"We're in Control"

36 Greenfields
Earith
Cambridgeshire,
PE28 3QH

"We're in Control"

www.4QD.co.uk Email to: esupport@4QD.co.uk

Instruction Manual

DNO series controllers

DNO-5 and DNO-10

1: Contents

2: Models

Two models are available, for different current ratings and with different options.

Each is configurable by an on-board link for 12v, 24, or 36v. 36v operation.

DNO-5 50 Amps nominal 60A max typical

DNO-10 100 Amps nominal 120A max typical

The nominal current is available for around 1 minute (depends on mounting).

For some applications, e.g. double heading loco, two standard units can be interconnected in tandem via the expansion connector.

If the controller is set to to 12v, do not operate above 18v or the relays could be damaged.

The maximum voltage of the controller is 56v.

48v operation

The controller is not intended for 48v operation.

Be aware that a freshly charged 48v battery can be as high as 56v so may cause the motor to creep even if the speed input is set to zero. Also the controller will not be able to properly regenerate into a fully charges 48v battery so there will be no braking effect.

Otherwise 48v operation will not harm the controller.

3: Dos and Don'ts

Do

Read this manual.

Mount the controller properly so it cannot be contaminated by water, dirt or swarf.

Use fully insulated power connectors.

Fit a battery fuse. See page 5. This fuse may prevent the controller being destroyed in the event of a system fault. Especially vital when double-heading!

Fit a motor Suppression capacitor. A 10n 100v ceramic capacitor as close to the motor brushes as possible will increase reliability.

Check the service area of our wwws site if you have any problems or queries. There is also a lot of helpful information in other areas of the www site

Contact us before returning any controller. Contact is best by email.

Insulate all input circuitry so it cannot connect to chassis (battery -ve). Such a short may cause F2 to fail (see page 11).

Do not

Operate the controller with the cover missing. Dust, water and debris could destroy it.

Solder to the power connectors: it makes it impossible for us to fit them to our test jig if it ever needs repair. Solder is a bad conductor of electricity

Let any metal object contact the circuit board. Even with battery disconnected the circuit can still be live as the main capacitor can store charge for several hours.

Drill the heatsink or do any grinding, drilling or filing near the motor or controller. Metal particles in motor or controller can cause failure and will immediately invalidate any guarantees!

Disconnect the motor leads when the motor is running. The resulting arc may destroy the MOSFETs,

Do any work on the controller with the battery connected!

Try to test the controller with no motor connected. You won't harm the controller but reversing will not operate properly.

4: Safety

It is normal practise, on passenger carrying vehicles, to include some means of disconnecting the battery or motor in an emergency. This could be a "kill switch", or perhaps a removable link in the battery wire. This is to guard against a failure in the controller or wiring which, although very unlikely, could cause the motor to run at an uncontrollable top speed. You must not operate this switch with the motors moving as (on rare occasions) this could damage the controller.

Even without such additional safety features, the DNO range controllers are designed so that failure, (and particularly dangerous failure) is very unlikely.

Most dangerous faults have been due to water splashes or other contamination on the board - which is outside of our control. No manufacturer, however

careful, can guarantee what will happen in the event of such a failure - so keep the cover in place when using the controller.

All passenger carrying vehicles should, in any case, be fitted with a mechanical braking system to complement regenerative braking

Reversing

On the DNO controller series, reversing is normally 'dual ramp'. This means that, when the reversing switch is operated at speed, the controller slows down under control of the deceleration ramp to zero speed. Only then can the controller reverse - which may require the speed to be set to zero - and accelerate again under control of the acceleration ramp.

Reversing is done by monitoring the demand speed, after the ramp circuit and not by measuring the motor voltage so that, if the vehicle is reversed when going down a hill, the motor will still be rotating and the vehicle will be travelling when reversing occurs. Reversing can therefore be accomplished on any hill but it will be more or less violent if the gradient is steep depending on the setting of the ramp controls. The user is best advised therefore not to change direction on steep hills!

Dual Ramp reversing can be deactivated, when the reversing becomes pre-select. To disengage dual ramp, alter the header shown in the diagram opposite.

