PROJECT

VIBRATION DETECTION CIRCUIT

Students:

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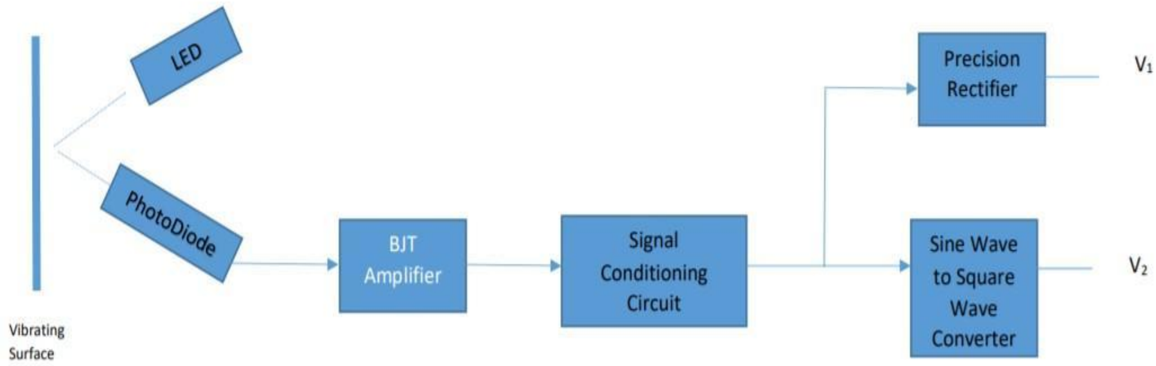
INTRODUCTION



Aim of the Project:

The purpose of this Project to determine the magnitude and frequency of the vibration by providing the mirror vibration and generating a signal from photodiode and expanding this signal with various circuit designs.

Equipment List:

1. Blue LED
2. Mirror
3. Vibrating motor
4. Photodiode(BPW21R)
5. BJT(BC 238)
6. Opamp (LM 741)
7. Capacitors(10µF,47µF,150µF)
8. Resistors

DesigN Process

1-Photodiode and LED Design:

Photodiode is a semiconductor component that communicates with light energy.Also,it is called light-sensitive diode.The photodiode passes current from the cathode to the anode end when the light falls on it.As the light intensity falling on the photodiode increases,the reverse leakage current value increases.The photodiodes are connected reverse to the circuit.

In this project,we used BPW21R as a photo diode.Our selection of LEDs is based on the Relative Spectral Sensitivity vs Wavelength graph in Figure 1.

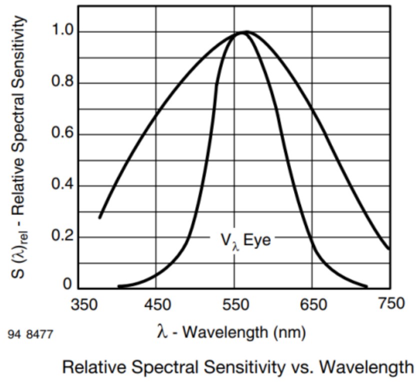
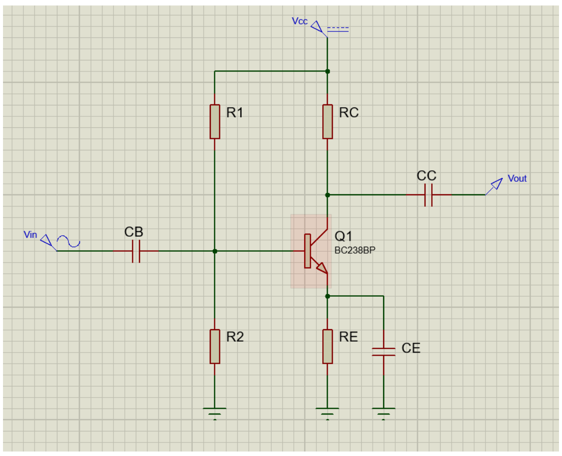


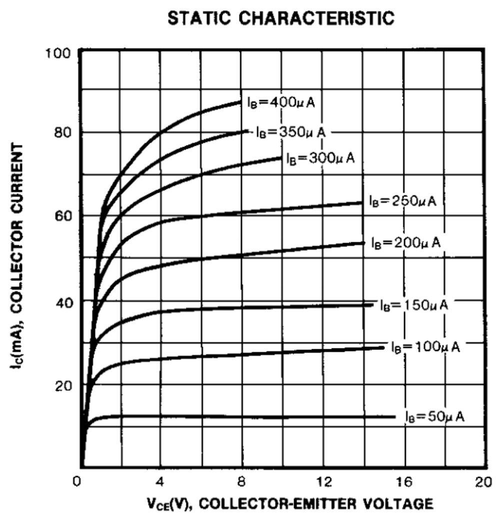
Figure-1

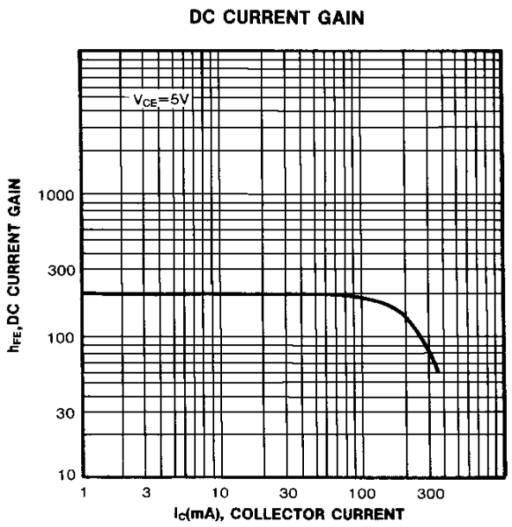
When choosing LED,we paid attention to the fact that the LED wavelength is between 370-700 wavelength.When we compared LED wavelengths,we decided that blue LED is the most suitable LED.Blue LED's wavelength is between 450-500.

2-BJT Amplifier Design



In this part,we decided to design common-emitter amplifier.We prefered BC238 as BJT.When choosing the resistance values,I tried to adhere to the static characteristic graph and DC current gain in datasheet.





