The G.E. BA-5A Limiting Amplifier using an audio Delay Line. (hint: X marks the spot)

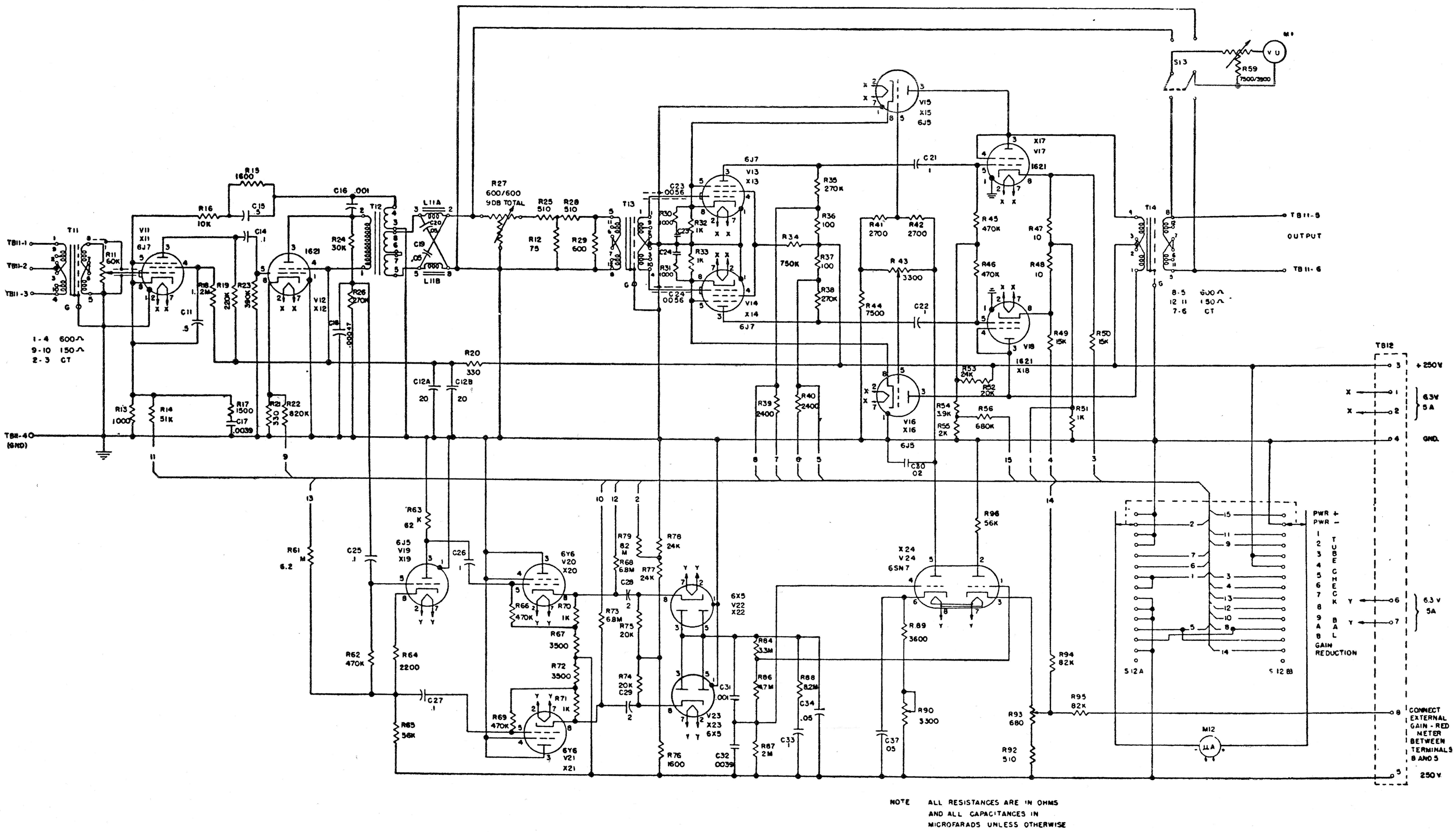


FIG. 10–5. Wiring schematic of General Electric BA-5-A limiting amplifier.

