# GEBZE TECHNICAL UNIVERSITY

## ELECTRONICS ENGINEERING DEPARTMENT

## ELEC 237

## EXPERIMENT – 4 REPORT

**PREPARED BY**



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**INGREDIENTS**

## 1. Introduction

Transistors are three terminal active devices made from different semiconductor materials that can act as either an insulator or a conductor by the application of a small signal voltage. The transistor's ability to change between these two states enables it to have two basic functions: "switching" (digital electronics) or "amplification" (analogue electronics). Then bipolar transistors have the ability to operate within three different regions:

- Active Region – the transistor operates as an amplifier and Ic = β*Ib
- Saturation – the transistor is "Fully-ON" operating as a switch and Ic = I(saturation)
- Cut-off – the transistor is "Fully-OFF" operating as a switch and Ic = 0

There are two basic types of bipolar transistor construction, PNP and NPN, which basically describes the physical arrangement of the P-type and N-type semiconductor materials from which they are made.

The Bipolar Transistor basic construction consists of two PN-junctions producing three connecting terminals with each terminal being given a name to identify it from the other two. These three terminals are known and labelled as the Emitter ( E ), the Base ( B ) and the Collector ( C ) respectively.

Bipolar Transistors are current regulating devices that control the amount of current flowing through them from the Emitter to the Collector terminals in proportion to the amount of biasing voltage applied to their base terminal, thus acting like a current-controlled switch. As a small current flowing into the base terminal controls a much larger collector current forming the basis of transistor action.

The principle of operation of the two transistor types PNP and NPN, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.

## Bipolar Transistor Construction

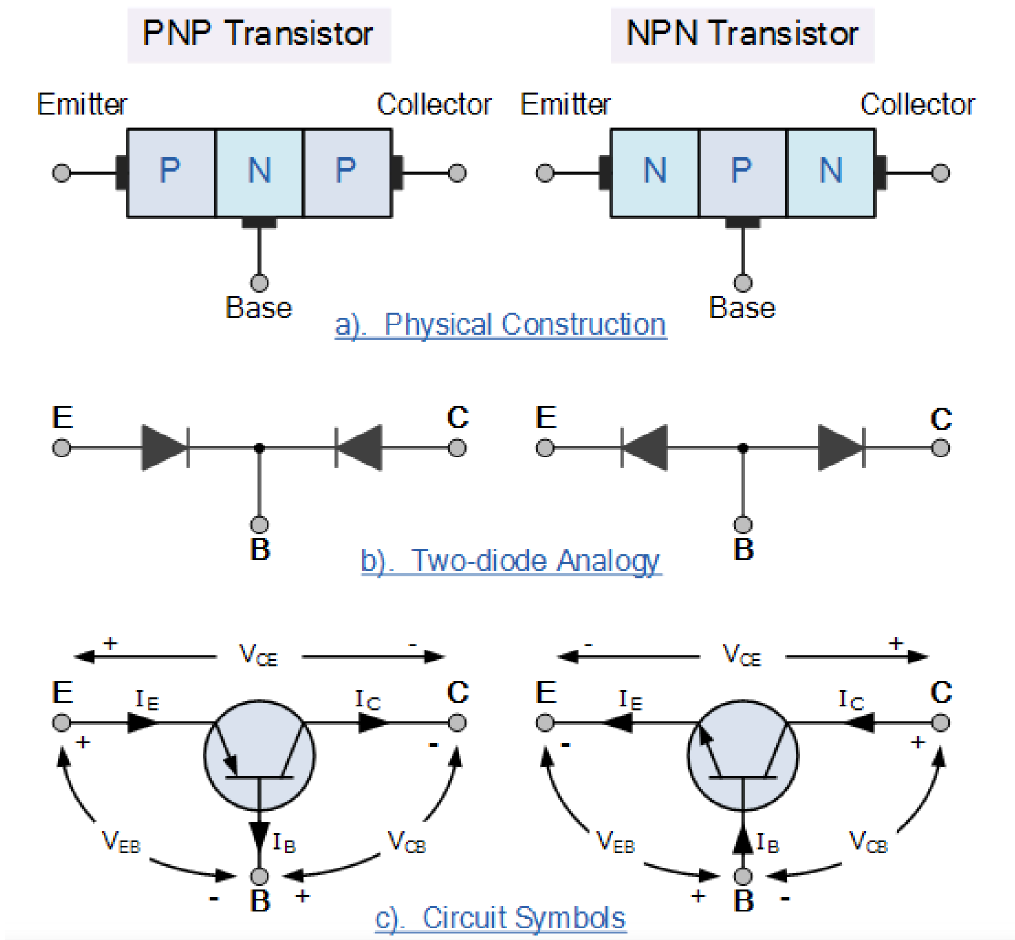



**Figure 1.** PNP and NPN BJT

$$\text{Alpha}, (\alpha) = \frac{I_C}{I_E} \quad \text{and} \quad \text{Beta}, (\beta) = \frac{I_C}{I_B}$$

$$\therefore I_C = \alpha . I_E = \beta . I_B$$

$$\text{as:} \quad \alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

$$\boxed{I_E = I_C + I_B}$$

**Figure 2.** BJT equations

Where: "Ic" is the current flowing into the collector terminal, "Ib" is the current flowing into the base terminal and "Ie" is the current flowing out of the emitter terminal.

Then to summarise a little. This type of bipolar transistor configuration has a greater input impedance, current and power gain than that of the common base configuration but its voltage gain is much lower. The common emitter configuration is an inverting amplifier circuit. This means that the resulting output signal has a 180o phase-shift with regards to the input voltage signal.

| | |
|---|---|
| $I_E = I_B + I_C$<br>$I_C = I_E - I_B$<br>$I_B = I_E - I_C$ | $\alpha = \frac{I_C}{I_E} = \frac{\beta}{1+\beta}$<br>$\beta = \frac{I_C}{I_B} = \frac{\alpha}{1-\alpha}$ |
| $I_B = \frac{I_C}{\beta} = \frac{I_E}{1+\beta} = I_E(1-\alpha)$ | |
| $I_C = \beta . I_B = \alpha . I_E$ | $I_E = \frac{I_C}{\alpha} = I_B(1+\beta)$ |

**Figure 3.** Relationship between DC currents and gains

## 2. Experiment

### 2.1. Component Familiarization and Identification

#### 2.1.1. Establishing Device Currents (npn)

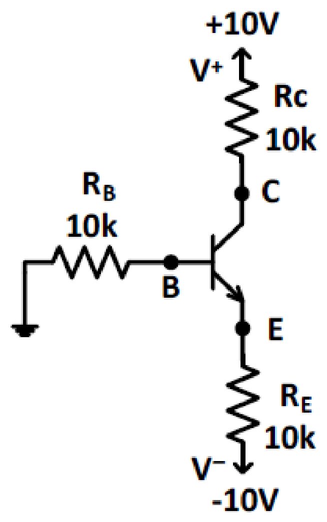



**Figure 4.** A flexible biasing circuit.

The voltages at B, E and C were measured relative to ground using DVM. Using these measurements, VBE, IB, IC, IE, α, β were calculated. Table 1 has been filled.

