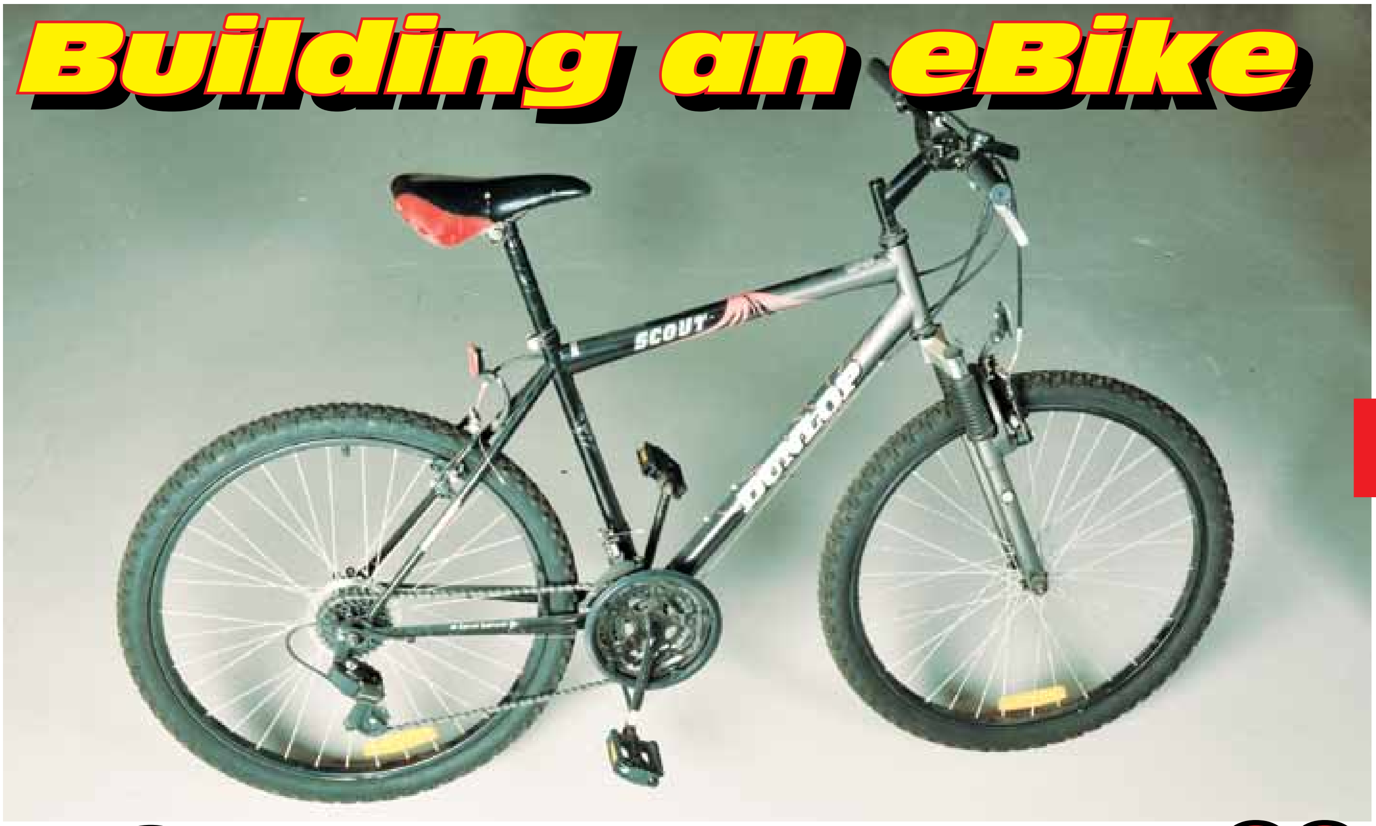
Building an eBike



POWER your (Puff,

Riding a pushbike is great exercise – until you come to hills! Unless your name is Evans or Armstrong et al, unless you're one of the lycra brigade who keep super fit by pedaling everywhere and anywhere, even if your pushie has 150 gears and weighs about a hundred grams, you often wish that you could have just that little bit of assistance when the going gets tough!

My first pushbike came courtesy of Santa when I started high school. And I've had one (or more) ever since. While I enjoy riding my pushie and acknowledge that it's one of the best forms of exercise, I'm the first to acknowledge that I'm not quite as fit as I once *thought* I was.

In fact, riding for any distance (with the emphasis on any!) certainly takes it out of me. So often I've wished for a motor of some sort to ease all those strained muscles, especially walking the bike up hills that have beaten me!

