R&D in Electrical & Computer Engineering

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Career Day — Baltimore Polytechnic Institute — April 2010
Today’s Outline

1. Engineering careers in general

2. Embedded systems issues
   — why does everything break?

3. Computers & their memory systems
   — how do I make my computer faster?

4. Design as modern engineering entrepreneurship
   — my take on *The World Is Flat* … and guitars
(Who Is This Old Guy?)

• **High school** (GA & FL): salutatorian, three-season athlete, into rock, law, sci-fi

• **College** (Harvard): astr/math, A/B student, one-season athlete, into music, food, art

• **Teaching** (Thayer): high-school math

• **Industry** (BT, PCM): software developer, system architect (employee #2)

• **Grad school** (Michigan): computer software and hardware ... research
Points to Take Home

• Engineering rocks

• Challenging & important problems exist

• Electrical engineer ≠ electrician
  Computer engineer ≠ programmer

• Anything that is in your head today can (should) be in your hands tomorrow

• People are willing to pay you to think (being smart is only a disadvantage now)
General Overview:
Career Paths in (E&C) Engineering
Your Career Options

College => Industry
=> Grad School => Industry
=> Research
=> Academics

Paths I Will Discuss (briefly):
• Industry => B.S. or M.S.***
• Industry/Research => Ph.D.
• Academics => Ph.D.***

*** Paths I have taken
Big Picture

In Computer & Electrical Engineering:

• Industry B.S. or M.S. Develop
• Industry/Research Ph.D. Design
• Academics Ph.D. Research Teach

Develop == Build
 Design == Justify Your Choices

Ph.Ds are paid to THINK
MSs and BSs are paid to DO
(mitigated by size of company)
## Big Picture

<table>
<thead>
<tr>
<th></th>
<th>Industry/BS</th>
<th>Industry/PhD</th>
<th>Academia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Salary Range (0yrs–10yrs)</strong></td>
<td>$60K–120K</td>
<td>$90K–150K</td>
<td>$80K–150K</td>
</tr>
<tr>
<td><strong>Job Security</strong></td>
<td>Okay</td>
<td>Good</td>
<td>Great</td>
</tr>
<tr>
<td><strong>Freedom</strong></td>
<td>Little</td>
<td>Some</td>
<td>Lots</td>
</tr>
<tr>
<td><strong>Respect</strong></td>
<td>Lots</td>
<td>Lots</td>
<td>Little</td>
</tr>
<tr>
<td><strong>Visibility</strong></td>
<td>None</td>
<td>Little</td>
<td>Lots</td>
</tr>
<tr>
<td><strong>Brief Job Description</strong></td>
<td>Develop</td>
<td>Design</td>
<td>Research &amp; Teach</td>
</tr>
<tr>
<td><strong>Perks of the Position</strong></td>
<td>Free coffee</td>
<td>Stock options</td>
<td>Talking to a captive audience</td>
</tr>
</tbody>
</table>
Start-Up Companies

• Enter at any level

• Flexible job description
  *(room to move around)*

• Flexible pay scales
  *(SMALL possibility of LARGE pay-off)*

• Collegiate atmosphere
  *(working day == noon to 3am)*

• Downside: RISK FACTOR
  *(not advised for those w/ mortgage, children, etc. — mitigated by size & age of startup)*
# Big(ger) Picture

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<th>Start-Up Company</th>
<th></th>
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<tbody>
<tr>
<td><strong>Salary Range (0yrs–10yrs)</strong></td>
<td>$50K–$120K or more</td>
</tr>
<tr>
<td><strong>Job Security</strong></td>
<td>None (… to Lots)</td>
</tr>
<tr>
<td><strong>Freedom</strong></td>
<td>Lots</td>
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<td><strong>Respect</strong></td>
<td>Lots</td>
</tr>
<tr>
<td><strong>Visibility</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Brief Job Description</strong></td>
<td>Design, Build, Test, Maintain, Deal w/ Customer, whatever</td>
</tr>
<tr>
<td><strong>Perks of the Position</strong></td>
<td>Cool atmosphere, intriguing problems, stock options?</td>
</tr>
</tbody>
</table>

Perhaps best of both worlds?
The Most Important Problem Today: Embedded Systems
Characteristics

- Dedicated function (not general-purpose)
- Interact with environment (real-time)
- Resource-constrained (power, space, cost)
- Safety-critical (loss of life, property, etc.)
- Increasing pressure on time-to-market

**THIS IS A BAD MIX**
BANGKOK (Reuters) - Security guards smashed their way into an official limousine with sledgehammers on Monday to rescue Thailand's finance minister after his car's computer failed.

