A HOME-BUILT FREQUENCY SYNTHESIZER FOR 45 TO 75MHz

John Crawley, GM3LBX*

(PART 2)

Section F. Loop 1 mixer and bandpass filter (Fig 12)

The buffered input to pin 3 of IC601 is from the selected vco in loop 1 (section A Fig 6) and will be between 45-75MHz. The amplitude at pin 3 should be approximately 50mV peak-to-peak. The input to pin 7 is from the 42MHz filter via the buffer TR602 and TR603. The amplitude need only be about equal to that on pin 3.

The bandpass filter L601-604 is designed to pass 2 5MHz up to 33MHz, and to reject frequencies above and below this band—particularly the 45-75MHz band, and the 42MHz component from loop 2.

The inductances L602 and 603 are Toko 10K formers wound with eight turns 32swg copper wire and mounted in screening cans. They have adjustable cores and a pot-core. L601 and 604 are Toko 3335R.

The filter should be adjusted by injecting a variable frequency into the empty socket of pin 5 of IC601 and monitoring the output. Adjust cores for a sharp cut-off above 35MHz.

Section G. Second loop vco etc (Fig 13)

The circuit for IC702 is similar to that in section E, except that it needs no crystal and that the reference frequency is divided down to 400Hz by using the highest available divisor, 8,192; this is programmed by leaving pins 5, 6 and 7 high.

The section is sited on the right centre of the pcb. L701 is a Toko Style MC120 No 100075. It has a screened inductance of 0·17μH. This vco (T603) should be tested after assembly to see that it runs in the region of 95MHz.

When checking the MC145151 here, and in the other place where it is used, there are two useful guides to what is going on inside it. Pin 10 is connected internally to the output of the main divider so that when all is well, this should be showing the reference frequency (400Hz in this case) if a counter is placed on the pin. Pin 28 is a lock detector output. It is high when the loop is locked and pulses low when out of lock. Some constructors may wish to use this pin to drive a l.e.d indicator to show when the loop is locked.

Section H. Loop two mixer and 6·4 filter (Fig 14)

TR801 buffers the input to pin 3 of the SL1640. The frequency at "n" and pin 3 should be between 95·3876 and 95·6432MHz when the loop is locked. TR802 is a tuned buffer to double the 44·545MHz from section C. The tuned circuit is L803 (12 turns of 28swg wire on a 1MΩ resistor 0·25W and a 2·8-12pF ceramic trimmer). The bandpass filter has two inductances of 15 turns, 32swg insulated copper wire on Toko 10K formers. Ready-wound devices such as 10K SW1 KANK3333 would do the job. The filter should be tuned to 6·4MHz sited in the middle of the right-hand edge of the pcb. Layout as in Fig 7.

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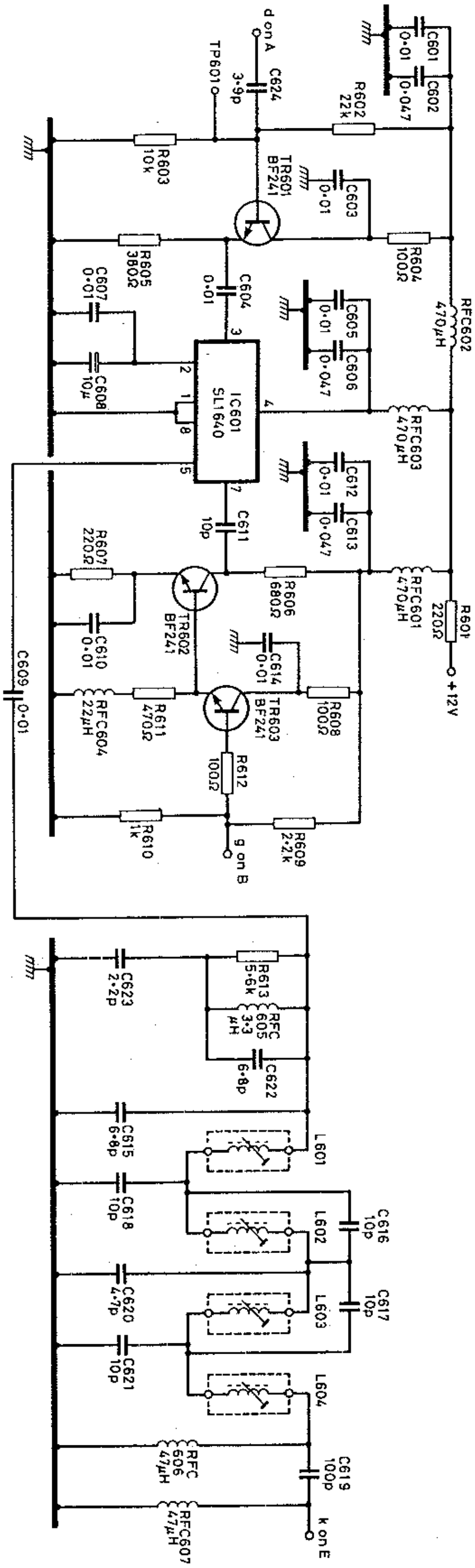
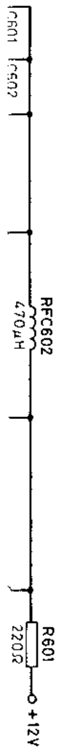


