ELEN30013 Workshop 9 & 10: Op amp

Marks:

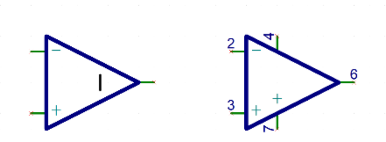
- **You should get the marks during the workshop**
- **You can only be marked in your workshop in Week 9 and Week 10**
- **If you complete both parts of the workshop in Week 9 you will also receive the week 10 attendance mark**

Week 9 (total 90)

Attendance: 20

Tasks: 70

1. Introduction



This workshop will focus on simulating and several common operational amplifier circuits. Op amps have wide range of uses and depending on component selection they can amplify very small signals or operate with a very high gain bandwidth, there are thousands of unique op amp models and depending on the circuit they can implement a wide range of operations making them an incredibly versatile component.

The general op-amp equation for the following diagram is given by: V_out = -A(V_p – V_n)

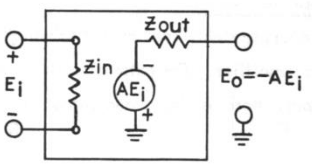


Figure 1: Circuit Model of the Single Ended Operational Amplifier (Credit TI OPAMP HANDBOOK)

Always be careful of how the A is signed and is the op amp is mirrored

The ideal op amp has the properties

1. A = ∞
2. R_in = ∞ (alternatively zero input current)
3. R_out = 0
4. V_p = V_n

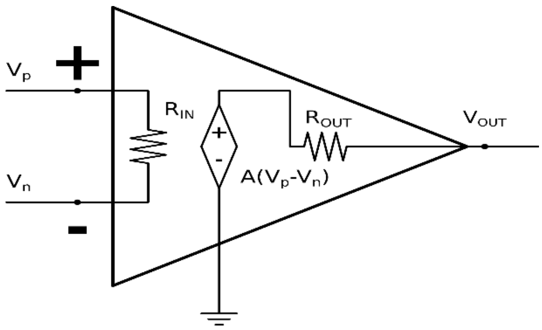


Figure 2: A more realistic op-amp

2. Detailed Analysis: Inverting Op amp

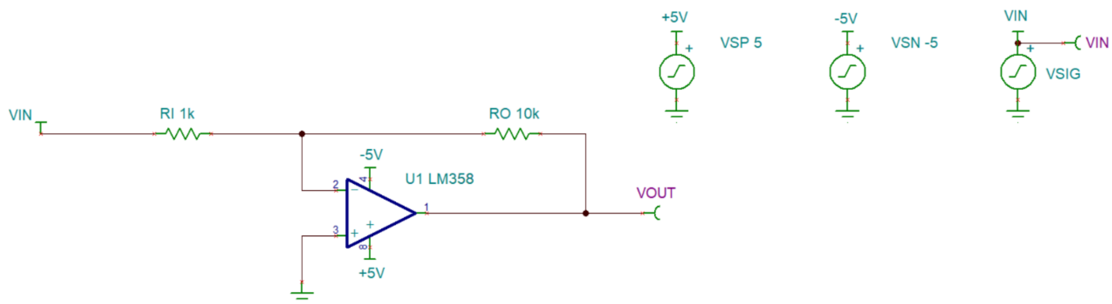


Figure 3: Inverting Op amp circuit

Task 1 (10 points): Part replacement.

The LM358 op-amp is provided in the kit and LM158 op-amp is a similar but different op-amp.

Note any differences between the LM158 and the LM358 op-amp.

LM158: https://www.ti.com/product/LM158

LM358: https://www.ti.com/product/LM358

Task 2 (10 points): Simulation transient analysis

Simulate the circuit using the **LM358** opamp to perform a transient analysis. Ensure you save or sketch the resulting graph when using the following settings:

- Op amp is LM358 from Spice Macros > Operational Amplifiers
- +5V positive supply rail
- -5V negative supply rail
- Sinusoidal input signal with a 250mV amplitude, 50Hz frequency, 0v DC offset
- Simulation duration of 50ms with zero initial conditions

Task 3 (10 points): Simulation frequency analysis

Use the signal analyser (T&M > signal analyser) to plot the gain (dB) when the circuit has a gain of 10 from 10Hz to 1MHz. Save or sketch the plot and note the frequency that the gain (dB) decreases by 3 dB (half power). Repeat this for a unity gain circuit using 10kΩ resistors.

