Pedro Cabrera 3/13/2024

Experiment 7

Bipolar Junction Transistor

Voltage Divider Biasing

Introduction:

The primary objective of this laboratory exercise is to explore and understand the principles of voltage divider biasing in bipolar junction transistors (BJTs). Voltage divider biasing is a crucial concept in electronic circuits, as it sets the DC operating point which is vital for the linear operation of amplifiers. Through this lab, we aim to establish a stable base voltage for a BJT amplifier circuit, which will allow for consistent performance despite variations in temperature or transistor beta (β) value. We intend to construct a voltage divider biased circuit and calculate various parameters such as base voltage (V_B), collector-emitter voltage (V_CE), and collector current (I_C). By comparing the theoretical computations with the measured results, we will assess the impact of emitter resistance on the operation of the transistor. This hands-on experiment will enhance our comprehension of electronic circuit design and the dynamic behavior of transistors, which is foundational knowledge for more advanced studies in electronics and electrical engineering.

Bench Parts and Equipment List:

1. Components:
    - BJT Transistor (2N3904)
    - Resistors:
        - *R*1: 10 kΩ
        - *R*2: 2.2 kΩ
        - *RC*: 3.6 kΩ
        - *RE*: 1 kΩ & 2kΩ
2. Equipment:
    - Power Supply
    - Multimeter
    - Breadboard

Discussion:

In analyzing the data collected from both the Multisim simulations and the physical benchwork in the lab, a notable trend emerged regarding the influence of the emitter resistance (R_E) on the stability of the transistor's operating point. As R_E was varied, its impact on the base voltage (V_B), collector-emitter voltage (V_CE), and collector current (I_C) was evident. With a 1 kΩ R_E, the circuit tended to have lower V_CE and I_C values compared to those with a 2 kΩ R_E. This aligns with the theoretical expectations, as increasing the emitter resistance should result in a higher V_E (emitter voltage), thereby reducing V_CE for a given supply voltage (V_CC). Additionally, the observed increase in I_C with a larger R_E suggests a shift in the operating point toward saturation, which is consistent with the common-emitter configuration behavior.

It is also important to consider the practical aspects of component tolerances as observed from the measured resistor values. The discrepancies between nominal and measured resistor values underscore the necessity of accounting for real-world variances in circuit design. These variances could be the reason behind any deviations from the expected theoretical outcomes.

Table 1

Resistor	Nominal	Measured
R_1	10kΩ	9.896kΩ
R_2	2.2kΩ	2.172kΩ
R_C	3.6kΩ	3.569kΩ
R_E	1kΩ & 2kΩ	981.5kΩ & 1.998kΩ

