The Selection, Connection, Reversing and Repair of

Electric Motors

by Robert W. Lamparter

Selecting a motor and connecting the electricals are the first challenges encountered after purchasing that long coveted machine tool. There are several types of single phase AC motors in current production in the U.S., but only two types are commonly used in powering our equipment.

TYPES OF MOTORS

For the purpose of clarity I will describe the features of the common types of fractional horsepower motors.

Universal or series motors are those having brushes and a wound rotor. An example of this type is that found in a portable drill or a Dremel tool. They are also distinguished by their noisiness.

Induction or shaded pole motors are the ones commonly used in window fans. They have a solid (squirrel cage) rotor and start slowly, gradually building up to speed.

Repulsion motors are old and uncommon, in my experience, but they may be encountered at a yard sale or flea market. Being old, they tend to be on the large size. They have a wound rotor and brushes electrically connected to each other but not to the stator windings. A large motor with brushes (assuming that the nameplate doesn't indicate a DC motor or generator) is the tip-off that you are likely examining a repulsion motor. This type of motor can be reversed by shifting the position of the brushes. Having seen one of these powering a large drill press in a local blacksmith's shop, I can be assured that they have enough oomph to drive low power machinery. I would not recommend investing in a repulsion motor since the remaining types of motor to be described will do the job much better.

The final three types of motors are the ones most suitable for powering home shop machinery: split phase motor (split phase start-induction run), capacitor start motor (capacitor start-induction run), and capacitor start-capacitor run motor. All are distinguished by a solid squirrel cage rotor and an audible click when the motor has been turned off and is slowing down. The split phase motor has no cylindrical hump on the outside for the capacitor; the other two types obviously do. The capacitor start-capacitor run motor will have either two capacitor humps or will have a capacitor with three separate electrical connections. By the process of elimination, it should seem obvious that a capacitor start motor will have a single capacitor that has only two electrical connectors.

All of the motors described operate on house current, which is single phase. Three phase motors are commonly found on used industrial machines and will not run on house current without an expensive rotary phase converter. The solid state phase converters are cheaper, but our local electric motor rewinder intimates they have a tendency to burn out. Perhaps another reader with personal experience with solid state phase converters could enlighten us. Because of a lack of experience with three phase power, I have found it best to avoid these motors. The maker's plate with the electrical information states whether the motor is single phase or three phase.

RECOMMENDATIONS ON TYPE AND SIZE OF MOTOR

Capacitor motors have a much greater starting torque than split phase motors. I prefer to use capacitor start motors on all tools except bench grinders. When the starting load is heavy, a split phase motor will take a long time to come up to speed. There are two problems with this. One is that a great deal of current is drawn, causing the shop lights to dim. The other is that the starting windings are a lighter gage wire; with repeated two- or three-second starting periods, the starter windings will eventually burn out.

Split phase motors are considered to be adequate for easy starting tools, such as grinders, drill presses, jigsaws, and the like. I have found the ⅓ hp split phase motor on my old Delta drill press to be adequate for all but the higher speeds. I plan to replace it with a ½ hp capacitor motor when I find one at a yard sale. If I had an industrial drill press with a No. 2 or No. 3 Morse taper, I would want a ¾ or 1 hp motor. A respected practitioner of our craft is quite satisfied with a ⅓ hp split phase motor on his 9″ South Bend lathe but admits to doing only light turning. I believe the manufacturer recommends a ½ hp capacitor motor. I had a ½ hp capacitor motor on my 12″ Clausing lathe. This never seemed to slow down even under heavy cuts, but a winding eventually burned out. From this experience, I infer that something more robust than a ½ hp motor is needed for a 12″ lathe. I suspect that a ¾ hp motor would have been adequate, but a 1.5 hp motor was the only used motor available when the old one burned out.

