Microcontrollers Exam 1:

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Executive Summary:

This purpose of this report is to describe the circuit and program created to record the voltage discharge of an Energizer Industrial 9v battery as well as comparing the data recorded to Energizers data sheet.

Introduction:

The purpose of this activity is to visualize how a 9v (volt) battery is discharged over time. To complete this activity several pieces of hardware were used: Raspberry Pi 3 Model B+ (shown in the figure below), a solderless breadboard, wires to build a circuit, resistors (2x 100 Ohm resistors both measured at 97.5 Ohms), an 8-bit chip (ADC0831), miniature snap terminal to connect to the 9v battery, and an Energizer industrial 9v Battery. Software used for this activity includes a Linux based operating system, and a programming environment of choice (I used "Thonny", a pre-installed IDE on the Raspberry Pi's operating system). The purpose of using a Raspberry Pi is so the user can interface with the GPIO (General Purpose Input-Output) pins to send signals through the circuit to interface with the 8-bit ADC0831 chip to record voltage data from the 9v battery. All circuits built and results observed will be discussed further in the following **Results/Analysis** section. All code written will be included in the **Appendices** section.

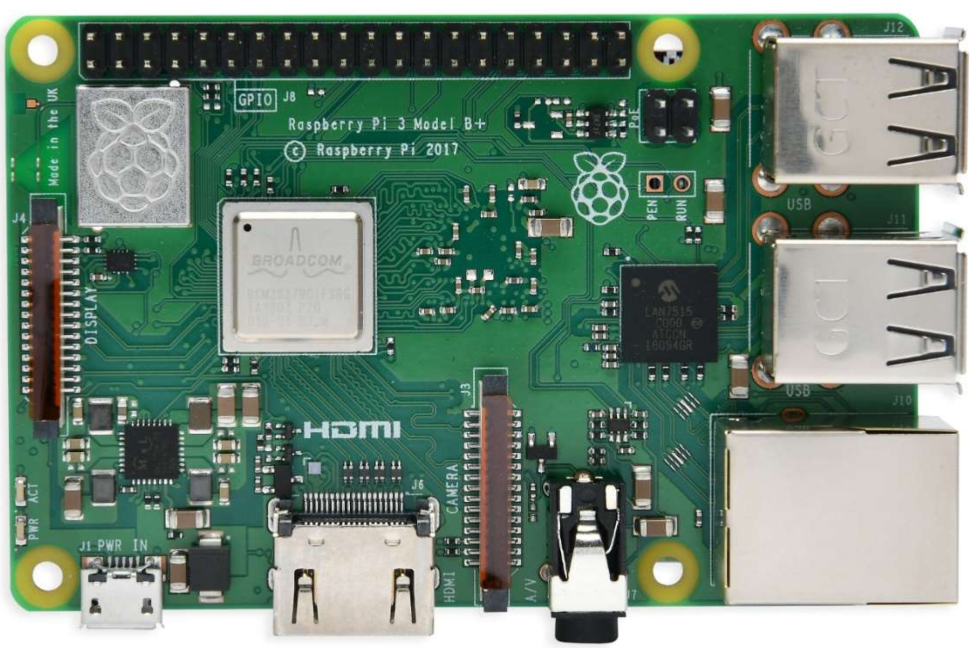


Figure 1 Raspberry Pi 3 Model B+. This is the board used to program the circuits built throughout this lab. The GPIO pins can be seen at the top. Each pin will have the ability to be programmed.

To make it easier to interface with the GPIO pins of the RPi, a GPIO header will be connected to the RPi using a 30-pin connector the header pins will be connected to the solderless breadboard. A figure of the GPIO header will be provided below along with a reference card from the manufacturer with GPIO pin labeling.

