

FEATURES

- PRTD Temperature Measurement Range**
- Typical IC Measurement Error $\pm 1^\circ\text{C}$**
- Includes Two Matched Current Sources**
- Rail-to-Rail Output Instrumentation Amp**
- Uncommitted, Rail-to-Rail Output Op Amp**
- On-Board +2.5 V Reference**
- Temperature Coefficient ± 25 ppm/ $^\circ\text{C}$**
- +5 V or ± 5 V Operation**
- Supply Current 4 mA Max**
- 10 μA Max in Shutdown**

APPLICATIONS

- Temperature Controllers**
- Portable Instrumentation**
- Temperature Acquisition Cards**

GENERAL DESCRIPTION

The ADT70 provides excitation and signal conditioning for resistance-temperature devices (RTDs). It is ideally suited for 1 k Ω Platinum RTDs (PRTDs), allowing a very wide range of temperature measurement. It can also easily interface to 100 Ω PRTDs. Using a remote, low cost thin-film PRTD, the ADT70 can measure temperature in the range of -50°C to $+500^\circ\text{C}$. With high performance platinum elements, the temperature change can be extended to 1000 $^\circ\text{C}$. Accuracy of the ADT70 and PRTD system over a -200°C to $+1000^\circ\text{C}$ temperature range heavily depends on the quality of the PRTD. Typically the ADT70 will introduce an error of only $\pm 1^\circ\text{C}$ over the transducer's temperature range, and the error may be trimmed to zero at a single calibration point.

The ADT70 consists of two matched 1 mA (nominal) current sources for transducer and reference resistor excitation, a precision rail-to-rail output instrumentation amplifier, a 2.5 V reference and an uncommitted rail-to-rail output op amp. The ADT70 includes a shutdown function for battery powered equipment, which reduces the quiescent current from 4 mA to less than 10 μA . The ADT70 operates from either single +5 V or ± 5 V supplies. Gain or full-scale range for the PRTD and ADT70 system is set by a precision external resistor connected to the instrumentation amplifier. The uncommitted op amp may be used for scaling the internal voltage reference, providing a "PRTD open" signal or "over-temperature" warning, a heater switching signal, or other external conditioning determined by the user.

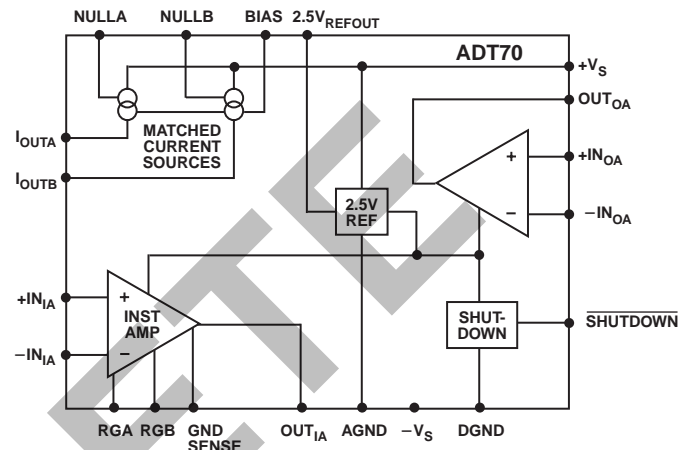
The ADT70 is specified for operation from -40°C to $+125^\circ\text{C}$ and is available in 20-lead DIP and SO packages.

*Patent pending.

REV. 0

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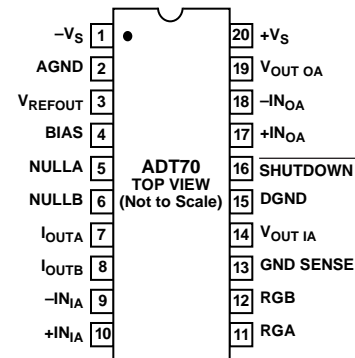
FUNCTIONAL BLOCK DIAGRAM



PIN CONFIGURATIONS

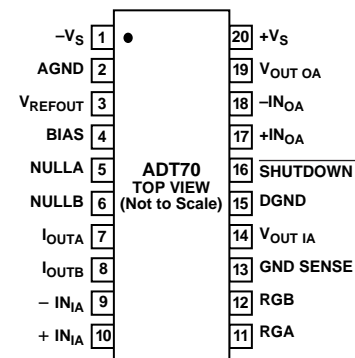
20-Lead P-DIP

(N Suffix)



20-Lead SOIC

(R Suffix)



ADT70—SPECIFICATIONS ($V_S = +5\text{ V}$, $-40^\circ\text{C} \leq T_A \leq +125^\circ\text{C}$ unless otherwise noted)

Parameter	Symbol	Conditions	Min	Typ	Max	Units
SYSTEM CONFIGURATION						
Gain		$R_L = 1\text{ k}\Omega$	1.234	1.295	1.364	mV/ Ω
Line Regulation			-2.25	± 0.35	2.25	%/V
CURRENT SOURCES						
Output Current	I_{Q1}, I_{Q2}	$R_L = 1\text{ k}\Omega$		0.9		mA
Output Current Mismatch	$I_{Q1} - I_{Q2}$	$R_L = 1\text{ k}\Omega$	-2	± 0.5	2	μA
Voltage Compliance				$-V_S$ to $+V_S - 1.5$		V
INSTRUMENTATION AMP						
Input Offset Voltage	V_{IOS}	$T_A = +25^\circ\text{C}$	-700	± 150	700	μV
Output Offset Voltage	V_{OOS}	$T_A = +25^\circ\text{C}$	-500	± 100	500	μV
Input Bias Current	I_B	$T_A = +25^\circ\text{C}$	-12	± 5	12	mV
Input Offset Current	I_{OS}	$T_A = +25^\circ\text{C}$	-7	± 3	7	mV
Common-Mode Rejection	CMR	$V_{CM} = 0.5\text{ V to } 3\text{ V}$	-75	± 40	75	nA
Output Voltage Swing	V_{OUT}	$R_L = \infty, V_S = \pm 5\text{ V}$	-60	± 30	60	nA
Power Supply Rejection Ratio	PSRR	$+4.5\text{ V} \leq V_S \leq \pm 5.5\text{ V}$	-3	± 1	3	nA
			65	85		dB
			$-V_S + 25$		$+V_S - 25$	mV
			-2.5	± 0.5	2.5	mV/V
VOLTAGE REFERENCE						
Output Voltage		$T_A = +25^\circ\text{C}$	2.485	2.5	2.515	V
Load Regulation		$I_L = 0\text{ mA to } 1\text{ mA}$	2.49	2.5	2.51	V
Temperature Coefficient				250		ppm/mA
Line Regulation		$+4.5\text{ V} \leq V_S \leq \pm 5.5\text{ V}$		± 10		ppm/ $^\circ\text{C}$
				± 75		ppm/V
OPERATIONAL AMPLIFIER						
Input Offset Voltage	V_{IOA}	$T_A = +25^\circ\text{C}$	-1,000	± 400	1,000	μV
Input Offset Voltage Drift	$T_C V_{IOA}$		-800	± 200	800	$\mu\text{V}/^\circ\text{C}$
Input Bias Current	I_B	$T_A = +25^\circ\text{C}$	-75	± 40	75	nA
Input Offset Current	I_{OS}	$T_A = +25^\circ\text{C}$	-60	± 30	60	nA
Open-Loop Voltage Gain	A_{VOL}	$R_L = \infty$	-3	± 1	3	nA
Output Voltage Swing	V_{OUTA}	$R_L = \infty$		2		V/ μV
Common-Mode Rejection Ratio	CMRR	$V_{CM} = 1\text{ V to } 4\text{ V}$	$-V_S + 10$		$+V_S - 10$	mV
Power Supply Rejection Ratio	PSRR	$\pm 3\text{ V} \leq V_S \leq \pm 6\text{ V}$	85	105		dB
Slew Rate	SR	$T_A = +25^\circ\text{C}, A_V = 1,$ $V_{IN} = 0\text{ V to } 4\text{ V}$	88	110		dB
			100	150		dB
				0.17		V/ μs
SHUTDOWN INPUT						
Input Low Voltage	V_{IL}				0.8	V
Input High Voltage	V_{IH}		2.4			V
POWER SUPPLY						
Supply Current	I_{SY}	$R_L = 1\text{ k}\Omega$		3.5	5	mA
Shutdown Supply Current	I_{SD}			10	30	μA
Supply Voltage	V_S		+4.5		+5.5	V
Dual Supply Voltage			± 4.5		± 5.5	V

Specifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage	+16 V
Output Short-Circuit Duration	Indefinite
Storage Temperature Range	
N, R Package	-65°C to +150°C
Operating Temperature Range	-40°C to +125°C
Junction Temperature Range	
N, R Package	-65°C to +125°C
Lead Temperature (Soldering, 60 sec)	+300°C

NOTE

*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Type	θ_{JA}^*	θ_{JC}	Units
20-Lead SOIC (R)	74	24	°C/W
20-Lead PDIP (N)	102	31	°C/W

NOTE

* θ_{JA} is specified for device in socket/soldered on circuit board (worst case conditions).

CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the ADT70 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

ORDERING GUIDE

Model	Temperature Range	Package
ADT70GR	-40°C to +125°C	20-Lead SOIC
ADT70GN	-40°C to +125°C	20-Lead PDIP

TRANSISTOR COUNT: 158



OBSOLETE

ADT70

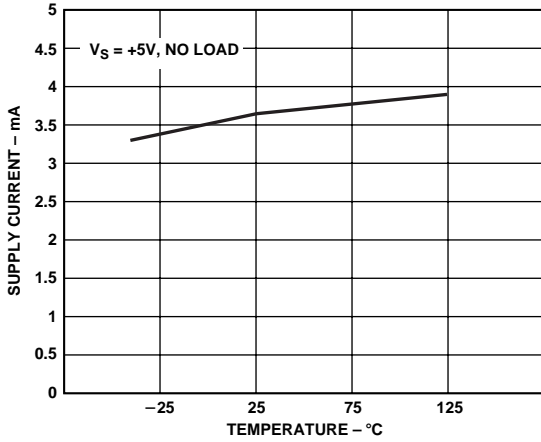


Figure 1. Supply Current vs. Temperature

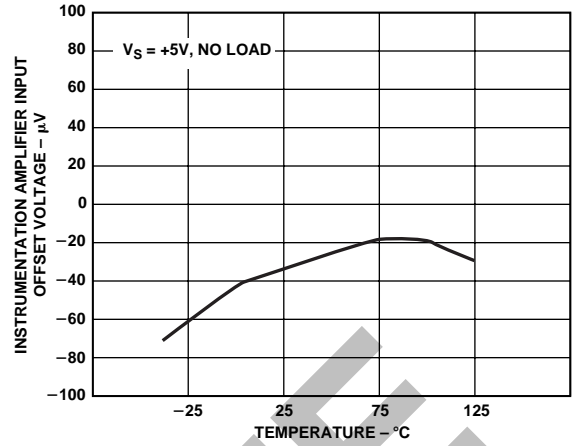


Figure 4. Instrumentation Amplifier Input Offset Voltage vs. Temperature

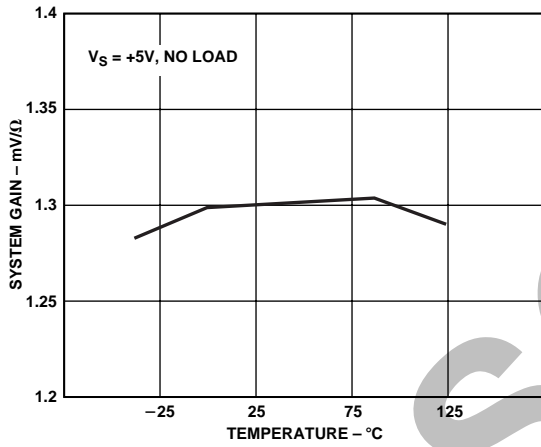


Figure 2. System Gain vs. Temperature

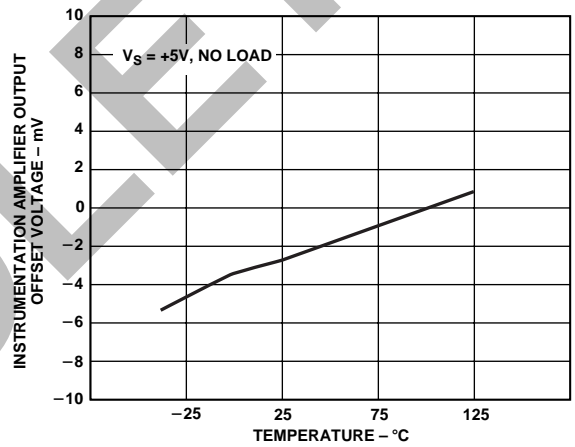


Figure 5. Instrumentation Amplifier Output Offset Voltage vs. Temperature

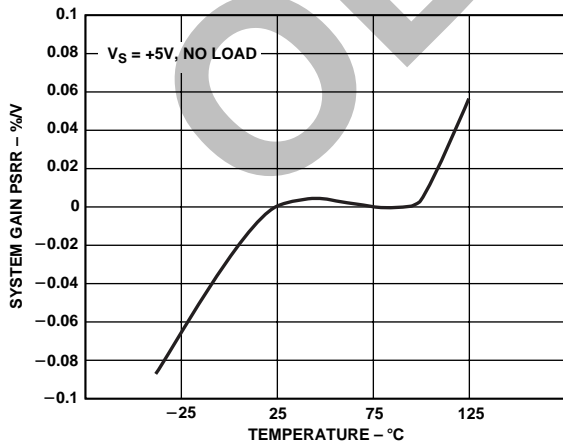


Figure 3. Total System Gain PSRR vs. Temperature

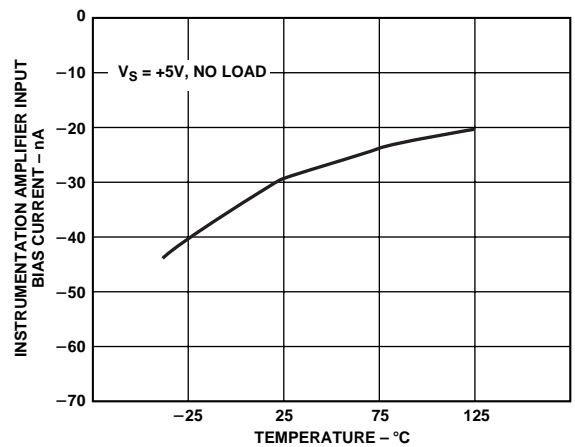


Figure 6. Instrumentation Amplifier Input Bias Current vs. Temperature

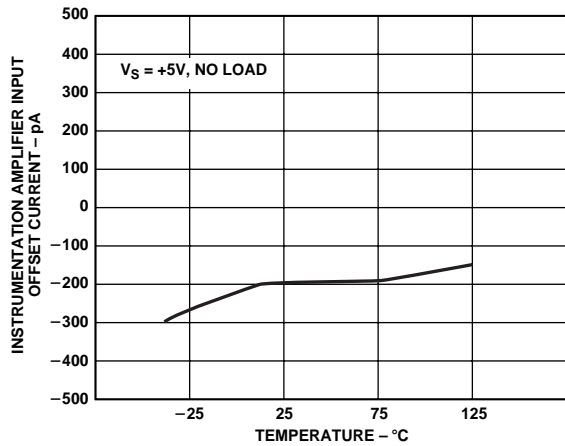


Figure 7. Instrumentation Amplifier Input Offset Current vs. Temperature

