Battery Lifetime GUI
User's Guide

1. Introduction

The Battery Lifetime Graphical User Interface (GUI) is a tool that can be used to quickly estimate battery lifetime for different battery types and different use cases. Figure 1 shows the electrical schematic of the circuit solved in the GUI. Besides estimating battery lifetime, this tool can be used to compare the three basic DC/DC converter topologies: buck, boost and buck-boost. Depending on the application scenario, that is, battery discharge profiles and type of load, the most suitable topology can then be selected.

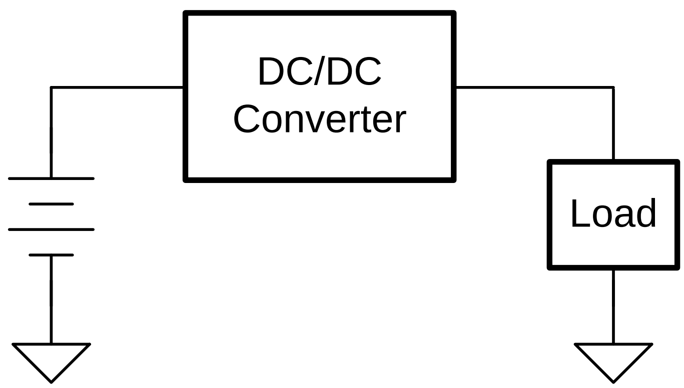


Figure 1: Electrical Circuit Solved in the GUI

2. Application Installation

The Battery Lifetime GUI is delivered as a MATLAB application. Within the .zip file, there is a .mlapp file with the source code, and the "Application" folder with a precompiled .exe file. The source code can be executed in the MATLAB's App Designer. Alternatively, if the full version of MATLAB (2020a) is not available, the user can download and install free MATLAB runtime (v9.8), and use the precompiled executable located in the "Application" folder. The correct version of the runtime and the download link is given in the readme file which is placed in the "Application" folder.

3. GUI Sections

The user interface of the Battery Lifetime GUI is shown in Figure 2. The following sections explain separate parts of the GUI, namely:

1. Main buttons function
2. Battery configuration
3. Converter configuration
4. Load configuration
5. Battery discharge curve plot
6. Results plot

