RF and Microwave Components

VOLTAGE CONTROLLED OSCILLATOR (VCO) VERIFICATION

Markus Lörner, Market Segment Manager
Alexander Nähring, Product Manager

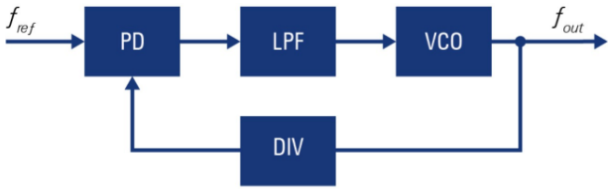
ROHDE&SCHWARZ

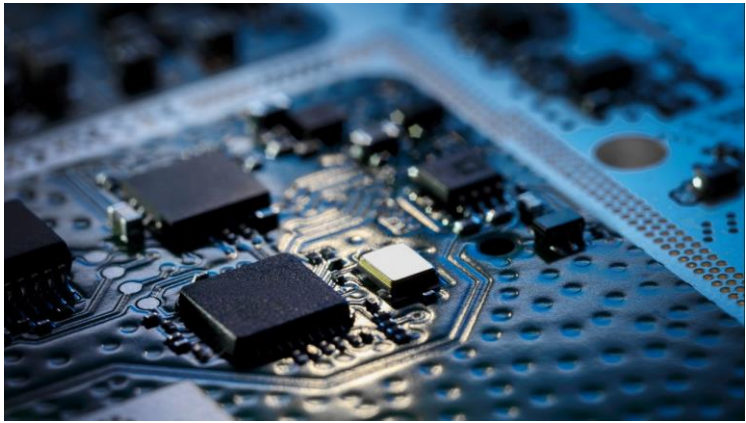
Make ideas real

WHY CARE ABOUT VCOS?

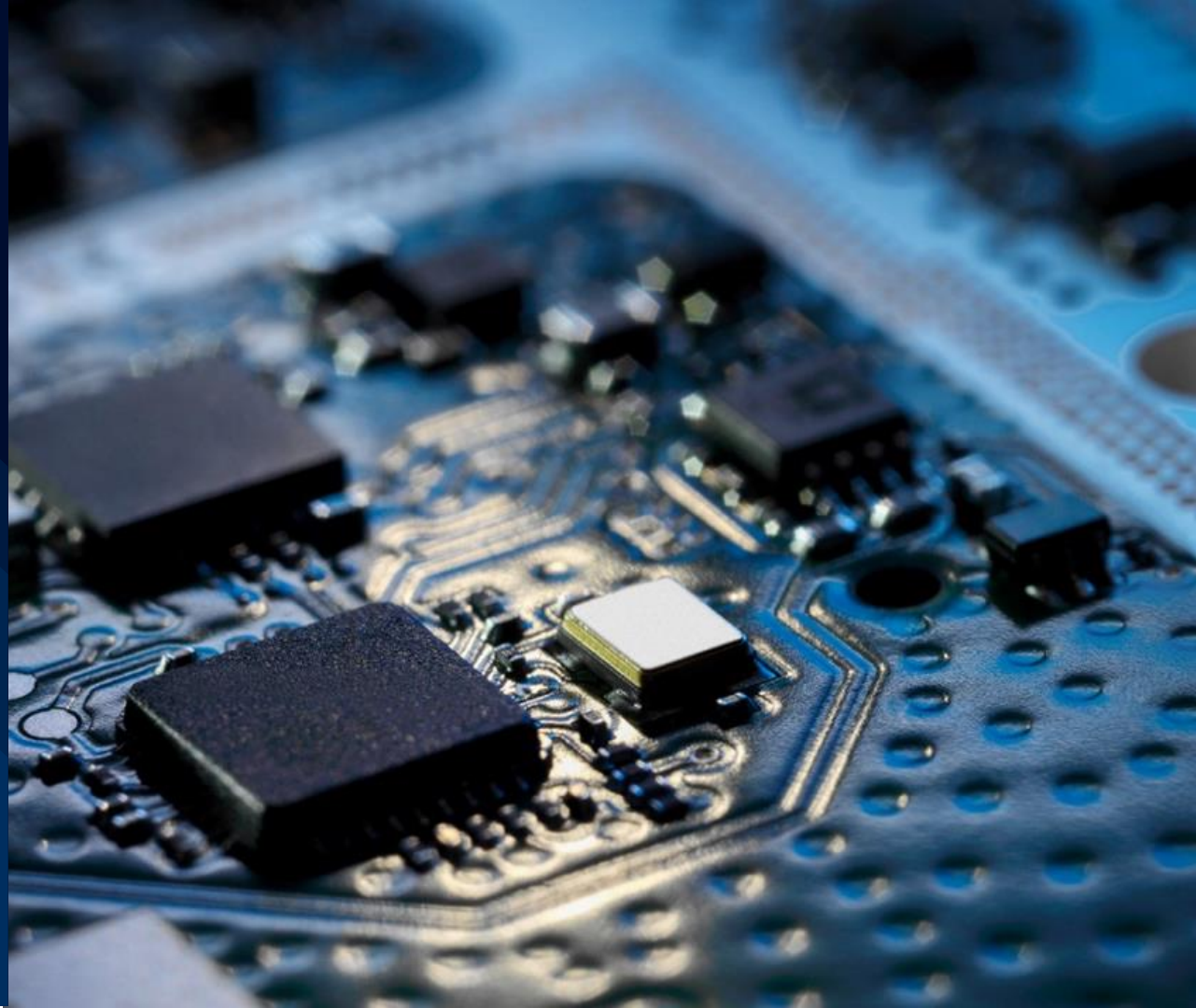
- Our world has become wireless
- Data links use different frequency bands for transmission (5G, satellite links, radar, …)
- Oscillators generate the frequencies to transport the data

- VCO: **V**oltage **C**ontrolled **O**scillator
  - Tunable for different frequency bands
  - Create radar chirps through tuning
  - Fine frequency adjustment within a locked loop (PLL) synthesizer





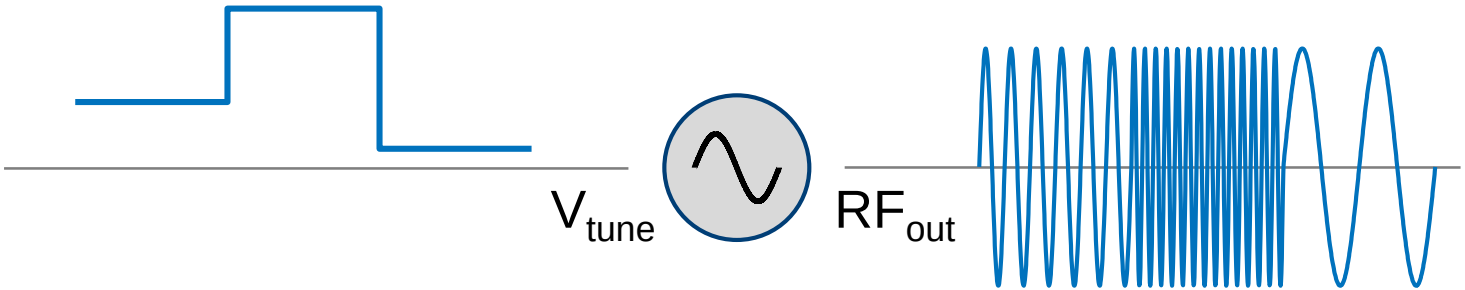
- VCO basics
- VCO key characteristics
- VCO verification including a live demo
- Summary



VCO BASICS

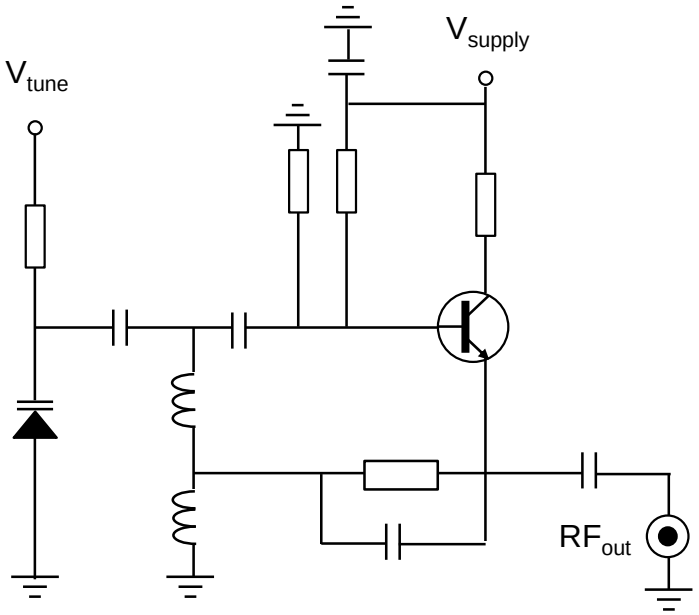
OSCILLATORS

- Oscillators create an RF carrier, mostly sinusoidal
  - Base for any RF design
  - Fixed or variable frequency
  - Often used in PLLs
- In a Voltage Controlled Oscillator, output frequency is controlled via input voltage



LOOKING INSIDE THE VCO

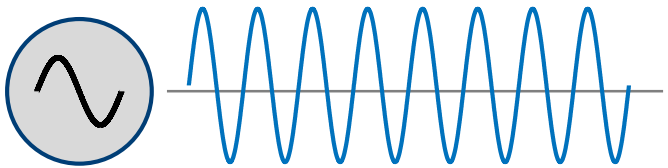
- Different approaches used
- Varactor diode is a common building block as variable capacitance
- Trade offs in design
  - Bandwidth vs
  - Signal purity
- Optimization in simulation and measurement- aided approach



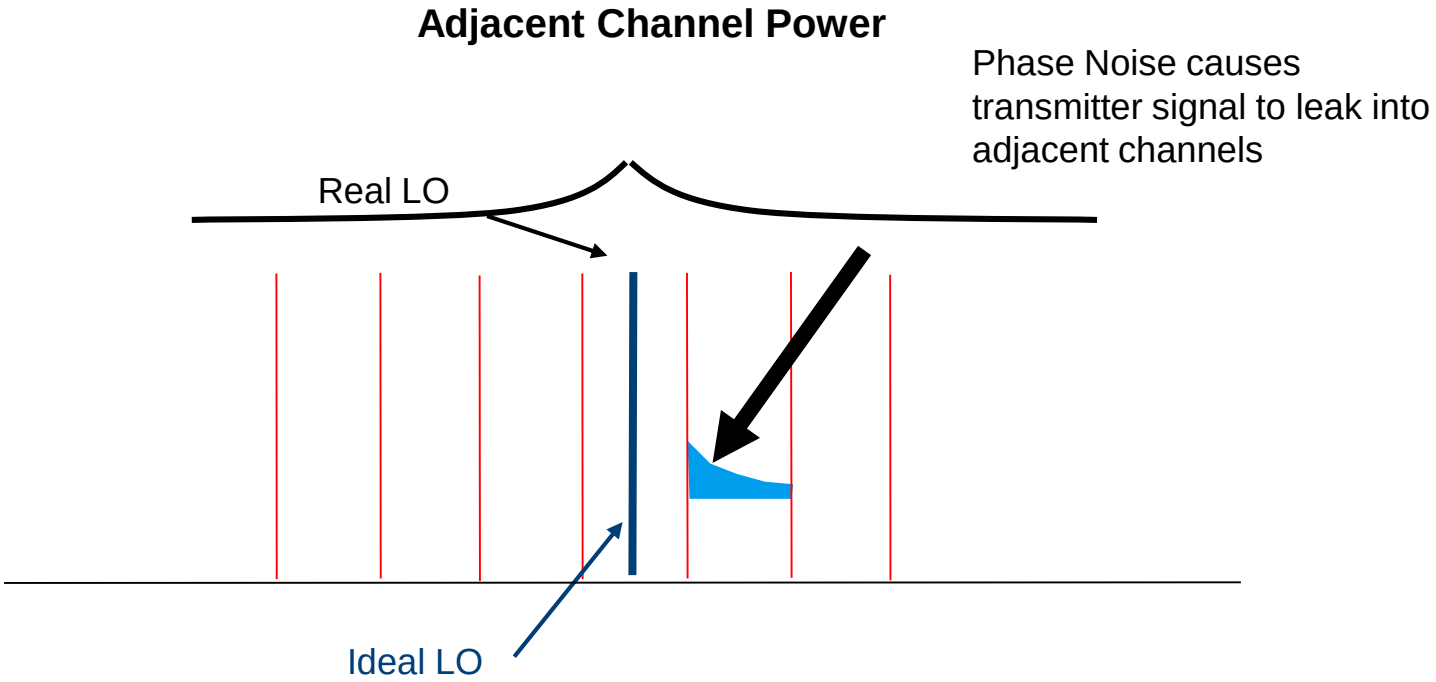
IDEAL VCO

- Fixed frequency VCO
  - Constant frequency
  - High signal purity – low phase noise
  - Stable while supply voltage varies
  - Stable while load varies

- Frequency-tuned VCO
  - Linear tuning behavior
  - Stable output power
  - High signal purity – no harmonics or spurs
  - Constant power consumption