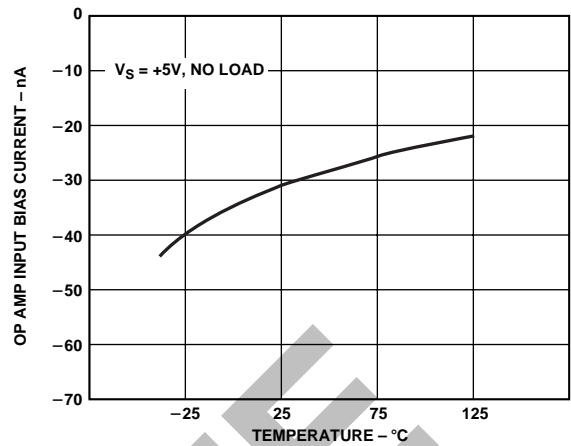


Figure 10. Op Amp Input Bias Current vs. Temperature

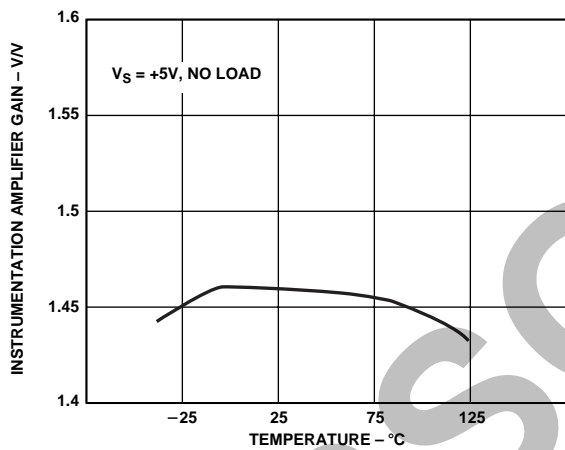


Figure 8. Instrumentation Amplifier Gain vs. Temperature

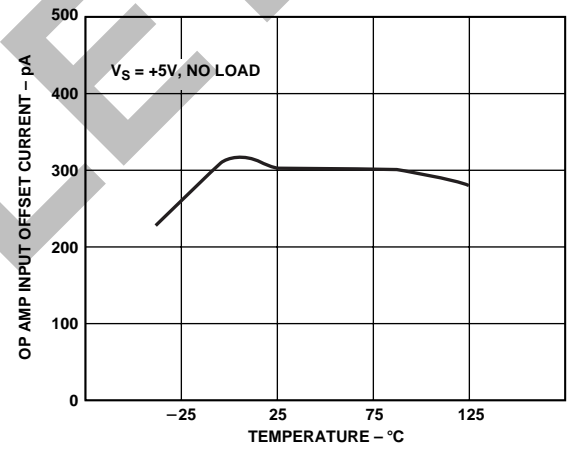


Figure 11. Op Amp Input Offset Current vs. Temperature

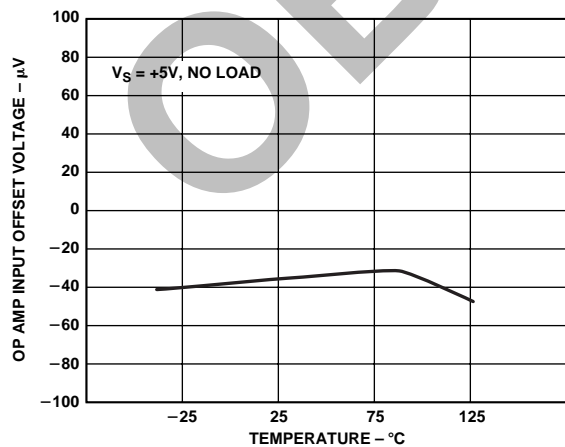


Figure 9. Op Amp Input Offset Voltage vs. Temperature

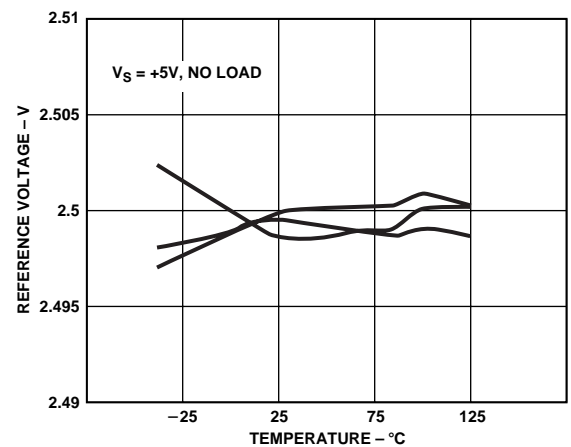


Figure 12. Reference Voltage vs. Temperature

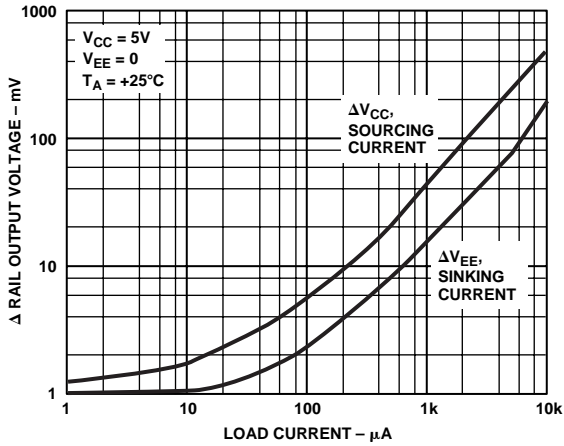


Figure 13. Op Amp Output Voltage from Rails vs. Load Current

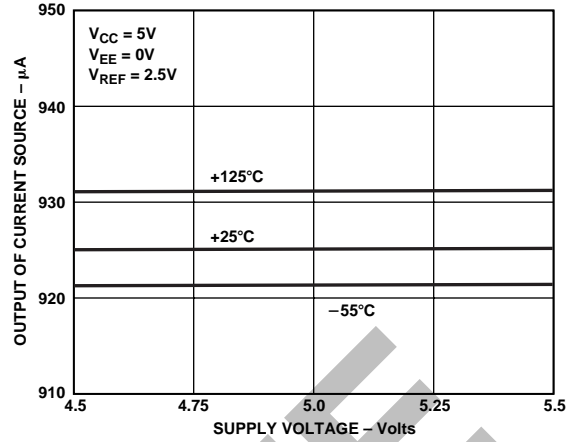


Figure 16. Output of Current Source vs. Supply Voltage

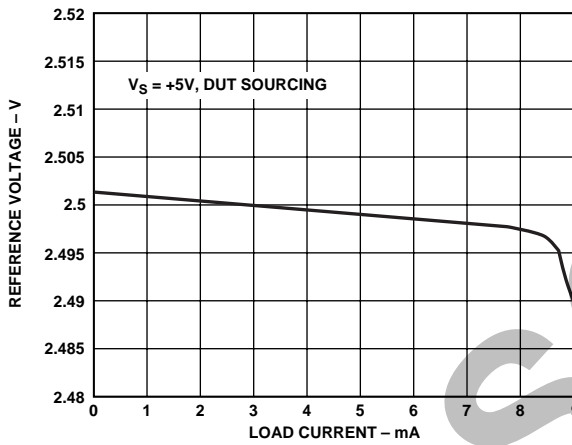


Figure 14. Reference Voltage vs. Load Current

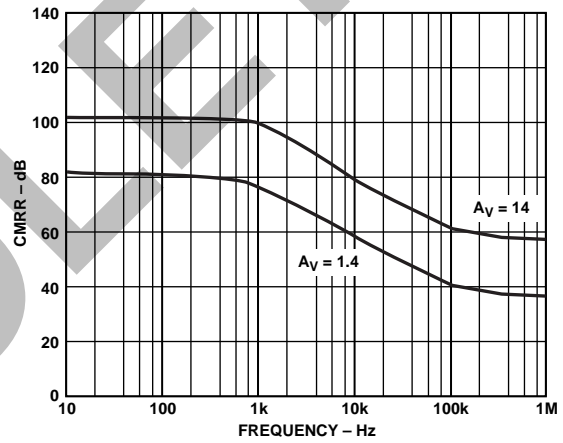


Figure 17. In Amp CMRR vs. Frequency

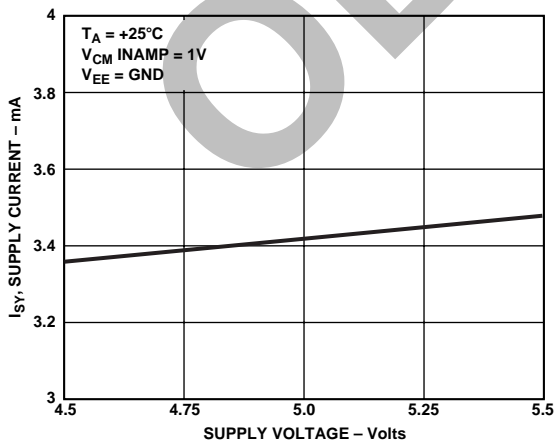


Figure 15. Supply Current vs. Supply Voltage

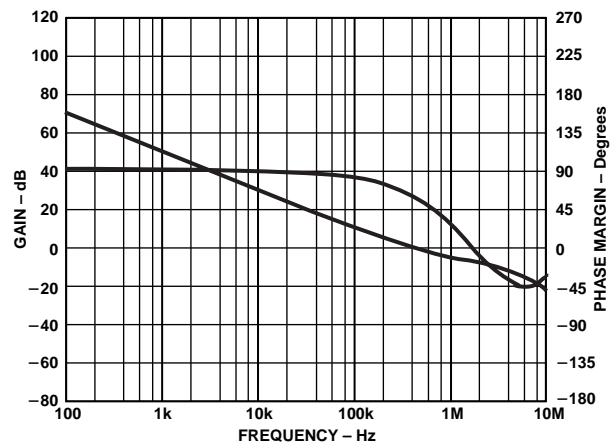


Figure 18. Op Amp Open Loop Gain and Phase vs. Frequency

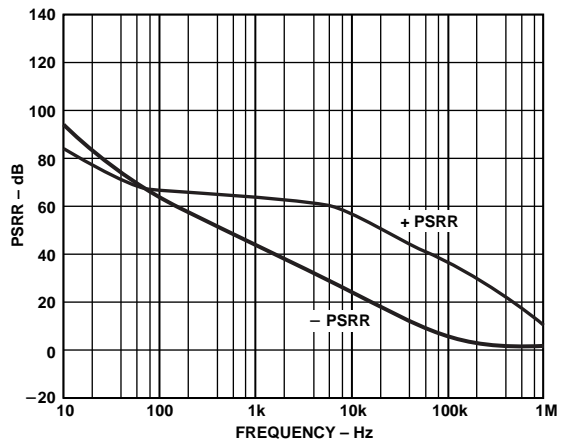


Figure 19. In Amp PSRR vs. Frequency - $A_V = 1.4$

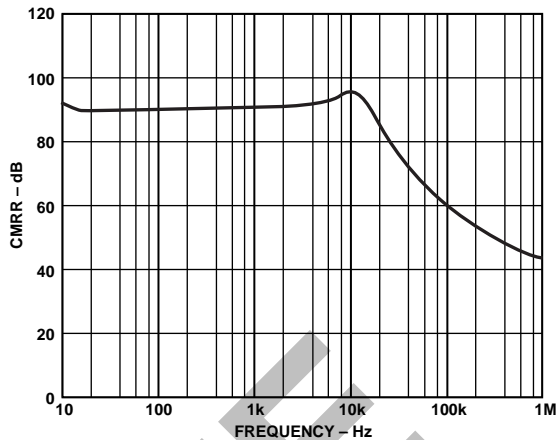


Figure 22. Op Amp CMRR vs. Frequency

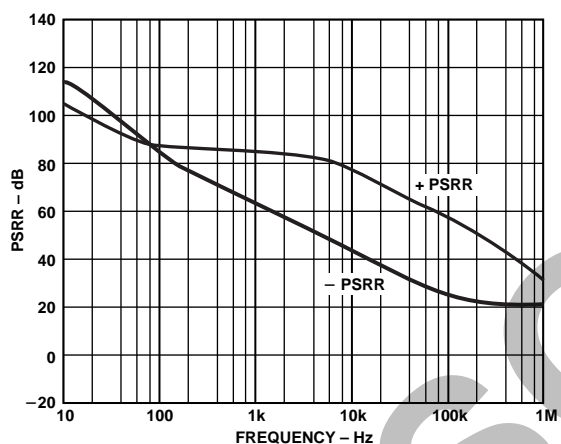


Figure 20. In Amp PSRR vs. Frequency - $A_V = 14$

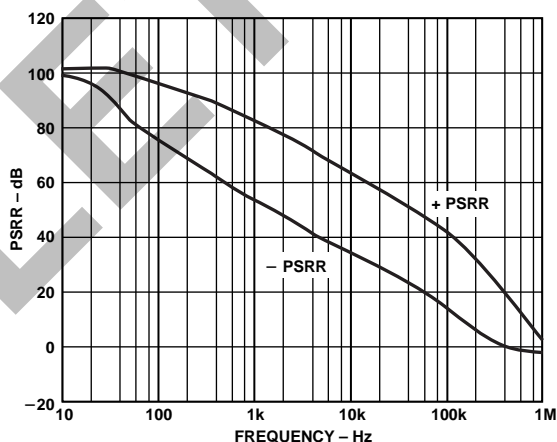


Figure 23. Op Amp PSRR vs. Frequency

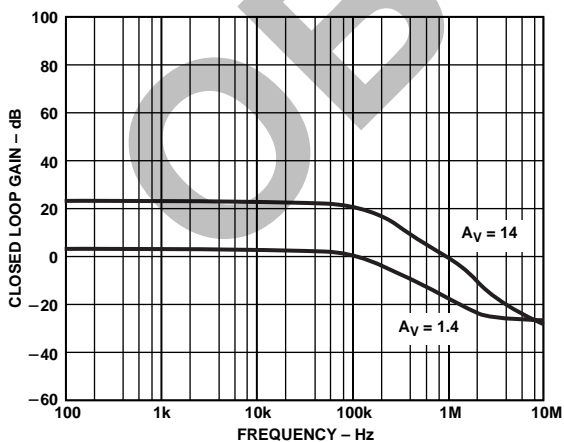


Figure 21. In Amp Closed Loop Gain vs. Frequency

