PH217 Lab 8 - Operational Amplifiers

(2 weeks)

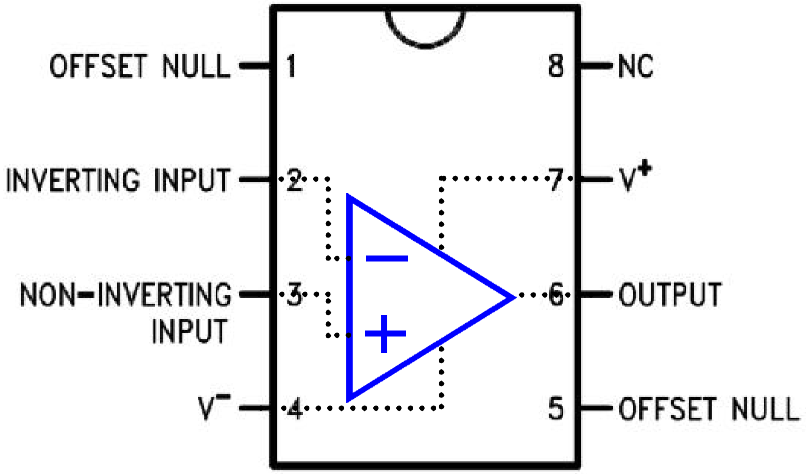
Objectives:

1. Learn the basic properties of op-amps.
2. Construct and analyze several op-amp circuits.
3. Recognize limitations of real op-amps.

Hints and Precautions:

1. Make sure the V+ (pin 7) and V- (pin 4) of the 741 are connected to +15 and -15 volts respectively.
2. Use short wires and shielded (BNC) cables as much as possible to minimize high frequency noise pickup.
3. Install 1 μF capacitors from the power supplies to ground near the op amp to filter noise on the power supply lines.
4. Check the pin diagram below for proper connections. **The diagram is a top view**.

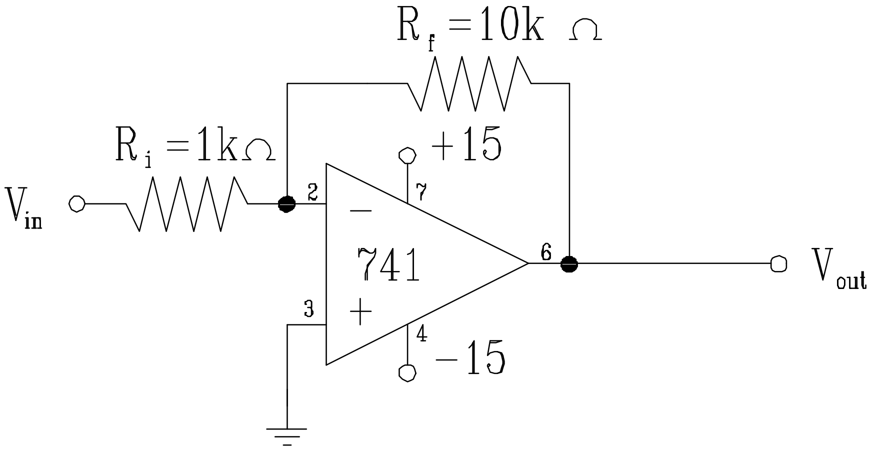
Dual-In-Line or S.O. Package



Procedure:

