

# **A Widlar-Bandgap based Intermediate-Frequency Voltage-Controlled Oscillator for GSM/DCS Transceiver ICs**

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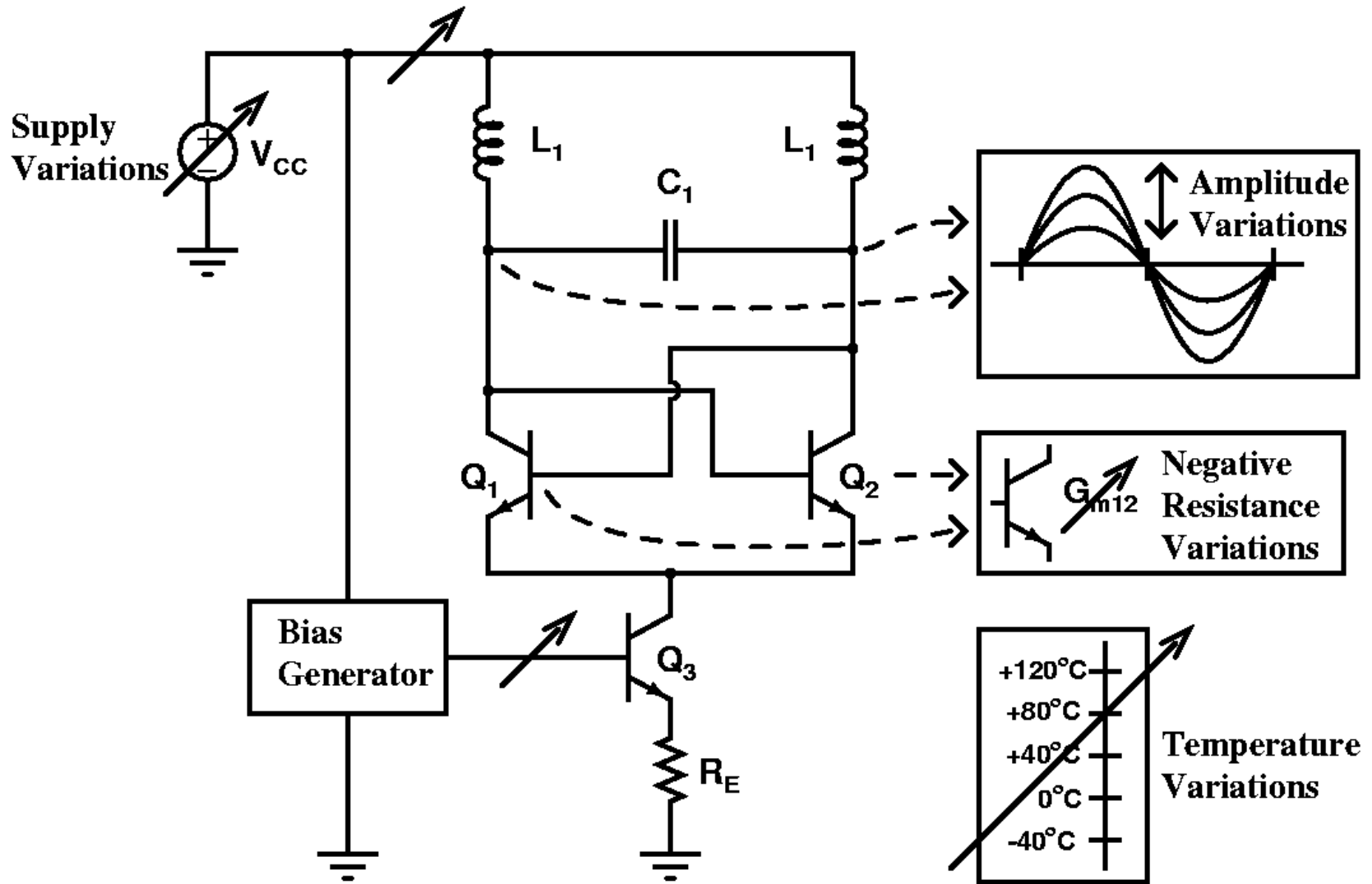
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# Outline

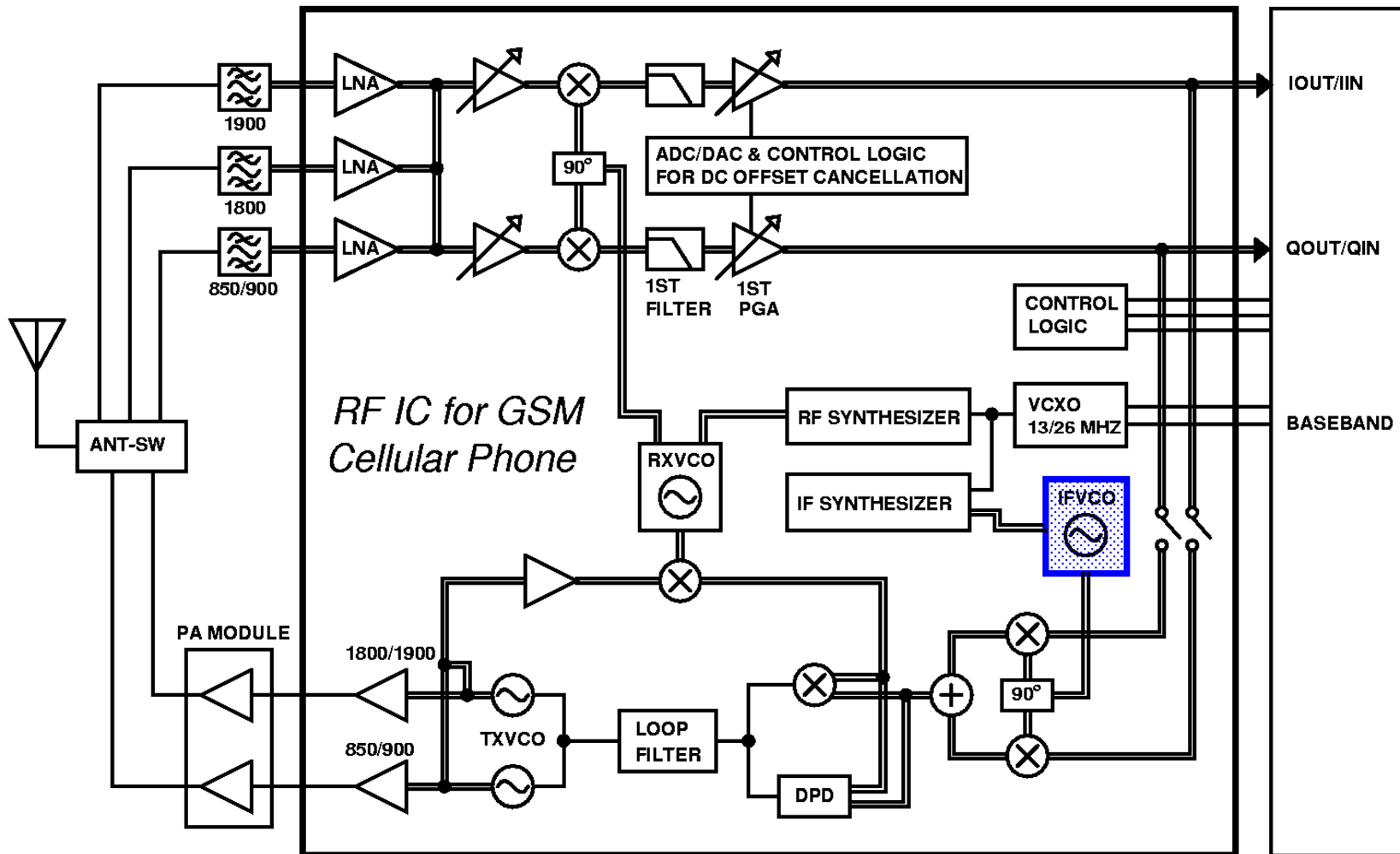
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- Introduction
- Application: RF IC for GSM cellular phone
- Approaches for supply and temperature insensitive VCO:
  - Conventional approach: using bandgap-referenced VCO bias current
  - Embedded approach: VCO embedded in Widlar-bandgap
- Simulation results
- Experimental results
- Summary
- Acknowledgements

