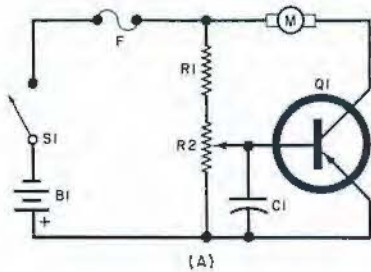# Solid State

By Lou Garner
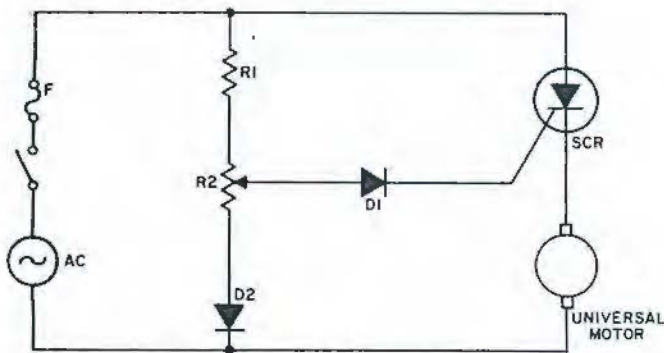
MOTOR CONTROL CIRCUITS

WITHIN industry, solid-state devices and circuits are used extensively for controlling and driving electric motors and other electromechanical actuators, including solenoids, linear drives and electric valves. Similar techniques can be just as valuable for a variety of hobbyist, experimenter and home projects. Typically, solid-state circuits can be used in constant- and variable-speed motor controls for toys, and household appliances such as mixers, stirrers, grinders and fans, workshop tools, including drills and sanders, and even in more sophisticated applications, such as tape recorders and computer floppy-disk drives. The range of potential applications, in fact, is virtually endless, limited only by the imagination, skill, and resources of the hobbyist.

Small dc motors of the type used in many toys can be controlled easily using a single low-to-medium-power transistor. A typical circuit is given in Fig. 1A. Here, the motor's current, hence its speed, varies as Q1's base bias is adjusted by potentiometer R2. Although a pnp transistor is shown, an npn type can be used, if preferred, simply by reversing the battery and motor connections. Bypass capacitor C1 is optional, as is the fuse. If the transistor is used at or near its maximum ratings, a suitable heatsink should be provided to prevent overheating. In some applications it may be necessary to connect a small bypass capacitor (0.05 to 0.1 µF) across the motor terminals to reduce noise. Actual component values will depend, of course, upon the supply voltage, the transistor's
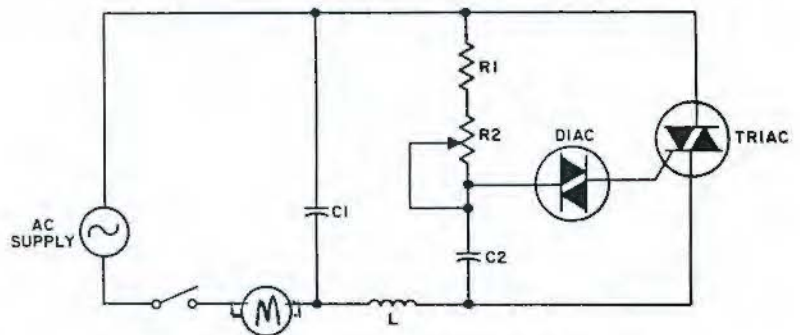

Fig. 2. A typical triac light-dimmer circuit that can also be used for motor control. Component values depend on specific devices used and intended application.
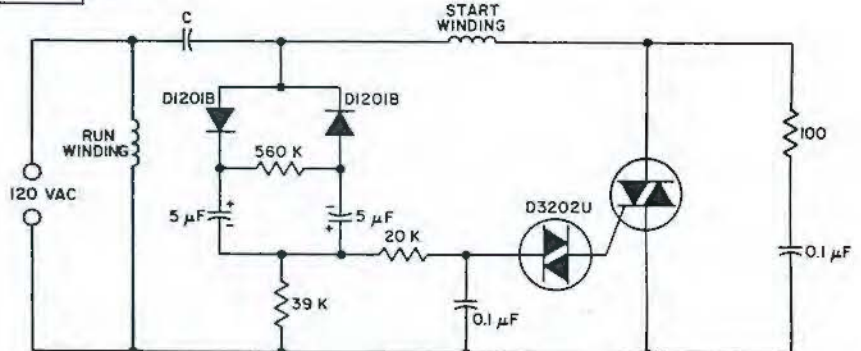

Fig. 3. Here solid-state devices are used in circuit of starting winding for medium and higher-power ac motor.