**Table 1.** Operating points of the BJT in Figure 4.

| $V_B$ | $V_C$ | $V_E$ | $V_{BE}$ | $I_B$ | $I_C$ | $I_E$ | $\alpha$ | $\beta$ |
|---|---|---|---|---|---|---|---|---|
| -26.5mV | 068 V | -0.685 V | 658.5mV | 2.65uA | 0.932mA | 0.932mA | 0.997 | 351.7 |
| | | | | $\frac{Vb-0}{10k}$ | $\frac{10-Vc}{10k}$ | $\frac{Ve-(-10)}{10k}$ | 0.99 | |

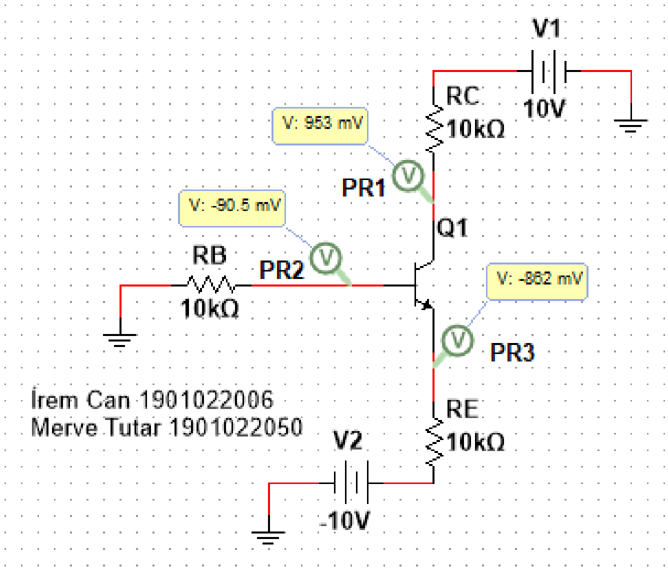



**Figure 5.** BJT voltaje measurement

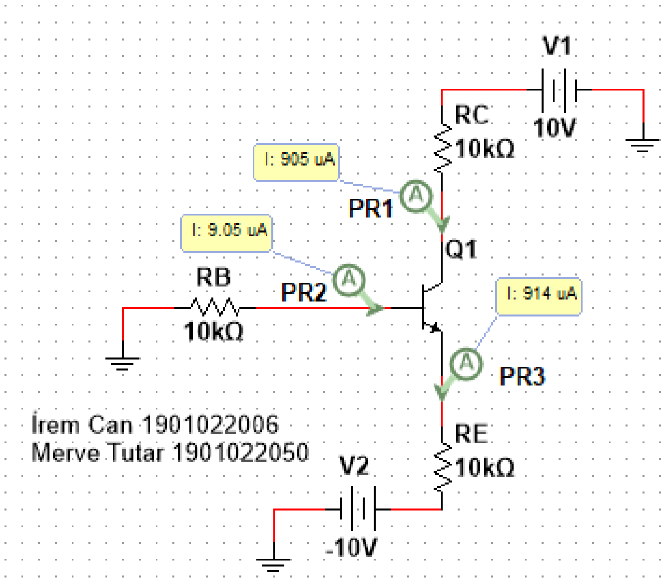



**Figure 6.** BJT voltaje measurement

**Table 2.** Operating points of the BJT measuring in Multisim

| $V_B$ | $V_C$ | $V_E$ | $V_{BE}$ | $I_B$ | $I_C$ | $I_E$ | $\alpha$ | $\beta$ |
|---|---|---|---|---|---|---|---|---|
| -90.5 mV | 953 mV | -862 mV | 771.5 mV | -9.5 µA | 905 µA | 914 µA | 0.989 | 95.26 |

$$V_{BE} = V_B - V_E = (-90.5 - (-862))\ \text{mV} = 771.5\ \text{mV}$$

$$I_B \times \beta = I_C \Rightarrow -9.5 \times \beta = 905$$

$$\beta = 95.26$$

$$\alpha = \beta / (\beta+1) \Rightarrow 0{,}989$$

### 2.1.2. Identifying the Controlling Junction and Junction Current

V- is increased to -5V and the voltages at B, E and C are measured according to the values in Table 2. It is grounded using DVM. The calculation steps in 2.1.1. are repeated and the relevant fields are filled. With V- = -5V, V+ was reduced to +5V and the steps just mentioned were repeated.

**Table 3.** Operating points of the BJT in Figure 1 with different supply voltages.

| | $V_B$ | $V_C$ | $V_E$ | $V_{BE}$ | $I_B$ | $I_C$ | $I_E$ | $\alpha$ | $\beta$ |
|---|---|---|---|---|---|---|---|---|---|
| $V^- = -5V$ $V^+ = +10V$ | -1.25V | 4.89V | -1.90V | 0.64V | 0.125mA | 1.189mA | 1.15mA | 0.999 | 499 |
| $V^- = -5V$ $V^+ = +5V$ | -49.2mV | 0.643V | -0.649V | 599.8 | -4.92uA | 0.635mA | 1.06mA | 0.997 | 444 |

