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rec.audio.tubes tube tester project, by Steve Bench

Click **here for updated Schematic**

Click on **here for a variable voltage filament supply** to accomodate odd voltage power triodes (2A3, 300B, 50, etc.)

Background:

There are 3 fundamental Vacuum Tube (Valve) constants. These are transconductance (gm), plate resistance (rp) and mu. For tetrode and/or pentode devices, mu is not significant, since the plate resistance is usually much higher than the load resistance. There is a simple relationship between these: mu = gm * rp. In a triode, the mu is substantially geometric factor, so it does not change much as the tube ages. Rather, the gm decreases with time and the rp increases. Therefore, a measure of the goodness of a tube is generally related to its measured gm. This is done in a "transconductance" tube tester, but, as the specific voltage and current used in a particular application is not possible or practical to set up, this limits the usefulness of the traditional tube tester. The purpose of the described device is to circumvent these limitations, and allow evaluation of tubes under operating conditions really used in your specific application.

DEFINITIONS:

Transconductance:

This is defined as the incremental change in plate current for an incremental change in grid voltage, with all other parameters (plate voltage, for example) held constant. The way this is done is to place a small AC voltage (lets say 100 mV) on the grid and measure the output AC current on the plate. In practice, this is done by measuring the voltage across a small resistor, (lets say 100 ohms) connected from plate to a constant DC voltage source. The current can be controlled by placing a constant current source in the cathode circuit of the tube under test, and bypass the cathode for AC purposes. For the example given (100 mV AC on the grid, and a 100 ohm plate "current sensing" resistor), a transconductance of 1 mS (1000 micro mhos) would be indicated as a 10 mV signal across the 100 ohm resistor.

Mu:

This is defined as the incremental change in plate voltage for an incremental change in grid voltage, with all other parameters (plate current, for example) held constant. The way this is done is to place a small AC voltage (lets say 100 mV) on the grid and measure the resulting AC voltage on the plate, with the plate connected to a high impedance load (current source). For the example given, (100 mV AC on the grid), a mu of 20 would be indicated as a 2 volt signal at the plate. Note: The "resistance" of the constant current load must be substantially higher than the plate resistance of the tube under test for the results to be accurate. Plate resistance: This is defined as the incremental change in plate voltage for an incremental change in plate current with all other parameters held constant. This is not directly measured in the proposed project (at least initially) but is calculated by the formula rp = mu/gm.

SYSTEM BLOCKS:

Sources:

1. Filament Voltage: Initially fixed at 6.3VAC (no grumbling, we'll "improve" on this over time). This supply is referenced to about 40VDC to allow realistic confirmation of (no) heater to cathode leakage or shorts.

2. Plate (anode) Voltage: Lets say 300 VDC, at 50 mA max. Initially this will be allowed to vary from about 40 volts to

about 300 volts, controlled by a small potentiometer operating a regulated supply. The 50 mA allows both small signal and power tubes to be measured. This supply is current limited at 50 or so mA, to handle the defective "shorted tube" case.

3. Screen Voltage: Same as #2, independently controlled. 4. Plate current: Actually a part of plate voltage control. This is operable only in "mu" mode to provide a high impedance load as indicated above. The actual tube current is controlled by the cathode current sink (see below), and this is adjusted for the test condition voltage.

4. AC: 100 mV sine wave at about 1 kHz. This source is protected against grid to plate or grid to cathode shorts.

Sinks:

1. Cathode current: Variable from about 100 microamps to 50 mA via a potentiometer controlling a constant current circuit. This allows gm/mu to be measured at any desired current level. Combined with the variable plate voltage source, gm/mu can be measured over a range of voltage and current. This sink is tied to a negative (about) 60 volt source, to simulate bias conditions to about -60 volts, primarily for testing of power tubes. Notice that the actual voltage applied to the tube will therefore be up to about 360 volts.

Controls:

1. (S1) On/Off.

2. (S2) gm/mu switch.

3. (S3) Side1/Side2 switch for switching between "halves" of dual triodes.

4. (S4) Triode/Pentode switch to allow "triode connection" of pentodes.