THEORY OF OPERATION

1. CIRCUIT ANALYSIS

A. General. The Limiting Amplifier unit is composed of three sections. Refer to the Block Diagram, Fig. 12. Tubes V11, V12 and their associated circuits compose the pre-amplifier section. Tube V13, V14, V15, V16, V17, V18 and their associated circuits compose the variable-gain or controlled amplifier section. Tubes V19, V20, V21, V22, V23, V24, and their associated circuits compose the bias generator section.

In order to minimize variations in the operating characteristics of the Limiting Amplifier due to line-voltage variations, the plate-supply voltages are regulated.

B. Pre-amplifier section. The purpose of the pre-amplifier is to amplify the input signal to such a level that it can supply both the controlled amplifier and the bias generator section.

The audio-signal voltage of the output of the pre-amplifier section feeds the controlled amplifier section through a lattice network composed of L11-A, L11-B, C19, and C20. This network delays the signal voltage reaching the control amplifier until sufficient gain reduction has been effected by the bias generator circuit.

C. Controlled amplifier section. In the controlled amplifier, tubes V13, V14, V17, and V18 form a conventional two-stage push-pull amplifier. Tubes V15 and V16 are so connected that they apply negative feedback from the plate of the output stage to the cathodes of the input stage. The plate to cathode impedances of V15 and V16 determine the amount of negative feedback. This impedance changes with control-grid voltage; it, therefore, comprises the variable-gain amplifier.

The voltage change in the plate circuit of V24, which is in a positive direction, is applied to the grid of the feedback tubes V15 and V16, and thereby reduces the gain in the controlled amplifier.

