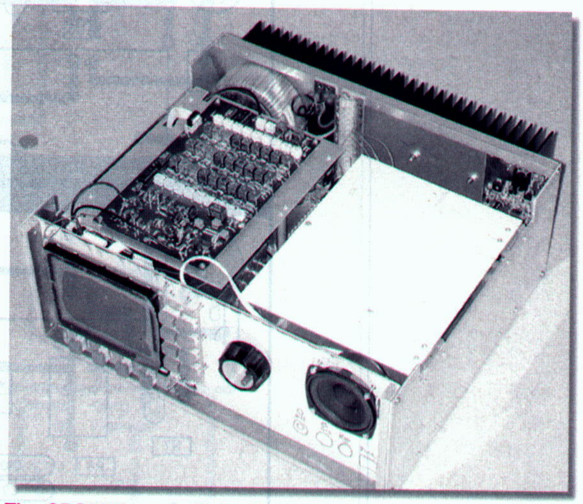
THE CDG2000 HF TRANSCEIVER

Part three, by Colin Horrabin, G3SBI, Dave Roberts, G8KBB, and George Fare, G3OGQ *

THE POST-MIXER amplifier follows the front-end and, apart from amplifying the signal to overcome the losses in the front-end caused by the filters and the mixer, provides the main filtering for SSB and CW signals.

The circuit is shown in **Fig 14**. The 9MHz signal from the front-end at 50Ω is matched by T1 and applied to a quad FET amplifier stage TR1 to 4, providing about 14dB gain at a very low noise figure. The output at about 200Ω is matched to the filters by T2 (to 50Ω) and then to the filters by C9,10 and L1 (to 500Ω) which is then routed via RLY2 and RLY1 which are switched along with RLY4 and RLY3 by TR5 to TR8. The output is matched to 50Ω by the L-network L2, C19 and 20. The relay contacts are DC-wetted, as in the front-end. This is essential to keep the relays functioning correctly at low signal levels. The effect of

** 1 Old Hall Close, Higher Walton, Warrington WA4 6SZ.*



The CDG2000, as built by G8KBB, having only one knob and 12 pushbuttons, reflecting the computer bias of the design.

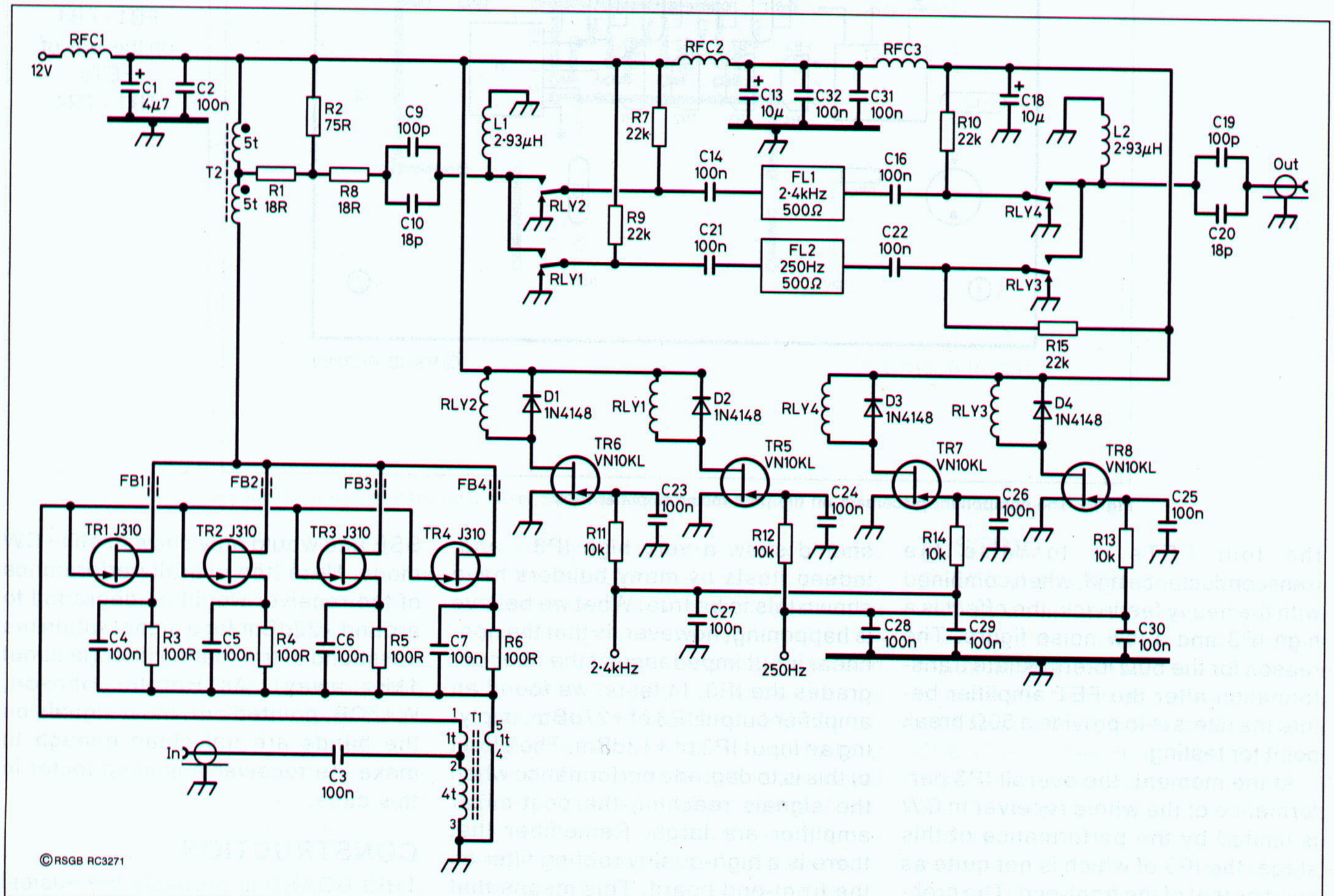
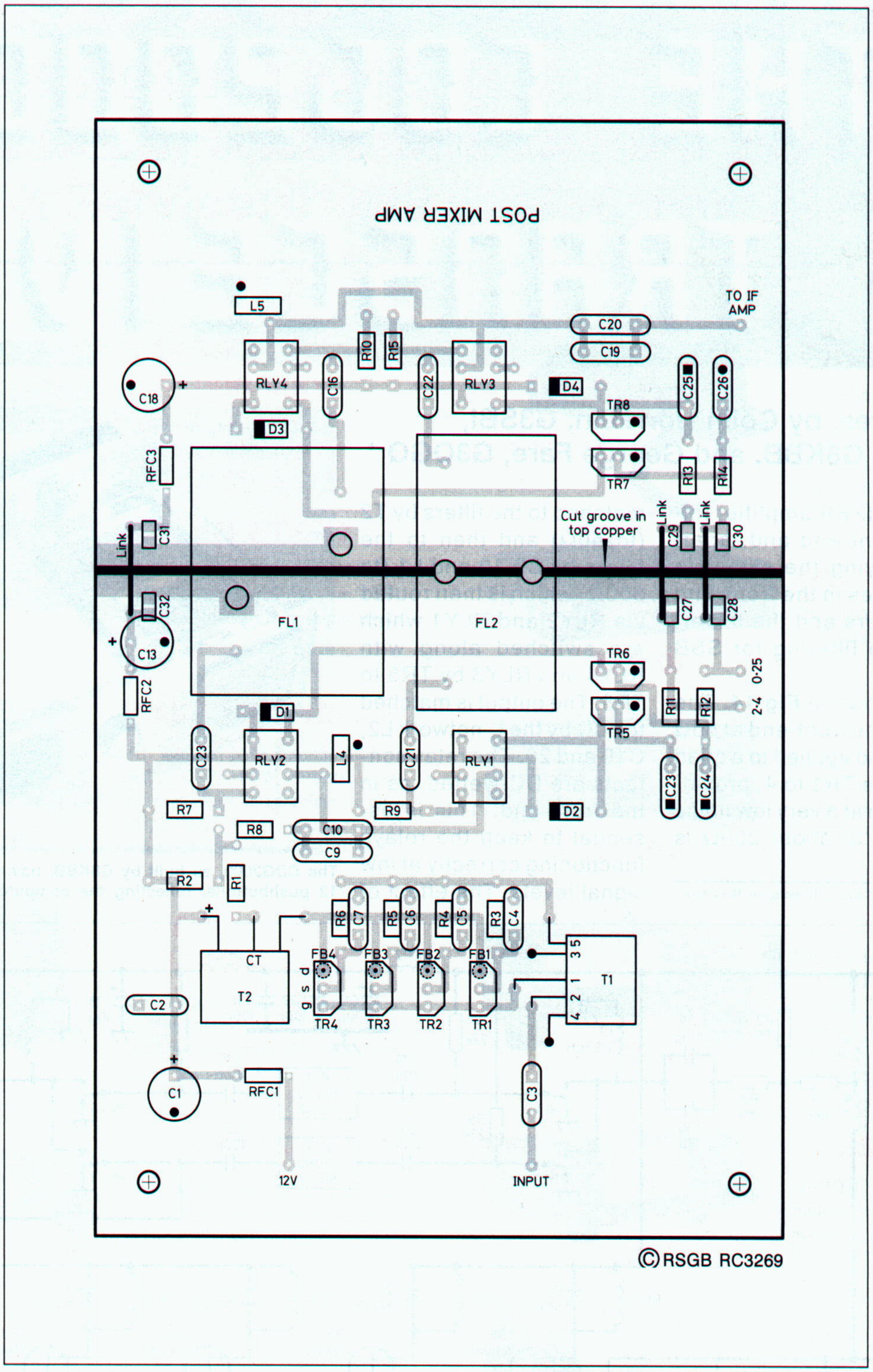


