Testing Vacuum Tubes with a Tektronix Model 576 Semiconductor Curve Tracer

Plotting plate current versus plate voltage curves is a useful way to determine the operating characteristics of a vacuum tube. The display of a family of curves shows the characteristics of a tube over the full range of grid and plate voltages. Unlike tube testers that show a simple characteristic such as transconductance at only one operating point, curves show you everything at once. By comparing the characteristic curves to the manufacturer's published data an accurate evaluation can be made of the condition of the tube. For service work in the repair shop a simple test on a tube tester is usually sufficient to determine whether a particular tube is still serviceable but there are times when you need more information than a tube tester can provide. Matching several characteristics of a pair of audio tubes is one example. Another is determining whether a power tube is capable of providing book value output power at maximum design plate current and voltage.

For matching tubes to each other single point comparison of transconductance, plate current or other parameters can be very misleading. Matching is greatly simplified when you can see the transconductance, plate resistance and plate current graphically represented over the entire operating range of plate and grid voltages. With a curve tracer A-B comparisons between two tubes can be made with the throw of a switch. Additionally the Tek 576 has the capability to plot the transconductance or the amplification factor over the range of grid voltages. Running a comparison of curves for several different screen voltages is also a big advantage over single point testing.

I had a pair of 6973 audio power output tubes that read the same value of transconductance on a Hickok 539C tube tester to within one small division on the meter. Plotting a family of curves using the book value of 250 volts screen bias showed that they were not even close. I ran the curves again at 130 volts, the screen voltage that the 539C uses. They showed a better match but still not close enough for a pair.

During the boom years for vacuum tubes Tektronix sold the model 570 vacuum tube curve tracer to do plate curves and other plots on vacuum tube characteristics. Today a used model 570 is a rare and expensive instrument to buy. When transistors became dominant, Tek introduced the model 575, 576 and 577 semiconductor curve tracers to fill the need to test semiconductors. (Figures 1 and 2) The 575 was a vacuum tube based design that served the purpose for the transistors of the day but with a maximum of 200 collector volts and -2 volts of bias it had very limited usefulness for testing tubes. It can be modified to produce higher grid voltages and some people have done this to test tubes.

The 576 was a transistor based design far more advanced in features. It was capable of up to 1500 volts, 10 amps and 220 watts of power. On the 350 MAX PEAK VOLTS range most suitable for tube testing it could supply 500 milliamps of average plate current or 1 amp peak pulsed. It could provide up to -40 volts of grid bias making it very adaptable to testing tubes. The 576 had the great advantage of a digital display next to the CRT that read out the vertical and horizontal settings, the grid voltage setting and the calculated vertical scale in Beta for transistors or Gm for FETs and tubes. This is a highly desirable feature for photographic recording because all of the plot scales are recorded along with the curves right there on the photo. It also had an illuminated graticule that showed up on the photo. For these and for other reasons the 576 is the most desirable of the classic semiconductor curve tracers. The 576 was available from the factory without the digital display as a "MOD 301W" but I have never seen a sample with this option.

The 577 was functionally equivalent to the 576 but there is no digital display, illuminated graticule or calibrated DISPLAY OFFSET function and it is not capable of as much power as the 576. Like the 576 it is capable of up to 1500 volts and 10 amps but only 100 watts of power. For small signal tubes it is equivalent to the 576 in performance. Two versions of the 577 were sold, one with the standard CRT and another with a storage type CRT. The storage tube could store the result from a single shot plot and overwrite a second one for comparison. I never found this to be all that useful and, with the availability of inexpensive digital cameras, CRT display storage is pretty much unnecessary and far inferior in image quality to a digital photo.

On the 400 MAX PEAK VOLTS range the 577 could supply 150 milliamps of average plate current or 310 milliamps peak pulsed. For most audio power tubes like the 6V6GT, 7591A, KT-66, 45 and 6BQ5 this is quite adequate. For the big guys like the 6L6GC, 7027A or especially the 6550 and KT-88 it is a little under powered. It will plot the curves as long as you keep the screen at or less than 250 volts, the control grid always negative and don’t run the plot for more than a few minutes.

Both the 576 and 577 feature an operator protection interlock. For any voltage setting that may be high enough to cause an electrical hazard to the operator the collector voltage is inhibited unless the interlock is satisfied. Normally the interlock is satisfied by a plastic protective box supplied with the curve tracer. (Figure 3) The box snaps onto the test pad area and completely encloses the device under test. It has a hinged lid for access to the device. When the lid is closed there is a pin that presses on the interlock switch located in the lower left corner of test pad area enabling the collector voltage. The protective box is almost always missing when you buy a used curve tracer and they rarely show up for sale.

Some of the 577 models had a small red momentary action pushbutton switch on the front of the apron that would manually bypass the interlock. Tektronix had second thoughts about that feature and later on they urged owners to return the instrument and have it removed. Home built tube test adapter modules are equipped with a built in actuator to satisfy the interlock and the module is enclosed so that dangerous voltages are not exposed to the operator.

