The Bricklin EV-1

Design Specifications and Owner's Manual

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Introduction

How the Bricklin Was Chosen

I have been the owner of a 1975 Bricklin since 1976. When I initially purchased the vehicle it had approximately 5,000 miles on the odometer. The Bricklin was my daily driver for a couple of years, and then it began to sit for longer and longer periods of time. For many years it resided in my garage doing nothing more than taking up much needed space.

At one point I decided to take the Bricklin to Michigan to have air-doors and a console installed. Upon returning, it sat in the garage again. When I finally began to drive it, I found that it was not running very well. I decided to have it brought back to life, in a more invigorated form. I had the engine rebuilt, added a 4BBL Holley carburetor, aluminum high-rise manifold, headers, aluminum radiator, and other miscellaneous items (i.e. new brakes, fluids, etc.). I also decided to change the original color from “suntan” to another original color, “white”. I prepaid for all the work. After five years the vehicle was returned by the shop that performed the above mentioned work. I learned a valuable lesson about paying for the work performed in advance of the work actually being performed.

Though I had hoped the performance would be greatly improved, it turned out the work was very sub-standard. After >$15,000 the vehicle barely ran without dying, and the paint job was seriously flawed. I was quite disenchanted, and the vehicle went back to the garage space it had become accustomed to. After 37 years the 1975 Bricklin still had less than 34,000 original miles.

Unlike the Bricklin, I continued to work, and to build a new company renown for powerful electric motors commonly used in converting vehicles from gasoline burning internal combustion engines, to pure electric motor power. Series wound, brushed DC Motors are capable of producing enormous amounts of torque at stall speed. A single WarP 11 motor has a peak stall torque of 1,959 ft-lbs. - if you could provide it with enough amperage (~3,951 Amps). The amount of torque developed is based upon the Amperage squared (I^2). Simply put, if you double the amperage you quadruple the torque – at least until saturation occurs at which time the torque increase becomes linear. The voltage supplied to the motors determines the RPMs the motor will spin at. This is a nearly linear relationship. If you double the motors voltage, you will double the RPMs, and thus the HP (Horse Power). Actually, it is slightly more than double since most losses are fixed. There are limits as to how much voltage and amperage these motors can sustain, but they are quite robust.

Using early versions of these powerful electric motors a battery powered dragster was developed that was capable of 60' times under one second (.986). Unfortunately, the lead-acid or PbA batteries of the late 1990's were not capable of sustaining the power level needed to maintain that rate of acceleration for more than a few seconds. Even so, the vehicle was capable of 10 second ¼ miles nearing 130 MPH.

Batteries

Super-capacitor testing was performed in the dragster in conjunction with NASA Illinois and the NASA Glenn Research Center. When the super capacitors were connected in parallel to the battery pack, they became slaves of the batteries. This meant that they could not output any power exceeding what the PbA batteries were capable of. But, the testing of the super capacitors did lead us to another new battery technology generally referred to as Lithium chemistry based batteries.

In the late 1990's lithium batteries developed a rather poor reputation for catching fire in laptop computers. But, technology has marched forward, and today's Lithium-Iron-Phosphate cells, when used in the proper manner, have shown that they are much more robust and safer than the batteries of a decade before.

The LiFePO4 batteries provide enough power to triple the range of electric vehicles that were powered by PbA batteries. Additionally, lithium batteries have an extremely long life, are not as affected by hot or cold temperatures as PbA , are lighter than PbA, more powerful than PbA, display no memory effect, and have high discharge and charge rates. The downside of the LiFePO4 batteries is that they cost approximately two to three times the cost of PbA batteries. Due to their long life they are actually less expensive then using PbA when amortized over time.

For the Bricklin EV-1, a quantity of 48, 3.65 Volt, LiFePO4 prismatic cells rated at 160 Amp hours each were chosen. The original gas tank was removed and 18 of the cells were placed in a replacement box located in the original gas tank position and arranged in a similar manner to those shown in the Illustration below.

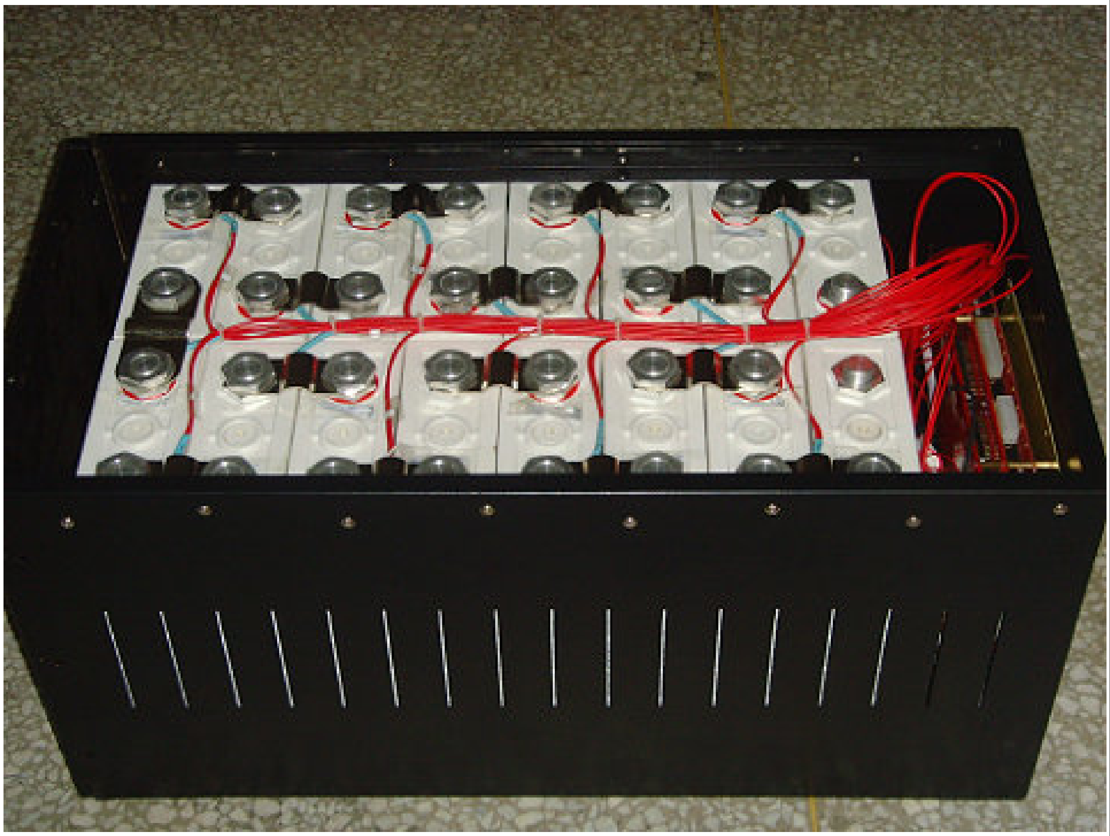

Illustration 1: Example of 16, LiFePO4 prismatic cells with BMS

The rest of the cells (30) are arranged under the hood of the vehicle and above the electric motor. All of the cells were connected in series to provide a fully charged pack voltage of 172.8 Volts (48 * 3.6). The cells weigh 11.53 pounds (5.23 kg) each and are 6.65” W X 3.35” D X 9.72” H (169 X 85 X 247 mm).

The cells are rated at 3C which means they can output 3 times their Ampere-hours rating, or 480

Amps continuously. For short bursts they are capable of 1280 Amps (8C) for 5 seconds, 800 Amps (5C) for 15 seconds and 800 Amps (5C) for 60 seconds. They have a life cycle of 2,000 at 80% Depth of Discharge (DOD). Lower DOD will extend the life of these batteries, while 100% DOD will shorten their life to approximately 1,000 cycles.

Battery Management System

To ensure that the expensive battery pack is properly balanced and protected, a Battery Management System or BMS has been installed. It is critical for safety and performance that the cells be well balanced both on charge and discharge. Every cell in the battery pack may not need the exact same amount of energy restored when a battery pack is charged. Similarly, when cells are discharged, some cells may be depleted quicker than others.

These conditions may be due to slight variances in the manufacturing process, or by the interconnects within the battery pack – such as loose or corroded connections. Even subtle differences, such as the placement of the cells can affect the performance of a cell due to temperature. Batteries surrounded by other cells will heat up quicker and stay warm longer, while cells on the end of the pack will generally cool quicker. Though the differences are relatively small, over time, they can have a cumulative effect on the overall condition of the battery pack or individual cells.

The BMS helps ensure that no cell in the pack is over charged and also that no cell falls below a predetermined low Depth Of Discharge (DOD) state, in the case of the Bricklin EV-1 the low cut-off discharge of each cell should be 2.5 Volts (120 Volts). For additional safety, this has been adjusted to 2.6 Volts (~125 Volts).

Once a cell reaches 3.5 Volts the BMS shunts any current provided to a cell to other cells, or if all cells are charged, simply signals a shut off to the charger.

