A 1.2V Low-Power 2.4GHz 0.18µm CMOS Quadrature VCO

X. Redondo, J. Pallarés, **F. Vila**, L. Terés
and F. Serra-Graells

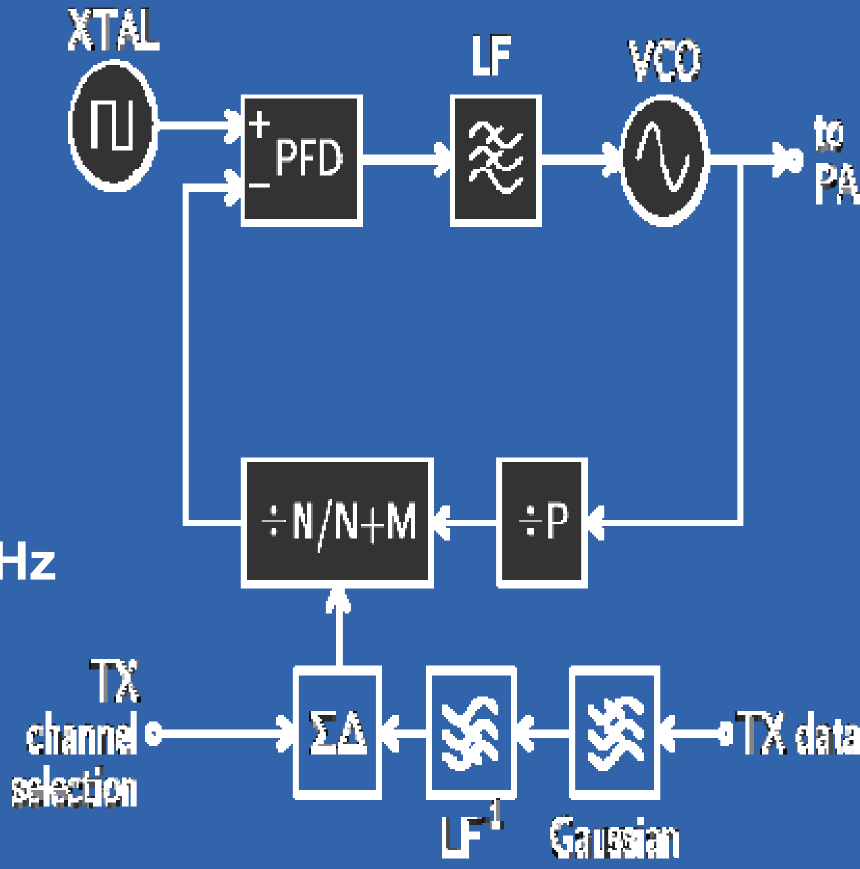
System Integration Department
Institut de Microelectrònica de Barcelona
Centre Nacional de Microelectrònica - CSIC
Spain

November 2008

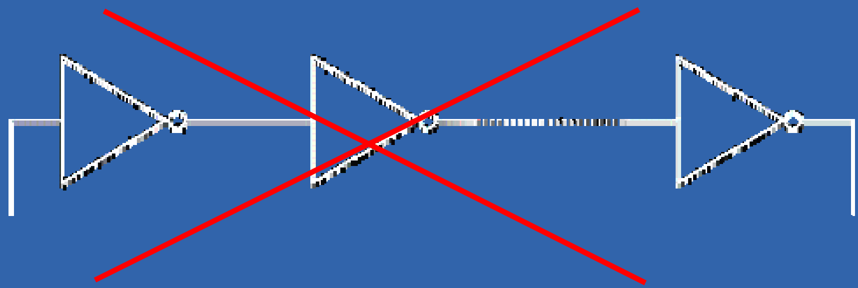
1 Introduction

Scenario

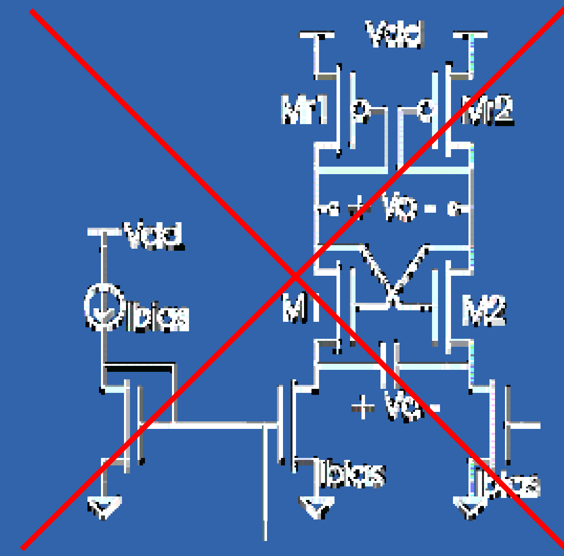
- Very **Low-Power Superheterodyne** TX/RX
- PLL with Sigma-Delta Modulation
- QVCO specs:
  - ✓ **Frequency BandWidth: 2.40-2.48GHz**
  - ✓ **Phase noise at 1Mhz: -72dBc/Hz**
  - ✓ **Phase noise at 2Mhz: -95dBc/Hz**
  - ✓ **Phase noise at 3Mhz: -105dBc/Hz**
  - ✓ **Quadrature** 90º
  - ✓ **Low-Gain < 30MHz/V**
  - ✓ Very **Low-Power < 1mW at 1.2V Power Supply**
  - ✓ **Technology: 0.18μm 1poly 6 metal 1.8V**



