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APPLICATION BULLETIN
Mailing Address: PO Box 11400, Tucson, AZ 85734 • Street Address: 6730 S. Tucson Blvd., Tucson, AZ 85706 • Tel: (520) 746-1111
Telex: 066-6491 • FAX (520) 889-1510 • Product Info: (800) 548-6132 • Internet: www.burr-brown.com/ • FAXLine: (800) 548-6133

PRECISION ABSOLUTE VALUE CIRCUITS

By David Jones (520) 746-7696, and Mark Stitt

You can build a precision absolute value circuit using two op amps and two precision resistors. If you use an op amp and an IC difference amplifier, no user supplied precision resistors or resistor adjustments are required. Circuits shown are suitable for precision split supply operation and for single-supply operation. When used with a rail-to-rail op amp, the single supply circuit can approach a 0 to 5V full-wave rectified output from a ±5V input when operating from a single +5V power supply.

The circuit shown in Figure 1 is a split supply circuit preferred when high input impedance is desired. To understand how the circuit works, notice that for positive input signals D_1 becomes reverse biased resulting in the active circuit fragment shown in Figure 2. A_1 drives the non-inverting input of A_2 through forward biased diode D_2. The feedback to the inverting inputs of A_1 and A_2 is from the output of A_2 through resistors R_1 and R_2. Since no current flows through resistors R_1 or R_2, in this condition, V_{OUT} is precisely equal to V_{IN}.

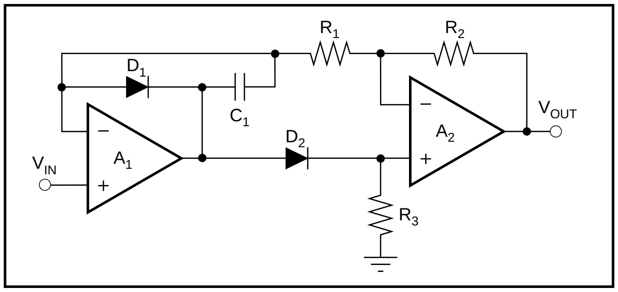

FIGURE 1. Precision Absolute Value Amplifier has High Input Impedance and Requires Only Two Matched Resistors.

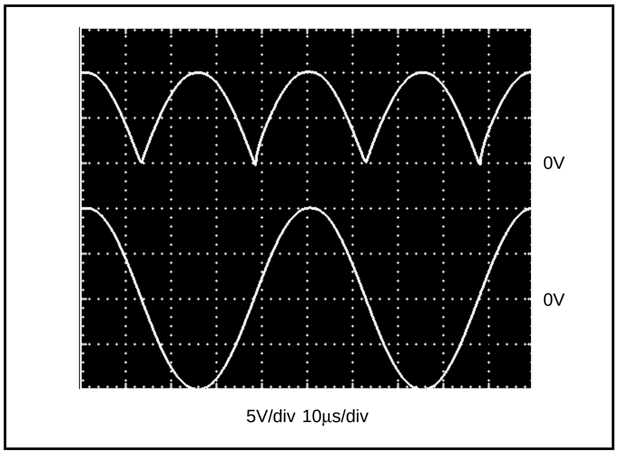

FIGURE 1.1. The Circuit Shown in Figure 1 Shows Good Performance at 20kHz with a ±10V Sine Wave Input. The slight distortion on the leading edge of the rectified output waveform results from the slew of A_1 as it transitions from forward biasing diode D_1 to forward biasing diode D_2. This example uses an OPA2132 high-speed FET input dual op amp operating from ±15V power supplies.

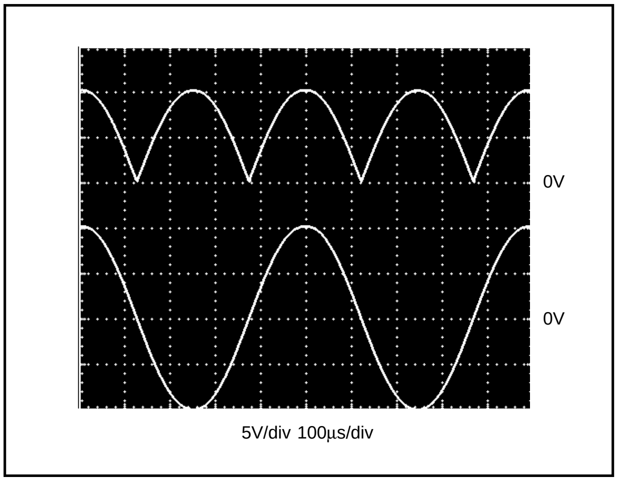

FIGURE 1.2. No Distortion is Visible in the Output Waveform of the Figure 1 Circuit When the Input Bandwidth is Reduced to 2kHz. Other conditions and components are the same as in Figure 1.1.

