Refrigeration Service Engineers Society
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UNDERSTANDING ELECTRICAL SCHEMATICS
Part 2

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INTRODUCTION

In this section, you will take a look at a packaged gas/electric system, which is a relatively complex heating and cooling unit. The wiring diagram for this equipment is more difficult than those you studied in Part 1—but again, the schematic as a whole can be simplified by breaking it down into its basic circuits. As you examine individual control circuits and the associated components that they operate, the overall diagram becomes easier to understand, as do the various machine functions. The schematics in this section may include some symbols with which you are not familiar. For your convenience, many of the schematic symbols currently used and recognized by the HVAC/R industry are collected in Figure 16 at the end of this chapter.

SWITCH SYMBOLS

Generally speaking, a wiring schematic shows the condition of a piece of equipment *when there is no power being applied to the unit*. Therefore, if a switch is depicted as being *normally open* (N/O) or *normally closed* (N/C), remember that the position of the switch is shown as it appears when there is no power applied to that circuit. If there is any deviation from this practice, there will be an explanatory note on the schematic.

As you may know, a switch is characterized by the number of contacts (or *poles*) and the number of positions (or *throws*) it has. Think of the number of poles as the number of circuits that the switch can control at one time, and the number of throws as the number of paths a single circuit can take. Figure 1A, for example, shows both a normally open and a normally closed *single-pole, single-throw* (SPST) switch. This type of switch either opens or closes one circuit. Figure 1B shows a *single-pole, double-throw* (SPDT) switch. Again, only one circuit can be controlled at any given time, but in this case the switch has two different "connected" positions, which means that it can direct current to either of two paths.

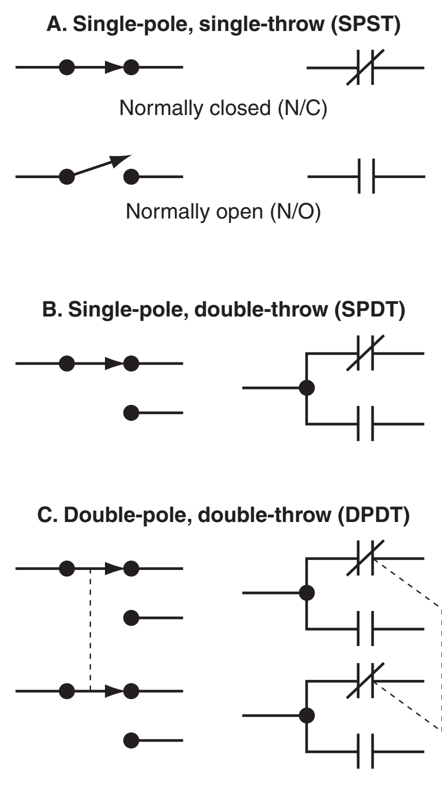


Figure 1. Switch symbols

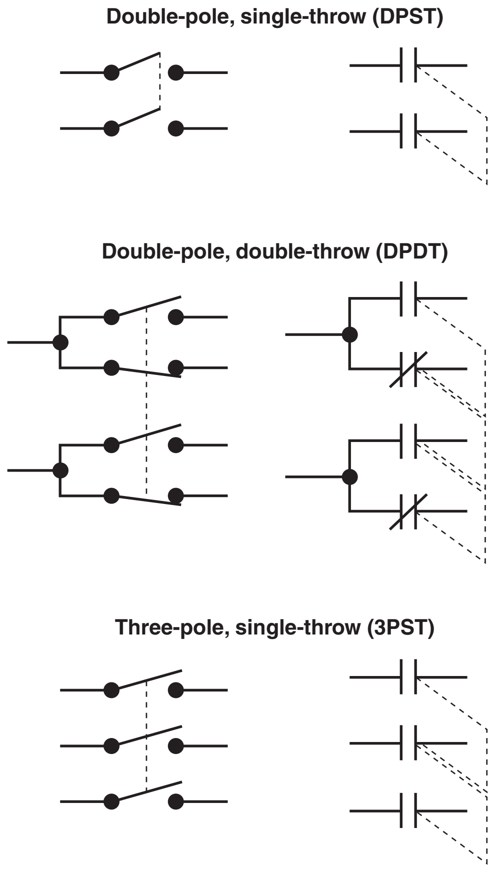


Figure 2. Multiple-pole switches

A switch that can control more than one circuit at a time is shown schematically as having more than one set of contacts. Look back at Figure 1C on the previous page. It shows an example of a double-pole, double-throw (DPDT) switch, which can control two circuits at the same time. The dashed line represents the mechanical connection, and tells you that the contacts move together, but are not connected electrically. Figure 2 above shows a few of the many other variations that are possible in depicting multiple-pole switches.

Controls

Pressure and temperature controls are switches, too, and they also may be configured with various combinations of poles and throws. The position of the switch "arm" in the schematic symbol indicates the operation of the control. In Figure 3, for example, the temperature switch (RS-2) is shown with the arm *above* the contacts. This signifies that the switch opens on a rise in temperature and closes on a drop in temperature. The pressure switch (AFS-2) is shown with the arm *below* the contacts. This signifies that the switch opens on a drop in pressure and closes on a rise in pressure.

An example of an SPDT limit switch (LS) is shown in Figure 4. When there is an increase in temperature, the contacts "C" to "N/C" move to the "N/O" position. When the temperature decreases, the contacts "C" to "N/O" move back to the "N/C" position.

Relays

Relays are electrically operated control switches. The schematic symbols used to represent relays are the same as those for manually operated switches, except that relay symbols often include a solenoid coil. There are several possible ways of depicting the solenoid coil. Figure 5 shows two different schematic representations of a DPDT relay. Note that multiple-pole relays, like multiple-pole switches, are connected mechanically but not electrically.

Contactors

A *contactor* is a type of heavy-duty relay that handles higher voltages and higher currents than a control

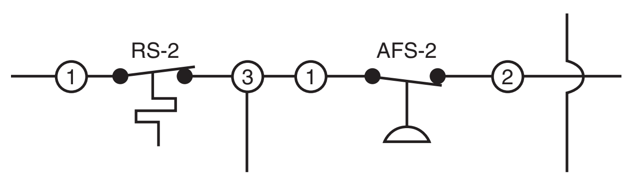


Figure 3. Temperature and pressure controls

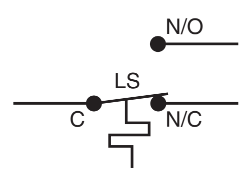


Figure 4. SPDT limit switch

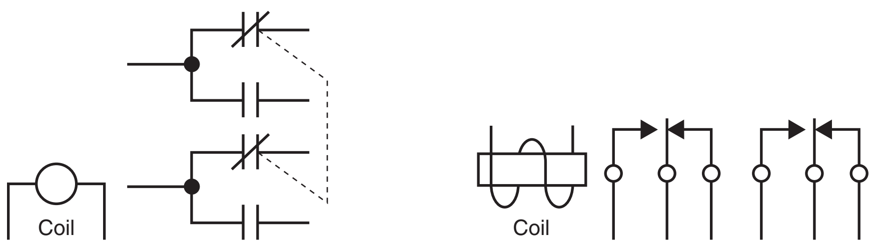


Figure 5. DPDT relays

relay. Contactors appear nearly identical to relays on schematic diagrams. Some manufacturers employ contactors that use a single set of contacts. A "bus bar" is placed over the connection where the other set would be, as shown in Figure 6. Figure 16 at the end of this chapter includes many other symbols for switches and relays.

