

Crusoe™ Power Management

Cutting x86 Operating Power Through LongRun™

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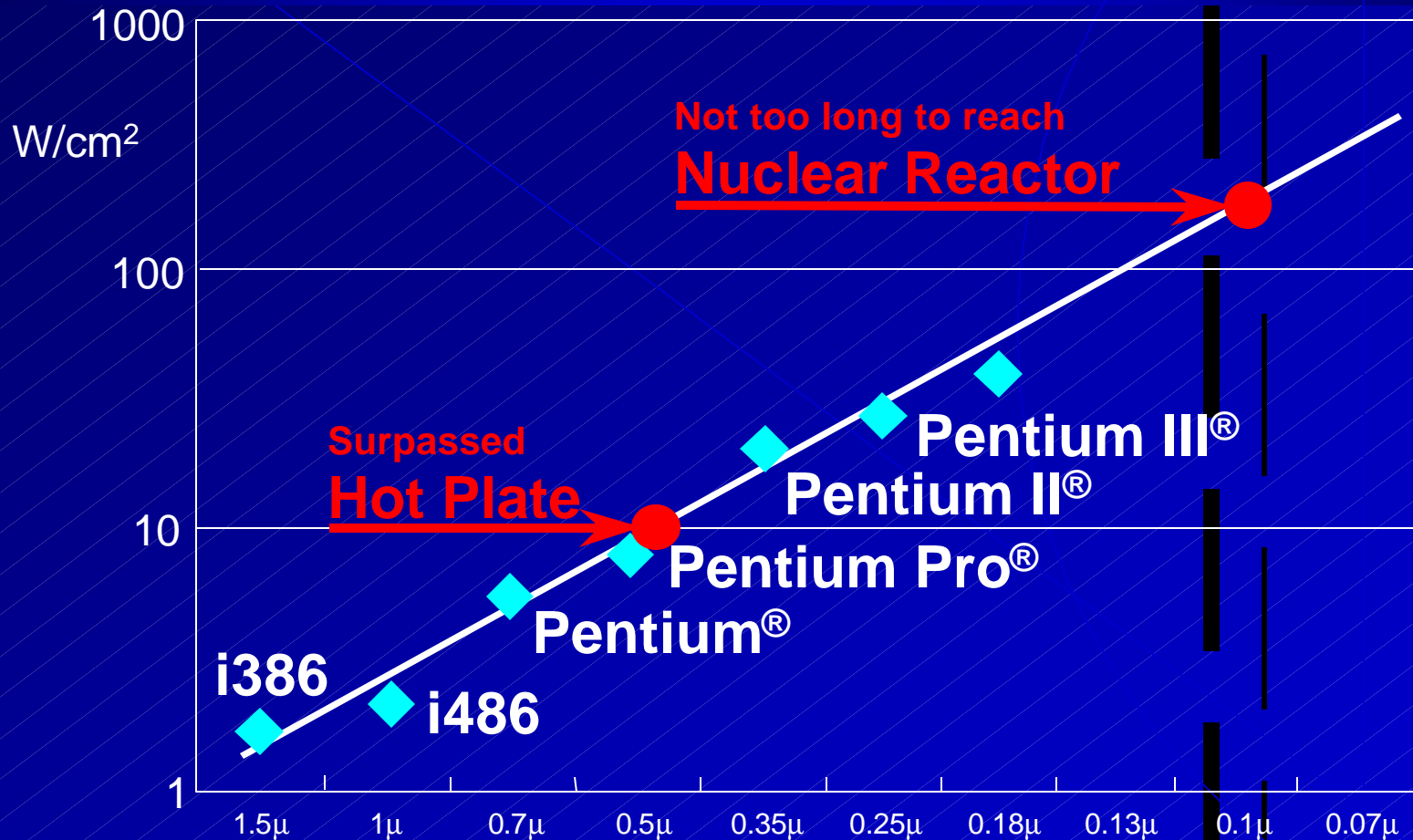


Overview

- ◆ Key Challenges for Mobile Computing
 - ◆ “Portability” (weight) and “Ease of Use” (battery life)
 - Power consumption is the key limiting factor
- ◆ Solution - Crusoe Processor
 - ◆ Full compatibility with traditional x86 power management model
 - ◆ Significantly lower power
- ◆ LongRun
 - ◆ Transmeta’s new invention to drive breakthrough power savings
 - Adaptive Power Control (performance on demand)
 - Advanced Thermal Control (thermal envelope expansion)

Power Density

The Fundamental Problem



Source: Fred Pollack, Intel. New Microprocessor Challenges in the Coming Generations of CMOS Technologies, Micro32

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The Solution ... Use Software

The Software-Based Microprocessor

$$P_{power} = C_{capacitance} \times V_{voltage}^2 \times F_{frequency}$$

- ◆ Innovation - Code Morphing Software
- ◆ Effect - Replace Millions of Logic Transistors with Software
 - ◆ ... and transistors translate into capacitance
- ◆ Benefit - Significantly Reduces Power Consumption of x86 Power States

