Lab 1 – Feasibility Model Phase 1

ECE 298 – S2021

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# Part 1 – Project Design Requirements

1. **Functional Requirements**
   1. Requirement
   2. …
2. **Non-functional Requirements**
   1. Requirement
   2. …
3. **Constraint Requirements**
   1. Requirement
   2. …

# Part 2 – Project Considerations for I/O

## **Project Sensors and User Inputs**

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## Project Actuators and User Outputs

**Motor**

An actuator required for the project is a DC motor that will control the speed of rotation of the wheelchair’s wheels.

**Motor Connection**

Due to the high-current draw of a brushless DC motor, the motor will be connected to the MCU via a transistor whose gate voltage is connected to the analog OUTPUT pin on the MCU, and whose source voltage is provided by the power supply. The MCU will control how much current flows through the transistor to adjust the speed of rotation of the motor.

**Battery-Level Sensor**

A circuit will be connected to the external battery to measure its voltage level over time.

**Batter-Level Sensor Connection**

The circuit that will sense the battery level, whose maximum possible value is assumed to be 20 V, will be connected to the ADC peripheral device of the MCU. The voltage of the battery will be sent through a buffer, which will then be connected to a voltage divider whose output range (for an input range of 0-20 V) is 0-3.3 V, the maximum voltage of the ADC.

