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Construction of a Constant-current Power Supply for Spot Electrolysis

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Construction of a Constant-current Power Supply for Spot Electrolysis

by Stephen Roberts

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Author

Stephen Roberts is a senior furniture conservator with the Department of Canadian Heritage, Historic Resource Conservation Laboratory in Dartmouth, Nova Scotia. Formerly he was an objects conservator with the Maritime Museum of the Atlantic in Halifax, Nova Scotia. Stephen became interested in electronic applications for treating artifacts while completing an internship at the Canadian Conservation Institute.

Abstract

A method for building a small, lightweight power supply that provides low constant current is described. The unit is powered by a 110-V alternating-current wall outlet and uses economical, easy-to-acquire components. It is specifically designed to treat localized corrosion on metal objects.

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Contents

Introduction

For a considerable time, electrolytic reduction has been used to treat corroded metal objects. As well, a number of articles have been published on the theory and techniques of electrolysis. This publication describes a method for building a small, spot electrolysis device that controls the current. This device has been used to treat small areas of corrosion on furniture hardware and plated metals. It has also been useful in treating composite artifacts and metal archaeological finds.

Manufactured units that perform electrolytic reduction on localized corrosion on metal objects are expensive, and frequently do not provide low current regulation. When performing spot electrolysis on a metal artifact, a number of variables come into play that affect current flow, such as concentration of the electrolyte, surface area of the anode compared with the cathode, and the degree of corrosion (resistance). A current-limiting control can prevent very high current density on the artifact, thus avoiding undue heat, vigorous hydrogen evolution, and embrittlement. Depending on the voltage rating, a direct-current source, such as an unregulated battery, may cause sporadic current surges on areas of the artifact, subjecting it to unwarranted stress. A current-limiting power source provides a way to control the rate of the electrochemical reaction.

The device described in this publication is a direct-current power supply with current-limiting control. Most spot electrolysis devices require a low current, so this device has a maximum supply of approximately 120 mA[1]. A schematic diagram is provided in case the device is to be built on contract (Figure 1). However, by following the instructions given below, conservators can build this unit themselves.

Procedure

The only risk during construction is to the components, so exercise caution during the procedure.

Please read the text thoroughly before starting construction.

The materials can be easily obtained from local electronics supply stores. The parts list is followed by a brief description of the components.

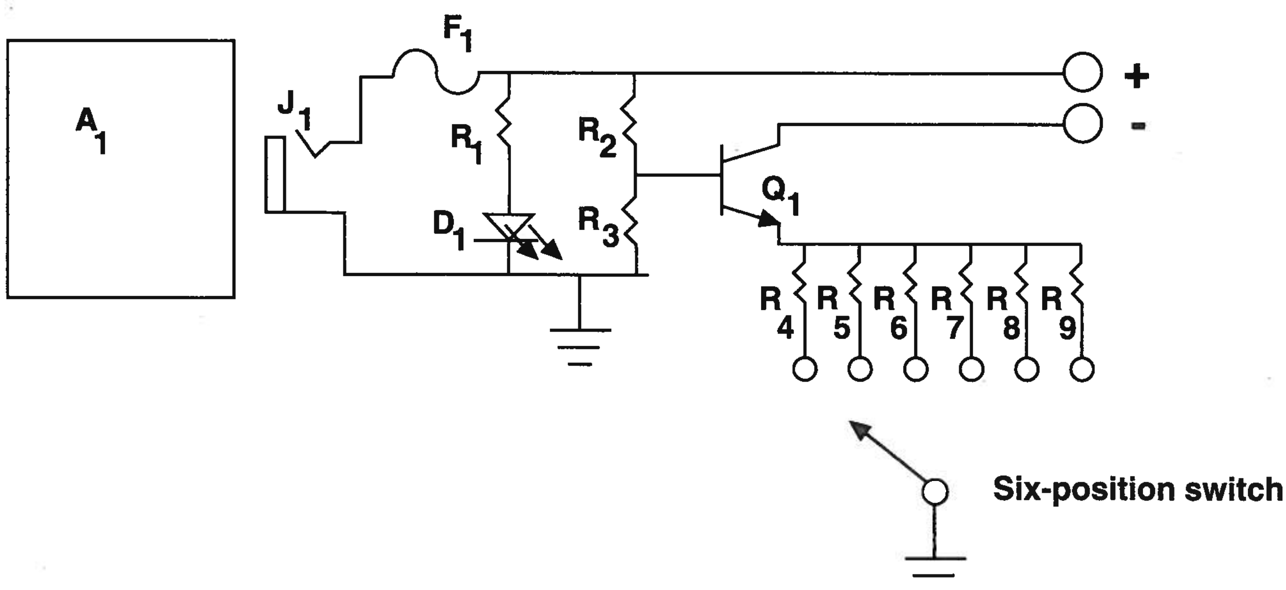


Figure 1. Schematic diagram of the spot electrolysis device.

