

CHOOSING A DC MOTOR & CONTROLLER FOR AN EV.

By Edward Booth, November 2008-11-18

Introduction.

Choosing the traction motor for an EV can be quite simple, if you follow a logical decision-making path.

It should be said at the outset, that AC motors are more efficient than their DC counterparts, but they are also much more expensive. DC remains the system of choice for most home builders with a limited budget.

In many ways, DC is a little easier for the not-so-technically minded, but DC can be more dangerous volt-for-volt than AC. Over about 80volts, neither is “safe” without following the strictest protocols.

The controller is a bit more difficult to choose. You need to decide whether you want regenerative braking, and what your maximum and cruising current draws will be. If in doubt, err on the high side. It is very frustrating to have the performance throttled by lack of current, and continuous over-drawing of current can damage the controller or cause it to shut down.

The Choice of Motor.

There are many brands and types on the market, but it is advisable to stick to those that are well supported, and have a good track record.

Permanent magnet motors (Perms) are very efficient in their optimum rev range, but less so out of it. They tend to be a bit on the small side and are prone to overheating. They are best suited to motor bikes or similar, where their small size makes them attractive.

Be aware that the Perm PMG132 has a design that can retain carbon dust from the brushes, and in damp weather, this can cause arcing in the brush housing. The Company were unhelpful, and denied fault, so be warned!

Etech motors tend to be small, also, but, by my observation, have been very reliable, if not particularly sprightly. Again, they are best suited to bikes, or low-speed, light town-cars.

This brings us to the major players, Advanced DC (ADC) and Warfield Electric (Warp). These two brands are virtually identical in specification, and can be interchanged freely.

There is considerable information available about the range of both these brands, and it would take too long to list all the motors available.

I have chosen to list the ADC range here, but the corresponding Warp motors can be substituted.

The motors for cars start at 6.7" diameter and go up to 9" for normal use. There are also 11" and 13" motors available, but these are for racing and sport, and are not covered here.

The ADC motors are:

- K91-4003 (6.7" dia. x 11.5" short motor) Volt range 72-96volt.
- X91-4001 (6.7" dia. x 15.3" std, motor) Volt range 72-144volt.
- L91-4003 (6.7" dia. x 15.3" fast motor) Volt range 72-120volt.
- 203-06-4001 (8" dia. x 14.7") Volt range 72-120volt.
- FB1-4001 (9" Dia. x 15.6") Volt range 72-144 volt.

The voltage ranges of the motors are:

- K91-4003; 48-96volt,
- X91-4001; 72-144volt,
- L91-4001; 72-120volt,
- 203-06-4001; 72-120volt
- FB1-4001; 72-144volt.

The above information is from the ADC website, and, presumably, reflects their official position. However, it seems to be accepted that the 8" and 9" motors can be run at voltages up to 192. Careful monitoring of temperature would be necessary in such cases, and the warranty would probably be voided.

To select one of these for your vehicle, the following is a guide:

Vehicles up to 750kg:

- K91-4003 where space and range are more important than speed.
- X91-4001 for long range and good performance at 120V.

- L91-4003 for performance and speed.
- 203-06-4001 for racing and sport, but lower range.

Vehicles 750-1250kg:

- X91-4001 very efficient, long range, sedate performance.
- L91-4003 good performance and acceleration.
- 203-06-4001 high performance and/or hilly terrain.
- FB1-4001 for racing and sport, or heavy payloads

Vehicles 1250-1600kg:

- L91-4003 for commuting with few hills.
- 203-06-4001 good performance in hilly terrain.
- FB1-4001 hilly terrain and heavy payloads.

Vehicles 1600-2000kg:

- 203-06-4001 for city commuting
- FB1-4001 for heavy loads and hilly terrain.

Clearly, there is a trade-off between power and range. An increase in voltage will increase the power, while maintaining the range to some extent, but with an increase in overall weight.

My article on selecting a suitable vehicle for your EV conversion sheds more light on this. An FB1-4001 running on 72 volts would give less that startling performance and poor range in a heavy vehicle.

A would-be builder should be able to find a suitable motor in that lot, but it is essential that he/she answer the decision questions very honestly.

