

# Three Levels of Power Management

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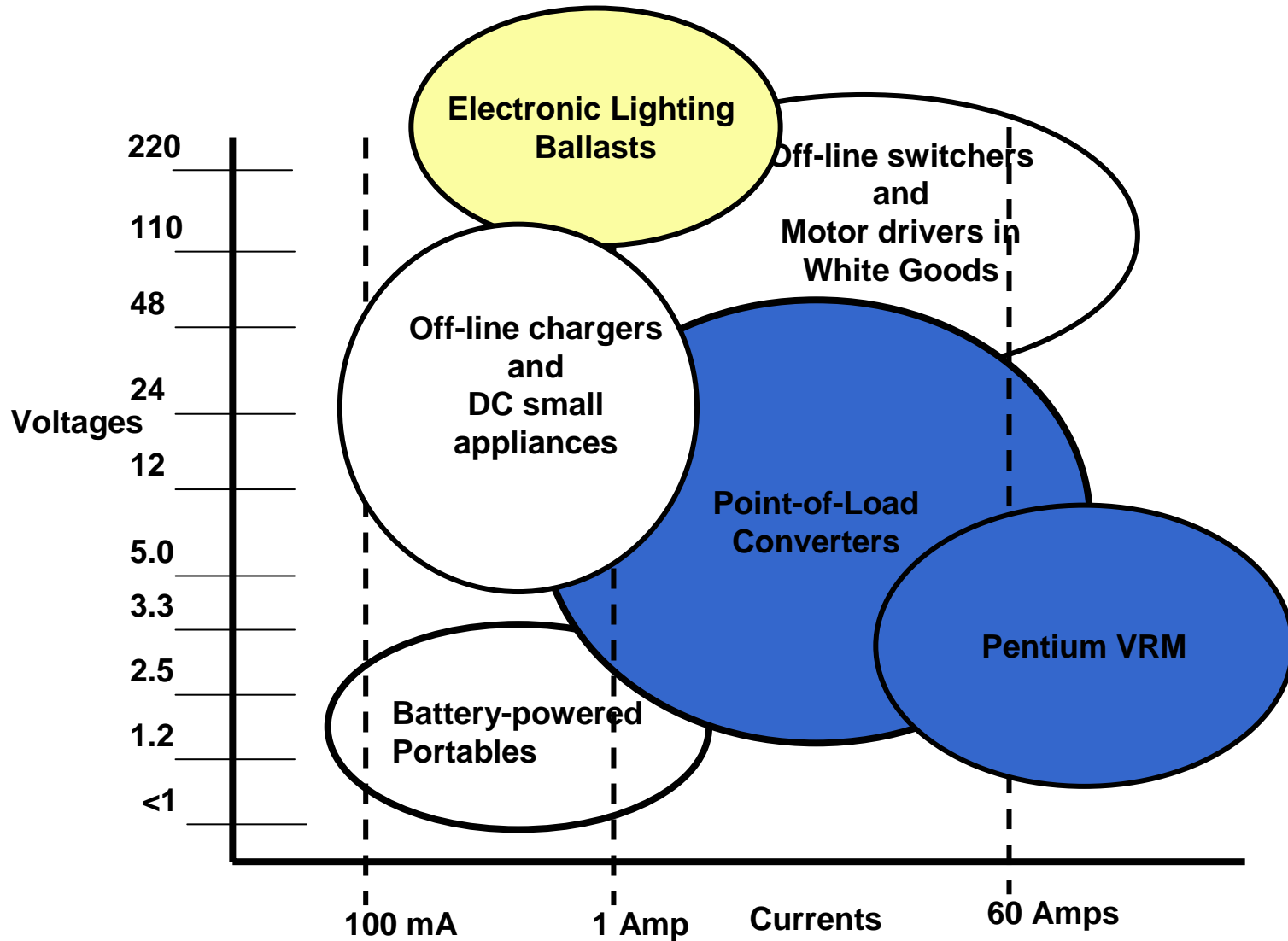
# Agenda: A focus on semiconductor devices

- Defining Power Management
  - A superset of voltage regulation
  - Where efficiency is the key concern
- Three levels of Power Management
  - Energy transfer in buildings and home appliances
  - Point-of-Load converters in large computer systems
  - Voltage regulators in battery-powered portables

