# Electronics Merit Badge

## Class 3

Requirement 4 A & B

What makes Digital Electronics "Digital"? How is this different than an "Analog" circuit?

How would you use a digital circuit to control something?

# Digital Electronics

Computers use digital electronics.

Computers equate voltages with logical values. This is how electronic computer circuits can be made to do counting and other ‘math’ functions.

5 volts = logical 1   and   0 volts (ground) = logical 0

Computers use **Transistors** to act as logical switches to do counting.

Requirement 4B

Requirement 4 A & B

What is the “**Decimal**” number system?

What is the “**Binary**” number system?

What is the “**Hexadecimal**” number system?

Requirement 4B

# Decimal – Base 10

- In base 10, there are 10 unique digits (0-9).
- When writing large numbers (more that 1 digit), each column represents a value 10 times larger than the previous column.
- We say, how many 1’s, how many 10’s and how many 100’s are there?

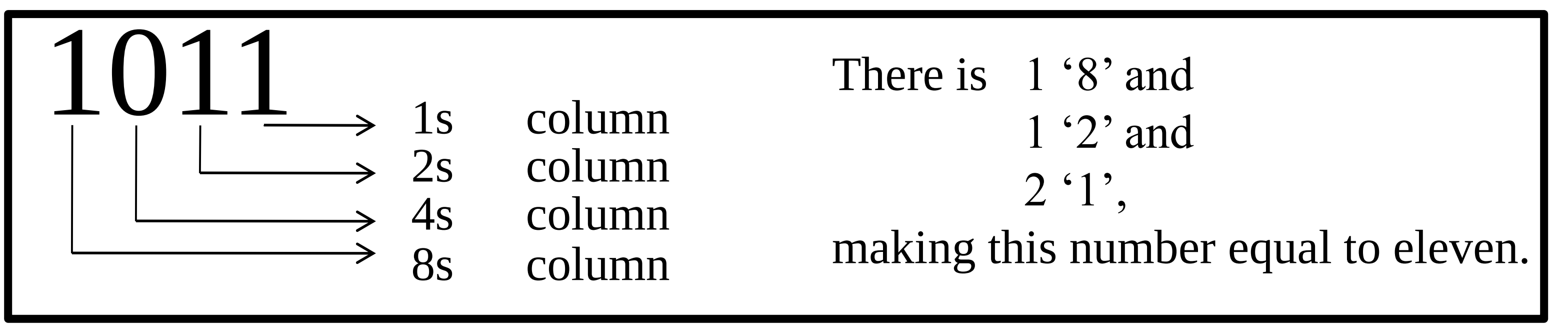
123

1s column
10s column
100s column

There is 1 ‘100’ and
2 ‘10’s and
3 ‘1’s,
Making this number equal to one hundred and twenty three.

# Binary Base 2

- In base 2 (binary) there are two numbers, 0 and 1.
- When writing large numbers (more that 1 digit), each column represents a value 2 times larger than the previous column.
- We say, how many 128s, how many 64s how many 32s, how many 16s, how many 8s, how many 4s, how many 2s and how many 1s are there?

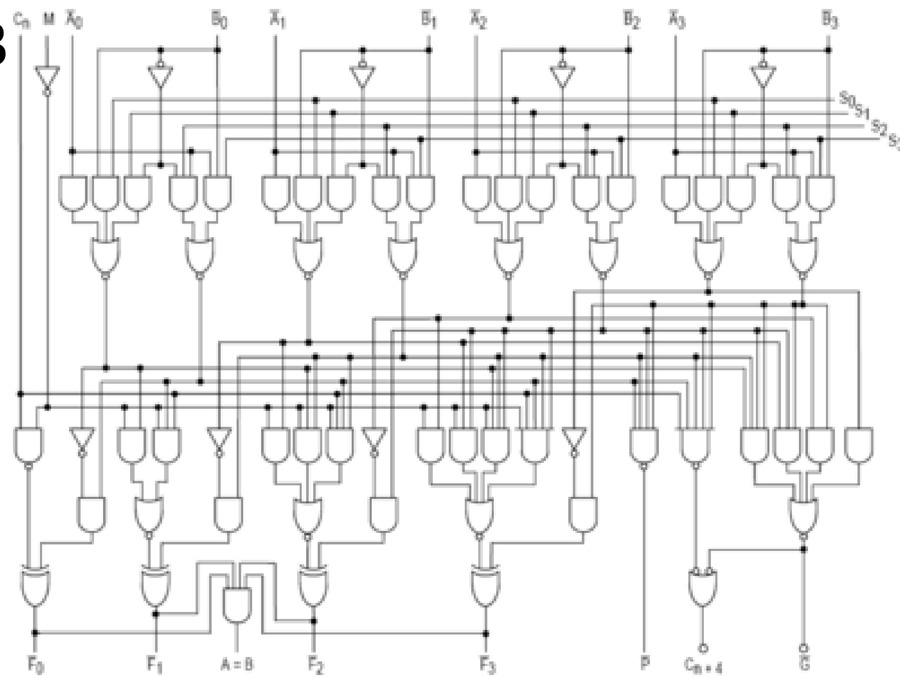


# Digital Electronics

A **BIT** is the basic unit of **DATA** in computing and digital electronics.

A **BYTE** is 8 BITS long. **WORD**s are made of Bytes- 2, 4 or 8 BYTES long .

**Kilobyte** (Kb) is 1,024 Bytes (1 Thousand)
**Megabyte** is 1,048,576 Bytes (1 Million)
**Gigabyte** is 1,073



# Counting to 16 in Binary

| number | 16 | 8 | 4 | 2 | 1 | Binary |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 00000 |
| 1 | 0 | 0 | 0 | 0 | 1 | 00001 |
| 2 | 0 | 0 | 0 | 1 | 0 | 00010 |
| 3 | 0 | 0 | 0 | 1 | 1 | 00011 |
| 4 | 0 | 0 | 1 | 0 | 0 | 00100 |
| 5 | 0 | 0 | 1 | 0 | 1 | 00101 |
| 6 | 0 | 0 | 1 | 1 | 0 | 00110 |
| 7 | 0 | 0 | 1 | 1 | 1 | 00111 |
| 8 | 0 | 1 | 0 | 0 | 0 | 01000 |
| 9 | 0 | 1 | 0 | 0 | 1 | 01001 |
| 10 | 0 | 1 | 0 | 1 | 0 | 01010 |
| 11 | 0 | 1 | 0 | 1 | 1 | 01011 |
| 12 | 0 | 1 | 1 | 0 | 0 | 01100 |
| 13 | 0 | 1 | 1 | 0 | 1 | 01101 |
| 14 | 0 | 1 | 1 | 1 | 0 | 01110 |
| 15 | 0 | 1 | 1 | 1 | 1 | 01111 |
| 16 | 1 | 0 | 0 | 0 | 0 | 10000 |

# Hexadecimal - Base 16

- Hexadecimal represents numbers as base 16.
- It is easier to write and read a large number by describing it in Hex rather than in Binary.
- Each number column is a power of 16 higher.
- The digits for hexadecimal are 0-9, A,B,C,D,E,F.

