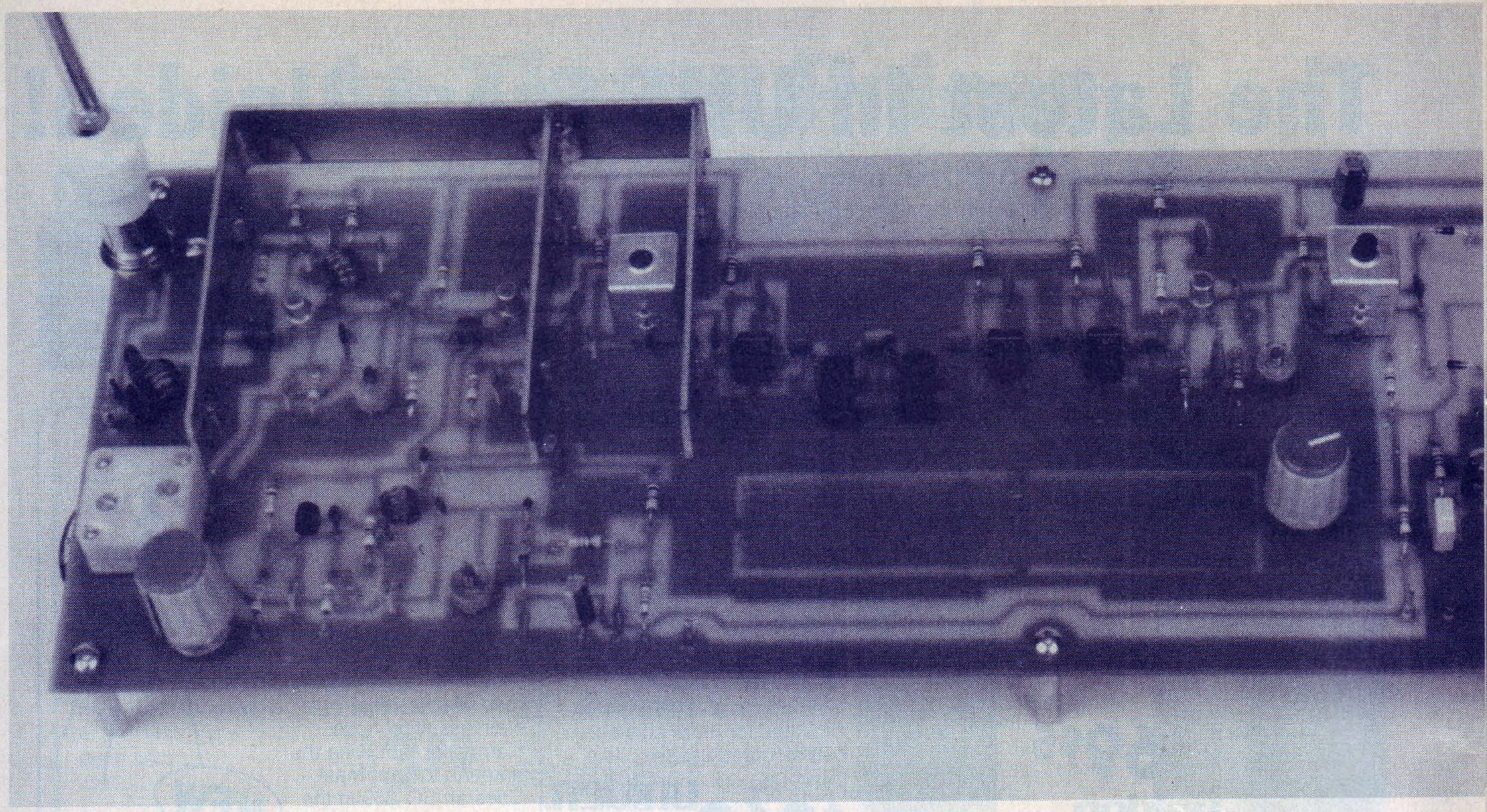

BUILD AN FM RADIO TRAINER; PT.1

This FM Radio Trainer is ideal for learning the basics of FM circuitry. By building it, you will not only gain a very good understanding of FM receiver principles but will also acquire an FM radio which has very good performance.

By JOHN CLARKE

The AM Radio Trainer described in SILICON CHIP in June 1993 was very popular with schools and TAFE colleges as a project to demonstrate receiver principles. However, since then, many popular AM stations have moved across to the FM band, so many people would now prefer to build an FM radio.

The SILICON CHIP FM Radio Trainer is designed as a learning aid for people studying electronics. Most mono FM receivers use one or two integrated circuits (ICs), with a few external components. However, for this design, we have opted for a more discrete approach, so that the major circuit blocks are all clearly separated.

To simplify construction, we have produced a PC board which has a screen printed overlay. This shows the position of each component plus its circuit interconnections. In addition, the layout on the PC board closely follows the circuit layout, so that the novice can easily come to grips with the functions of the various components.

Although some ICs have been used in the circuit, each only performs a single task. The circuit is therefore discrete in the sense that each functional block is separate and this makes it easy to understand what it does. The tuner is also easy to build and align, despite the fact that some coil winding is involved (full details will be published next month).

The alignment is carried out with the aid of a simple 10.7MHz oscillator, which we will describe next month. Apart from that, the only other items required for alignment are a multimeter and a plastic trimming tool.

Performance

The performance of the FM Radio Trainer is shown by the accompany-

Main Features

- Ideal for learning FM receiver circuitry
- Mono output
- On-board amplifier & loudspeaker
- Battery powered for safety
- Circuit & PC board overlay have same layout
- Excellent signal-to-noise performance
- Low distortion
- Receives local & strong distant stations with on-board extendable antenna
- Automatic frequency control (AFC) keeps radio on-station
- Calibrated tuning dial
- Reduction drive for ease of tuning
- Easy alignment using a simple IF oscillator & a multimeter

ing graphs and the specifications panel. As shown, the usable RF signal level is around 30µV, at which point the audio signal level is about 6dB down (half level). At 100µV, the signal-to-noise ratio is better than 70dB which is quite a good figure. The ultimate signal-to-noise ratio is 82dB and there are very few commercial tuners which would approach this figure.

So although the radio is not super sensitive, it provides excellent performance on all local stations, with good reception for signals up to 70kms away. In fact, this receiver will better many commercial receivers when it comes to performance.

What is FM anyway?

Before getting involved in how the circuit works, let's first take a look at the basic principles of FM transmission.

