FT-221 and FT-225

muTek limited
rf technology

Our front-end board has been designed to bring the receiver performance of the FT221 and 225 series transceivers up to a very high standard. The design has evolved from work done by Ian White, G3SEK, and has been used extensively for advanced experimental work, contests and routine communication.

The original front-end board fitted by Yaesu suffers from several deficiencies. The chief of these are a distinct deafness (noise figures of 8 - 10dB are not unusual in unmodified transceivers!) and a susceptability to strong-signal overload problems. Fitting a preamp. can help in the first case, but at the expense of dynamic range. Strong signal effects are often not recognised as such, but with the present level of 144MHz activity there can be few operators able to completely disregard signal handling problems. Of course there will always be those who will remain convinced that a little extra gain at the front-end can only do good.......

The muTek front-end board has been designed to eliminate the need for preamplification whilst considerably improving the useful dynamic range. To overcome the design problems has required very careful attention to the linearity of the mixer and amplifiers with particular care being given to the effects of proper gain distribution.

The rf stage is a very low noise ion-implanted dual-gate mosfet. The device used is capable of a device noise figure of around 1dB. We have chosen to trade nf with dynamic range, resulting in a system nf of 2dB or a little less. This is more than adequate for terrestrial operation, and is probably quite acceptable for eme in most circumstances.

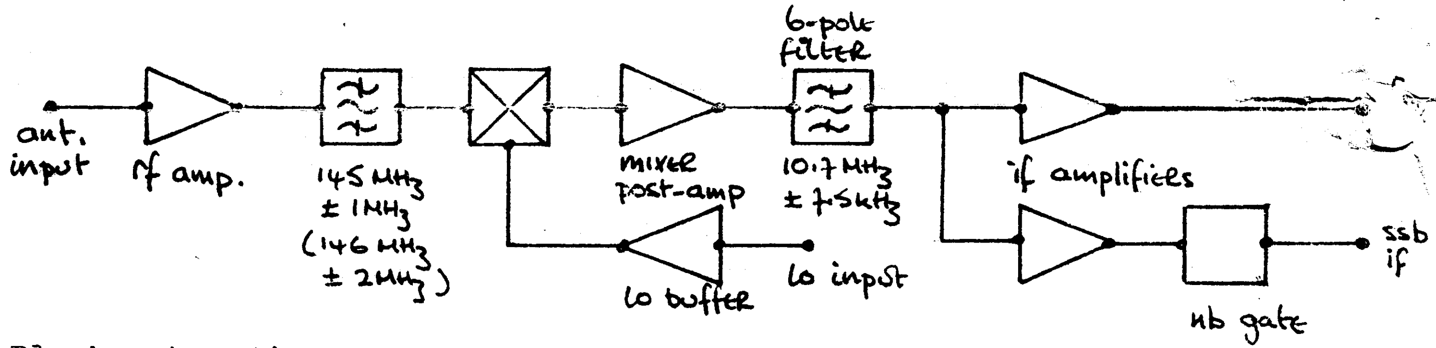
Following the rf stage is a three-pole bandpass filter which has been dimensioned to provide either a 2 or 4MHz bandwidth with excellent stopband performance.

A ring mixer was chosen in preference to the more usual fet for two reasons: the most obvious is that it is much easier to achieve adequate dynamic range with the ring. A second possibly more subtle reason is that the inherently balanced structure of the ring results in cancellation of the am components of the local oscillator noise sidebands. Proper termination of the mixer is essential for reproducible high-performance operation: our design does this.

The mixer post-amplifier is a dual-gate mosfet in a feedback circuit operating at high drain current for excellent intermodulation performance This also provides the correct source impedance for the following 15kHz bandwidth six-pole crystal filter.

Dual-gate mosfet if amplifiers for both the ssb/cw and fm if strips follow the filter and interface with the existing circuitry.

The cicuit is constructed using good quality components on a high-quality plated-through-hole printed circuit board. Installation is aided by step-by-step instructions.



Block schematic.

Technical Data.

Noise figure:	≤ 2dB	
Image rejection:	> 65dB	
Blocking (gain compression):	>120dB	(strength of signal on 144.4 MHz required to produce gain compression of -76dBm signal on 144.3MHz)
Spurious-free dynamic range: (intermodulation)	>85dB (typ ≈ 90dB)	(strength of individual tone in two-equal-tone pair (144.2 and 144.3MHz) required to generate 3rd order intermod. product on 144.1MHz at 0dB s/n.)

