250MHz Phase-Locked Source

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The Vectron 250MHz oscillator module shown in **Photo 1** appears to be reasonably popular on the surplus market: several have been seen on the stands at rallies and roundtables. It can be identified by having an SMA output connection and three pins for voltage supplies and tuning. There are also plenty of similar-looking ones around with other obscure frequencies, so buy with care!

The unit is completely sealed in a casing of 50mm square and 20mm high plus connections, and cannot be opened without a hot plate or hot-air gun. It appears to have an internal regulator which allows it to work properly with anything over 9 Volts supply. An examination of the output spectrum and frequency stability suggest that internally the module starts off with a 62.5MHz oscillator (sub harmonics are just detectable at -60dBc or thereabouts) and has a tuning range of a few hundred Hz centred on 2 - 3V on the tuning pin. There is a frequency adjustment trimmer accessed by removing a screw on the side of the module. This appears to be a quite critical adjustment, and it is easy to shift the frequency by several kHz if it is moved too far. The oscillator module is not ovened and stability readings suggest it *may* be temperature compensated. It gives quite a clean low phase-noise signal and so will make an excellent clock for an AD9852 DDS, which can then be used to directly generate any arbitrary frequency up to around 110MHz. When fed with a low phase noise clock and its own internal PLL multiplier is not used, this DDS chip can give a signal suitable for multiplying up to microwave frequencies.

Mike G0MJW used an identical module as a master clock for the DDS sources forming the GB3RAL 40/50/60/70MHz beacons, where it was phase locked to a 10MHz reference from a GPS locked source. Mike used the Reflock 2 board by CT1DMK [1] to do the phase locking and, as this had an upper input frequency limit of around 120MHz, needed a divide-by-two prescaler to bring the oscillator frequency down to a useable value. As the Reflock employs a large division ratio resulting in a low comparison frequency, the loop bandwidth becomes very low, lock up time increases, and loop filter becomes more critical.

Although the Reflock set-up worked well, 250MHz is a direct multiple of the 10MHz reference and I knew there had to be an easier way, so looked for a way to lock the VCXO module to the master reference directly. Reference [2] describes how harmonics of a divided down reference in a sampling mixer can be used to lock a 100MHz VCXO for a microwave Local Oscillator. But, how well could an even simpler version be made to work with 10MHz input instead of the few 100kHz comb spectrum used previously? All diode-ring mixers work to some extent at odd harmonics of their LO signal, albeit with increasing mixer loss as the harmonic level rises [3]. So, I tried an SRA-1 mixer and directly fed the output from a 10MHz reference at around +6dBm to one port. The VCXO signal at +3dBm was connected to the other RF port, and a scope on the IF connections was used to see what came out. After adding a bit of filtering (a 47nF capacitor across the scope input) to remove the 250MHz and 10MHz components leaking through, the result was a 5mV peak-peak sine wave at the difference frequency of a few hundred Hertz. Useable, but a bit too low a voltage for comfort. I then added a reference input buffer made from 74AC00 CMOS gates to drive the mixer with a square wave at 10MHz at about +13dBm. This raised the mixer output to 30mV Pk-Pk - Perfect!

The circuit in **Figure 1** shows how this leads to a finished design. The 30mV IF is raised in level by a low noise NE5532 op-amp in a quasi-differential circuit configuration. The SRA-1 mixer has both sides of its IF port accessible and using a differential amplifier-type architecture removes any need for the op-amp to handle negative input voltages, so no negative rail is needed. It also allows the output to be centred on a reference voltage, which here is conveniently taken from the 5V supply needed for the input buffer. The amplifier gain is set at around times 300 and can be changed by altering the single feedback resistor. This particular Vectron VCXO requires a lower tuning voltage at its centre frequency, so the op-amp centre-voltage output is reduced to about 2.3V with two further resistors.

Phase Locked Loops using crystal oscillators inherently have a low loop bandwidth due to the restricted frequency pulling range of the crystal, and when a high comparison frequency is used the PLL becomes very benign to set up. The inherent maximum bandwidth possible is given by the product of the tuning sensitivity in Hz/Volt of the VCO and the phase detector Volts/radian. The oscillator module gives about 200Hz /Volt frequency shift, and the phase detector / differential amplifier combination results in about 2 Volts / radian leading to a PLL bandwidth in the region of 500Hz.