Fig 12, Section F. Mixer and broadband filter



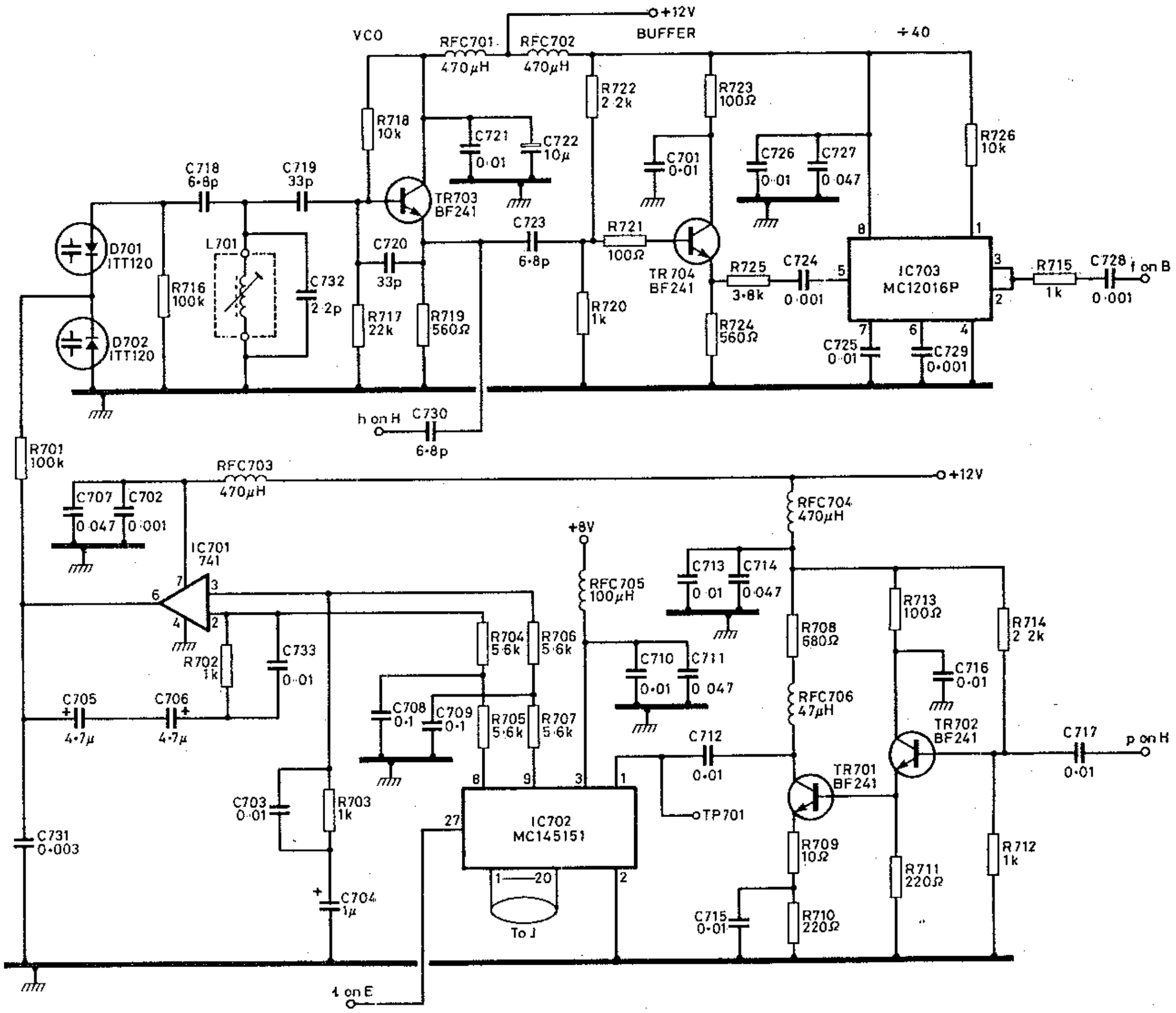


Fig 13. Section G. Second loop phase discriminator and lpf

