Another Look at the Like New Circuit

A low distortion low noise mixer for those who use tubes

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It's always nice to find a better circuit. Improving the operation of a piece of gear is in more ways than one a rewarding activity. And also in constructing new homebuilt items a new circuit may mean the difference between poor and good performance or enable the builder to eliminate a tube or two.

A very good practice before firmly committing yourself on a new circuit is to try it out on a breadboard. With a little care its normal operating conditions can be approximated well enough to give a good idea what it will do when installed in the finished chassis. Experience gained during breadboarding is likely to be valuable during the final debugging session and helps in planning circuit layout.

Simple circuits, if they will do the same job, are generally preferable to complex ones. One such circuit is the Like New circuit presented in the October 1961 issue of 73 Magazine. This uses a twin triode to replace the complex and noisier pentagrid converter. Requiring a simpler tube and only one supply voltage, it offers the same or better performance. A good trade!

But the circuit as originally presented seemed to suffer from two shortcomings. These were, loading of the local oscillator and a question of its stability with tube and component aging.

With the local oscillator grid resistor returned to the cathode rather than ground, there is no bias on the second triode unless the local oscillator is running. The bias comes from grid rectification so there is some loading on the oscillator.

The small resistor carrying cathode current has little control over how much current is flowing. If the vacuum tube properties change, so must the cathode current and the operating point.

This circuit looked like a good bet for a project of building a specialized receiver. It was not clear how it worked, but the glowing description was most encouraging. So a little thinking about it brought out the idea that it was very similar to a difference amplifier and as such might turn out to be a real linear mixer.

To make a long story short, it is not a linear mixer. The circuit, to work properly, must have a nonlinear element: the plate characteristics of the second triode appear to be in a region where an approximate square law transconductance rule holds. Of this more later.

