Designing A Greener, More Energy-Efficient World

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HEAT08

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ARM At The Heart Of Low Power

- ARM and its Partners enable the technology that lies at the heart of advanced low-power, high-performance, leading-edge digital products

ARM CONNECTED PARTNER

CPU, GPU, Fabric IP

Physical IP

- In 2007, ARM Partners delivered ARM® products in ~25% of all electronic devices sold worldwide

Trending Towards Energy Efficiency

- Concern for the environment is changing legislation and consumer behaviour

1879

The EPA's Energy Star 4.0 regulations, which took effect on July 20, 2007, require PC manufacturers to convert 80 percent of incoming electricity into usable computer power in order to be declared "energy efficient".

Korea's 1Watt plan: Mandatory warning label for products failing standby standard

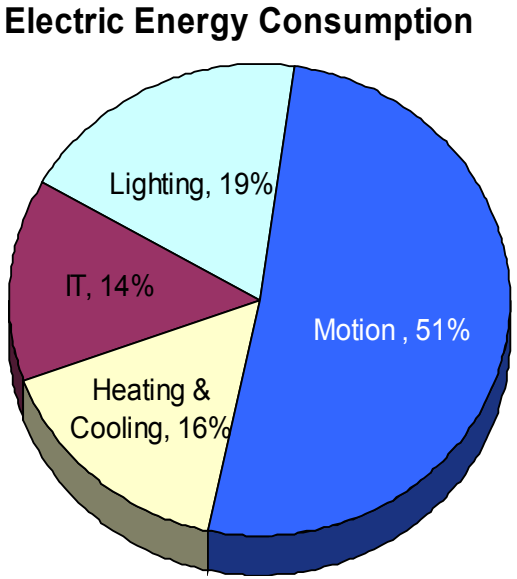
Sustainable Energy Use

- Total world consumption of energy is expected to increase 57% from 2002 to 2025 *
- Three pillars for sustainable energy
  - Efficient transformation of primary energy to end-use energies
  - Efficient use of end-use energies
  - Use of renewable energies
- All three pillars must be developed equally!

* EPRI, ACEEE, IMS Research

- Means reducing total energy consumption
  - Making applications more intelligent in energy use
  - Making applications understand energy demand times (and energy costs)

- More than half of electrical output is used in motion
  - USD $7.3B wasted per year due to poor efficiency in the control of electric motors

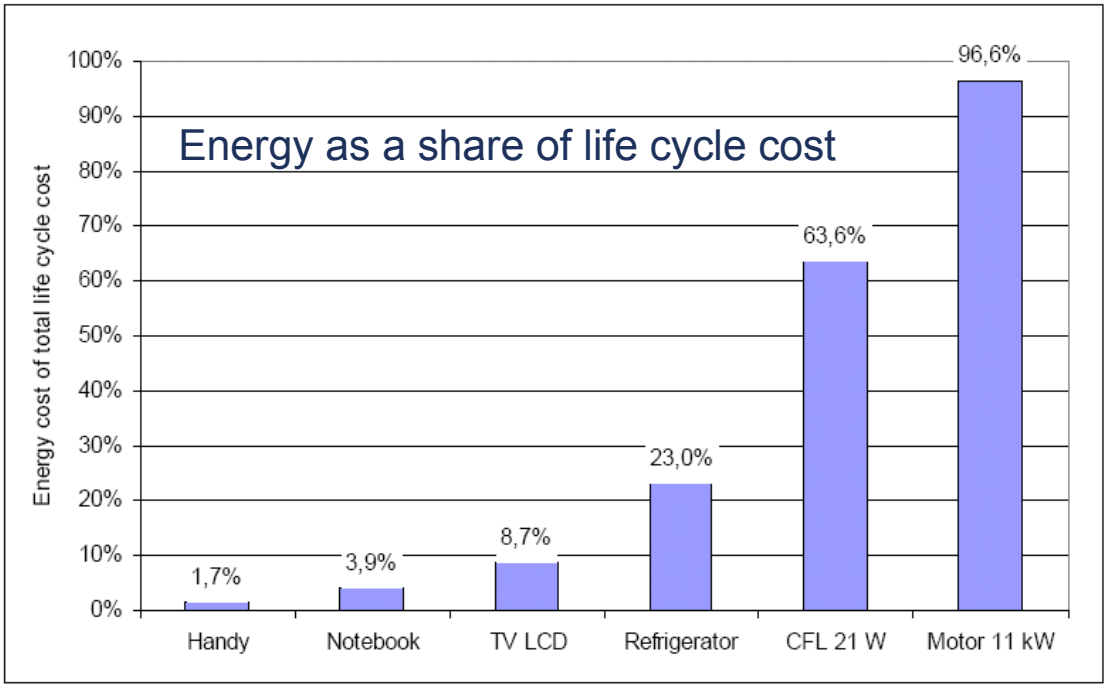


Source: EPRI, ACEEE, IMS Research

Low Power Through Intelligent Control

- Intelligent Motor Control
  - By adding electronic control to inverter motors, energy savings can be as much as 60%