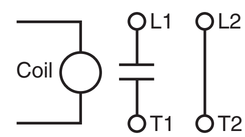


Figure 6. Two-pole contactor with bus bar

THE BASIC DIAGRAM

Let's take a look at a "generic" schematic of a packaged heating/cooling unit. In order to illustrate the various options that may be possible with a unit of this kind, the schematic has been put together by taking parts from several different manufacturers. Because of its complexity, the schematic is broken into three parts. Figure 7 (spread across pages 4 and 5) shows the high-voltage components, and Figure 8 (pages 6 and 7) shows the low-voltage or control circuits. There normally is no "point-to-point" or line diagram with this type of schematic, but a component layout is often provided. This is shown in Figure 9 (pages 8 and 9).

EQUIPMENT

In order to service any piece of equipment, you first must know what you are working with. Even before you begin a visual inspection of the equipment itself, a quick look at the schematic will give you a general idea of the type of equipment and its components. In Figure 7, for example, it's easy to spot the two compressors—therefore, you can assume that this is a two-stage cooling system. Likewise, in Figure 8 you can see two ignition systems—again, you can conclude that this is a two-stage heating system. With just a quick glance at the schematic, you have determined what the unit is. As you become more experienced, you also may have a good idea of the kinds of problems that you may encounter with a particular type of equipment.

RELAYS

As you saw earlier, relays can and do have many contacts. A single relay may have a function in two, three, or sometimes four different circuits. Its contacts may be located in various parts of the schematic, and you must know how to find them if you are to know how the unit works. In our generic diagram, several relays provide lockouts for the cooling and heating sections, which means that the two sections cannot come on at the same time.

Locate control relay CR-1 at the bottom of Figure 8 (line 183). Now look at the detail shown in Figure 10A (found on page 10). As you can see, control relay CR-1 has five sets of contacts that are operated by one coil. The first two sets of contacts, CR-1a and CR-1b, are found on lines 42 and 48, respectively (see Figure 10B). The third set, CR-1c, is found on line 77 (see Figure 10C). The fourth set, CR-1d, is found on line 149 in the low-voltage section of the schematic (see Figure 10E). The last set, CR-1e, is found on line 90 (see Figure 10D). Remember that when a number in the right-hand margin of Figure 10A is underlined, it designates a set of normally closed (N/C) contacts.