FM or frequency modulation is a method of applying information to a radio frequency (RF) carrier. If the RF carrier is fixed at one particular frequency and level, then the only way that information can be conveyed is by switching the RF signal on and off. This is the technique used for Morse Code.

By suitably modulating the carrier with another signal, however, we can transmit speech or music. One method is to vary the level of the carrier as shown by the bottom waveform of Fig.1. This technique is called amplitude modulation (or AM) and we can detect these changes in amplitude using a suitable AM receiver that's tuned to the carrier frequency.

Frequency modulation (or FM), on the other hand, conveys information by varying the frequency of the carrier. Fig.1 shows a typical FM waveform. Note that the amplitude of this waveform is kept constant.

At the other end, the variations in carrier frequency are detected (or demodulated) in the receiver to recover the original audio. Any variations in amplitude that may occur in the received signal are effectively ignored, which means that FM receivers are far less prone to electrical interference than their AM counterparts.

Broadcast band FM transmitters

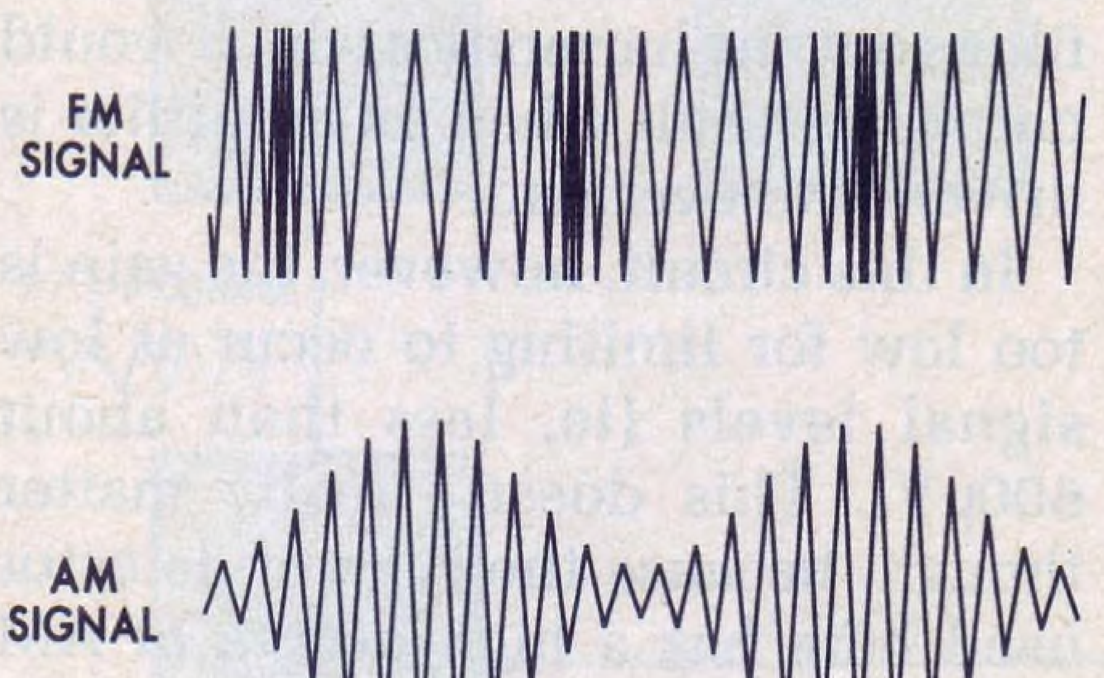

Fig.1: an FM signal (top) conveys information by varying the frequency of the carrier. In an AM signal, it is the carrier amplitude that is varied.

modulate the RF carrier by a maximum of 75kHz above and below the carrier frequency. They also include pre-emphasis, whereby signals above 3.183kHz (a 50µs time constant) are boosted. These signals are subsequently restored to normal in the receiver using a complementary de-emphasis circuit. The idea here is to reduce high-frequency noise in the output of the tuner.

Block diagram

The circuit for the FM Radio Trainer is based on the superheterodyne principle. Fig.4 shows the general configuration. The antenna at left feeds into a bandpass filter, which is a parallel resonant circuit comprising inductor L1 and two capacitors. These tune the filter to the centre of the FM band (ie, to around 100MHz).

Following the bandpass filter is an RF amplifier stage. This stage has a parallel resonant circuit which is tuned by L2 and variable capacitor VC1. The latter is one section of a tuning gang capacitor and can tune the RF amplifier to any nominal frequency from 88-108MHz. The bandwidth of the tuned circuit is about 200kHz.

By this means, the wanted (or tuned) signal is amplified, while other signals are rejected.

Following the RF amplifier, the signal is fed to the mixer (Q2 & T1) where it is mixed with the local oscillator signal. VC3, the second section