Figure 1

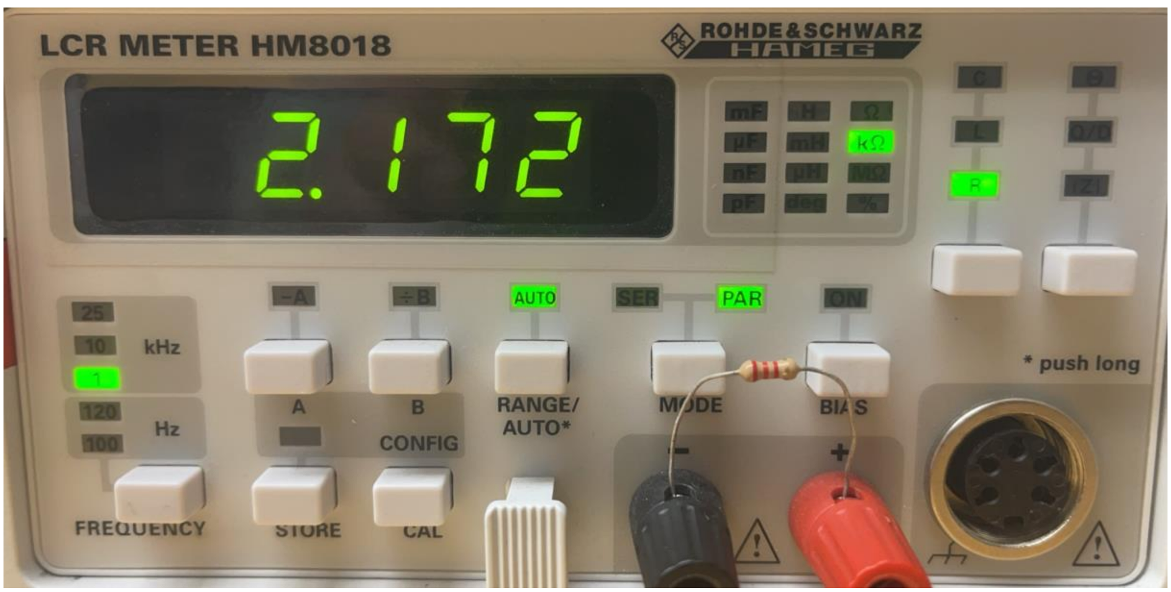


Figure 2

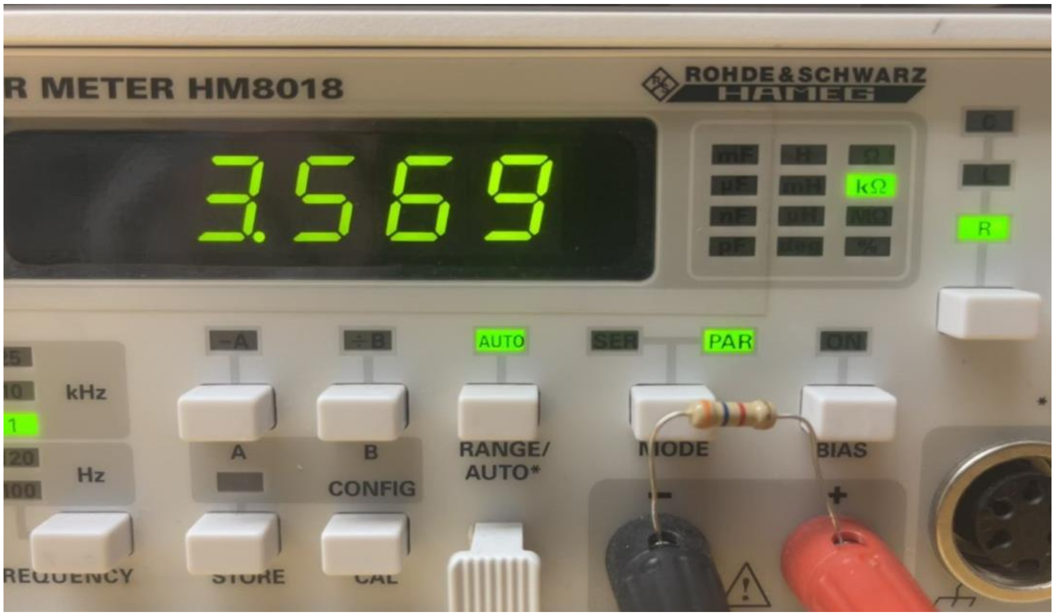


Figure 3

Figure 4

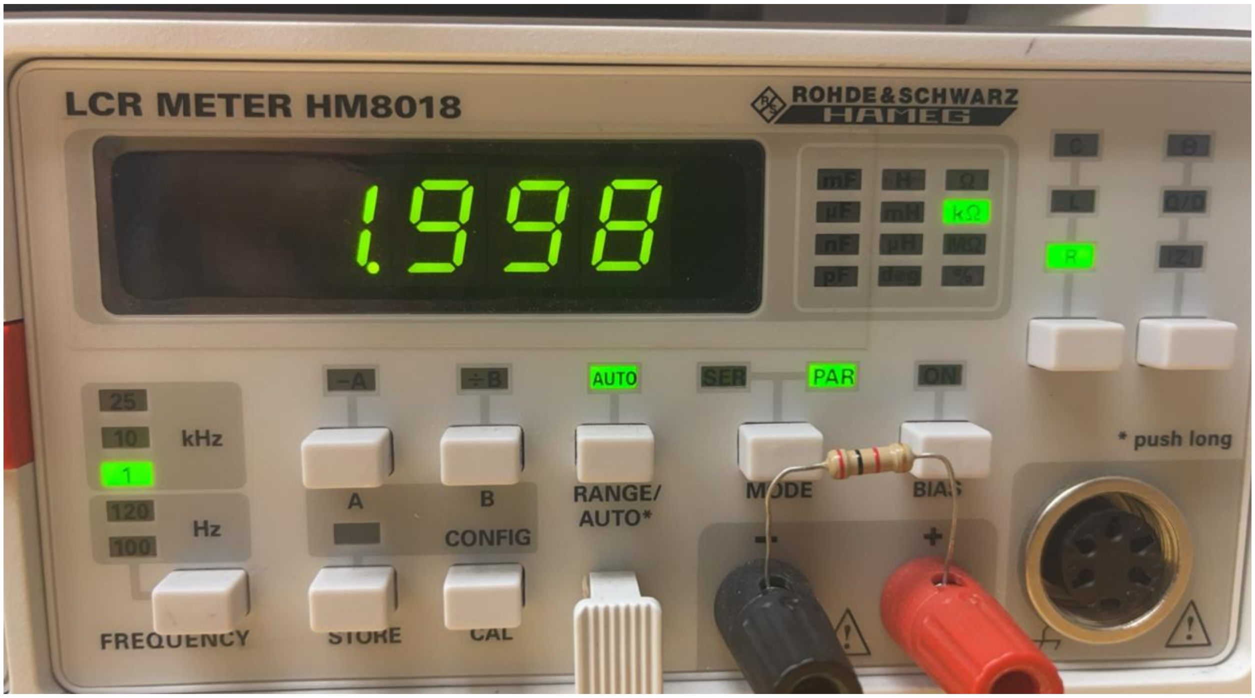


Figure 5

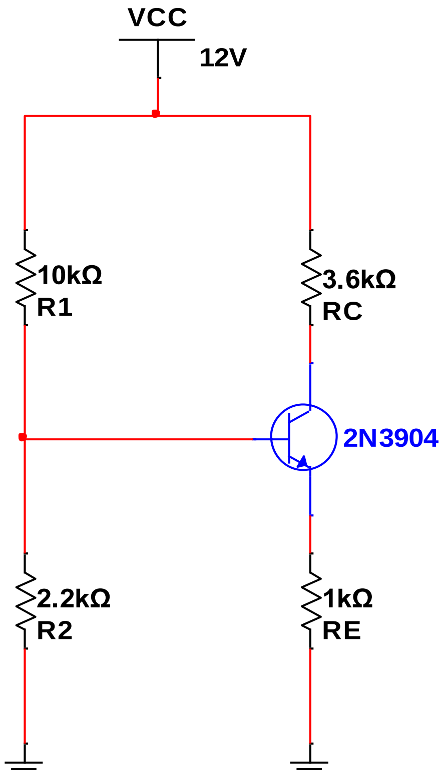
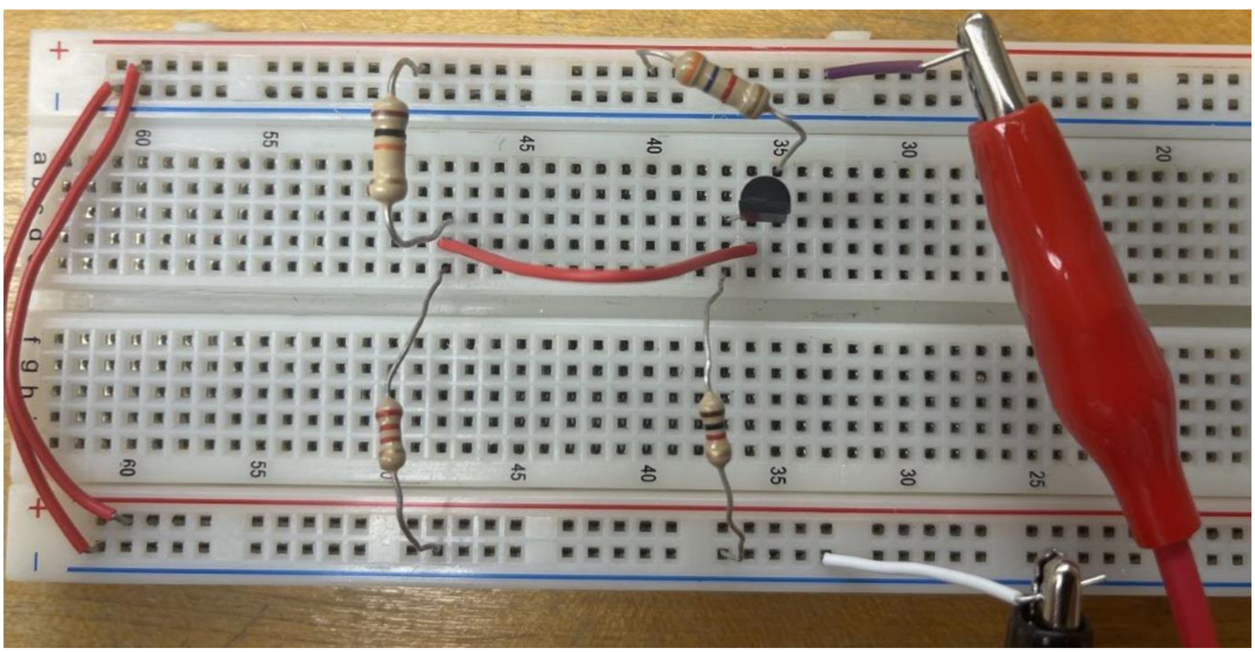


Figure 6

Figure 7



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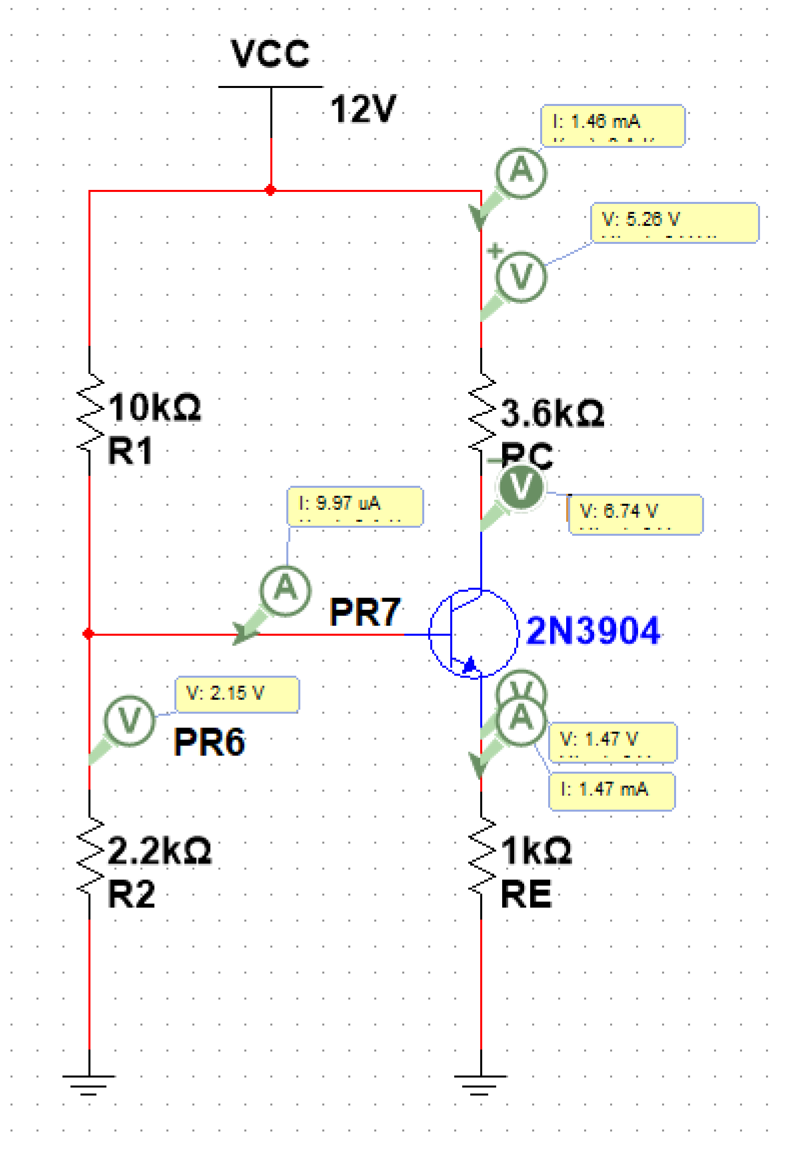


Figure 9

The following images are all the probe placements, as well as the measured value for V_B, V_E, V_C, V_{RC}, I_B, I_C, and I_E at $R_E = 2k\Omega$ respectively.

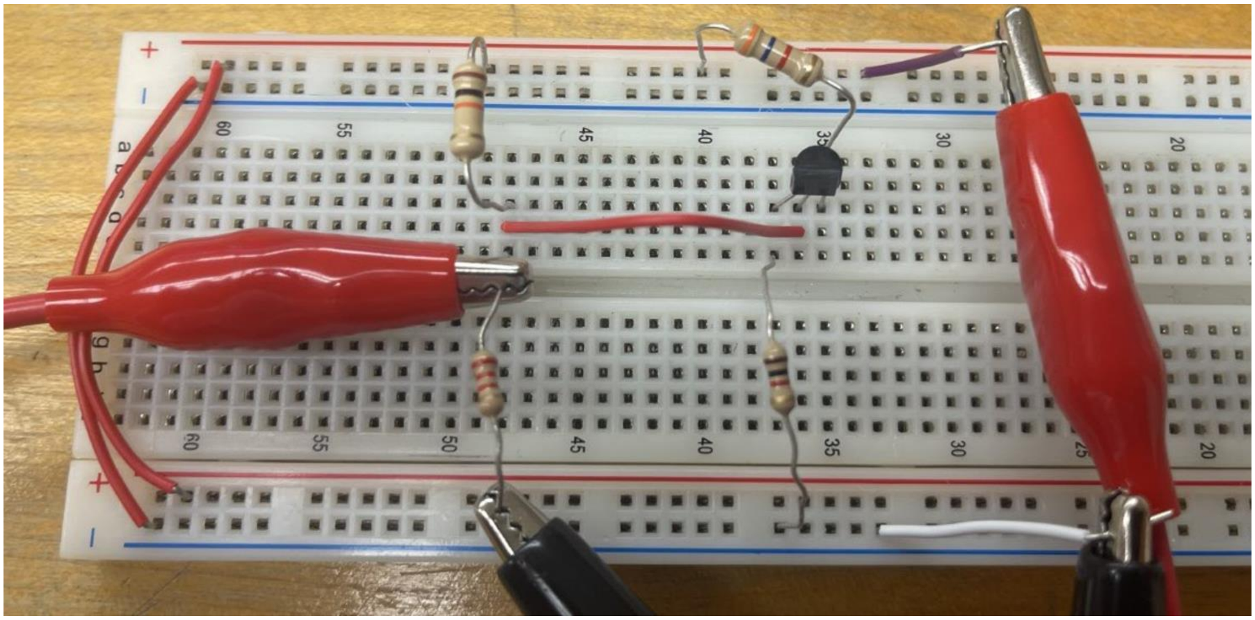


Figure 10 – V_B

Figure 11

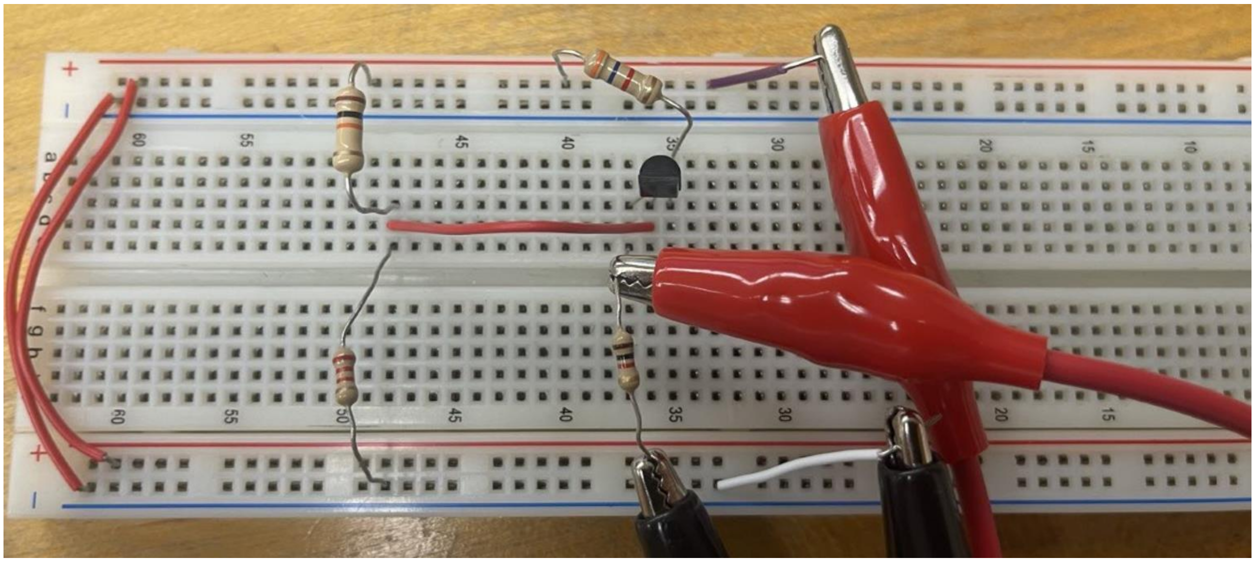
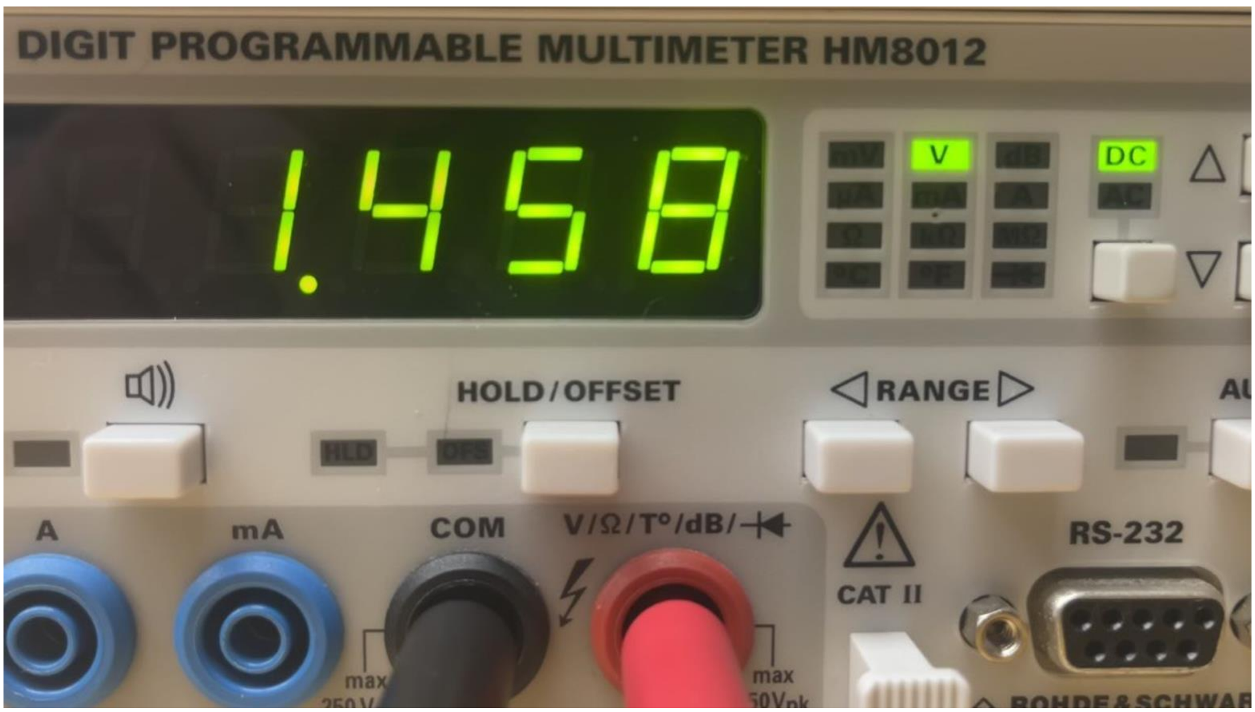


