BUILD FM stereo adapter

No coils or transformers are needed for this add on. That means no tricky alignment is required. Add it to your FM radio

by LEONARD D'AIRO

AS TRANSMITTED BY AN FM BROADCAST station, a stereo multiplex signal consists of an upper channel containing the so-called left minus right information, a lower channel containing left plus right information, and a 19-kHz pilot carrier. It is the 19-kHz signal that is multiplied to 38 kHz in the stereo multiplex adapter and used to separate the composite multiplex signal into its left and right components.

Conventional multiplex adapters use tuned transformers to generate the 38-kHz signal, but in the transformerless version described here the tuned transformers are replaced by simple R-C type notch filters. The advantage of using these filters is simplified alignment by eliminating the need for a stereo multiplex generator, and no special components are required, thereby reducing overall cost.

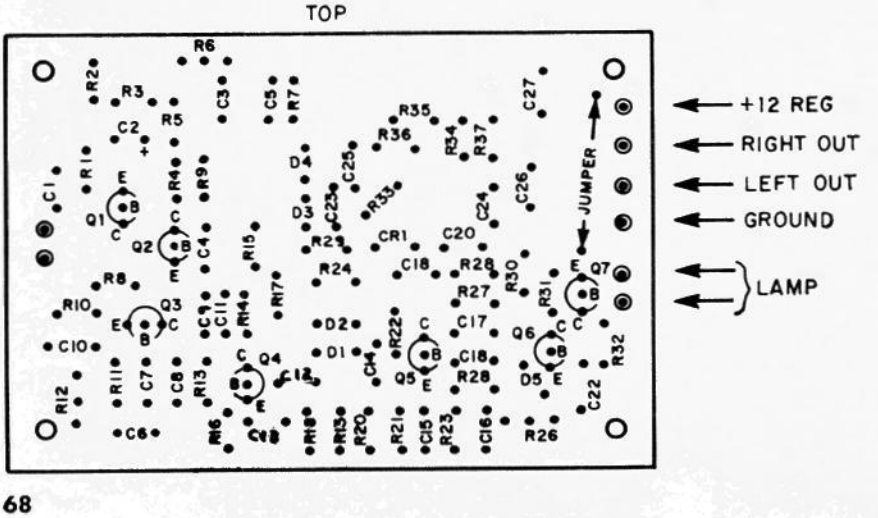
The notch filter has a very sharp reject capability (Fig. 1) and can be tuned over a limited range by an inexpensive potentiometer. When used in the feedback leg of a high-gain amplifier stage, it will cause the stage to act as a narrow bandpass filter (Fig. 2). This characteristic occurs when the signal frequency is the same as the notch frequency of the filter. At this point the series resistance of the filter approaches infinity, the signal fed back to the base from the collector is reduced to almost zero and the output signal approaches maximum. At frequencies other than the notch frequency, the series resistance of the filter is low, the signal fed back is large, and amplifier gain is reduced. Thus we have in effect a tuned amplifier stage without the use of inductances.

Multiplex adapter design

The major problem is designing any stereo multiplex adapter is to generate a clean and stable 38-kHz signal that is in the proper phase relationship with the 19-kHz signal that is transmitted by the broadcast station. Unless this is done, separation of the composite signal into its left and right components will not occur and a monophonic output will result.

The required conditions are met by this transformerless version. The 19-kHz signal is amplified, filtered, doubled, amplified again, and then applied to the demodulator matrix in proper phase.

PARTS LAYOUT AND PATTERN FOR PRINTED CIRCUIT. Both drawings are full-size. Note the two large holes near the center of left edge on the layout drawing. The upper one is the input and the lower is ground. On foil pattern, the left edge (as shown) corresponds to the top in the parts layout. Circuit board, G-10, drilled is available as part RE371B for $4.50. All semiconductors for this unit as part RE371T $4.75. Complete kit of all parts and board $19.50. Order from Photolume Corp., 118 E. 28th St., New York, N.Y. 10016.



Examining the schematic diagram (Fig. 3), the composite multiplex signal from the FM tuner is passed through a broadband, high-gain amplifier (Q1, Q2). This amplifier has an input resistance of about 100,000 ohms so as not to overload the FM detector output. Amplifier gain is high so it will operate with only a 5-mV signal. This makes it compatible to use with low output solid-state tuners. When used with high-output tuners, such as the vacuum-tube types, it is necessary to insert a 500,000-ohm potentiometer between the tuner and adapter to reduce the tuner output level to an operating level where overdrive and its resulting distortion will not occur.

