# Patareide uurimistöö

## Ettevalmistus

- Valida välja patareid (erinevate brändide omad, hoida pilk peale lausetel nagu “extra life” ja “50% longer lasting” jms. Hiljem kinnitada nende autentsust.
- Võrdlus ainult alkaline patareide vahel.
- Algpinge 1.5V DC, algvool ~100mA.
- Võrdlus käib nii erinevate brändide vahel (nt Duracell AAA ja Procell AAA) kui ka erinevate patareide liikide vahel (AA ja AAA)

## Tehnika, millega uurimust läbi viiakse

- UNI-T UT161D Multimeeter
- Arvuti koos UNI-T logimistarkvaraga
- ARCOL HS25 15R takisti, 15ohm, 25W
- Patarei hoidik juhtmetega

## Valitavad patareid (kõik alkaline)

- AA Procell 1.5V
- AA DURACELL PLUS 1.5V "100% longer lasting"
- AA DURACELL 1.5V TAVALINE
- AA VARTA tööstuslik
- AAA Procell 1.5V
- AAA DURACELL PLUS 1.5V “100% longer lasting”
- AAA DURACELL 1.5V TAVALINE
- AAA VARTA tööstuslik

## Analüüs ja kokkuvõte

- Üleüldine brändidevaheline võrdlus
- Üleüldine liikidevaheline võrdlus
- “Pikem eluiga” lausete paikapidamine

## Uurimisküsimused

- Kui kaua kestab Duracelli AA patarei võrreldes Procelli ja Varta AA patareiga? Samuti AAA patareid?
- Kui tõene on patareide pikemajalisema eluiga väide?
- Kuidas on võrreldavad omavahel nt AA ja AAA patareid sama pinge & äravoolu all?

## Eesmärk

- Võrrelda erinevaid patareide brände omavahel.
- Kontrollida brändide väiteid.
- Võrrelda erinevaid patareide liike omavahel.
- Kirjutada kokkuvõttev artikkel teval.ee lehele.

## Allikad

- https://ember-climate.org/insights/research/eu-battery-storage-is-ready-for-its-moment-in-the-sun/
- https://setis.ec.europa.eu/system/files/2021-01/Attitude_of_European_car_drivers_towards_electric_vehicles-a_survey.pdf

## Protsess

- Patarei pannakse hoidikusse ja ühendatakse takistiga.
- Multimeeter ühendatakse takisti mõlemasse otsa ja mõõdetakse pinget.
- Multimeeter on USB juhtmega ühendatud arvutiga ja arvutis töötab 24/7 UNI-T tarkvara, mis mõõdab ja salvestab pinge. Tarkvara salvestab pinge ja kellaaja iga sekundi tagant.
- Katse lõppeb, kui mõõdetud pinge on 1.1V DC.
- Peale katset arvutused, et teada saada patarei mahtuvus ja kestus.

## Järjekord ja tulemused

### AA Patareid

- AA DURACELL 1.5V TAVALINE
  Algus: 19/09/2024 07:57:10 @ 1.55V DC

Lõpp: 20/09/2024  09:59:34 @ 1.1V DC
Kestus: 26h, 2min, 24s
~2346mAh

- AA DURACELL PLUS 1.5V "100% longer lasting"
  Algus: 17/09/2024  13:47:41 @ 1.558 V DC
  Lõpp: 18/09/2024 16:56:19  @ 1.1 V DC
  Kestus: 27h, 8min, 38s
  ~2918mAh

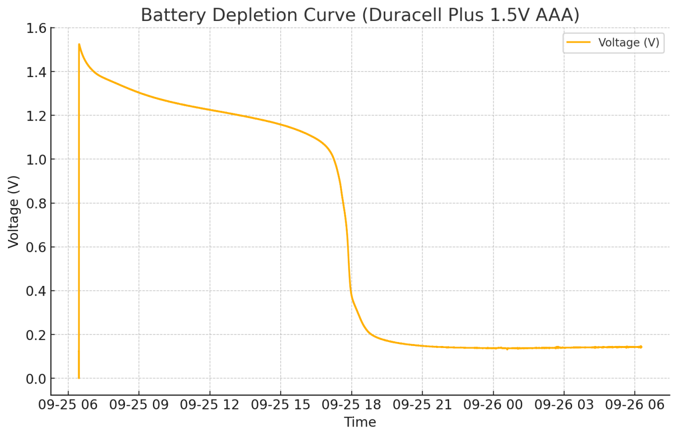
- AA VARTA
  Algus: 20/09/2024  12:31:27 @ 1.54V DC
  Lõpp: 21/09/2024  12:46:29 @ 1.1V DC
  Kestus: 24h, 15min, 15s
  ~2040mAh

