The Frequency West brick are more Versatile than Advertised

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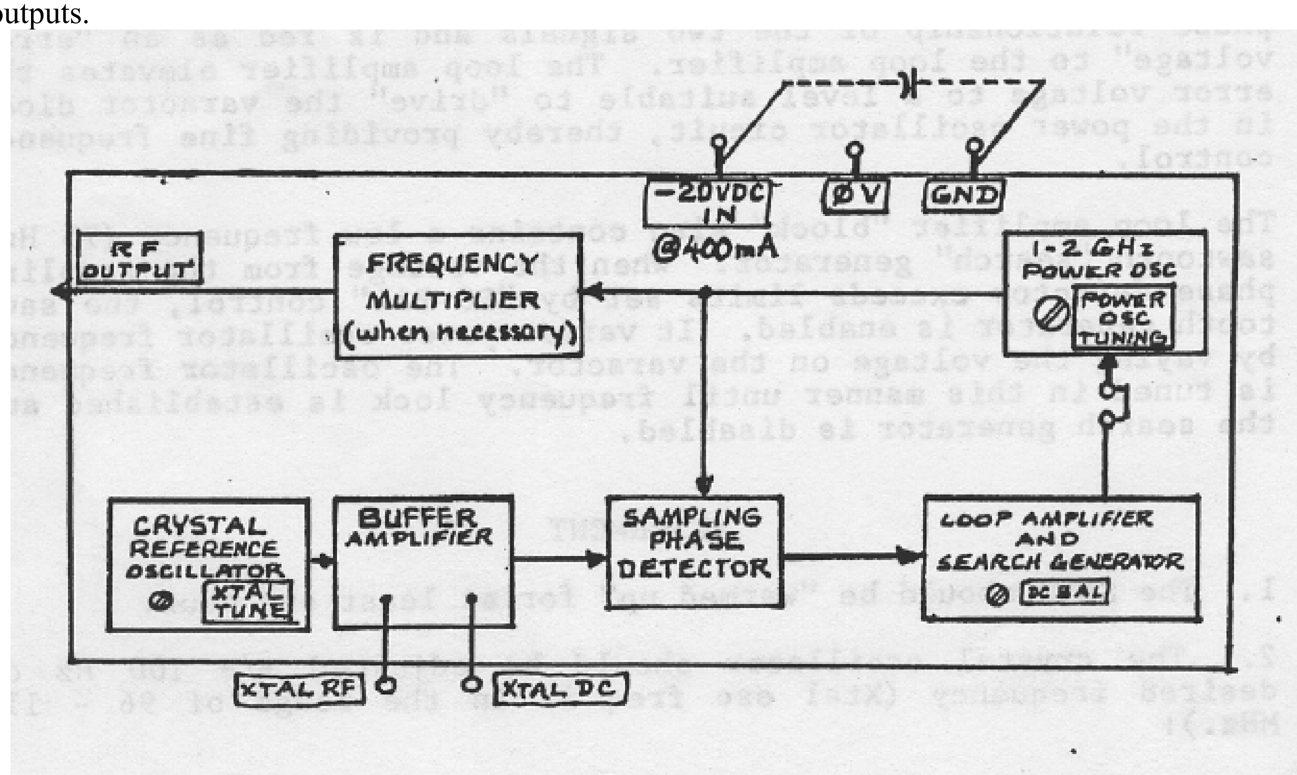
I have found Frequency West bricks with external reference whether factory or modified will lock to inputs from about 65 MHz to 140 MHz. Typically 0 dBm is adequate reference power. Outside the range 85 to 110 MHz they require more drive. Because of the increasing drive requirement I haven't tried much higher than 140 MHz. And then crystal oscillators are harder to make work going higher in frequency and new crystals are expensive. Basically all the bricks double the crystal frequency to the phase detector and then lock the 1.5 to 2 GHz VCO and pick harmonics off that VCO for the output. The VCO to output multiplier can be 4, 5, 6, 7, or 8 in typical designs that I'm interested in.. The phase detector harmonic can be any harmonic of the phase detector running at twice the reference frequency. The apparant design range is VCO 14 to 20 times the crystal, and those factors multiplied 1 to 8 depending on the desired output frequency to have output that passes through the output filter. This Frequency West block diagram from their brochure says the VCO can tune below 1.5 GHz but I think all the ones I've tried in the 8 to 12 GHz range tuned 1.5 to 2 GHz. I see in my scribbled notes that one with output centered on 13GHz that the VCO computed to be locked on 2.338 GHz for one combination of reference and output frequency. So the VCO may go higher for higher outputs and lower for lower outputs.



