

# Designing Power For Sensitive Circuits

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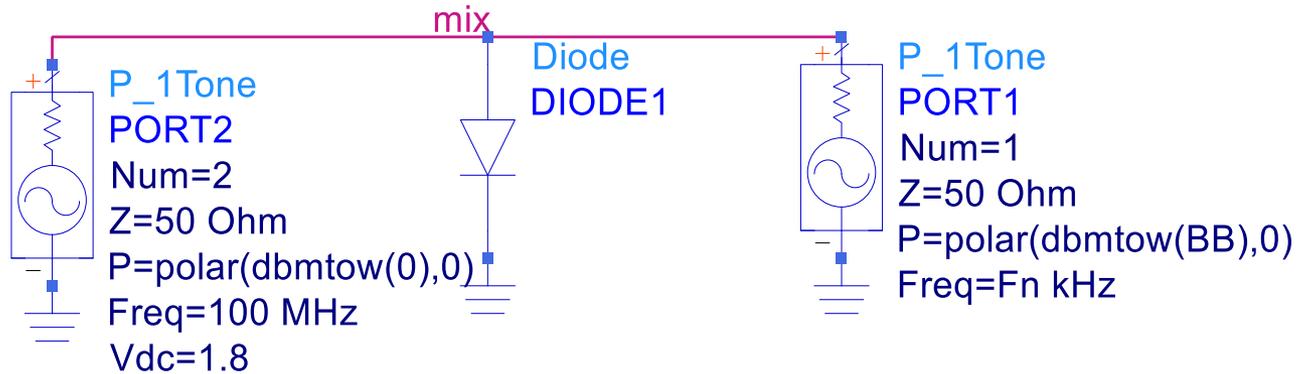
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# What are sensitive circuits?

Many low power circuits are **hyper-sensitive** to power supply noise.

Examples of hyper-sensitive circuits include clock oscillators (XOs), low noise amplifiers (LNAs), phase locked loops (PLLs), mixers and precision voltage references to name just a few.

# Sensitivity to power supply noise

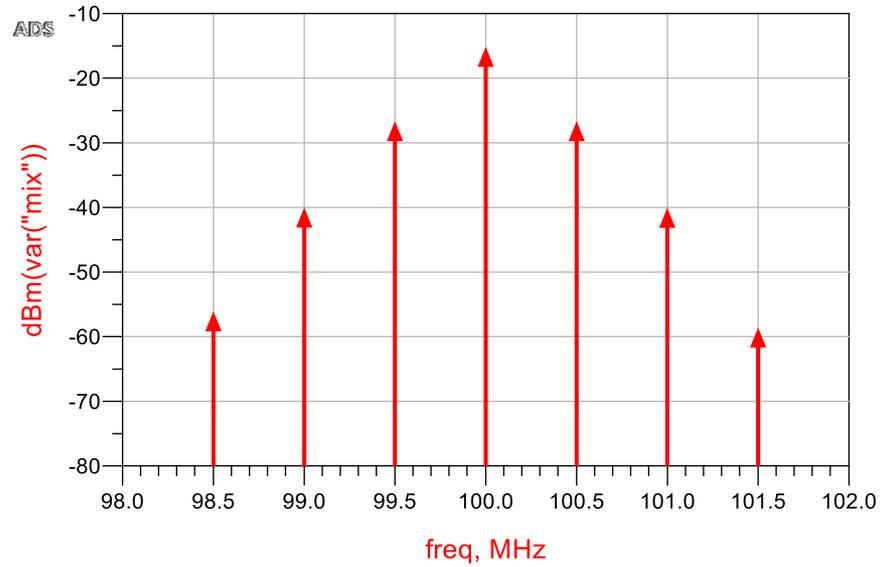
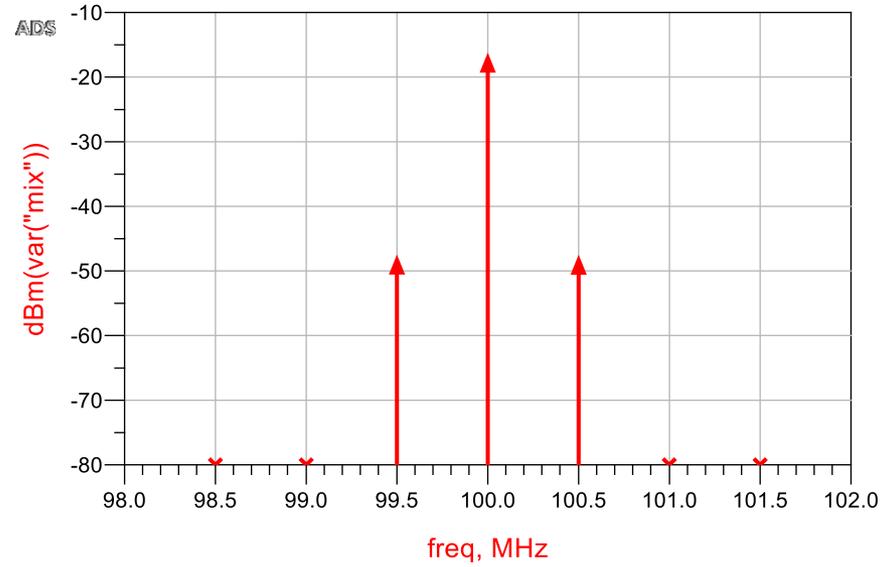
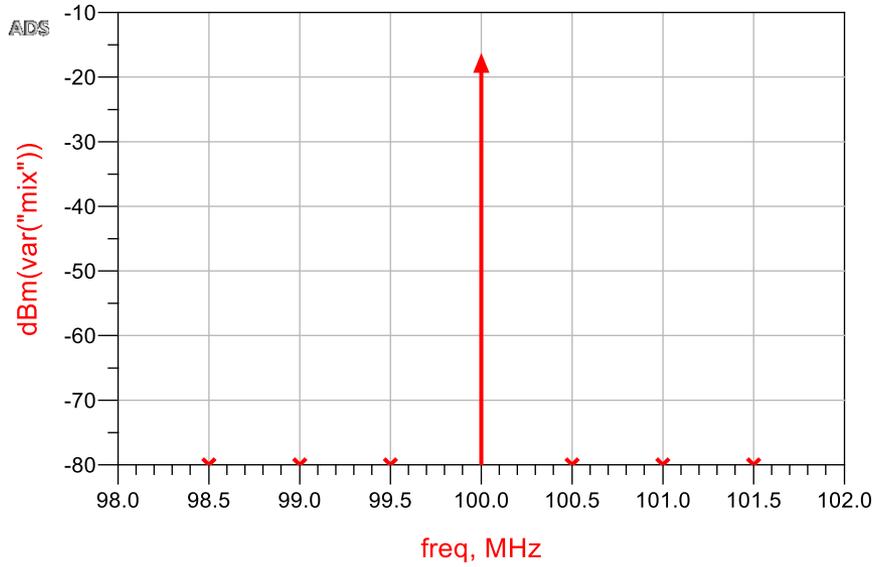


