Vibration Sensor

Skill Level : Easy

Over view

The name of this design is self explanatory , the circuit detects sharp “knocks” or “high frequency” oscillations and converts the sensors minute voltage level into something more use full. The applications of such a circuit might seem very narrow to the inexperienced electronics enthusiast as you do not posses the skills needed to widen the use of this circuit yet. I aim to widen your perspective through out this tutorial and to give you the skills needed to expand on this circuit to such a degree that it will be perfect for your application.

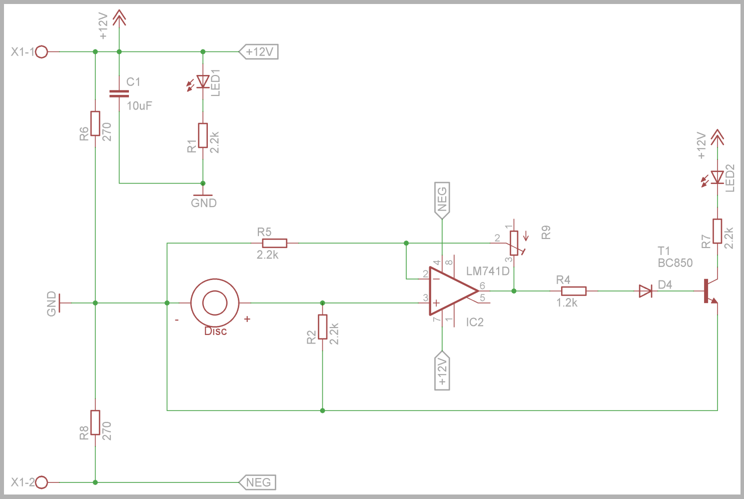


Figure 1

Above is the schematic diagram of the sensing part of the vibrations sensor. The schematic can be split up into four main parts.

1) The power supply
2) Piezo electric disc
3) The amplifier
4) Interface output stage

The power supply

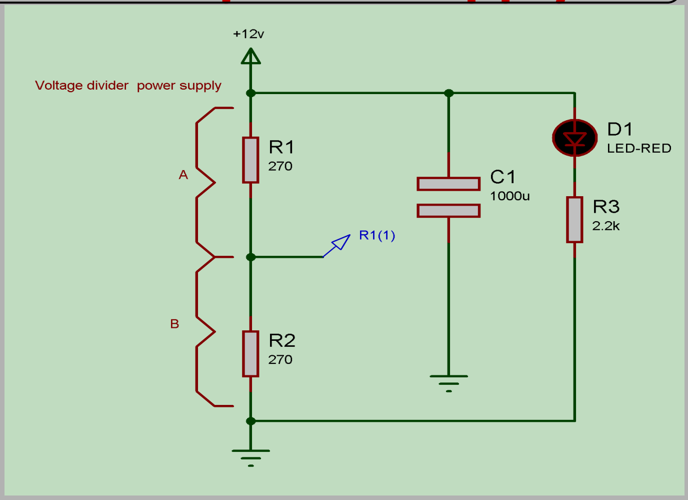


Figure 2

This is a basic voltage divider circuit, the two resistors in series both have the same value of resistance , hence by Ohms law of series circuits the current through both resistors will be the same, hence the voltage over both resistors will be the same, but only because they have the same current flowing through them and because they have the same value of resistance. This can be proven by applying Ohms law.

1) Get the total resistance

R1 + R2 = 270 + 270 = 540 ohm.

2) Measure supply voltage

Vs = 12V DC

3) Calculate the max current

I = V/ R

Hence the total current through R1 and R2 is 12V/540ohm = 22.22mA.

Hence the voltage over R1 = voltage over R2 = I*R

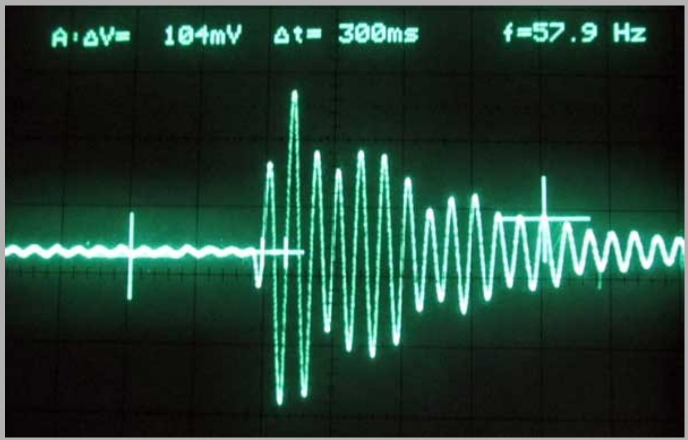
22.22mA * 270 ohm = 6V.

Now for the tricky part, if we apply lets say for arguments sake 12V DC to our voltage divider circuit and we get 6V over R1 and 6V over R2 then the point between the two resistors is 6V lower than the 12Volt supply and 6V above the 0V ground rail. So if we decide to use this midpoint between our two resistors as our “ground” we are left with a 6V positive supply and a 6V negative supply. Imagine this like if you are standing in the middle of a room with two walls on each side of you. From your point of view the wall to your right is lets say positive 6m away and the wall to the left is negative 6m away, note that this is from your perspective, the distance from wall to wall is still12 meter but from your point of view they are both 6 m away.

