ANALOG DEVICES

AN-692
APPLICATION NOTE

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Universal Precision Op Amp Evaluation Board

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INTRODUCTION

The EVAL-PRAOPAMP evaluation board accommodates single op amps in many packages. It is meant to provide the user with multiple choices and extensive flexibility for different applications circuits and configurations. For evaluation in smaller packages, we currently have boards available that will accommodate the following packages: SOIC, MSOP, SC-70, and SOT-23. For more information regarding layouts and schematics for board-specific packages, please refer to the following application notes: AN-732 (SOIC), AN-733 (MSOP), AN-734 (SC-70), and AN-735 (SOT-23). This board is not intended to be used with high frequency components or high speed amplifiers; however, it provides the user with many combinations for various circuit types including active filters, difference amplifiers, and external frequency compensation circuits. A few examples of application circuits are given in this application note.

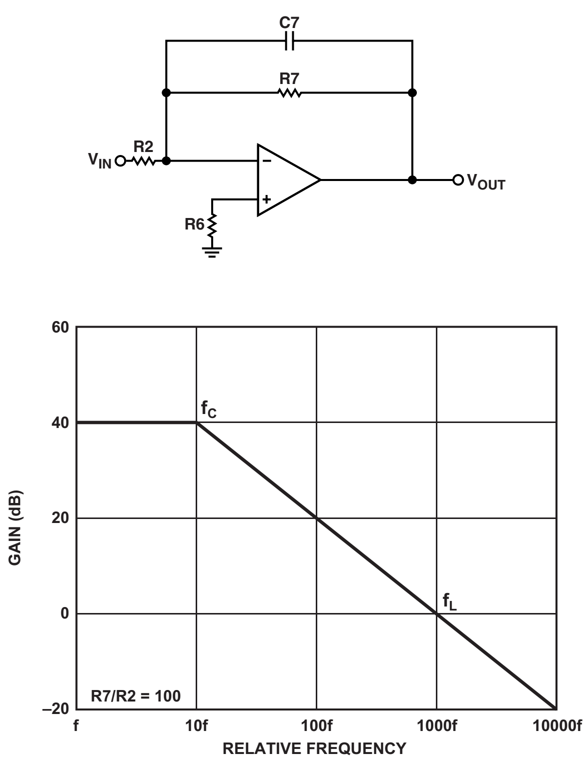

Figure 1. Simple Low-Pass Filter

LOW-PASS FILTER

Figure 1 is a typical representation of a first order low-pass filter. This circuit has a 6 dB per octave roll-off after a close loop –3 dB point defined by f_C. Gain below this frequency is defined as the magnitude of R7 to R2. The circuit might be considered as an ac integrator for frequencies well above f_C; however, the time domain response is that of a single RC, rather than an integral.

$f_C = 1/(2\pi \times R7 \times C7)$; –3 dB *frequency*

$f_L = 1/(2\pi \times R2 \times C7)$; *unity gain frequency*

$Acl = -(R7/R2)$; *close loop gain*

R6 should be chosen equal to the parallel combination between R7 and R2 in order to minimize errors due to bias currents.

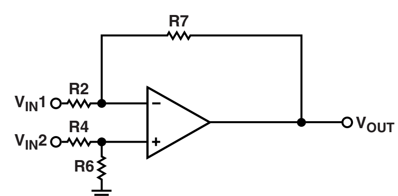

Figure 2. Difference Amplifier

DIFFERENCE AMPLIFIER AND PERFORMANCE OPTIMIZATION

Figure 2 shows an op amp configured as a difference amplifier. The difference amplifier is the complement of the summing amplifier and allows the subtraction of two voltages or the cancellation of a signal common to both inputs. The circuit shown in Figure 2 is useful as a computational amplifier, in making a differential to single-ended conversion or in rejecting a common-mode signal. The output voltage V_{OUT} may be thought as being made up of two separate components:

1. A component $V_{OUT}1$ due to $V_{IN}1$ acting alone ($V_{IN}2$ short-circuited to ground.)
2. A component $V_{OUT}2$ due to $V_{IN}2$ acting alone ($V_{IN}1$ short-circuited to ground.)

The algebraic sum of these two components should be equal to V_{OUT}. By applying the principles expressed in bullets 1 and 2 and by letting R4 = R2 and R7 = R6, then:

$V_{OUT}1 = V_{IN}1\ R7/R2$

$V_{OUT}2 = -V_{IN}2\ R7/R2$

$V_{OUT} = V_{OUT}1 + V_{OUT}2 = (\ V_{IN}1 - V_{IN}2)\ R7/R1$

Difference amplifiers are commonly used in high accuracy circuits to improve the common-mode rejection ratio, typically known as CMRR.

