MTTS 2008 MicroApps

Accurate Phase Noise Measurements Made Cost Effective

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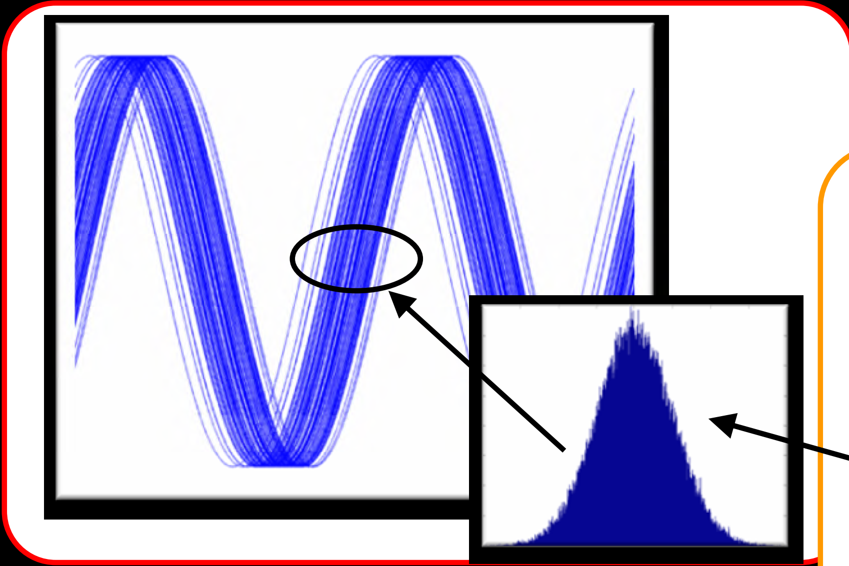
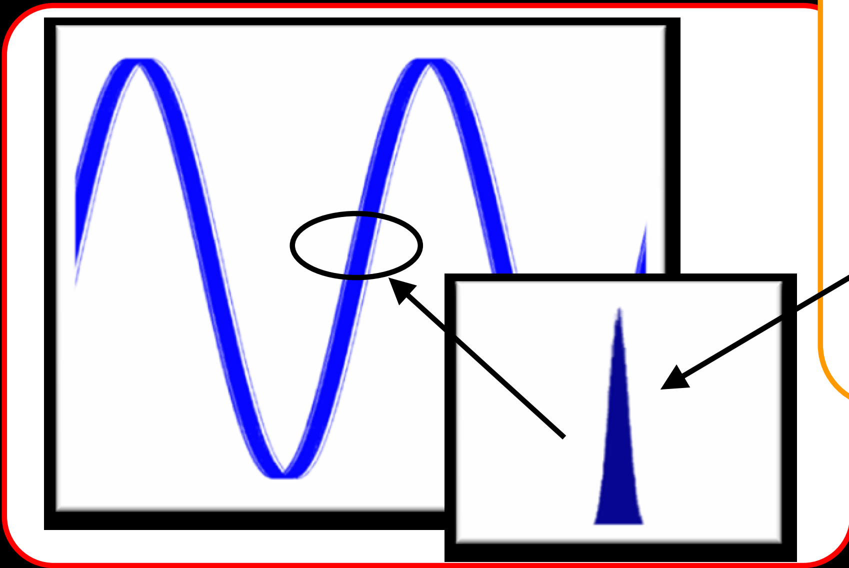
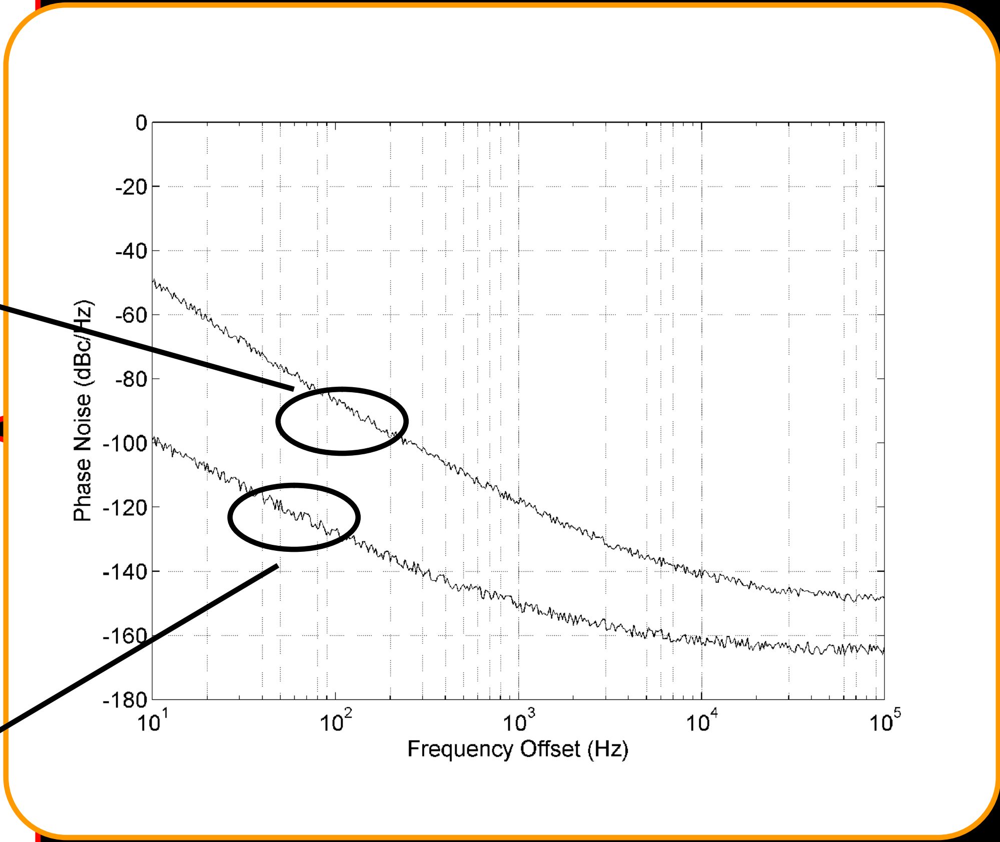
Presentation Outline

- Phase Noise Intro – Additive and Absolute
- Oscillator Phase Noise Measurement Setup
- Theory
- PLL Basics for Phase Noise Measurements
- Baseband Measurements
- Calibration
- Taking the Measurements

