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White paper on battery backups for vehicles.

Overview

Battery backups are used when loss of power would cause trouble with the system. Primary electrical power in a vehicle consists of the alternator and the SLI (starting-lights-ignition) battery. Loss of power in a vehicle can mean that the SLI battery is missing or has failed, or that a "brown out" has occurred exposing equipment to lower than required voltage. For example:

Stolen battery. When the SLI battery is removed or disabled the alarm system or Lowjack system is disabled unless an backup is provided.

Engine cranking. When the starting motor is engaged the high currents needed causes the system voltage to sag into a "brown-out." A battery backup can switch to an auxiliary battery during cranking to prevent critical equipment from experiencing failure or damage.

Extended run time. If the vehicle's electrical bus is turned off the battery backup can keep computers and video equipment alive for data upload or continuous security.

Switching errors and noise spikes. Sensitive equipment can be protected from spikes and dropouts during electrical problems.

Accidents. A collision could disable the SLI battery, whereas a battery backup located somewhere else in the vehicle could keep communications and cameras alive.

What equipment might need to be backed up?

Alarm systems and LoJack GPS
Dash cams
Video Recorders
Computers
Radios
Cradle Points, modems and routers
Computers
Point of sale units and fare pillars
Instrumentation for testing, monitoring and troubleshooting

Engine cranking

The electrical system of vehicles is designed to have a trade-off between the high current needed for starting the engine and the battery cost and weight. The battery is chosen to be lightweight and inexpensive, but still be able to start the car. Figure 1 is a trace of the voltage and current of an SLI battery as a 4-cylinder engine is started.

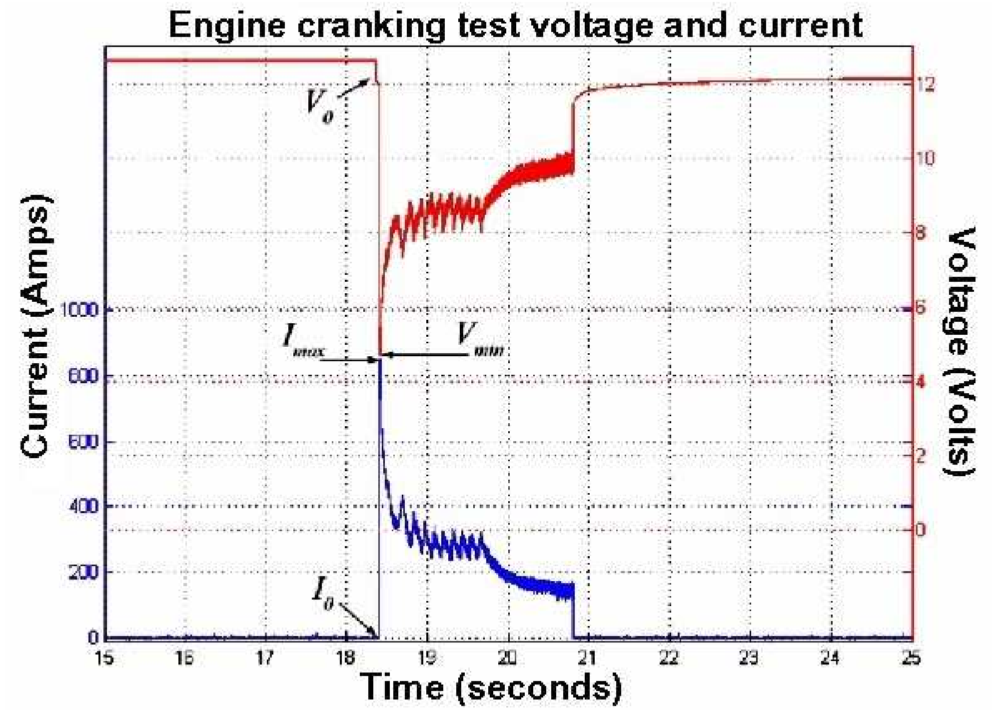

Figure 2. The current and voltage during engine cranking of a 4-cylinder engine.

Several interesting features can be seen here. When first energized the motor is stalled, and the field coils need to be energized. This requires over 650 amps to flow into the motor. This is higher than the current would be in a locked-rotor condition while the magnetic field builds up. As the motor starts to rotate the current quickly drops to about 400 amps. The current then pulses, reaching a peak every time one of the cylinders reaches top dead center under compression. As the engine begins to fire the speed increases and the current drops until the starting motor is disconnected from the battery. The time to start the engine is about 2.4 seconds, and the total charge drawn can be estimated to about 0.25 amp-hours. The energy lost by the battery is 3-5 watt-hours.

During the actual engine turning the starting motor is consuming about 3200 watts.

