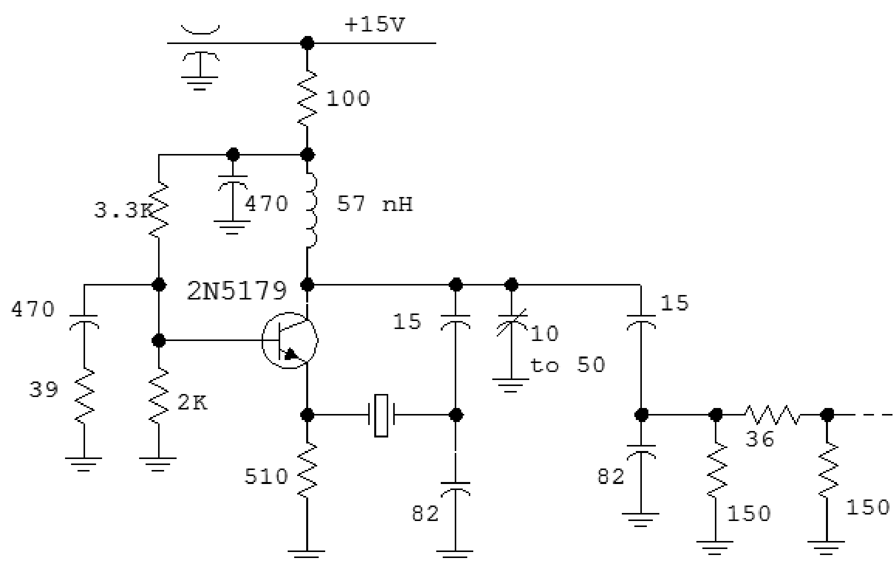
SA/TG Update – Overtone Crystal Oscillator Modifications

13May098, editing on 1June9, w7zoi

There are two circuits that have offered challenge during the construction of the August/September 1998 QST Spectrum Analyzer. The 110 MHz bandpass filter is one while the other is the 2nd local oscillator. A new bandpass filter was presented in a note of Dec 9, 2008, "Mixed Form LC Bandpass Filters." (w7zoi.net, "Designs & Experiments") This note addressed the issues related to both the 100 MHz 2nd local oscillator for the analyzer as well as the 110 MHz oscillator in the tracking generator.

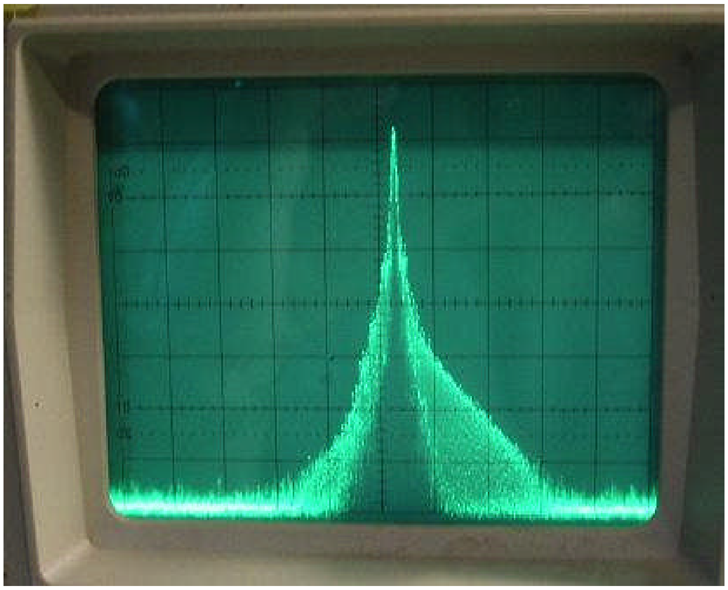
Many builders encountered problems with the oscillators. In some cases, they were hard to tune. While the circuits would tune OK when a resistor was substituted for the crystal, tuning remained fussy when the crystal was inserted. I observed this to some extent with the experimental versions of the circuit that I have here. Assuming a crystal was in the circuit (rather than a resistor), the variable capacitor could be tuned for maximum output. Tuning away from the peak could be problematic. If the cap was tuned in one direction, the oscillator output would decrease smoothly before oscillation would stop. However, tuning from the peak in the other direction would cause the oscillation to stop immediately. The Butler circuit that K7TAU and I used is shown below:



