Lab 5 Part B – LED Night Light Design and Prototyping

GOAL

The overall goal of Lab 5 is to demonstrate a battery powered LED night light. LED brightness is controlled using a phototransistor and PWM.

OBJECTIVES

Lab5a: (1) Design the triangle wave generator, photosensor, and comparator.
(2) Simulate your design in Multisim.

Lab5b: (1) Build a prototype on a breadboard.
(3) Test your prototype to validate your design.

Lab5c: (1) Build a soldered version.
(2) Demonstrate and hand in a working system.

GENERAL GUIDELINES

1) Each student builds his/her own circuits.
2) Test stations (e.g. oscilloscope, computer) must be shared.
3) You are allowed (even encouraged) to help each other. Of course, Professor Hedrick will be around to provide assistance as well.
4) **Use neat wiring for your circuits! Starting in Lab 2, a messy circuit will cost you 1 pt (out of 10 for the demo).**
5) Keep your circuit components organized to make it easier to do the subsequent labs!
6) Each student must turn in his/her own lab report. See the course website for the template.

Honor Code Compliance: **You must turn in your own work**! Blatant duplication of circuit analysis, design, simulations, and/or lab reports will result in ZERO points and possible reporting to the Honor Council.

NOTE: There will be one lab exam near the end of the term. The lab exam will test each student's ability to use Multisim and prototype a circuit.

PARTS AND MATERIALS

- Power supply, scope, scope probes, banana cables
- Lab kit containing breadboard, wires, wire stripper, and other tools
- LM358 op amp (one)
- LM311 comparator (one)
- SFH3310 Phototransistor (one)
- C503B-WAN white LED (one)
- Resistors: You choose! (a whole bunch)
- Capacitors: You choose! (one)

0.1 uF for power supply bypass (optional)

- AA batteries (three)
- AA 3-pack battery holder (one)

INTRODUCTION

The overall goal of Lab 5 (two weeks) is to build a battery-powered LED night light. The LED brightness depends on the ambient light level. You get to keep the soldered version of your circuit (includes battery pack)! The overall specifications are the following:

1) $+V_{CC}$ = 4.5 V (three AA batteries) and $-V_{EE}$ = 0 V
2) Lamp is a single white LED
3) Automatic dimmer: A light sensor (phototransistor) measures the ambient light level. High ambient light will cause the LED to turn off. Low ambient light will cause the LED to become bright.
4) LED dimming is performed with PWM, where the PWM signal is implemented with a triangle wave generator and comparator.

Some other circuit features are the following:

1) Use a LM358 chip, which contains TWO op amps (suitable for single-supply operation).
2) Use a LM311 voltage comparator (suitable for single-supply operation with output current up to 50 mA).
3) The phototransistor is the SFH3310, which is good for detecting visible wavelengths.
4) The white LED is the C503B-WAN made by Cree.
5) The peak current of the LED should be $I_{LED} \approx 20$ mA (can be slightly higher or lower).
6) You can directly drive the LED with the LM311 comparator – this keeps the parts count low (nice!).

PART 1: TRIANGLE WAVE GENERATOR PROTOTYPE

This is where you validate your triangle wave generator design.

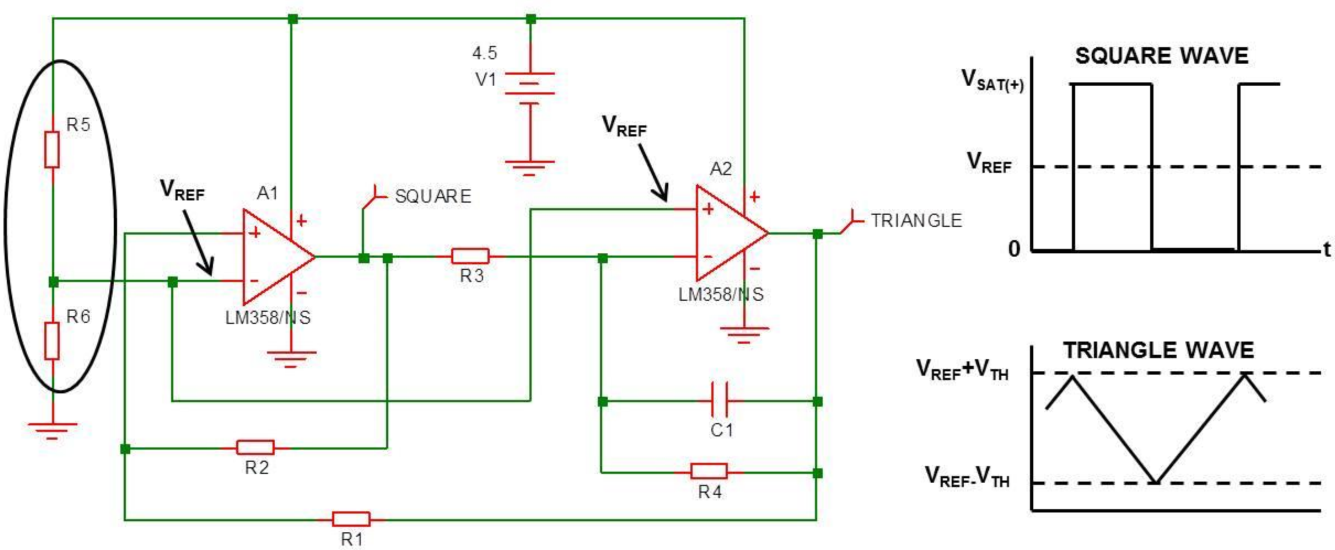

Fig. 1: Triangle wave generator.

