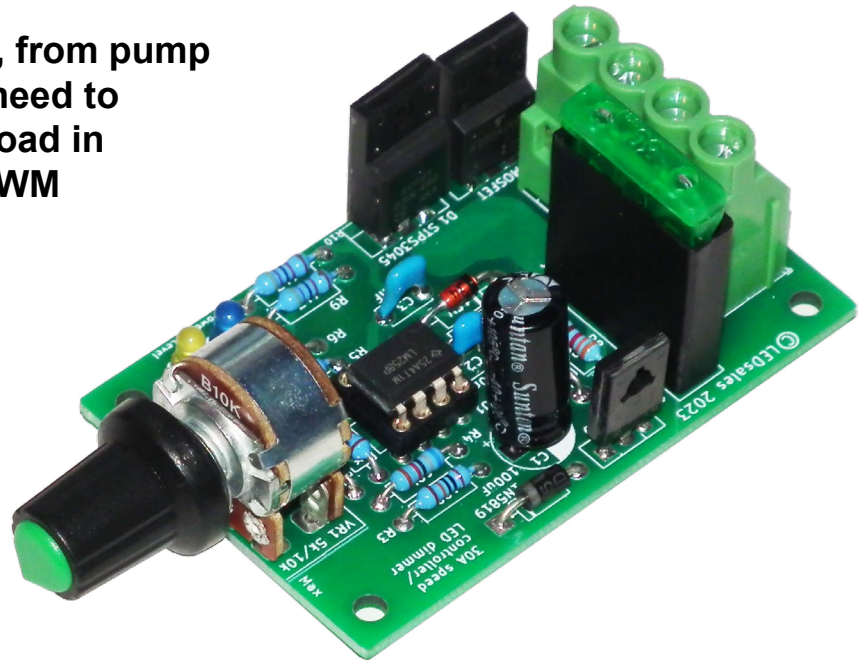


Build a simple 30 amp DC speed controller

There are many devices using DC, from pump motors to LED light strips. If you need to vary the power going to your DC load in a simple and robust way, then a PWM (pulse-width modulation) speed controller will usually provide the solution.

This project enables you to build a simple but robust 30A speed controller suitable for DC voltages up to 24V or so. It is suitable for controlling dimming LED or incandescent lights to controlling the speed of brushed DC motors which are often found in solar and DC pumps. It can even be used to control the speed of small electric vehicles such as go-carts. Indeed, any DC device that can handle PWM control may be suitable for use with this speed controller.



This project has been designed either to be built into an existing appliance if there is room, or to be fitted into its own case and wired in-between the power source and the device to be controlled.

If you use a standard plug on the input lead and a matching socket on the output one, then the controller can be used with any DC device you have that is within its 30 amp continuous rating and is capable of being controlled in this way.

This will mean most motor- and element-type appliances, as well as LED lighting that uses resistors for current control, such as 12V and 24V LED strips.

How does it work?

The controller works by switching the power to the load on and off very quickly, with varying ratios of on-time to off-time. This effectively allows the power to be varied from zero per cent to 100 per cent of maximum, giving full control over the amount of power supplied to the load.

