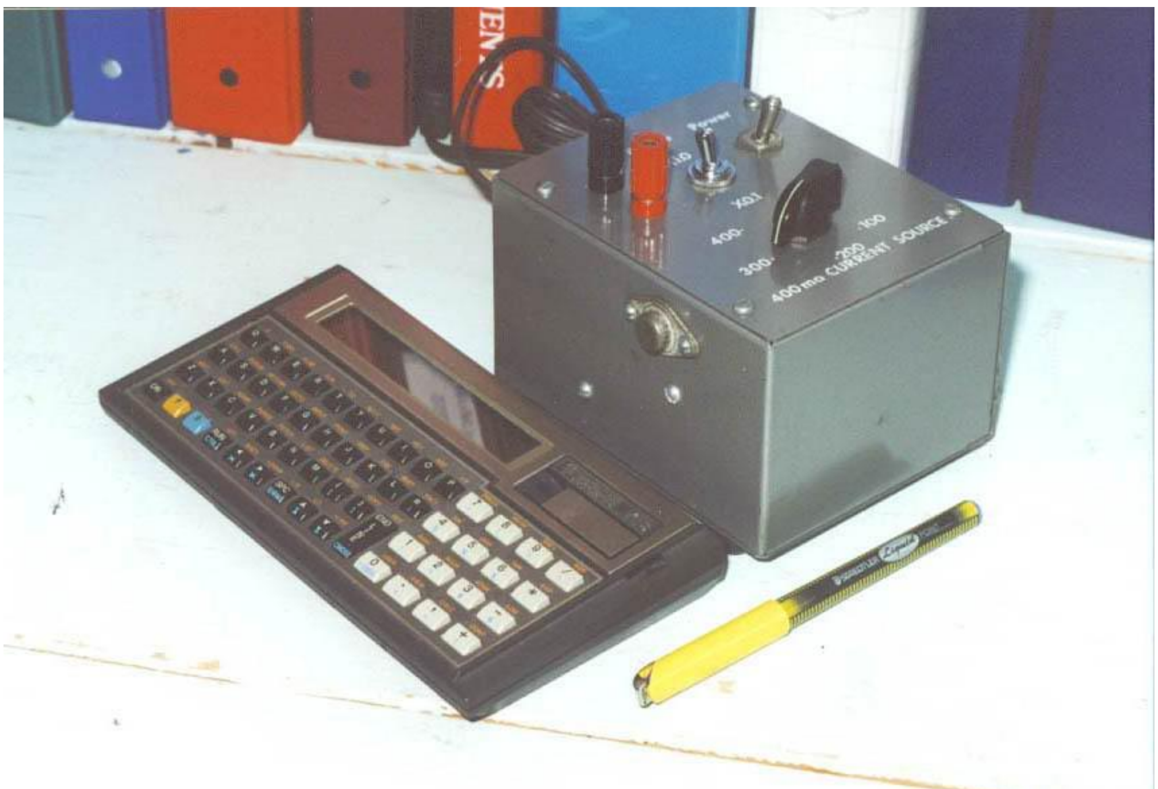