## HARMONIC BALANCE

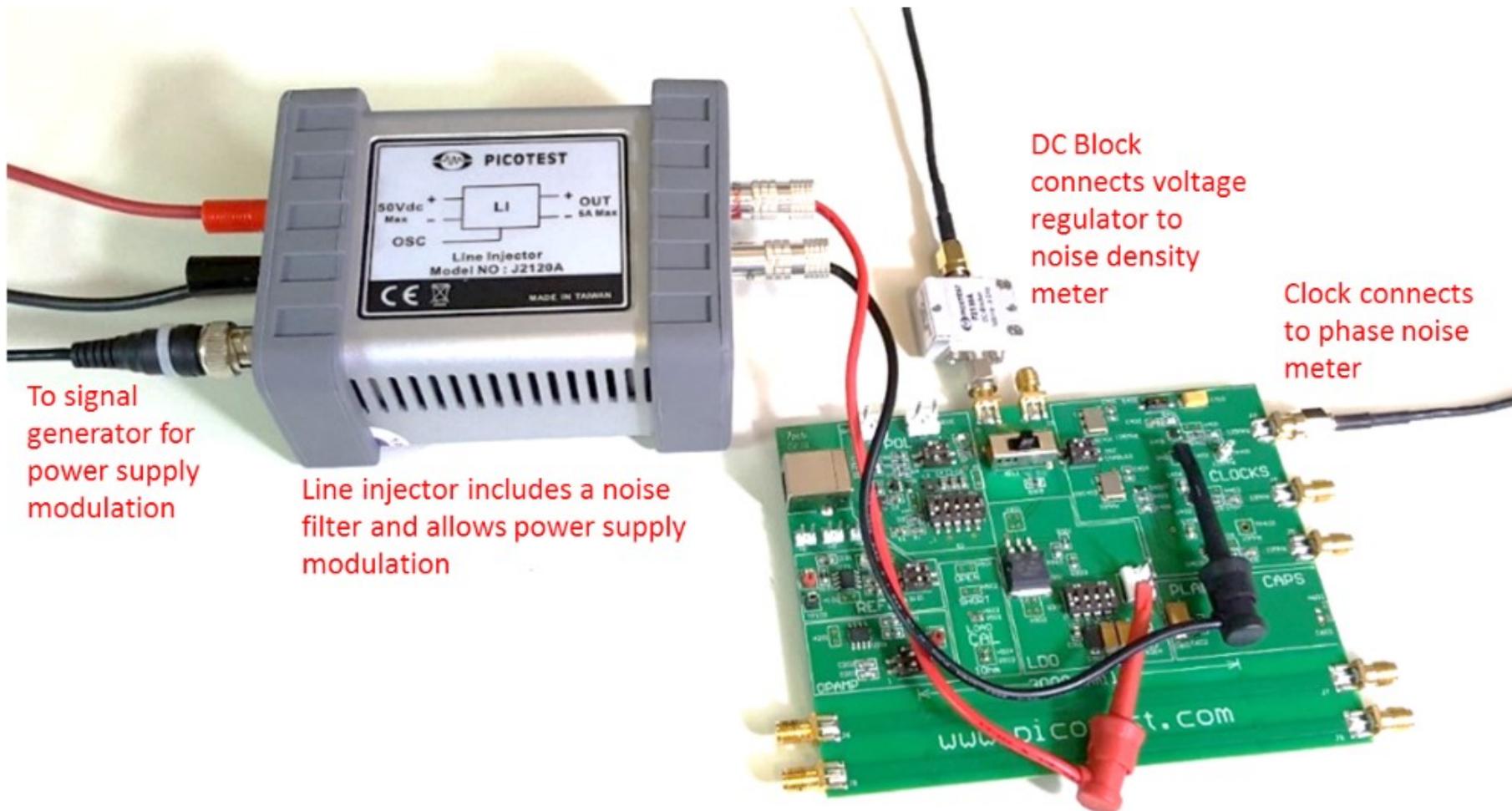
HarmonicBalance  
 HB1  
 Freq[1]=100 MHz  
 Freq[2]=Fn kHz  
 Order[1]=1  
 Order[2]=15



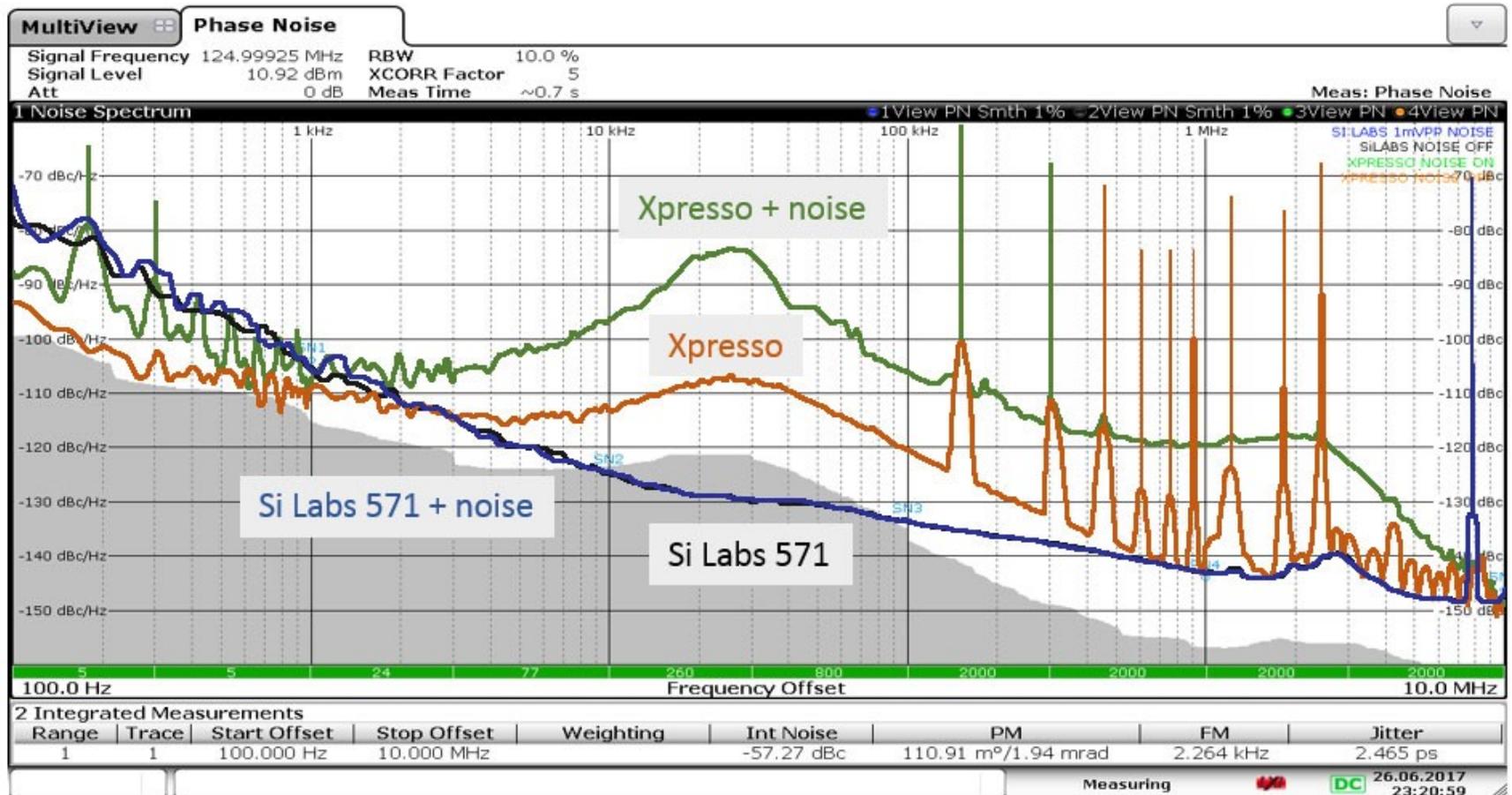
**VAR**  
**VAR1**  
 Fn=500  
 BB=-65 {t}



