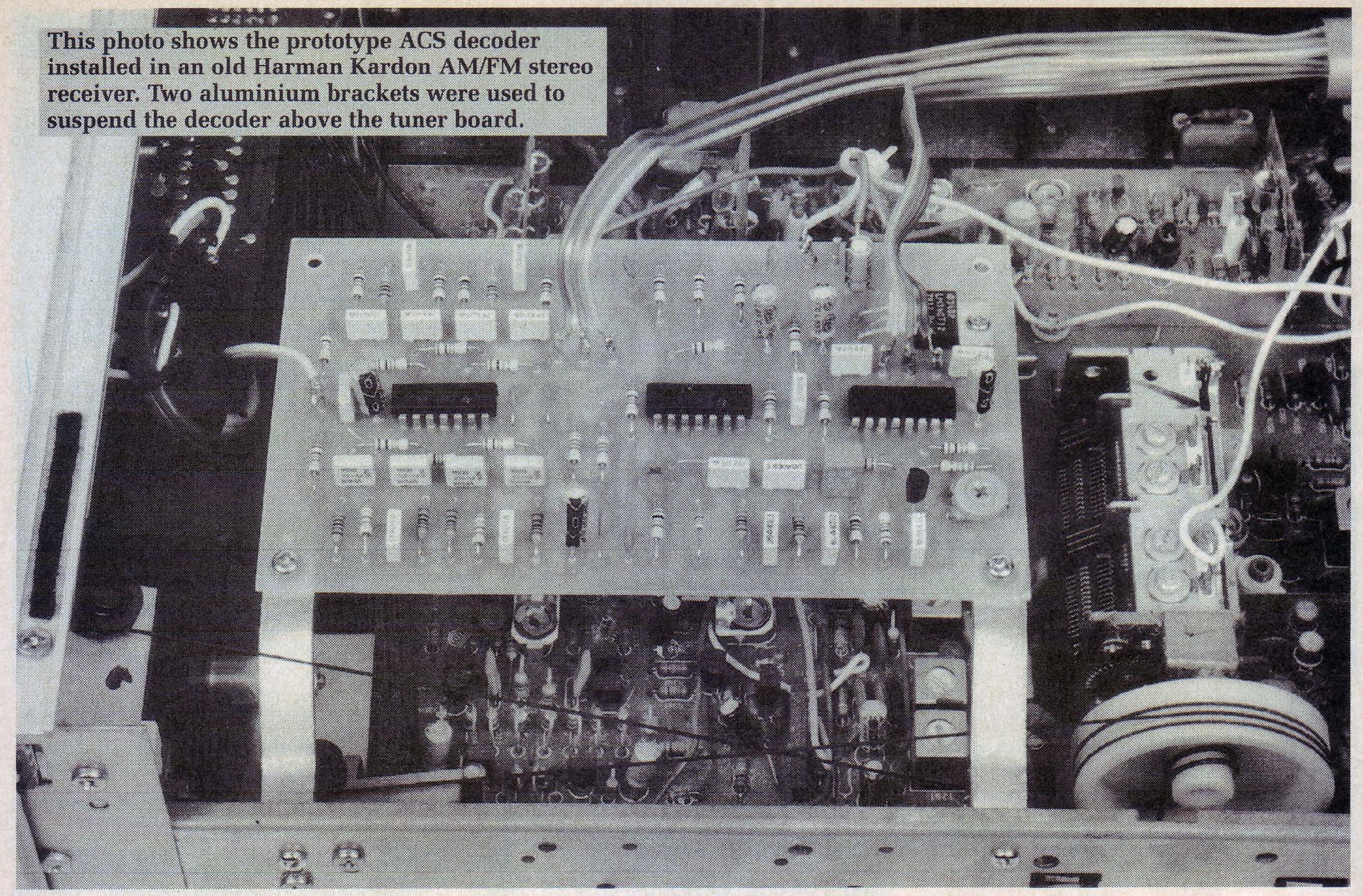


This photo shows the prototype ACS decoder installed in an old Harman Kardon AM/FM stereo receiver. Two aluminium brackets were used to suspend the decoder above the tuner board.

A subcarrier decoder for FM receivers

Many FM stations are now radiating piggyback signals with their normal stereo transmission. You can't decipher these "hidden" signals using a standard FM receiver but you can by adding this low-cost ACS decoder.

By JOHN CLARKE

The jargon doesn't sound very enlightening but ACS stands for Ancillary Communication Service. This is a technique whereby a normal FM broadcast transmitter carries one or two extra subcarrier signals that ride "piggyback" along with the normal FM stereo transmission.

These hidden transmissions have no affect on standard FM mono and stereo receivers. Only the main signal can be detected by such receivers, so most people are unaware that ACS signals are even being broadcast. To listen to these extra signals, you need to fit an ACS decoder such as the unit described here to your FM receiver.

Despite this, you've probably already heard ACS broadcasts. Many department stores and shopping centres now use this service to provide background music for their customers. And the program content is usually just straight music, with no voiceovers or advertising.

Other ACS services include foreign language, news and special interest programs.

Signal transmission

Before we describe how our ACS decoder works, let's take a look at how the ACS signals are added to the FM signal.

A normal FM stereo transmission is made up of three components: (1) an L+R mono signal modulated from 0-15kHz; a stereo pilot tone at 19kHz; and a multiplexed L-R difference signal centred on 38kHz. These compo-

