

Lab 6: Op amps

Introduction

"A man's got to know his limitations."
- Inspector Harry Callahan, "Magnum Force"

Lab procedure - Op amps

1. Shown below is the basic circuit that forms the basis for this lab. Construct this circuit on your protoboard. R_a and R_b are of your choosing with the restriction that they be of same value and between 1 and 100K ohms. C2 and C3 are used to hold the IC to the ground plane. The TS358 should have its "wings" clipped as we did with the quad transistor IC package. The leads for C2 and C3 should be short, less than 0.5in.

V_{cc} , V_{ee} should have short (4in) flying leads to make a easily changed power connection to the IC. $V_{cc}/2$ should have a short flying lead that can be connected to or disconnected from the op amp.

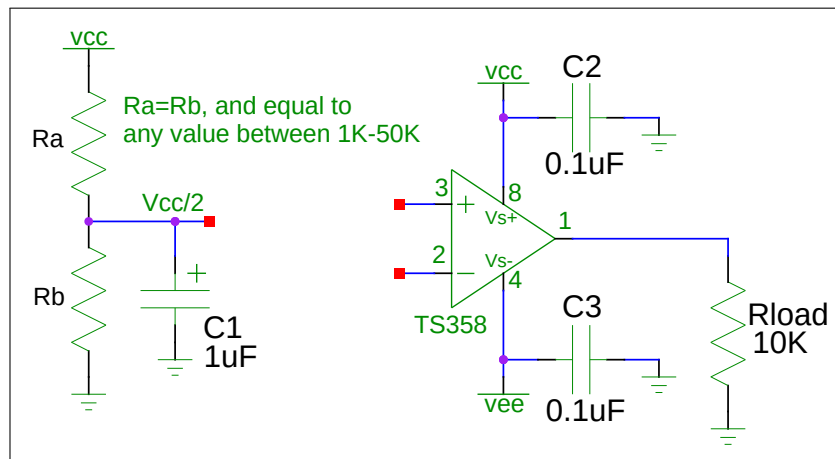


Figure 1: Basic Setup for op amp lab

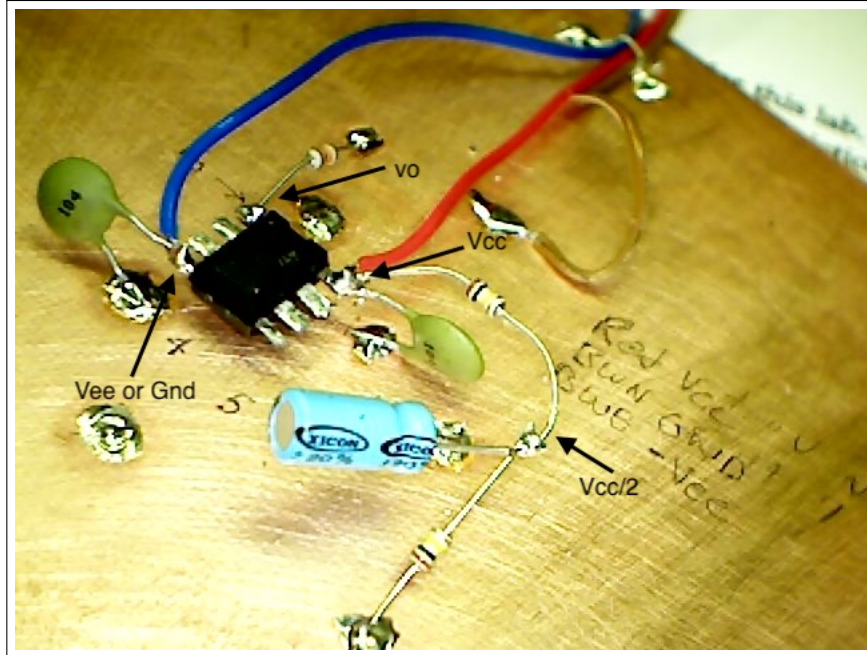


Figure 2: Basic Setup, Physical Layout

- Copy the schematic in Figure 3 into your lab notebook. From available lab parts determine values for R_1 and R_f that will create an amplifier with a gain between 2 and 5. Values for R_1 and R_2 (R_f) should be between 1K and 50K ohms.

