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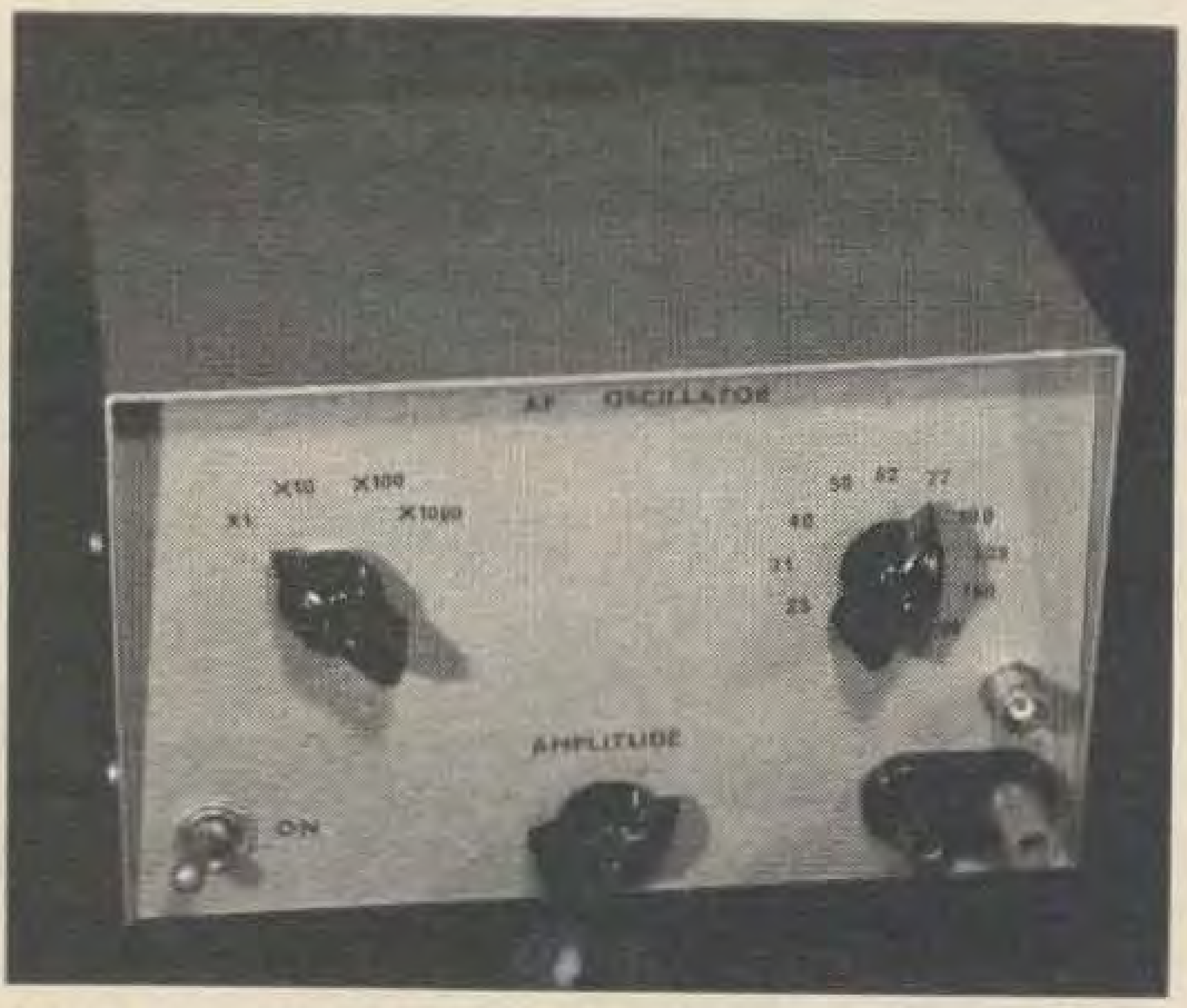
A Transistor Wien Bridge Oscillator

In this article, W6GXN discusses the evolution of a Wien Bridge audio oscillator that generates 25-200,000 Hz sine waves with very low distortion.

Virtually every audio oscillator, that the author has ever seen in laboratory use, is of a type called the Wien Bridge. This type of oscillator is characterized by a particular configuration of R-C tuning network. The original circuit of the Wien Bridge Oscillator is shown in **Fig. 1**, as it was first constructed using vacuum tubes.

In **Fig. 1**, the two stage circuit sustains oscillations because of the phase-shift of the bridge (at a particular frequency) *and* the phase shifts of the two amplifiers (assumed constant over the frequency range of interest). Such an RC oscillator would produce a highly nonlinear waveform (like that of another R-C oscillator, the astable multivibrator), if it were not for the nonlinear resistance "r". The resistance r is variously called a positive-temperature-coefficient thermistor, a barretter, or a light bulb.