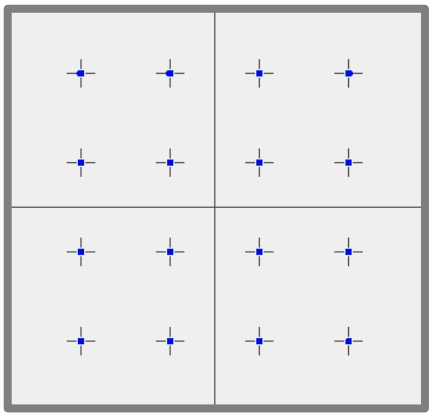


PHASE NOISE IN VCO DESIGNS – WHY CARE?
IMPORTANT IN COMMUNICATION SYSTEMS TRANSMITTERS

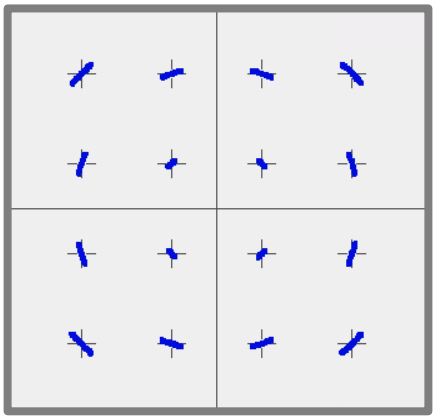


PHASE NOISE IN VCO DESIGN – WHY CARE?
IMPORTANT IN DIGITAL MODULATION

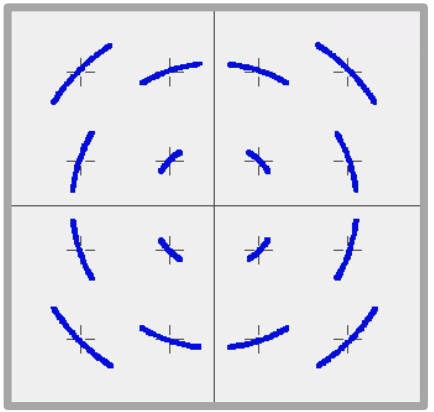
Modulation quality (phase error, EVM) is degraded by phase noise



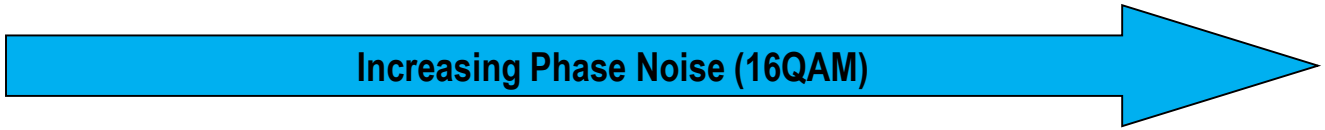
0% EVM (ideal)



