Gerd Otto, DC 6 HL

A Variable Crystal Oscillator (VXO) with a Pulling Range of Approximately 200 kHz at 144 MHz

A variable crystal oscilator (VXO) is to be described that has been especially designed for use in conjunction with the mini-SSB transceiver for 144 MHz described by the same author in (1). This oscillator provides a very clean signal with a level of approximately 7 dBm. This can be tuned from 135.15 to 135.35 MHz, which corresponds to an operating frequency range of 144.15 to 144.35 MHz for the transceiver, in other words for the SSB-range. Details are to be given regarding calculation of the crystal frequency, which means that this oscillator can also be designed for other frequencies. The dimensions of the screened module are only 74 mm × 37 mm × 30 mm. It will be seen that its length corresponds to the width of the transceiver, which means that the oscillator can be located adjacent to the crystal filter of the transceiver.

1. CIRCUIT

Variable crystal oscillators are preferably used when a relatively narrow frequency range is to be covered continuously – in contrast to channel switching with FM transceivers. The frequency stability corresponds to a value between a conventional crystal oscillator and that of a good VFO (LC-oscillator with variable capacitor or diode tuning). Such variable crystal oscillators (VXOs) have been described several times in VHF COMMUNICATIONS – the last one was a version with eight crystals, whose frequency ranges overlapped (2).

In order to ensure a sufficiently wide pulling range, a fundamental crystal is used at one sixth of the output frequency The crystal oscillates together with the dual-gate FET T 1 (Fig. 1). The pulling inductance L 1 and the output circuit comprising L 2 allow the pulling range and the maximum output level to be adjusted with very slight interaction. Due to the control voltage generated across diode D 1, the output voltage of T 1 remains virtually constant over the whole pulling range.

The push-pull push-push doubler equipped with Schottky diodes D 4 and D 5 is provided subsequent to the oscillator and generates a frequency of 45 MHz. This is followed by a subsequent bandpass filter equipped with inductances L 4 and L 5 which is used to filter the 45 MHz signal, especially to suppress its subharmonic 22.5 MHz, and to supply a clean drive signal for the frequency tripler equipped with T 2.

The 135 MHz signal generated in the tripler is fed to a three-stage filter and is available at the output at a level of at least 7 dBm. This power level is sufficient for driving standard Schottky diode mixers such as SRA-1, IE-500, MD-108.

1.1. Selection of the Crystal

In order to obtain the required pulling range of 200 kHz at the final frequency in the 2 m band, it is necessary – as already mentioned – to use a fundamental crystal at one sixth of the required

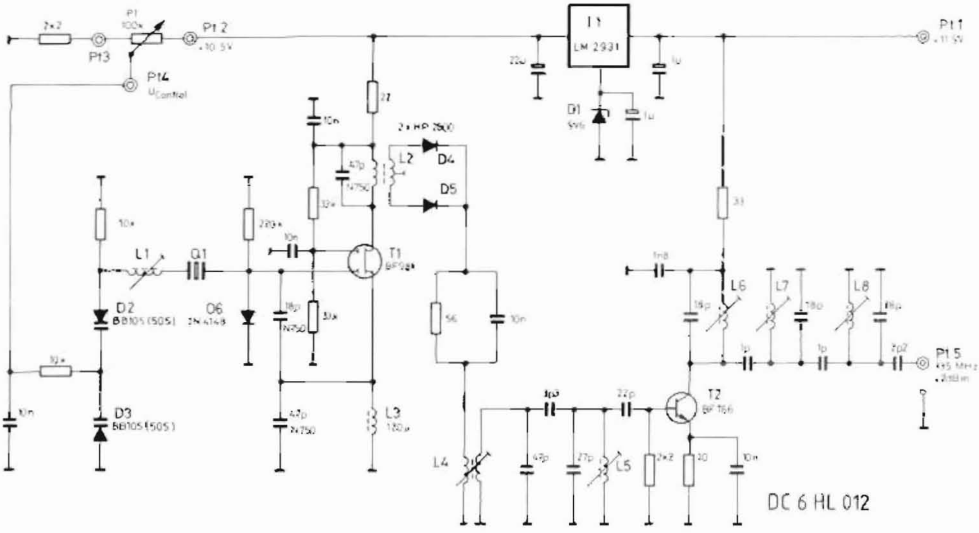

Fig. 1: Variable crystal oscillator frequency multiplication of six-times the crystal frequency

frequency. Since the pulling range is non-symmetric to the nominal frequency (2), the specifications of the crystal should be calculated according to the following equation:

$$f_Q = \frac{f_{ll} + 150\,\text{kHz}}{6} = \frac{f_{ul} - 50\,\text{kHz}}{6}$$

f_{ll} = lower frequency limit
f_{ul} = upper limit of the pulling range

With a pulling range of 135.15 to 135.35 MHz, f_Q will be 22.55 MHz. It is sufficient for one to order a fundamental crystal in a HC-43/U (HC-18/U) for the calculated frequency that is designed for a capacitive load of 30 pF.

