Bi-Directional DC Motor Speed Controller 5-32Vdc (3166v2)

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. Help with component identification can be found on our website at www.quasarelectronics.com/componentid.htm. If you are unsure about any aspect of the assembly or use of this product please contact our Support Team before proceeding.

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.

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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 center position on the pot is OFF, forcing the motor to slow and stop before changing direction.

SPECIFICATIONS

Voltage: The kit and motor use the same power supply. Since the maximum operating voltage of the LM324 is **32VDC** then this is also the maximum voltage available to run the motor.

Current: The IRFZ44 MOSFET can handle 49A; the IRF4905 can handle 74A. However the PCB tracks that run from the MOSFET pins to the screw terminal block can only handle around 5A. This can be increased by soldering wire links across the PCB tracks. If you do then check that the MOSFETs don't get too hot – if so then bigger heatsinks will be required.

However **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 transistion 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.

The overall effect is that even if the PCB tracks and heatsinks are uprated as described above the maximum current the board can handle is about 10 Amps.

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 increases 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

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.

NOTE: Provision is made on the PCB for some zener diodes, labelled Z1-4. These are no longer required and have NOT been supplied.

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. **Loosely** secure them together using the supplied 3mm 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. They will be the last items fitted to the PCB.

It is recommended that components be inserted and soldered in the following order:

1. All the resistors and diodes.

   Note: The PCB has provision for some zener diodes labeled Z1-4. These are no longer required and have not been supplied.

   Note: There are two (2) pads on the PCB that need to be filled with solder to improve the through connection. One is marked '**FILL WITH SOLDER**'. The second one is marked '**SOLDER BOTH SIDES**'. This is one end of zener diode Z2 which is no longer required. Make sure these two pads are filled with solder as required.
2. The 14 pin IC socket
3. 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.
4. Transistors Q1 and Q2 and capacitor C1.

5. The electrolytic capacitor C2.
6. The 2-way screw terminal blocks. These should be joined together to make a 4-way block before inserting into the PCB.
7. Potentiometer P1
8. The previously assembled heatsink/MOSFET modules. Make sure they are fitted the right way around. The IRFZ44 should be facing towards the screw terminals. Remember to solder the heatsink pins to the PCB – this is necessary for mechanical strength.
9. Fit the LM324 to the IC socket.

There is one last thing to do. There is one via (pin through) on the PCB that needs to be filled with solder. It is just above Q6. It is marked with the words "FILL WITH SOLDER". **This must be done so that the via can handle the current.**

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.

Opamps 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.

Opamp 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 centered 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 causes 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.

HOW TO CONNECT
The motor connects to the **M1** and **M2** terminals.
The power supply connects to the **V+** and **GND** terminals.

TROUBLESHOOTING
Most faults are due to assembly or soldering errors. Verify that 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.

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

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PARTS LIST – 3166V2

Resistors (0.25W carbon film unless specified)

100R	R15	1
4K7	R9,14	2
10K	R2,7,10,11,12,13	6
12K	R8	1
33K	R6	1
47K	R3	1
100K	R1	1
220K	R4	1
470K	R5	1
100K potentiometer	P1	1
PCB mounting		

Capacitors

10nF 63V box poly	C1	1
100nF mono, 0.1”	C3	1
100uF 63V electrolytic	C2	1

Semiconductors

1N4004	D3	1
1N4148	D1,2	2
BC547 transistor	Q1,2	2
IRF4905 P-channel Power MOSFET	Q3,5	2
IRFZ44 N-channel Power MOSFET	Q4,6	2
LM324 Quad opamp	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, 3 x 8mm	2
Nuts, 3mm	2
3166V2 PCB	1

DATASHEETS

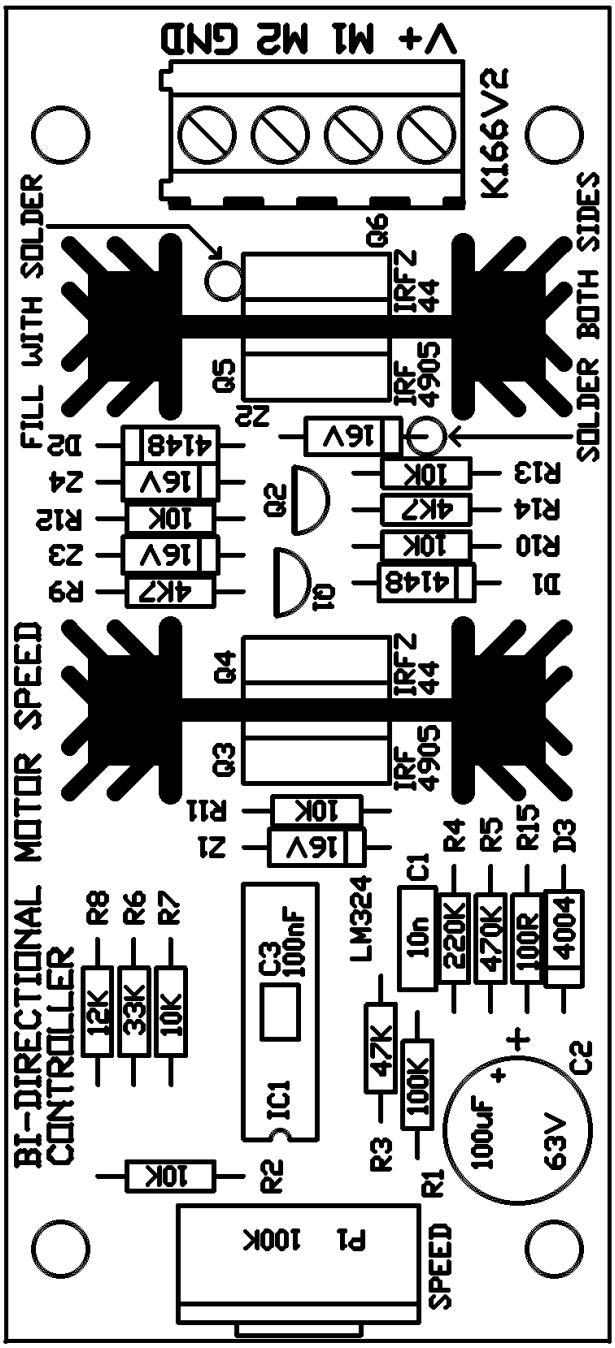
IRFZ44, IRF4905 MOSFETs - www.irf.com

LM324 quad opamp - www.national.com

CONTACT DETAILS

For our full range of kits see our website at http://www.quasarelectronics.com

Product page: http://www.quasarelectronics.com/3166v2.htm



NOTE:

PCB has provision for some zener diodes labelled Z1,2,3,4. These are not required any longer and have not been supplied.

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