1. Inverting amplifier

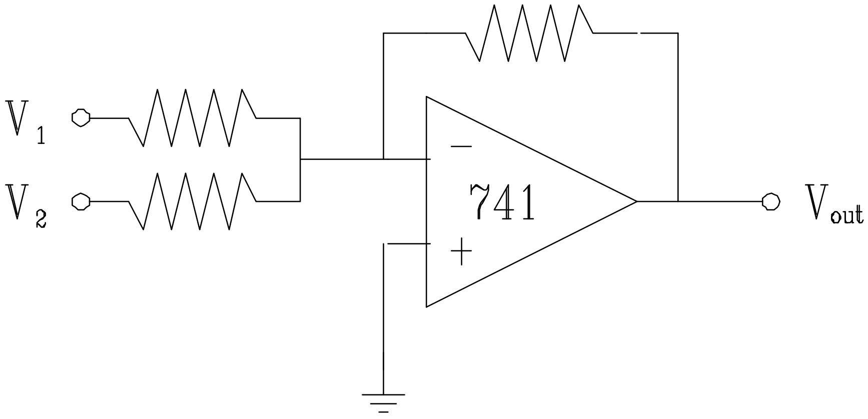
Construct an inverting amplifier using a 741 op-amp with a 1 kΩ input resistor and a 10 kΩ feedback resistor. What do you expect for the voltage gain? Input a 1V_{pp} 1kHz sine wave with no DC offset, measure the gain at a few different frequencies (measure every decade as we did in the RLC lab) and record the results. In particular, how high in frequency can you go without deviating from what you expect? What happens at very high frequencies?



2. Summing amplifier

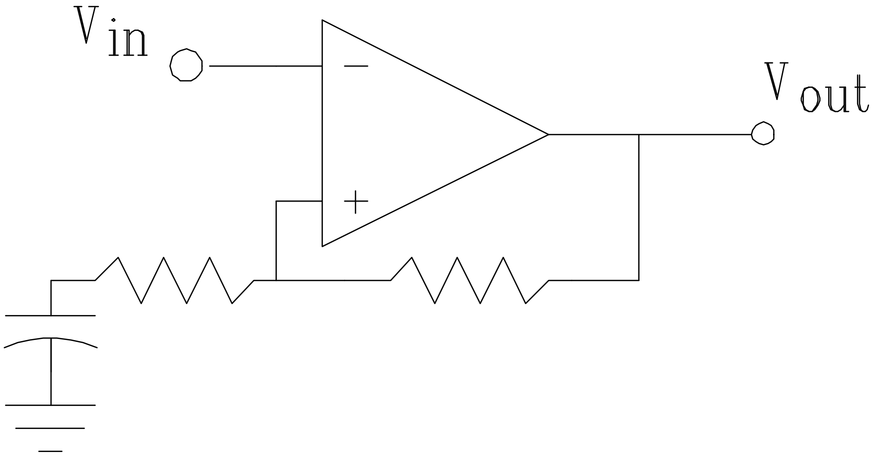
Construct a two input summing amplifier using a 741 op-amp with 100 kΩ resistors for both input and feedback resistances. Using your function generator and a variable DC source, generate a few different input voltages and measure the output. NOTE: You can make a variable DC source by connecting one end of a 10 KΩ potentiometer to 5 V DC, the other end to ground, and taking the variable output from the wiper.

Does the output agree with what you would expect? What is the voltage at the summing point? Change one of the input resistors to 50kΩ and re-measure the output for the input voltages used in the last part of this section. How does this modification change the output? Is this consistent with what you expect (check the textbook)?



