THE AUTOMATIC VOLUME CONTROL TOOL
OR
COMPLETING THE RESTORATION

by
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RADIOACTIVITY-2024

WHY TALK ABOUT Automatic Volume Control??

Mainly because of my use of Email to pass advice and suggestions to other radio restorers and in doing so have learned:

1. Very few restorers pay any attention to the AVC circuit if the radio plays at all, after the major problems have been solved.
2. Of these restorers, a good percentage have trouble finding the AVC system in the radio, and have almost never tested the AVC circuit to be sure it functions properly.
3. And some restorers do not know what it is for, and how it operates, especially in high-end radios that might employ Delayed AVC, multi-level AVC, and Amplified AVC, to say nothing about QAVC.

Automatic Gain Control = Automatic Volume Control

Does it replace the manual volume control? NO.

Do all radios have AVC? NO – But most radios receiving AM have AVC – And FM radios have a form of AVC, using a LIMITER stage or an FM detector stage (ratio detector) which provides the equivalent of AVC.

If it is not working, can the radio still work OK? YES, if all else is functional. BUT, the volume will vary as the signal getting into the radio varies in strength – especially if it is an automobile radio, where traveling among varying town or country streets and building densities causes fading.

BUT – the common reaction regarding AVC is:

If the radio still plays, why worry about the AVC? Besides, the Rider or SAMS' references often remind the service technician to **disable AVC** before aligning the tuned circuits in the set. WHY??

We will cover that in a minute or two.

How much amplification change results from AVC, in its attempt to compensate for serious fading?

AVC typically varies the overall gain of the receiver by up to 60 or 70 decibels, resulting in residual volume fading of perhaps 10 to 15 decibels.

The simplest form of AVC in AM radios is this:

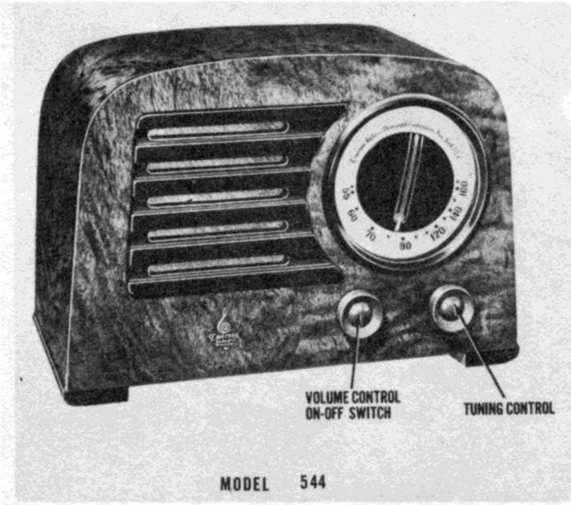
When the radio signal arrives at the final detector (extracting the audio) the carrier level, expressed as a negative voltage, is fed back as control-grid bias for the amplifier stage or stages, which usually are variable-mu tetrodes, pentodes, and/or the RF input grid of the 1st detector stage.

With this sort of feedback, the carrier level reaching the final detector tends to stay at a nearly fixed level despite variations in the signal strength of the radio signal entering the radio.

In other similar applications, such as radar receivers, the function is usually called AGC (for Automatic Gain Control).

Examples of AVC in AM radios

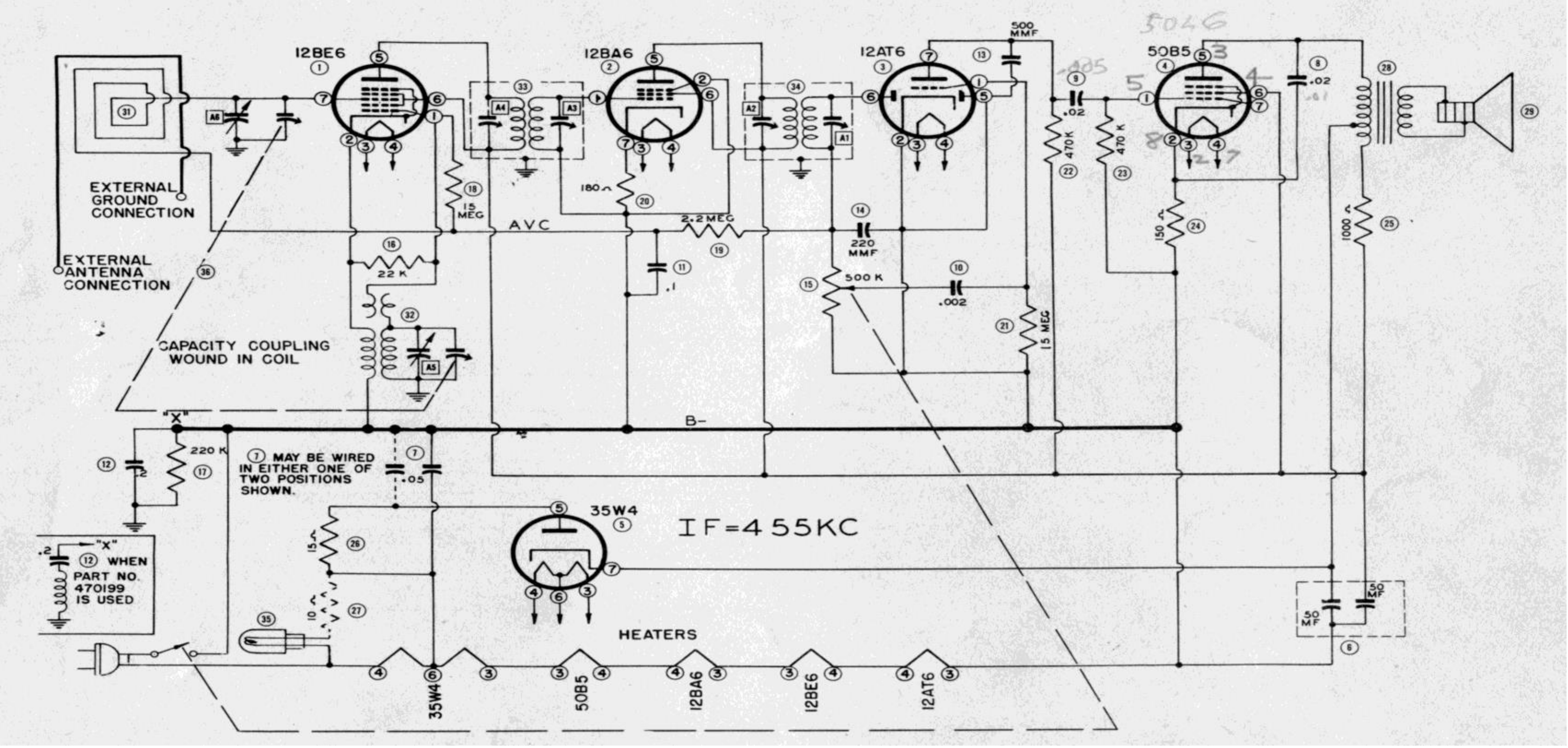
Here’s a simple comparison of two very small radios.



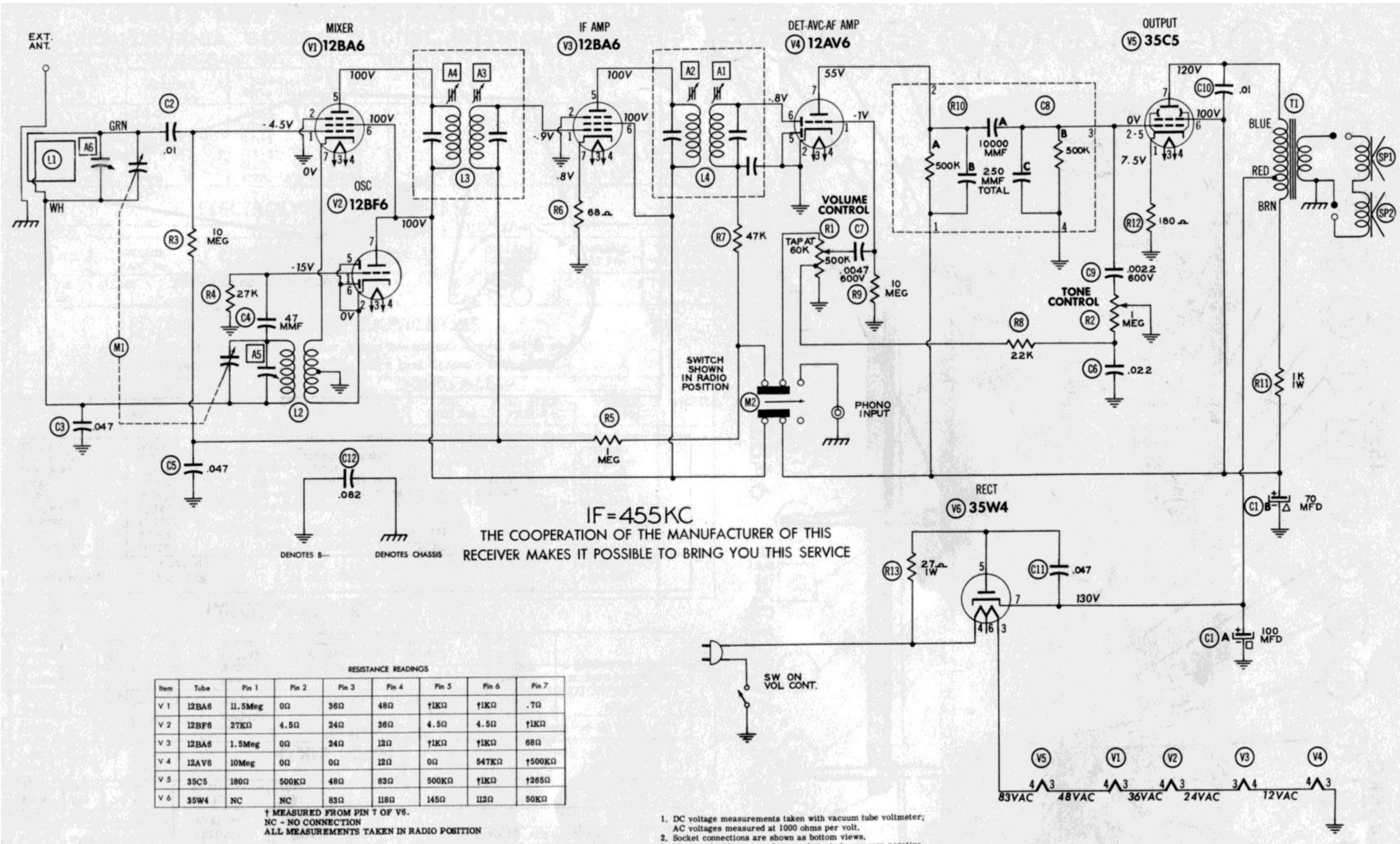
1. Emerson 544

2. Coronado RA48.

The Emerson 544 radio is typical low-end AA5 in which the AVC controls only one tube's gain, but is helped avoiding 'blasting' when tuning between stations, by including a simple QAVC circuitry. QAVC is a quieting (squelch) circuit for avoiding audio bursts when scan-tuning across stations.



