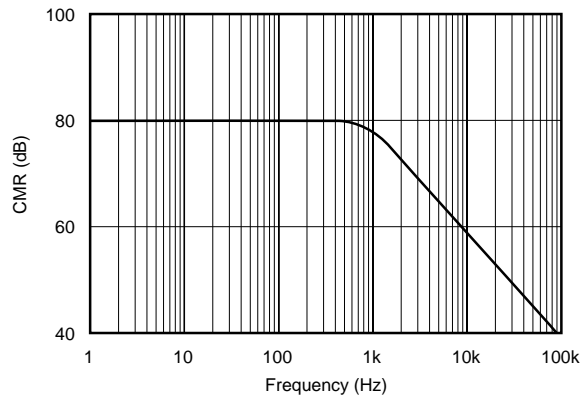
POSITIVE COMMON-MODE VOLTAGE RANGE
vs POSITIVE POWER SUPPLY VOLTAGE



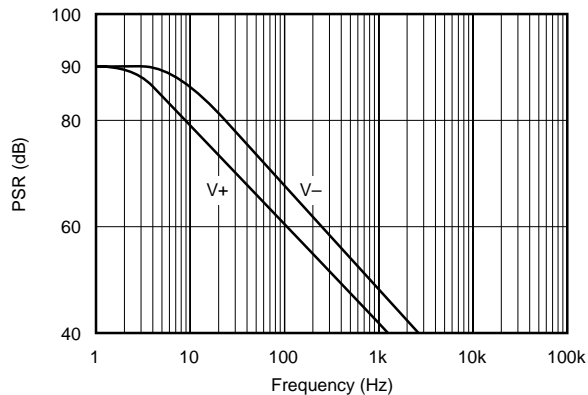
NEGATIVE COMMON-MODE VOLTAGE RANGE
vs NEGATIVE POWER SUPPLY VOLTAGE



COMMON-MODE REJECTION
vs FREQUENCY



POWER-SUPPLY REJECTION
vs FREQUENCY



THEORY OF OPERATION

Refer to the figure on the first page. For 0 to 5V output with 4–20mA input, the required transimpedance of the circuit is:

$$V_{OUT}/I_{IN} = 5V/16mA = 0.3125V/mA.$$

To achieve the desired output (0V for 4mA and 5V for 20mA), the output of the amplifier must be offset by an amount:

$$V_{OS} = -(4mA)(0.3125V/mA) = -1.25V.$$

The input current signal is connected to either +In or –In, depending on the polarity of the signal, and returned to ground through the center tap, C_T . The balanced input—two matched 75Ω sense resistors, R_S —provides maximum rejection of common-mode voltage signals on C_T and true differential current-to-voltage conversion. The sense resistors convert the input current signal into a proportional voltage, which is amplified by the differential amplifier. The voltage gain of the amplifier is:

$$A_D = 5V/(16mA)(75\Omega) = 4.1667V/V.$$

The tee network in the feedback path of the amplifier provides a summing junction used to generate the required –1.25V offset voltage. The input resistor network provides high-input impedance and attenuates common-mode input voltages to levels suitable for the operational amplifier's common-mode signal capabilities.

BASIC POWER SUPPLY AND SIGNAL CONNECTIONS

Figure 1 shows the proper connections for power supply and signal. Both supplies should be decoupled with $1\mu F$ tantalum capacitors as close to the amplifier as possible. To avoid gain and CMR errors introduced by the external circuit, connect grounds as indicated, being sure to minimize ground resistance. The input signal should be connected to either +In or –In, depending on its polarity, and returned to ground through the center tap, C_T . The output of the voltage reference, Ref Out, should be connected to Ref In for the

necessary level shifting. If the Ref In pin is not used for level shifting, then it must be grounded to maintain high CMR.

GAIN AND OFFSET ADJUSTMENT

Figure 2 shows the circuit for adjusting the RCV420 gain. Increasing the gain of the RCV420 is accomplished by inserting a small resistor in the feedback path of the amplifier. Increasing the gain using this technique results in CMR degradation, and therefore, gain adjustments should be kept as small as possible. For example, a 1% increase in gain is typically realized with a 125Ω resistor, which degrades CMR by about 6dB.

A decrease in gain can be achieved by placing matched resistors in parallel with the sense resistors, also shown in Figure 2. The adjusted gain is given by the following expression

$$V_{OUT}/I_{IN} = 0.3125 \times R_X / (R_X + R_S).$$

A 1% decrease in gain can be achieved with a $7.5k\Omega$ resistor. It is important to match the parallel resistance on each sense resistor to maintain high CMR. The TCR mismatch between the two external resistors will effect gain error drift and CMR drift.