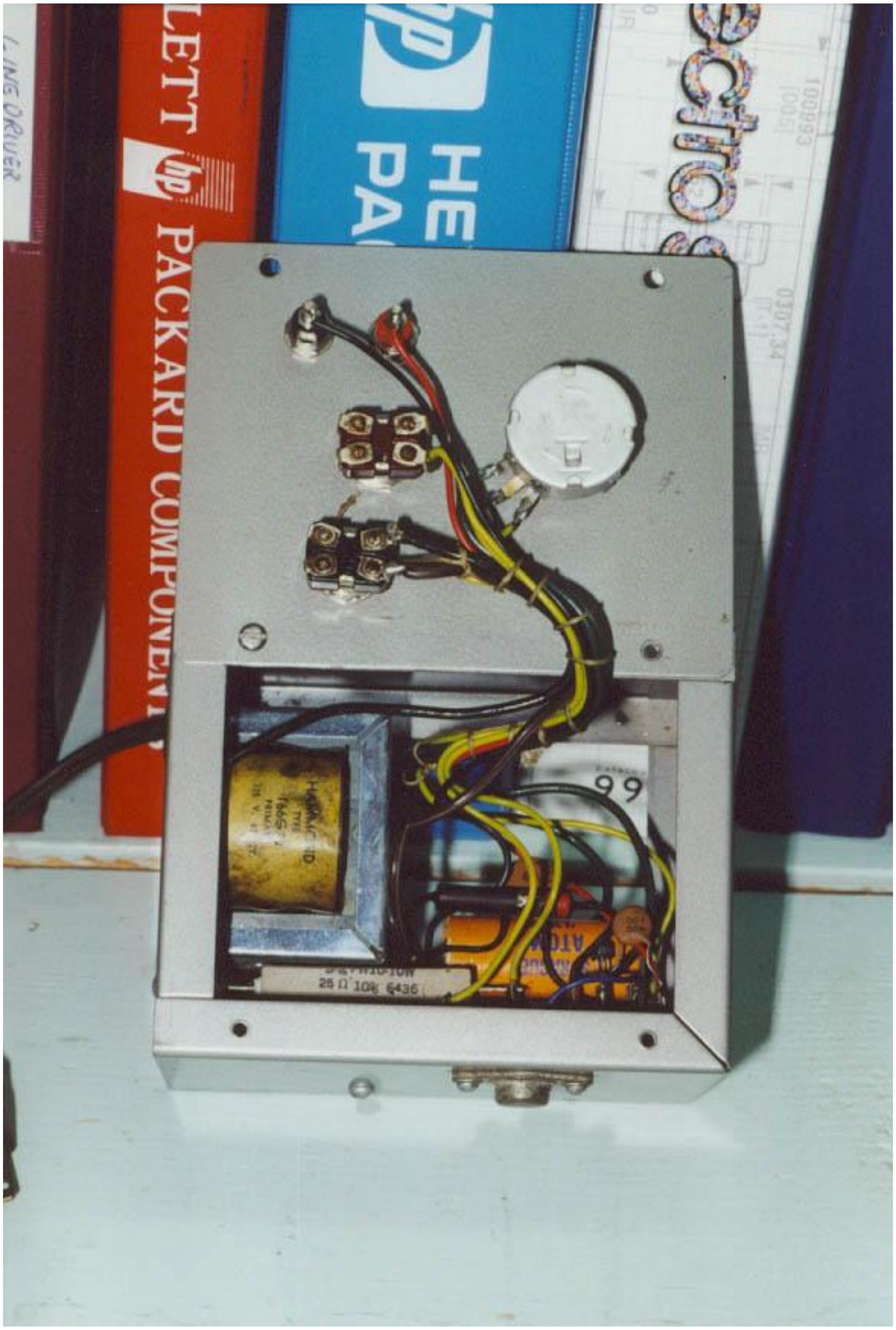
The Constant Current Regulator