Building a bike for the teacher

Some months ago our esteemed editor and I visited a school which regular readers would be familiar with because we've featured it before in SILICON CHIP: Mater Maria Catholic College in Warriewood, near our editorial office on Sydney's northern beaches.

We were there at the invitation of Dave Kennedy, the school's electronics/technology teacher, to review the major projects being built by his senior students for their Higher School Certificate.

Most of those projects came from the pages of SILICON CHIP; many were variations on those projects (and those variations were where some of the builders struck snags!).

Having spent the best part of a day talking to the students and solving (we trust!) many of their problems, we were intrigued to spot what was going on (through the glass) in the classroom next door. Here his younger (year nine) students were building an electric pushbike.

In fact, Dave Kennedy had purchased a brand new pushie (nice bike, Dave!) and an electric motor conversion kit specifically for the students to gain some "hands on" experience.

The bonus was that when it was fin-

By Ross Tester

Puff) Pedal Pushie!

ished, Dave could ride to school – about 5km or so across mainly flat terrain but with a nasty hill at each end. It was for these hills which Dave hoped a motor would keep him from becoming too hot and bothered when he reached school each morning.

The completed bike looked pretty impressive – from the fire-engine red frame through to the in-wheel motor and controller, along with all the controls and wiring necessary.

One of the students, Alex, even took a few photos of it for us.

But this started us thinking – why not a project in SILICON CHIP showing how to build an electric bike (or, to be more accurate, how to convert an existing bike to electric-assist).

By the time we got back to the office, the editor and I were convinced that many readers would like to know how they could bring that old pushie back to life (you know, the one with flat tyres hanging on the garage wall!) and perhaps get some benefit by way of (power assisted) exercise.

So we approached the distributors of the kit which Dave Kennedy had purchased – Rev-Bikes in Victoria (**www.rev-bikes.com**) [see end of article] and this article is the outcome.

Legal or not legal?

This was our first question. Is it legal to put a motor on a pushbike and use it on public roads?

The Year 9 class from Mater Maria with the newly-converted "Diamondback" mountain bike. At left is Malcolm Faed, whom readers will recall converted his ute to battery/electric power (June 2009 issue).

We're not lawyers (even of the bush variety) and it took a bit of digging to get the answer.

This appears to us to be yes. . . but!

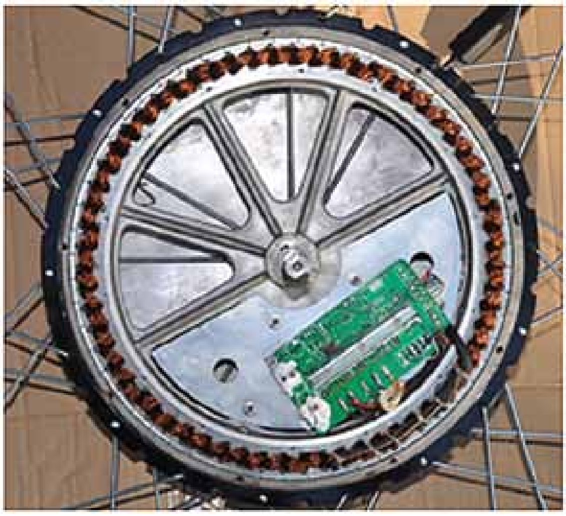
The rules appear similar (if not identical) in all states but we will use NSW regulations as our yardstick.

Quite simply, according to the NSW RTA website (**www.rta.nsw.gov.au/registration/unregisteredvehicles/scootersminibikes.html**) you can put a motor on a pushbike with the aim of assisting pedaling, as long as the output power of that motor does not exceed 200W.

There are two points to note here: first is the motor is not intended to replace pedaling as the means of propulsion – it is there to assist.

Indeed in most European countries the motor doesn't work at all unless the pedals are being pushed (thankfully, they haven't brought that one in here . . . yet!)

The second point is that limitation of 200W. To be frank,



Lay out all components on a table or clean floor to check that you have everything. Here the tube/tyre is already fitted and there are some differences between this kit (the Mater Maria kit) and the one we used. At right is a shot inside the "Magic Pie" motor, which also shows the integrated controller.

that's not much at all, especially if it is pushing around a 100kg rider. Again, it will only assist you, not really propel you.

There are lobby groups currently trying to have that raised to at least the European standard of 250W – again, not much, but better than 200!

If the motor is rated at higher than 200W, then the pushbike becomes a motorbike and must be registered as such – except that it is almost impossible to do so because the "motorbike" does not have all of the equipment demanded by Australian Design Rules, such as turn indicators, brake lights and so on. Catch 22 all over again!

Just as importantly, the rider must be licensed to ride a motor bike – again, impossible if they are under age.