Phase Noise is Related to Jitter







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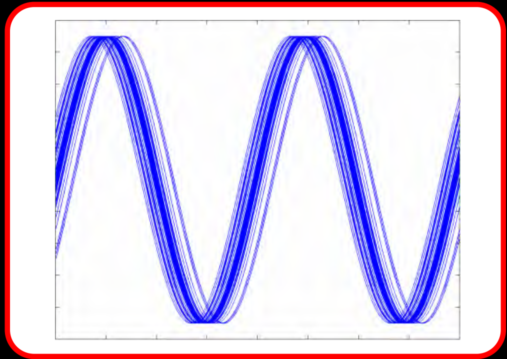
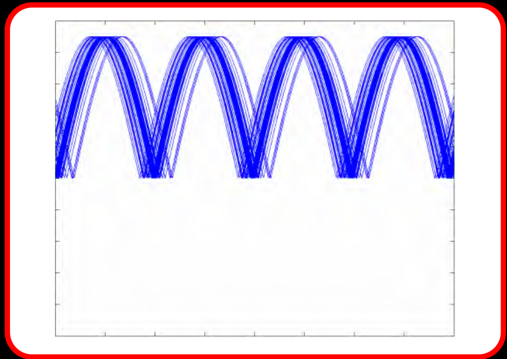
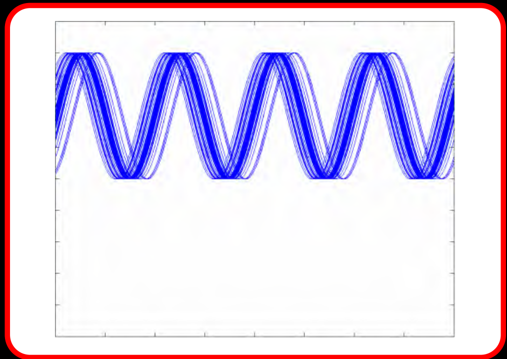
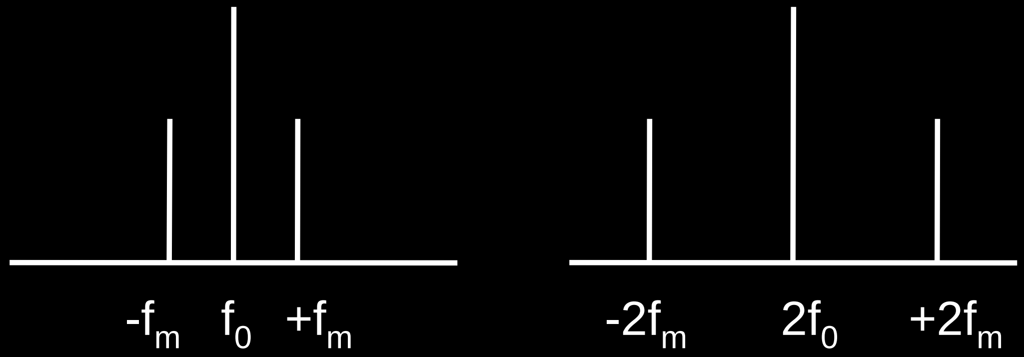
Phase Noise & Freq Multipication





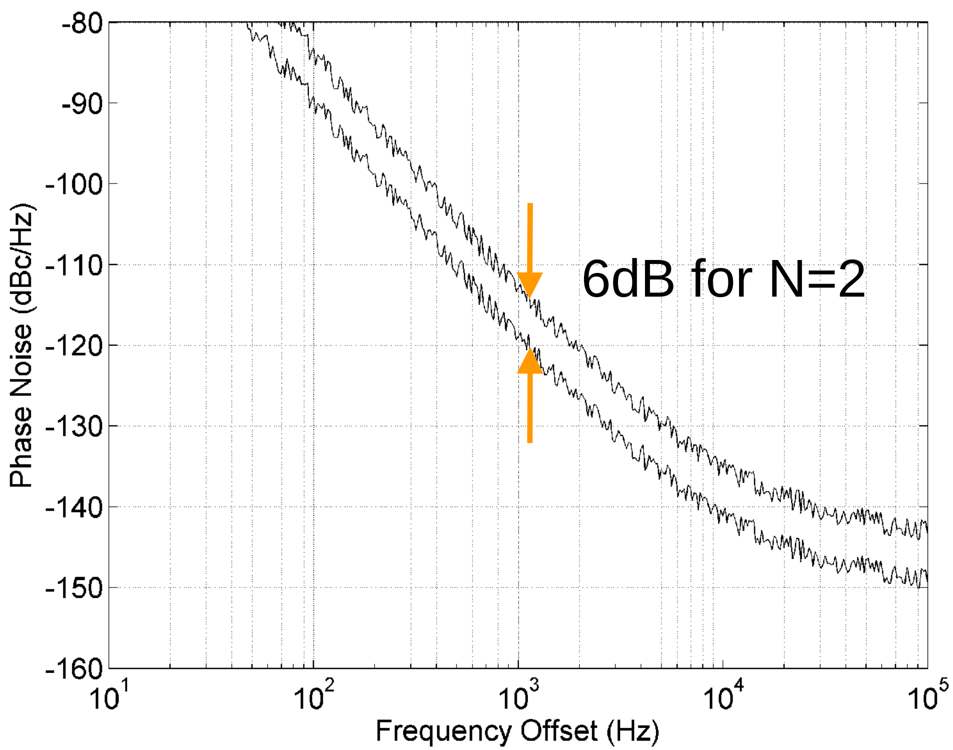


- Jitter remains CONSTANT through ideal Frequency Multipication
  - Phase Noise increases during Frequency Multipication
    - Phase Noise is relative to Carrier