- AA Procell 1.5V
  Algus: 23/09/2024  06:33:07 @ 1.53V DC
  Lõpp: 24/09/2024  07:13:29 @ 1.1V DC
  24h, 42min, 32s
  ~2085mAh

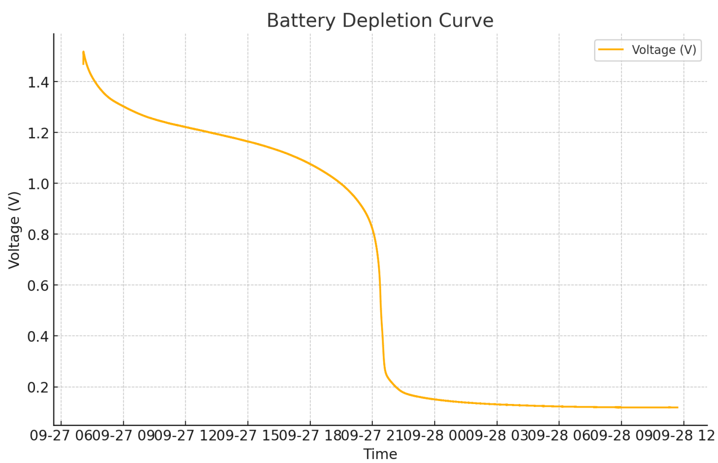
## AAA Patareid

- AAA DURACELL 1.5V TAVALINE
  Algus: 24/09/2024  07:37:39 @ 1.53V DC
  Lõpp: 24/09/2024  17:52:20 @ 1.1V DC
  Kestus: 10h, 14min, 14s
  ~ 1063.89 mAh

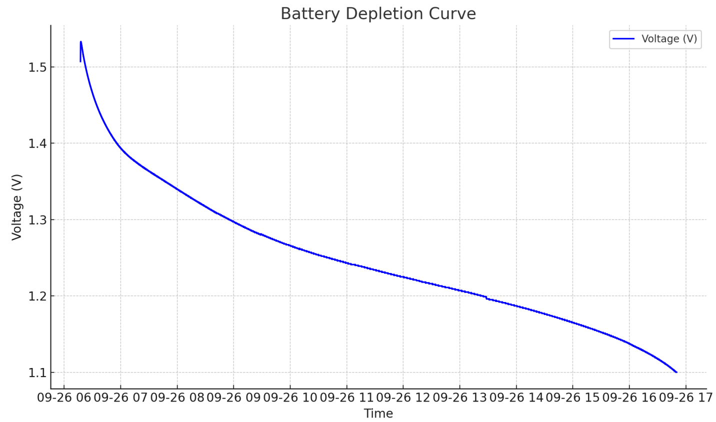
- AAA DURACELL PLUS 1.5V “100% longer lasting”
  Algus: 25/09/2024  06:27:47 @ 1.524V DC
  Lõpp: 25/09/2024  16:23:09 @ 1.1V DC
  Kestus: 9h, 55min, 22s
  ~ 1053 mAh




- AAA VARTA
  Algus: 27/09/2024  07:04:07 @ 1.517V DC
  Lõpp: 27/09/2024  17:22:04 @ 1.1V DC
  Kestus: 10h, 17min, 57s
  ~ 1240 mAh




- AAA Procell 1.5V
  Algus: 26/09/2024  06:17:31 @ 1.531V DC
  Lõpp: 26/09/2024  16:50:04 @ 1.1V DC
  Kestus: 10h, 32min, 33s
  ~ 905.6 mAh




Märkused:

- Kohe alguses pinge tõuseb ~0.1V võrra enne langemist
- Kestuse arvutused on tehtud algusajast kuni 1.1V DC-ni. Märgitud “Algus” on aga kõrgeim pinge katse alguses.