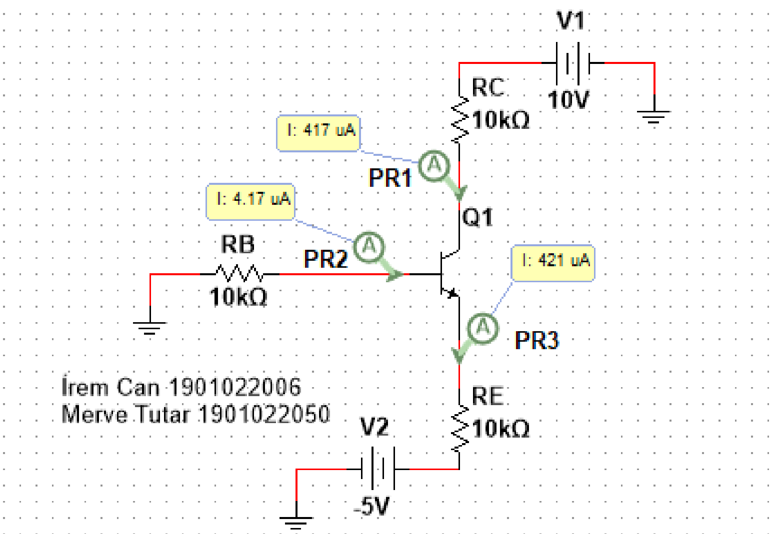



**Figure 7.** BJT current measurement when V- = -5V

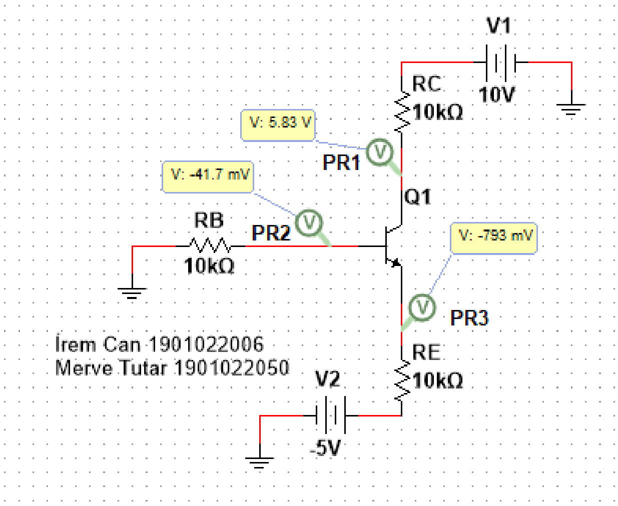



**Figure 9.** BJT voltaje measurement when V- = -5V

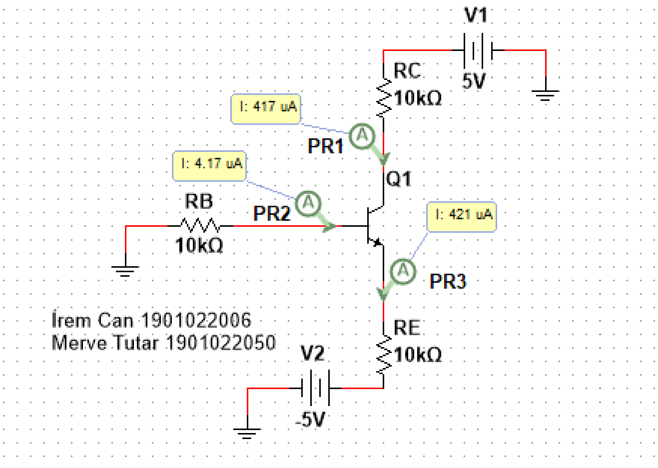



**Figure 10.** BJT current measurement when V- = -5V, V+ = 5V

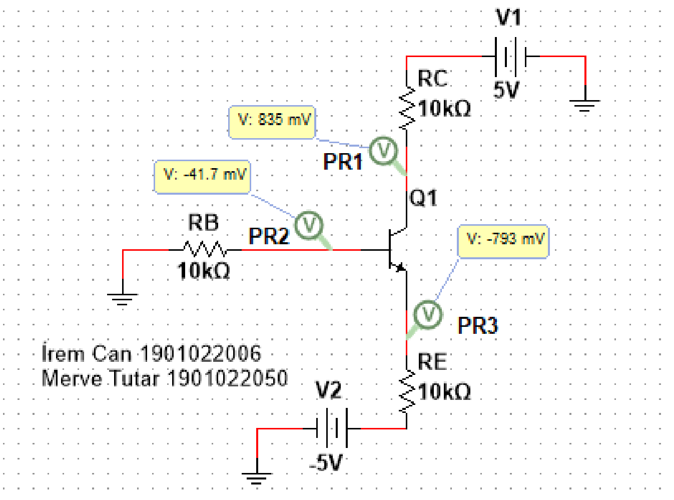



**Figure 11.** BJT voltage measurement when V- = -5V, V+ = 5V

**Table 4.** Operating points of the BJT in Figure 1 with different supply voltages.

in Multisim

| | $V_B$ | $V_C$ | $V_E$ | $V_{BE}$ | $I_B$ | $I_C$ | $I_E$ | $\alpha$ | $\beta$ |
|---|---|---|---|---|---|---|---|---|---|
| ***V- = -5V* *V+ = +10V*** | -41.7 mV | 5.83 V | -793 mV | 834.7 mV | 4.17 µA | 417 µA | 421 µA | 0.990 | 100 |
| ***V- = -5V* *V+ = +5V*** | 41.7 mV | 835 mV | -793 mV | 834.7 mV | 4.17 µA | 417 µA | 421 µA | 0.990 | 100 |

(V- = -5V), (V- = -5V, V+ = 5V) (the values are the same)

$$V_{BE} = V_B - V_E = (-41.7 - (-793)) \text{ mV} = 834.7 \text{ mV}$$

$$I_B \times \beta = I_C \;\Rightarrow\; 4.17 \times \beta = 417$$

$$\beta = 100$$

$$\alpha = \beta / (\beta+1) \;\Rightarrow\; 0{,}990$$

## 2.2. Other, Less-Stable Biasing Schemes

### 2.2.1. Base-Current Bias

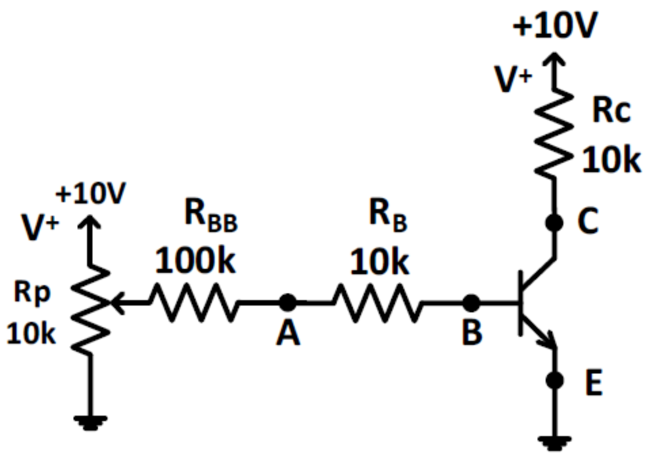



**Figure 12.** A bad base-current-biasing circuit.

The voltage at the C node was measured by adjusting the potentiometer until Rp $V_C$ = +5V. The voltages at nodes A and B were measured with the DVM. The transistor was heated while measuring $V_C$. The new value of $V_C$ is noted in Table 5. Then the transistor was removed. A new one was placed in its place and the above operations were repeated.