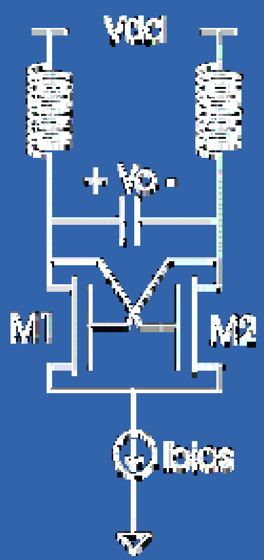
Ring Oscillator



Relaxation Oscillator



LC Oscillator



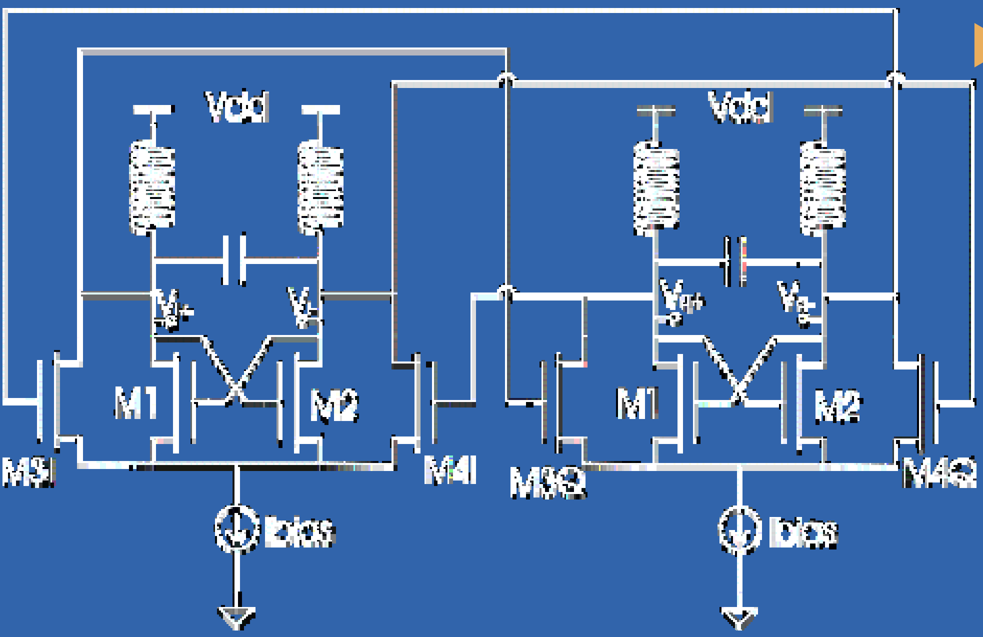
Avantatges:

- Low phase noise
- One transistor Oscillators
- High frequency resonators
- High spectral purity

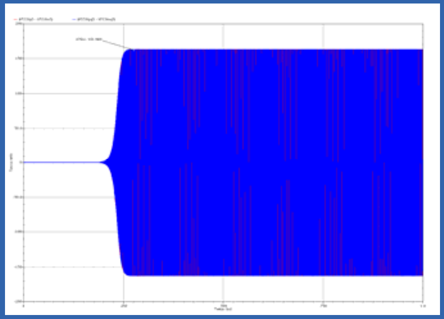
Drawbacks:

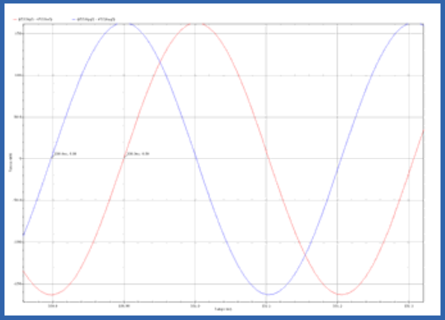
- Low Q factor

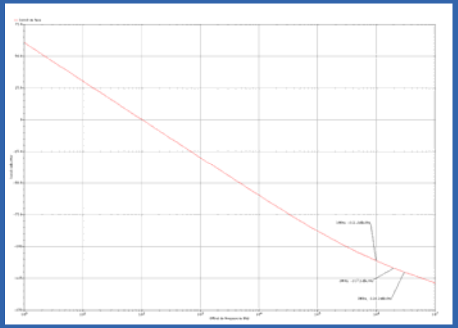
Active quadrature



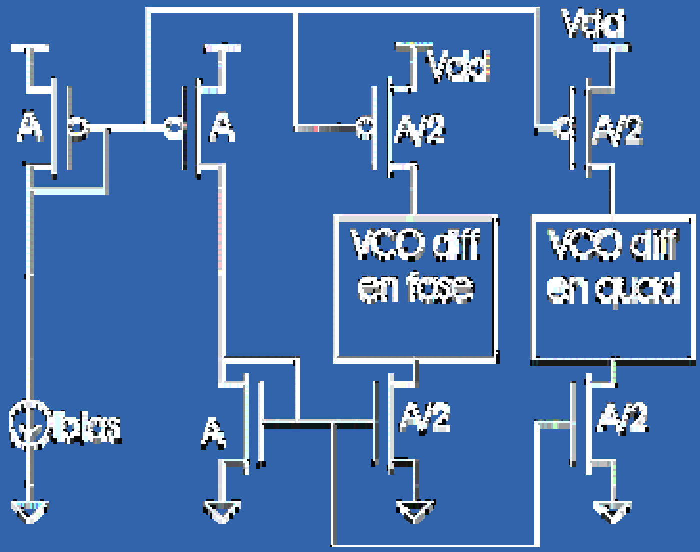
- Simulation Results
  - Output Voltage = 550 mVpp
  - Stabilization Time = 90 ns
  - Quadrature Error = 0.2º
  - Phase noise (3MHz) = -120dBc/Hz
  - Harmonic difference = 50 dB
  - Mismatch immunity ↑



