3166v3 - Bi-Directional DC Motor Speed Controller 5-28Vdc, 5A

General Guidelines for Electronic Kits and Assembled Modules

Thank you for choosing one of our products. Please take some time to carefully read the important information below concerning use of this product. The assembly and operating instructions are on the following pages.

WEEE Directive (Waste Electrical and Electronic Equipment)
Notice To All European Union Citizens.
Important environmental information about this product.
The crossed out wheeled bin symbol on this product, package or documentation indicates that disposal of this product after its lifecycle could harm the environment. Do not dispose of this product (or batteries if used) as unsorted municipal waste. It should be disposed by a specialized company for recycling. The unit should be returned to your distributor or to a local recycling service. Please respect the local environmental rules. If in doubt contact your local authorities about waste disposal rules.

Safety: General rules concerning safe use of our Kits or Modules

To ensure your safety, please observe these safety measures. In no way are these complete. As safety requirements vary, please check with your local authorities, in order to comply with local requirements. If in doubt, seek the help of a qualified person.

Battery or wall-adaptor operated devices are safe devices. They do not require special attention unless mains voltage is connected to an output e.g. a relay.

To ensure electrical safety, and also protection from fire or personal injury, make sure your mains operated equipment complies with these safety hints:

- Use a suitable plastic enclosure. If a metal enclosure is used, make sure it is properly earthed.
- Use a power switch if the device consumes more than 10W. Use a double pole switch for mains operated, transformer-less kits.
- Mount a fuse in series with the mains switch. Use a slow blow (T) 50mA fuse for transformers up to 10W and a 100mA fuse for transformers up to 20W.
- Use a mains input connector, or a robust power cord with a clamp.
- Internal wiring carrying mains voltages must have a minimum cross-sectional area of 0.5mm$_2$.

If supplied, attach the power rating label near the power cord of the device and fill-out the mains voltage, frequency, power consumption and fuse values.

Troubleshooting and Support

90% of non-working kits are due to poor soldering.

We operate a Get-You-Going service for non-working kits but there is a charge based on the time and components needed to complete the repair. Quite often it is not economically viable for us to repair and it is cheaper to supply a new ready-made product at full cost.

Disclaimer

Quasar Electronics reserves the right to change product specifications or to discontinue products without notice. Quasar Electronics cannot be held responsible for any loss or damage, direct or indirect, which might occur from the use of a product. Quasar Electronics Kits or Modules are intended for educational and demonstration purposes only. They are not intended for use in commercial applications. If they are used in such applications the purchaser assumes all responsibility for ensuring compliance with all local laws. In addition, they are not suitable for use as or as a part of life support systems, or systems that might create a hazardous situation of any kind.

General Guidelines for Motor Controllers

Thank you for choosing one of our motor controllers. Please take some time to carefully read the important information below concerning use of this product.

WARNING

Please read and follow the product manufacturers instructions. Mains powered motor controllers must only be fitted by a suitably qualified person. Please ensure all relevant local health and safety standards are observed and implemented. This information is not intended to be all-inclusive as to the appropriate manner and/or conditions of use. Factors pertaining to certain conditions of use may involve other or additional safety or performance considerations. The safe and appropriate use remains the responsibility of the customer.

Please also note the following points:

- **A suitable value safety fuse should be fitted to the motor supply**
- **Many parts of mains voltage motor controllers including heatsinks operate at potentially lethal mains voltages and must be housed in a suitable isolating enclosure to avoid injury or death**
- **Ensure adequate ventilated to avoid overheating and component damage**
- **The motor controller should have a capacity of at least 25% above the motors peak power requirement. Please do NOT rely on motor rating plates for power consumption figures as they are often quote average not peak power. Before connecting the motor controller, you should use a meter to verify the motors actual peak power at start-up and under full load.**

Failure to observe these points may lead to equipment damage or personal injury. If in doubt please seek help from a suitably qualified person.

If you are unsure about any aspect of the use of this product please contact our Support Team before proceeding.

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Documentation date: 28 October 2019

INTRODUCTION

This kit controls the speed of a DC motor in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions.

Normally, switches are used to change the direction of rotation of a DC motor. Change the polarity of the applied voltage and the motor spins the other way! However this has the disadvantage that a DPDT switch has to be added to change the polarity of the applied voltage. Now you have two things to control the motor – a direction switch as well as the speed control.