Figure 12



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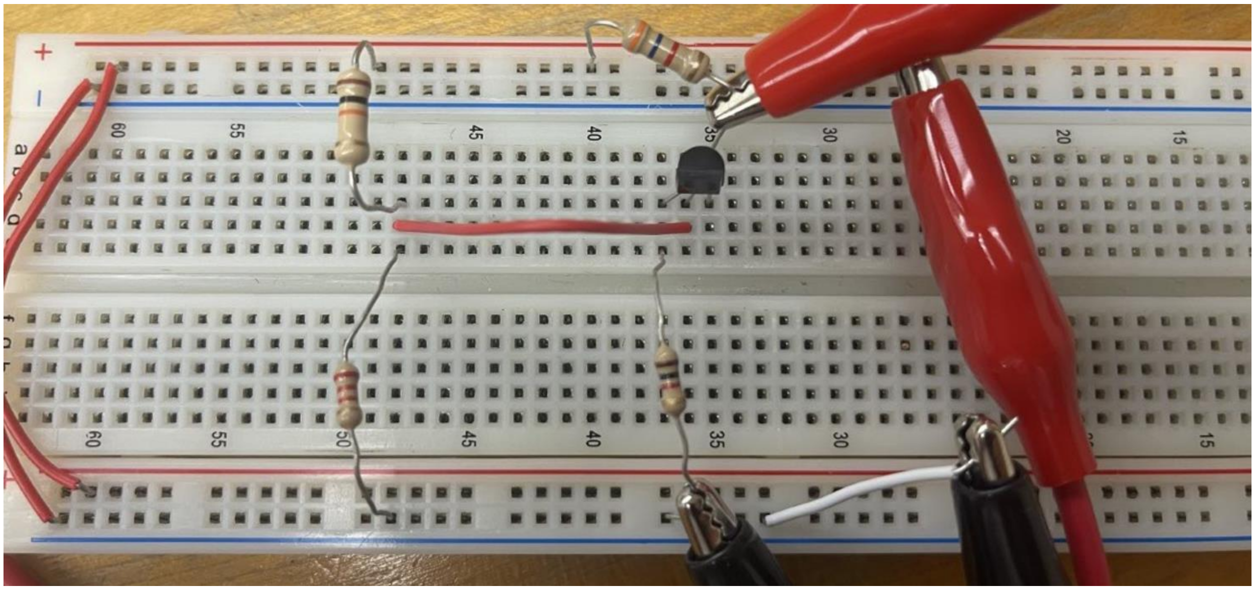

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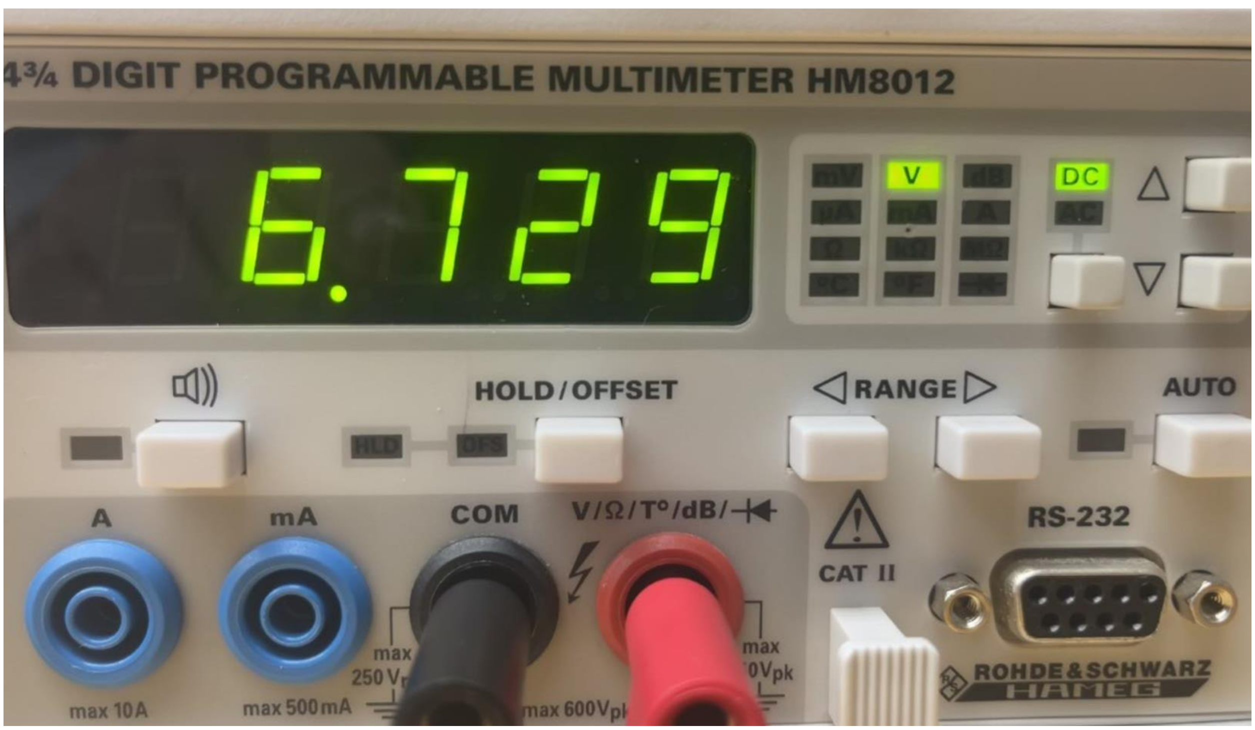

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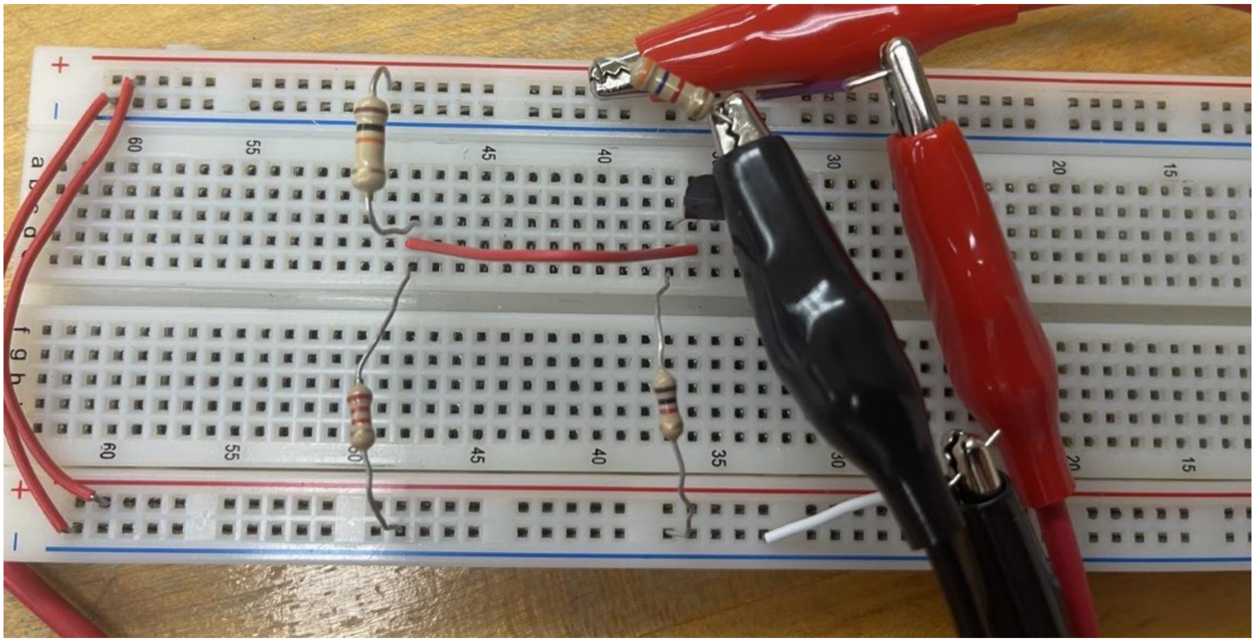
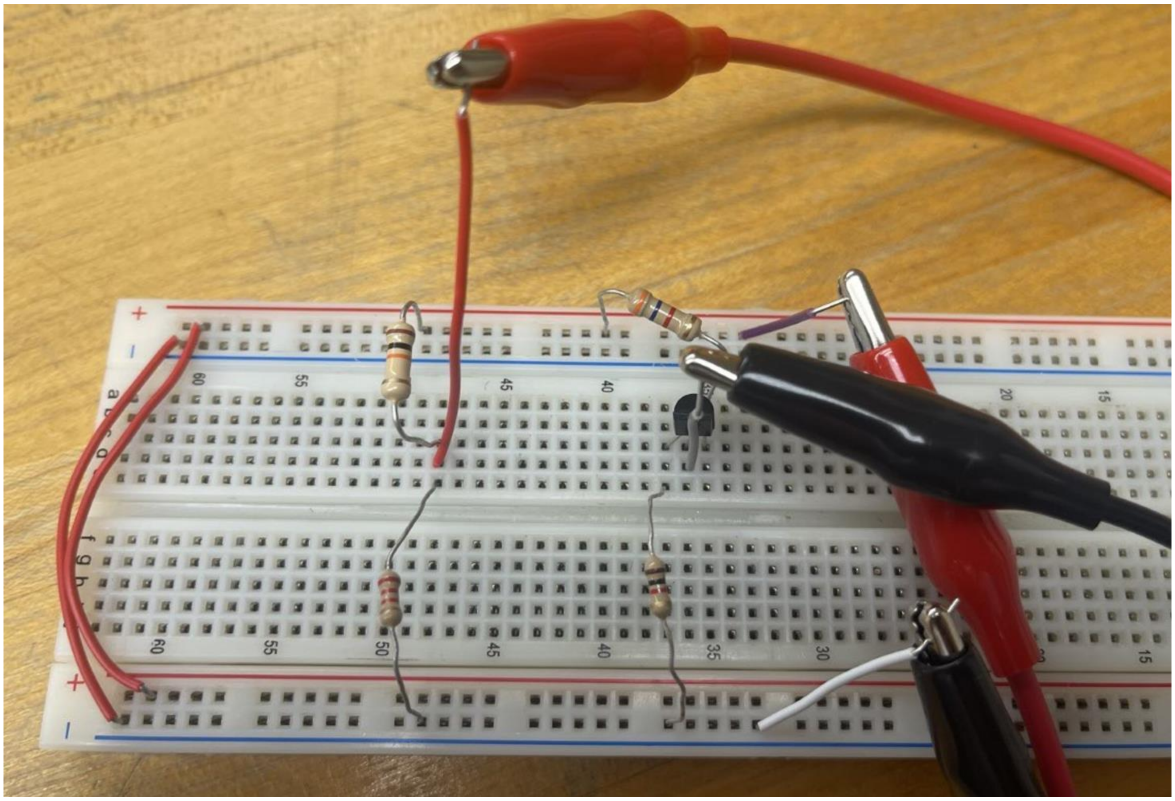