The Tektronix semiconductor curve tracers were designed to be highly flexible with the ability to test all types of bipolar and field effect transistors of either polarity at relatively high voltages. Add on a filament supply and triode tubes are easily tested as N channel depletion field effect transistors. With a screen bias supply beam power and pentode tubes are tested the same way.

FUNCTIONAL DESCRIPTION

I’ll describe basically how a curve tracer works in vacuum tube triode terms. The curve tracer supplies a DC voltage to the plate of the tube that ramps from zero up to a voltage that is selected by the operator then back to zero at a rate of 120 times per second. This voltage is plotted on the horizontal axis of the Cathode Ray Tube as the plate voltage. The current draw from this supply is plotted on the vertical axis as the plate current. A constant signal voltage is provided to the grid for the duration of each ramp. The grid is held at zero volts for the first ramp. After the first ramp the grid voltage is “stepped” up to the next level, much like climbing a stair, and held constant for the next plate ramp. With each additional ramp the grid voltage is increased by a fixed amount until it reaches the maximum number of steps then it drops back to zero and starts over. The number of steps and the grid voltage step size is determined by the operator.

Let’s say we want to use one volt per step on the grid. For the first cycle the curve tracer applies zero volts to the grid then ramps the plate voltage from zero to maximum and back down again. The plate voltage and current are plotted and one curve is traced on the screen. For the second ramp the curve tracer steps the grid voltage to minus one volt and repeats the plate voltage ramp, plotting the voltage and current for a second trace. This continues until up to ten traces are plotted in sequence, each with a higher negative grid voltage. When the maximum number of steps is reached the grid voltage is set to zero and the process repeats. Because this is done rapidly in succession the entire family of curves appears simultaneously on the screen.

What the curves show you are the plate current for every plate voltage from zero to maximum for a discrete set of user selected grid voltages. (Figure 4) The vertical spacing between any two curves, the change in plate current for a change in grid voltage at a constant plate voltage, is representative of the transconductance. The slope of the curves, the change in plate current for a change in plate voltage at a constant grid voltage, represents the plate resistance. In this figure I have added the identification text, graph scales and grid voltage numbers to the raw plot. The curve tracer does not do that for you.

For pentodes and beam power tubes the process is exactly the same except that you must also supply the screen grid with a constant DC voltage. Testing a pentode in the triode configuration is as easy as connecting the screen grid to the plate instead of a screen bias supply.

The ordinary means of connecting semiconductor devices to the curve tracer for testing is accomplished by an appropriate module that plugs into the test pad area of the curve tracer. Two modules can be plugged into the test pad area to allow comparison of two devices. The device to test is selected by a “LEFT-OFF-RIGHT” A-B switch located next to the test pad area of the curve tracer. Tektronix did their homework well in designing a selection of plug-in modules to test the various types of transistor packages. While they did not sell test modules with tube sockets on them you can make your own and use the modules to test a variety of tube types from nine pin miniature twin triodes to octal beam power pentodes.

The tube test modules are wired such that the plate pin of the tube socket is connected to the COLLECTOR terminal of the curve tracer, the grid to the BASE and the cathode to the EMITTER terminal. The heater/filament pins are connected to banana jacks for attachment to an external power supply. For the pentode module a second pair of banana jacks is provided to connect to an external screen power supply.

Typically you need only two test modules to test many of the popular audio tubes. (Figure 5) One module has an octal and a nine pin miniature socket prewired for testing many types of twin triodes. Selecting which triode twin to test is done with the LEFT-OFF-RIGHT switch on the curve tracer. (Figure 6) The second module has two octal sockets prewired for 6L6 basing to test or compare two beam power pentodes. Many audio tubes use this basing so the module is very versatile. An A-OFF-B selector switch is built in to the pentode test module in order to switch the screen grid bias along with the plate and control grid voltages from one tube to the other.

For other power tubes like the octal based 7591A or the nine pin miniature based 6BQ5 that don’t match 6L6 wiring, special basing adapters can be used to convert the base wiring of the tube to that of a 6L6. (Figure 7) A basing adapter can be also be used to change the standard socket wiring to test beam power pentodes in the triode configuration. Old four and five pin based triodes like the 01A, 26, 27 or 45 can easily be adapted for testing by using basing adapters. You can even test rectifier tubes using a basing adapter. Two section tubes like the 5AR4 full wave rectifier would adapt to the twin triode module because of the need to test two sections on one base. A/B matching of the two sections can be done for critical applications like the type 83 and 5Y3 used in Hickok tube testers. Single section rectifiers like the 35Z5 would adapt to the pentode module.

For generic tube testing a pod of several common sockets can be assembled with a pigtail cable attached. (Figures 8, 9) The pigtail wiring can be done on an as-needed basis to connect the socket pins to the various power supplies and curve tracer connections or you can make a fancy patch panel with jumper cables similar to what Tektronix did with their model 570. This is useful for onesey-twosey tests on odd tubes that you don't test frequently. Connection of the pod wiring to the curve tracer is made using a special module with binding posts on it instead of tube sockets. (Figure 10) You can use a commercially available three position banana plug to binding post adapter to make the connections but you will also have to satisfy the high voltage protection interlock built into the curve tracer that the modules usually take care of.