$$\sin(\theta)\cdot\sin(\theta)=\frac{1}{2}-\frac{1}{2}\cos(2\cdot\theta)$$

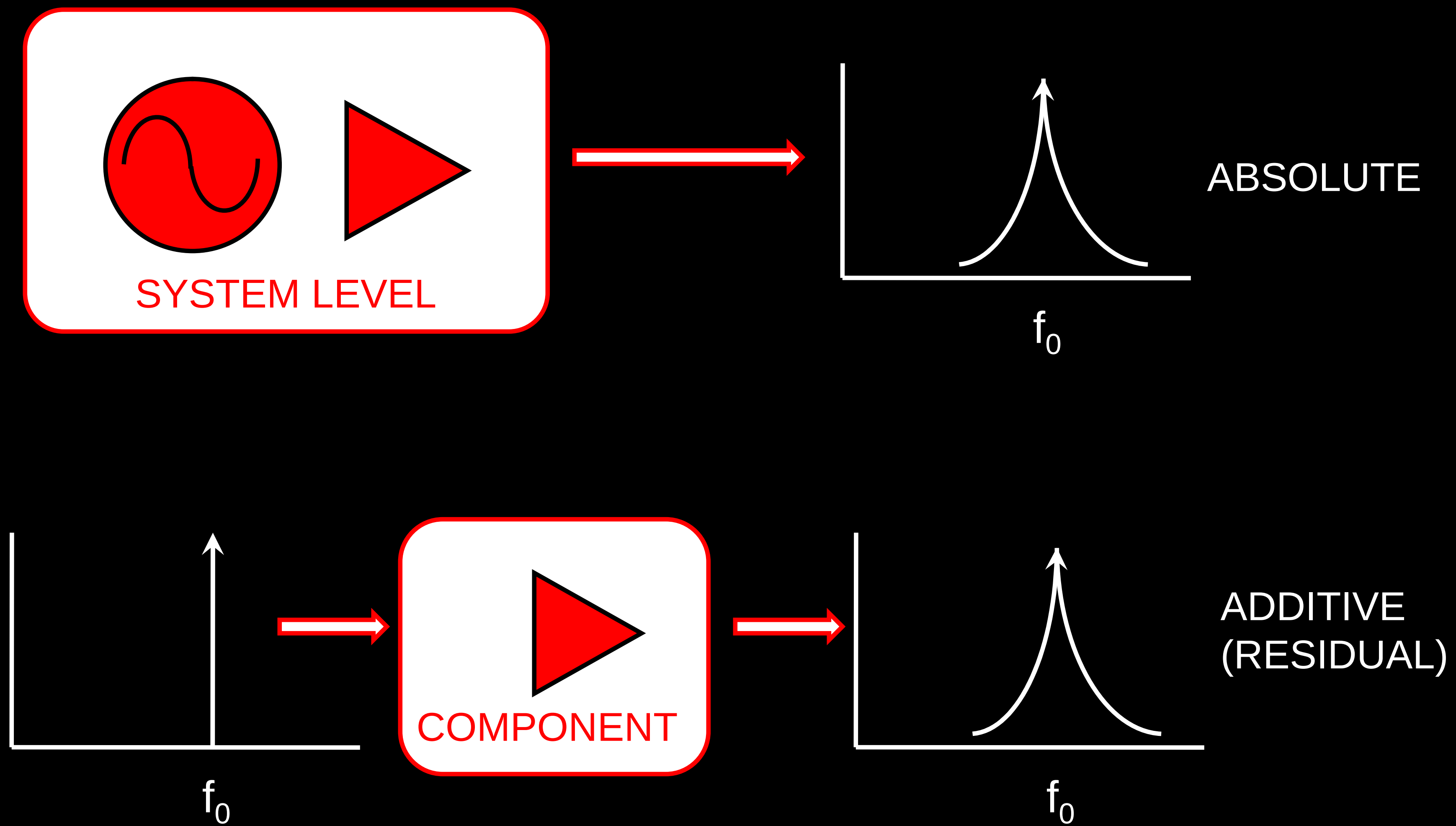
Phase Noise & Freq Multiplication



$$20 \cdot \log_{10} N$$

N = Multiplication Factor

Absolute vs. Additive (Residual)



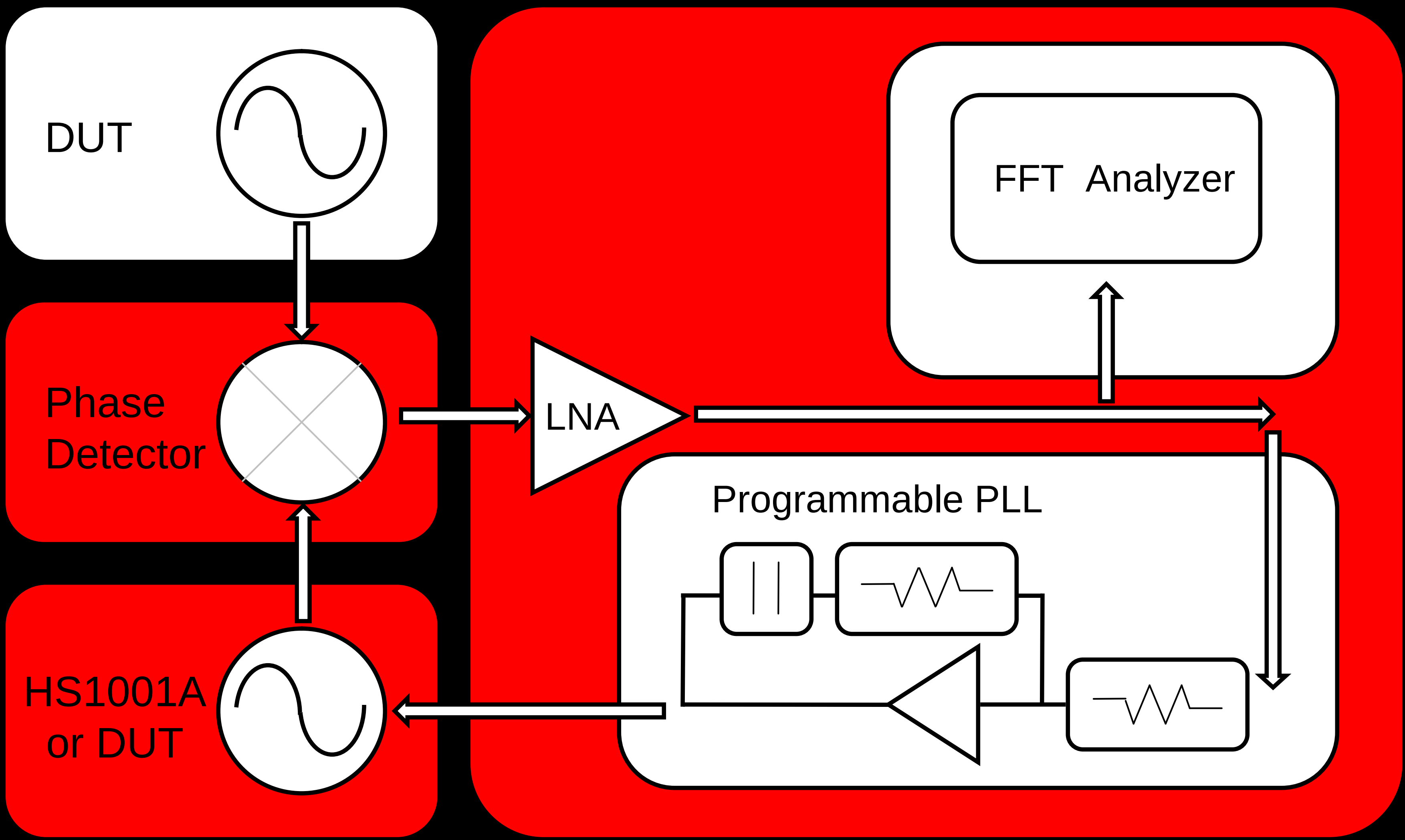
Measurements vs. Cost

Components are available to build a Phase Noise Test System if engineering know-how and time is available.

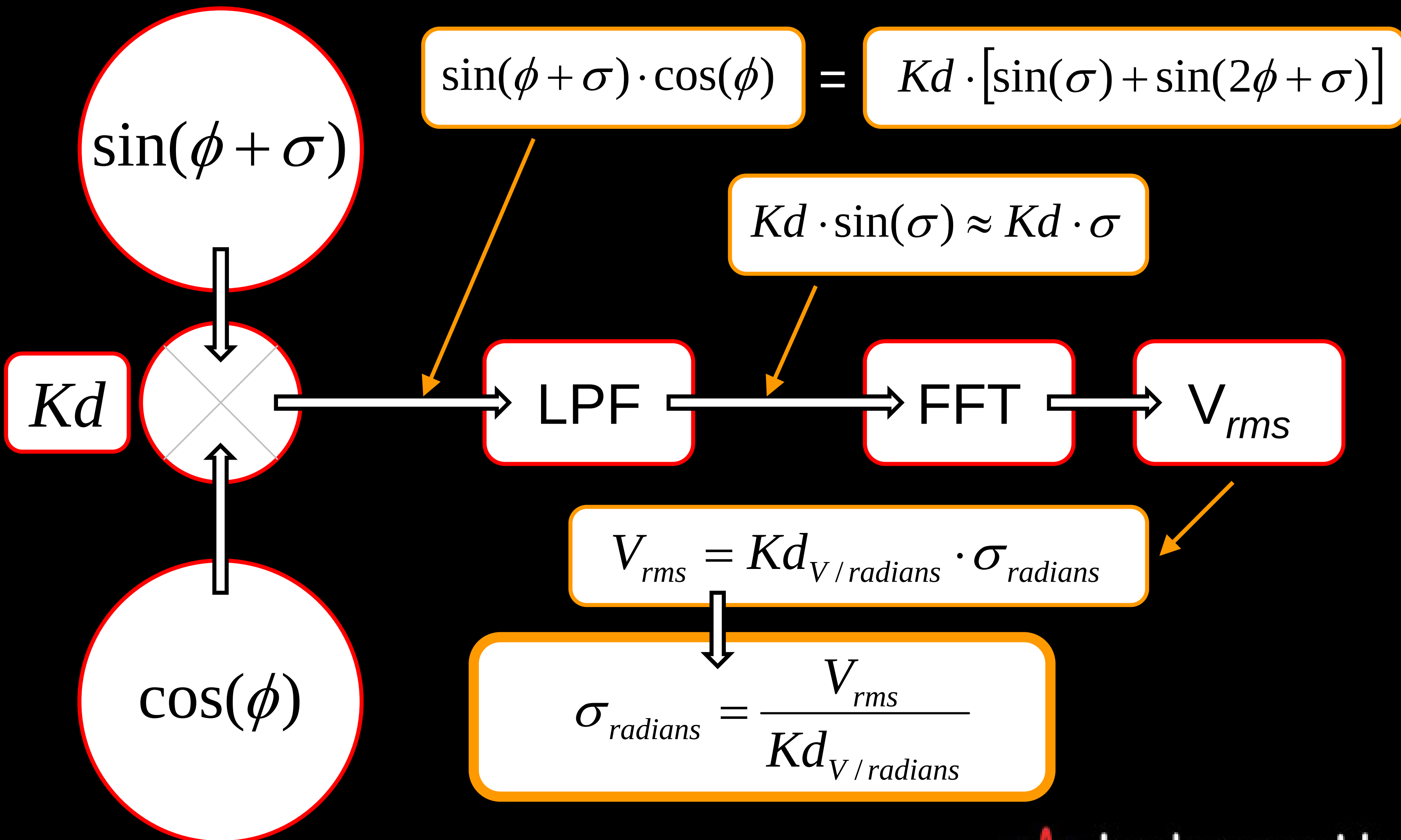
There are specific Phase Noise Test instruments available for a high price tag.