- Intelligent Consumer Appliances
  - DTV/STB turn themselves off when not in use



Each $1 invested in more efficient electrical appliances saves $2.2 in investment in power plants & networks

Source:
International Energy Agency, Beijing, June 2007

Intelligent Motor Control

Motor Applications

High end

- Robotics
- Servo positioning
- PLC …

Appliances

- Refrigerator
- Washing machine
- Air conditioner
- Cooking hood
- Dishwasher …

- Frequency converters
- Air conditioners
- PMAC pumps
- Treadmills, Stair stepper…
- Elevator control

Middle range

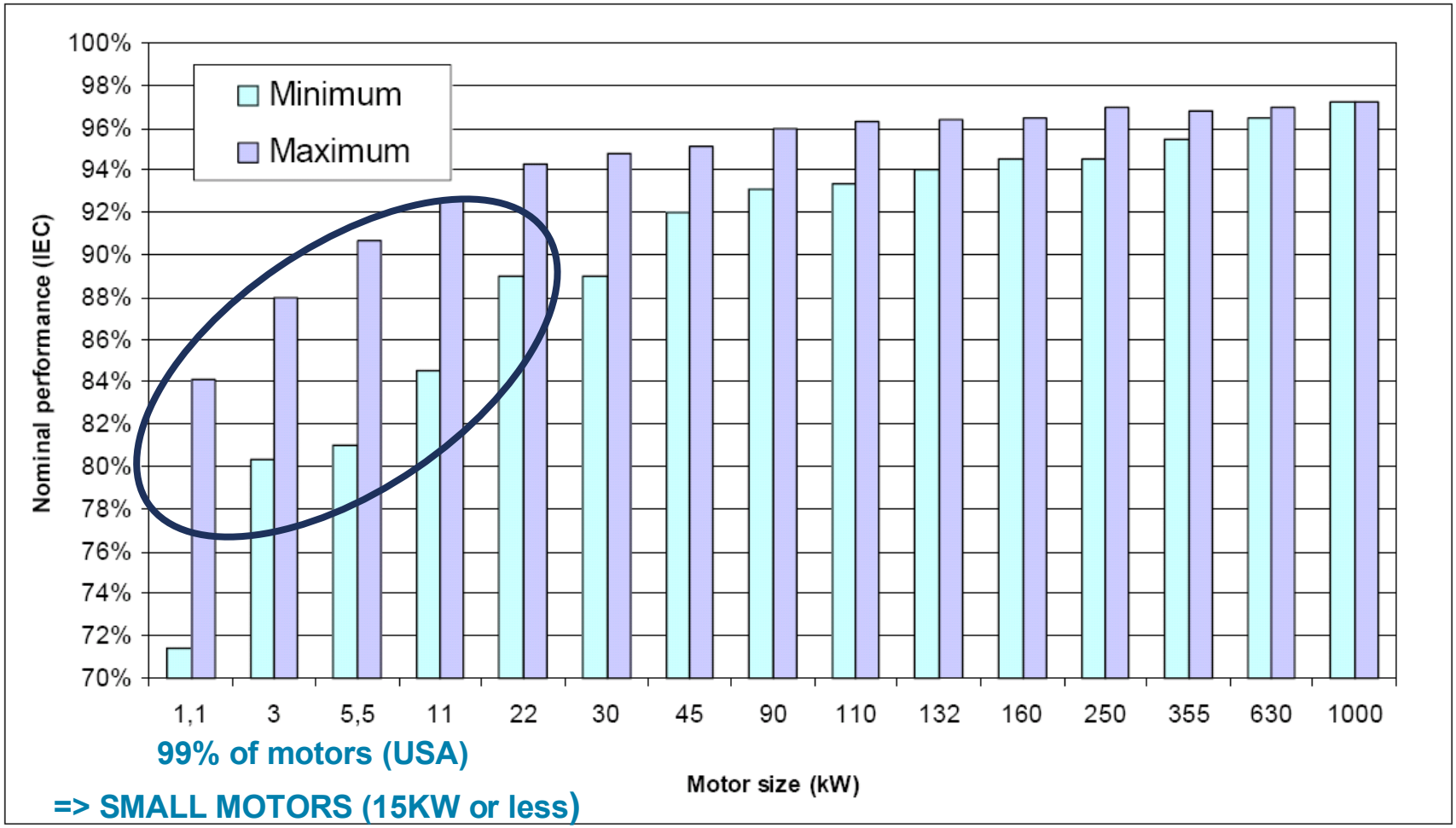
Industrial/HVAC

- HVAC actuators and fans
- Continuous applied air pressure
- Electric bike
- Electric wheelchair
- Industrial inverter
- Vending machine
- Vacuum pump…

Lowest cost

- Hair dryer
- Food processor
- Power tools
- Vacuum cleaner …

Motor Efficiency (50 Hz 4-pole)