When the vehicle is being driven and a cell (or pack) drops below a predetermined minimum a audible buzzer will sound to notify the driver of the low cell or pack condition. Running cells, or the pack, below the established minimums can seriously damage the battery pack, individual cells, and possibly other electronic controls, and even the motor. Care must be exercised to ensure the battery pack is maintained in proper working order.

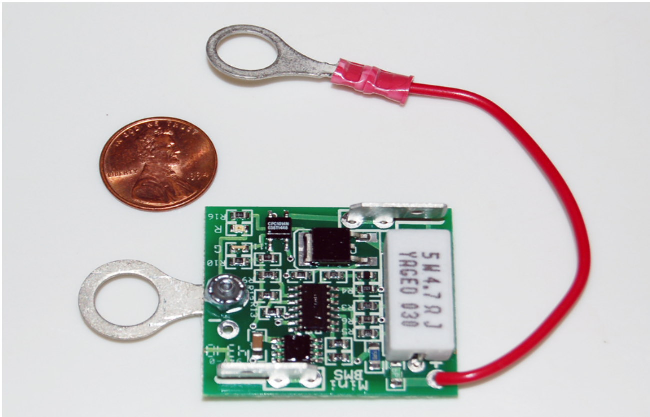

Illustration 2: Battery Management System - single cell module

Power

The progress in power electronics and electric motor controls has advanced by leaps and bounds over the past decade. Pulse Width Modulated (PWM) high power DC motor controllers that are capable of >3,500 Amps at >400 Volts (~1,400 kW) are readily available. And, unlike the controllers of the 1980's and 1990's, the new generation of high power motor controllers are safe and smooth in operation.

What does this 1,400 kW really equate to? Well, the formulas work like this:

Watts = (Volts * Amps)
HPe[1] = (Watts / 746)

The result would be:

Watts = (400 * 3500)
HPe = (1,400,000 / 746) or 1,877 HPe

But, realistically, you need to account for the losses (efficiency) of the electrical system. It would be easier, and closer to reality to say:

HPe = (1,400,000 / 1000) or 1,400 HPe (after losses)

Unlike Internal Combustion Engine (ICE) vehicles that produce torque and HP that is usually nearly equivalent to one another (~1 HP to ~1 ft lb), it should be noted that the type of electric motor being used in the Bricklin EV-1 produces almost 2 ft. lbs of torque per HP produced.

As a side note, mechanical horsepower is calculated as:

HPm[2] = ((Ft. Lbs * RPM) / 5252)

Motor Selection

Even though the NetGain Motors, Inc. WarP Motors are recognized as the most robust production motors for EV applications, a single motor cannot handle the potential amount of input power from these extraordinarily powerful motor controllers for more than a few milliseconds (not to mention the impact on the rest of the drive-line).

To avoid destroying the motors (and the drive-line), it is quite common to utilize:

- lower power settings on the motor controller,
- lower power motor controllers,
- larger and more powerful motors,
- multiple motors to share the power,
- some combination of the above options.

1 HPe = Horsepower electrical
2 HPm = Horsepower mechanical

In the case of the Bricklin EV-1 we choose to use a lower power motor controller as well as a larger single motor. The combination used in the Bricklin EV-1 will be a standard WarP 11 Motor powered by a single 1,400 Amp NetGain Controls, Inc. WarP-Drive Industrial Controller.

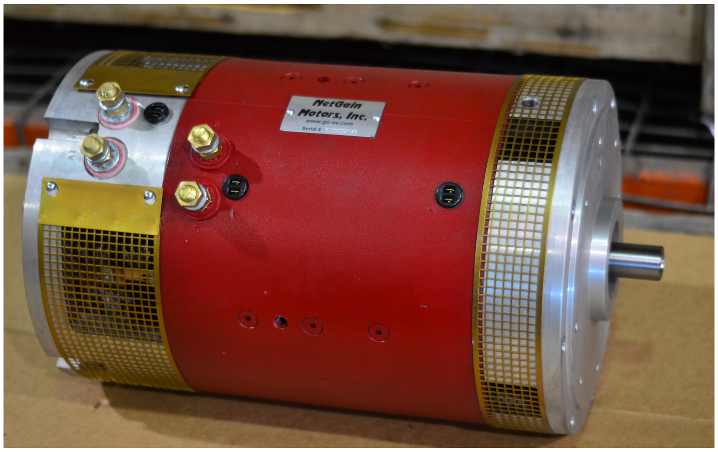

Illustration 3: NetGain Motors, Inc - WarP 11 Motor

A single motor is more than adequate for the Bricklin when coupled to the original Bricklin FMX transmission. Multiple motors were considered and offer some advantages. Besides "sharing" the workload and providing a "backup" in case of a single motor failure, dual motors [when powered by a single controller] may be wired together either in series or on parallel.

In series mode both motors will see full amperage, but only ½ the voltage. This mode provides maximum torque. When wired in parallel, both motors see ½ the amperage and full voltage. This mode produces maximum horsepower. It is possible to control the switch between series and parallel with the flip of a switch.

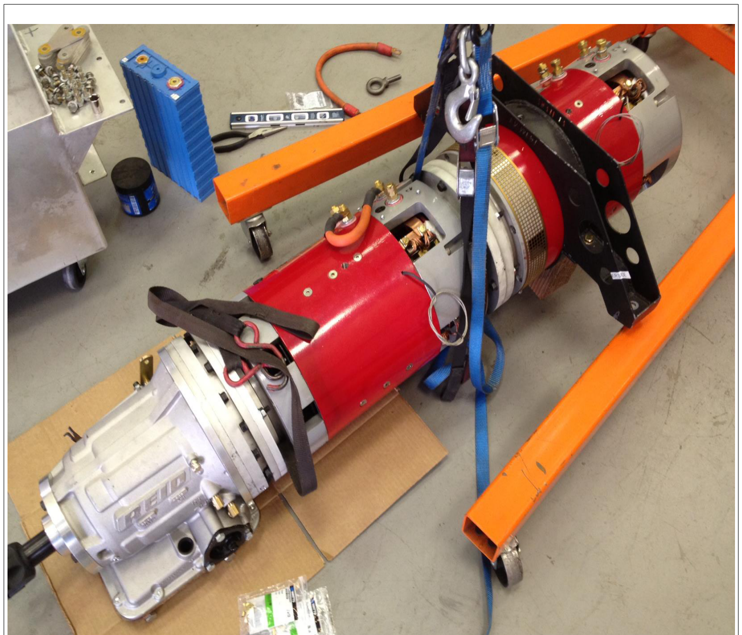

Illustration 4: Dual WarP 11 Motors coupled to transmission

It would be a possible to add a second motor and controller and double the power potential, but this vehicle is being built as a daily-driver, so some restraint must come into play. Additionally, the weakest link must always be considered, and dual controllers might require a stronger battery pack then the one being used, and it is unlikely the rear differential could withstand 830+ ft. lbs of torque.

Controller Selection

The selection of the high power motor controller was made based upon a number of design criteria. Since the controller is being used in an automotive environment it must be of automotive quality and support CANbus as well as OBD-II. OBD-II was not required in vehicles until 1996 and since the 1975 Bricklin did not require OBD-II, this is a significant upgrade to the vehicle. This automotive quality requirement significantly narrowed the search for viable controllers.

As the controller will be placed under the hood of the vehicle it must be able to withstand a potentially harsh environment - it must also be as watertight as possible.

All high power connections must be protected from the environment, as well from anyone who decides to poke around under the hood. The WarP-Drive Industrial motor controller is the only controller on the market that provides these features. Additionally, the gland nuts used to pass all cables into the inside of the controller provide stress relief, as well as being watertight.

An additional feature required is the ability to “idle” the electric motor when the vehicle is in a “run state”. This is necessary to power automatic transmissions, as well as running some “appliances” such as a power steering pump, air conditioning or even an alternator to keep the 12-Volt battery system charged.

