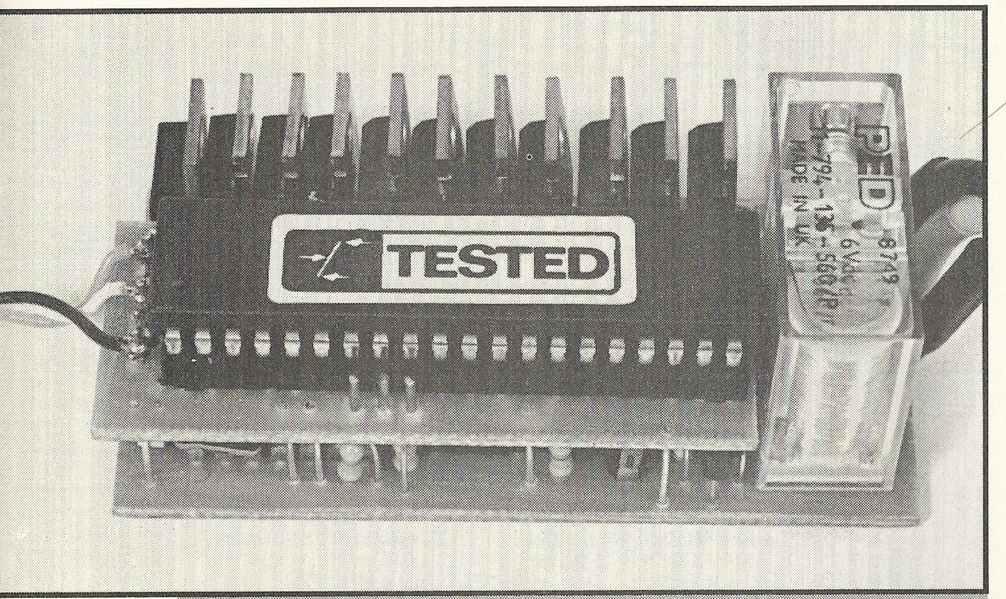
UNDER CONTROL

FET's, Electronic, Resistor—what suits you best.



Above: The latest Schumacher Speed controller now available—sets itself up and has an immediate full power device for quick getaways.

Speed controllers fall into two main categories, the mechanical or resistor type and the electronic type. Although the purpose of both types is the same, namely to vary the speed of the motor, the way in which they work is entirely different.

The resistor type

The resistor type is mechanically operated by a servo. The servo moves a wire link or actuating arm which in turn moves the speed controller switch. Even here there are variations. The earliest versions of resistor speed controllers were wire wound resistors with a wiper arm moving over the wire making electrical contact. Very similar in operation to the wire wound controllers found in electronic and electrical apparatus, but designed to carry substantial amounts of electric current. These wire wound speed controllers are still available and there has been detailed changes to improve reliability. However the basic design has remained unchanged since they were first introduced in 1:12th racing. Most kits if they are supplied with a speed controller have fixed resistors. These are brought into circuit by means of a wiper board switch. The resistors are mounted remote from the wiper board, usually in a suitable position to aid heat dissipation.

