Target Impedance and Rogue Waves

Steve Sandler, Picotest

Target Impedance and Rogue Waves

Steve Sandler, Picotest

INTRODUCTION

$$Z_{target} = \frac{\Delta V}{\Delta I}$$

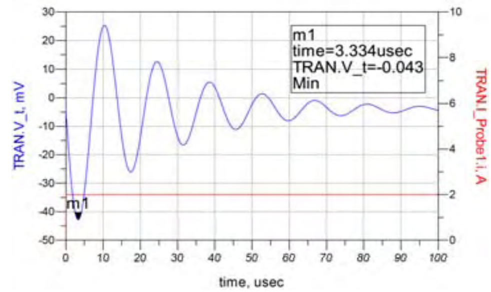
Tolerable voltage noise (ΔV)

Expected current noise (ΔI)

$$\Delta V_{target} = Z_{target} \cdot \Delta I$$

Step

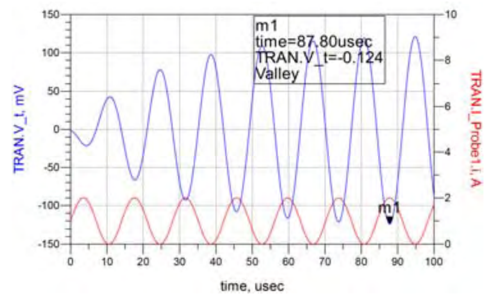
$$\Delta V = \Delta I \cdot \sqrt{\frac{L}{C}} \cdot e^{\frac{-\pi}{4Q}} = 39mVpk$$



$\Delta I = 2Amps$
$\Delta V = 39mVpk$

Resonant Sine

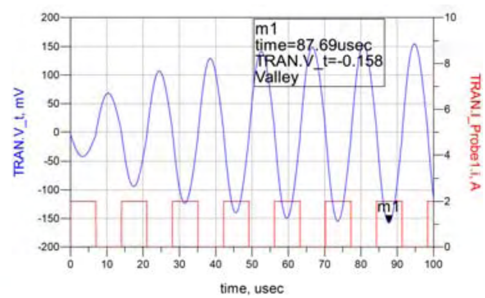
$$\Delta V = \Delta I \cdot \sqrt{\frac{L}{C}} \cdot \frac{Q}{2} = 123mVpk$$



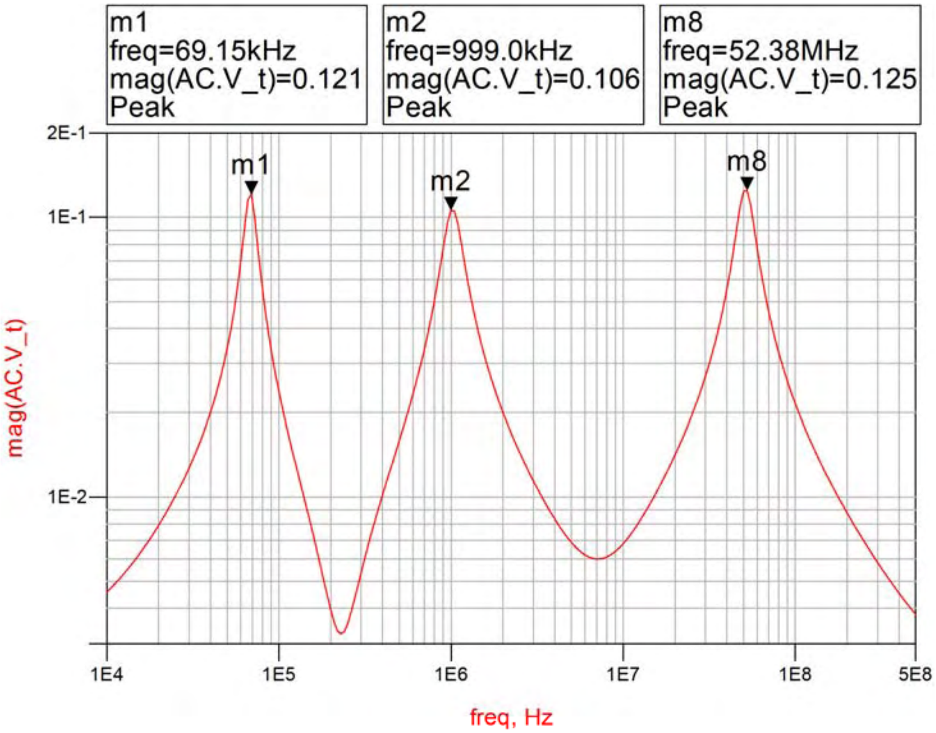
$\Delta I = 2Amps$
$\Delta V = 123mVpk$

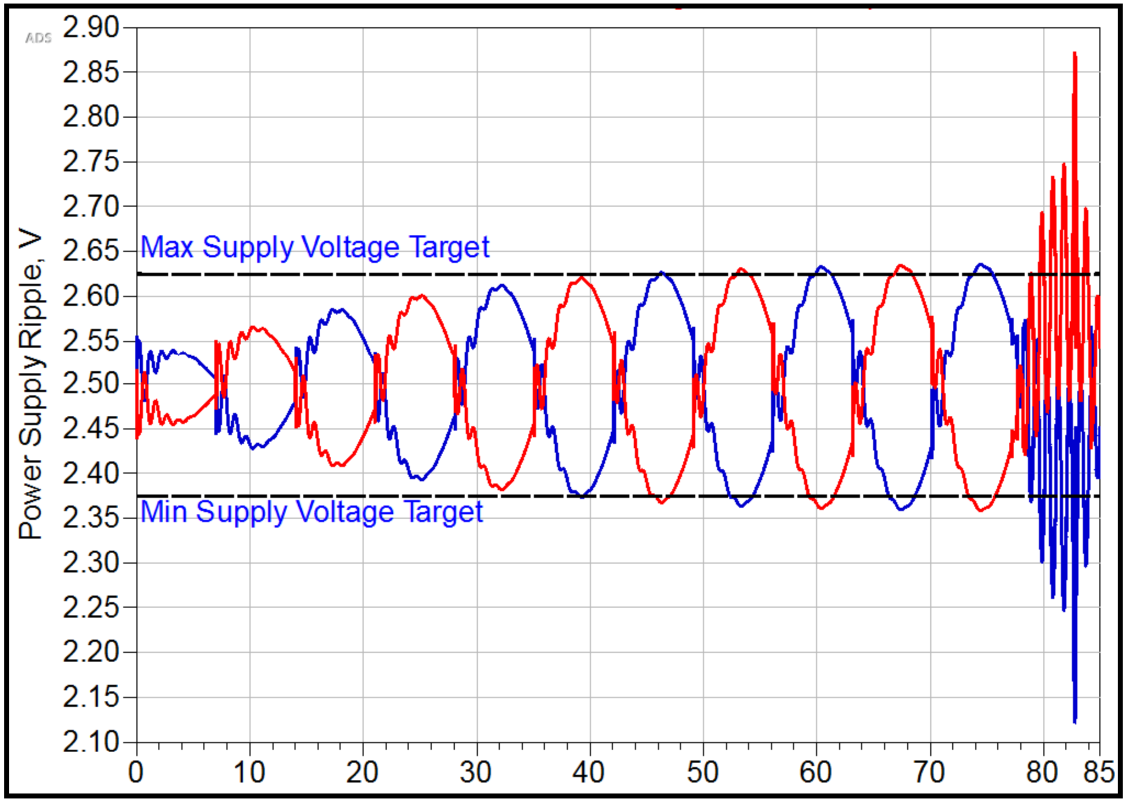
Resonant Square

$$\Delta V = \Delta I \cdot \sqrt{\frac{L}{C}} \cdot \frac{2Q}{\pi} = 157mVpk$$



$\Delta I = 2Amps$
$\Delta V = 157mVpk$





$$\Delta V_{target} \approx \Delta I \cdot \frac{4}{\pi} \sum_{0}^{n} Z_i$$

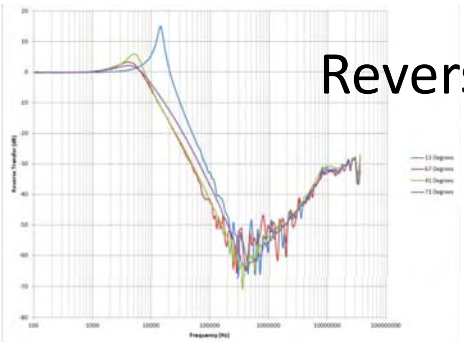
CHAPTER 1: MANAGING NOISE

Table 1. Example V_{CC} Core Voltage Power Supply Operating Conditions [(1)]