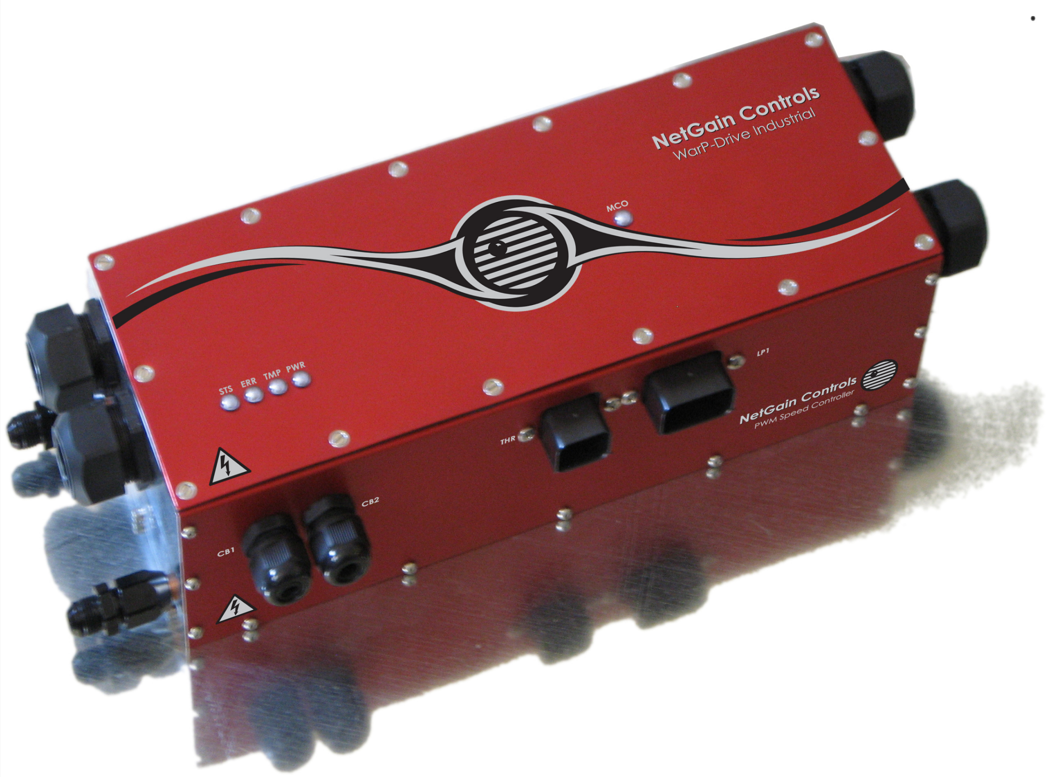

Illustration 5: WarP-Drive Industrial - Motor Controller

The power to offer performance exceeding the original vehicle required that the controller be of a liquid cooled design.

The WarP-Drive Industrial is the only controller on the market that could meet all of these requirements as well as providing additional flexibility which includes the ability to be field upgraded to higher power levels through a firmware download over the Internet.

Some of the additional features include:

- 160/260/360 Volt DC input capability (field upgradeable via software download)
- 1000/1200/1400 Amps available (field upgradeable via software download)
- 550 Amps continuous rating with 1.5 GPM liquid cooling
- Dimensions: 22x7x4 in.
- Weight: 23 lbs .
- Built-in precharging
- Dual CANbus ports
- Film capacitors in the power section
- Completely sealed device.
- Battery connections on one end, motor connections on the other for added safety
- 1/2" OD copper tubing for liquid cooling
- dual current sensors for added safety
- completely isolated throttle channels for added safety

Range

We can obviously produce more than adequate horse-power and torque, but one of the concerns people who are considering an electric vehicle have is RANGE! In the industry we refer to this as "range anxiety". The range of the vehicle can no longer be calculated as miles per gallon, rather a more common calculation is kW/mile. There are numerous factors that will determine the range.

Some of the factors that must be considered are, coefficient of drag, frontal area, rolling resistance, speed on level terrain, speed on grade, the percent grade, gear ratios, and tire diameter, drive-train efficiencies, temperature (which affects viscosity of fluids), and other factors. The rate of acceleration also plays a significant roll in range, as does the maximum speed.

For the Bricklin EV-1 we are targeting a conservative range of 75 miles at 50 MPH. The range would be increased if traveling on level terrain without any stops at 45 MPH. Likewise, it will be significantly decreased if traveling at 75 MPH on hilly terrain, or if making very quick starts.

The energy needed to accelerate mass over time is quite significant. Therefor, rapid 0 -60 MPH acceleration, though possible, will have a significant impact on the range. This holds true with ICE vehicles as well, though the abundance of fuel stations makes it fairly convenient to refuel.

Maintaining a particular speed (on level terrain) requires far less power then it takes to obtain the speed. For instance, the reason you need 300 HP (and 300 ft. lbs. of torque) in your normal daily driving vehicle is to allow you to accelerate the vehicles mass quickly and obtain the desired speed quickly. Once the vehicle reaches approximately 60 MPH, on level terrain, it normally requires only 20 -30 HP to maintain the speed. Depending upon the grade of the road, speed, the road surface, and other factors, it might require more than twice that horsepower to climb a hill.

Most internal combustion engine vehicles are designed in such a manner that the crankshaft is spinning around 2,000 RPMs at 60 MPH. At this speed and RPM the ICE engine is close to it's optimum efficiency – around 25% (usually less, and an average efficiency that is far less). The electric motors can reach efficiencies of greater than 90%. Plus, when the electric vehicle is stopped at a stoplight, the electric motor is generally not receiving any power – unless it is necessary to idle the electric motor to power "appliances" as stated previously.

Charging System

The Bricklin EV-1 utilizes the latest technology for charging its LiFePO4 battery pack. A Power Distribution Unit (PDU) known as the PulsaR has been designed and manufactured by NetGain Controls, Inc. and is carried on-board the vehicle. This unit is also used to power the original 12-Volt electrical system of the vehicle (lights, radios, etc.) It accomplishes this by converting the high voltage traction pack to ~12 VDC and keeping the original 12-Volt battery fully charged.

Illustration 6: NetGain Controls, Inc. - PulsaR, Power Distribution Unit (PDU)

This liquid cooled PDU unit is more than just an extremely powerful battery charger. This unit utilizes CANbus communications, and can use AC input to charge the batteries at up to 24kW, but also provides DC fast charging capability of up to 150kW. This capability would normally be accomplished from electric vehicle to electric vehicle, or from a stationary battery pack to the vehicle battery pack. This high power capability also means that it will be able to use future charging methods from auto manufacturers that have not been officially released.

The selection of the charger was based upon similar criteria as the motor controller selection. The only charger available that met (exceeded) the criteria is the PulsaR Power Distribution Unit from NetGain Controls, Inc.

The features of the PulsaR unit include:

- Works with up to 370 Volt DC battery pack
- 500 Amp controller (optional, and not included in the Bricklin EV-1)
- Up to 24 kW AC Charging
- Internal DC-DC converter with up to 53 Amps provided to high quality connector, voltage adjustable from 12 to 15 Volts via trim pot
- DC fast charge up to 150 kW
- Liquid cooling with large ½ in. diameter tubes for low pressure drop
- Native J1772 compatibility
- All contactors built in
- Dimensions: 18.5 x 14.5 x 5.5 inches
- 34 lbs. total weight
- Built-in precharging
- CANbus
- Film capacitors in the power section
- Completely sealed device with cable glands for all power cable connections and high quality waterproof connectors for all other wiring
- Intelligent PWM control for external motor blower
- Liquid cooling pump control output
- Provision for charging to/from external battery pack to/from traction pack

Transmission

As previously mentioned, the electric motors are extremely powerful and may be rotated in either a clock-wise or counter-clockwise rotation. For this reason, many people believe a transmission is not required. But, reverse rotation is not optimal for the WarP Motor design, so having a transmission allows for easy reversing of the vehicle as well as other advantages.

Direct drive applications also introduce a safety risk. If there were a catastrophic failure in the electrical system that caused the motors to see full battery pack power, there would be no way to stop the vehicle. The motors would have no problem overpowering the brakes, and unless a fuse blew or a safety switch was successfully thrown, there would be no way of stopping the motors.

A transmission allows for a manual disconnect in extraordinary situations. Although the motors have the torque to get the vehicle moving, they will draw far more amperage for a longer period of time without a transmission. As with ICE engines, the motors have a sweet-spot where they like to operate. This is normally in the 2,000 - 4,000 RPM range. The rule-of-thumb for these electric motors is: the electric motors are most efficient when run about 1,000 RPMs higher per gear than the ICE engine.

The transmission also provides a “Park” position that locks the transmission. Since the motors normally spin freely, parking on a hill without a transmission is not easily accomplished unless there is a parking brake. The original Bricklin SV-1 utilized a mechanical drive speedometer driven by a cable to the transmission. This same cable is used and makes it quite simple to maintain the original speedometer. It is also possible to use a GPS speedometer.

Illustration 7: Bricklin EV-1 FMX Transmission

Gauges & Instrumentation

An electric vehicle driver should be aware of what the vehicle is doing in a similar manner to the original ICE vehicle. This requires the replacement or addition of some gauges. An oil pressure gauge is no longer required, but a gauge to display amperage the motor is receiving is quite useful. Though the engine coolant temperature is no longer needed, it may be useful to monitor the coolant temperature of the motor controller and/or battery charger. The WarP Motors also provide a thermistor to allow monitoring the internal motor temperature. The existing fuel gauge can be converted using a Coulomb counting device so that the driver has a visual display of the fuel available (battery State Of Charge SOC).

Illustration 8: Rechargecar.com - Fuel measuring device

Torque – Android App

A tachometer should be connected so that the motor RPMs may be monitored.

