PACKAGE AND PLATFORM VIEW OF INTEL'S FULLY INTEGRATED VOLTAGE REGULATORS (FIVR)

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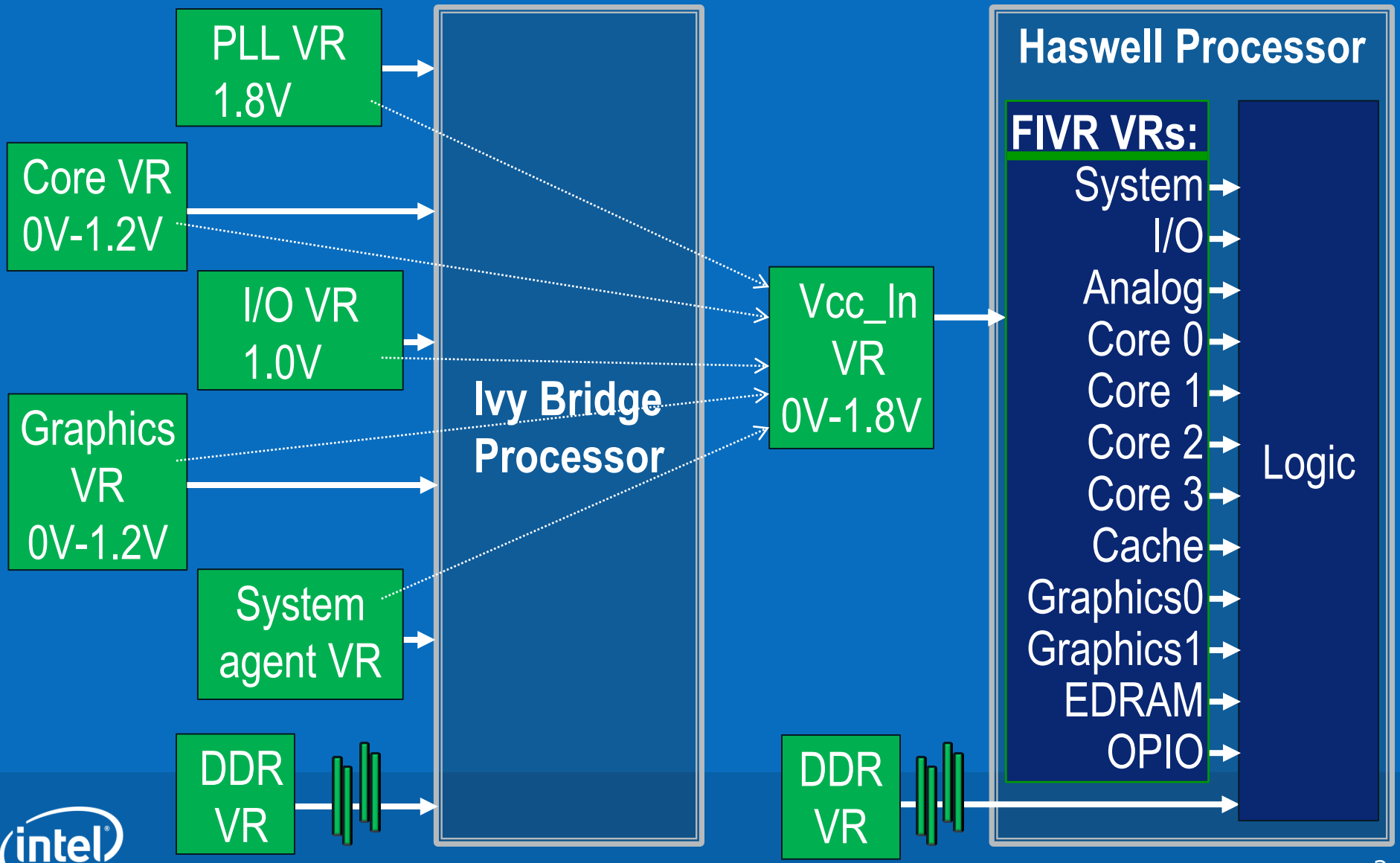
Ivy Bridge Platform Haswell Platform



FIVR At a Glance

- 140MHz switching frequency
- Up to 16 phases per VR
- Up to 80MHz unity gain
- Non-magnetic package trace inductors
- MIM caps
- Silicon current density of 31 Amps/mm^2
- Typical efficiency of 90% in turbo

FIVR Value Proposition

- Platform footprint, cost & thickness reduction
  - Smaller XYZ ➔ more features, thinner handhelds
- Platform power component cost reduction, while doubling graphics, adding EDRAM, doubling vector hardware…

Today's Focus

- Battery life improvement
  - Reports of over 50% increase vs prior generation
- Graphics power-perf improvement
  - Tens of % improvement in constrained form-factors

