AC Motor Speed Controller

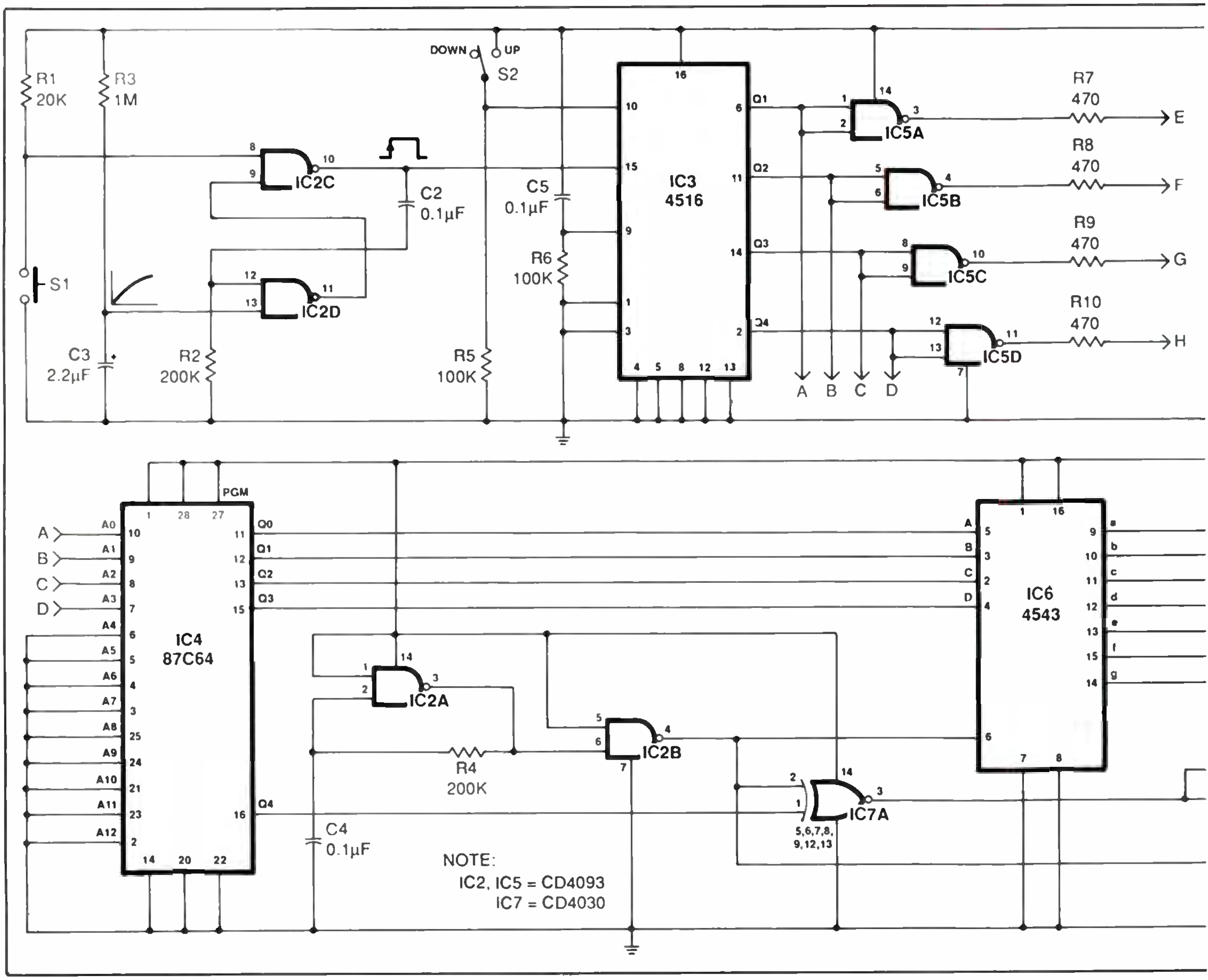
Setting speed of an ac motor with optical couplers and a binary counter

By Ricardo Jiminez-G

Are you looking for an elegantly simple and low-cost circuit for controlling the speed of an ac motor? If so, here is one you should look into. It uses four optocouplers and a single binary counter as the speed-control elements and features a decimal numeric display as well.

About the Circuit

The schematic diagram of the speed-controller circuit is shown in Fig. 1. This circuit controls the speed of ac motor *M* by changing the conduction angle of triac *Q1*. At the heart of this circuit are optical couplers *IC8* through *IC11*, which control triac *Q1*. A resistive network made up of



R11, *R12*, *R13* and *R14* controls the magnitude of the current that passes through diac *D1*. Hence, the conduction angle depends upon the state of the four parallel *R11* through *R14* resistors. Four resistors give 16 possible steps, making a 15-speed ac motor controller. By adding more resistors, optocouplers, up/down counters and EPROMs, it is possible to obtain 31, 63, etc., speeds from the circuit.

