

Add-on decoder for AM stereo

AM stereo is now broadcast in Australia on an experimental basis. This add-on decoder works with the Motorola C-QUAM system. We show how to add it to two recent Playmaster tuners.

by JOHN CLARKE & GREG SWAIN

There is growing pressure in Australia for the official introduction of AM stereo. As we go to press, the Department of Communications has yet to give its decision as to whether all four competing AM stereo systems will go ahead or whether one system, such as the Motorola, will be preferred. The other three systems are Harris, Kahn and Magnavox.

In the United States, the Motorola system is currently the front runner. It has been chosen by more radio stations than any other and has been adopted by several major car manufacturers, including General Motors, Ford, Chrysler and Nissan. Many Japanese hifi companies have also adopted the Motorola system. That's not to say that the other systems will disappear — it's possible that tuners capable of

automatically decoding all four systems will be developed.

With the situation unlikely to be resolved in the near future, we have decided to present this decoder based on the Motorola C-QUAM system. There are currently five stations using the Motorola system in Australia: 2WS in Sydney; 3UZ, 3KZ and 3AK in Melbourne; and 5KA in Adelaide.

Let us state right from the beginning, though, that many AM tuners are not capable of being converted to stereo. We'll explain the reasons for that later and give you some pointers on choosing a good candidate for conversion. In addition, we'll show you how to add the decoder to the Playmaster AM/FM Stereo Tuner (Nov '78) and the Playmaster Hifi AM Tuner (Dec '82).

What is C-QUAM

C-QUAM is an acronym for Compatible QUadrature Amplitude Modulation. That's certainly a mouthful — let's see what it means.

First, the system is compatible with existing tuners. That means that any ordinary (mono) AM tuner can receive a stereo broadcast and produce the same result as if it received a mono signal. The AM stereo system does not make existing tuners obsolete.

Second, C-QUAM is a quadrature system which means that it uses the relationship between two carrier signals that are 90° out of phase to encode the left minus right (L-R) information. At the same time, the mono signal (L+R) is the conventional amplitude modulated signal.

There's a problem with quadrature modulated signals though. They produce distortion in the envelope detectors (usually a diode) of normal AM tuners. That's because the envelope detector sees the sum of the two carriers. As shown in Fig. 1a, the magnitude of the sum of those two vectors — which the tuner's envelope detector would see — is:

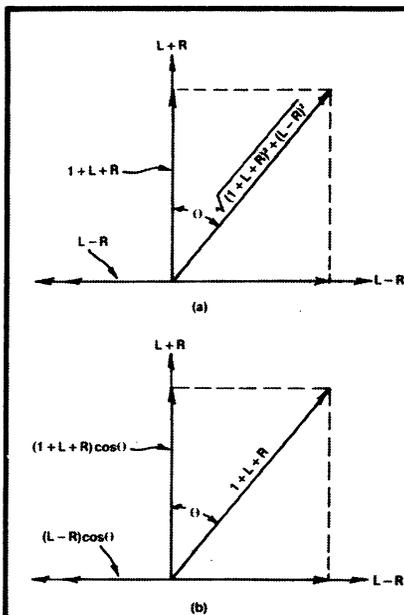


Fig. 1: To avoid distortion in normal AM tuners, quadrature signals must be converted to a compatible form.

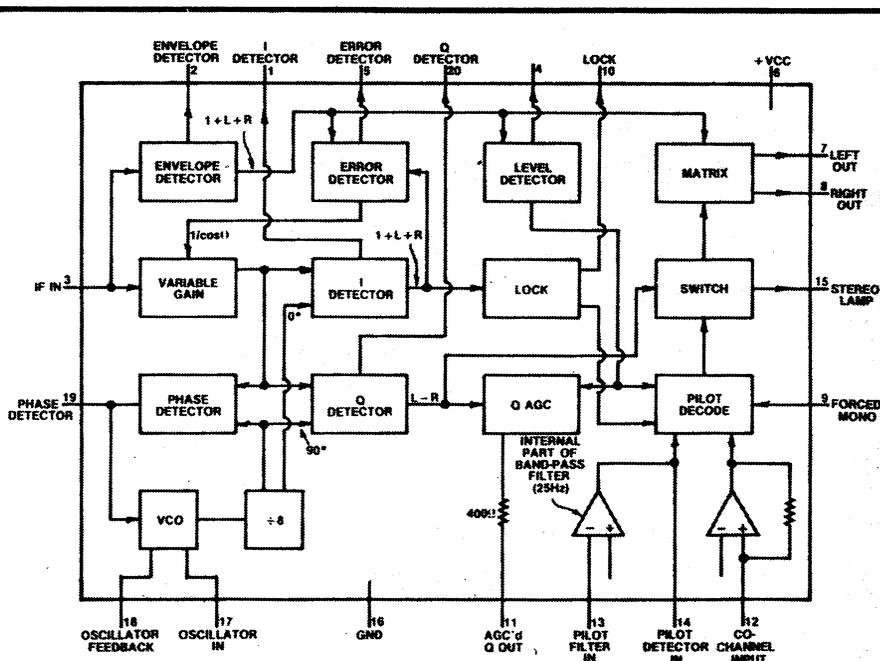
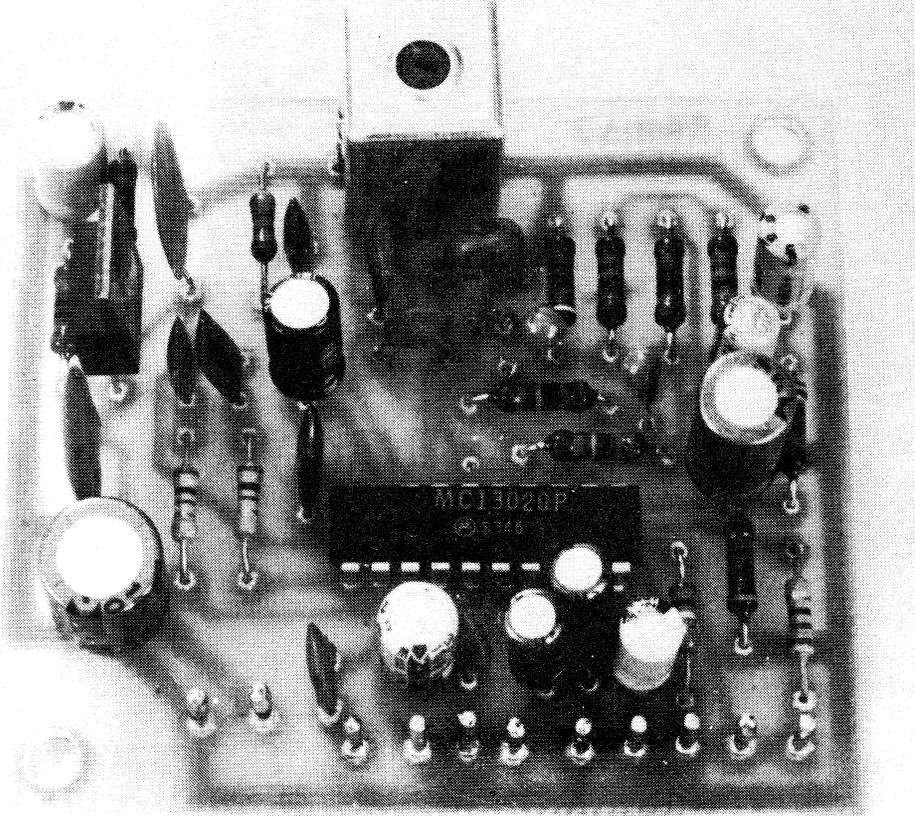


