Resistors and Bipolar Transistors

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1 Experiments

1.1 Experiment 1: Bipolar Transistor Characteristics

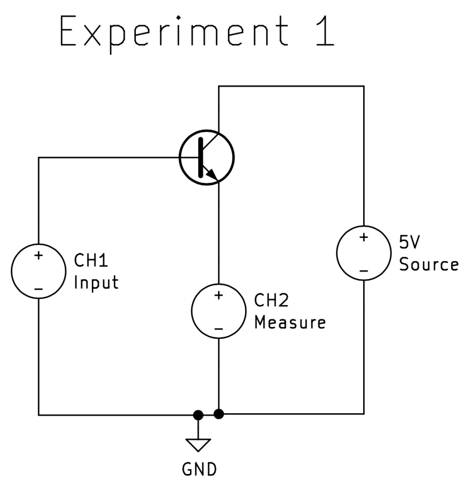


Figure 1: Schematic for Experiment 1

Figure 2 shows the relationship between the collector and base current and the base voltage for the circuit seen in Figure 1. The relationship is very linear; as this plot is a semilog plot, this implies that the collector current does have an exponential relationship with the base voltage. The base current drops off when the base voltage approaches 0.45V - it actually drops down to $10^{-27}A$, a clear measurement error. We attribute this to the SMU. To avoid graph skewing, we've truncated this erroneous data from the dataset, but it has certainly affected measurements throughout Experiment 1 and 2.

Figure 3 shows a semilog plot of β vs. I_b, where I_b is on the log scale. We call β the current gain, and consider it dimensionless - this is because it is a scaling factor between two values both of units A, implying that it itself does not have any units. β is not constant with respect to I_b. However, the value of β is fairly constant when I_b is greater than $10nA$. More particularly, β appears constant for any range of current within one order of magnitude after $10nA$, i.e. between $10nA$ to $100nA$, between $100nA$ to $1\mu A$, between $1\mu A$ to $10\mu A$, etc. We also note that as β is derived from I_c and I_b, it is heavily affected by the errors seen in measurement, and was truncated to show the important characteristics.

Figures 4a and 4b show log-log plots of the incremental base resistance r_b and g_m over I_b and I_c, respectively. They are plotted with their corresponding theoretical fits, using the collector characteristics extracted from the previous theoretical fits in this experiment. The theoretical fits match the data very well

