A VACUUM TUBE CURVE TRACER ADAPTER FOR ALL TEKTRONIX SEMICONDUCTOR CURVE TRACERS
© Dennis Tillman W7pF, dennis@ridesoft.com
Figure 1  Front cover—Tektronix 577 Semiconductor Curve Tracer displaying the characteristic curves of a TRIODE VACUUM TUBE.
AN INEXPENSIVE VACUUM TUBE CURVE TRACER ADAPTER
FOR ALL TEKTRONIX SEMICONDUCTOR CURVE TRACERS
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INTRODUCTION

By combining a Tektronix 575, 576, 577, 5CT1N, or 7CT1N Semiconductor Curve Tracer (SCT) with a vacuum tube tester you can turn your SCT into a universal curve tracer capable of testing vacuum tubes and semiconductors. A small adapter board which can be built for under $80\(^1\) is described in this paper that can be added to many vacuum tube testers to display the characteristic curves of thousands of vacuum tubes on any Tektronix curve tracer. No modifications are necessary to the curve tracer.

John Kobbe designed the original Tektronix 570 Vacuum Tube Curve Tracer more than 60 years ago and a few years later he designed the 575 Semiconductor Curve Tracer. Both of these instruments set the standard for curve tracers for years to come. But the advent of semiconductors meant that many 570s were scrapped by the early 1970s. Today they are quite rare and highly prized instruments.

After 60 years most 575s have been replaced with newer curve tracers. Many have by now passed into the hands of hobbyists. Frequently, they are offered to anyone interested in owning one rather than see them scrapped. This means they can be commonly found at bargain prices. With the adapter described in this paper a 575 (or any of Tektronix' semiconductor curve tracer) becomes a universal curve tracer capable of testing semiconductors and vacuum tubes.

Custom built Vacuum Tube Curve Tracers were almost always inherently limited by the choice of tube sockets and filament voltages they provided. This meant they could often only test a few tube types from the same “tube family”. The *ideal* way to make a Vacuum Tube Curve Tracer (VTCT) is to combine a Semiconductor Curve Tracer (SCT) with an ordinary vacuum tube tester. This has many significant advantages over designing and building your own custom vacuum tube curve tracer:

- The pre-wired test sockets of a tube tester allow the greatest variety of tubes to be tested.
- All of the standard filament voltages are provided by design in every tube tester. It would be impossible to find a transformer that has all these different secondary filament taps today.
- Only a few engineers understood the capabilities and their importance of a curve tracer. As a result they were well cared for and lightly used. For this reason most curve tracers, including 575s, are almost always fully functional and in good shape.
- If you don’t already own a 575 SCT they can be found for less than $50. Since they are too heavy to justify shipping the best place to find them is Craig’s List, or ham radio swap meets. You can place Want Ads in Craig’s List for a 575 curve tracer.
- The 576 and the 577 (storage or non-storage versions) curve tracers are an excellent choice for testing vacuum tubes. They have a higher collector voltage capability that can come in handy when testing power tubes.
- The 5CT1N and 7CT1N were introduced as low cost, simpler, alternatives to full featured curve tracers. They can also be used (with lower total power capability) to test many vacuum tubes.

When combined with a vacuum tube tester, the VTCT adapter described in this paper will turn any Tektronix SCT (575, 576, 577, 5CT1N, or 7CT1N) or Telequipment CT-71 into a universal SCT and VTCT. No changes are necessary to the SCT. It will still test all semiconductors exactly as before.

A working Tektronix 570 curve tracer sells at auction for $5,000 or more. By comparison used vacuum tube testers are readily available for less than $100 on eBay, Craig’s List, at local ham radio swap meets, and local antique radio swap meets. Several years ago I paid $25 for my 575 SCT and $30 for my EICO 667 vacuum tube tester.

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\(^1\) The adapter described in this paper was built entirely from parts available from Mouser (USA) and Farnell / Newark (Europe). A detailed parts list (with part numbers) is included at the end of this paper.
TEKTRONIX CURVE TRACER FEATURE COMPARISON

Table 1  Tektronix and Telequipment¹ Curve Tracers

<table>
<thead>
<tr>
<th>CURVE TRACERS →</th>
<th>570</th>
<th>575 Standard</th>
<th>575 MOD-122C</th>
<th>576 Standard</th>
<th>576 with 176</th>
<th>577 D1 or D2</th>
<th>5CT1N &amp; 7CT1N</th>
<th>CT-71 ¹</th>
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<tr>
<td>HORIZ. VOLTS (MAX)</td>
<td>500V</td>
<td>200V</td>
<td>400V</td>
<td>1,500V</td>
<td>350V</td>
<td>1,600V</td>
<td>300V</td>
<td>1,000V</td>
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<td>1A</td>
<td>0.5A</td>
<td>100mA</td>
<td>8A pulsed</td>
<td>40mA</td>
<td>6mA</td>
<td>10mA</td>
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<tr>
<td>VERT. AMPS / DIV (MIN)</td>
<td>20uA</td>
<td>10uA</td>
<td>10uA</td>
<td>5mA</td>
<td>5mA</td>
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<td>10uA</td>
<td>5nA</td>
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<td>1.0A</td>
<td>200mA</td>
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<td>10mV</td>
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<td>2V</td>
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<tr>
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<td>4 to 12</td>
<td>4 to 12</td>
<td>4 to 12</td>
<td>1 to 10</td>
<td>1 to 10</td>
<td>1 to 10 or 10 to ~95</td>
<td>0 to 10</td>
<td>1 to 10</td>
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<td>+8 steps</td>
<td>none</td>
<td>none</td>
<td>±10X step</td>
<td>±10X step</td>
<td>±10X step</td>
<td>±5X step</td>
<td>±1X step</td>
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<tr>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>HEATER VOLTS</td>
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<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
<td>N/A</td>
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<tr>
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<td>NO</td>
<td>NO</td>
<td>NO</td>
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<tr>
<td>GRATICULE SIZE</td>
<td>10x10 Div.</td>
<td>10x10 Div.</td>
<td>10x10 Div.</td>
<td>10x10 cm</td>
<td>10x10 cm</td>
<td>10x10 cm</td>
<td>10x10 cm</td>
<td>²</td>
</tr>
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<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
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</tr>
</tbody>
</table>

¹ Telequipment CT-71 Curve Tracer. Telequipment is owned by Tektronix.
² Graticule size and storage are determined by the mainframe the 7CT1N and 5CT1N are used in

The 576 and the 577 are the most capable (and the most expensive) vacuum tube curve tracers due to their extensive feature set, very high maximum plate voltage, and wide range of grid voltage steps.

A useful feature of the 577-D1 is CRT Storage. By choosing a storage mainframe such as the 7313, 7514, 7613, 7623, 7633, 7834, or 7934 for the 7CT1N it will also have storage capability. Likewise the 5111, 5113, 5115, or 5441 storage oscilloscopes would add storage capability to the 5CT1N.

The 575 Mod 122C is capable of testing vacuum tubes with 400V at 1A. Its small maximum voltage step is remedied by the X10 and X100 voltage step amplifier of the VTCT Adapter. The 575 has the same capabilities as the 575 Mod 122C except the plate voltage is limited to 200V.