Fig. 2: Block diagram of the MC13020 AM-stereo decoder IC.



The assembled stereo decoder. There is also a capacitor under the PCB.

could eliminate the problem by multiplying each carrier axis by the cosine of the angle that resulted from the addition of the $L + R$ and $L - R$ signals. Fig. 1b shows that when this is done, the result is the $1 + L + R$ signal that we want — the standard AM tuner sees this signal as the same signal received from a monaural AM broadcast. Thus we have complete compatibility.

The C-QUAM system also adds a 25-Hz pilot tone to the $L - R$ information at 4% modulation. This serves several purposes: it signifies that a stereo transmission is present; it permits decoding of the $L - R$ signal, and it aids in the control of mono-stereo switching.

The MC13020P

At the heart of the decoder is a single integrated circuit, the Motorola MC13020P. This is housed in a standard 20-pin dual-in-line package. A block diagram of the IC is shown in Fig. 2 while Fig. 3 is a schematic of the complete decoder circuit.

Taking an overall look at the block diagram of the decoder IC (Fig. 2), we see that the decoder takes the output of the AM IF amplifier, decodes the C-QUAM signal, and provides left- and right-

$\sqrt{(1 + L + R)^2 + (L - R)^2}$.
However, the envelope detector in a standard AM tuner expects to see simply the carrier and the left and right channel

audio, or $1 + L + R$. It is the difference between the two expressions that is the cause of the distortion problem. Motorola found, however, that they