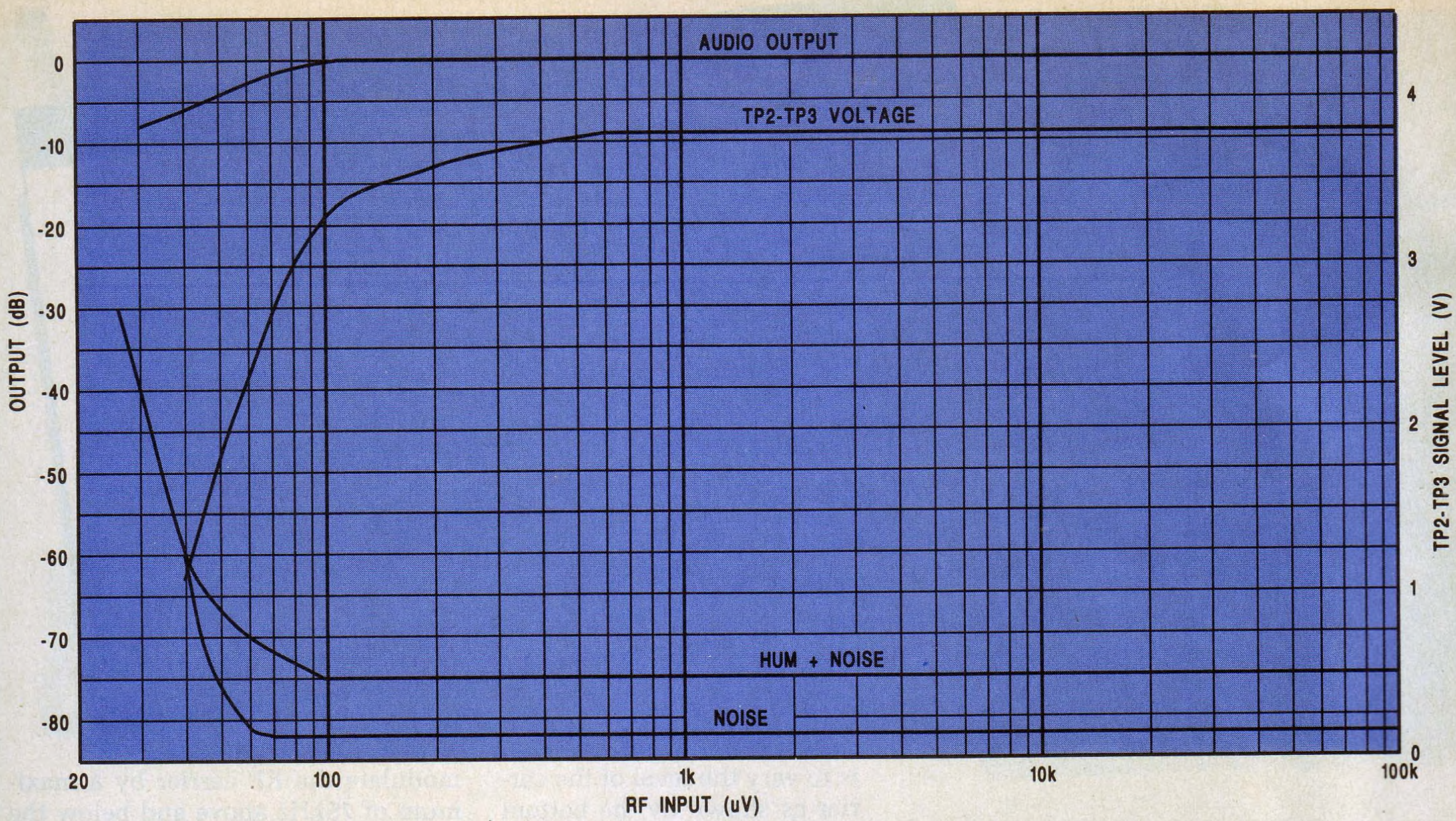

Fig.2: these curves plot the hum & noise performance of the prototype. They also show the audio output level & the filtered detector output (TP2-TP3) voltage. Full limiting does not occur until the RF input reaches about 600µV but this is not important in this circuit due to the type of detector employed.

of the tuning gang capacitor, tunes the local oscillator by resonating with inductor L3. In operation, the local oscillator runs at 10.7MHz less than the tuned RF signal (ie, it runs from 77.3-97.3MHz, depending on the setting of VC3).

It is in the mixer that the superheterodyne process takes place. The word "heterodyne" refers to a difference in frequency or beating effect, while the "super" prefix refers to the fact that the beat frequency is supersonic (ie, well beyond the range of human hearing).

Four signals are produced as a result of the mixing process: the two original signals plus the sum and difference frequencies. These are then passed to an IF (intermediate frequency) amplifier and bandpass filter stage based on IC1-IC3, XF1 and Q4. This stage is tuned to ensure that only the 10.7MHz difference frequency (now known as the IF) is allowed to pass.

In reality, the IF amplifier consists of four separate amplifier stages (IC1, IC2, IC3 & Q4) which, when losses in the bandpass filter are taken into account, have an overall gain of about 1000. This figure is low by comparison with typical FM tuners which generally have an IF gain of 10,000 or more to ensure that the IF signal is driven into limiting.

Limiting

Limiting simply refers to the fact that the signal is driven well into overload in the IF amplifier stages. This is done to eliminate any amplitude variations in the tuned signal before it is fed into the demodulator. This is one of the factors that enables FM tuners to reject atmospheric and man-made noise.

Note that no distortion is introduced by the limiting process because the final stage is tuned to 10.7MHz. This filters out any harmonics which would normally result when an amplifier is driven into overload.

In this circuit, however, the gain is too low for limiting to occur at low signal levels (ie, less than about 600µV). This doesn't really matter though, because the type of detector used here has a high degree of AM rejection.

As alluded to earlier, the local oscillator frequency always "tracks" the tuned frequency of the RF amplifier so that the difference between their output frequencies is 10.7MHz. So if the radio is tuned to 88MHz, the local oscillator will be set to 88 - 10.7 = 77.3MHz. Similarly, if the radio is tuned to the upper limit of the FM band at 108MHz, the local oscillator operates at 97.3MHz.

All this happens automatically by virtue of the 2-section tuning gang – one section controlling the RF amplifier and the other the local oscillator.

The 10.7MHz difference frequency is standard for broadcast band FM receivers. The big advantage of producing an IF signal is that we now only need to provide gain at one frequency rather than for the whole 88-108MHz range which would require complicated filters and a multi-gang capacitor to track with the local oscillator.

The output from the IF stage is now fed to a demodulator (T4, D1 & D2) to recover the audio signal. This stage also includes the necessary de-emphasis to compensate for the pre-emphasis in the treble of the transmitted signal. From there, the demodulated audio is fed to an audio amplifier (IC4) and this then drives the loudspeaker.

Automatic frequency control

There's one important feature that we haven't yet mentioned and that's the AFC line. AFC stands for automatic frequency control and it works to keep the local oscillator in lock with the tuned signal, so that the radio does not drift off station. It also produces a "snap-in" effect, whereby the station suddenly locks in as the tuning approaches the station frequency.

As shown on Fig.4, the AFC line is derived from the demodulator. The resulting control voltage is then fed back to the local oscillator. We'll examine the control action in some detail when we come to the circuit description.

