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The Daystrom / Weston CA-1630 Electron Tube Analyzer

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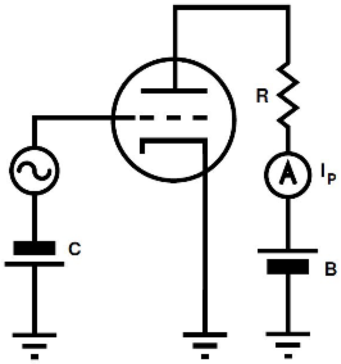
The colorful CA-1630 is more than just a drug-store tube tester, rather, it is a precision laboratory-grade equipment to accurately measure the transconductance of a wide variety of vacuum tubes. Its vintage is late 1950s or early 1960s. The tester was recapped and realigned October 2017, and prepared for use.

The tester measures the *transconductance* of vacuum tubes. Transconductance is the characteristic of a tube that measures its ability to amplify a signal.

Small-signal Amplifier

Standard receiving-type tubes may be considered to be voltage-controlled current controllers.



Here is a triode tube in a circuit with a "B" battery that supplies the positive DC voltage to the plate of the tube and a "C" battery that supplies a negative DC bias voltage to the control grid.

An electron current flows from the cathode to the plate and to the "B" battery through the plate ammeter that measures the plate current I_p. Changing the negative bias voltage on the grid will change the plate current that flows through the tube and the "B" battery. For smaller receiving tubes, the grid intercepts a negligible amount of current.

Transconductance

The transconductance figure of merit of a vacuum tube is the ratio of the change of plate current I_p to the change of grid voltage.

Ohm's law tells us that as a current *I* travels through a resistor *R*, the voltage *V* induced across the resistor lets us calculate the value R of the resistor by the formula

$$R = V / I$$

The resistance is the voltage across the resistor divided by the current through the resistor, and the units of resistance is ohms.

In measuring the transconductance of vacuum tubes, we will turn this equation upside-down, as we would like to know what happens to the change of plate current for a given change in grid voltage, so we can define a new unit, *conductance*, with the symbol *G*, by inverting the above equation, and expressing the conductance by the change of plate current divided by the change of grid voltage:

$$G = \text{change of } I_p / \text{ change of } V_g$$

The conductance of the resistor is calculated by dividing the current through the resistor by the voltage across the resistor. The unit of conductance is M*ho*, which is ohm spelled backwards.

This unit is used in tube testing as the current *I* in the plate circuit is a function of the voltage *V* applied to the grid. A higher conductance implies a higher gain of the tube.

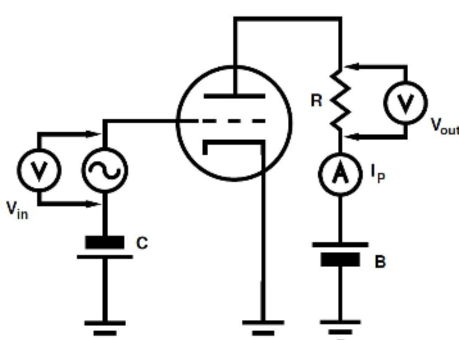
For most receiving tubes, the numerical value of transconductance is much less than one, so the usual unit is *microMho*, or units of one-millionth of a Mho.

Voltage Gain

Usually an amplifier stage is configured to produce a voltage gain, which is the change of output voltage for a given change in input voltage to the grid, supplied by a voltage generator whose voltage is V_{in}. This is an AC voltage that is added to the DC bias supplied by the "C" battery.

In the plate circuit of the amplifier, a resistor (or transformer, or other load) is inserted. The plate current flowing through the tube, measured by the ammeter A causes a voltage drop V_{out} across the resistor *R*, and by ohm's law, $V_{out} = I_p R$. The AC component of the signal in the plate circuit is measured by the AC voltmeter V_{out}, and the voltage gain of the circuit is $V_{out} / V_{in} = G \times R$. In actual circuits, *R* combines the load resistor, the tube plate resistance and the load of the stage following this amplifier stage. The voltage gain is proportional to the transconductance of the amplifier tube *G*.

Measurement of Transconductance



In this and other laboratory-type testers, DC power supplies are set to the tube operating conditions, with the bias adjusted to produce a required plate current. After the DC operating conditions, the grid bias from the "C" battery and the plate voltage from the "B" battery have been established, the DC current I_p through the tube is measured to verify the tube matches the published DC characteristics of the tube.

To measure the transconductance of the tube operating at these DC conditions a small AC voltage V_{in} is supplied to to the grid, and the AC component of plate current I_p induces an AC voltage across the resistor *R* in the plate circuit V_{out}.

