Digital Technology and Computing Devices

Introduction

CSCI E 45a: The Cyber World – part A

Learning goals

- Understand the fundamental building blocks of cyberspace
- Understand some of the key historical developments in their evolution
- Understand some key terms and concepts

This module

01000001

8 bits = 1 byte

Werner Buchholz
July 1956

- This module touches on topics many of you might consider very basic
- But, don't be fooled…

Topics

Gordon E. Moore

Grace Hopper

- It's all about bits - R
  - Bits, bytes, oh my!
- From a single bit to a processor - R
  - A quick view into how we went from a simple switch to the incredibly complex processors of today
- The evolution of computers - O
  - Key milestones in the history of computing devices and technologies

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Topics

- The generic computing device - R
  - Understanding the structure of a generic computing device through the walkthrough of a sample mother-board
- Important concepts - R
  - Key terms that we will refer to in the rest of the course, or are important for you to understand other parts of the course

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4 Gordon E. Moore http://www.computerhistory.org/semiconductor/assets/img/400x400/1965_1_1.jpg

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5 Open Source Initiative logo

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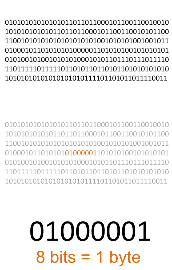
It's all bits

CSCI E 45a: The Cyber World – part A

Cyber world, an entirely made up world

- The physical world is analog
- Walter Isaacson's four key characteristics of computers
  - Digital
  - Binary
  - Electronic
  - General purpose

Bits

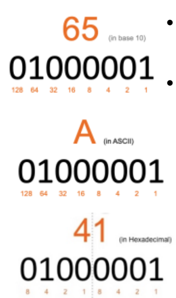


- Bits – binary digits
  First appeared in a 1948 paper "A Mathematical Theory of Communication" by Claude E. Shannon
- n bits codify 2^n possibilities
- A byte (or octet) is 8 bits
  Werner Buchholz – July 1956

Big Idea

The same bits can be interpreted differently, and used for different purposes

Reading bits



- The same bits can be read to mean different things
- Encodings map bits to other values
  - E.g., American Standard Code for Information Interchange (ASCII)
  - E.g., Hexadecimal (base 16):
    - 0,1,2,3,4,5,6,7,8,9,a,b,c,d,e,f,10,11,12,13,14,15,16,17,18,19,1a,1b,1c,1d,1e,1f, etc.
      - The letters are case insensitive

Representing anything using bits

- Text based encodings
  - Bits map to text
  - The text itself contains additional information to express complex information
  - E.g., HTML
- Binary based encodings
  - Bits map to pre-defined structures
  - E.g., Red/Green/Blue (RGB) encoding for a pixel

Code, data, or both

- Bits = Code = Data
- Code – bits interpreted as action/programs
- Data – bits representing data
- Implication:
  Code is data and data is code

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Packaging bits

- Bits are used and manipulated as "packages" of bits, or more specifically, packages of bytes
- Many ways to package bytes:
  Files
  Network packets
  Database record
  Memory block
  Etc.

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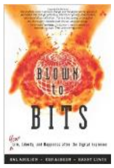
Big Idea

Bits are inherently neither good nor bad

9

The problem with bits



- How do you differentiate some bits from others
  - Good/bad bits
  - Higher/lower priority bits
- Subjectivity can be a problem
- Intent can be hard to assess
- Bits are dual-use technology
  - Can satisfy more than one goal

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An example, steganography

The hidden message:
Hi Scott! How are you?

- Steganography – message hidden in selected bits
  - from the Greek: *steganos* meaning covered/protected, *graphei* meaning writing
- The same bits are:
  - An image
  - And a secret message

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2	Cover of Walter Isaacson's Innovators
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Digital Technology and Computing Devices

From a single bit to processor

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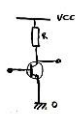
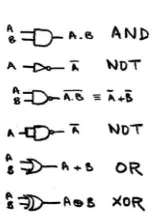
Creating a single bit



- A simple electrical switch
  - Can be ON or OFF
  - Presence or absence of voltage
- In the olden days, relays and tubes were used
- In the mid-40's the transistor was introduced

Wired logic

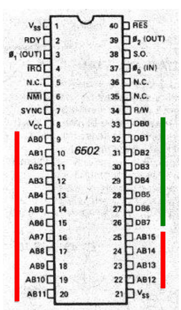


- By combining a few transistors one can create basic logical operators: AND, OR, NOT, etc.
- Complex logic can be assembled by combining these basic operators

A single bit memory device

- The "flip flop" – a.k.a. the "bistable multivibrator"
- Invented by two British physicits in 1918: William Eccles and F. J. Jordan
- Different flavors exist, but the single bit memory one is known as an SR latch

