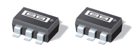
INA139
INA169



SBOS181A – DECEMBER 2000 – REVISED JANUARY 2003

High-Side Measurement CURRENT SHUNT MONITOR

FEATURES

- **COMPLETE UNIPOLAR HIGH-SIDE CURRENT MEASUREMENT CIRCUIT**
- **WIDE SUPPLY AND COMMON-MODE RANGE**
- **INA139: 2.7V to 40V**
- **INA169: 2.7V to 60V**
- **INDEPENDENT SUPPLY AND INPUT COMMON-MODE VOLTAGES**
- **SINGLE RESISTOR GAIN SET**
- **LOW QUIESCENT CURRENT (60µA typ)**
- **SOT23-5 PACKAGE**

APPLICATIONS

- **CURRENT SHUNT MEASUREMENT: Automotive, Telephone, Computers**
- **PORTABLE AND BATTERY-BACKUP SYSTEMS**
- **BATTERY CHARGERS**
- **POWER MANAGEMENT**
- **CELL PHONES**
- **PRECISION CURRENT SOURCE**

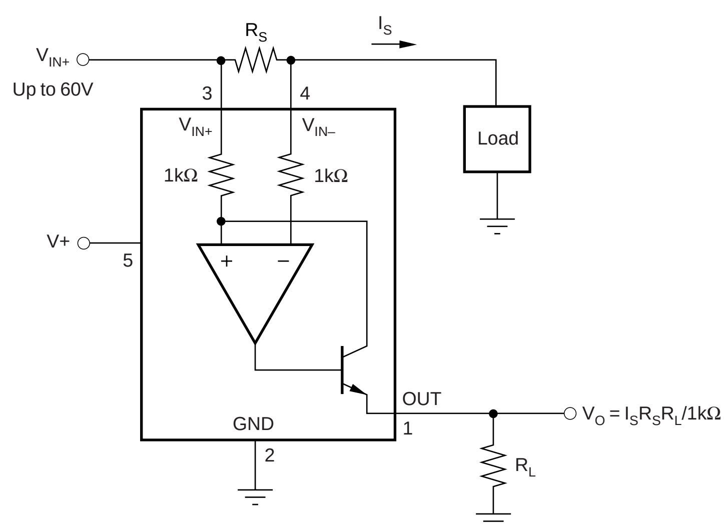
DESCRIPTION

The INA139 and INA169 are high-side, unipolar, current shunt monitors. Wide input common-mode voltage range, high-speed, low quiescent current, and tiny SOT23 packaging enable use in a variety of applications.

Input common-mode and power-supply voltages are independent and can range from 2.7V to 40V for the INA139 and 2.7V to 60V for the INA169. Quiescent current is only 60µA, which permits connecting the power supply to either side of the current measurement shunt with minimal error.

The device converts a differential input voltage to a current output. This current is converted back to a voltage with an external load resistor that sets any gain from 1 to over 100. Although designed for current shunt measurement, the circuit invites creative applications in measurement and level shifting.

Both the INA139 and INA169 are available in SOT23-5 packages and are specified for the –40°C to +85°C industrial temperature range.



PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR(1)	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
INA139	SOT23-5 Surface-Mount	DBV	–40°C to +85°C	E39	INA139NA/250	Tape and Reel, 250
"	"	"	"	"	INA139NA/3K	Tape and Reel, 3000
INA169	SOT23-5 Surface-Mount	DBV	–40°C to +85°C	A69	INA169NA/250	Tape and Reel, 250
"	"	"	"	"	INA169NA/3K	Tape and Reel, 3000

NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com.

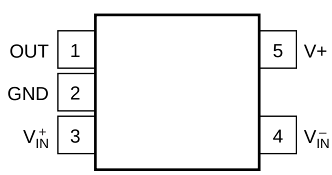
ABSOLUTE MAXIMUM RATINGS(1)

Supply Voltage, V+	
INA139	–0.3V to 60V
INA169	–0.3V to 75V
Analog Inputs, V_{IN+}, V_{IN-}	
INA139	
Common Mode	–0.3V to 60V
Differential (V_{IN+}) – (V_{IN-})	–40V to 2V
INA169	
Common Mode	–0.3V to 75V
Differential (V_{IN+}) – (V_{IN-})	–40V to 2V
Analog Output, Out	–0.3V to 40V
Operating Temperature	–55°C to +125°C
Storage Temperature	–55°C to +125°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s)	+300°C

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

PIN CONFIGURATION

Top View **SOT**



ELECTROSTATIC DISCHARGE SENSITIVITY

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.

ELECTRICAL CHARACTERISTICS

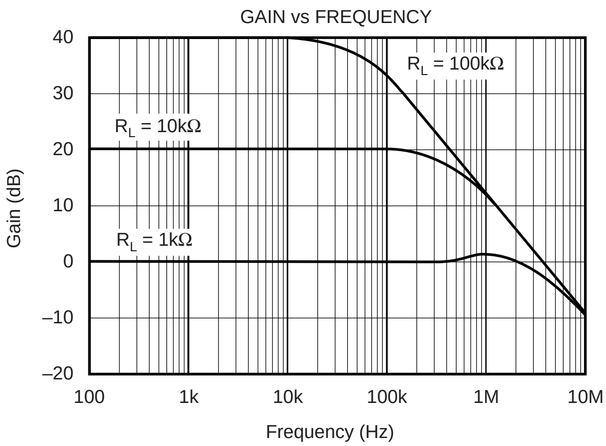
At T_A = –40°C to +85°C, V_S = 5V, V_{IN+} = 12V, and R_{OUT} = 25kΩ, unless otherwise noted.