Notes: 1) All signal strengths are wrt noise floor/2.4kHz bandwidth (≃ -142.5dBm)

2) All measurements are performed at the input link on the board.

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FT221/225GT front end

Our front-end board has been designed to bring the receiver performance of the FT221 and FT225 series transceivers up to a very high standard. The design has evolved from work done by Ian White, G3SEK, and has been used extensively for advanced experimental work, and routine communication.

The original rf board fitted by Yaesu suffers from several deficiencies. The chief of these are a distinct deafness (noise figures of 8 - 10dB are not unusual in unmodified transceivers!) and a considerable susceptability to strong-signal overload problems. Fitting a preamplifier can help with the first problem but at the expense of dynamic range. Of course, strong signal problems are not always recognised as such, but with the present level of 144MHz activity there can be few operators who are able to completely disregard signal handling problems. Of course there will always be those people (including some manufacturers!) who will remain convinced that a little extra low noise preamplification can only do good .....

The muTek rf board has been designed to eliminate the need for preamplifiers while vastly improving the dynamic range of the system. To overcome the design problems presented has required careful attention to the linearity of the mixer and amplifiers with particular care being given to proper gain distribution.

The rf stage is a very low noise ion-implanted dual-gate mosfet (BF981) This device is capable of a genuine (device) noise figure of around 1dB. We have chosen to trade nf with dynamic range resulting in a system nf of perhaps 2dB or a little less. This is more than adequate for normal terrestial operation, and is probably quite acceptable for eme in most circumstances!

The rf stage feeds a three-pole bandpass filter; this has been dimensioned to provide a 2MHz bandwidth centred on 145MHz (4MHz centred on 146MHz) with excellent stopband performance. The filter - which has relatively high dissipation losses - is terminated with a resistive pad. This not only ensures that the filter is adequately terminated, but also provides a very important broad-band termination for the input port of the ring mixer.

A ring mixer was chosen in preference to the more usual fet for two reasons: the most obvious is that it is much easier to achieve adequate dynamic range with the ring. A second, possibly more subtle reason, is that the inherently balanced structure of the ring results in cancellation of local oscillator am noise. As the phase locked translation loop lo in the 221 and 225 series generates quite large am noise sidebands, a balanced mixer is mandatory.

Proper termination of the mixer is essential for reproducible high performance operation. The lo is terminated with a 5dB pad: this ensures a good broadband match. There is enough power available at the output of the class-A lo buffer to ensure proper mixer performance. The mixer port which requires most careful termination is the if output. The network here has several functions: it must transform the 50Ω output impedance of the diode ring to the optimum source impedance required by the mosfet post amplifier; it must ensure that the mixer has a dc earth return, and most importantly, it must provide a satisfactory termination for the vhf and uhf products generated in the mixing process. The 10.7MHz impedance transformation is accomplished with an L-network, while the rf choke provides the earth return. The series RC network on the mixer output provides a monotonically increasing return-loss with frequency, thus ensuring proper termination of the vhf and uhf mixing products.

The mixer post-amp is a low noise mosfet which is operated at a high drain current for good intermodulation performance. Although some degradation of the noise figure can be seen, it is still very low and has a minimal effect upon the mixer nf. The device also provides the correct source impedance for the following 6-pole crystal filter.

After the crystal filter the linearity requirements become less severe, but the same circuit techniques are employed. Dual-gate mosfets are used for both the fm and ssb if head amplifiers. The output of the ssb amplifier drives the noiseblanker gate.

The circuit is constructed on a very high quality plated through hole pcb.

