Listen to hidden FM transmissions

Subcarrier adaptor for FM tuners

This simple adaptor circuit fits in your FM tuner and lets you tap into hidden FM transmissions.

By JOHN CLARKE & LEO SIMPSON

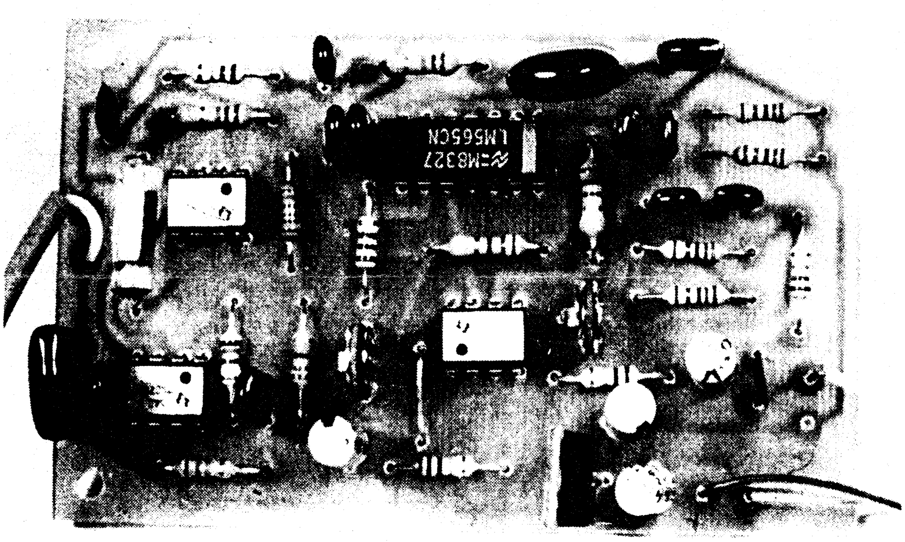
Just recently the Department of Transport & Communications announced that it is ready to authorise subcarrier transmissions on FM broadcasts. Testing of these transmissions is going on right now and you can listen to them by building this simple adaptor circuit.

In America, subcarrier transmissions on FM broadcasts have been used for years. The Americans refer to these services as Subsidiary Communications Authorisation or SCA. It is based on a 67kHz subcarrier which is placed on the main FM carrier.

In Australia the same system is being used but it will be known as Supplementary Monophonic Transmission (SMT) which will be generally recognised as an Ancillary Communications Service (ACS). Not a very inspiring name, is it?

Australian tests have been on single sub-carrier transmissions at 67kHz but developments in the USA provide for multiple sub-carriers, some carrying digital data and others carrying audio.

Now 67kHz sub-carrier transmissions are about to be authorised as regular services in Australia. To coincide with this, we have designed a suitable adaptor which can be hooked into most FM tuners with a minimum of fuss. Low in cost, it uses just a few readily available integrated circuits.



This the ACS adaptor board, shown about 30% larger than actual size. All the parts are readily available.

Before we describe the circuit of the adaptor, let's briefly talk about FM subcarrier transmissions. They will have no effect on standard FM mono and stereo radios. Also, they will be fully compatible with all existing FM radios, whether stereo or mono. In fact, unbeknown to the great mass of FM listeners, test transmissions have been going on for some time.

But while all FM radios are presently unaffected they are able to pick up the sub-carrier transmissions and, with the addition of an adaptor such as the one we describe here, able to detect the audio signals which will generally be music.

While we were developing this adaptor circuit, the ABC in Sydney was running ACS test transmissions on 2ABC-FM. The audio modulation was the program simultaneously being broadcast by AM station 2BL. In the near future, ACS broadcasts are likely to be background music suitable for offices and factories.

SILICON CHIP'S ACS Adaptor is built on a compact printed circuit board (PCB) accommodating three low cost op amps — a phase lock loop IC, a 3-terminal regulator and a handful of resistors and capacitors.

