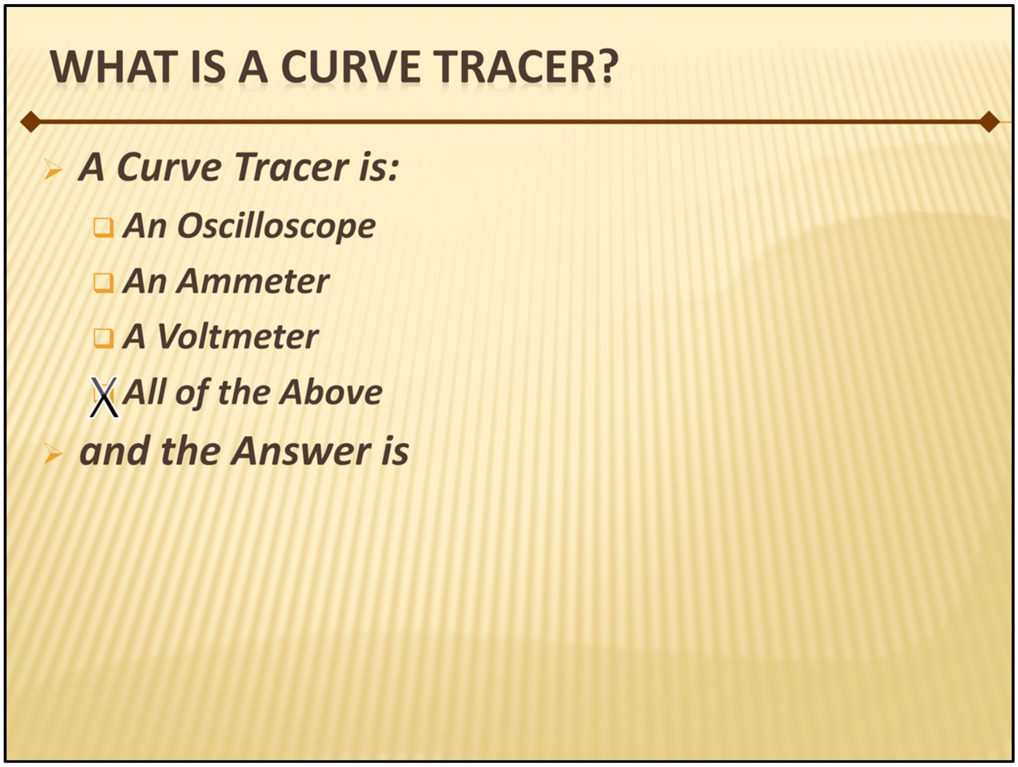
- I am the $2 tube guy, and I am all about tube testing.
- Curve Tracers provide graphic plots that characterize semiconductors and tubes
- I am going to cover:
- How they work
- What the measure
- The makes and models of curve

tracers you may want to consider getting



To illustrate - using a 2K ohm resistor connected between the emitter and collector (cathode and anode), we see the current increasing linearly (vertical) as we increase the voltage (horizontal)

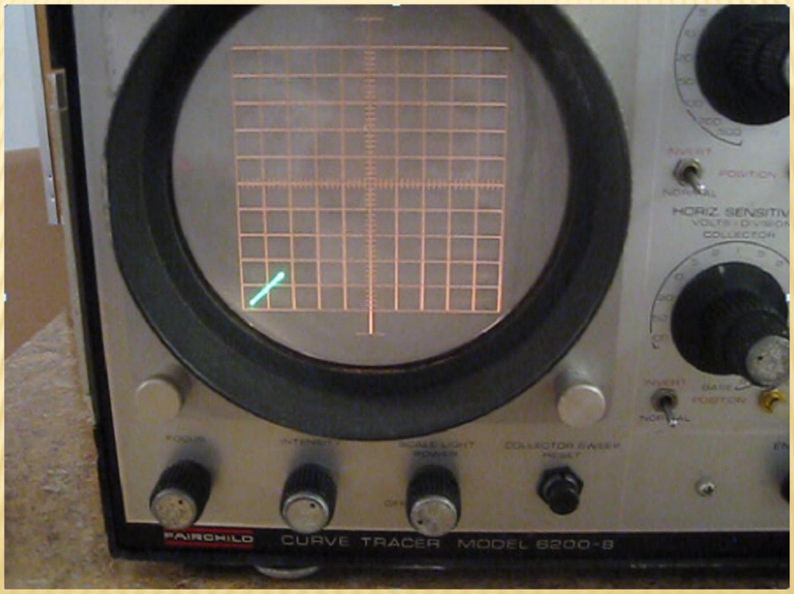
2K Ω RESISTOR

To illustrate - using a 2K ohm resistor connected between the emitter and collector (cathode and anode),

2K Ω RESISTOR

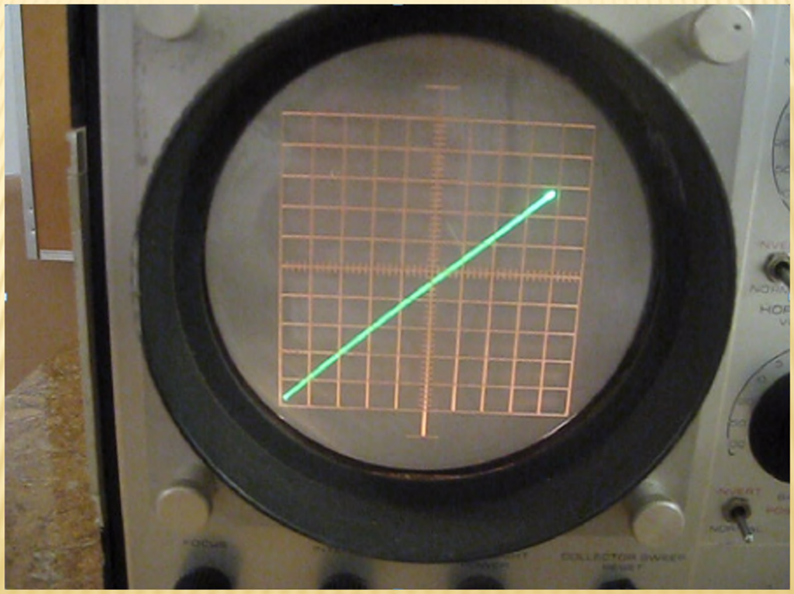
As we increase the Collector Sweep Voltage,

2K Ω RESISTOR

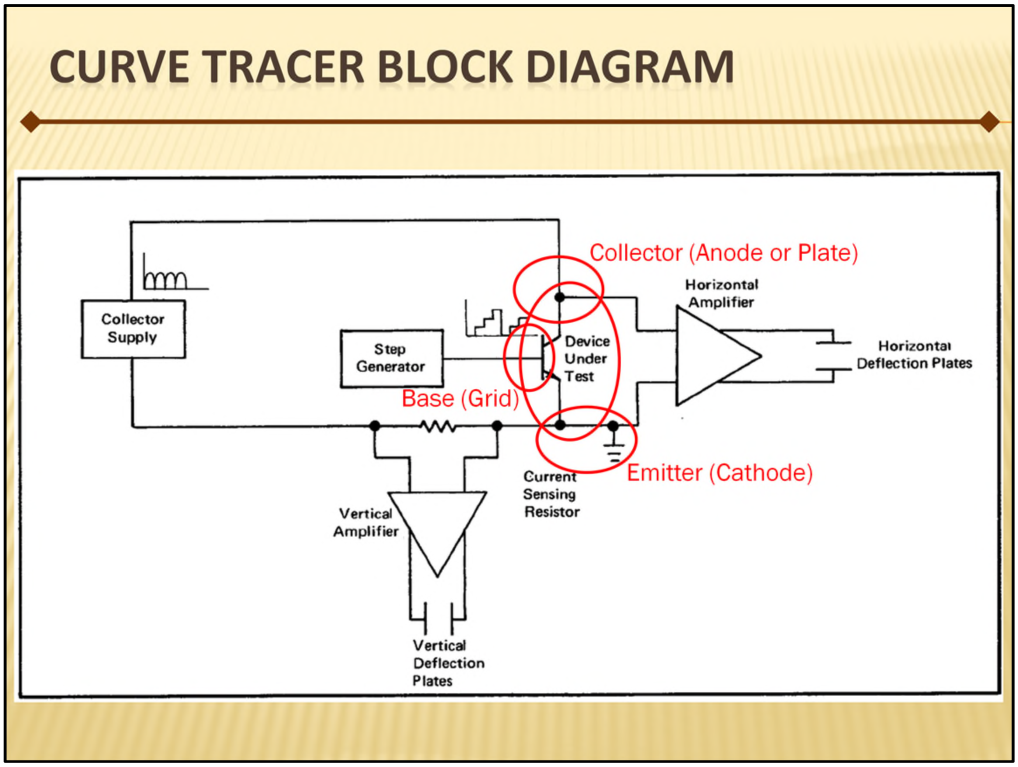


we see the trace increase linearly from a low voltage (from the left) and a low current (from the bottom)

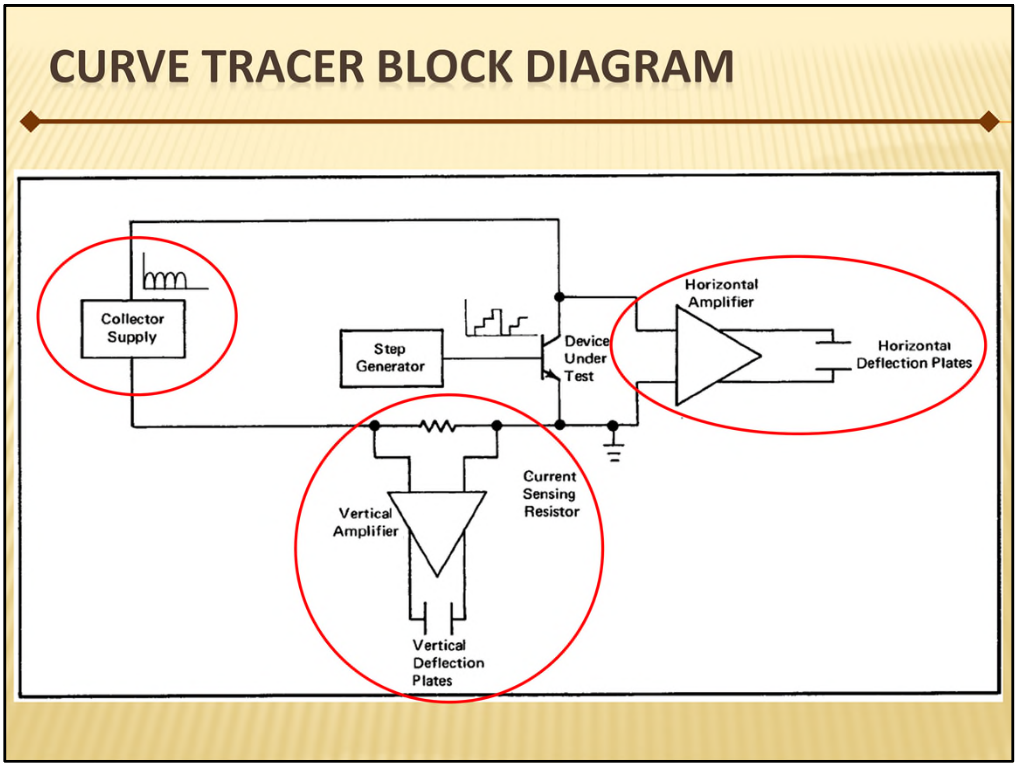
2K Ω RESISTOR



to a high voltage (to the right) and a high current (to the top)