When the circuit of **Fig. 1** is in its desired state, the tubes are running in class A, and the output is sinusoidal. A change in operating state toward class C (which would produce a much larger output of highly distorted waveforms) causes more current to flow in the R_3-r side of the bridge. This increases the temperature of the light bulb (r), which causes its resistance to rise. The increase in resistance of r causes the gain of the amplifier stage V_1 to decrease, which restores our original operating level.



Front view of W6GXN's Wien Bridge audio oscillator.

To see how the lamp resistance varies with current, **Fig. 2** depicts a (commonly used) 6 watts 120 V lamp E-I plot, with several lines of constant resistance drawn in for reference. The translation of the tube-type Wien Bridge circuit into a transistorized version has had many problems, and the solution of these problems has been so complicated that the basic simplicity of the Wien Bridge oscillator often has been lost. In many a transistorized Wien Bridge audio oscillator, when the problem areas have been designed around, the resultant circuit hardly resembles the original Wien Bridge at all. This is not bad, per se, and several good Wien Bridge audio oscillator designs have come forth using bipolar transistors.[1,2]

Basically, the reason that the Wien Bridge oscillators using bipolar transistors are so hard to build is that ordinary transistors have a relatively low input impedance in the common emitter configuration.

In **Fig. 3**, we see a hypothetical Wien Bridge oscillator using bipolar transistors. Since the input impedance from base to ground is fairly low (approximately h_{fe}xf), this low impedance shunts R_2 and upsets the requirement that $R_1 = R_2$. Also, since h_{fe}xr is amplitude sensitive, frequency will be dependent on amplitude. These two problems generally force the designer to:

1. Use low values of R_1 and R_2, together with large values of C_1 and C_2. This means that resistance tuning *must* be employed.
2. Use some other negative feedback method for controlling amplitude, rather than the simple lamp-in-the-emitter method. Negative temperature coefficient thermistors and forward-biased diodes are two of the nonlinear elements used for this.

With the advent of field effect transistors, the design of simple solid-state Wien Bridge oscillators came within easy reach. The FET has an inherently high input impedance in the common source configuration. However, most of the designs that the author has seen using an FET as the input amplifier, have **not** used the same sort of lamp amplitude control as used in the older tube-type circuits.[3,4,5]

The circuits below were redesigned from the old vacuum tube Wien Bridge circuits, for simplicity and ease of understanding. The first attempt, **Fig. 4**, used the same type light bulbs as do many of the tube type oscillators, and also used capacitive tuning.

The circuit of **Fig. 4** used one of the relatively new insulated gate FET's, the RCA 3N98. With a maximum design-capacitance in each section of the variable capacitor of 500 pF, at the minimum operating frequency, very high resistances (many megohms) were required for R_1 and R_2. At such a high impedance level, the circuit readily picked up 60-Hz ripple, and it was quite essential that it be enclosed in a shielded cabinent.

The bridge-sensing amplifier was the only FET in the circuit, since this was the only place where one was *needed*. A conventional bipolar voltage amplifier Q_2 and a complimentary emitter-follower completed the oscillator. The emitter-follower was used to provide a low output impedance. The circuit was powered by a separate +28 volt regulated supply.

Since the main frame of the dual variable capacitor was the common terminal, which was connected to the gate of Q_1, one would expect a fairly large stray capacitance to ground in shunt with C_2. This had to be equalized by a trimmer (C_3) across C_1 if oscillation was to be maintained near minimum C settings of the dual variable. Also, of course, an insulated (ceramic) shaft coupling had to be used on the variable capacitor shaft and the capacitor frame had to be supported by ceramic or high-quality plastic insulators. C_4 and C_5, in parallel with C_1 and

