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Introduction

This describes all parts and instructions necessary to assemble a 16 channel fast scan cyclic voltammetry system. Please note that this manual is periodically being updated with more through instructions and pictures and therefore some sections are incomplete.
System Setup
Computer and LabVIEW

Parts List

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>eBay or Newegg</td>
<td>n/a</td>
<td>HP Z420 Workstation E5-1620 Quad Core*</td>
<td>1</td>
<td>n/a</td>
</tr>
<tr>
<td>National Instruments</td>
<td>781100-01</td>
<td>PCIe-7841 R Series Card</td>
<td>2</td>
<td>$5,035.00</td>
</tr>
<tr>
<td>National Instruments</td>
<td>776249-03</td>
<td>RTSI Bus Cables</td>
<td>1</td>
<td>$65.00</td>
</tr>
<tr>
<td>National Instruments</td>
<td>189588-02</td>
<td>SHC68-68-RMIO Multifunction Cable for R Series - 2 meters (used later)</td>
<td>2</td>
<td>$228.00</td>
</tr>
</tbody>
</table>

Note: we understand that the computer listed is a legacy model and will need to be ordered from a 3rd party vendor through Newegg, eBay, etc. We apologize for this inconvenience, but we have not found another computer model that is 100% compatible with our code. Other computers have worked, but after ~45 minutes of continuous recording the data becomes corrupted, which requires the program to be restarted.
Installation Instructions

**Step 1: Installing the PCIe-7841r Cards and RTSI Cable**

With the computer off, install the PCIe-7841r cards in to the appropriate PCIe slots in the computer. It helps to keep a slot between them as this makes installing the RTSI cable easier. Note the serial number of the cards (Figure 1, red arrow) and which position the cards are in relative to one another.

Next, install the RTSI cable (Figure 1, blue arrow) to connect the cards together. The choice of connectors to use and the overall orientation do not matter. The image here shows the installation of 2 cards, but 4 are possible for 32 channels; however, the 4-channel RTSI cable must be purchased instead (National Instruments #776249-04).

![Figure 1 - Installed PCIe-7841r cards connected with a RTSI cable (blue arrow).](image)

**Step 2: Installing the Drivers**

Visit, [https://www.ni.com/en-us/support/downloads/drivers/download.ni-r-series-multifunction-rio.html](https://www.ni.com/en-us/support/downloads/drivers/download.ni-r-series-multifunction-rio.html) and download the latest R-series drivers for Windows. If you don't have an account then create one. Run the setup.exe file and use all of the default settings. Accept the license agreement when asked. Make sure at least one run-time environment (2018 or later) is being installed when prompted with the list of drivers and packages.

After rebooting the computer run the NI MAX program. Click on the arrow next to “Devices and Interfaces”. Then, click on the “RIO0” entry and note the serial number. This will be Card/Board/Cable 0 when referenced throughout the manual. Any other entries
listed will follow the same referencing system. Label the backside of the computer with the RIO number of each card using the previously documented serial numbers and physical positions.
Power
The power supply unit provides power to the headstages, which routes through the Breakout Box. The isolation transformer helps to diminish external line noise and leads to a cleaner overall signal.

Parts List

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDW</td>
<td>184802</td>
<td>Tripp Lite Isolation Transformer 1000W</td>
<td>1</td>
<td>$293.99</td>
</tr>
<tr>
<td>Digikey</td>
<td>BK1672-ND</td>
<td>B&amp;K Precision 1672 Power Supply</td>
<td>1</td>
<td>$489.00</td>
</tr>
<tr>
<td>Digikey</td>
<td>501-1583-ND</td>
<td>Green Banana Plug Cable, 4”</td>
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<td>$5.29</td>
</tr>
<tr>
<td>Digikey</td>
<td>501-1044-ND</td>
<td>Red Banana Plug Cable, 18” (choose best length for lab’s setup)</td>
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<td>$5.89</td>
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<tr>
<td>Digikey</td>
<td>501-1043-ND</td>
<td>Black Banana Plug Cable, 18” (choose best length for lab’s setup)</td>
<td>1</td>
<td>$5.89</td>
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</table>
Assembly Instructions

Step 1: Plugging in the Isolation Transformer and Power Supply
Plug the isolation transformer into a standard 120V wall socket. Next, plug the power supply into one of the isolation transformer's sockets.

Step 2: Connecting the Banana Cables and Setting the Voltage
Replicate the banana plug cables and labeling as seen in Figure 2. Before powering up, set all four dials to their furthest counterclockwise position. Power up the unit and slowly increase each current knob until the respective red CC light turns off and the green CV light turns on. Next, set both voltage dials such that the display reads 15.0V, then power off the unit. Mark on the case where the dials line up with 15.0V (optional).

Figure 2 - Power supply configuration.
Breakout Box

The breakout box is the integrating interface between the NI cards, power supply, headstage/probe, digital inputs, and the stimulus isolator.

Parts List

The quantities listed below are for making a single breakout box.