5. (VR1) Plate voltage control.

6. (VR2) Plate current voltage adjust (mu mode).

7. (VR3) Tube current control.

8. (VR4) Screen voltage control (tetrode/pentodes only).

Indicators:

1. 2 jacks for DMM connection. The DMM measures AC voltage in gm mode, and DC plate voltage and AC voltage in mu mode.

2. Green Power LED.

3. Yellow LED that illuminates if grid is driven positive.

4. Red LED that illuminates on H-K leakage or short.

5. Red LED that illuminates on high current (plate etc shorted).

Sockets:

1. Octal: (7AC/7S/8EP) Handles KT66/EL34/6L6/6550/6V6-GT (pins 1&8 connected together).

(Uncle Ned notes: 7027 would require disconnecting Pin 1 from Pin 8. 6BG6-G/GA and 6CD6-G/GA/7867 by adding a plate/anode cap. Possibly 6B4-G could be accomdated too...)

2. Octal: (8BD) Handles 6BL7/6SN7/6SL7/6AS7/6080/6336/6528 etc.

3. 9 pin: (9A) Handles 12AT7/AU7/AX7/ECC81-3/12BH7 etc.

4. 9 pin: (9AJ/9DE) Handles 6DJ8/6BK7/BQ7/BZ7/6CG7/6922 etc.

5. 9 pin: (9V) Handles 417/5842

6. 9 pin: (9BF) Handles 12BY7/12GN7/ etc.

7. 9 pin: (9CV) Handles 6BQ5/6CW5/7189/El84 etc.

8. 7 pin: (7BK/7CM) Handles 6AU6/6AH6/6GM6 etc (pins 2&7 connected together).

OPERATION:

gm test:

Procedure:

Plug the tube into the appropriate socket, set the gm/mu switch to the gm position. Set the desired plate voltage and the desired current level. Read the AC voltage on the DMM.

Reading GM 1 mV 100 umhos (0.1 mS) 10 mV

1000 umhos (1.0 mS) 100 mV 10000 umhos (10.0 mS) etc.

A "constant current" is fed into the cathode. This is bypassed for the transconductance measurement. This allows the grid-cathode voltage to be established by the tube itself. There is a warning LED to indicate that the desired current has caused the grid to go into grid conduction region. This constant current is one of the "variables" that we can use to evaluate the tube under test, so that gm can be plotted vs current. A constant voltage is set onto the plate, and this is the other "variable" we can use to evaluate the tube under test. A 100 mV AC signal is applied to the grid, and the gm is found by measuring the AC voltage produced across a 100 ohm sampling resistor. mu test: Procedure: Plug the tube into the appropriate socket, set the gm/mu switch to the mu position. This test is only going to work with triodes. Set the desired level, and adjust the "plate current voltage adjust" to the desired plate voltage level by reading the DC voltage with the DMM. Then switch the DMM to AC voltage and read the AC voltage on the DMM.

Reading MU

100 mV 1 V

1.0 V 10

10.0 V 100 etc.

A "constant current" is fed to the cathode. This is bypassed for AC purposes to allow the mu measurement. This allows the grid-cathode voltage to be established by the tube itself. There is a warning LED to indicate that the desired current has caused the grid to go into grid conduction region. This constant current is one of the "variables" that we can use to evaluate the tube under test, so mu can be plotted vs current. The plate voltage is established via a quasi-constant current source whose output resistance is much higher than the plate resistance of the tube, allowing an accurate mu measurement. This allows plate voltage to be varied, so that mu may be plotted against plate voltage. The mu is found by simply measuring the AC voltage on the plate.

