Eiata

An EV conversion project.

Ryan W. Alexander
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ABSTRACT

The first-time conversion with a high school student of a 1990 Mazda Miata with a damaged engine to a fully electric vehicle with SAE J1772 charging with performance specifications matching or exceeding the original car.

PROJECT DEFINITION

DESIRED FUNCTIONAL OBJECTIVES

The vehicle should drive with similar performance compared to the original gas vehicle and have sufficient range to complete the daily commute of the user – about 40-60km per day.

The stock 1990 1.6l Miata makes 116 horsepower and accelerates from 0-100 km/h in 9 seconds.

DONOR VEHICLE SELECTION

The vehicle to be converted from combustion to electric is called a donor vehicle. A major factor in the range of a vehicle that is driven in the city and has to accelerate and stop frequently is the mass of the vehicle. Fundamentally, a lighter vehicle takes less energy to accelerate, and wastes less energy into the brakes as it stops. Therefore, a strong preferences is placed on lighter vehicles. An original rear wheel drive powertrain is also preferred to simplify the mating of the electric motor to the factory transmission.

Vehicle	Estimated Weight	Drivetrain
1st Generation Mazda Miata	2100 lb	Rear wheel drive / front engine
2nd Generation Mazda Miata	2300 lb	Rear wheel drive / front engine
3rd Generation Mazda Miata	2410 lb	Rear wheel drive / front engine
Suzuki swift	1650 lb	Front wheel drive / front engine
Honda CRX / Del Sol	1713 lb	Front wheel drive / front engine
1st Gen Smartcar	1600 lb	Rear wheel / rear engine

Around the time that the project began, there was a 1st generation Mazda Miata for sale in the same area with a non-running engine. After inspection it seemed to be in good condition and because of the non-running condition of the car, the price was reasonable. In addition to the car being lightweight, it is convertible and is well-known in the car enthusiast community as one of the best values for a ‘fun’ car.

BUDGET AND TIMELINE OBJECTIVES

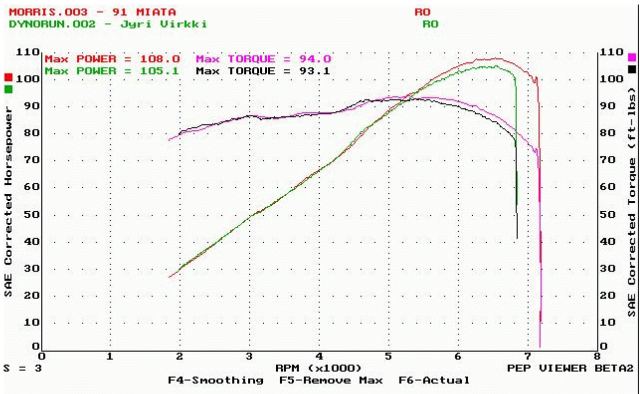
From the onset, the project was intended to take a minimum amount of time while accomplishing the functional objectives. As a result, decisions were made to reduce the total number of labour hours that needed to be dedicated to the project to the intended specifications.

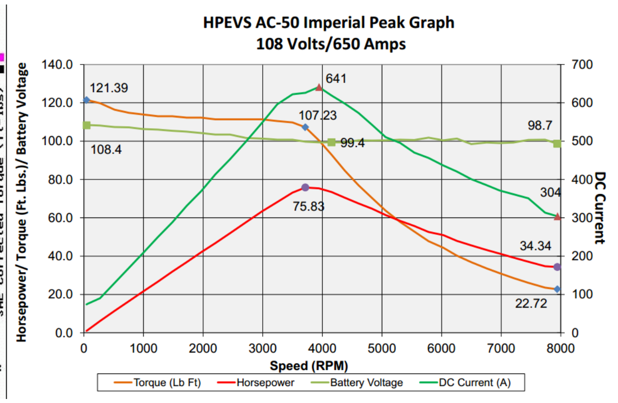
BACKGROUND

MOTOR AND CONTROLLER

Since time efficiency is a priority, the motor will be sourced with its controller. In the EV conversions that have been documented on time, direct current (DC) or alternating current (AC) motors are used. In short, DC motors provide greater torque and AC motors allow for superior efficiency and regeneration. An AC motor and controller combination was chosen to allow for regeneration and for the increased efficiency.

An HPEVS AC-50 motor was considered for the motor. The figures below show the power and torque of the original engine on the left and the electric motor on the right.





Until 4000 RPM, the electric motor provides at least 20% more torque than the original combustion motor. Although the peak horsepower is lower in the electric motor, the electric powertrain will ‘feel’ more powerful due to its increased axle torque at low speeds which results in an increase in acceleration, particularly from low speeds.

Batteries

Both lithium-based and lead acid AGM batteries were considered for use in the car, however it was not possible to achieve both the vehicle performance and range goals with the lead acid batteries. There are several types of lithium batteries available that would be able to meet the performance and range goals, however most of them have challenges with thermal runaway and potential fire if not used with care. LiFePO4 batteries are more stable and were chosen for this reason.

Using the well-reputed calculator in the do-it-yourself electric car community at www.evsource.com, based on tested vehicle ranges based on inputs of vehicle range and battery capacity with 80% discharge, a 36sp1 battery pack of 100Ah LiFePO4 cells is suggested to be able to achieve a 77km range. This exceeds the range requirement. Combined with the other electrification components, the total mass of the system is close to the stock engine weight.