The blue curve shows that the battery voltage mirrors the current during the test. It starts at about 12.4V When the solenoid is engaged the voltage drops to about 4.2V, then recovers to about 8V during the actual cranking. By the time the engine is running it gets up to 10V. Then when the solenoid is released the battery raises to 12V. (The alternator is not connected in this test.) The total resistance of the system, including battery internal resistance, wire, solenoid and starting motor is calculated to be about 0.01 ohms.

It is this voltage sag that can cause equipment to crash during starting. There is also a considerable amount of low frequency electrical noise while all this is happening. So a battery backup that will switch to a steady, clean power source during engine starting can prevent equipment crashes and extend equipment life.

Extended run time after the power is turned off.

In some fleets it is standard procedure to switch the SLI battery off, so that it is not drained while the vehicle is stored overnight or longer. This keeps any equipment or lights that are left on from draining the SLI battery. But this procedure also prevents data uploading, alarm systems, and security cameras from continuing to function. A battery backup can provide power for these functions without compromising the SLI battery.

Battery backups

PowerStream battery backups are designed to keep your equipment from losing power or rebooting during engine start-up, in buses, cars, and other vehicles. This ensures these spikes and sags in power don't shorten the life of your mission critical electronics. We do this by providing uninterrupted, clean, consistent power to your equipment, extending the life of your electronics.

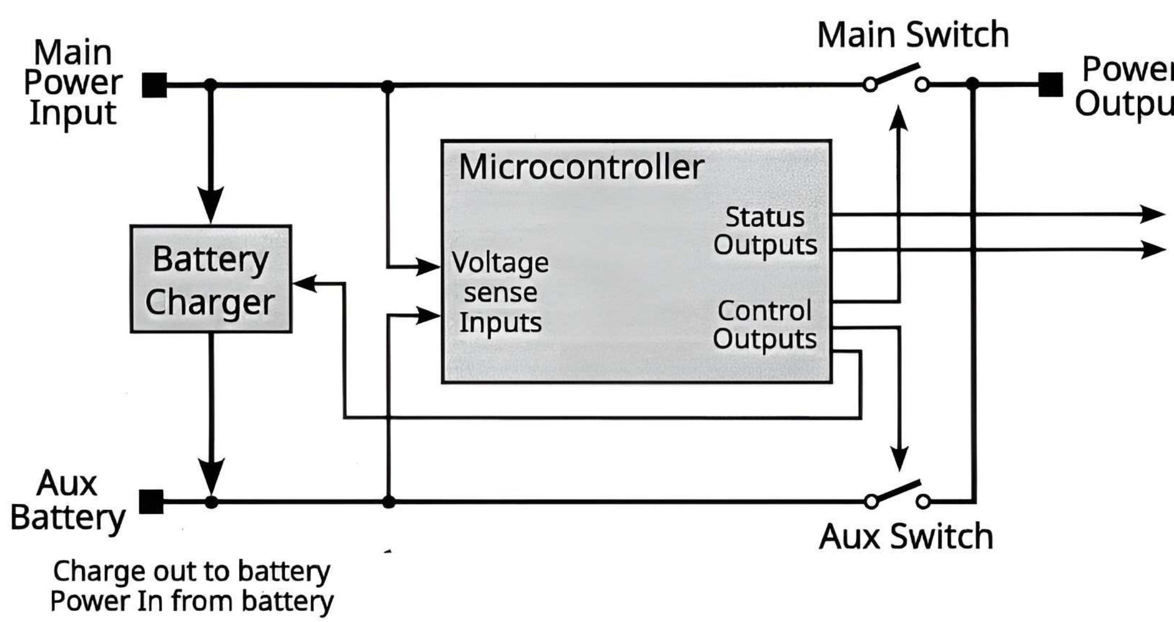

Figure 3. Block diagram of the PowerStream battery backups.

Theory of Operation

Figure 3 shows the basic block diagram. In order to keep from running an extra wire to the ignition the microprocessor monitors the voltage on the vehicle's electrical bus. This lets it determine when the engine is running. It decides whether to switch the load to the main vehicle power or to the auxiliary battery based on these voltage levels.

In addition there is a built-in battery charger that controls how much power is being diverted to charge the auxiliary battery, and allows the auxiliary battery to be charged even if the input voltage is too low by boosting the voltage when needed. This is a smart, accurate charger that cannot overcharge or damage the auxiliary battery.

The backup prevents your equipment from running the vehicle's battery down, avoiding jump-starts. It switches over to the auxiliary battery when the engine is shut off and the alternator stops or the car's or bus's battery drops below 11.8 volts. This means you never have to worry about that after-market equipment leaving you with a dead battery in the morning.