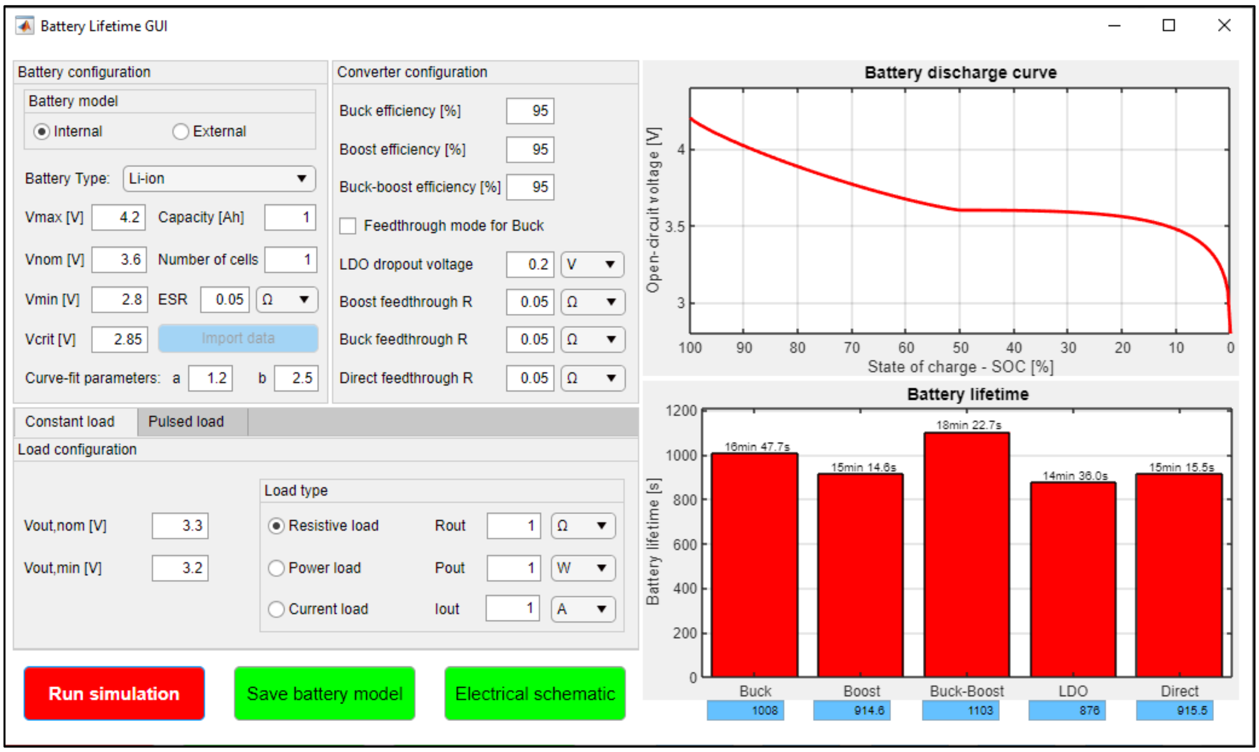


Figure 2: Application User Interface

3.1 Main Buttons Function

The main buttons shown in Figure 3, which are found at the bottom of the GUI, have the following functions:

1. **Run simulation:** When pressed, the application carries out all the computations and plots both the battery discharge curve and the resulting battery lifetime.

2. **Save battery model:** This button can only be used when the software has already compiled a battery model. Once pressed it allows the user to save the battery model into a .csv file in the form of a look-up table. The format of the .csv file is shown in Figure 4. This file format is compatible with the Keithley Instruments' Model 2281S-20-6 Precision DC Supply and Battery Simulator, thus the file can be immediately uploaded as a battery profile in the device.
3. **Electrical Schematic:** Pressing this button shows the schematic of the circuit that the GUI is simulating.

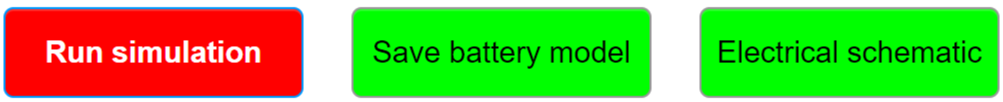


Figure 3: Main Buttons

	A	B	C
1	PW_MODEL_PW2281S_20_6		
2	Capacity=0.001AH		
3	SOC(%)	Open Voltage(V)	ESR(ohm)
4	0	2.8	0
5	1	3.1547	0
6	2	3.243	0
7	3	3.2999	0
8	4	3.342	0
9	5	3.3751	0
10	6	3.4022	0
11	7	3.4249	0
12	8	3.4443	0
13	9	3.4611	0
14	10	3.4758	0

Figure 4: Output File Format of the Exported Battery Model

3.2 Battery Configuration

In this section the user can configure the battery discharge curve. There are two ways to achieve this, depending on the selection in the "Battery model" check box:

1. By manually inserting values of typical battery specifications that can be found in the datasheet of the battery. These values are used as inputs to an internal battery model to create the discharge curve:
   - In the “Battery type” selection it is possible to select the chemistry of the cell, which loads default voltage values and shape of the discharge curve.
   - V_{max} is the open-circuit voltage of the battery at full charge.
   - V_{nom} is the nominal open-circuit voltage (usually at half charge).
   - V_{min} is the open-circuit voltage at fully discharged battery.
   - V_{crit} is the lowest operating open-circuit voltage of the battery. Note that V_{crit} should be selected so that $V_{max} > V_{crit} > V_{min}$ and $V_{crit} < V_{max}$). Once the battery voltage reaches V_{crit}, the calculation stops.
   - The capacity of the battery is in units of Ah.
   - Number of cells specifies the number of series connected cells of the same type.
   - ESR is the internal resistance of the battery.
   - If needed, the curve fit parameters “a” and “b” can be independently modified to change the shape of the battery discharge, as shown in Figure 6.