How are the motors tested?

As far as we are able to ascertain, authorities (Police, traffic, etc) cannot test motorised pushbikes in any state, simply because they do not have any equipment to do so.

In most cases, the motors (especially in-wheel types) do not have any power or other identification on them so the boys in blue cannot even look up a reference to say "You're nabbed!"

Anecdotal evidence suggests police tend to use their own judgement – if you are whizzing along a road at 50km per hour, not pedaling, they might take a slightly more jaundiced view of you than where you are riding at a slower speed and at least appear to be pedaling!

So which motor to go for?

We'll get on to motor specifics in a moment but the source we obtained our motor from has several different models available – not only various sizes (to suit most bikes available in Australia) but also in power levels.

First is a 200W motor so it is absolutely legal, regardless. It's also the cheaper alternative.

Second is a much more powerful motor – rated at 1000W – which can be "governed" down in output power via the use of a computer program.

As perverse as the high power motor option sounds, that's the way we went for the SILICON CHIP pushie power conversion. Why?

Most importantly, the higher-power motor programmed down would be operating way below its maximum rating, therefore its longevity is much more assured. A 200W motor would be operating at maximum most of the time, therefore wear and tear would be expected to be much more a factor.

Secondly (and yes, this does sound like a cop-out!) we knew that we would have the opportunity to use the bike on some mountain bike tracks on private property where that extra power would come in real handy. By taking along a notebook computer, it would only take a few moments to re-program the motor to full power and back down again.

Having said all that, SILICON CHIP does not endorse, in any way, the fitting of an over-powered (ie, >200W) motor to a pushbike for on-road use.

Front or rear . . . or both?

There is one other consideration, that is whether to fit the motor to the rear, to the front or even (as we have seen in pictures only), both front and rear!

Assuming you're only going to fit one motor, there are arguments for both fitting to the rear and fitting to the front.

The rear, which suits a 135mm fork width, should mean best traction, because it is driving the wheel which is normally driven by the pedals/chain. However, this puts a lot more weight at the rear of the bike, possibly resulting in less control (eg, steering can be a little "vague", etc).

A front motor, (100mm fork width) should be easier to fit (no problem with gears etc) and also the weight is more evenly distributed, which theoretically at least, gives the best control.

Fairly obviously, fitting a motor to both front and rear would result in a lot of power – but it would also be just as obvious that you were running significantly more than 200W and could automatically draw the attention of the authorities that you don't really want.

It would also be a quite expensive exercise, not to mention the difficulties of controlling those two motors as one.

One further point: regardless of the motor to be fitted, they aren't suitable for carbon-fibre or other lightweight bikes. You need a strong, steel fork to take the strain.

Which battery?

There's a range of batteries available to not only suit the motor you choose but also give extra performance.

The voltage of the motor you install determines the amount of power or torque you will get; the higher the voltage, the faster the take-off.

Our kit came with a 48V motor so we obviously needed 48V battery. The one supplied was a Li-ion type but you'll find other types to choose from on the Rev-Bikes website.

For example, they also have LiFePO4

The wheel as supplied with a 1000W Magic Pie 48V in-wheel electric motor. This is one of several models available.

The spokes are usually loose to prevent warping in transit. A $6 spoke key soon had them nice and tight.

types 24V (16Ah), 36V (12 or 16Ah) or 48V (10Ah). LiFePO4 are more expensive but charge in half the time as Li-ion and last twice as long.

All come with a mains charger (an optional solar charger is also available). A battery management system monitors each cell within the battery for the longest possible life.

The range with a fully charged battery depends on the type and capacity but as a minimum, you would expect 30km or so per charge without significant regenerative braking.

The kit

Meanwhile, back at the ranch . . . we approached Rev-Bikes and explained who we were and what we proposed. They were most helpful in our discussions and agreed that an article in SILICON CHIP would be a great idea.

So within a few days, a large package arrived from Rev-Bikes and we got ready to attack a perfectly good Dunlop 26" mountain bike.

Well, attack is probably a bit harsh as you don't have to make any real changes to the bike, except for fitting the motorised wheel, the battery and all the controls.

First of all . . .

Lay all the components out on a table or garage floor to ensure that everything is supplied. It also makes life easier later on if you identify the various components now. The photo actually shows the Mater Maria kit which is slightly different to that which we obtained.

Charge the battery

While going through the various assembly steps, it's a good idea to plug the battery into its mains charger so that when you want to use it, it's fully charged.

The battery charger plugs into a socket on the battery pack which is revealed when you raise the handle 90°. The battery does not have to be plugged into the motor or controls to charge.

