Name:____________________ UIN: | | | | | | | | | | Section AB/BB: [ ]

Experiment 7: PWM Motor Wheel Balance

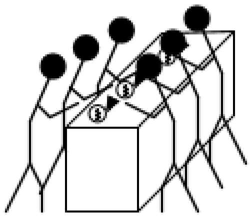
Laboratory Outline:

In the prelab, you constructed a square wave signal with an adjustable duty cycle typically called a Pulse-Width-Modulated (PWM) signal. In an earlier lab, you used different resistances to attempt to balance the speed of your two wheels. While this method was effective, it also had a very low power efficiency ($\eta = \frac{P_{useful}}{P_{input}}$) and was prone to motor stalls if attempting to significantly reduce the speed.

Today, we will implement a method of wheel balance that utilized the MOSFET-based motor drives for high efficiency and PWM control for high-motor torque and lower risk of motor stalling. A single potentiometer allows for a simple method of adjustment to make the car run a straight path.

Notes:

Breakout Session #1



Collaborate.

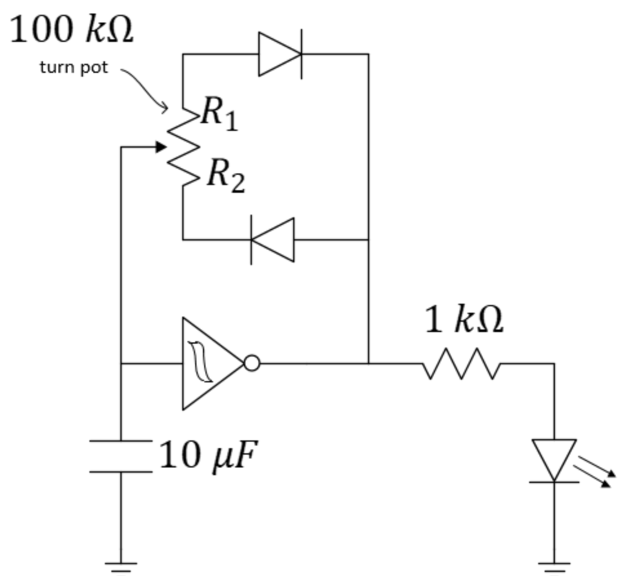


***Figure 1**: Circuit schematic of an oscillator with a selectable duty cycle.*

Notes:

Modeling…Input High

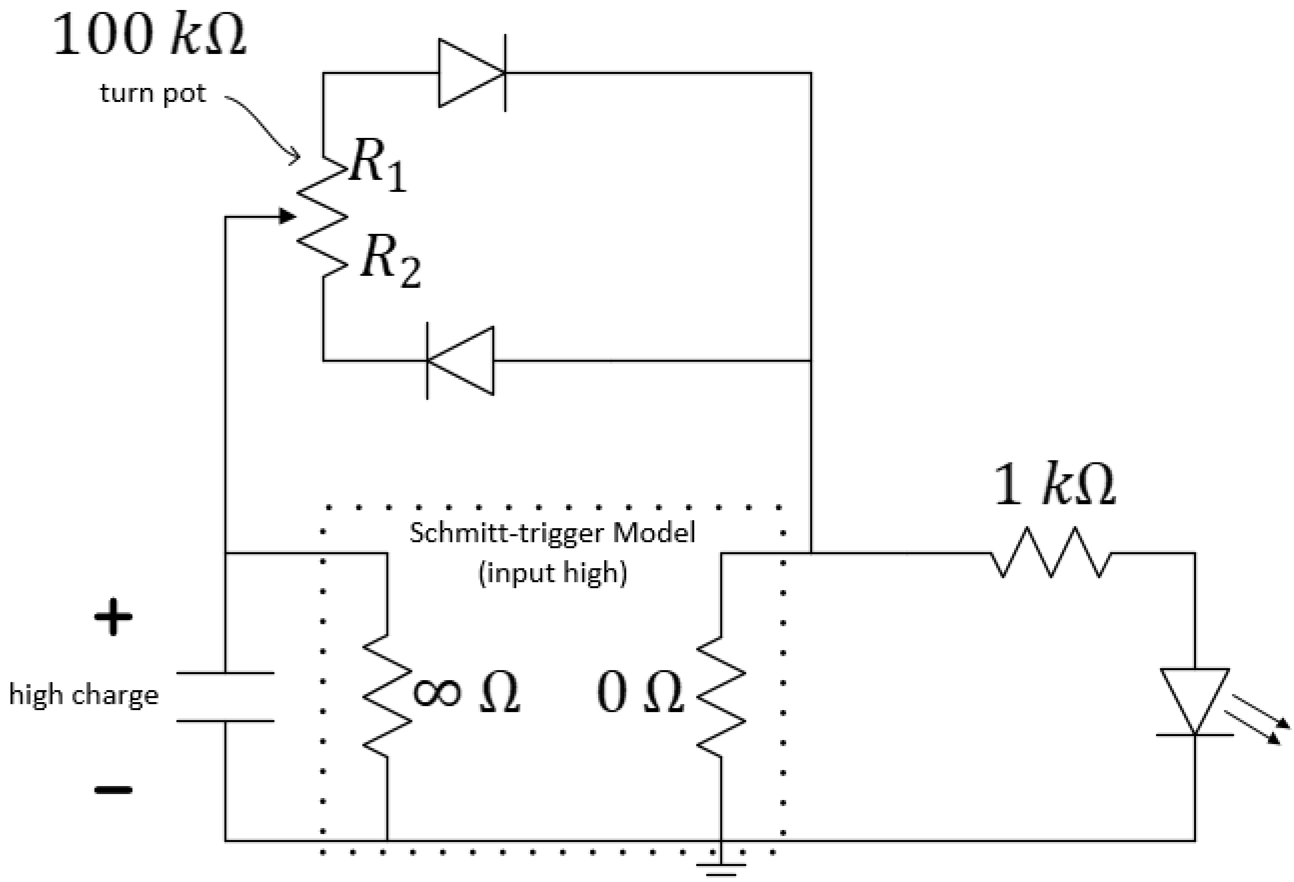


***Figure 2**: Oscillator with Schmitt-trigger modeled for “input high” (output LED is off).*

Question 1: On Figure 2, mark