

EE 101	Spring 2006	Date:	Lab Section #
Lab #4		Name:	
Diodes and Digital Signals		Partner:	

Abstract

A signal that has a continuously varying amplitude and/or frequency is called an *analog* signal, while a signal that has only a set of specifically allowed amplitudes and frequencies is known as a *digital* signal. The continuous sine wave and triangle wave signals used in the previous lab are examples of analog signals. A common type of digital signal can represent the two logic states '1' and '0' that are used in binary arithmetic. There are a variety of ways in which the '1' and '0' states can be represented, such as different voltage levels, polarities, frequencies, and combinations of these.

After completing this experiment you should:

- (1) Be able to calculate the duty cycle of a pulse waveform given the waveform's pulse width and repetition period,
- (2) Be able to approximate the current that flows in a simple diode circuit,
- (3) Be able to measure the voltage and current in a simple diode circuit,
- (4) Be able to wire a typical light emitting diode (LED) display on a prototype board so as to illuminate a desired segment on the display.

Introduction and Theory

Digital logic circuits such as microcomputers typically use different voltages to represent the binary digits '1' and '0'. For example, in our robot system we will use +5V to represent a logic 1 and 0 V to represent a logic 0. If the voltage switches from a logic 1 to a logic 0 on a regular basis, we can observe a *pulse* waveform using the oscilloscope.

Pulse waveforms are described in terms of the pulse repetition period, or pulse frequency, and the pulse high time, or pulse *width*. The ratio of the pulse width to the pulse period is called the *duty cycle*, and is typically expressed as a percentage. For example, a pulse waveform with a 20 millisecond (ms) period and a 2 ms pulse width has a duty cycle of $\left(\frac{2}{20}\right) \times 100\% = 10\%$.

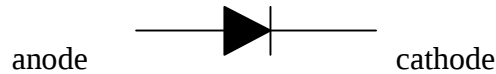


Figure 1: Pulse waveform with 10% duty cycle

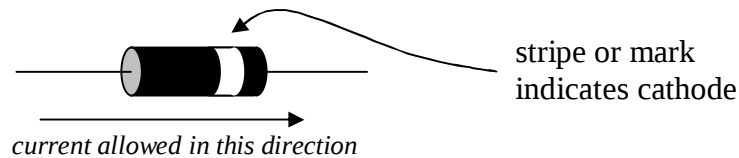
A *diode* is a two-terminal semiconductor circuit element that allows electrical current to pass in only one direction. In effect it functions as a "flow valve" – current is allowed to pass in one direction through the diode, but is prevented from passing through in the opposite direction. Diodes are marked to indicate in which direction electrical current will flow, so diodes have polarity; that is, *they need to be placed in a*

circuit in the correct direction. The two diode wires are referred to as the *anode* and the *cathode*, in order to match the terminology originally used with vacuum tube diodes.

Schematic Symbol:



Typical package:



Although a diode allows current to flow through in one direction, it does this at the expense of a small voltage drop across the diode. Typically this forward bias voltage drop for a diode is about 0.5 V to 0.6 V, and this voltage is relatively independent of the amount of electrical current flowing through the diode. An example of the current vs. voltage relationship for a diode is shown below.

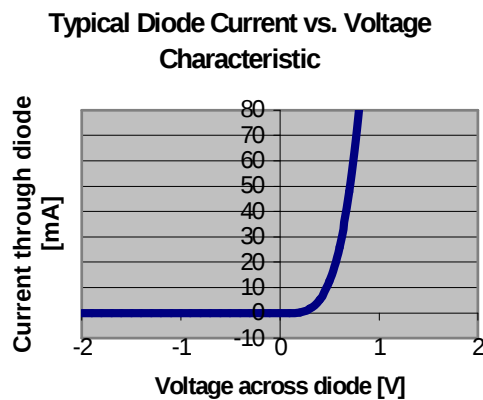


Figure 2: Diode Characteristics

In this lab exercise you will be using a special type of diode: the *light-emitting diode*, or LED. LEDs are diode devices that produce light when a current of the proper polarity is provided. There is no glowing hot resistive filament in an LED like there is in an incandescent light bulb. In fact, it is VERY IMPORTANT that the current through the LED be limited by including a series resistor so that the device does not overheat.

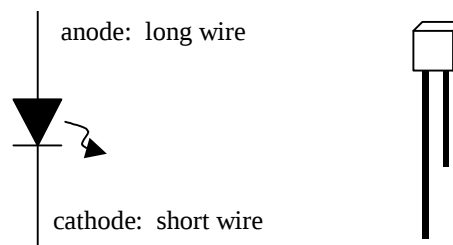


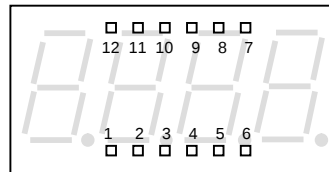
Figure 3: Light-Emitting Diode

The schematic symbol for a light-emitting diode is shown in Figure 3. The LED's symbol is just like that of the regular diode but with the addition of a wiggly arrow representing the light. The LED itself operates similarly to a regular diode, except the forward voltage is more like 1.5-2.0 V instead of 0.5-0.6

V. Single LEDs come in a variety of shapes and sizes. Usually the LED has a long wire for the anode and a short wire for the cathode. Be sure the device is placed into your circuit with the proper orientation.