CIRCUIT DESCRIPTION

The power supply uses 2 12.6VCT transformers connected back to back. This is used for the 6.3V for the filaments then provides an isolated (about) 105-110 volts AC. Two DC voltages are developed. The first is a voltage tripler to give back a loaded voltage of about 330VDC (With no tube load, it provides about 400 volts). This wimpy approach was taken purposely to minimize heat loading on the "guts" of the circuit under abnormal (shorted tube) conditions. A 2.2 mA constant current source drives a set of zener diodes, to establish a constant voltage reference of about 306 volts. This is fed to 2 separate VFET "source follower" regulators. The gates are simply fed with pots refered to the regulated voltage. Each regulator is also current limited. The second main supply is a negative half wave rectified supply that provides 60 to 100 volts (depending on load current) for the constant current source that drives the cathode(s). The negative supply has a fairly healthy 20 mA bleeder on it. In the bleeder string is a 10 volt zener used to provide a voltage reference for the current source, and a 5.1V zener sitting on the ground side. This is used to drive a CMOS 1 kHz oscillator.Each regulator is current limited by a simple transistor "starving" the gate of the source follower. The 22 ohm "sampling" resistor causes current limit to occur at about 25 mA. This resistor may be altered if desired. The plate side is limited at 55 mA by using a 10 ohm resistor. The main tube current source uses a 10 volt zener to establish a constant gate voltage, adjustable from about 2.5 to about 10 volts. This causes the 133 ohm resistor in the FET source to provide a constant current of about 0.1 mA to about 50 mA.

A word of caution on the FETs. Make sure the resistor that's in series with the gate lead is AT THE FET. This prevents the critters from oscillating at some VERY high frequency. Also, note that although these parts are rugged IN THE CIRCUIT, they can be blown by static charge while assembling the circuit.

The 1 kHz oscillator is a schmitt trigger oscillator. The "triangle" is fed through another part of the inverter package, which rounds it a bit more and then filtered and divided to 100 mV. This produces a relatively pure sine wave with less than 1k source impedance.

The 6.3VAC is referenced to 51VDC via a 47k resistor and a LED. This provides indication of heater to cathode leakage or short. Using "universal" 120-240 transformers allows easy build by anyone. Note that the second transformer is powered from the first one (the 12 volt windings are coupled together) and the high voltage produced is always wired 120V.

Note however, the first transformer should be wired for either 120 or 240 depending on your high tension source.

CALIBRATION:

After conpleting the unit and finding the 4 or 5 things you did wrong, you should be pleasantly suprised by the green LED ON.

With NO tubes installed, the following voltages should be present:

Point	Voltage	Notes
A	420VDC	380 to 430 volts is OK

B	306VDC	296 to 316 volts is OK
C	----------------->>>	This will vary from 0 to 300 volts depending on VR1. If you set this to about 200 volts, then measure current to ground, you should see about 55 mA (50-65).
D	------------------>>>	This will vary from 0 to 300 volts depending on VR3. If you set this to about 200 volts, then measure current to ground, you should see about 25 mA (20-30).
E	-100V	-80 to -110 volts is OK. This is the current source output.
F	-110VDC	-85 to -120 is OK.
G	-100VDC	Should be 10 volts more positive than F.
H	-4.6VDC	Yeah, I know its a 5.1V zener. Trust me.
J	------->>>>	This will vary form 0 to about 250 mV AC rms 1 kHz. The frequency ought to be within 200 Hz of 1kHz. Level is controlled by VR4.

Calibrate Plate Voltage (VR1):

With a voltmeter connected to point C, calibrate VR1. This will be linear taper. I find I can make minor "ticks" every 10 volts, major ticks every 50 volts from 0 to 300 volts. Since there is no "load" on this point, you could temporarily place a 100k resistor to ground to provide some load to make the calibration more accurate.

Calibrate Screen Voltage (VR3):

Same procedure as above. except point D and calibrating VR3.

Calibrate current source (VR2):

Connect a milliameter from point E to ground. You should start to see current flowing at about 20 degrees of rotation on VR2. If you have to go much more clockwise to see current flowing raise R15 (270k) to 330k or higher. If you see more than 100 uA flowing fully counterclockwise lower R15 to 220k or lower. The 220k across the pot (R17) creates a somewhat log taper. I found I could make minor ticks .1 mA to .5 mA, then 1 mA, then 1 mA ticks from 1 to 10 mA, 2 mA ticks to 20 mA, and 5 mA ticks from 20 to 50 mA.

