THE CDG2000 HF TRANSCEIVER

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

(hence 'CDG2000')

Part one of a major new series describing a new HF transceiver design combining 'a high-performance receiver with a fairly standard transmitter'. Readers who have been following the items in Pat Hawker's 'Technical Topics' pages on the quest for low-noise oscillators will recognise the provenance of the series. Part one introduces the project, and outlines some of the aims and achievements of the design.

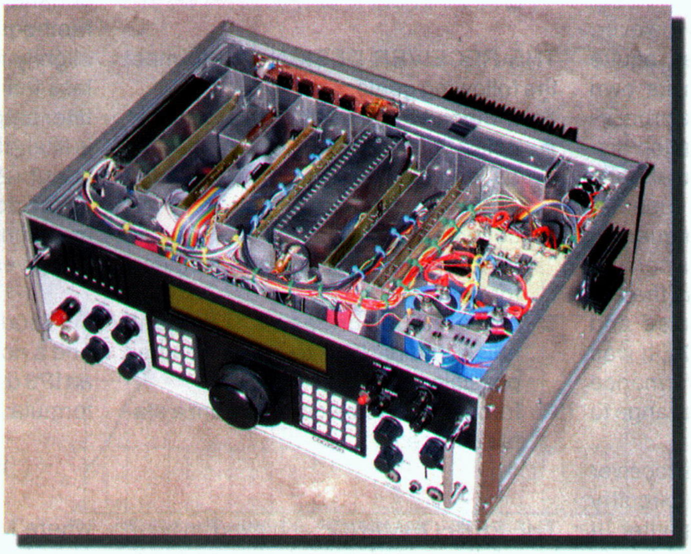
THE DESIGN of an HF transceiver today cannot easily be performed by one person. Although RF considerations must predominate, expertise in computer hardware and software as well as digital circuitry, is essential. Thus a team of three was formed, each with his own expertise, with a desire to design a transceiver with receive performance at least equal to the best currently on the commercial market, and one which could be reproduced by an experienced amateur constructor.

We do not claim that this is the last word in analogue circuitry. It *is*, however, designed to offer the best performance we could achieve with a design that is reproducible. On a practical note, its modularity lends itself to replacement of modules as time progresses. Unlike many commercial transceivers, it does not offer unlimited bells and whistles, many of which, on inspection, appear to be no more than sales gimmicks. We *have* included those features that we consider to enhance operation, the receiver exceeding most commercial designs with regard to performance. Receive IP3 (third order intercept) is about +40dBm. Noise figure is around 10dB. On SSB, 10dB(S+N) / N is about 0.22µV (-120dBm). Its oscillator phase-noise levels and close-in performance achieve -140dBc / Hz at 9kHz offset from carrier and -150dBc / Hz at just over 20 kHz on the 20-metre band.

We do not expect that many people will want to make exact copies. It is a project intended for the experienced amateur only. If your motive in home construction is to save money, this design is not for you, but if you want the best receive performance possible at a price lower than commercial rigs, then this may be of use. If you take only a couple of ideas for your own design, we suggest that you look at the synthesiser and the front-end.

In this series we will present some of the modules. These include the front-end board, post-mixer amplifier, IF amplifier, synthesiser and controller. Those modules that do not appear will be made available via the Warrington Amateur Radio Club website (see 'WWW.'). A CD-ROM will also be made available by the authors.

In this introductory part, we will discuss the system design and present an overview of the main elements. The aim is to achieve excellence in a modular fashion so that, as new techniques become available (and affordable), they can be readily incorporated into the transceiver, enhancing performance or improving operator convenience.



During the series, we shall be featuring photographs of the same transceiver as constructed by each of the authors. Each contains the same modules, but is built to individual preferences. This model was built by G3OGQ.

DESIGN PHILOSOPHY

THERE IS NO DOUBT that the fairly near future will see the introduction of all-digital amateur designs, but a study of current state-of-the-art designs rules them out on grounds of performance. Doubtless, in years to come, digital design will catch up with analogue design and economic grounds will ensure its adoption. It is clear that the designs most of us grew up with are now far removed from current design, as is evident from recent items in G3VA's 'Technical Topics' column.

It was therefore decided to produce a predominantly-

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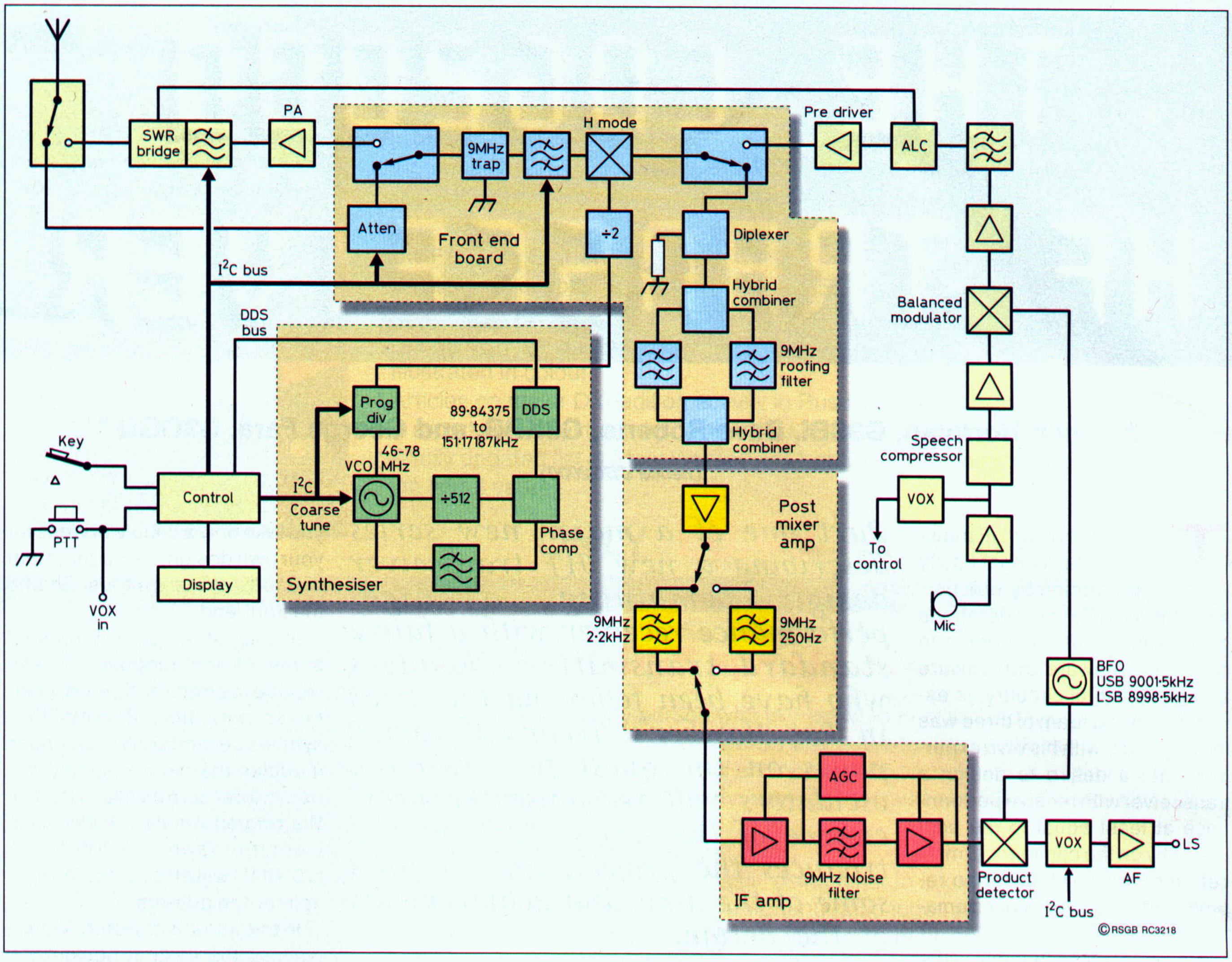

Fig 1: Block diagram of the transceiver.

analogue design, but with computer-controlled functions and digital audio circuitry.