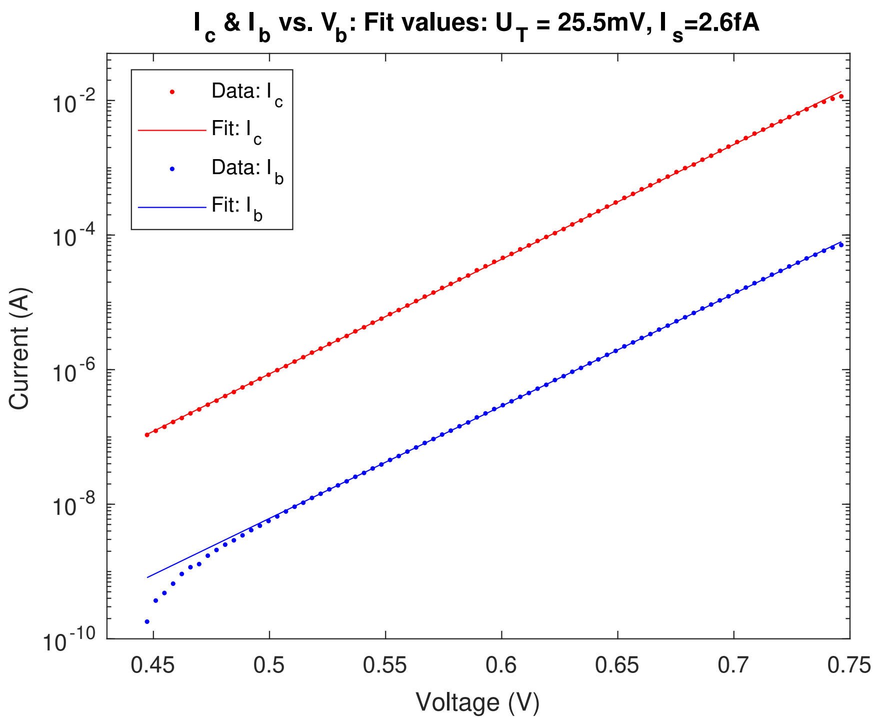


Figure 2: Semilog plot of I_c and I_b vs. V_b

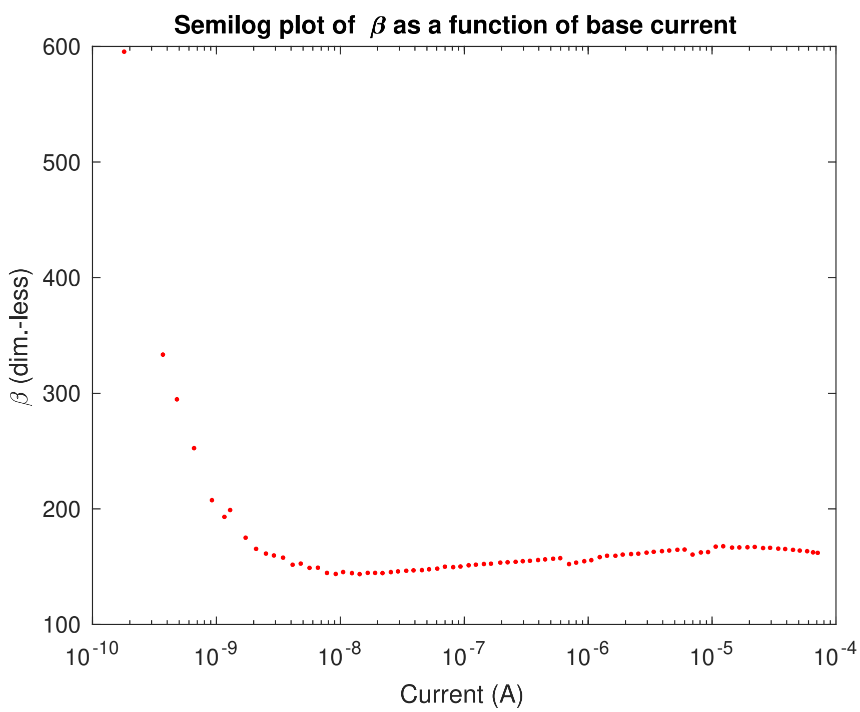
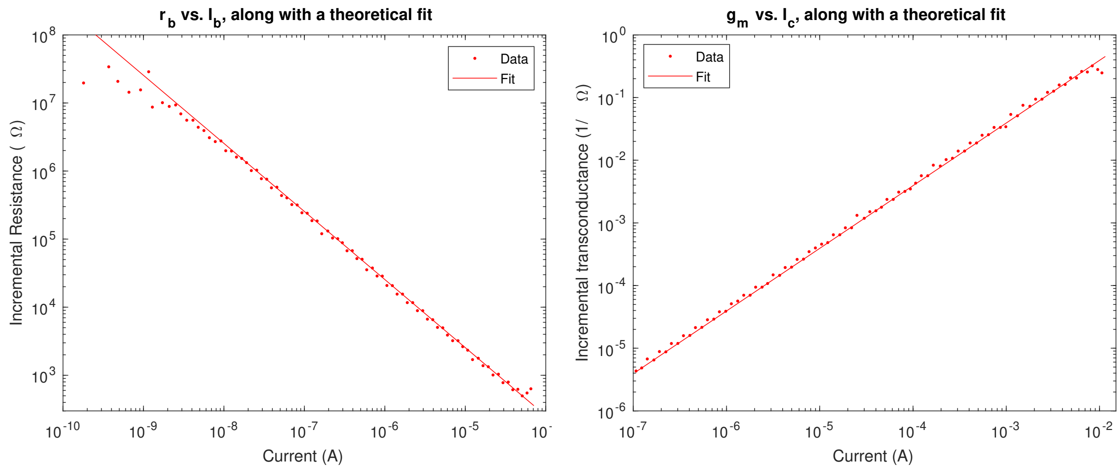


Figure 3: Semilog-x plot of β vs. I_b

in both cases. For the r_b case, there is some slight scattering of data as the base current becomes very small and approaches $100pA$, but is quite okay apart from that.