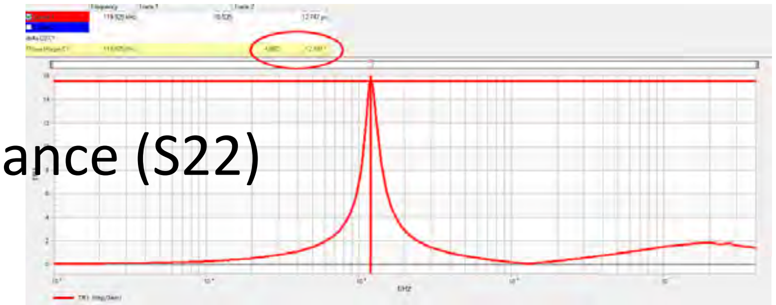
Symbol	Description	Condition	Minimum	Typical	Maximum	Unit
V_{CC}	Core voltage and periphery circuitry power supply (C1, C2, and 12 speed grades)	—	0.87	0.90	0.93	V
	Core voltage and periphery circuitry power supplier (C2L, C3, C4, I2L, 13, 13L, and 14 speed grades)	—	0.82	0.85	0.88	V

$$Z_{target} = \frac{\Delta V}{\Delta I} = \frac{30mV}{50\% \cdot Imax}$$

CHAPTER 2: MULTIPLE NOISE PATHS

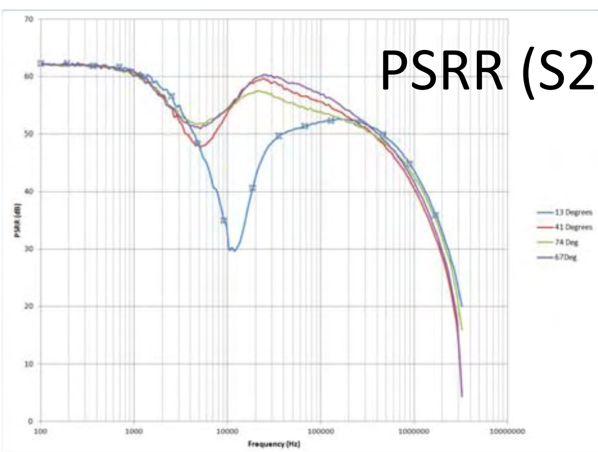


Reverse (S12)



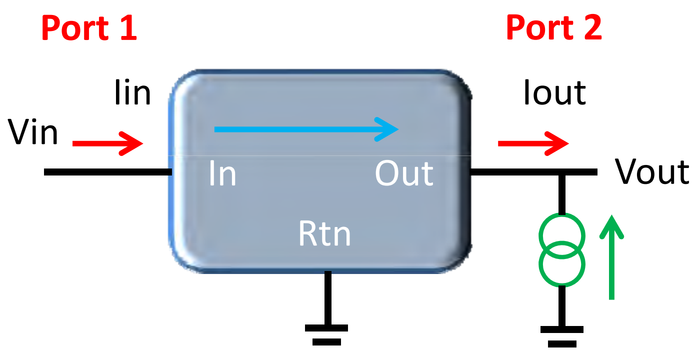
Output Impedance (S22)

Output noise/spikes (S22)

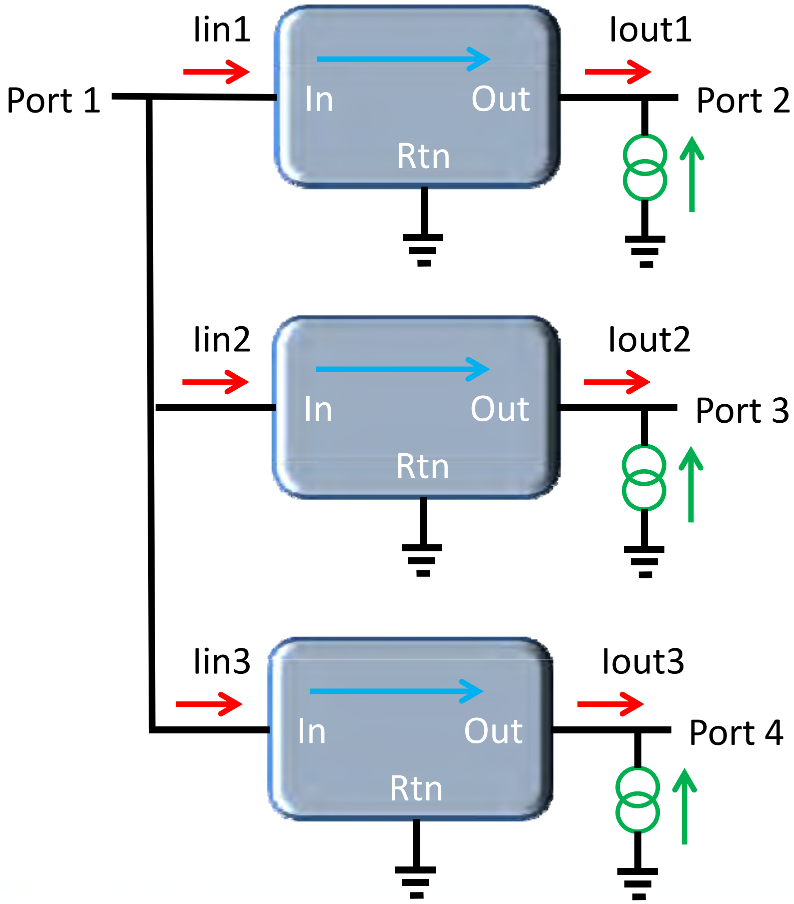


PSRR (S21)

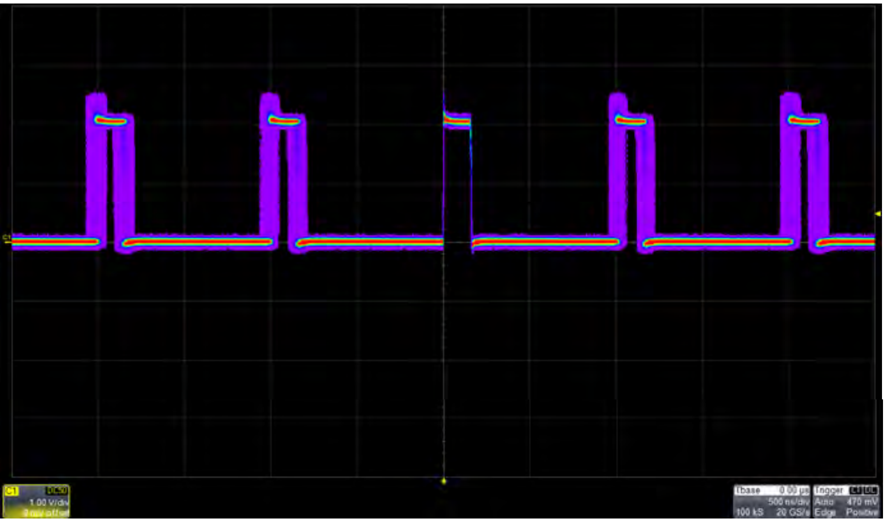
Input impedance (S11)