**Table 5.** Operating points of BJT in Figure 12 under different temperature conditions.

| Node Voltage | Transistor 1 | Transistor 2 |
|---|---|---|
| $V_A$ | 0.557 V | 0.482 V |
| $V_B$ | 128 mV | -0.20 V |
| $V_{C\_cold}$ | 5.39 V | 5.31 V |
| $V_{C\_hot}$ | 165 mV | 192 mV |

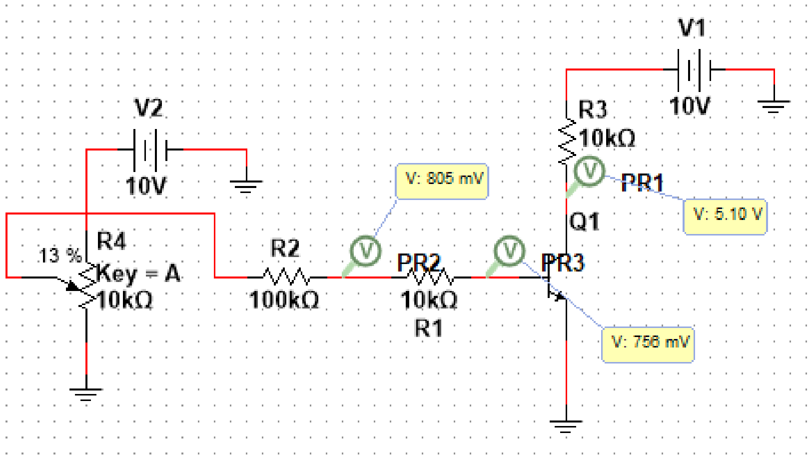



**Figure 13.** A, B, C nodes voltage measurement

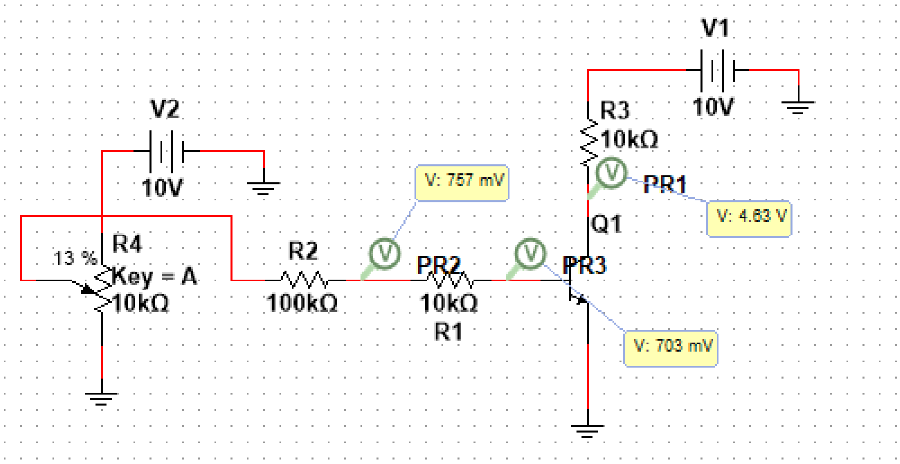



**Figure 14.** Voltage measurement of nodes A, B, C after the transistor is heated.

The potentiometer value is set to 13 percent in Multisim because when increased to 14 percent the voltage value of point C drops to 4.63 V. The best results are obtained at this percentage value. The transistor temperature is set at 65 degrees. During the experiment, the heating of the BJT was done with a lighter and instant measurement was taken. The data has been added to the relevant tables.

**Table 6.** Operating points of BJT in Figure 12 under different temperature conditions.

| Node Voltage | Transistor 1 |
|---|---|
| $V_A$ | 757 mV |
| $V_B$ | 756 mV |
| $V_{C\_cold}$ | 5.10 V |
| $V_{C\_hot}$ | 4.63 mV |

### 2.2.2. Fixed Base-Emitter-Voltage Biasing

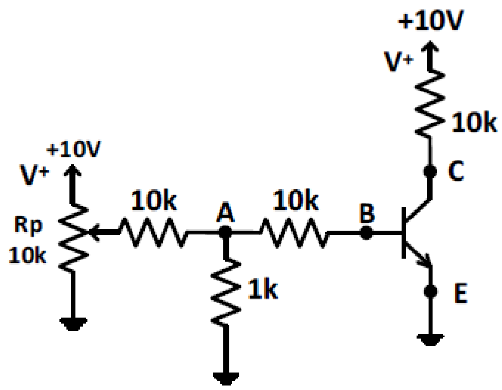



**Figure 15.** A bad base-voltage-biasing circuit.

**Table 7.** Operating points of BJT in Figure 15 under different temperature conditions.

| | |
|---|---|
| $V_A$ | 0.582V |
| $V_B$ | 0.594V |
| $V_{C\_cold}$ | 5.1V |
| $V_{C\_hot}$ | 2.8V |