LEDs can be assembled into groups to form numerical displays. The common 7-segment LED display has a separate LED for each portion of the digit. The internal wiring of the 4-digit 7-segment (plus decimal point) common-anode display in your lab kit is shown below.

Top View:



Pins (on bottom) numbered counterclockwise

Detail:

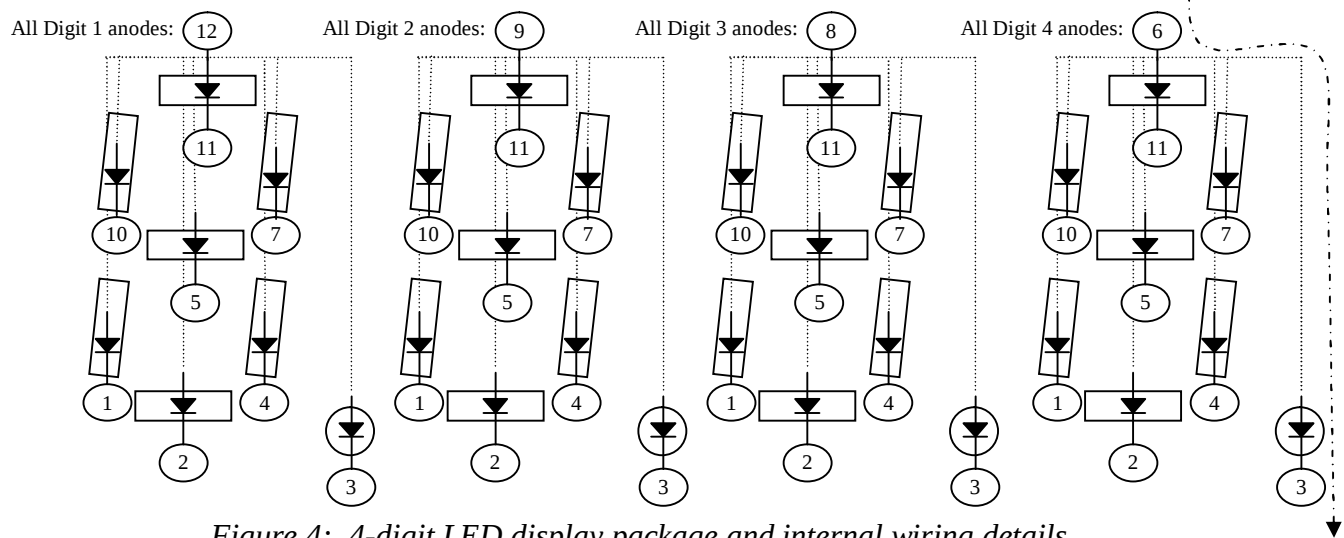


Figure 4: 4-digit LED display package and internal wiring details

For example, if you want to light up the decimal point next to digit #4, you would connect a circuit so that current would flow into pin number 6 and out of pin number 3.

Prelab

PL1. Consider the diode circuit illustrated in Figure 5 in which $R = 470\ \Omega$.

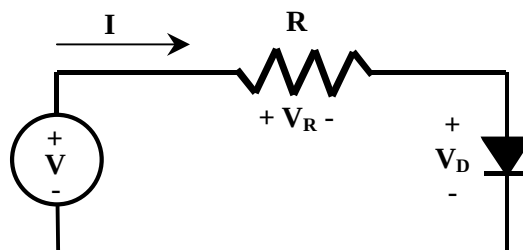


Figure 5: A diode circuit

Using the “piecewise linear” model of the diode we studied in lecture and found in the course note set, calculate the current and voltage levels requested in Table I. In the space provided below the table, show your calculations for the following cases: $V = -2\text{ V}$, $V = 0\text{ V}$, $V = 1\text{ V}$, $V = 6\text{ V}$.

TABLE I: Predicted Values for the circuit of Figure 5

V	V_R	V_D	I
-2 V			
0 V			
0.4 V			
1 V			
1.5 V			
2 V			
2.5 V			
3 V			
3.5 V			
4 V			
4.5 V			
5 V			
6 V			

Instructor's initials_____

Equipment

Your circuit prototype board, your lab kit (containing resistors, light-emitting diodes (LEDs), 4-digit 7-segment LED display, and alligator clips), a diode provided by the instructor during lab, and the bench power supply, function generator, oscilloscope, multimeter, and banana cables furnished in the lab.

Procedures

P1. Using the bench power supply to establish the DC voltage, construct the circuit of Figure 5 (found in the prelab). As you will be asked to measure voltages and currents in the circuit for several values of input voltage, determine how to use the DMM to complete the following table.

