Vacuum tube projects contain potentially lethal voltages. DO NOT attempt to use these boards unless you are familiar with safe high voltage handling techniques.

Those of us who use vacuum tubes (or valves if you prefer) in our hobby or business will know that research and development before punching chassis can be a difficult task. There are those also that don't punch chassis, but use printed circuit boards for our designs. Creating a chassis or run of circuit boards before a design is proven, can be messy and resource/material wasting task. In the case of printed circuit boards, the chances of the copper foil lifting before the design is complete, is a real risk.

These experimenter circuit boards are designed to be used repeatedly with more soldering/desoldering operations than a standard printed circuit board. Built from heavy duty 2.4mm fibreglass laminate and coated on the solder side against contamination, whether your intentions are for single use for an existing developed project or for use in conjunction with a solderless breadboard or alone as a development unit, the boards will provide you with a trouble free platform for a long time.

FEATURES

- Heavy duty design
- Predrilled to accept 9-pin miniature (noval) or octal PCB mount sockets
- No PCB sockets? No problem! The boards are predrilled for chassis mount socket use with standoffs
- Multiple pads per tube pin
- On board constant current sources/sinks (CCS)
- CCS trimmer pads drilled for most US/EU, vertical/horizontal trimmers
- Room for small heatsink with the CCS
- Pads for potentiometer, one per tube
- Predrilled mounting holes for permanent installation in a project
- Holes will accept up to a standard #6 screw

The following information will help explain the uses and benefits of these features, but is by no means limited to this. With creativity and imagination, there are far greater uses for these boards than can be listed in this simple documentation.
Mounting the sockets

With the case of noval PCB mount sockets, they come in large base and small base. Your board is designed to accept the large base miniature sockets (do not confuse large base with the magnoval 9-pin sockets often used for TV horizontal output tubes or dampers). All new manufacture and most old manufacture pin sizes will fit the board. Some older noval sockets have very large pins and may not fit correctly. If this is all you have, this can be rectified by either pre-soldering extension pins, or redrilling the holes if the pin size does not exceed the pad size. The same rules apply to the octal board, but they have no large or small basing, they are standardized.

Circuit boards with correctly mounted PCB sockets

The Experimenter PCB’s also come with the option of using a chassis mount socket instead of a PCB mount one. There are holes drilled for two sizes of chassis mount socket (large and small mount) for the noval and one size for the standardized octal socket.

You simply solder on bare tinned wire (bus wire is great) onto your socket first, thread it through the appropriate pin holes and screw on the chassis socket as per the pictures below.
Constant Current Source / Sink

When building tube amplifiers with high voltage gain, or balanced differential amplifier or phase splitters, it is advantageous to use a CCS in either the anode or cathode circuit, depending on your requirements. These Experimenter PCB's come with an area for a solid-state CCS to serve the tubes in the signal path.

9-Pin PCB CCS

Octal PCB CCS
Designing tube circuits is far beyond the scope of this simple guide, but there are some simple math formulas to effectively use the CCS availability in your designs.

Why one PNP and one NPN? Or more technically correct, one current source (PNP) and one current sink (NPN). Current sources used on the anode (plate) of a gain tube increase its gain and linearity over the use of a resistor. This configuration is known as an active load. The current source can also be used in small power amplifier output stages as part of a parafeed circuit.

A current sink is used on the cathode of gain stages in differential amplifiers. Many circuits, like balanced microphone or line inputs, or balanced output tube drivers in push pull power amplifiers use a current sink in their common cathodes. This configuration is known as a long tailed pair.

One of the major advantages of any CCS is it provides an infinite load impedance (though in practice it’s closer to anywhere from one to tens of megohms). Secondly, it isolates the power supply rails by that impedance (B+ or ground), greatly increasing the power supply rejection ratio (PSRR) of hum and noise.