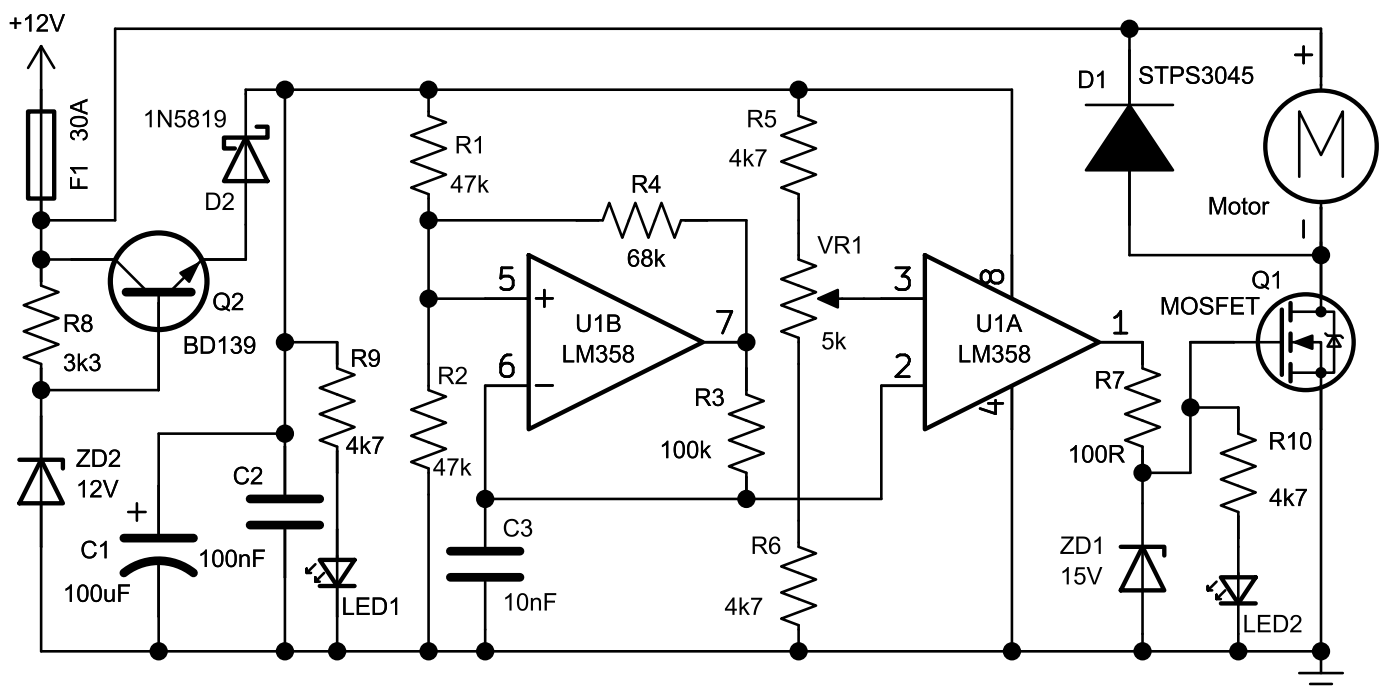


Figure 1. The circuit schematic diagram for the speed controller.

The circuit is based around the LM358 dual op-amp integrated circuit (an LM258 may be supplied, this has a wider temperature range but works the same otherwise). This IC is used to drive a device known as a power MOSFET (which stands for Metal Oxide Silicon Field Effect Transistor, which is why we always use the term MOSFET!), which is, in effect, a very fast voltage-controlled switch. The MOSFET switches the power to the appliance on and off to achieve variable power control.

Let's look at the circuit in a bit more detail. The second half of the IC, 1b, its associated resistors, R1 to R4, and capacitor, C3, are wired in such a way as to cause a triangle wave to appear across the capacitor, C3.

This wave is then applied to one of the inputs of the other half of the IC, 1a, which is wired to act as a comparator. As its name suggests, the comparator compares the incoming triangle wave voltage to a reference voltage on its other input. When the reference voltage is higher than the triangle wave voltage, the output of the comparator will be high. When it is less, the output will be low.

By varying the reference voltage by means of a potentiometer VR1 (the speed control knob if you like) the output of the comparator will be a rectangle wave with a fixed frequency but with an on-time to off-time ratio proportional to the reference voltage.

Switching that power

In order to allow the dual op amp (LM358 or LM258) to control large amounts of power, the circuit uses a power MOSFET, as mentioned earlier. We use a TK100A06N1 263 amp MOSFET. This device will block up to 60 volts and has an on resistance of less than 3 milliohms and so dissipates very little power itself.

The MOSFET is used to switch the load, be it a motor, light, or whatever, on and off at a rate of around 1000 times per second (1kHz). How long the appliance receives power for each cycle depends on the position of the speed control potentiometer. Note that VR1 is a dual pole 10k potentiometer wired in parallel, so that it operates as a 5k pot. The dual pot is much more rigid and reliable when soldered to the PCB. For off-PCB use, a single pole 5k potentiometer is fine.

When the pot is turned all the way anticlockwise, the MOSFET will remain off all of the time. With the pot rotated all of the way clockwise, the MOSFET will remain on all of the time, thus running the load at full power. In between these two positions, there is an almost infinite number of settings available, giving complete control over the power delivered to the load.