Fig. 1. Two basic motor control circuits. The one at (A) uses a transistor, while (B) is a circuit using an SCR for control.

characteristics, the type of operation required, and the motor's rating. As a general rule, however, the values are not critical. Generally, $R1$ is chosen to limit $Q1$'s maximum base bias and thus its maximum collector current and the top motor speed, with $R2$, typically from five to twenty times $R1$'s value. If, for example, a 100-ohm resistor is used for $R1$, $R2$ might have a value from 500 to 2000 ohms. Similarly, if $R1$'s value is, say, 10,000 ohms, $R2$ might range from 50,000 to as much as 200,000 ohms. Where the motor's *minimum* as well as its maximum speed must be limited, a second fixed resistor can be connected between $R2$'s lower terminal and the power source, thus limiting its bias control range.

Line-operated "universal" (ac/dc) series motors of the type found in many home appliances and small power tools can be controlled effectively using the SCR circuit illustrated in Fig. 1B. Suggested by RCA in *Power Options from the Powerhouse* (publication No. 2M1169), the design uses two general-purpose diodes, an SCR, a fixed resistor ($R1$) and a control potentiometer ($R2$). As in the transistor circuit, the actual component values depend on the specific semiconductor devices used, the motor characteristics, and the mode of operation needed. RCA suggests SCR types S2060, S2061, and S2062 for motors requiring up to 4 amperes, type S2600 for requirements to 7 A, and type S2800 if as much as 10 A is needed. Again, heat sinking may be required.

As long as maximum ratings are observed, most triac light dimmer circuits also can be used as light-duty speed controls for household appliances and small power tools. A typical circuit was described in this column in December, 1977, and another is given in Fig. 2. As before, the component values depend on the specific devices used and the intended application (i.e., motor rating and desired control range). Typical values, however, are 0.1 µF for $C1$ and $C2$, 100 µH for L, 2.2k to 4.7k for $R1$, and 50k to 250k for $R2$. The diac may be type D3202Y or D3202U, while the triac may be types 2N5757, T2301 and T2302 for loads of up to 2.5 amperes, type T2500B for loads up to 6 A, and types 2N5571, 2N5572, T2800, T2850, T4100 and T4120 for requirements up to 15 A.

Unfortunately, not all ac motors are amenable to solid-state speed control. With synchronous and induction motors, for example, speed is essentially fixed and is determined by design and the

power-line frequency. Any variation from the design speed is caused by "slippage" due to loading. Attempts to reduce speed by controlling the line voltage or current may result in a severe loss of torque and power, perhaps even causing a stall and burn-out.

Despite the limitations, solid-state controls can be used effectively for medium and higher power ac motor switching applications. Suggested by RCA, the motor-starting switch illustrated in Fig. 3 is a typical example. Suitable for medium-power motors operating on standard

household ac lines, the motor-starting circuit uses a triac as an automatic switch for the motor's start winding and its associated phase-shifting capacitor, C. The triacs used may range from types T2800 and T2850 for current requirements of up to 8 amperes to types 2N5567, 2N5569, and T4120 for loads of up to 15 A, or types 2N5441 and T6420 for currents of up to 40 A.