TABLE II: Measured Values for the circuit of Figure 5

V	V_R	V_D	I
-2 V			
0			
0.4 V			
1 V			
1.5 V			
2 V			
2.5 V			
3 V			
3.5 V			
4 V			
4.5 V			
5 V			
6 V			

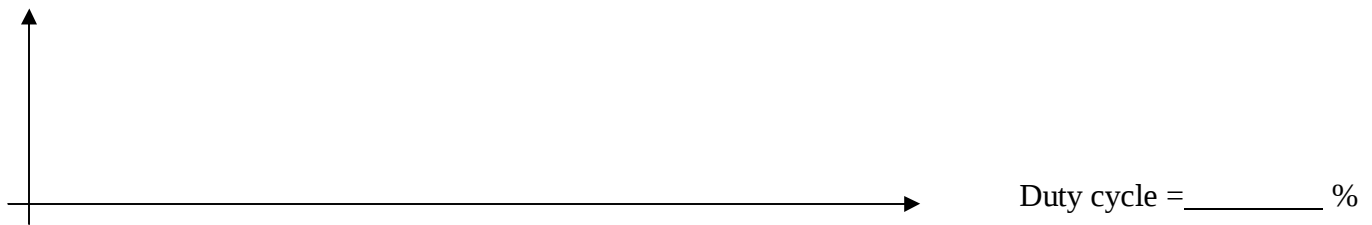
Comment on the agreement between the values calculated in Table I and those you measured in Table II.

In Lab 6 we will use MATLAB to plot your measured data and thus create an I-V curve for the IN4004. We are now finished with the circuit of Figure 5.

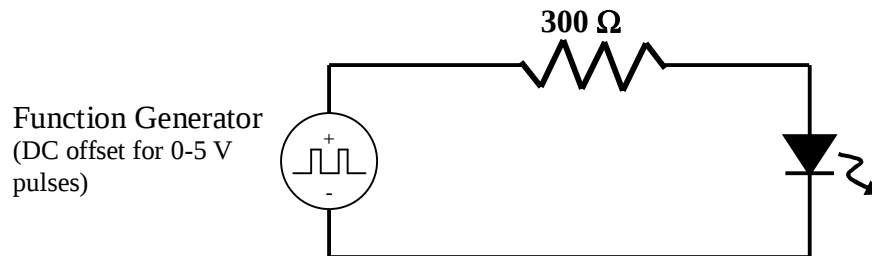
P2. → Turn on the function generator and set the controls to create a pulse waveform with a 1 kHz repetition frequency: press the square wave and the positive pulse button together. Observe the waveform with the oscilloscope and verify the pulse repetition frequency is 1 kHz. Choose a sweep rate on the scope so that about two cycles of the waveform are visible on the screen, and adjust the function generator amplitude so that the waveform is 5 volts peak-to-peak.

Note that the waveform has longer “low” portions and shorter “high” portions. Using the DC Offset knob on the function generator (pull and twist), adjust the level upward so that the waveform is zero volts during the low portions and +5 volts during the high portions.

Carefully sketch the waveform below, *including the time and voltage details*. Also calculate the duty cycle (ratio of “high” duration to one waveform period).

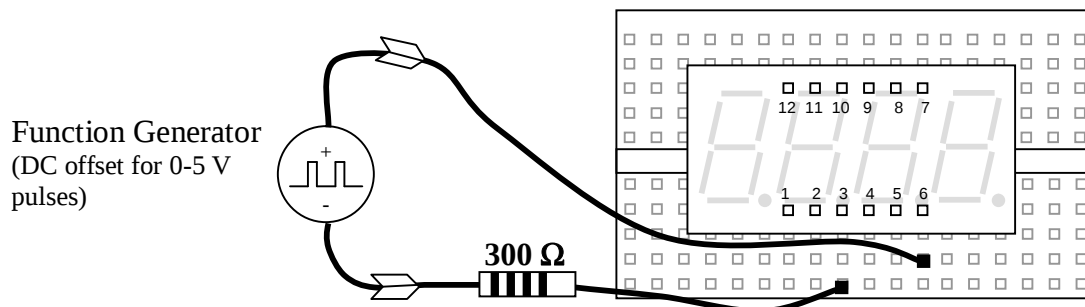


P3. → Now construct the circuit below on your breadboard. The LED should be illuminated slightly.



Decrease the frequency of the function generator until your eyes can just start to see the LED flickering on and off. What frequency is it? _____. Then continue decreasing the frequency until the LED flashes about once per second. To what frequency does this correspond? _____

P4. → Now place the 4-digit 7-segment display onto the breadboard so that it straddles one of the grooves. Arrange the wiring so that the decimal point of the 4th digit is illuminated, as shown below, by using jumper wires and alligator clips. Remember that you **MUST** include the series resistor to limit the current through the LED segment!



Using the circuit diagram and pin labels from Figure 4, move the wires on the breadboard to demonstrate that you can illuminate any of the segments. Demonstrate this for your instructor or lab TA.

Instructor/TA initials _____

P5. → Finally, use the 4-digit display, the dual in-line package (DIP) switch module, eight $300\ \Omega$ resistors, and the fixed +5V output of the DC bench power supply so that each switch controls one of the segments of digit 1. Demonstrate your circuit for the instructor or lab TA.

Instructor/TA initials _____