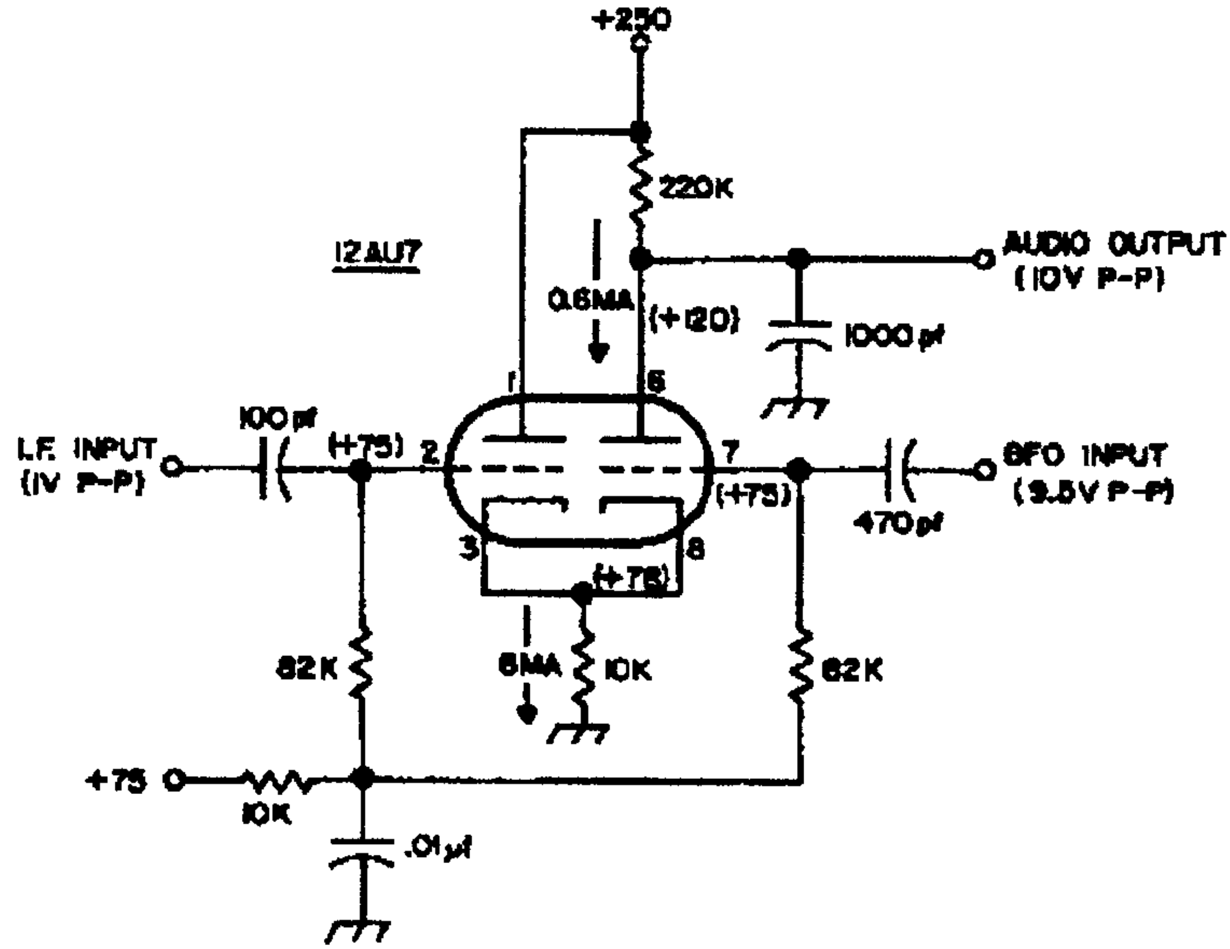

Fig. 1. Modified Like New mixer circuit.

Fig. 1 is a diagram of the completed circuit as used. Although it looks rather different from the original Like New circuit, the changes are really only skin deep. It is arranged to have improved resistance to overloading, better bias stability, and does not require any power from the local oscillator to generate its bias voltages.

The biasing system will look strange to the amateur eye. It is not a conventional practice to operate grids at plus 75 volts and use great big cathode resistors. However, this works out well.

The values shown are those that were obtained using a 12AU7 twin triode and the circuit resistances shown. Also indicated are circuit currents and the peak to peak values of the signal voltages. Both inputs were slightly below 6 Mhz, with frequencies a few hundred cycles apart. It was used as a second detector; conversion of an *IF* signal to audio.

A good place to start in discussing this circuit is the biasing system. A constant-current or long-tailed bias network sets the tube operating points. This name refers to the large resistor from cathodes to ground, which determines the tube current. An indication of how powerful its control is may be found by supposing the tube current to be momentarily disturbed by a 1 mA increase.

This will produce a 10 volt voltage change on top of the resistor. With a transconductance of around 5 mA/V, the 1 mA increase in current will cause the tube to turn off about 50 mA. If any change in cathode current is countered by a change 50 times greater in the opposite direction, the long-term stability of the current will have to be pretty good.

This resistor is selected by, first, deciding how much current is to flow. Then a convenient grid voltage is decided on—something like ten times the anticipated grid-to-cathode voltage is a good choice. This sets the cathode voltage roughly and a plate characteristics

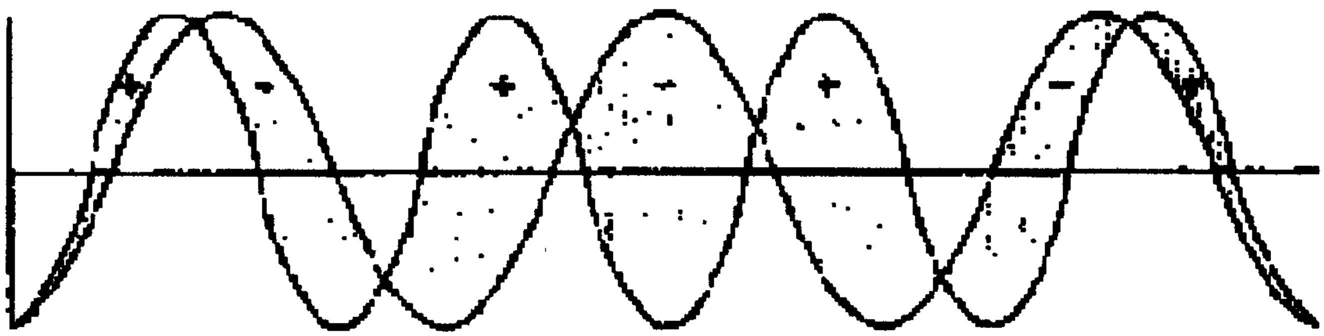

Fig. 2. Result of perfect addition of two sine waves of slightly different frequency, but the same amplitude.

chart together with an educated opinion about the anticipated size of the anode resistor locates the quiescent point which in turn locates more exactly the grid to cathode voltage.