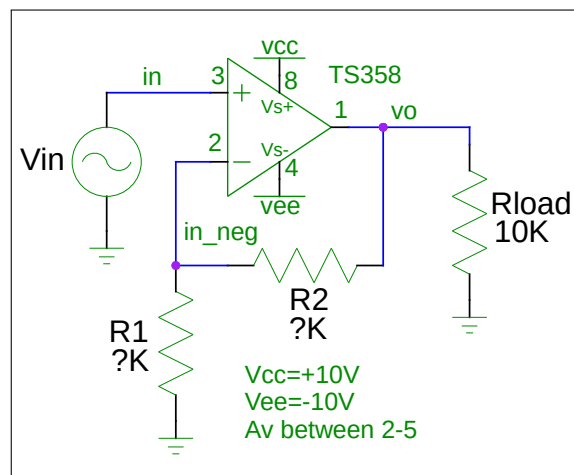


Figure 3: Non-inverting amplifier

Run a Ngspice simulation of the non-inverting amplifier and check its operation. You will need the subcircuit and spice files, [LM358.subckt](#), [opamp1.sp](#). Ignore the unrecognized parameter warnings from Ngspice. The spice file must be edited before it will run.

- (a) What gain did you calculate and what gain did you get?
 - (b) What waveform do you see at the op amp inverting input?
3. Now build this circuit on your protoboard.
4. The function generator must be set for a zero DC offset (knob at 12'o'clock position) because the op amp is DC coupled in this circuit. See figure 3. Set the generator for a 1Vpp input signal at 1Khz.



Figure 4: DC Offset Knob on Function Generator

The power supply must be connected for dual (plus and minus) supplies. This configuration is shown below.

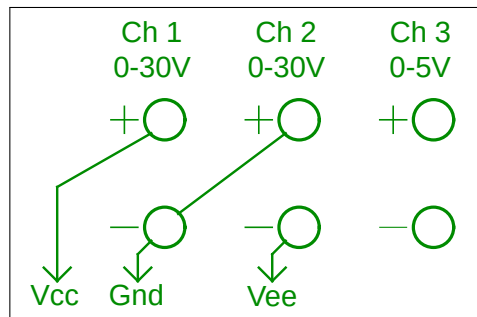


Figure 5: Power Supply Connection for dual supplies

- (a) Did you get the same gain as in simulation?
- (b) What waveform do you see at the inverting op amp input?
- (c) Capture the waveforms at nodes in and vo on the oscilloscope and store on a USB stick. Paste this into your lab notebook.

5. Copy the schematic into your lab notebook. Using the resistor values used with the non-inverting amplifier, design an inverting amplifier a gain roughly between -2 and -5. Modify the spice file from the non-inverting amplifier to make a new inverting amplifier spice file.
 - (a) Copy the modified spice file into your lab notebook. You only need to write out the netlist portion, not any simulation directives or other commands. Run a Ngspice simulation of the inverting amplifier below and check its operation. Ignore the unrecognized parameter warnings from Ngspice.

