

The SS-40, a receiver kit for beginners: stable and sensitive.

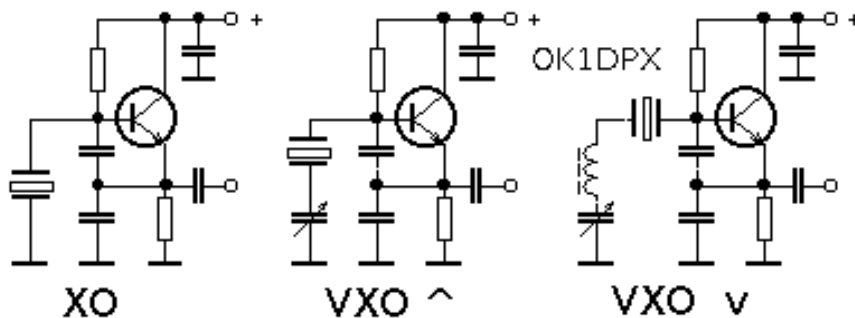
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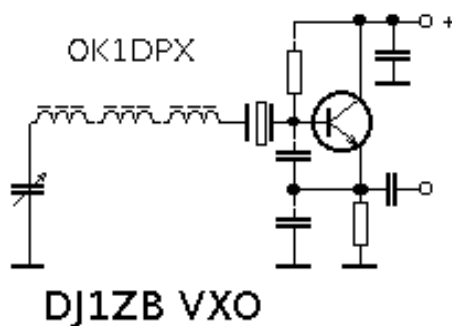
Since last May the 4 State QRP Club is offering an economical kit for beginners with which you can build a magnificent CW receiver for the 40 meter band. The name itself says all: stable and sensitive. And responsible for this stability is a variable crystal oscillator. As a relatively unknown circuit, I will start this article telling some things about the VXO.

VXO is the acronym for Variable Xtal Oscillator, an oxymoron if you remember that quartz crystals have always been used for frequency-stable oscillators. Petr, OK1DPX, has a great page <http://www.quido.cz/qrp/quattro/quattro.htm> where he has shown the different types of VXO.



Crystal oscillator, and two types of variable crystal oscillator.

In the fixed oscillator (XO) the crystal is grounded. If you put the crystal in series with a variable capacitor to ground is possible to pull the oscillation frequency slightly upward. With an inductor in series it is possible to pull the frequency down. The variation which may be achieved is very small, around 0.1% of the fundamental frequency of the crystal. For a crystal of 7 MHz, it would be about 7 kHz. The Japanese Mizuho Co. managed to obtain much larger ranges for its HTs, at the expense of using crystals with a special cut, hard to get and relatively expensive, limiting thus its spread.



VXO designed by DJ1ZB, with several small-value inductors in series.

That has not prevented the search of other solutions. Ha-Jo, DJ1ZB, published in SPRAT (Bulletin of the G-QRP Club) in the spring of 1992, a circuit that could achieve tuning ranges much wider by using several small inductance in series instead of one of a greater value. In 1995, the New England QRP Club organized a "Build a good VXO" contest, won by Joe, N2CX, applying the same principle. WA8MCQ explained in the list QRP-L that "the effect is due to the fact that the lower value inductors have a self-resonance at much higher frequencies. A single reactor could self-resonate at a frequency lower than the one of the crystal, having thus a capacitive behavior, while small chokes in series behave like inductive, which is what you want".



Parallel arrangement of the inductance in the "Forty" rig for greater tuning range.

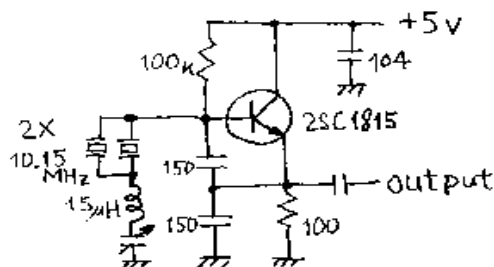
Another discovery by Ha-Jo was that it is possible to extend the tuning range by dividing the inductance on two identical inductors arranged in parallel next to each other and playing with the separation between them to change their mutual coupling. This was successfully applied by Luc, F6BQU, on his 40 meter SSB transceiver "Le Forty" <http://lpistor.cher-alice.fr/forty1.htm>.

The VXO uses a 12 MHz crystal and, by changing the position of the two inductors (they look like brown resistors on the picture) in parallel, I could get on my kit up to 70 kHz of range. The inductors should be separated from the circuit board to reduce the effects of the ground plane, and must be high-Q inductors.