The transconductance G is then calculated as $G = V_{out} / V_{in} \times R$.

The CA-1630 Tester

This tester provides independent adjustable power supplies for the “B” and “C” batteries, as well as independent adjustable power supplies for the tube heater and the screen grid (grid 2 between the control grid and the plate). Any other grids in the tube are normally connected to the cathode.

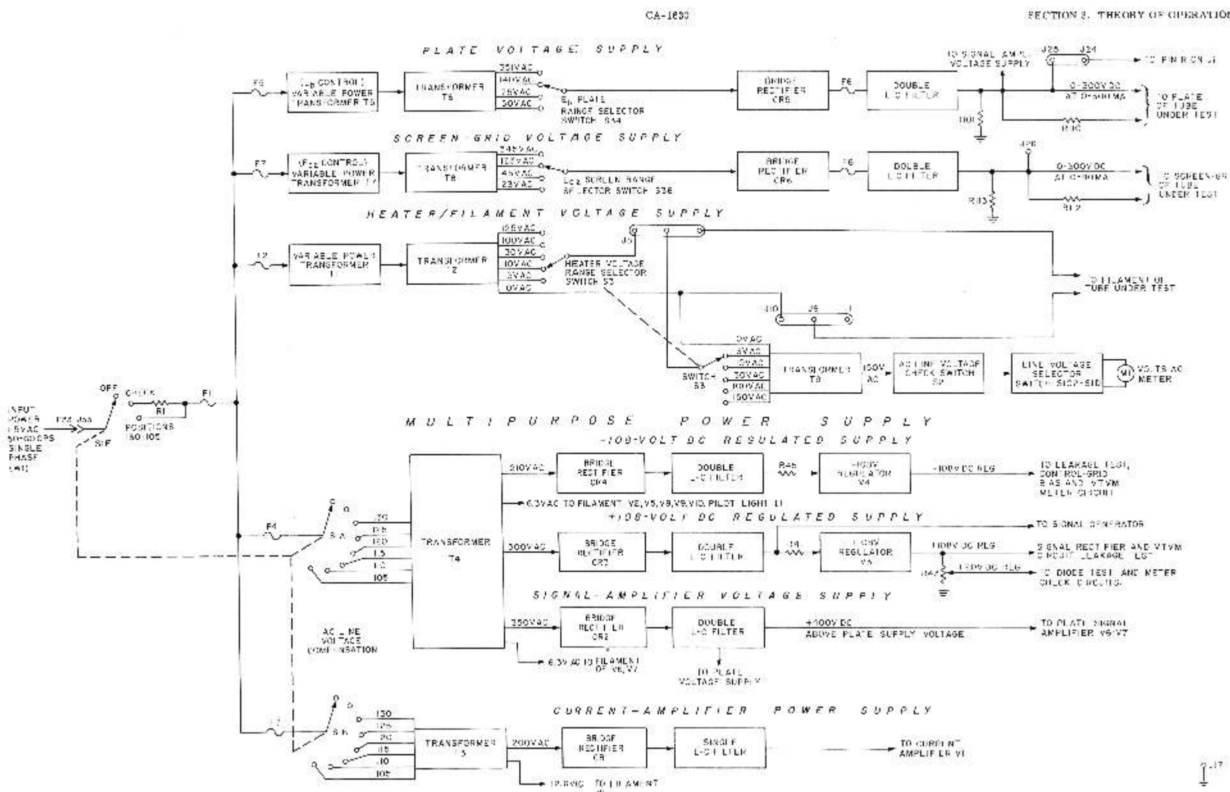
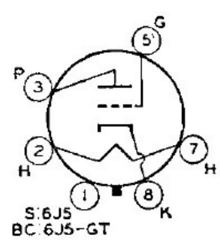


Figure 2.
Functional Block Diagram of Analyzer Power Supply

In setting the analyzer, the power supplies are connected through switches on the front panel to the tube elements. These details can be found in any tube manual. This diagram shows the pin-out for a 6J5 triode, followed by the operating characteristics for the tube.