The other components on the circuit diagram are used for power filtering and spike protection. C1 and C2 filter the power to the circuit itself, while ZD1 is used to clip any voltage spikes that may cause damage to the MOSFET gate.

Diode D2 isolates the drive circuit from the battery voltage if the voltage drops suddenly, as will happen when the FET switches on and supplies current to the load. The fast diode, D1, is there to protect the circuit and MOSFET from high-voltage spikes generated by inductive devices such as motors etc.

Whether you are running the unit from 12 or 24 volts, a simple voltage regulator regulates the power supply to the rest of the circuit. It is made of R8, ZD2 and Q2. The resistor R8 supplies a small current to the base of the BD139 transistor, Q2. Because the Zener diode ZD2 drops a fixed voltage of around 12V, the base of Q2 is maintained at this voltage regardless of the input voltage. Q2 acts as a voltage follower, with its emitter output voltage around 0.3V lower than its base, or around 11.7V. As you might expect, if the power supply voltage is at 12V or less then the output of Q2 will be less, but it's really only there to regulate the voltage when you are using a higher power supply voltage, such as 24V.

That's just about it for the circuit, except for a few resistors. R5 and R6 are used to give the potentiometer a bit more range. The triangle wave from IC 1b does not swing right across the whole voltage range available. It only varies by about a third to a half of the available voltage, i.e. from four volts up to eight volts and then back down again in a twelve-volt system. The two resistors allow the pot to cover just a bit more than this range, thus giving a better control range. R7 is there to limit the current flow rate into and out of the MOSFET gate.

The final components are the two resistors R9 and R10 and LEDs LED1 and LED2. R9 powers LED1 whenever there is power to the circuit and is a simple power-on indicator, while R10 feeds a small current to LED2 directly from the output of the LM358. This LED will glow in proportion to the setting of the potentiometer and is a direct indication that the circuit is working as intended.

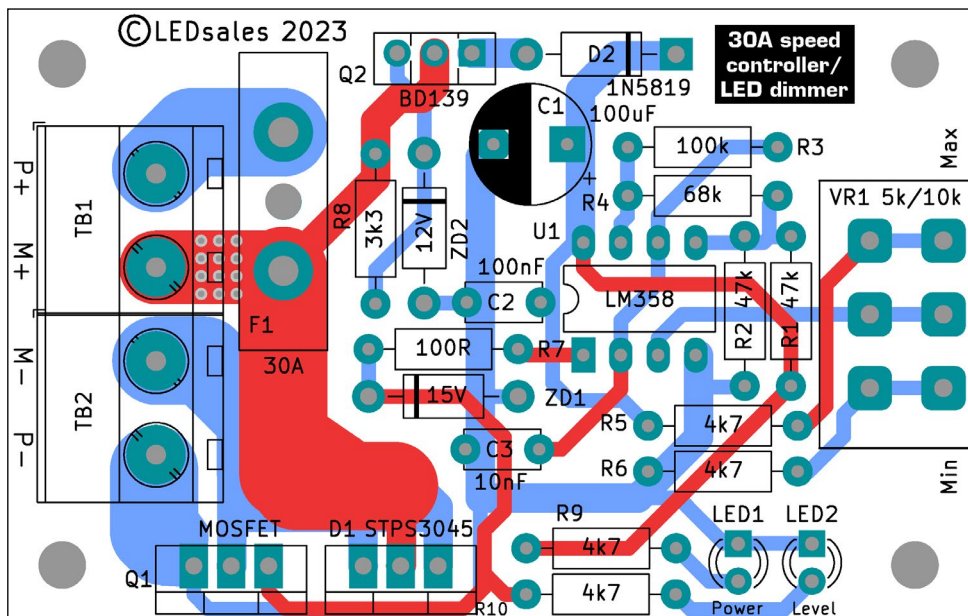


Figure 2. The overlay diagram for the speed controller.

Assembly

The kit is built on a double-sided PCB measuring around 66mm x 42mm with 2 ounce copper traces (twice as thick as regular PCBs) to handle the current. There is nothing really tricky about the assembly, just watch out for the polarised devices such as C1 and the IC. Make sure you use the supplied IC socket, in case you kill the IC somehow and need to replace it. The two indicator LEDs have their anodes (long leads) towards the edge of the PCB, while the BD139 transistor has the plastic face to the edge of the PCB.

