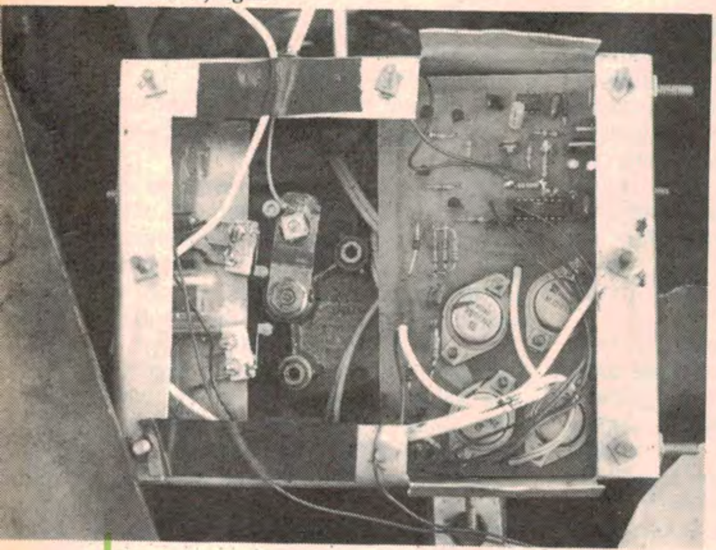
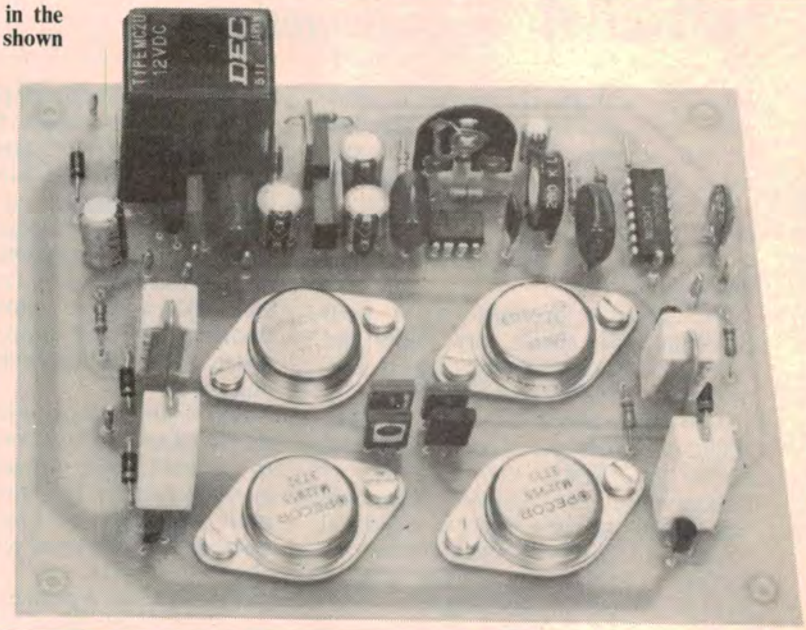
Below is an early prototype throttle actuator as installed in the author's Mazda Capella. The final version of this board is shown below, right.





Cruise control

Commercial cruise controls are available on some new cars and on the aftermarket, but usually cost around $200. This versatile design can be built for less than half that figure.

Have you ever driven long distances in the country, your foot getting cramped and wishing you had something that would automatically control the speed of the car? This cruise control will do the job. It is easy to build and install, uses readily available parts, and will maintain the speed of your car to within about 2% of the set speed.

To operate the unit, it is only necessary to bring the vehicle up to the desired speed and press the engage button. Press another button or the brake pedal and the cruise control is disengaged. Press the resume button and the car will resume the previous speed setting.

Passing another car is no problem since pressing the accelerator pedal further simply overrides the cruise control. When your foot is removed from the accelerator, the cruise control takes over as before and the car resumes the set speed. A new cruising speed can be set at any time simply by pressing the engage button at the desired speed.

In operation, the cruise control keeps the acceleration proportional to the difference between the set speed and the actual speed. A windscreen wiper motor is used to control the throttle setting and this can be obtained cheaply from a wrecker's yard.

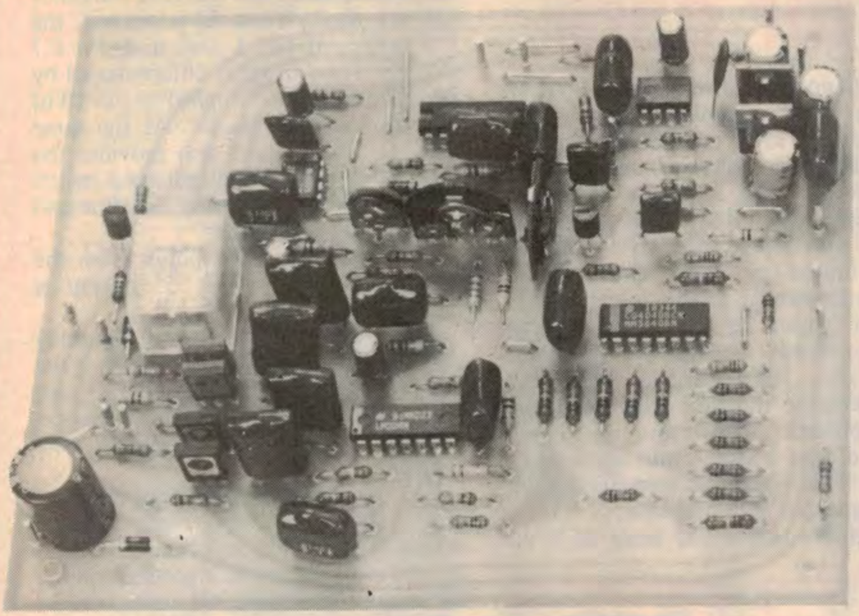
How it works

The cruise control circuitry has been split into two sections. One part, called the *signal processor,* sits under the dashboard and tells the other part, called the *throttle actuator*, what to do. The throttle actuator sits in the engine compartment and controls the throttle setting.

The signal processor sends a control voltage to the throttle actuator. This is called the *error signal*. If the error signal is above 5V, the throttle is opened further. Conversely, if the error signal is below 5V, the throttle is backed off. The rate at which the throttle is opened up or backed off is proportional to the difference between the error signal and the 5V rail.

The error signal is actually a voltage that is dependent upon the set speed, the actual speed, and five times the derivative of the actual speed. Note that the derivative of the speed is acceleration.