There is also a half sped reverse feature which can be engaged.

Battery charging

When the DNO is not operating, the absolute maximum safe voltage is 56v, regardless of the on-board voltage selector. So charging the batteries with the controller still connected will cause no problem.

However you should make arrangements such that the vehicle cannot be started up or driven with the charger still connected.

5: Dismantling and re-assembly

To adjust the controller or to change operating voltage, you will need to remove the cover - which is a tight snap-fit.

Unscrew the four M3 countersunk screws that hold the cover in place. Now lift the tag end of the cover up as shown below. It is a firm fit and needs a firm pull.

Now pull the cover horizontally off the input connectors.

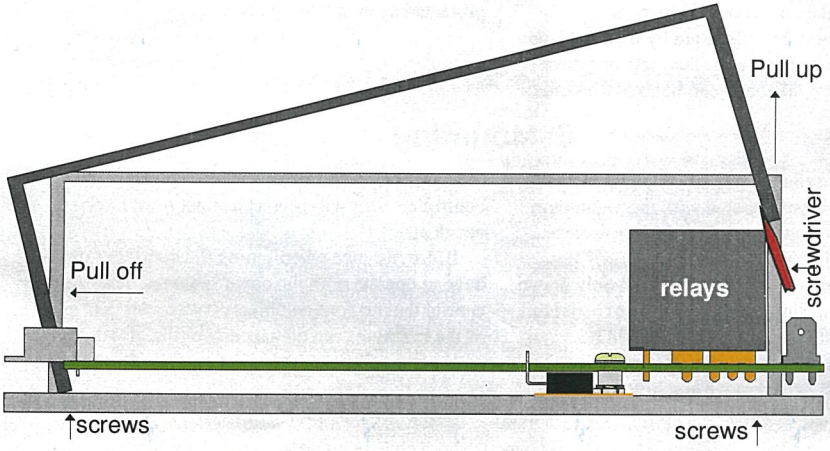
Refitting the cover is the reverse process.

But **do not do this while the battery is connected.**

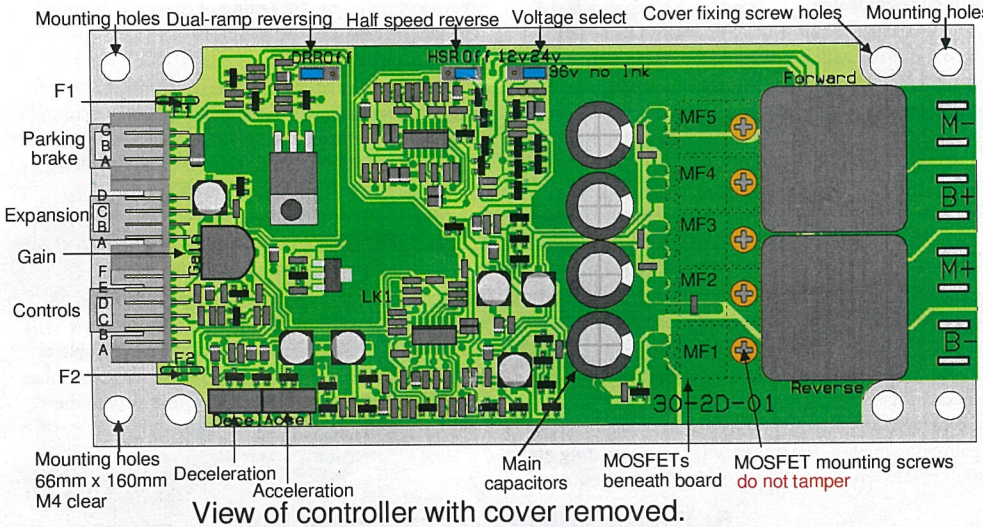
The connectors are a snug fit in the aperture in the case - do not force them.

You will need to use a small screwdriver blade to "shoehorn" the cover over the relays as shown in the diagram. This is best done at one corner of a relay.

Refitting the cover needs some force (so be careful not to bend the connectors) as it is a tight fit but once over the relays it snaps into place.



