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A Transconductance Tube Tester Test Standard

By Joel Hatch

This article discusses building a transconductance test standard for calibrating and checking a mutual conductance/transconductance type tube tester.

Tube testers come in a wide variety of styles and types. In my opinion, the better ones use some scheme to measure the tube's transconductance (also referred to as mutual conductance).

Note: For this article, I define transconductance as the small change in plate current caused by a small change in grid voltage. Author Alan Douglas has written a book titled *Tube Testers and Classic Electronic Test Gear* that provides a great tutorial on how tube testers work[1].

While reviewing the calibration procedure for my Hickok 800K[2], I found a diagram of a standard to use in calibrating my tester provided by Mr. Schoo. However, it looked a bit too cumbersome to set up and seemed impractical to use on my other tube testers.

Looking further on the ′net, I couldn't find a transconductance standard, so I decided to make up a simple test standard that anyone could use. I nicknamed it "Gut Checker™," because it quickly checks whether or not the "guts" of a tube tester are working properly. I settled on an octal-style plug for my final design, with aluminum housing to help protect it from abuse and minimize the possibility of shocking the user.

Operation is quite simple. Set up your transconductance type tube tester to test a 6SN7 style tube, insert the test standard, depress the "Test" button, and read the tube tester's meter. Compare the indicated reading on the tube tester with the test standard, and you should be within the tube tester's specifications. If not, you may need to calibrate or repair your tube tester.

Because I didn't have a good idea on tube tester accuracy from reading through the manuals of my two tube testers, I made up some values. I targeted the transconductance test standard to be better than 5% accuracy, assuming that most technology 50 years or so old is probably only accurate to within about 5–10% anyway. My results were a bit better than that.

DESIGN PROCESS

First, I wondered how high a voltage was present on the pins of a tube tester. I measured my Hickok 800K and RCA WT-110A. I was somewhat surprised to find a basic difference in what the two tube testers used for biasing, input signal, plate voltages, and overall design philosophy in measuring a tube's parameters.

Apparently, the design of the Hickok 800K—and its close relatives, the 600 and 6000 series—doesn't really provide a clean DC supply of voltage. It provides what amounts to a varying AC voltage. (Subsequent to measuring it

PHOTO 1: OCTAL TO BANANA PLUG TEST SOCKET

ABOUT THE AUTHOR

Joel Hatch served in the US Navy from 1975–1981 as an electronic technician (nuclear). He then attended Ohio State University, receiving a BA in biochemistry and an MS in nuclear engineering (instrumentation). While working at OSU's reactor lab, Mr. Hatch completely renovated and updated the reactor's safety and control system's old 50s/60s era "tube" nuclear electronics into solid-state/ICs. In 1993, Mr. Hatch left OSU and worked several years for the Air Force developing test methods and procedures for electro-optic components used in air and spaceflight with emphasis on nuclear survivability. Mr. Hatch returned to Ohio in late 1997 and continued to work in the fields of space and satellite technology evaluating and testing electro-optic and solid-state electronic devices and components in cosmic radiation environments. Currently, Mr. Hatch works as a reliability engineer for a large telecommunications company developing tests and verifying operation of telecom amplifiers in extreme environmental stress conditions, and continues as a consultant in the nuclear and space radiation effects field.

and looking around for more information, I've heard it referred to as "pulsing AC.") The input grid signal is on the order of 2.5V RMS, and may be adjusted higher, depending on the tube selected. On the other hand, the RCA WT-110 Cardmatic type tube tester has a filtered DC, less than 2V RMS ripple voltage (probably suitable for technology 50 years ago) on the plate and a very stable grid input signal of 1V RMS.

From my own experience, I encourage all electronic designers and technicians to become familiar with what signals are being applied to their tubes and measure their tube testers' biasing and stimulus voltages and signals. It is relatively cheap—compared to potentially ruining good tubes—to purchase an octal tube saver from a surplus supply store and periodically measure all voltages. As an added benefit, for experimental purposes, you can also measure the parameters with a tube installed. Reference 3 contains a couple of useful websites for looking up information on tube testers.

Next, I looked into what type of tube base I could purchase. Though I use both octal and miniature tubes in my preamplifiers and line stage amplifiers, I settled on a base/plug that could fit into an octal type of tube base. Octal bases are larger, having more room to fit in the electronic components/parts required for the transconductance standard and more easily obtained from a wide variety of sources, both new and surplus.

I obtained representative octal plug (bases) from Angela Instruments, Antique Electronic Supply, Jameco, and WPI. I ended up using the WPI plug base, which is actually the same as an Amphenol CP-8. By the way, I didn't have any luck sourcing out a blank/empty 9-pin miniature base.

For experimental purposes, I made a breadboard out of 3/16″ thick phenolic (garolite XX, available from McMaster-Carr), and drilled out eight holes to mount banana plug style colored jacks (*Photo 1*). I soldered 18 AWG wire between the banana plug lugs and the octal plug's pins. This provided a convenient way to attach banana to mini-hook style jumpers between the tube tester or transconductance test circuit and transconductance standard's breadboard, or, on occasion, a 6SN7 or 12SN7 tube for evaluation, measurement, and comparison purposes.