This article was originally published in the July 2001 Issue of AudioXpress magazine.

It shows how a constant current source can be used to accurately measure small resistances such as transformer windings & non-linear devices such as semiconductors.

John L Stewart PEng, April 2012

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The Constant Current Regulator

Many experimenters have at least a passing experience with constant voltage regulators & their application. This is probably not the case with constant current regulators. In this article I will show some of the ways in which you can use a CC Regulator & how you can build a low cost version for experimental use. You can test in two ranges. They are zero to 40 mA & zero to 400 mA.

Ever wonder how you could make accurate measurements of small resistances such as tube heaters or incandescent bulbs, whether hot or cold? How about semiconductor diodes? The result for all will depend on current applied by the meter, something you won't know.

And what about audio or power transformer windings? An ordinary Volt-Ohm-Meter (VOM) or Digital Multimeter (DMM) does a poor job. With a constant current source & your meter you can make accurate 4-terminal measurements, free from contact & lead resistance. It can also be used as a battery charger. Mine was built in 1969 & has been in use since. It looks & works well.

Yours does not need to look the same or even use the same parts. The design is simple & flexible. Here is how.

Circuit Description

**A Hammond 166G20 Transformer along with a diode bridge & 500 μF Cap provides the required DC. A variable reference voltage is tapped off by R1, the 5K Wirewound Pot. Drop across the base-emitter junction of the 2N4143 is about 0.6 volts. If the test points are shorted, the resulting current depends only on the tapped off reference voltage minus 0.6 volts applied to resistance in the 2N4143 emitter circuit.
Refer to the schematic.**

For example, if the tapped off reference was set to 5 volts & S2 was in the low range (open) the resulting current would be (5.0 – 0.6) / 220 or 20mA (4.4 volts across 220 ohms). You can set the current by connecting a milliamp meter to the test terminals. Once set the current meter does not have to be left in the circuit. The regulator circuit will maintain this current up to the voltage limit of its supply less a bit for drop across the transistors.

If you were now to connect a transformer winding of 300 ohms to the test terminals you could measure 6 volts with the same VOM. To avoid contact resistance caused errors the resulting voltage is measured on the transformer leads, not the CC Regulator terminals. Refer to Figure 2.

Closing S2 the HI/LO switch connects the 25 ohm, 10 watt resistor in parallel with the 220 ohm resistor. The parallel combination results in about 22.5 ohms so that current output increases by 10X.

The silicon diode D in series with the Zener compensates for temperature drift in the Zener diode. I used a 12 ohm, 1/8 watt resistor in the transformer primary to act as a fuse. It hasn't blown yet.

Construction

I managed to get my version of the CC Regulator into a 4x3x5 inch box made by Hammond, but any box or chassis you find convenient will do. I used a terminal board made by Vector to mount all of the small parts. The terminal board approach works well if you intend to stuff everything into a small enclosure.

The 2N3054 power transistor is mounted on the outside surface of the box on it's insulator. The box is made of steel so that you might think this would act as a poor heat sink for the 2N3054. That doesn't seem to be the case since the transistor never to gets more than warm to the touch.

There are no electrical connections to the box.

Uses

Twice in the past month I've found application for my CC Regulator. In one instance I wanted to make accurate measurements of power transformer primary & secondary resistance. I used a Radio Shack DVM to set up the conditions & measure the results. You can see them in Table One.

The other case was where I needed to know the cold resistance of filaments in some power pentodes (33), which are directly heated. Their resistance depends upon the applied current. When cold they measured 1.85 ohms but at the operating current they were 11.3 ohms. For this kind of measurement you have to wait while the filament temperature stabilizes. It takes one to 5 seconds. These kinds of measurements aren't possible with a VOM or DMM alone. You can see the results in the graph labeled 33 Heater.

I have added the plot of a 5 ohm resistor to the graph so that you can see how an ordinary resistor compares to a tube heater. While the tube heater plot is above the 5 ohm line it is less than 5 ohms. As the heater temperature rises the resistance increases & the heater plot crosses the 5 ohm line. When the heater plot is below the 5 ohm line it is more than 5 ohms. The heater plot is typical of most metal conductors.

You might wonder what application knowledge of electrical resistance of incandescent bulbs could have. One of the most famous electrical patents ever issued was to William Hewlett. It was for a Wein Bridge Audio Oscillator which used a small tungsten bulb as a stabilizing device in a feedback network. The HP200A oscillator became the first successful product to be marketed by Hewlett & David Packard.

The graph labeled Compare Lamps is a comparison of three small lamps. The 3S6-120V was used by Heathkit in their version of the Bridged "T" Oscillator. You would find two of the 6S6-240V in the Hewlett-Packard 200CD Wide Range Oscillator which uses a Wein Bridge. Measurement of these characteristics at each point could take up to 30 seconds while the lamp filament temperature reaches steady state after the test current is set.

Compare Power Diodes plots the forward characteristic of three common semiconductor diodes from different eras. You can see how the Selenium Rectifier sags as the current increases. Nevertheless, they are still widely used in automotive battery chargers since they are very forgiving of accidents. They are also used as surge suppressors since they usually have a large thermal capacity. Silicon Diodes make very good low voltage regulators either singly or a few in series. Germanium power diodes are not much used anymore. I still have some in my junk box.

Compare Leds looks at conduction in Light Emitting Diodes. You can see the large difference between red & green Leds. Some designers use Leds as a low voltage regulators, where Zeners don't go. Unlike Zeners, they are noise free. They are also a good indicator that the circuit is or isn't working.

