DRILL SPEED CONTROLLER

An easy-to-build gadget that lets you vary the speed of your power drill, or any other domestic appliance that is powered by a univeral electric motor.

THIS PROJECT CAN BE USED to control the speed of virtually any domestic electric drill, power saw, grinder, sander, or other power tool that incorporates a universal electric motor. It enables the motor speed to be smoothly varied from zero to about 75% of maximum via a single control, and incorporates built-in compensation to maintain the motor speed virtually constant at any given speed setting, regardless of changes of load. This latter facility is of great value when tackling low speed jobs like drilling masonry or using fly-cutters on sheet metal, etc.

Construction

All components except C1, RV1, and SW1 are mounted on the single PCB, so construction should present few problems provided that care is taken to fit all semiconductors in the correct polarity. It must be emphasised, however, that the controller is connected directly to the mains without the use of an isolating transformer, so care must be taken to ensure that there is no likelihood of any dangerous conditions arising. Under no circumstances touch the wiring when the unit is connected to the live mains.

The SCR used on the prototype circuit is a C106D type, but the design can in fact be used with virtually any 400 volt SCR with a current rating greater than 3 Amps. We didn't bother to fit a heat sink to the SCR on the prototype, but it is probably a good idea to do so in practice. If you do fit a heat sink, make sure it can't come into contact with any other components or wires.

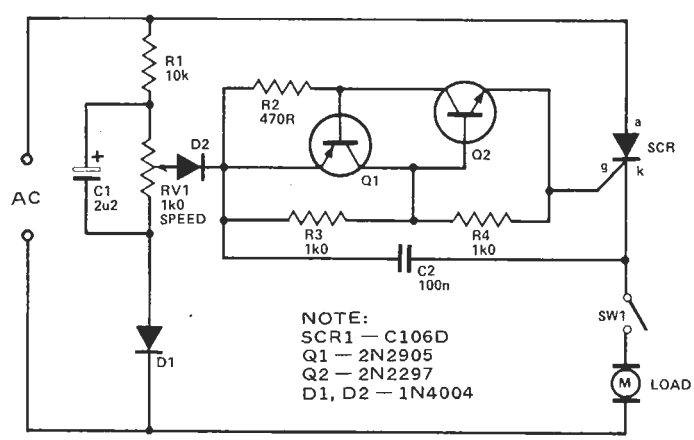
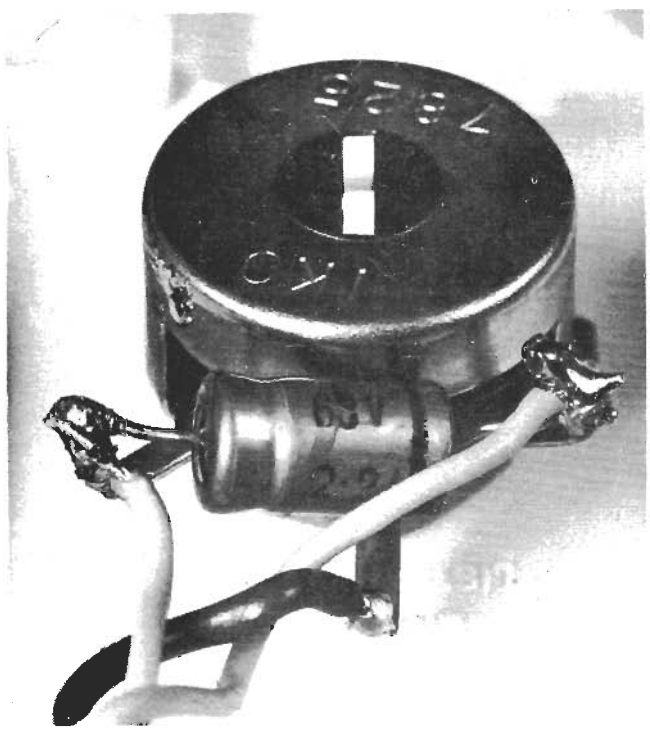


Fig. 1. Circuit diagram of the HE Drill Speed Controller.



Mounting capacitor C1 on the control potentiometer RV1.