## Project MCU Internal Resources

{Details}

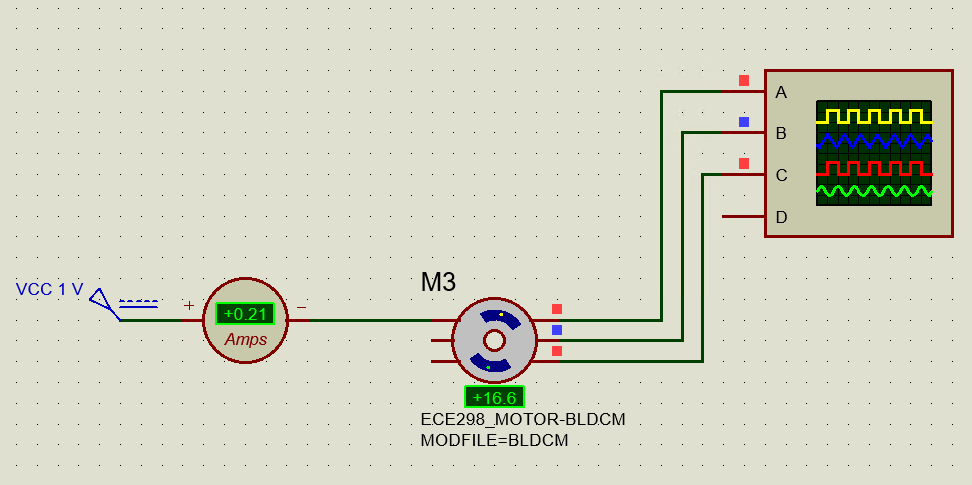
# Part 3 – Device Testing Methodology

## Device 1 – ECE298-MOTOR-BLDCM

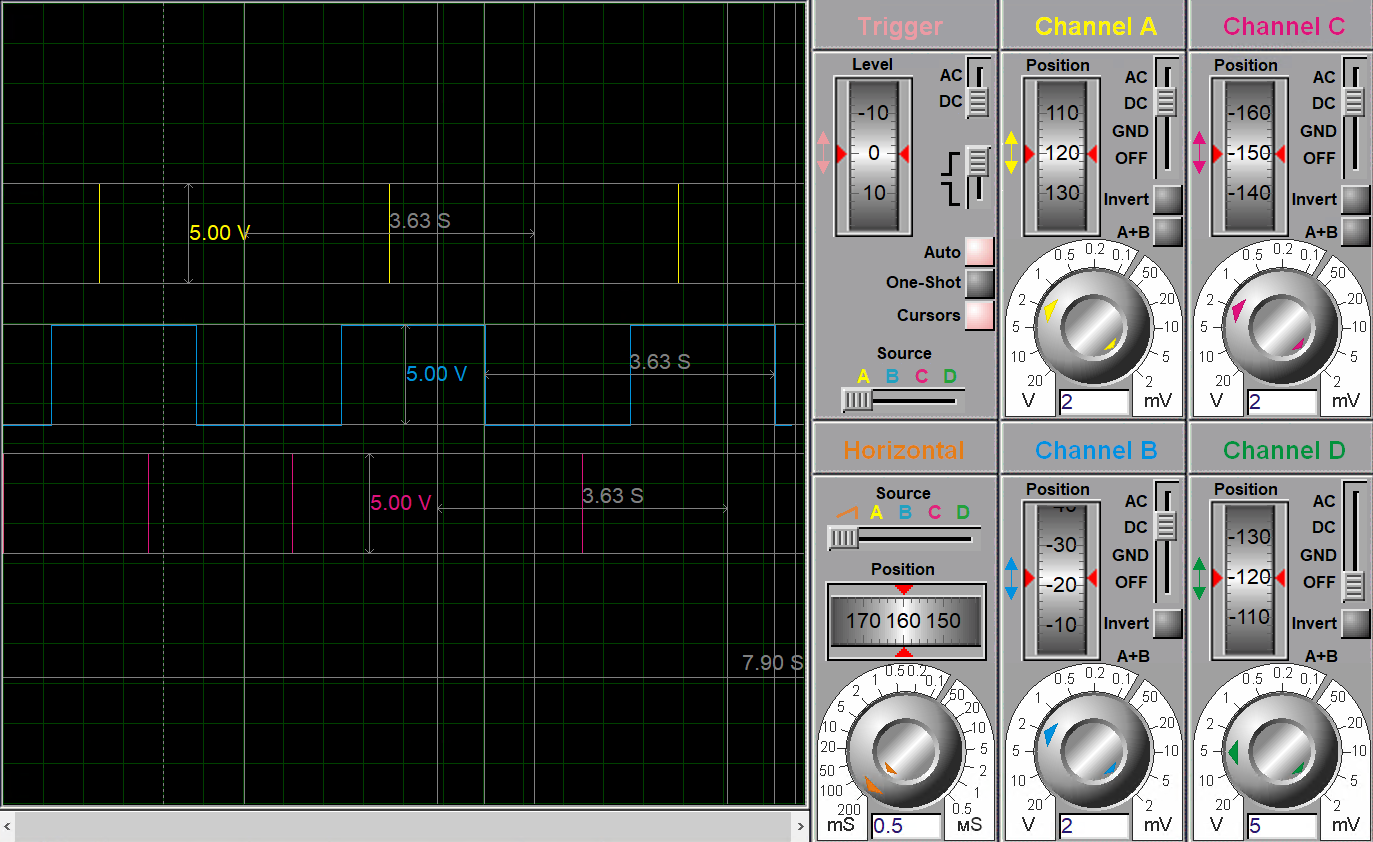
The ECE298-MOTO-BLDCM is the brushless DC motor that will be used to control the speed of revolution of the wheels on the wheelchair. This motor’s rotation speed is controlled by a DC voltage, and the voltage/current that the motor draws from a power source is proportional to the rotation speed of the motor.

To control the device, a voltage source will be connected to the P1A pin only (explained below). This voltage source will be an analogue output pin from the MCU (check if this is allowed!!).

The schematic used to test the DC brushless motor is below:

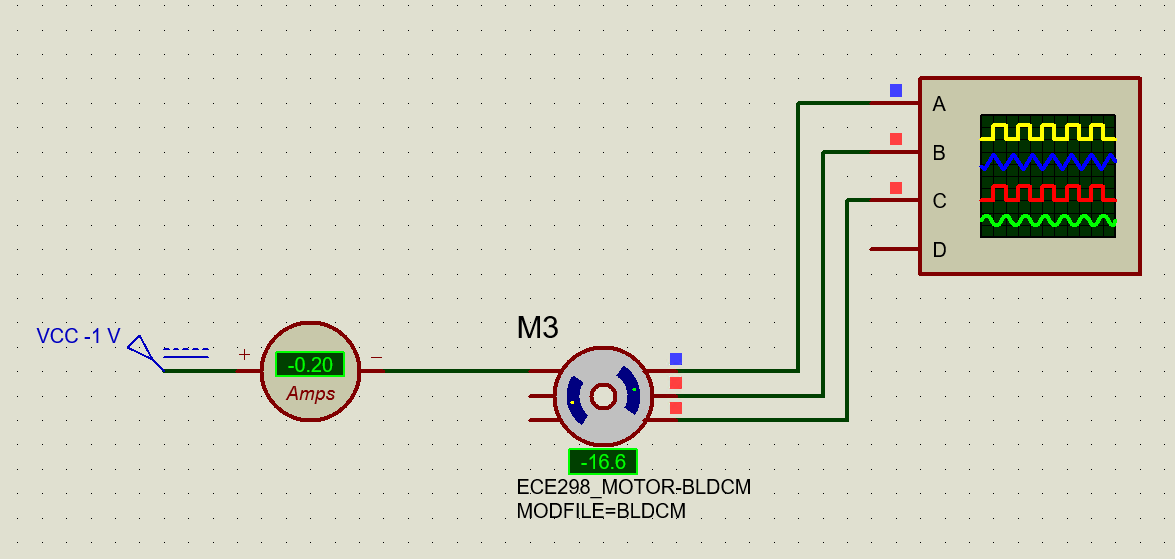


The DC motor’s P1A pin is connected to a voltage source of 1 V, drawing an average current of around 200 mA. The output B[1..3] pins are connected to an oscilloscope to monitor the output of the motor. It is seen that the rotation speed (in RPM) of the motor is directly proportional to the voltage supplied, where, at 1 V, the motor’s rotation speed is 16.66 RPM. The current drawn is similarly proportional to the rotation speed, drawing 200 mA/16.66 RPM = 12 mA/RPM. Below is an oscilloscope capture of the output of the B[1..3] pins for the same schematic:

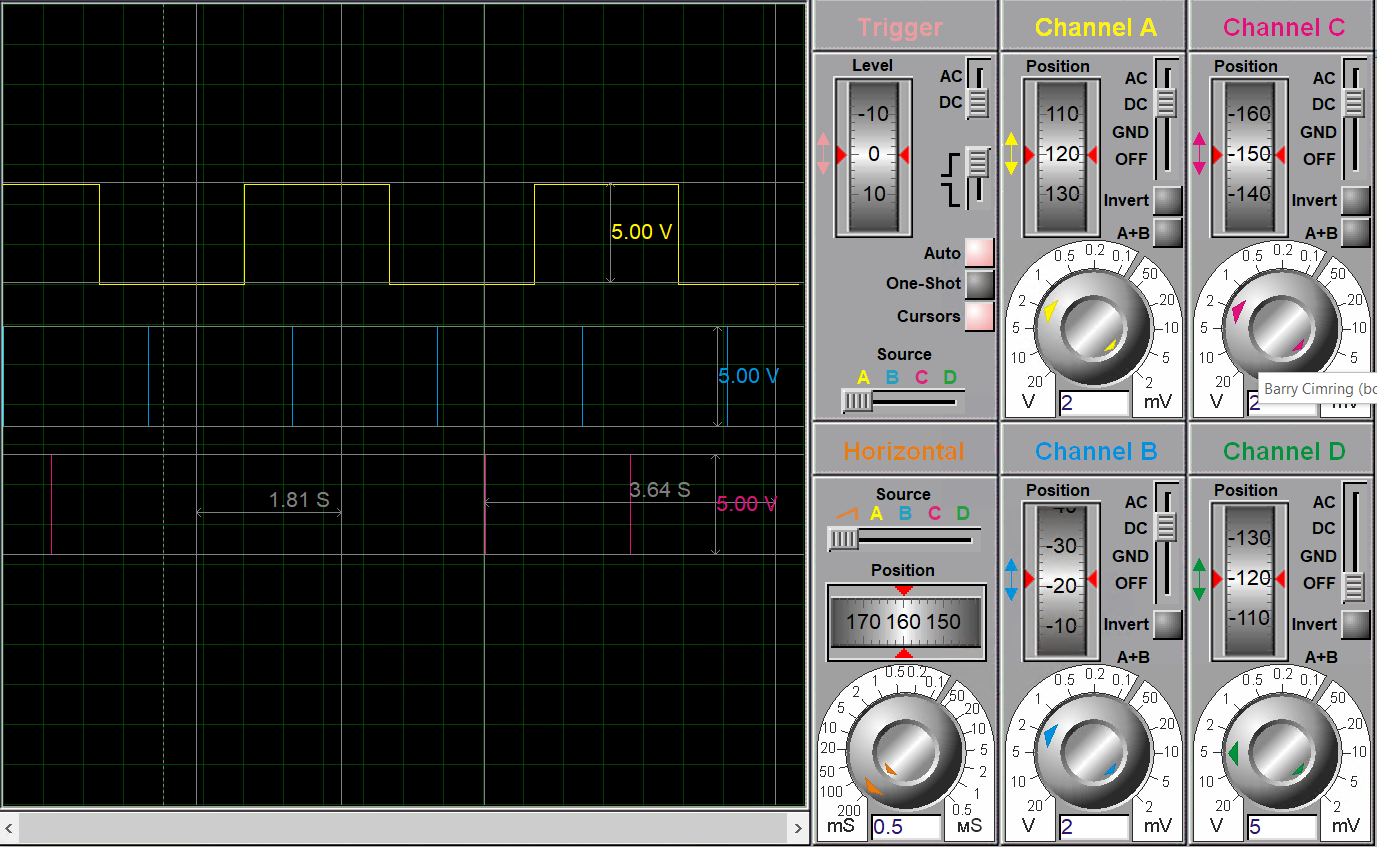


It is shown that to identify a forward rotation, the rising edge of B1 is when B2 is low. It is shown the output of the motor is a square wave from 0-5 V with a period of 3.63 s at 1 V input. This period is inversely proportional to the rotation speed. The duty cycle of the square wave is 50%.