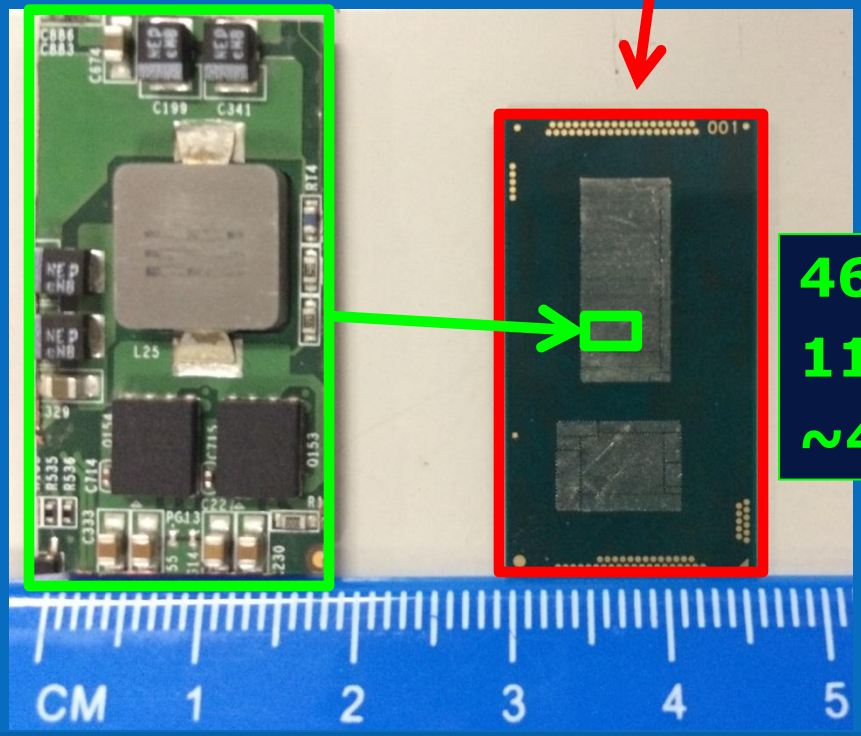
Volume Scales ~1/Frequency

One 30A VR phase, prior generation Ultrabook

300kHz Switcher

800mm^2

CPU and PCH chips plus 7 multi-phase FIVRs 140MHz Switchers 495mm^2

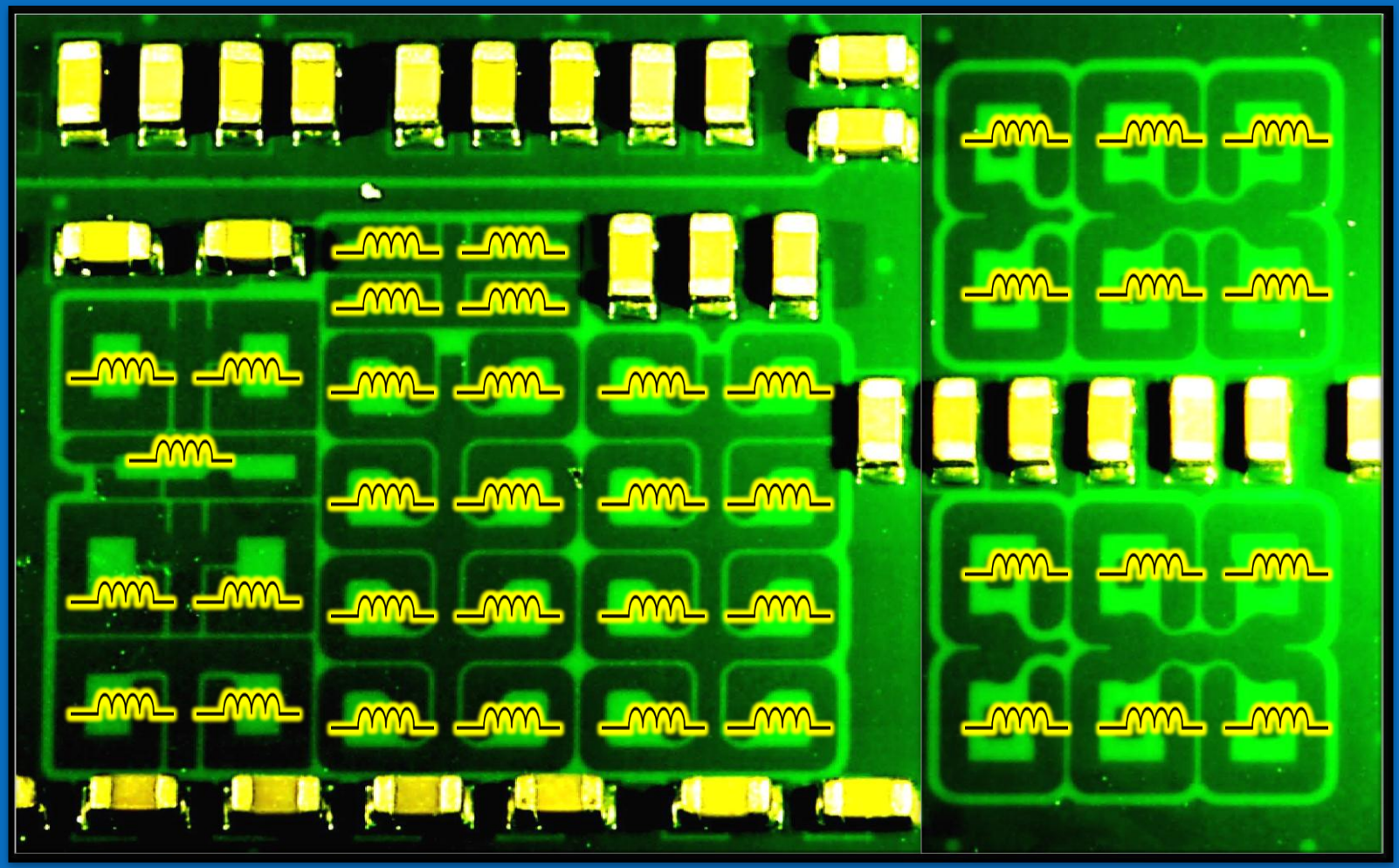


466x Frequency

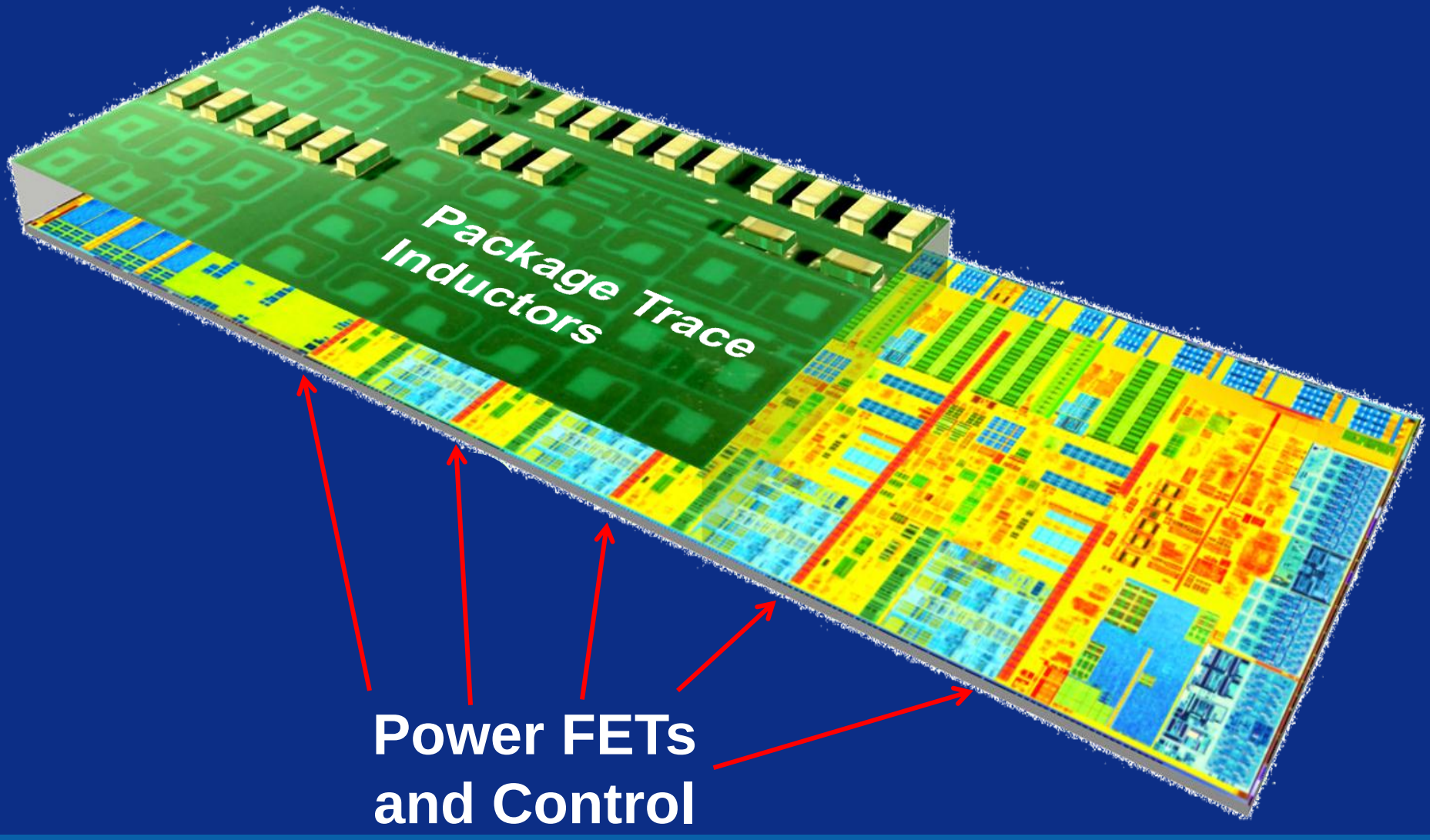
111x area shrink

~4x thickness shrink