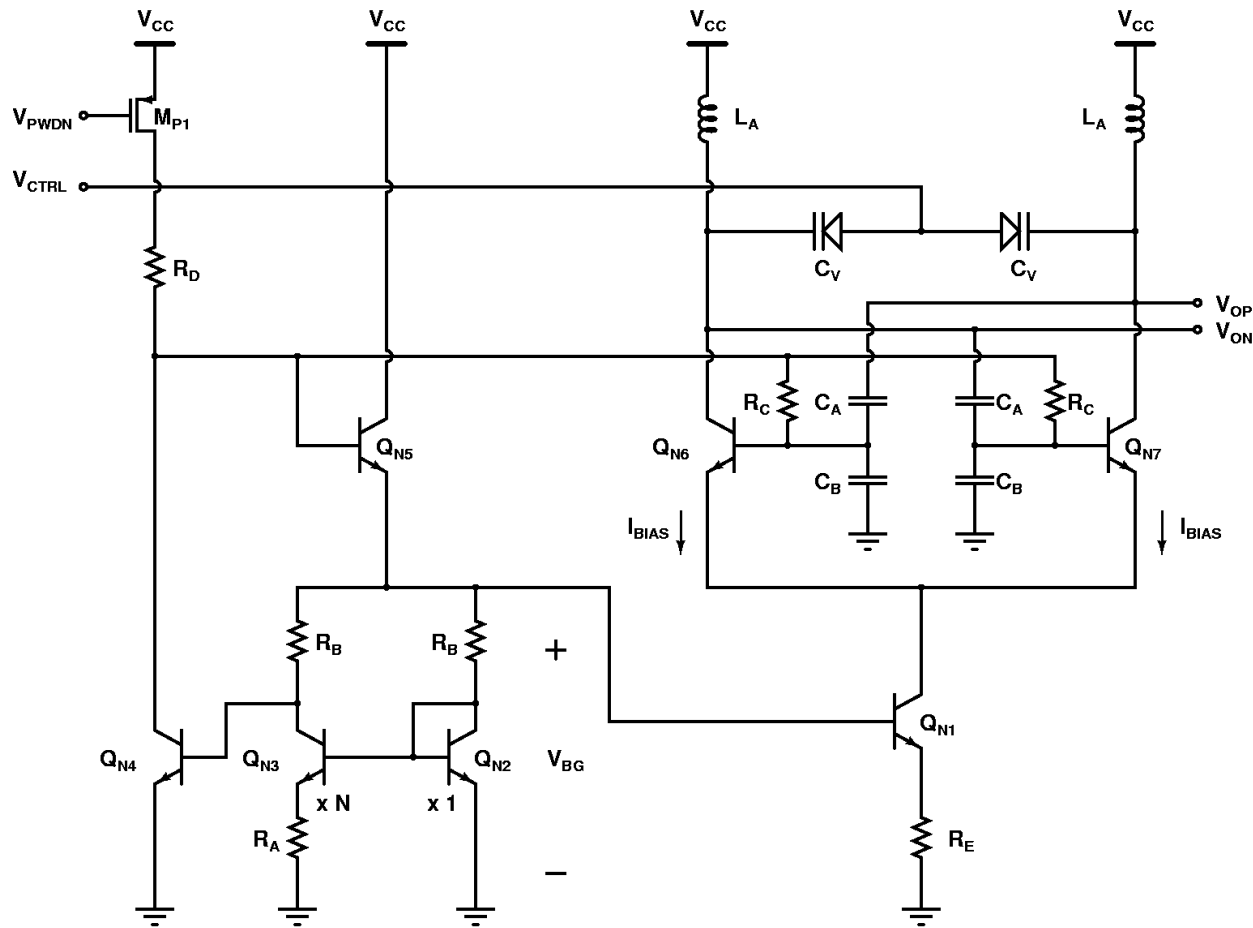
# Introduction



# Application: RF IC for GSM Cellular Phone



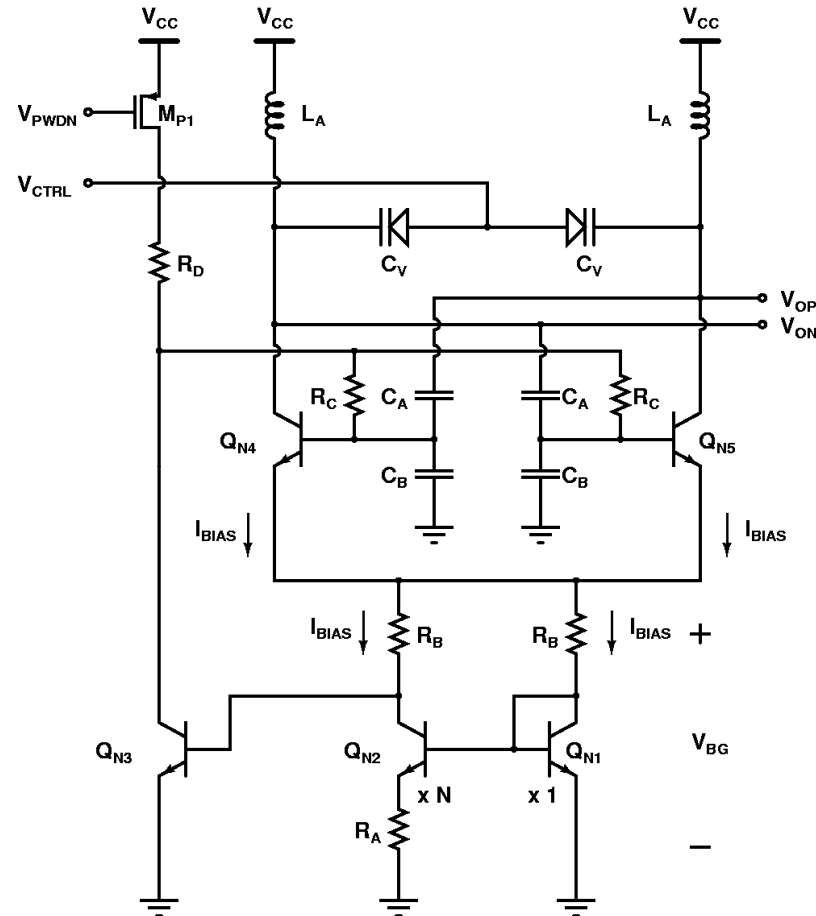
# Conventional Approach for DC-Bias of VCO



**Bandgap reference  
(Widlar bandgap)**

**VCO with supply insensitive DC-bias &  
temperature insensitive loop gain**

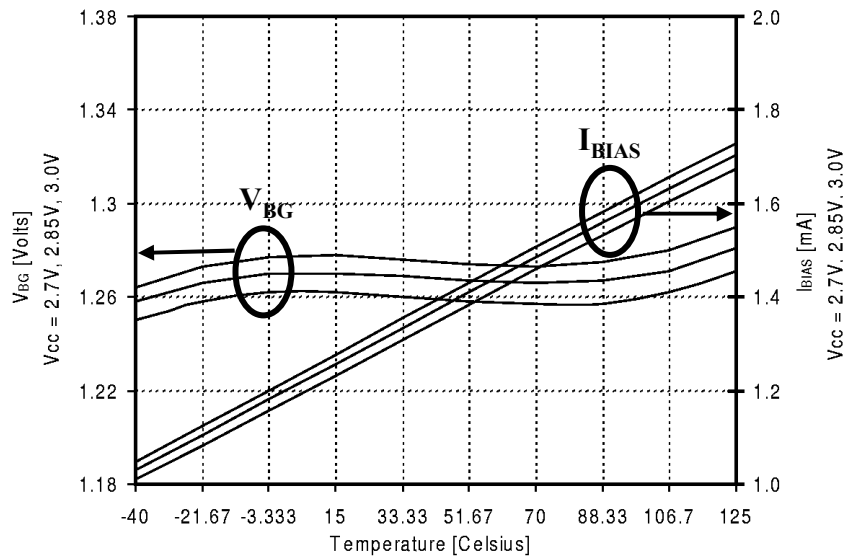
# Embedded Approach for DC-Bias of VCO



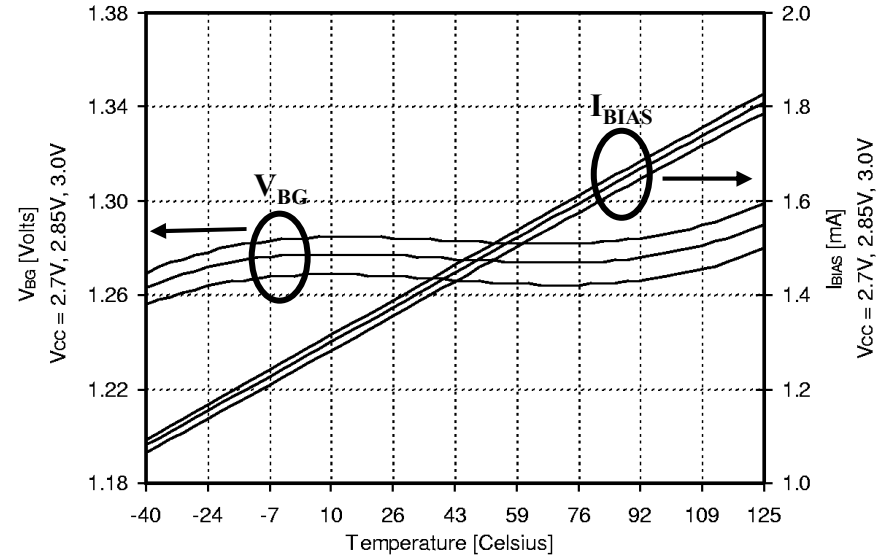
**VCO embedded in Widlar-Bandgap for supply insensitive DC-bias & temperature insensitive loop gain - eliminated devices for low power and less noise**