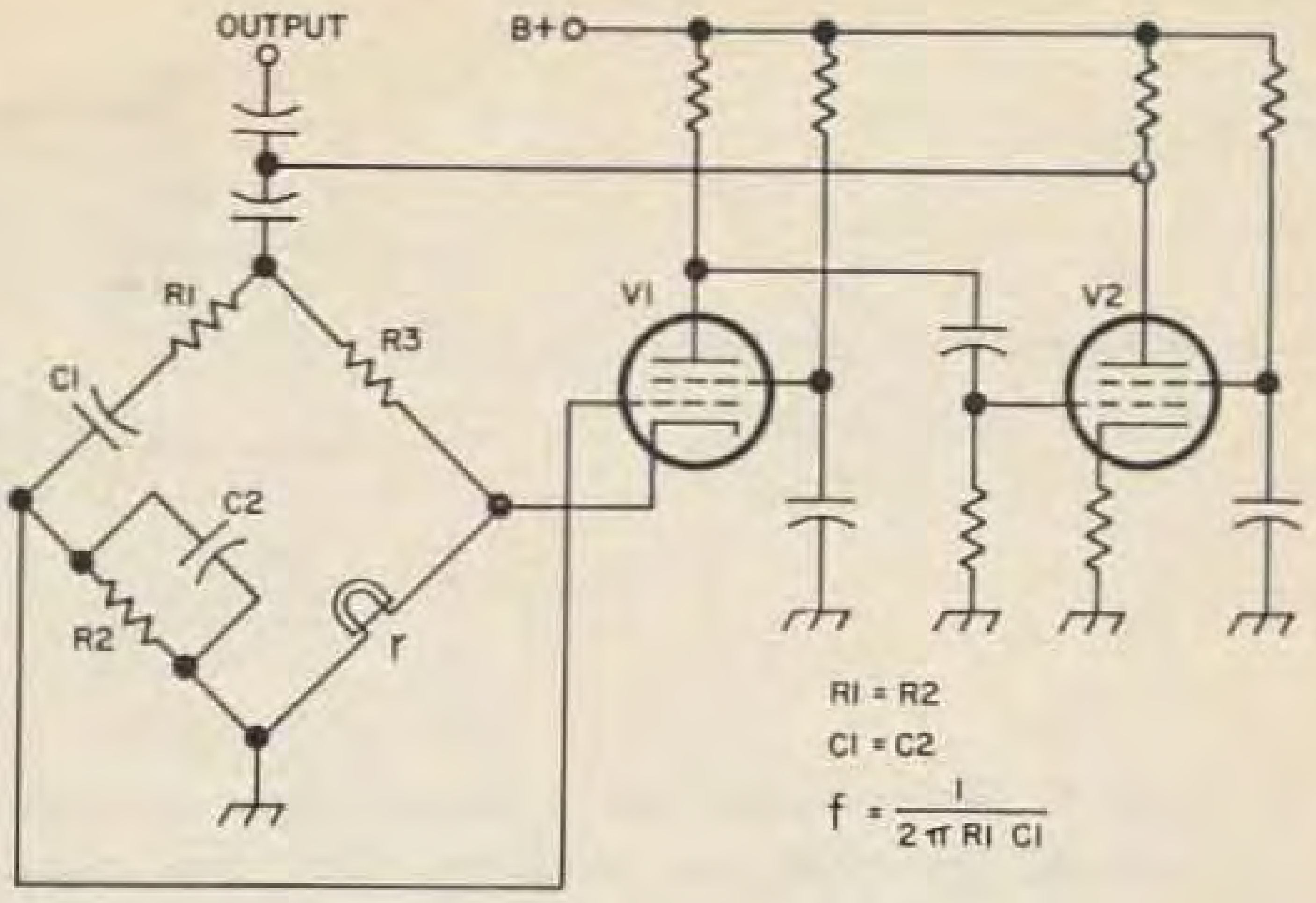


Fig. 1. Typical tube-type Wien Bridge audio oscillator.