The FW model MS-830XEL-30 set for 12750 MHz divided by 7 would put the VCO at 1,821.428571 MHz, and 18 times a reference frequency of 101.190476 MHz center of both design ranges for an overall multiplication factor of 126. In my experience that VCO would lock at that frequency with the reference frequency as low as 65.051, plus 70.0549, 75.892857, 82.792208, 91.071429, 101.190476, 113.839286, 130.102041, and maybe 151.785714. These all would produce an ouput of 12,750.000 MHz. Actually the practical limit for the output frequency range is only the bandwidth of the output filter, probably at least 600 MHz at 12,750. And often listed on the name tag. It is possible to move the output filters some but is not a simple adjustment. Manually sweeping with a good signal generator for the test reference I have found down below about 70 MHz that there is a lock harmonic, for any input in that range, within the VCO sweep search range. That makes it unreliable about powering up on a particular harmonic. What that means is that the VCO search sweep range is at least 60 to 70 MHz. I don't trust it to pick the same harmonic as I want so I avoid using references that low in frequency other than the signal generator tests.

The VCO should tune down to 1.59375 GHz and multiply to 12750 by a factor of 8. And then there's a whole different sequence of reference frequencies using multipliers of 192, 176, 160, 144, 128, 112, 96, and maybe 80. Of reference frequencies of 66.40625, 72.443182, 79.6875, 88.541667, 99.609375, 113.839286, 132.8125, and maybe 159.375.

I use a DC coupled oscilloscope to monitor the phase detector output test point. As I tune the VCO or the reference, when there's no phase lock the detector output sits at 0 or a significant fixed positive voltage. When I get close enough for lock the detector voltage moves towards the middle of the range and the optimum tuning point is to have the phase detector voltage at the middle of its operating range. That allows for the greatest power up error in both directions for later use.

You can pick your output frequency or reference frequency by the harmonics combining the effects of the two multiplier factors to get output to the filter pass band if you run the mechanical adjustment of the VCO frequency through its 1.5 to 2 GHz range that is typical. Anyway without moving the VCO setting it will lock at all the above input frequencies give or take that about 5% output filter bandwidth. Multipliers will be 196, 182, 168, 154, 140, 126, 112, 98, and maybe 84. With an 12.75 GHz output filter of 600 MHz bandwidth, the VCO can range from 1556 to 1631 for its 8th harmonic to pass through the filter and can range from 1778 to 1864 for its 7th harmonic to pass through filter. If the VCO tunes below 1.5 GHz, the 9th harmonic of 1383 to 1450 will pass through the filter. Then the reference frequency can be any even division of the desired VCO frequency chosen for the desired output frequency where the reference is between 70 and 140 MHz and the reference to VCO multipler is an even number. The internal crystal oscillator is more or less restricted to the factory defined frequency range without going in and expanding the tuning range of the crystal oscillator. These bricks are definitely more versatile with the external reference.

A set of inputs I have fed to a brick for 12024 output. First two colums are the input range that produced a phase lock, then the reference frequency for 12024 output and the multiplication factor.

Reference +1.5 dBm

54.449-59.146	57.807	x 208 = 12024
59.645-61.618	60.120	x 200
62.542-64.334	62.625	x 192
64.608-66.987	65.347	x 184
67.424-70.409	68.319	x 176
70.524-73.723	71.57	x 168
74.07 - 77.421	75.15	x 160
77.98 - 81.472	79.105	x 152
82.3 - 85.99	83.50	x 144
87.945-90.9	88.412	x 136
92.69 – 96.69	93.937	x 128
105.434-110.554	107.357	x 112

113.991-119.031	115.615 x 104	
123.480-129.035	125.25 x 96	+5 dBm Ref
134.841-140.649	136.636 x 88	+8.5 dBm Ref
148.58	150.3 x 80	+10.5 dBm Ref

With the VCO frequency at 3006 MHz it might have been a CTI imitation of a FW brick.

