Using the Verticom MTS1500 Series Oscillators

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Introduction

This project had origins while in hospital at the end of December. There was to be a New Year's Day auction selling off a Dallas ISPs equipment. I wouldn't be out of hospital in time so WA5VJB was asked to pick up "something interesting". The item I got was a 39GHz head unit, used as a wideband ISP link. Opening the waterproof box I found PCBs loaded with integrated circuits which could have been useful for the junk box, ***but*** were coated in thick layers of varnish. There were some mixers and 39GHz RF stages but no data could be found on them. Attention was then drawn to a couple of microwave oscillator units mounted on large heatsinks both connected to a 50MHz reference oscillator. Removing the units they were both found to be Verticom MTS1500e-169-01 units covering 18125 to 19175MHz. No information could be found on them despite an extensive web search, so they were put aside.

Later in the year, shortly after publishing the writeup on the MC2000 oscillator in Feedpoint (1) I received an email from Alan Avery, VK2AXA saying he had a couple of MTS1500E-169-02, 12490-13335 MHz Verticom YIG oscillators which required SPI signals; could I modify the MC2000 code to drive them? The good news was that he had the datasheet. When the data sheets arrived it was found to contain information on the whole range of MTS1500 oscillators (reproduced in figure 1) and the programming details are shown in figure 2

Figure 1 MTS1500 Model parameter

Model #	Freq(min)	Freq(max)	Mult	FL	FH	STEP	FO	Fref	Fosc	DacGain
MTS1500-151-01	11200	12000	X1	11200	12000	0.416666667	10500	26.25	12000	0.5
MTS1500-151-02	10575	11400	X1	10575	11400	0.625	9975	26.25	11400	0.5
MTS1500-151-03	12200	13350	X2	6100	6675	0.625	7350	26.25	6900	0.5
MTS1500-162-01	7820	8210	X1	7820	8210	0.5	6825	10.5	8210	0.5
MTS1500-162-03	10490	11100	X1	10490	11100	0.5	9975	10.5	11300	0.5
MTS1500-168-04	6450	6833.33	X1	6450	6833.33	0.4167	7350	26.25	6900	0.5
MTS1500-168-05	8100	8483.33	X1	8100	8483.33	0.4167	7350	26.25	8500	0.5
MTS1500-178-01	8000	9000	X1	8000	9000	0.5	7350	10.5	9100	0.46
MTS1500-241-01	5800	6800	X1	5800	6800	0.25	7350	10.5	6900	0.46
MTS1500-591-10	5900	6425	X1	5900	6425	0.5	7350	10.5	6900	0.5
MTS1500-888-01	8900	9800	X1	8900	9800	0.5	8400	10.5	9800	0.5
MTS1500-888-02	7100	8000	X1	7100	8000	0.5	6300	10.5	8200	0.46
MTS1500-888-03	8600	9500	X1	8600	9500	0.5	7875	10.5	9700	0.46
MTS1500-888-04	9000	9350	X1	9000	9350	0.5	8400	10.5	9700	0.5
MTS1500-888-05	9750	10150	X1	9750	10150	0.5	8925	10.5	10400	0.5
MTS1500-888-06	9300	10000	X1	9300	10000	0.5	10500	10.5	10400	0.46
MTS1500-888-08	6000	6500	X1	6000	6500	0.5	7350	10.5	6900	0.5
MTS1500-888-09	6500	7500	X1	6500	7500	0.5	5775	10.5	7500	0.5
MTS1500-888-10	6400	7200	X1	6400	7200	0.5	7875	10.5	7400	0.5
MTS1500-888-11	11200	12000	X1	11200	12000	0.5	10500	10.5	12000	0.5
MTS1500-9511	9500	10500	X1	9500	10500	0.5	8925	10.5	10500	0.5
MTS1500E-168-07	9216.67	9496.67	X1	9216.67	9496.67	0.58333	8400	26.25	9700	0.5
MTS1500E-168-08	17600	18470	X2	8800	9235	0.5	9975	10.5	9700	0.5
MTS1500E-169-01	18125	19175	X2	9062.5	9575	0.5	8500	10	9700	0.5
MTS1500E-169-02	12490	13335	X2	6245	6667.5	0.625	7500	25	6900	0.5
MTS1500E-176-01	8750	9750	X1	8750	9750	0.5	10500	10	9750	0.5