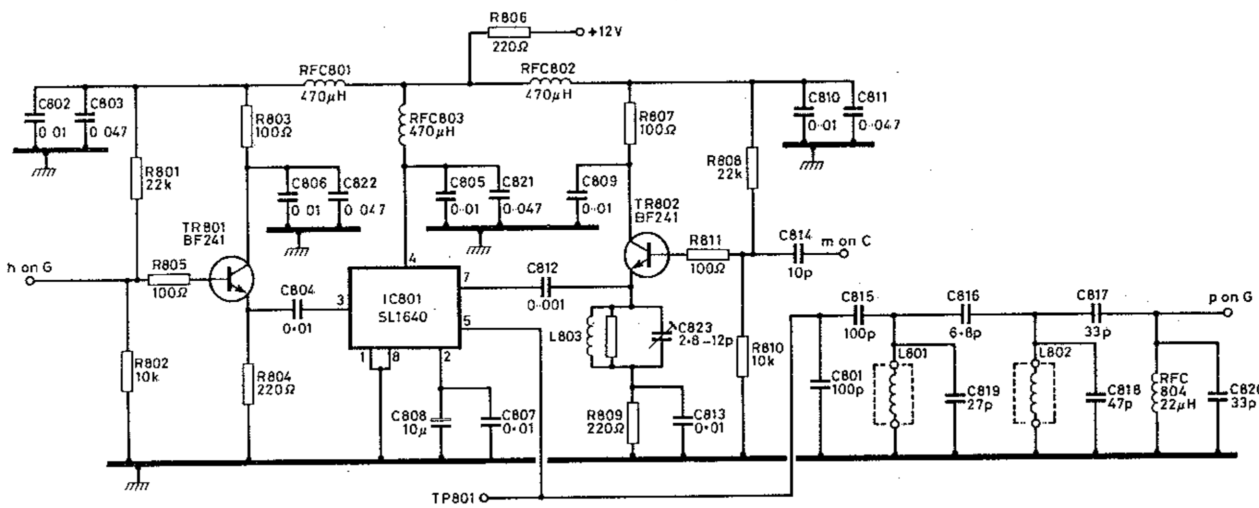


Fig 14. Section H. The mixer and 6·4MHz filter in Loop 2

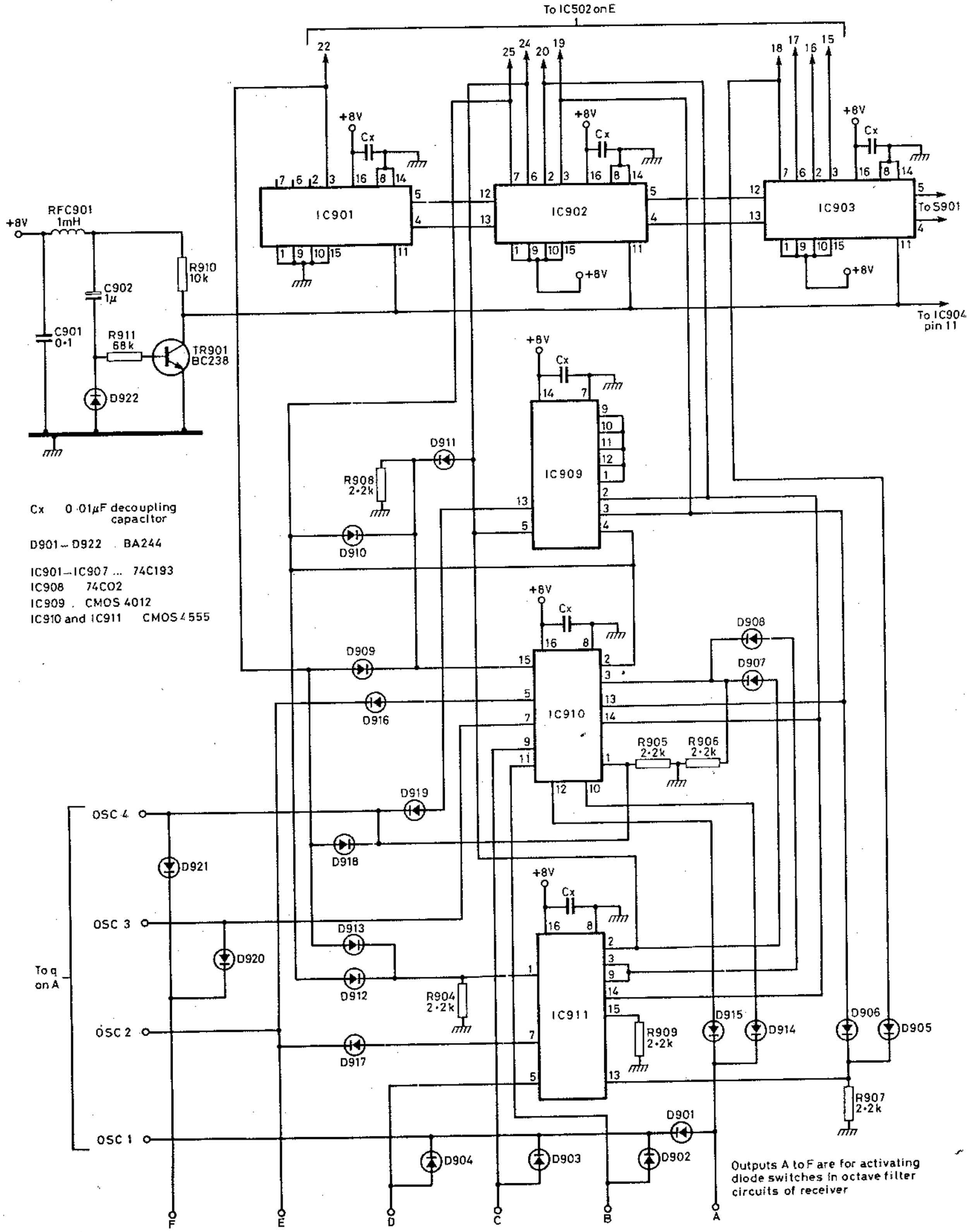
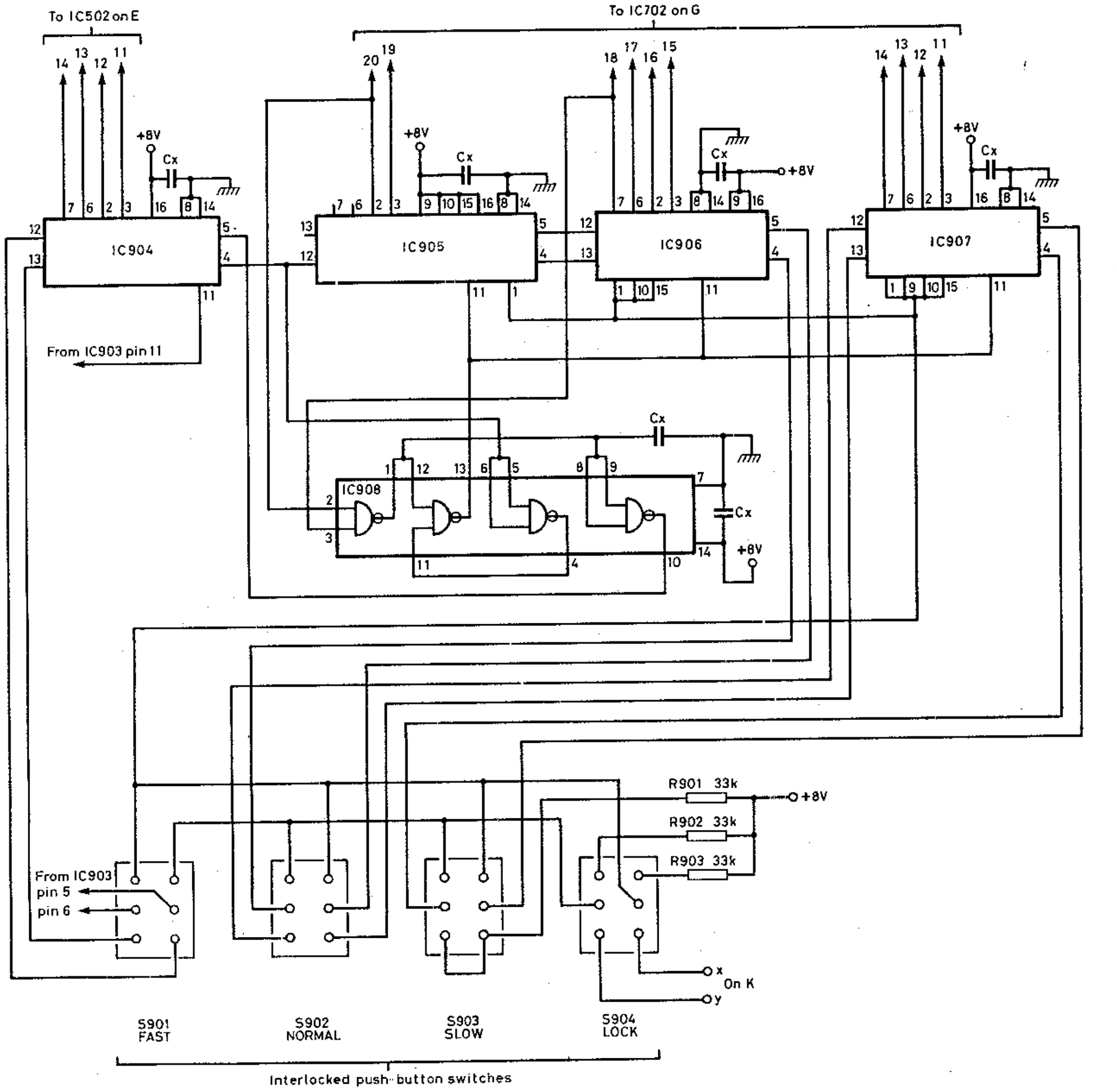