TUBE TRANSCONDUCTANCE

Then I needed to decide on a value of transconductance to design the standard. As an initial target, I selected the 6SN7/12SN7 tube as the baseline element for this project. I have several brands of these very common tubes on hand for use in my line stage amplifier.

I downloaded the tube's data sheet from the internet[4] and reviewed the specifications/transconductance graphs for this tube under various bias conditions. I correlated this to the data contained on the Hickok tube tester's self-

CAUTION

1. The case of the 10M45S is connected to the anode and may be at a high voltage potential. Shorting this to the case may shock you if you touch it. Prior to potting the circuit, make sure it doesn't touch the external aluminum sleeve (housing) wall. As in all electronic projects, use common sense when dealing with voltages greater than about 25V.
2. After making up your transconductance standard, use a multimeter to ensure the case does not touch any internal circuitry. Also, perform a set of tests using 300V on the plate and measuring the outside case temperature to determine how long you can operate the device before it becomes too hot.

contained data sheet. A normal transconductance for this tube is approximately 2600µS. (Throughout this article, the measurement unit for transconductance is siemens, which replaces the now-obsolete mho).

After looking through various websites to see what others have done, I didn't find anything quite to my liking. The closest thing I could find was a constant-current source load using an IXYS switchable current regulator on Pete Millett's website—a site that is great for providing the RCA HB3 tube reference manual as well[4]. I ordered a few of the model 10M45S, TO-220 packaged devices from Digi-Key's website, and performed some initial tests to determine their suitability. IXYS' website has several good tutorials and suggestions for using this product[5].

I set up a test circuit for measuring a tube's transconductance using a schematic diagram from an article appearing in the Jan. 1964 issue of *Radio-Electronics* (*Fig. 1*)[6]. Using typical operating values for a tube contained in the tube's specification sheet, you can determine a tube's transconductance, Gm, as follows:

1. Apply typical operating voltage to the tube's plate (for 6SN7, approximately 125V DC)
2. Apply typical bias voltage to the tube's grid (for 6SN7, approximately −1 to −2V DC)
3. Apply a small test signal to the tube's grid (for experimentation I use 100mV RMS)
4. Measure the voltage drop across the load resistor, R1 (for experimentation I used a value of 100Ω for the test load resistor and a measured voltage drop of 27.0mV RMS)
5. Calculate the tube's transconductance by the following formula:

$$Gm = \Delta \text{ Vload (RMS)}/[\Delta \text{ Vsignal (RMS)} \times \text{Rload (Ohms)}]$$

In these experimental values, the 6SN7 tube's transconductance is calculated as follows:

$$Gm = 27.0\text{mV RMS}/[100\text{mV RMS} \times 100\Omega]$$

$$Gm = 0.0027\text{S} = 2{,}700\mu\text{S}$$

FIGURE 2: PLOT OF TRANSCONDUCTANCE VS. CURRENT SETTING RESISTOR, RX (WHERE RX IS EQUIVALENT TO THE SERIES R3 + R4 IN *FIG. 4* AND R1 IS SET TO 0Ω).

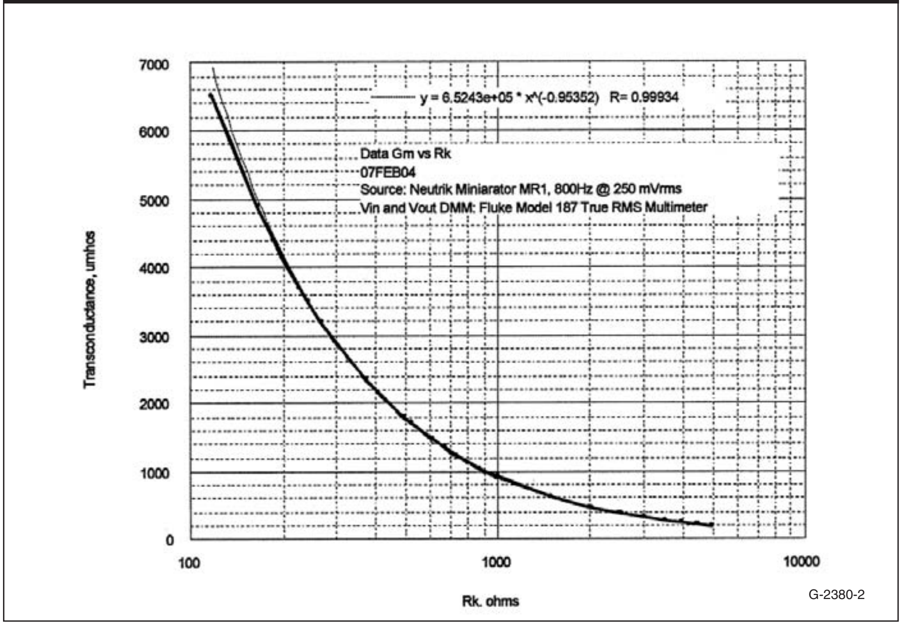
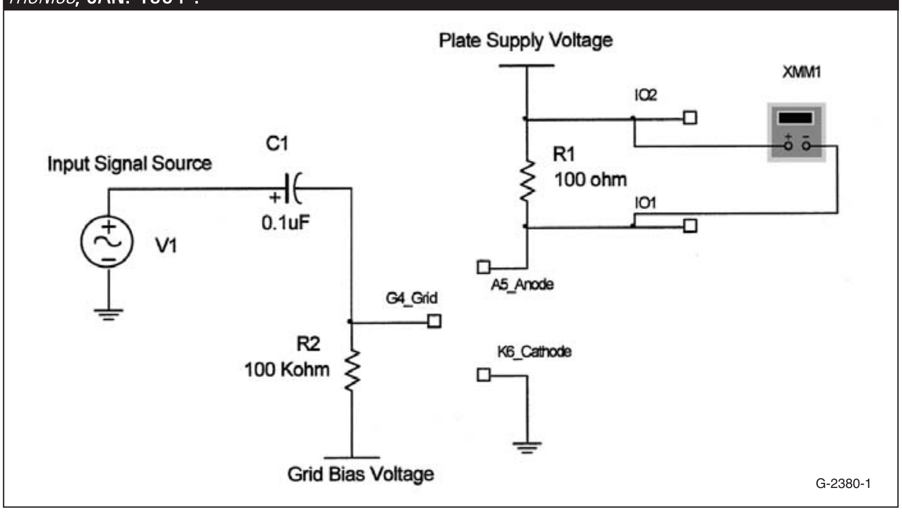