Compare Pilots shows the characteristics of two common incandescent pilot lamps.

I have used logarithmic scaling for these plots since that allows presentation of the results over a wide range of currents.

References

www.hammondmfg.com
www.vectorelect.com
www.tubesandmore.com

John Stewart is a Professional Engineer (Electrical) with experience in both power & communication systems. He developed his experience with vacuum tubes while working on various research projects at Ferranti Packard & U of T Physics from 1957 to 1965. Then began many years of hitech sales of test equipment, semiconductors & land survey equipment with Hewlett Packard, Rohde & Schwarz, Etc.

PARTS LIST

400 mA CONSTANT CURRENT SUPPLY

AE indicates Antique Electronics
RS indicates Radio Shack

C1	**500 μf**	**50 vdc electrolytic**
C2	**1000 pF**	**600 vdc ceramic**
C3	**8200 pF**	**600 vdc ceramic**

Hammond 166G20 Transformer

Hammond 1415B 4x3x5 Box or RS p/n 270-253

S1, S2 SPST Switch RS p/n 275-651

10 volt 2 Watt Zener

Binding Post, black AE p/n S-H2131B
Binding Post, red AE p/n S-H2131R

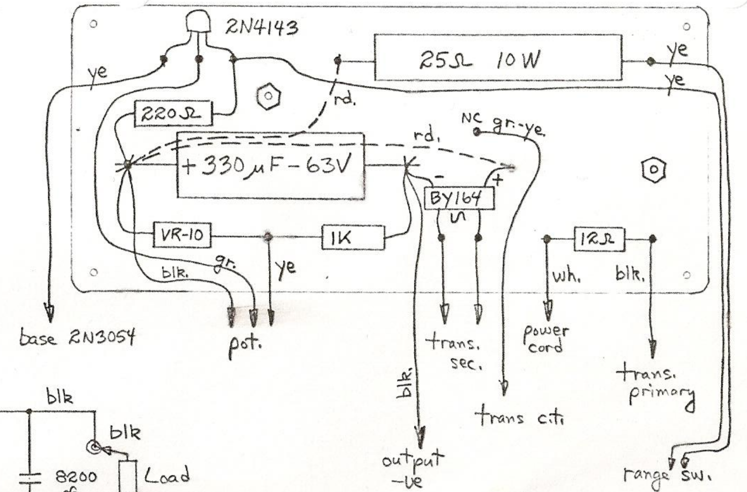
2N3054 NPN Transistor & Mica Insulating Kit
2N4143 PNP Transistor

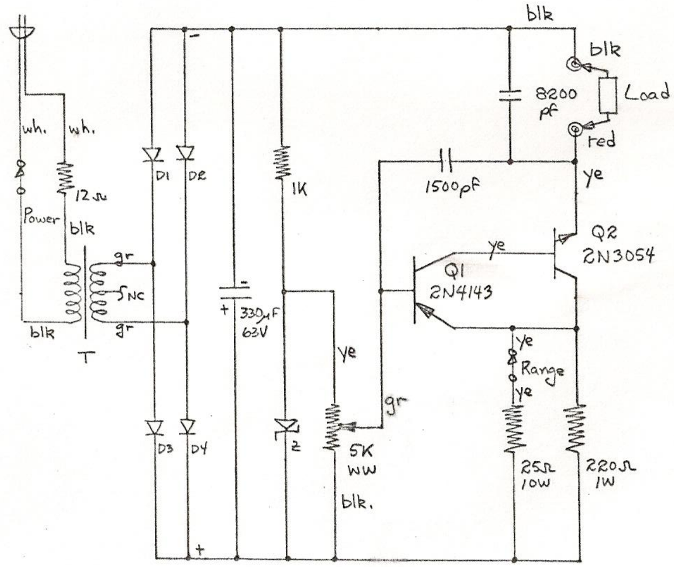
R1	**12 ohms, 1/8 Watt**
R2	**1K, ½ Watt**
R3	**25 ohms, 10 Watt**
R4	**220 ohms, 2 Watts**
R5	**5K Linear Pot.**

