LM 358 Op Amp

Skill Level: Intermediate

OVERVIEW

The LM 358 is a duel single supply operational amplifier. As it is a single supply it eliminates the need for a duel power supply, thus simplifying design and basic application use. One draw back is that the single supply does not offer a negative voltage supply. Due to this the output will not be-able to go below 0V otherwise the waveform will cutoff also known as clipping.

Clipping happens when a wave hasn't reached the max amplitude and stops at a point and stays constant causing a flat peak if you clip a sine wave. Clipping can often be heard in audio amplifiers when the speaker distorts small clipping percentages may go unnoticed to the ear so bare this in mind when using a LM358 for an audio pre amplifier etc.

If you have small signals and need a more useful reading we could amplify it using the op amp, this is commonly used in sensors.

Lets say we have a signal of 50mV and we want it to interface with a Microcontroller or so on we need to amplify it till we get 5V this allows a small change of the sensor to have a big change on the Microcontrollers input this means we have greater accuracy of data that's being sampled.

Some of many Op-Amp applications:

- Voltage Buffers
- Wave form generators (square, sine, triangle)
- Differentiators and Integrators
- Low Pass and High pass Filters
- Comparators

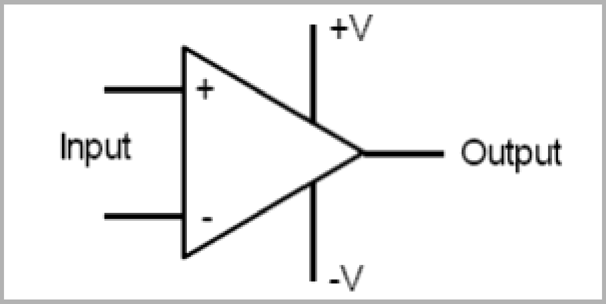
AMPLIFIER

Figure 1: LM358 Duel Op-Amp DIP 8

The LM358 is a duel op-amp, meaning there's two op amps in one IC. We will only work with one for now.

One op amp consists of a Non-inverting input, inverting input and output as you can see in Figure2.

Figure2 : Op-Amp Example

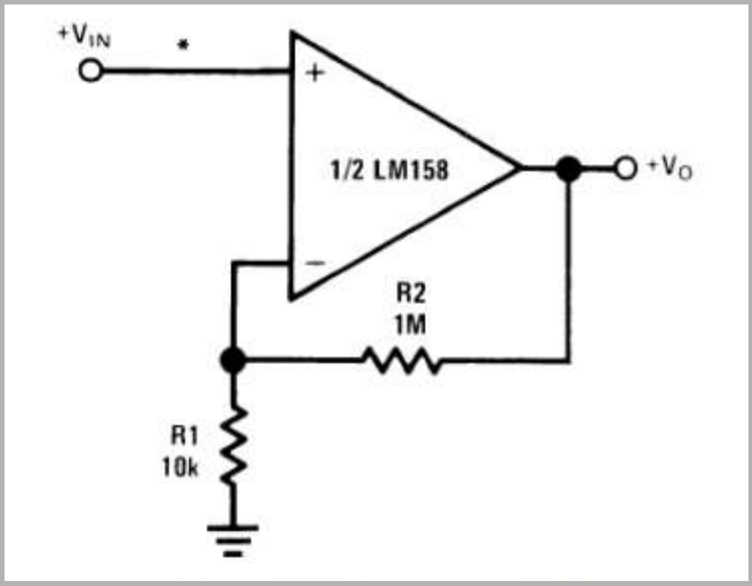


The + input represents non-inverting input, - input represents inverting input and +V connects the positive pole of the power supply and –V connects to the negative pole (GND). Inverting means the opposite output of the original input, therefor if you have 5V on the inverting input and a gain of 0.5 v/v you will have 2.5V on the output.

For non-inverting if you have 2.5V on the input and a gain of 2 v/v you will have 5V on the output.

So how do we calculate gain? Well gain is determined by the Rf and Ri ratios. The resistor Rf forms a feed back loop and as one applies Ohms law and the voltage divider rule a set ratio of the output voltage will cancel out some of the input. Remember that an op-amp is a differential amplifier, amplifying the difference between the (-) inverting and (+) non-inverting inputs.

Figure3: Non-Inverting Amplifier



In Figure 3 a non-inverting amplifier schematic has been constructed, please note that R2 = Rf and R1 = Ri.