ADEQUACY OF SHOP WIRING AND THE MERITS OF 220-VOLT OPERATION

Next comes the job of wiring the motor. First look on the motor's information plate for the operating amperage and determine if the shop wiring and fusing are adequate. According to Sears and Roebuck's "Simplified Electrical Wiring," the starting currents of motors are roughly three times the operating current listed. For practical purposes, unless the starting time of the motor is prolonged by a heavy load, the operating current of the motor will determine if the breaker is going to trip. As an example, at 110v, a typical ½ hp motor will operate on 7 amps or less, but will draw 22 amps when starting. In my old house which had 15-amp breakers, I never overloaded the circuit with a ½ hp motor.

If you acquire a piece of equipment that exceeds your shop's electrical capacity, you're going to have to do some wiring. The purchase of my air compressor presented me with this problem. At 110v its operating current was 17.8 amps and the 15-amp breaker would trip rather frequently. At the time, I didn't know how easy it was to add a circuit breaker and run a 220v line, so I tapped into one of the 20-amp circuits in the house and used 12-gage wire to run a new 110v line to the shop.

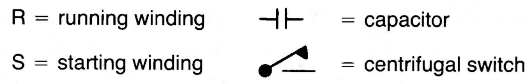
A few years later, a machinist friend introduced me to the concept of using 220v current for the machines. I had always assumed that heavy wire such as that used on dryers and ranges was needed for 220v work. Not so! Those wires are heavy because dryers and ranges pull currents in the realm of 30 and 50 amps, respectively. Actually, a reduction in the wire gage may be enabled by running a motor at 220v. When a motor is rewired to run at 220v, its operating amperage is halved. Thus, the compressor that pulled 17.8 amps at 110v only drew 8.9 amps at 220v. When I finally ran my 220v line to the shop, I used a 15-amp breaker and 14-gage wire. What a difference it made in how quickly the compressor started. I used the same outlet as I was using for 110v, but painted a sign on the outlet that labeled it as being 220v. I doubt this outlet meets the electrical code since the special receptacles for 220v physically prevent a 110v appliance from being plugged in; however, I feel this practice is acceptable in one's home shop. On motors that will operate at either 110 or 220v, I prefer to run them on 220v since there is much less dimming of the lights and much quicker starting at this voltage.

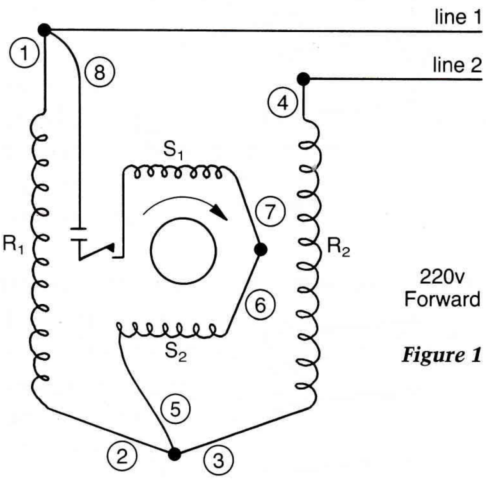
For future reference, remember that fuses and circuit breakers protect the wiring of the house from overheating and burning while inside a wall, and therefore are sized to be compatible with the house wiring they protect – not the machine connected to it. This is why it's dangerous to just put a larger fuse or breaker on the circuit to your shop without improving the wiring. 12-gage wire will carry 20 amps, 14-gage wire 15 amps, and 16-gage wire 10 amps. Home wiring is fairly straightforward, but the details are beyond the intent of this article. I refer the reader again to the previously mentioned booklet sold by Sears and Roebuck for an expanded description of the procedure.

INTERNAL WIRING CONNECTIONS: CHANGING FROM 110V to 220V OPERATION

Next we turn our attention to the internal wiring arrangements of split phase and capacitor motors. They are almost identical except that the capacitor start motor has a capacitor. Both motors have two types of windings – starter windings and running windings. The starter windings determine the direction of rotation. They are of a light gage wire since they are only used briefly for starting and then are disconnected from the circuit by a centrifugal switch when the motor is almost up to speed. The click heard when the motor is slowing to a halt is the centrifugal switch clicking the starting windings back into the circuit. The lead numbering system I present in my diagrams, Figures 1 through 4, is used in three motors in my shop, all of which are of different manufacture. One of them is British in origin. I assume the numbering system is universal, but I can't be assured of this since I haven't found these diagrams in print. If there is a wiring diagram on your motor, so much the better; you don't need me. If not, I'll give you as many tricks to identify the leads as I can:

