By Chuck Houghton,* WB6IGP

MICROWAVE

Above and Beyond, 1296 MHz and Up

The Qualcomm "Omnitrack" DRO Synthesizer

The Qualcomm DRO (dielectric resonant oscillator) synthesizer normally operates on a frequency of 2620 MHz and has an output power of +10 dBm. Frequency stability is under control of a dielectric resonant controlled oscillator (DRO). This ceramic puck stabilizes the oscillator, and synthesizer phase-locked-loop (PLL) circuitry must be modified to change the output to another frequency more desirable for amateur microwave use.

Unfortunately, the DRO synthesizer is controlled by its divide-by reference of 1.25 MHz (random-access [RA] counter set to divide reference 10 MHz by 8). A solution was to change the RA counter to divide the stock frequency of 10 MHz by 64 for a new reference frequency of 156.25 kHz. There are many possibilities, but for this application the irregular frequency steps limited those frequencies that could be reached by the PLL chip. Modification of the DRO took the form of adding solder—bits of copper or short lengths of copper wire soldered to the top of the DRO, stretching the DRO resonance. This could be a small coupled pF capacitor, or an inductance used to tweak the DRO to a new frequency (free-running frequency near desired operation point).

The above is where this project lay for some years. Then while cleaning out the shed and trying to reorganize material stored there, I came upon a large box of DRO synthesizers. At the same time, I revisited the file of material and modification notes that John Stevens, WB2BYP, and I had worked on previously. I had done the original modification work using the stock reference frequencies of 1.25 MHz and 156.25 kHz, but John saw a much better use for these DRO synthesizers, working his plan around a new reference frequency of 1 MHz. This allowed many other possible frequency combinations that were capable of being reached by reprogramming the PLL dividers and constructing a new divider (divide by 10) to produce a 1-MHz reference from the 10-MHz TCXO (temperature-compensated crystal oscillator).

John put together a great modification procedure and gave me his permission to cover it here. I am sure it will be met with great interest, especially because the synthesizer PC boards are still available from the author (WB6IGP) for modification to other useful microwave frequencies.

Modification for 2592 MHz

The sequence of images and comments builds upon my article entitled "Above and Beyond," which appeared in the June 1994 issue of *73 Magazine*. I had known about these synthesizers for a few years, and only recently started thinking about

*Member San Diego Microwave Group, 6345 Badger Lake Avenue, San Diego, CA 92119
e-mail: <clhough@pacbell.net>

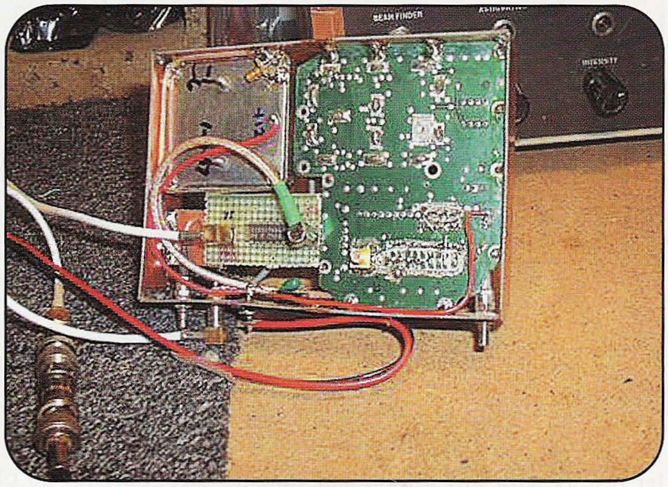


Photo A. Bottom of the synthesizer PC board with pins of the synthesizer chip isolated by dremel-cutting around each pin to isolate them for experiments on other frequencies.

them as an LO (local oscillator) or marker generator for microwave experimentation. I had been looking for a signal source that I could lock to a 10-MHz TCXO for field use or as a GPS-disciplined oscillator. I wanted to know with some accuracy where the band edges are at 10368 and 24192 MHz. Jud, K2CBA, uses one of these as the basis for an LO in his homebrew 10-GHz transverter. The frequencies at which the synthesizers lock with the Omnitrac 10-MHz TCXO are limited in utility, but if you are open-minded about what to use as an IF and have a rig that will do it, you can use the boards with minor mods.