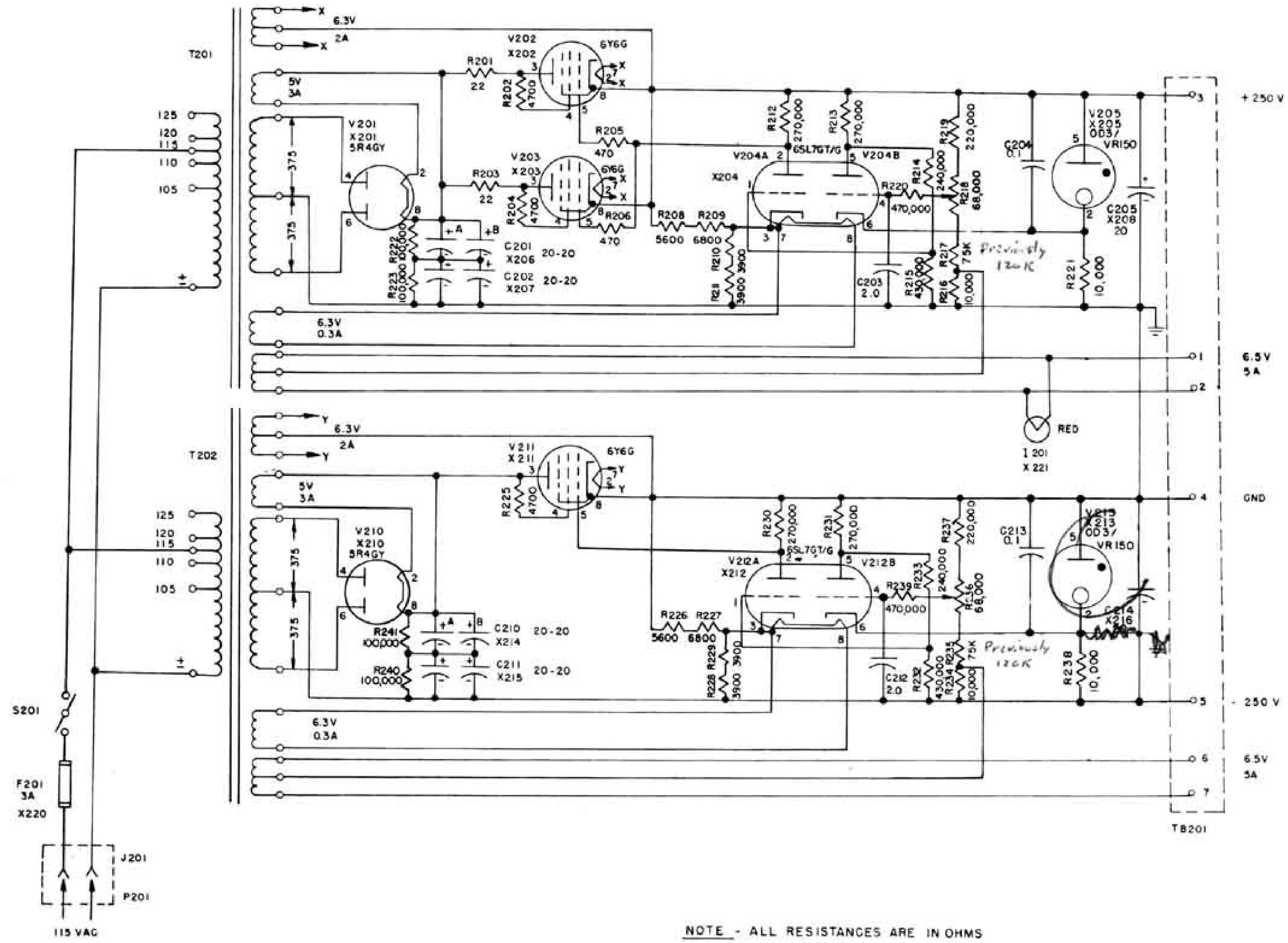
D. Bias generator section. It is desirable to obtain adequate control bias to cause a reduction even with the peaks of very short duration. The control bias generating section utilizes circuits that provide extremely fast development of the automatic control voltage. Tube V19 is a phase inverter to supply signal to the push-pull cathode followers V20 and V21. Tubes V20 and V21 provide a suitable low-impedance charging source for the diodes V22 and V23. Diodes V22 and V23 are biased so that gain reduction occurs at a predetermined input amplitude. Full-wave rectification in diodes V22 and V23 produces the required d-c bias potential across their r-c load circuit.

Tube V24 is a dual triode. The first triode section of V24 serves the dual purpose of an inverter and of a slope adjuster. The second triode section of V24 serves the purpose of indicating the degree of gain reduction on the calibrated meter, M11.

2. PERFORMANCE ANALYSIS

A. General. This amplifier will permit a much higher degree of limiting without any audible evidence of limiting action and with essentially no over-modulation. This performance is obtained through the use of a very high compression ratio, a very short attack time and an automatic variation of recovery time.