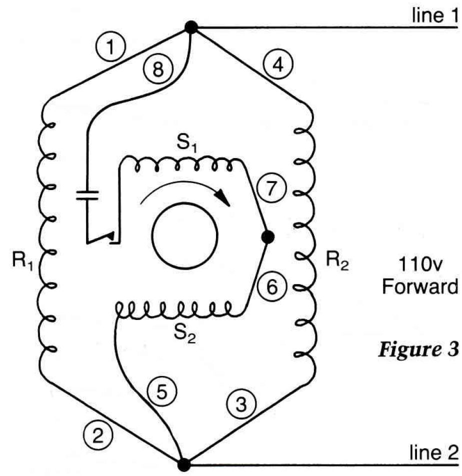
Lead No. 8 is the one usually attached to the capacitor or centrifugal switch. Leads No. 6





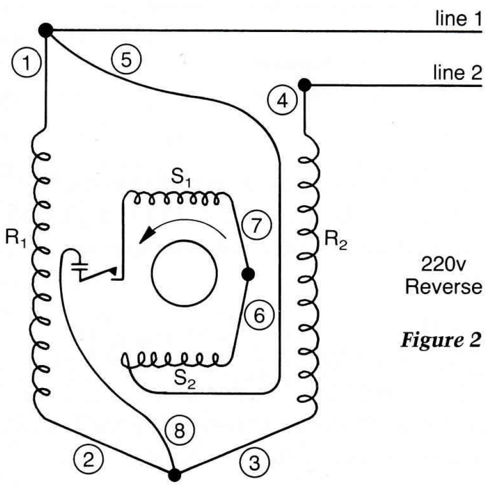
220v
Forward

Figure 1



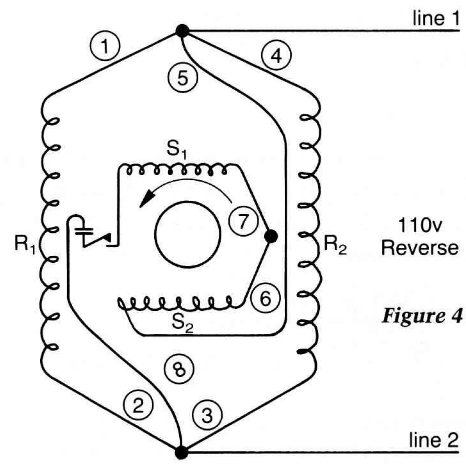
110v
Forward

Figure 3



220v
Reverse

Figure 2



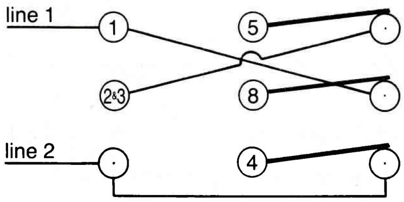
110v
Reverse

Figure 4

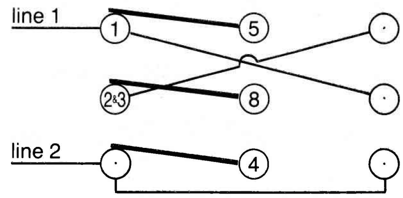
and 7 are usually buried somewhere in the motor and aren't seen. If three leads are twisted together, they probably represent two running winding leads and a starting winding lead. According to an article in *Model Engineer* (Volume 145, Number 3620, November 1979, page 1262), the starting windings have a slightly higher resistance than the running windings. On my Brooks 1.5 hp motor, the starting windings have a resistance of 2.2 ohms and running windings have 1.2 ohms of resistance. Take the utmost care in making these measurements since a dirty contact will alter the measurement. If only four leads come to the terminal board, two are probably running winding leads and two are probably the starting winding leads No. 5 and 8. I can't cover all the possibilities, but that should help you in getting started.

