A Synchronous Oscillator FM-Stereo Adapter

This FM-stereo adapter is designed to convert most existing FM tuners to stereo. All that is required is 0.5-volt output at the FM detector.

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NOW THAT THE Federal Communications Commission has approved a system for stereophonic FM broadcasting, Crosby Electronics Inc. (a subsidiary of Crosby Teletronics Corporation—one of the initial proposers of FM multiplex) set about to fill the many requests from dealers and consumers for a medium priced, reliable adapter for FM-stereo. The result of this work is the Crosby Model MX-101 (see *Fig.* 1). Measuring only $5\frac{1}{4} \times 4\frac{1}{2} \times 9$-in., the Model MX-101 is a universal adapter, in that it will decode stereo when connected with any tuner or receiver which provides at least 0.5-volt total output from the multiplex output jack of the particular receiver with which it is to be used when total deviation at the transmitter occurs. This criterion renders virtually all tuners usable with the MX-101 although there are some tuners which have outputs lower than 0.5 volt and therefore will not provide sufficient 19,000 cps pilot carrier to insure "lock in" of the local oscillator.

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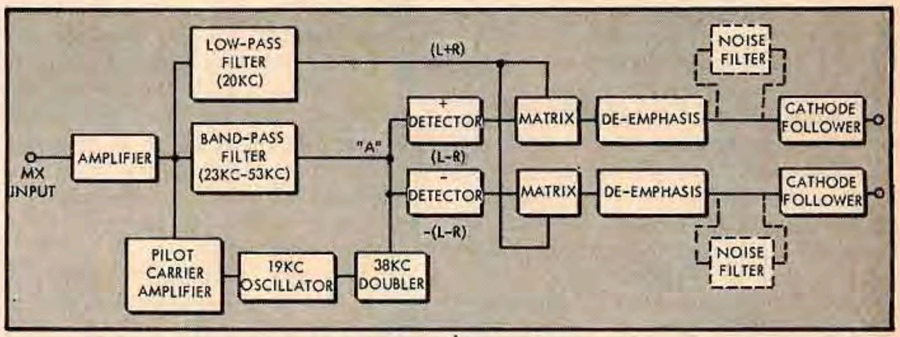

Fig. 2. Block diagram of the MX-101.

Fig. 1. Crosby MX-101 FM-stereo adapter.

Circuit Block Diagram (*Fig.* 2)

The entire signal recovered from the multiplex output jack of the existing tuner or receiver is first fed to a stage of amplification. Approximately 10 db of over-all amplification is provided in this stage. The amplified composite signal is then utilized in three distinct fashions. The upper block consisting of a low-pass (23,000 cps cut-off) filter removes everything from the composite signal but the pre-emphasized L+R (monophonic) signal. This signal will be used subsequently for matrixing with the recovered L-R signal.

The center block, consists of a band-pass filter which passes frequencies from 23,000–53,000 cps. These are the signal elements which contain the L-R information in the form of carrier suppressed, double sidebands. For example, a 1000 cps L-R tone would be represented in the composite signal by two sidebands, 37,000 and 39,000 cps, the 38,000 cps subcarrier having been suppressed from the normal AM waveform.

The first lower block consists of a 19,000 cps pilot-carrier amplifier. It will be recalled that this pilot carrier, as prescribed in the approved system, can have a maximum amplitude of only 10 per cent of full modulation of the main carrier. As was noted above, a tuner having an output of 0.5 volt for full modulation would produce only 0.05

volts of 19,000-cps pilot carrier and even this low voltage would only be present under conditions of full limiting in the tuner or receiver. Thus, even lower tuner outputs may be expected in practice. For this reason, the pilot signal must be further amplified. It is this amplified signal which is used to synchronize the normally free-running 19,000 cps local oscillator which is shown as the next block in this lower chain.

Much thought has been given to the importance of stability in this local oscillator. For example, let us consider an oscillator with 0.02 per cent stability. Well, 0.02 per cent stability of a 19,000 cps oscillator represents 3.8 cycles of drift under free-running conditions. The FCC, in its report, indicates that *3 deg.* of shift is all that can be tolerated between the transmitted pilot and the 19,000 cps generated in the receiver itself. Three degrees represents 1/120 of *one cycle*. Obviously, such oscillator stability could only be achieved if a crystal oscillator (probably oven controlled) were used in home adapters. The economics of the situation preclude such refinements. Thus, it is not so much oscillator stability that is important here, as the ability of the pilot carrier to effectively *lock* the local oscillator to its own frequency and phase. For this reason, emphasis has been placed on adequate amplification of the 19,000 cps pilot.