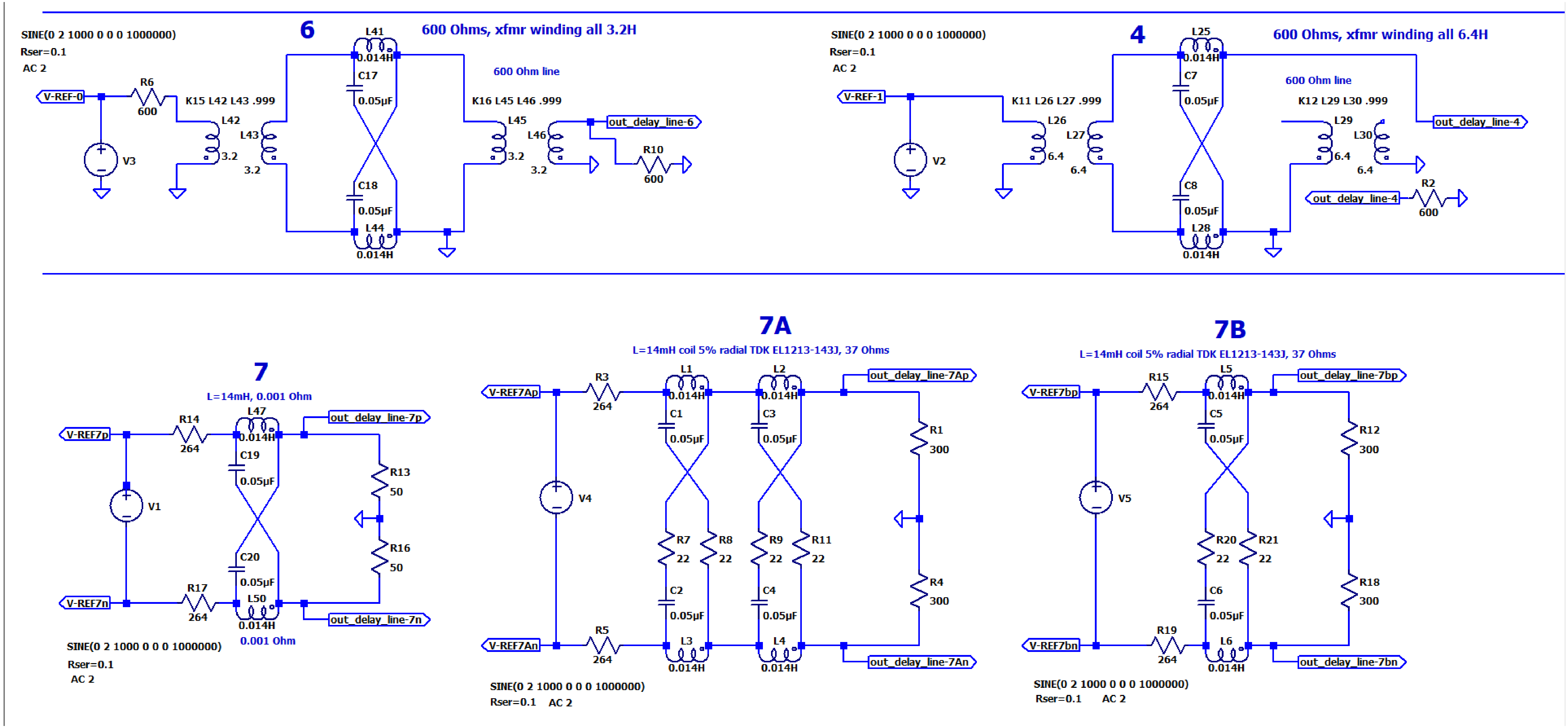
REACTOR		
L1 thru L10	Not used	
L11	Dual reactor: inductance 18 millihenries ± 10%, each section. Thordarson Type #T-50263, or equivalent. (Includes L11A and L11B).	M-7474919
L11A	Part of L11.	
L11B	Part of L11.	



NOTE - ALL RESISTANCES ARE IN OHMS AND CAPACITANCES IN MFD.

Fig. 10 Elementary Diagram of Power Unit (P-7770203, Rev. 7)