[1] All measurements follow the International System of Units. The following abbreviations have been used: A=ampere; cm=centimetre; m=metre; mA=milliampere; mm=millimetre; V=volt; W=watt; Ω =ohm.

Parts List

Qty.	Item	Code*
1	NPN power transistor, Ic 1 A or greater	Q_1
1	a.c. to d.c. adapter (general purpose), 12 V, 500 mA	A_1
1	in-line or surface-mounted fuse holder	F_1
1	1-A fuse	F_1
3	1500-Ω resistors, 0.25 W	$R_{1,2,3}$
1	390-Ω resistor, 0.5 W	R_4
1	200-Ω resistor, 1 W	R_5
1	120- or 133-Ω resistor, 1 W	R_6
1	100-Ω resistor, 2 W	R_7
1	82-Ω resistor, 2 W	R_8
1	68-Ω resistor, 2 W	R_9
1	light-emitting diode (LED) with holder or surface-mount-type LED	D_1
1	3.5-mm (1/8-in.) input jack	J_1
1	3.5-mm (1/8-in.) plug to match input jack (additional plug needed if battery pack is used)	
2	banana jacks	
1	pair of test probes to fit banana jacks	
1	one-pole, six-position or two-pole, six-position rotary switch rated for at least 300 mA	
1	control knob to fit rotary switch	
1	plastic experimental enclosure approximately 150 x 80 x 50 mm deep	
1	1 m of 20- to 30-gauge hook-up wire	
2	alligator clips	
1	rosin core solder, small coil	
2	small machine bolts and nuts	
1	heat sink to fit transistor	

*Codes refer to components in the schematic diagram in Figure 1.

Description of Main Components

Adapter

A transformer and rectifier that convert alternating current (a.c.) from the wall outlet to direct current (d.c.) that powers the device. Adapters are housed in protective plastic cases to isolate them from high a.c. voltage.

Fuse (and fuse holder)

Fuses are safety devices installed in electrical circuits to protect humans and components from electric charges. In this case, the fuse protects the adapter should the wires short-circuit by accident.

Resistors

Resistors limit current flow and provide voltage drops at the appropriate places. Nine resistors are required in this circuit. The coloured bands on the resistors are codes for resistance (measured in ohms) and power rating (measured in watts). Ratings are printed on some larger resistors. It is important that the power rating of the resistors exactly match or exceed those listed.

Transistor

Transistors are solid-state devices made from a semiconductor material that controls the flow of current. For this circuit, the chosen transistor is a power transistor with a collector current (Ic) of 1 A or greater. The reason for the high current rating is unmarked and must be checked against the pin diagrams on the package.

Rotary switch

This is a multiple-setting switch. In this circuit, a one-pole, six-position switch is needed. Two-pole, six-position switches seem to be the most common variety, and will work well using just one pole and the six settings (terminals) that go with it. The switch needs to be rated for at least 300 mA.

3.5-mm (⅛-in.) input plug and 3.5-mm (⅛-in.) jack

The 3.5-mm input plug is connected at the end of the a.c./d.c. adapter, replacing the existing plug, unless a matching jack can be found to install in the experimental box (3.5-mm plugs and jacks are a more common item).

Two banana jacks with test probes to match

Banana jacks have plastic bodies that cover an internal metal connector, and are colour coded. Black is always designated negative, and red positive. Test probes with banana plugs attached are available for electronic testing and troubleshooting applications. They serve very well as positive and negative leads for electrolysis.

Light-emitting diode (LED)

LEDs draw very little current. The unit does not need a light in order to work; however, the LED indicates that the power is on. An LED needs to be connected through a resistor in order to limit the current flowing through it. Electricity will only flow in one direction through an LED, so polarity is important. The longer lead is always designated positive.

Miscellaneous

The plastic experimental box, solder, soldering iron, drill, 22- to 30-gauge hook-up wire, pliers, hacksaw, etc. are all self-explanatory. Some familiarity with these tools is assumed. Access to a multimeter that will record voltage and current readings is useful, but not essential. However, most conservation laboratories own one and it can be invaluable for checking batteries, fuses, motors, a.c. and d.c. voltages, etc.

These definitions have been kept brief so that the project is not hampered by a great deal of electronic theory. See "Further Reading" for references to more information on electronics and electrolysis.

Techniques

For reliable operation of the spot electrolysis power supply, good soldering practices are essential.
Here are a few guidelines:

- Use a low-wattage soldering iron (25–40 W).
- Use rosin core solder specially formulated for electronic applications.
- To solder, heat the connections for a few seconds with the tip of the iron, and, with the iron in place, apply the solder.
- Allow the solder to flow around the connection before removing the iron. *The whole process should take no more than five seconds.*
- Do not use excessive amounts of solder. A small, rounded blob joining components is adequate.
- Allow connections to cool before moving them.
- Keep the soldering iron tip clean and shiny by quickly wiping the tip while hot with a damp cloth.
- Transistors and other components cannot take much heat. Shunt heat away from smaller components by gripping their leads between the component and the joint being soldered with a pair of pointed pliers.
- Practice soldering techniques on small scraps of wire and old components until you can make a secure, neat join in five seconds.

