

Power Delivery for the Next Generation Mobile Platform

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Agenda

The Mobile Notebook Environment

Optimizing for Energy Efficiency

- Battery Life and Energy Star

The Mobile Notebook Power Delivery State of the Art

The Multi-Core Environment & Future Trends

Summary and Conclusions

Optimizing for Energy Efficiency

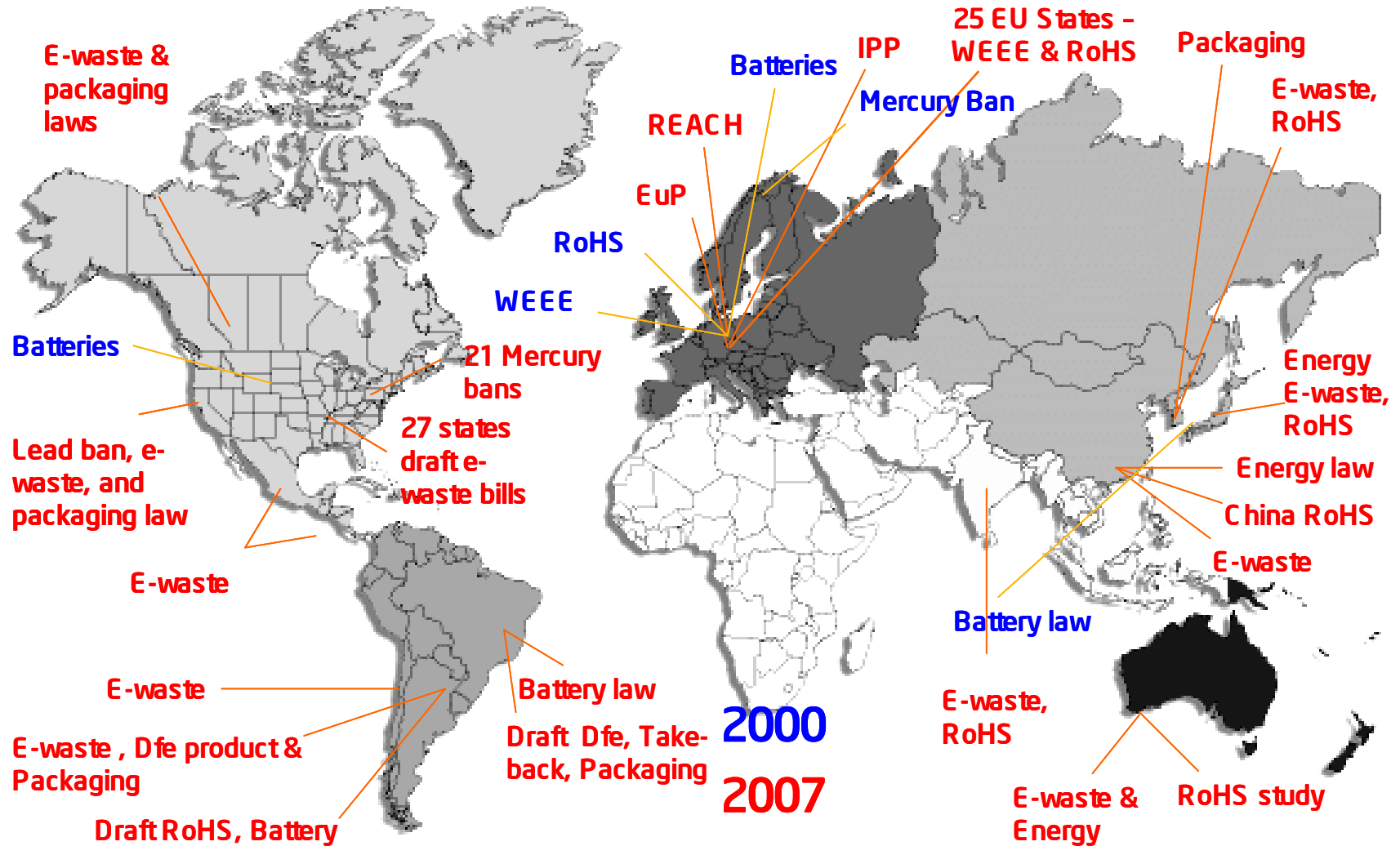
Source: NPD, 2000

Prices of Non-Energy Star vs. Energy Star Appliances

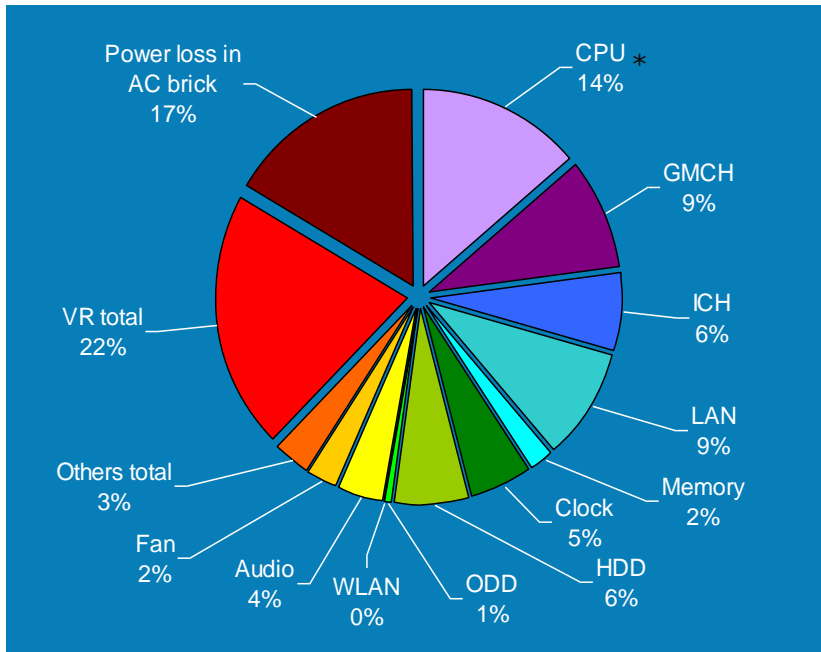
Category	Average Price of Non-Energy Star	Average Price of Energy Star	Energy Star Price Premium
Dishwashers	\$376	\$404	7 %
Air Conditioners	\$257	\$279	9 %
Washing Machines	\$379	\$869	129 %
Refrigerators	\$650	\$1,118	72 %

Energy Star appliances command premium prices. In spite premium, the study indicates consumers are shopping for energy efficiency.”