the “loop” through which the capacitor discharges. Label that loop “L1”.

Notes:

Modeling…Input Low

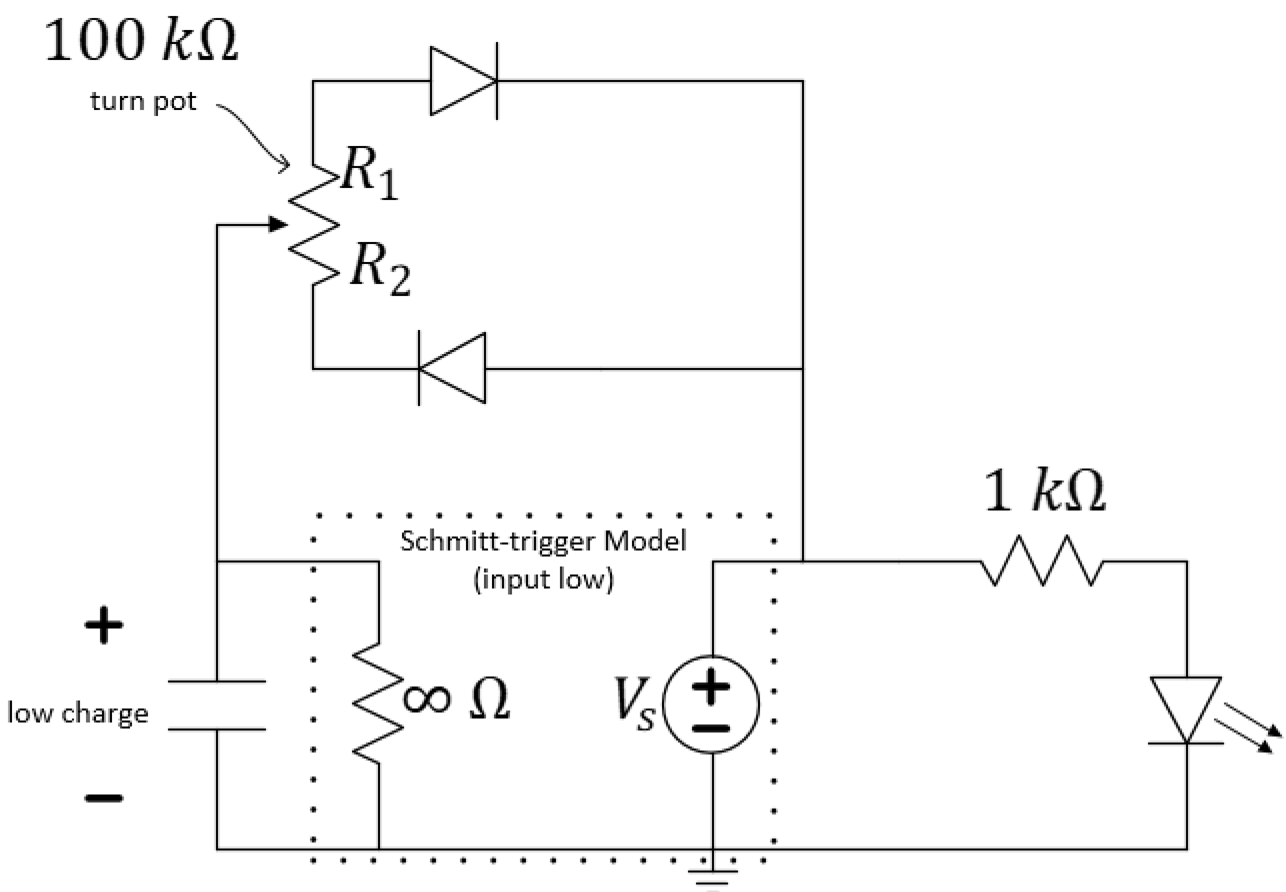
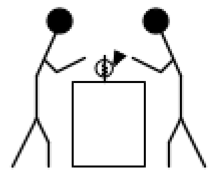