Most high-performance receivers today feature multiple conversion with a high first intermediate frequency. This is very cost-effective, reducing the need for good band-pass filtering in the front-end, and improving image rejection. However, multiple intermediate frequencies require multiple oscillators, each with its own noise problem etc, leading to the production of 'birdies' and intermodulation distortion. We therefore decided to adopt a conventional single-conversion superhet with a fairly low intermediate frequency, but using a divided-down synthesiser running at VHF. This technique has the advantage of reducing phase noise and avoids the use of multiple VCOs. It was also decided that the best performance would be achieved by limiting the range to the amateur bands only.

Initial work concentrated on the receiver design, as a great deal of the circuitry would be common to the transmitter. It would be true to say that the receiver is the main part of the design, and that its performance has been the main focus - the transmitter chain is something of an afterthought but, nevertheless, benefits from the common use of the mixer, synthesiser and band-pass filters. The block diagram of the overall transceiver is shown in **Fig 1**.

RECEIVER DESIGN GOALS

THE RECEIVER DESIGN was to meet the following goals:

- IP3 point to be as high as possible;
- noise figure to be as low as possible *as long as it did not compromise IP3 performance*;
- coverage of amateur bands only, so as to maximise signal-handling performance;
- close-in performance (sideband noise, filters, IP3) to be as good as possible;
- frequencies to be derived from a stable source.

PERFORMANCE ACHIEVED

THE PERFORMANCE achieved, in brief, is as follows, and we welcome comparison with equipment reviews that have appeared in *RadCom*.

Measurements indicate an IP3 in the region of +40dBm. This performance is maintained for close-in signals. It is limited in part, not by the mixer, but by the coils in the band-pass filters, being up to 13dB better for hand-wound coils than for commercial inductors. Details of both methods will be given. IP3 degrades slightly for CW signals with an offset of less than 2kHz, due to the post-roofing-filter amplifier. With an IP3 of +40dBm, it is likely that the 1dB compression point is about +25dBm.

The noise figure is around 10dB, varying slightly from band to band. On SSB this gives a noise floor of:

$$(-174+10\times\log(2200)+10)\text{dBm},$$

or -130dBm [1]. With an IP3 of +40dBm and a noise floor of -130 dBm, this gives an IP3 dynamic range of 113dB using the formula:

$$\text{IP3 DR} = 2\times\frac{\text{IP3}-\text{MDS}}{3}\ \text{dB},$$

where MDS is the minimum discernible signal - the noise floor.

Sideband noise of the VCO varies by band, due to the use of programmable dividers. On 14MHz it measures -140dBc / Hz at an offset of 9kHz, and -150dBc / Hz at an offset of 22kHz. The detailed performance is shown in **Fig 2**.

In respect of local oscillator leakage from the antenna socket, the transceiver performance is comfortably within the relevant limits defined in CEPT / ERC / REC 74-01 and ETSI specification ETC 300-684. The requirement is -57dBm; the worst-case measurement (which occurs at 29MHz) is -90dBm, with the best case being -108dBm at 18.1MHz.

How good a performance is needed? Tests by members of the RSGB Technical and Publications Advisory Committee (TAPAC) suggested that, in normal usage, an amateur is unlikely to require a receiver with a spurious-free dynamic range (SFDR) exceeding 95dB. The design presented here is 18dB better than this. It may be that this is more than is normally needed, but gives some margin for future proofing or for more onerous situations, where adjacent signals are encountered at higher levels than normal. In this regard, local oscillator noise leading to reciprocal mixing is more troublesome than pure IMD performance, and the design presented also achieves very good phase-noise performance. Subjective comparisons demonstrated at the Warrington Amateur Radio Club reveal that it performs better than most current commercial designs, even under normal band conditions.

Finally, a plot of the signal-to-noise ratio against input signal level is shown in **Fig 3**. This was measured at 14.220MHz.

BLOCK DIAGRAM

The block diagram of the complete transceiver, shown in Fig 1, is deceptively simple. Each block represents a module, built on the same size board, with the exception of the front-end. A more detailed explanation of each function will be given with the description of each module.

Tracing the receive path first, the signal from the antenna is fed to an antenna changeover relay and applied to the front-end board. This is instead of feeding the signal through the low pass filter board which is used in transmit only, to avoid any attenuation due to ripple in the passband of the low-pass filters. The signal is then applied to an attenuator, which can be switched to give 0, 6, 12 or 18dB attenuation by means of two relays. Where the extreme sensitivity of the receiver is not required, attenuation provides even better IP3 performance. A 9MHz trap follows, which helps to attenuate signals at the intermediate frequency.

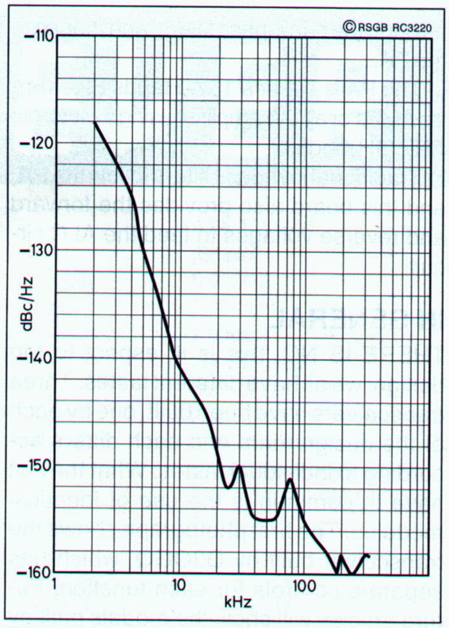

Fig 2: Sideband noise measured at 14MHz as a function of the frequency offset.

The nine band-pass filters which follow are identical in design, except for those covering the 10, 18 and 24MHz bands. All are relay-switched with DC-wetted contacts. Diode switching in the RF path is not an option in this transceiver, because relay switching provides superior IMD performance.

Following is the H-mode mixer [2] developed by G3SBI which is fed by the local oscillator signal frequency divided by two. After the mixer, the signal is split into the receive / transmit paths. The received signal is fed to a diplexer and then to the roofing filter - two filters fed 90° out of phase with a hybrid combiner at each end.

Following the front-end board, the signal, now at 9MHz, is fed to the post-mixer amplifier board which has a four-FET amplifier with a gain of about 14dB. The main filters are on this board, one for SSB and one for CW.

Notice that there is no amplifier before the roofing filter and no AGC signal external to the IF unit.