There are two methods for nulling the RCV420 output offset voltage. The first method applies to applications using the internal 10V reference for level shifting. For these applica-

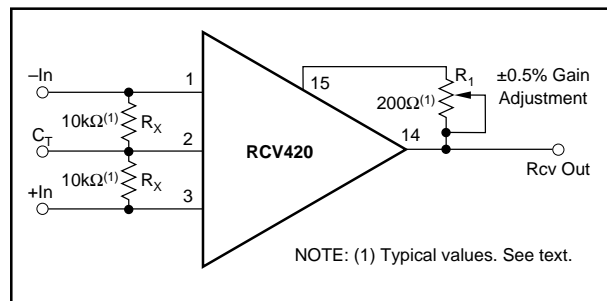


FIGURE 2. Optional Gain Adjustment.

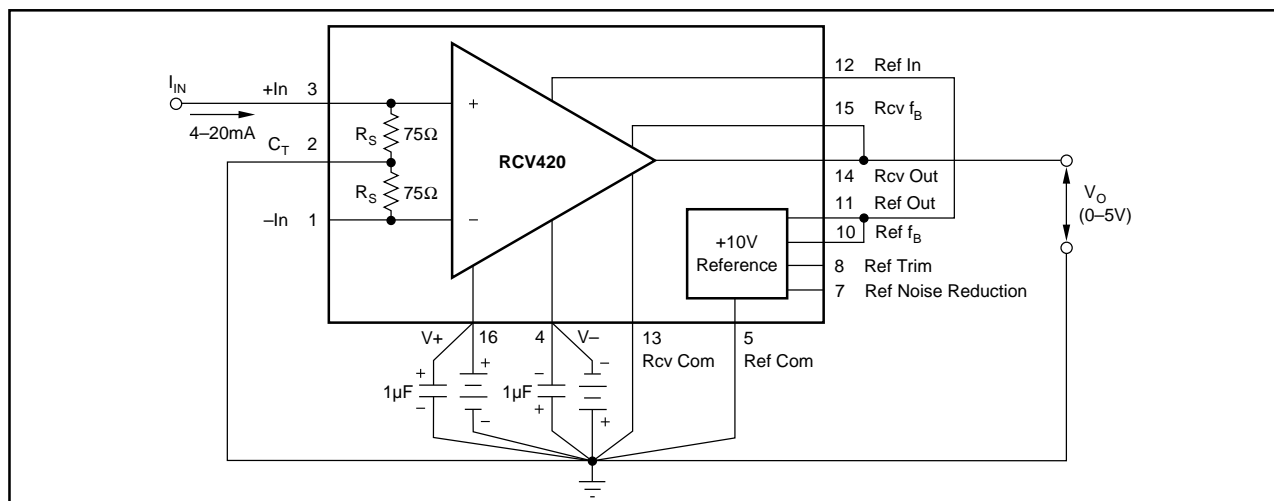
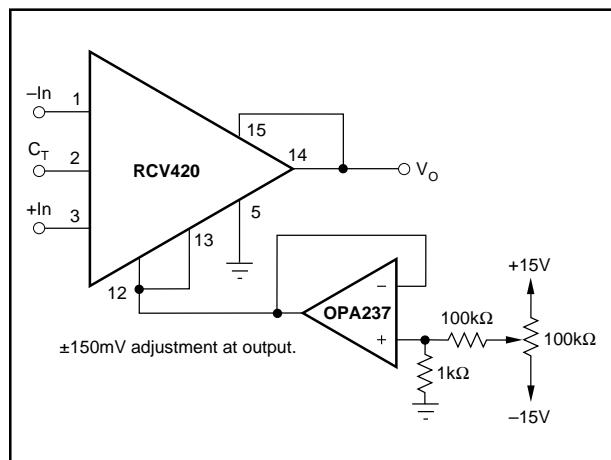


FIGURE 1. Basic Power Supply and Signal Connections.

When the voltage reference is not used for level shifting or when large offset adjustments are required, the circuit in Figure 3 can be used for offset adjustment. A low impedance on the Rcv Com pin is required to maintain high CMR.