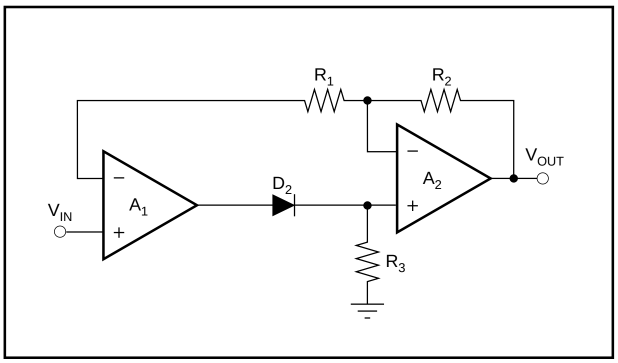

FIGURE 2. Positive Input Voltages to the Figure 1 Circuit Result in This Circuit Fragment. The circuit operates as a precision unity gain voltage follower. No errors are produced by the forward-biased diode, D_2, or the resistors.

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When the input voltage to the absolute value amplifier shown in Figure 1 becomes negative, D_2 becomes reverse biased resulting in the active circuit fragment shown in Figure 3. A_1 drives R_1 through forward biased diode D_1 to a voltage equal to V_{IN}. A_2, R_1, and R_2 form a simple unity gain inverting amplifier. R_1 and R_2 must be carefully matched to provide accurate gain = –1V/V to match the +1V/V gain for a positive input signal. Compensation capacitor C_1 ensures the circuit is stable with A_2 in the feedback loop. For good stability and best speed, set the $C_1 \bullet R_1$ pole equal to about 1/4 the unity gain bandwidth of A_2.

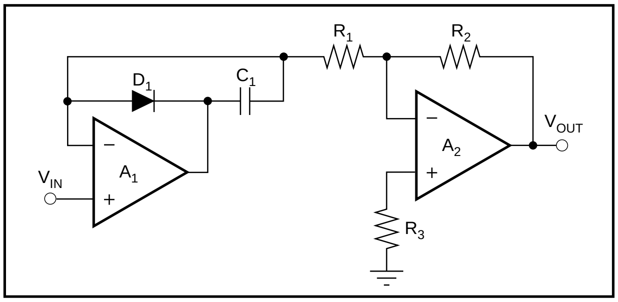

FIGURE 3. Negative Input Voltages to the Figure 1 Circuit Result in This Circuit Fragment. The circuit operates as a simple inverting amplifier. Resistors R_1 and R_2 must be matched to achieve a precise gain of –1V/V.

You can use a monolithic difference amplifier in place of A_2, R_1, and R_2 to eliminate expensive matched resistors or resistor trimming. The circuit using a difference amplifier is shown in Figure 4.

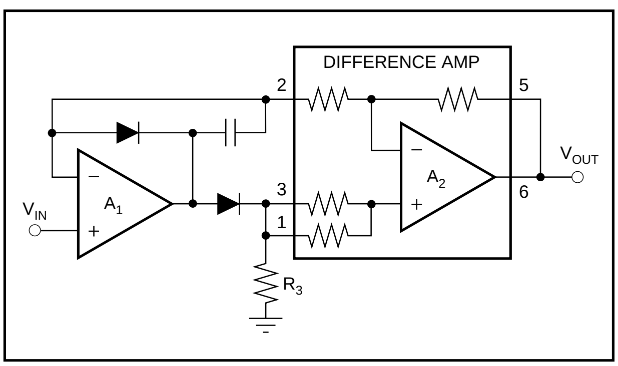

FIGURE 4. Building the Figure 1 Circuit With a Precision Difference Amplifier IC Eliminates the Need for User Supplied Precision Resistors or Resistor Trimming.

The circuit shown in Figure 5 may be preferred for single supply applications. The previous circuits operate with a series diode in the signal path. Although feedback eliminates any error due to the diode, the voltage drop reduces the potential dynamic range of the circuit by the diode drop voltage. In the Figure 5 circuit, the diode is not in the signal path and does not reduce dynamic range. In fact, the Figure 5 circuit can provide full signal range within the limits of the op amp. Since the inverting amplifier input can operate below the power supply rail, the circuit can actually accommodate negative input voltages!

Figure 5 circuit operation is similar to the previous circuits. For positive inputs, the diode is reverse biased and has no influence on the circuit. A_2, R_1, R_2, and R_3 operate as a precision voltage follower as described previously except that A_2 is driven by resistor R_3 instead of the forward biased diode. For this circuit to operate properly, the inputs of A_1 must remain high impedance within the entire operating range of the absolute value circuit. And, of course, the op amp outputs must swing to the negative power supply rail on input and output without phase inversion. This condition is satisfied by many CMOS, JFET, and some bipolar-input op amps—see op amp recommendation table.