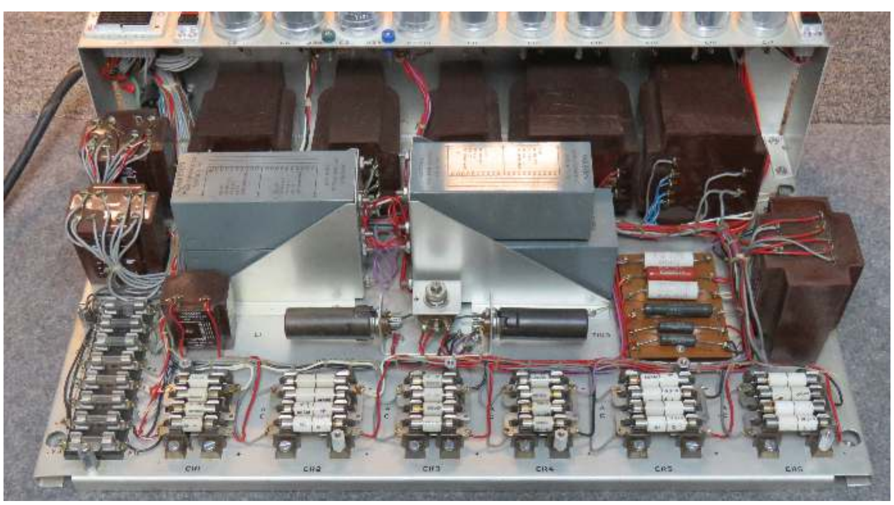
Characteristics:

Plate Voltage	90	250	volts
Grid Voltage	0	−8	volts
Amplification Factor	20	20	
Plate Resistance	6700	7700	ohms
Transconductance	3000	2600	μmhos

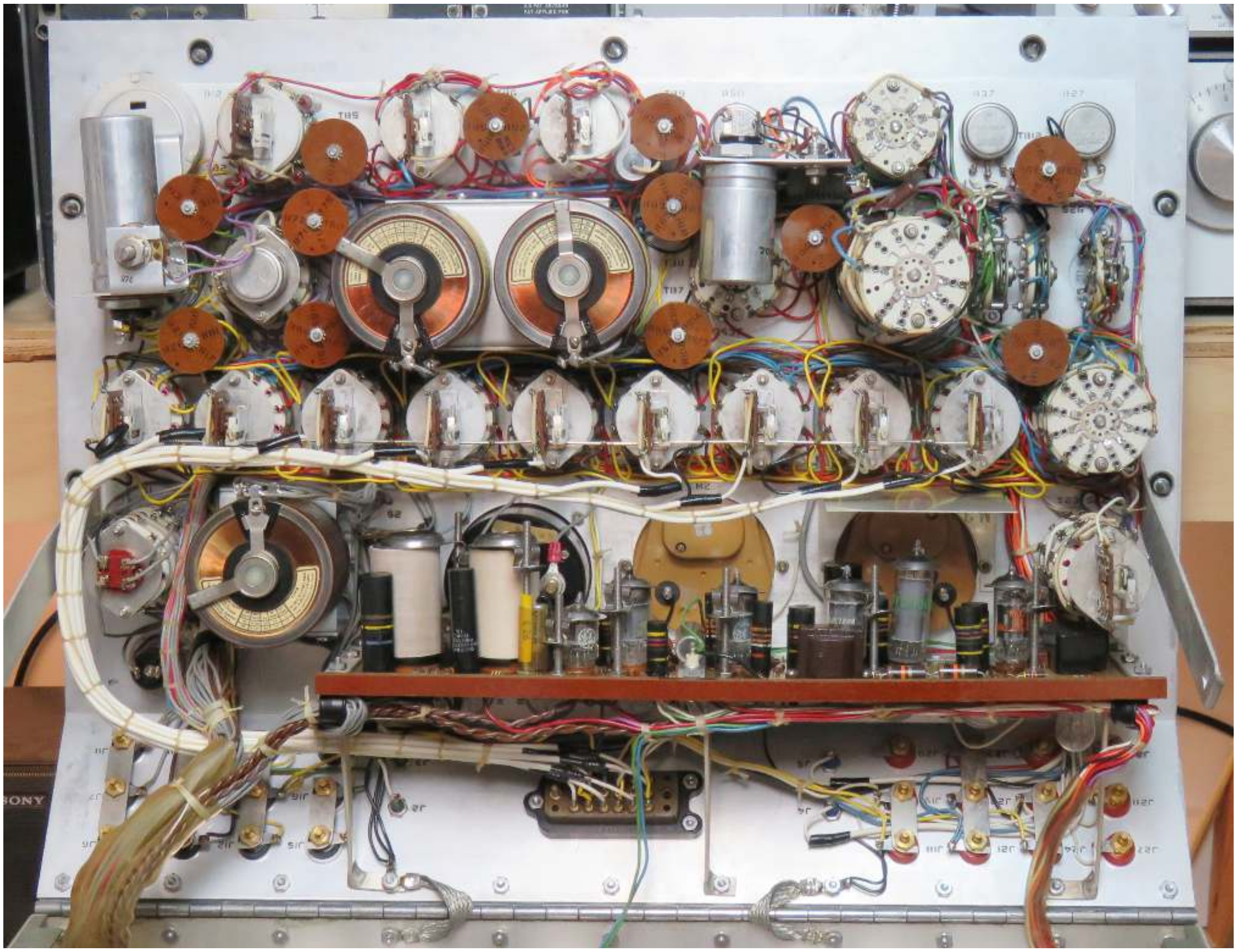
Then, using the tube manual values, the filament voltage is set up and measured on the smaller AC voltmeter and all the DC voltages are set up and measured on the large DC voltmeter. The electrode currents are then measured on the DC milliammeter and compared to the tube manual values.

