Project 721

Aircraft Band Converter

AN INTEREST IN what can be heard on the shortwave frequency bands between 3 MHz and 30 MHz often kindles an interest in what can be heard 'beyond' 30 MHz, apart from TV and FM broadcasting stations.

For many communications hobbyists a variety of fascinating services can be found on the very high frequency (VHF) bands above 30 MHz. One of the more interesting bands lies between 118 MHz and 126 MHz — the aircraft band.

Domestic aircraft communications, both private and commercial, generally involve a pilot talking from his plane to a traffic controller at an airfield as well as talking to other pilots. Signals from aircraft can be heard over quite long distances as they are flying quite high and thus the horizon, from the aircraft, can be up to several hundred miles away.

There are 360 channels allocated in the aircraft band, each assigned a specific use or for use in a particular area. Amplitude modulated (AM) transmission is used which simplifies the requirements for a receiver to listen on this band.

Apart from a hobbyist interest, we have had occasional enquiries from readers who wish to have a receiving system to monitor a particular channel or channels for various reasons.

This converter should suit either purpose very well.

The Converter

Why a converter — why not a complete receiver? Firstly, a shortwave listener will already have a receiver. A converter to 'change down' the aircraft band frequencies to a suitable band between 3 MHZ and 30 MHz is a simple, and inexpensive, solution. For those wishing to monitor some portion of the aircraft band the output of the converter could be connected to an ordinary multi-band transistor portable to provide quite adequate results. Alternatively, a fixed frequency IF (intermediate frequency) strip with detector and audio stages could be constructed.

For simplicity and cheapness we have modified an existing and well-proven design — the ETI707A 144 MHz solid state converter. This was designed for radio amateurs and others interested in reception of signals on the 144 - 148 MHz band. It was originally described in the February 1976 issue and since then many hundreds have been successfully built — by beginners and experienced constructors alike. It is a very successful design, so why re-invent the wheel?

The converter is crystal locked — that is, a quartz crystal oscillator is mixed with the signals from the antenna, the signals then appearing at a lower frequency at the converter output. The frequency of the crystal used will determine the frequency band of the converter output.

For a number of reasons, we chose the output (or IF) frequency to be around 10 MHz. Inexpensive crystals are available for the aircraft band to give an IF output from the converter of 10.7 MHz — a standard IF frequency. The same crystals can be employed if you wish to use a tunable shortwave receiver following the converter. There is a minor inconvenience though — the tunable receiver's dial has no simple relationship to the input frequency. The advantage is that inexpensive crystals cost around half that of a crystal made to order to provide a direct frequency relationship.

The choice is up to you. Choosing and ordering crystals is covered later in the article.

As the converter has quite a deal of gain, resulting in very good sensitivity, an RF Gain control has been provided. Very strong signals on a channel near to the one being monitored may cause interference. Judicious use of the RF gain control will reduce or remove the interference while enabling you to still hear the desired signal. Then again, a very strong signal on the channel you are monitoring may overload your receiver, resulting in very distorted reception. Reducing the RF gain will remove the problem.

PARTS LIST — ETI 721

Resistors all ¼W, 5% *

R1 . . . . . 150R
R2, 3 . . . . 100k
R4 . . . . . 150R
R5 . . . . . 1M
R6 . . . . . 56k
R7 . . . . . 560R
R8 . . . . . 680R
R9 . . . . . 10k
R10. . . . . 4k7
R11. . . . . 470R
R12. . . . . 270R

Potentiometer

RV1 . . . . 100k A pot

Capacitors

C_c. . . . . . 22p ceramic
C1. . . . . . 6p8 ceramic
C2 - C5. . . 1n ceramic
C6 - C8. . . 6p8 ceramic
C9. . . . . . 1n ceramic
C10. . . . . 100p poly or ceramic
C11. . . . . 10n poly or ceramic
C12. . . . . 100p poly or ceramic
C13. . . . . 68p poly or ceramic
C14. . . . . 47p poly or ceramic
C15. . . . . 6p8 ceramic
C16. . . . . 1n ceramic
C17. . . . . 6p8 ceramic
C18. . . . . 10n poly or ceramic

