HOW THINGS WORK - ELECTRONIC SPEED CONTROLLERS

The simplest circuit for powering a model boat electrically is shown in Fig 1. It consists of a motor, a battery and a switch. When the switch is OFF there is no voltage across the motor brush contacts so the motor does not run. When the switch is ON, the full battery voltage is applied to the motor and it runs at full speed.

Terrific - so what happens if your boat is trundling around the pond at full speed and a duck or another model crosses its bows? How do you manoeuvre the model slowly into the bank so that you can pick it up out of the water? How do you reverse it out of that bed of reeds into which it has drifted? Cleary we need some better way to control the motor than just an ON/OFF switch.

For a long time the only way to control the speed of a simple DC motor such as those used in our models was to connect another load in series with it - a load which you could vary so that it would change the voltage applied to the motor and thus slow it down. Fig 2 shows such a device; it's a variable resistor called a rheostat. It consists of a coil of thickish, un-insulated wire with a mechanical wiper contact which moves along the coil. In model applications this was done by connecting the wiper to the output arm of a servo.

With the wiper in the Fast position (Fig 2) the resistance between the battery-end of the coil and the wiper contact is small so most of the voltage from the battery appears at the motor brush contacts. In the drawing the voltage across the rheostat is 1v, leaving 11v for the motor i.e. practically full speed.

Move the wiper to the other end of the coil and its resistance increases to the point where most of the battery voltage is taken up by the rheostat, leaving a small voltage and a slow-running motor. Job done - in *theory*, that is…………

There are two main problems here. The rheostat “absorbs” power from the battery and gets rid of it by heating up, so the battery is ALWAYS working flat out even when the motor is running slowly. If you think about it, the rheostat isn’t that far removed from a small electric-fire element, complete with nichrome wire, so it's gonna get pretty warm. The other problem is that the motor needs a minimum voltage across its brush terminals simply to overcome its own inertia and begin to run. If the rheostat absorbs too much power then this starting voltage will never be achieved and the motor will just sit there and look contemptuously at you, while the battery is quickly flattened by the rheostat. Notwithstanding these two major drawbacks, there was a popular range of resistive speed controllers for boats called Bob's Boards. These were quite effective but they were suitable only for relatively low-current motors, and the art of matching the motor to the correct value of board was one which many modellers didn't acquire. The boards also required frequent maintenance.

Now a slight diversion….. think about cycling along on a flat road. While you're pumping steadily on the pedals, the bike is under full power and maintains a constant speed. If you then stop pedalling for a while, the bike will coast under its own momentum (and yours) until it either stops or you begin to pedal again. Naturally, the more often you stop pedalling then the longer it will take to finish your journey i.e. your *average* speed will be reduced.

Now think about the same sort of logic applied to an electric motor circuit. If you switch the motor ON and OFF by “pulsing” the switch (Fig 4) then you can effectively reduce the *average* speed of it and so slow down the model over a fixed distance. If you allow the pulses to take some time then you will likely see the model actually slow down and pick up speed again. Increase the frequency of the pulses (Fig 5) and you will begin to smooth out that jerky movement, as the motor has less time to freewheel and slow down before it's fired up again.

If you look at a simple graph which compares the ON and OFF times with the voltage applied, then it will look like a series of vertical rises, flat plateaux and vertical drops to zero; or a “square wave” (Fig 6).

Now imagine that you can switch the pulses on and off very quickly e.g. fifty times a second. You will see that the power is ON for half of the time so has the effect of running the motor at half-speed - as if you were applying an *average* voltage of 6v from a 12v battery. There is no power loss in a resistive load here; full power is being applied to the motor at all times. Neither is there a problem with a low start-up voltage as the full 12v is being fed to the motor - it's simply being switched very quickly.

In Fig 6 the period of time spent ON is the same as the time spent OFF (10 milliseconds). The ratio between ON and OFF is therefore 1:1; this is often referred to as the Mark:Space Ratio. If you leave the motor ON for three times as long is it is OFF then the Mark:Space ratio increases to 3:1 and the effect is to increase the speed of the motor, as if the average voltage applied were now 9v. See Fig 7. Similarly, reduce the Mark:Space down to 1:3 and the motor runs at ¼ speed - Fig 8. With a proportional radio you can move the transmitter stick anywhere between its limits so the Mark:Space is almost infinitely variable, which means you now have a fully proportional way of controlling the speed of a motor with little power loss and no start-up issues or jerky movements. So what about reversing out of those reeds, then?