BJT has 3 region which are cut-off,saturation and active region.In order to use the BJT as an amplifier,BJT must work in the active region.For this,it is important to select the resistance values properly.Otherwise,BJT can shift to saturation and cut-off regions.

The common emitter amplifiers have high voltage and current gains.It is used in the design of many devices and systems.Also,another reason for making this selection is that the common emitter amplifiers are fully stable.The characteristics of common emitter amplifiers;

-Polarization was done from a single V_{cc} source.

-Base polarization was provided with R_1 and R_2.

-With the C_B capacitor,DC current was prevented from entering the input source.

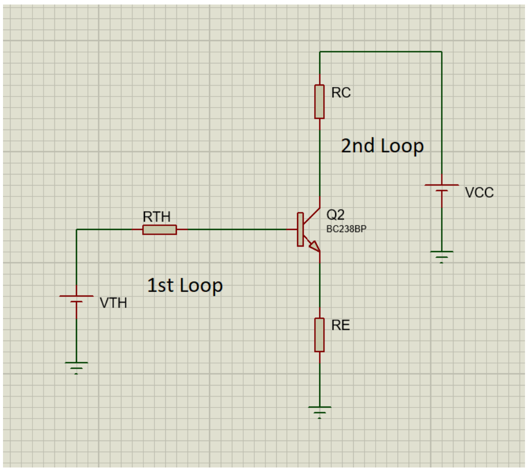
-A negative feedback was provided with R_E resistance and balanced operation was provided.

-The C_E bypass capacitor is a short path fort he AC signal current.This prevented the loss of AC energy on the R_E resistance.Also C_E capacitor in DC operation the stability of the transistor was preffered for providing.

-The R_E resistance reduces the gain of the transistor in AC operation.This effect of R_E was eliminated with a parallel connected C_E capacitor.

ANALYSIS OF BJT

-DC ANALYSIS



As the first step for the DC Analysis of the circuit,the DC equivalent circuit is drawn as seen above.For DC equivalent,the capacitors in the circuit are considered open circuit and the signal source is ignored.Firstly,the resistance and voltage of thevenin are calculated.

$$R_{TH} = \frac{R_1.R_2}{R_1+R_2}$$

$$V_{TH} = \frac{R_2}{R_1+R_2}.V_{CC}$$

Kirchhoff Law are applied separately for two loops.

1st Loop:

$$-V_{TH} + I_B.R_{TH} + V_{BE} + I_E.R_E = 0$$

$$I_E = (\beta + 1)I_B$$

$$V_{TH} - V_{BE} = I_B[R_{TH} + (\beta + 1)R_E]$$

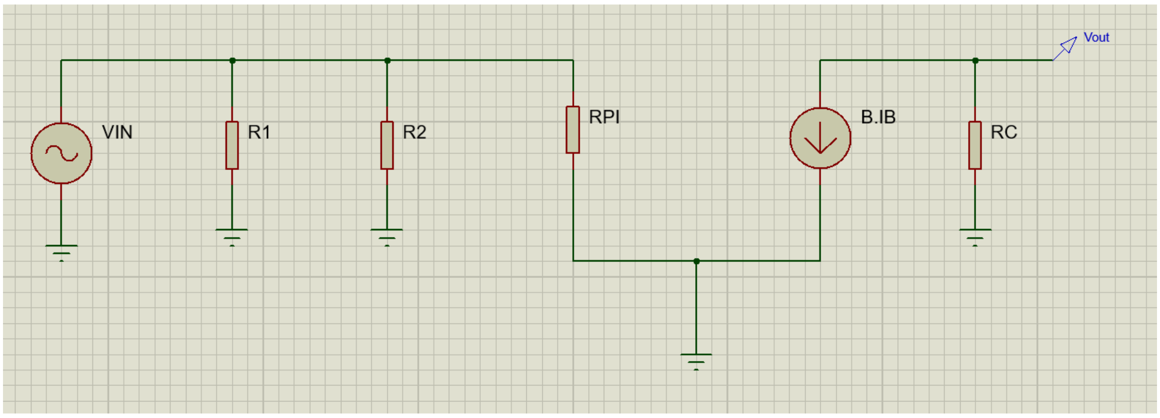
2nd Loop

$$-V_{CC} + I_C.R_C + V_{CE} + I_E.R_E = 0$$

$$I_C = \beta I_B$$

$$V_{CC} - V_{CE} = I_B[\beta R_C + (\beta + 1)R_E]$$

-AC ANALYSIS



The first step for AC Analysis of the circuit is to draw the AC equivalent circuit and then apply the r-π model as seen above.For AC equivalent,DC sources and capacitors are considered short circuit.Also,the current on the R_C is from ground to output voltage.

$$-V_{in} + i_B . r_\pi = 0$$

$$V_{in} = i_B . r_\pi$$

$$r_\pi = \frac{26mV}{I_B}$$

$$-V_{out} - \beta i_B . R_C = 0$$

$$V_{out} = -\beta i_B . R_C$$

$$A_v = \frac{V_{out}}{V_{in}} = -\frac{\beta . R_C}{r_\pi}$$

DETERMINING THE RESISTORS

$$V_E = \frac{V_{CC}}{10}$$

$$R_E = \frac{V_E}{I_E} \cong \frac{V_E}{I_C}$$

$$R_C = \frac{V_{RC}}{I_C} = \frac{V_{CC} - V_{CE} - V_E}{I_C}$$

$$V_{BE} = V_B - V_E \text{ so } V_B = V_{BE} + V_E$$

For the circuit to operate efficiently,it is assumed that the current through R_1 and R_2 should be approximately equal to and much larger than the base current(at least 10:1).This fact and the voltage-divider equation fort he base voltage provide the two relationships necessary to determine the base resistors.

$$R_2 \leq \frac{1}{10}\beta R_E$$

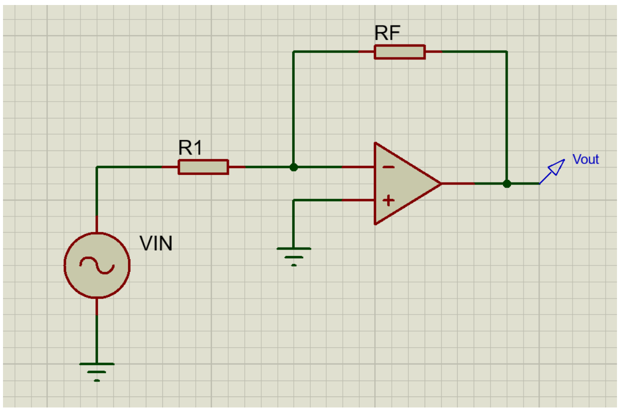
and

$$V_{TH} = V_B = \frac{R_2}{R_1+R_2}V_{CC}$$

3-Opamp Design

Since our signal from BJT is too low,we have designed opamp.We prefered to design inverting opamp in this process.