CURVE TRACER CONTROLS

(Figure 11) At first glance a semiconductor curve tracer is a complicated and mysterious instrument. The various controls can be divided into related functions and understood individually. The five major sections include the VERTICAL, DISPLAY OFFSET, HORIZONTAL, STEP GENERATOR and COLLECTOR SUPPLY. Other secondary controls for graticule and readout lamp intensity, CRT focus and CRT intensity complete the adjustments. The upper half of the control panel contains the CRT display and the associated controls for the presentation of the traces. The lower half of the panel contains the controls that adjust the signals and voltages that are applied to the device being tested.

VERTICAL

The VERTICAL channel of the curve tracer displays the collector or plate current. The gain is controlled by a rotary switch in the upper right corner of the control panel. This works very much like the vertical gain control of an analog oscilloscope. The vertical gain is set in a 1-2-5 sequence from 1 microamp per division to two amps per division. A maximum of 20 amps can be displayed on the screen. The extreme counterclockwise position of this switch is the STEP GEN position. In this position the vertical channel displays the step generator voltage on the grid instead of the plate current. The scale is one step per division for any step generator voltage or current setting whatever that happens to be. For tubes only the voltage step settings would be used. In this mode the grid voltage can be plotted on the vertical axis against the plate voltage on the horizontal axis which is a plot of the amplification factor. The 577 does not have this function. There is a second scale on this switch for emitter leakage current. Since this is strictly a transistor function I will not describe it.

VERTICAL POSITION – HORIZONTAL POSITION

Just below the vertical control is the section for controlling the precise position of the display on the screen. The VERTICAL and HORIZONTAL position controls have two parts. The inner knob controls the position of the spot continuously plus or minus about two and a half divisions. The outer knobs switch the position up or down, left or right in five or ten division increments.

DISPLAY OFFSET

To the right of the POSITION controls is the DISPLAY OFFSET switch. The DISPLAY OFFSET switch has two functions. The inner switch has four positions, two for vertical X1 or X10 magnification, and two for horizontal X1 or X10 magnification. The normal off position for this switch is straight up. Setting the inner switch to the X1 position for either vertical or horizontal moves the display by five divisions to the center of the selected axis and enables the outer part of the switch. The outer switch is a precision position offset control from zero to ten divisions in half division steps. The precision position switch can only move the display down or to the left in calibrated steps. Setting the inner switch to the X10 setting magnifies the display by a factor of ten. The outer ring setting is also affected by the X10 magnification causing the position settings to become zero to 100 divisions in five division steps. These controls allow the operator to precisely zoom and pan a portion of a curve and examine it closely. Tek thought of everything. The precision position offset capability was dropped from the later model 577.

HORIZONTAL

Below the display offset control is the HORIZONTAL gain control. The horizontal channel displays the plate voltage. The gain is controlled by a rotary switch set in a 1-2-5 sequence from .05 volts per division to 200 volts per division. A maximum of 2000 volts can be displayed on the screen. Rotating the switch counterclockwise past the 200 volt per division position changes the function of the horizontal display from plate voltage to grid voltage. Grid voltages can be displayed in a 1-2-5 sequence from .05 volts per division to 2 volts per division. In this mode the plate current can be plotted on the vertical axis against the grid voltage on the horizontal axis which is a plot of the transconductance.

Like the vertical gain switch, the extreme counterclockwise position of the horizontal gain switch is the STEP GEN position. In this position the horizontal channel displays the step generator. The scale is one step per division for any step generator voltage or current setting whatever that happens to be. For tubes only the voltage step settings would be used.

STEP GENERATOR

There are three rotary STEP GENERATOR controls and a set of 13 pushbutton switches to control the step generator. The NUMBER OF STEPS switch is a rotary switch that allows you to select the number of grid voltage steps that you want to use from one to ten. The center knob of this control sets the current limit for the grid steps. This is used for testing transistors and should remain in the 2 Amp position when testing tubes.

Below the number of steps switch is the step offset control. This is a voltage control that allows you to apply a continuously adjustable DC offset to the grid signal steps. The voltage range is dependent on the step voltage setting. It is calibrated from zero to ten equaling zero to ten steps of DC bias. For example if the step generator is set for .5 volts per step then the control provides from zero to five volts of DC bias for settings of zero to ten on the adjustment knob. Just below the control knob are three pushbutton switches. These switches labeled ZERO, AID and OPPOSE select whether the added offset will be turned off, added to the steps, or subtracted from the steps respectively. It should be noted that the aid or oppose function works exactly the same no matter what the step polarity is.

The next row down is the pulsed steps control switches. In pulsed mode the curve tracer supplies a constant DC voltage instead of a ramp to the plate and the grid step signal in short stepped pulses in order to minimize the power dissipation in semiconductor tests. This function is not used for vacuum tube testing and can destroy some tubes a very short time. Always use the STEPS mode for testing tubes.