The 5CT1N and the 7CT1N are the least capable due to the limited front panel space, internal volume, and mainframe power limitations. Yet they are capable of 300V plate voltage. Their most significant test limitation is the plate current which is only 6mA at 300V. The 7CT1N is a desirable plugin so it tends to be expensive. The 5CT1N is nearly identical but fewer of them were made so they can be hard to find.

The 575 is the least expensive curve tracer, and the most capable one given its low price and local availability. It is quite large and heavy however.

The Telequipment CT-71 is uncommon but it also works if you remove the triple banana plug from the VTCT and insert the 3 wires directly into the CT-71’s front panel press-in connectors.

TEKTRONIX CURVE TRACERS

Proceeding clockwise from the upper left on the next page is the 570 Vacuum Tube Curve Tracer that made the Tektronix name synonymous with curve tracers, followed by the 575, 576, and 577.

The 5CT1N in a 5110 mainframe is at the top left of the following page and at the top right is a Telequipment CT-71 curve tracer. Telequipment is owned by Tektronix.

Two 7CT1N curve tracer plugins can be seen simultaneously displaying the curves of a 2N5484 N-Channel FET and a 6AU6A Sharp Cutoff Pentode in a 7844 Dual Beam oscilloscope on the back cover.
Figure 2  Clockwise from the upper left: The 570 was the first Tektronix curve tracer; The 575 Transistor Curve Tracer was next followed by the 576 and the 577.
VACUUM TUBE TESTER FEATURE COMPARISON

Tube testers fall into several distinct categories in order of increasing capability. They are: Filament Continuity Tester; Tube Checker; Emission Tester; Parametric Tester; and Mutual Conductance Tester. All but the mutual (or dynamic) conductance testers are too simplistic to serve our purposes. Wikipedia defines a mutual conductance tube tester as:

"one that tests the tube dynamically by applying bias and an AC voltage to the control grid, and measuring the current obtained on the plate (anode), while maintaining the correct DC voltages on the plate and screen. This setup measures the transconductance of the tube, indicated in micromhos."

Connections to the vacuum tube’s electrodes are made via an array of switches or by many more individually wired tube sockets that achieve the same purpose.

The EICO 667 Dynamic Conductance Tube Tester which was used in this paper measures the dynamic conductance (plate conductance, mutual conductance, and emission) of diodes, triodes, tetrodes, and pentodes. The 667 is characterized by a small number of sockets—eight in this case—which are all that are needed to test thousands of different vacuum tubes. The advantages of fewer sockets, such as this tube tester uses (many others take this approach too) are simpler wiring, a smaller footprint, and lower manufacturing cost. The principal disadvantage is a switch matrix of 13 six-position lever switches is needed to connect each of the 13 possible tube pins to the correct heater, plate (anode), screen, and grid voltages. It takes time to configure these switches, and there is a risk of making errors.

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3 Ibid
The most common tube testers available today use the minimal socket count approach. An example of this approach is the EICO 667 used in this paper. This is what it looks like:

![EICO 667 Dynamic Conductance Tube and Transistor Tester](image)

**Figure 4** LEFT: Exterior view of the EICO 667 Dynamic Conductance Tube and Transistor Tester. Note the array of 13 lever switches and the limited number of sockets which is characteristic of the switch-matrix design concept. RIGHT: Interior view: Note the extensive wiring. This is common to all vacuum tube testers.

An alternative design approach is to have as many tube sockets as possible. The advantage to this approach is simpler setup once you locate the correct socket for your tube number which in many cases will share the socket’s pin assignments with a “family” of tubes that have common pin-outs.

Examples of tube testers that take this approach are: B & K Dyna-Quik Model 700, shown in Figure 4, Century Fast Check, and Accurate Instrument Model 257. The disadvantage to this concept is the wiring costs associated with all the sockets and the space they require. Testing is faster since setup is minimized with this design approach which is important when testing many tubes.

![B&K DynaQuik Dynamic Mutual Conductance Tube and Transistor Tester](image)

**Figure 5** B&K DynaQuik Dynamic Mutual Conductance Tube and Transistor Tester. Note the large number of sockets which minimizes test setup time and setup errors.
It is easy to spot which approach the manufacturer took. The tube tester will either have a few sockets, many switches, and a few dials, like the EICO 667, or it will have numerous sockets, few switches, and a few dials like the B&K Dyna-Quik 700. Regardless of the design it will work when connected to an SCT provided it is a mutual (or dynamic) conductance tester. All of the sockets, voltages, and pin connections you need to turn your SCT into a VTCT are already present on a mutual (or dynamic) conductance vacuum tube tester. This means the tedious work has already been done for you.

Finding a suitable vacuum tube tester will be a little harder than finding an SCT because so many more models were made and documentation for each was not as well preserved. Search for the key word “conductance” in the tube tester’s name. SCTs present a simpler challenge because there are only five models to choose from, they all will work, and there is excellent documentation for each of them. Some models that should work are listed at the end of this paper.

Figure 6  EICO 667 tube tester schematic. Note the numerous transformer taps for filament voltages (upper right), the switch matrix (left side). The MERIT switch (middle) is where the VTCT adapter will be connect to the 667.
From the schematic for the 667 it is apparent that the important connections to a diode are: the filament, the cathode, and the plate (anode). A triode adds a control grid to this. A tetrode adds the screen grid. Finally, a pentode adds a space-charge suppressor grid. To test a triode the 575 needs little more than a filament transformer and many quick and simple VTCTs have taken this approach. But generally speaking triodes require larger grid voltage steps than the 575 can provide. This requires amplification of the voltage steps of most Tektronix SCTs by a factor of 10X and, in some cases, even 100X. In addition the amplifier’s output steps must be able to cover a range between +5VDC and -50VDC. This is the first requirement the VTCT adapter must meet.

Tetrodes and pentodes require an additional variable screen grid supply that is capable of supplying at least 200VDC at up to 40mA of screen current each time the plate voltage drops below the screen voltage. This occurs 60 times per second on the 570 VTCT as well as on all Tektronix SCTs. This variable screen supply is the second requirement the VTCT adapter must meet.

THEORY OF OPERATION

For the complete schematic see figure 27 on page 34 of this paper.

There are two functions necessary for a semiconductor curve tracer to test any vacuum tube:

1) A stepped negative DC grid voltage which can go from +10V to -70V to test any tube.
2) A 0V to 300VDC Screen Grid supply capable of providing 4mA on average, and as much as 40mA peak, to test tetrodes and pentodes.

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SCTs do not have a screen grid supply for tetrodes and pentodes. The screen grid improves on the triode as follows according to the RCA Radiotron Designer’s Handbook:

“The function of the screen is to act as an electrostatic shield between the grid and the plate, reducing the grid-to-plate capacitance. The screen is connected to a positive potential (less than the plate) in order to counteract the blocking effect which it would otherwise have on the plate current. Owing to the comparatively large spaces between the wires in the screen, most of the electrons from the cathode pass through the screen to the plate. So long as the plate voltage is

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higher than the screen voltage, the plate current depends primarily on the screen voltage and only to a slight extent on the plate voltage.\(^5\)"

"The plate voltage of pentodes having high plate resistance has only a very minor effect on the plate current, provided that it does not come below the screen voltage.\(^6\)"

The VTCT adapter includes a 0 to 200VDC screen supply. The highest voltage tap in the EICO 667 vacuum tube tester powers this supply so it is currently limited to +200VDC. It must be capable of supplying 20 to 40mA each time during the 60Hz cycle that the collector voltage (which drives the plate) drops to zero. Ideally, the screen supply would be capable of providing +350VDC at 40mA.