The filtered signal then goes to the IF amplifier board, which is the excellent design [3] of Bill Carver, W7AAZ (formerly K6OLG), modified to fit on a Eurocard of 160 x 100mm, these dimensions being common to all modules except the front-end. A noise filter is fitted between the second and third amplifier stages. AGC is derived on this board and applied to the IF amplifiers. The S-meter is also driven from here, but the level is altered by the control board to reflect changes in sensitivity following switched-in attenuators, changes of gain with band etc, all of which can show a difference in signal strength when, of course, none exists.

The product detector, a double-balanced diode mixer is part of the next board, which also incorporates the transmit exciter.

The resultant audio signal is then fed to the DSP board (where noise reduction takes place) and on to the audio amplifier. The DSP is a re-boxed commercial unit for which no information will be given. An alternative that combines receive and transmit DSP with DDS generation of the transmit signal is under construction.

The local oscillator signal is derived from a very low-phase-noise synthesiser which runs at 46 to 78MHz. The VCO is a novel two-tank oscillator design [4] by Colin Horrabin, developed further by John Thorpe for his excellent AOR7030 design. To understand the operation of the synthesiser consider, as an example, how a local oscillator signal for the 1.8MHz band is generated. For 1.8MHz, we require a local oscillator frequency of 10.8MHz (1.8 + 9MHz). This frequency is applied to the mixer after the divide-by-two IC on the front-end board. We therefore need a synthesiser output of 21.6MHz. Our VCO covers 46 to 78MHz so, in order to generate a 21.6MHz signal, we need to produce a

Fig 3: Signal-to-noise ratio as a function of signal level at 14.220MHz.

VCO signal at 64.8MHz and then divide the frequency by three. The VCO frequency is also divided by 512 in a phase-locked loop, and when the resultant frequency of 126.5625kHz is compared with a similar frequency from the DDS, the loop will lock. The synthesiser is controlled by a DDS reference derived from the control board, which is based on a high-end PIC microcontroller, the PIC17C766. It controls all functions of the transceiver by means of switched power, an I^2C bus and a separate DDS bus. It provides an on-screen S-meter and power meter, remote control and enough processing power to update the display without compromising tuning.

The transmit path shares many of the circuits of the receive path.

The 9MHz BFO signal is keyed in the transmit exciter board for CW operation, an automatic keyer function being included in the control unit. For SSB, the microphone signal is fed through an optional speech processor to the transmit exciter board which also includes the VOX circuitry.

The DSB signal from the balanced modulator is fed to the pre-driver board, which also includes the SSB filter and ALC-controlled amplifier. Following this board, the signal, either CW or SSB, is fed to the H-mode mixer on the front-end board, through the band-pass filters, and thence to the PA.

The PA is either a 15W Hands Electronics AMP1 or a 20W amplifier using a Motorola AN779H module.

Traditional low-pass filters follow the PA, and this board also provides the forward and reverse voltages to feed the ALC circuit.

IN GENERAL

THERE IS NO 'this is it' aspect to the design; we all have different tastes. Three transceivers have been built, one by each of the design team and each differs according to individual tastes. What they all have in common is the use of identical modules. The first photograph shows the transceiver built by G3OGQ, which has separate controls for each function. Future articles will show the models built by the other authors, illustrating their individual preferences.

Further development proceeds; for instance, SSB will be generated directly at 9MHz using a DDS modulator with audio processing being performed in a companion DSP unit that also performs receive DSP functions.

There will also be the facility to control the transceiver from a computer.

Each month, a separate module will be described. At present, there is no intention to supply PCBs, although we will think again if demand warrants it. Layouts etc will, however, be available from the Warrington Amateur Radio Club website.

NEXT MONTH

THE DESIGN DESCRIPTION begins in earnest next month, when the front-end board will be covered in detail.

REFERENCES

[1] For details of this formula, see *Radio Communication Handbook*, (RSGB) sixth edition, p6.10.

[2] 'Technical Topics', *RadCom* January 1996, pp65, 68.

[3] 'A High Performance AGC / IF Subsystem', by Bill Carver, K6OLG, *QST* May 1996, pp39-44.

[4] This topic is discussed most recently in 'Technical Topics', *RadCom* April 2002, pp64, 69.

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www.

Warrington ARC	**www.warc.org.uk**
Hands Electronics	**www.rf-kits.demon.co.uk**
AN779H module available from suppliers such as Mainline, or see the Motorola website	**www.motorola.com**

THE CDG2000 HF TRANSCEIVER

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

LAST MONTH, the CDG2000 project was introduced, outlining the design goals and the achieved performance. The series continues with a detailed description of the first board.

THE FRONT-END BOARD

THE FRONT-END comprises the following main blocks:

- relay switching for transmit / receive and attenuators;
- a 9MHz notch filter;
- a set of band-pass filters;
- an H-mode mixer;
- an SSB-bandwidth roofing filter;
- a computer control interface.

A block diagram is shown in **Fig 4**.

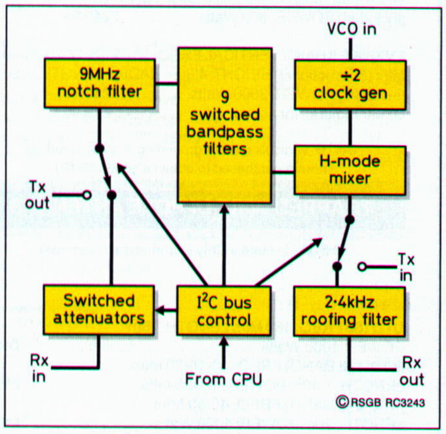

Fig 4: The front-end block diagram.

The board is controlled by means of a two-wire I^{2}C bus. The controller may change the transmit/receive switching, attenuator and band pass filters. This interface is optional; it may be replaced by a parallel interface by omitting the I^{2}C bus interface chips and connecting a logic-level signal to the relay drivers or also by omitting the relay drivers and driving the relays directly.

The attenuator provides two switchable attenuators of 6 and 12dB, allowing 0 to 18dB of attenuation in 6dB steps. The nine band-pass filters are one per band. In each case, the band filters cover a complete band, there being no separate 500kHz filters for 10m, where a single filter covers the band. A notch filter reduces IF breakthrough.

The local oscillator frequency from the synthesiser is divided by two in order to provide two signals 180° out of phase for the H-mode mixer.

The mixer is bi-directional, accepting either a 9MHz transmit input and generating a transmit signal, or generating a 9MHz IF from an incoming RF signal.

The receive signal is passed through a 9MHz roofing filter before being output to the IF.

DETAILED CIRCUIT

THE FULL CIRCUIT diagrams are shown later. Each of the main blocks, as defined in Fig 4, is detailed below.

ATTENUATOR

The attenuators are simple resistive pads. Each presents 50Ω input and output. The relays are under the command of the controller via the I^{2}C bus. The main point to note, as is the case with all relays on the front-end, is that the contacts carry a DC 'wetting' current. This is to ensure that they do not develop poor (noisy) contacts in use.

NOTCH FILTER

The performance of the notch filter is shown in **Fig 5**. This is by measurement, not calculation. Its purpose is to prevent large signals at the IF frequency of 9MHz getting through to the IF.

The green line shows the reference signal, and the red line the loss through the notch filter. As can be seen, it presents a loss of over 40dB at the desired frequency, and its loss is negligible on any of the amateur bands with the exception of 10MHz, where it incurs a loss of 1.5dB. This is the band where it is most needed, as the desired signals are but 1MHz away from the IF.