Other gauges that may be useful are: motor voltage, battery pack voltage, motor amperage, and battery pack amperage. Since we are trying to preserve the original instrumentation cluster while adding the new instrumentation needed we have chosen to use an Android based tablet display and an application called “Torque”.   Torque is a very versatile application that allows the Android tablet to display various OBD-II information in a wide variety of displays, such as analog sweep gauge, digital gauge, graphs, etc. If the Android device is GPS enabled, Torque can also display the GPS speed.

Torque can also be used to display (and record) RPMs or any data supplied by the WarP-Drive Industrial Controller or PulsaR Power Distribution Unit.

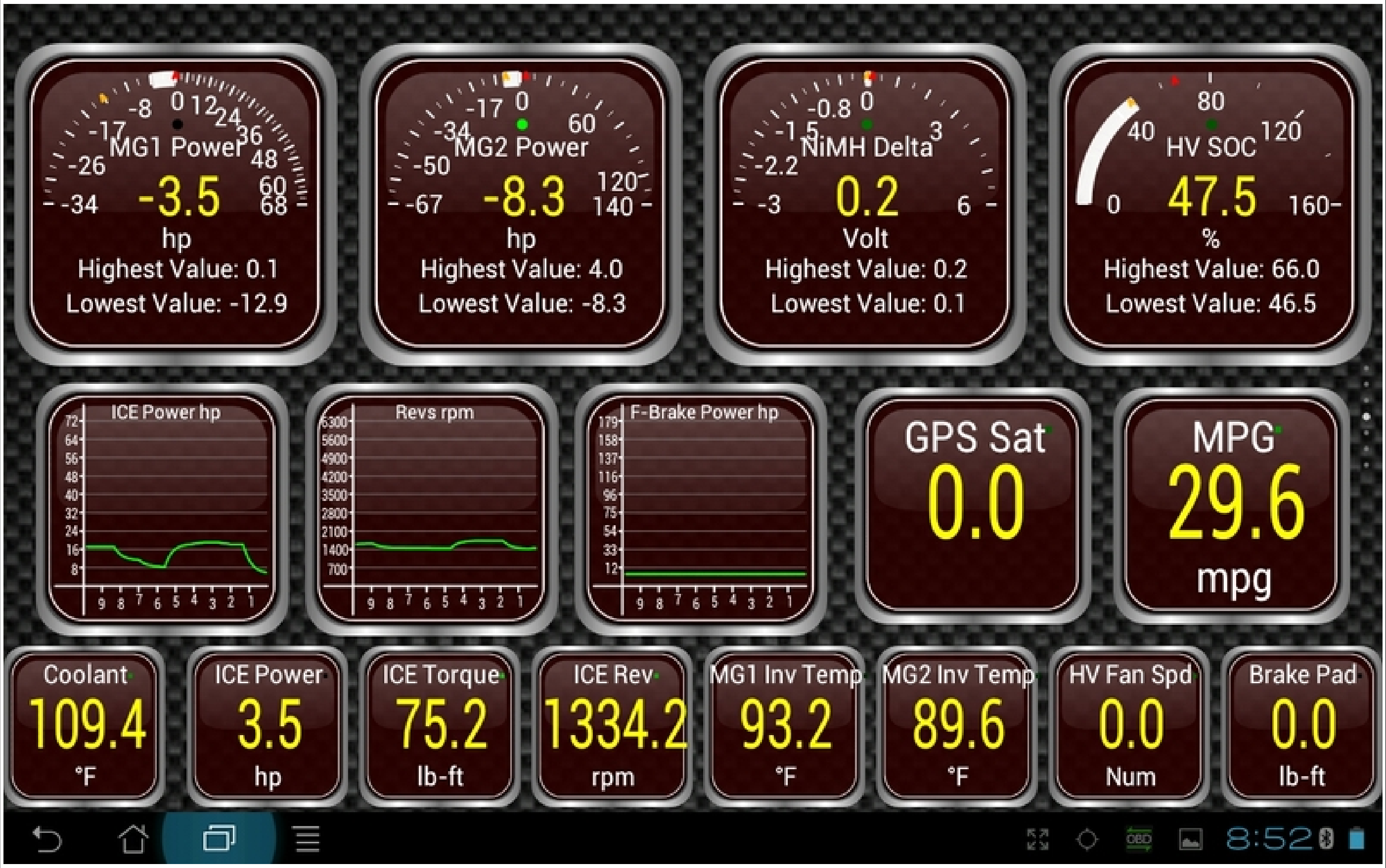

Illustration 9: Android Torque application showing various gauge types

Torque allows you to view live OBD-II motor and controller data on your Android phone or tablet.

Some of the features of Torque are:

- Fully customizable dashboard screens - Design your own layouts and custom dials, use your own themes
- Retrieve Fault Codes (DTCs) and clear Check Motor lights - View fault descriptions using the built-in databases
- Upload live OBD-II data to your web server or the torque web viewer in real-time
- Check the performance of your vehicle with BHP / Torque / 0 -60 & Quarter Mile widgets

The “Torque” application receives information from a Bluetooth OBD-II device. Unfortunately, since the Bricklin SV-1 predates OBD and OBD-II specifications, it is necessary to add a Bluetooth OBD-II device that connects to the motor controller and is driven off of the CANbus. Since the WarP-Drive Industrial Motor Controller and PulsaR Power Distribution Unit are both CANbus enabled, it is a trivial matter to enhance the dashboard of the Bricklin EV-1 with a completely digital dashboard. In actuality, we have chosen to keep as many of the original gauges intact as possible. Where necessary, the original gauges have been “enhanced” to provide similar information as they originally did, for instance the fuel gauge has been updated with a Coulomb counting device. To handle the additional gauges in a simple and consistent manner, the Android tablet works very well.

Illustration 10: OBD-II to Bluetooth Adapter

WarP-Drive Interface Module

Illustration 11: NetGain Controls, Inc. - WarP-Drive Interface Module

It is also possible to add a NetGain Controls, Inc. Interface Module (IM) to the vehicle. The "IM" module may be mounted on the windshield, or built-in, or not used at all, depending upon the drivers needs. The IM module is an alternative to the Android based Torque application. It should be noted that in order to upgrade the WarP-Drive Industrial software an "IM" module is required. Many of the EV conversion shops will upgrade the software using their IM module, or loan the IM module to someone that needs to update their firmware.

The IM module has numerous features, including:

- Data logging to a mini-SD card from all internal sensors in the WarP-Drive. Some of the internal sensors are: motor current, voltage, battery current, battery voltage, chill plate temperature, pulse width, throttle position, internal power supply voltages, external supply voltage, error and warning codes, and controller operating state. Data can then be viewed on a computer which accepts an SD card using the included adapter.
- Firmware upgrades to the WarP-Drive controller.
- Real-time display of the above data parameters on a variety of screens.
- Real time clock with super-capacitor battery backup. Set the time once, and even when unplugged, the time will be accurately kept.
- Easy in-vehicle mounting using a windshield suction-cup mount (provided).
- Powered over the connection to the WarP-Drive so only a single cable is required to operate.
- Extremely sleek and compact design fits comfortably in your hands.
- The interface module's firmware can easily be updated by simply obtaining the new firmware file by download, copying the upgrade files to the mini-SD card, inserting the card into the

Interface Module, and power cycling the unit. Seconds later, the unit is running with upgraded firmware.
- Settings are saved to non-volatile memory so powering up after disconnecting from power will provide previously set configuration

Operating Notes and Suggestions

Driving an electric vehicle is very similar to driving any normal ICE vehicle. But there are some interesting differences and subtleties that can enhance your experience. Most of these derive from the very low noise levels and the lack of engine compression you may be familiar with in driving an ICE powered vehicle. The Bricklin EV-1 is a true plug-in electric, battery powered vehicle – not a hybrid.

Starting

There is really no analog to "starting" with an electric vehicle. To drive, you do have to "turn on" the vehicle by applying voltage to the controller. But it always starts and there is little indication that it is "running" until you step on the throttle.

It is a good idea to place the gear selector in neutral and apply the hand brake before energizing the system.

Turn the ignition key two detents to clockwise (right). You may here a "CLICK" as the main power contactors are closed. When you release the key from this position, it should return to the run position. A single red indicator light should light on the dash indicating the vehicle is ready for operation. If you are running Torque on an Android tablet, the display should provide you with status indicators. You may also hear some very quiet, but audible sound from the coolant pump, heat exchanger fan, and forced air cooling fan for the DC motor in the engine compartment.

Gear Selection

The Bricklin EV-1 uses the original AMC Model 20, 8.9", 3.15:1 differential **[to be verified]** as was used in the original Bricklin SV-1 vehicle. To power the vehicle in the reverse direction, you will need to place the transmission into reverse. Depress and hold the brake pedal as you pull the shift lever back into the reverse location. Gently depress the throttle keeping in mind that the vehicle has enormous power potential.

