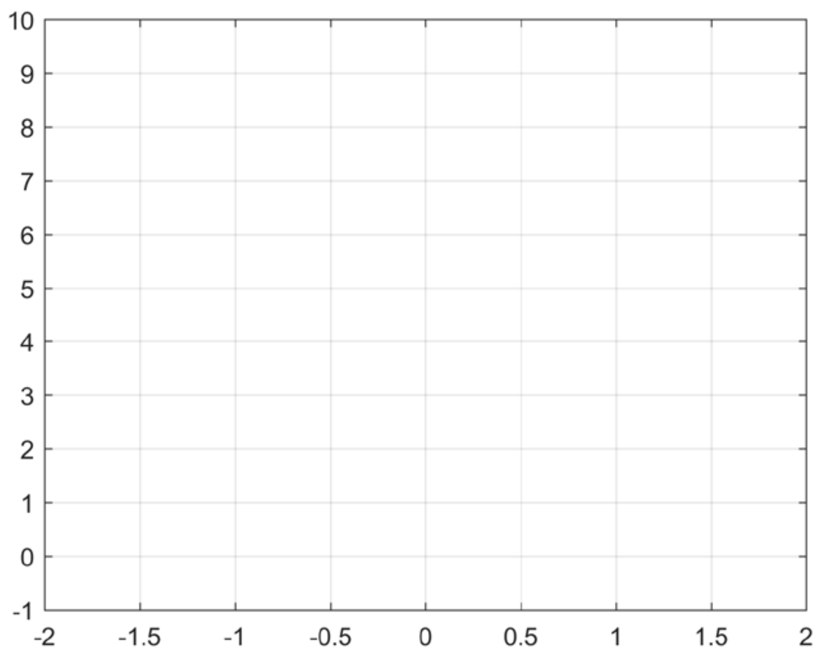
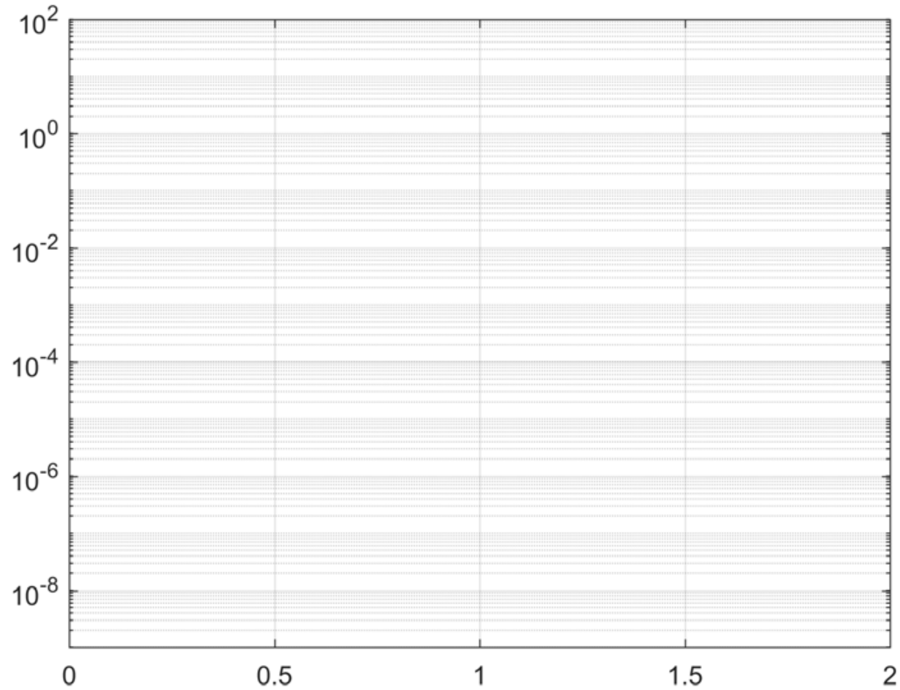
Laboratory 8: Light-emitting Diodes (LEDs) with Digital Control
In this laboratory, you will explore the behavior of LEDs using basic resistive networks.

Required Parts: 3 100 Ohm resistors, 1 1kOhm resistor, 1 10 kOhm resistor, 1 100kOhm, and 1 MOhm, 1 LED, 1 RGB LED.

