Unlocking the Mystery of Precision Inductors in High Volume Production RF Test Environments

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As consumer wireless devices continue to become an everyday part of our lives, the silicon to drive these devices increase in complexity, and levels of integration. Frequency synthesizers provide tuning capability at some intermediate frequency, often above the actual carrier frequency. Buried behind the glamour of the Phase Lock Loop circuitry hides a lonely oscillator, starved for current and real estate, neglected and nearly forgotten.

Oscillators provide the heartbeat of the entire system. Without oscillation, nearly no sub-systems of the transceiver can be tested. The typical oscillator consists of a fixed inductor, and a variable capacitor. The capacitor provides the tuning, and thus phase-lock to a reference oscillator. The inductor's value, as small as it is, may consume too much real-estate on the die. Designers opt for moving this component into the die-package.

This presents an interesting challenge during KGD RF test. The probe must provide an inductance to the die which mimic's the die-package inductor. In many cases, the greater challenge is the inductor Q, not its inductance. With decreasing bias current in the FET, the demand on Q increases. Limited Q, and probing contact resistance may compromise the circuit's ability to oscillate.

This poster unlocks the mystery of when inductor Q is a bona-fide probing issue, and when it is not. In many cases, Q may be dismissed through correlating measurement data against sample data. In other cases where the demands on Q are justified, the designer may need to consider design-for-test (DFT) options within the oscillator circuitry.

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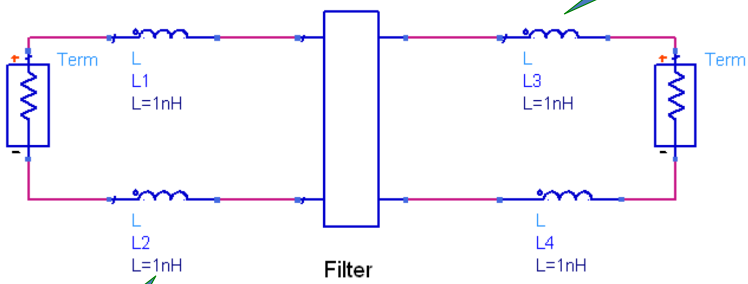
Emulating Lead Inductance

Narrow Bandwidth Filters

Understand the behavior of your circuit under test, as the bond wire inductance varies slightly.

Each Bond Wire represents roughly 1nH of series inductance

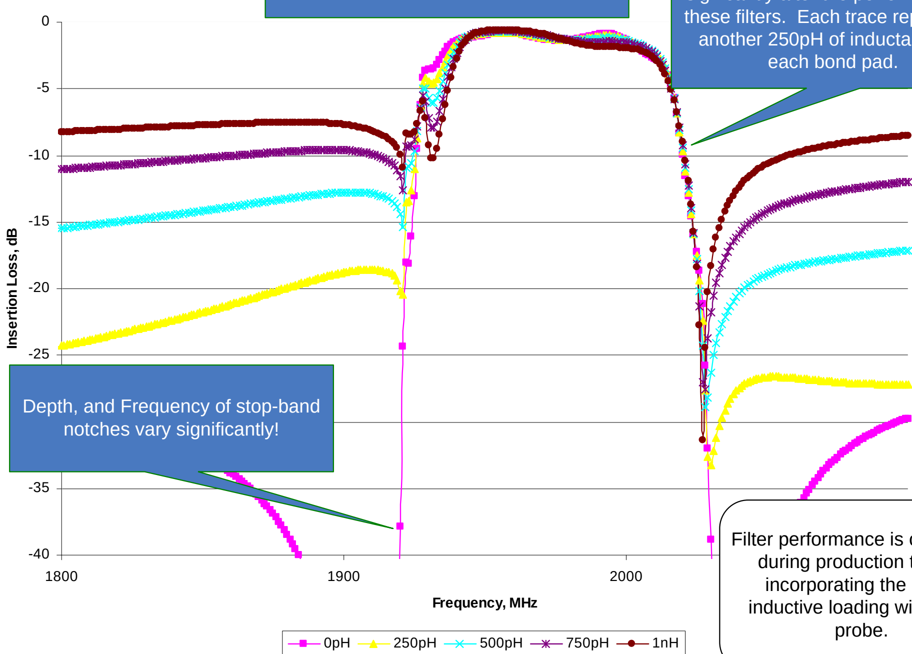


"Ground" bond wires have inductance too!