Figure 16

Figure 17



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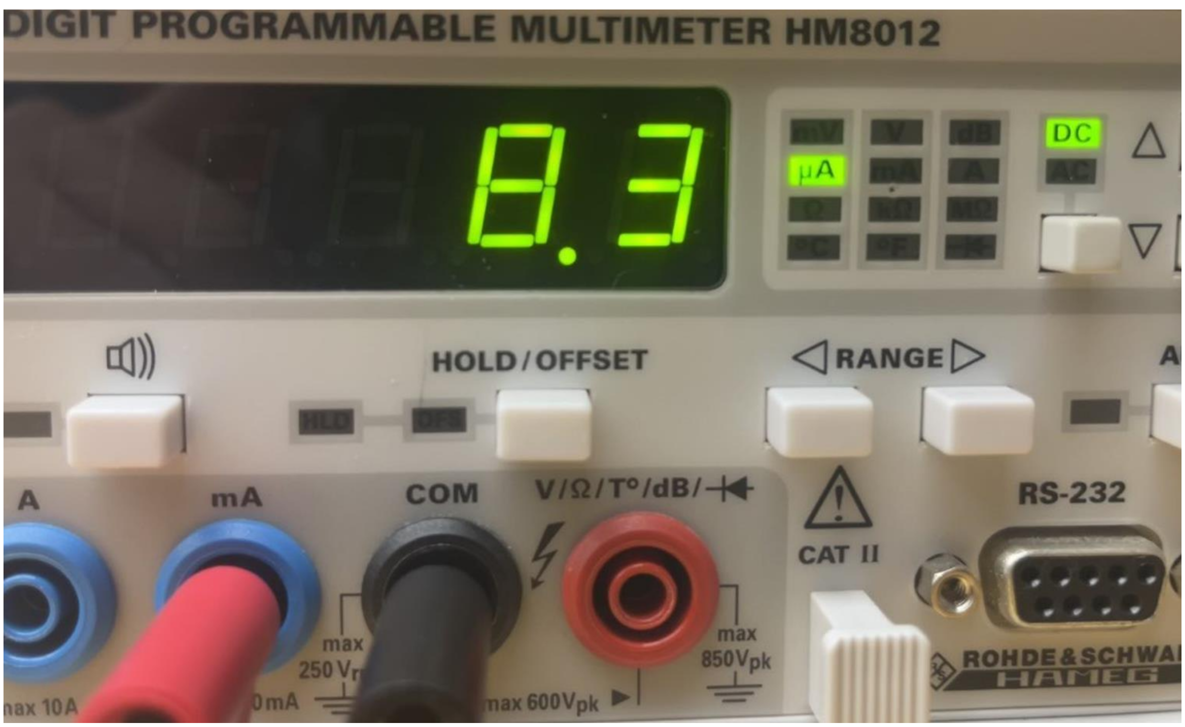