In 2002 Jim, K8IQY, published an excellent work on the characterization of quartz crystals and their use in extended range VXO: <http://www.k8iqy.com/testequipment/pvxo/pvxopage.htm>, and Wayne, NB6M, did very interesting experiments, using both authors the same concept of using several small inductors in series: <http://www.amqrp.org/projects/NB6M%20contestvxos/VXO%20Experiments.html>. As a result of Jim's work the American QRP Club offered for a while a kit to build what was called the "Precision VXO" <http://www.njqrp.org/pvxo/>.

The Super VXO

But perhaps the revolution in this field came from the works of two Japanese hams, JA0AS, Shimizu-san, first president of JARL QRP Club, died in 1996, and JH1FCZ, Okubo-san, also known as one of the co-inventors of the Hentena: <http://homepage3.nifty.com/lzk/ANT3.html>. Tadashi has a small kit business for young people, and between 1975 and 2001 he published a newsletter called "Crazy Franzy Zippy" where the circuit appeared in 1980. Even today he publishes a newsletter for QRP and homebuilding called Cirq, which you may download from his webpage <http://www.fc3-lab.com/backnumber.html>. The circuit, which differs from other for the use of two identical crystals in parallel, was well known in Japan but did not achieve worldwide fame until Makoto, 7N3WVM, spread it in the QRP-L list in October 1996: <http://qrp.kd4ab.org/1996/961030/0004.html> and his website: <http://www.qsl.net/7n3wvm/supervxo.html>.



*An example of super VXO
Drawing by 7N3WVM*

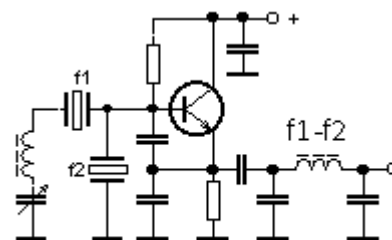
Original hand sketch by Makoto, 7N3WVM.

The commotion caused on the QRP circles was enormous: Tom, N100Q, conducted a laboratory analysis: <http://qrp.kd4ab.org/1996/961106/0027.html>. By analyzing the dynamic behavior of the two crystals in parallel with a network analyzer, Tom found that the Q value decreased to one half, as well as the insertion loss and the series resistance. The latter would make the losses lower in the oscillator, improving performance.

In 1997 Jim, K8IQY made SuperVXOs trials with multiple crystals, giving far greater tuning ranges than with a single crystal: <http://qrp.kd4ab.org/1997/971009/0076.html>.

In fact, these experiments may be considered as a previous part of the development of the SS40 receiver. Pete, N6QW, followed the recommendation by Jim for a VXO with two doubling crystals which he called the "Super super VXO": <http://www.jessystems.com/morexcvrs.html>. JK (Joao Kolar), PY2WM, did tests with 1, 2 and 3 crystals in a SuperVXO for 14 MHz, and the obtained tuning ranges were 11, 20, and 32 kHz, respectively: <http://py2wm.qsl.br/VXO/VXO-e.html>. Petr, OK1DPX, experimented with a double crystal within the same capsule: <http://www.quido.cz/qrp/quattro/quattro.htm>. Curiously, in 1995 G3ESP published in SPRAT a circuit with two different crystals in parallel, one fixed and one variable, which yielded the frequency mixing of the two crystals: <http://www.zerobeat.net/g3ycc/widevxo.htm>.

In addition to the Forty of F6BQU, other designers have used VXOs on their rigs. Dan Tayloe, N7VE, famous for its super mixer, used a superVXO on his hybrid transceiver "Firefly" comprised of an SDR receiver and a conventional transmitter: <http://www.qrpkits.com/firefly.html>. And, of course, the SS40, the subject of this article.