For safety, always work in a well-ventilated area and avoid breathing the fumes. Never leave a plugged-in soldering iron unattended.

Construction

Step 1

Remove the existing d.c. plug from the a.c./d.c. adapter wire (Figure 2a) and strip about 6 mm of insulation off both leads (wires). Determine which wire is positive and which is negative. Most adapters have a white strip running down the side of the positive wire (Figure 2c), but sometimes the white strip is on the negative side.

Figure 2a.

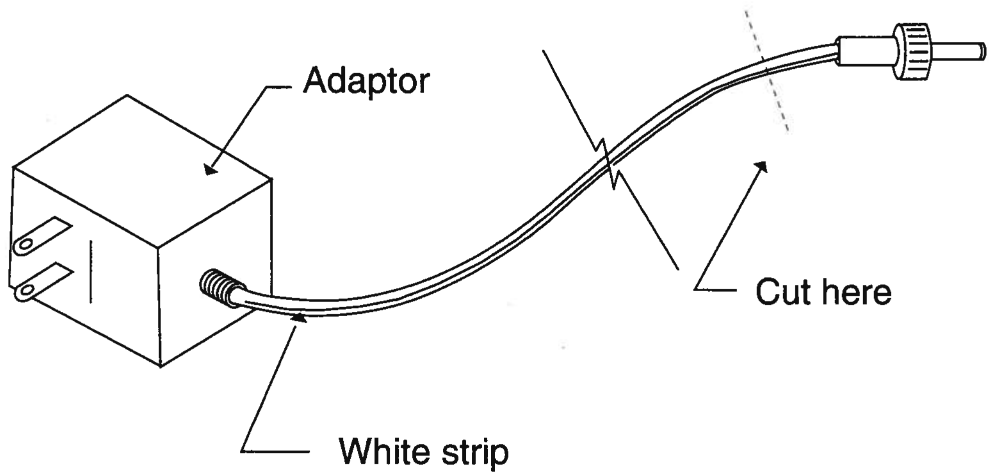


Figure 2b.

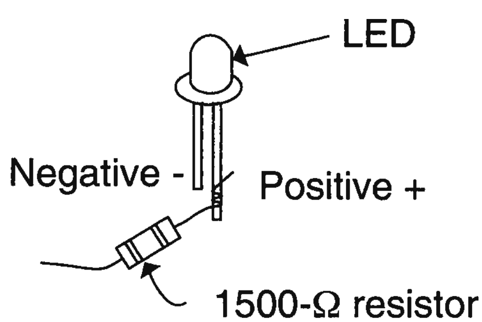
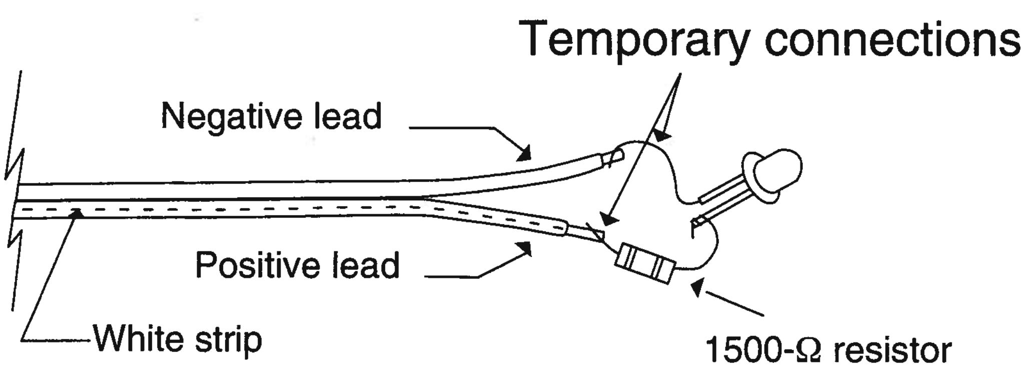


Figure 2c.

