Vacuum tube tester schematic

This project began as a simple but quality vacuum tube tester. But it soon turned into a quest for a highly accurate tool like the legendary tool maker, Hewlett Packard (now Keysight), could have built... Now, HP (Keysight) has never been a tube tester and I'm not a graduate of that sacred company, but I love how they designed their equipment: It was built to last and always seems to exceed expectations. So as the design process continued and questions of accuracy and stability of the goals came up, it was natural to try to do the best I reasonably could. But it is a slippery slope and it took seven years to complete this project. It was a cliffhanger to the end, but the result is pretty much everything I've always wanted in a tube tester! The results produced by the unit can be seen in the interim series of evaluations of 7591 tubes here. Could you build it? All documentation and PCB design files for Vacuum Tube Analyzer (VTA) are available for download at the end of this article. [It's called an analyzer to distinguish it from tester tubes that don't use constant DC supplies. In contrast, you can use it to render the characteristics of DC and AC.] I always wanted it to be something others could build. Therefore, all parts (except sludge) are over-opening types. I even have other PCBs that I can make available. But in truth, the answer to the question is that it would be difficult and costly to reproduce. However, I am putting it all out there in the hope that parts of the system might be useful to people or that some might find it as a useful or interesting example. Therefore, this will be an overview rather than the detailed type of building article usually found elsewhere on this website. See Builders Advice at the end of page 2. A simple tube analyzer easy to use, that is. The front panel layout on the right shows the general organization. After setting the pin connection in gold at the bottom, you can use the controls in red to set the heating, grid, plate and screen voltage. Meter-1 in blue shows the voltage values for it. Turning on the Power and TEST switches in green starts the test. Results like currents, Gm and Gp are read from Meter-2 in purple. Also Ip is duplicated on the Meter-1 for convenience. The test parameters may come directly from the original tube data books or from a given table. Basic specifications Measurements made: DC voltage and current for heating, grille, screens and plates. Transducer (Gm), platform conductivity (Gp = 1/Rp) Total precision target: 0.1% in primary ranges. 20,000 meters. Gm and Gp AC test levels: Grid ±50mVpk, Motherboard ±1Vpk. Physical: Weight 23.1-pounds, Total dimensions 15W 6H 18D. Voltage Load measurement: 10Mohms Current load measurement: (No effect on reading or regulation.) Motherboard, Screen 10.2ohms. Hi 10.2ohms, Lo 1020ohms. Heater 0,03 ohms Supply voltage and current limits: Supply current Spec Current Limit heater 1,25 to 13V 3A < 8,4V, 2A > 8.4V 3.3A < 8.4V, 2.2A > 8.4V* Grid +3 to -100V -10mA, +3mA -20mA, +6mA Plate 0 to 400V 100mA 130mA Display 0 to 400V 20mA 30mA *Current displayed heater is a warning LED. The actual limit is about 5-6A. Measurement and resolution ranges: (there are two, 4.5-digit meters.) Resolution measurement Heater Voltage 20V 1mV heater Current 20A 1mA mains voltage 200V 0.01V distribution current 20mA 0.01uA plate Voltage 2000V 0.1V plate current 200mA 0.01m A Screen Voltage 2000V 0.1V Screen Current 20mA 0.001mA Transconductance 40000umho 0.1umho Plate Conductance (1/Rp) 2000umho 0.01umho Plate Cond. as for Rp 500ohms min 1% to 1Mohm Remarkable features dual 4.5-digit meters make it easy to portray things like Gm vs Ip, Ip vs Vp, Ip vs Vg, Je vs Vp, Gp vs Vp and other common pairs. The voltage of the tube is precisely regulated to refer to the voltage at high stability (as well as the AC level Gm/Gp), so there is no need to rejust the voltage. The voltage adjustment pots are 3 revolutions, including grid-fine control, making the setting accurate but efficient. Virtual soil on the board eliminates gm error from low Rp and improves Gp resolution by 3.2 times more than typical techniques. (recital) Current limiters with indicators of all four supply for protection. Built-in calibration standards 0,01 % at gm =10000 and Gp=1000umho. Square waves, AC test signals and synchronous detector improve accuracy, reject humming and noise, and avoid AC detection errors. Low AC signal levels (for Gm and Gp) reduce the error rate from non-linear tubes. The grid test level is only 100mVpp and the board is only 2Vpp. Separate drive and sensory lines eliminate defects from the decrease in wiring voltage. Separate heaters and cathode-law reasons prevent the heater current from affecting other values. Separate ground sensory lines eliminate errors caused by ground current. Closed cover, internal fan and crack cools the system while keeping the circuit dust-free. It uses the entire