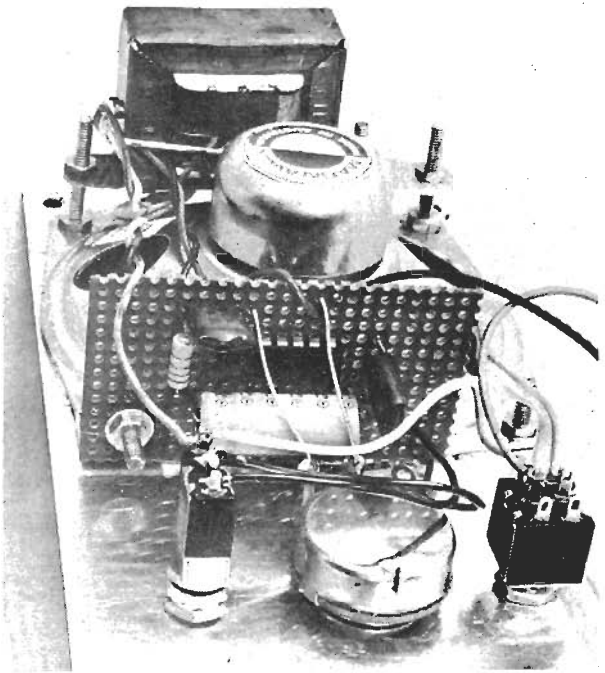


Fig. 5. The method of assembly may readily be seen from this internal view.

PARTS LIST

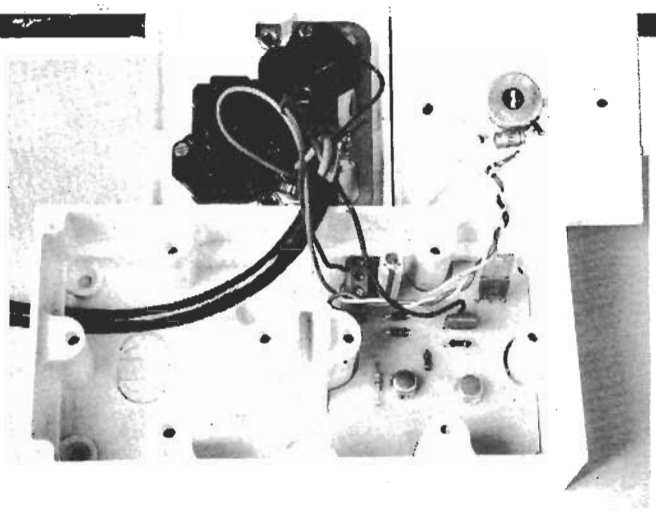
R1	2.7 ohm ½ watt 5%
C1, C2,	100n polyester
C3	47U 16 volt-electrolytic
IC1	LM380
T1	10k to 8R audio transformer
RV1	2M log rotary

	System 1	System 2	System 3
SW1	DPDT pushbutton	SPDT pushbutton	DPDT pushbutton
SW2	—	SPDT pushbutton	DPDT pushbutton
SW3	—	—	SPDT pushbutton
SW4	—	—	SPDT pushbutton
SW5*	SPDT toggle	SPST toggle	SPST toggle

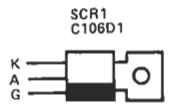
Loudspeakers 15 ohm 3" diameter
Six to 12 volt battery. *
Plastic or metal box, piece of matrix board, bolts and nuts etc.
* required for battery versions only.

Power Supply

D1-D4	IN4001 or similar
C4	470u 25 volt electrolytic
C5	25u 25 volt electrolytic
T2	120/12.6 volt
SW6	DPST toggle



Inside the HE Drill Speed Controller, use of a PCB is strongly recommended, especially when using a line powered project.



Leadout for SCR1. Note the position of the heat-sink mounting hole.

PARTS LIST

RESISTORS (All ¼W 5% unless stated)

R1	10k 5W
R2	470R
R3,R4	1k0
POTENTIOMETER	
RV1	1k0 2W
CAPACITORS	
C1	2μ2 63V
C2	100n polyester
SEMICONDUCTORS	
SCR1	C106D
Q1	2N2905
Q2	2N2297
D1,D2	IN4004

HOW IT WORKS

A universal motor, when running, generates a voltage that opposes that of the supply. This voltage is called the back EMF, and is proportional to the motor speed. The HE drill speed controller uses this back EMF to sense motor speed, and automatically adjusts the power fed to the motor so that it's speed remains reasonably constant under varying load conditions. The speed setting is variable via RV1.

Because of its back EMF characteristics, a universal motor runs at about 75% of its normal maximum speed when it is fed from a half wave rectified power line.

The HE controller uses an SCR (silicon controlled rectifier) to gate half-wave power to the drill motor. The SCR acts like a very fast self-latching power switch. The point at which it turns on during a half cycle depends on the setting of RV1, and on the back EMF of the motor. If the SCR is turned on near the end of each positive half cycle, very little power is fed to the motor; if the SCR is turned on at the start of each positive half cycle, high power is fed to the motor. The SCR turns off automatically at the end of each positive half cycle.

In the initial description of circuit operation, let's assume that SW1 is closed, and let's also ignore the presence of Q1-Q2 and their associated resistors and C2, and assume that D2 is connected directly to the gate of the SCR. In this case R1-RV1 and D1 form a half-wave voltage divider that feeds an adjustable voltage to the gate of the SCR via D2. The SCR turns on when it's gate becomes slightly positive to it's cathode, and the point at which this occurs depends on the setting of RV1 and on the back EMF, and hence speed, of the motor.