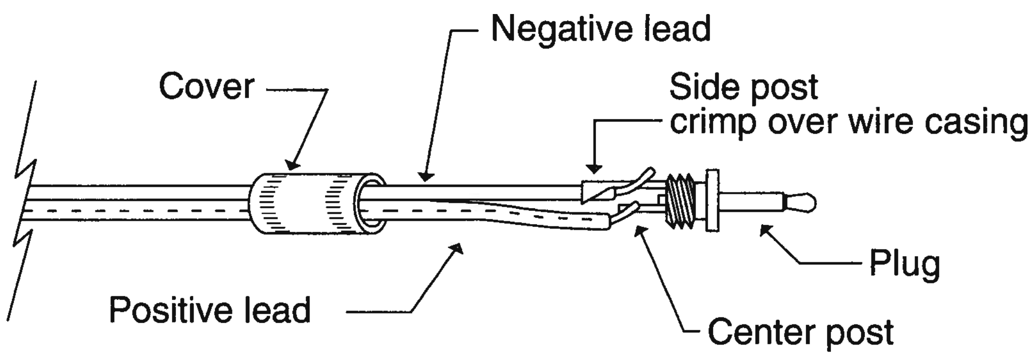


If a multimeter is not available to check the polarity of the two wires, connect and solder the 1500-Ω resistor to the positive (longer) lead of the LED (Figure 2b). Temporarily connect the LED across the adapter wires to the resistor (Figure 2c). Plug the adapter into the wall outlet. LEDs only conduct electricity in one direction, so if the LED lights up, the wire connected to it through the resistor is positive. If not, switch the connections around. Once the positive lead has been found, label it with a small piece of tape and remove the temporary connections. Leave the 1500-Ω resistor attached to the positive lead of the LED.

Step 2

Install the new plug on the end of the adapter wire that was cut. Unthread the cover of the 3.5-mm plug and slip it over the adapter wires (Figure 3). Connect and solder the positive lead from the adapter to the centre post of the plug. Connect and solder the other lead to the side post. The side post should also be crimped over the wire casing for extra security using the lugs provided. If using plugs with metal covers, ensure that they do not come in contact with the positive post when threading back on. Replace cover.

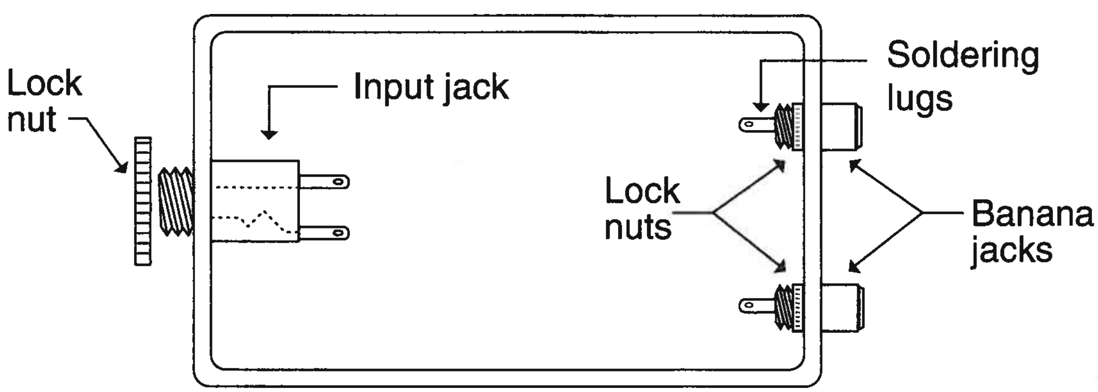
Figure 3.



Step 3

Drill a hole in the centre of one end of the experimental box large enough to install the 3.5-mm input jack. Drill two holes on the other end of the box and install the banana jacks. The soldering lugs on the banana jacks may have to be bent out (Figure 4).

Figure 4.



Step 4

Take a thin sheet of steel or aluminum (approximately 2.5 x 6 cm) and drill a hole to bolt the transistor at one end, and another hole to bolt it to the experimental box at the other end. Bend it into a “Z” shape to make a heat sink, as shown in Figure 5. Transistors can become quite hot when in use, so this metal will act as a radiating surface, dissipating the heat. Transistors often come with mica washers in order to isolate them electrically from heat sinks or metal enclosures. Heat sinks can be bought, but they are easily made. If only a metal experimental box is available, ensure that the heat sink is isolated from the box.

Use a small countersunk machine bolt to attach the heat sink to the experimental box. The leads to the transistor should not make contact with the heat sink. Do not bolt the transistor too tightly to the heat sink because it is delicate. Place the transistor and heat sink about 3 cm from the input jack (Figure 5).