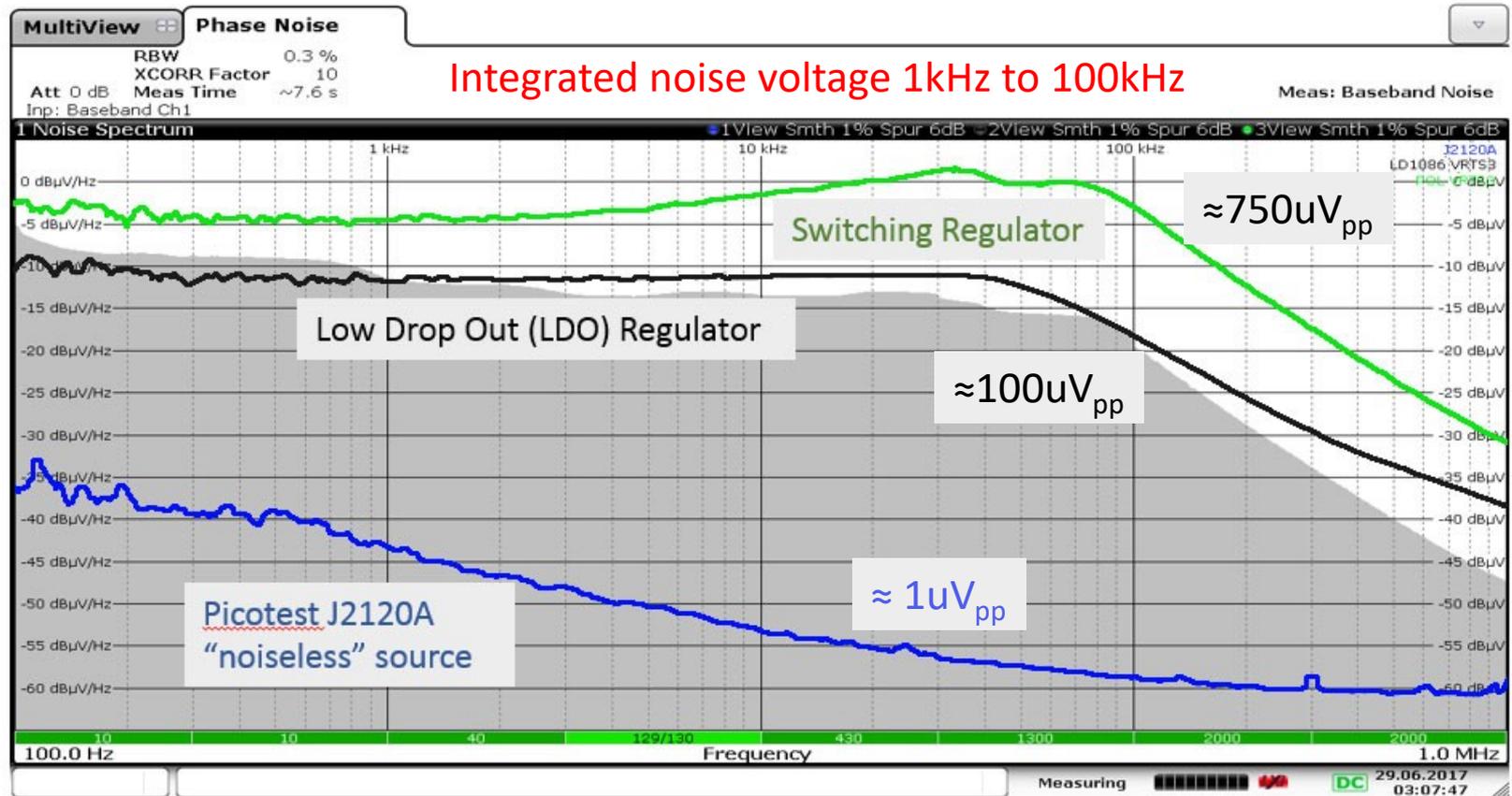
# Defining Sensitivity



# Not all sensitive circuits are sensitive

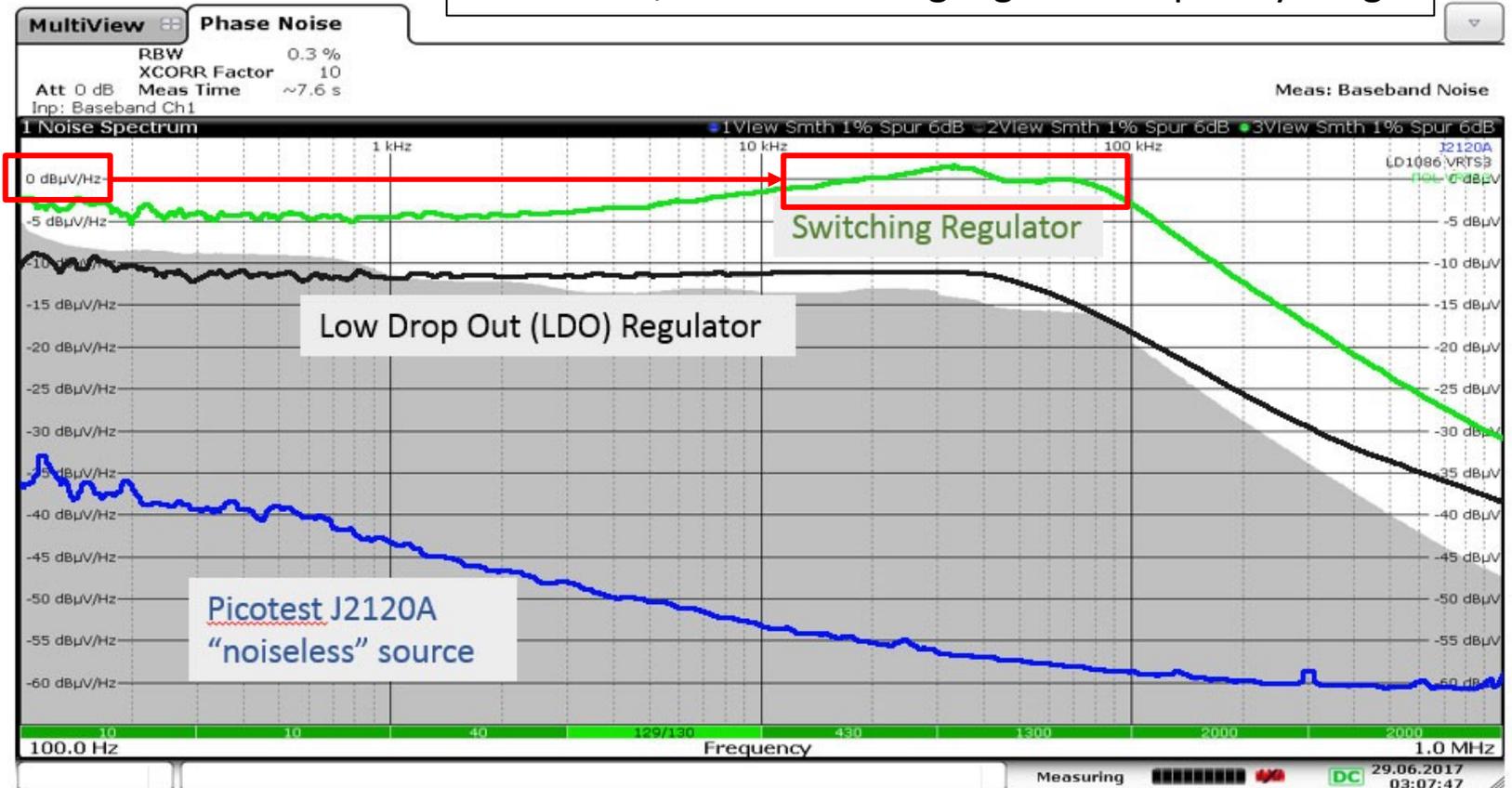


# Noise Density 3 Voltage Regulators



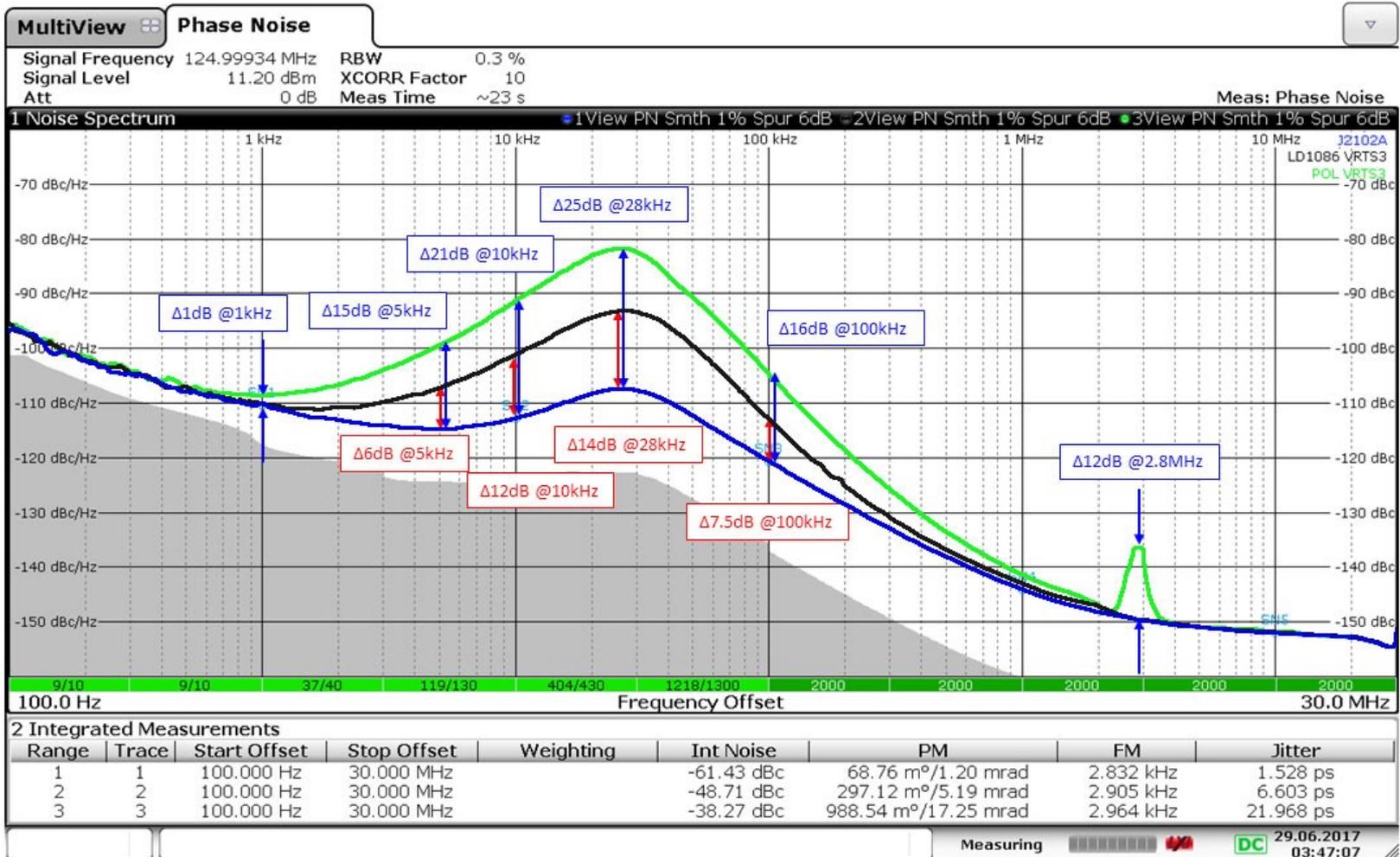
# Switching Regulator Noise Density

The switching regulator noise density is a little above  $1\mu\text{V}/\sqrt{\text{Hz}}$  in the highlighted frequency range