Figure 2 MTS1500 Data word format

CW1

B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30
0	0	0	0	0	0	0	0	0	1	R LSB	R	R	R	R

B31	B32	B33	B34	B35	B36	B37	B38	B39	B40 *
R	R	R	R	R	R	R	R	R MSB	1

*FIRST BIT
SHIFTED IN

CW2

B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
G LSB	G	G	G	G	G MSB	0	0	0	0	C LSB	C	C	C	C

B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30
C	C	C	C	C MSB	0	0	0	0	0	S LSB	S	S	S	S MSB

B31	B32	B33	B34	B35	B36	B37	B38	B39	B40	B41	B42	B43 *
0	O	P LSB	P	P	P	P	P	P	P	P	P	P MSB

The oscillators did indeed require SPI signals as in the previous projects (2) (3), easily generated in an 8 pin flash programmable PIC. The data needed to be sent was 2 words, control word 1 (CW1) and control word 2 (CW2). CW1 is 40 bits long, CW2 is 43 bits long. CW1 contains the reference divider ratio control (R; 14 Bits) which is fixed for a particular model. . CW2 contains the loop gain control (G; 6 Bits), Pretune control (C; 10 bits), and feedback divider ratio control (S; 5 bits, P; 11 bits)). Therefore to change the frequency only the CW2 word needs changing after CW1 has been written once. From the data sheets the values are calculated as follows:-

Fout= [(32*P) + S] x STEP + F0

N= abs (Fout-FO)/STEP

P= INT (N/32)

S=N – 32 * P

R = Fref/STEP

Pretune control (C) = INT (512-DACGain*(Fosc – Fout) + 0.5)

Gain = .269* (Fout-FO/ (FH-FO)

Loop Gain control (G) = INT (1.66*((1/Gain)-1))

Where:-

Fout = Desired output frequency

FL = Low end of specified tuning range (defined in tuning parameter table)

FH = High end of specified tuning range (defined in tuning parameter table)

Fosc = Frequency of internal oscillator with 0 tuning current (defined in tuning parameter table)

FO = Internal mixer offset frequency (defined in tuning parameter table)

DAC Gain = Scale factor to adjust DAC range (defined in tuning parameter table)

Example

Put mts1500e-169-01 on 18994MHz (18994 times 4 = 75976MHz)

As the unit contains a doubler the design frequency is 18994/2 = **9497MHz** = Fout

From the data sheet:-

Fl = 9062.5 Fh = 9575 Fosc = 9700 FO = 8500 DAC Gain = 0.5 Fref = 10 STEP = 0.5

Substituting we get the following decimal values. The binary value with the required number of bits is shown in brackets after the decimal value.

N = ABS (9497-8500)/0.5 = 1994

P = INT (1994/32) = **62 (00000111110)**

S = 1994 – 32 * 62 = **10 (01010)**

R = 10/0.5 = **20 (00000000010100)**

Pretune control (C) = INT (512-0.5*(9700-9497) + 0.5) = **411 (0110011011)**

Gain = .269* (9497-8500/ (9575-8500) =0.249

Loop Gain control (G) = INT (1.66*((1/4)-1)) = **4 (000100)**

Assembling these values as in figure 2 we get:-

CW1 = 100000000010100100000000000000000000000

CW2 = 000001111100001010000001100110110000000100

These are the values that have to be sent as SPI signals to the unit. Very little adjustment to the MC2000 code was needed to send the data to the Vectron unit. The software was written in assembler using the free MPLAB IDE software from Microchip (4). It was decided to incorporate the facility for the PIC to move between two frequencies depending on the state of pin 4 of the PIC. This would allow programming a second frequency for receiver local oscillators. The other frequency programmed in this case was 9443MHz (75976 to 432MHz RX LO). The assembler listing is available at (5).

Circuit

The circuit diagram used for testing is shown in Figure 3. The component listing is shown in Table 1.A PCB was designed, the layout is shown in Figure 4 with the component layout in Figure 5. Note the 7812 and 7808 regulators, LED and C4, C5 and C6 are not mounted on the board. The regulators both require a heatsink. Figure 6 shows the populated board mounted on the MTS1500-169-01. A 0.1” right angled female header was used to plug the PCB directly onto the pins of the oscillator.