# Who worries about efficiency (and why)?

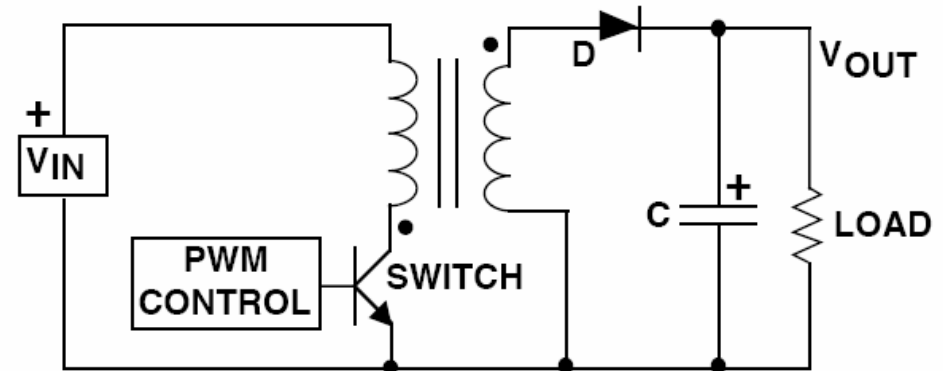
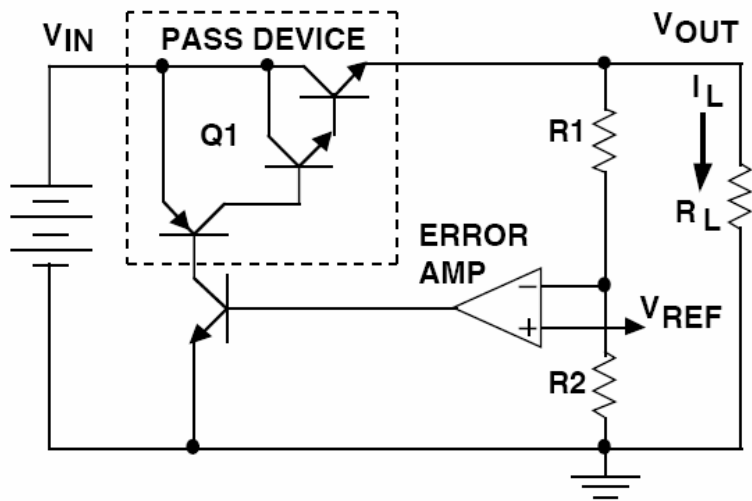
- Under electronic control home appliances could save billions of dollars in energy costs
- Point-of-load (POL) controllers seek to minimize heat dissipation in servers and switching stations
- Low-voltage regulators promote battery life in feature-laden cell phones

# Applications of Power Management ICs



Source: Gartner Dataquest (October 2005)

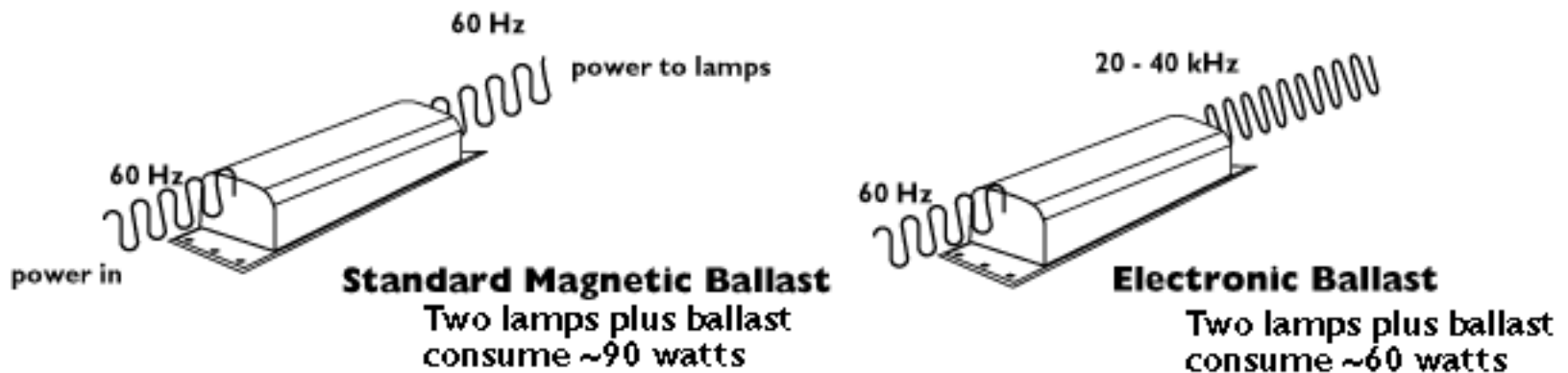
# Linear vs. Switching regulator topologies



