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Microwave signal source

Sam Jewell presents an updated version of his 1.1 to 1.3GHz microwave signal source.

INTRODUCTION. My design for the 'DDK001' L band source was first published in the *RadCom* Microwaves column in 1987 and in volume two of the RSGB *Microwave Handbook*. Supplies of the PCBs dried up many years ago after a key component became unavailable, effectively making the design obsolete.

Ongoing demand for sources for use as local oscillators, test sources and small 1.3GHz transmitters encouraged me to update the original design. The new, compact, version 2 DDK001 local oscillator source (2001LO) covers the frequency range from about 1150MHz to 1305MHz, determined by the available Toko helical filters used in the final multiplier stage. Output level is typically +7dBm at 1152MHz and the output spectrum is cleaner than the original 001 source. The following description assumes an output frequency of 1152MHz (LO frequency for 2m IF at 1296MHz, among other applications).

Although the new 2001LO follows the same architecture as the older 001 design, I have made several significant changes. The side-coupled stripline filters have been replaced by discrete component lumped element band pass filters in the first two positions and by a Toko 2-pole helical filter in the output stage. This final filter determines the frequency range of the source. An external high stability source can be connected in place of the internal crystal oscillator if required.

I have continued to use the two-stage Butler bipolar transistor overtone crystal oscillator. This design has been endlessly analysed with respect to its phase noise performance and stability. Whilst there can be little doubt that the Driscoll and some other Butler variants can produce better phase noise performance, it is still a versatile and low noise oscillator design that is easy to align, forgiving of component variation and reliable in operation. The oscillator has proven itself over the years and even when multiplied up to 10GHz the phase noise performance is still good. Butler oscillators have been operating in the GB3MHL and GB3MHX (JO02PB) beacons for over 20 years without failure.

A finished 2001LO source is shown in **Photo 1**.

PHOTO 1: One of the prototype sources. This version uses different trimmer capacitors to those specified. The red trimmers shown are now replaced by black bodied 4 to 25pF trimmers.

CIRCUIT DESCRIPTION. An overtone crystal oscillator drives a series of frequency multiplier stages with inter-stage filtering to define the output frequency. The overall multiplication is 12, implemented as x3 in the Butler oscillator stage and then two frequency doubler stages.

The circuit diagram is shown in **Figure 1**.

Common base amplifier, TR1, is the oscillator maintaining stage. Its collector tank circuit is tuned to the crystal overtone frequency (96MHz). The tuned circuit is heavily damped by R6. Trimmer C5 resonates the circuit. This stage is also used as the input buffer amplifier when an external source is to be connected.

TR2 is an emitter follower with its output feeding the overtone crystal. Its collector is tuned to 288MHz, the third harmonic of the crystal overtone frequency. Soft limiting is used to reduce phase noise degradation, but this results in low harmonic output levels. A compromise has had to be made here.

Since the crystal is connected between the emitters of TR1 and TR2, the feedback is in phase, which allows oscillation. Capacitors C9 and C10 allow the crystal to be pulled over a few hundred Hz at 96MHz. L2 may not be necessary but can be used if required in order to allow the crystal to be pulled onto frequency. In practice, C10 should be used to set the oscillator frequency and C5 used to peak the output, although there will be strong interaction between the settings of these capacitors.

The quality of the crystal oscillator is largely determined by the quality of the crystal used. Cheap crystals may not prove to be so economical in terms of performance.

L3, C13, C15, L4 and C14 form a 288MHz band pass filter. This is sharply tuned and only the recommended trimmer capacitors should be used to ensure resonance is achieved at 288MHz. Top capacitive coupling is provided by C15.

TR3 is the frequency doubler from 288MHz to 576MHz with L5, C28, C19, L8 and C29 forming the band pass filter at this frequency. Bias stabilisation is provided by returning R13 to the collector side of R14.

TR4 is the frequency doubler from 576 to 1152MHz and uses a similar bias arrangement to that of TR3. A Toko 5HW series helical filter selects the second harmonic of the 576MHz drive. The PCB connections are for the Toko 'F' pin-out configuration filters (5HW 115045A-1195, 5HW 120050F-1225 and 5HW 125055F-1305).

A 78M08 surface mount voltage regulator provides a stabilised 8V to drive the source.