A capacitor in the feedback loop limits the PLL bandwidth to around 300Hz which kills any 10MHz component that may try to get through, but otherwise has little effect on the PLL functioning. In fact, it proved more important to properly decouple supply rails and control leakage around the mixer than it was to worry about loop filtering.

Initially as the output level from the VCXO module was more than adequate to drive both the SRA-1 and the DDS clock input, I just used a passive splitter to provide the 250MHz signals to both. When locked, 10MHz sidebands were present at about -40dBc on the output port, making it unsuitable for a DDS clock without further filtering. Clearly these weren't due to the PLL, so it had to be direct leakage around the mixer and splitter. A few dB of attenuation before the SRA-1 input helped, but not enough to reduce spurii to acceptable levels before the drive level became too low for the PLL to function. By doing-away with the splitter, and adding around 25dB attenuation, followed by a modamp buffer giving an additional 20dB of reverse isolation, these sidebands were reduced to better than -70dBc. The modamp used for the buffer was intended to be a MAR-6 (20dB gain, Pout max = +6dBm) but in error * I picked a MAR-8 out of the spares drawer and soldered into the breadboard. The device functioned perfectly well in this position even with the sub-optimum biasing, so rather than replacing after noticing the mistake, I just left well-alone! Presumably it is acting as a quite effective limiter when incorrectly biased like this.

With 10MHz reference applied, the PLL locks up immediately it is turned on and the pull-in range of the VCXO appears to be of the order of several hundred Hz. Certainly well beyond the VCXO's amount of day-to-day drift. As an experiment, a 5MHz reference input was then tried. Even order harmonics are normally cancelled out in the mixer, so this design oughtn't to work when a reference of 5MHz is used. However, to my surprise it did lock up although the PLL did appear to be a bit 'twitchy' and had poor lockup performance. Looking at the output of the 74AC00 buffer showed that it was not a perfect square-wave and actually had a 40% duty cycle. This meant a level of even harmonics were therefore present on the mixer input and allowed a limited lock-up to the 50^{th} harmonic. However, this is not an ideal situation. If it really is necessary to use an even harmonics of the reference, it would be better to pre-multiply to a higher frequency, for example to 10MHz with a simple push-pull doubler, before applying to the mixer. (In fact my normal lab frequency standard is generated by a 5MHz source which passes thorough a diode 'full-wave rectifier doubler' before being buffered and distributed).

Photo 2 shows the breadboard phase locked source, built birds-nest style. I don't intend producing a PCB for this, and the circuit is so simple and uncritical than any build method can be used. Just pay attention to supply voltage decoupling and layout, keeping 10MHz harmonics away from the 250MHz path to the output.

*	The colour coding spot on MAR series modamps starts off sensibly – Brown for the MAR-1, Red for the MAR-2, Orange, Yellow etc. But, for some perverse reason, MAR-6 devices have a White spot (which looks Grey) and MAR-8 devices have a Blue spot. *Why ???*

References:

1) Reflock 2 http://www.tapr.org/kits_reflock_ii.html
2) A Simple Way of Phase Locking Microwave Local Oscillators. Scatterpoint April 2004. Can also be found at http://www.scrbg.org/g4jnt
3) Minicircuits catalogue http://www.minicircuits.com/pages/s-params/SRA-1+_VIEW.pdf

