

ROB-70001: Battery Fuel Gauge

User Manual



Revision History

Date	Author	Notes
10/30/2025	J. Leonard	Initial revision

Introduction

The BFG (Battery Fuel Gauge) is a simple and effective way for FRC teams to manage their collection of lead-acid (PbA) batteries. The BFG not only tracks battery state of charge, but the health of the battery as well. It monitors discharge current, current spikes, voltage dips, depth of discharge and more, 100 times a second 24 hours a day to estimate the overall health of the battery. Since the BFG is always connected it knows how hard each battery was used, how it was cared for, and can compile all that data into a simple health metric that you can instantly view from the onboard OLED display.

The BFG draws ultralow standby current and is designed to be left connected to a battery all season, for the life of the battery. When the battery is worn out, the BFG may be reset and moved to a new battery.

The onboard OLED display turns off when the battery is inactive (neither charging or discharging). The display will wakeup any time electrical current is measured, CAN traffic is detected, or after the 'Wake' button is pressed. Pressing the 'Wake' button again will cycle the display through each of it's different pages

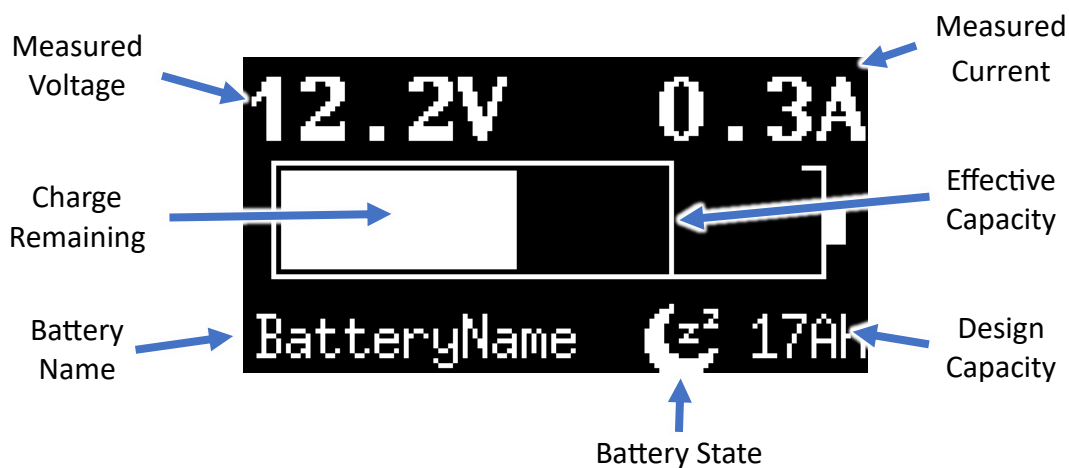


Display Pages

Home

The default page when the OLED display wakes up is 'Home'. This page is designed to summarize the state of the battery at a glance. It reports the measured battery voltage and current along with battery-shaped Charge Indicator.

The Battery Name in the lower left corner is user-configurable and can be used to uniquely identify each battery.



Parameter	Meaning
Measured Voltage	The instantaneous measured battery voltage
Measured Current	The instantaneous measured battery current. Positive numbers indicate discharge and negative numbers indicate charging.
Charge Remaining	How much energy is left in the battery considering the current RMS discharge rate. When this number reaches zero the battery may have some chemical protentional energy remaining, but it will be unable to continue delivering the same discharge current
Effective Capacity	Composite value that takes into the battery's capacity (which changes over time) and the discharge rate. The amount of energy that can be extracted from a lead-acid battery goes down as discharge current increases. This number describes how many Ah/Joules a fully charged used battery could deliver at the current RMS current
Design Capacity	How much charge a brand new, fully charged battery could deliver in Amp-hours

Battery Name	User-definable name used to identify the battery
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Battery State Image	Meaning
	The battery is actively charging
	The battery has completely charged and may be removed from the charger. The charger is either trickle charging or has entered a 'float' mode.
	The battery has not charged or discharged for a long period of time (10+ hours). The state of charge is estimated using the open circuit voltage and will update as the battery self-discharges

The 'Home' page charge indicator packs a lot of information in a small area. It primarily displays two values: the Effective Capacity (how much energy could a fully charged battery deliver) and the Charge Remaining (how much useful energy is available).

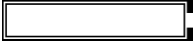
Charge Remaining is represented by the solid filled white box within the Charge Indicator and it is an absolute value (Amp-hours, not percent). The relative strength of any two batteries may be compared simply by looking at the length of this solid white box. Whichever battery has the longest white box is the battery that should be used in competition.