# Kokkuvõte

AA patareidest kestis kõige kauem ja oli kõige suurema mahuga Duracell plus 1.5V, väitega “100% longer lasting”. Väide aga paika ei pidanud - katsest näeme, et Duracell plus kestis tavalisest Duracell patareist ajaliselt vaid 1h 6min, ehk 4.2% kauem. Kõige nõrgem AA patarei oli VARTA tööstuslik 1.5V patarei, nii kestuselt kui ka mahult. Nimelt kestis Varta AA patarei 24h, 15min, 15s. Muidugi ei tohi ära unustada, et patareid Procell ja Varta on tööstuslikud ja katsetatud Duracelli patareid laiatarbelised. Sellegipoolest näeme, et Duracell Plus “100% longer lasting” kestab, võrreldes kõige “kehvema” patareiga, vaid ~ 1h 47min, ehk ~7.7%. kauem.

Võrreldes patareide mahtusid, saime arvutuste käigus patarei Duracell Plus mahuks 2918mAh ja tavalise Duracelli mahuks 2346mAh.  Võrreldes tööstuslikke patareisid Varta ja Procell näeme, et Procell on nii mahult kui ka kestuselt parem. Procell kestis Varta patareist 27min kauem ja on 45mAh võrra suurema mahuga. Arvestades, et keskmine inimene Euroopas ostab kuni 20-30 patareid iga aasta (SETIS - SET Plan information system)(Ember) näeme, et on võimalik säästa odavama patarei pealt kuni 13€. See summa ei pruugi tunduda suur tavainimesele, aga kui näiteks teil kulub patareisid rohkem, tuleb see näitaja kindlasti mängu.

AAA patareidest kestis üllatavalt kõige kauem teine kõige odavam patarei - Procell 1.5V AAA. Procell kestis kokku 10h, 32min ja 33s mahuga ~905.6mAh, ületades Vartat ajaliselt 15min võrra. Sellegipoolest on patareil Varta AAA katse suurim maht, mahuga ~1240mAh. Katse kallim patarei - Duracell Plus, andis ka kõige halvema tulemuse. Duracell Plus AAA kestis vaid

9h, 55min, 22s mahuga 1053mAh. Võttes arvesse, et Duracell Plus maksab 3€ rohkem kui Procell, on see väga üllatav.

Katse silmnähtavaks võitjaks osutus Procelli tööstuslik mudel. Ei tohi ära unustada, et Procell kuulub samuti Duracelli alla, aga läbiviidud katsest on näha, et Procelli hinna-kvaliteedi suhte pärast tasub nende patareide ostmine ennast rohkem ära, kui Duracelli laiatarbebrändi ost. Samuti ei tohi ära unustada Varta patareid - Varta tulemused olid igas katses Procelliga peaaegu võrdväärsed, kui ainult natukene halvemad ja võttes arvesse, et Varta patareid on paarkümmend senti odavamad Procelli omadest, võib ka see olla hea valik.

Lõpuks peaks ka märkima, et iga patarei on natukene erinev ja käitub teistmoodi erineva takistusega. Kui 15Ω takistusega osutus võitjaks Procell, siis 30Ω takistusega võib olla selleks näiteks Duracelli laiatarbebränd.

/Katsed on tehtud piiratud arvu juhuslike patareidega, see katse ei ole lõplik tõde ja teiste tulemused võivad erineda.

# Mahtude arvutused

## DURACELL 1.5V AA TAVALINE

### 1. Understanding the Setup

- **Resistor**: A 15-ohm resistor is used to discharge the battery.
- **Voltage Range**: The battery discharges from its initial voltage (around 1.5V) to 1.1V.
- **Objective**: To calculate the mAh (milliampere-hour) capacity of the battery, considering that the depletion is uneven over time.

### 2. Loading the Depletion Data

- The depletion data is recorded over time, showing the voltage values at each timestamp.
- I used this data to see how the battery voltage changes as time progresses.

### 3. Filtering the Data

- Some rows in the data had 0V values, which do not represent actual voltage readings. I filtered those out, keeping only valid voltage measurements.

### 4. Time Management

- Each voltage reading had a corresponding timestamp. To process this, I converted these timestamps into elapsed time in seconds from the start of the test.

### 5. Current Calculation

- The battery is discharging through a resistor, so we can calculate the current (in amperes) at each point using Ohm's law:

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

  - Where:
    - $I$ is the current (in amperes),
    - $V$ is the voltage (in volts),
    - $R = 15\,\text{ohms}$.
  - For each voltage reading, I calculated the corresponding current.

