Converting Ham Internationals To 10m

Roger Alban, GW3SPA, looks at this widely available range of CB rigs and explains how they can all be modified to 28MHz.

During the late 1970s, when the growth of CB use in America had outgrown the 40 channels available, a number of manufacturers decided to offer CB sets that were capable of operating on 80 channels and 120 channels. Although these sets did not meet the FCC specification, they found their way into the hands of the CB enthusiast.

One of the manufacturers, Ham International, has their headquarters based at Ghent, Belgium and are still manufacturing good quality 120 channel multimode transceivers intended for the CB market around the world. Ham International manufacture a number of different models all capable of operating on 120 channels offering AM, FM, and SSB modes of operation.

The CB manufacturers offered a variety of different models in an attempt to sell more sets. To date the author has tracked down seven 120 channel sets all manufactured by Ham International that either use the same PCB, or whose method of frequency generation is very similar. **Table 1** shows the relationship between eight sets manufactured by Ham International and the PCB numbers found on the sets. For example, the top of the range base station model, the Jumbo, uses the same main PCB as the Ham Major M360, and the Multimode II. Whereas the top of the range mobile model is the Concord II which uses the same PCB as the Trystar 747 mobile rig. The main differences between the various models seems to be the inclusion or exclusion of transmit course tuning. This enables the user to tune 5kHz either side of the frequency selected by the channel control switch.

Table 2 gives the manufacturers specification quoted for each model together with the different facilities offered. There is one main common bond between all these models, that is the way the sets working frequency is generated which also lends itself to being easily converted to the amateur 10m band.

The Band Oscillator

If the set is to be converted to operate 10m band, the value of the band crystal oscillator will need to be changed. To be able to calculate the required value of crystal, we need to derive some formula using simple arithmetic and a small amount of algebra. These are shown nearby in the box 'Calculating Band Oscillator Crystal Values'.

If you decide to stick with the possibilities of re-crystalling the set on the upper part of the 10m band using the three band crystal positions, as most people will, then the crystals you will require are high band 21.2525MHz, mid band 21.0525MHz, low band 20.8525MHz. The sets new operating frequencies are shown in **Table 3**.

Also remember that when ordering crystals, the specification must be fundamental crystals, operating at about 28 pF, +/− 20pp at 25°C. *If you happen to own a Multimode II, or a Jumbo, then the crystal frequencies must be half of the crystal frequencies*

CB MODEL	MAIN PCB No	PPL PCB No	XTAL OSC PCB No	SWR PCB No	ROGER BEEP PCB	NOTES
COLT 1600DX	PTBM125A4X	–	–	–	–	
HAM MAJOR M360	PTBM059C0X	PTSY016A0X	–	–	–	
MARCO CB-747	PTBM121D4X	–	PTOS110R0X	PTSR007A0X	–	
TRYSTAR 747	PTBM121D4X	–	PTOS110A0X	–	–	
MULTIMODE II	PTBM059C0X	PTOS006A0X	–	–	YES	BAND CHANGING XTALS AT ½ FREQ THEN MULTIPLY BY ½
CONCORDE II	PTBM121D4X	PTOS011A0X	–	PTSR021A0X	YES	
HIGH GAIN 2795	PTBM121D4X	–	PTOS011A0X	–	–	
JUMBO	PTBM059C0X	PTOS006A0X	–	PTSR017C0X	YES	BAND CHANGE XTALS AT ½ FREQ THEN MULTIPLY BY 2

Table 1 The PCB numbering system for the Ham International range of CBs.

	COLT1600DX	HAM MAJOR	MARCO CB747	TRYSTAR 747	MULTIMODE 2	CONCORD 2	HIGH GAIN	JUMBO
FREQ RANGE (MHz)	26.515-26.955							
LOW	26.965-27.405	26.965-27.405	26.965-27.405	26.965-27.405	26.965-27.405	26.965-27.405	26.965-27.405	26.965-27.405
MID	27.415-27.855	27.415-27.855	27.415-27.855	27.415-27.855	27.415-27.855	27.415-27.855	27.415-27.855	27.415-27.855
HIGH	27.865-28.305	27.865-28.305	27.865-28.305	27.865-28.305	27.865-28.305	27.865-28.305	27.865-28.305	27.865-27.305
EMISSION AM/FM/USB/LSB	YES	YES	YES	YES	YES	YES+CW	YES	YES
RX SENSITIVITY AM (uV at 10dB S/N)	1	0.7	1	1	0.7	0.7	0.7	0.7
RX SENSITIVITY FM (uV at 20dB S/N)	1	0.5	1	1	0.5	0.5	0.5	0.5
RX SENSITIVITY SSB (uV at 10dB S/N)	0.5	0.2	0.5	0.5	0.2	0.2	0.2	0.2
SKIRT SELECTIVITY AT 6dB DOWN	UNKNOWN	AM/FM 6kHz SSB 2kHz	AM/FM 5kHz SSB 2.2kHz	AM/FM 5kHz SSB2.2kHz	AM/FM 6kHz SSB 2kHz	AM/FM 6kHz SSB 2kHz	AM/FM6kHz SSB 2kHz	AM/FM 4kHz SSB 2kHz
AUDIO OUTPUT AT 10% dist INTO 8 OHMS (Watts)	2	3.5	2	2	3.5	3.5	3	3
FINE TUNE RANGE	+/-800Hz	NO	+/-800Hz	+/-800Hz	+/-800Hz	+/-800Hz	+/-800Hz	+/-800Hz
COARSE TUNE RANGE	+/-5kHz	+/-4kHz	NO	NO	+/-4.5kHz	+/-4.5kHz	+/-4.5kHz	+/-5kHz
SQUELCH RANGE (uV)	0.5-300	0.7-300	0.5-500	0.5-500	0.7-300	0.7-300	0.7-300	0.7-300
TX POWER SSB (PEP (W))	12	12	12	12	12	12	12	12
TX POWER AM(W)	7.5	4	7.5	4	4	4	7.5	4
TX POWER FM (W)	10	4	7.5	12	4	4	7.5	4
TX COARSE TUNE	+/-5kHz	NO	NO	NO	+/-4.5kHz	+/-4.5kHz	NO	+/−4.5kHz
NOISE BLANKER	YES	YES	YES	YES	YES	YES	YES	YES
AUTO NOISE LIMITER	YES	NO	NO	NO	NO	YES	NO	YES
RF GAIN CONTROL	YES	SWITCH	SWITCH	SWITCH	SWITCH	YES	YES	YES
FM DEVIATION+/-1.5kHz	YES	YES	YES	YES	YES	YES	YES	YES
SWR FACILITY	NO	NO	YES	NO	NO	YES	NO	YES

Table 2 The manufacturers spec for each model.

shown above because the oscillator frequency is doubled by the tuned circuit comprising T1 before being injected into the mixer.

