PreLab 5: Design Project

• GOAL

This is a team project involving two or three students. The main requirement is that the project involves pulse width modulation (PWM). Choose one of the following topics (see next page for more details):

This is a three-week lab:

- Lab 5a: Circuit design (calculations and simulation), start building/testing individual circuits.
- Lab 5b: Finish individual circuit testing, start soldering
- Lab 5c: Finish soldering, final demo
- NOTE: You may need to work outside of normal lab hours to complete what you need to do. Having said that, Buma can provide assistance since he is actually on campus this time (as opposed to being away at a conference … sorry about that! ☹).

• PRELAB OBJECTIVES

1) Choose your team and determine who will work on what circuit(s)
2) Each student must turn in the following for their individual circuit:
   a) List of circuit requirements (e.g. input signal voltages, triangle wave amplitude, frequency, load current)
   b) Hand-drawn "generic" circuit schematic without component values (these will be calculated during lab).

• GENERAL GUIDELINES

1) **Team**:
   - You must work on a team (two or three students). Close interactions within a team are obviously important, but interactions between teams are also encouraged! Help each other out, bounce ideas off each other, provide moral support, etc. As a team, you should decide how to divide up the "circuit sections". Each student is responsible for building/testing/soldering their circuit.
2) **Lab Notebook**:
   - Each student should keep a lab notebook to keep track of Google searches, jot down ideas, observations, calculations, questions, etc. The lab notebook doesn't have to be an actual notebook (i.e. a folder is fine).
3) **Demo**:
   - The entire system should be modular, where the individual circuits can be easily connected or disconnected (e.g. using headers).
   - Each student must demo his/her own circuit.
   - Each team must demo their complete system.

• DESIGN CONSTRAINTS

Any project has constraints! In particular, the available components (datasheets on course website) are shown below:

- ICs:
  - Single Supply op amps: LM358 (bipolar), TL972 (rail-to-rail output CMOS)
  - Timer: LMC555 (rail-to-rail output CMOS)
  - Sockets: 8-pin DIP (for soldering into perf board)
- Transistors:
  - Npn: 2N3904, 2N4401, TIP31, TIP120 (Darlington)
  - Pnp: 2N3906, 2N4403, TIP32, TIP121 (Darlington)
  - N-channel: 2N7000, BS170, IRF520
  - P-channel: ZVP3310, ZVP2106, IRF9520
- Comparators:
  - LM311 (single), LM393 (dual)
- Potentiometers:
  - Single turn: 1K, 10K, and 100K
  - 25-turn: 1K, 10K, and 100K
- Resistors:
  - Standard 5% values (1/4W rating)
- Capacitors:
  - Ceramic: 10pF, 100pF, 1nF, 10nF, 100nF
  - Electrolytic: 1uF, 4.7uF, 10uF, 47uF, 100uF, 330uF, 470uF
- 3.2” x 2.5” Perf board (for soldering)