The Airline set uses 6 tubes (swapped a 12BA6 plus 12BF6 for the AA5's 12BE6). The AVC controls that 12BA6 and the 12BA6 IF amplifier.



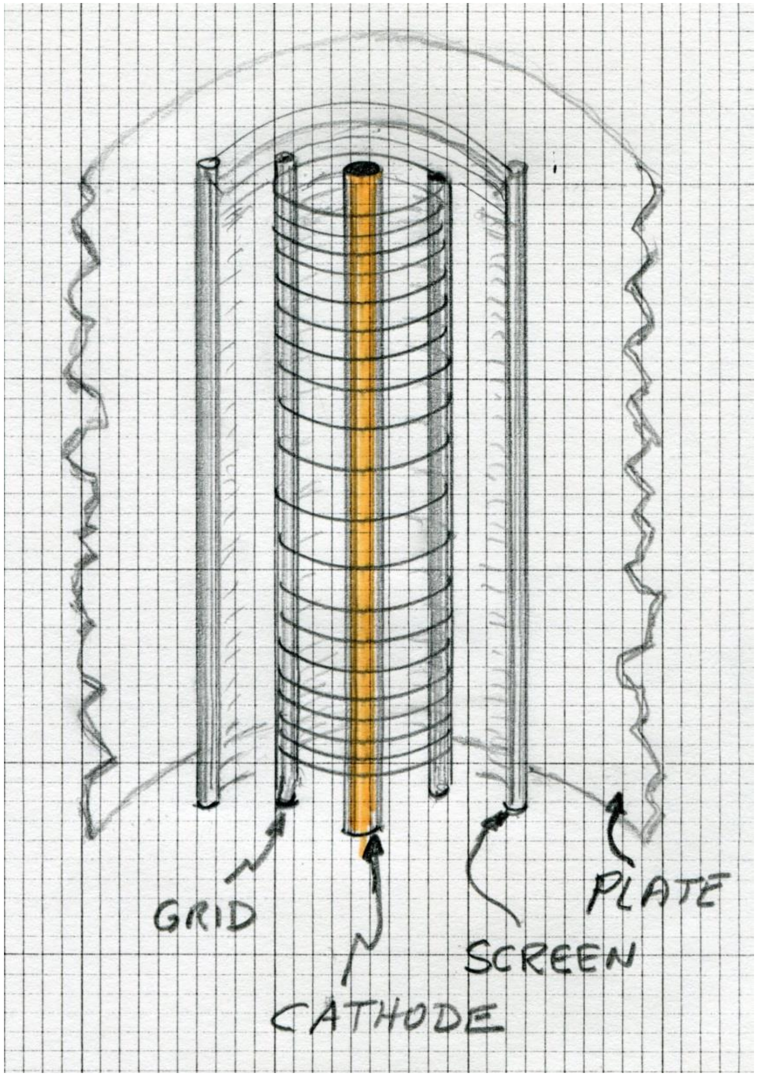
RESISTANCE READINGS

Item	Tube	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7
V 1	12BA6	11.5Meg	0Ω	36Ω	48Ω	†1KΩ	†1KΩ	.7Ω
V 2	12BF6	27KΩ	4.5Ω	24Ω	36Ω	4.5Ω	4.5Ω	†1KΩ
V 3	12BA6	1.5Meg	0Ω	24Ω	12Ω	†1KΩ	†1KΩ	68Ω
V 4	12AV6	10Meg	0Ω	0Ω	12Ω	0Ω	547KΩ	†500KΩ
V 5	35C5	180Ω	500KΩ	48Ω	83Ω	500KΩ	†1KΩ	†265Ω
V 6	35W4	NC	NC	83Ω	118Ω	145Ω	112Ω	50KΩ

† MEASURED FROM PIN 7 OF V6.
NC - NO CONNECTION
ALL MEASUREMENTS TAKEN IN RADIO POSITION

Looking back toward the beginnings of AVC/AGC, when Hazeltine and several others all thought they had discovered it, the key to its success was the invention of the "variable-mu vacuum tube." You realize, this is the same as the "remote-cutoff-tetrode, pentode, or 1st detector signal grid."

Note the spiral control grid; its pitch is changing as a function of its length, giving it variable degree of control of the electron flow from cathode to screen and plate.

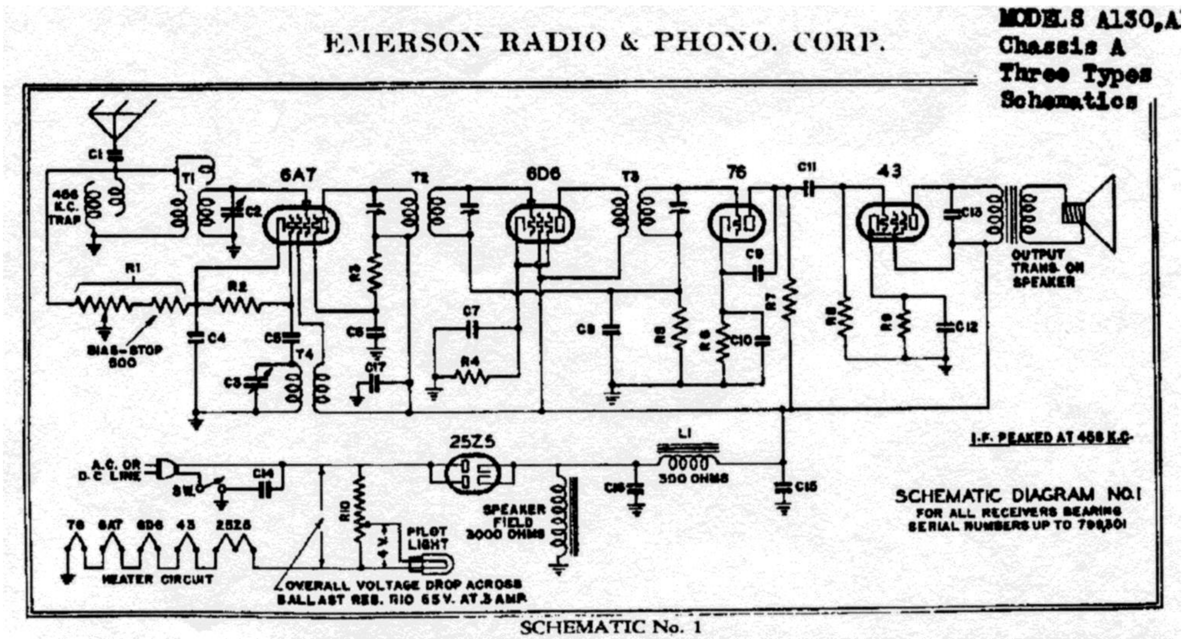


Who invented AVC, and did it have to wait for the invention of the variable-mu tube?

Harold Wheeler was the likely inventor, although there were objections raised that the circuit wasn't any more than the product of logical engineering using known circuit elements and principles.

And, to make things yet less logical, there were manufacturers who inserted the basic feedback of the detection circuit output to the RF (and IF, in some cases) amplifier grids whilst employing sharp cutoff tubes there. And it worked, sort-of, but not well, producing distortion and a form of motorboating.

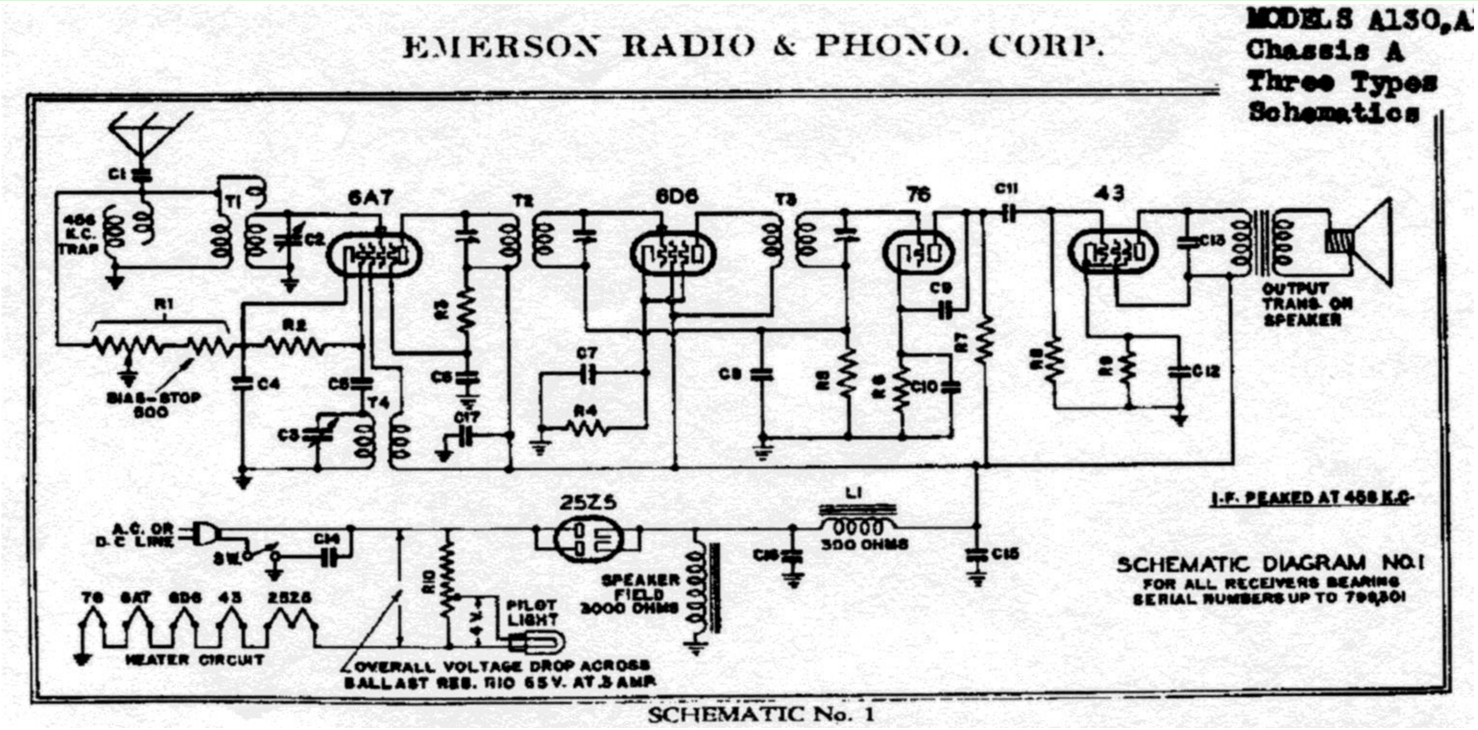
At first, not all manufacturers found AVC easy to implement.
Emerson, for example, had a hard time with their pioneer AVC set, Models A130 and A132, both using chassis A.



