# Compatible Stereo Multiplex Adapter

LEONARD FELDMAN*

**The first Multiplex adapter to appear on the market is described fully, together with details of its operation. This design will demodulate and matrix M-S stereo signals to feed out right and left channel information.**

Now that stereo discs and stereo tapes are solidly entrenched upon the hi-fi scene there remains but one important signal source which is devoid of uncompromising stereo—FM. The high fidelity industry, which is responsible for the so-called re-birth of FM, has not deliberately overlooked FM insofar as stereo is concerned. Many men in many places have been working on the problem for years with varying degrees of success and utilizing many techniques.

In the interim, some broadcasters have resorted to other schemes in their eagerness to provide *some* stereo service to their listeners. Notable among these early systems are simultaneous AM-FM stereo broadcasts in which one channel of a stereo program is transmitted via the AM transmitter while the other channel utilizes the FM transmitter. A system employed in Los Angeles for some time involves the use of *two* complete FM stations (at different frequencies—hence *two* FM tuners required) each broadcasting one channel of a stereo program. There have also been some experimental TV-FM combination broadcasts and even some AM-TV combination deals (stereo maybe, fidelity never!). In the case of AM-FM and AM-TV it is clear that the fidelity of one channel (the AM side) under most circumstances will be inferior to the other, due almost entirely to the narrow-band superheterodyne receivers, not to mention time delay between transmitters, (which serves to destroy or distort the stereo effect), difference in signal strength between the two channels (volume settings which afford balance during daylight may be all wrong in the evening!), static interference, and so on. In the case of all three systems it is clear that anyone not possessing *both* means of reception who desires to listen to the particular program monophonically will hear a totally unbalanced program. Some broadcasters, aware of this problem, have confessed to "mixing back in" a bit of the left channel into the right and a bit of the right into the left to avoid indignant phone calls from monophonic listeners who want to know "what's happening down at the station?" Thus, in effect, the stereo listener doesn't quite have stereo, for all his dual tuners, amplifiers, and speakers and the monophonic listener doesn't quite have a complete program.

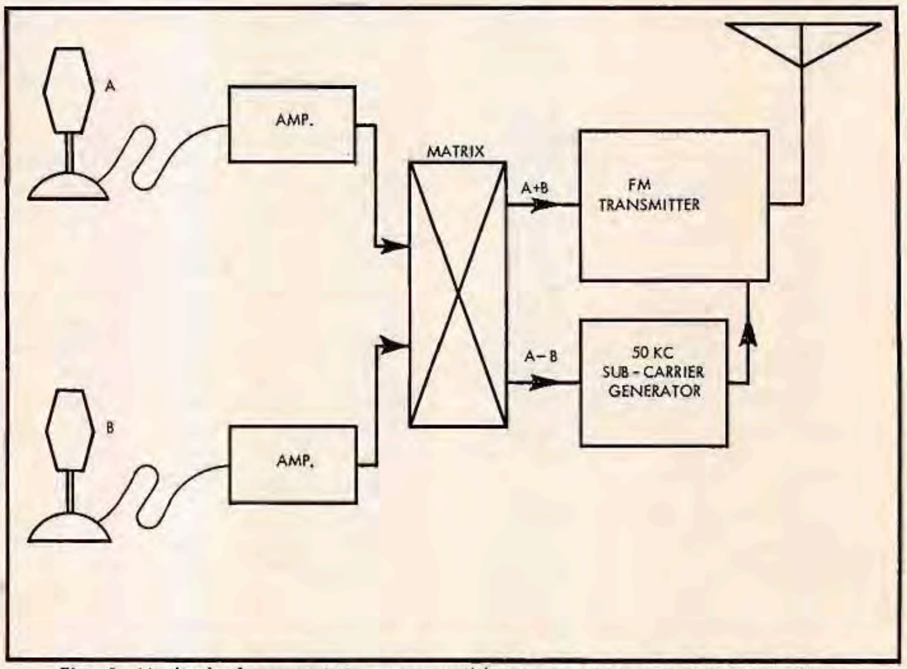


Fig. 1. Method of transmitting compatible stereo over one FM transmitter.