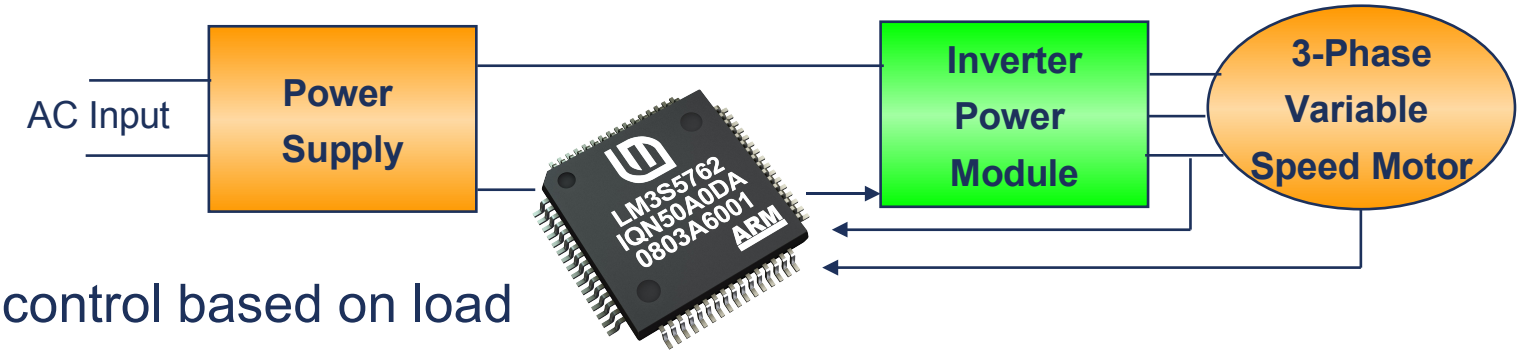
Source: EuroDEEM database 2005, 29 manufacturers, 7200 motors

Motor Energy Losses

- Majority of appliances run open-loop with only speed control
  - Majority of motors are oversized
  - No consideration of load
- Crude control methods
  - Hard Start (increases start-up current)
  - Hard Stop (applies brake force to reduce speed – wasted power)
  - Coarse speed stepping (more current used than actually required)
- Wasted energy dissipated in the form of heat

Motor Control Savings

- Measuring values more accurately and more often as motor spins, leading to improved control and less wasted energy



- Energy
  - Speed control based on load
  - Soft Start/Stopping
  - 20% reduction in speed can save up to 50% of the energy
  - Savings of 18%-24% off all electricity usage

Source: Allegro Microsystems Inc

- Reliability
  - Reduced speeds and load control increases lifetime of motor
  - Soft Start/Stopping reduces electrical wear in windings

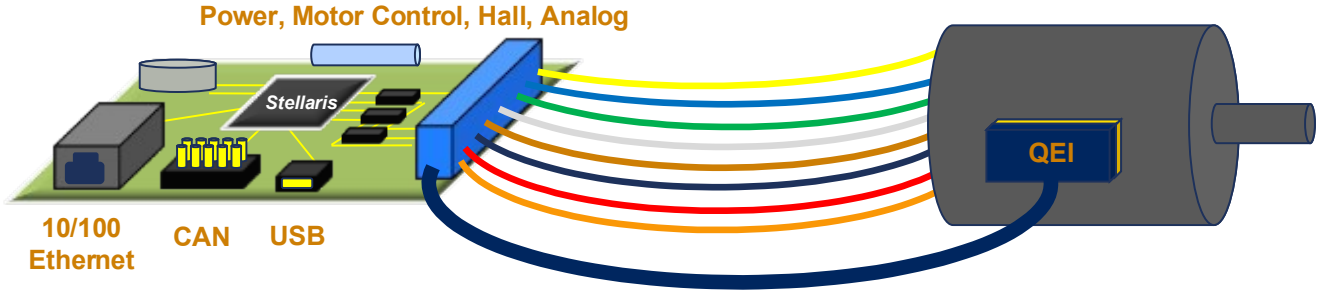
The Luminary Micro Solution

Fully Integrated Stellaris MCUs

- ARM Cortex-M3 core with single-cycle Flash
- Advanced Motion Control
- Integrated Deterministic Connectivity
- Easy adoption / learning curve through 10-min Out-of-the-Box Evaluation Kits

Production-ready Modules

- Customizable modules for drop-in implementation
- Multiple motors supported
- Multiple connectivity options
- Copy-exactly with Open-tooled HW and SW



Motion Control Reference Designs

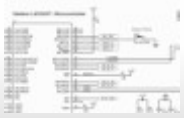
- Open-tooled HW/SW Reference Design Kits
- Motor included for out-of-the-box demonstration
- Fully documented, available for download, and in stock

