From glowbugs@sco.theporch.com Thu Mar 27 18:38:38 1997
Return-Path: <glowbugs@sco.theporch.com>
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          by uro.theporch.com (8.8.5/AUX-3.1.1)
          with ESMTP id SAA14341 for <shimshon@uro.theporch.com>;
          Thu, 27 Mar 1997 18:38:37 -0600 (CST)
From: glowbugs@sco.theporch.com
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          by sco.theporch.com (8.8.5/SCO-5.0.2) with SMTP
          id AAA22503; Fri, 28 Mar 1997 00:36:50 GMT
Date: Fri, 28 Mar 1997 00:36:50 GMT
Message-Id: <199703280036.AAA22503@sco.theporch.com>
Errors-To: ws4s@infoave.net
Reply-To: glowbugs@sco.theporch.com
Originator: glowbugs@sco.theporch.com
Sender: glowbugs@sco.theporch.com
Precedence: bulk
To: Multiple recipients of list <glowbugs@sco.theporch.com>
Subject: GLOWBUGS digest 488
X-Listprocessor-Version: 6.0 -- ListProcessor by Anastasios Kotsikonas
X-Comment: Please send list server requests to listproc@sco.theporch.com
Status: O

GLOWBUGS Digest 488

Topics covered in this issue include:

Date: Wed, 26 Mar 1997 19:06:02 -1000
From: Jeffrey Herman <jeffreyh@hawaii.edu>
To: Glowbugs List <glowbugs@theporch.com>
Subject: Using a tetrode or pentode as a triode
Message-ID: <Pine.GSO.3.95q.970326190403.20446D-100000@uhunix3>

Thought this might be of interest to many of you; picked it off
the ARRL email server.
7.3W, Jeff KH2PZ

From: info-serv@arrl.org

Subject: Re: Synthesized Triode from Tetrode or Pentode

By Dave Newkirk/ July 28, 1993

Connecting together the screen and control grid of a tetrode (or the suppressor, screen and control grid of a true pentode) turns the tube into a high-mu triode. The resulting tube may be, but is not necessarily, a *zero-bias* triode. True zero-bias tubes are designed to be so, and must be operated according to their designer's specs to work well with zero bias. Too much plate voltage on a zero-bias triode can overcome its grid's control and make it draw too much plate current when idling. So a high-mu triode synthesized by connecting together the multiple grids of a screen-grid tube *may or may not* be operated as a zero-bias tube, depending on its resulting control characteristics and how you power the tube.

Relatedly, a screen-grid tube connected as a high-mu triode may not necessarily exhibit the low-IMD characteristics of a good, designed-for-low-IMD zero-bias triode. In other words, you wouldn't necessarily synthesize a 3-400Z by high-mu- triode-connnecting a 4-400. (Even a 3-400Z is old hat. There are newer, better zero-bias tubes, where *better* equates to "lower intermodulation distortion.")

I haven't mentioned so far what is probably obvious: Connecting a well-screened screen-grid tube as a triode means that it's no longer a screen-grid tube. An amplifier built with a tube connected in this way must be (A) neutralized if the tube is operated grounded-cathode or (B) operated in grounded-grid so its connected-together grids can act as a screen or (C) configured as a cathode follower (which is largely impractical if you want significant power output).

This sets us up for the next question:

What would happen to a beam-power tube, such as a 6DQ5, if its screen is connected to its control grid? It would act as a high-mu triode. *But*--and this is very important--it *couldn't* be operated grounded-grid (without neutralization, that is)! This is so because, like many beam power tubes, the 6DQ5's beam-forming elements are internally hardwired to its cathode. This bypasses the shielding afforded by grounding its control and screen grids. Beam power tubes that cannot be operated in grounded-grid without neutralization include the 807, 1625, 6146 and many TV sweep tubes. *Some* TV sweep tubes and RF beam power tubes (6KD6, 5763) bring their beam-forming elements out to a separate pin. *These* can be operated in grounded-grid without neutralization; you'd ground their control grids, screens and beam-forming plates for RF. You have the option of tying all the grids together for dc or feeding them separately. This gives on one last issue:

There's one more important issue in using screen-grid tubes as high-mu triodes, grounded-grid or not. By construction, a tube's control grid exerts more control over its electron stream than its screen; it's closer to the cathode than the screen and made of finer wire. Further, screen-grid tubes are intended for applications in which the screen is *considerably more positive* than the control grid. *Because of this, severe grid overdrive will likely result* if the control grid and screen are merely tied together (for dc *and RF) during high-mu-triode operation because the screen operates at the same potential as the grid and therefore doesn't draw them past and away from the grid as it does when it's significantly more positive than the grid. *GE Ham Notes* (see enclosed) goes into detail on this, as does V. S. Campbell and W. S. Skeen, "Grounded Screen-Grid Operation for Tetrodes," *QST*, Nov 1959, pp 37-39. (The introductory box for this article goes like this: "A tetrode with control grid and screen tied together to form a high-mu triode for a grounded-grid circuit makes a very simple arrangement. However, this type of operation invariably results in excessive control-grid dissipation. This article shows a simple method of avoiding this difficulty.") It's therefore important to monitor element currents individually, at least until the circuit is finalized, when operating a screen-grid tube as a high-mu triode.