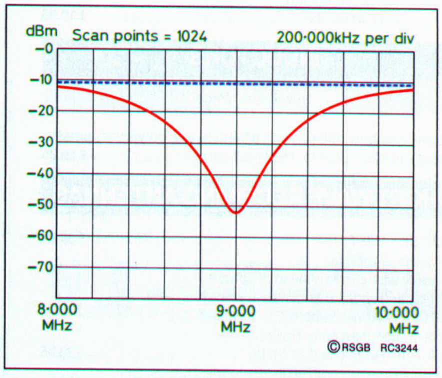

Fig 5: The notch filter response.

The overall performance in terms of IF rejection is a combination of the notch, band-pass and RF port isolation loss of the mixer.

BAND-PASS FILTERS

There is one band-pass filter per amateur band. The filters are 3-section Butterworth designs, with a loaded Q of about eight, varying a little by band. The 50Ω design impedances determine the coefficient capacitors (those to ground), and the series

Band (m)	dB loss at band centre	dB loss at band edges relative to band centre		IP3 (dBm)	
		Low	High	Output	Input
160	2.0	-0.50	-0.75	33.0	35.0
80	1.5	<-0.25	<-0.25	37.3	38.8
40	2.0	0.00	<0.25	31.5	33.5
30	3.0	0.00	0.00	26.7	29.7
20	2.0	0.00	0.00	42.0	45.0
17	3.0	0.00	0.00	32.0	35.0
15	2.8	0.00	0.00	40.0	42.8
12	2.5	0.00	0.00	40.0	42.5
10	2.0	-0.10	-1.00	34.5	36.5

Table 1: Band performance.

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Band (m)	dB loss at band centre	dB loss at band edges relative to band centre		IP3 (dBm)	
		Low	High	Output	Input
15	4.0	0.00	0.00	25.0	29.0

Table 2: Performance with Toko coils on 15m - cf Table 1.

LC circuits define the bandwidth and resonant frequency. The values chosen were based on Toko ready-wound components. The basic design is the same as for the crystal filters shown in the *RSGB Radio Communication Handbook* [5], and the performance of each is tailored to the band in question with losses that vary slightly by band as shown in **Table 1**. You will notice some significant variation in the readings for IP3. This is because two different types of coil were used in its construction. The 21 and 24MHz filters used Lodestone Pacific L45-6 formers, the rest used pre-constructed Toko coils. It was found that the performance of the receiver was different using Lodestone and Toko coils in the band-pass filters. The variation in performance was up to 15dB, as can be seen from **Table 2**. It is presumed that this is due to saturation in the cores, but opinion varies. The Lodestone formers have the same pin connections as the Toko coils and fit the same PCB, but the cases are marginally larger with substantial ferrite content. See WWW. for more details.

Why, then, do we show the Toko data? Not everyone will want to wind coils and not all coils were appreciably different. The board takes both types of coil and the constructor can decide which to use. The components list shows both Toko and hand-wound Lodestone inductors.

Performance plots of all the filters are available from the Warrington Amateur Radio Club (WARC) website. Examples of the 7MHz filter are shown in **Fig 6** and **Fig 7**. Note the effect of the 9MHz trap. The wideband performance plot is limited by the analyser used in the measurement, not by the filter.

The insertion loss, when all relays were off, was measured. It was found that the loss was acceptably small to 20MHz but, from there, rose significantly to be only 30dB at 200MHz. To improve this, the relays were decoupled and inductors fitted in series with each relay control line. This reduced the signals at 200MHz by over 40dB. Specifically, the relay coils on the aerial side were decoupled with 10nF capacitors, the mixer-side relays by 1nF and the series inductors between the relay coils were 0.82µH, self-resonant at 200MHz. Additional connections from the earth tracks between the relays to the ground plane were made in three places on each side. The 12V line was also decoupled and filtered in the same way.

MIXER

The mixer has already been exhaustively described before in both 'Technical Topics' [6] and in the *RSGB Radiocommunication Handbook* [7]. It is capable of excellent performance both with regard to IP3 and insertion loss. The VCO is applied to IC1, a high-speed JK flip-flop which produces two signals 180° out of phase at the desired local oscillator frequency. These are then fed to the mixer. The mixer is formed by three identical transformers and a high-speed bus switch. Note that the supply to the mixer is not 5V but 7V, derived from a 317-type regulator, while the flip-flop is driven at 5V. Both supplies are well filtered. The input signal from the local oscillator is a CMOS-level signal and may be applied directly to the JK flip-flop, but the board is designed to allow other oscillators to be employed, and a signal between 0 and 10dBm may be used.

The JK flip-flop may be either the 74AC112 or 74AC109 according to availability, but a slight adjustment of the PCB tracking will be needed for the 74AC112.

The insertion loss of the mixer has been measured at between 4dB at 30MHz and 5.5dB at 2MHz. Its input IP3 is 37dB at 14MHz and 40dB at 3.5MHz. This is below the levels first reported for this configuration [6], and is believed to be due to changes in the manufacture of the transformers. It has, however, been measured consistently.

Isolation across the mixer has been measured at between 45dB and 65dB from the RF port to the IF port.

ROOFING FILTER

The roofing filter's job is to protect the post-mixer amplifier from large signals. It must also possess a large IP3 itself and present an acceptable load to the mixer. The filter actually comprises the following parts:

- a diplexer to present 50Ω at frequencies removed from the 9MHz IF;
- a hybrid coupler to drive two band-pass filters;
- the two band-pass filters;
- a hybrid combiner at the output of the filters.

Why the complexity? The use of this type of structure has been described many times before, for example in *RadCom* [8]. The main reason is that a filter on its own will be nowhere near its design impedance outside its passband. Combining two identical filters, however, allows the errors to be cancelled, leaving a much more stable impedance.

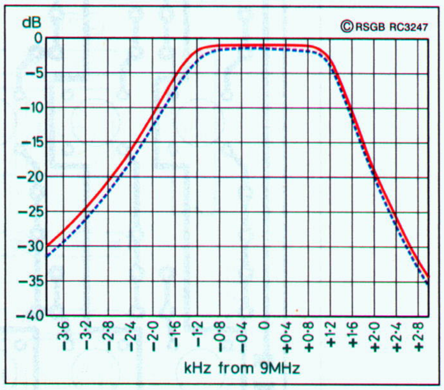


Fig 8: The individual roofing filters.

In our design, each of the two band-pass filters is constructed from four ladder networks of identical 9MHz crystals. The performance of these can be seen in **Fig 8**. The two curves show the measured performance of the two filters. The overall performance of the two filters and the diplexer / hybrid is shown in **Fig 9**. The insertion loss is about 2dB for the filters, diplexer and hybrids combined.

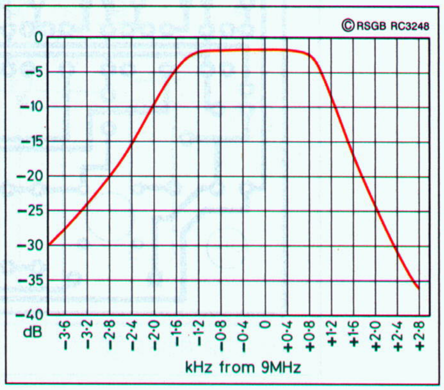


Fig 9: Overall roofing filter shape (loss of diplexer, hybrids and roofing filters).