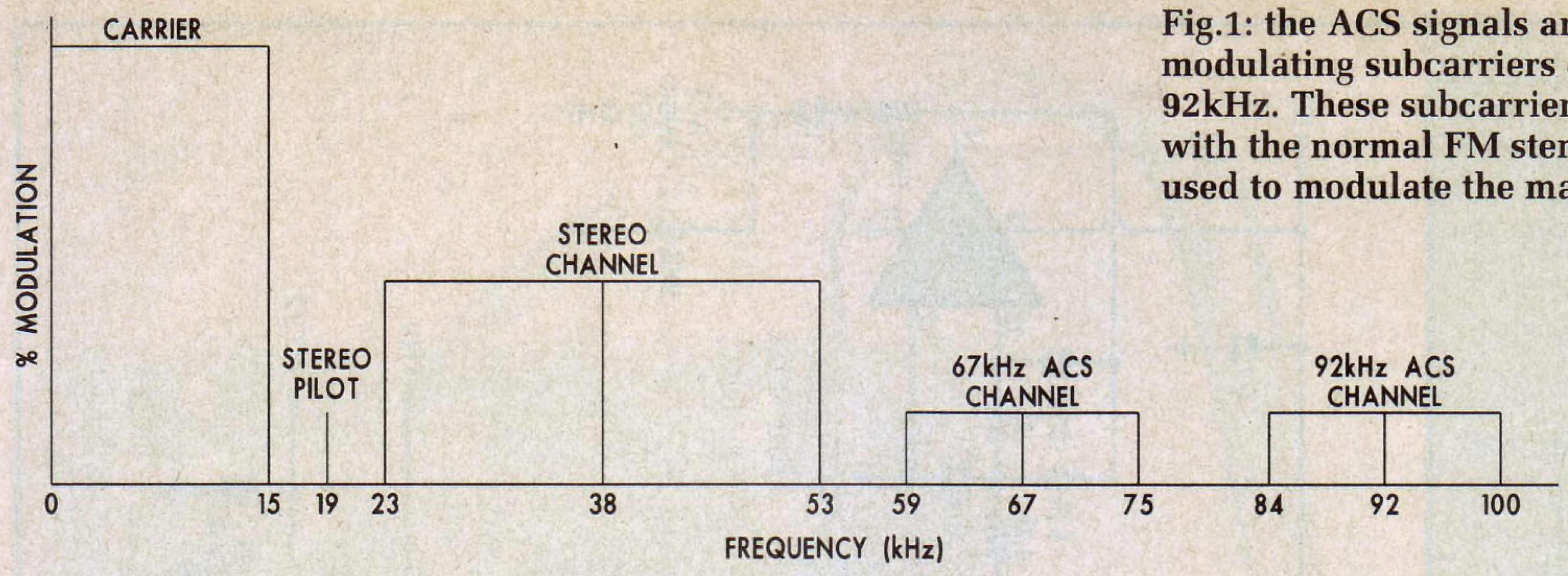


Fig.1: the ACS signals are produced by modulating subcarriers centred on 67kHz & 92kHz. These subcarriers are then mixed with the normal FM stereo components & used to modulate the main carrier.

nents are mixed together and used to modulate the main carrier out to 53kHz – see Fig.1.

By contrast, the ACS signals are produced by modulating subcarriers centred on 67kHz and 92kHz. These two frequencies are well above the upper limit of the L-R difference signal to avoid interference. As a further precaution against interference, the ACS signal bandwidths are limited to just 6kHz. They are mixed at low level with the existing stereo components before being used to modulate the main carrier.

ACS decoding

At the receiving end, these ACS subcarrier signals are ignored by a standard FM receiver since they fall well outside the passband. In fact, the detected 67kHz and 92kHz subcarriers are effectively removed by the 50μs de-emphasis filtering. So, to detect ACS signals, we need to modify the receiver by fitting an ACS decoder immediately following the FM demodulator, before any filtering takes place.

The ACS decoder described here can be switched to decode either ACS subcarrier (ie, either 67kHz or 92kHz). This is done using a single toggle switch; there are no other controls to worry about. The recovered audio output is fed into an auxiliary input of an amplifier.

Once fitted, the unit is very easy to use. All you have to do is tune your receiver to an FM station and select the appropriate auxiliary input on the amplifier. An ACS signal will now be heard (provided, of course, that the station is transmitting ACS signals). If the station is transmitting two ACS signals, the alternative signal can then be selected using the toggle switch.

Provided you live in a good signal area and have a reasonable antenna, the ACS signal should be quite clean. But don't expect it to sound as good as a regular FM stereo signal. That's because of the restricted bandwidth (6kHz) and the fact that the signal is mono only. In addition, an ACS signal has only relatively low deviation, so you'll need a strong signal to avoid hiss.

It should be possible to fit the ACS Decoder to most FM tuners and receivers, and even to many portable FM receivers. Basically, there are a couple of ways you can go about this. First, if there is sufficient room, the unit can be fitted inside the receiver itself and powered from an existing supply rail. In fact, the prototype was fitted inside an old Harman Kardon receiver – see photos.

Alternatively, you could mount the decoder inside a separate case and run it from a suitable DC plugpack supply. We'll have more to say about the installation later on.

Block diagram

Fig.2 shows the block diagram of the ACS Decoder. Its input signal is extracted from the FM demodulator in the receiver and is fed to two bandpass filter stages centred on the ACS subcarrier frequencies. These filters separate the ACS subcarriers from each other and from the other components of the normal FM stereo signal.

S1a selects between the filter outputs, after which the selected subcarrier is boosted by amplifier stages IC2a-IC2c. The boosted signal is then fed into a phase lock loop (PLL) demodulator to recover the audio.

Immediately following the PLL stage is a 150μs de-emphasis stage. This rolls off frequencies above 1061Hz, thereby reducing noise in the audio signal and compensating for the 150μs boost (pre-emphasis) given to the audio signal before transmission. Finally, the recovered audio is fed to the output via a low pass filter which removes the original subcarrier plus any other unwanted components above 6kHz.