FIGURE 1: TEST CIRCUIT FOR MEASURING DUT TRANSCONDUCTANCE ADAPTED FROM "CIRCUIT DIAGRAM FOR MEASURING TRANSCONDUCTANCE OF VACUUM TUBES," FROM *RADIO ELECTRONICS*, JAN. 1964[6].



As noted in the *Radio Electronics* article, if the DC voltage drop across the test load resistor is greater than about 1% of the power supply's DC voltage, reduce the value of the load resistor.

EVALUATION

After checking out a few more tubes to make sure the test circuit agreed with both of my tube testers, I connected the 10M45S device into the standard test circuit diagrammed in the datasheet and evaluated various values of anode to cathode voltage versus cathode current setting resistor, Rx, and various input signals to confirm (and measure) plateau currents. My input signal source was set over a range of 100mV RMS to 5V RMS, and the load resistor, which I used to measure the current change at the drain of the 10M45S, was 100Ω or 50Ω. I used a Fluke Model 187 True RMS Multimeter to measure all voltages and Agilent E3615A and HP 6209B power supplies for bias and plate voltages. I used a B&K Model 3011B Function Generator or Neutrik Minirator MR1 for input signals.

The IXYS 10M45S worked very well for the initial evaluation. Some benefits of this device are its rated operating voltage (up to 450V), TO-220 package for easily attaching a heatsink to dissipate heat generated at the higher operating voltages, and its easy procurement from a large supply house—Digi-Key. I decided to order some additional precision resistors to perform more detailed checks of the device's operating points and develop a set of operating curves from which to select the desired transconductance value I was looking for.

As you can see in *Fig. 2*, the plot of transconductance versus the setpoint resistor Rx in IXYS data sheet and R3 + R4 in *Fig. 4* is a log/log relationship. This was great! As an engineer, I like nice solutions/equations for data plots.

Figures 3A and *3B* show data for another set of tests to measure input voltage versus transconductance. Here, a small problem developed, as the 10M45S has an internal bias point that limits it to operate to only around 3V or so. After this point, the input circuit of the device becomes overloaded/swamped and the transconductance decreases.

The transconductance standard is fairly frequency insensitive over the audio band, less than 0.5% deviation, which is a bit better than the Fluke 187 DMM is technically specified to measure, so I also re-measured the sensitivity using a Tektronix TDS 220 Oscilloscope for comparison purposes to ensure accuracy. *Figure 5* shows a plot of the frequency response versus transconductance with a constant input voltage.

Using a single transconductance standard for both the Hickok and RCA required a bit of a compromise. The Hickok's higher input signals needed to be attenuated, or they would overdrive the 10M45S.

As noted in *Figs. 3A* and *3B*, the IXYS current regulator circuit I was using as a basis for the standard would start to decrease in its output/transconductance, reducing to approximately 2% or 3% of the stated value at an input grid voltage of approximately 2.5V RMS. This was a bit lower than what the Hickoks were supplying when set to measure tubes under the standard GOOD-REJECT setpoint parameters, and a bit too close for when the Hickok was set to measure transconductance directly off the meter (first red calibration dot on English dial). I wanted a transconductance standard that was more consistent between different types of tube testers.

The solution was to add a simple voltage divider at the input, resistors R1 and R2, which divided the input voltage in half. *Figure 5* is a schematic diagram of the final transconductance standard circuit. I selected R3 and R4 (*Fig. 4*) for a value of 284Ω, equivalent to 3,000µS. Half of this is 1,500µS, which, coincidentally, is right in the middle of the Hickok's meter face when the calibration dot on the English dial is set to read 3,000µS full scale. Because of the higher value of transconductance, the running temperature of the transconductance standard increased a bit; however, it didn't seem to affect its stability at all.