123

- 1s column
- 16s column
- 256s column

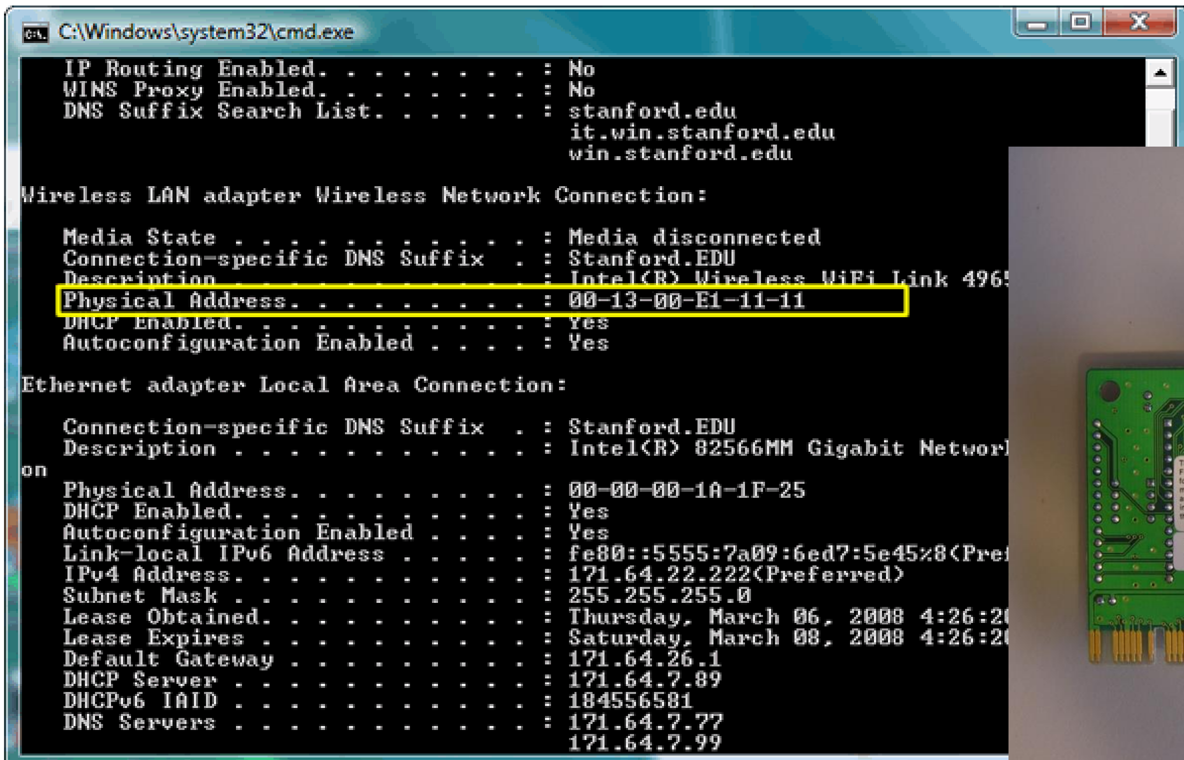
There are 1 ‘256’ and 2 ‘16’s and 3 ‘1’s, making this number equal to 291.

# Counting to 16 in Binary AND Hex

| Decimal | 16 | 8 | 4 | 2 | 1 | Binary | Hex |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 00000000 | 0 |
| 1 | 0 | 0 | 0 | 0 | 1 | 00000001 | 1 |
| 2 | 0 | 0 | 0 | 1 | 0 | 00000010 | 2 |
| 3 | 0 | 0 | 0 | 1 | 1 | 00000011 | 3 |
| 4 | 0 | 0 | 1 | 0 | 0 | 00000100 | 4 |
| 5 | 0 | 0 | 1 | 0 | 1 | 00000101 | 5 |
| 6 | 0 | 0 | 1 | 1 | 0 | 00000110 | 6 |
| 7 | 0 | 0 | 1 | 1 | 1 | 00000111 | 7 |
| 8 | 0 | 1 | 0 | 0 | 0 | 00001000 | 8 |
| 9 | 0 | 1 | 0 | 0 | 1 | 00001001 | 9 |
| 10 | 0 | 1 | 0 | 1 | 0 | 00001010 | A |
| 11 | 0 | 1 | 0 | 1 | 1 | 00001011 | B |
| 12 | 0 | 1 | 1 | 0 | 0 | 00001100 | C |
| 13 | 0 | 1 | 1 | 0 | 1 | 00001101 | D |
| 14 | 0 | 1 | 1 | 1 | 0 | 00001110 | E |
| 15 | 0 | 1 | 1 | 1 | 1 | 00001111 | F |
| 16 | 1 | 0 | 0 | 0 | 0 | 00010000 | 10 |

# The MAC address; An example of Hexadecimal

- Because base 16 is an even multiple of base 2, an 8 digit base 2 number can be represented in 2 characters. An Ethernet adaptor's physical address is a value represented by 6- 2 digit Hex numbers.




# Binary codes for alpha-mumeric symbols.

## Decimal - Binary - Octal - Hex – ASCII
## Conversion Chart

| ecimal | Binary | Octal | Hex | ASCII | Decimal | Binary | Octal | Hex | ASCII | Decimal | Binary | Octal | Hex | ASCII | Decimal | Binary | Octal | Hex | ASCI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 00000000 | 000 | 00 | NUL | 32 | 00100000 | 040 | 20 | SP | 64 | 01000000 | 100 | 40 | @ | 96 | 01100000 | 140 | 60 | ` |
| 1 | 00000001 | 001 | 01 | SOH | 33 | 00100001 | 041 | 21 | ! | 65 | 01000001 | 101 | 41 | A | 97 | 01100001 | 141 | 61 | a |
| 2 | 00000010 | 002 | 02 | STX | 34 | 00100010 | 042 | 22 | " | 66 | 01000010 | 102 | 42 | B | 98 | 01100010 | 142 | 62 | b |
| 3 | 00000011 | 003 | 03 | ETX | 35 | 00100011 | 043 | 23 | # | 67 | 01000011 | 103 | 43 | C | 99 | 01100011 | 143 | 63 | c |
| 4 | 00000100 | 004 | 04 | EOT | 36 | 00100100 | 044 | 24 | $ | 68 | 01000100 | 104 | 44 | D | 100 | 01100100 | 144 | 64 | d |
| 5 | 00000101 | 005 | 05 | ENQ | 37 | 00100101 | 045 | 25 | % | 69 | 01000101 | 105 | 45 | E | 101 | 01100101 | 145 | 65 | e |
| 6 | 00000110 | 006 | 06 | ACK | 38 | 00100110 | 046 | 26 | & | 70 | 01000110 | 106 | 46 | F | 102 | 01100110 | 146 | 66 | f |
| 7 | 00000111 | 007 | 07 | BEL | 39 | 00100111 | 047 | 27 | ' | 71 | 01000111 | 107 | 47 | G | 103 | 01100111 | 147 | 67 | g |
| 8 | 00001000 | 010 | 08 | BS | 40 | 00101000 | 050 | 28 | ( | 72 | 01001000 | 110 | 48 | H | 104 | 01101000 | 150 | 68 | h |
| 9 | 00001001 | 011 | 09 | HT | 41 | 00101001 | 051 | 29 | ) | 73 | 01001001 | 111 | 49 | I | 105 | 01101001 | 151 | 69 | i |
| 10 | 00001010 | 012 | 0A | LF | 42 | 00101010 | 052 | 2A | * | 74 | 01001010 | 112 | 4A | J | 106 | 01101010 | 152 | 6A | j |
| 11 | 00001011 | 013 | 0B | VT | 43 | 00101011 | 053 | 2B | + | 75 | 01001011 | 113 | 4B | K | 107 | 01101011 | 153 | 6B | k |
| 12 | 00001100 | 014 | 0C | FF | 44 | 00101100 | 054 | 2C | , | 76 | 01001100 | 114 | 4C | L | 108 | 01101100 | 154 | 6C | l |
| 13 | 00001101 | 015 | 0D | CR | 45 | 00101101 | 055 | 2D | - | 77 | 01001101 | 115 | 4D | M | 109 | 01101101 | 155 | 6D | m |
| 14 | 00001110 | 016 | 0E | SO | 46 | 00101110 | 056 | 2E | . | 78 | 01001110 | 116 | 4E | N | 110 | 01101110 | 156 | 6E | n |
| 15 | 00001111 | 017 | 0F | SI | 47 | 00101111 | 057 | 2F | / | 79 | 01001111 | 117 | 4F | O | 111 | 01101111 | 157 | 6F | o |
| 16 | 00010000 | 020 | 10 | DLE | 48 | 00110000 | 060 | 30 | 0 | 80 | 01010000 | 120 | 50 | P | 112 | 01110000 | 160 | 70 | p |
| 17 | 00010001 | 021 | 11 | DC1 | 49 | 00110001 | 061 | 31 | 1 | 81 | 01010001 | 121 | 51 | Q | 113 | 01110001 | 161 | 71 | q |
| 18 | 00010010 | 022 | 12 | DC2 | 50 | 00110010 | 062 | 32 | 2 | 82 | 01010010 | 122 | 52 | R | 114 | 01110010 | 162 | 72 | r |
| 19 | 00010011 | 023 | 13 | DC3 | 51 | 00110011 | 063 | 33 | 3 | 83 | 01010011 | 123 | 53 | S | 115 | 01110011 | 163 | 73 | s |
| 20 | 00010100 | 024 | 14 | DC4 | 52 | 00110100 | 064 | 34 | 4 | 84 | 01010100 | 124 | 54 | T | 116 | 01110100 | 164 | 74 | t |
| 21 | 00010101 | 025 | 15 | NAK | 53 | 00110101 | 065 | 35 | 5 | 85 | 01010101 | 125 | 55 | U | 117 | 01110101 | 165 | 75 | u |
| 22 | 00010110 | 026 | 16 | SYN | 54 | 00110110 | 066 | 36 | 6 | 86 | 01010110 | 126 | 56 | V | 118 | 01110110 | 166 | 76 | v |
| 23 | 00010111 | 027 | 17 | ETB | 55 | 00110111 | 067 | 37 | 7 | 87 | 01010111 | 127 | 57 | W | 119 | 01110111 | 167 | 77 | w |
| 24 | 00011000 | 030 | 18 | CAN | 56 | 00111000 | 070 | 38 | 8 | 88 | 01011000 | 130 | 58 | X | 120 | 01111000 | 170 | 78 | x |
| 25 | 00011001 | 031 | 19 | EM | 57 | 00111001 | 071 | 39 | 9 | 89 | 01011001 | 131 | 59 | Y | 121 | 01111001 | 171 | 79 | y |
| 26 | 00011010 | 032 | 1A | SUB | 58 | 00111010 | 072 | 3A | : | 90 | 01011010 | 132 | 5A | Z | 122 | 01111010 | 172 | 7A | z |
| 27 | 00011011 | 033 | 1B | ESC | 59 | 00111011 | 073 | 3B | ; | 91 | 01011011 | 133 | 5B | [ | 123 | 01111011 | 173 | 7B | { |
| 28 | 00011100 | 034 | 1C | FS | 60 | 00111100 | 074 | 3C | < | 92 | 01011100 | 134 | 5C | \ | 124 | 01111100 | 174 | 7C | \| |
| 29 | 00011101 | 035 | 1D | GS | 61 | 00111101 | 075 | 3D | = | 93 | 01011101 | 135 | 5D | ] | 125 | 01111101 | 175 | 7D | } |
| 30 | 00011110 | 036 | 1E | RS | 62 | 00111110 | 076 | 3E | > | 94 | 01011110 | 136 | 5E | ^ | 126 | 01111110 | 176 | 7E | ~ |
| 31 | 00011111 | 037 | 1F | US | 63 | 00111111 | 077 | 3F | ? | 95 | 01011111 | 137 | 5F | _ | 127 | 01111111 | 177 | 7F | DEL |