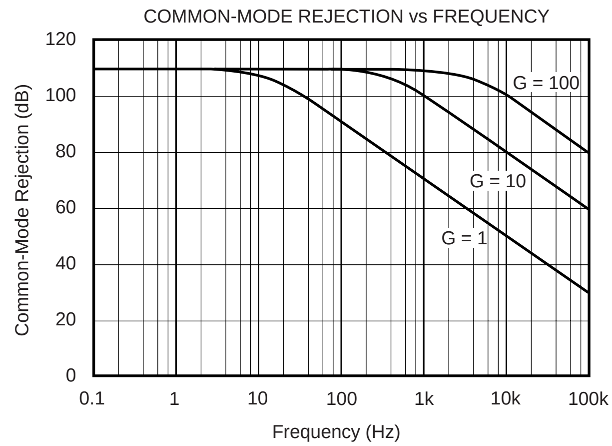
PARAMETER	CONDITION	INA139NA			INA169NA			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
INPUT								
Full-Scale Sense Voltage	V_{SENSE} = (V_{IN+}) – ($V_{IN–}$)		100	500		✻	✻	mV
Common-Mode Input Range		2.7		40	✻		60	V
Common-Mode Rejection	V_{IN+} = 2.7V to 40V, V_{SENSE} = 50mV	100	115					dB
	V_{IN+} = 2.7V to 60V, V_{SENSE} = 50mV				100	120		dB
Offset Voltage[1] RTI			±0.2	±1		✻	✻	mV
vs Temperature	T_{MIN} to T_{MAX}		1			✻		µV/°C
vs Power Supply, V+	V– = 2.7V to 40V, V_{SENSE} = 50mV		0.5	10				µV/V
	V– = 2.7V to 60V, V_{SENSE} = 50mV					0.1	10	µV/V
Input Bias Current	(V_{IN+}) – ($V_{IN–}$)		10			✻		uA
OUTPUT								
Transconductance	V_{SENSE} = 10mV – 150mV	990	1000	1010	✻	✻	✻	µA/V
vs Temperature	V_{SENSE} = 100mV		10			✻		nA/°C
Nonlinearity Error	V_{SENSE} = 10mV to 150mV		±0.01	±0.1		✻	✻	%
Total Output Error	V_{SENSE} = 100mV		±0.5	±2		✻	✻	%
Output Impedance			1 || 5			✻		GΩ || pF
Voltage Output								
Swing to Power Supply, V+			(V+) – 0.9	(V+) – 1.2		✻	✻	V
Swing to Common Mode, V_{CM}			V_{CM} – 0.6	V_{CM} – 1.0		✻	✻	V
FREQUENCY RESPONSE								
Bandwidth	R_{OUT} = 10kΩ		440			✻		kHz
	R_{OUT} = 20kΩ		220			✻		kHz
Settling Time (0.1%)	5V Step, R_{OUT} = 10kΩ		2.5			✻		µs
	5V Step, R_{OUT} = 20kΩ		5.0			✻		µs
NOISE								
Output-Current Noise Density			20			✻		$pA/\sqrt{Hz}$
Total Output-Current Noise	BW = 100kHz		7			✻		nA RMS
POWER SUPPLY								
Operating Range, V+		2.7		40	✻		60	V
Quiescent Current	V_{SENSE} = 0, I_O = 0		60	125		✻	✻	µA
TEMPERATURE RANGE								
Specification, T_{MIN} to T_{MAX}		–40		85	✻		✻	°C
Operating		–55		125	✻		✻	°C
Storage		–65		150	✻		✻	°C
Thermal Resistance θ_{JA}			200			✻		°C/W

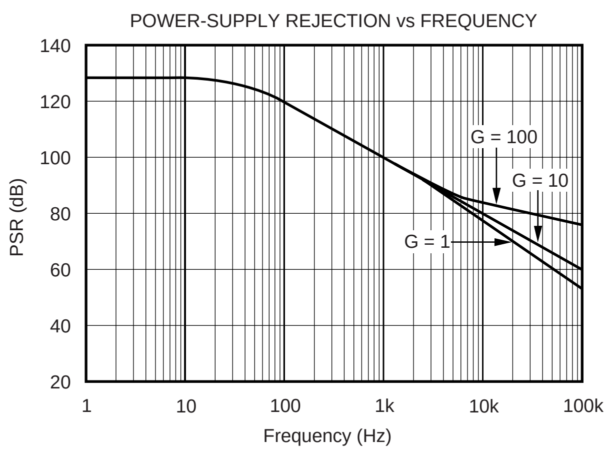
✻ Specification same as for the INA139NA.