Tr_1	BF981	QA-00-981	D_1	1N914	ED-00-914
Tr_2	3SK74	QA-00-074	D_2	1N914	ED-00-914
Tr_3	3SK74	QA-00-074	D_3	1N914	ED-00-914
Tr_4	3SK74	QA-00-074	D_4	1N914	ED-00-914
Tr_5	BF274	QA-00-274	D_5	BA379	ED-00-379

Edge connector pin allocations

Pin 1	gnd	Pin 7	mkr/nc	Pin 13	nc
Pin 2	agc	Pin 8	gnd	Pin 14	ssb if
Pin 3	+13.5V	Pin 9	fm if	Pin 15	blanker
Pin 4	gnd	Pin 10	gnd	Pin 16	gnd
Pin 5	antenna	Pin 11	nc	Pin 17	lo
Pin 6	mkr/nc	Pin 12	gnd	Pin 18	gnd

Installation

There are two small internal modifications that are required in order to make the muTek rf board compatible with the unmodified FT221/225. They are both reversible.

The first provides a switched 13.5V line to power the new rf board on receive only. The original board operates from an 8V rail which potentially limits dynamic range.
The second is to switch the 8V supply to the noise blanker if strip. The noise blanker gate doubles as a diode switch for the ssb filter t-r switching. To improve the blanker action we have redimensioned the blanker gate biasing. A result of this is that diode switch needs to be solidly reverse biased in order to avoid losses in the ssb transmit mode.

The modifications described below apply to both the FT221 and FT225. We strongly suggest that the voltage checks detailed are made to confirm the function of the relevant pins. If you have any queries please don't hesitate to contact us.

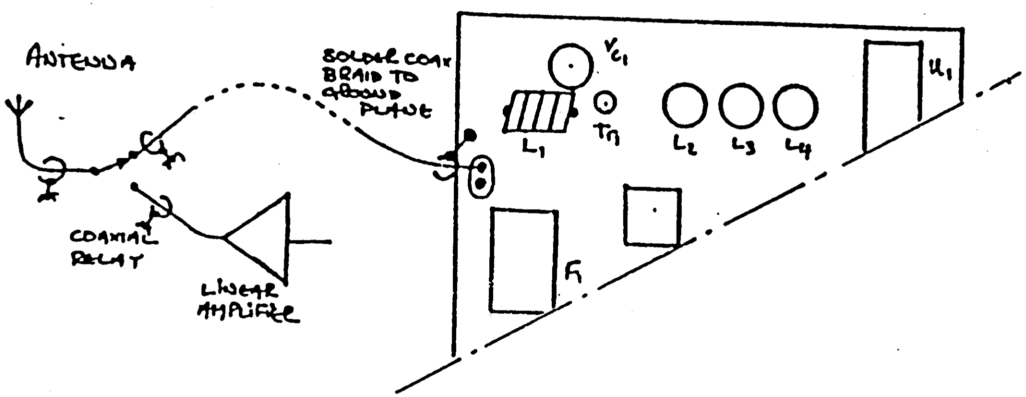
1) Remove both the top and bottom covers of the transceiver.
2) Remove the original rf board.
3) Remove the metal carrier from the original rf board.
4) Fix the carrier to the muTek board, taking care to ensure that the orientation is the same as the original.
5) Turn the transceiver over to expose the underside.
6) Locate Pin 18 on the ssb if unit edge connector - this may also be labelled Pin 9B - it has 13.5V on receive and 0V on transmit.
7) Locate Pin 3 on the rf unit edge connector.
8) If Pin 3 has a lead connected to it, remove the lead and insulate the free end.
9) Run the longer of the two leads supplied between Pin 18 (9B) of the ssb if unit edge connector and Pin 3 of the rf unit edge connector.
10) Locate Pin 13 on the fm if unit - this will have 8V on it.
11) Remove the leads soldered to this pin (if there is a decoupling capacitor soldered to the pin, don't remove it.) Insulate the bare ends of the leads, which should remain soldered together.
12) Locate Pin 9 - this may also be labelled Pin 5A - on the ssb if unit edge connector. This has 8V on receive and 0V on transmit.
13) Run the shorter of the two leads supplied between Pin 13 of the fm unit edge connector and Pin 9 (5A) of the ssb unit edge connector.
14) Turn the transceiver the right way up.
15) Plug-in the muTek rf board. (The track side of the board faces the front)
16) Check the receiver performance on an antenna.
17) Refit the top and bottom covers.
18) Now get in amongst the dx!

Notes

1) It may well be necessary to reset the s-meter zero and full-scale adjustments.