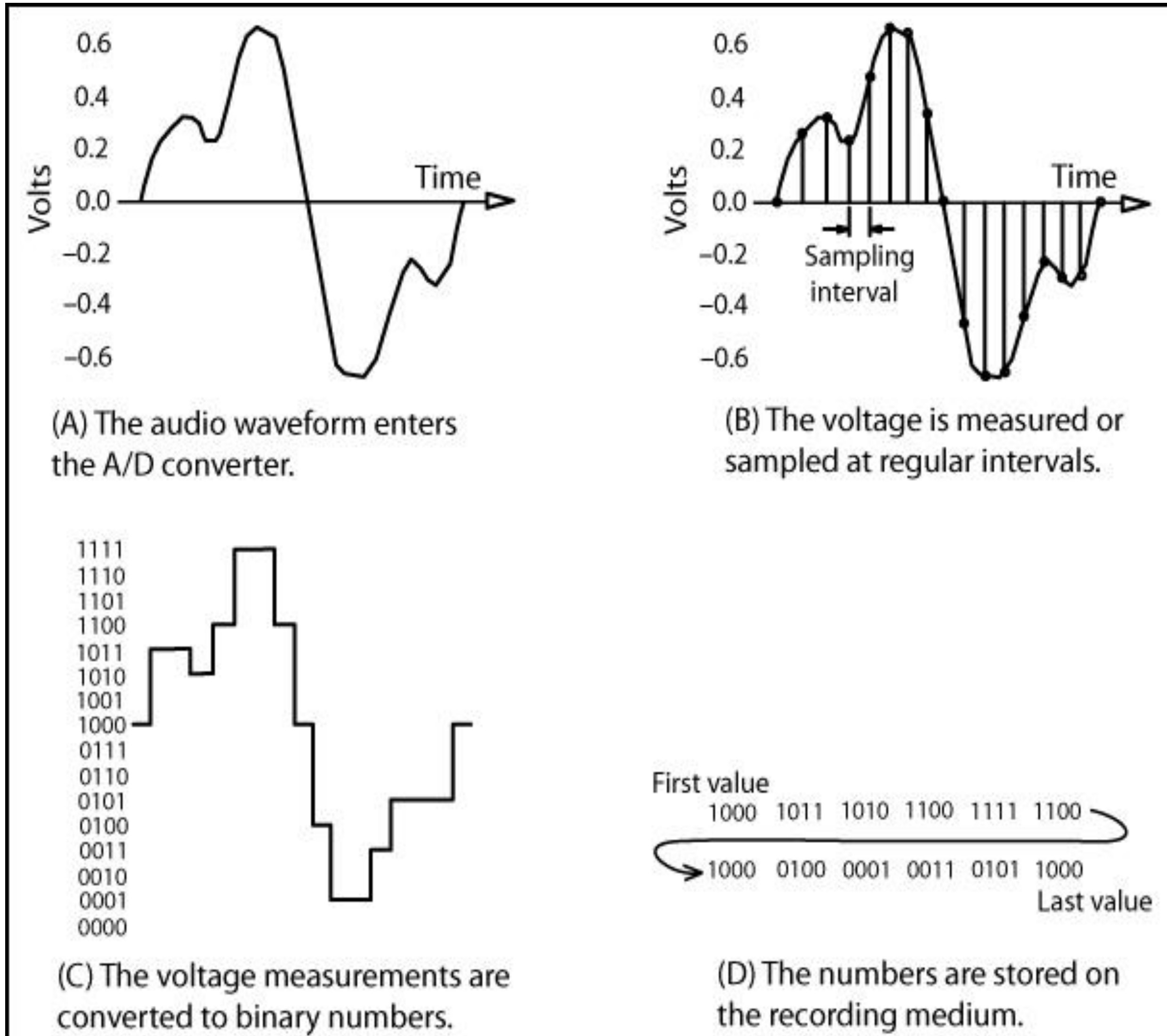
# Converting Analog signals to Digital

Analog signals can be converted to digital signals by means of “Sampling”.

Digital words that represent an analog signal can be converted back by decoding the bits back to a voltage level and filtering the resulting square wave to smooth the edges.

The higher the sample frequency, the more accurate the representation.

The larger the digital word, the more accurate the representation.



Convert several numbers from Decimal to Binary and Hexadecimal values.

# Binary, Decimal and Hexadecimal compared

Requirement 4B Part 2

| Binary | Decimal | Hexadecimal |
|---|---|---|
| 0000 1111 | 15 | 0F |
| 0001 0001 | 17 | 11 |
| 1000 1110 | 142 | 8E |
| 1111 1111 | 255 | FF |
| 0011 1111 | | 3F |
| 0001 0110 | 22 | |
| | 96 | 60 |

Compute the missing value:

# Binary, Decimal and Hexadecimal compared

Requirement 4B Part 2

| Binary | Decimal | Hexadecimal |
|---|---|---|
| 0000 1111 | 15 | 0F |
| 0001 0001 | 17 | 11 |
| 1000 1110 | 142 | 8E |
| 1111 1111 | 255 | FF |
| 0011 1111 | **63** | 3F |
| 0001 0110 | 22 | |
| | 96 | 60 |

Compute the missing value:

# Binary, Decimal and Hexadecimal compared

| Binary | Decimal | Hexadecimal |
|---|---|---|
| 0000 1111 | 15 | 0F |
| 0001 0001 | 17 | 11 |
| 1000 1110 | 142 | 8E |
| 1111 1111 | 255 | FF |
| 0011 1111 | **63** | 3F |
| 0001 0110 | 22 | **16** |
| | 96 | 60 |