Zero, +5V, +10V and +12V supply rails are required for the circuits of both parts. This is achieved by using two 7805 voltage regulators in each section. Both 7805 inputs are connected to the car battery. One has its ground connection to earth (negative terminal of the car battery) and its output is +5V. The other 7805 uses this output as its ground, so its output is +10V. A 1kΩ resistor is connected between the output of the first 7805 and earth to ensure that no current flows back into the output of the first 7805. The +12V rail is simply the car battery voltage.



The signal processor (left) controls the throttle actuator. Below is another view of the throttle actuator installation.

for cars

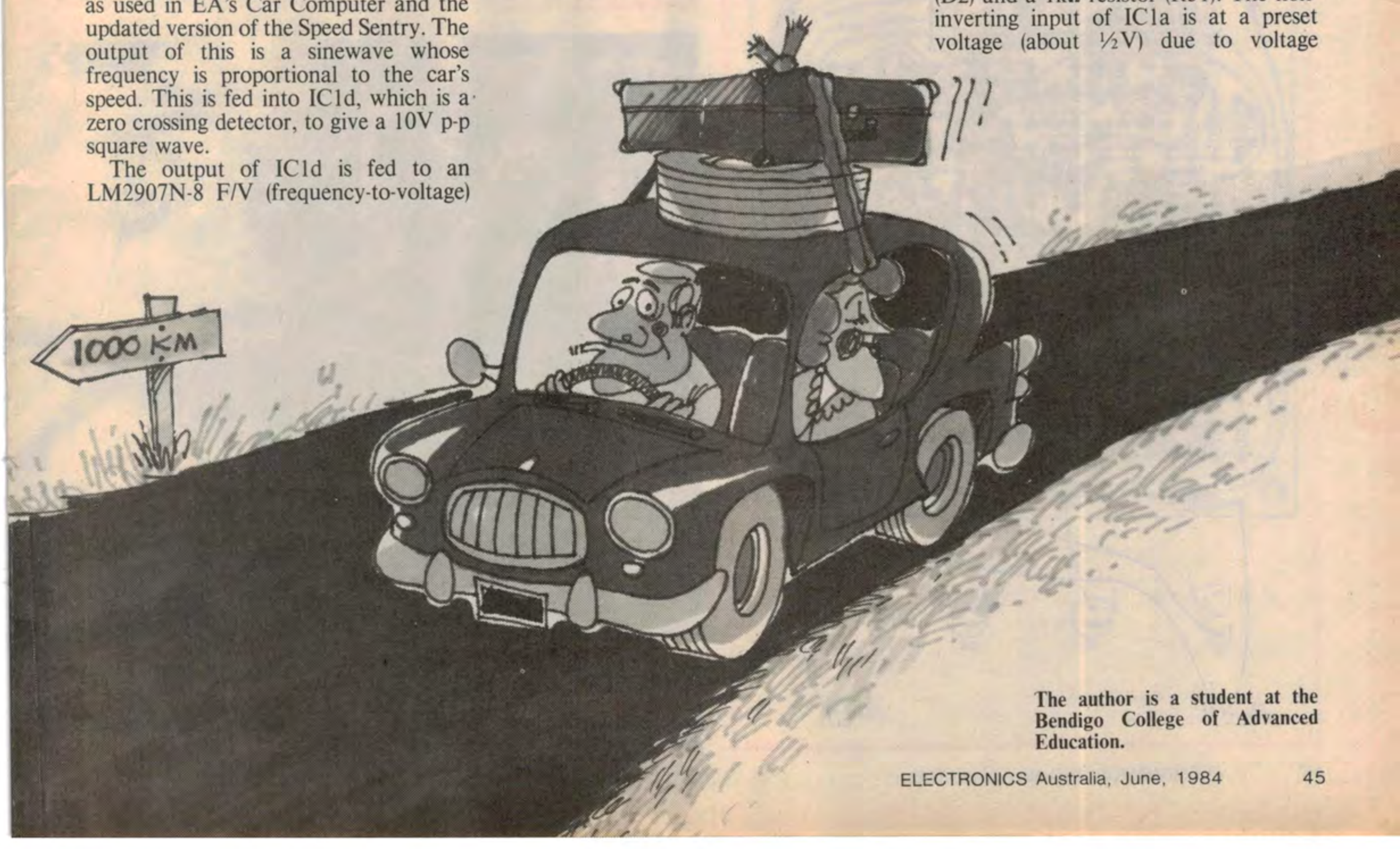
by JOHN KONING

Signal processor

The speed sensor consists of a coil and four magnets attached to the driveshaft as used in EA's Car Computer and the updated version of the Speed Sentry. The output of this is a sinewave whose frequency is proportional to the car's speed. This is fed into IC1d, which is a zero crossing detector, to give a 10V p-p square wave.

The output of IC1d is fed to an LM2907N-8 F/V (frequency-to-voltage) converter (IC5) which gives a voltage that is proportional to the car's speed. This voltage is then fed to a multi-stage RC filter network and thence to buffer amplifier IC2a. From there, the signal passes via C18 to differentiator stage IC2d and also via R42 to unity gain inverter IC2c. The outputs of the differentiator and the inverter are then fed into a summing amplifier involving IC1b.

The output of IC2c is also fed into comparator IC1a which has its output connected to the summer via a diode (D2) and a 1kΩ resistor (R51). The non-inverting input of IC1a is at a preset voltage (about ½V) due to voltage



The author is a student at the Bendigo College of Advanced Education.

Cruise control for cars

divider R47 and R48.

What happens is that when the speed drops below a certain level, the inverter output voltage falls below the voltage at IC1a's non-inverting terminal and the comparator's output goes high, driving the summer's output (pin 7 of IC1b) low. This tells the throttle actuator to close the throttle. When the speed is above this critical level, the comparator's output goes low but is blocked by D2 and thus has no effect on the summer's output.

This is a built-in safety measure designed to stop the cruise control being used below a certain speed, which is about 20km/h depending on the car.

To register the speed that you want the car to go at, a CD4040 counter (IC4) and an R-2R digital-to-analog (D/A) converter (R9 to 27 and IC2b) are used. Note that 1% tolerance metal film resistors are used here for accuracy. What happens is that when you have reached your desired speed, you press the engage button and the counter's clock input is connected to the zero crossing detector output for 0.7 seconds. The counter records the number of input pulses over this period, which is proportional to the car's speed, and the D/A converter converts the digital output of the counter into an analog voltage. This voltage is then applied to the summer via R28 and trimpot R29.