# Simulated DC Operating Point Characteristics (SpectreRF)

## Conventional Approach



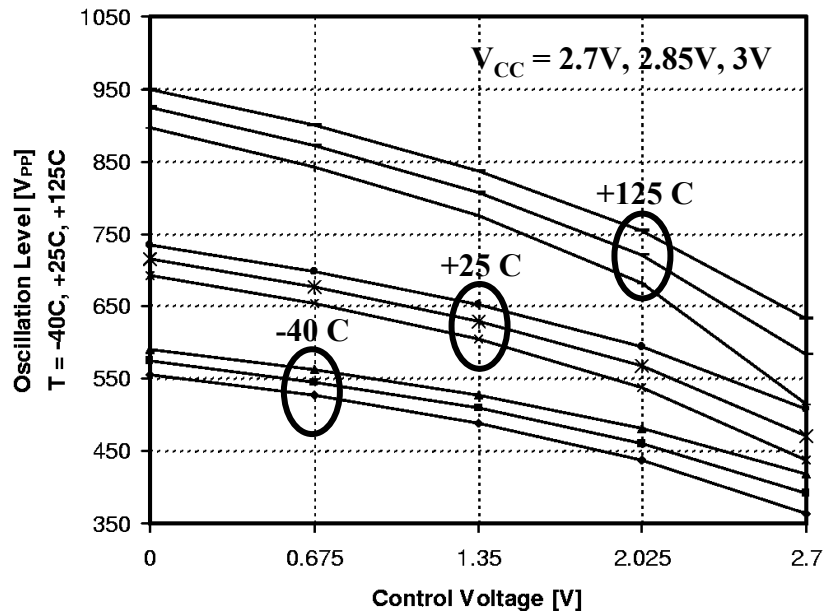
## Embedded Approach



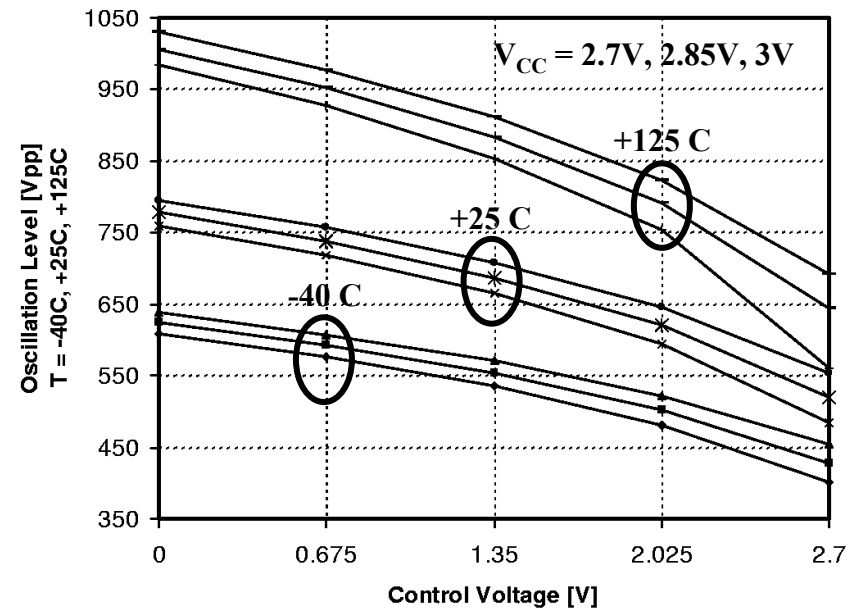
**Embedded approach achieves same DC-bias behavior as conventional approach  
(PTAT bias current  $\rightarrow g_m$  of VCO NPN's constant over temperature)**

# Simulated VCO Steady State Characteristics (SpectreRF)

## Conventional Approach



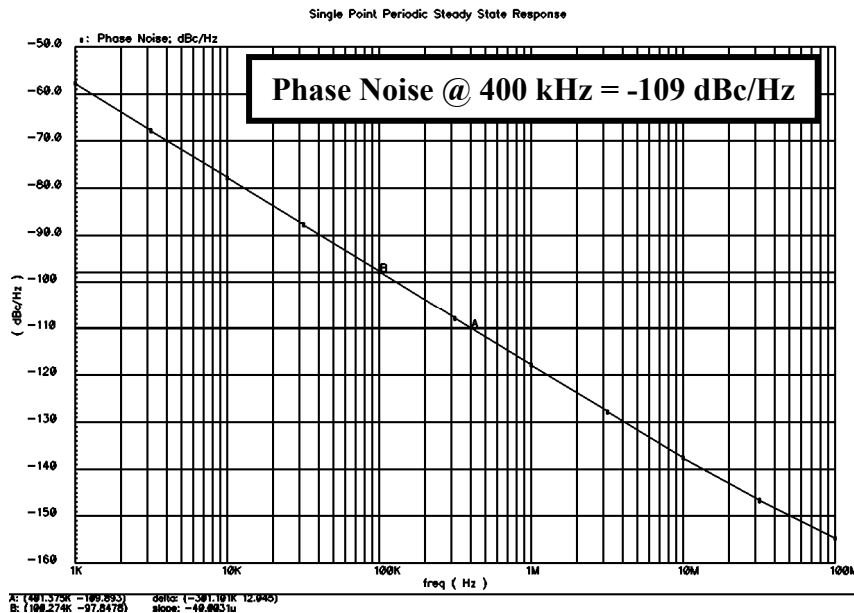
## Embedded Approach



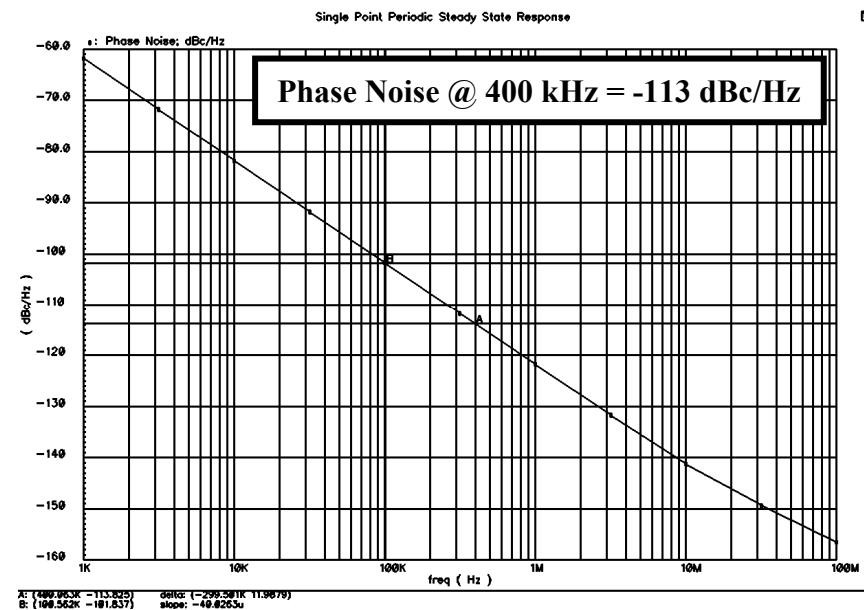
**Embedded approach achieves the same VCO steady-state characteristics as conventional approach (oscillation amplitude increases with temperature)  
Small variation in oscillation amplitude over supply variation**