Semiconductor curve tracers (SCTs) do not have voltage steps large enough to drive a low-mu triode from full conduction to cutoff. The VTCT adapter includes a Grid Voltage Step Amplifier that has gains of X1, X10 and X100 and an output range of +5VDC to -50VDC for this purpose. The OpAmp is powered by asymmetric +6VDC and -50VDC power supplies. The combined voltage difference from the +6VDC supply and the -50VDC supply of +56VDC is below the 60VDC limit of the OPA551 High Voltage OpAmp. It is important not to exceed this 60V limit with the OPA551 OpAmp.

The +6VDC supply uses D11 as a half wave rectifier from the 9VAC filament tap of the EICO 667. This is filtered by a 220uF capacitor (C11) and regulated by VR1, a 78L06 integrated circuit. It would be desirable to increase the +6VDC to +12VDC to allow the grid to be driven to +10VDC for certain tubes. The OpAmp will have to be replaced with a higher voltage OPA454 before this change can be added.

The -50VDC supply uses D41 as a half wave rectifier from the 70VAC filament tap of the EICO 667. This is filtered by a 100uF capacitor (C41) and fed to the collector of Q41, a high gain (40 < h\(_{\text{FE}}\) < 150), high voltage (V\(_{\text{CEO}}\) = 300V), MJE5731 PNP TO-220 transistor, configured as a simple fixed voltage emitter follower. The base of Q41 is connected to a 51V 1N5369 Zener diode. Ideally it would be desirable to allow the grid to be driven to -70VDC for certain tubes. It will be necessary to replace the OpAmp with a higher voltage OPA454 before this change can be made.

The OpAmp amplifies the base voltage steps from the semiconductor curve tracer, when necessary, by a factor of 10 or 100, or it leaves them unchanged if they are large enough as is to drive the control grid of the vacuum tube. The OpAmp is capable of providing up to -20V grid steps, but at present the maximum negative grid voltage swing is approximately -50VDC.

The 0VDC to +200VDC variable screen grid power supply uses D51 as a half wave rectifier from the 180VAC plate tap of the EICO 667. This is filtered by a 220uF capacitor (C51) and fed to the collector of Q51, a medium gain (30 < h\(_{\text{FE}}\) < 150), high voltage (V\(_{\text{CEO}}\) = 400V), TIP50 NPN TO-220 transistor configured as a simple emitter follower. The base voltage, which can be varied from 0 to 200VDC is provided by a 200V 1N5388 Zener diode which is connected to the top end of the Screen Voltage potentiometer. Varying the pot feeds the base of Q51 with a voltage that varies from 0VDC to 200VDC and the emitter follows this with a 0.7VDC drop. The 200V Digital Panel Meter displays the voltage applied to the screen grid of a pentode. When testing triodes the screen voltage can be set to 0V. A recent improvement (still being evaluated) involved replacing R53 with an E-562 Semitec 5.6mA Constant Current Diode. This compensates for the large positive temperature coefficient of the 1N5388 200V Zener diode improving its voltage stability to <1%.

All of the voltages necessary to power the adapter’s amplifier, screen grid supply, and DPM come from selected transformer taps of the EICO 667.

\(^5\) Ibid, p. 7
\(^6\) Ibid, p. 18
**EICO 667 MODIFICATIONS**

To modify the tube tester to be driven by the signals coming from a Tektronix curve tracer it was necessary to determine where to break the connections going to the grid, the screen and the plate (anode) inside the EICO 667. The filament wiring did not need to change. The cathode is always grounded in this tube tester and it did not change either. So it was only necessary to trace out three voltage paths to break into. It is extremely valuable to have a schematic for your tube tester when you trace these signal paths. Tube testers may be simple in concept but they are all a maze of wires inside. Without a schematic you risk serious injury from dangerous voltages and currents.

In the EICO 667 there is a 6 pole momentary lever-switch called MERIT. The MERIT test is an emission reading for diodes and rectifiers, and a dynamic conductance (combined plate conductance, mutual conductance, and emission) reading for triodes, tetrodes, and pentodes. From the EICO 667 schematic it was apparent that the MERIT switch was the most important wiring point to connect to.

1. The control grid voltage goes through the MERIT lever-switch position F. This grid will be driven by the Base Step Generator of the Tek SCT. The base voltage steps from the SCT will need to be increased 10X or 100X to test triodes and 1X or 10X to test tetrodes and pentodes. Control grid voltage amplification will be provided by a high voltage OpAmp on the adapter PC Board.

2. The screen grid voltage goes through the MERIT lever-switch position E. There is no equivalent connection to the Tektronix SCT. Screen current is normally about 4mA, but it rises sharply if the screen becomes more positive than the plate. This happens for a large part of every collector sweep cycle for all Tektronix SCTs. The screen grid will be powered by a variable 200VDC power supply on the adapter PC Board, capable of supplying up to 40mA for the times when the plate voltage drops below the screen voltage.

   Pentodes are almost unaffected by changes in supply voltage, and the plate current changes little as plate voltage varies. Plate current in a pentode is controlled by the screen grid so this voltage is specified when testing a pentode. A 0 to 200VDC Digital Panel Meter (DPM) is an essential part of the design of this adapter to set and monitor the screen grid voltage specified in the datasheets of pentodes and tetrodes.

3. The plate (anode) voltage goes through the MERIT lever-switch position D. The plate will be driven directly by the Collector Sweep Generator of the SCT.

4. The cathode will be connected directly to the Emitter contact of the curve tracer which is grounded (a Common Emitter configuration). All of the cathodes in the EICO 667 are grounded.

There was little room on the front panel of the 667 for the new controls needed for these modifications. Fortunately the 667 had a transistor tester feature on the front panel that could be appropriated for the new controls. Anyone who owns an SCT will not need the primitive transistor testing capabilities of a tube tester like the EICO 667. So the transistor tester switches and sockets were sacrificed to make room for the new controls on the front panel. This also freed up enough room inside the tube tester for the adapter’s PC Board. The PC Board occupies an absolute minimum amount of space to insure it will fit into any tube tester. It measures 2" W x 2.8" L x 1.32" H (5.1cm x 7.1cm x 3.3cm).

In case the native tube testing capabilities of the EICO 667 turned out to be useful later on a 3 pole double throw (ON—ON) “Transfer” toggle switch was added to permit quick selection of the new VTCT capabilities or the old Dynamic Tube Tester capabilities with the flick of a switch.