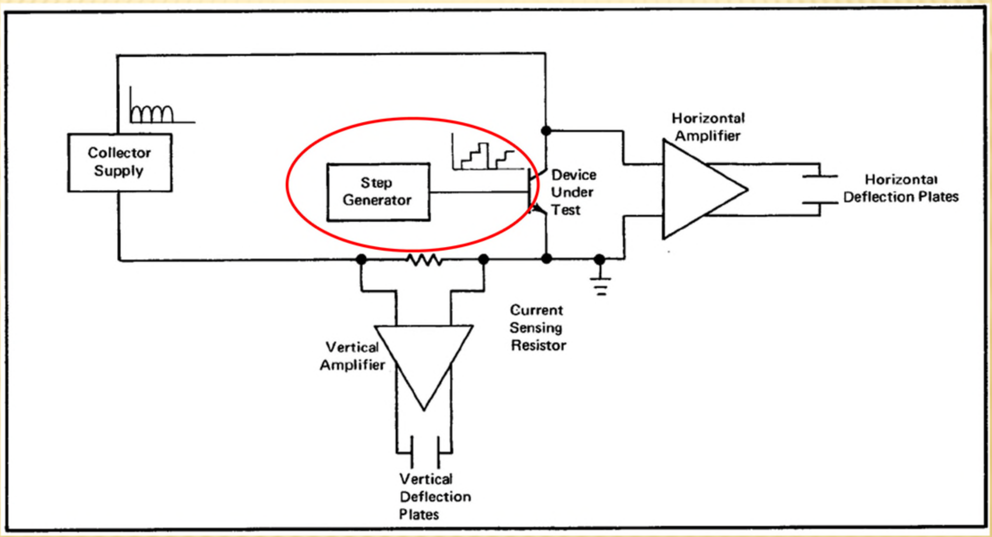


The device under test can be a diode, transistor or vacuum tube.
The Emitter (transistor) or Cathode (vacuum tube) is tied to ground.
The collector provides voltage across the unit under test. For a vacuum tube, this is the bias on the input signal.
The Base is provided either as a voltage or a current. For a vacuum tube, this would be the Grid input signal and the bias voltage, which is normally negative.

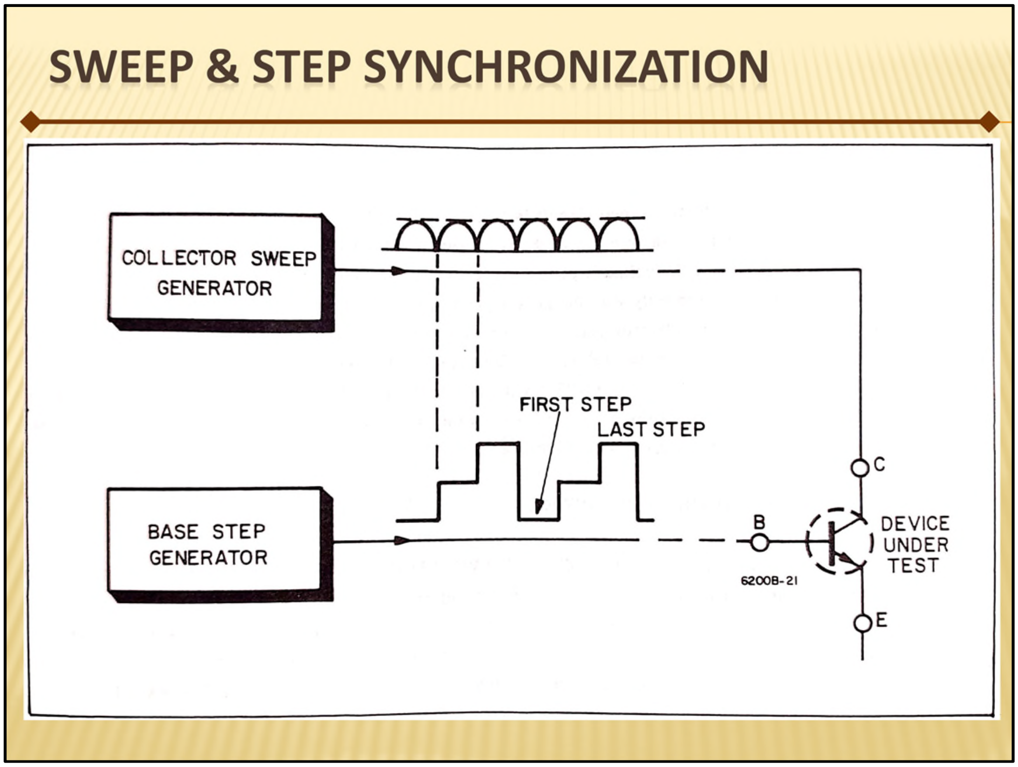


The collector supply provides the DC voltage across the device under test. For a vacuum tube, this would be the plate voltage, generally in the range of a hundred to hundreds of volts.
The collector supply voltage across the device under test drives the horizontal deflection plates of the oscilloscope, showing the voltage across the device.
The collector supply voltage across current sensing resistor drives the vertical deflection plates of the oscilloscope, showing the current across the device.

CURVE TRACER BLOCK DIAGRAM



The Step Generator generates lower DC voltages in steps. The amount of voltage between the steps, the polarity of the steps, and the number of steps can be adjusted. For a vacuum tube, each step provides an increasing amount grid bias voltage, either positive or negative.

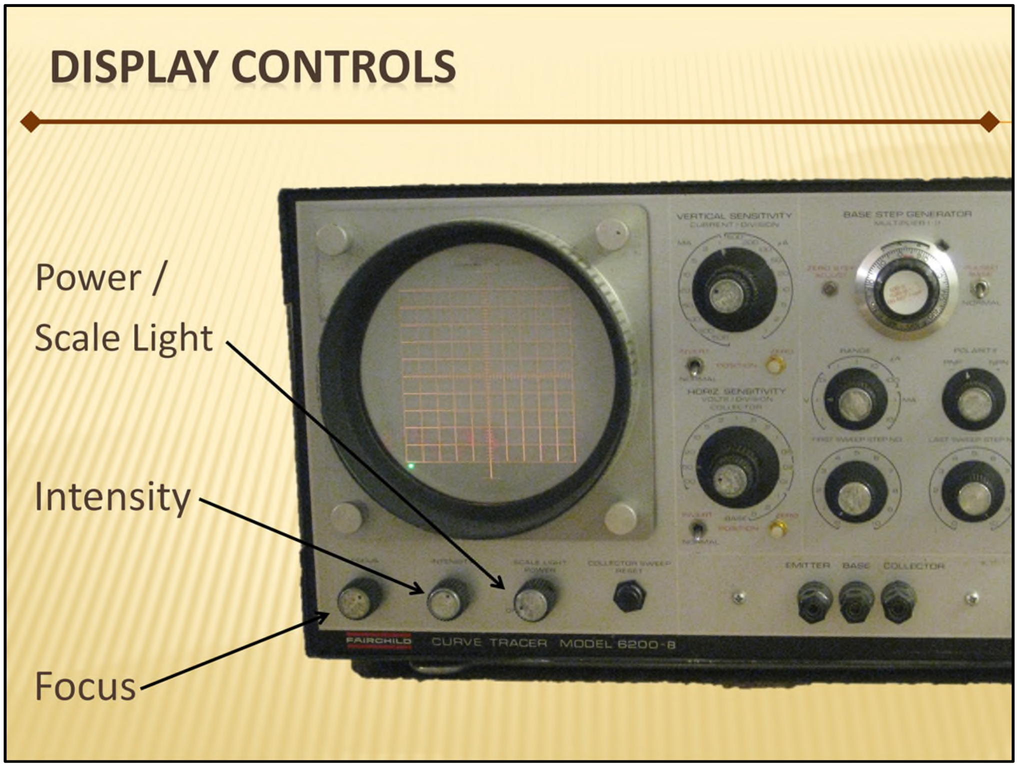


Each sweep of the Collector Sweep Generator is synchronized to each step of the Base Step Generator.

CURVE TRACER CONTROLS

This is a Fairchild / Systron-Donner 6200B Curve Tracer

Nearly all curve tracers have similar controls



Power On/Off and Scale Light Control
Intensity
Focus
Vertical and Horizontal Sensitivity

VERTICAL/HORIZONTAL CONTROLS

Vertical Sensitivity ranges from a maximum of 500 Milliamps per division on the graticule to a minimum of 1 Microamperes per division.
Horizontal Collector Sensitivity ranges from a maximum of 100 Volts per division to .01 Volts per division, or Base Sensitivity from .1 Volts per division to .5 volts per division.
The Center Knob on each control is for the positioning of the cursor.

BASE STEP GENERATOR CONTROLS

To the right of the Vertical and Horizontal Sensitivity controls on the 6200-B are the Base Step Generator Controls

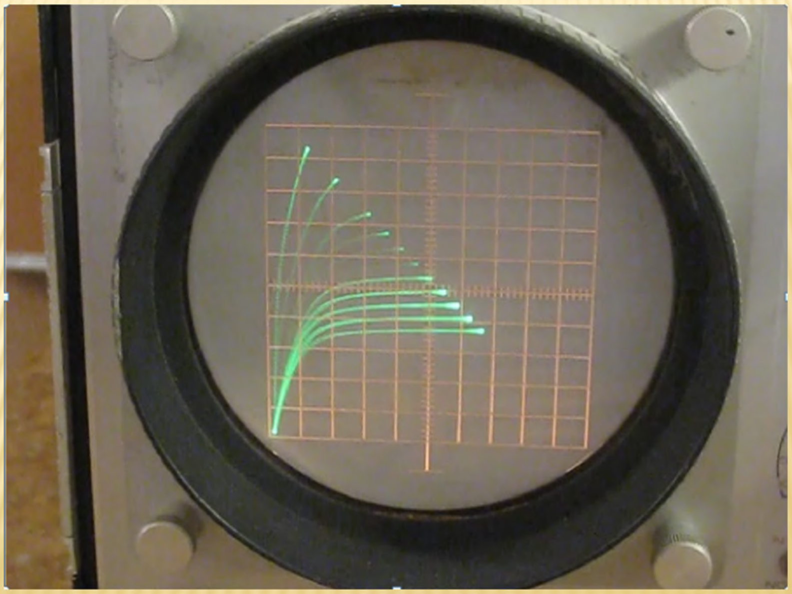
BASE STEP GENERATOR CONTROLS

Starting from the bottom are the First Step and Last Step controls of the Base Step Generator. As depicted, the first step to be displayed is step 3, and the last step to be displayed is step 7.
The Range Control is either in. 01 to 1 volt steps, or in amps from .1 Microamperes to 10 Milliamps.
The Polarity switch is negative for PNP transistors (and negative tube grid voltages) or positive for NPN transistors.
At the top is a 1 to 11 Multiplier control which works in conjunction with the Range switch. This allows the steps to be as much as 11 times the Range control setting.
If the Range control is set to 1 Volt, the Multiplier can adjust the step range from 1 and 11 volts.