Calculating the operating conditions for a tube operating in grounded-grid is relatively straightforward for true triodes, as explained in G. Grammer, "Input Impedance and Fed-Through Power in Grounded-Grid Amplifiers," Technical Topics, *QST*, Dec 1958, pp 32-35, 184. Calculating these parameters *isn't* straightforward if you want to run a screen-grid tube in grounded grid and apply normal screen voltage to the screen while grounding it for RF; experiment will likely be necessary to determine particulars in this case.

Date: Wed, 26 Mar 1997 20:11:32 -1000
From: Jeffrey Herman <jeffreyh@hawaii.edu>
To: Glowbugs List <glowbugs@theporch.com>
Subject: Sweep tube linearity
Message-ID: <Pine.GSO.3.95q.970326201045.3740A-100000@uhunix3>

From: info-serv@arrl.org
Subject: INFO response: TUBEDATA.SUM

From: ornitz@kodak.kodak.com (Barry Ornitz)
Newsgroups: rec.radio.amateur.misc
Subject: Sweep tube linearity, etc. (Was: tube finals melt a lot)
Date: 5 Jun 91 22:55:45 GMT

In an earlier article, I had written about the linearity of sweep tubes and small transmitting tubes.

>A real problem with all of the sweep tubes - including the 6146 too, was the
>poor linearity of the tubes. I always wondered why no manufacturer ever used
>6550's. The power level and voltage ratings of these high linearity tubes
>would have been ideal. The Hi-Fi manufacturers were the only companies that
>seemed to use them.

Perry Scott, AA0ET, replied:

>The Radio Handbook contains a table of distortion products for various
>sweep tubes. The 6146 is rated at -24 dB of 3rd order IMD, while the
>6LQ6 is rated at -18 dB. Some of the linearity problems occur because
>of lack of tuned input, which presents a varying load to the exciter in
>a grounded grid configuration. Another remedy for nonlinearity is to
>use the venerable pi-L to keep the neighbors happy.

>I have never heard bad reports on the sweeps I use in the 520 or the
>6x6LQ6 linear. If the nonlinearity is just a specsmanship thing, then
>I'll be nonlinear. In general, I think sweeps have been much maligned
>by people that didn't understand their limitations. They are less
>forgiving of design blunders than real transmitting tubes.

I am not sure whether Perry is talking about data from the ARRL Handbook or Bill Orr's book. The table in Bill Orr's "Handbook" is from an article he initially published in Ham Radio Magazine (back in 1968, I think). The data given were for Class AB1 service, grid driven. It should be noted that some of the tubes were pushed very hard, often well beyond their normal ratings. In general, the intermodulation distortion of these tubes would be 3 to 5 dB better if they were operated in a cathode-driven mode due to the negative feedback inherent in this operation. However, we are talking about sweep tubes as final amplifier tubes in older SSB exciters, where usually two or more sweep tubes are operated in parallel, and are grid driven with a tuned circuit on the grid and plate. External sweep tube kilowatt amplifiers are a different issue altogether.

I have listed some of W6SAI's data on sweep tubes below, along with data on some other older tubes, and some data on a few higher power transmitting tubes and even one power FET. The data is for grid-driven, AB1 operation except where marked with an asterisk which signifies cathode driven operation or with a caret which signifies class AB2 operation.

RF LINEAR AMPLIFIER SERVICE FOR SSB AND CW
GRID DRIVEN, CLASS AB1 (Except * Cathode Driven,^ AB2)