In my *73 Magazine* article I discussed some of the frequencies that are available with a minimum number of modifications, and I provided some good schematic information. Note that you may have to do some drawing out of the circuit to satisfy your curiosity regarding some of the board's finer detail, such as the reference filter and VCO (voltage-controlled oscillator). One of the boards I modified had some workmanship errors that contributed to a failure in the supply voltage to the VCO buffer amp. It was an easy fix, however, and the unmodified board came up with +10 dBm at 2620 MHz. Jud and I discussed the utility of the boards during some Monday evening 2-meter chats, and a couple of ideas came to mind. A few evenings spent at the test bench led to some interesting findings. I wanted the lock-to frequencies to come out in more convenient values for common IFs with low side injection.

What followed is the Qualcomm synthesizer with modifications to place it on 2592.000 MHz (10368.000 divided by 4). I am using this for a marker generator. The reference is running

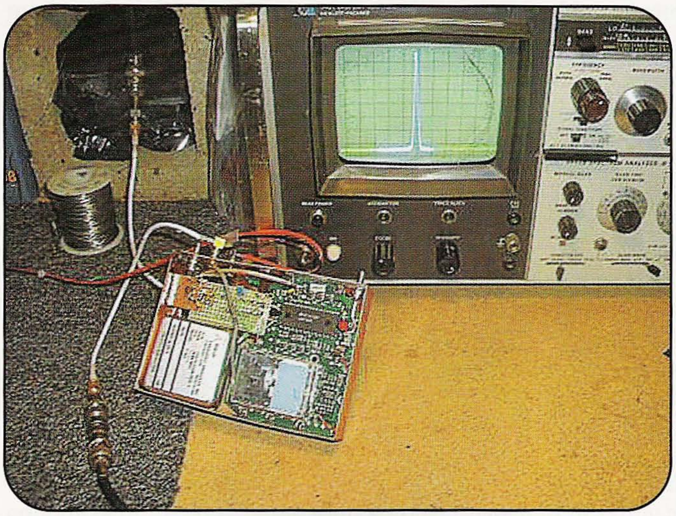
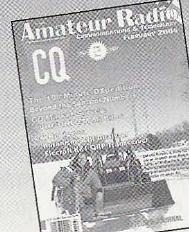


Photo B. Top of the synthesizer showing added perf-board transistor amp and 10-MHz TCXO used to provide clock input to the synthesizer via a new, added 7490-divide-by-10 chip.

at 1 MHz, and the *R* divider is set to 8. That gives an internal reference frequency of 0.125 MHz. The advantage of this is the lock-up points now occur at more convenient frequencies in the 2.5-GHz region. The existing scheme divides the 10-MHz reference oscillator by 8 to yield 1.25-MHz reference steps, yet the lock-up frequencies are less useful. By dividing the reference oscillator by 10 using a 7490 decade counter, and giving the chip 1 MHz instead of 10 MHz, the 0.125-MHz reference step is achieved without changing to a different external TCXO. You have to by-pass the on-board reference frequency filter to introduce the 1-MHz signal from the decade divider. The great thing about this is that the LO or marker generator can be run from an inexpensive 10-MHz TXCO for better stability than open-air or heated-crystal oscillators.

For 2592 MHz the *N* counter has to be set to 80, and the *A* counter has to be set to 16. I dremel-tooled the board to isolate all the *A* and *N* counter pins on the MC145152 (see photo A for the bottom of the PC board). This was more work than needed, but it allowed me to play with programming different frequencies. I put a 1/4-inch lead of #22 wire on the DRO to add some parasitic inductance to achieve lock. Note that there is a "slice-to-tune" element on the existing PC board that can be played with to yield a more convenient open-loop oscillation frequency. Output is about +10 dBm. I did not bring in the loop filter to limit the phase noise, as I was looking for an ultimate accuracy signal source, more so than an LO. If it were used as an LO, you would want to add capacitance to the loop filter to reduce receive reciprocal mixing noise from nearby stations due to oscillator phase noise. The existing amount of capacitance will have to be increased by a factor of about 10.