Fit the tube/tyre

The wheel rim is "double walled" to ensure that it can handle the enormous torque generated by the electric motor. Apart from that difference, fitting the tube and tyre is exactly the same as on a conventional wheel, with the possible exception of the valve stem.

Rev-Bike suggest buying a tube with a long valve stem to go through the double wall and also avoid pressure on the tube if stretched; these should be available at better bike shops.

(I'll admit that I used the existing [standard stem] tube and tyre. It takes a bit of manipulating but it is possible to use a tube with a standard-length valve stem).

Fit the gear cassette

When I was a kid, they used to be called gear clusters – the multi-gear assembly for chain gears. A new one will cost about $30 but we wanted to use the existing one and save the money.

If you are doing so, you may need help in removing it – there's a special tool which does the job in seconds. My local bike shop did it for me without charge. While you've got the gear cassette off, a good clean with some kero and a wire brush won't do any harm!

Fit brake disc (optional)

If your bike has disc brakes, there is provision on the motorised rim for fitting. Otherwise, you use the existing caliper brakes but note that you may need to reposition the shoes. In fact, we found it easiest to remove the brakes altogether while fitting the wheel – they just get in the way.

Not only that, you'll be fitting new brake handles so will probably have to replace the brake cables as well.

Loose spokes!

As we were examining the components, we were a little perturbed to find most of the spokes in the wheel rather loose. Apparently this is normal practice to avoid the wheel warping in transit (something we didn't know about).

With the aid of a spoke key ($6 at the local bike shop) we proceeded to tighten all the spokes before we went any further.

The easiest way to do this is to use an old front fork mounted vertically (eg, in a vice). You'll almost certainly need to bend the forks apart a little to accommodate the wider rear wheel hub. Loosely mounting the wheel in this fork will not only make access simple but allow you to spin the wheel easily, looking for any "wobbles" or warped sections caused by too loose or too tight spokes.

Remember that you tighten the spokes on the opposite side of the warp to pull the rim back to the centre.

You also need to ensure that the motor/axle is centrally located within the rim. If the rim moves up and down as it rotates, that needs to be corrected. You tighten both sides by the same amount to pull an eccentric (out-of-round) rim back in. It's a trial and error routine;

Fitting the tube and tyre is much the same as a "normal" bike wheel. Rev-Bikes suggest using a tube with a long valve stem, but we elected to use our old tyre and tube. As you can see the valve stem pokes through the double-wall rim with more than enough length.

They call them gear cassettes – this one came off the original wheel and was easily fitted to the new (powered) wheel – it simply screws on.

you may find that correcting a warp results in the wheel being more eccentric – or vice versa.

Make small adjustments – no more than half a turn at a time – and when you think you've got it right, it's best to leave the wheel overnight (or at least a few hours) to allow it to "settle".

Fit the wheel

The powered wheel slots into position in the same way as the original. However, you may need to pull the frame apart slightly (maybe 10mm or so) to fit the new wheel. It helps to have a second person on hand to assist with this.

The power and control wires exit the hub on the left side (ie, the side opposite the chain/gears). To keep them from getting tangled in the wheel etc, while building, loosely fasten them to the frame with a cable tie.

It is important – in fact it's vital with a powered wheel – that the wheel nuts are done up as tight as you can get them. Ideally, you should use a ring spanner or socket for this – don't use a shifter because they ruin far more nuts than they do up!

It's also vital that the wheel is placed exactly on the centre line of the bike – there should be exactly the same distance between the rim and the frame on both sides. This is no different to any wheel you fit to a bike. Similarly, the wheel should have no wobbles nor eccentricities (see earlier notes).

Torque Bar

You might also consider the installation of a Torque Bar, which is designed to ensure the axle doesn't slip in the forks. This is particularly necessary where high voltage motors are pulling a lot of weight, or in certain kinds of forks which don't lock the axle in well. These are also available from Rev Bikes for $25.

Check the chain/gears

The gear changer (derailleur) is obviously fitted during the previous step (under the axle nut) but before going any further, check that it travels freely and the chain also travel freely within it and around the gears. Move the gear lever so that the gears change from lowest to highest gear – a small adjustment might be needed on the derailleur if the actual gear positions are different on the powered wheel.

Re-check tightness

We don't want to harp on it but for safety's sake, go back and check that the wheel nuts are still tight and that the wheel hasn't moved. While you're about it, check your front wheel nuts too – you can't be too careful.

Fit the battery plate to the battery rack

The battery is designed to slide in and out on a plate fixed to the battery rack. Once in place, the key which controls the bike locks the battery box in place via a pin into the plate.

The battery plate fastens to the rack via four 6mm screws with Nyloc nuts. A washer under the head of each one allows a little play until you get the position correct.