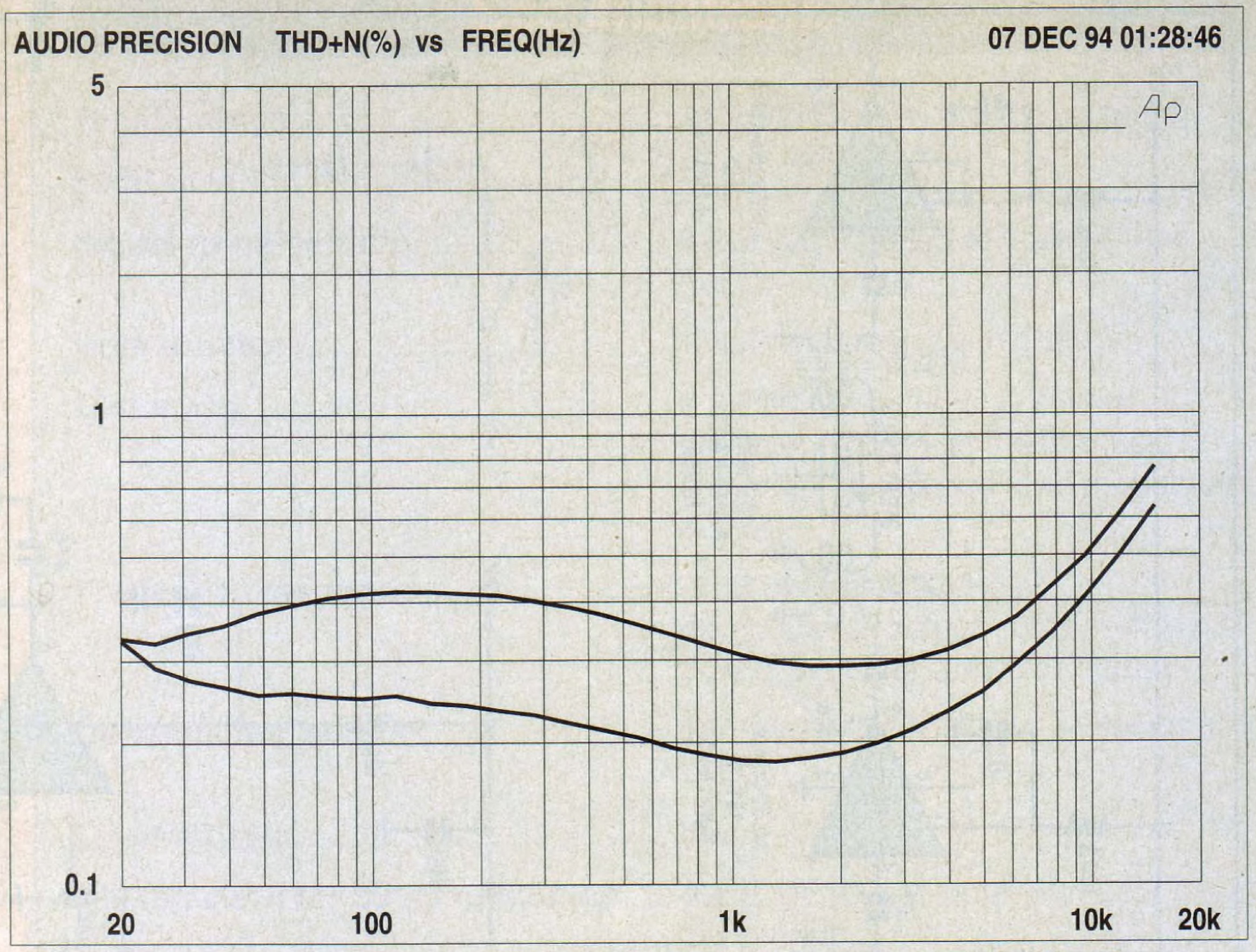

Fig.3: the tuner has excellent distortion characteristics, as revealed by these plots at 60kHz deviation & 75kHz deviation (measured at the demodulator output). Note that the THD is 0.32% at 1kHz & 75kHz deviation & less than 0.2% at 1kHz & 60kHz deviation.

Circuit details

Refer now to Fig.5 for the circuit of the FM Radio Trainer. It's main components are dual-gate Mosfets Q1, Q2 & Q4, high frequency transistor Q3, three HF (high frequency) gain blocks (IC1-IC3), and audio amplifier stage IC4. The function of each stage is shown on Fig.5 and, in addition, each stage can be directly related back to the block diagram (Fig.4).

Starting at the antenna, the incoming RF signal is coupled to the junction of two capacitors (39pF & 47pF) which, together with parallel inductor L1, form the input bandpass filter. A 1kΩ resistor is included in parallel with L1 and this damps out the Q of the filter so that it covers the entire FM band without adjustment.

This input filter prevents signals with frequencies outside the FM band from entering the circuit and possibly overloading the following stages.

Following the input filter, the RF signal is fed via RF1 to Q1. This is a BFR84 dual-gate Mosfet amplifier which operates in common source configuration. Its quiescent current is set by the 330Ω source resistor and this is bypassed by a .01µF capacitor to ensure maximum AC gain. The gain is set to a high value by biasing G2 to around 6.5V, as set by the 10kΩ and 27kΩ bias resistors.

The amplified signal appears at Q1's drain and is tuned mainly by variable capacitor VC1 and inductor L2. Note that the junction of L2 and the 47Ω decoupling resistor is bypassed by a .01µF capacitor. As a result, L2 is effectively grounded at this point as far as RF signals are concerned. The same technique is used to provide an RF ground for one side of L3 in the local oscillator.

The 56pF capacitor in series with VC1 effectively reduces the tuning capacitance range from 2-160pF to 1.9-41pF. This is done to restrict the bottom end of the tuning range to the