The cathode must be positive with respect to the grid. So the required bias voltage is added to the previously fixed grid voltage, which gives the cathode voltage. The cathode voltage is divided by the cathode current to obtain the size of the cathode resistor—and there you have it. With this resistor in place, the anode current will show considerable resistance to being changed by various sizes of anode load resistance.

Since the grids do not draw any current, a resistance divider carrying a mil or so supply lines can fix the grid voltages, but in order to avoid coupling from one grid to the other through the bias network, there should be a generous by-pass capacitor to ground.

Now let's look at what goes on in this circuit. There are two conditions to consider: DC conditions with no signal at all on either grid, and the slightly revised operating conditions when signals are coming into both grids. Since these conditions are not very different it is simplest to discuss only the operating conditions.

Although both cathodes are connected together and both grids are biased to the same voltage, the two triodes are in very different parts of their operating regions. There is over 7 mA flowing through the left triode and about 0.6 mA flowing through the right one. This is because of the difference in plate voltages: most of the current is going to the triode with highest anode voltage. Consequently the LH triode is a strong, healthy cathode follower and the RH triode is a weak, nonlinear amplifier working into a very large load resistor.

Fig. 2 shows why this is required for best operation. The two sine waves are of slightly different frequencies. The chart is constructed by drawing them both same size. and shading in the area between them, marking these areas plus when one curve is on top and minus when the other is on top. This situation repeats itself periodically and may be charted out to extremely long times if desired. However the main ingredients of the situation appear quite early.

Namely, if we use a circuit that puts out the exact instantaneous difference voltage of these two frequencies the output isn't going to be of much value. But if somehow one kind of difference—say the one labeled plus—can be emphasized over the other, the result will be a signal emphasizing the real difference between the two frequencies.

This explains why the second triode must he operated at a very small plate current. In this region it is near cutoff and its curve of plate current as a function of grid to cathode voltage is strongly curved. If the grid to cathode voltage goes more negative, the anode current can change only a little—if it goes more positive, the anode current can increase considerably.

In short, this circuit is a nonlinear amplifier of the difference between two frequencies. I have to admit to Jim Kyle that my previous understanding of how this circuit worked was wrong!

This leaves only the function of the second anode bypass capacitor to discuss. It is necessary to bypass RF from the second anode to ground. In another way of speaking, it smooths out the anode current so that the following circuit sees only the average current. It does not need to be a very large capacitor since the second triode has a high output resistance and it would not be very hard to bypass its entire output to ground. A properly chosen capacitor can give a rolloff curve to de-emphasize the higher frequencies, a simple step for reducing the effects of noise.

As it is presently being used, this circuit gives good gain, is immune to the blocking effects of noise, and appears to be as good as it is supposed to be. It makes a much better second detector than the converter tube it replaced. With appropriate revisions it can be used as a first detector which brings us full circle since that is the originally described application!

With this circuit available, the amateur builder can develop and build a really good receiver with only one or two kinds of tubes—all triodes. For instance, the input RF amplifier would be a cascode. This would feed some version of the 73 mixer circuit, with triode local oscillator. From here we would go to a crystal *IF* as described in the April 1961 issue of 73. This would then feed a twin triode circuit similar to that just described. and one or two more triodes would make up the output stages.

If this were properly done. only three tuned circuits would be required in the entire receiver. They would be, the input circuit, the RF to mixer interstage coupling, and the local oscillator tuning circuit. The BFO would be a crystal oscillator. For the higher frequency ham bands or as a narrow-range receiver fed by a converter it would be necessary to tune only the local oscillator. The first *IF* input? Use a resistor! Think about it-it can be done! . . . W2DXH

(Editor’s Note: Again, as Keats Pullen pointed out, eliminating any pulling on the oscillator can be accomplished by simply using another cathode follower between the LO (or BFO in this case) and the mixer grid.)