6: Features



View of controller with cover removed.

The diagram above shows the DNO-10 which has five MOSFETs and four main capacitors. The DNO-5 has three MOSFETs (MF2, MF4 not fitted) and two capacitors. Otherwise, the DNO-5 is the same as the DNO-10.

The cover has been removed - the 4 cover fixing screws are accessible from the underside of the aluminium base.

Speed pot and reversing and ignition switch input are via a 6 pin connector, supplied.

Also included

Expansion connector, see page 10.

Parking brake connector, see page 8.

Power & Motor connections are by 6.3mm blade connectors on top of the board. Two sets of power connections are provided and can be used for control wires or for extra motor wires as you wish.

The DNO is compatible with the older VTX. All connections are interchangeable except for the expansion connector which can only be used to connect two DNO boards. It cannot be used to connect a DNO to a VTX.

The DNO includes an over-current trip. This will trip the controller of if motor current reaches the current limit for a period of about 17 seconds.

The DNO may be used from 12v through 56v by an on-board setting. So the same model may be used with a 12v, 24v or 36v battery.The DNO is also protected against battery reversal.

6: Mounting

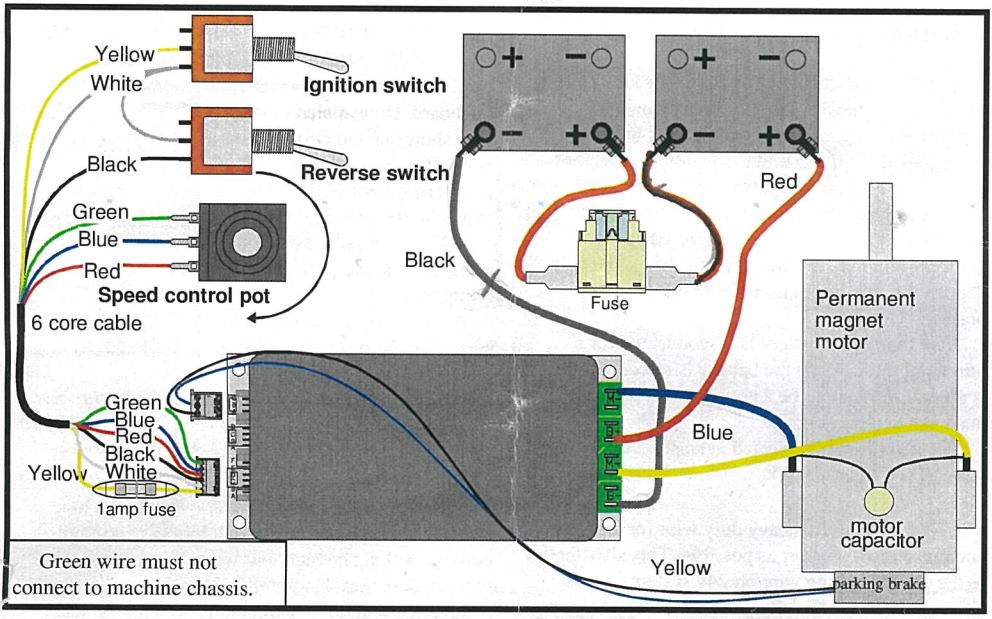
The DNO controller should be mounted by the 4 corner holes. It is best mounted with the aluminium base at the bottom as this will give best resistance against water ingress.

In most applications, high current will only drawn for short periods so little heating will be experienced. However, the DNO's base heatsink should be mounted on additional metal if high current is expected: this will help remove any heat generated.

Keep the plastic cover in place when operating the controller - this will protect against most likely accidents.

If, for instance when setting the controller up, you have to operate with the cover removed be extremely careful that no foreign objects (swarf, wires or parts of the machine) can contact any of the board.

8: Connections



Simple wiring

On the 6 way multicore control wire, yellow is internally connected to battery +ve. White and black may also be battery +ve (depending on the control switches). Green is battery -ve and blue and red are the control pot. A short circuit in the wiring between these two groups will cause problems!