Power Comparison

Substantial Power Reduction, Delivered by Crusoe

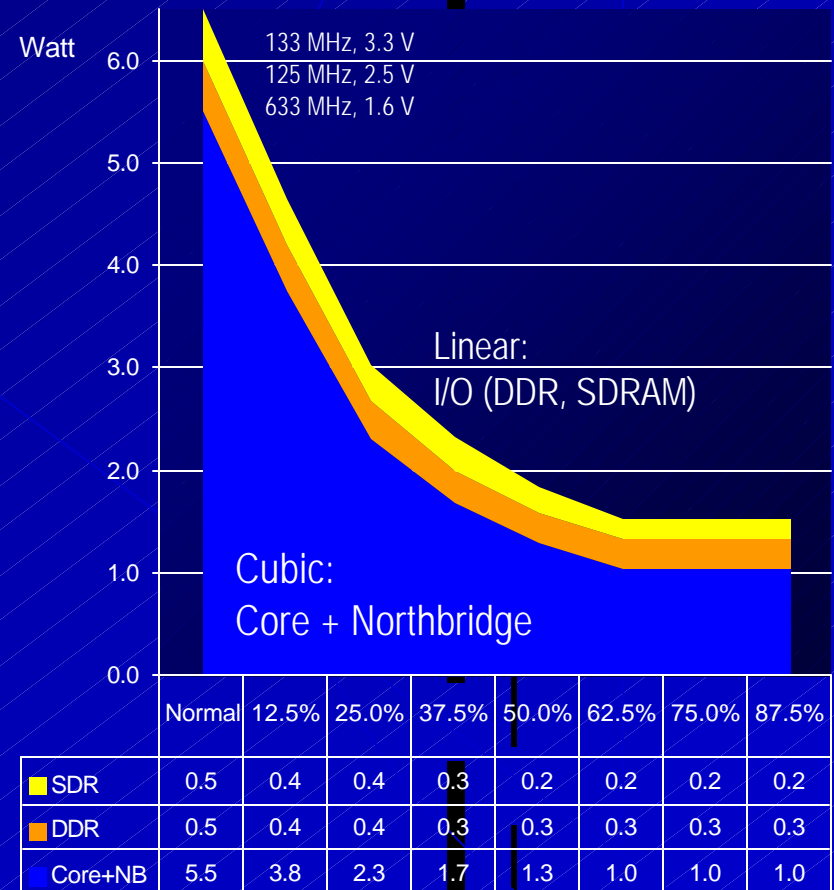
	Conventional Mobile x86 Solution			Crusoe TM5400 Integrated North Bridge		
	Processor	North Bridge	Total	LongRun™		
	650 / 500 MHz 1.6 / 1.35 V	3.3 V	650 / 500 MHz 1.6 / 1.35 V	633 ↔ 300 MHz 1.6 ↔ 1.2 V		
Normal (C0)	14.0 / 8.0	2.0	16.0 / 10.0	6.5 ↔ 1.5		Watts
AutoHALT (C1)	1.7 / 1.1	2.0	3.7 / 3.1	0.9 ↔ 0.3		Watts
Quick Start (C2)	1.3 / 0.8	2.0	3.3 / 2.8	0.6 ↔ 0.2		Watts
Deep Sleep (C3)	500 / 300	~1000	1500 / 1300	55 ↔ 49		mW

LongRun Adaptive Power Control

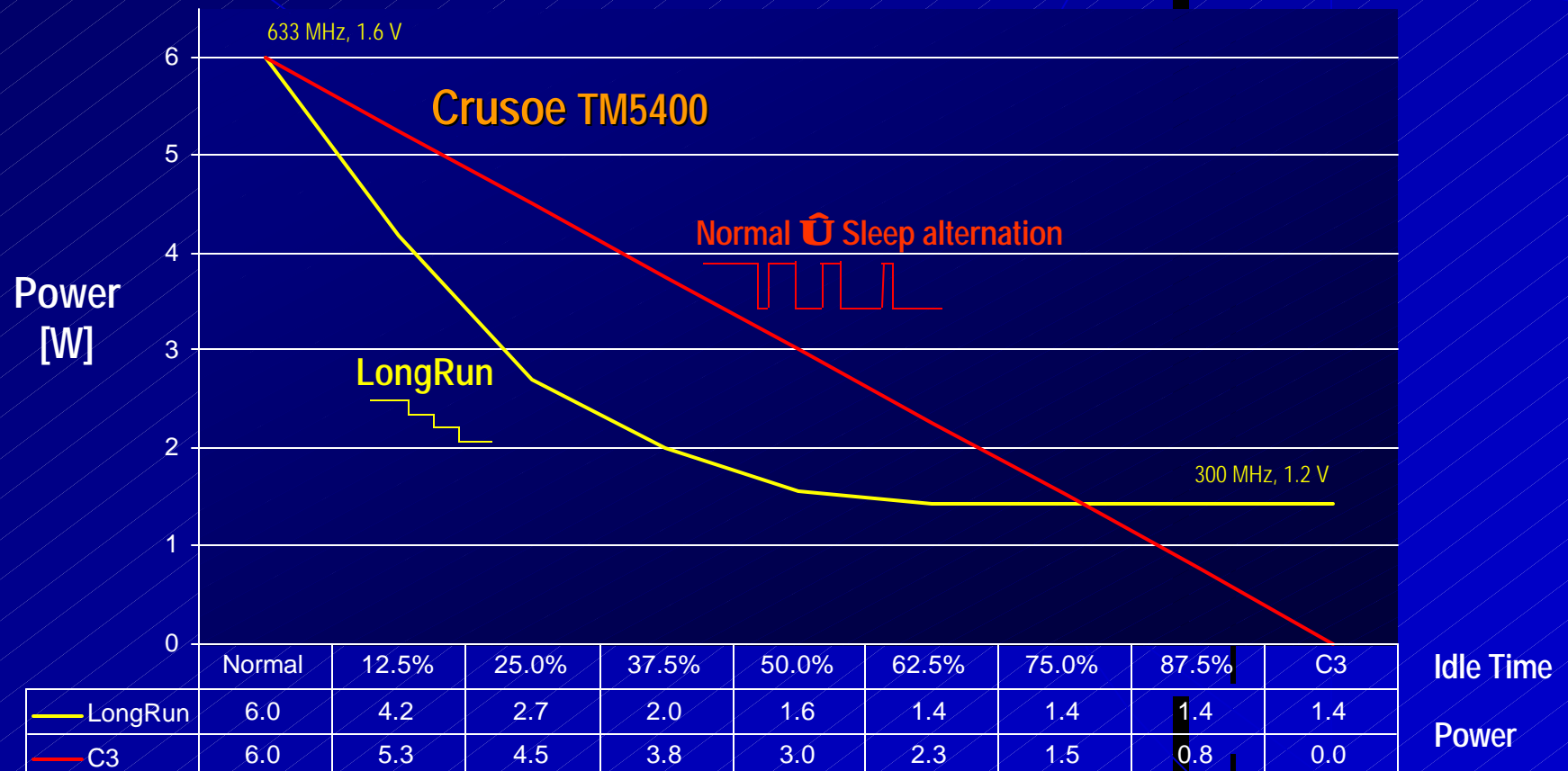
Maximize Battery Life With Performance on Demand