In electronics, components see voltage levels as explained above, this givens rise to some wonderful things but also to some major problems. Depending on your application and the sensitivity of your project.

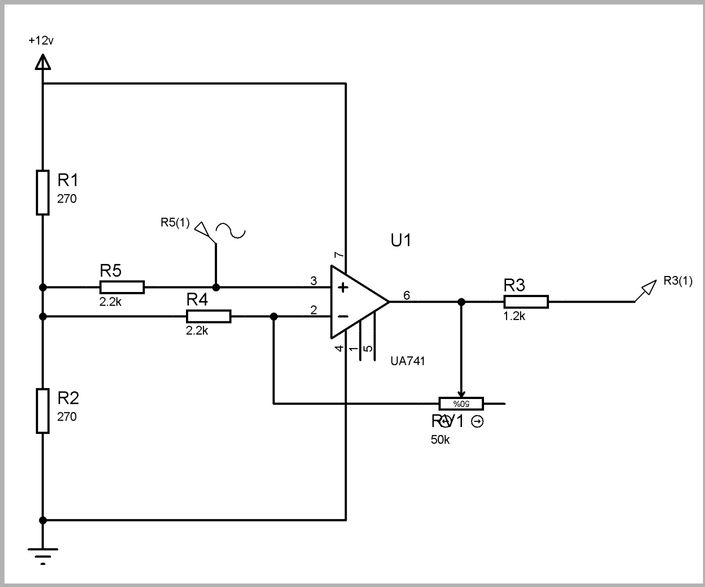
The piezo electric disc

By definition piezoelectricity is the electric charge that accumulates in certain solid materials such as crystals in response to applied mechanical stress. The word piezoelectricity means electricity resulting from pressure. This pressure might not always be physical contact with the sensor. It can be a pressure wave “energy displacement” disrupting the molecules in the crystal causing it to give out an electric signal similar to the frequency of the disrupting wave.



The Amplifier

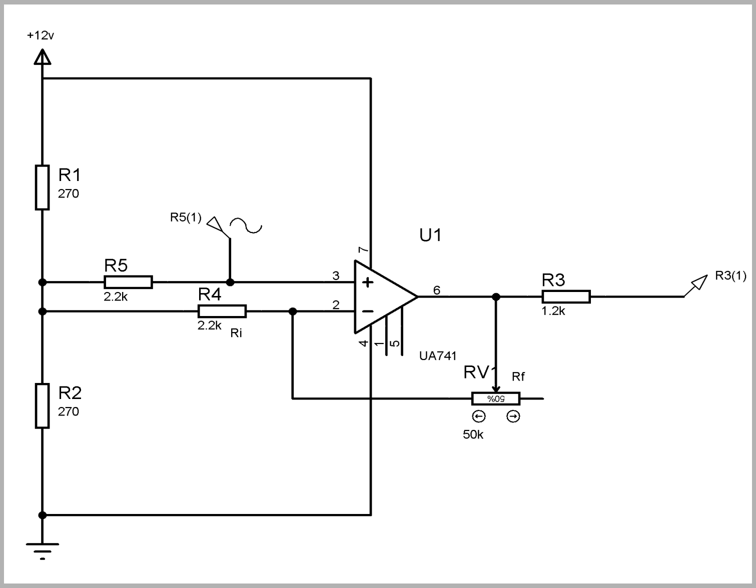
The amplifier used in this circuit is a UA741 operational amplifier, it is designed for dual supply use meaning it must have a negative rail and a positive rail to function correctly. This is why we need the split supply for this circuit.



Above is the general non-inverting amplifier setup. As you can see the resistors setting the gain of the op-amp is all tied to the mid point of the voltage divider resistors, this point acts as a virtual ground and lets the op-amp think is it being supplied with +- 6V. This is an easy solution if your circuit is small and low current. The problem here is that all the other components must be tied to this point between the resistors as well. Remember that the op-amp’s virtual zero point is actually 6 volt. Thus it has an output of 6 volts if measured from pin 6 to ground. Thus if you tie a transistor to the op-amp’s output and then to true ground the transistor is likely to be saturated fully and opened completely. This is why all the other components on the board must also be tied to this virtual ground point.

The amplifiers gain is set by 2 resistors, named Rf and Ri, the ratio between these two resistors determines the gain of the amplifier. For the UA741 the max gain is 200 000, in terms of voltage you will get

10V out if you apply 50micro volts to the input. This is absurd as you will never get a circuit that does not have a constant ripple of 50 micro volt.



In this case the gain is set to 12.364. this can be proven as follows.

Av = 1 + Rf/Ri

Av = 1+ 25k ohm / 2.2k ohm

Av = 12.364

Thus if you have an input voltage of 104mV like in figure3 you will have an output voltage of 12.364 times the input voltage

Thus Vout = Av * Vin

Vout = 0.104V * 12.364

Vout = 1.731 Volt

The gain can be set by adjusting the potentiometer Rf to a higher value. Lets say the potentiometer was set for 50k ohm.

