

# **Design for MOSIS Educational Program (Research)**

T7CW-AL

## Project Title

Low-Power Self-Cascode VCO Design for Biomedical Telemetry  
Application

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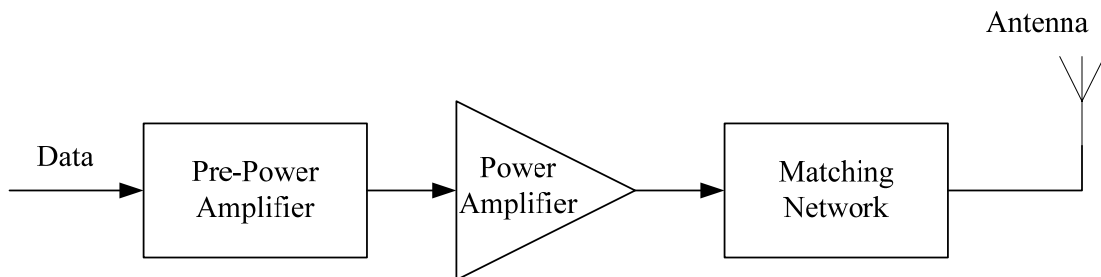
## 1. Objective

The objective of this project is to design a low-power VCO for wireless biomedical telemetry applications.

## 2. Introduction

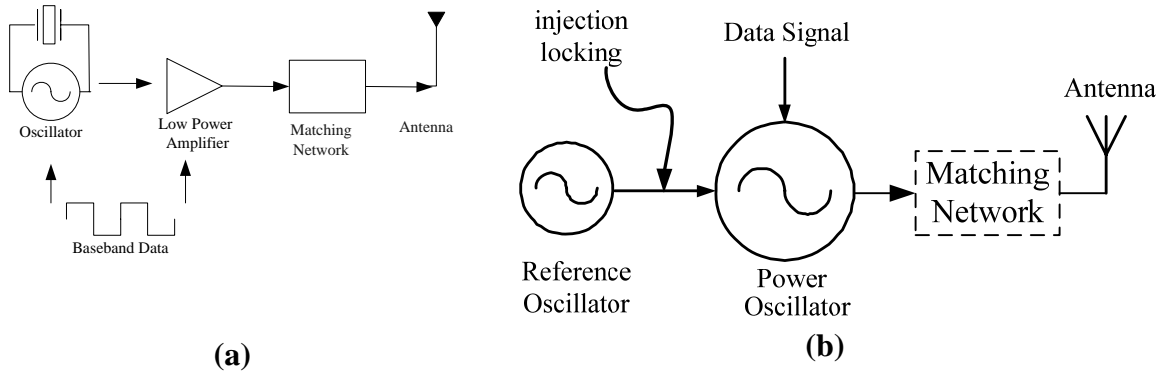
Recent technological improvements of healthcare monitoring equipments, micro- and nano- fabrication processes and wireless communication technologies have led to the development of miniature, light weight, and energy-efficient circuit solution for biomedical sensor applications. Significant research has focused on investigating continuous *in vivo* measurement and monitoring of various physiological variables by means of an implantable sensor. In most cases, the sensor output is an analog current signal, which needs to be transmitted out of the biological environment (i.e. human body) so that the signal can be detected externally for analysis and initiation of necessary actions.

Low-power transmitter with high efficiency is essential for short range wireless communication. Usually for short range wireless communication, radiated power is low in the range of 0 dBm (1mW) that is lower than the power consumption of Power Amplifier (PA) and Pre-Power Amplifier block (see Figure 1). Again, low-power Power Amplifier



**Figure 1: Block Diagram of a Conventional Transmitter Architecture**

requires high drive requirements from Pre-Power Amplifier block which ultimately increases the power consumption of Pre-Power Amplifier block. Therefore, merely increasing the efficiency of PA does not guarantee the overall transmitter efficiency. To resolve this problem, injection-locked transmitter architecture has got greater interest because of its better spectral purity in output signal compared to direct modulation transmitter (see Figure 2).



