Notes on the Driscoll VHF Overtone Crystal Oscillator

Tom Clifton kc0vsj@yahoo.com *Mon Dec 28 00:19:34 UTC 2009*

Interesting read on a **low phase noise oscillator by Chris Bartram GW4DGU**
http://www.christopherbartramrfdesign.com/blaenffos/oscillator/VLNO.pdf

Bruce Griffiths bruce.griffiths@xtra.co.nz *Mon Dec 28 01:21:06 UTC 2009*

There are several VHF crystal Oscillators designed by M Driscoll. The one shown is merely derived from one variant. It has an unecessary constraint on setting the crystal current. Much better results are obtained by implementing the diode clamp as a capacitively coupled peak to peak detector the output of which is connected to a low noise dc source. The crystal current can then be adjusted by varying the dc source voltage.

Bruce

Bob Camp lists@cq.nu *Mon Dec 28 04:51:57 UTC 2009*

Hi
The feedback network in the Fig 7 schematic makes a lot more sense than the network in the first Fig 7 ....

Bob

Bruce Griffiths bruce.griffiths@xtra.co.nz *Mon Dec 28 05:52:12 UTC 2009*

An inductor in series with the 220 ohm emitter resistor will improve the phase noise floor. The MMIC output amplifier has a wider bandwidth than necessary and doesn't have a particularly high reverse isolation. One could improve this by substituting a CB cascade or other discrete amplifier cascade. Alternative methods of extracting the signal from the collector of the second transistor may be more effective in maintaining a low phase nose floor.

Bruce

dk4xp@arcor.de dk4xp@arcor.de *Mon Dec 28 19:10:52 UTC 2009*

In theory, yes. But already with only 220 Ohms, Q3 will oscillate wildly at a few hundred MHz. The mechanism is this: Somewhat hot RF transistor NE688, collector at RF ground, emitter at high-ish impedance ---> When you measure into the base, you see a negative resistance in series with a few pF. Add L6 = 82 nH with the other side at RF ground and you have built the usual negative-impedance VCO for VHF/UHF. The crystal and the intended feedback network just don't matter any more. I should have re-read my own Dubus article on oscillator simulations from 6 years ago before I tried the Distaw. :-(Other people have observed the wild oscillations, too.

> *The MMIC output amplifier has a wider bandwidth than necessary and*
> *doesn't have a particularly high reverse isolation.*

Also, it has 20 dB gain, that alone guarantees a less than ideal far-off noise level. The BAS70 clips at less than 1 V pp, this should be more. Could be easily done in the Rohde style with a decoupled DC divider and one Schottky that points from the divider to the collector circuit.
I have changed my own locked VHF crystal oscillator back to Butler - this time single stage with 3* cheap NXP BF862 in parallel, common gate. The gate can be grounded directly, needs no voltage divider and decoupling.
Input impedance of the 3 FETs is abt. 7 Ohms, which brings us close to the point of diminishing returns for the usual 45 Ohm crystal.
The BF862 works to 700 MHz, so it is just fast enough and won't surprise me at 3 GHz.

regards, Gerhard dk4xp

Bruce Griffiths bruce.griffiths@xtra.co.nz *Mon Dec 28 21:04:35 UTC 2009*

> *The mechanism is this: Somewhat hot RF transistor NE688, collector at> RF*
> *ground, emitter at high-ish impedance ---> When you measure into > the*
> *base, you see a negative resistance in series with a few pF.*

Using a transistor with a higher ft than necessary in an oscillator circuit isnt usually a good idea.

> *Add L6 = 82 nH with the other side at RF ground and you have built*
> *the usual negative-impedance VCO for VHF/UHF.*
> *The crystal and the intended feedback network just don't matter any more.*
>
> *I should have re-read my own Dubus article on oscillator simulations from*
> *6 years ago before I tried the Distaw. :-(*
> *Other people have observed the wild oscillations, too.*
>

Even without significant inductance between the oscillator transistor base and ground the shunt capacitance of the crystal itself can cause parasitic oscillations to occur. A high frequencies the base is grounded via the tank capacitor, and the emitter impedance exhibits a negative resistance in series with an inductance.
Driscoll actually used ferrite beads on base and collector leads to suppress such oscillations. The location of these beads is clearly shown in the original paper. Driscoll used a capacitively split tank so that there is a capacitor from the oscillator transistor base to ground.