Compute the missing value:

# Binary, Decimal and Hexadecimal compared

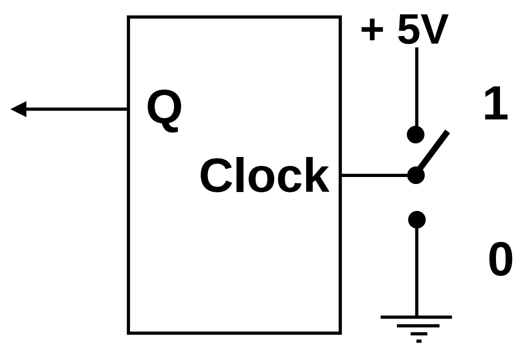
Requirement 4B Part 2

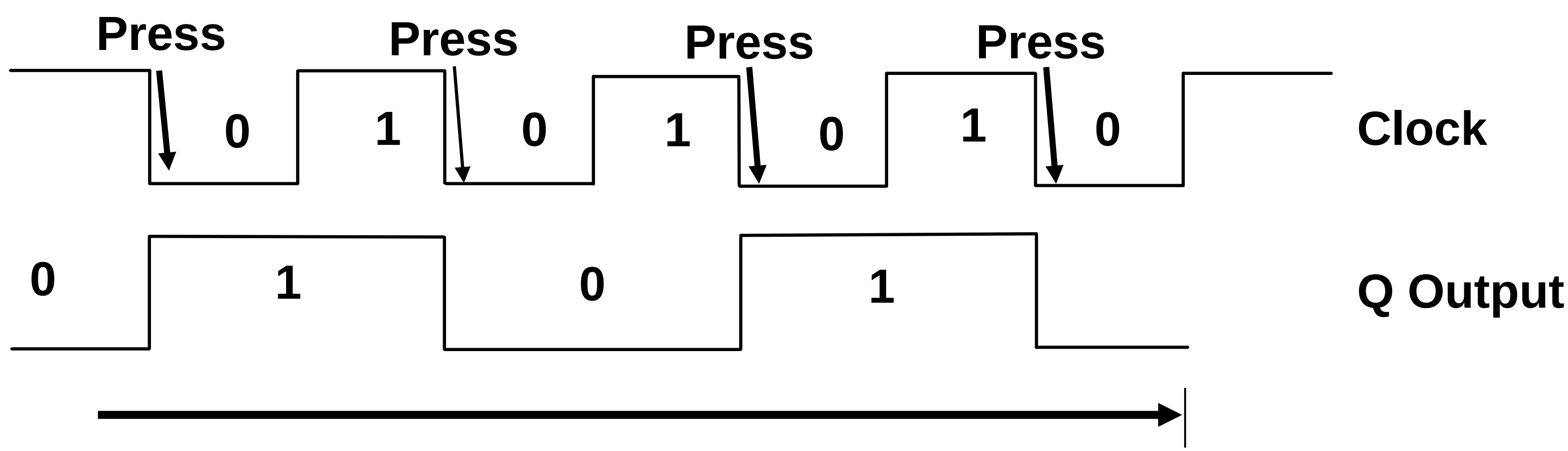
| Binary | Decimal | Hexadecimal |
|---|---|---|
| 0000 1111 | 15 | 0F |
| 0001 0001 | 17 | 11 |
| 1000 1110 | 142 | 8E |
| 1111 1111 | 255 | FF |
| 0011 1111 | **63** | 3F |
| 0001 0110 | 22 | **16** |
| **0110 0000** | 96 | 60 |

# FLIP-FLOP

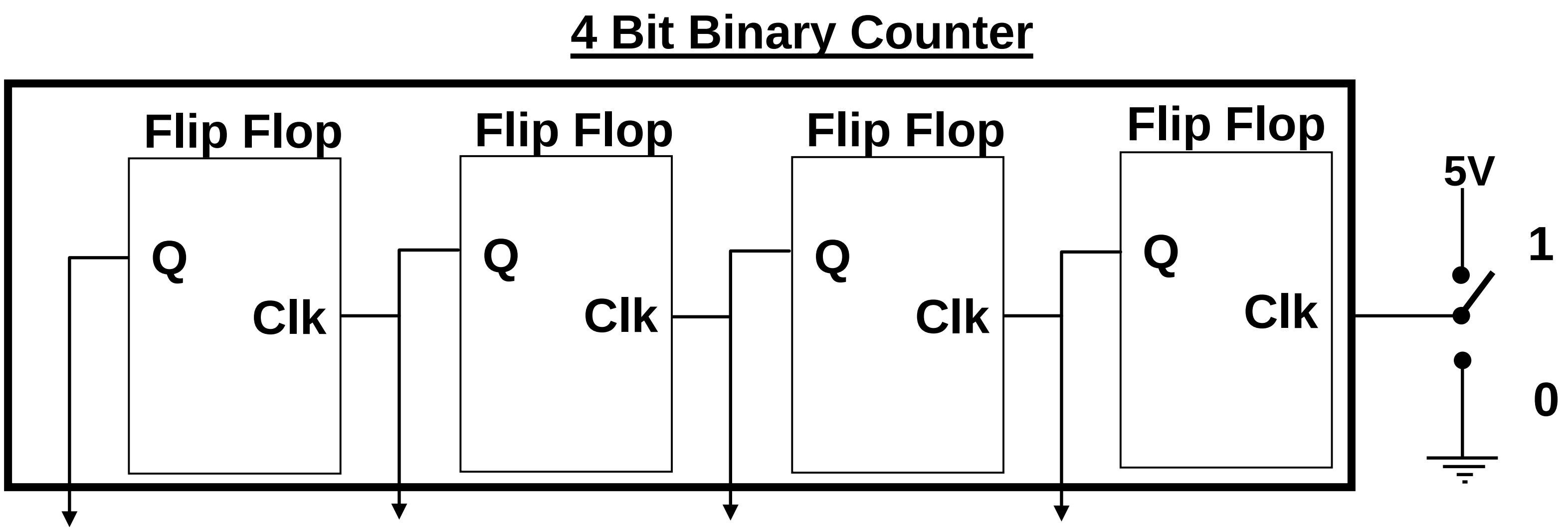
**A FLIP-FLOP is a device that changes state each time it is switched in the same direction.**
**Press the switch, the clock goes to 0 volts (logical 0).**
**Release the switch, the clock goes to 5 volts (logical 1).**
**The output (Q) changes state on each 1 to 0 transition of the clock.**
**A flip-flop basically divides the clock by 2.  It takes 2 clock transitions to make the output change once.**

