CHOOSING A DC MOTOR & CONTROLLER FOR AN EV.

By Edward Booth, 5 January 2012

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 more expensive. DC remains the system of choice for most home builders with limited budget and technical skill.

Possibly the biggest deciding factor is whether you wish to retain the gearbox, or drive directly to the wheels via the differential. If the latter is your choice, you will almost certainly need DC, as these motors develop full torque from zero revs, whereas AC motors have a torque curve similar to a petrol engine, and need lower gears to get going.

The benefit of omitting the gearbox is the reduction of weight, but it is best suited to rear-wheel-drive vehicles as front-wheel-drive incorporates the differential into the gearbox!

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.

AC has the advantage of automatic regenerative braking (regen) which is; recharging with throttle off downhill and/or while braking etc., but this is only important where useful regen will be available (hills and heavy traffic). Also, Pb/acid batteries are poorly suited to regen, and Lithium batteries are pretty well essential to get any useful benefit.

DC regen is available with separately excited motors (see D&D below), but the controller needs to be carefully set up (programmed) to optimise this. It’s not for the faint hearted. Note: these can usually only be used in systems up to about 84Volts

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 motorbikes 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 have been 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.

There is also a range of KOSTOV motors (Origin: Bulgaria) available from Australian distributors. These range from 9” to 13”.

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

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 heavy vehicles, racing and sport, and are not covered here.

The ADC motors are:

- K91-4003 (6.7”dia. x 11.5” short motor)
- X91-4001 (6.7”dia. x 15.3” std, motor)
- L91-4003 (6.7”dia. x 15.3” fast motor)
- 203-06-4001 (8”dia. x 14.7”)
- FB1-4001 (9”Dia. x 15.6”)

The voltage ranges of the motors are:

- K91-4003; 48-96volt,
- X91-4001; 72-144volt,
- L91-4003; 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 192V. 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
- L91-4003 for performance and speed.
- 203-06-4001 for racing and sport, but heavier, with lower range.

Vehicles 750-1250kg:

- X91-4001 very efficient, long range, sedate performance.
- L91-4001 good performance and acceleration.
- 203-06-4003 high performance and/or hilly terrain.
- FB1-4001 for hills, 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.
- Consider the 11” and 13” options

Note that the Warp 9” has a version with an in-built universal joint, which is very useful for direct drive with no gearbox.

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 than 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 two thirds 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 Zeva are available fairly readily. The former and last 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 the system 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.

There is also a Chinese-built motor and controller pack (from ZIBO MOTOR CO agency) available at a relatively low cost, but it is very heavy for its relatively low power output. This is a viable "budget" option for cars under 1 tonne.
For more information on these kits/components check Suzi Auto Services – www.suziauto.com

Costing.

At the time of writing this, the AU$ is close to parity with the $US. Prices fluctuate with several factors, but are currently 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 1231IC-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 might have risen 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, batteries etc). 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) – www.aeva.asn.au 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 new 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