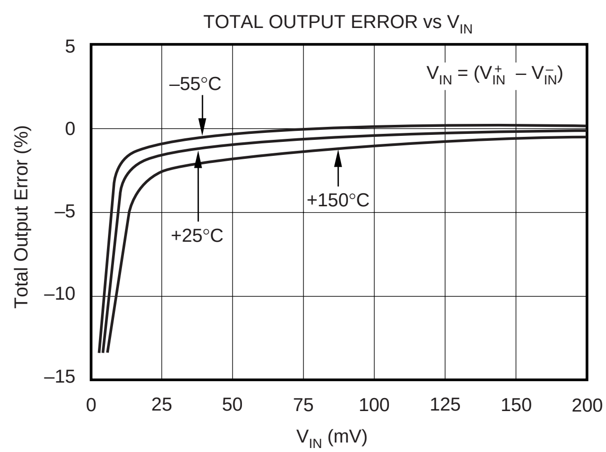
NOTE: (1) Defined as the amount of input voltage, V_{SENSE}, to drive the output to zero.

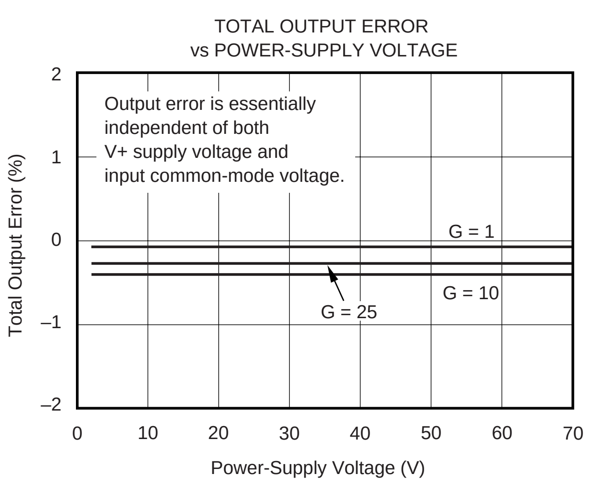
At T_A = +25°C, V+ = 5V, V_{IN+} = 12V, and R_L = 25kΩ, unless otherwise noted.

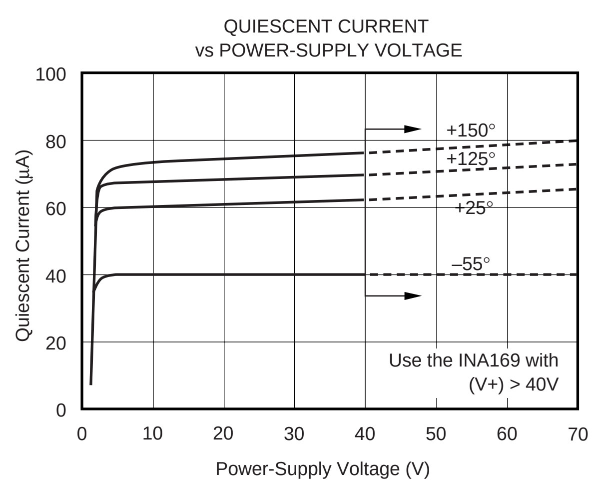




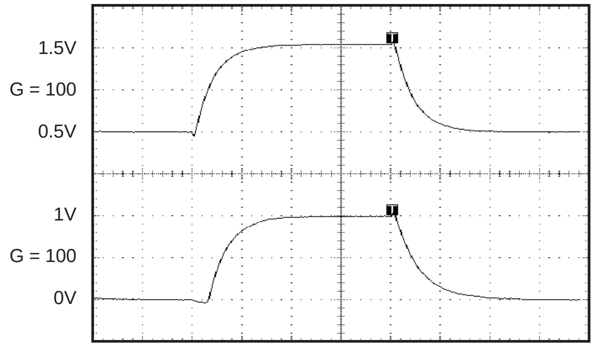






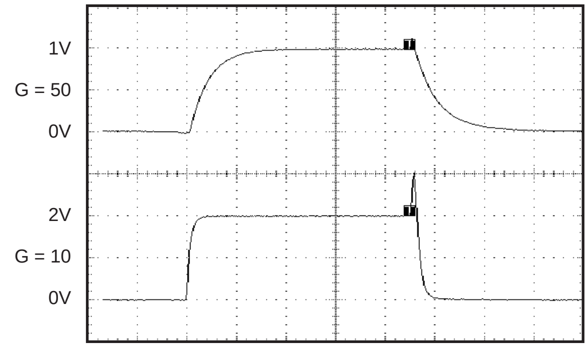


STEP RESPONSE



20µs/div

STEP RESPONSE



10µs/div

OPERATION

Figure 1 shows the basic circuit diagram for both the INA139 and the INA169. Load current, I_S, is drawn from the supply, V_S, through the shunt resistor, R_S. The voltage drop in the shunt resistor, V_S, is forced across R_{G1} by the internal op amp, causing current to flow into the collector of Q1. The external resistor, R_L, converts the output current to a voltage, V_{OUT}, at the OUT pin.