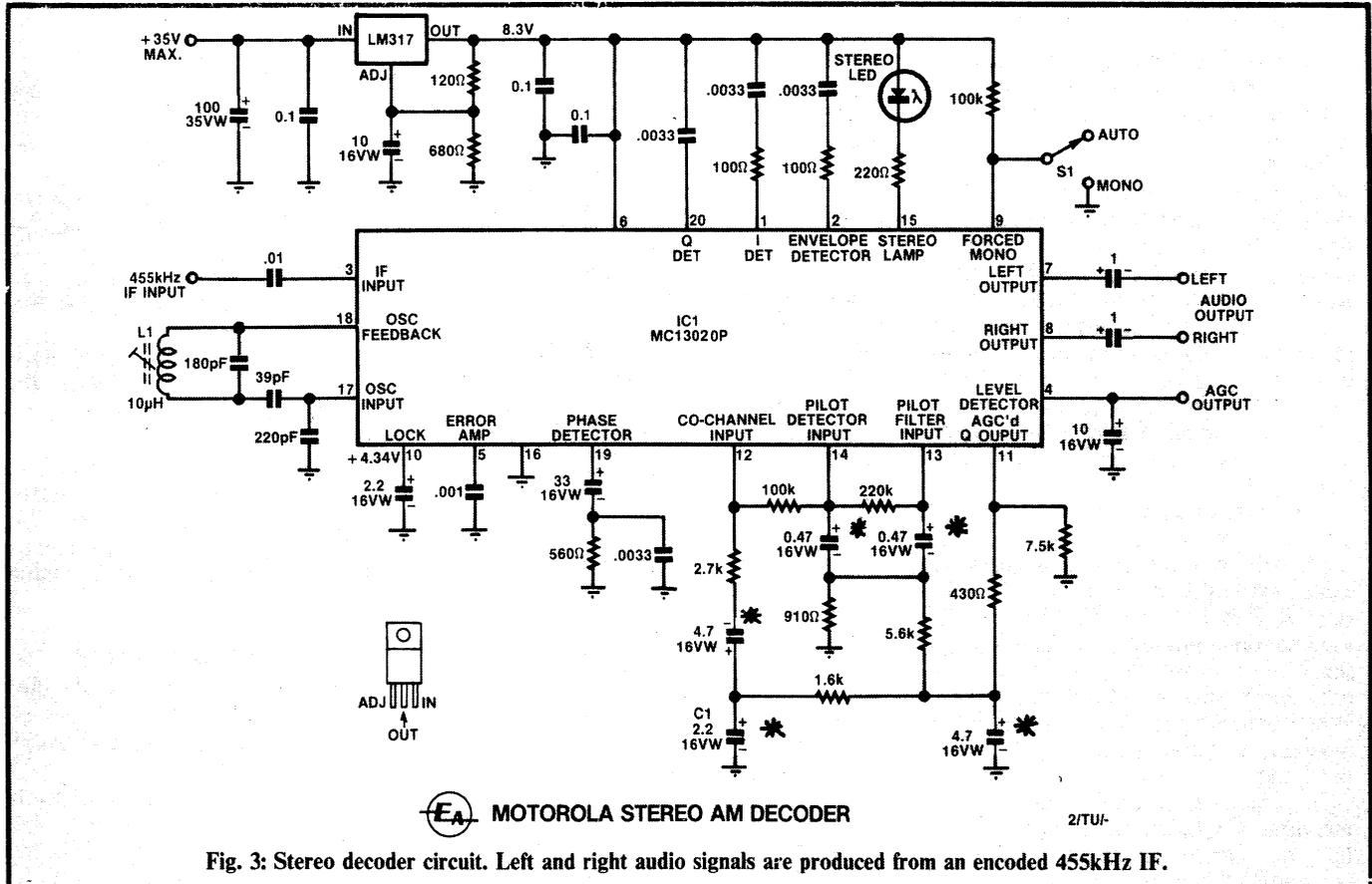
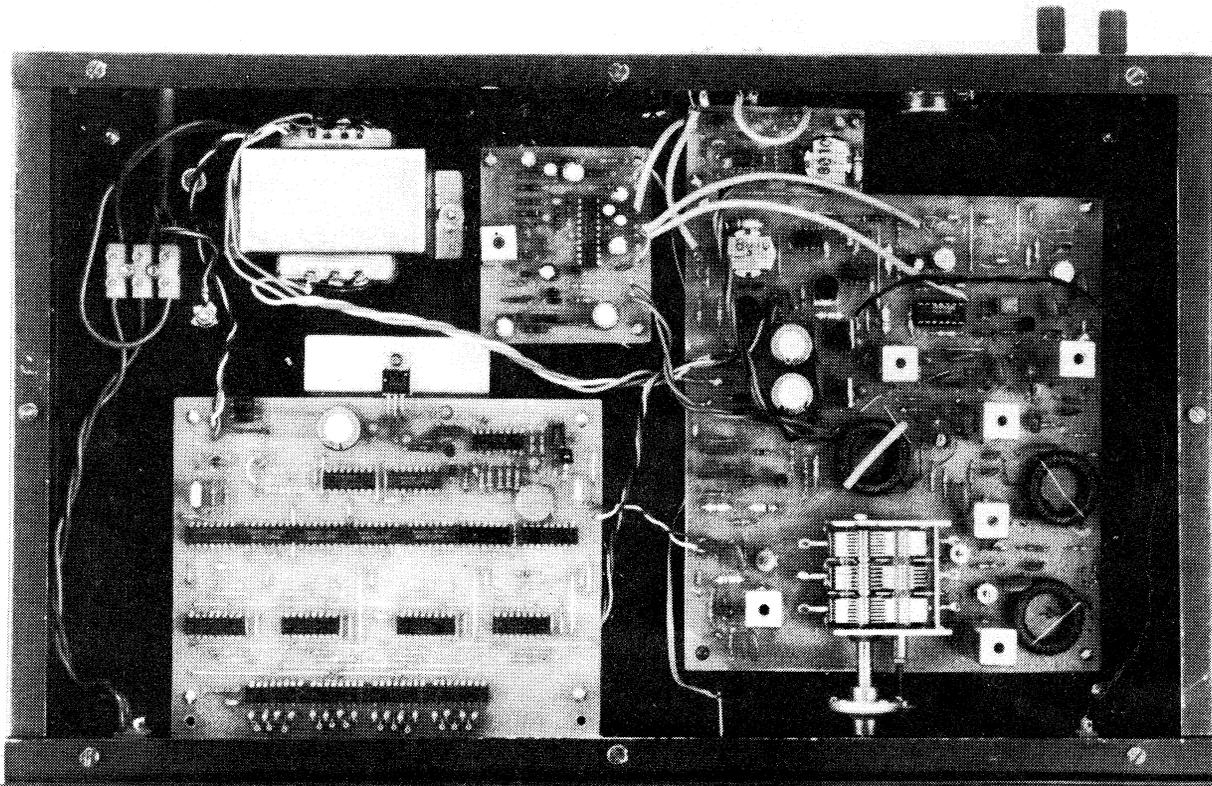


Fig. 3: Stereo decoder circuit. Left and right audio signals are produced from an encoded 455kHz IF.



The decoder PCB fits easily inside the HiFi AM Tuner cabinet.

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channel audio outputs. In the absence of a good stereo signal, it will produce an undegraded mono output from both channels.

The first step in decoding the stereo information is to convert C-QUAM to QUAM. That conversion is accomplished by comparing the outputs of the envelope detector and the I (L + R) detector in the error detector.

Let's say, for example, that the incoming signal is monaural. Then it consists only of L + R information, and the envelope detector and I detector see the same signal. Therefore the error detector does not produce an error signal.

However, when the incoming signal is stereo, there will be an error signal produced. The envelope detector sees the same signal as it did before (L + R) because it is not sensitive to the phase modulation. But the I detector is sensitive to phase modulation and sees only the (L + R) $\cos\theta$ information. When both signals are sent to the error detector, a $1/\cos\theta$ correction factor is produced.

In the variable-gain block, the incoming C-QUAM signal is multiplied by the $1/\cos\theta$ factor to derive a conventional quadrature or QUAM

signal. This can be synchronously detected by conventional means.

The process to detect or demodulate the conventional quadrature signal involves first deriving a reference phase from the transmitted signal. That's the purpose of the phase-locked-loop (PLL) that we'll now describe. The phase detector is a product detector — its output is equal to the product of the two input signal voltages (in this case, a reference carrier from the VCO and the QUAM signal from the variable-gain block). If the two signals are of the same frequency and 90° out of phase, the filtered DC output of the detector will be zero. This DC output is fed back to the VCO as an error signal. Thus, the VCO locks onto the input carrier frequency and we have our phase reference to the I and Q demodulators.

The RC network on pin 19 (see Fig. 3) filters the output of the phase detector to ensure a steady DC error signal to the VCO.

The internal VCO operates at eight times the IF input, thus ensuring that its frequency is well outside the broadcast band. Typically, the IF will be 455kHz so the VCO runs at 3.64MHz. Note, however, that many synthesised tuners use a 450kHz IF and this requires a

VCO frequency of 3.6MHz.

Coil L1 and the capacitor network on pins 17 and 18 (Fig. 3) set the VCO frequency. This network is easily adjusted to suit either IF.

The level detector senses carrier level and operates on the Q AGC (automatic gain control) block to provide a constant amplitude 25Hz pilot signal at pin 11. It also sends information on signal strength to the pilot decoder.