Fig 15 Section J. Frequency control, part 1. Part 2 on facing page



Section J. The up/down counter (Fig 15)

The main function of this section is to control the state of the programming inputs to the MC145151 in the two loops. IC901-7 are all 74C193. These are cmos up/down binary counters which have their parallel outputs on pins 3, 2, 6 and 7. The count on these is implemented with each falling edge on pin 5 (the up-count pulses) and decremented with each pulse falling edge on pin 4 (the down-count pulses). Pins 12 and 13 are the "carry" and "borrow". Parallel data inputs are at pins 15, 1, 10 and 9.

The main tuning is done by the introduction of up or down pulses to pins 4 or 5 on IC907. The tuning pulses are derived from a "shaft encoder". (I used an Alps device from Cirkit—an LA226 (stock No 48-00226) and a decoder circuit, which routes the up and down pulses separately to the correct pins). These pulses are then routed to the selected part of the counter-chain by the press switches SW1-4. R901, 902 and 903 keep the inputs of unused parts of the counter high when they are switched out. If this is not done, they will oscillate. IC908 (74C02) limits the count for loop 2 to the range between 15744 and 16383, and passes on a carry or borrow pulse as appropriate to the rest of the counter chain which controls the count in loop 1. On IC901 and 902, the parallel data inputs are wired to preset the counter to a point near the low-end of the frequency spectrum of the synthesizer. Other builders may wish to set the count at other parts of the band. The BC238 (TR901) generates a negative-going pulse at switch-on which performs the preset operation.

A further part of this section (IC909, 910, 911) deals with the selection of the appropriate vco in loop 1 and also the selection of the correct front-end filter in the receiver. There are seven board pins for connecting the control lines to the front-end filters. From the front of the pcb they are: **(a)** up to 1MHz; **(b)** 1 up to 2MHz; **(c)** 2-4MHz; **(d)** 4-8MHz; **(e)** 8-16MHz; **(f)** combines the outputs of the sixth and seventh pins via diodes for 16-30MHz.

Since there are a large number of wire links and diode links in this section, reference should be made to the detailed overlay: Fig 7.

IC909 is a CMOS4012, a double four-input NAND gate. IC910 and 911 are CMOS4555 decoders. Table 1 gives the truth table for these.

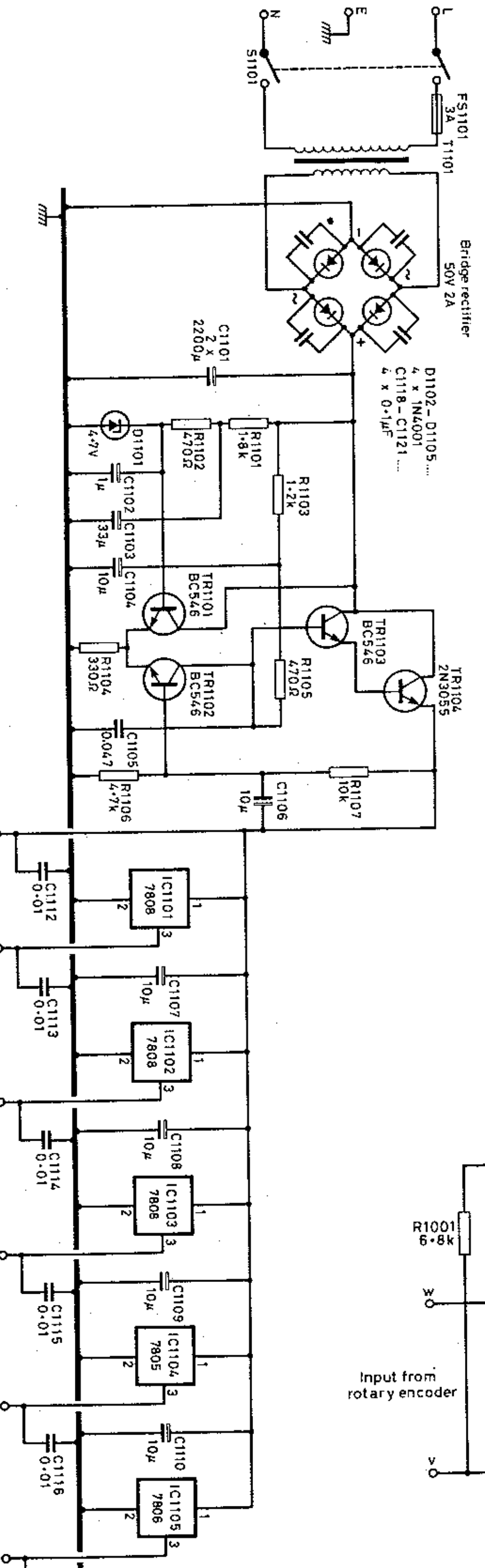


Fig 17. Section L. Power supply and regulators (with spare power for receive etc). These provide spare power at 12V and 6V for the receiver board

Section K. Pulse decoder (Fig 16)
This section is on a small separate pcb (Fig 20) which can be mounted directly over the rotary encoder. The circuit and layout are self-explanatory. IC1002 and 1003 shape the pulses and the flip-flop IC1001 routes them to the up or the down line x and y. I added the resistor R1007 to protect the 4013, which appeared to be suffering from surges of spiky voltage. Anyway, the last one has lived on, so all seems well.

The rotary encoder gives 50 pulses per revolution of the shaft. It has three terminals, the outer ones go to w and v and the centre one to ground. Choose the direction of rotation for up and down as best suits your ideas on such things. Fig 21 shows the component placing.