2) The addition of a relatively narrow-band crystal filter prior to the noise amplifier inevitably causes some deterioration of the noise-blanker performance. We have redimensioned the the blanker-gate circuitry in order to minimise this effect. However some reduction in performance can be expected, particularly with low-level noise pulses.
We have also observed that when the original board has been used with a preamplifier, the dynamic range has been so small that the rf board has been acting as an rf noise limiter..!

3) In circumstances where the lowest possible noise figure is required, the transceiver's internal antenna change-over circuit losses may be unacceptable. In order to bypass the antenna relay, we have provided a link (INPUT LINK) in the antenna input microstripline which may be broken to allow a direct connection to be made to the rf stage gate circuit.

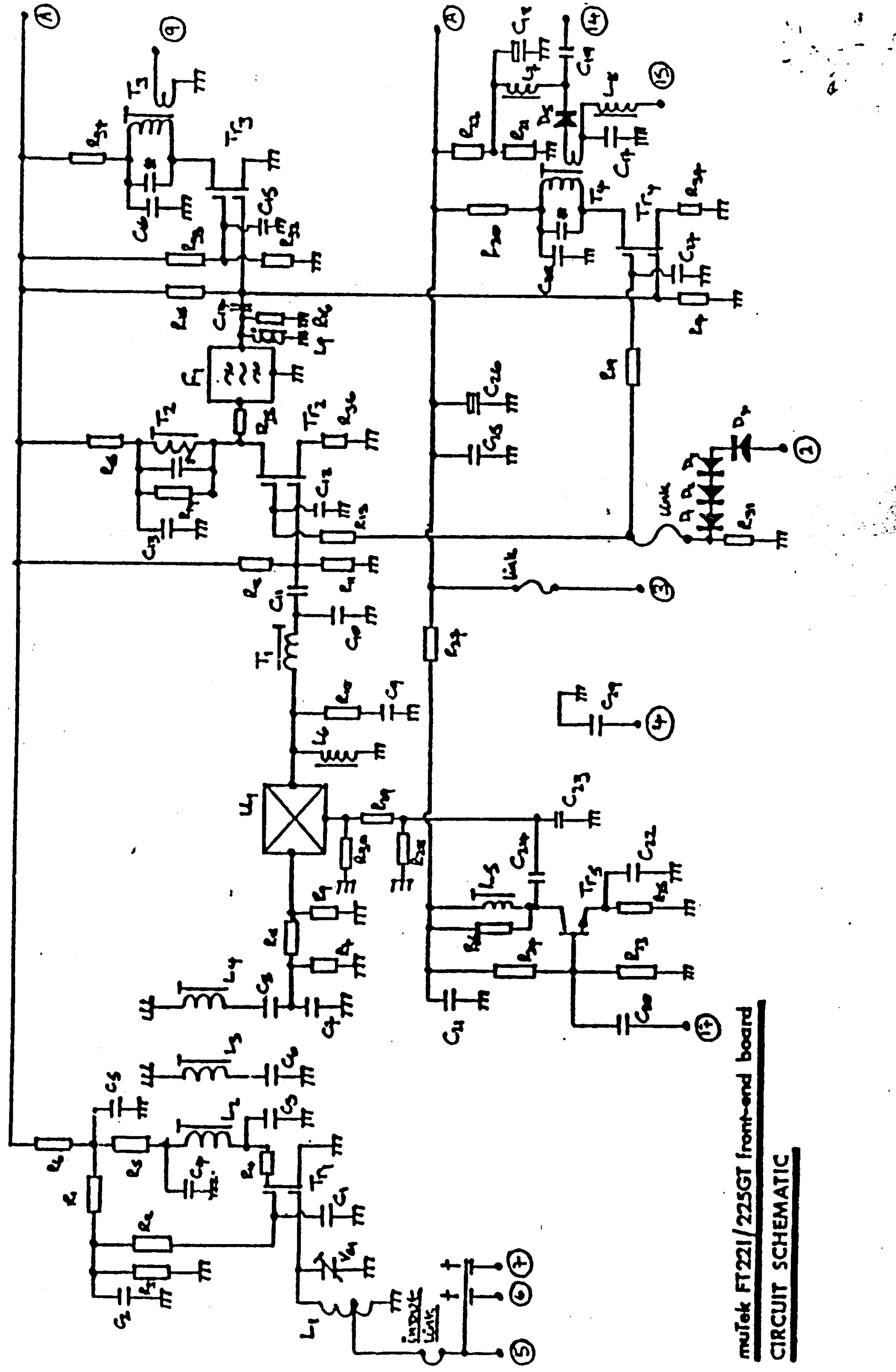


Test data

Serial Number: 7730

Date: 18/7/84

Noise figure 1.8 ±0.5dB