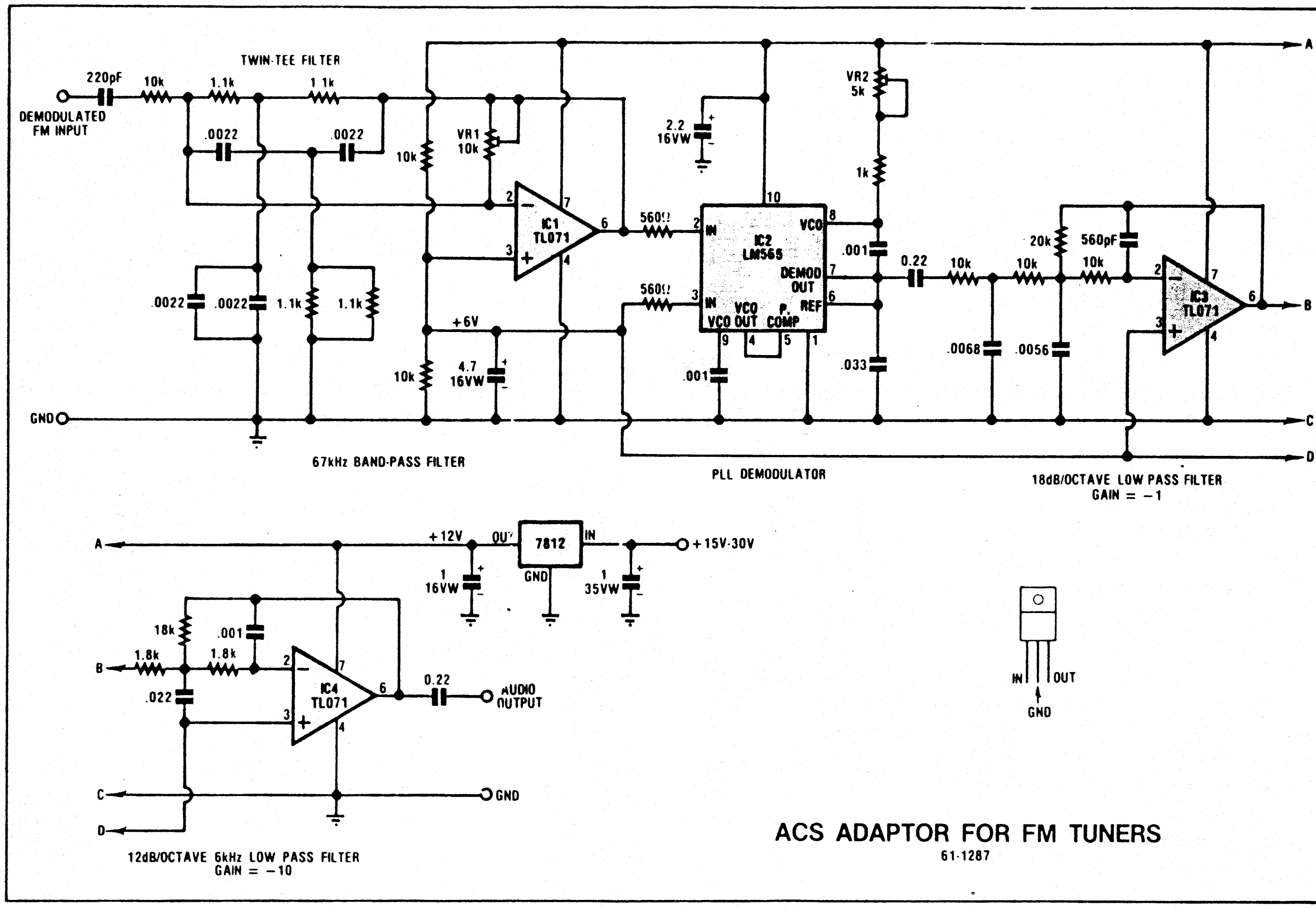


Fig.2: the circuit for the ACS adaptor is essentially just a phase lock loop with input and output filtering stages. Note that TL081 op amps may be substituted for the TL071s.

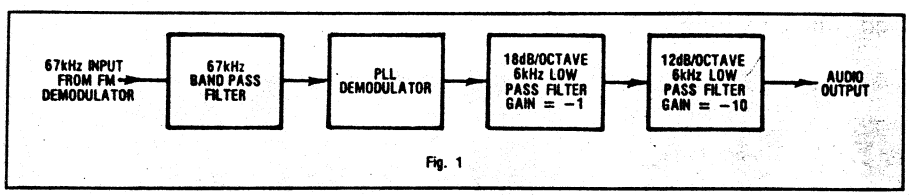


Fig.1: this block diagram shows the four circuit functions of the ACS Adaptor. The corresponding functions are also marked on the circuit diagram (Fig.2).

