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Egad! *A* Nine-Tube Linear
–results from the W7CSD test bed

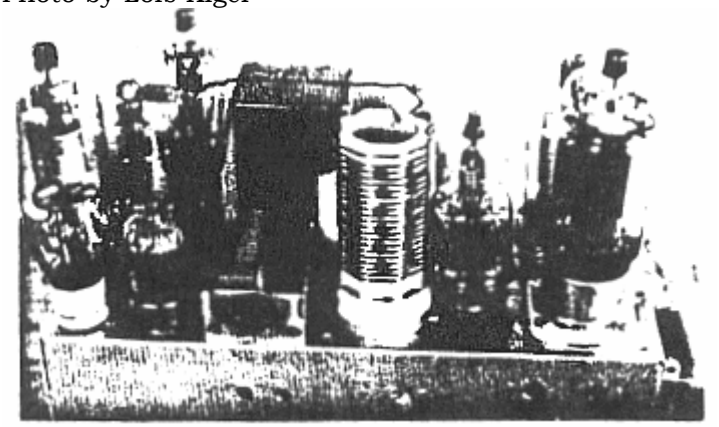
The photo bears out the title. But, no, I don't run all nine tubes in the amplifier at the same time. The photo represents the chassis used to test each of the tubes individually. I mounted all the sockets, wired the filaments and screen grids, but the plate and control grids were moved from tube to tube during the process of experimenting. In the case of grounded-grid, filament wiring also was altered.

What's the purpose of all of this?

There are a lot of reasons for buying an FT-7 or a TS-120V or an Argonaut. They are great for camping or for use where you have to use a battery. But at times you would like to have a little more power. Obviously, you could buy the TS-120S or the FL-110 linear or maybe build a solid-state linear yourself, complete with low-pass filters. But I have an apple box full of tubes. So, I decided to find out what kind of a tube linear would do the best job.

There are some problems.

Photo by Lois Kiger



The amplifier test chassis! Only one tube is used at a time.

Grounded-Cathode

First of all, you can scan the tube data in one of the older ARRL *Handbooks* and find that, seemingly, it is possible to build a kW amplifier that requires very few watts of drive in the grounded-cathode configuration. You might have to neutralize the amplifier, but that is not a major concern. OK, so you build up this mighty fine structure and you try to get from the solid-state broadbanded driver to the grid circuit of your amplifier. If you just link couple, you will find that the impedance match is so bad that nothing comes out of your exciter. You can put 50 Ohms across the link (or in series with the link) and this will make the exciter much happier. You may get a little more out of the amplifier than the 10 Watts from the exciter but not much. I gave it up as a bad idea.

Possibly, you could design some impedance matching network between a 50-Ohm generator and the grid in a class AB vacuum tube. But there ought to be an easier way.

Grounded-Grid Circuit

Another route seems to be the grounded-grid circuit. As will be seen, this has possibilities with some refinements, but it is very doubtful that with 10 Watts drive you can go to more than a few hundred Watts input with a single stage. You easily could go to a kW with a two-stage linear. Actually, the commercial solid-state amplifiers are not getting a power gain much in excess of 10, either. Here, again, with grounded grid, the input impedance varies from tube to tube and may be a country mile from 50 Ohms.

In the past, many companies have built grounded-grid linears with an untuned input. Hallicrafters, Loudenboomer, and DenTron more recently have done this, just to name a few. It worked very well if you had a 100-Watt tube-type driver. With the advent of 100 Watt broadband solid-state rigs, it doesn't work well at all. This is doubly true if you have a 10-Watt solid-state rig. So, DenTron and possibly others are installing tuned input circuits in their linears and marketing tuned input kits to be installed in existing amplifiers.

If you are going to build your own, two less-than-desirable conditions exist. First of all, you will have to wind a big bifilar-wound ferrite filament choke unless you use an indirectly-heated cathode tube like the 7094. Second, if you are going to get the maximum out, you will have to build a band-changing input tuner or half a dozen switchable, fixed tuned inputs for that many bands.

EXPERIMENTAL RESULTS

Grounded Grid Circuit

Table 1 shows the results of driving seven different tubes with an FT-7, as shown in Fig. 1.

