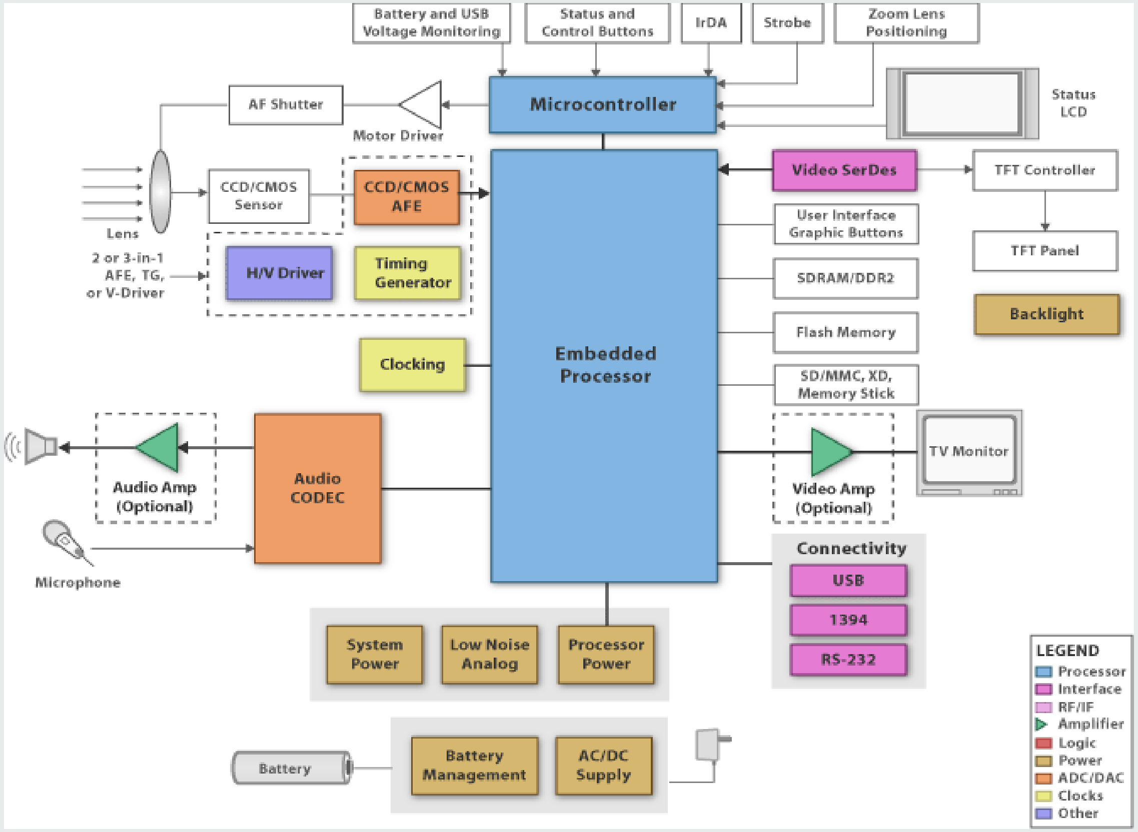
Computer Electronics

Lecture 5: Computer History & Economics

Computer vs. Embedded Systems

- Computers
  - A Personal Computer (PC): desktop or laptop
  - A server: cloud computing
- Embedded system
  - An Anti-lock Brake System (ABS) for a vehicle
  - A washing machine
  - A smart phone?
- Both computers and embedded systems contain processors

Example: a digital camera



Design concerns

- Size and weight
- Cost
- Safety and data security & privacy
- Performance
- Energy consumption
- User friendly interface
- Environmental impact