In summary then, the 67kHz and 92kHz subcarriers are first separated

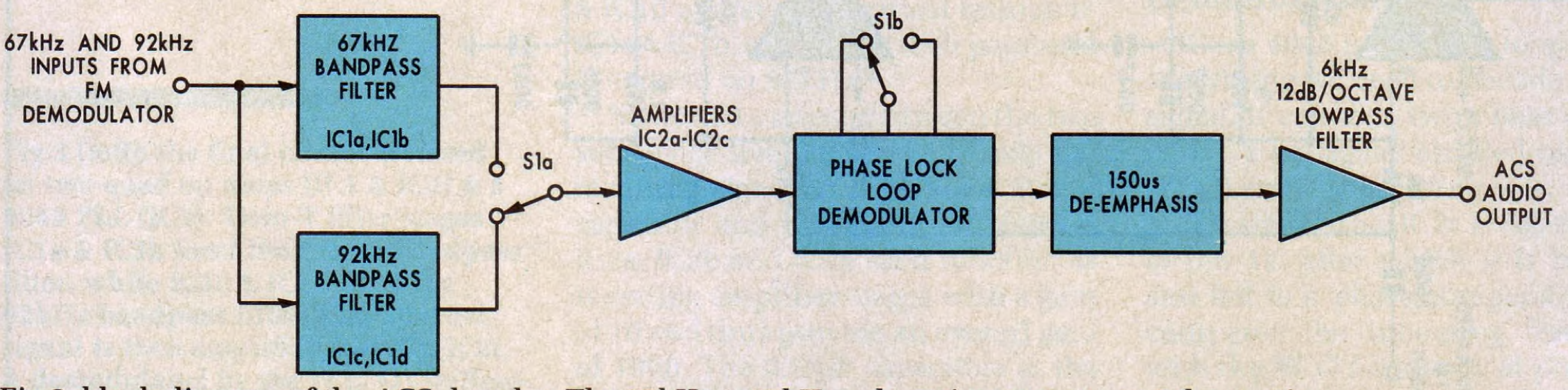
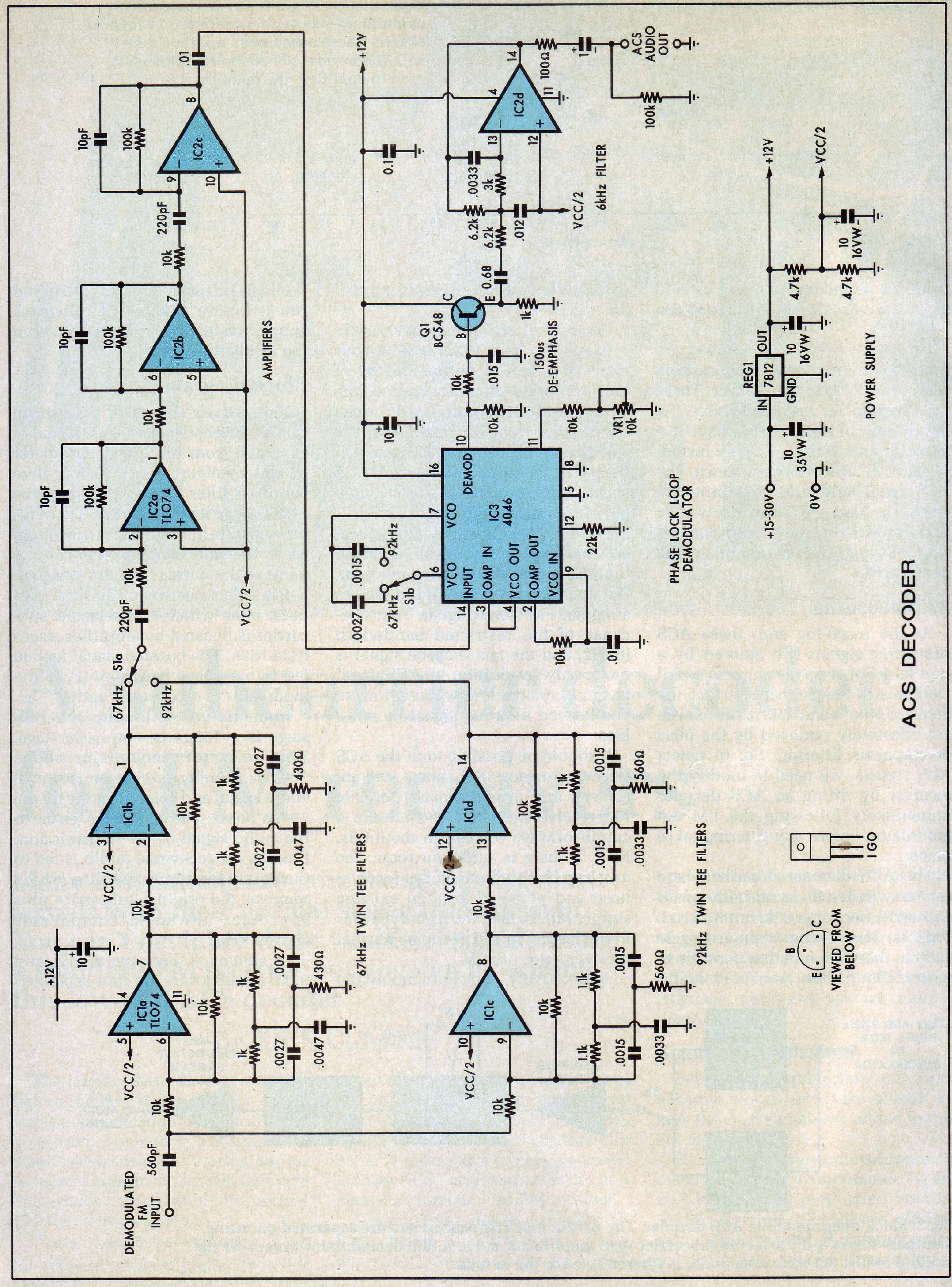
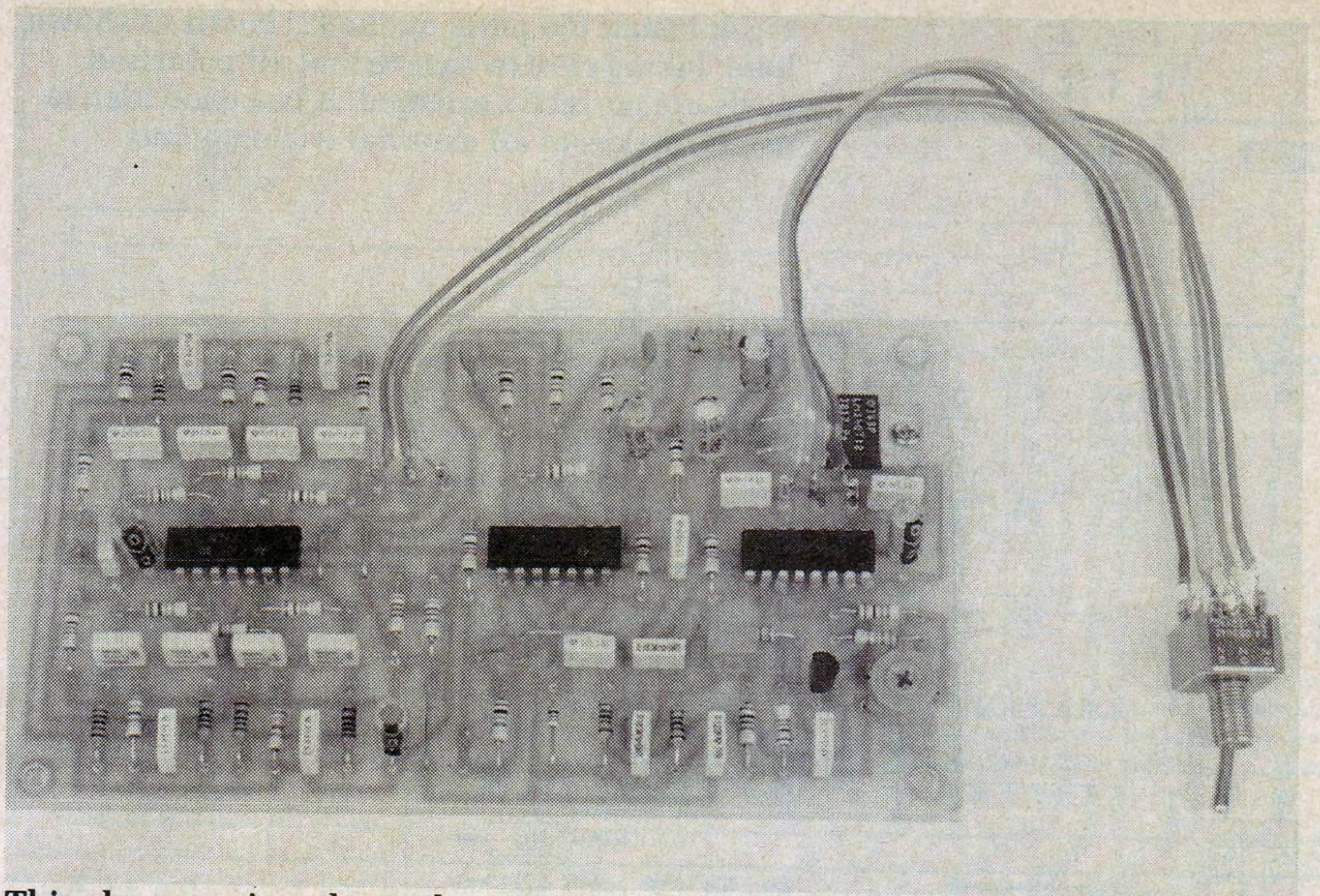