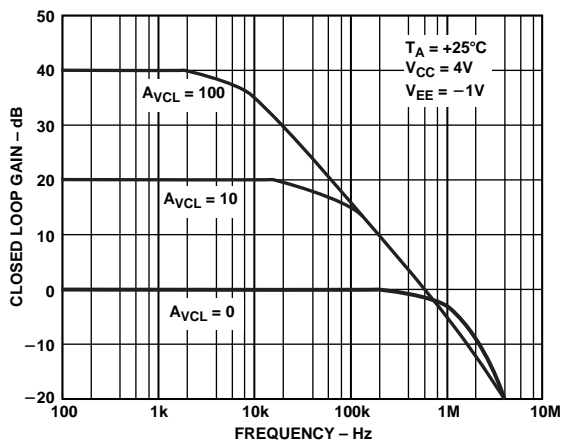


Figure 24. Op Amp Closed Loop Gain vs. Frequency

ADT70

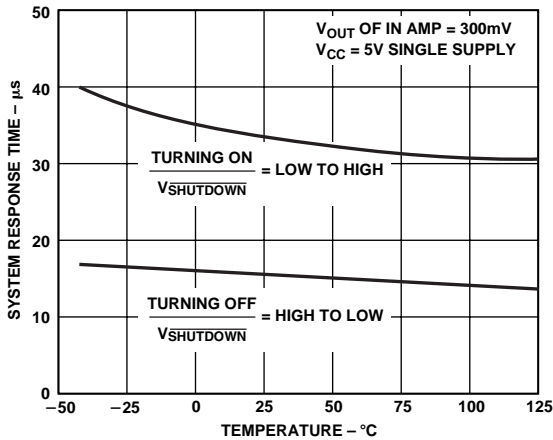


Figure 25. System Response Time from Shutdown vs. Temperature

FUNCTIONAL DESCRIPTION

The ADT70 provides excitation and signal conditioning for resistance-temperature devices (RTDs). It is ideally suited for 1 kΩ Platinum RTDs (PRTDs), which allow a much wider range of temperature measurement than silicon-based sensors. Using a low cost PRTD, the ADT70 can measure temperatures in the range of -50°C to +500°C.

The two main components in the ADT70 are the adjustable current sources and the instrumentation amplifier. The current sources provide matching excitation currents to the PRTD and to the Reference Resistor. The instrumentation amplifier compares the voltage drop across both the PRTD and Reference Resistor, and provides an amplified output signal voltage that is proportional to temperature.

Besides the matching current sources and the instrumentation amplifier, there is a general purpose op amp for any application desired. The ADT70 comes with a +2.5 V reference on board.

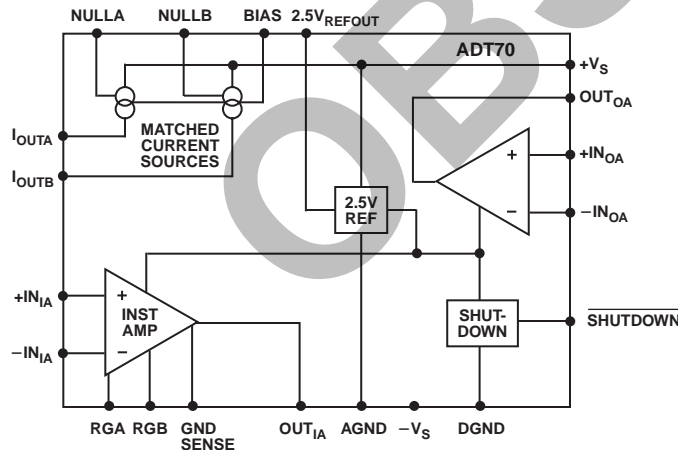


Figure 26. Block Diagram

What is an RTD?

The measurable temperature range of the ADT70 heavily depends on the characteristics of the resistance-temperature detector (RTD). Thus, it is important to choose the right RTD to suit the actual application.

