Diodes and Transistors

Introduction

Introductory material on the physics of semiconductor devices is available in a set of notes that can be found on the Physics 209 website. Please read these before proceeding since this experiment is designed to complement those notes and to give you the opportunity to explore the properties and uses of diodes and transistors.

Diodes

A diode has a very non-linear I-V characteristic given by

$$I = I_0(e^{eV/k_BT} - 1) \quad \textbf{(1)}$$

where $\boldsymbol{V}$ is the voltage across the diode, T is the temperature in Kelvin, e is the charge of the electron, k_B is Boltzman's constant, and $\boldsymbol{I}$ is the current passing through the diode. When reverse-biased ($V<0$) the diode passes very little current, but when it is forward-biased the current rises very rapidly with increasing voltage. For silicon diodes the current rises very rapidly as the bias voltage reaches 0.6 Volts.

First, you will test Eq. 1 using the circuit shown below. A really good test of an exponential temperature dependence involves measuring $\boldsymbol{I}$ over as many decades as possible. That is, if you can do measurements where $\boldsymbol{I}$ varies by several factors of 10 (from microamps to milliamps for instance) you can make a convincing test of exponential behaviour and try to extract k_B from your data. A variable resistor, together with a 10 kΩ resistor is used to supply the variable current to the diode. This current can be determined by measuring the voltage across the 10 kΩ resistor. Simultaneously, one can directly measure the voltage across the diode. Negative currents can be measured by flipping the orientation of the diode in the circuit.

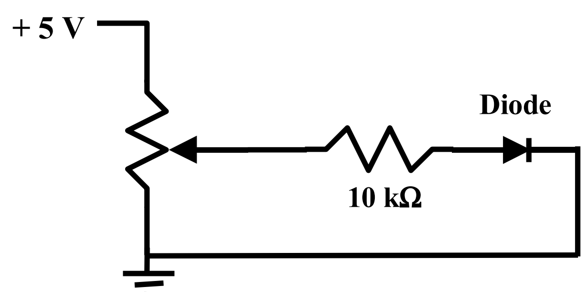

Fig. 1

Diode as a Rectifier

One way to see the diode in action in a circuit is to apply an AC voltage as shown in Fig. 2 below. Try applying a 60 Hz voltage using the function generator and measure the voltage across the 1 kΩ resistor, making careful note of the differences. You should find that the diode passes positive voltages, but not negative ones, something known as rectification. In one further step, you can place a capacitor in parallel with the resistor to generate a simple DC voltage supply. The principle here is that if you make the time constant of the RC combination much longer than the period of the 60 Hz generator voltage, then the rectified voltage can be converted to a positive voltage with a small ripple on it. Choose a resistor that makes this ripple less than 5% of the overall DC voltage.

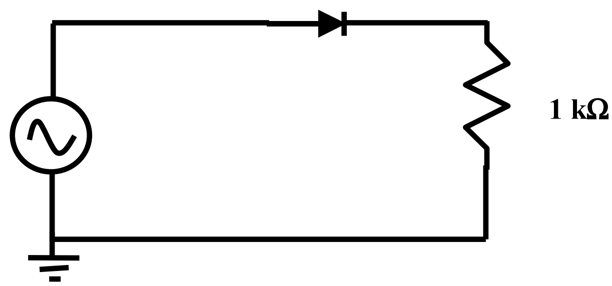

Fig. 2

Transistors

Current amplification can be demonstrated in the simple transistor amplifier circuit shown below. Remember that the transistor only functions when the junction from the base to the emitter is forward-biased. Therefore, if you are trying to amplify an AC signal from the function generator, you have to add a DC component (use the DC offset of the generator) that is large enough that the junction is forward biased throughout the AC cycle. When thing are set properly you should observe an AC voltage across the 2 kΩ resistor that matches the AC voltage supplied by the generator. Make note of the limitations on this over a range of AC amplitudes and DC offsets. Finally, demonstrate that this circuit does provide current amplification by measuring the voltage across each of the resistors (you'll need to use the DMM to measure the RMS voltages) and then calculating the current entering the base to the current leaving the emitter.

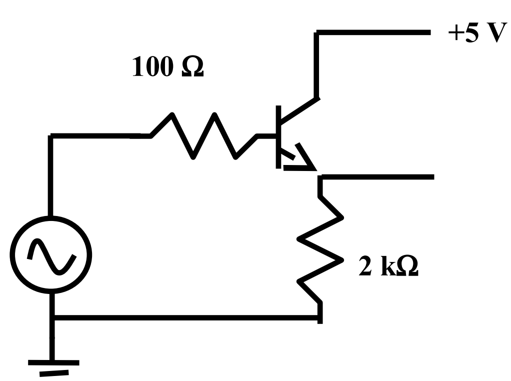

Fig. 3

The circuit shown in Fig. 4 provides voltage amplification. Measure the amplitude of the output voltage and compare it to the voltage across the function generator in order to determine the amplification. Again, you will need to provide a DC offset to the input signal in order to keep the base-emitter junction forward-biased. Check the limitations on the linear response of the amplifier (the range over which the output is proportional to the input). Finally, replace the resistor at the collector with other values (100 kΩ for instance) and demonstrate how the resistors determine the amplification.

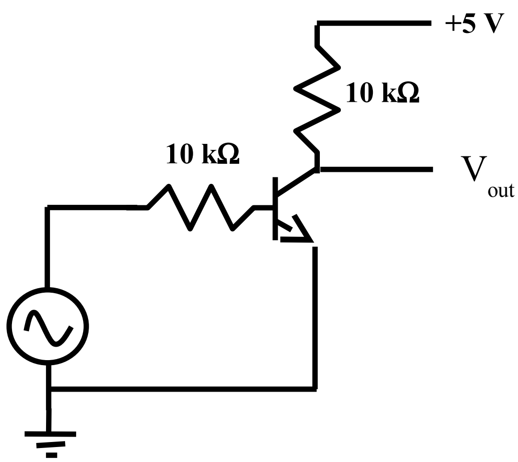

Fig. 4

Prelab Question:

1. Manipulate Eq. 1 into a form in which you will be able to use a linear least squares fit to analyze your diode I-V characteristics.
2. In a real amplifier it is undesirable to require that the input signal have a large DC component. Design a circuit that provides a DC offset so that the base-emitter junction is forward biased even if the input signal has no DC component. You can attempt your own design and also look up other possibilities on the WEB or in any electronics text. Test the bias circuit out as the last part of your experiment