The principle of operation of the resistor speed controller is to act as a voltage dropping device. By placing the resistor in series with the motor the voltage drop across each component will be proportional to its resistance. So to slow the motor down, reduce the voltage applied to it. However the motor requires substantial amounts of current to make it deliver any useful torque. This means that the resistors that drop the voltage must also be capable of handling the same current as is flowing through the motor. Here we have the first problem. The voltage is dropped by converting the electrical energy into heat, and quite a lot of heat. You do not have to be good at maths or physics to see what is going on. Consider a motor on minimal load drawing six amperes. The voltage available from the *Ni-cad* is 7.2 volts. This means that if we assume no loss of energy in connectors or coupling wire the motor resistance is 1.2 ohms. In fact losses in the connecting wire and connectors can be significant, but we will come back to that later. Typically a switched resistor speed controller uses two 0.3 ohm resistors wired in series for the slowest speed setting and one in series for the next fastest speed and no resistors for flat out. This means that if we assume the motor resistance is 1.2 ohm then at the slowest speed setting the speed controller resistors must dissipate nearly ten watts of energy, and at the mid speed setting the single resistor must dissipate 7 watts. Quite a challenge for such a small device. Remember that we have been talking about the current drawn by kit motors such as the *Mabuchi* 540 series. Move into the high performance league and current consumption goes through the roof. Start up current is easily into the forty ampere range, although this does drop as motor speed picks up. It is no wonder that the speed controller resistors get hot. In fact the resistance wire glows red hot. To help disperse the heat and to prevent the wire simply burning up in the air, it is encased in a ceramic block. This also has the advantage of reducing the chance of anyone catching hold of the resistor getting really serious burns, although from experience I can tell you it still hurts (a lot). Back to those connectors and the wire used to join everything together. Remembering that we used resistors of 0.3 ohm to give a good range of motor speed control it also follows that any other small resistance in the circuit would have the same effect. Of course this would be undesirable as we only want to switch in a known resistance. The value of resistance we are talking about is so small, namely 0.3 or even less it is quite easy to find this introduced in the most unexpected places. Connectors can easily account for measurable losses. The wire used to connect motor, speed controller and batteries can easily add up to 0.5 ohm and provide unwanted loss. Bad connections onto the motor can spoil an otherwise satisfactory installation. Finally the speed controller itself. Most of the switched resistor types use a wiper board. This is nothing more than a sliding contact moving over a printed circuit board. The resistance between the board and the moving contact can easily be 0.05 ohm or more. All of these points introduce unwanted losses which shows up as heat. Any heat generated between batteries and the motor will use valuable energy. This will sap your car's performance and reduce your running time. Prevention and cures are usually straight forward. Make sure that wiper board is clean and that the track is not worn away. Also the moving arm must make good strong contact against the wiper board. Problems here are usually cured by replacing the worn unit with new. All connectors must be in good order, they do not last forever and the wires into the connectors must be a sound electrical joint. This also applies to the motor connections. The insulation of the connecting wire must be in good condition and if it needs replacement make sure you use a suitable type. Wire with silicon insulation is the best and good model shops stock this in handy lengths. Keep all connecting wires as short as possible, every millimetre adds unnecessary loss. The variable resistor type of speed controller is not so popular these days. The main problem is the difficulty in maintaining a good contact on the hot wire resistor. However some drivers still like this type of unit and it is well suited to controlling the lower power motors.

Whichever way you look at resistor type controllers they are inherently inefficient. They simply dump energy as heat. In any electrically powered vehicle this is not a desirable thing to do, as the energy source is finite, i.e. the batteries will go flat. The latest range of resistor speed controllers also include an output to power the receiver and servo's. This is done by tapping off the drive battery and reducing the voltage to a suitable level and providing a lead to plug into the receiver battery input.

Electronic speed controllers

The first thing that you notice about electronic speed controllers is the price. Even the most expensive resistor speed controller is nothing compared to the electronic types. Electronic speed controllers have gone through many stages of development and have become more sophisticated and reliable. It should be stressed that they are not indestructible, and if you think that changing over to an electronic controller will be problem free, then you may be disappointed. It is also worth remembering that abuse and misuse will cost a lot more to fix than the simpler mechanical type controller, and unless you are familiar with the sophisticated world of electronics, you will need to send the unit away for repair.

So here's a closer look at the working of the electronic type to see why it is so different to the mechanical type.

The way in which electronic speed controllers work is to switch the supply to the motor on and off very quickly. If we slow this down and imagine that we are controlling a lamp. Switching the lamp on and off will of course flash the lamp. If we switch the lamp on for half a second and then off for half a second, over the whole second we would have supplied half of the available power to the lamp. If we now switch the lamp on for one quarter of a second and then off for three quarters of a second we would have supplied only one quarter of the available power to the lamp. Now if we start switching the lamp on and off faster and faster, but still keeping the same ratio of on to off times the lamp will appear to be on all the time because our eyes will not react fast enough to spot the on and off periods. However the lamp will appear to be dim because it is not getting the full power. Increase the on time and reduce the off time and the lamp will appear to become brighter, reverse the process and the lamp will dim. Yet during the on time the lamp is in fact fully on and at its full brightness but this will only be a portion of the complete on/off cycle.