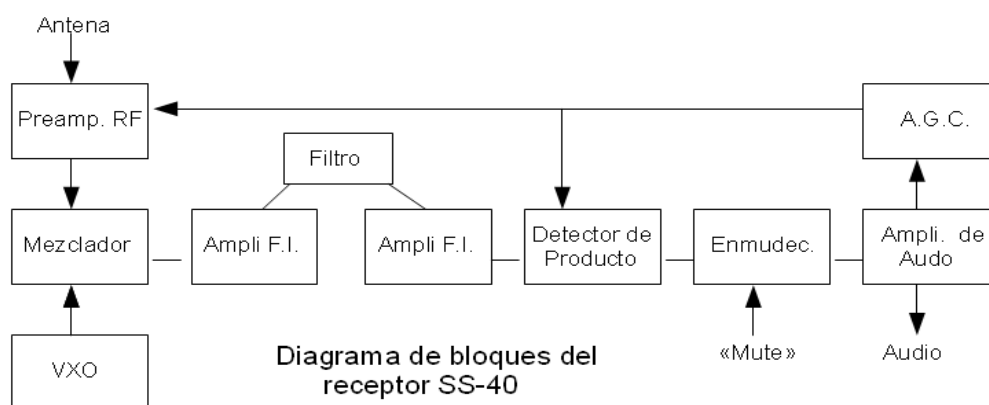
G3ESP VXO

G3ESP mixed VXO which also acts as mixer.

The SS-40 kit

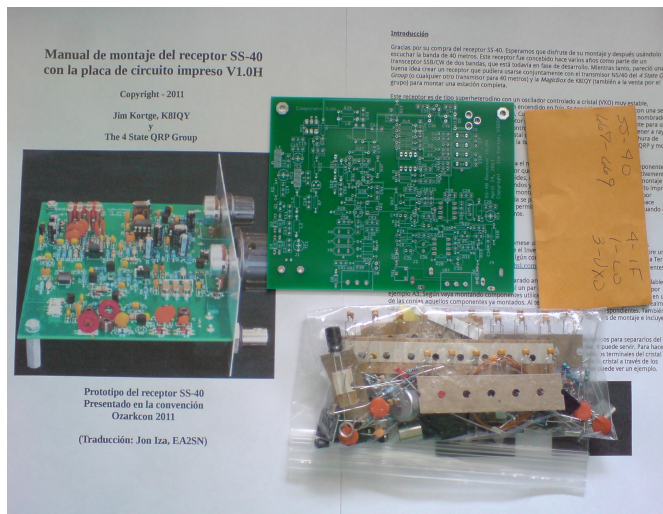
Jim Kortge, K8IQY, is a well known designer in the QRP scene, so appreciated that his merit got him a place in the QRP Hall of Fame. He has designed a large number of rigs and accessories, the best known of all, replicated by many fans around the world, is surely the 2N2-40, a CW transceiver for 40 meters using only 2N2222 transistors: <http://www.k8iqy.com/qrpriqs/2n240/2n240page.html>. The construction was done using the 'Manhattan' style, or 'paddyboard' "for the Aussies, and deserves a whole article about it. As a result of his previous works and studies on quartz crystals and oscillators, he got the the idea of designing a VXO-based CW receive, with a narrow crystal filter, high sensitivity and a good AGC. And, more important, using a relatively large circuit board for an easy assembly making it appropriate for novice kit builders. Jim gave the rights to the "4 State QRP Club," which allocates the small profit left by each kit to fund the annual QRP convention in the Ozark Mountains, the Ozarkcon. The club also offers a xtal-based transmitter kit, the NS-40, designed by David Cripe NM0S, which with just 14 parts gets a respectable 5 W output power with an efficient class E amplifier and, as a general-purpose accessory for QRP lovers, fitting perfectly between these two kits, Jim designed a fairly complete T/R switch, the "MagicBox", which allows for QSK up to 50 words per minute. Both kits also offered by the 4SQRP, and will be the subject of an article later. <http://www.wa0itp.com/4sqrpkitindex.html>.

Description of the SS-40 receiver



It is a classic superheterodyne circuit, as shown in the block diagram. The RF goes to a FET preamplifier, whose gain is controlled by the AGC, which gets the control signal from the audio circuit. The mixer is a double balanced type, using a commercial mixer from Minicircuits; it is an SMD part but it is not very difficult to solder. The VXO uses three 16.257 MHz crystals in parallel and, as a variable capacitor, a large capacity varactor MVAM109 is used. The IF stage uses a dual low-noise op-amp, the LT1253. The first operational amplifier is a post-mixer one before the 4-pole crystal filter at 9.213 MHz prepared from crystals hand picked one by one by Jim to have a frequency spread less than 10 Hz. The second op-amp goes after the filter and before the product detector made with an NE602. Between the IF amplifier and the detector there is a second AGC control point. The balanced output of NE602 is used to place a very effective muting circuit with two FET, and the receiver ends with an audio amplifier with an LM386.