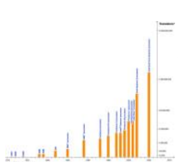
Structure of a basic processor



- Address and Data bus
  - Actual pins on the chip
  - Everything is based on reading/writing data to/from "memory"
- Internal registers
- Processing unit
  - Instruction set

Moore's law

Gordon E. Moore



- "Cramming more components onto integrated circuits" Electronics Magazine April 19th 1965
- For a given area, circuit density doubles every 18-24 months
- Derived implication: at a given price point, a computer's power/capacity doubles every 18-24 months

The network is the computer

- Coined by John Gage while at SUN Microsystems
- Implication:
  Networked machines (working together) are a machine
- Metcalfe's Law – the value of a network is proportional to the number of connected nodes/users

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5 6502 chip http://www.sbprojects.net/projects/izabella/assets/images/6502.jpg

6 Gordon E. Moore http://www.computerhistory.org/semiconductor/assets/img/400x400/1965_1_1.jpg

6 http://download.intel.com/pressroom/images/events/moores_law_40th/Microprocessor_Chart.jpg

7 SUN Microsystem logo and tag line

8

Digital Technology and Computing Devices

The evolution of computers

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The pre-computer times



- Thousands of years of human evolution
- Blaise Pascal, Jacquard Looms
- The Babbage, Lovelace partnership – The Analytical Engine

Ada Lovelace's notes/concepts:
- Multi-purpose, programmable
- Useful for non-arithmetic applications
- Algorithms, functional programming
- Lovelace's Objection: Machines are not capable of independent thinking


Ada Lovelace


Charles Babbage

The pre-computer times


Herman Hollerith


Alan Turing

- Herman Hollerith and the 1890 U.S. census mechanical tabulator
  - From 8 years to 1 year
  - The beginning of IBM
- Alan Turing's Turing machine
  - The Logical Computing Machine, a mathematical model of a simple processing machine
  - Simulates a simple CPU

Mainframes – the "big irons"

- Enormous, and very expensive machines
- Initially single use/purpose machines
  - Census tabulation
  - Ballistics calculations
- ENIAC, MARK I
- Quite a few mainframes still in use, and slowly being evolved

Grace Hopper

Grace Hopper

- U.S. Navy officer
- First programmer on the Mark I
  - Working with Howard H. Aiken
- Credited for:
  - Writing the first compiler
  - Being the first to use the expression "debugging the system"
  - Being a key contributor to COBOL

Minis and workstations

- Minis
  - Making the mainframe more affordable, more accessible
- Workstations
  - The original personal computer (for business)
  - Adoption closely correlated to key network developments

Networking - the alter ego to computing

- Sneaker net
- Point to point, serial links, character based
- Advanced Research Projects Agency NETwork (ARPANET) 1969
- IBM's Systems Network Architecture (SNA) 1974
- DARPA's TCP/IP early 70's

Networking - the alter ego to computing

- Xerox's Network System (XNS) 1977
- Open Systems Interconnection (OSI) 1978
- French TRANSPAC and the Minitel - 1982
- Consumer broadband late 90's
- "Always on" for the consumers (broadband and cellular data)

The transition to personal computing

- The Xerox Alto
- The Altair 8800
- The Apple I
- The IBM Personal Computer
- The Apple II

The personal computing revolution

- *A (small) computer on every desk and in every home*
  Bill Gates
- Fueled by the hobbyists
- And subsequently by early "gamers"
- Many proprietary models
- BASIC often the language of choice

The mobile device revolution

- Brings interesting new characteristics
  Always on, small form factor, location aware
- *Nowadays, phones are really computers that happen to provide phone services*
  Jim Waldo
- The best tracking device

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10 Ben's computers

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The generic computing device

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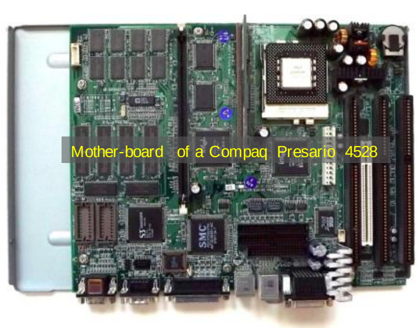
1



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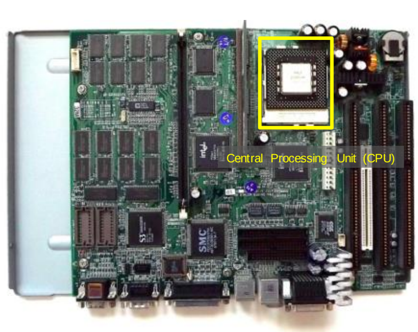
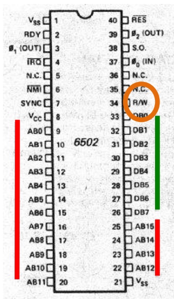