A basic physical property of any metal is that its electrical resistivity changes with temperature. Some metals are known to have a very predictable and repeatable change of resistance for a given change in temperature. An RTD is fabricated from one of these metals to a nominal ohmic value at a specified temperature. By measuring its resistance at some unknown temperature and comparing this value to the resistor's nominal value, the change in resistance is determined. Because the temperature vs. resistance characteristics are also known, the change in temperature from the point initially specified can be calculated. This makes the RTD a practical temperature sensor, which in its bare form is a resistive element.

Several types of metal can be chosen for fabricating RTDs. These include: Copper, balco (an iron-nickel alloy), nickel, tungsten, iridium and platinum. Platinum is by far the most popular material used, due to its nearly linear response to temperature, wide temperature operating range and superior long-term stability. The price of Platinum Resistance Temperature Detectors (PRTDs) are becoming more competitive through the wide use of thin-film-type resistive elements.

Temperature Coefficient of Resistance

The temperature coefficient (TC, also referred to as α) of an RTD, describes the average resistance change per unit temperature from the ice point to the boiling point of water.

$$TCR \left(\frac{\Omega}{\Omega/^\circ C} \right) = \frac{R_{100} - R_0}{100^\circ C \times R_0}$$

R_0 = Resistance of the sensor at 0°C

R_{100} = Resistance of the sensor at +100°C

TCR = Thermal Coefficient of Resistance.