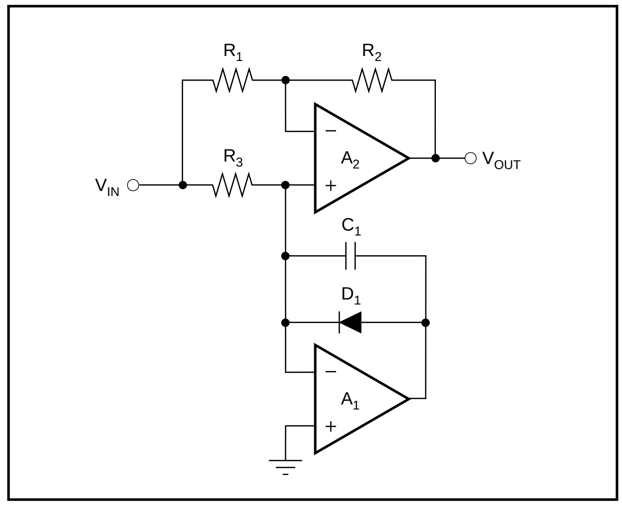

FIGURE 5. This Precision Absolute Value Circuit is Well Suited for Single-supply Circuits.

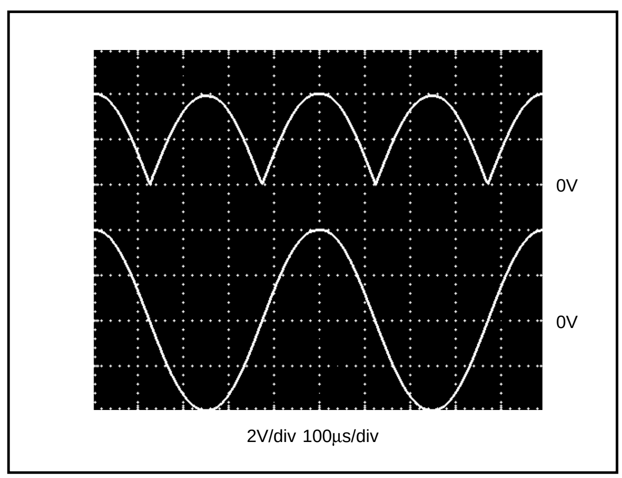

FIGURE 5.1. The Circuit Shown in Figure 5 Shows Excellent Performance at 2kHz with a ±4V Sine Wave Input. This example uses an OPA2340 CMOS op amp operating from a single +5V power supply. Notice that the input range of the circuit is 4V below the power supply rail.

When the input voltage to the absolute value amplifier shown in Figure 5 becomes negative, the diode is forward biased holding the non-inverting input of A_2 at virtual ground. A_2, R_1 and R_2 form a simple unity-gain inverting amplifier as before.

Also, as before, you can use a monolithic difference amplifier in place of A_2, R_1, and R_2 to eliminate the need to purchase expensive matched resistors or trim resistors. The circuit using a difference amplifier is shown in Figure 6.

Various op amps and difference amplifiers can be used for absolute value amplifiers depending on the application. Table I shows amplifier recommendations for selected applications.

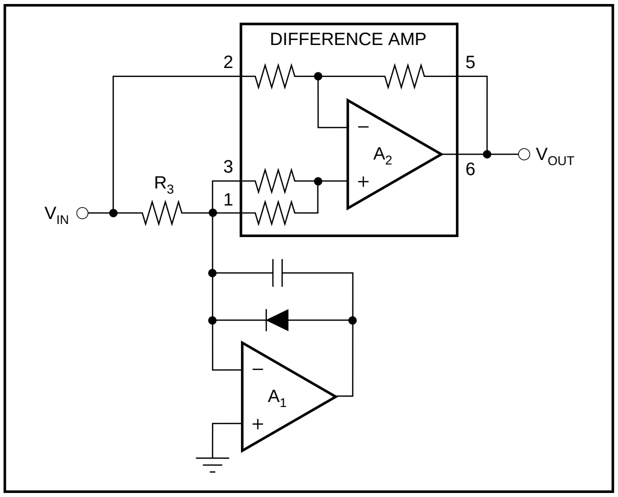

FIGURE 6. Building the Figure 5 Circuit With a Precision Difference Amplifier IC Eliminates the Need for User Supplied Precision Resistors or Resistor Trimming.