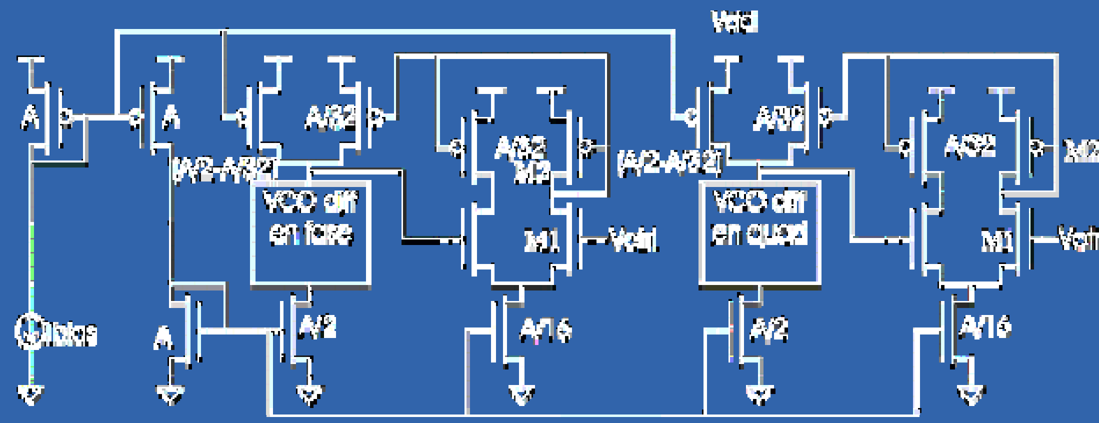




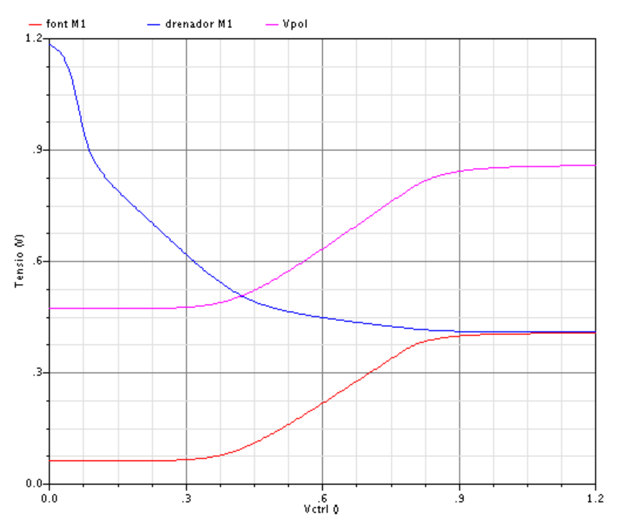
- Double current source



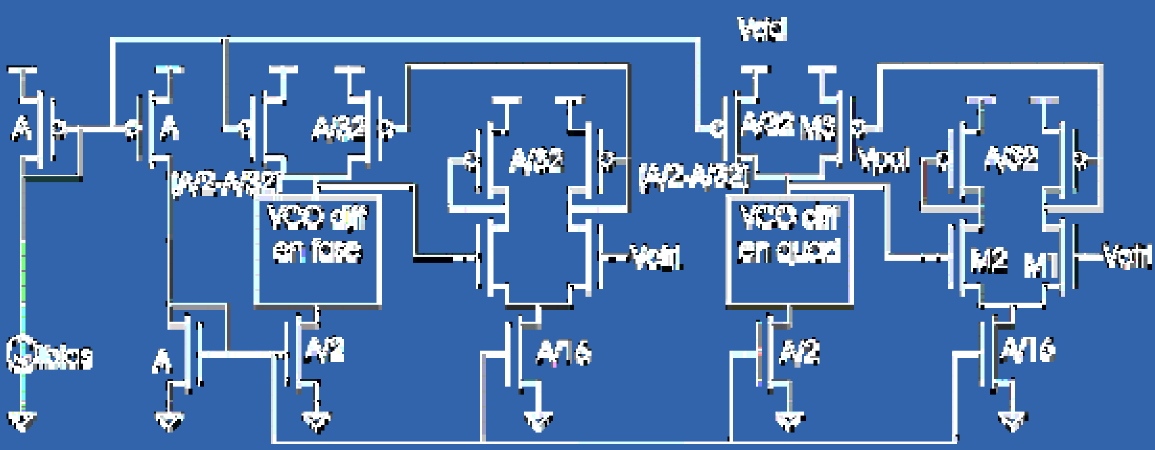
- Polarization control using reference follower