This is the principle behind electronic speed controllers. The combined on and off time of one complete period on most speed controllers is one fiftieth of one second. To put it another way there are fifty on/off periods every second. Instead of controlling a lamp

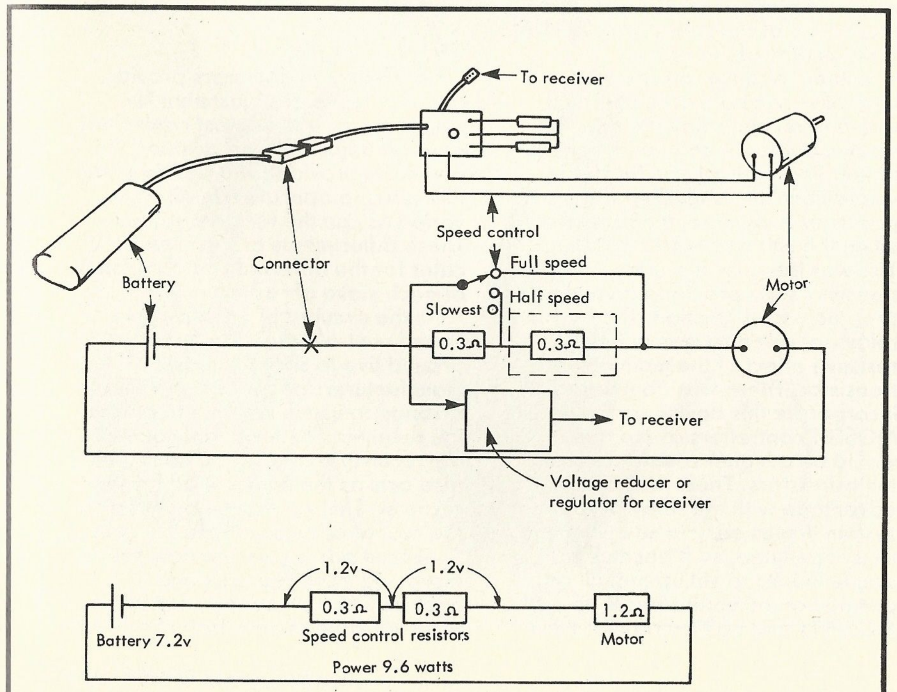


FIG. 1

they are designed to control motors (they will in fact control lamps equally as well). Because of this speed it is virtually impossible to detect the on/off switching. You may just notice the motor buzzing if you just have the motor trying to operate or running very slowly. This buzzing is the fifty hertz pulse being applied to the motor with a large portion of off time and a small amount of on. Other than the very slowest speed you will not notice the pulses being applied to the motor other than the motor's final RPM. The choice of fifty pulses per second is because most (if not all) receivers pulse out the information received from the transmitter at fifty hertz (or pulses per second) and designers of speed controllers use this to run the speed controller, or at least ensure compatibility between the receiver and speed controller. What advantage is there in this method of working? During the on time the motor is receiving the full battery voltage the torque at the motor will be a maximum even if it is on for only a short period. This means that the motor should still develop high power even if the RPM is low, unlike the resistor type of controller where the current to the motor is limited hence reducing the power available.

As the on time is increased so the RPM will increase, yet still maintaining a constant value of torque.