FIRST AND LAST STEP CONTROLS

Using a 2N5484 Silicon Junction Gate Field-Effect Transistor or JFET Amplifier to generate curves.

FIRST AND LAST STEP CONTROLS

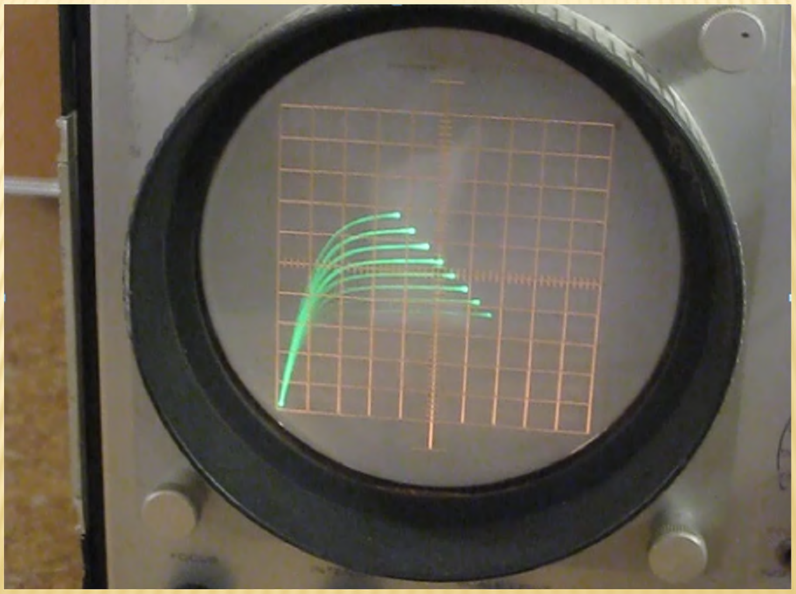


All Steps on.

FIRST AND LAST STEP CONTROLS

Last Sweep Step control adjusted.

FIRST AND LAST STEP CONTROLS

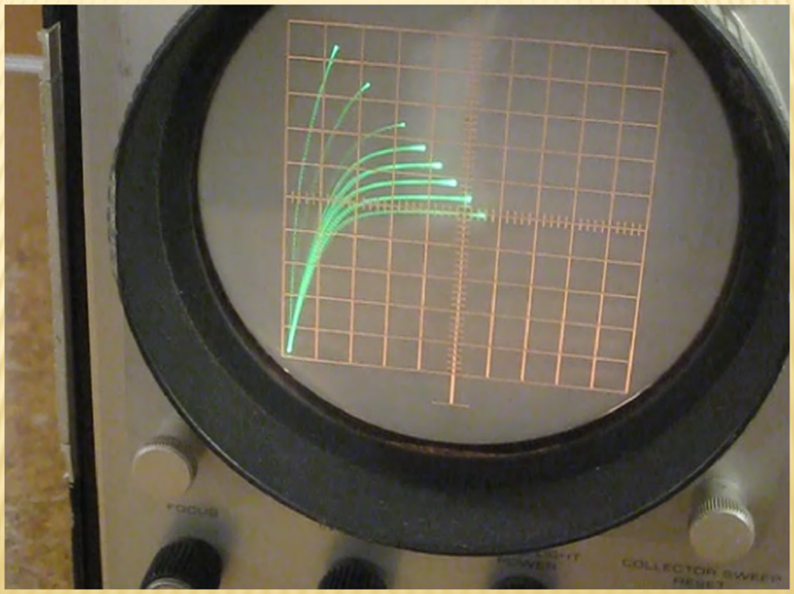


Three last steps (to the left) turned off.

FIRST AND LAST STEP CONTROLS

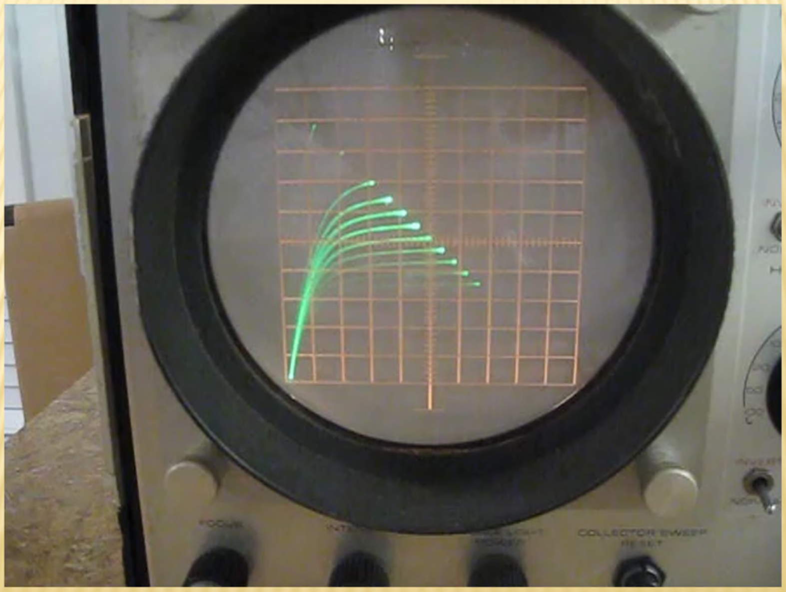
First Sweep Step Control adjusted.

FIRST AND LAST STEP CONTROLS



Three First steps (to the bottom) turned off.

BASE STEP MULTIPLIER CONTROLS

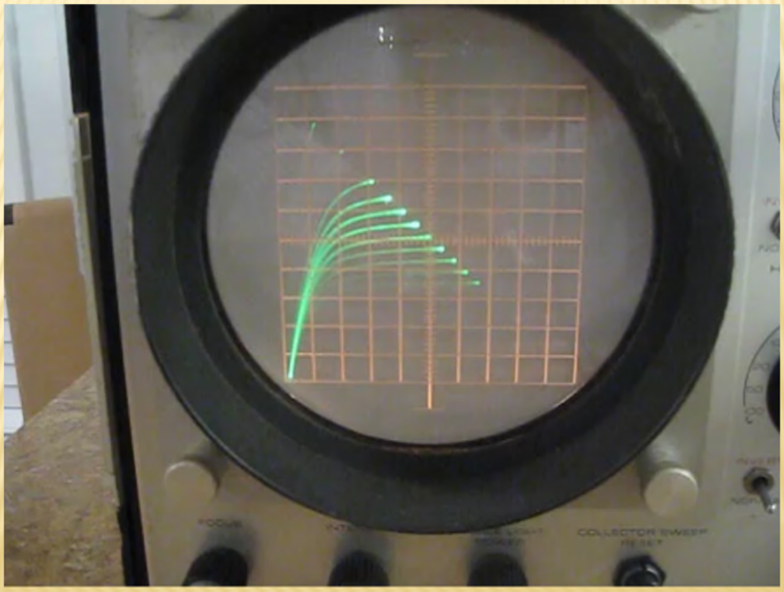


We can see how the First and Last Step controls function to turn off or on the first and last steps of the Base Step Control, and the Magnifier control changes the voltage spacing between the curve steps.

BASE STEP MULTIPLIER CONTROLS

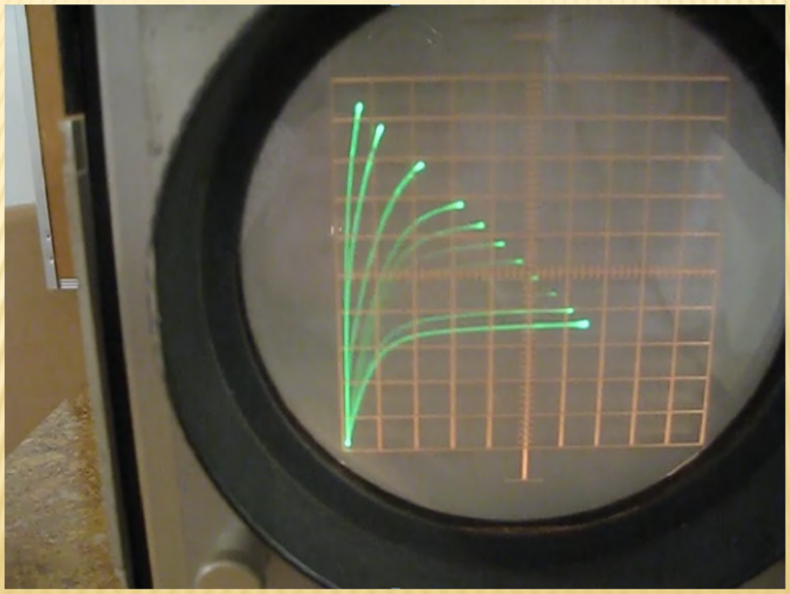
As the Magnifier control changes

BASE STEP MULTIPLIER CONTROLS



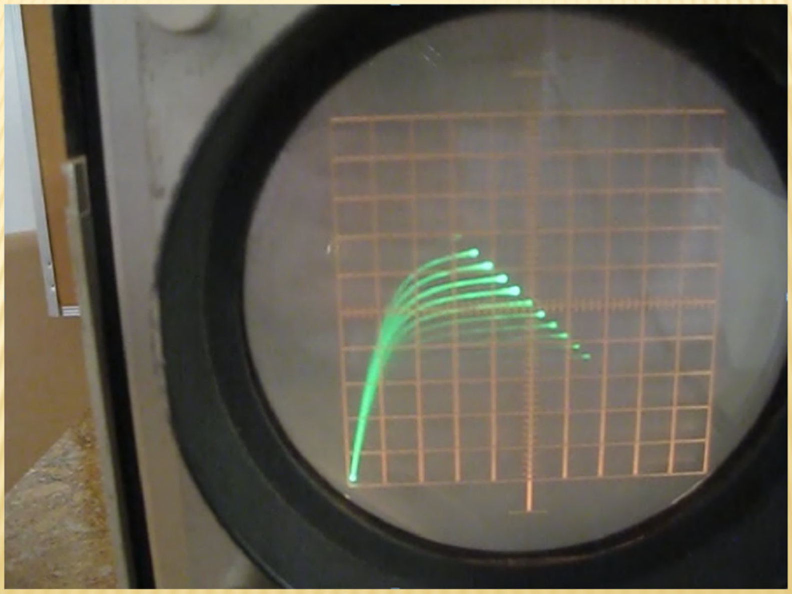
the voltage spacing between the curve steps