Set AC Level (VR4):

Connect an AC VM from point J to ground. Set the voltage to 103 mV +/- 2 mV with no load otherwise attached. This will make the operating voltage very nearly 100 mV across the range of currents and voltages. Thats all there is to the calibration.

PARTS LIST

Most of the parts are available from Digi-key or Mouser. The exception is the tube sockets, so you'll have to go to Ned.

I have not listed chassis, hardware, knobs, and the like. Use what you like. I used an old Lafayette (!) rip off of the old Ten-tec boxes that is about 12"x8"x 6" or so. Also, sometimes there's a price break at a larger quantity, so feel free to order extras for another project. E.g., 1N4007 diodes. I generally order 100 at a shot, you can use the extras by bending the end of each lead slightly. They are perfect for hanging ornaments on your (place your holiday here) tree. Ho Ho Ho!

Ed. Note: We have the sockets and most of the capacitors (or higher voltage rating equivalents). There are, I'm pretty sure, SK or ECG equivalents for most of the diodes & transistors, if you want to buy them at local distributors.

QTY.	DESC	REF
6	100 uF 350V Elec.	C1, C2, C3, C6, C7, C8
2	47 uF 450V Elec.	C4, C5
1	47 uF 10V Elec or Tant.	C9
2	.1 uF mylar, poly, etc.	C10, C13
4	.01 500V+	C11, C14, C16, C17
1	1.0 uF 50V+	C12
1	.22 uF 50V +	C15
9	1N4007 1A 1KV diodes	CR1-7, CR18, CR19
1	Hi efficiency green LED	CR8
6	51V 5% .5 watt zeners	CR9-14
1	Hi efficiency red LED	CR15
1	5.1V .5 watt 5% zener	CR16
1	10V 1W 5% zener 1N4740	CR17
1	1A fuse-of sufficient voltage rating,ie: not an automotive fuse	F1
1	fuseholder-depends on type of fuze used.	
1	Linecord -- country dependent	
1	dual binding post	J1a,b
1	MPSA92 350v PNP TO-92	Q1
2	MPSA42 350v NPN TO-92	Q2, Q3
3	IRF820 TO220 VFET(you can substitute IRF820, 830, 840 or IRF710, 720, 730, 740)	Q4, Q5, Q6
3 --	Heat sinks for the FETs	Mouser p/n M532-569022B00 or equiv
12	470 ohm 1/4w 5%	R1, R27-37
1	47k 1/4w 5%	R2
1	100K 2W 5%	R3
4	10k 1/4w 5%	R4, R18-20, R23, R26
6	1M 1/4w 5%	R5, R9, R22, R25
1	10 ohm 1/4w 5%	R6
3	100 ohm 1/4w 5%	R7, R8, R10
1	470k 1/2w 5%	R11
1	22 ohm 1/4w 5%	R12
1	200 ohm 2w 5%	R13
1	3.3k 5W 5%	R14
1	270k 1/4w 5%	R15
1	133 ohm 1/2w 1%	R16
1	220k 1/4w 5%	R17
1	200k 1/4w 5%	R21
1	160k 1/4w 5%	R24
1	SPST switch	S1
2	DPDT switch	S2,S3

1	3 position switch	S4
2	120/240v to 12.6VCT 40W mains transformer	T1,T2
1	74HC04 (not HCT)	U1
1	7 pin tube socket	V1
2	Octal tube sockets	V2,V3
5	9 pin tube sockets	V4-V8
3	1 meg lin taper pot	VR1, VR2, VR3
1	2 k trimmer pot	VR4

Hi All, Modifications to the gm/mu Tester - Rev B

1. During checkout, I found one condition of plugging tubes (sideways - one pin was broken and 2 others shorted) that I could cause the plate regulator to break, so I've added two zeners to prevent that from happening in the future.

2. Added a 4D 4 pin socket for 811's etc. This also adds a 5th switch to "short" heater to cathode.

3. A second schematic page is now available... this adds a variable regulator to the filament source, to provide a variable filament voltage from 2.5 to 12.2 volts. This is not required for operation of the basic tester, but provides coverage for 2A3's, 50's etc. Add it if you like.