TUBE TYPE	PLATE VOLTS V	SCREEN VOLTS V	GRID VOLTS V	ZERO SIG Ib0 ma	MAX SIG Ib ma	MAX SIG Ic2 ma	PLATE LOAD ohms	INPUT PWR W	USEFUL PWR Po W	AVG DISS W	3-ORD IMD dB
6146	600	200	-46	25	103	9	3570	61	41	16	-25
	750	200	-51	25	118	7	2825	88	55	28	-22
	800	290	-69	30	125	10	3620	100	59	35	-24
	800	290	-77	25	180	13	2300	145	91	45	-19
807	600	300	-34	18	70	8	4300	42	28	12	-23
	750	300	-35	15	70	8	5200	53	36	14	-23
6DQ5	500	150	-46	48	170	17	1800	85	54	27	-28
	600	150	-46	48	182	13	1625	91	56	29	-26
	700	150	-49	35	182	11	2210	127	78	41	-23
	800	180	-67	30	250	13	1710	200	121	70	-19
6550	680	340	-39	48	140	20	3010	95	67	26	-32
	800	290	-33	45	127	15	3920	102	70	29	-30
6HF5	500	140	-46	40	133	5	1900	67	35	29	-27
	800	125	-45	30	197	7	2170	158	100	48	-21
6JE6	500	125	-44	40	110	4	2300	55	30	24	-26
	750	175	-63	27	218	15	1850	163	102	51	-20
6MJ6/	750	175	-60	25	215	9	1850	161	102	49	-18
6LQ6	800	200	-69	25	242	13	1850	197	124	60	-18
4CX300	2K	350	-55	100	250	5		500	300		-27
8930	2K	350	-63	90	290	30	4000	580	350		-27
*^8877	2.7K	triode	-8.2	92	740	--	1820	2000	1085		-40
*^	3.5K	---	-8.2	182	1000	--	2000	3500	2075		-38
*3CX500A7	4K	triode	-9	400	1250	--	1800	5000	3000		-37

*	5K	--	-11	400	1450	--	1800	7250	4000	-35
*	6K	--	-12	400	1550	--	1800	9300	5000	-38
MRF150	50	TMOS		250	3750	--		333	150PEP	-32

A few points should be noted from the data: 1) as the tubes are pushed harder to get higher outputs, the distortion products increase; 2) the 6550 tube shows considerably lower IMD than do comparable sweep tubes at a similar power level (this is expected since the 6550 was designed for low distortion); and 3) _real_ transmitting tubes, i.e. those designed for high power service, show far superior IMD ratings. Unfortunately, Bill did not publish data on the 6JB6A's and 6JS6C's popular in many early SSB rigs (Drake and Yaesu).

I included the data on the MRF150 TMOS power FET to show how far solid-state devices have come. It has excellent IMD characteristics.

Perry stated that the nonlinearity of the tubes could be handled with some extra tuned circuits. This is only partly true. Higher levels of harmonics, caused by the tube nonlinearity, were usually no problem with the tube rigs because most had excellent Pi-network outputs which required tuning (not broadbanded) and were fairly high-Q. However, the nonlinearity also presents itself as INTERMODULATION distortion, an in-band phenomena which the extra tuned circuits can do nothing about. Consider a simple case of a two-tone signal on 80 meters where two signals are to be amplified by the tube, one at 3.900 MHz and one at 3.901 MHz. Third order IMD will create new signals at 2*f1 - f2 and 2*f2 - f1, or in this case 3.899 MHz and 3.902 MHz. Fifth order IMD will produce signals at 3.898 MHz and 3.903 MHz. These are in-band signals and the extra tuned circuits will do nothing to filter these; however, they might eliminate the problems with the third and fifth harmonics. Excessive IMD can be easily heard - the SSB people call it flat-topping. Your signal gets "mushy" and your bandwidth becomes excessive; other people up and down the band suddenly hear "buckshot" from your signals. IMD increases rapidly as the tubes are driven to saturation.

So one important thing to consider if you have one of the older tube rigs is NEVER try to push the power output higher than the manufacturer recommends if you want to remain popular with others on the band (the same thing applies to solid-state rigs too).

Nonlinearity is not a specmanship thing, it causes real problems. But do not let this scare you off from using an older rig however. Most of these rigs were capable of good IMD performance by reducing their drive slightly. If you have access to an oscilloscope, it is easy to adjust the rig for the best drive levels and power output consistent with low distortion. The reduction in power will usually be slight, barely enough to show on your contact's S-meter, but the IMD will be much lower. You will also get considerably better tube life. Also keep the tubes cool if you want them to last. Usually all it takes is just turning the microphone gain down a little. I might add that you must be especially careful when using an external speech processor with many of the older rigs. By decreasing the peak to average power ratio, speech processors effectively run up the average power. Many of the older rigs using sweep tubes were not rated for this increase in average power. If you have the manufacturers original specifications, look at the difference between the SSB PEP power levels and the CW/RTTY power levels to see the effect of increased average power.

External, multiple sweep tube kilowatt amplifiers, on the other hand, are an atrocity in my opinion. The increase in IMD performance obtained by cathode driven operation is almost always lost because of the use of parallel tubes. Unless perfectly matched tubes are used in these amplifiers, distortion performance will suffer. The only thing going for these amplifiers was the low tube cost (in their day). Look at the 8877 specs if you want to see low distortion. External amplifiers are a different issue than we have been discussing, however, and I prefer to leave the discussions on this to another day.