Fig 14: The post-mixer amplifier circuit.



NOTES

C27 - C32 are SMC and mounted on the track side

FB1 - FB4 on the legs of FETs TR1 - TR4

Fig 15: The component placement on the post-mixer amplifier PCB.

the four FETs is to raise the transconductance and, when combined with the heavy feedback, the effect is a high IP3 and a low noise figure. The reason for the 50Ω intermediate transformation after the FET amplifier before the filters is to provide a 50Ω break point for testing.

At the moment, the overall IP3 performance of the whole receiver in CW is limited by the performance of this stage, the IP3 of which is not quite as good as that of the front-end. The problem is that the quad FET amplifier should show a very high IP3 - and, indeed, tests by many builders have shown this to be true. What we believe is happening, however, is that the non-linear input impedance of the filter degrades the IP3. In tests, we found an amplifier output IP3 of +27dBm, implying an input IP3 of +13dBm. The effect of this is to degrade performance when the signals reaching the post-mixer amplifier are large. Remember that there is a high-quality roofing filter on the front-end board. This means that the effect of poor IP3 is minimal in SSB and would only show itself in CW mode. Here, the overall performance of the receiver would be degraded to around +22dBm for a signal within the passband of the roofing filter (ie about 1kHz away). As Harold Johnson, W4ZCB, pointed out, most signals on the bands are not clean enough to make the receiver a limiting factor in this case.

