

## AC COUPLING INSTRUMENTATION AND DIFFERENCE AMPLIFIERS

### FEATURING CIRCUITS FOR:

**INA117  $\pm 200V$  DIFFERENCE AMPLIFIER • INA106-BASED  $\pm 100V$  DIFFERENCE AMPLIFIER • INA105 AND INA106  $G = 1, 10$  DIFFERENCE AMPLIFIERS • INA101, INA102, INA103, INA110, INA120 INSTRUMENTATION AMPLIFIERS**

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The need to glean AC signals from DC in the presence of common-mode noise frequently occurs in signal conditioning applications. AC coupling to an instrumentation amplifier (IA) or difference amplifier can be used to accurately extract the AC signal while rejecting DC and common-mode noise.

Adding capacitors and resistors to AC couple the inputs of an instrumentation amplifier or difference amplifier seems like an obvious approach for AC coupling, but it has problems. The DC restoration circuits shown in this bulletin have the same transfer function but without the foibles.

Common-mode rejection of a difference amplifier depends on extremely precise matching of input source impedance. Adding RC networks to the inputs of either an IA or a difference amplifier can significantly degrade the CMR, especially for AC inputs. Even if the CMR is trimmed, maintaining performance over temperature can be a problem.

The DC restoration circuits shown solve this problem by placing a low-pass network in the feedback to the reference pin of the IA or difference amplifier. The low-pass pole translates into a high-pass function as referred to the input with  $f_{-3dB} = \text{Gain}/2\pi \cdot R \cdot C$ . The Gain term refers to the Gain from the reference pin to the output of the IA or difference amplifier. The selection guide shows this Gain term as the "High-pass multiplier".

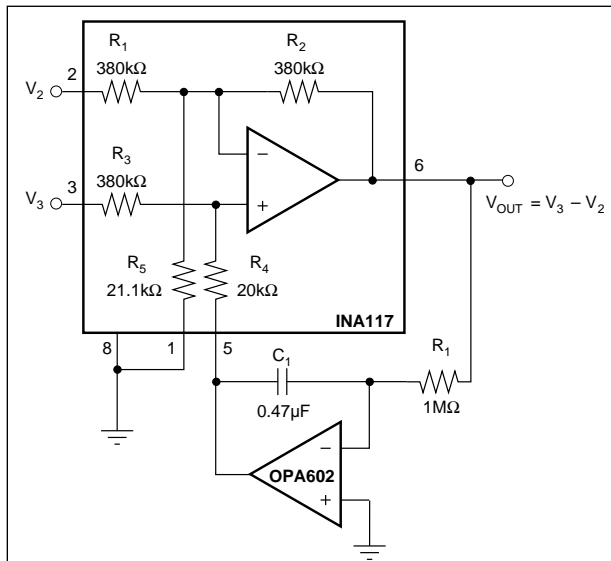


FIGURE 1. AC-Coupled INA117.

The DC-restored INA117 is shown in Figure 1. With the values shown, the high-pass zero is  $\approx 6.5\text{Hz}$ .

The INA117BM has a CMR of 86dB min. If improved CMR is required for the DC restored INA117, use the circuit shown in Figure 2. Since the trim resistors are small, they will not degrade the stability or drift performance of the INA117.

The INA117 has a common-mode input range and differential offset range of up to  $\pm 200V$ . If a lower common-mode and differential offset range of  $\pm 100V$  is acceptable, the INA106 can be used for lower noise and twice the small signal bandwidth (400kHz vs 200kHz).

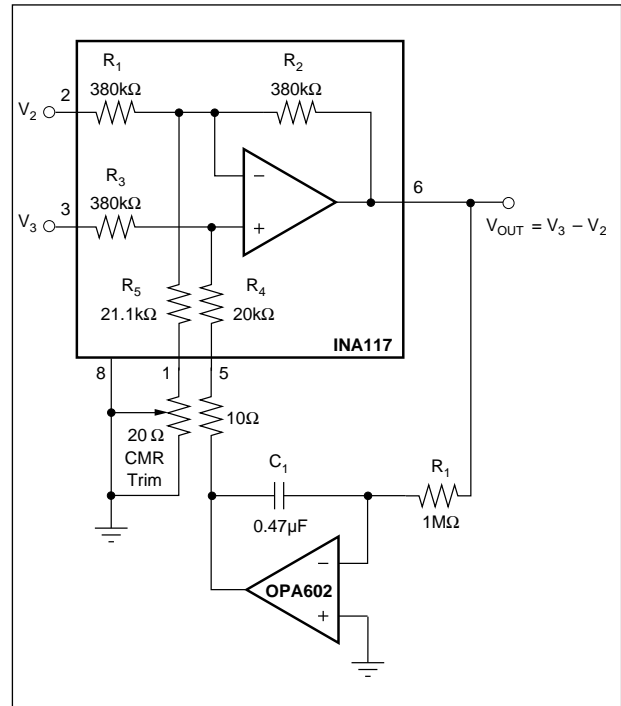


FIGURE 2. AC-Coupled INA117 with CMR Trim.