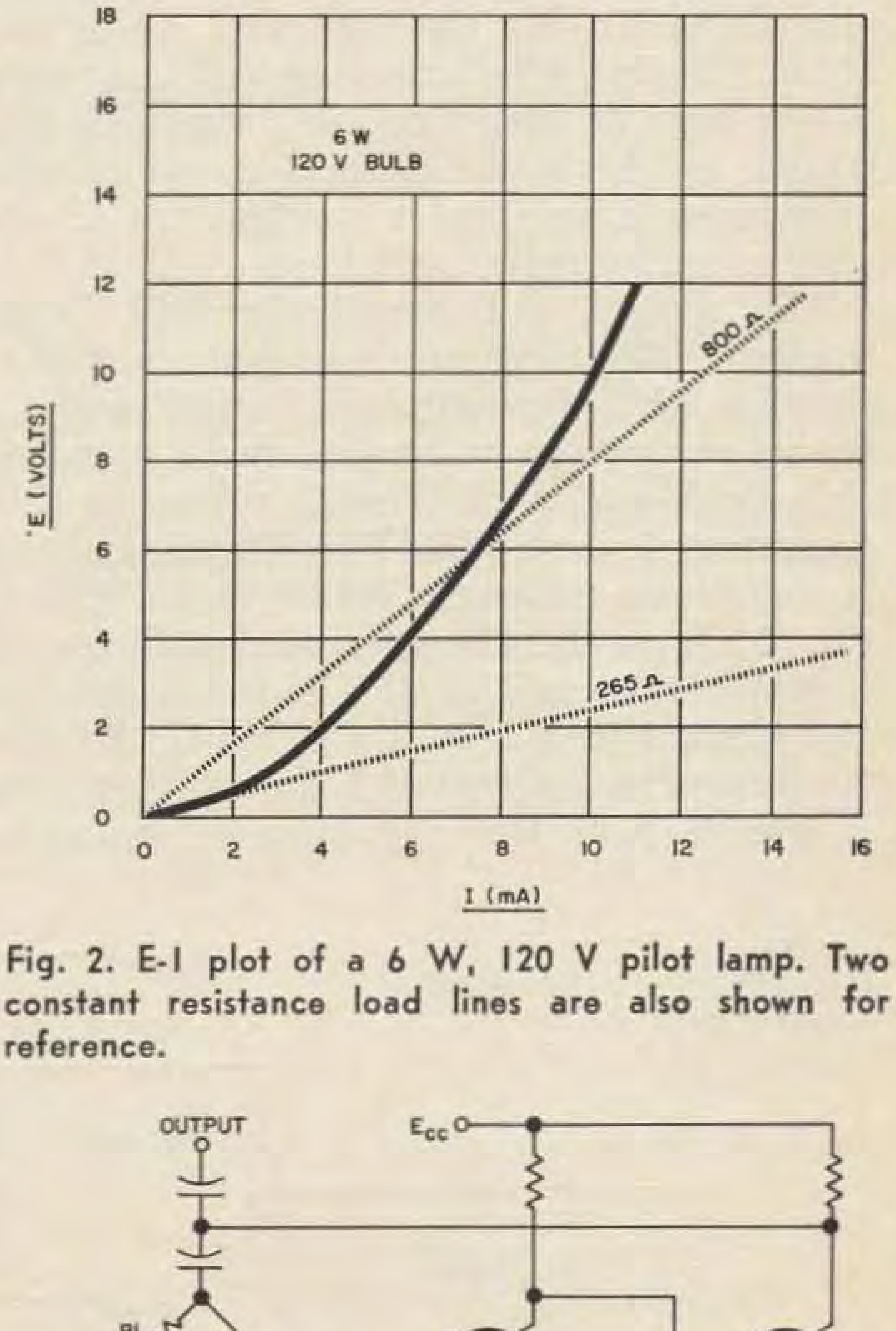


Fig. 2. E-I plot of a 6 W, 120 V pilot lamp. Two constant resistance load lines are also shown for reference.