(a) r_b vs. I_b

(b) g_m vs. I_c

Figure 4: Log-log plots of the incremental base resistance and transconductance

1.2 Experiment 2: Emitter-Degenerated Bipolar Characteristics

Figure 6 shows a plot of the measured I_c vs. V_b in the circuit shown in Figure 5, for three different R_x values - 30100Ω, 3010Ω, and 301Ω. The measured collector characteristic and theoretical fit from Experiment 1 is added to the plot as well. The collector characteristic and fit match the linear portion of the data well, implying that the data does show the standard transistor behavior before saturation due to the emitter degeneration.

Figures 7, 8, and 9 show separate linear plots of I_c vs. V_b along with linear fits for the three resistor values. The linear portion of the graph corresponds to the resistor-dominated portion of the I-V characteristic. The theoretical fits for each graph fit to this linear portion; the slope parameter of the fits will give us $1/R$. The value of $1/\text{slope}$ is shown for each graph; these values are very nearly equal to the R_x value for that response. We attribute the small differences in actual resistor value to measurement error. This shows that the theoretical fits are consistent with the data.

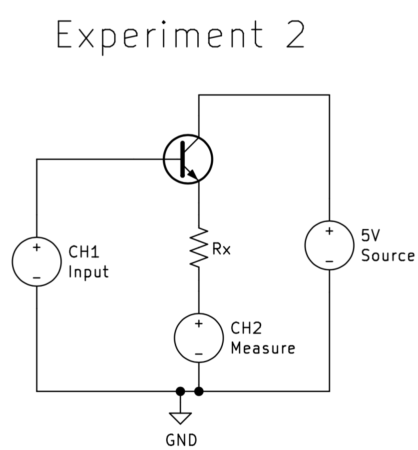


Figure 5: Schematic for Experiment 2

Figures 10a and 10b show log-log plots of the incremental base resistance R_b and G_m over I_b and I_c, respectively. They are plotted with their corresponding theoretical fits, using the collector characteristics extracted from the previous theoretical fits in this experiment. The theoretical fit matches well in saturated