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Instruments</td>
<td>777145-02</td>
<td>CB-68LPR Unshielded 68-pin I/O Connector Block</td>
<td>2</td>
<td>$129.00</td>
</tr>
<tr>
<td>Grainger</td>
<td>1ME96</td>
<td>#4-40 x 3/ 8&quot; Screw</td>
<td>1 pk</td>
<td>$2.07 (pk)</td>
</tr>
<tr>
<td>Mouser</td>
<td>650-M27500-20SD1T23</td>
<td>20 AWG Wire</td>
<td>30 ft</td>
<td>$1.24 (ft)</td>
</tr>
<tr>
<td>Digikey</td>
<td>225FE-ND</td>
<td>Female D-Sub 25-pin Connector</td>
<td>2</td>
<td>$1.57</td>
</tr>
<tr>
<td>Digikey</td>
<td>377-1210-ND</td>
<td>Shielded Box</td>
<td>1</td>
<td>$113.00</td>
</tr>
<tr>
<td>Digikey</td>
<td>ARF1063-ND</td>
<td>Co-Axial (BNC) Connector</td>
<td>2</td>
<td>$5.33</td>
</tr>
<tr>
<td>Digikey</td>
<td>367-1169-ND</td>
<td>D-Sub Jack Screw</td>
<td>2</td>
<td>$1.40</td>
</tr>
<tr>
<td>Digikey</td>
<td>J151-ND</td>
<td>Red Banana Test Connector</td>
<td>1</td>
<td>$0.93</td>
</tr>
<tr>
<td>Digikey</td>
<td>J152-ND</td>
<td>Black Banana Test Connector</td>
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<td>$0.77</td>
</tr>
<tr>
<td>Digikey</td>
<td>399-14006-ND</td>
<td>0.1uF Ceramic Capacitor</td>
<td>1</td>
<td>$6.40</td>
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<tr>
<td>Digikey</td>
<td>PTF651K0000B YEK-ND</td>
<td>1kΩ Metal Film Resistor</td>
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<td>$4.44</td>
</tr>
<tr>
<td>Digikey</td>
<td>BC4461CT-ND</td>
<td>3kΩ Film Resistor</td>
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<td>$0.29</td>
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<tr>
<td>Digikey</td>
<td>HM1481-ND</td>
<td>Bumper Feet*</td>
<td>1 pk</td>
<td>$9.06 (pk)</td>
</tr>
<tr>
<td>Grainger</td>
<td>1VE49</td>
<td>#6 x 1/4&quot; Sheet Metal Screw*</td>
<td>1 pk</td>
<td>$3.50 (pk)</td>
</tr>
</tbody>
</table>

*Optional purchase

Required Tools and Supplies:
- Soldering iron, solder, and flux (Grainger #1UYJ2)
- Wire strippers (22 AWG) and cutters
- Dremel (or other rotary saw capable of cutting metal)
- Drill with metal compatible bits (1/8", 1/2", and 9/16")
- Phillips screwdriver (P1)
- Flathead screwdriver (3mm)

Optional Tools and Supplies:
- Heat gun and heat shrink tubing (recommended sizes: 3/32" and 1/8") or liquid insulation (GC-Electronics #10-1762)
- Label maker
- Precision knife (for removing tubing)
- Helping hands soldering aid, clamps, pliers (for holding and manipulating wires while soldering)
- 100% isopropyl alcohol (IPA)
## Channel Mapping

<table>
<thead>
<tr>
<th>Screw Terminal (J#)</th>
<th>DB25 Pin</th>
<th>Channel Number</th>
<th>Screw Terminal (J#)</th>
<th>DB25 Pin</th>
<th>Channel Number</th>
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<tbody>
<tr>
<td>J68</td>
<td>DB1-6</td>
<td>1</td>
<td>J68</td>
<td>DB1-10</td>
<td>9</td>
</tr>
<tr>
<td>J66</td>
<td>DB1-8</td>
<td>2</td>
<td>J66</td>
<td>DB1-11</td>
<td>10</td>
</tr>
<tr>
<td>J65</td>
<td>DB1-18</td>
<td>3</td>
<td>J65</td>
<td>DB1-12</td>
<td>11</td>
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<tr>
<td>J63</td>
<td>DB1-20</td>
<td>4</td>
<td>J63</td>
<td>DB1-13</td>
<td>12</td>
</tr>
<tr>
<td>J62</td>
<td>DB1-1</td>
<td>5</td>
<td>J62</td>
<td>DB1-15</td>
<td>13</td>
</tr>
<tr>
<td>J60</td>
<td>DB1-2</td>
<td>6</td>
<td>J60</td>
<td>DB1-16</td>
<td>14</td>
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<td>J59</td>
<td>DB1-3</td>
<td>7</td>
<td>J59</td>
<td>DB1-17</td>
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<td>J57</td>
<td>DB1-4</td>
<td>8</td>
<td>J57</td>
<td>DB1-19</td>
<td>16</td>
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</tbody>
</table>
**Wire Labels**

Below is a sheet of wire labels that may be helpful in keeping wires organized while building. The labels are written such that the route of the wire is readily available (i.e. the label “B0 J68 | DB1-6” would indicate the wire’s path from block 0, terminal J68 to the 6 pin on the DB25 port).

