SPEED CONTROLLERS

THROUGH THE AGES

Nick Marson follows the history of speed controllers.

To the best of my knowledge the history of speed controllers doesn't extend back as far as the Stone Age. I have, however, been involved with racing model cars for a long time, possibly before most of the readers of this article were even born!

A couple of years ago I visited Phil Booth's model shop in Newthorpe. Tucked away in a corner were some very impressive trophies, the largest being his World Championship trophy. Phil commented that the trophies were older than the majority of his customers!

So racing model cars has been around for a long time and every indication is that the hobby is still expanding and will be here for a long time to come.

The focal point has changed over the years, 1/8 circuit was predominant in the 1970's and early 80's, along with 1/12 circuit. The real 'population explosion' happened in the early 1980's when 'Tamiya' launched their 'Rough Rider' off road car.

We now had models that could run on a surface that didn't have to be specially prepared and were powered by electric motors. In short this meant you could run the car in your back garden, or on any piece of rough ground, and not upset your neighbours!

As with any competitive activity, the victor is largely decided by who has the superior technology available at that time. This fact, coupled with the human desire to win, has led to vast improvements in the equipment that is being raced today when compared to that of yesteryear.

Most of the advancements tend to be a gradual evolutionary process (the current model being a minor improvement over the last one), rather than quantum leaps in technology.

Quantum leaps are almost a guarantee for success, provided that you are the only one with the latest gadget!

Definition

A speed controller is a device that controls the speed, and in some cases direction of the car we are controlling.

On an internal combustion engine, as used in 1/8 cars, the speed control is the carburettor which regulates the amount of fuel and air that is available for combustion. In an electric car the speed controller basically regulates the voltage that is applied to the motor.

This article is going to look at the evolution of 'speed controllers', with their quantum leaps.

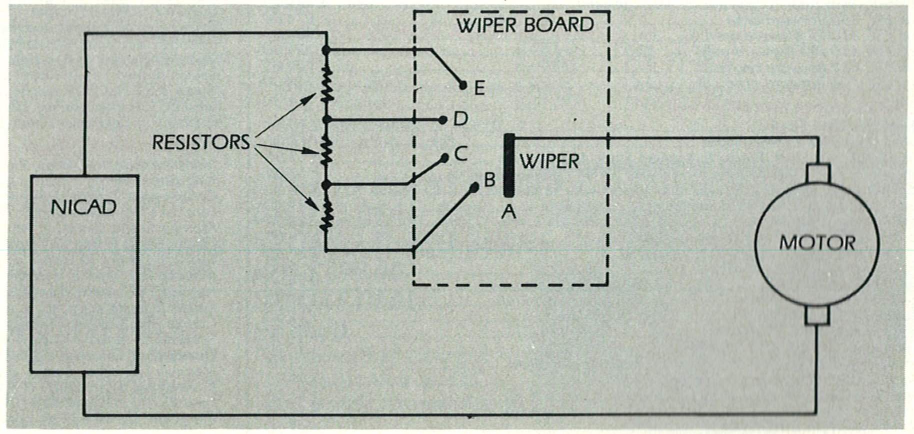
Having always designed and used my own speed controllers it is likely that some major breakthrough will go unmentioned. Apologies if this should prove to be the case. All complaints should be addressed to the Editor!

With the advent of 1/12 scale circuit cars the speed controllers used were of the mechanical type and fell into one of two types:

A) Switched resistors.
B) Variable resistor.

A) Switched resistor

This was generally achieved using a servo to move a pair of contacts around a wiper board (the 'Tamiya' style of mechanical speed controller is a more sophisticated version of this). As the wiper progresses around the board, different values of resistance are switched on in 'series' with the motor.