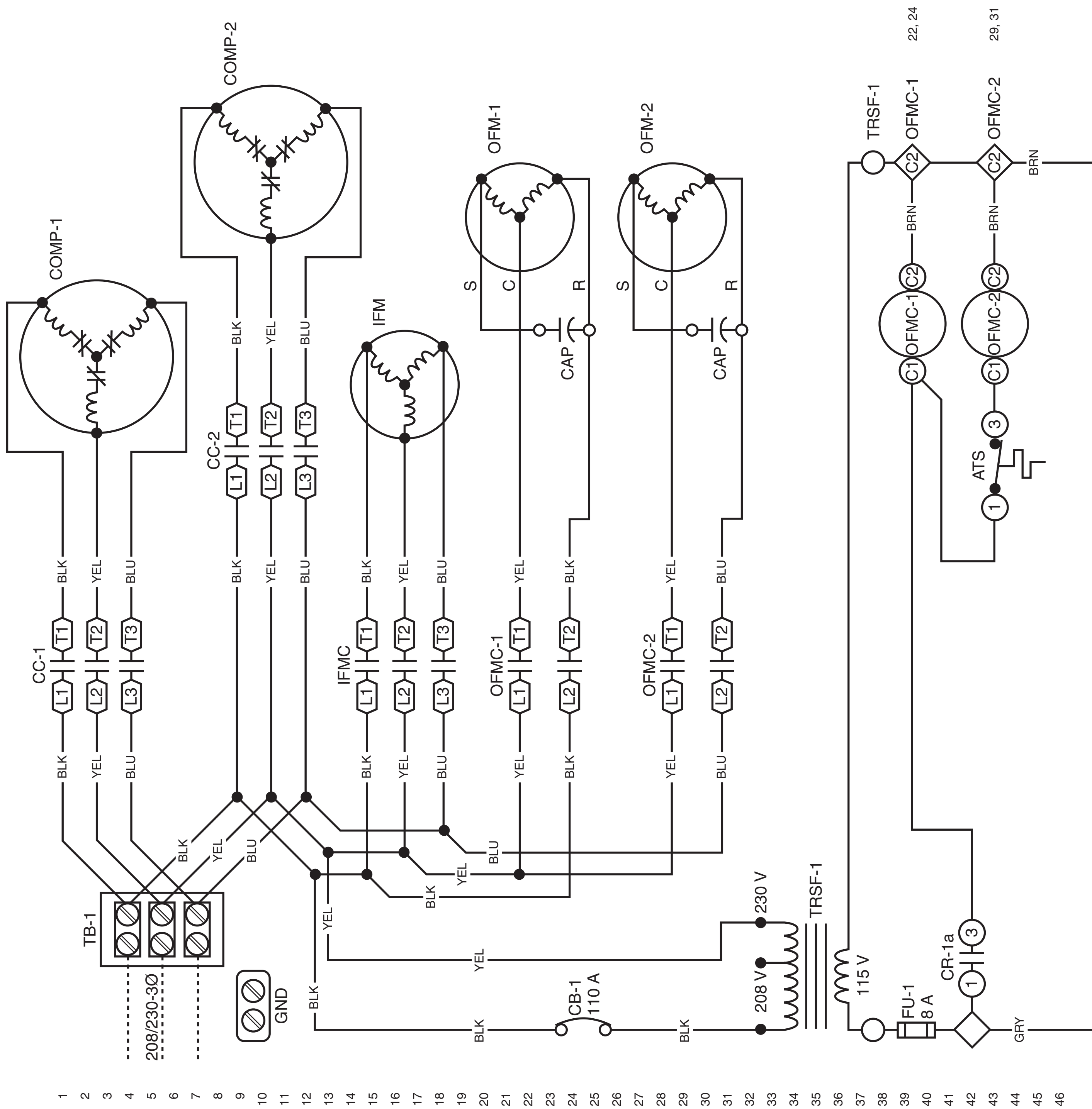


Figure 7. High-voltage circuits

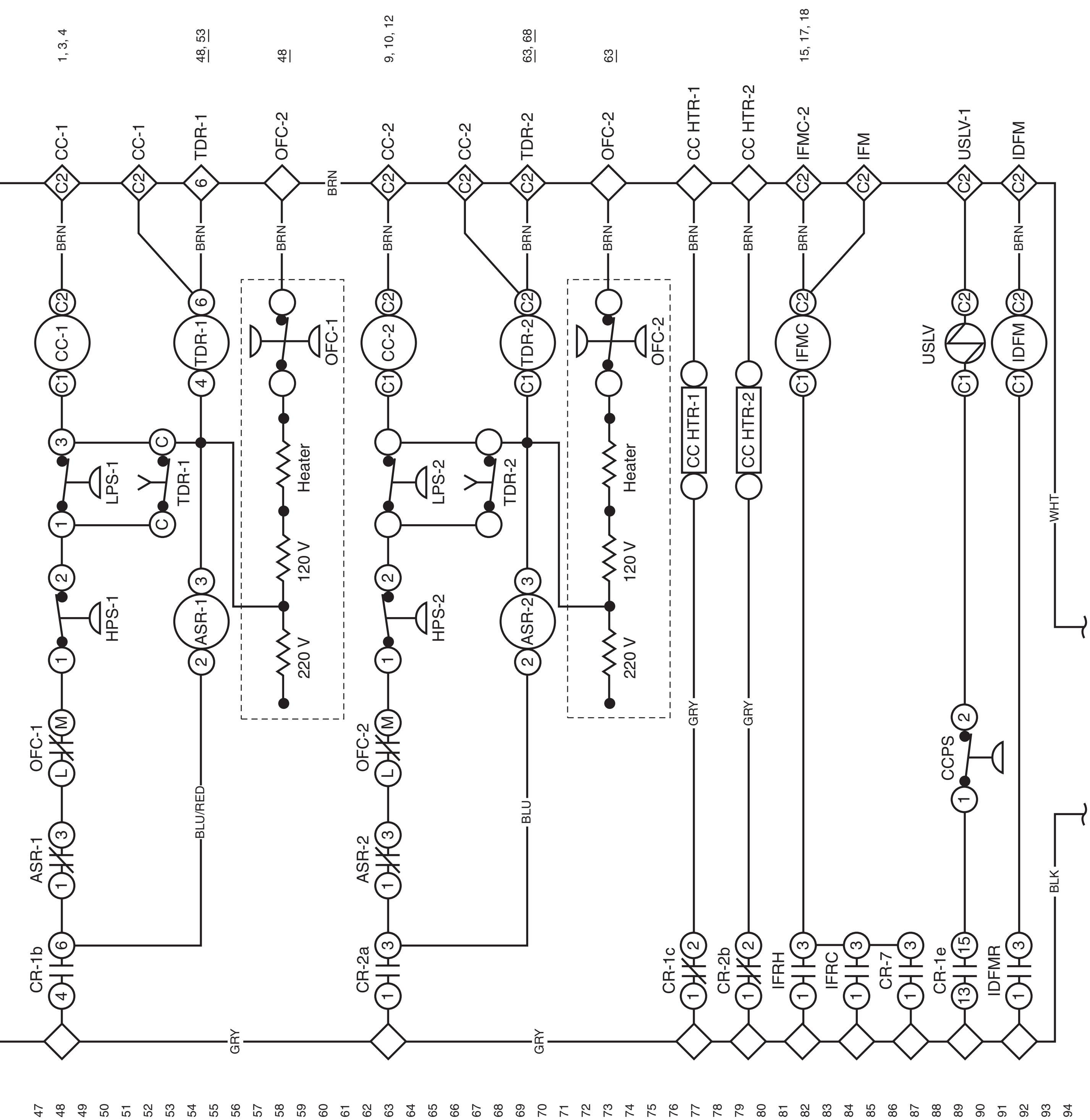


Figure 7. High-voltage circuits (continued)