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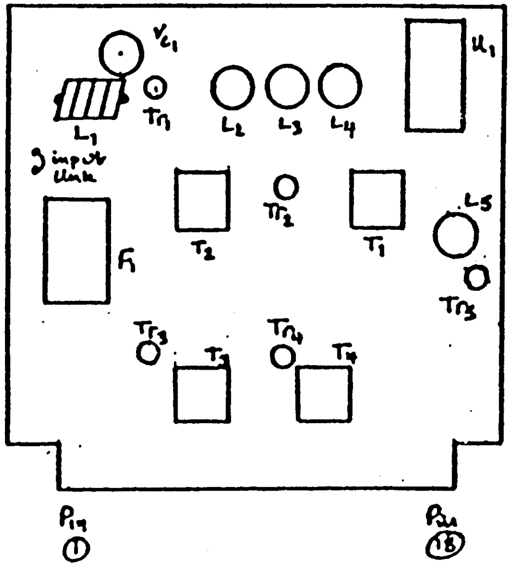
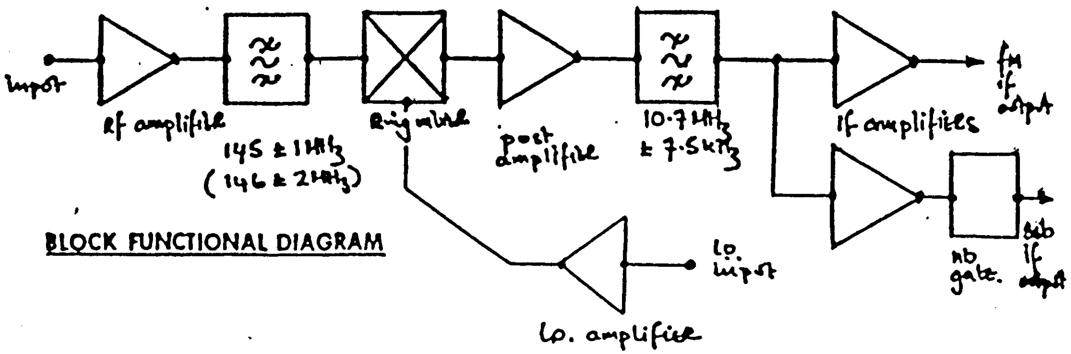


MAJOR COMPONENT LOCATIONS



BLOCK FUNCTIONAL DIAGRAM

C_1	1n0 pc	CA-00-130
C_2	1n0 pc	CA-00-130
C_3	8p2 pc	CA-00-802
C_4	1n0 pc	CA-00-130
C_5	1n0 pc	CA-00-130
C_6	12p pc	CA-00-112
C_7	n10 pc	CA-00-120
C_8	12p pc	CA-00-112
C_9	n10 pc	CA-00-120
C_{10}	68p pc	CA-00-618
C_{11}	1n0 pc	CA-00-130
C_{12}	10n pc	CA-00-140
C_{13}	10n pc	CA-00-140
C_{14}	1n0 pc	CA-00-130
C_{15}	10n pc	CA-00-140
C_{16}	10n pc	CA-00-140
C_{17}	10n pc	CA-00-140
C_{18}	1u5 tb	CD-00-165
C_{19}	1n0 pc	CA-00-130
C_{20}	1n0 pc	CA-00-130
C_{21}	1n0 pc	CA-00-130
C_{22}	1n0 pc	CA-00-130
C_{23}	47p pc	CA-00-417
C_{24}	10p pc	CA-00-110
C_{25}	1u5 pc	CD-00-165
C_{26}	1n0 pc	CA-00-130
C_{27}	10n pc	CA-00-140
C_{28}	10n pc	CA-00-140
C_{29}	1n0 pc	CA-00-130
VC_1	10p pf	
L_1		LA-00-003
$L_2 \ldots L_5$		LA-00-002
L_6	47u rfc	LB-00-417
L_7	22u rfc	LB-00-212
L_8	m22 rfc	LB-00-222
L_9	15u rfc	LB-00-115