We will apply 49.5mV to the +Vin and our Rf = 1MΩ and Ri = 10kΩ .

There for we can calculate the output for the non-inverting op=amp as follows.

Figure4: Non-inverting Formula

Av = 1 + (Rf/Ri)

Rf = Resistance Feedback (Ω)

Ri = Resistance Input (Ω)

Av = Voltage Gain (V/V) : volts per volt

Now since we know the values we can substitute them into the formula to find the output voltage.

Av = 1 + (1MΩ /10kΩ)

Av = 1 + 100

Av = 101

From the equation we determined the gain will be 101 v/v, meaning if we apply 1V to the input we will theoretically have 101V on the output. This is true but it is not applicable as the maximum supply voltage is 32V but we applying 49.5mV to the input therefor we can use the values calculated.

Vout = Av x Vin

Vout = 101 x 49.5mV

Vout = 4.9995V

So using 49.5mV will give us 5V rounded off, we will need to calculate the required voltage supply to the op-amp. This voltage will be higher than the max output voltage you require due to a voltage loss in the op-amp. In the data sheet it will be named **Voltage Swing** use the typical value in this case its 5mV which is neglect able but some op-amps are 1.5V so you would need 6.5V Vcc.

For a single supply op amp the inverting layout is rarely used due to the absence of a negative supply rail. Although the inverting layout can be used the theory applies to duel supply op-amps as well.

Figure5: Inverting Op-Amp Formula

$$Av = - Rf/Ri$$

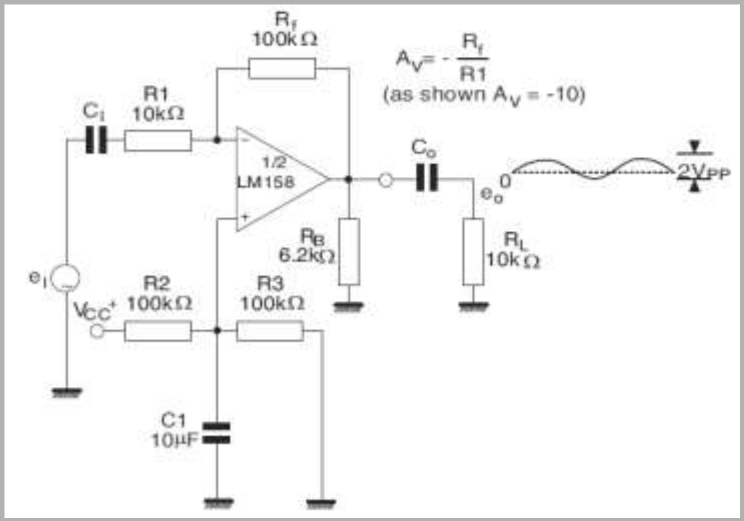
Rf = **Resistance Feedback (Ω)**

Ri = **Resistance Input (Ω)**

Av = **Voltage Gain (V/V) : volts per volt**

The same method applies to the inverting amplifier layout except you do not add 1 but a minus sign will be present and the input will now move to where Ri was once grounded and the non-inverting input will now be grounded. It isn't recommended to use the LM358 in inverting orientation as it could result in clipping although an AC signal layout can be made using capacitors and resistors to allow an ac output. This layout is more complex than a Split power supply layout so for normal dc analysis the LM358 will work perfectly. The UA741 split power supply op-amp will be discussed in the next article.

