

1.4.1: Dusk-to-Dawn Light

Overview:

In this lab, we will create our first circuit which appears to “do” something which is readily perceivable without instrumentation. The circuit operates as a “dusk-to-dawn” light; the circuit turns a light on when the ambient light level goes below a certain level.

Before beginning this lab, you should be able to:

- State Ohm’s law from memory
- Use Ohm’s law to perform voltage and current calculations for resistive circuit elements
- Use a digital multimeter to measure resistance, current, and voltage (Labs 1.1, 1.2.1)
- Use transistors as dependent sources (Lab 1.2.2)
- Use color codes on resistors to determine the resistor’s nominal resistance
- State KVL and KCL from memory

After completing this lab, you should be able to:

- Use a bipolar junction transistor (BJT) as a dependent source
- Use a photoresistor to measure ambient light levels
- Use an LED as a light source
- Integrate a number of components into an overall system

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit
- Digital multimeter (optional)

Symbol Key:

	Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.
	Analysis; include principle results of analysis in laboratory report.
	Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.
	Record data in your lab notebook.

General Discussion:

In this part of the lab assignment, we will create a light-sensitive lighting system. A photocell – a light-sensitive resistor – will be used to sense the ambient light level. A Bipolar Junction Transistor (BJT) will be used as a switch to turn on a light-emitting diode when the ambient light level becomes low. The circuit we will use is shown in Figure 1.

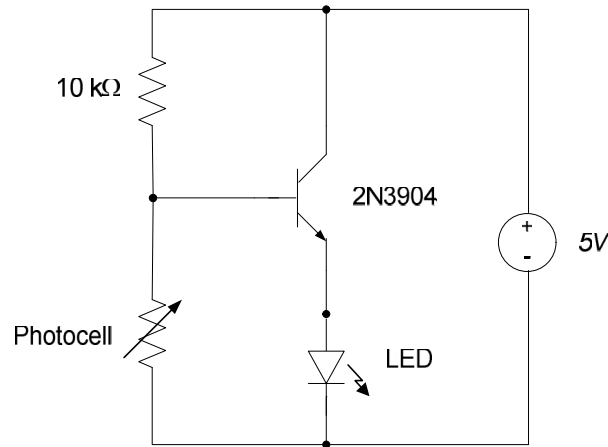


Figure 1. Dusk-to-dawn lighting circuit.

There are several unfamiliar components in the circuit of Figure 1: a photocell, an LED, and a BJT. A detailed understanding of the operation of these components is beyond the scope of this lab, but a brief overview of their operating characteristics is provided below. Later courses in a typical electrical engineering curriculum will provide background information necessary to fully understand these components.

Diodes and LEDs:

Diodes are two-terminal semiconductor devices that conduct current in only one direction. The terminals of a diode are called the *anode* and the *cathode*; diodes are intended to conduct current from the anode to the cathode. Diodes have a minimum *threshold voltage* (or V_{th} , usually around 0.7V) that must be present between the anode and cathode in order for current to flow. If the anode voltage is not at least V_{th} greater than the cathode voltage, no current will flow. Likewise, if the cathode voltage is greater than the anode voltage, the diode is said to be *reverse-biased* and no current will flow. In an ideal diode, if the diode voltage equals the threshold voltage (plus a small amount), then unlimited current can flow without causing the voltage across the diode to increase. And, if the diode is reverse-biased, no current will flow regardless of reverse-voltage magnitude.

As with diodes, LED's are two-terminal semiconductor devices that conduct current in only one direction (from the anode to the cathode). The small LED chips are secured inside a plastic housing, and they emit light at a given frequency when a small electric current (typically 10mA to 25mA) flows through them. When the voltage difference across the LED exceeds the threshold voltage of the LED, current flows through the LED and light is emitted. If the LED voltage is less than the threshold voltage, no current flows and no light is emitted. LEDs are available in a number of colors; the Digilent analog parts kit contains red, yellow, and green LEDs.

Since LEDs are *polarized* devices, they must be placed in the circuit with the correct orientation; the anode must be at higher voltage potential than the cathode in order for the diode to emit light. An LED schematic symbol is shown in Figure 2 below, together with a sketch of a physical LED. The anode and cathode on a physical LED can be identified because the anode pin is longer than the cathode pin and the cathode side of the plastic diffusion lens is typically slightly flattened.