Proof-of-Concept

- Stellaris MCUs / Modules
- http://www.youtube.com/watch?v=or5cVYpAJYg

End-to-End Solution Source Files

Royalty-Free



Schematics

Placement

Bill of Materials

Gerbers

Motor App and DriverLib Source

Control / Config GUI

The European Motor Market

- Switching to energy efficient motor driven systems can save Europe up to 341 billion kWh/€31 billion per year in electricity*
  - Equivalent to **sixty-four** 600MW power plants!
- What is the problem?
  - Slow market introduction of high-efficiency motors
  - Standards drive market share for high-efficiency motors**
    - Countries with mandatory standards: >70% savings
    - Countries with voluntary standards: <10% savings
- The cause and solution to the problem?
  - Regulation, financing, awareness and technology

* EUP, BERR, Eurostat, AEPUK

** SEEEM 2006

Intelligent Consumer Appliances

No fans,
just cool devices

CE Device Revolution in the Modern Home

- If we cast our minds back to the mid 1970s, the CE devices in common use in the home then were:
  - 1 TV
  - 1 radio
  - 1 camera
  - 1 'Hi-Fi' sound system/cassette player and
  - 1 telephone

Gadget	Quantities	Founding:
Television	2-3	Lounge, kitchen, bedroom(s)
Video cassette recorder	1	Lounge, bedroom(s)
DVD player or recorder	1-2	Lounge, bedroom
STB digital box/satellite or cable TV receiver	1	Lounge
Music sound system	2	Lounge, bedroom
Mobile phone	3	Various
MP3 player	1-2	Various
Computer (PC or Mac)	1	Bedroom, study or communal space
Laptop	1	Various
Printer	1	Bedroom, study
Scanner/fax	1	Study
Cordless phone and handsets	3	Lounge, kitchen, bedroom
Answering machine	1	Lounge, hallway
Games console	1	Lounge, bedroom
Broadband modem/router	1	Various
Digital camera	1	Various
Camcorder	1	Various
Radio	2	Various

- By 2020 it is projected that Consumer Electronics products, combined with ICT equipment, will make up an extraordinary 45 % of all appliance related electricity use in the home

Source: The Ampere Strikes Back; EST

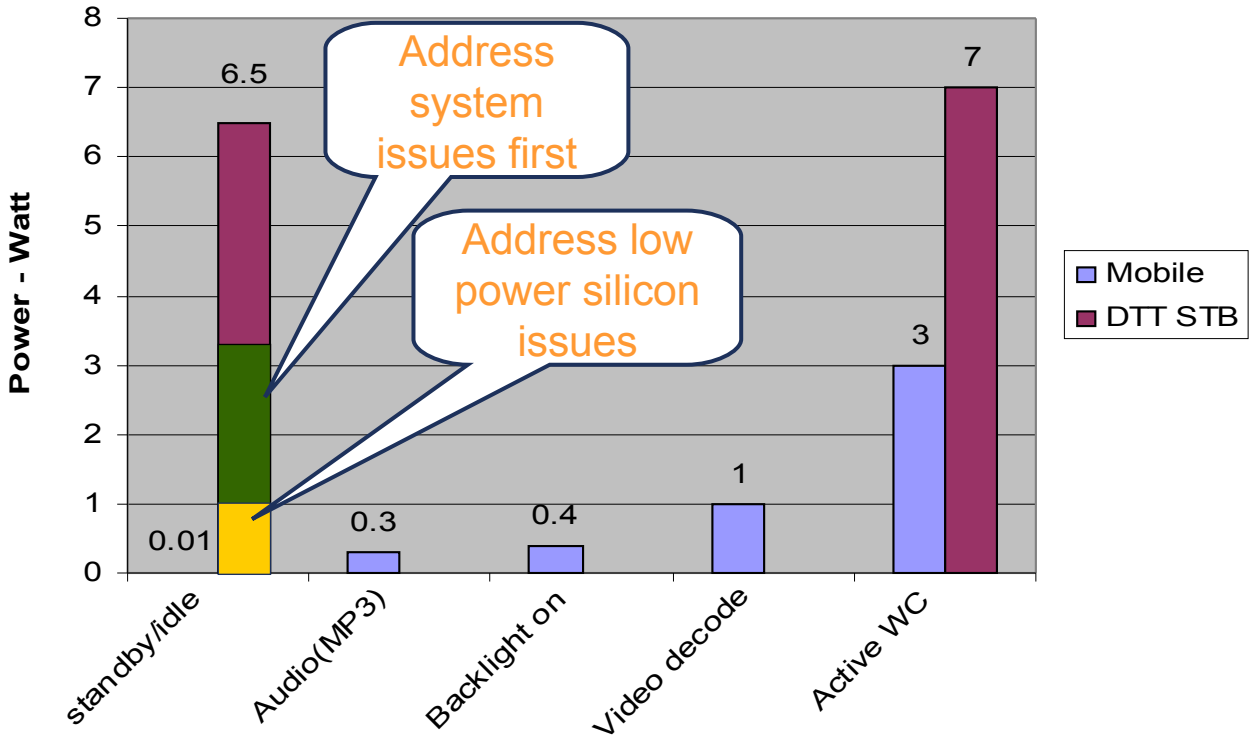
Home Entertainment - The Complex STB

- Greater functionality can require more power
  - More tuners, high-definition
  - Home networking connectivity
  - Set Top Boxes (STBs) active on multiple networks
  - Increased decode capability across multiple rooms
- Need high-performance, energy efficient processing!