Analysis of the kit and assembly process.

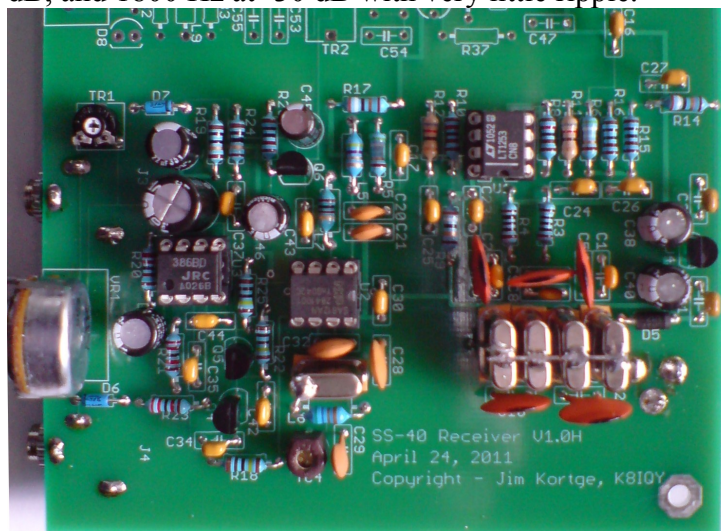


After receiving the package and making the inventory I started mounting the kit. Being designed as a beginner kit the printed circuit board is relatively large, so that there is space between parts, and all connectors and controls are mounted on the PCB, eliminating thus all wiring errors. The manual is organized in steps, many of which end with tests, which allows for an easy finding of bugs and errors, ensuring the ultimate success.

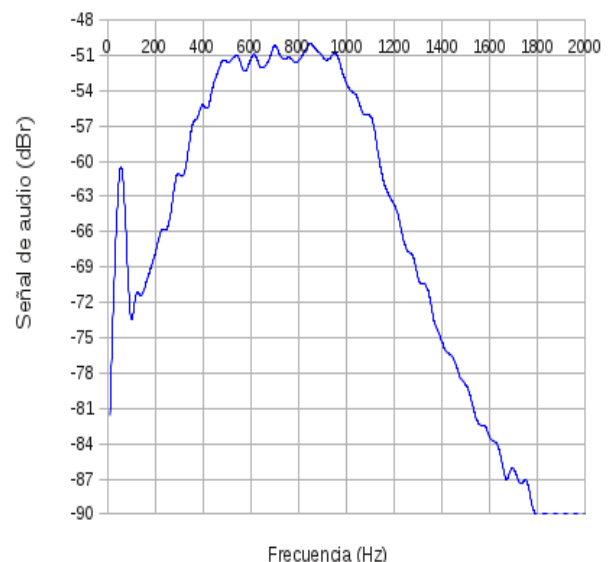
With the power supply, amplifier, audio, mute and product detector already built one may test that it "receives" in the frequency of the IF. I used for that an RF generator, but you can use an "open" rig able to transmit on that frequency, used on a dummy

load at low power.

Once the crystal filter and the IF amplifier are built you get a fixed-frequency receiver in 9.213 MHz. By varying slightly the frequency of the external signal you may feel the effect of the crystal filter, which is very narrow. Later on, I checked the filter response with Spectrogram <http://www.w5big.com/spectrogram.htm> and results were excellent: about 600 Hz bandwidth at -3 dB, and 1800 Hz at -30 dB with very little ripple.



Respuesta del filtro con una fuente de ruido



Filter response plot: the peak at the left is the AC hum.

Once the VXO is built, its operation may be checked by using a general coverage receiver in the vicinity of 16.245 MHz. It is mounted in three stages because, besides the oscillator, it has two amplifier stages to get the +7 dBm required by the balanced mixer. It carries a transformer made with a binocular ferrite core, not too difficult to prepare. The VXO requires the crystal capsules to be grounded for maximum tuning range, which reaches 30 kHz. The frequency response is almost linear with the tuning potentiometer used in the kit, and when a large button is used no fine-tuning is required.