chassis as a radiator. Accurate, switching, heating power minimizes heat while providing up to 3.3A (5A short). Any pin can be switched to an external connecting point for use with laboratory supplies and meters. Ferrite beads on all connection pins insure stability for high-Gm tubes. The additional auto-range function for high range Gm extends the subtraction of the maximum transmission value to 40000umho. The VTA front panel was designed using natural symbols, not those from the old days. Example: use Vp instead of Va for board voltage. Therefore, we use the natural symbols in this article as defined below. Item Natural Classic heater h f c k Grid g g1 or c1 Screen with g2 or c2 Plate p a or b Voltage V E Test results are mostly read on the meter2, so its function switch shows Available. The meters formats below indicate ranges and resolutions: Units of the 19999 Ih format. mA Ig lo 199.99 uA Ig hi 19.999 mA Ip 199.99 mA is 19.999 mA Gm lo 1999.9 umho Gm hi 19999. umho Gm nad* 19999. X10 umho Gp lo 199.99 umho Gp hi 1999.0 umho *Gm hi auto-ranges by 10X above 19999, valid up to 4000 x 10 (40000). Step 100X from Ig hi to Ig lo uses a 4.5-digit meter to provide a 1% resolution for 1uA. Physical layout The design is based on a 15 x 15 x 4.5-inch, oblique, aluminum chassis made by LMB-Heeger, which you can see a little better in the photo below on the right. All electrical components and modules are mounted on the top cover and the bottom is mainly just a cover. In this way, there are no connectors or hanging guides between the top and bottom. Down to the left is the inside of the unit. (Click for a larger pic). The marked sections are listed below. Main plate with DC controllers, measuring system and dither generators. Internal fan mounted on the annoying to control air circulation. The airflow is up here, via PCBs. Since the baffle is closed at the top and bottom of the chassis, the air must pass through the triangular area near (K). There is no opening, so the entire aluminum chassis becomes a cooler. The power supply board includes unregulated-screen boards, grid and heating supplies. It also includes unregulated auxiliary consumption needs for plate regulators, image and heaters, plus unregulated consumables for each meter. Main transformer. The meter-1 includes a STORAGE PM-328 4.5-digit meter plus a visible additional plate with precise reference, distribution regulators, profit adjustment at high stability and input protection. The meter-1 function switch with mounting plate for the logic of the decimal pointer and units. The auto-reaching addition for the Meter-2 extends the Gm limit to 40,000umho. Meter-2 with similar properties to Meter-1 (E). Switch functions meter-2 with functions (F) plus relay controlled, precise, 10X divider. Control switches: (top to bottom) Power, TEST, Pentode/Triode, Gm/Gp Calibrate. Pin switches connect each pin to one of eight functions: NC, Ground, Heater, Heater-ground, Grid, Screen, Plate, External-connection. Voltage control: (top to bottom) Screen, Plate, Grid-fine, Grid, Heater. Main cooler. Electrical equipment is mounted directly on the radiator, through the holes in the chassis. Block Diagram Overview Click the block diagram above for the high-resolution version. The basic task of the VTA is to ensure the supply of plates, grilles, screens and heaters and measuring devices for all DC voltages and currents, plus Gm and Gp. (Rp = 1/Gp) The tube under test is inserted into one of the sockets represented in the small block at the top. Pin connections are set in the switch matrix in the large block on the left. Lines from the switching nut to the rest of the VTA selected tube pins such as plate, screen, grille, heater heater (cathode/suppressor grid). Two separate lines are switched to each tube pin: drive and sense. The power supply current uses the drive line and the sensory line is used for measuring and remotely sensing plates and heaters. This scheme practically eliminates errors due to a decrease in voltage in the wiring VTA. It's like you put a meter right on the tube socket. Switching and power supply The switch-out from the switch nut (except the heater) passes through the TEST switch to disconnect the tube when the test does not pass. The heater remains connected in standby mode and meter-1 looks at the supply voltage instead of the voltage on the tube pins. This supports the setting of heating and power supply. We'll discuss the Gm/Gp cal switch below. Along the bottom of the diagram block we see a plate, grid, screen and heating supply, as well as auxiliary ±15V deliveries that are used internally in each of the exact supply tubes. (The heater source develops its own, internal operating voltage.) Each tube supply comes with an up-to-date restriction and front panel overload indicator to let you know when it can't meet your current demand. DC and Gm MeasurementsMeter-1 can display any supply voltage of the tube, so it is used to