# Assessing the Damage



# Simplest Noise Filter

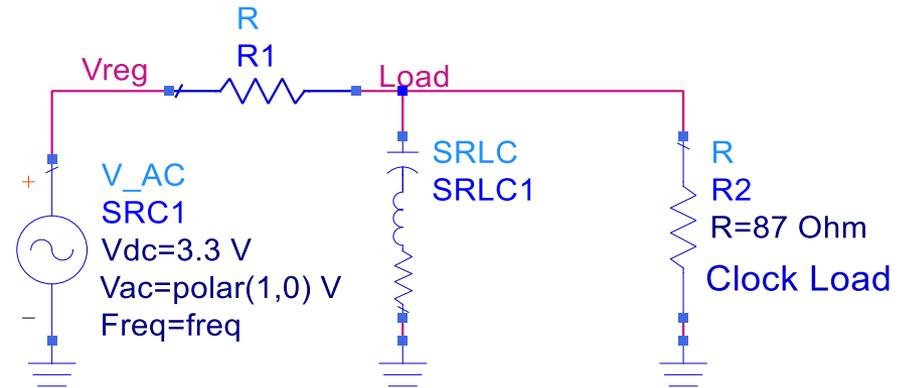
Regulation and noise are not the same thing and counterintuitively they oppose each other

How much voltage can you give up?

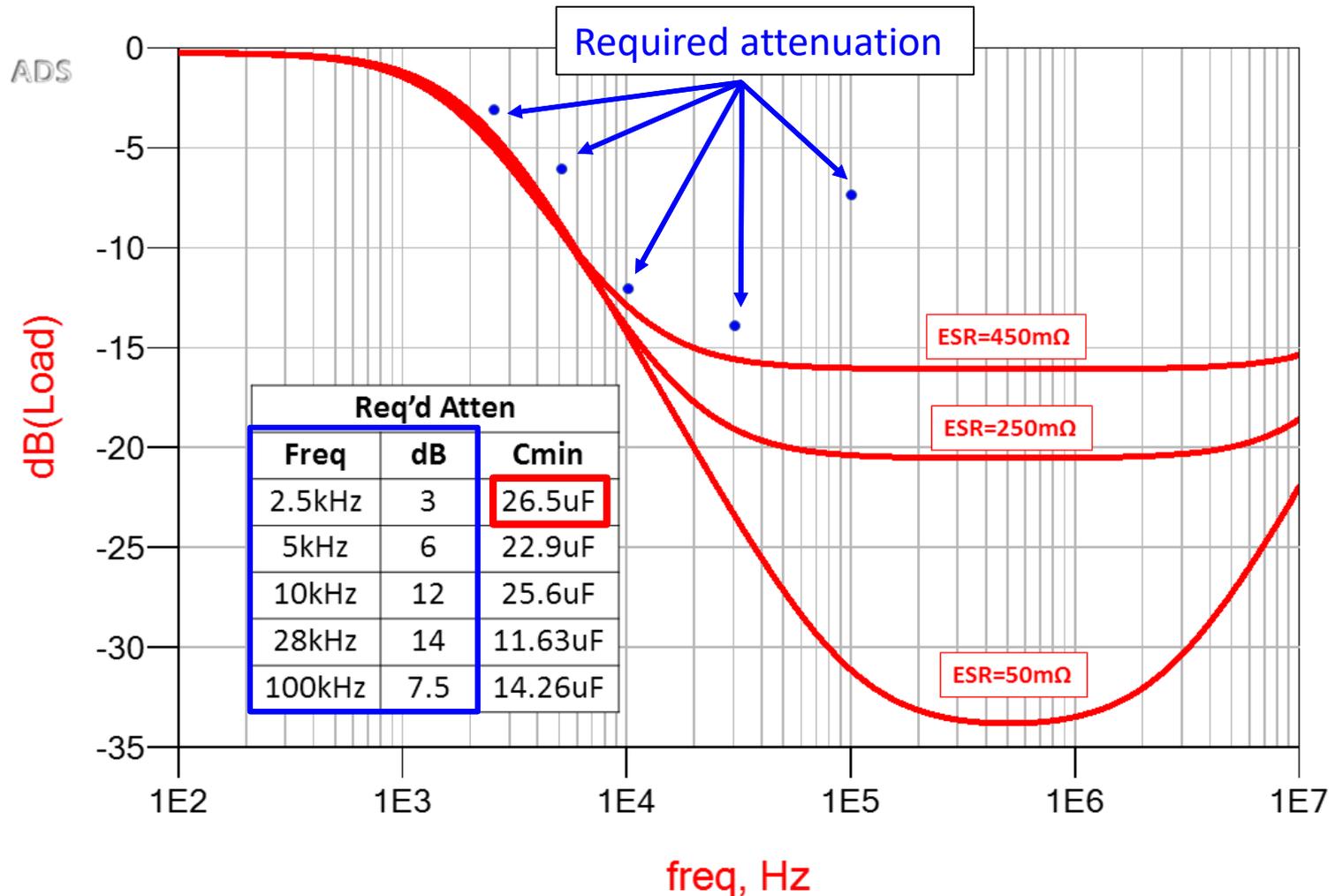
$$R1 = \frac{100mV}{I_{dc}} = \frac{100mV}{39mA} = 2.60\Omega$$

$$C1(dB, f) = \frac{0.159 \cdot \sqrt{e^{0.2303 \cdot dB}} \cdot e^{-0.115 \cdot dB} \cdot \sqrt{e^{0.2303 \cdot dB} - 1}}{R \cdot f}$$

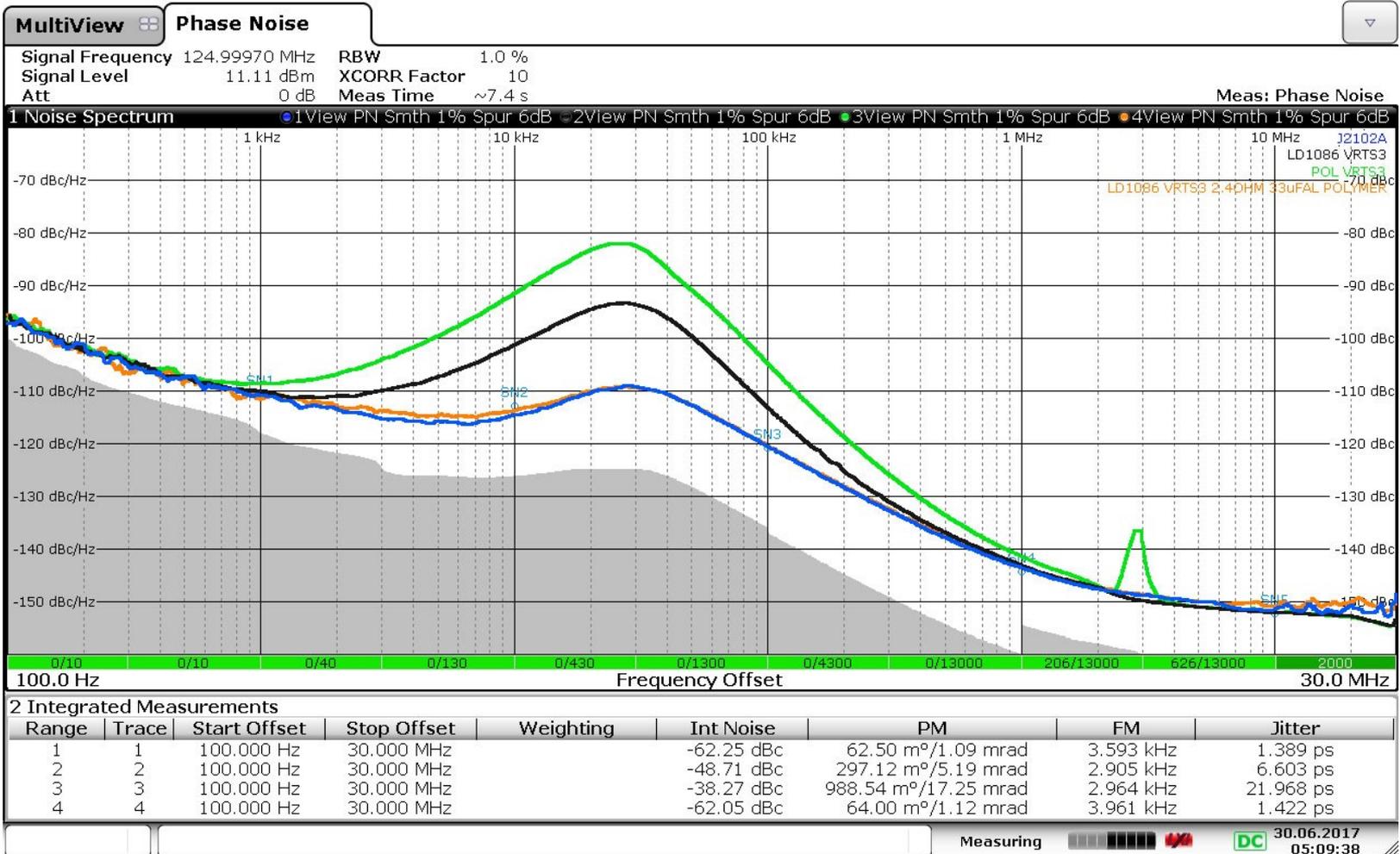
$$ESR_{max} = \frac{0.707 \cdot R}{e^{0.115 \cdot dB_{max}} - 1}$$