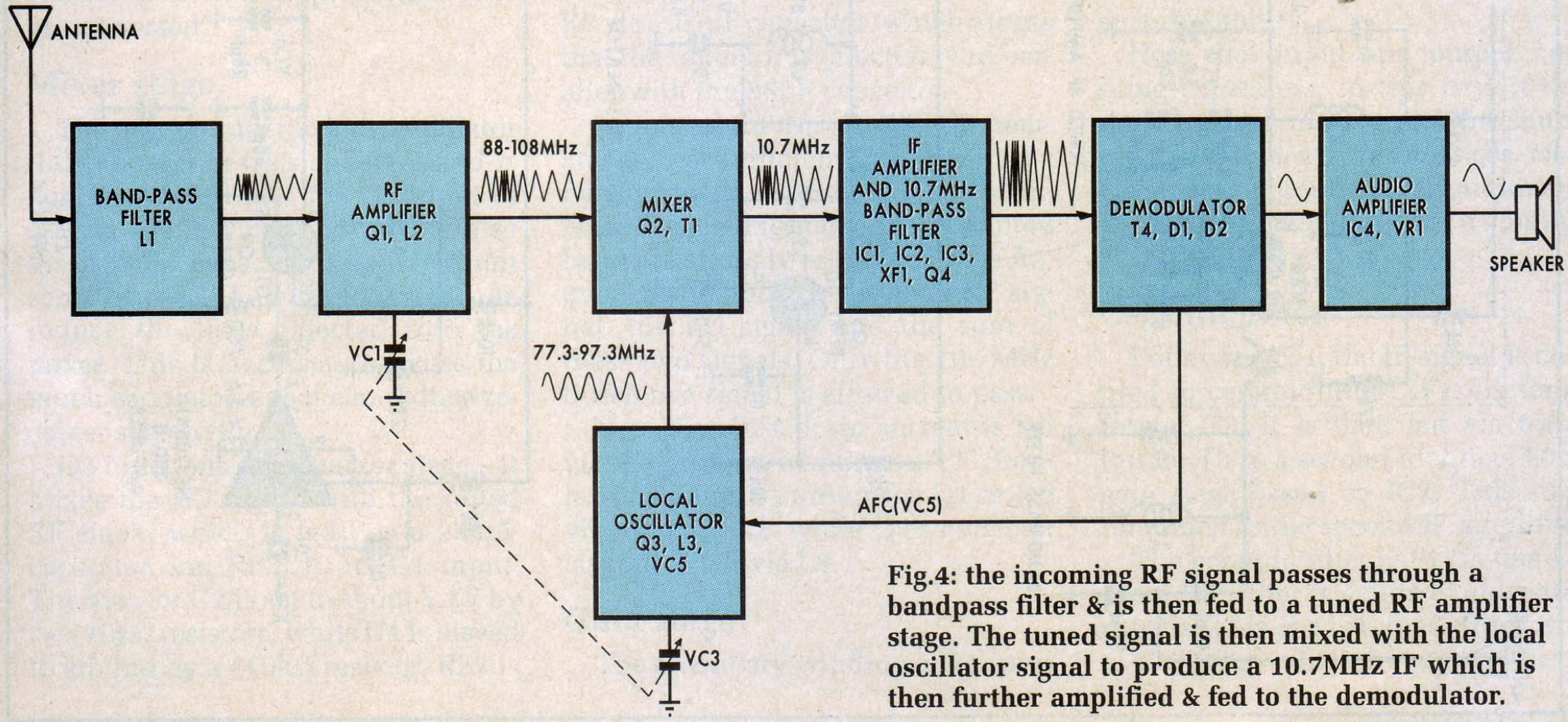

Fig.4: the incoming RF signal passes through a bandpass filter & is then fed to a tuned RF amplifier stage. The tuned signal is then mixed with the local oscillator signal to produce a 10.7MHz IF which is then further amplified & fed to the demodulator.

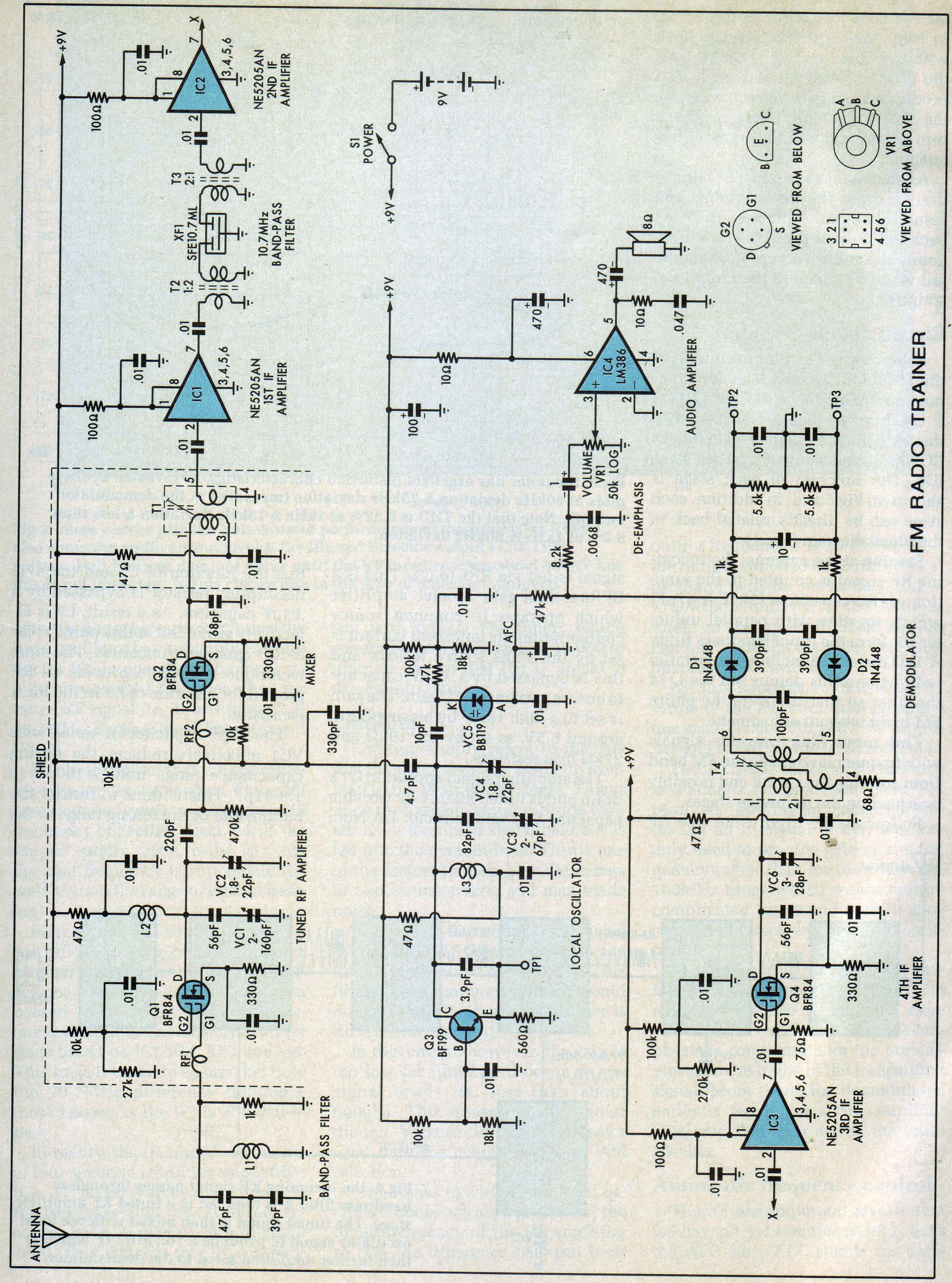
FM RADIO TRAINER
NE5205AN 2ND IF AMPLIFIER
IC2
XF1 SFE10.7ML
10.7MHz BAND-PASS FILTER
T2 1:2
T3 2:1
NE5205AN 1ST IF AMPLIFIER
IC1
T1
S1 POWER
9V
+9V
IC4 LM386
AUDIO AMPLIFIER
VOLUME VR1 50k LOG
DE-EMPHASIS
8Ω
AFC
VC5 BB119
DEMODULATOR
D1 1N4148
D2 1N4148
T4
TP2
TP3
VIEWED FROM BELOW
VR1 VIEWED FROM ABOVE
MIXER
Q2 BFR84
SHIELD
TUNED RF AMPLIFIER
Q1 BFR84
VC1 2-160pF
VC2 1.8-22pF
VC3 2-67pF
VC4 1.8-22pF
VC6 3-28pF
RF1
RF2
L1
L2
L3
BAND-PASS FILTER
ANTENNA
LOCAL OSCILLATOR
Q3 BF199
TP1
4TH IF AMPLIFIER
Q4 BFR84
NE5205AN 3RD IF AMPLIFIER
IC3