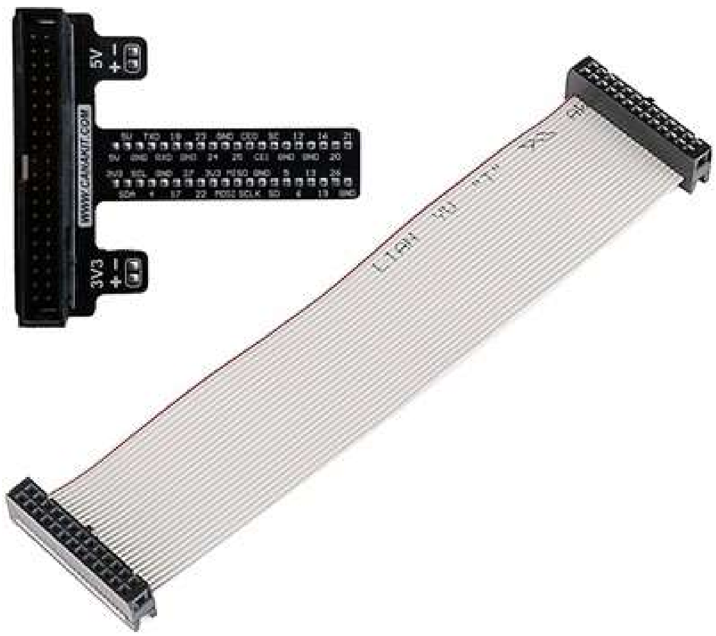


Figure 2. GPIO Header with 30-pin connector.

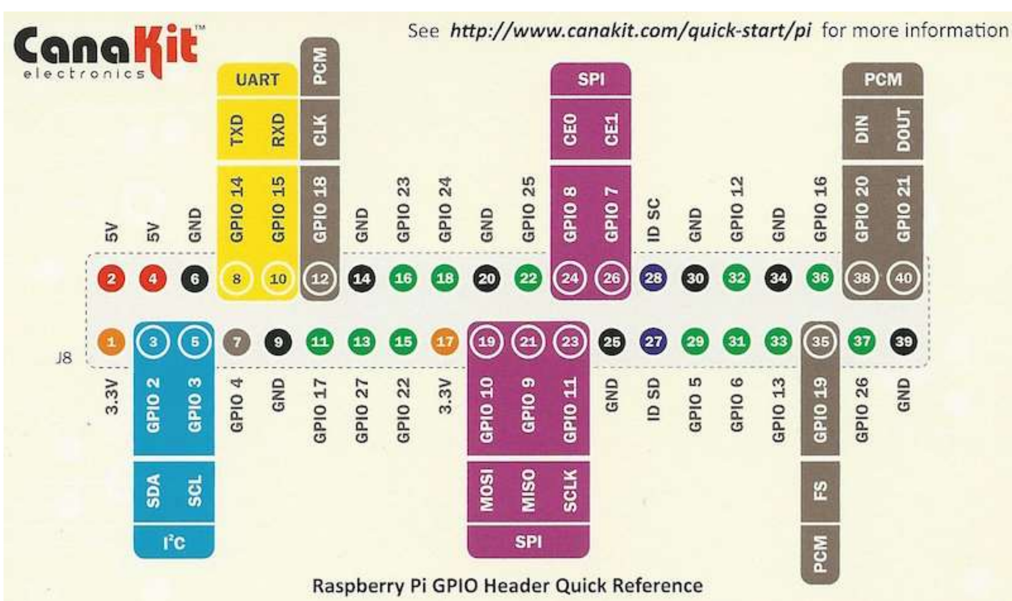


Figure 3. GPIO header quick reference card. Includes the pin numbers and GPIO port labeling.

Results/Analysis:

Part 1: Circuit Design

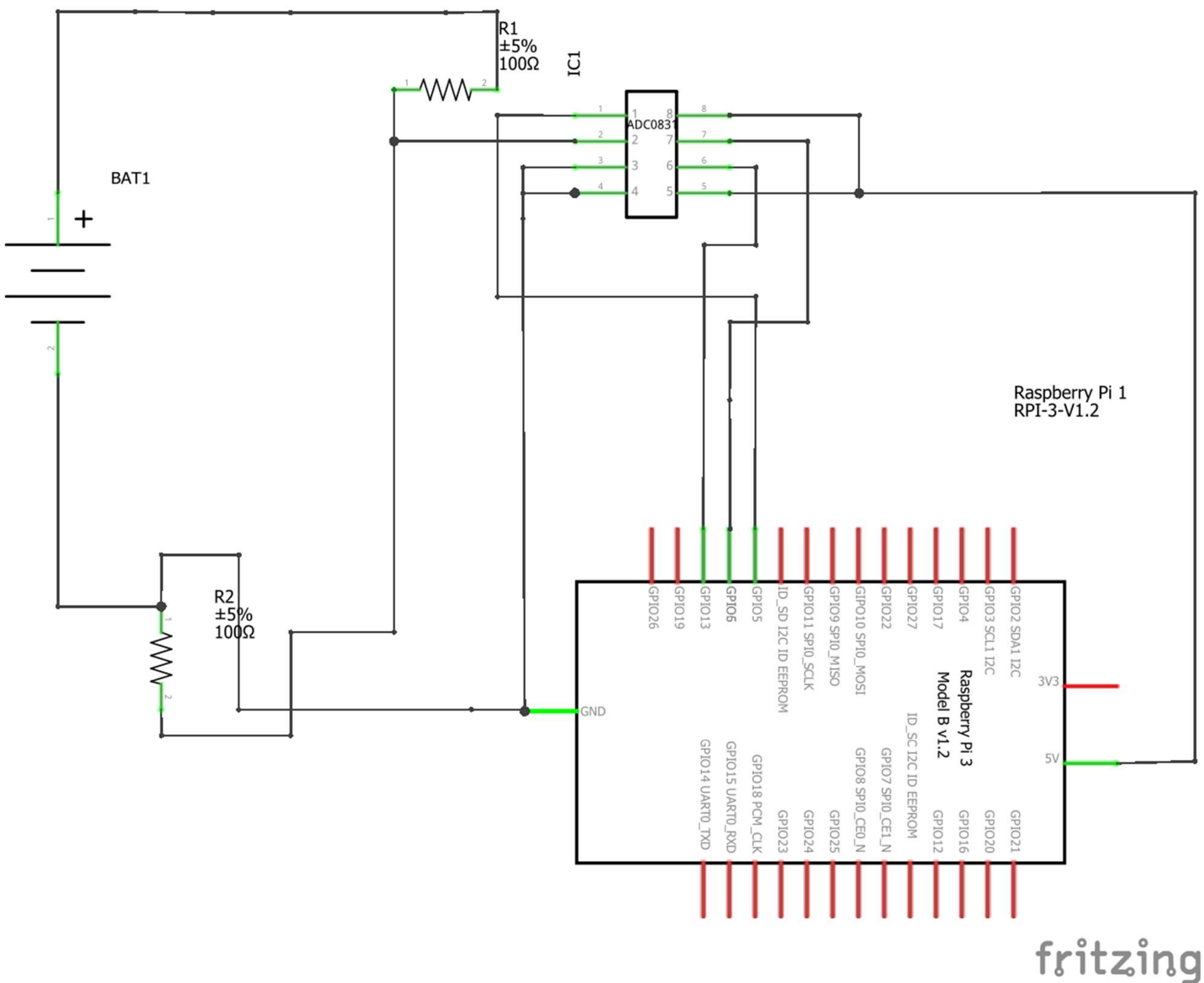


Figure 4. The circuit schematic for the voltage discharge activity (Hardware visual is included in the **Appendices** section along with ADC0831 pinout)

When building the circuit, wiring the ADC0831 (referred to as ADC from now on) chip to the RPi is the easiest way to start to avoid confusion later. Pin 1 (CS) of the ADC chip attaches to GPIO 5 on the RPi, Pin 2 (V_{in+}) connects between R1 (100 ohms) and R2 (100 ohms) to gather voltage data from the 9v battery (reasoning behind this will be discussed shortly). Pin 3 (V_{in-}) and Pin 4 (GND) are both connected to the GND terminal of the RPi. Pin 5 (V_{ref}) and Pin 8 (V_{cc}) both connect to the 5v pin of the RPi. Pin 5 does not supply power to the ADC chip, instead it provides a reference voltage to compare against the voltage being read from Pin 2. Pin 8 on the ADC chip that provides power to the chip. Lastly, Pin 7 (CLK) connects to GPIO 13 on the RPi.

I chose the values of R1 and R2 to be 100 ohms each because the ADC chip can only read voltages between 0 volts and 5.0 volts. By constructing a voltage divider using the 100 ohm resistors, the voltage of the battery is cut in half to 4.5v, thereby allowing the voltage to be readable by the ADC chip:

$$V_{out} = \frac{V_{source} \times R_2}{(R_1 + R_2)}$$

$$V_{out} = \frac{9.0V \times 100\Omega}{(100\Omega + 100\Omega)}$$

$$V_{out} = 4.5V$$

Now that the voltage has been divided in half in the circuit to make it readable by the ADC chip, the value read can now be multiplied by 2 in the program to display and record the correct voltage for plotting the data.