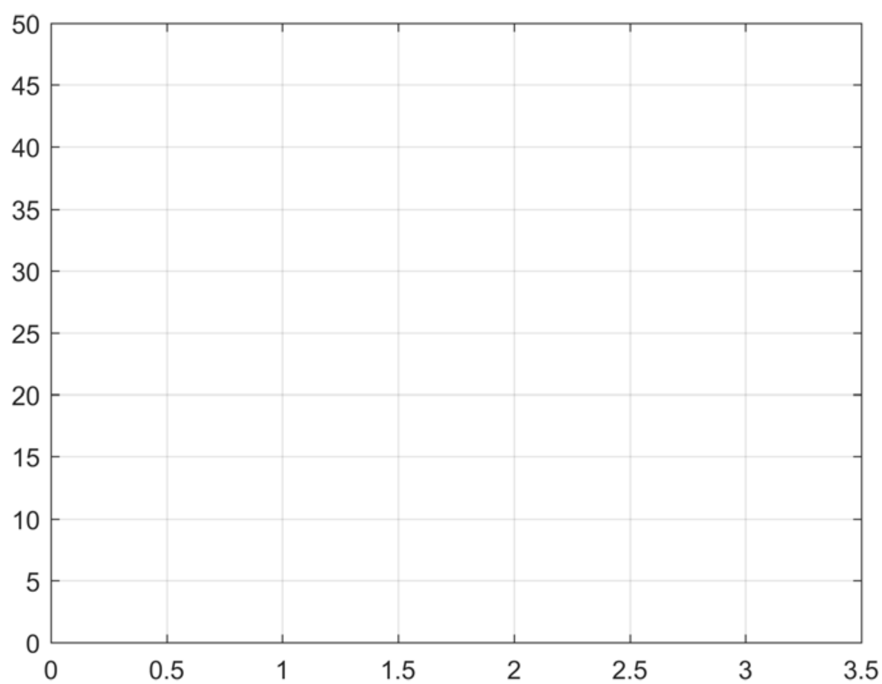
Step 1. Use the Diligent wavegen source to sweep the voltage across the LED from -2V to +2V. Recall from lecture that red LEDs require around 2V forward bias to generate light. Change the voltage across the diode in 200 mV steps and use the ammeter of the DMM to record the diode current. Do not exceed 20 mA in the diode. Plot the diode's *i*-*v* characteristic below.



Step 2. Recall that $\log_{10} i_D \approx \log_{10} I_S + \frac{1}{\log 10}\frac{v_D}{v_T}$ Can you find I_s and v_T by plotting the drain current from 0.5 to 2 v in 100 mV (or smaller if needed) steps and drawing a line that determines I_s and v_T.



Step 3 Attach the LED in series with a 100 Ohm resistor. Use graphical analysis to find the operating point ($V_{D,Q}$ and $I_{D,Q}$) assuming that the maximum voltage is 3.5 V. You can use your data from the previous problem (Step 1).



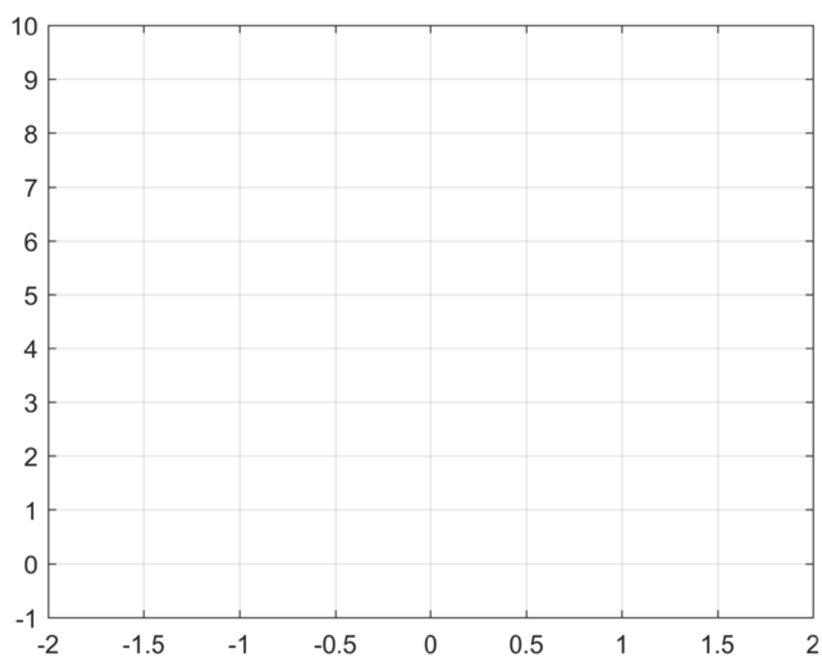
Step 4. Attach an LED in series with each of the resistors below. Using the DD2, apply 3.5 volts across each one simultaneously and compare the brightness. Also record the current through each of the networks. Can you explain why one is brighter than the others (in one sentence)?

