BE 3600 BIOMEDICAL INSTRUMENTATION (LAB) –

Experiment 3: Electrical Soldering

OBJECTIVE: Learn how to use a soldering iron.

☞ *PRECAUTIONS*

(1) Common Problems

It was reported that the 90% of problems in electronic kits returned back to the manufacturers for malfunction could be attributed to poor quality of the soldering. Wire connections can be defective if the solder has not run into all the crevices of the connecting wires and wet the metals properly. Most of this is due to application of insufficient heat during the soldering process. The beginners seem to fear that they are going to damage the components with the applied heat and so they apply it too sparingly.

(2) Need to be Safe

For your own safety, and for the safety of those around you, treat a hot soldering iron with respect since it can be a dangerous tool!

One of the first rules for safety is to form good habits when using a soldering iron. Always lay the iron down in the same place during standby between connections. It is best to use a soldering iron stand to hole the iron. This not only protects the work surface from the heat from the soldering iron, but it also makes it difficult for you to accidentally touch the hot tip of the soldering iron. Thus the habit of recognizing that particular spot as one to be avoided. Place your iron in a stand when idle. The safest stands are those with a guard of perforated or wire screen material surrounding the iron, although open stands do also prevent fire as they keep the iron away from the surfaces. If a stand is not available, make sure that the iron tilts back on its handle, the point of leverage being the heat guard. Flammable objects must be kept away from hot iron, including hair and loose clothing. Be constantly aware of people working near you, or standing nearby. Before putting the iron down on the bench, look to see that there is nothing there.

☞ BACKGROUND on SOLDER

- SOLDER

Solder that is used for electronic circuits is an alloy of of lead and tin that melts at a temperature that is lower than the melting temperatures of either the lead or the tin alone. Solder guarantees positive electrical continuity, and it ”locks“ mechanical connections securely. However, solder is soft and cannot always be depended on to hold two pieces of metal together by itself if a long-lasting and secure connection is important. By itself it has rather poor mechanical strength, and under some circumstances can be pulled apart with ease. This means that there should first be a good mechanical connection. Wires should be wrapped around a terminal post, or put through a terminal hole and bent over or wrapped, before soldering to produce the initial strain relief. A wraparound connection by itself, however, is also a poor connection. Wire is pliable and can become loose. Furthermore, the thin oxide coating that forms on copper and other normal soldering metals can introduce resistance in the connection, enough to effect the performance of the circuit, if heavy current is involved.

For the best results, use a combination of a good mechanical connection, a mechanical strain relief and proper soldering. In a properly soldered connection, the flux dissolves away the oxide and the solder forms an intermetallic bond with the metals being soldered.

- FLUX

If a freshly brightened piece of copper were maintained in an inert atmosphere, there would be no problem in making solder connections to it without the aid of flux. Because of the inert atmosphere the surface of the copper would remain pure, and heated solder would wet it easily. But the oxygen in the air attacks copper, and forms a thin layer of copper oxide. When copper is exposed to the air long enough the oxide appears as a green tarnish. But even if the copper is exposed only a few minutes there is enough oxide formed to prevent soldering to the copper. And that is where the use of a flux comes in.

A soldering flux will act on the oxides that form on the surface of many metals. The thin tarnishes become soluble in the flux, and the flux will evaporate when it is heated to its boiling point. In a normal solder connection, the soldering iron is not drawn across the surface of the connection, but held against the wire connection. As flux-cored solder is held against the heated connection, the flux melts out of the core and in liquid form spreads across the surfaces of the connection. As the iron is held against the terminal, the flux heats up still more, reacts with the tarnishes of the base metals, floats them away, then boils out into the air. As the iron heats the connection still further, the solder melts and flows into the crevices of the connection.

- CLEANLINESS

The flux will clean off the thin oxide coating on copper wire or tinned leads. It will not remove grease, paint, heavy corrosion from years of storage, or the skin oils from sweaty fingers. In order for the solder to do a good job of wetting, the metals must be clean and bright. Brand-new components are clean and should be in solderable condition. Usually the only requirement is to keep your fingers off the leads as much as possible. Handle the parts by their bodies: hold printed-circuit boards from the edges, as you would a precious photograph or a compact disk. On the other hand, previously used parts must be cleaned with a few swipes of fine sandpaper.