HYBRID APPROACH: Purchase appropriate, versatile test equipment and accessories as Phase Noise Test subsystems saving design, calibration and setup time.

Hybrid Test System: 3 to 5 Devices



Theory: Test System Summary



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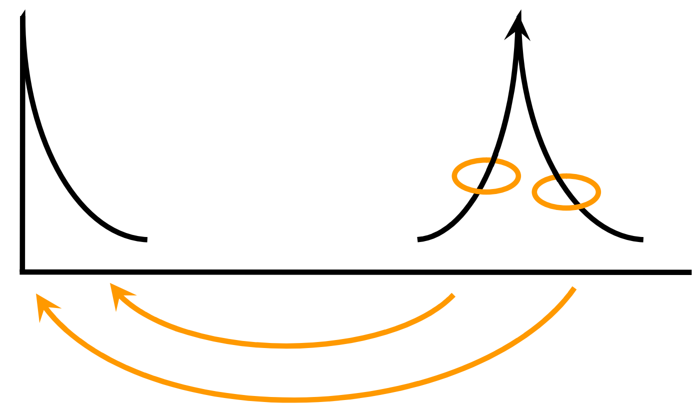
Theory: DSB vs. SSB

$$\sigma_{DSB} = \sqrt{\sigma_{upper}^{2} + \sigma_{lower}^{2}}$$

$$\left|\sigma_{upper}\right| = \left|\sigma_{lower}\right| = \left|\sigma_{SSB}\right|$$

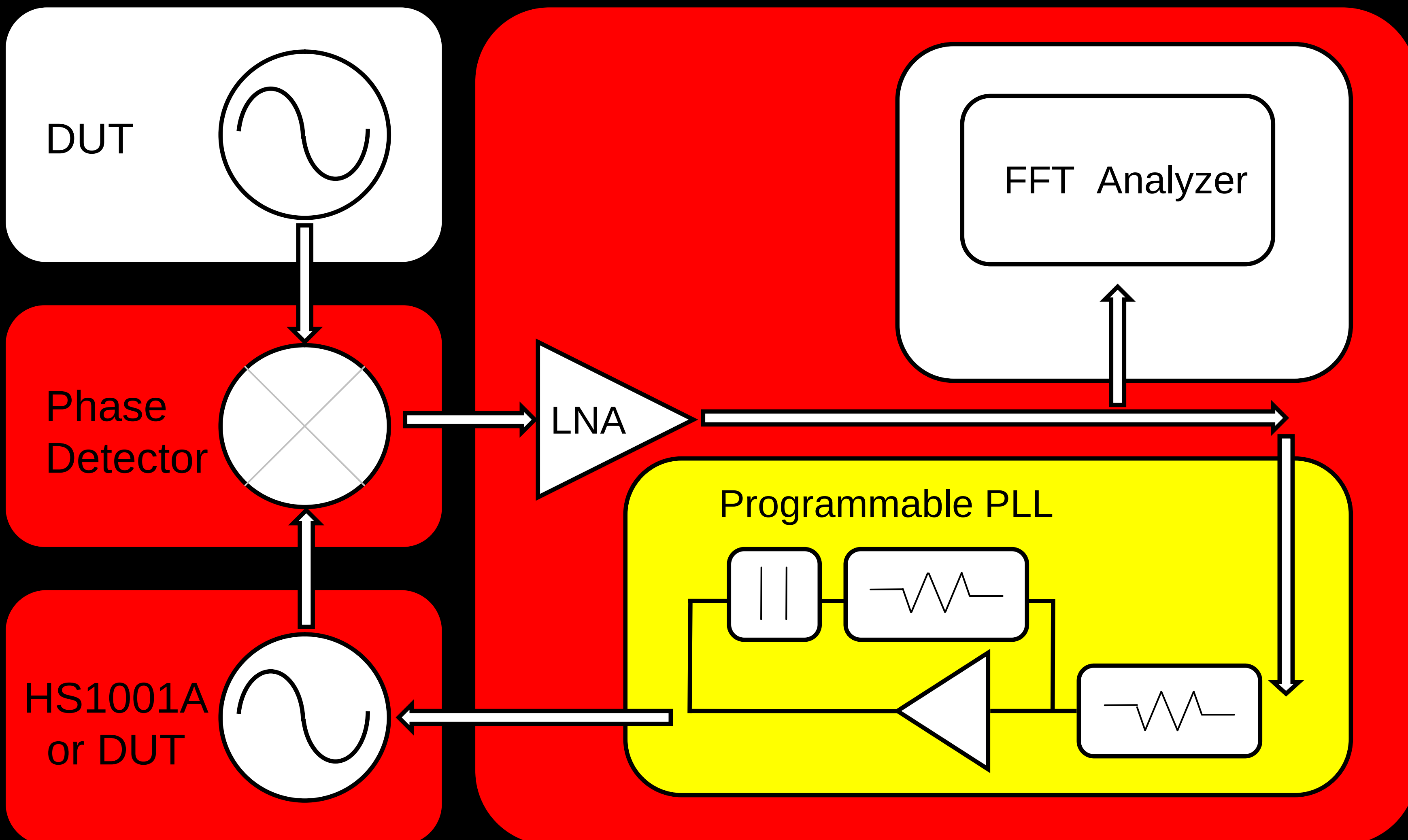
$$\sigma_{DSB} = \sqrt{2} \cdot \sigma_{SSB}$$