Fig.5 (left): each stage in the circuit is labelled & can be directly related back to the block diagram (Fig.4). Dual-gate Mosfet Q1 forms the heart of the tuned RF amplifier, while Q2 is the mixer. IC1, IC2, IC3 & Q4 form the IF amplifier stages, & T4, D1, D2 & their associated resistors & capacitors form a ratio detector. Varicap diode VC5 provides AFC for the local oscillator.

Specifications

Tuning range	88-108MHz (FM broadcast band)
50dB quieting sensitivity	18μV
Signal-to-noise ratio	82dB with respect to 150mV (see Fig.2)
Hum & noise	-75dB with respect to 150mV
Distortion	0.32% THD at 1kHz & 75kHz deviation; <0.2% at 1kHz & 60kHz deviation (measured at demodulator output)
Frequency response	-3dB at 3Hz & 30kHz at demodulator output; -3dB at 40Hz & 30kHz at power amplifier output
Demodulator output	150mV RMS for 75kHz deviation at 1kHz
De-emphasis	50μs
AM rejection for 30% modulation	30dB for 100μV input; 53dB for 1mV input
Current drain	110mA @ 9V & minimum volume
Minimum operating voltage	5.5VDC
Maximum operating voltage	10.5VDC

Note: although a 9V battery can be used to power the FM RadioTrainer, it will have a relatively short life. For prolonged usage, we recommend powering it from a 9V 300mA DC plugpack. Be sure to remove battery first.

broadcast band. In addition, trimmer capacitor VC2 is included in parallel with these two components and is used to set the minimum tuning capacitance. It is adjusted during alignment so that the maximum tuning frequency is 108MHz.

Local oscillator

Q3 and its associated components make up the local oscillator. This transistor is biased by the 10kΩ and 18kΩ resistors connected to its base, and by a 560Ω emitter resistor. It oscillates by virtue of its tuned collector load and the 3.9pF feedback capacitor between its emitter and collector.

The collector load is tuned using VC3, while the series 82pF capacitor effectively reduces VC3's range to 2-37pF (down from 2-67pF) to limit the bottom end of the frequency range to the required value. VC4 sets the minimum capacitance across L3 and is adjusted during alignment to set the upper frequency limit of the local oscillator.

For this reason, a test point (labelled TP1) has been provided at Q3's emitter to allow a frequency meter to be connected.

Mixer stage

The output from the local oscillator (LO) appears at Q3's collector and is lightly coupled into the G2 input of Q2 via a 4.7pF capacitor. Note also that a 330pF capacitor is used to shunt some of the LO signal to ground, to reduce the level injected into the mixer. This is necessary because too much oscillator signal can reduce receiver sensitivity.

Q2 functions as the mixer stage – it mixes the LO signal with the tuned RF signal which is fed (via a 220pF capacitor and RF2) to its G1 input. The bias for G2 is set to about 5.1V by two 10kΩ resistors, while G1 is biased to ground by a 470kΩ resistor. RF2 is included to prevent parasitic oscillation in Q2.

Q2's drain load is tuned to 10.7MHz using a 68pF capacitor and an adjustable ferrite-cored inductor (the primary winding) in IF transformer T1 (between pins 1 & 3). Note that the pin 3 end of the primary is grounded at RF via a .01μF capacitor, which means that the inductor is effectively in parallel with the 68pF capacitor.

As a result of this tuning, Q2 operates as a very efficient amplifier over a narrow band centred on 10.7MHz, while frequencies outside the wanted band are strongly rejected. These frequencies include the original RF signal, the LO signal and the sum of these two signals. Only the 10.7MHz difference signal is allowed to pass.

Note that Q2's drain current is fed via the primary winding in T1. Similarly, the drain current for Q1 is fed via inductor L2, while Q3's collector current is fed via L3.

Gain stage

The secondary winding of T1 (pins 5 & 4) now couples the IF signal from the mixer to gain stage IC1 via a .01μF capacitor. IC1 is an NE5205AN wideband high-frequency amplifier which operates with a fixed gain of 20dB (x10). Its supply rail is derived from the 9V rail via a 100Ω resistor and is decoupled using a .01μF capacitor to ensure stability.

Note that input and output coupling capacitors, in this case .01μF, must be used here to prevent shunting of the internal bias voltages. Note also that the input and output impedances of the NE5205AN are a nominal 75Ω.

Ceramic filter

Following IC1, the IF signal is coupled to ceramic filter XF1 via transformer T2. It is then fed via transformer T3 to a second identical 20dB gain stage based on IC2. This stage functions as the second IF amplifier.