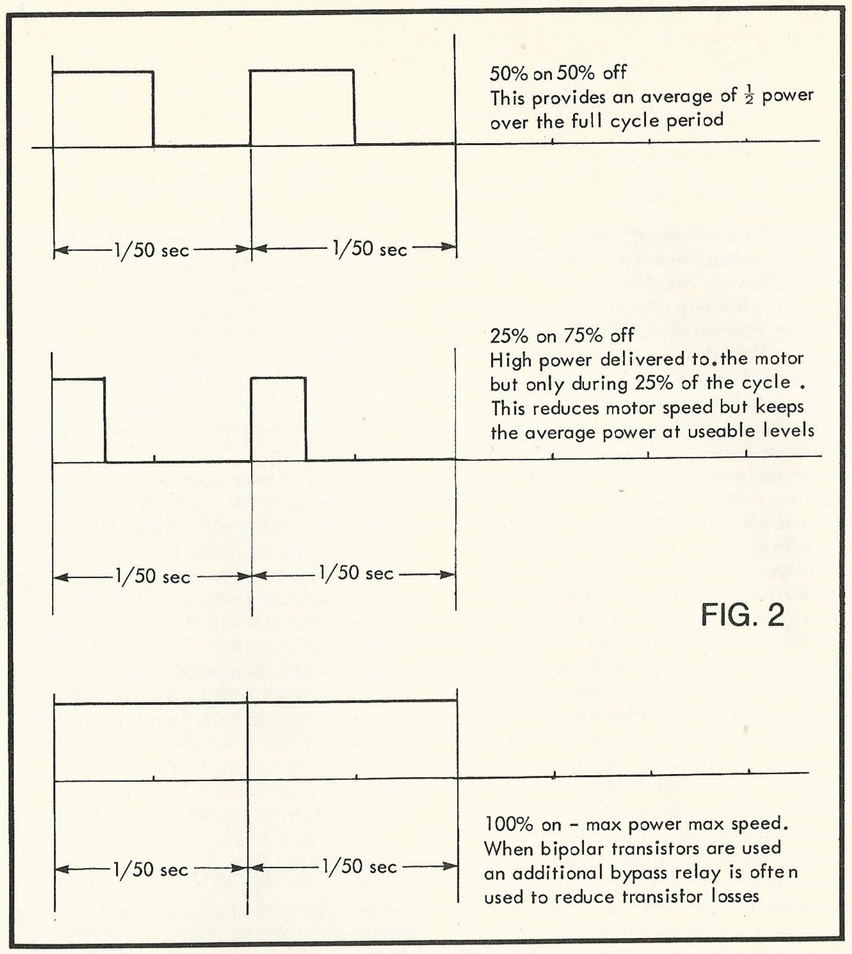


FIG. 2

The first appearance

When electronic speed controllers first made an appearance the only type of transistors available to designers were the bi-polar type. These could be made (at some cost) to control the sort of currents used in model cars. However there was a disadvantage. The main power transistor used to switch the high current at 50 pulses per second to the motor did in fact use power themselves. This was particularly noticeable when the transistor was working in its mid range i.e. not flat out. It was not unusual to find transistors with holes burnt clean through, where they had become so hot. With the introduction of high power MOSFETs the problem almost disappeared overnight. The great thing about this type of transistor is that you can gang them together in parallel to provide a much greater current carrying capacity. We see now some speed controllers offering current carrying capacities of 200 and 300 amperes. These are in fact theoretical values as in an RC car the other components in the circuit, namely wire, connectors and even the motor and battery itself is likely to restrict the amount of current flowing around a circuit. The best of these controllers can offer forward resistances in the order of 0.04 ohm. This is fine if you need forward only speed controllers. Those fitted with reverse use either an electronic reversing arrangement which adds resistance or more often than not a relay is incorporated to provide reverse. It is usually this relay that provides the point of maximum resistance. Attempts can be made to keep the relay resistance to a minimum by using twin contacts and thick contact material but even the very best relays will introduce measurable resistance. Also because the relay is likely to be the only moving item it is also the most likely point of failure. If anything dictates the quality of the speed controller it is the quality of the relay.

Without reverse the speed controller can be extremely small, with a reversing relay the size can easily double, as can the weight. On the earlier types of non MOSFET speed controllers another relay was provided to by-pass the transistors when the unit was working flat out. This was because the early transistors still provided a voltage drop across its junction. The by-pass relay operated to miss out the resistive effect of the main power transistor. There was no need to incorporate this device on the latest MOSFET controllers as the relay would be a higher resistance than the transistors. There was one advantage with the relay by-pass system. It was easy to see when the relay operated, so it became a simple matter to set up the full on position of the controller. With MOSFETs and no moving parts it is impossible to hear or see when they become full on, so either an LED is provided in the unit or a separate plug-in unit is available for setting up. A similar problem occurs with the relayless reversible types, so another LED is incorporated to help with this setting.

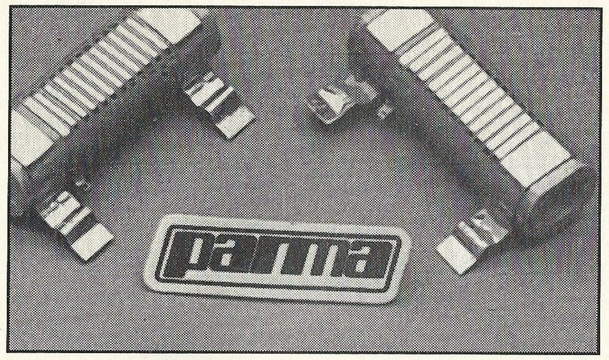
A point worth noting is that most MOSFET speed controllers with reverse do not work as well in reverse as they do forward. Manufacturers often fit a less powerful set of transistors for reverse working as they consider that this will be a much less used facility.