- Circuit construction
  - Your breadboard circuit will be your template for soldering, so think carefully about where you place components and how they are wired!
  - Be NEAT!
  - Try to minimize the number of criss-crossing wires (OK to have a few).

- Circuit testing
  - Configure the benchtop power supply to provide +4.5V and GND for your circuit.
  - Use the scope to measure the triangle wave output and Schmitt trigger output.
  - Record a snapshot of the triangle wave output and Schmitt trigger output.
  - Measure the max, min, and peak-to-peak amplitude of the triangle wave.
  - Measure the triangle wave frequency.
  - Measure the max, min, and peak-to-peak amplitude of the Schmitt trigger output.
  - Does your circuit satisfy the design requirements (hopefully, yes)?

PART 2: PWM DESIGN

You've completed the hard part of the system prototyping! The remaining part is the photosensor and PWM-based LED driver.

- Photosensor Design
  - The phototransistor is basically a light sensitive transistor.
  - There are only two pins (emitter and collector).
  - There is no base, because the "input" is the incoming light.
  - Configure the phototransistor as a common-emitter (see Fig. 2).
  - When there is NO light, V_C = 4.5V.
  - When there is lots of light, V_C should saturate at $V_{CE,SAT}$ (see datasheet page 3).
  - Choosing the appropriate R_C is a little tricky, since it depends on the light response of the phototransistor and the ambient light level.
  - Let's assume that "bright light" corresponds to an irradiance of 10 $\mu W/cm^2$.
  - Use the largest value for the photocurrent I_{PD} (page 1 of datasheet).
  - What value of R_C (choose 5% value) is needed to saturate the phototransistor?

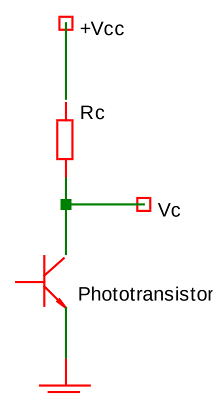

Fig. 2: Phototransistor in common-emitter configuration.

- PWM-based LED Driver design
  - Use the LM311 comparator to directly drive the LED (see Fig. 3).
  - Assume the output of the LM311 (with pull up resistor) can swing between 0 and +4.5V.
  - Think about which input is connected to the triangle wave.
  - Think about which input is connected to the photosensor output.

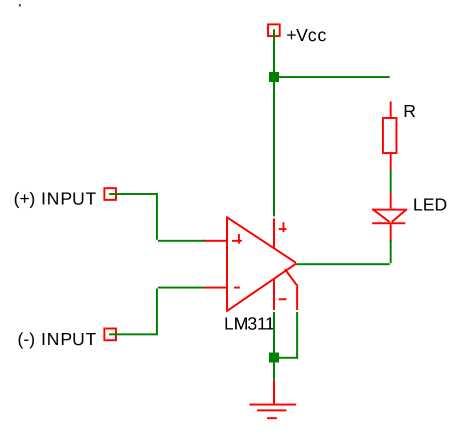

Fig. 3: PWM driver using LM311 comparator.

- What value of R (choose 5% value) is needed to drive the LED with 20 mA (or slightly more)? The LED forward voltage is on the datasheet.

PART 4: PWM PROTOTYPE

- Circuit construction
  - Build your photosensor and PWM-based LED driver.
  - The longer pin is the emitter of the phototransistor (see datasheet).
  - The LM311 requires Pin 1 and 4 grounded, while Pin 8 is $+V_{CC}$ (see datasheet).
  - Think carefully about component placement!

- Circuit testing
  - Use the scope to measure V_C of the photosensor with (1) the room lights on (2) hand covering the phototransistor.
  - If V_C does not swing from 0.1V to over 3V, then reduce R_C with a lower value (about 5x lower).
  - Repeat until you get reasonable performance.
  - Write down the values of V_C with (1) bright ambient light (2) dark ambient light.
  - Use the scope to record snapshots of the PWM output of the comparator with (1) bright ambient light (2) dark ambient light.
  - The LED brightness should change as you move your hand across the phototransistor.

➢ **Demo the scope trace of the PWM output to Professor Hedrick .**

(End of Lab 5 Part b)