Inverting opamp changes the phase angle of the output signal exactly 180 degrees out of phase with respect to input signal.We used two external resistors to create feedback circuit and make a closed loop circuit across the amplifier.



In the above image,R_1 and R_F provide the necessary feedback throughout the opamp circuit.The R_1 resistor is the signal input resistor and R_F resistor is the feedback resistor.The feedback is connected across the opamp's negative terminal and the positive terminal is connected across the ground.Also V_+ and V_- is the same.

$$V_- = V_+ = 0$$

$$\frac{V_- - V_{in}}{R_1} + \frac{V_- - V_{out}}{R_F} = 0$$

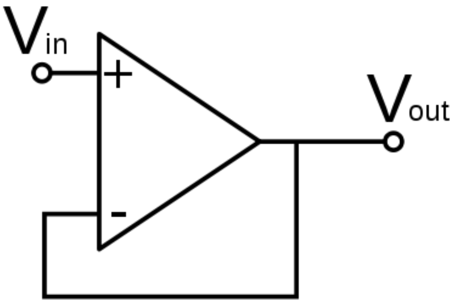
$$\frac{V_{out}}{R_F} = -\frac{V_{in}}{R_1}$$

$$V_{out} = -\frac{R_F}{R_1} V_{in}$$

$$A_v = -\frac{R_F}{R_1}$$

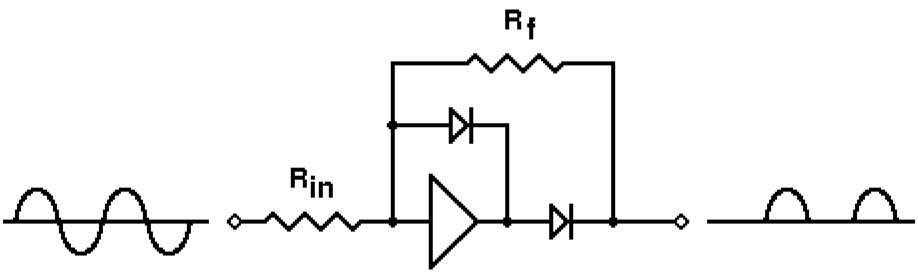
4-Buffer Design

Buffer opamp circuits transmit the input signal to the output without changing it at all.We designed this circuit to make the impedances suitable and to isolate the circuits from each other.The voltage gain in the buffer circuit is 1.



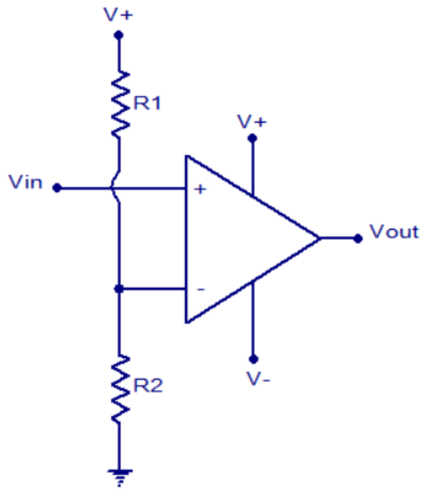
5-Precision Rectifier Design

The purpose of designing this circuit was to obtain DC output.We used two 1n4001 diode.When we used diode signal converts AC to + cycle.We want to obtain DC output.So,we must to keep low ripple voltage.So,we selected high capacitor and resistor value.Signal converts nearly DC.



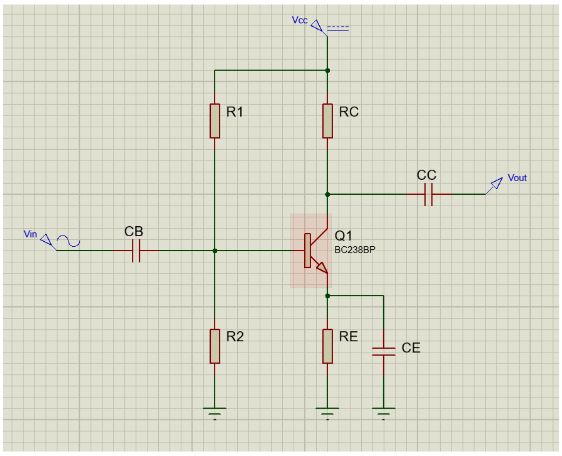
6-Comparator Design

In non-inverting comparator the reference voltage was applied to the inverting input and the voltage to be compared was applied to the non-inverting input.Whenever the input voltage to be compared goes above the reference voltage,the output of the opamp swings to positive saturation and vice versa.



CALCULATIONS,SIMULATIONS AND MEASURED

BJT:



We assumed I_{CQ} and V_{CEQ} values.

