A Comparison of Approaches to Carrier Generation for Zigbee Transceivers

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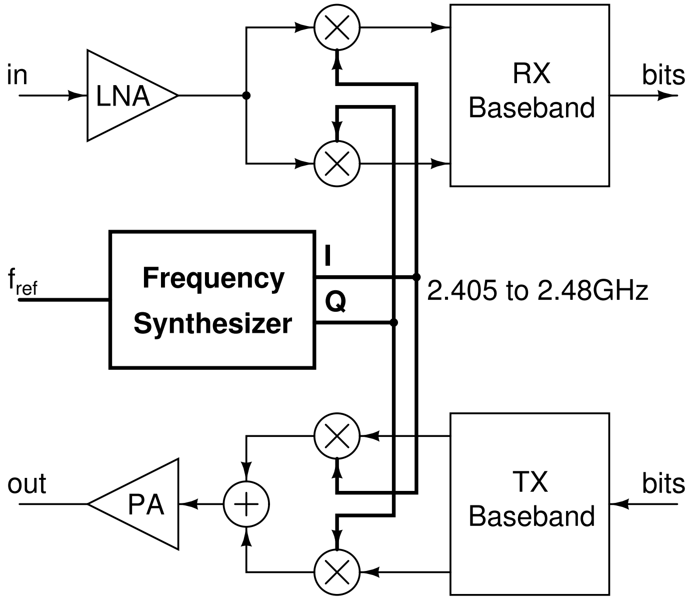
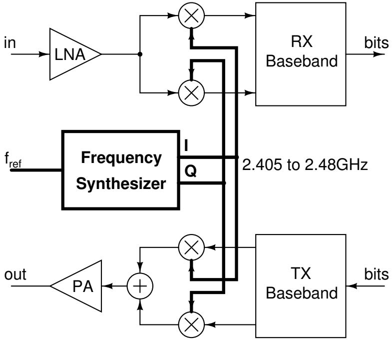
Zigbee transceiver

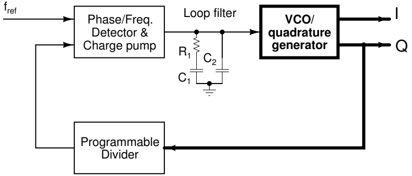


Outline

- Local oscillator requirements
- IQ generation by dividing a double frequency waveform
- IQ generation by multiplying half frequency waveforms
- Design details
- Simulation results
- Conclusions

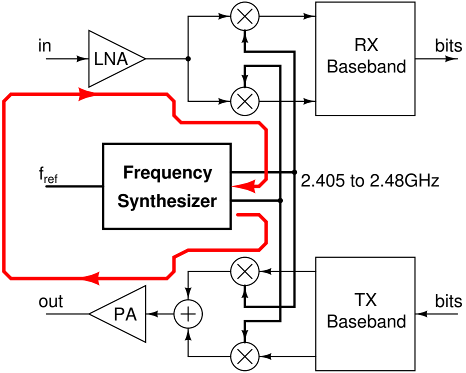
Local oscillator requirements





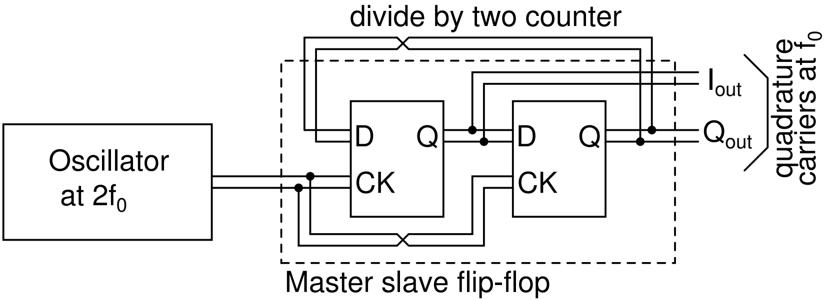
- 2.405-2.48 GHz in 5 MHz steps
- Phase noise ≤ -92 dBc/Hz at 3.5 MHz offset
- Settling time $\leq 200\,\mu$s (to 40ppm accuracy)
- Spurs ≤ -20 dBc @ 5 MHz, ≤ -50 dBc @ 10 MHz