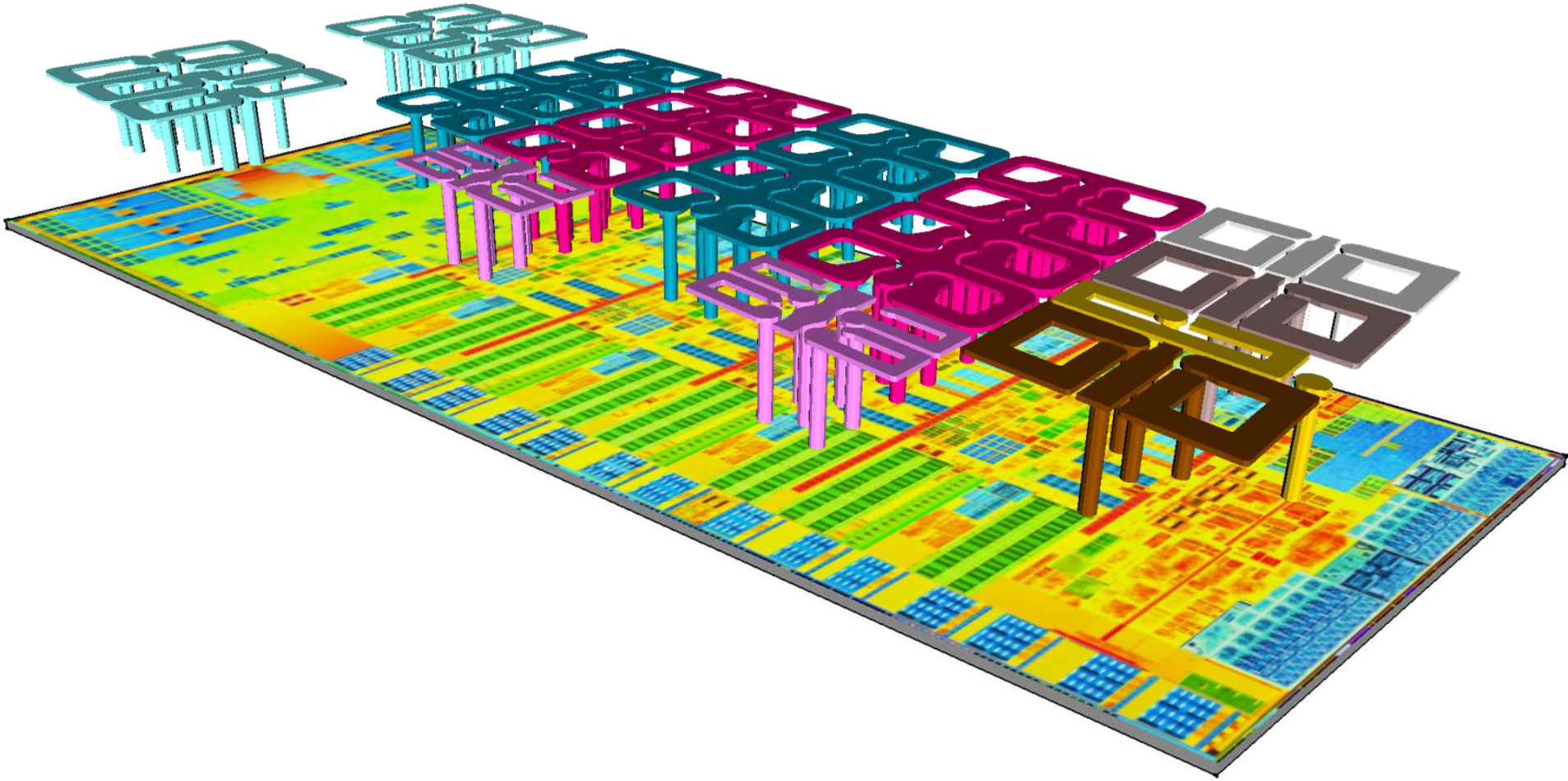
FIVR Photo - Package Underside



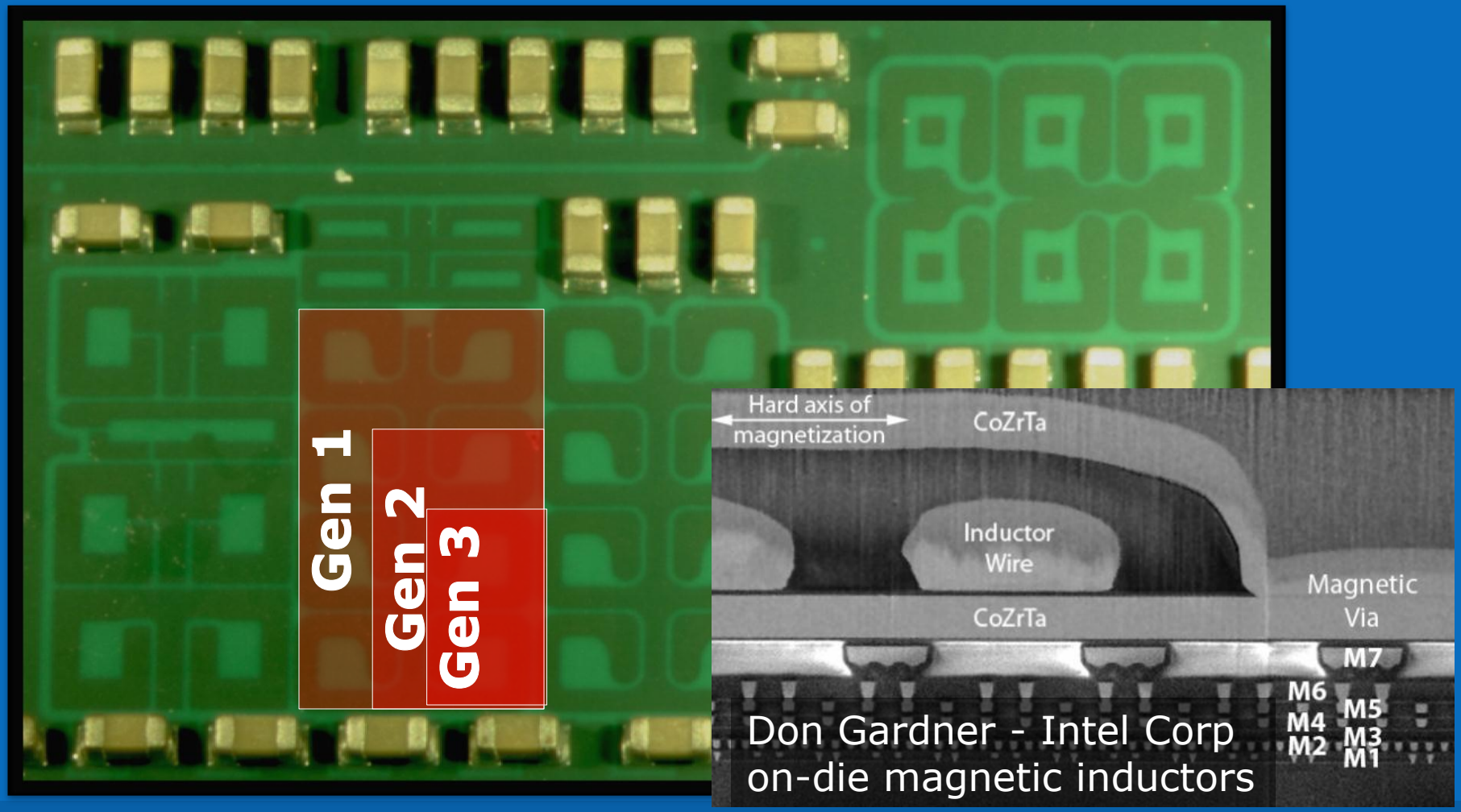
FIVR Cutaway View



XRAY View – FIVR Inductors

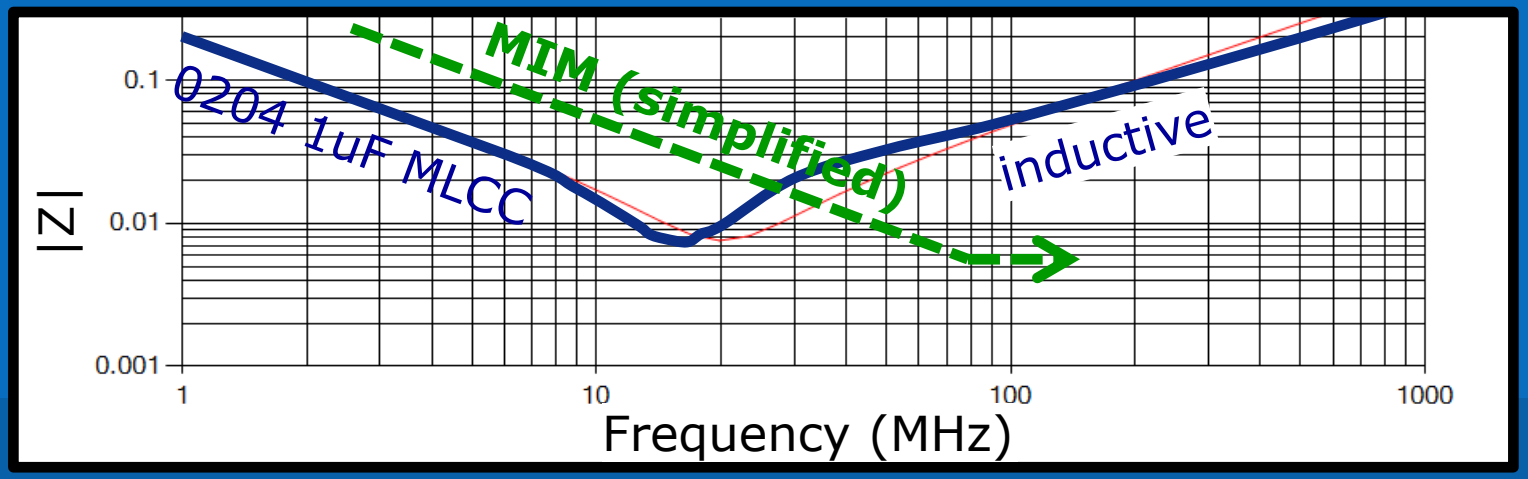


Future Scaling Issue & Solution

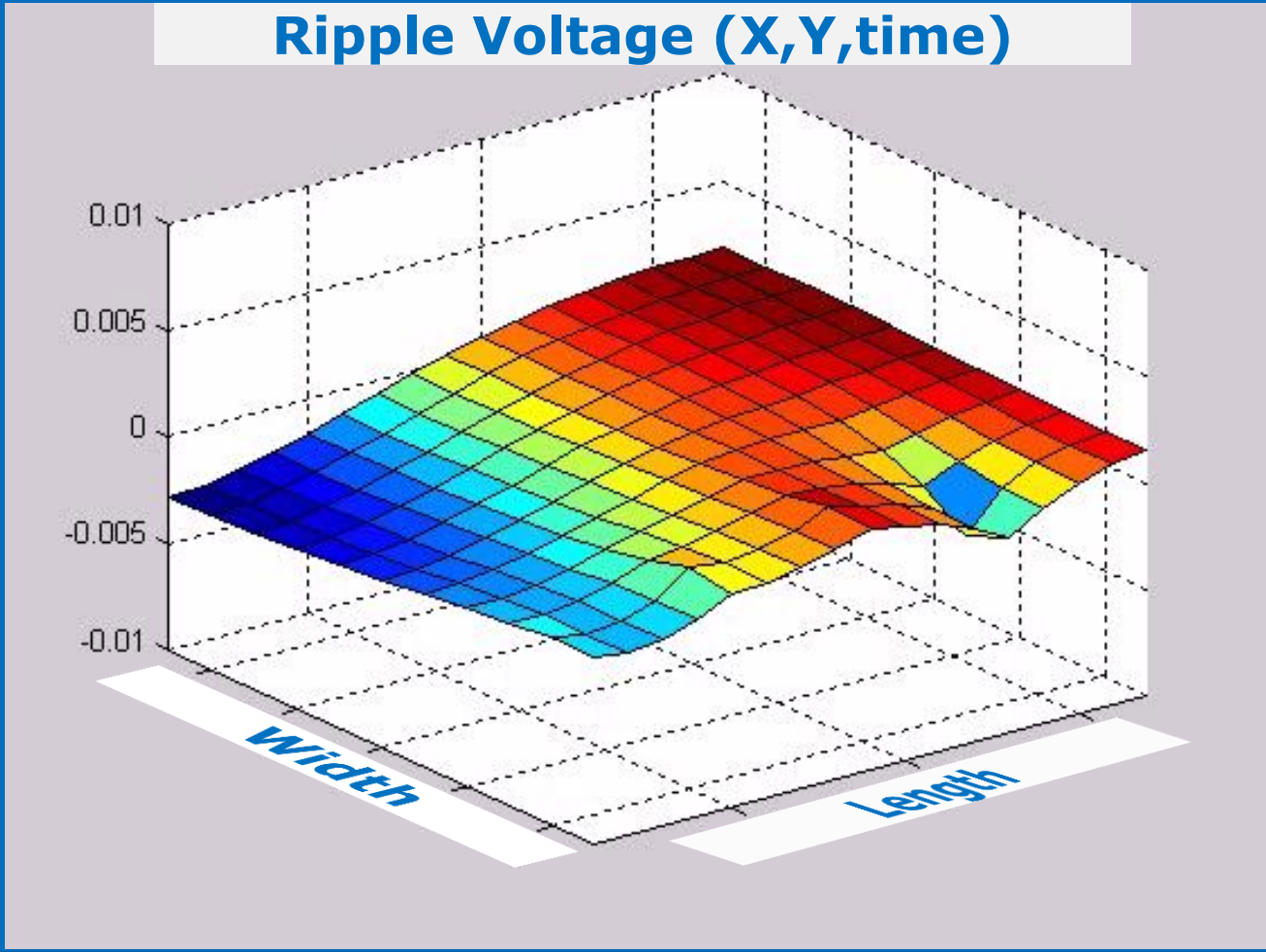


Typical Package Cap vs MIM

- Reverse geometry 0204 1uF cap impedance curve
- Package cap inductance raises HF Z (70 milliohm @140MHz)
  - Needs high frequency parallel die capacitance
- No inductance for uniformly distributed MIM capacitor & uniformly distributed load, so no high frequency increase in Z
  - Nonuniform loads get "complicated"
  - Real loads and real phases are nonuniform