CONSTRUCTION

THIS BOARD is probably the easiest one in the transceiver to construct, and

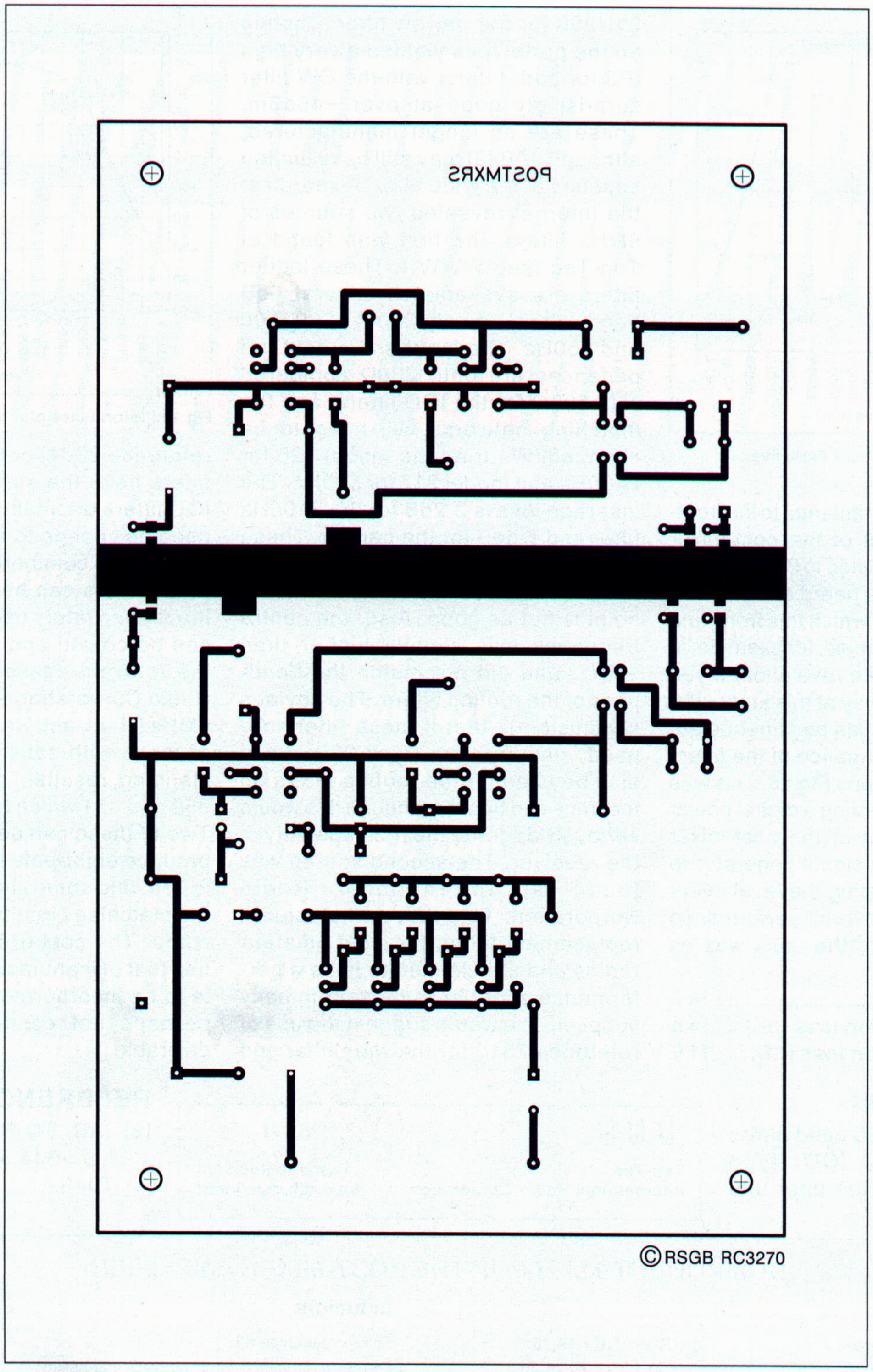


Fig 16: The tracking of the post-mixer amplifier PCB as seen through the board from the component side.

should pose no problems. The component layout is shown in **Fig 15** and the track layout in **Fig 16**. There are only six surface-mounted components, which are mounted on the track side, and should be fitted first. The only other problems which are likely to arise are with the transformers T1 and T2.

T1 and T2 are constructed on Amidon balun cores BN-61-202, although BN-61-302 is an acceptable alternative. T2 is wound with 5 turns bifilar at about 5 turns per inch (25mm). Note the phasing of the winding. T1 has a secondary of one turn. Coaxial braid can be used for this with the primary wound through it, or brass tubes can be fitted through each hole, connected together at one end and to ground and sources at the other as shown on the circuit diagram. Braid from RG174 (or, if available, its silver-plated equivalent) is ideal. The turns on L1 and L2 should occupy about 270° of the toroid. A ferrite bead is slipped over the drain leg of each J310 before soldering to the track. The ferrite bead material is not critical; type 43 will do fine.

TESTING

CHECK THE OPERATION of the relays with an ohmmeter by applying 12V to the relevant control pin to the PCB. A signal at 9MHz should then be traced through the board and should emerge with about 10dB amplification when the SSB filter is selected. We tested the front-end board together with this one at this stage by connecting the two boards together and applying a 0dBm signal from a signal generator to the LO input of the mixer, grounding a relevant pin of IC3 (Fig 11, July) to switch the

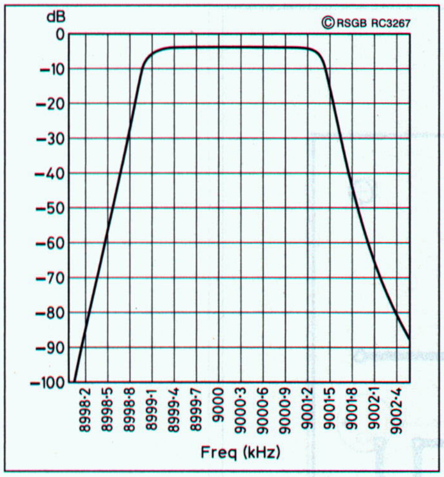


Fig 17: Insertion loss of the 2.5kHz filter.

band. Connecting an antenna to the front-end and the output of the post-mixer board to a receiver tuned to 9MHz should enable signals to be heard at the excellent performance of which this front-end is capable. 7MHz signals, for example, in the evening, will be a revelation. If you can tear yourself away at this stage, the rest of the receiver can be constructed!

The typical performance of the filters is detailed in **Fig 17** and **Fig 18**. This was measured by connecting a digital power meter to the output of the post-mixer amplifier unit and a signal generator to the input and recording the level every 100Hz or so. The overall performance summary for one of the units was as follows:

Amplifier gain (dB) 14.2
2.4kHz filter insertion loss (dB) 4.4
250Hz filter insertion loss (dB) 11.0

COMPONENTS

THE PROTOTYPES used filters manufactured by IQD, type 90H2.4B for the wide filter and 91H250 for the narrow filter. Testing on the prototypes yielded a very high IP3 for both filters, with the CW filter surprisingly good at over +45dBm. These are no longer manufactured, although JAB [9] may still have limited supplies of the wide filter. A search of the Internet revealed two sources of 9MHz filters, the first was found at Ten-Tec (see WWW.). These ladder filters are available at several 6dB bandwidths, namely 2400, 1800, 500 and 250Hz. The input and output impedances are both 200Ω compared with 500Ω for the IQD filters, and the matching networks will have to be changed. We tried the model 220 for 2400Hz and model 217 for 500Hz. The insertion loss is 2.2dB for the 2400Hz filter and 7.5dB for the narrow. These losses are lower than those of the IQD filters by about 2dB, but the intercept point is not as good. Also, the centre frequency was slightly higher than 9MHz, and did not match the bandpass of the roofing filters. The obvious conclusion is that if these filters are used, similar filters (type 220) could also be used for the roofing filters on the front-end board, although this would seriously degrade the IP3 capability of the receiver. The second source was found at International Radio Corporation. This firm manufactures replacement filters for most amateur radios and are claimed to have a performance superior to those originally supplied. We would suggest the use of reference 2310 for the wide filter and reference 2304 for the narrow. These filters have the same Z_{in} / Z_{out} as the IQD filters originally used, and should need no change to the design. Failing the use of commercial filters, home-made filters can be used. As a start, the roofing filters used in the front-end can be copied and modified to cover the relevant passband. International Radio Corporation also supply kits for 9MHz filters, and we have obtained two of these with satisfactory, if not outstanding, results. These are reference 350 and 351 which are each four-pole. Two of these can be wired in series to produce eight-pole filters. The Z_{in} / Z_{out} is 200, and some slight modification to the matching circuits would have to be made. The cost of the kits is roughly half that of manufactured filters. If DSP is to be incorporated, the CW filter is perhaps not essential, but is still desirable.

