# EE 109 – Intro to Embedded Systems

Unit 0:

Class Introduction

Computer Organization



# Welcome to CENG!





http://blog.tmcnet.com/blog/rich-tehrani/uploads/facebook-datacenter-electrical-large.jpg
http://www.cmu.edu/news/image-archive/Boss.jpg
http://prisonerofclass-5933.zippykid.netdna-cdn.com/wp-content/uploads/2013/05/iphone.jpg
http://firstcallappliance.com/wp-content/uploads/image/microwave.jpg
http://www.engadget.com/2011/02/19/intel-to-spend-5-billion-on-new-14nm-fab-in-arizona-creating-4/
http://www.amazon.com/Fisher-Price-T-M-X-Tickle-Me-Elmo/dp/B000ETRE0Q
http://oeatech.net/wp-content/uploads/2011/03/RADARSAT2-satellite.jpg



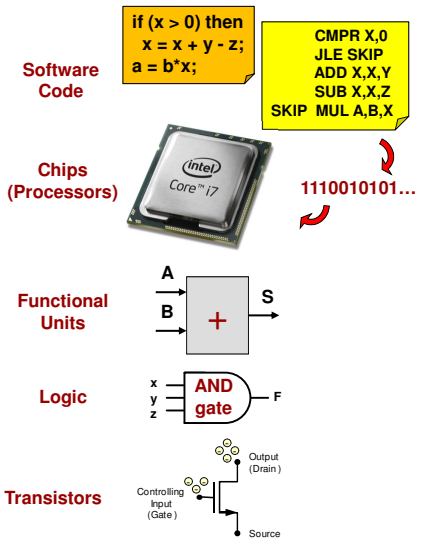
# What is Computer Engineering

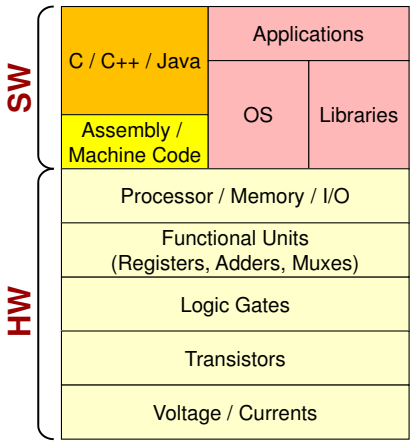
- Computer Engineering is…
  - Computer Science
    - Focus on information and transforming information into more useful forms (i.e. algorithms and computer programs)
  - Electrical Engineering
    - Focus on designing circuits and systems that physically manipulate information (i.e. a high or low voltage => 1 or 0) or other mechanical systems
- Design, implement, and test *devices and systems*
- Getting your hands dirty!
  - Designing circuits, using lab equipment, and building s***!

Goal of CECS: To develop engineers who can span the complex inter-relationship of computer hardware and software, creating and designing system solutions



# Computer Engineering as Abstraction Levels



# You Can Do That…

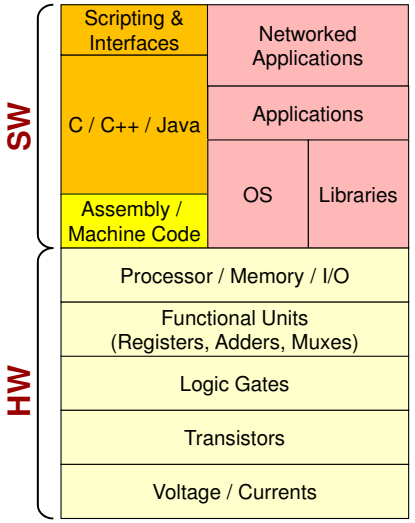
**Cloud & Distributed Computing**
(CyberPhysical, Databases, Data Mining,etc.)