Choice of oscillator frequency

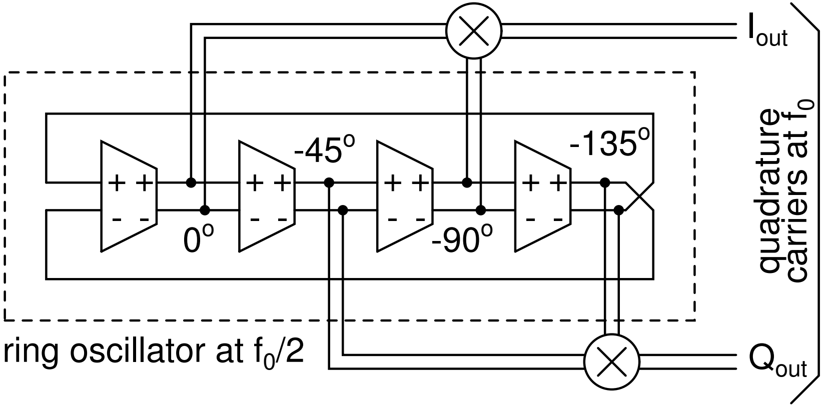


- Tx signal coupling pulls the oscillator and increases jitter
- Oscillator frequency should be different from the carrier

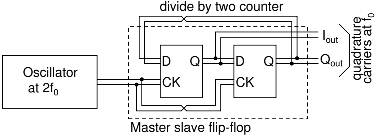
Quadrature generation using divide-by-2

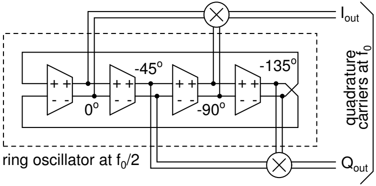


Quadrature generation using multiplication



Comparison

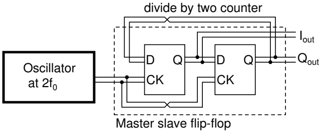


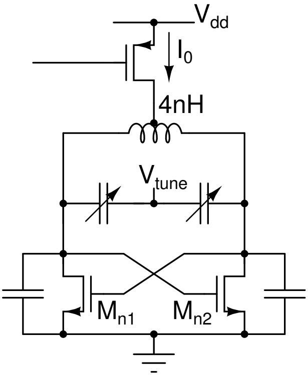


- Higher frequency
- LC oscillator
- Lower phase noise
- More area

- Lower frequency
- Ring oscillator
- Higher phase noise
- Compact

LC oscillator

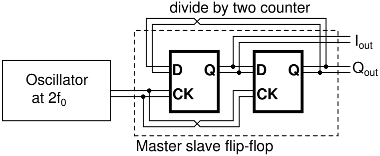


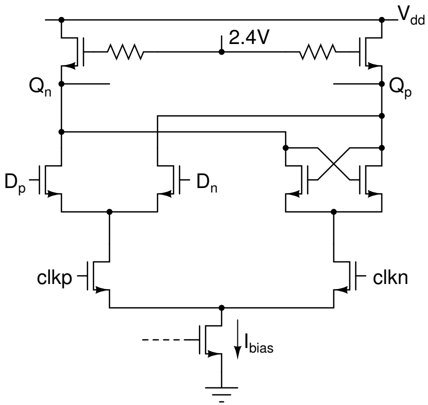


- 140 μm square spiral
- 6 turns
- 6 μm trace width

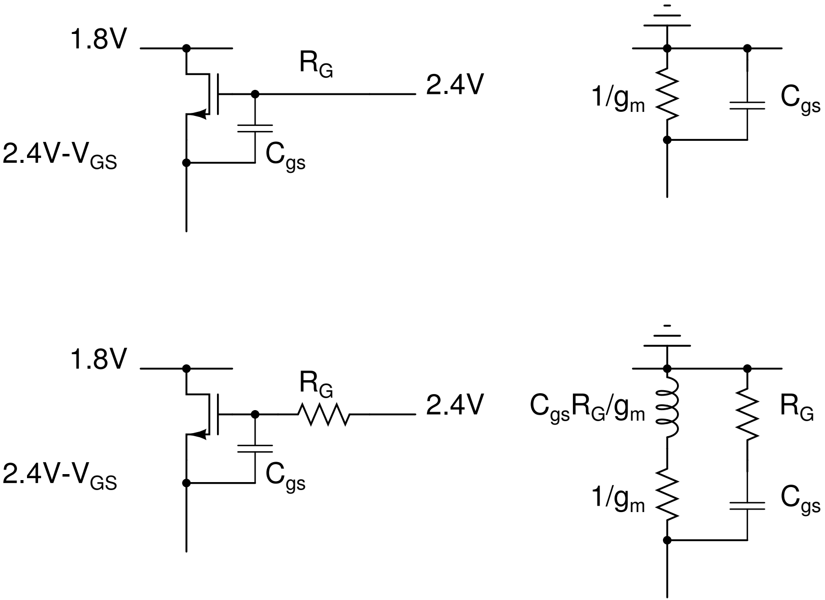
- 2.06 μm thick top metal
- 2 μm spacing
- 5 section distributed model for simulations