Ensure that the inputs and outputs are correctly set so that only VSIG is an input and VOUT is an output. For the voltage supplies ensure that they are set using a DC value and not a unit step function or similar.

With the signal analyser select VOUT under channel and select on then begin by clicking Start in the Mode section.

Task 4 (10 points): Breadboard schematic

Using the breadboarding template diagram to plan the inverting op-amp circuits to be tested using an AD2. The circuit should be able to test verify the simulations in Task 2 and 3 while listing all parts, settings and wiring. The testing the circuit should be able to be conducted while only referring to the breadboard diagrams produced for this task.

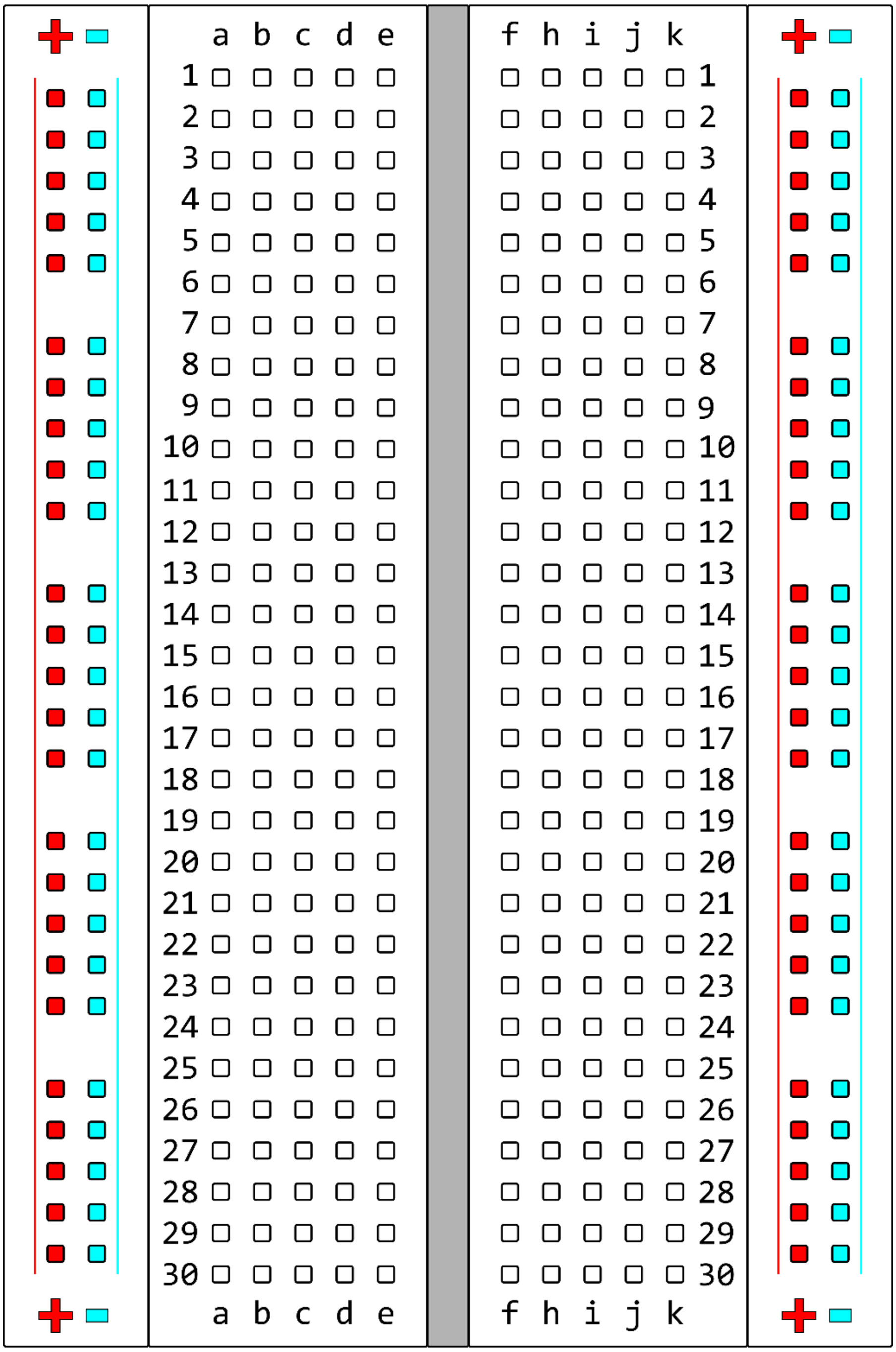


Figure 4: Breadboard template

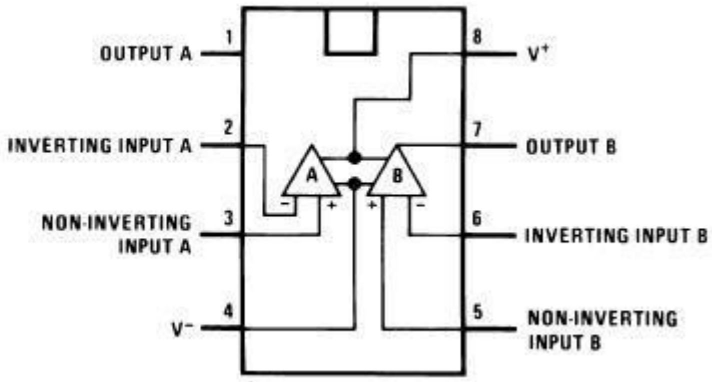


Figure 5: LM358 pinout and internal structure

Task 5 (10 points): Testing

