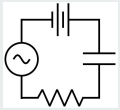

Measuring Internal Resistance

Charlie Coleman

Jose Antonio Conde

Aparna Shekar

Junior Design
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MDH 1018
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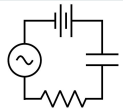
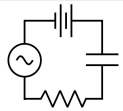


Goal

- To find the internal resistance of a 7.2 V rechargeable battery



Outline

- Our approach
  - First approach
  - Second approach
  - Final approach
- Procedure
  - Experiment
  - Formulas and theorems
  - Calculations
- Results
- Conclusions

Our approach: First

- Battery in series with a resistor
- The voltage measured and compared it with its theoretical value
- Problems:
  - The battery couldn't draw enough current
  - The resistances had to have a large enough power rating to handle the voltage going through it

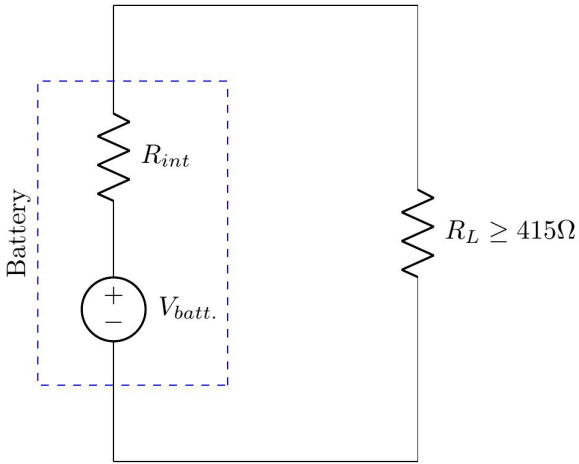


Figure 1: Initial concept for internal resistance measurement

Our Approach: Second

- Combination of AC source with a transformer
  - Step up current
  - Step down voltage
- Battery in series with AC source of 7.2 V (peak)
- Initial calculations based on 8:1 transformer
- Problems:
  - Inconsistent internal resistances (ranged from 18-400Ω) due to inductance of the transformer

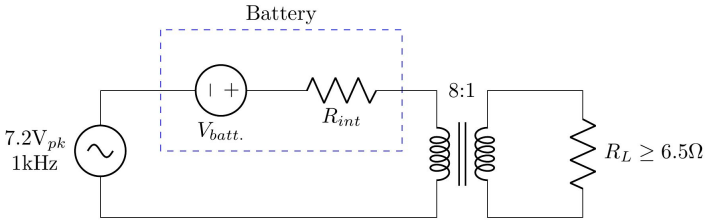
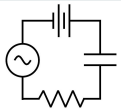


Figure 2: Our second attempt at measuring the internal resistance



Our Approach: Final

- Capacitors act like an open circuit with DC voltage
  - Allowed use of smaller resistors
- Needed to ensure capacitor was capable of 7.2V
  - Used 470μF 16V capacitor
- Changed frequency and observed effects
  - Found internal impedance of battery

Circuit Diagrams for Final Approach

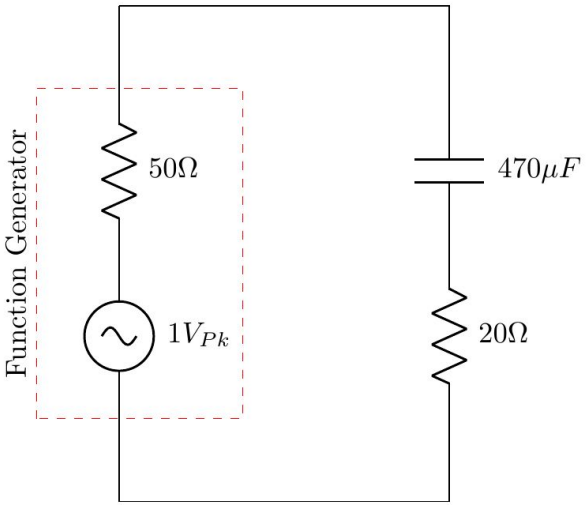


Figure 3: The circuit used to find the impedance of the circuit without the battery

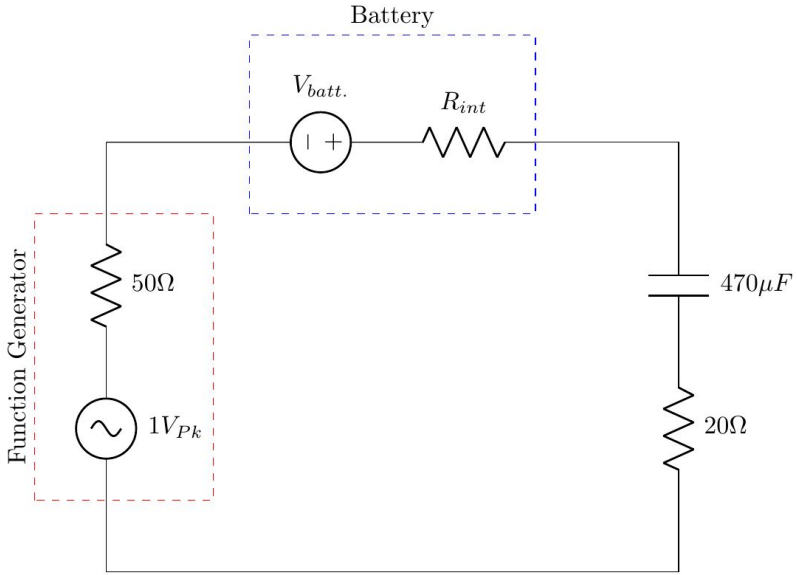
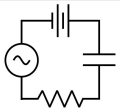