The ceramic filter (XF1) is there to provide further rejection of unwanted signals. This is a bandpass filter with a 10.7MHz centre frequency and a

PARTS LIST

1 PC board, code 06303951, 363 x 115mm, with screen printed component overlay
3 pieces of blank PC board, 19mm x 70mm
2 pieces of blank PC board, 25 x 90mm
1 piece of blank PC board, 19 x 90mm
1 35mm diameter self-adhesive tuning dial
1 57mm diameter 8-ohm loudspeaker
1 9V PC-mount battery holder plus mounting screws
1 9V 216 battery
1 SPDT toggle switch (S1)
6 25mm tapped spacers plus 6-screws
2 15mm diameter knobs
1 50kΩ log pot (16mm) (VR1)
1 panel mount PAL socket
1 PAL line plug with plastic outer case
1 715mm telescopic antenna (eg, Tandy 270-1406) plus 2 x 20mm screw & nut
1 miniature dual tuning gang, 2-160pF & 2-67pF, with dial & mounting screws (VC1,VC3)
1 Murata SFE10.7ML 10.7MHz ceramic filter (XF1)
1 16mm pot shaft assembly (see text)
1 13mm round screw-on rubber foot
20 PC stakes

Semiconductors
3 NE5205AN wideband amplifiers (IC1-IC3)
1 LM386 power amplifier (IC4)
3 BFR84 dual gate VHF Mosfets (Q1,Q2,Q4)
1 BF199 NPN VHF transistor (Q3)
1 BB119 varicap diode (VC5)
2 1N4148 signal diodes (D1,D2)

Capacitors
2 470µF 16VW PC electrolytic
1 100µF 16VW PC electrolytic
1 10µF 16VW PC electrolytic
2 1µF 16VW PC electrolytic
1 .047µF MKT polyester
22 .01µF ceramic
1 .0068µF MKT polyester
2 390pF ceramic
1 330pF ceramic
1 220pF ceramic
1 100pF NP0 ceramic
1 82pF NP0 ceramic
1 68pF NP0 ceramic
2 56pF NP0 ceramic
1 47pF NP0 ceramic
1 39pF NP0 ceramic
1 10pF NP0 ceramic
1 4.7pF NP0 ceramic
1 3.9pF NP0 ceramic

Trimmer capacitors
2 1.8-22pF trimmers (VC2,VC4)
1 3-28pF trimmer (VC6)

Resistors (0.25W, 1%)

1 470kΩ	3 1kΩ
1 270kΩ	1 560Ω
2 100kΩ	3 330Ω
2 47kΩ	3 100Ω
1 27kΩ	1 75Ω
2 18kΩ	1 68Ω
4 10kΩ	4 47Ω
1 8.2kΩ	2 10Ω
2 5.6kΩ	

Coils & ferrites
2 Neosid type A adjustable inductance assemblies; 99-007-96 base, former, can & F29 screw core (T1,T4)
2 balun formers, 6 x 13 x 8mm; Philips 4313 020 4003 1 (T2,T3)
2 RFI suppression beads, Philips 4330 030 3218 2 (RF1,RF2)

Wire
1 300mm length of 0.8mm ENCW
1 1-metre length of 0.25mm ENCW
1 1-metre length of 0.125mm ENCW
1 300mm length of 0.8mm tinned copper wire
1 40mm length of 3-way rainbow cable
1 40mm length of twin loudspeaker lead

Miscellaneous
Plastic alignment tool, four rubber feet for mounting PC board, 10.7MHz alignment oscillator (to be described)

280kHz bandwidth. However, it does require nominal 300Ω source and output loads to obtain the correct amplitude and frequency characteristics.

This requirement has been provided by including T2 and T3. These two transformers provide the correct 75Ω:300Ω and 300Ω:75Ω impedance matching between IC1 and XF1 and between XF1 and IC2. If you are wondering why these transformers only have a 2:1 turns ratio, just remember that the impedance ratio is multiplied by the square of the turns ratio. So a 2:1 winding ratio produces the 4:1 impedance ratio required.

The output from IC2 appears at pin 7 and is fed to a third IF amplifier stage based on IC3. From there, the signal is coupled to G1 of dual-gate Mosfet Q4 which functions as a fourth IF amplifier stage. Its drain load is tuned to 10.7MHz by a 56pF capacitor, trimmer VC6 and the primary of T4. The 75Ω resistor on G1 provides the correct loading for IC3.

Taken together, the four IF amplifier stages and the bandpass filter provide a gain of about 1000 at 10.7MHz, with a bandwidth (or selectivity) of 280kHz. This means that signals at 10.7MHz ±280kHz are amplified and fed through to the demodulator, while higher and lower frequencies are excluded.

Demodulator

To demodulate an FM signal, the demodulator (or detector) must produce a change in audio level as the signal deviates from the 10.7MHz centre frequency. The greater the deviation, the greater the output level that must be produced. The frequency of the recovered audio depends on the rate of the deviation.

Fig.6 shows the response curve of the demodulator. This is often called an "s-curve" but the important thing is that it is linear over the -75kHz to +75kHz deviation range. As the frequency is shifted above 10.7MHz, the demodulator voltage goes increasingly positive. Conversely, as the frequency shifts below 10.7MHz, the demodulator voltage goes increasingly negative.

The demodulator is based on the windings in T4 plus diodes D1 and D2 and their associated capacitors. The secondary winding (pins 6 & 5), along with its parallel 100pF capacitor, resonates at a nominal 10.7MHz