5% EVM

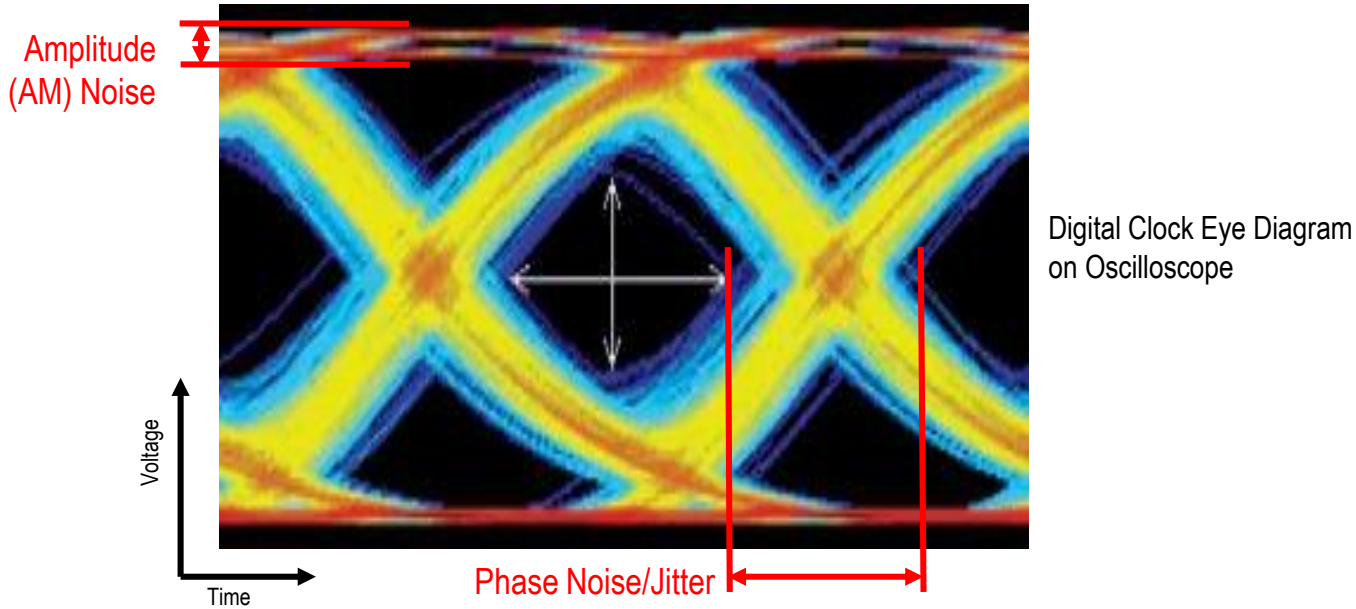


15% EVM



PHASE NOISE IN VCO DESIGNS – WHY CARE?
IN DIGITAL DESIGNS

High Phase Noise = High Jitter



Digital Clock Eye Diagram
on Oscilloscope

Jitter peaks can cause transmitted symbol errors which increase bit error rate and limit usable data rate

WHAT IS PHASE NOISE?

- **Ideal Signal (noiseless)**

$$V(t) = A \sin(2\pi\nu t)$$

where

A = amplitude

ν = frequency

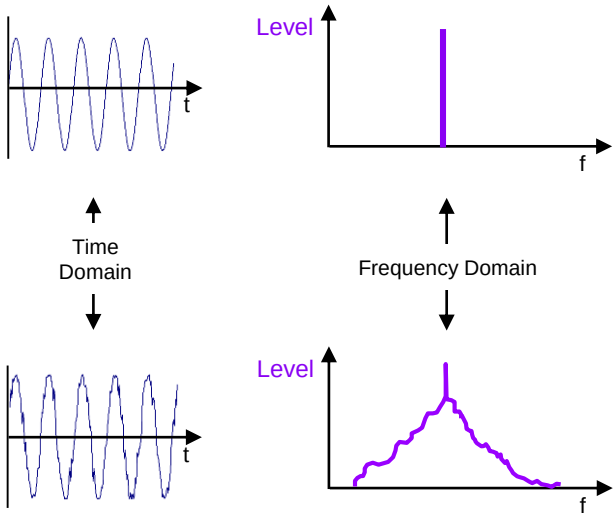
- **Real Signal**

$$V(t) = [A + E(t)] \sin(2\pi\nu t + \phi(t))$$

where

$E(t)$ = amplitude fluctuations

$\phi(t)$ = phase fluctuations

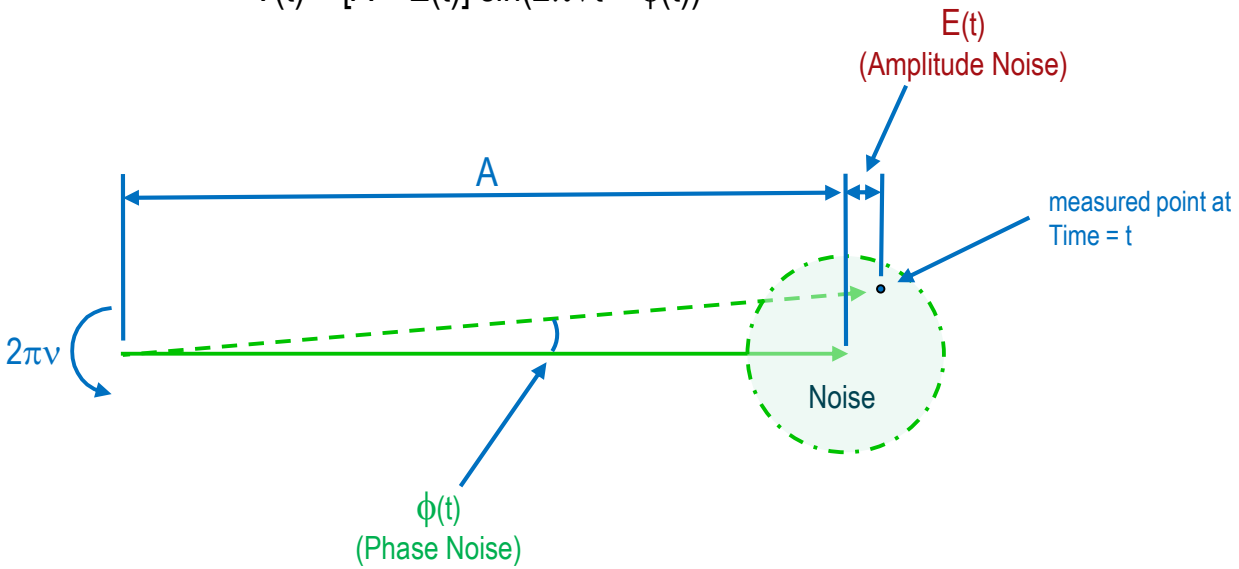


- **Phase Noise: unintentional phase modulation, spreads signal spectrum in frequency domain**
- **Phase Noise: equivalent to jitter in the time domain**

WHAT IS PHASE NOISE?