This is the radio's 1st schematic, for serial numbers up to 799301

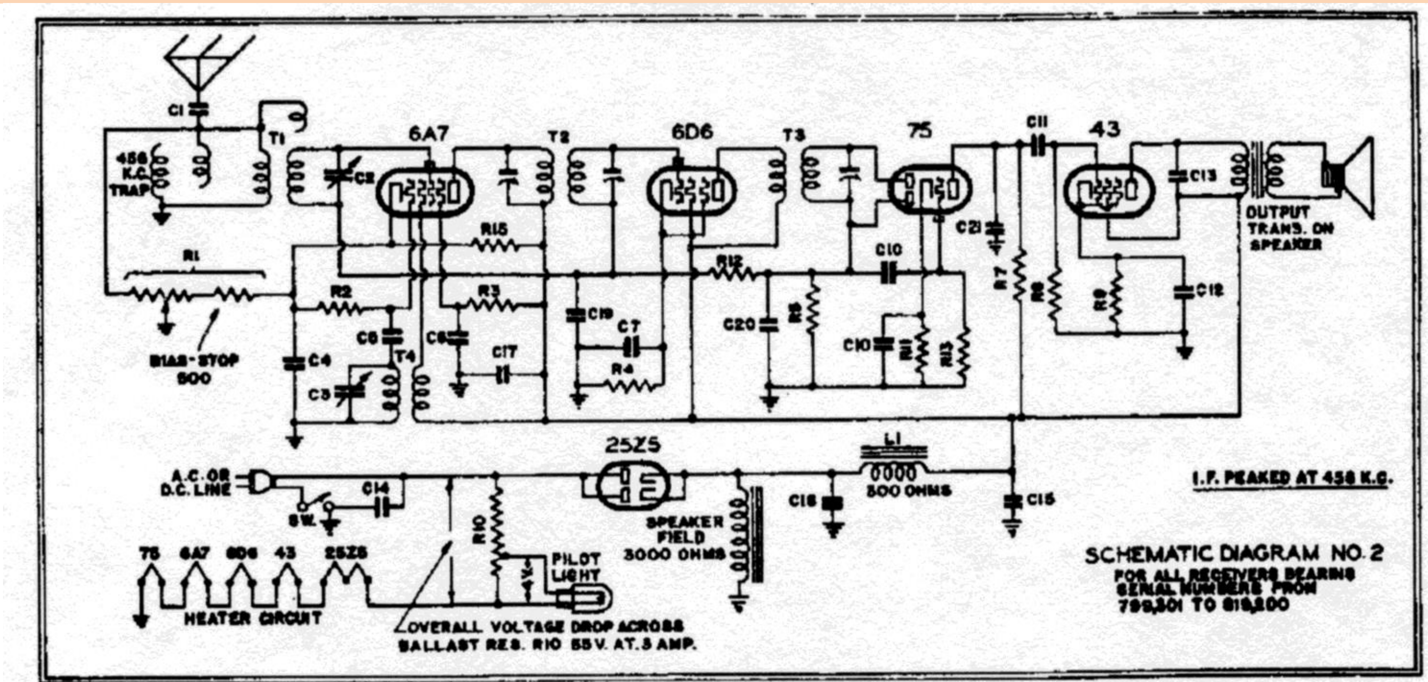
The circuit designer must have heard that you feed back a negative voltage developed by the detector to an amplifier grid (*which must use a variable-mu tube, like 6D6, 6A7, 44, 37, 51, or 78 at that time*) but he forgot the rest of the instructions.

Trouble is, though, that radio circuit does its manual volume-controlling by shorting out the antenna and raising the bias on the first tube, both of which reduce the signal input to the radio. The AVC will fight that sort of behavior.



The Emerson engineer misunderstood what the AVC purpose was. He probably imagined it to correct for gain-changing issues in the radio, and forgot that his volume control was also one of those.

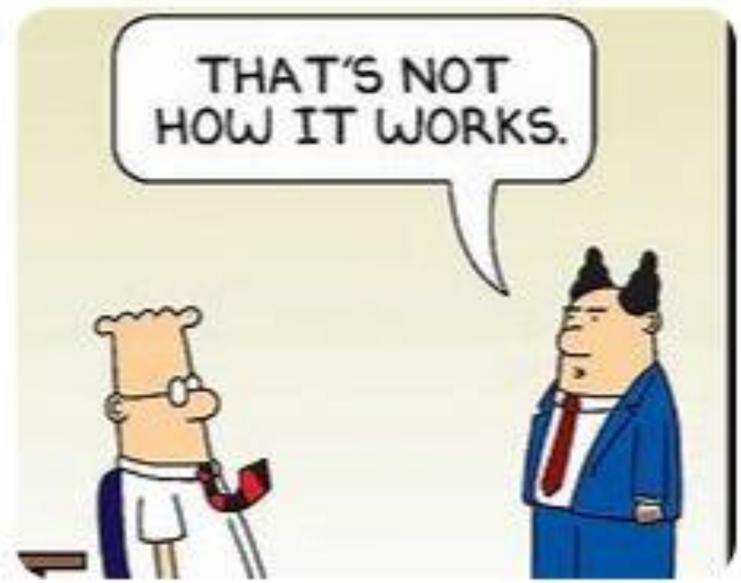
The Emerson designer reacted to the continuing complaints. He thought the complaint was that his initial attempt at AVC was inadequate, so he boosted the fed-back bias developed by the detector. He re-drew the schematic and gave the production line the new data.



SCHEMATIC No. 2

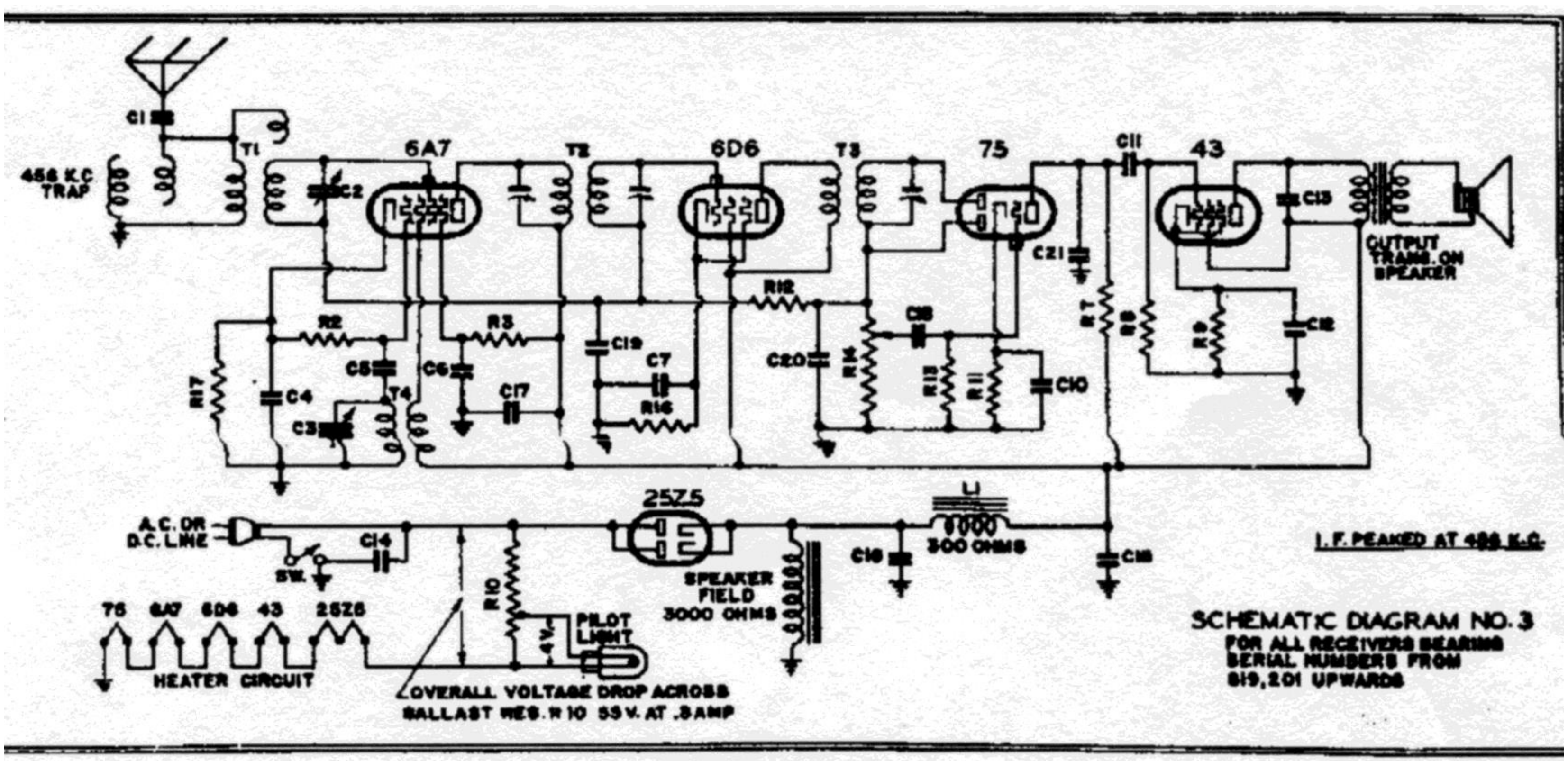
So, from serial 799301 to 819200, Emerson used this circuit, feeding back the AVC bias to ALL the stages up front, and using a type 75 tube as diode detector/audio amplifier combination, like so many competitors did.