Figure 6 shows a plot of one of the final units operating at a temperature of 105°C. Too hot for fingers, but the unit was stable after operating for over 24 hours at this temperature with drift less than 0.5% (tolerance of my test and measurement equipment). Note that the input voltage divider improves the device's insensitivity to higher input signal voltages. The transconductance is pretty steady and does not change by more than 2% of its initial setting until approximately 4.5V RMS. This is a significant improvement over the initial circuit and allowed for calibration

FIGURE 3A: INPUT SIGNAL LEVEL VS. TRANSCONDUCTANCE.

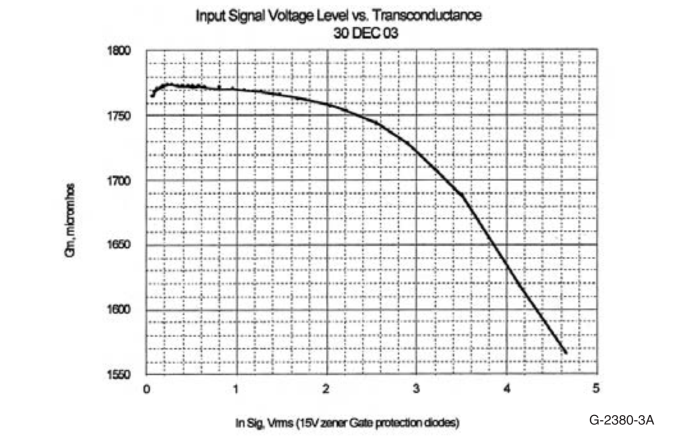
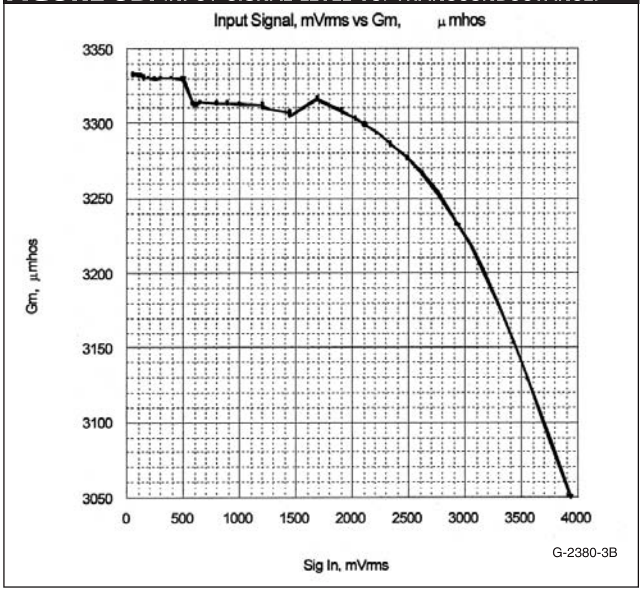


FIGURE 3B: INPUT SIGNAL LEVEL VS. TRANSCONDUCTANCE.



checking of both the RCA and Hickok 800K tube testers.

FINAL PROTOTYPE DESIGN

After success with a couple of prototypes (*Photo 2*), I decided to refine the layout of the board and make a PCB that would fit on top of the octal plug and allow an aluminum tube to fit over the exterior for safety, ruggedness, and reliability. I use ExpressPCB, which provides quick turnaround, reasonable prices, and free layout software. I was able to design a set of ten boards for under $100. As it turns out, standard 1″ thin wall aluminum tubing fits snugly over the CP-8 octal plug, so I didn't need to do any special machining to "hog out" an aluminum tube.

I was able to fit a single test standard in a package the size of a standard octal tube (*Photo 3*). I securely fastened the aluminum tube to the octal plug with a hot-melt glue gun, then backfilled the inside with non-conducting epoxy my machine shop friend had (Hysol E-60NC by Loctite). I used a "slip on" style TO-220 heatsink (Aavid HS210 from Digi-Key) instead of the larger bolt-on type seen in the prototype photo (*Photo 2*).

I think any heatsink that will fit inside your case without touching the external aluminum case should work, provided you don't plan to leave it turned on for long periods of time (more than 5 or 10 minutes), so that the case doesn't become too hot to touch. I leave it up to the experimenter/ technician to measure and determine how hot their standard gets over time when used on their own tube tester.

During the prototype stage, I managed to blow up two of the IXYS current regulators—another reason to buy a few units prior to experimenting. One device failed while testing it on the Hickok tube tester, and the other on the test bench. I reviewed my design and the notes provided by IXYS, and subsequently added diodes D1, D2, and D3. Diodes D1 and D2 protect the 10M45S

PHOTO 2: FINALIZED PROTOTYPE CIRCUIT BOARD WITH LARGE HEATSINK (FOR TESTING).

FIGURE 4: CIRCUIT DIAGRAM OF TRANSCONDUCTANCE TEST STANDARD AND PROTOTYPE CIRCUIT (NOTE: R3 AND R4 SELECTED FOR TRANSCONDUCTANCE VALUE OF 3,000µS WHEN SETTING THE INPUT VOLTAGE DIVIDER RESISTOR, R1 = 0Ω AND 1,500µS WHEN R1 = 100KΩ, SEE TEXT).