- IRON and TIP

The soldering iron has one purpose: to heat the connection so that applied solder and flux ill melt onto the connection. But the right amount of heat is one of the parameters for getting good solder connections. The ideal temperature is hardly ever achieved, but the object is to get as near to it as possible.

It takes about 370°F to begin to melt the solders usually used in electronics. It takes about another 150 to 200°F at the tip of the iron to allow for fast heat transfer as the iron is applied to the connection. This adds up to about 620°F for the smallest connections. Large connections, with their fast heat transfer from the soldering iron tip, could require a tip temperature as high as 1000°F. It is not true that the hotter the iron the better the solder joint, since too much heat will char the flux and make it ineffective, resulting in a poor connection. Excessive heat can also damage the component being soldered and the circuit board upon which the component is to be soldered.

Because it is important to transfer heat from the iron to the connection as fast as possible, the tip contour must be such as to present the maximum surface to the connection. To put this is terms that we used in class, we want minimal thermal resistance between the soldering iron tip and the place where we want to melt the solder. A pyramid or modified chisel shape is about the best for average use, particularly in the home or workshop. There are many special shapes, but they are usually only useful in production soldering where the shape fits the specific connection.

Lastly, the condition of the tip is important. It must be well tinned with a bright coat of solder, and have no corrosion spots or pits. A good coat of solder is the best way of transferring heat quickly from the iron to the connection.

- HEAT SINKING

The heat from the soldering iron is important to melt the solder, but it can also be transported along a component's lead wire into the component. In the case of heat-sensitive components such as semiconductor devices, this heat can damage the component. Often when soldering these devices, especially where the lead wires are short, it is necessary to draw the heat away from the lead wire before it enters the component. This can be done by firmly grasping the wire between the solder joint and the component with a needle-nose pliers or a special tool known as a heat-sink clamp so that the heat transported along the lead wire is deflected from the component. This can also be minimized by quickly soldering the connection before much heat has time to ascend the wire to the component, but this runs the risk of a poor joint if insufficient heat is used.

- COLD SOLDER JOINTS

One of the biggest tribulations in trouble shooting electronic circuits that do not function properly, function intermittently or suffer from a lot of noise is finding the source of these problems. Often it is due to a "cold solder joint". This is a case where the solder has not flowed completely over the wire or the terminal, and good electrical contact has not been established. Sometimes there is the situation that good electrical contact occurs after the joint is established, but as the solder cools and contracts the contact is broken or stresses are set up that cause the joint to fail at some later time. In all of these cases, the joint appears to be just fine when observed by the naked eye, but in fact there is a microscopic crack between the wire or the contact and the solder. This can cause much frustration for engineers and service technicians! The best way to prevent this is to make sure that the contacting surfaces are clean before soldering and to use just the right amount of heat from the iron; a skill that comes with experience.

- CARE OF IRONS

Iron care is devoted mostly to the tips. Good-quality irons will last a lifetime if they are not abused. Since the tip is part of the radiating system that establishes safe temperature equilibrium, an iron should never be left on without the tip installed. Otherwise, the internal heat may rise to a temperature too high for long element life. When excess solder accumulates on a tip, wipe it off on a wet sponge, but never hit your iron against the workbench. When an iron has cooled off, you can remove the tip. On hollow-core standard irons, a light tap, with the tip out, will knock out the internal corrosion particles.

- WIRE STRIPPING

The ends of a hookup wire should be stripped of their insulation. A hand stripper is a device that holds the wire behind the part to be stripped, and then uses a pair of sharp claws to grip and cut the insulation, and pull it away from the wire. Insulation can be stripped off wires without special tools. A sharp knife can do it, but it is a tedious job and not recommended. Another method is with diagonal wire cutters. Cut a circle around the insulation with the cutter; then with the cutter in the circle pull the insulation off. The insulation should be cut back to about 1/8 inch beyond the calculated point of solder. If the insulation ends near the connection some of the plastic material could melt into the connection and prevent good wetting by the solder. If it is too far away, you may lose the protection of the insulation against shorts with other wires nearby. It might take few attempts to get good at this.