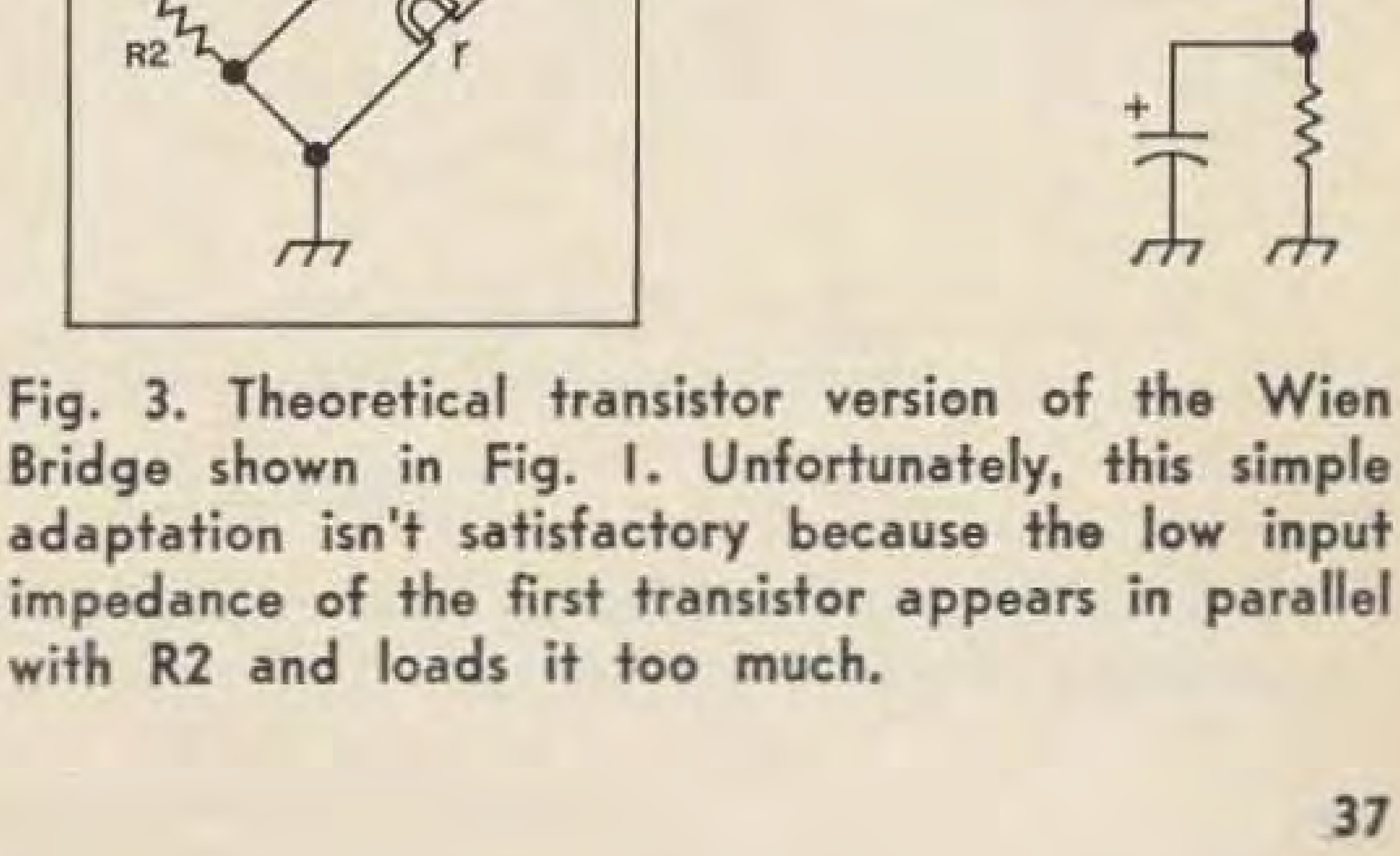


Fig. 3. Theoretical transistor version of the Wien Bridge shown in Fig. 1. Unfortunately, this simple adaptation isn't satisfactory because the low input impedance of the first transistor appears in parallel with R2 and loads it too much.

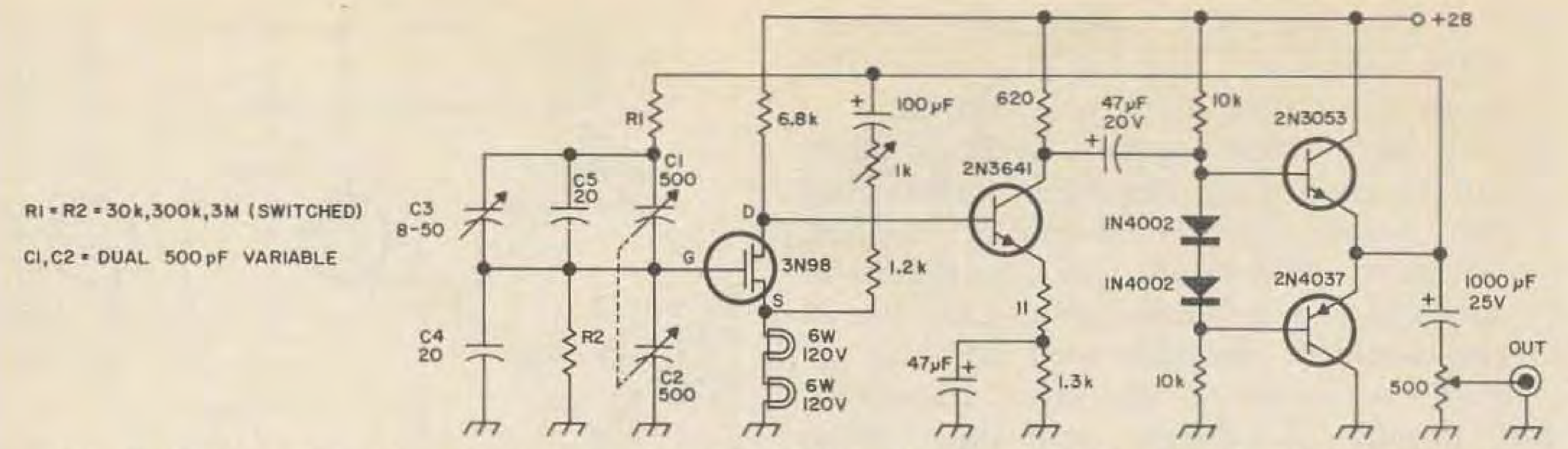


Fig. 4. First version of a moderately successful Wien Bridge oscillator. For low frequencies, R1 and R2 have to be so large that the circuit is very susceptible to noise and hum.

C_2 were simply to fix the minimum tuning capacitance.

The design worked quite well in the ranges above 100 Hz, but the lowermost range (10 Hz to 100 Hz), where the required resistance values were 30 megohms, was unreliable, as feared. At this point, capacitive tuning was abandoned in favor of a combination of capacitor and resistor switching.

The second and more successful Wien Bridge audio oscillator was built using a junction FET. By switching both R and C, bridge component values are more manageable (and available). The C values in this second version are 0.52 µF to 500 pF, and the R values are between 100 Ω and 3300 Ω. **Fig. 5** shows the circuit of the oscillator; it is very similar to **Fig. 4.** The feedback control element used here is a Sylvania 120 MB lamp for which a typical E-I curve is shown in **Fig. 6.** Note that this lamp allows us to use a single bulb to operate at a source resistance of about 600 Ω. Also, the Sylvania 120 MB is physically smaller than most 120 V bulbs and fits a small bayonet pilot lamp socket, like that for a #47 or NE51. The lamp is available from Allied Radio for $0.46. The oscillator is constructed in a LMB-WIA cabinet, as shown in the photos.

