The Ins and Outs of Basic SCHEMATIC SYMBOLS

A practical approach to reading and understanding the schematic diagrams used to explain how HVACR systems operate.

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Being able to understand and discern schematic or wiring diagrams can quickly lead to diagnosing a problem with a system or component. However, reading and comprehending schematics can be daunting. Although most manufacturers use their own format, many of the diagrams follow a set pattern and can be considered road maps to get from one point to another. In this three-part series, technicians will learn where and how to read components and power supplies. [Editor’s Note: Some illustrations in this article are not complete. They have been cut due to a lack of editorial space and only show what is being discussed in each section of this article.]

The majority of the schematic symbols used by the HVACR industry are standard and easily identified, even if they are drawn by different manufacturers. Along with symbols, an identifying letter or number describing the device is placed in a list, either at the bottom or the side of the diagram. At some location, these components are connected together by lines to represent the power or voltages going to or from them on the illustration.

Most schematics are broken down into areas of power distribution, and most diagrams list the high-voltage section at the top and the low-voltage section at the bottom. Along with power distribution, there are usually specific control and component placement areas as well. So diagrams typically show a power supply, a load or device to be operated, and finally a switch or control device.

POWER SUPPLY

The first item on any schematic is normally the power supply, which is drawn by lines connecting it to many of the varied components. Lines are drawn according to the circuit that
they are controlling. Ordinarily thicker lines represent high-voltage or high-current power supplies (see Figure 1), as opposed to thinner lines that indicate low-voltage or low-current circuits (see Figure 2).

Solid lines are usually referenced as the wiring within the unit that is being serviced, and they are typically numbered or color-coded to define the circuit or application that they control. There is no set precedent on this, as it is up to the designer’s discretion.

Depending on the application or type of equipment, dashed lines are normally used to connect an external component to the equipment or the equipment to external components. Dashed lines follow the same principle as the solid lines: thicker lines are generally high-voltage or power-supply connections, and thinner lines are low-voltage or lower-current-supply connections. Figure 3 illustrates the difference between the high and low external-component-powered connections.

The lines within the equipment may be drawn as single or multiple connections, which is accomplished several ways. Depending on the circuit, they can be shown as being (refer to Figure 4): joined at a terminal block (1); or connected and joined by a wire nut (2). The connections also might be tied at a common screw terminal on a printed circuit board (3). Some diagrams just show the lines meeting at a particular point (4), or connected together by a single dot (5). Again, there is no official standard method and the method used will vary between manufacturers.

Schematics should be drawn to make tracing circuits as simple as possible. Wires may cross one another without making an actual connection, which can be somewhat confusing since a technician will not know what the engineer or designer was trying to depict. This crossover can be shown several ways.

Figure 5 shows two ways lines are most often illustrated to cross without connecting to each other. The first and most commonly used is the crossover of two wires or lines, where they may cross or pass-over another line (1). It is very easy to confuse this format, due to the similarity in the simple connection shown in Figure 4 (4). The second is a half loop that seems to jump over the line as is being depicted in Figure 5 (2).
LOADS

Loads, or the power-consuming or -controlled devices, can be anything from a simple coil or light bulb to a large motor compressor. The first—and probably the most power-consuming—are motors and motor compressors; Figure 6 depicts typical motor diagrams. Figure 7 shows several of the loads that consume less power, such as a simple coil to a multi-tapped transformer to a light bulb.

These also can be illustrated many ways depending on the function and design of the equipment, and the manufacturer’s preferences. All transformers, solenoid coils and motors are basically coils of wires. They are considered to be inductive loads. Heaters and lights are called resistive loads and behave differently in a circuit.

SWITCHING DEVICES

In order to separate the power supply from the load, some form of control or switch is needed. There are literally thousands of different types of switches and controls used in the HVAC industry, but these can be divided into a few categories.

First is the manually controlled switch, which is manipulated by a human operator and is normally marked as such. Figure 8 gives an example of several types of these switches in various positions representing the actual movement of the switch. All controls normally use the same terminology for the switching action. The rotary switch that has a single pole and seven positions is marked by SP7P. This is just one variation on this and can be anything from a 2-pole 5-position (2P5P) to a 10-pole 2-position (10P2P) switch.