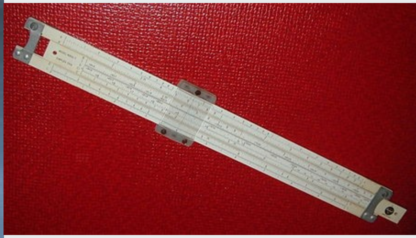
Computer evolution

- The word “computer” is used since the XVII century to designate a human worker in charge of performing calculation series
  - Navigation tables, astronomy, tides (sea levels), etc
- From the XIX century the word began to be used to designate a machine that performs programmed actions and calculations
  - A simple calculator is not a computer
  - A computer must execute “programs”
- Advantages of using a machine vs. human
  - Speed, no errors, repeatability, no weekends, vacation or labor laws to obey

Before the first machine computer

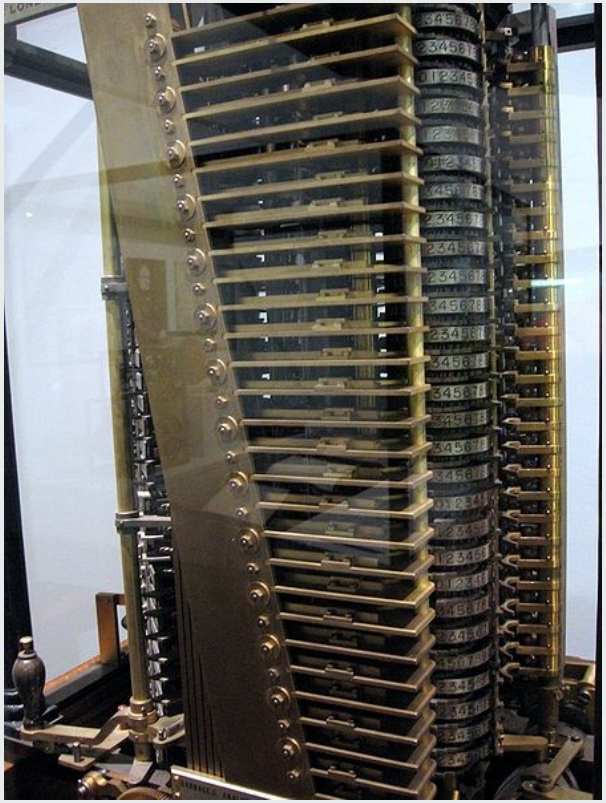
Several calculator apparatuses

- Abacus (2400 AC)
- Antikythera’s mechanism and astrolabe (150-100 AC)
- Al Jazari’s clock (1206, programmable)
- Napier bones (1617, John Napier)
- Slide rule (1620, William Oughtred et al.)



The first modern computer

- The Analytical Engine (1833, Charles Babbage)
- Only finished in 1991 for London's Science Museum
- Mechanical, powered by steam engine
- Uses punched cards for program and data Input/Output



Capabilities of the Analytical Engine

- Addition, subtraction, multiplication, division
- Conditionals (if statements)
- Program loops (jumps)
- Processing unit separated from data storage unit
- Sounds familiar?

Evolution aspects from 1833

- From mechanics to electronics
- Electronic component evolution: relays, vaccum tubes, transistors, integrated circuits
- Transistor evolution; bipolar to MOSFET
- Number representation: analog, digital base 10, digital base 2
- What is stored in memory: program, data, program and data
- Users: researchers, companies, everybody
- Applications: specific to general purpose to specific

War as main driver...

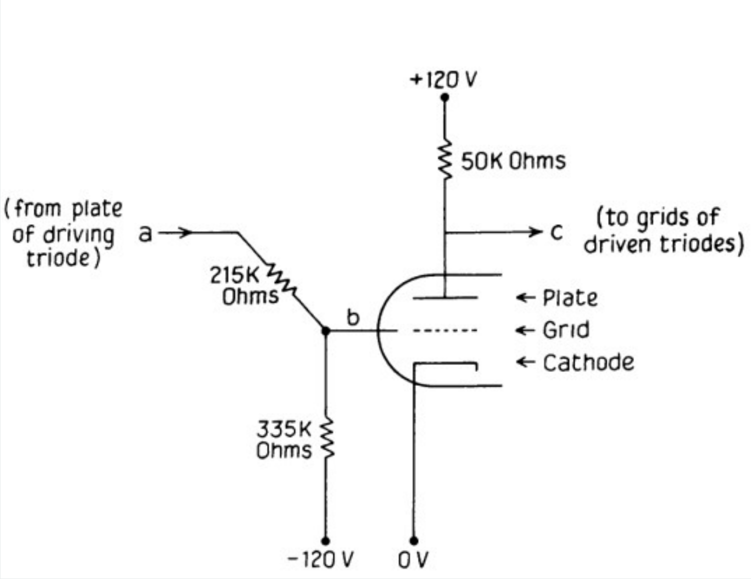
- Z3 (1941, Konrad Zuse): electromechanical using relays
- ABC - Atanasoff-Berry Computer (1939): vacuum tubes, the 1st electronic computer, digital, binary numbers
- Colossus (1943,Tommy Flowers): electronic binary digital computer, vacuum tubes