Using only the documents produced in Task 4 build the inverting op-amp circuit. Save both the raw data (File > Export > Acquisition) and plots making sure to include the device serial number. Note down any debugging or any alterations to the breadboarding plan or clearly mark what was updated. Compare the simulated results with built results making specific numerical reference to how similar or dissimilar they are.

3. Common Op-amp Applications

This section there will be a number of common op-amp circuits and the aim is to:

1. Identify the gain or output equation
2. Simulate the circuit with Tina-Ti
3. Construct the circuit and verify the circuits behaviour using an AD2

3A. Non-Inverting Amplifier

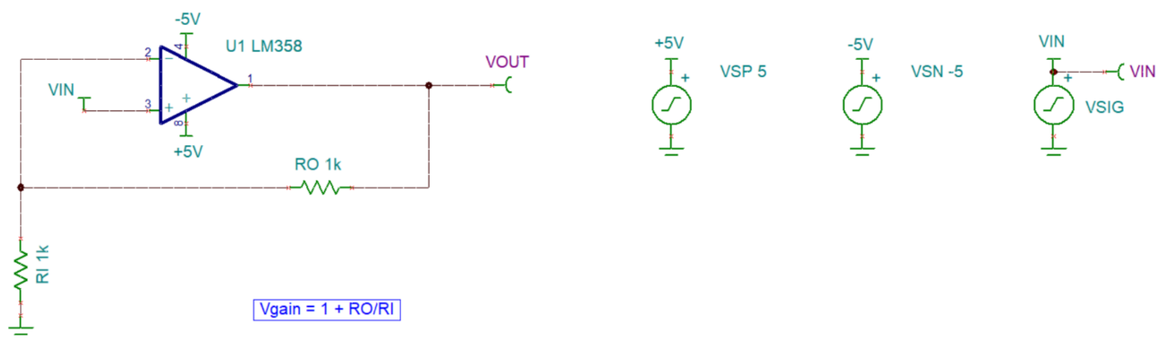


Figure 6: Non-inverting Op amp circuit

For this test use RI as a 1kΩ resistor and R0 as 1kΩ resistor then replace R0 with a 10kΩ resistor, do this for both the simulation and constructed circuit. Use a sinusoidal voltage signal as the input signal with an amplitude of 250mv, a frequency of 1kHz and a 0V DC offset.