R_1	82k	RA-00-842
R_2	100R	RA-00-120
R_3	39k	RA-00-349
R_4	150R$	RA-00-125
R_5	100R	RA-00-120
R_6	100R	RA-00-120
R_7	470R	RA-00-427
R_8	11R	RA-00-111
R_9	470R	RA-00-427
R_{10}	51R	RA-00-511
R_{11}	39k	RA-00-349
R_{12}	1M0	RA-00-160
R_{13}	39k	RA-00-349
R_{14}	1k5	RA-00-135
R_{15}	10R	RA-00-110
R_{16}	3k3	RA-00-333
R_{17}	39k	RA-00-349
R_{18}	1M0	RA-00-160
R_{19}	39k	RA-00-349
R_{20}	100R	RA-00-120
R_{21}	3k9	RA-00-339
R_{22}	5k1	RA-00-531
R_{23}	4k7	RA-00-437
R_{24}	33k	RA-00-343
R_{25}	150R	RA-00-125
R_{26}	10k	RA-00-140
R_{27}	100R	RA-00-120
R_{28}	180R	RA-00-128
R_{29}	27R	RA-00-217
R_{30}	180R	RA-00-128
R_{31}	10k	RA-00-140
R_{32}	39k	RA-00-394
R_{33}	82k	RA-00-842
R_{34}	100R	RA-00-120
R_{35}	1k5	RA-00-135
R_{36}	39R	RA-00-319
R_{37}	100R	RA-00-120
F_1		FA-00-001

These component values are given for guidance; $ denotes a component which may be adjusted on test.

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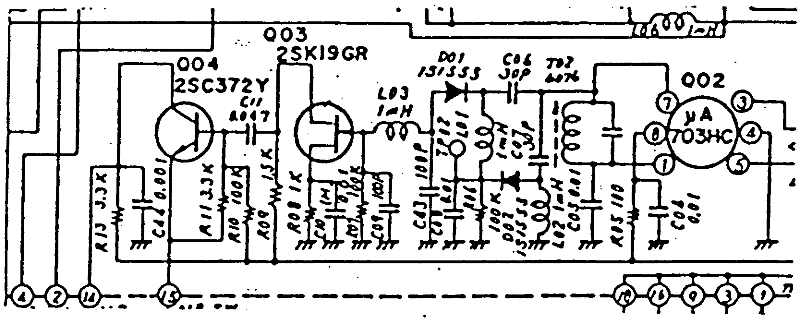
Yaesu FT221/225 series

August 1983

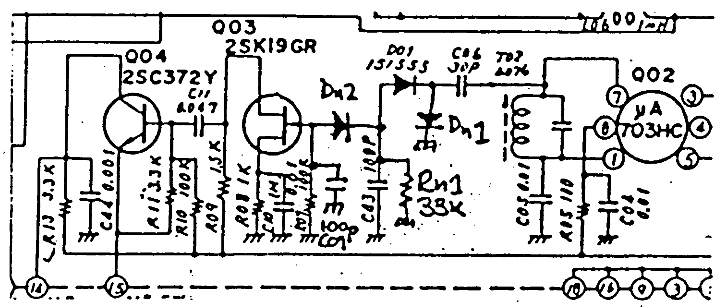
Improved noise blanker performance.

The design of the noise blanker in both transceivers is virtually identical although component designations may vary. In essence the modification involves increasing the size of the blanking pulse applied to the diode gate driver circuit (Q03/Q04).
The two cicuit diagrams show the relevant parts of PB1463 before and after modification. The new shunt diode Dn1 can be the 1S1555 removed from the secondary detector position whilst the series diode should be a silicon switching diode such as a 1N4148. The 33k resistor should be a reasonable quality 0.25w carbon film resistor such as a Mullard/Philips CR25 or a Piher PR25 although this is obviously not critical!

Before modification



After modification



This modification comes from a reputable source, and although it has been briefly tested at muTek, we are unable to guarantee its suitability for all transceivers in the series. In other words the modification is made at the owner's risk!

Directors Christopher Bartram Jane Bartram Stephen Prior Secretary Susan Whitehead