Figure 19

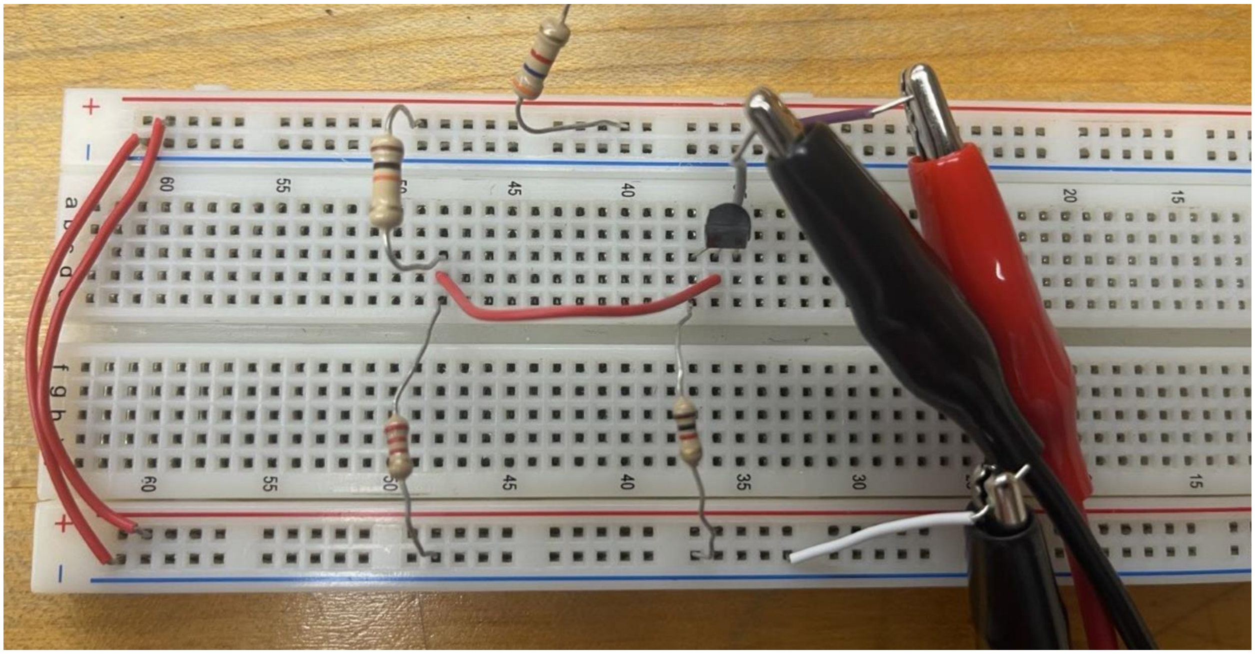


Figure 20

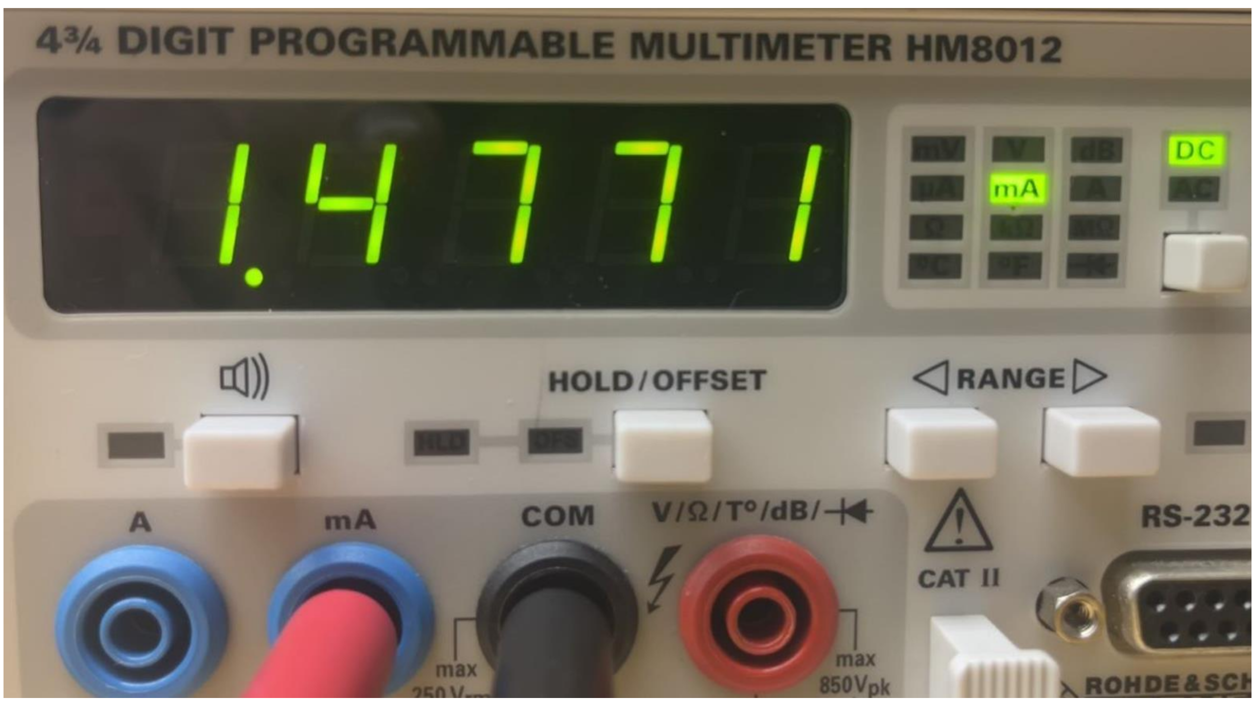


Figure 21

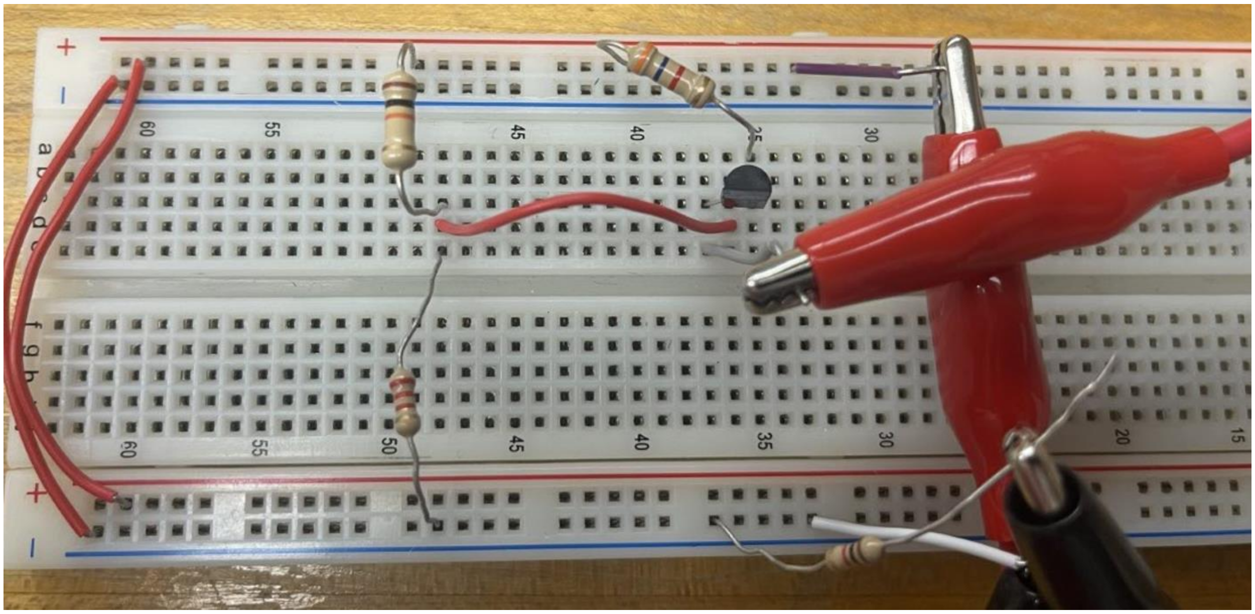
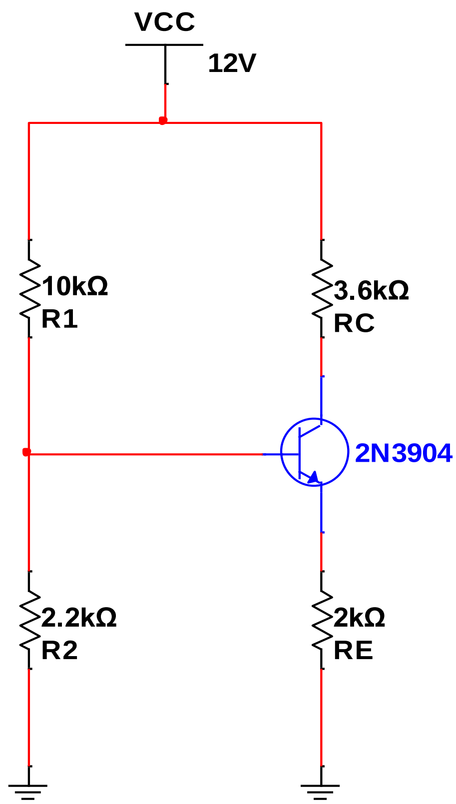


Figure 22

Figure 23



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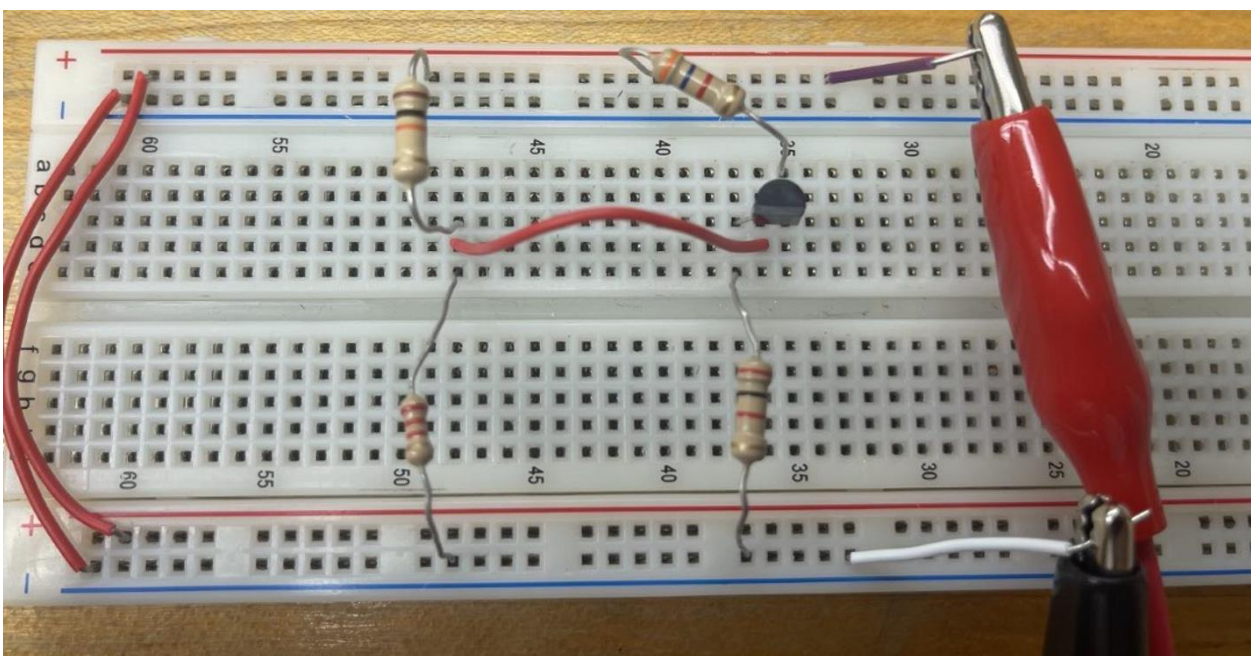


Figure 25

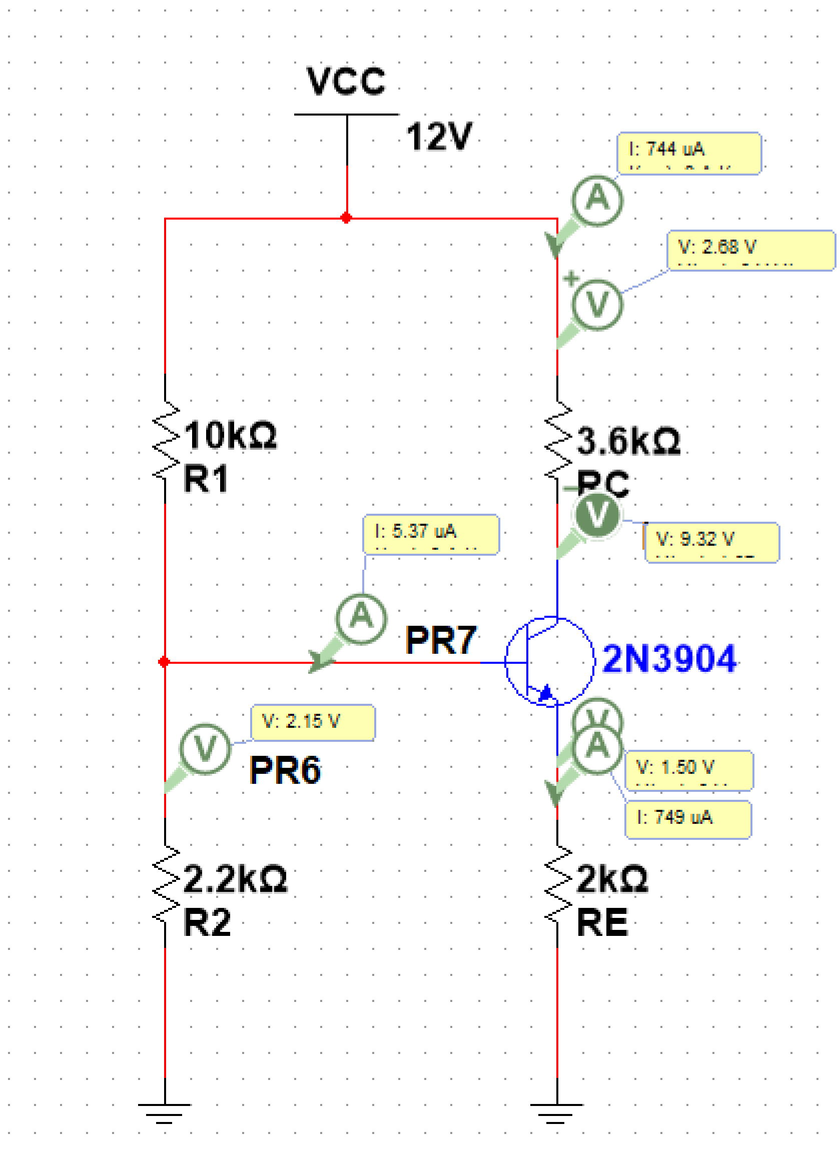


Figure 26

The following images are all the measuring probe placemets, as well as the measured value for V_B, V_E, V_C, V_{RC}, I_B, I_C, and I_E at $R_E = 2k\Omega$ respectively.