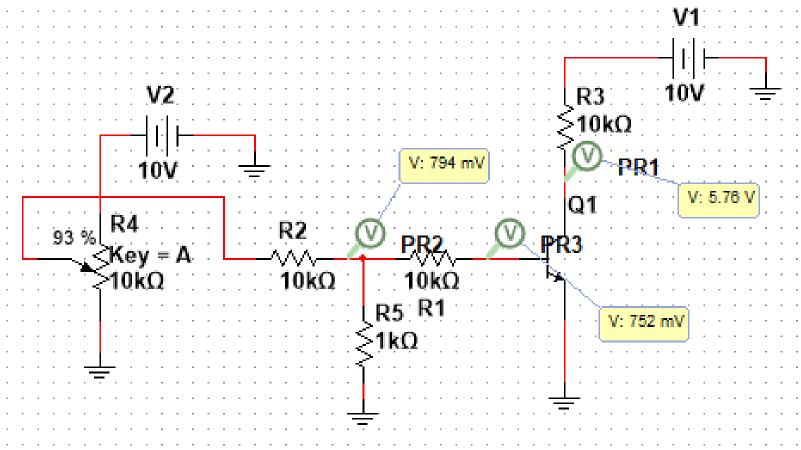



**Figure 16.** A, B, C nodes voltage measurement

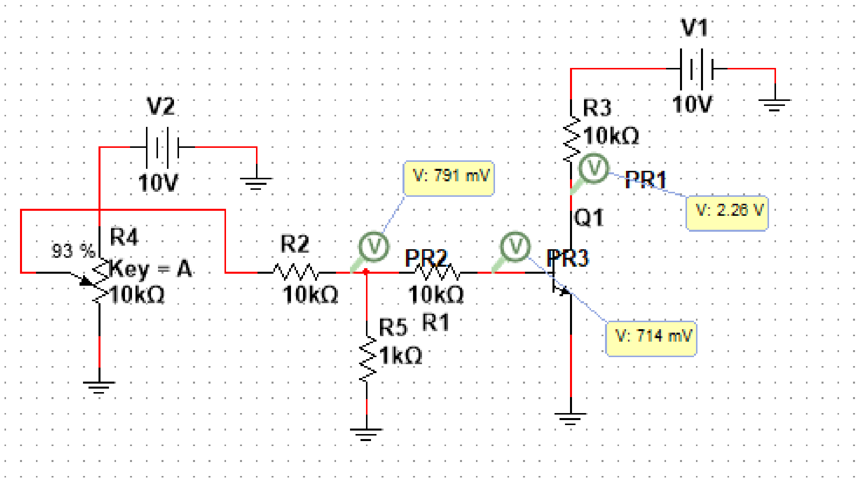



**Figure 17.** Voltage measurement of nodes A, B, C after the transistor is heated.

In Multisim, the potentiometer value is set at 93 percent because when increased to 94 percent the voltage of point C drops to 3.91 V. The best results are obtained at this percentage value. The transistor temperature is set at 65 degrees. During the experiment, the heating of the BJT was done with a lighter and instant measurement was taken. The data has been added to the relevant tables.

**Table 8.** Operating points of BJT in Figure 15 under different temperature conditions in Multisim

| | |
|---|---|
| $V_A$ | 794 mV |
| $V_B$ | 99.0 mV |
| $V_{C\_cold}$ | 752 V |
| $V_{C\_hot}$ | 2.26 V |

## 2.3 The BJT as Amplifier

A transistor is an electronic component that has three terminals. Terminals are base-emitter, collector and base. It used in different electronic projects and circuits for switching and amplification process. Amplification is process through which weak input signal is amplified to a larger level.

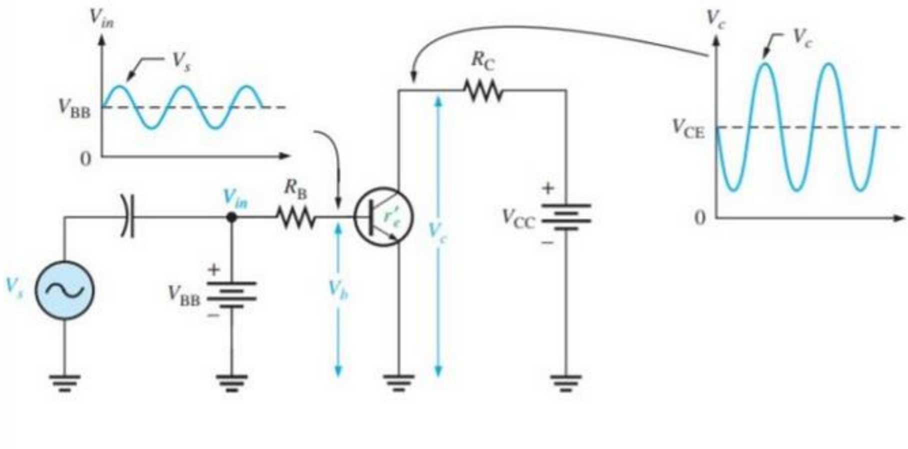



**Figure 18**. Basic transistor amplifier circuit

While the circuit shown in Figure 4 uses arather bad bias design, being a combination of base-current and base-voltage biasing, it is relatively convenient for the measurement of gain of a particular transistor under stable environmental conditions. Incidentally, the presence of the potentiometer RP is, generally speaking, a sure sign of less-than-ideal design.

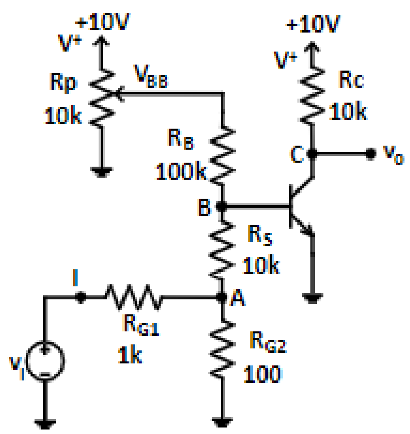



**Figure 19.** A badly-biased but otherwise-interesting amplifier

### 2.3.1 Voltage Gain and Input Resistance:

The circuit is connected as shown in Figure 18.

a) When Vi is on, the DC voltage at RP C is set to be 5V. Note the exact value of VC using DVM.