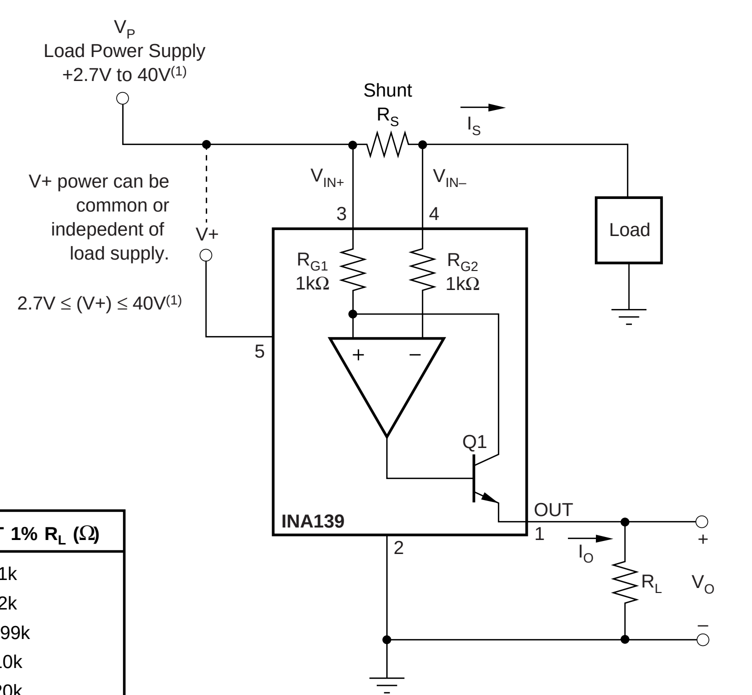
The transfer function for the INA139 is:

$$I_O = g_m\ (V_{IN+}) - (V_{IN-}) \quad (1)$$

$$\text{where } g_m = 1000\mu A/V \quad (2)$$

In the circuit of Figure 1, the input voltage, $(V_{IN+}) - (V_{IN-})$, is equal to $I_S \bullet R_S$ and the output voltage, V_{OUT}, is equal to $I_O \bullet R_L$. The transconductance, g_m, of the INA139 is 1000µA/V. The complete transfer function for the current measurement amplifier in this application is:

$$V_{OUT} = (I_S)\ (R_S)\ (1000\mu A/V)\ (R_L) \quad (3)$$



VOLTAGE GAIN	EXACT R_L (Ω)	NEAREST 1% R_L (Ω)
1	1k	1k
2	2k	2k
5	5k	4.99k
10	10k	10k
20	20k	20k
50	50k	49k
100	100k	100k

NOTE: (1) Maximum V_P and V+ voltage is 60V with the INA169.

FIGURE 1. Basic Circuit Connections.

The maximum differential input voltage for accurate measurements is 0.5V, which produces a 500µA output current. A differential input voltage of up to 2V will not cause damage. Differential measurements (pins 3 and 4) must be unipolar with a more-positive voltage applied to pin 3. If a more-negative voltage is applied to pin 3, the output current (I_O) is zero, but will not cause damage.

BASIC CONNECTION

Figure 1 shows the basic connection of the INA139. The input pins, V_{IN+} and V_{IN-}, must be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance. The output resistor, R_L, is shown connected between pin 1 and ground. Best accuracy is achieved with the output voltage measured directly across R_L. This is especially important in high-current systems where load current can flow in the ground connections, affecting the measurement accuracy.

No power-supply bypass capacitors are required for stability of the INA139. However, applications with noisy or high-impedance power supplies can require decoupling capacitors to reject power-supply noise; connect the bypass capacitors close to the device pins.

POWER SUPPLIES

The input circuitry of the INA139 can accurately measure beyond its power-supply voltage, V+. For example, the V+ power supply can be 5V whereas the load power-supply voltage is up to +36V (or +60V with the INA169). However, the output voltage range of the OUT terminal (pin 1) is limited by the lesser of the two voltages (see the Output Voltage Range section).

SELECTING R_S AND R_L

The value chosen for the shunt resistor, R_S, depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High values of R_S provide better accuracy at lower currents by minimizing the effects of offset, whereas low values of R_S minimize voltage loss in the supply line. For most applications, best performance is attained with an R_S value that provides a full-scale shunt voltage of 50mV to 100mV; maximum input voltage for accurate measurements is 500mV.

R_L is chosen to provide the desired full-scale output voltage. The output impedance of the INA139 OUT terminal is very high, which permits using values of R_L up to 100kΩ with excellent accuracy. The input impedance of any additional circuitry at the output must be much higher than the value of R_L to avoid degrading accuracy.

Some Analog-to-Digital (A/D) converters have input impedances that will significantly affect measurement gain. The input impedance of the A/D converter can be included as part of the effective R_L if its input can be modeled as a resistor to ground. Alternatively, an op amp can be used to buffer the A/D converter input, as shown in Figure 2, see Figure 1 for recommended values of R_L.

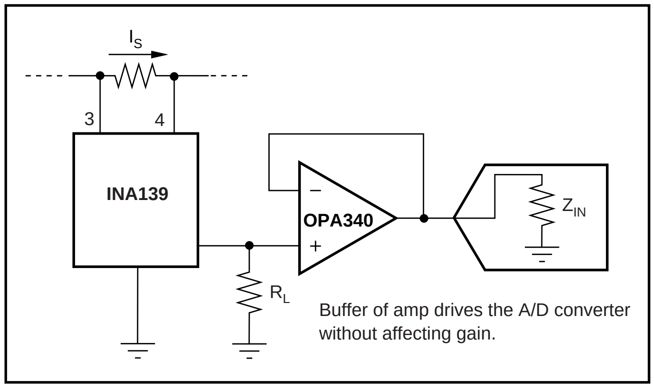


FIGURE 2. Buffering Output to Drive the A/D Converter.