Battery Management System (BMS)

With LiFePO4 batteries, it is important that the voltage of the individual cells remains within the range of the chemistry. If the cells are allowed to go higher or lower than the voltage range, they can lose their capacity and be irreversibly damaged.

The MiniBMS battery management system offers high and low voltage protection as well as top balancing of the cells via shunting each time the batteries are charged. It also has the ability to sound a buzzer in the driver compartment to indicate if the voltage of one of the cells is going too low – this informs the driver to drive more conservatively to reduce the chances of battery damage.

Charger

The charger for the high voltage pack was selected to be the Elcon PFC 2500W charger. It is able to charge 80% of the batteries's capacity in 6 hours on a 120V outlet, and 3.7 hours when connected to a 230V outlet or public charging station. This allows for 10km of range to be fast-charged in under half an hour at 0.23 C.

DC-DC Converter

The DC-DC converter serves to mimic the function of the alternator in the combustion vehicle. It keeps the 12v system topped up which runs the vehicle lights, ignition, and HVAC system.

System Integration

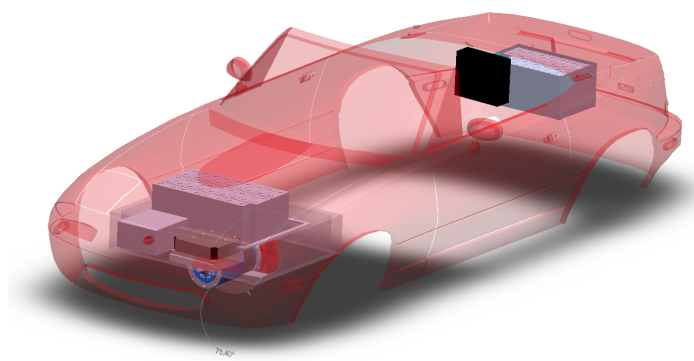
Mass Properties

To maintain the handling characteristics of the vehicle without needing to modify the suspension, it is important that the vehicle after electrification has mass properties similar to the vehicle before electrification. After the combustion powertrain was removed, the vehicle was placed on scales to measure its mass properties with and without the driver. This is shown to the left.

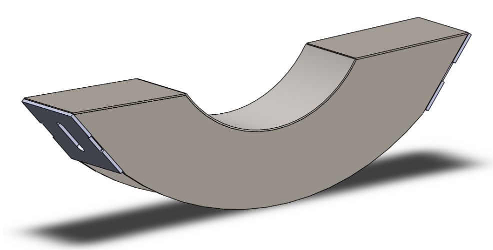
Each component was weighed and its proposed position in the vehicle was estimated. With the position and mass of each component known, it is possible to calculate its contribution to the mass distribution of the vehicle. Once the locations of the heavier components other than the batteries were known,

Layout

The components to go into the car were measured and laid out in CAD to determine the optimal placement.



Motor Mount Design



The motor mount was designed to support the motor securely under all driving scenarios. It bolts in where the combustion engine was mounted and is isolated with rubber to reduce the transmission of motor noise into the car while driving.

Construction

Before the electrical components could be fitted, the combustion components were removed. This included the radiator, engine, alternator, engine computer, power steering pump, and exhaust system. To help offset the costs of the conversion, these components can be sold as spare parts.

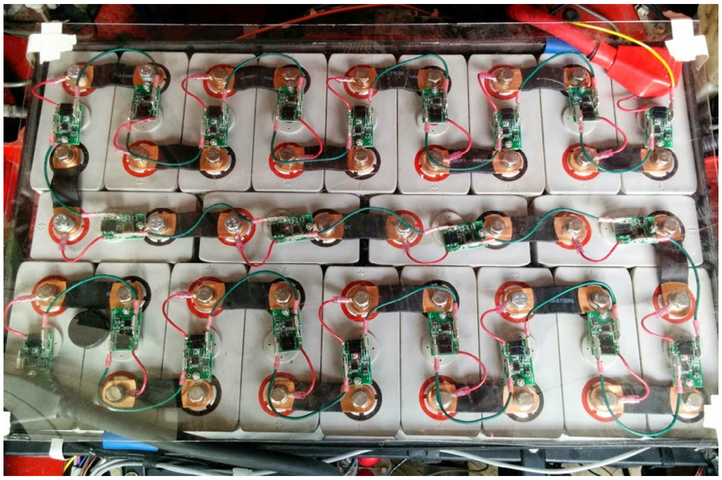
Component Installation

Below is a picture of the electric motor mated to the transmission prior to reassembly.

Wiring

Each wire in the system had its current and length calculated to ensure it was the proper gauge. Under the vehicle, care was taken to safely mount the cables so that they would be out of the way of road debris that could be kicked up and damage the insulation of the wires.

To the right is an image of the front battery pack assembled with the BMS boards connected.



Final Steps

Range Testing

The vehicle still needs to be tested to determine whether the range target has been met. This will be done by driving incrementally further and further while keeping a close monitor on the batteries.

Performance Assessment

Tests for the vehicle's acceleration times will be performed to verify performance against the combustion vehicle version.