Real Behavior "Complicated"



FIVR ➔ Thinner Handhelds

Ivy Bridge

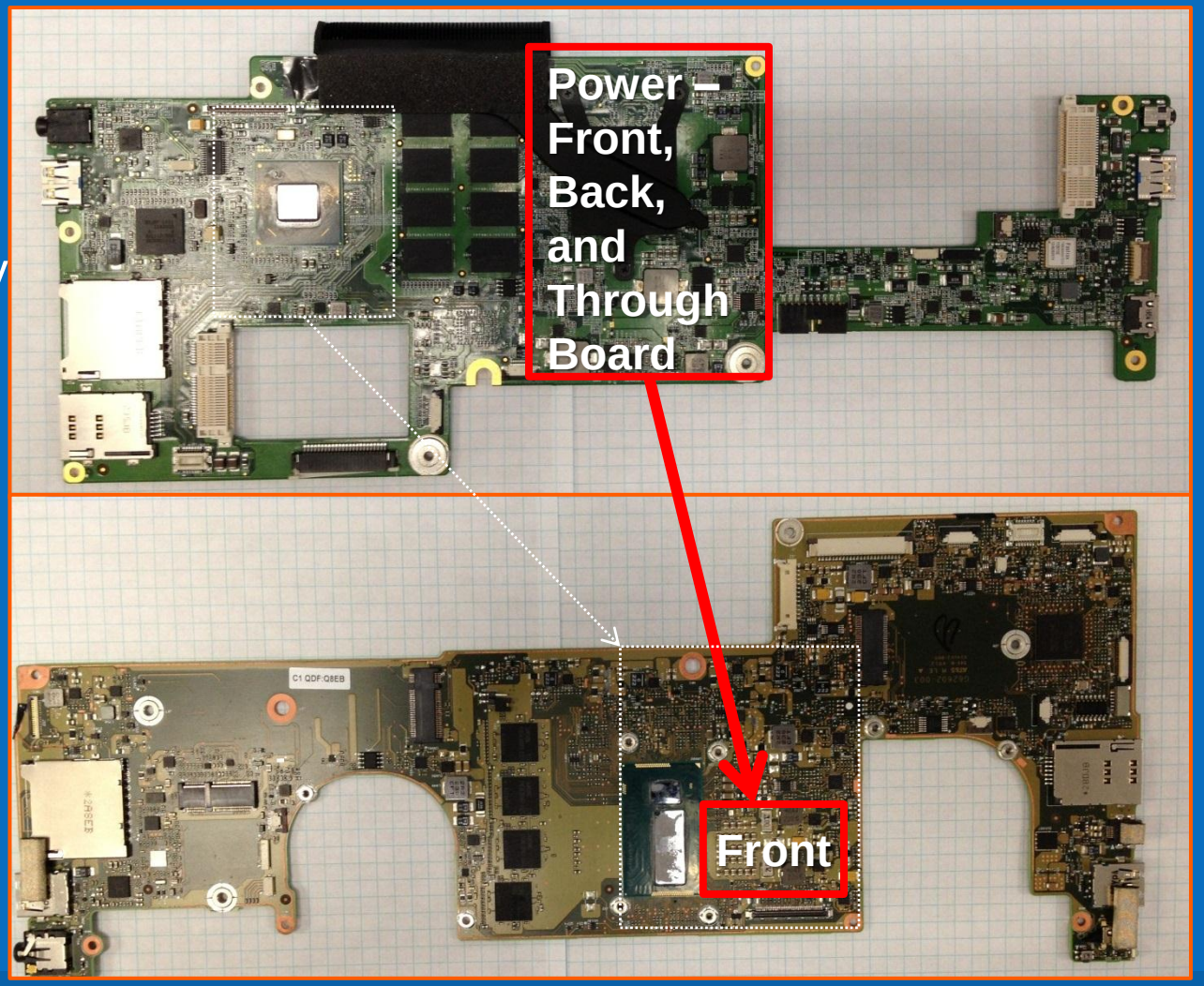
Backside all power

Big inductors, butterfly mounted through board

Haswell

Backside bare

Small inductors & caps & 75% fewer

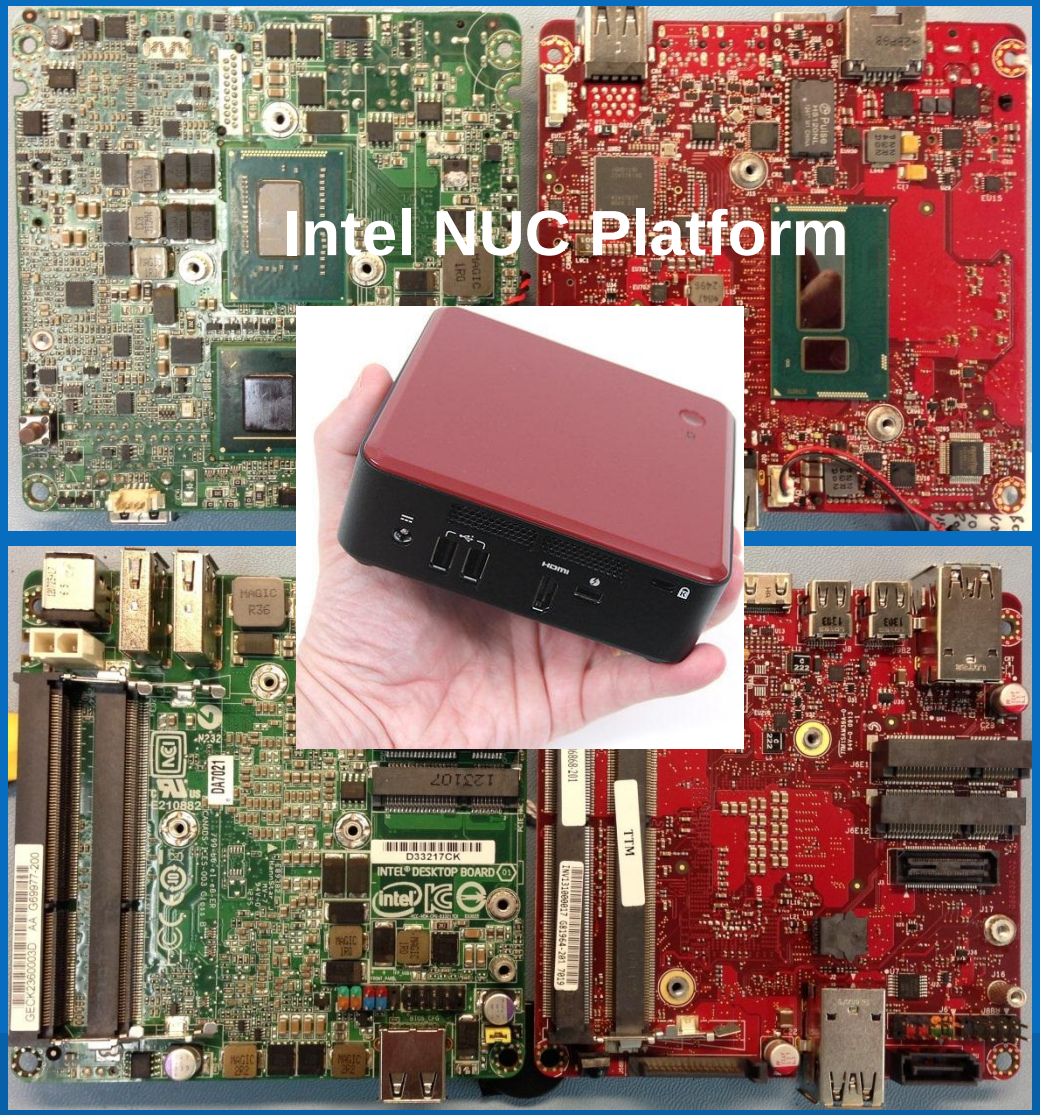


2mm thinner – cheaper - 10% larger battery

FIVR ➔ More Platform Features

Ivy Bridge

- × ~~SATA~~
- × ~~Analog audio~~
- × ~~IR remote~~
- • One USB3.0 two USB2.0
- • LAN **or** Thunderbolt

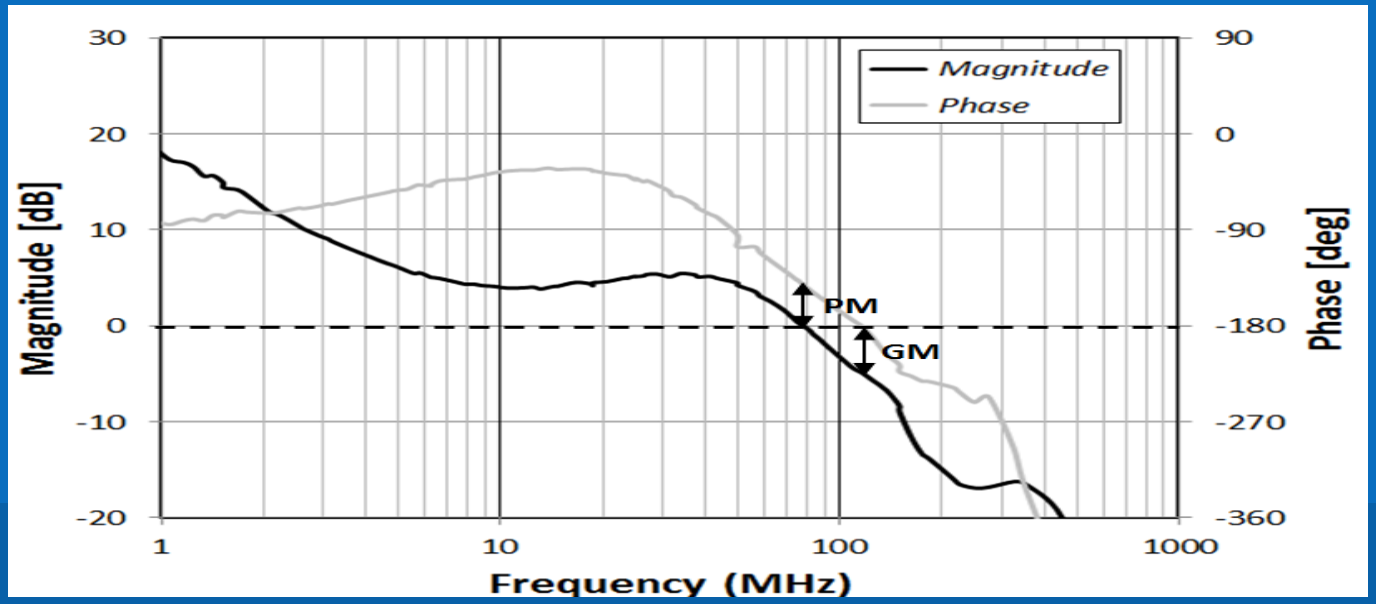


Haswell

- ✓ SATA
- ✓ Analog audio
- ✓ IR remote
- • Four USB3.0
- • LAN **and** Thunderbolt
- • 2x graphics
- • Free space to add more features
- • ~$5 Saved in power BOM

High UGB, Fast Transitions
A Fringe benefit of miniaturization