- AM Noise and Phase Noise on a Phasor Diagram:

$$V(t) = [A + E(t)] \sin(2\pi\nu t + \phi(t))$$

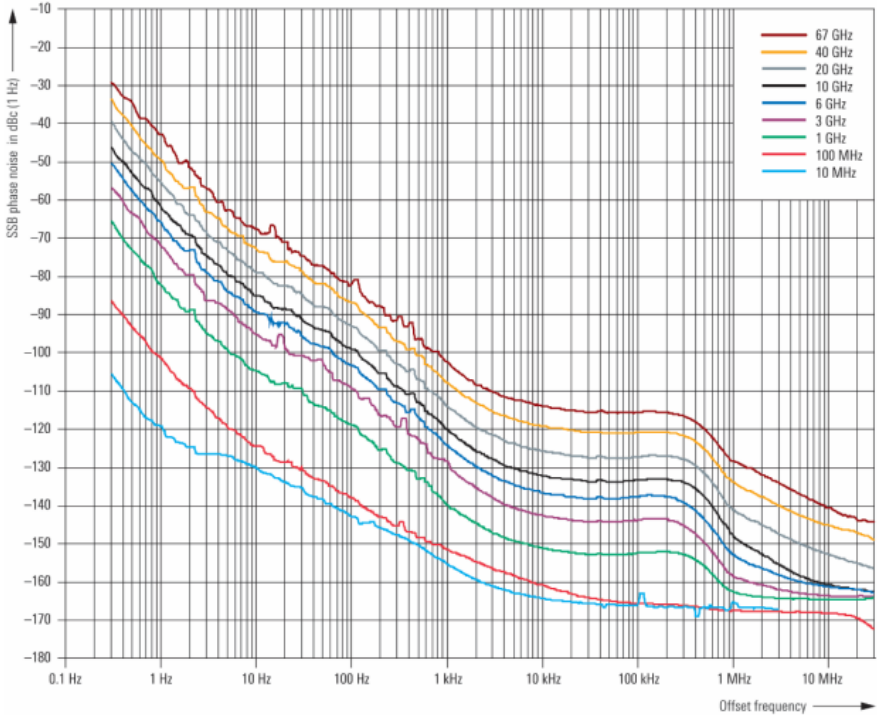


ADDITIONAL COMPLICATION WITH PHASE NOISE

- As frequency ↑ also phase noise ↑
- Reaching to mmWave frequencies or even D band in 6G research, phase noise will become even more important for modulation capabilities

- Rule of thumb:

  2x frequency → 6 dB more phase noise



Phase noise plots at different frequencies
Example: R&S SMA100B with options

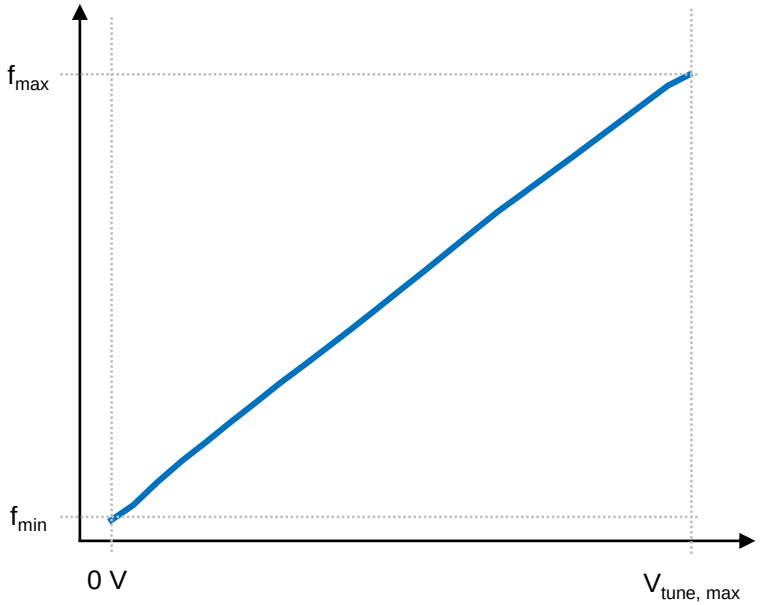
VCO KEY CHARACTERISTICS

WHAT NEEDS TO BE VERIFIED ON A VCO?

