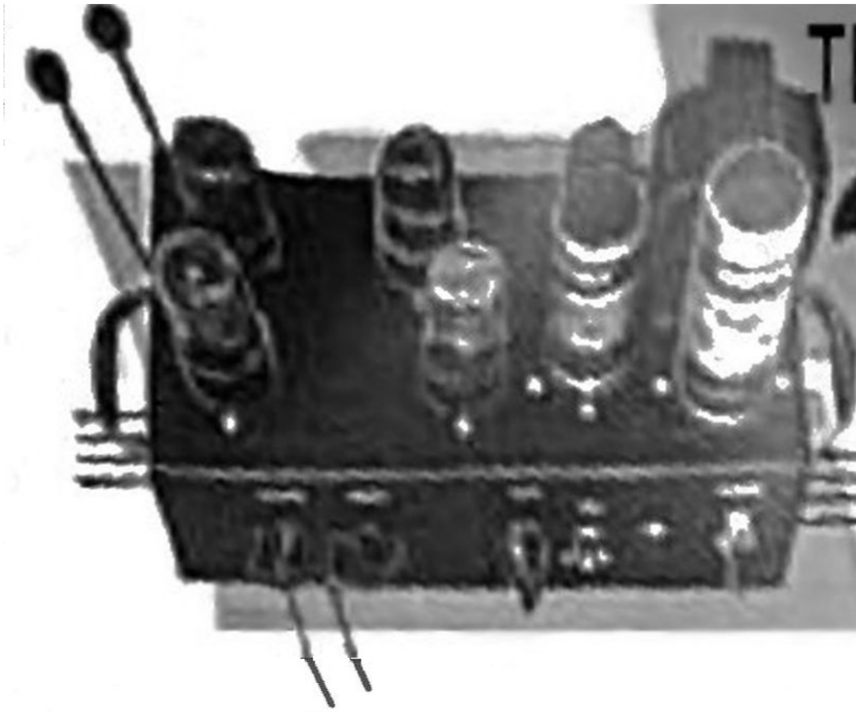
THE UNIVERSAL *Vibrato*



By

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A phase modulator circuit which can be used with guitars, organs, pianos, etc., to produce a realistic vibrato effect.

IN THE course of a great deal of investigation into the electronic production and control of music and publication of the results, the writer has received quite a number of requests for a vibrato circuit from guitarists and others. Until recently the only circuit capable of imparting vibrato to music originating from fixed-frequency sources was the elaborate electromechanical scanner used in some *Hammond* organs, and it is impractical for individuals to construct. Now, however, an entirely practical, easily constructed all-electronic circuit does exist. The writer has employed it in somewhat modified form in the "universal vibrato," a completely self contained device.

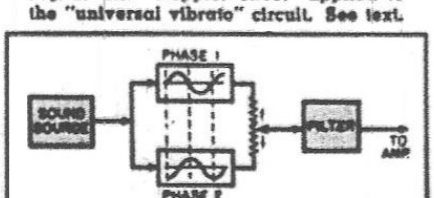
Either vibrato or tremolo is an important factor in music of almost every kind. To note its effect, hum a single tone, keeping the pitch perfectly constant as far as possible. Whether you are a crow-voiced musical duffer or a Metropolitan tenor, you will note that the tone is musically uninteresting. Now listen to a professional singer on the radio or from a record and note that when he sings a single tone he does *not* keep the pitch or frequency constant. He varies it up and down slightly at a rate somewhere between about 5 and 8 cycles-per-second. This pitch variation is known as "vibrato." It makes a tone interesting.

The violinist or other stringed-instrument player does the same thing by moving the finger with which he is pressing down a string. This varies the effective length of the string between 5 and 8 times per second and gives the vibrato frequency variation. Everyone who has seen a violinist play remembers that the left hand is always in vibratory motion; it is kept so to produce vibrato.

A few instruments have tone sources whose pitch cannot be varied. One of these is the pipe organ, whose pitch depends on the dimensions of the pipes. Another is the harmonica, whose pitch depends on the dimensions and mass of the reeds. In those instruments vibrato is impossible and the substitute is tremolo. Tremolo is a periodic variation in volume. In the organ it is produced by alternately blocking and unblocking the orifice in the chamber containing the pipes by mechanical means. In the harmonica tremolo can be produced by the vibratory movement of a hand at the rear of the instrument, closing and opening a path between the reeds and the outer air.