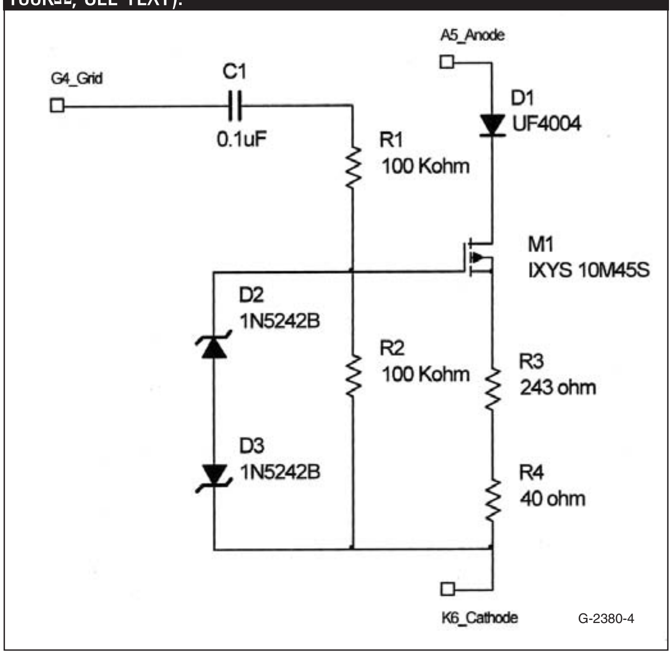


FIGURE 5: PLOT OF FREQUENCY DEPENDENCY ON OUTPUT GM.

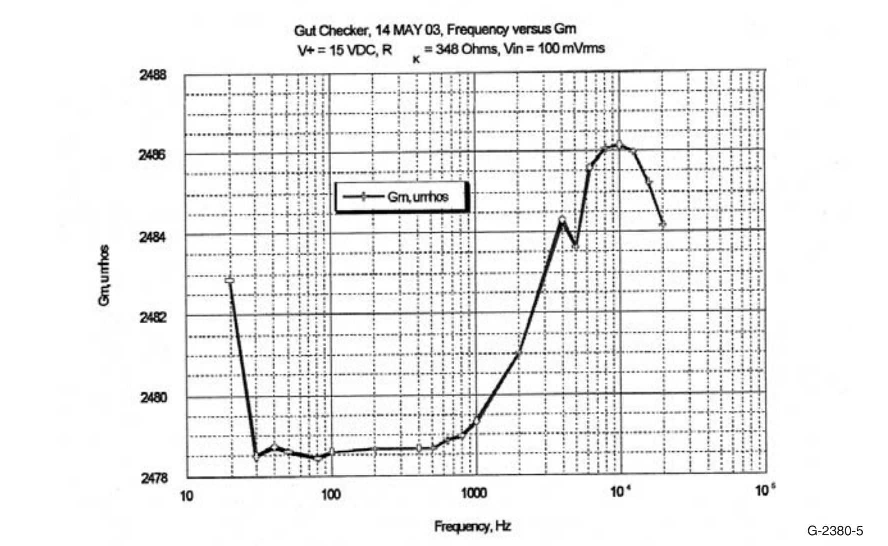


PHOTO 3: HOUSING ASSEMBLY FOR 1,500µS TRANSCONDUCTANCE STANDARD.

gate from an overvoltage condition on the input, and D3 protects the device from reverse current transients—this was the likely culprit for the unit failing in the Hickok. Because I didn't have an ESD-safe table, the second unit was probably damaged as a result of plugging and unplugging from the test breadboard. Subsequent to these added diodes, no more units failed during the remainder of the production of the first set of ten prototypes.

I carried out final measurements for a series of ten devices. The standard deviation of all these devices was less than +2/–0% of the 1,500µS, at levels of input signal voltage to 3.0V RMS. I tailored each of the standards by splitting the setpoint resistor, Rx, into two standard resistor values of 243Ω and 40.2Ω, manufactured by Vishay, with a tolerance of 1% (available from Mouser). I bought several values of each resistor and sorted through them prior to pairing them up. You could probably buy ten of each resistor and select the two that provide you with 284Ω.

This will give you a transconductance standard within ½% of 1,500µS under most operating conditions I ex-

BUILDING THE TUBE TESTER "GUT CHECKER"

1. Rough-cut a single circuit board (*Photo 4*) from the master printed circuit board set. A band saw or shear press works fine for this.
2. Trim down the edges of the TT "Gut Checker" circuit board. The outer circle is 1″ diameter. I use this as my reference for fitting within the octal plug base. After I've sanded it down, I test-fit it to the base (*Photo 5*).
3. Clean circuit board off with isopropyl alcohol and soft, non-shedding cotton rag to remove residue from the sanding process and make board ready for soldering (*Photo 6*). This board has already been pre-tinned from the PCB supplier (Express PCB).
4. Insert "grid" input signal dropping resistors R1 and R2. In *Photo 7*, R1 is a direct short, as this transconductance standard is going to be used in an RCA WT-110A Tube Tester. For Hickok 800 style tube testers, R1 and R2 form a dropping network to set the maximum input voltage applied to the gate of U1 to less than 2V RMS.
5. Insert diode D1 and solder in place. I found that when laying out the board, it is easier to place a line where the cathode of the diode is to be positioned (*Photo 8*). Tube testers, such as the Hickok 800 style, apply AC voltage to the plate of tubes during test. Diode D1 prevents damaging the current regulator, U1, by reverse voltage between cathode and plate terminals.
6. Insert diodes D2 and D3 and solder into place. Zener diodes, D2 and D3, are connected back to back (*Photo 9*) and protect the gate of U1 from input "grid" signal overvoltage.
7. Insert transconductance setpoint "cathode" resistors R3 and R4 and solder into place (*Photo 10*). In this example, the combined resistance, "Rx" (see *Fig. 2* and Plateau Current versus External Resistance of IXYS 10M45S—data sheet) was set to 284Ω to simulate the normal transconductance of a 6SN7 triode of 2700µS.
8. Insert input coupling capacitor, C1, and solder into place (*Photo 11*).