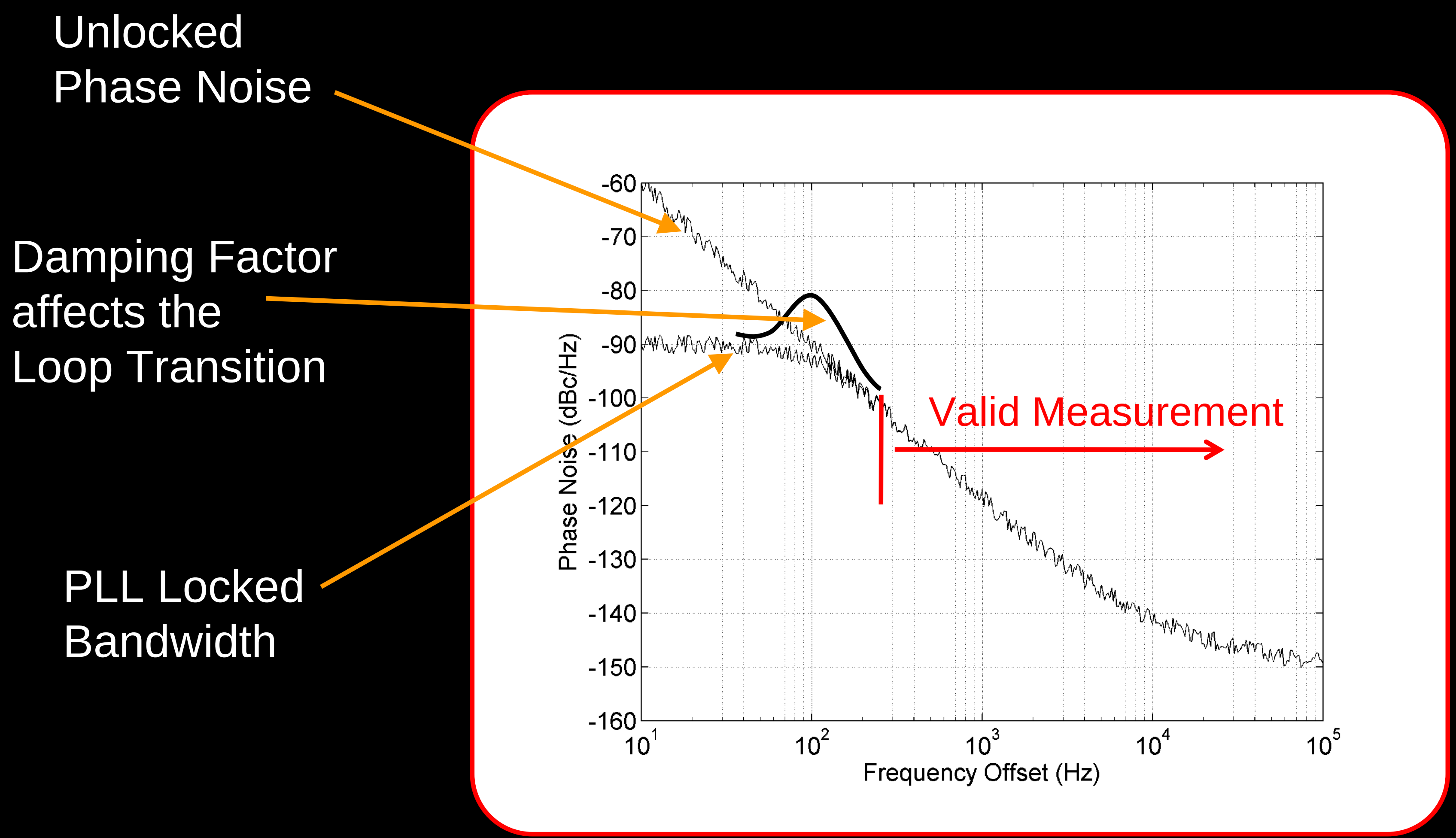
A Baseband Measurement is a **Double Sideband Measurement**

NOTE: there is a 3dB Difference!

Measurement Setup: PLL



Absolute Phase Noise: PLL



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PLLs for Phase Noise Measurements

Phase Locked Loops are used for locking two oscillators together, making their phase noise coherent

Within the lock bandwidth: the phase noise measurements are NOT valid without an accurate knowledge of the PLL loop

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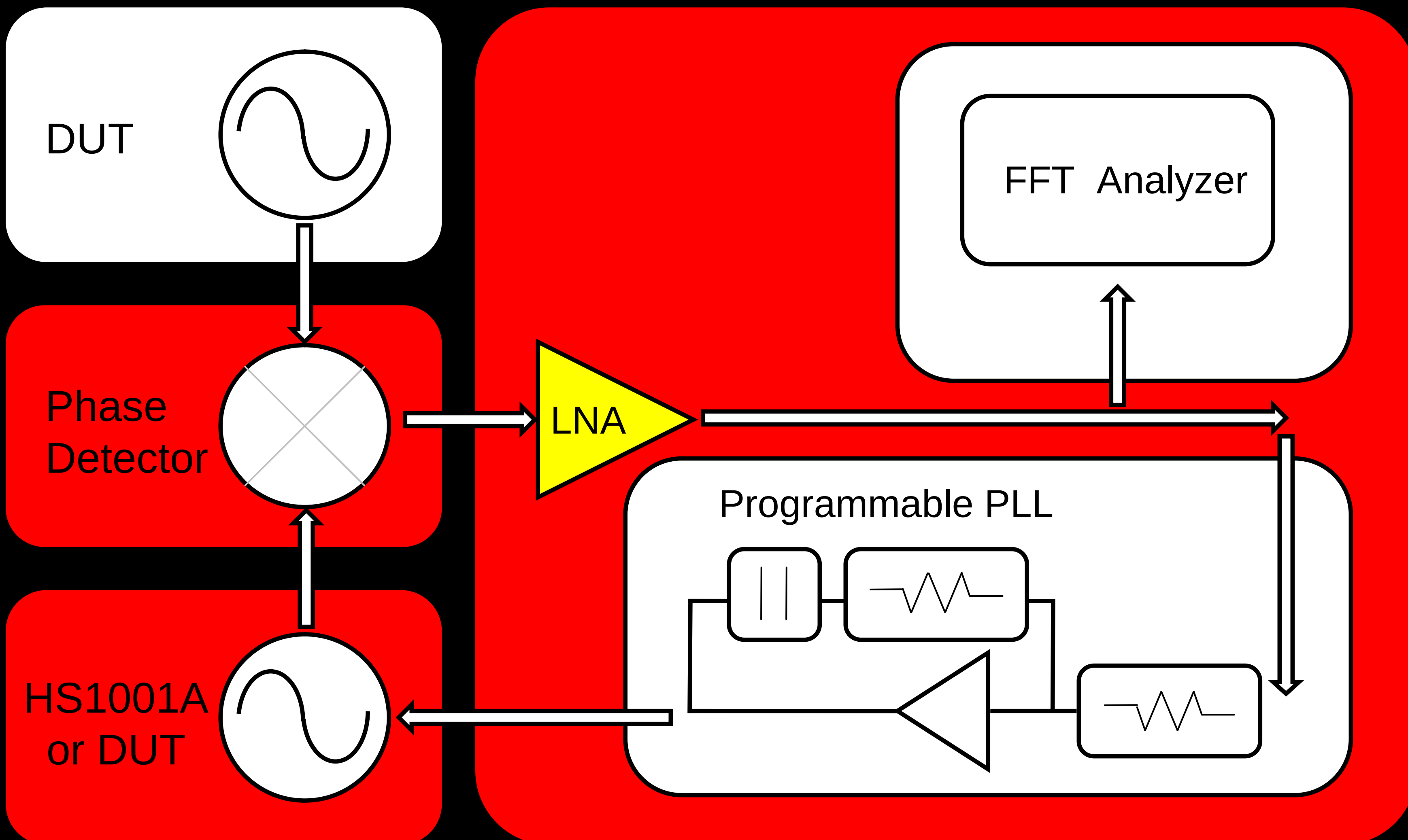
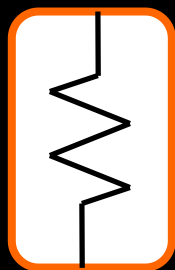
Measurement Setup: LNA