# Determining the Capacitor

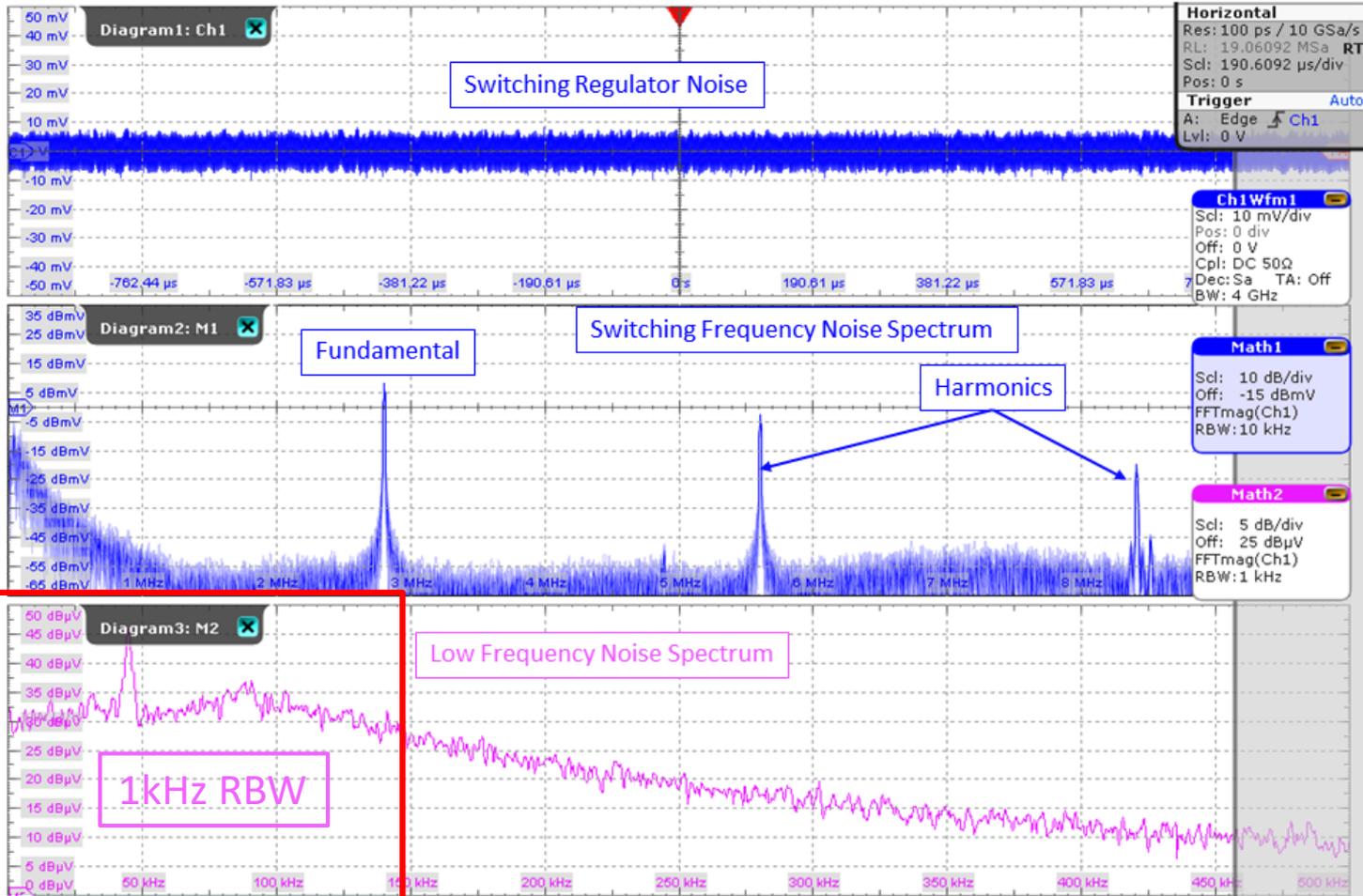


# 33uF/30mΩ ESR + 2.4Ω Filter

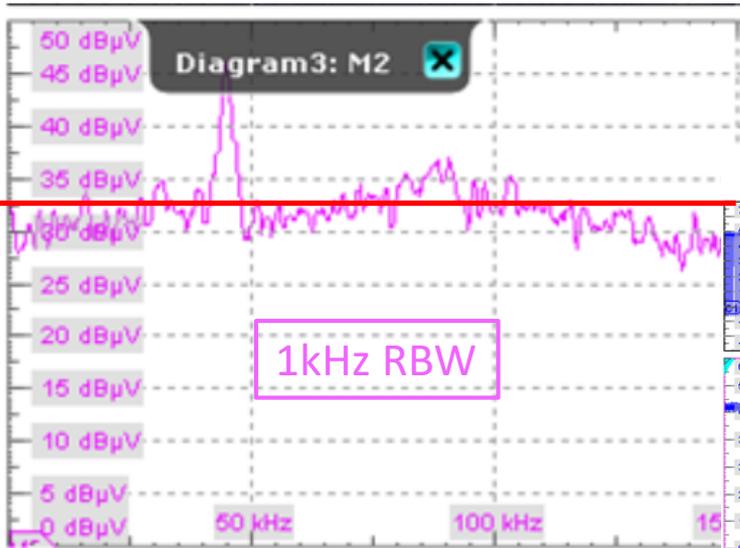


# Unexpected Noise – 2.8MHz POL

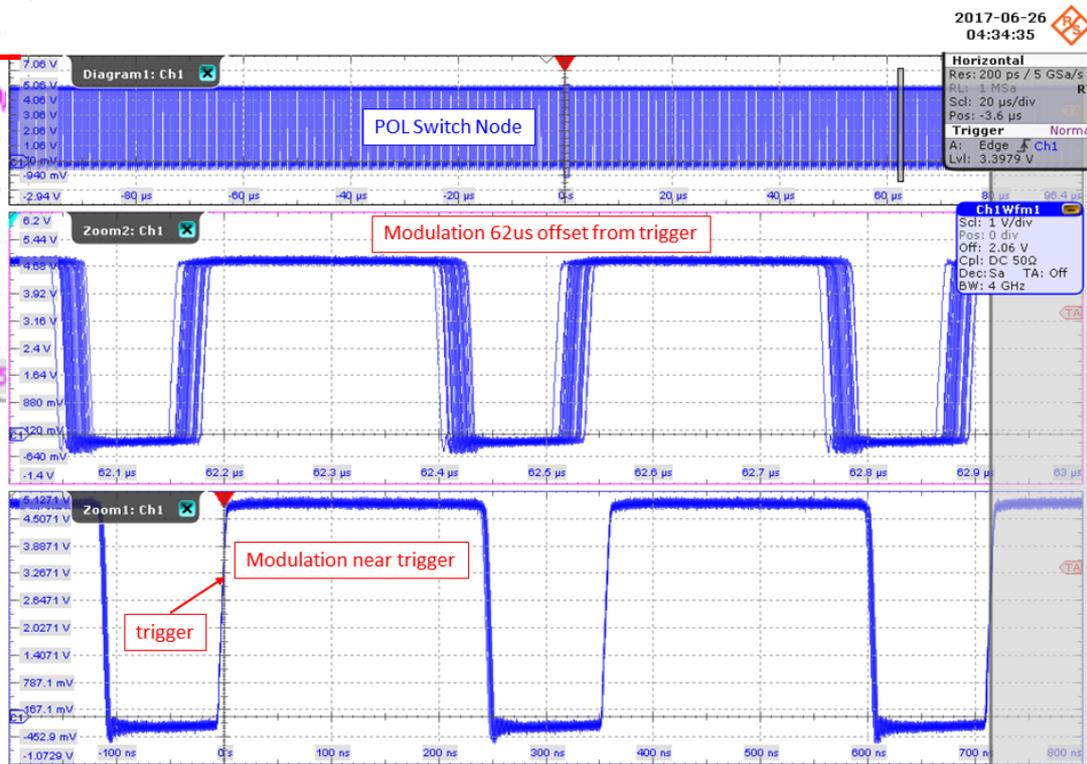
2017-06-26 04:45:11



# Why The Low Frequency Noise?



This is in very good agreement with the signal source analyzer noise density measurement