Tasks 6 (10 points):

1. Record both simulations DC transient plots showing at least 3 cycles of the input signal.
2. Calculate the voltage gain of both simulations.
3. Record the acquisition data and plots of both tests in Waveforms of both the input and output voltages.
4. Calculate the voltage gain as a result of the constructed circuit and numerically compare against the simulated and theoretical voltage gain of for R0 = {1kΩ, 10kΩ}.

3B. Linear current output

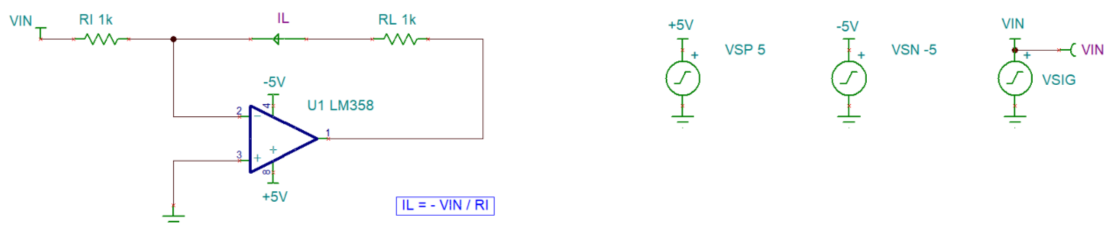


Figure 7: Linear current output Op amp circuit

Tasks 7 (10 points):

1. Select appropriate component values such that an input voltage in the range of –5V to +5V will result in a current through the load between –5mA and +5mA.
2. Simulate the circuit using your component selection with a range of load resistor values. Record all data acquisition used and plots. What is the highest resistance than can be used before the circuit fails to provide +/-4.5mA?
3. Construct the circuit and validate your component selection while first using RL as a 100Ω resistor (linear) and then using an LED (Non-linear) in two separate tests. Record all data acquisition used and plots.

Suggested end of Week 9

Week 10 continue

Week 10 (total 70)

Attendance: 20

Tasks: 50

3C. Integrator

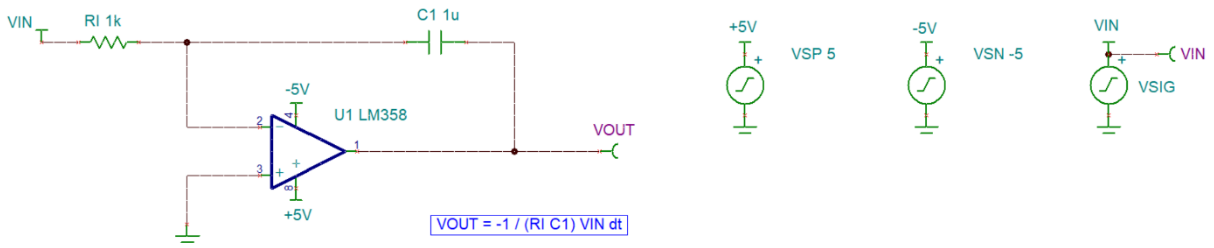


Figure 8: Integrator Op amp circuit

Tasks 8 (10 points):

1. Simulate the circuit above using a 1kΩ resistor and a 1uF capacitor. Use a sinusoidal as the input signal with an amplitude of 500mV, a frequency of 100 Hz and a 0V DC offset. Verify the input output voltage relationship in terms of phase and amplitude. Record all DC transient analysis plots .
2. Construct the circuit and test the circuit using an AD2. Record all data acquisition used and plots.
3. When testing this circuit what is the main issues regarding the output voltage level?
4. Research opamp application documents and find 2 different ways to resolve the issue?