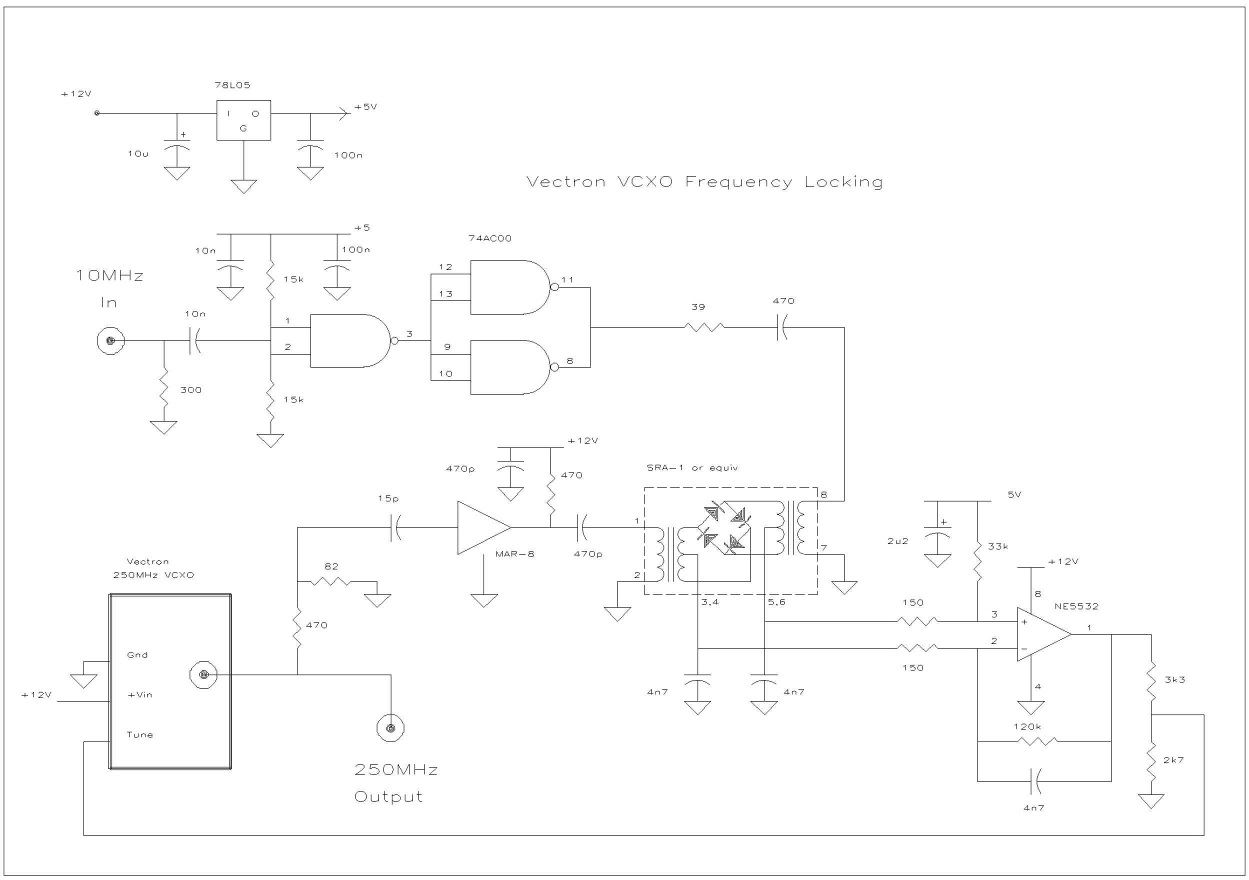

Figure 1 250MHz Reference Locking

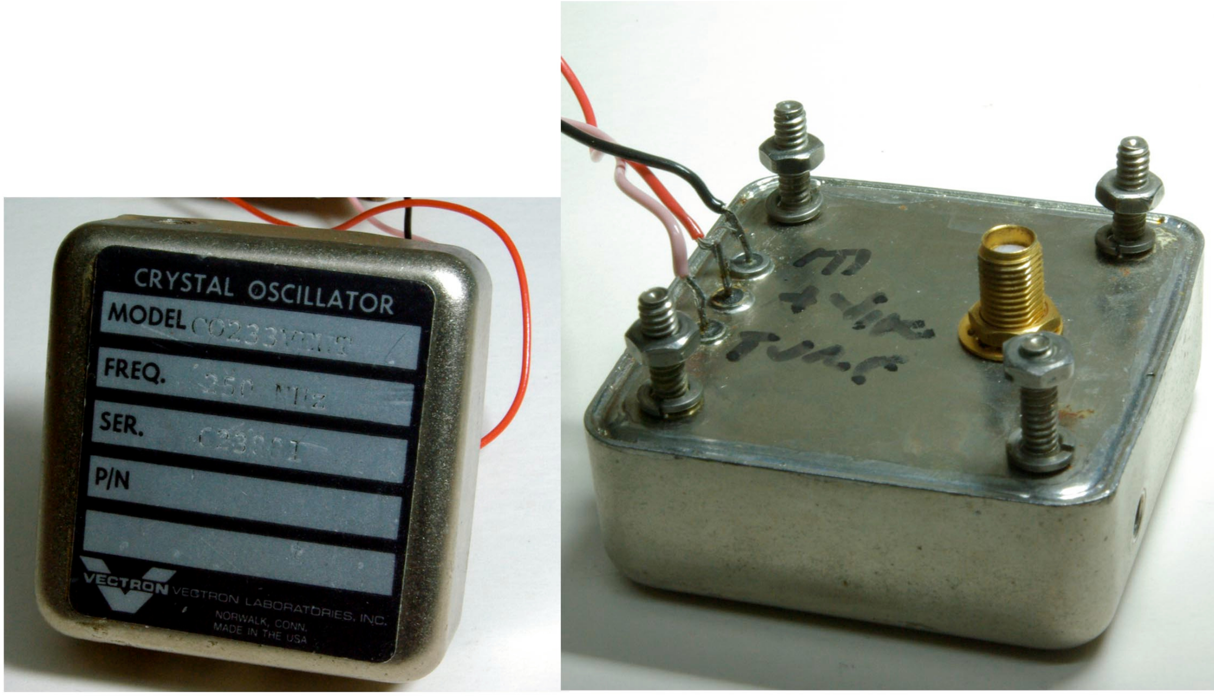