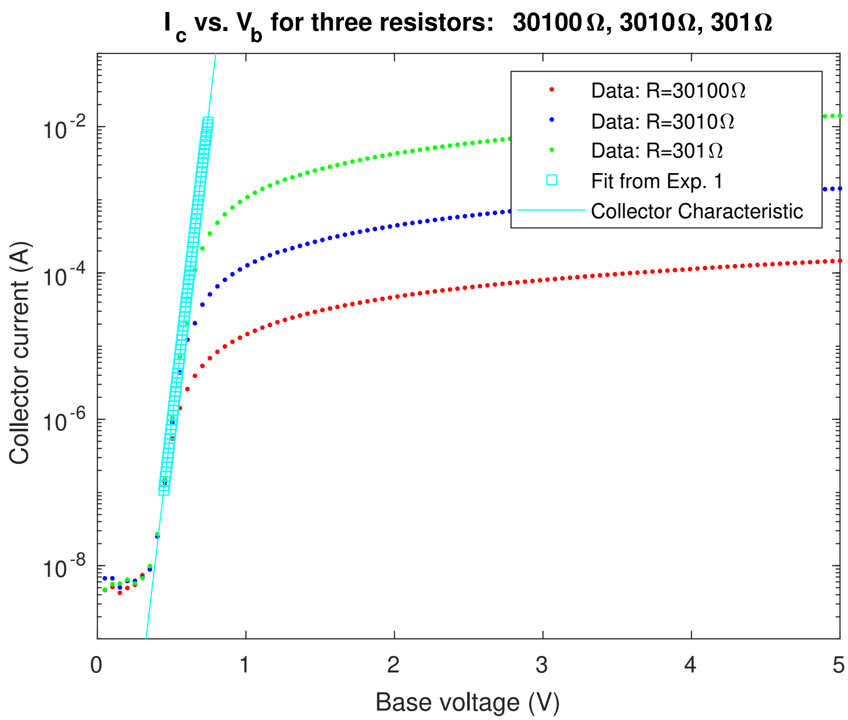


Figure 6: Semilog plots of I_c vs. V_b for all three resistors

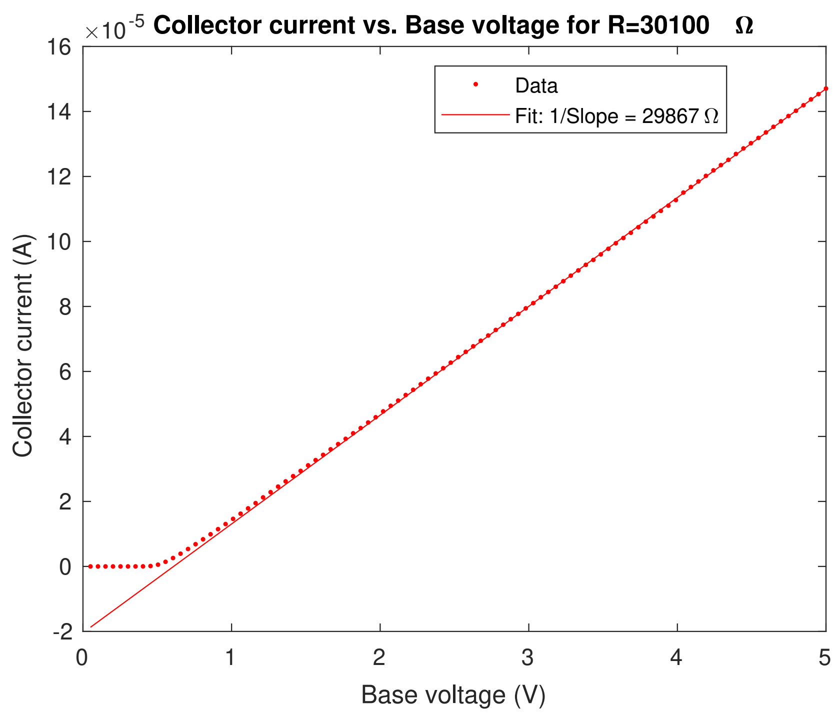


Figure 7: Semilog plots of I_c vs. V_b for $R = 30100\Omega$

area of the response, but it is too shallow to follow the response in the non-saturated region. We assume that this is because of the compounding of errors seen in Experiment 1. We believe this as we used fit parameters determined in Experiment 1 - specifically β and U_T - which are influenced by the SMU measurement errors