Bridge 1 of AE p/n BR34
or 4 of AE p/n 1N4005
or 4 of AE p/n 1N4937

D 1N4005 or 1N4937
(any small power diode)

Knob AE p/n P-K307
Terminal Board
Feet, pkg. of 4, AE p/n P-H1308
Assorted screws, nuts & washers





T - Hammond 166G25 25V 0.5 Amp
D1-D4 Philips BY164 Diode Quad
Z - Zener ; VR10 (10V)
Q1 - Transitron 2N4143 ; Hfe ≈ 200 ; Vceo 40V
Q2 - 2N3054 ; Hfe ≈ 25 ; Vce 60V

400 ma Constant Current Source
NOV 28/69

4 Terminal Measurement

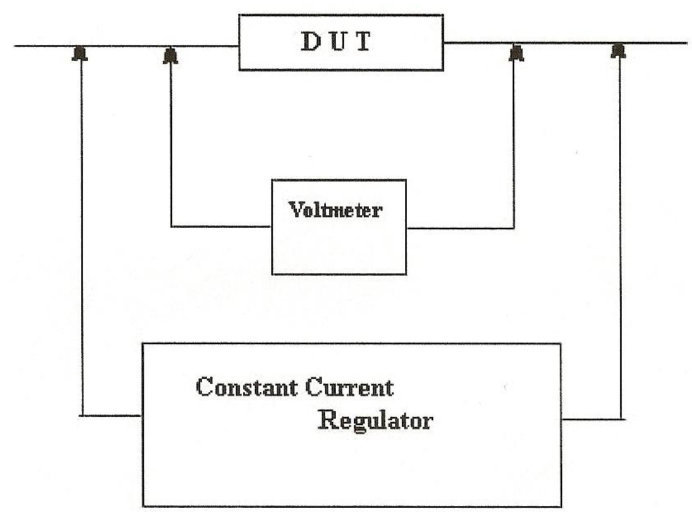


Figure 2- Constant Current Regulator Test Setup

file- CCREG TEST

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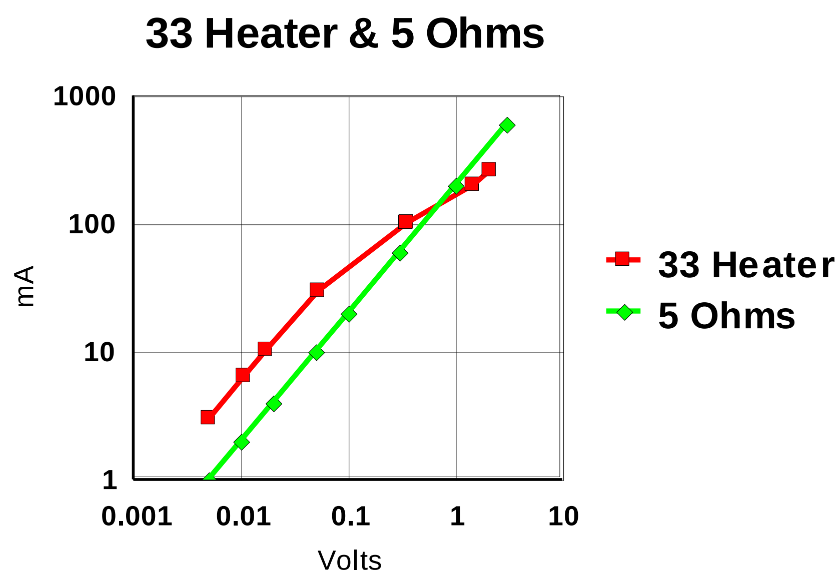