Set em-up!

Different manufacturers provide different types of adjustment for setting up. However most controllers have an adjustable off position. If reverse is provided the position that this starts to operate can also be varied as can the full on position. These adjustments are necessary to cater for the different characteristics of each make of radio.

As the circuitry of an electronic speed controller usually operates at around five to six volts most manufacturers of speed controllers arrange to use this output to power the receiver. The lead that connects the receiver to the speed controller also acts as the power lead for the receiver. This saves weight and also the cost of additional receiver cells.

As time passes we are now seeing more and more features and sophistication on speed controllers. A recent innovation is the



Left: Different ohm rated resistors from Parma which give a mechanical form of speed control. Below: Black Box produce this controller with separate reverse facility.

introduction of heat sensors to shut down the controller if it overheats. Non linear control is also making an appearance. This allows more transmitter stick movement over the lower speed region of the controller, and less movement at the top speed end. The limit of speed controller development is far from over. As time passes we will see more and more sophisticated and reliable devices for controlling motor speed, all we must do is learn the skills to make the best use of the technology.

List of suppliers . . .

FUTABA	Distribution—Ripmax, Enfield, Middx, EN3 7SI. MC112B—Fwd, Reverse + brake. Built-in LED adjustment indicator—10 Fets MC111B—As MC112B but with 12 Fet and additional brake trim
M.F.A.	Distribution—Model Flight Accessories. Electro Buggy throttle Mk2—36 amps max. no low volt supply for receiver.
PARMA	Distribution—Helger Racing, 18 Manor Farm Drive, Chingford, London, E4 6HJ. Resistor speed controllers only
JR/Mac-GREGOR	Distribution—MacGregor Industries. MacGregor—uses Bi-polar transistors— designed for standard motors
INTRONICS FIREFLY	Distribution—Intronics, Claerwen, Bexhill Road, Pevensey, East Sussex BN24 5JT. Low loss forward only GT Buggy fwd + reverse Sixfet 1:12th
PB	Distribution—PB Racing Products, Downley Road, Havant, Hants PO9 2NJ. Forward + reverse with setting up L.E.D.s (fixed price servicing)
ACOMS	Distribution—Riko, 13–15A High Street, Hemel Hempstead, Herts, HP1 3AD.
ATI.	Fwd, reverse + brake. Built-in LED setting up indicators
TEKIN	Distribution—S.R.M. Racing, 140 West Street, Fareham, Hants, PO16 0EL.
LASER	Distribution—Lesro Models, Stony Lane, Christchurch, Dorset, BH23 7LQ. comfet fwd + reverse + brake 5 fet fwd only type—used by many top racers 6 fet compact. fwd, reverse + brake
DEMON	Distribution—Demon Products, PO Box 12, Aldershot, Hants. Market leader, probably more Demons than any other speedo made. Demon King Fwd, reverse + brake 6 fet Proking Fwd, reverse + brake 8 fet Super King Fwd, reverse + brake 8 fet 400A version Big Devil Fwd + brake $\frac{1}{12}$ type
NOVAK	Distribution—Central Models. Eliminator fwd only NESC—1 fwd only NESC—4 cheaper version of NESX-1 fwd only
NOSRAM	Distribution—Malvern Models. Fwd, reverse + brake 8 fet—thermal overide on reverse International fwd only 8 fet
MAGIC K80	Distribution—Elite Models, 145 Newgate Lane, Mansfield, Notts, NG18 2QD. K80—fwd only K80 R—fwd, reverse + brake
SPEED-MASTER	Distribution—Speedmaster, 30 Mancroft Road, Caddington, Luton, LU1 4EL. Silver star—fwd, reverse + brake. Fet—single set up control Gold star—fwd only
MOLE	Distribution—Mole Technology, The Sidings, Cammock Lane, Settle, N. Yorks BD24 9RP. New speed controller for cars available around Autumn 1988
K.O.	Available from—Penn Models, 317 Penn Road, Wolverhampton WV4 5QF. Elite Models, 145 Newgate Lane, Mansfield, Notts, NG18 2QD. CX1—World champion winner probably world smallest speedo fwd only
SANWA	No distributor Vortex fwd only
FASTLINE	Distribution—Fastline, 50 Nunnery Road, Frome, Somerset. Fwd, reverse + brake—built in LED setting up indicator 5 fets fwd only