Fig.2: block diagram of the ACS decoder. The 67kHz & 92kHz subcarriers are separated out using bandpass filters & the selected subcarrier then amplified & fed to a PLL demodulator to recover the audio. Finally, the recovered audio is filtered & fed to the output.


ACS DECODER
DEMODULATED FM INPUT
67kHz TWIN TEE FILTERS
92kHz TWIN TEE FILTERS
AMPLIFIERS
PHASE LOCK LOOP DEMODULATOR
150us DE-EMPHASIS
6kHz FILTER
POWER SUPPLY
ACS AUDIO OUT
IC1a TL074
IC2a TL074
IC3 4046
Q1 BC548
REG1 7812
VR1 10k
+15-30V
0V
+12V
VCC/2
VIEWED FROM BELOW



This close-up view shows the completed ACS decoder board. It should fit inside most FM tuners & receivers & can be powered from an existing 15-30V DC supply rail. Note that the decoder will not interfere with the reception of normal FM stereo transmissions.

out using bandpass filters. The selected subcarrier is then amplified and fed to a PLL demodulator to recover the audio. Finally, the recovered audio is filtered and fed to the output.

Circuit details

Refer now to Fig.3 for the circuit details. This can be directly related back to the block diagram. IC1a & IC1b form the 67kHz bandpass filter, IC1c & IC1d form the 92kHz bandpass filter, IC2a-IC2c are the amplifier stages, IC3 is the PLL demodulator, and IC2d is the 6kHz low pass filter.

In greater detail, the input signal is picked off from the FM demodulator via a 560pF capacitor and coupled to pin 6 of IC1a via a 10kΩ resistor. IC1a and IC1b together function as cascaded twin-T filter stages centred on 67kHz. In the case of IC1a, the two 1kΩ feedback resistors and the .0047μF capacitor to ground form one half of the twin-T filter, while the two .0027μF capacitors and the 430Ω resistor form the second half of the filter.

Because the twin-T filter network has a high impedance at 67kHz, IC1a essentially functions with a gain of one at this frequency due to the 10kΩ feedback resistor. At the same time, frequencies on either side of the 67kHz centre frequency are heavily attenuated by the filter action. So IC1a allows the 67kHz subcarrier to pass through while drastically curtailing frequencies that are outside the passband.

The output of IC1a appears at pin 7 and is fed to a second twin-T filter stage based on IC1b. Note that cascaded filter stages have been used here to ensure adequate attenuation of the adjacent stereo signals and the ACS subcarrier at 92kHz. Filter stages IC1c & IC1d operate in identical fashion to IC1a & IC1b, except that their passband is centred on 92kHz.

Switch S1a selects between the two subcarrier frequencies and feeds the resulting signal to IC2a via a 220pF capacitor and a 10kΩ input resistor. IC2a, IC2b and IC2c each function as inverting amplifier stages with a gain of 10 and thus provide an overall gain of 1000. The 220pF capacitors at the inputs of IC2a & IC2c roll off the response below 67kHz, while the three 10pF feedback capacitors limit the high frequency response to reduce noise in the signal.

Fig.3 (left): the final circuit is based on two quad op amps (IC1 & IC2) & a 4046 PLL (IC3). Twin-T filter stages IC1a & IC1b form the 67kHz bandpass filter, while IC1c & IC1d form the 92kHz bandpass filter. The selected signal is then amplified by IC2a-IC2c & demodulated by the PLL. Q1 buffers the demodulated signal, while IC2d rolls off the response above 6kHz to reduce noise.

Demodulation

IC3, a 4046 phase lock loop IC, has everything we need to decode the FM signal. It contains two phase comparators, a voltage-controlled oscillator (VCO) and a source follower.

The signal from IC2c is AC-coupled to pin 14, after which it is buffered and fed to a phase comparator. This compares the incoming frequency with the VCO frequency at pin 4 and produces an output at pin 2. This output is then filtered and applied to pin 9. It controls the VCO so that it

PARTS LIST

1 PC board, code 06303951, 137 x 80mm
1 DPDT toggle switch (S1)
11 PC stakes
1 10kΩ 5mm horizontal trimpot (VR1)

Semiconductors
2 TL074 quad op amps (IC1,IC2)
1 4046 CMOS phase-lock loop (IC3)
1 7812 12V regulator (REG1)
1 BC548 NPN transistor (Q1)

Capacitors
1 10μF 35VW PC electrolytic
4 10μF 16VW PC electrolytic
1 1μF 16VW PC electrolytic
1 0.68μF MKT polyester
1 0.1μF MKT polyester
1 .012μF MKT polyester
2 .01μF MKT polyester
2 .0047μF MKT polyester
3 .0033μF MKT polyester
5 .0027μF MKT polyester
5 .0015μF MKT polyester
1 560pF ceramic or MKT polyester
2 220pF ceramic
3 10pF ceramic

Resistors (0.25W, 1%)

4 100kΩ	4 1.1kΩ
1 22kΩ	5 1kΩ
14 10kΩ	2 560Ω
2 6.2kΩ	2 470Ω
2 4.7kΩ	1 100Ω
1 3kΩ	

Miscellaneous
Hook-up wire, solder, mounting brackets, screws, nuts, etc.