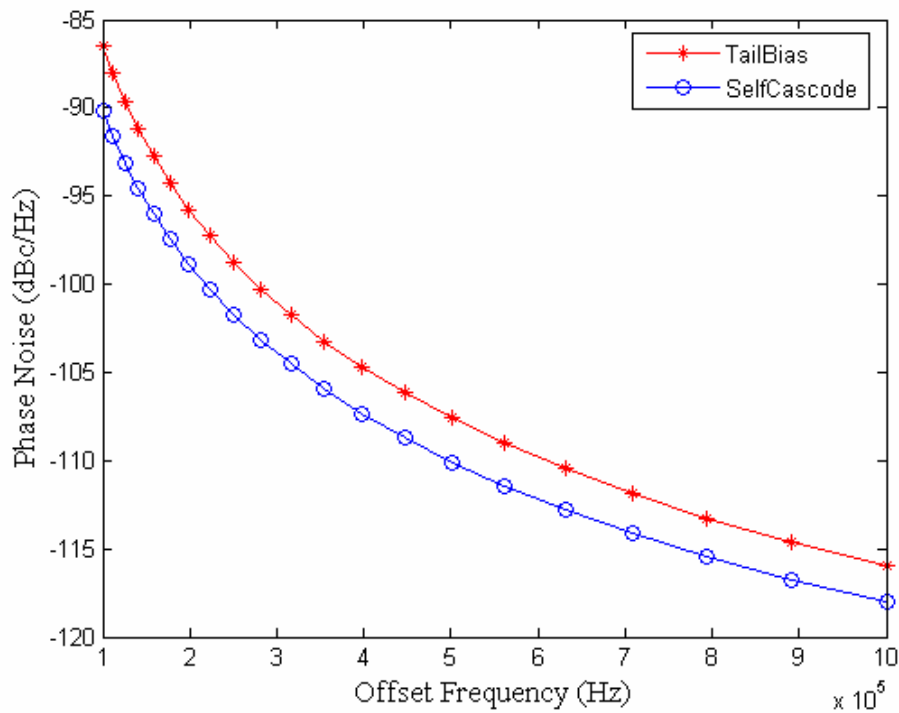
**Figure 2: Block Diagram of (a) Direct Modulation Transmitter (b) Injection-locked Transmitter**

Structure of oscillator and types of injection are two crucial design criteria for low-power injection-locked oscillator design. Tail MOSFET injection structure requires additional voltage headroom and direct injection structure has a potential chance to increase power consumption. Body-terminal coupling has inherent property of low-voltage operation due to elimination of tail MOSFET and low-power operation due to low transconductance,  $g_{mb}$ . Again, conventional NMOS only differential cross-coupled LC oscillator architecture can work with low power supply voltage but their current is relatively high due to relatively lower output resistance in each conducting path. To overcome this problem, we have used self-cascode oscillator structure which provides higher output resistance in each conducting path but still capable of operating with lower power supply voltage. Therefore, in this project we have used self-cascode oscillator structure with body-terminal coupling for the development of a low-voltage low-power injection locked oscillator which will facilitate towards the development of low-power injection-locked transmitter architecture.

### 3. Low-Power Body-Coupled Self-Cascode VCO Design

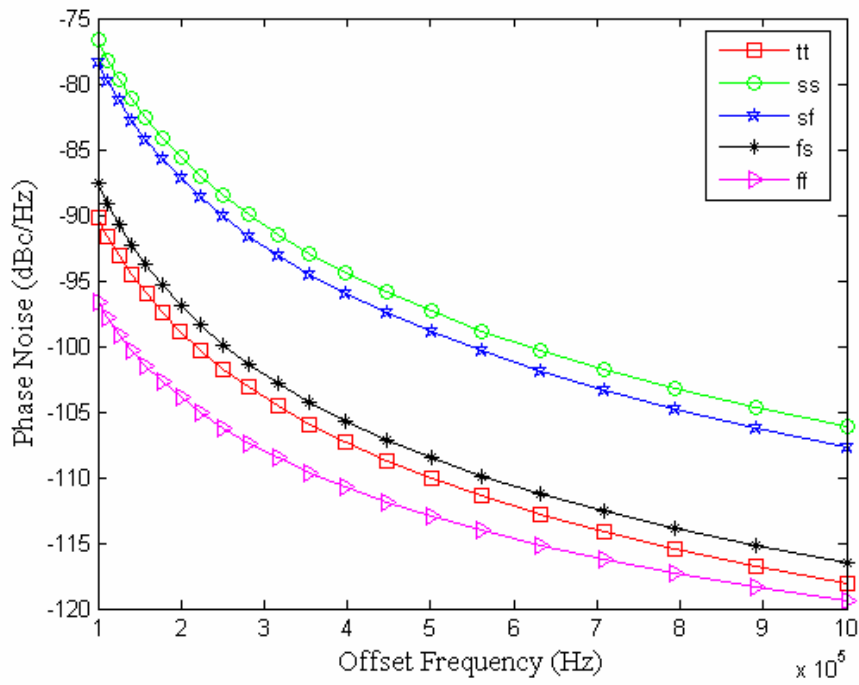
Self-Cascode oscillator structure consists of two series MOSFETs in each conducting branch where the gates of each series MOSFETs are tied together. Series connection of MOSFETs provides higher output resistance in each conducting branch. Simulation results show that the self-cascode structure consumes much less power compared to that of the conventional structure for the same output swing. Again, self-cascode structure provides less phase noise compare to that of the conventional structures. For body-level injection, we have used PMOS transistors in self-cascode oscillator structure that have lower flicker noise performance and do not require expensive fabrication process. We have also used body-bias control in our design to control the oscillation frequency and power consumption of the oscillator.