The complaints got worse. Now the volume control did not affect volume except to shut the signal off entirely when twisted all the way to the left. The AVC was excellent, but it was still in direct competition with the manual volume control.



I imagine Mr. Abrams visited the engineer about this time, because that model, after serial number 819201, became an AA5 (300 mA style). The schematic is on the next slide.

The final version of the Emerson A130/A132: using the standard AA5 design, and even enjoying a bit of Delayed AVC!!



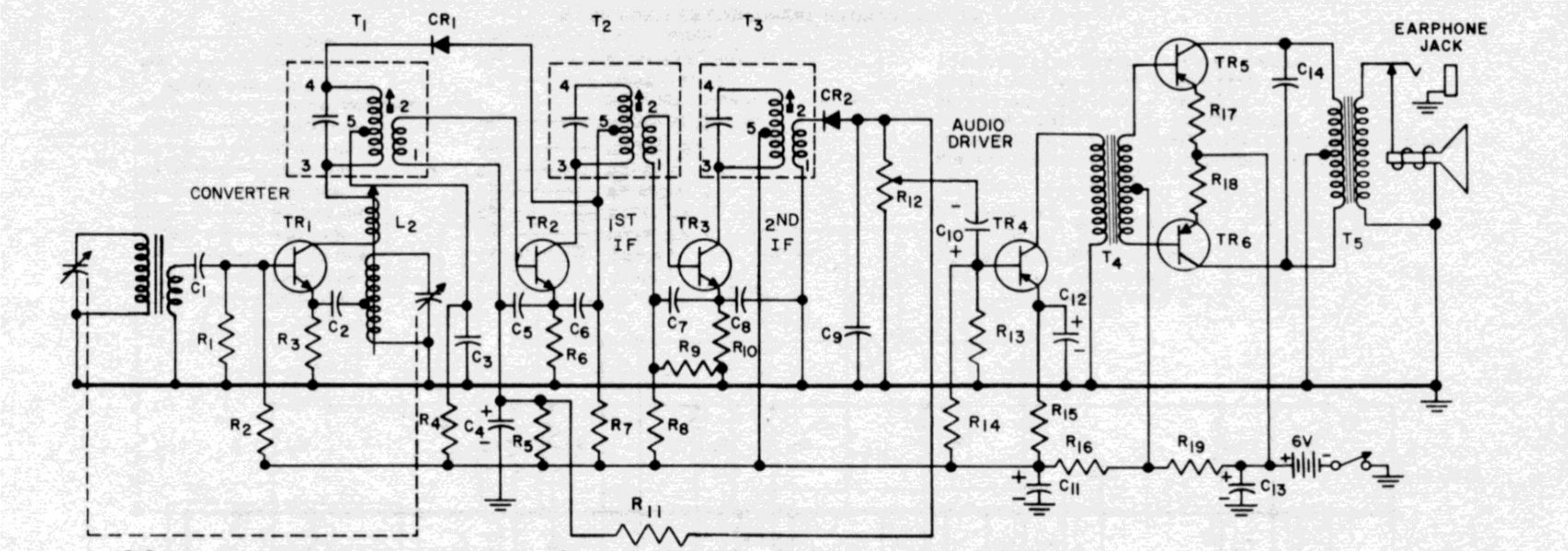
SCHEMATIC No. 3

Did he say "Delayed AVC?"

Yes; it's a term hung onto the process by a radio grunt, not a grammarian.

It's called that not because it arrives late, but because it doesn't start working unless the need for it is significant. Remember that AVC acts to <u>reduce</u> the gain of the receiver if the signal arriving at the demodulator (creating the audio) increases, so Delayed AVC ignores the increase if the overall strength of the signal is very weak.

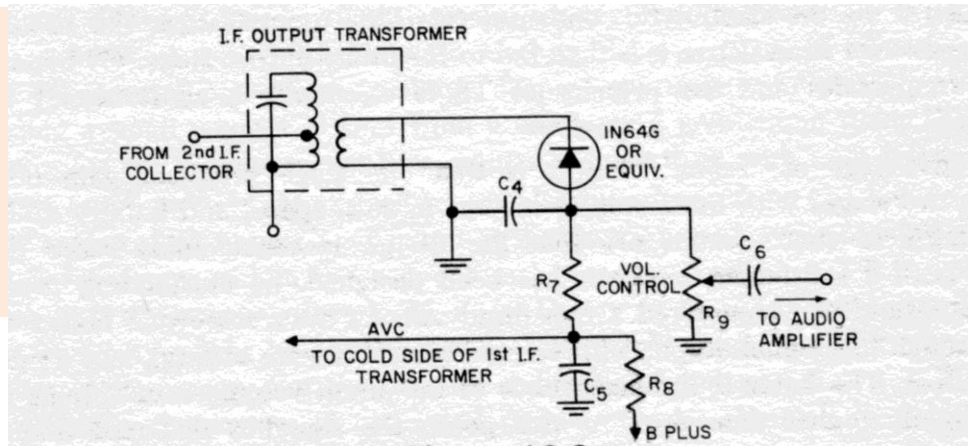
Transistor radios also employ AVC, but it usually requires two or more control loops to get rid of the fading caused by the changing radio orientation and position if it is portable.

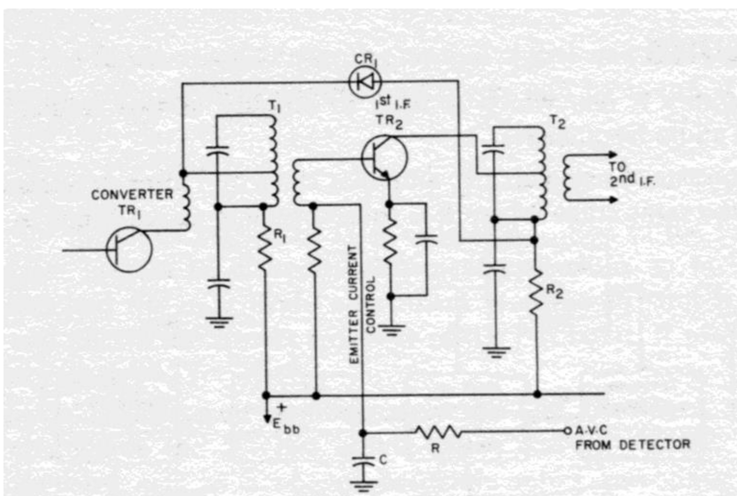


This is a 6-transistor broadcast-band portable with a pair of AGC loop circuits.

These are the two AGC loops in that transistor radio

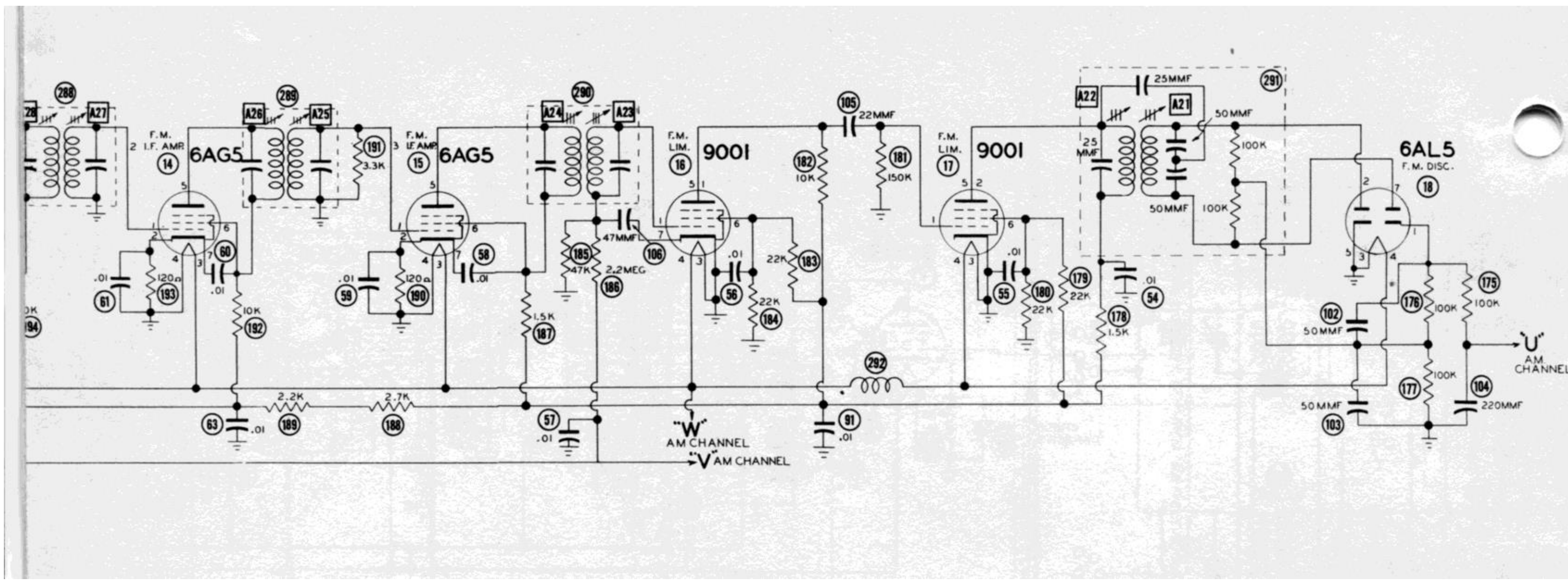
The diode is the detector, here, creating negative audio voltage for the vol. control and for the AVC bus.