**WHAT CAN I EXPECT WITH THE CURVE TRACER I MAY ALREADY OWN?**

Anyone with a Tek SCT probably has the skills and parts needed to add the VTCT adapter to a tube tester and turn their SCT into a universal curve tracer. If you don’t already have an SCT then the most obvious curve tracer to look for is the 575. Since thousands were made they are still abundant, and almost free at this point. The 575’s 200V collector supply is perfectly usable, but the 400V 575 MOD 122C is better. The 576 and 577 are ideal. The 5CT1N and the 7CT1N have limitations which may or
may not be a consideration for your intended application. Their most significant limitations are a 0.5W maximum power; 4 peak voltages (7.5V, 30V, 75V, and 300V), and a short circuit current of 6mA on the 300V range or 24mA on the 75V range.

More importantly, you must accommodate the different front panel wiring of the 5CT1N and the 7CT1N. The base and the collector leads of the adapter must be reversed to work with these two curve tracer plugins to test FETs and tubes. The easiest way to do that is to reverse the wires coming from the tube tester at the triple banana plug that will plug into the E/S, B/D, and C/G banana jacks of the 5CT1N and 7CT1N. If you notice Tek has warned you in advance of the necessary change. Ordinarily the Base would be paired with the Gate (B/G) and the Collector would be paired with the Drain (C/D). If this change is not made the high collector voltages from the SCT will, at the very least, damage the OpAmp on the adapter board.

WHAT YOU WILL NEED TO MAKE THIS VTCT

You need a mutual conductance or dynamic conductance tube tester with a schematic and operating instructions. Each tube tester is different and has different directions but most important is the schematic. There are hundreds (thousands actually) of tube testers on eBay at any one time but they should also be available on Craig’s List (USA), at flea markets, at ham fairs, and at antique radio swap meets. Only buy one if it has documentation and a schematic or you can get them on the internet. $50 to $100 is a reasonable price to pay. They are quite simple in design but they have so many wires it may take a while until you understand where to connect the adapter and mount the new controls.

To be compatible with the VTCT adapter the vacuum tube tester must have a transformer winding of approximately 160VAC (and no more than 180VAC) for the adapter’s screen grid power supply. The rectified voltage from this winding should not exceed 260VDC at TP1. If it does, bad things can happen.

There must also be a transformer winding of approximately 60VAC to 70VAC. The rectified voltage from this winding should not exceed 120VDC at TP4 or bad things may happen. 70VAC is a common filament voltage so all tube tester transformers will have a tap for this.

Finally, there must be a transformer winding of 8 to 11VAC. The rectified voltage from this winding should not exceed 14VDC at TP6. If it does that could be bad. 9.0VAC is a common filament voltage so all tube tester transformers will have this tap. Either one can be used.

Simple machine shop / metal working skills are necessary to make ¼” holes for the Tube Tester / Curve Tracer transfer toggle switch, for the Screen Grid Voltage pot, and for the Step Voltage Gain rotary switch. In addition you will need to make a rectangular hole for the Screen Grid Voltage DPM.

A gold plated printed circuit board, which uses thru-hole component mounting, is available from the author to making building it simple. Anyone with moderate electronic construction experience should be able to assemble the PC board in less than 2 hours. All of the parts, including the PC Board, can be bought for less than $80.00. The Mouser and the Farnell / Newark part numbers are included in the parts list to facilitate ordering. In a few cases I indicated where a Mouser / Farnell / Newark part cost as much as 3 times what you would pay for a similar part bought elsewhere on the internet.

There are three sets of connections on the board. They are all located along one edge and they each have a different number of wires to insure that connectors, if they were used, could not be accidentally inserted on the wrong header pins. Eight troubleshooting test points are brought out along another edge. Five mounting holes are available along a third edge for securing the PC Board to the chassis inside the vacuum tube tester.
TWO CHARACTERISTIC CURVES THIS ADAPTER CAN’T DISPLAY (THE 570 CAN)
The original 570 vacuum tube curve tracer was designed specifically for displaying the characteristic curves of vacuum tubes. Because semiconductors behave differently from vacuum tubes, SCTs do not need to display some of the curves that VTCTs must display. The Operating Instructions section of the 570 Instruction Manual show these additional vacuum tube displays that are unique to the 570:

1. Pentode Screen Current vs. Plate Voltage: None of the SCTs can display this set of curves.
2. Pentode Screen Current vs. Grid Voltage: None of the SCTs can display this set of curves.
3. Plate Current vs. Grid Voltage: Each curve tracer has different capabilities for this set of curves:
   - The 576 and 577 can display this by switching the HORIZ VOLTS/DIV knob to BASE VOLTS or STEP GEN.
   - The 575 can display this by switching the HORIZONTAL VOLTS/DIV knob to BASE SOURCE VOLTS.
   - The 5CT1N and 7CT1N cannot display this.

It would be useful to measure a vacuum tube’s screen current and grid current on an SCT like the 570 does but it would be too complicated and/or too costly to do this.

MATCHING TUBES WITH THE VACUUM TUBE CURVE TRACER
With a simple adapter (or set of adapters) the Vacuum Tube Curve Tracer can be used to match tubes or to confirm the match between separate halves of dual triodes. Figure 22 shows a prototype adapter displaying a pair of 6AU6A pentode curves in a variety of display formats on a 577-D1 Curve Tracer. The storage capability of the 577-D1 makes it easy to display the characteristic curves of two tubes several different ways. NOTE: These adapters must be wired to be compatible with “families” of tubes that share the same pin assignments. Their simple design makes it practical to create adapter variations that will work with other “families” that have different pin outs or that use different sockets.

7-PIN MINIATURE PENTODE MATCHING ADAPTER
A 7-pin miniature tube plug was wired to two 7-pin sockets to demonstrate the ability of the VTCT to match two 6AU6 pentodes. Pins 2, 3, 4, and 7 of the tube plug were connected to the same pins of both 7-pin sockets. The three wires coming from the tube plug that corresponded to the 6AU6’s control grid (pin 1), screen grid (pin 6), and plate (pin 5) were connected to the 3 center contacts of a 3-Pole Double Throw (3PDT ON-OFF-ON) switch. The 3 left contacts of the switch were connected to pins 1, 6, and 5 of the right 7-pin socket and the 3 right contacts of the switch were connected to pins 1, 6, and 5 of the left 7-pin socket. Toggle the 3PDT switch left or right to display the curves of the right or left.

The complete list for every receiving tube base can be found in the Terminal Diagrams Designations section of any RCA Receiving Tube Manual. The list for all the tubes that are pin compatible with the 6AU6 pentode is listed under tube base 7BK (JEDEC No. E7-1), a Small-Button Miniature 7-Pin tube base: It includes the 3AU6, 3BA6, 4AU6, 6AH6, 6AH6WA, 6AK6, 6AU6A, 6AU6WB, 6BA6, 6BD6, 6HR6, 6HS6, 12AC6, 12AF6, 12AU6, 12BA6, 12BD6, 12BL6, 12CX6, 12DZ6, 12EA6, 12EK6, 18GD6A, 19HR6, 19HS6, 19MR9, 26A6, 5749, 6660, 7543, BA6, EF93, EF94, HF93, HF94, M8108, PM04, W727, and XF94.