Master slave divide by two

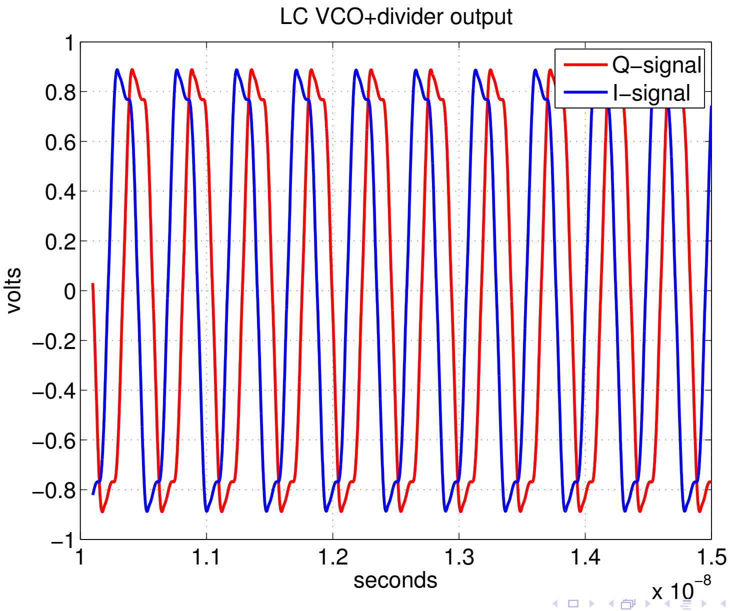




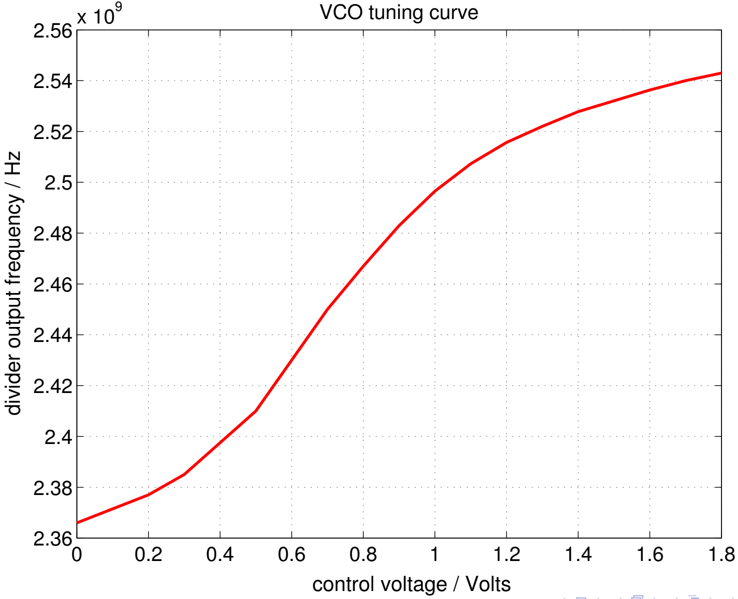
Active inductor load



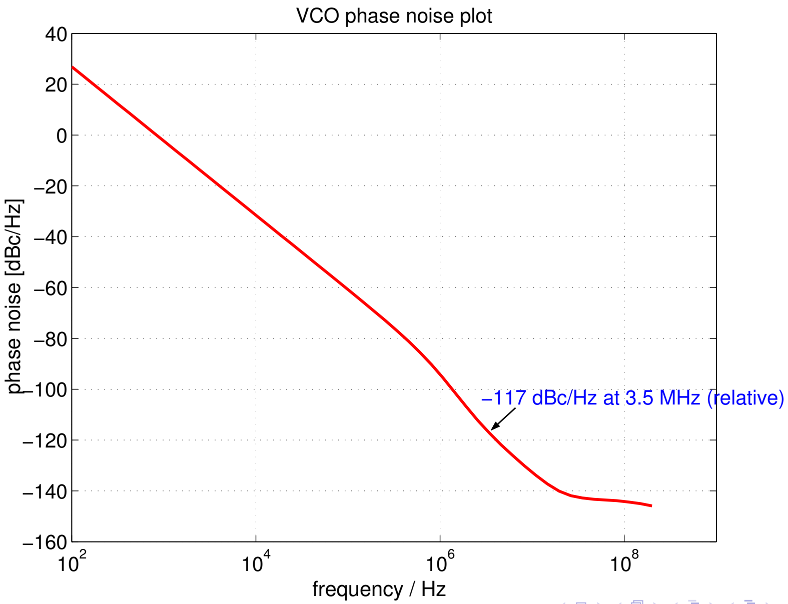
LC VCO+divider waveforms



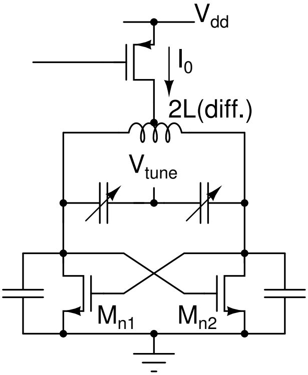