Note that the hole in the plate (which the pin mates with) goes toward the front. This way the key is also towards the front and the handle on the battery box goes towards the rear.

Fit the battery rack

The two vertical bars screw into two holes on the bike frame, immediately adjacent to the axle. Most bikes these days have these and they are invariably tapped to 6mm.

The front of the rack connects to the bike frame via two short extension arms (in the kit) which can be adjusted fore-and-aft to place the rack just where you want it. They're obviously intended for bikes with horizontal holes through the frame.

Where your frame doesn't have suitable holes, the two extension arms need to be secured to the frame, immediately below the seat (saddle) stem. There's a variety of bike frame designs so you will have to make the best arrangement for your frame. Just remember that the battery pack is one of the heavier components – you certainly don't want it coming adrift as you're riding along.

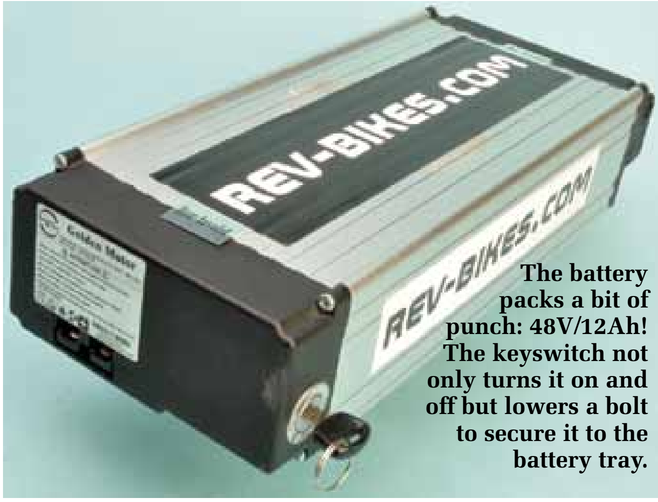
Fit the handlebar controls

Four "controls" need to be fitted to the handlebars. The obvious one is the throttle control/battery level indicator – in our kit, it was a lever type but there is also a twist-type available.

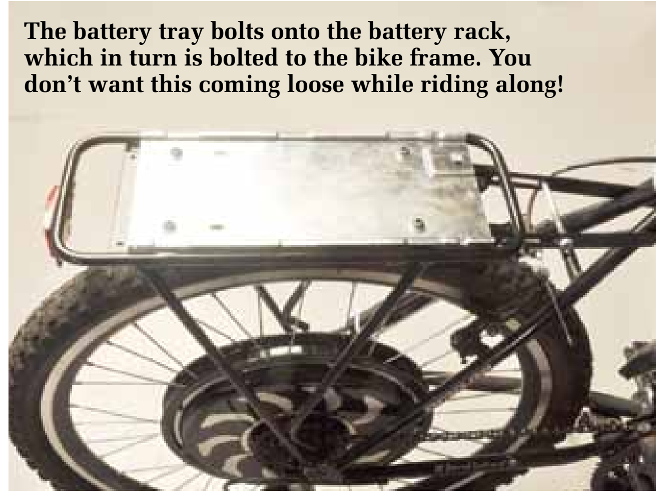
Whether you fit this to the right or left is a matter of preference – we chose the left side because it appeared to be designed this way. Also, on a pushbike, you should be giving hand signals with your right hand, so your left hand remains on the control/handlebar. But how long is it since you've seen a pushbike rider give a hand signal?

However, there is also an argument for fitting it on the right because motorcycles and scooters usually have their throttles on the right.

The second control is the cruise and



The battery packs a bit of punch: 48V/12Ah! The keyswitch not only turns it on and off but lowers a bolt to secure it to the battery tray.



The battery tray bolts onto the battery rack, which in turn is bolted to the bike frame. You don't want this coming loose while riding along!

horn buttons – these logically go on the opposite side to the throttle.

The other two controls are the special brake handles. As well as the mechanics for pulling the brake wire (just as any brake handle) these also contain a switch which engages regenerative braking whenever the handles are squeezed (ie, the motor becomes a generator and returns some electrical energy to the battery when braking).

To fit any of these controls, you're going to need to remove the handlebar grips. If, as in our case, those grips have been in place for a few years, no amount of twisting or tugging will remove them – we had to cut ours off with a box cutter knife. Fortunately, a new pair of grips is included in the kit (NOTE: don't fit the new ones until you are absolutely sure of the position of everything else!).

Another fly in the ointment could be your chain gear shifter(s). On our bike, the shifters were mounted close to the grips – just where we wanted to mount the throttle and cruise/horn buttons. So we had to move them towards the centre of the handlebars.