adjust the voltage. It also can display a plate stream. Meter-2 is used to display results and can show any current of power tube, as well as Gm and Gp. When selected Gm, accurate, 100mVpp, 1kHz signal is stored at the mains voltage. The block of gm/gp detector above the plate measures the amount of ALTERNATING current generated by the tube and thus reads Gm. There are two optional ranges (2000umho, 20000umho) and also an auto-range function that extends the value to 40000umho. Measuring Gp instead of Rp When gp is selected, accuracy, 2Vpp, 1kHz, dither signal is stored on the voltage plate. Now the detector in the perimeter of the board shows the alternating current caused by the dither, and it is read as Gp (plate conductivity). The resistance plate, Rp, is 1/Gp. Why read gp instead of Rp? This is because a GP is what you get if you want to try it with a fixed network voltage. To read Rp directly, we will need to provide a source of AC current to the board and be able to read a wide range of AC voltages that results. This is more difficult and prone to error. By reading gp, we can keep the board swing at a very low ±1Vpp, but accurately measure the resistance of the plate from 500ohms to 1Mohm or higher. 0.01% Gm and Gp CalibratorTo help achieve the overall accuracy target of 0.1%, I decided to include a calibrator for Gm and Gp. While DC measurements can be easily checked using laboratory equipment, ensuring AC accuracy using the metering approach used would be difficult without the calibrator. When the Cal switch is switched on, the VTA circuits switch from the tube to the calibration circuit. For Gm uses precision opamp and high voltage MOSFET to the exact value of Gm, which is set by 0.01%, low-tempco resistance. The value of Gm is 10000umho, half the full scale. The check right now, after months of use, shows 9997umho, showing only 0.03% drift. The Circuit Gp cal is similar, in addition to the input signal comes from dither voltage on the board. It provides a GP reading of 1000.0umho, half full-scale. Photo A tour of the development Click on the image for a caption photo gallery covering six years of development: good, bad and ugly! Expand the full-screen window to enjoy high-content photos. You can navigate using the keyboard: Home, , , Exit. Here's another: Three interesting schematic topics, complete documents and more! Comments readers: Steve L. August 27, 2019, at 14:43Hi Francesca: Yes, there are still PCBs for VTA, but I doubt that this project would be a good solution for you. For details, see Could you build it? and click on the link Advice for builders. However, the same link is the coverage of Ronald Dekker's µTracer, which is a very affordable and real project that could fill your needs. You can find a complete review and building an article that covers that on the home page. Thank you for your question. Posted by Francesca Smith on August 27, 2019, at 8:05 a.m. I have a CA-1630, but its still hard to move and the prices for the RCA WT-100 are through the roof now. In any case, it's inspiring to say the least. Francesca Posted by Steve L. June 05, 2019 - 07:32 AmHi Roberto, It's nice to hear from Argentina! Thank you for your kind post and I hope your uTracer design goes well! Posted by Roberto Lopez Santoro, June 5, 2019, at 7:11 Congratulations Steve! I have not yet started building my uTracer, and all these fantastic ideas and suggestions will be very useful to me and all the lucky ones who will have their uTracer. I live in Buenos Aires and Am attentive to all the communications that Ronald Dekker makes. Posted by Steve L. on November 24, 2018 - 7:20hi Brian, it's nice of you to say that. What an amazing collection of tube analyzers you have! Each of them would be worthy of being fanatics of pride and joy. Thank you for posting. Posted by Brian Beck November 24, 2018 - 6:35am Incredibly impressive work! As the owner of the Daystrom CA-1630, New London 901A and RCA WT-100A, I would be proud to have your piece in my collection! Posted by Steve L. March 21, 2018 - 2:06 PMHi Mark, I really appreciate your thoughtful comment. Yes, the CA-1630 is really, really impressive! And colorful too! :) This illustrates that there were some excellent laboratory tube analyzers back in the day. --- Thanks! Posted by Mark Henze March 21, 2018 - 10:36amYy you could have the title of this article, What if Weston/Daystrom were still doing tube testers? Layout reminds you CA-1630. Your engineering, however, is much smarter than hp. Using a square wave signal with a synchronous rectifier that excludes the front and end passages of the edges is an excellent piece of thinking – very innovative! Posted by Steve L. on February 10, 2018 - 5:14pmHi Nebojsa, Thank you for a nice comment and for a link from the Facebook Tube Tester group. It looks like a very interesting group and I will join it soon. All the Best Posted by Nebojsa February 10, 2018 - 5:08 pm Add your comments here... Here...