The second half of the Charge Indicator is the Effective Capacity. This is the white outline which surrounds the Charge Remaining box. When a battery is fully charged (or when it hasn't been used for many hours) the Effective Capacity box describes the current battery capacity – how much energy the battery could hold if it were fully charged. This capacity starts out somewhere near 18Ah and slowly gets smaller each time the battery is charged and discharged. As the battery is discharged the BFG watches the discharge rate. As the average discharge rate increases the Effective Capacity will also decrease. What this is really saying is that the faster you discharge a PbA battery, the less energy it will be able to deliver before falling below its minimum cell voltage.

Again, Effective Capacity is an absolute value (Amp-hours, not percent) and can be used to compare the relative health of multiple batteries. This becomes particularly useful when there is a mix of new and used batteries. When choosing a battery for a robot match, first choose the battery with the longest solid white line (Remaining Charge). If multiple batteries have the same Remaining Charge, select the battery with the longest white outline (Effective Capacity)

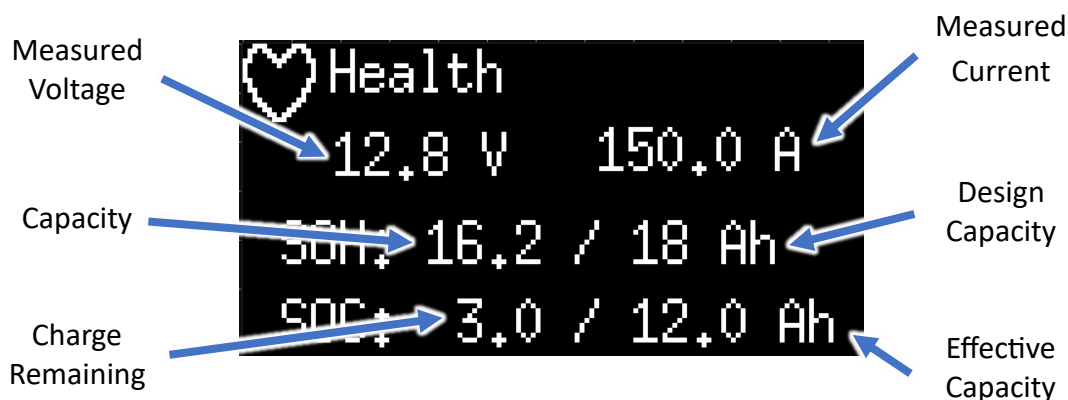
The following table provides examples and explanations of various Charge Indicator displays:

Charge Indicator	Meaning
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	The battery is fully charged and the battery can deliver at least 18Ah. In other words, it is a new battery and can deliver the full design capacity charge if the battery is discharged over a 20-hour period (0.05C).
	The battery is fully charged (because the filled rectangle is the same width of the Effective-Capacity box), but the Effective Capacity is reduced. This could be because this is an old battery and it can only store a fraction of its original design capacity, or it can mean the discharge current is high and the battery can only deliver a fraction of what it could at a slow discharge rate.
	Battery is 75% discharged. The Effective Capacity is high (this is a new battery and it is being discharged slowly), but the Charge Remaining (the filled white box) only occupies about 25% of the Effective Capacity (the white box). About 4.5Ah (25% of 18Ah) is available for useful work
	Charge remaining (filled white box) is the same as the previous example, meaning this battery can still deliver close to 4.5Ah, but the effective capacity is much lower. This is an older battery or the discharge current is high.
	Battery is about half full and could deliver about 9Ah
	Battery is empty and should be charged.

Health Page

The 'Health' page describes the instantaneous state of the battery including the measured voltage, current and estimated capacity. It provides the numeric values represented by the Charge Indicator on the 'Home' page.



