C Program Adventures

From C code to motion

ECE 100
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From C code to motion

- C Code
- Motion

```
x=5;
if (x!=y)
{
 z=0;
}
else
{
 z=1;
}
```

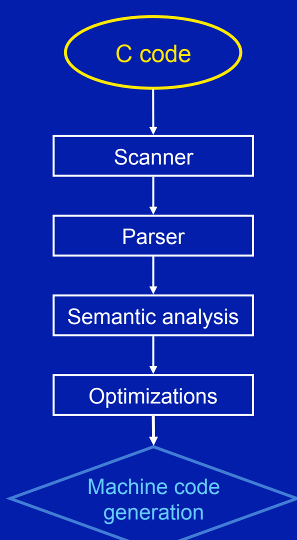
Process Outline

- Compilation of C code
- Virtual machine program
- Program download

- Assembly program generation
- Microcode execution
- Signals exchange

- Voltage control
- Motors control
- Sensors communication

Compilation Steps



- Input : C code
- Scanner - lexical analysis
  – Recognize parts of the language
- Parser – syntax analysis
  – Check the syntax of a language
- Semantic analysis
  – Consider the meaning of the program
- Optimizations
  – Improve speed
  – Reduce memory requirements
- Output : Virtual machine code
  – To be also translated to assembly language

C and Assembly Code Example

- If – then – else statement

C code

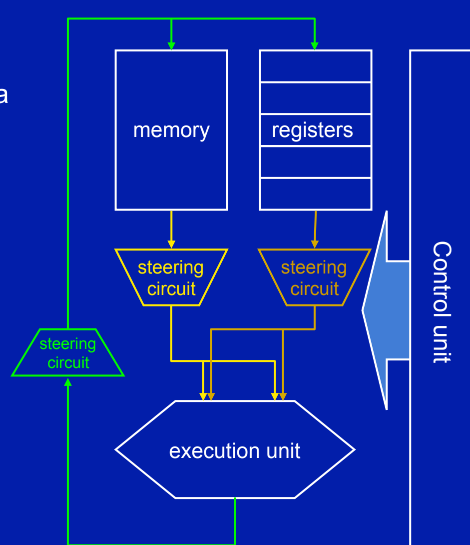
```
if (x!=y)
{
  z=0;
}
else
{
  z=1;
}
```

Assembly

```
   MOVE.L _x, D7
   CMP.L _y, D7
   BNE.S L1
   MOVE.L #1, _z
   BRA L2
L1 CLR.L _z
L2 …
```

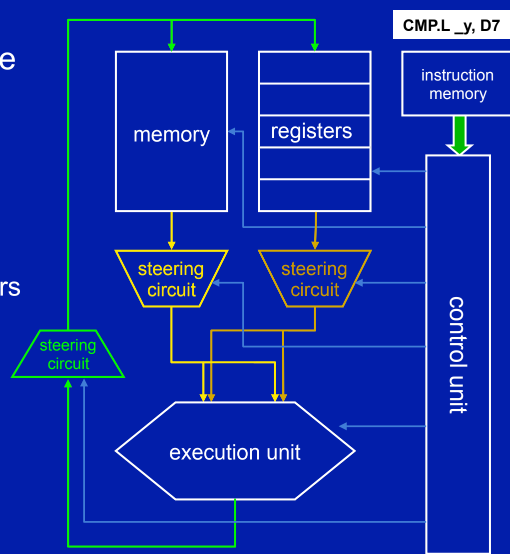
Microprocessor Components

- Storage space
  - Store instructions and data
  - Memory and registers
- Execution unit
  - Arithmetic operations
  - Comparisons
- Busses
  - Data transfer
  - Steering circuits
- Control unit
  - Operation synchronization
  - Instruction selection



Code Execution

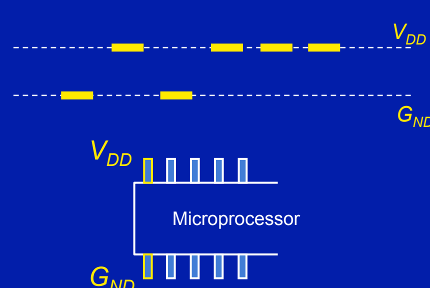
- Download assembly code
  - Into instruction memory
- Read instruction
  - In control unit
  - Specify control signals
- Read data
  - From memory and registers
- Steer data
  - To execution unit
- Execute operation
  - In the execution unit
- Store data
  - To memory or registers