$$Power = c \times v^2 \times f$$

- ◆ Dynamically adapt both frequency and voltage to performance demands
- ◆ Mechanisms in CPU
 - ◆ Fully programmable
- ◆ Policies in CMS
 - ◆ Adapt f to demand
 - ◆ Reduce v proportionally
 - Cubic power savings!



LongRun Adaptive Power Control vs. Traditional Power Management



Notes

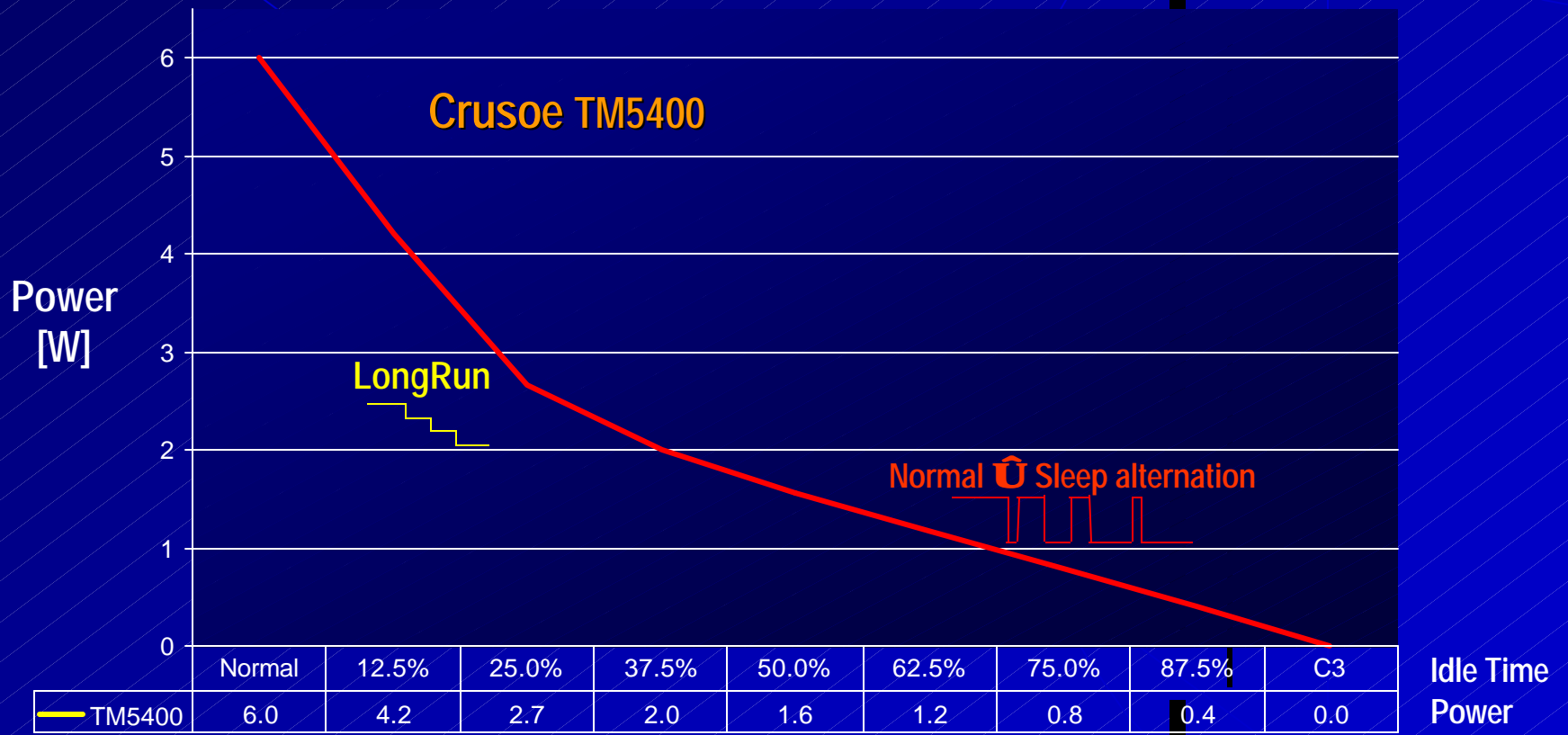
- ¹ Power numbers include Northbridge
- ² DDR-only configuration