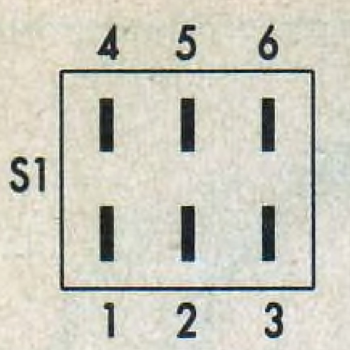
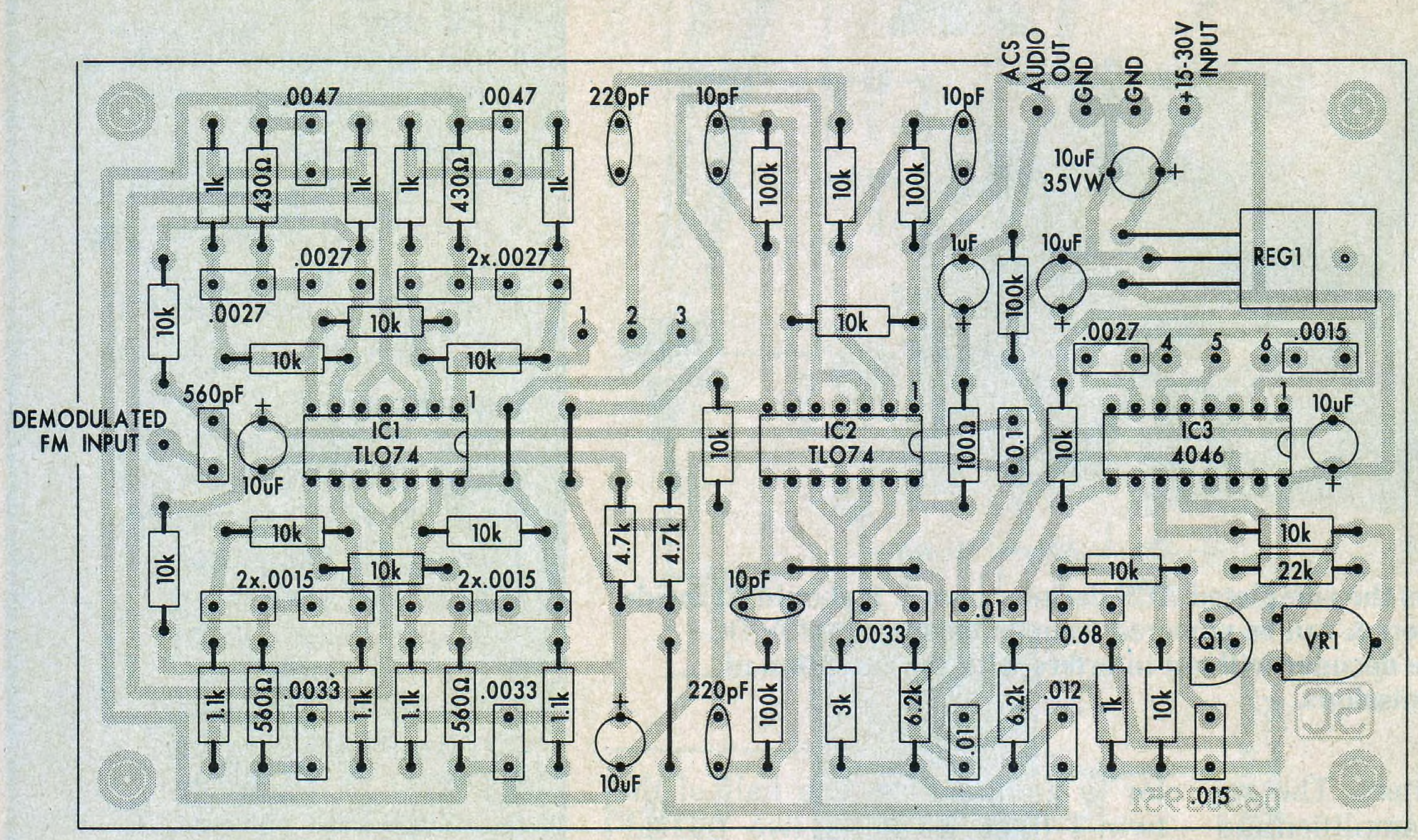


Fig.4: install the parts on the PC board as shown here, taking care to ensure that all polarised parts are correctly oriented. It is a good idea to use PC stakes at all external wiring points.



remains in lock with the input signal.

The filtered VCO control voltage represents the phase difference between the incoming signal and the VCO signal and thus represents the audio modulation on the subcarrier. However, rather than extracting the demodulated audio directly from pin 9, it is taken from the output of the internal source follower at pin 10 instead. This ensures that we don't load down the VCO control signal and create further distortion.

S1b selects the free-running VCO frequency by switching in the appropriate capacitor value between pins 6 & 7. When the .0027μF capacitor is selected, the VCO free-runs at 67kHz. Alternatively, when the .0015μF capacitor is selected, the VCO free-runs at 92kHz. VR1 sets the centre frequency and the locking range.

Immediately following the PLL is the 150μs de-emphasis network. This network is simply a low-pass filter and consists of a 10kΩ resistor and a .015μF capacitor. The filtered signal is then buffered by emitter-follower stage Q1 and fed to the 6kHz low-pass filter stage (IC2d). Two 6.2kΩ resistors, a .0033μF capacitor and a .012μF capacitor make up the filter components.

This stage operates with a gain of -1 for frequencies below 6kHz and rolls off the response at 12dB per octave for higher frequencies. Its output appears at pin 14 and is coupled to the output terminals via a 100Ω resistor and a

RESISTOR COLOUR CODES

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	4	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	22kΩ	red red orange brown	red red black red brown
❑	14	10kΩ	brown black orange brown	brown black black red brown
❑	2	6.2kΩ	blue red red brown	blue red black brown brown
❑	2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1	3kΩ	orange black red brown	orange black black brown brown
❑	4	1.1kΩ	brown brown red brown	brown brown black brown brown
❑	5	1kΩ	brown black red brown	brown black black brown brown
❑	2	560Ω	green blue brown brown	green blue black black brown
❑	2	470Ω	yellow violet brown brown	yellow violet black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown

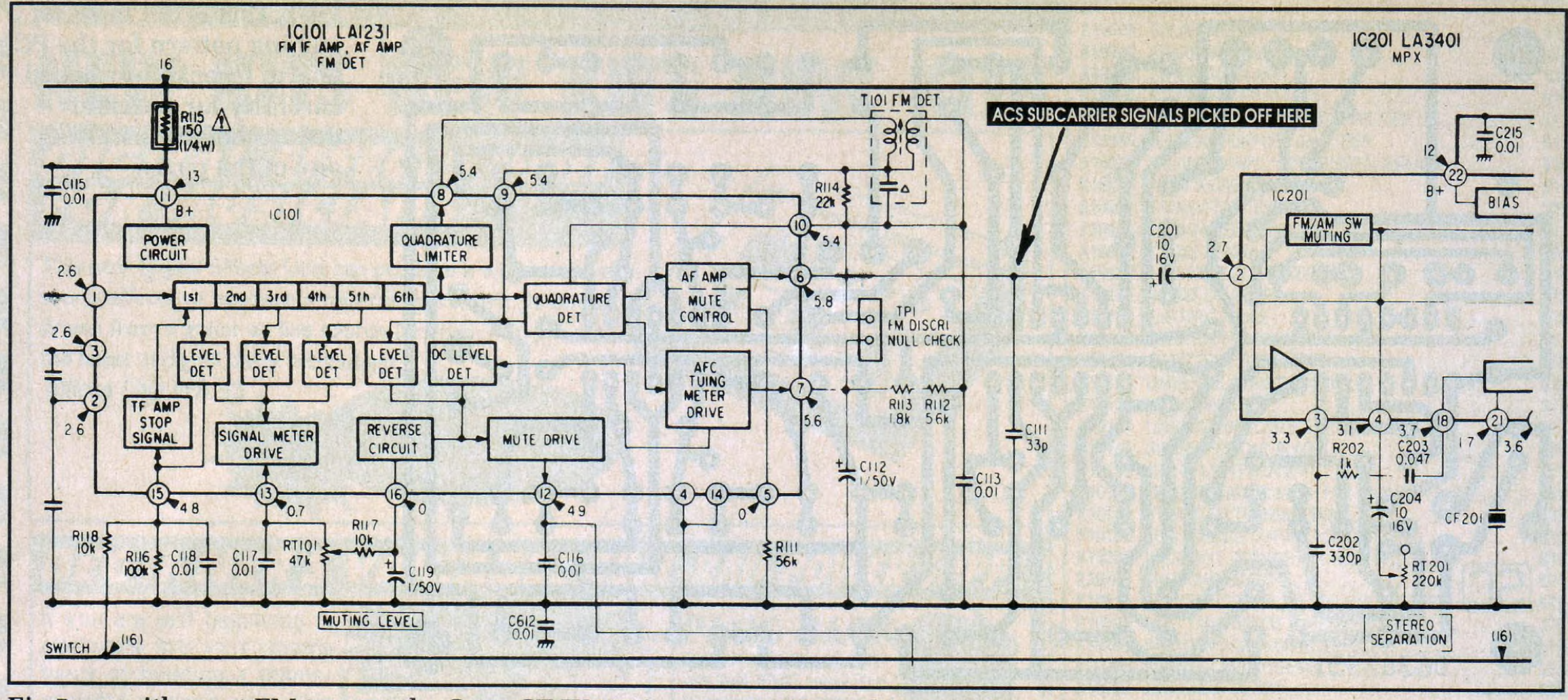


Fig.5: as with most FM tuners, the Sony ST-JX220A uses two ICs to do most of its FM processing. These are: (1) an IF amplifier & demodulator IC; & (2) a following multiplex (MPX) stereo decoder IC. The most convenient point to pick off the subcarrier signals is at the output of the demodulator (detector) IC.

1μF capacitor. The associated 100kΩ resistor prevents large offset voltages from appearing at the output.

Power for the circuit can be derived from just about any +15-30V rail (normally from inside the receiver). This is fed to 3-terminal regulator REG1 to derive a +12V supply rail. In addition, a half-supply rail (Vcc/2) is derived via a voltage divider consisting of two 4.7kΩ resistors and this biases all the non-inverting inputs of the various op amp stages.

Construction

All of the parts for the ACS Decoder except switch S1 are installed on a PC board coded 06303951. Fig.4 shows the assembly details.

No particular order of assembly need be followed but we suggest that you start by installing PC stakes at the 11 external wiring points. The two wire links can then be installed, followed by the resistors, capacitors and ICs. Make sure that the ICs are correctly oriented and use your multimeter to check each resistor value before installing it, as some of the colours can be difficult to decipher.

Finally, complete the board assembly by installing VR1, transistor Q1 and REG1. Note that REG1 is mounted flat against the PC board with its leads bent at right angles and is secured using a screw and nut. Don't bother wiring up the switch at this stage; that step comes later, when the unit is installed inside a receiver.

Initial tests

Once the board assembly has been completed, connect your multimeter in series with the +15V supply input and apply power. A 12V DC plugpack will make suitable temporary power supply, as it will have a no-load output of about 17V DC and will only be lightly loaded. Check that the quiescent current is no more than about 25mA (no input signal).

If it is much more than this, switch off immediately and locate the source of the problem before proceeding (check the ICs and the regulator).

Assuming all is well, check that the regulator output is at +12V. You should also find this voltage on pin 4 of IC1, pin 4 of IC2 and pin 16 of IC3. Finally, check that +6V is present on pins 3, 5, 10 & 12 of both IC1 and IC2.

Installation

The ACS Decoder can be mounted inside the receiver using suitable brackets and the toggle switch mounted on the rear panel. This done, the switch can be wired to the PC board using rainbow cable – see Fig.4. The power supply connections (+15-30V & ground) can be run using hook-up wire.

Ideally, you should have a circuit diagram of your receiver so that you can find a suitable supply rail. **Important: make sure that the ACS Decoder and all connecting leads are kept well away from any mains wiring inside the receiver.** In addition, you should run a separate earth lead between the switch body and the metal chassis if the switch is not earthed via the rear panel (eg, if the rear panel is plastic).

If you are installing the decoder inside a receiver, the audio output lead can be internally connected to a spare pair of line input sockets (eg, aux). This lead can be run using light-duty hook-up wire. Note that you will have to connect the two sockets in parallel, since the decoder only has a single mono output.

Alternatively, if the board is mounted inside an FM tuner, the decoder's output can be run to an additional RCA socket installed on the rear panel.