Make sure the green wire to the pot does not connect to chassis: this can also cause problems!

Control Fuse

Note the 1A fuse in the yellow wire. If this is omitted, a mistake in the wiring can blow fuse track F1 on the controller. Controllers returned for repair with the fuse tracks blown will be subject to a handling charge. See page 11.

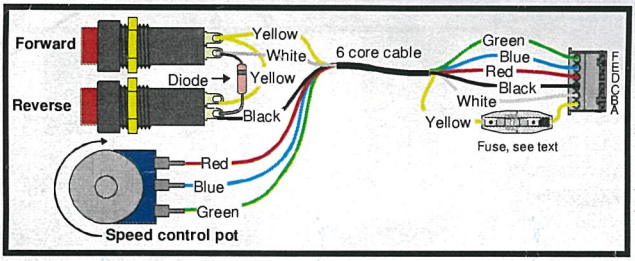
Battery Fuse

Note the fuse in the battery line. A circuit breaker is equally suitable. This will protect against some system faults and may prevent the controller being destroyed. It is vital when double heading. A sensible value for this fuse is the same as the motor current A larger fuse can be fitted (70 amp max), but will give less protection. Use the smallest value fuse which does not cause nuisance blowing: if the controller is giving more current than it can readily handle it will simply trip out or get hot. See also pages 10 (Section 13) and 11 (Section 14 -Fuses).

Motor Capacitor

See page 2.

Push buttons



Instead of two switches (ignition and forward / reverse) you may use two push-and hold buttons. Wiring is shown left: note the extra diode (any small signal diode, e.g. 1N4148). Without this, reverse will not work.

The diode's Cathode (the end with the band) should be connected to White.

Power Connections

Battery wiring

Battery connections to the controller are shown in the diagram opposite. Use only good quality battery connectors: the controller feeds current back into the battery during braking and if a battery connector falls off when braking this regenerated current can pump up the voltage on the dud battery connection.

Although the controller is protected against damage from this, it is not advised. The same will happen if a fuse or circuit breaker opens during braking.

Note that, if the battery is disconnected for a minute of more, when the battery is re-connected, it is normal for there to be a noticeable spark as the main capacitors charge.

The controller is protected against reversed battery, but will not work.

Wire size. Use heavy duty wire for the battery and make them as short as possible. This also applies to the battery linking wire on 24v systems. 4mm (12awg) wire is 'officially' rated to handle 41 amps continuously. At 100 amps it gets too hot to touch within about 60 seconds, so it is fairly well matched to the DNO 5. 6.0mm² (10awg) is advised for the DNO 10. Thicker wire will cause no problems, so use the thickest you have.

Use of wire that is too long (and/or too thin) will cause loss of power, but more importantly the main capacitors (see 'features' diagram above) will heat up. Heat will shorten the operating life of capacitors.

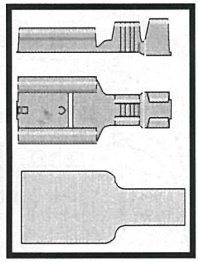
Reverse Polarity protection is integral. It is in the battery negative connection, implemented by MF1. Therefore **the green wire to pot zero is not and must not be directly connected to battery -ve.** If such a short to chassis occurs here:

1: reversing the battery will cause damage - blowing the on-board fuse F2.

2: a bad battery connection (or wiring that is too thin) will blow the on-board fuse F2.

Crimp Contacts

It is ***VERY IMPORTANT*** that you use fully insulated crimps: the power connections are close to the board. Uninsulated crimps may short out and destroy the controller. Best of all use 'F type' crimps with vinyl covers shown in the drawing.



4QD can supply these pre-crimped - they require a special crimp tool.

Also be aware that the main capacitor can store charge for a long time (several minutes) so the potential for damage is there after the battery has been connected.

Motor wiring

This is not so critical as battery wiring: too long and/or too thin wire will cause a loss of maximum current, will get hot and will waste battery power but will not damage the controller. However, wire which is too thick will do no harm either so we recommend the same wire for the motor as for the battery.

