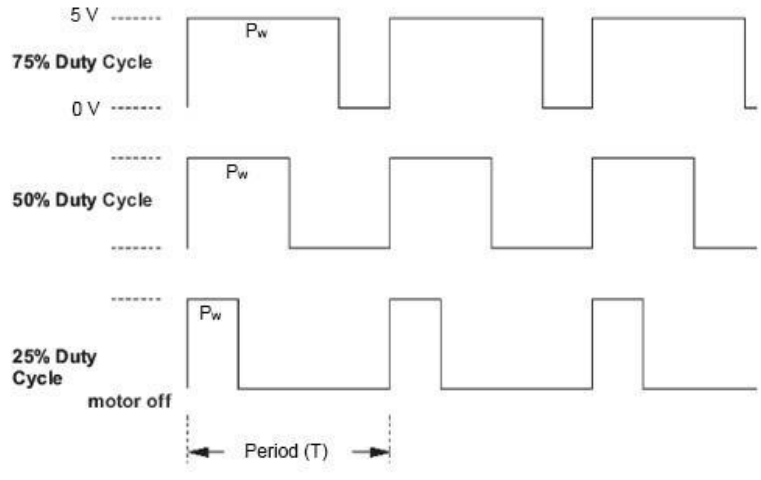
Lab 7 Benchtop Pulse Width Modulation (PWM)

ENGR 1204: Electrical and Computer Engineering Module

Basic Electrical Theory

- Basic Electrical Definitions and Relationships
- Voltage or Volts – "Pressure", Potential Energy
    - Analogy: Voltage in electrical circuits is like pressure in a water pipe. The higher the voltage (pressure), the higher the current through the wire (pipe).
    - Symbol: V (1 mV = 0.001 V; 1 μV = 0.000001 V)
        - m for "milli" = 10^{-3}
        - μ for "micro" = 10^{-6}
    - Unit: V
- Current – "Flow", Kinetic Energy
    - Analogy: Current in electrical circuits is like the rate of flow of water in a pipe.
    - Symbol: I
    - Units: A for Amperes or "Amps" (1 mA = 0.001 A; 1 μA = 0.000001 A)
- Resistance – "Push Back", hinders flow
    - Analogy: Resistance in electrical circuits is like having gravel or sand in a water pipe that is slowing down the flow rate.
    - Symbol: R
    - Unit: Ω or Ohms (1 kΩ = 1000 Ω)
        - k for kilo = 10^{3}
- Microcontroller units (MCU) are small computers on a chip that run software. MCU chips are often placed on small circuit boards for development of a design, such as on the Arduino Uno (the blue circuit board on the robot). Pins on the MCU (and thus on the Arduino board) can output digital values (0 or 1) as determined by the software program.
    - False = Low = 0 = 0.0 Volts
    - True = High = 1 = 5.0 Volts



- Period is T (in seconds, S)
- Frequency is f (Hz), period/s): f = 1/T
- Pulse Width is P_W, which is how long signal is high (5 V), (in seconds)
- Duty Cycle is D: D = (P_W/T) * 100%, expressed as percent.

Pulse Width Modulation (PWM) is a way to have digital circuits control an actuator, such as a servo motor.

Pre-Lab Work

Start a Lab Report in a MSWord Document (one per person). Use the cover sheet template provided on Brightspace. Name your file according to the following format:

- ELE_lastname_firstname_sectionNumber_Lab1Report.docx
- So if your name is Joe Smith, and you are in section 30, the name of your file is:
- ELE_Smith_Joe_30_Lab1Report.docx.

- Put your name, team member names, class, and the date on the cover sheet. The Lab number is 1, and the Lab Name is Pulse Width Modulation. It is NOT the name of the room.

- Calculate (show equations and numbers and answer for each in your report)
  - The motor needs a Period of 20 ms. What is the frequency?
  - If the PW is 1.3 ms, what is the Duty Cycle?
  - If the PW is 1.7 ms, what is the Duty Cycle?

The motor in the robot is a Servo motor of type Continuous Rotation. The above frequency, amplitude and duty cycles will control the motor.

Make and fill in this table from your calculations. The servo motor is only to be given signals at this frequency and within the range of duty cycle.