Tubes	Plate Volts Ep	No Signal Plate Currant Io mA	Plate Current w/excitation Ip	Grid Volts Eg	PA/P7
6146		No	No	—10	Less than 2:1
829B	450	Good	Good		(G3 tied to K internally)
6LQ6	900	5	200		9:1
7094	1500	40	160	0	12:1
813	1500	10	60	0	2:1
4-125A	1500	5	35	0	1:1
4-400A	1500	20	86	0	6:1
3-400Z	1500	50	160	0	12:1
811	1500	35	85	0	1:1

*Table 1. Grounded-grid amplifier test results. All grids tied together;*un-tuned *input.*
**Power output of amplifier compared to power output of FT-7.*

The 6146 and the 829B tubes have the suppressor grid internally connected to the cathode and just don't function very well in grounded-grid. However, note the gain of the 6LQ6. If all you are looking for is 100 Watts out, this may be the answer. Almost any TV transformer and bridge circuit will give you the makings of a power supply. The circuit is simple and does not require filament chokes. The 7094 is a dandy, but expensive. So is the 3-400Z and would be even better with 3000 volts. At a glance you could conclude the 813, 4-125, and 811 are flat tubes. Not so. They just mismatch 50 Ohms too far. The 4-400A is not so far off and also might look better with 3000 volts.

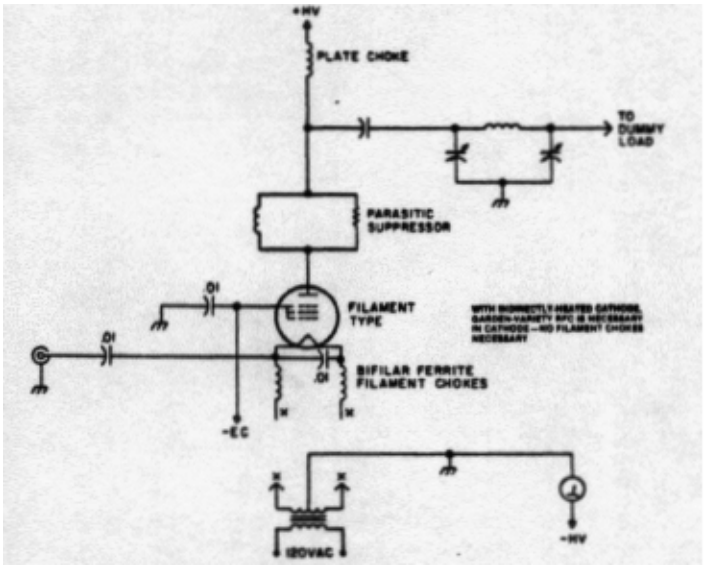


Fig. 1. Grounded-grid amplifier test circuit.

Table 2 shows data for the same amplifier with a home-brew antenna tuning unit between the FT-7 and the amplifier (Fig. 2).

Tubes	**Ep**	**Ic**	**Ip**	**Eg**	**PA/P7**
6LQ6	900	5	210	—10	12:1
7094	1500	40	190	0	18:1
813	1500	10	155	0	14:1
4-125A	1500	5	80	0	10:1
4-400A	1500	20	135	0	12:1
3-400Z	1500	50	165	0	14:1
811	1500	35	125	0	12:1

Table 2. Grounded-grid amplifier test results. All grids tied together; tuned *input.*

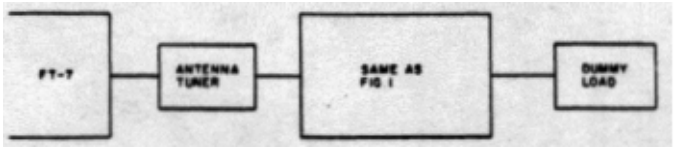


Fig. 2. Block Diagram of test circuit of Fig. 1 using tuned input circuit (antenna tuner).

This unit was adjusted to give a 1:1 swr presented to the FT-7. Note that the power gain has skyrocketed in all cases. The 7094 gain has gone to 18:1! The 3-400Z might be nearly this high using 3000 volts. If you have an 811 in the junk box, it now looks like a winner at 12:1. Again, you might go this route with the 6LQ6. But you do have some kind of an input tuned circuit to add. It adds hardware, takes up space, and is another circuit that needs to be manually adjusted.