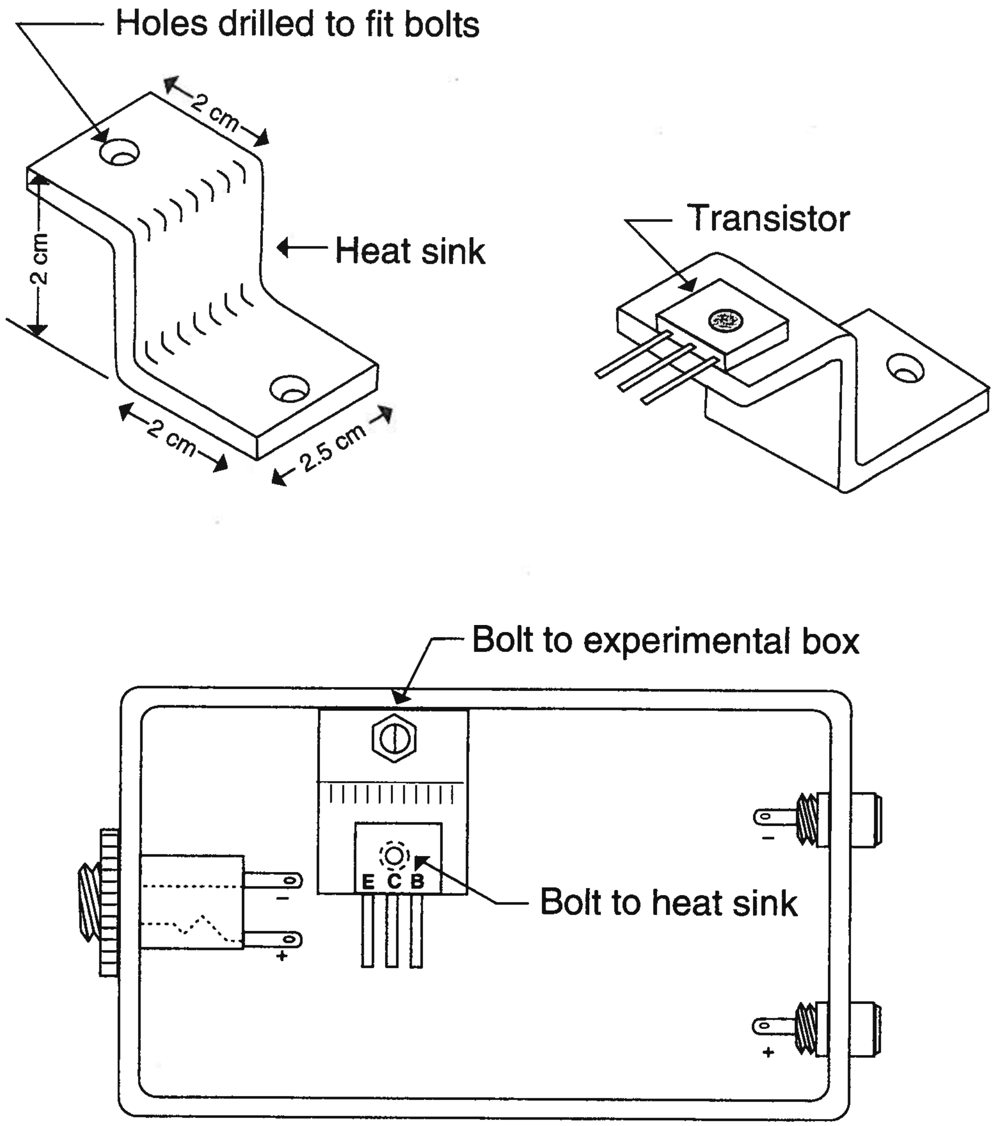


Figure 5.

Step 5

The rotary switch comes with a much longer shaft than needed. Grip the shaft in a vise and cut it off with a hacksaw, 1 cm from the threads. This will leave enough room to secure the knob. Using pliers, bend the tab down on the rotary switch (Figure 6).

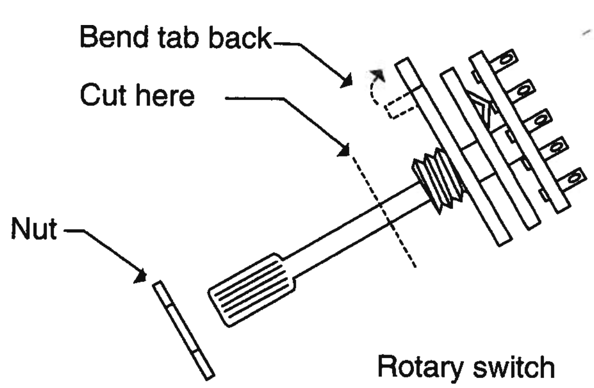


Figure 6.

Drill a hole in the lid of the experimental box just large enough to allow the threads of the rotary switch to pass through. Place this hole closer to the side of the box containing the banana jack because space will be needed for the resistors and switch. Drill a second hole where the LED will be mounted (Figure 7a). The hole should be drilled to accommodate a plastic snap-in LED holder or a surface-mount-type LED as appropriate (Figure 7b). This light can be placed anywhere, but do not allow it, when the lid is closed, to come into contact with other components. Add a 15-cm-long hook-up wire to the LED leads so that the box can be opened easily. Attach these wires with solder as described below.

Figure 7a.