The properly phased and "locked" oscillator output is then passed through a doubler stage, which results in a 38,000 cps output in every sense the equal of the carrier originally suppressed at the transmitter. (This carrier was dubbed an "exalted carrier" many years ago by Mr. Murray Crosby.) The carrier is reinserted (by passive mixing) to the related sidebands and the conventional and familiar AM envelope may be readily observed at point "A" in the block diagram.

To recover the L-R content of the signal, we need merely use a conventional AM detecting diode. Since both (L-R) and – (L-R) will be required for algebraic matrixing, however, two such diodes are actually used, connected in opposite polarities.

The L + R signal (which has been waiting patiently all this time) is now added to (L-R) to produce 2L and to – (L-R) to produce 2R. Because the signal derived from the tuner has as yet not been de-emphasized, it is necessary to pass the resultant L and R signals through conventional 75 microsecond de-emphasis networks, to restore correct frequency response.

It has been universally recognized that while the monophonic listener receives a non-degraded signal-to-noise ratio even when stereo transmission is in progress, the stereo listener will not be so fortunate. Estimates of signal-to-noise degradation for the stereo listener have been made by knowledgeable engineers at anywhere from 13 to 20 db for a given signal strength. This means that what *was* a 40 db signal-to-noise ratio for a given condition (and therefore quite tolerable) may now result in a 20 db signal-to-noise ratio when stereo is broadcast (recognized by one and all as quite intolerable). Of course, antenna installation improvement may well provide part of the answer. Unfortunately, most FM set owners are conditioned to the idea that a "hank of wire" loosely thrown around the living room baseboard is all that is required in the way of an antenna for FM reception. This simply won't do for stereo. Recognizing that we can't change everyone's thinking overnight, we have therefore incorporated a "noise filter" at the output of each channel which should help to cut down "hiss" in noisy areas. *Caution:* It will also cut down highs—in much the same way that the "record scratch filter" on your amplifier does. It is our feeling, however, that stereo without hiss and with some sacrifice of high-frequency response is still better than stereo steeped in background noise. If noise had been what we wanted we could have been content with the AM-FM simulcasts which we hope are seeing their last days!

The block diagram then shows a pair of cathode follower outputs, to enable long cable lengths between adapter and