Two Areas For Possible Efficiency Gains

- The System-on-Chip (SoC)
- The client software that runs on the STB and how it interacts with the Service Provider

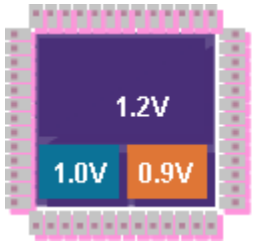
Efficiencies can approach mobile phone levels with cooperation from all players



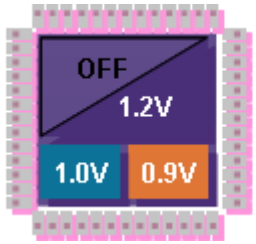
The System-on-Chip (SoC)

- Power Management Techniques

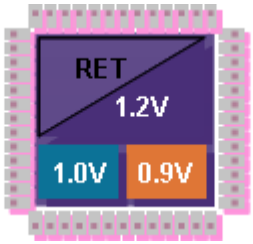
Process	Design	Architecture	Software
Multi-Threshold Multi-Voltage SOI Low-K Body bias Copper metal SiGe substrates	Multi-Threshold Multi-Voltage Clock Gating Power Gating Low power circuits Power-aware memories	H/W vs. S/W Implementation Algorithm/ Implementation Trade-offs	Compilers Power-aware OS Hibernation modes Memory access



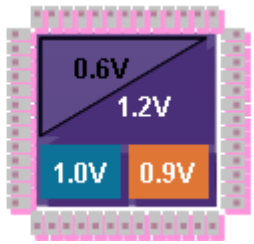
Multi-Voltage (MV)



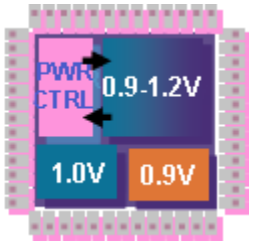
MTCMOS Power Gating (shut down)



Power Gating with State Retention



Low VDD Standby

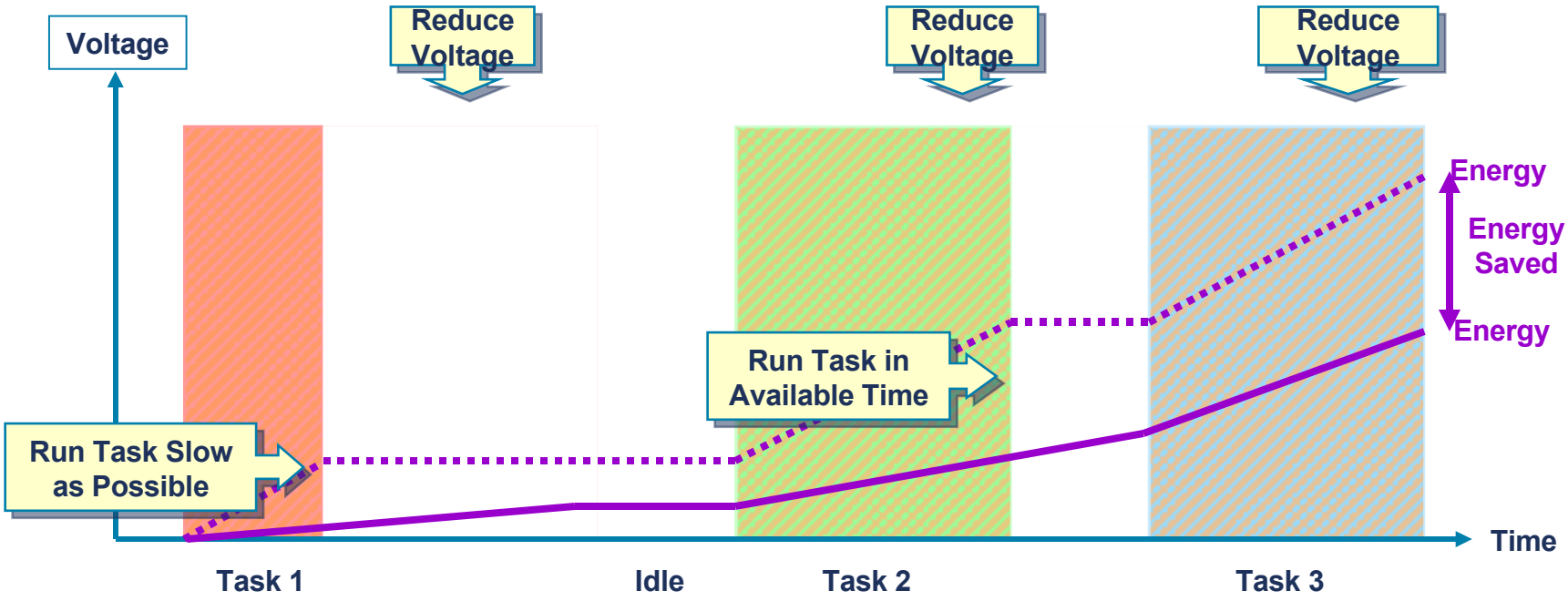


Dynamic or Adaptive Voltage Frequency Scaling (DVS, DVFS, AVS, AVFS)