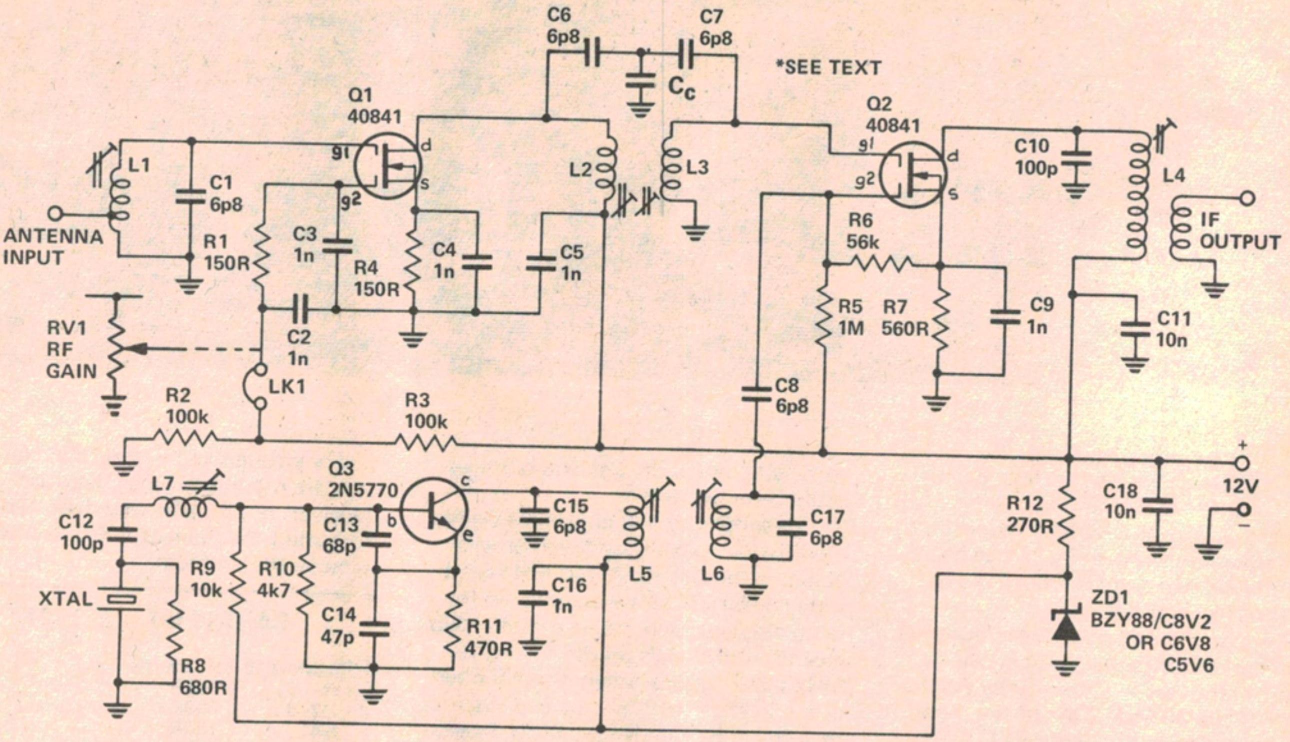
Semiconductors

Q1, 2 . . . . MFE131, 40673, 40841
Q3 . . . . . 2N3563, 2N3564, 2N5770
ZD1. . . . . BZY88/C8V2 or /C6V8 or /C5V6 or /C5V1

Miscellaneous

7 x 722/1 Neosid coil formers
3 x 7100 Neosid screening cans
2 x 7300 Neosid screening cans
7 x Neosid ferrite slugs, 4 x 5 x 10/F29
coil wire
pc board . . ETI 707A
crystal . . . see text
zippy box (see text), 2 coax sockets, 2 x 20 mm, 6 BA spacers, nuts, bolts, etc.

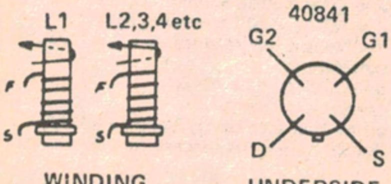
*Resistor values may be plus or minus one standard value either side of those quoted without ill effect. Capacitor values should not be altered.



Coil Data

Wind L2, L3, L4, L5, L6 and L7 *clockwise* up the former. L1 is wound *anti-clockwise* up the former. The start of each coil is the 'cold' or 'earthy' end. All slugs are F29 type ferrite.

L1	5 turns, 22 B & S tinned copper wire spaced over 10 mm, tap at 2 turns from cold end.
L2, L3	6½ turns, 22 B & S enamelled wire, spaced over 8 mm.
L4	25 turns closewound with enamelled wire, any gauge between 25 and 30 B & S, 5 turn link at top of former.
L5, L6	5½ turns, 22 B & S enamelled wire, closewound.
L7	*10 turns, 22 B & S enamelled wire, closewound, for crystals in the range 30 MHz to 50 MHz. *6 turns for crystals in the range 50 to 70 MHz.