$I_{CQ} = 6mA$

$V_{CEQ} = 5.2V$

$V_{CC} = 12V$

β=265

$$V_E = \frac{1}{10}V_{CC} = \frac{1}{10}.12 = 1.2V$$

$$R_E = \frac{V_E}{I_E} \cong \frac{V_E}{I_C} = \frac{1.2}{6mA} = 200\Omega$$

$$R_C = \frac{V_{RC}}{I_C} = \frac{V_{CC} - V_{CE} - V_E}{I_C} = \frac{10 - 5.2 - 1.2}{6mA} = 0.933 \cong 1k\Omega$$

$$V_B = V_{BE} + V_E = 0.7 + 1.2 = 1.9V$$

$$R_2 \leq \frac{1}{10}\beta R_E$$

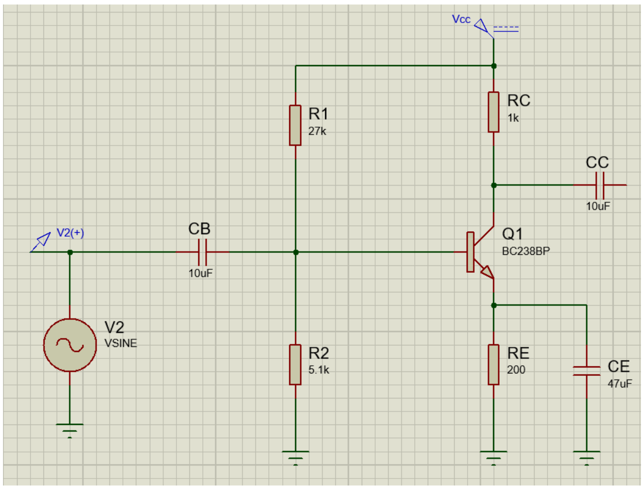
$$R_2 \leq \frac{1}{10}.265.(0.2k\Omega)$$

$$R_2 = 5.3k\Omega \cong 5.1k\Omega$$

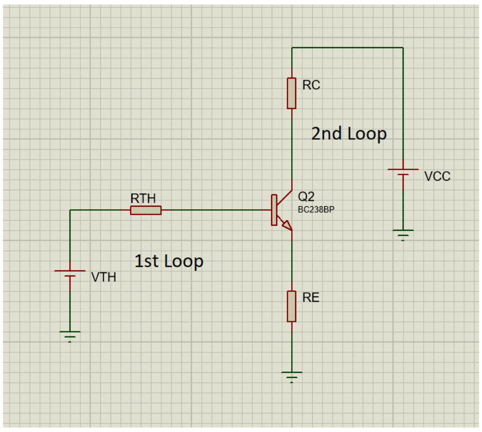
$$V_B = 1.9V = \frac{(5.2k\Omega).12V}{R_1 + 5.2k\Omega}$$

$$1.9R_1 + 9.88 = 62.4$$

$$R_1 = 27.6k\Omega \cong 27k\Omega$$



DC Analysis:



$$R_{TH} = \frac{(27k\Omega).(5.1k\Omega)}{32.1k\Omega} = 4.36k\Omega$$

$$V_{TH} = \frac{5.1k\Omega}{32.1k\Omega}12V = 1.98V$$

$$1.98 - 0.7 = I_B(4.36k\Omega + (266)(0.2k\Omega)$$

$$I_B = 22.24\mu A$$

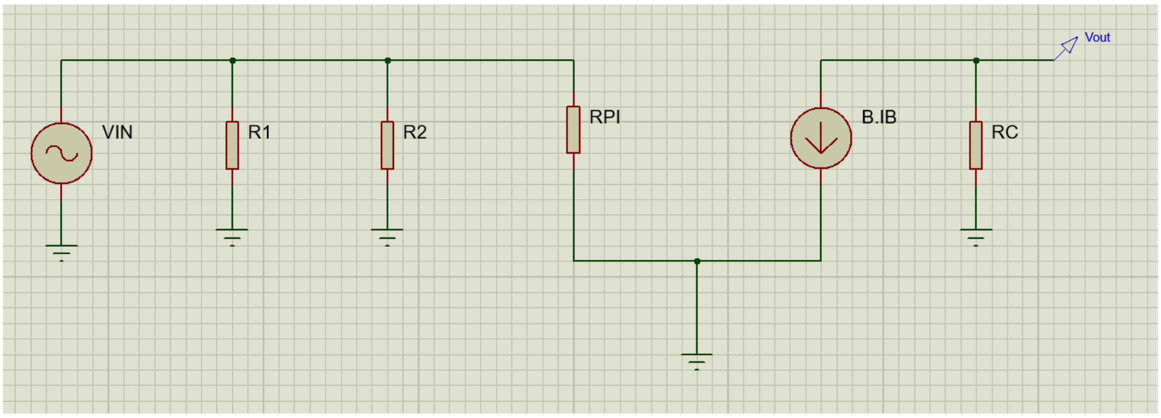
$$I_C = \beta I_B = 5.89mA$$

$$I_E = (\beta + 1)I_B = 5.92mA$$

$$12 - V_{CE} = \left(22.24x10^{-6}\right)(4360\Omega + 266x200\Omega)$$

$$V_{CE} = 4.92V$$

AC Analysis:



$$R_{eq} = \frac{R_1 . R_2}{R_1 + R_2} = \frac{(27k\Omega).(5.1k\Omega)}{32.1k\Omega} = 4.36k\Omega$$

$$r_\pi = \frac{26mV}{I_B} = \frac{26x10^{-3}}{22.24x10^{-6}} = 1.17k\Omega$$

$$V_{in} = i_b r_\pi$$

$$V_{in} = 6mV = 6x10^{-3}V$$

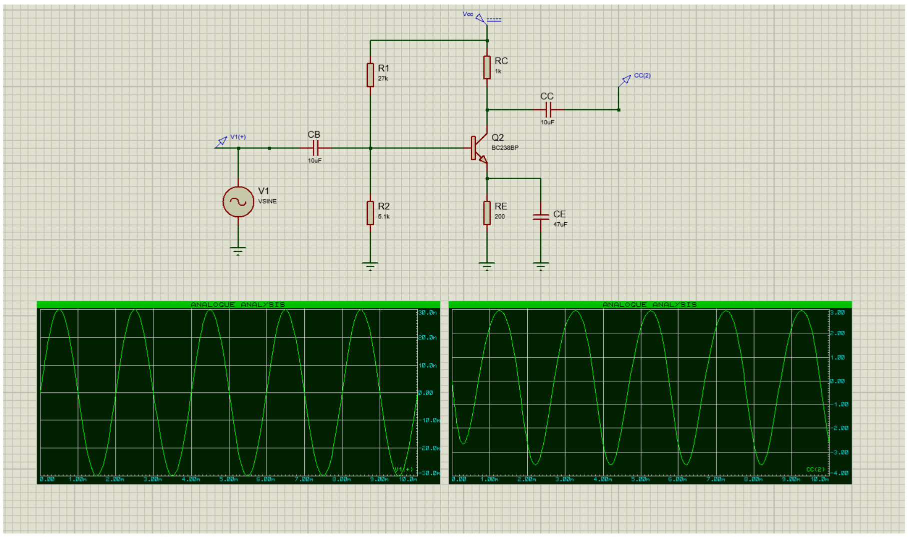
$$i_b = \frac{6x10^{-3}V}{1170\Omega} = 5.13\mu A$$