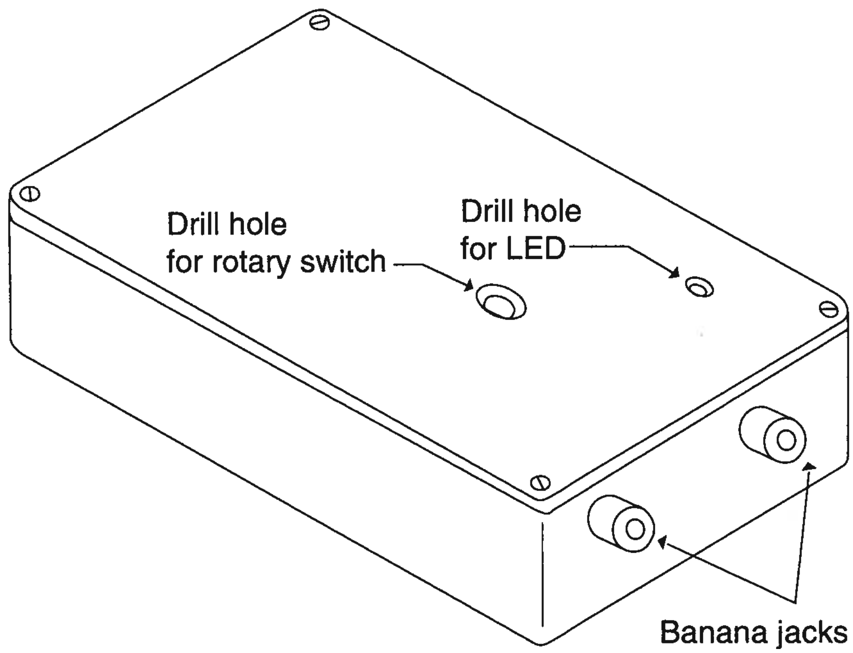
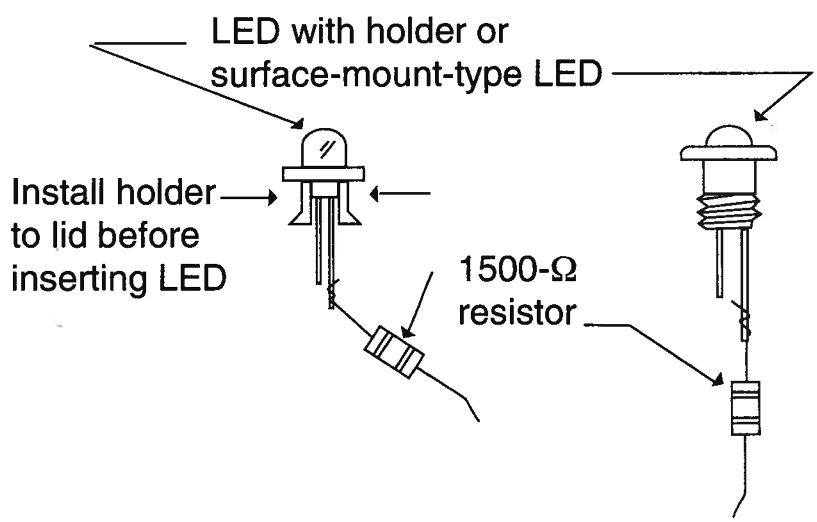


Figure 7b.



Step 6

All connections from here onwards should first be made mechanically by crimping the wires in place with pliers. Only after all connections have been made and checked for errors should they be soldered.

Remove fuse from fuse holder. Connect one lead of the fuse holder to the positive post of the input jack, and connect the other lead to the positive (red) banana jack. A length of hook-up wire may have to be added in order to reach the positive banana jack (Figure 8a).

Figure 8a.

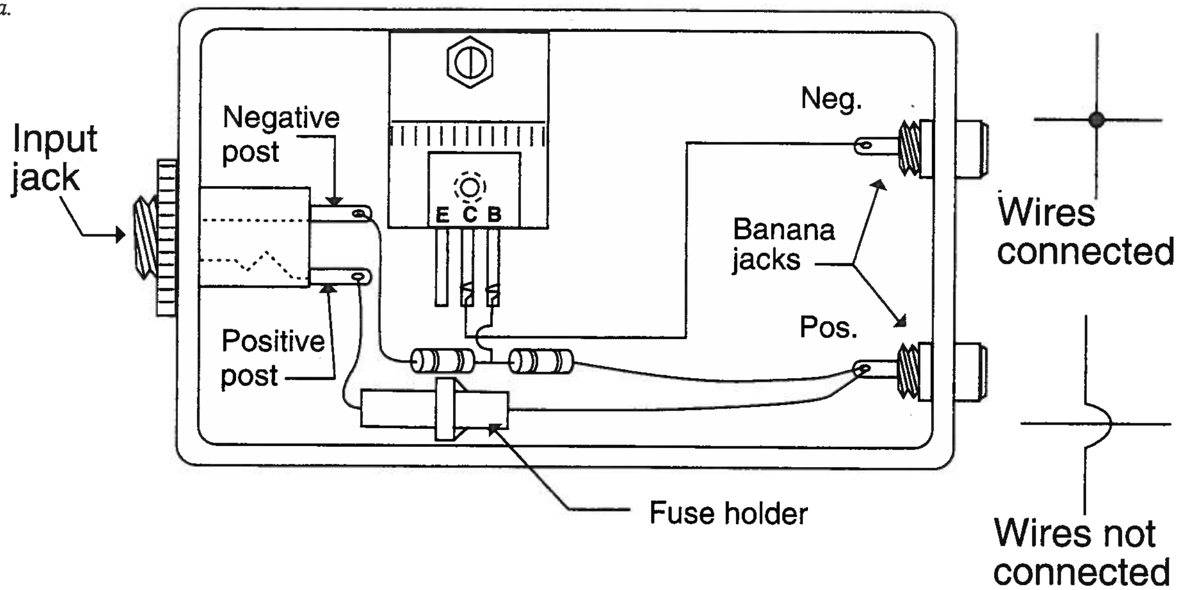


Figure 8b.