#### Compatibility

The present situation recalls a similar state of confusion which existed when an early form of color TV broadcasting was prematurely approved by the FCC. Until the decision was revoked, owners of TV receivers faced the prospect of neither receiving color pictures *nor* black and white whenever a color broadcast was on the air unless they were prepared to invest considerable money in a new receiver. Fortunately, compatible color TV came along just in time and the sophistication of its engineering was so great as to force immediate reversal of a not-too-old FCC decision.

We are equally fortunate at this juncture in our quest for stereo broadcasting, for along has come compatible FM stereo. Much of our thanks must go to Mr. Murray G. Crosby, a pioneer in the field of FM multiplexing. Mr. Crosby has been granted patents covering his process and we explain it here.

#### Sum and Difference

The stated aim of the Crosby system is to transmit a stereo program over a single FM station in such a manner that anyone having *only* an FM receiver will receive the entire program material in balanced form. To do this, the main FM carrier must transmit the *sum* of the left and right channels, labelled A and B in *Fig.* 1. Simple resistive or inductive mixing adds the two signals in what has been called a matrixing network. In addition, a second signal is derived

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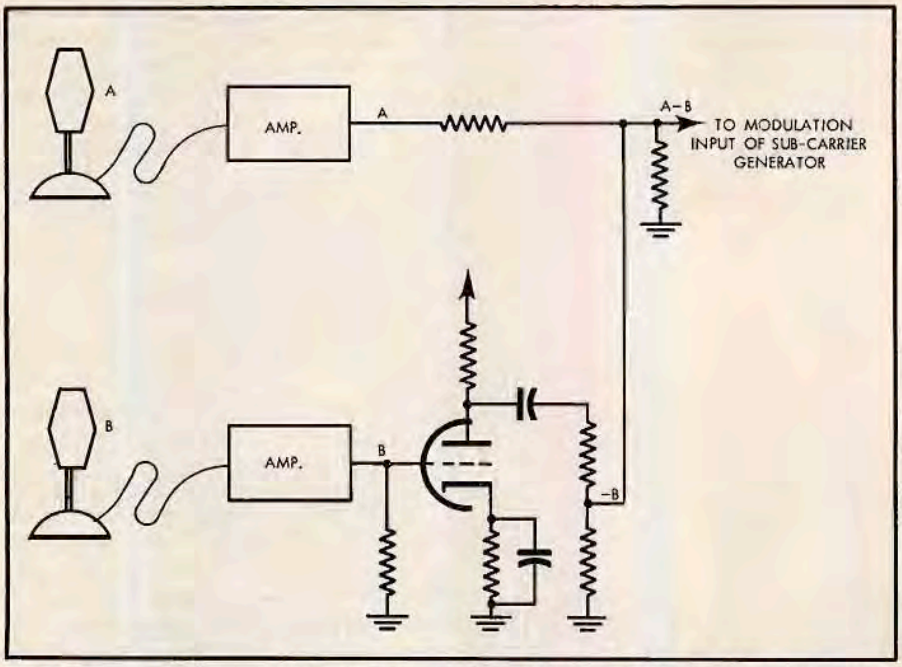


Fig. 2. One possible means of achieving the "A – B" signal. The "B" signal is passed through a triode phase inverter, making it "– B", which is then mixed resistively with the "A" signal, forming "A – B".

from the matrixing network. This signal is $A-B$, or in other words the difference between what the left and right microphones "hear." Clearly, this difference is really the stereo information content, in much the same way that the 3.58-mc color carrier contains the color information content in color TV. The $A-B$ information is used to frequency modulate a 50-kc generator between limits of 25 and 75 kc. This ultrasonic signal is then used to modulate the main FM transmitter along with the regular $A+B$ audio information. Each modulating signal is allowed a frequency deviation of 37.5 kc, so that the total deviation is still only 75 kc just as in standard FM broadcasting. Thus, the channel width per FM station remains unchanged and, as a consequence, so does the number of stations possible in a given area. (Consider this versus the California-two-FM-station per-stereo-broadcast technique which, if carried to extremes could result in half as many stations throughout a given area.)