The remaining gears are 1st, 2nd and 3rd identical to the original Bricklin SV-1. A straight back and forth configuration with 1st gear forward, and 2nd gear when pulled back, and 3rd gear when pulled completely down. It should be noted that it is possible to start from a dead-stop in 2nd gear, but it is easier on the motor, batteries and controller if you start in 1st gear. The main difference between the use of the original Bricklin SV-1 transmission and its use in the Bricklin EV-1 is that the transmission must be down-shifted MANUALLY! If you do not return the gear selector lever to 1st gear when you come to a stop after driving in 3rd gear, it will remain in 3rd gear, so when you start up it will be from 3rd gear. This may take a bit of getting used to. There is no clutch in this vehicle, it is a fully automatic, manual shifting of the gears.

It would be possible to replace the original rear differential gear ratio to obtain greater acceleration, or to obtain a higher top speed. Though the motor is capable of a top speed of ~5,500 rpm, it is normally electronically limited to 5,000 rpm. You will quickly ascertain that first gear is simply needed to assist the start-up, especially on inclines, but 2nd gear is all that is normally needed up to 45-50 MPH.

With an electric vehicle, you should never use the electric motor to “hold a position” on an incline. Use the brakes to hold the vehicles position. Using the electric motor to maintain a position on an incline may possibly damage the electric motor, though with an automatic transmission this damage potential is greatly alleviated.

Driving

Take care during acceleration your first few weeks of driving this car. A great deal of the sense of speed and acceleration is derived from the “roar of the engine” we are accustomed to in ICE vehicles. There is no roar from an electric vehicle and you can find yourself exceeding the speed limit in just a few seconds.

Similarly, there is no engine compression to slow you down when you take your foot off the throttle. The vehicle rolls freely down the road with no electric power applied and you will quickly learn to glide long distances using no energy at all, in many cases actually accelerating in even slight downhill terrains.

Be aware that subliminally we are all acculturated to the sound of automobiles. We’ve been around them all our lives. And, they make a very recognizable sound. This vehicle does not make that sound. Be on the alert for pedestrians, children, pets, and even wildlife. It may be necessary to honk the horn to alert people nearby of your approach or to install a sound system that warns others of your approach.

Range

We rate the Bricklin EV-1 as a 75-mile vehicle. We have several indicators to remind you what your State Of Charge or SOC is at all times. And, in the event you discharge it too far, the vehicle will automatically go into “limp mode”, and an audible buzzer will sound. In limp mode you can still drive the vehicle, but the throttle input is cut to a fraction of its normal value, and it can take several painful minutes to accelerate to 30 mph. This allows you to “creep” or “limp” to a safe area out of traffic or a nearby place where you can recharge the cells sufficiently to proceed.

The actual range you get will vary dramatically depending on your driving style. Higher speeds take greater energy to overcome the wind resistance, so at 70 mph you will not likely achieve 75 miles – perhaps 50. Strong accelerations also consume more energy. Use of the electric defroster/heater and air-conditioner will also use energy – reducing range slightly.

If range is your issue, you will very quickly learn a kind of “push and glide” technique for extending your range. There is no real trick to it, it comes quite naturally in driving the vehicle. Most drivers quite naturally adapt to this in a short time.

Operating the Heater and Defroster

Your Bricklin EV-1 features a ceramic heating unit that provides almost instantaneous heat. A small but powerful heating element and blower are installed under the dash and they are wired to the original control mechanisms.

The heater uses about 9 amperes from the pack so you can calculate 9 Ah from your pack total for an hour's heat. This would reduce your range by about 5%.

Braking

Due to the weight of the batteries, the Bricklin EV-1 is just slightly heavier than the ICE engine version. We very carefully designed this vehicle for a 60/40 front/rear weight distribution closely matching the original Bricklin SV-1 and have added slightly stiffer springs to support the additional weight.

Running out of gas in an ICE vehicle is pretty much penalty free. You pour in an additional gallon of petrol and drive to the gas station. In an electric car, running your battery pack completely empty is another matter as it can potentially destroy the $10,000+ battery pack!

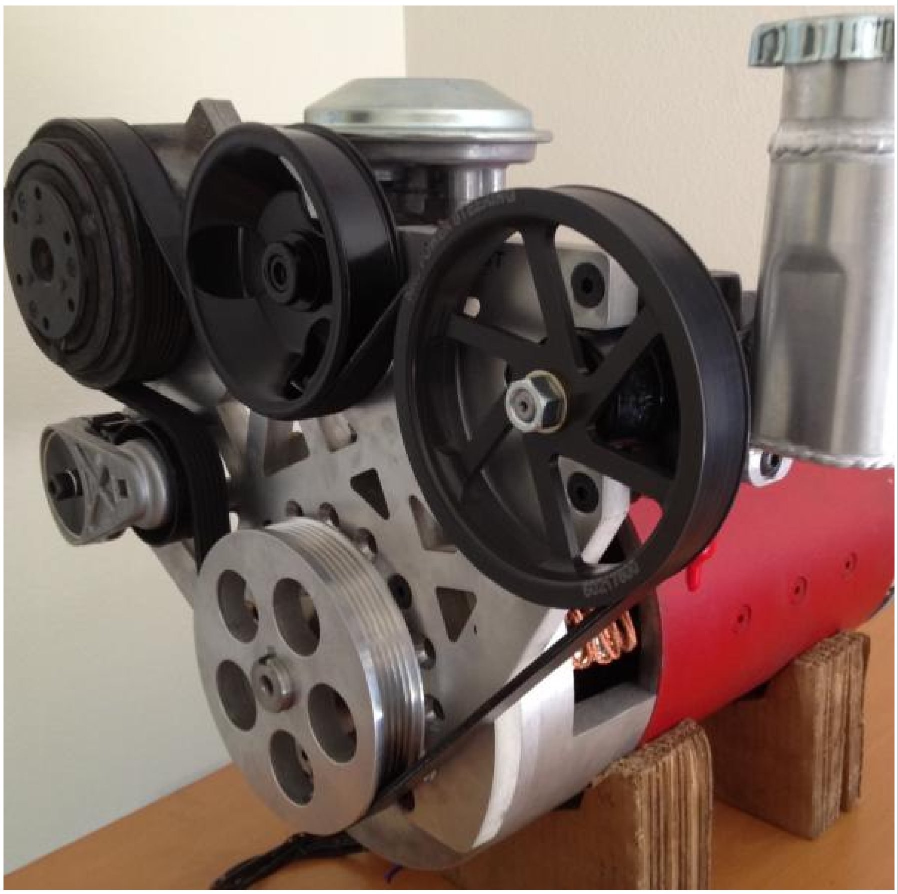

Illustration 12: EV West Accessory Plate & Pump System

The Bricklin EV-1 features power front wheel disk brakes and drum rear brakes (these may be upgraded to rear disc brakes in the near future) to increase the stopping power.
The use of power brakes requires a vacuum pump be used. For this reason we have chosen an accessory plate that attaches to the front of the motor and allows us to add “accessories” such as a power steering pump, alternator, air conditioning pump, and vacuum pump. The only “kit version” of this product is made by http://www.evwest.com and is pictured below:

An additional note: we are accustomed to parking an ICE vehicle “in gear” and trusting the engine compression to keep the vehicle from rolling away. The DC electric motor does not provide any such compression and ergo, the Bricklin EV-1 will, in all likelihood, roll down the hill if the parking brake is not applied and/or the transmission is not placed into a locked position (Park). Never leave the vehicle unattended without the handbrake applied. This brake locks the rear wheel brakes and is capable of holding the vehicle position.

Similarly, always RELEASE the hand brake before beginning a drive. The Bricklin EV-1 features a cell pack of 48, 3.6v Lithium Ion Iron Phosphate (LiFePo4) cells connected in series to produce a nominal pack voltage of ~172 Volts DC. These cells have a capacity of 160 Ah, or 27,520 watt-hours. In normal driving, energy is consumed at a rate of about 1.8Ah per mile, or 288 watt-hours per mile providing you with a maximum theoretical range of approximately ~95 miles.

Emergency Disconnect

Illustration 13: Emergency Disconnect Switch (the BIG red button)

The Bricklin EV-1 electric vehicle is engineered to be safe in all instances. But it does consist of electronic control devices, and if they fail, predicting the failure mode is difficult.

In the unlikely event you encounter a situation where the vehicle is accelerating without your command, there are several options to recover:

1. Remove your foot from the throttle and ensure no carpeting or mats are interfering with throttle operation.

2. Turn off the ignition key. Unlike a gasoline engine, there is no damage to the engine here and there is no analog to the "dieseling" concept in an ICE vehicle where it runs out of control even without ignition voltage. You are effectively removing all "fuel" from the motor – a heavy duty contactor relay will open, removing pack voltage from the controller.

3. In the incredible event that steps one and two both fail to disable the main battery pack, a heavy duty manual emergency disconnect switch (the BIG red button) is provided on the rear end of the center console against the carpeted area. Push this button in to completely disable the battery pack. ONLY use this switch in an emergency or when storing the vehicle for long periods of time as it completely disconnects the battery pack and resets all your instrumentation.