9-PIN MINIATURE DUAL TRIODE MATCHING ADAPTER
A 9-pin adapter can be made for confirming that the two halves of popular 9-pin miniature tube base (9A or Noval base) dual triode tubes such as the 6AU7, 12AE7, 12AT7, 12AU7, 12AX7, 12BH7,

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8 RCA Receiving Tube Manual RC-30, 8 / 1975, RCA, Distributor and Special Products Division, Cherry Hill Offices, Camden, N. J. 08101, p. 597
12DW7, and ECC83 are matched to name a few. To check that the separate halves are matched the heater pins (pins 4, 5, and 9) are connected to a 9-pin socket from the 9-pin plug. The cathodes on pin 3 and pin 8 are wired together. Pin 7 of the tube plug (the section 1 triode’s grid pin coming from the tube tester) is wired to one center contact of a Double Pole Double Throw (DPDT ON-OFF-ON) toggle switch and pin 6 of the tube plug (the section 1 triode’s plate pin coming from the tube tester) is wired to the other center contact. The two left switch contacts go to pins 7 and 6 respectively of the 9-pin socket. The two right switch contacts go to pins 2 and 1 respectively of the 9-pin socket. To test both halves of the tube set the tube tester up to test the first section of the dual triode. By toggling the switch to the left or right the characteristic curves of each half of the dual triode are displayed on the curve tracer.

OCTAL DUAL TRIODE MATCHING ADAPTER
In similar fashion octal dual triodes such as these members of a pin compatible family consisting of the 6AS7, 6BL7GT, 6BX7, 6SL7GT, and 6SN7GT can be matched using a single octal socket.

IMPRESSIVE RESULTS
The VTCT adapter combines these three elements into a flexible, accurate and repeatable instrument:

- The accuracy of the Tektronix Semiconductor Curve Tracers.
- The ability of a tube tester to test any tube.
- Large grid voltage steps and a variable screen supply.

The resulting curves displayed by the VTCT and adapter are identical to the ones in the manufacturer’s data sheets. The displayed curves are more than accurate enough to be used to make measurements of the three most important parameters of a tube and to identify when a pair of tubes have matching parameters. The most important vacuum tube parameters are:

- **Amplification Factor**: The ratio of change in plate voltage to the change in grid voltage for a constant plate current.
  \[ \mu \equiv \frac{\partial v_p}{\partial v_G} \]

- **Plate Resistance**: The quantity which expresses the ratio of an increment of plate potential to the corresponding increment of plate current when the grid potential is kept constant.
  \[ r_p \equiv \frac{\partial v_p}{\partial i_p} \]

- **Mutual Conductance (Transconductance)**: The quantity which gives the ratio of an increment of plate current to the corresponding increment in grid potential for constant plate potential. It has the units of μSiemens (new 1971 SI unit) or alternatively the old unit, μmhos.
  \[ g_m \equiv \frac{\partial i_p}{\partial v_G} \]

These three parameters are determined by the tube’s internal construction. The three parameters are interrelated by this formula:

\[ \mu = r_p g_m \]

Screen photos showing how to calculate \( \mu, r_p \) and \( g_m \) for a 12B4A triode and for a 6AU6A pentode from the tube’s characteristic curves are at the end of this paper.

The usual orders of magnitudes of the tubes parameters for conventional triodes are approximately:

- \( \mu \): 2.5 to 100 (no units)
- \( r_p \): 0.5Ω to 100,000Ω
- \( g_m \): 500 to 10,000μA / V, or μSiemens (new 1971 SI unit) or, the old unit, μmhos.

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The plate resistance $r_p$, plate-grid transconductance $g_m$, and amplification factor $\mu$ of a pentode are defined exactly as for a triode (but with the suppressor and screen grid held constant)\(^{11}\).

Measurements were performed on several of the screen photographs confirming the ability of the VTCT to display accurate values for $\mu$, $r_p$, and $g_m$ that are in agreement with the published values for these parameters from the tubes datasheet(s).

### ADDITIONAL CONSTRUCTION DETAILS

**VIEW FROM THE OUTSIDE OF THE EICO 667**

![Adapter Front Panel](image)

The VTCT adapter PC Board is mounted in the EICO 667 front panel along with the screen grid voltage DPM and control pot, the Tube Tester / Curve Tracer Transfer switch and the X1 / X10 / X100 Step Voltage Gain switch for amplifying the base steps of the SCT.

**VIEW FROM THE INSIDE OF THE EICO 667**

![Internal view of the VTCT Adapter PC Board, its controls, and the DPM mounted inside the EICO 667 vacuum tube tester.](image)

The front panel for the new controls was made using AlumaJet printable aluminum. The graphic image of the front panel is printed on the AlumaJet using an inkjet printer. More information can be found at [https://alumajet.com/](https://alumajet.com/).

MetalPhoto photo-sensitive anodized aluminum is a similar product. It also works on an ink jet printer. More information can be found at [https://metalphoto.com/](https://metalphoto.com/).

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\(^{11}\) Millman and Halkias, p. 171
INTERCONNECTING CABLING

The VTCT adapter has three sets of connections along one side (the left side in this photograph). In this photo montage you can see that standard 0.1" (2.54mm) center Molex connectors were used to make the three cables removable.

There is a row of 8 pins along the top edge in this photograph. These are test points to assist in troubleshooting.

The Molex connectors and the row of 8 pins are a convenience not a requirement.

If you do use the Molex connectors note that each of the three has a different number of pins (6, 5, and 7 pins). This was done to insure the Molex connectors could not be accidentally interchanged.

From top to bottom the 3 cables are:

6 Wire: Three wires in this cable are connected to the tube tester’s 180VAC, 70VAC and 8VAC transformer windings. The other three wires plus the wire from the curve tracer Collector go to the cathode, grid, screen, and plate connections of each of the lever switches.

5 Wire: Three wires go to the screen voltage adjustment pot. The remaining 2 wires go to the wire from the Curve Tracer Base and its shield.

7 Wire: Three wires go to the Screen Voltage 200V DPM. The remaining 4 wires go to the Grid Voltage Step Gain rotary switch.
FUTURE DIRECTIONS

It would be desirable to increase the range of the voltage step amplifier from the present limits of +5VDC to -50VDC to at least +10VDC to -100VDC. This would allow the VTCT to drive nearly every low-mu triode from saturation to cutoff. The present voltage limitation is due a lack of high voltage OpAmps in DIP packages (which make assembly easy). The current OpAmp, although limited to a 60V output swing has one very important capability – it can operating from asymmetric +6V and -50V power supplies. An OPA454, which is only available in a SO-PowerPAD surface mount package, would be able to provide the desirable +10V / -100V grid voltage range. It will be necessary to evaluate the OPA454 to see if it can handle the +15V / -105V asymmetric power supply voltages this would require.

It would also be desirable to increase the adjustable screen voltage to at least 400V. This represents a greater challenge because there are usually no transformer windings in a vacuum tube tester that can generate that much voltage. A voltage doubler might work in some cases but not in others. For the cases where an appropriate voltage tap is not available for a voltage doubler the only solution may be to add a separate 400V transformer. The 115V winding for the grid voltage step amplifier OpAmp will not be a problem because good vacuum tube testers have a transformer winding for 115V filaments.

