A Like-New

Mixer Circuit

By Staff

73 Magazine

October, 1961.

Would you like to improve the sensitivity and the stability of your receiver?

If you would, and don't mind delving underneath the chassis a bit, one of the quickest routes is to modify front-end circuitry. The technical article, "Up Front," in our March issue contained a rather complete collection of improved front-end circuits.

However, here's one which escaped attention when the article was prepared-and which has escaped almost everyone's attention since it was first developed. That's why we're calling it a "like-new" circuit; it's been around for a spell but it might as well be new since almost no one knows of its existence.

Before going into this circuit, it might be well to review the characteristics of a good mixer. The ideal mixer in a superhet receiver should:

(1) produce no spurious frequencies,
(2) provide ample gain for the signal,
(3) contribute no noise to the signal,
(4) provide complete isolation between oscillator and signal to prevent undesired radiation,
(5) present as light a load as possible to the oscillator to preserve frequency stability.

These characteristics, at least to a degree, are mutually incompatible with most conventional circuits. For instance, isolation of the oscillator from the signal circuit usually requires screening grids in the mixer tube, which in turn raise the mixer noise level and violate objective 3.

As pointed out in our aforementioned technical article, the best compromise to date has been the 6AC7 used as a pentode mixer, following the circuit described in Langford-Smith[1]. This circuit provided low noise, adequate gain, little in the way of spurious output, and adequate isolation for most purposes.

However, the particular version of the twin-triode cathode-coupled mixer which we're describing here outdoes the 6AC7 on all counts except gain, and runs it a close race there. On top of this, it can be installed in any set which uses an octal-base, a 9-pin, or a 7-pin mixer tube without changing the socket, since suitable twin triodes are available in all three basings.

The circuit is not original; it was found in K. A. Pullen's book "Conductance Design of Active Circuits," a volume[2] which incidentally should be in the library of every serious ham designer (plug unsolicited; Radio Bookshop please copy), and was field-tested in a vintage BC-779 in comparison with both a 6L7 and a 6AC7.

Results were judged on a purely subjective basis, due to lack of test instruments suitable for adequate and accurate measurements. numerical values mentioned here are calculated figures, but the field tests confirm them as closely as possible.

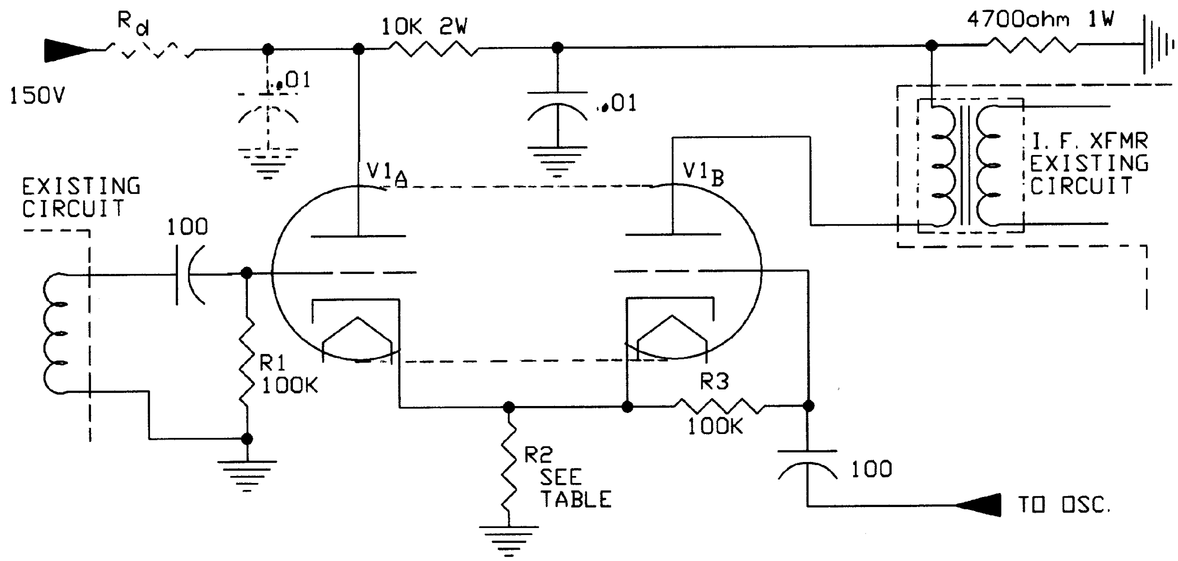

Fig. 1.

The full circuit is shown in the schematic, Fig. 1. Table I lists parts values and operating conditions which vary with different tube types or design objectives.

At first glance, you may be led to believe that this is approximately the same circuit as that recommended by Geisler[3] or Lee[4], or may be a version of the Crosby triple-triode product detector[5]. While the general configuration is similar, the circuit operation and its advantages are radically different.