PHOTO 4

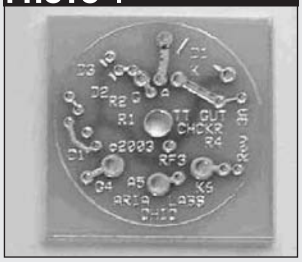


PHOTO 5

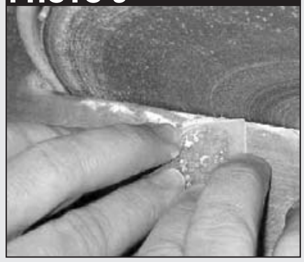


PHOTO 6

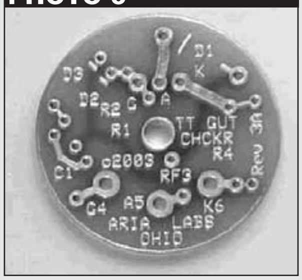


PHOTO 7

PHOTO 8

PHOTO 9

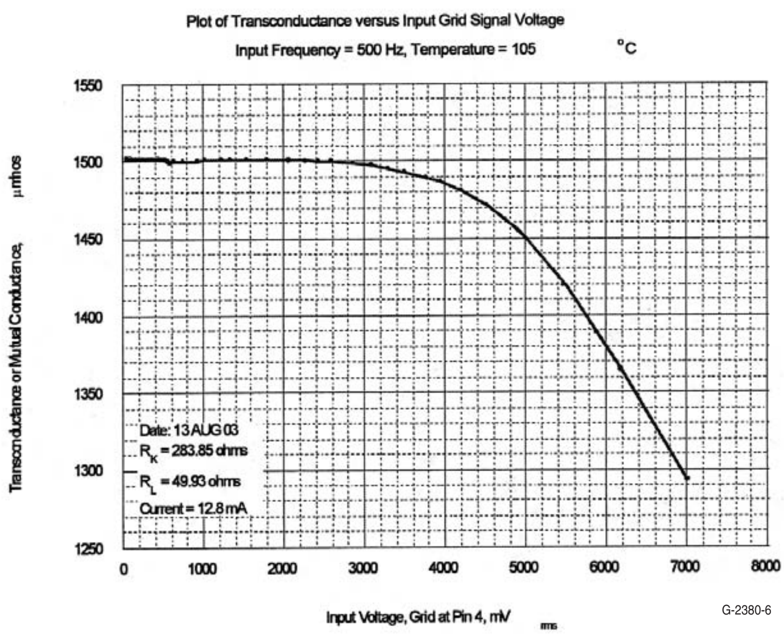
perimented with. I also matched the input resistors—R3 and R4—within 0.1kΩ (essentially the tolerance of my multimeter reading) of each other—though once again, if you bought several 100kΩ resistors and sorted through them, you should be able to find a pair that match within the limits of your multimeter's resolution.

SUGGESTIONS

Since the transconductance standard does not need a heater, these pins are not connected. You could connect a precision high power resistor between the heater pins 7 and 8 to check out whether the filament supply is operating properly under load conditions. I did not include this provision, because it may cause the transconductance test standard to heat up too much when operated for several hours. For short-term readings—less than a couple of minutes—the heating shouldn't be a problem. The unit drifts very little, less than ½%, with respect to temperature up to 100°C (*Fig. 6*).

For my applications, since I run my tubes under constant DC supply conditions, I preferred to use the RCA tube tester, which has much better plate voltage regulation and a more stable and lower voltage input stimulus signal. The only problem with the RCA is the meter face doesn't directly read out

FIGURE 6: INPUT VOLTAGE VS. GM AT HIGH TEMPERATURE.



in microsiemens. I've seen this on some military-type Hickok tube testers as well. However, by subsequently calibration-checking it against a couple of known transconductance standards, I was able to come up with a meter correction factor.

This technique should work with most transconductance type tube testers and provide an indication of your meter's accuracy across its full-scale operating range. If you have a non-µS reading type of meter—for example, a linear scale from 0 to 10, 0 – 125, and so on—by building a set of standards at 1,000 and 2,000 and 3,000µS, you should be able to calibrate and check most tube testers' panel meters for linearity/accuracy and determine the corrections needed. For standard µS reading meters, you should be able to check the tube tester's linearity. I recollect from my old Navy training that most panel meters usually read best between $\frac{1}{4}$ scale and $\frac{7}{8}$ scale. In this particular example for the Hickok 800K, the reading will be right in the middle of the scale.