DVFS Principles

- Energy consumption is proportional to the Frequency, but also the Square of the voltage (dynamic power dissipation).
- DVFS saves energy by running the tasks as slowly as possible (and at low voltage)

$$E \int_0^t (C(V_{DD})^2 f_c \quad V_{DD} I_Q) dt$$



Only need to run *just* fast enough to meet the application deadlines

Power Management Partnerships

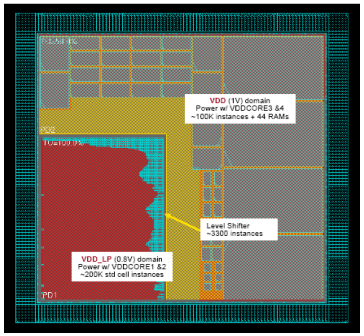
APPLIED MATERIALS

cadence

tsmc

Low power 90nm Test Chip

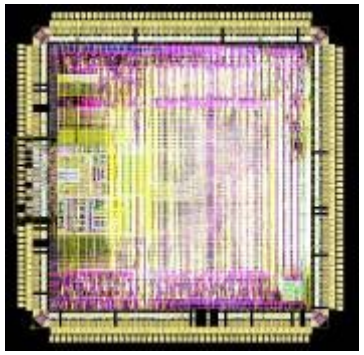
- Silicon demonstrated 40% reduction in energy consumed
- Combining ARM processor with ARM Physical IP Power Management Kit



SYNOPSYS

Leakage Management 90nm Test Chip

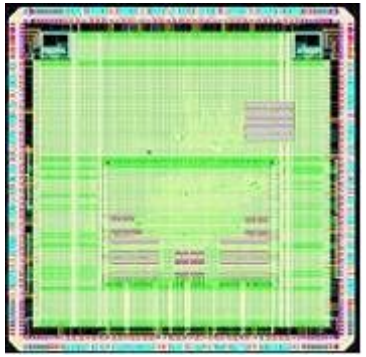
- Assess entry/exit costs of sleep modes
- Solving issues related to current in-rush problems
- 99% leakage avoidance



tsmc

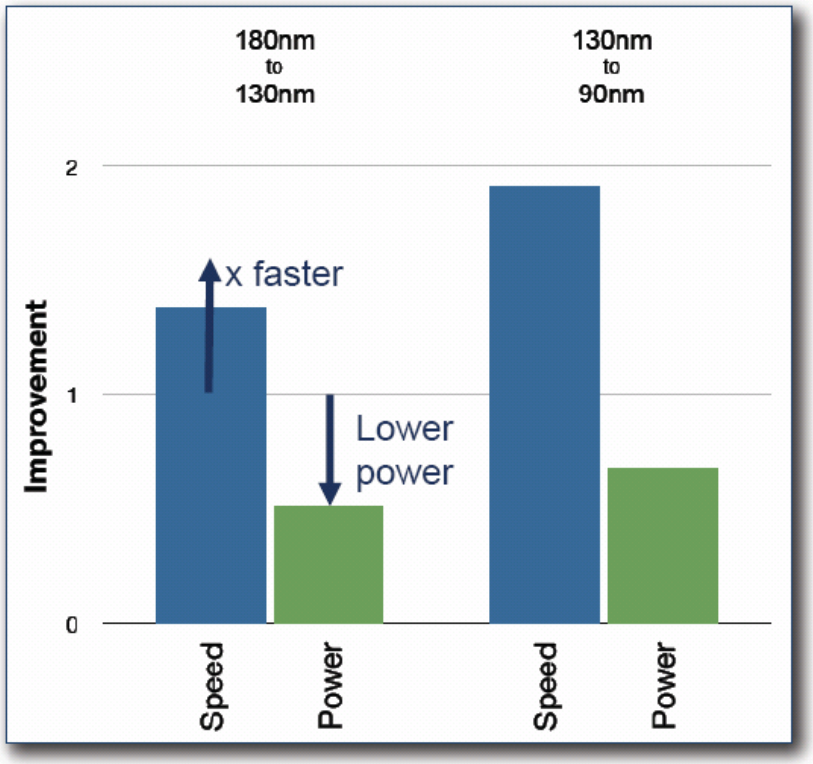
65nm Low Power Test Chip

- Demonstrated over 50% dynamic power reduction
- Reduced standby leakage by a factor of 8