Let’s look at the typical schematic diagrams for the CCS:

**Typical CCS Schematic Diagrams**
Values for the components used will depend on a few factors:

- Transistor types chosen
- Current required
- Available voltages present

Let's say for example you wish to use a current source in the plate of a 12AX7A for high gain. You have a supply voltage of 300 volts and want the plate voltage to be at 150 volts and 2mA of plate current.

- Chose the LED's for the bias. If you use the recommended 3mm generic red LED's shown in the schematic, typical forward voltage drop will be between 1.2 and 1.8 volts. Let's assume 1.5 volts.
- Chose the transistor. Q3 will never have that much across it, so it can be 2N3906, 2N4403 or other general purpose PNP transistor. Q4 on the other hand, will bear the brunt of the voltage present. For a low power circuit, like our 2mA example, a 2N6520 will suffice.
- Figure out R5:

The value of this resistor will depend on which voltage you use for the CCS B+ as well as the transistor's hfe. The hfe is the ratio of collector current resulting from a driving base current, at a specific test voltage. Manufacturer's specifications sheets on the transistor will provide this information. Always use the minimum specification for your calculations. If you do not know this information, assume 100. If you have a house marked or other transistor with unknown hfe (bulk packs of transistors from a hobbie store for example), assume much less, as low as 40.

For an example, let's assume you have chosen 2N3906 for Q3 and 2N6520 for Q4. Both transistors will have a hfe of over 100, so let's assume 100. The required base bias current will be:

\[ \text{2mA} / 100 = 20\mu\text{A} \]

To give a little headroom for losses, double this figure to 40\(\mu\text{A}\). This is a good rule of thumb when dealing with any CCS, since we don't live in a perfect world.

Remember we have 2 LED's, each with assumed voltage drops of 1.5V each. The required voltage drop across R5, should you feed it from the high voltage B+ of 300V will be:

\[ 300V - 3V = 297V \]
Then by using simple Ohm's Law, we find the value of R5 to be:

\[ R = \frac{E}{I} \]

or

\[ R = \frac{297}{0.00004} = 7,425,000 \text{ ohms or about 7.5 megohms} \]

This is not a practical value for our circuit, as well as not being a typical 5% resistor value. The next practical value in a tube experimenter's box will likely be 4.7Meg. You can of course, use 1Meg, or even 470K without damaging the transistors. But a rule of thumb for a stable CCS is to *let the transistor's hfe do the work!*

Now we know the current through the resistor and the voltage across the resistor, always double check what power rating will be needed. We use Ohm's Law again:

\[ P = E \times I \]

\[ P = 297 \times 0.00004 = 0.01188 \text{ watts} \]

Looks like an ordinary ¼ watt resistor will suffice, right? Hold on! Look at a typical ¼ watt resistor's maximum voltage handling capacity – it's usually around 200 to 250V. We have 297 volts across this resistor. It may break down and destroy the circuit or worse, cause a fire. Use ½ or a 1 watt resistor in its place, not because you need the power rating, but typical ½ watt resistors breakdown at around or over 300V and 1 watt and higher values, 400 to 500V is typical.

Can we avoid the pitfalls of placing such a large voltage across R5? You bet we can! If you have a lower voltage supply floating around your circuit for pentode screens, say a second B+ of 150V, you can tie the PNP CCS “ground” to that voltage and recalculate the values above for the difference between the two supplies – in this example, the difference would be 150V. You could than use a ¼ watt resistor safely.

- Figure out R4 and R6:

Calculating these resistors will be easier if we first look at it as one resistor for the moment. Let's call this temporary “one resistor”, Rx.

This is the resistance that will determine the current delivered by the CCS. It is very critical and can vary with different characteristics of the transistors, even replacements of the same type! That is why one resistor is made variable to allow fine tuning.
Choosing this resistor is also more difficult, because it's more complex than just making a CCS for 2mA. We want 2mA through the tube, yes, but with the tube's plate at ½ the supply voltage. If we supplied a tube that drew 2mA with 2mA, the plate voltage would be practically zero, because the CCS is delivering 2mA minus the tube's draw of 2mA = null voltage. If however we have the CCS supply 4mA, the tube will draw ½ of that. Half the current = half the supply voltage, which will give us our needed 150V on the plate of our 12AX7A.