<table>
<thead>
<tr>
<th>Block</th>
<th>Terminal</th>
<th>Port</th>
<th>Block</th>
<th>Terminal</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>B0</td>
<td>J68</td>
<td>DB1-6</td>
<td>B1</td>
<td>J68</td>
<td>DB1-10</td>
</tr>
<tr>
<td>B0</td>
<td>J66</td>
<td>DB1-8</td>
<td>B1</td>
<td>J66</td>
<td>DB1-11</td>
</tr>
<tr>
<td>B0</td>
<td>J65</td>
<td>DB1-18</td>
<td>B1</td>
<td>J65</td>
<td>DB1-12</td>
</tr>
<tr>
<td>B0</td>
<td>J63</td>
<td>DB1-20</td>
<td>B1</td>
<td>J63</td>
<td>DB1-13</td>
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<tr>
<td>B0</td>
<td>J62</td>
<td>DB1-1</td>
<td>B1</td>
<td>J62</td>
<td>DB1-15</td>
</tr>
<tr>
<td>B0</td>
<td>J60</td>
<td>DB1-2</td>
<td>B1</td>
<td>J60</td>
<td>DB1-16</td>
</tr>
<tr>
<td>B0</td>
<td>J59</td>
<td>DB1-3</td>
<td>B1</td>
<td>J59</td>
<td>DB1-17</td>
</tr>
<tr>
<td>B0</td>
<td>J57</td>
<td>DB1-4</td>
<td>B1</td>
<td>J57</td>
<td>DB1-19</td>
</tr>
<tr>
<td>B0</td>
<td>J51</td>
<td>3 kΩ RESISTOR</td>
<td>B1</td>
<td>J10</td>
<td>DB2-8</td>
</tr>
<tr>
<td>B0</td>
<td>J48</td>
<td>TO STIM ISO (+)</td>
<td>B1</td>
<td>J43</td>
<td>DB2-7</td>
</tr>
<tr>
<td>B0</td>
<td>J42</td>
<td>TO STIM ISO (-)</td>
<td>B1</td>
<td>J42</td>
<td>DB2-6</td>
</tr>
<tr>
<td>B0</td>
<td>J14</td>
<td>TO STIM ISO (-)</td>
<td>B1</td>
<td>J41</td>
<td>DB2-5</td>
</tr>
<tr>
<td>B0</td>
<td>J17</td>
<td>GND</td>
<td>B1</td>
<td>J40</td>
<td>DB2-4</td>
</tr>
<tr>
<td>B0</td>
<td>J17</td>
<td>FILTER</td>
<td>B1</td>
<td>J39</td>
<td>DB2-3</td>
</tr>
<tr>
<td>B0</td>
<td>J17</td>
<td>FILTER</td>
<td>B1</td>
<td>J38</td>
<td>DB2-2</td>
</tr>
<tr>
<td>B0</td>
<td>J17</td>
<td>FILTER</td>
<td>B1</td>
<td>J37</td>
<td>DB2-1</td>
</tr>
<tr>
<td>B1</td>
<td>J3</td>
<td>DB2-22</td>
<td>B1</td>
<td>J3</td>
<td>DB2-22</td>
</tr>
<tr>
<td>B1</td>
<td>J17</td>
<td>FILTER</td>
<td>B1</td>
<td>J23</td>
<td>DB1-23</td>
</tr>
<tr>
<td>B1</td>
<td>J17</td>
<td>FILTER</td>
<td>B1</td>
<td>J24</td>
<td>DB1-24</td>
</tr>
<tr>
<td>IN</td>
<td>(RAMP)</td>
<td>DB1-14</td>
<td>V+ (+15V)</td>
<td>DB1-5</td>
<td>V- (-15V)</td>
</tr>
</tbody>
</table>
Wiring Diagram
This diagram can be taped to the inside of the lid of the box for quick reference
Assembly Instructions

Step 1: Cutting the Box

The box design that will be shown in this manual will follow this layout, with gray areas representing the vertical walls of the shielded box, and the connector blocks and power on the same side of the box as the pre-drilled vents (Figure 3). This layout is not mandatory, however this guide will focus on the design below.

![Figure 3 - Layout schematic (left) and resulting box (right).]

Tips for cutting the box:
- Remove the panel from the box and prop on between steady surfaces (i.e. wood blocks) as the metal is malleable and will bend under the pressure of the drill/Dremel.
- Trace out the cuts directly on the panels for precise cuts. Clean the box with IPA to remove any stray marks later.
- Be aware of how high the cuts need to be as the NI connector blocks may sit at different heights depending on what size standoffs are used.
- Hand turn a larger drill bit on drilled holes to clean up the edges and allow for connectors to sit flush with the box.

Connector Blocks: Cut a 6.5cm x 1cm hole with additional 7mm x 2mm linear cut on the bottom edge to allow for the connector to latch to the box without adding additional stress to the connector block. The NI connector blocks have a groove on the top edge of the connector (Figure 4). By feeding this through the hole and latching it, the connector blocks will stay in place and make for an easier and more secure connection (Figure 4).
The bottom of the box also needs to be drilled in order to hold the NI Connector Blocks firmly in place. Drill 4 holes (using 1/8” drill bit) for each connector block so that the middle of the standoffs (that should have been included with the NI Connector blocks upon arrival) will match. To mark the area to drill, secure the panel with the connector block holes cut out in place. Then latch the connector block in the hole and mark around the base of the standoffs with a pencil to mark the drill hole placement. (see Appendix for a template that can be aligned under the connector block and taped in place for easy drilling).

Once the holes have been drilled, use the #4-40 screws to secure both connector blocks (Figure 5). The box is shipped with 4 self-adhesive bumper feet, adding those to the bottom of the box at this point will prevent the screws from scratching work surfaces and allow for a steady surface to work with when soldering.

**DB25**: Cut a 4cm x 1cm hole.

**Banana Jacks and Stim Iso Ports**: Cut a 1cm radius hole for each.

NOTE: One banana jack is used to ground the box. This can also be accomplished by directly grounding to the box; however, the metal of the box will need to be exposed from under the paint via use of a dremel or sand paper for a proper connection.
Step 2: Soldering DB25 Port

Measure out 22 pieces of 30cm of wire for each DB25 connection that will be able to reach its designated screw terminal. Labeling the wires at this point will help to keep the box organized. Strip the insulation and shielding from the tips of the wires. It's recommended to strip the outside insulation 3/8" and the inner insulation 1/8". Solder a wire in place for every DB25 pin that is designated on the Wiring Map. As a quick reference all pins except 21, 22, and 25 will be assigned a wire. While not required, 10-15mm length of shrink tubing (3/32") or liquid insulation can be used on these connections if so desired.

IMPORTANT: Do not tin both ends of these wires at this point. Wires that will terminate at the connector block screw terminals should not be tinned as the screw terminals will put additional stress on tinned wires and may cause them to break over time.