BASE STEP MULTIPLIER CONTROLS



increases

BASE STEP MULTIPLIER CONTROLS

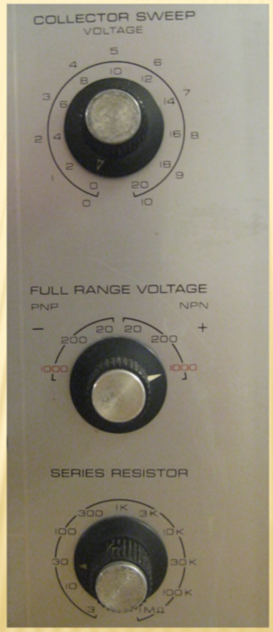


and decreases

COLLECTOR SWEEP CONTROLS

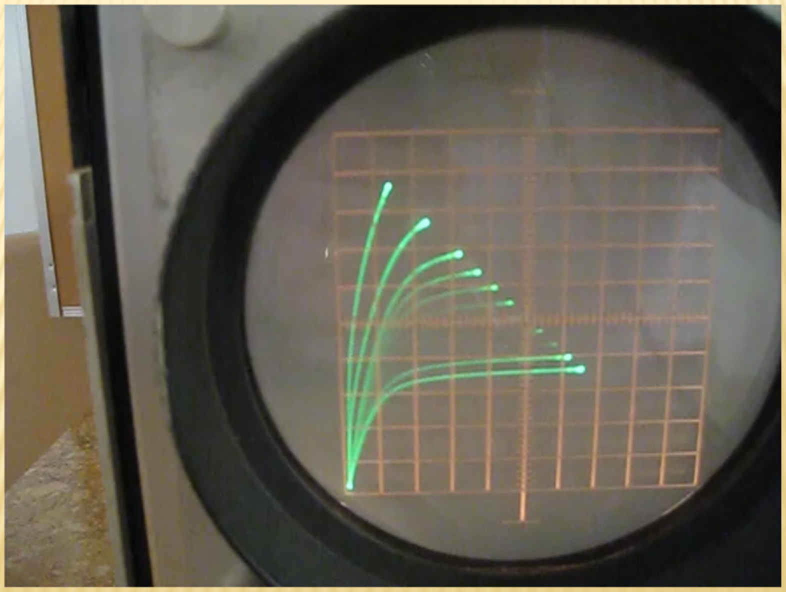
The next set of controls are those for the control of the Collector Sweep Generator.

COLLECTOR SWEEP CONTROLS



Starting from the bottom is the control knob for the current limiting series resistor, very important for protecting delicate transistors.
The Full Range Voltage knob control allows for the selection of full range DC sweep voltages, either positive of negative. The max voltages range from 20 to 1,000 volts.
The top knob control turns a variac for the fine control of the sweep voltage from 0 to the full range voltage selected by the middle knob.

COLLECTOR SWEEP VOLTAGE ADJUSTMENT

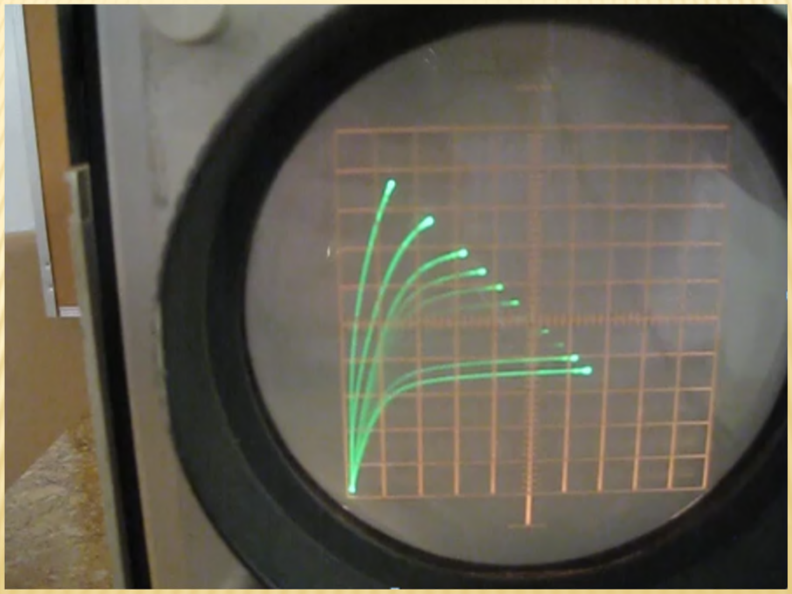


As the Collector Sweep Voltage control is decreased and then increased, we see the curves extending less to the right, and then further to the right.

COLLECTOR SWEEP VOLTAGE ADJUSTMENT

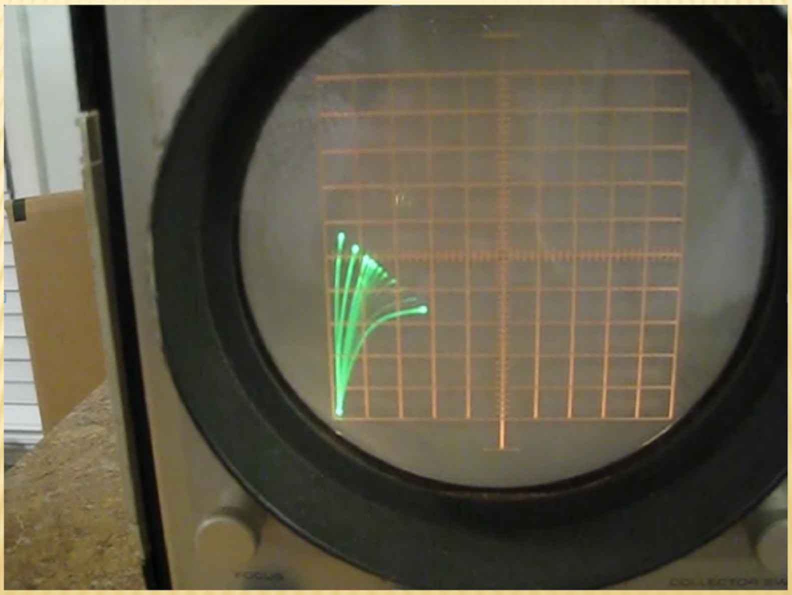
As the Collector Sweep Voltage control is adjusted

COLLECTOR SWEEP VOLTAGE ADJUSTMENT



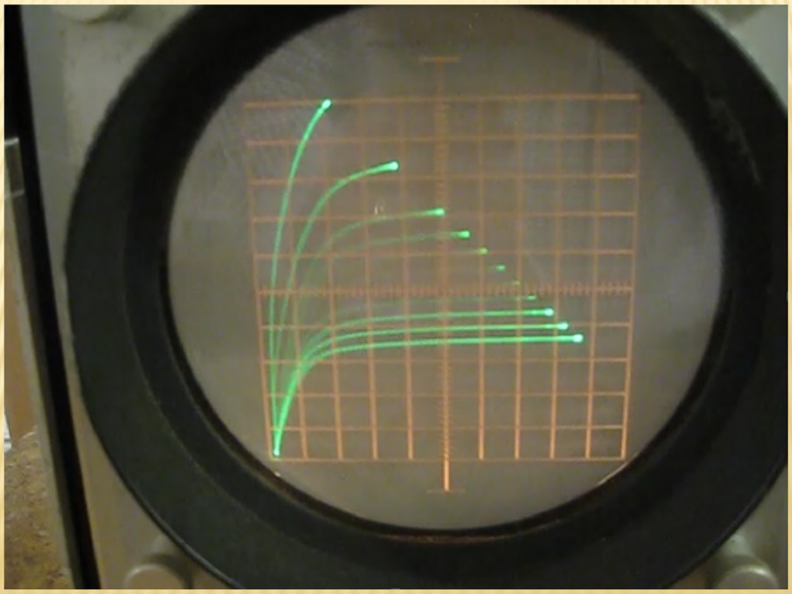
we see the curves extending

COLLECTOR SWEEP VOLTAGE ADJUSTMENT



less further to the right as the voltage is decreased

COLLECTOR SWEEP VOLTAGE ADJUSTMENT



more further to the right as the voltage is increased

WHAT CAN YOU DO WITH A CURVE TRACER

- ***Most are designed for the test of:***
  - ***Transistors – Already Demonstrated***
  - ***Diodes***
- ***Can be adapted to test:***
  - ***Rectifier Tubes***
  - ***Amplifier Tubes***

1N4001 DIODE TEST

This is how you mount and test a 1N4001 diode for a forward voltage test.
The diode starts out with low conductivity, but then starts conducting: 5 milliamps at .65 volts , and 10 milliamps at .7 volt.
Running it up to 1000 volts, I couldn’t get this diode to a reverse breakdown