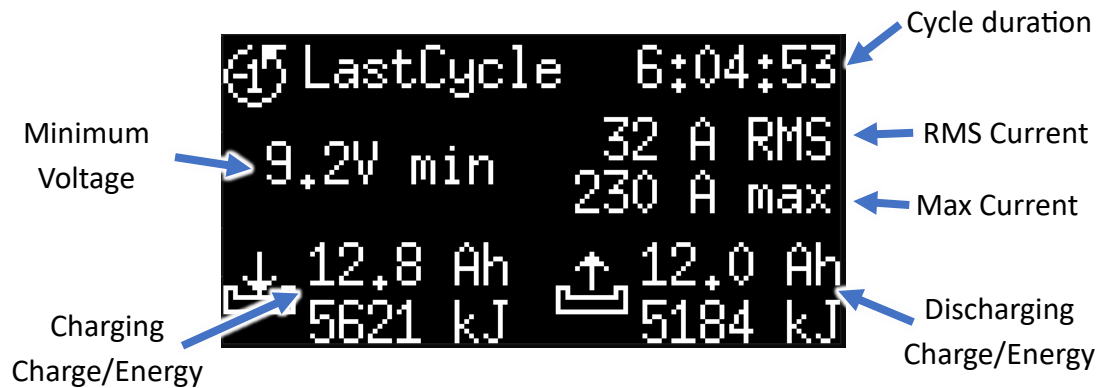
Parameter	Meaning
Measured Voltage	The instantaneous measured battery voltage
Measured Current	The instantaneous measured battery current. Positive numbers indicate discharge and negative numbers indicate charging.

Capacity	How much charge a fully charged battery could deliver in Amp-hours. This number is often larger than 18Ah for a brand-new battery and will decrease as the battery wears out. Capacity divided by design-capacity is commonly referred to as State-of-Health (SOH)
Design Capacity	How much charge a brand new, fully charged battery could deliver over a 20-hour discharge (0.05C) in Amp-hours
Charge Remaining	How much energy is left in the battery considering the current RMS discharge rate. When this number reaches zero the battery may have some chemical protentional energy remaining, but it will be unable to continue delivering the same discharge current without the cell voltage falling below the lower limit. Charge Remaining divided by Capacity is commonly referred to as State-of-Charge (SOC)
Effective Capacity	Composite value that takes into account the battery's capacity (which changes over time) and the discharge rate. The amount of energy that can be extracted from a lead-acid battery goes down as discharge current increases. This number describes how many Ah/Joules a used, but fully charged battery could deliver at the current RMS current. Effective Capacity is always less than or equal to Capacity

Last Cycle Statistics

The 'LastCycle' page describes battery statistics since the last time the battery was charged. A cycle begins when the battery is removed from a charger and begins discharging. The cycle ends when the battery is reconnected to a charger and is fully recharged.

The BFG resets each of the last cycle statistics each time a new cycle begins.



Parameter	Meaning
Cycle duration	Time in hh:mm:ss since the battery began discharging this cycle. In other words, if the battery was fully charged and then set on a shelf for a week, this number will not begin increasing until the battery is connected to a robot and begins discharging.
Minimum Voltage	Minimum battery voltage since the start of the cycle (since the battery was last fully charged). This number is useful for diagnosing brown-outs.
RMS Current	RMS average of the measured current since the battery first began discharging. The RMS current takes the square of the measured current, then integrates it. This means this average is weighted more heavily to large current spikes and can be used as an approximation for how 'hard' the battery was discharged.
Max Current	Maximum discharge current measured since the start of the cycle
Charging Charge/Energy	How much energy was put into the battery since the start of the cycle
Discharging Charge/Energy	How much energy was extracted from the battery since the start of the cycle

Last Match Statistics

The 'Match' page describes battery statistics during the last robot match. The match start and end times are estimated by monitoring the battery discharge current. Matches begin when the discharge current exceeds 1A. Matches end when the discharge current is less than 1A continuously for two minutes.



Parameter	Meaning
Match duration	Time in hh:mm:ss since the match began.
Minimum Voltage	Minimum battery voltage since the start of the match. This number is useful for diagnosing brown outs.
Voltage at start of match	Measured battery voltage when the match started
RMS Current	RMS average of the measured current since start of the match.
Max Current	Maximum discharge current measured since the start of the match.
Discharging Charge/Energy	How much energy was extracted from the battery since the start of the cycle

Battery Lifetime Statistics

The battery 'Lifetime' summarizes the battery history. It describes the battery age in days, number of charge/discharge cycles, as well as the minimum battery voltage. Each of these numbers can help in determining when it is time to recycle and replace a used battery.



Parameter	Meaning
Battery Age	Time in days since the battery
Number of cycles	Number of complete charge/discharge cycles since the battery was new. This number does not necessarily increase for partial charges. The battery must be fully charged to increment this count.
Battery Manufacturer	Selected battery manufacturer. Used to fine tune the state estimation model for a particular battery
Battery Design Capacity	Battery design capacity for a new battery. This number is always 18Ah for FRC legal batteries.
Minimum Voltage	Minimum battery voltage over the life of the battery
Maximum Discharge/Energy	Maximum energy which was extracted from the battery during any cycle