**Applications**
(AI, Robotics, Graphics, Mobile)

**Systems & Networking**
(Embedded Systems, Networks)

**Architecture**
(Processor & Embedded HW)

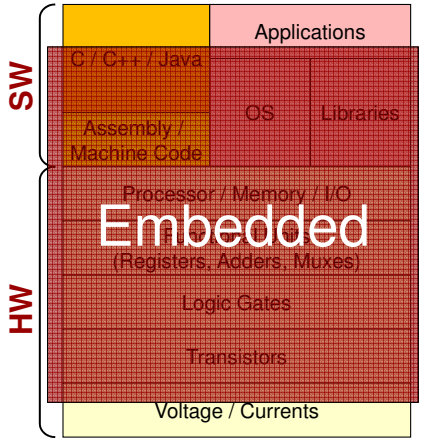
**Devices & Integrated Circuits**
(Semiconductors & Fabrication)






# Goals of this Course

- Embedded systems
- Programming
  - C language
- Computer organization
  - CPU, memory, I/O, etc.
- Digital logic
  - Basic logic functions
- Electronics
  - Voltage, current, basic circuit theory





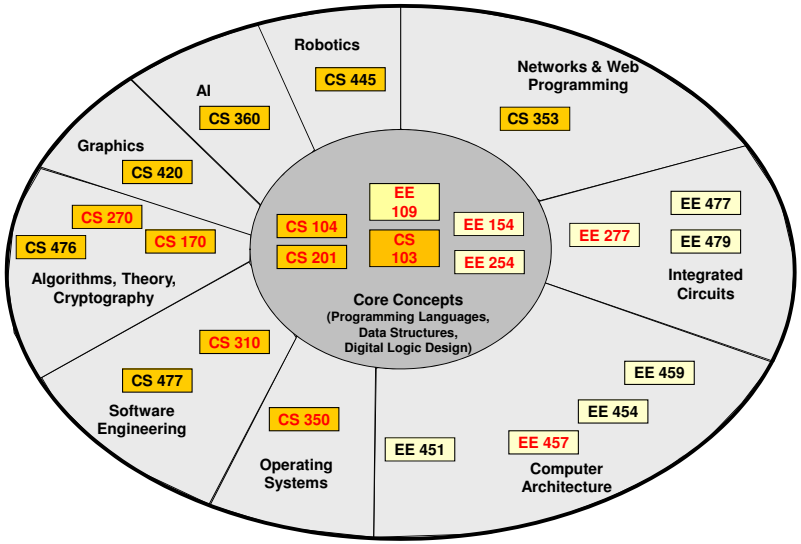

# Full Timeout - Syllabus



# Course Advice

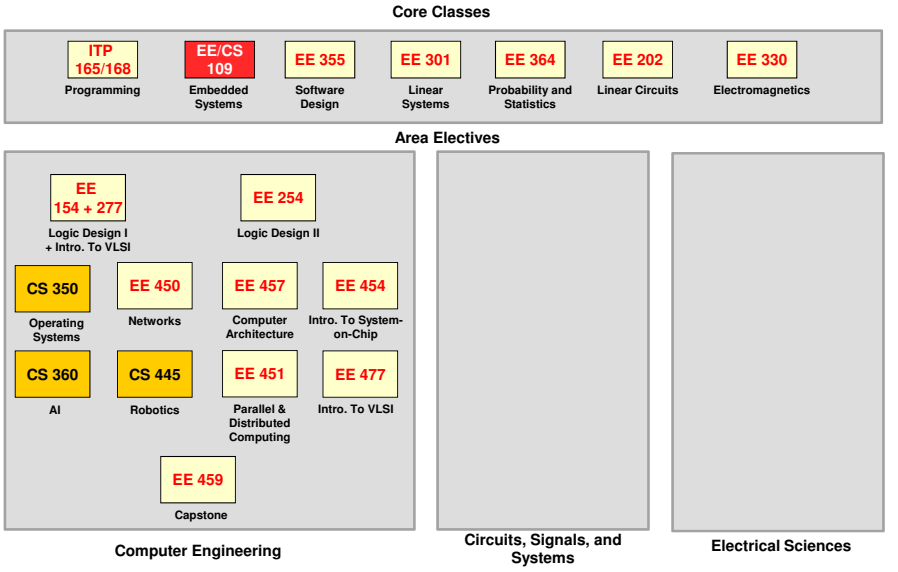
- Catch the wave!
  - Underestimate the time you will need and your ability to get your work done
  - Limit extracurricular activities in the 1st semester
  - Don't let shame or embarrassment keep you from the help you need
- You're here to learn not to be taught
  - Be active and engaged
  - Do not be afraid to fail
  - http://ceng.usc.edu/~bkrishna/TheDangersOfClassroomTeaching.pdf

