Data Analysis and Visualisation Project

Yelaman Zhenis

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1 Abstract

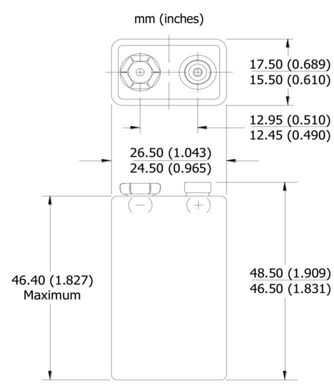
Generally, a battery is considered to be dead when the initial voltage stated by manufacturer has fallen below 60%, which is usually stated by a company itself. The purpose of this project is to determine the useful life of a 9V battery, or how long does it take for battery to get discharged.

2 Introduction

A battery is filled with reagents, connecting a battery to the circuit causes chemical reaction. During the reaction there is a an electron flow from anode(negatively charged plate) to cathode(positively charged plate) which causes the circuit to operate. As the chemical reactions inside the battery uses up limited reagents, the battery performance will drop.[5] The battery that was used for this project is manufactured by Energizer Alkaline 9V battery (Figure 1). The battery is considered "dead" if its voltage drops to 4.8V.[1]

To record the data of the battery, it is going to be connected to Raspberry Pi using ADC0831

(a) Visual of A Battery

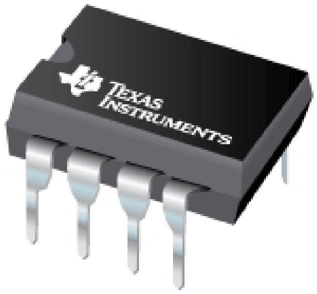


(b) Dimensions of A Battery

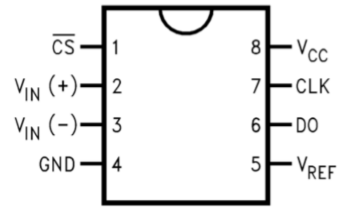
Figure 1: Representation of A Battery Utilized

chip and voltage divider. Raspberry Pi is a minicomputer that capable of connecting and talking to microcontroller chips to record and manipulate data via programming languages. Refer Figure 6 for Raspberry Pi's pinout.

The ADC0831 is a chip that was designed to take data for you with minimum effort, because the process is automated. The chip is a 8-bit serial input/output analog/digital converter chip. Basically, it converts an analog measurement to binary, so it can interact with you through computer.[2] See Figure 2 for chip.



(a) Visual of ADC0831 chip



(b) Pin Map

Figure 2: ADC0831 Microcontroller Chip

The voltage divider allows us to decrease input voltage to desired output voltage value by varying resistors in circuit shown in Figure 3.

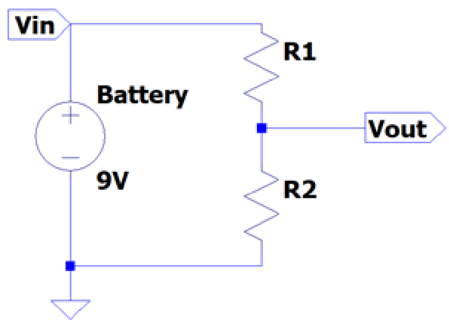


Figure 3: The Voltage Divider

From the Figure 3 we can see the current flow is:

$$I = \frac{V_{in}}{R_1 + R_2} \tag{1}$$

The voltage across the second resistor is $V_{out} = I * R_2$, which yields

$$\frac{V_{out}}{R_2} = \frac{V_{in}}{R_1 + R_2} \tag{2}$$

Rearranging term in Equation 2, it can be shown:

$$\frac{V_{out}}{V_{in}} = \frac{R_2}{R_1 + R_2} \tag{3}$$

This voltage divider relationship allows output voltage to be any desired value.[4]

3 Analysis

Indentation at the top of the chip (Figure 2b) determines where the top is and helps to indicate which pin is which. Basic pin setup is: $V_{in}(+)$ is the analog input, and DO is the serial output. V_{ref} and $Vin(-)$ are used calibrate chip by applying certain voltage. V_{dd} (V_{cc}) and GND are used for supplying power to the chip. CS is for active low chip set, and CLK is for clock. So, to take measurements using chip, the CS pin must receive a signal from the Raspberry Pi that starts high and goes low. This signal should stay low until you end your program. CLK input must receive a single clock pulse to state that the conversation should start at the next clock pulse. For this chip, a clock pulse starts low, sets high, and goes low again, 8 more clock pulses are required to complete the conversation. Each time a clock pulse is received by CLK, another of the serial bits is sent by the DO output. See Figure 4 for final setup.

