

2.8 GHZ – 5.7 GHZ VERY FAST UWB CCO USING DISCRETE-PACKAGED SIGE RF TRANSISTORS

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Abstract: A simple and successful design for ultra-wideband current-controlled oscillator (UWB CCO) is presented. The circuit uses discrete-packaged transistors and lumped elements. The tuning range of the CCO exceeds one octave in the lower microwave frequency range with reasonable phase-noise performance. Further it achieves a very high tuning speed: its 3 dB FM bandwidth exceeds 400 MHz.

2,8 GHz – 5,7 GHz zelo hiter ultra širokopasoven tokovno krmiljen oscilator z diskretnimi SiGe RF tranzistorji

Ključne besede: tokovno krmiljen oscilator, fazni šum, modulacijska pasovna širina, diskretni SiGe tranzistorji

Izveček: V prispevku je predstavljena preprosta in učinkovita izvedba ultra širokopasovnega tokovno krmiljenega oscilatorja (ang. UWB CCO) izdelanega z diskretnimi elektronskimi elementi. Frekvenčni razpon oscilatorja, ob sprejemljivih vrednostih faznega šuma, presega eno oktavo v spodnjem mikrovalovnem frekvenčnem področju. Njegova zasnova omogoča izredno hitro modulacijo; 3 dB frekvenčna modulacijska pasovna širina presega 400 MHz. Osnovna aplikacija predstavljenega oscilatorja je bila simulacija uklenitve kompleksne elektro-optične fazno sklenjene zanke (ang. OPLL), v kateri je oscilator nadomeščal laser. Oscilator je sicer mogoče uporabiti tudi v hitrih mikrovalovnih vezjih (sklopi s fazno sklenjeno zanko) in drugih aplikacijah širokega frekvenčnega spektra.

1 Introduction

UWB voltage or current-controlled oscillators /1-3/ found place in many applications of transmitting data over a wide spectrum with high data rates and in some other special applications. In this paper, we propose a current-controlled oscillator (CCO) using discrete-packaged SiGe:C transistors, capable of very fast tuning over a wide frequency range. Our particular application of the described CCO was the simulation of a complicated electro-optical system in a very fast electro-optical phase-locked loop (OPLLs) /4/, where the CCO simulated an yet-to-be-developed laser.

2 Circuit design

The core of proposed CCO consists of a cross-coupled NPN transistor pair T1 and T2 (see Fig. 1), forming a negative-impedance circuit (NIC) and providing positive feedback to produce oscillation. The NIC is loaded by an external lumped inductor to determine the frequency of the oscillation. DC bias current is fed through the center tap of the inductor on the positive side and through the 56 Ω resistor to the common-emitter node on the negative side. In this CCO circuit no varactor diodes are employed.

The external inductor includes two pieces of thin copper foil soldered to an unetched part of a FR4 printed-circuit board as shown on Fig. 2. This inductor also performs as a transistor holder. The two packaged transistors are first soldered together and then held at a specified height above the FR4 board by the inductor. The inductance value is selected

by the height of both transistors above the FR4 board. A recommended height for stable and continuous oscillation was found about 2.5 mm above the ground plane.

Lowering the transistors reduces the inductance and increases the operating frequency. Unfortunately this also narrows the tuning range of the CCO and may produce unstable operation, mainly due to the parasitic inductances of the bonding wires inside the transistor packages.

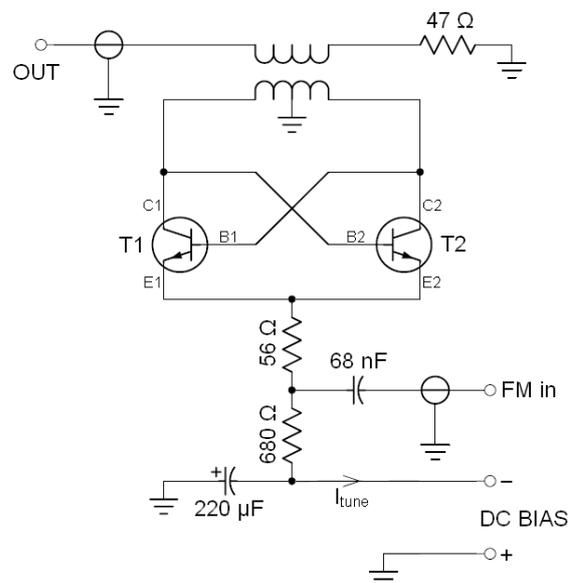


Fig. 1 Ultra-wideband current-controlled oscillator (UWB CCO) circuit design

The CCO is tuned by changing the bias current I_{tune} through 680 Ω and 56 Ω resistors. A 56 Ω resistor is also used for good impedance matching on the FM input. The CCO output is inductively coupled. This coupling is intentionally made very loose to avoid affecting the CCO tuning performance. The output power can be restored by an additional buffer amplifier if required. A practical solution for the output coupling is a 47 Ω resistor installed above the transistors where the resistor leads act as a coupling loop.