Remember that the weight goes up with motor size, and the number of batteries (and weight) rises with voltage. Even Li/ion batteries weigh a fair bit, although they tend to be only about half as heavy as Pb/acid.

The decisions don't end there. Next one must decide on whether to use regenerative braking, as this will determine your circuitry. The current draw is also a factor.

The choice of controllers is fairly limited. Alltrax make an excellent range of controllers up to 72volts and 450amps. These will power the smaller 6.7" motors quite well, and for a fraction of the cost of the larger units.

Controllers by Curtis, Kelly and Zilla are available fairly readily. The former can be bought in Australia, which can save a lot of hassles. There are others, too, but you will probably have to track them down and import them yourself. Consider the backup if you need it!

Another system worth considering is the D&D separately excited motor/controller pack (SepEx). This is a 6.8"dia motor which is 11" long (similar to the K91-4003), but, instead of being series wired, the armature and field are independently controlled by the controller. This allows for the torque to be optimised at low revs, while increasing the speed at the top end.

The SepEx system comes as a tuned pack and uses a Sevcon SEM PPAK controller rated at 425amps. The voltage range is 60-84volt. It appears that they are only available by importing yourself.

Performance is similar to the ADC K91-4003, but it automatically comes with regen braking.

If you are building an EV under 750kg, this system is definitely worth considering. To date, there do not appear to be any larger SepEx motors available, but they will probably come.

Costing.

At the time of writing this, the AU\$ has been in free-fall, and the prices of the recent past will be but a sweet memory.

When the AU\$ was up within 5% of the US\$, the prices went something like this:

- K91-4003 about \$1500
- X91-4001 about \$1700
- L91-4003 about \$1700
- 203-06-4001 about \$2500
- FB1-4001 about \$3400
- Alltrax AXE 7245 about \$900
- Curtis 1231C-8601 about \$2500
- D&D SepEx motor & controller system, about US\$1450 plus freight, customs, etc (allow about AU\$2200)

Remember that all these prices will have risen by up to 45% in recent times! So my costing is really only roughly relative.

These prices differed a bit, depending on where they were bought, and included a fair margin for importing etc. The same motors could be bought for as little as 2/3 of these prices from the US, but then came customs, import agents/brokers, GST, etc, all of which closed the gap a bit. BUT! All the gains of self-importing can be lost if the goods are faulty and must be returned to the US. You will not get much of your import outlay back, and you may have to do battle with a dealer who “frankly couldn’t give a damn!”

Ebay and second-hand deals can be very attractive, but consider the risks.

It is certainly worthwhile going online to American sites to see what is out there, and many of the smaller items can be purchased to advantage, but, if we want an Australian Industry to be here when we want it, and to provide backup service, we need to support it. It’s as simple as that.

Conclusion.

By now, you should have a fair idea of what car and motor you plan to use. It is now possible to calculate the weight of the vehicle (less the ICE bits and plus the weight of the motor). You should know what voltage you need, so you can calculate what batteries can be fitted without exceeding the Manufacturer’s GVM.

This is a good time to review your choice of vehicle. Does it still look OK? How will all these new bits fit in it? Will it still do what you wanted it to do?

There are sites on the net, which list conversions by others and how they perform. Check your plans against these.

Join the Australian Electric Vehicles Association (AEVA), and meet others who have done it before you. They can help you to source parts, and share some of the pitfalls.

You will find that many claims will conflict. Everyone has their favourite way of doing things. They can get pretty passionate about it! But the fact remains, that there is no “one” way.

You will have to sift all the information, make judgements on who to believe and what seems right for you, then, get on with it.

Some people collect vast amounts of data, only to become paralysed by indecision. Sometimes it is better not to know everything!

Be very honest with yourself. Do not be afraid to go back to the drawing board if data comes to hand. Try to make changes at the planning stage, and not when you are deep into the project.

Only now should you consider buying the vehicle and major components,

Order the larger parts as soon as you have finalised your decisions (and have the money), as some parts will need to come from overseas, and will take some time.

This will give you some time to look at other factors, and read up on how to do it. Now is the time to be talking to your local Department of Transport and “tame” Engineer. Do it early.

This paper is by no means definitive, and is the best I could do at the time. I relied heavily on the net and my own experience. There will be people with far more knowledge than myself, and I welcome any additions or alterations to the text. Edward Booth