With the increasing popularity of solid-state motor controls, several semiconductor manufacturers have developed special IC's for such uses. The ICH8510/
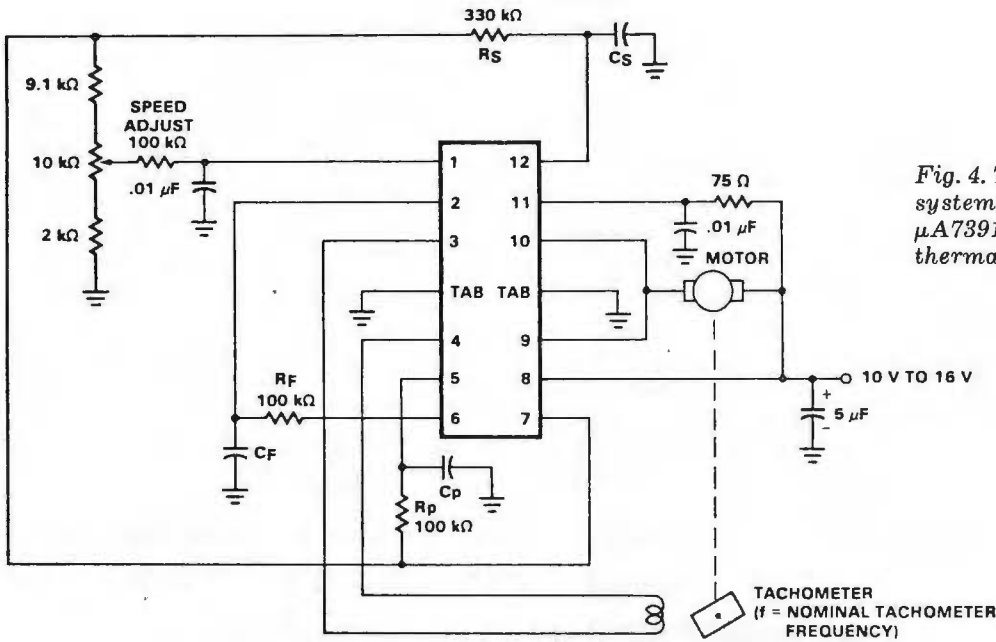
Fig. 4. Typical closed-loop system using the Fairchild μA7391 IC. The circuit includes thermal and overvoltage protection.

8520/8530 family offered by Intersil, Inc. (10710 N. Tantau Ave., Cupertino, CA 95014) is a representative example. Assembled in 8-pin TO-3 style metal cases, the devices are hybrid power amplifiers designed specifically for driving linear and rotary actuators, electric valves, push-pull solenoids, and ac or dc motors. Available for operation on dc supply sources of up to ±30 V, the ICH8510 will supply an output current of up to 1 A, the ICH8520 up to 2 A, and the ICH8530 up to 2.7 A. The devices are protected against inductive kickback by internal power limiting, have integral frequency compensation, offer an equivalent dc gain of better than 100 dB, and require a standby quiescent current of only 20 mA.

Manufactured by the Fairchild Camera and Instrument Corporation (464 Ellis Street, Mountain View, CA 94042), the μA7391 represents another type of motor-control IC. It is designed for precision, closed-loop, systems such as capstan drives in automotive and portable tape players, in floppy-disk drives for computer memories, and in data cartridge drives. Assembled in a 12-pin power package DIP with heavy heatsink tabs, the device will deliver a motor starting surge current of up to 3.5 A and a running current of 2 A. It can be operated on dc source voltages from 6.3 to 16 V. Intended for use with an external motor driven tachometer generator, it will accept tachometer inputs from 100 mV to 1.0 V p-p. The device includes voltage regulator, pulse generator, comparator, thermal sensor, overvoltage sensor, and stall timing threshold and latch circuits as well as driver and power amplifier stages. In operation, the tachometer generator supplies an input signal proportional to motor speed. This signal is converted into fixed amplitude pulses and integrated by a standard R-C network before application to a comparator, where it is compared to a reference voltage representing the desired speed. The result of the comparison controls the duty cycle of the pulse width modulated switching motor drive output stage, thus closing the system's feedback loop and holding the motor speed to the rate established by the reference voltage. The thermal and overvoltage sensor circuits provide shutdown for self protection while the "stall timer" circuit protects the motor itself from burn-out during extended mechanical jams.

A typical application circuit featuring the μA7391 is illustrated in Fig. 4. The circuit component values will vary with the characteristics of the motor and tachometer used.