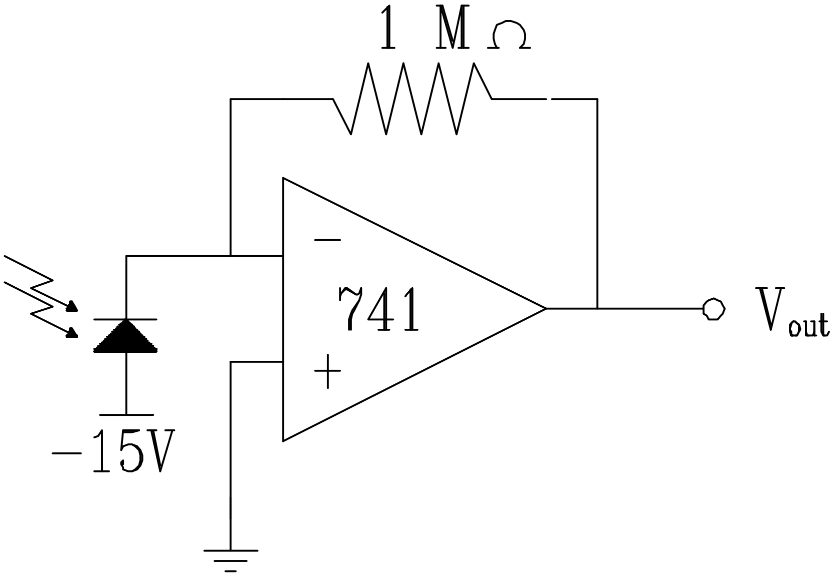
3. Non-inverting AC Amplifier

Construct a non-inverting AC amplifier using a 741 Op-Amp (see diagram below). Select values of resistances and capacitance to give a gain of around 10 and a breakpoint frequency of around 100 Hz (NOTE: You probably won't be able to get exact values for gain and breakpoint since our selection of component values is limited and the tolerances are quite wide.)   Measure and record the gain in decade frequency steps from 10 Hz to 100 kHz. Did your circuit performance meet your design requirements?



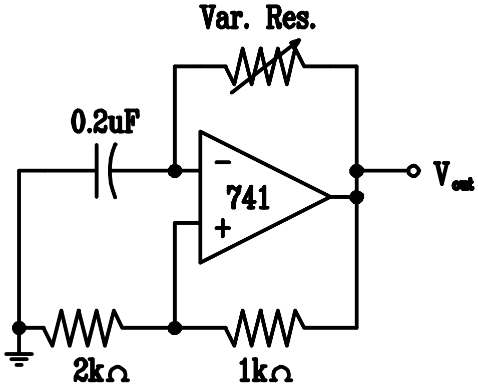
4. Current to Voltage Converter - Application to Photodiodes

Construct a current to voltage converter using a 741 Op-Amp. Record the output signal (scope trace).



5. **Relaxation oscillator**

Construct the circuit shown below using a 741. Use a variable resistor box for the feedback resistance. Does the waveform have the expected frequency? Measure the frequency as a function of the resistance in the feedback. What is the duty cycle? What are the minimum and maximum voltages measured? Draw a representative output.

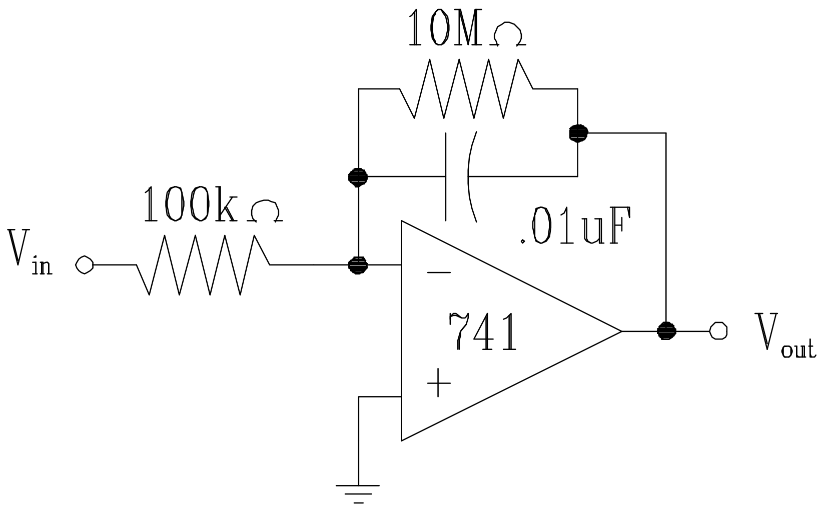


6. **Op-Amp non-ideal behavior - Nulling the offset**

Construct an inverting amplifier with a gain of 100 and an input impedance of 1 kΩ using a 741 Op-Amp. Ground the input end of the input resistor and measure the output voltage. The measured output voltage is an amplified (by 100) offset. To correct for this offset, install an offset null circuit per the diagram shown in the 741 engineering data sheet (bottom of page 1). Measure the change in output voltage as the null potentiometer is varied across its range. Adjust the null potentiometer for an op-amp output voltage of 0. **Save this circuit for the next section.**