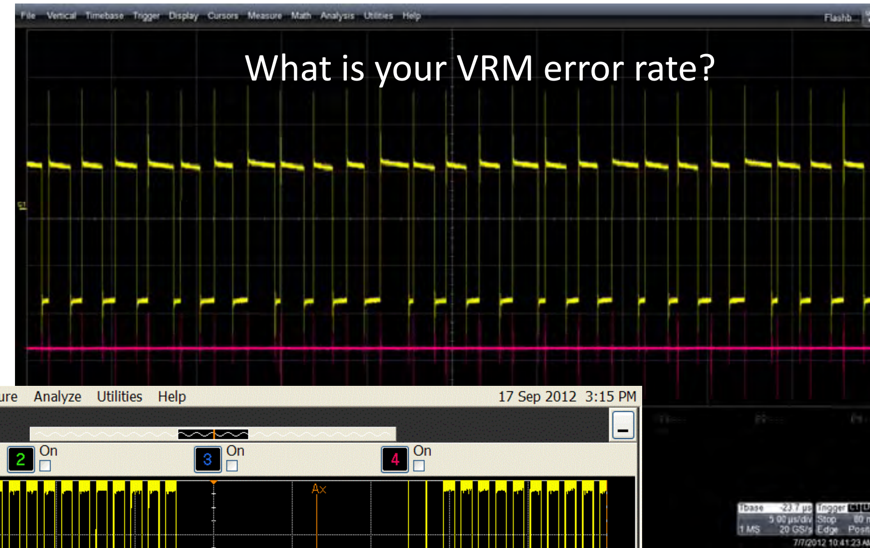


OBVIOUS PATHS THROUGH MULTIPLE VRM'S

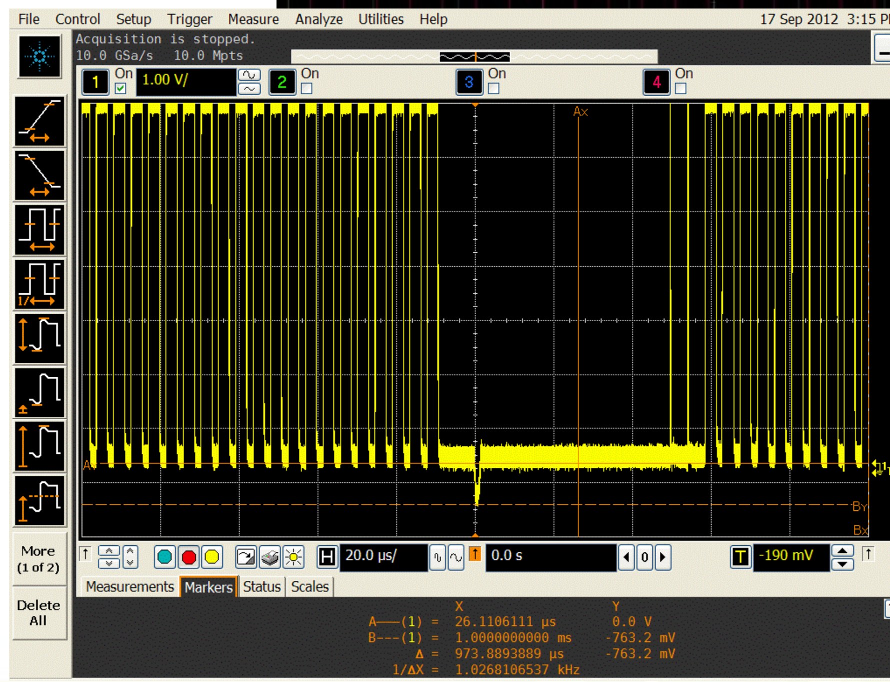


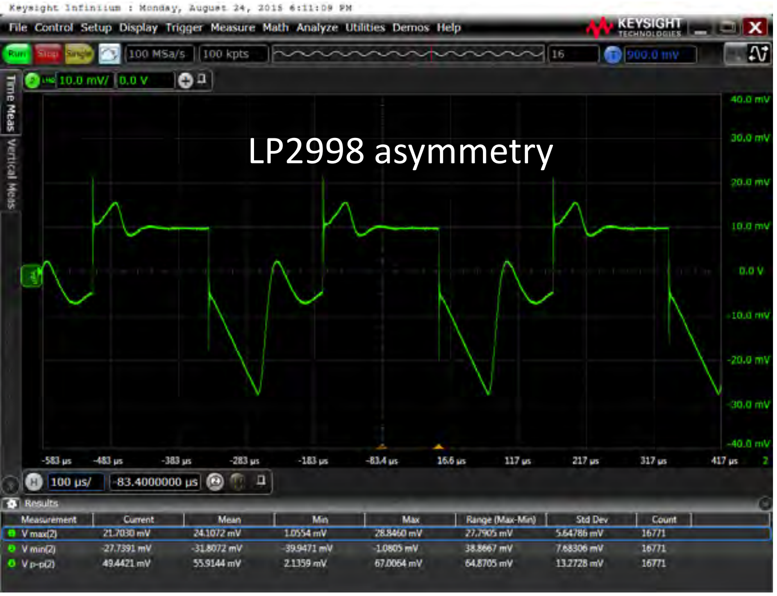
S11	S21	S31	S41
S12	S22	S32	S42
S13	S23	S33	S43
S14	S24	S34	S44