1.2. Special Components

T 1: BF 981 (Philips), BF 907 (TI) or similar low-noise DG-MOSFET in a plastic case
T 2. BFT 66 (Siemens) or similar low-noise UHF transistor in TO-18 case
I 1: LM 2931 (National Semiconductor)
D 1: C5V6 zener diode
D 2, D 3: BB 505 B or 505 G
D 4, D 5: HP 2800 (Hewlett Packard) or similar Schottky diode
D 6: 1 N 4148, 1 N 4151 or similar switching diode
L 1 32 turns of 0.2 mm dia. enamelled copper wire in special coil set, (7V 1S) with core (yellow), (previously: blue). Glue the winding to the coil former with the aid of a dual-component glue without bubbles. Manufacture as shown in **Figure 2.**
L 2: 13 + 2 + 2 turns, wire and coil set as for L 1. Glue the windings into place. Manufacture as shown in **Figure 3.**
L 3: Miniature choke 120 μH
L 4: 2 + 8 turns, wire and coil set as for L 1. Manufacture as shown in **Figure 4.**
L 5. 8 turns, wire and coil set as for L 1. Connection diagram is given in Figure 2.
L 6 – L 8: Ready-wound coil type 05118.

Crystal: see Section 1.1.
Case: Metal case, 74 mm × 37 mm × 30 mm
Tuning potentiometer: 100 kΩ, 10-turn helical potentiometer

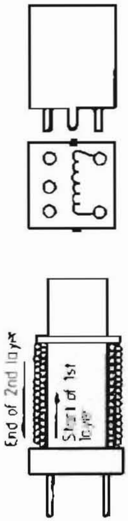

Fig. 2:
Connections of L 1 and L 5 (top), and winding diagram of L 1 (below). Two layers of 16 turns, each!

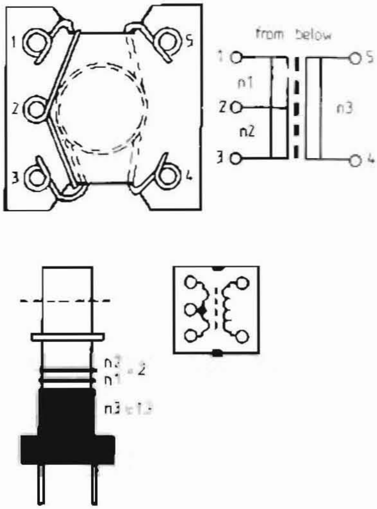

Fig. 3:
Winding and connection diagram of L 2

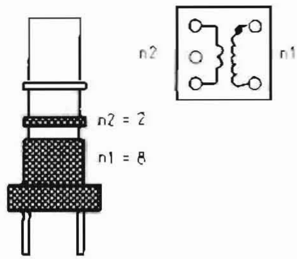

Fig. 4:
Winding and connection diagram of L 4

2. CONSTRUCTION

All components are accommodated on the double-coated PC-board DC 6 HL 012 as shown in Figure 5. This board is 70 mm × 32.5 mm and its ground surface is arranged so that no RF-currents from subharmonics can flow to the output pins.

The component connections designated with crosses should be soldered on both sides of the board (through-contacts).

Inductances L 1, L 2, L 4, and L 5 are wound according to the above-shown illustrations (Fig. 2–4). It is important that the winding of L 1 is carried out in two layers using 0.2 mm enamelled copper wire. A single-layer winding using a thinner wire would lead to too low a winding capacitance and too low a Q. Transistor T 1 is solde-

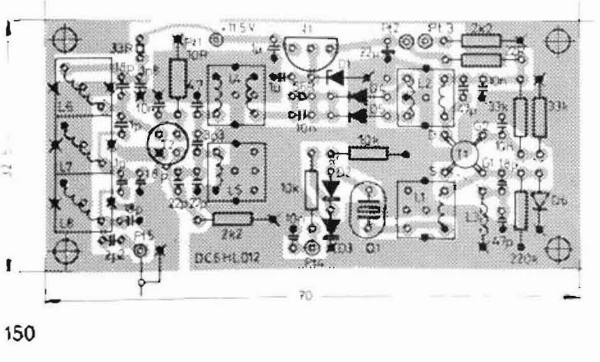

Fig. 5:
The double-coated PC-board is to be soldered on both sides of the board (through-contacts) at the positions designated with a cross.

red onto the PC-board with the marking facing towards the board.