Below the pulsed mode switches are the STEP FAMILY and RATE CONTROL sections. In the REP mode the step generator runs continuously tracing curves. In the SINGLE mode the step generator runs through one set of steps then stops at zero volts until the SINGLE switch is pushed again. This is useful when running curves on a high power semiconductor so that the heat dissipation does not become excessive.

Either a direct view of the CRT or a photo of the screen can be taken during a single plot of a family of curves. This eliminates the need to run the semiconductor at high power for extended periods with the risk of overheating it. Since receiving tubes normally don't need external heat sinks and, unlike transistors, they run high plate current with zero bias, operating a tube in the single trace mode is not a useful function. There is a way to set up the controls to reverse the step direction and safely do single family plotting starting from maximum bias instead of zero but it doesn't get you much for the trouble and I won't go into detail.

The rate switches control the step rate. At the NORM rate the steps advance at the same rate as the plate voltage ramp, one step at a time for each complete ramp cycle. In the 2X mode the steps are changed at twice the normal rate. Each step is increased not only at the ramp zero voltage position but also at the ramp maximum voltage. This effectively doubles the rate by drawing a curve when the plate voltage ramps up and the next curve when it ramps back down. The .5X mode halves the ramp rate by running two complete ramp cycles for each step. Some of these modes are useful for getting a better looking plot but in most cases the NORM rate is perfectly acceptable.

To the right of the STEP GENERATOR pushbutton area are the .1X and INVERT buttons. In the IN position the .1X switch causes the steps to be one tenth of the step AMPLITUDE setting. This changes the scale of the amplitude settings from the normal .05 to 2 volts per step to a range of .005 to .2 volts per step. This function may be useful for tubes with a very large transconductance.

Right below the .1X switch is the step polarity INVERT button. With the button set for the OUT position the step polarity is normal for transistors. Set for the IN position the polarity of the steps is reversed. This is the normal setting for tubes.

COLLECTOR SUPPLY

Now we come to the controls that set the polarity and amplitude of the voltage applied to the plate. There are two primary controls for the plate voltage. To the far left just below the CRT is the MAX PEAK VOLTS switch. This is a range switch that sets the maximum voltage in four ranges of zero to 15, 75, 350 and 1500 volts. Concentric on the MAX PEAK VOLTS switch is the SERIES RESISTORS switch. The setting is changed by pulling out on the outer knob and rotating it independently of the MAX VOLTAGE. This switch sets the value of a resistor in series with the device under test. The resistor setting limits the maximum peak wattage that the test device will dissipate. There is a wattage scale on the knob as a guide for the operator, 220 watts being the highest setting that the curve tracer will allow.

The wattage limit function is a very simple system where increasingly higher value resistors are placed in series with the device to limit the amount of power dissipation by dropping more and more of the available plate voltage as the plate current rises. The lowest value resistor on the 350 volt range is 140 ohms in series. What this means is that, depending on your AC power line voltage, you have about 400 volts to start with from the collector supply with a 140 ohm resistor in series. As you draw current from the supply the resistor drops some of that voltage. The more current you draw the less voltage you have on the device due to this drop. It displays on the CRT as an imaginary limit line drawn from the maximum plate voltage at zero milliamps upward and to the left to the maximum plate voltage at the highest plate current. (Figure 12)

The maximum rated plate current for the 350 volt range is 500 milliamps. At the nominal 350 maximum peak volts setting with the 220 watt series resistor of 140 ohms you can calculate the approximate maximum plate voltage at various currents using ohms law. Starting at zero plate current you would have about 400 volts on the plate plus or minus a few volts depending on your AC power line voltage. At 50 milliamps the drop across the 140 ohm series resistor is about 7 volts so you have 393 volts on the plate. At 100 milliamps the drop is 14 volts leaving 386 volts. At 200 milliamps the drop is 28 volts leaving 372 volts. At 500 milliamps the drop is 70 volts leaving 330 on the plate. The calculated plate voltages are higher than actual since there are more internal losses than just the series resistor.

The maximum rated plate current for the 1500 volt range is 100 milliamps. For the 1500 volt range the 220 watt series resistor is 3000 ohms. You would not ordinarily plot a family of curves on an audio tube with a 1500 volt plate supply so let's assume something more realistic. For the plate supply set to 600 volts the 50 milliamp voltage drop on a 3000 ohm resistor is 150 volts leaving 450 volts on the plate. At 100 milliamps the drop is 300 volts leaving 300 volts on the plate. At 200 milliamps you lose all 600 volts across the resistor, you are dumping 120 watts into it and burning it up. The curve tracer will actually supply a lot more current than it is rated for so you must pay attention to the settings and not allow the plate current to go much above 100 milliamps on the 1500 volt range or 500 milliamps on the 350 volt range.

Below the MAX PEAK VOLTS / SERIES RESISTORS switch is the VARIABLE COLLECTOR SUPPLY control on the front apron. This control adjusts the plate voltage continuously from zero to the maximum setting on the MAX PEAK VOLTS switch.