	Frequency (Hz)	**Period (ms)**
	50 Hertz	20 ms
	Duty Cycle (%)	**Pulse Width (ms)**
Minimum Allowed Value	6.5%	1.3 ms
Allowed Value	7.5%	1.5 ms
Maximum Allowed Value	8.5%	1.7 ms

Lab Procedures

Materials

- Servo motor (1);
- BNC-to-alligator clip leads (2);
- Banana-to-alligator clip leads (1 pair).

Setup and Observe Square Waveform of PWM

- Setup the benchtop instruments as follows.
- Use two BNC cables to connect Waveform Generator (Output) to Oscilloscope (Channel 1). Clip the same color alligator clips together. Turn on both instruments.
- Setup the Waveform Generator
    - Push the Channel button
        - Set Output → On
        - Set Output Load → High Z
    - Waveforms → Square
    - Frequency → to your calculated frequency in Hz
    - Amplitude → 5 Vpp (Volts peak-to-peak)
    - Offset → 2.5 V
        - Duty Cycle (between max and min of your table).
- Setup Oscilloscope,
    - Hit the Auto-Scale button. Ensure correct square shape waveform.
        - 0 V is lowest voltage of square wave
        - 5 V is highest voltage of square wave
        - Duty cycle ranges so PW is between 1.3 ms and 1.7 ms.
- Setup Oscilloscope to make Measurements:
    - Hit "Meas" (measure button). Set up Oscilloscope to measure Amplitude, Period, Duty Cycle, and +Width (for PW).
    - Practice changing the Duty Cycle (to those within your range) and ensure Duty Cycle on Oscilloscope changes.
- In <u>report draw and label the key parameters (units of X, Y axes, T, PW, etc.) for one example of a waveform</u>. You may take pictures of the oscilloscope display to put in your report, but still need to add these arrows and labels to them. Label the following (arrows, parameter symbol, number value with unit). Example of well-labeled waveform is at the bottom of this document.
    - Amplitude, V, in volts (V)
    - period, T, in seconds
    - pulse width, PW, in ms (Note: PW is +Width on oscilloscope)
    - calculation for duty cycle (no arrows since derived calculation, just write on plot somewhere)

Control and Rotate the Motor

- Now try to control the Motor. ***Make sure the power supply output is off.*** Wire up the motor as described:
    - Set up the bench power supply for 6.0 V. Then press the button to turn off the output (but not the power supply).

    - Use the long black line on motor to connect all Grounds (Black wires):
        - Oscilloscope Black
        - Waveform Generator Black
        - Power Supply Output 1 Black
        - Motor Black
    - Connect the PWM square wave signal:
        - Oscilloscope Red
        - Waveform Generator Red
        - Motor White or Yellow
    - Connect "6V" Power Plugs on Power Supply as follows
        - Power Supply Red to Motor Red

- Check the setup with the Instructor or lab technician **before** applying power!
- Turn on the Power Supply (Output On). Adjust the Duty cycle between the ranges that were calculated.

- Fill in the printed chart you made during the Pre-Lab work with this information (put this table in your report). The range is between what you calculated for Duty Cycle % for PW of 1.3 ms to 1.7 ms

Motor Behavior	**Duty Cycle (%)**	**PW (ms)**
Max Clockwise Rotation	6.5%	1.3 ms
Slow Clockwise Rotation	7.4%	1.480 ms
Stopped (no rotation)	7.5%	1.5 ms
Slow Counterclockwise Rotation	7.6%	1.520 ms
Max Counterclockwise Rotation	8.5%	1.7 ms

Demo function of the motor to the instructor.

Submit the Report (*(each person turns in their own report)*)

Save your report as a PDF file from MSWord.
Report should include

- Cover Sheet
- Title section at top (name, lab, class, date)
- Introduction
    - Short summary of what you did, procedure, and results
- Procedure and Result
    - Present your calculations, waveform diagram, and table
    - Clearly explain your method and discuss results
    - Picture of your project, and table to explain your work (if any)
- Conclusion
    - Short summary of your report. Did you achieve your goal? Discuss problems that you faced and what you did to solve it?
- Submit Report to Brightspace for Lab 7.

Example of well-labeled waveforms: