A 10-14 GHZ QUENCHABLE MMIC OSCILLATOR

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ABSTRACT

A wideband negative resistance MMIC oscillator chip has been designed and tested for fast switching DRO and VCO applications. This MMIC has an on-chip quench circuit which allows for very fast switching of the oscillator without affecting the active device bias. The MMIC which also has an on-chip resistive heater section located in close proximity to the active device minimizes frequency drift due to temperature variations. The switching performance was measured with the chip configured as a DRO; its frequency settled within 0.6 MHz of the final frequency in only 0.5 us. This MMIC configured as a VCO achieved wideband tuning from 10 to 14 GHz.

INTRODUCTION

Previous work on MMIC oscillators has shown good VCO and DRO performance at X and Ku bands [1,2]. For many switched oscillator applications, the device is either shut off by switching the gate or drain bias or by using a separate switch structure at the RF output. Switching the device current is a slow process as it takes time for the current to stabilize, typically on the order of milliseconds. The variation in drain current, after the device is turned on, results in small changes in device Cgs and consequently affects the oscillator frequency. One solution to this problem is to keep the device current constant and turn the oscillator off by suppressing the negative resistance. A method of quenching the negative resistance which uses a control diode placed in the feedback path of the oscillator has been shown [3]. The work in this paper has made use of a passive FET switch as the negative resistance control device, allowing for easy integration of the quench circuit in MMIC.

CIRCUIT DESIGN

A common source oscillator configuration was selected to achieve wide negative resistance frequency coverage while exhibiting a minimum of S11 phase angle excursion. This configuration allows the widest tuning range performance to be achieved and the quench function can be added by inserting a switch FET at the source of the oscillator FET as shown in Figure 1.

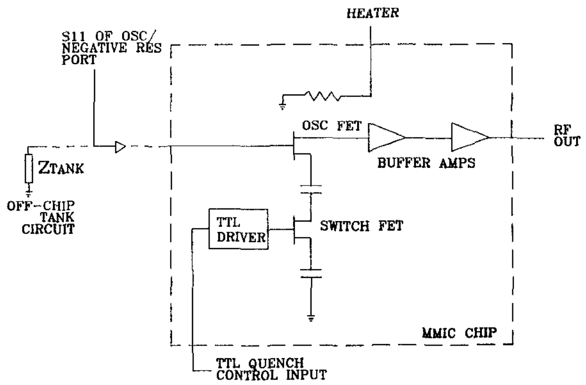

Figure 1 Quench Oscillator Schematic Diagram

The FET oscillator with quench circuit was analyzed using small-signal equivalent circuit FET models to predict and optimize circuit performance. The size of the switch FET used to quench the negative resistance needs to be chosen carefully. The FET must be large enough

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so that when quenched (Vgs=0), the oscillator S11 falls below unity. In the other condition (Vgs=Vpinchoff), the drain-source capacitance should be small enough to achieve the negative resistance required for high frequency operation, and also not be a significant portion of the feedback for temperature stability. A DC block is utilized at both terminals of the switch FET to isolate it from the oscillator bias and to DC float the switch FET above ground. This eliminates the need for any negative supply voltages to control the switch FET. The oscillator feedback consists of the parasitic capacitance of the quench circuit plus additional bondpads which were included to allow for feedback adjustment.

Using the gate to turn on the FET switch, the drain-source resistance of the switch quenches the negative resistance and hence the oscillator is turned off. When the source FET is pinched-off, the negative resistance of the oscillator is restored and the oscillator turns on. The variation of small-signal negative resistance as a function of the source FET state is shown in Figure 2. In either of the two states, the oscillator current remains relatively constant avoiding problems with frequency changes due to current.

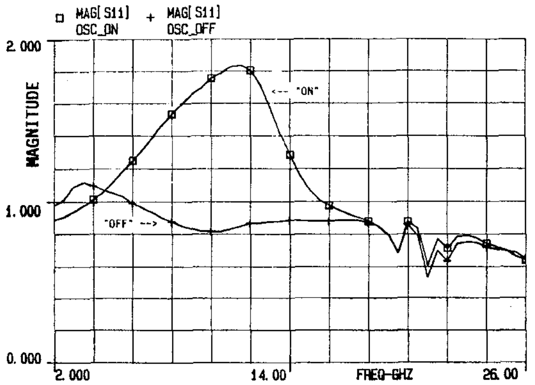

Figure 2 Magnitude of Quench Oscillator S11 for "ON" and "OFF" States.