4. A "plate cap" is added to the schematic for testing things like 811's, and 6DQ6 and related 6AM socketed tubes in the 7AC socket.

5. There was one "unclear" portion on the schematic in the tube socket connections. This is clarified.

6. See below for settings to test a number of common tubes, so you don't have to look them up.

Page 1 BOM (Bill Of Materials)Changes:

Qty	Description	Ref	Designator
1	SPST Switch	S5	Same as S1.
2	15V .5w Zener	CR20, CR21	1N5235B
1	4 pin tube skt	V9	
1	Plate Cap		

Page 2 BOM:

Qty	Description	Ref	Designator
2	1000 uF 25V	C101, C102	
1	.01 uF disc	C103	
5	3A 40V Schottky diode	CR101-CR105	1N5822
1	50 uH 5A inductor	L101	(actually 68 uH)
2	2.2k 1/4W 5%	R101, R102	
1	Maxim MAX724	U101	Available from DigiKey
1	Heat Sink		Same as on Pg 1

1	10k lin taper	VR101

Page 2 Calibration Procedure:

With a DVM connected to the output going to the filaments, calibrate VR5 at 2.5, 3, 5, 6, 6.3, 6.6, 7.5, 10, 12, 1.2 volts. Check this voltage with a 50C5 (or 35W4 etc) plugged into the 7BK socket as a load. This voltage should not substantially change with load. Regards, Steve

Steve's gm/mu Tester. "Standard" Readings for many Tubes.

Note: Vf is 6.3V unless otherwise indicated. To test other than 6.3V tubes, you must build the Filament circuit shown in the schematics' second page. For the 4D socketed parts, you must turn ON S5, which connects cathode and filament. Note the shorted H-K LED will come ON in this case. P after the socket means use the plate cap to hook up the plate.

THIS LIST IS NOT INTENDED TO BE ALL INCLUSIVE! Many of the tubes not listed here can be found in the GE Essential Characteristics book.

Vf=Filament voltage. Va= Plate or anode voltage. Vg2=Screen or grid #2 voltage.Does not apply to triodes.Vg1=Negative grid voltage. Only given for power triodes. Ik=cathode current. gm=transconductance as expressed in micromhos (typical US designation,1000 umho is equal to 1 ma/V, 1 ma change in anode current for 1 volt chage in grid (g1) voltage). mu=amplification factor. Only given for small triodes.

Note that the gm and Ik given are for **typical** new tubes. Depending on the tube type, variations of 10 to 20% can be expected to be seen, **even for unused tubes,**generally the higher the Ik or gm, the wider the variation that one can expect. High gm tubes such as 6DJ8, 7308, 12GN7, etc, are often factory spec'd to as wide as a -20 +40% tolerance in gm. Others may show an increase in Ik after being "cooked" with plate current for awhile, so if your NOS Mullard 12AX7's test too low, try running them for a while, then retest them.

Tube	Socket	Vf	Va	Vg2	Vg1	Ik	gm-umho	mu
2A3	4D	2.5	300	--	-45	50	4200	
6A3	4D		300	--	-45	50	4200	
6AG5	7BK		250	150		8.5	5000	
6AH6	7BK		300	150		12.5	9000	
6AJ5	7BK		30	30		3.5	2300	
6AK5	7BK		180	120		10	5100	
6AQ8	9AJ		250	--		10	5700	59
6AS6	7BK		120	120		9	3200	
6AS7	8BD		150		-45	60	2000	
6AU6	7BK		250	150		15	5200	
6BA6	7BK		250	100		15	4400	
6BC8	9AJ		150			10	6200	35
6BD6	7BK		250	100		12	2000	
6BG6	7AC-p		250	250		75	6000	
6BH6	7BK		250	150		10	4600	
6BJ6	7BK		250	150		12	3600	
6BK7	9AJ		150			18	8500	40