Data Interpretation

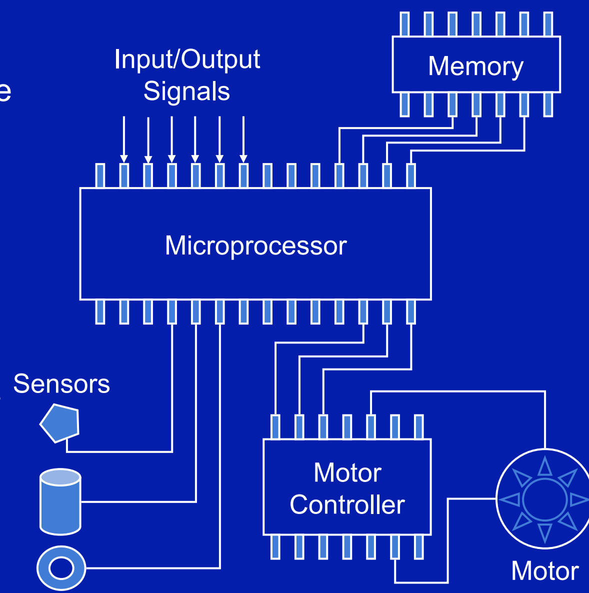
- Binary numbers
  - Use digits 0 and 1only
  - Binary digit: bit
  - 16+4+2+1=23
- Example
  - Binary representation of number 23

- Voltage level representation
  - Power supply V_{DD} : logic “1”
  - Ground voltage G_{ND} : logic “0”
  - Example
    - V_{DD} = 5 Volts
    - G_{ND} = 0 Volts



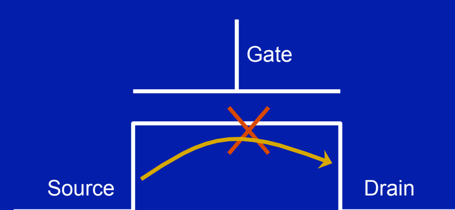
Communicating with the Outside World

- Microprocessor role
  - Generate and receive signals
  - Realize changes in environment
  - React to those changes
- Handling of signals specified by assembly code



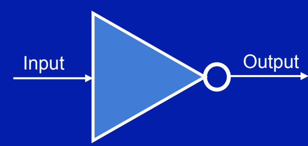
Electronic Switches

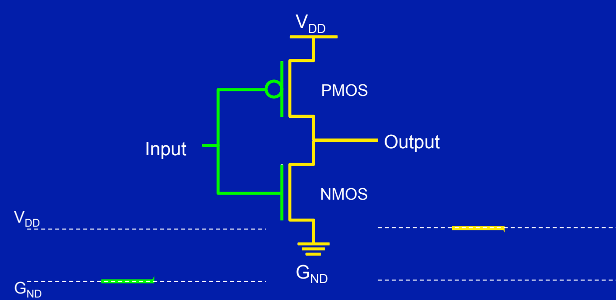
- Change in voltage level
  - Using switches
- Transistors
  - Primary electronic switches
- Transistor ON
  - Applied voltage at the gate
  - Current flows from source to drain
- Transistor OFF
  - No voltage at the gate
  - Current stops flowing from source to drain



Signal Inversion

- Basic logic gate
  - Logic inverter
  - PMOS Transistor
    - ON for input level “low”
  - NMOS Transistor
    - ON for input level “high”

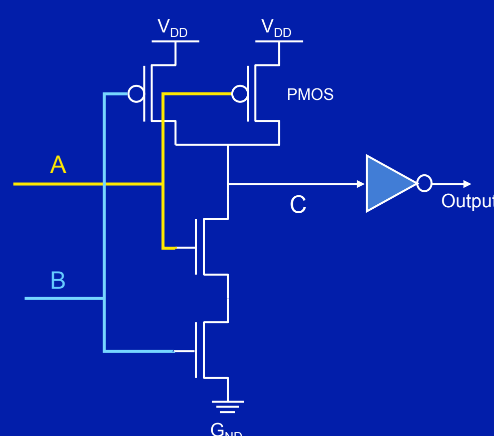




Logic Gates

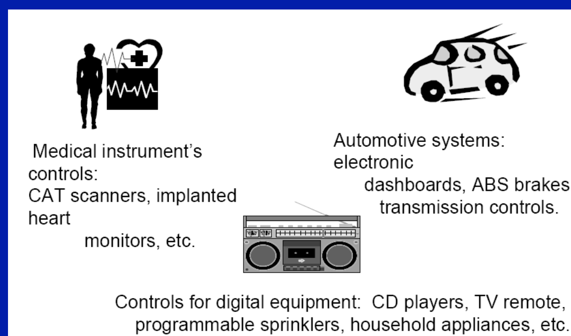
- Example:
- AND gate

A	B	C	Out
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1



Embedded Systems

- Embedded Systems are ***application specific computing*** systems.
- Each day, our lives become more dependent on 'embedded systems', digital information technology that is embedded in our environment.



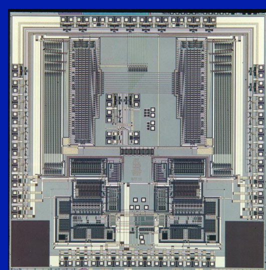
Embedded Systems

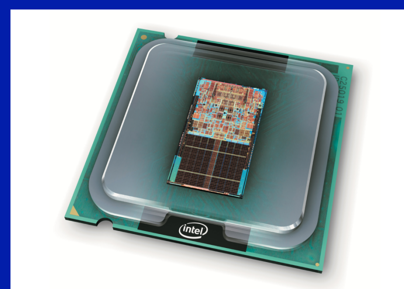
- Embedded systems are everywhere -- More than 98% of processors applied today are in embedded systems, and are no longer visible to the customer as 'computers' in the ordinary sense.