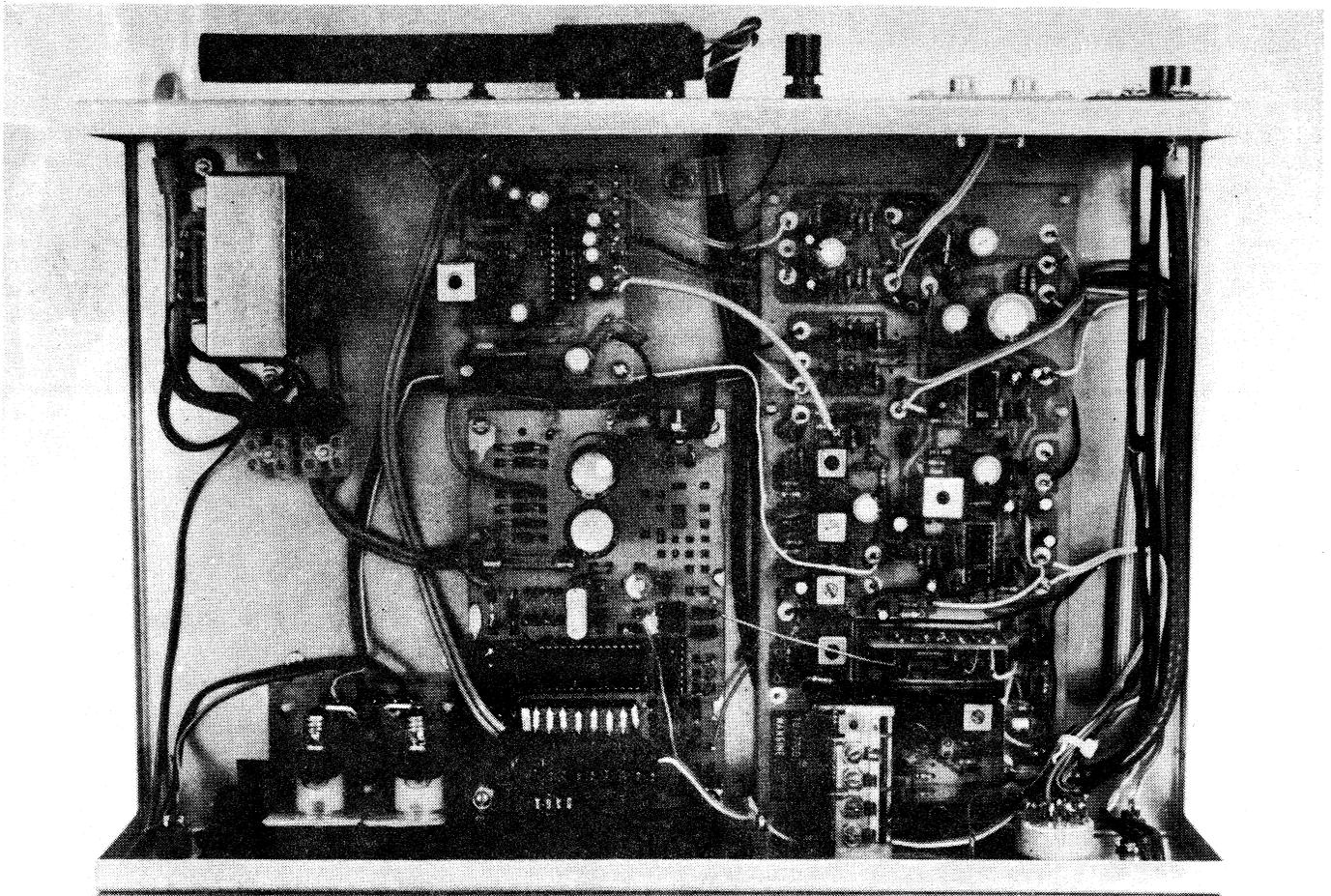
The Q AGC (pin 11) output drives a low-pass filter, made up of a 400 Ω internal resistor, a 7.5k Ω resistor, a 430 Ω resistor and a 4.7 μ F capacitor.

From that point, an active filter (made up of both internal and external components) is coupled to the pilot decoder, pin 14, and another low-pass filter is connected to the co-channel input, pin 12.

Stereo/mono switching

Automatic stereo/mono switching is performed by the pilot decode block. This has two modes of operation which we will now describe.

On a strong signal, the decoder will switch to stereo after it sees seven consecutive cycles of the 25Hz pilot waveform. When conditions are bad,



Playmaster AM/FM tuner with the stereo decoder fitted.

however, the pilot decoder detects the interference and waits until it sees 37 consecutive cycles of the 25Hz pilot tone (that takes about 1.5 seconds) before it goes into the stereo mode.

Switch S1 provides manual switching to mono operation by pulling pin 9 low. This switch can be regarded as optional and, in fact, was not used for the Playmaster tuner conversions.

If no pilot is detected for seven consecutive counts, it is assumed the incoming signal is mono and the decoder is again switched to the long count. This reduces the possibility that noise or signal-level fluctuations will cause stereo triggering. The decoder will also switch to the long count if the PLL is out of lock, or if interference is detected by the co-channel detector before seven cycles are counted (each disturbance will reset the counter to zero). The level detector prevents the decoder from going into stereo if the IF input level drops 10dB, but will not affect the pilot counter.

Finally, the decoder will automatically switch to mono if there is a 50% reduction in the level of the 25Hz pilot signal into the pilot decode circuit.

Once the decoder has entered the

stereo mode, it will switch instantly back to mono if either the lock detector at pin 10 goes low, or if the carrier level drops below the preset threshold. Seven consecutive counts of no pilot will also cause the switch to mono.

When all inputs to the pilot-decode block are correct, and the appropriate (long or short) count is completed, the switch block is enabled. This turns on the stereo-indicating LED and passes the L - R information to the matrix block. The matrix block decodes the stereo information and presents the left and right channel signals to pins 7 and 8 respectively.

In stereo mode, the co-channel input (pin 12) is disabled. Co-channel or other noise is now detected by negative excursions of the I detector. When those excursions reach a critical level, the lock detector switches the system to mono, even though the PLL may still be locked. This scheme prevents chattering in and out of stereo because of a marginal signal or high noise-levels (such as during a thunderstorm).

