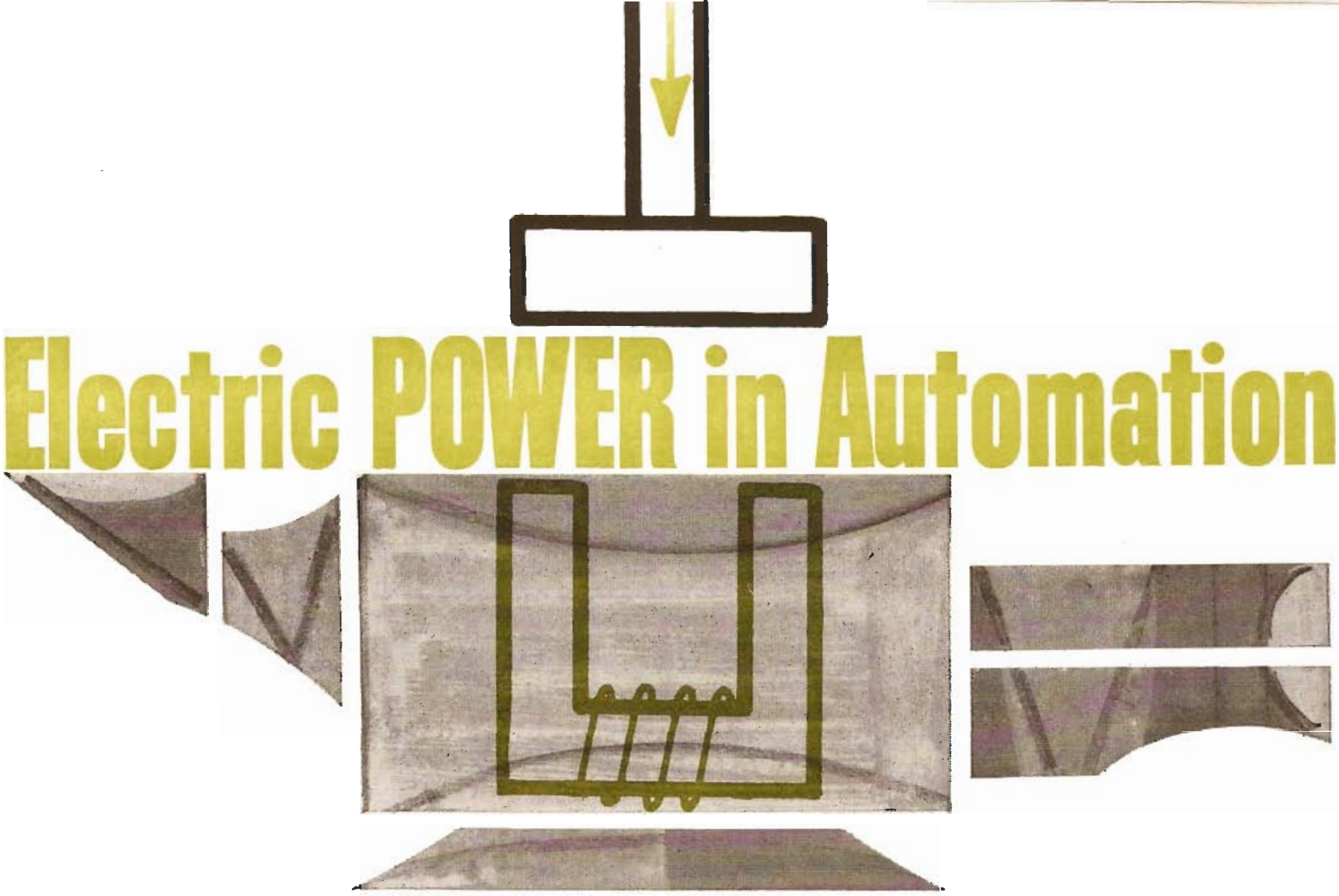

Electric POWER in Automation

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Solenoids and motors are frequently used to carry out the functions dictated by a control system.

AT FIRST glance, the title may indicate the treatment of a rather superfluous subject. Electrical power is obviously used in automation. However, we are not concerned here with electricity as it is used to activate electronic sensing and control circuitry and associated devices. Aside from the existence of these circuits, every automatic system has "muscles" that carry out the decisions made by the rest of the system. Electrical power is often the necessary muscle power.

After the sensing circuits and the electronic "brains" (or decision-making circuits) have had their say, how are the decisions executed? How is the output of a control system translated into the physical force that moves, hammers, bends, pulls, or otherwise shapes a work piece?

Many types of actuators are used to provide the final muscle power. Hydraulic or pneumatic principles are used in many of these actuators. Many others are electrical machines—like the electric motor. Such devices are much older than the field of electronics as we know it today. Yet, partly because of the needs of electronics, there has been such development in the field of electrical power machinery that today's motors bear as little resemblance to their forebears as do today's automobiles to those of 1913 vintage.