Figures 1 and 3 show the comparison between a motor set up to run on 220v versus one wired to run at 110v. Note that the starting windings are connected in series with one of the running windings when the motor is wired to run at 220v. A few years ago when I bought a used ¾ hp motor to replace the three phase one that came in my Hardinge mill, a less than attentive employee at the motor rewinders instructed me to connect starting winding leads No. 5 and 8 to running winding leads No. 1 and 4 – in essence, to the full 220v input. The motor ran fine for two months, and then one time on starting, it smoked, made a horribly loud vibrating noise, and rotated at only a fraction of its normal speed. Fortunately, only the capacitor had failed. When I purchased the new capacitor, I inquired about the wiring connection on this motor since it was different from two others in my shop. The owner of the rewinding shop instructed me to place the starting windings in series with the running windings so that they would absorb some of the current going to the starting windings and capacitor, prolonging their life expectancy.

DRUM SWITCH CONFIGURATION
220v

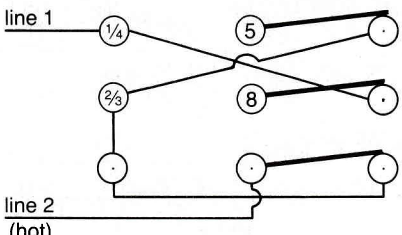


Forward
Figure 5

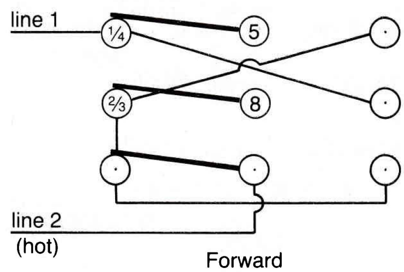


Reverse
Figure 6

110v



Reverse
Figure 7



Forward
Figure 8

Having converted a motor to run on 220v, it is worthwhile to test it at 110v first. If wired correctly, it will run at a somewhat slower than normal speed.

REVERSING THE ROTATION AND WIRING DRUM SWITCHES

Reversing the rotation of a motor is often desired. From Figures 1 through 4, it is evident that reversing the connections of the starting winding leads No. 5 and 8 is all that is necessary. In Figures 5 and 6 are the wiring diagrams for the terminals in a drum switch controlling a 220v motor. Figures 7 and 8 show the same switch wired for a 110v motor. Note that the only difference in the internal wiring of the drum switch between 110v and 220v is a link between the terminals on the lower left. Pay attention to the fact that in Figures 7 and 8 Line 2 is the hot or live wire.

Several years ago, when the previously mentioned ½ hp motor in my lathe burned out, I didn't have a reversing switch but only the standard single pole wall switch controlling the current flow. Thoughtlessly, I had connected this switch to the neutral (white) lead. When the motor started to hiss and smoke, I quickly flipped the switch off. Much to my alarm, the motor continued to hiss, smoke, and run! When the winding burned, it shorted to the motor frame and a circuit was completed from the hot wire through the remaining windings to the ground wire. I had to dash to the breaker box to shut off my lathe. (Thank goodness I've never tried to save a few cents by buying electric cord without a ground wire or, in this case, I might have *been* the ground wire.)

This same flow occurs in the wiring of the drum switch for 220v since both of the lines are hot (live), and Line 1 is directly connected to the motor without an intervening switch. In my own shop, I solved this problem with a magnetic starter; more on these later. Figure 9 shows an alternate type of drum switch configuration which may be encountered. By now you should have some idea of how to arrange the connections, so I won't illustrate these. If you're still in your salad days and can't afford a drum switch, an alternative is to utilize a four-way switch, the type used in household wiring when three or more switches control the same circuit. The electrical connections are illustrated in Figures 9 through 13.

There are two types of four-way switches – cross type and through type – and you'll have to determine which type you have with an ohmmeter or test lamp. I have illustrated the connections for a 110v motor only, but there's no reason the same setup couldn't be used for 220v operation. With a four-way switch you'll need a separate switch to turn the motor on and off.