Resistor Equivalent Voltage Noise



$$N_{thermal} = \sqrt{4kTBR}$$

$$50\Omega = 0.91nV/\sqrt{Hz}$$

$$500\Omega = 2.87nV/\sqrt{Hz}$$

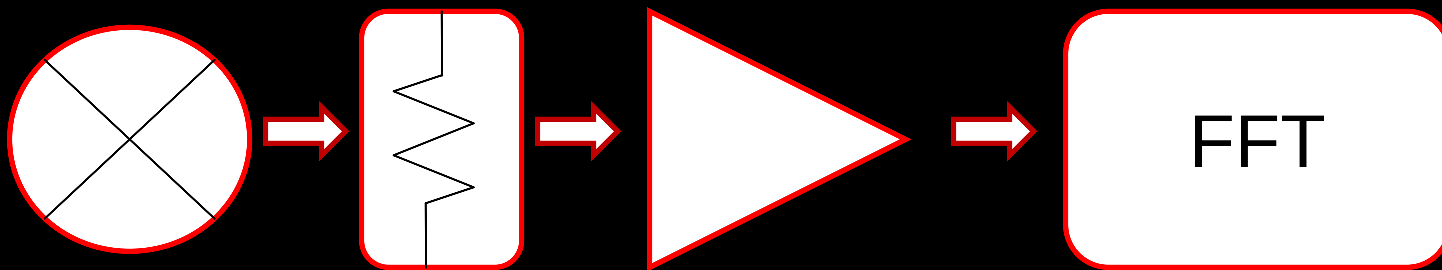
$$5k\Omega = 9.10nV/\sqrt{Hz}$$

Signal To Noise Ratio = $V_{rms} / V_{thermal}$

Baseband Low Noise Amplifier

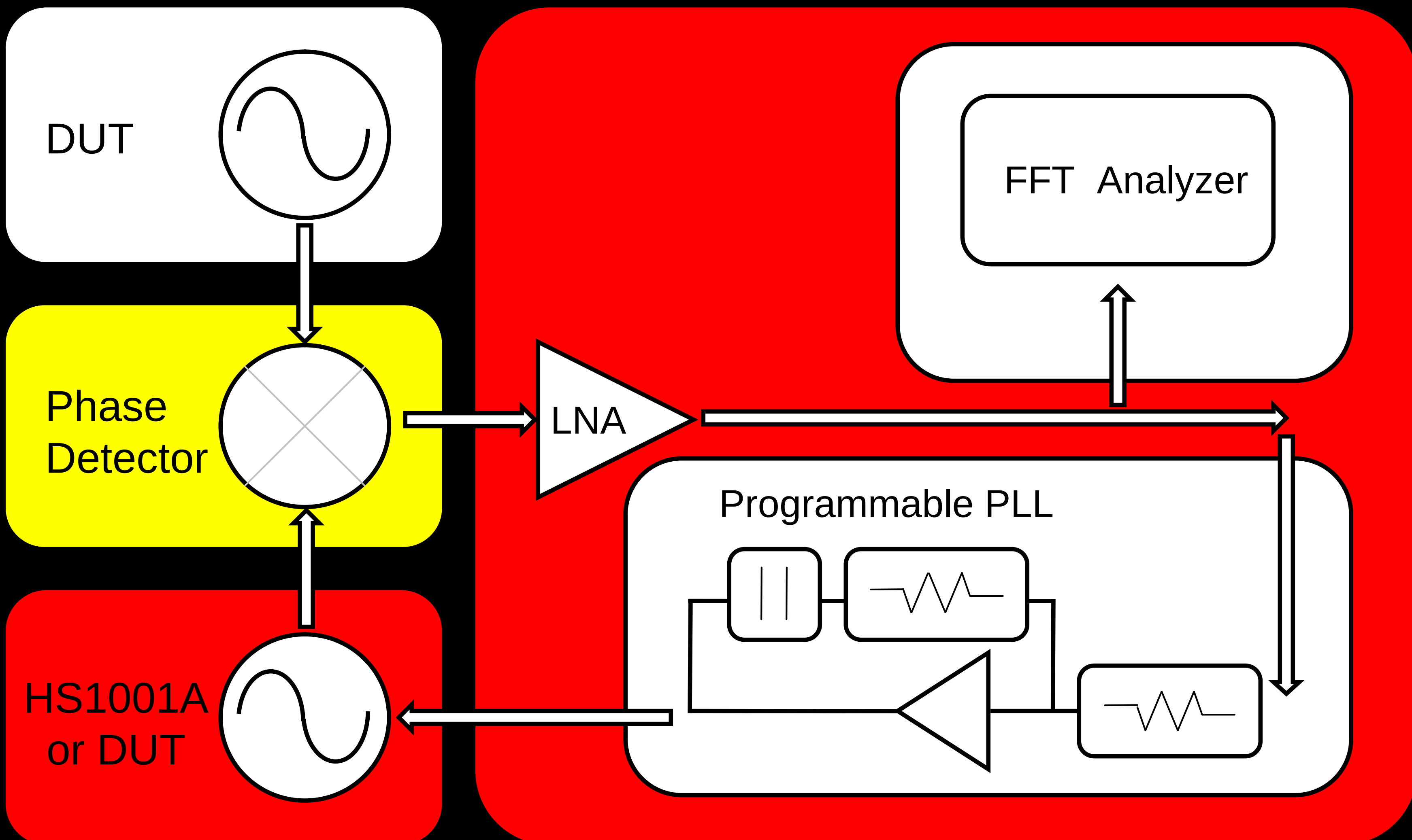
$$50\Omega = 0.91nV/\sqrt{Hz}$$

$$LNA \approx 1.0nV/\sqrt{Hz}$$

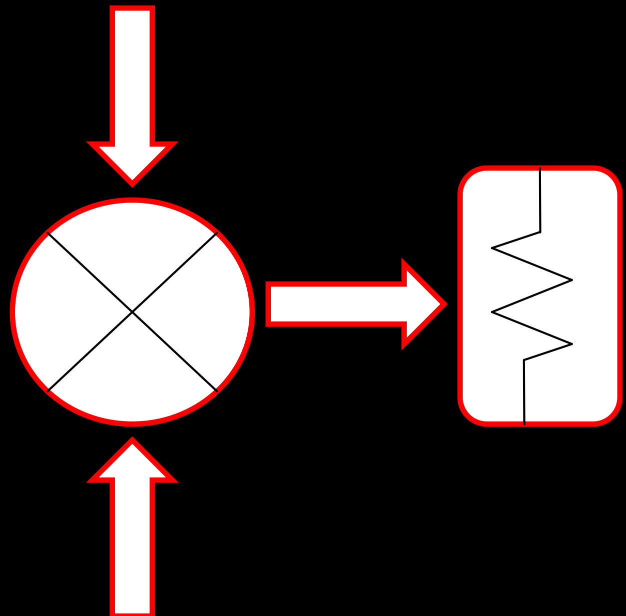


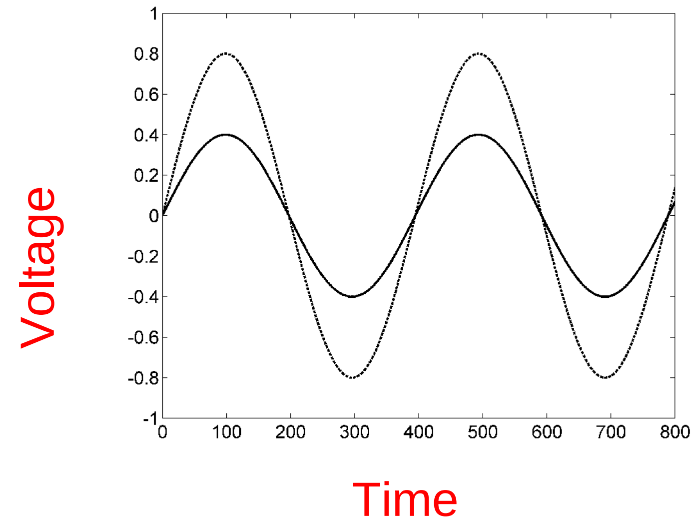