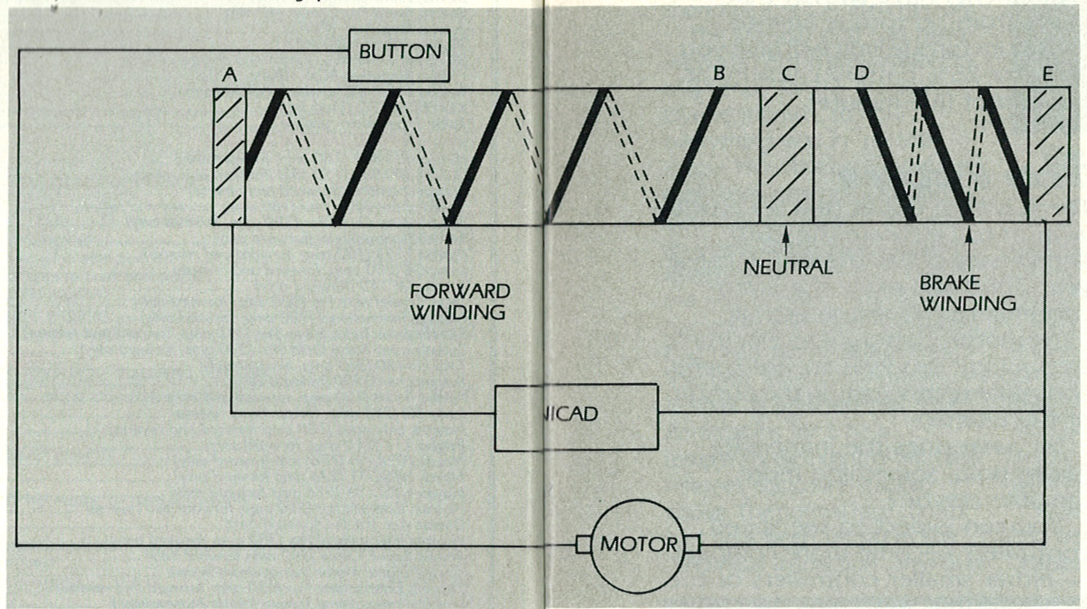
Position 'A' would be neutral, 'B' would give minimum drive (maximum resistance in series with the motor), 'C' is faster, 'D' faster again and 'E' is flat out (no resistors in series with the motor).

The advantages with this type of speed controller are:

1) It is cheap.
2) There is a good chance of rectifying faults (generally broken wires or dirty contacts).

The disadvantages are:

1) Slow response time. (This can be improved however by using a faster servo).
2) A fixed number of speeds available — i.e. not proportional.
3) Inefficient — battery power is being wasted heating up the resistors.



B) Variable resistor

This type of speed controller tended to be of American origin and consisted of a length of resistance wire wound in a spiral around an insulator. An additional winding was also incorporated for the brakes.

Position 'C' is neutral, 'B' is minimum drive and 'A' maximum drive. 'D' is minimum brake and 'E' maximum brake.

The button was connected to the servo via a springy metal arm that kept it in contact with the windings. The more turns of resistance wire between 'A' and 'B', the more the speed controller approached a proportional type controller. In fact this was the main advantage of this type of speed controller over type 'A'.

Being the most popular type, minor improvements appeared, i.e. speed controllers with different values of resistance between 'A' and 'B' in the diagram could be purchased to best suit your motor/track combination. Clamp arrangements were added to point 'A' to effectively push the button down when full speed was selected. This reduced the contact resistance between the button and point 'A', the effect being that more voltage was supplied to the motor.

Micro switches were then added to enable reverse to be selected.

Enter the Electronic Speed Controller...

Contrary to what you might expect, the British were using electronic speed controllers well in advance of them becoming accepted as the norm in the U.S.A. The Americans persevered for some time with variable resistor type controllers.

At this time 'MOSFET's' as we now know them were not available. The ones that were available were very expensive, large and had an unacceptable 'RDSON' (more on this later), so 'bipolar transistors' were chosen as the primary drive source for the motor. Somehow the signal from the receiver that tells us where the throttle stick is had to be converted into a signal to drive the motor. In fact this is simple.