Relación Tensión del VXO vs. F

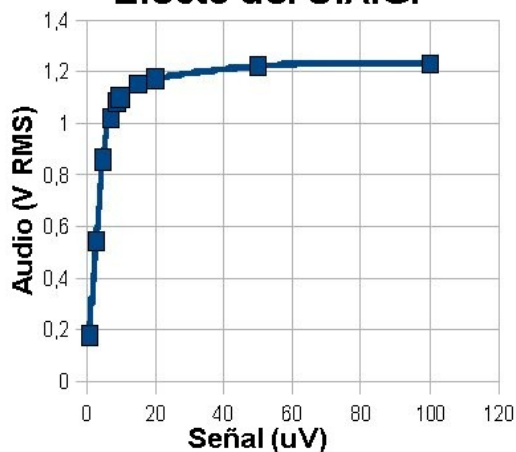


VXO Response

With the mixer built we have a crude receiver, not very sensitive, but that works perfectly. I listened with it a CQ by CT1ACS. A 1 μ V signal may be heard on the speaker, and 10 μ V sound strong. To complete the assembly we need to complete the RF preamplifier and the second part of the AGC circuit. There are two toroids with a single winding, not a major constructive difficulty. The adjustment can be done by ear or with some type of generator. The preamp has three adjustable capacitors which are very responsive to tuning. If the receiver initially seems deaf you only need to tweak the three trimmers and the magic happens. Jim called the SS-40 receptor is sensitive and stable. Stability is great: once the receiver is on, if there is a station on the passband at that time, one may leave the receiver without touching the controls: the tone of the station will not change unless it is the other the one that "slips" :-). The sensitivity of the receiver, once set, is fantastic. In a preliminary trial, with the PCB on top of the table, with no shielding of any kind, I managed to measure a minimum discernible signal MDS of 0.08 μ V (-128 dBm). Jim, K8IQY, got even better values that put

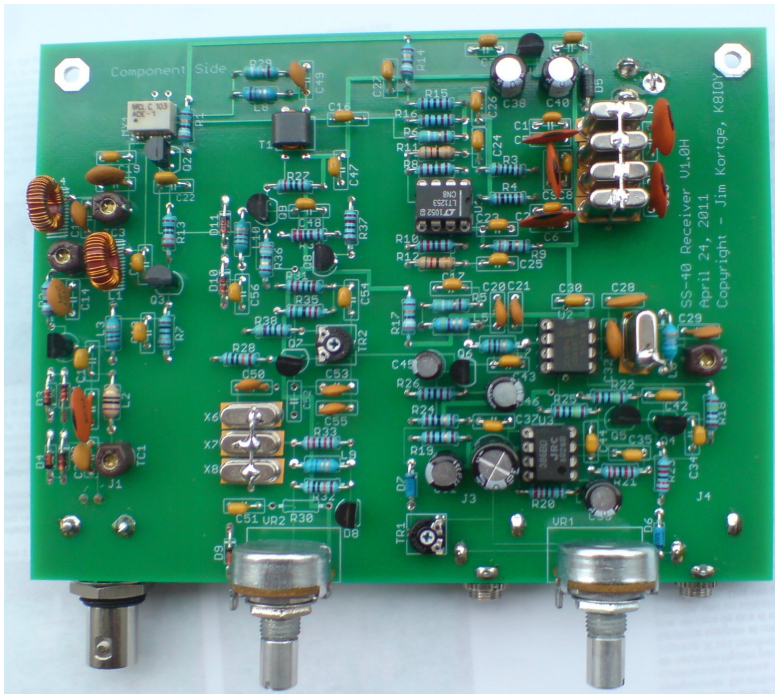
this rig up to par in performance with commercial rigs with lots of bells and whistles. But perhaps what caused me the greatest impression was the very low noise of the receiver. If you have no antenna connected, the rig is virtually silent, and you may only notice a slight hiss when the volume is cranked up above 90% of the pot range. The jump that occurs when you plug the antenna in makes the audio level to increase by 30-40 dB (equivalent to the gap between the noise-floor of the receiver at the noise-floor of the band). The AGC works very well, and when the signal exceeds 10 μ V the audio response becomes flat. There is, therefore, no risk of damaging the ears when your "friend" down the street turns on his kilowatt ...

Efecto del C.A.G.



Boxing the PCB

The PCB is designed to fit in a box manufactured by TenTec, the TP41. Fortunately the Spanish Retex company has a similar model, the Minibox MB10. For the NS-40 and the MagicBox dimensions are similar, so it can be a good measure to get several cases cases.



Final conclusion

This kit can be a great learning experience in electronics and radio. The receiver, though limited on its tuning range, stands up very well when compared with other, more expensive rigs in terms of sensitivity and selectivity, because it has a narrow filter of high quality. And it can be the first step for a complete economic station, simple to build and effective.