   Hint:

   - Ti op amp handbook,
   - Ti AN-31 Amplifier Circuit Collection,
   - Search for similar industry resources

3D. Differentiator

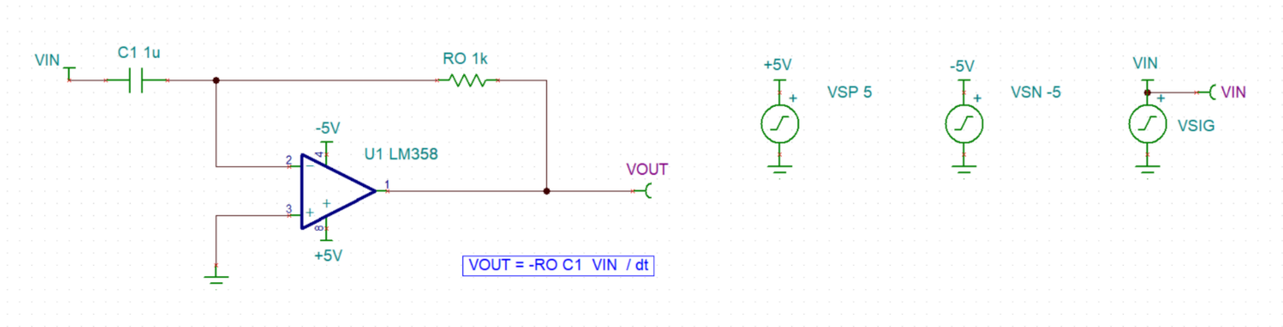


Figure 9: Differentiator Op amp circuit

Tasks 9 (10 points):

1. Simulate the circuit above using a 1kΩ resistor and a 1uF capacitor. Use a sine wave as the input signal with an amplitude of 1V, a frequency of 50 Hz and a 0V DC offset. Verify the input output voltage relationship or comment on any differences. Record all DC transient analysis plots.
2. Construct the circuit and test the circuit using an AD2. Record all data acquisition used and plots.

3E. Voltage adder

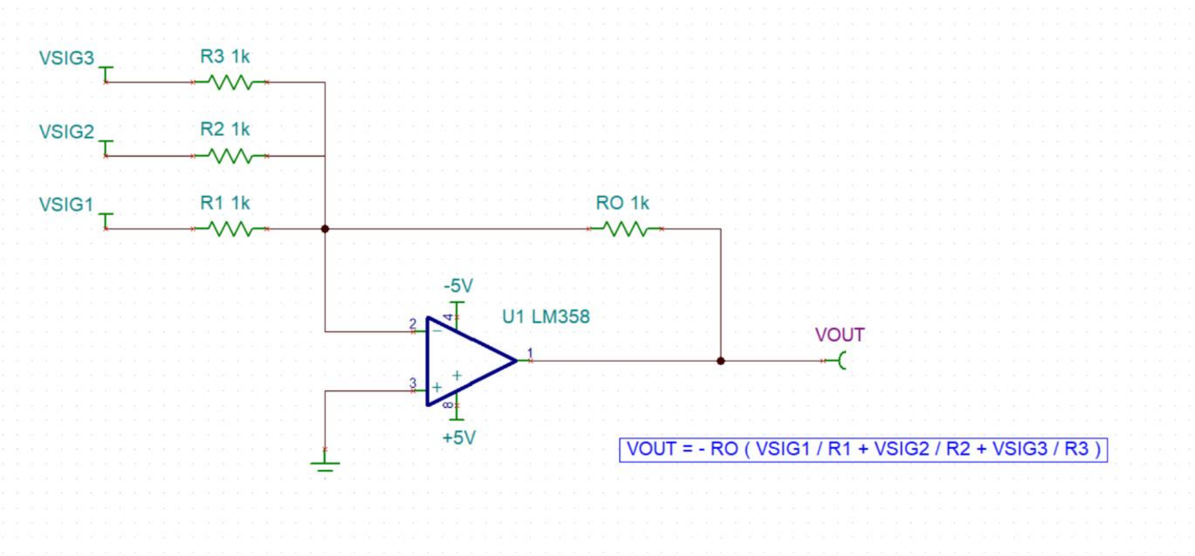


Figure 10: Voltage adder Op amp circuit

Tasks 10 (10 points):

1. Simulate the circuit using various time varying signals
2. How would you alter this circuit so that the output equation was equal to the positive sum:

   VOUT = + RO (VSIG1 / R1 + VSIG2 / R2 + VSIG3 / R3)
3. How would you alter this circuit so that the output is equal to average voltage of the inputs?