Circuit breaker, fuse, isolator.

A circuit breaker or fuse should always be fitted in a battery operated system. The main advantage is that it will enable the battery to be disconnected in the event of an emergency or for security.

It is also possible to get a battery isolator switch. These are normally fitted to lorries, buses and boats to isolate the battery in an emergency.

Battery condition meter.

Pins A and F (yellow and green on the diagram) are directly connected to the battery so that you may use them to connect a battery condition meter.

9: Controls

6 way connector.

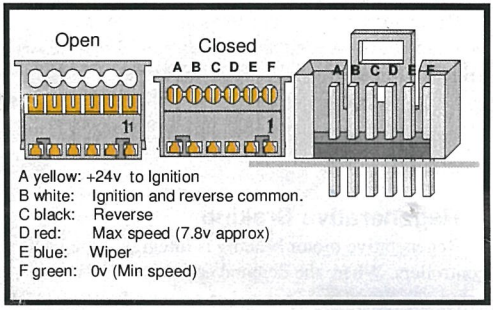
The mating connector supplied is suitable **only** for the correct size of wire.
Acceptable wire sizes are:
. . . 7 stranded 0.22-0.25mm²
. . . Equivalent 24 AWG (7/32 AWG)

It is an Insulation Displacement Connector (IDC) which 4QD have chosen because it is so very easy to use and very dependable. - but only with the correct wire!

Do not strip the insulation from the wires, simply push them into the top part of the open connector and squeeze it closed in a vice or with suitable parallel action pliers. As you do this the tines of the contacts bite through the insulation to make contact with the conductors.

Make sure the ends of the wires are flush with the back of the connector or it will not fit the socket properly. Cut off any protruding ends.

Wire which is too thin will not make contact. Wire which is too thick will damage the tines.



Do not use single strand (telephone) wire: it will make unreliable contact and easily breaks.

You can re-open a closed connector by gently moving the tabs at the sides of the top cover outwards to disengage the latches while lifting the cover slightly, one side at a time.

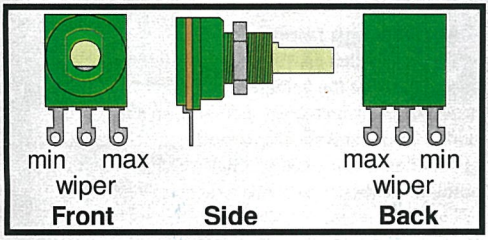
Speed pot.

We suggest a 10K linear pot, although other values from 4K7 to 20K, linear or log, can be used.

The gain adjustment on the controller alters the amount of rotation required before full speed is reached: this enables a simple lever operated control by means of a lever arm screwed onto a standard rotary pot.

The simplest speed control is an ordinary rotary pot: this won't give any 'dead man' control as the pot won't return to zero when it is released. 4QD can supply a spring return to zero hand control. Alternatively 4QD can supply a plunger operated pot (linear position sensor), suitable for incorporating into a foot pedal.

The drawing below shows the pot supplied by 4QD.



DNO-5 and DNO-10

¶ Use as voltage follower

Instead of a pot, the input may be fed from a variable voltage. 0v (common) to pin F, signal input (+ve) to pin E. A resistor (10k) should be connected from pin D to pin F to over-ride the internal pot fault detector circuit.

Zero speed will be for zero voltage input and full speed voltage may be adjusted (by the pre-set) to be from 3v to above 20v. Input impedance is 100K.

If pin D is shorted to pin E (and the 10K present) the gain control may be used as a pre-set speed control.

Ignition and reverse inputs are both high impedance (voltage controlled). High activates. Thresholds are around 5v and 7v.

On/Off switch

Circuitry in the controller switches it off (zero current consumption) unless there is a voltage on pin B.

Beware of changing any switch when the motor is running: the motor will brake to a halt more or less quickly, depending on the deceleration ramp setting.

With the ignition off, or even with the battery disconnected, the relays short out the motor so free-wheeling is not possible. To freewheel properly the motor should be disconnected.