The SPST switch in Figure 8 represents a single pole and a single-throw action. However, there are times when it is necessary to control more than one circuit at a time, which can be accomplished by mechanically connecting two or more switches together. The DPST, or double-pole single-throw device, does just that. There are instances when one circuit has to be turned off and one circuit has to be turned on at the same time. An SPDT, or single-pole double-throw, switch does that by closing one circuit and opening another circuit at the same time. They also can be connected together mechanically to create a DPDT, or a double-pole double-throw device. This can be used to control two individual circuits simultaneously. The last items to note are the terms N/O (normally open) and N/C (normally closed). These describe the position of the switch when no power is applied to the circuit.

Second are electrically controlled switches. Relays are operated by voltage or current, depending on the piece of
equipment it is incorporated into, and they follow the same format as the manually controlled switches. The difference is the controlling medium. Relays, contactors and starters fall into this category. They are drawn the same way as switches, but are linked with the controlling circuit and the controlled circuit.

**Figure 9** illustrates how relays are typically drawn on diagrams. It is important to remember that the coil and contacts may be separated from each other. In that scenario they are marked accordingly (this will be described later).

Contactors, like relays, are controlled by another circuit, but they control larger currents and higher voltages. They look very similar to relays on diagrams and they are drawn as N/O devices. **Figure 10** illustrates how contactors are generally drawn on a schematic.

The starter diagram in **Figure 11** illustrates the difference between a contactor and a starter. Please note the overload protection built into it. These overloads are wired so that they are actually in series with the device that is to be protected. It is important to remember that the coil and contacts may be separated from each other just as the relays are. In that scenario they are marked accordingly (this also will be described later).

The contactor or starter device may have a single set of secondary contacts or several sets of auxiliary (AUX) contacts. These will open or close as the contactor or starter is energized or de-energized. **Figure 12** illustrates a 3-pole contactor with an N/C set of auxiliary contacts (Note: They are closed when no power is supplied to it).

When the contactor closes, the AUX contacts will open, and when the contactor opens the AUX contacts will close again. This is used for a number of ancillary devices, such as crankcase heaters and lockout controls.

Some switches are automatic—not opened manually or electrically—and are operated by another medium. Usually these controls are pressure, temperature, flow, limit and time (**Figure 13** shows six common examples of medium controllers). The switch can be closed or opened by an increase or a decrease in the medium, which is usually shown on the diagram itself by the arm of the switch. If the arm is shown under the power-supply line, it indicates that an increase in the medium will close the switch. When the arm is drawn above the power-supply line, decreases in the medium will apply. The reverse of this is when the control or switch is normally closed. **Figure 14a** shows an N/O example of pressure controls and **14b** shows N/C pressure controls.

Some manufacturers will make controls that are SPDT so
that there are two operations with one control. Figure 15 is an example of an SPDT temperature control.

DISCRETE DEVICES
A discrete component is one that does not consume power or make a physical change, such as capacitors, transformers, fuses, circuit breakers, batteries and one that is a necessary complementary device to the circuit. The capacitor is drawn using a pair of parallel lines or as a pair of lines with one of them slightly curved. Figure 16 is the standard capacitor symbol (the asterisk indicates the outside foil of the capacitor.)

The resistor or resistance heater is drawn as a series of triangular lines or squares joined together, indicating resistance to the circuit. Figure 17 illustrates the resistor and a resistance heater.

Transformers are drawn as two coils of wire placed parallel with each other as illustrated in Figure 18. They can have multiple primaries or multiple secondaries. They are sometimes shown with parallel lines, which denote an iron core, or without the lines. If the diagram shows the transformer without the lines, it means the designer either forgot them or meant to draw an aircore transformer—these are not used frequently in the industry because they work at much higher frequencies than those generally found in HVACR equipment. Numerous symbols are used for components drawn by different manufacturers, such as some of the general types of safety devices illustrated in Figure 19.

The industry becomes more complex and continues to use different types of components that are not categorized, that are used in diagrams today. Figure 20 is a prime example of some of the more common ones. Figure 21 shows common examples of electronic devices and components being employed in our industry.

MISCELLANEOUS ITEMS
Many times manufacturers will put complete items of a schematic on one printed circuit board. These circuit boards will contain relays, capacitors, resistors, and many other discrete...
and passive components. The commonly used ignition board is for a specific type of self-contained circuit—a device that would be too difficult or too large to put on the diagram, or they are proprietary. With so many examples of these devices, it is difficult to detail how to read every possible schematic of those available.

Part 2 of The Ins and Outs of Basic Schematic Symbols will incorporate the components discussed here into individual circuits, and will appear in the March 2011 issue of RSES Journal.

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