# CECS Curriculum (Fall)





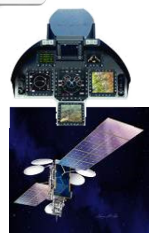

# EE Curriculum (Spring)






# Careers

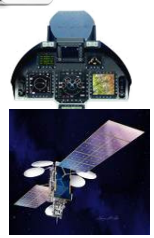
- Information Technology
- General & High Performance Computing
- Telecomm and Networking
- Media & Entertainment
- Automotive
- Robotics
- Aerospace / Defense



# Careers

- Information Technology
- General & High Performance Computing
- Telecomm and Networking
- Media & Entertainment
- Automotive
- Robotics
- Aerospace / Defense
- Academia / Research

# Companies

- Information Technology
- Semiconductor & General computing
- Telecomm and Networking

- Facebook, Apple, Google, MS
- Intel, AMD, IBM, Motorola, HP
- Qualcomm, Cisco

- Media & Entertainment
- Automotive
- Robotics
- Aerospace
- Startups

- EA, Disney, Riot Games
- Ford, etc.
- JPL, iRobot
- SpaceX, Boeing, Raytheon
- Embark, Zboard

2 of the top 10 fastest-growing job markets will be Computer Science and System (CENG) Engineers

* U.S. Department of Labor



# Research at USC

- Integrated Media Systems Center
  - Sound, video, online collaboration, streaming media research
- Information Sciences Institute
  - AI, Internet, Advanced Processing Systems research
- Institute for Creative Technologies
  - Virtual Reality, Graphics, Animation, Games



# Media

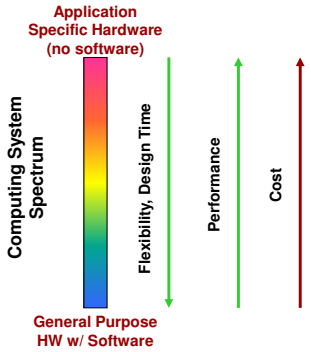
- Robotics
  - http://www.isi.edu/robots/superbot/movies/FoxNews.swf
  - http://www.isi.edu/robots/superbot/movies/SuperBot.swf
- **Virtual Reality**
  - http://www.youtube.com/uscict#p/u/13/Fh9gIswxbvU
  - http://www.youtube.com/uscict#p/u/0/0U7-q_9YV5c

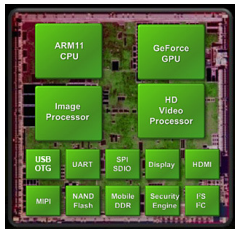


# EMBEDDED SYSTEMS

# Digital System Spectrum

- Key idea: Any "algorithm" can be implemented in HW or SW or some mixture of both
- A digital systems can be located anywhere in a spectrum of:
  - ALL HW: (a.k.a. Application-Specific IC's)
  - ALL SW: An embedded computer system
- Advantages of application specific HW
  - Faster, less power
- Advantages of an embedded computer system (i.e. general purpose HW for executing SW)
  - Reprogrammable (i.e. make a mistake, fix it)
  - Less expensive than a dedicated hardware system (single computer system can be used for multiple designs)
- Image Processing: System-on-Chip (SoC) approach
  - Some dedicated HW for intensive JPG/MPG decoding operations
  - Programmable processor for UI & other simple tasks



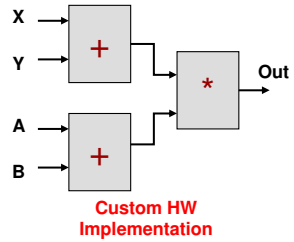




http://www.xbitlabs.com/images/news/2008-06/nvda_tegra_chip_scheme.jpg

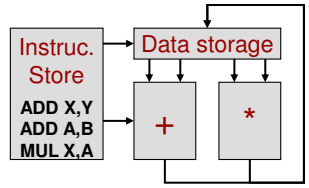


# Processing Logic Approaches

- Custom Logic
  - Logic that directly implements a specific task
  - Example above may use separate adders and a multiplier unit
- General Purpose Processor
  - Logic designed to execute SW instructions
  - Provides basic processing resources that are reused by each instruction
- What if I want to perform:
  - X*Y + A*B
  - What's easiest to redesign?