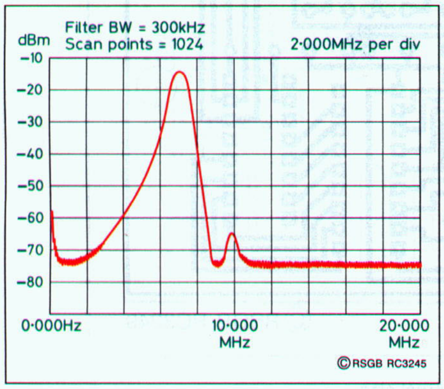


Fig 6: The 7MHz filter.

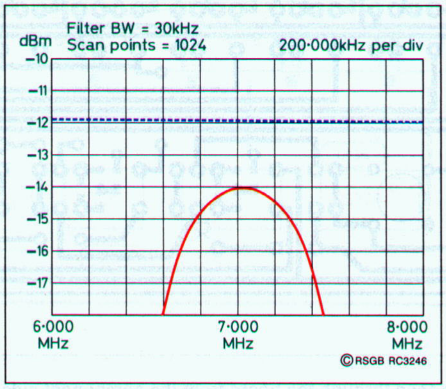


Fig 7: The 7MHz filter (see text).

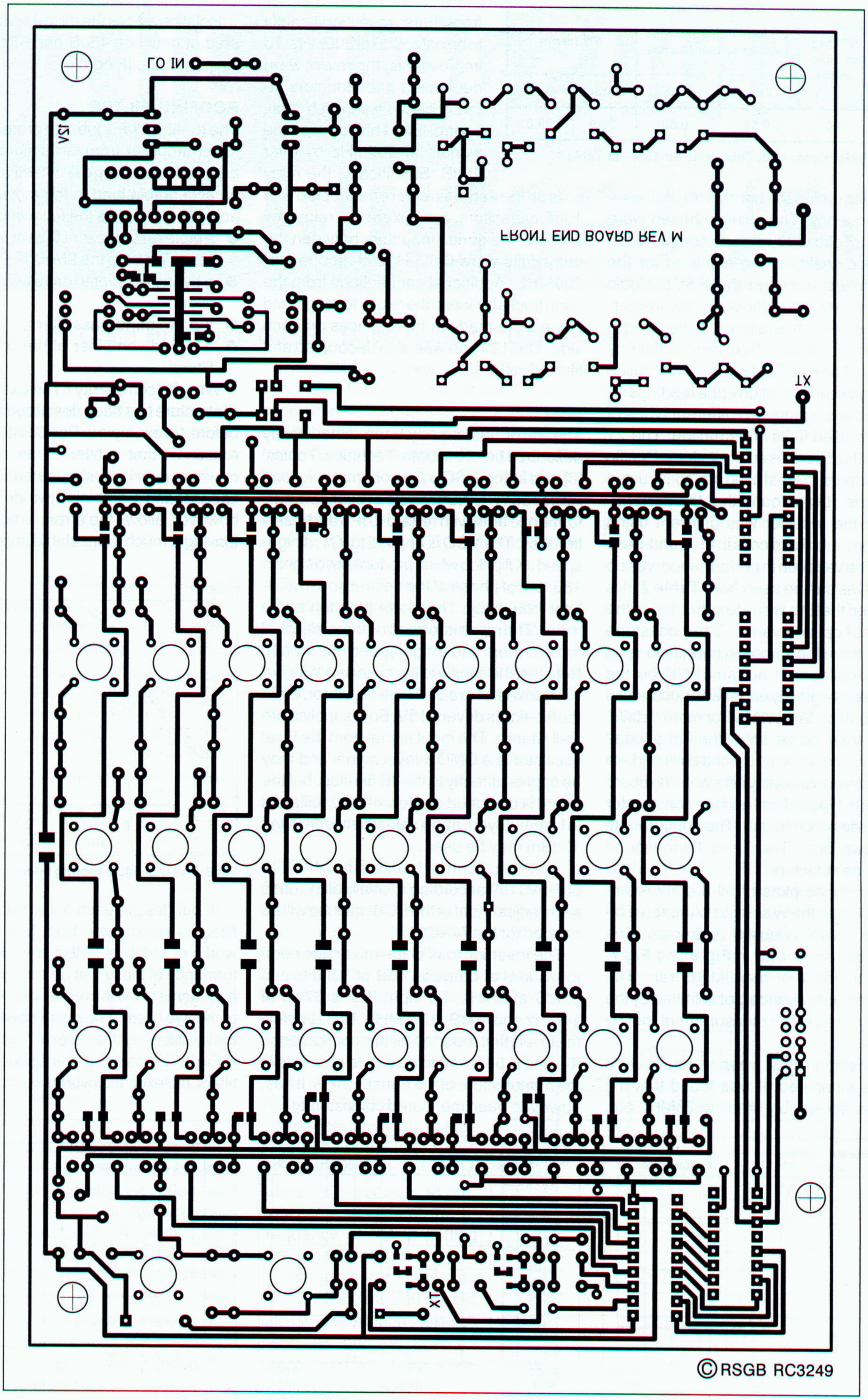


Fig 10: Front-end PC board tracking, as seen through the board from the component side. Actual size.