We see that, in the same way, the motor will rotate in the opposite direction with the same magnitude of RPM if a negative voltage is applied:

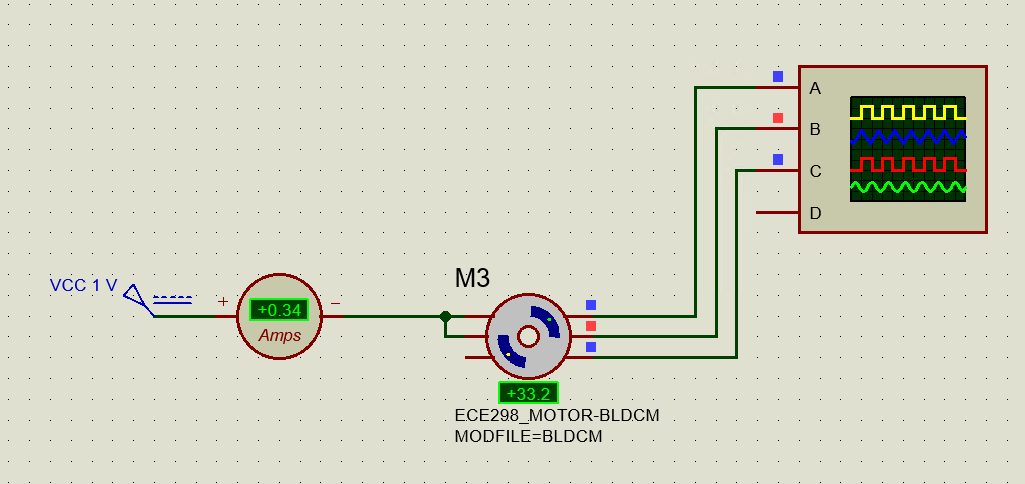
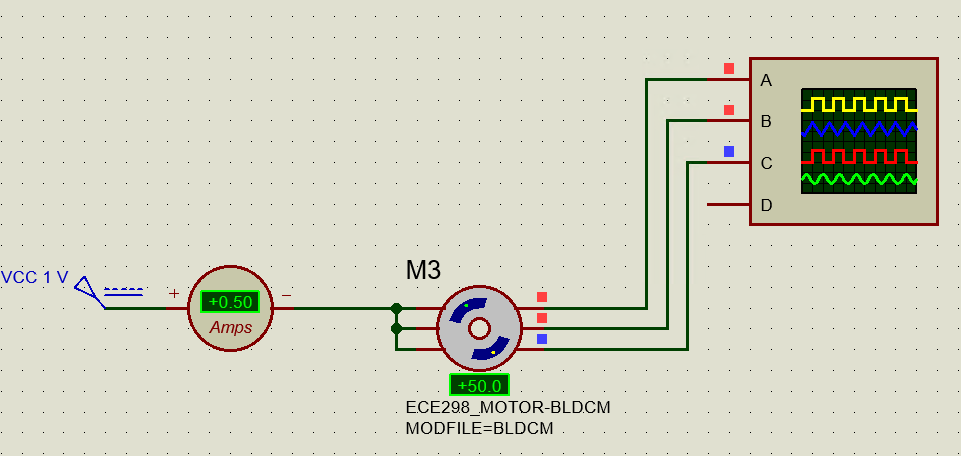


Likewise, the output corresponding to the speed of the motor looks like:



Where the rising edge of B1 occurs when B2 is high, and the rising edge of B2 occurs when B3 is also high – the opposite of a positive directed rotation.