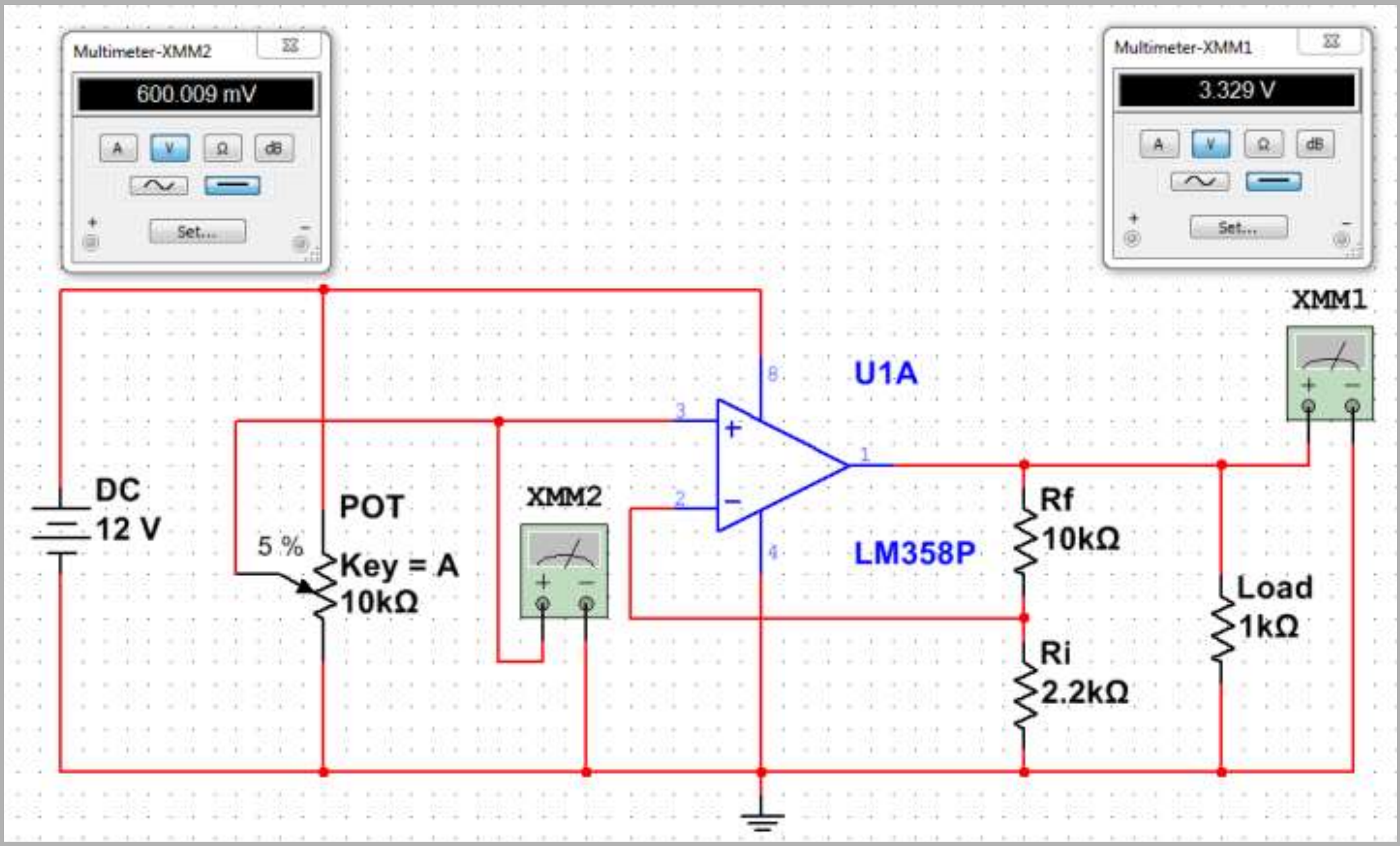
Figure6: AC Coupled inverting amplifier



Useful Tips to keep in mind:

- Using any amplifier in inverting mode places your output waveform 180° out of phase this phase shift will result in sound cancelation if an existing sound driver is running at 0° meaning in non-inverting and in phase. When working with AC circuits a well understanding of AC circuit analysis will be helpful especially when capacitors are involved as a capacitor acts as a block for dc but allows ac to flow, even though ac can flow through a capacitor its capacitance will have a certain impedance at different frequencies.
- An op-amp has an extremely high input impedance and thus allowing your signal to have minimal current characteristics around 20nA is required.
- The LM358 has around 40mA current out parameters, so stay with in them its possible to add a transistor to the output if biased correctly you may drive higher current loads staying in the linear region.

LM358 EXAMPLE CIRCUIT



In the above example circuit we have a DC analysis op-amp layout. As one can compute the Av of the amplifier is as follows:

$$Av = 1 + (10K\Omega / 2.2k\Omega)$$

Av = 1 + 4.545

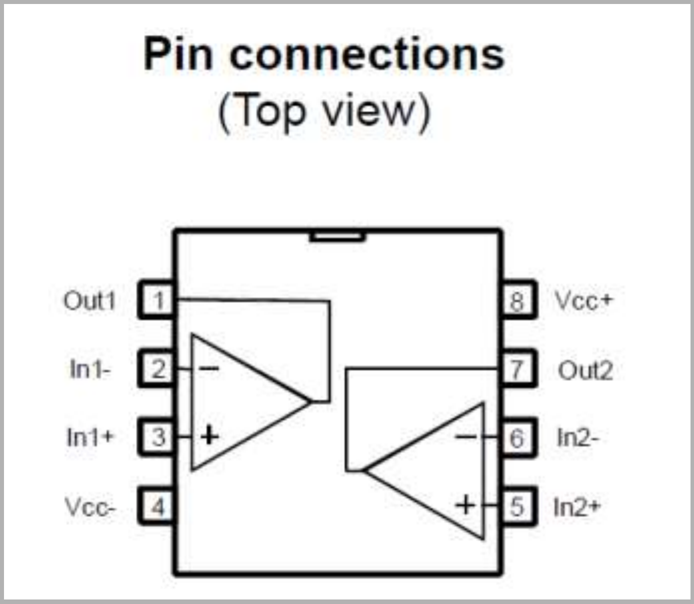
Av = 5.545

Av is 5.545 if we take the Vin put on Pin 3 which is 600mV and multiply it with the Av we get **3.327V** at the output and over the load resistor.

The calculated answers are very close to the simulator, the simulator does include the tolerances of resistors which was set in at 5% as that's your common resistor tolerances.

You may make Rf and Ri potentiometers as well and see what the results are bare in mind to measure the resistance so you can back up your readings with a theoretical calculation.

PIN OUT:



COMPARATOR

One of the simpler circuits and commonly used circuits are the op-amp comparators. A comparator basically compares two voltages and if one is greater than the other the output of the op-amp is either ON or OFF.

Comparators have found many uses in Day Night switches, simple Analog to Digital Converters, electronic thermostats and even regulated power supply's.

There are two components we will have to work with in order to determine at what voltage will it switch ON and at what voltage it will switch OFF.

Component 1: Reference Voltage

The reference voltage is a set voltage that will be used to compared against the sensing voltage.

Component 2: Sensing Voltage

Sensing voltage will be the input voltage, this voltage could come off a operational amplifiers output if the real sensors changes are too small to work with. If we have the sensing voltage created via a potentiometer we may ignore using an op-amp to amplify any signal as we will have a reasonable voltage difference to work with.

The sensing voltage can be applied to the non-inverting input, this will ensure that once the sensing voltage has exceeded the Reference voltage that must be placed on the inverting input the op-amp will turn ON.

If we apply the sensing voltage to the inverting input and the reference voltage to the non-inverting input we will have the op-amp OFF when the sensing voltage is above the reference voltage and the op amp ON when the sensing voltage is below the reference voltage.

Reference voltage can be created using a voltage divider resistor network or a zener diode. There are many ways to create a reference voltage but we will use a zener diode for stability even if the supply voltage changes slightly.

Figure7: Zener Diode

One should note that a zener diode is used in reverse bias compared to a normal diode and the Rs for the zener is vital otherwise it will get over powered and burnout.

Current through a zener can be calculated as follows:

$$Iz = (Vdd - Vz)/Rs$$

Rs = Resistance Series With Zener (Ω)

Vdd = Supply Voltage (V)

Vz = Zener Voltage

Once the Current through the zener has been calculated the Power Dissipation must be calculated.

Most zeners are 500mW to 1W, we will use a 1W zener

$$Pz = Vz \times Iz$$

Pz = Power Dissipation (Watts)

Iz = Current Zener (A)