There is a wide variety of motors and solenoids in current use, and many of them have been influenced in their design by the electronic circuits that regulate or control them. Although the electronic technician who must maintain industrial systems is not ordinarily expected to work directly on the power machinery, he must know something about the nature and function of such equipment and understand how it fits into the over-all system. Often such an understanding is essential to determine whether a system failure is or is not in his portion of the combination. To be able to read prints and follow other basic maintenance literature, he must be able to recognize basic symbols for devices that are non-electronic.

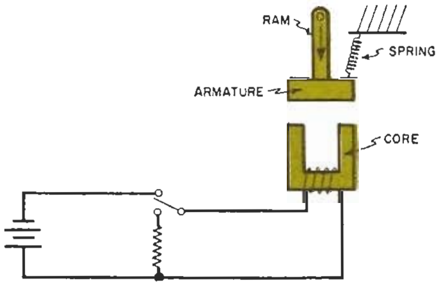
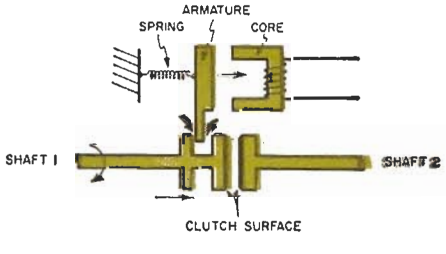


Fig. 1. Electromagnetic field of activated solenoid's core pulls in armature.

Fig. 2. A solenoid may be used to engage or disengage a friction clutch.



Conversion into Motion

Practically all of the electrical machines in existence do not convert electrical energy *directly* into a motion or pressure, but do so by first setting up a magnetic field and then using the magnetic force between two iron pieces. A simple example is the solenoid shown in Fig. 1. When current flows in the coil, a magnetic field is set up in the iron core and this attracts the *T*-shaped ram which, in turn, is put into motion.

Basically there are only two types of motion possible with electrical machines, linear or rotary. The first is usually obtained by solenoids and the second—the largest application of electricity in automation—is the action of an electric motor. In the latter, the attraction and repulsion between the stationary pole pieces and the rotating member generate the rotation and the torque.

Solenoids

In many automation systems, solenoids are used to perform quick, short strokes that do not require too much force and are not part of a continuous process. For example, a solenoid can be used to open the latch of a door or push a "reject" stamp against a defective unit in an automatic inspection line. Only rarely is one used in riveting, making eyelets, punching, or other less simple operations. The reason for this lies in the basic mechanics of solenoid action.

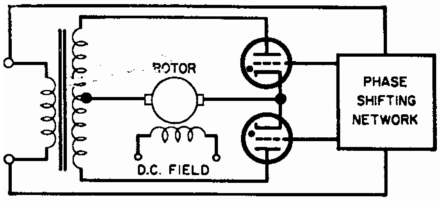


Fig. 3. This arrangement for speed control is used with large d.c. motors.

As shown in Fig. 1, a spring keeps the armature or moving section separated from the main core so that the former remains in this position until power is applied to the coil. Fundamental electricity teaches us that current through the coil builds up as a function of time and inductance, and this means that it takes a little time until full current flows through the coil. The magnetic force is strictly proportional to the current flowing through the coil, and it therefore does not reach its peak until the current is maximum.

Magnetic attraction is a function of the square of the distance between the two elements. This means that the force applied to the armature is smallest at the start and increases as the ram moves closer to the core. In other words, the armature starts moving slowly and gathers force until it smacks against the core. This feature alone presents a mechanical problem that limits the use of solenoids to intermittent-duty applications.

When the actuating switch is opened, the energy stored in the coil must be dissipated and, since arcing would quickly wreck the switch contacts, arc suppressors or dummy loads (like the resistor shown) must be used.

Solenoids are always used together with some mechanical linkage and, if the linkage sticks, the solenoid will often fail to operate, since the starting force is usually small. In many instances, a solenoid is part of some other control mechanism, such as the clutch shown in Fig. 2. Actually the entire assembly of clutch, armature, and plunger usually is a single, integrated unit, but the action of the solenoid can be understood better by separating them in the drawing.

Shaft 1 rotates and, when the solenoid pushes the clutch surfaces together, shaft 2 is connected to shaft 1. In this arrangement, there are two major sources of friction, shown by the heavy arrows in Fig. 2, which must be overcome by the holding power of the solenoid. When this friction becomes too great—due to lack of lubrication, for example—the clutch will fail, even though the solenoid may still be in good condition. Solenoids are often used to control valves in hydraulic or pneumatic systems. The same servicing problems apply there, and it is always wise to make sure that solenoid failure is *not* due to mechanical trouble in the related mechanism.