7. Op-Amp Integrator (Low Pass Filter)

Using the nulled op-amp circuit constructed in the last section construct an integrator circuit using values of 100kΩ for R1, 10MΩ for R2 and 0.01μF for the capacitor. Use the function generator to inject sine wave AC input signals over a wide range of frequencies (every decade again) and record input and output levels. This circuit is very sensitive to input signal DC offset so, if the output is saturated at either + or – 15 volts, adjust the function generator DC offset until the output reference level returns to zero. An alternative is to add a 1μF blocking capacitor on the input to remove the DC level. What is the relationship between input and output levels? What is the role of the 10MΩ resistor in the feedback path? Remove it and see what happens. Observe the integrator outputs for different input waveforms (triangle and square wave). Record the input waveforms and resulting output waveforms.

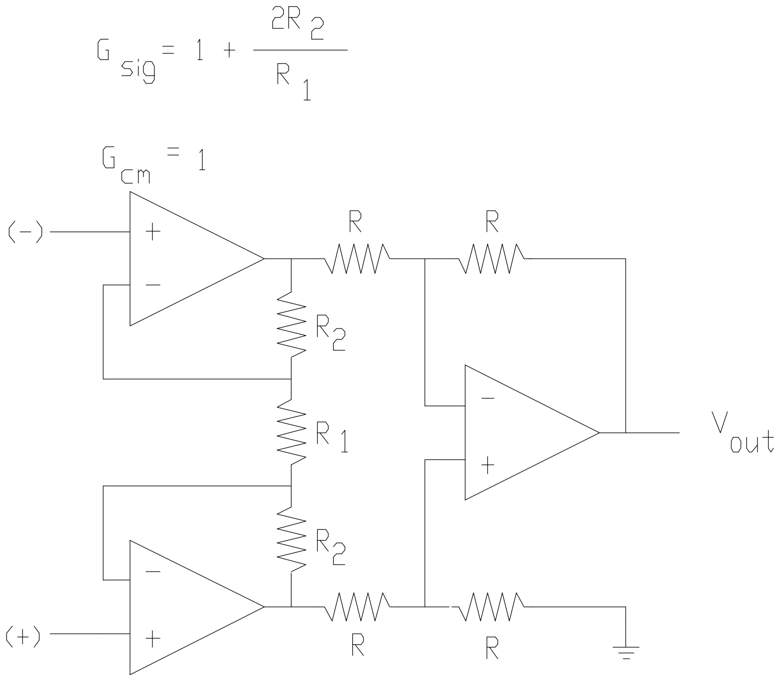


8. Instrumentation Amplifier

Construct an instrumentation amplifier following the circuit shown. This is an amplifier designed to reject common mode signals (i.e. signals that appear on both input leads) that often interfere with, or even obscure, the signal you are trying to amplify. Choose resistor values to give a reasonable overall gain (around 10) for the input amplifiers and a gain of 1 for U_3.

Test your instrumentation amplifier to see if you met your design goals. Inject a 2 V p-p high frequency AC signal into both inputs and record the output signal. How far was the input attenuated at the output? Now inject a 1 V p-p 1 kHz signal with no DC offset to one of the amplifier inputs and ground the other input. What is the output level?

One quick way of testing for common mode rejection is to place your fingers on the inverting and non-inverting inputs and see if the noise you inject is ignored (yes, you make a pretty good antenna for noise signals). Of course this isn't a good idea if you are using FET op-amps with no protection circuitry. You could end up destroying your circuit.



Instrumentation Amplifier