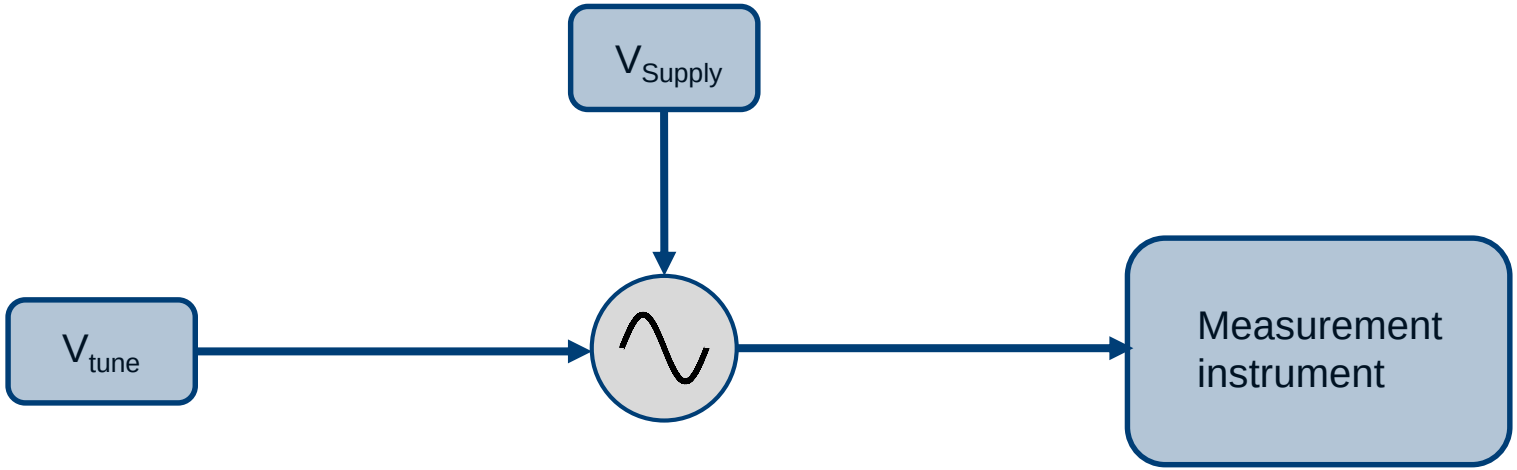
- **Tuning** range and linearity / sensitivity over tune voltage
- **Frequency pushing** due to varying supply voltage
- **Frequency pulling** based on load impedance

- **Output power** over frequency / tune voltage
- **Power consumption** over frequency / tune voltage
- **Settling time** based on tune voltage jump

- **Harmonics and spurs** over frequency / tune voltage
- **Amplitude and Phase noise** over frequency / tune voltage



BASIC TEST SETUP



- 3 basic building blocks
- All need to be synchronized for the different tests

  → Any chance to have them in ***one*** instrument?

VCO MEASUREMENTS

R&S® VCO & PHASE NOISE PORTFOLIO

► **R&S®FSWP**

– Ultra high-end phase noise tester, signal & spectrum analyzer

► **R&S®FSPN**

– Dedicated, high end phase noise and VCO tester

► **R&S®FSW with option FSW-K40**

– Phase noise analysis option for spectrum analyzer

– No x-corr for PN, no VCO testing

– Measurement options for spectrum analysis and VSA up to 8.3 GHz

R&S® VCO & PHASE NOISE PORTFOLIO

R&S®FSWP

- **Extensible feature set, including:**
  - Simultaneous PN/AM measurement
  - Cross correlation with ultra high end sources
  - VCO characterization with 3 DC sources
  - Pulsed & additive/residual phase noise
  - Transient analysis, settling time measurement
  - Real spectrum analysis
  - VSA and IQ based analysis up to 320 MHz

R&S®FSPN

- **Essential features for PN and VCO testing**
  - Simultaneous PN/AM measurement
  - Cross correlation with high end sources
  - VCO characterization with 3 DC sources
  - Spectrum monitor
  - Transient analysis, settling time measurement