When the circuit is first powered up, the *R3/C3* network disables the monostable multivibrator made up of *IC2C* and *IC2D* for a period of 0.43 second and the *R6/C5* network resets counter *IC3* to zero. Under these conditions, the motor will not run because the LEDs inside the four optocouplers are not turned on. The four NAND gates that make up *IC5* are configured here as inverters. They function as buffers that supply the 13 milliamperes of current required by the LEDs inside each optocoupler.

To start running the motor, normally-open pushbutton switch *S1* must be pressed. Counter *IC3* then changes its zero state to decimal 1 (0001). This generates a pulse at the pin 6 Q1 output of *IC3*, which is coupled through *IC5A* and pulses on the internal diode of optocoupler *IC8*. This "enables" *R11* to transmit the voltage across *C6* to the gate of *Q1*. With diac *D1* between *C6* and the gate of *Q1*, however, the triac does not immediately turn on.

As the 117-volt ac source passes through zero on each cycle alternation, the charge on *C6* increases. Only when the potential across capacitor *C6* reaches 30 volts, which is the break-over potential of the diac, is *D1* triggered into conduction. When the diac triggers on, the charge on *C6* is "dumped" into the gate and trig-

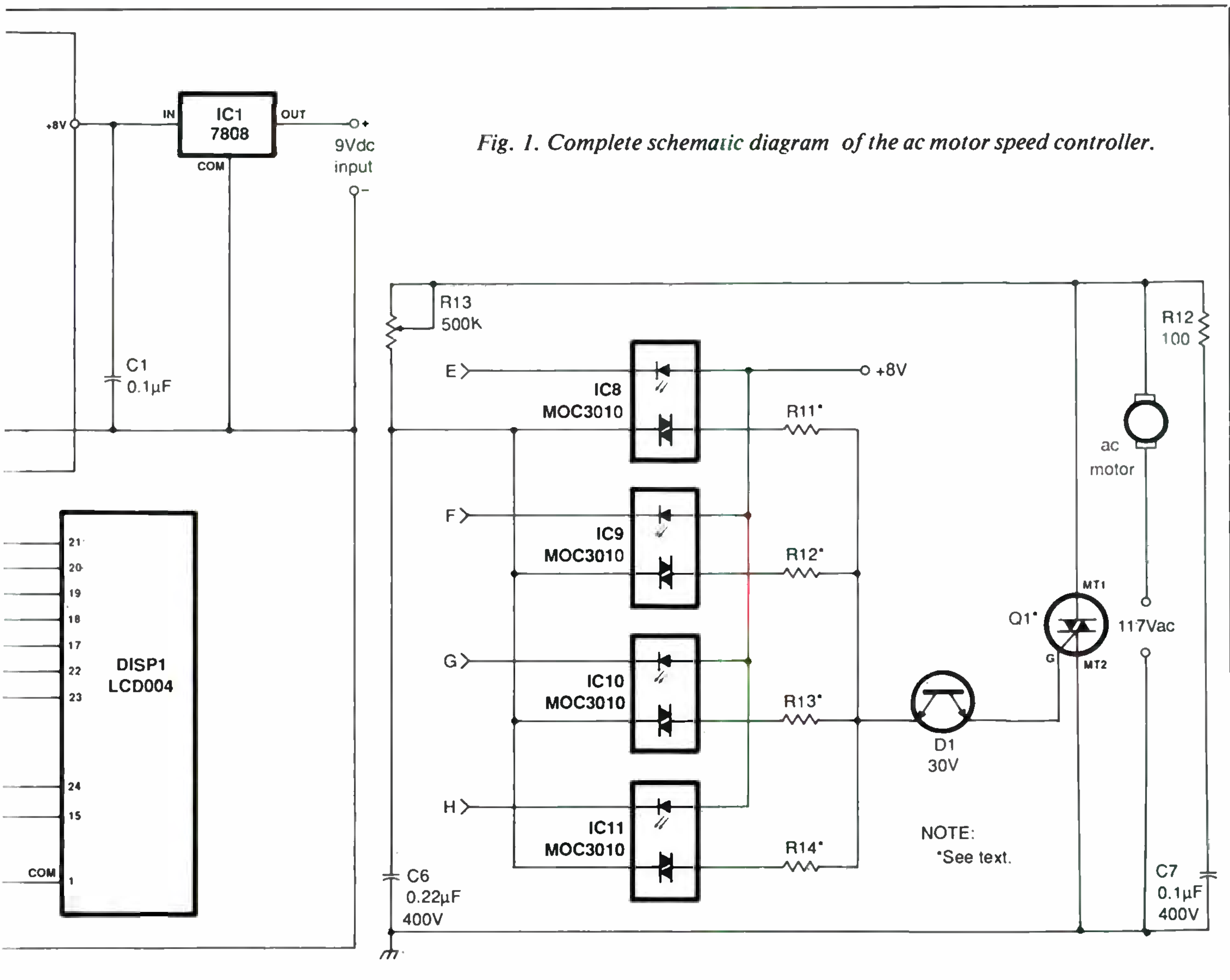


Fig. 1. Complete schematic diagram of the ac motor speed controller.

