Experiment 2
OP AMPs - A Basic Analog Building Block

Introduction

The purpose of this experiment is to explore several basic operational amplifier circuits. An industry-standard OP-AMP - the '741 - will be used with one or two 15-V power supplies.

Equipment Needed

This experiment requires the use of a function generator and an oscilloscope having dual-trace and X-Y capability . The IEEE-488 interface to the scope will be used to record waveform data and X-Y plots for use in the lab report. When asked to "record" a waveform, the student should use the "Benchlink" software to copy an image of the oscilloscope screen to a floppy disk, or his/her personal account, so that it can later be reproduced in the lab report. Be certain that all scale factors (vertical sensitivities, locations of zero-voltage baselines, and the horizontal time scale) are also preserved. The reference section of this lab manual contains a data sheet for the '741 OP-AMP.

Procedure

Construct the circuit of Fig. 1 using a "Protoboard." For best results, assign one bus on the Protoboard to be the ground bus, and run separate short wires from each grounded connection (including C1, C2, the signal source V_{in}, pin 3 of the OP-AMP, and scope ground leads) to this bus. Set the two dc power supplies for 15 V each, with their current limiters set for not too much more than 50 mA.

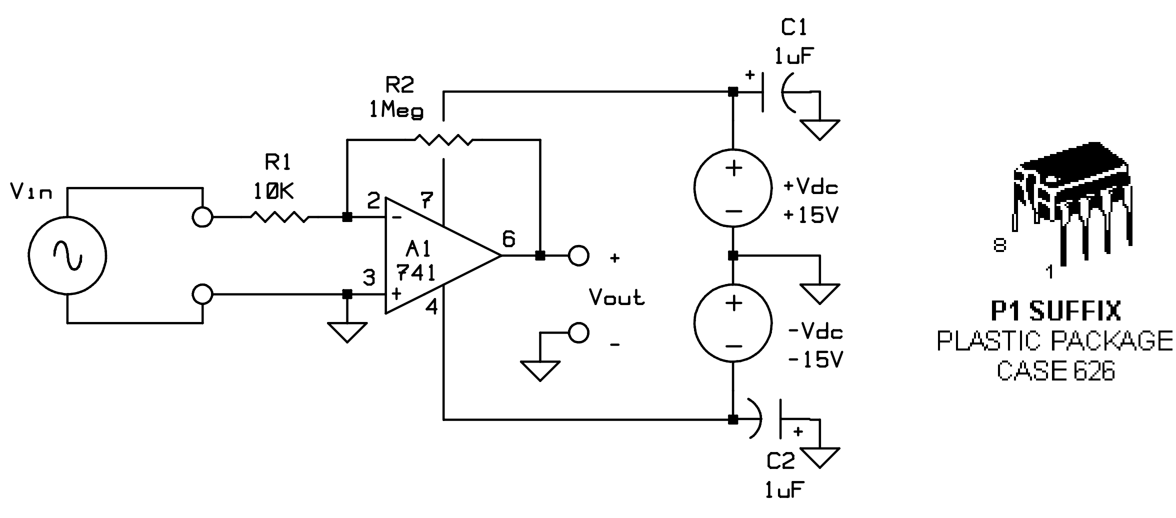

Fig. 1. Inverting amplifier.

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1. Set the function generator to produce a 1-kHz 100-mV p-p sine wave with zero dc offset and apply this to the input named "V_{in}." Monitor both V_{in} and V_{out} with the dual trace oscilloscope. View the two waveforms on the same time axis, and measure their peak-to-peak values. It is helpful to turn on the bandwidth limiter on channel 1 to reduce the high-frequency noise. Record the two waveforms. Calculate the voltage gain, defined to be the ratio of the amplitude of V_{out} to that of V_{in}.

2. Make careful measurements of the voltage gain at each of the following frequencies: 100 Hz, 1 kHz, and 10 kHz.

3. Increase the 100-Hz input amplitude gradually until there is distinct clipping occurring on both the upper and lower peaks of the output waveform. Record the two waveforms on the same time scale. Set the scope for its X-Y mode, and display V_{out} on the vertical axis, with V_{in} on the horizontal axis. Record the resulting X-Y plot of V_{out} *vs.* V_{in}.

4. Change the dc power supplies to +5 V and -15 V. Set the function generator for a 100-Hz 100-mV p-p sine wave with zero dc offset. Observe the amplifier input and output waveforms while gradually increasing the input amplitude until distinct clipping appears on both peaks of the output waveform. Record the resulting X-Y plot of V_{out} *vs.* V_{in}.

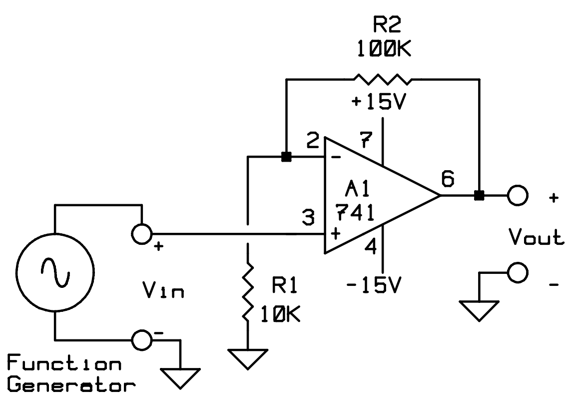

Fig. 2. Non-inverting amplifier.

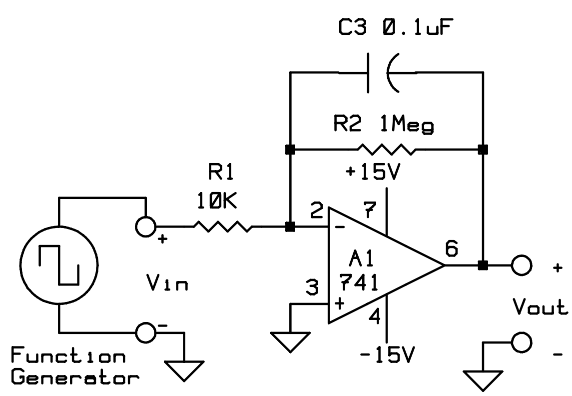

Fig. 3. Integrator with dc stabilization.

Construct the "non-inverting" amplifier shown in Fig. 2. Use both positive and negative 15-V power supplies with bypass capacitors as was done in Fig. 1. You will note that these power supplies are not shown explicitly in Fig. 2 (they seldom ever are).

1. Set the function generator to produce a 1-kHz 1-V p-p sine wave with zero dc offset and apply this to the input named "V_{in}." Monitor both V_{in} and V_{out} with the dual trace oscilloscope. View the two waveforms on the same time axis, and measure their

peak-to-peak values. Record the two waveforms. Calculate the voltage gain, defined to be the ratio of the amplitude of V_{out} to that of V_{in}.

Construct the integrator shown in Fig. 3, using both positive and negative 15-V power supplies. For C3, use a plastic- or paper-dielectric capacitor. (Do not use an electrolytic type.)

1. Set the function generator to produce a 1-kHz 20-V p-p square wave with zero dc offset. Monitor both V_{in} and V_{out} with the dual trace oscilloscope. View the two waveforms on the same time axis, and record them.

2. Short the two input terminals, and observe the zero-signal output with the dc voltmeter. Measure the dc output voltage (it should be close to, but not precisely equal to zero).

3. With zero input signal, disconnect the dc stabilization resistor R2 while monitoring the output voltage. Describe what happens.

Report

Your report should address the following:

1. Predict the ideal voltage gains of Figs. 1 and 2, based on an infinite-gain OP-AMP.
2. What is the distinction between the "inverting" and "non-inverting" configurations?
3. Discuss the maximum allowable output signal level in Fig. 1. What determines the saturation levels of V_{out} ?
4. Why is the measured gain of Fig. 1 frequency dependent?
5. Predict the ideal transfer function of Fig. 3 if R2 were omitted.
6. Why is the integrator output voltage not zero with zero input signal?
7. What happens when R2 is pulled? Why?

OP-AMPs actually have a finite gain which is frequency dependent. Fig. 4 gives a model for the '741 to be used in this report. Note that the gain-frequency product is about equal to 10^6, with the largest possible gain of 200,000 occurring at 5 Hz and lower.

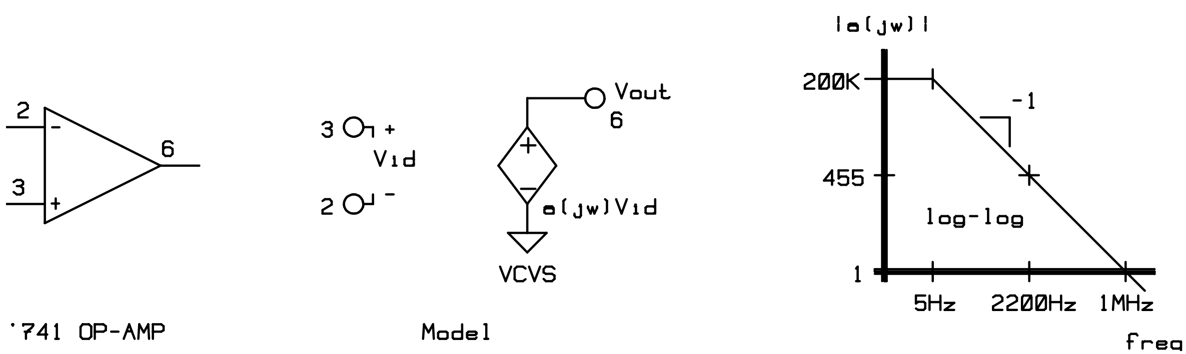

Fig. 4. Model of '741 OP-AMP as a differential amplifier with frequency-dependent gain.