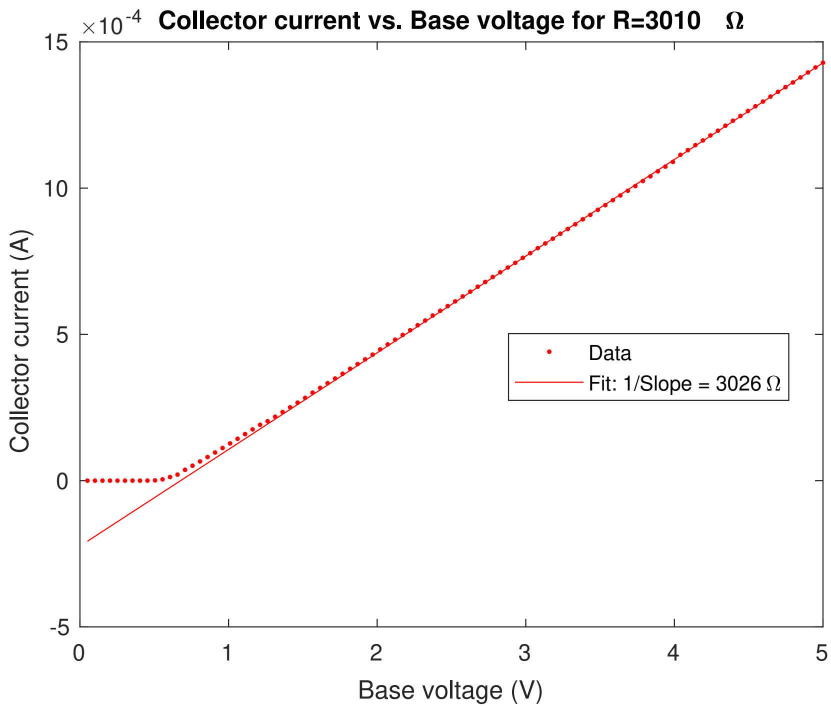


Figure 8: Semilog plots of I_c vs. V_b for $R = 3010\Omega$

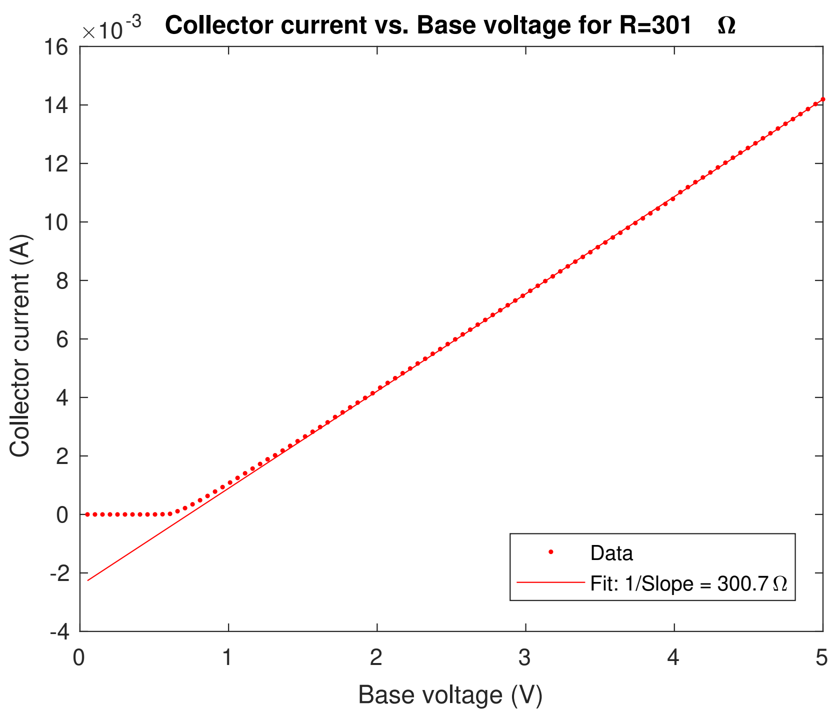
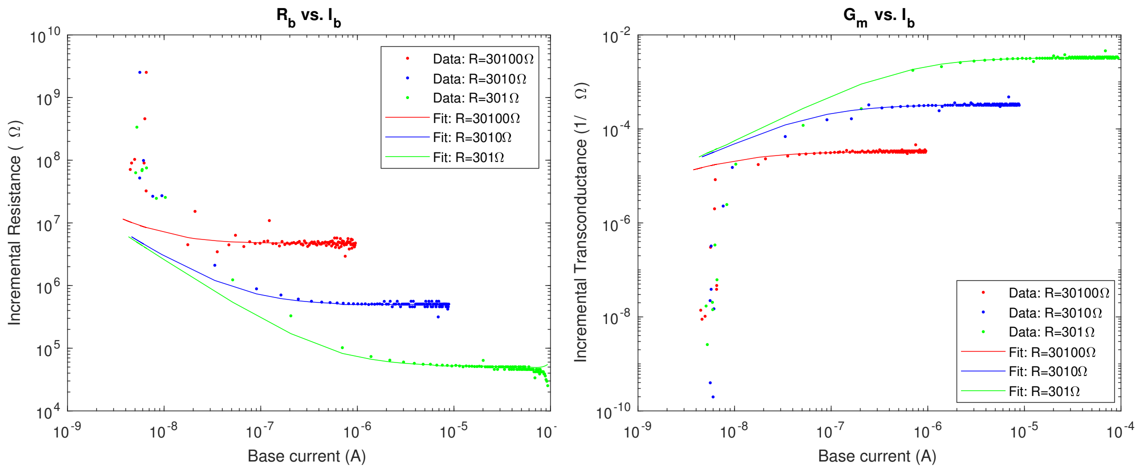