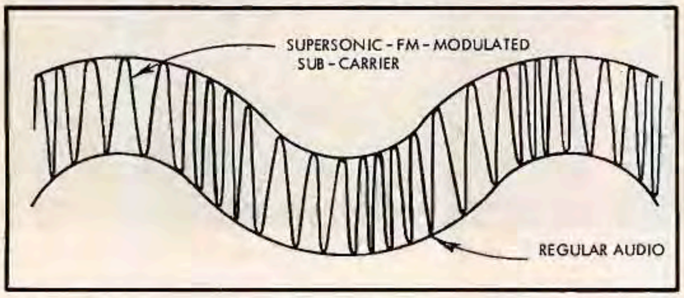


Fig. 3. Typical output of FM tuner when multiplex is broadcast. Information on sub-carrier is inaudible without suitable converter.

Just in passing, in case you are puzzled as to how the $A-B$ signal can be derived electronically, one possibility is shown in *Fig.* 2. In this arrangement, the $B$ microphone channel, after suitable amplification, is applied to a triode amplification stage having a gain of one. Since the plate signal is 180 deg. out of phase with the grid signal, the output of this stage is $-B$. This electrical quantity is then added passively through resistive networks to the $A$ channel (which has *not* undergone phase reversal) yielding a total signal which is, in every way, $A-B$. It is this signal which is used to modulate the multiplex sub-carrier.

#### Monophonic Listening

Suppose a listener tunes into an FM station using this technique and that he has only an FM receiver. The demodulated signal appearing at the output of his tuner contains both $A+B$ audio as well as a supersonic sub-carrier, varying in frequency between 25 and 75 kc. The signal would be somewhat like that shown in *Fig.* 3. The supersonic sub-carrier will be inaudible to the listener and all he will hear is the "regular" program. But this regular audio has been stated to be the sum of $A+B$ which is just another way of saying *the entire program,*—not stereo, of course, but still the entire program, not just the left or right side of the orchestra. This listener has therefore lost nothing and has spent nothing.

Now, suppose the listener desires full stereo programming at home. The inexpensive adapter which will accomplish this feat has only two functions: 1, to amplify and de-modulate the sub-carrier; and 2, to do a little simple algebra. The first of these functions is easily accomplished. The level of sub-carrier after the FM-discriminator of the main receiver is through with it is of the order of 0.25 volts, a nice hefty signal compared to the microvolts into an r.f. stage. All that is needed is a bit of amplification, some limiting and some FM detection scheme. Best of all, no high-Q tuned circuits are required, for this signal is *practically audio.* One vital requirement that does remain is that we eliminate the regular $A+B$ channel completely, so that it does not get involved with the $A-B$ signal we are trying to extract. A high-pass filter which rejects all frequencies below 20 kc (hence anything being broadcast on the main channel) does the trick.

As for the algebra, once $A-B$ has been recovered, it is quite simple. First we add the two signals, $(A+B)+(A-B)=(A+B+A-B)=2A$. But $2A$ just means $A$ twice as loud. Next we subtract: $(A+B)-(A-B)=(A+B-A+B)=2B$, which is nothing less than $B$ twice as loud. Thus we have recovered the separate left and right channels intact and can feed them to our newly acquired stereo amplifier by means of a pair of cables, just as we are now doing with tape and stereo cartridges.