Also, it is not a good idea to suddenly reverse the voltage on a DC motor while it is spinning. It can cause a current surge that can burn out the speed controller. Not to mention any mechanical stress it can cause as well. This kit overcomes both these problems. The direction and speed is controlled using a single potentiometer. Turning the pot in one direction causes the motor to start spinning. Turning the pot in the other direction causes the motor to spin in the opposite direction. The centre position on the pot is OFF, forcing the motor to slow and stop before changing direction.

SPECIFICATIONS

Supply Voltage: 5 - 28Vdc Maximum

N.B. The board is NOT SUITABLE FOR USE WITH A LEAD ACID BATTERY! Use a regulated mains power supply instead.

Current: 5 Amps Maximum

Fit an 8A protection fuse to the positive supply line (V+) to protect the board from excess current.

Although the IRFZ44 MOSFET can handle 49A and the IRF4905 can handle 74A, the PCB tracks that run from the MOSFET pins to the screw terminal block can only handle around 5A as supplied. Their capacity can be increased by soldering along the PCB tracks which have been left bare (no solder resist).

Doing this may allow the board to handle higher currents of up to 10A but it depends on individual applications so you proceed at your own risk! Check the MOSFETs don't get too hot – if they do, bigger heatsinks will be required.

The real limiting factor is how fast the MOSFETs are switched. Most of the power dissipation in a MOSFET occurs when in its linear region. Therefore the transition from ON to OFF (or OFF to ON) should be as fast as possible. MOSFETs have high gate capacitance so, to overcome this, they should be driven by a low impedance source. The gate drive circuitry used in this kit does not have a low enough impedance to do this.

SPEED CONTROL OF DC MOTORS

Basically, there are three ways to vary the speed of DC motors:

1. With the use of mechanical gears to achieve the desired speed. This method is generally beyond the capability of most hobbyist home workshops.

2. Reducing the motor voltage with a series resistor. However this is inefficient (energy wasted in resistor) and reduces torque. The current drawn by the motor will increase as the load on the motor increases. More current means a larger voltage drop across the series resistor and therefore less voltage to the motor. The motor now tries to draw even more current, resulting in the motor "stalling".

3. By applying the full supply voltage to the motor in bursts or pulses, eliminating the series dropping effect. This is called **pulse width modulation (PWM)** and is the method used in this kit. Short pulses means the motor runs slowly; longer pulses make the motor run faster.

KIT ASSEMBLY

Please read all of the assembly instructions before you start and in particular ensure you understand Step 2 and Step 10.

Check the components supplied in the kit against the parts list. In particular identify the IRFZ44 and IRF4905 MOSFETs. They look the same so do not get them mixed up.

1.Before mounting any components to the PCB we need to assemble the MOSFETs to the heatsinks. Take an IRFZ44 and IRF4905 MOSFET and fit to either side of a heatsink. For 3-hole heatsinks, use the centre hole. **Loosely** secure them together using the supplied M3 screw and nut.

The MOSFETs need to be perfectly in line with the heatsink. The easiest way to do this is to mount the whole assembly onto the PCB, making sure that the heatsink pins and MOSFET leads fit into their respective holes. **Don't solder anything.**

Make sure the heatsink is sitting right down onto the PCB then tighten the screw and nut. Repeat for the other assembly then **put them aside as they will be the last items soldered to the PCB**.

It is recommended that the board is assembled in the following order:

2. Fill the via-hole pads (3 positions)

There are two (2) large via-hole pads on the PCB that need to be filled with solder to improve the through connection. These are the pads where the two outer power tracks going to Q5 and Q6 pass from the bottom to the top (component) side of the board.

They are marked with arrows leading from the text "**FILL WITH SOLDER BOTH SIDES**". Make sure these two pads are filled with solder from both sides of the board but **DO NOT SOLDER THE COMPONENT PADS** yet!

There is a third smaller via-hole just above the text "Q6" that you can also fill with solder.

3. All the resistors and diodes.

4. Capacitor C3. This fits inside the IC socket. Make sure it doesn't poke up too high before soldering otherwise it will interfere with inserting the IC into the socket.