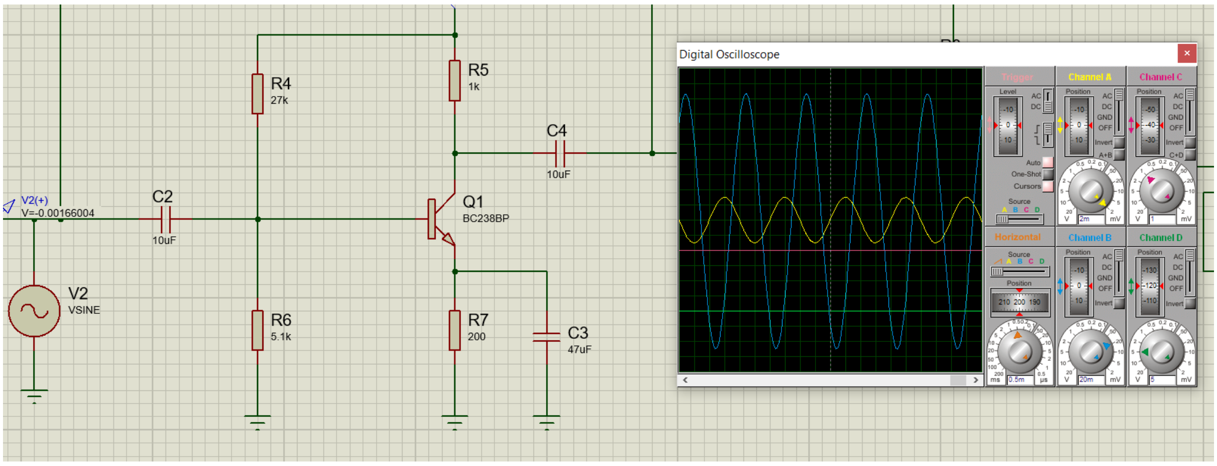
$$V_{out} =- \beta i_b R_C$$

$$V_{out} =- 265\left(5.13x10^{-6}A\right)(1000\Omega)$$

$$V_{out} =- 1359x10^{-3}V$$

$$A_v = \frac{V_{out}}{V_{in}} = \frac{1359x10^{-3}}{6x10^{-3}} \cong 226$$





OPAMP:

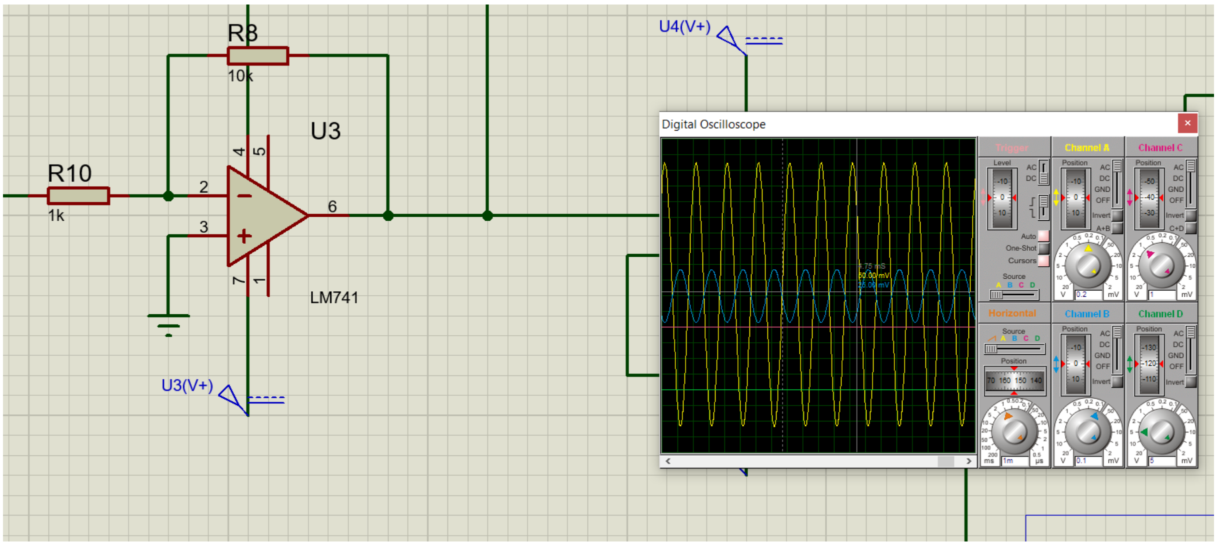
$$V_{out} = -\frac{R_F}{R_1} V_{in}$$

$$A_v = -\frac{R_F}{R_1}$$

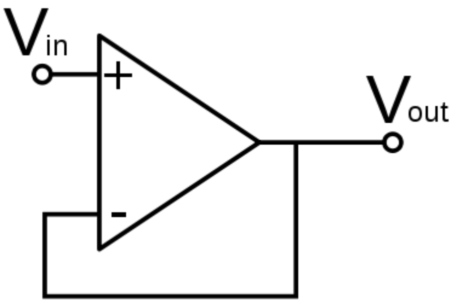
We have chosen 1k so that the resistance of R_1 is almost equal to R_{out} in the BJT circuit.And then we want to have 10 gain in the opamp circuit.