Figure3. Circuit Diagram

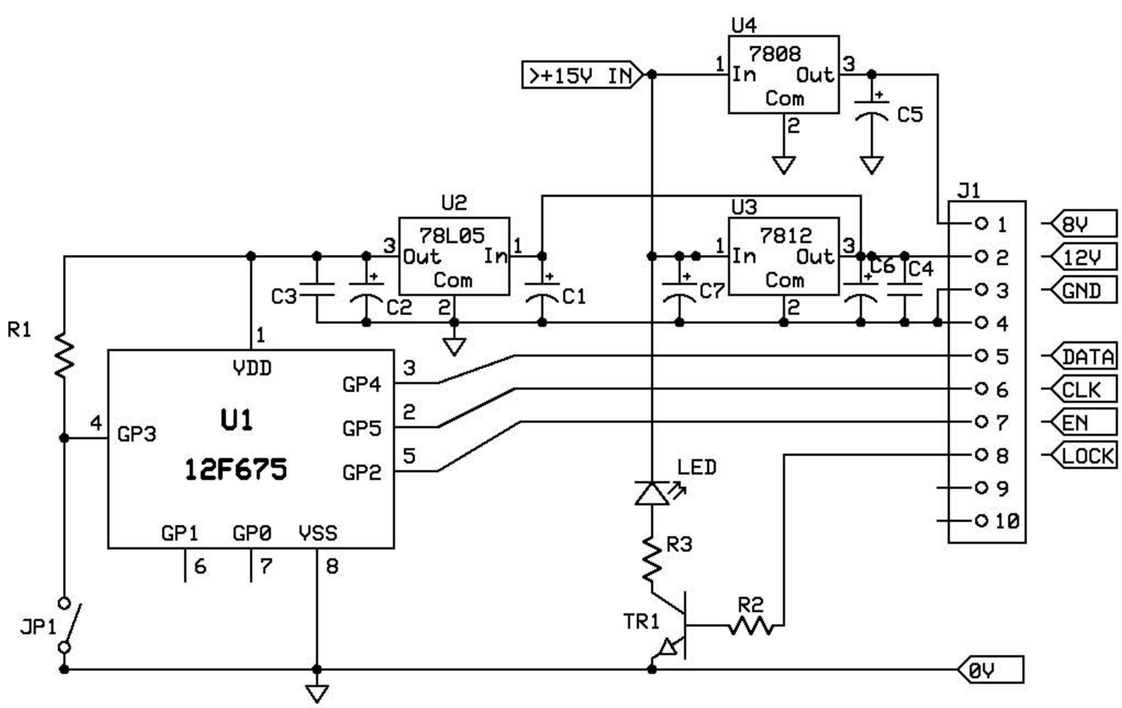


Table 1. Component listing

Component	Value	Component	Value
U1	12F675	R3	1k
U2	78L05	C1, 7	0.1u 25V Tant
U3	7812	C2, C5, C6	1uF 25V Tant
U4	7808	C3, C4	0.1uF ceramic
R1	10k	LED	To suite
R2	2k2	JP1	2 pin 0.1” jumper