# Simulated VCO Phase Noise Characteristics (SpectreRF)

## *Conventional Approach*

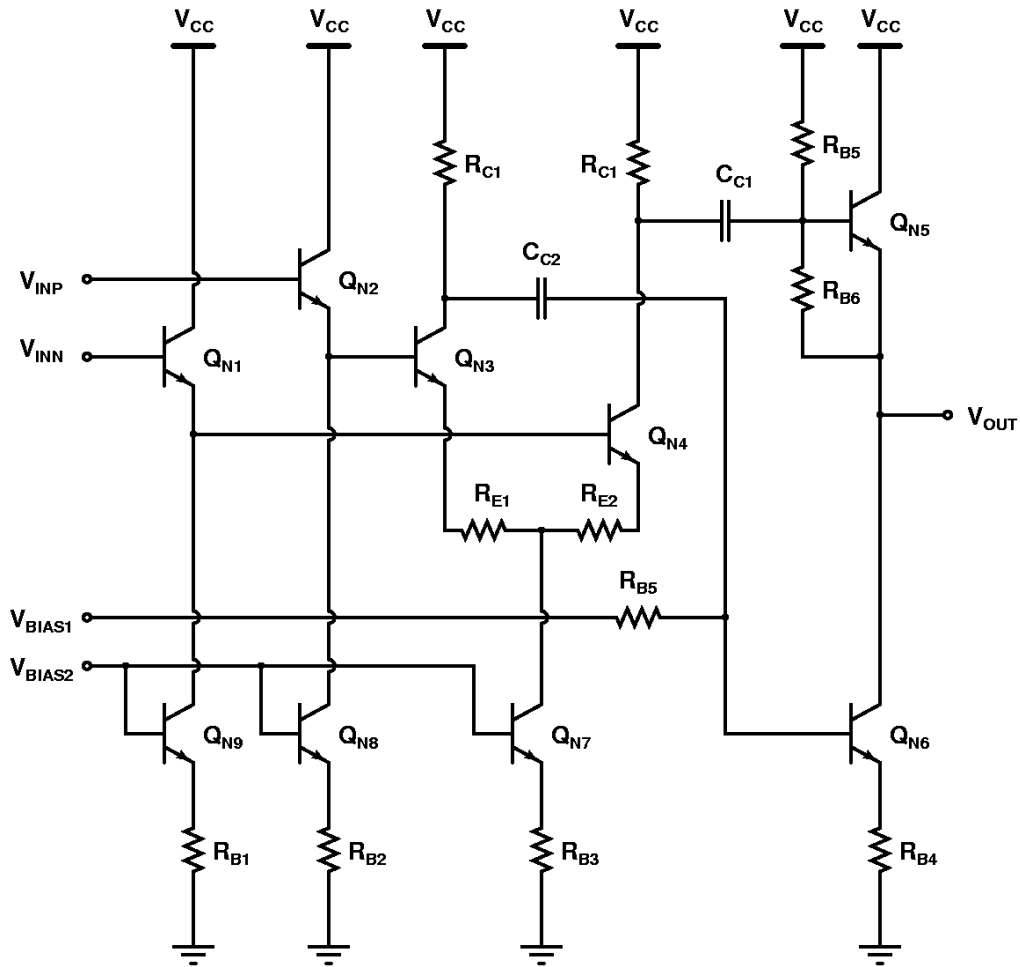


## *Embedded Approach*



**Embedded approach achieves 4 dB better phase noise over conventional approach  
(same VCO voltage-swing & power consumption in VCO-core)**