If you wish to decrease the effectiveness of the interference sensing (to keep the decoder in its stereo mode in

the presence of some narrow spike type of interference), the 2.2 μ F capacitor, C1, may be increased to as much as 47 μ F.

Power for the circuit is derived from any convenient +10 to +35V DC rail within the tuner and regulated to +8.3V by an LM317 3-terminal regulator. This output voltage is set by the 120 Ω and 680 Ω voltage divider on the OUT and ADJ terminals. Note that the supply rail must be able to deliver up to 40mA continuously.

Selecting a suitable tuner

Not every AM tuner can be converted to receive broadcasts in stereo. But if you are careful when you examine the tuner's capabilities, the conversion should go smoothly. Here's what to look for:

1. **Old vacuum-tube radios** are unacceptable. You'll undoubtedly have problems because of the high voltages and temperatures involved.

2. **Cheap pocket radios**, clock radios, small table radios, and the like should not be used in most cases. They typically have narrow bandwidths, poor sensitivity, and self-generated phase and frequency modulations that can seriously degrade channel separation and

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increase distortion and noise. (The C-QUAM system uses phase-related information, so the decoder is sensitive to phase variations or modulation.)

3. Some manually-tuned tuners, whether variable-capacitor or variable-inductor types, may cause audible microphonics when in stereo mode. (The Playmaster tuners are quite OK in this regard.) Receivers with self-contained speakers may also be subject to

microphonic problems because of the speaker vibrations. Those vibrations may generate phase modulation and the associated problems of poor separation, distortion, and noise.

4. The local oscillator must be stable and produce a reasonably clean sinewave. An unstable oscillator or a severely distorted waveform may cause distortion.

5. Tuners with synthesizer front ends

or logic-controlled varactor tuning are best adapted to AM stereo because of the more precise, automatic tuning, and better immunity to tuning disturbances. However, those types of receivers are not guaranteed to be trouble free. Phase modulation can originate from the PLL comparison frequency and may appear as an audible tone. Extra filtering may be needed on the control voltages from the logic circuits.

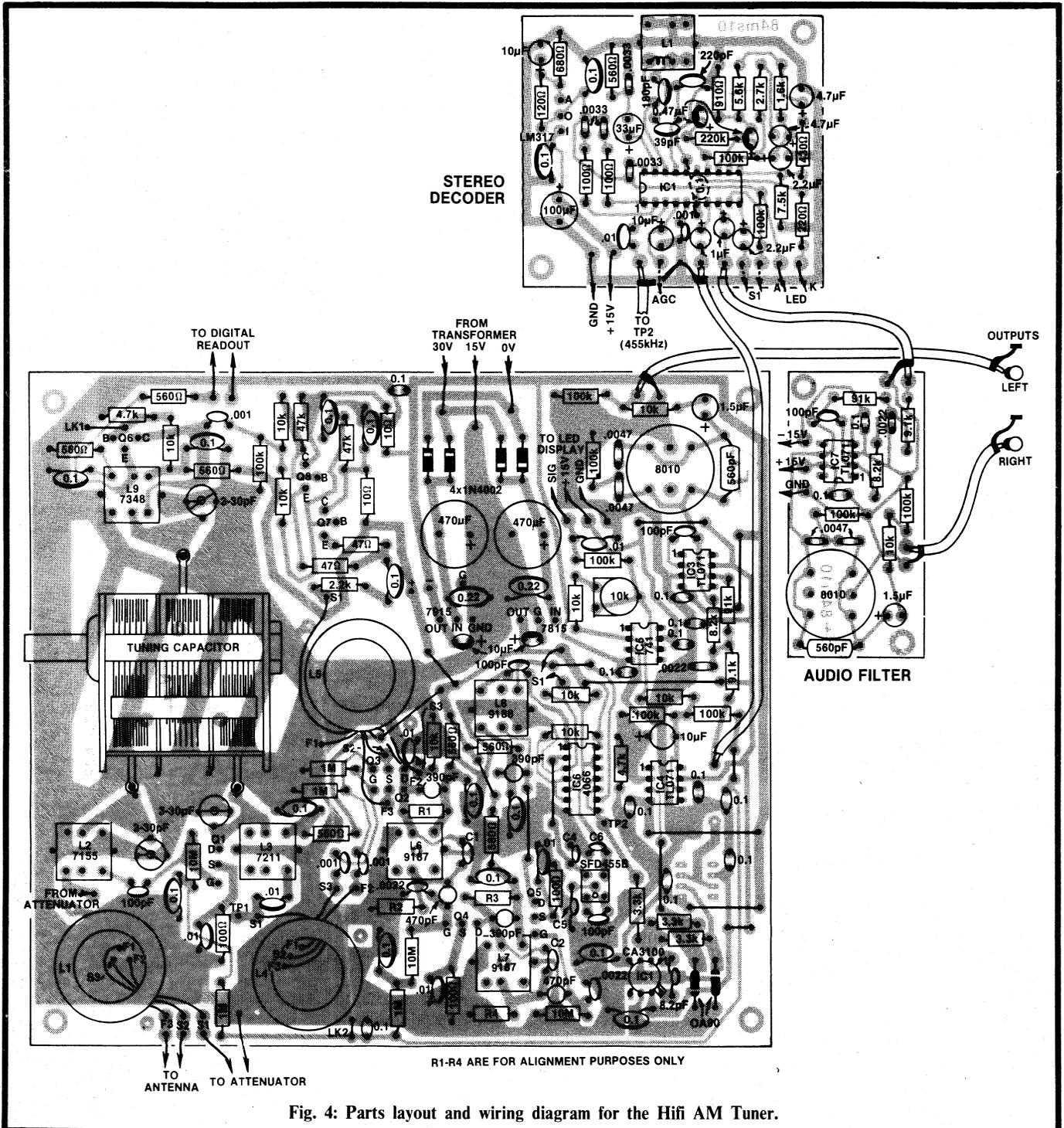


Fig. 4: Parts layout and wiring diagram for the HiFi AM Tuner.

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6. The AGC system of the tuner should be effective enough to provide a generally constant IF input to the decoder from all stations. In some tuners which use an IC for the AM tuner section, it is not possible to gain access to the IF signal.

7. A major advantage is a tuner with a tuned RF amplifier at the front end. The increased sensitivity and selectivity aid in stereo reception and stability.