***Figure 3**: Oscillator with Schmitt-trigger modeled for "input low" (output LED is on).*

Question 2: On Figure 3, mark the "loop" through which the capacitor charges. Label that loop "L2".

Notes:

At Your Bench



Build the motor-control circuit below that includes an adjustable wheel-speed balance potentiometer. You should see the familiar motor-drive circuits as well as the recently-constructed oscillator. You may be surprised to see three Schmitt-trigger inverters in this design. The first Schmitt-trigger is used in the PWM oscillator design. The second Schmitt trigger buffers the oscillator circuit from the MOSFET of one motor-drive circuit so that that circuit does not cause a significant load on the oscillator that might affect its behavior. The third Schmitt-trigger inverter inverts the previous signal such that the duty cycle of the second wheel is mirrored of that of the first motor. That is, while the first wheel is driven by duty cycles that can be adjusted from 0 to 100%, the second wheel is driven by duty cycles that vary from 100% to 0%, respectively. The two duty cycles will always follow $\%dc_1 + \%dc_2 = 100$.

Notes:

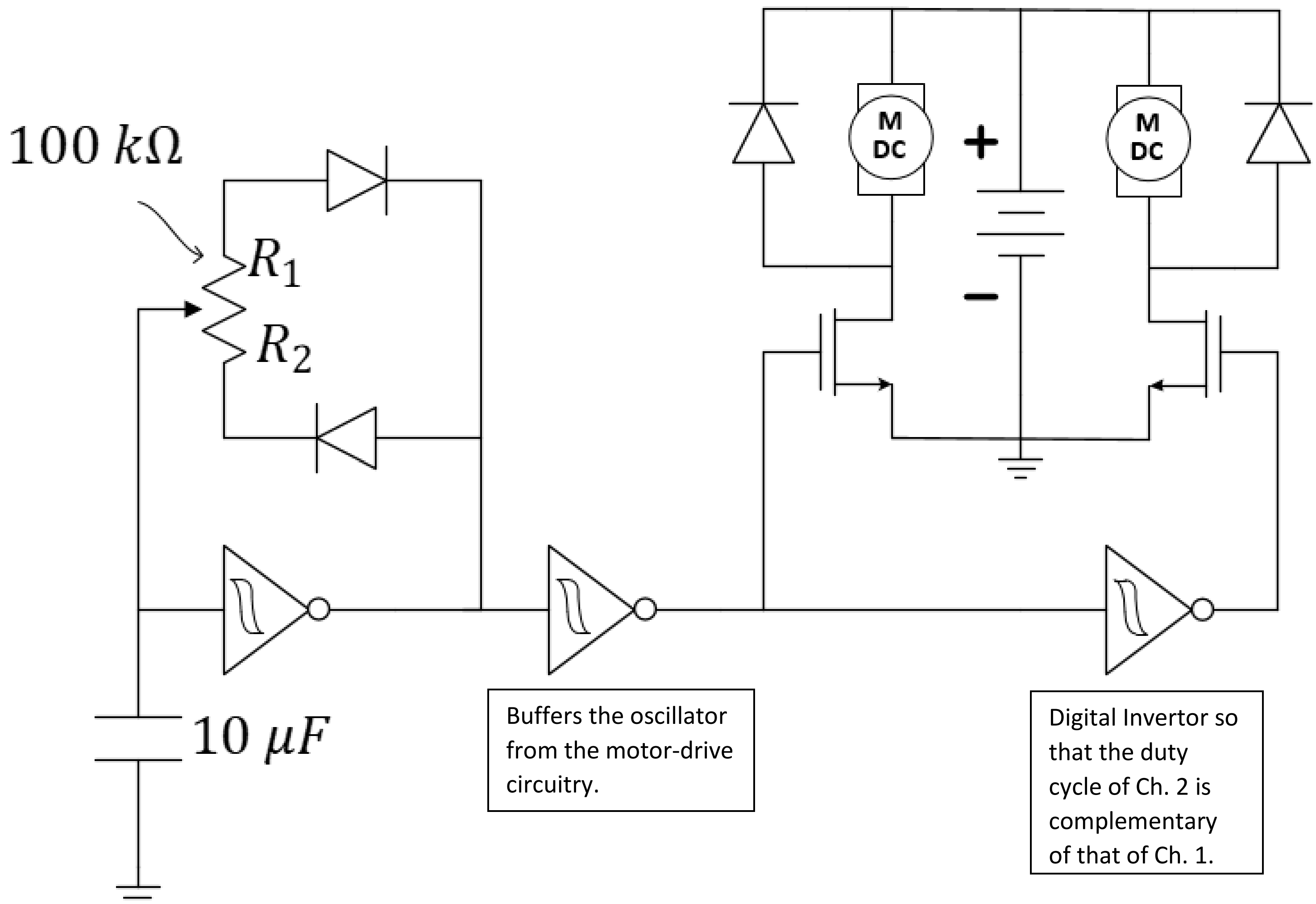


Figure 4: *PWM-based wheel balancer. Warning: The $10\ \mu F$ capacitor is polarized! Be sure to insert the negative lead into the ground rail.*

Disconnect the motors from the positive side of the battery to disable them for now. Place the probes of **channels 1 and 2** between the circuit ground and the two outputs of the inverters (MOSFET gates) as shown in the figure below. After pressing the **Default Setup** button on the scope, adjust the scopes **vertical, trigger, and horizontal settings**, respectively, to get a nice view of the two *orthogonal* waveforms. **Use your 100 $k\Omega$ potentiometer to adjust the duty cycle so that Channel 1 is at 40% and Channel 2 at 60%.** Use the **measure button** to do this accurately.