The MOSFET and D1 will need to be connected to heatsinks if the controller is to control large currents. The simplest way to do this is to fit the completed circuit inside a diecast metal box and use the box as a heatsink. The MOSFET and D1 are located at the edge of the PCB to make this simple, but make sure you leave their leads long enough to bend them clear of the PCB for mounting. The devices are attached to the heatsink with a small bolt and nut along with a silicone rubber heat transfer washer and plastic isolating bush.

Make sure you use the supplied heat transfer washers and plastic bushes for good thermal conductivity and electrical isolation. Remember, for uninsulated versions, the tab on the diode is connected to its cathode, so its heatsink will be at supply voltage unless you use an insulating bush on the bolt of D1. The case of the FET is also its drain terminal, so it should be isolated from the heatsink with the supplied silicone washer. Note that you may receive a MOSFET and D1 with full plastic encapsulation. In this case, you won't need the plastic bush, just the bolt, nut and silicone washer.

The unit also incorporates a blade fuse holder socket, and a 30 amp fuse is supplied. This should be adequate to protect the FET should a short occur on its output, as it has a pulse current capacity of 584 amps! Be careful when soldering the pins of the fuse holder, as it can take a bit of heat, but don't overheat it. You can choose to leave out the fuse holder, and simply bridge the fuse holder positions on the PCB with a stout wire, but if you do this you must include some form of over-current protection in the supply to the speed controller, such as an external fuse holder or circuit breaker—never connect the speed controller directly to a battery or other power source without over-current protection!

The power connections to the board are made via a heavy duty terminal block. This is rated at 30 amps, and can take cables up to 4mm², so should be adequate for most uses!

The speed control potentiometer solders directly to the PCB, but you can also connect it via three-core hook-up wire if desired.

Parts List

Qty	Component	ID
1	TK100A06N1 MOSFET or similar	Q1
1	BD139 NPN transistor	Q2
1	LM358 or LM258 dual op-amp	U1
1	STPS3045CT 30A Schottky diode	D1
1	1N5819 1 amp fast diode	D2
1	15V 1 watt Zener diode	ZD1
1	12V 1 watt Zener diode	ZD2
2	47k ¼ watt resistor	R1, R2
1	100k ¼ watt resistor	R3
1	68k ¼ watt resistor	R4
4	4k7 ¼ watt resistor	R5, R6, R9, R10
1	100R ¼ watt resistor	R7
1	3k3 ¼ watt resistor	R8
1	16mm 5k potentiometer (dual 10k)	VR1
1	100uF 35V electrolytic capacitor	C1
1	100nF monolithic capacitor	C2
1	10nF monolithic capacitor	C3
1	8 pin IC socket	
1	Printed circuit board	PCB
2	30A, 2-way terminal block	TB1, TB2
1	Blue 3mm LED	LED1
1	Yellow 3mm LED	LED2
1	30 amp blade fuse	F1
1	Blade fuse holder	FH1
1	Knob	
2	3mm x 10mm screw	
2	3mm nut	
2	3mm tooth washer	
2	TO-220 rubber washer	
2	TO-220 plastic bush	

The smoke test

Once the assembly is complete, it is time to apply power and check that all is well. Connect a reasonably sized light bulb (say, a 50 watt halogen of suitable voltage rating) to the output and, with the pot turned fully anticlockwise, apply power. Nothing should happen except the power LED should light. As you turn the knob clockwise, the lamp should begin to glow and the level LED will increase in brightness, both reaching full brightness just before the knob reaches its limit. If the pot works in reverse to this, then you need to swap the two wires to its outer terminals.

If all is well, then turn the pot back to about halfway and let the whole thing run for a while, making sure that you monitor the MOSFET's and diode's temperatures. If they get too hot, then you either need heatsinking or something is wrong with the circuit.

Note: Should the controller experience a failure, spare MOSFETs, diodes etc can be purchased from LEDsales, just email orders@ledsales.com.au.

Modifications

The kit as provided will run at 900-1000Hz. Lower frequencies mean less power dissipated in the FET, but in some cases, the frequency will be audible, depending on the load and power supply. If this is the case in your application, then you can change the frequency by changing the value of capacitor C3. To increase frequency, decrease the value, and vice versa to lower the frequency. We found that a capacitor of 1nF will increase the frequency to around 6kHz, a 670pF capacitor brings it close to 10kHz.