	Typical prior generation VR	FIVR
Unity Gain Bandwidth	≤ 80kHz	≤ 80MHz
Core and Graphics voltage max transition times	100's of microseconds	100's of nanoseconds



Power States – 2.6-122x Lower

Package State	Actions taken in various Package States	Ivy Bridge CPU power (W)	Haswell CPU power (W)
C0	Cores, Graphics active	17 W (TDP)	15 W (TDP)
C6	Core's and Graphics FIVRs off DDR in self refresh	2.3	0.9 1/2.6
C7	System agent & DDR IO gated off. CPU critical arrays on Sustain Rail.	2.2	0.85 1/2.6
C8	Display & IO FIVRs off. LLC flushed System Agent gated off. Vin = 1.2V.	N/A	0.077 1/29
C9	Vin set to 0V	N/A	0.018 1/122
C10	Platform power target of 100mW or better.		N/A

2x-3x Turbo Power Headroom

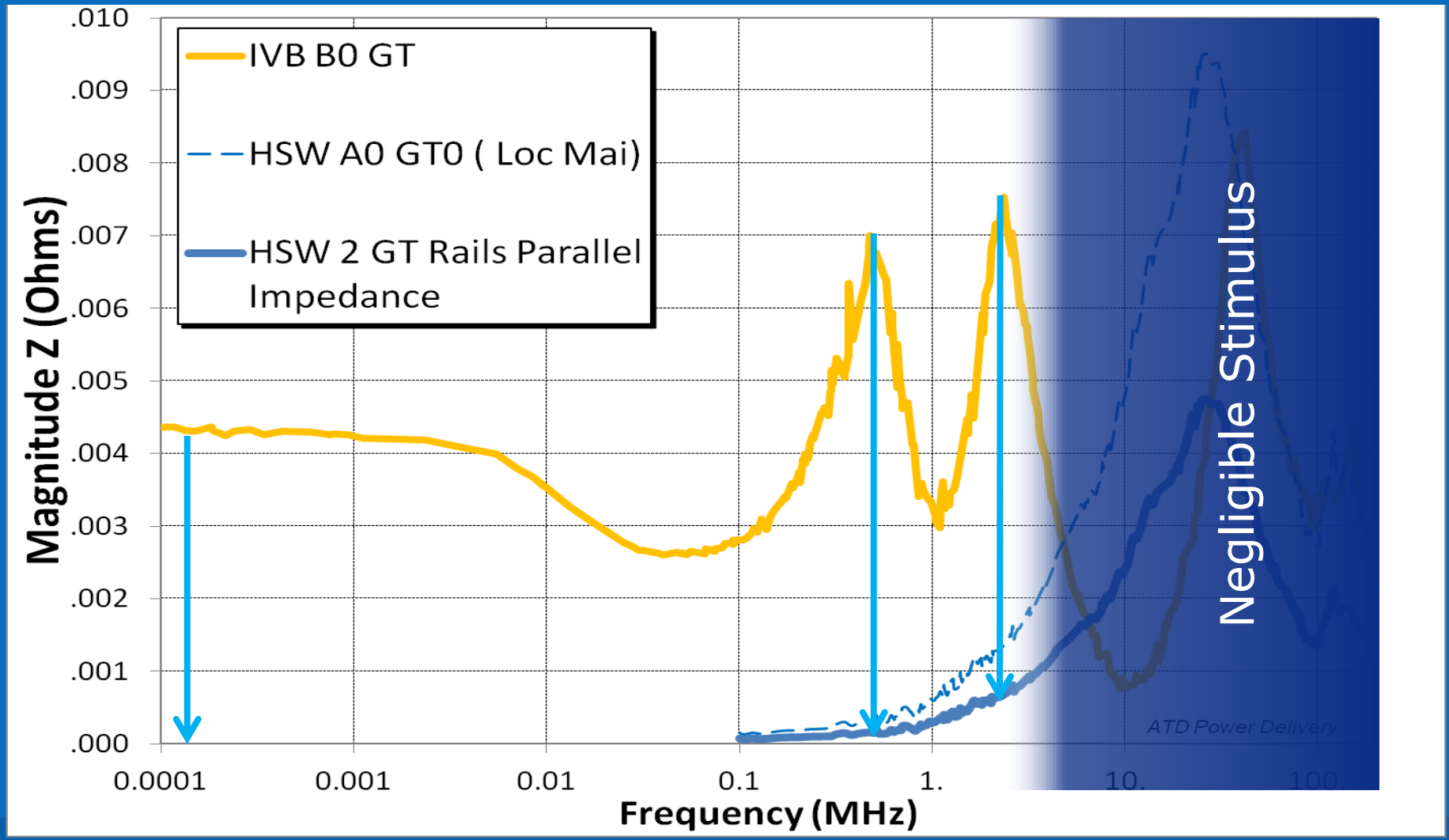
Small platform example:

- Old platform rails 1phase each:
  - Graphics: 30A inductor @ ~1V ➔ ~30W max
  - Cores: 30A inductor @ ~1.1V ➔ ~33W max
- FIVR platform's input rail:
  - 2 30A inductors @ 1.7V ➔ 102W max (shared dynamically)
  - Core-only workloads: Triple the available turbo power
  - Graphics workloads: Double the available turbo power for graphics

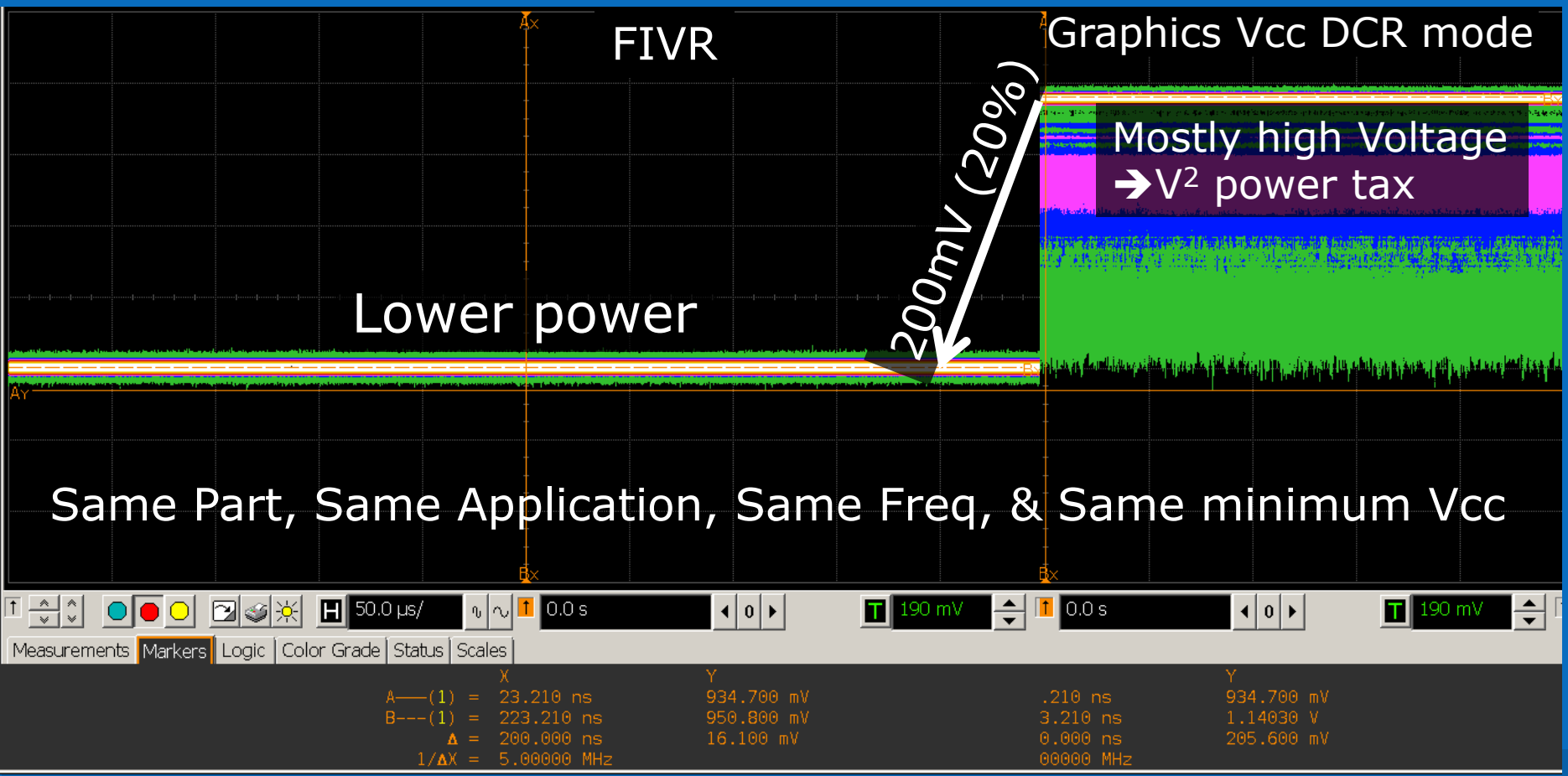
More Turbo Power Headroom ➔ More Performance