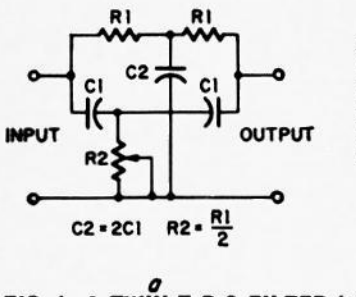
After amplification, the signal is passed through a 19-kHz bandpass filter stage which amplifies only the 19-kHz signal. This is done with a notch filter and transistor (Q3).

The 19-kHz signal is then passed through a phase-splitter (Q4) and doubled to 38 kHz by diodes D1 and D2 in a push-push doubler circuit. The resulting 38-kHz signal is then amplified by the 38-kHz bandpass amplifier (Q5), producing a clean, stable signal that is in the proper phase relationship with the transmitted signal.

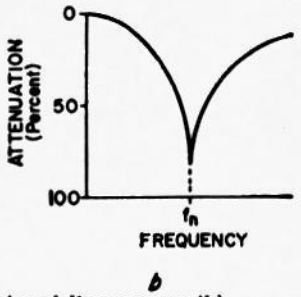
Now that the 38-kHz signal has been generated, the next step is to apply it to the stereo demodulator matrix along with the upper and lower channel information so it can be processed and separated into left and right channels. This is done by splitting off the upper channel information (through C5), combining it with the 38-kHz signal, and applying it to the diodes (D3, D4) of the demodulator matrix.

At this point, with just the upper channel information applied to the matrix, the output of the adapter contains only the left minus right information. If connected to a stereo amplifier system a monaural output on a stereo signal would result with no output on a monaural signal.

To get stereo output on a stereo signal from the matrix, the lower channel information must also be applied. This is done by resistive sum-

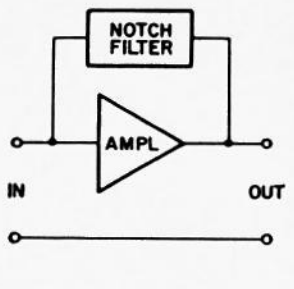


a



b

FIG. 1—A TWIN-T R-C FILTER (a) and its response (b).



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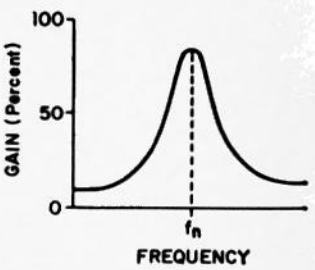

b

FIG. 2 (right)—FEEDBACK loop (a) provides bandpass curve (b).

All resistors ½-watt 10% unless noted
R1, R22—33,000 ohms
R2—390,000 ohms
R3, R8, Q25 R35—22,000 ohms
R4, R10, R23, R28—1000 ohms
R5—27 ohms
R6—potentiometer, 50,000 ohms, subminiature Lafayette 99T6145 or equal)
R7, R29, R30—10,000 ohms
R9—220,000 ohms
R11, R13, R21—5600 ohms
R12—potentiometer, 5000 ohms, subminiature (Lafayette 99T6145 or equal)
R14—470,000 ohms
R15, R16, R17, R18, R19, R24, R25, R27—4700 ohms
R26—potentiometer, 1000 ohms, subminiature (Lafayette 99T6142 or equal)
R31—2700 ohms
R32—100 ohms
R33, R36—68,000 ohms
R34, R37—47,000 ohms
All capacitors miniature ceramic disc. 50 WVdc, 20% unless noted
C1—.05 μF
C2—30 μF, 12V, submin electrolytic
C3, C22—10 μF, 12V, submin electrolytic
C4, C5—470 pF
C6—.003 μF
C7, C8—.0015 μF
C9, C11, C19, C20, C21—.01 μF
C10, C15—0.1 μF
C12, C13, C26, C23, C24, C25—.001 μF
C14—330 pF
C16—.004 μF (two .002 μF in parallel)
C17, C18—.002 μF
C27—100 μF, 15V, submin electrolytic
Q1, Q7—MPS3702 or equal
Q2, Q3, Q4, Q5, Q6—MPS3393 or equal
D1, D2, D3, D4, D5—1N60
LM1—miniature pilot lamp: 6V, 60 mA (Lafayette 99T6262 or equal)