Do you remember the article I wrote about relay switches? No? Then go and read it NOW! You'll find that one of the functions of a relay is to change over the flow of a current from the Normally Open contacts to the Normally Closed. If we put such a relay into the circuit of our motor pulsing device then we can use it to reverse the direction of the current through the motor. Every schoolboy should know that this makes the motor rotate in the opposite direction - Fig 9. NOW we have the knowledge required to control the motor in both speed and direction.

Fig 10 shows both a diagram and a photo of our P79 Condor Electronic Speed Controller. The signal from the transmitter is decoded inside the receiver and sent down the Signal wire to the microprocessor in the speed controller. This in turn switches the high-power MOSFET transistor(s) on and off very quickly and at the required Mark:Space ration to vary the motor speed, while the microprocessor also puts the relay contacts in the correct positions for Forward and Reverse.

Easy, innit?

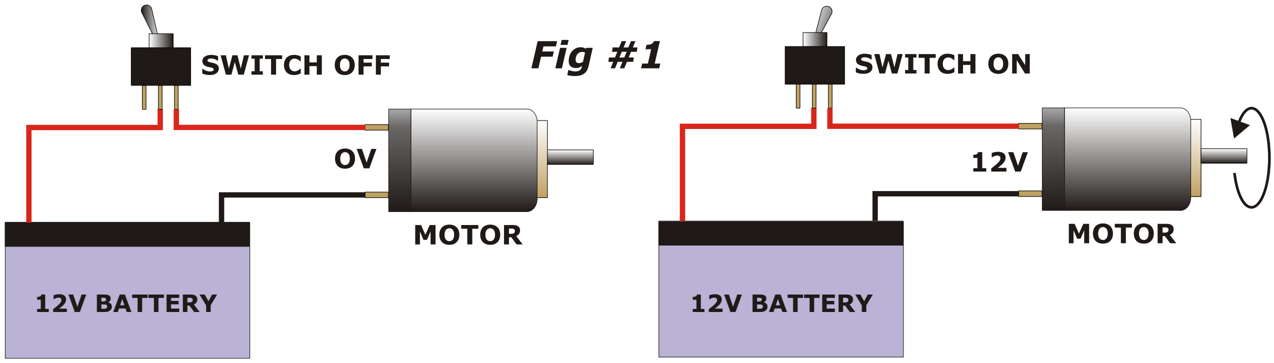


Fig #1

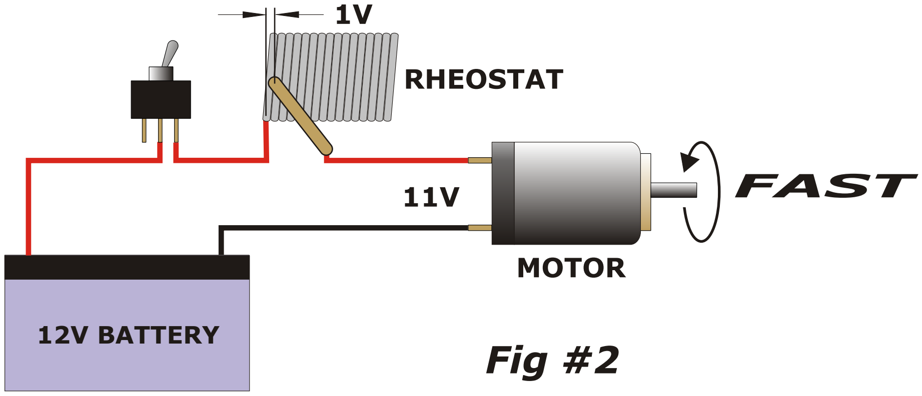


Fig #2

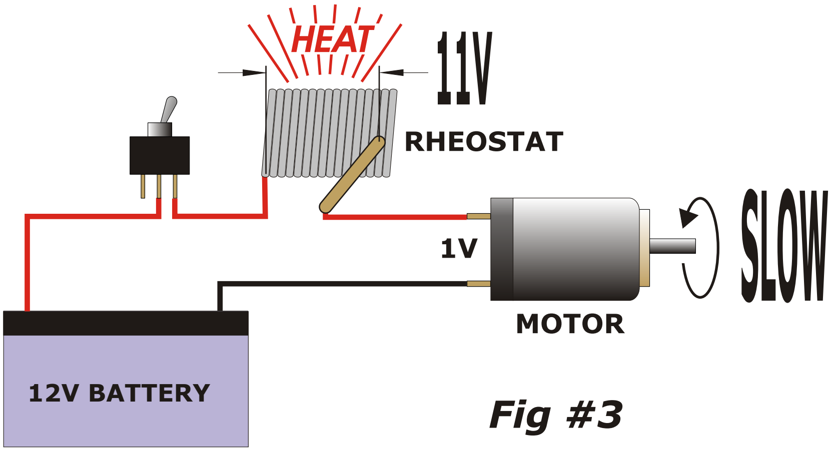
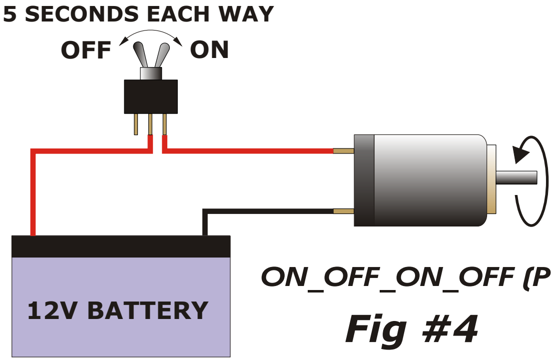
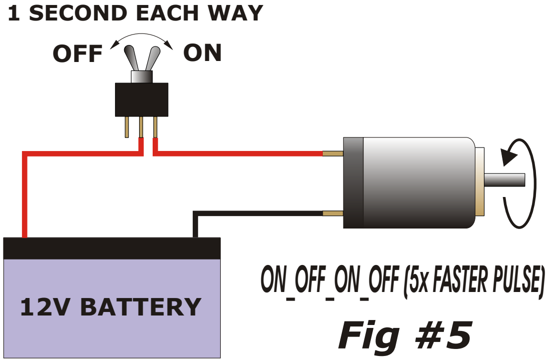


Fig #3



ON_OFF_ON_OFF (PULSE)

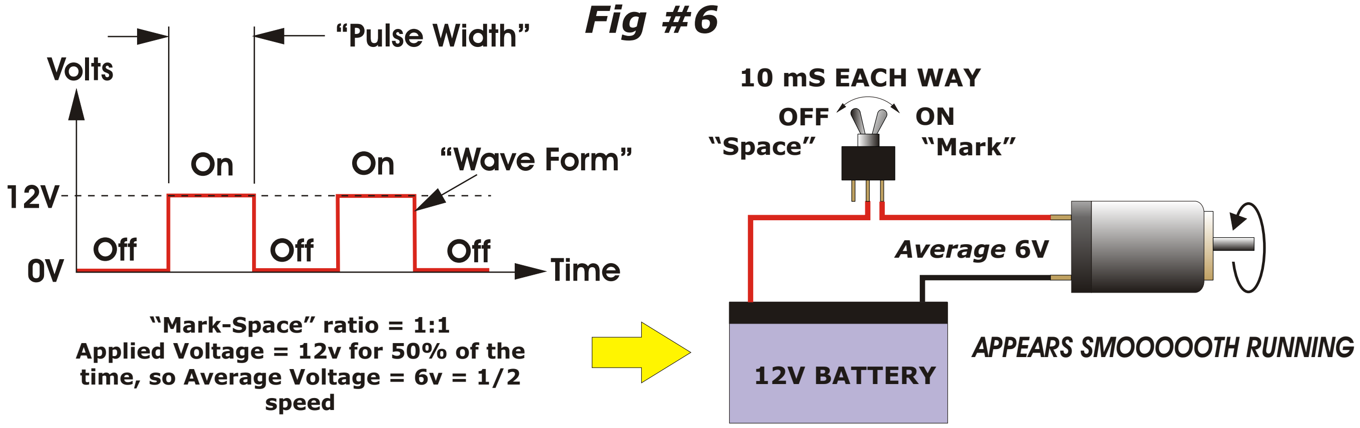
Fig #4



ON_OFF_ON_OFF (5x FASTER PULSE)

Fig #5

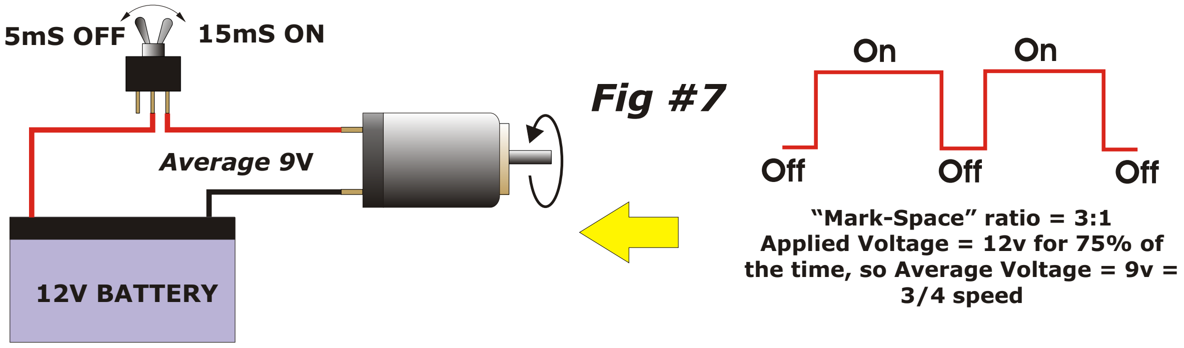
Fig #6



"Mark-Space" ratio = 1:1
Applied Voltage = 12v for 50% of the time, so Average Voltage = 6v = 1/2 speed