#### Dimensional Control

The set-up for stereo reception is shown in *Fig.* 4. As you can see, if you already have stereo in any form, all you

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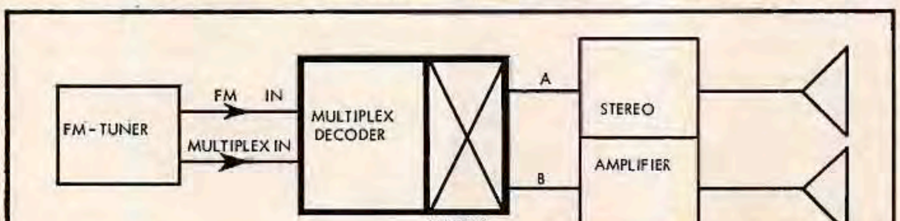


Fig. 4. How the multiplex stereo converter fits into a typical stereo installation.



its of 25 and 75 kc. This ultrasonic shown in Fig. 2. In this arrangement, the main channel) does the trick.

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will need to add for compatible FM stereo reception is a multiplex adapter such as the Madison Fielding MX-100, which is shown in the schematic form in *Fig.* 5. The cost of the adapter is small, compared with the price of a quality FM tuner and, as such, does not represent a major investment in terms of the reward.

The adapter could have been built with no controls whatsoever. As has been pointed out, no form of tuning is necessary. Simply tune the FM tuner to a station broadcasting stereo and the whole thing pops into place. We could not resist adding two very flexible controls once we realized the advantages to be gained. If $(A+B)$ of itself yields monophonic sound and if $(A+B)+(A-B)$ and $(A+B)-(A-B)$ yield fully stereophonic sound then it follows that $(A+B)+\frac{1}{2}(A-B)$ and $(A+B)-\frac{1}{2}(A-B)$ will yield *half as much* aurally apparent separation and, more amazingly $(A+B)+2(A-B)$ and $(A+B)-2(A-B)$ will yield twice as much separation. Here's what it all means: if, because of space limitations, the two speakers of your system have necessarily been placed too close together to really derive full stereo effects from your other stereo sources, you can actually "spread the sound apart" electronically with the aid of the DIMENSION control on the MX-100 adapter. Conversely, this same control can help "pull the orchestra together" if you suffer from the new audio affliction known as "hole in the middle."

The two inputs of the MX-100 are labelled MULTIPLEX IN and FM IN. A very short cable should be used to connect from the multiplex output of the standard FM tuner to the MULTIPLEX IN jack to prevent attenuation of the 50-kc sub-carrier. The second input is for connection of the regular FM output of your tuner. The first of these signals—the multiplex subcarrier—is fed through a cathode follower $V_{1A}$. This stage serves to isolate the signal and create a source impedance suitable for application to the low-pass and high-pass filters which follow. The signal at the cathode of $V_{1A}$ is of the order of 0.25 volts (assuming that the tuner feeding the adapter has reached full limiting). The main audio carrier is removed from the signal by two full T-section constant-k filters having a cut-off frequency of 20 kc. The 5-mh inductances in the leg of each of the T-sections need not be "high-Q" in terms of r.f. circuits, but their inductance must be held to fairly close tolerances. Between the two high-pass filter sections is a single T-section low-pass filter having a cut-off frequency of 75 kc with a terminal impedance equal to that of the high-pass sections (1200 ohms). The purpose of a sharp cut-off filter *above* 75 kc is to eliminate any high-frequency noise which might be