3

Structure of a basic processor



Source: izabella.me.uk

- Address and Data bus
  - Actual pins on the chip
  - Everything is based on reading/writing data to/from “memory”
- Internal registers
- Processing unit
  - Instruction set

4

Interrupts

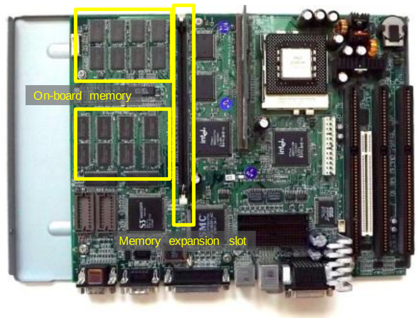
- Constant polling vs. interrupt
- Hardware interrupts
  - IRQ, NMI pins
  - e.g., mouse movement, key pressed on keyboard, network packet received, etc.
  - Some interrupts are “un-maskable” (e.g. Scott ☺)
- Similar concept has been extended in software

5

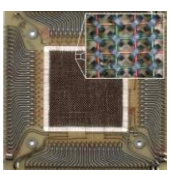
CPU processing power is based on…

- Clock speed
- Number of cores
- Bus widths and speeds
  - Could apply to internal arithmetic unit, address bus, or data bus
- Instruction set – what can be done in a single cycle
  - Reduced Instruction Set - RISC
  - Complex Instruction Set - CISC

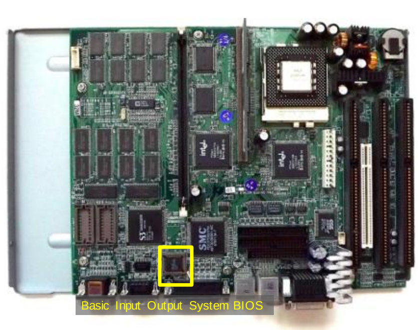
6



Memory



- Core memory (Magnetic Non-volatile)
  - Kilo-words
- Volatile storage
  - Mega to Giga-words
  - Random Access Memory (RAM)
  - Forgets when it looses power
- Non-volatile storage
  - Read Only Memory (ROM)
  - EPROM, UV PROM, EEPROM, Flash Memory, etc.



Boot software

- BIOS or Firmware
  - Now is stored in Flash memory so the firmware can be updated, and some configuration data can be stored (e.g., time-zone)
- New Unified Extensible Firmware Interface (UEFI) provides additional flexibility and supports secure boot

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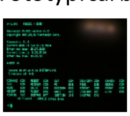
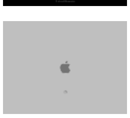
Prototypical boot sequence

1. Power is turned on
2. CPU goes through an initialization sequence
   - Uses boot software (BIOS/Firmware) to get started
   - Power On Self-Test (POST) to assess system well-being
   - Inventories some of its devices

11

Prototypical boot sequence, contd.





3. Then starts reading Operating System from "disk"
   - Can use secure boot that verifies integrity of each element involved in booting before executing it
4. Operating System goes through its startup

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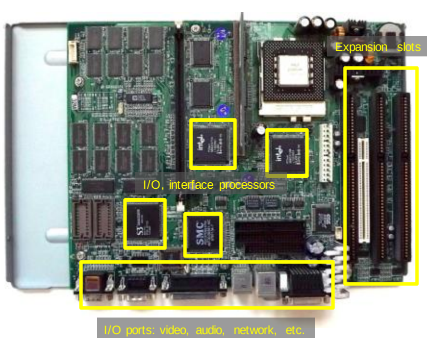
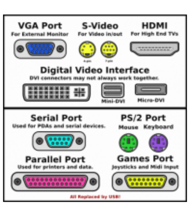
Secure boot sequence

- Cryptographic security verification on the boot software before starting
- Which is then used to read an initial chunk of the Operating System, which is then verified before starting…
- Computer manufacturer decides what software is ok to run



Input/Output

- Interfaces or devices:
  - Storage
  - Video
  - Keyboard, Mouse, Trackpad, etc.
  - Network Interface
  - USB port
  - Mic/Headset port



- Use interrupts and memory locations to communicate with the rest of the system

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4 “Motorola 6502 pinout“ - http://www.izabella.me.uk/assets/images/6502.jpg

5 “We interrupt this program” - http://www.lettherecordshowfilm.com/images/galleries/Art/We-Interrupt-This-Program.jpg

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11 "Award BIOS first screen" by Result of executing a ROM image dump in QEMU/KVM. Some retouching was needed, because the bottom of the screen was overdrawn with garbage after a while in the emulator.. Via Wikipedia - https://en.wikipedia.org/wiki/File:Award_BIOS_first_screen.png#/media/File:Award_BIOS_first_screen.png