Electric Motors

There is probably no home in the U. S. today that does not have at least several electric motors of one kind or another. Because most homes use a.c. power, these motors will tend to be of the induction type; but in industry d.c. motors are also used widely. There are motors that fit into a wrist watch and run a year from a battery the size of a dime; and then there are motors having over 1000-horsepower output that require a room full of electronic gear for starting and speed control. In between these extremes are a series of standard motor types in wide use for specific industrial applications. Some of these types are not involved too frequently as parts of an automation system. Others, like the servo motor, are particularly useful in positioning and other operations that are automated.

To understand the relationship to the over-all system of any motors used, the electronic technician should know something about the characteristics of the various types. He should also be able to recognize them as they are symbolically represented on the prints he will use in tracing and troubleshooting. The most commonly used types are represented in Fig. 4, and Table 1, which is coordinated with this illustration, provides information about the units that can be helpful.

In addition to the windings shown here, the reader should understand that other starting, compensating, and con-

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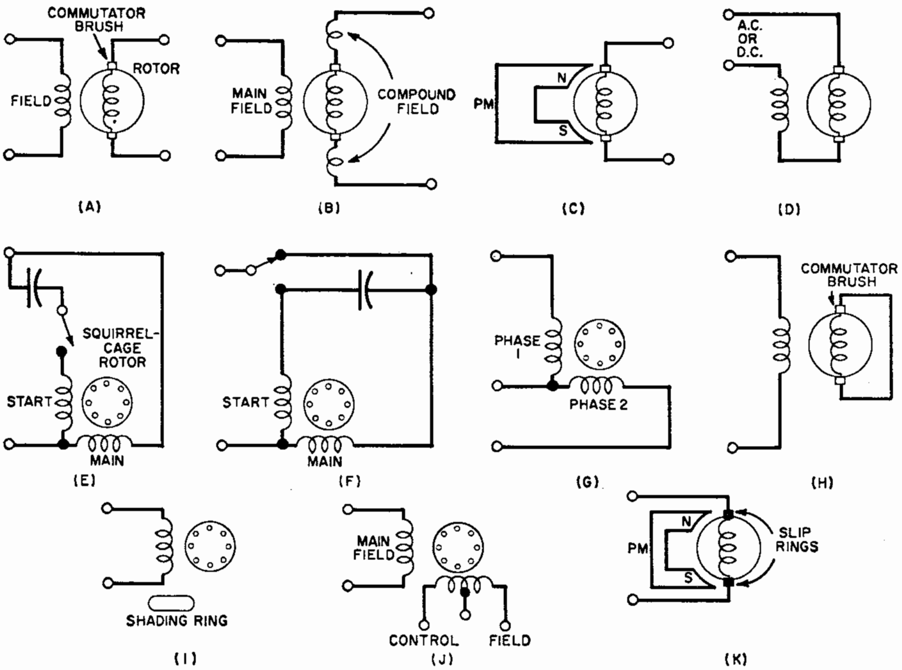


Fig. 4. Symbols for motor types that may be encountered in automated systems.

Table 1. Useful information concerning the common motor types shown in Fig. 4.

TYPE & FIG. 4 REFERENCE	STARTING TORQUE	SPEED CONTROL	OPERATING FEATURES	TYPICAL APPLICATIONS
D.c. shunt (A)	Medium	Thyratron or voltage control	Adjustable speed; constant torque or constant power	Pumps, conveyors, wire and paper winding
D.c. compound (B)	High	Usually not used	Speed adjustable over small range; high but varying torque	Flywheel drive, shears, punch presses, hoists
D.c.-PM field (C)	Low	Power tubes or transistors		Fans, blowers, battery-operated devices
Universal series d.c. or a.c. (D)	Very high	Thyratron, saturable reactor, series resistor	High speed; high efficiency	Hoists, cranes, vehicles, hand tools, appliances, general utility
Capacitor start a.c. (E)	Very high	Saturable reactor	Limited range of speed control as torque drops with voltage	Compressors, pumps, blowers
Capacitor running (reversible) (F)	Low	Usually not used	Speed varies greatly with load	Fans, blowers, centrifugal pumps
Squirrel-cage induction (poly-phase) (G)	Depends on type used	Saturable reactor, resistors	Available in six classes of performance characteristics	General-purpose industrial motor used as main power source for heavy machinery
Repulsion-start, induction-run (H)	Very high	Usually not used	High starting-current surge	Pumps, compressors, conveyors
Shaded pole (I)	Very low	Usually not used	Relatively inefficient, but low in cost	Fans, blowers, heaters, phonographs
Servo (J)	High	Power amplifier, saturable reactor	Accurate control through special control winding	Positioning systems, computers
Synchronous (K)	Low	None	Constant speed depends on number of poles and line frequency	Clocks, timers, blowers, fans, compressors