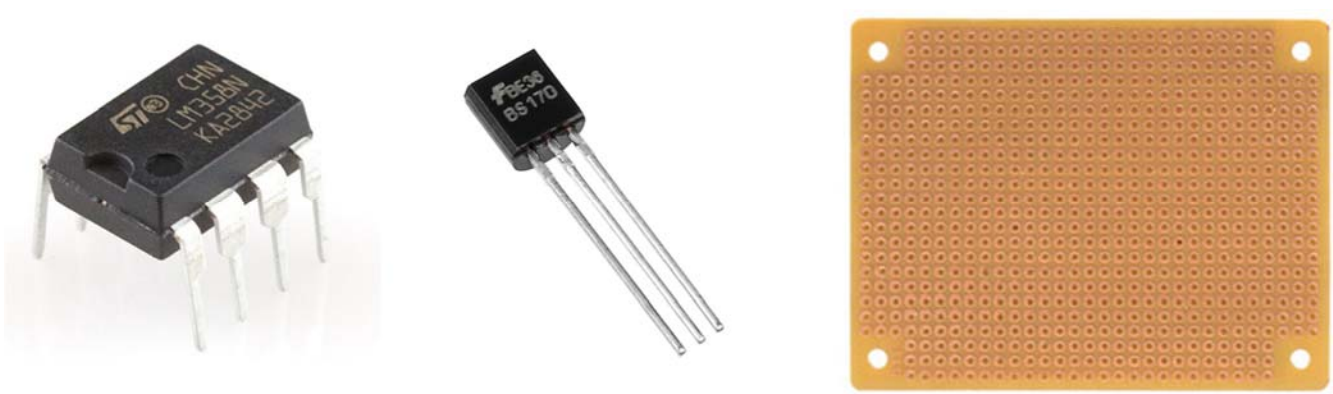

Fig. 1: Keep in mind the available components in your circuit designs! Each circuit “module” must fit in the perf board (right figure).

• PROJECT TOPICS

1) <u>Two-Axis Servo Motor Driver</u>

- Goal: Manual control of a two-axis servo motor system.
  - The user turns two knobs, one for each servo motor.
  - The servo position (e.g. +/- 90 deg) should be proportional to the control knob's range of motion. Turning the knob completely clockwise or counter-clockwise should cause the shaft to turn +90 or -90 deg, respectively.
  - You will test your system on a pan-tilt mount (e.g. for a small web cam) similar to that shown in Fig. 1.
- Design considerations:
  - Servo motor: The pan-tilt mount uses two "sub-micro size" servo motors. Check the datasheet (see course website) to confirm that a +5V DC supply will work!
  - PWM parameters: Consult the many servo tutorials on the web to get an idea of the required frequency and duty cycles.
  - Triangle wave generator: Choose an op amp (Schmitt trigger + integrator) or 555-based design. The peak-to-peak triangle wave amplitude should be somewhere between $V_{CC}/3$ to $V_{CC}/2$.
  - Control: Potentiometers are an obvious choice here. What is not obvious is that you may want to add a resistor above and below the potentiometer to match the range of motion between the potentiometer and servos. Remember that the triangle wave peak-to-peak amplitude is somewhere between $V_{CC}/3$ and $V_{CC}/2$!
  - Comparators: Remember that comparators have open-collector outputs, so they need pull-up resistors (see Lecture 11 notes)! As always, smaller resistors produce faster response but dissipate more power.
  - Remember that the system should be modular. This allows each student's circuit to be individually tested and yet easily connected to other circuits to form the overall system.

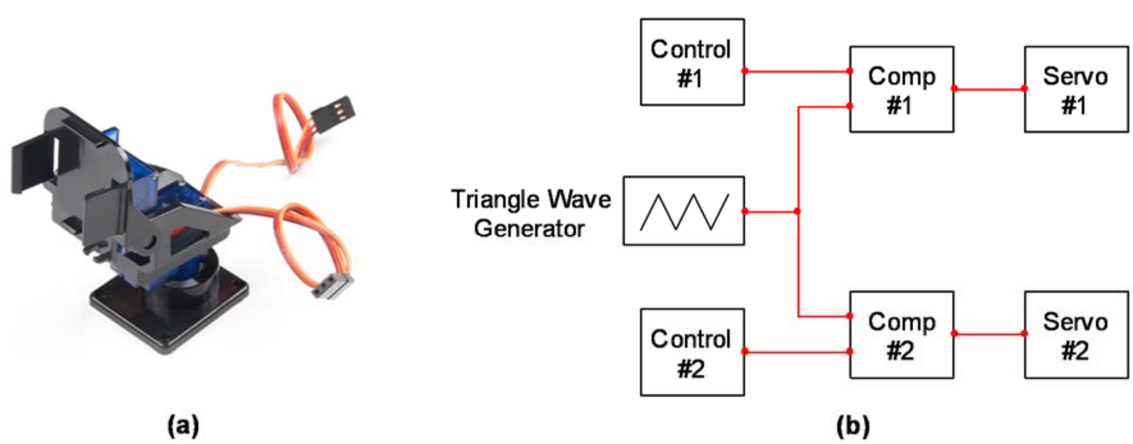

Fig. 2: (a) Typical pan-tilt mount using two servo motors. (b) A possible block diagram of the system. It is up to the team members to determine who is responsible for which blocks!