Despite noise issues, efficiency favors switching technology

Source: National Semiconductor

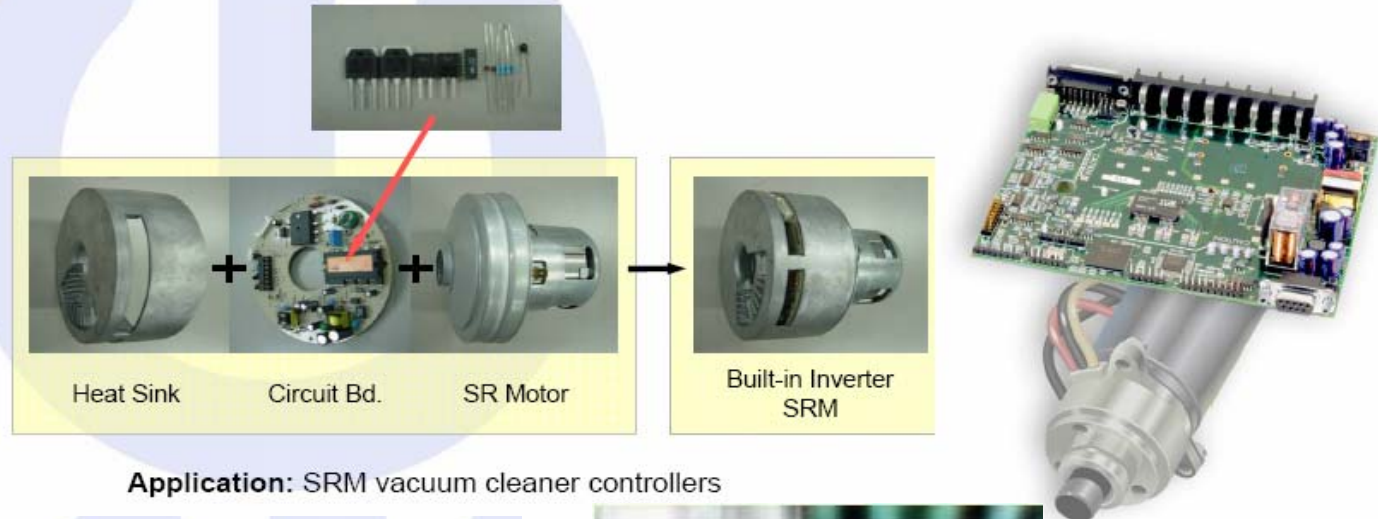
# Electronic Lighting Ballasts work like switchers



- Lamp manufacturers specify lamp electrical input characteristics (lamp current, starting voltage, current crest factor, etc.) required to achieve rated lamp life and lumen output specifications.
- Semiconductor manufacturers supply the high-voltage MOSFETs and toggle circuits that drive the ballast.

# IGBTs, Power MOSFETs and Controllers increase the efficiency of motors in home appliances

Source: Fairchild Semiconductor



Application: SRM white goods controller



Application:  
Variable-reluctance motors

# Improving the standby efficiency of offline power supplies

Consume less than 1 watt in standby?

APPLICATION	CIRCUIT	OUTPUT		P <sub>OUT</sub> @ 1 W INPUT (W)		P <sub>IN</sub> @ NO-LOAD (W)		MEETS 1 WATT	MEETS E.C.
		W	VDC	115 V	230 V	115 V	230 V		
AC Adapter/Charger	EP-14	3 W	9 V	0.70 0.58	0.09 0.20	✓	✓		
AC Adapter/Charger	EP-16	2.75 W	5.5 V	0.70 0.66	0.21 0.25	✓	✓		
High Speed Digital Modem	EP-18	10 W	3.3 V, 5 V, 30 V	0.36 0.34	0.48 0.52	✓	N/A		
DVD	EP-29	11 W	3.3 V, 5 V, ±12 V	0.73 0.69	0.02 0.028	✓	N/A		
AC-DC Power Supply	EP-34	30 W	12 V	0.67 0.59	0.16 0.27	✓	✓		
Home Appliance	EP-8	1.2 W	12 V	0.70 0.68	0.05 0.09	✓	N/A		
LCD Monitor/TV Adapter	EP-33	45 W	12 V	0.67 0.56	0.17 0.29	✓	✓		
Set-top box	EP-13	43 W	3.3 V, 5 V, 12 V, 18 V, 30 V	--- 0.13	--- 0.70	✓	N/A		

Source: Power Integrations



# Many competitors in a slowly-growing market

## Device Types, Functions Performed and Selected Vendors )

Devices	Functions	Vendors
Power factor correction (PFC) devices	Aligns AC current and voltage waveforms for great efficiency	International Rectifier
Rectifier diodes	Converts AC waveforms to DC pulses	STMicroelectronics, Semtech, Vishay and Toshiba
IGBTs	Specialized high-power transistor meant to drive inductive loads (motors)	STMicroelectronics, Hitachi, On Semi and Microsemi
Bipolar power transistors	Current amplifiers	On Semiconductor, Fairchild Semiconductor and STMicroelectronics
MOSFET power transistors	Switching transistor used to drive high-current pulses	Vishay, International Rectifier and Toshiba
Power controllers	Pulse generator with power transistors on-chip (or in-package)	Fairchild, Vishay and International Rectifier