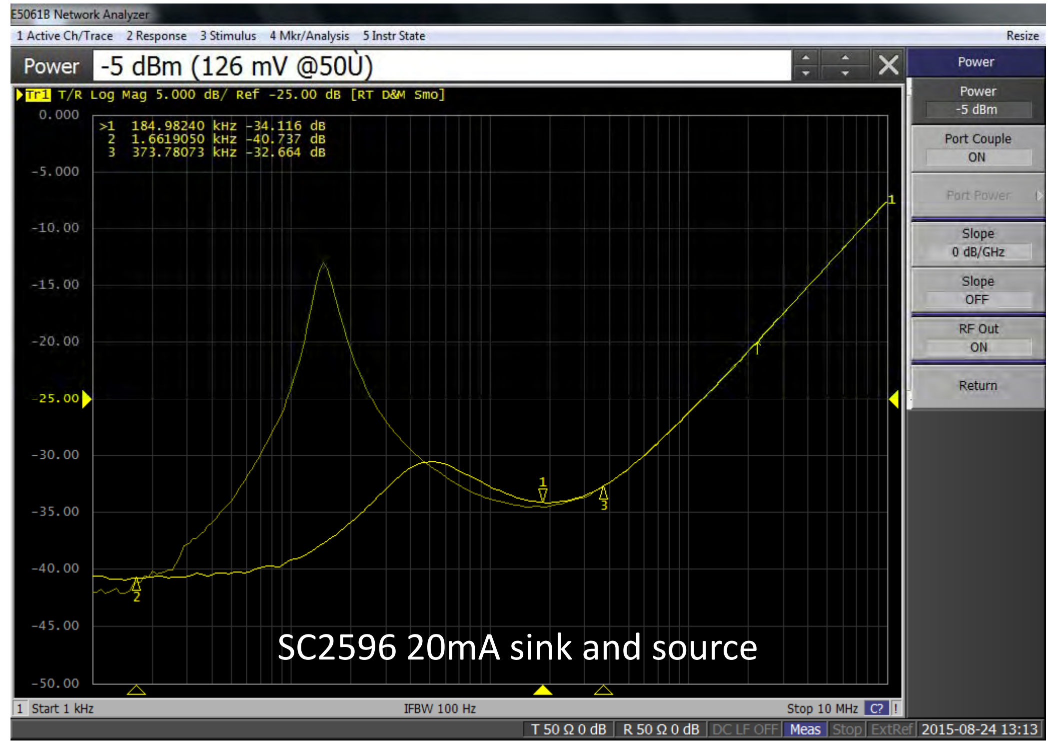


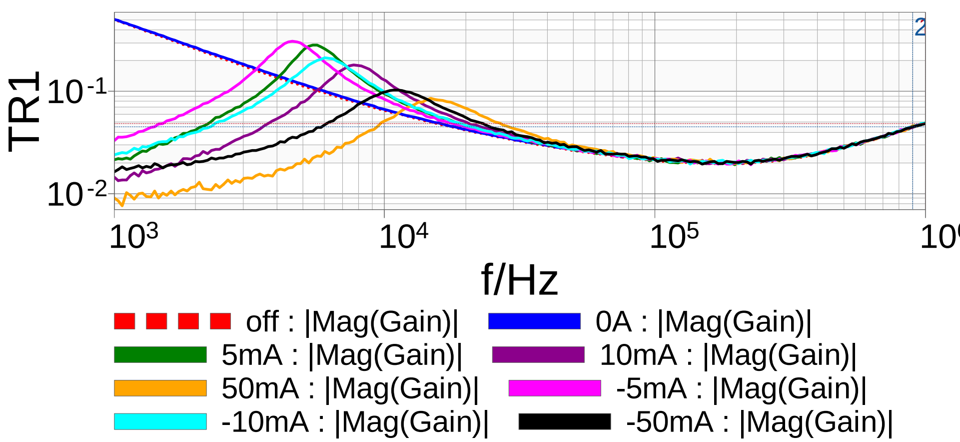

What is your VRM error rate?


There aren't many aspects that are truly small signal


File Control Setup Trigger Measure Analyze Utilities Help
17 Sep 2012 3:15 PM
Acquisition is stopped.
10.0 GSa/s 10.0 Mpts
1.00 V/
20.0 µs/
0.0 s
-190 mV
More (1 of 2)
Delete All
Measurements Markers Status Scales
A——(1) = 26.1106111 µs 0.0 V
B---(1) = 1.0000000000 ms -763.2 mV
Δ = 973.8893889 µs -763.2 mV
1/ΔX = 1.0268106537 kHz







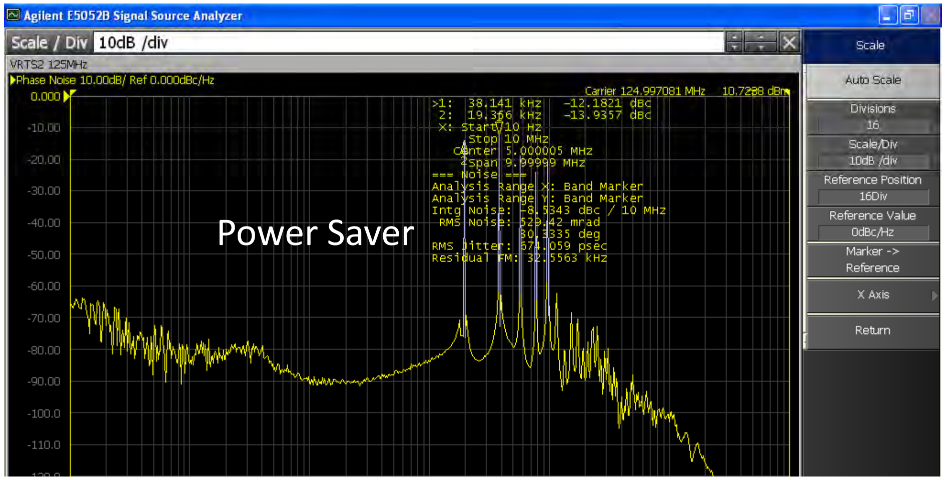
And as these DDR termination regulator measurements show, performance isn't always symmetrical or small signal

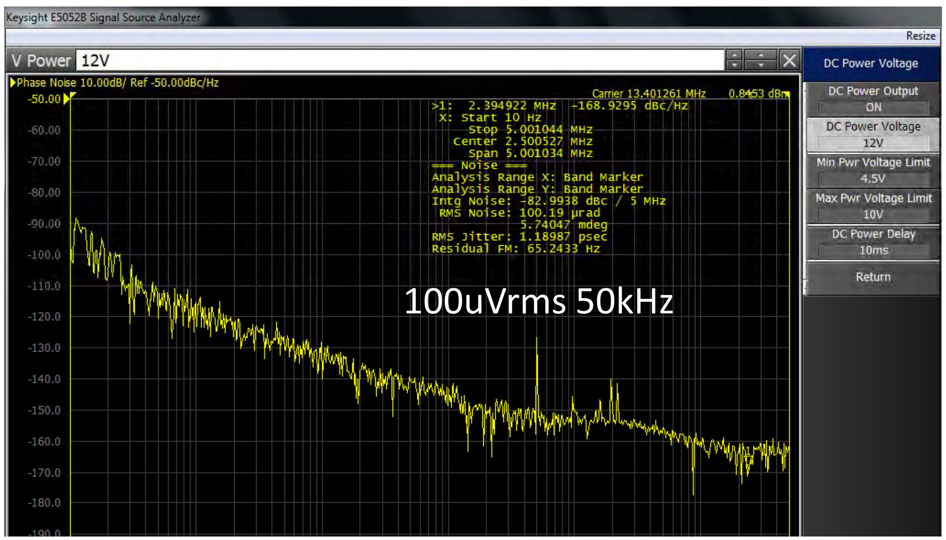
$$\Delta V \approx \Delta I_f \cdot \frac{4}{\pi} \sum_{f=0}^{\infty} Z_f + \sum_{n=0}^{\infty} V_n$$

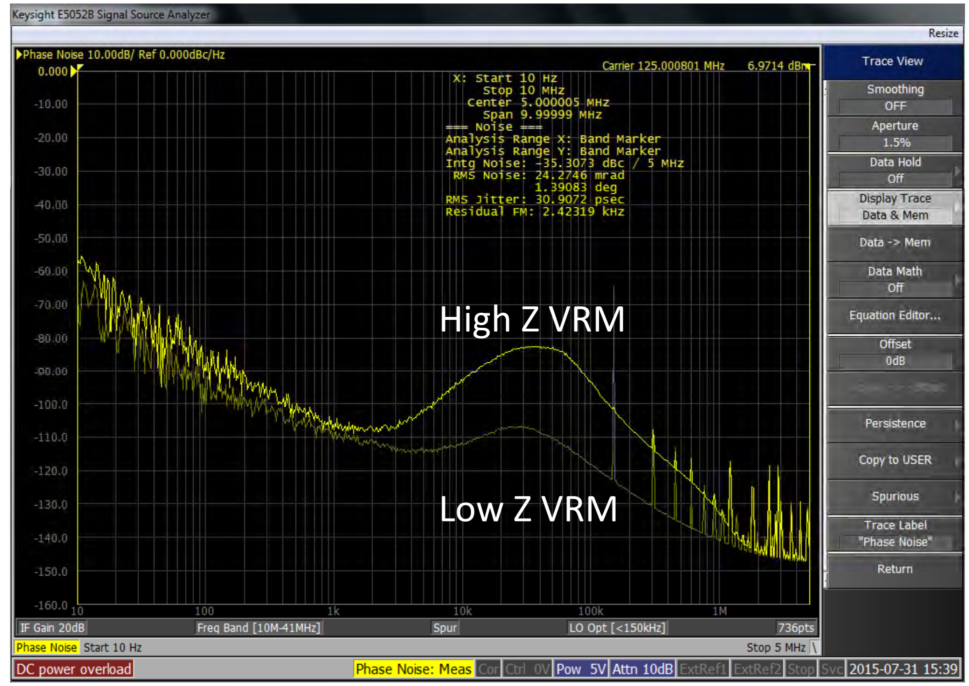
n is inclusive of **<u>all the noise terms</u>** that we have spoken about (and some we may have missed):