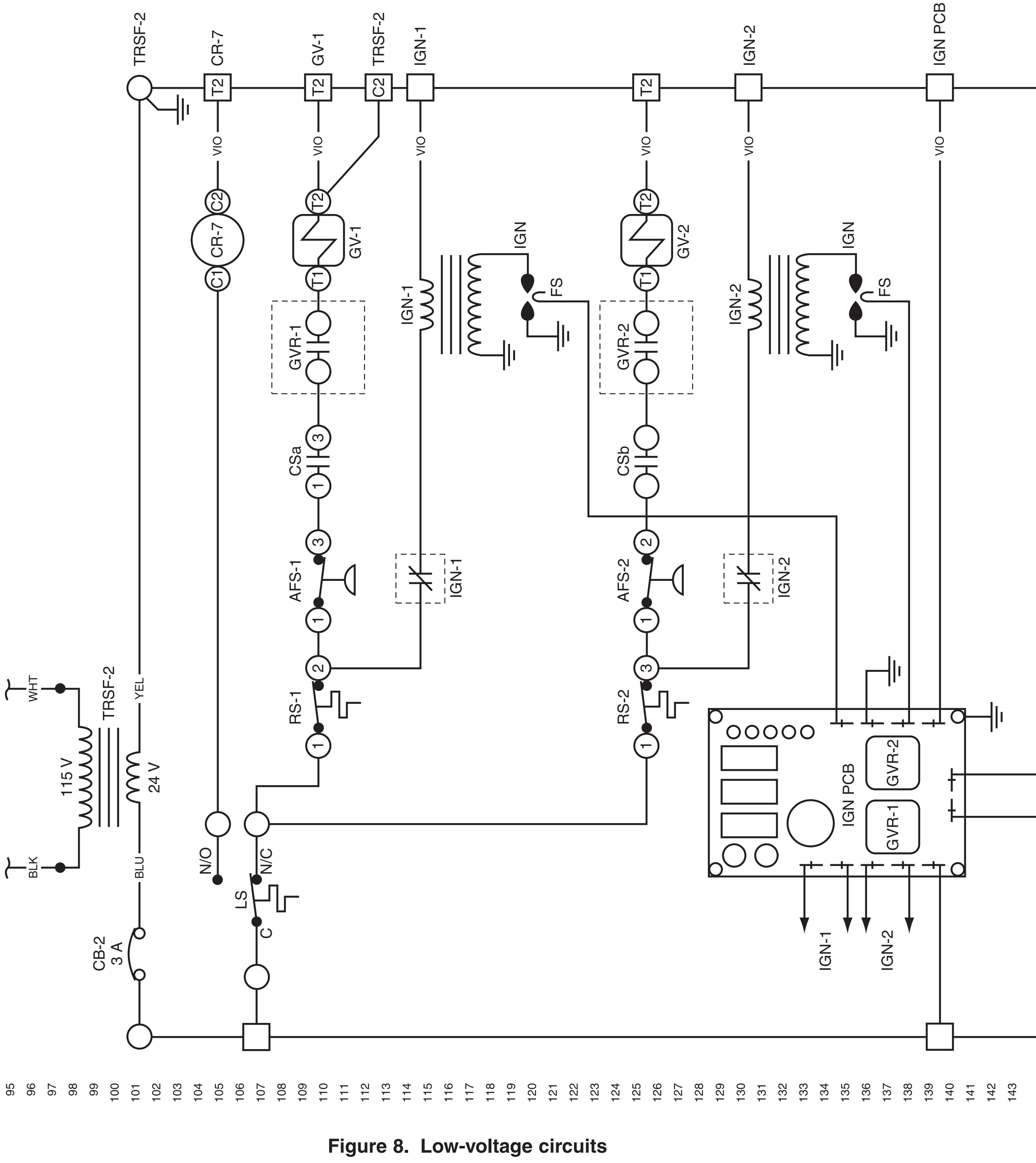


Figure 8. Low-voltage circuits

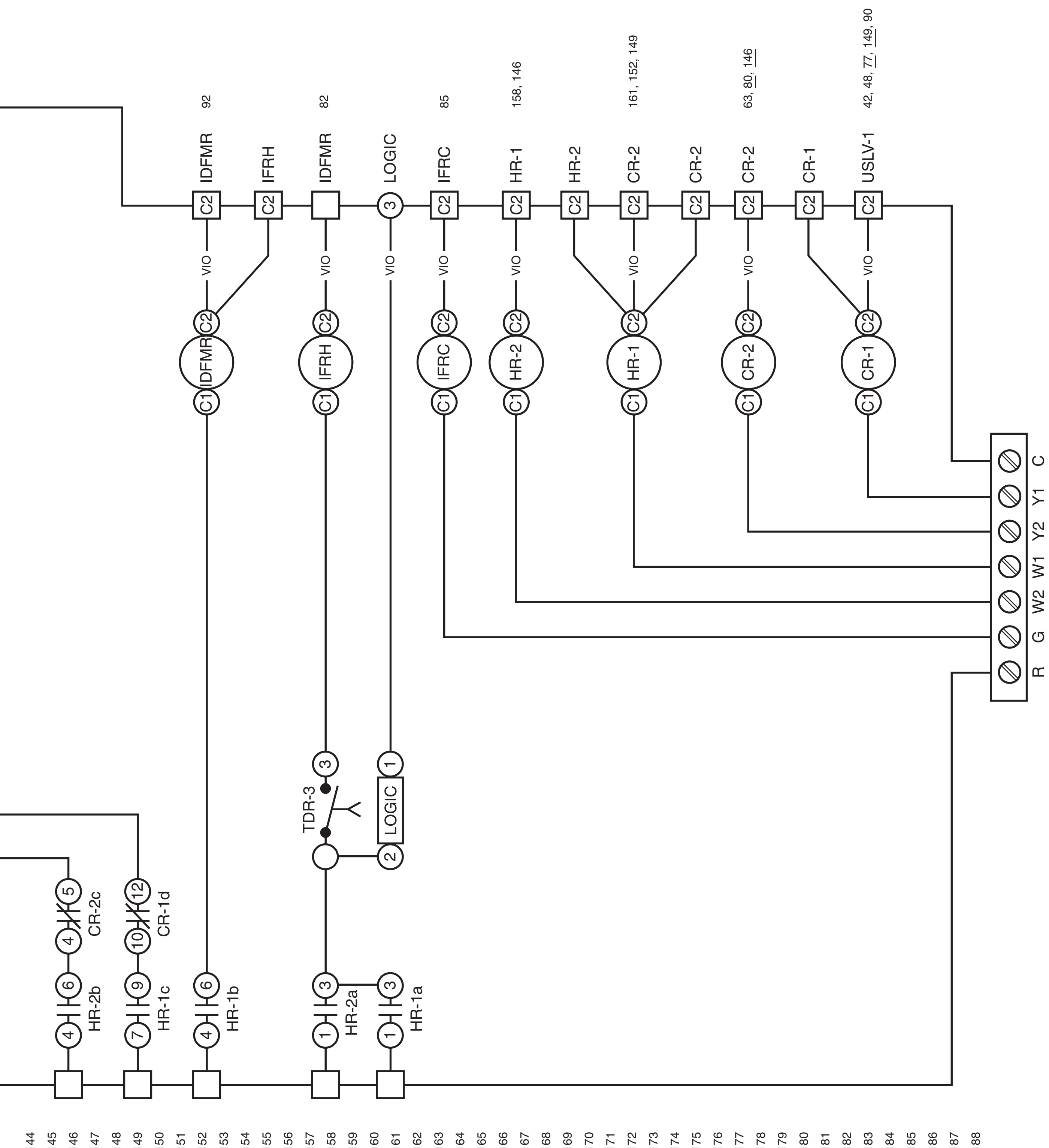


Figure 8. Low-voltage circuits (continued)