To achieve this, a 555 timer (IC3) in monostable mode and a BC548 transistor (Q1) are used. When S2 is pressed, the 555 output at pin 3 goes high for 0.7 seconds. This output is differentiated by R6, R7 and C8 and applied to pin 10 of IC4 to clear the counter. At the same time, the 555 output also provides the supply rail for Q1 which acts as a switch between the zero crossing detector and the input of the counter.

So IC4 only receives pulses from the speed sensor when the 555 output is high.

The output of IC1b (the summing amplifier) is the error signal, which is the set speed voltage minus the actual speed voltage minus five times the acceleration voltage. R31 is a pullup resistor for the summer.

We now come to the output circuitry of the signal processor. Normally, the output of IC3 is low and hence Q4 is on and Q5 is off. When S2 is pressed and the 555 output goes high, Q5 turns on (Q4 off) and triggers relay 1 which latches on via its second set of contacts. Note that Q3 also turns on since base current flows via Q5, R53 and R54.

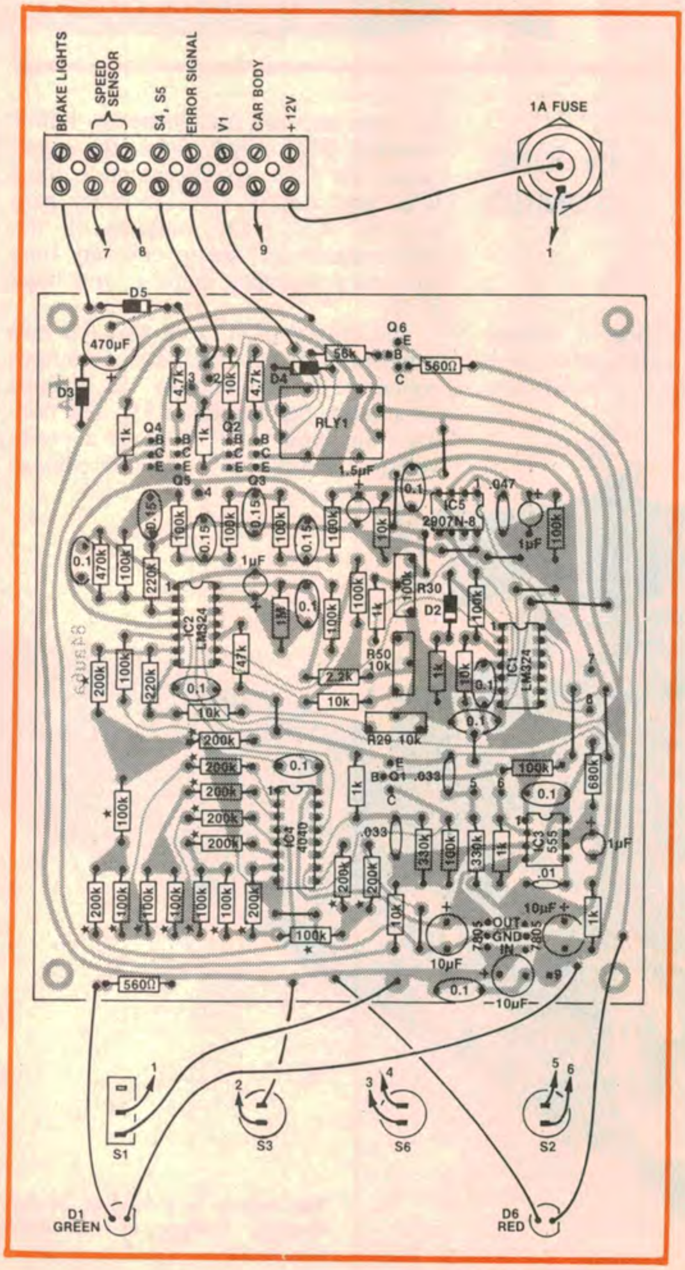
Transistor Q2 is normally off. If, however, the brake lights turn on, or switches S3, S4 or S5 are closed, Q2 will turn on and Q3 and the relay will turn off. When the relay is off, the error signal output of the signal processor circuit is tied to earth. When the relay is latched on, the signal processor output is tied to the output of the summer (IC1b).