Players of instruments capable of vibrato must be fairly skillful to produce it. Many amateur guitarists do not have that skill. They employ contact microphones and amplifiers to give their instruments Hawaiian guitar effects. To provide the desired periodic variation some of these amplifiers contain tremolo circuits. Such circuits consist of a low-frequency oscillator, the output of which varies the gain of an amplifier stage at the oscillator frequency.

Fig. 1. The "Doppler effect" applied to the "universal vibrato" circuit. See text.



Unfortunately, however, tremolo—volume variation—is not nearly as pleasing as vibrato—frequency variation. But while it is easy to vary the volume of music, it is not as easy to vary its pitch electrically.

The "universal vibrato" does this seemingly impossible job. It can take music from any source whatever—any instrument, from a contact microphone, radio, records, tape—and vary its pitch up and down at a rate 5 to 8 times per second to produce the same effect as if the player had himself produced the vibrato. This means not only that the guitar player can have vibrato without working at it, but also that other instrumentalists can do the same. Of equal interest is the fact that instruments on which vibrato cannot be produced at all—pipe and reed organs, some *Hammond* organs, piano, etc.—can now have it, and some very interesting new effects are possible.

How It Works

The "universal vibrato" is a phase modulator. Its principle has been thought of before, but an embodiment of it was recently designed in detail and brought out commercially in a spinet electronic organ made by *Wurlitzer*, the Model 44. This organ has reeds as tone sources. The designers were dissatisfied with the tremolo which was produced by rotating vanes in front of the speaker on previous models and designed this circuit to provide a genuine tremolo.

To visualize how the principle works, remember the old illustration of the Doppler effect. A train is approaching you, blowing its whistle. As the train gets closer the pitch of the whistle seems to rise, reaching a maximum as the train reaches you. Then, as the train goes away the whistle pitch descends again.

The vibrato is like the moving train whistle. But instead of approaching and passing the listener, it travels on a reciprocating path — moving forward and backward, approaching, backing away, approaching, and backing away. Thus we hear the whistle pitch rise and fall, rise and fall. All this despite the fact that the whistle itself — steam blown against a mechanical whistle device—really remains at quite constant pitch as far as the train engineer (who remains at a constant distance from it) is concerned.

What is really happening, from the viewpoint of the trackside listener, is phase modulation. If the train remains a constant distance away, the pitch is constant. It takes a certain amount of time for the sound to reach the listener's ears; and all parts of the wave take the same amount of time, so that the ear hears each part of the wave in the proper order and with the same time separation as at the source.

When the train is moving toward the listener, however, that is not true. As the train gets nearer, the time required for the sound to get to the ear constantly decreases. As a result, the second half of the wave, for instance, gets to the listener before it ought to. And since the two parts of the wave are closer together at the ear than at the whistle, the ear assumes that the frequency is higher.

This Doppler effect is simply a case of advancing phase. The principle is used commonly in phase-modulated r.f. transmitters to produce frequency modulation. And this is exactly what happens in the "universal vibrato."

The idea is block-diagrammed in Fig. 2. The sound source, whatever it may be, is converted to audio by a microphone, tuner, pickup, or whatever it may be. From it two separate audio signals are derived. Each signal is an exact replica of the original, but they are displaced from each other in phase by approximately 90 degrees. In Fig. 2 phase 2 lags phase 1.

The two phase-displaced signals are connected (for illustration purposes only) by a potentiometer. The arm of the potentiometer is constantly moving up and down 5 to 8 times per second. At each end of the potentiometer the arm picks up maximum signal from one phase and minimum from the other. At medium positions it picks up a proportional amount of each. Thus the signal on the potentiometer arm is constantly varying in phase. As it travels toward the phase-1 signal, the signal it picks up is advancing in phase and the frequency apparently rises; as it moves toward phase 2, the phase is retarded and the frequency decreases.

Note that if the arm stops in a single position, the frequency remains constant. The two signals simply mix at the arm and produce a single signal of the same waveform as either signal and with a phase which is the resultant of the two, according to the proportion in which they are mixed. Since the ear is not sensitive to phase as such, the result, amplified and radiated from a loudspeaker, will sound just like any ordinary signal.