Mount everything just tight enough to keep them in place – that way, you can move everything around so that nothing interferes with anything else.

Pay particular attention to the gear shift levers, brake levers and throttle controls – take them right through their travels and adjust their positions as necessary.

When you're happy with the position of all the handlebar controls, tighten everything and secure the cables to the handlebar post or frame with cable ties.

As a very last step – and possibly only after you've ridden the bike for a few hours – push the handlebar grips into place. The reason this is the last step is that they are rather difficult to get off once on!

Connecting it all together

This section appears to be the most challenging but is actually relatively easy, as all the connectors are colour coded. So all you have to do is connect colour to colour and you shouldn't go astray.

The biggest problem you will have is the length of the cable – it's obviously made to handle much longer bikes (a tandem, perhaps?) and you will have the best part of a metre too much.

It would be tempting to cut and re-solder all the connectors so that the right length of cable remained but we thought that was tempting fate (and was also too much like hard work!) so we wrapped the excess cabling around the underside of the battery rack and made it as neat as possible with cable ties.

Also use cable ties to secure the bunch of cables to the bike frame in as many places as you want – just remember to keep clear of any bare brake or gear changer cables.

Slide in the battery

The (now fully charged!) battery pack slides onto the rack via the adaptor plate you fitted earlier. When it is fully home, turning the power key on the battery pack also lowers a "bolt" through a matching hole in the adaptor plate, locking it in place.

Finishing the cabling

Now it's time to connect the control cable and power cable. These mate with the two cables emerging from the motor.

Make sure the key is in the off position before this step.

The control cable has a multi-way connector. If you look closely, you'll see arrows on both plug and socket – line up the arrows and the two halves should mate easily. Push them all the way home – they are waterproof when fully engaged.

Be careful with this: it's quite easy to get them off alignment and if you do (we did!) you'll end up with bent pins in the connector (we did!). This has only one minor drawback: your bike won't work! (It didn't!)

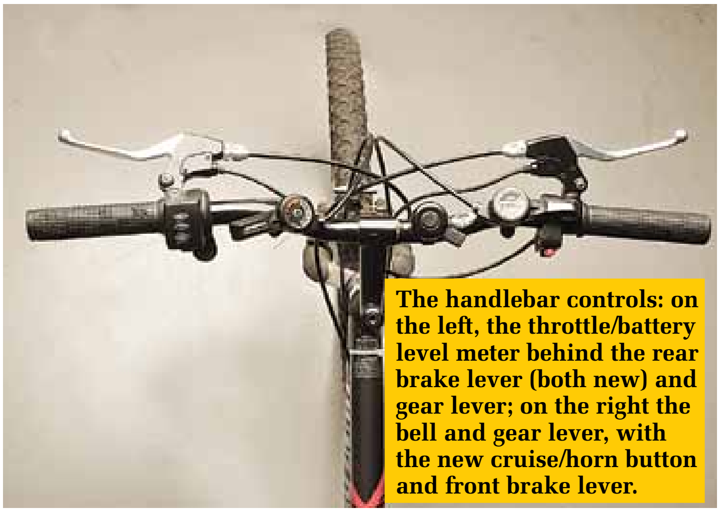
If you do manage to bend the pins, you're going to need a pair of very fine needle nose pliers, a good magnifying glass and a strong light.

Finally, connect the power cable, + to + and – to –, to the only cable left emerging from the motor. The opposite end of this cable has a large plug which connects to the battery output. It is polarised but make sure you haven't forced it in the wrong way – again, it's + to + and – to –.

We found that one of the connectors in this plug had pushed too far back to make reliable connection – a judicious rearrangement with a pair of fine pliers soon fixed this problem.

Checking it out

We know you're itching to turn it on and ride off into the sunset but before you do, check (and tighten if necessary) all Allen screws, Phillips screws, nuts, etc – your safety depends on everything being ship-shape. Most important (again!) are the two nuts which hold the powered wheel on – the motor means there are very large stresses on the wheel so tighten it up!



The handlebar controls: on the left, the throttle/battery level meter behind the rear brake lever (both new) and gear lever; on the right the bell and gear lever, with the new cruise/horn button and front brake lever.

The power and control cables are fastened securely to the bike frame with cable ties.

Also tighten any cable ties fully and snip their ends off, mainly for neatness but also to ensure that any ends don't interfere with brakes or any of the controls. And it's better to have too many cable ties than not enough.

Boxing it up

A large box was supplied to contain all of the cable connections, to keep them out of the weather.

We thought this was a bit of overkill and will be substituting a small jiffy box instead; something unobtrusive that will sit in front of the battery box.