- Internal ripple and noise
- Frequency modulation noise
- Duty cycle modulation noise
- Large signal transients
- Intentional and unintentional Glitches (lightning, engine crank, fuse blow)
- Fault recoveries (soft-start is generally not functional)
- Turn-on overshoot
- Initial, temperature and age (and in some cases radiation) tolerance

$$\Delta I_f \cdot \frac{4}{\pi} \sum_{f=0}^{\infty} Z_f \approx \Delta V - \sum_{n=0}^{\infty} V_n$$

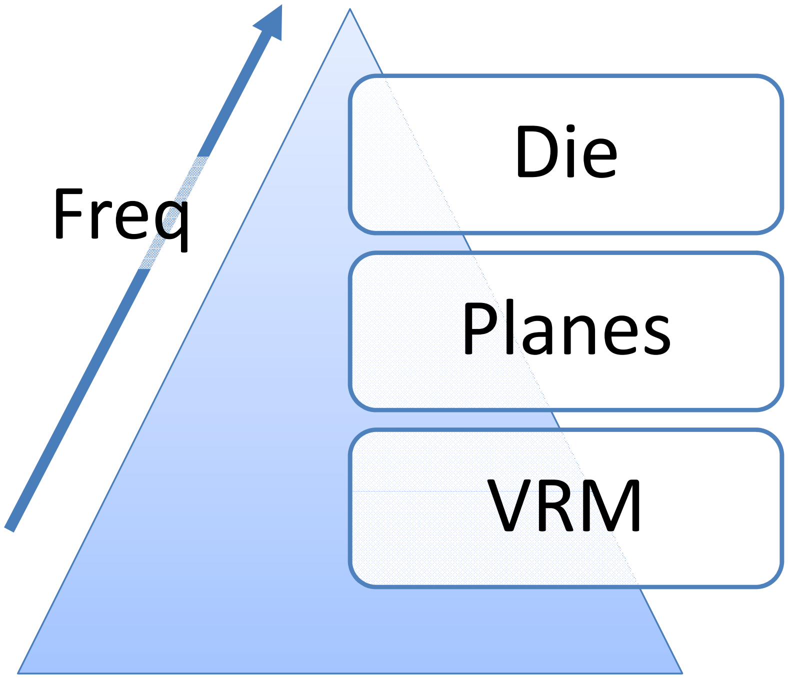






CHAPTER 3 – BUDGETING FOR ΔV

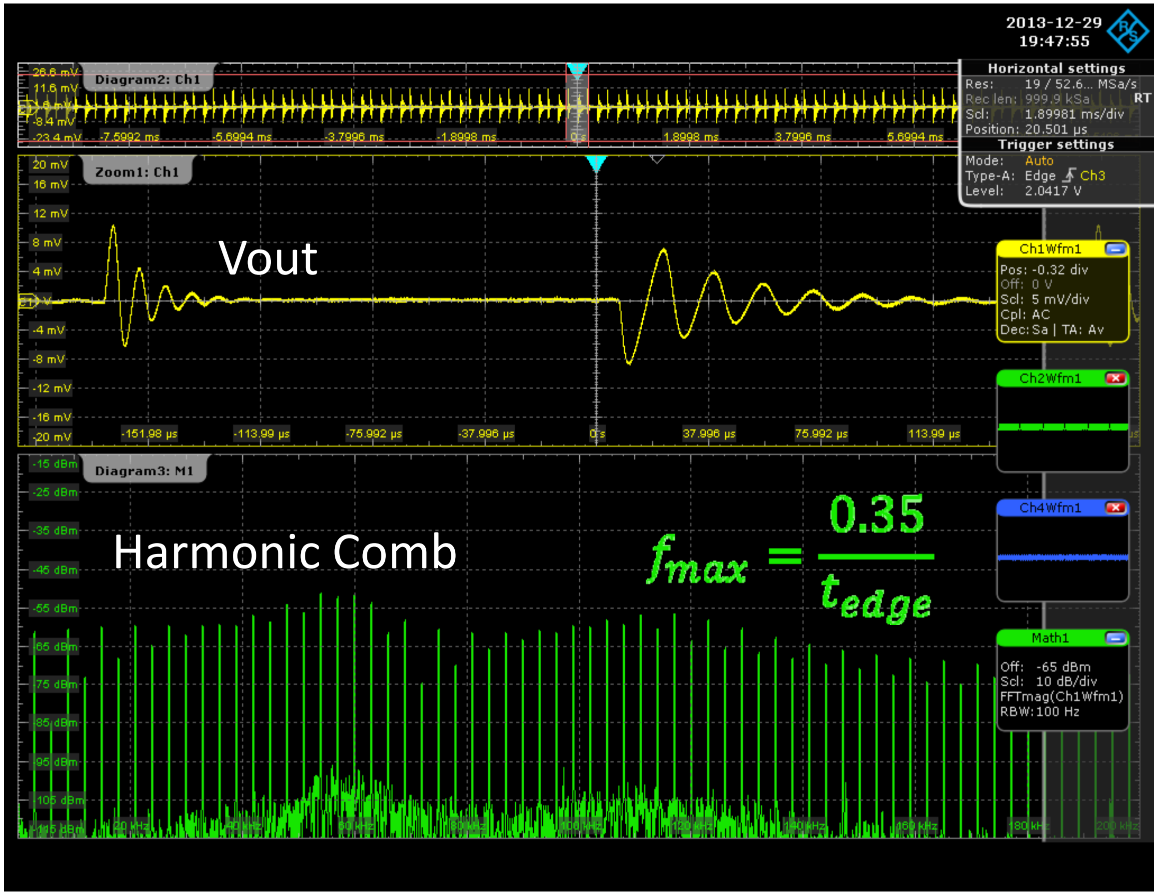
CHAPTER 4 – LOW FREQUENCIES SCARE ME

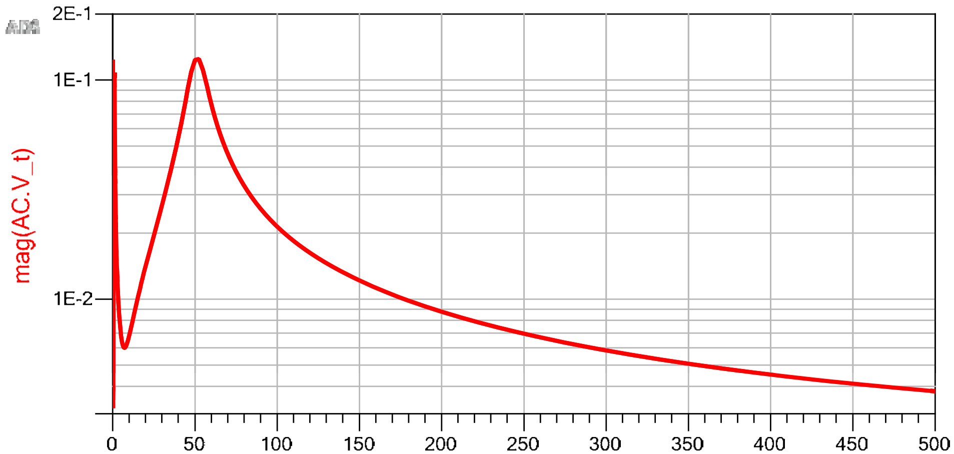


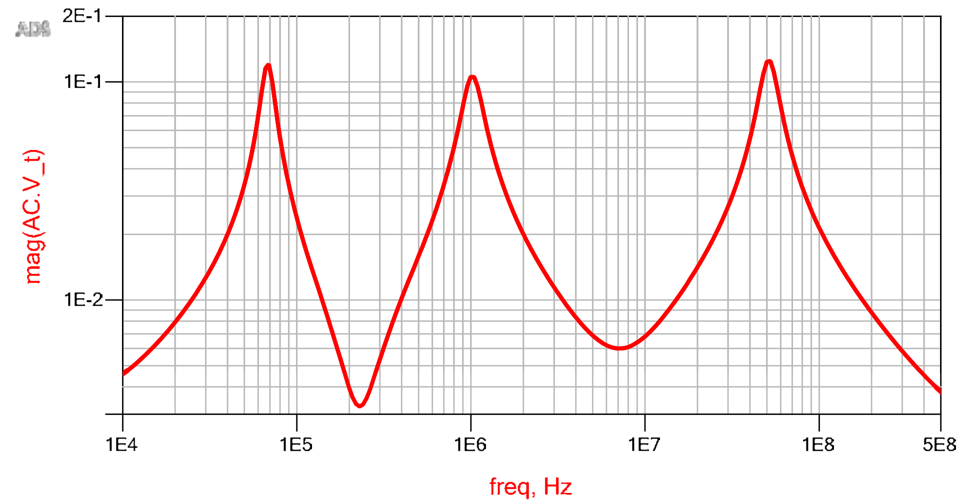