5. The 14 pin IC socket.

6. Transistors Q1 and Q2 and capacitor C1.

7. The electrolytic capacitor C2.

8. The 2-way screw terminal blocks. These should be joined together to make a 4-way block before inserting into the PCB.

9. Potentiometer P1

10. Read the whole of step 10 before proceeding! Fit the previously assembled heatsink/MOSFET modules. **Make sure they are fitted the right way around.** The IRFZ44 should be facing towards the screw terminals.

If you are going to solder along the power tracks to increase their current rating (as shown in Figure 1) DO NOT SOLDER the pins of the heatsink nearest the terminal blocks. Remove this heatsink after soldering the MOSFETS. Run solder along the two short lengths of bare TOP tracks going to Q5 and Q6, making sure it flows around the component leg.

Check for shorts, refit heatsink and solder the mounting pins to provide mechanical strength.

Carefully run a good amount of solder along all four bottom power tracks. Take care not to short adjacent tracks. You will need a steady hand and good soldering skills to do this. We found it easiest to do the inner tracks first.

Fig. 1 – Soldered power tracks (10 Amps max. rating)

For standard 5 Amp rating, ignore the text in the box above and solder the heatsink/MOSFET assemblies as shown in Figure 2.

Fig. 2 – Standard soldering (5 Amps maximum rating)

11. Finally, fit the LM324 to the IC socket.

HOW IT WORKS (refer to schematic)
The circuit can be broken down in four parts:

1. Motor control – IC1:A
2. Triangle wave generator – IC1:B
3. Voltage comparators – IC1:C and D
4. Motor drive – Q3-6

Let's start with the motor drive section, based around MOSFETs Q3-6. Only two of these MOSFETs are on at any one time. When Q3 and Q6 are ON then current flows through the motor and it spins in one direction. When Q4 and Q5 are ON the current flow is reversed and the motor spins in the opposite direction. IC1:C and IC1:D control which MOSFETs are turned on.

Op-amps IC1:C and IC1:D are configured as voltage comparators. The reference voltage that each triggers at is derived from the resistor voltage divider of R6, R7 and R8. Note that the reference voltage for IC1:D is connected to the '+' input but for IC1:C it is connected to the '-' input. Therefore IC1:D is triggered by a voltage greater than its reference whereas IC1:C is triggered by a voltage less than its reference.

Op-amp IC1:B is set up as a triangle wave generator and provides the trigger signal for the voltage comparators. The frequency is approximately the inverse of the time constant of R5 and C1 – 270Hz for the values used. Reducing R5 or C1 will increase the frequency; increasing either will decrease the frequency.

The peak-to-peak output level of the triangle wave is less than the difference between the two voltage references. Therefore it is impossible for both comparators to be triggered simultaneously. Otherwise all four MOSFETs would conduct, causing a short circuit that would destroy them.

The triangle waveform is centred around a DC offset voltage. Raising or lowering the offset voltage changes the DC position of the triangle wave accordingly. Shifting the triangle wave up cause's comparator IC1:D to trigger; lowering it causes comparator IC1:C to trigger. When the voltage level of the triangle wave is between the two voltage references then neither comparator is triggered.

The DC offset voltage is controlled by the potentiometer P1 via IC1:A, which is configured as a voltage follower. This provides a low output impedance voltage source, making the DC offset voltage less susceptible to the loading effect of IC1:B. As the 'pot' is turned the DC offset voltage changes, either up or down depending on the direction the pot is turned.

Diode D3 provides reverse polarity protection for the controller. Resistor R15 and capacitor C2 are a simple low pass filter. This is designed to filter out any voltage spikes caused by the MOSFETs as they switch to supply power to the motor.

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HOW TO CONNECT

N.B. The board is NOT SUITABLE FOR USE WITH A LEAD ACID BATTERY! Use a regulated DC power supply instead.

Fit an 8A protection fuse to the positive supply line (V+) to protect the board from excess current.

The power supply connects to the **V+** and **GND** terminals.

The motor connects to the **M1** and **M2** terminals.

TROUBLESHOOTING

Most faults are due to assembly or soldering errors. Check you have the right components in the right place.

Inspect your work carefully under a bright light. The solder joints should have a 'shiny' look about them.

Check that there are no solder bridges between adjacent pads and tracks.