Testing another brick with the reference held constant and mechanically tuning the VCO for the available output frequencies. First column the reference frequency. Then the total multiplication factor, the output frequency, the VCO frequency and the VCO multiplication factor.
Varying the VCO mechanical tuning for variations on an input reference frequency.

105.001	x 96	10080.092624	1680	x 6
105.001	x 102	10710.098182	1785	x 6
105.001	x 108	11340.079786	1890	x 6
108	x 102	11015.960	1836	x 6
107.998	x 96	10367.942	1728	x 6
107.999	x 105	11339.924	1620	x 7
100.002	x 102	10200.190	1700	x 6
100.002	x 108	10800.213	1800	x 6
100.002	x 114	11400.230	1900	x 6

It may be possible to tune the amplifiers between the reference and the phase detector to minimize the required reference power but a few dBm is so easy to achieve with a wide selection of dependable MMIC like MGA-0685 it isn't worth the bother of trying to tune the circuits that weren't designed to be tuned in the field.

It may be possible to drive the reference input in the 200 MHz range, and avoild the frequency doubling but I haven't tried that.

The step recovery multiplier multiplies by any integer. The reference is doubled for the phase detector so the PLL only works to lock the VCO on even multiples of the reference frequency input.

The output filters I've looked at retuning hid the tuning screws under the stick on label and use tiny tuning screws requiring allen wrenches in the range of .027 to .054” with lock nuts in the range of 3/32” to 3/16” hex. To lock the nuts without losing the tuning adjustment its important to have a nut driver that will pass the allen wrench, like a 1/4” square drive socket to match the nut used with finger power on the outside of the socket, providing its wall is thin enough to fit the recess. I didn't find the socket I bought for that today. I haven't yet tuned any filters either.

CRYSTALS

Most bricks with internal use crystals in the TO-5 three lead package in a small crystal oven. There are at least a couple crystal houses that can make them for a fairly high price. ICM is one of them that is a very reliable crystal maker. Unfotunately a recent ARRL newsletter said ICM is going out of business soon. There are particular temperature, mode, and external capacitance specifications to be met if one wants the frequency to be precise.

Two lead HC-49 crystals with wire leads have the same spacing for the leads and the same diameter lead wire. The HC-49 crystal is taller and won't allow the crystal oven lid to be replaced most of the time. There is a short version but not often available from distributors in frequencies useful for bricks.

Surplus Sales of Nebraska has surprisingly decent prices on crystals and a large selection in this frequency range, few on even frequencies, mostly on odd frequencies useful for odd multiplication factors. And probably 5 th overtone in the 100 MHz range, but 5th overtone crystals seem to work well on their third or 7th overtone and 3rd overtone crystals work decently on their 5th and 7th overtone, sometimes even their 9th overtone, and while the overtone frequencies tend to not be exactly 3, 5, 7, or 9 times the fundamental, 5/3 times the 3rd or 7/3 or 9/3 gets very close to the oscillation frequency. So a 5th overtone 108 MHz crystal would have a fundamental near 21.6 MHz but would oscillate on 64.800 or 151.200 MHz. and a third overtone crystal marked 64.800 would oscillate on 108 or 151.2 MHz. Fundamental crystals tend to be processed to be less likely to oscillate on overtones and the overtone frequency usually is a few kHz off nx (3, 5, 7) the fundamental. Probably because the fundamental mode most often uses the crystal in parallel resonance mode and the overtones usually use series resonance modes. And with such surplus crystals you never know what the rated temperature the crystal was made for. The frequency vs temperature curve can be selected at manufacture by the angle of the quartz plate with respect to the major quartz crystal axis from the bulk crystal. Its optimum for temperature control if the local frequency vs temperature slope is flat, that give the best stability with slightly varying oven or environmental temperature. Sometimes working for more precise temperature control to use a $5 surplus crystal vs a $50 custom cut crystal is a very workable option.

KO4BB has a compendium on these bricks, specification tables, their schematics, modifications, and factory tune up procedures. http://www.ko4bb.com, search for brick or frequency west.

I believe most bricks built to compete with Frequency West copied the circuits closely and so work the same way and have the same way beyond the factory specifications versatility.

73, K0CQ