Step 3: Soldering the Power, Banana Jack, and Stim Iso Ports

Secure the BNC connectors for the Stim Iso ports, banana jack, and DB25 connector in place within the box. Keeping the panels separated from the box will make soldering easier. Solder the connections on the Stim Iso ports as described in Figure 7. Use 1/8" shrink tubing on the Stim Iso ports and the banana jacks to insulate the wider connections and 3/32" shrink tubing to insulate the thinner connections.
Figure 7 - Each Stim Iso Port is one BNC connector with the center (tip) pin shown on the chart as the positive terminal, and the ring (ground) tab as the negative terminal. Soldered BNC (left) and schematic (right).

It is recommended to color code the banana jacks with red being for positive, black for negative, and green for the ground. The ground wire will be routed to the banana jack and block 1 terminal J17. The positive jack will be routed to DB25 #1 pin 5 and the negative jack will be routed to DB25 #1 pin 9 (Figure 8).

Figure 8 - Banana jacks from outside of the box.

Step 4: Creating the Reference Wire

Cut eight 8cm and six 5cm pieces of wire; these will reach between the reference terminals on the connector blocks and route by following the wiring diagram. Use longer pieces between terminals that are further apart and shorter pieces for terminals that are closer to each other. Because multiple wires will be assigned to the same terminal, stripping a longer length of the outer insulation away from the wire than the inner insulation will allow for more wires to fit in with minimal stress to the wire tips (Figure 9).
Step 5: Wiring the DB25 to the Connector block

Route each wire from the DB25 connector to its respective terminal on the connector block. Bundling wires that go to the same connector block will help keep them sorted and out of the way while matching them to their respective terminals. In this guide, blue masking tape was used for easier visibility in this guide (Figure 10).

IMPORTANT: It is not recommended to solder or tin wires going into the screw terminal, as the pressure exerted by the screw will cause the solder to flow over time and may cause the wires to become brittle and break.
Step 6: Building the Analog Filter

The analog filter is constructed using a 1kΩ resistor soldered in parallel with a 0.1μF capacitor. Assembling the filter (Figure 11) outside of the box and then making the final solder to DB25 pin 14 before routing the rest of the wires to their appropriate terminals will make this step much easier and lessen the chances of burning insulation off of other wires. Four 20cm lengths of wire should be enough to reach each screw terminal on both boards. A shorter length, 5-7cm, will be enough to make the connection between the 3kΩ resistor and the analog filter.
Final Touches

Below are some suggestions to finish off the box:

- Label ports inside/outside the box (channels, polarity of ports, etc.)
- Tie wire bunches together to keep them together
- If not done so already add bumper feet to keep the box elevated so the screws on the bottom do not drag on surfaces.
- If shrink tubing was used, be sure to check that all junctions with the tubing have been properly shrunk to size.
Breakout Box to Headstage Cable

This cable connects the breakout box to the headstage. It carries the signals for the 16 individual channels, supply voltage, reference (GND), and input (Ramp). In addition, it can carry the stimulation signal supplied by an external source that routes through the breakout box.

Parts List

The quantities listed below are for making a single cable.

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digikey</td>
<td>225ME-ND</td>
<td>Male D-Sub 25-pin Connector</td>
<td>1</td>
<td>$1.42</td>
</tr>
<tr>
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<td>925UAE-ND</td>
<td>D-Sub Enclosure</td>
<td>1</td>
<td>$10.93</td>
</tr>
<tr>
<td>Digikey</td>
<td>MB24S-50-ND</td>
<td>24 Conductor Wire Bundle (50')</td>
<td>1</td>
<td>$147.01</td>
</tr>
<tr>
<td>Grainger</td>
<td>22KY60</td>
<td>1/16&quot; ID Heat Shrink Tubing (25')</td>
<td>1</td>
<td>$11.45</td>
</tr>
<tr>
<td>Omnetics</td>
<td>A79029-001</td>
<td>36 Position Dual Row Female Nano-Miniature with 18.0&quot; 34 AWG Lead-Wire - Omnetics Breakout‡</td>
<td>1</td>
<td>$104.44</td>
</tr>
<tr>
<td>Mouser</td>
<td>992-DB25F-TERM</td>
<td>DB25 Female Breakout Board</td>
<td>1</td>
<td>$15.74</td>
</tr>
</tbody>
</table>

‡Typically has a 6-8 week lead time. Prices are based on the minimum quantity needed to reach the vendor’s $200 per part minimum order. Contact the vendor directly for the most up to date pricing.

Required Tools and Supplies:

- Razor blade
- Small pointed scissors (Grainger #22UN25 or similar)
- Wire strippers (28 AWG) and cutters
- Source of fire (candle, blowtorch, Bunsen burner, etc.) or hot-tweezers
- Fine tip soldering iron, solder, and flux
- Multimeter capable of detecting continuity/shorts
- Heat gun

Optional Tools and Supplies:

- Interface Board
- Wooden block
- Removable mounting putty
- Hot glue gun
Cable Mapping

Below is the standard wire mapping for the cable. This mapping does not include the colors from the Omnetics connector cable as there are repetitions in the colors. How to properly map and connect this the Omnetics cable will be covered in the assembly instructions.

<table>
<thead>
<tr>
<th>System Channel</th>
<th>24 Wire Bundle Color (Major – Minor)</th>
<th>DB25 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Black – Blue</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Red – Blue</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Black – Red</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Blue – Black</td>
<td>4</td>
</tr>
<tr>
<td>V+ (+15V)</td>
<td>Blue – Red</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>Black – Green</td>
<td>6</td>
</tr>
<tr>
<td>REF2 (GND)</td>
<td>Red – White</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Brown – Black</td>
<td>8</td>
</tr>
<tr>
<td>V- (-15V)</td>
<td>Yellow – Black</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>White – Black</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>Black – Yellow</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>Green – Red</td>
<td>12</td>
</tr>
<tr>
<td>12</td>
<td>Green – Black</td>
<td>13</td>
</tr>
<tr>
<td>In (Ramp)</td>
<td>White – Red</td>
<td>14</td>
</tr>
<tr>
<td>13</td>
<td>Red – Black</td>
<td>15</td>
</tr>
<tr>
<td>14</td>
<td>Black – White</td>
<td>16</td>
</tr>
<tr>
<td>15</td>
<td>Orange – Black</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>Brown – Red</td>
<td>18</td>
</tr>
<tr>
<td>16</td>
<td>Red – Brown</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>Red – Green</td>
<td>20</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>21</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>22</td>
</tr>
<tr>
<td>From Stim +</td>
<td>Yellow – Red</td>
<td>23</td>
</tr>
<tr>
<td>From Stim -</td>
<td>Red – Yellow</td>
<td>24</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>25</td>
</tr>
</tbody>
</table>