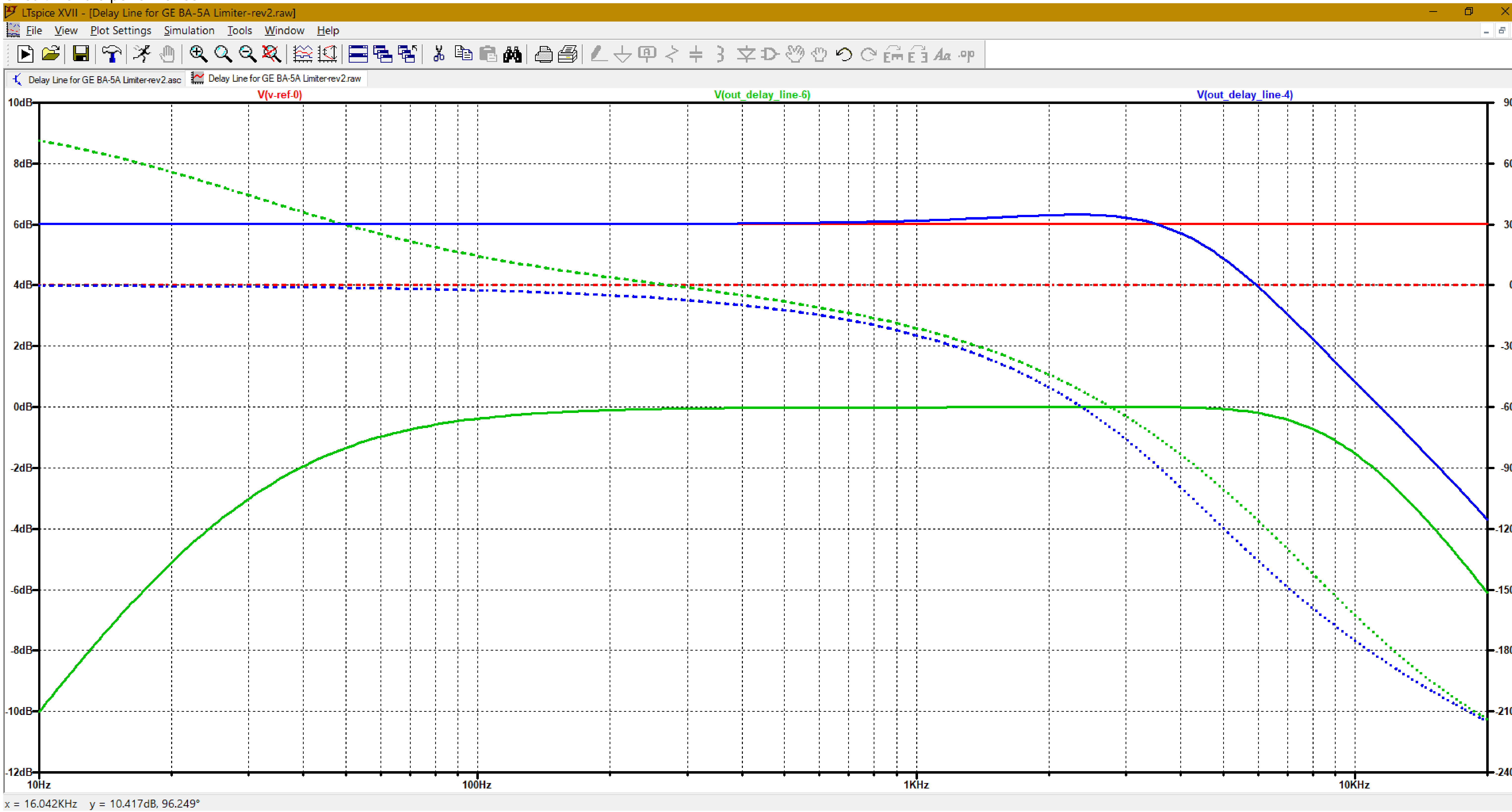
No doubt the strictest audiophiles will give raspberry noise and ignore this, but what do I care, I like unusual things and the BA-5A is one. It is not based on variable-mu, but on variable gain by means of variable feedback, and claims to never let a peak through, unlike many compressors and limiters, which have finite attack times. This sweet thing appears to attack the signal before it's there, instead of 100-150us after it appears and the ship has sailed, the horse is out of the barn, etc. Rather than try to explain it in a bombastic manner, I'll let the words and diagrams of General Electric speak for themselves, and then give a couple of simulations for the delay line so that it can be built and experimented with by DIYers. On that note, there are other tube and solid state (I am told) limiters which use a delay line, so it is worth a look.