In the common source FET oscillator configuration, the impedance at the source terminal is quite high due to the low value of feedback capacitance needed to optimize the negative resistance. This requires the switch FET impedance to be held very constant during the oscillator "ON" state, otherwise, any impedance changes in the switch FET would affect the oscillator frequency. The problem is minimized by biasing the switch FET well into its pinch-off state. To further minimize any possible influence of the switch FET on the oscillator, a FET inverter buffer was added to the quench control input line. This allows very accurate and controlled switching using a conventional TTL control signal.

MMIC FABRICATION

These ideas have been used to implement a negative resistance oscillator with a FET switch quench circuit and a buffer amplifier which is realized in a 71 x 46 mil size. Figure 3 shows a photograph of the MMIC oscillator chip with the TTL compatible quench circuit visible in the lower left corner.

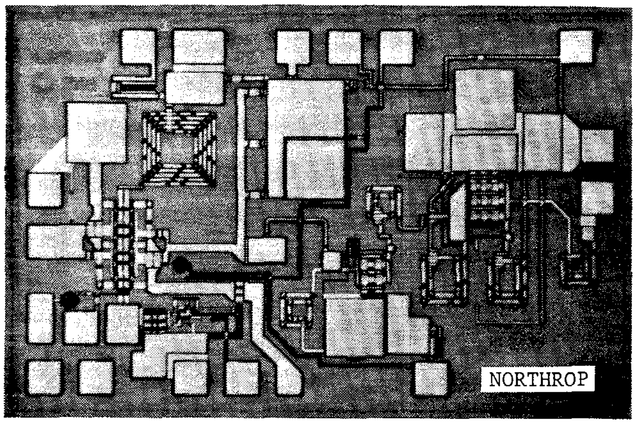

Figure 3 MMIC Quench Oscillator Chip

The chip was fabricated at an outside foundry using an ion implantation process. The FET devices utilized 0.5 um gate geometry which was defined using a lift-off technique. The MMIC integration contains 1.4 mm of FET periphery, 56 pF of MIM capacitance, 20 nichrome and implant resistors, 6 rectangular inductors and 2 n+ diodes. Wet etch vias are used for low inductance grounds, and the chip is passivated to improve reliability and yield. The on-chip heater circuit utilized nichrome resistors for adequate current handling and temperature stability.

MMIC PERFORMANCE

Two versions of the quenchable oscillator were built using the single MMIC chip design, including a stabilized DRO and a wideband VCO. The operation of the quench circuit was verified and no spurious oscillations were detected for either type of oscillator in the "OFF" state.

A DRO was assembled, as shown in Figure 4, using a 10 mil thick alumina substrate with 50 ohm match-terminated transmission line to interface with the MMIC chip. A 0.205" X 0.082" dielectric resonator was coupled to the 50 ohm transmission line using the TE01δ mode. The output frequency of the quench DRO was measured to be 11.583 GHz, with an output power of 11.8 dBm.

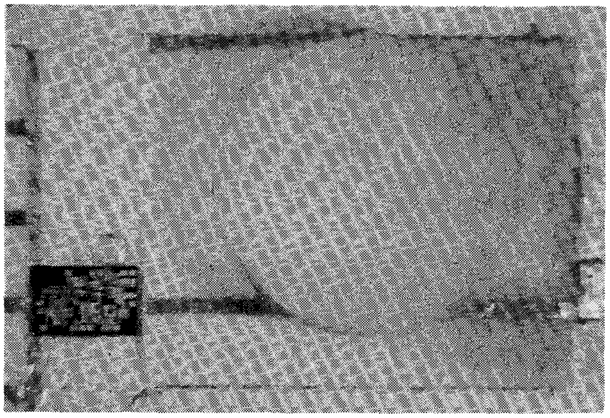

Figure 4 Quenchable DRO assembly

The settling time of the DRO was measured using a high speed frequency acquisition test setup. The DRO output frequency was measured to be within 0.6 MHz of the final frequency only 0.5 us after the quench control was switched to turn the DRO on. The measured frequency versus time response is shown in Figure 5.

A wideband VCO was also built using a silicon hyperabrupt chip varactor bonded to the negative resistance port of the quench oscillator MMIC circuit. This VCO was tested over a varactor tuning range of 0 to 20 volts. The measured MMIC VCO tuning response, is shown in Figure 6. The tuning range was 9.7 to 14.4 GHz, and the RF power was 10.2 +/- 2.4 dBm. The bias requirements for the quench VCO are 55mA and 30mA at 8 volts for the oscillator and buffer amp sections respectively. The quench circuit allows the VCO to be switched on and off in less than 0.5 us.