$$N_{system} = \sqrt{0.91nV^2 + 1.0nV^2} = 1.35nV/\sqrt{Hz} = -177.4dBV/\sqrt{Hz}$$

Measurement Setup: Phase Detector



Mixers as Phase Detectors

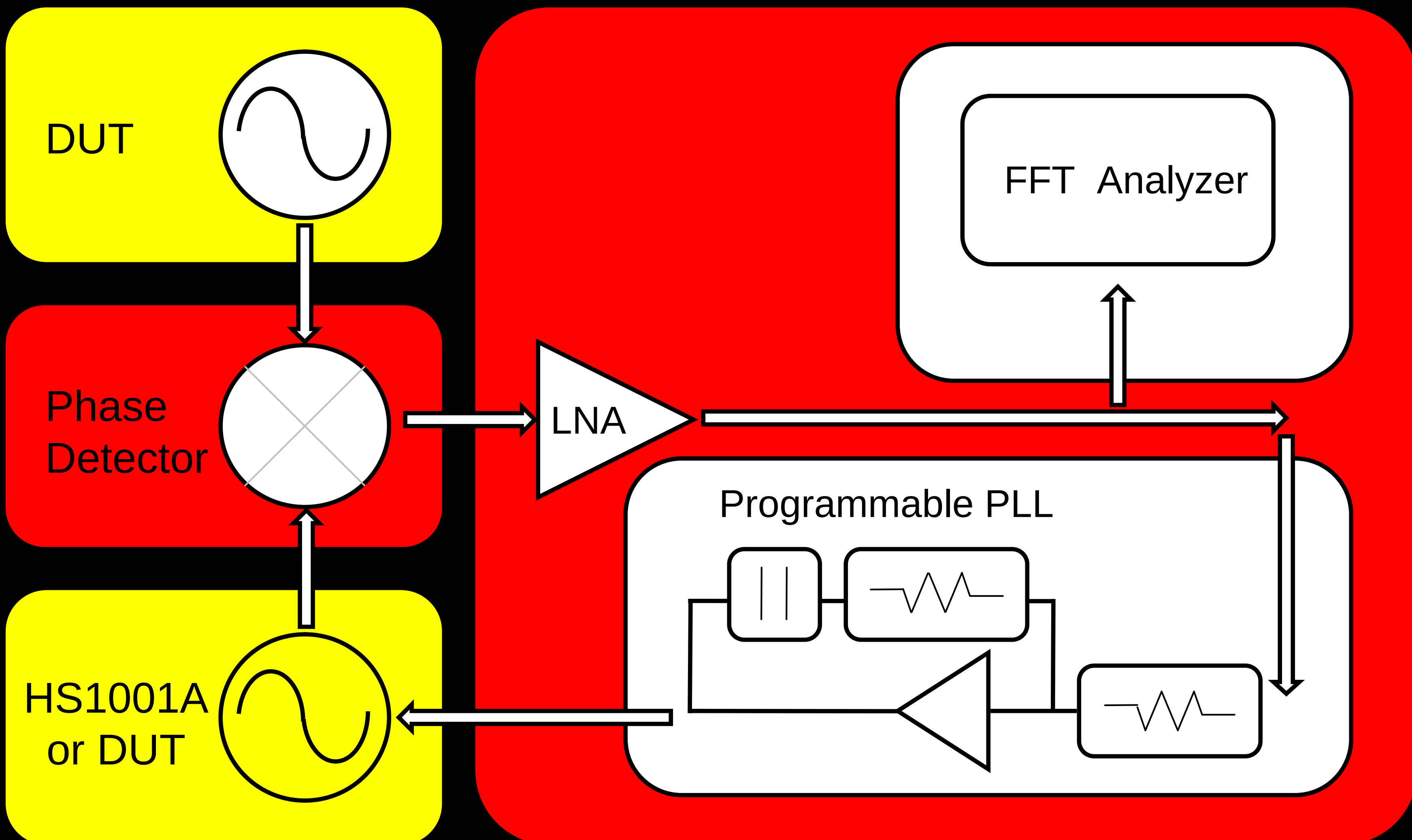




$$V_{rms}[dB]_{50\Omega} = -11dBV$$
$$V_{noise}[dB]_{50\Omega} = -177.5dBV$$
$$SNR = -166.5dBc$$

$$V_{rms}[dB]_{500\Omega} = -5dBV$$
$$V_{noise}[dB]_{500\Omega} = -170.8dBV$$
$$SNR = -165.8dBc$$

Measurement Setup: Phase Locking



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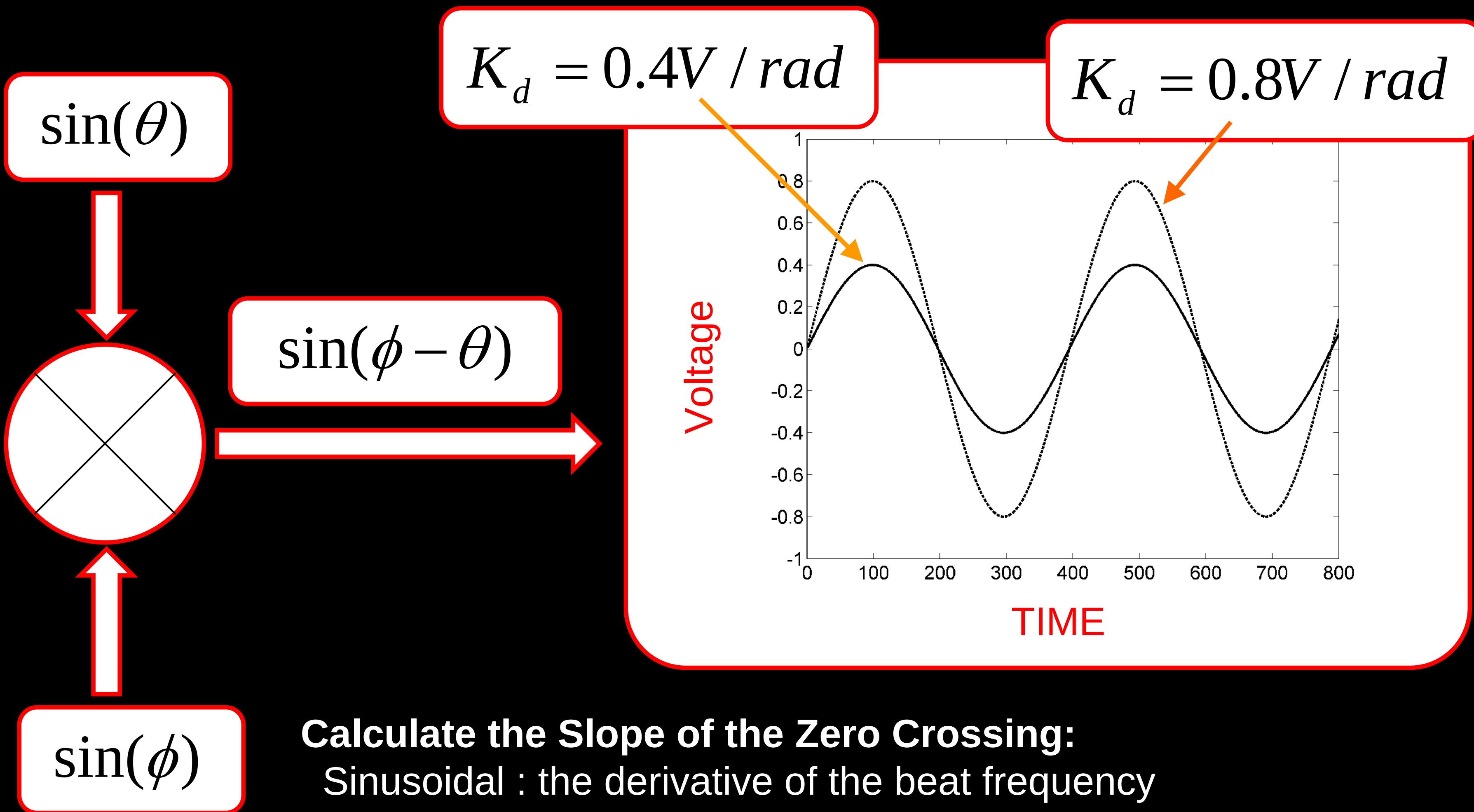
Test System Calibration