Level shifting the RCV420 output voltage can be achieved using either the Ref In pin or the Rcv Com pin. The disadvantage of using the Ref In pin is that there is an 8:1 voltage attenuation from this pin to the output of the RCV420. Thus, use the Rcv Com pin for large offsets, because the voltage on this pin is seen directly at the output. Figure 4 shows the circuit used to level-shift the output of the RCV420

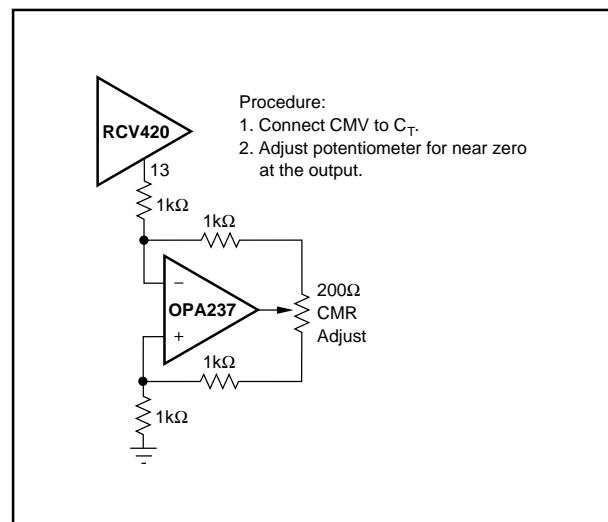


The diagram shows a three-stage instrumentation amplifier. The first stage is an RCV420 precision centred gain amplifier configured with pins 1, 2, and 3 as inputs, and pins 10, 11, 12, 13, 14, and 15 as outputs. Its non-inverting input (pin 3) is biased with a +10V reference. The second stage is an OPA237 precision op-amp configured as a voltage follower, with its non-inverting input (pin 3) connected to the output of the RCV420 (pin 10) and its output (pin 1) connected to the non-inverting input of the third stage. The third stage is an INA105 precision instrumentation amplifier configured with pins 1, 2, and 3 as inputs, and pins 4, 5, and 6 as outputs. Its non-inverting input (pin 3) is connected to the output of the OPA237 (pin 1) and its output (pin 6) is connected to the -10V reference. The overall output voltage is given by the equation: $V_O = (0.3125)(I_{IN}) + V_{ZERO}$.

using the Rcv Com pin. It is important to use a low-output impedance amplifier to maintain high CMR. With this method of zero adjustment, the Ref In pin must be connected to the Rcv Com pin.

Two factors are important in maintaining high CMR: (1) resistor matching and tracking (the internal resistor network does this) and (2) source impedance. CMR depends on the accurate matching of several resistor ratios. The high accuracies needed to maintain the specified CMR and CMR temperature coefficient are difficult and expensive to reliably achieve with discrete components. Any resistance imbalance introduced by external circuitry directly affects CMR. These imbalances can occur by: mismatching sense resistors when gain is decreased, adding resistance in the feedback path when gain is increased, and adding series resistance on the Rcv Com pin.

The 75Ω sense resistors are designed for a maximum continuous current of 40mA, but can withstand as much as 250mA for up to 0.1s (see absolute maximum ratings). There are several ways to protect the sense resistor from



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overcurrent conditions exceeding these specifications. Refer to Figure 6. The simplest and least expensive method is a resistor as shown in Figure 6a. The value of the resistor is determined from the expression

$$R_X = V_{CC}/40\text{mA} - 75\Omega$$

and the full scale voltage drop is

$$V_{RX} = 20\text{mA} \times R_X.$$

For a system operating off of a 32V supply $R_X = 725\Omega$ and $V_{RX} = 14.5\text{V}$. In applications that cannot tolerate such a large voltage drop, use circuits 6b or 6c. In circuit 6b a power JFET and source resistor are used as a current limit. The 200Ω potentiometer, R_X , is adjusted to provide a current limit of approximately 30mA. This circuit introduces a 1–4V drop at full scale. If only a very small series voltage drop at full scale can be tolerated, then a 0.032A series 217 fast-acting fuse should be used, as shown in Figure 6c.

For automatic fold-back protection, use the circuit shown in Figure 15.

VOLTAGE REFERENCE

The RCV420 contains a precision 10V reference. Figure 8 shows the circuit for output voltage adjustment. Trimming the output will change the voltage drift by approximately 0.007ppm/°C per mV of trimmed voltage. Any mismatch in TCR between the two sides of the potentiometer will also affect drift, but the effect is divided by approximately 5. The trim range of the voltage reference using this method is typically $\pm 400\text{mV}$. The voltage reference trim can be used to trim offset errors at the output of the RCV420. There is an 8:1 voltage attenuation from Ref In to Rcv Out, and thus the trim range at the output of the receiver is typically $\pm 50\text{mV}$.