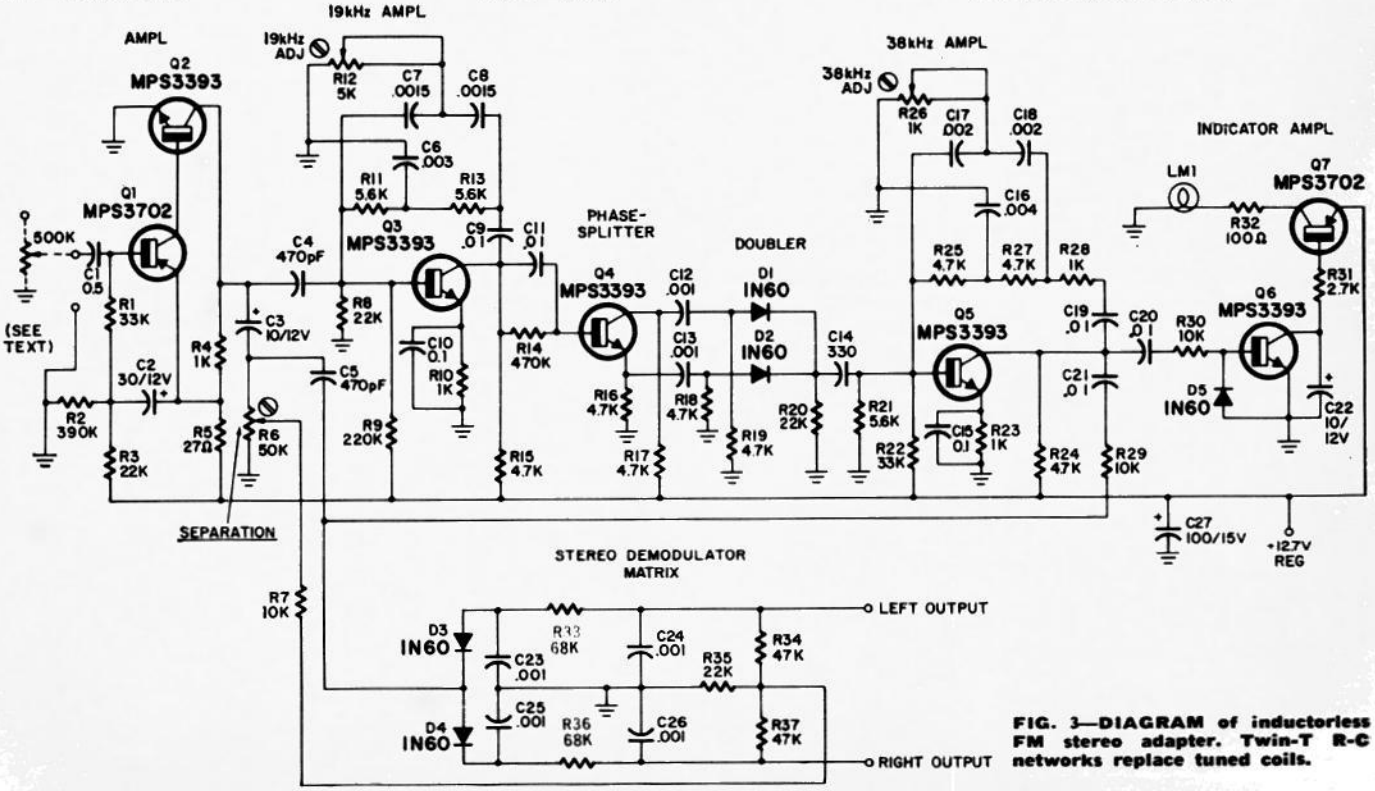

FIG. 3—DIAGRAM of inductorless FM stereo adapter. Twin-T R-C networks replace tuned coils.

ming of the lower channel information into the two legs of the matrix. When the amplitude levels of both channels of information are the same, then maximum stereo separation occurs. Matching amplitude levels is done via the separation control, R6.

An indicator lamp (LM1) is used to show when the multiplex adapter is operating. This lamp, connected in series with current limiter resistor R32 to Q7's collector, lights only when a 38-kHz signal is at the collector of Q5. The signal is detected by diode D5, amplified by Q6, and applied to Q7. The sensitivity of Q6 is such that the lamp will light to full brilliance only when the 38-kHz signal is strong enough to operate the demodulator matrix.