Figure 9: Semilog plots of I_c vs. V_b for $R = 301\Omega$

mentioned earlier.



(a) R_b vs. I_b (b) G_m vs. I_c

Figure 10: Log-log plots of the incremental base resistance and transconductance for the emitter-degenerated case

1.3 Experiment 3: Follower Voltage Transfer Characteristics

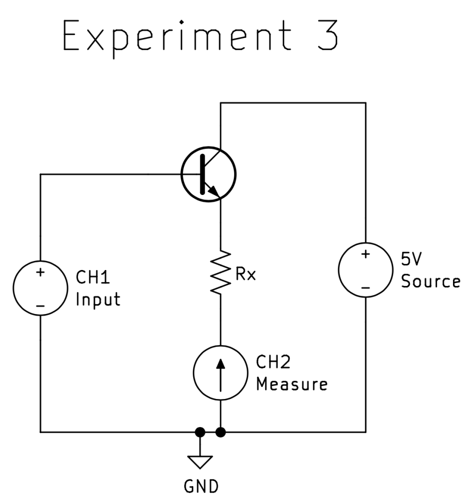


Figure 11: Schematic for Experiment 3

The incremental voltage gain or V_{out}/V_{in} is approximately 1 for the emitter follower. In actuality it is slightly lower around .98. The difference between V_{in} and V_{out} is approximately $.67V$. We expected a value in this range because the saturation voltage of the diode is $0.6V$.

1.4 Experiment 4: Inverter Voltage Transfer Characteristics

The following are derived from Figure 14. For the 6040Ω resistor, the incremental voltage gain of the amplifier is 1.89. For the 9090Ω resistor, the incremental voltage gain of the amplifier is 2.79. For the 12100Ω resistor, the incremental voltage gain of the amplifier is 3.67. These values roughly align with the ratio between the particular resistor and the resistor on the emitter.