While we're on the topic of making-do, I'll pass on another pearl. Shoe eyelets make nice electrical connectors. Just wrap the bare wire around the post and crimp. Sometimes a rap in the hole with a center punch is needed to expand it so that it will fit over a screw terminal. Next you'll need four- or five-wire "cable" to run from the switch to the motor. Since cable is not available in my small town, I've made my own using ⅝″ ID clear plastic tubing and different colors of 14 or 16 gage *multistrand* wire. If the cable isn't too long, a coat hanger can be used to pull the wires through.

MOTOR PROTECTION AND MAGNETIC STARTERS

Motor protection is often neglected. The fusebox or circuit breaker does nothing to protect the motor in case of an overload. They just protect the house wiring so it doesn't start to burn while hidden in a wall.

Dayton sells a single pole fractional horsepower manual motor starter, stock No. 5X269, that lists for $22. Their two-pole model No. 5X270 should be used for 220v hookups and lists for $26. A heater element matched to the operating amperage of the motor must be bought separately and lists for $4.

Many used machines come with the motor protection device still attached. In some cases they are manual devices and in others they are magnetic starters. Almost invariably these devices are set up for three phase operation, so you'll have to follow the instructions inside the lid to make the conversion to single phase operation and the proper voltage. You'll have to buy one or two heater elements to match the operating amperage of the motor to be protected. A list of the part numbers for the heater elements is usually printed inside the lid with the connection instructions. These cost about $7 apiece. On magnetic starters, also look at the label on the magnetic coil to be sure it's the correct one for the voltage you intend to use. The protection device is placed in the circuit between the plug and the drum switch. Thus, the sequence is: plug and cord leading into protection device, then the drum switch, and then the motor. Some motors have thermal overload protectors built in. I suppose they work, but I've been less than trusting of them since the only motor in my shop to have one was the lathe motor that burned out. I confess that only the more expensive motors in my shop are protected.

Before moving on to the next topic, a final reminder – always include a ground wire in all your circuits so that if a short develops, you aren't the ground.

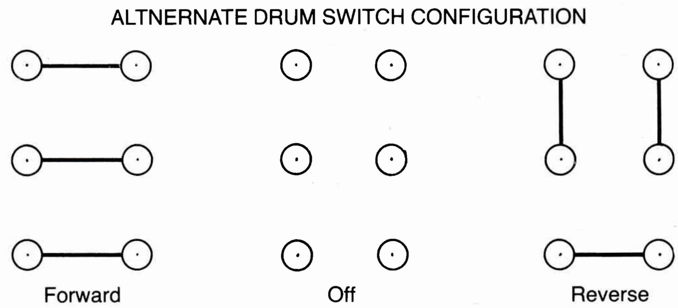


Figure 9

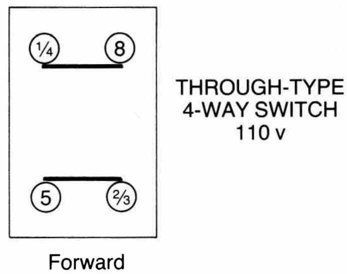


Figure 10

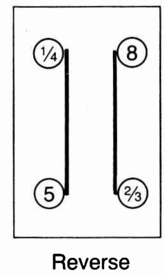


Figure 11

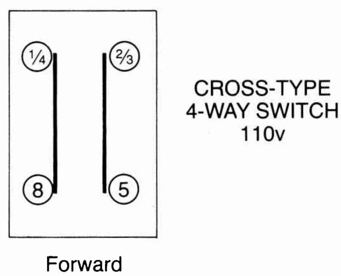


Figure 12

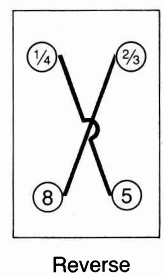


Figure 13

TROUBLESHOOTING

There are only a limited number of things that can go wrong electrically with split phase and capacitor motors. Listing what can go wrong is easy. Explaining how to isolate the circuits for testing is difficult, and you'll have to use your own ingenuity plus the wiring schemes I've given you. You'll need an ohmmeter or a test lamp to do the testing.