WINDING DIRECTION

UNDERSIDE VIEW

Construction

The printed circuit board has been specially designed for this application and no other construction technique should be employed unless you are very experienced in circuit construction at these frequencies.

It is best to commence construction by mounting the coil formers. They may be glued on the board over the pilot holes or the board drilled to the appropriate diameter for the base of the formers and then gluing the formers in place. Use the shield cans to locate and/or hold the formers on the pc board when gluing them directly to the board. It is wise to insert the slugs in the formers *after* gluing to avoid accidentally gluing them to the formers. The best type of glue to use is one of the 'instant' bond glues such as "Superglue", "Bondza", "Super 500" etc. Many glues available will not bond to pc substrate materials — particularly fibreglass pc material.

The next step is to wind the coils. They may be wound *in situ* if you wish, alternatively they may be wound on a suitable diameter former (such as a 5 mm or 3/16" drill shank) and then slipped over the formers on the board.

Take careful note of winding direction and the start and finish connections. Refer to the component overlay when soldering the coil leads in place. Do not mount the shield cans until all the minor components have been soldered in place.

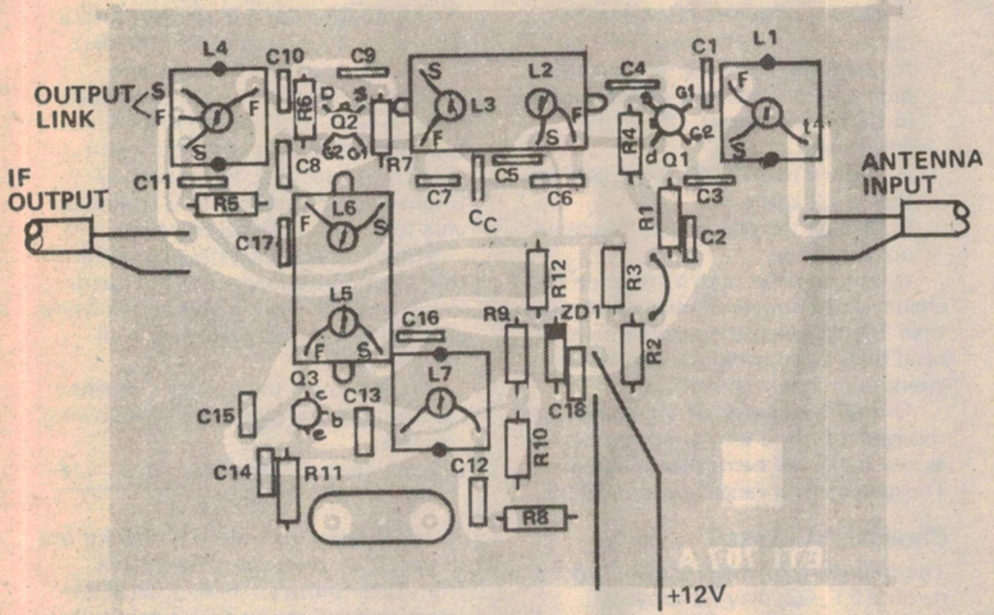
When mounting the minor components take particular care with orientation of the transistors, FETs and the zener diode. All components should be mounted right down on the pc board to minimise lead length. Stakes or pins should be used for the connections to the antenna input, IF output and dc connections.

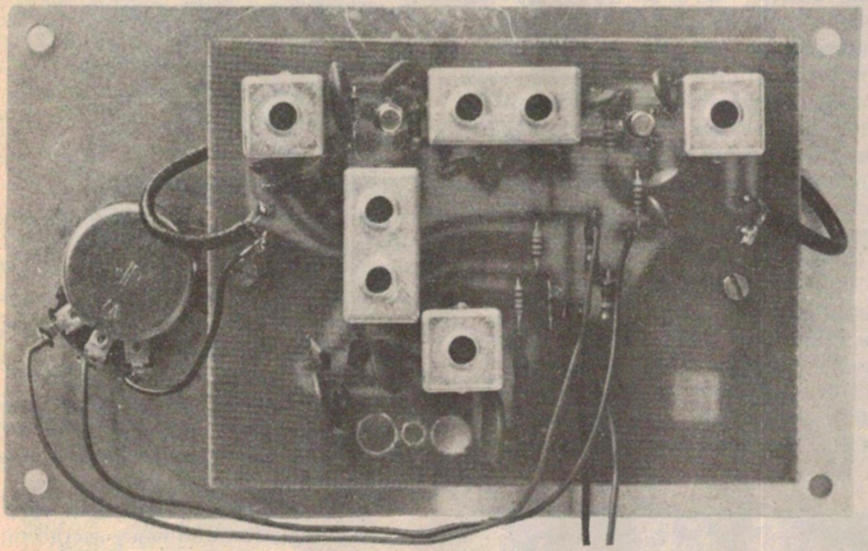
There is provision on the pc board to mount a crystal socket for a 'style-D' crystal. These have a 12 mm pin spacing and stand about 20 mm high. Alternatively, if the smaller size crystals are used, having a pin spacing of 5 mm or pigtail connections, then they may be soldered in place under the board. Take care when doing this. Do it quickly and use the minimum amount of heat to avoid damaging the crystal.