The key point is the low value of plate voltage supplied to V1B. Pullen recommends only that V1B's plate supply be "considerably" lower than that for V1A. The best operation was found with 50- and 150-volt supplies, respectively, and component values shown are for use with these voltages.

By operating the two nominally-identical triode sections with a common cathode resistor but at two different plate-supply voltages, a relatively small change in current in one tube will cause a large change in the gain of the other. This is accomplished without sacrificing average gain in either tube.

In addition, the cathode-follower action of each stage completely isolates the oscillator from the signal circuit. Since the signal sees only a pair of triodes, noise is not increased.

This circuit is a true linear mixer rather than a detector; its output contains only the two original frequencies and the "product" of the original signals (numerically equal to the sum and difference frequencies but without their usual noise content). The chain of spurious frequencies usually found in detection-type mixer circuits is absent.

Those who have tried triode mixers before, even of the cathode-coupled variety, may wonder about gain. Calculations showed that the version first tested should have shown a conversion gain of about 20, as compared to the calculated pentagrid mixer gain of about 5 under the same conditions.

The test signal was a broadcast station with consistent strength. S-meter reading with the pentagrid mixer was recorded and the twin-triode circuit then substituted and mixer alignment readjusted. The S-meter showed just under 2 units improvement.

Considering the free-wheeling calibration of most S-meters, and this one was no exception, this is a remarkable correlation of theory and experiment. Frankly, we disbelieved it and substituted another tube which had a calculated gain of 13. After realignment, the S-meter dropped one unit.

Regardless of such gain figures, which are dependent on many variables not all of which are under control, this version of the twin-triode mixer shows more signal gain than many pentagrid mixers. Its noise figure is so low that mixer noise simply disappears, even with three *IF* stages following. The result is almost complete silence between stations, leading one to believe at first that the circuit is a dud. Then, though, a fading long-hop signal will come through, moving almost instantly out of the no-signal region into clear audibility, and the design is vindicated.

Every type of twin-triode tube tested to date works in this circuit, but some give better results than others. As noted in Table I, oscillator injection voltage requirements vary drastically from tube to tube. In a like manner, sensitivity varies.

Among octal-base tubes, the 6SN7 gives greatest gain but requires higher voltages to get there. The 6SL7 develops its gain (just half an S-unit less) with much weaker signals and much less oscillator injection. Therefore, the 6SL7 is recommended.

Table I.
Voltage Requirements for Various Tubes and Values of R2 With Typical Conversion Gain

Tube	6SN7 (also 12AX7)			6SL7 (also 12AU7)			12AT7			6J6	
Value of R2	100	500	1000	100	500	1000	100	500	1000	100	1000
Input--Voltage (Signal)	2.1	10.5	21	0.32	1.6	3.2	1.4	7.0	14.0	2.1	21
Input--Voltage (Osc.)	2.5	11.5	22.4	0.42	1.9	3.6	1.6	7.0	13.1	2.3	22
Conversion-Gain if IF Xfmr impedance Is 50K ohms (For Comparison)	18.5	18.3	18.0	13.9	13.7	13.6	100	150	160	80	130

Dozens of twin triodes are available on 9-pin bases; among the most popular are the 12AX7, the 12AU7, and the 12AT7.

The 12AX7 is directly comparable with the 6SL7, and the 'AU7 with the 'SN7. However, the 12AT7 is the hottest tube available for this circuit, with a gain of more than 100 and comparatively low injection- and signal-voltage requirements, so it's the only recommended type. If you're willing to change sockets, the 12AT7 is the best for any set regardless of original tube type.

In the 7-pin basing, there's only one choice – the 6J6. Aside from the fact that the 6J6 is the only 7-pin twin triode easily available, it is surpassed only by the 12AT7. Gain is in the neighborhood of 100 (see Table I).

The entire circuit is simplicity itself to install. Remove all old connections from the mixer-tube socket, being careful not to cut short either the grid lead from the tuning coil or the plate lead from the *IF* can. Then rewire according to the schematic.

If you don't have +150 vdc available in your receiver (many don't), install resistor Rd and its bypass capacitor (shown on the schematic in dotted lines). Value of Rd must be determined by trial and error. Start with 50K ohms, and work down until you find the resistor which gives 150 volts at point A after everything has warmed up.

With the new mixer installed, you'll have to realign the mixer tuned circuits. The cathode-follower inputs reduce input capacity so drastically as to completely detune the stage, so don't be surprised if nothing comes through at first.

The input capacity change has least effect at the low end of any band, so it's best to reverse normal alignment procedure and start by adjusting the *trimmer capacitors* in the tuning assembly at the *low end*. Simply adjust for maximum signal strength (or higher S-meter reading).

Next, tune to the high end of the band and rock the trimmer slightly to see if the adjustment is optimum. If not, adjust the trimmer again for the best high-end signal strength.