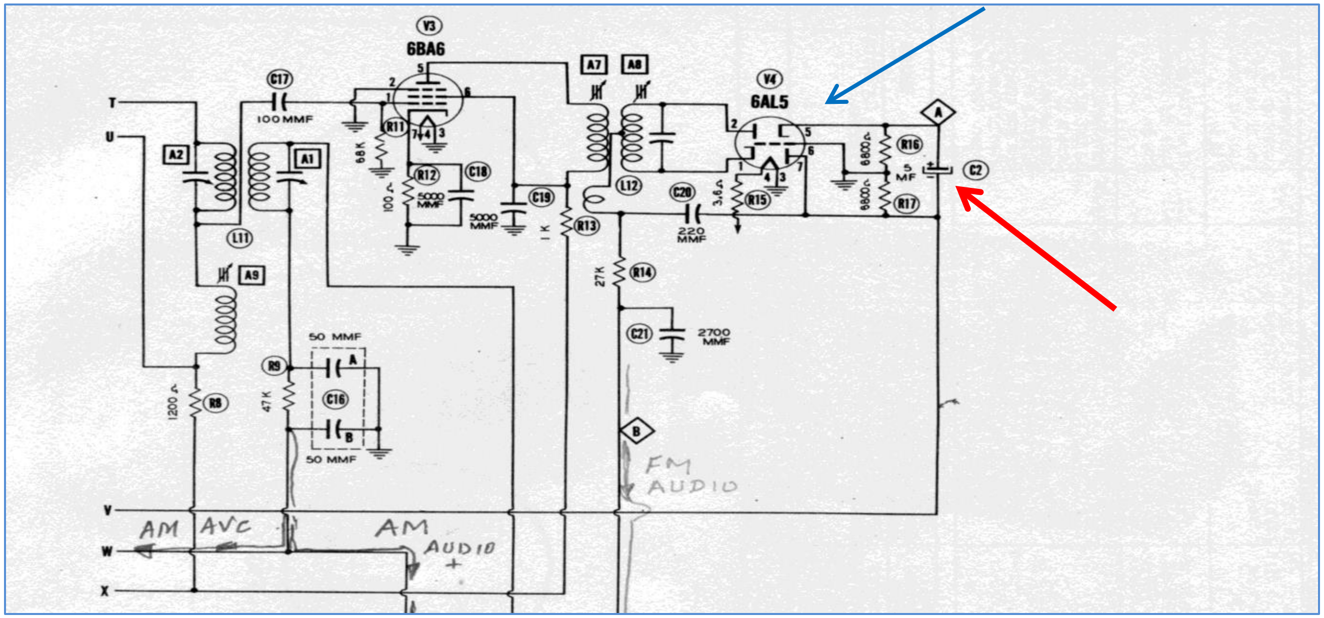
The diode marked CR1, at the top of this diagram, lowers the gain of the preceding stage to boost the AVC effectiveness.

FM radios and AM/FM sets in FM mode, use either a limiter stage of IF amplification or use a ratio detector as their demodulator stage. Both resist the effects of amplitude variation, usually caused by fading, especially in automobile or portable receivers.



Here is the very high-end Meissner 2961 AM/FM set's schematic in the region of IF amplification and detection. Being Armstrong-faithful, Meissner used the discriminator as FM detector, which responds to amplitude as well as frequency. To prevent amplitude fluctuations from affecting the audio, he added a limiter stage ahead of the discriminator.

Eliminating the limiter stage was important to the bean counters, so many radio designers opted for the ratio detector to demodulate FM, rather than the Armstrong discriminator.



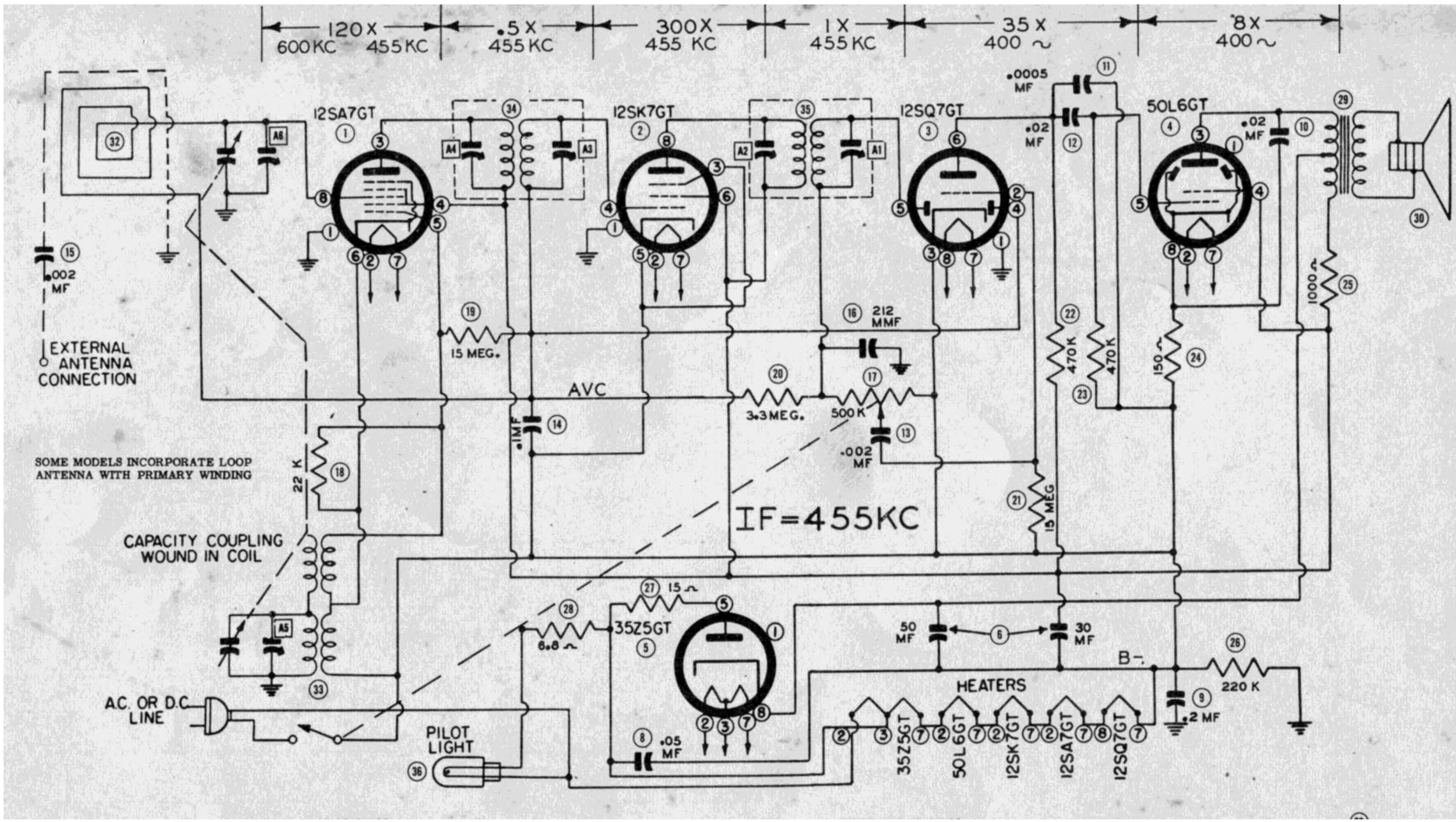
The blue arrow points to the 6AL5 dual diode with one of them reversed, compared to the pair in the discriminator (previous slide). The red arrow points to the 5 uF capacitor which helps achieve freedom from amplitude fluctuations by loading/unloading the 6AL5 diodes feeding it.

But the main difference between limiting (in FM radios) and AVC (in AM radios) is in the basic structure of the circuit.

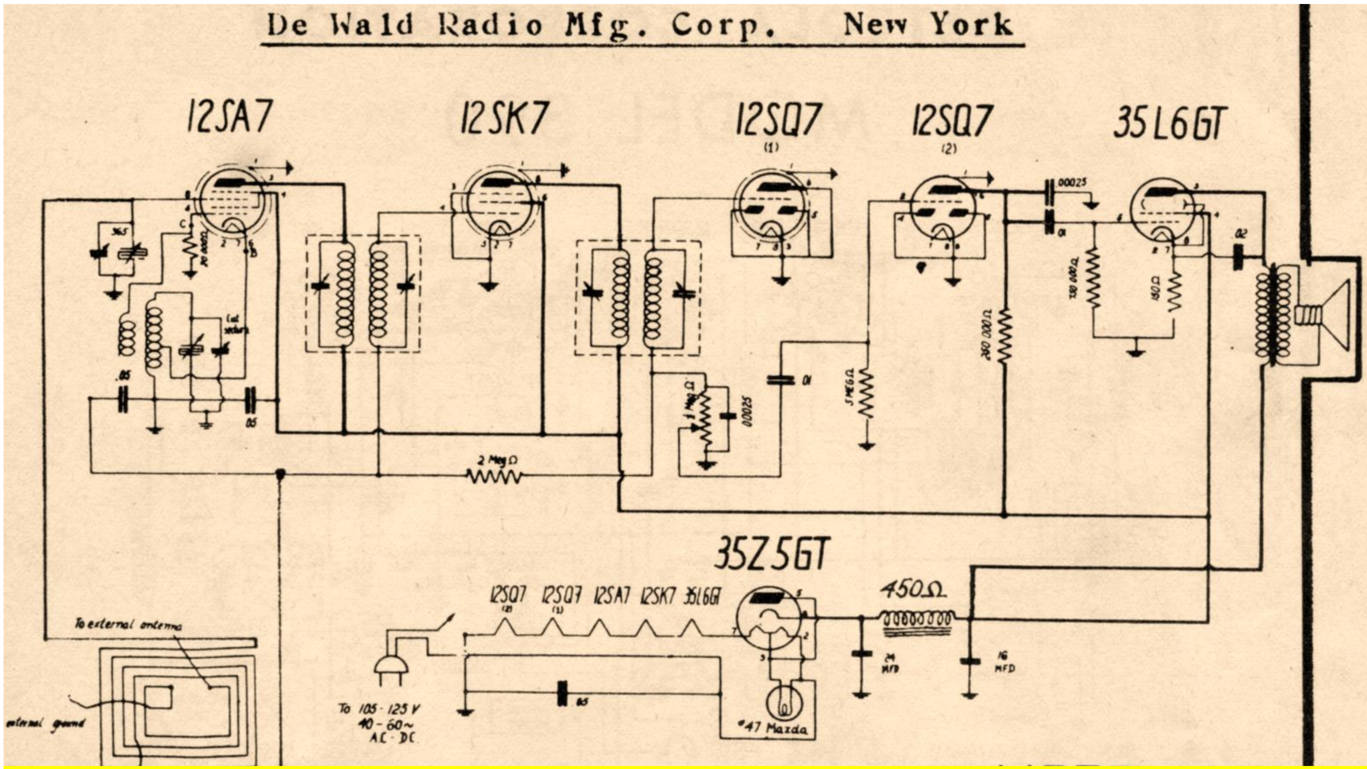
In the FM case, the limiter simply treats all IF waveforms to a circuit that makes them all emerge with the same peak-to-peak amplitude, so that any amplitude-sensitive reactions in the detector circuit in extracting the audio program are pre-cluded.