Section L. Power supply (Fig 17)
Three regulated 8V supplies, one at 5V regulated and a 12V regulated supply are required for the synthesizer. In addition, a 6V regulated supply is provided for the receiver board; and the 12V line is hefty enough to run a two or three watt audio output stage on the receiver. The mains transformer used is a Drake P1215, a 12VA job. It runs warm when the receiver is working and some builders may prefer a larger unit. If the synthesizer is to have sole use of this power then the P1215 is certainly ideal. Heat sinking for the regulators and for the 2N3055 is provided by the enclosure side. Figs 22 and 23 show the pcb layout and component placing. The board can be soldered directly onto the transformer secondary lugs. The other end is supported on a 0·75in pillar.

Enclosure

I mounted the synthesizer in the top-half of a steel box, 350mm by 230mm. The lower-half houses the rest of the receiver. The synthesizer compartment, which is 60mm deep, also houses the power supply and the rotary encoder and decoder. Fig 5 shows the scheme. The pcbs are on 0·75in pillars, the larger board needs five. Coaxial lead-throughs are required for the connections to the receiver of the injection frequencies.

Inter-board wiring

These are: (a) mains power to transformer via fuse and switch (not shown); (b) 8V lines to section J, E and G; (c) 12V to the pin in the top right-hand corner of the board, just above section C. The latter must run right round the board wherever 12V is required, and various wire links are needed as shown on the overlay. The two leads carrying the up and down pulses from the decoder board are most easily soldered to the front pair of pins on the "lock" switch.

Each board needs an earth-line to ground the board to the enclosure. The 5V line goes to the left-hand side of the board to feed the display, and another 5V line goes to the decoder board. In the first instance it is best to make all these leads long enough to enable the builder to lift the whole of the large pcb out of the enclosure for the exciting job of de-bugging.

Alignment

This needs to be tackled slowly and calmly! Get section J and the tuning pulse system working perfectly first. Check with a logic tester if you have one, but a voltmeter will do. Check output of pulses at the decoder, "up" pulses only on one line, and "down" pulses only on the other. Next check

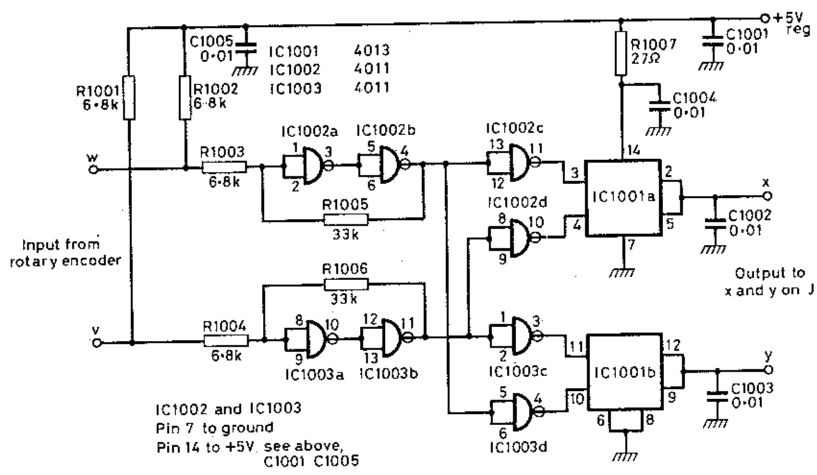


Fig 16. Section K Pulse decoder

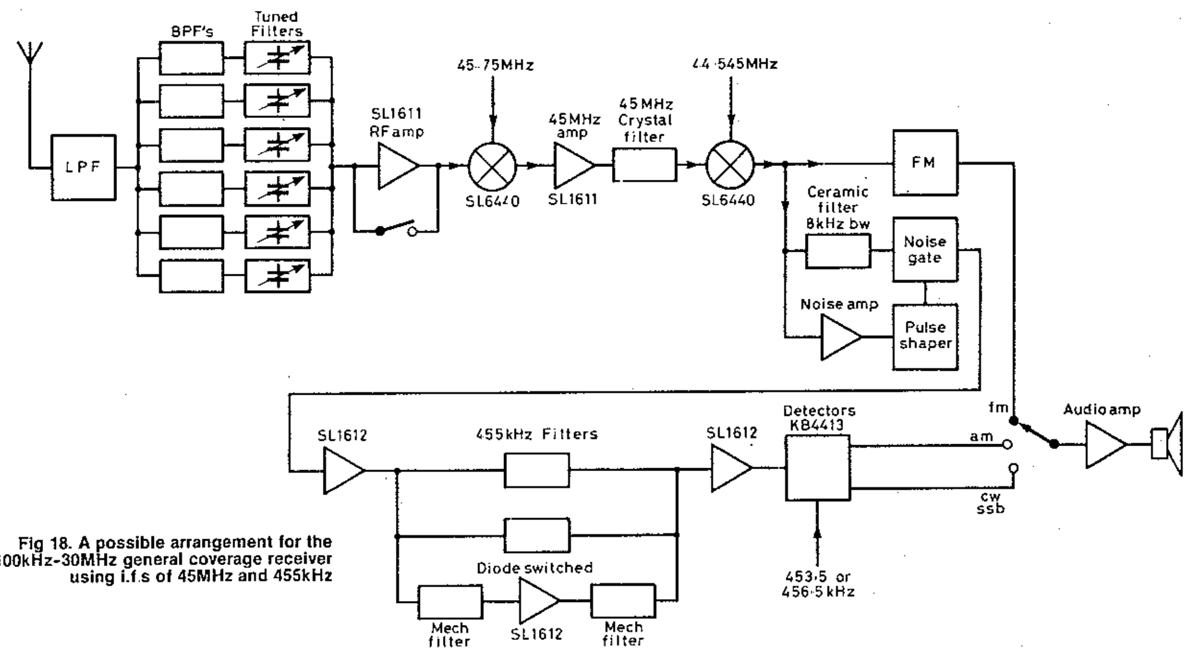


Fig 18. A possible arrangement for the 100kHz-30MHz general coverage receiver using i.f.s of 45MHz and 455kHz

the count on the whole string of 74C193s, checking the output pins 3, 2, 6, 7 in that order, and check the continuity of the lines to the equivalent pins on the MC145151. Remember that a common fault is bridged tracks on the pcb where the copper tracks are very close. The whole board should be examined in a good light with a magnifying glass.