Custom HW Implementation




GP Proc. Implementation of (X+Y)*(A+B)



# Embedded Systems

- An embedded system is…
  - A special purpose computer that is designed into a larger device to perform some amount of dedicated tasks
- Utilize a microcontroller…
  - Laptops or desktops contain a ***microprocessor***
  - Embedded systems contain ***microcontrollers***
  - *What's the difference?*
    - Microprocessor is part of a larger computer system w/ RAM and general purpose I/O
    - Microcontroller is a single-chip with RAM and I/O to control specific electro/mechanical devices



# A Comparison

- Different microprocessor and microcontroller based systems

| | PC (Core i7) | iPhone (A6 chip) | MIPS32 (PIC32MX…) | Arduino (ATMega328) |
|---|---|---|---|---|
| **Clock speed** | 3 GHz | 1.3 GHz | 80 MHz | < 20 MHz |
| **Data size** | 64-bits | 32-bit | 32-bits | 8-bits |
| **RAM** | 8 GB | 1 GB | 16 KB | 2 KB |
| **Storage** | 1 TB | 32 GB | 128 KB | 32 KB |
| **Cost** | $1,000 | $650 | $6.04 | $2.88 |

# Engineering Design

Engineering is

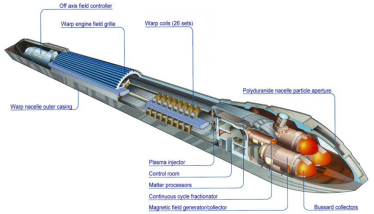
Design with Constraints



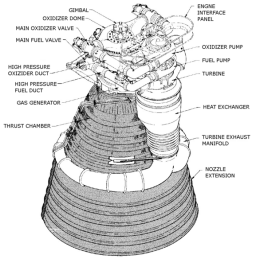
# Engineering Design

Artists and engineers both design things, but differently.

Artist: “We’ll create a spaceship powered by a warp drive.”




Engineer: “We need to build a rocket engine that works.”






# Engineering Design

What constraints does an engineer face when designing something?

| | | |
|---|---|---|
| Cost | Performance | Reliability |
| Durability | Ease of use | Weight |
| Power | Size | Safety |
| Environmental | Political | etc. |



# Engineering Design

The constraints may differ depending on the product.

Medical implant device: Reliability > Cost

Toy: Cost > Reliability

# Engineering Design

Example: Design a device for use in a Pinewood Derby to see which car finishes 1st, 2nd, etc.

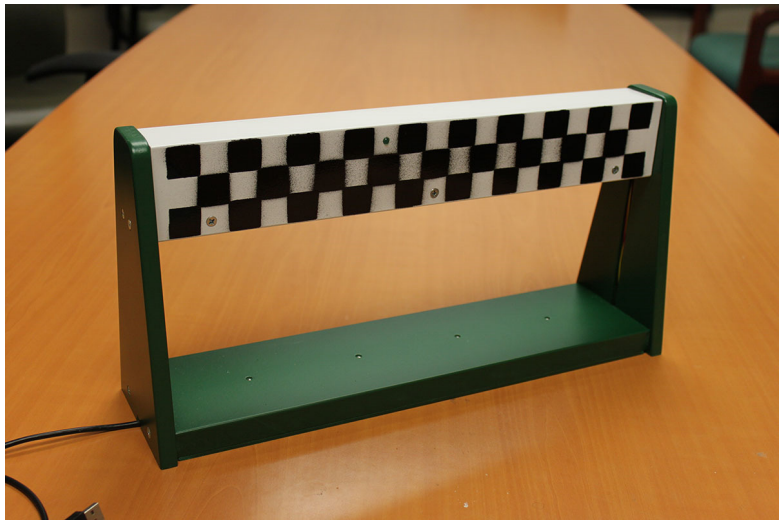



# Engineering Design

What constraints does the engineer have to consider?