Ringing produces a noise comb with harmonics at all sum and difference frequencies

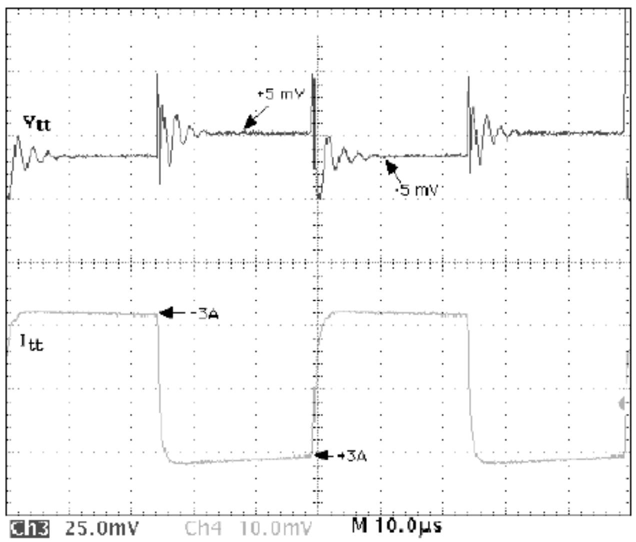
The LOWER the repetition rate the closer the spurs!

Note the large signal effect









Note that

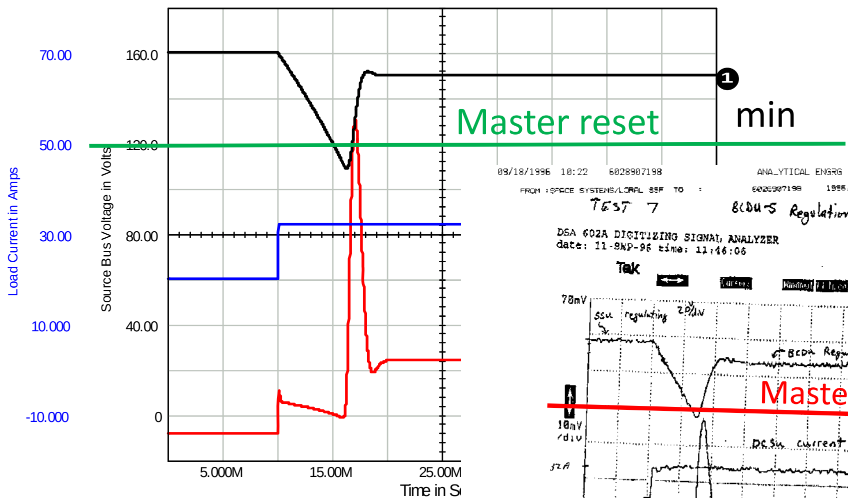
- In this DDR regulator there appear to be multiple frequencies at the edges – hard to see with linear scales. Should be windowed
- Only large signal performance is shown
- Only natural response is shown

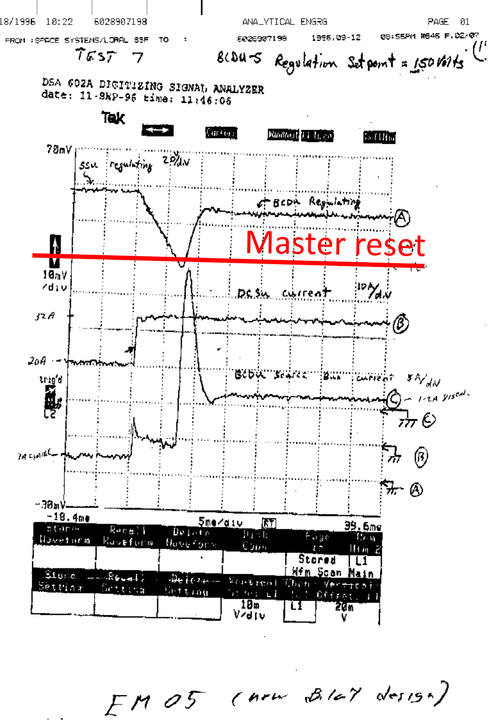
CHAPTER 4 – MISSING THE TARGET

Means someone loses a <u>lot</u> of money!

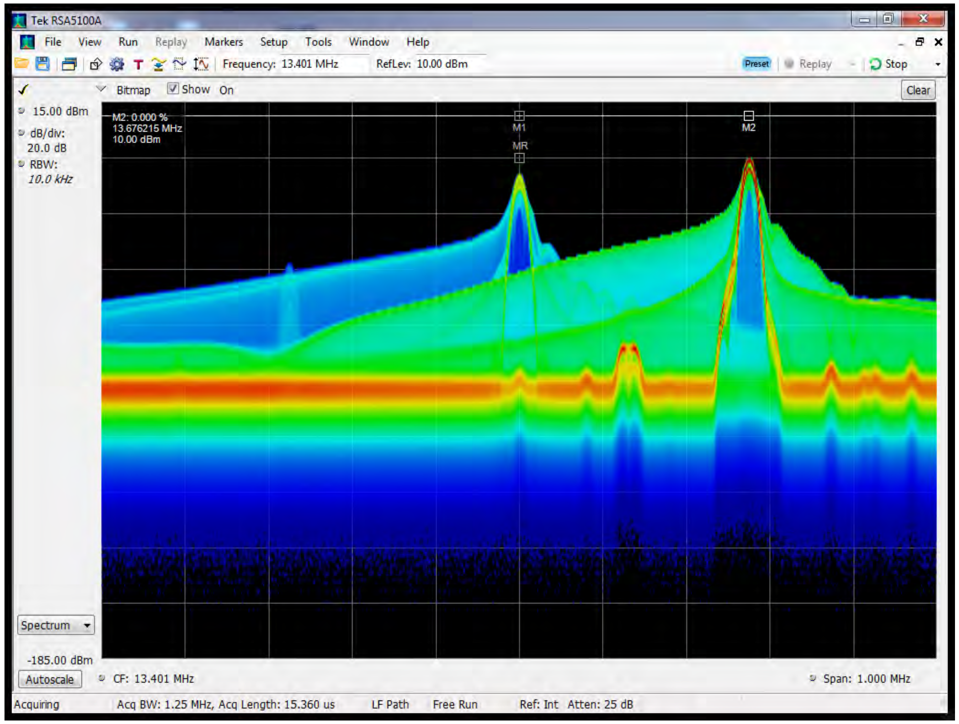
http://vocabspace.wikispaces.com/file/view/money_in_trash.jpg/108783189/money_in_trash.jpg