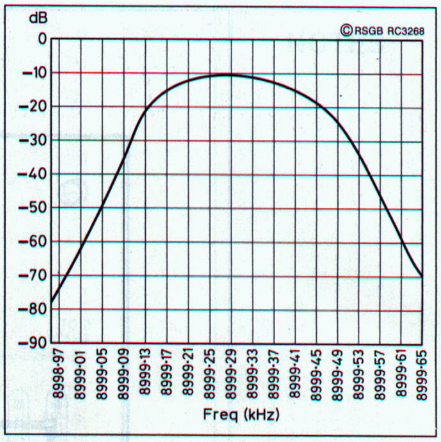


Fig 18: Performance plot of the 250Hz filter.

WWW.

Ten-Tec	**www.tentec.com**
International Radio Corporation	**www.qth.com/inrad**

REFERENCE

[9] JAB, PO Box 5774, Birmingham B44 8PJ. Tel: 0121 682 7045. ♦

COMPONENTS LIST FOR THE POST-MIXER AMPLIFIER

Capacitors

100n multi-layer ceramic	C2,3,4,5,6,7,14,16, C21,22,23,24,25,26
18p polystyrene	C10,20
100p polystyrene	C9,19
100n surface-mount 0805 NPO (COG)	C27,28,29,30,31,32
4µ7 16V tantalum	C1
10µ 16V tantalum	C13,18

Resistors 0.25W metal film 1% MF25 series

18R	R1,8
100R	R3,4,5,6
75R	R2
10k	R11,12,13,14
22k	R7,9,10,15

Relays

SPCO RS 345 038	RLY1,2,3,4

Inductors

Ferrite bead,type 43	FB1,2,3,4
Ferrite bead with 5 turns 30SWG enamelled	RFC1,2,3
2.93µH, 32 turns 30SWG enamelled on T37-6 toroid	L1,2
4:1 transformer, 5 turns bifilar on Amidon BN-61-202	T2
Transformer, **primary**: 5 turns 0.315mm enamelled, tap 4 turns from ground; **secondary**: 1 turn coax braid on BN-61-202	T1

Semiconductors

J310	TR1,2,3,4
VN10KL	TR5,6,7,8
1N4148	D1,2,3,4

Filters (see text)

IQD crystal filter 90H2.4B	FL1
IQD crystal filter 91H250	FL2

NEXT MONTH: the authors describe the IF unit, having a low noise figure at its input, and allowing control of its operating parameters.

THE CDG2000 HF TRANSCEIVER

Part four, by Colin Horrabin, G3SBI, Dave Roberts, G8KBB, and George Fare, G3OGQ *

THE ROLE of the IF unit is to accept a single, band-limited signal from the post-mixer amplifier and to amplify it to a level suitable for a 'standard' +7dBm diode product detector. It should do so in such a way that the level delivered is 'constant' for any input signal over a 120dB dynamic range. It must possess a low noise figure at its input and allow control over its operating parameters.

The IF unit presented here is not our design. Bill Carver, K6OLG (now W7AAZ), produced an excellent one in 1996 which was published in *QST* [10]. It is also described in the *RSGB VHF/UHF Handbook* [11].

If you refer to the block diagram in part one of this series, you will note that there is no AGC shown at all. This is because the AGC is local to the IF strip. With no preamplifier, there is no need for external AGC.

What made Bill's design so good was that it had a carefully-designed fast / slow AGC circuit to handle sudden signal increases, and it was based on high-quality Analog Devices XAMP family amplifiers [12].

As Bill pointed out in his *QST* article, the handling of sudden signal level changes fundamentally affects how the recovered signal sounds. The IF possesses a fast and a slow AGC loop. When a sudden increase in signal occurs, the fast loop responds to it and reduces its gain. The slow loop is on the 'other' side of a noise filter and responds slowly. The composite AGC signal is a combination of the two AGC circuits. A block diagram of the IF is shown in **Fig 19**. The effect of this dual-loop AGC is to produce an output signal that does not suffer distortion on the initial signal peaks.

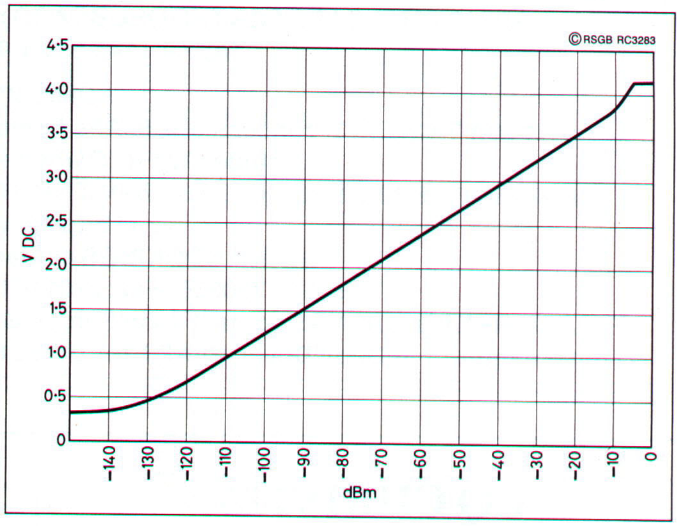


Fig 20: S-meter output range from an early version of the unit.

A full description will not be given here; the reader is referred to the *QST* or *RSGB VHF / UHF Handbook* articles. The input amplifier is a single J310 FET amplifier carefully matched to the 50Ω input impedance, providing 12dB of gain and matching the input impedance of the AD600. Each AD600 is a dual variable-gain amplifier with each stage providing 40dB of gain control range. The first device thus produces 80dB of control range.

The signal then passes through a crystal filter that is designed to remove wideband noise. Without this, there would be too much noise in the circuit to allow gain control over a 120dB range. The next AD600 is not used to provide another 80dB of control - a total of 160dB would be pointless. Instead, one half is used to give another 40dB to the AGC-controlled IF strip, giving a range of 120dB, and the final stage is used to adjust the output signal level. This is how the unit delivers a constant audio level over its whole AGC controlled range - but it can be tweaked to personal taste if you prefer.

