Physics 80 Lab Manual

January 18, 2019

Chapter 1

The Speed of Light in Air

1.1 Pre-lab Calculations

1) Suppose . Hint: assume a .

2)

3) What is the definition of the meter ? What is the exact value of the speed of light in vacuum?

1.2 Introduction

In this lab, you will measure the speed of light in the air by measuring the time between sending and receiving a flash of light over a known distance, evaluate statistical and systematic uncertainties and compare it to the known value. In the process, you will learn how to use your scope to make time measurement.

The flash of red light is created by a pulsed laser diode, a device very similar to a laser pointer, except this laser is switched on and off (pulsed) at a very high rate: 1 million times per second (1 MHz). Whenever laser diode is pulsed a "trigger" pulse is sent to the oscilloscope. The pulsed beam of light is detected by a fast photo-diode detector and a "signal" pulse is sent to the oscilloscope. The time difference between the two pulses Δt can be measured as a function of the distance L between the laser/detector apparatus. Assuming that the time difference between the two pulses depends only on the time it took the light to travel the distance L one can determine the phase velocity of laser diode light in the air: $v_{red} = \frac{L}{\Delta t}$.

1.3 Measuring the I-V Curve of a Diode

In this section you will measure the I-V curve of a 1N914 diode, and compare your results to the curves available from the device data sheet. To avoid taking a bunch of measurements by hand, we will use a trick to plot the curve directly on your oscilloscope using the XY mode.

Consider (but don't build!) the circuit in Fig. 1.1a. The voltage between points P_2 and P_1 is proportional to the current passing through the diode, and the voltage between points P_1 and G is the voltage across the diode. So if we could display $P_2 - P_1$ versus $P_1 - G$ on your scope we could use this circuit. Unfortunately, this is not possible on your scope, because (1) the only valid place

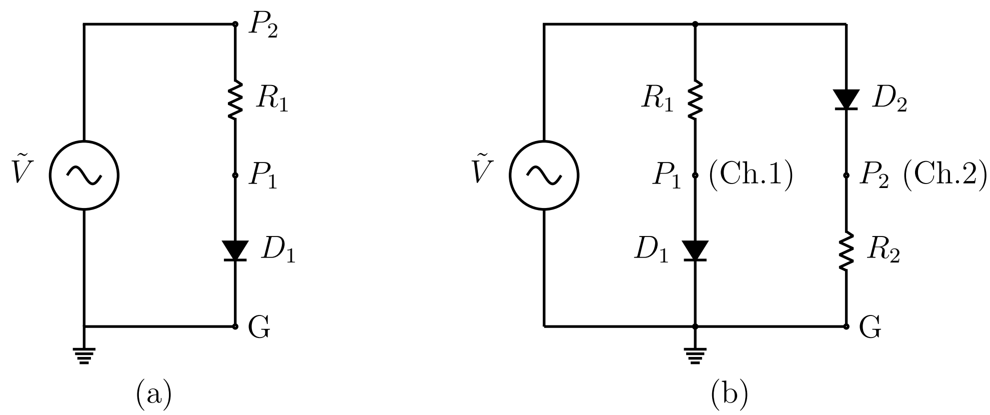


Figure 1.1: Diode circuits for (a) demonstrating rectification and (b) plotting the diode IV curve on your oscilloscope.

to put the scope probe ground shield clips is at the point G (Why?) and (2) you can only display Channel 1 versus Channel 2 in XY mode.

The solution is to drive two copies of the diode in series resistor, with the component order reversed, as in Fig. 1.1b. This way, we can connect the probe ground shields as required at point G, put the voltage across the diode on scope Channel 1 by connecting the probe tip at P_1, and put the voltage across the resistor (proportional to current through the diode) on scope Channel 2 by connecting the probe tip at P_2.