To the right of the MAX PEAK VOLTS switch is the collector supply POLARITY switch. The settings are mainly used for testing different types of semiconductors. Three settings are possible; AC, + (NPN), and – (PNP). All tubes are tested using the + (NPN) switch position to apply a positive polarity voltage to the plate. The – (PNP) setting applies negative polarity voltage to the plate and is never used. The AC setting applies 60 Hz AC. This is useful for testing a number of things like triacs and zener diodes but never for tubes.

On the far right of the COLLECTOR SUPPLY area is the MODE switch. The MODE switch has three positions: NORM, DC and LEAKAGE. The NORM setting applies the usual ramped voltage to the plate. In the DC mode a constant DC voltage is applied to the plate instead of a ramp. The LEAKAGE setting is another DC mode used only for testing base emitter leakage in transistors. Below the MODE switch is the LOOPING COMPENSATION control. This is used to adjust the compensation for capacitive leakage when measuring extremely low plate currents. Under ordinary testing situations this control will not be used.

MISCELLANEOUS CONTROLS

-GRATICLE ILLUM adjusts the brightness of the crosshatch graticule on the CRT. The dark graticule marks on the CRT are usually the best for direct viewing without illumination. Graticule illumination is used when making photographic records of the family of curves.

-READOUT ILLUM adjusts the brightness of the digital readout display and the associated bezel markings. The readout illumination is adjusted for comfortable direct viewing and for proper exposure when making photographic records of the curves.

-INTENSITY adjusts the brightness of the CRT. Adjust for comfortable direct viewing or for proper exposure of photographic records of the curves. Always adjust the CRT brightness to the minimum comfortable intensity in order to prevent phosphor burn, especially when the collector voltage control is at minimum and there is just a spot on the screen.

-FOCUS controls the focus of the CRT.

-LEFT-OFF-RIGHT is the switch that selects which of the two devices to test on the test pad area. Switching between the two sides rapidly allows easy comparison of two devices.
-TERMINAL SELECTOR SWITCH is located on the test pad area above and to the right of the LEFT-OFF-RIGHT switch. It is for reversing the connections of the Emitter and Base on a transistor to test the device in common Emitter or Common base mode. For testing tubes it should always be left in the clockwise EMITTER GROUNDED/STEP GENERATOR position.

INDICATOR LAMPS
-The green lamp next to the power switch indicates that the power is on.
-The yellow COLLECTOR SUPPLY VOLTAGE DISABLED lamp next to the green pilot lamp indicates that the operator voltage protection interlock is not satisfied and the collector voltage is disabled.
-The red lamp to the left of and above the LEFT-OFF-RIGHT switch indicates that the collector supply is enabled and dangerous voltages may appear on the device terminals. The lamp itself is failsafe. If it burns out or is removed the collector supply will remain disabled.

SETUP FOR TRIODE PLATE CURVES
Testing tubes is fairly straightforward once you understand what the controls and switches do. I'll start with an example testing a 6SN7 twin triode using the triode test module. First we'll set up the switches and controls on the curve tracer then we'll discuss how to interpret the results and adjust for differences in tube characteristics.

To make it absolutely clear for the beginner I'll define the settings for every switch and control in this example.

POWER: ON
MAX PEAK VOLTS: 350
MAX PEAK WATTS: 220
SERIES RESISTORS: 140
GRATICLE ILLUM: Full counterclockwise
READOUT ILLUM: Adjust for comfortable viewing
VARIABLE COLLECTOR SUPPLY: Full counterclockwise
POLARITY: + (NPN)
MODE: NORM
LOOPING COMPENSATION: As found
LEFT-OFF-RIGHT: OFF
TERMINAL SELECTOR: EMITTER GROUNDED/STEP GENERATOR
INTENSITY: Adjust for comfortable CRT intensity
FOCUS: Adjust for best focus
VERTICAL: 2 Ma per division
VERTICAL POSITION(Outer knob): Set to center position arrow
VERTICAL POSITION FINE: Adjust to place trace on horizontal graticule line zero (see illustration)
HORIZONTAL POSITION(Outer knob): Set to center position arrow
HORIZONTAL POSITION FINE: Adjust to place trace on vertical graticule line zero (see illustration)
DISPLAY OFFSET(Outer knob): Clockwise limit (zero)
DISPLAY OFFSET(Inner knob): Straight up
DISPLAY INVERT button: Out (non-inverted)
DISPLAY ZERO: As found
DISPLAY CAL: As found

HORIZONTAL: 50 volts per division
NUMBER OF STEPS(Outer knob): 10
NUMBER OF STEPS(Inner knob current limit): 2 Amps
OFFSET MULT: Counterclockwise limit (zero)
STEP GENERATOR AMPLITUDE: 1 Volt per step
OFFSET ZERO: In
OFFSET AID: Out
OFFSET OPPOSE: Out
STEPS: In
PULSED STEPS 300us: Out
PULSED STEPS 80us: Out
STEP FAMILY REP: In
STEP FAMILY SINGLE: Out
RATE 2X: Out
RATE NORM: In
RATE .5X: Out
STEPMULT .1X: Out
STEP/OFFSET POLARITY: In (invert)
EMITTER GROUNDED: STEP GEN

-Plug the twin triode module into the test pad firmly so that the red collector voltage interlock indicator lights up.