4. In the further unlikely event none of those steps work, you can always put the transmission into neutral. The motor may self destruct if the load is immediately removed at high rpm but it is a last resort tactic that could save a life.

Charging

Most new electric vehicle owners are somewhat focused on two questions:

How far can I go on a single charge?
How long does it take to recharge the car?

These questions are of course valid, and somewhat interrelated.

In actually using the vehicle you will quickly learn neither is really very important to most drivers.

The quick answer is 75 miles, and 7 hours. Both are actually extremely variable. The 75 miles is quite variable depending on how you drive the car. We have driven the vehicle in testing over 100 miles in urban stop and go while still within the 162 Ah limit. Similarly, driving 90 miles per hour on the freeway will not only deplete the pack within 50 miles, but can result in a speeding ticket.

The amount of charge time depends on how far you have driven the vehicle and how much power you are capable of dumping back into the battery pack, and what the battery pack can handle coming in.

In actual practice, American drivers **AVERAGE** 39.4 miles per day and the **MEDIAN** daily drive is 26 miles, meaning half the licensed drivers average 26 miles per day or less.

The LiFePo4 cells are truly remarkable devices and account for much of the expense of the electric vehicle. They exhibit very few of the churlish characteristics of lead acid, nickel cadmium, or nickel metal hydride cells. For example, there is NO advantage to fully discharging these cells - ever. There is no memory, and there is no need to ever fully charge them. They do not sulfate, they need not be “balanced”, they do not take water, and they really behave quite remarkably well in both hot and cold temperatures. You may note about a 10 -15% decrease in range in temperatures below freezing.

Illustration 14: Typical charging plug used on electric vehicles

But, they do NOT like to be overcharged!

And, they do NOT like to be over-discharged! By limiting your driving to 75 miles on a charge, these cells should last for >2000 charging cycles. By way of comparison, lead acid cells of the very best industrial design are typically good for 350 cycles (from fully charged, to fully discharged, to fully recharged).

If you limit your driving to 50 miles between charges, you can FURTHER extend the life of these cells by 50% to 3000 cycles.

What this means in actual practice is that you can charge when and where you like, as often as you like, without regards to cell chemistry quirks. And a lesser cycle doesn’t really count as a full cycle.

For example, let’s say you drive 12 miles on errands in the morning and return home for lunch. Go ahead and plug it in. That you are not going to do a “full charge” means nothing to the LiFePo4 cells. A 30 -minute recharge is fine. Then return to errands or whatever after lunch, when you return home, plug it in again. You are not “using up cycles” in this way, you are actually extending the life of the cells dramatically.

To prevent overcharging, we have provided a charger that charges at a constant current level until the pack reaches a voltage of ~168. At that point, it switches to constant voltage mode and holds that voltage at ~168 until the current required to do so diminishes to a couple of amperes. At that point it shuts off automatically.

It will NOT come back on later at any point automatically. To restart it, you would have to remove the power connection and reconnect it to reset the charger.

The result is that the charging procedure is quite simple, plug a 120 Volt AC or 240 Volt AC power source into the provided charging port, and walk away. You may also use the J1772 style plug that is provided under the rear license plate.

Illustration 16: J1772 Plug and outlet

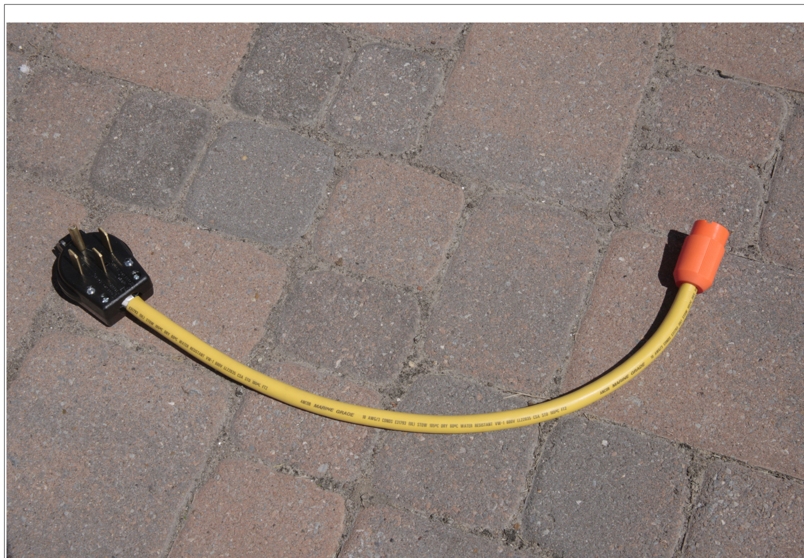

Illustration 15: 240 VAC to 120 VAC power cord adapter

If using a typical electric plug at home, you would use a normal NEMA 5-15 three-prong male plug. You would connect the female end of a HEAVY extension cord into it, and the male end of that cord into an ordinary wall receptacle.

The vehicle comes equipped with a heavy duty 12 gauge three conductor extension cord quite suitable for charging from 120 VAC outlets. Also provided is a heavy duty NEMA 14-50 adapter. This is the type of connector most often found on electric ranges but also at RV parks across the country. This adapter will connect the two phases of 240 VAC service to the two blade prongs of the charge port, and the neutral of the two phases to the ground pin.

Illustration 17: NEMA 14-50 240 VAC plug

The battery pack in the vehicle is completely isolated from the frame of the vehicle and ground. So grounding the circuit accomplishes nothing in any event.

In this way, you can use the same charge port from either 120 Volt AC or 240 Volt AC sources. Your electrical box in your house or building usually has two 120 Volt AC phases for 240 Volt AC. In almost all lighting and sockets in your house, you only use one of the phases – typically half the circuits on one phase and the other half on the other phase. But an electrician can easily wire a NEMA 14-50 range/oven connector into your garage to provide 240 Volt AC charging to your car. The charge for this varies based on how far the circuit box is located from where the outlet is located, but is often available at $200 -$400 and no special code provisions beyond this are necessary. A 60 AMP circuit breaker is more than adequate.

When connected to 240 Volt AC the Pulsar Power Distribution Unit and charger will initially charge the ~170 Volt DC battery pack at about 24.5 amperes. This will continue until the pack voltage reaches ~168 Volt DC. At that point, the current will begin to decrease. If you leave it charge unattended, you can tell that it has completed when the current indication is less than a couple of amperes. The charger itself is totally silent and so the meter is the only indication you will have that it is actually charging.

If you completely deplete the 160 Ah in the pack, at 24 amperes it would reach full charge in about six hours and 45 minutes.

If you use 120 Volt AC connections, this time could be doubled.

You can see that the vehicle charges faster from 240 Volt AC, and the actual charge time is totally dependent on how many ampere-hours have been removed from the pack by driving the car. Thus, taking advantage of charging when it presents itself is a good idea. We refer to this as “opportunity charging”.

The vehicle uses a DC-DC converter that is an integral part of the PulsaR Power Distribution Unit to convert the ~170 Volt DC pack voltage to 13.2 Volt DC to keep a 12 Volt DC battery at an optimum state of charge in order to power the auxiliary equipment on the vehicle such as the radio, clock, headlights, water pump, and instrumentation. Much like the 12 Volt DC battery in your ICE car, this is “on” all the time. There may be some minor drain of the traction batteries all the time.

If you are going to store the vehicle unused for an extended period of more than a week or two, you can shut off this DC-DC converter by setting the emergency disconnect switch to off. This may reset all instrumentation in the car.

Most owners typically plug the vehicle in at night and allow it to charge overnight.

Once you have a 240 Volt AC charge port in your garage or driveway, the act of connecting the cable to the charge port on the vehicle only takes a few seconds.

The unexpected result of all this is that your vehicle does have limited range. But each morning when you go to get in it, it has a totally full tank. And you will quickly learn that you were actually spending a LOT of time going to the gas station in your other cars and you never have to do so with the Bricklin EV-1. It’s just full all of the time. And it is almost noticeable how easy it is to “refuel”.

Charging Costs

Because of the lack of mass production, electric vehicles can be expensive to produce using costly low volume components, and we’ve used the very best components currently available. The LiFePo4 cells are really what has made electric vehicles finally viable and practical, but they are expensive.

As a result, economy is not the reason to purchase an electric vehicle. It is more a personal identity statement and a move toward cleaner air and less dependence on foreign energy sources. Plus, electric vehicles are a tremendous amount of fun to drive. As it so happens, they are also much less expensive to own and operate.

The Bricklin EV-1 features a 27,648 Wh battery pack, of which we will limit use to about 22,000 Wh. The vehicle should average ~250 Wh per mile and there are some losses of efficiency in the charging process.