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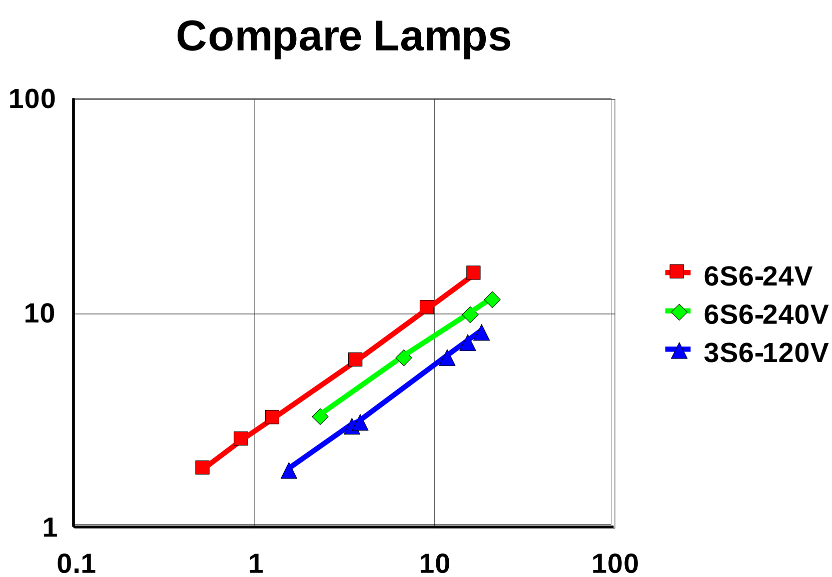

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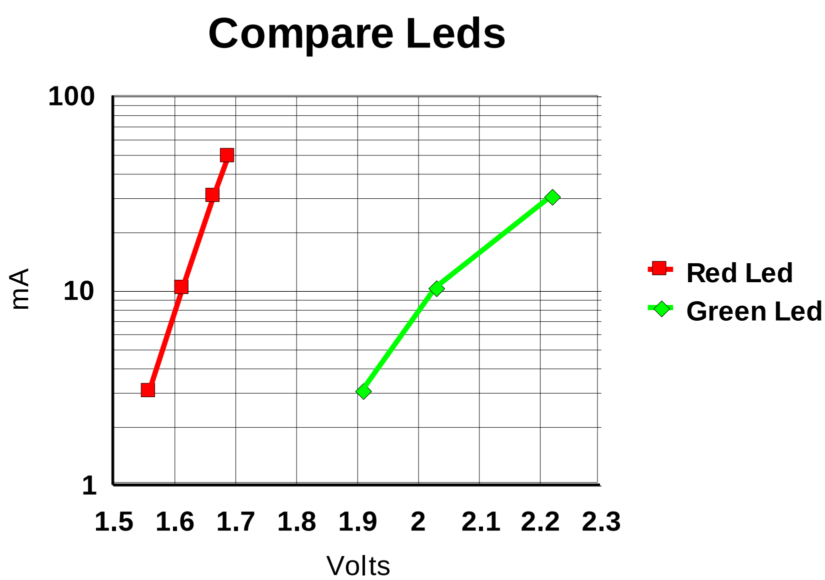

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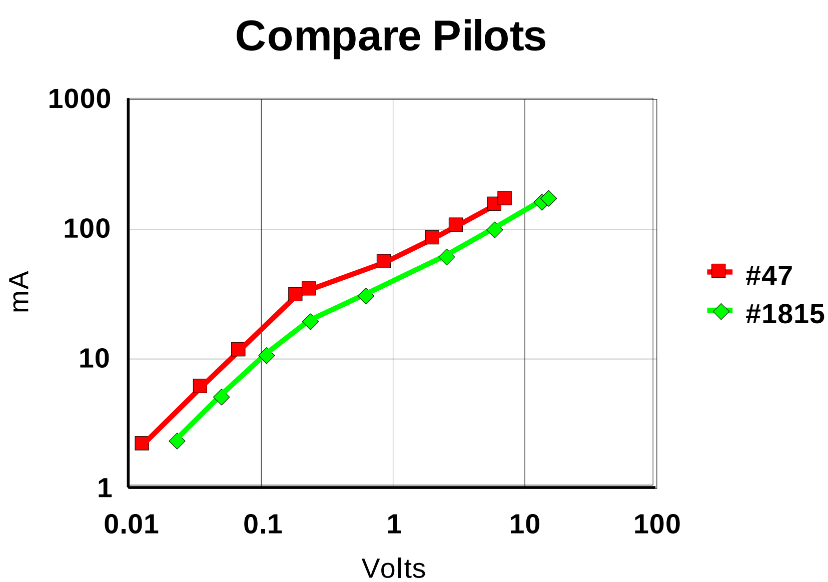