If desired, the crystal may be mounted separate from the pc board. Keep lead length between the crystal and the board connections as short as practicable in this case.

The shield cans for the coil assemblies should be mounted last. It may be a wise idea to check that the converter is working before soldering the shield pins to the pc board.

The completed converter may be mounted in a suitable box. The one we used was a small 'zippy' box measuring 159 x 96 x 50 mm overall. They are available from a number of component suppliers. The pc board was mounted on the aluminium panel using two spacers. Antenna and IF output sockets, along with the RF gain pot, were also mounted on the panel and dc power





leads taken through a hole in the side of the box. Small lengths of coax cable were used to connect the input and output sockets to the pc board connections.

Alignment

The particular method of alignment will depend on how you will be using the converter. To commence the alignment you will need to have on hand the appropriate aligning tool. You will need a plastic screwdriver-tip alignment tool to suit the Neosid ferrite cores. They are readily available from many suppliers. Most general purpose alignment tool kits available will have a suitable tool. These kits cost around $2 - $3, contain four tools with various tips and are generally called 'TV alignment' kits.

You will need a dc power supply delivering between 12 and 15 volts; the converter will draw between 30 and 50 milliamps. A receiver with a S-meter is a decided advantage when aligning the converter. You will need a signal generator, with AM modulation, covering the range 118-126 MHz.

If you are using a tunable receiver for the IF, then the following procedure should be followed:

Connect the converter to the receiver. Use a short length of coax cable. If the converter is working you will notice an increase in the noise level on a sensitive receiver when power is applied. You can check that the crystal oscillator is working by removing the crystal temporarily — a decrease in the noise from the receiver will be noticed.

1. Set the receiver frequency to the middle of the tuning range of the converter's output. The converter RF gain should be at maximum all through the alignment procedure.

HOW IT WORKS – ETI 721

The circuit is quite straightforward, comprising an RF stage (Q1), a mixer (Q2) and an overtone crystal oscillator-multiplier (Q3). Dual-gate MOSFETs are used in the RF and mixer stages as they have good gain, low noise figure and good freedom from crossmodulation and overload problems.

Signals from the antenna are first amplified by Q1 and passed to gate-1 of the mixer Q2. The oscillator, Q3, is set to a precise frequency by the crystal. The injection frequency to gate-2 of the mixer is derived from the collector of Q3, being two or three times the crystal frequency. The signal frequency and the injection frequency are mixed in Q2, their *difference* is selected by the tuned circuit in the drain – this is the desired output frequency.

A low-Q tuned circuit, L1-C1, is used between the antenna input and gate-1 of Q1. The antenna input impedance is *mismatched* to the impedance of the gate to optimise noise figure. The drain of Q1 is coupled to gate-1 of the mixer, Q2, via a double-tuned, bandpass coupling circuit consisting of L2, C6, Cc, C7 and L3. A combination of inductive coupling and common-capacity coupling is used to achieve a wide bandwidth.

Gate-2 of Q1 requires a bias of +6V for full stage gain. A link between gate-2 decoupling (R1,C2,C3) and the junction of R2-R3 allows for the connection of a gain control potentiometer.

The mixer has about 1.5 volts of bias applied to gate-2. The conversion frequency is injected at this gate and a small amount of forward bias improves the mixer conversion gain. The output, or IF, is coupled via L4 which is resonant at 10 MHz with C10. This is a low-Q tuned circuit for the broad bandwidth necessary if the tunable IF receiver is used.

The crystal oscillator stage, Q3, is designed to cope with either third or fifth overtone crystals and may double or triple the crystal frequency in the collector. Tuned circuit L5-C15 selects the appropriate harmonic. Energy is coupled from L5 to L6 which is resonated to the required frequency with C17. These two tuned circuits filter the injection frequency. This prevents any spurious mixing occuring in Q2.

Coil L7 is used to 'trim' the crystal frequency.

A regulated supply to Q3, provided by the zener diode, ZD1, prevents power supply variations from affecting the crystal frequency.