Adjusting The Band Oscillator

For those of you contemplating this conversion, remember it is not just a straightforward exchange of band crystals, the set will need to be re-tuned. You will also require a frequency counter, oscilloscope, and a digital DC voltmeter. Before removing the old band crystals, select channel 30 on the high band and measure the DC voltage with a digital meter at test point 1 on the PTBM121D4X PCB, or test point 2 on the PTBM059C0X PCB. The voltage reading should be in the region of 1.33V.

Table 3 The new channel and frequency allocations.

CHANNEL	LOW	MID	HIGH
1	28·46	28·86	29·26
2	28·47	28·87	29·27
3	28·48	28·88	29·28
4	28·50	28·90	29·30
5	28·51	28·91	29·31
6	28·52	28·92	29·32
7	28·53	28·93	29·33
8	28·55	28·95	29·35
9	28·56	28·96	29·36
10	28·57	28·97	29·37
11	28·58	28·98	29·38
12	28·60	29·00	29·40
13	28·61	29·01	29·41
14	28·62	29·02	29·42
15	28·63	29·03	29·43
16	28·65	29·05	29·45
17	28·66	29·06	29·46
18	28·67	29·07	29·47
19	28·68	29·08	29·48
20	28·70	29·10	29·50
21	28·71	29·11	29·51
22	28·72	29·12	29·52
23	28·75	29·15	29·55
24	28·73	29·13	29·53
25	28·74	29·14	29·54
26	28·76	29·16	29·56
27	28·77	29·17	29·57
28	28·78	29·18	29·58
29	28·79	29·19	29·59
30	28·80	29·20	29·60
31	28·81	29·21	29·61
32	28 82	29·22	29·62
33	28·83	29·23	29·63
34	28 84	29·24	29·64
35	28 85	29·25	29·65
36	28 86	29·26	29·66
37	28 87	29·27	29·67
38	28 88	29·28	29·68
39	28·89	29·29	29 69
40	28·90	29·30	29·70

After taking this reading replace the old band crystals with the new and with a 10pF capacitor connected to terminal 1 on the oscillator board (PTOS011A0X PCB), measure the frequency and amplitude of the band crystal oscillator on each band. The frequency of the oscillator can be adjusted by altering the trimmers CT1, CT2, and CT3. The frequency measurement should be carried out on the AM/FM/USB mode. The core of T1 should be adjusted for maximum amplitude.

If you cannot obtain a sharp peak in tuning T1, you will have to replace the internal tuning capacitor of T1 for a 68 pF one to replace this, the transformer and the screen have to be completely removed from the PCB. The internal tuning capacitor will be found inside the base of the coil former and should be removed carefully. Replace the metal screen and resolder the transformer on to the PCB. The new 68pF tuning capacitor can be soldered across the coil of the transformer on the back of the PCB. When T1 has been successfully tuned, switch to LSB. Transistor Q2 should now conduct and the output frequency of the crystal oscillator should drop by 3kHz. If it doesn't, adjust CT4 until you obtain the correct frequency offset.

In the case of the band oscillator the following procedures will need to be followed. Connect a 10pF capacitor to the output of T1 and measure the amplitude and frequency of the crystal oscillator. The output presented at test point 4 was found to be quite low and insufficient to drive my digital frequency meter. With the set switched to FM/AM/USB mode, the frequency of the crystal oscillator can be adjusted by altering the trimmers CT2, CT3 and CT4.

With the set switched to the LSB mode, the frequency of the band crystals should drop by 1.5kHz. Remember that the crystal oscillator is operating at half the frequency of other models' band oscillator and it is doubled by the tuning circuit, T1. Therefore the frequency shift measured on LSB at the output of T1 will be 3kHz. If this is not so, then adjust trimmer CT5 until you achieve the required offset. Tune the core of T1 for maximum amplitude, again changing the value of the internal tuning capacitor if necessary.

The VCO

The remaining PLL circuitry is similar for all the models and modification work is, of course, the same. A DC voltage reading has been taken at test point 1 or 2 depending on the model you

Calculating New Band Crystal Oscillator Values

We know that the transmit/receive frequency for AM/FM/USB is derived from Fo, the frequency injected into the receiver first mixer minus 10.695MHz.

Thus:- Ftx = Fo − 10.695 . . . equation 1.

Fo is the output frequency of the band pass filter which is produced by additive mixing, adding together the frequencies of the VCO, Fvco and the frequency of the band crystal oscillator Fxtl.

Thus:- Fo = Fvco + Fxtl . . . equation 2.

If we now substitute equation 2 for Fo into equation 1, we obtain,

Ftx = Fvco + Fxtl − 10.695 . . . equation 3.

We also know that Fin, which is obtained from the output of the low pass filter, is derived by subtracting the frequency of the VCO from the frequency of the band select crystal oscillator.

Thus:- Fin = Fxtl − Fvco . . . equation 4.

Re-arranging equation 4, we obtain

Fvco = Fxtl − Fin . . . equation 5.

Substitute Fvco in equation 5, into equation 3 we obtain

Ftx = Fxtl − Fin + Fxtl − 10.695

Ftx = 2Fxtl − Fin − 10.695 . . . equation 6.

In equation 6, the only unknown quantity is Fxtl, which is the required frequency for the band select crystal. So if we re-arrange equation 6, we obtain the final equation

Fxtl = (Ftx + Fin + 10.695)/2

where Fxtl is the operating frequency of the band crystal oscillator,

Ftx is the transmit/receive frequency of the set and Fin is the input frequency to the programmable divider.