The AGC circuits also provide an accurate logarithmic signal output - see **Fig 20**. This is used to drive the S-meter on the controller of the CDG2000, or it may be used to drive an analogue meter. In order to compensate for attenuator setting changes or band-by-band gain differences, the controller can be used to provide an offset to the AGC signal so that the S-meter always reads correctly.

There are two controls for the IF unit - 'IF gain' and 'AGC hang time'. These may either be driven by pots or by a digital-to-analogue converter. The CDG2000 controller provides for this.

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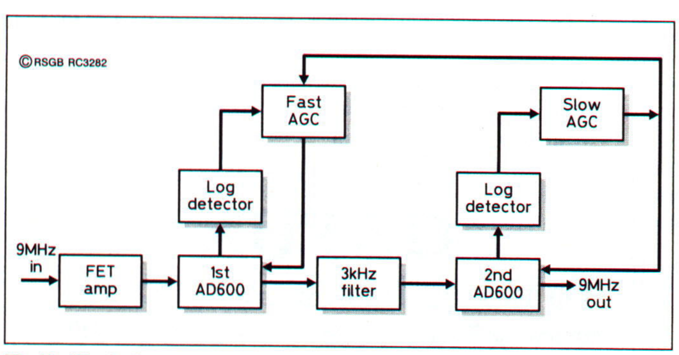

Fig 19: Block diagram of the IF unit.

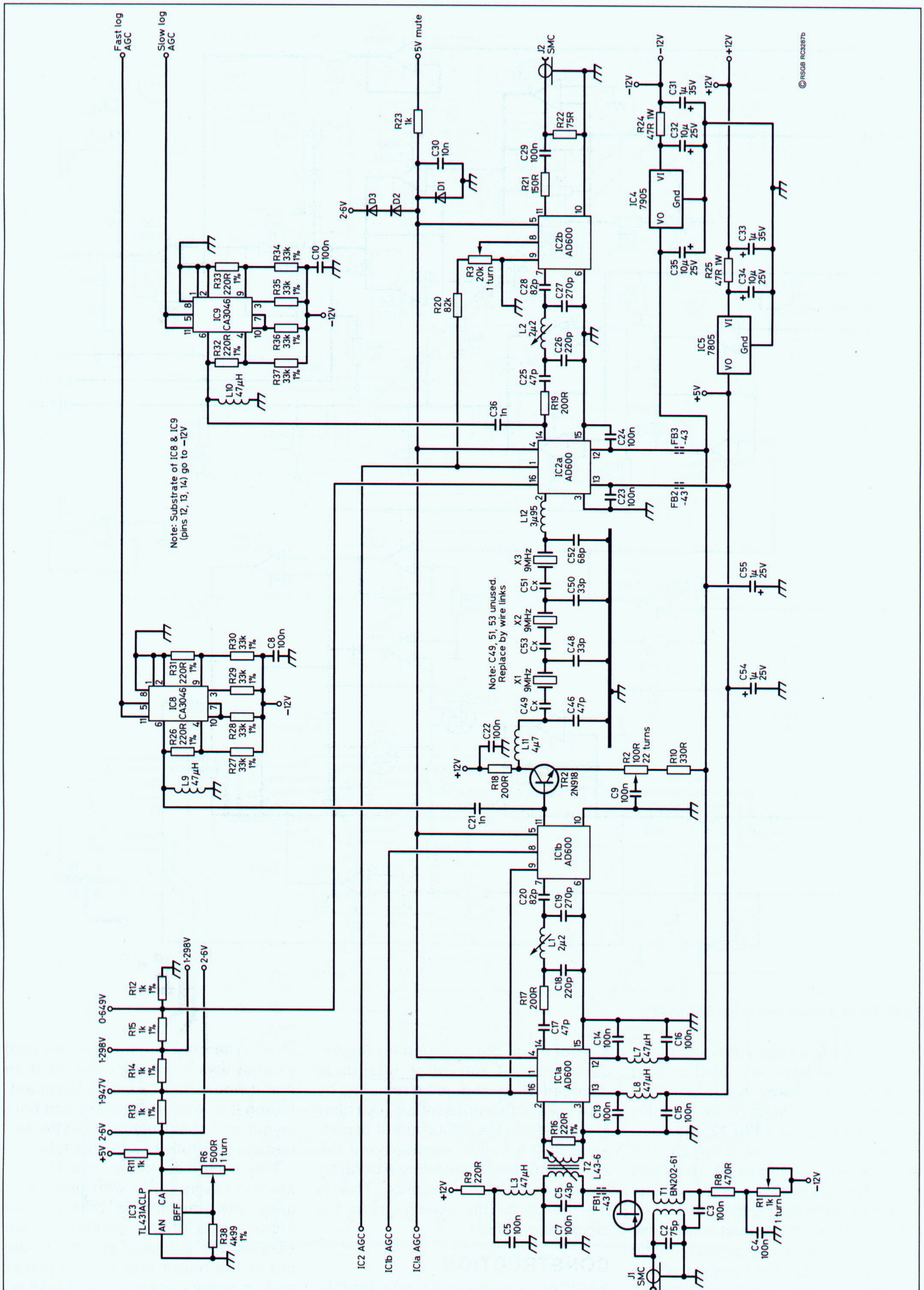

Fig 21: Circuit diagram part 1 - the signal path.