Proper adapter operation will produce a stereo separation of at least 30 dB from 50 Hz to 15 kHz, and 40 dB from 100 Hz to 10 kHz. Power requirements are approximately 8 mA at 12 volts, increasing by 60 mA when the indicator lamp is lit. A regulated power supply, such as shown in Fig. 4, should be used for optimum performance.

Construction and test

The adapter was built onto a 2½" X 3½" printed circuit board. Any method of construction suitable to the reader can be used. The only restriction is to be careful when wiring and keep lead lengths to a minimum.

Whether using a printed circuit board or any other method of construction, a simple and mistake-proof assembly method is to wire and test one circuit at a time.

The broadband amplifier is assembled first, making sure that the correct components are placed in their proper places. Upon completion, connect a scope to the collector of Q2, and apply a 5 mV, 19-kHz signal to the input. Watch the waveform on the scope to make sure no clipping or other distortion is present.

When operation of the amplifier is satisfactory, wire the 19-kHz bandpass amplifier. Connect the scope to the collector lead of this stage and apply voltage. With the 19-kHz signal still applied to the input amplifier, adjust R12 for maximum output. If the waveform is clipped or otherwise distorted, reduce the input level to the input amplifier, and again adjust R12 for a peak in output. If distortion still persists, or if R12 will not cause a peak, replace Q3 with another transistor or transistors to clear up the problem. Although the adapter was designed to accept and use almost any silicon transistor in the 50 to 200 beta range, it is still possible for a given type not to function properly in the circuit. In this case transistor replacement is the only remedy.

The next stage(s) wired is the phase-splitter (Q4) and frequency doubler. Connect the scope to the output side of the diode doubler. The waveform at this point will be slightly distorted due to diode unbalance, but the waveform amplitude should be constant. The frequency of the waveform should also be twice that applied to the base of Q4. That is, if four cycles appear at the base of Q4, then eight cycles should appear at the output of the diode doubler. If not, either replace the diodes or further reduce the input to the high gain stage.

Once the previous stages are operating satisfactory, wire up the 38-kHz stage next. Operation and test of this stage is the same as that of the 19-kHz stage, except for frequency. Any troubles encountered are to be corrected in the same manner as that previously described for the 19-kHz amplifier.

The indicator lamp is wired and tested next. The only precaution is to twist the leads for the lamp together to prevent the possibility of any 38-kHz signal feedback to the input which would cause a high noise level in the output.

Finally, the demodulator matrix is wired. Make sure the diodes are wired correctly. Testing the matrix is done with an "on the air" signal.

Alignment and operation

When the adapter is complete, connect the adapter input to the detector output of an FM tuner (ahead of the de-emphasis network) using the 500,000-ohm potentiometer mentioned earlier if necessary. The connecting cable should be short, preferably 18 inches or less. This avoids high cable capacitance that could attenuate the high frequency components of the multiplex signal. Tune to a station that is broadcasting stereo.

Connect an oscilloscope to the collector of Q3, apply voltage, and adjust R12 for maximum output. If you have trouble, reduce the input level to the adapter with the potentiometer. Next connect the oscilloscope to the collector of Q5 and adjust R26 for maximum output, adjusting the input level to the adapter as required. Make sure the waveform at this point has twice the amplitude as that observed at Q3. During this portion of the alignment, the stereo indicator lamp should light whenever R26 is adjusted for maximum output. The lamp should go out whenever the tuner is detuned from a stereo signal.

After alignment is complete, connect the left and right adapter output leads to a stereo amplifier system. Adjust the separation control, R6, for maximum separation. If separation does not occur, or is poor, then either the diodes are defective or backwards.

In field tests of this multiplex adapter, the FM detector output of a pocket portable FM receiver was used to provide the multiplex signal. The left and right output were connected to emitter-follower stages, the outputs of which were connected to miniature earphones of the type usually supplied with portable sets. Performance was excellent. Power for the adapter was supplied by 8 penlite cells. Fig. 5 shows the arrangement of this setup.

R-E

FIG. 4—SIMPLE REGULATED POWER SUPPLY for the adapter operates from a 12-volt filament transformer and fullwave bridge. **FIG. 5 (right)—AUDIO AMPLIFIER** for stereo phones.