Let us test the formula. From a previous example, channel 30 on the high band corresponds to an operating frequency of 28.205MHz. From Table 4 we can see that the value of Fin for channel 30 will be 2.21MHz. If we know substitute the data into the formula, we obtain

Fxtl = (28.205 + 2.21 + 10.695)/2 = 20.555MHz

which is the frequency of the crystal used on the high band in the unmodified set.

We can now calculate the value of the crystal required to convert the set for use on the amateur 10m band. It is usual to select channel 30 on the high band to correspond with the calling frequency for 10m FM working ie 29.60MHz. Therefore the value of the crystal required will be

Fxtl = (29.60 + 2.21 + 10.695)/2 = 21.2525MHz.

It is also worth while considering recrystalling the mid and low bands as well since all the models listed in Table 1 are multimode transceivers. However there is a problem. The VCO is so designed that it can only operate over three consecutive blocks of 40 channels. If for example you try to cover the CW portion of 10m as well as the FM portion, the VCO will be unable to provide the frequency sweep that will be required. The VCO tuned circuit, is encapsulated in a rectangular block of solid plastic covered by a green plastic skin, and does not therefore lend itself to easy modification. If you want to increase the operating bandwidth of the set, you will have to replace the green plastic blob with the circuit shown in Fig 2.

Table 4 Truth table of the programme lines for each channel.

CHANNEL	Fin (MHz)	÷N	P8	P7	P6	P5	P4	P3	P2	P1	P0	HEX ADDRESS	
1	2.55	255	0	1	1	1	1	1	1	1	1	F	F
2	2.54	254	0	1	1	1	1	1	1	1	0	F	E
3	2.53	253	0	1	1	1	1	1	1	0	1	F	D
4	2.51	251	0	1	1	1	1	1	0	1	1	F	B
5	2.50	250	0	1	1	1	1	1	0	1	0	F	A
6	2.49	249	0	1	1	1	1	1	0	0	1	F	9
7	2.48	248	0	1	1	1	1	1	0	0	0	F	8
8	2.46	246	0	1	1	1	1	0	1	1	0	F	6
9	2.45	245	0	1	1	1	1	0	1	0	1	F	5
10	2.44	244	0	1	1	1	1	0	1	0	0	F	4
11	2.43	243	0	1	1	1	1	0	0	1	1	F	3
12	2.41	241	0	1	1	1	1	0	0	0	1	F	1
13	2.40	240	0	1	1	1	1	0	0	0	0	F	0
14	2.39	239	0	1	1	1	0	1	1	1	1	E	F
15	2.38	238	0	1	1	1	0	1	1	1	0	E	E
16	2.36	236	0	1	1	1	0	1	1	0	0	E	C
17	2.35	235	0	1	1	1	0	1	0	1	1	E	B
18	2.34	234	0	1	1	1	0	1	0	1	0	E	A
19	2.33	233	0	1	1	1	0	1	0	0	1	E	9
20	2.31	231	0	1	1	1	0	0	1	1	1	E	7
21	2.30	230	0	1	1	1	0	0	1	1	0	E	6
22	2.29	229	0	1	1	1	0	0	1	0	1	E	5
23	2.26	226	0	1	1	1	0	0	0	1	0	E	2
24	2.28	228	0	1	1	1	0	0	1	0	0	E	4
25	2.27	227	0	1	1	1	0	0	0	1	1	E	3
26	2.25	225	0	1	1	1	0	0	0	0	1	E	1
27	2.24	224	0	1	1	1	0	0	0	0	0	E	0
28	2.23	223	0	1	1	0	1	1	1	1	1	D	F
29	2.22	222	0	1	1	0	1	1	1	1	0	D	E
30	2.21	221	0	1	1	0	1	1	1	0	1	D	D
31	2.20	220	0	1	1	0	1	1	1	0	0	D	C
32	2.19	219	0	1	1	0	1	1	0	1	1	D	B
33	2.18	218	0	1	1	0	1	1	0	1	0	D	A
34	2.17	217	0	1	1	0	1	1	0	0	1	D	9
35	2.16	216	0	1	1	0	1	1	0	0	0	D	8
36	2.15	215	0	1	1	0	1	0	1	1	1	D	7
37	2.14	214	0	1	1	0	1	0	1	1	0	D	6
38	2.13	213	0	1	1	0	1	0	1	0	1	D	5
39	2.12	212	0	1	1	0	1	0	1	0	0	D	4
40	2.11	211	0	1	1	0	1	0	0	1	1	D	3

are modifying. Reconnect the voltmeter to the test point and adjust the tuning core of the VCO until you obtain the previous reading of 1.33V.

If you are retaining the original VCO circuitry and using the set over only 40 channels, then the tuning core will have to be unscrewed by a few turns. When you have obtained the desired voltage reading the VCO should now be correctly tuned and the PLL loop functioning correctly.

Modifying The VCO

If you choose to use the set on the three consecutive groups of 40 channels on 10m, then you will find that the existing VCO circuitry will not track the entire 120 channels. I found the VCO would only track over 114 channels on 10m. On the 11m CB band, the VCO was capable of tracking approximately 130 channels. The change in the L to C ratio is the prime cause for this tracking problem on 10m. The VCO voltage swing varied between approximately 1V up to 6V. It was therefore found necessary to remove the existing VCO tuned circuitry by unsoldering the five connections on the main PCB and replace it with the circuitry shown in **Fig 2.**

The circuit is constructed on Vero board of the same floor measurements as of the encapulated circuitry removed. The layout of the various components is shown in Fig. 3. The five connecting terminals are constructed out of stiff wire and soldered to the back of the Vero board. The coil is wound on a Toko coil former and surrounded by a pot core and screen can. The new circuit board should be installed in place of the encapsulated VCO and the five connecting terminals soldered to the main PCB.

After installing the new VCO, reconnect the digital voltmeter to test point 1 (or test point 2) and adjust the tuning core of the VCO to obtain a voltage reading of 2.48 volts on the same channel as before. This should then correspond to approximately 5.12V on channel 1 on the low band.