two 1500-Ω resistors connected in series

Step 7
Connect two 1500-Ω resistors in series (i.e., end-to-end) (Figure 8b), then connect one lead of the series resistors to the negative post of the input jack, and the other lead to the positive post of the banana jack (Figure 8a). A length of hook-up wire will also be required here.

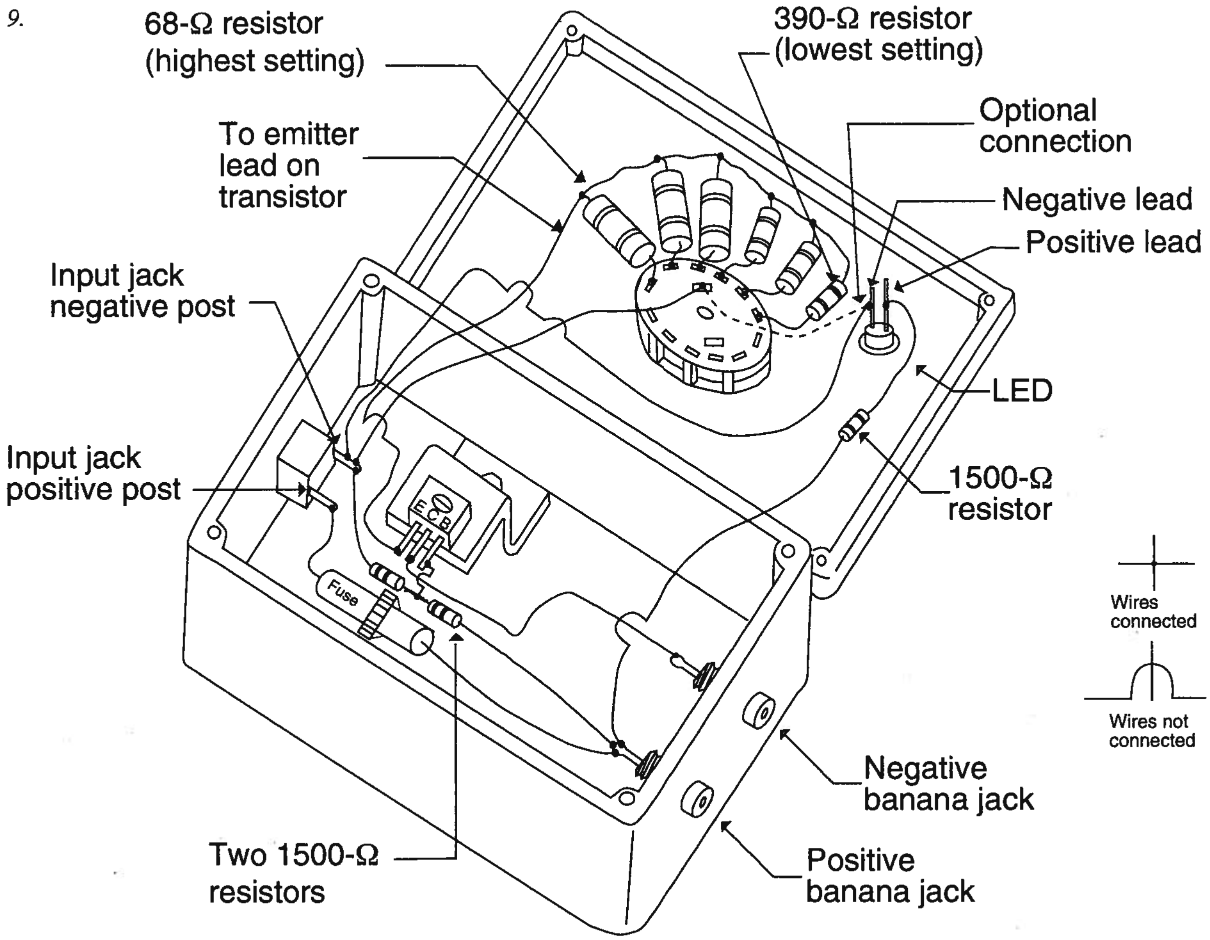
Step 8
Once the pin layout of the transistor (emitter, connector, base terminals or leads) has been established (as described in "Description of Main Components"), connect a small piece of hook-up wire from the base lead of the transistor to the middle of the two 1500-Ω resistors. Take a length of hook-up wire and make a connection from the collector lead of the transistor to the negative (black) post of the banana jack (Figure 8a).