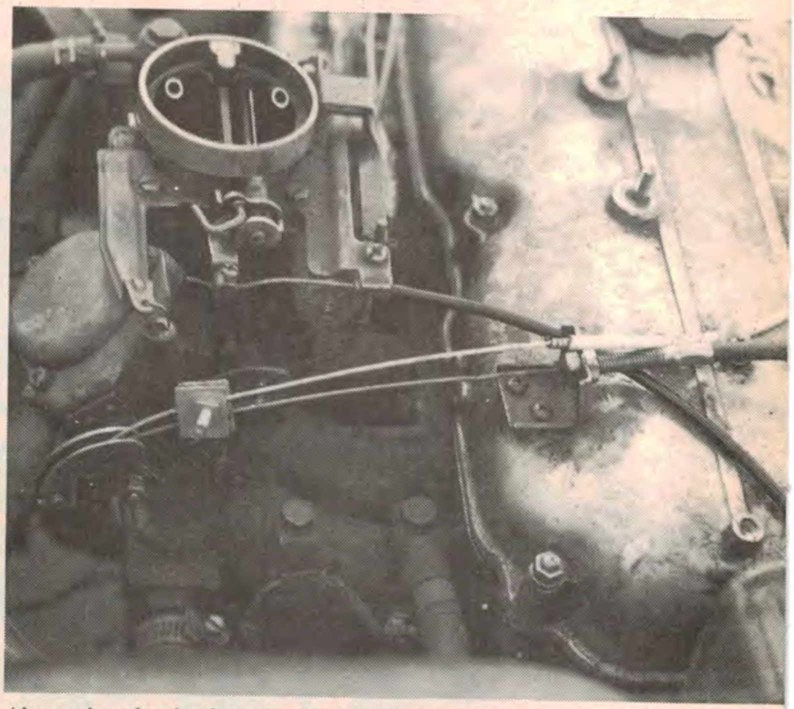
This arrangement ensures that the

We estimate that the current cost of parts for this project is approximately

$70

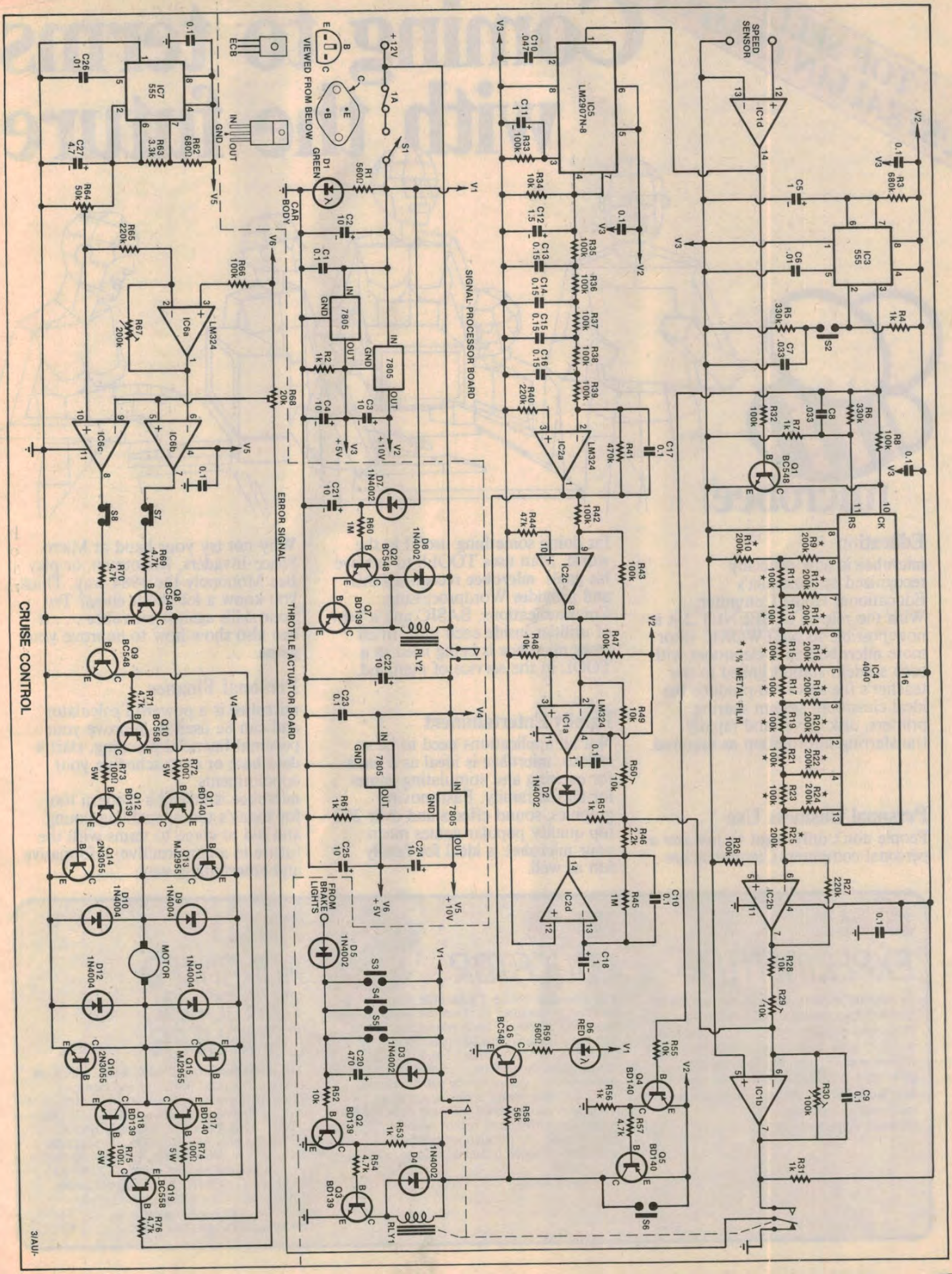
This does not include the windscreen wiper motor, brake cable or metal cases.





Above: view showing how the throttle actuator cable is paralleled with the existing throttle cable.

Left: parts layout for the signal processor PCB. The resistors marked with asterisks must be 1% types.



CRUISE CONTROL

Cruise control for cars

throttle is released when the Cruise Control is disengaged.

Note that when S1 is initially closed, current flows via D3, C20, R52 and the base of Q2 until C20 is charged up. This holds the Cruise Control disengaged for about five seconds after switch on and is necessary because the 555 triggers when S1 is closed.

S6 is the resume switch and allows the Cruise Control to be re-engaged at its previous speed setting. It is simply wired in parallel with Q5 and, when pressed, latches on the relay. Alternatively, the Cruise Control can be re-engaged by bringing the car back to the desired speed and pressing S2.

The status of the Cruise Control is indicated by LEDs D1 and D6. D1 is a green or orange LED that indicates when the Cruise Control has been turned on (S1 closed), while D6 is driven by Q6 and turns on when the Cruise Control is engaged (ie, when relay 1 is latched on).

Throttle actuator

So much for the signal processing circuitry. Let's now turn our attention to the throttle actuator. This comprises ICs 6 and 7, transistors Q7 to Q20, and the windscreen wiper motor.

The windscreen wiper motor is driven by a dual totem pole transistor arrangement so that the full battery voltage is applied in both forward and reverse directions. The four diodes D9 to D12 are flywheel diodes and protect transistors Q13 to Q16 by quenching back EMF from the motor.

Pulse width modulation of the windscreen wiper motor driving voltage is used to ensure maximum mechanical torque at various speeds, a measure which also ensures maximum electrical efficiency since the transistors operate in switchmode.

The pulse width modulation is achieved by using a 555 (IC7) in astable mode and an LM324 quad op-amp (IC6). The 555 oscillates at 42Hz. The output is taken from pin 6 of the 555 and consists of a triangular waveform that peaks at 6.7V (⅔Vcc) and bottoms at 3.3V (⅓Vcc). This is reduced to peak at 5V and bottom at 2.5V by R64, which is a trimpot connected as a voltage divider.

When the signal processor output falls below 5V (indicating that the car is over the set speed or is over-accelerating), comparator IC6c drives Q9. Q9, in turn, drives Darlington pair Q17 and Q15, as well as Q10, Q12 and Q14. Thus, when the signal processor output falls below 5V, Q14 and Q15 are pulsed on and the windscreen wiper motor is driven in one direction to close the throttle.

