Complete 12V Automotive Electrical System using a Lithium Ion Battery

John Santini
VP Engineering, TDI Power

Historically, automotive electrical systems have been based on lead-acid battery technology. Until the 1950's, electrical systems were typically powered by 6V lead acid batteries, and then during the 1950's, they transitioned to 12V electrical systems. These systems are a nominal 12.6 volts DC with no current being drawn. Once the engine is running however, the voltage rises to approximately 14 volts. For the most part, the voltage is always at the 14 volt level whenever the vehicle is operational. The one area where this may not be maintained is with the engine idling and a heavy accessory load. In this situation, the load may exceed the alternator output and the battery may be called upon to supply the difference for a short period of time.

The goal of this project is to develop a 12V auxiliary electrical system for an electric vehicle which supplies 14 VDC under all conditions, which has the required battery backup to keep key vehicle systems "alive" when the vehicle is off, and to convert power from the traction battery to the 12V auxiliary system in the most efficient manner possible, under all operating conditions. The key features are as follows:

- Small DC/DC converter operates at high efficiency during periods of low power draw, also keeps the battery topped off.
- Large DC/DC converter sized for maximum steady state power requirements
- Built-in Lithium Ion battery for 14V energy storage, and to supply transient energy peaks
- Sealed system requires no maintenance and can be located anywhere in the vehicle.
- Power distribution built in, with "smart" current limiting to disconnect shorted or overloaded zones,

The small DC/DC converter is sized to be able to provide the required 14V power under the most common operating conditions. It's smaller size allows it to operate near peak efficiency all the time. Conversion efficiency is never below 90%, because the converters are all off when the current draw drops to standby levels, and the battery supplies the energy, which would be the case when the vehicle is parked. When the battery needs recharging, the converter turns on and charges at full power, assuring high conversion efficiency. The converter then shuts down until the load increases (as when the vehicle is driven). It will also replace any energy removed from the battery during momentary current peaks or surges which exceed the small DC/DC converters output rating, before the other DC/DC converters start.

This system includes a long life Lithium Ion battery in place of a conventional Lead-Acid battery. The reason for this is because a normal "12 volt" electrical system operates closer to 14.5 volts when the engine is running. A 4 cell Lithium Ion battery will have a "full charge" voltage of approximately 14.6 volts, and start supporting intermittent loads at approximately 13.2 volts, which is ideal for the automotive electrical system. Because of the "standby" nature of the battery useage, this battery is projected to last over 10 years, or the life of the vehicle. It will always be kept fully charged (>75%) and should not be subjected to excessive heat. The sizing of the Lithium Ion battery in an electric vehicle is solely to provide energy storage for pilot circuitry which must remain powered up while the vehicle is off, and to power the emergency flashers in the event the vehicle becomes disabled. With the move to LED marker lights, the load of the flashers is much lower than it was previously. The typical flasher load is less than 1 amp, and the flasher duty cycle results in an average current draw of less than 0.5 amps.

A typical current budget for an electric vehicle is typically less than a gasoline or diesel powered vehicle. The engine requires significant 12V power for the fuel pump and ignition., which are not needed in an electric vehicle. Also, high power loads such as the heating, air conditioning and power steering are typically powered directly from the traction battery. The various loads represented by different driving scenarios are listed below. Realistically, the "cold snowy night" scenario is still pretty extreme because it has both hi beams on as well as wipers on high speed, but it probably represents pretty much the "worst case" loading scenario lasting more than 10 seconds.

Item	sunny / clear	hot / sunny / clear	night / clear	night / cold / snow	momentary worst case
Vehicle computer	1.1	1.1	1.1	4.2	4.2
Interior lights	0	0	1.4	1.4	1.4
Cabin air blower	4.2	12.8	4.2	21.5	21.5
Brake lights	0.1	0.1	0.1	0.1	0.1
Headlights (lo beam)	0	0	11.1	0	0
Headlights (hi beam)	0	0	0	13	13
Marker lights	6.4	6.4	6.4	6.4	6.4
Windshield wipers (high)	0	0	0	18	18
Radio	2	2	2	2	5
Horn	0	0	0	0	7
Heated seats (6A ea)	0	0	0	6	12
Rear window defroster	0	0	0	20	20
Power door locks	0	0	0	0	8
Power Windows (15A each)	0	0	0	0	60
Anti-lock Brakes	0	0	0	0	20
Coolant pump	3	8	3	3	3
Cooling fan	4	10	4	0	0
Totals:	**20.8**	**40.4**	**33.3**	**95.6**	**199.6**

Typical EV Auxiliary Loads (amperes)

As can be seen in the above table, there are a number of loads which can all be on together, which results in a very high peak current (approximately 200amps). Loads like anti-lock brakes, power windows and power door locks are only momentary loads, and can easily be supported by the battery if necessary. Much more realistic loads would be those in the first 3 columns. These loads represent driving in hot and cold weather, day and night.

The unit also includes a power distribution panel. The function of this panel is to serve as a conventional "fuse block". All circuits are protected by solid state current limiting, so fuses will not need to be replaced in the event of a short or an overload. Blinking LED's indicate tripped circuits. Recycling power from the keyswitch resets all tripped circuits and performs a system "retry".

System Block Diagram