Passive-Grid Circuit

A third possible approach is the "passive-grid" circuit. I built a big one of these several years ago, driven with an FT-101[1]. The *1979 ARRL Handbook* has such a circuit, as does one of the older Bill Orr *Handbooks*. The ARRL used an 833, whereas the other one used some kind of a big tetrode, If you have a 100-Watt tube or solid-state exciter, it's a good circuit. With 10 Watts, and using a positive screen voltage, it may be attractive to some. The input impedance is 50 Ohms, almost all resistance. I used seven 390-Ohm 2-Watt resistors in parallel. This makes

the FT-7 or other solid-state 10-Watt exciter very happy. Unfortunately, it also limits the amount of voltage that can be applied to the grid. The one disadvantage is the necessity of a screen supply. In the test case, the screen and control grid voltages were adjusted for optimum output. Control-grid voltage was supplied from batteries.

Table 3 shows the results of driving the passive-grid circuit (Fig. 3) and also applying optimum positive potential to the screen.

Tube	Ep	Io	Ip	Eg	E_{SCREEN}	PA/P7
829B	460	10	200	—10	110	5:1
6146	900	20	100	—20	100	5:1
6146A	900	30	110	—20	110	6.8:1
6LQ6	460	30	100	—20	50	4:1
	900	30	130	—20	50	7:1
813	900	75	100	—10	250	2.5:1
	1500	100	130	—20	400	5:1
4125A	1500	75	100	—10	200	5:1
	1500	75	100	—20	270	5:1
4-400A	1500	170	200	—20	270	10:1
	1500	170	190	—10	200	10:1
7094	900	25	170	—20	170	10:1
	1500	40	200	—20	90	12:1
701A*	1500	30	200	—10	70	20:1

*Table 3. Passive-grid circuit with positive screen supply test results. *701A—uncommon surplus tube. Used in identical circuit but another physical setup.*

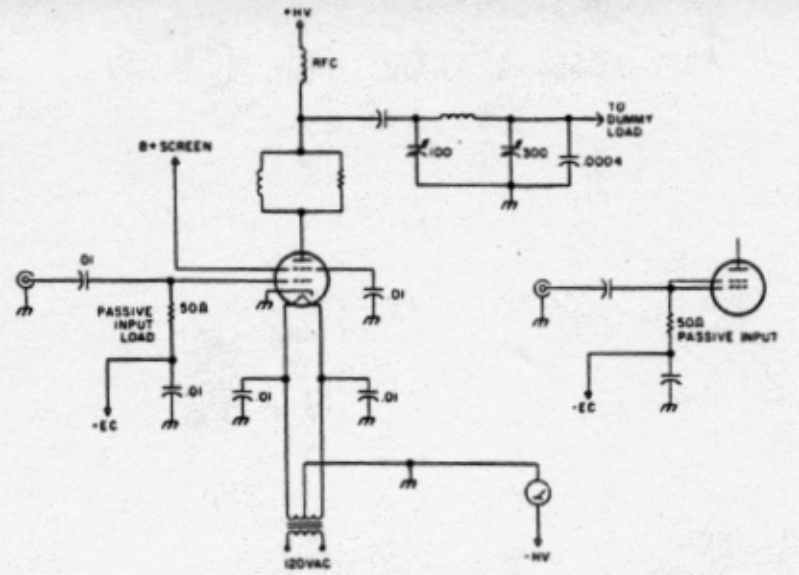


Fig. 3. Passive-grid amplifier test circuit. Screen grid is held positive.

The results compare fairly well with the grounded-grid un-tuned input. The 701A which is not a common tube, is tops and the 7094 and 4-400 look fairly good. Again, the 4-400 would look better with higher voltage. The simplicity of the circuit has something going for it.

Table 4 is same circuit, except that it has all grids tied together, if there are more than one. This is singularly unimpressive although the 3-400Z still might look very good at higher voltage. Both of the passive-grid circuits might look much better if you had a 100-Watt driver

and, of course, a 100-Watt non-inductive 50-Ohm passive-grid resistor.

Tube.	Ep	Io	IL	Ec	PA/P7
829B	460	5	130	0	5:1
	900	20	175	0	5.41
6146	900	40	90	0	5:1
6146A	900	30	100	0	5.4:1
6LQ6	900	10	125	—10	6:1
811	1500	20	50	0	2.1
813	900	0	30	0	1:1
	1500	10	50	0	1.5:1
4-125A	1500	0	30	0	Less than 1:1
4-400A	1500	25	75	0	3.2:1
3-400Z	1500	50	110	0	8:1
7094	900	20	85	0	5:1
	1500	40	110	0	8:1

Table 4. Passive-grid test circuit results after tying all grids together.