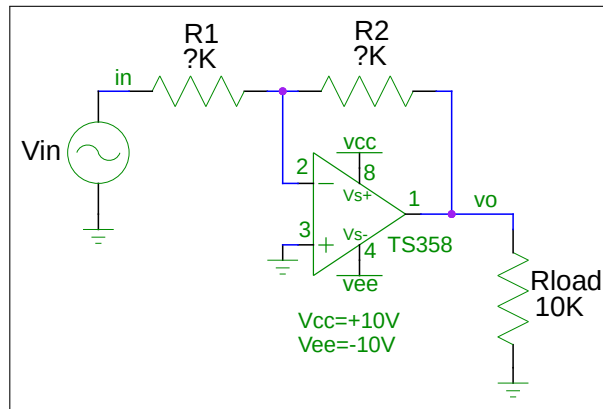


Figure 6: Inverting amplifier

- (b) What gain did you calculate and what gain did you get?
 - (c) What waveform do you see at the inverting op amp input?
6. Build the inverting amplifier on your protoboard and apply a 1Vpp input signal. The waveform generator must be set to have zero offset (knob at 12 o'clock position) because the op amp is DC coupled in this circuit.
 - (a) Did you get the same gain as in simulation?
 - (b) What waveform do you see at the inverting op amp input?
 - (c) Capture the waveforms at nodes in and vo on the oscilloscope and store on a USB stick. Paste this oscilloscope capture into your lab notebook.
7. Copy the schematic in Figure 7 into your lab notebook. With the resistor values used in the previous amplifiers, create a single-supply, inverting amplifier a gain roughly between -2 and -5.

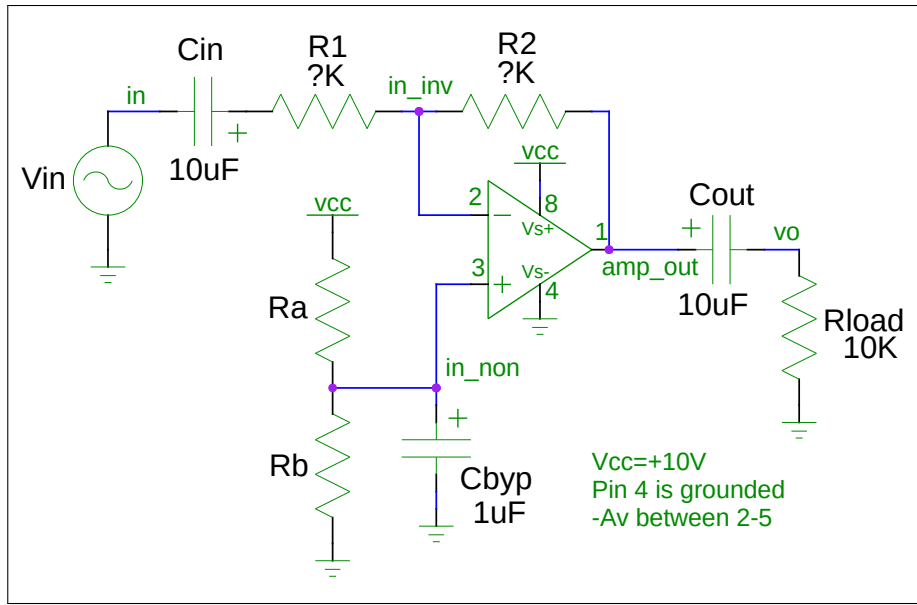


Figure 7: Single-Supply Inverting amplifier

Run a Ngspice simulation of the inverting amplifier below and check its operation. Modify the previous spice file to make this new one. Ignore the unrecognized parameter warnings from Ngspice.

- (a) What gain did you calculate and what gain did you get?
 - (b) What waveform do you see at the inverting op amp input?
8. Now build this circuit on your protoboard. Pin 4 of the op amp will be grounded this time, not connected to V_{ee} . Just put a short wire between pin 4 and the ground plane. The non-inverting input will be connected to the R_a , R_b voltage divider circuit previously built. Be sure to observe the polarity markings on the capacitors.

Apply a 1Vpp input signal. The waveform generator DC offset makes no difference in this case because the input is AC coupled.