-Insert a known good type 6SN7 tube into the octal socket.

-Connect a dual banana to dual banana cable to the HEATER jacks.

-Connect a source of 6.3 volts rms AC or 6.3 volts DC to the banana cable and allow the tube to warm up.

-Rotate the VARIABLE COLLECTOR SUPPLY control clockwise to the stop. Adjust the CRT intensity and focus as necessary to get a sufficiently bright clear trace. This voltage setting represents a maximum plate voltage of about 350 volts.

-Set the LEFT-OFF-RIGHT switch to the LEFT position.

A set of curves will be displayed for triode number one. (Figure 13)Triode number one, as defined by the RCA Receiving Tube Manual, is connected to base pins 4, 5 and 6. Set the LEFT-OFF-RIGHT switch to the RIGHT position and observe that the curves for triode number two appear. (Figure 14)Triode number two is defined as connected to base pins 1, 2 and 3.

Observe that the digital display to the right of the CRT indicates the vertical, horizontal and step generator settings. The bottom digital gm display shows the value of “2 m” meaning 2 millimhos per division (or 2000 micromhos in more common terminology). Changing the VERTICAL setting to 5 milliamps per division closes up the spacing of the curve family and puts the end of the top curve on screen. The digital gm display will change along with the VERTICAL scale setting to indicate the new gm scale of 5000 micromhos per division. (Figure 15)

Change the STEP GENERATOR to 2 volts per step (Figure 16) and observe that the display changes to 2500 micromhos per division. The separation between the curves is doubled and the entire family expands downward reflecting the larger voltage steps applied to the grid. To make a visual comparison between the two triodes quickly alternate the LEFT-OFF-RIGHT switch back and forth. The differences between the two triodes are readily seen similar to this overlaid composite. (Figure 17)

OK so what is this telling us? Comparing the curves to the published plot in the manufacturer's tube manual you can see whether the tube being tested is similar or showing signs of low transconductance or poor emission. If the manufacturer's data does not show a plot you can use the DC operating characteristics. For a 6SN7 the typical conditions are:

PLATE: 250 volts
GRID: -8
PLATE RESISTANCE: 7700
TRANSCONDUCTANCE: 2600 micromhos
PLATE CURRENT: 9 milliamps

As you know the vertical scale is the plate current, the horizontal scale is the plate voltage just like the curves in a tube manual. (Figure 18) Each curve in the family shows a graph of the plate current from zero to 300 volts on the plate for a fixed value of grid bias. The ten curves show the plate current for grid bias of zero to -20 volts in two volt steps. A change in plate current for a change in grid bias is the transconductance. Graphically this is displayed as the distance from any given curve to the next one at a fixed plate voltage.

You can read the plate current at any plate voltage for any given grid bias. Let's use the book values and see how our triode compares. Set the LEFT-OFF-RIGHT switch to the LEFT position and change the VERTICAL to 2 milliamps per division to expand the scale for easier reading. The figure (Figure 19) shows the expanded family of curves for 6SN7 triode 1. Follow the 250 volt plate voltage vertical graticule line up to the -8 volt grid bias curve and read the plate current. We see that the -8 volt curve intersects the 250 volt plate voltage line at 7.6 milliamps.

The transconductance is determined at any given plate and grid voltage by counting the number of divisions between two curves at a fixed plate voltage and multiplying by the scale factor. Referring to the curves, (Figure 20) at a plate voltage of 250 volts there are 2.8 divisions of distance from the -6 to the -8 volt grid bias curve. For a scale factor of 1000 micromhos per division this shows 2800 micromhos of transconductance. At 100 volts on the plate the distance from the -4 to the -2 volt curve is 1.9 divisions equaling 1900 micromhos.

The change in plate current for a change in plate voltage at a fixed grid bias is the plate resistance. Take another look at the 6SN7 (Figure 21) triode curves. The slope of the curves indicates the plate resistance. Curves with a sharp upward slope show a low resistance since the plate current goes up quickly with plate voltage. With -8 volts on the grid and 240 volts on the plate the current is 6.4 milliamperes. At 260 volts on the plate the current is 8.75 milliamperes. The increase of 20 volts on the plate divided by the increase of .00235 amps plate current equals 8500 ohms.

TRANSCONDUCTANCE PLOT

From the spacing between the curves you can see how linear the transconductance is over the range of operating points. The figure (Figure 22) shows a family of curves for a type 01A triode at 200 peak volts on the plate. Notice the uniform spacing of the curves one to another. While this is useful, you can see the linearity more directly on a transconductance plot.

By changing the HORIZONTAL gain switch to the STEP GENERATOR setting, the grid voltage is plotted on the horizontal axis against the plate current on the vertical axis, a transconductance plot. (Figure 23) Since the grid voltage goes negative the plot disappears off the left edge of the screen. To get the curves on screen you must also offset the plot to the right ten divisions by rotating the outer ring on the calibrated HORIZONTAL POSITION switch two steps to the clockwise limit. You can't use the DISPLAY OFFSET which only shifts five divisions to the right.