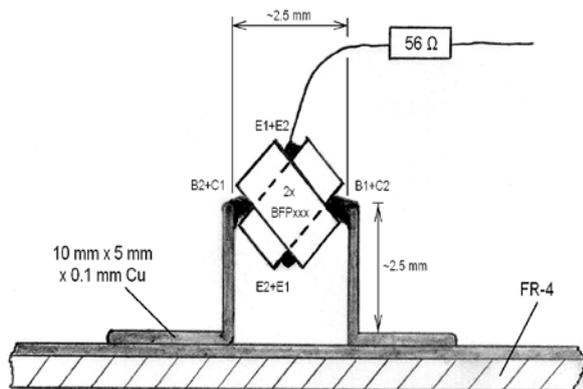


Fig. 2 Transistor mounting in U-shaped Cu holder on FR-4 laminate; the inductance value is selected by the height of both transistors above the FR4 board

3 Measurement results

Practical experiments were made with several different silicon, SiGe and SiGe:C transistors from the BFP series manufactured by Infineon in common-emitter packages SOT-343 and TSFP-4. All CCOs were built on 1-mm thick FR-4 laminate and shielded in a metal box. Microwave-absorber foam was placed above the circuit inside the box to suppress parasitic resonances. Lead-acid batteries were used as noise-free power sources for phase-noise measurements. Transistor types BFP405, 420, 520, 620 and 740 were tested. The best results were achieved with the SiGe:C transistor BFP740 as shown on the following figures.

The CCO tuning curve and output power are shown on Fig. 3. The frequency of the CCO changes from 5.72 GHz to 2.85 GHz when tuning current changes from 1.4 mA to 48 mA. The output frequency is inversely proportional to the operating current resulting in a hyperbolic tuning curve. The tuning slope therefore changes from 100 MHz/mA at the upper frequency limit down to 47 MHz/mA at the lower frequency limit.

The output power stays around -22 dBm in the frequency range from 2.85 GHz to 4.0 GHz and decreases down to -40 dBm at the upper frequency limit.

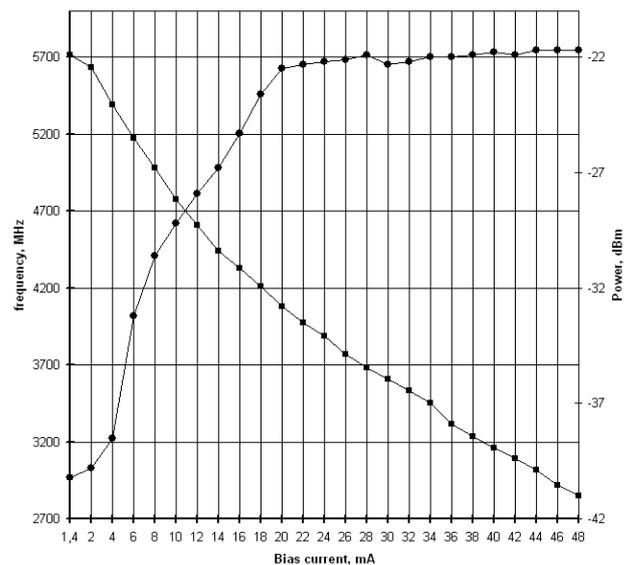


Fig. 3 Frequency and output power against tuning current I_{tune}
 ■ - frequency
 ● - power

The CCO phase noise was measured with a HP8565 Spectrum Analyser and is shown on Fig.4. The phase noise increases towards the upper frequency limit where the operating current is very low and the CCO shows a tendency to turn off and/or jump into another oscillation mode due to transistor-package parasitics.

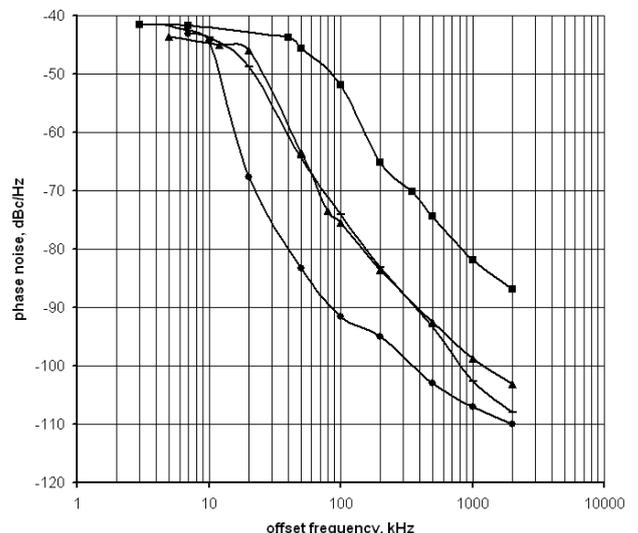


Fig. 4 Measured phase noise at different oscillation frequencies
 ■ - oscillation frequency @ 5.7 GHz
 ▲ - oscillation frequency @ 5.0 GHz
 — - oscillation frequency @ 4.0 GHz
 ● - oscillation frequency @ 3.0 GHz

The tuning speed of the presented CCO was measured as the frequency-modulation bandwidth that is commonly referred to in the industry /5/. An Agilent E4438C Signal

Generator was connected to the FM input while the CCO output was monitored on a HP8565 Spectrum Analyser. The measured 3 dB modulation bandwidth of the proposed CCO exceeded 400 MHz. In other words, the presented CCO is more than 10-times faster than commercially available varactor-tuned VCOs.

4 Conclusion

A novel, discrete-component design of a CCO achieves a wide tuning range and fast modulation capability using standard, low-cost electronic components. Its phase noise is sufficiently low to allow several different wide-tuning-range applications. The CCO tuning speed is much faster than that of varactor-tuned oscillators, allowing very fast electronic and electro-optical PLLs.

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