For this type of application, CMRR depends upon how tightly matched resistors are used; poorly matched resistors result in a low value of CMRR.

To see how this works, consider a hypothetical source of error for resistor R7 (1 – error). Using the superposition principle and letting R4 = R2 and R7 = R6, the output voltage would be as follows:

$$V_{OUT} = \left\{ \frac{\left[\frac{R7}{R2}\left(1 - \frac{R2 + 2R7}{R2 + R7}\right) \times \frac{error}{2} \right]}{VD + \left(\frac{R7}{R2 + R7} \times error \right)} \right\}$$

$$V_{DD} = V_{IN}2 - V_{IN}1$$

From this equation, A_{CM} and A_{DM} can be defined as follows:

$A_{CM} = R7/(R7 - R2) \times error$

$A_{DM} = R7/R2 \times \{1 - [(R2+2R7/R2+R7) \times error/2]\}$

These equations demonstrate that when there is not an error in the resistor values, the A_{CM} = 0 and the amplifier responds only to the differential voltage being applied to its inputs; under these conditions, the CMRR of the circuit becomes highly dependent on the CMRR of the amplifier selected for this job.

As mentioned above, errors introduced by resistor mismatch can be a big drawback of discrete differential amplifiers, but there are different ways to optimize this circuit configuration:

1. The differential gain is directly related to the ratio R7/R2; therefore, one way to optimize the performance of this circuit is to place the amplifier in a high gain configuration. When larger values for resistors R7 and R6 and smaller values for resistors R2 and R4 are selected, the higher the gain, the higher the CMRR. For example, when R7 = R6 = 10 kΩ, and R2 = R4 = 1 kΩ, and error = 0.1%, CMRR improves to better than 80 dB. For high gain configuration, select amplifiers with very low I_{BIAS} and very high gain (such as the AD8551, AD8571, AD8603, and AD8605) to reduce errors.
2. Select resistors that have much tighter tolerance and accuracy. The more closely they are matched, the better the CMRR. For example, if a CMRR of 90 dB is needed, then match resistors to approximately 0.02%.

CURRENT-TO-VOLTAGE CONVERTER

Current may be measured in two ways with an operational amplifier. Current can be converted to a voltage with a resistor and then amplified, or current can be injected directly into a summing node.

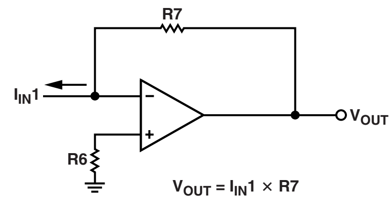

Figure 3. Current-to-Voltage Converter

Figure 3 is a typical representation of a current-to-voltage transducer. The input current is fed directly into the summing node and the amplifier output voltage changes to exactly the same current from the summing node through R7. The scale factor of this circuit is R7 volts per amps. The only conversion error in this circuit is I_{BIAS}, which is summed algebraically with $I_{IN}1$.

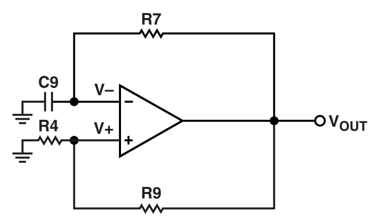

Figure 4. Bistable Multivibrator

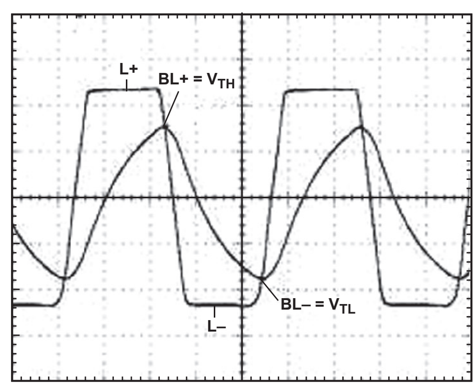

Figure 5. Output Response

GENERATION OF SQUARE WAVEFORMS USING BISTABLE MULTIVIBRATOR

A square waveform can be simply generated by arranging the amplifier for a bistable multivibrator to switch states periodically as Figure 5 shows.

Once the output of the amplifier reaches one of two possible levels, such as L+, capacitor C9 charges toward this level through resistor R7. The voltage across C9, which is applied to the negative input terminal of the amplifier denoted as V–, then rises exponentially toward L+ with a time constant τ = C9R7. Meanwhile, the voltage at the positive input terminal of the amplifier denoted as V+ = BL+. This continues until the capacitor voltage reaches the positive threshold V_{TH}, at which point the bistable multivibrator switches to the other stable state in which V_O = L– and V+ = BL–. This is shown in Figure 5.