Looking at the curves now we see a transconductance plot for the same 01A. Each of the curves is now a vertical line of varying height representing the plate current for each value of grid bias at 200 plate volts. I have "connected the dots" of the tops of the lines to illustrate the transconductance curve. The curve tracer does not do this for you. From the plot you can see the transconductance is very linear from about -12 all the way up to zero volts grid bias. The value of the transconductance is determined the same way as with the plate V/I family. Measure the number of divisions of vertical distance from one line tip to the next and multiply that times the scale factor on the curve tracer "β or gm PER DIV" digital display. At -10 to -8 grid volts the curve shows a value of 800 micromhos. At -14 to -16 the value has dropped to 650. By manually adjusting the peak plate voltage up or down you can observe the values and the linearity of the transconductance at any plate voltage for comparison.

This illustrates why no two service type tube testers will give you the same value of transconductance. The test result is greatly dependent on the grid bias and plate voltage that you are looking at. If you want the nominal book value transconductance you have to use the same voltages and currents that the tube manufacturer used. The curve family does exactly that.

PENTODE MODULE

Pentodes are tested pretty much the same as triodes with a few precautions. With triodes the LEFT-OFF-RIGHT switch on the curve tracer selects which of the two triode twins to test. Because pentodes have three elements that must be switched, control grid, screen grid and plate, the switching must be done on the tube test module instead. For pentode testing the pentode module is placed on the test pad area of the curve tracer and the LEFT-OFF-RIGHT selector switch is placed in the RIGHT position. Connect an external screen power supply to the test module using a banana to banana cable. Be sure to observe the correct polarity. (Figure 24)

Set the screen and plate voltages to the desired values before switching the A-OFF-B selector on the test module. For power tubes you will have to start with a VERTICAL setting of 10, 20 or more milliamps per division. This can be changed up or down to fit the curve family on the CRT without going past the edge. The plate and screen voltage can be found in the manufacturer's data manual such as the RCA Receiving Tube Manual RC series. Use the class A_1 TYPICAL OPERATION data listings. For a 6V6GT or 6L6GC you should use 250 volts on the screen with the plate at 350 volts maximum. Switch the A-OFF-B selector on the module to the tube you wish to test. For a good tube the curves should look something like the figure (Figure 25) A bad tube will show low plate currents and weak transconductance as in this figure. (Figure 26) If two tubes are installed in the module you can make a comparison between them by quickly alternating the A-OFF-B switch on the module back and forth. Never do this with the LEFT-OFF-RIGHT switch on the curve tracer.

Most pentodes have a very high plate resistance since they are constant current devices. As the plate voltage goes up the plate current changes very little as seen in the plate curves for a 6V6GT.

You must be especially careful never to apply screen grid bias without plate voltage or you can easily overheat the screen. Never manually run the plate voltage down or flip the LEFT-OFF-RIGHT switch to the OFF or LEFT position while the curves are plotting. Always use the A-OFF-B switch on the tube test module to select the tube for testing and set it to the OFF position before making any changes to the settings.

BASING ADAPTERS

You can use the pentode module to test a variety of other tube types, such as nine pin miniature pentodes or four pin antique triodes, by adding a basing adapter. A basing adapter is essentially an octal tube base with a socket piggybacked to it such as these adapters used to test 6BQ5 tubes. (Figure 27) Inside the adapter the wiring from the base to the socket changes the connections of the tube that you want to test to match the pin connections on the test module. Another example is the octal to four pin adapter. The four pin adapter is wired such that the filament, grid and plate connections on the socket come out on the proper octal pins. Popular tubes such as 01A, 26, 45, 2A3 and others plug right in.

For indirectly heated tubes such as a 6V6GT the polarity of the heater supply doesn't matter. For testing filamentary triodes such as an 01A the filament polarity does matter. This is why the heater connection on the pentode test module is polarized. For filamentary tubes always connect the heater/filament supply to the tube with the proper polarity as defined in the tube data or inconsistent results will be seen in the curve families. For some filamentary triodes like the 26 or 45 that are designed to be operated on an AC filament supply you must use DC instead because the basing adapter connects one end of the filament directly to ground and not to a center tapped transformer or hum balance resistors as was done in the radios that those tubes were used in.

RECTIFIER TUBES

Rectifier tubes such as type 80, 5Y3, 5R4, 5U4 and 6CA4 can also be tested with appropriate basing adapters or with a socket pod. (Figure 28) For rectifiers you are looking for the amount of plate current at various plate voltages as determined from the tube manufacturer's data. The RCA HB-3 manual is the best source for plate curves on rectifiers. The slope of the plate current curve is the important characteristic to look at. The figure (Figures 29, 30, 31) shows the published curve on the left, a normal rectifier curve and a bad curve on the right. Notice that the weak tube has more horizontal slope to the plate curve especially, at higher plate currents, indicating higher plate resistance due to limited emission. The weak tube was very sensitive to heater voltage and changing the setting of the plate voltage caused the slope of the curve to drift up and down from cathode heating. It is interesting to note that the weak tube tested fair to good on a Hickok 800A tube tester while the curve shows an obvious deficiency.