But in AM, with AVC there is a feedback loop which detects any increase or decrease in the IF carrier amplitude, pays no heed to whether the Broadcaster simply changed power level, or the RF signal pathway to the receiver somehow changed in its loss or the receiver circuitry simply changed its overall gain, and the AVC system makes a deliberate adjustment in overall receiver gain to try to compensate.

Most AM receivers use a diode as the final detector, because the diode operates best over a wide range of signal amplitudes, yielding a relatively undistorted audio waveform for the audio stages to work with.



In most radios after about 1936, the diode was built into another tube, usually a triode, which was handy, because the very next function after detection was to feed the audio signal emerging from the detector to the audio amplifier, by way of the volume control. And the audio amplifier was the triode portion of that same detector tube.,



Of course, some, like DeWald here, went nuts when they were told the 12SQ7 could serve both detection and amplification duties.

But, remember that the diode consists of an anode *and a cathode*, The anode, here being the little plate situated down near the tube's stem and facing or surrounding the cathode, The cathode-plus-little plate anode form each diode.

Keep this in mind, because now we are somewhat constrained with what else we do with that 6SQ7-type duo-diode-plus-triode.

Like for example, we would not think of using that 6SQ7 triode as part of a flip-flop circuit or some circuit that gets its current shut off by switching the cathode to a high positive voltage. **That cathode must serve two masters: the triode and the diode(s).**

The beauty of the 6SQ7/12AT7 series of tubes is that their cathode can be grounded and the triode grid will make its required bias by stealing a few electrons from the cathode from time to time.

But, you may ask, what is the purpose of putting TWO of these diodes in the tube?

Well, the diode detection process is one of rectification of the signal applied to the detector. The Intermediate Frequencies (IFs) used in the early superhets was not very high in frequency, and so the use of full-wave rectification in the detector would double the carrier frequency, which would make the residual carrier in the output audio easier to filter out.

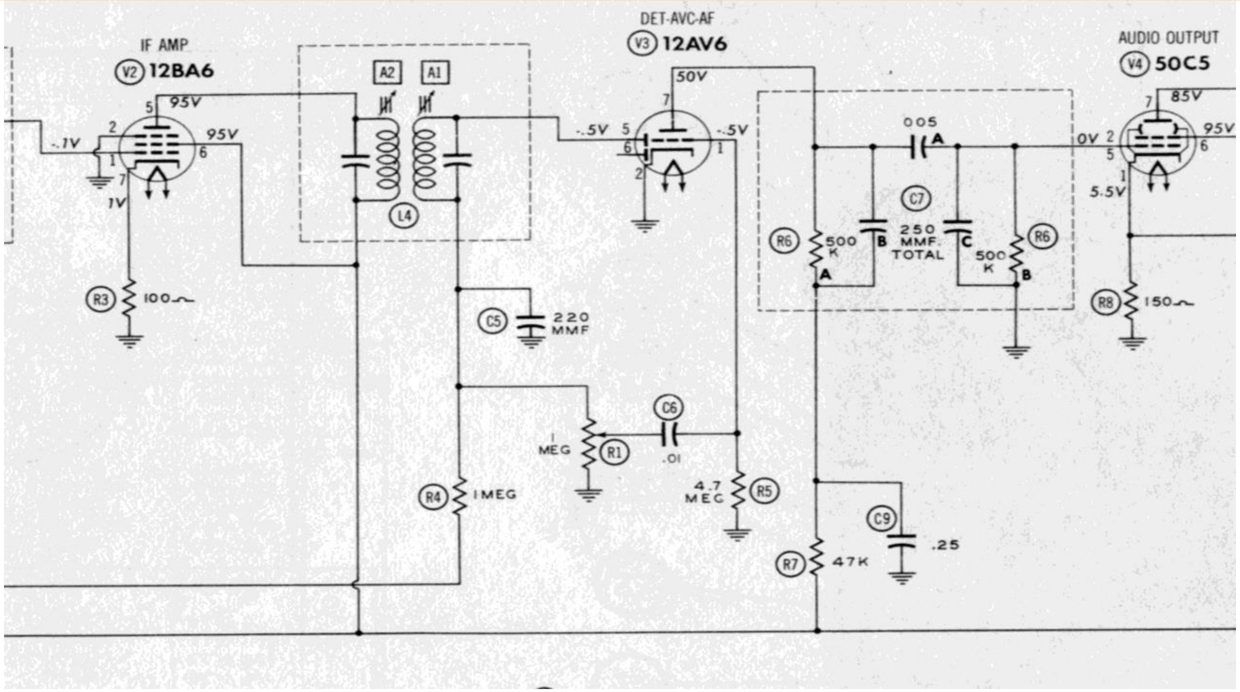
However, at about this time, the IF and RF amplifier tubes used were becoming far better, allowing higher-frequency Ifs to be used, obviating the benefits of full-wave detection vis-à-vis half-wave.

And…not everyone subscribed to half-wave detection, as we see in this Scott AW-15 radio, which used a full-wave detector (type 55 tube) to replace the Wunderlich which graced (?) their original version of that set.

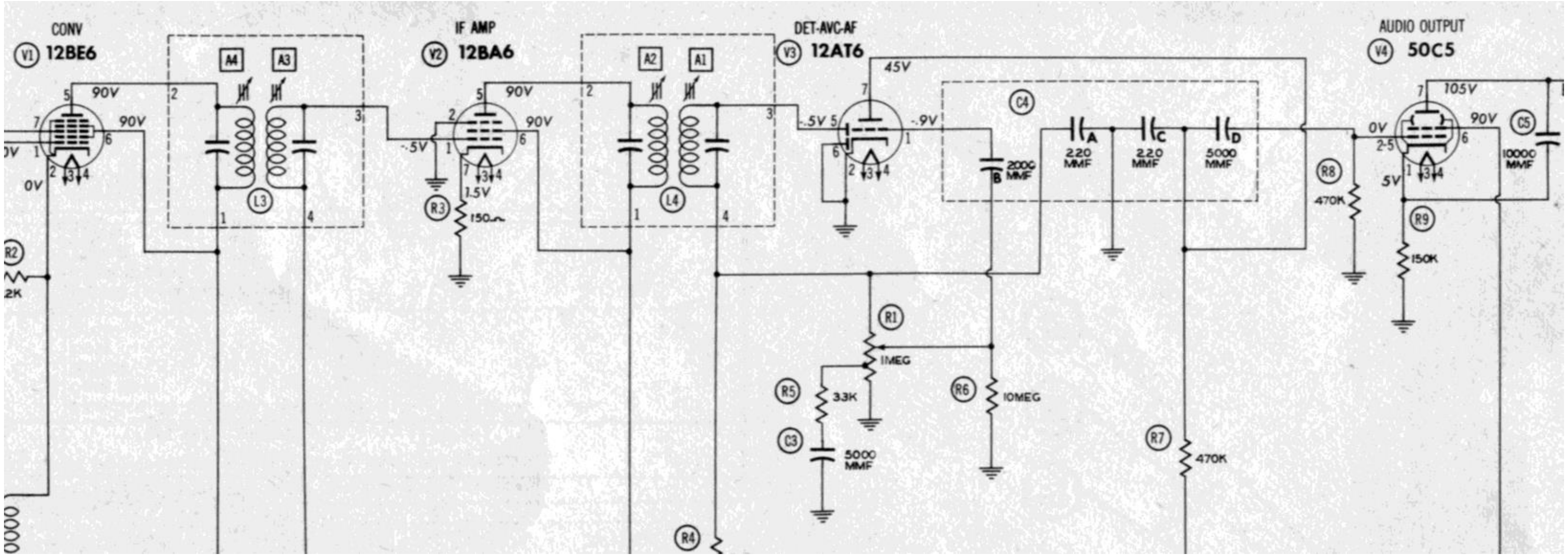
So what did the radio designers do with the second diode, if it wasn't really needed for most radios, which worked quite well with half-wave diode detection.

They found many "uses," all touted as improvements:

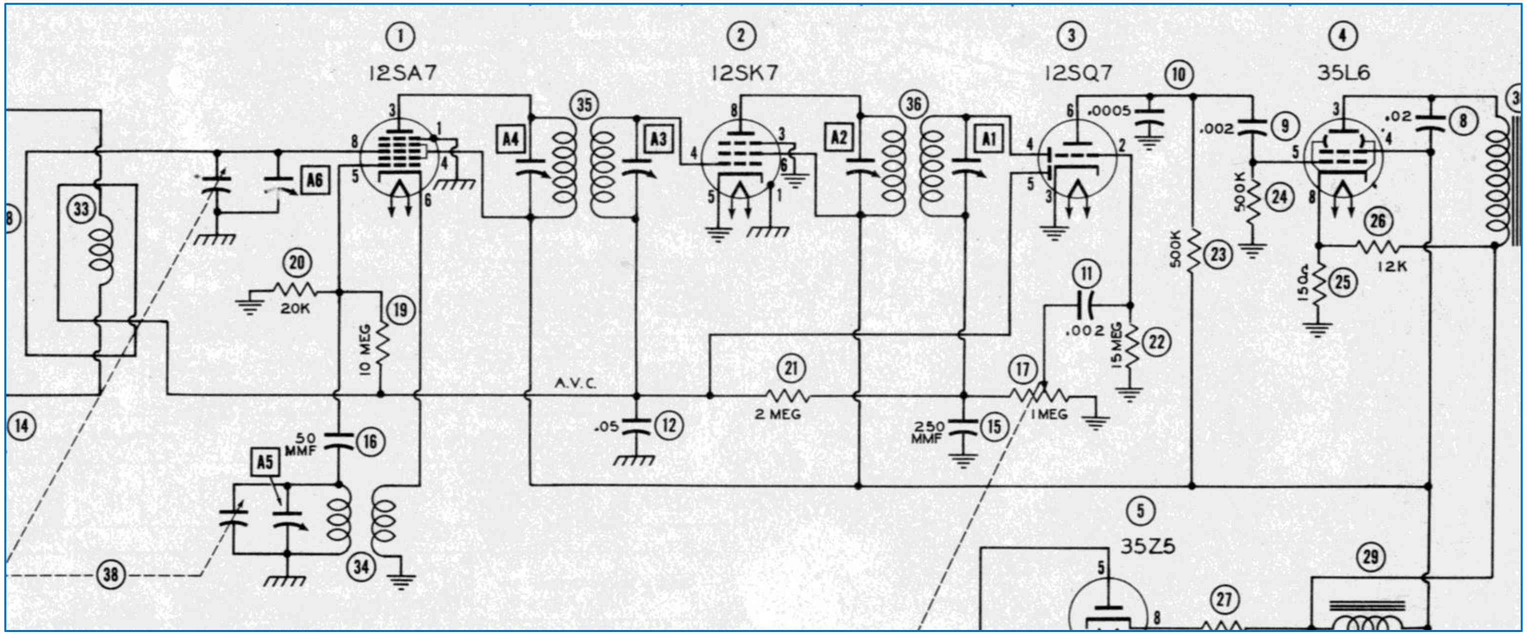
1. Here we see in the Admiral 5X2, they **ignored** that second diode.