CHAPTER 4 – EXAMPLES OF NOISE

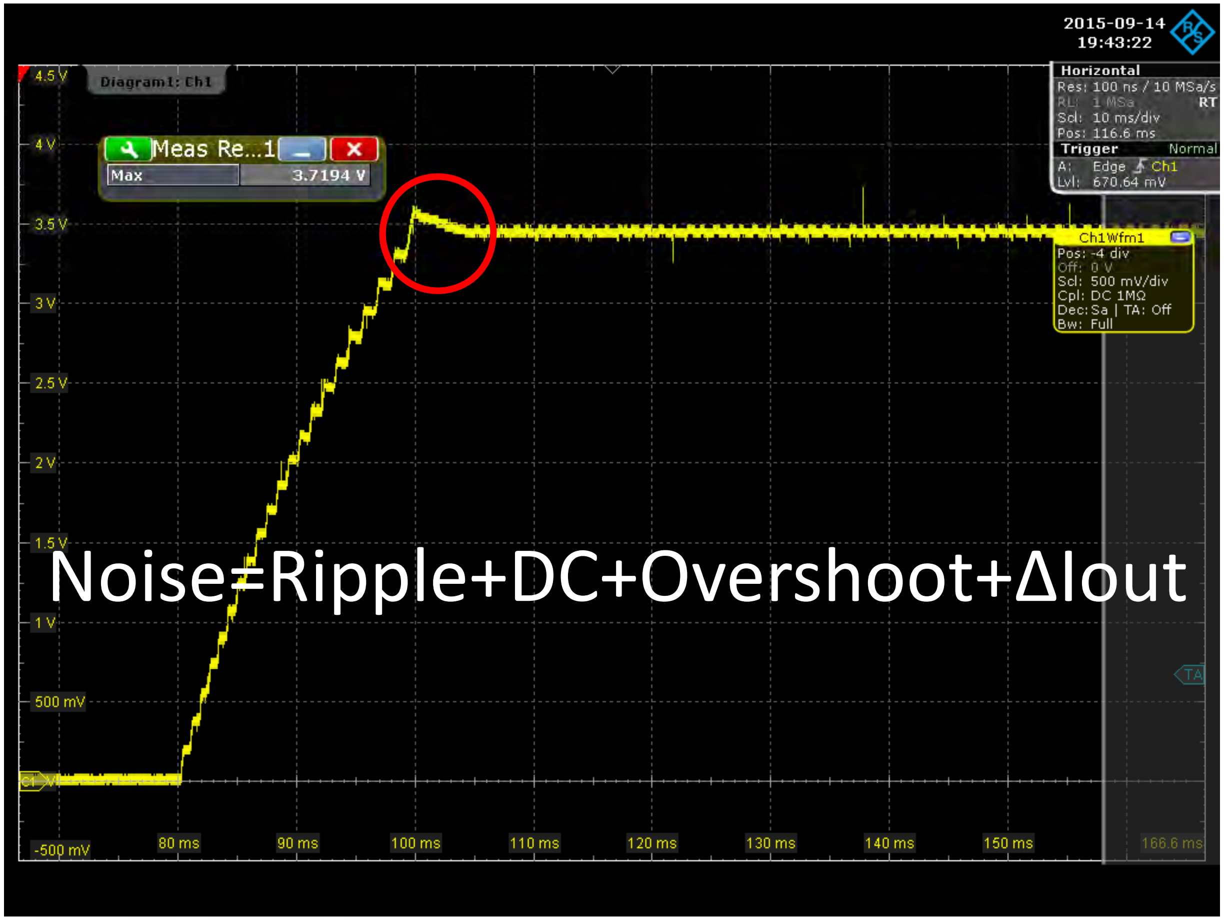




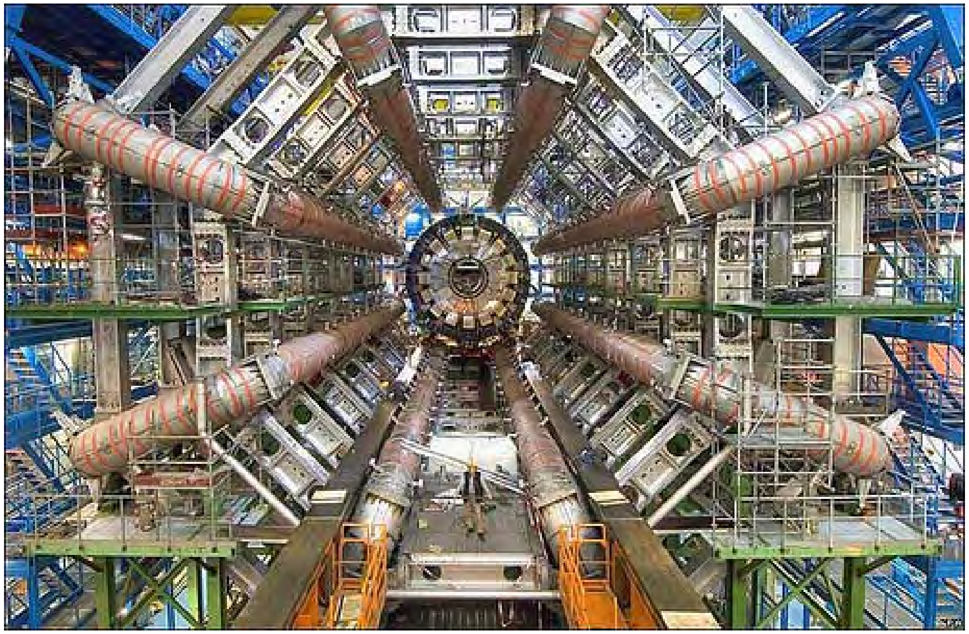
ISS during Eclipse
Main power rail falls
below master reset for
The station……every 90
minutes!