Figure 4. PCB Layout

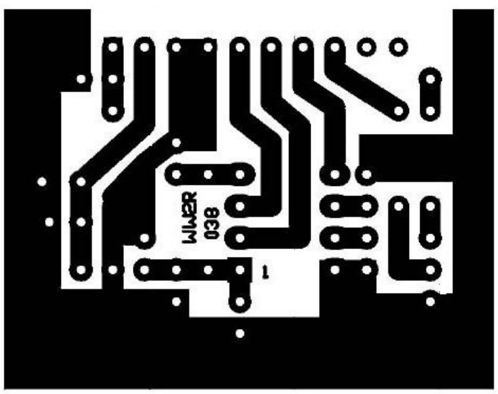


Figure 5. Component overlay

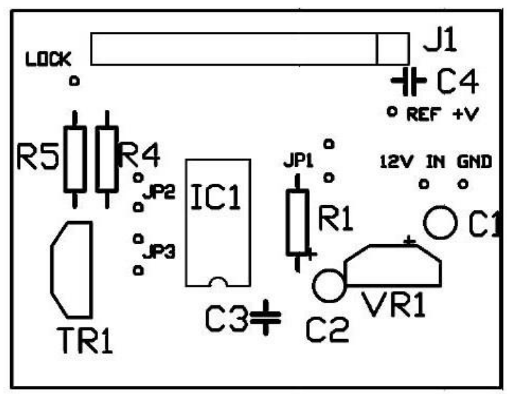
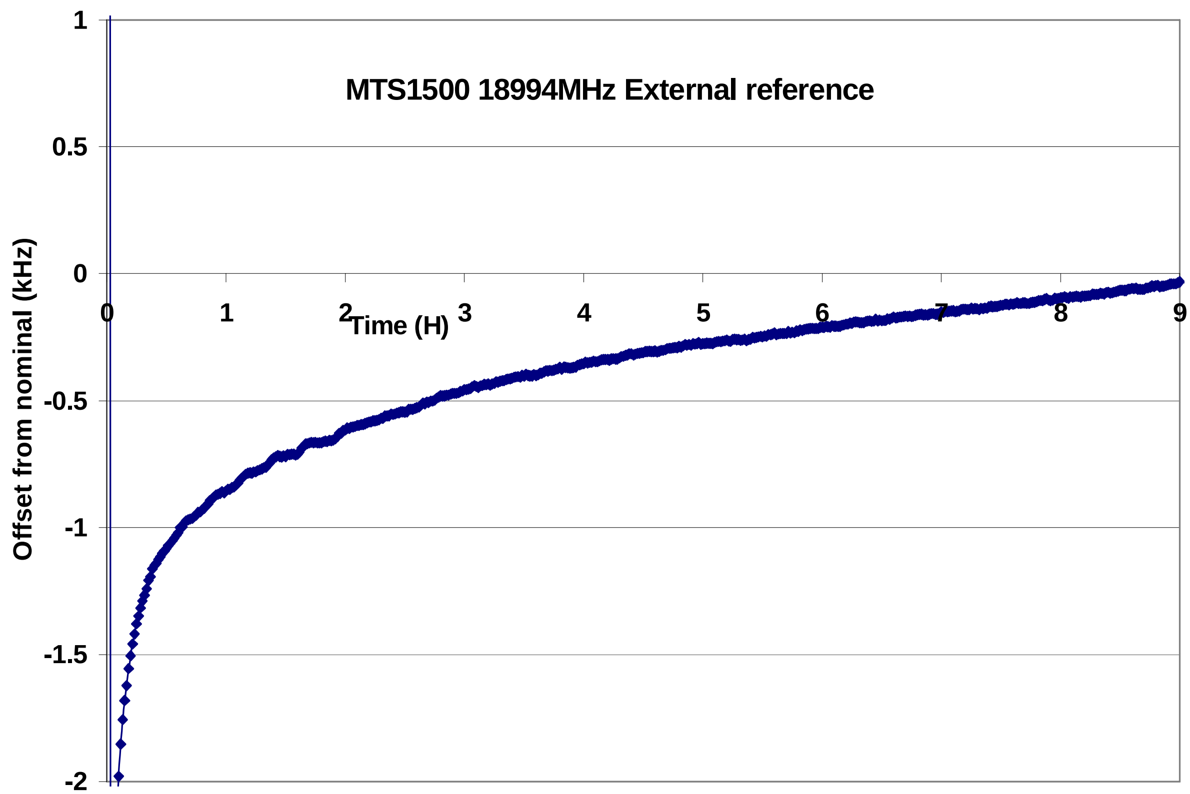