# Factors affecting implementation

- Government and utility company incentives

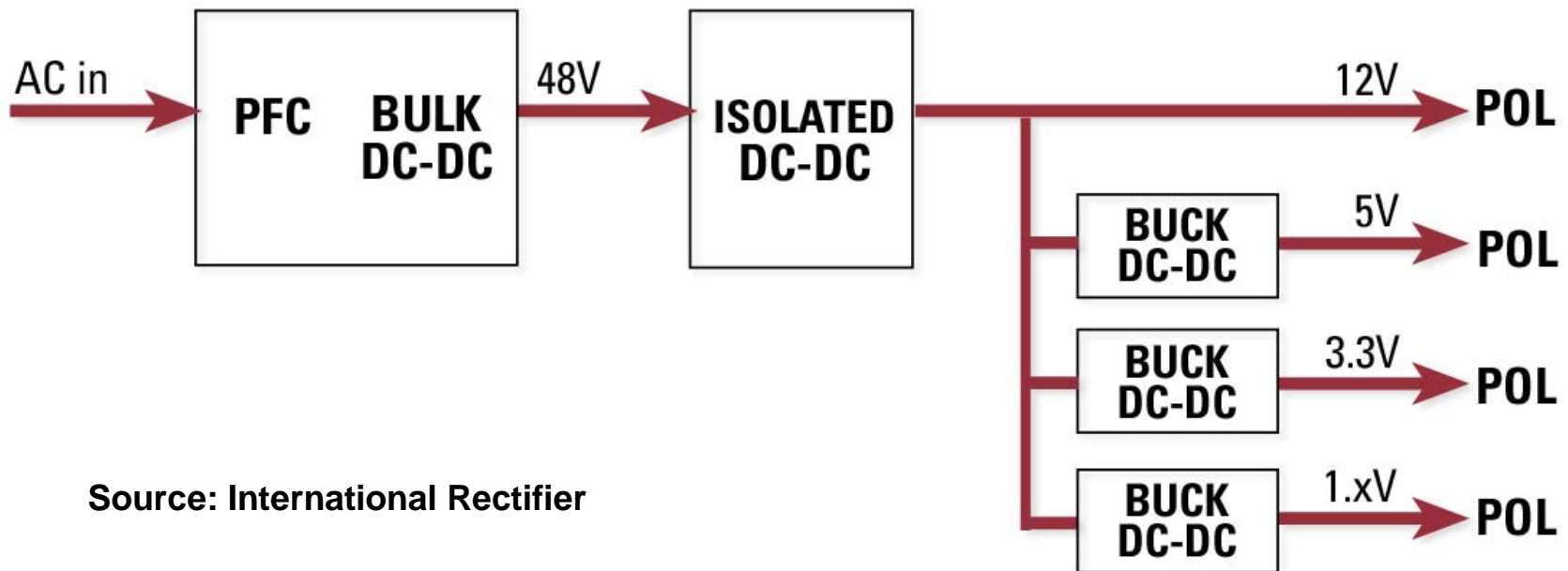
- Energy Star
- Blue Angel (Germany)
- Energy 2000 (EU)
- California Energy Commission



- The “feel good” factor (e.g. Toyota’s Prius)
- Projected energy shortages have not impacted semiconductor growth favorably or unfavorably
- Conclusion: The adoption of energy-saving electronics in home appliances will remain slow