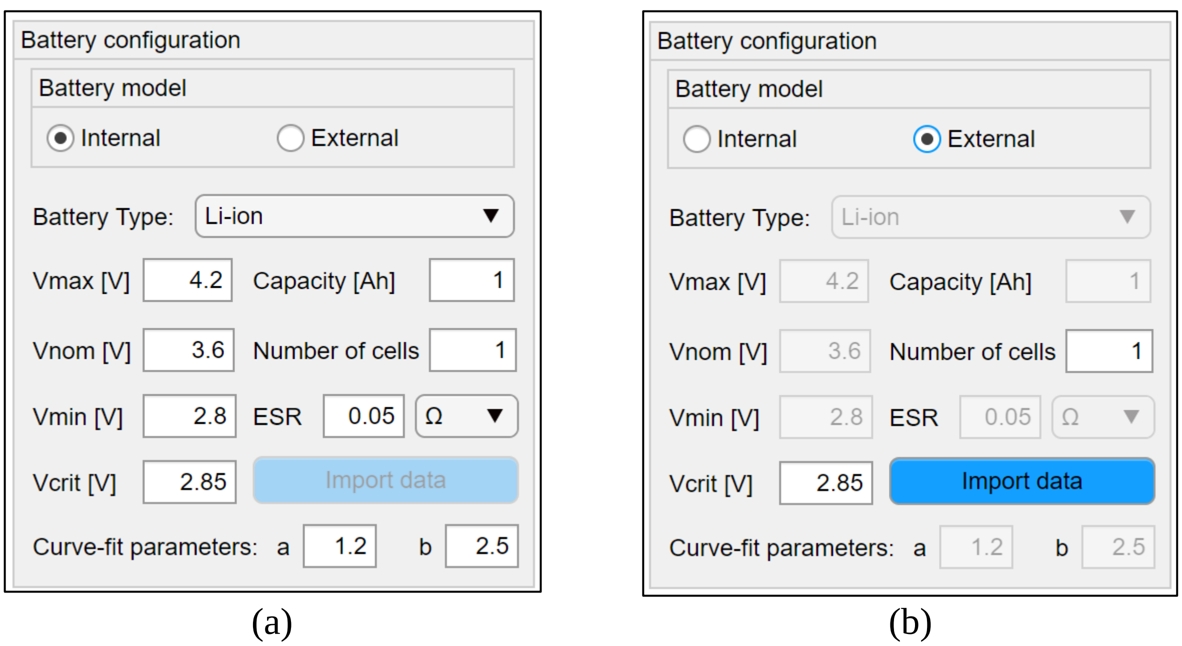


Figure 5: Inserting Battery Parameters:
(a) Manually, (b) Importing External File

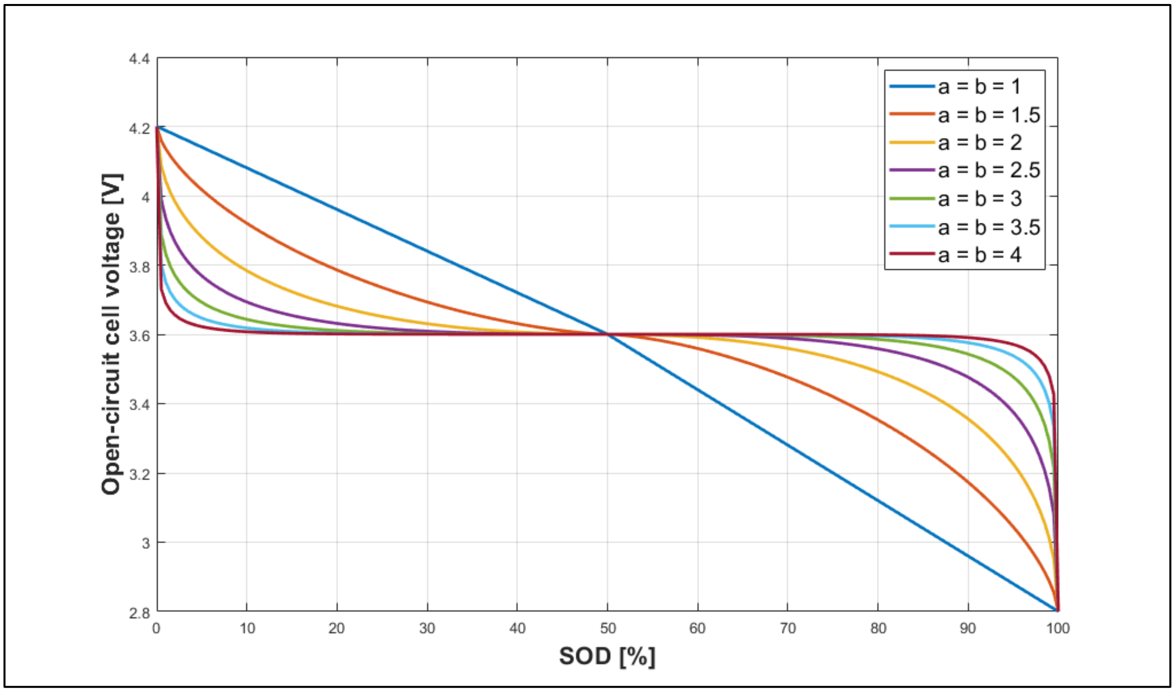


Figure 6: Battery Discharge Curve for Different Fitting Coefficients

2. Loading external battery by clicking on "Import data". Figure 7 shows the format needed to import the battery discharge curve. The number of data points is not limited. Note that V_{crit} and the number of series connected cells still have to be manually inserted.

