Designing a Notebook PC

Emerging Trends in Electrical and Computer Engineering
Carnegie Mellon University

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New World. New Thinking:

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It’s hard to predict the future!

Scientists from the RAND Corporation have created this model to illustrate how a “home computer” could look like in the year 2004. However, the needed technology will not be economically feasible for the average home. Also, the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now, scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use and only...
Personal Computer Average Price Is Going Down

Facts & Trends
• PC cost reduction is always a market requirement, especially for emerging countries
• Technology improvements and standardization lowering PC’s cost - continuing commoditization of PC including laptops
• Profit from PC sale becomes marginal
• IC - PC industry core technology cost down
  – Chip technology process will use 0.13um-0.09um in 3-5 years, and many foundries have the production line
  – The mask fee continues to decline

Observations & Implications
• Personal computer price and cost continues downward ➔ harder to make profit consistently
$1000 Buys...

1E+12
1E+9
1E+6
1E+3
1E+0
1E-3
1E-6

Year
1900 1920 1940 1960 1980 2000 2020

Computations/sec
Mechanical
Vacuum tube
Electro-mechanical
Discrete transistor
Integrated circuit

after Kurzweil, 1999 & Moravec, 1998
The ThinkPad X60 – Design Areas of Focus

Communications

Battery Life
- Up to 8.0 hours with one battery
- Support for 2nd battery

Performance

Thermals

Expansion

Safety

Ergonomics

Component Protection

2.69 lbs.
1.0" thick

Component Protection
Processors

Facts & Trends

- Frequency differentiation is no longer of value to most users
  - Only a few small percent of users will pay for highest frequency parts
- Users require relevant additional function to justify higher price processors (ROI)
  - Hardware security, Virtualization, Manageability
- Processor vendors need ability to scale die size to reflect new market demands
  - Multi-core critical as die size can scale from entry (one core, one thread) to high end (8 cores, 8 threads) allowing processor vendors to price based on cost

Observations & Implications

- Intel/AMD can offer extremely low cost processors for emerging entry price cells
- Common architecture can scale to high end (gamers, etc.)
- Addition of hardware security and virtualization enables PC OEM’s to offer differentiated offerings
Processors – Many Cores on one die

• Today – 2 Cores (mainstream)
• Just announced – 4 cores
• Tomorrow – 8 Cores

By approximately 2010 you will have a 16-way server on your lap
Processors

Facts & Trends

Thermals are a problem for both notebooks and desktops

*Past:* Higher Performance = Higher Clock Frequency

- Higher Power Consumption

Thermal Issue

Multi-Core processor can achieve better performance and power saving for Multi-Thread applications

Better Power Efficiency

*Performance*

*WATT*

- Serial Execution
- Parallel Execution

Intel convergences mobile and desktops dual core processor architecture in 2006

Observations & Implications

- Thermal strategy will continue with multi-core processors
  - (4 cores – 8 cores – 16 cores) over time
Power Density: The Fundamental Problem

Need to Keep the Junctions Cool
- Performance (Higher Freq.)
- Lower leakage (Exponential)
- Better reliability (Exponential)
Liquid Cooled ThinkPads

Super Efficient Heat Exchange

- Moderates Temp.
- Increases Battery Life
- Full Speed Processors

Heat affects battery life
Thermal - Facts and Trends

• Heat Source
  – Processor (Power & Density growing)
  – DC/DC and Voltage Regulator
  – Communication Card (WWAN, WLAN)

• Other requirements for better thermal design
  – Windows Vista’s new GUI (Aero Glass)
  – Reduction in system size
  – Customer’s Request for lower temperature skin

– Graphic (Integrate and Discrete Model)
– Memory
– High Speed HDD / Optical Drives
1. Omni Direction Fan / Laminar Flow Fan
Horizontally installed fins are connected together with columns. It can provide a lot of air. Need to decrease cost

2. Silent Owl Blade
Surface of normal blades is smooth. Owl fan has a small bump on each blade. It is more silent than normal fan. It can supply a lot of air. Need to decrease cost

3. Liquid Cooling System
It can convey heat from system side to top side. Need to decrease cost

4. Cooling Dock
System is additionally cooled when docked.

5. Thermal Capacitor
Thermal Capacitor can temporarily store heat
Thermal - Recommended Future Thermal Solutions  2/2

6. Thermal Insulation Sheet (Vacuum Pack)

Vacuum pack is less conductive of heat than air. Need to decrease cost.

7. Effective System Design

It is effective to have a lot of inlet/outlet louvers, to have low air flow resistance, to have a fan at the back corner with two exhausts and so on.