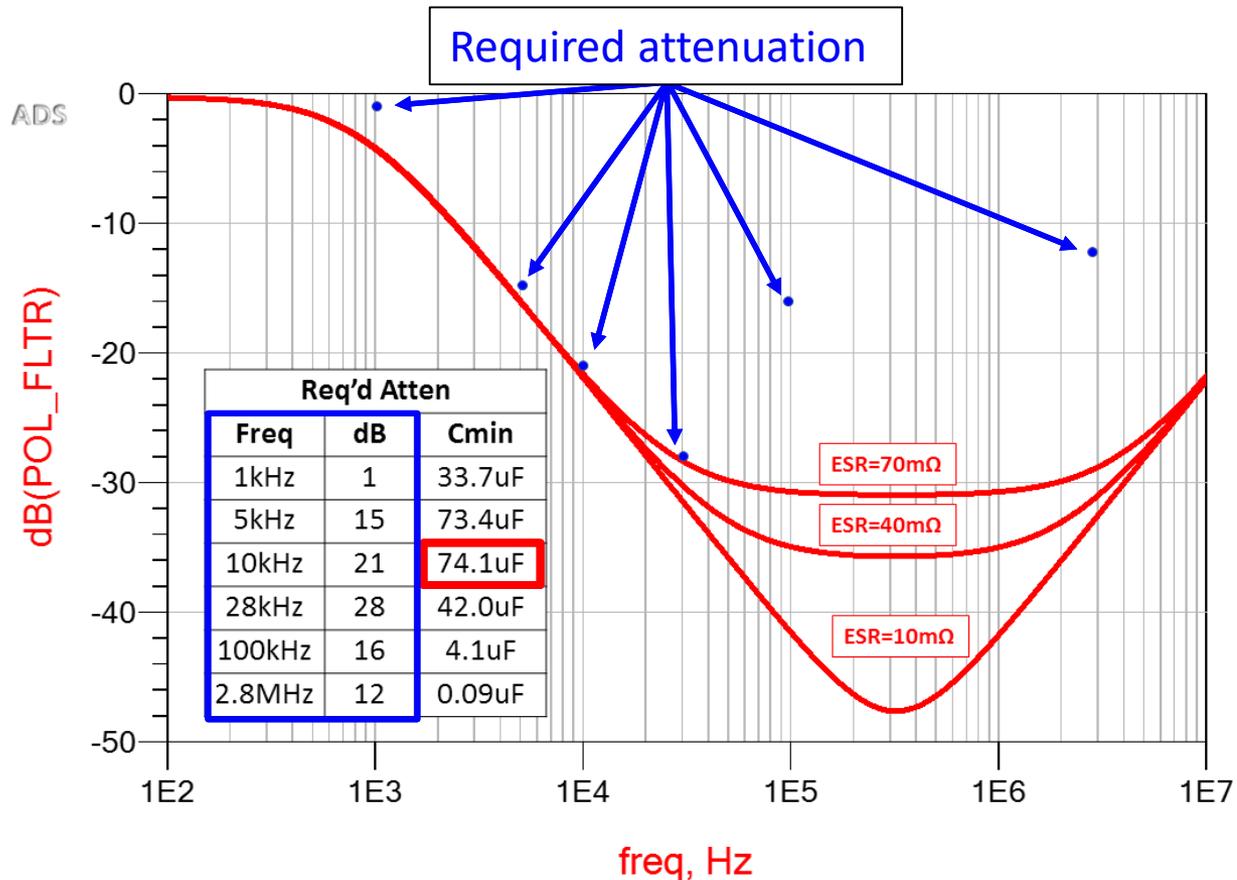


32dBuV at 1kHz RBW (40uVpk)

$$32dBuV \cdot \sqrt{\frac{1Hz}{1kHz(RBW)}} \cong 1.2uV/\sqrt{Hz}$$

# The modulation noise is accounted for

Despite the 2.8MHz switching frequency it's the 10kHz range that defines the filter



# About Ferrite Beads

For Q=0.5

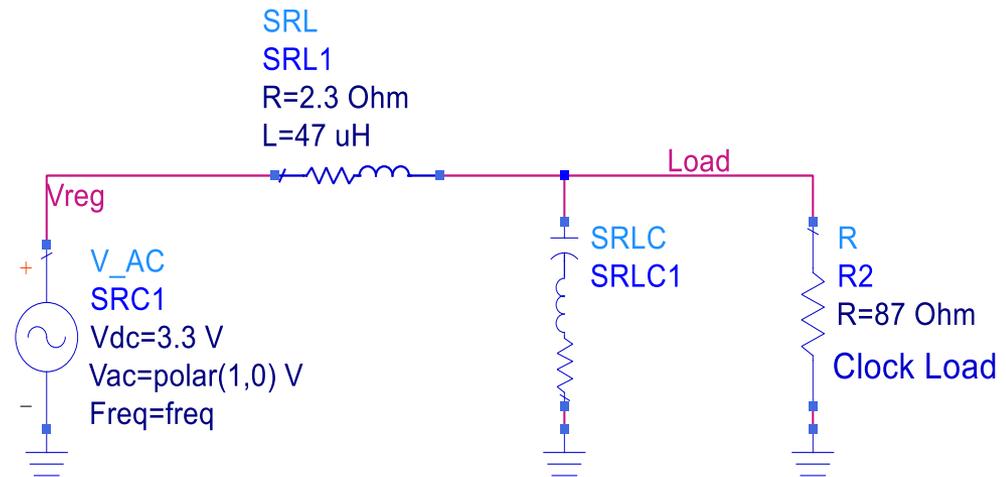
$$L_{max} = 0.5 \cdot C \cdot R^2$$

IF R approaches zero

then **NO INDUCTANCE ALLOWED**

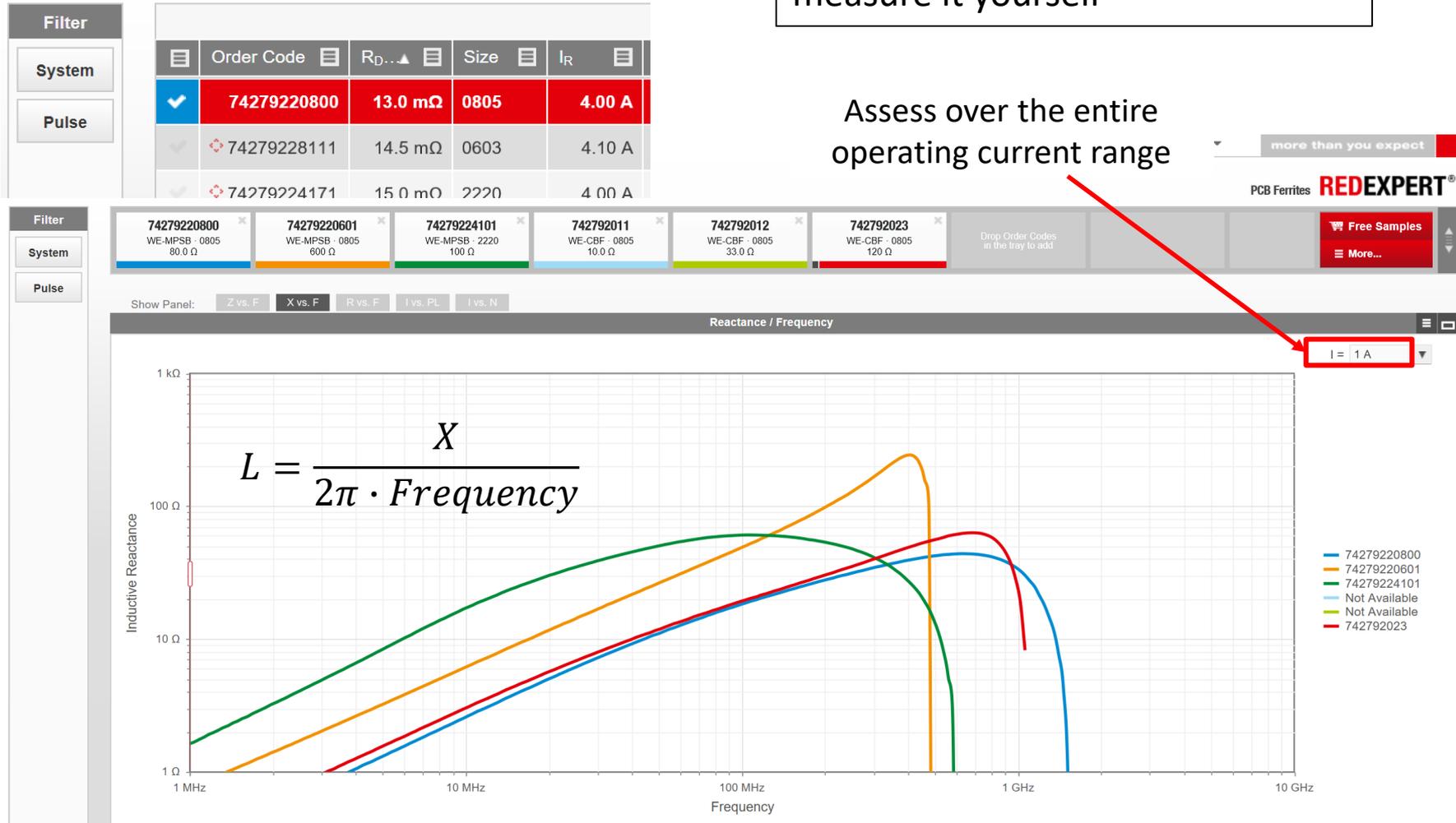
$$ESR_{max} = \frac{0.707 \cdot R}{e^{0.115 \cdot dB_{max}} - 1}$$