The high-frequency noise (to 1MHz) of the voltage reference is typically 1mVp-p. When the voltage reference is used for level shifting, its noise contribution at the output of the receiver is typically 125μVp-p due to the 8:1 attenuation from Ref In to Rcv Out. The reference noise can be reduced by connecting an external capacitor between the Noise Reduction pin and ground. For example, 0.1μF capacitor reduces the high-frequency noise to about 200μVp-p at the output of the reference and about 25μVp-p at the output of the receiver.

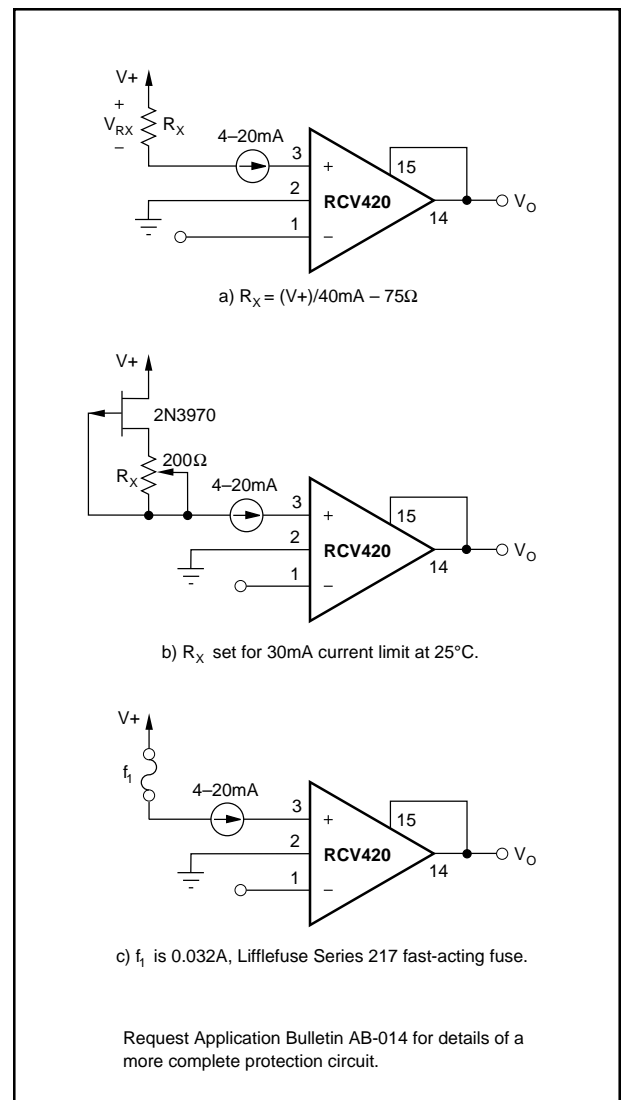


FIGURE 6. Protecting the Sense Resistors.

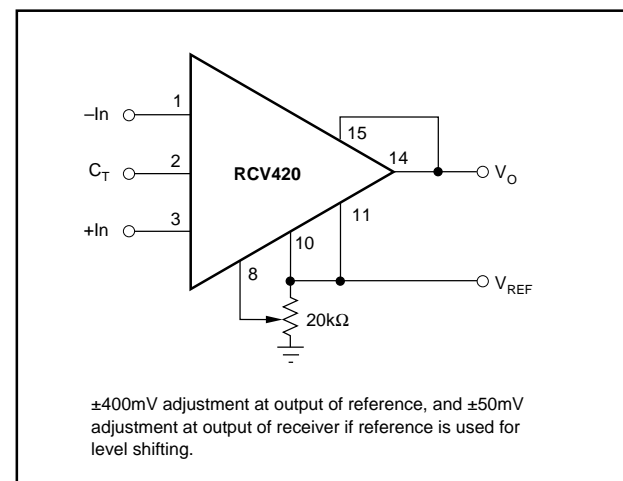


FIGURE 7. Optional Voltage Reference External Trim Circuit.