PARTS LIST

Semiconductors
D1—30-volt diac
IC1—7808 fixed +8-volt regulator
IC2,IC5—CD4093 quad 2-input NAND gate
IC3—4516 counter
IC4—87C64 or similar EPROM
IC6—4543 decoder
IC7—CD4030 XOR gate
IC8 thru IC11—MOC3010 or similar triac-output optical isolator
Q1—Triac (see text)

Capacitors
C1,C2,C4,C5—0.1-µF, 16-volt disc
C3—2.2-µF, 16-volt electrolytic
C6—0.22-µF, 400-volt disc
C7—0.1-µF, 400-volt disc

Resistors (¼-watt, 5% tolerance)
R1—20,000 ohms
R2,R4—200,000 ohms
R3—1 megohm
R5,R6—100,000 ohms
R7 thru R10—470 ohms
R11 thru R14—See text
R12—100 ohms
R13—500,000-ohm, linear-taper, panel-mount potentiometer

Miscellaneous
DISP1—LCD004 liquid-crystal display module
M—Existing ac motor
S1—Spst momentary-action pushbutton switch
S2—2-position slide or toggle switch 9-volt dc, 150-mA plug-in power supply

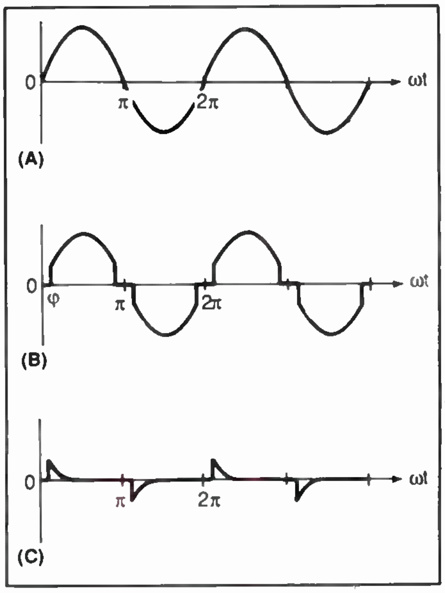


Fig. 2. Typical waveforms: (A) 117-volt rms sine wave from ac line; (B) load voltage if triac turns on when source voltage reaches instantaneous value of 30 volts; (C) gate current waveform produced by C6 discharging through D1.

gers on triac *Q1*. When this occurs, the motor begins to operate at its slowest speed.

Incrementing counter *IC3* by using *S1* to have the monostable oscillator pulse input pin 15 of *IC3* will cause the motor to operate at a faster speed, depending upon which and how many of the optocouplers are triggered on. For this to occur, though, DIRECTION switch *S2* must be in its UP position. Placing this switch in the DOWN position will have just the opposite effect.

EPROM *IC4*, an 87C64 chip, is used here to represent the 16 steps of the controller that are counted off in the *DISP1* LCD display. The EPROM's program is given in the table. Decoder *IC6* converts the output from the EPROM into a format that can be used by *DISP1*. Note that the Q4 output at pin 16 of *IC4* is coupled to input pins 15 and 24 of *DISP1* through XOR gate *IC7A*. (Note: The other XOR gates in *IC7* are not used in this circuit.)

Schmitt-trigger inverters *IC2A* and *IC2B* make up a 40-Hz oscillator that drives the LCD's backplane and decoder *IC6*'s phase input at pin 6 according to the recommendation given in the CD4543's data sheet.

Your choice of triac for *Q1* will depend upon the amount of current required to operate the motor. The greater the demand, of course, the higher should be the current rating of the triac chosen. This current rating should be at least 1.25 times the maximum amount of current the motor will normally draw.

A good starting value for the parallel resistor network made up of *R11* through *R14* (and any other networks you might incorporate into your controller design) is 10,000 ohms. That is, if you use 10,000 ohms for *R11* (R), *R12*'s value should be 5,000 ohms (R/2), *R13*'s should be 2,500 ohms (R/4) and *R14*'s should be 1,250 ohms (R/8).

As you can see in the upper-right corner of the schematic, this circuit receives its 8-volt dc power from a simple voltage-regulator circuit that is fed from a common 9-volt dc plug-in power supply. If you build the circuit from scratch, you might want to incorporate the dc power supply in the basic design, using a 12.6-volt, 150-milliampere transformer, bridge rectifier assembly and large-value filter capacitor in place of the plug-in power supply.

Bear in mind when assembling the circuit, that all unused segments of the LCD004 display module must be tied to common pin 1 of the assembly. Also, when putting the circuit into operation, adjust the setting of *R11* to a value of 250,000 ohms. **ME**

EPROM Program—Converts Binary Code into BCD Code

Hex Address	Hex Data
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
A	10
B	11
C	12
D	13
E	14
F	15