The simplest circuit for the DC-restored INA106 is shown in Figure 3. The INA106 is reversed from its normal Gain-of-10 configuration. The  $100k\Omega$ ,  $10k\Omega$  resistors form a 11/1 voltage divider on the input so that  $\pm 100V$  at pins 1 and 5 are divided down to less than  $\pm 10V$  at the op amp inputs. The  $R_5$ ,  $R_6$  network provides the proper feedback Gain for an overall unity-gain transfer function. Since the precise resistor matching of the INA106 is disturbed by the  $R_5$ ,  $R_6$  network this circuit requires trims for both CMR and Gain.

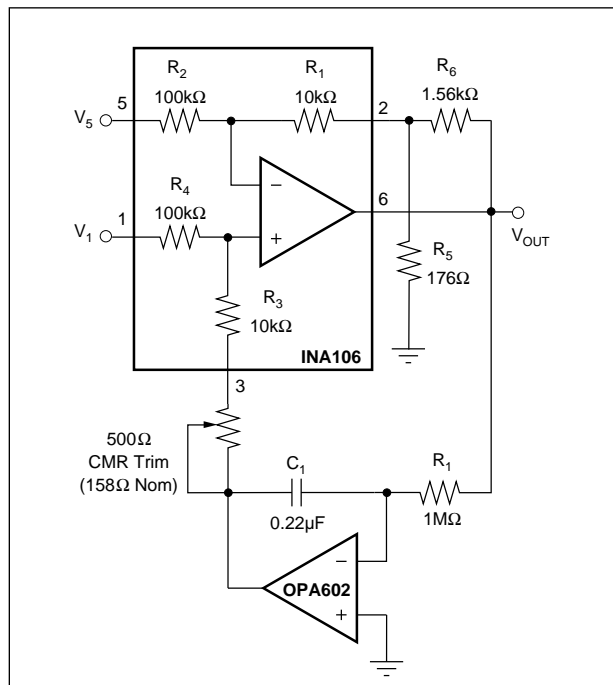


FIGURE 3. AC-Coupled  $\pm 100\text{V}$  Difference Amp Using the INA106.

Furthermore, Gain and CMR adjustments using  $R_5$ ,  $R_6$ , and the  $500\Omega$  trim pot connected to pin 3 are interactive. The excellent CMR stability vs time and temperature of the INA106 is preserved since the added trim resistors are small.

If you want to use the INA106 for a  $\pm 100\text{V}$  DC-restored difference amplifier without any trims, use the circuit shown in Figure 4. Gain is set directly by the  $R_5$ ,  $R_6$  divider. The buffer amplifier,  $A_2$ , presents a low impedance to the feedback resistor in the INA106 to preserve resistor matching and CMR.

## SELECTION GUIDE

(AC-coupled difference and instrumentation amplifiers)

$V_s = \pm 15\text{V}$

MODEL	GAIN [V/V]	COMMON MODE INPUT RANGE [V]	DIFFERENTIAL OFFSET RANGE [V]	NOISE (RTI) [ $\text{nV}/\sqrt{\text{Hz}}$ ]	BANDWIDTH (-3dB) [Hz]	HIGH PASS MULTIPLIER (See Text)
INA117	1	$\pm 200$	$\pm 200$	550	200k	19
INA106 <sup>(1)</sup>	1	$\pm 100$	$\pm 100$	300	400k	10
INA105	1	$\pm 20$	$\pm 10$	60	1M	1
INA106	10	$\pm 11$	$\pm 1$	30	500k	1
INA101 INA102 INA103 INA110 INA120	<sup>(2)</sup>	$\pm 7$ <sup>(3)</sup>	$\pm 10$	1 <sup>(2)</sup>	6M <sup>(2)</sup>	1