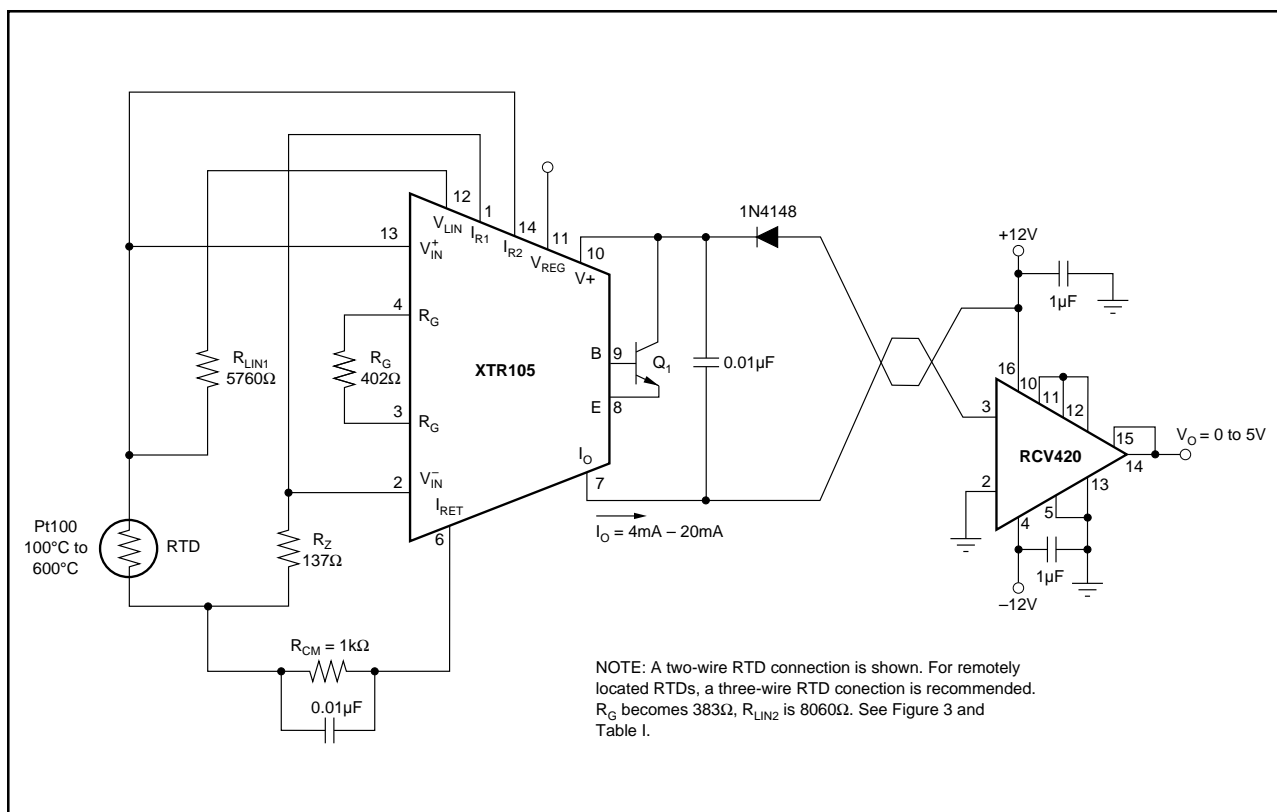


FIGURE 8. RCV420 Used in Conjunction with XTR101 to Form a Complete Solution for 4-20mA Loop.