For example, a platinum thermometer measuring 100 Ω at 0°C and 138.5 Ω at 100°C, has $TCR = 0.00385 \Omega/\Omega/^\circ C$.

$$TCR = \frac{138.5 \Omega - 100 \Omega}{100 \Omega \times 100^\circ C} = 0.00385$$

The larger the TCR , the greater the change in resistance for a given change in temperature. The most common use of TCR is to distinguish between curves for platinum, which is available with TCR s ranging from 0.00375 to 0.003927. The highest TCR indicates the highest purity platinum and is mandated by ITS-90 for standard platinum thermometers.

Basically, TCR s must be properly matched when replacing RTDs or connecting them to instruments. There are no technical advantages of one TCR over another in practical industrial applications. 0.00385 platinum is the most popular worldwide standard and is available in both wire-wound and thin-film elements.

Understanding Error Source

The ADT70 uses an instrumentation amplifier that amplifies the difference in voltage drop across the RTD and the reference resistor, to output a voltage proportional to the measured temperature. Thus, it is important to use a reference resistor that has stable resistance over temperature. The accuracy of the reference resistor should be determined by the end application.

The lead resistance of wires connecting to the RTD and the reference resistor can add inaccuracy to the ADT70. If the reference resistor is located close to the part, while the RTD is located at a remote location connected by wires, the lead-wires' resistance

would contribute to the difference in voltage drop between the RTD and the reference resistor. Thus, an error in reading the actual temperature could occur.

Table I. Copper Wire Gauge Size to Resistance Table.

Lead-wire AWG	Ohms/foot at +25°C
12	0.0016
14	0.0026
16	0.0041
18	0.0065
20	0.0103
22	0.0162
24	0.0257
26	0.0413
28	0.0651
30	0.1027

From Table I the amount of lead-wire resistance effect in the circuit can be estimated. For example, connect 100 feet of AWG 22 wire to a 100 Ω Platinum RTD (PF element). The lead-wire resistance will be: $R = 100 \text{ ft} \times 0.0162 \text{ } \Omega/\text{ft} = 1.62 \text{ } \Omega$. Thus the total resistance you have with the PRTD will be:

$$R_{TOTAL} = 100 \text{ } \Omega + 1.62 \text{ } \Omega = 101.62 \text{ } \Omega$$

Since the 100 Ω reference resistor is assumed to be relatively close to the ADT70, the lead-wire resistance is negligible. This shows 1.62 Ω of inaccuracy.

From the PRTD's data sheet, the PRTD's sensitivity rating (Ω/°C) can be used with the lead-wire resistance to approximate the accuracy error in temperature degree (°C). Following the example above, the sensitivity of the 100 Ω PRTD is 0.385 Ω/°C (taken from PRTD data sheet). Hence the approximate error is:

$$Error = 1.62 \text{ } \Omega / 0.385 \text{ } \Omega/^\circ\text{C} = 4.21^\circ\text{C}$$

assuming the reference resistor is constant at 100 Ω throughout the temperature range.

As shown above, this is a significant inaccuracy, especially for applications where the PRTD would be hundreds of feet away from the ADT70. To reduce lead-wire error it is recommended to use a larger sensitivity RTD; 1 kΩ instead of 100 Ω. Furthermore, in the application circuit section, Figure 28 illustrates how to eliminate such error by using the part's general purpose op amp.

Self-Heating Effect

Another contributor to measurement error is the self-heating effect on the RTD. As with any resistive element, power is dissipated in an amount equal to the square of the excitation current times the resistance of the element. The error contribution of the heat generated by this power dissipation can easily be calculated. For example, if the package thermal resistance is 50°C/W, the RTD nominal resistance is 1 kΩ and the element is excited with a 1 mA current source, then the artificial increase in temperature (Δ°C) as a result of self-heating is:

$$\Delta^\circ\text{C} = I^2 R_0 \times \theta_{PACKAGE}$$

$$\Delta^\circ\text{C} = (1 \text{ mA})^2 \times 1000 \text{ } \Omega \times 50^\circ\text{C/W}$$

$$\Delta^\circ\text{C} = 0.05^\circ\text{C}$$

where:

$\theta_{PACKAGE}$ = thermal resistance of package

R_0 = value of RTD resistance

APPLICATION INFORMATION

As shown in Figure 27, using a 1 kΩ PRTD, 1 kΩ reference resistor, 49.9 kΩ resistor between RGA (Pin 11) and RGB (Pin 12), and shorting BIAS (Pin 4) with VREFOUT (Pin 3) together, the output of OUT_{IA} (Pin 14) will have a transfer function of

$$V_{OUT} = 1.299 \text{ mV}/\Omega \times \Delta R_{(PRTD \text{ RESISTANCE} - \text{REFERENCE RESISTANCE})}$$

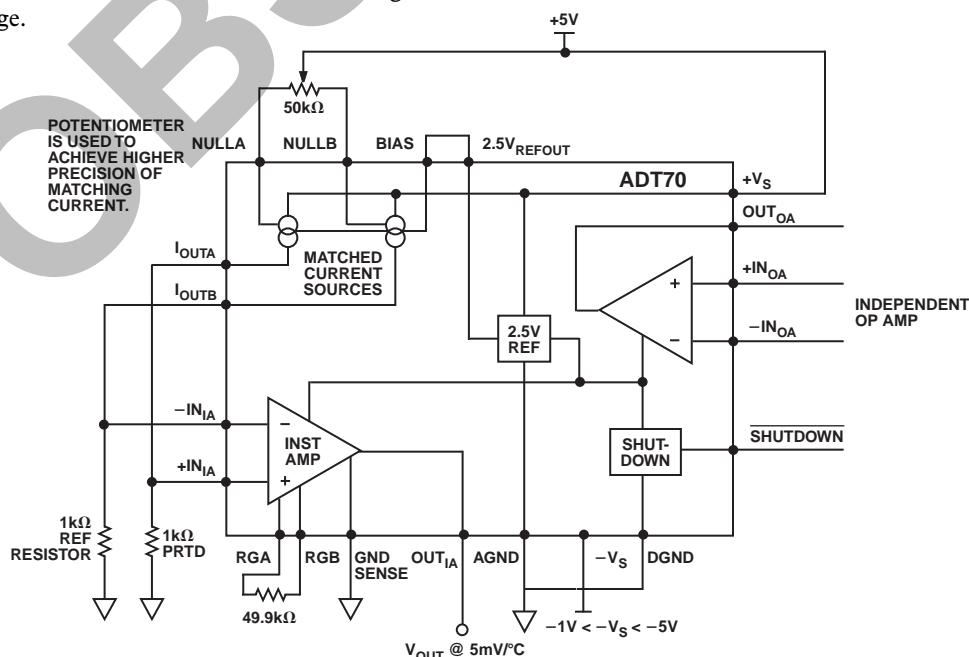


Figure 27. Basic Operational Diagram

achieve in a single supply application where the negative rail is ground or 0 V. Therefore, to achieve full scale operation the output of ADT70 should be shifted by 1 V to allow for operation in the 0 V to 5 V region.

The most straightforward method to shift the output voltage incorporates the use of the GND SENSE as shown in Figure 29. To shift output voltage range apply a potential equal to the necessary shift on the GND SENSE pin. For example, to shift the output voltage, OUT_{IA} , up to 1 V to GND SENSE, apply 1 V to GND SENSE. When applying a potential to GND SENSE, care should be taken to ensure that the voltage source is capable of driving 2 k Ω and does not introduce excessive noise. Figure 29 uses the on-board 2.5 V voltage reference for a low noise source. This reference is then divided to 1 V and buffered by the on-board op amp to drive GND SENSE at a low impedance. A small 500 Ω potentiometer can be used to calibrate the initial offset error to zero.