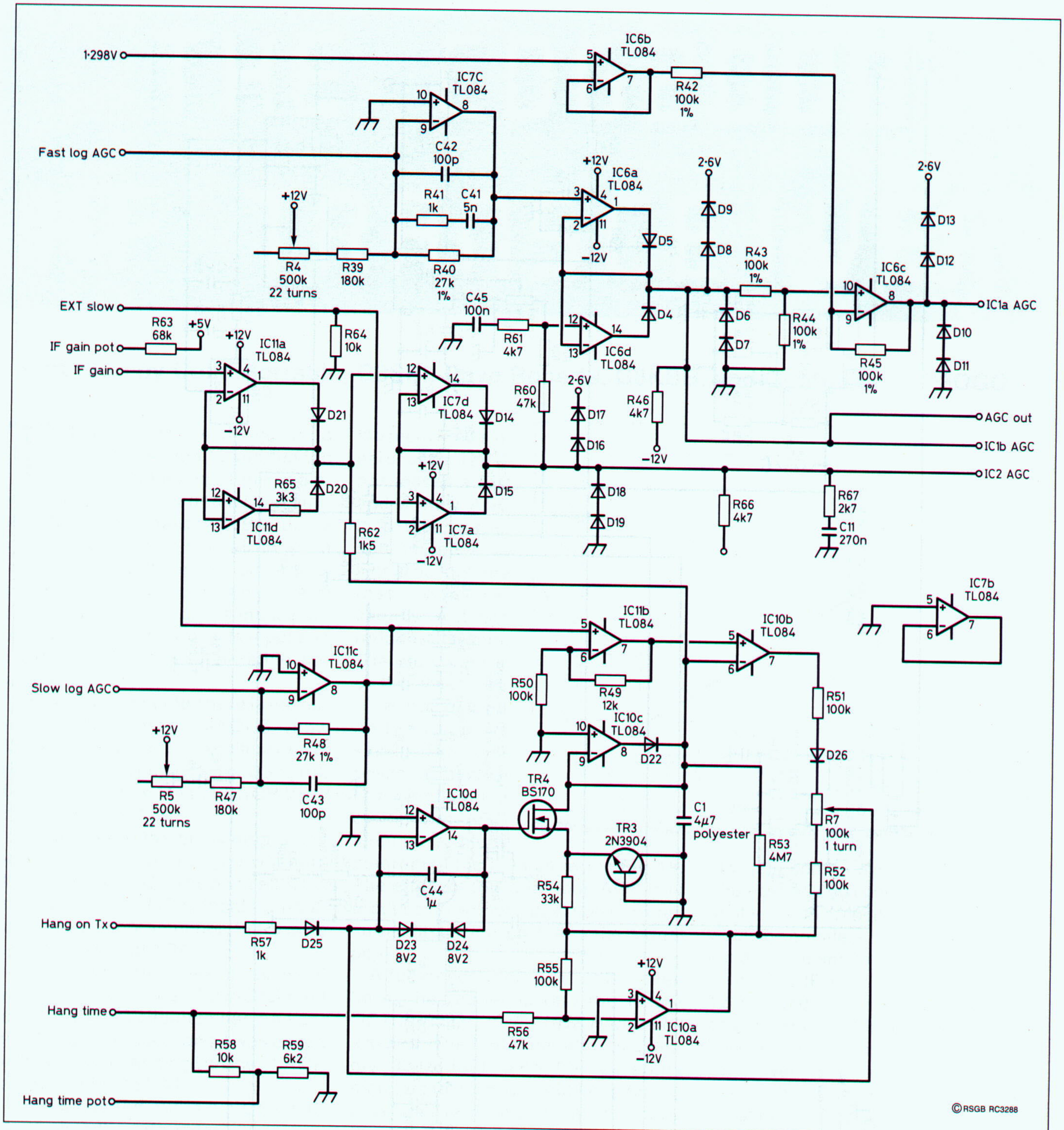

Fig 22: Circuit diagram part 2 - the AGC circuits.

IF gain rarely needs adjustment. Finally, control lines are used to hold the AGC voltage when on transmit.

A full circuit diagram of the IF unit is shown in **Fig 21** and **Fig 22**, the component layout is shown in **Fig 23**, and the PCB tracking in **Fig 24**. Note that the PCB is tracked for a simple crystal filter made of 9MHz crystals. The exact details of this filter depend on whether you have spare crystals or ready-made filters to hand. See Bill's original article for details. The diagram shows series capacitors between the crystals. These are not used, but provided for the experimenter if the filter design is changed. They should be replaced by wire links in this application. The filter is matched to the 100Ω output impedance of the buffer amplifier and the 200Ω input of the following AD600 by standard L-match networks. This is the reason for the asymmetry in the component values.

CONSTRUCTION

BASICALLY, we liked Bill's design [10] a lot, and saw no reason to change it at all. The only substantive physical change was to re-track the PCB so that it would fit on a single Eurocard. Fitting it in was a squeeze, and both layout and construction must be carried out carefully to avoid instability.

The ICs are socketed - the AD600s are not cheap - but with that much gain, the earthing is critical. The ground pins of the sockets on the AD600s are soldered directly to the top of the board (the ground plane) and, in some cases, to the tracks on the bottom as well. Turned-pin sockets