### 6. Convert Current to Milliampere (mA)

- Since the standard battery capacity is usually measured in milliampere-hours (mAh), I converted the current to milliamperes (mA) by multiplying the current by 1000:

  $I_{\text{mA}} = I_{\text{A}} \times 1000$

### 7. Integration of the Current Over Time

- The depletion is not linear, so I couldn't just use a simple average to find the total current drawn. Instead, I needed to integrate the current over time to account for the changing current.
- **Trapezoidal Rule**: I used a method called the trapezoidal rule to numerically integrate the current over the time period. This gives us an approximation of the total charge drawn from the battery.

$$\text{Total charge (Ah)} = \int I(t)\,dt$$

  - Where:
    - $I(t)$ is the current at time $t$,
    - $dt$ is the time interval between readings.

- After calculating the total charge in ampere-hours (Ah), I multiplied it by 1000 to get milliampere-hours (mAh).

### 8. Result: Total Battery Capacity

- The final calculated capacity was approximately **2346 mAh**. This result takes into account the uneven depletion curve of the battery as the current decreases along with the voltage over time.

# DURACELL PLUS 1.5V AA

## Step 1: Understanding the Data

The data consists of two key columns:

- **Time (Date/Time)**: When each voltage measurement was taken.
- **Voltage (Value)**: The measured voltage at that time.

Here's a preview of the cleaned data (after removing invalid entries like 0V readings):

| Date/Time | Voltage (V) |
|---|---|
| 2024-09-17 13:47:39 | 1.541 |
| 2024-09-17 13:47:40 | 1.551 |
| 2024-09-17 13:47:41 | 1.558 |
| 2024-09-17 13:47:42 | 1.563 |
| 2024-09-17 13:47:43 | 1.565 |
| ... | ... |

## Step 2: Calculate the Current Over Time

Ohm's Law tells us that the current $I$ is related to the voltage $V$ and the resistance $R$ by the formula:

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

Since the resistor has a resistance of $15\,\Omega$, the current for each time point is calculated as:

$$I(A) = \frac{\text{Voltage}}{15}$$

For example, if the voltage at a given time is 1.541V:

$$I = \frac{1.541}{15} = 0.1027\,A$$

Repeating this for the first few data points:

| Date/Time | Voltage (V) | Current (A) |
|---|---|---|
| 2024-09-17 13:47:39 | 1.541 | 0.1027 |
| 2024-09-17 13:47:40 | 1.551 | 0.1034 |
| 2024-09-17 13:47:41 | 1.558 | 0.1039 |
| 2024-09-17 13:47:42 | 1.563 | 0.1042 |
| 2024-09-17 13:47:43 | 1.565 | 0.1043 |

### Step 3: Calculate the Time Differences

Next, we calculate the time differences between each voltage reading. The data provides timestamps, and by subtracting consecutive timestamps, we get the time intervals in **hours**.

For example:

- Between **2024-09-17 13:47:39** and **2024-09-17 13:47:40**, the time difference is 1 second or $\frac{1}{3600}$ hours.

For the first few entries:

| Date/Time | Time Diff (hrs) |
|---|---|

| | |
|---|---|
| 2024-09-17 13:47:39 | N/A |
| 2024-09-17 13:47:40 | 0.000278 |
| 2024-09-17 13:47:41 | 0.000278 |
| 2024-09-17 13:47:42 | 0.000278 |
| 2024-09-17 13:47:43 | 0.000278 |

### Step 4: Integrating Current Over Time

To find the total charge (capacity), we need to calculate the sum of the current over time. Since the current changes unevenly, we can't just multiply the current by the total time. Instead, we need to integrate the current over each small time interval.

This is done using **numerical integration**. A simple method for this is to use **Simpson's Rule**, which is a method of approximating the integral of a function by dividing it into small segments.

For each small time interval, we multiply the current by the length of the time interval:

$$\text{Capacity in Ah} = \sum(\text{Current in A} \times \text{Time Interval in Hours})$$

We then sum these values to get the total charge in **ampere-hours (Ah)**.