Analog versus digital

- Analog: continuous range, susceptible to electromagnetic noise
- Digital: discrete range, noise immune
- Digital resolution: number of bits (32 or 64 bits)

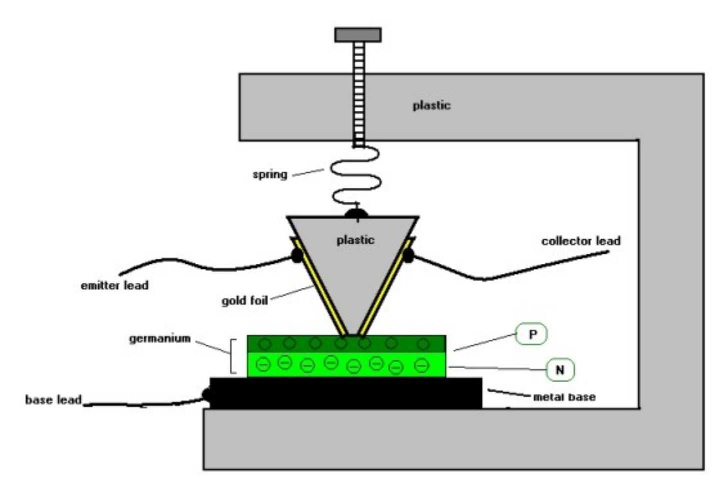
Logic gates in the ABC computer

- Negative logic
  - 0: High Voltage
  - 1: Low voltage
- Implemented using vacuum tubes
- 30 operations per second!
- Vacuum tubes big, unreliable, power hungry



The transistor

- John Bardeen and Walter Brattain,
  - Bell Labs, 1947, using germanium
  - A 3-pin controlled switch



Transistors, integrated circuits (IC), systems on chip (SoC)

- Logic gates made of a few transistors
  - Initially diodes and resistors also used
- Integrated circuits (John Kilby, 1958)
  - made of many integrated logic gates
  - Kilby received the Nobel prize in 2000
- From Bipolar devices to MOS devices
- Current feature size: 5nm (minimum length, not the width, the W/L is an important parameter)
- Current density: billions (10^9) of transistors per SoC

Computer Economics

- Project management
- Team building
- Product
  - Purchasing 3rd party components
  - User interface
  - Packaging
  - Documentation

Project management

- Really crucial and complex task as computers are complex products
- Managers are competent, experienced and well paid
- It is a very broad activity: engineering, design, team management, marketing, sales, etc

Project management tasks

- Building a team
- Planning development
- Process: implement work flows
- Choosing the target technology and 3rd party components
- Validation, verification and production testing

Team building

- Take into account the experience of each individual (to avoid common mistakes)
- Take into account the expertise of each individual (to match the tasks)
- Take into account the inter-personal capabilities of each individual (to ensure efficient communication)