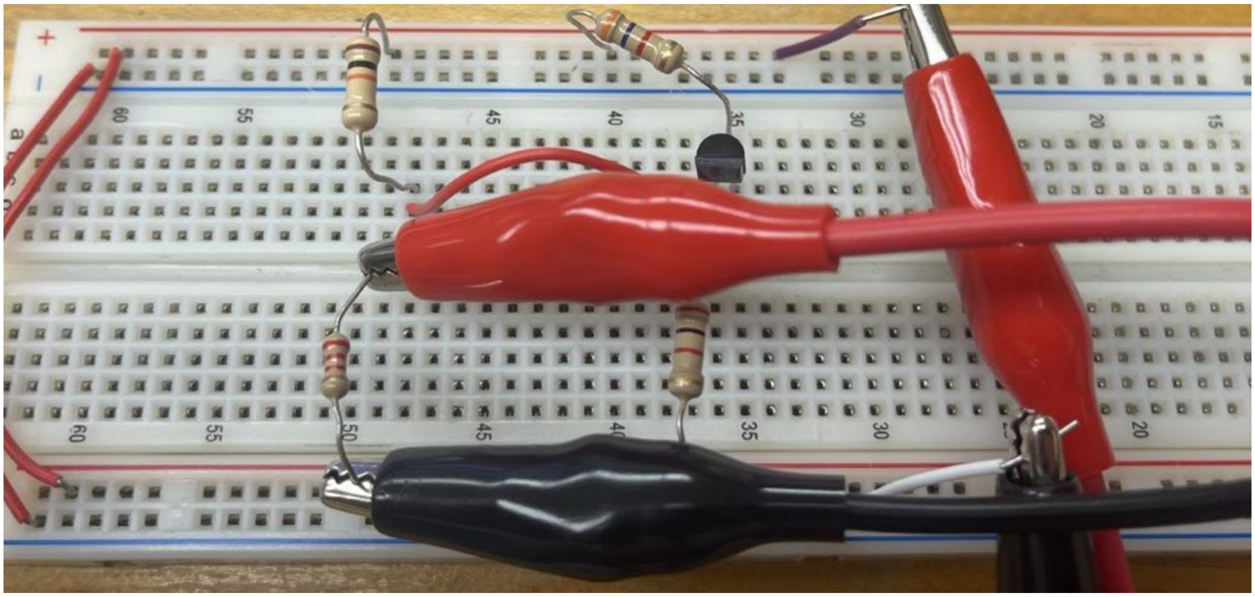
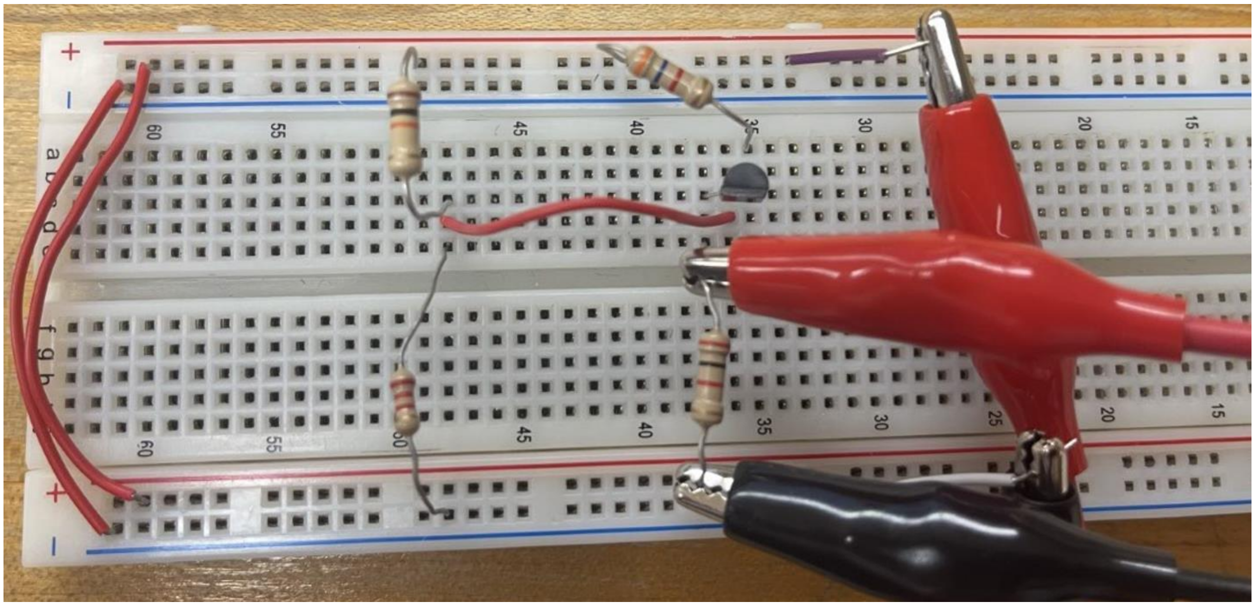


Figure 27

Figure 28



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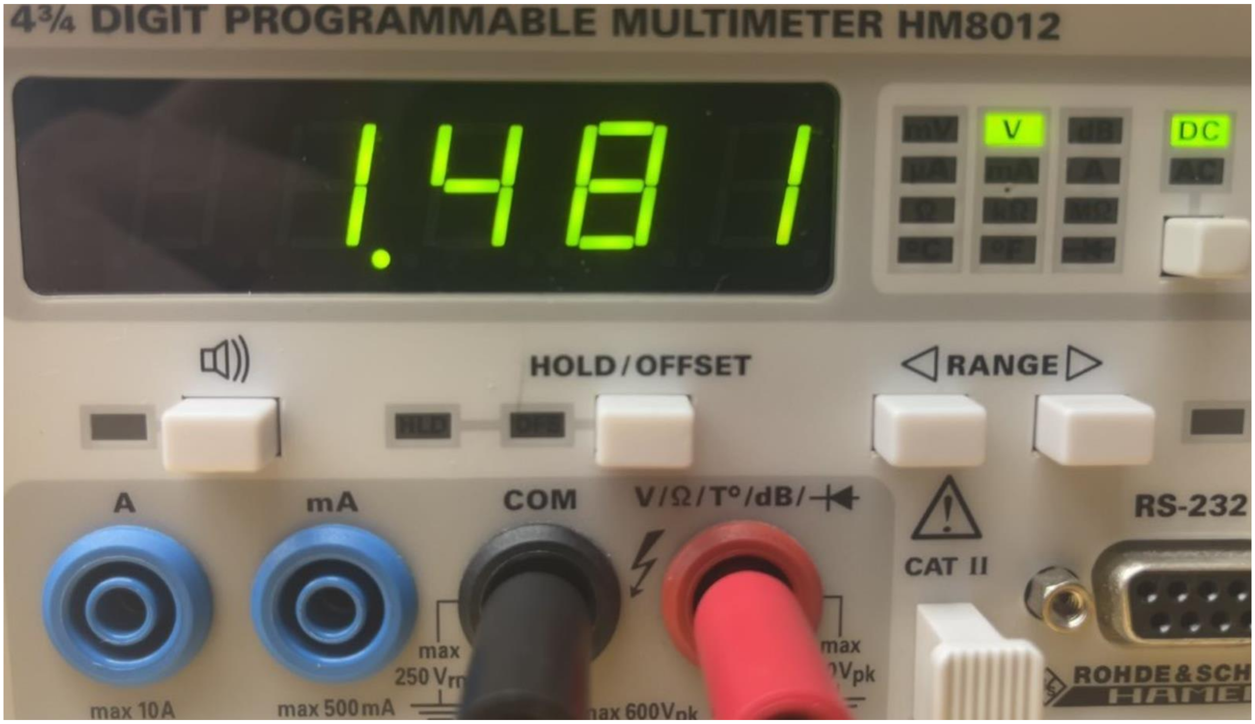