How it works

Fig.1 shows a block diagram of our circuit. The 67kHz signal present at the output of the FM detector (in the radio to be modified) is first fed to a 67kHz bandpass filter and then to a phase-lock loop (PLL) which recovers the audio modulation on the 67kHz sub-carrier.

The audio output of the PLL is then passed through a low pass filter which attenuates frequencies above 6kHz at the rate of 18dB/octave. Another 12dB/octave lowpass filter stage completes the conditioning of the signal before it is passed to an external audio amplifier.

Fig.2 shows the complete circuit. Op amp IC1 and associated components provide the 67kHz bandpass filter. A twin-T network comprising four 1.1kΩ resistors and associated 0.0022μF capacitors is connected in the feedback network of the op amp. This gives some gain at 67kHz and heavy attenuation for frequencies above and below this frequency.

An additional passive filter at the input to the twin-T network (220pF and 10kΩ) provides some additional rolloff for frequencies below 67kHz.

In practice, the bandpass action covers a frequency range of about 10kHz above and below the 67kHz centre frequency. VR1 sets the gain of the bandpass filter stage.

IC2 is a Signetics NE565 phase-lock loop which demodulates the 67kHz frequency modulated (FM) signal from IC1. The NE565 PLL consists of a voltage controlled oscillator (VCO) set to 67kHz and a comparator which compares the incoming frequency modulated 67kHz signal at pin 2 with the VCO signal fed into pin 5.

The output of the comparator represents the phase difference between the incoming signal and the VCO signal and is therefore the audio modulation of the subcarrier. Treble de-emphasis (150μs) is provided by a 0.033μF capacitor (pin 7).

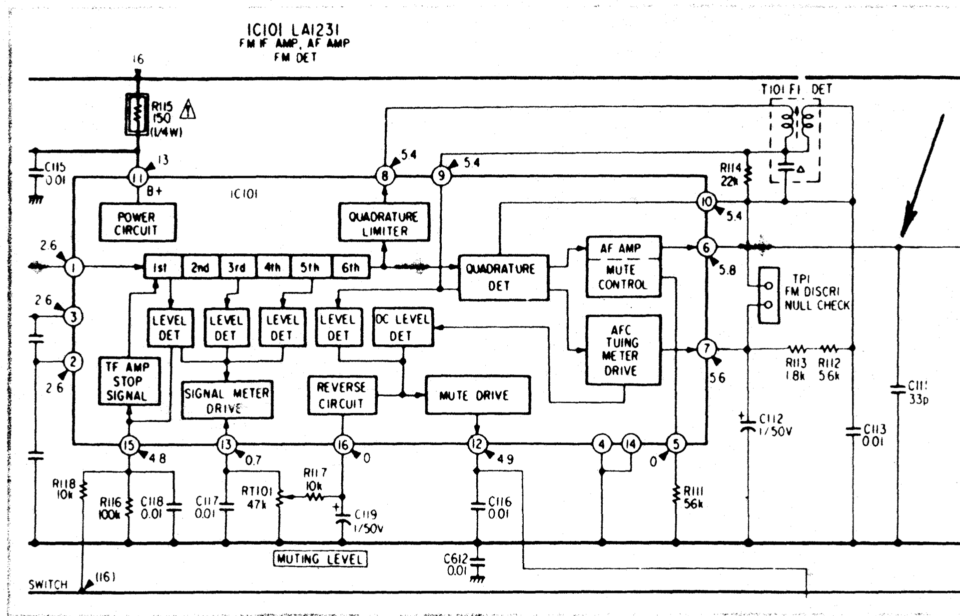
The free-running VCO frequency is determined by the 0.001μF capacitor at pin 9 and the resistance between the positive rail and pin 8 (1kΩ in series with VR2). VR2 adjusts the oscillator frequency (also known as the "centre frequency") so that the incoming signal is within the lock range of the PLL.

