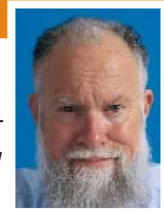
ELECTRONIC DESIGN 50 Celebrating Fifty Years



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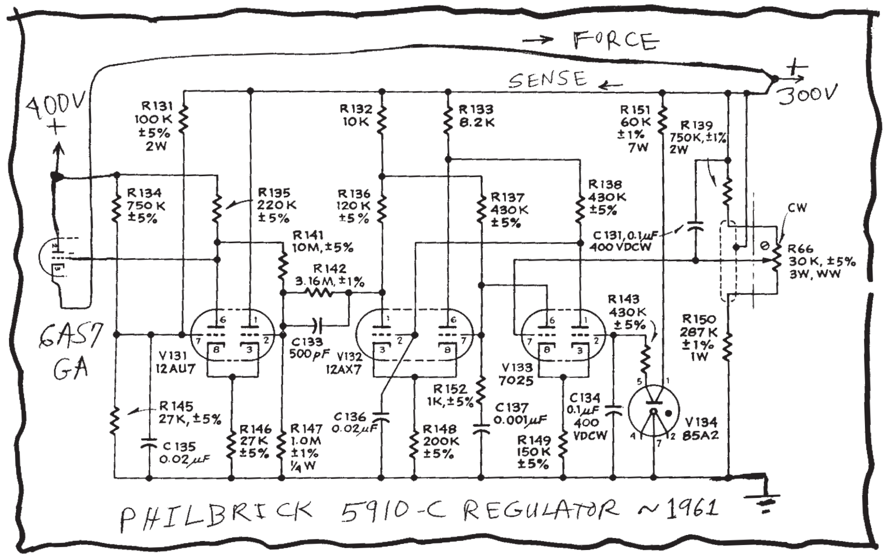
pease porridge

What's All This Ripple Rejection Stuff, Anyhow? (Part 1)

Recently, I helped a guy who needed low output ripple on a power supply. His 1000-V output required low, submillivolt ripple. I designed a couple of circuits for him. Details soon. To make sure that I wasn't missing any tricks, I looked up a voltage regulator, the Philbrick 5910, designed by my old colleague Bruce Seddon about 42 years ago. It was optimized to provide ±300 V dc at 100 mA *(see the figure)*, or 300 mA in a larger R-300 power supply when additional output tubes are paralleled.



Anybody can design an operational amplifier (op amp) with a gain of 100,000 or 1,000,000 at dc. But this one needed to swing its output 80 V dc plus 15 V p-p at 120 Hz, with a summing-point error of less than 150 µV ac rms. That's 100 dB of gain at around 120 Hz! Forty years ago, most regulator amplifiers had two-stage amplifiers. But this one used three dual triodes for each supply, + and – 300 V. Two *honest* stages of 12AX7 provide a lot of gain (µ = 100), and the 12AU7 (µ = 20) gives a good healthy drive to the grid of the output tube (6AS7GA).

Additionally, the positive feedback of R132, R133, and R141 provides much more gain—even at 120 Hz, and at dc. Although the output pass tube (6AS7GA) has a µ of only 2, this amp can easily drive the grid to any necessary voltage, whether no-load or full-load, low-line or high-line. Also, it has submillivolt gain error, for line, load, or ripple.

There are good bypass capacitors, such as at C131 and C134, to filter and bypass the noises for frequencies above 4 Hz. That helps keep the output's noise below 250 µV rms. This amplifier was also optimized for fast bandwidth. The output bypass capacitors (not shown) were 150 µF at 525 VDCW, specified with good low R_S.

The 5910 dual regulator amplifier was built in a little boxy subassembly. The tubes stuck up above the box, with the passive components mounted on turret terminals along the insides of the box.

I bought a 30-year-old R-300 that was still in very good shape. I used a Variac to turn up the line voltage very *slowly* to "form up" the electrolytics. It would be harmful to apply full line power right away. I fired it up and it regulated nicely.

After I did a general check-out, it was time to do noise testing. I used a series stack of three 25-W light bulbs to draw ~190 mA of load. The ripple voltage on the main ("upstream") filter capacitors rose to 9 V p-p. The output ripple-plus-noise increased from 100 µV rms to perhaps 120 µV—truly negligible, barely 3 ppm (p-p) of the dc output, even at full load. The ripple was barely 40 µV p-p. Not bad! The load regulation was submillivolt, and the line regulation was very good too.

So it's encouraging that 40 years ago, a high-gain three-stage op amp could provide excellent ripple rejection, and that old machine still runs well today. Soon, I'll show how to get low ripple voltage by adding an add-on circuit to an existing high-voltage supply. Perhaps using a fast FET op amp running on ±6 V.

I'm looking forward to using that old R-300 to run a whole bunch of tests on various old vacuum-tube operational amplifiers. I've been waiting to do that for years! We rarely use vacuum tubes these days, but here's a good example of how tubes could do some very good work. I'll have more comments on the old art of designing with tubes, and the early days of operational amplifiers, 40 or more years ago.

All for now. / Comments invited!

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