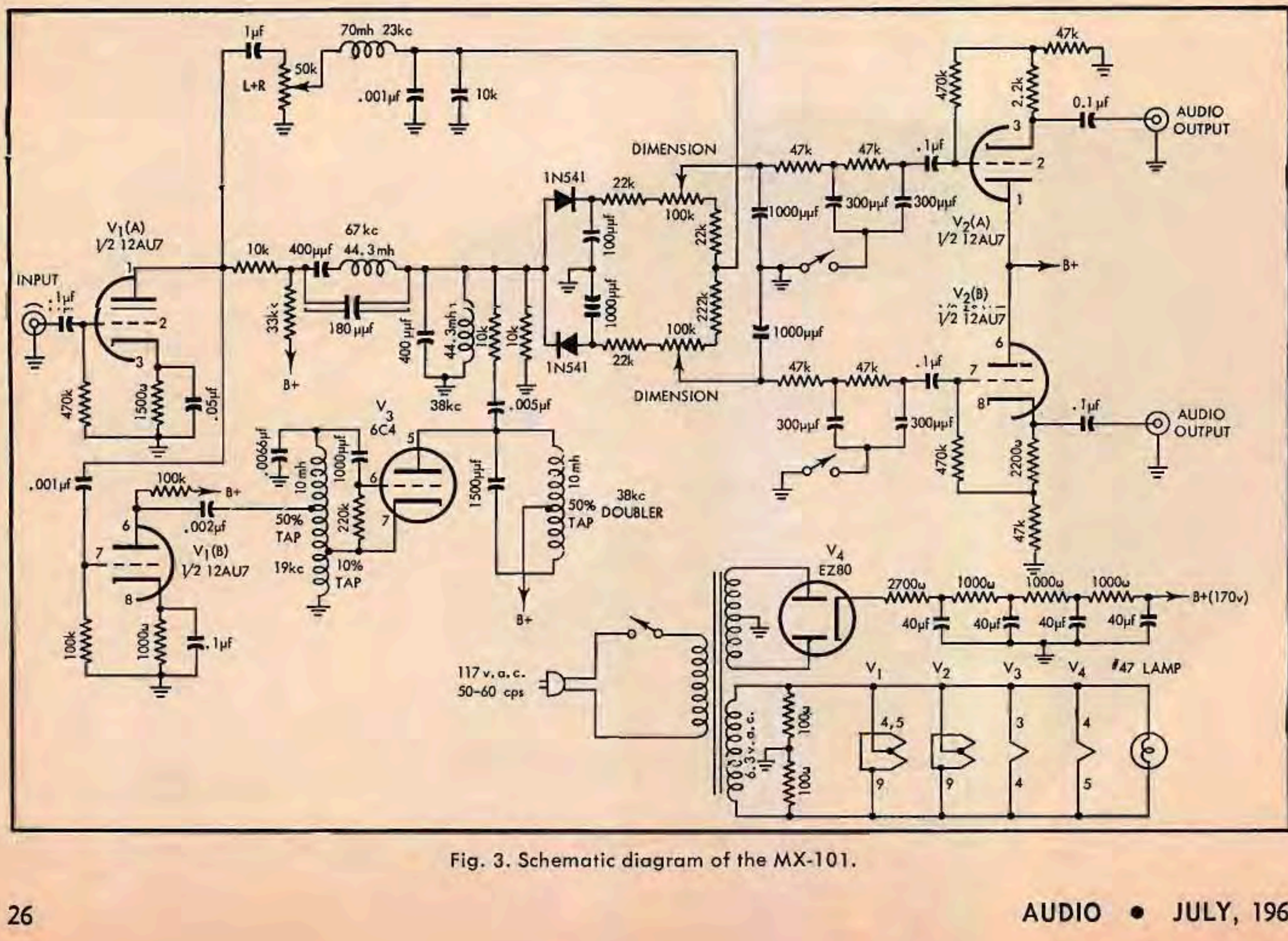

Fig. 3. Schematic diagram of the MX-101.

amplifier with no sacrifice of highs and no increase in hum.

Circuit Diagram of the MX-101

A complete circuit diagram of the Model MX-101 is shown in *Fig.* 3. The reader is cautioned that certain elements of this circuit are covered by patent and may not be utilized for commercial purposes without a licensing agreement.

There are several points of interest which can be seen by referring to this schematic. One section of a 12AU7 is used as the first amplifier of the composite signal. The other half of this 12AU7 is used as the pilot carrier amplifier. It will be noted that tuned circuits are not used in this second stage. These were not necessary for two reasons. First, the value of coupling capacitors chosen (0.001 μf to the grid, 0.002 μf from plate to oscillator tank circuit) are sufficiently small as compared with their terminating impedances as to attenuate main channel (30 cps to 15,000 cps) frequencies. Secondly, both these groups of frequencies and those associated with the L-R channel (23,000 to 53,000 cps) are sufficiently removed in frequency from the 19,000 cps oscillator as to cause no pulling effect on the oscillator itself. Had straight amplification of the 19,000 cps signal been used in lieu of a local oscillator, the amplifying circuits would all require high-Q tuned circuits throughout, to prevent possible doubling of the higher audio frequencies and their subsequent interference in the "exalted carrier injection" process.

The oscillator itself is a conventional Hartley type, in which the synchronizing signal is applied at a centertap on the coil of the tank circuit. Approximately 6–8 volts (of 19,000 cps) can be measured at the top of the tank circuit and, as a consequence, 10 volts or more of d.c. bias will be measured at the grid of the 6C4. It is operation at this nonlinear point of the 6C4's dynamic curves that results in substantial doubling in the tank circuit in the plate of the 6C4, which is, of course, tuned to 38,000 cps. Observation of the waveform at pin 5 of the 6C4 by means of an oscilloscope will show sine-wave trains in which the first cycle is somewhat greater in amplitude than the second, with the third cycle larger again, the fourth smaller etc. This indicates that the signal, although predominantly 38,0000 cps, does contain a small amount of residual 19,000 cps signal as well. The presence of this residual 19,000 cps signal in no way affects the performance of the signal as a carrier suitable for reinserting into the (L-R) sidebands. A .005 μf capacitor serves to couple the subcarrier to the junction point of the two detecting diodes, at which point all the sidebands are also present. The choice of correct amount of subcarrier for injection at this point was perhaps the most difficult decision which had to be made in the design of the MX-101.

On the one hand, approximately 30 per cent modulation of the total envelope would lend itself to the most distortion-free AM detection and audio recovery. On the other hand, it is desirable to recover as much audio as possible in one fell swoop, so that no further audio amplification would be required and so that best signal-to-hum performance might be obtained. To complicate the situation further, there is absolutely no consistency from tuner to tuner as to the amplitude of subcarrier sidebands that might be obtained (since this factor is governed strictly by the design of the given tuner) as compared with available 38,000 cps carrier (which is governed purely by the adapter itself).