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LongRun Adaptive Power Control

Crusoe Power Profile



Notes

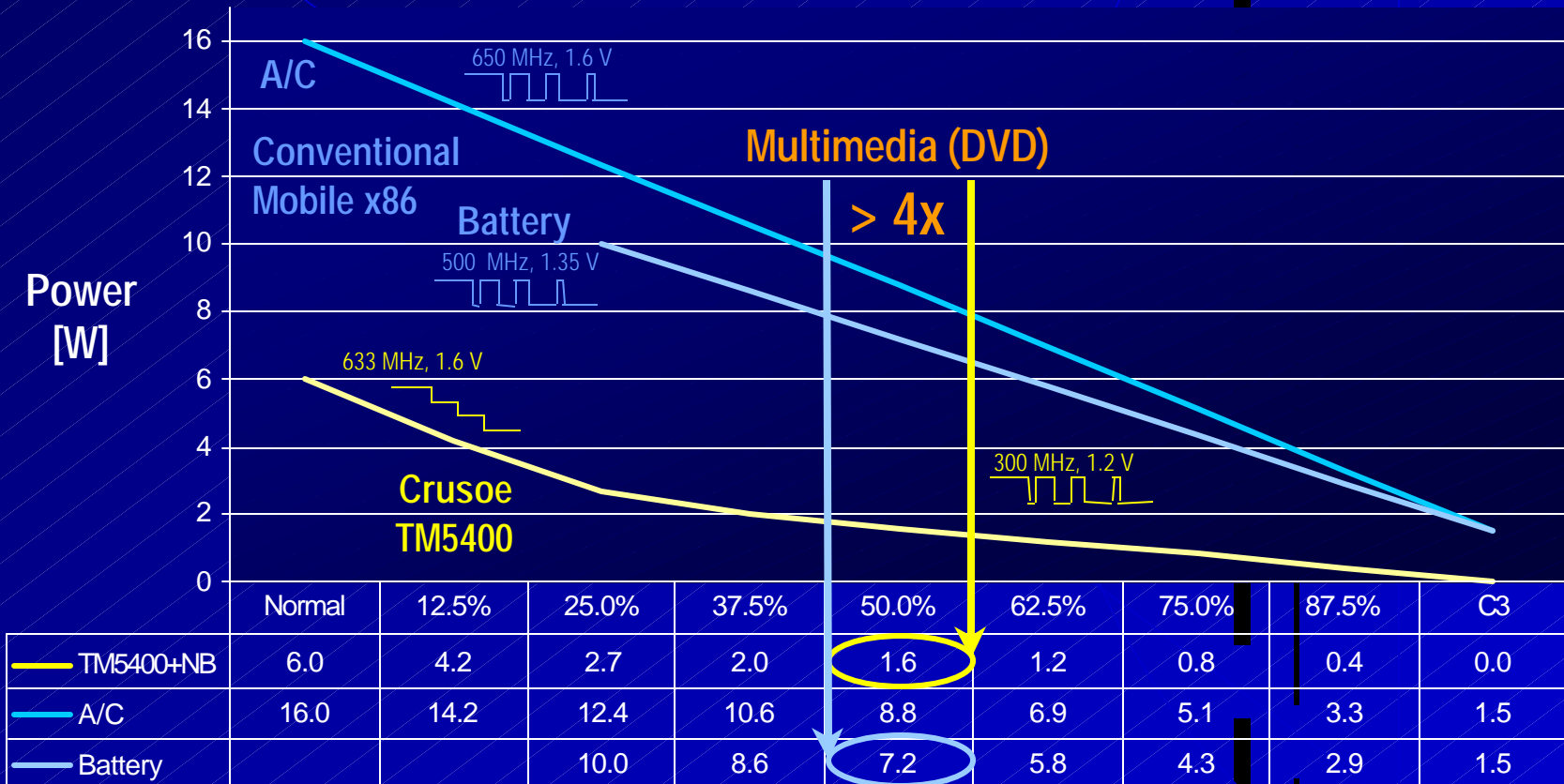
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The LongRun Effect