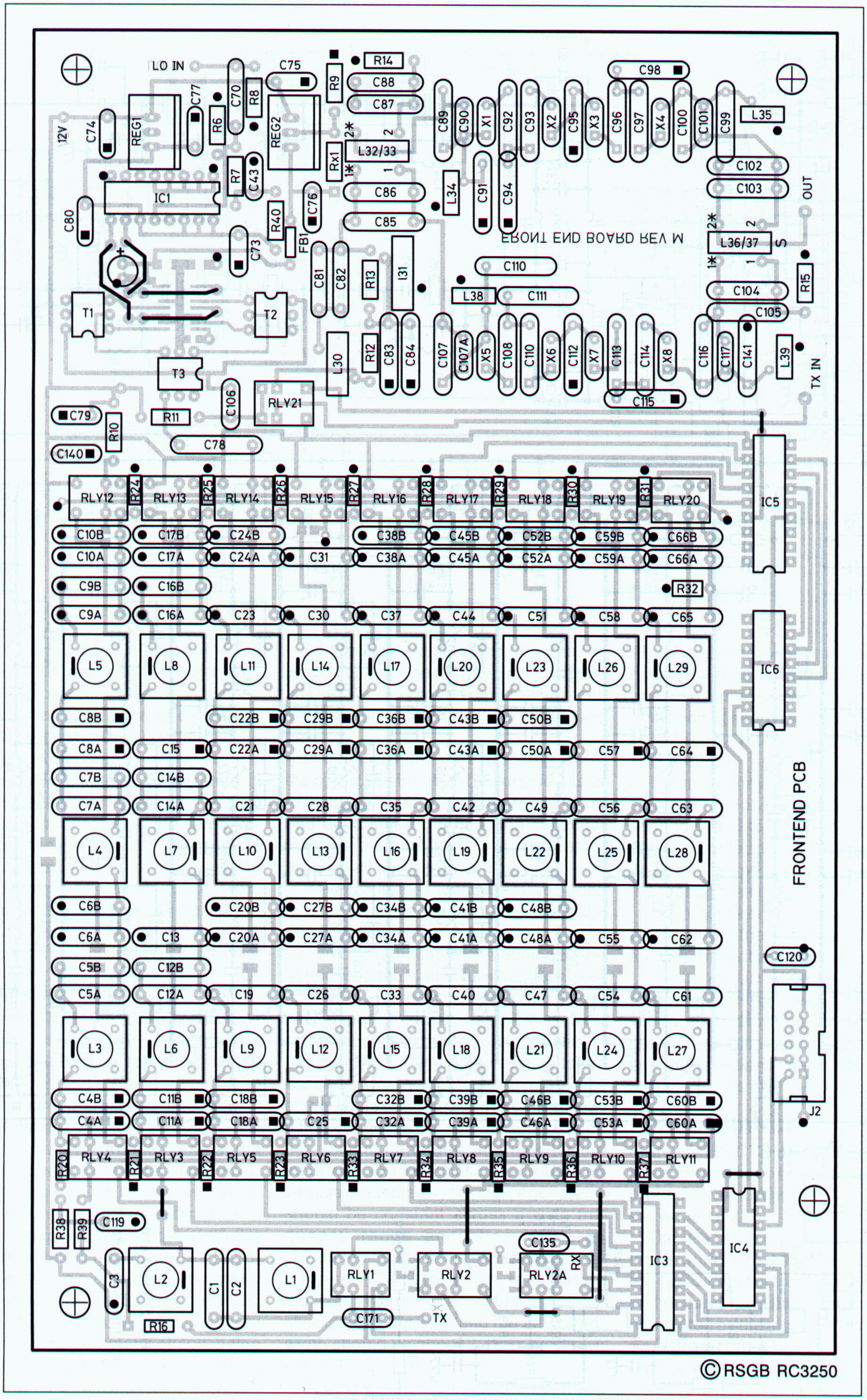


Fig 11: The component side of the PCB. Actual size.

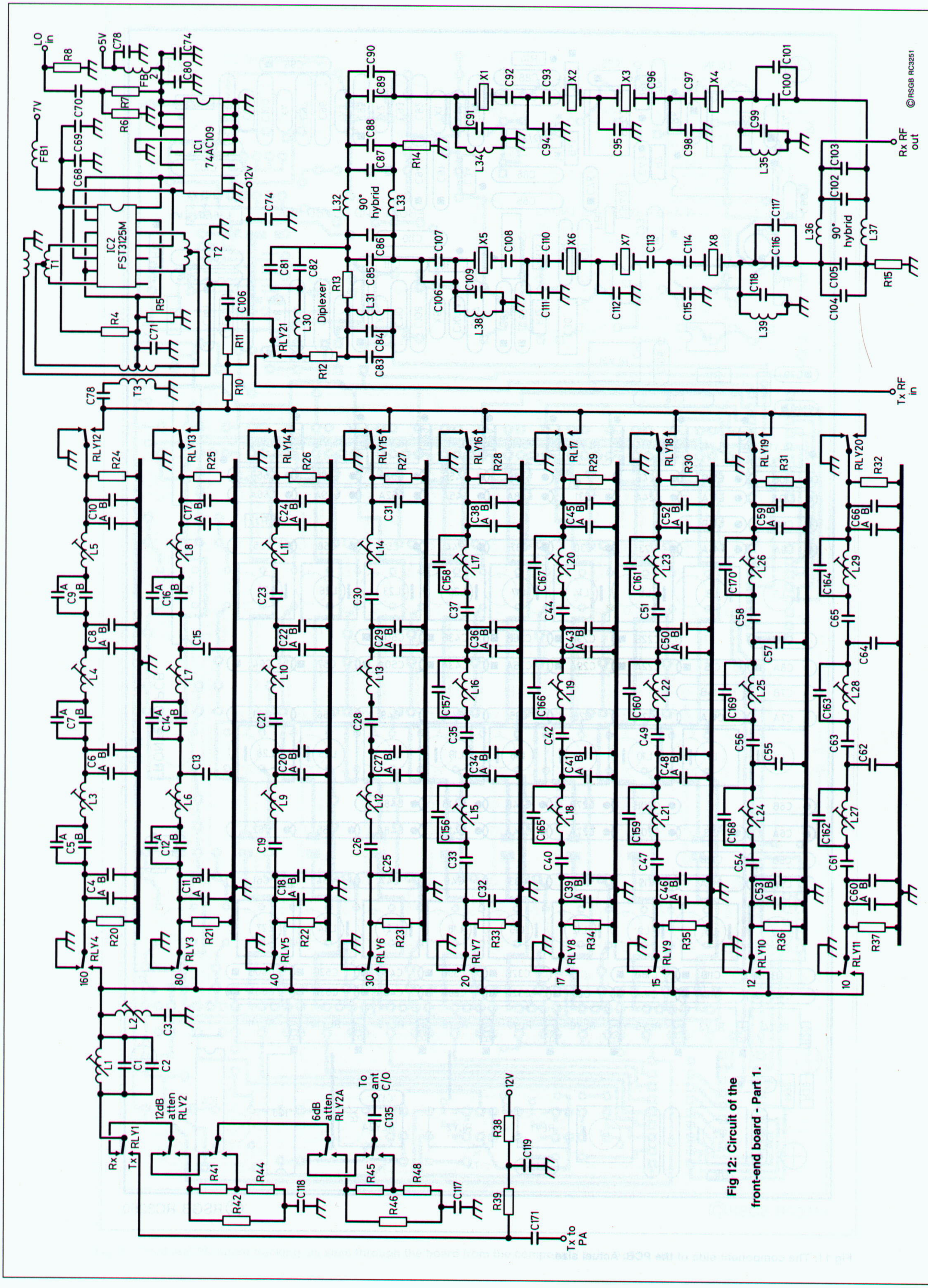


Fig 12: Circuit of the front-end board - Part 1.