6BL7	8BD		250			40	7000	15
6BQ5/ EL84	9CV		250	250		45	10500	
6BQ6	7AC -p		250	150		45	5200	
6BQ7	9AJ		150			9	6000	35
6BS8	9AJ		150			10	7200	36
6BX7	8BD		250			42	7600	10
6BX8	9AJ		65			9	6700	25
6BZ6	7BK		125	125		18	8000	
6BZ7	9AJ		150			10	6800	36
6BZ8	9AJ		125			10	8000	45
6CA7/ EL34	7AC		250	250		45	10000	
6CB6	7BK		125	125		17	8000	
6CD6	7AC-p		175	175		75	7700	
6CG7	9AJ		250			9	2600	20
6CW5/EL86	9CV		170	170		45	10000	
6DN7 (sec 1)	8BD		250			8	2500	22.5
(sec2)			250			41	7700	15
6DJ8/ ECC88	9AJ		90			15	12500	33
6EM7 (sec 1)	8BD		250			1.5	2200	66
(sec 2)			150			45	7000	5.4
6F6	7AC		250	250		40	2500	
6GM8/ ECC86	9AJ		7			.9	2600	14
6JK6	7BK		125	125		15	18000	
6K6	7AC		250	250		37	2300	
6L6	7AC		250	250		45	5100	
6SL7	8BD		250			2	1500	70
6SN7	8BD		250			9	2600	20
6V6	7AC		250	250		45	4100	
10	4D	7.5	300		-20	20	1600	8
12AT7/ ECC81	9A		250			10	5500	60
12AU7/ECC82	9A		250			10	2200	17
12AV7	9A		150			18	8500	41
12AX7/ ECC83	9A		250			1.2	1600	95
12AY7	9A		250			3	1700	44
12BH7	9A		250			11	3100	16.5
12BY7	9BF		250	180		32	11000	
12BZ7	9A		250			2.5	3200	98
12GN7	9BF		250	150		35	36000	
12HG7	9BF		300	135		35	32000	
50	4D	7.5	300		-45	20	3800	
275A	4D	5.0	150		-40	17	1600	2.6

300B	4D	5.0	300	-61	60	5500	3.8
350B	7AC		300 250		80	7700	
417A	9V		150		26	24000	43
811A	4D -p		300		30	1500	95
5751	9A		250		1	1200	70
5998	8BD		120		45	15000	5.4
6336	8BD		200	-45	185	11000	2.7
6528	8BD		110		45	30000	9
6550	7AC		275 275		45	10000	
6922	9AJ		90		12	11500	33

6SU7 8BD see 6SL7

12AD7 9A see 12AX7

12AZ7 9A see 12AT7

12DF7 9A see 12AX7

12DM7 9A see 12AX7

12DT7 9A see 12AX7

12DW7 9A sec1 = 12AX7, sec2 = 12AU7

572 4D -p see 811A

5691 8BD see 6SL7

5692 8BD see 6SN7

5725 7BK see 6AS6

5749 7BK see 6BA6

5814 9A see 12AU7

5842 9V see 417A

5881 7AC see 6L6

5965 9A see 12AV7

6072 9A see 12AY7

6080 8BD see 6AS7

6113 8BD see 6SL7

6136 7BK see 6AU6

6188 8BD see 6SL7

6189 9A see 12AU7

6201 9A see 12AT7

6265 7BK see 6BH6

6485 7BK see 6AH6

6520 8BD see 6AS7

6660 7BK see 6BA6

6661 7BK see 6BH6

6662 7BK see 6BJ6

6679 9A see 12AT7

6680 9A see 12AU7

6681 9A see 12AX7

6851 9A see 5751

7025 9A see 12AX7

7189 9CV see 6BQ5

7247 9A sec1 = 12AX7, sec2 = 12AU7

7308/E188CC see 6922

7581 7AC see 6L6

7728 9A see 12AT7

7729 9A see 12AX7

7730 9A see 12AU7

7867 7AC-p see 6CD6

8431 9AJ see 6ES8

ECC81 9A see 12AT7

ECC82 9A see 12AU7

ECC83 9A see 12AX7

ECC88 9AJ see 6DJ8

E88CC 9AJ see 6922

EL34 7AC see 6CA7

EL84 9CV see 6BQ5

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