Inductors have limited Q as well. Determine circuit behavior with varying contact resistance.

Narrow Bandwidth Filters

Precision bond wire loading can signicantly alter the performance of these filters. Each trace represents another 250pH of inductance on each bond pad.



Depth, and Frequency of stop-band notches vary significantly!

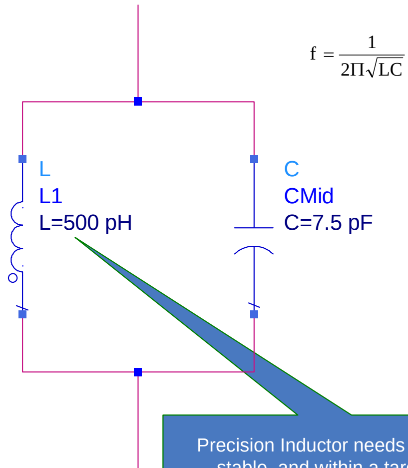
Filter performance is confirmed during production test by incorporating the same inductive loading within the probe.

Inductor Trimming for Phase Lock Loop Circuits

Setting Target Inductance

Example: VCO Sweep from 2500 to 2700 MHz

$$f = \frac{1}{2\Pi\sqrt{LC}}$$



Precision Inductor needs to be stable, and within a target inductance window

Consider a tuning capacitor with a range of 6 to 10pF.

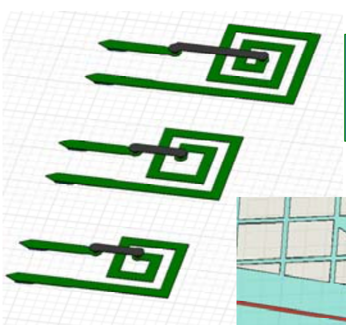
F_{tune} = 2251 to 2906 MHz, easily spanning the VCO frequency range.

How far away from the target inductance of 500pH can the inductor be?

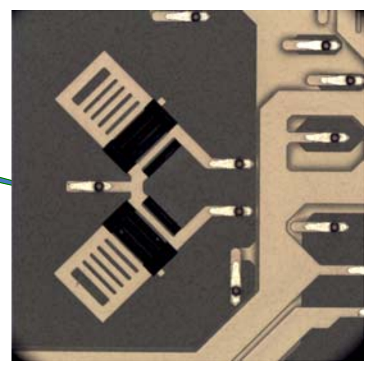
At C=10pF, Fmin < 2500 MHz → L=406pH
At C=6pF, Fmax > 2700 MHz → L=579 pH
Acceptable Tolerance window is (579-406) 173pH

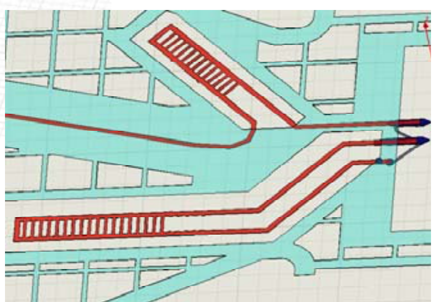
Choose a target inductance that allows your VCO to sweep the entire frequency range with as much error tolerance as possible.

Trimming Inductors for Production Probing



Inductor is suspended within the routing layer of the probe. Inductance is set by laser-trimming in 50pH increments.