OUTPUT VOLTAGE RANGE

The output of the INA139 is a current that is converted to a voltage by the load resistor, R_L. The output current remains accurate within the *compliance voltage range* of the output circuitry. The shunt voltage and the input common-mode and power-supply voltages limit the maximum possible output swing. The maximum output voltage compliance is limited by the lower of the two equations below:

$$V_{OUT\ MAX} = (V+) - 0.7V - (V_{IN+}) - (V_{IN-}) \quad (4)$$

or

$$V_{OUT\ MAX} = (V_{IN-}) - 0.5V \quad (5)$$

(whichever is lower)

BANDWIDTH

Measurement bandwidth is affected by the value of the load resistor, R_L. High gain produced by high values of R_L will yield a narrower measurement bandwidth (see the Typical Characteristics). For widest possible bandwidth, keep the capacitive load on the output to a minimum.

If bandwidth limiting (filtering) is desired, a capacitor can be added to the output, as shown in Figure 3, which will not cause instability.

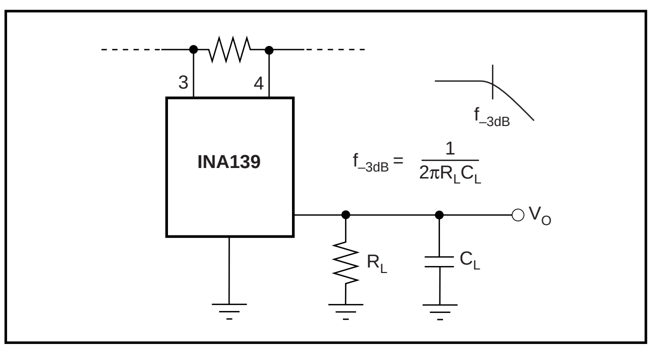


FIGURE 3. Output Filter.

APPLICATIONS

The INA139 is designed for current shunt measurement circuits (see Figure 1), but its basic function is useful in a wide range of circuitry. A creative engineer will find many unforeseen uses in measurement and level shifting circuits. A few ideas are illustrated in Figures 4 through 7.

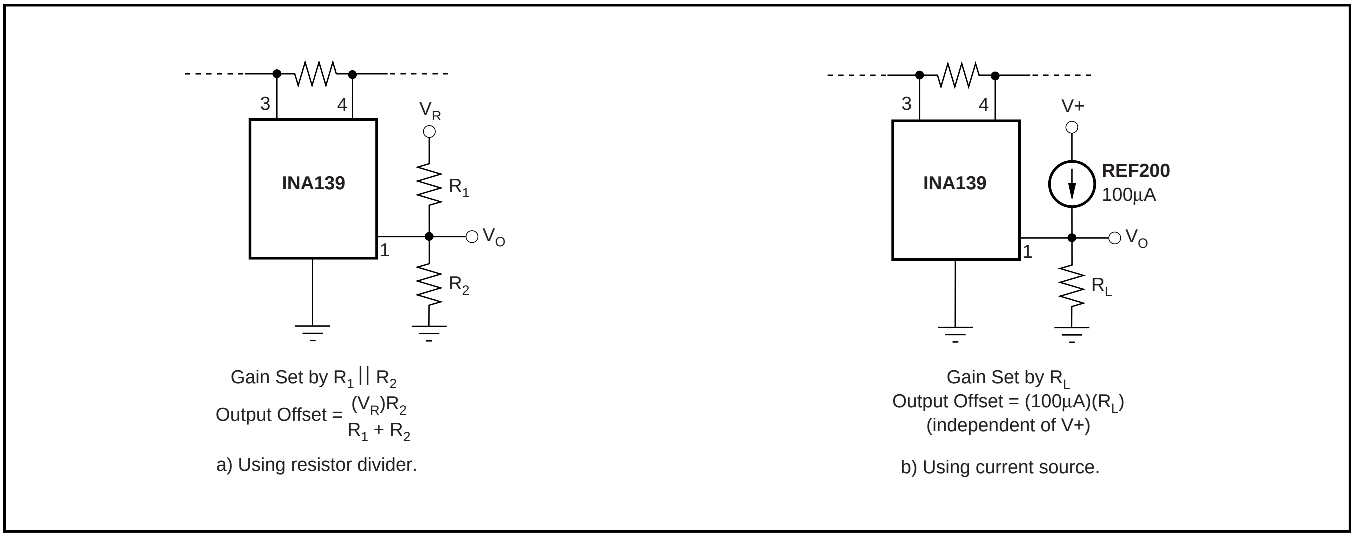


FIGURE 4. Offsetting the Output Voltage.