$$R = \frac{100mV}{I_{dc}} = \frac{100mV}{39mA} = 2.60\Omega$$

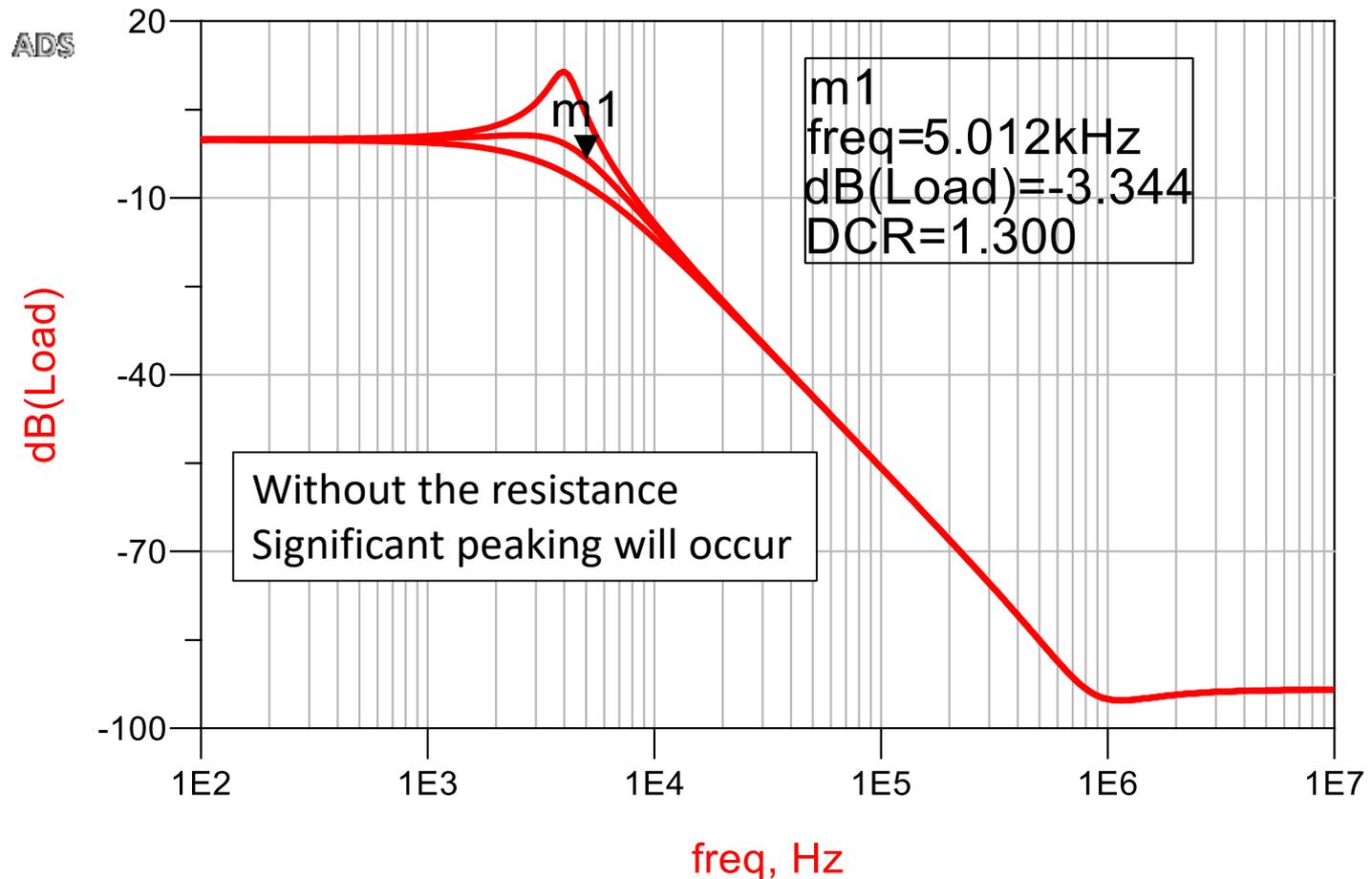




Bead datasheets generally include DCR and high frequency resistance, but look for Inductive reactance and DC Bias data or measure it yourself



# 0.3, 1.3 and 2.30hm resistance



# “RF” Ultra-Low-Noise Options

The precision ultra-low-noise voltage regulator offers precision in the output voltage and low noise

BUT

Count the capacitors!

Is this better or just different?

Precision voltage vs ultra-low noise

## TYPICAL APPLICATION CIRCUIT

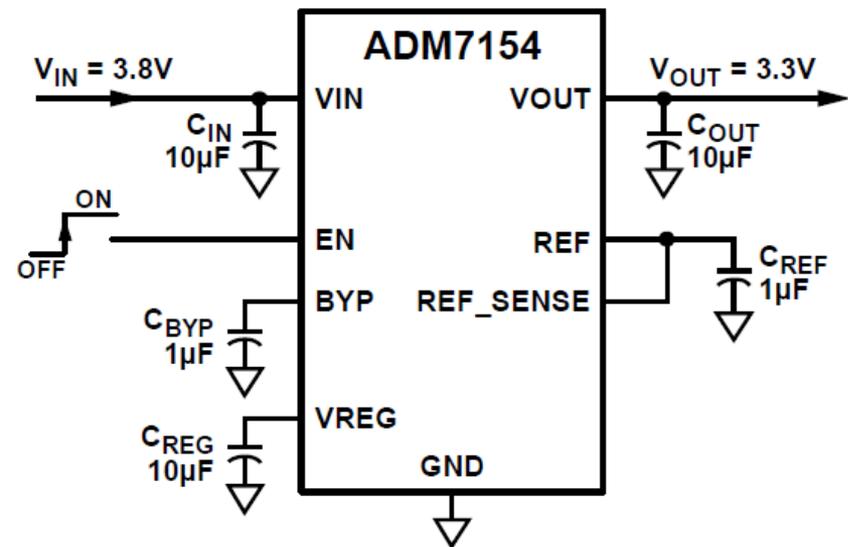
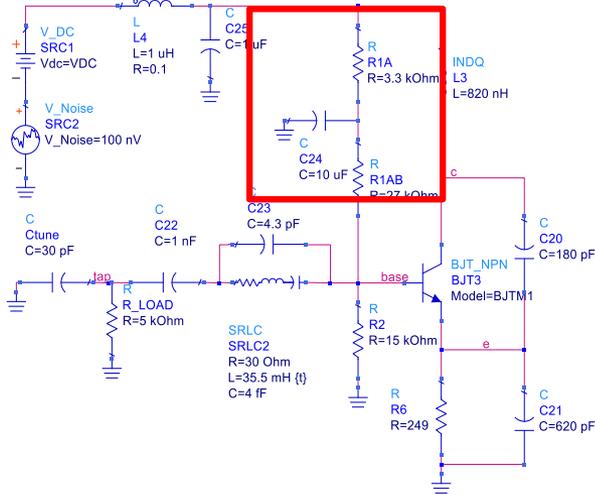


Figure 1. Regulated 3.3 V Output from 3.8 V Input

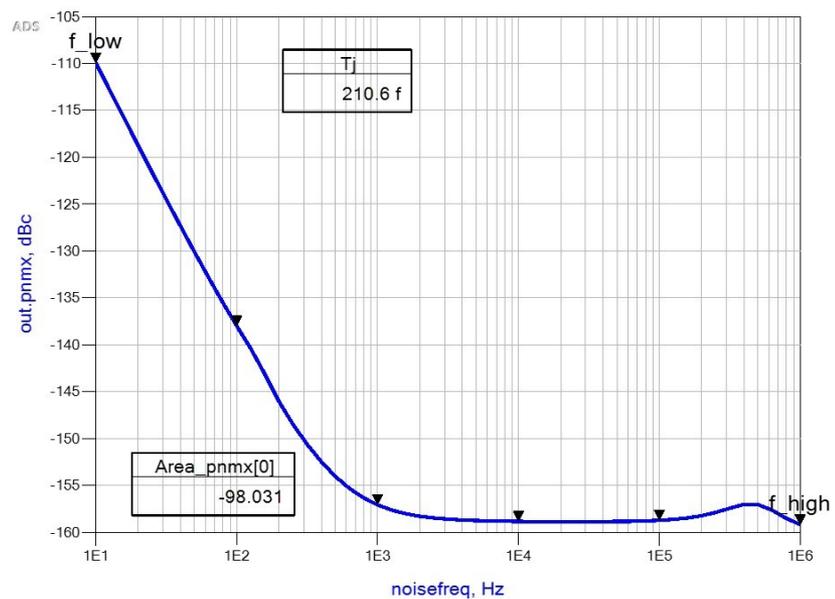
# Top Tips



Low current bias also needs to be filtered.