Electric Power

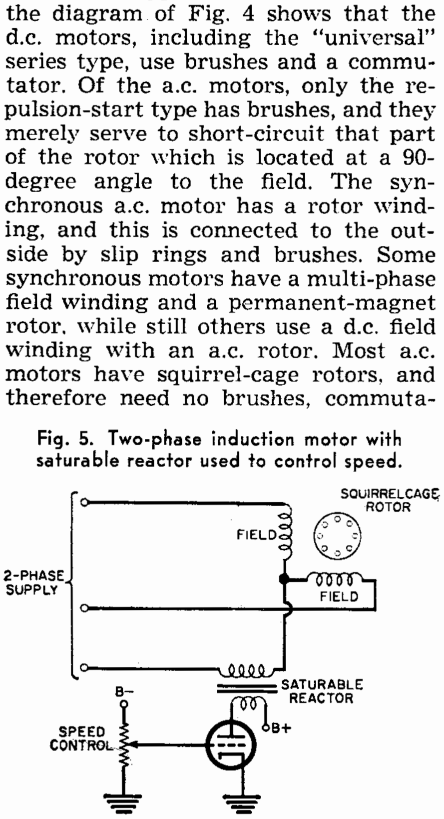
(*Continued from page* 43)

trolling windings are used in some special-purpose variations. The number of poles, number of phases, and the coil design all can vary considerably among the types to produce a still greater variety.

For example, a simple, squirrel-cage motor can operate on two, three, or any number of phases, depending on the field windings. The torque, starting and running, as well as the efficiency, speed regulation characteristic, and other factors can be varied by the skewing of the copper bars in the rotor, by the depth and shape of the slots in which the copper bars are mounted and, naturally, by the field winding itself.

Further study of a particular motor is much simpler when one knows at least what type it is. A brief look at the diagram of Fig. 4 shows that the d.c. motors, including the "universal" series type, use brushes and a commutator. Of the a.c. motors, only the repulsion-start type has brushes, and they merely serve to short-circuit that part of the rotor which is located at a 90-degree angle to the field. The synchronous a.c. motor has a rotor winding, and this is connected to the outside by slip rings and brushes. Some synchronous motors have a multi-phase field winding and a permanent-magnet rotor, while still others use a d.c. field winding with an a.c. rotor. Most a.c. motors have squirrel-cage rotors, and therefore need no brushes, commutators or slip rings, which are usually sources of motor troubles.

Fig. 5. Two-phase induction motor with saturable reactor used to control speed.



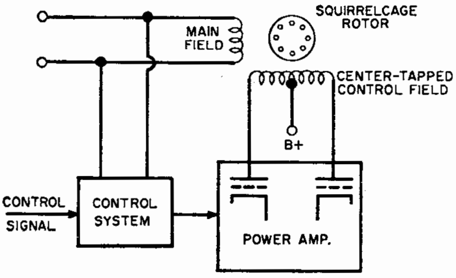


Fig. 6. Simplified servo motor system with power amplifier to regulate speed.

The connections of the control system can be understood better if we know *how* it controls the motor; for this reason, we have shown some typical, basic control circuits in Figs. 3, 5. and 6. The first of these is used in the speed control of relatively large d.c. motors, such as the kind used to drive the take-up reel in a paper processing plant. The motor (Fig. 3) is a d.c. shunt type and its speed is varied by adjusting the current through the rotor. Two push-pull thyratron rectifiers are controlled by the phase-shifted signals on their grids. If the motor were really large, ignitrons would take the place of the thyratron tubes.

Fig. 5 shows a typical a.c. induction-motor, speed-control system. Only two phases are shown, but the same saturable-reactor scheme is often used with as many as twelve phases. Here the speed is reduced by reducing the supply voltage, and this is done by varying the d.c. bias, which controls the impedance of the saturable reactor. As more plate current is drawn, more d.c. bias is generated in the reactor, and the inductance drops, allowing the motor to get more supply voltage.

In Fig. 6, a simple servo motor control is shown, without the feedback loop that is frequently used for remote positioning. This loop and its explanation are the subject for a separate article. Nevertheless, the motor-control circuit should be understood in connection with typical power amplifiers. Here one motor winding is connected to the power line while another winding, which controls the motor speed, receives its power from the push-pull output amplifier.

Conclusion

Electric power is converted into mechanical motion either by solenoids or by motors. Solenoids generate linear motion but, since this is not very efficient, they are not used for higher power applications. Rotary motion is generated by electric motors, of which a wide variety is used in automated systems. Different types of motors exhibit different torque and speed characteristics. Control circuits for these motors are generally limited to regulating the supply voltage or current and thereby the speed. Although three typical, basic motor-control schemes were shown here, a host of variations of these circuits actually will be encountered in the field. —30—