2) Red Green Blue (RGB) LED Driver with Dimming Control

- Goal: Manual control of each color in a tri-color LED.
  - The user turns three knobs, one for each color.
  - The color brightness should be proportional to the control knob's range of motion. Turning the knob completely clockwise or counter-clockwise should cause the LED color to be fully on or off, respectively.
- Design considerations:
  - RGB LED: An RGB LED is basically three LEDs in a single package, but there are only four leads (see Fig. 3a) rather than six. Check the datasheet (see course website) to determine the wiring details and typical operating current and voltages!
  - PWM frequency: Consult the many servo tutorials on the web to get an idea of the required PWM frequency for LED illumination applications.
  - Triangle wave generator: Choose an op amp (Schmitt trigger + integrator) or 555-based design. The peak-to-peak triangle wave amplitude should be somewhere between $V_{CC}/3$ to $V_{CC}/2$.
  - Control: Potentiometers are an obvious choice here. What is not obvious is that you may want to add a resistor above and below the potentiometer to match the range of motion between the potentiometer and LED brightness. Remember that the triangle wave peak-to-peak amplitude is somewhere between $V_{CC}/3$ and $V_{CC}/2$!
  - Comparators: Remember that comparators have open-collector outputs, so they need pull-up resistors (see Lecture 11 notes)!
  - Remember that the system should be modular. This allows each student's circuit to be individually tested and yet easily connected to other circuits to form the overall system.

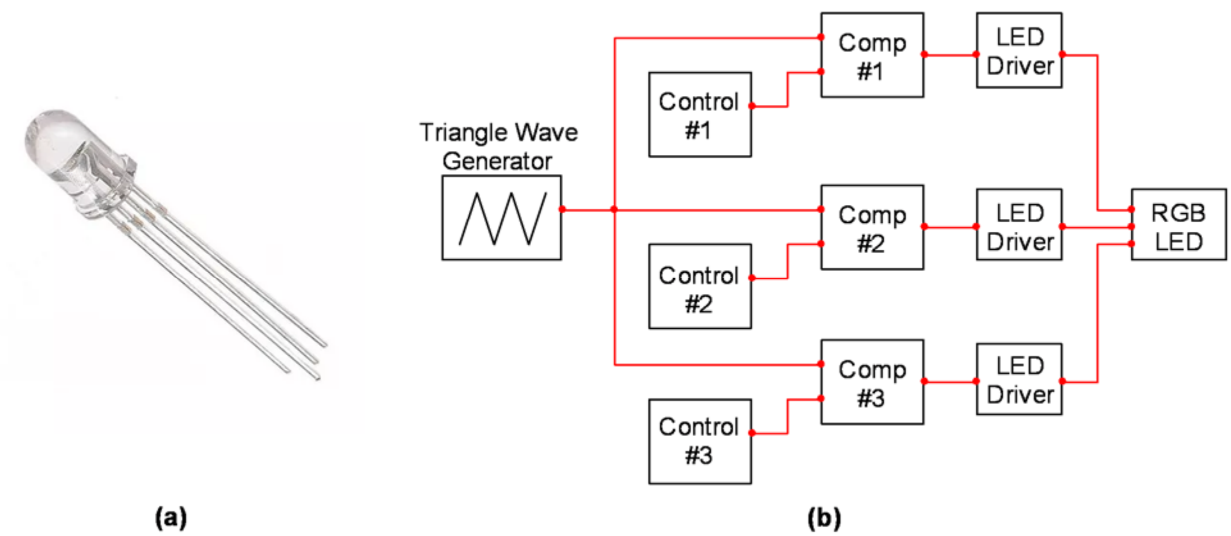

Fig. 3: (a) Typical tri-color LED. (b) A possible block diagram of the system. It is up to the team members to determine who is responsible for which blocks!