Check that no IC pins are bent up under the body of the IC. This can sometimes happen when inserting ICs into sockets. Check the IC orientation is correct.

PARTS LIST

Resistors, 0.25W carbon, 5% (gold band)		
100R (brown black brown)	R15	1
4K7 (yellow, violet, red)	R9,14	2
10K (brown, black, orange)	R2,7,10,11,12,13	6
12K (brown, red, orange)	R8	1
33K (orange, orange, orange)	R6	1
47K (yellow, violet, orange)	R3	1
100K (brown, black, yellow)	R1	1
220K (red, red, yellow)	R4	1
470K (yellow, violet, yellow)	R5	1
100K potentiometer	P1	1
Capacitors		
10nF 100V box poly (103)	C1.	1
100nF mono (104)	C3	1
100uF 63V electrolytic	C2	1
Semiconductors		
1N4004	D3	1
1N4148	D1,2	2
BC547 transistor, NPN	Q1,2	2
IRF4905 P-channel Power MOSFET	Q3,5	2
IRFZ44 N-channel Power MOSFET	Q4,6	2
LM324, Quad Op-amp	IC1	1
Miscellaneous		
IC socket, 14 pin, for IC1		1
Screw terminal block, 2 way (joined to make a 4-way block)		2
Heatsinks for MOSFETs Q1-4		2
Screw, M3 x 8mm (or 10mm)		2
Nuts, M3		2
3166v3 PCB		1

DATASHEETS

IRFZ44, IRF4905 MOSFETs - **www.irf.com**

LM324 quad Op-amp - **www.national.com**

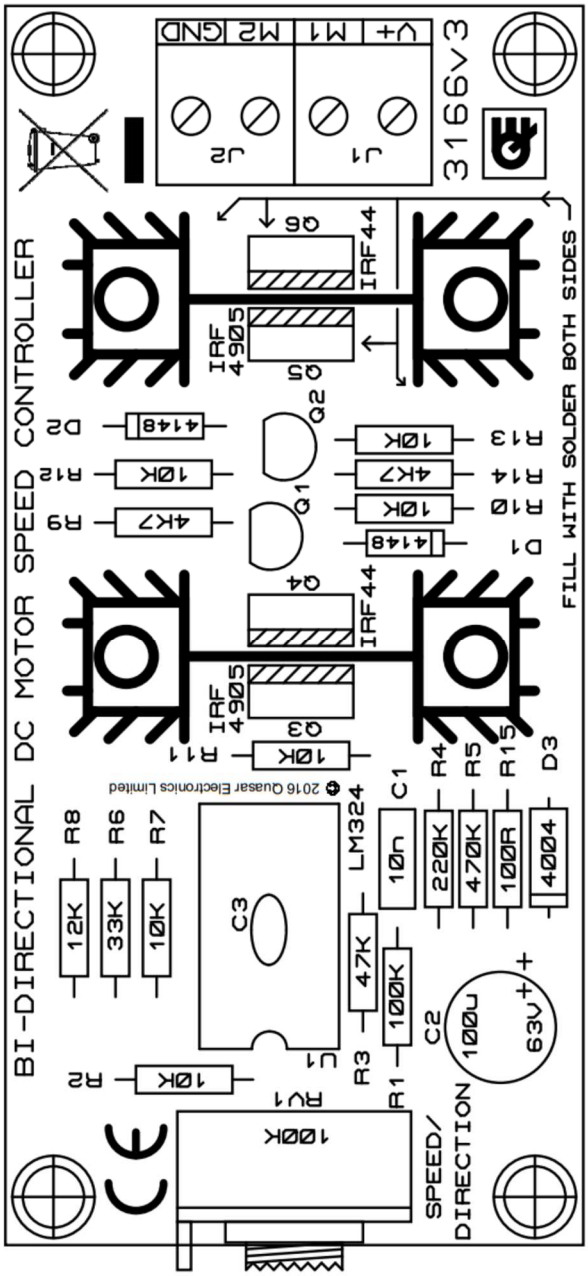
CONTACT DETAILS

For our full range of kits see our website at **quasarelectronics.co.uk**

Product page: **quasarelectronics.co.uk/3166.htm**

For any technical problems or questions, contact us at **support@quasarelectronics.co.uk**

PCB LEGEND



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