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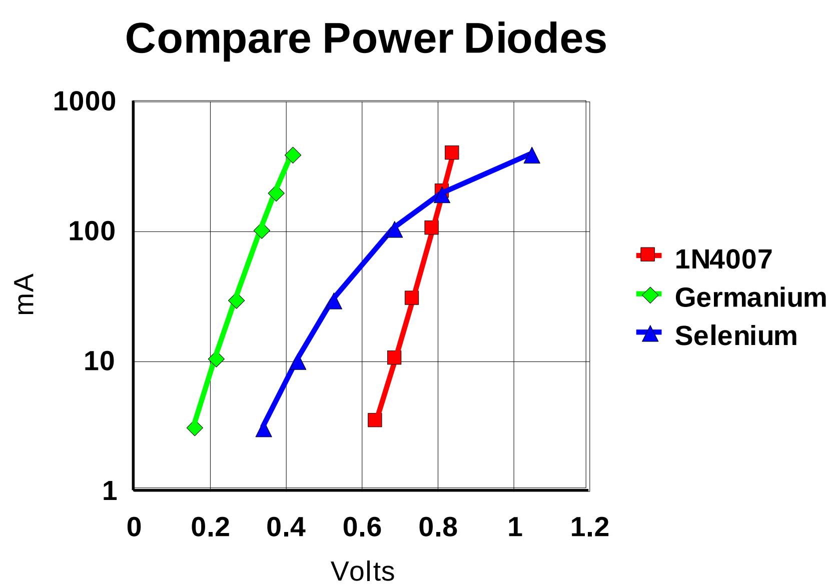
Table One

Hammond 271X Power Transformer Winding Resistance Measurements

Applied 20.1 mA from CC Regulator

Winding	Measured millivolts	R Calculated ohms
Primary	**135.9 mV**	**6.76 ohms**
6 Volt	4.2	0.209
5 Volt	3.6	0.179



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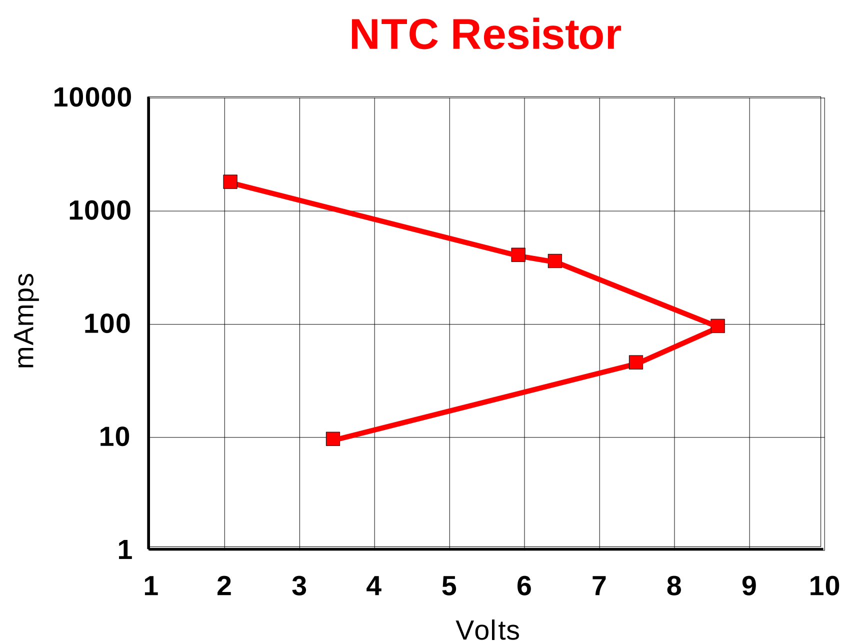

Measured data using a constant current generator in 4 terminal mode.

Applied I	Measured E	Calculated R
9.23 mA	3.48 Volts	377 Ohms
34.7	7.52	217
91.8	8.61	94
345	6.44	18.7
390	5.95	15.26
1.73 Amps	3.65	2.11

This NTC was made for the TV Buz. Connects between the power plug & the power source. Made by Nutronics in Sarasota, FL. About 40 years old. Because of thermal inertia the measurement settling times are long, up to 10 minutes.