The faster the arm travels up and

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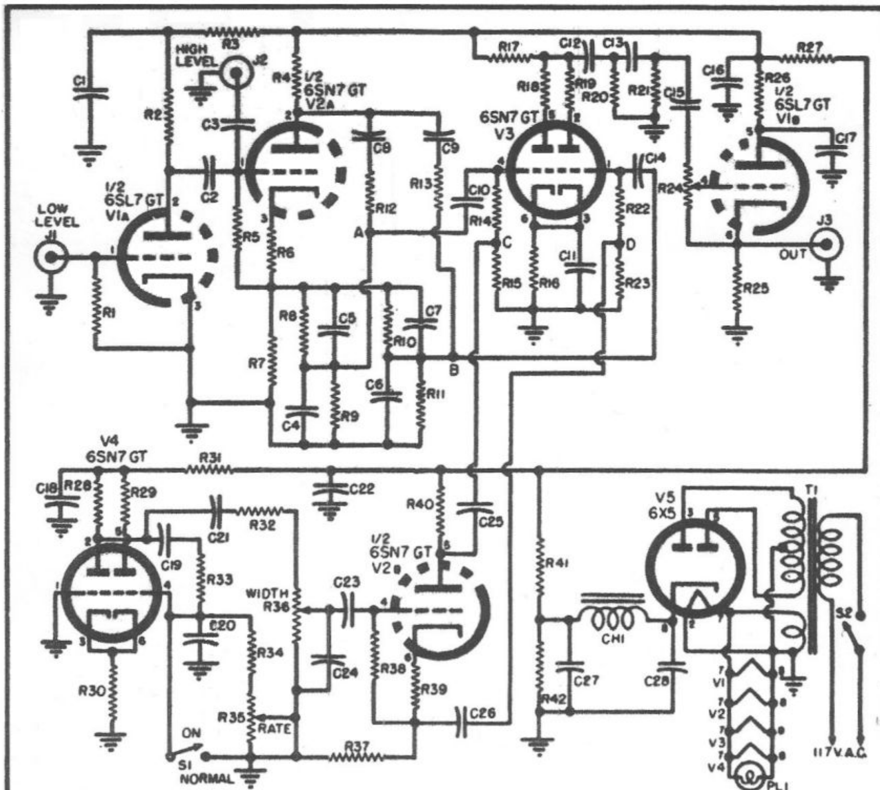