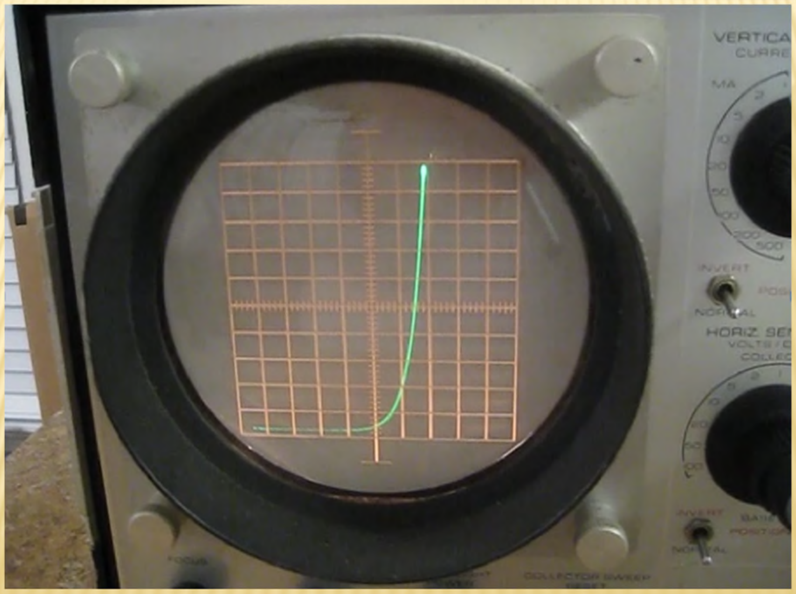
1N4001 DIODE TEST

Turning up the Collector Sweep Voltage

1N4001 DIODE TEST

The diode starts out with low conductivity,

1N4001 DIODE TEST

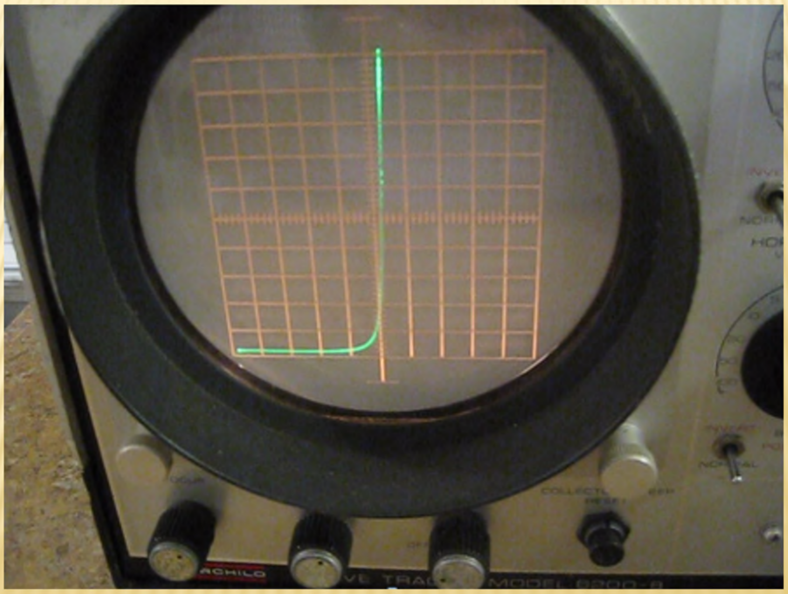


but then starts conducting: 5 milliamps at .65 volts , and 10 milliamps at .7 volt.
Running it up to 1000 volts, I couldn’t get this diode to a reverse breakdown

GERMANIUM DIODE REVERSE VOLTAGE

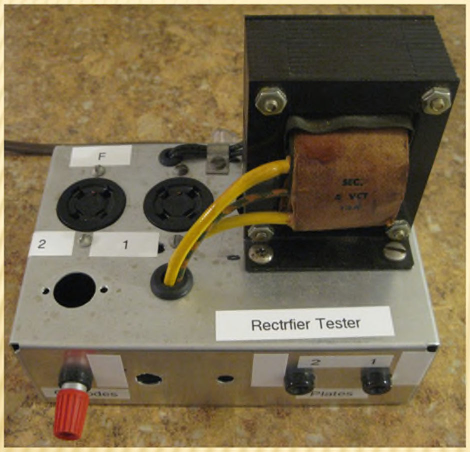
Testing a Germanium 1N64 diode
Horizontal sensitivity set to 1 volt per division
Vertical sensitivity set to 20 milliamp per division

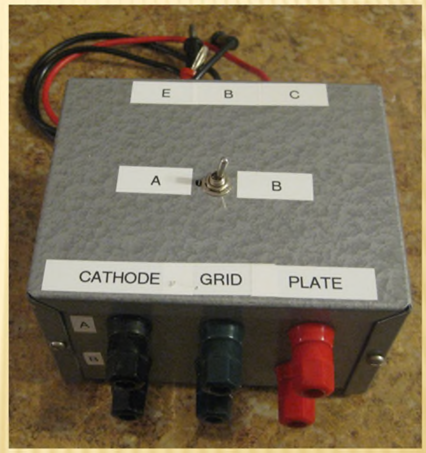
GERMANIUM DIODE REVERSE VOLTAGE



Turn up the collector voltage and see that the reverse breakdown occurs at 5 volts

EXTRA TOOLS NEEDED TO TEST TUBES





Need a voltage source for the tube filament voltage.
The item on the left is for the testing of rectifier tubes.
The item on the right allows for the testing of either side of a dua tube, or the matching of two separate tubes.

EXTRA TOOLS NEEDED TO TEST TUBES

Plus we needed a breadboard with tube sockets and connecting leads.

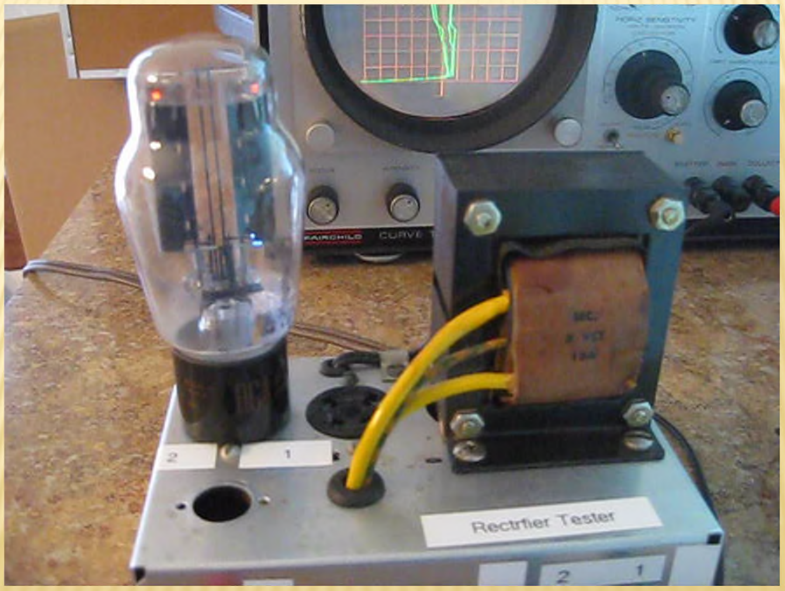
80 RECTIFIER TUBE

An 80 tube is used in many radios from the 30's

80 RECTIFIER TUBE

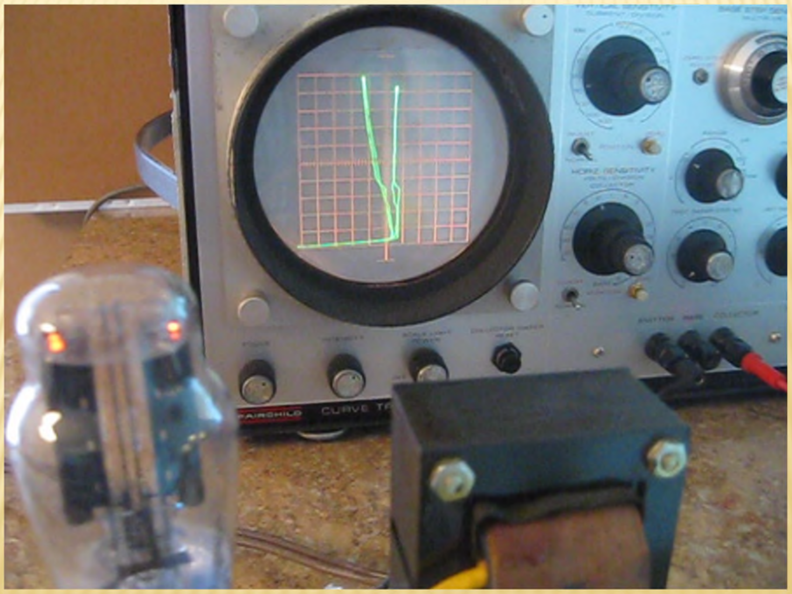
As the collector voltage is increased, the signature is similar to that of a diode.

83 RECTIFIER TUBE



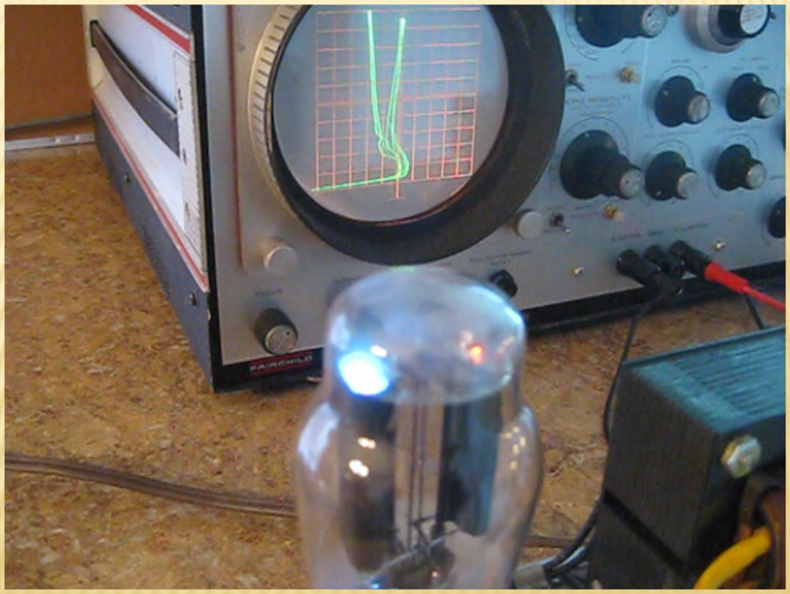
The 83 Rectifier tube contains mercury vapor. This tube is used extensively in tube testers.

83 RECTIFIER TUBE



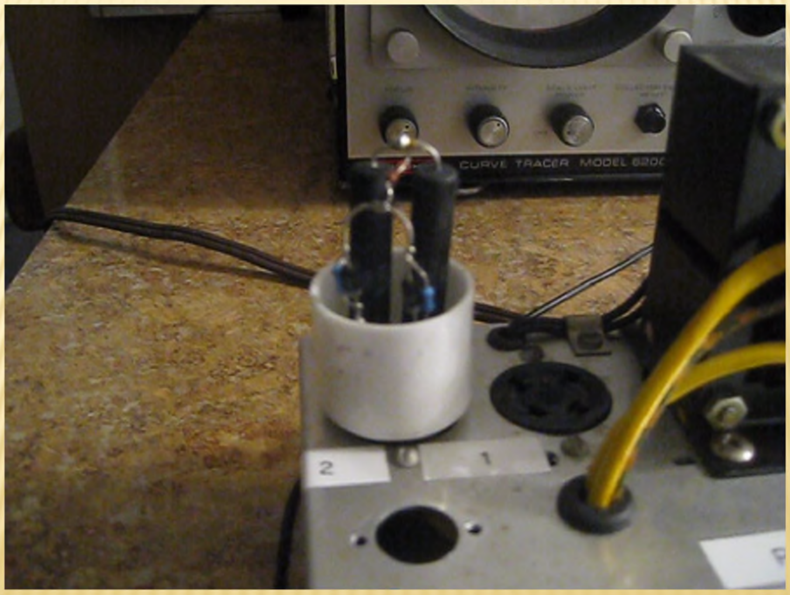
This is what a stable 83 tube signature looks like.