The capacitor then begins to discharge, and its voltage, V–, decreases exponentially toward L–. This continues until V– reaches the negative threshold V_{TL}, at which time the bistable multivibrator switches to the positive output state, and the cycle repeats itself.

It is important to note that the frequency of the square wave being generated, f_O, depends only on the external components being used. Any variation in L+ will cause V+ to vary in proportion, ensuring the same transition time and the same oscillation frequency. The maximum operating frequency is determined by the amplifier speed, which can be increased significantly by using faster devices.

The lowest operating frequency depends on the practical upper limits set by R7 and C9.

Using the name convention outlined on the PRA OPAMP evaluation board, the circuit should be connected as follows:

B = R4/(R4 + R9); feedback factor (noninverting input)

T = 2R7 × C9 × ln((1 + B)/(1 – B)); period of oscillation

f_O = 1/T; oscillation frequency

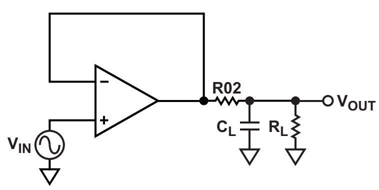

Figure 6. Series Resistor Compensation

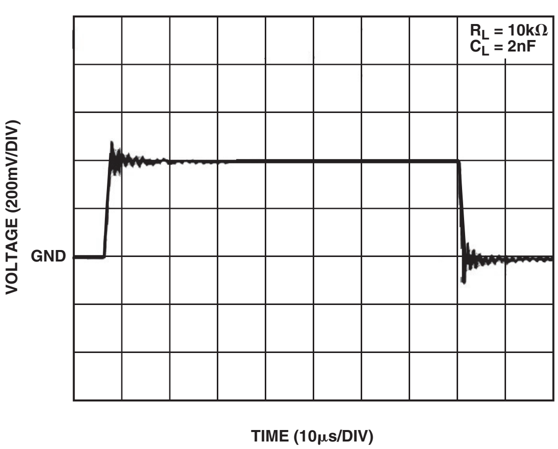

Figure 7. Capacitive Load Drive Without Resistor

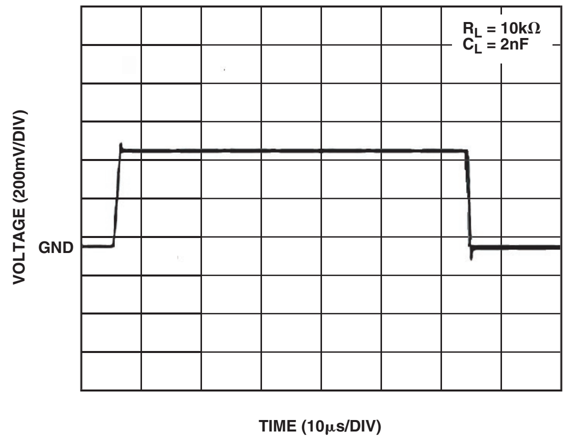

Figure 8. Capacitive Load Drive with Resistor

EXTERNAL COMPENSATION TECHNIQUES

Series Resistor Compensation

The use of external compensation networks may be required to optimize certain applications. Figure 6 is a typical representation of a series resistor compensation for stabilizing an op amp driving capacitive load. The stabilizing effect of the series resistor can be thought of as a means of isolating the op amp output and the feedback network from the capacitive load. The required amount of series resistance depends on the part used, but values of 5 Ω to 50 Ω are usually sufficient to prevent local resonance. The disadvantages of this technique are a reduction in gain accuracy and extra distortion when driving nonlinear loads.