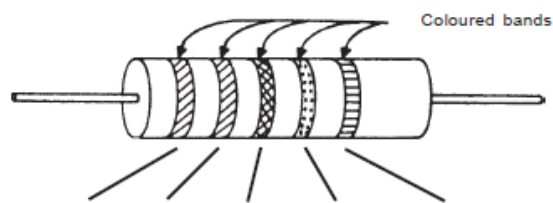
Bear in mind that with higher frequencies, the FET is doing a lot more switching and so will dissipate more power, so will definitely need to be mounted on a heatsink. For example, at the default frequency, we found that it runs just fine with no heatsink on a 14A load, but at 6kHz it gets warm fast and definitely needs heatsinking at that power level.

Identifying the parts of your speed controller kit

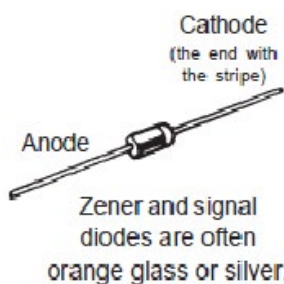
The following guide should help you to identify the parts and assemble it successfully.

Resistors

The coloured bands represent numbers and multipliers as shown in the table. Some resistors have four bands (two digits, a multiplier band and a tolerance band) while some resistors have five bands. Five-band resistors are read in the same manner as four-band resistors, except that the first three bands are digits, the fourth a multiplier and the fifth the tolerance band.



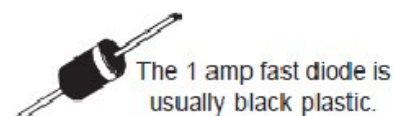
Colour	Hundreds	Tens	Units	Multiplier	Tolerance
Black	0	0	0	1	20%
Brown	1	1	1	10	1%
Red	2	2	2	100	2%
Orange	3	3	3	1000	
Yellow	4	4	4	10,000	
Green	5	5	5	100,000	
Blue	6	6	6	1,000,000	
Violet	7	7	7		
Grey	8	8	8		
White	9	9	9		
Gold				0.1	5%
Silver				0.01	10%



Zener diodes

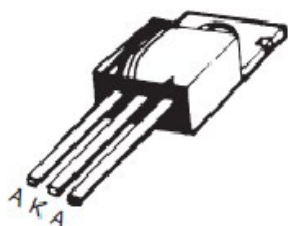
The 12 volt Zener diode will be marked with 1N4742 or will have the code 12V at the end of its number.

The 15 volt Zener diode will be marked with 1N4744 or will have the code 15V at the end of its number.



Fast diode

The 1N5819 diode will be marked 1N5819. It will be black with silver markings.



Power diode

The power diode, D1 is easily identified—it is the big one with the metal (or insulated) tab, just like the MOSFET, but will be marked STPS3045CT or similar.

Capacitors

Most of these are not polarised and can be installed either way around. The 0.01uF (10nF) may be marked 103 or 10nF. The 0.1uF (100nF)

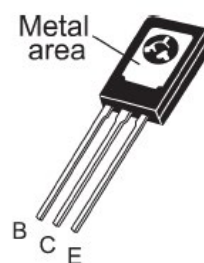
may be marked 104 or 100nF.

The 100uF capacitor is the big barrel-shaped one. Note that this is polarised and must be installed the correct way around! The negative terminal is often marked with a big line or minus symbol.



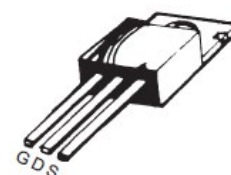
The BD139

The BD139 has a metal side and a plastic side with writing on it. The metal side goes towards capacitors C1 and C2.



The FET

The FET will be marked TK100A06N1 or similar. Note that the FET must be installed the correct way around, with the back of the device facing towards the edge of the PCB.



The LM358

This is the 8 pin device. Note that it must be installed the correct way around. Pin 1 is marked with a small dot, and the pin 1 end of the chip will have a semicircular notch or mark. The IC socket also has this notch, so make sure it is installed the correct way around also, as this notch is used to indicate device polarity.