**Un-used wires:** Black – Orange and Black – Brown.
Omnetics Breakout Connector Mapping

Below is the mapping for the Omnetics breakout connector. The numbering and lettering correspond to the system channels column in the Cable Mapping table.

R2 = Electrochemistry Reference
In = Ramp Signal
Assembly Instructions

Step 1: Preparing the 24 Wire Bundle

First, cut the 24 wire bundle to the overall desired length. From one end remove 4cm of primary insulation (razor blade), braided mesh (scissors), and foil (scissors). Separate the wires and strip away 4-5mm of insulation from each individual wire. Cut away the black-orange and black-brown wires (major-minor colors). If the stimulation signal is not going to be routed through the cable then the yellow-red and red-yellow wires can be cut away. After stripping the insulation, tin the exposed wire by twisting the ends, dipping them into flux, and applying a small amount of solder (Figure 12).

![Cut, stripped, and tinned wires for DB25 connector end.](image)

At the other end of the 24-wire bundle, remove the desired length of primary insulation, braided mesh, and foil. For freely moving animal experiments we recommend exposing 8-12” as this minimizes the amount of torque on the animal. Separate the wires, **but leave the red-white and white-red pair twisted**, and strip away 4-5mm of insulation from each individual wire. Cut away the black-orange and black-brown wires (major-minor colors). If the stimulation signal is not going to be routed through the cable then the yellow-red and red-yellow wires can be cut away. After stripping the insulation, tin the exposed wire by twisting the ends, dipping them into flux, and applying a small amount of solder (Figure 13).
Step 2: Preparing the Omnetics Breakout Wires

To prepare the Omnetics breakout wires, first remove the unused wires. Flipping the connector to the backside (no lettering showing) remove all but the two left most wires (Figure 14). Save these cut wires to use for practice when removing insulation. Lastly, trim the remaining wires to the desired length. For freely moving animal experiments, we recommend leaving the wires at their original length as this minimizes the amount of torque on the animal.
To remove the insulation from the Omnetics breakout wires a flame is the quickest method. This can be a small blowtorch, candle, Bunsen burner, etc.; the key requirement is that it is hands free once lit. Using the saved wires from before, practice removing the insulation by passing the wire through the flame. The extreme heat will cause the insulation to contract. Once 4-6mm can be consistently exposed, apply this technique to the actual bundle (Figure 15). Alternatively, use a set of hot-tweezers to strip away the insulation.
Step 3: Soldering the 24 Wire Bundle to the Male DB25 Connector

Before soldering the wires to the DB25 connector, thread on the D-sub enclosure’s cable slot entry tab (Figure 16, red arrow). Using the Cable Mapping table, solder each colored wire to the corresponding DB25 connector pin. A wooden block with putty can help during soldering (Figure 16).

![Figure 16 - Wires soldered to DB25 connector with threaded cable slot entry tab (red arrow).](image)

Step 4A: Soldering System Channels 1-16, V+, and V-

Plug the DB25 male connector into the DB25 female breakout board, which will make checking for continuity easier. If the Interface Board is available, then plug the Omnetics breakout connector into that (lettering on both connectors should be facing in the same direction). For connections, reference the Cable Mapping table and interface board or the Omnetics Breakout Connector Mapping diagram if the interface board is not available.

Pre-thread all wires (except for red-white and white-red wires) with 2cm pieces shrink tubing. If the wires are too short to do this without the tubing coming off, then thread each wire just before soldering.

Starting with the Omnetics wires, isolate system channel 2 wire. From the 24-wire bundle isolate the brown-black wire. Solder these two wires together (Figure 17). Using the multimeter’s continuity setting (see the multimeter’s manual for this information), check the continuity by touching one probe to the female breakout board’s pin 8 and the
other probe to the interface board’s via labeled 2 (Figure 18). Alternatively, touch the probe directly to the corresponding Omnetics pin. If touching just one Omnetics pin is problematic, then insert a 30GA needle into the pin and then touch the probe to the needle. If the meter beeps, then continue connecting the wires using the Cable Mapping table and interface board or the Omnetics Breakout Connector Mapping diagram if the interface board is not available. DO NOT solder REF2 (GND) and In (Ramp), red-white and white-red, respectively. If the multimeter does not have a continuity setting, then measure the resistance and look for values less than 0.5Ω.

![Figure 17 - System channels 2 and 3 connected to brown-black and brown-red wires, respectively. Once soldered, the Omnetics wires can be removed from the putty. Not shown, already threaded shrink tubing.](image-url)
Step 4B: Soldering System Channels REF2 (GND) and In (Ramp)

Before connecting REF2 (GND) and In (Ramp), the Omnetics wires for these signals need to be twisted together (Figure 19). This helps to reduce noise.

Once the Omnetics wires are twisted together, thread the shrink tubing on the red-white and white-red wires, and make the appropriate solder connections.

Step 5: Attaching a Stimulation Electrode

If using a stimulation electrode follow the same procedure in the previous steps. Make sure the stimulation electrode reaches beyond the end of the Omnetics connector by about 2-3” to account for the height of the headstage. If necessary, add in additional wire (cut away black-brown and black-orange can be used here).