### Step 5: Converting to mAh

Once we have the total capacity in Ah, we multiply by 1000 to convert it to milliampere-hours (mAh):

$$\text{Capacity in mAh} = \text{Capacity in Ah} \times 1000$$

### Example for First Few Data Points:

For simplicity, let's break down a few steps with actual numbers:

1. The current at **13:47:40** is $0.1034\,A$ and the time interval between **13:47:39** and **13:47:40** is $0.000278\,\text{hours}$.

   The charge during this small interval is:

$$0.1034 \times 0.000278 = 0.0000288\,\text{Ah}$$

2. The current at **13:47:41** is $0.1039\,A$, and the charge for the interval between **13:47:40** and **13:47:41** is:

$$0.1039 \times 0.000278 = 0.0000289\,\text{Ah}$$

Repeating this process for all the data points, we sum up these small charges and multiply by 1000 to get the capacity in mAh.

### Step 6: Final Result

After applying Simpson's rule to the entire dataset (27 hours of data), the total battery capacity comes out to:

$$\text{Total Capacity} \approx 2918\,\text{mAh}$$

This is the total amount of charge the battery was able to deliver before its voltage dropped to 1.1V under a 15-ohm load.

VARTA 1.5V AA

### 1. Understanding the Setup

- **Battery:** VARTA 1.5V AA
- **Depletion:** The battery is depleted by a 15-ohm resistor.
- **Test ends:** The test stops when the battery reaches 1.1V.

Data for the test includes timestamps and voltage readings over time as the battery depletes.

### 2. Load the Data

The data contains columns such as timestamp, voltage readings, and other technical information. I focused on the two key columns:

- `Date/Time`: The time when each voltage measurement was recorded.
- `Value`: The voltage value at that point in time.

### 3. Filter Out Low Voltage at Start

Initially, there were very low voltage readings (0.001V), which didn't represent the actual start of the depletion test. These low values were excluded so that the test is analyzed only from a meaningful starting point, which in this case is when the voltage is at least 1.1V.

### 4. Calculate Depletion Time

- **Start Time:** This is the timestamp when the first meaningful voltage (≥ 1.1V) was recorded.
- **End Time:** This is the timestamp when the battery voltage dropped to 1.1V or below.

The difference between these two timestamps gives the **total time taken** for the battery to deplete. This difference was approximately **87,315 seconds**, or about **24.2 hours**.

### 5. Calculate Current

You mentioned that the battery was depleted using a **15-ohm resistor**. Ohm's Law $(I = \frac{V}{R})$ was used to calculate the current (III) at each point in the test:

- Voltage (V) is taken from the data.
- Resistance (R) is 15 ohms.

For each timestamp, the current was calculated by:

$$I(t) = \frac{V(t)}{15}$$

Where $V(t)$ is the voltage at time $t$.

### 6. Integrating Current Over Time

To calculate the total **charge** delivered by the battery (which determines capacity), we need to integrate current over time:

- The total charge is the area under the curve of current versus time. Since the current varies, we used **trapezoidal integration**, which approximates the area under the curve by summing up trapezoid areas between each pair of time points.

The formula used was:

$$\text{Total Charge (Ah)} = \int I(t)\, dt$$

Where $I(t)$ is the current at each time step, and $dt$ is the time difference between consecutive measurements.

This integration was performed using the time series data, and the result was converted to **Amp-hours (Ah)**. Finally, it was converted to **milliamp-hours (mAh)** by multiplying by 1000.

### 7. Final Capacity Calculation

After performing the integration, the total charge (capacity) delivered by the battery from ~1.5V down to 1.1V was approximately **2040.87 mAh**

### Summary of Results:

- **Depletion Time:** ~24.2 hours
- **Battery Capacity:** ~2040.87 mAh, based on the actual current drawn through the 15-ohm resistor during the test.

# PROCELL 1.5V AA

## 1. Cleaning the Data

- The raw data had some measurements where the voltage was recorded as 0V, which are illogical or noise. I removed these rows to ensure accurate calculations.
- I only kept the rows where the voltage was greater than 0.

## 2. Converting Timestamps

- The data included timestamps for each voltage measurement. To calculate the time intervals between each measurement, I converted the `Date/Time` column from a string format to a **datetime** object.
- After this conversion, I calculated the time difference between each successive measurement. This gave me the time interval in **seconds** (`Time_diff_s`).