If the high end required adjustment, return to the low end but this time adjust the coil slug for maximum signal. Then return to the high end and readjust the trimmer. You may have to repeat this slug-at-low-end-and-trimmer-at-high-end procedure several times to restore tracking, since the change in input capacity usually amounts to about 10 mmfd, which upsets original tracking adjustments. However, with patience the tracking can be made to surpass the original condition.

For the theory-minded, here's how this mixer operates

First, imagine that the second half of the tube, V1B, is not in the circuit at all. Signal voltage supplied to the grid of V1A varies the tube's plate current, and this variation of current through cathode resistor R2 varies the instantaneous voltage from the cathode end of R2 to ground.

Now add V1B to the circuit, but keep the oscillator turned off. The circuit is now a cathode-coupled amplifier. Since it is biased to operate in a linear region, the only output frequency is the signal frequency, which is bypassed to ground through the *IF* transformer. Output is nil.

Remove the signal voltage from V1A, apply the oscillator voltage to V1B, and the situation is reversed. Now V1B is the cathode follower and V1A the grounded-grid amplifier (with no load in the plate circuit). Output is still zero.

With both signal and oscillator voltages applied, the situation changes. V1B is a grounded-grid amplifier for the signal, but its bias is being changed also by the oscillator signal and as a result its gain varies from zero (at cutoff) to maximum (zero bias) at the oscillator frequency.

Thus, at the instant when signal voltage is high and oscillator voltage is low, V1B will have maximum gain and output will be high. If oscillator voltage is high at that instant, output will be low because V1B's gain will be zero.

This can be expressed mathematically too The gain of two cascaded amplifiers is equal to the product of their individual gains. That is,

$$K_{total} = K_1 \text{ x } K_2.$$

In this circuit, K_1 is equal to the gain of V1A and K_2 is equal to the gain of V1B.

However, gain is equal to the product of the tube's mutual conductance and the effective load resistance, and the mutual conductance of a tube is determined in part by its grid bias. If this bias is changing at a rapid rate, as it is in this circuit, the gain will be equal to average gain times the rate at which bias changes, or

$$K_2 = K_{2AV} \text{ x } F_{osc.}$$

Plugging this equation back into the original total gain equation gives us:

$$K_{total} = K_1 \text{ x } K_{2av} \text{ x } F_{osc}.$$

Since the output signal is, by definition, equal to the input signal times the total gain, we have for an input signal

$$F_{sig}$$

an output of

$$K_{total} = K_1 \times K_{2av} \times F_{osc} \times F_{sig}$$

, and since AC signals are *vector* rather than *scalar* quantities, the indicated multiplication must be carried out by vector rather than by straight arithmetic methods. The result is that the output consists of the original two frequencies, the numerical sum of the original frequencies, the numerical differences, *and nothing more.*

Getting away from the exotic mathematics, the big difference between this process and detection-type mixing using non-linear devices such as diodes or overdriven tubes is that only four output frequencies are present. Harmonics and spurious outputs are not.

In addition, the cathode follower is far more tolerant of overload than is any other basic amplifier circuit, and as a result no clipping or distortion occurs in the mixer.

A common problem with many conventional mixers is cross-modulation, in which two carriers become "intertwined" and an unwanted signal rides in on the one you want.

Even under extreme conditions, such as local injection of a signal strong enough to almost block the *IF* strip, cross-modulation could not be induced in this mixer. Apparently this is another by-product of its unusual method of operation.

Although no tests have yet been made, Pullen's analysis of the circuit indicates that it should provide a good high-output product detector for converting SSB and CW to audible signals; simple substitution of an RC coupling network (or an audio transformer) for the *IF* transformer is the only circuit change, though you might want to increase the value of resistor R2.

In summary, this overlooked mixer circuit appears to offer extreme advantages over more conventional circuits in all of the five characteristics of the ideal mixer, with fewer parts than usually required. It works as well in the set as it does "on paper" in the design stage, and can easily be adapted to any receiver. Try it, and let us know how it works for you.

References:

1. Langford-Smith, F., “Radiotron Designer's Handbook”, Fourth Edition, Radio Corporation of America, Harrison, N. J., 1968, pages 988 and 967.
2. Pullen, K. A., “Conductance Design of Active Circuits”, John F. Rider Publisher, Inc., New York, 1969.
3. Geisler, Leonard, "Souping The Super-Pro," CQ Magazine, December, 1957, page 80.
4. Lee, Cmdr. Paul, "Save Your Super-Pro For SSB," CQ Magazine, September, 1958, page 52.
5. 73 Staff, "Beat Generation," 73 Magazine, February, 1961, page 28.

Uncited by number. 73 Staff, "Up Front," 73 Magazine, March, 1961, page 32.

(Editor’s Note: In the original circuit, as published by Keats Pullen, a triode HFO’s output is coupled through another cathode-follower to the input grid of the mixer, V1B. This substantially alleviates, if not totally eliminates, the pulling on the oscillator that was noticed in the follow-up 73 Magazine article of August 1966 entitled “Another Look at the *Like New* Circuit”)