R_1—2.2 megohm, ½ w. res.
R_2, R_{14}, R_{22}, R_{33}—470,000 ohm, ½ w. res.
R_3, R_{25}—10,000 ohm, ½ w. res.
R_4, R_7, R_{37}, R_{40}—22,000 ohm, ½ w. res.
R_5, R_{15}, R_{23}—1 megohm, ½ w. res.
R_6, R_{16}—2200 ohm, ½ w. res.
R_8, R_{10}—390,000 ohm, ½ w. res.
R_9, R_{11}, R_{42}—150,000 ohm, ½ w. res.
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R_{18}, R_{19}—15,000 ohm, ½ w. res.
R_{20}, R_{21}—100,000 ohm, ½ w. res.
R_{24}—100,000 ohm, audio taper, pot
R_{26}, R_{31}—4700 ohm, ½ w. res.
R_{27}, R_{41}—4700 ohm, 1 w. res.
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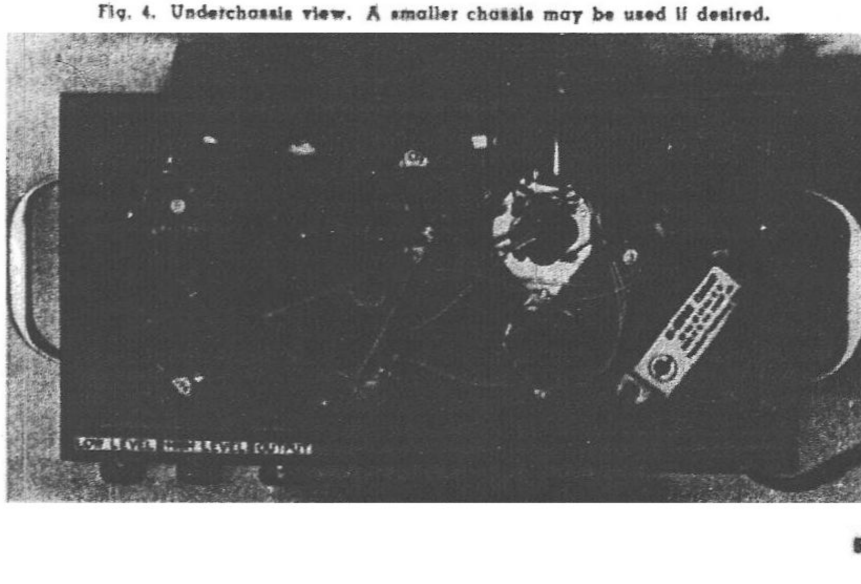
R_{32}—330,000 ohm, ½ w. res.
R_{34}—220,000 ohm, ½ w. res.
R_{35}—150,000 ohm, audio taper, pot
R_{36}—500,000 ohm, audio taper, pot
R_{38}—560,000 ohm, ½ w. res.
R_{39}—1200 ohm, ½ w. res.
All ½ w. resistors to be ±10%
C_1-C_{11}-C_{18}-C_{22}—40/20/40/20 µfd., 350/25/350/350 v. elec. cond.
C_2, C_3—.01 µfd., 600 v. cond.
C_4—200 µµfd., 600 v. ceramic cond.
C_5—100 µµfd., 600 v. ceramic cond.
C_6—750 µµfd., 600 v. ceramic cond.
C_7, C_8—500 µµfd., 600 v. ceramic cond.
C_9—.002 µfd., 400 v. cond.
C_{10}, C_{14}, C_{23}, C_{26}—.1 µfd., 200 v. cond.
C_{12}, C_{13}, C_{15}—.03 µfd., 400 v. cond.
C_{16}-C_{17}-C_{27}-C_{28}—20/20/40/40 µfd., 450 v. elec. cond.
C_{19}—.05 µfd., 400 v. cond.
C_{20}—.05 µfd., 200 v. cond.
C_{21}, C_{25}—.1 µfd., 400 v. cond.
C_{24}—.25 µfd., 100 v. cond.
J_1, J_2, J_3—Single contact, shielded, chassis mounting connector
CH_1—20 hy., 15 ma. filter choke
PL_1—6.3 volt pilot light (No. 47)
S_1—S.p.s.t. non-snap action switch
S_2—S.p.s.t. toggle switch
T_1—Power trans. 230-0-230 v. @ 50 ma.; 6.3 v. @ 2.5 amps (Stancor PC8418 or equiv.)
V_1—6SL7GT tube
V_2, V_3, V_4—6SN7GT tube
V_5—6X5 tube

Fig. 3. Complete schematic diagram of the "universal vibrato" unit.

Fig. 4. Underchassis view. A smaller chassis may be used if desired.



The Vibrato

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down the higher will be the rate of frequency change. (Also, to a minor extent in practice, the greater will be the apparent total frequency variation.) If the arm travels all the way to the ends of the pot the frequency will vary to its greatest extent; but if it moves only a little way each side of center the amount of frequency change will be small Obviously then, the vibrato rate and width (or depth) can both be controlled

The filter which follows the potentiometer is there to remove the frequency component representing the movement of the pot arm itself, which is below 10 cycles

Electronic Circuits

In the actual device there are no moving parts, the whole job is done by invisible electrons The entire circuit is diagrammed in Fig 3

In the "universal vibrato" pre- and post-amplification have been added to the vibrato circuit itself to make it more versatile V_1, is a preamplifier for low-level inputs The high-level input is satisfactory for most purposes When it is used with the volume control at maximum the device has approximately unity gain, and the output voltage is practically identical to the input. V_5 is the output amplifier, a cathode-follower, allowing a long line to the main amplifier

The first tube of the vibrato circuit itself is V_2, the phase splitter It looks like an ordinary "long-tailed" phase splitter, with equal loads in cathode and plate circuits to produce two outputs 180 degrees apart And this is just what it is.

The requirement for the vibrato circuit is to obtain two voltages which are about 90 degrees apart at all frequencies Phase-shifting circuits are quite common, but the amount of phase shift, as well as the amplitude of the output, in any single circuit is entirely dependent on frequency. To make the phase separation fairly independent of frequency it is possible to take two voltages 180 degrees apart and pass them through phase-shift networks so designed that as one signal shifts in phase due to frequency the other also shifts in such a manner as to keep the angle between the two at about 90 degrees. The angle of either changes with frequency with respect to the original signal entering the phase splitter. But this does not matter as long as we can derive two signals whose *separation* in phase remains constant. An article, "Phase Angle Measurements at A.F.", in the *Radio-Electronic Engineering* Edition of this magazine for July, 1953, explains this in detail and gives the calculations, though for a different purpose.