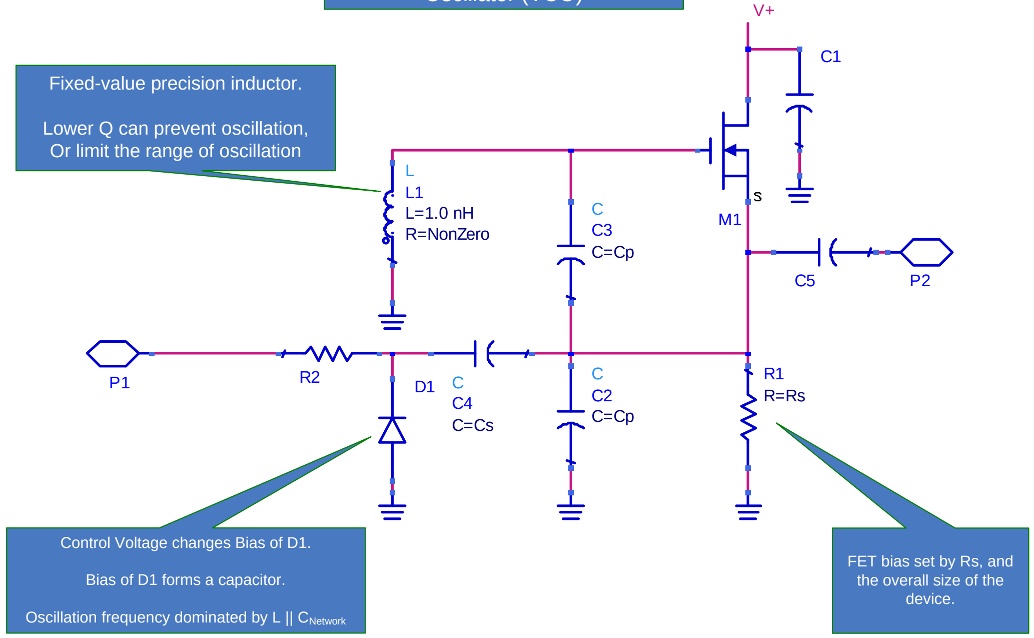


Example fixed-value and laser-trimmable inductors for production probing.

If the exact inductance is unknown prior to first silicon, design your probe card to incorporate a variable structure. Characterize your structure at minimum value, then trim the structure to center the VCO tuning range.

Overcoming Inductor Q during KGD Test

Generic Voltage Controlled Oscillator (VCO)



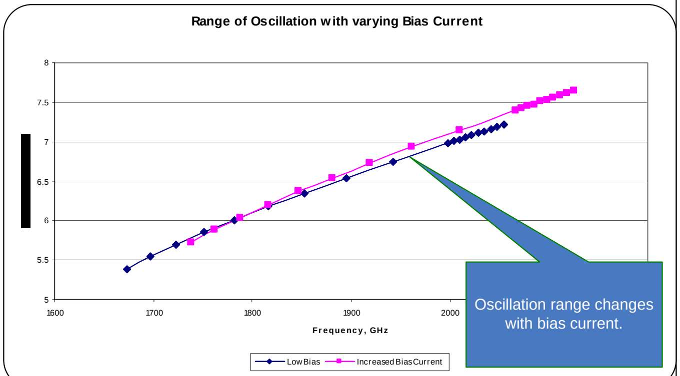
Known Good Die VCO / PLL "Design For Test."

Inductor Q is defined by:

$$Q = \frac{X_L}{R}$$

A "High Q" inductor is built by achieving the inductance value with the minimum amount of passive loss. This is usually achieved by winding the line around ferromagnetic material.

Within the thin film probe, Q is compromised by the lack of ferromagnetic material, and a small amount of contact resistance during probing.



Digital circuitry frequently contains extra devices, aimed specifically for the test phase of the device. These extra devices are never enabled after test. Still though, they serve a vital role at wafer sort.

High volume RF devices (such as cellular handset devices) run with the least amount of bias current possible (to extend battery life). To achieve this, the Q of the packaged device inductor must be high. During probing, sometimes this high Q cannot be achieved reliably.

By adding additional bias current to the oscillator, the limited Q can be overcome. This will increase output power of the oscillator, correct its frequency sweep range, and enable the rest of the device to be tested.