And in this Motorola, and many others, they grounded the second diode plate.



Many radios used the second diode to ensure that the AVC will not experience a positive spike or surge as a result of oscillating signal strength amplitude episodes.



Do hams use AVC-equipped radios?

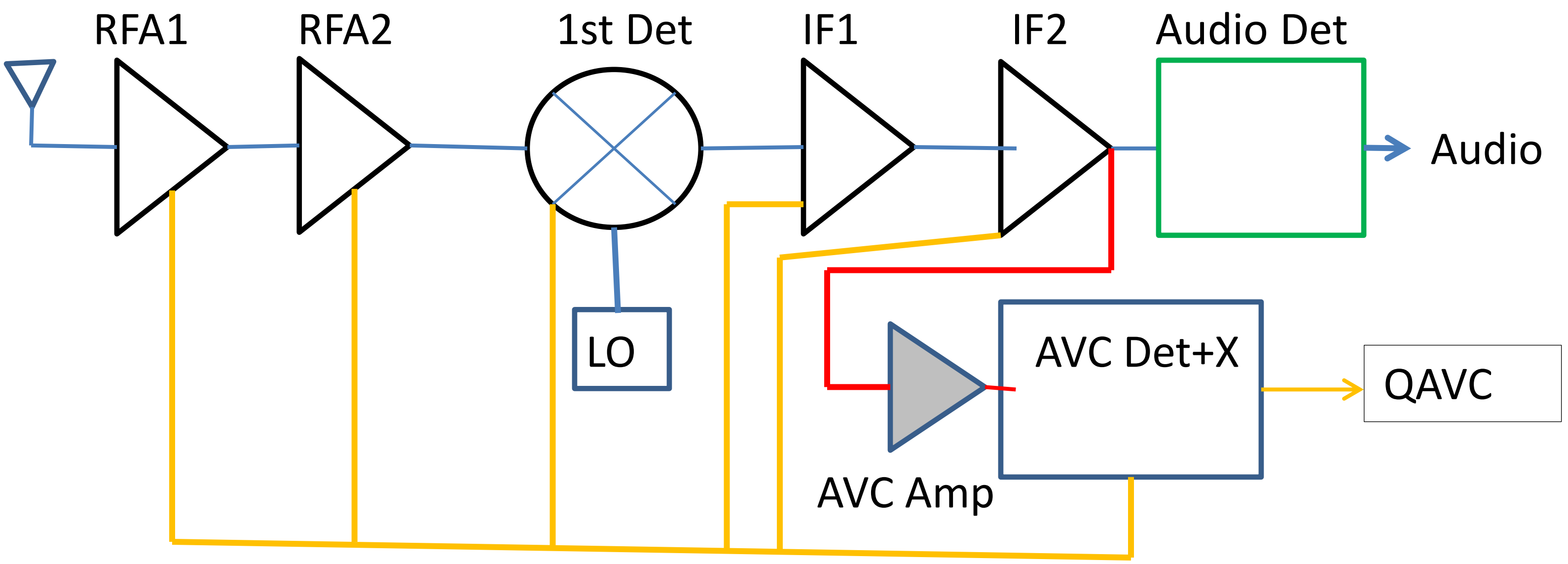
In A3 and similar modes, where there is a continuous carrier, AVC is a good property to have. But in "CW" or on-off keying, AVC, unless specially designed for this mode, is harmful to good CW listening, as it interprets the on-off carrier impulses as varying signal strength, and tries to react to it, The end result is poor CW hearability.

What is “Amplified AVC” as was advertised for radios like the Zenith Stratosphere and other high-end sets?

Several collectable radios used what was called “Amplified AVC” which usually meant that the detected IF output signal was passed through an amplifier before being routed to the various signal amplifying stages, to boost its effectiveness in holding the overall radio gain constant.

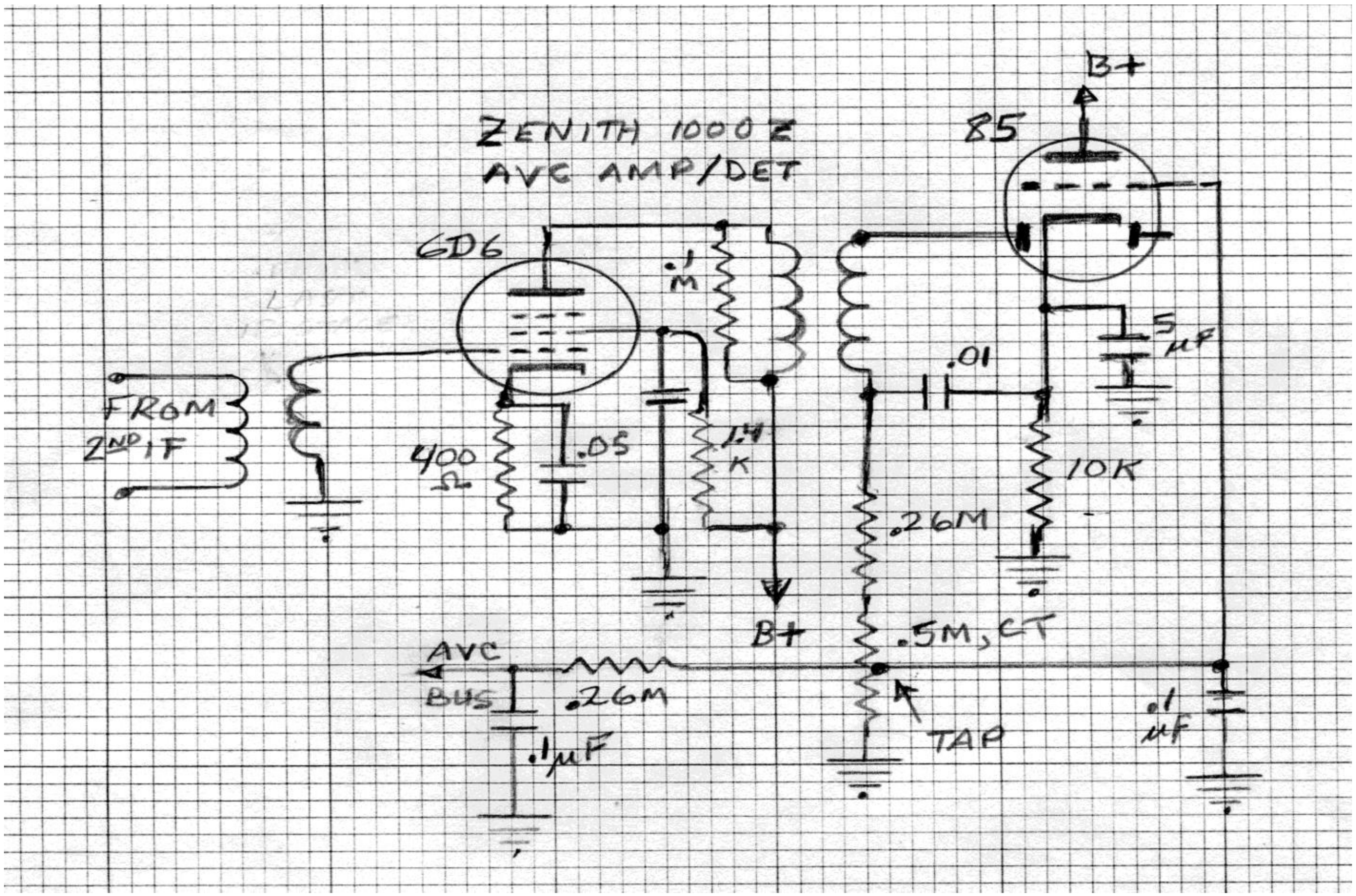
The Zenith 1000Z radio , called the Stratosphere, used an unusual AVC setup, called by Zenith “amplified AVC,” which did impose an amplifier stage expressly for the AVC, as we shall examine now.

This is a block diagram of the 1000Z signal path.



Legend: Black outlines-tuned amplifiers; Green outline= audio; Blue amp is untuned; blue trace is signal path; red trace is untuned tap off IF2stage; orange trace is AVC bus.

We now examine the contents of the box called "AVC Det and X", which is shown schematically here. It has a complex function part of which is to modify the amount of IF amplifier signal amplitude which will be accepted to form AVC bias voltage.



Note that the generation of the AVC voltage is exactly like that used much later in all of our AA5 radios. One of the diodes in the type 85 duo-diode-plus-triode will be impressed with the IF signal, via the IF transformer. As the IF sine-wave goes positive, it will be rectified, to form a negative D-C voltage .

In the AA5 radio, this is the program audio, which goes directly to the volume control potentiometer, after filtering off the IF sine wave ripple. Nothing new here… keep moving… nothing to see, folks.

Well, almost nothing. Those of you with 20-20 vision see that the 85 triode is not hooked up as an audio amplifier, but as a ***cathode follower.*** What the Sam Hill?

So the cathode sits there, resting, having risen in voltage to its quiescent level ever since the radio was powered on. And what is that quiescent level?

Well, in the type 85, a very low Mu tube (Mu=7-to-9), which means its cathode supplies current, until the cathode voltage is about 10 volts above that of the grid.