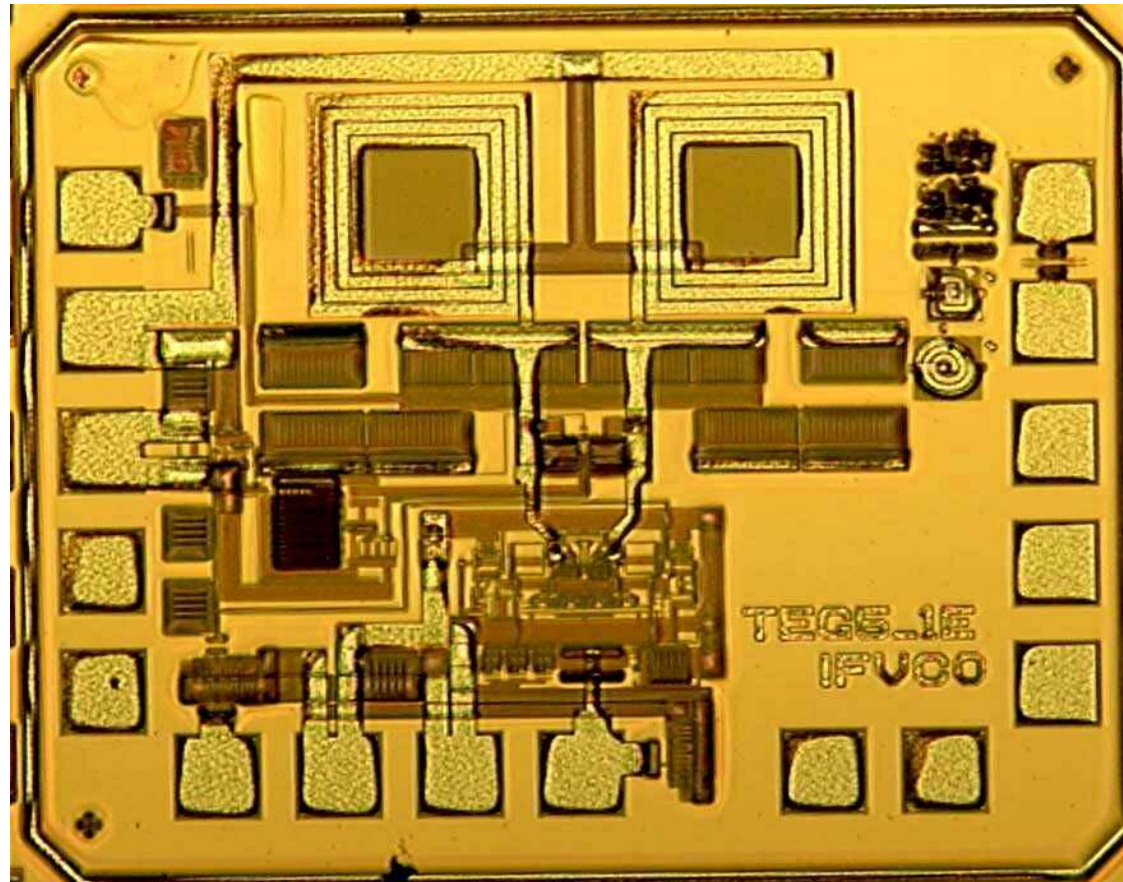
# Output Buffer Schematic



**Bipolar output buffer for driving the 50 Ohm measurement equipment**