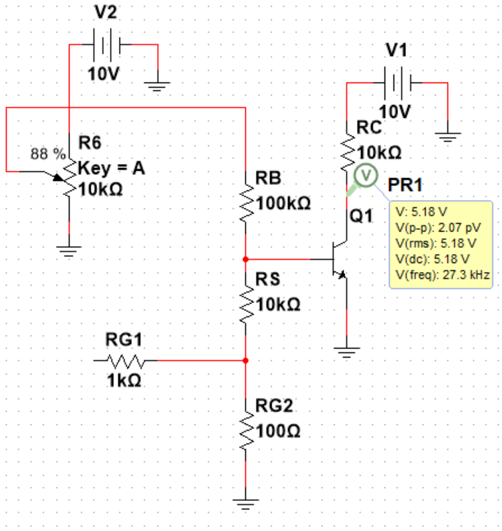



**Figure 20.** Simulation output for Vc

Vc = 5.18 V

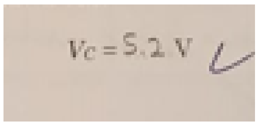



**Figure 21.** Experimental value for Vc

b) Connect the waveform generator to node I with vi is a sine wave at 1KHz. Using both channels of your oscilloscope, adjust the input-signal amplitude so that Vc is a sine wave with 2Vpp amplitude. Note the peak-to-peak value of the input signal.

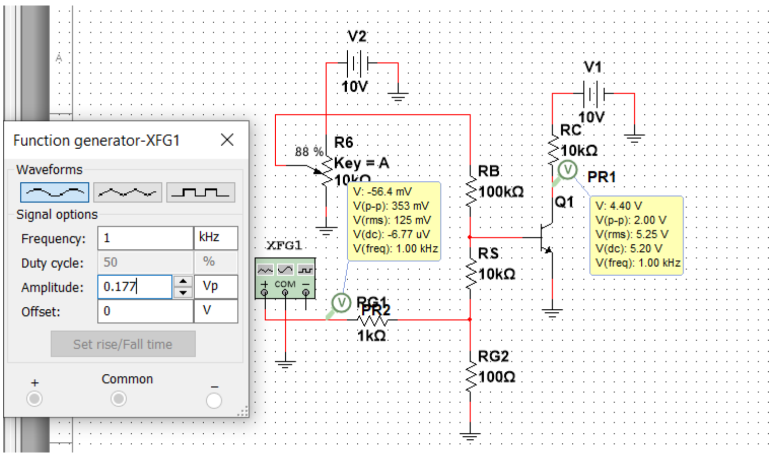



**Figure 22.** Vi value for Vc=2Vpp

While the Rp value was at the same value, the amplitude was manipulated until Vc= 2Vpp and the input voltage was measured.

Vi (p-p)= 0.35 V


**Figure 23.** Experimental value for Vi

c) The peak-to-peak values of the signals at nodes A and B were measured.

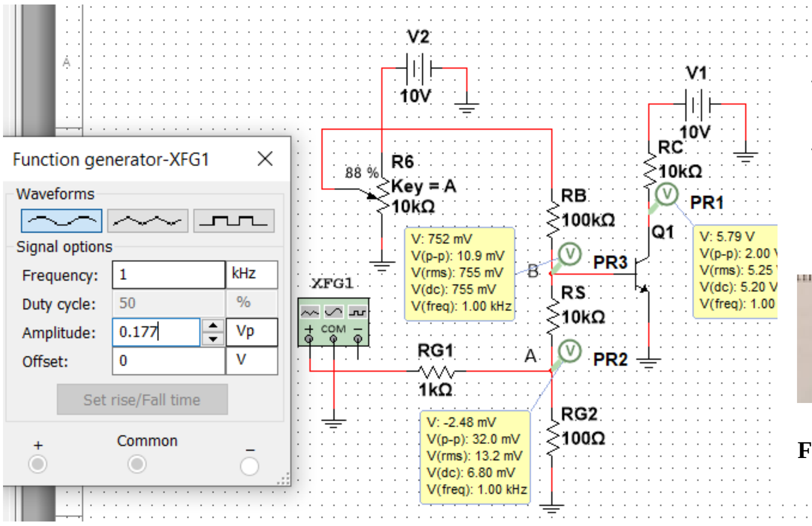



Figure 24. Peak to peak values at nodes A and B

Va (p-p) = 32.0 mV

Vb (p-p) = 10.9 mV

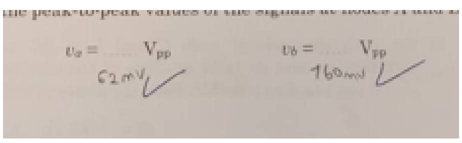



**Figure 25.** Experimental values for Va and Vb

## Table 9. CALCULATION AREA

| | | | | |
|---|---|---|---|---|
| $\frac{V0}{Vb}=\frac{2\,Vpp}{10.9\,mV}$ $=183,486\ v/v$ | $\frac{V0}{Va}=\frac{2\,Vpp}{32.0\,mV}$ $=62,5\ v/v$ | $\frac{V0}{Vi}=\frac{2\,Vpp}{0,35\,Vpp}$ $=5,71\ v/v$ | **Ib= 2.00 uA** | **using thevenin equivalent circuit** **Rinb = 2.32kΩ** |

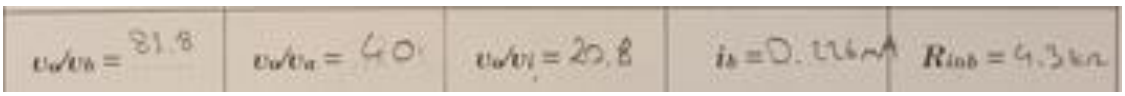



**Figure 26.** Experimental calculation values

### 2.3.2 Large Signal Distortion:

Distortion, in acoustics and electronics, any change in a signal that alters the basic waveform or the relationship between various frequency components; it is usually a degradation of the signal. Distortion of the output signal waveform may occur because: Amplification may not be taking place over the whole signal cycle due to incorrect biasing levels. The input signal may be too large, causing the amplifiers transistors to be limited by the supply voltage

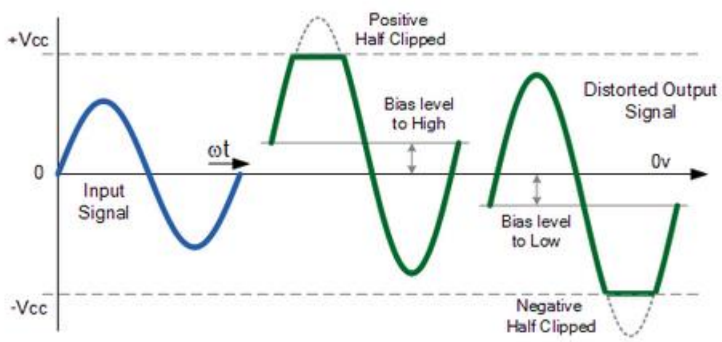



**Figure 27.** Amplifier Distortion

a) Voltages at nodes C and I were measured with a dual-channel oscilloscope. The input signal amplitude Vc was set to be a sine wave with an amplitude of 1Vpp. The peak-to-peak value of the input signal was noted.