	A	B	C	D
1	SOD_%	Voltage_V	ESR_OHM	Capacity_Ah
2	0	4	0.01	0.001
3	10	3.9	0.01	
4	20	3.8	0.01	
5	30	3.7	0.01	
6	40	3.6	0.01	
7	50	3.5	0.01	
8	60	3.4	0.01	
9	70	3.3	0.01	
10	80	3.2	0.01	
11	90	3.1	0.01	
12	100	3	0.01	

Figure 7: Format for importing external battery specifications

3.3 Battery Discharge Curve Plot

The battery discharge characteristic generated by the model or by the external data is plotted as shown in Figure 8. Note that the plotted curve shows the open-circuit voltage of the cell, not taking the battery ESR into account.

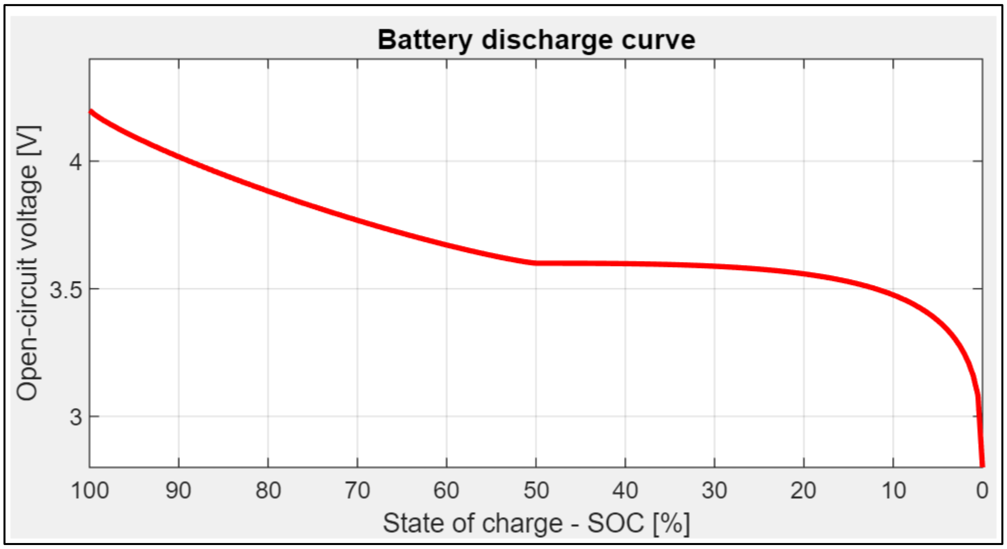


Figure 8: Battery Discharge Curve Plot

3.3 Converter Configuration

Figure 9 shows the converter configuration section of the GUI. The GUI makes calculations for three types of switch mode DC/DC converters:

- Buck
- Boost
- Non-inverting buck-boost

In addition two more configurations are considered, namely:

- Load is supplied through an LDO
- Load is supplied directly from the battery

It is possible to add a feedthrough capability to the buck converter by selecting the "Feedthrough mode for buck" option. The "LDO dropout voltage" is the minimum voltage drop caused by the LDO during its operation. "Boost feedthrough R" and "Buck feedthrough R" respectively are the resistances of the leads when the boost and buck converters are in "Bypass" mode. "Direct Bypass Resistance" is the resistance of the leads when the load is directly connected to the terminals of the battery (“Direct”).

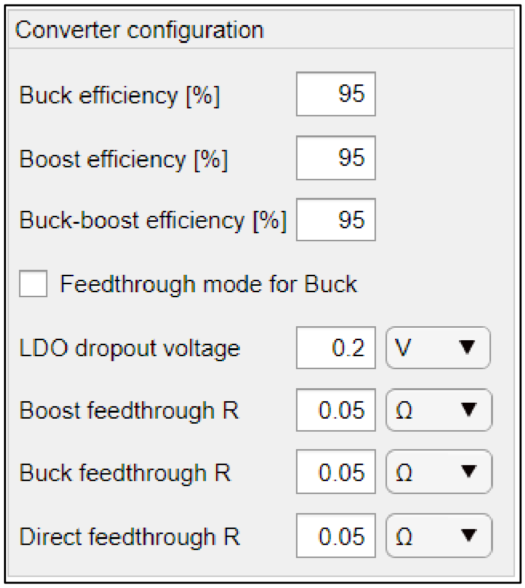


Figure 9: Converter Configuration Section

3.4 Load Configuration

This application can determine the battery lifetime for a constant load or for a pulsed current load, as shown in Figure 10. When the “Constant load” tab is selected, the load can be:

- Constant resistance
- Constant current
- Constant power

where:

- Rout is the resistance of the resistive load.
- Iout is the current draw of the constant current load.
- Pout is the power draw of the constant power load.