Figure 4: The circuit used to find the internal resistance of the battery

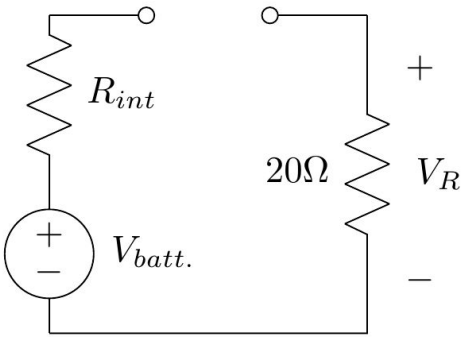


Procedure

1. Constructed **Figure 3,** but replaced the 20Ω resistor with a 1.3kΩ resistor
2. Set Function Generator to 1V_pk and 1kHz
3. Replaced the 1.3kΩ resistor with the 20Ω resistor after >3 seconds
4. Measured and recorded:
    a. I_{tot}
    b. $V_{20\Omega}$
    c. V_{FG} (function generator voltage)
5. Repeated these measurements for 2kHz, 3kHz, 4kHz, and 5kHz
6. Repeated 1-5 for the circuit in **Figure 4**

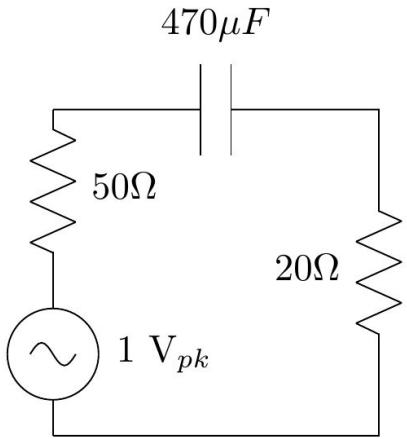
Procedure: Formulas and theorems

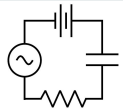
- Superposition theorem
  - To suppress a *voltage* source, replace it with a *short* circuit.
  - By solving these two circuits, we get the equation:



$$R_1 = \frac{V_{FG} - V_R}{I_{tot}} \text{ (without battery)}$$

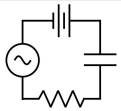
$$R_{int} = \frac{V_{FG} - V_R}{I_{tot}} - R_1$$





Procedure: Calculations

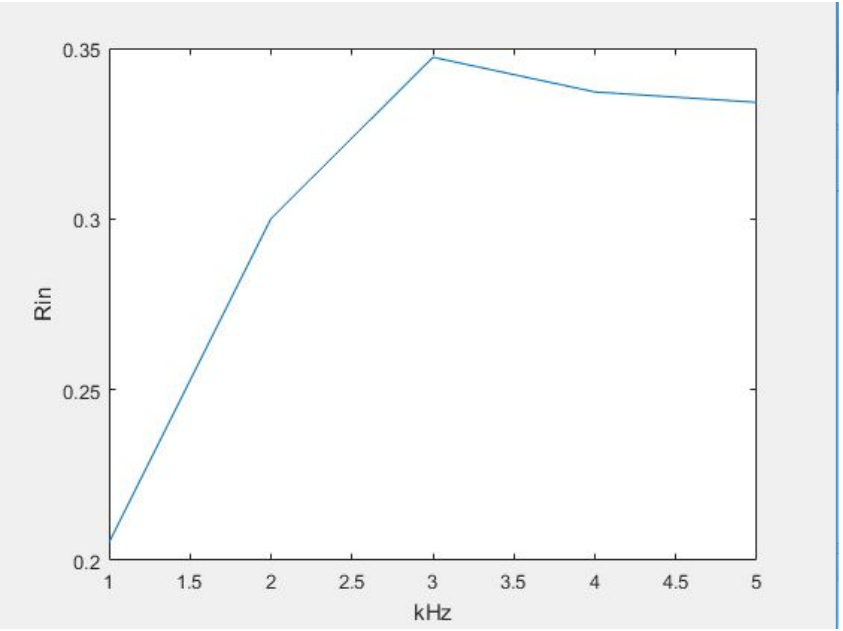
1. The capacitor opened the circuit with just DC source
2. Applied Kirchhoff's voltage law with the circuit with the battery voltage blocked
3. Calculated the total impedance from the known resistances
4. Used Ohm’s law to get the voltage through the total known impedance
5. Derived from there the resistor needed to fulfill Kirchoff’s law

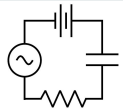


Results

	Without battery			With battery		
f (Hz)	V_R (V)	I_{tot} (mA)	R_1 (Ω)	V_R (V)	I_{tot} (mA)	R_{int} (Ω)
1000	0.19530	9.86	51.9074	0.19484	9.83	0.2052
2000	0.19537	9.88	51.7952	0.19501	9.83	0.3001
3000	0.19535	9.89	51.7449	0.19504	9.83	0.3474
4000	0.19535	9.89	51.7449	0.19514	9.83	0.3372
5000	0.19533	9.89	51.7469	0.19515	9.83	0.3342

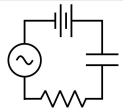
Results: Rin plot





Results: Precision and accuracy

- Mean of the Rin was 0.30482 Ω
- The value of the resistance matched our expectations
- We could not measure the accuracy without the real value of the internal resistance
- The variance of the Rin was 0.0034 Ω
- The data was precise regardless of the accuracy



Conclusions

- The results were consistent
- The samples that were taken matched our expectations
- Possible inductance in the battery as Rin changed with the frequency
- Possible errors due to impedance in wires used

References

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