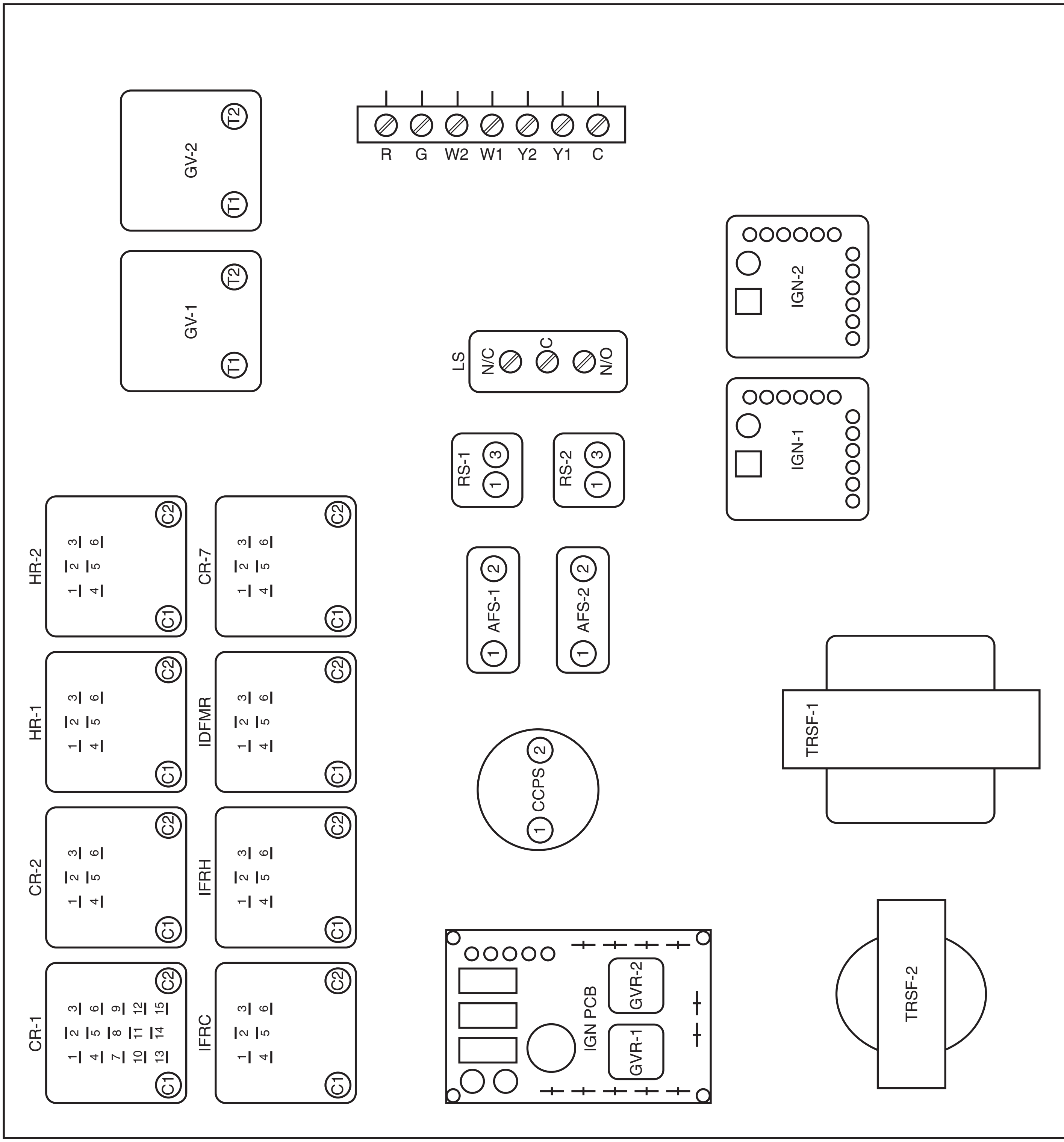


Figure 9. Component layout

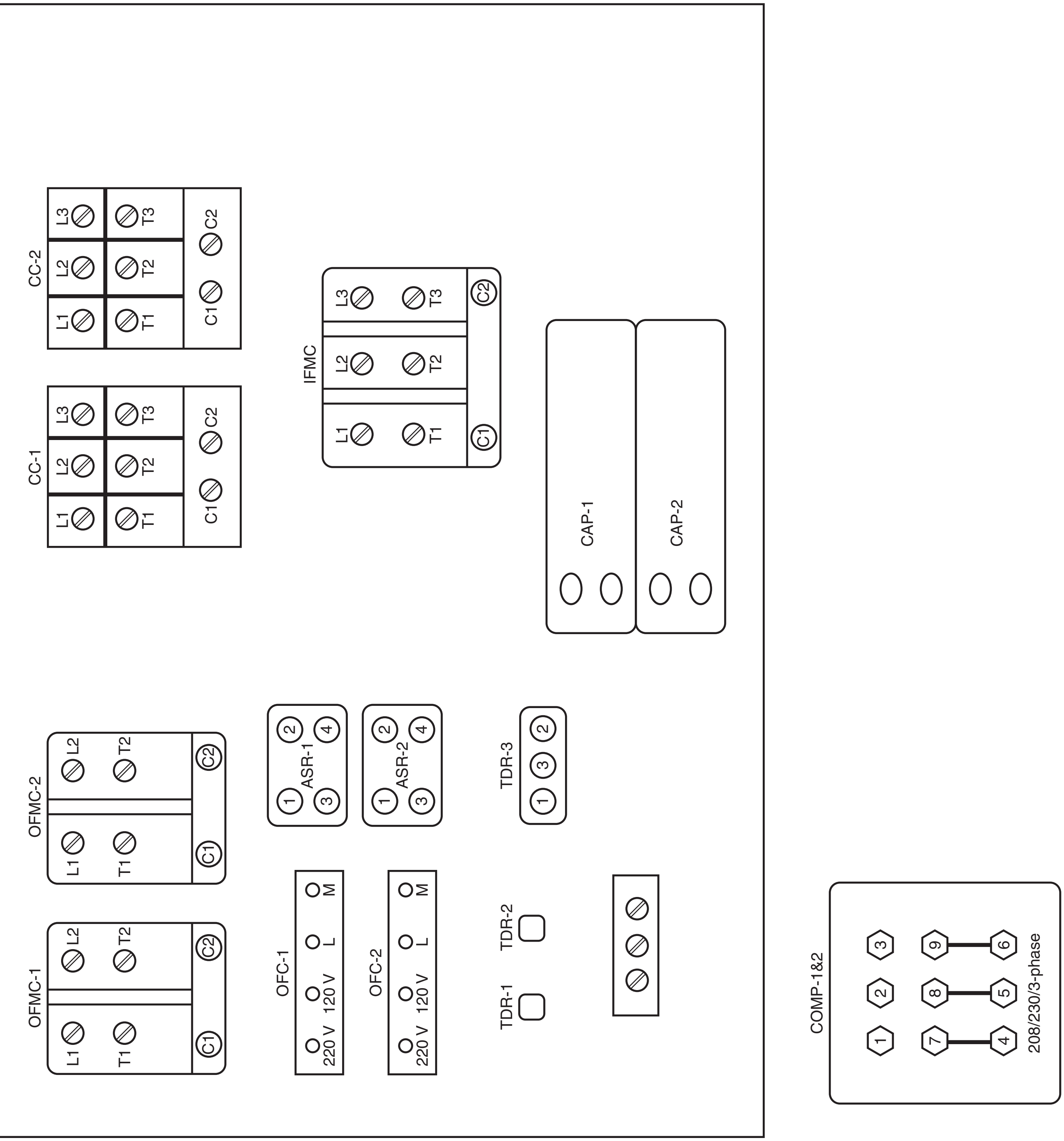


Figure 9. Component layout (continued)

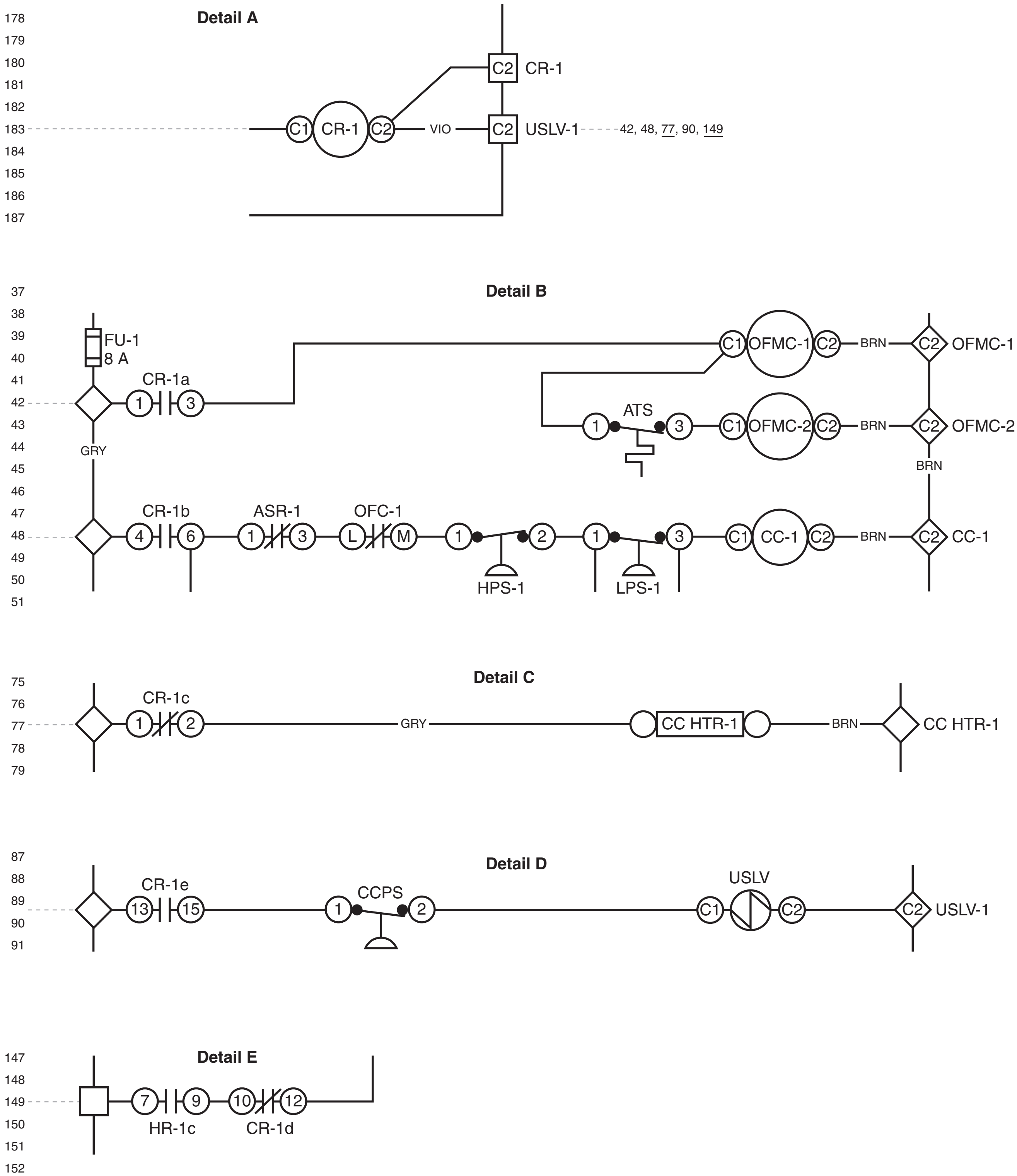


Figure 10. Locating control relay contacts

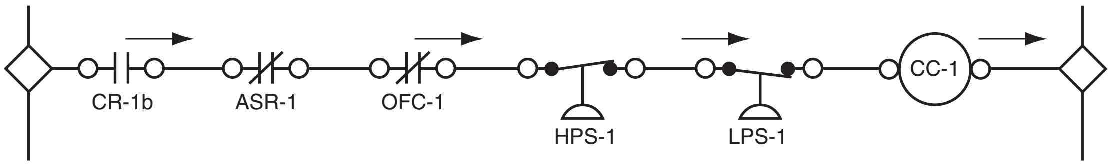


Figure 11. Series circuit

CIRCUITS

A schematic diagram can look complicated when viewed as a whole. However, as stated previously, it becomes much easier to analyze a problem if you break down the large diagram into smaller individual circuits. All electric circuits conform to one of three basic arrangements.