Make sure that the count control is working (IC908). Start with the output pins on IC905, 906, and 907 in J all high (except pins 6 and 7 on IC905 which should never show up high) and tune the count slowly down, by turning the knob in the right direction. When pin 7 on IC906 drops for the second time, the count has reached its limit and IC905, 906, and 907 should set back to high again. Check the up-count from the bottom limit; when all pins of IC905 have reached "high" (except pins 6 and 7 of IC905) the next "up" pulse should re-set to 15744 again ie to 11110110000000 The first four 1s of this number are there all the time on the MC145151 (pins 22, 23, 24 and 25 have no connection to them) so the highs on IC905, 906 and 907, should be on pin 3 of IC905 and pin 7 of IC906.

The next check is to see that the digital switching, IC909, 910, 911, is working correctly—only one vco should be "on" at a time! Check the inputs and outputs of IC910 and 911. If all is not well the truth table for the 4555 (Fig 19) will help.

Perhaps the most critical part of the setting-up is the tuning of the filters in sections B and F. The most convenient way to do this is to take out the SL1640 mixer immediately before the filter, and, using a suitable signal generator, inject 200mV or so into the empty mixer socket at pin 5. Watch the output of the filter after amplification by the following amplifier, and swing the signal generator slowly across the part of the spectrum we are concerned with. Take the 42MHz filter in section B first. The main concern here is to let through as much energy at 42 16MHz while keeping out the 44 545MHz component. This is quite a tall order and persons of wealth may prefer to order a special crystal filter! However with care and attention the filter shown will work very well.

If you have trouble getting a narrow enough passband, try reducing the coupling by making C212, 213, and 214 even smaller. Tune the filter so that the upper frequency of the pasband is at 42MHz, and the fall-off of response towards 45MHz as steep as possible.

The filter in section F is broadband. The coils are hand-wound, and you may want to alter the number of turns and experiment with different values of capacitance. The aim is to get a steep fall in response above 35MHz and a fall also below 2 5MHz, though this latter does not seem to be nearly so critical, and, in fact, needs no adjusting.

The lowpass filter before the display, situated on the left-hand end of the board, may give trouble. If the display is not steady, and all other indications are that the rest of the synthesizer is working properly, try the arrangement shown in the appendix.

Now turn to loop 2, sections G and H, and check for volts and oscillation. See that there is 44·545MHz from section C. Tune the doubler in section H, then, with a voltmeter on pin 6, IC701 section G, watch the voltage while you move the core in L701 (G). When the loop is locked, the voltage will rise and fall with equivalent movements of the core: move the core until the voltage is about 6V. If no lock is achieved, check the circuit and the tuning of L801 and L802 in section H. These can be peaked at 6 4MHz. When the loop is working properly, the voltage at R701 in section G should rise slowly as you tune, and then drop suddenly as the first part of the counter resets.

You should also look at the R701 point to see that the lowpass filter is working properly. To do this, substitute a scope at its most sensitive setting for the voltmeter; there should be no trace of the 400Hz reference frequency.

Next, turn to loop 1 and repeat the same procedure. Set the cores of each of the four vcos starting from the low-end. In each case set the core so that the tuning voltage is centred at about 6V.

Checking for sideband suppression

Since I do not possess a spectrum analyser or a receiver which will cover 45 to 75MHz, the final adjusting of the synthesizer was done using a receiver at 10MHz, and a double-balanced mixer with an injection from a Marconi signal-generator running at a frequency 10MHz higher than the frequency of the synthesizer. See Fig 19.

Using the lowpass filter in section E as shown, the 6 4kHz sidebands should be over 40dB below the output at the required frequency.

The bandpass filter in section B can be adjusted for the best "note"

Table 1. Truth table for the 4555 decoders

Pinout

1 Enable	16 +8V
2 A	15 Enable
3 B	14 A
4 Q1	13 B
5 Q2	12 Q1
6 Q3	11 Q2
7 Q4	10 Q3
8 Ground	9 Q4

Truth Table

E	A	B	Q1	Q2	Q3	Q4
H	x	x	L	L	L	L
L	L	L	H	L	L	L
L	H	L	L	H	L	L
L	L	H	L	L	H	L
L	H	H	L	L	L	H

Each 4555 has two decoders each with two inputs and four outputs plus an "enable"

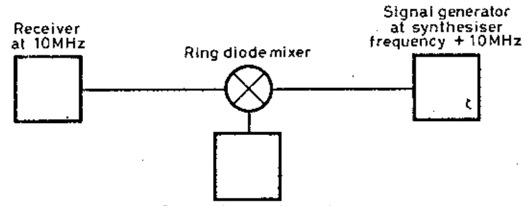


Fig 19. Using a receiver to check synthesizer output

Components list

SECTION A

R101	33k	4 of each
R102, 104, 106	100k	4 of each
R103	10k	4 of each
R105	100Ω	4 of each
R107	6·8k	4 of each
R108	22k	4 of each
R109	470Ω	4 of each
R110	2·2k	4 of each
R111, 116	1k	
R112	22k	
R113, 114	100Ω	
R115	10kΩ	
R117	220Ω	
C101, 102, 115	3·9pF	
C103	2·2pF	
C104, 106, 113	0·01µF	
C105, 114	0·047µF	
C107	6·8pF	
C109	39pF	4 of each
C110	10pF	4 of each
C111	100pF	4 of each
C112	See text	
C116, 117	0·01µF	4 of each
C118	10µF electrolytic	4 of each
L101	See text	
D101, 102	BB109	4 of each
D103	BA244	4 of each
TR101	BC238	4 of each
TR102	BC308	4 of each
TR103, 104, 105	BF241	4 of each
RFC101, 103, 104	470µH	
RFC102	10µH	
RFC105	1·2µH	

All RFCs are Toko 7BS series

SECTION B

R201	380Ω
R202	100k
R203	680Ω
R204	100Ω
R205	220Ω
C201	6·8pF
C202	2·2pF
C203, 204, 205, 207, 209	0·01µF
C206, 210	0·047µF
C208	10µF electrolytic
C211	10pF
C212, 213, 214	See text
C215	22pF
C216	3·9pF
C217, 218	4·7pF
L201, 202, 203, 204	Toko K3344
TR201	BF241
IC201	SL1640
RFC201, 202	470µH, Toko 7BS