As a result, it can take 23+ kWh from the wall to fully charge the car. Your electric bill is based on the number of kWh (kilowatt hours) used through your electric meter. The actual cost is based on your local electric utility rate. The national average for electricity at this writing is 11.75 cents per kWh. At that rate, if you drove the vehicle to full discharge, it will cost about $2.70 to recharge it. At 75 miles, this works out to about 3.6 cents per mile. If you get 100 miles per charge, it is 2..70 cents per mile.

At $3.75 per gallon and 20 miles range to the gallon, gasoline costs by comparison would be about 18.75 cents per mile.

This is NOT the reason electric vehicle owners seem to be smiling all the time. But they rarely apologize for it either.

Fast Charging

The PulsaR charger is located in the rear compartment behind the drivers seat. It is connected to the battery system through an Anderson connector on the left side of the vehicle as you face this from the front.

It is possible to charge from electric vehicle to electric vehicle with this charger and the proper cabling. It is also possible to charge from a standalone battery pack directly to the Bricklin EV-1 battery pack through the PulsaR PDU.

Adapters are also available to utilize other proprietary high-power charging stations as well. The Bricklin EV-1 boasts the most flexible and high power charger currently available.

In NO CASE should the system ever be charged above ~175.2 Volts DC.

Cooling System

One of the more expensive components of an electric vehicle is the electric motor controller. This device translates your throttle input into drive current to the electric motor and it is a central component of the drive system.

As a very high power semiconductor electronic device, in this case controlling up to 1,400 amperes of current to the drive motor, this is the most failure prone device in the car. Over the years, it has been our observation that heat causes controllers to fail, and that in the absence of heat, they last essentially forever.

The problem is that in switching ~170 Volts DC from the battery pack to the series wound, brushed DC motor, the motor controllers generate heat internally. The better this heat can be dissipated, the longer the controller will last.

One of the key design issues faced with the Bricklin EV-1 was this issue of heat removal. A liquid cooling system provides its own costs, maintenance, and component issues. But, we have designed a very strong cooling system for the controller and the PulsaR PDU, consisting of a long life pump, stainless steel covered hoses, a chill plate for the controller, a heat exchanger with fan, and a fill reservoir.

The only maintenance required of this is that you remove the fill reservoir lid occasionally and make sure it has coolant in it. This coolant should NOT fill the bottle, but typically be topped to about 2/3 of the bottle, with a 50/50% solution of glycol and water (anti-freeze). This will prevent the system from freezing in the winter, and provide very good cooling for the controller/charger.

This ensures maximum power and performance from the controller, and more importantly, maximum life from the controller and charger as well.

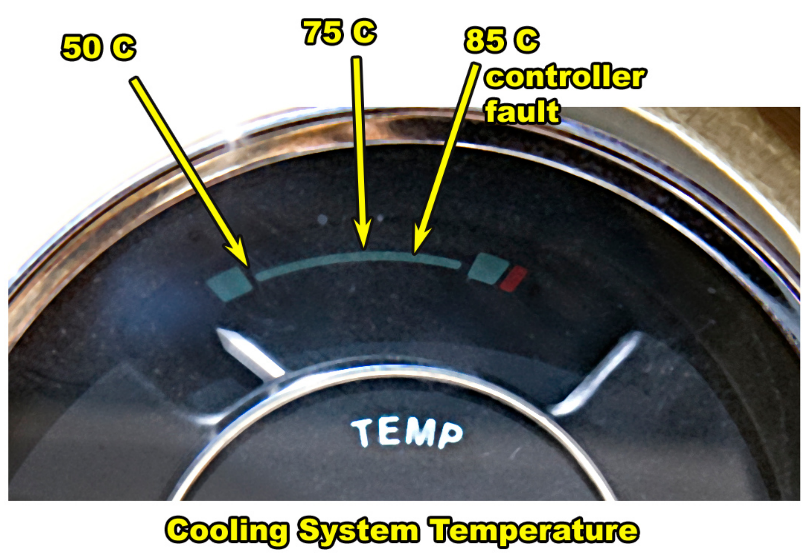

Illustration 18: Motor Temperature Gauge

The temperature indicator on the dash combination gauge does indicate controller temperature at the chill plate. In normal operation, the controller will be operating at 45°-55°C and this needle will be pretty much at the bottom of the gauge.

A mid range indication on the meter would indicate about 75°C. The controller goes into a current limit mode, it's own "limp mode" or "thermal cutback" at 80°C, or about ¾ gauge indication.

The WarP-Drive Industrial Interface Module (IM) will also indicate both motor and controller temperature as **MTemp** and **CTemp**. You can use the push-buttons to cycle through the various indications from the controller including voltages, rpm, amperes, MTemp and CTemp.

This has been tested at higher than posted speeds up steep hills in 100°F July weather. The cooling system, if properly operating, simply does not allow temperatures above 80°C. If you get a gauge indication past mid-range, check the CTemp on the IM module display. If it is above 80°C, you have had some failure of the cooling system and need to have it repaired.

Unlike an ICE vehicle, the system does not boil over and strand you. You will not burn up the controller or electric motor by continuing to drive it. If it does go into limp mode, simply park the vehicle for a few minutes and let it cool down. Cycle the ignition switch off and back on and you can continue to drive. The vehicle is perfectly operational.

The cooling system is driven by 12 Volts DC from the switched voltage distribution panel in the engine bay. Check the fuses there before attempting to have the vehicle repaired.

Tire Pressure

Maintaining tire pressure is a key technique to efficiency in ALL vehicles but critically so in an electric vehicle. Tire pressure should never exceed the maximum manufacturer rated tire pressure, but it is critical to maintain the maximum rated pressure for greatest efficiency. High tire pressure will greatly reduce rolling resistance and extend range.

If you prefer a softer ride, you may reduce the tire pressure to comfort, but this will also decrease the range of the vehicle.

Maintenance

For most experienced owners of electric vehicles, one of the most treasured aspects of these vehicles is the lack of routine maintenance. You do not have tune-ups, oil changes, spark plugs, or filters to deal with.

Tires do of course wear and the higher weights and pressures in an electric vehicle can cause them to wear at a modestly faster rate.

You do have a cooling system and it should be checked occasionally and kept charged with a 50% glycol solution.

The batteries actually require NO maintenance at all. But terminal connections, can over time, loosen from vibration and temperature. It is advisable to check these connections monthly to ensure they are clean and tight, with no visible corrosion or buildup. A poor connection can develop heat and pose a hazard.

One of the problems with electric vehicles at this time is finding service facilities to perform maintenance in the event of a true systems failure. Relays and fuses are potential failure items, although we’ve used the finest available components.

Fortunately, system failures are very rare. And, the number of EV conversion specialty shops is increasing all the time. The NetGain Motors, Inc website (http://www.go-ev.com) lists approximately 150 EV conversion facilities worldwide that may offer assistance should the need arise.

The usual problem with conversions is a lack of information as to how a particular vehicle is wired. We’ve included some detailed wiring diagrams in this manual to assist anyone attempting to troubleshoot the vehicle, and the pictorial nature of these diagrams serves as an aid to identifying components.

We’ve also made a conscious effort to use commonly available parts from noted producers to ensure spares availability. This is a very different approach to that of most OEM automotive manufacturers who’s business model is based on a continuing stream of revenue from owners who MUST purchase proprietary parts and components from the manufacturer.

The result is a vehicle, that by any comparison to an internal combustion vehicle, can be thought of as maintenance free. And, in the event of malfunction, the use of generic parts should make any necessary repairs both inexpensive and easy for anyone to accomplish.

Most EV owners are concerned about battery life. This is a central issue with electric cars and we’ve designed this vehicle for maximum extension of the life of these cells. We would expect 80% range after six to eight YEARS with these cells. The battery world is changing rapidly and we suspect you will want to upgrade your batteries long before they ever wear out. Again, by using generic, basically “commodity” cells, you are not locked into a proprietary battery module technology. As newer chemistry with higher energy densities arrive (and at likely even lower prices), you will be able to easily upgrade your vehicle to achieve greater range and performance.