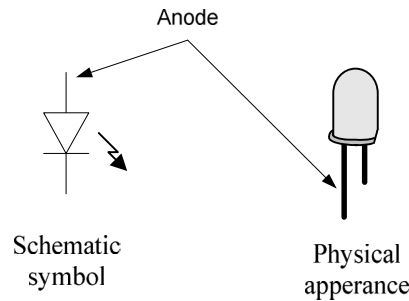


Figure 2. LED schematic symbol and physical appearance.

Bipolar Junction Transistors (BJTs):

In Lab 1.2.1, we used a MOSFET as a voltage controlled current source. Bipolar Junction Transistors, BJTs, are also conveniently modeled as dependent sources. Like MOSFETs, BJTs are three-terminal devices; the terminals of a BJT are called the base (B), the collector (C), and the emitter (E). The symbol commonly used to represent the type of BJT we will be using is shown in Figure 3(a). Our circuit employs a 2N3904 BJT; the physical appearance of this BJT is shown in Figure 3(b), along with the relative locations of the base, collector, and emitter for that BJT.



Figure 3. BJT symbol and physical appearance of 2N3904 BJT.

An extremely simplified discussion of a BJT's operation is as follows: application of voltage to the base of the BJT allows current to flow from the collector to the emitter of the BJT. Typically the current flowing into the base of the BJT is much smaller than the collector and emitter currents. Thus, the BJT can be conceptualized as a current controlled current source. Thus, if a power supply is connected to the collector of the BJT, the base voltage of the BJT can be used to control BJT's emitter current: increasing the base voltage typically increases the emitter current. In the case of two relatively discrete values of base voltage, the BJT can act as a

switch; low base voltages turn off the switch (the emitter current is zero) while high base voltages turn the switch on (the emitter current is non-zero).

Photocell:

Photocells (sometimes called *photoresistors* or *photoconductors*) are devices whose resistance changes according to the light intensity applied to the sensor. The photocells in the Digilent analog parts kits have resistances which vary from about $5\text{K}\Omega$ at relatively high light levels to about $20\text{K}\Omega$ at relatively low light levels. A variable resistor is commonly indicated on a circuit schematic by a resistor symbol with an arrow through it, as shown in Figure 4.

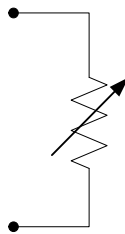


Figure 4. Variable resistor circuit symbol.

Pre-lab:

ANALYSIS

Apply KVL around the outer loop of the circuit of Figure 1 (as shown in Figure 5) to determine the voltage V_B for photocell resistances of $5\text{K}\Omega$ and $20\text{K}\Omega$. You may assume that the current into the base of the BJT is negligible.

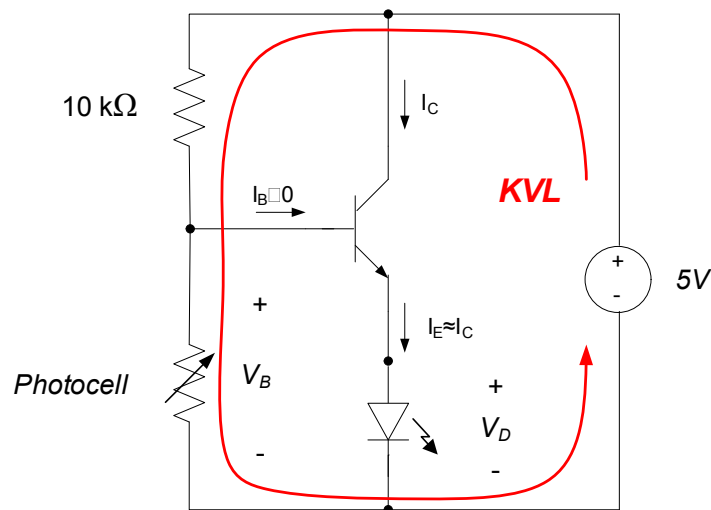


Figure 5. Circuit analysis to determine BJT base voltage.

Lab Procedures:

1. Construct the circuit shown in Figure 1. The LED should not light under normal light levels. Using the scope instrument on your Analog Discovery (or a DMM), measure the base voltage of the BJT (V_B in Figure 5) and the voltage difference across the diode (V_D in Figure 5). Record these voltages in your lab notebook and compare them with your calculated values from the prelab.
2. Cover the photocell; the LED should light up. Using the scope instrument on your Analog Discovery (or a DMM), measure the base voltage of the BJT (V_B in Figure 5) and the voltage difference across the diode (V_D in Figure 5). Record these voltages in your lab notebook and compare them with your calculated values from the prelab.
3. *Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.*

DATA

DATA

DEMO