As a general rule, layout and lead dress are not critical factors when assembling and wiring motor-control circuits, although good wiring practice should be followed, with care taken to observe all dc polarities and to avoid overheating the

semiconductor devices during installation. In addition, adequate heatsinks should be provided for the output drivers, whether transistors, SCR's, triacs, or IC's.

Readers' Circuits. Needing a visual indicator for his ac line-operated TRANSMIT/RECEIVE antenna relay, Ted Reiter (1442 Brook Drive, Titusville, FL 32780), replaced his standard spdt unit with a dpdt version, planning to use the extra contacts to control the indicator devices. After rejecting the use of neon lamps and short-lived incandescent types, Ted devised the circuit illustrated in Fig. 5. Permitting standard LED operation on the relay coil (ac line) voltage, Ted's design
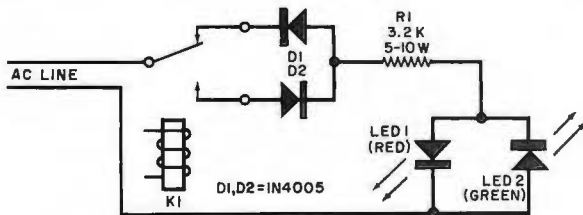
Fig. 5. Reader's circuit provides visual indication of whether relay is open or closed.

avoids the need for a step-down transformer, battery, or conventional dc power supply while retaining the low power and long life advantages offered by these devices.

Ted writes that virtually any LED's will work in his circuit, including low-cost "surplus" types, but warns that the series

dropping resistor, R1, gets rather warm during operation and should be mounted accordingly.

Edward C. Mauro (12 Pyramid Lane, Rochester, NY 14624) thinks readers may find his digital-logic automatic pump control circuit of interest and value. Used in conjunction with a transistorized relay to operate a water pump, Ed's circuit, Fig. 6, provides automatic level control for a water tank or sump. Ed writes that he uses his model to empty a dehumidifier tank
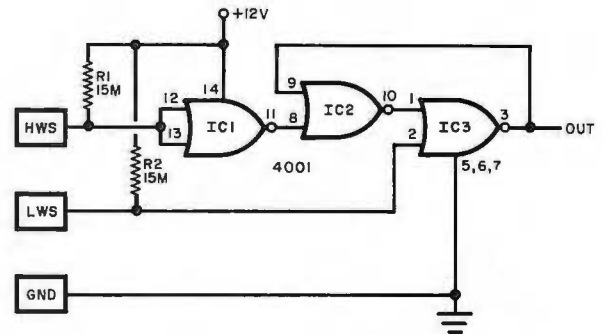
Fig. 6. Digital control circuit for a pump is controlled by level sensors.

automatically in the summer and to control the level in a furnace humidifier overflow holding tank in theTMS* winter.

Using standard CMOS 2-input NOR gates, the circuit's operation is straightforward and easy to follow. HWS and LWS are the high and low water sensors, respectively. When the

water level is below both, *IC3*'s output is low. As the water level rises past LWS, *IC3*'s output remains low until HWS is reached. At this point, *IC3*'s output goes high. Sensed by the transistorized relay, the high output switches the pump on. The water level starts dropping down past HWS, but *IC3*'s output remains high due to the feedback loop to *IC2*, and the pump continues to operate. When the water level drops below LWS, however, *IC3*'s output goes low and the pump shuts down completely.

Ed has specified inexpensive, readily available components in his design. The HWS, LWS and GND sensors are one-inch diameter sections of standard pc board (unetched). The LWS and GND sensors are suspended on insulated leads near the bottom of the tank, but above the pump intake level, while the HWS sensor is suspended at the desired pump "turn-on" level. The circuit may be assembled on perf board, a suitably etched pc board, or on a wirewrap breadboard, as preferred. It may be used with virtually any standard transistorized relay circuit compatible with CMOS output levels.