The capacitors are switched only each decade, and the resistors are switched in ten increments between decades. The seemingly-nonsensical increments of frequency were chosen to give points that are approximately evenly-spaced on semilog graph paper—the type of paper usually used when plotting the frequency response of an audio amplifier. The four pairs of capacitors were "built-up" starting with 0.47 µF, 0.047 µF, 0.0047 µF, and 470 pF capacitors, by adding small capacitors in parallel; a bridge was used. The resistors were all 1% tolerance types from

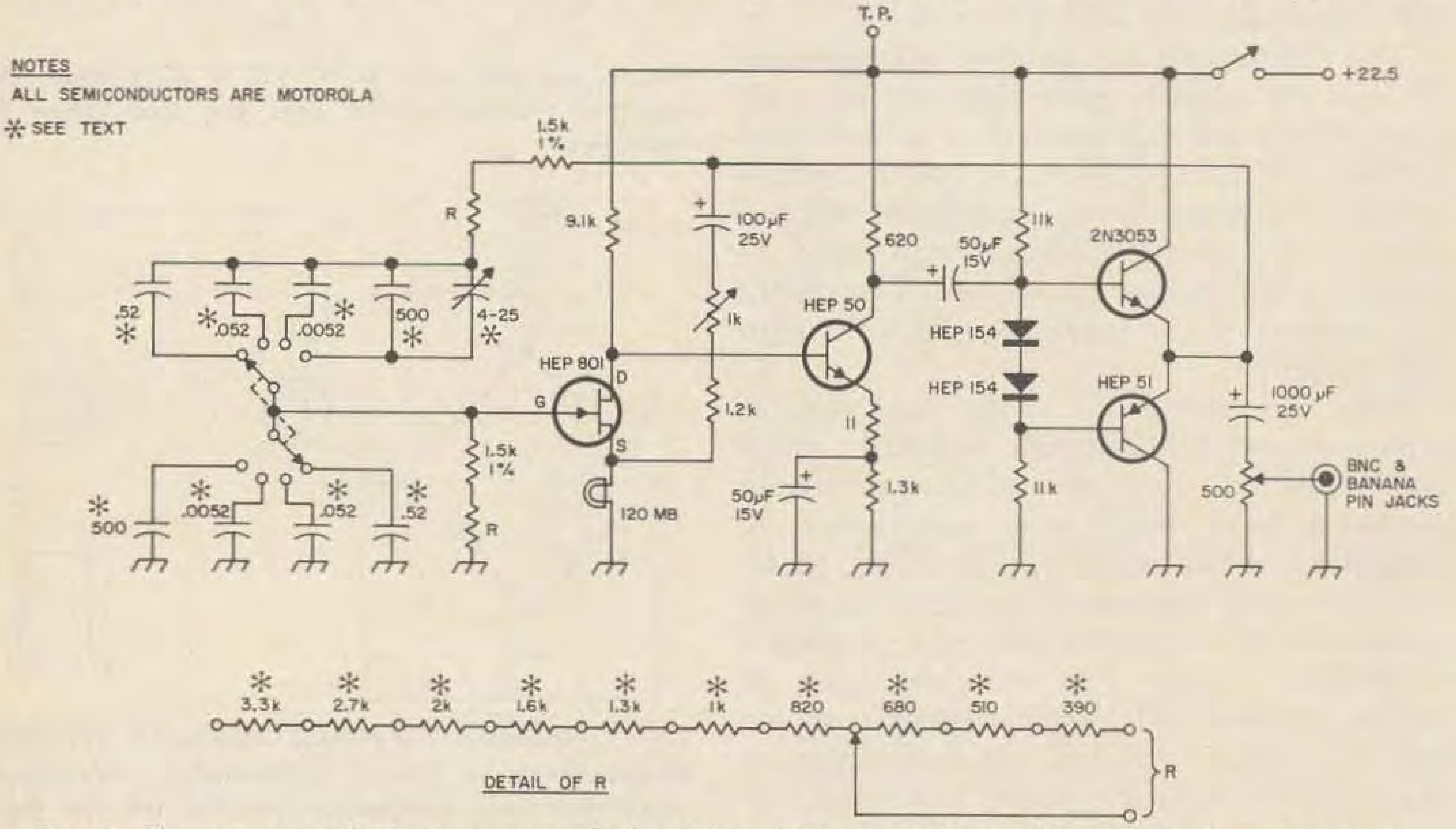
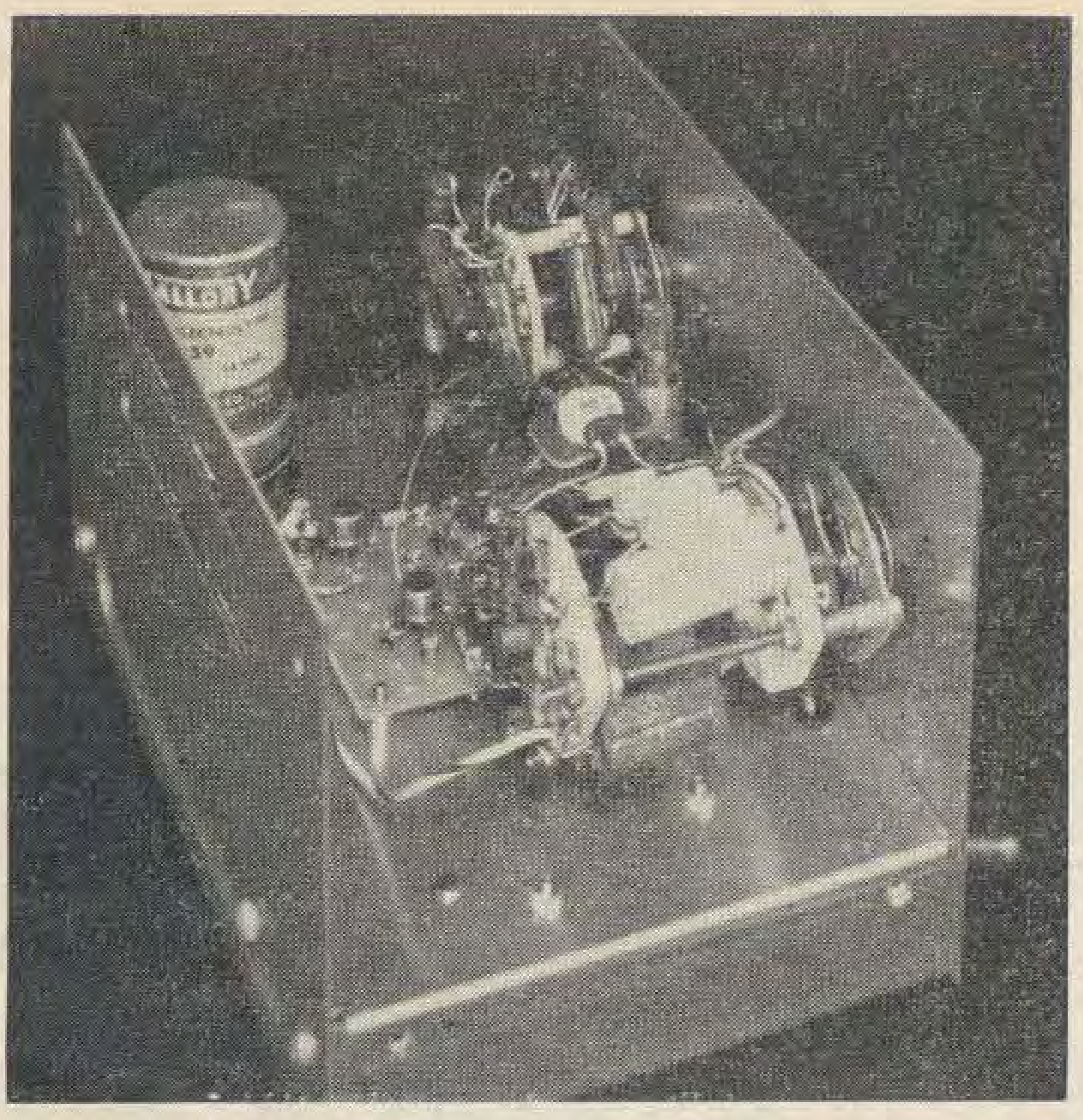