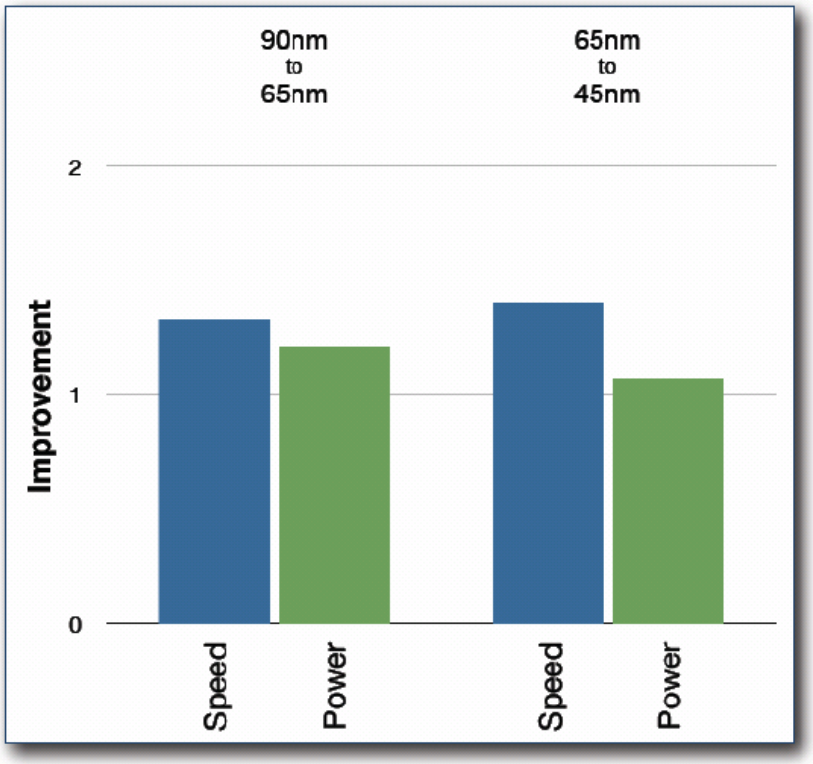
Process Is No Longer Providing Scaling

The good old days



- Everything improves significantly

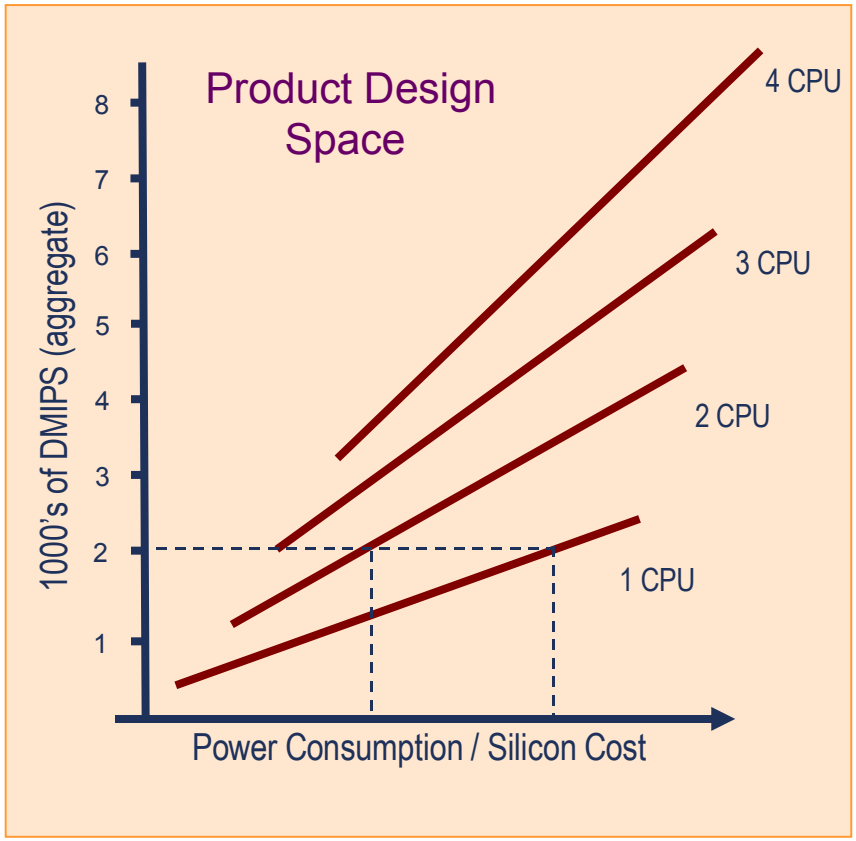
New reality



- Speed increases at the expense of energy consumption

Multiprocessing Provides The Solution

- ARM was first in multiprocessing
- Multiprocessing offers the flexibility of both high performance and low power
  - Many ARM processor-based SoCs today already have multiple processors
  - ARM11™ MPCore™ multicore processor has more than ten licensees developing chips for printers, HDTV, DSC, networking, and more
- New ARM Cortex-A9 processor further enhances MPCore technology