83 RECTIFIER TUBE EXHIBITING "HASH"



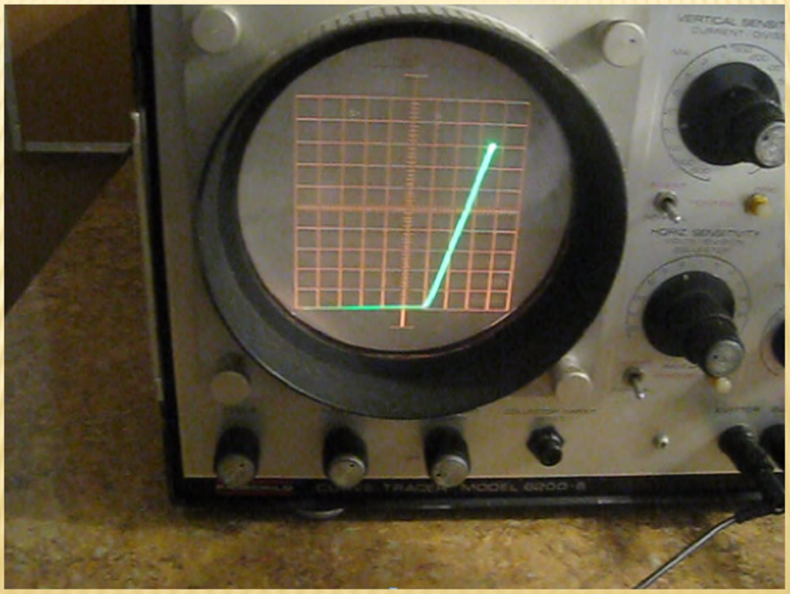
Some 83 rectifier tubes display a condition referred to as hash.

SOLID STATE 83 RECTIFIER



The 83 rectifier tube can be replaced with a specialized solid state device (not just 2 diodes).

SOLID STATE 83 RECTIFIER

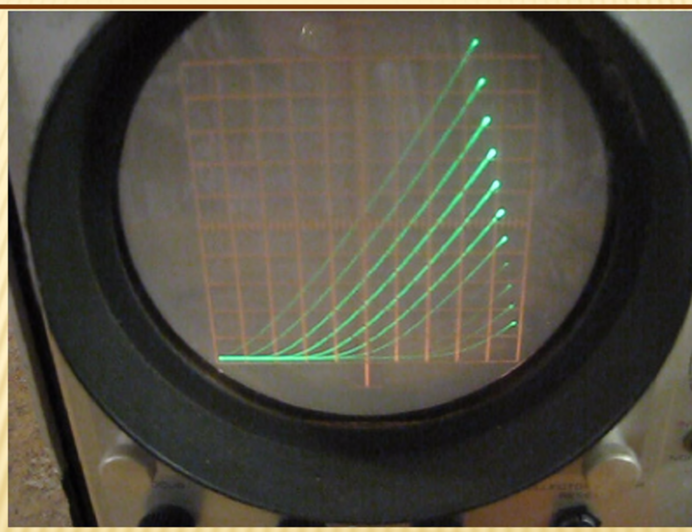


It displays a smooth rectification; no hash.

6C5 TRIODE

The simplest tube to test is a triode. Once you supply outside filament voltage, the curve tracer supplies everything else need to test the tube. With 500 volts on the plate and 1 volt grid bias steps,

6C5 TRIODE

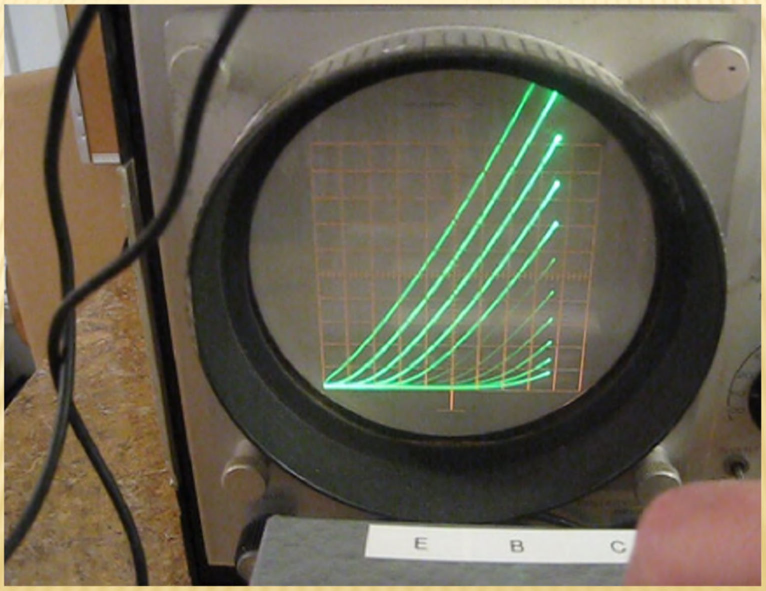


It generates performance curves.

12AX7 PAIRED TRIODE

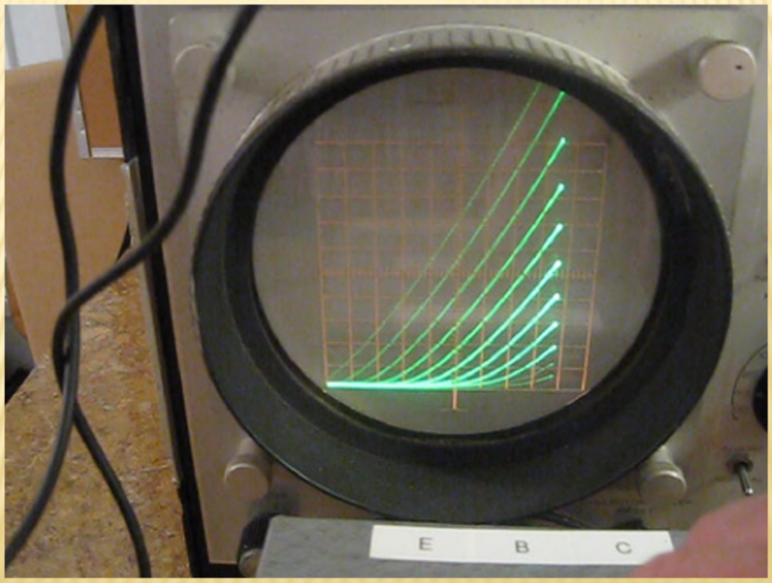
The 12AX7 contains two triodes in the same tube, and each of these should display nearly identical curves, indicating they are well matched.
Testing at 400 volts on the plate, .5 volt steps from 0 volts to -5 volts bias.

12AX7 PAIRED TRIODE



This is the curve for triode number 1.

12AX7 PAIRED TRIODE

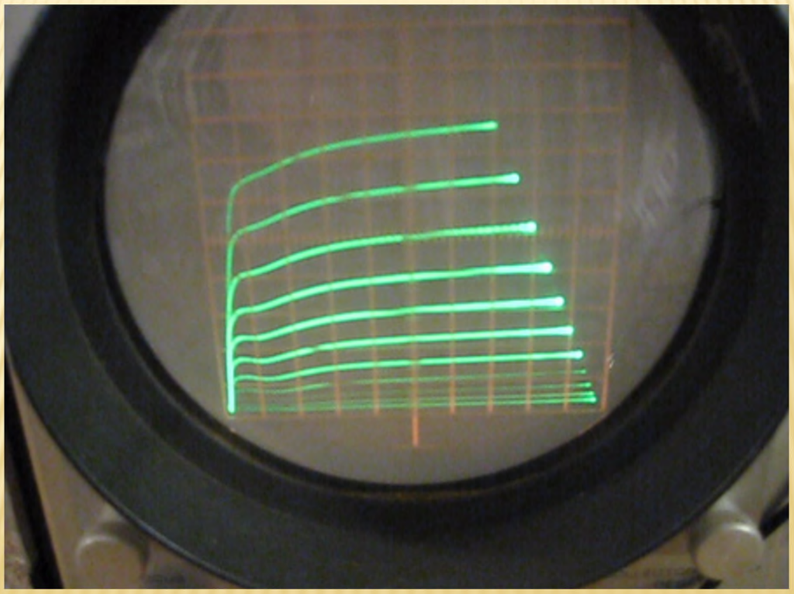


This is the curve for triode number 2.
We see this tube has very well matched elements.

6V6 POWER BEAM TUBE

The 6V6 is the little brother to the 6L6, and is a common audio tube.
To function normally as a pentode, it must not only be fed externally with 6 volts for the filaments, but must also be supplied with a screen voltage, at either 180 or 250 volts.
It was during the initial testing of the 6V6 tube when I encountered a limitation for my curve tracer. On the 1,000 volt scale the Fairchild 6200-B curve tracer I limited to a minimum of 100 ma of collector sweep. When the tube received 250 volts of screen voltage, a plate voltage sweep from 0 to 500 volts, and grid steps from 0 to 10 in 2 volt steps (0 to -20 volts), the tube exceeded 100 ma and tripped the Collector circuit breaker.
The tube did not exceed 100 ma when run on 180 volts of screen.

6V6 POWER BEAM TUBE



Using a Horizontal sensitivity of 50 volts per division, and a Vertical sensitivity of 10 milliamps per division, the tube did not exceed 100 ma when run on 180 volts of screen.

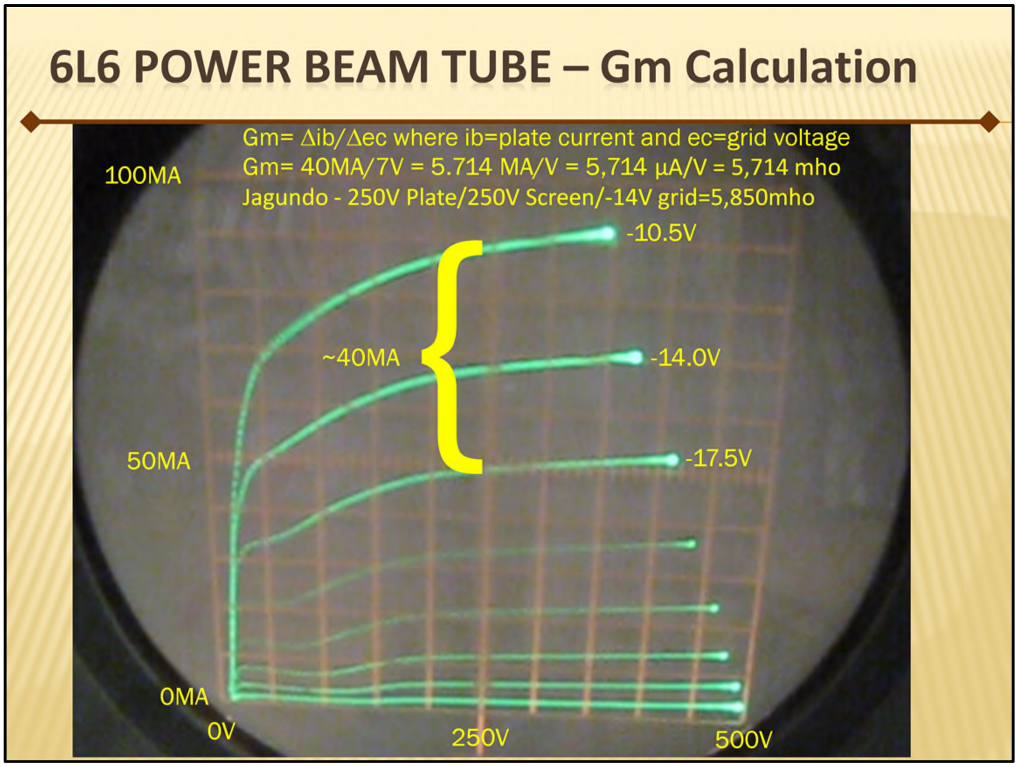
6L6 POWER BEAM TUBE

If we were having issues with the 6V6, the 6L6 would even further stress the curve tracer. Another way to reduce high Collector current is to not test the tube at near zero grid voltage.