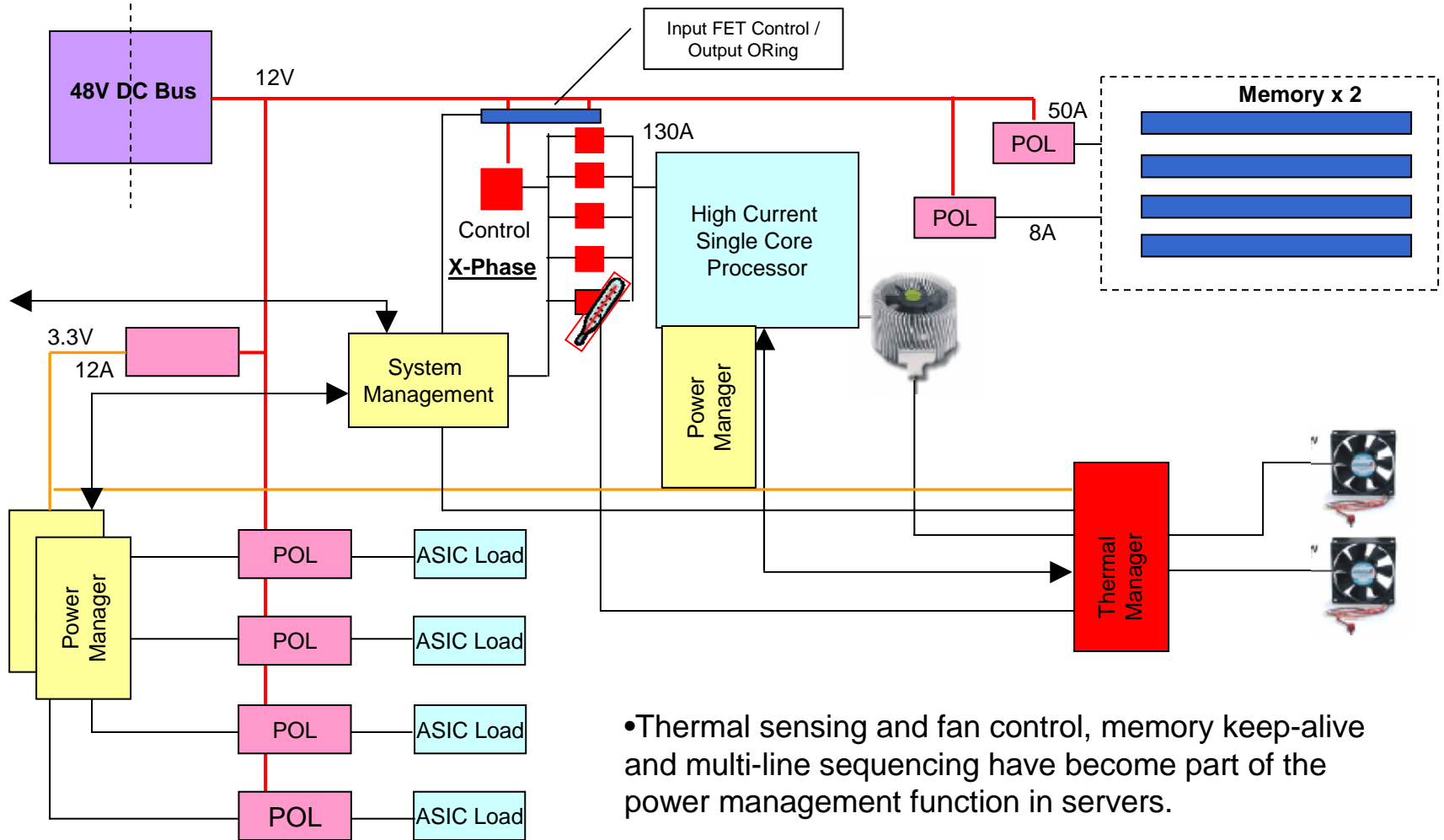
# Power management architecture for servers and mainframes use long chains