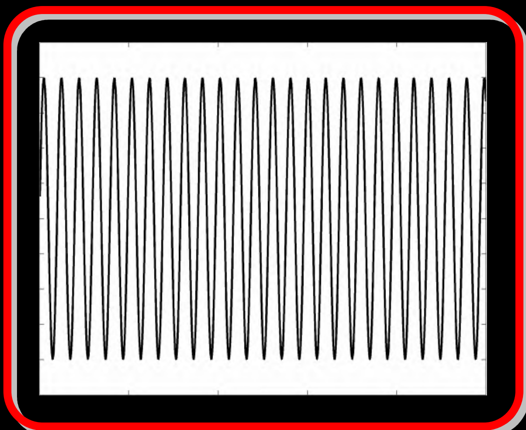
Calculate the Slope of the Zero Crossing:

Sinusoidal : the derivative of the beat frequency

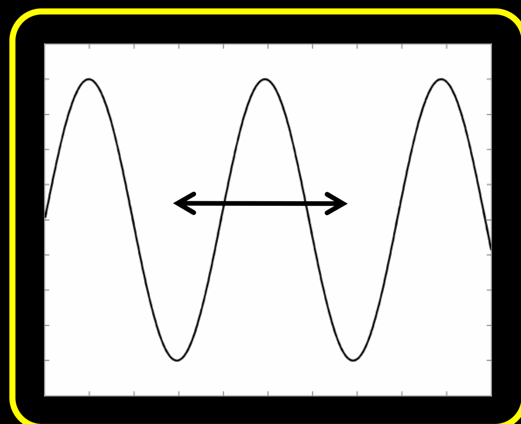
In other words… the peak voltage = Kd!!

Taking the Measurement: Locking

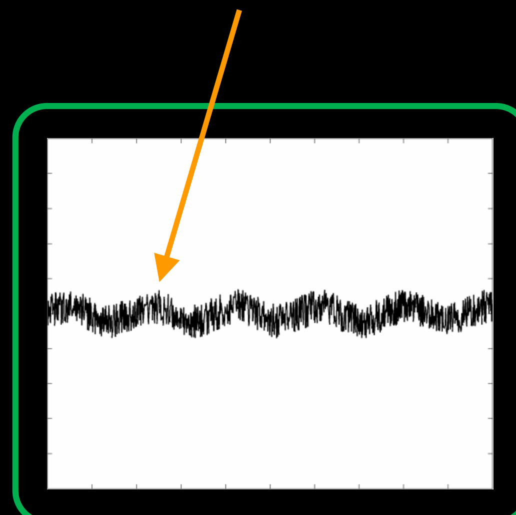
Unlocked



Beat Frequency decreases as synthesizer closes in on the DUT frequency



Spurs (60Hz) are observed as a small sinusoid



When the Synthesizer frequency is near the DUT frequency and within the lock bandwidth **they will lock together**

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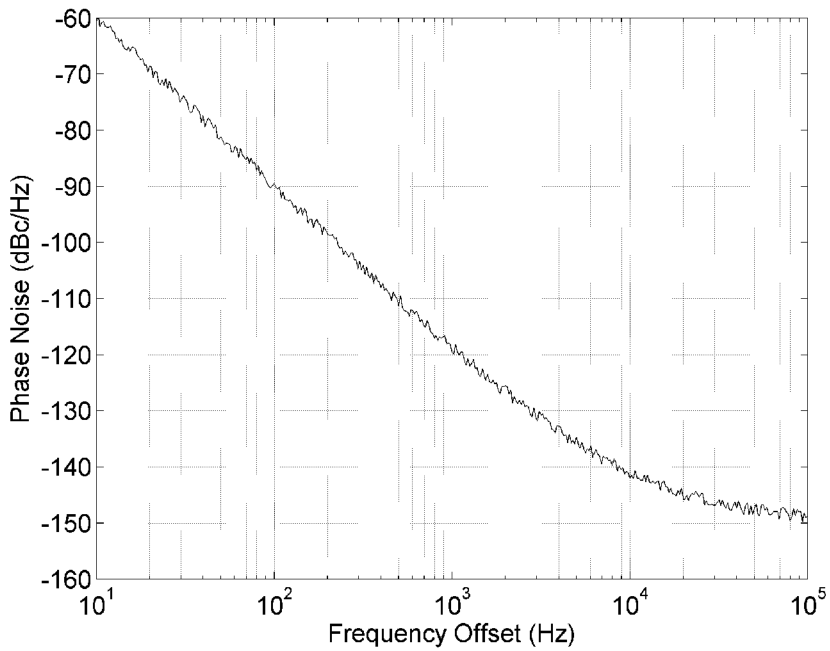
Taking the Measurement: FFT

Measurement Duration ~10x (1/ lowest frequency)

A 10Hz to 100kHz measurement will take ~ 1-2 seconds

Freq	110MHz
Kd	0.4
Preamp Gain	60dB
PLL BW	100Hz
PLL Damping Factor	1.5



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Test System Cost Summary

I. HYBRID TEST SYSTEM:

- 2 instruments: 1. Tunable, Ultra Low Phase Noise Source
  2. FFT Analyzer with integrated PLL
- Total Price: typically $6,500 to $8,500 (US)
- Fast setup with Accurate Measurements

II. Discrete Components Test System

- Component Count: approx 30 components MINIMUM
- Total Price: typically $10,000 to $50,000 (US)
- Slow setup time and component phase noise verification

III. Dedicated Phase Noise Test System

- Total Price: typically > $60,000 (US)
- Fast Setup, but with High Cost of Ownership

THANK YOU

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