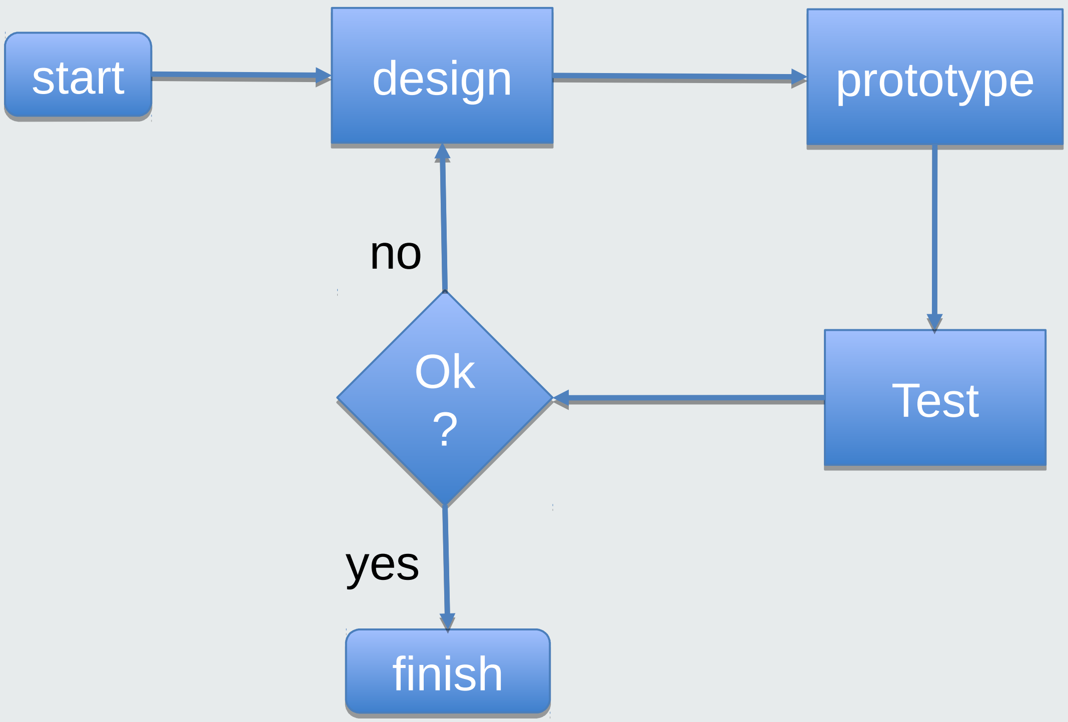
Team work

- One well defined task
- One well defined deadline
- One coordinator and spokesperson
- Each team member should have a clearly defined responsibility
- Each team member should be assessed continuously to detect
  - Difficulties, problems, inefficiencies

Planning development

- Divide development in parts, as independent as possible to enable parallel fast development
- Divide each part in hierarchical fashion, from top to bottom tasks
- At the bottom there will be development modules with a single purpose that can be given to different teams/people
- Reuse existent software and hardware modules as much as possible

Process: implement work flows



Project decision making

- There is no single solution
- There are many factors to take into account
- There are no free lunches
  – There are always pros and cons
- Find good enough solution
- No need to find the optimal solution

Non recurrent engineering (NRE) cost

- NRE is the development cost
- NRE is independent from the number of units produced
- When production starts NRE activities stop
- NRE grows with product complexity
  - Product complexity grows exponentially with features.
- Lower is better (bad news for engineers!)

How to decrease NRE

- Hire an experienced team
  - This is why big companies buy startups
- Optimize team size
  - Bigger or smaller will cause delay
- Use suitable machinery and tools
- Use Commercial Off the Shelf Components (COTS)

Unitary cost (UC)

- Cost for producing a single product unit
- NRE is excluded
- Lower is better
  - Increases profit margin
  - Allows more competitive pricing

How to reduce the unitary cost

- Buy cheaper components (watch quality)
- Balance make versus buy decisions
  - Apple dumped Imagination Technologies
- Increase scale
  - Produce more units with same resources
- Automate processes
- Optimize labor costs
  - Salaries
  - Legal obligations (make good use of labor laws)

Example profit calculation

- To create a product, it is estimated that
  - NRE = 2000
  - UC = 100
  - Selling price P = 300
- Compute the profit for
  - a) V=10 units
  - b) V=1000 units
- Profit = P*V-UC*V-NRE

  a) Profit = 0

  b) Profit = 198k
- Profit margin = Profit / Sales

  a) Profit margin = 0

  b) Profit margin = Profit /(P*V)=0.66 = 66%

Size matters: small is better!