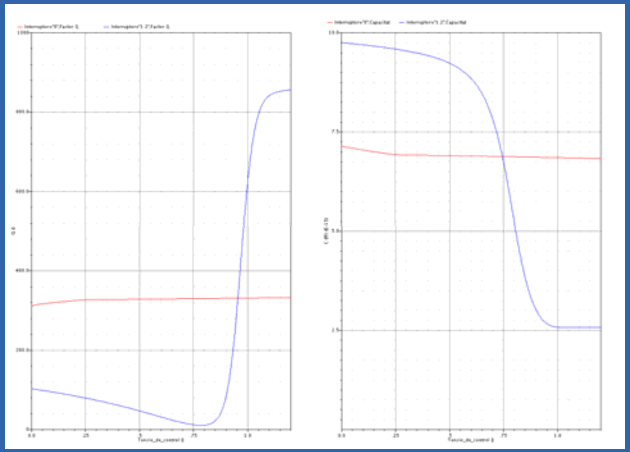
- Simulation Results



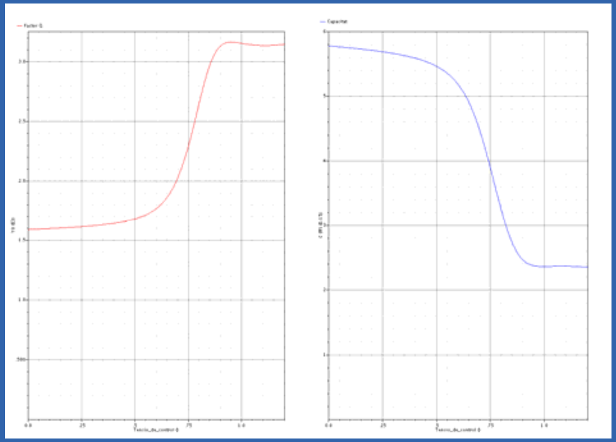
- Modified follower

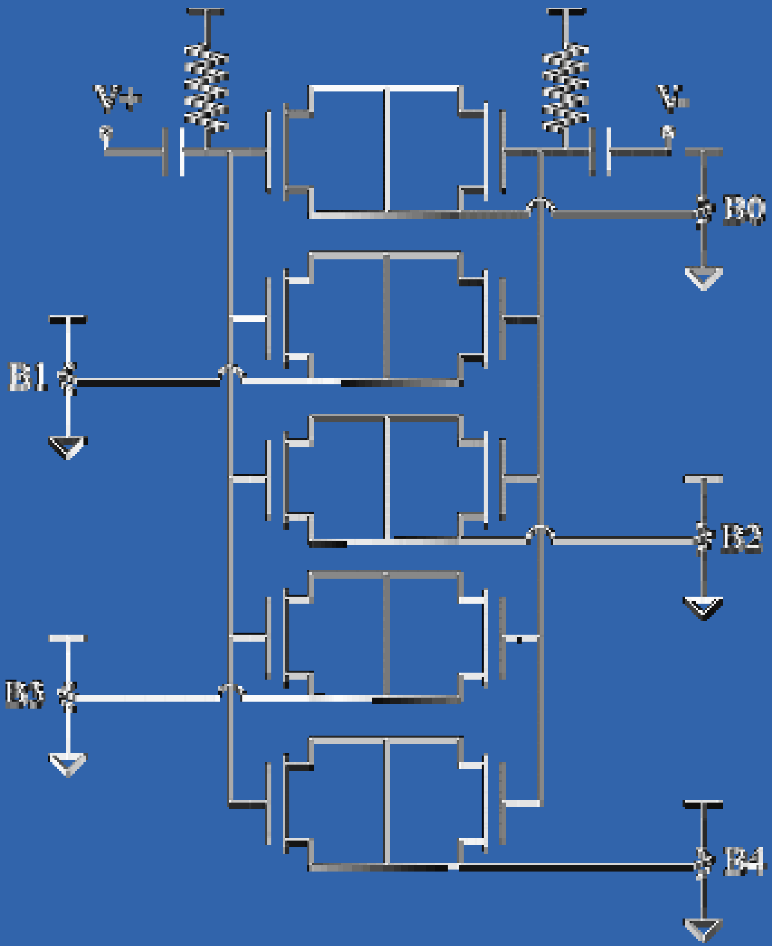


- Switch plus Transistor



- Transistor's operation region



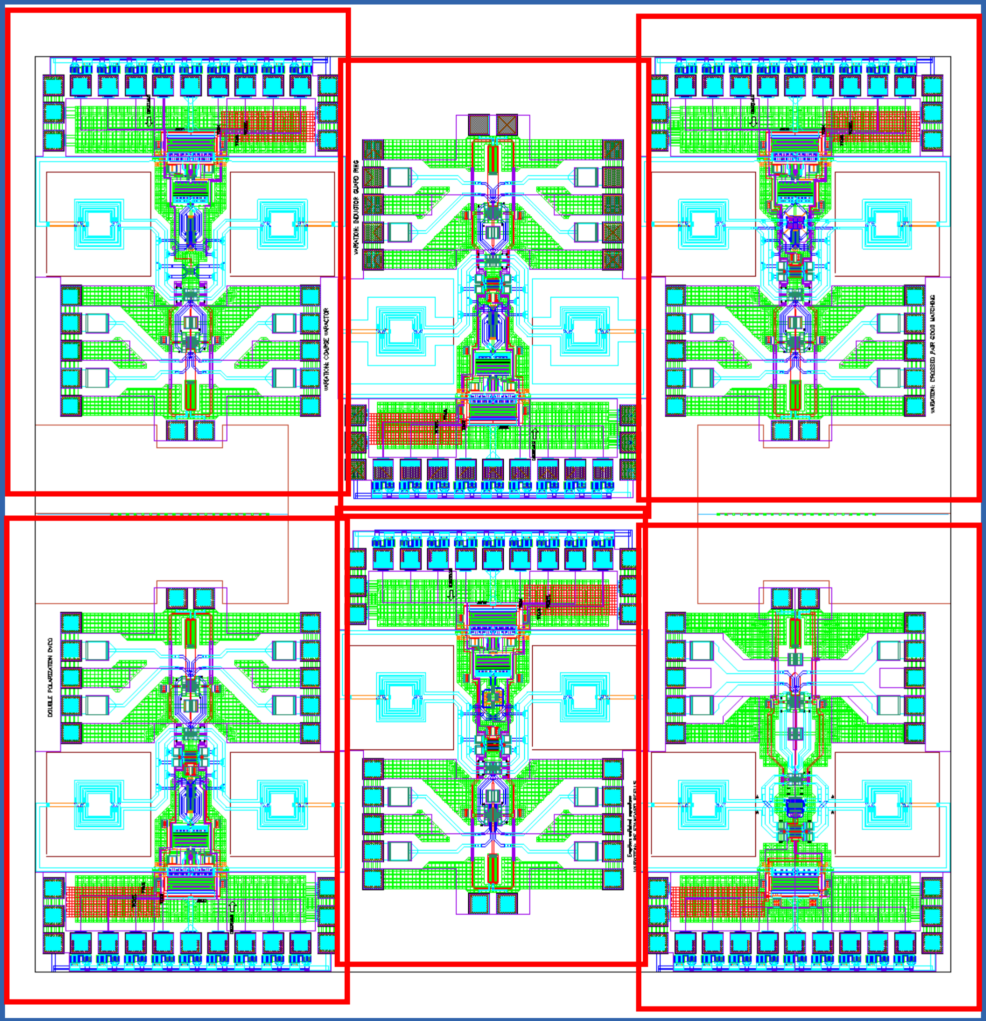