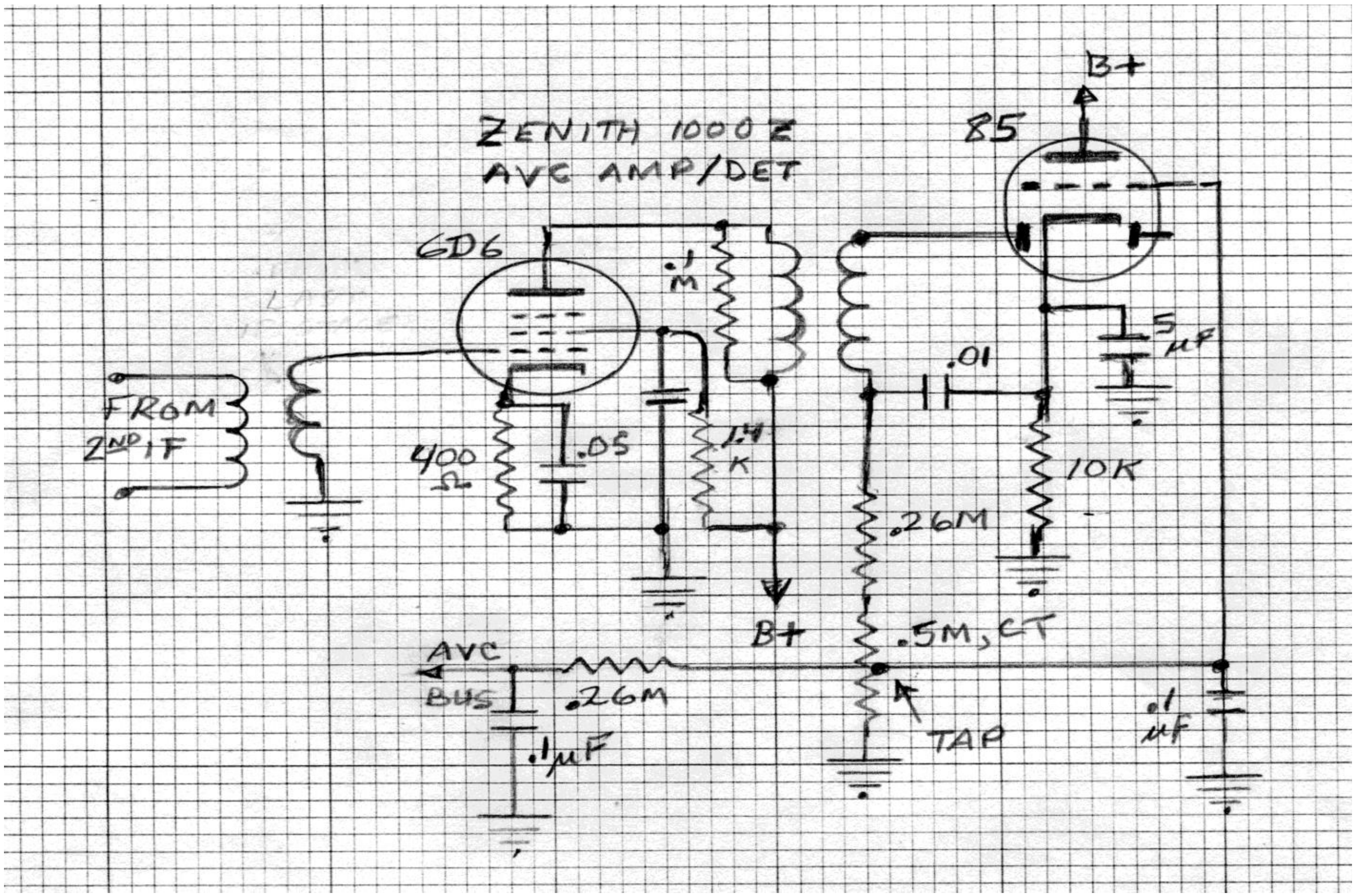
And the grid is being fed the AVC voltage.

And remember, the AVC voltage is being developed by the little diode-plate going positive compared to the cathode.

I thought I said, a while ago, that you shouldn't fiddle around with the cathode voltage in one of these 6SQ7 type duo-diode-plus-triode tubes.

Well, under normal circumstances you shouldn't. But Commander McDonald of Zenith was in a desperate battle with Scott Transformer Co., regarding who had the most elegant radio, and in such a battle, strange things get designed … and produced before the design has been checked …and re-checked.

Let's look again at the circuit that comprises Zenith's AVC amplifier.


ZENITH 1000Z
AVC AMP/DET
6D6
85
B+
.1M
.01
5 µF
FROM
2ND IF
400 Ω
.05
10K
.26M
B+
.5M, CT
AVC
BUS
.26M
.1µF
TAP
.1 µF

We have studied this circuit for some time, now, and find that the tap-point on the AVC diode's string of resistors that form the overall load, is unknown. The resistor shown there with a tap is actually a potentiometer in the actual radio. It is tapped, and it has a wiper, like any pot. The wiper is used to feed a QAVC circuit, which is to quiet the radio when there is very low AVC voltage. It does this by using an electro-mechanical relay to short out the audio feed to the power amplifier.

The consequence of this gap in our understanding of the details of that circuit is that various trials have been attempted in pure simulation, conducted by Joe Sousa, and the circuit ends up a feedback system with the limiting level of the overall AVC voltage which is stable, is critical.

But, you ask, what is critical about this situation?

You have to remember that the AVC voltage not only reduces the gains of all the RF amplifier, Converter, and IF amplifier stages in the entire radio….

AND

That same AVC voltage gets fed to the type 85’s grid.

Which means that the 85’s cathode voltage will also drop from its current 10-volt (positive) level….

Which means that the AVC voltage will increase (negatively), due the AVC diode getting more of the IF sine-wave….

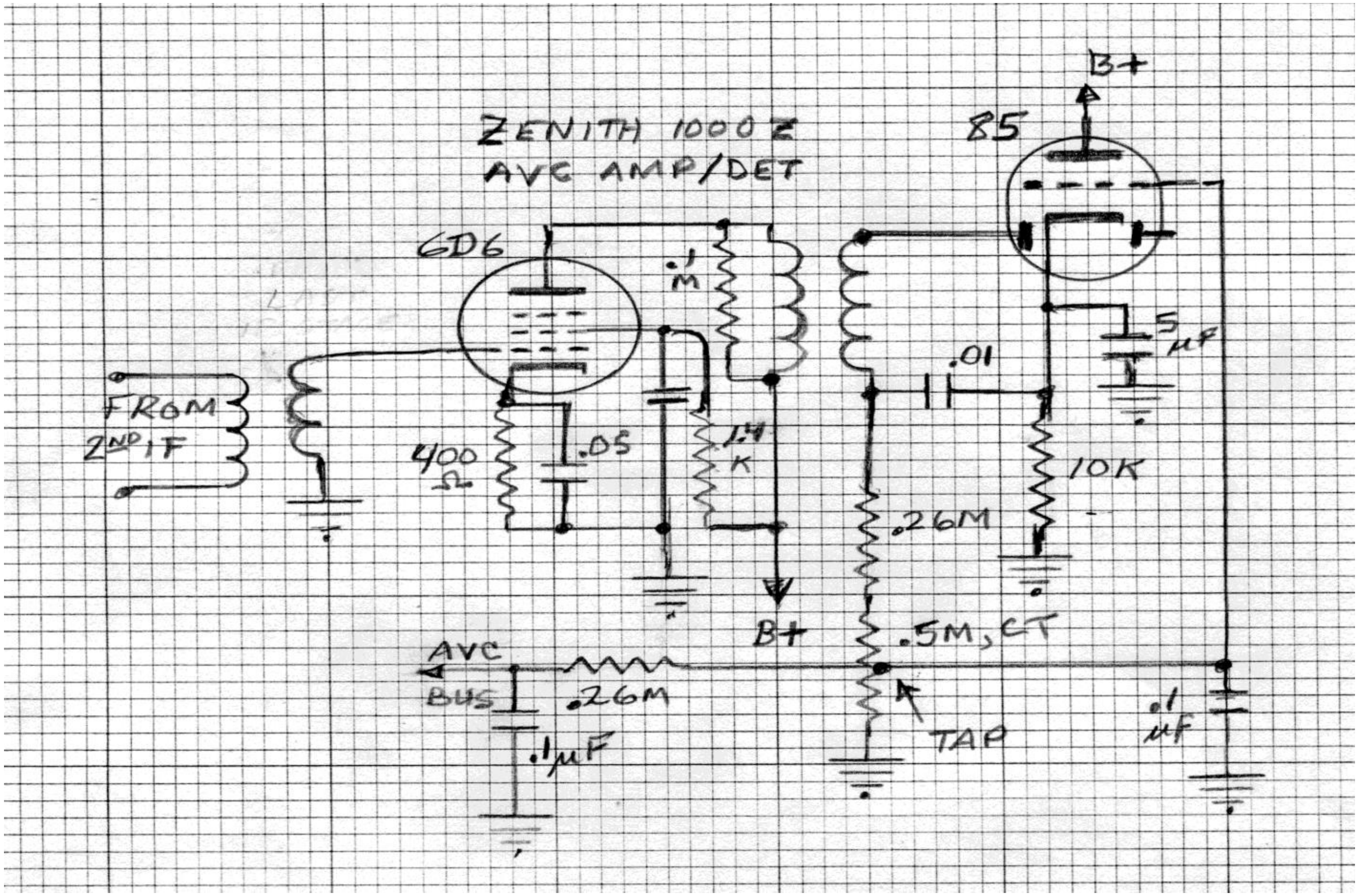
Which means that the RF, Converter, and IF gains will all drop due to the variable Mu property…..

What this means is that the radio can become a very throaty, high power (eight 6V6’s in push-pull-parallel) Evinrude imitator, under certain values of the resistors in that circuit.

Joe Sousa’s simulation used approximations everywhere, since it is based on tubes and transistors of far less age than this Zenith, and he had to substitute a lot of things.

He noted that the fraction of the diode–generated AVC voltage that is actually used as AVC voltage is unknown, but critical.

Let us conclude by running through the circuit carefully.



ZENITH 1000Z
AVC AMP/DET
6D6
85
B+
.1 M
.01
5 µF
FROM
2ND IF
400 Ω
.05
10K
.26M
B+
.5M, CT
AVC
BUS
.26M
.1µF
TAP
.1 µF

So I built a simulator that uses all the same sorts of things that Zenith used, adjusted for the differing resistances, voltages, and currents. I used 6BA6 tubes, adjusted in resistances and voltages to simulate 6D6s, for example, but used similar numbers of stages, to get the gain multiplying function, and it has some strays , like the real Zenith.

But, I didn't quite get it finished. I brought it and will take suggestions from anyone who cares to look at it.

It will be featured in the September *Radio Age*.

Questions???