- Higher burst frequency
- Larger graphics
- More cores

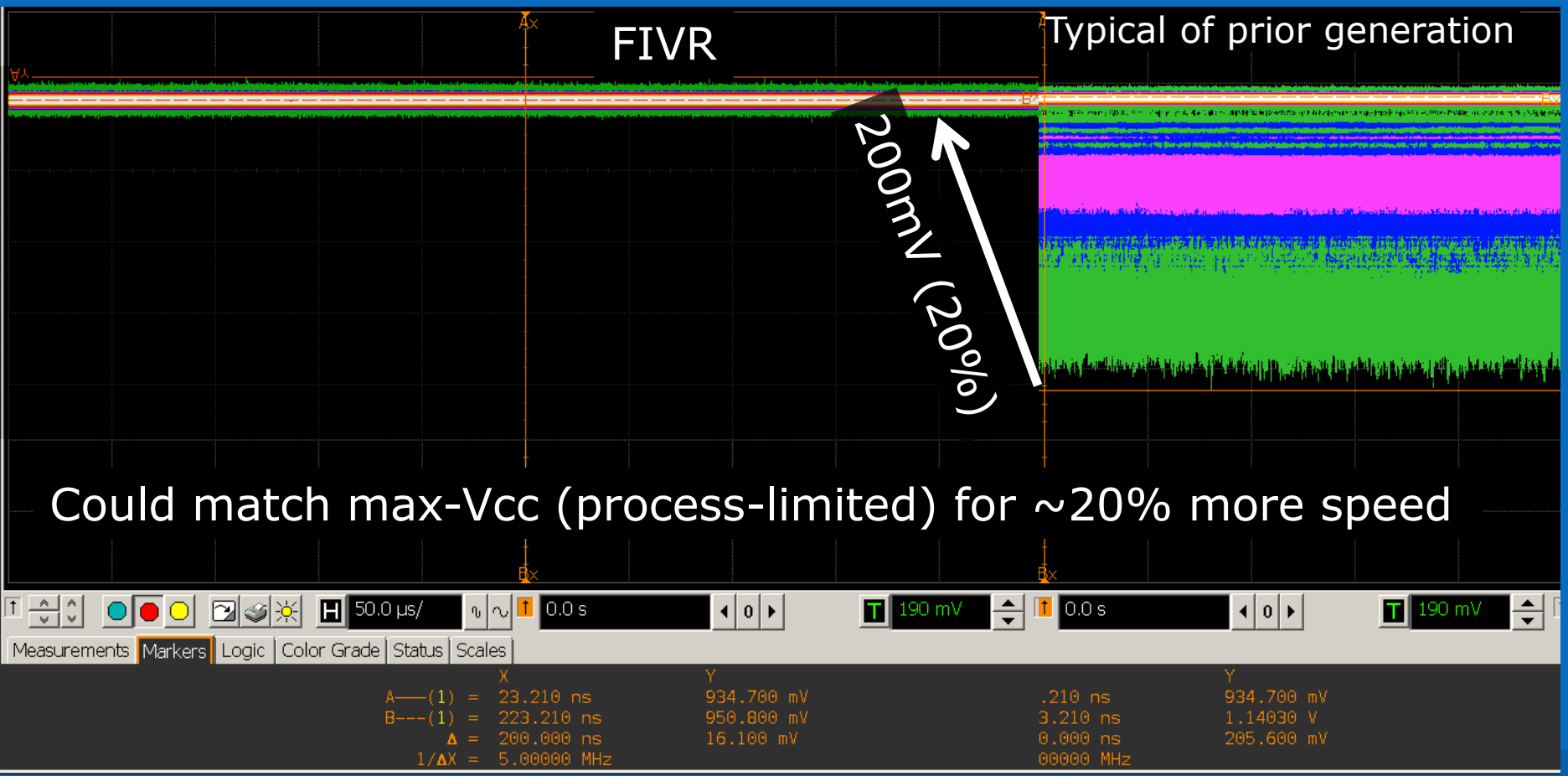
Graphics - 95% Lower Effective Z



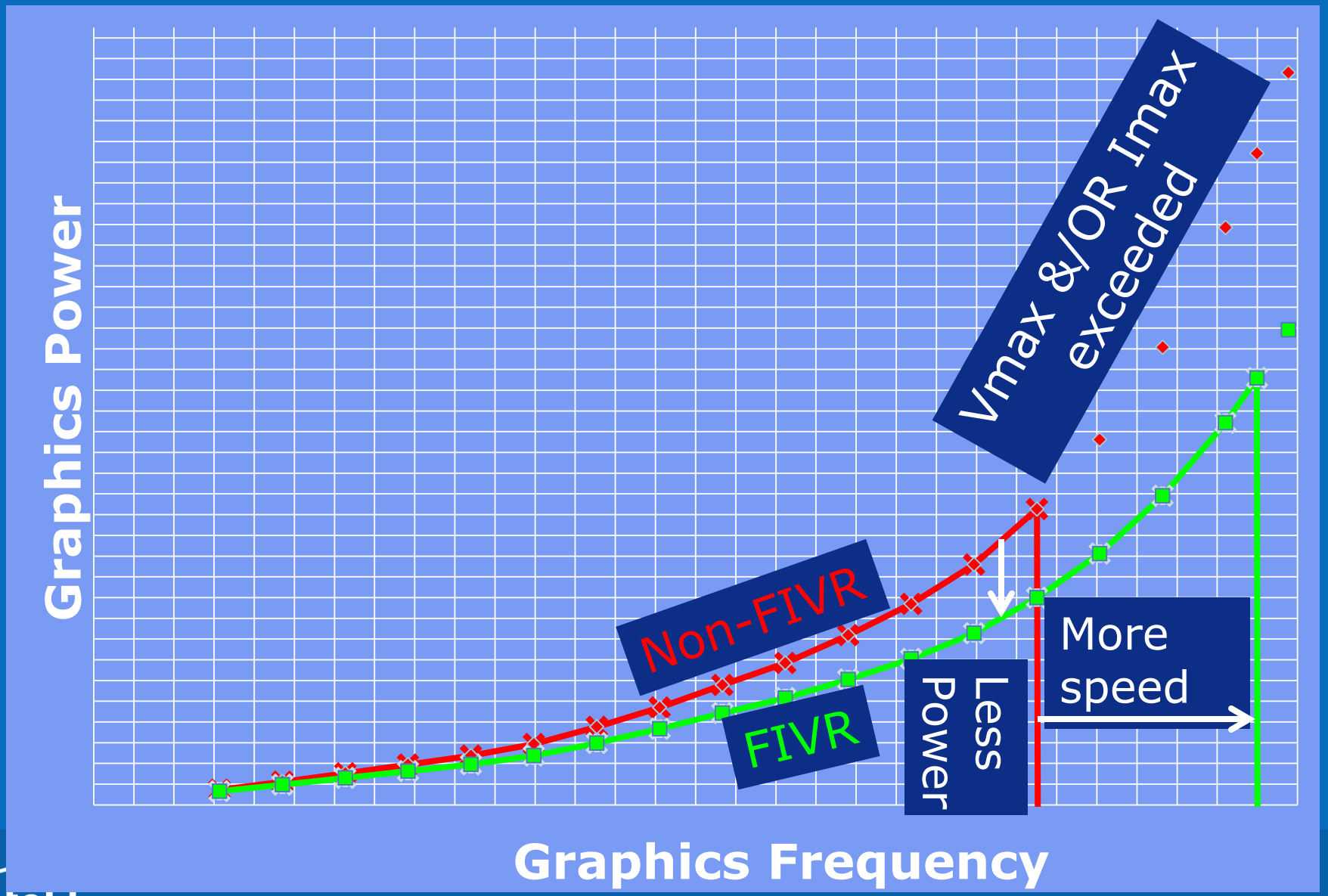
Graphics Power Reduction (Typical Example)



Graphics Speedup (Cut/Pasted Prior Example)



Lower Power, Higher Speed



Summary

- 140MHz switching enables integrated output filters
  - ➔On-die MIM capacitors; package trace inductors
  - ➔Thinner platforms, with more features
  - ➔ Reduced power component cost, while doubling graphics and core vector hardware and adding EDRAM
- Battery Increased life by upwards of 50% on many platforms
  - Quickly ramped input and output rails to support new sleep states
  - Set every rail to its optimal voltage
- Improved graphics power-perf 10's of %

Supporting Slides

90% Efficiency at Full Vout