In Fig 3 the result is produced by the networks R_8-C_2, C_4-R_9, R_{10}-C_3, C_6-R_{11}, C_7-R_{12}, and C_8-R_{13}. The two signals

present at points A and B are sufficiently close to 90 degrees apart at all audio frequencies to give the needed result.

Each of these signals is fed through a 0.1-μfd. blocking condenser to one grid of V_1. The plates of V_1 are connected through separate 15,000-ohm resistors (for isolation) to a common load resistor R_{11}. At this point, assuming the tube operates normally, we would have a single signal of the same waveshape as the input with phase halfway between those of the signals at A and B.

The tube is actually operating as an electronic switch, however. To points C and D is connected a locally generated signal of a frequency between 5 and 8 cycles. When this signal makes point C most negative and point D most positive, the left triode of V_1 is cut off and the right triode has maximum gain; the reverse is true as well. Thus at one time the signal from point A appears at the output and at another the signal from point B appears. This means that the output of V_1 is constantly changing in phase, which will appear as a constant change in frequency. We have thus frequency-modulated the audio input signal and imparted a genuine vibrato to it.

The network C-C-C-R-R-R is a high-pass filter, of which R also acts as a volume control. The filter prevents the switching action of V from appearing in the output as amplitude modulation of the signal. Some AM may appear but it contributes to the pleasantness of the effect. The filter also reduces the low-frequency response of the system somewhat, but this is unimportant for most musical instruments, which do not generate tones low enough to be affected. If necessary a sharp-cut-off LC filter can be substituted, tuning for a cut-off just below the lowest musical note to be passed.

The switching signal is generated by V, which is a simple RC sub-audio oscillator. The frequency is determined by C, R, C, and the series value of R and R. R is the vibrato rate control which varies the oscillator frequency to determine how fast the vibrato should be. S, stops oscillation when it is closed, removing the vibrato.

The oscillator output is carried through C and R to a potentiometer R. The arm of this pot goes to the grid of V, the vibrato phase splitter. R is the width control, which determines how much frequency change there will be on each vibrato cycle.

While V is a phase splitter of the same type as V, no further phase-shifting networks are added. The two 180-degree-separated low-frequency signals are fed to the two grids of V_1 in push-pull as the switching signals.

Construction

In the case of this particular gadget it is impossible to claim that the neatest possible layout was made.

Probably not enough time was spent figuring out on paper exactly what underchassis room had to be made available where. However, the model was not really too far off and readers can do a better job by noting where the crowding occurs and acting accordingly.

The basic unit is an "amplifier foundation" 10$^{1}/_{16}$" long and 5" wide. The circuit could probably be built on a slightly smaller chassis but this size seems about the best. The chassis-cover "foundation" unit is more useful than a chassis-and-cabinet setup because all controls can be on the chassis apron without looking incongruous. Where there is a cabinet the controls ought to be on the front panel, which would require long leads coming through the chassis.

Fig. 1 shows the chassis top with the cover removed. At lower left is V, with V to its right. The tubes at the rear are, left to right, V, V, and V. The underchassis view of Fig 4 shows that the filter choke is mounted under the power transformer by two of the same screws that hold the transformer down. Switch S, the vibrato "on-off" switch, is a surplus item taken from an SCR-274-N antenna junction box, but any kind can be used.

The reader with a vibrato requirement need not, of course, build his unit just as this one was designed. If it is convenient it can be built into an amplifier between any two stages that do not handle more than 10 volts of audio. In that case it can use the amplifier's power supply. The "B" requirements are only about 15 ma., although the existing filament transformer should be looked over to be sure that it will stand an additional 900 ma. drag required by the vibrato-circuit tubes, V, V, and V in Fig. 3.

In using the "universal vibrato" with instruments which are primarily acoustic (where amplification need not be used or where the acoustic sound will be louder than the amplified sound) the way to add the vibrato is to make a recording, placing the vibrato between microphone and amplifier or between two amplifier stages. Instruments of this kind include pianos, pipe organs, and the like.