LC VCO+divider characteristics

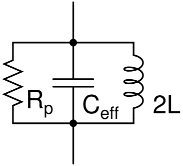


LC VCO+divider phase noise



Trade off phase noise for area/power?



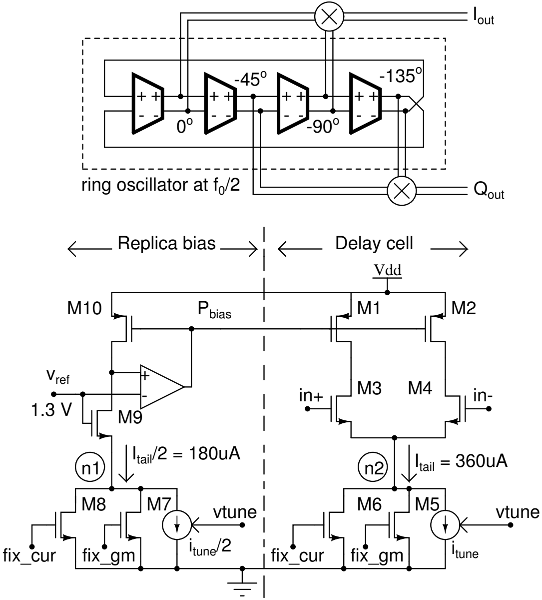


R_p: tank loss
(shunt equivalent)