Reversing

Reversing switch

Reversing switch connections are shown in the diagram above. When the switch is open, Forward is selected. Reverse ois selected by closingthe switch.

See also next page, Adjustments HSR and DRR.

Reverse threshold

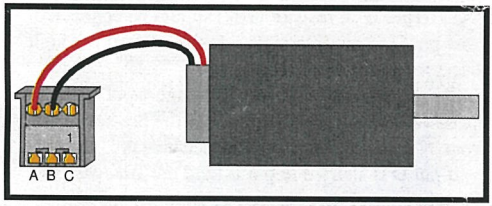
If you are reversing the controller from, for instance, a microcontroller, the threshold is around 5v. A voltage above this selects reverse, below the threshold selects forward.

Braking

Regenerative Braking

Regenerative motor braking is integral to the DNO controllers. When the demand speed is reduced below the actual motor speed, the controller starts braking, returning as much of the braking energy as possible back into the battery. The rate at which the braking acts is adjusted by means of the deceleration adjustment.

Regenerative braking does not work well at very slow speeds, simply because it relies on the motor turning to provide braking energy. If the motor is only turning slowly then it cannot give a lot of braking, so a vehicle will creep if parked on a hill. To stop this you can get motors fitted with an electromagnetically operated parking brake. When power is applied to this, the brake is removed and when power is removed the brake is applied by a spring.



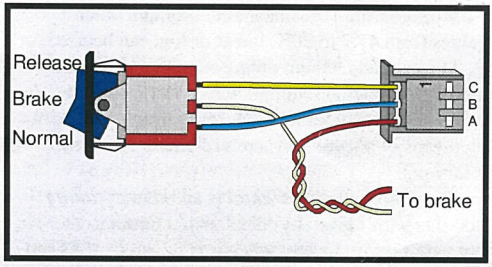
Parking Brake

Some motors are fitted with a separate solenoid released parking brake. The DNO controller has a circuit to drive such a parking brake brake: battery power is applied to the solenoid as demand speed is increased above zero and when the demand speed returns to zero, power is removed.

Parking brake is via the 3 pin connector, shown on the diagram 'Features'. Wiring is as the diagram below.

Pin A is battery +ve.

Pin C is 0v which can be used as you wish or can be used for an off - auto - on switch as below.



10: Adjustments

The adjustment presets are identified in the diagram on page 4.

Gain

Set this so that, at maximum required pot range, the controller just reaches full speed: this is easiest to do with the motor unloaded. Set the speed pot to your required maximum point (e.g. full up) then, listening to the motor, adjust the preset. It it usually quite easy to tell when the motor stops accelerating.

Maximum setting of the gain preset will give full output for about 3v input. Gain setting is slightly dependant on the setting of the ramps.

Ramps

The DNO series controllers incorporate linear ramps to control the acceleration and deceleration rates. These are user adjustable and you should adjust them to best suit your application.

Acceleration ramp

This is labelled as 'ACC' on the diagram: it is present to make the vehicle accelerate smoothly when the speed pot is increased suddenly, so as to avoid sudden surges and shocks to mechanical components. As supplied it is normally at half setting so that the motor takes about 2 seconds to accelerate. Adjust it

as you require to give smooth acceleration.

Clockwise decreases acceleration (increases time to full speed), anticlockwise increases acceleration (decreases time to full speed). If the acceleration is set too high (clockwise) the acceleration may be limited by the current limit, which does no harm but means that acceleration is not being controlled properly, so will be dependent on motor load.

Deceleration ramp

This is shown as 'DEC' on the diagram: it is present to make the vehicle decelerate smoothly when the speed pot is reduced suddenly. As supplied it is normally at half setting (about 3 seconds). Adjust it as you require to give smooth deceleration. You will usually find you require a lower setting (more anticlockwise) for DEC than for ACC. If the Decel time is set too low (anticlockwise) then the relays will drop out (and short out the motor) before regenerative braking has finished, giving a jerk before the vehicle stops completely. This will also shorten the life of the relays.