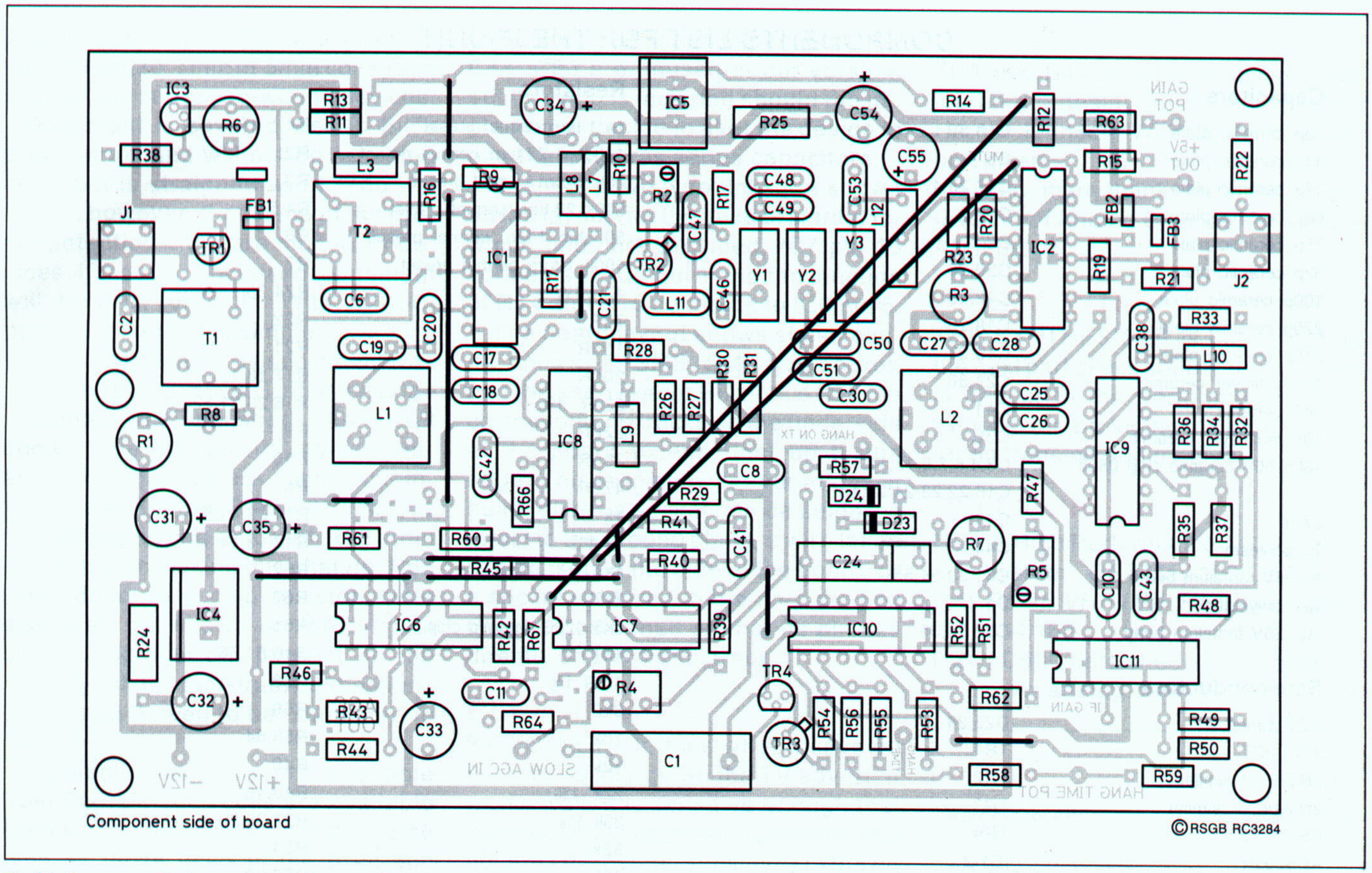

Fig 23: Component placement on the top of the board. On the underside are the SOT-23 diodes and chip decoupling capacitors.

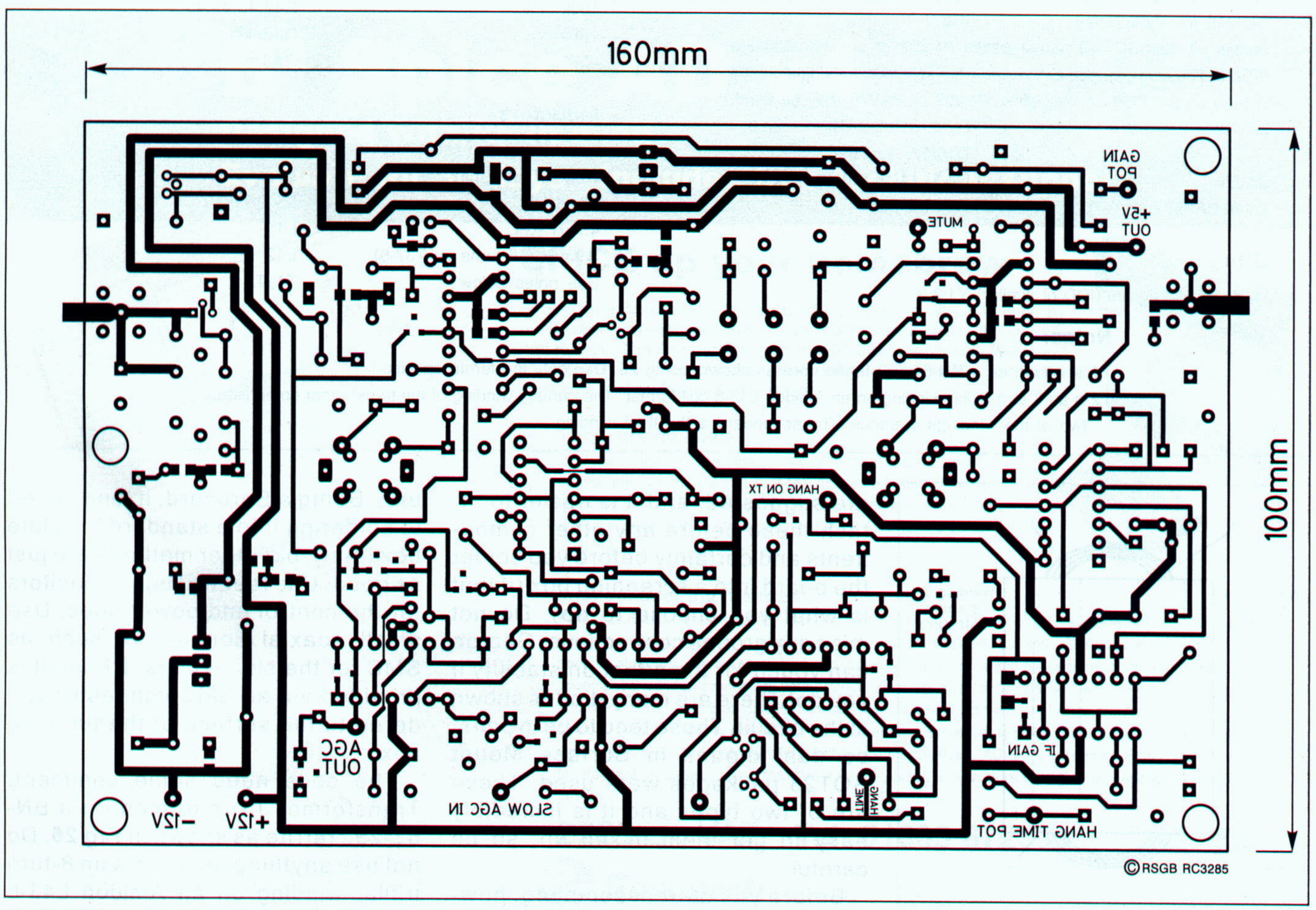

Fig 24: PCB tracking. Note the pads for the SOT-23 diodes.

COMPONENTS LIST FOR THE IF UNIT

Capacitors

33p ceramic plate	C48,50
43p ceramic plate	C6
47p ceramic plate	C17,25,47
68p ceramic plate	C52
75p ceramic plate	C2
82p ceramic plate	C20,28
100p ceramic plate	C42,43
220p ceramic plate	C18,26
270p ceramic plate	C19,27
1n multilayer ceramic	C21,36
4n7 ceramic	C41
10n multilayer ceramic	C30
100n 50V ceramic chip 0805	C3,4,5,7,9,13,14,15, C16,22,23,24,29,45
270n	C11
1µ polyester	C44
1µ 35V tantalum bead	C31,33,54,55
4µ7 polyester	C1
10µ 25V tantalum bead	C32,34,35

Semiconductors

8.2V Zener	D23,24
J310 FET	TR1
2N918 or similar	TR2
2N3904 or similar	TR3
BS170 FET	TR4
AD600JN	IC1,2
TL431 ACLP regulator	IC3
7905 regulator	IC4
7805 regulator	IC5
TL084 op-amp	IC6,7,10,11
CA3046 transistor array	IC8,9

Diodes all dual SOT-23, either series BAV99 or common-cathode BAV70. They are grouped as follows. Note final four are single diodes tracked on the PCB so that either BAV99 or BAV70 may be used.