It was found necessary to make a slight alteration to the low pass filter installed between the phase comparator and VCO. A 0.22 uF

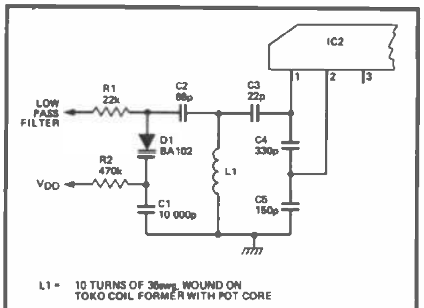
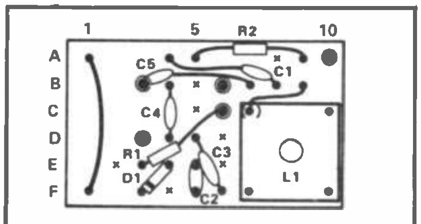


Fig.2 The replacement VCO circuit.



× DENOTES CUT TRACK WITH TWIST DRILL

● DENOTES TERMINAL POST CONNECTING VCO TO THE MAIN PCB

Fig.3 The new VCO is built on veroboard (viewed from the component side).

tantalum bead electrolytic capacitor was placed in parallel across R1 to improve the stability of the loop. Although the new VCO circuit extends the operating frequency range of the set, additional modifications have to be made to the two band pass filters, and the transmitter tuned circuits which are not covered in this article.

Transmitter Tuning

The next step in the modification procedure is to tune the transmitter power amplifier and drive circuits. With a SWR meter and a 50 ohm dummy load connected to the aerial socket, key the transmitter on channel 60 on the mid band on AM or FM. At the output of the PLL mixer IC2, a band pass filter comprising of T2 and T3 selects the frequency Fvco plus Fxtl which is fed to the receiver first mixer and transmitter mixer IC3.

The tuning cores of T2 and T3 must be adjusted to give a peak in output transmitter power. You may find you can not tune T2 and T3 on the new frequency. In which case the internal fixed tuning capacitors in the base of the coil formers will have to be replaced with lower fixed value capacitors soldered to the printed circuit side of the PCB as previously described. I found I could tune T2 and T3 without altering the value of the fixed capacitors.

The next step is to tune the band pass filter, T4 and T5, at the output of the transmit mixer IC3. The fixed tuning capacitors here had to be replaced for 33pF capacitors soldered to the back of the PCB. The output of the band pass filter is fed to the base of transistor, Q7, which is an emitter follower. This feeds RF preamplifier, Q8, which is tuned by T6 and C47, a 47pF capacitor. If you are unable to tune the preamplifier you will need to change the value of C47 for a 33 pF capacitor.

The output of T4 feeds, via C49, the base of the RF driver transistor Q9. The value of C49 was selected by the set manufacturer when the set was initially tuned back in the factory. It may be necessary to change the value of C49, which is normally about 390pF, for a lower value. The RF driver is tuned by L7. Again you may find it necessary to change the value of C53 which is normally a 220pF capacitor for 150 pF. No difficulty was experienced in tuning the RF power transistor stage. Repeat the tuning exercise until you have obtained maximum output on channel 60 on the mid band.

After completing this stage of the tuning, compare the output power of channel 60 on the mid band with channel 1 on the low band and channel 40 on the high band. If the output power is not the same, then you will have to readjust the tuning cores of the band pass filters to obtain as near as possible a constant power output across the new operating frequency range of the set.

Receiver Tuning

Tune the set to channel 60 in the mid band, and inject a signal of 29.10MHz into the aerial socket. Adjust the tuning cores of the receiver RF amplifier T7, T8, and T9 with the noise blanker switched on. Reduce the level of the injected signal until it is just audible from the set's loudspeaker and again adjust the tuning cores of T7, T8, and T9 for maximum audio. If you do not have a suitable signal source, the receiver front end can be tuned from an off air signal generated by another amateur station. Finally, with the dummy load attached, monitor the transmit output signal on the amateur station main receiver. Tune the receiver either side of the carrier frequency by more than 10kHz and ensure no stray sidebands exist.

If the set has passed this test it is now ready to be used on the air. Remember, that the operating frequency generated by the channel change switch logic code does not necessarily change in 10kHz steps from one channel to the next. The new operating frequency relationship with channel number is shown in Table 3. The cost of the modification using three new crystals is approximately £20.

Cut Price Conversion

A cheaper method of converting these models to 10m would be to retain one of the crystals and modify the program code to adjust the programmable divide number N to suit the requirements. Using the 20.555MHz crystal and changing the program code the value of Fin on channel 40 on the high band can be found by manipulating the equation derived in 'Calculating New Band Oscillator Crystal Values!'

Fxtl = (Ftx + Fin + 10.695)/2.

Then Fin = 2Fxtl − Ftx − 10.695.

On channel 40 we require the operating frequency of the set to be 29.7MHz. Therefore Ftx will be 29.7, and Ftxl will be the crystal frequency 20.555MHz.

Fin = 41.11 − 29.7 − 10.695 = 0.715MHz

This value of Fin makes the divide by N number for the programmable divider equal to 71.5. However, we must always have a whole number for the value of N. If we make the N equal to the nearest value of whole number, 72, how far do we need to pull the frequency of the 20.555MHz crystal to obtain the desired operating frequency of 29.7MHz? Using the formula

CHANNEL	P5	P4	P3	P2	P1	P0	BINARY NUMBER
CHAN 1	1	1	1	1	1	1	63
CHAN 30	0	1	1	1	0	1	29
CHAN 40	0	1	0	0	1	1	19

Table 5 Some switch logic codes for selecting channels 1, 30 and 40.

CHANNEL	P8	P7	P6	P5	P4	P3	P2	P1	P0	BINARY NUMBER
CHAN 1	0	0	1	1	1	0	0	1	1	115
CHAN 30	0	0	1	0	1	0	0	0	1	81
CHAN 40	0	0	1	0	0	0	1	1	1	71

Table 6 The required programme code for channels 1, 30 and 40 on the high band.