To minimise noise in the demodulated output, it is important to reduce the lock range of the PLL to a minimum. This is achieved by shorting pins 6 and 7 together. To a lesser extent, the lock range and therefore the noise output becomes smaller for lower input signals so we keep the input signal reasonably low without prejudicing the PLL's operation.

Following IC2 is the 18dB/octave filter employing IC3 which has a gain of one for wanted signal frequencies. This filter is followed by the final filter stage IC4 which has a gain of ten.

The adaptor is ideally powered from the tuner or receiver it is built into so we had to make its input voltage requirements non-critical. The solution is to use a 12V 3-terminal regulator which enables the circuit to be powered from any unregulated DC rail from +15 to +30 volts.

The three op amp ICs and the PLL are all biased to half the supply voltage by a voltage divider consisting of two 10kΩ resistors which is decoupled by a 4.7μF capacitor. The centre-point of this voltage divider is connected to pin 3 of each op amp and the PLL.



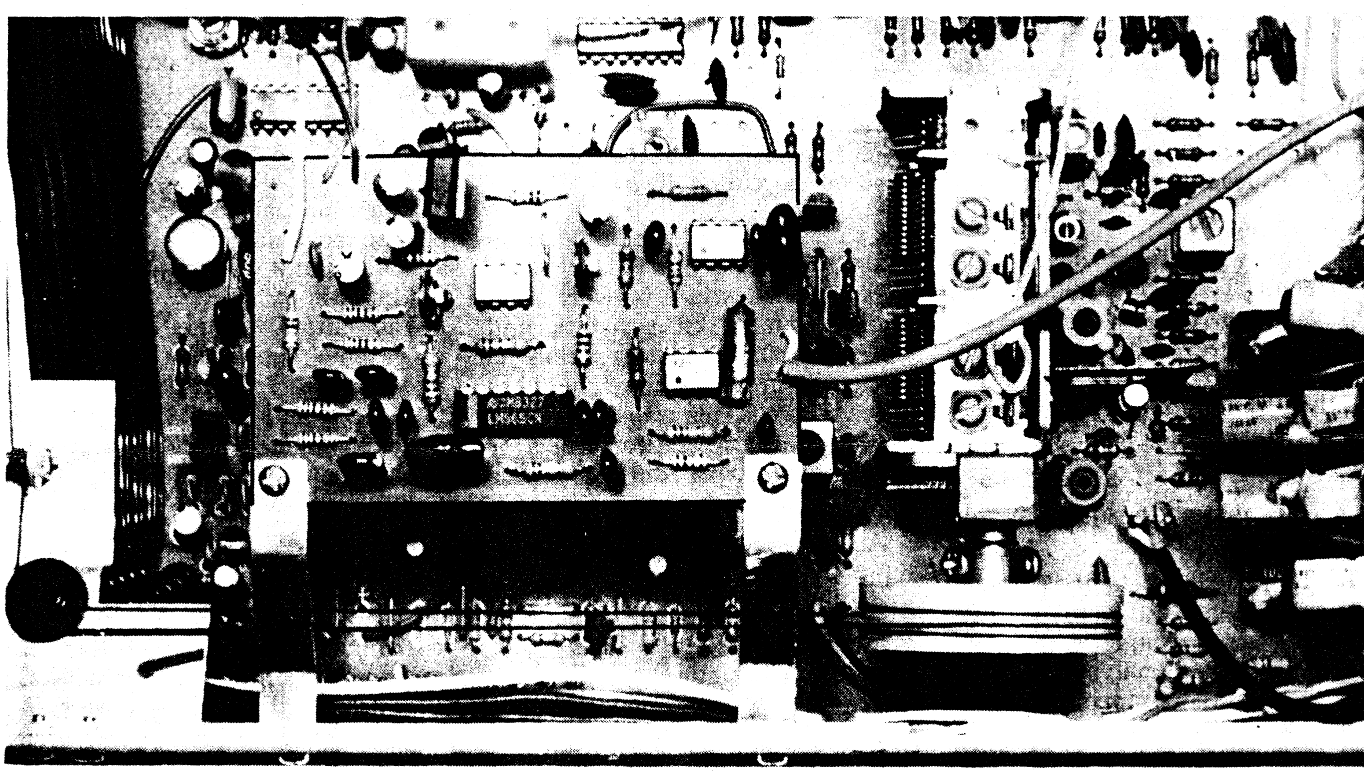
PCB assembly

The PCB for this project measures just 57 x 89mm and is easily assembled.