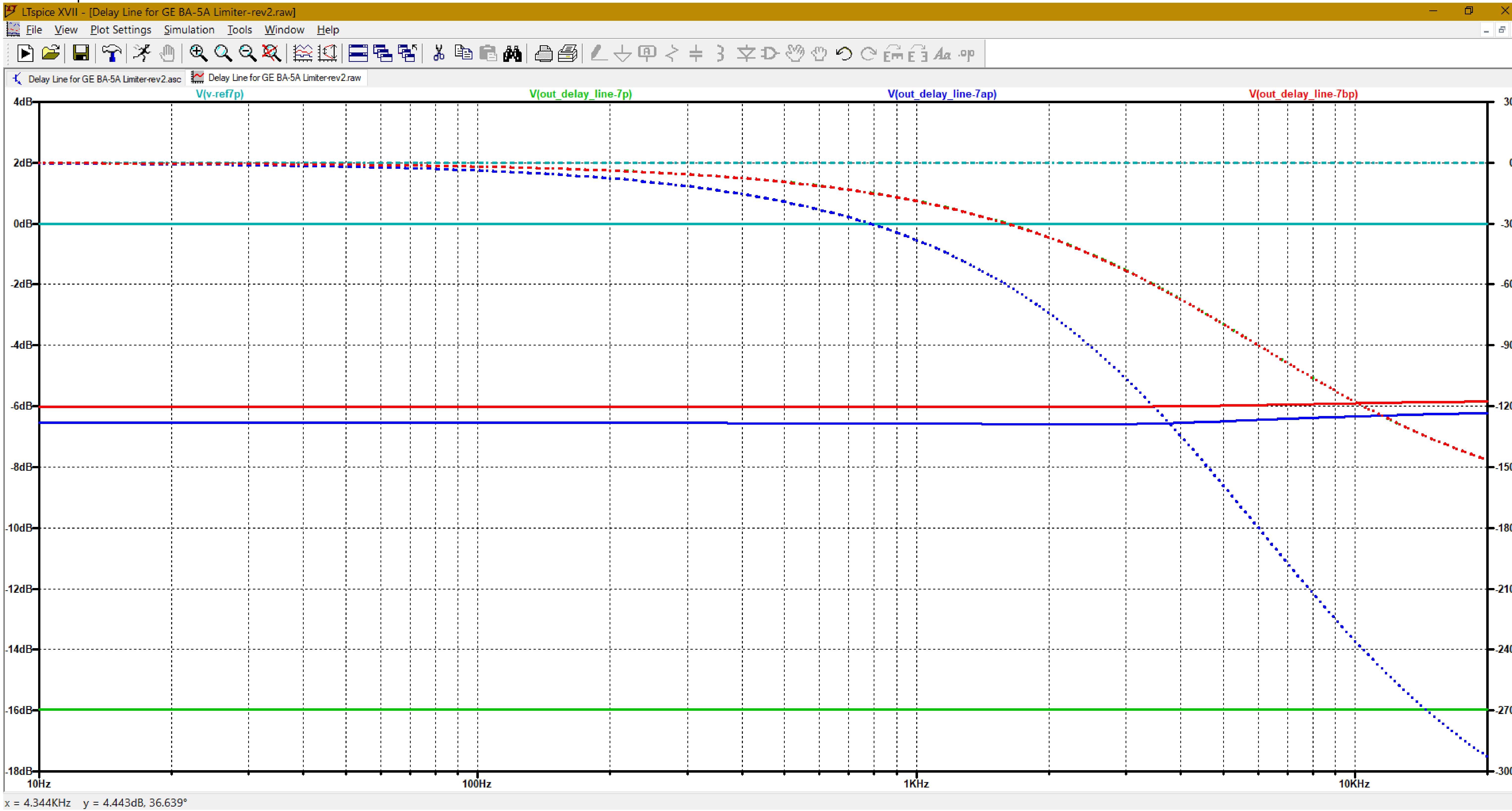
All except 7A and 7B have inductors with series resistance 0.001 Ohm. 4 and 6 use transformers, and the models are not refined so there are drop-offs in the frequency response at the ends. 7A and 7B were assigned 37 Ohms based on a part number. Unknown if that part is suitable for audio, but it exists. So, what these show is a floating reference (audio signal), and at the output, the center is grounded, making it all balanced. All the 7's were designed for transformerless (though the right transformer was evidently used by GE) and would lend themselves to cathode followers or op-amps, etc, the lower the Z driving this, the better the performance.