2. Tune the slug in L4 to obtain a peak in the receiver noise level.
3. Set all the other coil slugs flush with the tops of the coil formers.
4. Using the signal generator, with a fairly high output level, peak L4 again for best signal strength.
5. Set the generator to a frequency near 119 MHz and tune the receiver until you pick up the signal. Now adjust the slugs in L2 and L6 for best signal strength. Decrease the output of the signal generator so that these adjustments are made on a fairly weak signal.
6. Set the generator to a frequency near 125 MHz, or the highest frequency in which you are interested, and tune the receiver until you pick up the signal. Adjust the slugs in L1 and L5 for best signal strength. Keep the generator output at a low level for best results.

SOME CHANNEL ALLOCATIONS

Frequency	Channel Usage
118.1	Bankstown and other towers
118.7	Canberra Parafield towers
118.9	Melbourne departure
119.1	Club frequency
119.4	Sydney approach
120.5	Adelaide/Brisbane/ Melbourne/Sydney towers
120.9	Automatic information service
122.1	Area frequency
123.0	Sydney departure
124.2	Adelaide approach
124.4	Sydney approach
124.7	Brisbane/Melbourne approach
125.3	Sydney departure
125.8	Area frequency

7. Now set the generator to a frequency half way between these two frequencies. Tune the receiver to pick up the signal and adjust the slug in L3 for best signal. Check the adjustment of L4.
8. Return to 119 MHz and peak the slug in L2 again.
9. Repeat the procedure, 'touching up' each slug.

If the converter is to be used on one channel, or a couple of channels less than 1 MHz apart, then all the coils need only be adjusted for best signal strength on one channel.

Overall sensitivity of the converter-receiver system is very good, signals as low as 0.2 uV being clearly audible. The gain control range is about 20 dB.

Choosing A Crystal

The frequency injected at gate 2 of the mixer FET, Q2, may be above or below the signal frequency by an amount equal to the IF frequency. For a turnable receiver used as an IF, the injection frequency should be lower than the *lowest* signal frequency by 10 MHz. Thus, as you tune the receiver upwards in frequency from 10 MHz, you will tune signals above the lowest aircraft band frequency (118 MHz). In this way there will be a simple relationship between the signal frequency and the receiver's dial. If 10 MHz equals 118 MHz, 10.5 MHz will equal 118.5 MHz, and so on. For this situation the injection frequency will be 118 – 10 = 108 MHz. As the crystal oscillator output (collector of Q3) is twice the crystal frequency, the crystal frequency should be half of 108 MHz = 54 MHz.

If you use a tunable receiver then a fifth overtone crystal at 54.000 MHz should be ordered. Tolerance and adjustment range also have to be specified. A value of 20 parts per million (ppm) for tolerance and adjustment range is satisfactory. Firms such as Bright Star Crystals or Hy-Q should be able to supply a crystal to order.

Alternatively, a crystal at one-third the injection frequency may be used. Taking the 108 MHz injection frequency, as just illustrated a 36 MHz crystal may be used.

To determine the crystal frequency required for any case, use the following formula:

$$\text{Crystal} = \frac{\text{lowest signal frequency} - \text{IF}}{2 \text{ or } 3}$$

Inexpensive crystals intended for use in 'scanning' receivers are available from Dick Smith's. These provide an injection frequency *above* a particular aircraft channel frequency for the standard IF frequency of 10.7 MHz. For example, for the 125.8 MHz channel, the injection frequency is 136.5 MHz. These crystals have the channel frequency marked on them, not the crystal frequency.

Setting the crystal frequency

If you require accurate frequency readout then the crystal frequency will need 'trimming'. Coil L7 is provided for this purpose. For best results a digital frequency meter capable of measuring to 150 MHz is necessary.

Lightly couple the DFM to L5 or L6 via a small value capacitor and see if you get a sensible reading. You may need to connect it directly across gate-2 of the mixer, Q2.

Adjust L7 until you obtain the correct injection frequency according to the crystal chosen.

Multi-channel operation

If you intend using a fixed frequency IF (on 10.7 MHz) then a group of crystals may be used to select the desired channels of interest. A single-pole, multi-position switch may be used to select appropriate crystals.

Delete L7 on the pc board and replace it with a link. The components L7, C12 and R8 are also deleted. Each crystal needs to have this circuit attached. The channel switch is then connected with the pole to the junction of R9 and R10 and the trimming coil for each crystal connects to the appropriate switch contact.

If there is sufficient interest, we may later describe a 10.7 MHz IF and audio section to complement this project.