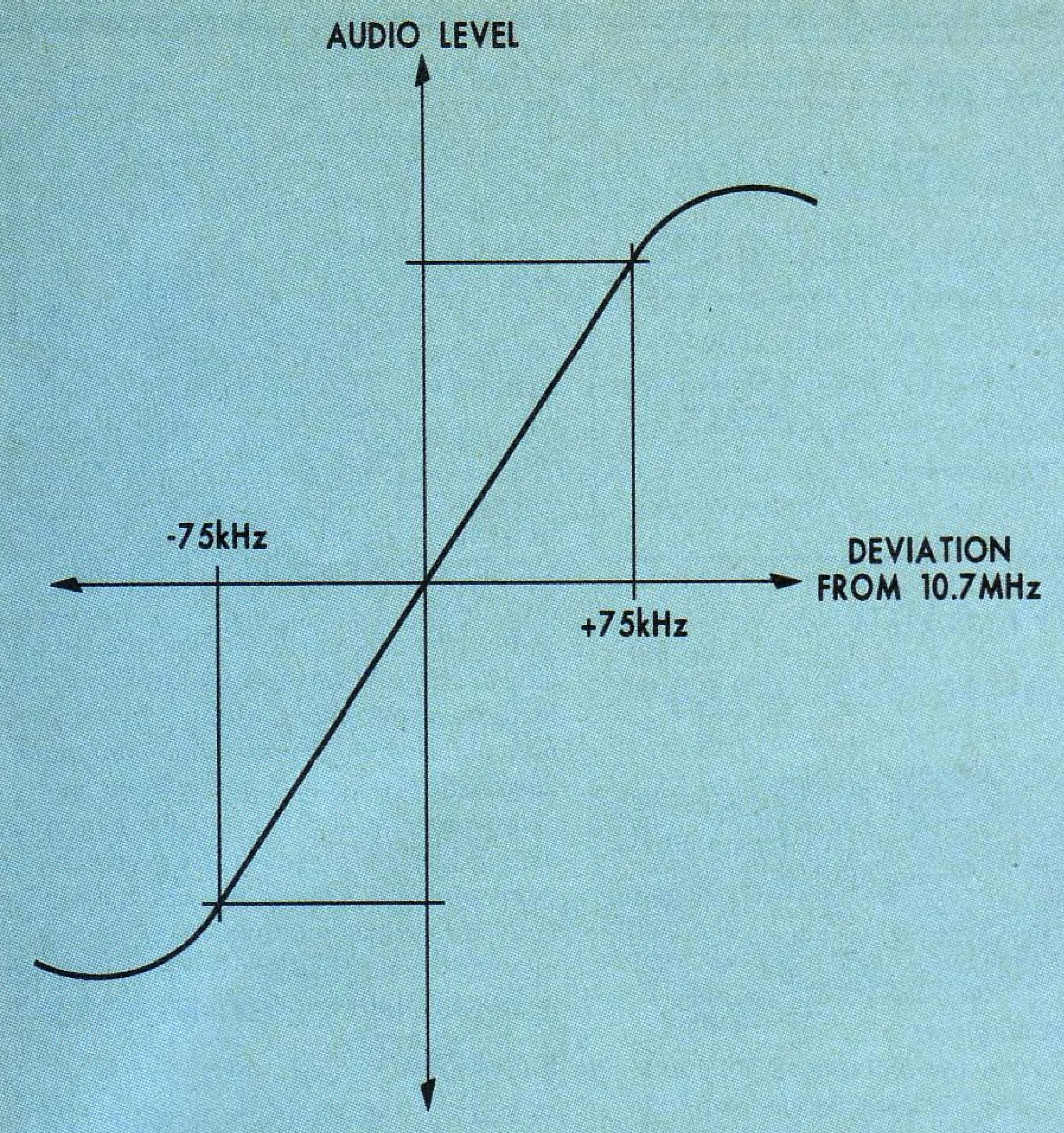

Fig.6: the response curve of the demodulator. Note that it is linear over the -75kHz to +75kHz deviation range. As the frequency is shifted above 10.7MHz, the demodulator voltage goes increasingly positive. Conversely, as the frequency shifts below 10.7MHz, the demodulator voltage goes increasingly negative.

and this is set during alignment by adjusting a ferrite slug in the coil.

In addition, there is a third winding (sometimes called a tertiary winding) which connects to the centre-tap of the secondary. The other end of this winding connects to the output of the demodulator (ie, the junction of the two 390pF capacitors) via a 68Ω resistor.

The tertiary winding is wound directly over the primary to ensure close coupling, so that the signal phases in both windings are the same. At the 10.7MHz resonance frequency, both ends of the secondary are 90° out of phase with respect to the primary and 180° out of phase with each other. In addition, the voltage across the secondary is 90° out of phase with the tertiary winding.

As a result, two equal voltages of opposite polarity are applied to D1 and D2 and so equal but opposite voltages are applied across the two 390pF capacitors. Since the voltages across the two 390pF capacitors are equal, their centre-point voltage is zero (and there is no output).

Any frequency deviations from 10.7MHz, however, produce a corresponding phase shift in the secondary. The centre-tapped secondary winding then becomes unbalanced, so that the voltage at one end (with respect to the centre tap) is greater than the voltage at the other.

Hence, when the FM signal is above 10.7MHz, the output from D1 is greater than the output from D2. Thus, the junction of the two 390pF capacitors goes positive. Conversely, when the FM signal is below 10.7MHz, the output from D2 is greater than the output from D1 and the junction of the 390pF capacitors goes negative.

Hence, as the FM signal deviates above and below 10.7MHz, the result is an audio signal at the junction of the 390pF capacitors.

AM rejection

In order to make the FM detector less sensitive to changes in the IF level, the total voltage across the two 390pF capacitors is stabilised so that it cannot vary at an audible rate. This is achieved using a filter network consisting of two 1kΩ resistors and a 10μF capacitor.

The effect of the 10μF capacitor is to keep the sum of the voltages across the two 390pF capacitors constant. This means that variations in the level of the FM signal will not produce variations in the output of the demodulator.

The two 5.6kΩ resistors and their parallel .01μF capacitors provide convenient test points which are used during the alignment procedure.

This type of FM demodulator is called a ratio detector. It differs from other FM detectors such as the Foster-Seeley detector because, as we have just seen, it incorporates AM rejection. This is important in the circuit because, as discussed earlier, limiting does not occur on low-level signals.

De-emphasis

The output from the demodulator is de-emphasised using an 8.2kΩ resistor and a .0068μF capacitor, and then fed to audio amplifier stage IC4. IC4 operates with a gain of 20; its output appears at pin 5 and drives an 8-ohm loudspeaker via a 470μF capacitor. VR1 functions as the volume control, while a Zobel network consisting of a 10Ω resistor and a series .047μF capacitor is connected across the output to ensure stability.

Power for the audio amplifier is derived from the 9V rail via a 10Ω resistor and a 470μF decoupling capacitor. This arrangement ensures a low impedance supply for IC4 over the life of the battery.

Automatic frequency control

As well as being fed to IC4, the demodulated signal is also filtered using a 47kΩ resistor and a 1μF capacitor and applied to the anode of varicap diode VC5. At the other end, VC5's cathode is connected via a 47kΩ isolating resistor to a 1.37V bias voltage, as set by a voltage divider consisting of 100kΩ and 18kΩ resistors.

Because it is a varicap diode, VC5 varies its capacitance according to the voltage across it. Its anode is at RF ground due to the .01μF capacitor, which means that VC5 and its series 10pF capacitor are effectively in parallel with the tuned circuit incorporating L3.

We can now see how VC5 provides automatic frequency control. When the radio is correctly tuned, the filtered output from the demodulator (ie, the AFC control line) is at 0V DC. However, if the local oscillator drifts off frequency, or if the tuning is slightly off frequency, then the AFC control line will apply a DC bias to VC5's anode.

As a result, VC5 changes its capacitance and this shifts the local oscillator back to its correct frequency. The 1μF capacitor across the AFC line provides a long time constant so that the low frequency audio response is maintained down to below 20Hz.

That describes the circuit description. Next month, we will continue with the full details on construction and alignment. **SC**