A second matter that complicates the choice of resistor, is it depends also on what the base-emitter voltage drop is on Q3. Again, this is variable not only between transistors of the same type, but the current through the base-emitter junction of Q3. Typically this value is around 0.7 volts, but can vary anywhere from 0.65 to 0.8 volts. For our example, we will assume 0.7V for our calculation of Rx. Using Ohm's Law again, we find:

\[ R = \frac{E}{I} \]

or

\[ Rx = \frac{0.7}{0.004} = 175 \text{ ohms} \]

So, for our example, Rx, or the total value of R4 and R6 should nominally be around 175 ohms. Let's create individual values now for R4 and R6.

We want to have some leeway for adjusting the CCS, so R6 is a trimmer. 200 ohms is a typical trimmer value. Midpoint of that 200 ohm trimmer will be 100 ohms. For R4 to complete our calculated Rx value, it would have to be 75 ohms, which is a standard 5% value. Few experimenter's have that value handy, so 68 ohms or 82 ohms will work too.

Why bother with R4 at all? Current limiting. If R4 wasn't there and you accidentally turn the trimmer too far, it will try and shove a very large amount of current into our 12AX7A example. *POOF!* You will have smelly smoke coming from the remains of your CCS and will have seriously shortened the life of your tube (if it didn't already give you a lovely lightning-globe display).

The on board CCS is not limited to such low current applications. There is room for a small heatsink (which would be needed for a parafeed output stage) and in the case of the octal PCB, two pads are provided for Q4 or Q1, since you may have to face the transistor the other way due to basing (pinout), or mount the heatsink towards the rest of the circuitry.
Final Notes on the CCS

While we gave the example for the current source, the PNP CCS, all the math applies to the sink, the NPN CCS. Just substitute the labels R1 for R5, R2 for R4, R3 for R6, Q1 for Q4 and Q2 for Q3.

A common issue is Japanese vs. American transistor basings. A lot of our junk boxes are full of salvaged Japanese transistors, but the CCS pads are for American basings. No problem!

Redressing Japanese transistor leads to fit American pad layouts

Piece of insulating spaghetti
What if you don't need the NPN and want two PNP? Or vice versa? This is easily done by switching components as shown below:

Transforming the NPN CCS Into Another PNP CCS
The POT Pads

On each board, there is a place to wire a potentiometer for use as a volume control. These are carefully placed at the edges, farthest way from the tubes and CCS with the ground rail towards the centre of the board, to provide some static shielding of the audio-active trace.
The Point Connections

Each tube pin comes out to three pads, labeled “P” with a number. There are more towards the board edges. These are general purpose and may be used to directly mount components to the board, or provide a lead out for external chassis or breadboard wiring.

Heater Pads

The 9-pin noval and octal PCB provides special pads for the most commonly used heater connections – pins 4 and 5 on the 9-pin board and 7 and 8 on the octal board. They are specifically placed to minimize hum being induced.

Should your tube require the heaters be fed at different pins, the multi-purpose point connections can be used. If the positioning induces hum into your circuit, try redressing the heater leads by twisting them and leading them out at right-angles to sensitive components. If hum is still present, consider a DC heater supply.

Mounting

The PCB is predrilled with four holes at the corners for permanent mounting. The holes will clear up to a #6 screw and are on 88mm x 148mm centres.

Credits

- Documentation and photographs by Gregg van der Sluys of Classic Valve Design ([http://www.classicvalve.ca](http://www.classicvalve.ca))
- CCS design based on one found in Morgan Jones book, Valve Amplifiers.

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