- **MIM plus Switch**

CMIM↑↑

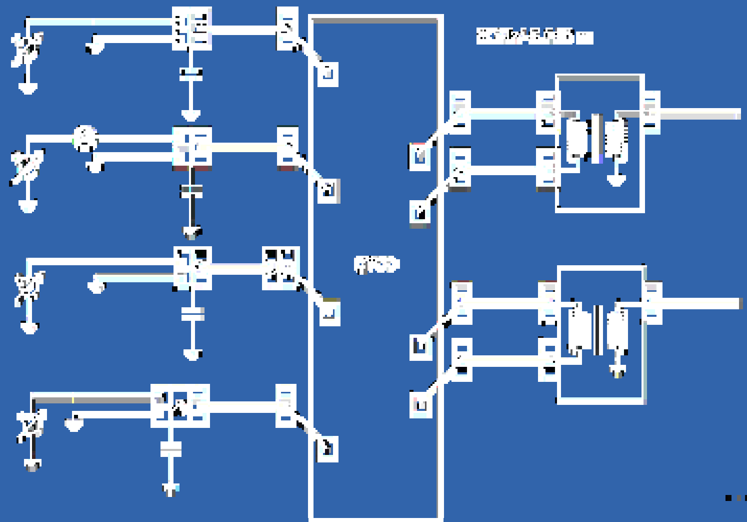
Full-Custom Layout Design

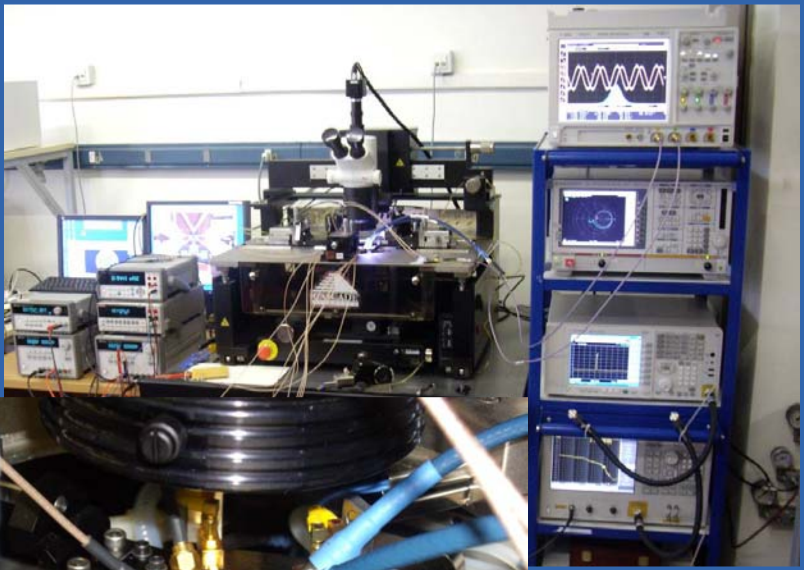
- Reference QVCO
- QVCO2 No-bias control
- QVCO3 Varactor
- QVCO4 N-Well Inductor
- QVCO5 Optimized Layout
- QVCO6 Standard Cells