Fig. 5. The most satisfactory version of the Wien Bridge oscillator. This circuit is used in the oscillator shown in the photos.



Interior of W6GXN's audio oscillator.

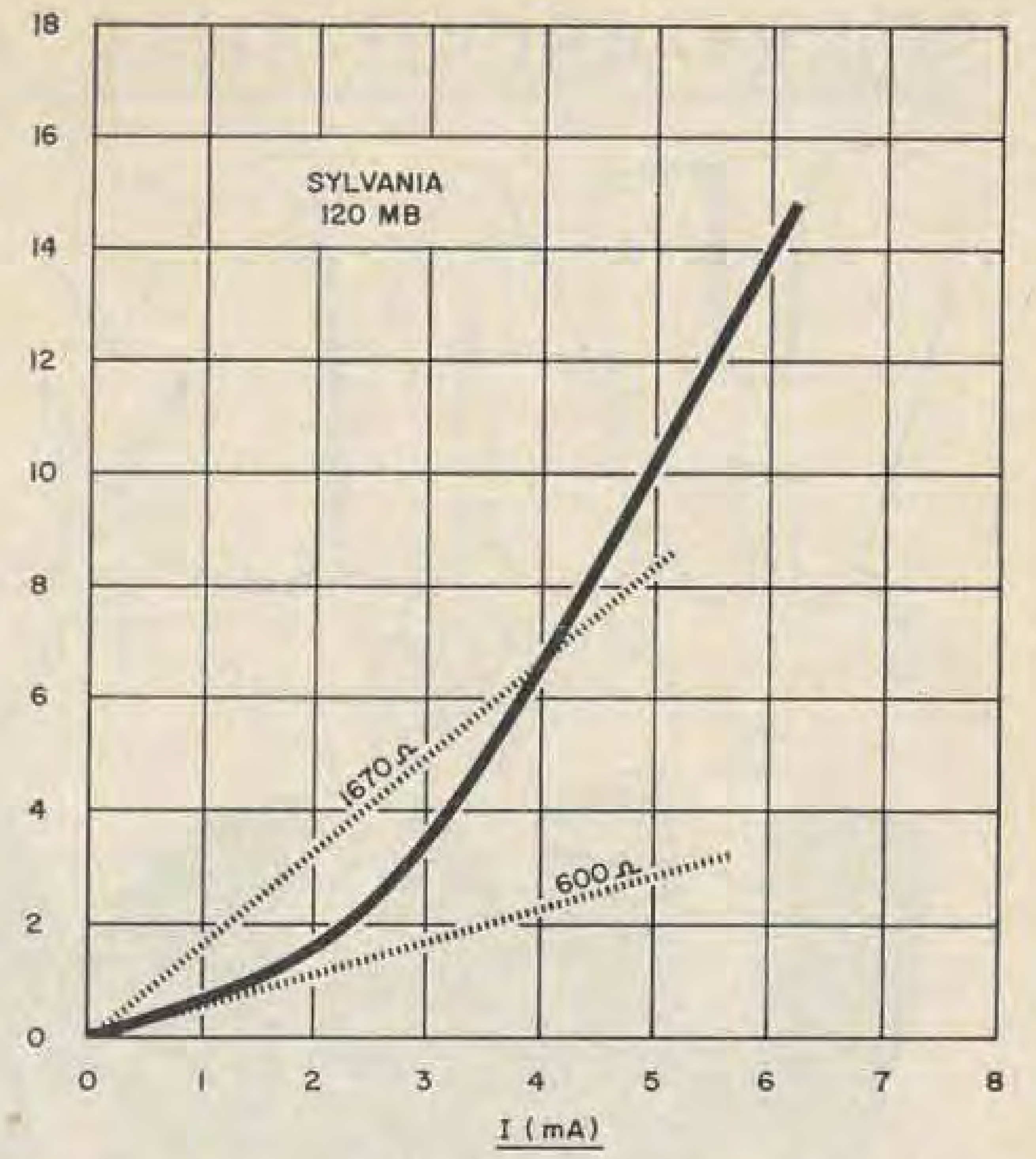


Fig. 6. E-I plot of the Sylvanis 120-MB pilot lamp.

a local surplus emporium; Their marked values were trusted.

As in the first oscillator, a small trimmer capacitor was placed in parallel with the C in the series arm of the bridge to make up for stray capacitance to ground (and the input capacitance of the FET.) This trimmer was not necessary except on the high range, where 500 pF capacitors were used.

A burgess U15, 22½ volt, battery was used to power the oscillator. It is mounted under the chassis in an Austin #113 battery clip. In this mounting configuration, the battery cannot damage the circuit board if it leaks. A test point is provided on the rear of the cabinet to test the battery voltage *under load.*

A quick check at 1000 Hz revealed that second harmonic content of the waveform was 48 dB below the fundamental. Higher harmonic content was greater than 50 dB down, with the even harmonics being the strongest. The output amplitude was within 1 dB across the entire frequency range.

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Proof Positive

Have you ever found yourself with a fine project to build, and then discovered that you have all the components on hand but the rf chokes used in the circuit? Perhaps you've wondered if any of the chokes you have in your junk box will work. Well, here's a way to find out. It's an old idea, but a good one. The only equipment you need is a grid dip meter. Set the GDO to the frequency of the part of the circuit in which you are going to use the choke. Then select a junk box choke that looks like it might work, and, holding one lead, touch the other to one of the exposed pins on the grid dipper coil. There will likely be a change in the GDO meter reading. The greater the change, the poorer the choke will work at the selected frequency. If little or no deflection is noted, the choke will work fine at this frequency. This is a good method for testing those TV peaking coils and other chokes found in so many junked TV sets.

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