Part 2: Program Flowchart

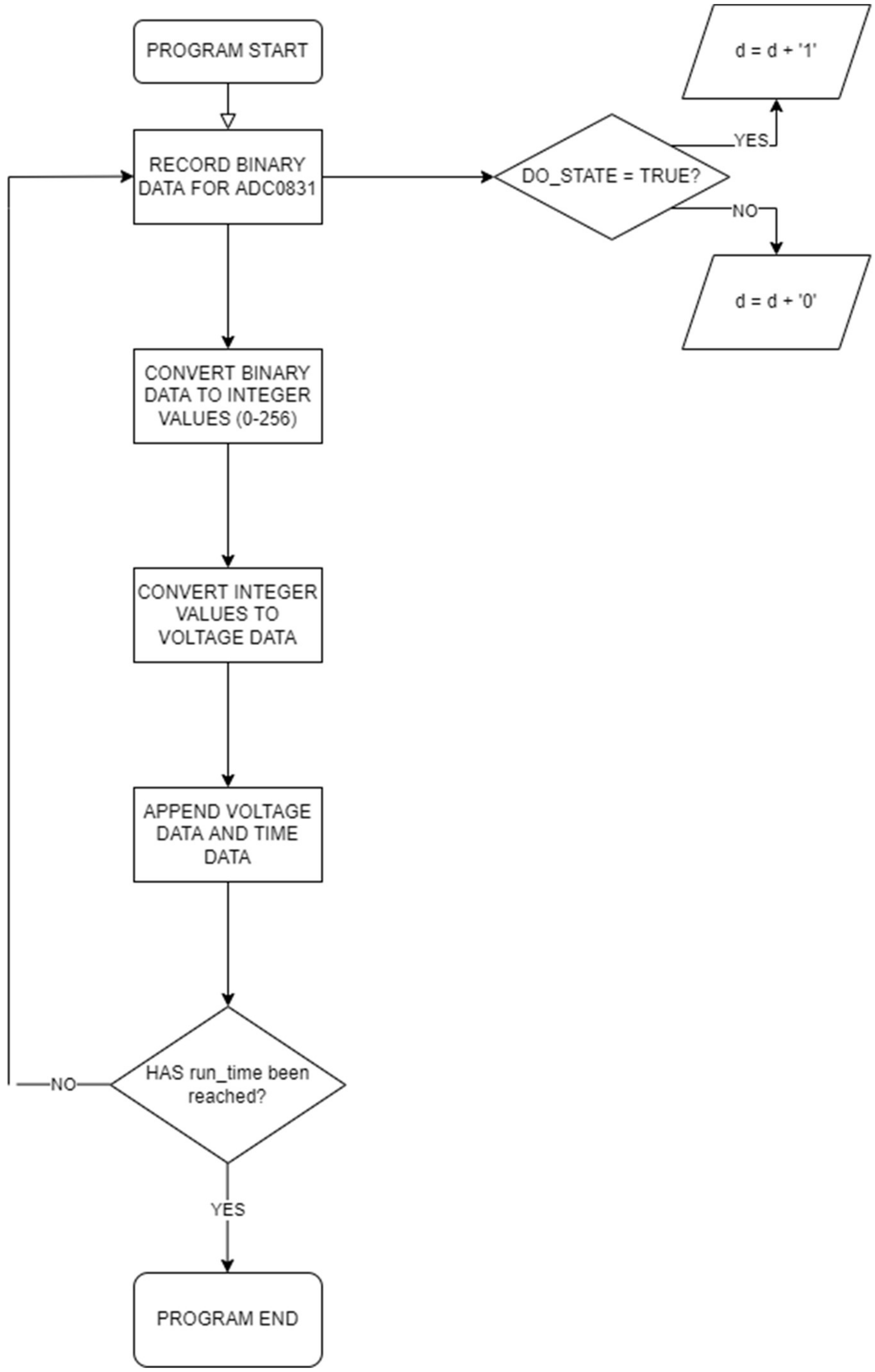


Figure 5. Program flowchart (program code will be included in in the **Appendices** section)