- (a) Did you get the same gain as in simulation?
 - (b) What waveform do you see at the inverting op amp input?
 - (c) Without an input signal, what DC voltages are present at nodes in_inv , in_non , and amp_out ?
 - (d) Capture the waveforms at nodes in and vo on the oscilloscope and store on a USB stick. Paste this oscilloscope capture into your lab notebook.
9. Copy the schematic below into your lab notebook. This is called a precision rectifier circuit.

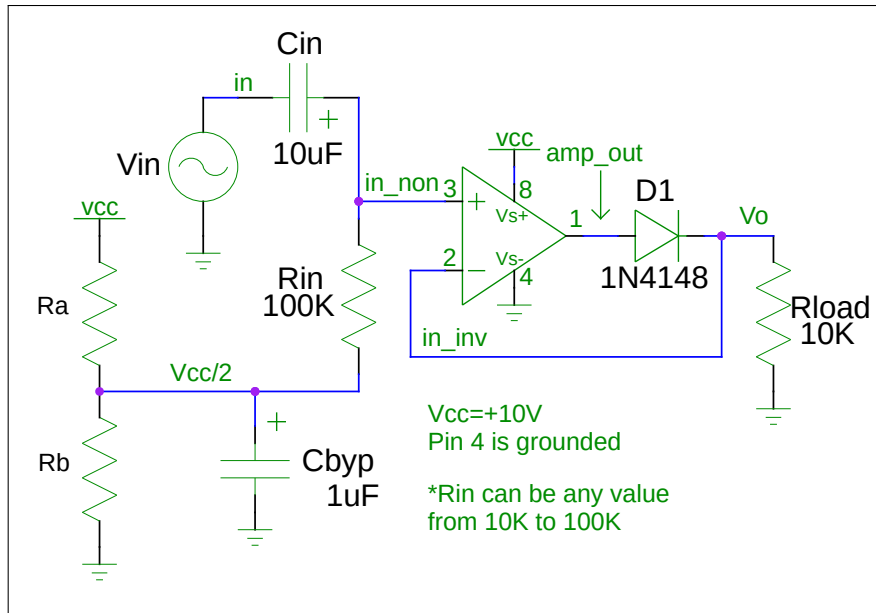


Figure 8: Precision Rectifier

Run a Ngspice simulation of the precision amplifier and check its operation. Use the following spice files: [1n4148.subckt](#) and [precision_rect.sp](#). Ignore the unrecognized parameter warnings from Ngspice. This spice file should run as-is.

- (a) How do the voltages at nodes `in_non` and `vo` differ? Should they differ? Explain.
10. Now build this circuit on your protoboard and apply a 1Vpp input signal. The waveform generator DC offset makes no difference because the input is AC coupled. Again, pin 4 of the op amp is grounded, not connected to V_{ee} . The non-inverting input is connected to the $V_{cc}/2$ circuit previously built through a $\approx 100\text{K}$ resistor. Be sure to observe the polarity markings on the capacitor.
- (a) Do the waveforms at `in_non` and `vo` differ?
- (b) Without an input signal, what DC voltages are present at nodes `in_inv`, `in_non`, and `amp_out`?
- (c) Capture the waveforms at nodes `in_non` and `vo` on the oscilloscope and store on a USB stick. Paste this oscilloscope capture into your lab notebook.

Your lab notebook should have the following:

- 2a (schematic, gain calculations, choice of R_a and R_b).
- 2b (comment on inverting input waveform).
- 4a (gain), 4b (waveform seen), 4c (captured waveform)
- 5a (modified spice netlist), 5b (gain calculated and actual), 5c (waveform comment)

- 6a (gain), 6b (waveform at inverting input), 6c (waveform capture at in and vo)
- 7a (schematic, gain calculated and actual), 7b (waveform at inverting terminal)
- 8a (gain) 8b (waveform at inverting input) 8c (DC voltages) 8d (waveforms at in and vo)
- 9a (schematic and voltage readings plus explanation)
- 10a (comment on waveforms) 10b (DC voltages) 10c (waveform capture)