The efficiency of each element is important in reducing energy consumption



Source: International Rectifier

# Regulators perform additional functions



Source: International Rectifier

# Many competitors in a growing market

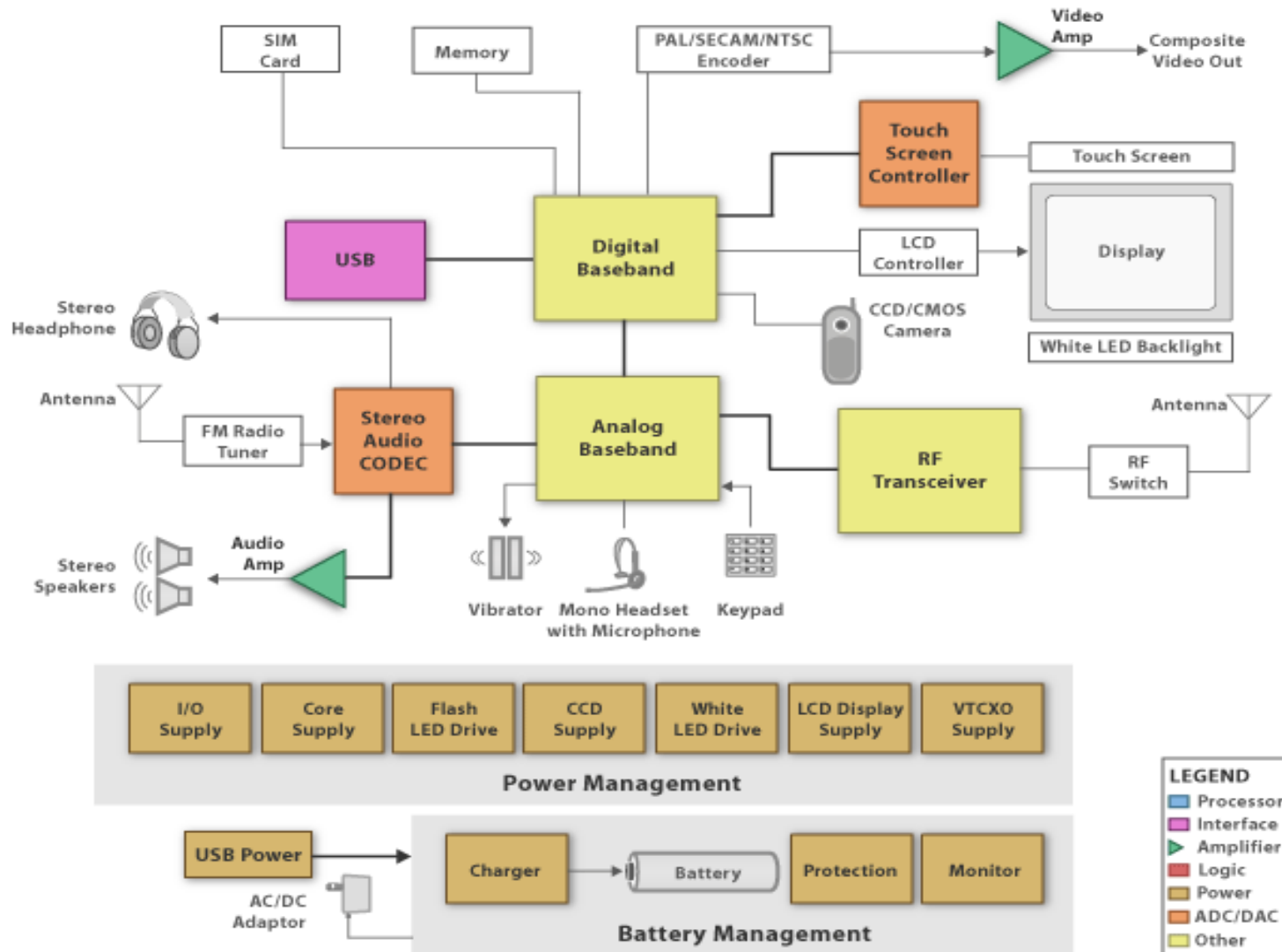
## Device Types, Functions Performed and Selected Vendors With Offerings in POL Applications

Devices	Functions	Vendors
Pulse-width modulators (PWMs), single-phase switch-mode controllers (without integrated power FETs)	Pulse generator for switch-mode power supply	National Semiconductor, Texas Instruments, Linear Technology Corp., Maxim, Intersil, Vishay, International Rectifier and Fairchild
Single-phase switch-mode controllers (with integrated power FETs)	Pulse generator with MOSFET drivers	Intersil and Fairchild Semiconductor
Multiphase switch-mode controllers (without integrated power FETs)	Multiple pulse generators on one chips — multiple outputs can be paralleled for higher current	Intersil, Fairchild Semiconductor, Linear Technology and Maxim
MOSFET power transistors	High-current switching transistors (coupled to pulse generators in high-current supplies)	Vishay and International Rectifier
Pentium VRM controllers/drivers	Specialized DC-DC converter meant to respond to transient current loads	Intersil (with Primarion), Fairchild, Semtech and Volterra
Digital power management	Digitizes the control loop in multichip switching voltage regulator	Texas Instruments

# Factors affecting POL adoption and use

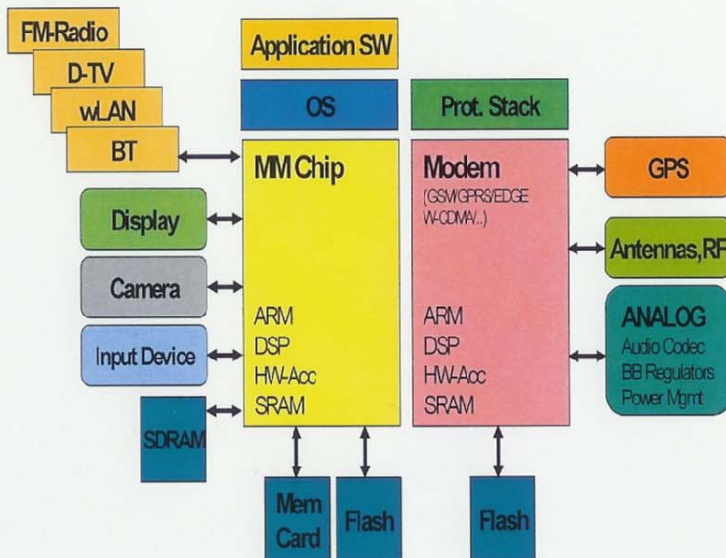
- Technical skill
  - Deliver high currents, minimal heat, small form factors
  - Eliminate (or reduce) the capacitors
  - Work on integrating the power FETs
  - Think about packaging the Inductor
- What about “digital power”?
- Conclusion: Point-of-Load have better possibilities for growth