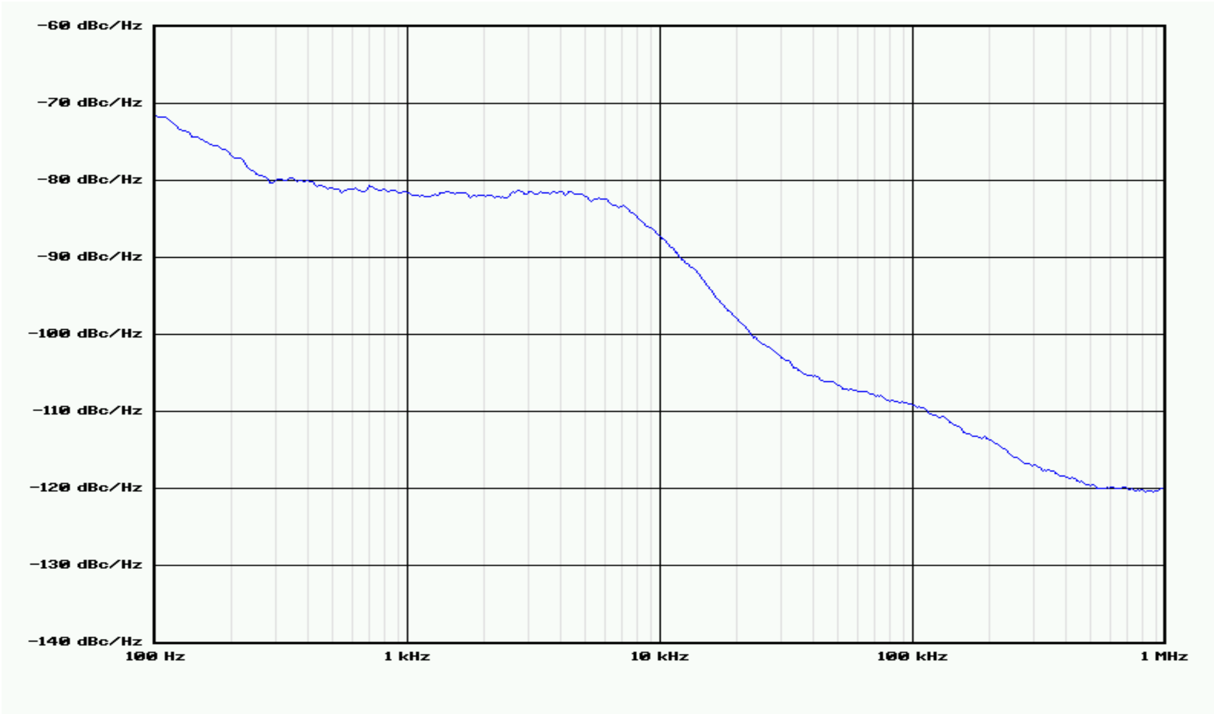
Figure 6. Populated PCB attached to unit

Results

Upon powering up the unit an output of 12dBm was seen on the correct frequency. Investigations showed that no current was being taken from the 8 Volt regulator, despite the need for 8V being specified in the data sheet. The unit took 0.7A from a 15 Volt supply. To test the stability of the unit readings of frequency were taken at 1 minute intervals using an HPIB controlled EIP548A counter with a Rubidium 10MHz reference oscillator. Communication between laptop and counter was done with a National PCMCIA GPIB card. The results are shown next



The oscillator took around 35 minutes to be within1kHz and stayed within 1kHz for 9 hours. The phase noise was measured using KE5FX's software (6), using an HP8563E spectrum analyser with a Rubidium 10MHz reference oscillator. The results were as follows:-



Further developments

Next the needs of VK2AXA were investigated. He required 2 dual frequency PICS for his units; 12600/12867.5MHz and 12672.5/13083.75MHz. It was at this point that it was decided that some way of automating the calculation of the values to be put in the PICS was needed to avoid having to repeat the calculations above. An .xls spreadsheet was developed (7) that automated the process, only the output frequency and the model number needed entering in the sheet to generate the outputs, the appearance is as follows:-