Vout,nom is the set/reference output voltage of the converters.
Vout,min is the minimum voltage for which the load in question can operate. Vout,min voltage is relevant for situations when the converter goes into feedthrough mode due to loss of regulation, for example when the input voltage is lower than the set voltage for buck converter. In that case, buck converter can

operate in feedthrough mode, if this option is selected in the converter configuration section. The output voltage will then follow the input voltage down to Vout,min voltage. Note the difference between Vout,min in the load configuration section and Vcrit in the battery configuration section. The time calculation stops when the battery voltage goes down to Vcrit or the output voltage goes down to Vout,min, whichever happens first.

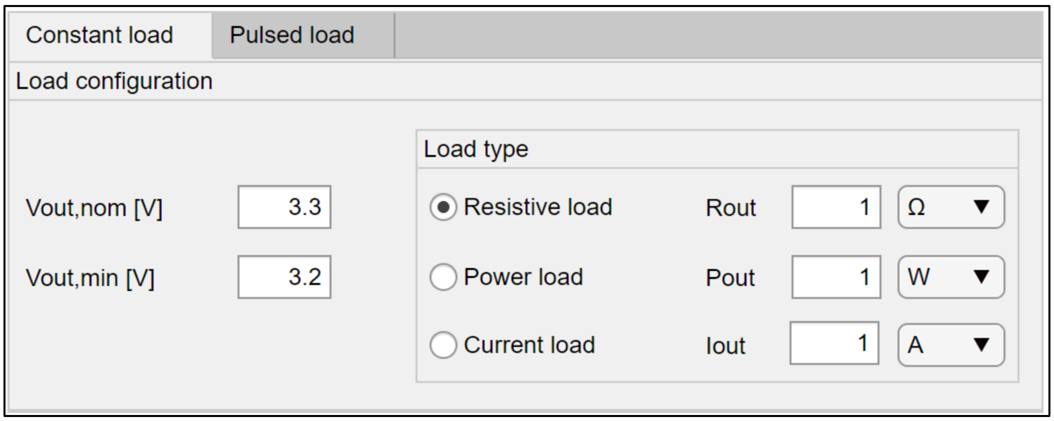


Figure 10: Load Configuration Section – Constant Load

When selecting the "Pulsed load" tab, the user can input a custom load current profile. The set output voltage and efficiency can be changed for each pulse to simulate dynamic voltage scaling. As an example, Figure 11 shows the load profile of a wireless sensor. The operating voltage of the sensor is 3.5 V during data transmission and 2.1 V during standby and measurement.