# Cell phone features multiply – each taxing battery life



# The applications processor and RF sections demands the most power

## Power Consumption of a Multimedia Mobile Phone



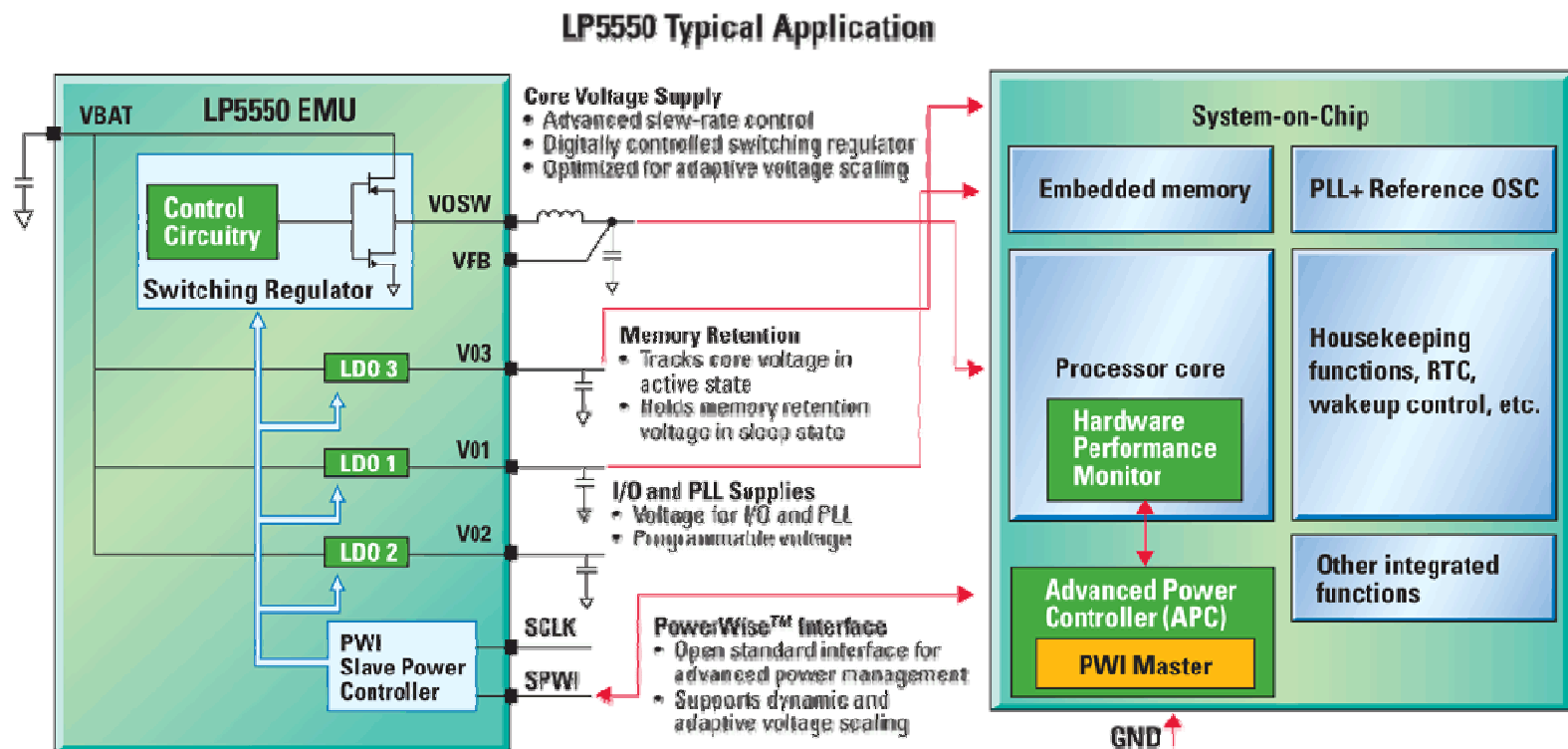
### Average Power Consumption

Cellular modem and RF amplifier	1200 mW
Application processor	600 mW
Memories	200 mW
UI (including display with backlight)	300 mW
Audio	300 mW
Other (BT, IrDA, Energy mgmt. etc.)	400 mW
<b>Total</b>	<b>3000 mW</b>