> *Also, it has 20 dB gain, that alone guarantees a less than ideal*
> *far-off noise level. The BAS70 clips at less than 1 V pp, this*
> *should be more. Could be easily done in the Rohde style with a decoupled*
> *DC divider and one Schottky that points from the divider to the*
> *collector circuit.*

A symmetric clipper (easily implemented by dc biasing an AC coupled 2 diode pp detector) has some advantages.

> *I have changed my own locked VHF crystal oscillator back to Butler - this*
>*time single stage with 3* cheap NXP BF862 in parallel, common gate.*
> *The gate can be grounded directly, needs no voltage divider and*
> *decoupling.*
> *Input impedance of the 3 FETs is abt. 7 Ohms, which brings us close to*
> *the point of diminishing returns for the usual 45 Ohm crystal.*
> *The BF862 works to 700 MHz, so it is just fast enough and won't surprise*
> *me at 3 GHz.*
>

Some of Driscoll's later low phase noise OCXOs employ an MMIC as the oscillator and use the crystal together with a diode limiter and matching circuits to match the crystal to the 50 ohm input and output impedance of the MMIC. A splitter at the MMIC output is used. One splitter output drives the feedback loop whilst the other is used to drive the output buffer.

Bruce

dk4xp at arcor.de dk4xp@arcor.de *Mon Dec 28 23:46:15 UTC 2009*

> *Von: Magnus Lindahl <sm4rwi at telia.com>*
> *Do you have schematics, PCB-design etc. to share on your design with 3**
> *BF862?*

I will publish the results in Dubus. (www.dubus.org) board size is 1.5 * 2.5 inch for oscillator, buffer, reference conditioner and PLL. No soldering without a microscope, however. Lots of SSOP16, sot-336, 0603 & friends.
I wanted to make a VHF crystal oscillator that could be locked to a 10 MHz reference and be used for the usual transverter designs. That required a locking grid of 333 or 500 KHz. Furthermore, I wanted to avoid microcontrollers and other stuff that had to be programmed. I wanted just normal stuff from Digi-Key and your favorite crystal supplier. (Also, I wanted a nice clock source for state-of-the-Art 16 bit ADCs).
The fine locking grid has a devastating influence on the design. Either one compares at 500 KHz, then locking to small error will take months, the pull-in range is ridiculous (I don't want an oven for the 100MHz) ---- or one compares to a harmonic of the 500 KHz, then the phase comparator gain is ridiculous and the PLL kills the 100 MHz phase noise.
Probably I'll give in and stay with a 10 MHz grid. That will help hams who want to multiply to 100 GHz and above.
I now have limited access to an Agilent signal source analyzer that does the three cornered hat thing with cross correlation to 2 precision oscillators close to real time.
I'm still stuck at -135 dB@ 100Hz @100 MHz, but without Rohde's limiter. (only antiparallel Schottky across tank circuit and with BFG196 emitter follower)
I'll test w/o the follower and with the new limiter in week 1/2010
There are many things still to explore: thin film vs thick film resistors, influence of emitter/source resistors, amplitude clamps, crystals, ...

regards, Gerhard DK4XP

U.L.Rohde/David P. Newkirk: RF/Microwave Circuit Design For Wireless Applications,
page 762++
Wiley, ISBN 0-471-29818-2

Grant Hodgson grant@ghengineering.co.uk *Tue Dec 29 17:52:38 UTC 2009*

I've had several discussions with Chris Bartram about this and similar VHF oscillators.
My understanding is that Chris' variant of this particular Driscoll osc. has been designed specifically for low close-in phase noise, and that is why the phase-shift network has a low-pass response (to try and reduce flicker noise) rather than the more common high-pass network. The NE688xx was chosen for the active devices due to it's claimed low flicker noise; the flicker noise parameters are actually specified on the datasheet for the NE68833 - which is quite unusual. The high Ft may not be desirable, but it seems that is the price to pay for low flicker noise.