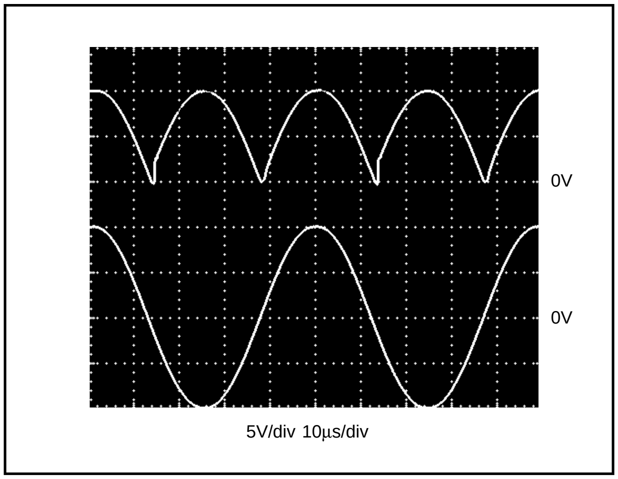

FIGURE 6.1. Figure 5 and Figure 6 Circuits Can Also be Used with Split Supplies with the Advantage of Improving Dynamic Range by Eliminating the Forward Diode Drop of the Figure 1 Circuit. However, A_2 must recover from saturation to the negative power supply rail before the circuit can accurately process negative input signals. This example uses an OPA134 high-speed op amp and an INA134 audio difference amplifier operating from ±15V power supplies with a 20kHz ±10V input.

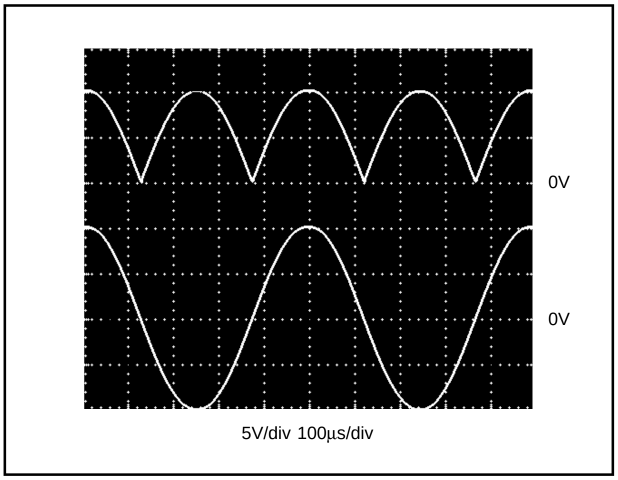

FIGURE 6.2. No Distortion is Visible in the Figure 6 Circuit When the Input Bandwidth is Reduced to 2kHz. Other conditions are the same as in Figure 6.1.

A_1	A_2	R_1, R_2 (Ω)	R_3 (Ω)	C_1 (pF)	SINGLE SUPPLY (V)	SPLIT SUPPLY (V)	CIRCUIT FIGURE	APPLICATION
1/2 OPA2237	1/2 OPA2237	10k	10k	100	—	±1.35 – ±18	1	Low Cost, High Z_{IN}
1/2 OPA2237	1/2 OPA2237	10k	10k	—	2.7 – 36	±1.35 – ±18	5	Lowest Cost, $V_S > 5V$
OPA237	INA132	(1)	10k	22	2.7 – 36	±1.35 – ±18	4 or 6	Above circuits with no precision resistors.
1/2 OPA2277	1/2 OPA2277	10k	10k	100	—	±3 – ±22	1	Best Precision, High Z_{IN}
OPA277	INA132	(1)	10k	22	—	±3 – ±18	4	Above circuit with no precision resistors.
1/2 OPA2130	1/2 OPA2130	100k	100k	22	—	±2.25 – ±18	1	Low Power, FET Input
OPA130	INA132	(1)	10k	22	—	±2.25 – ±18	4	Above circuit with no precision resistors.
1/2 OPA2132	1/2 OPA2132	10k	10k	47	—	±4.5 – ±18	1	High Speed, FET Input
OPA134	INA134	(1)	2k	22	—	±4.5 – ±18	4	Above circuit with no precision resistors.
1/2 OPA2336	1/2 OPA2336	1M	1M	—	2.3 – 5.5	—	5	Micropower
OPA336	INA132	(1)	100k	—	2.7 – 5.5	—	6	Above circuit with no precision resistors
1/2 OPA2337	1/2 OPA2337	100k	100k	—	2.7 – 5.5	—	5	Lowest Cost
OPA337	INA132	(1)	10k	—	2.7 – 5.5	—	6	Above circuit with no precision resistors
1/2 OPA2340	1/2 OPA2340	10k	10k	—	2.7 – 5.5	—	5	High Speed, Rail-to-Rail
OPA340	INA132	(1)	10k	—	2.7 – 5.5	—	6	Above circuit with no precision resistors.

NOTE: (1) Precision resistors are internal to the difference amplifier.

TABLE I.