Photo 1 Vectron Crystal Oscillator Module

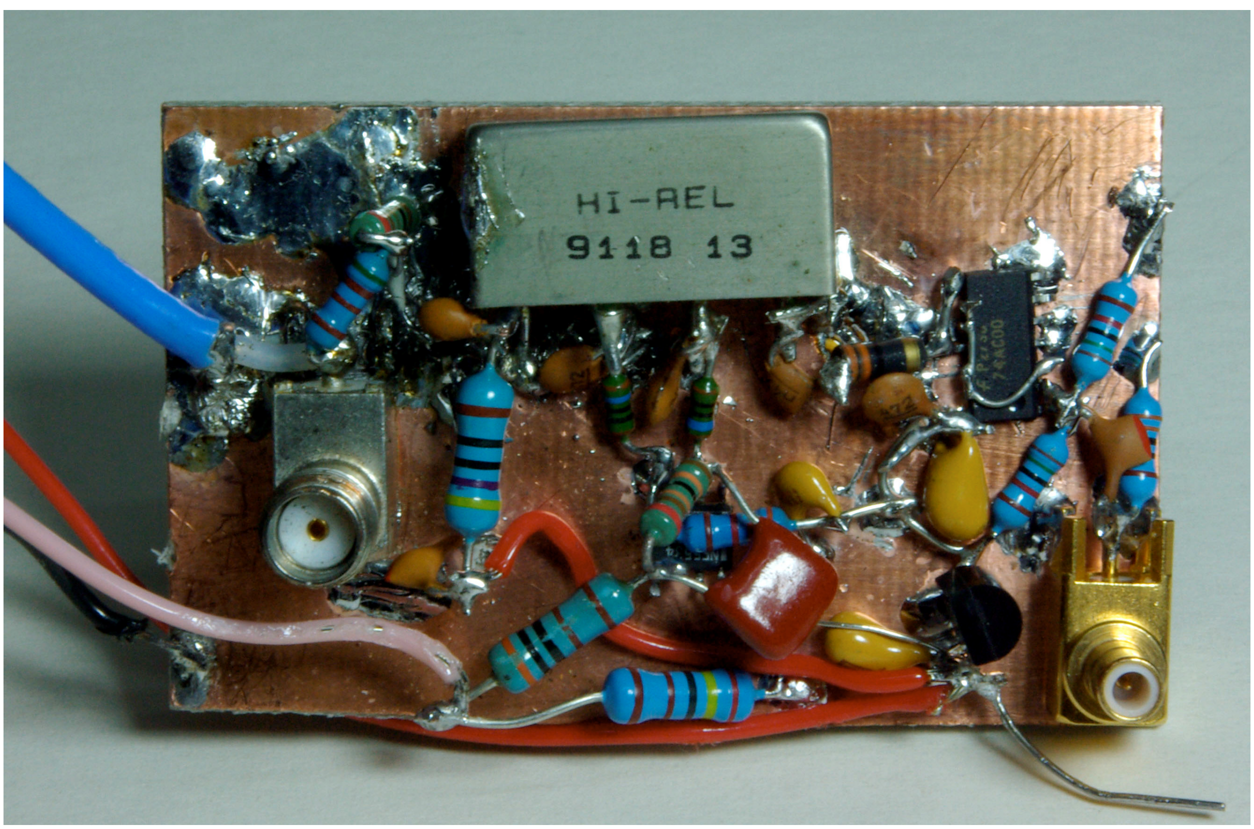

Photo 2 Breadboard PLL Unit