**Schematics, Components, and Soldering**

You learned the basic idea behind a schematic drawing in an earlier chapter. A schematic is a not-to-scale drawing of how a circuit is connected together, but it does not show any of the physical arrangement of the component parts. Schematics show electrical relationships, not physical ones, so parts that are right together on a printed circuit board may be shown far apart from one another, or things close together may be shown on opposite sides of the plan. Earlier on when studying Ohm’s law, you were presented with schematics like this one, which were used to determine the relationship between current, resistance, power, and voltage. This type of drawing is really only meant for circuit analysis.

![Schematic Diagram 1](image1)

The rectangle near the center represents an integrated circuit chip known as an “op-amp” or operational amplifier. It is being used as a central control agent for this dimmer. Looking to the top of the drawing you can see that the input voltage is +12 volts higher than the ground, which is shown at the bottom and is symbolized by the upside down triangle of horizontal lines. Many parts of the circuit must be connected to the ground potential, and you can assume that all of the triangles are connected together on the actual printed circuit board.

The jagged, saw tooth lines represent resistors, which you have seen many times in the previous chapters. Notice that two of them are shown with values of 1kΩ each (1000 ohms), another is rated at 100Ω and two watts of power, and that the last is listed at 50kΩ. This is a much higher value than the others, and if you look closely, you will see an arrow pointing to the center of this resistor. On a schematic this means that component is a variable resistor, a potentiometer that uses a small variable voltage to control a much larger one. This sort of arrangement is extremely common in electronics, where it can be seen as volume control knobs, sliders used to set dimmer levels, and mixing channels on a sound board.

Another type of drawing is the pictorial view, which as its name implies is more or less a drawing of what the finished product should look like. This particular drawing is of a variable power supply unit. Resistor R2 off to the left is the same sort of variable potentiometer as seen in the dimmer schematic above. Notice that several components (including the pot) are shown as being off the edge of the printed circuit board because they are not actually attached to it. The pictorial view does a
good job of showing how the components fit together in the device, but don’t give the builder much of an idea how the power supply should work electrically.

One other type of drawing to look at is the printed circuit board diagram. This one is for the same power supply unit as shown in the pictorial drawing above.

Printed circuit boards are used in virtually all modern electronics. Some are amazingly complex while others are very simple like the one here. A printed circuit board is used in place of wires. In an old tube radio, “jumper” wires were soldered to leads on the bottoms of tubes, capacitors, etc, in order to connect the components together as indicated in the schematic. All of that was rather bulky, and as electronics became smaller and more compact printed circuit boards were invented to make that possible.

Printed circuit boards are constructed from two types of materials that are sandwiched together so that they (hopefully) don’t come apart from one another. A thin plastic wafer board forms the basic structure of the piece, and a very thin copper foil is applied to one side of it. An etch resistor is applied to the copper foil, which could be as simple as a hand held Sharpie marker, or as complex as silk screening a computer generated design. After the resist has been applied to the foil, it is dipped into an acid solution which eats away all of the foil except for the parts that have been intentionally protected.

Rounded dots represent the points where components like resistors, diodes, and transistors will be connected. These are called pads. The connecting lines that take the place of wires are called traces. Small holes are drilled into the pads so that wire leads extending from the components can be inserted through the board. Most of the time, components are located on the wafer side and the leads are extended through to the copper foil side.
The leads are then soldered to the foil pads which are connected to the traces, which connects all of the components together in the manner indicated on the schematic.

*Soldering* is a method of connecting metals together by melting a third component on top of them. Unlike welding, where metals are connected by melting them both so that they flow together and form one unit, solder actually lays on top of the material. A flux helps the solder to make the connection.

The solder itself is an alloy of several different metals, most notably tin. In the past, lead was used because it has a very low melting point, but because it is very toxic lead-based solder has been discontinued. Solder is also used extensively in the plumbing trade, but this type is different and is not suitable for electronics work. Frequently, solder is sold wound up in a tube, or on a small spool.

Good soldering technique takes a bit of time to acquire, but even a beginner can have some success after a small amount of practice. It is very important to apply the heat of the iron in the proper manner for a solder joint to make a good connection. It is possible for a solder joint to appear solid to the eye, but be non-conductive none the less. This is called a “cold solder joint” because the pieces being soldered together were not hot enough for the solder to make a good bond with them. Generally, this type of mistake has a distinctly “gloppy” looking appearance because the solder has balled up on itself.

When properly applied, the solder should have a slightly concave shape to it, extending from the pad up to the lead. This shows that the solder ran to the hottest areas, the lead and the pad, rather than to itself. In order to make that happen, you should lightly press the tip of the iron against the intersection of the pad
and lead, wait for a moment, and then bring the solder into play. The solder will naturally flow toward the heat in the intended direction.

It is important however, to not to apply too much heat to the printed circuit board as this will cause the plastic to melt, and the copper foil to lift from its surface. Expect to spend some time repairing your first attempts at soldering.

Printed circuit boards are just one example of using solder to make electrical connections. Repairing cables used to transmit data information and audio signals is a much more commonly undertaken activity. XLR connectors are used throughout the entertainment industry, and wires for these types of cables must be soldered to the connector.

XLR type connectors come in a variety of different pin number types for different uses, some having as many as 7 pins, which means that same number of wires can be connected independently. The 5 pin variety is very commonly used for the DMX computer protocol. A 4 pin connector is used for many different types of lighting accessories, most notably color changers and/or gobo rotators. The 3 pin version is probably the most common because it is the standard microphone type, and it is also used for many moving light fixtures.

Soldering XLR connectors is done with the cable strain relief pulled down to reveal small tabs used as terminals. It is very important that the pin numbers within the XLR be kept in mind when making connections. The numbers are usually molded into the plastic which makes up the insulator inside the XLR. If not, you can easily keep things straight by plugging the male and female parts together. The small wires inside the cable bundle are color coded to make things easier. Just make sure that the color of the wire that goes to each terminal is the same on both sides of the mated connector so that pin #1, #2, etc., has the same conductor on either side.
TERMS USED IN THIS CHAPTER

Cold solder joint
Flux
Ground
Integrated circuit chip
Jumper
Lead
Pad
Pictorial drawing
Potentiometer
Printed circuit board
Resistor
Schematic drawing
Soldering
Strain relief
Trace
Variable resistor
XLR connector