12 DOS http://www.z80.eu/bootmsdos2.jpg

12 Win 7 http://www.theeldergeek.com/windows_7/images/Booting%20From%20W7%20DVD/TEG-0319.jpg

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Digital Technology and Computing Devices

Important concepts

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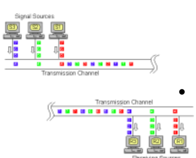
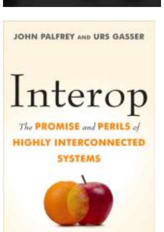
Multiplexing/De-multiplexing



- Multiplexing
  Intermingling streams of chunks of data into a composite data stream
- De-multiplexing
  Extracting individual streams from the sequence of chunks in a composite data stream
- Circuit based v. packet switching based models

Interop(erability)



- Allowing "things" to work together
  Focused on the interface between "things", and on standards for "things" to interoperate
  Open vs. Proprietary
- Two schools of thought
  Conformance to standards vs. interoperability testing
- The Gasser/Palfrey model
  Technical, Data, Human, and Institutional layers

Open source software

- Software for which the source code is publically available
  - Use of the source may still be constrained by licensing terms
  - Does not necessarily imply free
  - Generally implies many people are contributing to the design and coding of the software
- "free as in beer" vs. "free as in speech"
  - No cost vs. with little to no restrictions

Richard Stallman

Open Source Hardware

- Eric von Hippel - User led innovation
  - Needs driven innovation vs. profit driven innovation
  - Making things "hackable"
- Open Source
  - Published specs, and community of contributors
- E.g. Arduino, Open Kinect

Virtualization

- A few different meanings
  - When hardware becomes software
  - Simulating something with software
  - Creating a layer of abstraction
- Examples:
  - Virtualized machines, Virtualized network resources (e.g. VPN, VLAN), Virtualized storage
  - Virtual reality

Redundant Array of …

- Many small, less expensive, and less capable things working together can do more and be more resilient than a single big, expensive thing
- New traffic lights – multiple LEDs vs. single bulb
- RAID, RAIL, FEC, Highly distributed systems

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2 "Multiplexing and Demultiplexing" – Macao Computer Museum site - http://macao.communications.museum/images/exhibits/2_8_6_1_eng.png

3 "Steckernetzteil mit Adaptern IMGP2309 smial wp" by Smial (talk) - Own work. Licensed under FAL via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Steckernetzteil_mit_Adaptern_IMGP2309_smial_wp.jpg#/media/File:Steckernetzteil_mit_Adaptern_IMGP2309_smial_wp.jpg

3 Book cover for Interop – Publisher Basic Books http://cloudfront-assets.techliberation.com/wp-content/uploads/2012/06/Palfrey-Gasser-Interop.jpg

4 "Richard Matthew Stallman" by Sam Williams - Taken from the cover of the O'Reilly book w:Free as in Freedom: Richard Stallman's Crusade for Free Software. Licensed under CC BY-SA 3.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Richard_Matthew_Stallman.jpeg#/media/File:Richard_Matthew_Stallman.jpeg

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5 Open Hardware logo

5 Open Kinect logo

6 "VR-Helm". Licensed under Public Domain via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:VR-Helm.jpg#/media/File:VR-Helm.jpg

7 SETI @ Home logo

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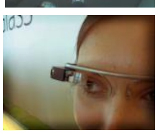
Digital Technology and Computing Devices

Conclusion

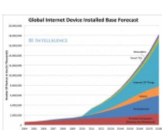
CSCI E 45a: The Cyber World – part A

The increasing density of the digital fabric



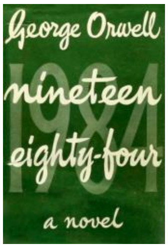
- Physical control systems
  - Buildings, transportation, etc.
- Smart clothes and wearable electronics
- Radio Frequency ID (RFID)
- Sensor networks
- The "Internet of things"
- The "Internet of everything"

Observations



- The building blocks of cyber space are…
  - …getting smaller in size
  - …increasing in number at a faster pace
  - …always connected
  - …embedded in the environment

Observations, contd.



- A blessing and a curse
  - Technology augmented reality offers new amazing possibilities
  - Privacy, independent thinking/action becomes much harder if not impossible for most

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3 "Internet device install base forecast" – Business Insider - http://static3.businessinsider.com/image/5266dc686bb3f788390592 51-480/deviceforecast.png

4 "1984first" by George Orwell; published by Secker and Warburg (London) - Brown University Library. Licensed under Public Domain via Wikipedia - https://en.wikipedia.org/wiki/File:1984first.jpg#/media/File:1984first.jpg