Build the circuit in Fig. 1.1b using a 1N914 fast switching diode for D_1 and D_2 and $R_1 = R_2 =$ 10 kΩ. Set your function generator for high-impedance output, providing AC with peak to peak voltage of 20 V at a frequency of 100 Hz. Before switching to XY mode, make certain that your Channel 1 has no voltage offset (that is, zero voltage is located at the origin) or else your diode output voltage won't be calibrated properly in your output plot. Once you set this, try not to adjust the offset of Channel 1 or you'll have to redo it! To minimize noise, set the bandwidth limit "On" for both channels (this is available in the menu for each input channel as "BW Limit").

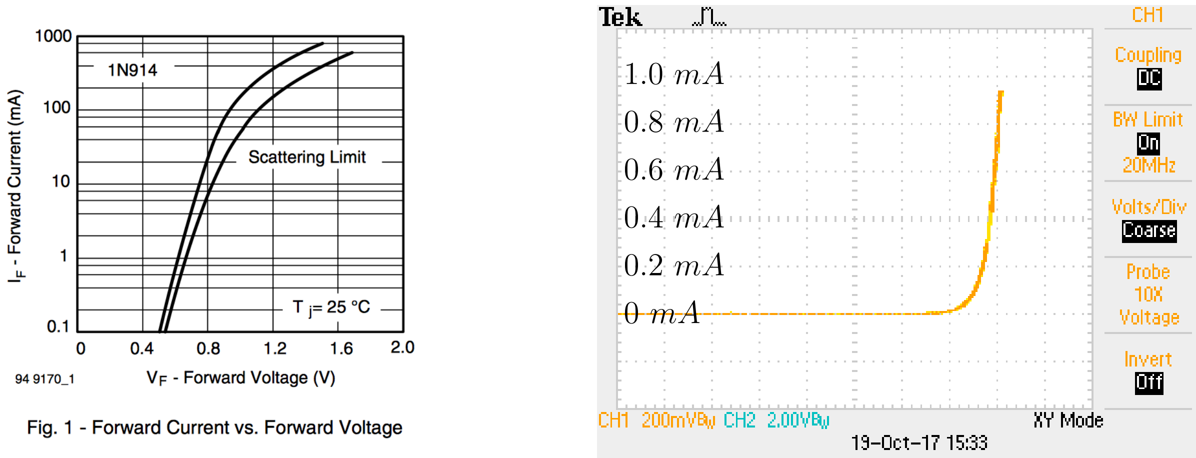
Set the scope into XY mode, and see if you can reproduce the diode IV curve in Fig 1.2b. Beats jotting down voltages in your logbook doesn't it? Now jot down the voltage you expect across the diode for a current of 1 mA in your logbook. Where they overlap, does your measured IV curve agree with the curve from the component data sheet in Fig. 1.2a?

1.4 Rectifying an AC Signal

Set your function generator to provide an AC source with frequency 100 Hz and peak-to-peak voltage $V_{\mathrm{pp}} = 5$ V. Build the circuit in Fig. 1.3 using a 1N914 diode for D and $R = 1.8$ kΩ.

With your scope probe ground shield clips both properly connected to the ground at G, monitor the voltage at points P_1 and P_2. Sketch the voltage across the resistor R and the voltage supplied by the function generator versus time on the same plot in your lab book.

Using your scopes amplitude measurement feature, measure precisely (i.e. to within 50 mV precision) the voltage drop across the diode at the peak current value, by measuring the difference between Channel 1 and Channel 2 of your scope at the peak. Is this operating point consistent with your results from the previous section and the pre-lab calculations?



(a) (b)

Figure 1.2: IV curves for the1N914 from (a) data sheet, and (b) as you will measure in this lab. In the scope trace, the Channel 2 (Y) with scale set to 2 V measures the voltage across a 10 kΩ resistor, so each division corresponds to 200 μA as indicated.

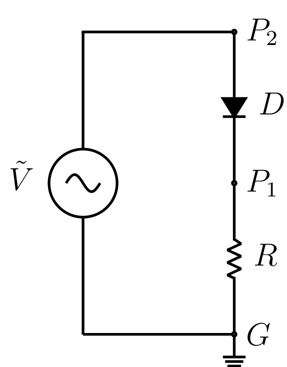


Figure 1.3: A diode rectification circuit.

1.5 Lab Report

Your report should include all of your measurements and a comparison with your calculation.