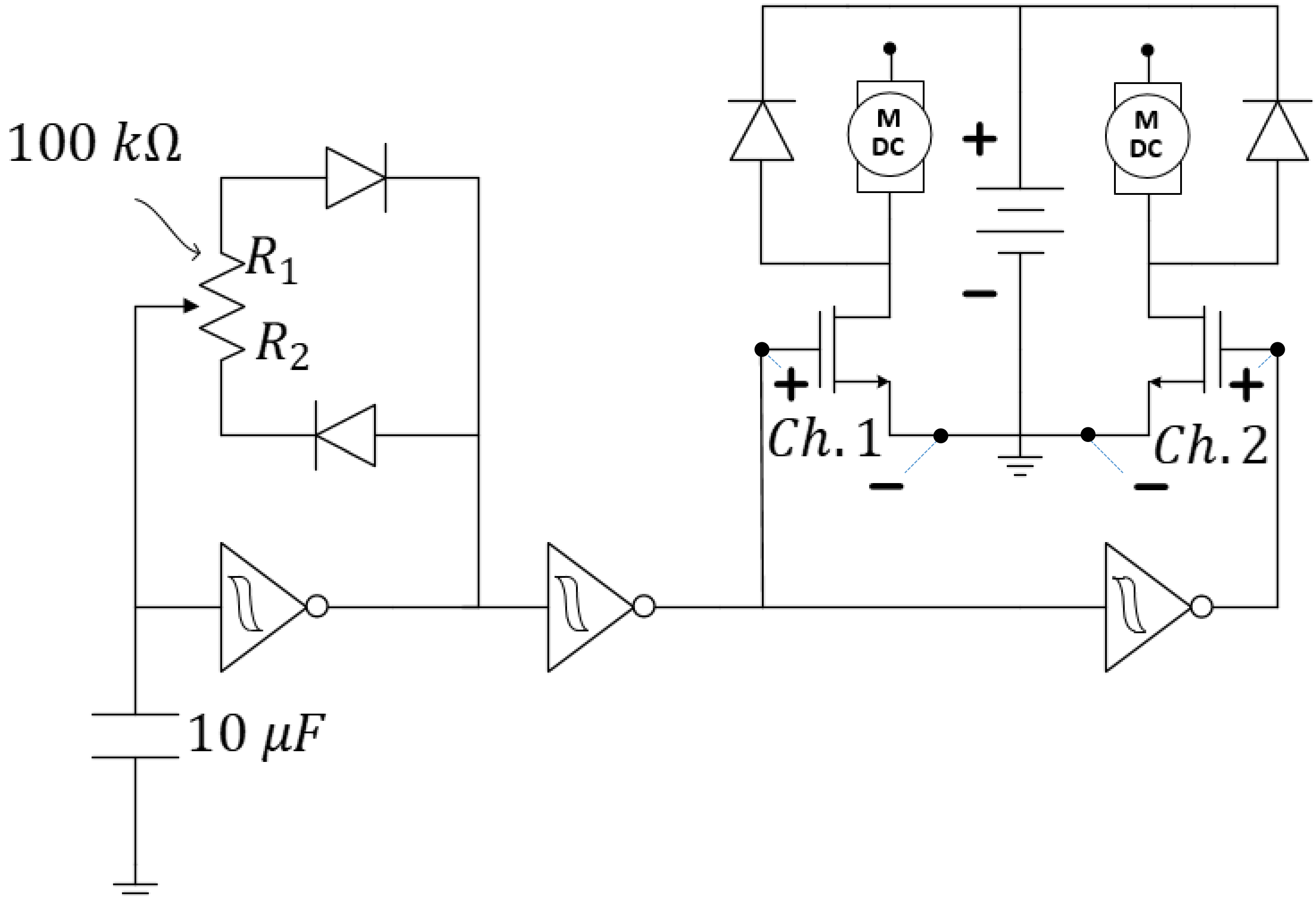


Figure 5: *Disable the motors and use the oscilloscope to view and record the orthogonal outputs of the oscillator.*

Notes:

The term **orthogonal** is derived from the Greek orthogonios ("ortho" meaning right and "gon" meaning angled).

Orthogonal concepts have origins in advanced mathematics, particularly linear algebra, Euclidean geometry and spherical trigonometry.

What is orthogonal? - Definition from WhatIs.com

Notes:

Question 3: Use software to collect these waveforms. You will print them and include them with this lab report.

Save this circuit! Store this motor-drive circuit for next week with your car chassis in the locker and take your kit (and its breadboard) home for Prelab#8.

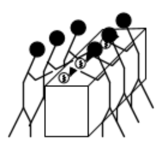
Mini-Project Modules

Mini-Project Modules provide students with options to investigate new concepts! As time allows, do one or more of the modules before returning to the laboratory's core procedure.

This week, we highly recommend the following ***Mini-Project modules:***

***Mini-Project* 8B The Clipping Circuit**	***Mini-Project* Schmitt Trigger IV**	***Mini-Project* Voltage-Follower Buffer**

Breakout Session #2


Collaborate.

When called back to the breakout, work in teams of 8 to brainstorm on final project ideas! See below.

Notes:

Learning Objectives

- Use the running-motor model you determined prior, estimate the RMS current drawn by the motor at a known RMS voltage.
- Adjust your PWM signal to different duty cycles, make observations on the oscilloscope, save your data.

You are now ready to build a self-navigating vehicle. In the process, you have learned to model devices, predict behavior, build circuits, analyze circuit behavior, measure circuit parameters, and troubleshoot using the oscilloscope as a window into your work.

Breakout: Final Project Ideas!

The final project will soon be upon us! Now is a great time to start brainstorming with your fellow classmates about ideas. Think about your interests…do you like music? Make a music synthesizer. Do you enjoy solving everyday problems? Build a calibrated coffee warmer. Do you like robotics? Build a robotic dog that responds to a call.

Acceptable projects should characterize a sensor and utilize that sensor to control a non-trivial circuit to accomplish a task.