SECTION C

R301, 305	22k
R302, 304	5·6k
R303	1k
R306	4·7k
R307	220Ω
R308	10k
C301, 304, 307, 308	0·01µF
C302, 306	22pF
C303, 310	10pF
C305, 309	0·047µF
X301	Crystal 44·545MHz with 20pF in series
L301, 302	K3335 (1·2µH)
RFC301, 302	100µH, Toko 7BS
TR301, 302	BF241

SECTION D

R401, 407, 408	100k
R402, 405, 409, 413	100Ω
R403, 406, 410, 411, 416	220Ω
R404	380Ω
R412	68k
R414	680Ω
R415	150Ω
C401, 418	2·7pF
C402, 403, 404, 405, 406, 408, 409, 410, 412, 420, 423, 430, 431, 433, 434, 436	0·01µF
C407	10µF
C411, 421, 427, 428, 429, 432, 435, 437, 438, 439	0·047µF
C413, 414	3·9pF
C415	4·7pF
C416, 426	2·2pF
C417, 419, 422	0·001µF
C424	10µF electrolytic
C425	12pF
RFC401, 402, 403, 404, 406, 408	470µH
RFC405	1mH
RFC407	10µH
L401, 402, 403, 404, 405	3·3µH Toko 7BS
TR401, 402, 403, 404, 405	BF241
IC401	SL1640
IC402	HD10551
LCD	FC177 Cirkit 39-17700

SECTION E

R501, 519	100Ω
R502, 506, 514	1k
R503	560Ω
R504, 511, 512, 518	3·3k
R505, 507	33k
R513	2·2k
R515, 516, 517	220Ω
R510	10Ω
C501, 510, 511, 516, 517, 518, 519, 520	0·01µF
C502, 512, 521, 522, 523	0·047µF
C503, 508, 509	0·1µF
C504, 505	1µF
C506, 507, 513, 514	0·001µF
C515	6·8pF
X501	Crystal 3·2768MHz. HC18U Cirkit 45-03000
TR501, 502, 503	BF241
IC501	741 op-amp
IC502	MC145151
RFC501, 503, 505, 506	470µH
RFC502	100µH
RFC504	3·3µH

SECTION F

R601, 607	220Ω
R602	22k
R603	10k
R604, 608, 612	100Ω
R609	2·2k
R610	1k
R611	470Ω
R613	5·6k
C601, 603, 604, 605, 607, 609, 610, 612, 614	0·01µF
C602, 606, 613	0·047µF
C608	10µF electrolytic
C611, 616, 617, 618, 621	10pF
C615, 622	6·8pF
C619	100pF
C620	4·7pF
C623	2·2pF
C624	3·9pF
L601, 602, 603, 604	See text
RFC601, 602, 603	470µH
RFC606, 607	47µH
RFC605	3·3µH
TR601, 602, 603	BF241
IC601	SL1640

SECTION G

R701, 716	100k
R702, 703, 712, 716, 720	1k
R704, 705, 706, 707	5·6k
R708	680Ω
R709	10Ω
R710, 711	220Ω
R713, 721, 723	100Ω
R714, 712, 722	2·2k
R717	22k
R718, 726	10k
R719, 724	560Ω
R725	3·8k
C701, 702, 703, 710, 712, 713, 715, 716, 717, 721, 725, 726, 733	0·01µF
C704	1µF tantalum
C705, 706	4·7µF tantalum
C707, 711, 714, 727	0·047µF
C708, 709	0·1µF
C718, 723, 730	6·8pF
C719, 720	33pF
C722	10µF electrolytic
C724, 728, 729	0·001µF electrolytic
C731	0·003µF
C732	2·2pF
L701	0·17µH Toko MC120 100075
TR701, 702, 703, 704	BF241
IC701	741 op-amp
IC702	MC145151
IC703	MC12016p
D701, 702	ITT120
RFC701, 702, 703, 704	470µF
RFC705	100µH
RFC706	47µH

SECTION H

R801, 808	22k
R802, 810	10k
R803, 805, 807, 811	100Ω
R804, 806, 809	220Ω
C801, 815	100pF
C802, 804, 805, 806, 807, 809, 810, 813	0·01µF
C808	10µF electrolytic
C811, 821, 822	0·047µF
C812	0·001µF
C814	10pF
C816	6·8pF
C817, 820	33pF
C818	47pF
C819	27pF
C823	2·8–12pF min ceramic
RFC801, 802, 803	470µH
RFC804	22µH
TR801, 802	BF241
IC801	SL1640
L801, L802	15 turns of 32swg wire on 10k former with pot-core
L803	12 turns 28swg enam copper on 0·25W 1MΩ resistor

SECTION J

R901, 902, 903	33k
R904, 905, 906, 907, 908, 909	2·2k
R910	10k
R911	68k
C901	0·1µF
C902	1µF electrolytic
C903–12	0·01µF for decoupling the ics and for pin 12 on IC8
IC901, 902, 903, 904, 905, 906, 907	74C193
IC908	74CO2
IC909	CMOS4012
IC910, 911	CMOS4555
D1–22	BA244
RFC901	1mH Toko 7BS
TR901	BC238

SECTION K

R1001, 1002, 1003, 1004	6·8k
R1005, 1006	33k
R1007	27Ω
C1001, 1002, 1003, 1004, 1005	0·01µF
IC1001	CMOS4013
IC1002, 1003	CMOS4011

SECTION L

R1101	1·8k
R1102, 1105	470Ω
R1103	1·2k
R1104	330Ω
R1106	4·7k
R1107	10k
C1101	2 × 2 200µF electrolytic
C1102	1µF
C1103	33µF
C1104, 1106, 1107, 1108, 1109, 1110	10µF electrolytic
C1105	0·047µF
C1112, 1113, 1114, 1115, 1116, 1117	0·01µF
C1108, 1119, 1120, 1121	0·1µF
T1101	Transformer Drake 12VA P1215
D1101	Zener diode, 4·7V Cirkit 12-00478
D1102, 1103, 1104, 1105	4 rectifier diodes, 1N4001 or similar
TR1101, 1102, 1103	BC546
TR1104	2N3055
S1101	Mains switch
FS1101	3A fuse
IC1101, 1102, 1103	Regulators 7808
IC1104	Regulator 7805
IC1105	Regulator 7806