Step 6: Shrink the Tubing

After all continuity checks have been made, shrink the tubing around the solder joints using a heat gun (Figure 20).
Step 7: Testing the Cable

Test the cable functionality by using a dummy cell. If everything checks out, proceed to the next step. If not, double-check the connections which might require cutting away the tubing and re-soldering.

Step 8: Finalizing the Cable

After the cable has gone through the final checks, the ends can be secured with hot glue. At the DB25 end, after securing the cable slot entry tab in its slot and pushing the wires away from the screw holes, apply hot glue (Figure 21). Wait for the glue to harden before letting go of the cable. Before securing the cover, drop in the cable slot block tab and jackscrews. In this assembly, the strain relief screws and spring are not used, as this is accomplished by the hot glue.
Figure 21 - Wires secured in D-Sub enclosure using hot glue. Also note the addition of the cable slot block tab (bottom left) and jackscrews (threaded through the DB25 connector).

After closing the housing, more hot glue can be applied where the cable exits, for additional reinforcement (Figure 22).

Figure 22 - Hot glue applied to cable slot entry tab for additional reinforcement.
At the Omnetics end, hot glue can be applied to provide both strain relief and a grasping point when handling the cable (Figure 23).

*Figure 23 - Hot glue applied to Omnetics end of the cable to provide strain relief and a grasping point.*
Interface Board

The interface board is used to test electrical connections when assembling the Breakout Box to Headstage Cable.

Parts List

The quantities listed below are for making a single board.

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custom PCB</td>
<td></td>
<td>16CH FSCV Interface Board (click link to access files)</td>
<td>1</td>
<td>Will vary by manufacturer</td>
</tr>
<tr>
<td>Omnetics</td>
<td>A79024-001</td>
<td>36 Position Dual Row Male Nano-Miniature Connector ‡</td>
<td>1</td>
<td>$62.75</td>
</tr>
</tbody>
</table>

‡Typically has a 6-8 week lead time. Prices are based on the minimum quantity needed to reach the vendor’s $200 per part minimum order. Contact the vendor directly for the most up to date pricing.

Required Tools and Supplies:

- Soldering iron with a fine tip (0.1-0.2mm), solder, and flux (Grainger #1UYJ2)
- 2-part epoxy (Grainger #1FBG8)
- Mixing dish
- 1mL syringe with a 23G needle or a cotton tip applicator

Optional Tools and Supplies:

- Forceps
- 100% isopropyl alcohol (IPA)
- Cleaning brush cut to ~5mm (Digikey #473-1048-ND)
Assembly Instructions

Step 1: Ordering the Custom PCB

If not already done so, order the custom PCB by following the link in the parts list. The download contains design files, specifications, and manufacturing instructions.

Step 2: Soldering the Omnetics Connector

Apply a small amount of solder to the lower row’s (corresponding to the Omnetics connector’s outer/top pins) two corner pads that lead to channel 2 and V-. Position the Omnetics connector on top of the soldered pads and reapply heat to solder the pins to their respective pads. Solder the remaining outer pins to their respective pads.

To solder the inner pins, first place some solder on the iron’s tip. Then gently push the iron tip through the outer pins to reach the inner pins. Repeat this process for the remaining inner pins. If an outer pin bends out of place, reposition it using a pair of forceps. Clean the pins and pads with 100% IPA.

Step 3: Securing the Omnetics Pins

Mix up some 2-part epoxy. Pull the mixture into a 1mL syringe, wipe the excess from the tip and threads, and firmly attach a 23G needle. Gently push the epoxy out through the needle and apply it to the Omnetics pins (Figure 24, red arrow). Applying too much force will cause the needle to come off the syringe. Alternatively, use the wooden end of a cotton tip applicator to apply the epoxy. Let the epoxy cure overnight.

Figure 24 - Interface board with Omnetics pins secured with 2-part epoxy.
**Headstage**

This headstage connects to the array on one end and to the Breakout Box to Headstage Cable on the other end.

**Parts List**

The quantities listed below are for making a single board. Quantities required may be greater than the number of boards being assembled as many assembly houses require extra parts.

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
</tr>
</thead>
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<tr>
<td>Custom PCB</td>
<td>16CH FSCV Headstage (click link to access files)</td>
<td>1</td>
<td>Will vary by manufacturer</td>
<td></td>
</tr>
<tr>
<td>Omnetics</td>
<td>A79024-001</td>
<td>36 Position Dual Row Male Nano-Miniature Connector ‡</td>
<td>1</td>
<td>$87.18</td>
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<tr>
<td>Omnetics</td>
<td>A79041-001</td>
<td>18 Position Dual Row Female Nano-Miniature Connector ‡</td>
<td>1</td>
<td>$34.63</td>
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<tr>
<td>Digikep</td>
<td>ADA4062-4ACPZ-R7DKR-ND</td>
<td>4 Channel J-FET Amplifier Circuit*</td>
<td>4</td>
<td>$3.21</td>
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<tr>
<td>Digikep</td>
<td>490-3104-6-ND</td>
<td>6pF Capacitor*</td>
<td>16</td>
<td>$0.085</td>
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<tr>
<td>Digikep</td>
<td>541-4.99MLDKR-ND</td>
<td>4.99Ω Resistor*</td>
<td>16</td>
<td>$0.038</td>
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<td>Digikep</td>
<td>490-5920-6-ND</td>
<td>0.1uF Capacitor*</td>
<td>2</td>
<td>$0.10</td>
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<tr>
<td>Newark</td>
<td>82K7797</td>
<td>Gold Pin</td>
<td>1 pk</td>
<td>$9.89 (pk)</td>
</tr>
</tbody>
</table>

‡Typically has a 6-8 week lead time. Prices are based on the minimum quantity needed to reach the vendor’s $200 per part minimum order. Contact them directly for the most up to date pricing.