If the motor doesn't even hum when you plug it in, it's either not getting any power at all or there's a break in one of the circuits inside the motor. Look at the windings. If one or more looks blackened and smells burnt, it's probably burned out. It doesn't seem profitable for motor repairmen to rewind small single phase motors, so if you've burned out a winding, you're probably going to have to replace the motor.

If the motor hums but won't turn, there are several possibilities, all dealing with the starting windings. Check to see that all the connections are in the right place. Look for burned windings. Examine the capacitor. If it has leaked a few drops of oil, it's no good. Remove the wires to the capacitor and test it with an ohmmeter set on the 100x or 1000x scale. The needle should briefly swing toward 0 ohms and then drift back to the high end of the scale. If it doesn't swing toward 0 ohms, short the capacitor terminals with a screwdriver and try the test again; the capacitor may have had a small charge that would interfere with this test.

The centrifugal switch normally is closed and passes current when the motor is stopped. If it doesn't, pull the bell ends off of the motor frame and look at the centrifugal switch contacts. Push the contacts together and test them with the ohmmeter to be certain they do or don't transmit current. Oil or grease from the bearings can prevent the contacts from closing. Look at the contact surfaces for pitting or burning. If they need it, brighten them up with a point file or emery paper, taking care not to get the emery dust in the bearing.

If you don't hear a click when the motor's slowing down, the centrifugal switch isn't working. Pull the bell ends off the frame and look at the centrifugal switch. The weights should be moveable although stiff because of spring tension. If the bearings are extremely worn, the rotor may touch the frame and prevent the motor from operating. I've never seen this, but I'd expect to find a lot of play in the motor shaft and either bright spots or burned spots inside the frame where the rotor was rubbing.

If the motor starts but just doesn't seem to have as much power as it should, look to see if one of the windings looks burned. Check to see that all the electrical connections are correct and clean. Make sure you don't have the motor wired to run on 220v when you're only using 110v.

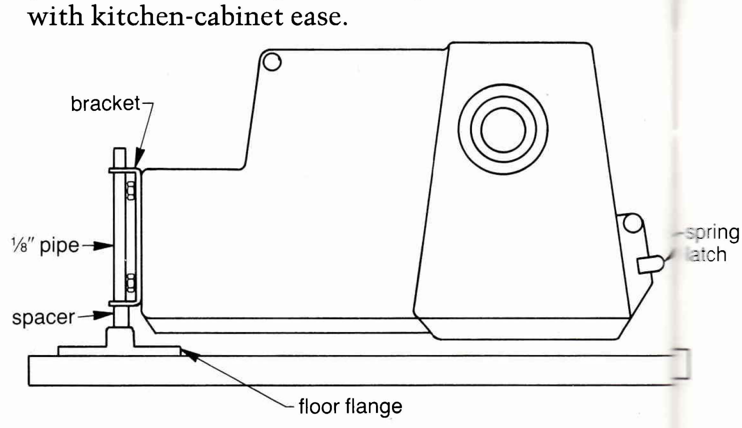
A number of publications have served as references to supplement what has flowed spontaneously from my pen, and the reader may find the following references helpful: "Simplified Electrical Wiring," Sears, Roebuck and Company; *Electric Motor Test and Repair* by TAB Books, Inc., obtained from a regular advertiser in *HSM*; and *Model Engineer* Volume 145, Number 3620, pages 1260-1263, and Number 3622, pages 1414-1416.

Improved Atlas 6" Lathe Gear Cover

by C. M. Luchessa

Most owners of the Atlas 6" lathe will probably share my dissatisfaction with the original pulley and gearbox cover assembly. Like myself, they have carelessly jeopardized safety at times when the somewhat awkward mounting and removal procedure was bypassed in a time-saving tradeoff.

The general outline of an alternate mounting scheme shown in Figure 1 comes close to duplicating the hinged-type gear guards supplied with older model lathes which permitted easy access to the drive belt and gear train enclosure. Here (Figure 1) the plastic cover is attached to a swivel post mounted on the rear lathe bench with a small floor flange. A brass snap spring attached to the front of the gearbox allows the operator to open and close with kitchen-cabinet ease.



COVER ASSEMBLY

Figure 1