I added the lock indicator to help diagnose lock conditions. I think this really is a big help, and it is right there and easy to do. It just takes an LED hanging off one of the pins on the white pin header. Note that it is dark when open loop, dim when unlocked, and bright when locked. This is an inexpensive, useful feedback. The modified synthesizer will hit all common LO frequencies for amateur bands, as well as the in-band signal. For example, it can be made to hit 10224/4 as well as 10368/4. It also will hit the band and LO frequency squarely at 24192. It will hit an 18th sub-multiple of 47088 MHz, as well as the



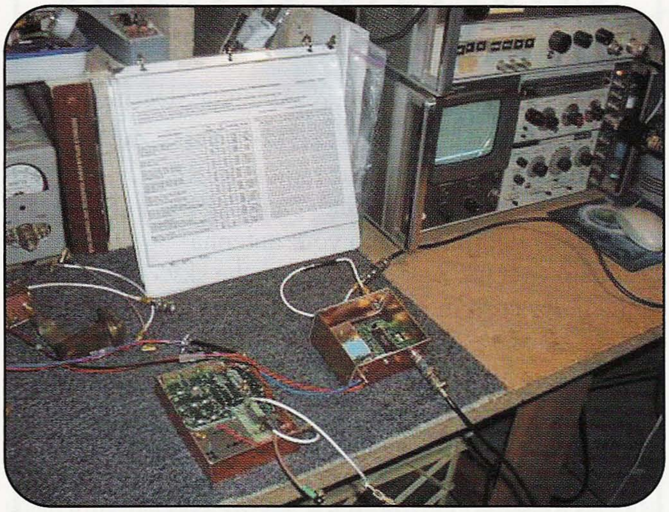


Photo C. The modified synthesizer operating at 2688 MHz on John, WB2BYP's workbench with a spreadsheet in the background for programming the synthesizer.

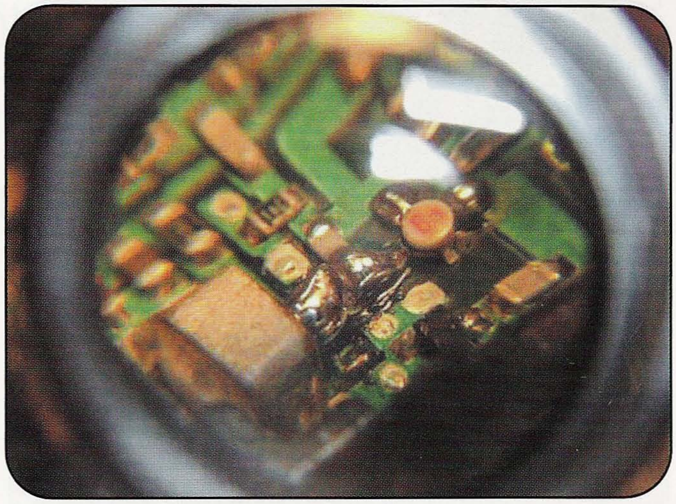


Photo D. Modification of DRO synthesizer by adding a drop of solder to the DRO ceramic element to change resonance to a frequency other than the stock 2620 MHz.

frequency 144 MHz below that. If you are using a DB6NT mixer that runs LO at half or quarter frequency, you can find these frequencies, too.

Note that the frequency to hit the 18th sub-multiple of 47088 is easily within the range of the unmodified DRO. Keeping the DRO is advantageous, as it is fairly high Q. To hit the other frequencies you will have to substitute an L/C combination with a tiny Johanson trimmer or equivalent and resonate close to the intended frequency. I know this works between 2 and 2.5 GHz, although I have not pushed it up to 3 GHz yet. More to follow.