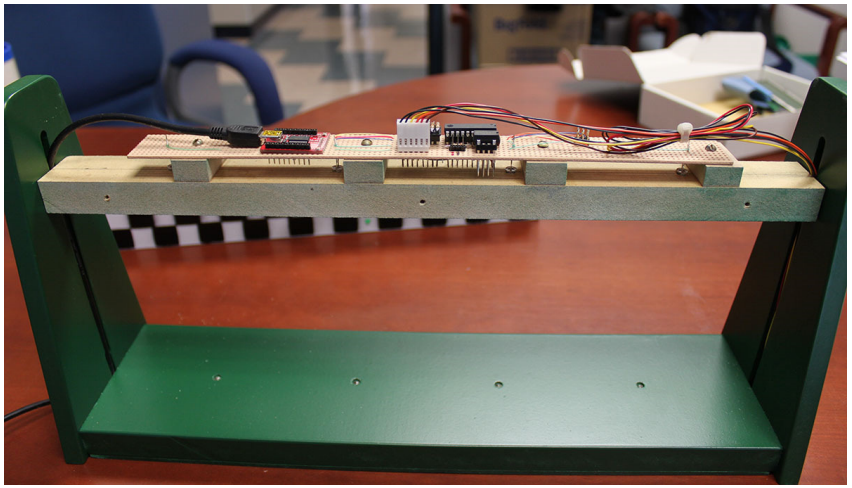


# Engineering Design





# Engineering Design



# Engineering Design



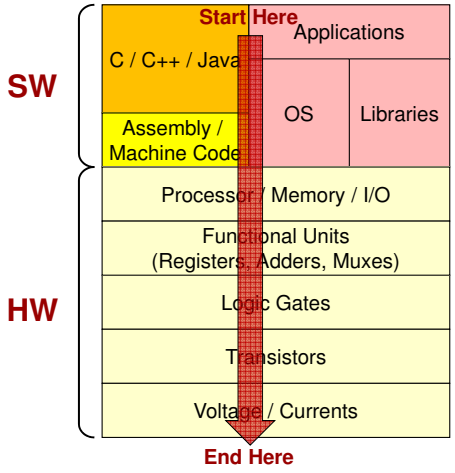
How does your computer work?

# COMPUTER ORGANIZATION OVERVIEW



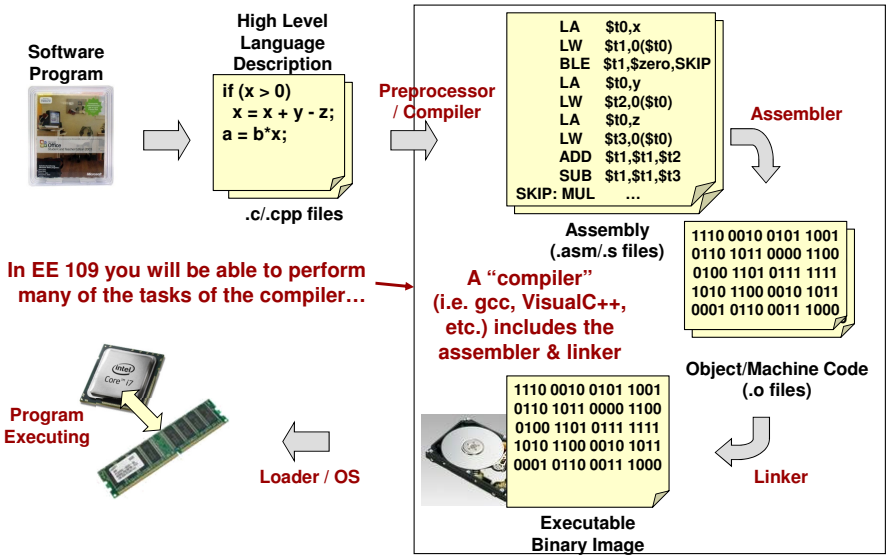
# Computer Systems Tour

- How does a SW program get mapped and executed on a computer
- What components is a computer composed of and what are their functions
- How does the architecture affect performance






# Software Process



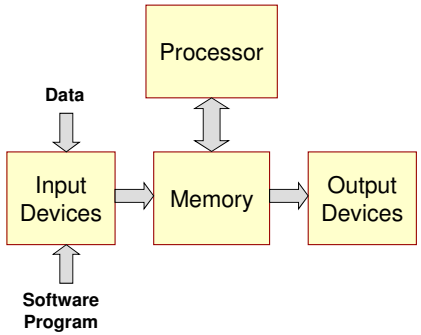
# Compiler Process

- A compiler such as 'g++' performs 3 tasks:
  - Compiler
    - Converts HLL (high-level language) files to assembly
  - Assembler
    - Converts assembly to object (machine) code
  - Static Linker
    - Links multiple object files into a single executable resolving references between code in the separate files
  - Output of a compiler is a binary image that can be loaded into memory and then executed.
- Loader/Dynamic Linker
  - Loads the executable image into memory and resolves dynamic calls (to OS subroutines, libraries, etc.)