At the present time low cost off-the-shelf Chinese DPMs only go to 200VDC. In time the Chinese may start making DPMs for higher voltages.
MAKE AND MODEL TUBE TESTERS TO LOOK FOR

This list of tube testers will continue to change over time. One thing is almost certain however, mutual conductance or dynamic conductance tube testers are the ones to look for. Emission testers are too simplistic inside. As a result they are unacceptable. The following lists can be used as a guide in searching for a suitable tube tester. Here is what the categories mean:

- **TESTED** means just that. They work with the VTCT adapter.
- **SHOULD WORK JUST FINE**: These are mutual conductance or dynamic conductance type tube testers and they should work with the VTCT adapter. Their manuals and/or their schematics contain the proper circuitry. There may be some variation in available voltages that may not be obvious without further examination.
- **UNACCEPTABLE**: These tube testers will not work based on an examination of the manual and/or schematics. Don’t waste any time on them.
- **POSSIBLY GOOD**: These looked promising but the available information was incomplete.
- **MOST LIKELY UNACCEPTABLE**: The available information was discouraging but incomplete so no definitive conclusion was possible.
- **NO INFORMATION**: There is such a make and model but there is no information on it.

### TESTED

<table>
<thead>
<tr>
<th>Tube Tester</th>
<th>Make</th>
</tr>
</thead>
<tbody>
<tr>
<td>EICO 667 Dynamic Conductance T.T.</td>
<td>EICO</td>
</tr>
<tr>
<td>EICO 665 Dynamic Conductance T.T.</td>
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</table>

### SHOULD WORK JUST FINE

<table>
<thead>
<tr>
<th>Tube Tester</th>
<th>Make</th>
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<tbody>
<tr>
<td>B&amp;K 707 Dynamic Mutual Conductance T.T.</td>
<td>B&amp;K</td>
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<tr>
<td>Marconi MU-101 Mutual Conductance T.T.</td>
<td>Marconi</td>
</tr>
<tr>
<td>Mercury Model 1000 Mutual Conductance T.T.</td>
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</tr>
<tr>
<td>Mercury Model 2000 Mutual Conductance T.T.</td>
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</tr>
<tr>
<td>Precise 111 GM and EM T.T.</td>
<td>Precise</td>
</tr>
<tr>
<td>Precise 116 GM and EM T.T.</td>
<td>Precise</td>
</tr>
<tr>
<td>Stark 9-66 Micromho Dynamic Mutual Conductance T.T.</td>
<td>Stark</td>
</tr>
<tr>
<td>Stark 121-22 / 12-22A Dynamic Mutual Conductance T.T.</td>
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</tr>
<tr>
<td>Supreme Model 45 Mutual Conductance Tube Checker</td>
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<tr>
<td>Supreme I-177B Military T.T. (Mutual Conductance)</td>
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<tr>
<td>Triplett Model 3423 Mutual Conductance T.T.</td>
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### POSSIBLY GOOD

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<td>Mercury 990</td>
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### MOST LIKELY UNACCEPTABLE

<table>
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<th>Tube Tester</th>
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</thead>
<tbody>
<tr>
<td>RCA 156</td>
<td>RCA</td>
</tr>
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</table>

### UNACCEPTABLE

<table>
<thead>
<tr>
<th>Tube Tester</th>
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</thead>
<tbody>
<tr>
<td>EICO 625 T.T.</td>
<td>EICO</td>
</tr>
<tr>
<td>Jewell 209, WD-209, 214, 533, 534, 538, 540</td>
<td>Jewell</td>
</tr>
<tr>
<td>Mercury Model 1101</td>
<td>Mercury</td>
</tr>
<tr>
<td>PACO T-60</td>
<td>PACO</td>
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<tr>
<td>Precision 612, 614</td>
<td>Precision</td>
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<tr>
<td>Radio City Products (RCP) 314, 803</td>
<td>Radio</td>
</tr>
<tr>
<td>Sencore TC130 Mighty Mite, TC162 Mighty Mite</td>
<td>Sencore</td>
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<tr>
<td>Simpson Models 325 &amp; 333, 220 &amp; 222</td>
<td>Simpson</td>
</tr>
<tr>
<td>Stark Model 9-11 and 9-55, 9-54T, 9-56, 9-99</td>
<td>Stark</td>
</tr>
<tr>
<td>Triplett 1210 and 1260</td>
<td>Triplett</td>
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### NO INFORMATION

<table>
<thead>
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<th>Make</th>
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<tbody>
<tr>
<td>Sencore TC114 and TC136</td>
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### VTCT ADAPTER PC BOARD EXTERNAL WIRING

<table>
<thead>
<tr>
<th>PC BOARD SIGNAL DESCRIPTION</th>
<th>SIGNAL NAME</th>
<th>PC BOARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>X100 gain position of the Grid Step Rotary Switch</td>
<td>X100 GAIN</td>
<td>X100 GAIN</td>
</tr>
<tr>
<td>X10 gain position of the Grid Step Rotary Switch</td>
<td>X10 GAIN</td>
<td>X10 GAIN</td>
</tr>
<tr>
<td>Unity gain position of the Grid Step Rotary Switch</td>
<td>X1 GAIN</td>
<td>X1 GAIN</td>
</tr>
<tr>
<td>Center lug of the Three Position Grid Step Rotary Switch</td>
<td>POLE</td>
<td>POLE</td>
</tr>
<tr>
<td>+6VDC Power to the Screen Voltage Digital Panel Meter</td>
<td>+6VDC</td>
<td>+6VDC</td>
</tr>
<tr>
<td>Ground for the Screen Voltage Digital Panel Meter</td>
<td>GROUND</td>
<td>GROUND</td>
</tr>
<tr>
<td>Digital Panel Meter Input from Screen Voltage</td>
<td>D.P.M.</td>
<td>D.P.M.</td>
</tr>
<tr>
<td>Connects to the Base Banana Jack of the Tektronix Curve Tracer</td>
<td>BASE</td>
<td>BASE</td>
</tr>
<tr>
<td>Connects to the Emitter Jack of the Tektronix Curve Tracer</td>
<td>GROUND</td>
<td>GROUND</td>
</tr>
<tr>
<td>Connects to the ground side of the Screen Voltage Potentiometer</td>
<td>GROUND</td>
<td>GROUND</td>
</tr>
<tr>
<td>Connects to the wiper of the Screen Voltage Potentiometer</td>
<td>SCREEN ADJ</td>
<td>SCREEN ADJ</td>
</tr>
<tr>
<td>Connects to the high side of the Screen Voltage Potentiometer</td>
<td>+200VDC</td>
<td>+200VDC</td>
</tr>
<tr>
<td>To Screen, Grid, and Cathode connections common to each path</td>
<td>GROUND</td>
<td>GROUND</td>
</tr>
<tr>
<td>Connects to the Screen connection (to all tube sockets)</td>
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<tr>
<td>Connects to the Grid connection (to all tube sockets)</td>
<td>GRID</td>
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<tr>
<td>70VAC from the 70V tap of the tube tester filament voltage selector</td>
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<td>70VAC</td>
</tr>
<tr>
<td>9VAC from the 9V tap of the tube tester filament voltage selector</td>
<td>9.0VAC</td>
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<tr>
<td>180VAC from the plate supply of the tube tester</td>
<td>180VAC</td>
<td>180VAC</td>
</tr>
</tbody>
</table>
TESTING YOUR ASSEMBLED VTCT ADAPTER

There are eight test points on one side of the PC Board. They are there to make it simple to test your work before placing the adapter in a tube tester.