What is needed to simplify the process is a simple map that says, "Ground these pins to get these frequencies." (The program.pdf document is provided with the synthesizer.) It's from

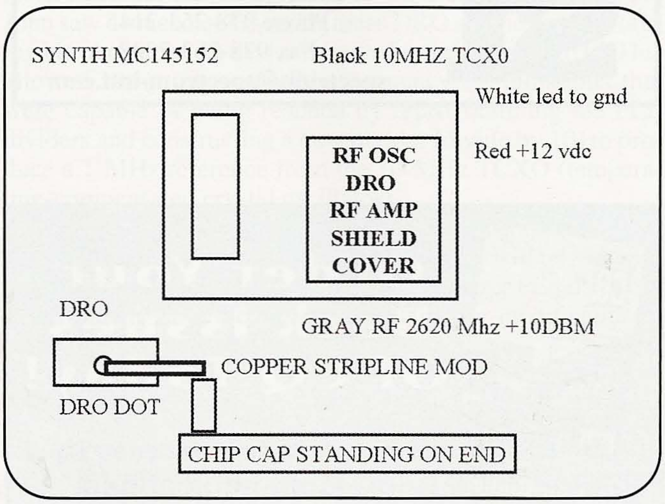


Figure 1. Connections for the test on 2620 MHz to verify the synthesizer works as a stock programmed unit. Also shown are details of the copper stripline added between the DRO center dot and the transistor to obtain a free-running frequency slightly above the desired frequency before programming the synthesizer.

an Excel sheet that John developed to calculate the combinations of programming the pin-for-pin synthesizer chip vs. frequency obtained. The synthesizer board is on the right, the 7490 is pasted onto the perf board, and the TCXO is on the lower left (see photo B for details of the top of the modified synthesizer with added transistor amp and TCXO 10-MHz oscillator). There is a 2N5179 buffer amp to build up voltage to the TTL IC. It would be better if there were a CMOS IC as the decade counter. The TTL 7490 was what I had at first. This is running off the GPS-disciplined oscillator in the photo. The ultimate accuracy at a reasonable cost can be had by using a GPS-disciplined 10-MHz oscillator for one part in 10 to the minus 12 accuracy. Translated to 10368 MHz, the accuracy is pretty darn good in comparison to homebrew, DEM, or DB6NT LOs. The stability is as good as you feed it.

Modification for 2688 MHz

Here is the second unit, modified for 2688 MHz. This frequency is 24192/9 and is useful as a signal source. This is done by setting *N* to 83 and *A* to 16, and driving the reference divider with 1 MHz. In this case I am sourcing the 1 MHz from the other synthesizer, running from the 10-MHz TCXO/decade divider. See photo C for this modified synthesizer on my workbench.

This is the modification to the DRO in order to get it to go significantly higher in frequency (see photo D). The DRO is the big block at about 8 o'clock in this crude view through an eye loupe. The VCO transistor is the device about in the center. This mod was accomplished by lifting the coupling chip capacitor into the air and putting a solder bead over the pad with the transistor. I removed the pad below the DRO connection and put a large bead on the DRO center pad. The chip capacitor now bridges the two low-inductance solder beads. With this technique I was able to get the free-run frequency up to 2718 MHz. This made the oscillator easy to pull in to 2688 with tuning voltage.

It is good to know that the DRO can be pushed this far in frequency, because there are a lot of useful frequencies if the oscillator can be made to lock above the design center of 2620 MHz. A signal source at 47088/27 = 2616 MHz is possible without mods to the DRO, and if the DRO can be pushed to 2816, a signal source for 76032 can be made. Lots of LO possibilities exist. However, for the most part they will require some creative mods to the DRO or the removal of the DRO, replacing it with a Johanson trimmer of small pF value and a strip of tweaked-to-frequency copper or a coil for lower frequencies. The oscillator should be made to free run about 20 MHz above the operating frequency to have a suitable lock voltage. The DRO is easy to remove by disconnecting the solder connection and heating up the body. This modification procedure by John, WB2BYP, can be found on the web at <http://www.storyavenue.com/qualcomm.htm> with John's conversion data and more details of the Qualcomm DRO synthesizer.