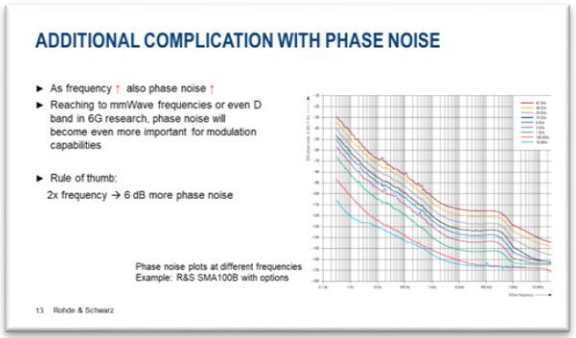
VCO TEST DEMO WITH R&S®FSPN

DEMANDING PHASE NOISE MEASUREMENTS

R&S®FSWP FOR MICROWAVE APPLICATIONS

***Microwave ready* – just a few accessories required:**

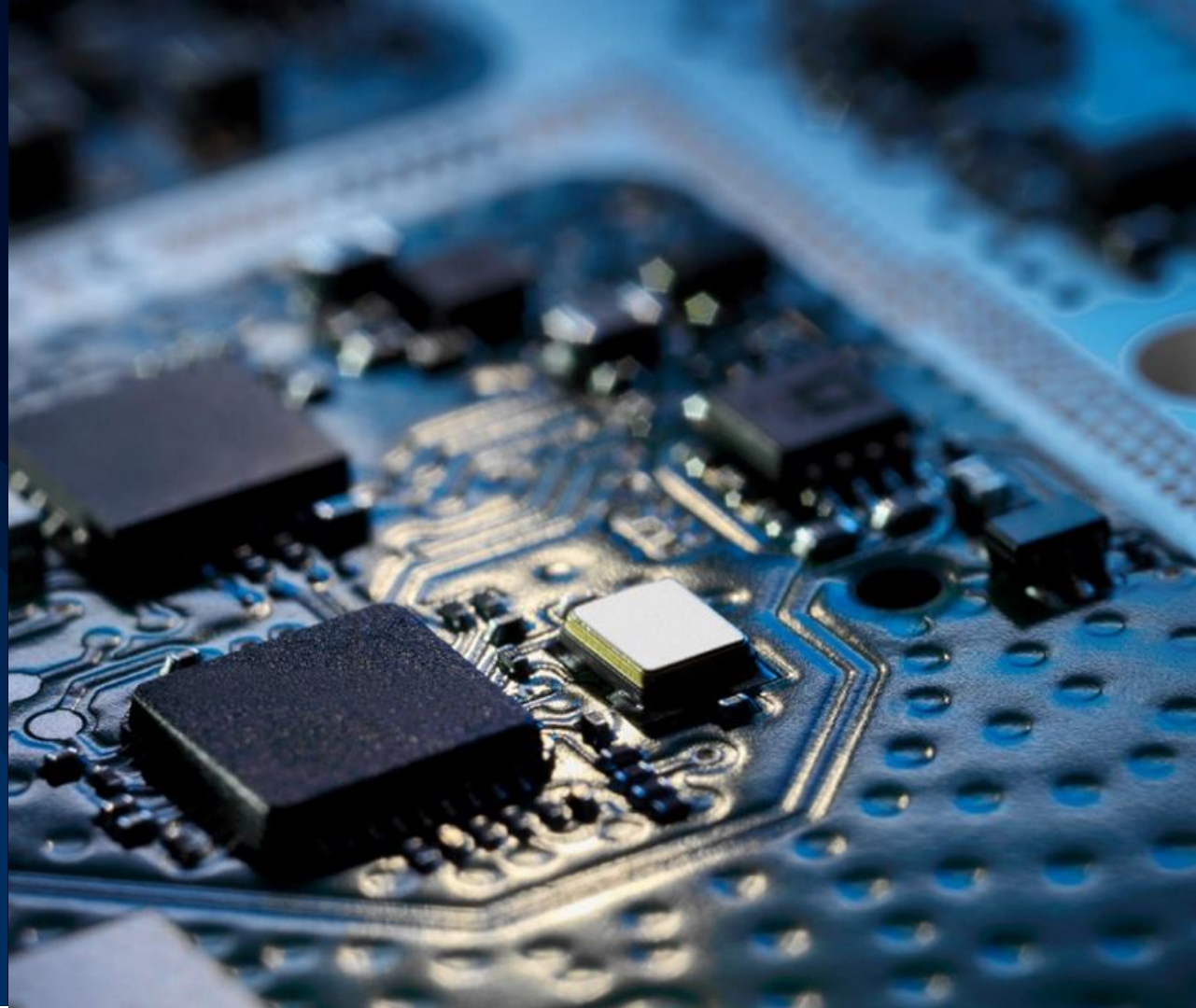
- Two harmonic mixers (R&S FS-Zxx)
- One splitter (RPG WPS)
- Two elbows



R&S®FSWP D-BAND DEMO

SUMMARY

- VCO are used in any RF design
- Influence system level performance
- All test can be done with a single tester platform in a fast and easy approach supporting
  - Characteristics
  - Performance
- Demanding phase noise tests supported up to D band and beyond



Find out more

WWW.ROHDE-SCHWARZ.COM/VCO-TEST

ROHDE&SCHWARZ

Make ideas real