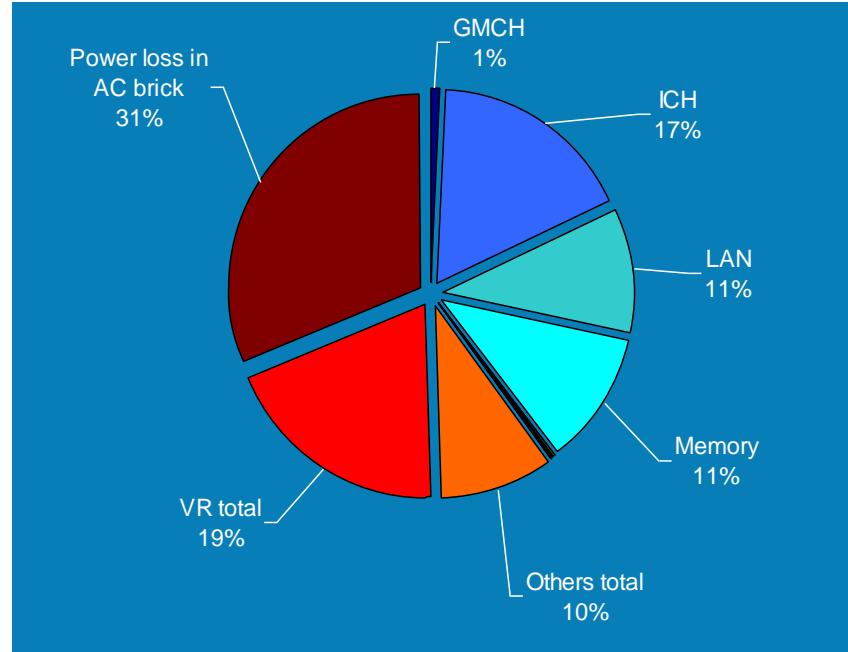
Regulation explodes – EU leading



Optimizing for Energy Efficiency: System Power Breakdown



S0 state



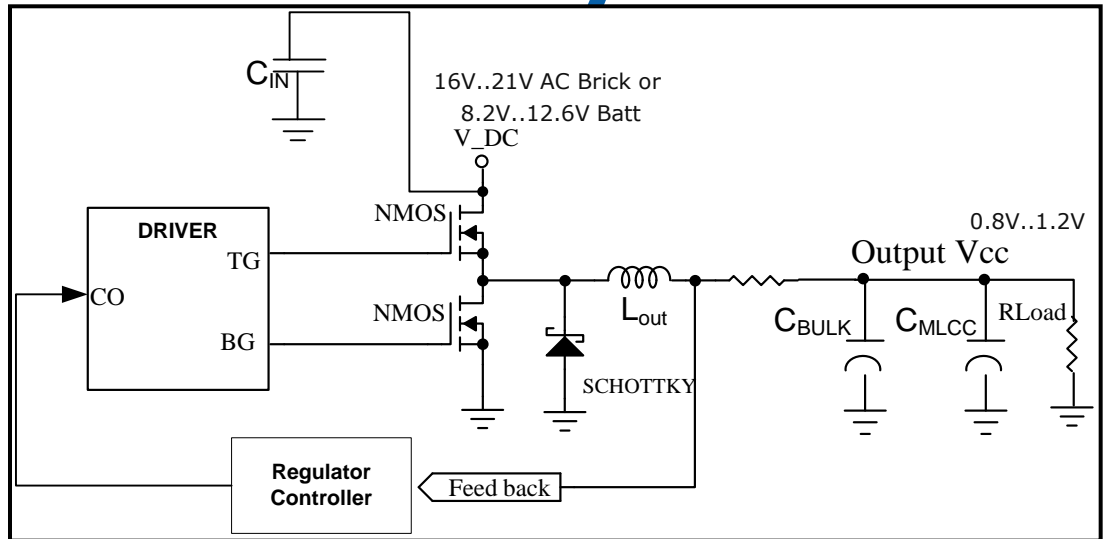
S3 state (WOL enabled)

High power loss in power delivery (AC brick + VRs)

*: Varies depending on the power scheme in AC mode. The chart shows CPU power at C3. With C4/Deep C4 enabled, the CPU power decreases by ~50%.

Typical CPU Core VR Today

- 2-3 phase
- fsw ~300kHz
- BW ~50kHz
- CBULK ~ 4x330uF
- CMLCC ~ 32x10uF
- Real estate ~625mm²
(bulk components only)
- BOM ~ \$6.5
- Efficiency at TDP ~ 86%