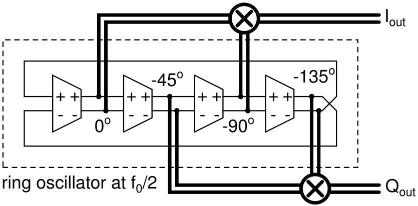
$$L(f) \propto \frac{1}{R_p}$$

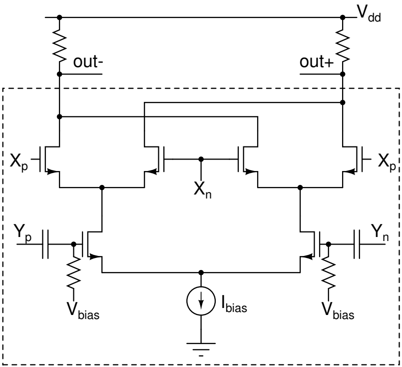
$$V_{ppd} = \frac{4}{\pi} I_0 R_p$$

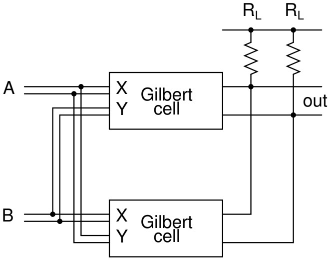
Ring oscillator delay cell



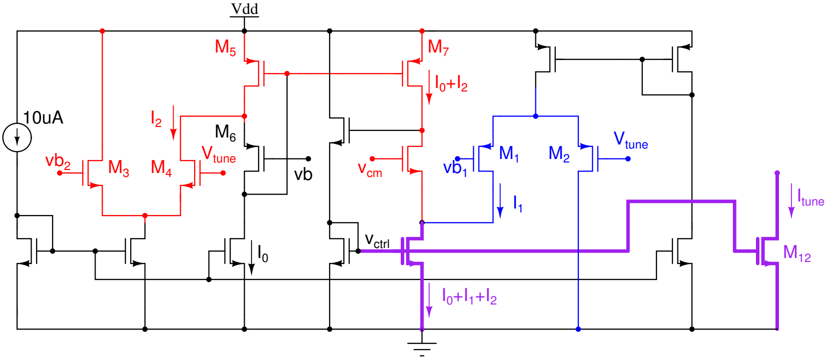