REFERENCES

1. Alan Douglas, *Tube Testers and Classic Electronic Test Gear*, Sonoran Publishing, LLC, © 2000.
2. Daniel Schoo, "Calibration Testing of the Hickok Model 600A Tube Tester," version 3.0, Sept. 2002, from Mr. Straub's website: http://www.0wned.org/%7Ehstraub/cal600.htm.
3. I have found the following two websites very helpful in providing information on Hickok tube testers. Bama's site also has lots of information on other testers, such as my favorite, RCA WT-110: http://www.0wned.org/%7Ehstraub/tubes.htm http://bama.sbc.edu/.
4. Pete Millett's website: http://www.pmillett.addr.com/. Pete also has RCA tube data sheets listed at http://www.pmillett.addr.com/tubedata/HB-3/masterindex.html.
5. IXYS Corporation website: http://www.ixys.com (see various data and information in the High Voltage Current Regulator category).
6. Overholts, R.W., "Transconductance and How to Measure It," *Radio-Electronics*, Jan. 1964.
7. MIL-HDBK 217 F, Reliability Prediction of Electronic Equipment.
8. Circuit board layout and manufacture: http://www.expresspcb.com.
9. I have also found these two books helpful in the design of the transconductance standard:

Latest Instruments for Servicing Radio-Television, Coyne School Publications, 1963.

Slurzberg & Osterheld, *Essentials of Radio-Electronics, 2nd Ed.*, McGraw-Hill Book Co., Inc., 1961.

I found that the most effective way to solder wire to the octal plug pins is to cut a 6″ length of 18-gauge stranded wire, removing the sheath from the last inch of the wire. Then mount the blank octal plug base into a small vise and fill each pin with solder. This prevents the Hysol (if you use it to seal/pot the test standard) from flowing out the open bottoms of the pin holes. (Yes, I found out the hard way the first time!) Then connect the small piece of 18AWG wire by heating the pin first, slipping in the wire until the insulation just touches the top of the plug, which leaves approximately $\frac{3}{8}$″ of wire protruding through the bottom of the pin.

After the solder cools, trim off the wire, flush with the bottom of the pin. Then trim the top section of wire to mount the circuit board. I found this easier than trying to cut the wires to their exact finished size, then stripping them, and holding them in place while soldering into the octal tube base plug. The longer wires made it much easier to deal with, and it was a simple matter

9. (optional) Insert resettable PolySwitch fuse, Raychem TR250-080, into RF3 and solder into place. This resettable fuse (*Photo 12*) limits current through U1 to less than 180mA should R3 or R4 short out. (**Note**: this is not needed when R3 and R4 are in series as shown in the circuit diagram for the final board.)
10. Insert U1, current regulator, and solder into place (*Photo 13*). **Caution**: ESD sensitive. Follow appropriate precautions.

11A. Insert "grid," "cathode," and "plate" wires into octal plug. Leave approximately ¼ to ½″ to allow solder to wick up inside hollow pin during soldering.
For triode no. 1 of a 6SN7 type tube:
Pin 4 = grid of unit no. 1
Pin 5 = plate of unit no. 1
Pin 6 = cathode of unit no. 1
These pins are labeled on the printed circuit board as: G4, A5, and K6, respectively (*Photo 13*).
This octal base (*Photo 14*), available from AES—part no. P-SP-476, is approximately ⅝″ high and provides a simple means to grasp and remove from the octal socket. Since this device does not have a protective housing in place, use suitable precautions to prevent electrical shock.

11B. Solder the lead wires into the octal plug base (*Photo 15*) and then trim flush. Sometimes solder may dribble over onto the outside of the base pin. After cooling down, carefully trim off the excess with an X-Acto knife and burnish/lightly sand or file (jeweler's file) with Scotch pad or similar, to remove any burrs and excess solder so that the pins fit easily into the Tube Tester's socket.

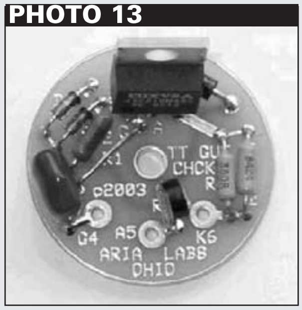
12. Place TT "Gut Checker" circuit board over the "grid," "plate," and "cathode" wires extending up through the base of the octal plug (*Photo 16*). Solder circuit board in place and trim off extra wire. Add heatsink to U1.

PHOTO 10

PHOTO 11

PHOTO 12

PHOTO 13



The Transconductance Standard is now ready for use. I recommend that you carefully measure the transconductance across a variety of input voltage levels, up to 5V RMS, and plate to cathode voltages, 50 to 250V DC, to determine the overall relative accuracy. For safety, attach some outer housing over the base plug and backfill with a potting compound to prevent electrical shock. Ensure that the heatsink does not touch the housing.