When the same power supply is connected to P1 and P2, the rotation speed, and current drawn, doubles. Likewise, when all three pins are connected to power, the rotation speed, and current drawn triples:

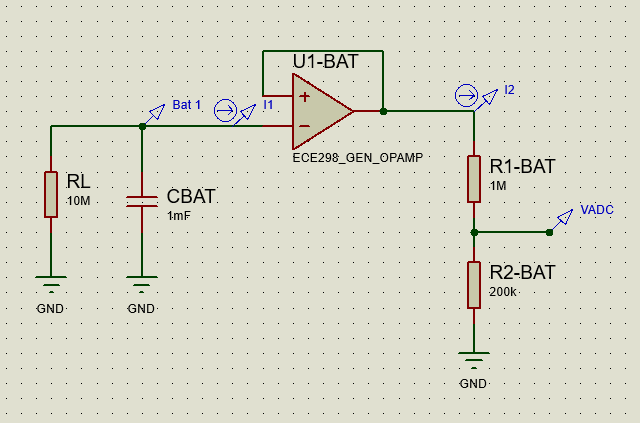
The same is true for negatively applied voltages.

## Device 2 – Battery-Level Sensor

The battery-level sensor circuit is designed to output a voltage between 0-3.3 V given an input range of 0-20 V, which is the assumed maximum voltage of an external battery for this application.

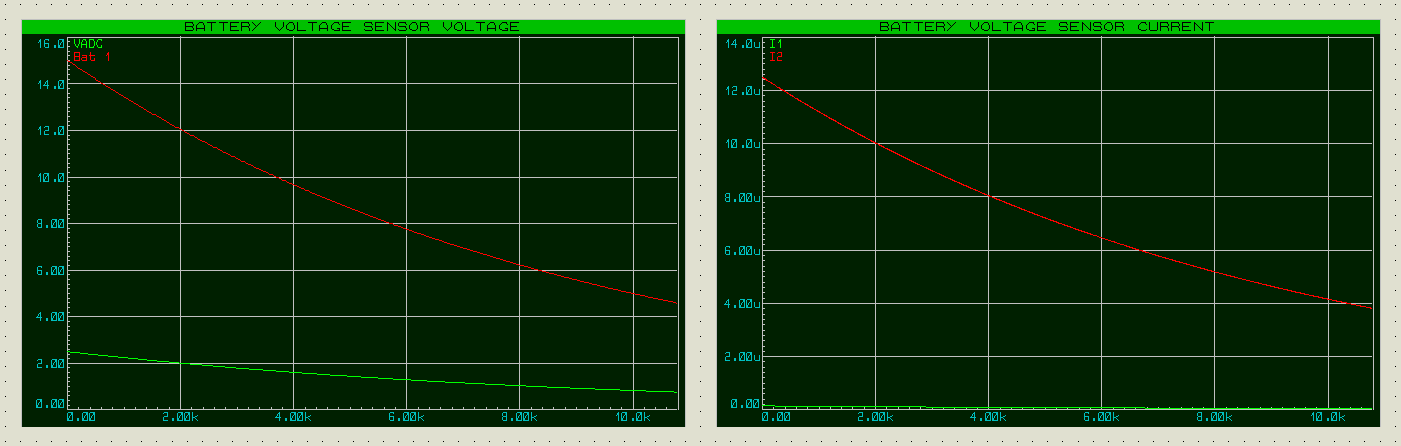
The output of this circuit will feed into the ADC peripheral of the STMicro…, which will be converted to a digital signal that the firmware of the MCU can read. Depending on the battery level, the MCU will determine which LEDs (indicating battery percentage) will be turned on.

A schematic for the battery-level sensor is shown below:



The battery is modelled by a large capacitor – CBAT – whose initial voltage is set to 15 V. The battery voltage is sent through a buffer to isolate the signal from the rest of the circuit (RL, representing the circuit load), which is the input of a voltage divider providing the correct maximum output rated for the MCU’s ADC. VADC will feed into the ADC of the MCU in the final implementation.

Due to the modelling of the external circuit as a large circuit, the battery’s voltage will drop exponentially over time (since the current drawn by the op-amp buffer is negligible). The lifetime of this battery is (rounded down). This is shown below in the time-domain voltage and current of VADC, Bat 1, I1, I2:



As shown the battery, in this configuration, retains at least 50% of its charge for 5.6k s = 1.5 h, which is exponentially decrease with the lifetime as stated above. The current drawn from the battery is negligible, and the current drawn in the voltage divider circuit is of the order of uA, which is also satisfactory. In this example the initial voltage read by the ADC would be 2.5 V – indicating to the MCU the battery is at 15 V charge.

## Device 3 – ECE298\_DCMOTOR\_ENCODER

The battery-level sensor circuit is designed to output a voltage between 0-3.3 V given an input range of 0-20 V, which is the assumed maximum voltage of

# Part 4 – System-Level Design

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