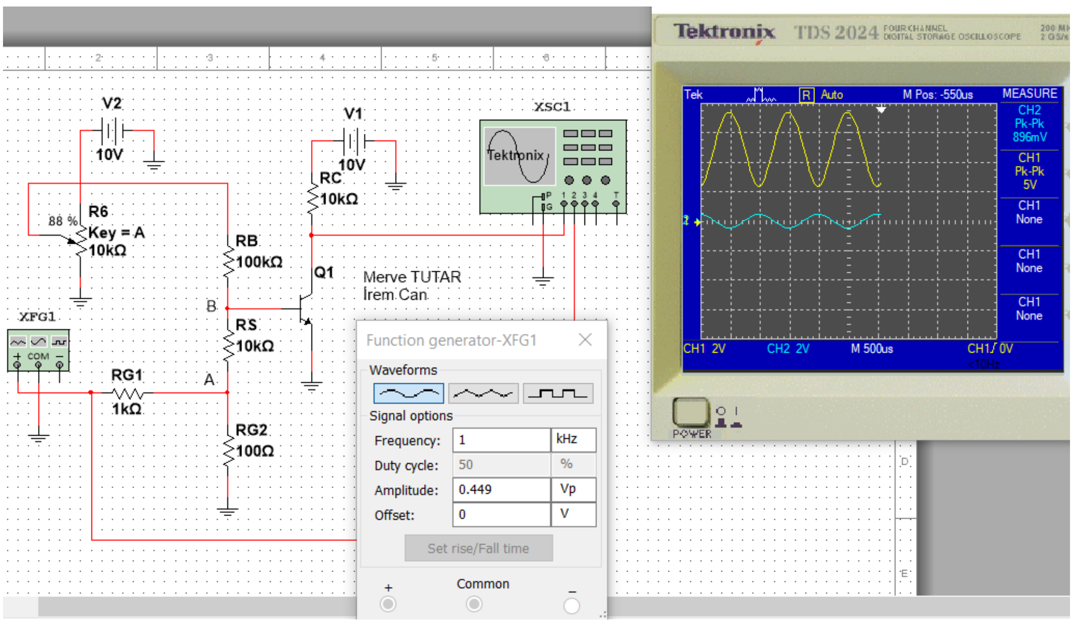
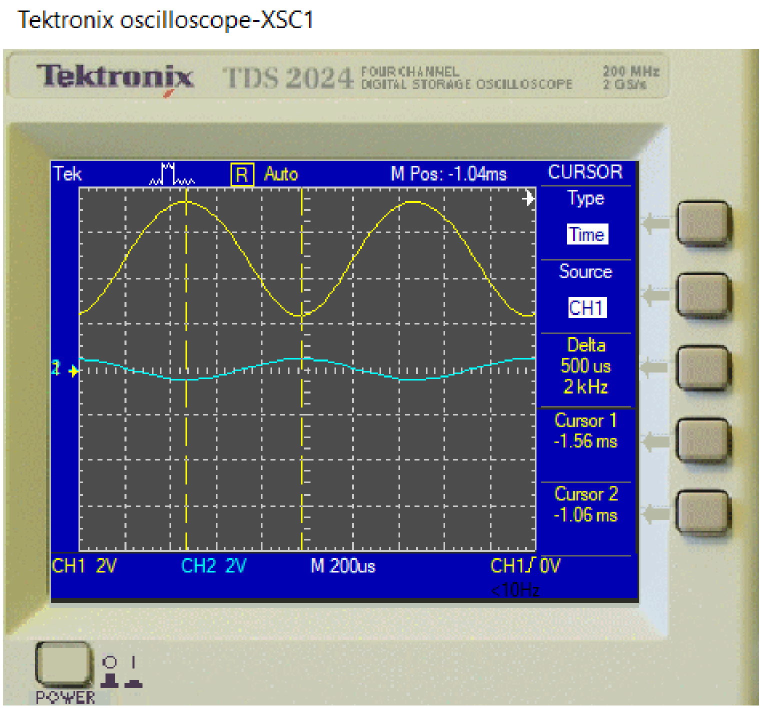



**Figure 28.** amplitude value that will make the Vc voltage value 5V on the function generatore

**Vi= 0.896 Vpp**

b) Both channels of C and I node were tuned in AC coupling. By adjusting the volt/division and dc level settings of the channels, the two signals were tried to overlap as precisely as possible. Note the phase of node C with respect to I.




$\Delta t$ = 500 us

f = 1kHz

$\Phi = 360 \times \Delta t \times f = 180°$

**Figure 29**. Measuring delta t

c) The input voltage was slowly increased while observing the voltages at the I and C nodes. It has been observed that the gain will start to change slightly at some point.

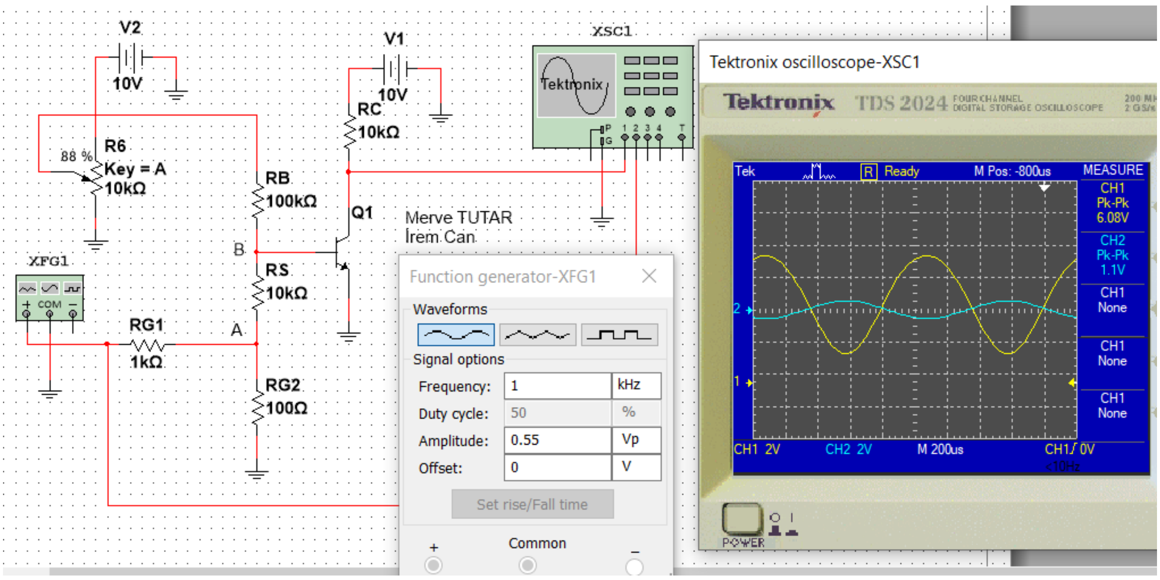



**Figure 30.** Input volatge=0.55 Vpp

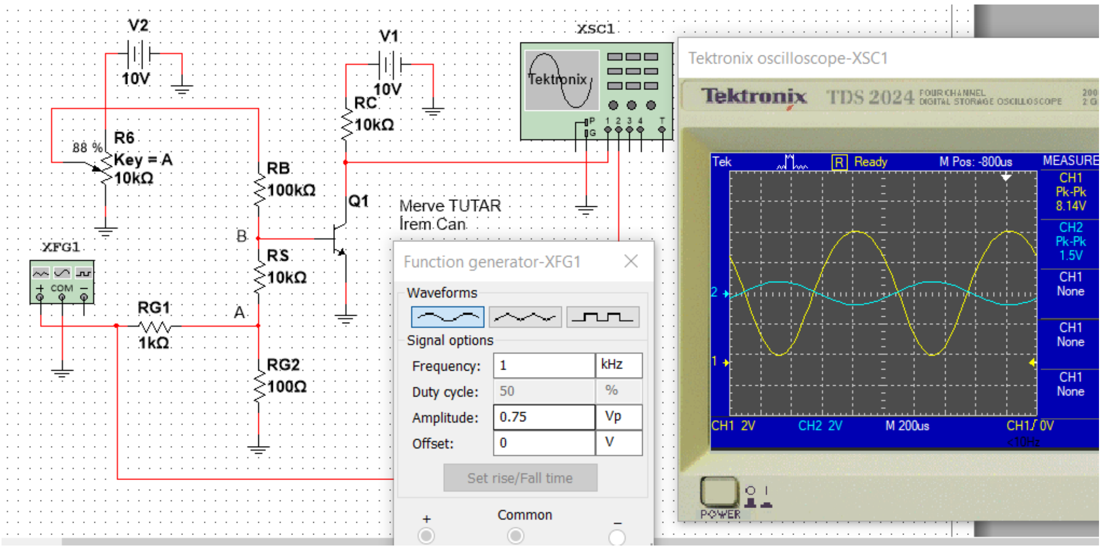



**Figure 31.** Input volatge=0.75 Vpp

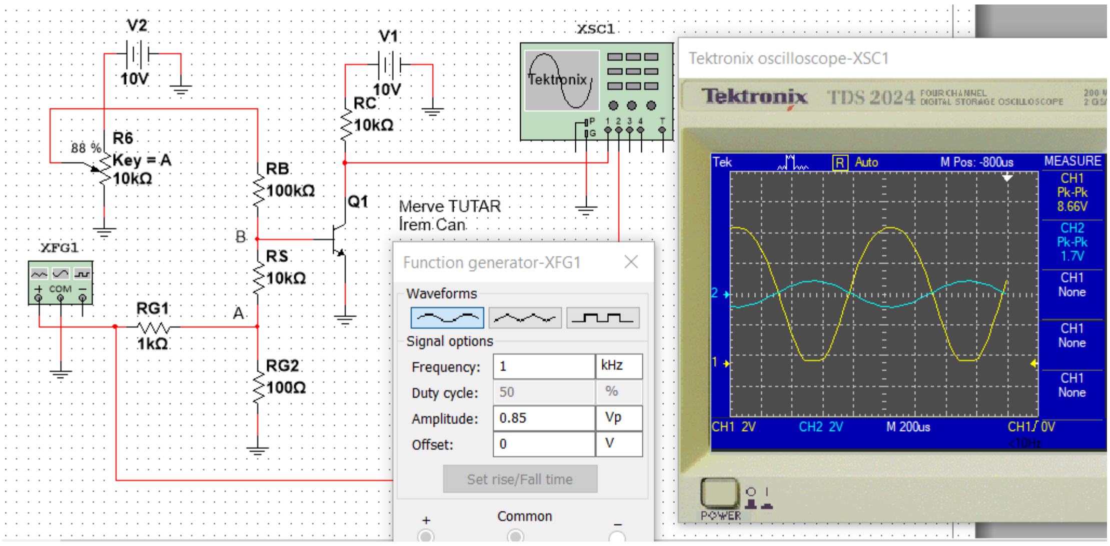



**Figure 32.** Input volatge=0.85 Vpp

## 3. Conclusion

In this experiment Bipolar Transistor Basics is used. We used concepts such as npn transistor, Identfying the controlling junction , Base-Current Bias, Base-Emitter Voltage, the BJT as Amplifier and Large Signal Distortion.

Base, emitter and collector voltages were measured and currents were calculated accordingly. The same measurements were repeated with different voltage supplies, and the a and b values were calculated. In this experiment, the use of potentiometer was learned. The value of Rp, which makes the voltage at node C 5 volts, was adjusted. Then the voltages at the A and B nodes were measured at this Rp value. When the transistor was heated, measurements were made again and changes in voltages were observed.

In the later part of the experiment, the input voltage was adjusted using the oscilloscope and the voltages at the nodes were measured. Gain calculations were made with the voltages found. phase angle calculation was done. The change of node voltages was observed by slowly increasing the input voltage.

There are some differences between the measurements we made during the experiment and the measurements we made in the multism program. We think that these may be due to the characteristics of the transistor used, calculation errors or the sensitivity of the device in measuring very small values.

## 4. References

https://www.electronics-tutorials.ws/amplifier/amp_4.html
https://electronicscoach.com/distortion-in-amplifier.html
https://www.tutorialspoint.com/amplifiers/transistor_as_an_amplifier.htm