Power Profiles



Notes

- 1 Power numbers include Northbridge
- 2 DDR-only configuration

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System Architecture

Standard Applications

No changes required



Closed loop

Standard Operating System

No changes required

Closed loop

Standard BIOS

No changes required

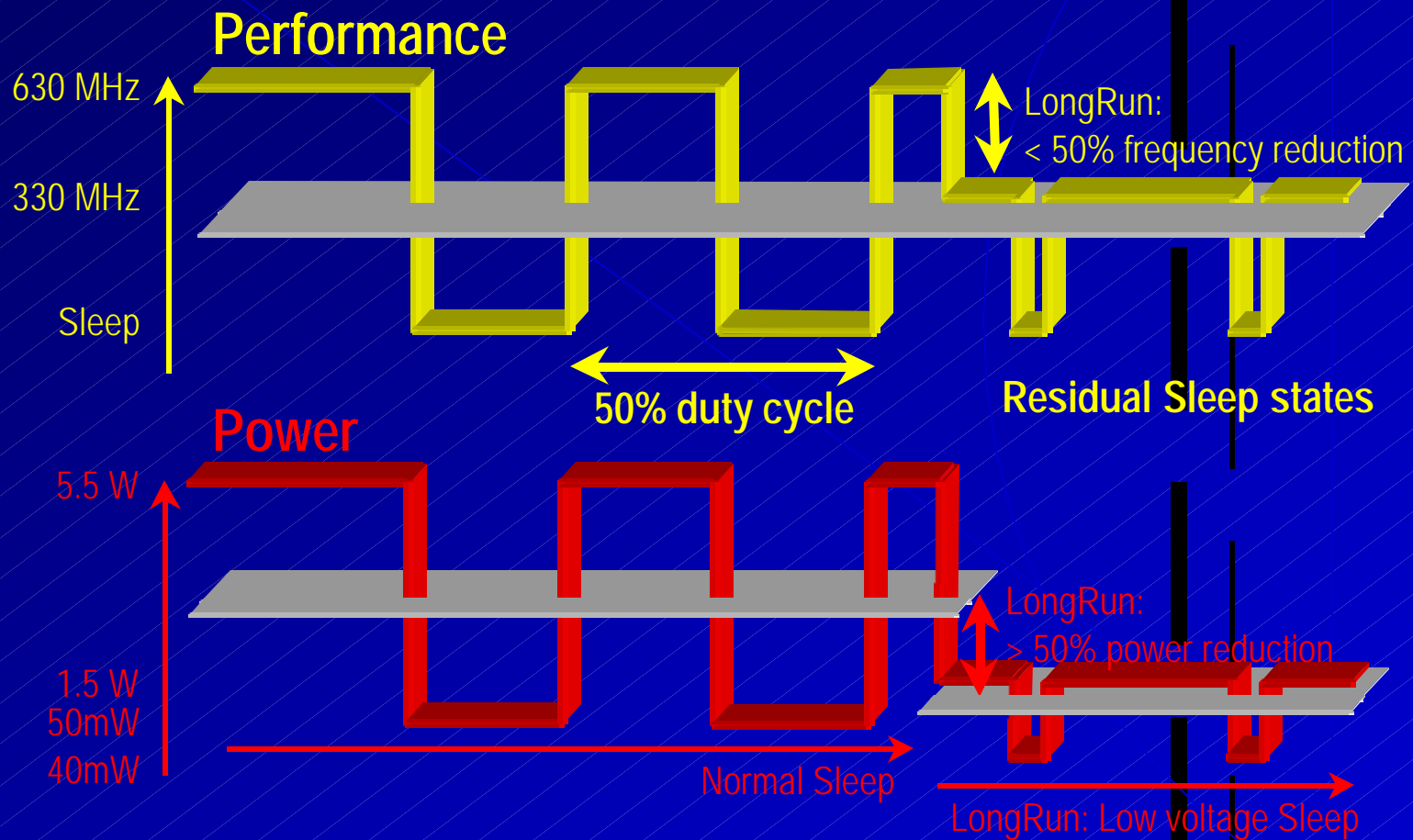
Closed loop

Crusoe TM5400 processor featuring Transmeta LongRun technology

Code Morphing software monitors system activity and dynamically adapts LongRun performance levels