Construction

All the circuitry, with the exception of the LED and the optional switch S1, is accommodated on a printed circuit board coded 84ms10 and measuring 72 x 65mm. Fig. 4 shows the parts layout.

No special procedure need be followed when assembling the PCB although we suggest that the smaller components be installed first. Note carefully the orientation of the semiconductors, electrolytic capacitors and the LED. We

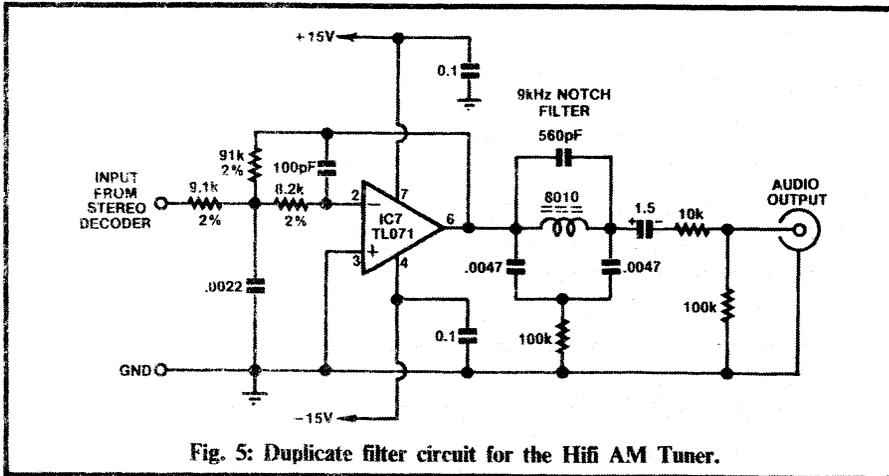


Fig. 5: Duplicate filter circuit for the HiFi AM Tuner.

used PC stakes to terminate the external wiring connections.

Coil L1 consists of 50 turns of 36 B&S enameled copper wire close wound on Neosid coil former (see parts list). This is fitted with an F16 ferrite core slug and a

shield can, and mounted directly on the PCB. Make sure that you terminate the coil leads to the base pins indicated on the parts layout diagram (Fig. 4).

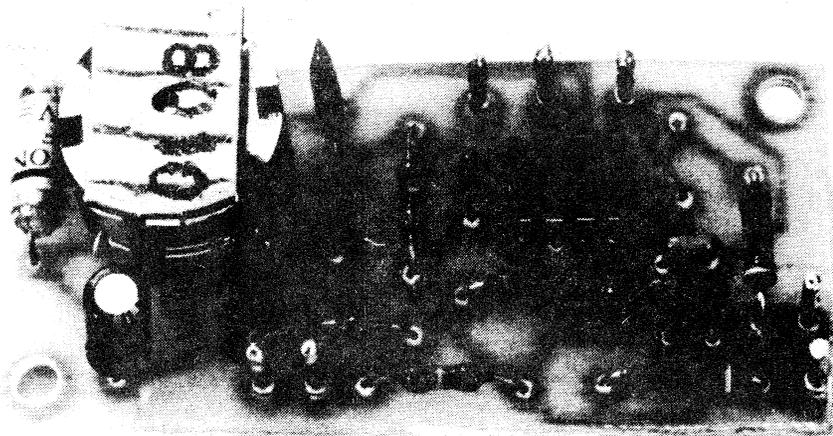
Note the $0.1\mu\text{F}$ capacitor shown dotted on the parts layout diagram. This mounts on the copper side of the PCB and is connected between pins 6 and 16 of the IC.

The AGC output is not used if converting an existing receiver, while the optional auto/mono switch was not used in the conversions to be described.

Installation

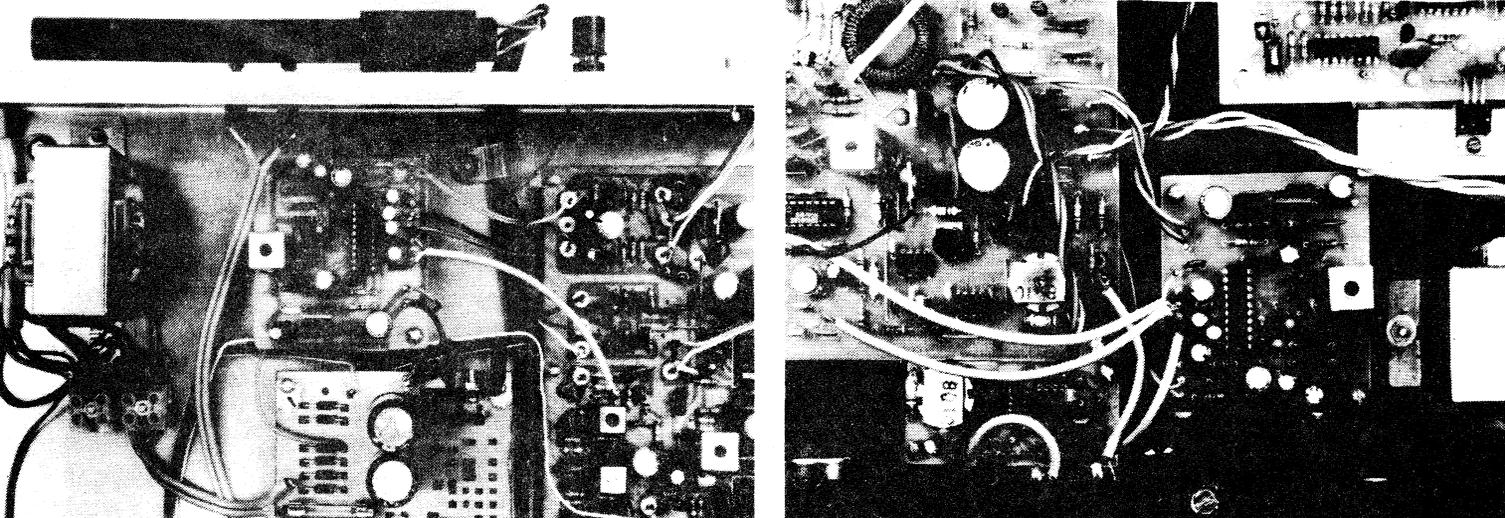
For quiet, clean stereo reception, the IF input signal level to the decoder must lie between 500mV and 1V peak-to-peak. If the tuner has a high IF output (ie, over 1V p-p), a series resistor can be added to drop the voltage to the desired level. The input impedance of the decoder is about $27k\Omega$.