NOTES (1) Reverse-connected, see figures 3,4, and 5. (2) Gain is adjustable from 1 to 1000+. Noise and bandwidth depend on Gain setting. INA103 has the lowest noise:  $1\text{nV}/\sqrt{\text{Hz}}$ , Gain = 1000. INA103 has the highest bandwidth: 6MHz, Gain = 1. INA102 is low power ( $750\mu\text{A}$  max). INA110 has FET inputs ( $I_b = 50\text{pA}$  max). INA101 has lowest drift ( $.25\mu\text{V}/^\circ\text{C}$  max). INA120 is a lower IQ INA101 with internal resistors for Gains of 1, 10, 100, and 1000. (3) Yes!, the common-mode input range of standard IAs is only about  $\pm 7\text{V}$  with  $\pm 10\text{V}$   $V_{\text{OUT}}$ ; see "Extended Common-Mode Instrument Amps", *Electronic Design*, December 22, 1988, pp 67, 68.

When using the DC restored  $\pm 100\text{V}$  difference amplifier shown in Figure 4, no trims are required for good CMR. However, the circuit shown in Figure 5 may be used to fine trim CMR if desired. Since the added trim resistors are small, they will not degrade the stability or drift of the INA106.

DC restoration can be used with any of the standard IAs shown in the table using the same technique as shown in Figure 6. Since all of these IAs use unity-Gain difference amplifiers, the high-pass multiplier is unity.

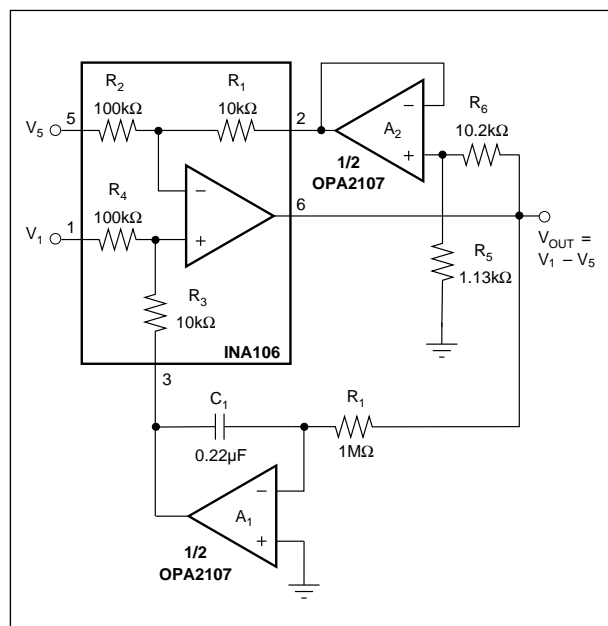


FIGURE 4. AC-Coupled  $\pm 100\text{V}$  Difference Amp Using the INA106 Requires No Trims.