No special points need to be watched when installing the parts on the PCB except that component polarities must be correct. Note also that IC1 has a different orientation to IC2, 3 and 4.

When assembly and soldering are finished, check your work carefully and then connect a DC supply of between 15 and 30 volts. Now check the voltage at the output of the 3-terminal regulator, at pin 7 of the TL071 op amps, and at pin 10 of the PLL. In each case the reading should be close to 12V. The voltage at pin 3 of each IC should be close

This photo shows the ACS adaptor installed in an older AM/FM stereo receiver, the Harman Kardon hk570i. We used two brackets to suspend the Adaptor above the tuner board of the receiver.



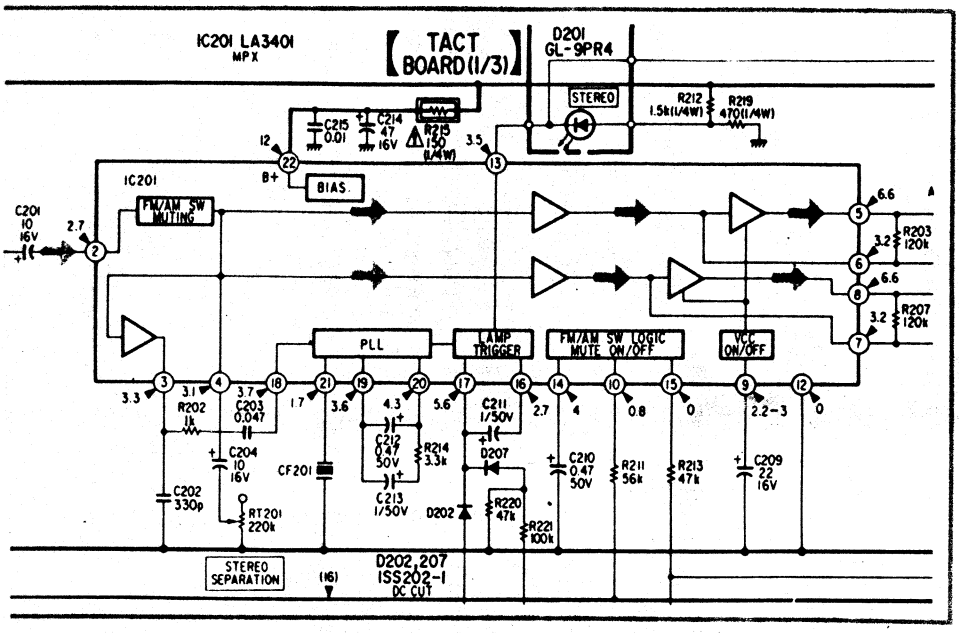


Fig.3: this is a portion of a typical FM/AM tuner (Sony ST-JX220A) showing where the ACS adaptor is tapped in, across C111, between the FM detector and the multiplex decoder.

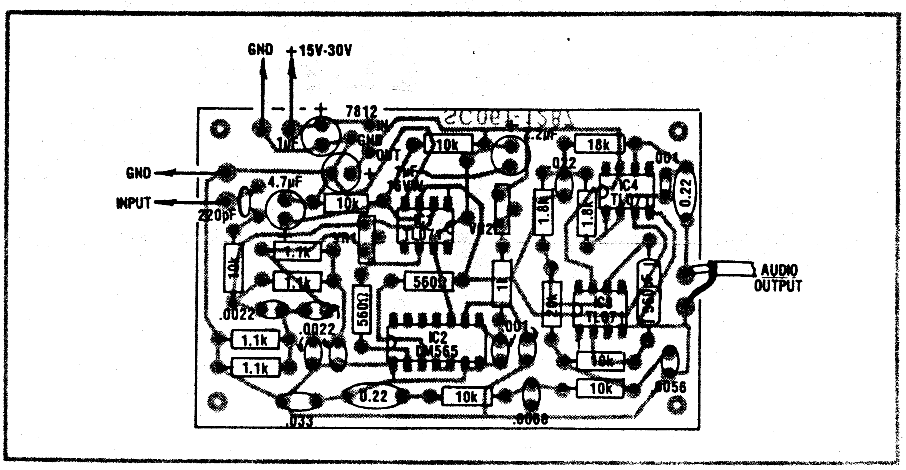


Fig.4: take care when assembling the board. Note that IC1 is oriented differently from IC3 and IC4.

to 6V and so should the voltage at pin 6 of each TL071.