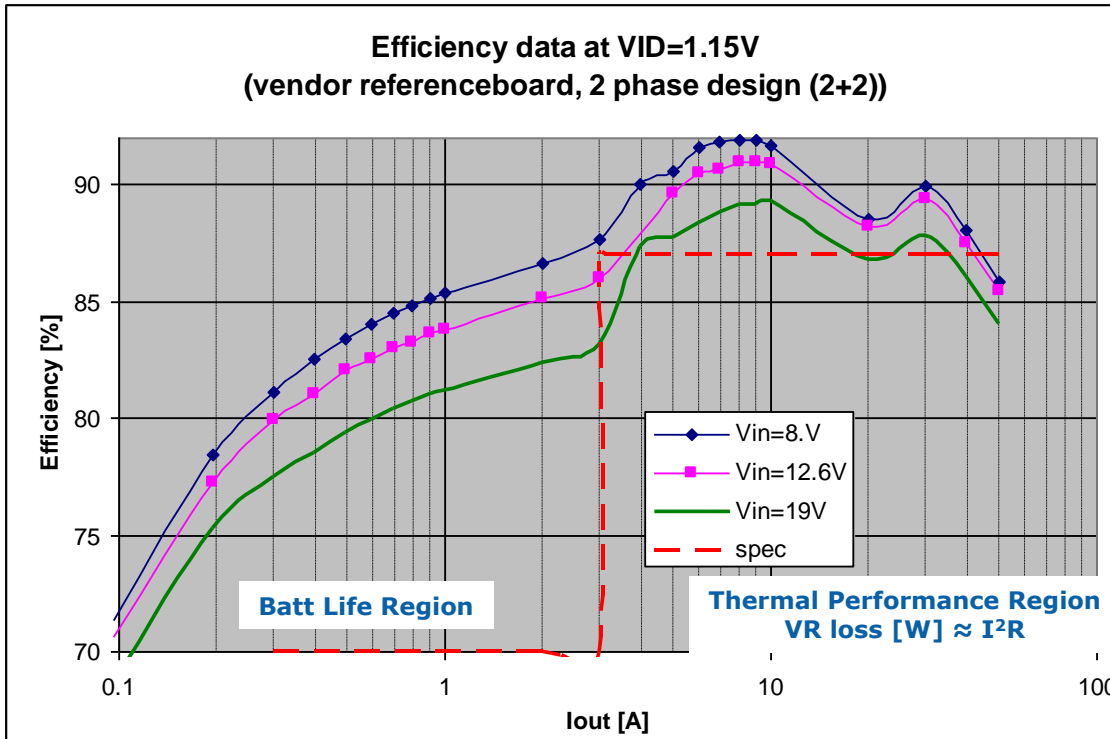
Single phase buck converter

CPU TDP=35W, Vin=19V, VID=1.1125V, -2.1mOhm, 25C

OEM	VR Power Loss (W)	Efficiency (%)	# of phases	FETs per phase
1	5.43	86.56	3	2
2	5.56	86.27	3	2
3	5.52	86.38	2	4