8. Thermal Management Function

- Adaptive Performance Control
- Intelligent control with temp. and power data
- Next generation Thermal / Power Management

9. Liquid Metal TIM

Normal TIM
Gallium Indium

Metal is 10 times more conductive of heat than current silicon type grease.
Facts

- Use environment: more extensive and use mode: more diversely

Damage reasons

- Drop while carrying
- Liquid spill
- Object dropped on unit
- Fall off desk while in use
- Packed too tightly in briefcase
- Extreme heat or cold exposure
- Abused/misused
- Normal wear/overwear
- Mishandled in travel
- Improper insertion of PC card
- Object left on keyboard when closed

Damage

- As stove
- As salver
- As chair

Weather

Biology

Mechanical

Use it anywhere

Nucleus

Use it anytime

War Field

As salver

As cushion

Facts

- Use environment: more extensive and use mode: more diversely

Damaged parts

- Display screen
- Case, Outer Casing
- Keyboard
- Hard Disk Drive
- System Board
- Hinges
- Latches
- Modem
- CD or DVD Drive
- Track/Mouse Pad, Point Ball

Implications: Drop and Spill are the main reasons!
Trends – Drop and Vibration

Key Parts

Drop Protect Technology

APS
Cusionless (Outer)

Rubber Cushion

Drop Protection Technology

• **Key parts and system passive protection**
  – Technology
    • Rubber and foam internal protection
    • Rubber and plastic external protection
  – Application
    • HDD and Display outer impact protection
      – Low hardness rubber or foam material with good damp feature
      – Enough rubber or foam size for deformation while impact
    • Outer case impact protection
      – High hardness rubber or plastic material
      – Little deformation while impact
  – Advantage
    • Cost-effective
    • Acceptable protection performance
  – Disadvantage
    • Large space needed
    • Increased the system depth
    • Worse temperature performance caused by material
Drop Protection Technology

- **Key parts Active Protection System (APS)**
  - Technology
    - Accelerometer technology
  - Advantage
    - Reduce the change of disk head crash the disk
  - Disadvantage
    - Still need protection for disk and spindle
    - Can not improve non-operation performance

**TUX Racer Game**
What Do NASCAR and ThinkPads have in common?
Roll Cage

- Magnesium alloy frame around critical ThinkPad parts
- Absorbs shock on drop similar to Formula 1 Racing cars
Layers of Protection – Hard Disk Drive

*Design Philosophy – More Protection is Better*

- Shock-absorbing feet
- Metal Protection Plate
- HDD Protection Pack
- Active Protection System
- Roll Cage
The Future – Hybrid and Solid State Hard Disk Drives

- **Hybrid Hard Disk**
  - A Nonvolatile cache (NV Cache) is added to the hard disk drive
  - Allows data to be read and written while platter is spun down
  - Data in cache can be persisted in case of power loss

- **SuperFetch proactively places the right content into memory**
  - Pre-populates memory based on current and historical use patterns
  - Page priority not based on simple Least Recently Used
  - Adapts to memory usage patterns, including complex usage scenarios

- **Application Boxing**
  - Set I/O priorities and limit memory working set

- **New concept in adding memory to a system:**
  - USB Flash Drives can be used as a cache
  - Random reads can be serviced more than 10X faster on average through the USB 2.0 bus than from HDD
Trends: water-proof

- Water-proof tech. trend:
  Seal → drain → key part
Seal Protection Technology

• **Immovable seal**
  – Technology
    • Compress rubber
    • Embedding sealant
  – Application
    • B face, C/D face, Touchpad, Fingerprint……
    • Keyboard, Switches
    • Screws
  – Advantage
    • Low cost
    • Simple process and acceptable effect
  – Disadvantage
    • Seal material fatigued, for long term compressed
    • Traditional rubber material with worse temperature feature
Seal Protection Technology

- **Movable seal**
  - Technology
    - Button design
    - Door design
    - Cabling design
  - Application
    - All kinds of outer Ports
  - Advantage
    - Convenient operation
  - Disadvantage
    - Seal effect control difficult
    - Seal material fatigued cause by frequent open & close
    - Heat retention
Spill Resistant Keyboards

Contained water spill

Keyboard
Dual Drainage Holes
Ergonomics

If you are going to sit in front of it for 8+ hours per day, it should be comfortable.

Seven row, ISO compliant seven row keyboard on all models

Choice of TrackPoint caps

Superior key attachment

Center scroll button
Layers of Protection – Display Screen

Goals: Protect against breakage, reduce wobble and long-term wear

Cover material chosen for stiff, yet lightweight properties

Thick Stainless Steel Hinges

Interlocking Tabs

Dual Latches

Full-contact display protection frame

Structural Display Arch

Interlocking Tabs
What’s Next: LCD Roll Cage

Today

Next Generation

4x Stress Reduction
The Challenge

**Trend** = Increase in performance/function of laptops - hotter processors, more system power, more function

**Action** = Innovate on power management to improve battery life, size and weight

- Enhanced power management by monitoring usage behavior
- Performance optimization within a specified battery life budget
  - Trade-off performance vs. battery life (smart throttling)
  - Trade-off thermal and acoustics
  - LCD Slow Refresh
    - Refresh rate control (60Hz -> 50Hz) without any usability impact (flicker)
- Lower power consumption CPU / chip set
Battery Technology Has Not Caught Up…

WHERE’S THE JUICE?
In the past 15 years, many laptop technologies have improved by an order of magnitude – or more. But Li-ion performance has remained flat ...