3) <u>Power LED Driver with Dimming Control</u>

- Goal: Manual control of the brightness of a power LED.
  - The user turns a knob to control brightness.
  - The LED brightness should be proportional to the control knob's range of motion. Turning the knob completely clockwise or counter-clockwise should cause the LED to be fully on or off, respectively.
- Design considerations:
  - <u>Power LED</u>: The power LED is already mounted on a heat sink since it dissipates a lot of power. Check the datasheet (see course website) to determine the typical operating current and voltage!
  - <u>PWM frequency</u>: Consult the many servo tutorials on the web to get an idea of the required PWM frequency for LED illumination applications.
  - <u>Triangle wave generator</u>: Choose an op amp (Schmitt trigger + integrator) or 555-based design. The peak-to-peak triangle wave amplitude should be somewhere between $V_{CC}/3$ to $V_{CC}/2$.
  - <u>Control</u>: A potentiometer is the obvious choice here. What is not obvious is that you may want to add a resistor above and below the potentiometer to match the range of motion between the potentiometer and LED brightness. Remember the triangle wave peak-to-peak amplitude is between $V_{CC}/3$ and $V_{CC}/2$!
  - <u>Comparators</u>: Remember that a comparator has an open-collector outputs, so they need pull-up resistors (see Lecture 11 notes)!
  - <u>Transistor switch</u>: Keep in mind that you only have a +5V supply. If one MOSFET doesn't have enough current rating, you can easily put multiple MOSFETs in parallel (see Fig. 4c)! Multiple BJTs in parallel are a different story – better to avoid this since variations in V_{BE} make it tricky to do properly.
  - Remember that the system should be modular. This allows each student's circuit to be individually tested and yet easily connected to other circuits to form the overall system.

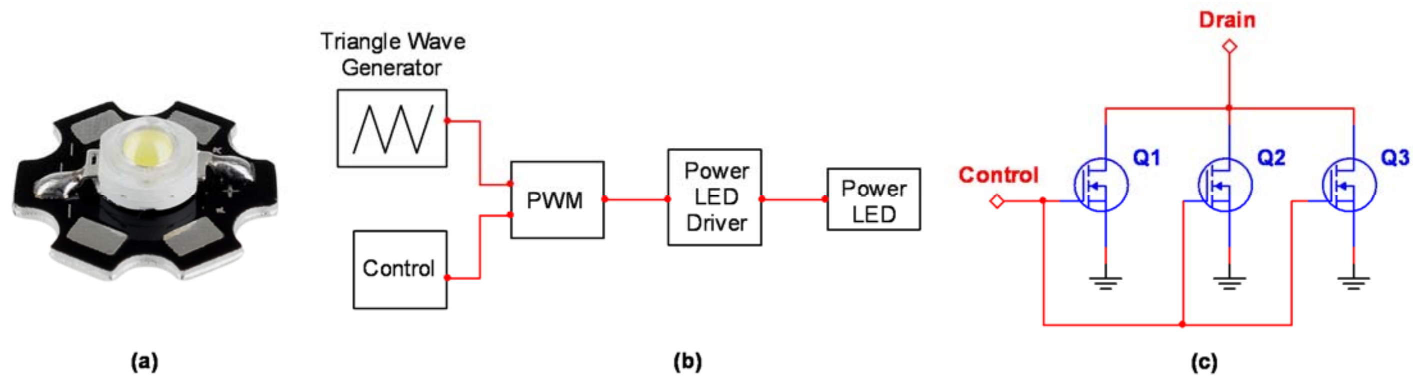

Fig. 4: (a) High power LED in a "star" surface mount device (SMD) package. (b) A possible block diagram of the system. It is up to the team members to determine who is responsible for which blocks! (c) You can easily use multiple MOSFETs in parallel to drive large currents. Nice!

➢ **<u>PreLab Tasks</u>**: 1) List of circuit requirements (e.g. input signal voltages, triangle wave amplitude, frequency, output load current)

2) Hand-drawn "generic" circuit schematic without component values (these will be calculated during lab).

(End of PreLab 5)