Warning

Be careful not to set the ramps to too fast a speed: if reversing is too fast the relays can arc, causing them to stick and also shortening their life. This is fully explained on our www site:

http://www.4qd.co.uk/serv/nccramp.html

Pinstrip adustments

Thee are 3 adjustments which are made by unplugging a shorting link from a pinstrip and re-positioning it. These are :identified on page 4.

Dual Ramp reversing (DRR)

DRR is the factory default. DRR means that, if the vehicle is reversed at speed, it automatically slows down under control of the deceleration ramp then reverses and speeds up under control of the acceleration ramp.

If DRR is switched off, reversing becomes **'Pre-Select'**. Changing the reversing switch does nothing immediately: the controller will start off in the pre-selected direction after speed is reduced to zero.

Half Speed Reverse (HSR)

Factory default: HSR is not selected. If you want reverse to be half forward speed, move the link.

Voltage adjustment

Three voltage ranges are selectable. Default operation is for 24v. For allowable voltage ranges, see page 12.

12v : shorting link to left

24v: shorting link to right

36v: shorting link removed.

11: Heat & Heatsinking and current trip

The rated current output of the controllers is with the heatsink hot. When cold they will give considerably more current. Thus the 50 amp version will in fact give about 60 amps when cold.

The current limiting used in 4QD's controllers senses the MOSFET temperature and automatically adjusts as the MOSFETs heat up. However, running the controllers at full current will cause speedy heating so the allowable continuous current may then depend on the external heatsinking.

So be aware of the temperature in the aluminium base: it won't hurt the controller is this gets to 100°C but this is dangerously hot to the touch! So don't allow it to get to hot to touch. If it does, then the controller needs additional heatsinking.

The DNO incorporates a trip circuit which switches the controller off if it is run at currents high enough to operate the internal current limit. This takes about 17 seconds to operate. If this trip operates - you are likely also to be overheating the controller and you need a bigger controller!

To reset the controller if the current limit trip operates, switch off the ignition switch and wait at least 1 minute before switching on again.

12: Expansion connector

This 4 way connector is for ganging two DNO controllers together, either for a two motor vehicle or for occasional use, as when double heading a loco.

When two standard controllers are connected together via the expansion connectors, one is used as the master and the second becomes the slave. The master should be connected normally and controls one motor and its parking brake (if fitted).

The slave controller needs only battery connections and connections to the second motor. It does not require any controls to be connected to the standard 6 pin input connector: if any controls are fitted to the slave, then a 'voting' system operates: If either ignition is on, both controllers operate.

If reverse is selected on one, both will reverse.

If speed is non-zero on both controllers, then the fastest selected speed will control both.

So to avoid confusion, simply plug **nothing** into the 6 way input connector on the slave!

The slave is to be connected to the master DNO via a 4 way cable between the two expansion connectors wired as the diagram.

It is important that the master and slave either work off the same battery or the two batteries should be connected in parallel. This could prevent severe damage to the slave if its battery fails or discharges before the master's.

When connecting up the slave link, both systems should be in an already operating state, i.e. with batteries connected. *Never connect the slave connection before connecting the batteries.*

This slaving system can be used as a permanent controller for a two motor vehicle, when the two motors will perform identically but with independent current limits. If two motors are used off one single 200 amp controller, then the full 200 amps current would available to drive either motor in stall conditions. With the DNO system, each motor may only draw up to 100 amps, limited by its own controller. The system therefore offers more protection to the motors. Also, if one motor gets disconnected the second motor will still be protected. Lastly, if there is a failure in one controller the chances are that the vehicle may still be operable on the other controller, providing an emergency 'get you home' service, albeit at reduced performance.

Pin functions

Pin	Colour	Function
A	Red	ignition
B	Yellow	direction
C	Blue	speed
D	Green	0v

13: Fault finding

Most faults are caused by external wiring. The majority of controllers returned have no fault, or simply a fuse track has been blown by a wiring fault (see page 11 for fuse information).

Controller is dead.

If the controller doesn't work at all check the following:

Pot fault detection

The controller has protection against a broken wire to the pot: If there is a broken wire , or if the pot resistance is too high (above about 25K) the controller will be dead.