I've built a couple of oscillators similar to Chris Bartram's design at around 116MHz, albeit with the more conventional 'high-pass' phase shift network, and they seem to perform quite well - certainly no sign of spurious high frequency oscillation, but that may be a function of PCB layout. I'm not aware of anyone yet measuring the close-in phase noise of the Bartram variant of this oscillator, and that's really the only way to verify or otherwise that the new topology gives any advantage in terms of close-in phase noise, compared to a similar, low cost design using similar crystals. BTW I've tried simulating the phase noise of this oscillator using ADS, but wasn't able to get meaningful results from the simulator, and on this occasion Agilent technical support were not able to resole the issues either. Maybe Microwave Office or Ansoft Designer would yield better results, but I haven't tried them. (LT Spice is unable to simulate phase noise of oscillators).

regards
Grant

> An inductor in series with the 220 ohm emitter resistor will improve the
> phase noise floor. In theory, yes. But already with only 220 Ohms, Q3
> will oscillate wildly at a few hundred MHz. The mechanism is this:
> Somewhat hot RF transistor NE688, collector at RF ground, emitter at
> high-ish impedance ---> When you measure into the base, you see a
> negative resistance in series with a few pF.

Using a transistor with a higher ft than necessary in an oscillator circuit isnt usually a good idea.

Bruce Griffiths bruce.griffiths@xtra.co.nz *Tue Dec 29 18:13:27 UTC 2009*

> Grant Hodgson wrote:
> *I've had several discussions with Chris Bartram about this and similar*
> *VHF oscillators.*
> *My understanding is that Chris' variant of this particular Driscoll*
> *osc. has been designed specifically for low close-in phase noise, and*
> *that is why the phase-shift network has a low-pass response (to try*
> *and reduce flicker noise) rather than the more common high-pass network.*

Since an overtone crystal is usually used a bandpass feedback network response is usually required to ensure that oscillation occurs on the desired overtone. The dc biasing network has more effect on the flicker noise than the RF feedback network.

> *The NE688xx was chosen for the active devices due to it's claimed low*
> *flicker noise; the flicker noise parameters are actually specified on*
> *the datasheet for the NE68833 - which is quite unusual. The high Ft*
> *may not be desirable, but it seems that is the price to pay for low*
> *flicker noise.*

Actually close in flicker noise is usually better for lower ft transistors with larger junction areas. According to the datasheet the device is obsolete or about to be phased out. I see no mention of flicker noise specs in the datasheet except perhaps in the models which are not guaranteed.

Bruce

dk4xp at arcor.de dk4xp@arcor.de *Tue Dec 29 20:20:38 UTC 2009*

> *My understanding is that Chris' variant of this particular Driscoll osc.*

> *has been designed specifically for low close-in phase noise, and that is*
> *why the phase-shift network has a low-pass response (to try and reduce*
> *flicker noise) rather than the more common high-pass network.*
> *The NE688xx was chosen for the active devices due to it's claimed low*
> *flicker noise; the flicker noise parameters are actually specified on*
> *the datasheet for the NE68833 - which is quite unusual. The high Ft may*
> *not be desirable, but it seems that is the price to pay for low flicker*
> *noise.*
> *I've built a couple of oscillators similar to Chris Bartram's design at*
> *around 116MHz, albeit with the more conventional 'high-pass' phase shift*
> *network, and they seem to perform quite well - certainly no sign of*
> *spurious high frequency oscillation, but that may be a function of PCB*
> *layout.*
> *I'm not aware of anyone yet measuring the close-in phase noise of the*
> *Bartram variant of this oscillator, and that's really the only way to*
> *verify or otherwise that the new topology gives any advantage in terms*
> *of close-in phase noise, compared to a similar, low cost design using*
> *similar crystals.*

When I get a sample in known working condition, I'll stress the friendliness of my customer to get it tested on their signal source analyzer.
What we already have seen is that crystals from the same production run may yield up to 15 or 20 dB worse phase noise at 100 Hz than the best. (in the same oscillator)
That confirms: Close-in to the carrier, the phase noise is dictated by the resonator. [1]

73, Gerhard DK4XP

Quelle:
time-nuts
Discussion of precise time and frequency measurement
https://www.febo.com/cgi-bin/mailman/listinfo/time-nuts