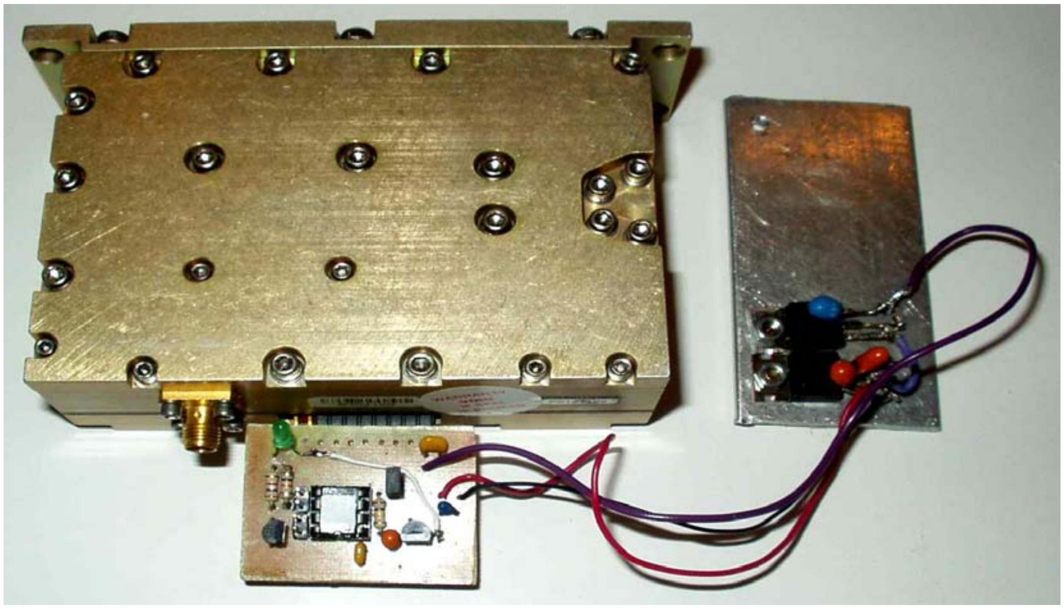
Source	Fl	Fh	STEP	FO	Fref	Fosc	DACGAIN	OUTPUT FREQ	Brick Calc Freq
mts1500e-169-01	9062.50	9575	0.5	8500	10	9700	0.5	18886	9443

	DECIMAL	BIN	
N	1886.00		
P	58.00	00000111010	11 bits
S	30.00	11110	5 bits
R	20.00	00000000010100	14 bits
C	384.00	0110000000	10 bits
G	0.235969		
GN	5.00	000101	6 bits

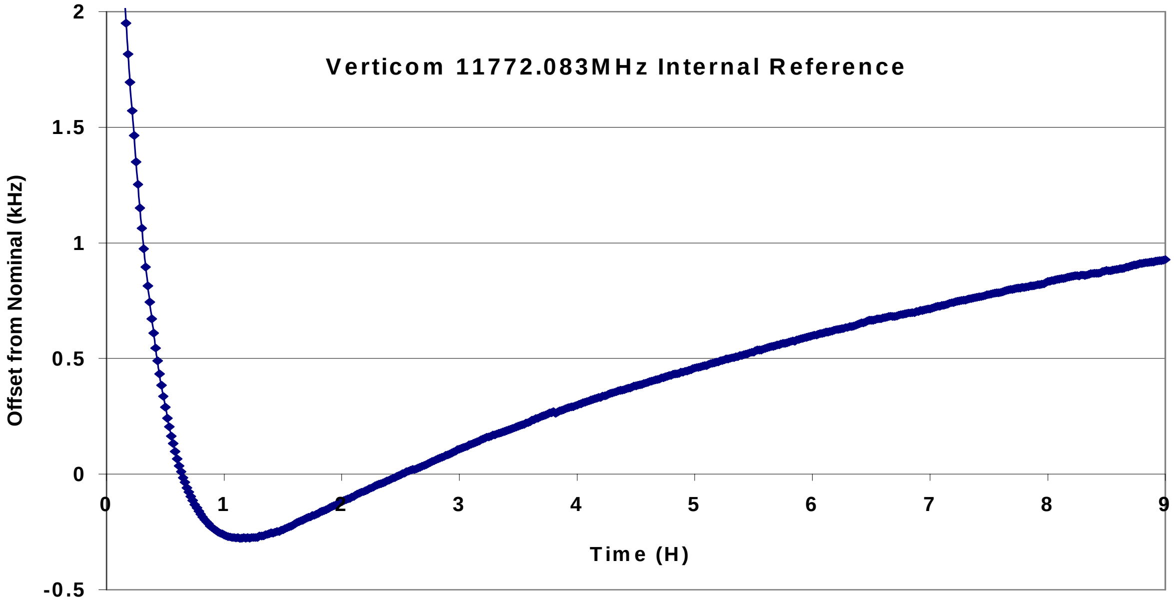
CODEWORD1 (BIN)	1000000000101001000000000000000000000000		80	29	00	00	00
			(HEX)				
CODEWORD2 (BIN)	0000011101000111100000001100000000000000101	000 ^HARD CODED	3A	3C	06	00	05
			(HEX)				

Note that Excel must have the Analysis toolpak plug-in installed for correct operation. If a frequency cannot be generated a warning will appear on the spreadsheet. The Excel programme also generates a sheet that can be cut and pasted into the assembler listing.