According to the RCA tube manual, the 6L6 tube is tested at 250 volts screen, 250 volts plate, and -14 grid. It is not typically operated at grid voltages closer to 0 volts (an operating area that is not linear).

Using 3.5 volt steps, and a first step of 3 (not 0), the top most (highest current) sweep is at -10.5 volts, with the next step at -14 volts grid.

Using a Horizontal sensitivity of 50 volts per division, and a Vertical sensitivity of 10 milliamps per division, we were able to test the tube at 250 volts screen, 0 to 500 volts on the plate, and 8 steps of 3.5 volts each covering -10 to -35 volts on the grid.

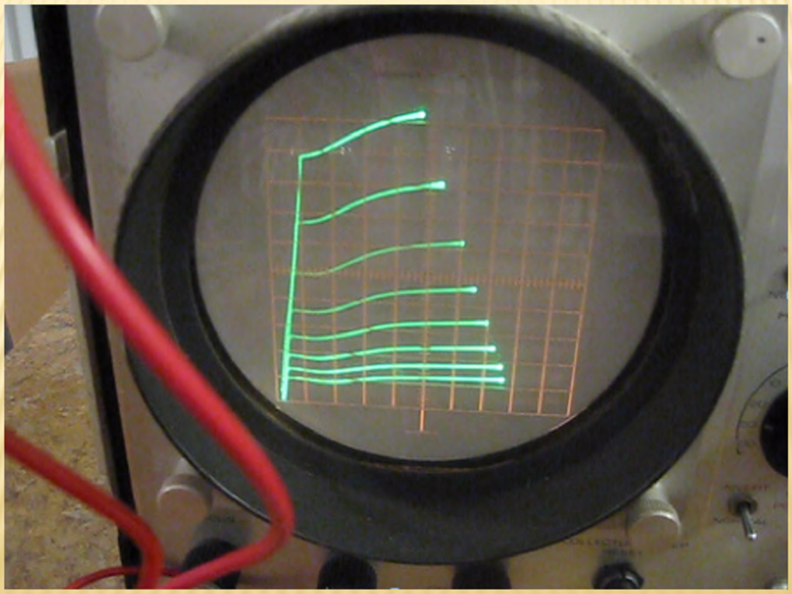


Using 3.5 volt steps, and a first step of 3 (not 0), the top most (highest current) sweep is at -10.5 volts, with the next step at -14 volts grid, and the next step at -17.5 volts.
Using a Horizontal sensitivity of 50 volts per division, and a Vertical sensitivity of 10 milliamps per division, we were able to test the tube at 250 volts screen, 0 to 500 volts on the plate, and 8 steps of 3.5 volts each covering -10 to -35 volts on the grid.
Transconductance (Gm) is calculated as the change (delta or Δ) in plate current (ib) divided by the change in grid voltage (ec). Using the two curves on either side of the -14 grid volt curve at the 250 volt plate voltage curve, we calculate Gm= 40MA/7V = 5.714 MA/V = 5,714 µA/V = 5,714 mho
This tube was tested on the Jagundo at 250 plate, 250 volts screen, and -14 volts grid yielding a Gm of 5,850 mho, which is within 2.5%.

6L6GC POWER BEAM TUBE - PAIR

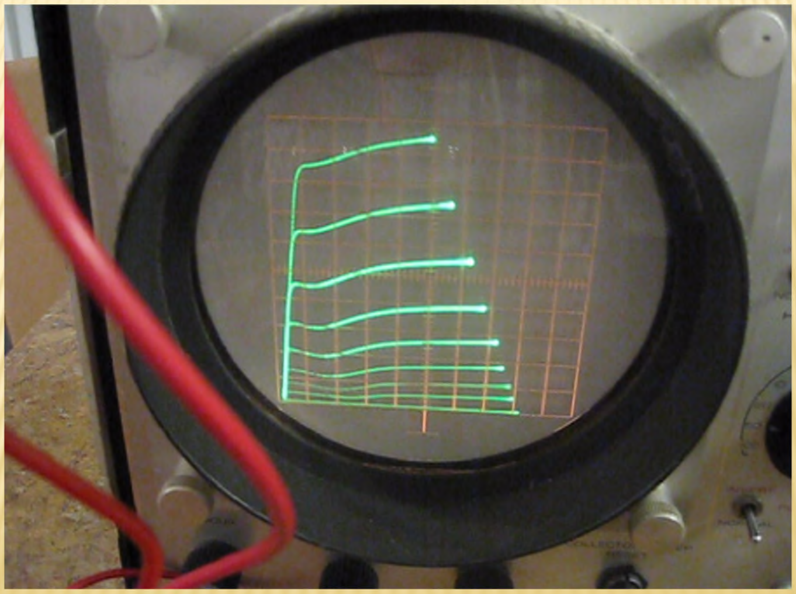
Using a Horizontal sensitivity of 50 volts per division, and a Vertical sensitivity of 10 milliamps per division, we were able to test these two audio tubes at 250 volts screen, 0 to 400 volts on the plate, and 8 steps of 3.5 volts each covering -10 to -35 volts on the grid.

6L6GC POWER BEAM TUBE - PAIR

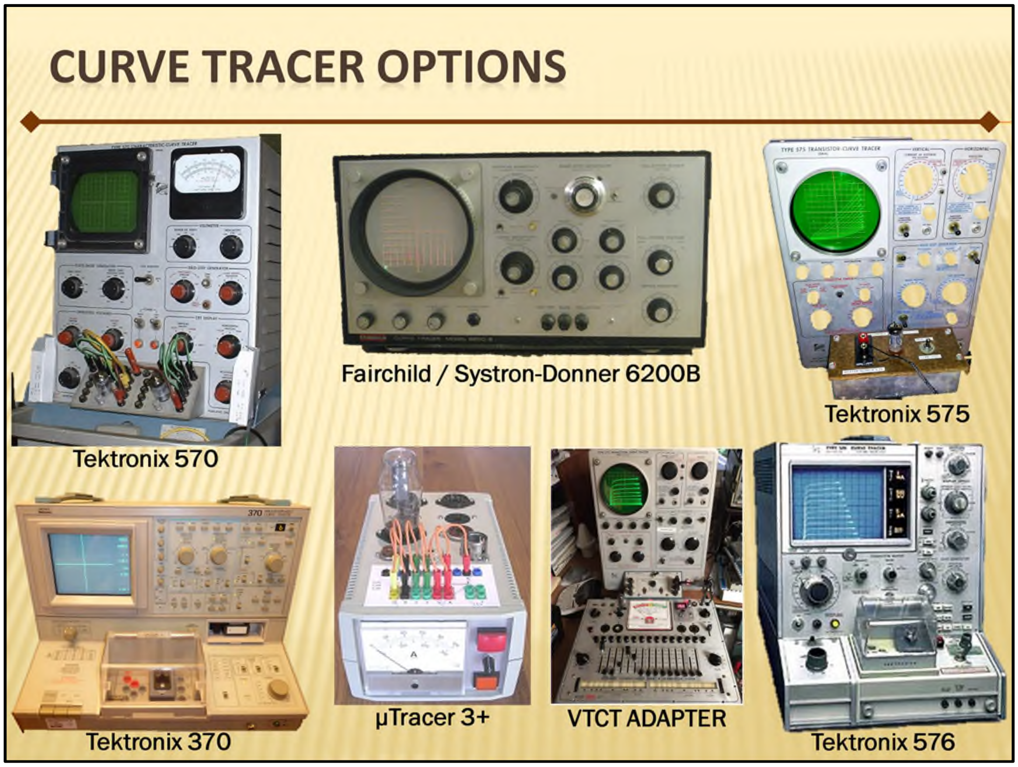


These are the curves for tube number 1.

6L6GC POWER BEAM TUBE - PAIR

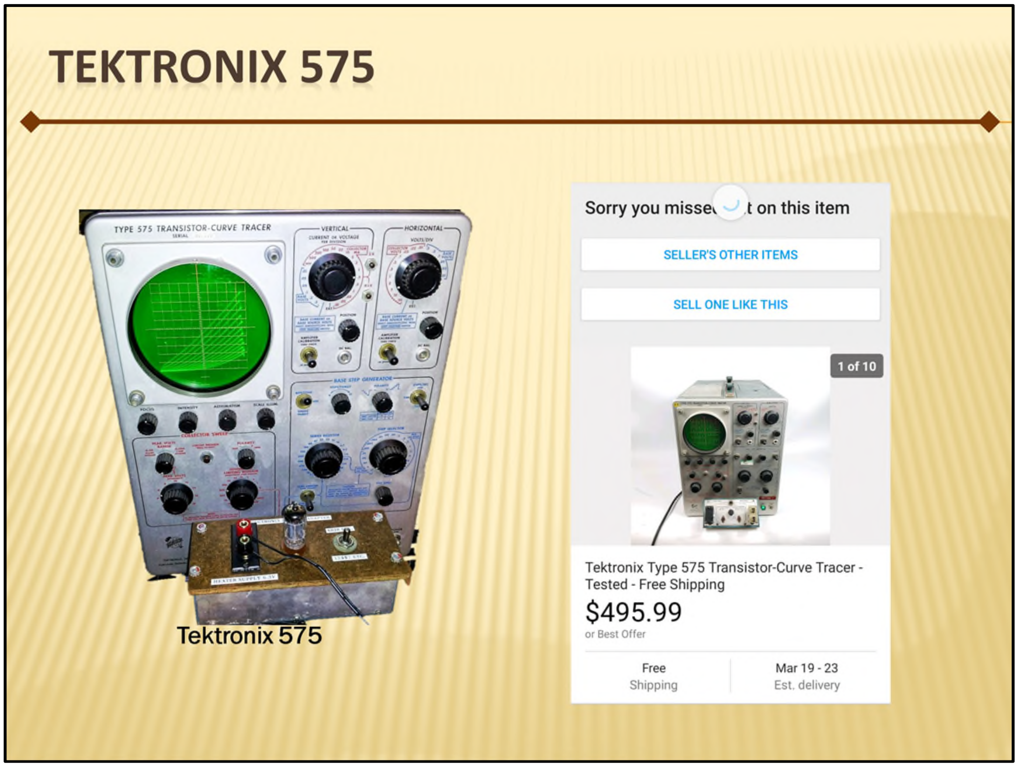


These are the curves for tube number 2.