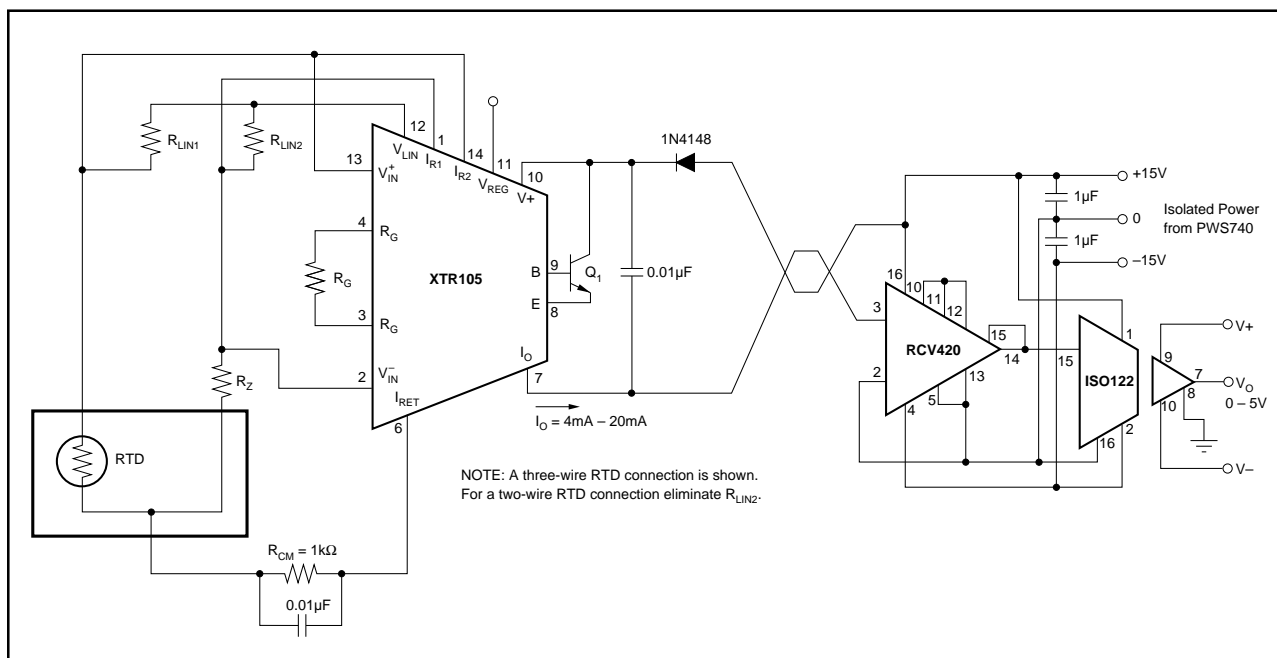


FIGURE 9. Isolated 4-20mA Instrument Loop (RTD shown).

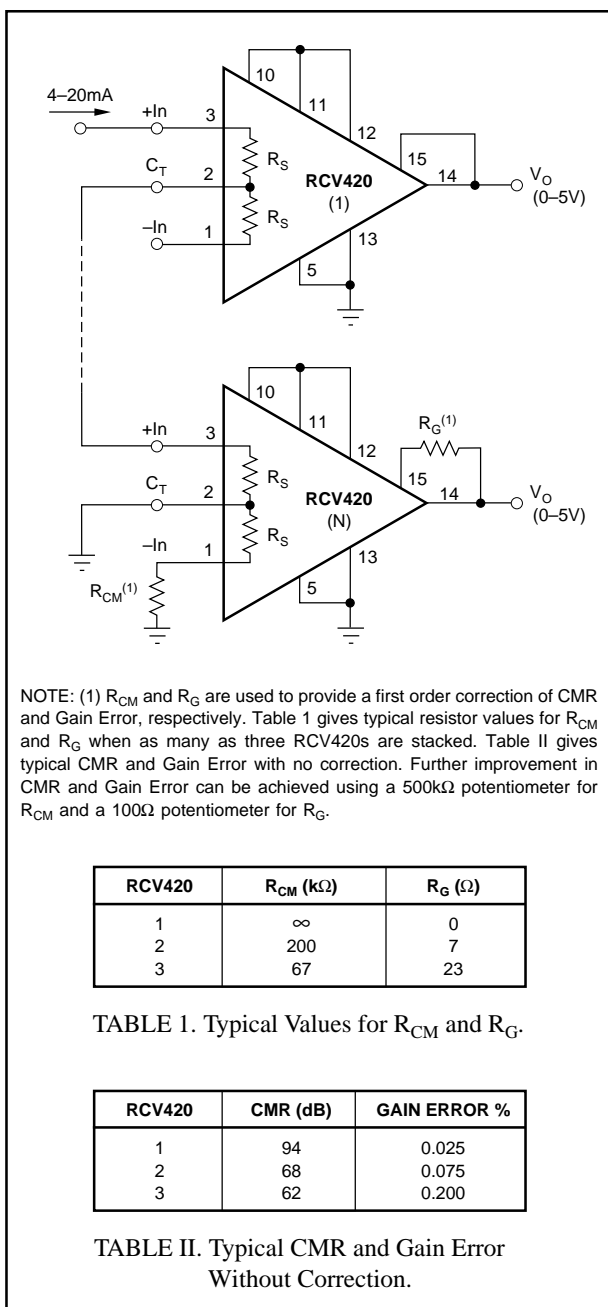


FIGURE 10. Series 4-20mA Receivers.

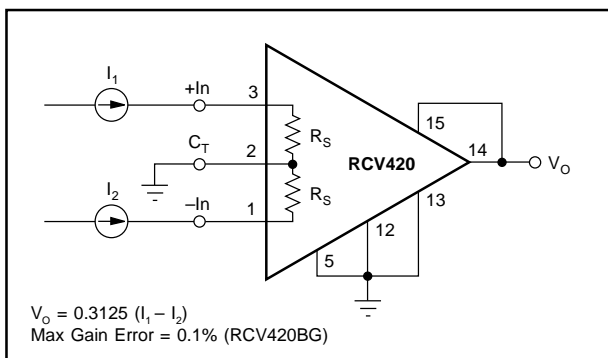


FIGURE 11. Differential Current-to-Voltage Converter.