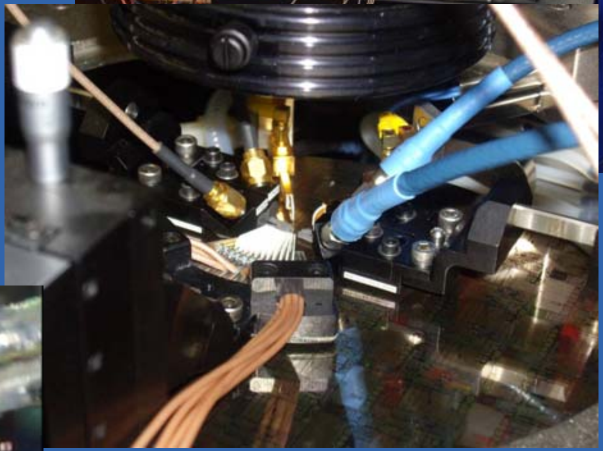


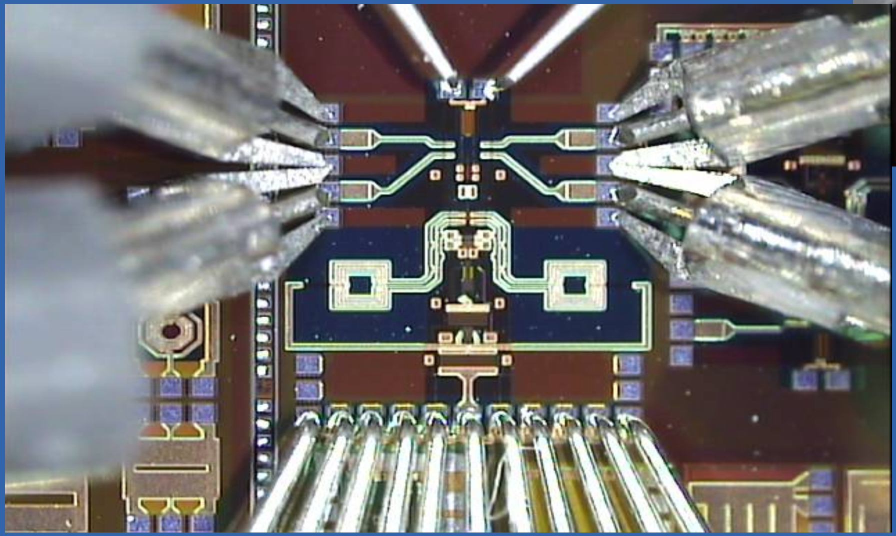
7 Experimental Results

Test bench



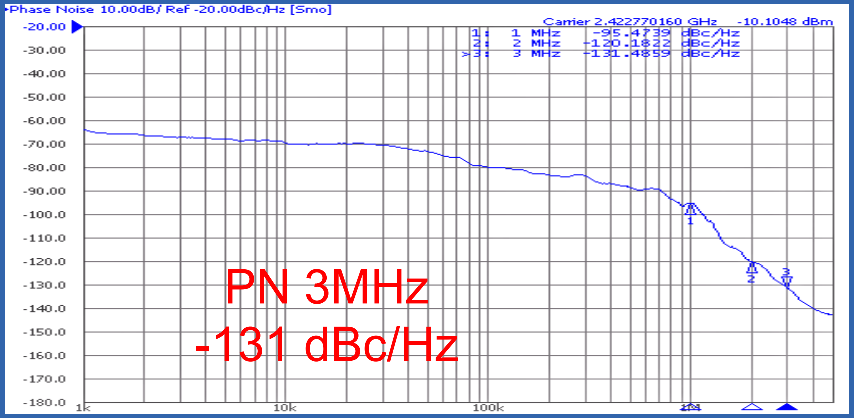


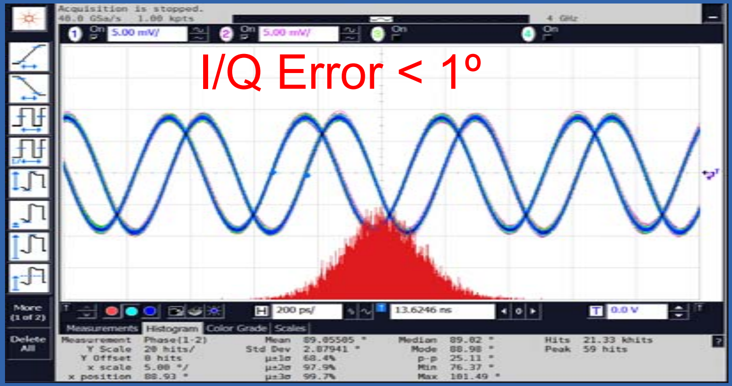


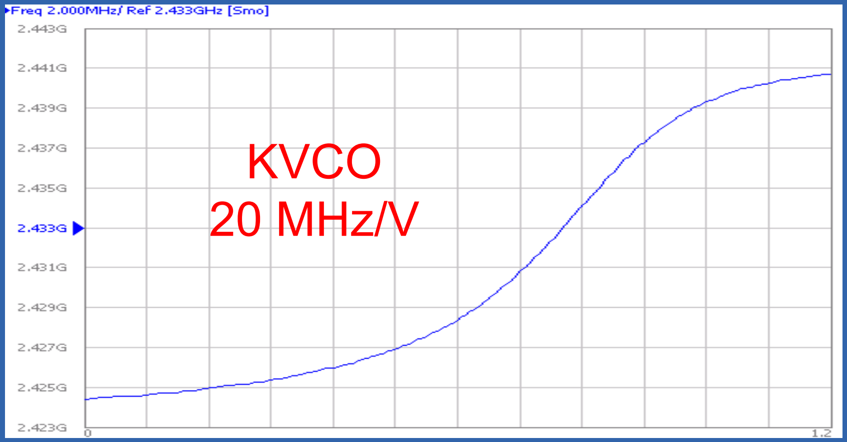


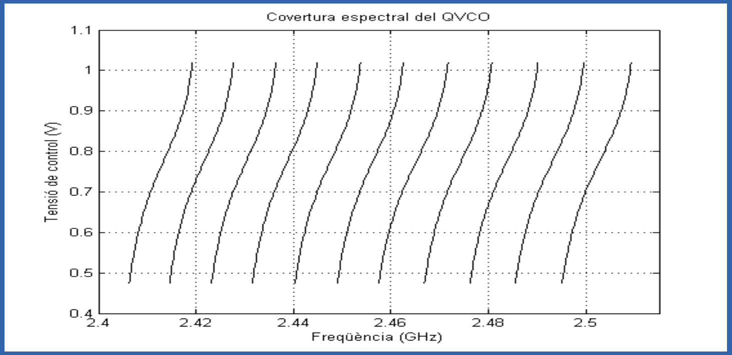
Reference QVCO Results

- **Power:** 700µA at 1.2V; **Freq.:** 2.45GHz