No attempt has been made to temperature stabilise the crystal oscillator as it is felt that where this is required, an external, low noise, stabilised crystal oscillator (OCXO), direct frequency synthesiser (DFS) or PLL could be used. However, the small housing used for the 2001LO source means that it is practical to enclose the entire unit within a temperature stabilised oven to control the whole of the unit and not just the crystal.

Where an external source is to be used, remove crystal X1 and add R18 and C32 as shown in Figure 1. Since the input impedance of the common base stage is low at about 7Ω it is necessary to increase the impedance, to achieve a decent match, by adding series 39Ω resistor, R18. The required drive is in the range -10 to +6dBm, with optimum drive at about -3dBm.

With the component values shown in

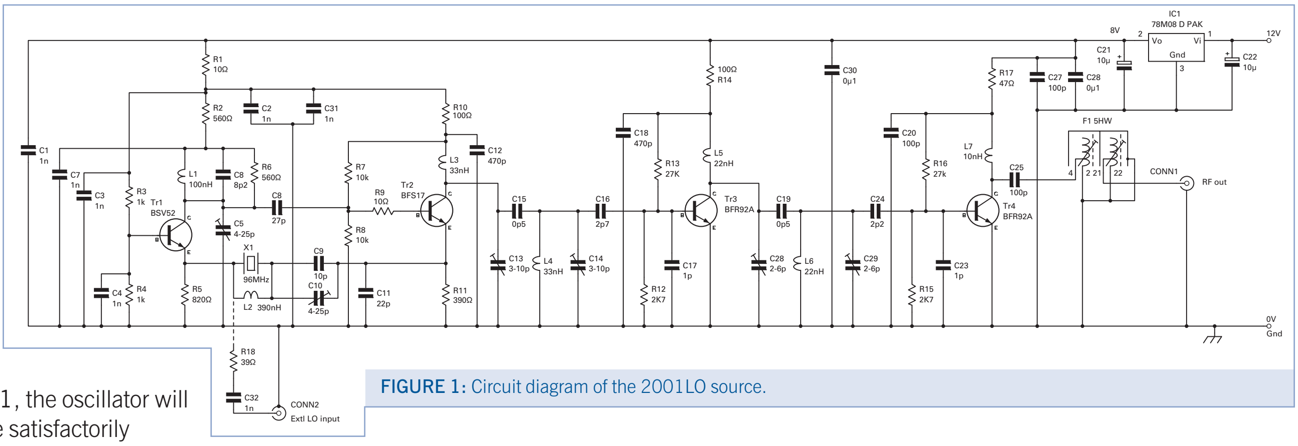

FIGURE 1: Circuit diagram of the 2001LO source.

Figure 1, the oscillator will operate satisfactorily between approximately 95MHz and 109MHz, giving an output of between 1150 and 1305MHz respectively. One of the three versions of the helical filter will be required to cover the whole frequency range.

CONSTRUCTION. The source is constructed on a 37 x 74 x 1.6mm, FR4, double sided PCB, shown in **Figure 2**. All the components used are surface mount devices (SMD) with the exception of the crystal and the helical filter. 0805 size passive components are used, with SOT23 packaged transistors, D-Pak voltage regulator and B case size tantalum polarised decoupling capacitors. The trimmer capacitors are Murata TZB4 series.

The source will fit into a Schubert 37 x 74 x 30mm size tin plate box, or it can be fitted into convenient die-cast aluminium or other housing as required. The Schubert tin plate box is available from G3NYK. If the tin plate box is used then it should be marked with a line around the inside 10mm down from the rim. This marks the position of the ground plane (copper side) of the PCB, with the component side of the board now 8.4mm below the rim of the box. The area above the PCB ground plane side is sufficient to clear the helical filter and crystal, which are both mounted on the ground plane side of the PCB.

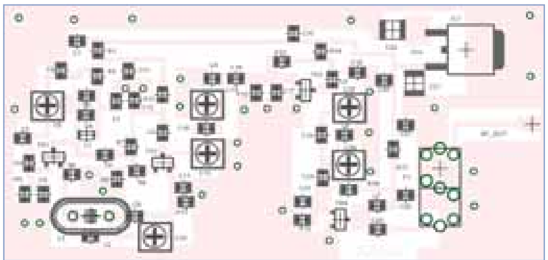

FIGURE 2: Component overlay, actual size.