*Part numbers for these items are for Digi-Reel packaging, which is required by the assembly house.

**Required Tools and Supplies:**

- Soldering iron with a fine tip (0.1-0.2mm), solder, and flux (Grainger #1UYJ2)
- 2-part epoxy (Grainger #1FBG8)
- Mixing dish
- Stiff wire no larger than 0.5mm in diameter. An ideal source are the resistor and capacitor lead trimmings from the Dummy Cell assembly.
- Wire cutters
- 1mL syringe with a 23G needle or a cotton tip applicator

**Optional Tools and Supplies:**

- Helping hands soldering aid
- Forceps
Assembly Instructions
The instructions below assume that the boards were manufactured by PCBWay and that the assembly will be performed by Screaming Circuits.

Step 1: Ordering Supplies
If not already done so, order supplies according to the quantity of boards being assembled and following Screaming Circuits’ rules for extra parts.

Step 2: Ordering the Custom PCB
If not already done so, order the custom PCB by following the link in the parts list. The download contains design files, specifications, and manufacturing instructions.

Step 3: Requesting Panelized Gerber Files
After your boards have been made, message the manufacturer and ask for the panelized Gerber files. Once received, place these files in the folder Assembly Files, which can be found by following the custom PCB link in the parts list.

Step 4: Generating a Quote
Visit Scream Circuits’ website and start a quote either directly through the link on the home page or create an account and then start. Enter the following technical information when prompted. Other fields not listed below (e.g. pricing, contact info, etc.) are to be entered by the individual generating the quote.

- Assembly Quote
  - Quantity: Multiples of 10 minus any PCBs marked as defective
  - Unique Part Count (BOM Lines): 6
  - Total Placements: 40
  - Thru Hole Placements: 0
  - BGA / QFN: Yes
  - Double Sided: Yes
    - What part types apply to this?: Check SMT
  - RoHS, Class III, ITAR: No

- PCB Fabrication Quote
  - Choose, Or skip fabrication sourcing, I'll source my own boards

- Parts Quote
  - Choose, Or skip part sourcing, I'll provide my own parts

- Project Files
  - Please select your preference for sending your files: I will upload my files now.
    - Zip the folder, Assembly Files, which must contain the panelized Gerber files and the existing parts lists, and upload.
- **Kitted Information**
  - Describe the box’s contents: All components and panelized PCBs
- **Starting Your Order**
  - It is likely the purchase is being made through a university and a formal quote must be generated. If that is the case choose, ‘request a formal quote’, at the bottom and proceed accordingly.

**Step 5: Packaging and Mailing Supplies**

Everything on the parts list except the gold pins will be mailed. Label the boxes of the A79041-001 and A79024-001 Omnetics connectors, S1 and S2, respectively. The remaining components should already have labels on them that indicate the manufacturer and manufacturer part number (not the Digikey part number). If this information is missing then add it.

Follow Screaming Circuits’ instructions for packing parts. Send the items to the provided address and be sure to include the order number in the address.

**Step 6: inspecting the headstages**

After receiving the headstages back from the assembly house, check that the pins of the Omnetics connectors are properly soldered to the board. This can be done by gently pushing against the pins using a pair of forceps. If any of the pins are loose, try to repair the solder joint using a soldering iron. It is critical that the iron is applied to the pins for a minimal amount of time as excess heat can travel to the amplifiers and damage them.

After checking the solder joints, an optional check on the quality of the assembly is to connect the headstages to the FSCV system with a dummy cell. This test can sometimes, but not always, point to which channels are problematic and can be potentially fixed by repairing a poor solder connection. As the Omnetics pins have not been secured with epoxy at this stage, connecting and disconnecting of the headstage should be done with extreme care. In addition, the internal reference switch on the dummy cell should be utilized during this test as the external reference pin has yet to be attached.

**Step 7: Securing the Omnetics Pins**

Mix up some 2-part epoxy. Pull the mixture into a 1mL syringe, wipe the excess from the tip and threads, and firmly attach a 23G needle. Gently push the epoxy out through the needle and apply it to the Omnetics pins at both ends (Figure 25, red arrows). Applying too much force will cause the needle to come off the syringe. Alternatively, use the wooden end of a cotton tip applicator to apply the epoxy. Let the epoxy cure overnight.
Step 8: Assembling and Attaching the Reference Pin

Insert a small piece of wire into the reference pin and solder the two together (Figure 26).

Next, insert the reference pin and wire assembly into either of the holes marked REF2 at the bottom of the headstage (Figure 27). Solder the assembly to the board from the underside and cut away the excess wire.
Figure 27 - Reference pin assembly attached to the headstage.
**Dummy Cell**

The dummy cell is used to simulate an array of electrodes. This can be useful for system debugging, headstage testing, and overall noise reduction.

**Parts List**

The quantities listed below are for making a single board.

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
</tr>
</thead>
<tbody>
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<td>Custom PCB</td>
<td></td>
<td>16CH FSCV Dummy Cell (click link to access files)</td>
<td>1</td>
<td>Will vary by manufacturer</td>
</tr>
<tr>
<td>Omnetics</td>
<td>A79040-001</td>
<td>18 Position Dual Row Male Nano-Miniature Connector ‡</td>
<td>1</td>
<td>$35.08</td>
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<td>Digikey</td>
<td>CKN10721DKR-ND</td>
<td>Slide Switch SPDT</td>
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<tr>
<td>Digikey</td>
<td>CF14JT33K0CT-ND</td>
<td>33kΩ Resistor</td>
<td>16</td>
<td>$0.40</td>
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<tr>
<td>Digikey</td>
<td>BC1072CT-ND</td>
<td>1000pF Capacitor</td>
<td>16</td>
<td>$0.167</td>
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<tr>
<td>Newark</td>
<td>82K7797</td>
<td>Gold Pin</td>
<td>1 pk</td>
<td>$9.89 (pk)</td>
</tr>
</tbody>
</table>

‡Typically has a 6-8 week lead time. Prices are based on the minimum quantity needed to reach the vendor’s $200 per part minimum order. Contact them directly for the most up to date pricing.