Series circuits

In a *series* circuit, components are arranged one after another, so that the same current flows through all of the components in one continuous path. Figure 11 shows an example of a number of switches and a relay coil connected in series. The direction of current flow is indicated by the arrows. Notice that the current must pass through all of the switches before it can energize the coil. If any of the switches is open, the coil cannot be energized.

Parallel circuits

In a *parallel* circuit, there are two or more separate paths or *branches* for current flow. A parallel circuit arrangement allows any one of a number of controls or switches to energize a load. Look at Figure 12A, for example. When *either* of relay contacts IFRH or IFRC is closed, current will pass through the circuit and energize coil IFMC. However, note that *both* IFRH or IFRC must be open in order for the coil to be de-energized.

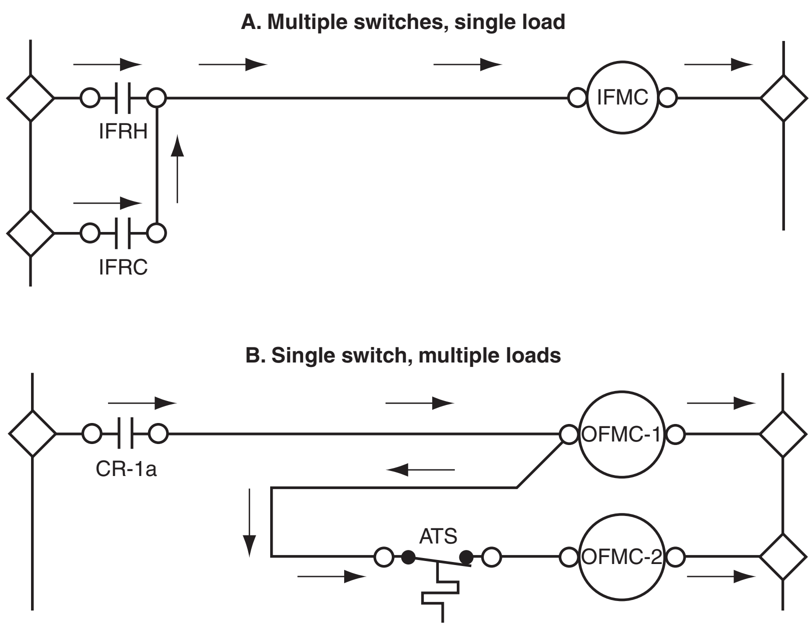


Figure 12. Parallel circuits

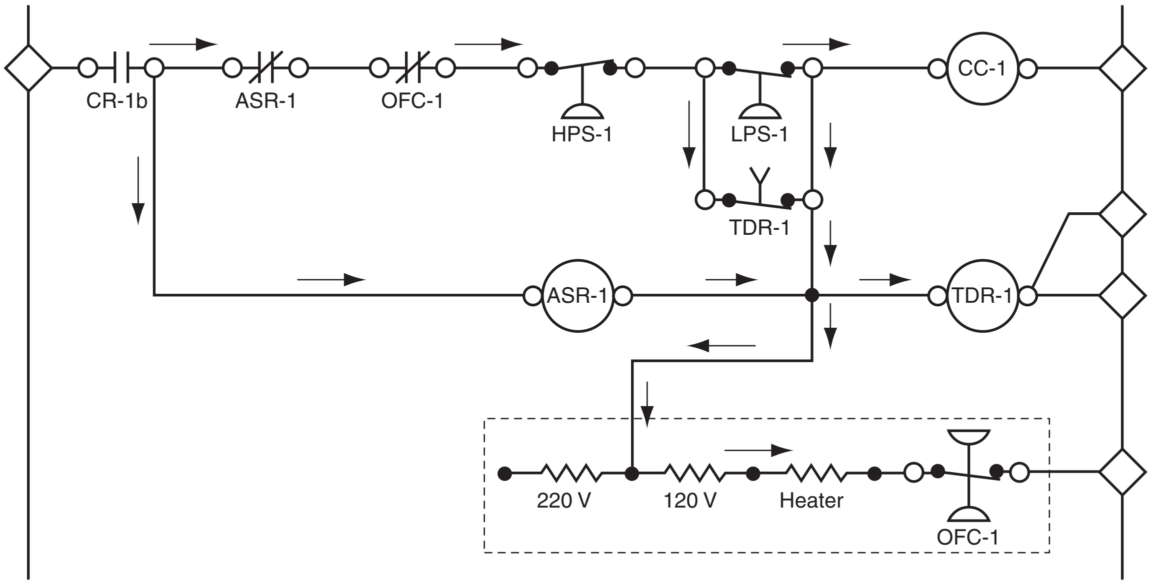
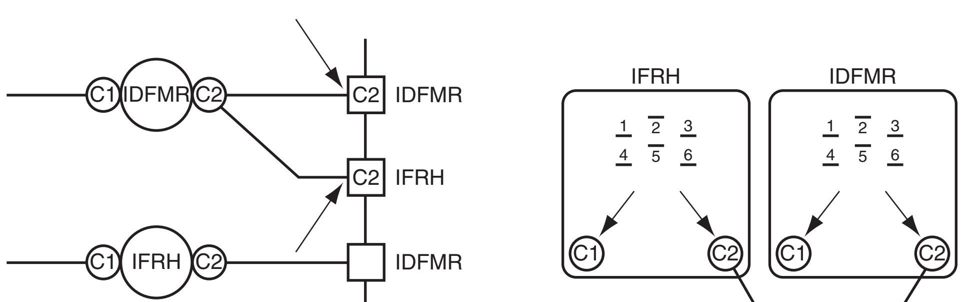


Figure 13. Series-parallel circuit

A single switch can energize several loads at the same time in a parallel circuit. All of the loads will get the same amount of current when the switch closes. In Figure 12B, for example, when switch CR-1a is closed, current will pass through the circuit and energize coil OFMC-1. And as long as thermostat ATS is closed, coil OFMC-2 also will be energized.

Series-parallel circuits

As the name implies, a *series-parallel* circuit is a combination of series (or single-path) and parallel (or multiple-path) circuits. Such a circuit allows some operations to proceed while stopping others. Series-parallel circuits are primarily used in control and safety applications. The detail shown in Figure 13 above illustrates a series-parallel circuit. When switch CR-1b closes, current flows through both branches of the circuit. As long as all of the switches ASR-1, OFC-1, HPS-1, and LPS-1 are closed, current passes through the upper branch and energizes coil CC-1. If any of the switches is open, however, the current will be allowed to pass only through the lower branch to coil ASR-1.



A. Schematic diagram **B. Component diagram**

Figure 14. Terminal connections

With all of the switches in the upper branch closed and coil CC-1 energized, current simultaneously passes through the TDR-1 contacts to the TDR-1 relay. This is a "delay-on-make" time-delay relay, which means that after a specified period of time, the TDR-1 contacts will open. This type of control is commonly used for low-pressure bypass during low ambient conditions.

When coil CC-1 is energized, note that current also passes through the 120-V resistor, through the resistor marked "Heater," and through differential pressure control OFC-1. This is an oil failure control. When oil pressure is sufficient, differential pressure control OFC-1 will open, thus taking the heater out of the circuit and preventing the OFC-1 contacts from opening.