Step 9
If the 1500-Ω resistor is not already attached to the *positive* lead of the LED (see Step 1), attach it now. Install the LED on the lid. Connect the positive lead of the LED resistor to the positive (red) banana jack. Connect the negative lead of the LED to the negative post of the input jack. Another option is to connect the negative post of the LED to the negative post of the rotary switch (Figure 9).

Step 10
With the rotary switch secured to the lid, install the resistors. Small resistors are colour coded according to their value. However, temporarily labelling them with a small piece of tape will help keep things organized. Connect each resistor to an outside post of the rotary switch starting with the 390-Ω resistor, which is the lowest current setting. Then connect the next lowest value of resistor. Repeat this procedure for all resistors. Be careful not to confuse the ohm values with the wattage values. The resistor leads can be cut a little shorter where required in order to prevent bare wires from touching one another. This makes the circuit neater and easier to troubleshoot.

If a two-pole rotary switch is being used (the most common kind), ensure that the pole being connected matches the six settings to which the resistors have been attached. This can be checked with a multimeter set on the continuity setting. Once the resistors are connected to the rotary switch, join the leads of all the resistors together (Figure 9). Connect a 15-cm length of hook-up wire from the joined resistors to the emitter lead of the transistor. Connect another 10-cm length of hook-up wire from the centre post of the rotary switch to the negative post of the input jack (Figure 9).

Figure 9.



Step 11

After carefully checking all connections, apply the solder on all connections requiring it. Install the 1-A fuse in the fuse holder and close the lid, making sure that the resistor leads are not touching one another or any other components. Electrical tape may be required to insulate exposed wire. Install the knob on the rotary switch. Plug the input plug into the input jack and the adapter into the wall outlet, and if everything is correct, the LED should be glowing.

Step 12

If a more portable application is required, the a.c./d.c. adaptor can be replaced with a 9- or 12-V battery. In this case, attach a 3.5-mm plug (to match the input jack) to a length of two-conductor wire, similar to that supplied with the a.c./d.c. adaptor. The other ends of the wire are connected to the battery by various means, depending upon the particular pole configuration of the positive and negative terminals of the battery. Alligator clips are the most versatile option.

Testing

To test the unit, a corroded nail and a small quantity of electrolyte are needed. The electrolyte is a 2–3% solution of either sodium hydroxide or sodium carbonate. Wrap a small piece of cotton batting around the tip of the positive test probe (the anode), and connect the negative test probe to the corroded nail (the cathode), either by holding it or by using an alligator clip. Wet the cotton batting with electrolyte and apply this to the corroded nail, or place a drop of electrolyte on the area being treated and touch the cotton-covered anode to the drop. [Make sure that only the wet cotton batting touches the corroded surface; if the anode is allowed to touch the nail directly no electrochemical reaction will occur.] With the current knob on its lowest setting, a few hydrogen bubbles should be visible around the cathode. Try the other settings to see if they are all working. Increased hydrogen evolution should be observed as the current increases.

If the current output is too high for a particular application, even at the lowest setting, it can be scaled down by using an a.c./d.c. adapter with a lower voltage output. Make sure that the adapter chosen has a current output of at least 300 mA. Some adapters are available with a switch that selects various voltages, usually from 3 to 9 V in 1.5-V increments.

The anode will become oxidized after some use and will have to be cleaned regularly with steel wool. Alternatively, a stainless steel needle can be connected by means of an alligator clip.

To complete the assembly of the power supply, labels must be applied to mark the switch settings. The values for each switch setting (measured in milliamperes) will vary depending on the tolerances of the resistors and the voltage of the a.c./d.c. adapter. Testing with a multimeter will give the exact current levels, but if one is not available, the following values will be close enough. Starting with the lowest setting the values are: 20, 40, 60, 80, 95, and 110 mA.

Troubleshooting

If the unit fails to work, follow this checklist in order:

1. Test all connections to see if any are loose, and check for "dry" joints, that is, where the solder failed to flow properly.
2. Ensure uninsulated wires are not touching one another in places where they should be separated.
3. Ensure that all positive and negative connections are correct throughout the circuit.
4. If a two-pole rotary switch has been used, ensure the correct poles have been selected.
5. Ensure the fuse is in place and is working.
6. Ensure that resistors of the proper value or rate are in the correct locations.
7. Ensure that the leads of the transistor are connected correctly.

Conclusion

This electrolysis power supply is fairly easy to construct and very economical to build (about CAN$75). Its small size makes it convenient to use. It is intended for short duration use in spot electrolysis applications, but it can also serve as the power supply for a small electrolysis tank, or for small electroplating applications. By replacing the a.c./d.c. adapter with a 9- or 12-V battery, it is easily transportable for field use. The ability to limit the current output during electrolysis provides the conservator with much greater control over the rate of reaction and provides additional safety for the artifact being treated.

Acknowledgements

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Further Reading

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