Start by removing the OPA551 OpAmp if you installed it already. This is to protect it until we have confirmed the power supplies are working.

+200VDC REGULATED SUPPLY
1. Connect the ground lead of a DC voltmeter to TP0 (GND).
2. Connect a 100K Screen Voltage Control pot to connections 09 (GND), 10 (ADJ), and 11 (200V).
3. Apply +250VDC to connection 01 (180VAC).
4. Verify that +250VDC appears at TP1 and at TP2.
5. Turn the Screen Voltage Control pot and verify the voltage at TP3 and at connection 18 (SCRN) goes from 0V to +200VDC.
6. Repeat steps 3 through 5 with +220VDC applied to connection 01 (180VAC).
7. Repeat steps 3 through 5 with +280VDC applied to connection 01 (180VAC).
8. Verify the heatsink of Q1 has no voltage on it. It should be isolated from Q1’s collector tab.

-50VDC REGULATED SUPPLY
1. Connect the ground lead of a DC voltmeter to TP0 (GND).
2. Apply -70VDC to connection 03 (70VAC).
3. Verify that -70VDC appears at TP4.
4. Verify that -50VDC appears at TP5 and U21 pin 4.
5. Repeat steps 2 through 4 with -85VDC applied to connection 03 (70VAC).
6. Repeat steps 2 through 4 with -65VDC applied to connection 03 (70VAC).

+6VDC REGULATED SUPPLY
1. Connect the ground lead of a DC voltmeter to TP0 (GND).
2. Apply +9.0VDC to connection 02 (9VAC).
4. Verify that +6.0VDC appears at TP7 and U21 pin 7.
5. Repeat steps 2 through 4 with +11.0VDC applied to connection 02 (9VAC).
6. Repeat steps 2 through 4 with +8.6VDC applied to connection 02 (9VAC).

GRID STEP VOLTAGE AMPLIFIER
1. Connect the single pole three way rotary switch to connections 12 (X100), 13 (X10), 14 (X1) and 15 (POL.).
2. Apply -70VDC and +9VDC to the adapter board.
3. Verify that -50V is present on pin 4 of the OpAmp socket.
4. Verify that +6V is present on pin 7 of the OpAmp socket.
5. Insert U21, the OPA551P OpAmp into its 8 pin socket.
6. Apply a 0.1Vp-p signal to connection 04 (BASE), turn the Grid Step Voltage Amplifier to X1 and confirm that the signal on connection 16 (GRID) is like the input signal and 0.1Vp-p in amplitude.
7. With the Grid Step Voltage Amplifier set to X10 confirm that the signal on connection 16 (GRID) is like the input signal and 1Vp-p in amplitude.
8. With the Grid Step Voltage Amplifier set to X100 confirm that the signal on connection 16 (GRID) is like the input signal and 10Vp-p in amplitude.

0V to 200VDC DIGITAL PANEL METER
1. Connect the DPM to connections 06 (DPM), 07 (GND), and 08 (6V).
2. Verify that it has +6VDC applied to it from the +6V regulator, and a variable 0 to 200VDC voltage applied to it from the Screen Supply.

MISCELLANEOUS
1. Verify the collector lead from the Tektronix curve tracer connects to the plate connection of the tube tester
2. Verify the screen supply from connection 18 (SCRN) of the VTCT adapter connects to the screen connection of the tube tester.
3. Verify the amplified grid voltage amplifier output on connection 16 (GRID) connects to the grid connection of the tube tester.

SCHEMATIC, PARTS LIST, PCB ARTWORK AND ASSEMBLED ADAPTER
The engineering drawings and parts list at the end of this paper should expedite construction of the VTCT adapter. A high quality double sided gold plated printed circuit board is available from the author.

ON-LINE RESOURCES
There are many on-line sites with vacuum tube data sheets and electronic copies of manufacturer’s tube manuals such as:

- Comprehensive List of Tube Data: [http://www.shinjo.info/frank/sheets0.html](http://www.shinjo.info/frank/sheets0.html)
- The National Valve Museum: [http://www.r-type.org/](http://www.r-type.org/)

These sites have many Vacuum Tube Tester Manuals and Schematics. You will need a schematic for your tube tester to be able to wire the adapter into it. A manual is helpful as well. These are the sites:

- Articles about tubes and tube testers: [http://alltubetesters.com/articles.htm](http://alltubetesters.com/articles.htm)
- Tube Tester and Test Equipment Manuals: [http://pacifictv.ca/wanted.htm#testequip](http://pacifictv.ca/wanted.htm#testequip)

These sites provide vacuum tube parts:

- [http://pacifictv.ca/socket.htm](http://pacifictv.ca/socket.htm)
- [https://www.tubesandmore.com/](https://www.tubesandmore.com/)
PHOTO ALBUM
The photographs at the end of this paper illustrate the many different combinations of characteristic curves it is now possible to display with each of the Tektronix Semiconductor Curve Tracers and a vacuum tube tester that has this VTCT adapter in it. Each of the Tektronix SCTs is shown under the same conditions except where indicated. The test setup for tetrodes would have been the same as for pentodes. The test results for a 576 SCT would have been identical to the results for the 577 SCT since they are interchangeable in terms of their capabilities.

SPECIAL THANKS TO ...

George Lydeck built several elegant and simple tube tester designs that were the source of much envy on my part. These inspired me to build my own, and when I was given a 575 my first thought was to base my design on his. George and his co-workers were kind enough to double check my results and to scan this paper for technical errors, omissions, or confusing explanations. During the development of my tube tester, George offered many helpful suggestions. He confirmed some of my results on a 570 curve tracer he has access to where he works. For more information about the very elegant tube tester fixtures George has built, see:

http://glydeck.blogspot.mx/search?updated-min=2012-01-01T00:00:00-08:00&updated-max=2013-01-01T00:00:00-08:00&max-results=8

Scroll halfway down the page to February 21, 2012 to see George’s pentode test fixture. Scroll to the end at January 6, 2012 where he shows his triode test fixture.

Dr. Aris Silzars, My collaborator on so many fascinating projects, kindly loaned me the tubes I used as my unwilling test subjects during the development of the Vacuum Tube Curve Tracer. Most of the tubes are none the worse for wear. A few pentodes and triodes changed to diodes during my testing much to my surprise! The virtual Aris maintains a presence at:

http://www.worldviewofglobalwarming.org/html/about.html

Charles Osborne once told me something that has stuck in my head ever since:

“Man’s creativity is limited by the capacity of his water heater”.

I think of that every time I am in the shower. It was during one of my more “creative” showers that I was struggling with the problem of how to add more filament voltages to George Lydeck’s design and still fit it on the 575 front porch that I had the inspiration to combine a 575 curve tracer and a tube tester into the best of both worlds. Thank you, Charles.