Similarly, when the signal processor output rises above 5V, Q8 is driven by IC6a and IC6b. This turns on Q13 and Q16, and so the windscreen wiper motor is driven in the opposite direction to open the throttle. S7 and S8 are limit switches which open at the throttle extremities to prevent the motor from being overdriven. S7 opens when the throttle is fully open, while S8 opens when the throttle is fully closed.

The duty cycle of the driving pulses increases the further that the throttle actuator output is away from 5V. Note that R67 is adjustable so that the duty cycle of the throttle opening driving pulses can be made longer relative to the throttle closing driving pulses, for a given error. The reason for this will be explained later.

Transistors Q7 and Q20, in association with C21 and R60, ensure that power to the throttle actuator is maintained for about 10 seconds after S1 is opened. This is to ensure that the throttle is fully released when the Cruise Control is switched off. When S1 is closed, C21 charges up via D7 and Q20 and Q7 are turned on. Relay R2 is thus also on and supplies power to the throttle actuator.

When S1 is opened, C21 discharges via

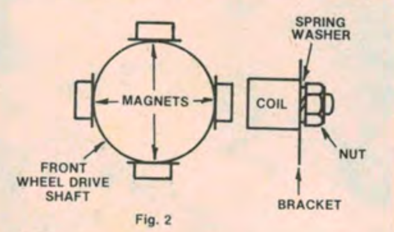


Fig. 2: coil and magnet arrangement for front-wheel drive cars.

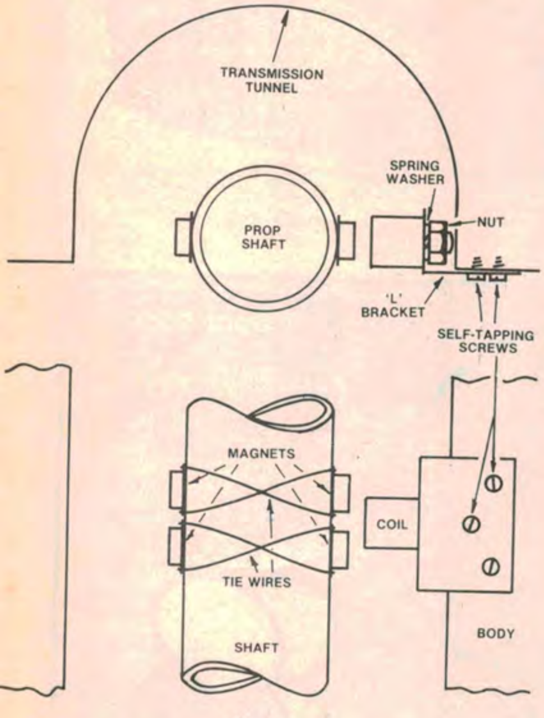
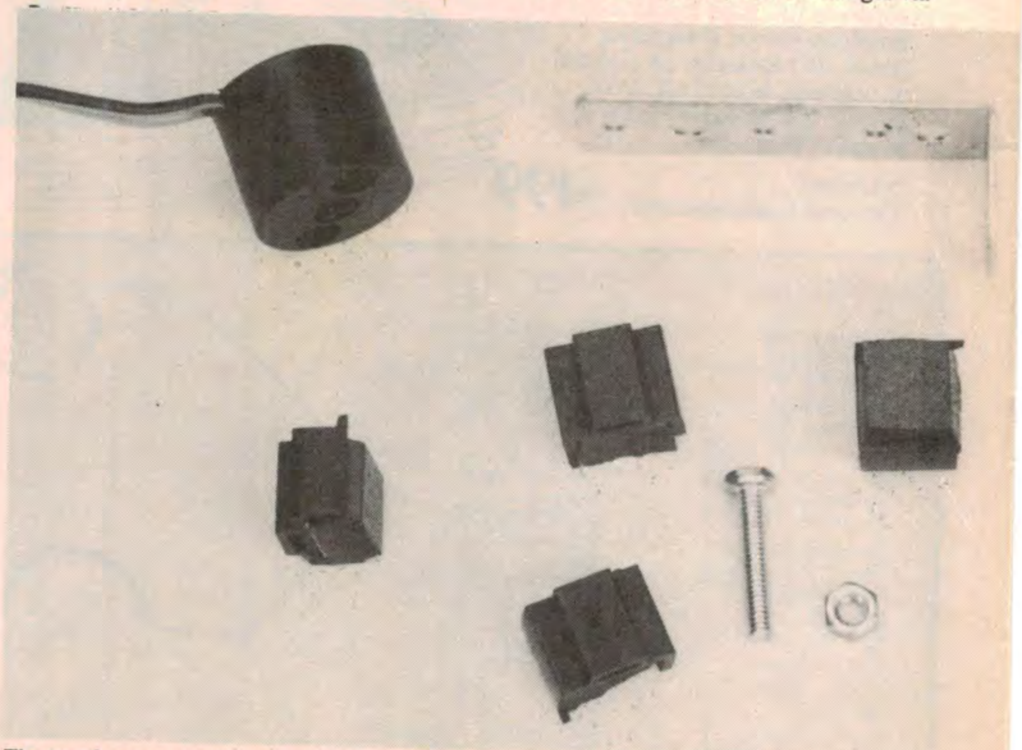


Fig. 1: speed sensor arrangement for rear-wheel drive cars. Note the twin magnet arrangement (see text).



The speed sensor consists of a pick-up coil, four magnets and a mounting bracket.

R60, keeping Q20, Q7 and relay 2 on for about 10 seconds. Relay 1 is off during this time and so the throttle actuator quickly closes the throttle.

The microswitches on the clutch (manual cars only) and gear lever are there to prevent the engine from revving if the clutch is pushed in or the car is knocked out of gear. The clutch microswitch should be closed when the clutch is depressed, while the gear lever microswitch should be open when the car is in top gear (manual) or drive (automatic) and closed otherwise.