**Required Tools and Supplies:**

- Soldering iron with a fine tip (0.1-0.2mm), solder, and flux (Grainger #1UYJ2)
- 2-part epoxy (Grainger #1FBG8)
- Mixing dish
- Wire cutters
- Masking tape

**Optional Tools and Supplies:**

- Helping hands soldering aid
- 100% isopropyl alcohol (IPA)
- Cleaning brush cut to ~5mm (Digikey #473-1048-ND)
Assembly Instructions

Step 1: Ordering the Custom PCB
If not already done so, order the custom PCB by following the link in the parts list. The download contains design files, specifications, and manufacturing instructions.

Step 2: Soldering the Omnetics Connector
Apply a small amount of solder to the lower row’s (corresponding to the Omnetics connector’s outer/top pins) two corner pads. Position the Omnetics connector on top of the soldered pads and reapply heat to solder the pins to their respective pads. Solder the remaining outer pins to their respective pads.

To solder the inner pins, first place some solder on the iron’s tip. Then gently push the iron tip through the outer pins to reach the inner pins. Repeat this process for the remaining inner pins. If an outer pin bends out of place, reposition it using a pair of forceps. Clean the pins and pads with 100% IPA.

Step 3: Securing the Omnetics Pins
Mix up some 2-part epoxy. Pull the mixture into a 1mL syringe, wipe the excess from the tip and threads, and firmly attach a 23G needle. Gently push the epoxy out through the needle and apply it to the Omnetics pins (Figure 28, red arrow). Applying too much force will cause the needle to come off the syringe. Alternatively, use the wooden end of a cotton tip applicator to apply the epoxy. Let the epoxy cure overnight.

![Figure 28 - Dummy cell with Omnetics pins secured with 2-part epoxy.](image)

Step 4: Soldering the Slide Switch
Apply a small amount of solder to the single pad closest to the long edge of the board. Position the switch on the top of the pads and reapply heat to the soldered pad to secure the switch’s pin. Solder the other two pins to their respective pads (Figure 29, red arrow).
Figure 29 - Dummy cell with a soldered slide switch.

Step 5: Soldering the Resistors and Capacitors

Bend the legs of the resistors so that they easily fit through their respective holes and allow the resistor to lay flat (Figure 30).

Figure 30 - Dummy cell populated with resistors.

Solder the resistors from the top side and then cut away excess wires from the bottom side. Next, push the capacitors through their respective holes which should not require any bending of the legs. After populating the capacitors, temporarily secure them to the board with a strip of tape (Figure 31). Flip the board over, solder the capacitors, cut away excess wires, and remove the tape.
**Step 6: Assembling and Attaching the Reference Pin**

Insert a small piece of wire into the reference pin and solder the two together (Figure 32).

Next, insert the reference pin and wire assembly into the hole at the top left of the board (Figure 33, red arrow). Solder the assembly to the board from the underside and cut away the excess wire.
Figure 33 - Reference pin assembly attached to the dummy cell.
Reference Jumper Wire

The reference jumper wire connects the headstage's reference pin to an implanted reference electrode or to the reference pin on a Dummy Cell. The pins on both the headstage and reference electrode or dummy cell should be the type listed below.

Parts List

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
<th>UNIT COST</th>
</tr>
</thead>
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<td>Digikey</td>
<td>A3049R-100-ND</td>
<td>26 AWG Wire</td>
<td>1</td>
<td>$42.46</td>
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<tr>
<td>Grainger</td>
<td>22KY60</td>
<td>1/16” ID Heat Shrink Tubing (25’),</td>
<td>1</td>
<td>$11.45</td>
</tr>
<tr>
<td>Newark</td>
<td>82K7797</td>
<td>Gold Pin</td>
<td>1 pk</td>
<td>$9.89 (pk)</td>
</tr>
</tbody>
</table>

Required Tools and Supplies:
- Soldering iron, solder, and flux (Grainger #1UYJ2)
- Wire strippers (26 AWG) and cutters
- Heat gun
- Super glue
- Forceps or needle nose pliers

Optional Tools and Supplies:
- Wooden block
- Removable mounting putty
Assembly Instructions

Step 1: Preparing the Wire

First, cut the wire to the overall desired length, typically 6-7cm is enough. From each end, strip away 3-4mm of insulation. After stripping the insulation, tin the exposed wire by twisting the ends, dipping them into flux, and applying a small amount of solder (Figure 34). If the putty and wooden block are available, place the wire in the putty as this will be helpful for subsequent steps. A benefit to using the putty and wooden block is that multiple wires can be prepared simultaneously. Alternatively, use a set of helping hands, provided nothing cuts through or “bites” into the wire.

![Figure 34 - Wire stripped of insulation and tinned ends.](image)

Step 2: Attaching the Gold Pins

Dip the tips of the gold pins into flux and attach one pin to each end of the wire using additional solder (Figure 35).
Step 3: Heat Shrink Tubing

Slip 1.5-2cm lengths of heat shrink tubing over each end of the wire/pin assembly to cover the solder joints. Make sure the end of the tubing and the circular/open portion of the pin are flush if not a bit lower than the opening (Figure 36, red arrows). Use the heat gun to shrink the tubing. Next, apply a small drop of super glue to the transition where the tubing ends and the exposed insulation begins (Figure 36, blue arrows). The glue will help to ensure that the tubing does not shift or loosen over time.
Appendix
FSCV Circuit Diagram

Drilling Template