The backup also isolates its internal battery so it won't try to participate in the engine cranking process.

Using microprocessor control allows us to tailor the switch-over voltages for various applications.

Explanation of the available set points

Parameter	Description	Range*	Standard value	
N Main off	Sets the voltage for switching to the auxiliary battery		13.1V	Decrease to allow the vehicle battery to run the load longer. Increase to prevent oscillation.†
P Aux off	Sets the voltage at which the auxiliary battery is turned off to protect it from over discharge	6V to 12V	10.5V	Decrease to allow more run time with possible battery degradation.
Main On	Sets the voltage at which the load is reconnected to the vehicle battery.	12V to 14V	13.5V	Increase to prevent oscillation.†

Charge On	The voltage at which the controller will start charging the auxiliary battery	12V to 14V	13.5V	Must be greater or equal to Main On. Boost converter allows the battery to charge even with the alternator off.
Charge Off	The controller will stop charging the auxiliary battery when the voltage at the Main Input falls below this value. Charge Off must be greater than Main Off or the charger will turn off when the Main Off is triggered.	11V to 14V	13.1V	Decrease if you typically need more charging time while the engine is off.
Aux On	The only way to restart the controller when the unit is shut off due to low auxiliary battery voltage is to raise the MAIN voltage above "MAIN ON" or to increase the auxiliary battery voltage above AUX ON. This can be done by using a battery charger or swapping out the auxiliary battery.	10.5V to 12.9V	12.5V	Increase this setting to prevent oscillation.†

* Typical ranges. Can be extended for special requirements.

† Oscillation can occur when the load is disconnected. Releasing the load causes battery voltage to bounce up, reconnecting the load causes the voltage to sag down. If there is not enough hysteresis this can cause oscillation.

Examples of set points in applications:

Application: Main Input is Vehicle 12V Power. Function is to prevent cranking or dropouts from effecting connected equipment		
Setpoint	Value	
Main On	13.5	Typically a vehicle bus voltage is above 13.8V. A fully charged 12V lead acid battery has an open circuit voltage of 12.9V. A Main on voltage of 13.5 ensures that we know the vehicle is running, even if under heavy load.
Main Off	13.1V	If the main voltage is less than 13.1V the engine is assumed to be off. If you want to run the load from the Main battery after the engine is off you can lower this value. Keep it above 11.8V to make sure the engine will start.
Charge On	13.5V	In this case the charger will start at the same time as *Main On.*
Charge Off	13.1V	The charger will turn off when the voltage falls to *Main Off* or *Charge Off*, whichever is higher. There usually isn't a reason to increase this value when the controller is used in a vehicle.
Aux On (Aux Reset)	12.6V	This is the voltage at which the load will be connected to the auxiliary battery after the controller has turned off due to *Main Off* and *Aux Off* being reached and a new auxiliary battery or separate battery charger (with enough current to supply the Load) has been connected to the auxiliary terminals. Open circuit voltage of a fully charged battery is 12.9V, but the *Aux On* value can be lower, as long as it is not so close to *Aux Off* to cause oscillation.
Aux Off	10.0V	At this voltage the battery is typically empty and allowing the battery to go much lower would damage the battery.

Application: Main Input is a 12V vehicle. Keep alarm system or video recording alive as long as possible.		
Setpoint	Value	Unit With the Main Input Connected by short leads to an Unregulated 12 Volt Power Supply and the Aux Input is connected by short leads to a Sealed Lead Acid Battery (Set points are dictated by the minimum voltage allowed on the output, which in this case is set to 10V which is also the turn off point for a standard SLA battery.)
Main On	13.5V	Typically a vehicle bus voltage is above 13.8V. A fully charged 12V lead acid battery has an open circuit voltage of 12.9V. A Main on voltage of 13.5 ensures that we know the vehicle is running, even if under heavy load.

Main Off	11.8V	Leaving the vehicle batter 11.8V ensures the engine can be started.
Charge On	13.5V	Charges when the alternator is running
Charge Off	13.1V	No need to charge the auxiliary battery when the alternator is off line.
Aux On	12.8V	High AUX-ON value prevents oscillation when the auxiliary battery is fully discharged.
Aux Off	8V	In this application keeping the power on as long as possible is more important that preserving the life of the auxiliary battery.

Application: Main Input is Vehicle Power. Long wires or small AWG gives large voltage drop when the load is connected.		
Setpoint	Value	
Main On	TBD	The setpoints in this application require some engineering, since the load current and wire resistance will determine what is needed for a stable system.
Main Off	TBD	
Charge On	TBD	
Charge Off	TBD	
Aux On	TBD	
Aux Off	TBD	