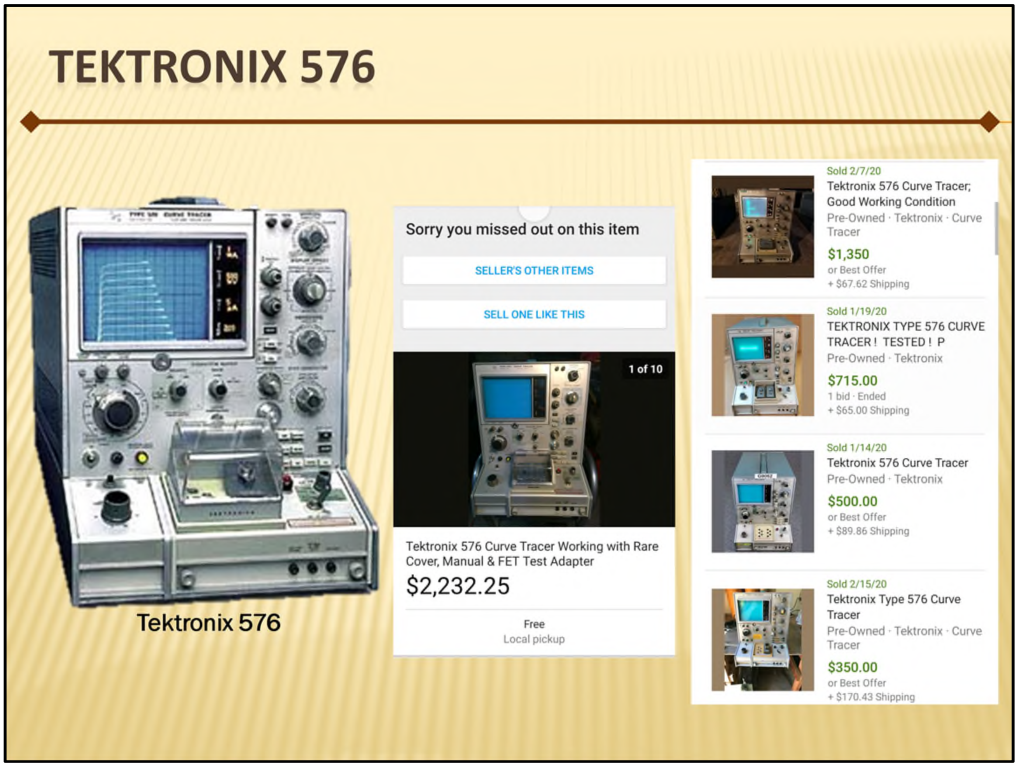


There are options for the purchase of curve races

Tektronix 570 is a true vacuum tube curve tracer.
Available form 1956 until 1966, it is tube based.
It will supply up to 13 steps of up to 10 volts each, and up to 500 plate volts with plenty of amperage. It had its own heater supply.
The drawback, they are nearly impossible to find. Only 1,000 were built, and they are all over 50 years old.
When you can find them, they are pricy.

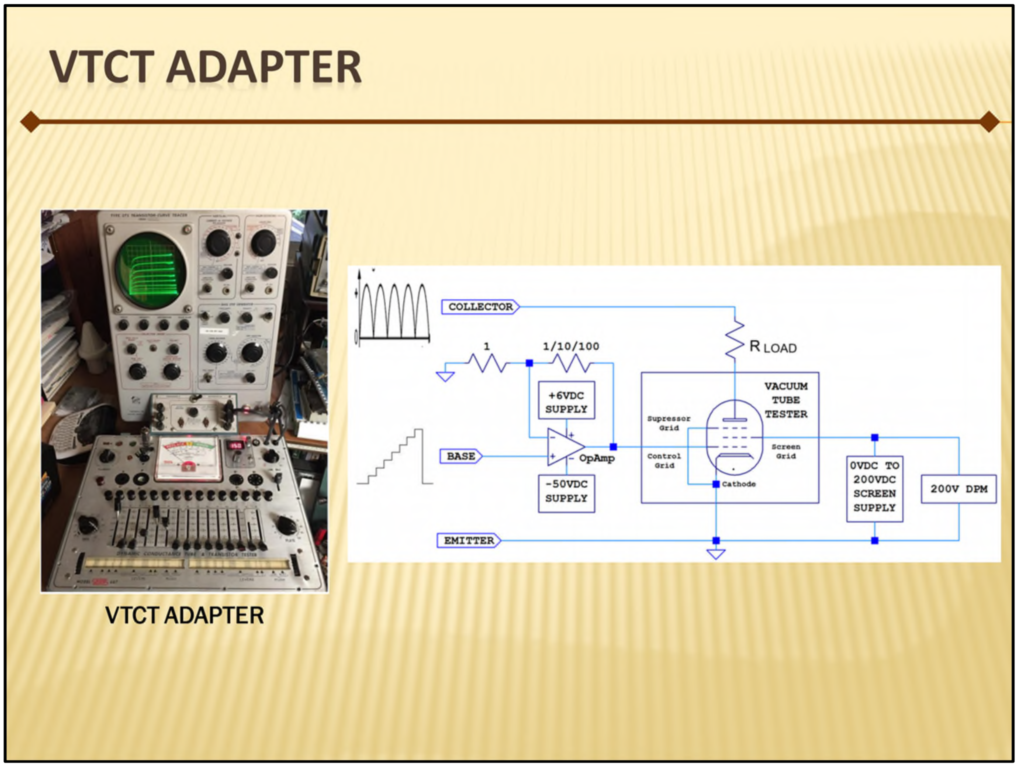


The Tektronix 575 followed the 570, and was designed to test semiconductors, not tubes. It is however tube-based (40 of them).
Sold from 1958 to 1971, they are much more plentiful than the 570 are more easily obtainable.
It has two drawbacks, limited collector (plate) voltage (200V) and limited base (grid) drive (10 sets of 1 volt each).
A mod kit, MOD 122C, doubled the plate voltage, but this can be limiting for testing high-end audio.
A external amplifier can be built to 10-fold the grid voltage steps.
These units are relatively affordable.

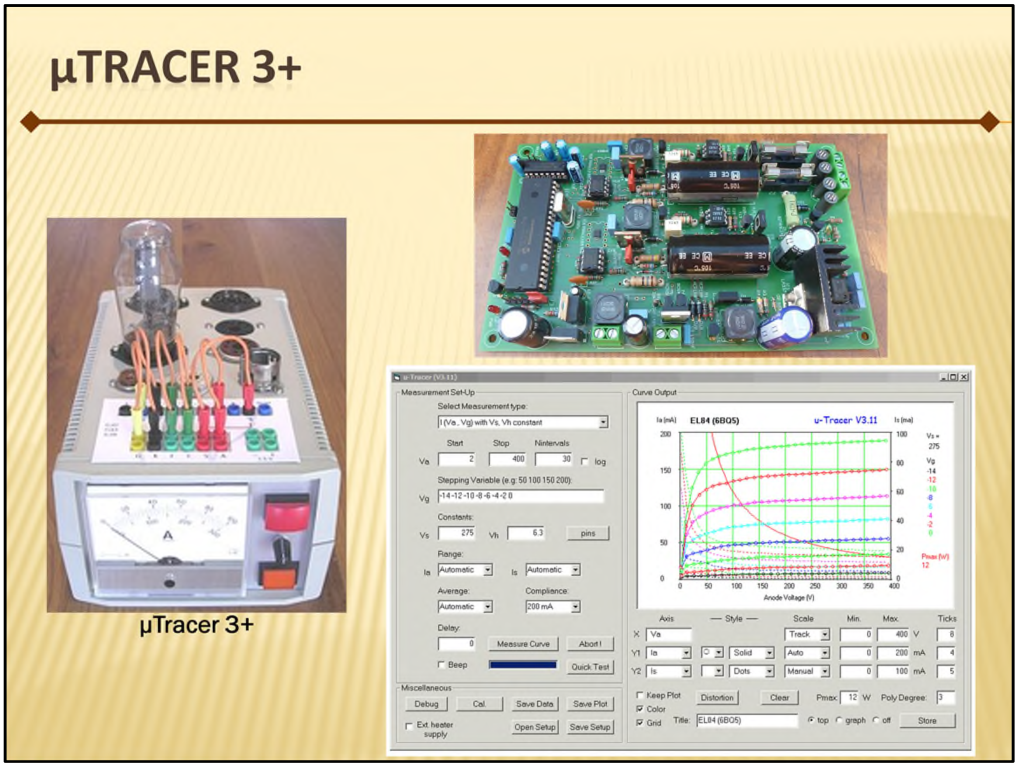


The Tektronix 576 followed the 575. At the time they were very expensive
A solid state unit designed strictly for semiconductor testing, they are far more adaptable for testing vacuum tubes, supplying sufficient collector (plate) and gate (grid) voltage. The latter 577 and succeeding curve tracers of the period were not as well suited for tube testing.
These units can be pricey, but are generally affordable.

The Tektronix 370 is a modern day semiconductor curve tracer. Plenty capable of testing tubes, it is rather expensive to crazy expensive.



The VTCT ADAPTER is something I have come across recently. It is a kit that can be built and incorporated into a variety of standard tube testers, using their switches, filament supply, and sockets, with a Tektronix curve tracer supplying the sweeps and displays. The kit only costs about $80 to build, but you must also supply a tube tester and a curve tracer.
Here is the block diagram.



The UTracer is a curve tracer for vacuum tubes. Available as a kit, it uses a Windows PC as the user interface and display.
The unit provides Plate voltages up to 400 volts and grid steps sufficient to test many tubes.
It supplies plate voltages just long enough to get the required measurements.
It sells for € 225 via PayPal, approximately $250 US.

Alan Douglas spoke highly of this unit, stating it was highly capable of testing vacuum tubes. Fairchild marketed the unit in 1967. All transistorized, the unit is well built. Systron-Donner purchased the design in 1969.

Rare, they are affordable. If there is a drawback, its that the only tech manual I have found so far is marked preliminary.

I liked it so much, I bought two of them, one Fairchild, and one Systron-Donner. They are not identical.

REFERENCES

- *Tube Testers and Classic Electronic Test Gear – Alan Douglas – Amazon and Google Books*
- *Curve Tracer Measurements - https://www.microwaves101.com/*
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