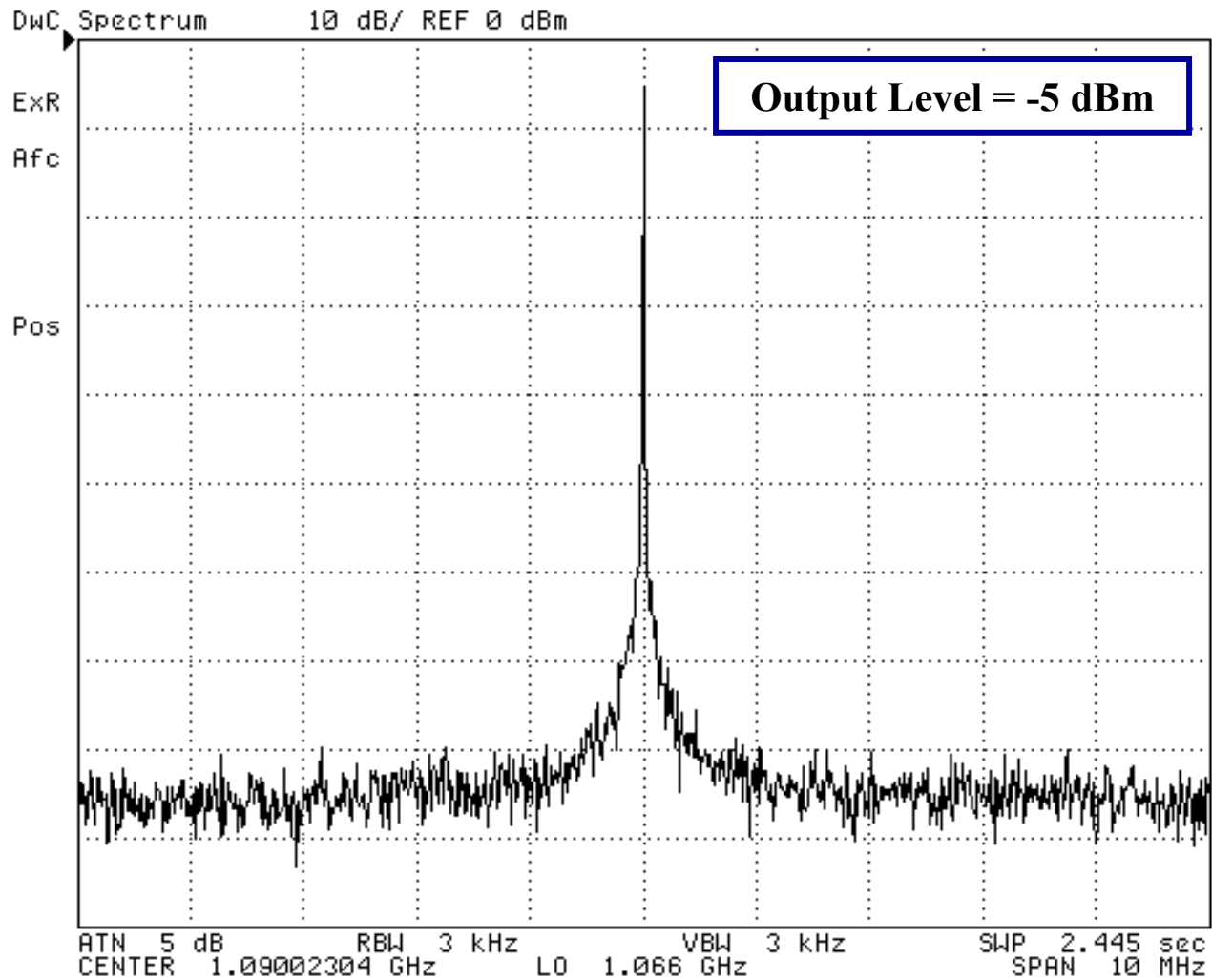
# Chip Microphotograph

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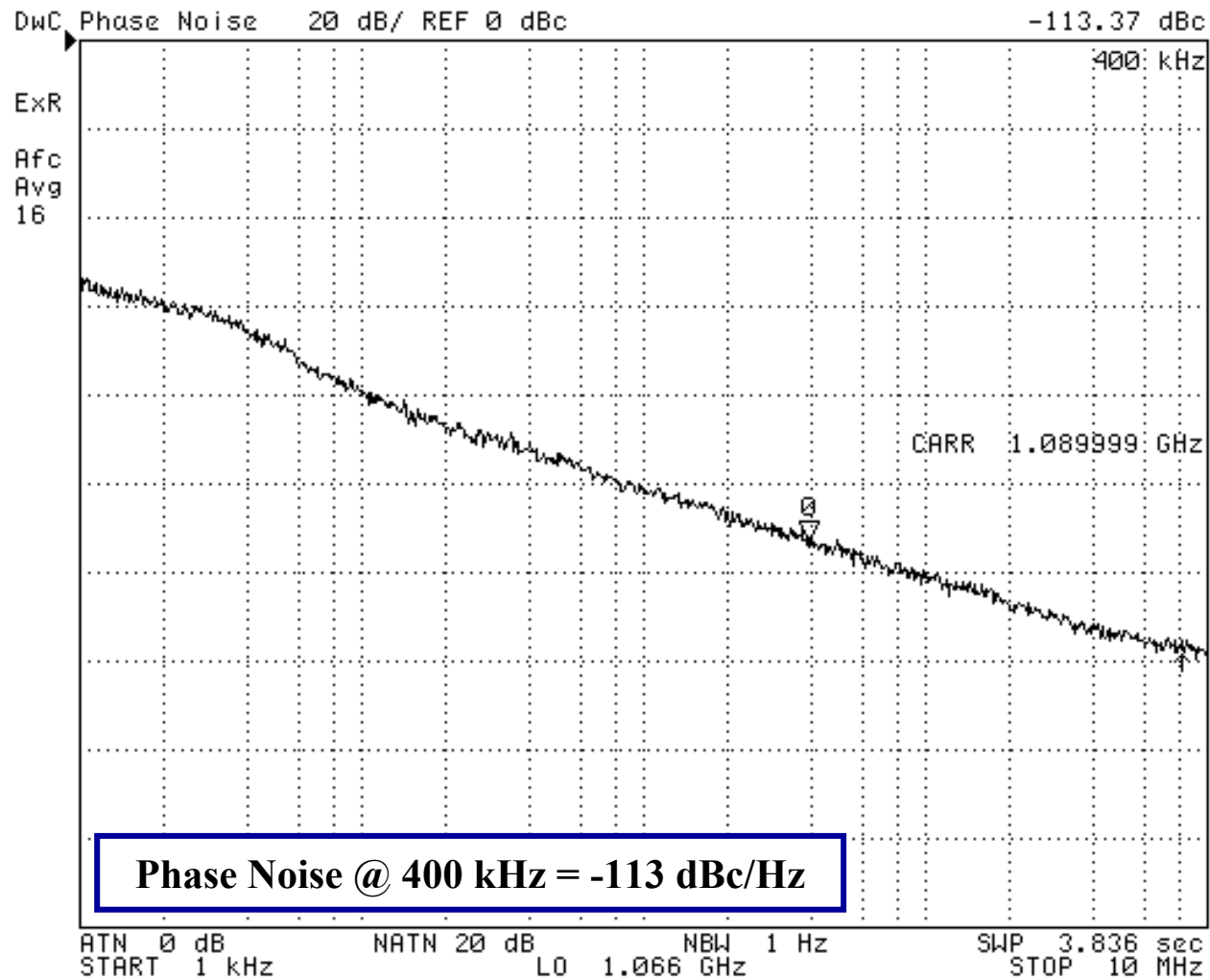