- SOLDERING

There are several steps for soldering:

- Following the removal of the insulating material, join the two metals to be soldered. Make good mechanical connections and keep resistor and capacitor leads as short as possible, unless otherwise specified. If socket terminals are used, use long-nose pliers to feed the ends of the components into one of the holes in the socket terminal. Twist the wire back around the rear of the terminal and squeeze it tight against the terminal. Usually, ending the lead tight against the backside of the terminal is adequate.
- Use opposite rule: First clean the iron - wipe off on a wet sponge, then melt a small blob of solder onto the iron tip. Then touch the solder coated iron tip to the connection, and we want molten solder touching connection with as large a surface area as possible; flat surface of iron. Then bring solder to opposite side of connection.

When the connection is sufficiently heated, the solder will melt over the entire connection. The connection should heat up in 2-3 seconds if the proper size iron is used.

- Check your soldering after allowing it to cool off for 15 seconds. You have a good connection if your solder has flowed over all surfaces to be connected, following the shape of the surfaces. It should appear smooth and bright and all wires in the connection should be well soldered.
- After soldering clean off any residual flux, Isopropyl alcohol and a tooth brush work well.

- DESOLDERING

Following an erroneous connection of replacing a failed component, it will be necessary to remove a component or wire. Rather than simply cutting the wire or the component, and leaving the solder joint in place, one can use the same tools to desolder:

(1) Cut the lead of the part to be replaced, close to the terminal as possible.

(2) Remove the component and its leads. First, find an end of the lead of the component to be removed. Then uses solder wick or sucking device to draw the hot solder away from the terminal. Then grab it with long nose pliers, bring the lead around to straighten it and pull the component out from the other side. Repeat process for other leads of the component.

EXPERIMENT: ELECTRICAL RESISTANCE BACKGROUND

In an electrical circuit, if two resistors R_1 and R_2 are connected in series the total resistance is:

$$R_{Total} = R_1 + R_2 \qquad \text{[Equation 1a]}$$

For ***N*** resistors connected in series, the general equation for their total resistance is:

$$R_{Total} = R_1 + R_2 + ... + R_N \qquad \text{[Equation 1b]}$$

If two resistors are connected in parallel, their equivalent resistance is:

$$\frac{1}{R_{Equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} \qquad \text{[Equation 2a]}$$

In the special case of two resistors this can be simplified to

$$R_{Equivalent} = \frac{R_1 R_2}{R_1 + R_2}$$

For ***N*** resistors connected in parallel with each other, the general equation for their equivalent resistance is:

$$\frac{1}{R_{Equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N} \quad \text{[Equation 2b]}$$

Electrical circuits may contain series or parallel connections, or both, as you probably already know. Any part of a series circuit may contain a segment with elements in parallel, and any branch of a parallel circuit or circuit segment may contain elements in series.

PROCEDURE:

1. You will be provided with four resistors. Measure their resistance with the digital multimeter set on the resistance scale and clean their lead wires. Indicate their resistance values in your notebook using a table similar to that shown below.

R1(Ω)	
R2(Ω)	
R3(Ω)	
R4(Ω)	

2. Use two resistors R_1, R_2 and solder them together in series, and measure the equivalent resistance. Write down your measured series resistance and calculate what the value should be based upon your measurements of the individual resistors.
3. Now connect the two other resistors in parallel and measure and calculate the resistance of the combination. Be careful in soldering these resistors, for you will need to desolder them for the next two parts of the experiment.
4. Use resistor R_3 and solder it together with the above circuit in parallel, and measure the equivalent resistance. Once again compare it with your calculated values.

5. Use four resistors to design three different circuits. Solder them according to your design and measure and calculate the equivalent resistance.

REPORT:

a. Why do we need to use solder when we connect electronics? Students (and some professors) sometimes use clip leads to make connections. Can you suggest why this might cause problems?
b. Why should we clean the lead wires resistors before soldering and how does the flux help in making a connection?
c. Describe the procedure of soldering.
d. According to the procedure 2, what is the equivalent resistance? Verify this value by calculation and discuss any differences found.
e. According to the procedure 3, what is the equivalent resistance? Verify this value by calculation and discuss any differences found.
f. According to the procedure 4, draw 3 different circuits. Verify the measurement results by calculation and discuss any differences found.