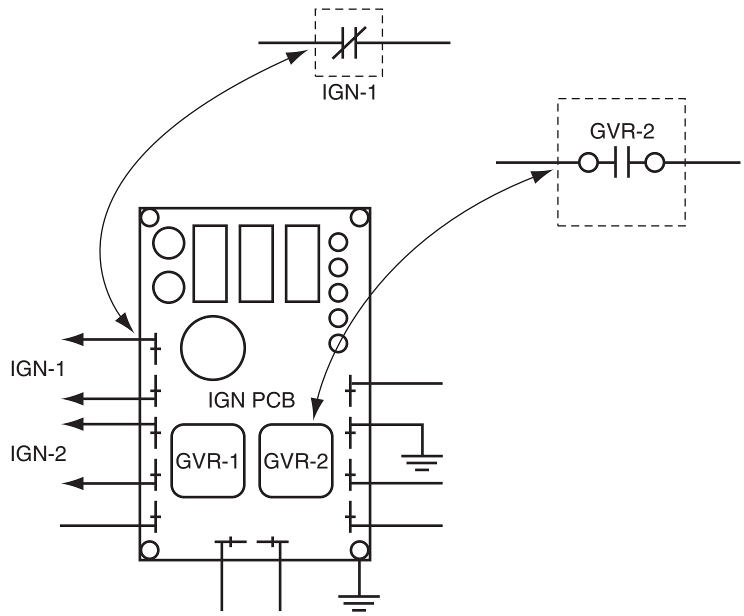


Figure 15. Relay connections on igniter printed circuit board

CONNECTIONS AND WIRING

In order to conserve wire and space, some manufacturers terminate more than one coil connection at the same point. This practice is depicted schematically as shown in Figure 14A, where the terminals from the IDFMR and the IFRH are taken off the same terminal connection. Note that the schematic shows two connections or wires at that point (the arrows point to the connection points). Because line diagrams are not used in complex schematics, the component diagram will show the terminal connections on the relays and other devices (see Figure 14B).

In some cases, a control or relay may not be shown as a replaceable item, or even as a component that can be tested. In Figure 15, for example, the timing contacts for the igniters are on the printed circuit board, but they cannot be physically replaced. The contacts themselves are usually shown enclosed in a "box" drawn with dashed or dotted lines. This same approach is used for the gas valve relay shown in Figure 15, and in some instances for fan relays as well.

LEGENDS

There normally isn't enough space on a schematic to accommodate the full spelling of each component. A legend listing many of the abbreviations used in the schematic that you have been studying is shown on the next page.

LEGEND

AFS . . . . . Air flow switch	IDFM . . . . . Inducer fan motor
ASR . . . . . Anti short-cycle relay	IDFMR . . . . . Inducer fan motor relay
ATS . . . . . Air temperature switch	IFM . . . . . Indoor fan motor
CAP . . . . . Capacitor	IFMC . . . . . Indoor fan motor contactor
CB . . . . . Circuit breaker	IFRC . . . . . Indoor fan relay (cooling)
CC . . . . . Compressor contactor	IFRH . . . . . Indoor fan relay (heating)
CC HTR . . . . . Crankcase heater	IGN PCB . . . . . Igniter printed circuit board
CCPS . . . . . Capacity control pressure switch	IGN . . . . . Igniter
COMP . . . . . Compressor	LPS . . . . . Low-pressure switch
CR . . . . . Cooling relay	LS . . . . . Limit switch
CS . . . . . Centrifugal switch	OFC . . . . . Oil failure control
FS . . . . . Flame sensor	OFM . . . . . Outdoor fan motor
FU . . . . . Fuse	OFMC . . . . . Outdoor fan motor contactor
GND . . . . . Ground	RS . . . . . Rollout switch
GV . . . . . Gas valve	TB . . . . . Terminal board
GVR . . . . . Gas valve relay	TDR . . . . . Time-delay relay
HPS . . . . . High-pressure switch	TRSF . . . . . Transformer
HR . . . . . Heating relay	ULSV . . . . . Unloader solenoid valve

Note: Figure 16 on the following three pages shows many of the schematic symbols used in the HVAC/R industry today.