Pedelec (PAS)

You may have noticed that we haven't bothered fitting the Pedelec controller – that's the device which allows the motor to run only while the pedals are being used. As mentioned earlier, it's a requirement in most, if not all EU countries but it is not a requirement in this part of the world.

If you do want to fit it you'll find fitting instructions on the website in the section on Programming. As it's not required here, we didn't bother with it.

Other "options"

You will notice on the lever throttle (which doubles as a battery level indicator) that there is a push-button switch with the word "lights" underneath. Similarly, on the other handlebar control there are two push buttons; a green button which is the cruise control and a red button for a horn.

The cruise control is self explanatory – it works the same way as a cruise control in a car. Once activated, it will hold your speed (as best it can) at the same level until you either push the button again or activate either of the brake handles.

The other two buttons are for options – not surprisingly, they are for lights and a horn. Because you have 48V available, a very bright head and tail light can be fitted, as can a much louder horn than you'd expect on a pushbike.

The wiring diagram (Fig.1) shows both these options and how they are fitted; if you don't have them don't worry – just ignore their fitting on the diagram.

Programming

The electric motor should work with-

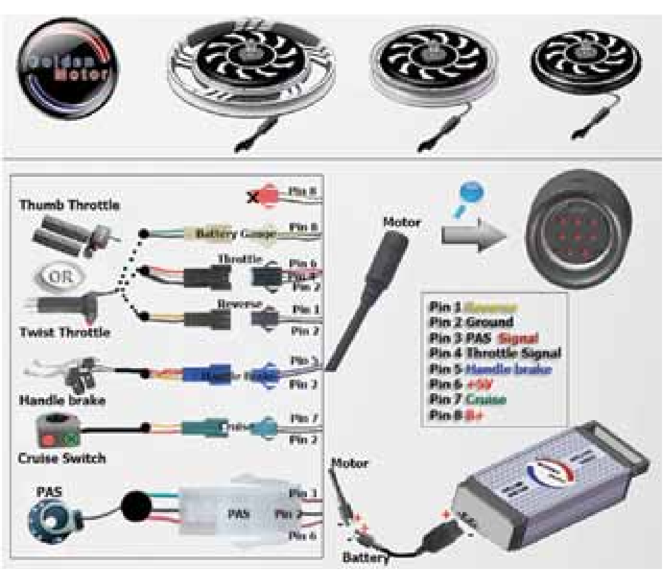


Fig.1: this wiring diagram, taken from the Rev-Bikes website, leaves a lot to be desired. Fortunately, the various plugs and sockets are colour-coded so it's reasonably straightforward to connect everything.

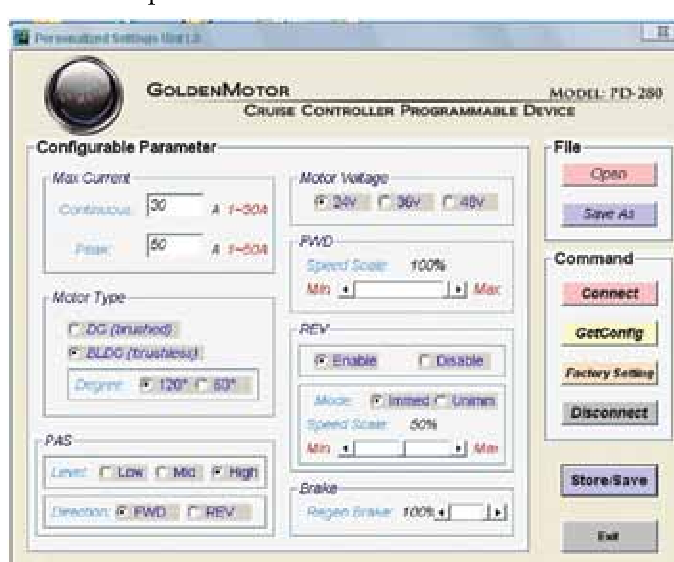
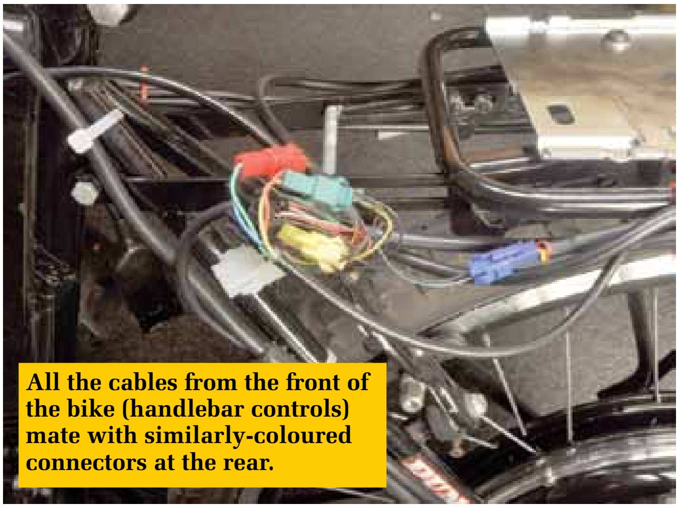
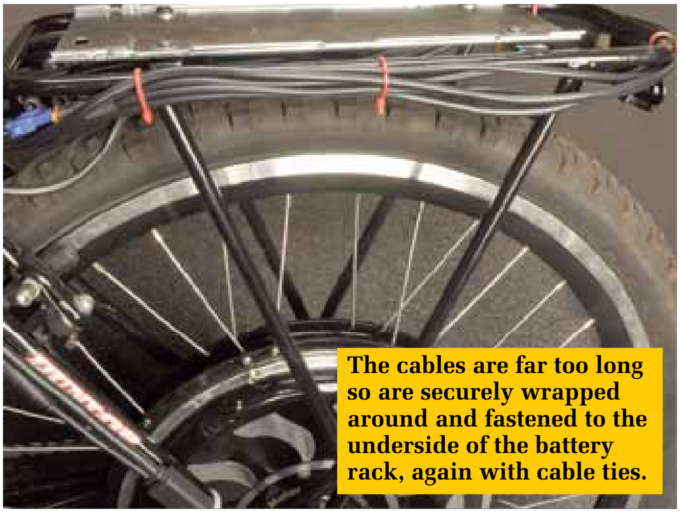