Original Circuit
Fig 7, page 41, August 98 QST

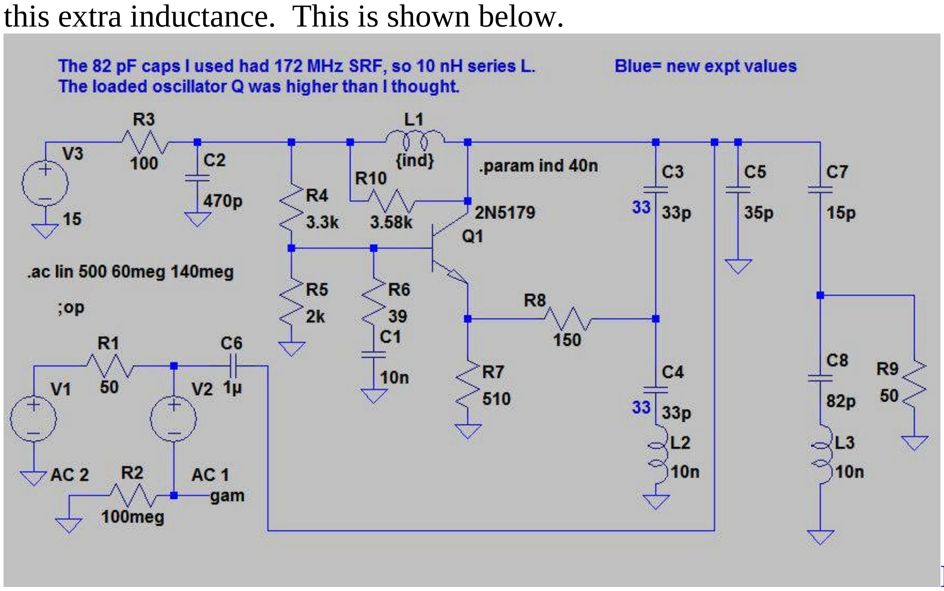
Butler crystal oscillator for overtone operation.

As frustrating as the tuning difficulties were, there could be an even worse problem. If the tuning was carefully adjusted (perhaps *misadjusted*?) with some (but not all) crystals, a squeeging mode could be found where the oscillator grew ugly sidebands. If present, this would severely compromise measurement results with a spectrum analyzer using these circuits. Squeeging is described in Chapter 4 of EMRFD and was described years ago by Clark and Hess in their classic text, "Communication Circuits: Analysis and Design," Addison-Wesley, 1971. A spectrum of the above circuit during this misbehavior is shown below:



110 MHz 5th overtone crystal oscillator with squeeging. This signal was observed in a 12 kHz resolution bandwidth with a span of 0.5 MHz per division.

Several details of this circuit were investigated. The first experiment evaluated some of the capacitors to better model them with regard to self inductance. This inductance was measured with a spectrum analyzer and tracking generator. Some parts were found to be especially sensitive in this regard. Major offenders were the 82 pF parts used in the network that extracts oscillator output and provide feedback to the crystal. More detailed modeling was done for oscillator starting with capacitor models that included this extra inductance. This is shown below.

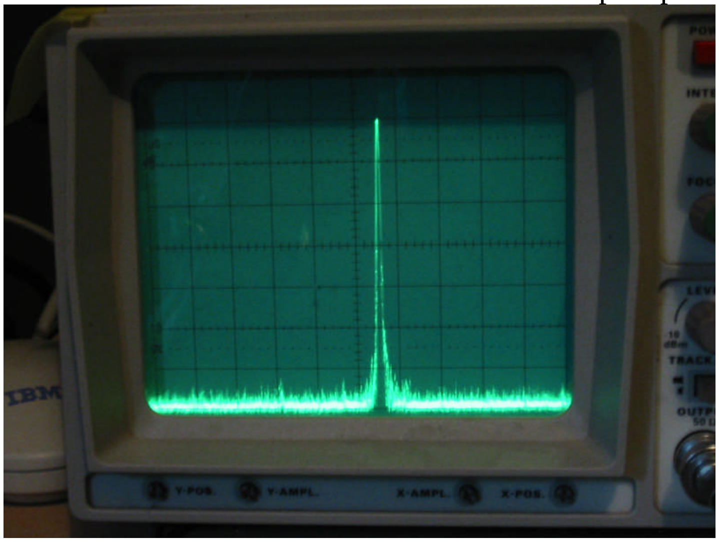


LT SPICE simulation to examine oscillator starting.