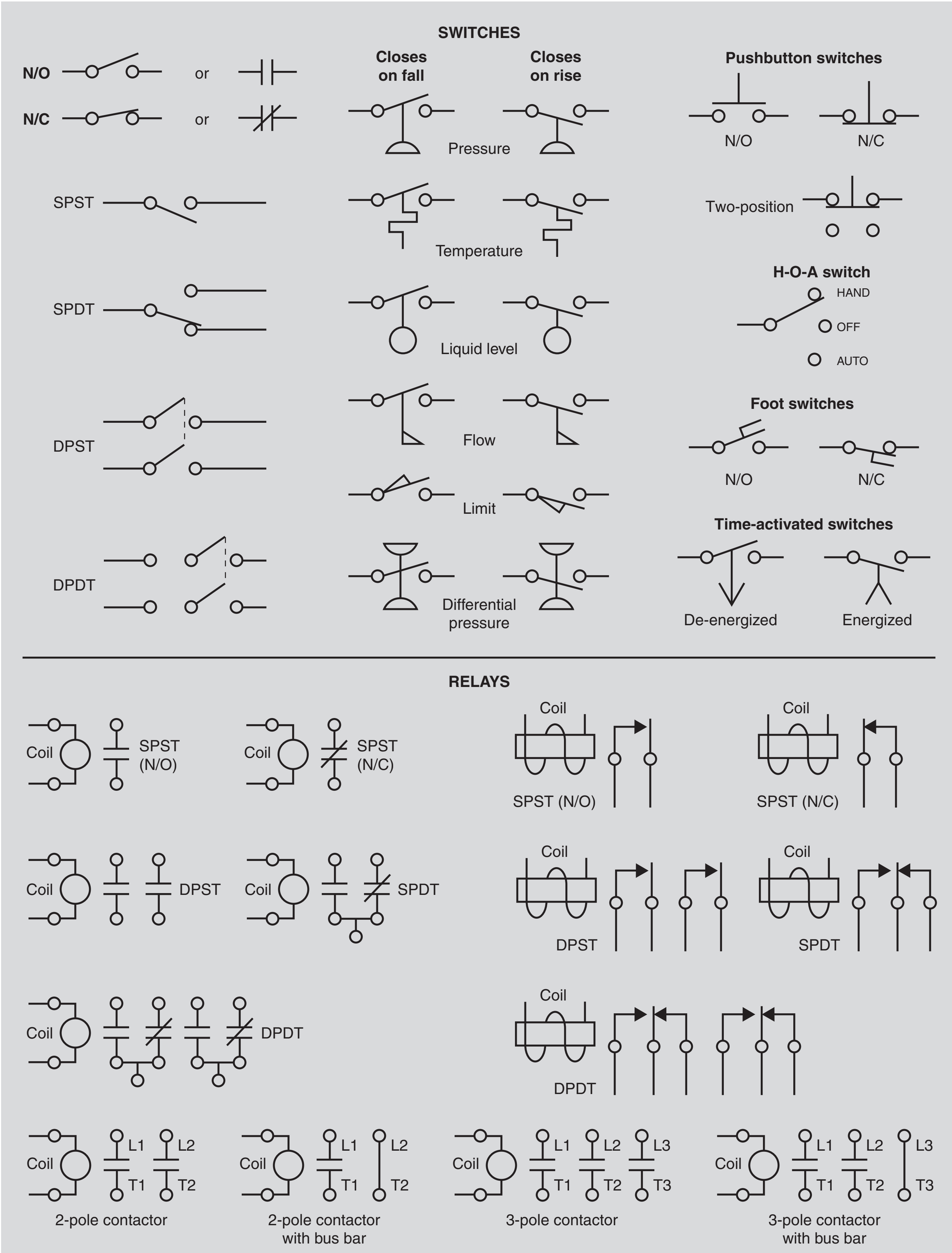


Figure 16. Schematic symbols

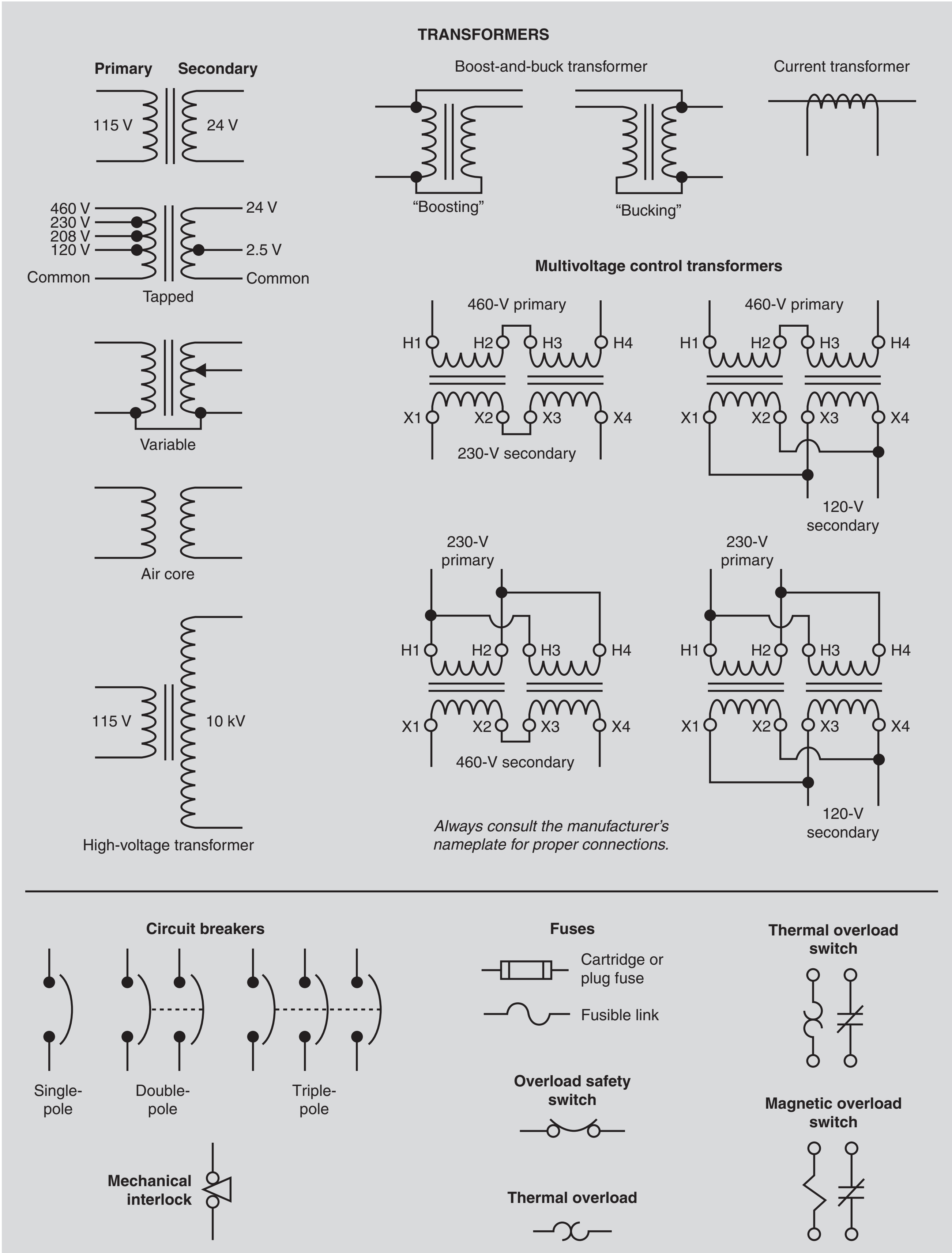


Figure 16. Schematic symbols (continued)

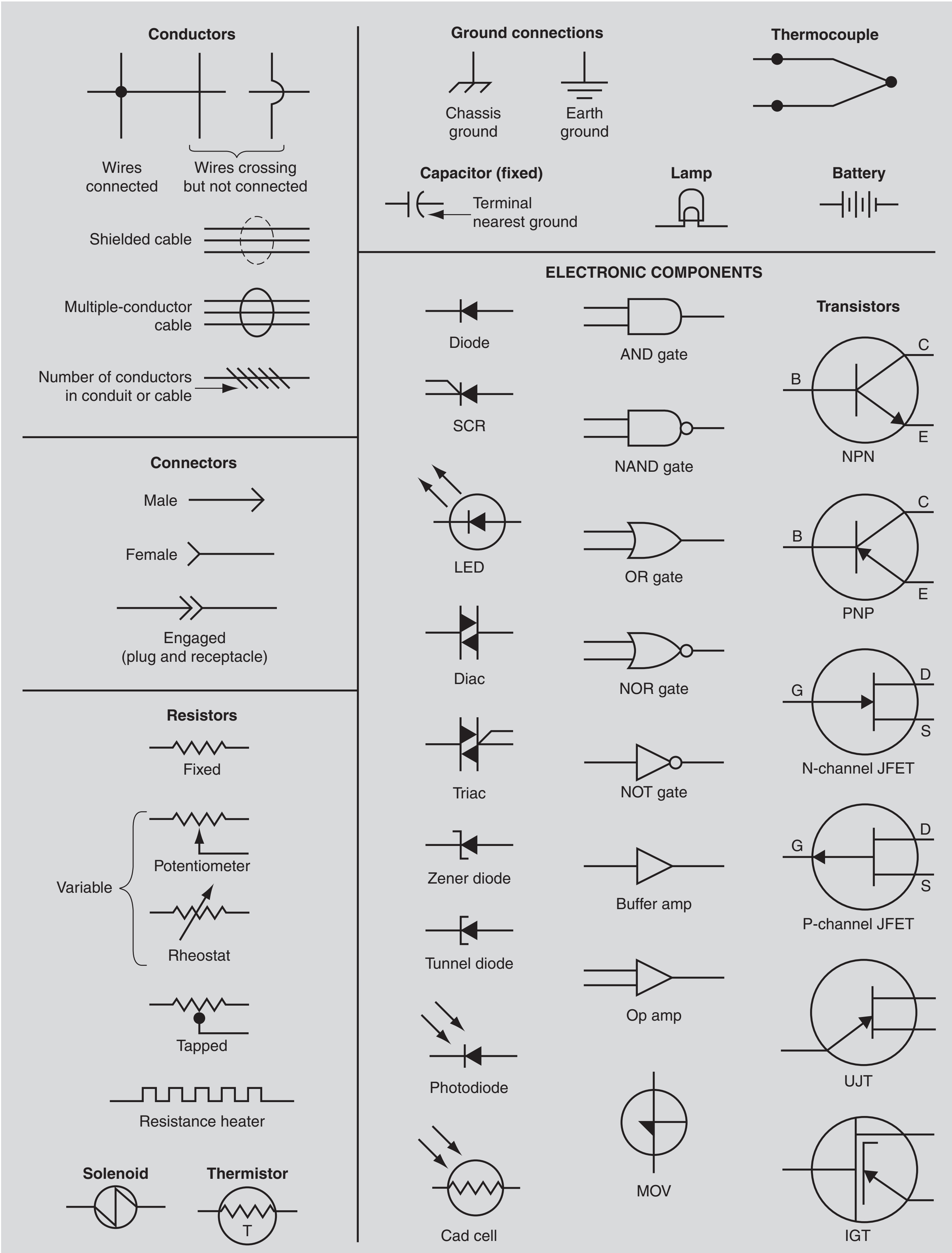


Figure 16. Schematic symbols (continued)

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