The IF input is derived from the final IF stage immediately preceding the



Above: The LF351 IC in the audio filter is taken from the HiFi AM Tuner PCB.

Below: Close up view of the stereo decoder connections for the Playmaster AM/FM tuner (left) and the HiFi AM Tuner.



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detector diode. Because AGC voltages are generally obtained from the detector, the existing detector should be left in circuit. To avoid conflict with the two audio channels coming from the decoder, the tuner's existing audio output must be disconnected.

The decoder assembly may be mounted in any convenient place inside the tuner, but try to keep it away from

major heat sources such as a power transformer, output transistors and heatsinks. Use shielded cable for the IF input and audio output connections and connect the cable shields to earth at one end only.

Failure to observe this precaution could result in an earth loop. The only common earth connection between the decoder PCB and the tuner is via the

power supply (see Fig. 4).

The left and right audio outputs have a nominal 200mV RMS output level and can be connected directly to the tuner or auxiliary inputs of a stereo amplifier. If the conversion is in an AM/FM tuner, the band switch wiring will have to be modified so that the outputs are not switched in parallel when in the AM mode.

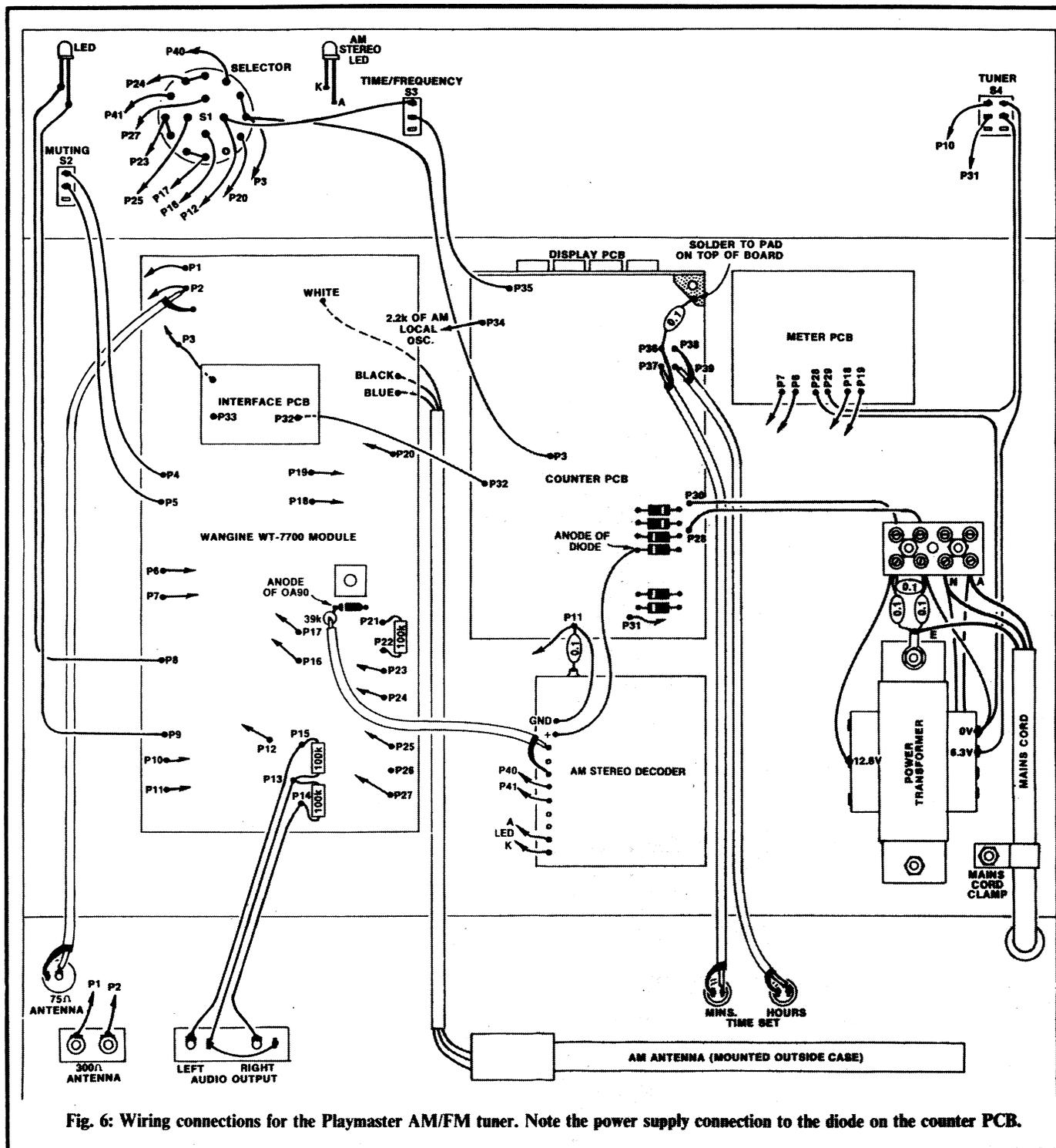


Fig. 6: Wiring connections for the Playmaster AM/FM tuner. Note the power supply connection to the diode on the counter PCB.

We estimate that the current cost of parts for the Stereo Decoder is

\$20-25

Parts for the Audio Filter are estimated to cost \$17-20. These prices include sales tax.

Once the installation has been completed, it is necessary to carry out the setting up procedure. Tune in a station, connect your DVM (or multimeter) to pin 19 of IC1, and adjust the slug in coil L1 for a reading of 4.1V. This done, check that the voltage on pin 10 is approximately 4.3V (note: this indicates that the VCO is in the "lock" condition).

You are now ready to check for stereo reception. Tune into your local stereo station (one that is broadcasting in C-QUAM) and check that the pilot LED lights after a few seconds. Note that accurate tuning is necessary for stereo reception — really, you must be "spot on".

If interference prevents stereo reception, try increasing C1 up to a maximum value of 47 μ F.