Fuses

Check the fuses, F1 and F2.

Check the voltage on pin D of the input connector. This should be about 7.5v when ignition is on.

No reverse.

If the controller won't reverse there are two distinct possibilities:

1 The motor still goes forward when reverse is selected.

2 The motor is dead when reverse is selected

The first fault is likely to be a wiring fault: the reverse signal is not getting to the controller. Measure the voltage on the black wire to pin C (measure with respect to battery –ve). If this is low (below about 6v) the controller will go forward. When high (above about 6v) the controller will reverse. The reversing switch connects this pin to battery positive to apply a voltage to reverse it.

The second fault is usually in the controller.

There are many more fault-finding hints in the service manual available on our www site.

14: Fuses

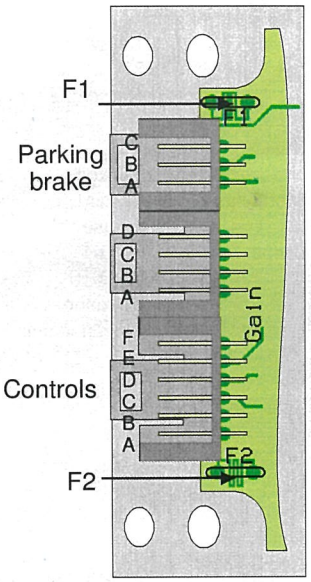
Two fuses are present to limit damage to the controller in the event of a major wiring problem to the control input.

These 'fuses' are zig-zag sections of track shown to the right. They are situated adjacent to the input connectors.

If a fuses is blown, solder a self-resetting fuse FSR-090 (see 4QD www site) in the holes provided. Or you can use a.fine piece of wire - a single strand from 7/0.2 cable is fine, but no thicker!

F1 is in the connection from B+to pins A of Parking brake and Input connectors. It can be blown by a wiring fault to earth on either set of wiring.

F2 is in the B- connection to all 3 connectors. It can be blown by the same fault that can blow F1, but it can also be blown by a fault from either input earth pin direct to the battery negative. More about this on our www site, service section.



15: Service

In the event of any problem please contact us (preferably by email) before returning a suspect controller.

There is also a lot of service and wiring information on our www site.

Common faults which stop the system functioning include such things as blown fuse tracks (see above) and faulty pot wiring.

Make sure you include your name, address and details of the fault with the returned controller.

Guarantee

If you think the controller is under guarantee, you must say when and where it was purchased.

Generally - if the fault is a manufacturing defect, we don't charge.

A handling charge will be made if working controllers are returned for test, or with only a fuse-track blown.

Otherwise charges made for service will depend on the age and condition of the controller and on the fault: as we tend to be fairly lenient in interpreting the guarantee!

16: Specifications

Operating voltages			user selectable on board
	12v setting	9v min 18v max	
	24v setting	15v min 30v max	factory default setting.
	36v setting	25v min 56v max	
		48v	see notes on page 2.
Supply current		25mA	at zero speed
Reverse battery protection		60v max.	
Motor speed	forward	0 to 100% full speed	adjustable
	reverse	0 to 100%/50% full speed	selectable
Output current	DNO-5	40A approx 1 minute	30v amp continuous
	DNO-10	75A approx 1 minute	60 amp continuous
	(continuous current will depend on mounting/cooling)		
Current limit (depends on motor)		DNO 5	approx 60 amps
		DNO 10	approx 120 amps
Overcurrent trip		17 seconds in current limit.	
Switching frequency		20kHz	approximately
Size		170mm x 80mm x 49mm	
Weight		390g	
Input		2k to 20k pot.	
Pot fault detect		greater than 25K	
Input voltage		3v to 20v for full speed	adjustable
Acceleration time		100mSec to 5 Sec	adjustable
Deceleration time		100mSec to 5 Sec	adjustable
Ignition input threshold		8v into 50k	approximately
Reverse input threshold		5v into 10k	approximately
Parking brake		1 amp max.	
Mounting holes:		4 off clear	66mm width X 170mm length