4. Use your two previous results of task 2 and 3 to simulate and then build an op amp circuit that sums 3 input voltages from an Arduino Uno and outputs the average. Output square waves with frequencies 10Hz, 20Hz, 40Hz. Use the AD2 to supply power to the op amp circuit as –5V and +5v. Ensure that the there is a common ground between the two devices. It should be constructed as a summer and inverter.

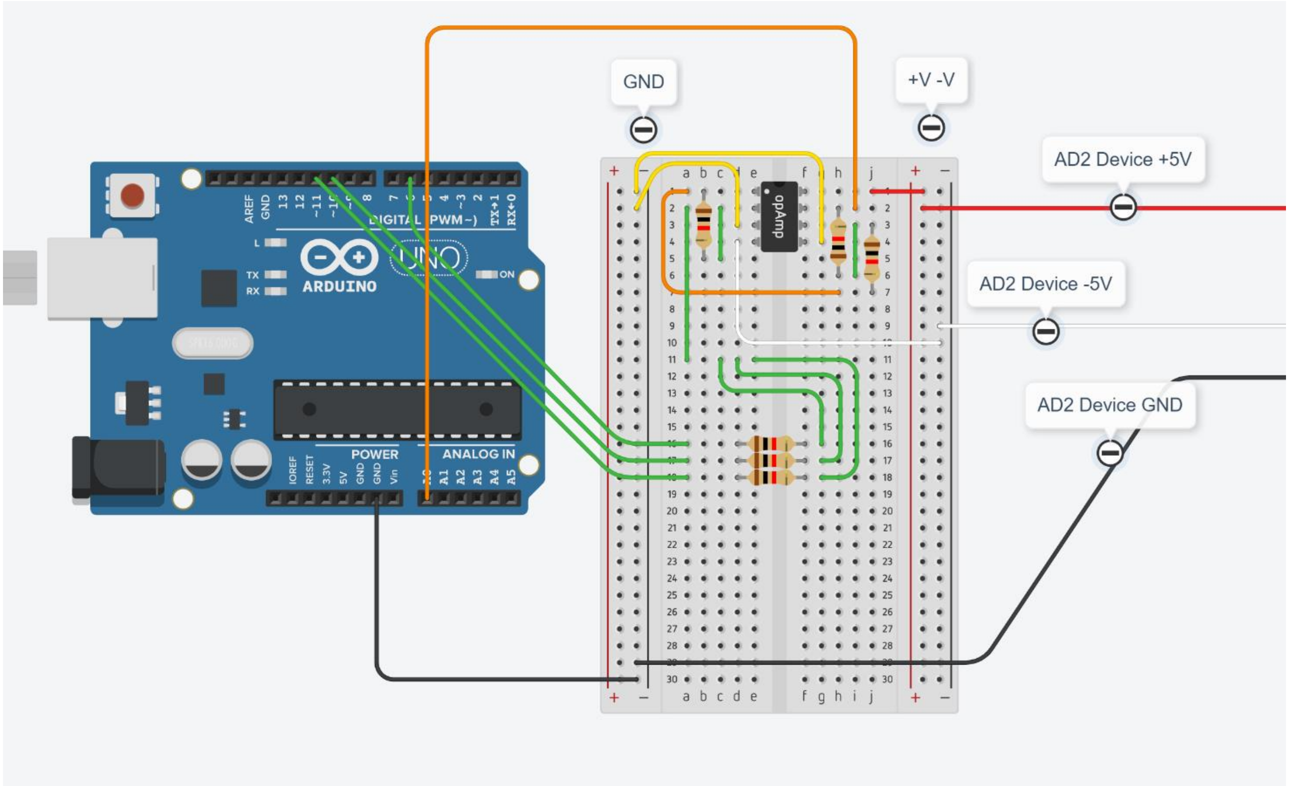


Figure 11: Voltage adder Op amp breadboard diagram

3F. Halfwave Negative Signal Rectifier & Mystery Circuit

Tasks 11 (20 points):