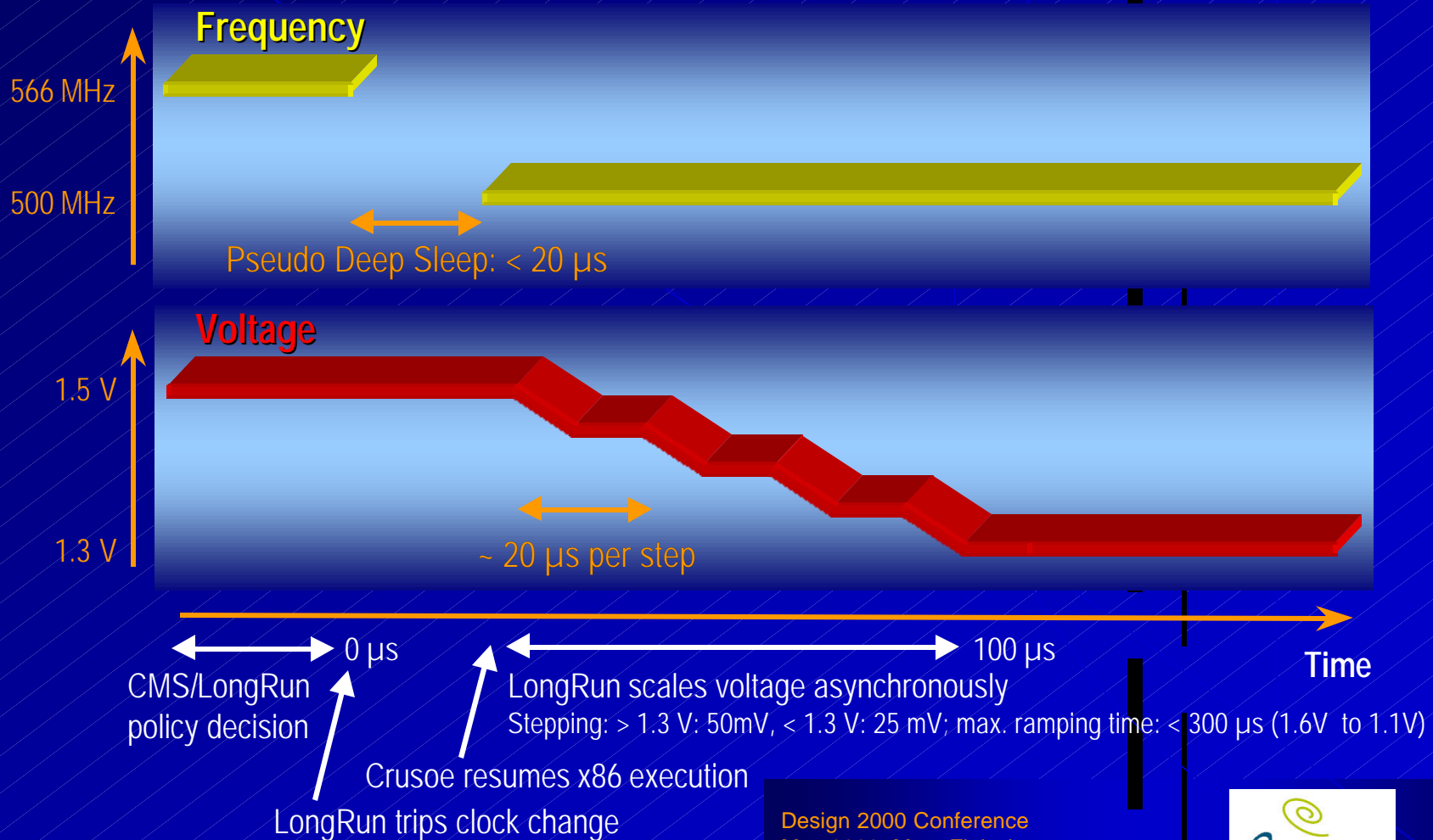
Performance on Demand

Duty Cycle \Leftrightarrow Effective Performance Level



Transition Dynamics

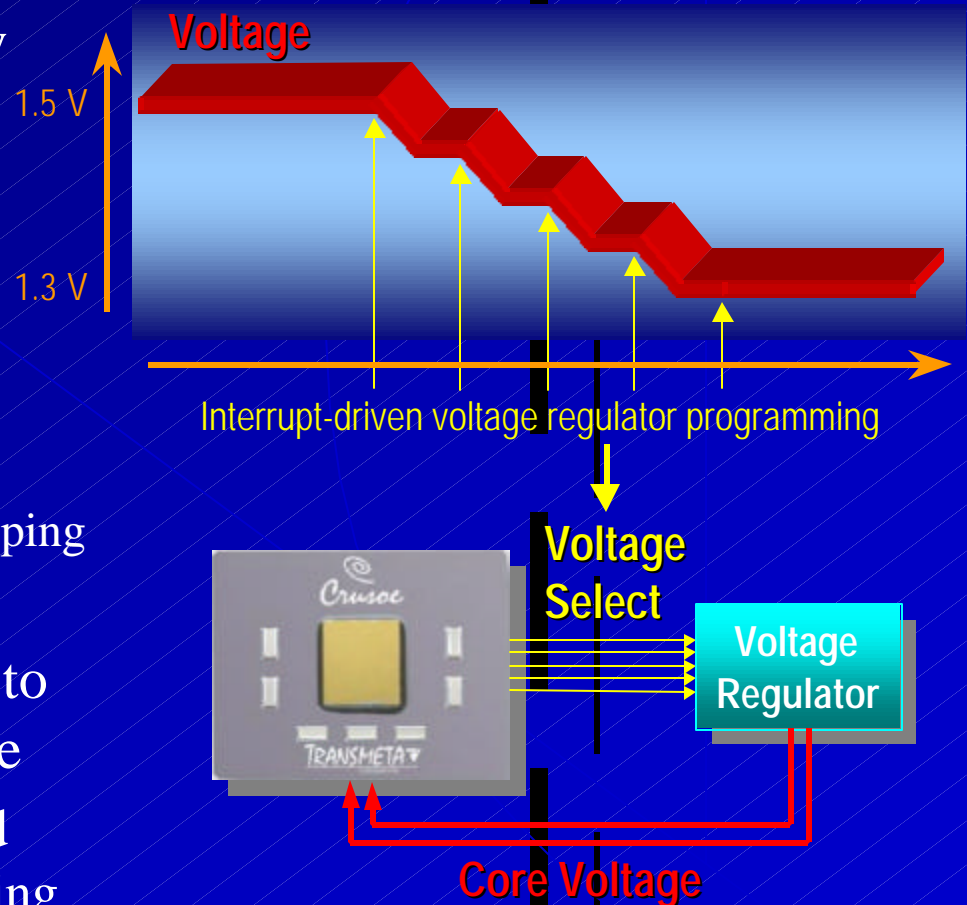
Fast Frequency/Voltage Scaling



Transition Details

Voltage Scaling

- ◆ TM5400 Core Voltage is Fully Under Software Control
 - ◆ Code Morphing Software directly controls voltage regulator pins (via internal processor register)
 - ◆ OEM configurable
 - ◆ CPU output pin/voltage mapping
 - ◆ Voltage settling interval
- ◆ Software Schedules Interrupts to Asynchronously Ramp Voltage
 - ◆ Allows sustained x86 forward progress during voltage ramping



Programming Interface

Processor and Northbridge

Adaptive Power Control

CPU interface

CPUID 8086 0001h

EDX:0 LongRun supported
 ECX Nominal core frequency

CPUID 8086 0007h

EAX Current core frequency
 EBX Current core voltage
 ECX Current performance percentage

MSR 8086 8010h

EDX Upper boundary (% of max. performance)
 EAX Lower boundary (% of max. performance)