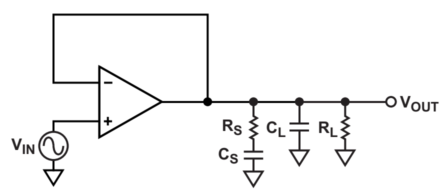

Figure 9. Snubber Network

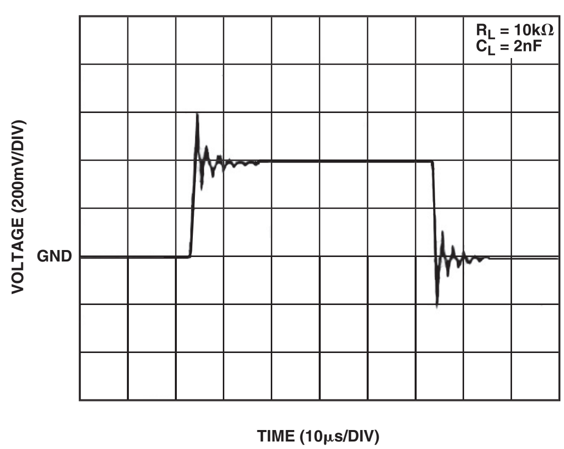

Figure 10. Capacitive Load Drive Without Snubber

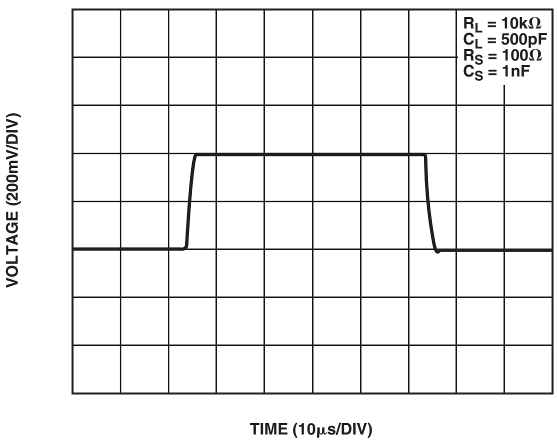

Figure 11. Capacitive Load Drive with the Snubber

Snubber Network

Another way to stabilize an op amp driving a capacitive load is with the use of a snubber, as shown in Figure 9. This method presents the significant advantage of not reducing the output swing because there is not any isolation resistor in the signal path. Also, the use of the snubber does not degrade the gain accuracy or cause extra distortion when driving a nonlinear load. The exact R_S and C_S combinations can be determined experimentally.

Adapters for specific packages can be found at the following URLs:

www.enplas.com
www.adapters.com
www.emulation.com

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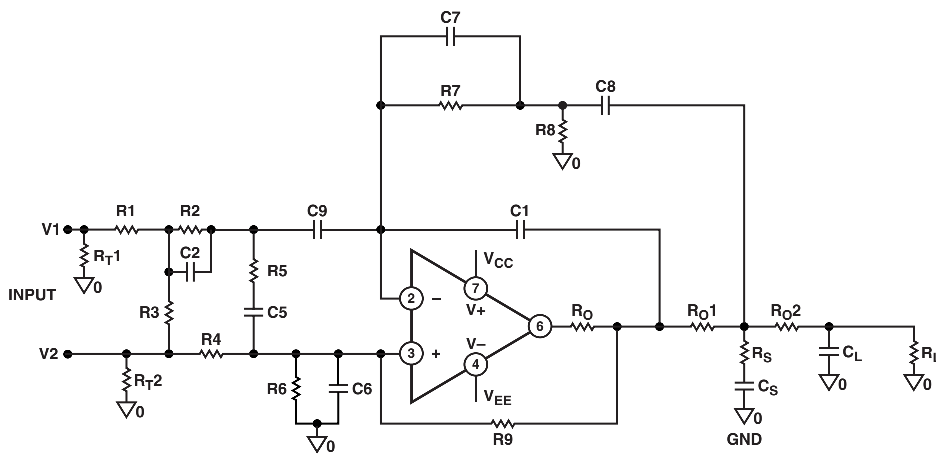

Figure 12. EVAL-PRAOPAMP Electrical Schematic

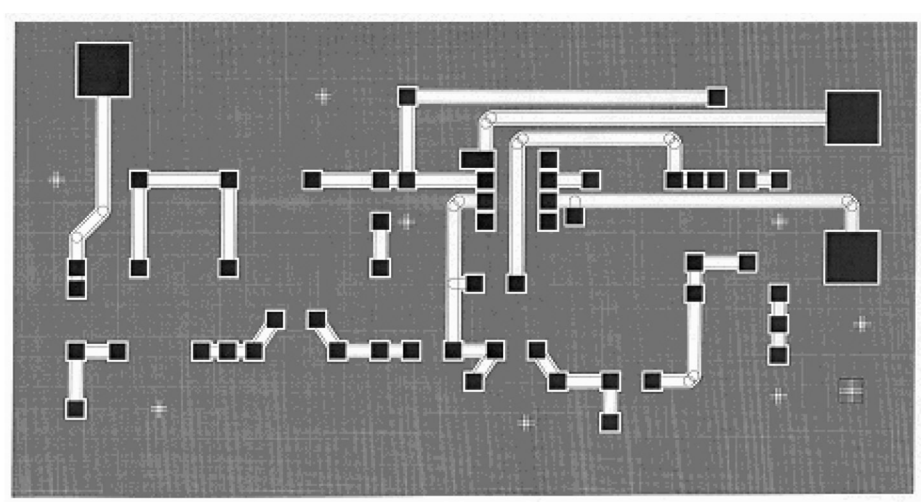

Figure 13. EVAL-PRAOPAMP Board Layout Patterns