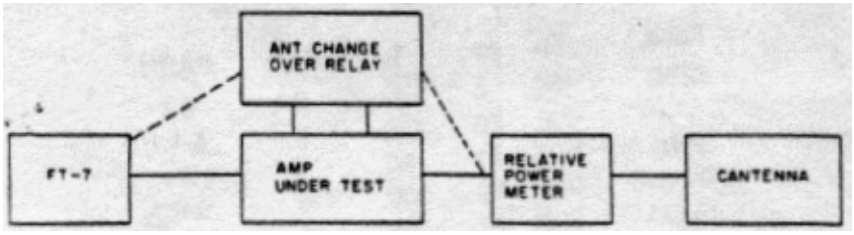


Fig. 4. Passive-grid amplifier test setup for common-grid configuration.

OK, fellas, study the data and draw your own conclusions.

Having been a teacher for most of my life, I know this is not the way to end. I see some strange expressions on your faces. You, in the front row, what's your problem?

How did I do the experiment and how valid is the data?

The FT-7 was connected through an antenna changeover relay through the amplifier under test and through an swr meter (which was also calibrated for relative power) to a Heath Cantenna. With the antenna relay not energized, the FT-7 was fed through to the load and the relative power was set to 10%. Then the antenna relay was energized and the amplifier fed to the load. If the meter reads 60%, we have a power ratio of 6:1. On the high output ones, I set the power meter at 100% with the amplifier on and then compared to the FT-7. If it reads 8% then we have a power ratio of about 12:1.

In each case, the amplifier voltages and loading were adjusted for maximum power out without getting the plate too red. The actual power ratios may be a little in error, but the differences are so great that the conclusions are evident. An rf ammeter might be used if you choose to use one. Since I^2R equals power, $(I_{amp}/I_{FT\text{-}7})^2$ will give you the power ratio.

What was the frequency of the tests?

I originally planned on 80 meters, but the tank circuit wouldn't reach that far, so l used 40 meters.

How about the long grid and plate leads going to some of the remote sockets on the chassis?

Not good at all. But you can get away with it on 40 meters. Nothing even threatened to take off and oscillate. But you better get those leads much shorter if you expect to work on ten.

What will this thing do on a real live antenna rather than a dummy load?

It will do just as well and very likely better. If you have a good antenna with a swr if 1:1 it will behave just like the dummy. If you have an antenna with an swr of 2:1, the FT-7 output to the antenna will be considerably reduced, but the pi network in the linear will overcome this and will have full output. Instead of a power ratio of 10:1, it might very well go to 12:1 or more.

What's the big difference between an amplifier for a 100-Watt exciter and a 10-Watt exciter?

Another very good question and one that a lot of you may not have thought about. If you have a 10-Watt exciter, you want to get all the power gain you can get. If you get a gain of 20, you still only have 200 Watts out. If you have a 100-Watt exciter, an amplifier with a gain of 6 is pretty good. You now have 600 Watts out and very near the legal limit of 1000 Watts in. A low-mu grounded-grid triode might be ideal. On the other hand, a 3-400Z (or 500Z) or a 4-400A in a passive-grid circuit would be quite adequate.

Which one did I decide to use?

Well, I built two. Both of them were chosen because I had the tubes. One was the grounded-grid, untuned input 7094 which I succeeded in getting inside a medium-sized cabinet complete with power supply. I can stick the outboard antenna (input) tuner in if I want to. The other uses the old Western Electric 701A in the passive-grid circuit with 70 volts on the screen. I had three of them and two sockets. (If anyone wants a 701A and a socket, make me an offer.) In any case, the decision rests on personal choice, what's in the junk box, and what you would settle for in the way of output.

A Bit of Confession

You would be surprised at the number of Master's and Doctoral dissertations that have been founded on a preconceived conclusion with a bunch of warped data to prove what the author already thought was so. Well, I had a preconceived conclusion that the passive grid circuit was just great and everybody should build one. Before starting on this little data collecting venture, I had already built the 701A. Since it worked so well, it must follow that all passive-grid circuits are fantastic. As you can see, my data disproves this hypothesis. On the other hand, it turns out that I have built a good case for the tuned-input grounded-grid for just about any tube you want to choose. I never did try the 701A, grounded-grid, but I suspect that it would be excellent. By the same token, a 4CX1500A might be good in a passive-grid, but I don't have one.

If you have a strange unknown bottle in your junk collection, cobble up a junker linear and see what it will do. Then build a finished model using whatever circuit works the best.

Have fun!

1. CQ, April, 1976, p. 31.

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