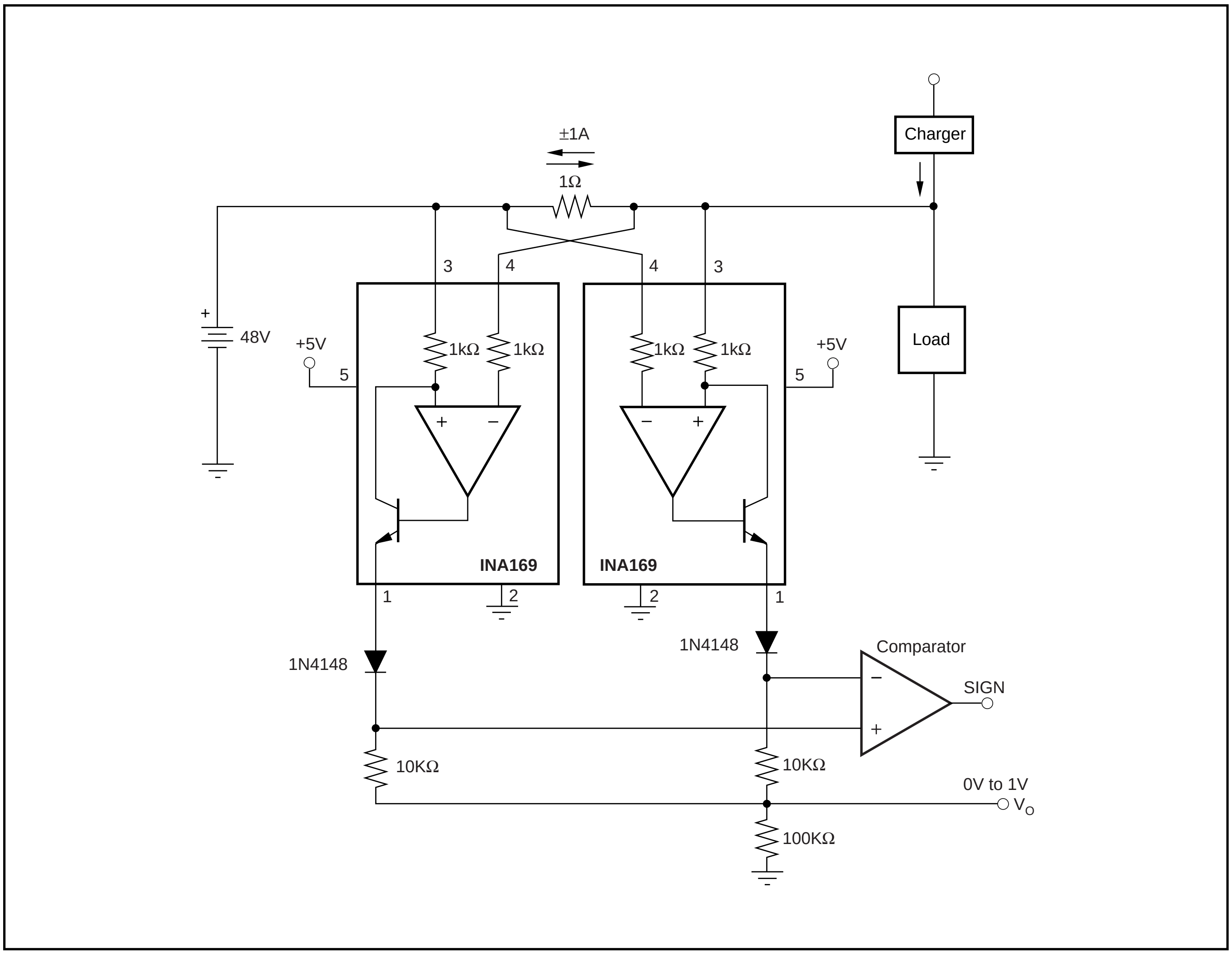


FIGURE 5. Bipolar Current Measurement.