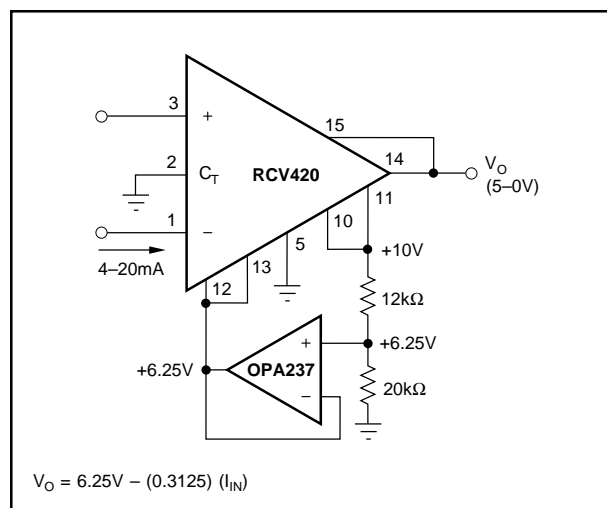


FIGURE 12. 4-20mA to 5-0V Conversion.

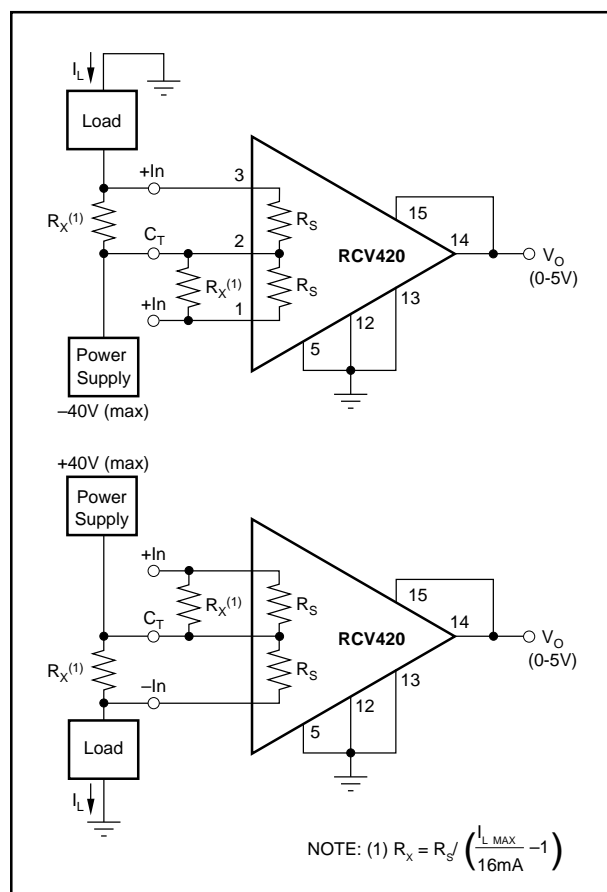


FIGURE 13. Power Supply Current Monitor Circuit.