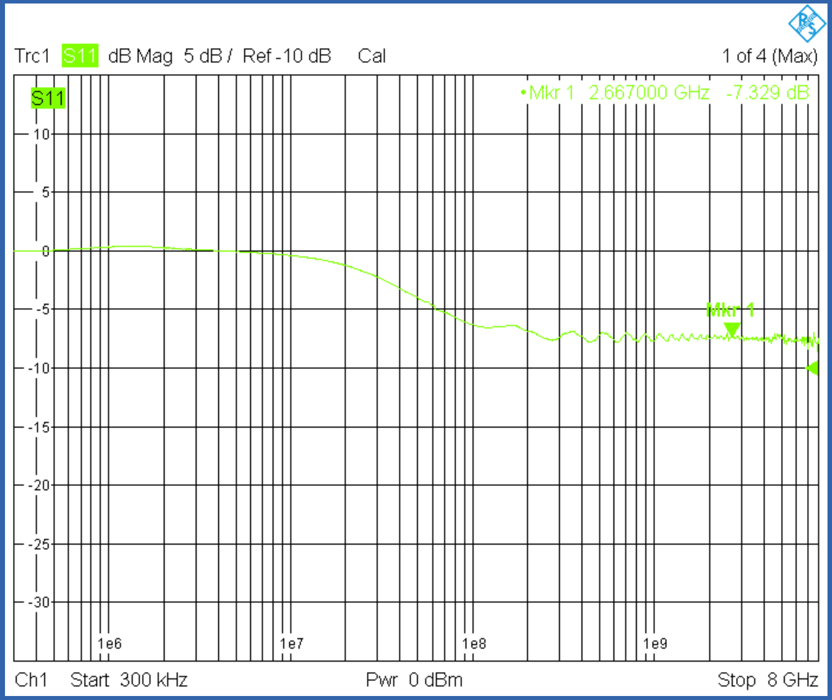


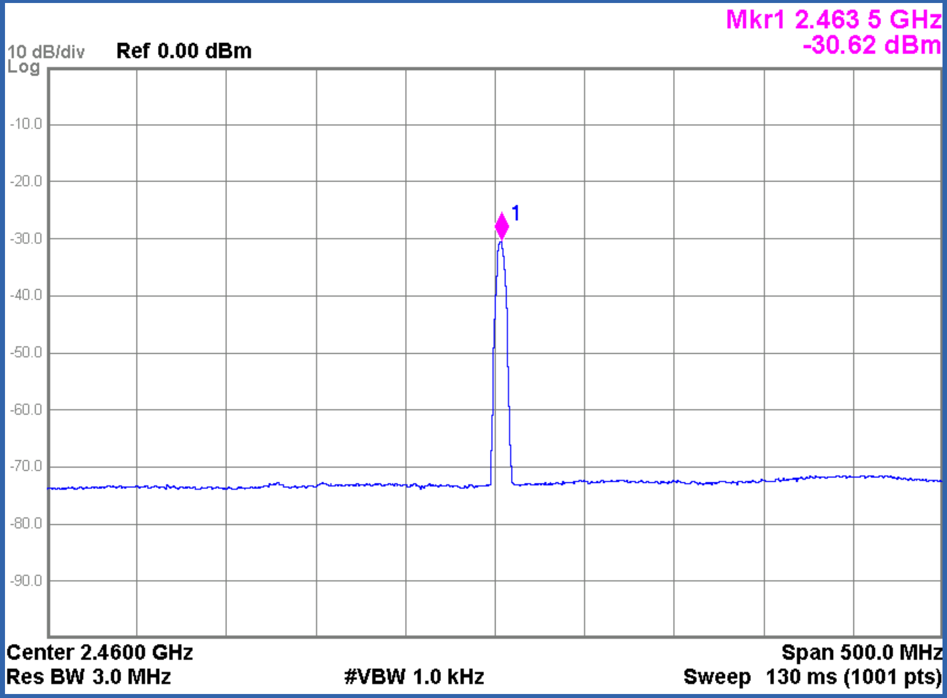




Output Power

- Test bench attenuation: 5.5 dB; Buffers gain : -18 dB.

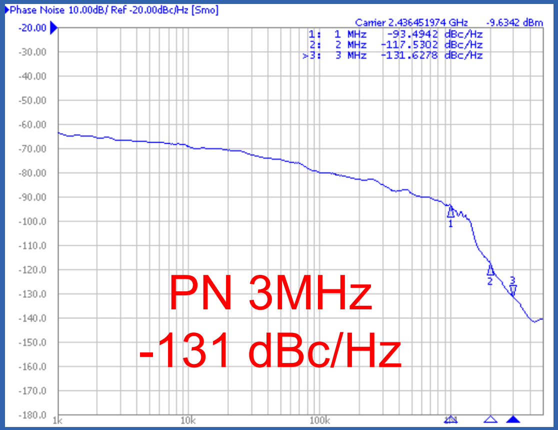




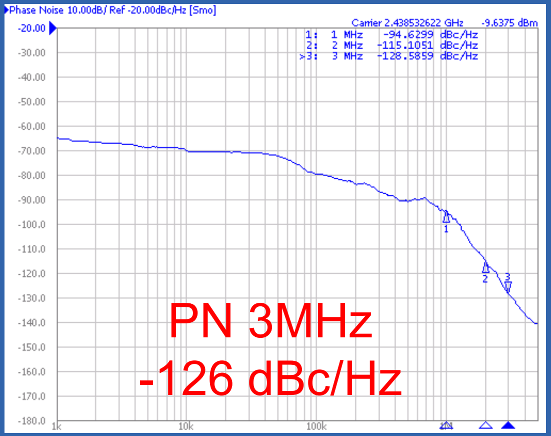
Output Voltage = 500 mVpp

Comparison with different versions

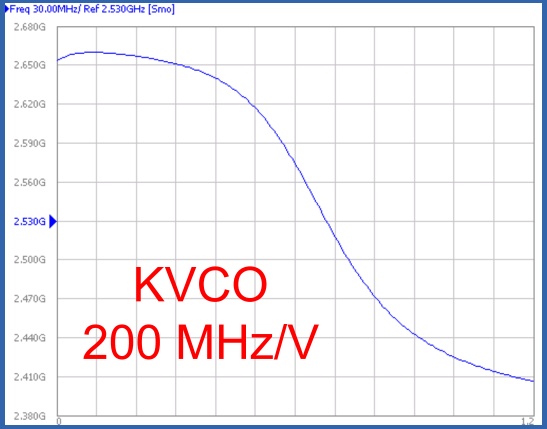
- Phase noise in QVCO2.