Figure 30

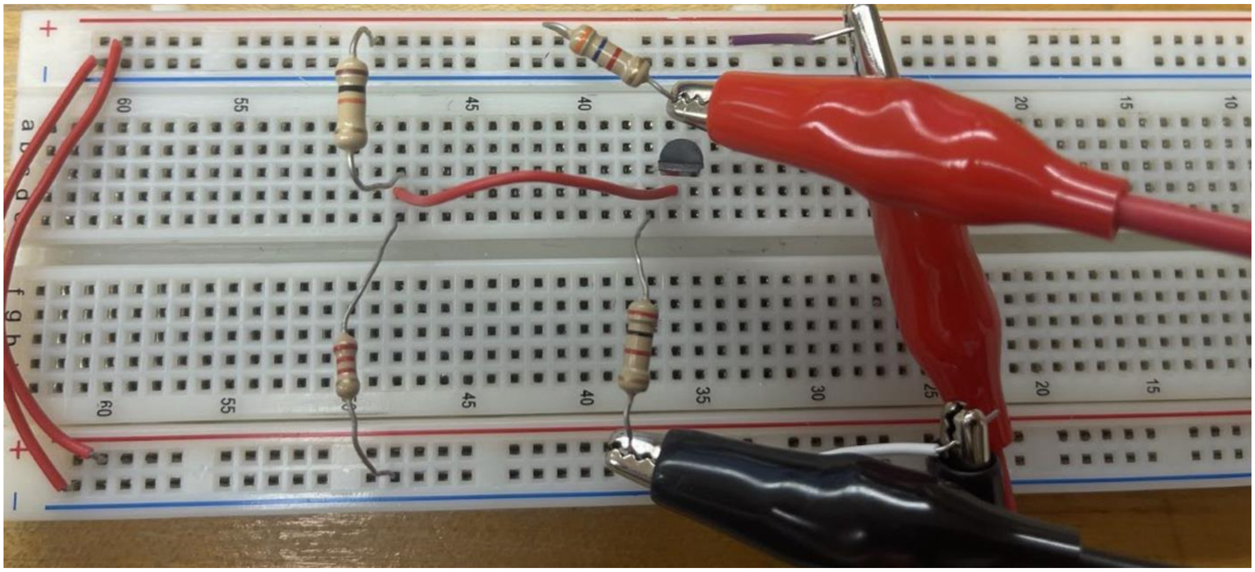

Figure 31

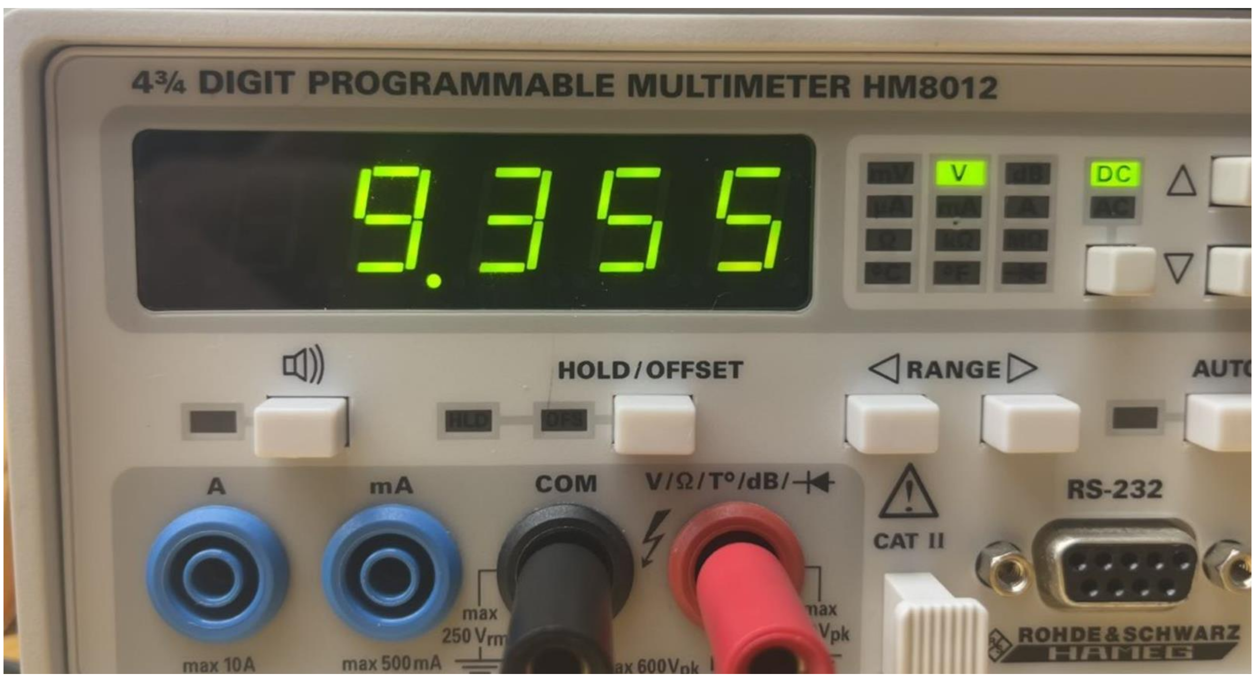

Figure 32

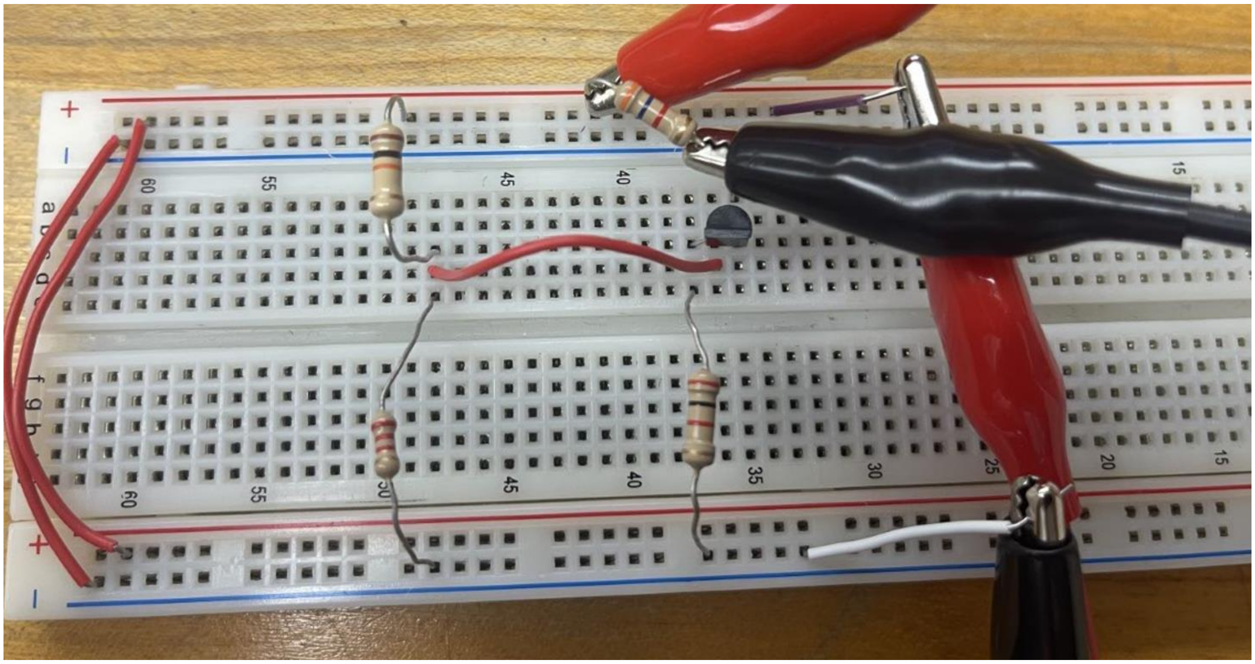

Figure 33

Figure 34

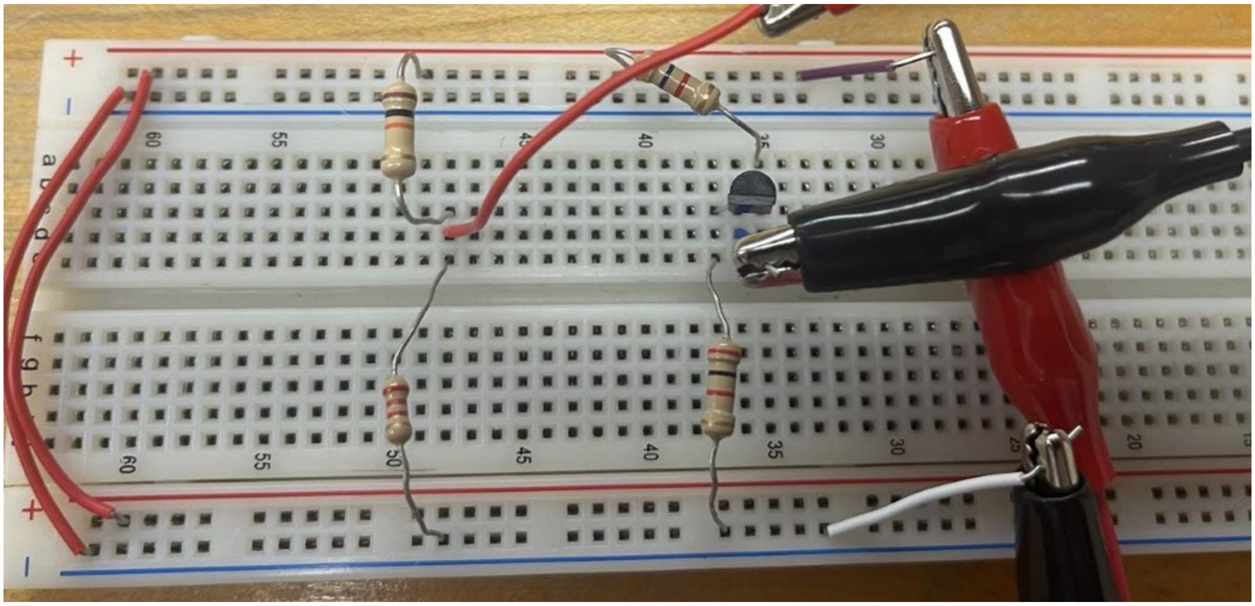

Figure 35

Figure 36

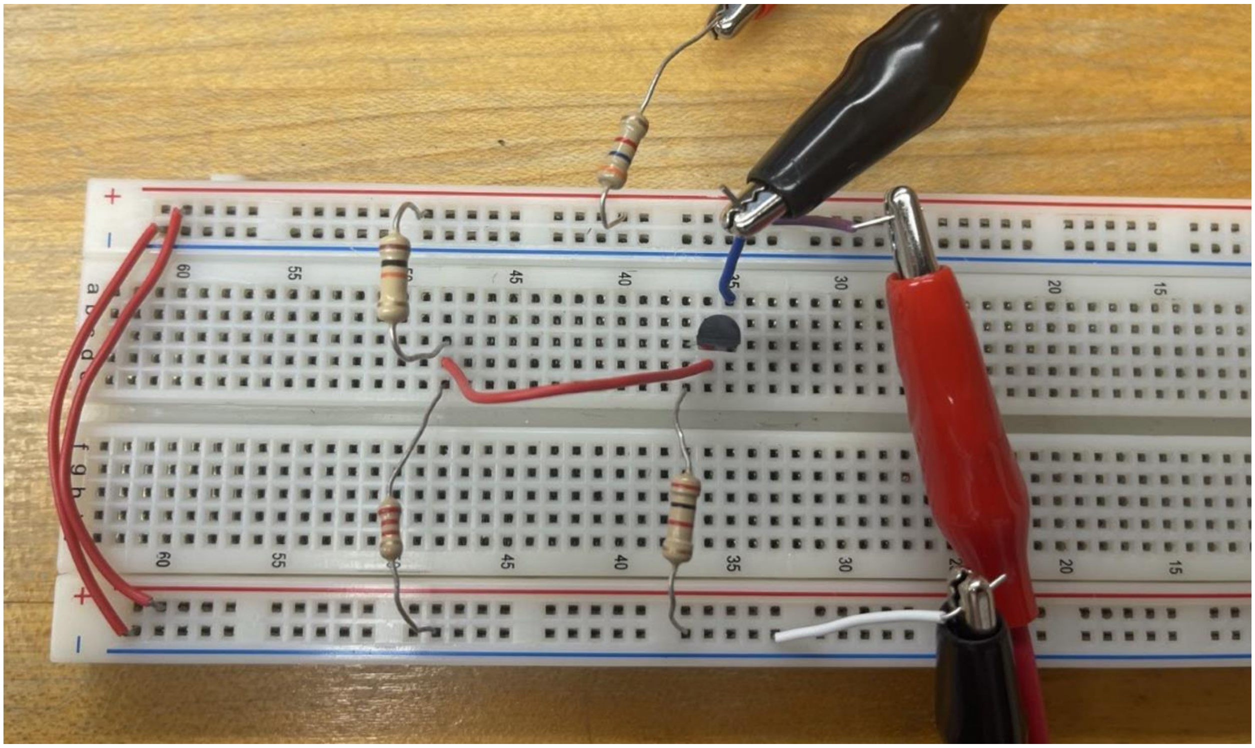

Figure 37

Figure 38

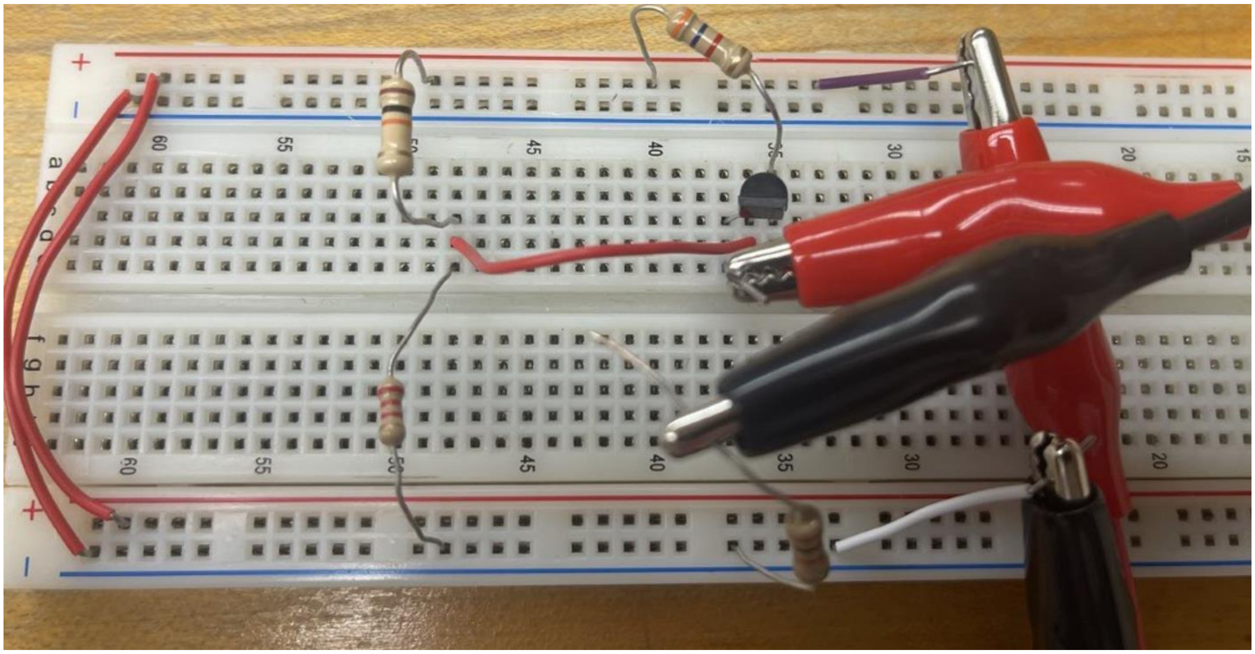

Figure 39

Figure 40

Furthermore, the beta (β) of the transistor, which is a measure of its current gain, was assumed to be constant for theoretical calculations. However, in practice, β can vary significantly between individual transistors, even of the same model, and this variation can impact the circuit's behavior, which was an important observation during the lab exercises.