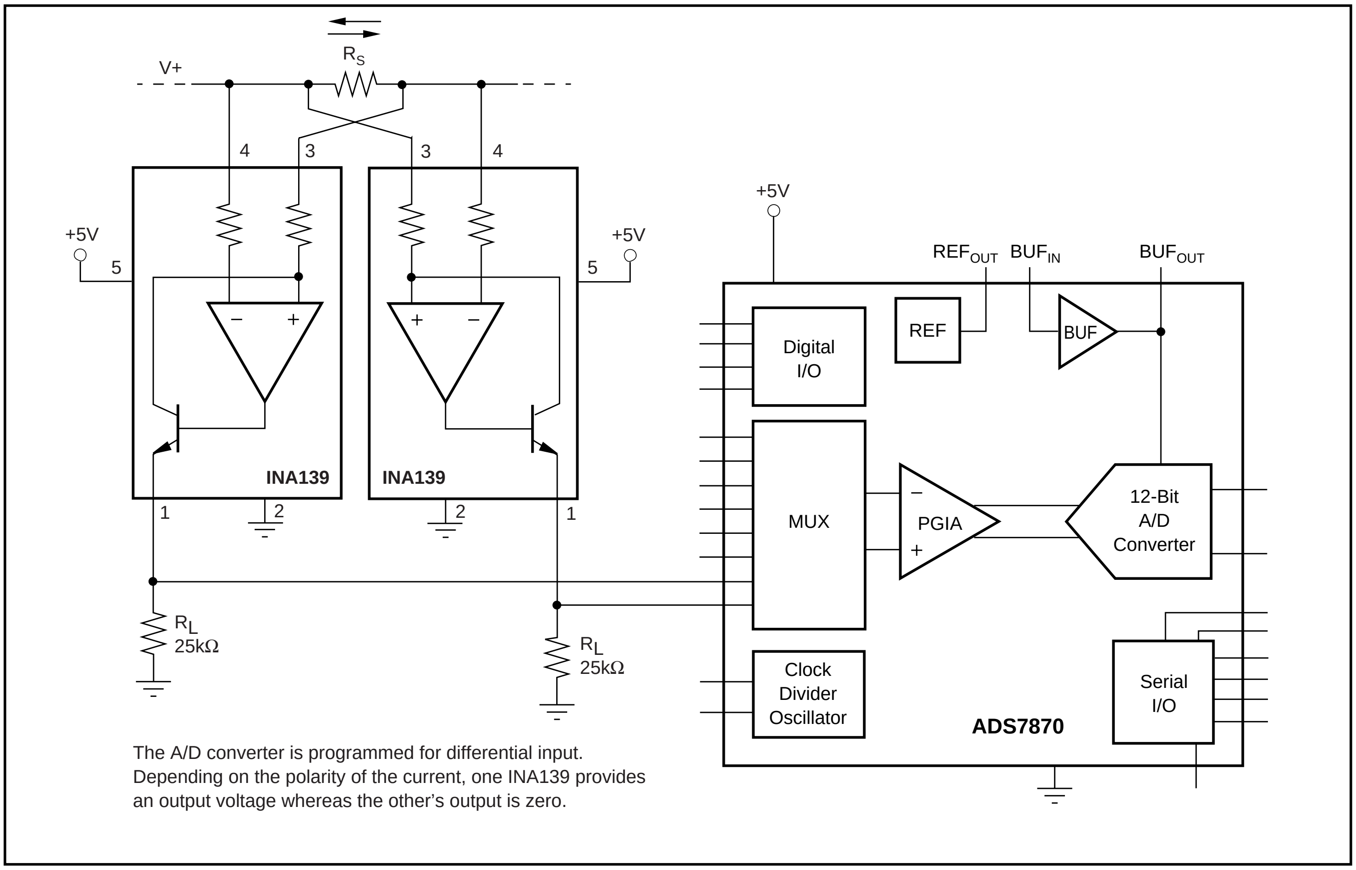


FIGURE 6. Bipolar Current Measurement Using a Differential Input of the A/D Converter.

