

Several new electric vehicle controllers have been introduced or are about to be introduced into the market, and I thought it might be a good idea to chronicle the differences in several controllers that are among the common choices for EV users. First, let me confine my discussion to DC controllers for now.

Discussion

The Curtis line of controllers is a well known, commonly used controller, but with very modest performance for normal sized cars and small trucks. It can be useful in limiting the energy used per mile, as it cannot deliver huge amounts, and therefore might be useful in achieving maximum range. The Raptor controller is a durable unit, but does not have the newer interfaces, and must be used with a 0-5K pot box. It appears to be priced with competitors with many more features.

Moving up the controller scale, next would be the the LogiSystems controllers. They make a great controller, placed in between the high end Zillas and WarP-Drives and the lower cost Curtis line. These LogiSystems are well built, very reliable, and have reasonable cooling to keep them operating smoothly. They are available as LogiSystems branded with plain aluminum cases, with heat sinks and fans.

Soon to be introduced is the MaxForcer SL (SL - street, low voltage) which is a feature rich controller designed for typical street conversions with battery systems of 156V or less, and providing healthy 1000 Amps. Future models will include SH and RH (R - racing) with voltage ratings in the 350 V range. It can be wired in as simple as Curtis and Logisystems controllers, however, it has extra inputs for motor temperature and speed sensor, and outputs for main contactor coil, tachometer and a dash light. The default configuration provides smooth and silent operation, although various parameters such as motor current limit, motor voltage limit, battery current limit, rpm limit, battery voltage sagging limit, accelerator response are user-programmable via included serial cable and RS232 or USB connection. Battery current limit and sagging control capabilities are especially useful for battery protection and extended range. The serial connection also provides streaming data that includes motor and battery current and voltages, controller and motor temperature, watt-hours, rpm and more. The data can be copied into an Excel spreadsheet and graphed.

At the upper end of the controller spectrum (in price and in performance) are the Soliton 1, the Zilla and the WarP-Drive. The Soliton 1 can be air cooled by it's fins and fans for most uses, but liquid cooling is accommodated. Liquid cooling on the Soliton 1 is optional as the heatsink has 1" tall fins and twin fans which do a pretty good job of keeping the controller cool even when pushed hard. If your need is 1000A for more than 15 seconds, and/or more often than every

90-120 seconds, then liquid cooling is suggested. For example, air cooling the controller tends to reach an equilibrium temperature of 60-65C when driving down the highway for extended times at 75mph (55kW). Soliton 1 makers pride themselves on the concept that the 1000A rating is not just for short time periods. Their testing shows 1000A for up to 15 seconds without liquid cooling, even longer with appropriate cooling.

The WarP-Drive and Zilla are realistically liquid cooled, available with at least 1000 amps, and in higher voltages for better performance. Soliton 1, Warp and Zilla all can have extremely quiet operation. It may be possible to hear a cooling fan, if installed, or the coolant pump, but only if the area is open to the listener. If they are in a closed area, like a closed hood, the fan and pump are not audible. The Soliton 1 has a minor controller whine, but this can be eliminated by changing the frequency to an inaudible range, with a very small loss in power. (OK, so I am hearing impaired, I can't hear them, even with a hearing aid.)

Both the Zilla and the WarP-Drive can be purchased with upgrades for higher voltages and for higher amperages. The Zilla needs to be built with the higher voltage or amperage in mind, where the WarP-Drive can be upgraded by the dealer or the end user through software. An interface module (IM) may be purchased or rented from WarP-Drive dealers to accomplish the upgrade. It is somewhat comforting to know that the base WarP-Drives are built with much more capability, and are only needing a software 'unlock' to have more power run through it. The purchaser knows that the physical build of the WarP-Drive already has the upgraded components inside the case. The Soliton 1 can be increased from 1000 amps to 1400 amps for racing (and used for short periods only!) This requires manufacturer's approval of a special racing application, and acceptance of a special racing warranty. Soliton 1's upgrade path is simple, using a computer connected with an ethernet cable. Either a standalone program can be used for updates, or you can use a web browser to interface with the data in the Soliton 1.