Advanced Thermal Control

Northbridge interface

Function 0, Register A8h

Bit 4 Thermal Management enabled

Bit 1:3 Power reduction level

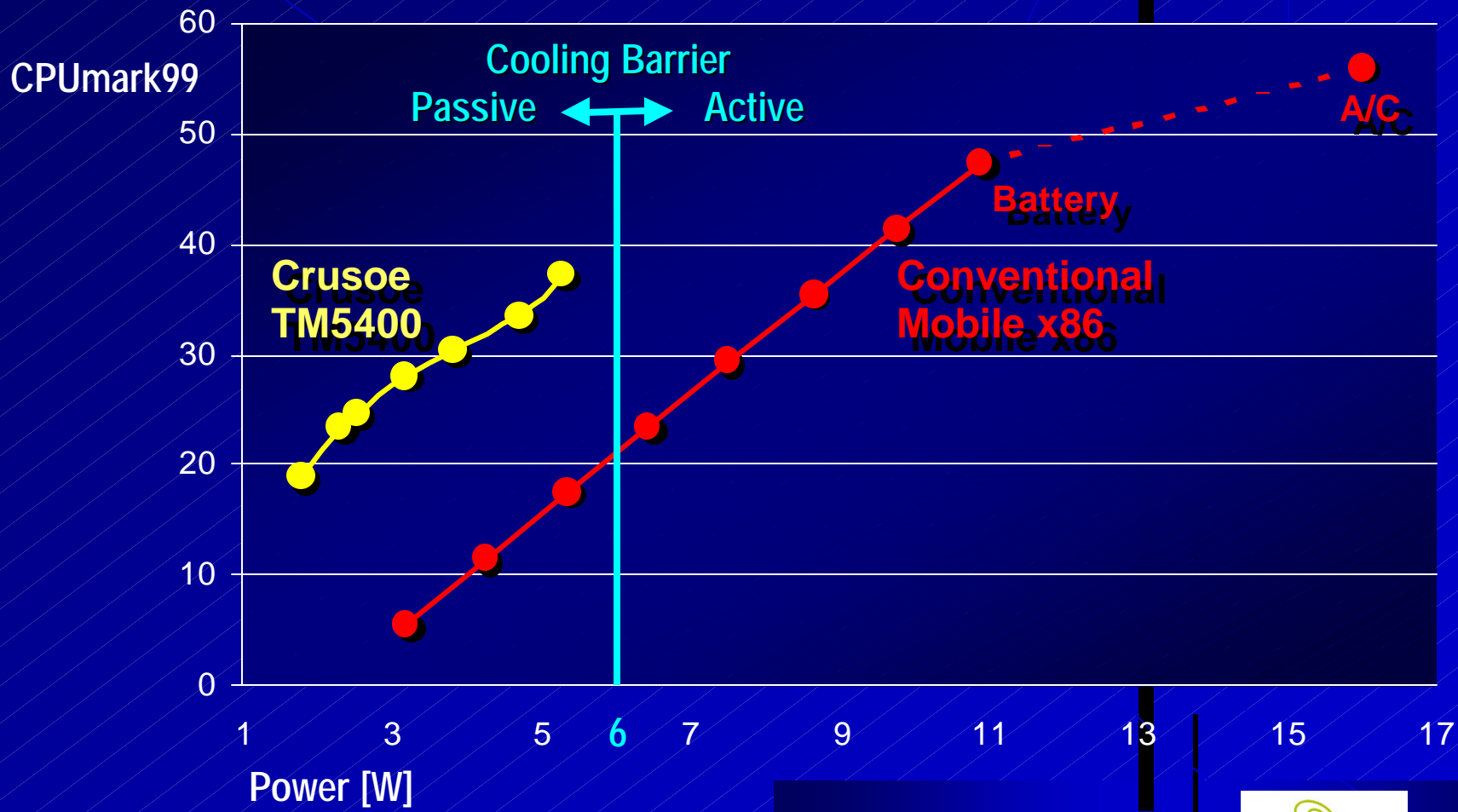
Bits	Mode
000	Reserved
001	Reserved
010	75.0%
011	62.5%
100	50.0%
101	37.5%
110	25.0%
111	12.5%