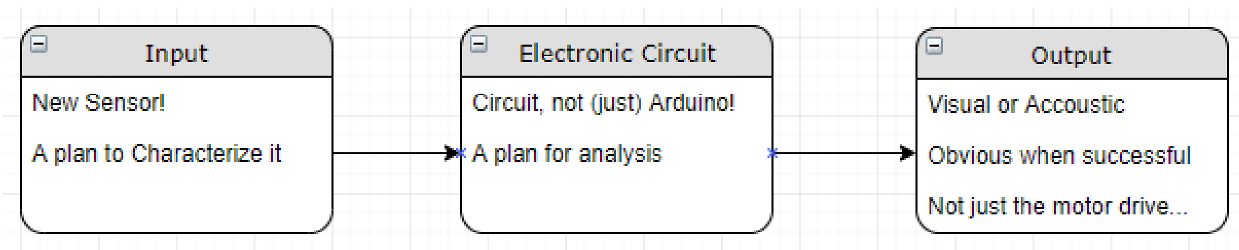


Figure 1: A generic block diagram depicting an acceptable final project.

Examples

1. **Not Acceptable**: A line follower sensor's output controls a motor-drive circuit. **Problem**: Biasing the sensor is trivial and the motor-drive circuit is straight out of the core lab procedure.

Notes:

2. **Acceptable**: A line follower sensor's output controls a motor-drive circuit, but utilizes a button to back up (via an H-Bridge) and turn left when encountering a wall. **Comment**: Acceptable because it utilizes multiple components in a more-complex manner.
3. **Not Acceptable**: The Ultrasonic sensor is characterized by the distance computed by an Arduino library as a book is placed in front of it. Arduino controls the motor-drive circuits. **Problem**: The output of the echo pin is a PWM signal that changes duty cycle based on distance. The students can learn more about ECE110 topics by characterizing the PWM signal directly. Also, there is no interesting circuit in this design. It merely contains a single sensor, the motor-drive circuit(s) from class, and Arduino carries the design.
4. **Acceptable**: A toy-model elevator is controlled by a motor-drive circuit that stops at each floor thanks to the feedback from a mounted Hall-effect sensor. **Comment**: Great! It is creative, uses a sensor from the kit, and requires circuitry that might not be too challenging to build but falls outside of the core procedures.

Below is a list of the sensors, actuators, and circuit elements available in your ECE 110 kit or *sometimes* available from your TA, along with some brief descriptions and potential applications. If you want a device we can't locate, you may be on your own to do the purchase…good reason to plan ahead! Also, look through the modules as well for great project ideas!

<u>Sensors and Inputs</u>

- Snap-action lever switches
  - Limit switches to detect when an object has reached a stopping point
  - Limit switch to detect a person is properly seated or that a safety device is properly located before operating a potentially-hazardous tool
- Pushbuttons
- Ultrasonic sensors
  - Measuring distance between the sensor and a solid object
- Photocell
  - Light sensor
- Infrared Emitter/Detector
  - Detect an object as it crosses the "beam"
  - Good for small distances (1 or 2 cm)
- Electret microphone
  - Low-output microphone; may require an amplifier to get a usable output signal
  - Clap-detector
  - Acoustic projects

Notes:

- Thermistor
  - Temperature sensor
- Piezo vibration sensor
  - Pick up “table knocks”, general vibrations, or even sound
- Flex sensor
  - Provides a variable change in resistance rather than just on/off like the snap action switch
  - Often used in glove-based controllers to sense bending of fingers
- Reed switch
  - Detects a nearby magnetic field
  - Often used to know if a door is open/closed
  - Might be used as a clever theft control device to disable a starter when magnet is absent
- Hall effect sensor
  - Also detects the presence of a magnetic field. Often used to detect the position of a rotating table, wheel, or other device.

<u>Actuators and Outputs</u>

- Servo Motor (PWM driven)
- H-Bridge-based Motor Drive
  - Often used to drive the car motors forward and backwards
  - Can reverse polarity/current through other devices
- LEDs
  - Used as indicators
  - Could be used in an array or cube configuration
    - Acceptable project output if used in one of these more complicated setups
- Speaker
- Hobby motor (DC)

<u>Circuit elements</u>

- Inverter
  - Used for logic devices, digital buffering, driving a loudspeaker (digital/PWM)
  - Oscillators
- Zener Diode (5.1 V)

Notes:

- Voltage regulator (change battery voltage to 5.1 V)
- Signal conditioning/clipping

- Op-Amp
  - Used in voltage buffer circuits
  - Used in amplifiers
  - Used in equalizer
- Comparator
  - Comparison of two signal levels
  - Used to transform one oscillator waveform into another
  - Used in Analog-to-Digital Converters
  - Used as an event trigger (say, cause a delayed action to occur when a large capacitor finally charges to a preset voltage from a voltage divider)
- Transistors
  - NPN BJT and MOSFET
  - Oscillation, control, amplification

Question 4: Discuss final project ideas and write some of the ideas here.