However, a voltage applied to GND SENSE is not the only method to shift the voltage range. Placing a 768 Ω resistor in the PRTD sensor path also shifts the output voltage by 1 V. This second method, as shown in Figure 30, is usually not recommended for the following reasons; the input voltage range of the op amps is limited to around 1 V from the negative and positive rails and this could cause problems at high temperature, limiting the upper range to 600°C; the physical location of this resistor (if placed at a distance from the ADT70) may have an impact on the noise performance. The method frees up the on-board op amp for another function and achieves the lowest impedance ground point for GND SENSE.

This brief section on ADT70 single supply operation has focused on simple techniques to bias the ADT70 such that all output voltages are within operational range. However, these techniques may not be useful in all single supply applications. For example, in Figure 3 the additional on-board op amp is operating at near ground potential which will create problems in a single supply application

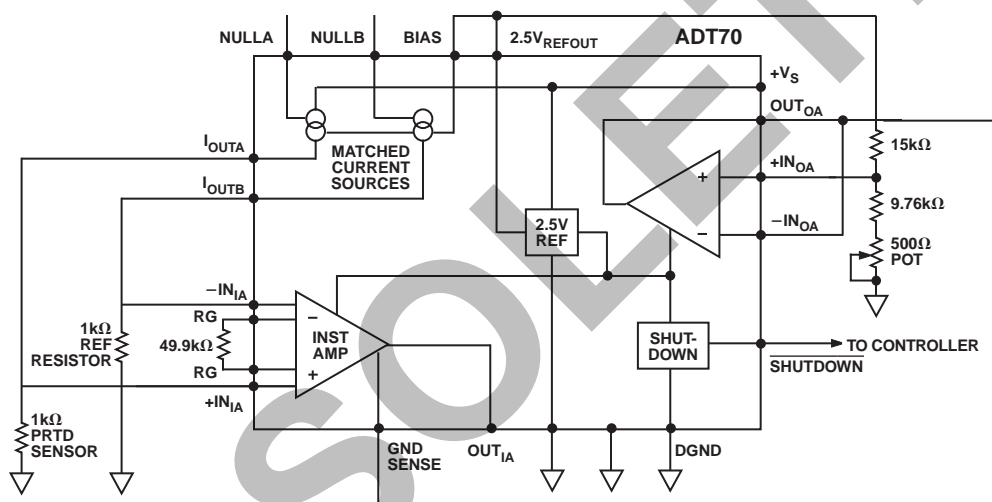


Figure 29. A Single Supply Application with Shifted Ground Sense Pin

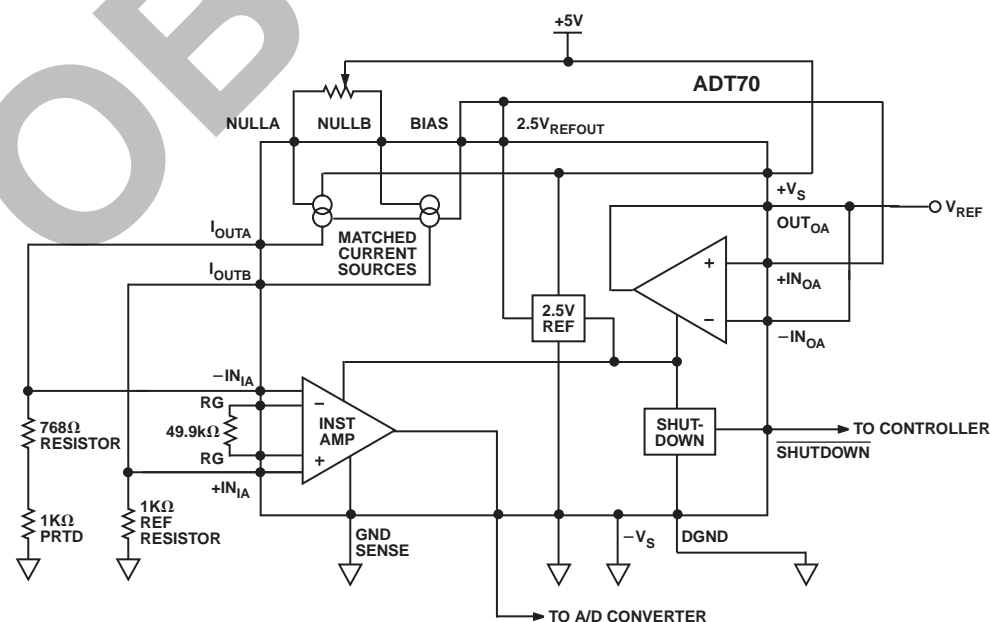


Figure 30. A Basic Single Supply Operational Diagram with Bias Resistor in Sensor Path

ADT70

because the input voltage range of the on-board op amp only extends to about 1 V above the negative rail. If the application requires the inputs of either the on-board amp or instrumentation amplifier to operate within 1 V of ground, it will be necessary to generate a “pseudo-ground.” Figure 31 illustrates a typical ADT70 “pseudo-ground” application. The Analog Devices’ ADR290, a 2.048 V reference, is being used to generate the “pseudo-ground.” The ADR290 was selected for the following reasons: low noise, ability to drive the required 5 mA in this application, good temperature stability, which is usually important in a PRTD application. However, one undesired effect of introducing the pseudo-ground is the loss in voltage range at high temperature. In our example, the PRTD will only operate from -200°C to $+400^{\circ}\text{C}$ corresponding to an input voltage range of 1 V to 4 V.

100 Ω PRTD Application Circuit

A 1000 Ω PRTD sensor scales by $3.85 \Omega\text{s}/^{\circ}\text{C}$, which is exactly ten times the scale of the 100 Ω PRTD sensor. The ADT70 has been designed to allow for 1000 Ω or 100 Ω PRTD sensors. Only the gain setting resistor R_G needs to be altered. For

a 100 Ω PRTD 0.00385 sensor, change R_G to 4.99 k Ω as illustrated in Figure 32. In single supply application, with a 100 Ω PRTD sensor, a “pseudo-ground” will be necessary because the inputs of the instrumentation amplifier will be within 1 V of the negative rail. See the section on single supply applications for more information.