PHOTO 14

PHOTO 15

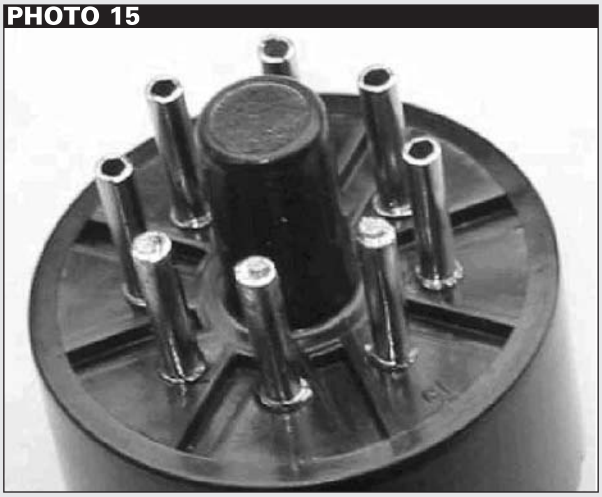


PHOTO 16

of trimming them up following soldering to the base's pins.

NOTES ON ASSEMBLY

After submitting the initial draft for this article, I thought it would be more beneficial to show a pictorial assembly guide (*Photos 4–16*). There are a few minor differences in the board contained in this article than shown in photos. The circuit board shown in the photos was one of the prototypes I still had remaining.

First, for the keen-eyed, the board is designed for R3 to be in parallel to R4. Subsequent to prototyping, I found it easier to set the current setpoint resistor by using R3 and R4 in series.

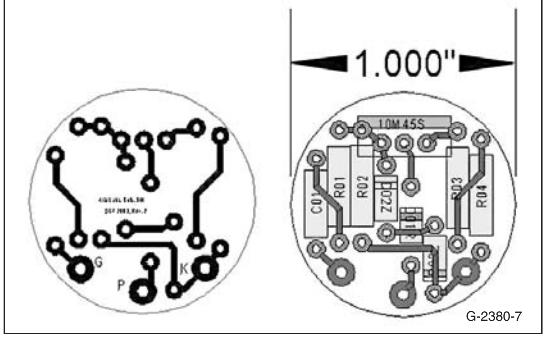
During the prototype stage, I also provided for a resettable fuse to protect against mishaps of faulty tube testers or accidental misuse during operation. I was a little leery after "toasting" two of the current regulator ICs during initial breadboard testing, so I added the fuse as a precaution. Subsequent to prototyping, I decided that this extra precaution wasn't really necessary and probably isn't needed with diode D1 (a high voltage rectifier diode—UF4004) to protect against reverse voltage transients (from Hickok type testers). I don't think the circuit—once assembled—will have a short of both R3 and R4 at the same time. The probability is extremely low for two resistors in series to both short out at the same time[7], which could cause excess current draw through the 10M45S.

As you can see, I designed this standard for use on RCA or similar tube testers with lower input signal test voltages, and, therefore, R1 is 0Ω (shorting wire). The circuit board used is from the initial prototype run.

I had trouble attaining a clean copy of the printed circuit board layout from ExpressPCB, so I redrafted it using Autosketch (*Fig. 7*). This drawing is referenced to 1.00″ diameter so the technician/experimenter can adjust the size accordingly if using a copy machine to transfer the layout to a circuit board. I also simplified the layout as well, removing the resettable fuse and converting the entire board to a single layer for easier manufacture using home etching methods.

If you have any questions or comments, please feel free to e-mail me at jhatch200@yahoo.com. *aX*

FIGURE 7: BOARD LAYOUT FOR SINGLE-SIDED BOARD, REV. 2, OCT '03. SCALE OF 1.0″ ADDED TO ENSURE BOARD IS PROPERLY SET UP FOR THOSE USING ART TRANSFER METHODS. (SCALE SIZE DOWN AS NECESSARY VIA ANY PICTURE/IMAGING SOFTWARE.) RESETTABLE FUSE NOT INCLUDED IN CIRCUIT BOARD.



For this experiment, and some of my other projects, I have found the following vendors to be very good sources of parts and supplies.

1. Angela Instruments (http://www.angela.com).
2. Antique Electronic Supply (http://www.tubesandmore.com).
3. Parts Connexion (http://www.partsconnexion. com).
4. WPI (http://www.wpi-interconnect.com).
5. Mouser (http://www.mouser.com).
6. Digi-Key (http://www.digikey.com).
7. Jameco (http://www.jameco.com).

PARTS LIST/RESOURCES:

Mouser No. 5989-250V.1, 0.1µF metal poly capacitor at 250V
Digi-Key No. HS121-ND, TO-220 heatsink (slips on over tab)
Mouser No. 512-1N5242B, 12V Zener diode at 0.5W
Mouser No. 71-RN60D-F-100K, 100kΩ 1% metal film resistor at 0.25W (matched)
Mouser No. 650-TR250-080U, 0.08A resettable fuse (optional for prototype)
Mouser No. 512-UF4004, rectifier diode, 400V at 1A
Mouser No. 71-RN60D-F-243, 243Ω 1% metal film resistor at 0.25W
Mouser No. 71-RN60D-F-40.2, 40.2Ω 1% metal film resistor at 0.25W
Digi-Key No. IXCP10M45S-ND, IXYS 10M45S switchable current regulator at 450V
Digi-Key No. TAH20P75R0J-ND, 75Ω TO-220 power resistor, 75Ω at 20W (optional)
Angela Instruments No. QQQ Octal Pin Plug (similar to WPI or Amphenol)

Note: I could only purchase Octal plugs in quantity from WPI. Subsequent to purchasing these, I found essentially the same octal plug on Angela's website at a very reasonable price and no minimum quantity buy requirement.