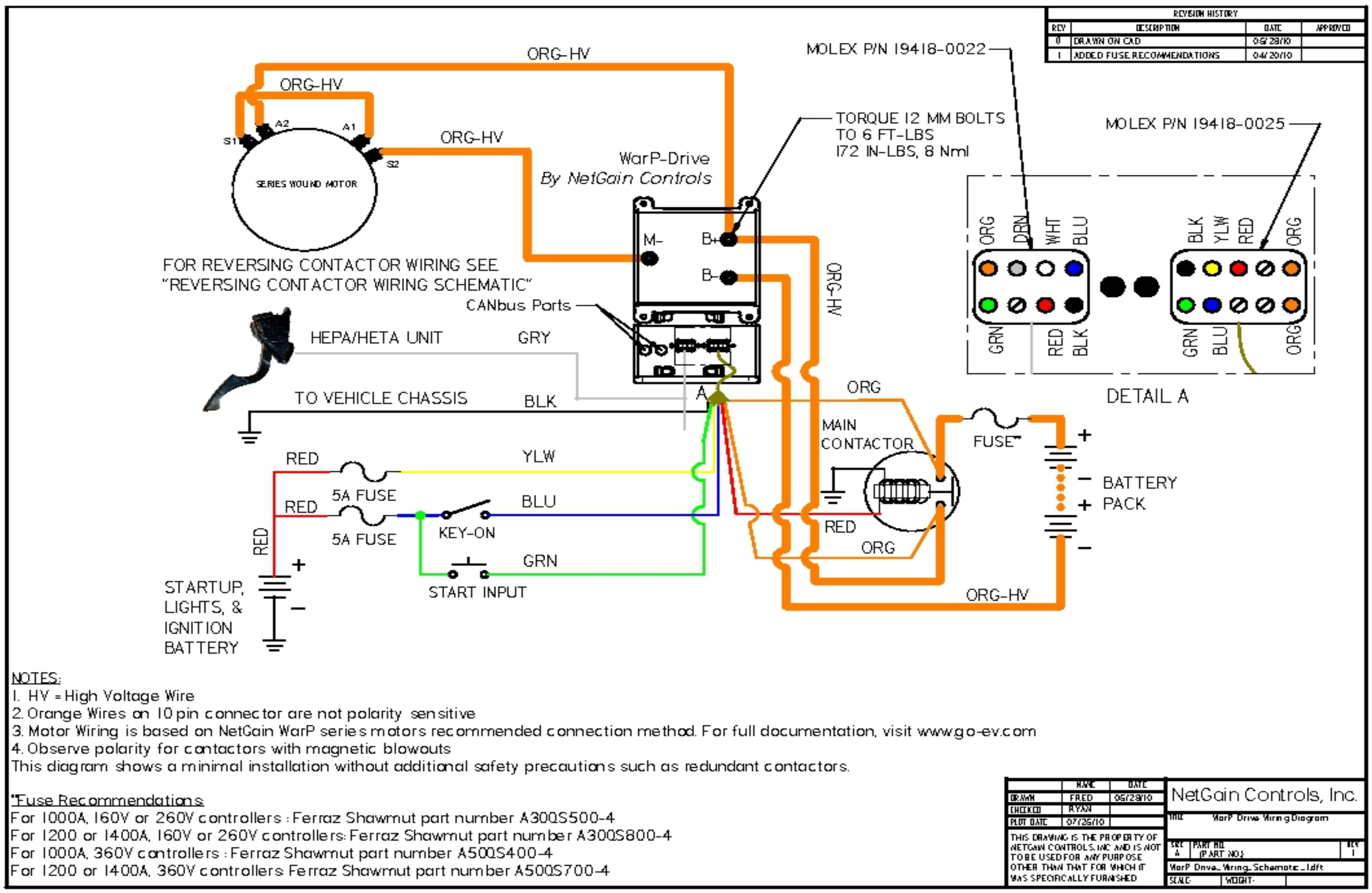

Illustration 19: Bricklin EV-1 High Voltage Power Distribution

Bricklin SV-1 History

The Bricklin SV-1 was a two-seat sports vehicle created by Malcolm Bricklin, and designed by Herb Grasse. It was manufactured from 1974 until early 1976. There were approximately 2,854 of the vehicles built during this time frame, and it is estimated that less than 1,120 still exist.

The original model name “SV-1” stood for “Safety Vehicle 1”. The Bricklin was designed with an integral roll cage, side beams, and bumpers that could withstand a 5 MPH crash without damage. There were few options available on the Bricklin. There were choices of five “safety” colors; white, red, suntan, orange and green. There was no spare tire, cigarette lighter or ashtray which were common in other vehicles of the time.

The most unique attribute of the vehicles were the powered gull-wing style doors. The doors were hydraulically actuated and opened and closed by depressing a switch.

The first year production vehicles included an AMC (American Motors Corporation) 360 cu. in. V8 (4 BBL) and most were equipped with a standard 4-speed transmission, though an automatic transmission was an option. Later production vehicles came equipped with a Ford 351 cu. in. V8 (2 BBL) Windsor engine and Ford FMX automatic transmission.

The front suspension were A-arms with coil springs over shock absorbers. The rear suspension was leaf springs on a straight axle with shock absorbers.

1975 Bricklin SV-1 Specifications	
Manufacturer	Bricklin Vehicle Corporation
Production Years	1974 - 1976
Quantity Produced	~2,854
Class	Sports car
Body Style	Two-door coupe
Engine	Ford Windsor 351 V8 (2BBL)
Compression	8.1:1
Horsepower	175 @ 3,800 RPM
Rear Axle Ratio	3.15:1
Tire Size	FR60 -15
Front Brakes	11 in. power discs
Rear Brakes	10 in. drums
Standard Equipment	Power Steering, Air Conditioning, Automatic Transmission, AM-FM Stereo Radio, Digital Clock,Tinted Glass,Hydraulic Gull-Wing Doors, Rear Window Defrost, Tilt Steering Wheel, Full Instrumentation, Radial Tires, Mag Style Cast Aluminum Wheels
Fuel Type/Capacity	Unleaded / 21 U.S. Gallons
Wheelbase	96.0 in (2,438 mm)
Length	178.6 in. (4,536 mm)

1975 Bricklin SV-1 Specifications	
Width	67.6 in (1,717 mm)
Height	48.15 (1.223 mm)
Curb weight	3,470 lb (1,570 kg)

Bricklin EV-1 History

The Bricklin EV-1 has been re-engineered and designed by Pioneer Conversions, LLC and NetGain Motors, Inc. NetGain Motors, Inc. is well known and established as the exclusive worldwide distributor of the most common line of DC electric motors used for conversion of gas powered vehicles to all electric (or hybrid). Pioneer Conversions, LLC is one of the most experienced EV conversion businesses in the world.

1975 Bricklin EV-1 Specifications	
Conversion Company	Pioneer Conversions, LLC & NetGain Motors, Inc.
Conversion Years	2012 - 2013
Quantity Produced	1
Class	Sports car
Body Style	Two-door coupe
Motor	Single WarP 11
Horsepower	~238 RWHP
Torque	~415 RWT
Transmission	Automatic, 3-speed, original FMX transmission adapted to electric motor
Rear Axle Ratio	3.15:1
Tire Size	FR60 -15
Front Brakes	11 in. power discs
Rear Brakes	10 in. drums (will become disc)
Standard Equipment	Power Steering, Air Conditioning, Automatic Transmission, AM-FM Stereo Radio, Digital Clock,Tinted Glass, Pneumatic Gull-Wing Doors, Rear Window Defrost, Tilt Steering Wheel, Full Instrumentation, Radial Tires, Mag Style Cast Aluminum Wheels
Fuel Type/Capacity	Lithium Iron Phosphate / 7.7 kW (160 Ah * 48 Cells @ 3.6 Volts) 172.8 nominal pack voltage
Battery Charger	NetGain Controls, Inc. PulsaR – 150 kW, liquid cooled, CANbus, J1772
DC-DC Converter	NetGain Controls, Inc. PulsaR – 53 Amps @ 12-15 Volts
Motor Controller	NetGain Controls, Inc. WarP-Drive II Industrial, 1,400 Amp * 360 Volt Liquid cooled, CANbus, Hall-effect Throttle Pedal
Wheelbase	96.0 in (2,438 mm)

Length	178.6 in. (4,536 mm)
Width	67.6 in (1,717 mm)
Height	48.15 (1.223 mm)
Curb weight	~3,470 lb (1,570 kg)

Performance

Original Bricklin SV-1 Performance vs EV-1 Performance		
	SV-1	**EV-1 (est.)**
Top speed: (theoretical without speed governor)	186 km/h / 116 mph	115 MPH
Acceleration: (km/h)		
0 -30 km/h (s):	1.9	
0 -40 km/h (s):	2.6	
0 -50 km/h (s):	3.3	
0 -60 km/h (s):	4.1	
0 -70 km/h (s):	5	
0 -80 km/h (s):	6.7	
0 -90 km/h (s):	8	
0 -100 km/h (s):	9.4	
0 -110 km/h (s):	11.1	
0 -120 km/h (s):	13.6	
0 -130 km/h (s):	15.9	
0 -140 km/h (s):	18.5	
0 -160 km/h (s):	25.1	
0 -180 km/h (s):	36.3	
0 -200 km/h (s):	109.6	
Acceleration: (mph)		
0 -20 mph (s):	2.1	
0 -40 mph (s):	4.5	
0 -50 mph (s):	6.8	
0 -60 mph (s):	8.9	6.0
0 -70 mph (s):	11.5	
0 -80 mph (s):	15.6	
0 -90 mph (s):	19.9	
0 -100 mph (s):	25.5	
0 -110 mph (s):	34.3	
0 -120 mph (s):	66.8	
0 - 1/4mile (s):	16.8	14.0
speed at 1/4mile:	133 km/h / 83 mph	
0 - 1km (s):	30.5	