Suppose, for example, that the motor is lightly loaded, and RV1 is set so that the motor runs at half-speed under this condition. If the load is now removed the motor speed will tend to increase, thus increasing the back EMF and countering the voltage set by RV1, so that the SCR will tend to fire later in each cycle and thus reduce the speed of the motor. The reverse action occurs if the motor load is increased. In either case, a negative feedback effect occurs which tends to cause the motor to operate at a constant speed in spite of load variations.

In extreme cases, when the controller is set for very low speed operation, this negative feedback causes power to be fed to the motor in 'bursts' or 'skip cycles' of half-wave power when the motor is lightly loaded, so that the motor seems to give an erratic form of operation. Capacitor C1 is fitted to reduce this skip cycling effect and give smoother operation.

The action of the Q1-Q2-C2 network, when it is triggered, is such that the SCR has to be supplied with gate current that is derived from RV1 slider. If the SCR is a sensitive type, like the C106D, RV1 can provide this gate current without trouble, but if the SCR is a low sensitivity device, RV1 may not be able to supply adequate gate current. Q1-Q2 and C2 are used to overcome this problem.

Q1-Q2 and their associated resistors act as a voltage-sensitive switch. In each half-cycle, C2 is able to charge up via RV1 slider. As soon as the C2 voltage rises to a suitable value, Q1 and Q2 both switch on and partially discharge C2 into the gate of the SCR, thus delivering a pulse of high current to the SCR gate, quite independently of any current-drive limitations of RV1 slider. The Q1-Q2 and C2 network thus enables virtually any SCR to be used in the SCR1 position, almost irrespective of its gate sensitivity characteristics.

Note when using the drill (or any other appliance) at low speeds that it's motor will run rather hotter than usual, since the motor's cooling fan efficiency is greatly reduced at low speeds. It is wise to occasionally pause and allow the motor to cool down when using it for long periods at low speeds.

Using The Controller

Plug the controller into the lines, plug the drill into the controller, and switch both units on. The drill speed can be varied from zero to about 75% of full speed via RV1. Note that there may be a 'dead' zone at both the low speed and high speed ends of the control, due to different drill motor characteristics and component tolerances within the controller. This is quite normal.

At very low speeds the drill runs rather jerkily under low load conditions, due to the 'skip cycling' method of speed regulation that is used in the design. This jerkiness decreases or disappears when the drill is loaded up.●

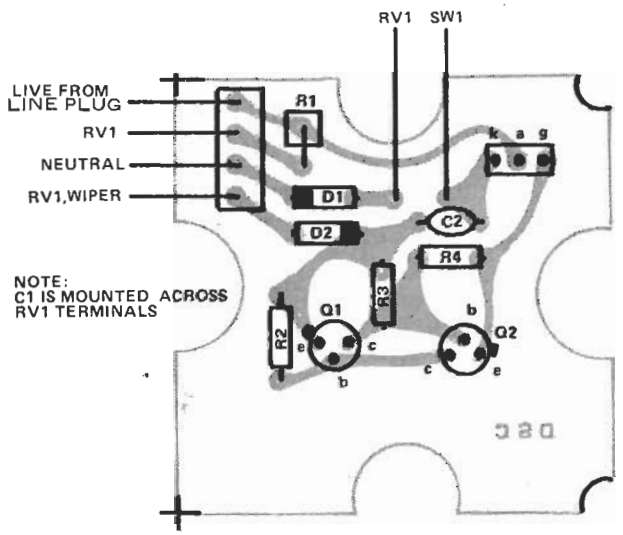


Fig. 2. PCB overlay, note position of the thyristor.

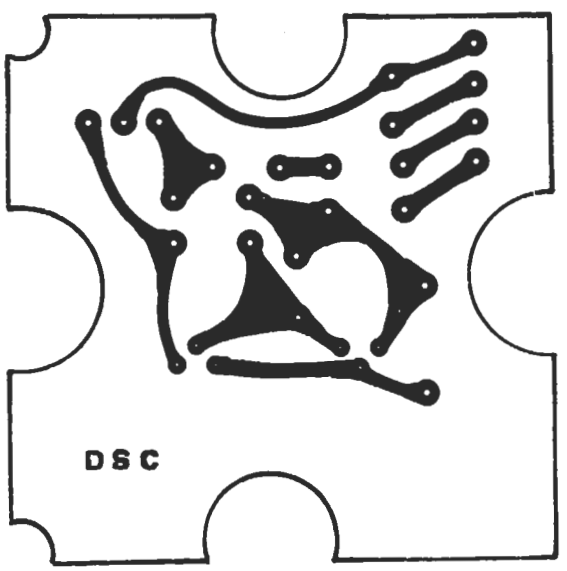


Fig. 3. PCB pattern for the HE Drill Speed Controller.