Include phase noise and jitter in your simulations

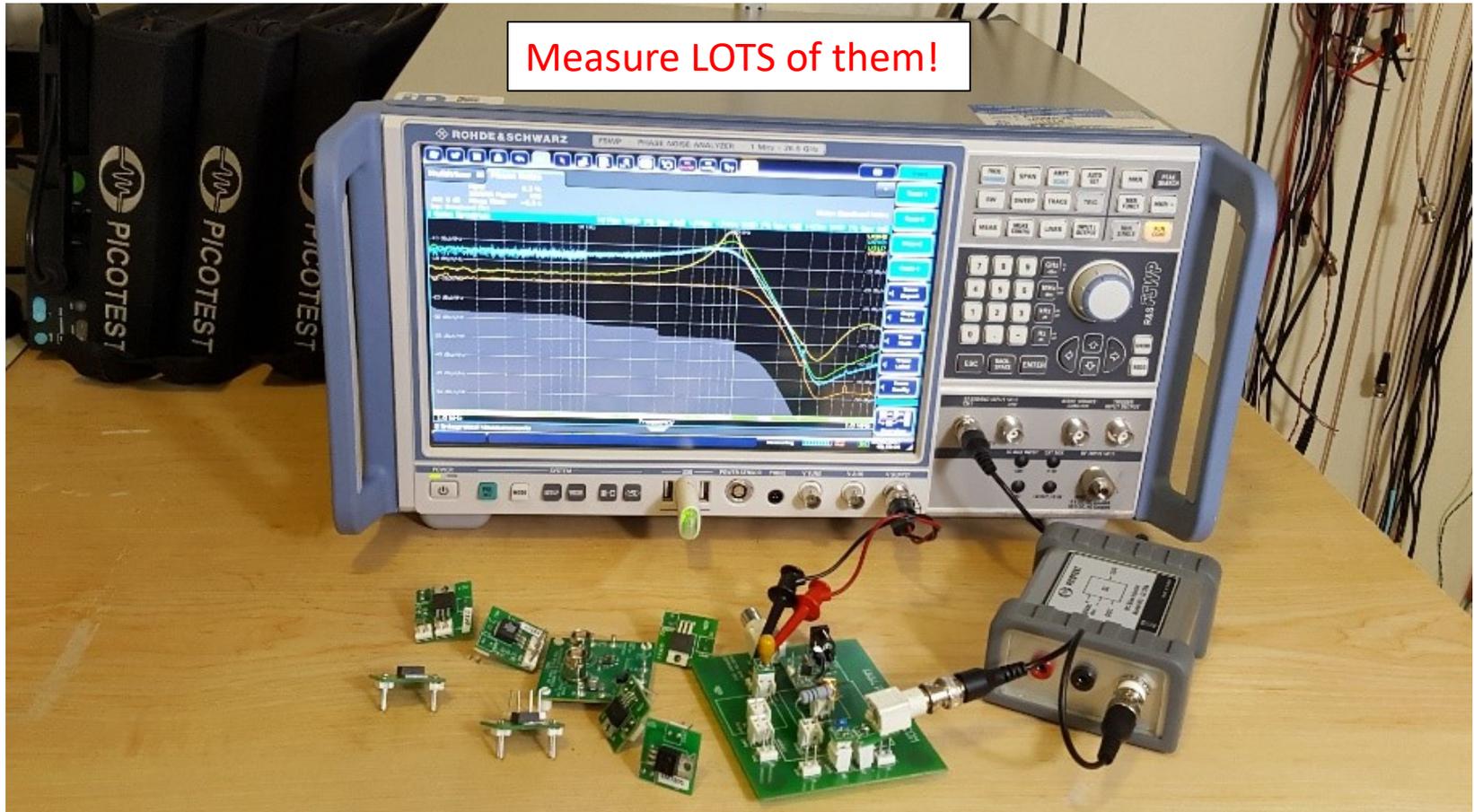
Higher value caps are generally better than lower value caps



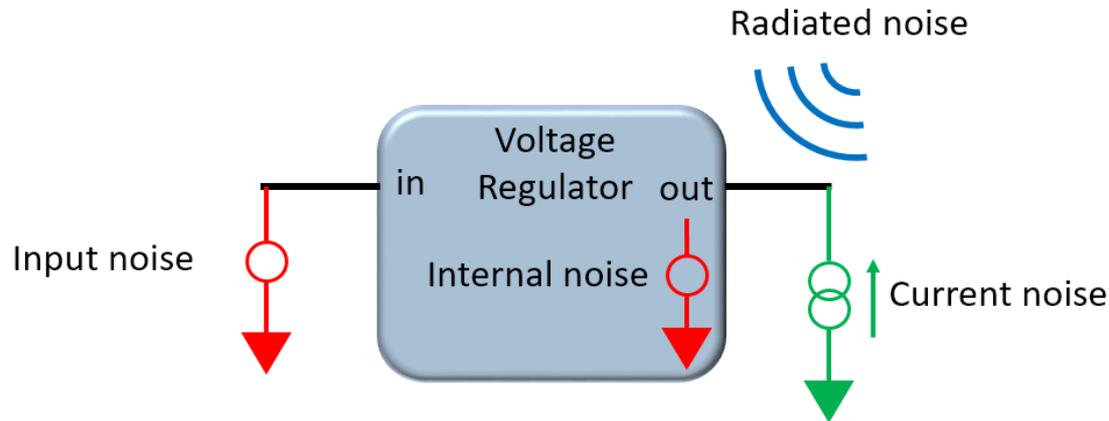
HB.freq[1]  
13.40391 MHz

noisefreq	f_low
10.00 Hz	-109.939
noisefreq	f_10
10.00 Hz	-109.939
noisefreq	f_100
100.0 Hz	-137.978
noisefreq	f_1k
1.000 kHz	-157.073
noisefreq	f_10k
10.00 kHz	-158.824
noisefreq	f_100k
100.0 kHz	-158.711
noisefreq	f_high
1.000 MHz	-159.195

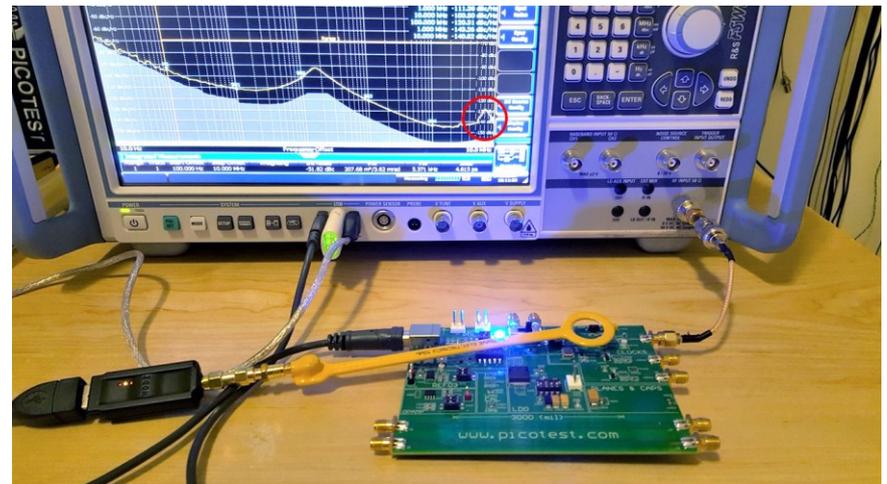
# Not all regulators are created equal



# Consider all the ways noise gets in



Watch the coaxial cables and power interconnects also



# Thanks for Attending this Session!

In this session I shared

- How to determine the circuit sensitivity to power supply noise
- How to choose the best voltage regulator
- How to design an optimum power supply noise filter
- A few of my top tips for designing power for sensitive circuits

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