PARTS LIST

1 PCB, code 84au6a, 140 x 120mm
1 PCB, code 84au6b, 131 x 110mm
1 mini PCB relay, 12V DPDT (Cat No. S4061, Jaycar, Altronics, Rod Irving)
1 DPDT relay, 10A contacts (DSE Cat No. S7200)
1 SPST toggle switch
3 momentary contact pushbutton switches
4 microswitches (S4, S5, S7 and S8 — see text)
1 panel-mounting 3AG fuseholder
1 1A 3AG fuse
2 LED mounting bezels
8 12mm spacers
1 8-way terminal block
2 metal cases to suit (see text)
1 windscreen wiper motor
1 bicycle brake cable
1 speed sensor (coil plus magnets, Jaycar)

Semiconductors

3 LM324 quad op amps
2 555 timers
1 CD4040 12-stage ripple counter
1 LM2907N-8 F/V converter (Geoff Wood Electronics)
4 7805 5V voltage regulators
5 BD139 NPN transistors
4 BD140 PNP transistors
5 BC548 NPN transistors
2 BC558 PNP transistors
2 2N3055 NPN transistors
2 MJ2955 PNP transistors
6 1N4002 diodes
4 1N4004 diodes
1 red LED (5mm)
1 green LED (5mm)

Capacitors

1 470μF/16VW PC electrolytic
7 10μF/16VW PC electrolytics
1 4.7μF/16VW PC electrolytic
1 1.5μF PC electrolytic
3 1μF PC electrolytics
4 0.15μF metallised polyester (greencap)
12 0.1μF metallised polyester
1 .047μF metallised polyester
2 .033μF metallised polyester
2 .01μF metallised polyester

Resistors (¼W, 5% unless stated)
2 x 1MΩ, 1 x 680kΩ, 1 x 470kΩ, 2 x 330kΩ, 3 x 220kΩ, 10 x 200kΩ 1%, 13 x 100kΩ, 7 x 100kΩ 1%, 1 x 56kΩ, 1 x 47kΩ, 6 x 10kΩ, 6 x 4.7kΩ, 1 x 3.3kΩ, 1 x 2.2kΩ, 8 x 1kΩ, 1 x 680Ω, 2 x 560Ω, 4 x 100Ω 5W

Trimpots
1 x 200kΩ, 1 x 100kΩ, 1 x 50kΩ, 1 x 20kΩ, 2 x 10kΩ

Miscellaneous
Machine screws and nuts, lockwashers, scrap aluminium, automotive cable, automotive wiring connectors, etc.

Construction

Construction of the Cruise Control is straightforward. The signal processor circuit is built on a printed circuit board (PCB) coded 84au6a (140 x 120mm), while the throttle actuator is built on a PCB coded 84au6b (131 x 110mm). These boards are housed in separate metal cases.

Begin construction by installing the parts on the signal processor PCB (84au6a). Install the resistors and wire links first, then the capacitors, relay and semiconductors in that order. Note that the resistors used in the R:2R ladder network are close-tolerance 1% types. These are marked with asterisks on the wiring diagram.

Take care to ensure that all polarised components are installed correctly. The CD4040 (IC4) is a CMOS device so the usual precautions apply. Earth the barrel of your soldering iron to the earth track on the PCB and solder the supply pins (8 and 16) first.

Note that the LM2907 is available in both 8-pin and 14-pin versions. The PCB is designed to accept the 8-pin version (ie, the LM2907N-8).

Once assembly of the PCB has been completed, it can be installed in its metal case. The front panel of the case carries the on/off, disengage, engage and resume switches and the two LEDs, while the rear panel carries an 8-way terminal block and an in-line fuseholder. Install the PCB on 12mm spacers, then complete the wiring to the front and rear panel hardware.

The case used for the prototype was homemade, but there's no reason why you can't use a standard metal case if you so wish. Because requirements will differ from vehicle to vehicle, the details are left to the individual. Some constructors, for example, may wish to mount the control switches and LED indicators on a separate panel which can be mounted in a more convenient location.

If ignition interference subsequently proves a problem, try using shielded audio cable for the switch leads.

Do not install the signal processor in the car at this stage. Before doing this, it is necessary to make a few adjustments and these will be described later on.

Attention can now be turned to the throttle actuator PCB (84au6b). Take particular care when installing the transistors and note that Q11 and Q12 face in the opposite direction to Q17 and Q18. The four power transistors are bolted directly to the PCB using machine screws and nuts.

It is a good idea to solder the nuts on the copper side of the PCB in order to ensure a reliable electrical connection.

The four 100Ω 5W resistors are mounted vertically on the PCB. Once mounted, these should be glued to the board with epoxy adhesive in order to prevent undue strain on the leads due to vibration.

There are two ways of installing the throttle actuator: either you can mount the PCB, windscreen wiper motor and microswitch assembly in a single metal case, or you can install the PCB in a smaller case and mount the windscreen wiper motor and microswitch assembly externally. The second option is recommended since it provides greater flexibility when installing the parts under the bonnet.

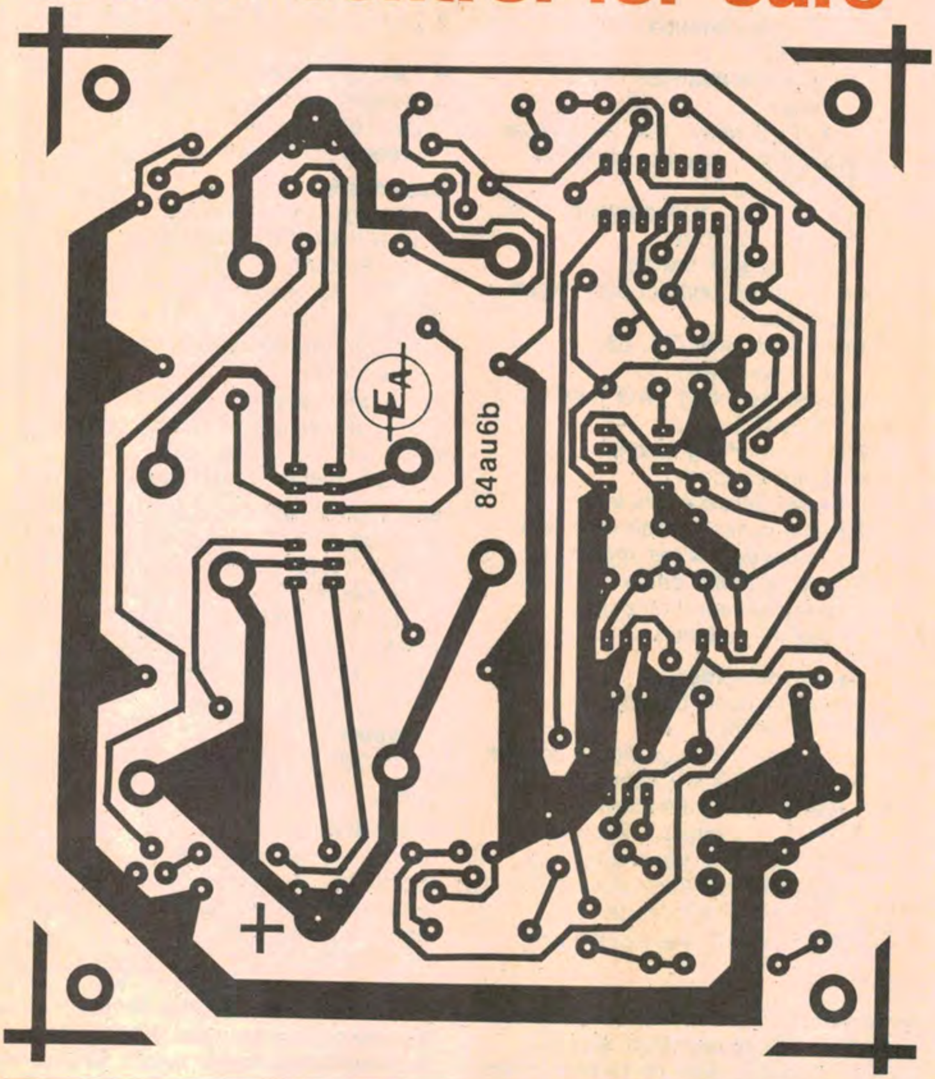
A bicycle brake cable is used as a throttle linkage between the throttle and the windscreen wiper motor. Details of the limit switch assemblies are left to individual constructors as the arrangement used will depend upon the windscreen wiper motor. Most constructors will probably use conventional microswitches, but magnet and reed switch assemblies may be more suitable for some installations.