Then Av = 1 + 50k ohm / 2.2k ohm

Av = 23.273

Thus Vout = 0.104mV * 23.273

Vout = 2.420 Volt

Now fact for fact the Rf resistor has changed with 25K ohm but the gain only doubled, if you change the Ri resistor the gain is much more significantly affected. For instance if we change Ri to 1K ohm

Av = 1 + Rf / Ri

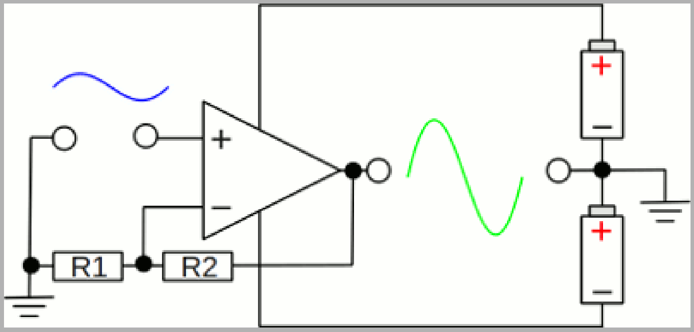
Av = 1 + 25k ohm / 1K ohm

Av = 26

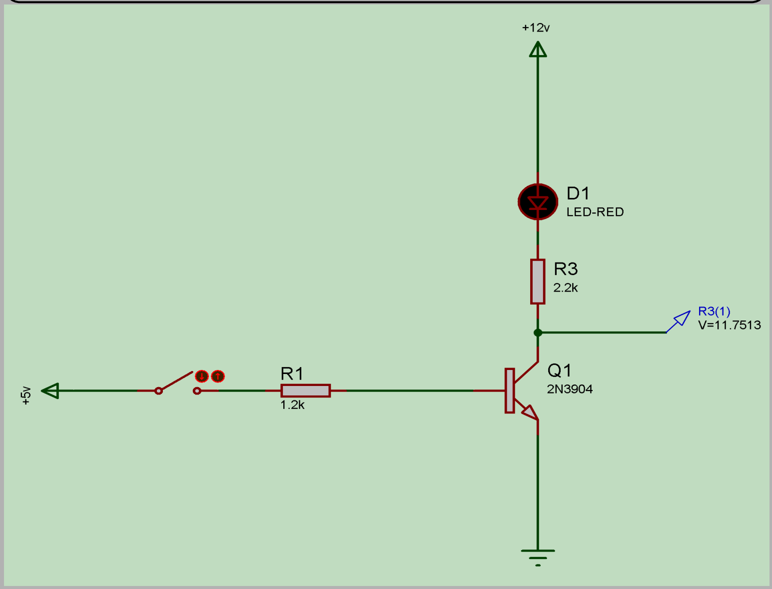
This is a much more significant gain then before, now max gain will be 51.

So max Vout will be 5.304 Volt.

Now we need to take into account our Vs to the circuit. Remember it is +6V and –6V. 5.304 volt is very close to 6V. The op-amp can be said to saturate with a gain of 51 for the given supply voltage due to internal losses and the maximum supply voltage. Increasing the gain beyond this point will not have any affect on the circuit for our application. The op-amp will simply "clip" the voltage as it cannot increase higher that the supply voltage. What this means it that you will end up with a semi-square wave for both positive and negative voltages.



Interface output stage



Notice that the switch is open at the moment. Thus the transistor is off. The output stage is high as can be see at probe R3(1) . If the switch is closed the transistor is open and the voltage at probe R3(1) drops to about 0.04V. Imagine the switch is the op-amps output, as the piezo disc detects a vibration the small voltage is amplified to about 5 volt and the transistor is switched on zeroing the output at probe R3(1).

The transistor has a parameter called VBEsat, this stands for base to emitter saturation voltage and is usually in the range of 0.7 volt. What this means is that the transistor will start to switch on rapidly after the op-amp applies a 0.7 volt to the base of the transistor.

This output stage can be used to interface with a variety of electronic IC's, this can be done by isolating the +12v line to your interface needs. Lets say you would like to measure the frequency of vibration and you are feeding the output from probe R3(1) into a frequency counter you will set the +12v to the frequency counter IC's supply voltage. In other words if the frequency counter IC has a 15V supply you will replace the +12V with +15V to merge your interface with the frequency counter IC.

Parts List

R1 = 2K2 : AA113

R2 = 2K2 : AA113

R4 = 1K2 : KB075

R5 = 2K2 : AA113

R6 = 270E : DB367

R7 = 2K2 : AA113

R8 = 270E : DB367

R9 = 100K : DB642

C1 = 10uF : EB761

LED1 = LED RED : AA361

LED2 = LED RED : AA361

PIEZO BUZZER

AU741 = OP-AMP : HB083

D4 = 1N4007 : HB053

D5 = 1N4007 : HB053

T1 = 2N3904 : AA006

K1 = RELAY : DB404

STRIP BOARD : QB056