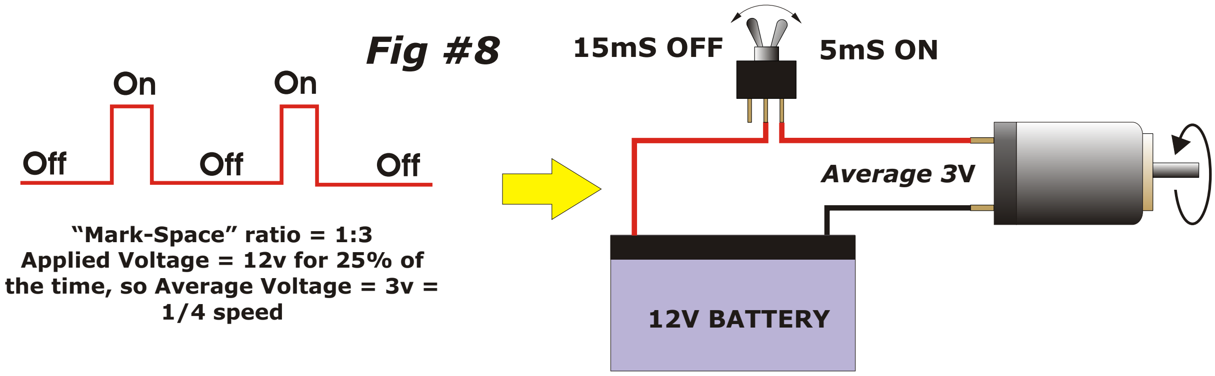
APPEARS SMOOOOOTH RUNNING

Fig #7



"Mark-Space" ratio = 3:1
Applied Voltage = 12v for 75% of the time, so Average Voltage = 9v = 3/4 speed

Fig #8



"Mark-Space" ratio = 1:3
Applied Voltage = 12v for 25% of the time, so Average Voltage = 3v = 1/4 speed

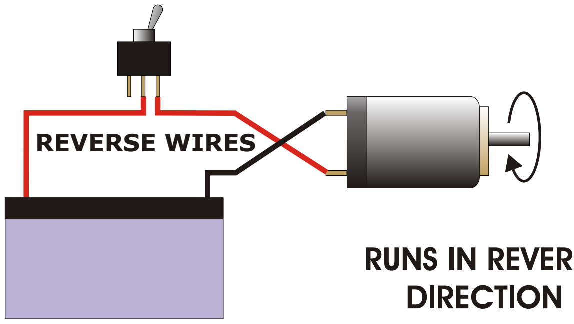
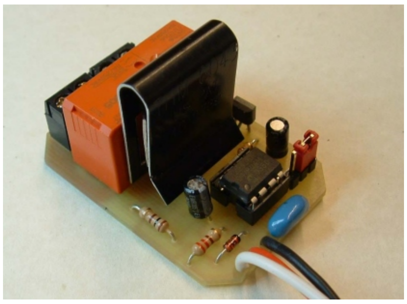


Fig #9

RUNS IN REVERSE DIRECTION



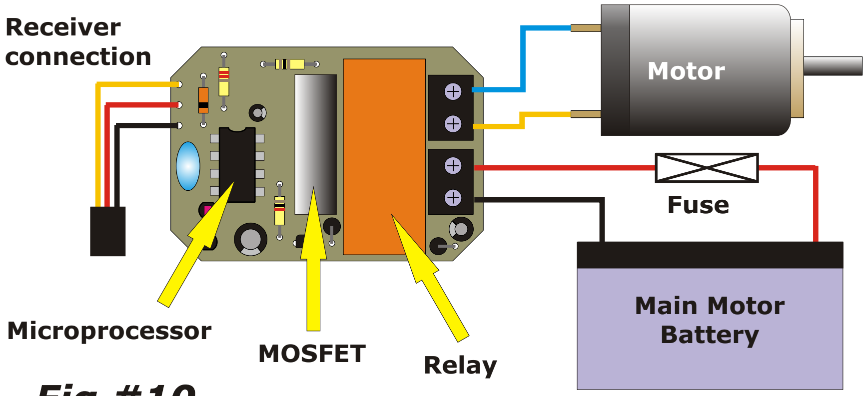


Fig #10