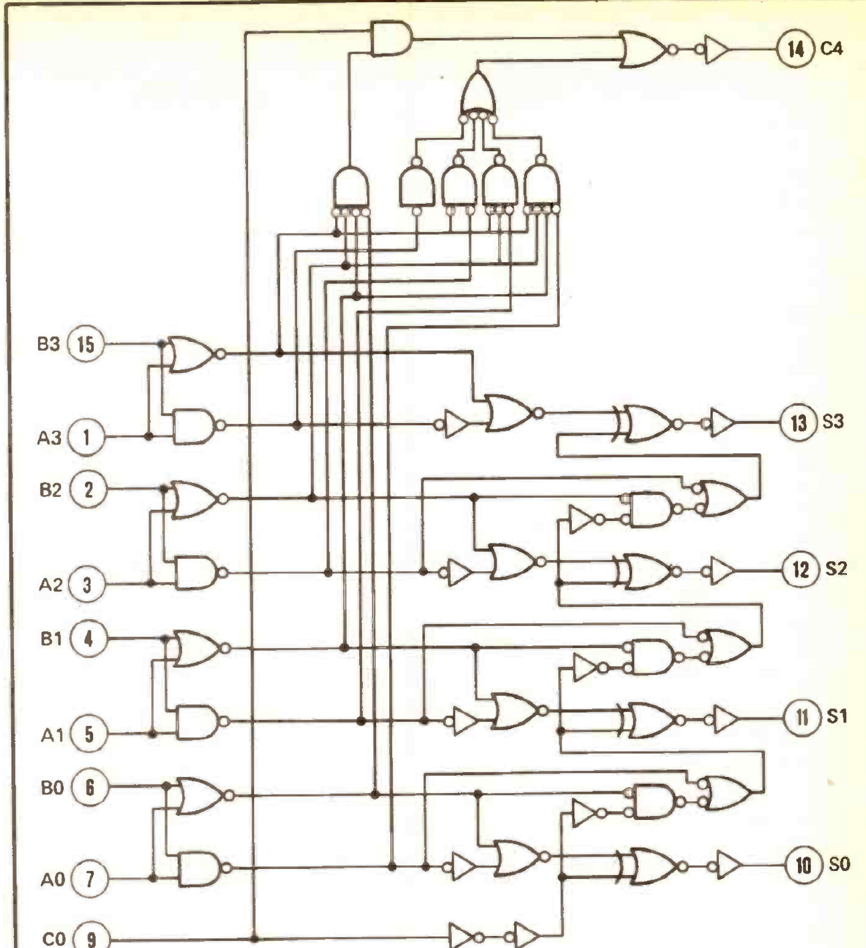


Fig.4 The circuit configuration for the 4008 binary adder IC. The pin out is shown on Fig.5.

to obtain the value of Fxtl, we obtain:-

Fxtl = (29.7 + 0.72 + 10.695)/2 = 20.5575MHz

I found it proved impossible for the existing crystal oscillator to increase the oscillator frequency by reducing the capacitance in series with the crystal.

If instead we make N = 71, then:-

Fxtl = (29.7 + 0.71 + 10.695)/2 = 20.5525MHz

The 20.555MHz crystal can be pulled down to 20.5525MHz on the PTOSO11AOX PCB by removing the 33pF capacitor in parallel with the crystal trimming capacitor, and replacing it with a 150pF capacitor. In the case of the PTBMO59COX PCB, a 150pF capacitor must be connected in parallel with the crystal trimming capacitor CT4. Some difficulty was experienced in pulling the frequency of the 10.2775MHz crystal down, such that the output doubled frequency from the secondary of T1 was 20.5525MHz. You may have to replace the 10.2775MHz crystal with a 10.27625MHz crystal. But it is a very small price to pay!

Binary Code

The existing binary code produced by the channel switch can be obtained from **Table 4**. In the unconverted set, the program lines PO – P5 are connected directly to the channel control switch, and program lines P6 and P7, are connected to Vdd which produces logic level 1. Program line P8 is grounded giving logic level 0. The actual binary value of the switch for each channel can be obtained from program lines PO-P5. **Table 5** shows the binary and logic levels for channels 1, 30, and 40. The binary value of the channel switch on channel 40 is 19. From the previous calculations we require a binary code of 71 with the crystal oscillator operating at