Fig.2: a screen grab of the programming software. It too is not particularly user-friendly, especially when it comes to setting that important power limit. As mentioned in the text, we'd be inclined to set maximums to 25% and hope for the best!



All the cables from the front of the bike (handlebar controls) mate with similarly-coloured connectors at the rear.



The cables are far too long so are securely wrapped around and fastened to the underside of the battery rack, again with cable ties.

out any programming on your part (ie, with the factory defaults). However, if you used the 1000W motor, it must be re-programmed down via the supplied USB cable before you can legally take it on public roads.

Download the Cruise Controller Programming Interface Software from www.rev-bikes.com.

It's a .rar file which you'll need to unpack, then load the resultant "PI200Setup.exe" file and you're away.

The USB cable plugs into the multi-pin connector which goes to the motor. The screen should look something like Fig.2 – and you can change any of the parameters you want. The motor is BLDC.

How do you set the power? If you set the power to minimum we believe you should be pretty close to the mark.

Theoretically, the minimum for a 1000W motor is 300W but if you allow for less than 100% efficiency of the motor – you'd have to be reasonably close. As we mentioed earlier, no-one has the means or equipment to measure the motor output anyway!

Security

With around $1300 worth of motor and battery, we imagine that an eBike would be a juicy target for thieves.

Of course, you could chain and lock your bike up when you leave it and always remove the key (which locks the battery box in place).

But we'd be more inclined, if at all possible, to remove the battery box completely and take it with you when not in use. That will make it so much harder for someone to purloin your powered pushie!

Conclusion

It's a wee ripper! Even programmed down, on the flat the motor managed to haul my 100kg around with apparent ease and on hills, you certainly notice the assistance from the motor.

The regenerative braking kicks in as soon as you touch the brake handles – it's nice to know gravity is giving you something back in the way of energy! SC

The finished eBike. Apart from tightening the spokes, total time to complete was only a couple of hours. It's still a standard mountain bike (albeit several kilos heavier!) which can be ridden normally if the battery goes flat.

WHERE FROM, HOW MUCH?

Our kit came from Rev-Bikes Pty Ltd, of Melbourne, Vic. Phone (03) 9024 6653 Web: www.rev-bikes.com

Price for the "Offroad" Kit (wheel with 1000W motor, 48V battery pack & charger, battery rack, controls and wiring) as seen here: $1295.00

SPECIAL SILICON CHIP READER OFFER:

Order this kit from Rev-Bikes before December 9 (for guaranteed pre-Christmas delivery) and they'll give you a huge discount, just for saying you saw the article in SILICON CHIP!
That's right: SILICON CHIP reader price is just $1150.00

BUT WAIT, THERE'S MORE!
They'll also throw in a FREE set of lights with orders placed during November!

Many options and accessories are also available such as a Solar Kit which charges your battery while sitting in the sun. Price is around $500 (depends on voltage).

See www.rev-bikes.com for more details.