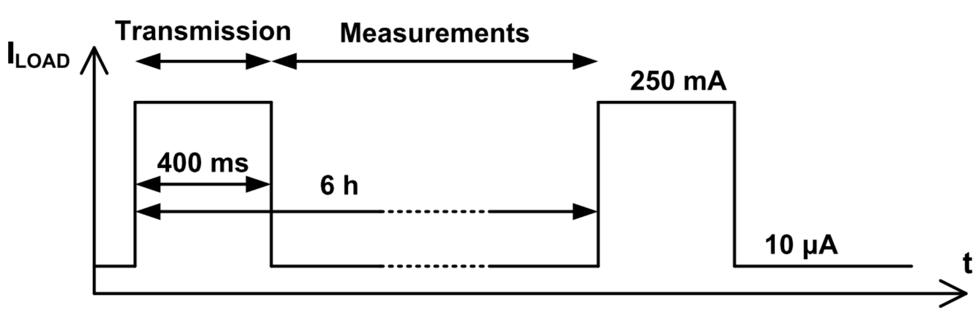
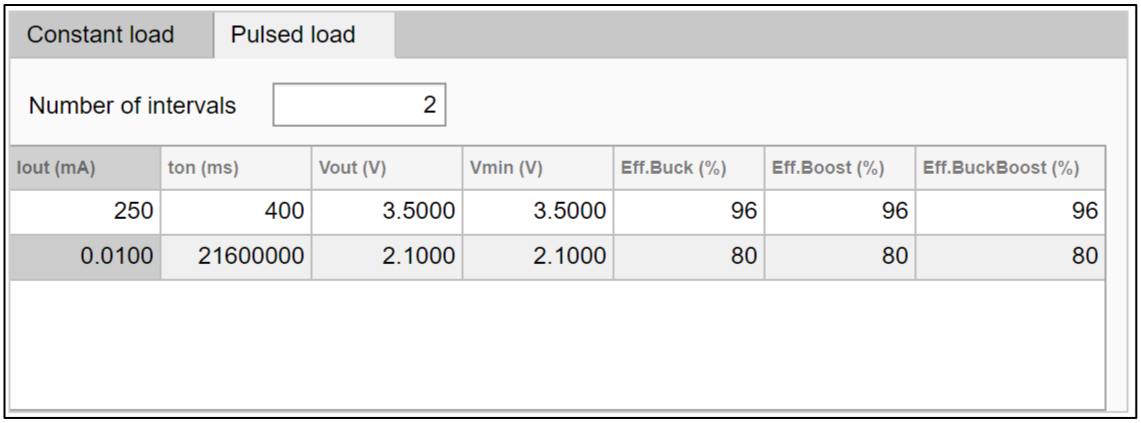


Figure 11: Load Profile of a

For this scenario, the input parameters are shown in Figure 12. Note that the converter efficiencies are also set differently for heavy load and light load conditions.



Constant load | Pulsed load

Number of intervals: 2

Iout (mA)	ton (ms)	Vout (V)	Vmin (V)	Eff.Buck (%)	Eff.Boost (%)	Eff.BuckBoost (%)
250	400	3.5000	3.5000	96	96	96
0.0100	21600000	2.1000	2.1000	80	80	80

Figure 12: Load Configuration Section – Constant Load

3.5 Result Section

The resulting battery life is presented on a bar plot for each topology, where the x-axis displays the type of the topology and the y axis is the battery lifetime. The total lifetime in seconds is also displayed numerically below the plot. Figure 13 shows the resulting battery lifetime for the default Li-ion battery settings and the pulsed load profile from Figure11. In this case, it can be seen that for this battery and load configuration, the buck-boost converter gives the longest battery life.

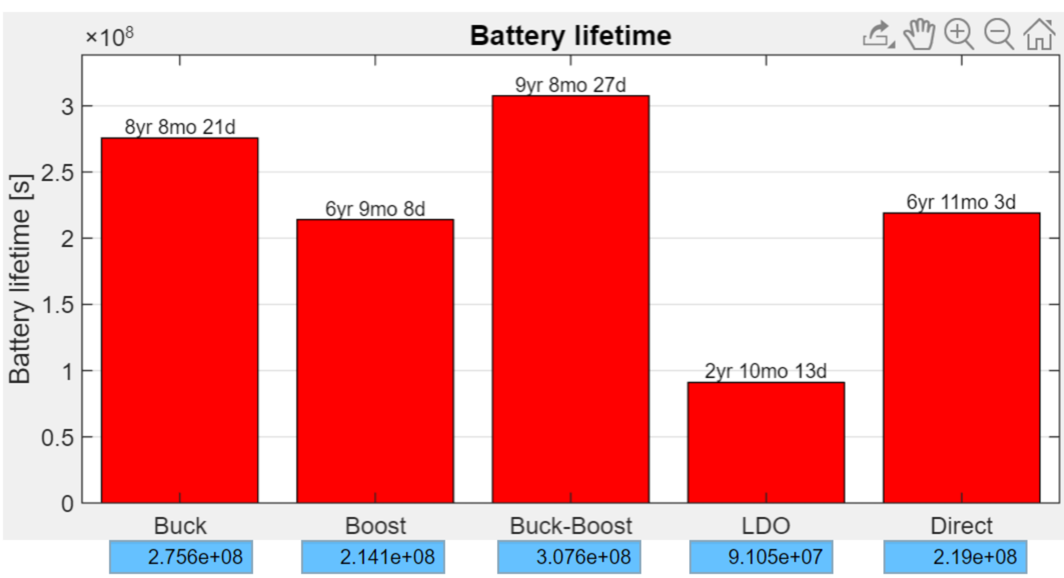


Figure 13: Battery Lifetime Bar Graph

For any questions about the Battery Lifetime GUI, reach out to:
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