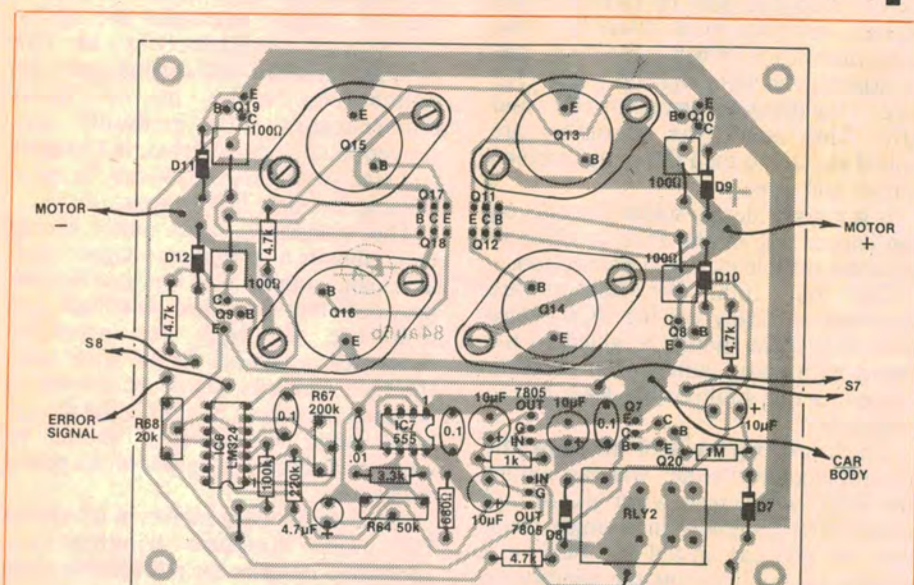
The windscreen wiper motor should preferably be a permanent magnet type, although a wound field type can be used provided that the field windings and armature windings are normally connected in parallel. In the latter case, the field windings should be connected between the output of relay 2 and the car body while the armature should be connected across the output of the power transistors.

Windscreen wiper motors in which the field and armature windings are connected in series are not suitable since the direction of this type of motor cannot be reversed.

At this stage, the throttle actuator can be installed in the vehicle but note that it will be necessary to retain access to the

Cruise control for cars





Parts layout for the throttle actuator PCB. Take care with component orientation.

trimpots for adjustments. The PCB has a "+" sign marked on it to indicate the output that goes positive when the throttle is being opened. The corresponding "positive" terminal of the windscreen wiper motor can be determined during installation by momentarily connecting it across the car battery and noting the polarity required to open the throttle.

Final adjustments

For proper operation of the cruise control, several trimpot adjustments have to be made. To do this, a signal source, a 12V power supply and an oscilloscope are necessary. If you don't have an oscilloscope, then an AC voltmeter will do.

After installing the throttle actuator and connecting it to the car battery, turn trimput R68 fully towards pin 14 of the LM324. Turn R64 fully towards the LM324 and R67 towards the power transistors. Now connect the anode of D7 to the positive battery terminal.

If you have a dual-trace oscilloscope, set the traces to "dc" and connect the earth leads of the probes to the car body. Make sure both traces are centred on the screen when the inputs of the probes are earthed. Connect one probe to the 5V rail and the other (set to 10:1) to the wiper of R64. Adjust R64 until the triangle waveform just touches the 5V rail trace.