# Hardware Components

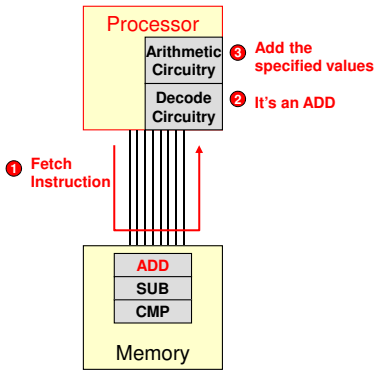
- Computer hardware can be classified into three categories
  - Processor
    - Performs operations on data
    - Pentium, PowerPC, etc.
  - Memory (RAM & ROM)
    - Temporary storage for data and program (instructions)
  - Input/Output Devices
    - Supplies and consumes data
    - Supplies the program
    - Keyboard, Mouse, Monitor, Hard Drive
- Many variations due to different performance, cost, reliability, power factors






# Processor

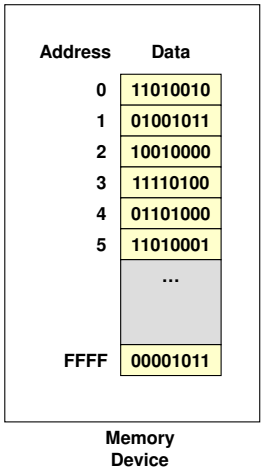
- Performs the same 3-step process over and over again
  - Fetch an instruction from memory
  - Decode the instruction
    - Is it an ADD, SUB, etc.?
  - Execute the instruction
    - Perform the specified operation
- This process is known as the **Instruction Cycle**





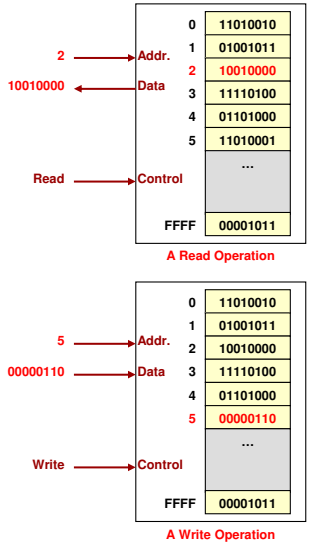

# Memory

- Set of cells that each store a group of bits (usually, 1 byte = 8 bits)
- Unique address assigned to each cell
  - Used to reference the value in that location
- Numbers and instructions are all represented as a string of 1's and 0's



# Memory Operations

- Memories perform 2 operations
  - Read: retrieves data value in a particular location (specified using the address)
  - Write: changes data in a location to a new value
- To perform these operations a set of address, data, and control inputs/outputs are used
  - Note: A group of wires/signals is referred to as a 'bus'
  - Thus, we say that memories have an address, data, and control bus.





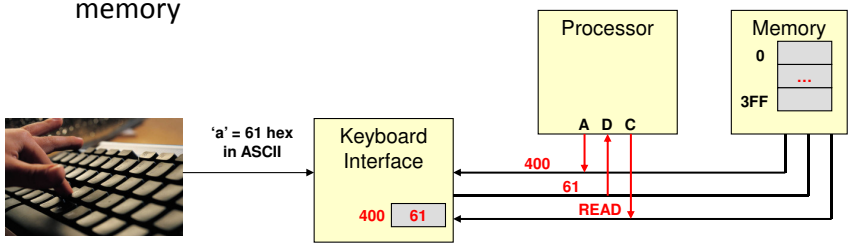

# Memory Types

- RAM (Random Access Memory)
  - Most memory types are random access
  - RAM really has come to mean the memory can be both read and written
  - Volatile: Contents are lost on power-off
- ROM (Read-Only Memory)
  - Data values are programmed prior to shipping and cannot be rewritten by the processor
  - Non-volatile: Contents are retained w/o power



# Input / Output

- Keyboard, Mouse, Display, USB devices, Hard Drive, Printer, etc.
- Processor can perform reads and writes on I/O devices just as it does on memory
  - I/O devices have locations that contain data that the processor can access
  - These locations are assigned unique addresses just like memory






# Input / Output

- Writing a value to the video adapter can set a pixel on the screen