Frequency doubler



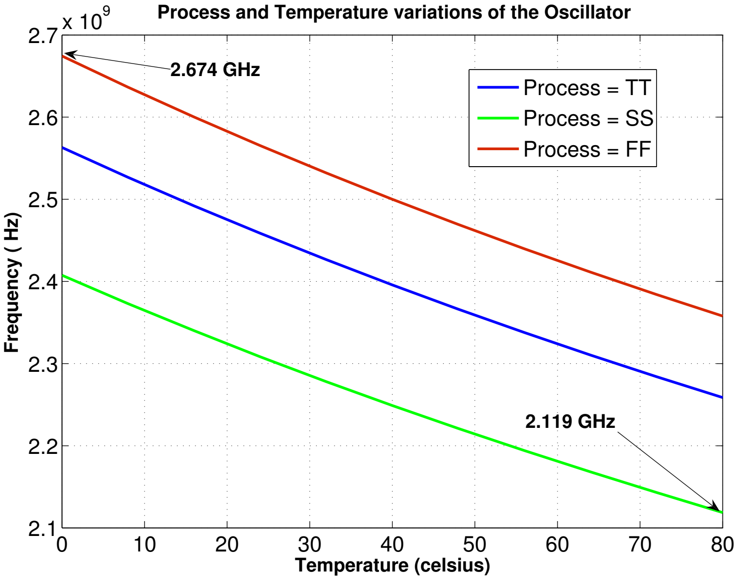




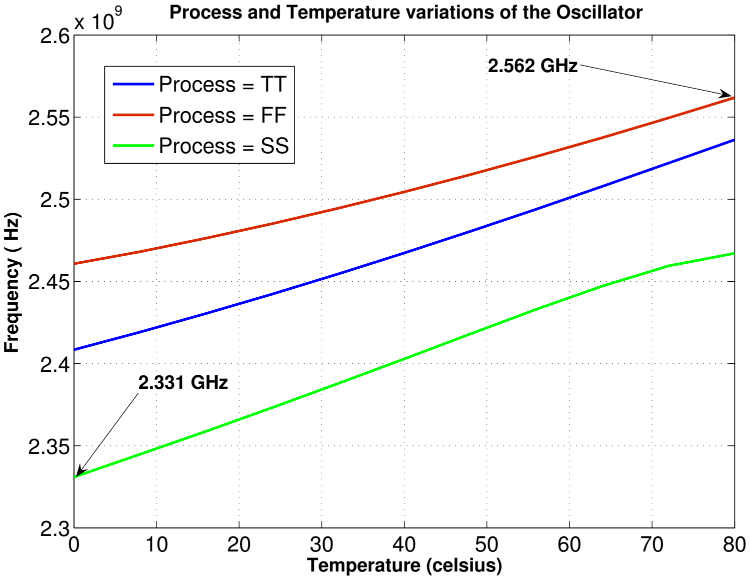
Voltage to current converter



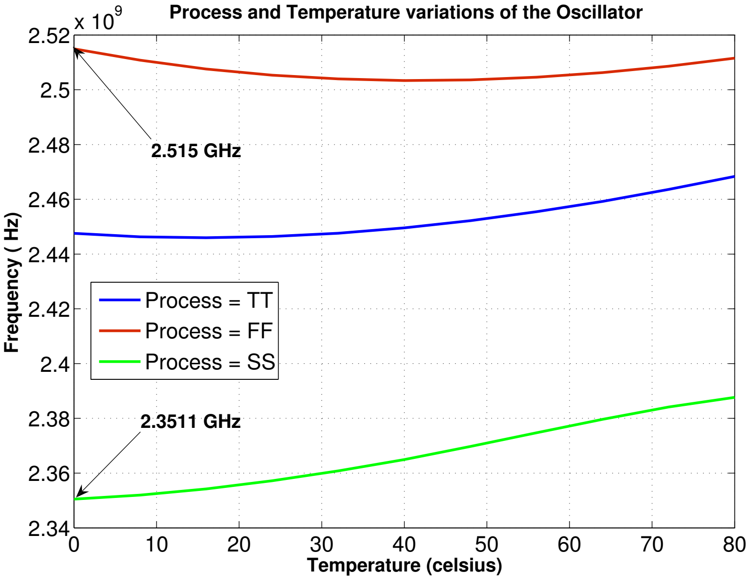
Ring VCO with a constant current biasing