Battery technology is the single greatest inhibitor to a lighter laptop

Source: Wired November 2006
Battery Technology Has Not Caught Up... (cont.)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CAPACITY (Milliamp Hours)</th>
<th>RECHARGE TIME (Minutes)</th>
<th>LIFESPAN (Recharge Cycles)</th>
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</thead>
<tbody>
<tr>
<td>1991</td>
<td>1,080</td>
<td>150</td>
<td>1,200</td>
</tr>
<tr>
<td>1999</td>
<td>540</td>
<td>360</td>
<td>500</td>
</tr>
<tr>
<td>2004</td>
<td>830</td>
<td>150</td>
<td>400</td>
</tr>
<tr>
<td>2006</td>
<td>900</td>
<td>30</td>
<td>300</td>
</tr>
</tbody>
</table>

SOURCES: HITACHI, INTEL, SONY

Source: Wired November 2006

Rapid charging technology is not the answer as it has its own perils
How To Increase Battery Life

Battery Life:
• Advanced Power Mgmt
• Improvements to Lithium Ion
• New Technology

Fuel Cells

ThinkPad Power Manager

Hybrid Battery Technology
Challenges of adding new standards

Gate Count/

- Network I/F Adapters (e.g., Gigabit Ethernet >100 K gates, little or no new code)
- Modems (e.g., v.90 PCI modems)
- USB 2 (Same as USB 1)
- P1394A/ OHCI host controllers (>100 K gates, lots of lines of new code)
- USB 1 Controllers (~20K gates, lots of new code)
- Protocol Overhead/New SW Code (e.g., OS, Driver, APIs)

Legacy (Serial Port, Parallel Port, PS/2, PCI Bus)

- 0 lines of new code (runs on all OS’es)
- 1,000’s of lines of new code (runs on some OS’es)
- 10,000’s of lines of new code (may run on future OS’es)
- 100,000’s of lines of new code (a vertical stack)

Standards that require new software stacks take much longer if ever to become industry pervasive
Mobile Experience - Wireless

Wireless Technology Landscape

- **New Antenna Technology**
- **Wireless Wide Area Network (WWAN)**
  - Choice of Technology CDMA or GSM
  - Working with FCC, Qualcomm and carriers on simplification of certification process
  - Expanding Carriers and Countries support
- **Wireless Local Area Network (WLAN)**
  - 802.11 n (MIMO) Increase Performance in 1Q07
  - Detail Chart
- **Personal Area Network (PAN)**
  - Ultra Wide Band (UWB) a better Bluetooth
Wireless UWB

- UWB is a new Short Range / High Throughput Wireless Technology
  - Fits in-between and overlapping with BT and WLAN
  - Up to 480Mbps physical rate now, >1Gbps in the future
  - Uses wide spectrum (3.1-10.6 GHz allocated; initial usage at 3.1 to 4GHz)
  - Very low power for data transfer compared to other wireless solutions
  - Avoids Interference better. Power is so low that other devices don’t detect it.

- UWB is not its own protocol. It is a physical interface for multiple protocols.
  - Currently USB (“Wireless USB”). Will expand to TCPIP, Bluetooth, VGA, DVI, etc…

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>900 MHz Cordless Phones</td>
<td>PCS</td>
</tr>
<tr>
<td>802.11b/g</td>
<td>802.11a</td>
</tr>
<tr>
<td>123456789</td>
<td>10</td>
</tr>
<tr>
<td>UWB (Several GHz)</td>
<td></td>
</tr>
</tbody>
</table>

Gbyte Transfer per 1000mA

- Most optimized for low power
Mobile Experience $802.11n$ - MIMO

$802.11a/g$ WLAN has one radio and two antenna. Only one antenna is used at a time.

MIMO use multiple radios and multiple antennas at the same time. MIMO increase communication speed by transmitting multiple streams over the air.
Next Generation Optical

Lenovo is supporting Blu-Ray
- 2x capacity
- All players are read/write (HD DVD has read only) → better cost for write devices

CD
- 700 MB
- 1.2 mm

DVD
- 4.7 GB/8.5 GB
- 0.6 mm

Blu-ray or HD DVD
- 50 GB - Blu-Ray
- 25 GB - HD DVD
- 0.1 mm
- 1.2 mm
A New Phase: PC Innovation Matters Again

A new phase –
- application of technology
  - for business advantage
  - as a companion tool
  - for our digital lifestyle

Time

Business Value

Phase one –
- speeds and feeds

Phase two –
- operational efficiency

Today