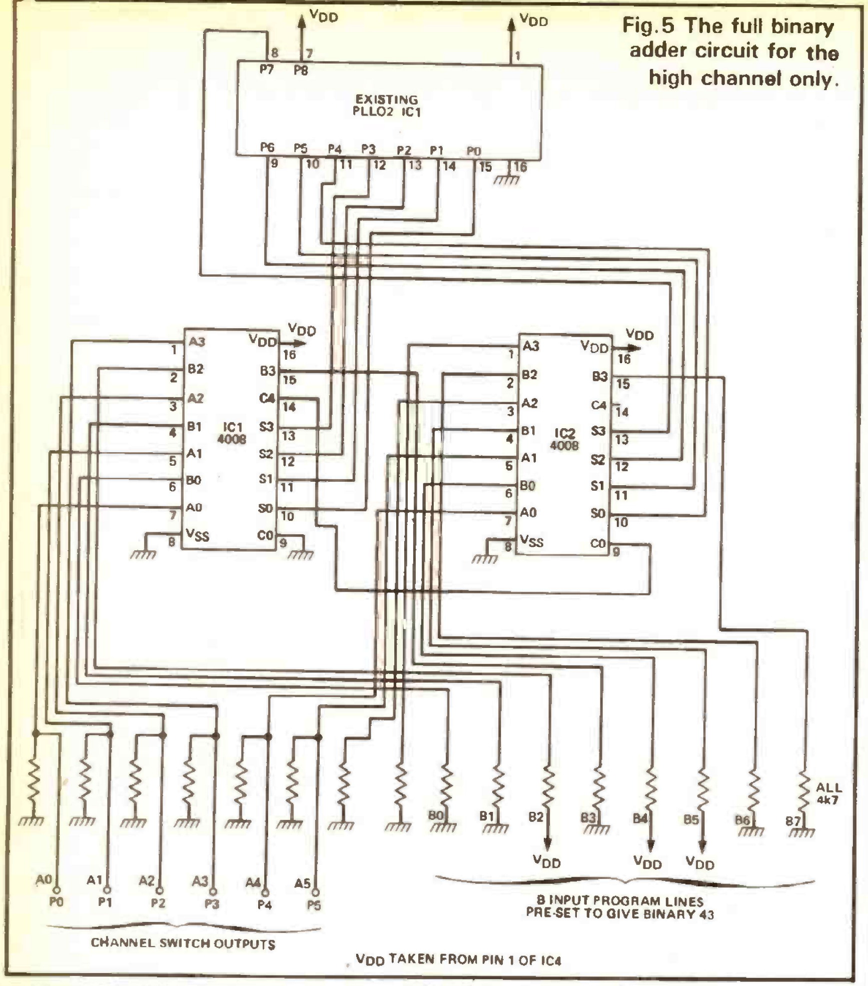


Fig.5 The full binary adder circuit for the high channel only.

How the Ham International Multimodes Work

PLL CIRCUIT

All the models listed in Table 1 use the same phase lock loop circuitry, which uses the PLLO2 chip to produce the various frequencies necessary for the set to operate on CB. The block diagram which is common to all the models is shown in Fig 1.

The PLL loop comprises of a reference crystal oscillator operating at 10.24MHz, which is fed to pin 3 of the PLL chip. Pin 3 is the input to a fixed frequency-divider, known as the 'divide by R' divider. This divides by a fixed number, 1024 to produce a 10kHz reference input to the phase comparator.

A sample of the output frequency produced by the PLL circuit is fed to pin 2 of the PLL chip. Pin 2 is the input to the programmable divider which divides the input frequency Fin by a number N. N is selected by a logic code produced by the channel switch. The output of the programmable divider is fed to the other input of the phase comparator where if compared with the reference 10kHz fed to the other input. The phase relationship between the two inputs to the phase comparator produces a DC voltage at pin 5 of the PLL chip which is fed to the VCO, via a low pass filter. Therefore the output voltage produced by the phase comparator, controls the output frequency of the VCO.

To produce the correct operating frequencies required for American CB, the VCO operates in the frequency range of 17.555MHz to 18.445MHz in the AM/FM/USB mode.

The technology used in the PLLO2 is quite old when compared with the technology available today. The maximum input frequency, Fin, to the programmable divider is limited to approximately 4.5MHz, because of the timing delays within the programmable divider. For the PLLO2 chip to be used in a circuit which generates frequencies suitable for CB, some form of prescaling or down mixing must be used to ensure that Fin remains below 4.5MHz. The circuit designer has opted for a very clever arrangement, where the output of the VCO is fed to a mixer which forms part of IC2, where the VCO frequency is mixed with the frequency of a crystal oscillator.

One of the predominant frequencies produced as a result of mixing comprise of the crystal oscillator frequency, minus the frequency of the VCO Fxtl – Fvco. This is the filtered out of the mixer by a low pass filter and fed to the input of the programmable divider — thus completing the loop. The other predominant frequency produced is Fxtl + Fvco obtained at the output of the mixer by a band pass filter comprising of T2 and T3. This frequency is fed to both the receiver first mixer Q22, and the transmitter mixer, IC3, where 10.695MHz is added, under transmit conditions on AM/FM/USB, to produce the final transmit frequency. This circuit configuration ensures that the VCO is operating at a frequency well below the operating frequency of the set and also ensures that Fin is kept below 4.5MHz.

THE PROGRAMMABLE DIVIDER

The value of the divide by N number is determined by the value of the binary logic code presented to the program code inputs P0 — P8, pins 7-15 on the PLL01 chip. The PLLO2 chip is a CMOS device where logic level 1 can be represented by a positive voltage anywhere between +4V up to approximately 9V. The logic truth table for the PLLO2 chip is shown in Table 7. The range of divide by N numbers varies between 2 and 511, where all the logic inputs are at logic level 1. From Fig. 1 it can be seen that the channel switch is permanently connected to program line inputs P0 — P5, P6 and P7 is permanently connected to Vdd, logic level 1, and P8 is grounded to give logic level 0. The input codes together with the resulting value of Fin is given in Table 4.

For the loop to be locked, it is necessary for the frequency being sampled by both inputs to the phase comparator to be at the same frequency namely 10kHz. By altering the divide by N number the frequency being generated varies in 10kHz steps. Thus from Table 4, it can be seen that the value of Fin jumps in 10kHz steps when the logic codes are changed by the rotation of the channel select switch.

You will also observe from Table 4 that the frequency in a small number of channel positions will jump forwards or backwards by more than 10kHz. This is due to the F.C.C. specification which calls for some frequencies to be skipped altogether. For example, the set operating frequency jumps 20kHz between channels 3 and 4 and again between channels 7 and 8. The most confusing jump in frequency is that which occurs downwards between channels 23 and 24.

Rotating discs connected to a common central shaft in the channel switch produce the program logic code. These are made from double sided PCB which has been etched to provide the correct logic codes for each channel selected. The central wiper contact is connected to Vdd. Internal pull down resistors are provided within the PLLO2 chip to produce logic level 0 when the channel switch contact is open and the program line is disconnected from Vdd.

Additional rotating discs provide the correct code to drive the two seven segment LED displays — the visual indication of the channel number selected. It would be very difficult to alter the program codes to make the channel number relate correctly to operating frequency, or to change the logic

Table 7 The truth table for the PLLO2 chip.