For mercury vapor rectifiers like the 83 the plate voltage drop will be quite a bit smaller and almost constant for variations in plate current. (Figure 32)The tube manuals don't include plate curves for mercury vapor rectifiers. Look at the specified plate voltage drop at rated current. Always preheat the filament for at least 30 seconds before starting the test to warm and condition the mercury fill. Set the MAX PEAK VOLTS switch to the 75 volt range and the HORIZONTAL at 2 volts per division. Start with the plate voltage set at zero and run it up slowly. Do not push the tube beyond the average rated plate current and note the plate voltage. You can compare the two halves and match them for critical use such as service in Hickok tube testers.

Note that because an 83 is a filamentary tube there is a bias on the cathode equaling the filament voltage. Because the filaments for the two plates are in series one will have more bias on it than the other because of the voltage drop along the length of the filaments. This doesn't seem like much but a look at the plate curve for the second plate shows a substantial difference. (Figure 33) To make an accurate comparison between the two plates you must reverse the filament polarity when plotting the second plate.

REFERENCE TUBES

Cold cathode glow discharge voltage regulator tubes can be tested. I don't test these very often so I use a socket pod with pigtail wires to connect the tube to the curve tracer. The plate is connected to the COLLECTOR terminal and the cathode is connected to the EMITTER terminal. The various reference tubes such as 0A2, 0A3, 0B2 and others are basically pre semiconductor era zener diodes. They have a specific plate voltage that remains relatively constant over a range of plate current.

Testing a gas discharge tube is done by starting the plate voltage at zero and advancing it slowly until the tube "strikes" or breaks down. (Figure 34) This is the Anode Breakdown Voltage. After breakdown the plate voltage drops to the average voltage. This can be seen as a sharp spike in plate current. As you run the collector voltage control higher the plate current rises rapidly while the plate voltage rises slowly. This is the regulation characteristic of the tube. You can use the DISPLAY OFFSET controls to expand the plot and show the characteristics in detail. (Figure 35) Change the horizontal to X10 and shift the plot to the left by 75 divisions. Look in the manufacturer's data manual for the specified reference voltage and operating current range to see if the tube is operating normally.

ELECTRICAL PROBLEMS

All electronics suffers from the effects of age on electrolytic capacitors. I have found several of the small axial lead aluminum electrolytic capacitors in these old instruments to have gone bad. Tektronix used the more expensive tantalum capacitors in many of the circuits and those are fairly reliable. One problem with every 576 that I have had contact with is intermittent pushbutton switch contacts. Display drifting or jittering and intermittent grid voltage are several of the problems dirty switches can cause. The switches can be removed and cleaned to restore full functionality but the job is fairly difficult. I have also seen vertical gain problems due to misadjusted relay contacts in the vertical gain circuit. The relays are called Printact® relays and they mount directly on the surface of the vertical amplifier board using metal clips to hold them in place. They have balance beam contacts on the bottom of the relay that rock back and forth contacting a special footprint of gold plated traces on the circuit board underneath to make the connections. If the contacts get dirty or don't apply enough pressure to the surface of the PC board traces they get intermittent or open. Cleaning and careful adjustment will fix that problem. The rotary switches are fairly reliable and don't cause trouble. Other common problems are burned out graticule/bezel lamps and bent interlock switches from foreign objects being jammed into the test pad safety interlock to defeat it.

Another problem that is rather simple but obscure is a collector warning lamp failure. The red collector voltage warning lamp just to the right of the test pad has a failsafe feature. If the lamp is removed or it burns out, the collector supply is disabled since the lamp cannot warn you of dangerous collector voltages. Only the original type of 14 volt 80 milliamp cartridge lamp can be used in this location because the relatively high lamp current is used to pick up an interlock relay. An LED replacement does not pass enough current to satisfy the fail safe circuit. In an emergency the yellow "COLLECTOR SUPPLY

VOLTAGE DISABLED” lamp can be substituted since it is identical to the collector warning lamp except for the color.

Just about every 577 I have seen has the LEFT-OFF-RIGHT switch damaged. Tektronix was expert at design and layout in their instruments but they really goofed on this one. The LEFT-OFF-RIGHT selector was placed on the front apron and stuck out beyond the frame. Any time the instrument was moved you were prone to smacking the switch against something and breaking the lever off.

While they have been discontinued for many years the model 576 and 577 curve tracers are still available at generally affordable prices. They frequently show up on ebay in various states of condition. This discussion of the Tek 576 is only an overview. The versatility and selection of operating conditions allows for much more than I have described in this basic article. I have left the interpretation of the curves and the meaning of the test results up to the reader. That subject could fill an article in itself.

REFERENCES:
Tektronix Type 576 Curve Tracer Instruction Manual, 070-0905-00, 1969
Tektronix Type 577 Curve Tracer Instruction Manual, 070-1414-00, 1973-1987
RCA Receiving Tube Manual RC-14, April 1942
RCA Receiving Tube Manual RC-24, October 1965
RCA Electron Tube Handbook HB-3, 5Y3, 83
General Electric Essential Characteristics, ETR-15 M, 1967