Part 3: Modeling

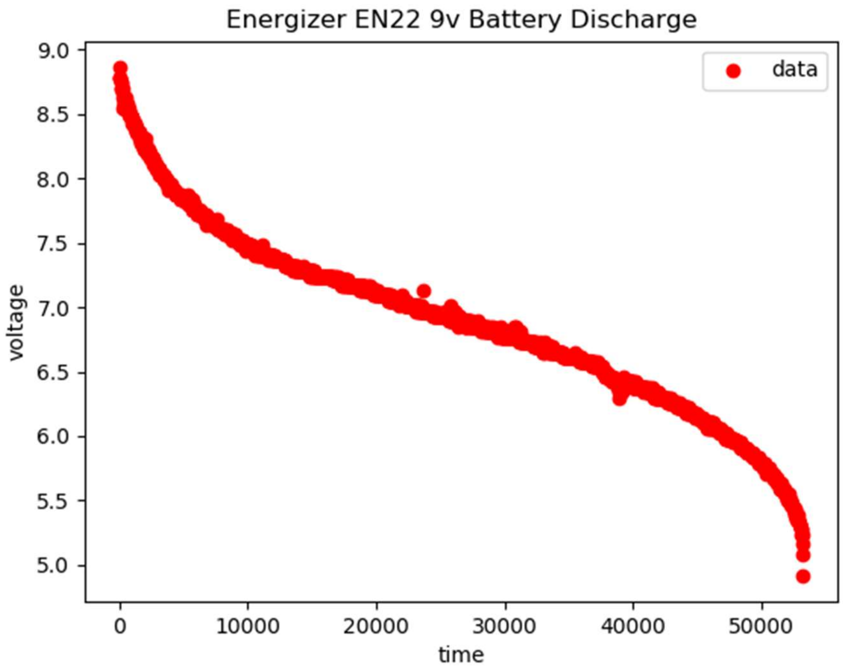


Figure 5. Plot of voltage data recorded over time. Vertical axis is voltage recorded. Horizontal axis is time passed in seconds (details on this below).

Figure 5 shows the recorded data plotted to show how the 9v battery discharges voltage. The horizontal axis on this plot shows the time in seconds. I attempted to change this value to hours but had difficulties. The time ranges from 0 seconds to about 52,000 seconds. The program run time was set to 54000 seconds (15 hours). The excess 2000 seconds (33 minutes) were deleted from the data file due to the quick drop from 4.8v to 1.22v. According to Energizers data sheet for the 9v battery, 4.8v is the lowest operating voltage the battery has and will no longer provide sufficient voltage to power the electronics using the battery.

The reasoning behind choosing 15 hours include using Ohm's law to determine the current the battery produces:

$$\frac{V}{R} = I$$

$$\frac{9.0V}{200\Omega} = 45mA$$

With a load current of 45mA an alkaline 9v battery (550mAh) is estimated to last about 12.22 hours. This was calculated simply by dividing the estimated battery capacity (550mAh) by the batteries load current (45mA). By choosing 15 hours for the programs run time will allow for minor margins in error in the battery's capacity. **NOTE:** The load current of 45mA is not constant throughout the entire measurement period. 45mA is to be used as an estimation leading to the overestimation in time required to measure the data from 9v to 4.8v.