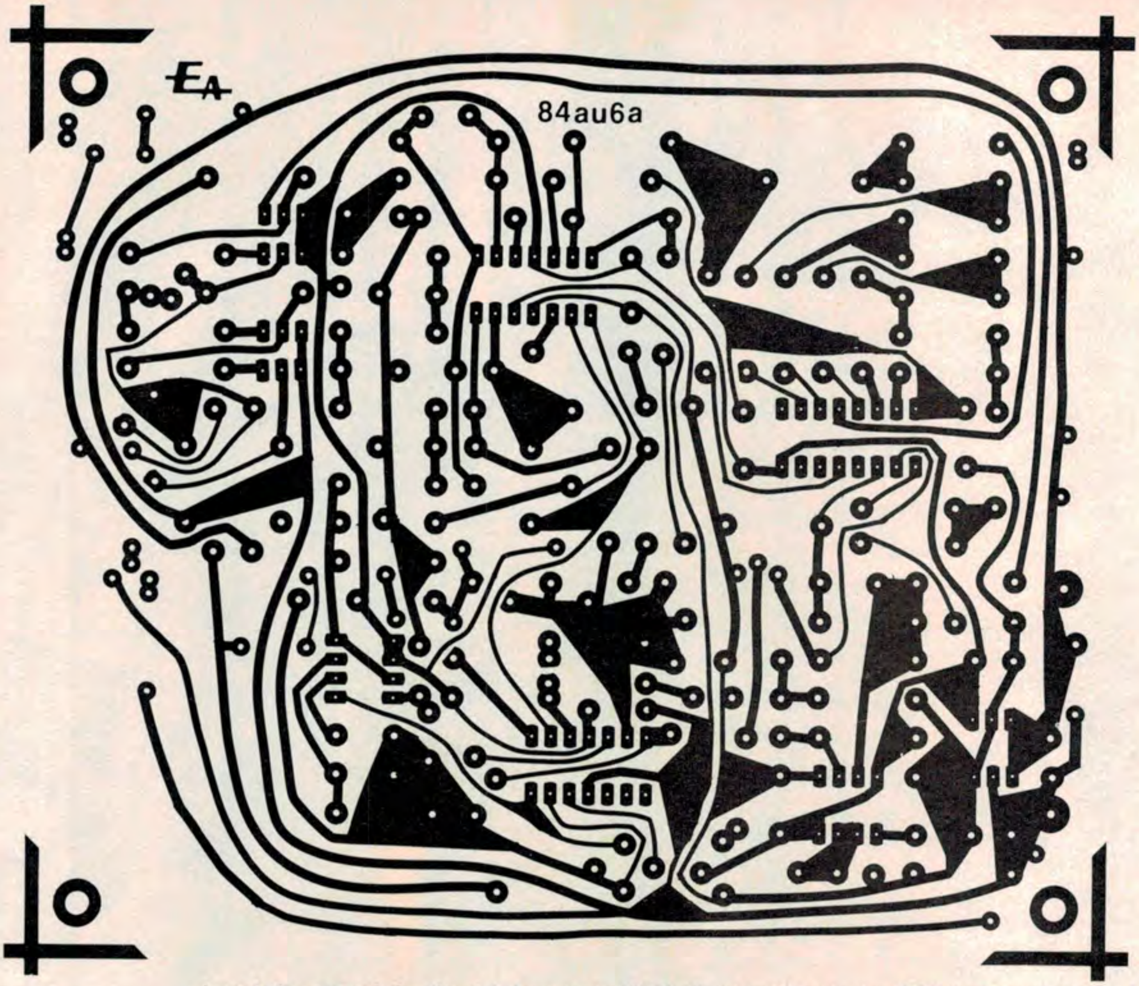
Alternatively, if you don't have a CRO, connect an AC voltmeter across the output of the throttle actuator and adjust R64 until the voltmeter gives a reading. R64 should then be backed off to the point where the voltage just disappears.

For the rest of the throttle actuator adjustments, disconnect the fuel line from the carburettor to avoid flooding the engine. Now connect the error signal input to the 10V rail. Turn R68 until the windscreen wiper motor slowly pulls the throttle open. Allow the windscreen wiper motor to fully open the throttle and trip limit switch S7. Now connect the error signal input to the 0V rail. The windscreen wiper motor should close the throttle, but at a faster rate than when it was opened. This is due to the throttle return spring.

You now have to alternatively open and close the throttle, each time turning R68 a bit further until the windscreen wiper motor travels at the maximum speed without ploughing through the microswitches. Now adjust R67 so that the windscreen wiper motor opens and closes the throttle at an equal rate.

On the signal processor board, turn trimpot R29 fully away from C9, turn R50 fully towards R29 and turn R30 fully away from R50. Connect the signal processor to a 12V power supply or a car

Cruise control for cars



Actual size artwork for the signal processor PCB. The throttle actuator PCB is on page 52.

battery. Connect the speed sensor inputs to a signal source of about 100Hz. Connect an oscilloscope or voltmeter between the 5V rail and the error signal output.

Now press the engage button. If the error signal output is above the 5V rail, turn R29 until the error signal is equal to the 5V rail. If the error signal is below the 5V rail, turn R50 until the error signal is equal to the 5V rail.

The signal processor can now be installed in the vehicle and the wiring run to the speed sensor, brake lights, throttle actuator, and clutch and gear lever microswitches. A normally closed spring loaded automotive switch will probably be the best way to go for the clutch microswitch, while the gear lever microswitch can take any form that's convenient. The main point to ensure is that the switch is open when the car is in top gear, and is closed otherwise.

Do not leave any of these switches out. The cruise control will not operate correctly if you do, and could even prove dangerous.

Figs. 1 and 2 show how the speed sensor is installed in rear-wheel drive and front-wheel drive cars respectively.

On rear-wheel drive cars, the sensor should be mounted as close to the gearbox as possible, where vertical movements of the tailshaft are minimal. The magnets are secured using tie wire and epoxy adhesive. Two magnets are shown at each position to compensate for longitudinal movements of the driveshaft.

The coil is mounted on an L-shaped bracket and secured to the car using self-tapping screws. Position the bracket so that there is a 25mm air gap between the coil and the magnets when they are directly opposite each other. Finally, carefully route the two-core cable from the coil to the speed sensor inputs on the signal processor.

On front wheel drive cars, the magnets are mounted at four locations, 90° apart. This is because the driveshaft on a front-wheel drive vehicle rotates much more slowly than the tail shaft on a rear-wheel drive vehicle. The magnets should be positioned either on the driveshaft coupling flange or, if this is not possible, as close to the inboard end of the driveshaft as possible.

Check to ensure that there is little relative movement between the pickup and the magnets as the suspension moves. Check also that the installation does not foul any other part of the vehicle over the full extent of the suspension travel.

Now we come to the road test. Drive to a quiet, preferably hilly, road, bring the car up to normal cruising speed, and engage the cruise control. Now ease your foot off the accelerator pedal — the cruise control should take over.

It is now a matter of adjusting R30, which is the error signal gain control, so that the cruise control gives a smooth response when going up and down hills, but keeps the speed to within reasonable limits. You should be able to adjust the gain to give a smooth response while keeping the speed to within 3km/h of the set speed.

Once the gain has been set, install the signal processor permanently under the dashboard.

Other speed setting methods

There are other ways of setting the speed besides bringing your car up to cruising speed and pressing a button, as in this design. You can in fact substitute a potentiometer for half the circuit of the signal processor and use this to set the speed.

If you wish to set the speed by adjusting a pot, then delete: IC3 and 4; Q4 and Q5; R3 to R24; R55, R56 and R57; and C5 to C8. Connect a 1kΩ pot between the 5V rail and the 10V rail and connect its wiper to R25. Replace R27 with a 100kΩ resistor and trimpots R29 and R50 with links.

The cruise control is now engaged by pressing the resume switch S6, while the speed is set by the 1kΩ pot.