R (Ohms)	100	1000	10k
Current (mA)			
Brightness			

Step 5 Reverse the LED polarity such that it operates under reverse-bias and replace the resistor with a 1MOhm. Apply a 3.5V supply to the diode. Can you measure a different voltage across the resistor when the LED is exposed to light versus when you cover it (i.e. with your hand) so that it does not get any light. Choose the resistor that achieves the highest voltage variation. This is the basis of a photodetector which is used to measure light intensity.

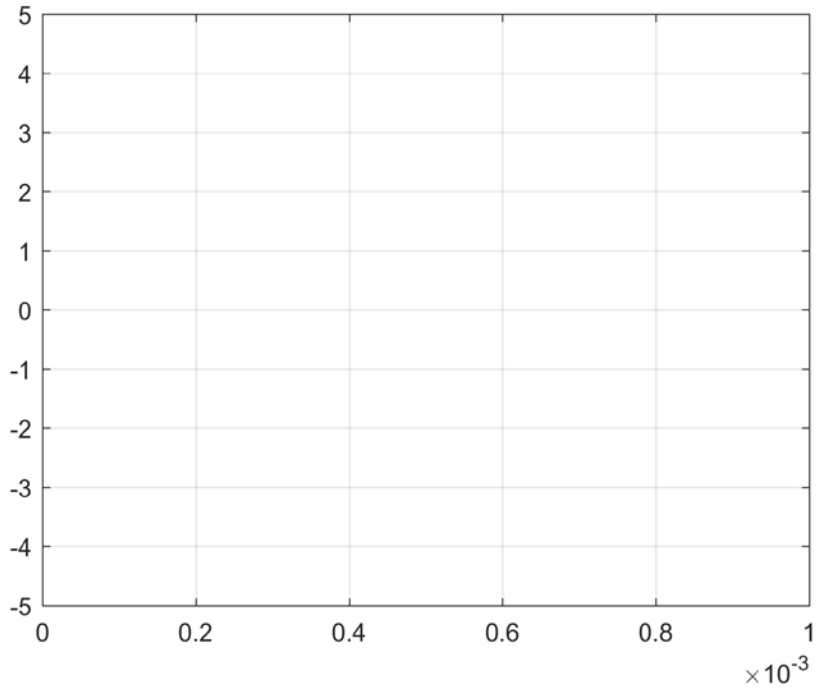
R	V when dark	V when light
10kOhm		
100kOhm		
1MOhm		

Step 6. Now we will switch from the red LED to the red-green-blue (RGB) LED. The RGB LED has a common cathode connection that should be grounded. Record the *iv* response through each LED on the common graph shown below. Which has the highest forward voltage? Does the highest energy light require the highest voltage?



Color	Red	Green	Blue
Diode voltage (V)			
Diode current (mA)			

Step 7. Using 100Ω resistors, add three resistors in series with each input of the(RGB) LED and apply the 3.3 V supply to each simultaneously. Using the same 100 Ω resistors, drive these three networks separately from the digital logical outputs at 3.3 V. Turn on each of the three outputs sequentially every 1 second for a duration of 1 second. Demonstrate that you can turn on and off each of the LED colors separately. Plot the diode voltage as a function of time.



Step 8. Program the Discovery 2 to turn on every possible combination of LED colors (000, 001, 010, ..., 111), a total of 7 transitions by using the logical output. What color or color combinations do you see?

Digital Code	Color(s)
000	
001	
010	
011	
100	
101	
110	
111	

Step 9. Program the Discovery 2 to go through each combination of LED colors (000, 001, 010, …, 111) at a frequency of 1 Hz, 10 Hz, and 100 kHz, in other words you can change the color every 1 s, 0.1s, or 10ms. How many separate colors do you observe at each rate, i.e. do you see 8 color steps? What difference do you see in the voltage at 1 Hz and 100 Hz? An LED screen has millions of these RGB diodes embedded in a thin layer and each diode is driven from an LED driver at a relatively high refresh rate. As you see from above, you can create different colors based on the combinations of RGB that are rastered very rapidly.

Frequency	Number of Colors
1 Hz	
10 Hz	
100 Hz	