After completing the PC-board, the outer frame of the metal box is soldered around the edge of the PC-board. The operating and tuning voltages are fed in via feedthrough capacitors (short types) of approximately 1 nF (4 pcs.). A thin coaxial cable (RG-174/U or PTFE-cable) is passed through a hole in the case and is directly soldered to Pt 5 and ground – solder pins are not necessary. A photograph of the prototype is given in Figure 6.

3. ALIGNMENT

Connect the operating voltage and the tuning potentiometer. Check the stabilized voltage of I 1 and D 1, it should amount to 10.5 V.

Set the potentiometer to the highest tuning voltage and turn out the core of L 1. The oscillator should commence oscillation on tuning L 2. This can be measured with the aid of a (high-impedance) voltmeter at the cathodes of the frequency doubler diodes: the reading should amount to 0.3 to 0.35 V.

Inductances L 4 and L 5 should be aligned for maximum current drain of the complete circuit: it should amount to 15 mA.

Align inductances L 6, L 7, and L 8 for maximum output power: an output power of approximately 10 dBm should be achieved.

Rotate the core of L 1 in, until the output frequency is aligned to $f_q \times 6 + 50$ kHz. The alignment potentiometer is now tuned to the lowest tuning voltage, which should result in $f_q \times 6 - 150$ kHz. If the inductance of L 1 is increased further by inserting the core, this will result in the pulling range to become considerably greater towards lower

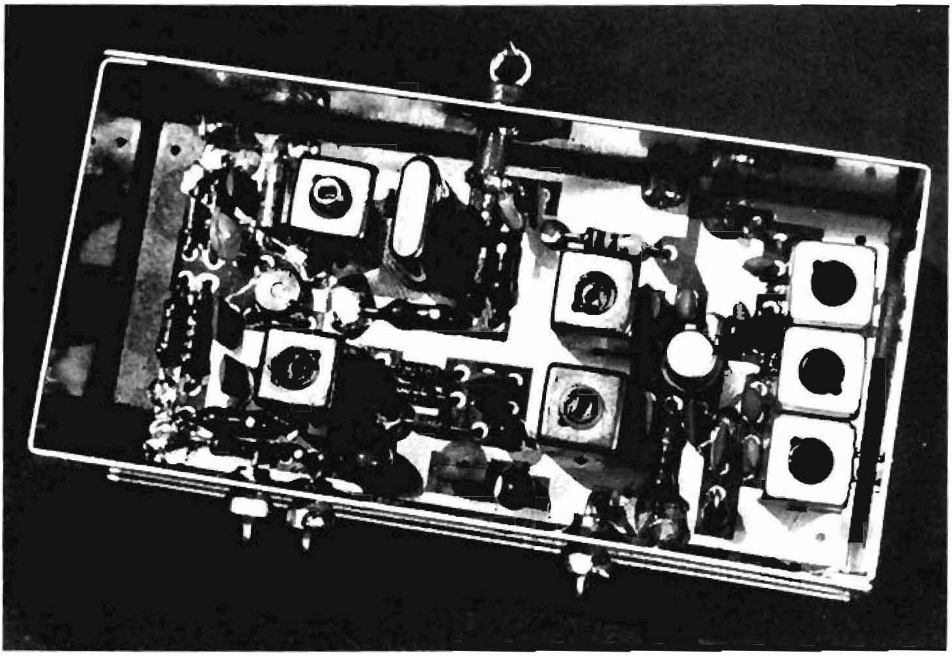

Fig. 6: The construction requires a steady hand, sharp eyes and a soldering iron with a narrow tip

frequencies. However, the frequency stability becomes less and less determined by the crystal on increasing the pulling range. For this reason, it should not exceed 200 kHz (−150 to +50 kHz from the nominal frequency).

4. MEASURED VALUES

Stabilized voltage (using 5V stabilizer and zener diode 5V6): 11.5 V.

Operating current (according to frequency): 16−18 mA

Frequency range: 135.15 to 135.35 MHz

Output power: ≧ 7 dBm (5 mW)

Spurious rejection (f_{ul} + 22.55 MHz): at least 80 dB

All others: at least 80 dB

Harmonic rejection (2nd harmonic): 80 dB

All others: at least 80 dB

Frequency stability for a temperature jump from 20 to 50°C: approx. 2 kHz.

Note:

As is the case of a VFO, this VXO should be mounted in a position in the transceiver or receiver where the lowest amount of heating occurs. In addition to this, it is advisable for the metal case of the oscillator to be surrounded with a layer of at least 5 mm of styrine foam.

5. REFERENCES

1) K. Schöpf, DB 3 TB:
A VXO-Local Oscillator for 144 MHz Transceivers VHF COMMUNICATIONS 14, Edition 2/1982, pages 84-88

2) B. Neubig, DK 1 AG:
Design of Crystal Oscillator Circuits, Part 1 VHF COMMUNICATIONS 11, Edition 3/1979, pages 174-190