Device/Product News. Three new series of fast turn-off SCR's intended for high-speed switching applications such as power inverters, switching regulators, and high-current pulsing are now available from RCA's Solid State Division (Box 3200, Somerville, NJ 08876). Identified as the S5800, S5801, and S5802 series, the new devices may be used at frequencies of up to 25 kHz. Each series includes five types with voltage ratings ranging from 200 to 600 volts. The turn-off times for an 8-A load is 6 μs for the S5800 series, 10 μs for the S5801 series, and 15 μs for the S5802 series. All the devices are supplied in JEDEC TO-220A/B plastic packages.
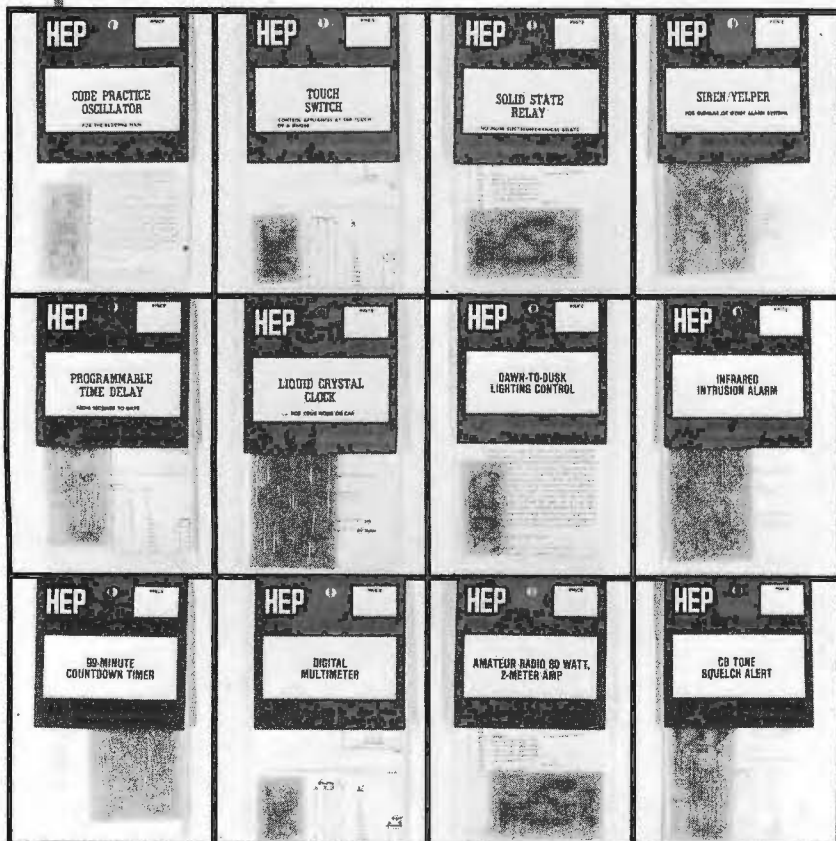
Motorola Semiconductor Products Inc. (P. O. Box 20912, Phoenix, AZ 85036) has added four new devices to its popular *Switchmode®* line of power transistors. Suitable for applications as motor controls, inverters, solenoid and relay drivers, and in deflection circuits, the new units include the 10-A types MJ13014 and MJ13015, with V_{ceo} ratings of 350 and 400 volts, respectively, plus two 20-A Darlingtons, types MJ10008 and MJ10009, rated at 450 and 500 volts.

Motorola also has a new FM stereo demodulator IC which is fabricated using the latest in I^2 L, Ion Implant, and Bandgap technologies. Designated type MC1309, the device requires no inductors and very few other external components. A single potentiometer sets initial subcarrier vco frequency in the PLL demodulator, while an external load resistor choice enables the unit to be inserted as a unity gain element in the FM receiver's audio path, and a LED driver output is provided to indicate stereo operation. For operation on 4.5 to 16 volts, the MC1309 is supplied in a standard 16-pin DIP.

National Semiconductor Corporation (2900 Semiconductor Drive, Santa Clara, CA 95051) has developed a family of negative three-terminal adjustable voltage regulators. Designated the LM137 series, the monolithic devices complement the LM117 series of positive three-terminal regulators. With outputs adjustable from -1.2 to -37 volts using only two external resistors, the units have integral thermal regulation and a current rating of 1.5 A. Other features of the series are a high ripple rejection of 75 dB and an rms output noise of a mere 0.003% of the output voltage up to 10 kHz. The LM137 devices are in TO-3, TO-5, TO-220 and TO-202 packages. ◇