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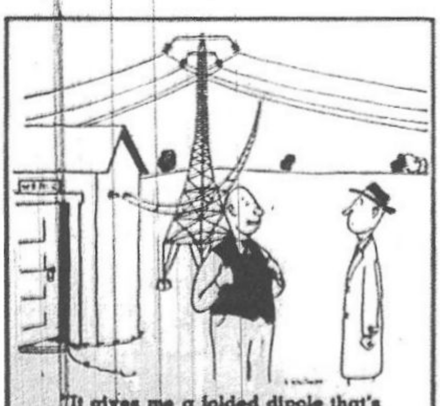
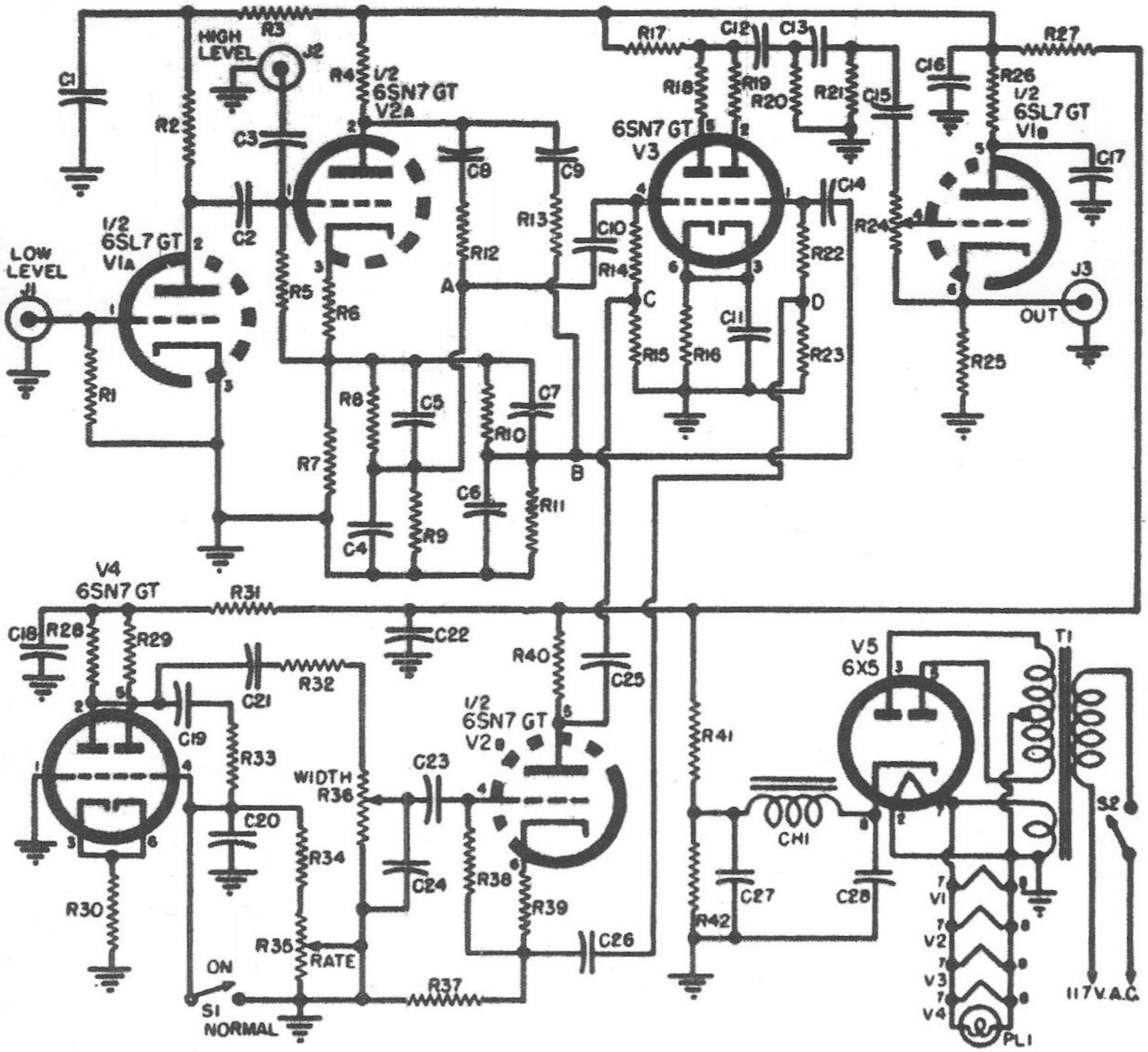


"It gives me a folded dipole that's about 1200 miles long . . ."



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