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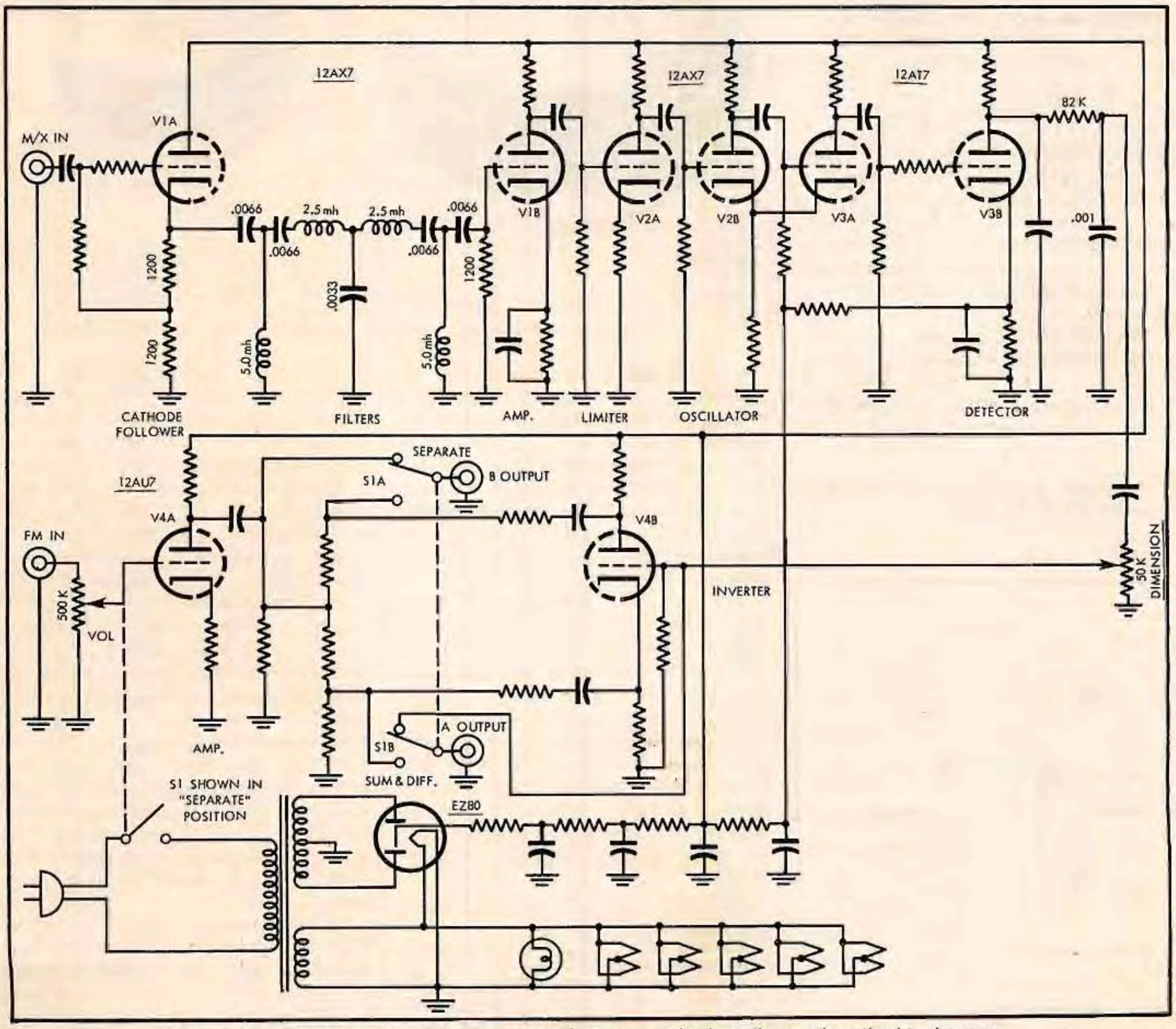


Fig. 5. Circuit arrangement of the compatible stereo multiplex adapter described in the text.

## MULTIPLEX

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later demodulated when the adapter is used with wide-band types of tuners having i.f. bandwidths as great as 1 megacycle or more. Thus, following these filters, the signal is made up entirely of frequencies ranging from 25 to 75 kc (with a nominal center frequency of 50 kc when no FM modulation is applied to the sub-carrier).