CAPACITOR CODES

	Value	IEC	EIA
❑	0.68μF	680n	684
❑	0.1μF	100n	104
❑	0.012μF	12n	123
❑	.01μF	10n	103
❑	.0047μF	4n7	472
❑	.0033μF	3n3	332
❑	.0027μF	2n7	272
❑	.0015μF	1n5	152
❑	560pF	560p	561
❑	220pF	220p	221
❑	10pF	10p	10

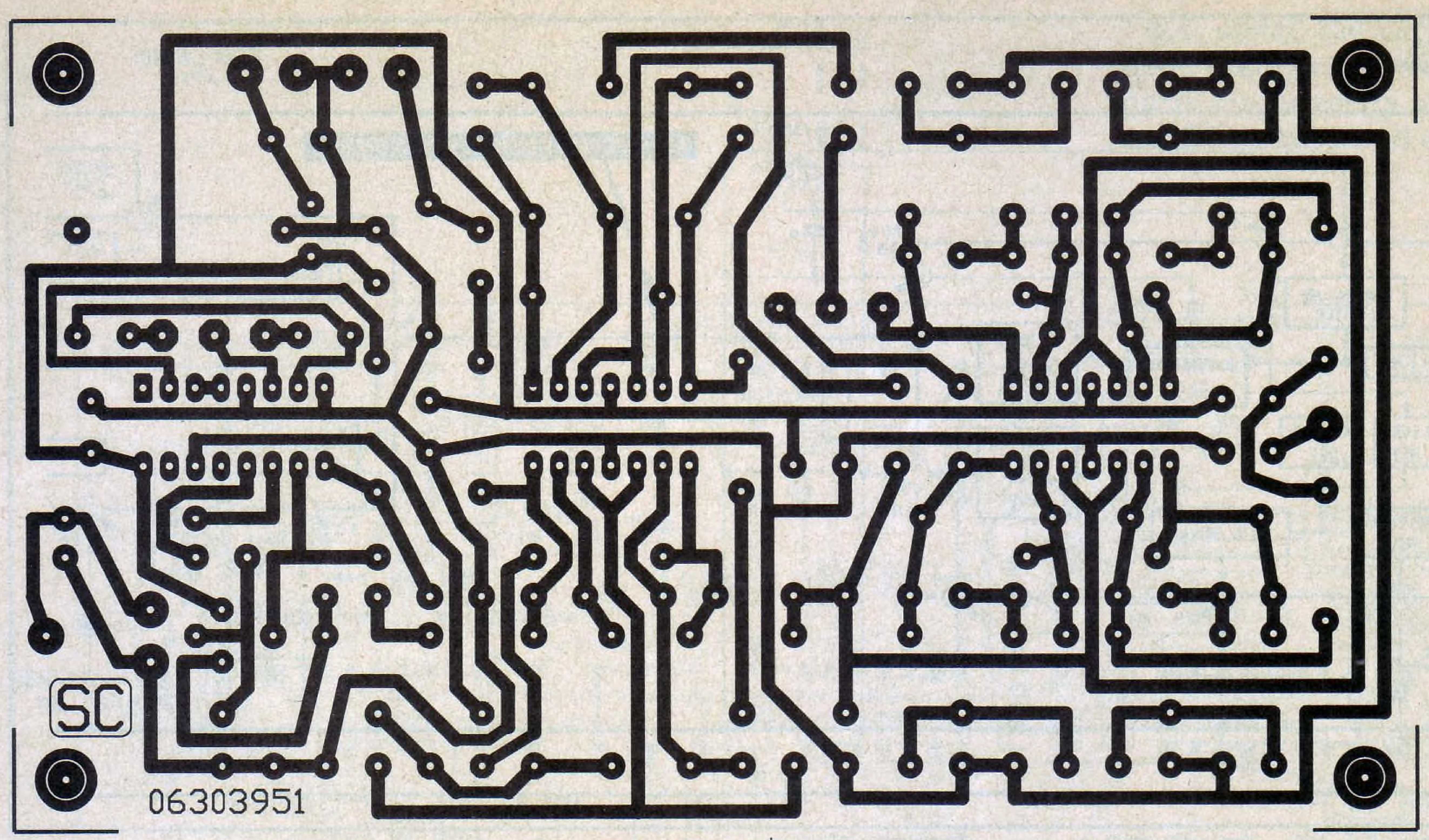
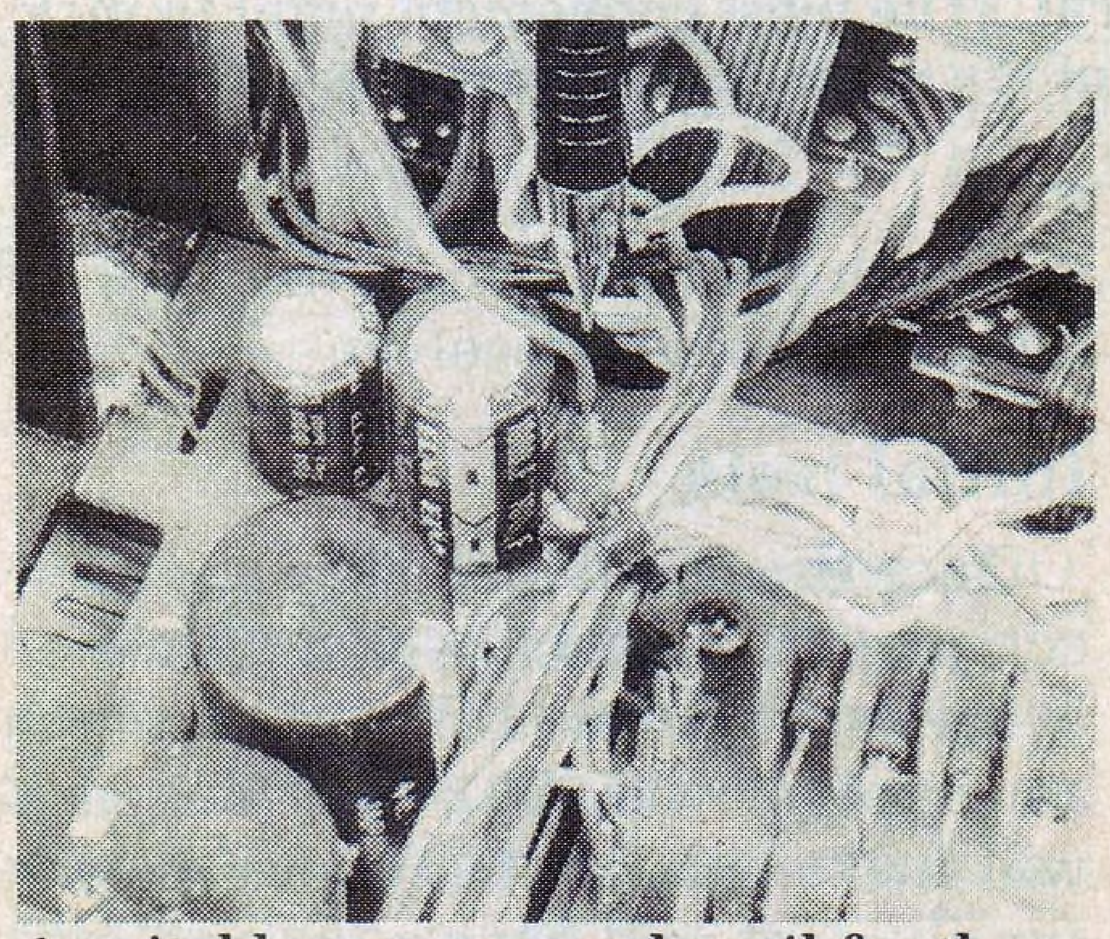


Fig.6: this is the full-size etching pattern for the PC board. Check your board carefully for possible defects before installing any of the parts.