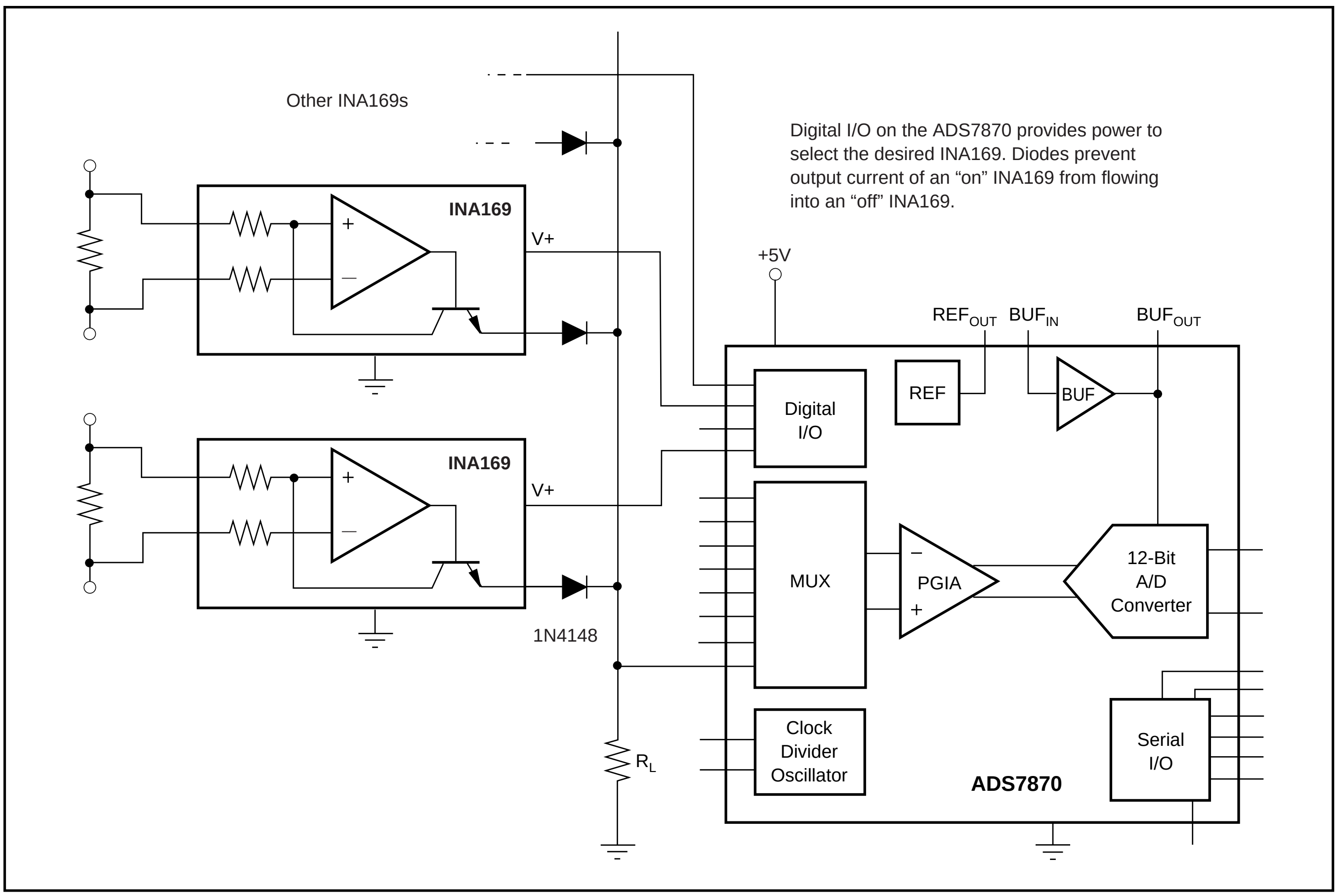
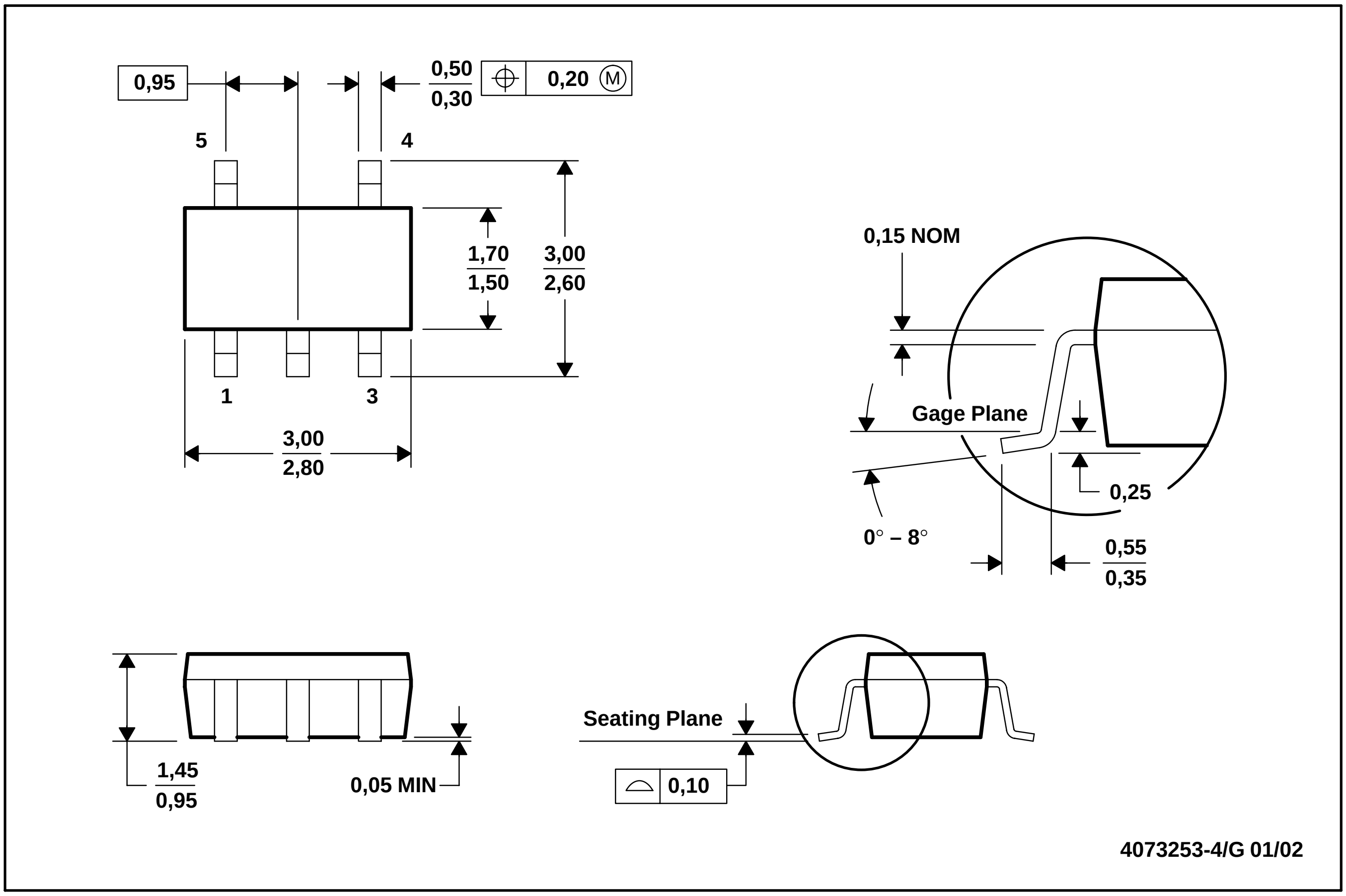


FIGURE 7. Multiplexed Measurement Using Logic Signal for Power.

DBV (R-PDSO-G5) **PLASTIC SMALL-OUTLINE**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO-178

IMPORTANT NOTICE

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