SELECTION									DIVIDE BY N
P_8	P_7	P_6	P_5	P_4	P_3	P_2	P_1	P_0	
0	0	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	0	1	3
0	0	0	0	0	0	0	1	0	2
0	0	0	0	0	0	0	1	1	3
0	0	0	0	0	0	1	0	0	4
•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•
0	1	1	1	1	1	1	1	1	255
•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•
1	1	1	1	1	1	1	1	1	511

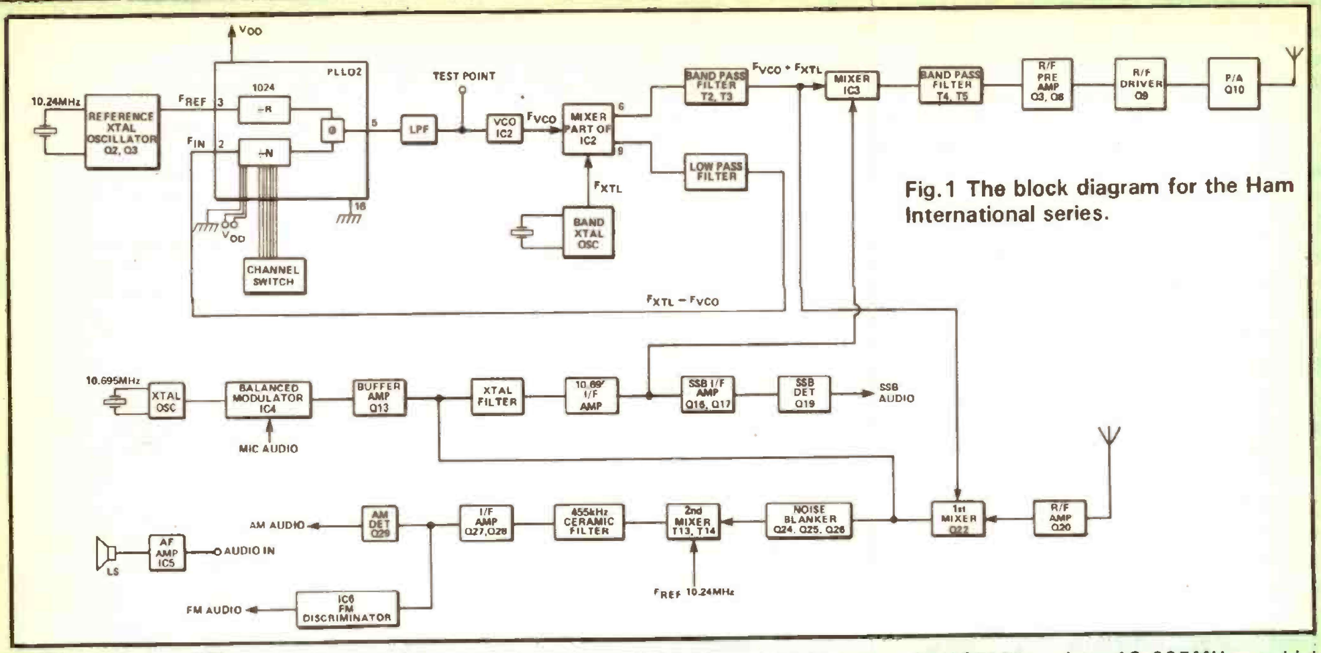


Fig.1 The block diagram for the Ham International series.

codes outright to alter the operating frequency say from 11m to 10m. One method of achieving this is to use an EPROM which will be discussed in the second part.

THE BANDS

Each band of 40 channels is selected by the down mixer crystal oscillator. This is sometimes refered to as the band crystal oscillator, whose frequency, Fxtl, is fed to a mixer which forms part of IC2. In the unconverted set, the three crystal frequencies for each group of 40 channels are 20.105MHz, 20.330MHz, and 20.555MHz for the PTBM121D4X PCB, and at half the frequency for the PTBM059COX PCB. The crystals operate in a fundamental mode with a capacity of about 28pF.

In the Multimode II and Jumbo models, the crystal oscillator circuit is different. The crystal oscillator is contained on PCB number PTOS006A0X and it oscillates at half the frequency. This is then doubled by a tuned circuit comprising T1 to arrive at the correct frequency to be injected into the mixer IC2.

LOOP FREQUENCIES

In the unconverted set, the VCO operates in the frequency range of 17.555 – 18.445MHz in the AM/FM/USB mode and 17.5535 – 18.4424MHz in the LSB mode. The additive products of mixing Fvco and Fxtl will produce frequencies operating in the range 37.66 – 39.0MHz in the AM/FM/USB mode and between 37.657 – 38.997MHz in the LSB mode.

A low pass filter selects the subtractive product of mixing and will appear in the frequency range from 2.55MHz down to 2.11MHz. The band crystal oscillator will oscillate at 20.105MHz on the low band, 20.330MHz on mid and 20.555MHz on high for the AM/FM/USB modes of operation. When the LSB mode of operation is selected, the crystal oscillator will operate at a frequency 3kHz lower. This is achieved by transistor Q2, which changes the capacitance in the crystal oscillator circuit. Remember the Multimode II and Jumbo models' crystal oscillators oscillate at half the frequency; so on LSB, the crystal will operate at 1.5kHz lower. This will turn out to be 3kHz lower when the frequency is doubled by T1.

SIDEBAND OSCILLATOR

The sideband crystal oscillator, Q11 or Q12 depending upon the model you have, will operate at 10.695MHz in AM/FM/USB mode, and 10.692MHz on LSB. The output Fvco + Fxtl of the band pass filter T2 and T3 is fed to the transmit mixer IC3. There it is mixed with the frequency generated by the sideband crystal oscillator to produce a transmit frequency in the 26.965 – 28.305MHz frequency range.

On SSB, double sideband modulation is produced at the output of the balanced modulator IC4 with the audio output signal from the microphone amplified by IC5. The output of the balanced mixer is fed to a crystal filter which has a pass band restricted to 3.5kHz. Thus allowing only one sideband to pass through depending upon the frequency of the sideband crystal oscillator.

THE RECEIVER

The receiver RF amplifier will amplify signals in the frequency range 29.965 – 28.305MHz. This amplified output from RF amplifier, Q20, is coupled through T9 to the receiver first mixer, Q22. Here the signal is mixed with the injected frequency derived from the output of the band pass filter T2 and T3. The injected frequency will always be 10.695MHz higher that the receiver frequency on AM/FM/USB and 10.692MHz on LSB to ensure that the signal is further amplified by the receiver first IF amplifier.