Calculations for R_E = 1 kΩ

$$\boldsymbol{R_{INBASE}} = \beta_{DC} * R_E = 150 * 1k\Omega = 150k\Omega$$

$$\boldsymbol{V_B} = VCC * \frac{(R_2 \parallel R_{INBASE})}{R1 + (R_2 \parallel R_{INBASE})} = \frac{2.17k\Omega}{1k\Omega + 2.17k\Omega} = 2.13\ V$$

$$\boldsymbol{V_E} = V_B - V_{BE} = 2.13V - 0.7V = 1.43\ V$$

$$\boldsymbol{I_E} = \frac{V_E}{R_E} = \frac{1.43V}{1k\Omega} = 1.43\ mA \approx \boldsymbol{I_C}$$

$$\boldsymbol{V_{RC}} = I_C * R_C = 1.43mA * 3.6k\Omega = 5.148\ V$$

$$V_C = VCC - V_{RC} = 12V - 5.143V = 6.852\ V$$

$$\boldsymbol{I_B} = \frac{I_C}{\beta_{DC}} = \frac{1.43mA}{150} = 9.53\mu A$$

$$\boldsymbol{\beta_{DC}} = \frac{I_C}{I_B} = \frac{1.43\ mA}{9.53\ \mu A} = 177.95$$

Calculations for R_E = 2kΩ

$$\boldsymbol{R_{INBASE}} = \beta_{DC} * R_E = 150 * 2k\Omega = 300k\Omega$$

$$\boldsymbol{V_B} = VCC * \frac{(R_2 \parallel R_{INBASE})}{R1 + (R_2 \parallel R_{INBASE})} = \frac{2.184k\Omega}{2k\Omega + 2.184k\Omega} = 2.151\ V$$

$$\boldsymbol{V_E} = V_B - V_{BE} = 2.151V - 0.7V = 1.451\ V$$

$$\boldsymbol{I_E} = \frac{V_E}{R_E} = \frac{1.451V}{2k\Omega} = 725\ \mu A \approx \boldsymbol{I_C}$$

$$\boldsymbol{V_{RC}} = I_C * R_C = 725.5\ \mu A * 3.6k\Omega = 2.612\ V$$

$$V_C = VCC - V_{RC} = 12V - 2.612V = 9.388\ V$$

$$\boldsymbol{I_B} = \frac{I_C}{\beta_{DC}} = \frac{725.5\ \mu A}{150} = 4.83\ \mu A$$

$$\boldsymbol{\beta_{DC}} = \frac{I_C}{I_B} = \frac{725.5\ \mu A}{4.29\ \mu A} = 171.67$$

Table 2

Parameters	R_E = 1kΩ Computed	R_E = 1kΩ Measured	R_E = 2kΩ Computed	R_E = 2kΩ Measured
V_B	2.13V	2.144 V	2.151V	2.149 V
V_E	1.43V	1.458 V	1.451 V	1.481 V
V_C	6.852V	6.729 V	9.388 V	9.355 V
V_{RC}	5.148V	5.27 V	2.612 V	2.628 V
I_B	9.53μA	8.3 μA	4.83 μA	4.29 μA
I_C	1.43mA	1.477 mA	725.5 μA	736.5 μA
I_E	1.43mA	1.351 mA	725.5 μA	705.6 μA
$\boldsymbol{\beta}$	150	177.95	150	171.67

When examining the effects of changing the emitter resistance (R_E) from 1 kΩ to 2 kΩ, the data illustrated that a higher R_E value resulted in a larger voltage drop across the emitter resistor, which in turn affected the V_CE and I_C.

The experiment provided practical confirmation of the theoretical characteristic curves for a BJT. Observing the shifts in operating points on the DC load line graphically demonstrated the influence of R_E on the saturation and cutoff regions of transistor operation. This hands-on experience is invaluable for understanding how various components and their interconnections can affect the overall performance of electronic circuits.

The data also suggested that while the theoretical model is a crucial starting point, actual component tolerances and variations in transistor parameters can lead to deviations from calculated expectations. This reinforces the notion that while simulation tools like Multisim are beneficial for initial design and testing, there is no substitute for real-world experimentation where components exhibit natural variations.

Experiment 7

Bipolar Junction Transistors

Voltage Divider Biasing

Voltage Divider Biasing is another technique used to set up the DC operating point for an amplifier circuit. Voltage divider biasing is the most effective method in establishing a stable operating point (Q point) for the amplifier circuit. This biasing technique provides a constant base voltage in spite of any changes in the base current.

Objective: To investigate the operation of voltage divider biased circuit.

Materials
- One power supply
- BJT Transistor (2N3904)
- 1kΩ, 2.2kΩ, 3.6kΩ, and 10kΩ Resistors

Input: Power supply
Output: Multimeter

1- Build the voltage divider circuit shown in Figure 1.
2- Measure the value of each resistor and record in Table 1.
3- Compute and measure each parameter listed in Table 2.
4- Change the emitter resistance R_E value from 1 KΩ to 2 KΩ and repeat step 3.

$V_B = V_{CC} \cdot \frac{R_{2Base}}{R_1 + R_{2Base}} = \boxed{2.13V}$ ($R_2 \| R_{inBase}$)

$R_{INBASE} = \beta_{DC} \cdot R_E$

$R_{INBASE} = 150K\Omega$

$V_E = V_B - V_{BE} = 2.13 - .7 = \boxed{1.43V}$

$I_E = \frac{V_E}{R_E} = \frac{1.43v}{1000\ \Omega} = \boxed{1.43mA} \approx I_C$

$V_{RC} = I_C \times R_C = 1.43mA \times 3.6k\Omega = \boxed{5.148v}$

$\beta_{DC} = \frac{I_C}{I_B}$

$I_B = \frac{I_C}{\beta_{DC}} = \frac{1.43mA}{150} = \boxed{9.53\mu A}$

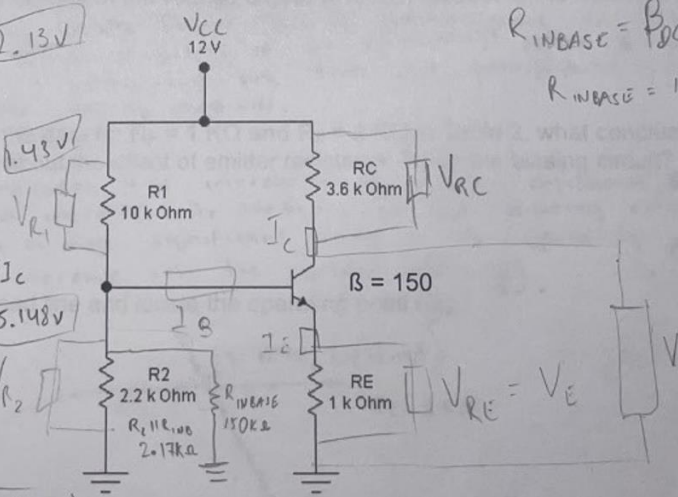

Figure 1

$V_C = V_{CC} - V_{RC} = 6.852V$

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Resistor	Nominal	Measured
R_1	10kΩ	9.896kΩ
R_2	2.2kΩ	2.172kΩ
R_C	3.6kΩ	3.569kΩ
R_E	1kΩ	981.5Ω

Table 1

ß 3.13.24

$\beta_{DC} = \frac{I_C}{I_B}$

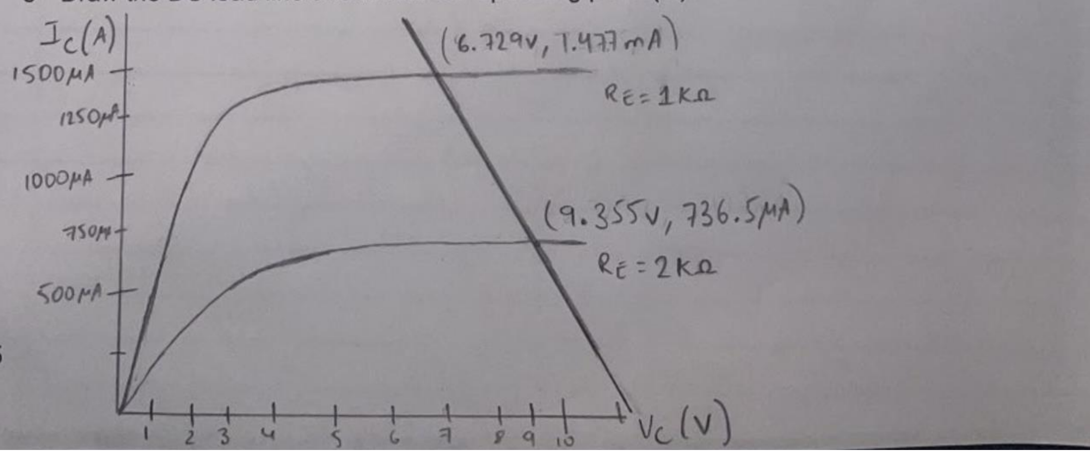
Parameter	R_E = 1 KΩ		R_E = 2 KΩ	
	Computed	Measured	Computed	Measured
V_B	2.13 V	2.144 V	2.151 V	2.149 V
V_E	1.43 V	1.458 V	1.451 V	1.481 V
V_C	6.852 V	6.729 V	9.388 V	9.355 V
V_{RC}	5.148 V	5.27 V	2.612 V	2.628 V
I_B	9.53 μA	8.3 μA	4.83 μA	4.29 μA
I_C	1.43 mA	1.477 mA	725.5 μA	736.5 μA
I_E	1.43 mA	1.351 mA	725.5 μA	705.6 μA
ß		177.95		171.67

Table 2

1- What is the advantage of the voltage divider bias with respect to the other biasing techniques? The Voltage Divider bias is advantageous for its ability to provide better stability of the transistor's operating point against variations in temperature and transistor beta(β) value compared to the other biasing methods.

2- By comparing the data for **R_E = 1 KΩ and R_E = 2 KΩ** in Table 2, what conclusion can you make about the effect of emitter resistance R_E on the biasing circuit? The data indicates that increasing the Emitter resistance R_E from 1kΩ to 2kΩ increases the stability of the biasing circuit, evidenced by a more significant shift in the operating point and a notable increase in the current gain (β).

3- Draw the DC load line and locate the operating point (Q).



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Conclusion:

The lab aimed to investigate the operation of a voltage divider biased circuit and its effects on the stability of a bipolar junction transistor's (BJT) operating point. This objective was successfully met, as we constructed the circuit, measured its parameters, and compared the results against theoretical predictions. The lab facilitated a deeper understanding of how changes in the emitter resistance (R_E) affect the transistor's behavior, reinforcing the theory that a higher R_E can enhance the stability of the operating point. Additionally, we observed the real-world implications of component tolerances and their effects on circuit performance. The insights gained from the discrepancies between calculated and actual measurements underpin the importance of considering practical variances in the design and analysis of electronic circuits. Overall, the lab was effective in bridging theoretical knowledge with practical application, providing a solid foundation for future electronic design endeavors.