$$V_{out} = -\frac{10}{1} V_{in}$$

$$A_v = -\frac{10}{1} = -10$$

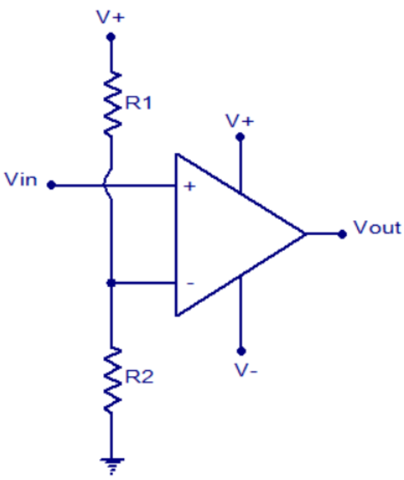


BUFFER:



$$V_{in} = V_{out}$$

COMPARATOR:



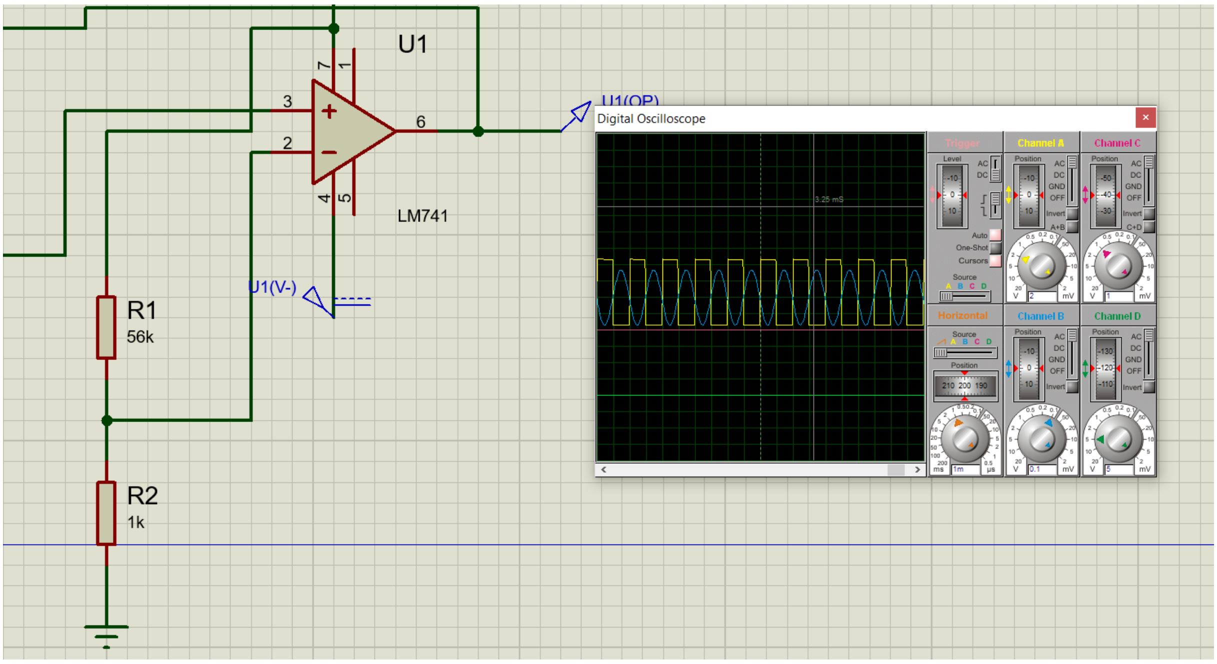
We assumed V_{ref} minimum voltage which was 0.1V to keep duty cycle at %50.