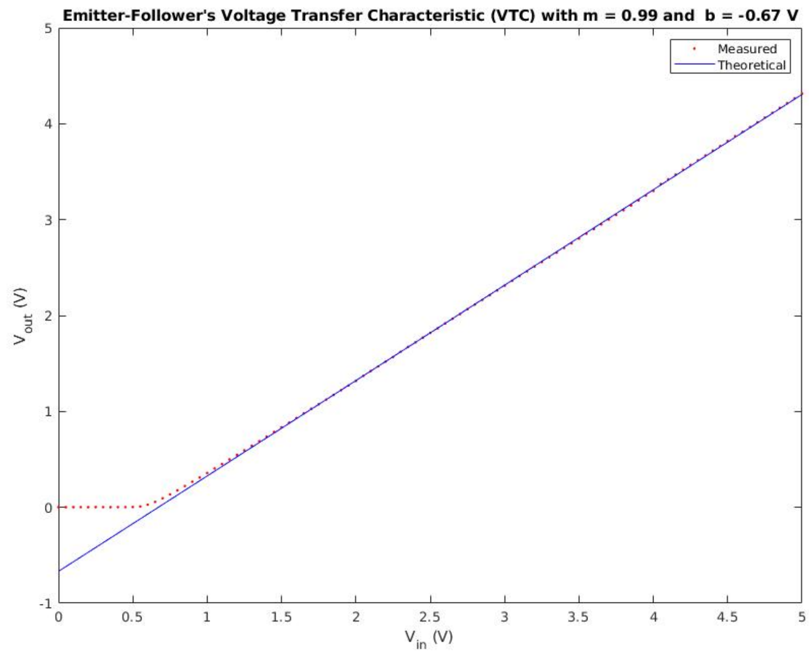


Figure 12: Emitter-Follower VTC

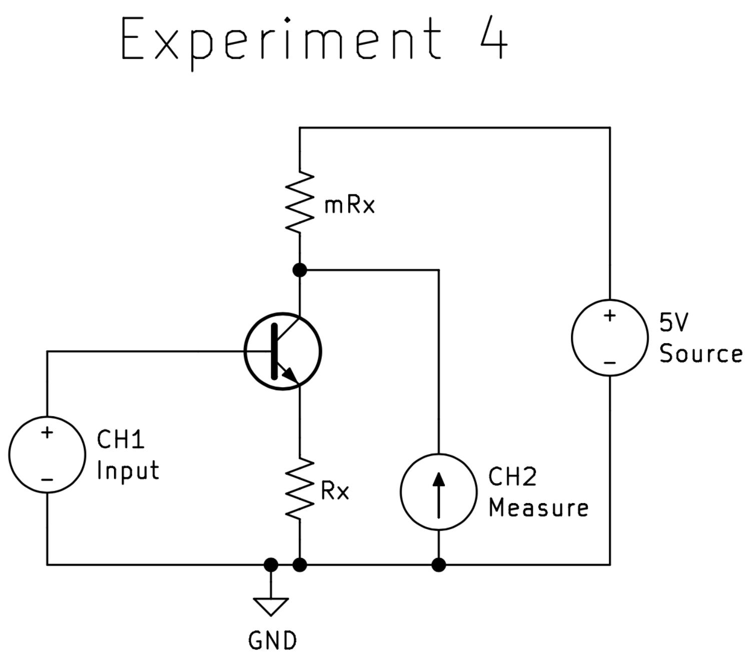


Figure 13: Schematic for Experiment 4

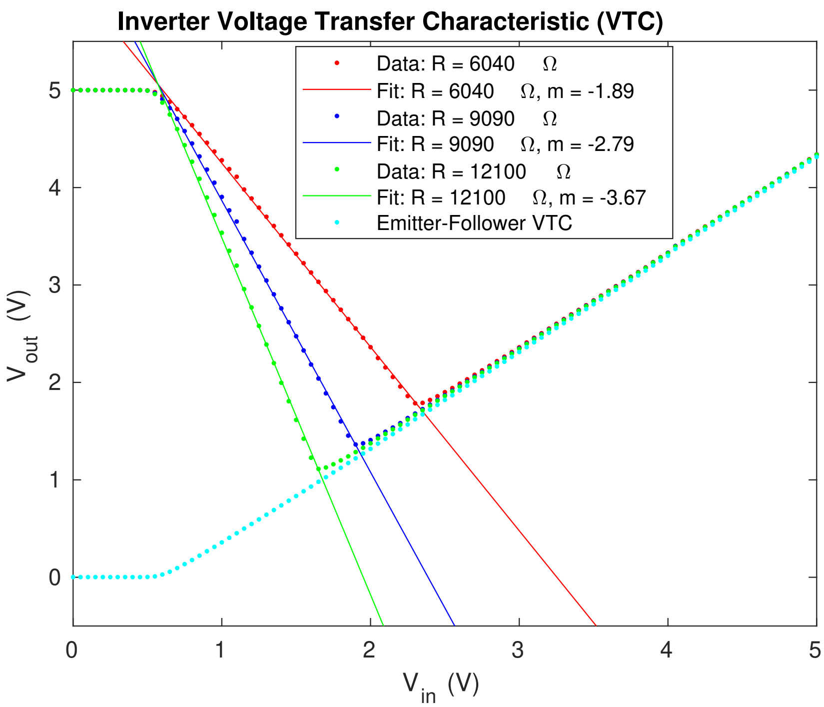


Figure 14: VTC curves for all resistors in the Inverter Setup