$V_{1B}$ is simply a stage of amplification, raising the amplitude of the signal to about 6 volts. $V_{2A}$ at first glance appears to be another stage of amplification. Actually, with a 6-volt signal applied to the grid and an un-bypassed cathode, it is a very efficient limiter stage, affording both positive and negative clipping of any residual noise present. The heart of the decoder is $V_{2B}$ and $V_{3A}$ which is a form of relaxation oscillator or "one-shot" multivibrator. For each cycle of subcarrier applied to the grid of this oscillator, it will produce one complete square wave cycle. With no positive voltage applied to its grid (in the absence of a subcarrier), the two triodes produce no oscillation. The circuit is alternately known as a Schmidt Trigger Circuit. At this point (the plate circuit of $V_{3A}$) we are therefore no longer dealing with the subcarrier (which, from different tuners, might have different amplitude and shape and lead to difficulties in subsequent demodulation) but with our own self-produced, consistently shaped square-wave train whose frequency corresponds exactly with that of the original sub-carrier at any given moment. The square waves are differentiated by means of the capacitive resistive network in the grid circuit of $V_{3B}$. The stage $V_{3B}$ is arranged to form a "counter detector" FM type of demodulator, one of the most distortion-free types of FM detectors possible. This form of detector "counts" the plate pulses and creates varying d.c. level based on the number of pulses per second. The 82-k ohm resistor and .001-µf capacitor combination serve as a de-emphasis network (just as your regular FM tuner output circuit) and further serve to remove a large amount of sub-carrier still present in the resultant output. Thus, at the top of the 50-k ohm DIMENSION control the $A - B$ signal contained in the supersonic sub-carrier is recovered. If desired, this signal can be fed as it stands to an amplifier by throwing slide switch $S_1$ (located on the rear of the chassis) to the SEPARATE position. The sound of $A - B$ is rather curious. It is decidedly deficient in lows (bass tones, being essentially non-directional in character, will have been equal in the $A$ and $B$ channels originally and will therefore have cancelled





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each other in the course of subtracting $A-B$). The remaining highs have a somewhat unearthly, echo-like quality about them. The purpose of slide switch $S_1$, however, was not to create meaningless sound-effects for the listener but rather to provide for what we feel will be the rare broadcaster who elects to broadcast stereo with one channel over the main FM carrier, and the other over multiplex, without the sophistication of the Crosby sum-and-difference technique. Such practice may be expected in some parts of the country until sufficient transmitting equipment can be built to meet the needs of every station desiring to adopt this system. In any case, with $S_1$ in the SEPARATE setting, the decoded multiplex channel is recovered at the $B$ output jack while the regular FM material, after undergoing some amplification through $V_{4A}$ is simply recovered at output jack $A$.

#### Re-Matrixing

Assuming that the station under consideration is utilizing the Crosby system, $S_1$ is thrown to the sum-and-difference position. In this setting, the $A-B$ signal (from the 50-k ohm DIMENSION control) and the $A+B$ signal (from the plate circuit of $V_{4A}$) are mixed resistively in phase $(A-B+A+B)$ to create the $A$ channel at output $A$ while the same signals are mixed in the plate circuit of $V_{4B}$ ($A-B$ having been inverted in phase) to re-create the $B$ channel $(A+B)-(A-B)$ at output $B$. The monophonic volume is first set up by means of the 500-k ohm control following the FM in jack. Then the balance control or individual level controls of your stereo amplifier are adjusted until the sound seems to be coming from directly between your two loudspeakers. Then simply add dimension, as required, by means of the DIMENSION control on the adapter. Once set, neither of these controls need be readjusted. The entire adapter, therefore, requires no additional "up front" space in the Hi Fi installation and can, if desired, be tucked away behind amplifier or tuner.

#### Is this the FM Stereo Answer?

We feel that the Crosby system of multiplexed FM *must* succeed because it is definitely in the public interest and, from a technical standpoint, will provide ideal stereo for those who want it without deteriorating the entertainment value of the accompanying monophonic program. Our decision has been, therefore, to make these converters available now so as to encourage FM broadcasters to embark on this adventure and assure them as great an audience as our production facilities will allow. Only time will tell whether or not we chose the "winning side." Æ



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