# Some manufacturers respond by turning down the CPU

## PowerWise devices monitor the ARM's activities



Source: National Semiconductor

# Controlling different parts of the system

## Aggressive Power Management

Power Mgt. Modes	Core	Peripherals	RAM	RTC	Wake-up	Current
Idle	Stopped	Active	Active	Active	NA	< 5ma
Power-Down	Stopped	Stopped	Inactive	Inactive	External Int., Reset	< 10 $\mu$ A
Hibernate	Power Off	Power Off	Power On	On	External Int., Reset	< 7 $\mu$ A
Deep Power-down	Power Off	Power Off	Power Off	Stopped (osc. off)	External Int.; Reset	< 5 $\mu$ A

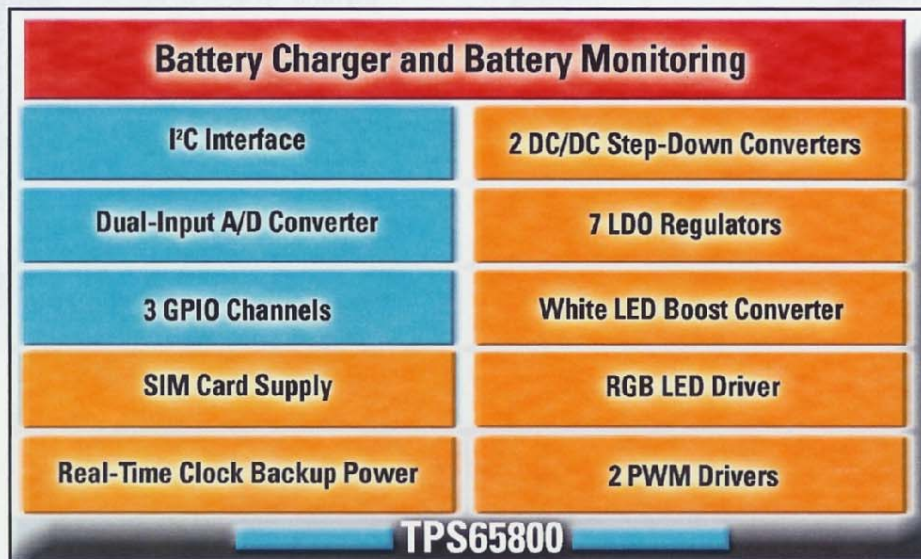
Independent power domains, power switches, and isolation buffers allow fine granularity in Power Management

Source: Intel

# Are PMICs the wave of the future?



## Single-Chip Battery Management + Power Conversion



- ◆ Power Control for up to 10 voltages: 3 DC/DC + 7 LDOs
  - Greater than 90% Efficiency over 3.3 V
- ◆ Integrated USB/AC Battery Charger with Dynamic Power Path Management
- ◆ White LED + RGB driver
- ◆ 10-bit, 60 $\mu$ S ADC optimized for battery management

Source: Texas Instruments

# Matching opportunities and players

## Device Types, Functions Performed and Selected Vendors addressing cell phones

Devices	Functions	Vendors
Buck-boost switching regulators	Low-voltage switching regulator that steps down or steps up battery voltage outputs	Linear Technology
LDOs	Linear regulator most efficiency in low-voltage, low-current applications	National Semiconductor, Linear Technology and Micrel
Switch-mode RF power amplifier (PA) drivers	Switching regulator whose output waveform approximates mobile phone callers' voice	Maxim and National Semiconductor
White LED backlight drivers	Step-up switching regulator providing constant current for LED arrays	Maxim, Linear Technology and Analogic Tech
Power management ICs (CPU monitors)	Monitors CPU instruction cycles to induce "sleep," "standby" or "wakeup" modes	National Semiconductor
Battery management ICs	Fuel gages and charging controllers for rechargeable batteries	Texas Instruments and Intersil
Integrated power management devices (PMICs)	Custom circuits with as many as 10 voltage regulators on one chip	Texas Instruments, Dialog Semiconductor and Qualcomm

Source: Gartner Dataquest (October 2005)

# The pointers for portable power management

- New features (high-res cameras with flash, MP3 music playback, HDD, etc.) will demand specialized regulators.
- White LED backlight drivers will continue to proliferate
- New Li-Ion battery chemistries will offer additional energy reservoirs, even below 3V. Expect a resurgence in buck-boost regulators.
- Major cell phone suppliers will buy integrated power management ICs which will cannibalize standard regulator slots.
- Conclusion: Learn to integrate and/or make friends with Nokia.

# On any level...

- ✓ We welcome your questions