**Flip-Flop**



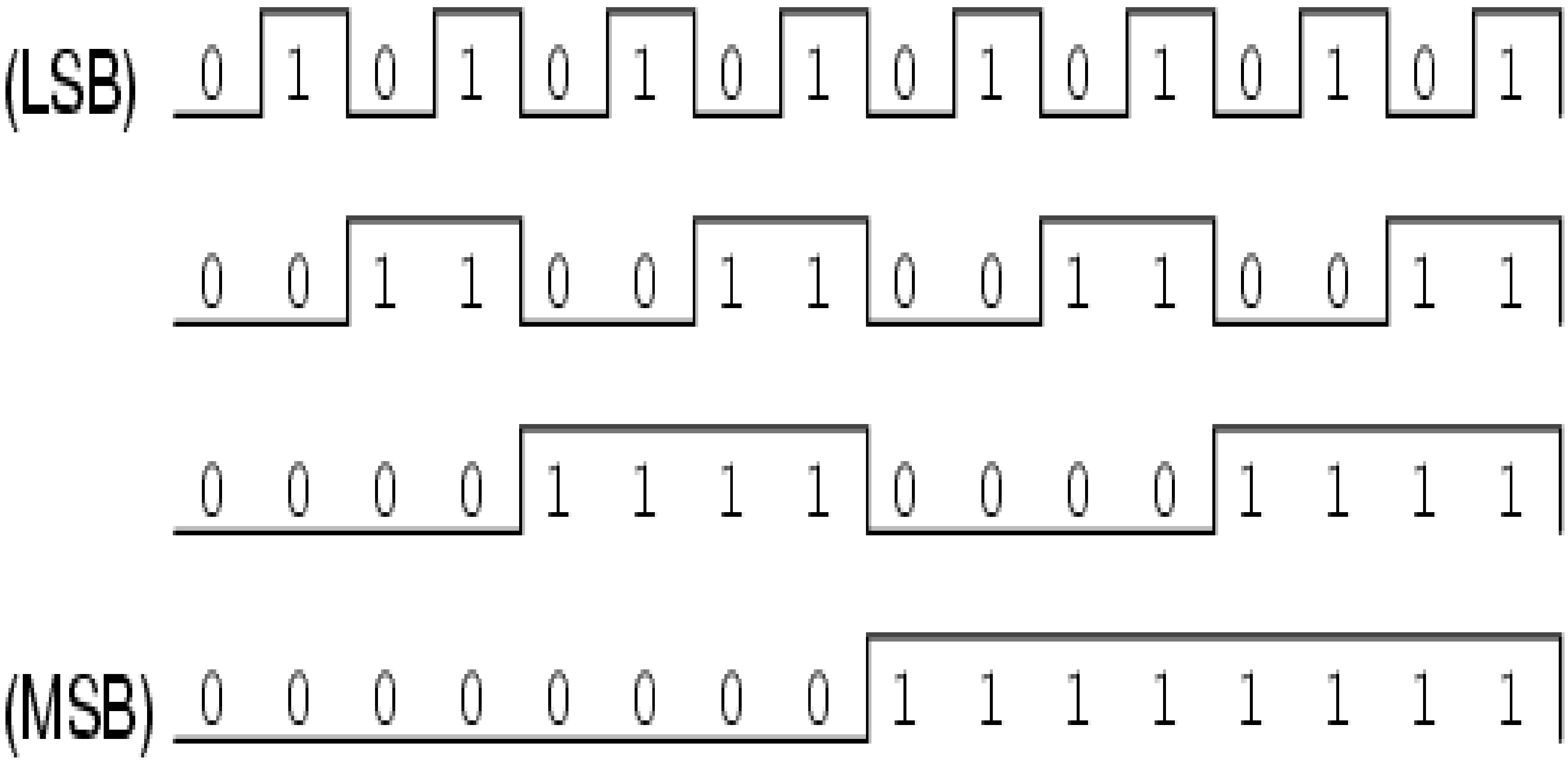
# Binary Counter using Flip-Flops




| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | press | |
| 0 | 0 | 0 | 1 | press | 1 |
| 0 | 0 | 1 | 0 | press | 2 |
| 0 | 0 | 1 | 1 | press | 3 |
| 0 | 1 | 0 | 0 | press | 4 |
| 0 | 1 | 0 | 1 | press | 5 |
| 0 | 1 | 1 | 0 | press | 6 |

# Binary Counter using Flip-Flops

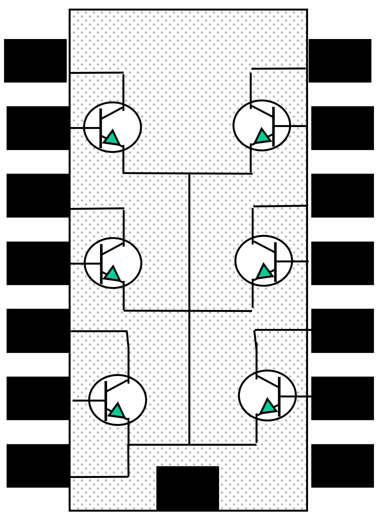
**4 Bit Binary Counter**



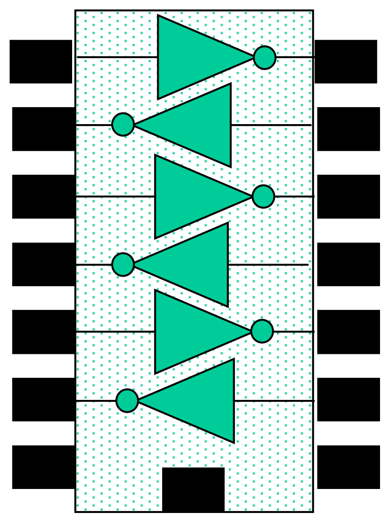
# Integrated Circuits

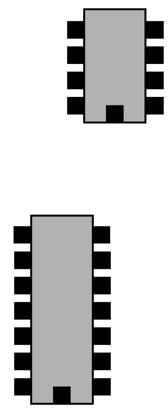
An integrated circuit (IC) consists of multiple transistors. The number of transistors can vary from just a few (circuits shown below), to several hundred million that are in a Pentium microprocessor.

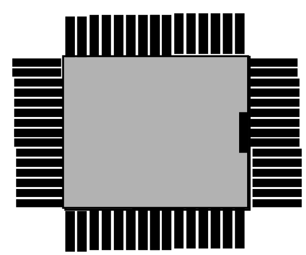
6 Transistors in one IC



This IC has 6 inverters
An inverter contains
6 Transistors = 36 total



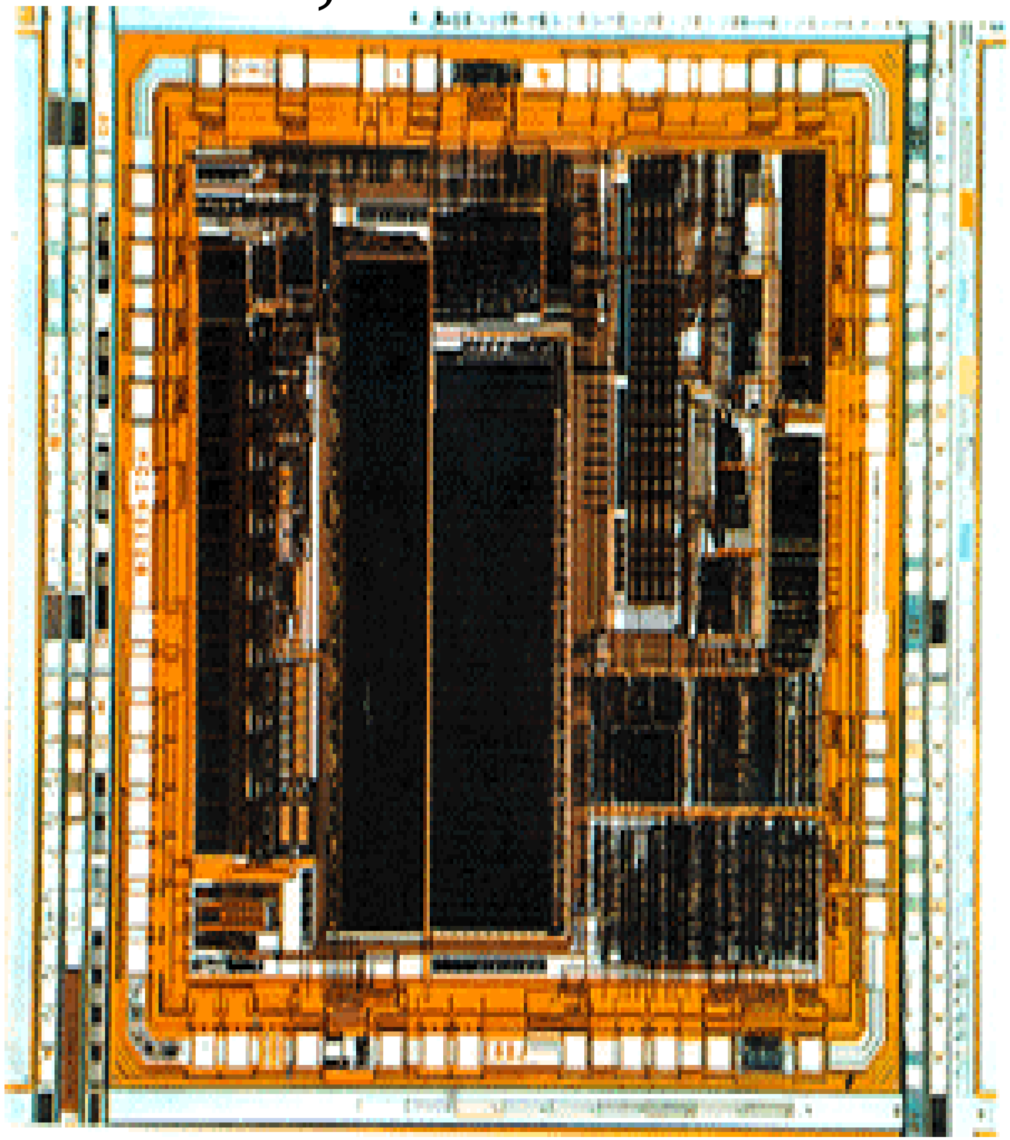


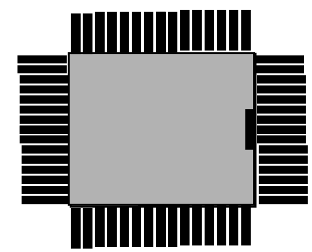


<u>Functions</u>

Inverters
Gates
Flip flops
Counters
Memory
MPU
Watch ICs
Calculators ICs
Microwave Timer ICs
Radio ICs
Dialer ICs
Car Controller ICs