Bit 0 LongRun supported



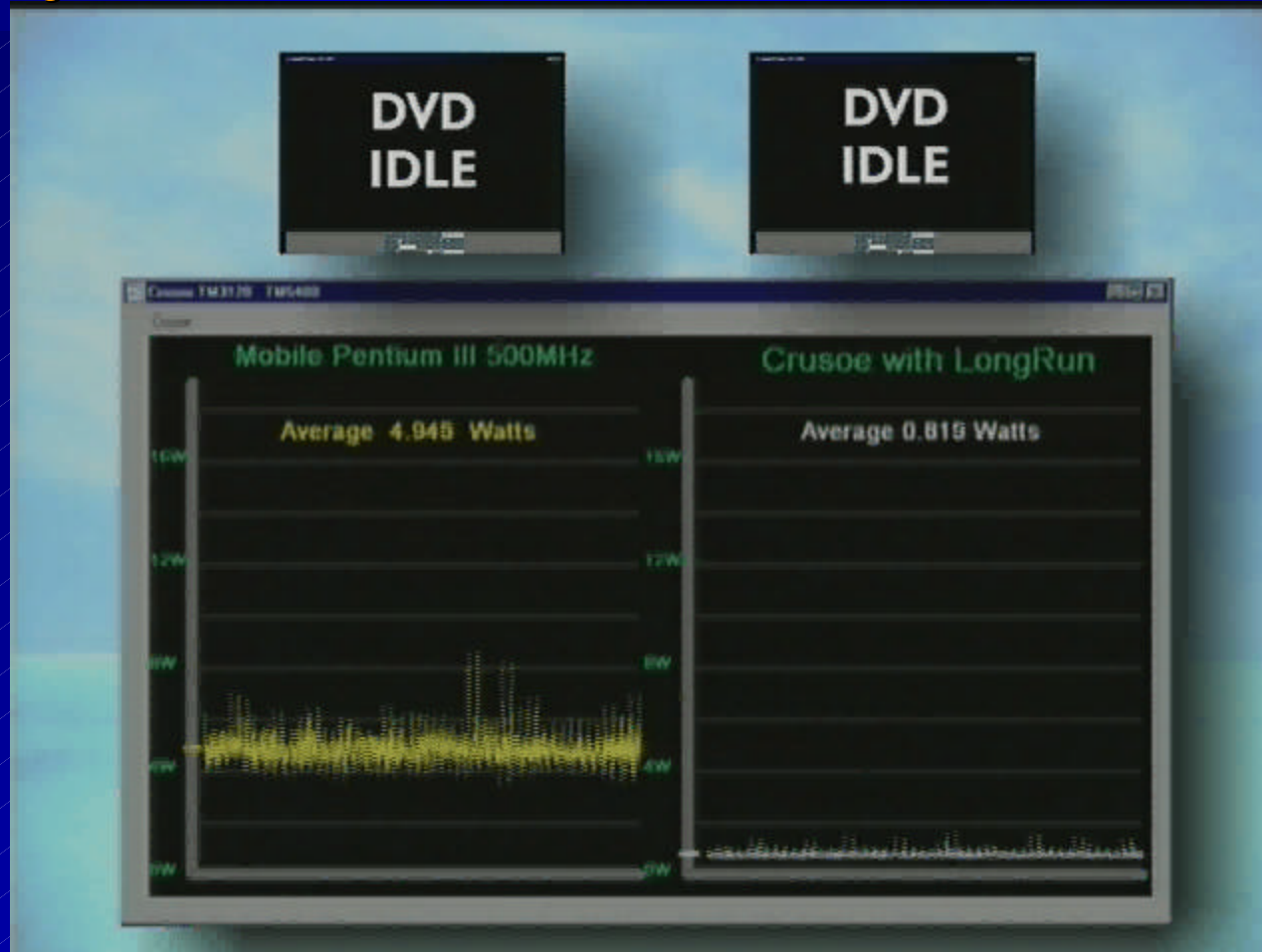
Energy Efficiency

Superior Performance in Small Form Factors



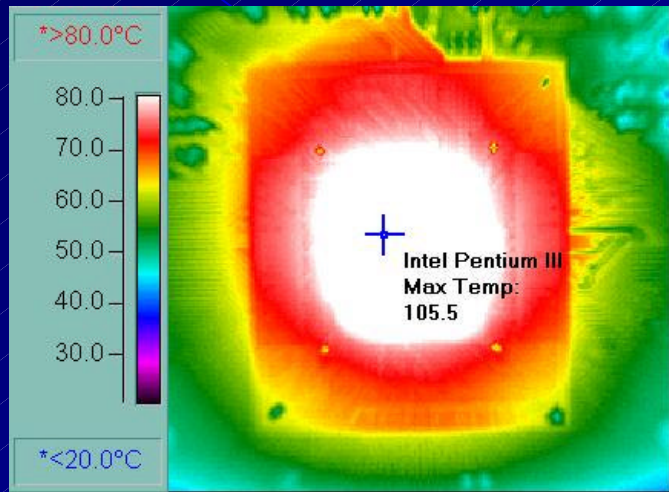
The LongRun Advantage

DVD Playback - Performance on Demand



The LongRun Advantage

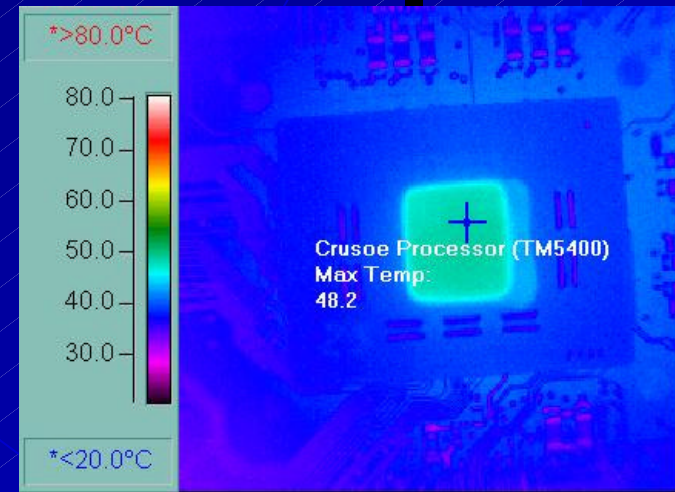
DVD Playback - Thermal Comparison



Conventional Mobile x86
Processor

105.5° C 221.9° F

Active thermal solution required
(Fan or overload protection)



Crusoe™ TM5400 Processor
with LongRun™

48.2° C 118.8° F

Passive thermal solution
(No fan or overload protection)

Summary

- ◆ Crusoe Supports the x86 Power Management Model with Significantly Reduced Power Consumption
 - ◆ Sleep: 4× (C1) - 30× (C3) power savings
- ◆ Crusoe Leverages Code Morphing Software to Drive Breakthrough Power Management - LongRun
 - ◆ Normal: 2× - 10× power savings
- ◆ Crusoe Leverages LongRun to Expand the Thermal Envelope
- ◆ Crusoe's Breakthrough Low-Power Technology Portfolio
 - ◆ Allows a whole new class of battery-powered devices
 - ◆ The full PC and Internet experience - Anywhere and Anytime