The amplifier chips that are used exclusively in our servos can be used for this function. There are several manufacturers throughout the world that produce this type of amplifier chip:

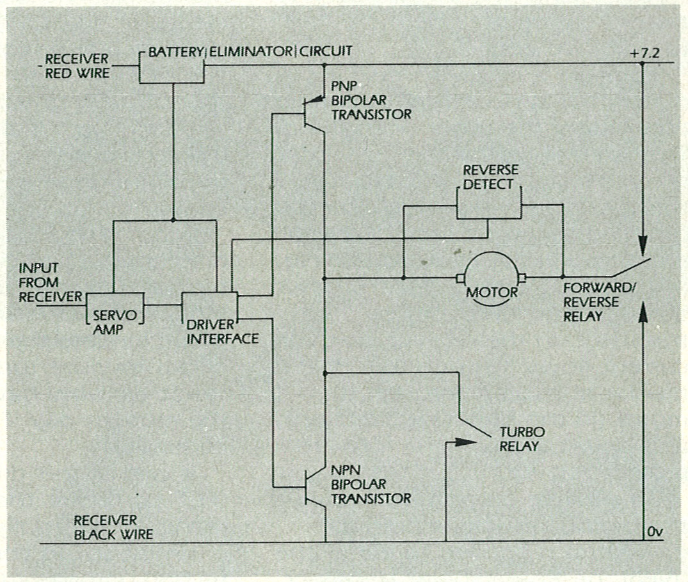
1 Ferranti (now Plessey) in Britain made a chip exclusively for Skyleader Radio Control (how many people can remember them?). After a short period this chip was made available to the general public.
2) Signetics in America.
3) Mitsubishi in Japan.

Each manufacturers device is different offering different drive characteristics. Quite simply you make your choice and pay the money!

I have always chosen the Ferranti device as I believe it offers superior motor drive characteristics. Judging by the number of speed controllers available using the other devices I guess there are an equal number of manufacturers that would vote for the Signetics or Mitsubishi types.

The figure represents a block diagram of a typical early electronic speed controller. It should be noted at this stage that Britain is one of the countries that uses forward and reverse speed controllers for competitive racing. In a lot of countries reverse is banned. The forward only controller is more efficient (it gets more volts to the motor), however this is of little consolation when your car is stuck and the marshall is asleep!!

A brief look at the items in the figure should help in the overall understanding of how the speed controller works.



Firstly the way in which the mechanical and electronic controllers vary the speed of the motor differs. You will recall that the mechanical controller achieved mid range speed by switching different resistor values in series with the motor. It was also noted that this was inefficient with regard to battery energy as the resistors heated up. A far better way is to switch the volts to the motor "on" and "off" very quickly (many times a second). This in fact is how variable speed drills and light dimmers work. If, for each "on" and "off" cycle, we vary the amount of "on" to the amount of "off" we are, in effect, varying the average voltage to the motor.

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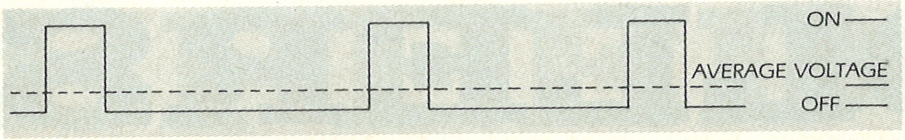
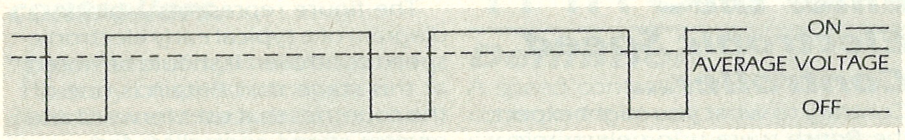


This represents a 'low' average voltage (more "off" than "on") and would therefore cause the motor to rotate slowly.



This represents a 'higher' average voltage (more "on" than "off") and would cause the motor to rotate faster. Clearly, if the waveform was "on" all the time this would represent maximum speed.

The above function is exactly what the servo amplifier does for us — the further the throttle stick is away from neutral the more "on" to "off" we get.

To make a motor reverse it's direction it is necessary to connect the battery the other way round. This is achieved by the forward/reverse relay and the 2 bipolar transistors. In the forward direction current flows from the +7.2 volt rail, through the forward/reverse relay, through the motor and down through the 'NPN' bipolar transistor. In the reverse direction current flows through the 'PNP' bipolar transistor, through the motor (in the opposite direction) and down through the forward/reverse relay.