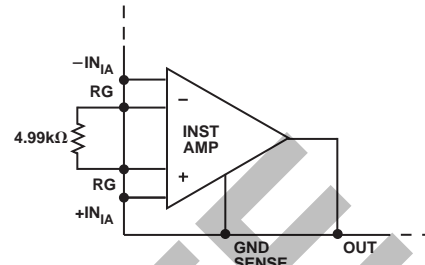


Figure 32. 100 Ω 0.00385 PRTD Application Showing New Value for R_G

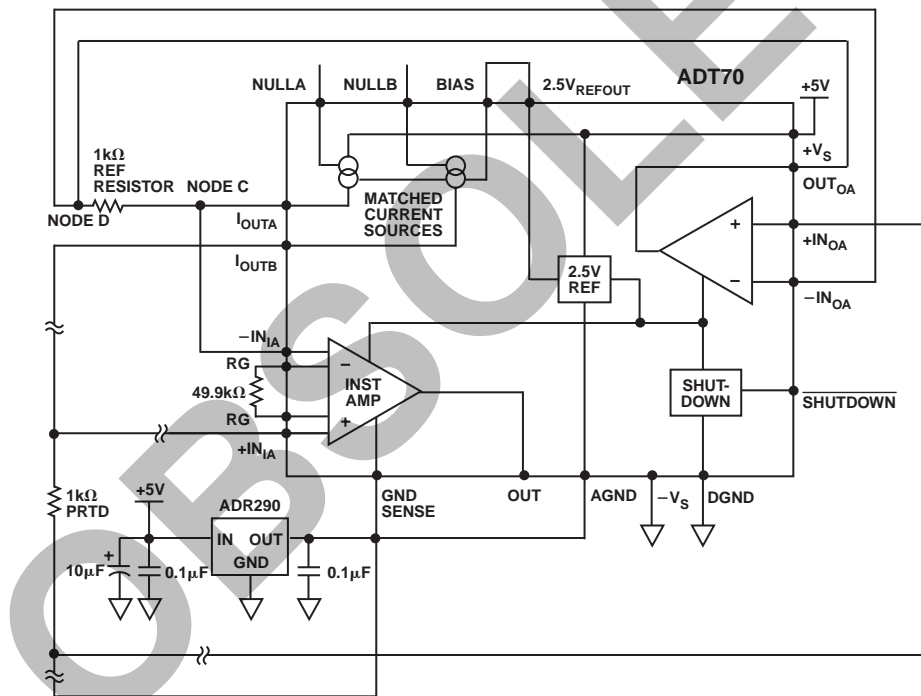


Figure 31. Single Supply Application with an ADR290 “Pseudo-Ground”

American PRTD Application Circuit

The majority of PRTD sensors use a scale factor of $0.00385 \Omega/\Omega/^\circ\text{C}$. This type of sensor is known as the European PRTD and is the most common PRTD sensor. However, there is also an American PRTD sensor that uses a scale factor of $0.00392 \Omega/\Omega/^\circ\text{C}$. Figure 33 illustrates the input section of the ADT70 configured for the American PRTD. The ideal value for RG is $50.98 \text{ k}\Omega$ when yielding a $5 \text{ mV}/^\circ\text{C}$ ADT70 output.

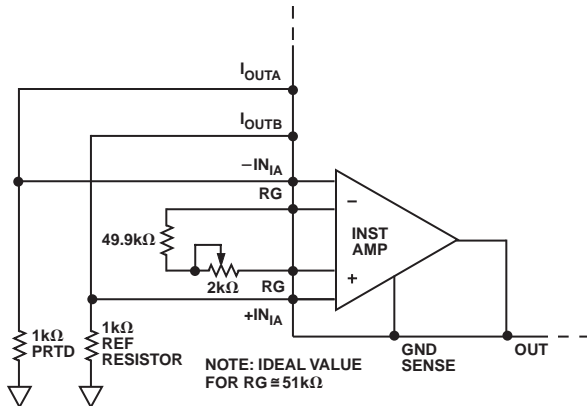


Figure 33. Typical PRTD Application with American $0.003916 \Omega/\Omega/^\circ\text{C}$ Scale; $1 \text{ k}\Omega$ Scale

Strain Gauge Sensor Application Circuit

Figure 34 illustrates a typical strain gauge bridge circuit. The versatility of the ADT70 allows the part to be used with most bridge circuits that are within the $50 \text{ k}\Omega$ to $5 \text{ k}\Omega$ impedance range. The sensor used in this circuit has two elements varying. If a constant current is driven into the sensor, a linear V_{OUT} is obtained. In addition, the ADT70 will work with most bridge circuits whether one-, two-, or all-element varying.

Securing Additional Current from the Current Sources

Some sensor applications need a higher excitation current to increase sensor sensitivity. There are two methods to increase the current from the on-board current sources of the ADT70. The most flexible method involves changing the voltage at the BIAS node. The equation for determining the BIAS potential vs. Output current is 2.5 V for roughly 1 mA , or in other words, to double the current output simply put 5 V into BIAS. The BIAS node should be driven with a low-noise source, such as a reference, because output current is directly dependent on BIAS voltage. Directly tying BIAS to the positive supply rail may produce too much current noise especially if the positive rail is not well regulated. The second method involves tying the two ADT70 current outputs together which doubles the current. Of course, this technique is most useful if, as illustrated in Figure 34, the application requires only one current source.

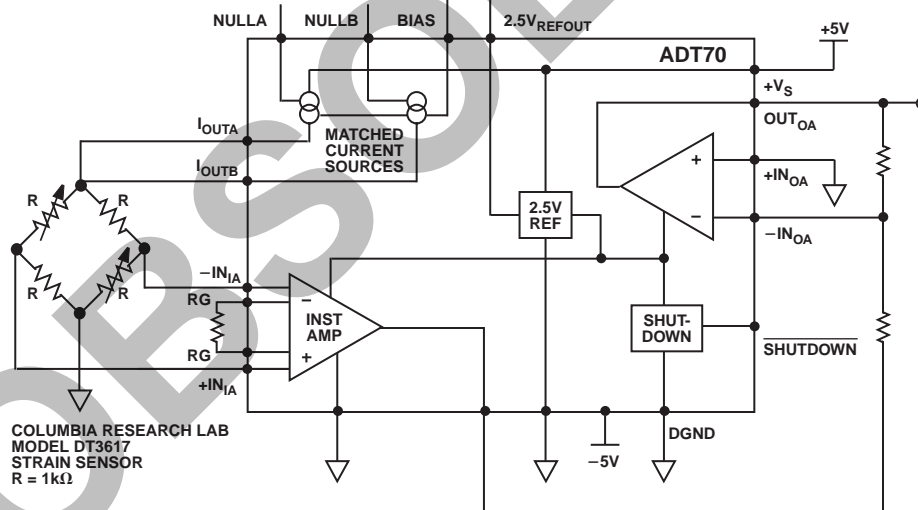
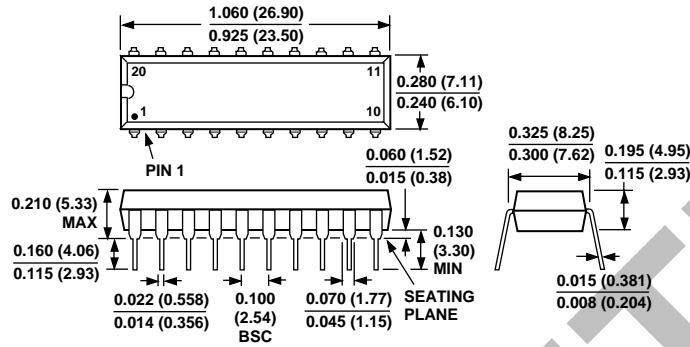


Figure 34. Typical Strain Sensor Application (Two Element Varying)

OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

20-Lead Plastic DIP
(P-Suffix)



20-Lead SOIC
(S-Suffix)