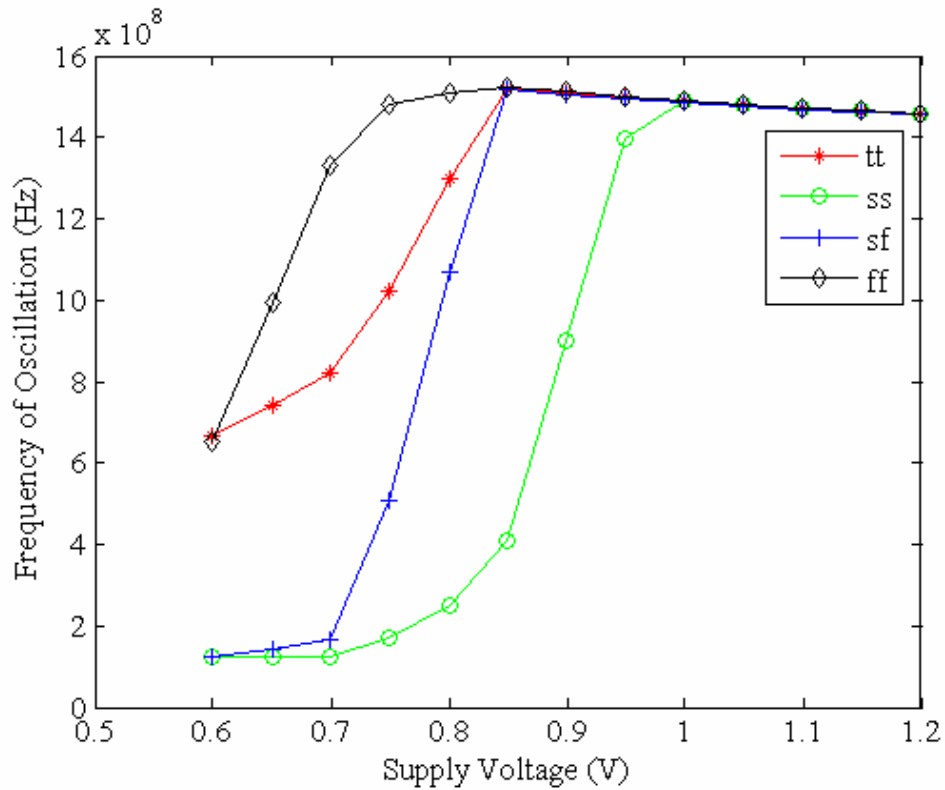


**Figure 4: Phase Noise comparison of conventional tail-biased VCO and self-cascode VCO**

Figure 5 depicts the phase noise comparison of self-cascode VCO for different process corners. Finally figure 6 shows the supply pushing of the designed self-cascode oscillator.



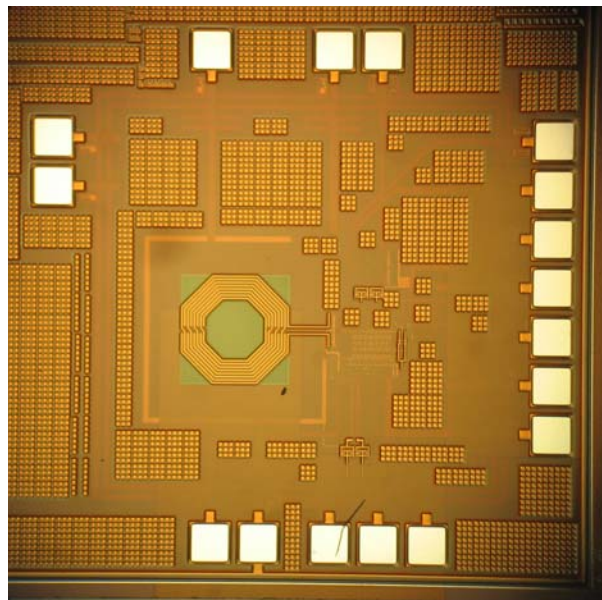
**Figure 5: Phase Noise of self-cascode VCO for different process corners**



**Figure 6: Supply pushing of Self-Cascode VCO**

## 5. Fabrication

The entire self-cascode VCO has been implemented using IBM7RF process. Figure 7 shows the microphotograph of the fabricated VCO chip. The fabricated circuit consumes almost 1 mm<sup>2</sup> of the total chip area.