Holders for all ics
Board pins for connections
Incremental encoder Alps LA226 Cirkit 48-00226
Connecting wire and miniature coaxial
All RFCs are standard value Toko 7BS or 7BA series

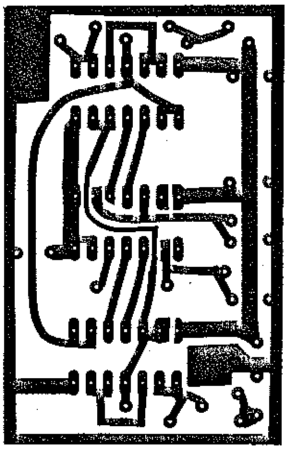


Fig 20. Pulse decoder pcb layout

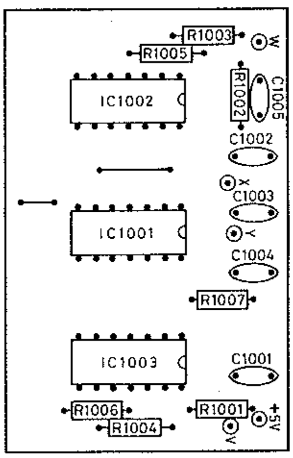


Fig 21. Pulse decoder component layout

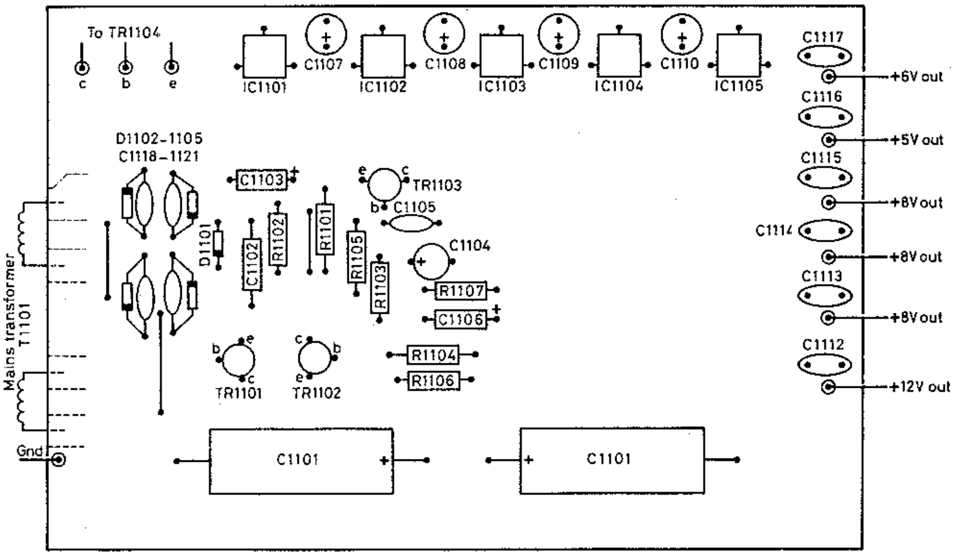


Fig 22. Power supply component layout

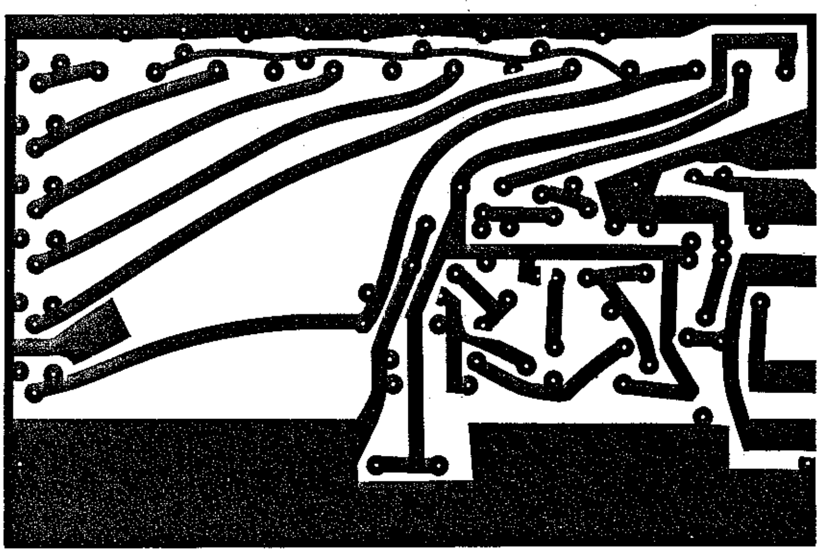


Fig 23. Power supply pcb layout

Putting the synthesizer to use

Each builder will have his own ideas about the ideal receiver circuit. I used chiefly the Plessey SL series ICs. Fig 18 shows the block diagram of the complete receiver. The 45MHz filter is a cheap two-pole crystal device, 45M15A, supplied by Cirkit. The two balanced mixers are SL6440. The synthesizer could very well drive a compact QRP all-band transceiver.

EDITOR'S NOTE

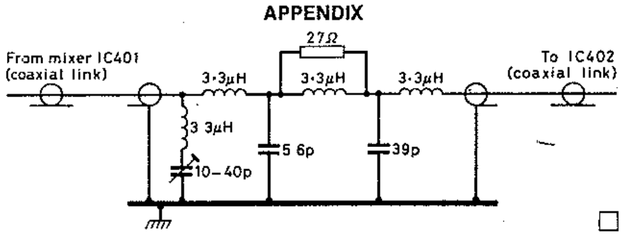
Because of its large dimensions, it has not been possible to reproduce the main pcb layout, the component layout for which (Fig 7) was published in Part 1. Photocopies of the master negative can be obtained on request from the editor at RSGB HQ.

Errata. In Part 1, page 562, under the heading "The circuit described by sections", Section A, lines 5, 7 and 10 for C122 read C112; line 8 for C102 read C112.

Components

All the components are readily available. Resistors are all carbon film 0.25W per cent. Capacitors: 0·1 are Mylar; 0.001, 0.01, 0.047 are low-voltage disc ceramic, smaller values are mostly ceramic chip. Electrolytics are 16V working radial leads, except those indicated on the components list. Builders interested in purchasing a set of pcbs for the project, should contact me.

APPENDIX



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