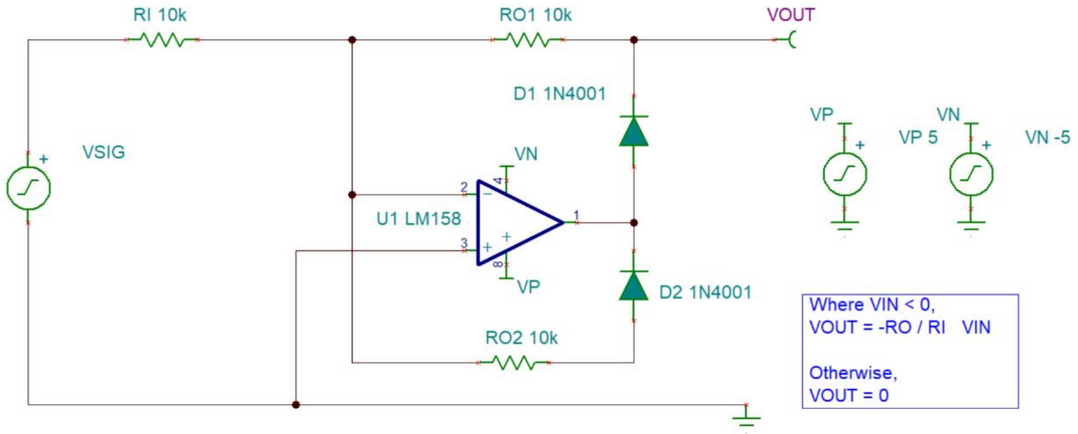


Figure 12: halfwave negative signal rectifier circuit

1. Simulate the halfwave negative signal rectifier circuit with an input signal as a triangular wave with a 2V amplitude at 500Hz with no DC offset. Record the resulting DC transient analysis plots.

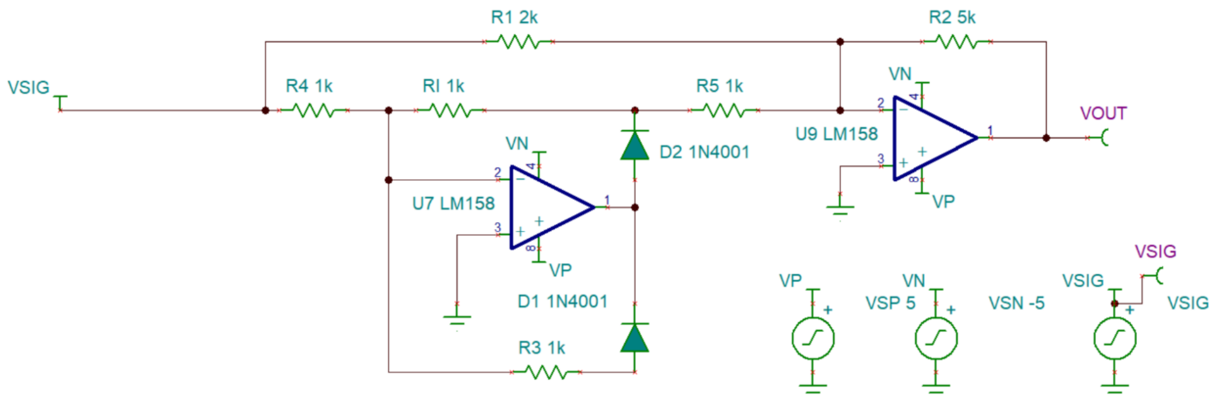


Figure 13: Mystery circuit

2. What function does this mystery circuit preform? Record any tests or research you conducted to determine the function.

Hint: Cascaded Op amps that have been covered in the workshop