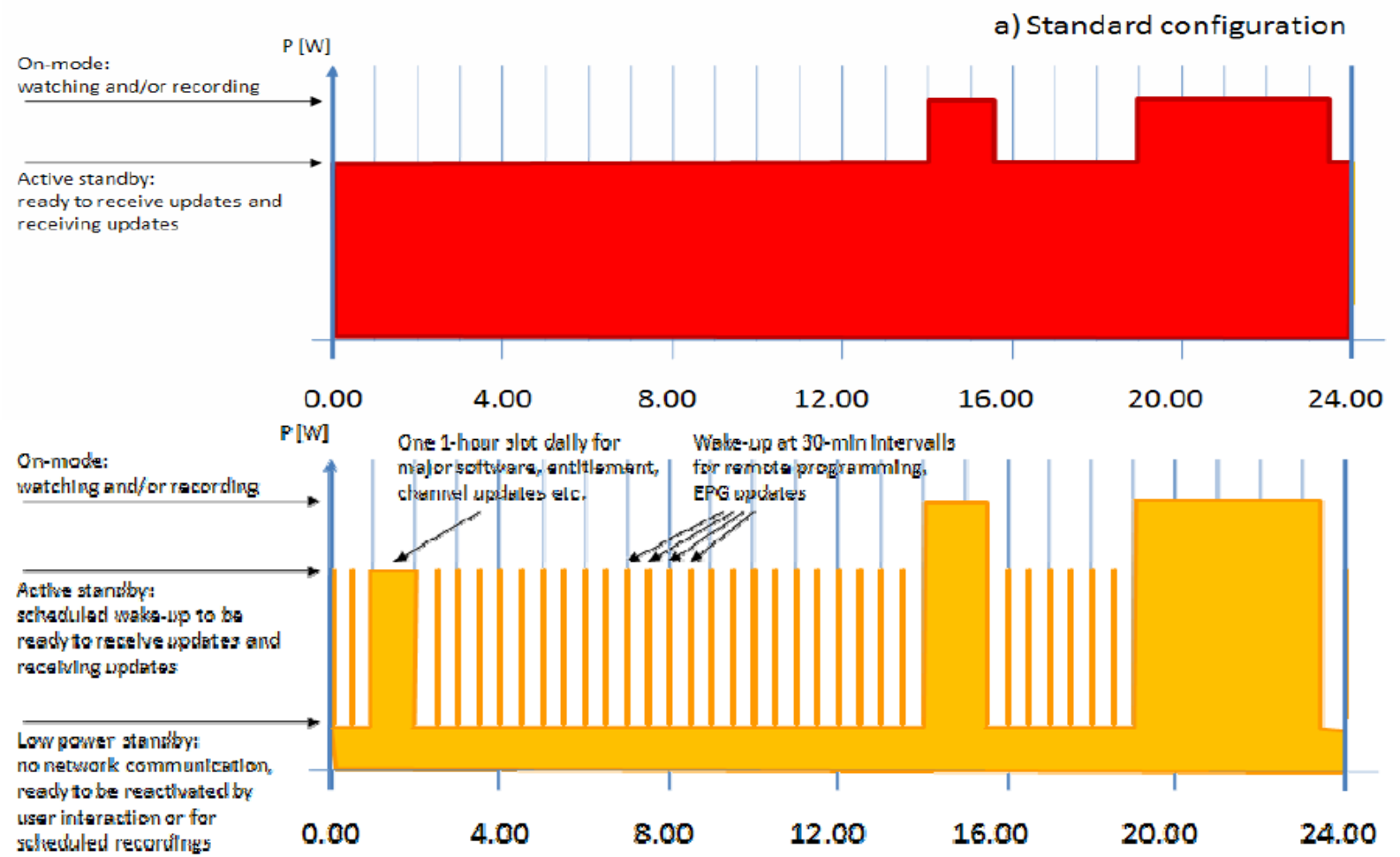


The Software That Runs On The STB

- Powering down tuners & blocks within SoC when not in use
- Monitoring presence on a network
  - Powering down home connectivity when not in use
  - Minimizing the frequency of communications / pings
- Transitioning from on-mode into standby after a certain period of in-activity
  - Drop into standby after 11 p.m. if there is no user activity for 2 hours
  - BSkyB (promotional) claims: Savings of 30 kWh yearly per STB

STB Power Consumption

- Complex STB with HDD and HD capability typically consume 23 W in on-mode and 14 W in (active) standby



Source: EuP Preparatory Study – Lot 18 Complex Set-top Boxes; Oct. 2008

Who Benefits From Energy Efficiency?

- Manufacturers can have a more reliable product
- Service Provider should have fewer product returns
- The Customer has lower energy bills
- The Government is helped with its energy policy
- The Environment is better protected

Technology Is The Key To Energy Efficiency

- ARM provides low power, intelligent control across a range of performance points
- Complex problems require partnerships to deliver a greener, more energy-efficient world