BAV99	D2/3, 6/7, 8/9, 10/11, 12/13, D16/17, 18/19
BAV70	D4/5, 14/15, 20/21
Either BAV99 or BAV70	D1,22,25,26

Other

9MHz A164A crystal (IQD or similar) Y1,2,3

Resistors

1k 1-turn cermet preset	R1
100ohm 22-turn cermet preset	R2
20k 1-turn cermet preset	R3
500k 22-turn cermet preset	R4,5
500ohm 1-turn cermet preset	R6
100k 1-turn cermet preset	R7
47R 1W	R24,25
75R	R22
150R	R21
200R	R17,18,19
220R 1%	R16,26,31,32,33
220R	R9
330R	R10
470R	R8
1k	R11,23,41,57
1k 1%	R12,13,14,15
1k5	R62
2k7	R67
3k3 1206 ceramic chip	R65
4k7	R46,61,66
4k99 1%	R38
6k2	R59
10k	R58,64
12k	R49
27k 1%	R40,48
33k 1%	R27,28,29,30,34,35,36,37
33k	R54
47k	R56,60
68k	R63
82k	R20
100k	R50,51,52,55
100k 1%	R42,43,44,45
180k	R39,47
4M7	R53

Inductors

Type 43 ferrite beads	FB1,2,3
2.2µH Toko 7mm	L1,2
47µH RFC	L3,7,8,9,10
4.7µH RFC	L11
3.95µH (36 turns on T37-6)	L12
See notes below	T1, T2

Notes:

T1 is wound on a BN-61-202 ferrite core as shown in Fig 25. Use only the ferrite specified.

T2 is an 8-turn trifilar winding on an Amidon L43-6 coil former. The primary winding of the transformer comprises two of the windings in series. The secondary is the third winding.

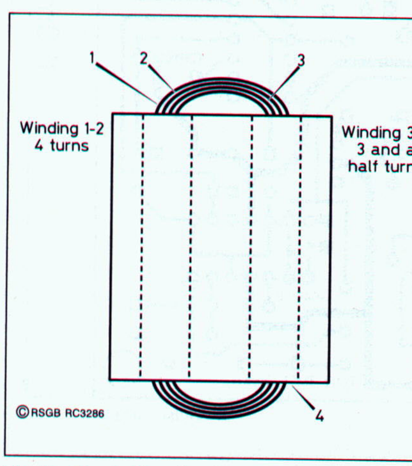

Fig 25: T1 winding details on a BN-61-202 core.

are suggested, and it is easier to attach these before any other components and certainly before you solder the board into a screening box (if that is what you choose to do). Do not miss any ground connections. George can vouch for the effect on stability if you do! There are many diodes shown in the circuit. These tend to be in pairs, so dual diodes in Surface Mount SOT23 packages were used. These are of two types and it is incredibly easy to get them mixed up, so be careful.

Before you start assembling, however, decide how you will screen the unit. Being a Eurocard, it lends itself to soldering into a standard tin-plate box (hint), but other methods are just as good. Use feedthrough capacitors for the control and power lines. Use small coaxial connectors such as SMC for the signal lines. RF input is provided via an SMC connector soldered to the surface of the tin plate box.

The coils need some comment. Transformer T1 is formed on a BN-61-202 ferrite as shown in **Fig 25**. Do not use anything else. T2 is an 8-turn trifilar winding on an Amidon L43-6 form. Coils L1 and L2 are off-the-shelf

2.2µH coils – the PCB is tracked to take 'standard' 7mm or 5mm coils such as the Toko series pre-wound devices.

Alignment is covered well in Bill's original text and will not be repeated here, but is straightforward. You will notice, however, that some of the pre-set potentiomaters are multi-turn devices. If these are not used, alignment will be very difficult. With 22-turn potentiometers, it is simple.

Finally, a slightly revised circuit was produced by Bill, K6OLG, after the original circuit was published. The circuit shown here follows his revised version. The changes are minor, and involved adding R65, R66, R67 and C11 and changing the value of R62 from 4k7 to 1k5. In making this change, R65 was added as a chip resistor. Note also that, not shown on the original circuit diagrams but present on the PCB layout, the substrate connections of IC8 and 9 need to be connected to -12V.

All semiconductors are available from Farnell. Toko coils are available from BEC. The crystals are the same type as those used in the front-end roofing filters.

The crystal filter is tracked out to allow the design to be altered. Specifically, the three series capacitors C49, C51, C53 are unused in our version, but tracking is included should the implementer decide to alter the design to one that requires series capacitors.

There are two wire links not shown on the layout (for the sake of clarity) for which pads are provided. IC7 pin 13 connects to IC2 pin 1 and the junction of R14 and R15 connects to IC6 pin 5.

The board layout shows signal connections as an SMB / SMC type socket, and the keen reader will notice that the corresponding tracks on the underside of the board extend right up to the edge. This is to allow for variations in build; either a socket can be soldered direct to the ground plane, a wire taken to a socket on the side of the board, or a socket soldered to the tin-plate box may be positioned so that its pin lies directly on the signal track.

PERFORMANCE

BASICALLY, "It does what it says on the box" to mis-quote the TV advert. It works well. It is sensitive enough that the post-mixer amplifier's performance governs the overall sensitivity of the rig rather than that of the IF strip.

Three words of warning, though. Screen it well.

ACKNOWLEDGEMENTS

THANKS, BILL, K6OLG, for doing a good job on the design, and thanks also to Harold Johnson, W4ZCB, for the support given.

Finally, many thanks to James Bryant, G4CLF, of Analog Devices, for sample AD600s.

NEXT MONTH

THE SYNTHESISER is the subject of the next part of this series. Its operation is critical to the performance of the transceiver, providing the local oscillator on transmit and receive.

REFERENCES

[10] 'A High Performance AGC/IF Subsystem', *QST* May 1996, p39ff

[11] *RSGB VHF/UHF Handbook* 1997, pp4.16ff

[12] AD600 data sheet, available from www.analog.com ♦

WWW.

Warrington ARC **www.warc.org.uk**

The Warrington ARC website carries its own version of the construction, on a month-by-month basis in parallel with *RadCom*, together with PCB layouts and up-to-date information.