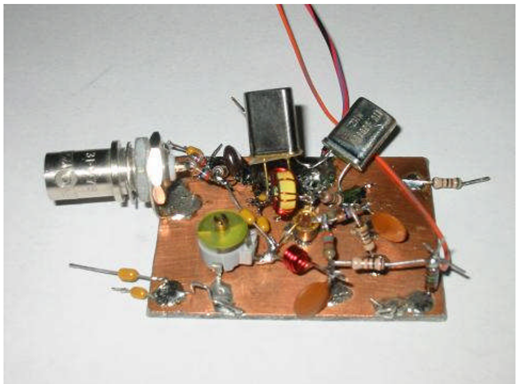
The feedback capacitors were changed and the tank inductor value reduced to enhance starting gain and to generate a more robust design, but that did not kill the squeeging observed with the 110 MHz crystal available.

Several available 5th overtone crystals were measured to establish the parallel capacitance. The 110 MHz crystal that produced the severe squeeging result was one purchased from Surplus Sales of Nebraska that had an atypically large C0=5.6 pF. The 100 MHz crystal we used for all earlier work was from Hy-Q, Inc. (now folded) and had C0=4 pF. A couple of high quality 100 MHz TO-5 can crystals from Colorado Crystal had even lower C0 values. I saw no squeeging with any of my 100 MHz crystals.

One often sees an inductor in parallel with the crystal used in this Butler circuit. The inductor is picked to resonate with the parallel crystal C0, essentially canceling it's effect. I ***had*** never found this inductor to be necessary. But I thought it wise to again examine this oscillator. The parallel C and the new inductor were both added to the simulation with no ill effects. Exact values did not seem to be needed. The L needed at 110 MHz to neutralize a parallel C of 5 pF is 420 nH, a value easily realized with an available powdered iron toroid core. The coil was quickly wound and tacked into the circuit and turned on. It worked like a charm with an output spectrum shown below:

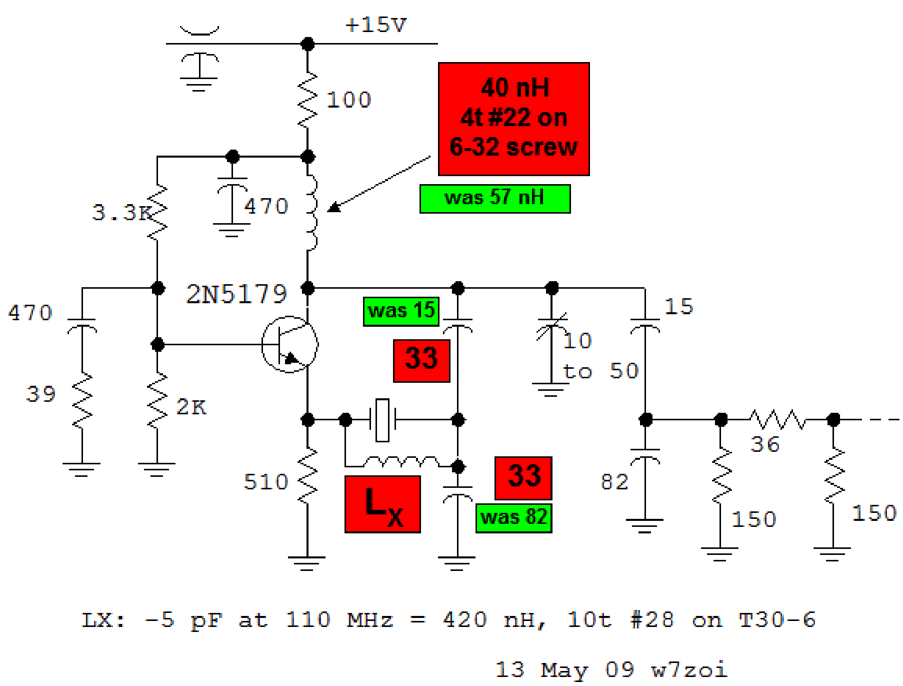


The output spectrum of the cleaner 110 MHz crystal controlled oscillator. The analyzer parameters are identical with the earlier photo.



The modified crystal oscillator. This is the same oscillator board used to develop the original 1998 circuit. Many unused components, including a crystal, are tacked onto the board for later examination.

The tuning of the new oscillator is no longer anomalous. The circuit can be tuned to a peak, and then slightly to either side without having oscillation stop. The final circuit, emphasizing old and new values is shown below:



Updated Overtone crystal oscillator. One set of circuit values worked well at both 110 and 100 MHz with only retuning of the variable capacitor required. The experimental version of this circuit tuned from 81 to 122 MHz when a 100 Ohm resistor was substituted for the crystal.