## 3. Calculating Current Using Ohm's Law

- The battery was being depleted through a **15-ohm resistor**. Using Ohm's Law:

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

where $I$ is the current in amperes, $V$ is the measured voltage, and $R$ is the resistance (15 ohms), I calculated the current at each point of the measurement.

## 4. Calculating Charge (mAh)

- The battery capacity is the total charge delivered, and the charge at each point is calculated using the formula:

$$dQ = I \times dt$$

where $dQ$ is the charge in **coulombs**, $I$ is the current in **amperes**, and $dt$ is the time interval in **seconds**.

- Since 1 **Ah** (ampere-hour) is equivalent to 3600 coulombs, I converted the total charge to milliampere-hours (mAh) by multiplying each charge value by $\frac{1000}{3600}$.
- I summed up the charge values for each time interval to get the total capacity in **mAh**.

**5. Summing the Capacity**

- The total capacity was calculated by summing up all the small charge increments across the test period. The final total came out to **2085.52 mAh**.

**6. Calculating Time to 1.1V**

- To calculate the time it took for the battery to deplete from the start until it reached 1.1V:
  - I found the last point in the dataset where the voltage was still above 1.1V.
  - Then, I subtracted the timestamp of the first valid measurement (start of the test) from this timestamp, which gave me the total elapsed time of **1 day, 42 minutes, and 32 seconds**.

This step-by-step process led to the final results of a total capacity of **2085.52 mAh** and a depletion time of **1 day, 42 minutes, and 32 seconds**.

## DURACELL PLUS 1.5v AAA

```
# Convert the 'Date/Time' column to a datetime format and the 'Value' column to numeric
data['Date/Time'] = pd.to_datetime(data['Date/Time'])
data['Value'] = pd.to_numeric(data['Value'], errors='coerce')

# Filter out any rows where the voltage value is missing or not valid
data = data.dropna(subset=['Value'])



import numpy as np

# Calculate the time difference between each measurement in hours
data['Time_Diff'] = data['Date/Time'].diff().dt.total_seconds() / 3600  # Time difference in hours

# Calculate the current using Ohm's law: I = V / R, where R is 15 ohms
data['Current_A'] = data['Value'] / 15  # Current in amperes

# Calculate the mAh for each segment: mAh = Current (A) * Time (h) * 1000 (to convert to mAh)
data['mAh'] = data['Current_A'] * data['Time_Diff'] * 1000

# Sum up the mAh values to get the total capacity
```

```
total_capacity_mAh = data['mAh'].sum()

total_capacity_mAh
```

## VARTA 1.5V AAA

```
# Convert the "Date/Time" column to datetime format and filter rows with valid voltage readings
data['Date/Time'] = pd.to_datetime(data['Date/Time'])
voltage_data = data[(data['Value'] > 0) & (data['Unit'] == 'V')].copy()

# Calculate the current at each point using Ohm's Law (I = V / R), with R = 15 ohms
resistance = 15  # ohms
voltage_data['Current (A)'] = voltage_data['Value'] / resistance

# Calculate the time differences in seconds between consecutive readings
voltage_data['Time Diff (s)'] = voltage_data['Date/Time'].diff().dt.total_seconds().fillna(0)

# Calculate the charge (Ah) for each time segment (Q = I * dt)
voltage_data['Charge (Ah)'] = voltage_data['Current (A)'] * (voltage_data['Time Diff (s)'] / 3600)

# Sum the charge to get the total capacity in Ah, and convert to mAh
total_capacity_mah = voltage_data['Charge (Ah)'].sum() * 1000  # in mAh

total_capacity_mah
```

## PROCELL 1.5V AAA

```
# Constants
R = 15  # Resistance in ohms

# Calculate the current using Ohm's law: I = V / R (current in amperes)
voltage_data['Current'] = voltage_data['Value'] / R  # Current in amperes

# Calculate the contribution to capacity from each time interval
# Convert time differences from seconds to hours (since we need mAh)
voltage_data['Time_Diff_Hours'] = voltage_data['Time_Diff'] / 3600
```

```
# Capacity contribution in mAh for each time interval: I * dt (convert current from A to mA by multiplying by 1000)
voltage_data['Capacity_mAh'] = voltage_data['Current'] * voltage_data['Time_Diff_Hours'] * 1000

# Total capacity is the sum of all capacity contributions
total_capacity_mAh = voltage_data['Capacity_mAh'].sum()

total_capacity_mAh
```