Charles maintains a wonderful site devoted to the RCA Selectron tube, a Selective Electrostatic Storage Tube used as a 4096 bit digital memory in 1940s era computing. This interesting site can be viewed here:

http://rcaselectron.com/index1.html

The TekScopes Forum:
After 16 years on Yahoo the TekScopes Forum moved to Groups.io in 2017. I joined TekScopes 2 years after Michael Dunn created it. Since I joined I have made many friends on TekScopes. I can ask any question I don’t know the answer to and someone somewhere around the world will respond with an answer. Membership is free and it is easy to join. Just go to the TekScopes home page at

https://groups.io/g/TekScopes

At the bottom is the email link to subscribe. Describe your interest in TekScopes or Tektronix and send the email. Approval usually takes less than 24 hours.
Figure 13  Clockwise from upper left: displaying the 6AU6A characteristic curves on a 575, a 577, a 5CT1N plugin, and a 7CT1N plugin. The 6mA current limit and fixed load resistors of the 7CT1N / 5CT1N mean the plate voltage can only swing part way across the CRT for the 0V to -2V grid steps.
Figure 14  Telequipment CT-71 displaying the 12B4A Low Mu Triode characteristic curves. Horizontal 20V / Div., Vertical 2mA / Div., Grid Steps -5V each.

Figure 15  Clockwise from upper left: displaying the 12B4A Low Mu Triode characteristic curves on a 575, a 577, a 5CT1N, and a 7CT1N plugin. Each curve tracer has the same settings. Horizontal: 20V / Div., Vertical: 1mA / Div., Grid Steps: -5V each.
The plate resistance, $r_p$, of the 12B4 is 830Ω. The loops are due to the Miller effect between the collector and base of the prototype.

The 6AU6A pentode’s characteristic curves match the RCA Receiving Tube Manual perfectly.

These are the 12B4 low mu triode curves from the Sylvania Technical Manual.

6AU6A characteristic curves. The dotted line labeled IC2 is the Screen current. As the plate voltage drops below the screen voltage the screen captures all of the plate current.
These are the first measurements made with the VTCT adapter prototype of a triode’s characteristic curves. They confirmed the adapter could make accurate measurements of the triode’s parameters from the characteristic curves. Shielding the base lead fixed the loops in the curves caused by Miller Effect capacitance.
These are the first measurements made with the VTCT adapter prototype of a pentode. This demonstrated to me the ability of the adapter to make accurate measurements of the pentode's parameters directly from the characteristic curves of the tube.
Figure 22  This is the $I_p$ / $V_g$ transfer characteristic of a pentode (Left) and a triode (Right).

Figure 21 shows the relationship between the tangent of the angle $\phi$ of the $I_p$ vs. $V_g$ characteristic curve and the transconductance ($g_m$) of the tube. The linear region of the vacuum tube’s transconductance, $g_m$, is plainly visible where the steps meet the straight line. This is where the plate current is directly proportional to the grid voltage.

- For the pentode (left photo) the linear region is between 0.0V and -2.0V of grid bias.
- The linear region for the triode (right photo) is between 0.0V and -2.5V of grid bias.

These photos were taken on a 577 curve tracer. The 577 has the ability to separate each of its 10 default steps into 10 “micro” steps that cover the same voltage range. With this feature it is possible to apply up to 95 individual steps to a vacuum tube’s grid and make additional measurements like the two shown above. Displaying 100 steps takes 10 times longer than displaying 10 steps. The capability of the 577-D1 to store the slow sweeping trace makes it possible to capture and display all 100 steps at once. The non-storage 575, 576, or 577-D2 require a camera to take a timed exposure.
Figure 23  Clockwise from top left: Prototype Tube Matching Adapter; 6AU6A pentode curves displayed in the upper and lower storage halves of the 577–D1 Storage Curve Tracer; same curves displayed side by side; same curves displayed full screen superimposed on each other. Settings: Horizontal: 50V / Div.; Grid: 1 V / Step; Screen: 200V, Vertical: 10mA / Div. upper right photo, 5 mA / Div. lower left and lower right photos.
Figure 24 Gold plated VTCT Adapter PC Board. Left: Component Side; Right: Solder Side. NOTE: The photograph on the right shows version 1.02 of the PC Board. The changes between v1.02 and v1.04 are cosmetic.

Figure 25 VTCT Adapter version 1.04 PC Board Artwork. Left: Component Side; Right: Solder Side.

Figure 26 Completed VTCT Adapter Board.
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<th>VTCT ADAPTER PARTS LIST</th>
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<th>EAGLE DEVICE / PACKAGE</th>
<th>DESCRIPTION</th>
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<th>US $</th>
<th>FARNELL / NEWARK</th>
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<td>J1  POMONA 2970-0 or 2970-2</td>
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<td>Triple Banana Plug</td>
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<td>J4  265-118ABHE-22</td>
<td>Wakefield-Vette FK-209</td>
<td>TO-220 Heat Sink</td>
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<td>PNP TRANSISTOR</td>
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<td>NPN TRANSISTOR</td>
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<td>R21 499 1/8W 1%</td>
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<td>SW1 1 POLE 3 POSITION</td>
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<td>84</td>
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<td>Available from the author</td>
<td>From the authors</td>
<td>$15.00</td>
<td>Available from the author</td>
<td>$83.43</td>
<td>TOTAL FOR ALL PARTS</td>
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Figure 28  Complete schematic (Version 1.04) of the Vacuum Tube Curve Tracer adapter circuitry.
### Printed Circuit Board (Version 1.04) parts layout.

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<th>BOARD LOCATION</th>
<th>PART NUMBER</th>
<th>SCHEMATIC LOCATION</th>
<th>BOARD LOCATION</th>
<th>PART NUMBER</th>
<th>SCHEMATIC LOCATION</th>
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<td>3D</td>
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<td>6B</td>
<td>1A</td>
<td>D51</td>
<td>2D</td>
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<td>TP5</td>
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<td>1D</td>
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*Figure 29*  Red locations are on the schematic. Green locations are on the PC Board.

*Figure 30*  Printed Circuit Board (Version 1.04) parts layout.
Figure 31  Back cover—Tektronix 7844 Dual Beam Oscilloscope simultaneously displaying the characteristic curves of an N-Channel Field Effect Transistor and a Pentode vacuum tube.
This Tektronix 7844 Dual Beam Oscilloscope* is displaying the characteristic curves of a 2N5484 N-Channel FET in the bottom half of the CRT using Beam 1, and the characteristic curves of a 6AU6A sharp cutoff pentode in the top half of the CRT on Beam 2 using the VTCT adapter described in this paper. Both sets of curves are displayed using 7CT1N Curve Tracer plugins simultaneously to illustrate the similarity between FETs and pentodes.

The measured $g_m$ of the 2N5484 FET is $2.8 \text{mA} / 0.8 \text{V} = 3.5 \text{mSiemens (3,500μmhos)}$. The specification is $3.5 \text{mSiemens}$ minimum.

The measured $g_m$ of the 6AU6A Pentode is $6.0 \text{mA} / 1.5 \text{V} = 4.0 \text{mSiemens (4,000μmhos)}$. The specification is $3.9 \text{mSiemens}$ minimum.

* Note: The simultaneous display and measurement of transistor and vacuum tube parameters can only be performed on a Tektronix 7844 Dual Beam Oscilloscope.