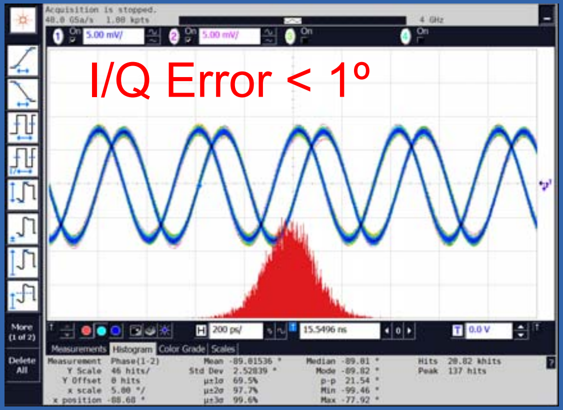
- Phase noise in QVCO4.



- Coarse Gain in QVCO3.

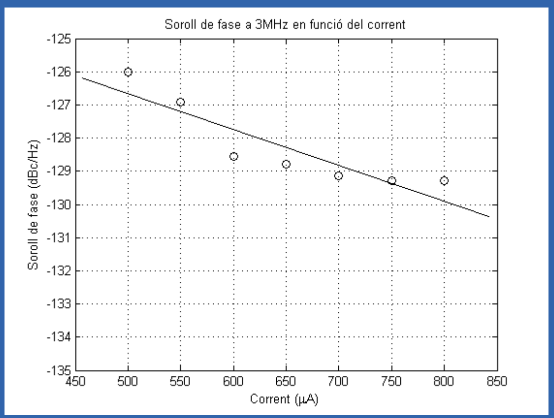


- Quadrature Error in QVCO5.

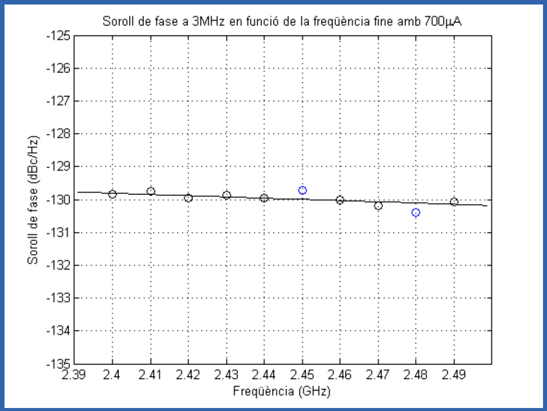


Parametric results

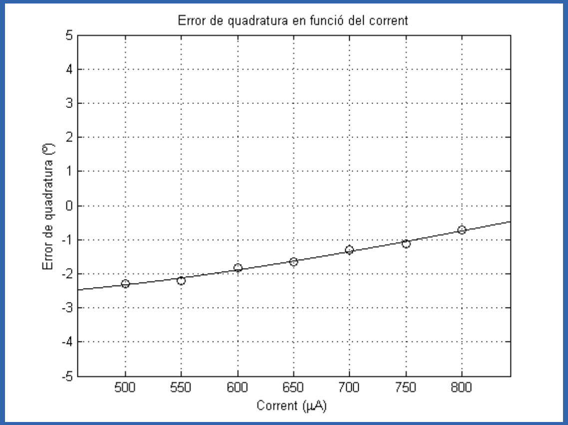
- Phase noise vs Current.



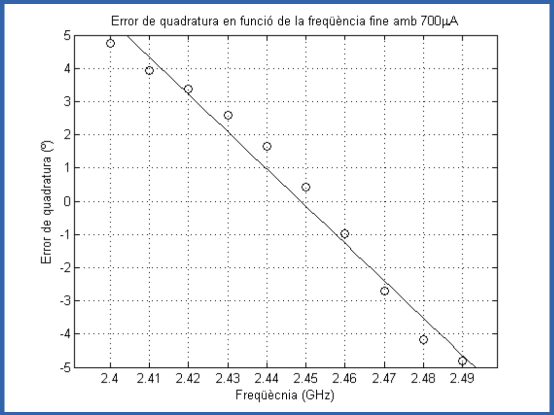
- Phase noise vs Frequency.



- Quadrature Error vs Current.



- Quadrature Error vs Frequency.



State of art comparison

- Figure of Merit: $$FOM = -L(\Delta f) + 20 \cdot \log\left[\frac{f_{osc}}{\Delta f}\right] - 10 \cdot \log(P_D)$$

Referència	V_{DD} [V]	I_{DD} [mA]	P_D [mW]	F_{osc} [GHz]	Δf [MHz]	L(Δf) [dBc/Hz]	FOM [-]
This work	1.20	0.70	0.84	2.50	3.00	-131.68	190.85
	1.00	5.00	5.00	6.00	1.00	-120.3	188.87
	1.30	16.00	20.80	2.27	3.00	-140.00	184.40
	1.80	3.20	5.76	5.50	1.00	-115.00	182.20
	2.00	15.00	30.00	1.57	0.60	-133.50	187.08
	2.50	8.00	20.00	1.85	3.00	-143.00	185.79
	1.25	1.74	2.18	2.01	1.00	-124.00	186.69
	1.20	4.40	5.28	6.00	1.00	-117.00	185.34
	1.80	9.70	17.46	5.00	1.00	-125.60	187.16
	2.50	8.75	21.88	5.20	1.00	-124.00	184.92
	0.70	7.40	5.18	2.40	1.00	-124.90	185.36
	1.80	6.00	10.80	2.60	0.10	-105.00	182.97
	1.80	1.60	2.88	2.40	3.00	-131.50	184.97
	1.20	12.25	14.70	2.45	1.00	-120.00	176.11

Conclusions

- Great results on **phase noise**.
- **Remarkable** results in FOM
- **Low-current** and **Low-Power Supply**.
- Varactor vs **capacitors bench.**
- Importance of **mismatch** in quadrature generation.
- **Amplitude noise** appears in very-low amplitude **output.**
- **Effective bias control** improvement.

Thank you for your attention!!!