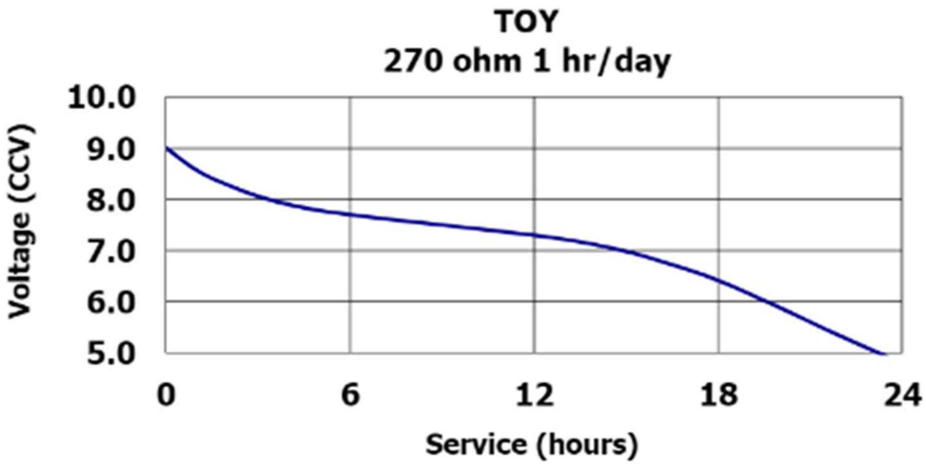


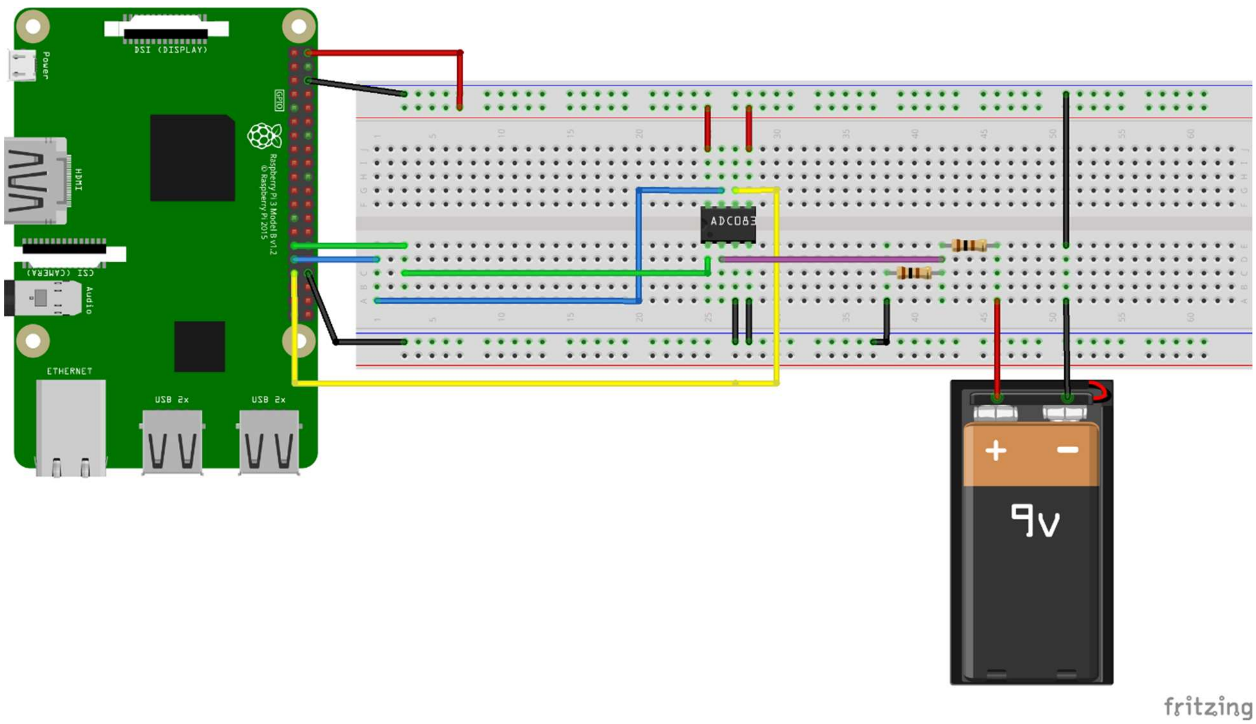
Figure 6. Testing data from the energizer industrial 9v battery data sheet.

Comparing the data plots from Figure 5 to Figure 6, the voltage discharge rate of the two figures is similar. The faster drop off rate of figure 5 could be the result of several factors such as: lower resistance in the circuit meaning a faster discharge rate, ambient room temperature (Energizer actually provides a range of operating temperatures and my personal testing area was well within range so unlikely a factor in testing).

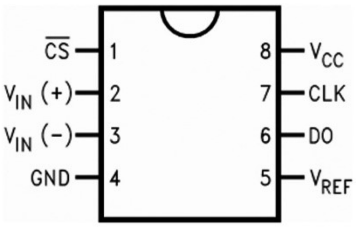
Conclusions:

In conclusion of this activity, the main objective of constructing a program and circuit to monitor and record the voltage discharge of a battery was successfully completed. By using Ohm's law, it was possible to estimate the time needed for the data recording program to record the necessary data to plot the voltage discharge.

Appendices:



Appendix 1: Hardware visual of the circuit created for this activity



Appendix 2: ADC0831 pinout

References:

Energizer EN22 Data Sheet

https://data.energizer.com/pdfs/en22.pdf