On the LTspice graphs, do not take to much for granted on the phase, since the frequency is swept, but note the responses and dB level in comparison to the hookups. What is of interest is the time delay, which can be had by assigning cursors to the reference signal and the output of the delay. Uniform and Long time delays are desirable, though at the upper octaves, limiting does not often occur so don't be put off by short delays up there.

Circuit 4 and 6 performance:

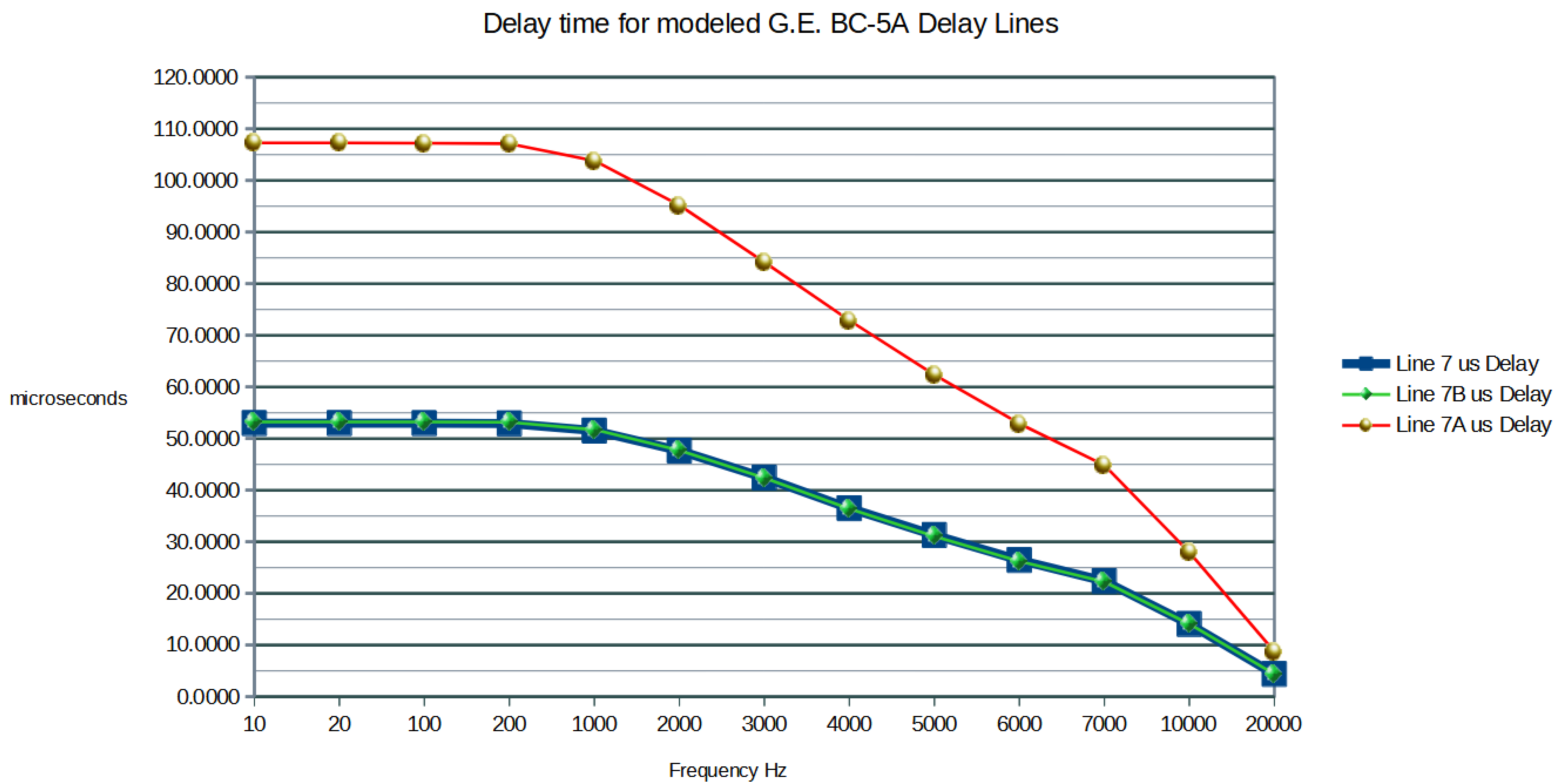


Circuit 7s' performance:



The diagrams are for LTspice, and the spice command is given, so anyone can use them.

Next, the delay performance of the circuit 7's:



If 50uS isn't enough look-ahead for intentionally-fast detection and control circuits, then follow one section with another as in Line 7A ??

Should anyone want to try to remake the BA-5A, note that the manual is scarce as are the units themselves which go for high money, the impedances of transformers are not all known, etc. etc.

There was interest going back to 2007 and maybe before, at least on the sites in the references, in making a DIY project of the famous GE BA-5A. It has apparently not come to fruition, and perhaps that is because there have been no experiments on the delay line, either with real parts or with simulations. I hope that the lazy work I have done with LTspice will show that it is possible to get a working delay line with the same value components as used in the BA-5A.

Such a delay line will have its faults for audiophiles to pick apart, as does the longer 4-section line of the Kahn Symmetra-Peak unit (phase rotator) used to augment A.M. and F.M. audio destined for those transmitters. The Symmetra-Peak was a different-purpose solution however, and treated as such in its design.

The short delay line has an advantage in that the inductance, and therefore the frequency-dependent delays which cause audiophiles to complain if they discover them, are low-impact compared to the individual delay sections in a 600 Ohm-normalized Symmetra-Peak model. But then, it's not a hi-fi peamp, it's a limiter. (Don't confuse with compressor or hard limiter/clipper)

In the G.E. instrument, most delay is at the lower frequencies where high programme material levels can cause clipping in a transmitter or recorder, and less delay is presented to the higher frequencies which give higher 'spatial cues' or whatever the hot-word is today.

The simple chart shown reflects one three of many experimental simulations demonstrated, which were aimed toward replicating and tuning the delay line's surrounding components for use in a transformerless balanced circuit giving a wide, flat frequency response and enough delay for a fast detector and control amp to stay ahead of the signal.

When including simulated LTspice transformers, the frequency response was constricted to something like communications or A.M. radio. I believe that real transformers would do much better, that is, G.E. did it in the 1950s. What is here is the best I was able to do at this time.

I believe it would be worthwhile to experiment with the audio delay line for those wanting an analog delay that would allow time for an AGC to act. The fastest analog tube units seem to act in about 100-150us. The detection is done before the delay, and the audio to be controlled is taken after the delay. It's like a kid running out of the house to do whatever he wants, and just before he gets to the door, the parent sees he's shirking chores and calls his name! Now that's control! The delay line gives the detector and control amp precious time to act before the signal gets past them.

I guess, when you absolutely must ensure something is completely destroyed, on time and every time, you use a proton cannon. When you don't want your solid-state-free limiting amp to pass a peak, ever, you use an analog delay line. Unless you are some kind of DSP or bucket-brigade heathen, in which case do what you want and harm none.

Please review the references at the end, from which some material has been lifted for better understanding. The schematic has been around on a disk drive a long time and I do not know where it came from. Note that in various forums, there are misstatements about the way this limiting amplifier works.

Please refer to:
https://shoonbass.com/ge-ba-5a-compressor-1954-diy (translate in google)

also search groupdiy.com for BA-5A:

https://groupdiy.com/search/284503/?q=ba-5a&o=relevance

https://groupdiy.com/threads/ge-ba-5a-vari-mu-limiter-guided-tour-needed-any-info.20588/

Book: "The Radio Manual", fourth edition, Sterling & Monroe, 1950. pp. 357-353