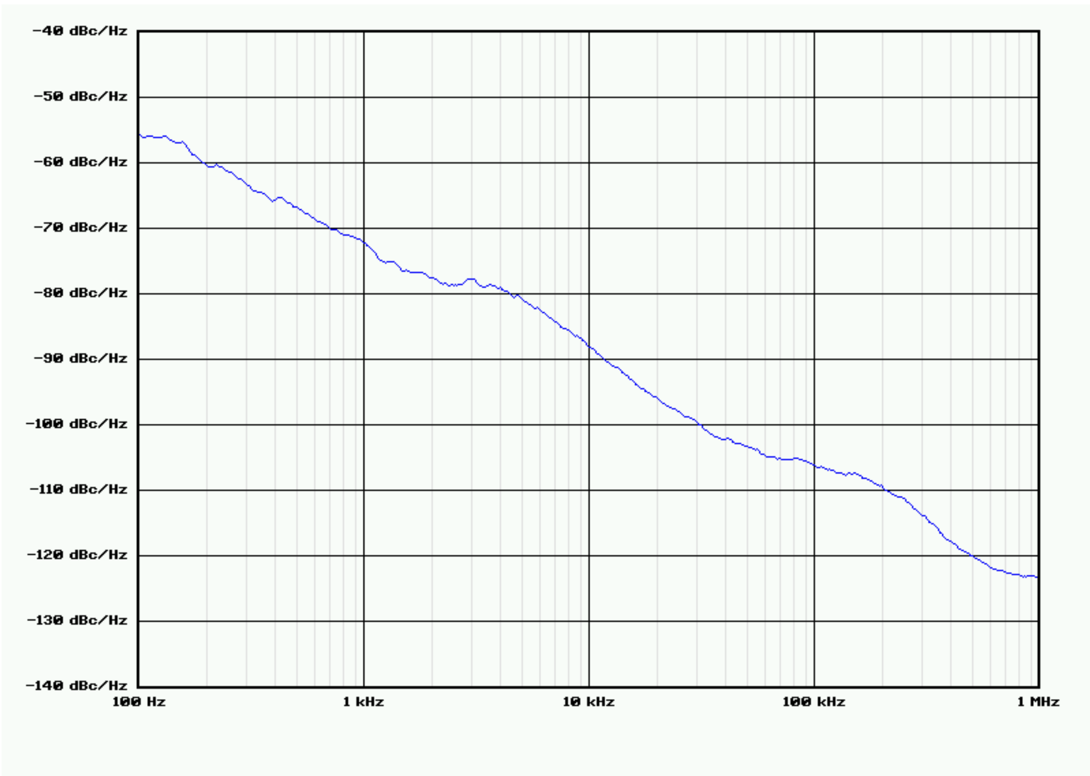
At this point an MTS1500-151-01 11.2 to 12GHz source was obtained. This had an internal oscillator which provided a 26.25MHz reference. It had steps of 0.416667MHz which meant it would be less versatile than the 19GHz version. After playing with Excel spreadsheets some useful frequencies were found. 11.66375GHz (47088/433), 11.772083333GHz (times 4 = 47088.333) and 11.88GHz (24192/432). To test the source it was programmed on 11.772083GHz and tested. This time it was noted that current was drawn from the 8V supply; it appeared that the 8V requirement mentioned in the datasheet is ***only*** needed for sources with ***internal*** oscillators. The Verticom unit took 0.7A at 12V, whilst the 50MHz oscillator initially took 0.5A dropping to 0.2A at 12V after initial heating.



Again to test the stability of the unit readings of frequency were taken at 1 minute intervals using an HPIB controlled EIP548A counter with a rubidium 10MHz reference oscillator. The results are as follows:-



The oscillator took around 20 minutes to be within 1kHz and stayed within 1kHz for 9 hours. The phase noise was also measured using the KE5FX software, with the following results:-



Conclusions

This article has described how to deploy a couple of MTS1500 oscillators. Having now done the hard part, of working out how they operate, the author awaits the publication of some articles using it with interest!

References

1. http://g4fre.com/mc2000.htm
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3. http://g4fre.com/dfs1201.htm
4. www.microchip.com
5. http://g4fre.com/mts1500.zip
6. http://www.speakeasy.org/~jmiles1/ke5fx/pn.htm
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