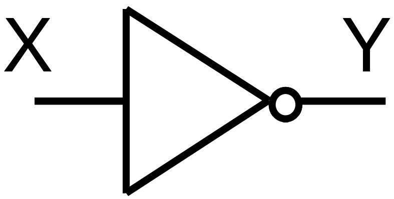
# Microprocessor Integrated Circuit: 60,000 Transistors





# Basic Logic Gates

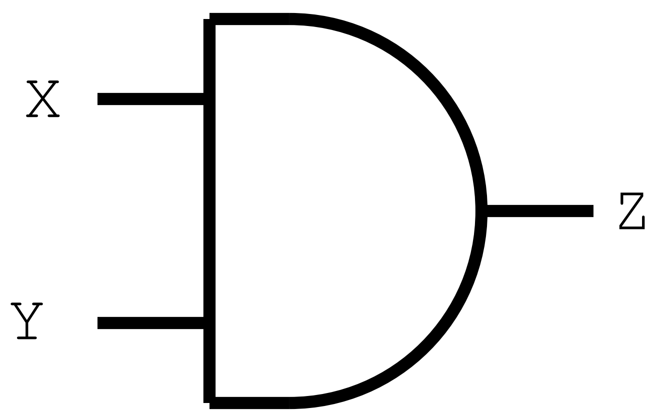
## NOT




Y = ~X

| X | Y |
|---|---|
| 0 | 1 |
| 1 | 0 |

## AND

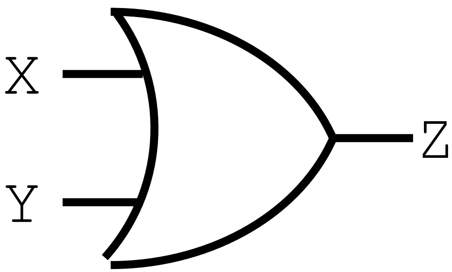



| X | Y | Z |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

Z = X & Y

# Basic Logic Gates

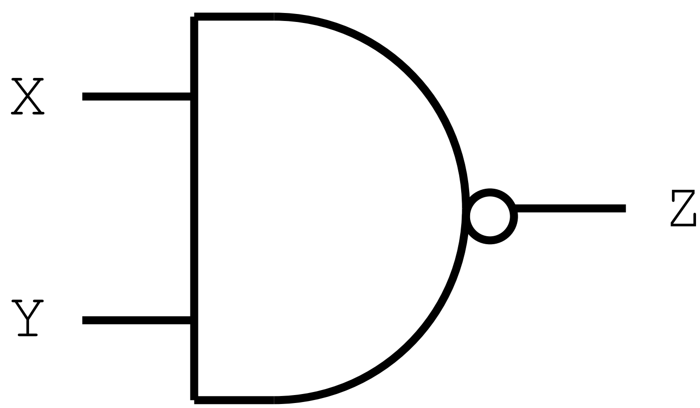
**OR**




| X | Y | Z |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

**`Z = X | Y`**

**NAND**

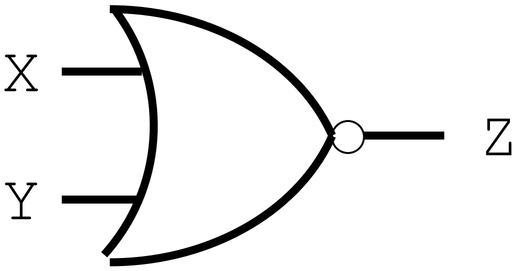



| X | Y | Z |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

**`Z = ~(X & Y)`**

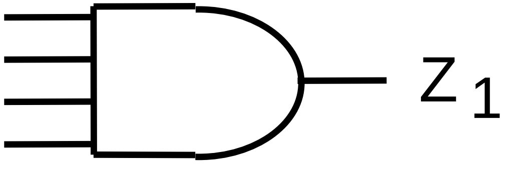
# Basic Logic Gates

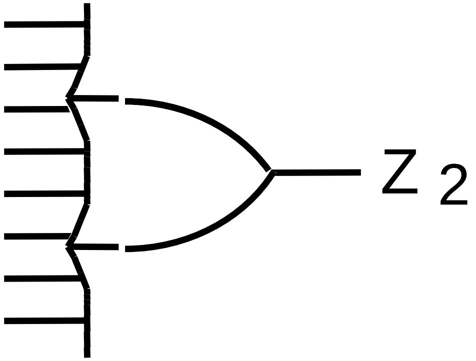
NOR



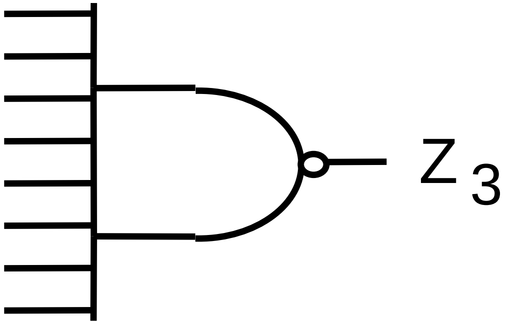

| X | Y | Z |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

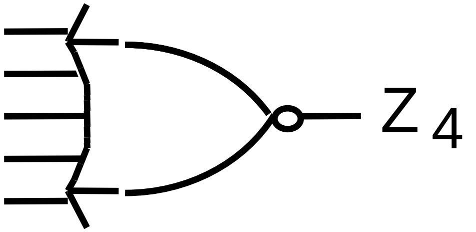
**Z = ~(X | Y)**



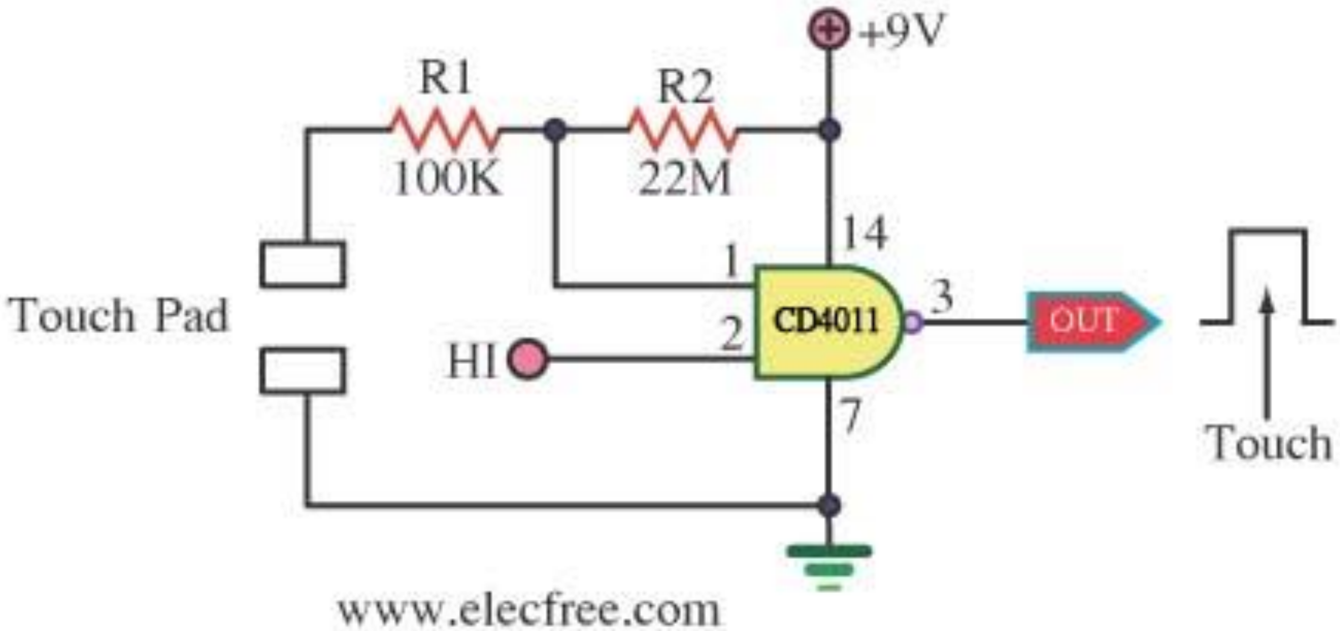

Multiple input gates