Next, mark the position where the two or 4 hole gold plated SMA RF output connector will be soldered to the outside of the box. Drill a 4mm diameter hole through the box in a position where the connector spill will lie flat to the PCB RF output track. If an external source is to be used, an SMA connector can be fitted at the other end of the box, near the crystal location.

Drill a hole in the end of the box for the supply feedthrough capacitor. This should be above the voltage regulator and on the short edge of the box near the RF output SMA connector.

My preference is to solder the PCB into the box *before* soldering the SMD parts into place. This avoids accidental damage to these small and sometimes fragile parts during the seam soldering process.

If you are making your own PCB for the source, it will be necessary to use thin wire through-board links to connect the ground plane to areas of the component side of the PCB. Normally these are plated through holes (PTH). Use 0.3 – 0.4mm diameter tinned wire through 0.5mm diameter holes. Use only 28SWG solder, both for the through board links and for soldering the SMD parts. Standard size 22SWG solder is unacceptable and will make a mess of the PCB.

The 2001LO PCB component overlay is shown in Figure 2.

ALIGNMENT. Apply +12V and check that the current draw is no more than about 50mA. If it's significantly higher, check for faults. Check for +8 volts at the output of IC1.

The source can be aligned with little more than a multimeter. However, this is not recommended as it can be difficult to ascertain if intermediate stages have been tuned to the correct frequency. A far better technique is to use a spectrum analyser with the probe described in the June 2008 *GHz Bands* column.

Tune the analyser to 96MHz with 1MHz span and set to the amplitude reference to 0dBm. Place the probe on the base of TR2 and adjust C5 for a strong 96MHz output indication (approximately -15dBm with the -20dB probe). C5 should be set around mid capacitance. Re-tune the analyser to 288MHz and place the probe on the base of TR3. Tune C13 and C14 for maximum 288MHz output (approximately -15dBm). C13 and C14 should be set to near maximum capacitance.

Re-tune the analyser to 576MHz. Place the probe on the base connection of TR4 and adjust C28 and C29 for maximum 576MHz output (approximately -15dBm). C28 and C29 should be set around mid capacitance.

Finally, re-tune the analyser to 1152MHz and set the amplitude reference to +20dBm. Connect the analyser to the output connector and adjust the cores of F1 for maximum output. This should be in the range +7 to +11dBm.

With a suitable means to accurately measure the output frequency, adjust C10 for 96.000000MHz. It may be necessary to remove C9 with some crystals. L2 is not normally required, but provision is made to add this inductor for use with some crystals that will not otherwise adjust onto frequency.

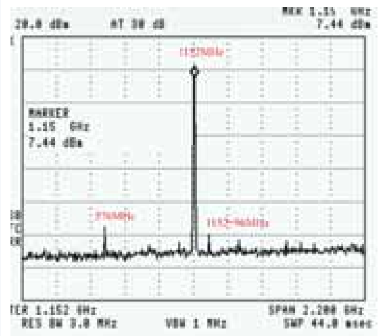

FIGURE 3: Output spectrum of the 2001LO from 50MHz to 2250MHz. The measured output is +9dBm at 1152MHz on narrow span. Half frequency (576MHz) is over 45dB down on the 1152MHz output. All other non-harmonic outputs are over 50dB down on the 1152MHz output.

There will be some frequency interaction with the adjustment of C13 and C14 as the TR2 frequency tripler will tend to pull the frequency. To a lesser extent, so will adjustment of C28 and C29.

WORK IN PROGRESS. By the time this is in print, small changes may have been made to the circuit. It is advisable to check my web page for the latest information before commencing construction. I hope to make PCBs available for this source for those who cannot make their own PCBs.

I have designed a compact 1296MHz receive converter to work with the 1152MHz local oscillator source. I plan to cover this in a future edition of *RadCom*.

REFERENCES

Members can download the PCB foil pattern and comprehensive components list from the RSGB *RadCom* Plus website at www.rsgb.org/membersonly/publications/radcomplus/index.php

BEC Distribution Ltd: www2.bec.co.uk/PG800/8heli/p114.htm

Farnell: www.farnell.co.uk

G3NYK: www.alan.melia.btinternet.co.uk