**Figure 7: Microphotograph of fabricated VCO chip**

## 6. Test Results

The fabricated VCO has been tested using Agilent E4407B spectrum analyzer. Figure 8 shows the power spectrum of the VCO output. To drive the pads of the chip, a driver was designed along with the VCO. The power output of the VCO signal depends on the driving capability of the driver. The spectrum in figure 8 is showing oscillation frequency at 1.31 GHz with power output of -33 dBm. With 1.1 V power supply, the power consumption of the core VCO block is in the range of 2 mW.

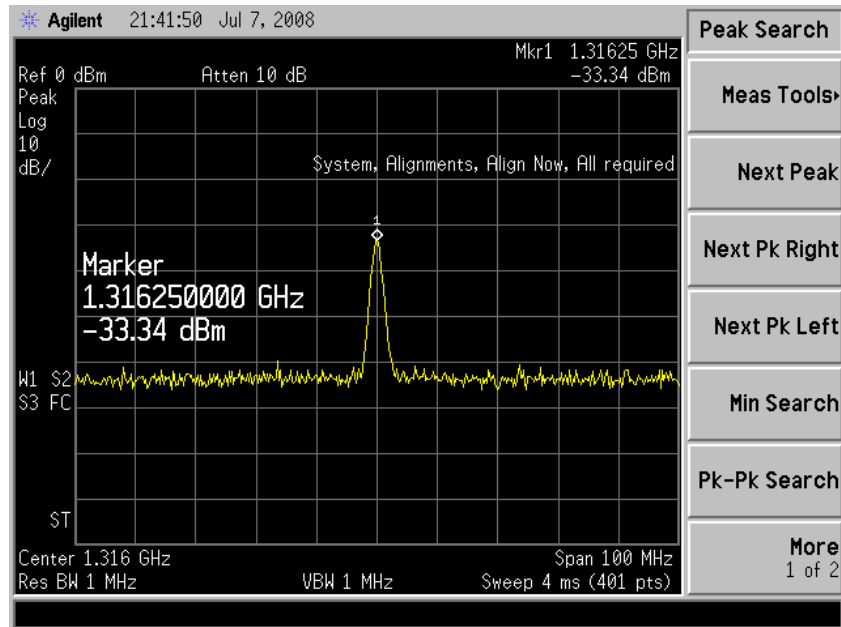


Figure 8: Power Spectrum of the fundamental frequency for 1.1 V supply

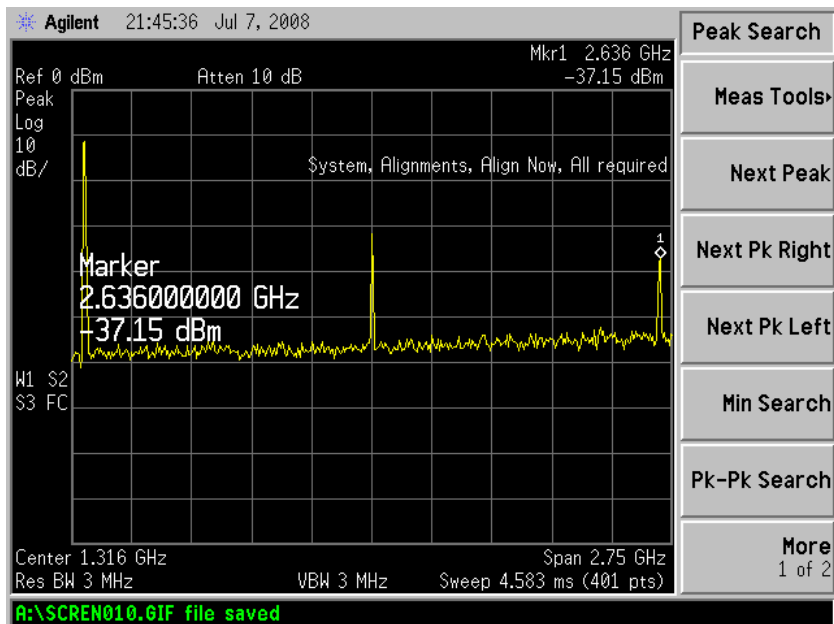


Figure 9: Power Spectrum of the self-cascode VCO showing both fundamental and 2<sup>nd</sup> harmonic peak

Figure 9 shows the power spectrum for both fundamental and 2<sup>nd</sup> harmonic signal. The power level of the 2<sup>nd</sup> harmonic signal is -37 dBm.

## **7. Conclusion**

A low-power self-cascode VCO has been designed and implemented using IBM7RF process. The VCO can operate with 1.1 volt supply and consumes a power in the range of 2 mW. The oscillator was designed to generate an output frequency of 1.4 GHz. Deviation of the oscillation frequency is due to the bond wire inductance and board parasitics. To improve the output power of the VCO, better driver and matching network should be used.