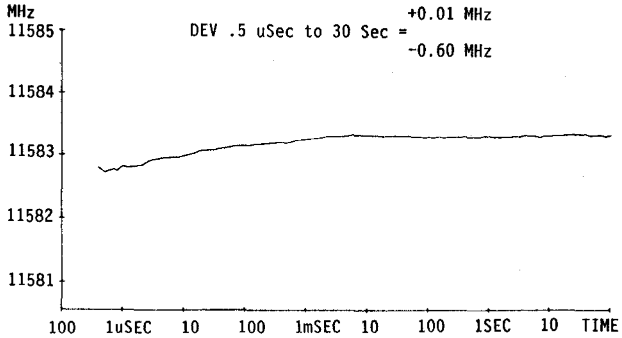

Figure 5 Quench DRO "Turn-On" Frequency Response. Time is measured relative to the quench trigger signal.

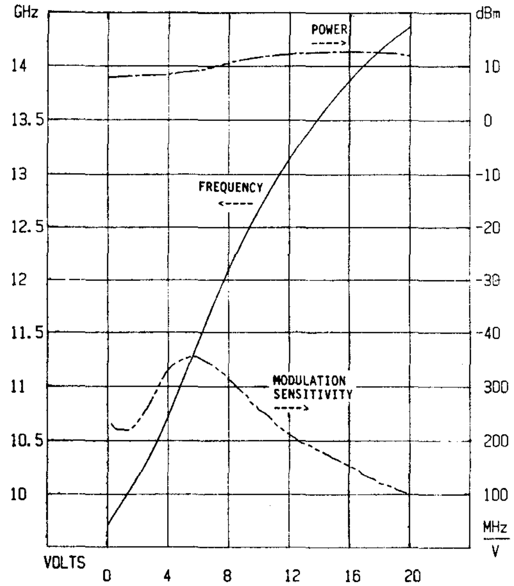

Figure 6 Measured Quench VCO Frequency and Power. The calculated modulation sensitivity is also indicated.

HEATER CIRCUIT

An important feature of a VCO is good frequency stability over wide temperature variations. Since a wideband VCO has a relatively low Q, its temperature stability is not very good. A heater can be used to maintain a constant chip temperature, thereby achieving frequency stability. This MMIC oscillator chip contains a distributed resistor heater in close proximity to the oscillator active device. This allows the device temperature to be maintained using a minimum of DC power in the heater circuit. The 4 mil thick MMIC chip is mounted directly to a tungsten-copper carrier plate providing a low thermal impedance. The quench VCO was tested over the temperature range of -55°C to +95°C, and the current through the heater was adjusted to maintain a constant frequency over the full temperature range. The heater current required as a function of temperature is shown in Figure 7.

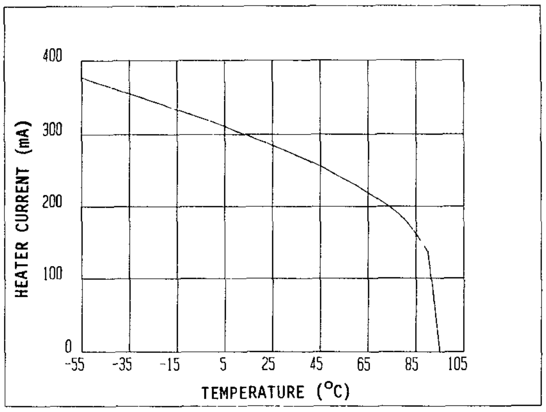

Figure 7 Measured heater current required over temperature to achieve a fixed RF output frequency.

The maximum DC dissipation required was 2.4 Watts at -55°C. This compares favorably against a typical MIC VCO where the complete assembly on its carrier was heated and required up to 10 Watts of heater power, representing a 4 to 1 reduction in maximum heater power. Further reductions in heater dissipation are possible if the thermal impedance between the MMIC and mounting case is increased. Because the MMIC heater is in such close physical proximity to the active device, the time required to stabilize the device temperature is significantly reduced. This heater circuit achieved its final temperature in less than 1 second, compared to 30 seconds for a VCO on a heated carrier. This would imply that the temperature may be controlled more accurately, resulting in less temperature deviation, and quicker initial "warmup" time.

CONCLUSION

A FET oscillator with buffer amplifier, TTL quench control circuitry and heater have been designed and integrated onto a single GaAs MMIC. The quench control allows for rapid switching of the RF output and this greatly reduces settling time compared to switching the drain current on/off. The switching FET is driven by a TTL interface driver which provides closely controlled switching voltages over the typical TTL voltage ranges. This circuit functions as either a DRO or a wideband VCO by connecting an appropriate tank circuit to the MMIC chip. With rapid switching and short settling time, the circuit can be utilized in pulsed applications and it could also be used in switched oscillator banks covering an ultra-wide frequency range without the need for high isolation switches. An on-chip heater, using resistive elements located in close proximity to the FET section, can provide temperature stability with significantly lower power requirements than previous MIC versions.

REFERENCES

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