**Embedded approach: 1 GHz IF-VCO in 0.35  $\mu\text{m}$  SOI BiCMOS  
(Chip size: 1.5mm X 1.2 mm)**

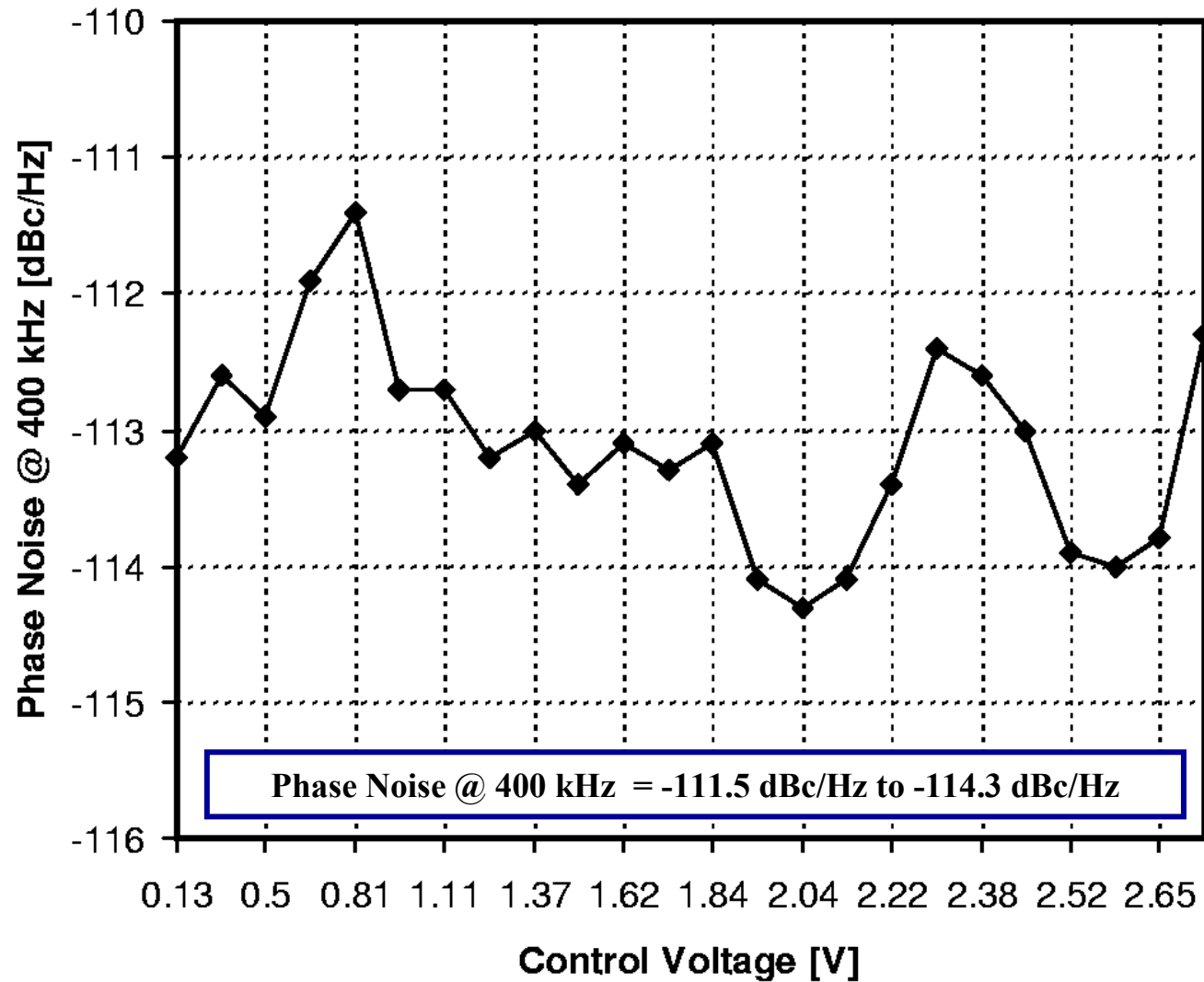
# Measured Output Spectrum



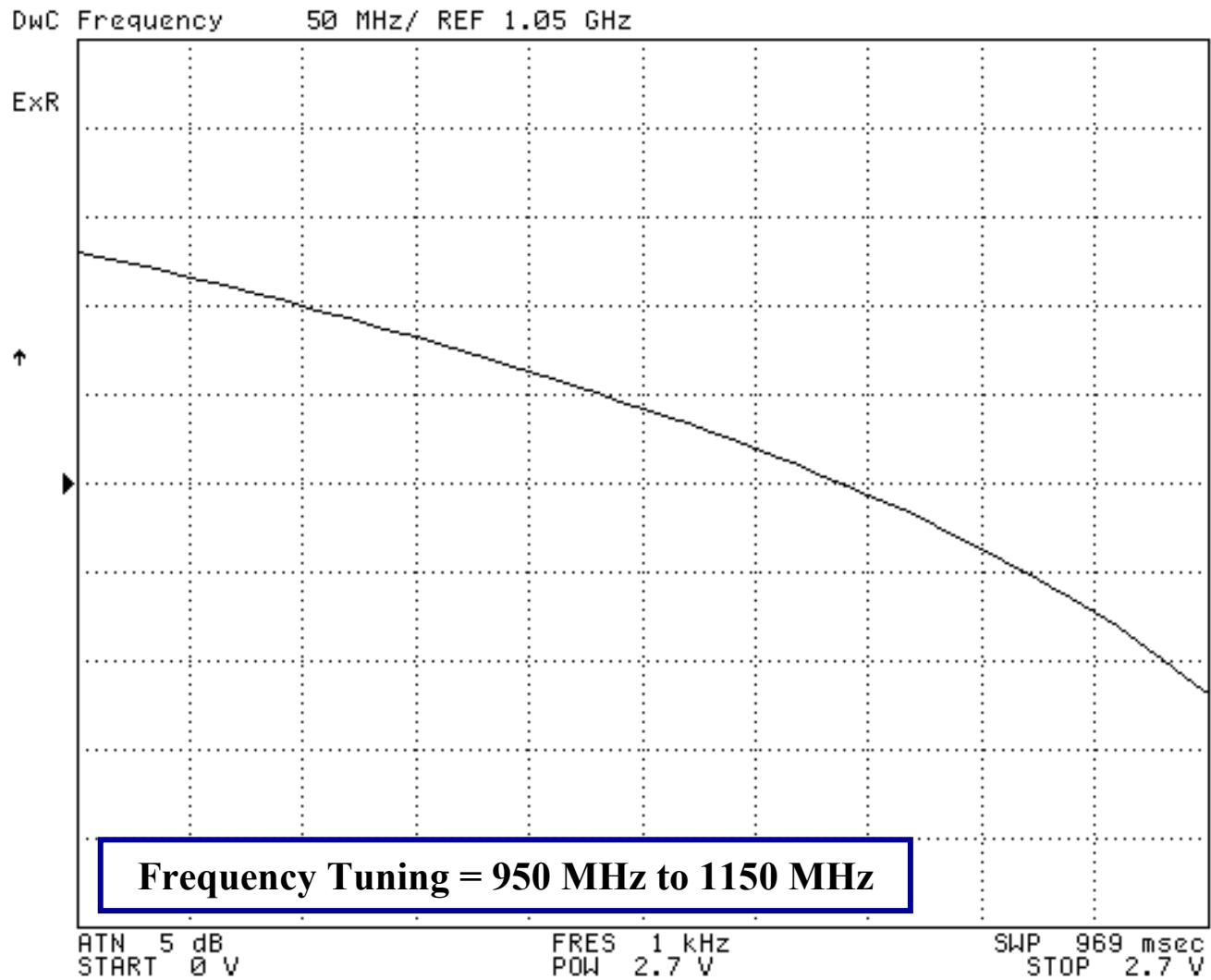
# Measured Phase Noise



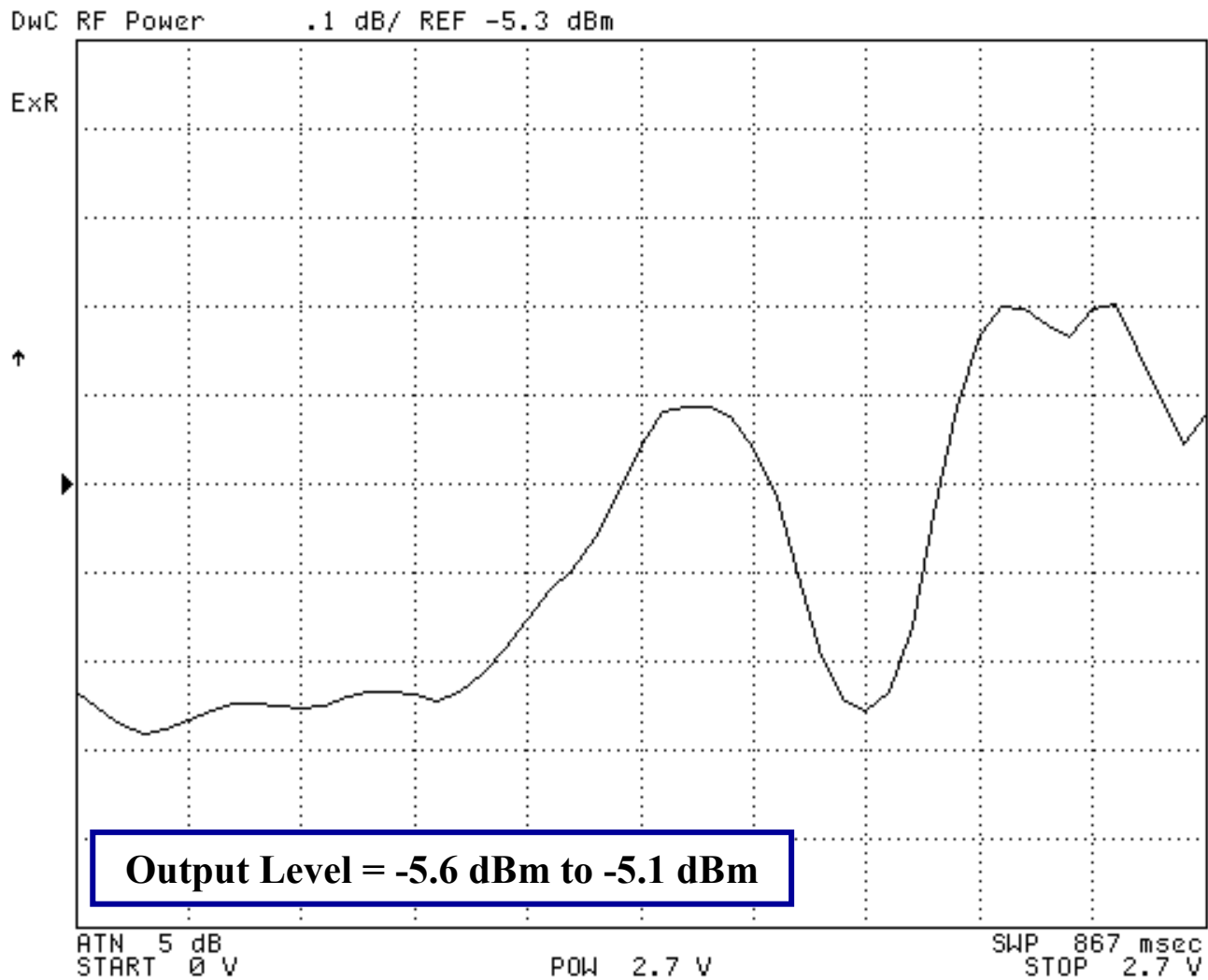
# Measured Phase Noise Control-Voltage Characteristics



# Measured Frequency Tuning Characteristics



# Measured Output Level Characteristics



# Summary

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<b>Characteristics</b>	<b>1 GHz VCO</b>	<b>500 MHz VCO</b>
Technology	0.35 $\mu\text{m}$ SOI BiCMOS	0.35 $\mu\text{m}$ SOI BiCMOS
Supply Voltage [Volts]	2.7	2.7
VCO Supply Current [mA]	4	4
Buffer Supply Current [mA]	11	11
Output Level [dBm]	-5.1	-3.4
Frequency Tuning [MHz]	931 - 1180	415 - 543
Phase Noise @ 100 kHz [dBc/Hz]	-102	-103
Phase Noise @ 400 kHz [dBc/Hz]	-113	-114

## Conclusion

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- Conventional VCO DC-bias approach
  - Supply variation insensitive DC-bias & oscillation amplitude
  - Temperature variation insensitive negative resistance
- Embedded VCO DC-bias approach
  - Same DC-bias & steady-state characteristics over supply & temperature as the conventional approach
  - Lower power and smaller chip area (due to eliminated devices)
  - Phase noise 4 dB better than conventional approach
- Embedded approach demonstrated in 1 GHz IF-VCO, implemented in 0.35  $\mu\text{m}$  SOI BiCMOS