- # transistors
- # code lines
- # memory bytes
- Specially important in portable products

Performance matters

- Performance metrics:
  - Execution time (latency)
  - Throughput (data processed per second)
    - Eg. Samples per Second
- Better performance generally leads to more competitiveness but
  - Requires more expensive components
  - Increases power consumption (watch battery life)
- A right balance must be found

High energy consumption consequences

- Shorter battery life
- Higher energy dissipation
  - Temperature rise
  - Need for cooling
  - Larger product size
  - Higher unitary cost

Flexibility means competitiveness

- Ease of adding / removing features
- Reactivity to market changes
- Software enabled flexibility
- Programmable hardware enabled flexibility

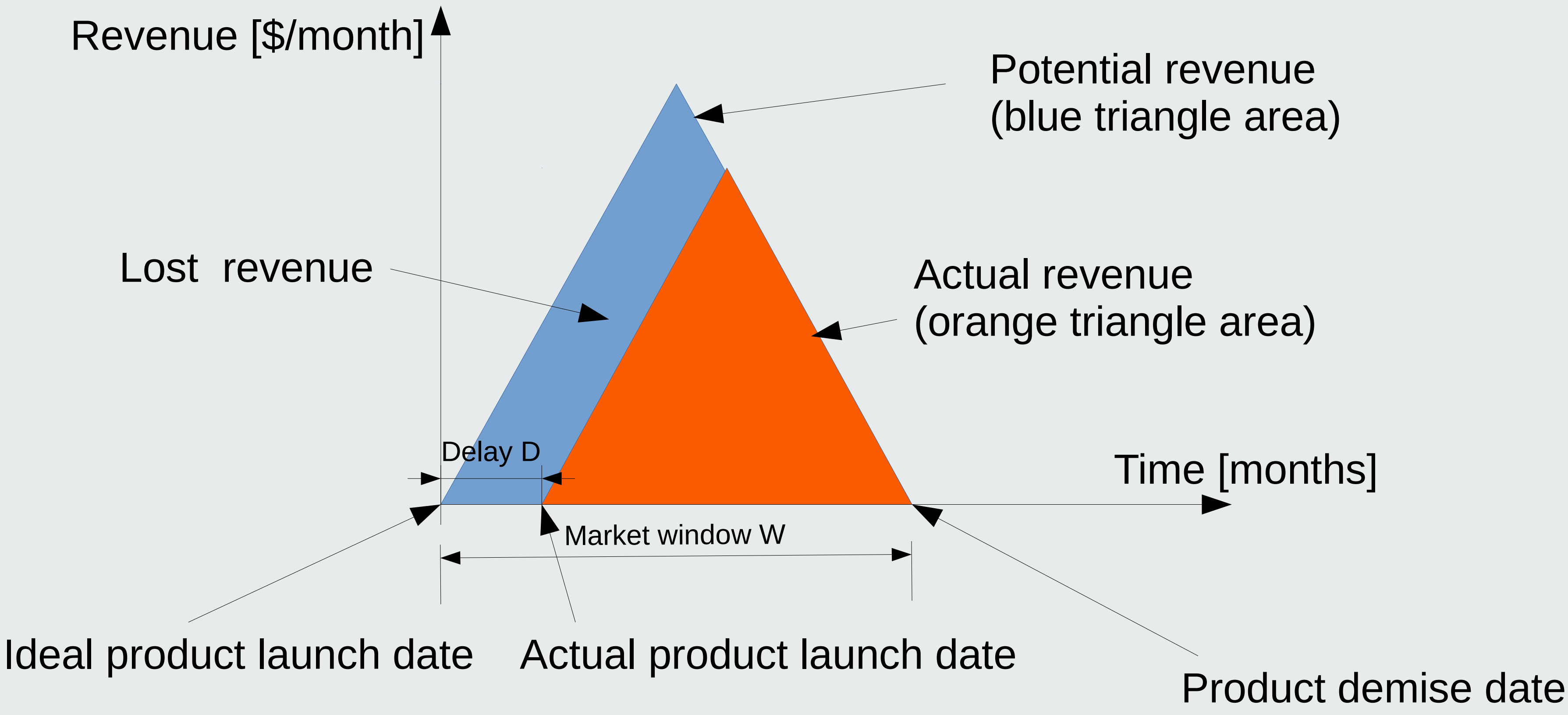
Time-to-prototype

- Time to build first prototype
- Validates the project choices
- Shows that performance is adequate
- Shorter is better
  - More time to make changes if needed
  - Faster market entry: investors happy

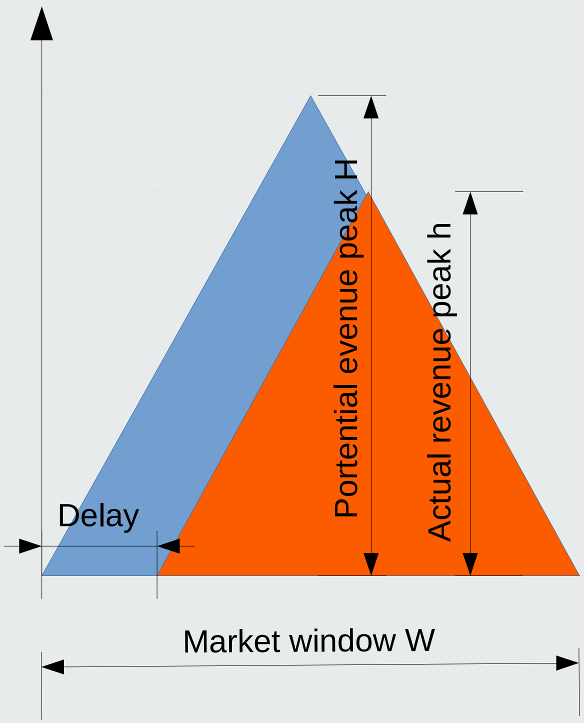