The tube electrode connections are made through the row of switches through the middle of the panel, for each of nine pins. The line voltage selector and header voltage are set with the two black switches in the upper left.

The group of switches in the lower left control the grid and plate power supplies, and the voltage and current scale factors for the two large meters. The other knobs are used in the course of the measurement of transconductance.



The power supply transformers (lots of them!) reside in the base, with the rectifiers and fuses. Three plug-in adaptors contain tube sockets for most common types.



The back of the panel shows a number of switches, and variable-voltage transformers for the heater, plate and grid 2 power supplies.

Measuring the Transconductance

The DC voltage and current conditions are established and the tube checked for possible shorts or out-of-range grid or plate currents, and then transconductance is measured.

The transconductance measurement introduces a small AC signal to the grid. (A large grid signal will swing the tube far away from the DC operating point, so the measured value will not be characteristic of the specified value at the DC operating point.)

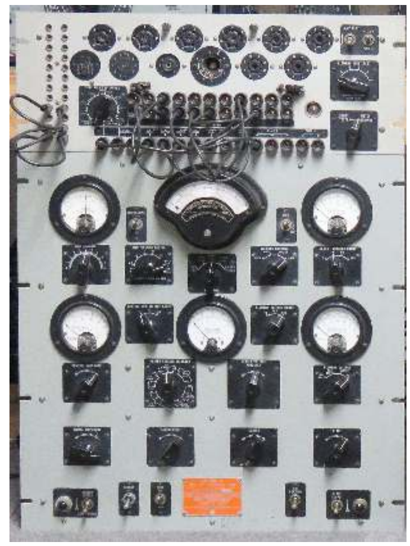
This tester injects a 0.1 volt signal to the grid at 10.5 kHz, and then measures the 10.5 kHz component in the plate circuit with a tuned voltmeter This avoids spurious signal that may be generated by 60 Hz hum in the power supplies or the heater circuit.

To keep the plate voltage from varying too much away from the DC value, the plate load resistor that the AC signal is generated across is just a few ohms, 2 ohms in the highest transconductance range, and up to 200 ohms in the lowest range, limiting the AC component of the plate voltage to a few volts. Thus, the tube is always operating very near its DC set-up values.

The transconductance is calculated and displayed from the measurement of the 10.5 kHz signal component across the plate load resistor.

The amplifier in the plate circuit may be set to wide-band to measure noise generated in the tube without an input signal.

Comparison to the AN/USM-31



This Weston-built tester shares with the CA-1630 the same approach to characterizing a vacuum tube: well-filtered DC voltages on the electrodes, and a small AC test signal. This tester is the US Navy version of the Weston 686 Type 9C.

The main differences to the CA-1630 are: a 60 Hz instead of 10.5 kHz test signal, and more meters permit simultaneous monitoring of all the test parameters. A jack panel serves to set up the connections to the tube pins. The filament voltage is measured at the tube base with separate connections for the filament voltmeter. For AC filament tubes, the center-tap of the filament transformer is variable to null out AC filament hum.

The plate load resistor is a constant 500 ohms, and to select the transconductance range, the grid signal is varied from 0.1 volt rms for the 30000 uMho range to 1 volt for the 3000 uMho range. For the lowest 600 uMho range, the test signal is 0.5 volt and a gain-stabilized amplifier increases the plate signal to the meter.

For tubes with low amplification factor, the low tube plate resistance can become a significant load across the 500 ohm plate load, so a range switch for low-mu tubes (3.5, 5, 7, 10, 15) is added that increases the plate load resistor so the parallel combination remains close to 500 ohms.

Comparison to Other Testers

Laboratory-type testers like the CA-1630 allow the tube to be tested at specific and measurable electrode voltages and currents at a small signal level. Most other transconductance testers do not specify the actual operating conditions so the measured transconductance cannot be compared to the specifications for the tube at a specific operating point.

This generally works well in most cases, but for small-signal amplifiers, such as 12AX7s, the grid signal swing moves the operating point well away from a specific operating point, so an absolute measurement is not available, and the tester data sheets are calibrated on the basis of a tube known to be good.