If everything is okey dokey, you are ready to install the adaptor in your FM tuner or stereo receiver.

Finding the signal

This is the tricky part. Ideally, you need access to the circuit diagram of your tuner or receiver. You need to identify a positive DC supply rail of between +15 and +30 volts. Then you need to find the output of the FM demodulator.

In a stereo tuner this comes before the multiplex decoder and treble de-emphasis networks. In a mono tuner, you must identify the demodulator output before de-emphasis. After de-emphasis, the 67kHz signal will be non-existent.

We have shown part of a typical FM tuner circuit (Sony ST-JX220A) as an example of where the 67kHz signal must be picked off. As with most medium priced tuners, it uses two ICs to do most of its FM processing. These are the IF amp and detector IC and the following multiplex (MPX) decoder IC. The most convenient point to pick off the 67kHz signal is at the input to the MPX decoder.

Setting up

Having found the signal and made the necessary connections from the adaptor to your tuner, the

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PARTS LIST

- 1 PCB, code SC061-1287, 57 x 89mm
- 3 TL071, LF351 FET input op amps
- 1 NE565 phase lock loop
- 1 7812 3-terminal 12V regulator

Capacitors

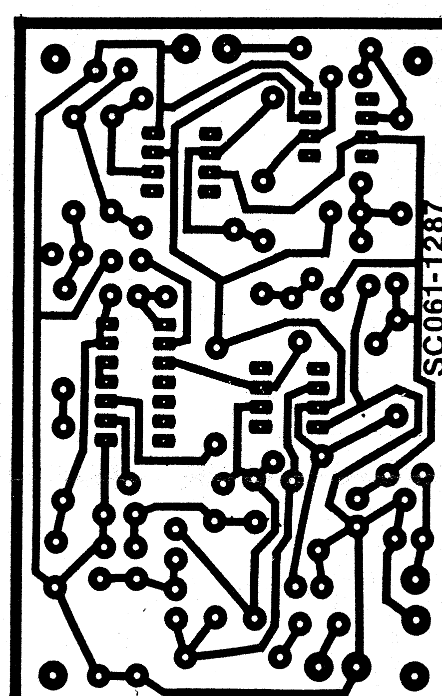
- 1 4.7μF 16VW PC electrolytic
- 1 2.2μF 16VW PC electrolytic
- 1 1μF 35VW PC electrolytic
- 1 1μF 16VW PC electrolytic
- 2 0.22μF metallised polyester
- 1 .033μF metallised polyester
- 1 .022μF metallised polyester
- 1 .0068μF metallised polyester
- 1 .0056μF metallised polyester
- 4 .0022μF metallised polyester
- 3 .001μF metallised polyester
- 1 560pF polystyrene
- 1 220pF ceramic

Resistors (0.25W, 5%)

1 x 20kΩ 2%, 1 x 18kΩ, 6 x 10kΩ, 2 x 1.8kΩ, 4 x 1.1kΩ 2%, 1 x 1kΩ, 2 x 560Ω, 1 x 10kΩ miniature vertical trimpot, 1 x 5kΩ miniature vertical trimpot

Miscellaneous

Hookup wire, audio leads, solder etc.



Full size PC artwork for the ACS Adaptor. Design by John Clarke. Luvverly, innit?

setting up procedure is relatively simple.

First, make sure that VR1 is set so that its wiper is turned toward the LM565. This will provide maximum signal level. Now adjust VR2 so that there is audio signal. Find the extreme settings of VR2 where the audio signal drops out, then set VR2 halfway between the two extremes.

VR1 is used to minimise noise from the audio signal when the FM signal level is poor. Adjust the trimmer until the sound becomes distorted and then back off the adjustment until distortion is no longer audible. If you have a strong FM signal, adjustment of VR1 will have no effect on the noise level and so it should be left at its maximum resistance setting.