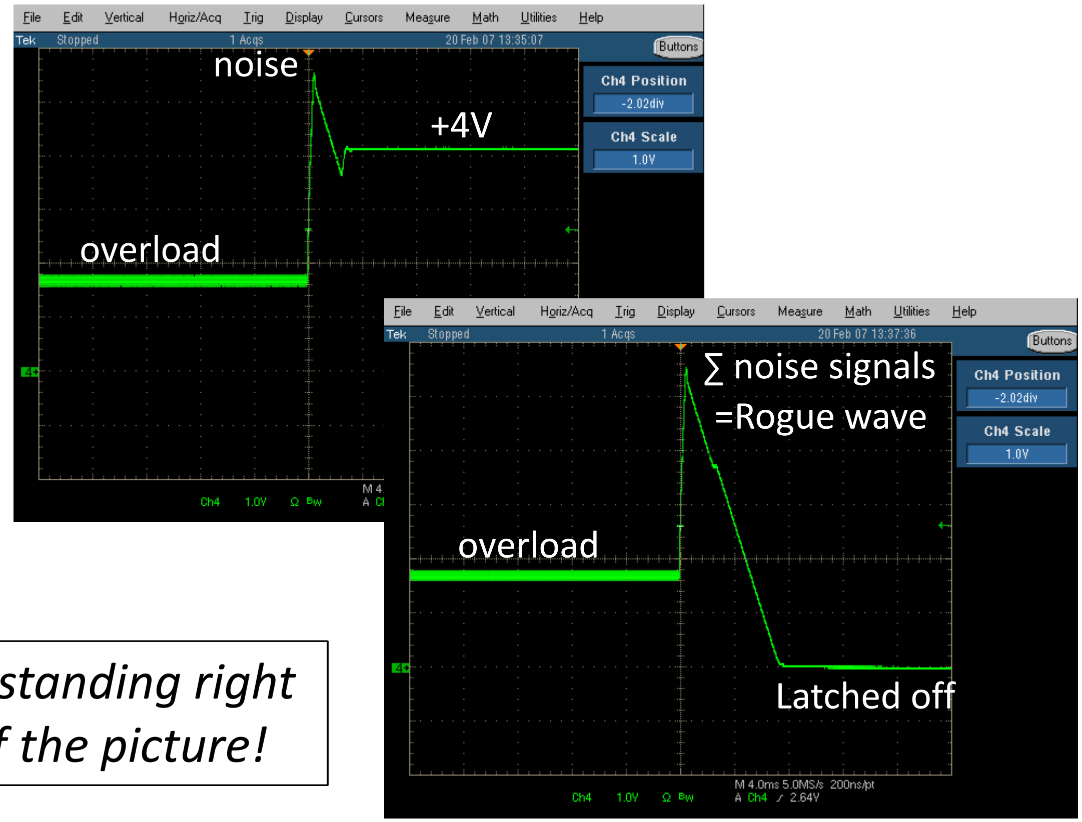
TURN ON OVERSHOOT CONTRIBUTES TO NOISE



THE PERFECT NOISE STORM



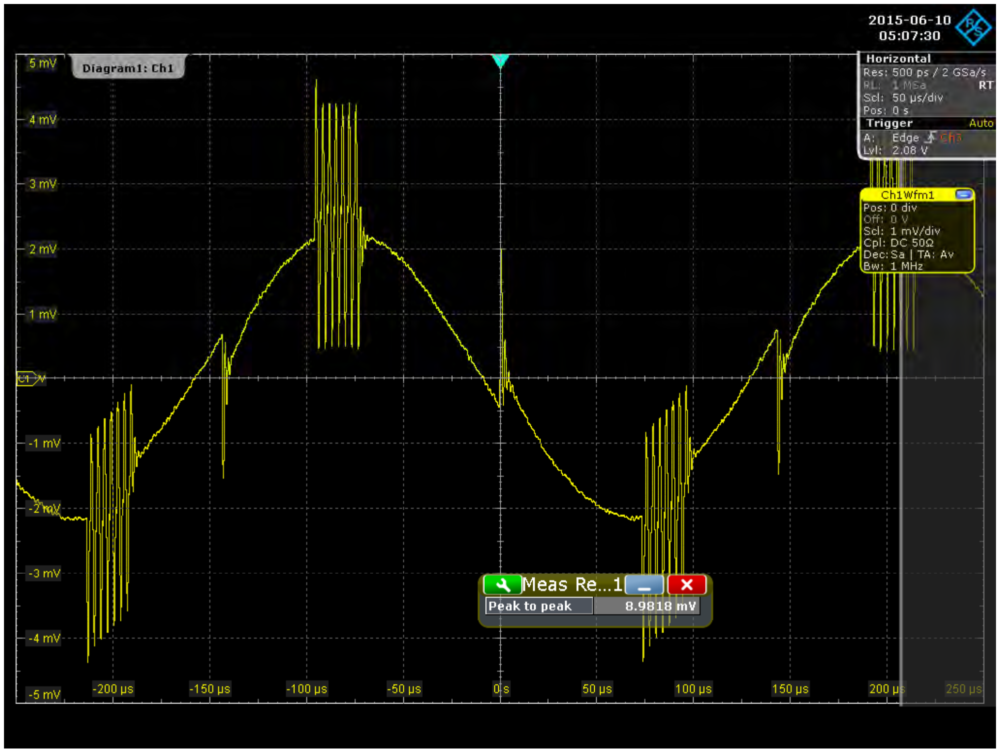
https://c1.staticflickr.com/3/2326/2046228644_05507000b3_z.jpg?zz=1



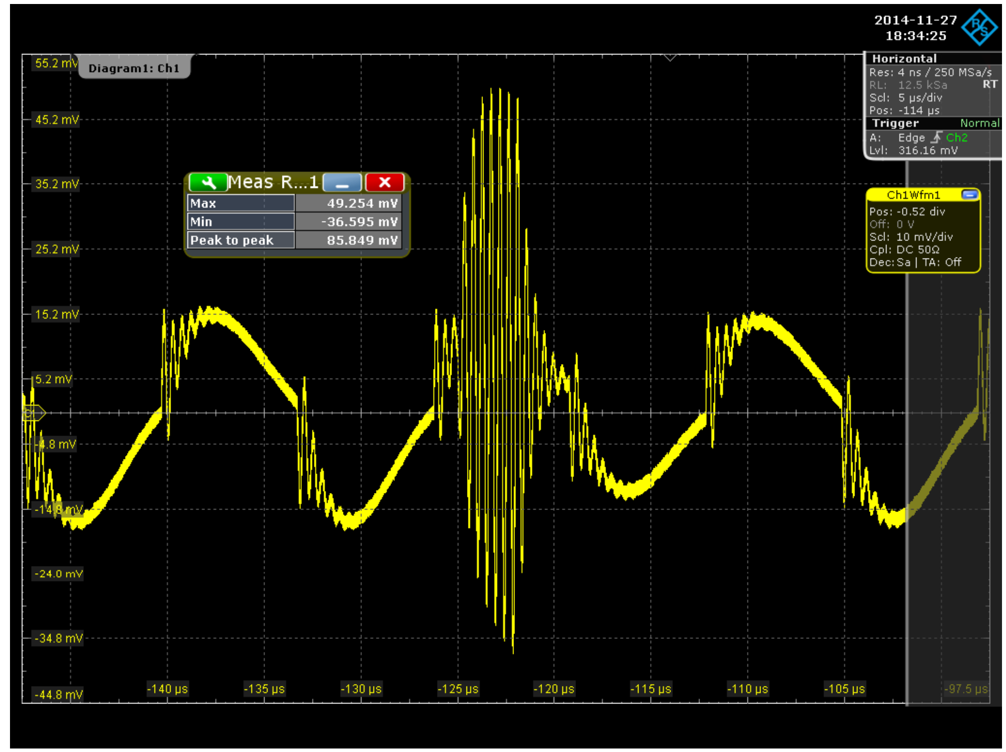
Trivia –The designer of this coil system was standing right in front of this guy and was CROPPED out of the picture!

CHAPTER 5 – SIMPLE ROGUE WAVES

DDR3 Termination regulator evaluation board



PICOTEST VRTS3 Demonstration board - modified



Thanks for Attending!

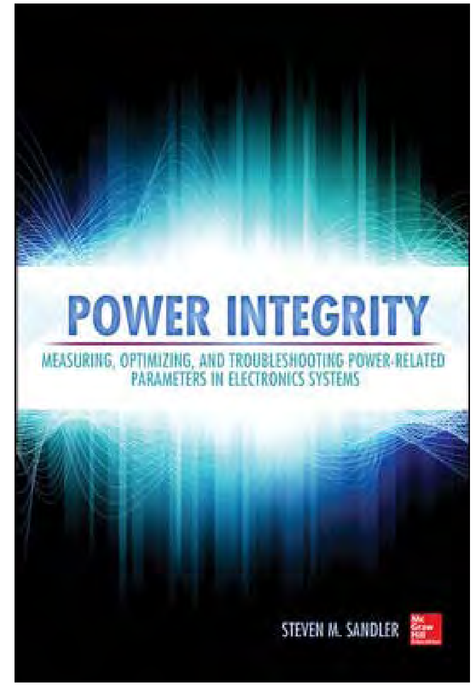
Keysight CERTIFIED EXPERT EDA SOFTWARE

Steven M. Sandler
Managing Director
www.picotest.com
(480) 375-0075

Steve Sandler has been involved with power system engineering for more than 37 years. Steve is the founder of of PICOTEST.com, a company specializing in accessories for high performance power system and distributed system testing.

He frequently lectures and leads workshops internationally on the topics of power, PDN and distributed systems. He is also the other of Power Integrity – from McGraw-Hill

He was also the recipient of the ACE 2015 Jim Williams Contributor of the Year ACE Award for his outstanding and continuing contributions to the engineering industry and knowledge sharing.



Contact me through our LinkedIn group – Power Integrity for Distributed Systems – or email me at Steve@Picotest.com