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Parameter	Value	Units	Conditions
Resistance of the 10kΩ resistor, R1	9.98 kΩ	ohms	with power off and disconnected from circuit (measured with ohmmeter)
Supply Voltage, $V_{+3.3}$	3.30 V	volts	Powered (measured with voltmeter)
Input Voltage, V_{PE1}	0.00 V	volts	Powered, but with switch not pressed (measured with voltmeter)
Resistor current	0.00A	mA	Powered, but switch not pressed $I=V_{PE1}/R1$ (calculated and measured with an ammeter)
Input Voltage, V_{PE1}	3.21 V	volts	Powered and with switch pressed (measured with voltmeter)
Resistor current	75.7mA	mA	Powered and switch pressed $I=V_{PE1}/R1$ (calculated and measured with an ammeter)

Table 3.1. Switch measurements.

Next, you can connect the input voltage to **PE1** and use the debugger to observe the input pin to verify the proper operation of the switch interface. You will have to single step through the code that initializes Port E, and PE1. You then execute the **Peripherals->TEXaS Port E** command. As you single step you should see the actual input as controlled by the switch you have interfaced, see Figure 3.1.

The next step is to build the LED output circuit. LEDs emit light when an electric current passes through them, as shown in Figure 3.8. LEDs have polarity, meaning current must pass from anode to cathode to activate. The anode is labeled **a** or + , and cathode is labeled **k** or -. The cathode is the short lead and there may be a slight flat spot on the body of round LEDs. Thus, the anode is the longer lead. LEDs are not usually damaged by heat when soldering. Furthermore, LEDs will not be damaged if you plug it in backwards. However, LEDs won't work plugged in backwards. Look up the pin assignments in the 7406 data sheet. Be sure to connect +5V power to pin 14 and ground to pin 7. The 0.1 μF capacitor from +5V to ground filters the power line. Every digital chip (e.g., 7406) should have a filter capacitor from its power line (i.e., pin 14 V_{CC}) to ground. The capacitor in your kit is ceramic, which is not polarized, meaning it can be connected in either direction.

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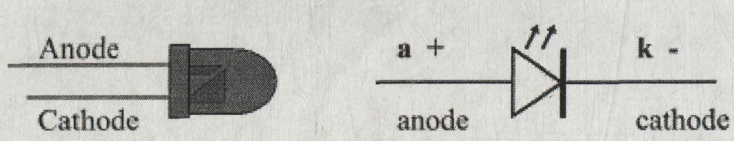

Figure 3.8. Left: a side view of an LED with leads labeled; Right: the corresponding circuit diagram

The circuit in Figures 3.2 and 3.3 used R10 as the 220Ω resistor. There are six 220Ω resistors R10 – R15 in the PCB artist starter file, any one of which could have been used.

Take the measurements as described in Table 3.2. The R10 measurement occurs before R10 is inserted into the circuit. Single step your software to make **PE0** to output. Initially **PE0** will be low. So take four measurements with **PE0** low, rows 2,3,4,5 in Table 3.2. Then, single step some more until **PE0** is high and measure the three voltages (rows 8,9,10 in Table 3.2). When active, the LED voltage should be about 2 V, and the LED current should be about 10 mA. The remaining rows are calculated values, based on these 8 measurements. The LED current (row 12) can be determined by calculation or by direct measurement using the ammeter function. You should perform both ways to get LED current.

Warning: NEVER INSERT/REMOVE WIRES/CHIPS WHEN THE POWER IS ON.

Row	Parameter	Value	Units	Conditions
1	Resistance of the 220Ω resistor, R10	217Ω	ohms	with power off and disconnected from circuit (measured with ohmmeter)
2	+5 V power supply V_{+5}	4.84V	volts	(measured with voltmeter, *notice that the +5V power is not exactly +5 volts*)
3	TM4C123 Output, $V_{\cancel{PE}}$ PEO input to 7406	50 mV	volts	with **PE0** = 0 (measured with voltmeter)
4	7406 Output, V_{k-} LED k-	3.54 V	volts	with **PE0** = 0 (measured with voltmeter)
5	LED a+, V_{a+} Bottom side of R~~10~~ 220	4.8 V	volts	with **PE0** = 0 (measured with voltmeter)
6	LED voltage	-0.541	volts	calculated as $V_{a+} - V_{k-}$
		0		calculated as $(V_{+5} - V_{a+})$/R10

$$\frac{4.84 - 4.86}{217} \simeq 0$$

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7	LED current	0	mA	and measured with an ammeter
8	TM4C123 Output, V_{PE0} input to 7406	3,25 V	volts	with **PE0** = 1 (measured with voltmeter)
9	7406 Output, V_{k-} LED k-	133.8 mV	volts	with **PE0** = 1 (measured with voltmeter)
10	LED a+, V_{a+} Bottom side of R10	2.06 V	volts	with **PE0** = 1 (measured with voltmeter)
11	LED voltage	1,93	volts	calculated as V_{a+} - V_{k-}
12	LED current	12.81 mA 12.11 mA	mA	calculated as $(V_{+5}$ - $V_{a+})$/R10 and measured with an ammeter

Table 3.2. LED measurements (assuming the 220 Ω resistor is labeled R10).

Part e - Debug Hardware + Software

Debug your combined hardware and software system.

Demonstration

(both partners must be present, and demonstration grades for partners may be different)

You will show the TA your program operation on the actual TM4C123 board. The TA may look at your data and expect you to understand how the data was collected and how the switch and LEDs work. Also be prepared to explain how your software works and to discuss other ways the problem could have been solved. Why the 7406 was used to interface the LED? I.e., why did we not connect the LED directly to the TM4C123. Why do you think you need the capacitor for 7406 chip? Why was the delay increased from 1 to 62 ms? How would you modify the software to change the rate at which LED flickers? What operating point (voltage, current) exists when the LED is on? Sketch the approximate current versus voltage curve of the LED. Explain how you use the resistor value to select the operating point. What is the difference between a positive logic and negative logic interface for the switch or the LED? We may test to see if you can measure voltage, current and/or resistance with your meter (so bring your meter to the demonstration).