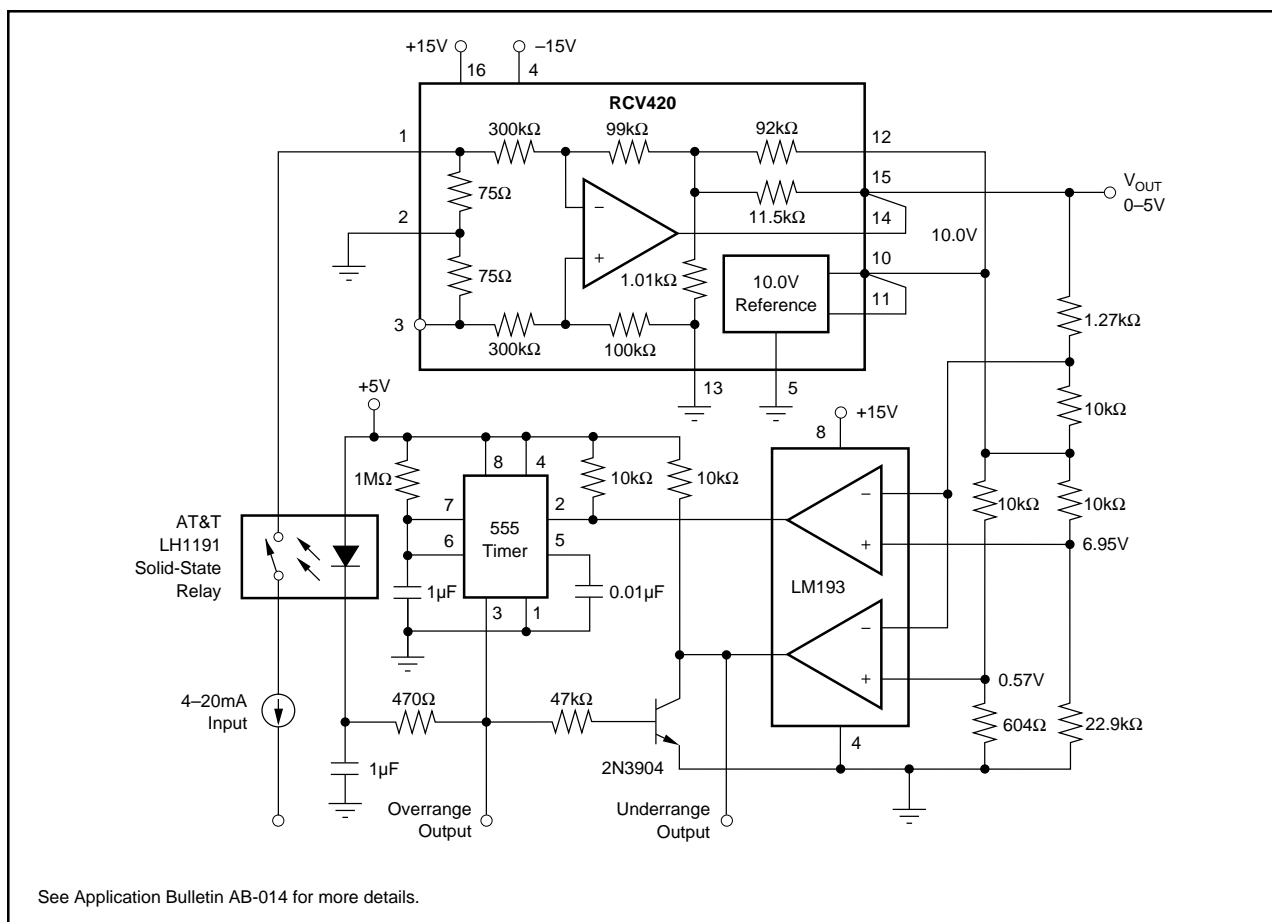


FIGURE 14. 4-20mA Current Loop Receiver with Input Overload Protection.

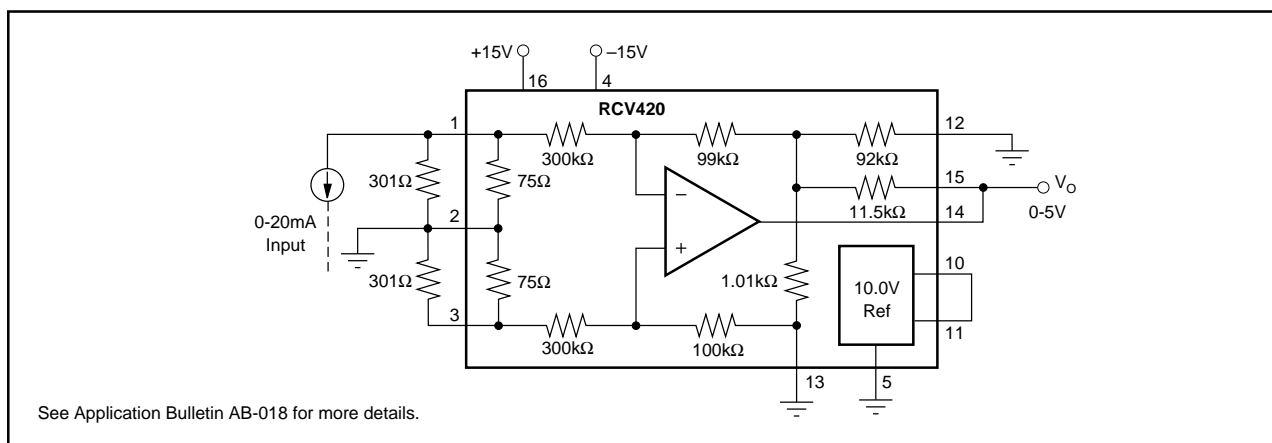


FIGURE 15. 0-20mA/0-5V Receiver Using RCV420.