FREQUENCY GENERATION

To fully understand the principles behind the operating frequencies generation, it is useful to select an operating frequency and follow it through the block diagram shown in Fig.1. In the un-modified set operating on AM/FM/USB on channel 30 on the high band, the operating frequency will be 28.205MHz. The frequency at the output of the band pass filter T2, T3 will be 28.205MHz plus 10.695MHz, which equals 38.9MHz. The VCO will be operating at a frequency of 38.9MHz minus 20.555MHz a resultant 18.345MHz. The frequency output from the low pass filter will be 20.555MHz minus 18.345MHz equalling 2.21MHz – the input sampling frequency Fin which appears at the input to the programmable divide by N divider.

You will remember that for the loop to be locked both inputs to the phase comparator must be at the same frequency. The frequency, 10.24MHz, of the reference crystal oscillator is divided by the fixed value, 1024, the divide by N divider. This appears at one input of the phase comparator at a frequency of 10.24MHz divided by 1024 which equals 10kHz.

Therefore, it is essential that the frequency presented to the other input of the phase comparator must also be 10kHz for the loop to be locked. With an input frequency to the programmable divider of 2.21MHz, the value of the dividing number N will be 2.21MHz divided by 10kHz which gives a value of 221. The logic levels that must appear on the program lines to produce a divide by N number of 221 will correspond to the binary value of 221 obtained from Table 7.

To obtain a binary value of 221 it is required that program lines 2^7, 2^6, 2^4, 2^3, 2^2, and 2^0 should be at logic level 1, and the remaining logic lines should be at logic level 0. This will give a binary value of 128 plus 64 plus 16 plus 8 plus 4 plus 1, which equals 221. This logic bit pattern for channel 30 and the value of Fin agrees with the information shown in Table 4.

The operating frequency of the set can be altered by changing the value of N which in turn changes the value of the DC output from the phase comparator. This also controls the operating frequency of the VCO, which after mixing will affect the value of Fin – thus completing the closed loop. The operating frequency of the set can also be changed by altering the frequency of the band oscillator or down mixer crystal oscillator. With this series, different bands of 40 channels are selected by altering the crystal frequency of the band oscillator.

20.5525MHz. Therefore some gadget needs to be inserted between the channel change switch and the program lines to the PLL chip.

A cheap method of altering the program code is by using binary addition. To obtain the desired binary code of 71 for channel 40, we need to add a binary value of 52 to the channel switch code of 19. This binary value difference remains constant throughout the 40 channels. Therefore the binary values for channels 1, 30, and 40 together with the required logic levels is shown in **Table 6**.

Adding Gadget

Motorola have on the market an integrated circuit which costs about £1, which will do the job of adding two binary numbers together. It is a 4000 series CMOS type 4008, which is a four bit binary full of adder with two four bit data inputs — A_0 — A_3 and B_0 — B_3 — a carry input C_0, four sum outputs — S_3, and a carry output C_4. The type 4008 also incorporates full look ahead across 4 bits to generate the carry output C_4. This minimises the necessity for extensive look ahead and carry cascading circuits. The full circuit configuration and pin out functions are shown in **Fig. 4**.

To obtain the required binary number two 4008's will be required. The circuit diagram of the binary adder circuit is shown in **Fig 5**. The input program lines for both IC1 and IC2 are grounded through 4.7k ohm resistors to ensure that they are at logic level 0 when not being used. The logic outputs of the channel change switch are connected to A_0 — A_3 for IC1 and A_0 — A_1 for IC2. A_2 and A_3 of IC2 are not used and are therefore grounded through 4.7k ohm resistors to ensure that they remain at logic level 0.

The B inputs for both binary adder ICs are fed via 4.7k ohm resistors to either Vdd or ground to achieve the binary value of 52. The carry output of IC1 is connected to the carry input of IC2 to obtain full carry over between the two binary adder ICs. The carry input of IC1 is not used and is grounded to ensure that noise cannot trigger the input to give an incorrect output code. The carry output of IC2 is not used and pin 14 is left open circuited. The power consumption for the 4008 is less than 2 milliamps and therefore it is acceptable to use the same voltage rail which feeds the PLL02 chip.

Construction

The two binary adder IC's are mounted on a small piece of Vero board. It is wise to use IC holders and complete the soldering before inserting the two ICs to avoid possible damage. The resistors are also mounted on Vero board and ribbon cable was used to connect the Vero board, channel switch and PLL chip. The Vero board was mounted to the side of the metal chassis using a right angle bracket of the style used to mount the other sub PCBs.

In the second part, Roger will be dealing with the extended frequency range, the EPROM to be used, and the repeater shift.

Free Readers' ADS!

WANTED

WANTED Yaesu YK-901 keyboard also a late FRG7700M reasonable proce please. Phone Colchester 394336 (Essex).

WANTED for spares non working Hammarlund HQ180 Rx, with clock timer. Also matching speaker model S-200 for HQ180A Rx. Must be in good condition. 0875 52317.

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WANTED Radcom and QST magazine reviews of Yaesu FT301 Tx/Rx and accessories. Expenses paid. Tel St Albans 39333.

WANTED for JR310 Trio, 19.955 MHz crystal and 10AZ narrow filter. Also any parts of chassis etc for JR310. Harmer, 9 Park Square East, Jaywick, Clacton, Essex.

WANTED Icom IC730 FM board. Must have fitting instructions etc or full circuit diagram and construction details — David GOAFP tel 0900 826461.

WANTED Practical Wireless 1930s 1960 Radio Constructor Bernard, book George Newnes, fair price paid. J Savage, 7 Weyhill Close, Park North, Swindon.

WANTED 3 element tri band beam and rotator must be good working order. Good price paid for right units. Phone 0647 52520.

WANTED Palm 2 or Palm 4 handheld transceiver or similar commercial equipment for V/UHF also lowband handheld, all must be complete. No silly prices please. Phone John 0280 702900.

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WANTED RTTY transceive program for Commodore C16, on cassette. Also copy of circuit diagram C16. G6KYT tel 0424 213479. 9 Collington Ave, Bexhill, East Sussex TN39 3PX.

WANTED urgently DSB 80,