Zilla low amperage connections are made through a Hairball, which can be purchased in pot box compliant form or in a form to take a Hall-effect sensor. Hall-effect sensors have better longevity, but are somewhat more costly at first. The WarP-Drive can only be controlled by a Hall-effect sensor, either a pedal or a pot box style replacement. WarP-Drive low amperage connections are made with water resistant, automotive type, plug in connectors. Soliton 1 low amperage connections are made by screw in connectors on a terminal strip behind a plastic cover.

Most Hall-effect sensors (pedals and assemblies) were designed to use two signals. In most automotive applications some checking is done to assure both signals indicate a similar demand, for example, acceleration. In the best EV controller systems, if the two channels appear to disagree on the request, an error code is generated. It has been determined that the WarP-Drive controller does this checking, not just on initiation, but through the entire range of pedal operation. Soliton uses an optional brake input to their logic, but it is unclear if they also use

both signals from a Hall-effect sensor.

The Zilla's Hairball has some interface for tachometer sensors, and is extremely configurable, although the basic configuration, as shipped, is close to a perfect compromise on settings. The WarP-Drive also has significant communication abilities. It has the ability to log data (including voltages, amperages, and throttle position data) to an SD card (Secure Digital). This allows the user to collect large amounts of data, and to remove the stamp-sized card and read it with their desktop computer. This data can then be extracted and graphed, and the many data points can easily be distilled into summary data. It is not necessary to bring a computer to the vehicle to download data. The WarP-Drive has several signals on an industry standard CAN bus that can be extremely useful. Current information on the CAN bus is a battery amps, motor amps, system voltage, controller output effective voltage, controller temperature and more. Future implementations will have GPS abilities, tachometer and speedometer output, battery state of charge, etc. Soliton has an ethernet port for data logging, built in web browser interface for settings and updates (only in Windows with DHCP turned on) Other computer configurations (Windows without DHCP, Mac, Linux) may be used with several system setting changes.

The Belktronix system is difficult to compare to the other controllers. It includes a controller, a battery management system for PbAc or LiIon, a 675W DC-DC converter and a charger, all packaged together. Available in 500 amp versions, or 800 amp versions, it is intended for systems with a maximum nominal voltage of 156 volts. An option on the larger charging system is a dual 120VAC input, for charging at 1200W on each AC input. This would come in handy for charging at work, using 2 outlets (would be harder to get a dedicated 240VAC outlet). It is an interesting design that integrates charging and battery management along with the controller functions, which is a logical way to approach the whole picture. We know that other major controller manufacturers are planning to add the charging to their controller in the near future, but this appears to be the first on the market.

See chart on following page.

Objective Data	LogiSystems®	Raptor®	Curtis®	Soliton 1 ®	Zilla®	Warp-Drive®	MaxForcer SL	Belktronix®
Voltages	72-120V, 120-144V*, 144-156V*	up to 156	up to 144*	300V(actually up to 342V)	up to: 156V*, 300V*, 348V*	up to 160V, 260V, or 360V, may upgrade later	48-156V operating at up to 200V	120-144V (up to 185V charge limit)
Amperages (Maximum - short spurts)	550 Amp*, 750 Amp*, or 1000 Amp*	1200 Amp	up to 500 Amp*, up to 550 Amp*	1000 A liquid cooled, 1400 A w/ racing agreement	1000 Amp*, or 2000 Amp*	Up to 1000, 1200 or 1400 A±	1000 Amp	500 or 800 Amps (500 Amps for 3-5 minutes)
Main Connects	End	End	End	End	End	Top	End	End
Throttle input	Special Pot box (0-5K) (included with LogiSystems)	0-5K Pot	0-5K pot	0-5+V source, or Hall-effect. May use Curtis type pot box if rewired with pullup resistor	Hairball can be wired for either Pot Box, or Hall-effect at time of order (Hall-effect \$30 more)	Hall-effect Water resistant connections.	0-5k pot, 0-10k pot, (Future-Hall- effect planned)	Mechanical plunger /optical pickup
Other Inputs	none	none	none	Tach Brake and Reverse input , can limit overspeed, or idle motor for Auto. Trans.	Tach input	CAN bus, water resistant connections. none yet, but planned.	Tach input, Motor temperature monitor input	Vehicle integration module
Style of Lo Amperage Connects	1/4 inch spade terminal	1/4 inch spade terminal	1/4 inch spade terminal	Screws on terminal blocks, covered	Hairball with screw clamping terminals	Automotive type push on, Water resistant connections.	¼ inch spade terminal	Protected ¼ inch spade terminals
Key Switch Interface	Needs Pack Voltage	Needs Pack Voltage	Needs Pack Voltage	12V only	Uses 12V signal from key	Uses 12V signal from key and start circuit	Pack voltage	24 Volt from part of pack. Vehicle Integrator uses start and run connections from vehicle wiring harness.
Need for precharge resistor	Not essential. Suggested by some.	Mfr. Claims not needed	Yes, not included	Built in	Built in.	Built In	Yes	Internal to Vehicle Integrator.
Additional interface	No	Trigger of main contactor. Remote display avail.	No	3 programmable outputs for driving 12V nominal and < 1A	Tach sensor output and other functions in Hairball	CAN bus, data logging, tach, pack V, motor/batt A, controller temp, and more.	Trigger of main contactor, remote dash light output, tach output, motor temp. input, Data logging	Vehicle Integrator sequences DC-DC, softstart, main contactor, cooling fan and controller enable
Cooling	case heat sink and fans	Air	case heat sink	Liquid or air, both built in.	Liq. Cooled, not included.	Liq. Cooled, not included	air or optionally liquid (not included)	Heat sink and larger fan
Absolute maximum wattage	156 kW	187 kW	72 kW	< ≈342 kW **	696 kW	504 kW	156 kW	72kW, 115kW
Maximum Wattage of Common unit	117 kW (156V 750A)	187 kW	72 kW	< ≈ 342 kW	156 kW	160 kW	156 kW	72KW