This audio output can then be connected via a Y-adapter shielded cable to the line inputs on your stereo amplifier.

You now have to find the signal at the output of the demodulator. In a stereo tuner, this comes before the multiplex decoder and treble de-emphasis networks. In a mono tuner, you must tap into the demodulated output before de-emphasis has taken place. After de-emphasis, the ACS subcarriers will be non-existent as we've already pointed out.

Fig.5 shows a typical FM tuner circuit (Sony ST-JX220A) as an example.



A suitable power supply rail for the decoder can usually be picked up from the regulator board inside the receiver.

As with most such tuners, it uses two ICs to do most of its FM processing. These are: (1) an IF amplifier & detector IC; and (2) a following multiplex (MPX) stereo decoder IC. The most convenient point to pick off the subcarrier signals is at the output (in this case, pin 6) of the detector IC.

Alternatively, the signal can be picked up at the input to the multiplex decoder IC.

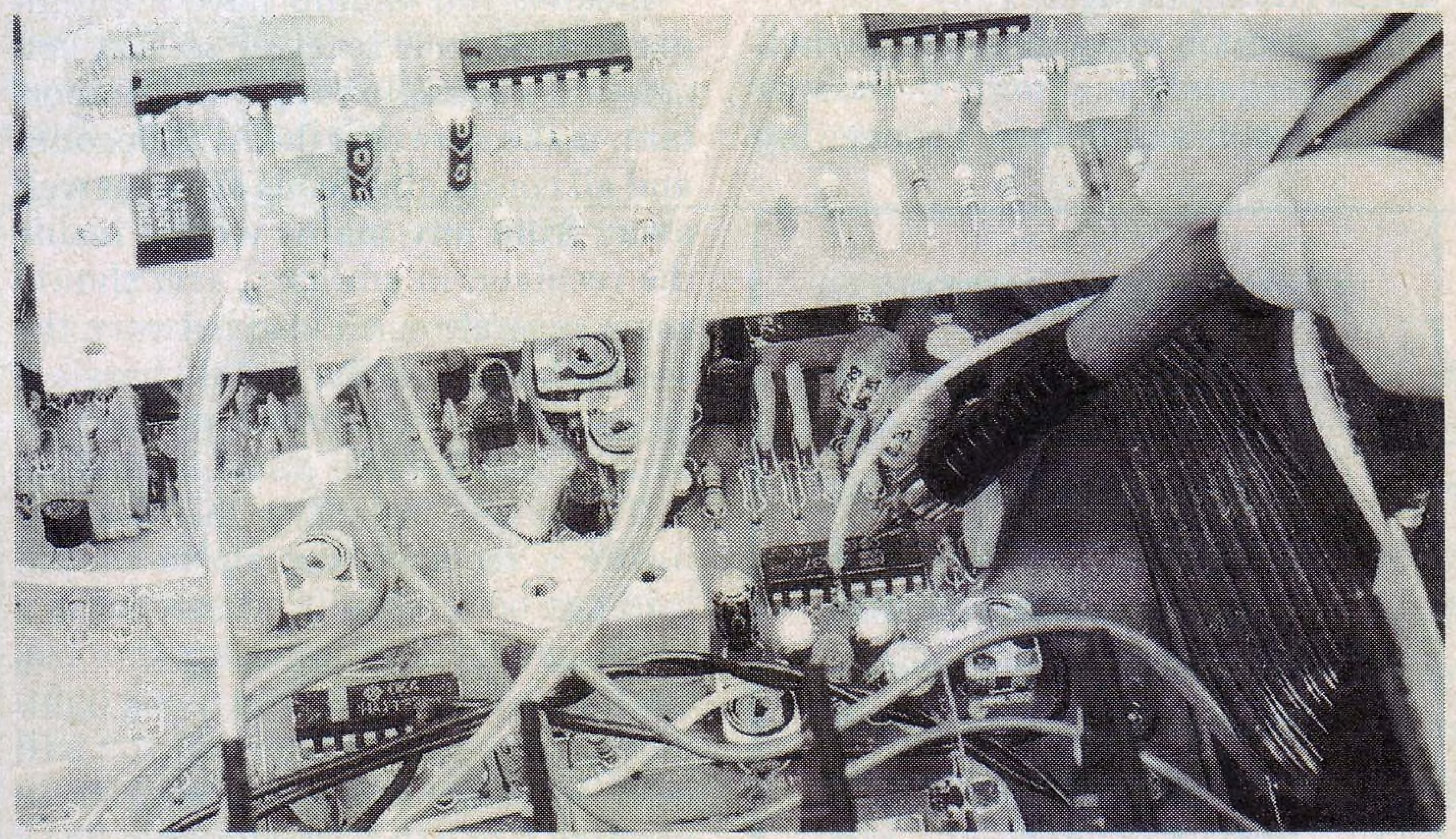
Testing

The ACS Decoder should initially be tested with S1 set to 67kHz and VR1 at mid-position. Apply power and tune in one of your regular FM stations. This done, select the ACS decoder (using the selector switch on the amplifier) and check for the presence of an ACS signal. If no signal is heard, try adjusting VR1 until a signal is heard. Failing this, retune to another station and try again.

When an ACS station comes up, adjust VR1 for best signal, then switch to the 92kHz position and adjust VR1 again so that both ACS signals can be heard. If no signal is present on 92kHz, try other stations in turn until you find one that's broadcasting ACS signals on both frequencies.

Copyright

Finally, readers are warned that recording or broadcasting received ACS programs without proper authorisation may breach copyright. If you have any doubts about your obligations, check with the copyright holder. **SC**



The signal for the prototype ACS decoder was derived by soldering the input lead directly to the output pin of the demodulator IC in the Harman Kardon receiver. If you don't have a circuit diagram of your receiver, use a CRO to determine which pin is the demodulated output. Alternatively, you may have to test each pin of the demodulator IC on a trial & error basis until an ACS signal is heard.