Vz = Zener Voltage

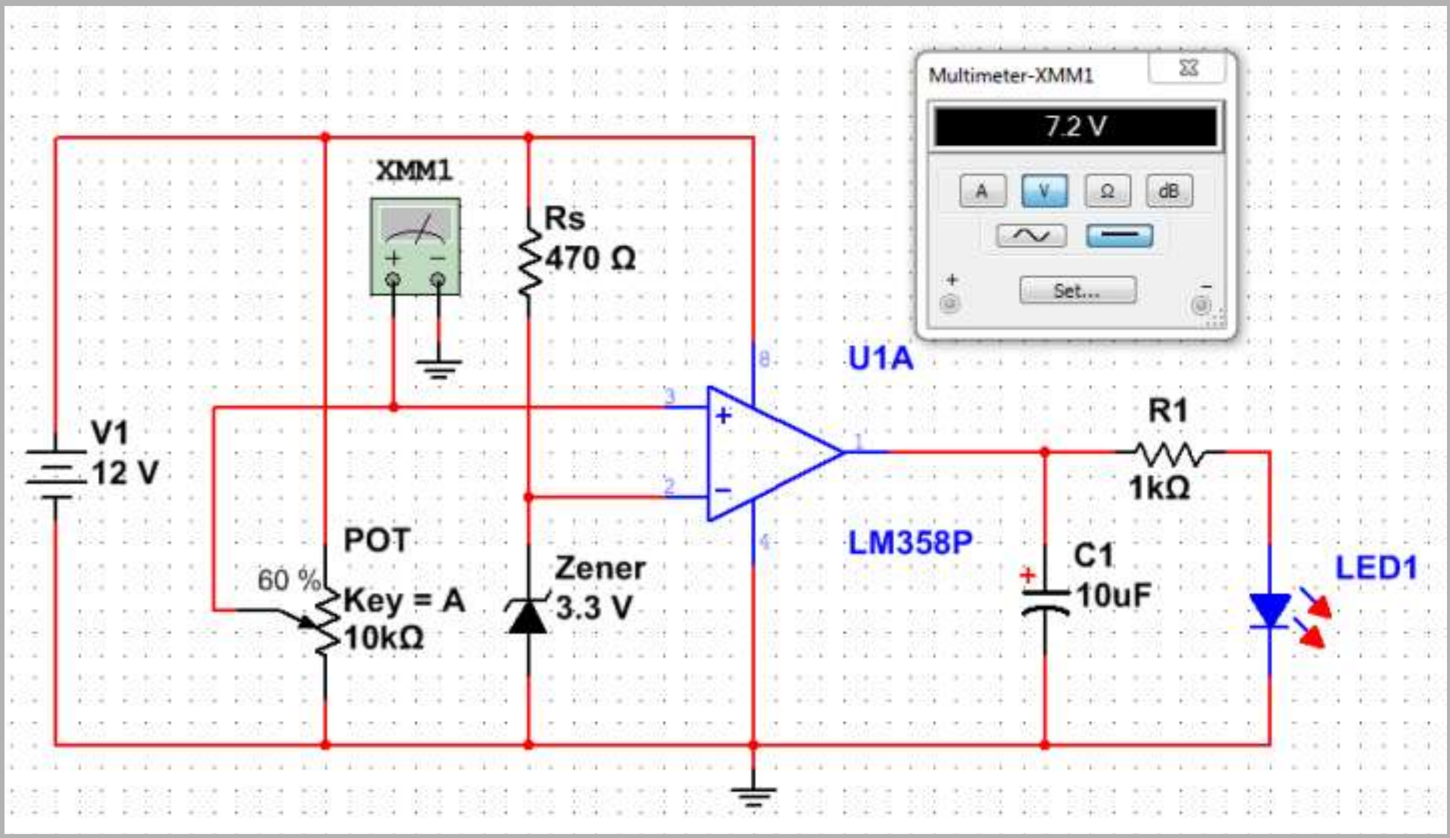
There for if we have a 3.3V 1W zener a 470Ω will work sufficiently.

In this comparator circuit the reference voltage was taken to the inverting input and the sensing voltage to the non-inverting input.

Adding a capacitor as in the schematic helps prevent oscillations when in the switching state. Any values can be used generally 1uF to 100uF works well.

COMPARATOR EXAMPLE CIRCUIT

In the circuit bellow the LED is on as you can see the Multi-meter XMM1 reads 7.2V this is the voltage from the potentiometer. If the voltage is below the 3.3V zener reference the LED will be off.



TROUBLE SHOOTING

Once the circuit has been constructed and any problems arise they could often be solved by a few simple checks as listed:

- **Nothings happening:**

  Ensure all connections are correct and make contact and check for the correct resistor values.

  Make sure the op-amp wasn't damaged with electrostatic discharge by placing a new one in.

- **No Reference Voltage:**

  Make sure that the zener is connected the right way around with the black stripe facing the resistor. Replace zener if problem persists.

PARTS LIST

ELECTRONICS 123 Stock codes:

Quantity	Description	Stock Code
1x	LM358 IC	HB084
1x	3.3V 1W Zener	HB337
2x	1 kΩ 1/4 Watt Resistors	DB056
2x	470 Ω 1/4 Watt Resistors	DB052
1x	2.2kΩ 1/4 Watt Resistors	DB060
1x	5mm Red LED	AA380
1x	10uF Cap	HB245

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