To achieve proportional drive to the motor the above pulsed waveform is applied to either the 'NPN' or 'PNP' bipolar transistor. Both transistors can be considered as high speed switches (say very fast relays). The main drawback with using bipolar transistors is that when they are switched "on" there is a considerable voltage drop across them (called 'VCESAT'). This means that not all the battery voltage is applied to the motor. To overcome this voltage drop a 'turbo relay' was added. The controller would sense when full power was being demanded by the transmitter throttle stick and operate the turbo relay. The turbo relay, in shorting out the NPN bipolar transistor, negated the 'VCESAT' problem.

Enter the MOSFET

By the mid 80s 'MOSFET' technology had improved to such a point that their cost and size had reduced whilst their performance had increased to such a point that they were now a viable proposition.

The 'MOSFET' parameter that is important for speed controllers is 'RDSON'. This is the resistance of the device when it is turned on.

The smaller this number the better the efficiency. By joining the 'MOSFET's' in parallel with each other the speed controller 'RDSON' equals the individual 'RDSON', divided by the number of 'MOSFET's'. Therefore a large number of 'MOSFET's' with a mediocre 'RDSON' may not be as good as a few high quality 'MOSFET's'. With 'MOSFET's' we do not have to worry about 'NCESAT' as we did with the bipolar transistors, and can therefore dispense with the turbo relay.

Referring back to the block diagram we can now replace the bipolar transistors with 'MOSFET's', modify the driver interface to accommodate these new devices, and throw the turbo relay away. What we now have is the basis of the modern day 'FET' speed controller.

It was at this time that my first 'FET' controller, the 'MARFET', was made commercially available.

Whilst speed controller technology was advancing in leaps and bounds, so was battery and motor technology. The motors of yesteryear were fairly mild 35 turn standard affairs. Today a 12 turn highly modified motor is not uncommon. There is no doubt in my mind that one of these monster motors would destroy one of the earlier bipolar controllers in no time at all!

About a year after the MARFET we produced the first 'NOSRAM' speed controller. This controller had more 'MOSFET's' of a superior quality, and a heavy duty relay to handle these hotter motors. A thermal sensor was added to the reverse/brake 'MOSFET's' to protect them from overheating. This was a lead that has slowly been followed by other manufacturers.

As time marched on 'MOSFET' technology was improving, resulting in even lower 'RDSON' devices being available.

Future editions of the 'NOSRAM' range of speed controllers featured improved internal circuitry, the latest 'MOSFET's', and in some instances even more 'MOSFET's'.

Enter the Torque Limiter

Torque limiting speed controllers were covered in an article in the September issue of Radio Race Car magazine. The top of the range of 'Nosram' controllers feature an adjustable torque limit control. Basically this allows you to modify the characteristics of your motor/car combination to suit the track that is being raced on. By using an amount of torque limit, wheelspin and wheelies for example can be tamed— making the car more driveable and thereby reducing lap times. An added bonus is that as the torque limit is increased so is battery run time. This allows you to gear up and still not dump. As a rule of thumb, experiments have shown that going from no torque limit to maximum torque limit will give you an extra 25% battery capacity at the end of five minutes.

The Future

There is little doubt that an article written to celebrate the 20th anniversary of Radio Race Car in the year 2000 will make the entire contents of this article archaic.

As motor, battery and electronic technology progress so will speed controller technology in the pursuit of the ultimate.

So what does the immediate future hold, something more tangible maybe?

You can expect to see speed controllers become more compact — either smaller controllers or the same size but with more goodies packed in. Higher levels of integration and the use of custom made silicon chips specifically designed for speed controllers.

Suffice to say 'Nosram' is currently working on three new controllers specifically for the model car market and we have no intention of being left behind. Unfortunately that's all I can say as it's a secret! However, if you order your copy of the 20th anniversary edition of Radio Race Car due in the year 2000, it may well be revealed on the first page!!

Bye for now, Nick Marson.