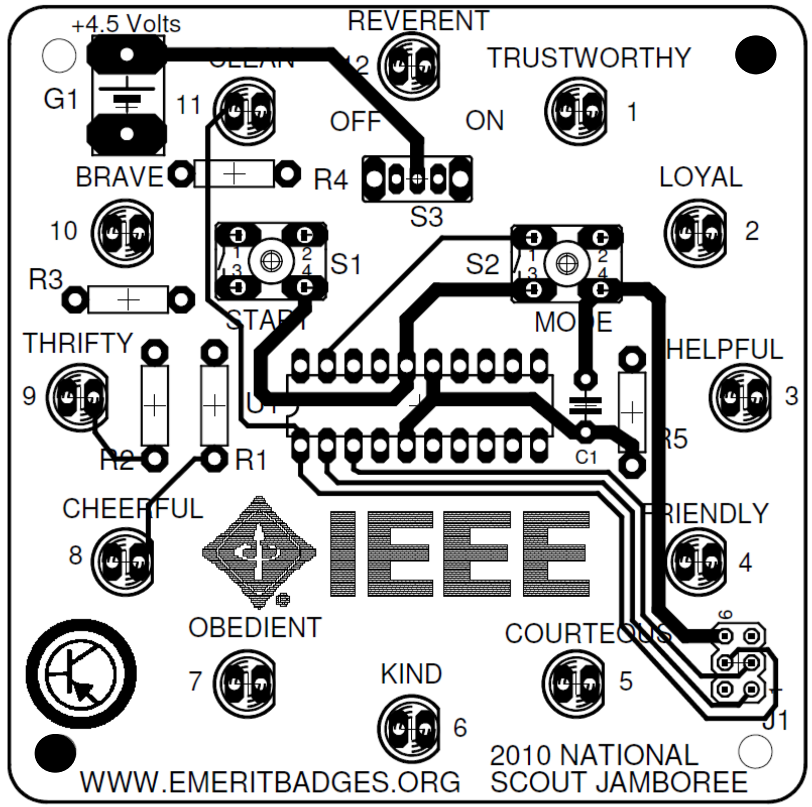
# Digital control Application;
# Simple digital touch switch with an NAND gate

Requirement 4B




**Here is a simple circuit that will turn on it's output when a finger is touched to the touch pad. R1 and R2 form a "Voltage Divider". A very small change (Capacitance of your finger) causes input to go High and triggers the NAND gate which goes low. A buffer inverter turns the output High.**

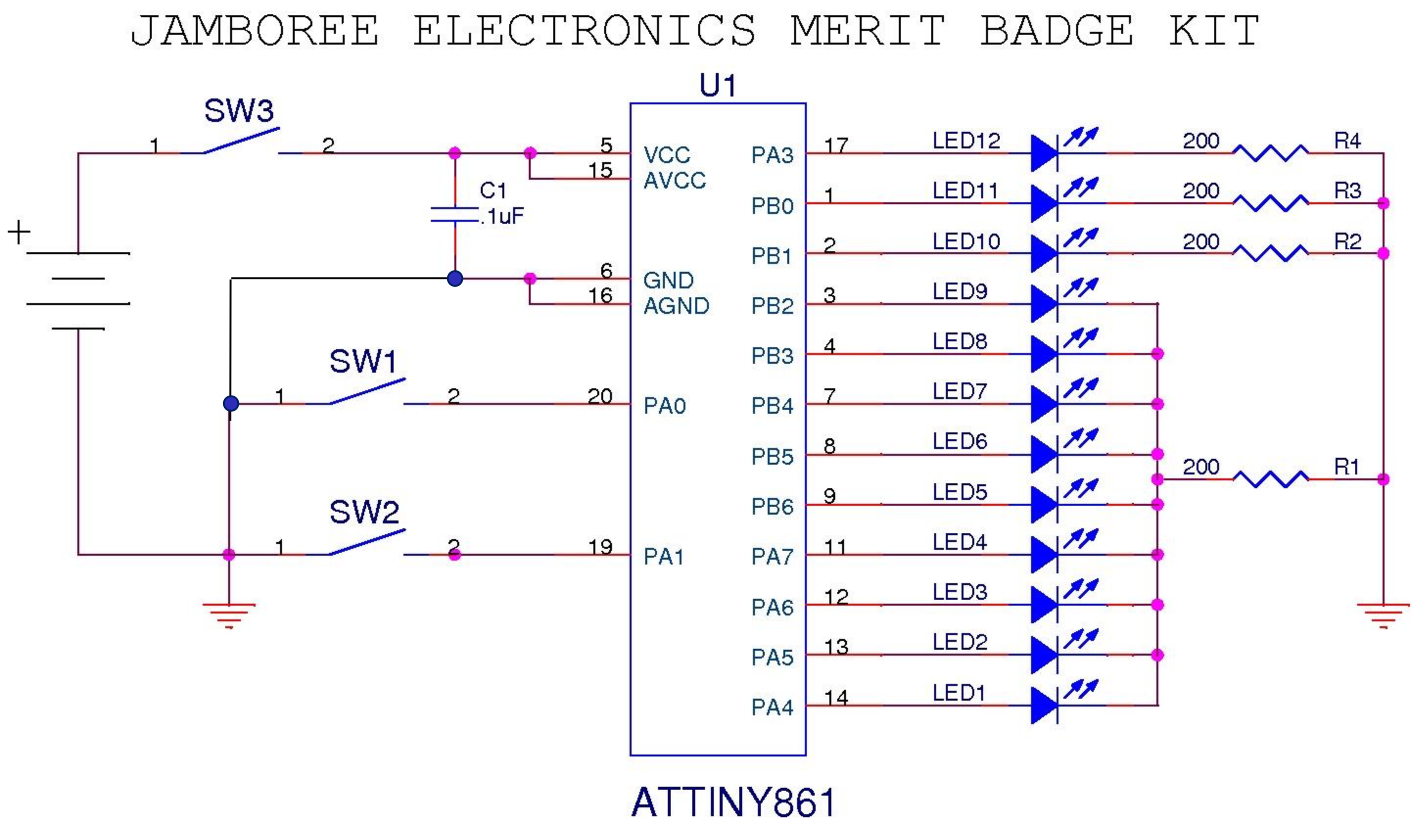
# Microprocessor Controlled Counter




**The kit contains a microprocessor that will drive 12 LEDs in a diminishing pattern. The LEDs can be displayed in many different pattern modes. Each mode starts as a fast pattern, and eventually slows to a stop.**

# Microprocessor Controlled Counter

Requirement 4B



# Requirement 6

Requirement 6

Find out about three career opportunities in electronics.

Discuss with and explain to your counselor what training and education are needed for each position.