$$\frac{V_{ref}-0}{R_2} = \frac{V_+ - V_{ref}}{R_1}$$

$$\frac{0.1}{R_2} = \frac{5-0.1}{R_1}$$

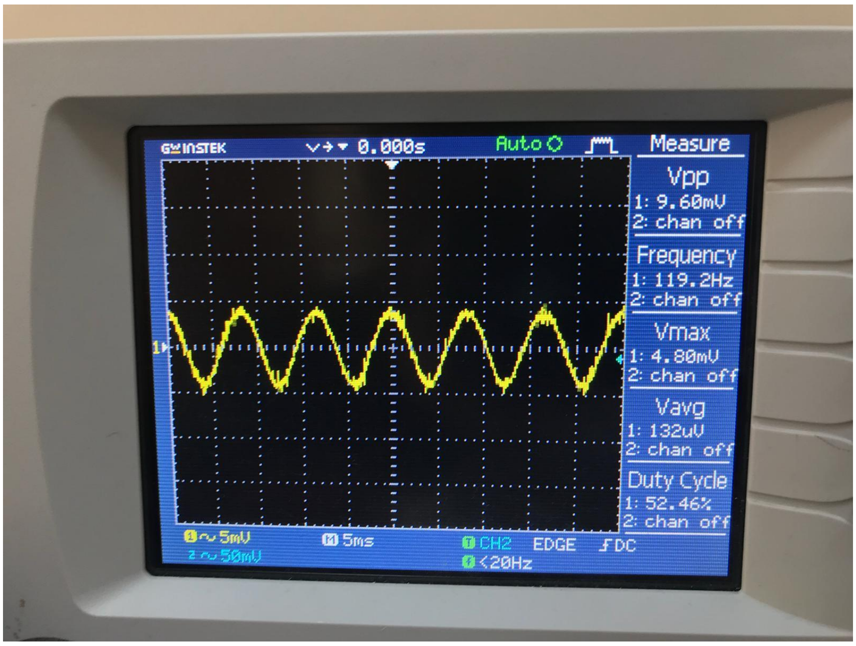
$$R_1 = 49R_2$$

$$R_1 = 56k \qquad R_2 = 1k$$

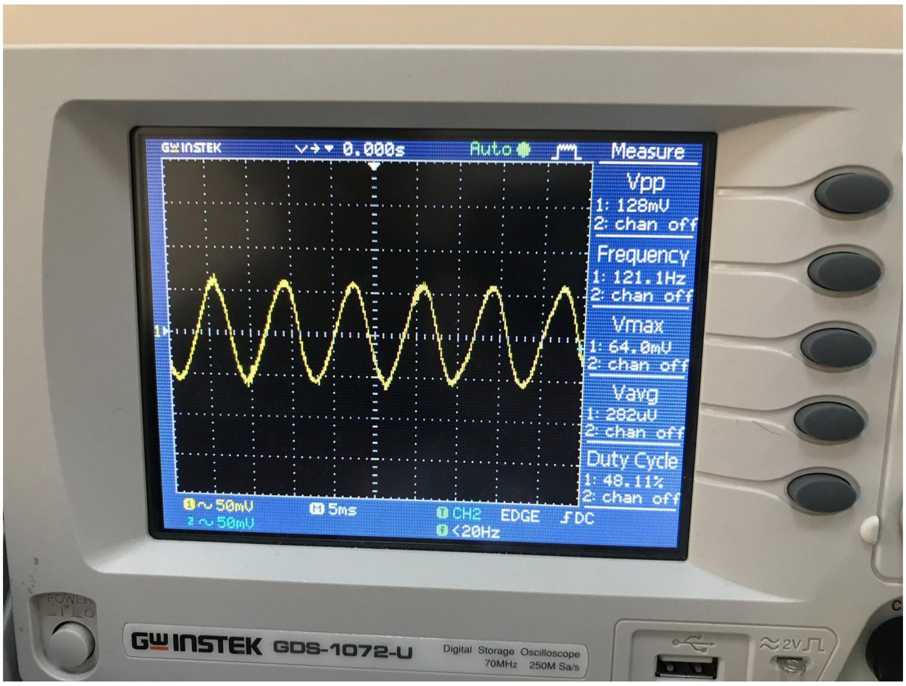


OSCILOSCOPE

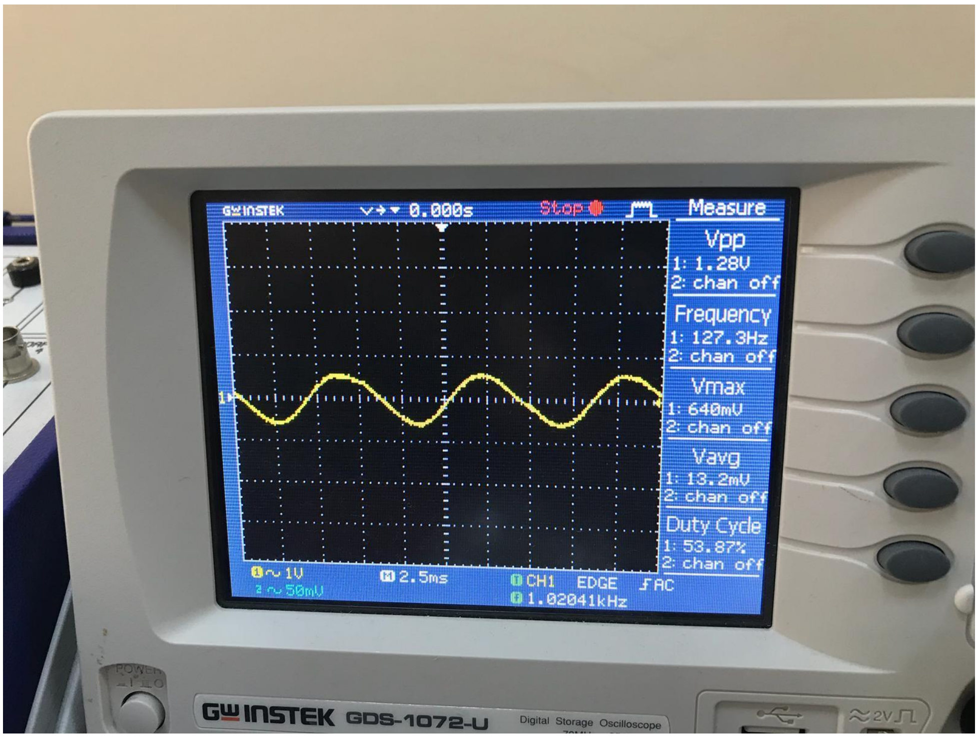
PHOTODIODE:



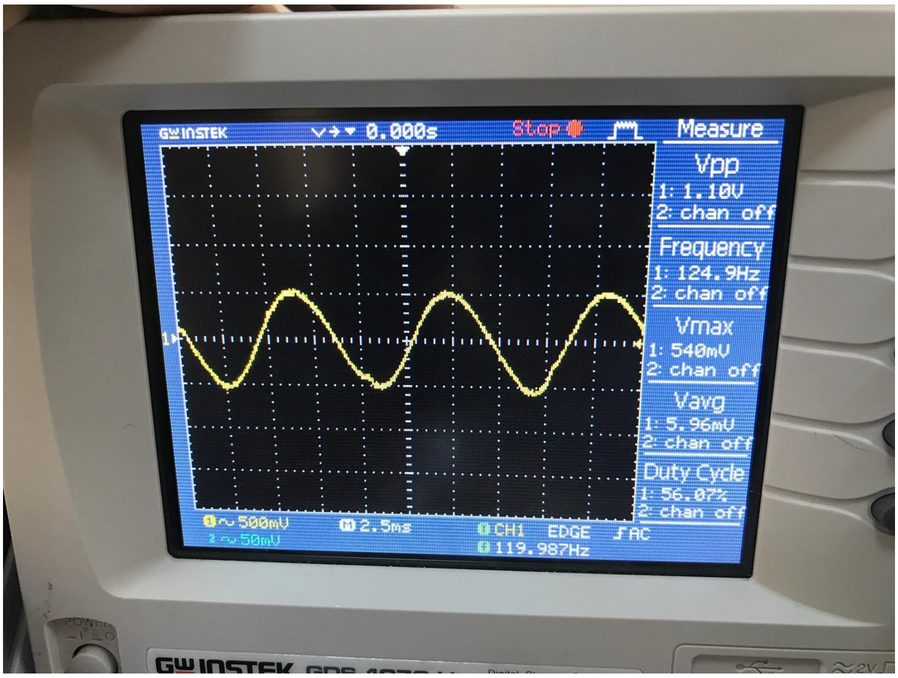
BJT:



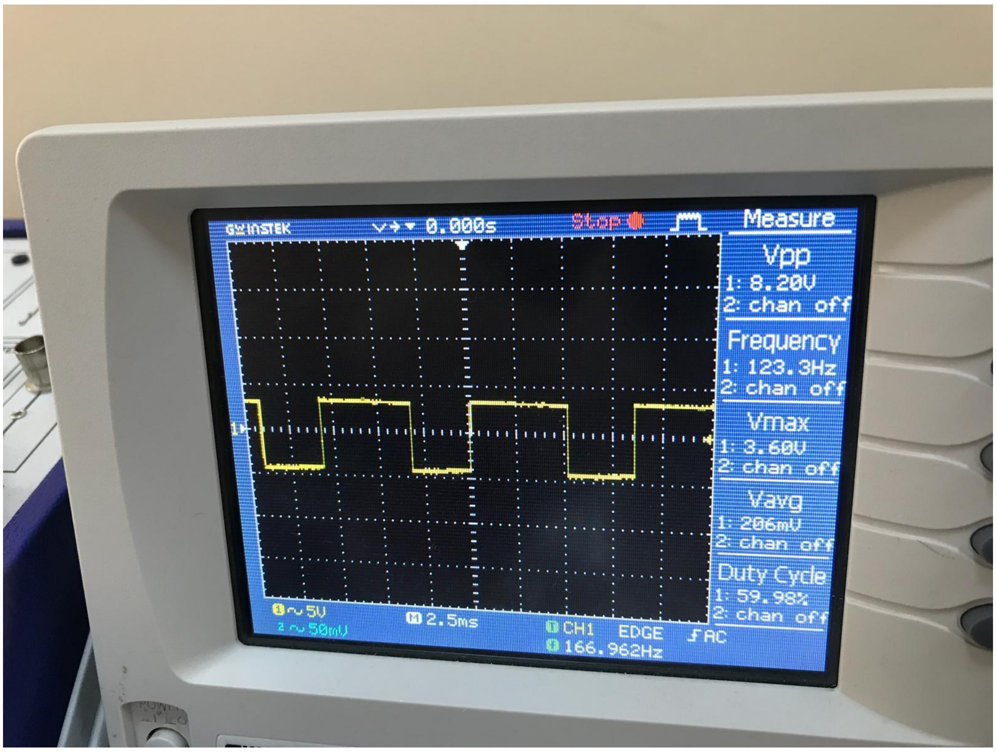
OPAMP:



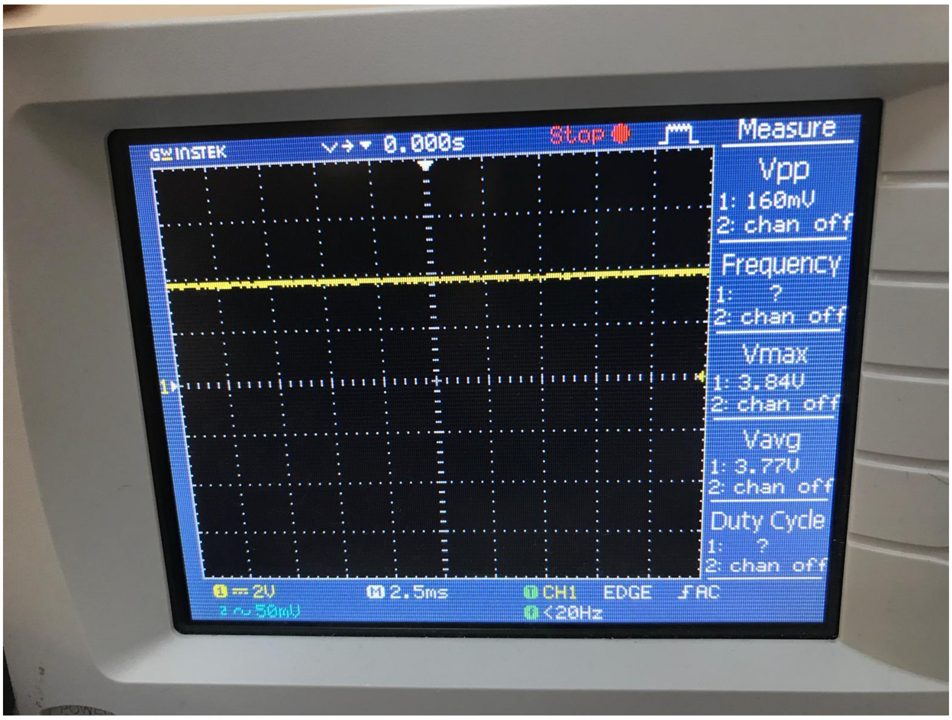
BUFFER:



COMPARATOR:



HALF-WAVE PRECISION RECTIFIER:



DISCUSSION

Aim of the experiment is thanks to photodiode we have obtained voltage and current through the light from the led and filtering the signal with some special circuits and specialized the circuits for increasing current and voltage.For this we use 5 circuits.These are BJT circuit,İnverter opamp circuit,Buffer circuit,comparator and precision circuit.

Firstly we use BJT circuit.We use it as a amplifier.For this we use BC 238 transistor.For using as a amplifier we use it at active region.For this we did some special calculations.Using this calculations we assumed the resistors.At bjt in measurement our gain is -12.But it is all circuits are connected each other.If we look just BJT circuit, our gain is 100.Decrasing at gain we thought because of common ground and the output resistance is greater than the input resistance of the future circuit.If we are increasing the resistance of the input circuit of the next circuit can increase our gain

For 2. Circuit we use inverting opamp.Reason of this is the voltage which is obtained from BJT is low.At inverting opamp Rf/R1 is gain.So Rf>R1. accordingly, we created the desired rate of gain.thanks to this we increased our voltage.But this isnt filter.For this we use buffer circuit. buffer circuit stabilizes the signal. this is preparing a nice environment for precision or comparator.

For third circuit we built comparator circuits.Aim of doing this change incoming sine wave to square wave.For this LM741 opamp.And at output we obtained 0-5 V TTL. In non-inverting comparator the reference voltage was applied to the inverting input and the voltage to be compared was applied to the non-inverting input.Whenever the input voltage to be compared goes above the reference voltage,the output of the opamp swings to positive saturation and vice versa.

Forth circuit is precision circuit.At outpur of this circuit 0-5 V DC voltage.At precision circuit we used diode.Diode allows current to flow in one direction.