Suchart Jaovisidha and his driver were trapped inside the BMW for more than 10 minutes before guards broke a window. All doors and windows had locked automatically when the computer crashed, and the air-conditioning stopped, officials said.

'We could hardly breathe for over 10 minutes,' Suchart told reporters. 'It took my guard a long time to realize that we really wanted the window smashed so that we could crawl out. It was a harrowing experience.'
Examples Abound …

Microsoft Technology
Hits the Road in
BMW 7 Series

Microsoft Navigates the Automotive Industry,
Enhances the Driver Experience

REDMOND, Wash. -- March 4, 2002
Problem: Components may be verifiable, but the System is not
A Tale of Two Design Flows

VLSI Design Flow:
characterized by strict design rules,
verifiable physical design
A Tale of Two Design Flows

Behavioral Design

Structural Design

Physical Design

Fabrication, Deployment

Logic (RTL) Representation

module fibonacci(clk2, rst_1, out_w);
input clk2, rst_1;
output [7:0] out_w;
reg [7:0] src1, out;
wire [7:0] out_w = out;
always @(posedge clk2)
begin
  if(!rst_1)
    begin
      src1 <= 1'd0;
      out <= 1'd1;
    end
  else
    begin
      src1 <= out_w;
      out <= src1^out_w;
    end
end
endmodule
A Tale of Two Design Flows

Behavioral Design → Structural Design → Physical Design → Fabrication, Deployment

Logic Libs & Synthesis → Physical Libs, P & R → Design Rule Checks

Schematic Diagram
A Tale of Two Design Flows

- Behavioral Design
- Structural Design
- Physical Design
- Fabrication, Deployment

- Logic Libs & Synthesis
- Physical Libs, P & R
- Design Rule Checks

Physical Layout
A Tale of Two Design Flows

Behavioral Design

Logic Libs & Synthesis

Physical Libs, P & R

Design Rule Checks

Structural Design

Physical Design

Fabrication, Deployment

Working Silicon
A Tale of Two Design Flows

Behavioral Design
- Logic Libs & Synthesis
- Logic (RTL) Representation

Structural Design
- Schematic Diagram

Physical Design
- Physical Libs, P & R
- Physical Layout

Fabrication, Deployment
- Design Rule Checks
- Working Silicon

VLSI Limitation:
you can build **Wires** or **Transistors**

VLSI Design Flow:
characterized by strict design rules, verifiable physical design
A Tale of Two Design Flows

Embedded Design Flow: characterized by nonexistent design rules, *ad hoc* methods for system-level verification
Examples Abound ...

Jet Propulsion Laboratory, California Institute of Technology
What I’m Known for:
Computers and Memory Systems
Perspective

~10 Billion/s → CPU
~10 Million/s →
~100 per sec →
< 1 Billion/s
Primer

CPU/$
Read A

Outgoing bus request

CPU/$
read data

Read B
Write X, data
Read Z
Write Q, data
Write A, data
Read W
Read Z
Read Y

MC

read data
read data

RD
PRE
ACT

BEAT

cmd

PRE
ACT
RD
WR

PRE
RD
WR

PRE
RD
WR

PRE
RD
WR

PRE
RD
WR
Napkin Math: Palm HD

- $1920 \times 1080 \times 36b \times 60\text{fps} = 560\text{MB/s}$
  ($\sim1\text{GB/s incl. ovhd}$)

- $3 \times 4 \text{ DDR800} = 1.2\text{GB/s, 600mW}$

- Power budget = $500\text{mW total}$ (DRAM 10–20%)
Limit: Cost

- CPUs: die area (& power)
  Systems: pins & power
  (desktop: power is cost
   embedded: power is limit)

- FB-DIMM (Intel’s solution to the capacity problem)
  observed former at cost of latter … R.I.P. FBD

- Whither PERFORMANCE w/o limits? 10x at least
Questions?

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More on Start-Ups: The Importance of (High-Tech) Design
Important development in last decade:

Manufacturing as a Service
The Basic Idea

You → Design Blueprint → Factory → Manufactured Device
The Basic Idea

Design Blueprints → Factories → Manufactured Device → Assembly

You
Some Blueprints
Some (other) Blueprints
Pros & Cons

- Can’t possibly compete with big companies
- Might fail
- Can’t afford it
- Window of opportunity?
- Idea already proven in marketplace (shareware, boutique electronics)
- Win/win situation (even company failure is good résumé material)
- Low risk/reward ratio (e.g., design SW is free)
- Start soon

Bottom line: a path well worth exploring
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goole bruce jacob
(btw, the one on wikipedia is my dad)