Proven conversions

We added the decoder PCB to the Playmaster Hifi AM Tuner and to the Playmaster AM/FM Tuner. Fig. 4 shows the wiring details for the Hifi AM Tuner.

As shown, the IF input for the decoder PCB is derived from test point TP2. This test point precedes the precision rectifier (IC1) in the tuner circuit. The precision rectifier (CA3100) is left in circuit and the audio chain broken by removing buffer amplifier IC2 (TL071) and the wire link between IC2's pin 6 and resistor R5 (9.1k Ω).

The left channel output from the decoder PCB is now connected to the tuner's existing audio filter (ie, to the input of the 9.1k Ω resistor). From there, the signal passes through the whistle filter to the left channel output socket. In the case of the right channel, a duplicate filter circuit must be constructed.

Fig. 5 shows the duplicate filter circuit. This is built on a PCB coded 84fi10 and measuring 67 x 33mm. Fig. 4 shows the parts layout and external wiring connections.

Both the decoder and filter PCBs are mounted in the chassis on 19mm standoffs. Power for the two PCBs is derived from existing supply points on the main tuner PCB. Don't forget to remove the wire link between the two output sockets, otherwise you definitely won't get stereo.

The indicator LED can be mounted on the front panel, adjacent to the signal strength display.

The setting up procedure is exactly as

PARTS LIST

Stereo Decoder Board

- 1 PCB, code 84ms10, 72 x 65mm
- 1 MC13020P stereo decoder IC (Motorola)
- 1 LM317T 3-terminal regulator
- 1 red LED
- 1 Neosid 722/1 coil former with 7100 screening can, F 16 screw core, and 5027/PLD base plate
- 1 200mm length of 0.125mm (36 B&S) enamelled copper wire
- 2 9mm standoffs

Capacitors

- 1 100 μ F/35VW PC electrolytic
- 1 33 μ F/16VW PC electrolytic
- 2 10 μ F/16VW PC electrolytic
- 2 4.7 μ F/16VW PC electrolytic
- 2 2.2 μ F/16VW PC electrolytic
- 2 1 μ F/16 VW PC electrolytic
- 2 0.47 μ F/16VW PC electrolytic
- 3 0.1 μ F ceramic
- 1 0.1 μ F ceramic
- 4 .0033 μ F metallised polyester
- 1 .001 μ F metallised polyester
- 1 220pF ceramic
- 1 180pF ceramic
- 1 39pF ceramic

Resistors (1/4W, 2%)

- 1 x 220k Ω , 2 x 100k Ω , 1 x 7.5k Ω , 1 x 5.6k Ω , 1 x 2.7k Ω , 1 x 1.6k Ω , 1 x 910 Ω , 1 x 680 Ω , 1 x 560 Ω , 1 x 430 Ω , 1 x 220 Ω , 1 x 120 Ω , 2 x 100 Ω

Audio Filter Board

- 1 PCB, code 84fi10, 67 x 33mm
- 1 TL071 op amp (use IC2 from Hifi AM Tuner)
- 1 8010 whistle filter coil
- 2 9mm standoffs

Capacitors

- 1 1.5 μ F/16VW PC electrolytic
- 2 0.1 μ F monolithic ceramic
- 2 .0047 μ F metallised polyester
- 1 .0022 μ F metallised polyester
- 1 560pF polystyrene
- 1 100pF ceramic

Resistors (1/4W, 5% unless noted)

- 2 x 100k Ω , 1 x 91k Ω 2%, 1 x 10k Ω , 1 x 9.1k Ω 2%, 1 x 8.2k Ω

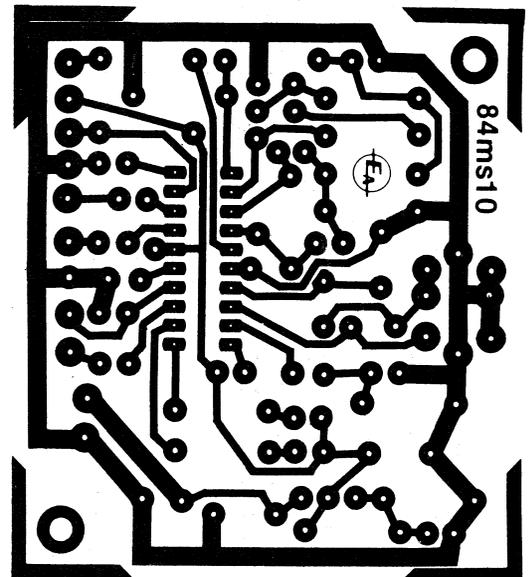
Miscellaneous

Machine screws and nuts, hook-up wire, shielded cable, solder, PC stacks etc.

The rest of the conversion is fairly straightforward and involves disconnecting the existing AM tuner output at P22 and running new output connections P40 and P41 from the decoder to the selector switch S1. Note that the existing link between P40 and P41 on S1 must be removed.

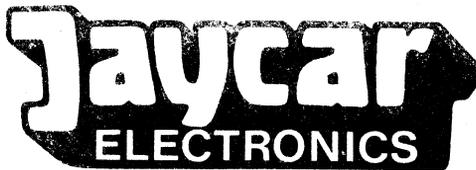
The indicator LED can be mounted on the front panel, adjacent to the AM designation for the selector switch (see photograph). If you wish to use whistle filters, then the February 1979 design should be duplicated and the two filters interposed between the decoder outputs and the selector switch. Don't forget the setting up adjustments as before.

Finally, would readers please note that we are unable to offer advice on adding this decoder to specific commercial tuners.



described in "installation" above, while the whistle filter is adjusted by rotating the ferrite cup for the best null (see page 70, February 1983).

Fig. 6 shows the conversion details for the Playmaster AM/FM Tuner. The 455kHz IF signal is most conveniently extracted by making a connection to the anode of the 0A90 detector diode. In this case, however, the available signal level must be attenuated using a 39k Ω series resistor.



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CONSTRUCTORS PLEASE NOTE

1).The construction article refers to two projects,a stereo decoder and a audio filter. This kit will only contain the components associated with the stereo decoder project.

2).It has been recommended that a number of electrolytic capacitors be substituted for either tantalum type or low leakage electrolytic.

These capacitors have been marked with an asterisk (*) on the circuit diagram.There are two 0.47uf, one 2.2uf and two 4.7uf.