- Embedded systems and all modern computing devices have been made possible with the invention of Integrated Circuits.

Integrated Circuits (IC)

- Incredible technology advances within the past 50 years spearheaded by the invention and vast adoption of integrated circuits and microchip design
- The digital revolution brought about by integrated circuits was one of the most significant occurrences in the history of humankind.





Transistors

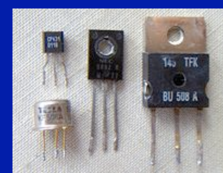
- Transistor was invented by William Shockley at Bell Telephone Laboratories on December 1947.

- They are the building blocks of all electronic circuits. They function as simple switches which can be turned on or off with a control voltage.

  – Transistors replaced vacuum tubes and transistors are miniscule in comparison, more reliable, longer lasting, produced less heat, and consumed less power.

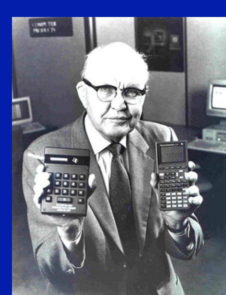
Transistors

- The transistor enabled engineers to design ever more complex electronic circuits and equipment containing hundreds or thousands of discrete components.
- But the problem was that these components still had to be interconnected to form electronic circuits, and hand-soldering thousands of components to thousands of bits of wire was expensive and time-consuming.
- The challenge was to find cost-effective, reliable ways of producing these components and interconnecting them.



Integrated Circuits

- The first integrated circuits were manufactured by Jack Kilby of Texas Instruments who filed a patent for a "Solid Circuit" made of germanium on February 6, 1959.
- Jack Kilby designed a calculator as powerful as the large, electro-mechanical desktop models of the day, but small enough to fit in a coat pocket. The resulting electronic hand-held calculator, of which Kilby is a co-inventor, successfully commercialized the integrated circuit.


Courtesy Texas Instruments

Integrated Circuits

- The integration of large numbers of tiny transistors into a small chip was an enormous improvement over the manual assembly of circuits using discrete electronic components.
- There are two main advantages of ICs over discrete circuits: cost and performance.
  - Cost is low because the chips, with all their components, are printed as a unit by photolithography and not constructed one transistor at a time. (Mass production capability)
  - Performance is high since the components switch quickly and consume little power, because the components are small and close together.

Large-Scale Integration

- The first integrated circuits contained only a few transistors. Called "Small-Scale Integration" (SSI), they used circuits containing transistors numbering in the tens.
- The next step in the development of integrated circuits, taken in the late 1960s, introduced devices which contained hundreds of transistors on each chip, called "Medium-Scale Integration" (MSI).
- Further development, driven by the same economic factors, led to "Large-Scale Integration" (LSI) in the mid 1970s, with tens of thousands of transistors per chip

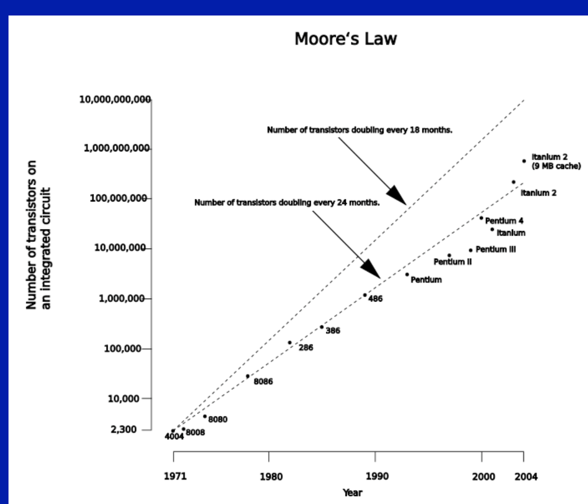
VLSI

- The final step in the development process, starting in the 1980s and continuing through the present, was "Very Large-Scale Integration" (VLSI). This could be said to start with hundreds of thousands of transistors in the early 1980s, and continues beyond ***several billion*** transistors as of 2009.

- Gordon Moore, co-founder of Intel, predicted in Electronics Magazine, April 1965 that:
  - "The complexity for minimum component costs has increased at a rate of roughly a factor of two per year ... Certainly over the short term this rate can be expected to continue, if not to increase"

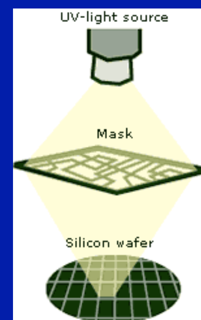
Moore' Law

- Moore's Law still holds true!!



Chip Fabrication

- Chip production today is based on photolithography. In photolithography a high energy UV-light is shone through a mask onto a slice of silicon covered with a photosensitive film.
- The mask describes the parts of the chip and the UV-light will only hit the areas not covered by the mask. When the film is developed, the areas hit by light are removed.
- Now the chip has unprotected and protected areas forming a pattern that is the first step to the final components of the chip.



Inverter Layout