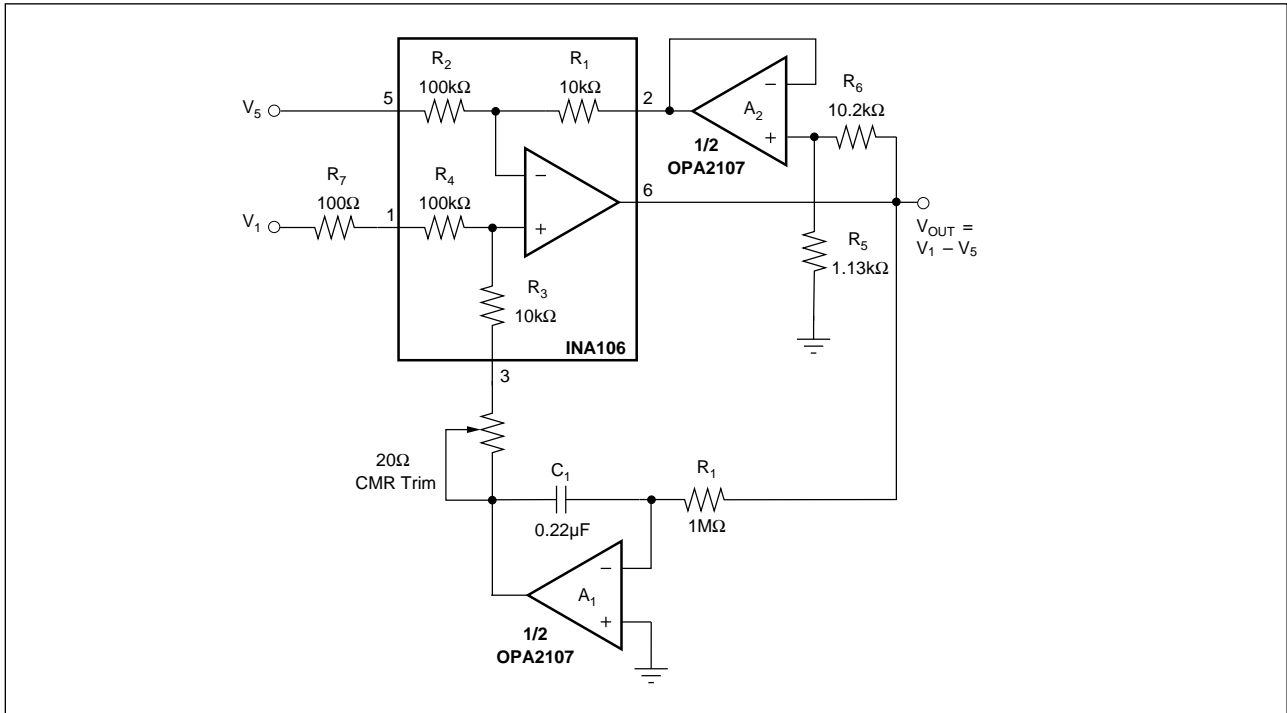


FIGURE 5. AC-Coupled ±100V Difference Amp Uses the INA106. Has CMR Trim.

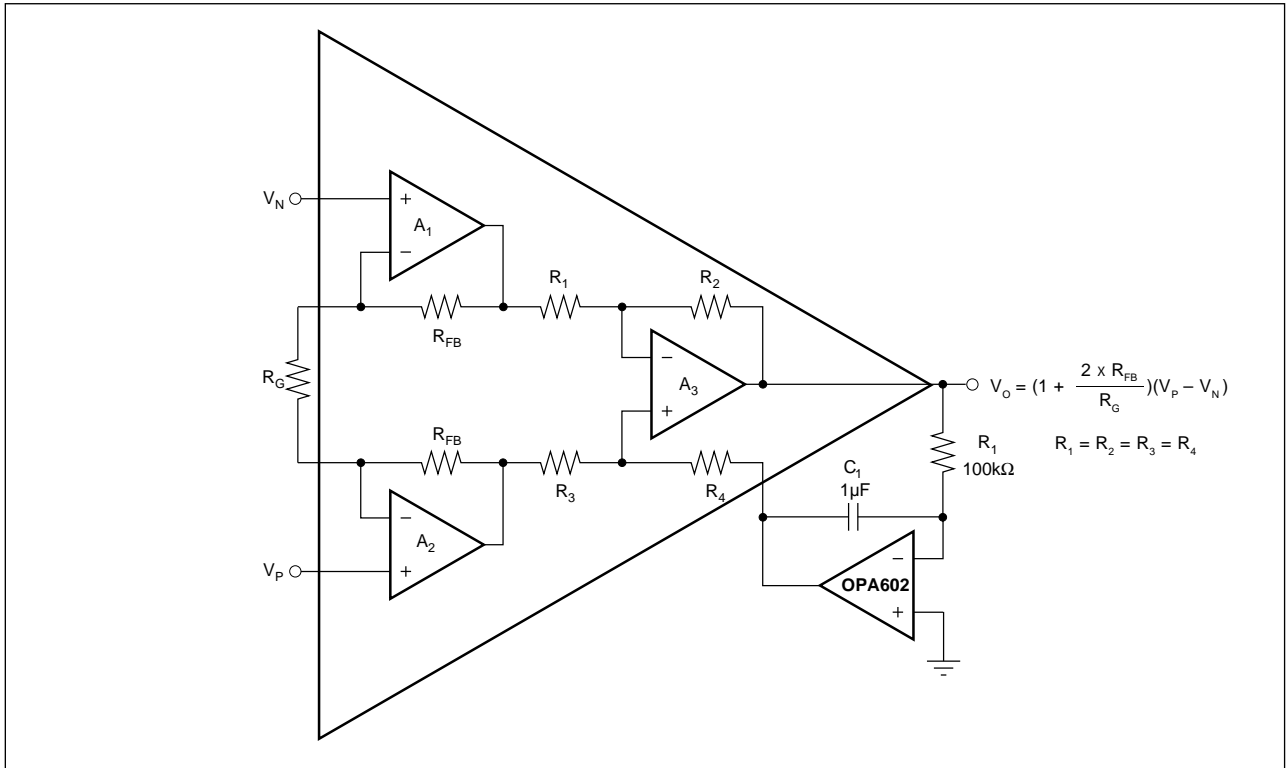


FIGURE 6. General AC-Coupled IA Circuit

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