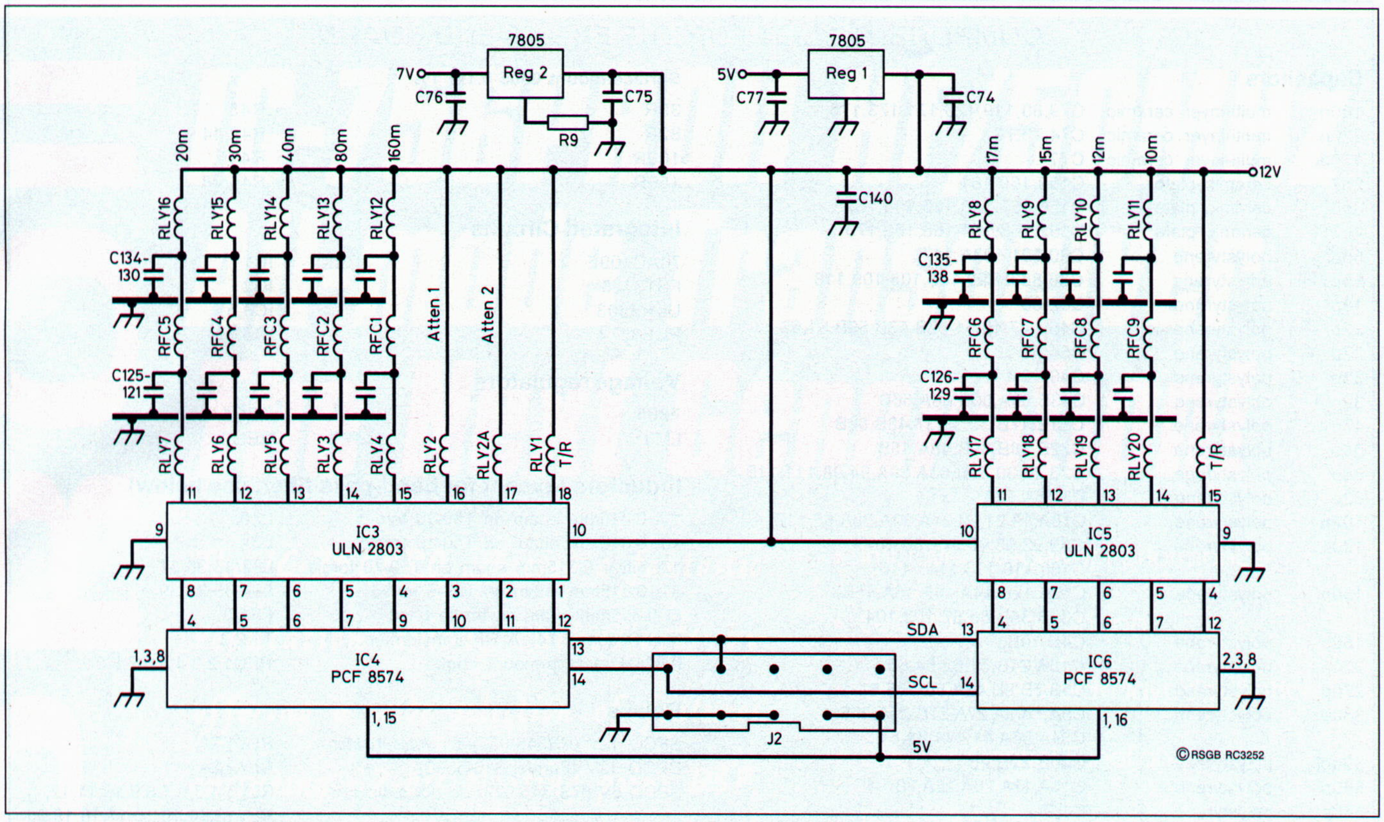


Fig 13: Circuit of the front-end board - Part 2.

The performance of each filter is not quite identical, resulting in a slight mismatch. No plot of return loss is available. As an alternative to discrete crystals, a PCB that takes standard commercial filters is also available.

When using discrete components in the roofing filter, care is needed. The filter is narrow and must be on the same frequency as the main crystal filters on the post-mixer amplifier board. If you wish to use commercial filters, we suggest you consider the International Radio Corporation (see WWW.). Further information can also be found on the WARC website.

CONSTRUCTION

THE FRONT-END BOARD is not a single Eurocard, unlike the other CDG2000 modules. This is because all the filters would not fit on one, and it made no sense to divide the circuit arbitrarily into blocks. The board measures 228 x 140mm. It is single-sided with a ground plane and a small number of wire links. The mixer active device, a CMOS bus switch, is surface-mounted on the rear of the board. Many decoupling capacitors and the inductors isolating the two sets of band-switch relays are also surface-mounted. **Fig 10** shows the tracking of the PCB, and **Fig 11** illustrates the top component placement, the complete circuit being shown in **Fig 12** and **Fig 13**. All artwork is available on-line from the WARC website, as are details of the under-board components not shown in Fig 11.

All grounds are soldered direct to the ground plane. Use turned-pin sockets for all DIP ICs, the ground pins of which can easily be soldered directly to the ground plane.

In construction, start with any part of the circuit you like, but it makes life easier to build the roofing filter before the mixer and don't insert the coupling capacitor from band-pass filter relays to mixer input until all parts are working.

Having built the roofing filters, you need to check that each is working correctly. The filters should be checked individually by removing the input connection to the hybrid for each filter in turn, replacing the filter input by a resistor. Each should be of similar performance – see Fig 8. Now connect both and the performance should be as in Fig 9. If you have access to the necessary test equipment, the return loss of the whole configuration should be low. If not, connect a 50 signal source such as a signal generator and monitor the input with a x10 oscilloscope probe. The voltage presented by the signal generator should be constant across a wide frequency range and show no large discontinuities near the 9MHz design frequency. The loss of the whole diplexer / hybrid / filter / hybrid assembly should be about 2dB, and the 3dB bandwidth should be about 2.4kHz as shown in Fig 9.

For the mixer, it is suggested that you check the voltages provided by the regulators before you fit the active devices. The 7V rail may need a 'tweak' to the resistors. Now fit the divide-by-two IC and use an oscilloscope to check its operation. It should work correctly to beyond 80MHz with a signal of between 0 and 10dBm.

The mixer may be tested by applying a signal to the local oscillator input and a second signal to the mixer input, with a 9MHz expected output that should be visible with a scope or spectrum analyser at the roofing filter output.

The notch filter should be tested before connection to the band-pass filters. Tune for maximum attenuation at 9MHz.

The band-pass filters should be tested one by one. The best way to align them is with a spectrum analyser and tracking generator. Failing this, tune all three for best signal at band centre, then tweak the outer two coils slightly for best shape.

PERFORMANCE

MANY ASPECTS of the performance of the front-end have been presented in the preceding text. What can be expected of the whole unit?

The IP3 of the band-pass filters varies from +30dBm to +45dBm, according to the types of inductor used. At the upper end of band-pass filter performance, it is dominated by the input IP3 of the mixer of +37dBm to +40dBm. Assuming a 2dB to 3dB band-pass filter loss, this gives an equivalent IP3 for the mixer at the input to the filter of +39dBm to +43dBm. If the band-pass IP3 is 43dBm, the overall IP3 is

COMPONENTS LIST FOR THE FRONT-END BOARD

Capacitors

100n	multi-layer ceramic	C79,80,119,120,171,173,176
220n	multi-layer ceramic	C74,75,76
470n	multi-layer ceramic	C77
2p7	ceramic plate	C159,160,161
3p3	ceramic plate	C156,157,158,165,166,167
4p7	ceramic plate	C162,163,164,168,169,170
5p6	polystyrene	C90,101,107A,117
15p	polystyrene	C86,88,91,99,103,105,109,118
18p	polystyrene	C82,83
22p	polystyrene	C46B,47,49,51,52B,53B,59B,61,63
27p	polystyrene	C54,56,58
33p	polystyrene	C40,42,44
39p	polystyrene	C43B,60A,60B,66A,66B
47p	polystyrene	C11B,17B,33,35,37,48B,50B
56p	polystyrene	C32B,38B,39B,45A,45B
68p	polystyrene	C26,28,30,39B,53A,59A,94,98,111,115
82p	polystyrene	C3,46A,52A
100p	polystyrene	C18A,19,21,23,24A,32A,38A,95,112
120p	polystyrene	C89,92,93,96,97,100,107, C108,110,113,114, 116
150p	polystyrene	C12A,12B,14A,14B,16A,16B, C34B,36B,85,87,102,104
180p	polystyrene	C4B,10B
220p	polystyrene	C18B,24B,31,62,64,65
270p	polystyrene	C5B,7B,9B,48A,50A,55,57
330p	polystyrene	C5A,7A,9A,27A,27B,29A,29B, C34A,36A,41,43A,81,84
390p	polystyrene	C20B,22B,25
560p	polystyrene	C11A,17A,20A,22A,70
680p	polystyrene	C1,2
1000p	polystyrene	C4A,10A
1800p	polystyrene	C6A,6B,8A,8B,13,15
10000p	polystyrene	C78
22µF 16V	tantalum	C43,69,73