4	5.518	84.28	2	3

*Customers Maximize ROI given
Cost | Area | Efficiency | Performance Tradeoffs*

Typical VR Efficiency Specification

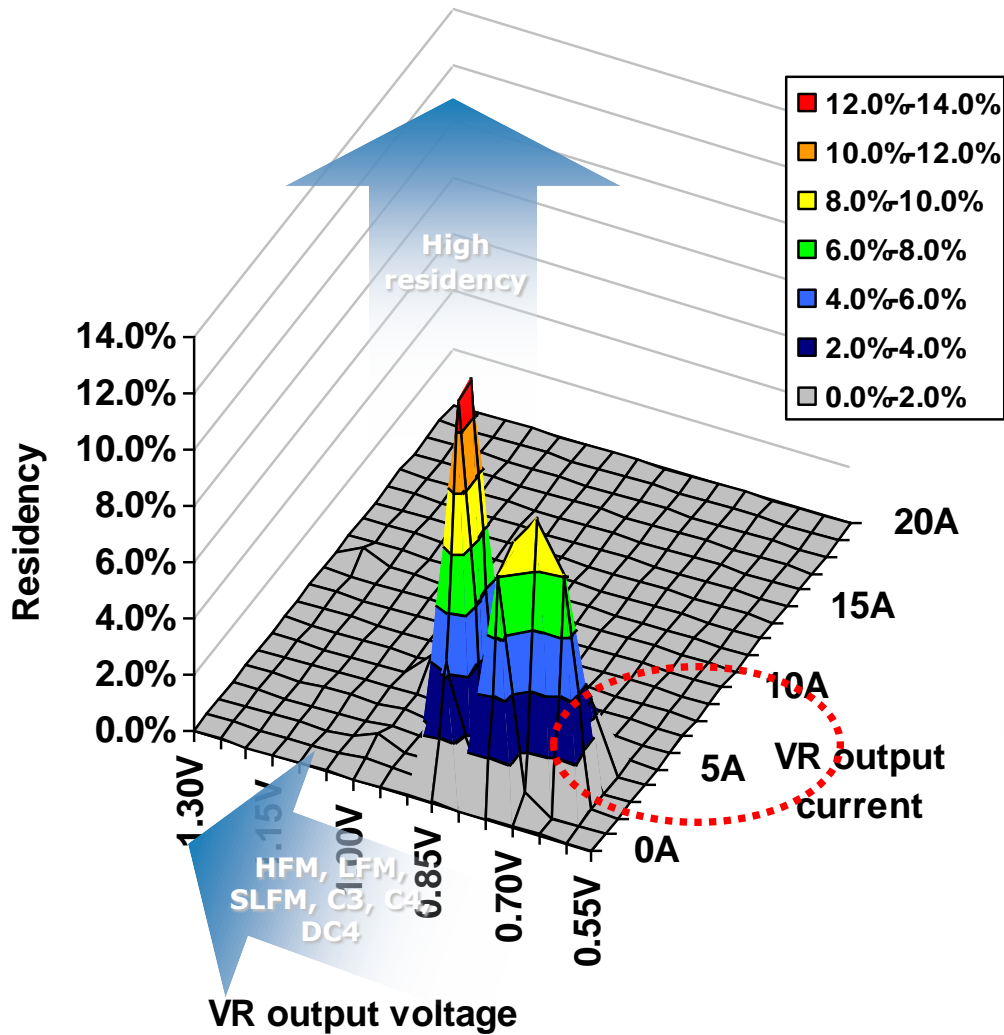


Efficiency optimized over full load range:

- Full load – all phases on
 - Mid load – single phase on
- Light load – DCM, PFM

State	Efficiency Target	ICC-CORE Level
Sleep	>70%	$0.3A \leq I_{CC-CORE} \leq 3A$
Sleep	> 70%	$3A \leq I_{CC-CORE} \leq 9A$
Active Mode	> 87%	$9A \leq I_{CC-CORE} \leq 18A$
Active Mode	> 87%	$9A \leq I_{CC-CORE} \leq TDC$

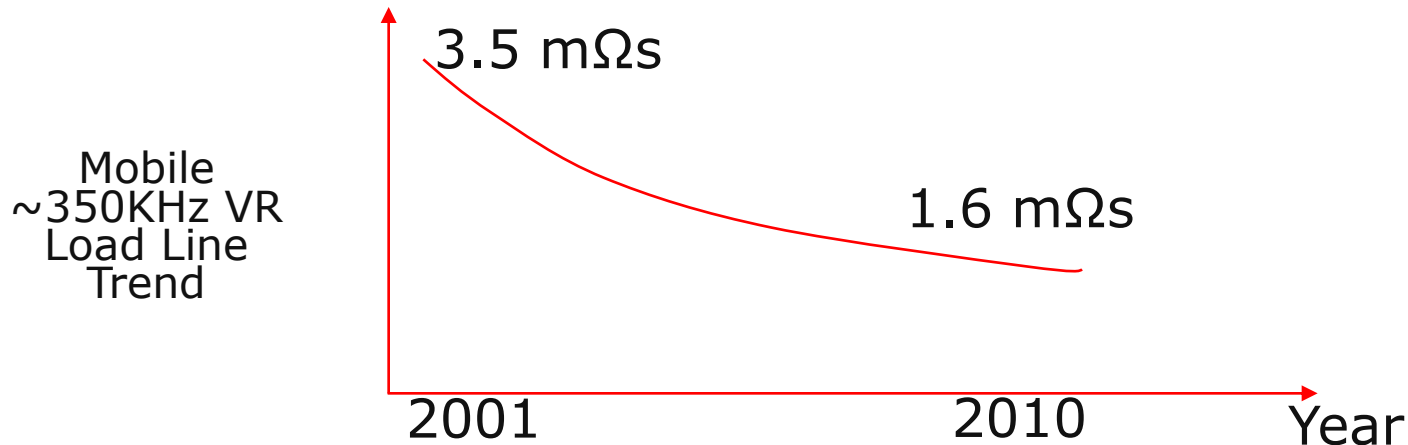
3D Histogram for IMVP Workload Analysis



Very high residency at low power in typical laptop usage models (DVD playback, office productivity, Energy Star)

Optimize the VR efficiency for light workload

Mobile VR State of the Art



- 300KHz Switcher unlikely to get better Output $|Z|$ (Load Line) performance for next few years
- Limited by Cap technology and routing losses
- For lower Load Line, a new sweet spot of VR performance must be attained

Summary: VR State of the Art

Load line from Regulator to CPU ~ 1.5 mOhms

- Nearly 75mV (7.5% frequency loss)

Single Rail, Single Stage 12-1V

Switching Frequency < 500 kHz

- High frequency caps needed to clamp MHz range noise below the load line

VR Efficiency $\sim 87\%$ @TDP, 70% at Low Current

- ~ 5 W TDP loss for a mainstream mobile 35W CPU
- ~ 1 W TDP loss on the board

What is Desired

Multi-Core Computing Creates an Opportunity for a Multi-Rail Configurable VR

- Independent rail control can improve average power
- Independent rails without configurability hurts Enhanced Dynamic Acceleration Technology (EDAT)
- Therefore, there is a need for granularity & configurability

Shallower Load Line improves Performance and/or Thermal Design Power (TDP)

- What not ~ ZERO mOhms?

Efficiency improvements significantly help battery life, TDP, and/or performance;

- Need to improve efficiency @ TDP and low current to meet future Energy Star Requirements

Board space is premium, especially in small form factor segments

- Large voltage step conversion could reduce space but reduces Efficiency
- Alternatively, two stage step conversion may also provide space reduction

Summary

Energy efficiency getting more prevalent for business and regulatory reasons

Power Delivery is a Big Factor in Improving Platform Efficiency

Significant gap between State of the Art and Desired Roadmap for power delivery

- Need non-linear improvements in VR technology

THANK YOU