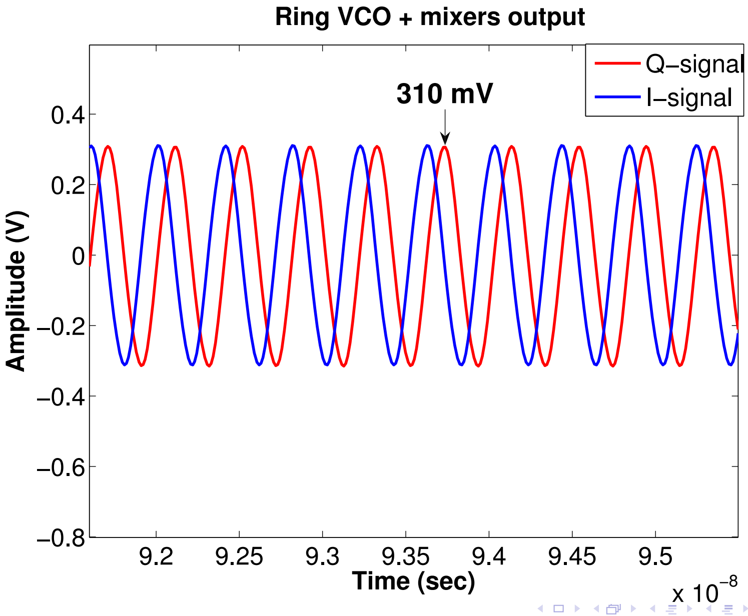
Ring VCO with a constant g_m biasing



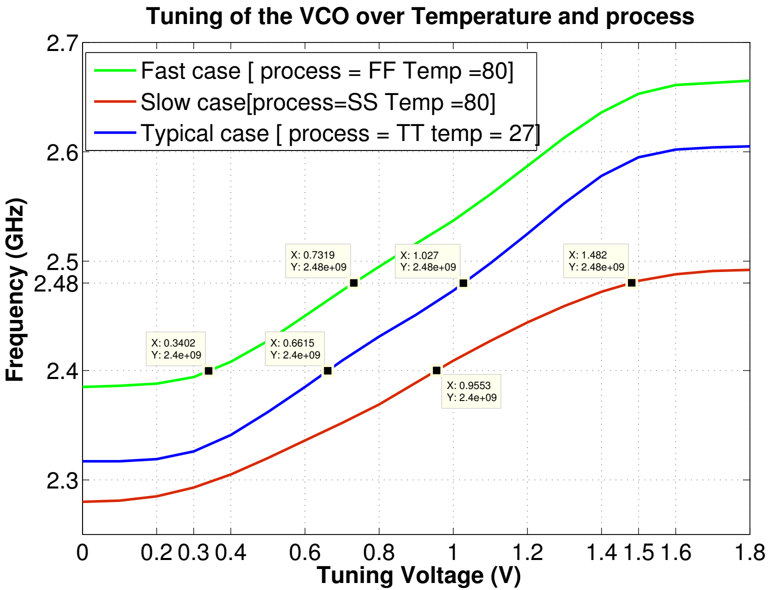
Ring VCO with mixed biasing



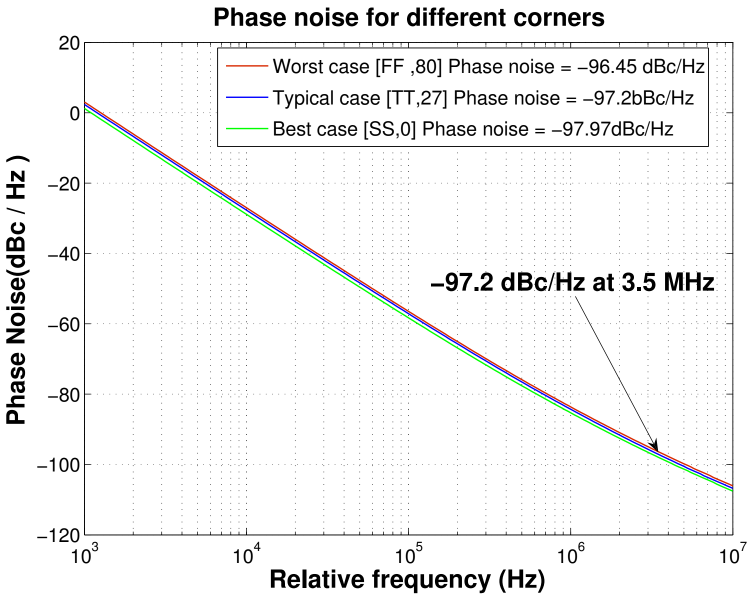
Ring VCO+doubler output waveforms



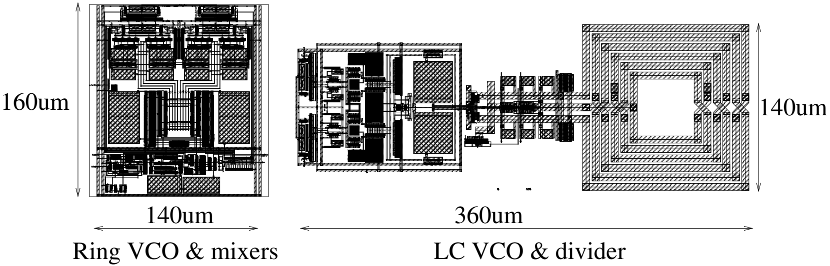
Ring VCO+doubler characteristics



Ring VCO+doubler phase noise



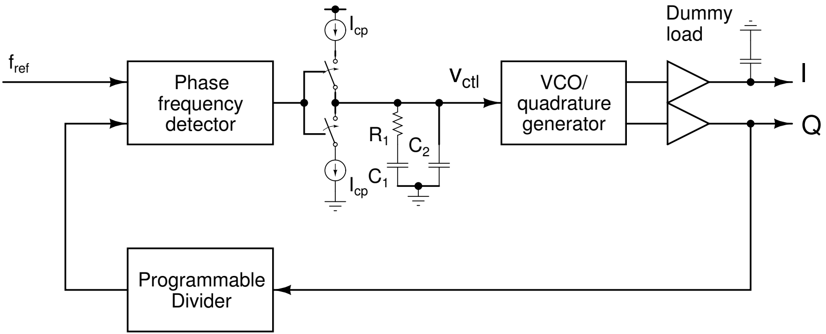
Quadrature generator layouts



VCOs: Performance summary

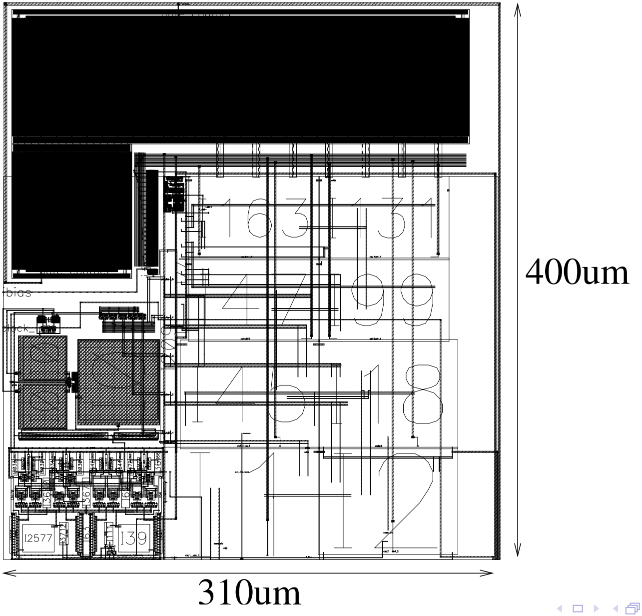
	LC osc. + divider	Ring osc. + doubler
VCO	1 mA	1.44 mA
Bias circuit	—	0.355 mA
V-I converter	—	0.1 mA
Divider	1.8 mA	—
Multipliers	—	0.45 mA each
Buffers	0.7 mA each	0.83 mA each
Total current	**4.2 mA**	**4.455 mA (nom.)** **6 mA (max.)**
Phase noise	**-117 dBc/Hz**	**-97 dBc/Hz**
Area	**360 μm x 140 μm**	**160 μm x 140 μm**
K_{vco}	**200 MHz/V**	**220 MHz/V**
Technology	0.18 μm CMOS	

Frequency synthesizer



- $K_{vco} = 200\,\text{MHz/V}$
- Loop bandwidth = 53 kHz
- zero: 9 kHz
- high freq. pole: 293 kHz

Frequency synthesizer layout



Frequency synthesizer: Performance summary

Programmable divider	1.09 mA
Differential to single ended converter	22 μA
Phase frequency detector	23 μA
Charge pump	20 μA
Bias generation circuits	350 μA
Total current	**1.5 mA**
Settling time	**110 μs**
Area	**400 μm x 310 μm**
Reference feedthrough	**-39 dBc (5 MHz)** **-50 dBc (10 MHz)**
Technology	0.18 μm CMOS

Conclusions

Ring oscillator based synthesizer

- Meets Zigbee specifications
- Consumes 40% higher power than an LC oscillator
- Occupies 2.25$\times$ smaller area than an LC oscillator

LC oscillator based synthesizer

- Phase noise much better than Zigbee requirements
- Area (quality factor) and power limited by amplitude

Comparison valid for finer geometries as well

- No significant advantage for oscillators
- Dividers, multipliers benefit from scaling

References

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