Applications

While the DRO synthesizer does have limitations, John has greatly improved the adaptability in his conversion by changing to a more useful reference frequency. I have done lots of different applications sticking with the 1.25-MHz reference frequency and its limited operation. For instance, we were able to use this synthesizer on our 47-GHz transceiver. We cut one pin open (TTL high) and grounded two other pins (TTL low) on the synthesizer chip, allowing operation on 2640 MHz. The idea was to use a Verticom very-high-quality BCD (binary coded decimal) controlled agile synthesizer operating at 10.44250 MHz. This LO drove a PECOM TX Module (multiply by 2 = 20.885 GHz + the LO drive to the IF port at 2.640 GHz for a output at 23.525 GHz). Doubling in frequency in our final harmonic mixer produced 47.05 GHz. Using an IF of 145 MHz produced 47.195 GHz. While the rig is not a barnburner, it has shown to be a reliable and simple rig to put together. Of course, the use of the MTS2000 Verticom synthesizer, the step frequency of which is 1 kHz from 8.7 GHz to 10.7 GHz, was a key element in making the system's main local oscillator easy to use.

The system's IF drive LO: The DRO synthesizer also proved quite versatile in its easy conversion to 2640 MHz because the stock synthesizer frequency steps are at 20 MHz, making its use in this application a no-brainer. I thought I would try to get the DRO oscillator to free run (no lock) somewhere in the 2592 frequency band. Remember, this is 2592 times 4, which equals 10368 MHz, a great test shot to demonstrate what I had to do to get there at this frequency of 2592 MHz.

First I removed the chip capacitor from the DRO center dot and the transistor on the PC board. Then, using a solder sucker, I removed the excessive solder from the DRO center connection to the PC board trace to leave the DRO center dot floating (isolated). I re-attached the chip capacitor standing up on the transistor side of the now open PC board trace and soldered it to this PC board trace. I fabricated a small section of copper tape that was a few thousands of an inch thick and soldered one end of it to the DRO center dot. I soldered the other end to the chip capacitor (top) while it was standing on end, thus inserting a new inductance coupled by the series chip capacitor between the transistor and the DRO center dot. As I write this, a half-hour has gone by and the frequency of the free-running oscillator is still 2593.73 MHz as read on my frequency counter. Not bad for free running!

The first frequency I came up with was 2400 MHz, while the oscillator was free running. That meant my copper inductance was too large. Changing the copper inductor (a short piece of copper tape about 3/16 by 1/4 inch was use for first trial) by removing some length and width a bit at a time brought the free-running oscillator up to 2593.73 MHz. During the process of soldering and unsoldering, the chip capacitor got lost when it went flying from the tool that held it. I replaced it with a 1.1-pF chip capacitor (not a surface-mount standard type, but a microwave type from ATC [American technical Ceramics], .050-size 1.1-pF chip capacitor to reach the 2592-MHz range). I found I could go down to approximately 2100 MHz by replacing the 1-pF chip capacitor with one in the 5-pF range.

The bottom line is first adjust the chip capacitor or change the dimensions of the copper stripline inductance to achieve a frequency close to the one in which you are interested. Then set the synthesizer chip pin for pin programming to achieve synthesizer lock. For an LED indicator, tie the white wire to one side of the LED and ground the other. If you want to go up in frequency, take some copper off the copper bit; to go down in frequency, add a small bit of copper to the stripline trace, making line dimensions larger.

Check out the synthesizer first by connecting a crystal 10-MHz source to the black-shielded lead, +12 volts to the red lead, and the LED to the white lead. The synthesizer should fire up and lock on 2620 MHz. If the LED is not on, reverse the connections to the LED—no lock LED off; lock okay LED bright (see figure 1). For connection power lock and RF input output wiring.

The configure the 7490 for dividing by 10, the pinout configuration is: 10-MHz input pin is 1; tie pin 11 to pin 14; ground pins 2, 3, 6, 7, 10; positive VDC on pin 5; and 1 MHz output on pin 12.

Summary

The synthesizers are available from me, WB6IGP. Two DRO synthesizers are $22 postpaid, U.S. dollars. The synthesizer requires a 10-MHz crystal source, which is not supplied in this package. Normally, a 10-MHz TCXO is used for this function. I provide some schematic detail and a copy of the programming spreadsheet that John developed, plus some other conversion details that were too numerous to include in this column. I will be happy to answer questions related to the synthesizer or other microwave-related queries. Please e-mail me at clhough@pacbell.net for a quick response.

In closing, I would like to thank John Stevens, WB2BYP, allowing us to publish his modification procedure and conversion data in this column.

73, Chuck, WB6IGP