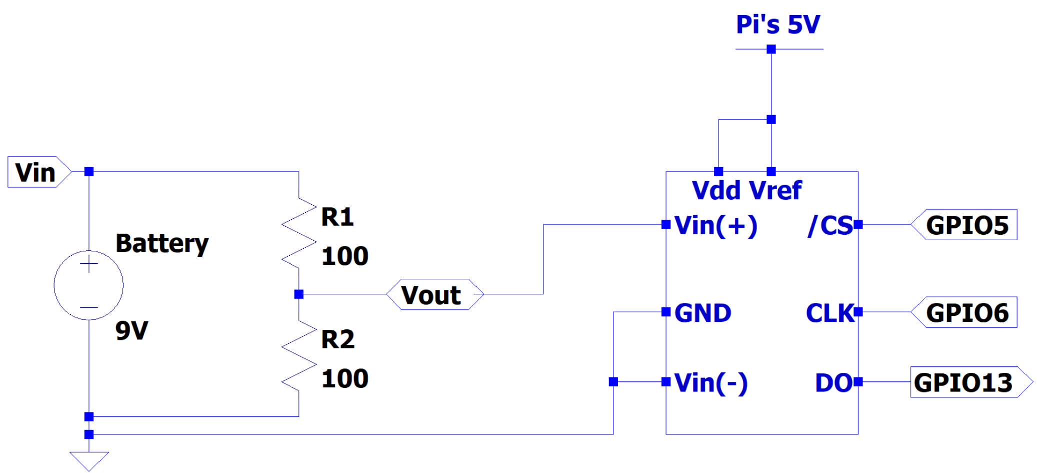


Figure 4: Final Circuit Build

According to ADC0831 datasheet[2], the chip is limited to measure only up to about 5V, so 9V straight into the chip might cause some problems. That is why voltage divider is utilized: letting both resistors R_1 and R_2 to be equal to each other Equation 3 will be $V_{out} = V_{in}/2$, where V_{in} is the battery voltage. Assuming battery has a steady current draw of 45 mA(5 pins in use)[3], applying Equation 1, we get $R_1 = R_2 = R = 104.2\Omega$. The voltmeter reading was $V_{in} = V_{battery} = 9.257V$, resulting $V_{out} = 4.606V$. To be more precise with the factor of 2, V_{in} and V_{out} were measured with voltmeter to be $V_{in} = V_{battery} = 9.257V$, resulting $V_{out} = 4.606V$, the factor of about 2.01 was obtained. Basically, multiplying voltage reading from the chip by 2.01, allows the battery voltage calculation to be more precise.
Raspberry Pi was left to record voltage value every minute. See Figure 5 for graph representation of data.[6] Linear regression was applied to period where the discharge is steady letting us to calculate battery capacity. Regression is on $t \in [2.55, 11.32]$, giving us the capacity:

$$Capacity = I * \Delta t = 45 * 8.77 = 394.65\ mA * h \tag{4}$$

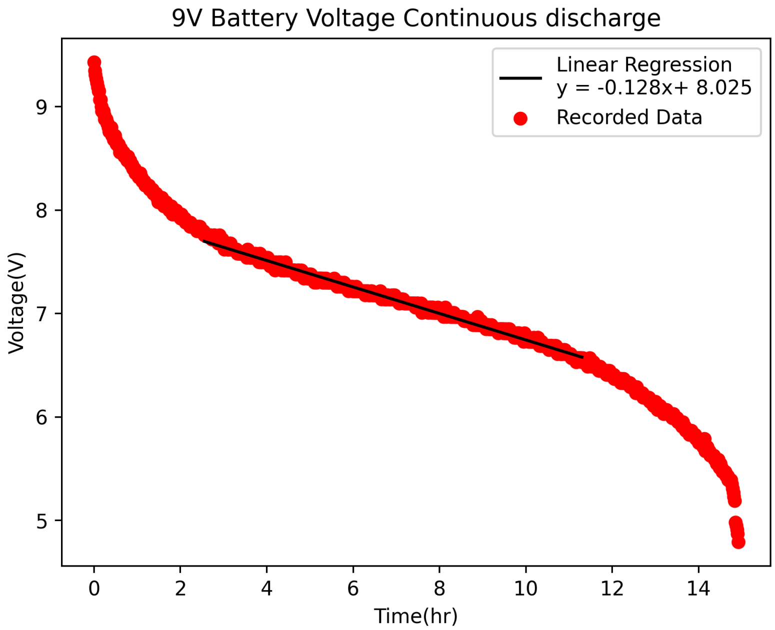


Figure 5: Data Visualization

4 Conclusion

To determine the useful life of a 9V battery, battery voltage was connected to Raspberry Pi, and Raspberry Pi collected data for fifteen hours, and as it reached the voltage value considered "dead", it stopped collecting data. Ohm's law was used to get an idea of what resistance value should be used for the voltage divider. Also, the relationship between V_{out} and V_{in} in a voltage divider was used to find $V_{battery}$, python program program was measuring the voltage that goes in our Raspberry Pi at a that time and it was multiplied by division factor to calculate an actual voltage of the battery. It was calculated that the capacity of the battery is $Capacity = 394.65\ mA * h$, which is expected by looking at continuous discharge in the datasheet of the battery.

5 Appendix

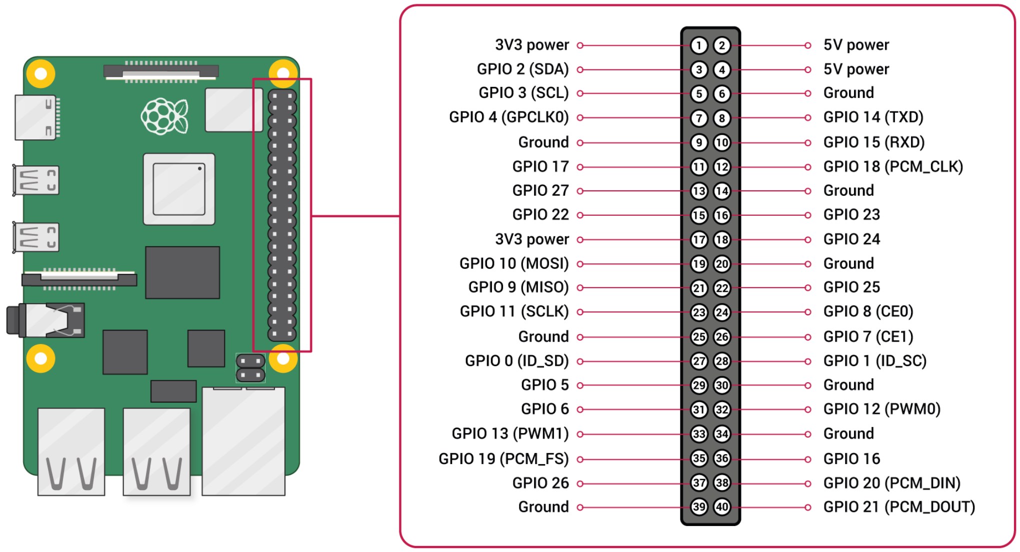


Figure 6: Raspberry Pi Pinout

References

[1] Energizer. Energizer EN22 Data Sheet.

[2] Texas Instrument. ADC0831 Chip Data Sheet.

[3] JeGX. Meet the Raspberry Pi GPIO Connector, Mar 2015.

[4] Curtis A Meyer. *Basic Electronics: An Introduction to Electronics for Science Students*. Curtis A. Meyer, 2015.

[5] Klaus Schmidt-Rohr. How batteries store and release energy: Explaining basic electrochemistry. *Journal of Chemical Education*, 95(10):1801–1810, 2018.

[6] Yelaman Zhenis. Project link.