Paul Nix, WB5AGF, asked about RF feedback to reduce distortion. The answer is yes, it works. The best references to this subject are as he suggested, Bill Orr's "Radio Handbook". {While I find W6SAI's discussions on antennas often wrong, Bill KNOWS transmitting tubes, amplifiers, and feedback}. Paul is correct in his statements that feedback lowers stage gains while enhancing linearity.

RF negative feedback is an entirely different design problem from negative feedback at audio frequencies. To cover all of the HF amateur bands, the feedback network need cover only slightly more than one decade in frequency. With good audio equipment, the feedback network must work over approximately four decades of frequency range. This is a much tougher problem to do properly. For this reason, many of the audio phreaks have abandoned negative feedback around multiple stages in favor of inherent feedback in individual stages. Collins was about the only amateur radio equipment manufacturer that did much with negative RF feedback in their rigs that I know about. Drake in the L4 amplifier also used the trick of smaller than normal values of the grid bypassing capacitors to obtain some additional negative feedback.

Mark Bitterlich, WA3JPY, and Gary Coffman, KE4ZV, also brought up the important point that the matching network on your rig must be tuned at the actual desired power level. You cannot tune up at low power and expect the same matching conditions at high power. One good way to handle this is to tune your rig into a dummy load at the desired power level. Then switch your rig to an antenna tuner to match the antenna. Do not adjust the transmitter at all after switching to the tuner - only adjust the tuner. I have often used an antenna noise bridge preset to 50 ohms to adjust the antenna tuner. In this way, I can tune up without ever putting a signal on the air. Gary mentions the special difficulty in tuning legal-limit amplifiers. One good way to do this involves a pulsed two-tone generator and a scope. You have to use a dummy load for the tests; it is not simple but it works.

Finally Perry Scott, AA0ET, suggested that I consider designing a 6550 based project and he also asked the price for the 6550.

To start with the second issue, Newark lists the 6550 for around $32. I have seen some audio importers price some 6550's at $15 for Chinese imports. I would tend to stick with the known manufacturers. Now for around $70, I can order the MRF150 transistors. So for new design, I would rather use the single TMOS device to get essentially the same power as a pair of 6550's. With proper care, it will never wear out and I like the lower voltages because of safety. Heat dissipation is easier with the transistor too since radiation cooling and forced convection are seldom needed.

As far as retrofitting 6550's into older rigs that used sweep tubes, you will have several problems. First the 6550 has a higher input capacitance than most of the tubes it will replace. The increase in feedback capacitance of the 6550 over most sweep tubes would also usually necessitate changes in the neutralization circuits. Thus you would have to make extensive modifications to the rigs. Finally the physical size of 6550's would mean having to greatly enlarge the final amplifier assemblies in most existing rigs.

In conclusion, I would agree with many others - if you can get one of the older tube ham rigs at a reasonable price that works well, do not worry excessively about the tubes and nonlinearity. Crank the power down a little and most of these tube rigs will work fine. Tune quickly though! Ask for HONEST signal reports from others you talk to on the ham bands. Make sure the rig is in proper neutralization and always replace the finals with matched sets (and re-neutralize after any change in finals or driver tubes). As good advice to newcomers to ham radio, find an older ham who may have used these rigs many years ago. They can often remember how to tune these rigs without the long-lost instruction manual, and they can help when you need parts or troubleshooting help too.

73, Barry WA4VZQ
ornitz@kodak.com

Date: Thu, 27 Mar 1997 11:26:12 +0100
From: Jan Axing <janax@li.icl.se>
To: glowbugs@theporch.com
Subject: Re: Sweep tube linearity
Message-ID: <333A4B44.1D9@li.icl.se>

Jeffrey Herman wrote:
<see his excellent post, a little too long to include in a reply>

As a curiosity, McIntosh used 8 6LQ6 in parallel PP in the MC3500 audio amplifier capable of 350 W out running the tubes in class AB2. However, I must admit that this amplifier is extremely complex with one of the most complex output transformers I've ever seen.

Next curiosity, 6550 is almost equivalent to the British KT88, another famous audio tube. The Brits also made a transmitting tube called TT21 and if I'm not totally lost, TT21 is exactly the same as KT88 except for the top plate connector. Its power performance is similar to 6146B. Can't find any IM performance data, unfortunately. Maybe someone has? TT21 is still available and should be easier to retrofit than 6550 thanks
to the plate cap.

One semi-modern rig using RF feedback is Kenwood TS-830. It's rated at 220 W PEP input using a pair of 6146B.

73's
--
Jan, SM5GNN
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End of GLOWBUGS Digest 488
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