Time-to-market

- Time from project beginning to product launch in market
- Shorter is better: arrive before competitors
- Delays have significant impact in profit margins
- Can be measured in months

Time-to-market delay effect



Time-to-market problems

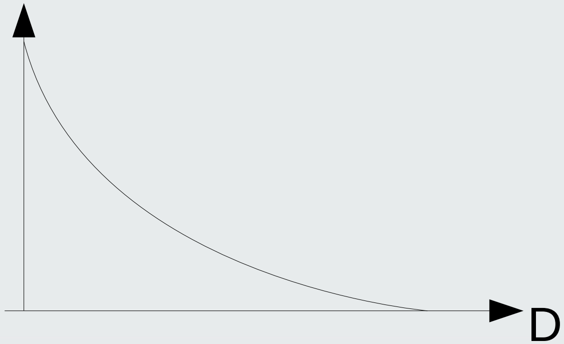


Potential revenue: $R_P = W*H/2$

Actual revenue: $R_A = (W-D)*h/2 = (1-D/W)*W*h/2$

$h = H*(1-D/W)$

$R_A = (W-D)*h/2 = W*H/2*(1-D/W)^2$



Safety, security and privacy concerns

- Probability that faulty behavior will cause harm to users
- Liability costs
- Damaged reputation costs for existing and potential customers

Environmental concerns

- Efficient use of energy
- Avoidance of hazardous materials
- Awareness is opportunity for differentiation

The ideal computer product

User

- Safe, Secure, Private
- Environmentally friendly
- Small size
- High performance
- Low energy consumption
- Low Price

Manufacturer

- Understand safety, security, privac
- Check environmental issues
- Work on form factor
- Target high performance
- Target low energy
- Low NRE, UC, D; High V