Surface-mount leadless multi-layer chip ceramic 50V

1n	multi-layer ceramic	C130,131,132,133,134,135,136,137,138
10n	multi-layer ceramic	C121,122,123,124,125, C126,127,128,129,139
100n		C68,71,117,118

Resistors

0.125W metal film 1% MF12 series

10k	R20,21,22,23,24,25,26,27, R28,29,30,31,32,33,34,35,36,37

0.25W metal film 1% MF25 series

51R	R12,13,14,15
56R	R8 - fit only if 50Ω source LO is used. Otherwise omit R8.
1k	R38
10k	R10,11,16,39
82k	R6,7
240R	R9

Surface-mount 1206 0.125W 1%

2k2	R4,5

Surface-mount 0805 0.1W 1%

39R	R45
82R	R42,44
100R	R41
150R	R46,48

Integrated Circuits

74AC109E	IC1
FST3125	IC2
ULN2803	IC3,5
PCF8574	IC4,6

Voltage regulators

7805	REG1
LM317	REG2

Inductors (except for band-pass filter, see below)

17t 0.315mm enam on T50-10 toroid	L30
16t 0.315mm enam on T50-10 toroid	L31
17t bifilar 0.315mm enam on T50-10 toroid	L32/33,36/37
31t 0.315mm enam on T37-6 toroid	L34,35,38,39
6t 0.315mm enam on ferrite bead	FB1,2
Mini-Circuits TT4-1A RF transformer	T1,2,3
0.82µH surface-mount choke	RFC1,2,3,4,5,6,7,8,9

Relays

SPCO 12V (RS345-038) *do not substitute*	RLY1,21
DPCO 12V (Farnell 310-3500)	RLY2,2A
SPCO 6V (RS 345-022) *do not substitute*	RLY3,4,5,6,7,8,9,10,11,12, RLY13,14,15,16,17,18,19,20

Crystals

9MHz parallel resonant in 30pF by C-MAC ref A164A	X1,2,3,4,5,6,7,8

{ (Sterling Components, Slough. Tel: 01753 779 000. Sterling's minimum order is 100 pieces - small quantities *may* be available from the authors.) }

Connector

10-pin box header	J2

Inductors for band-pass filters

	TOKO	Lodestone Pacific*	Ind (µH)
L1	E526HNA1000076	5t 0.4mm on L45-10-PCT-B-4	0.22
L2	KXNSK4173AO	20t 0.2mm on L45-6-PCT-B-4	3.52
L3,4,5	KANSK4960EG	39t Litz on L45-2-PCT-B-4	15
L6,7,8	BKANS9440HM	20t 0.2mm on L45-2-PCT-B-4	8.2
L9,10,11	BTKANS9443HM	25t 0.2mm on L45-6-PCT-B-4	5.6
L12	BTKANS9443HM	22t 0.2mm on L45-6-PCT-B-4	4.8
L13,14	154ANST10052	21t 0.2mm on L45-6-PCT-B-4	4.3
L15,16,17	KXNSK4173AO	18t 0.25mm on L45-6-PCT-B-4	2.8
L18,19,20	KANS12354BM2	16t 0.25mm on L45-6-PCY-B-4	2.4
L21,22,23	KANS12354BM2	15t 0.25mm on L45-10-PCT-B-4	2.1
L24,25,26	BTKANS9449HM	14t 0.25mm on L45-10-PCT-B-4	1.5
L27,28,29	KXNSK4172EK	12t 0.315mm on L45-10-PCT-B-4	1.3

{ * These coil formers offer a considerable improvement in performance over Toko. There is little difference in cost. See also WWW. }

+37dBm to +40dBm (roughly). For lower values of band-pass filter IP3, the performance of the filters will dominate. For higher performance, the mixer dominates.

Note that mixer IMD was measured in conjunction with the roofing filters, and was not noticeably degraded for close-in signals of a few kilohertz spacing.

The roofing filter works well for SSB signals in protecting the subsequent circuits, but close-in (ie for CW), IP3 will be degraded slightly if the post-mixer amplifier has inadequate performance. However, at these spacings, the chance of the received transmission being clean enough for the receiver's performance to dominate is very small indeed.

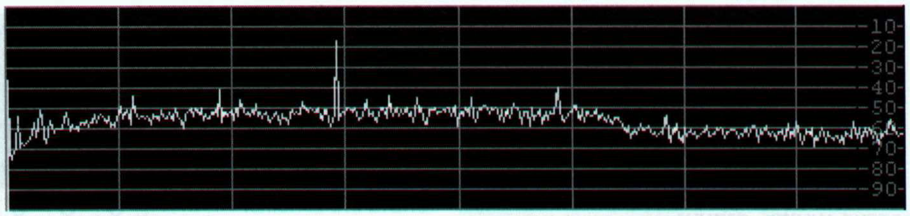
Overall noise performance was determined by measuring the 10dB SNR of the receiver using the test setup to be described in the article describing the synthesiser. On SSB it was found to be -120dBm ±1dB across all bands as shown in **Table 3**. The method used was to connect a PC sound card's microphone input to the output of the receive product detector and use DL4YHF's *Spectrum Lab* program (see WWW.) to determine SNR. The program displays the spectral analysis of the audio signal, as shown in the photograph. It is then instructed to calculate the largest signal in the range 1000 to 2000Hz and subtract from it the calculated per-Hertz noise power and a correction of 34dB to account for the bandwidth of the SSB filter, by executing the code:

`print(peak_a(1000,2000)-34-noise_n(1000,2000)),`

and to repeat this calculation every second.

Band (m)	Level (dBm) for 10dB signal-to-noise ratio
160	-121
80	-121
40	-121
30	-120
20	-120
17	-120
15	-119
12	-120
10	-119

Table 3: 10dB SNR measurements.



***Spectrum Lab* display.**

WWW.

Warrington ARC	**www.warc.org.uk**
International Radio Corporation	**www.qth.com/inrad**
DL4YHF *Spectrum Lab* program	**www.qsl.net/dl4yhf/spectra1.html**
Coil formers	**www.lodestonepacific.com**

This causes it to display directly signal-to-noise ratio once a second. Note that this is S / N *not* (S+N) / N.

Interestingly, a small improvement is possible by removing the 50 resistor in the roofing filter output hybrid. Could this be due to resistor-generated noise reflected back from the band-pass filters?

NEXT MONTH

LEAVING YOU TO COGITATE on this rhetorical question (the nearest we can get to a cliff-hanger), next month's instalment descibes the post-mixer amplifier. This unit is designed to overcome the losses in the front-end and to provide the main SSB and CW filtering.

REFERENCES

[5] *RSGB Radio Communication Handbook*, 6th Edition, Fig 6.46, p6.26.
[6] 'Technical Topics' *RadCom* Sep 1998 p58.
[7] *RSGB Radio Communication Handbook*, 6th Edition, pp6.48 to 6.53.
[8] 'RX84 Advanced Receiver', by T E Bay, OZ5KG, *RadCom* May - Sep 1994.

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