It was decided, after a survey of many existing tuners, that from 3 to 4 volts of 38,000 cps carrier should be made available at the "insertion point" (junction of diode detectors). The reasoning was as follows: Most tuners produce approximately 1 volt output at their detector outputs under conditions of 100 per cent deviation (75,000 cps). As has been stated, the first amplifier stage has an over-all gain of about 10 db, so that approximately 3 volts would be obtained at the plate of the 12AU7. This signal is divided by the two plate resistors (10,000 and 33,000 ohms) by about 3 db and then another 6 db of attenuation is provided by the action of the filter termination (10,000 ohms) at the junction of the diodes, so that approximately 1 volt is again present at the junction of the diodes, for conditions of maximum modulation. Therefore, 1 volt of AM on 3 to 4 volts of the 38,000 cps reinjected subcarrier results in an AM envelope which is just about ideal for best detection by the diodes. However, even double the output of L-R subcarrier components from some particular tuner would result in less than 50 per cent AM of the total envelope and would still not produce inordinate distortion figures upon detection of the waveform. Conversely, a tuner having only 0.5 volts of output for 100 per cent modulation would produce an AM envelope of nearly 20 per cent and would result in recovered audio somewhat lower than in the foregoing case, but certainly adequate in terms of the signal-to-hum capability of the adapter.

Following the L + R channel (upper part of the schematic), it will be noted that a 50,000-ohm potentiometer determines exactly the right amount of L + R to be matrixed with (L-R) and – (L-R) signals available from the 1N541 detectors. This control, normally factory adjusted, is important for still another reason. While the FCC permits equal modulation of both the main and subchannels, it is quite possible that individual stations may wish to vary that formula at the beginning. L-R in average musical programming is invariably less in amplitude than L + R. Thus, to take advantage of as much signal-to-noise capability as possible, a station may wish to transmit (L-R) at slightly higher relative amplitude than L + R. The station can do this without deviating from FCC specification, since (L-R) normally is lower in amplitude than L + R just by virtue of the nature of most stereo programming. Should a station arbitrarily elect to take advantage of this situation, it will be necessary to readjust the relationship between L + R and L-R at the receiving end for optimum stereo separation. The converse may be true at first, as well. Some stations may, because of present equipment limitations, be forced to ***attenuate*** the L-R component with respect to the L + R component simply because their subcarrier equipment is not presently capable of 90 per cent modulation of the main carrier. In this case too the L + R to L-R relationship may well have to be readjusted for best stereo separation.

At first glance, the "dimension" control may appear to be a repetition of the control just discussed. It actually differs in two ways. First, it is a front panel control, accessible to the user. As such, it can be used to "touch up" separation, increasing or decreasing the separation effect at will. For the perfectionist, however, it serves still another function. You will recall that de-emphasis takes place ***after*** matrixing in this particular design, and that this de-emphasis should be 75 microseconds for both L + R and L-R. For the L-R segment, this de-emphasis network consists of 22,000 ohms (nearest the diode) in series with 50,000 ohms (one-half of the 100,000-ohm dimension potentiometer), followed by a 1000 $\mu\mu$f capacitor to ground. This represents 72,000 ohms and 1000 $\mu\mu$f or 72μs. (Actually, some stray wiring capacity contributes the additional few microseconds required.) In the case of the L + R channel, the de-emphasis network is made up of a 22,000-ohm resistor (closest to the 70 mh low-pass filter) and the other half of the 100,000-ohm dimension potentiometer followed by the same 1000 $\mu\mu$f capacitor for a total of 72 microseconds. Now, while the capacitor used in this network is common to both L+R and L-R, the resistive component is not. Had fixed 75,000-ohm resistors been used, instead of potentiometer-plus-resistor combinations, even five per cent resistors might result in a maximum of

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15 μs difference in the de-emphasis characteristic of the L + R channels compared to the L-R. Such discrepancy would, in turn, alter the relative amplitudes of L + R and L-R at the high-frequency end of the spectrum to such a degree as to provide virtually no stereo separation at these higher frequencies. It can be readily appreciated that the amplitude of L + R must be equal to L-R at *all* frequencies for proper matrixing to take place and proper stereo separation to result.

For this more subtle reason, the dimension control was added. It is intended to be set at its midpoint, but slight rotation clockwise or counterclockwise may result in more precise and fuller separation at all frequencies. The effect is quite discernable even by the relative neophyte.

The printed-circuit noise filters are quite conventional. They have a high-frequency rolloff reaching a maximum of 12 db per octave and having a three db attenuation point at around 5000 cps. The pair of cathode followers are also quite familiar, and enable cable lengths of up to 200 feet or so to be used with no ill effects.

The entire adapter is self powered and consumes a mere 25 watts. It may be hidden out of sight, if desired, once initial adjustments have been made. Æ