Power reduction with higher controller temp.	No	No	Yes	rate of 2.5%/°C above 55°C	Yes	Yes	Yes	Yes
Silent Operation	Quiet fan noise	Internal fan, quiet fan noise	Controller whine at low throttle	Adjustable 'whine" to inaudible, very quiet	Quiet fan and pump	Quiet pump, may have quiet fan on radiator,	Quiet Fan or pump	Quiet fan. PWM @ inaudible 14khz
Retail Price	\$1,200 - \$1,800	\$2,600	\$1,400 - \$1,600	\$2,895- \$3,275	\$1,975 - \$5,075	\$1,950 - \$4,350	1,800 - \$2,000	Hard to compare, system includes battery monitors and charger. Also, 675W DC-DC included in charger enclosure 120V PbAc system \$2150 up to 144V LiIon system \$2890

Other Data	Logi-Systems®	Raptor®	Curtis®	Soliton 1®	Zilla®	Warp-Drive®	MaxForcer SL	Belktronix®
Connection Placement	End	End	End	Top	End	Top	Unk	End
Water resistance of connections	No	No	No	Some	No	Almost water proof, certainly water resistant.	Unk.	No
User data output	No	No	No	Some, ethernet port	Some	Ethernet port, CanBus, writeable SD card with CSV data	unk	unk
Safety of throttle (Redundant system)	No	No	No	Brake input overrides controller.	No	Monitors two Hall-effect channels.	Unk	unk
Microprocess or error in controller	Untrapped	Untrapped	Untrapped	Some trapping	Unk	Good trapping	Unk	unk
Errors shown	No	Optional, \$65 remote panel with 3 LEDs	No	Yes	Yes	Yes, 5 LEDs on controller, remote available	Unk	Unk
Controller cutback at hi temps	Yes	No	Yes	Yes	Yes	Yes	Unk	yes

® All Controller names are Trademarks of their respective owner (LogiSystems, Peter Senkowski, Curtis Instruments, EVnetics, EVComponents, and NetGain Controls).

* Indicates options available which must be specified on original order

⊕ Indicates options available which may be specified as upgrade by dealer

** Full current of 1000 Amps available only through 200V. "Slight derating above that"

Souces

http://evie-systems.com/index.php?main_page=index&cPath=52_53

<http://www.curtisinstruments.com/index.cfm?fuseaction=cProducts.DownloadPDF&file=1209.pdf>

<http://evnetics.com/soliton1specifications.html>

<http://www.evcomponents.com/SearchResults.asp?Cat=52>

<http://www.ngcontrols.com/WarP-Drive.html>

<http://www.belktronix.com/>