# Careers in Electronics
# IEEE emeritbadges Project
# 2017 National Scout Jamboree

emeritbadges.org

IEEE

# Electronics - Uses

- Computers, servers, networks
- Control of devices and machines - motors, robots, airplanes, cars, rockets, appliances
- Performing digital calculations – calculators, encryption, error detection/correction
- Storing and retrieving information - memory, CDs, DVDs, tapes, DNA (!)
- Communications - radio, TV, telephones, radar, satellites, Internet
- Medical Equipment - CAT and PET scanners, MRI, x-ray, EKG, EEG machines, pacemakers
- Manufacturing, testing

# Electronics - Uses

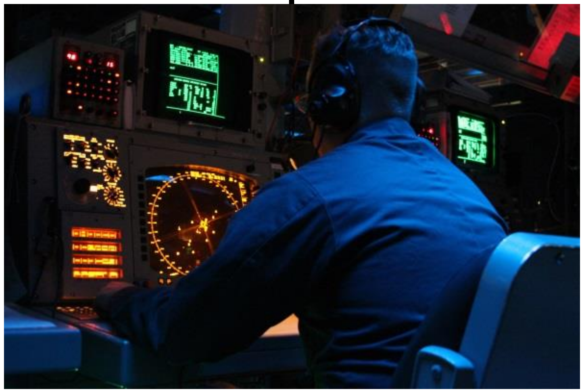
- Lighting, heating, cooling, security
- Entertainment – photography, music, video generation, storage, reproduction
- Power generation and distribution – power plants, electric grid
- Navigation (GPS), Transportation
- Military/defense – communications, weapons, navigation
- Converting energy from one type to another - audio output to speakers and headphones, MEMS machines to movement, lasers to light, etc.

# Sample Careers in Electronics

- Computing
  - System design
  - IC design
  - Computer Graphics
  - Cloud computing,
  - Network Security
  - "Internet of Things"
  - Components

# Sample Careers in Electronics

- Transportation
  - Power storage
  - Programming, Artificial Intelligence
  - Sensor development



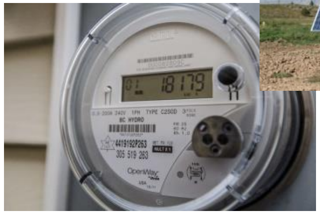
- Entertainment
- Navigation
- Control systems
- Aircraft
- Railroads

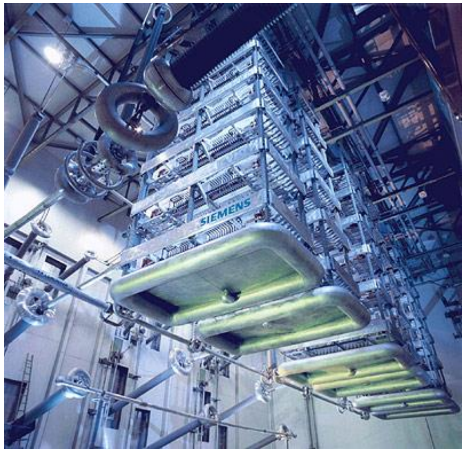
# Sample Careers in Electronics

- Medical and Emergency Medical Services
  - Transducers, sensors
  - Diagnostic machines
  - Blood pressure machines
  - Wearables and implantable devices

# Sample Careers in Electronics

- Power Generation/Distribution
  - "Smart grid" development and "Green Power"
  - "Things" for the "Internet of Things"
  - Renewable energy
  - Fuel cells
  - Nuclear fission, fusion reactor design and operation
  - Network Security
  - Home automation





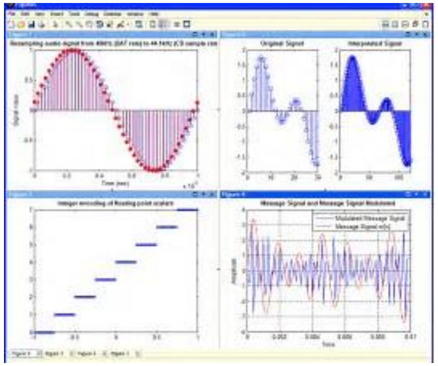

# Sample Careers in Electronics

- Military/Defense
  - Communications, RADAR
  - Artificial Intelligence
  - Drones
  - Weapons systems
  - IED/Bomb detection
  - Threat detection/countermeasures
  - Cyber Security
  - Navigation and tracking
  - Control systems
  - Robotics, exoskeletons
  - Nuclear fission reactor operation

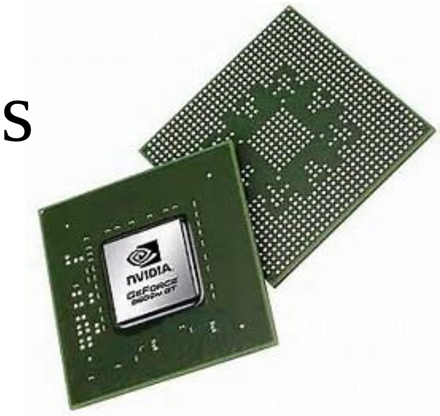



# Sample Careers in Electronics

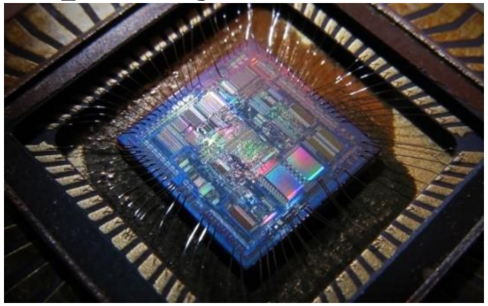
- Communications
  - Cell phones and infrastructure
  - Internet and infrastructure
  - Satellites
  - Radio – public safety, marine
  - Coding, encryption, error detection/correction
  - Digital Signal Processing
  - Modulation/demodulation

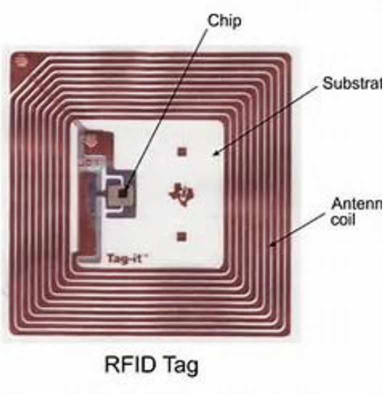


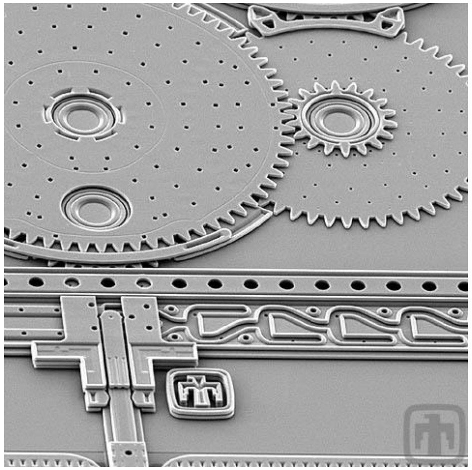
# Sample Careers in Electronics



- Components
  - ICs (Integrated Circuits)
  - Microcontrollers - e. g., Raspberry Pi, Arduino
  - Passives
  - Connectors, cables
  - Displays
  - Packaging
  - MEMS – micro electromechanical machines
  - Antennas
  - RFID







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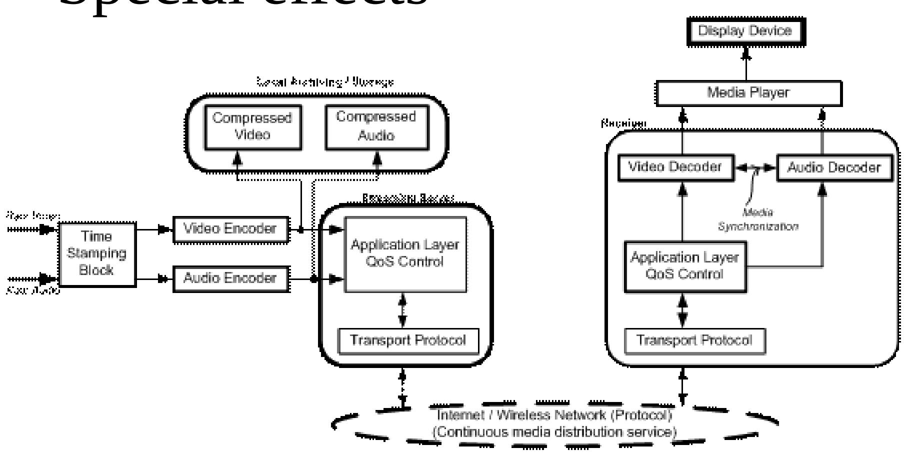
# Sample Careers in Electronics

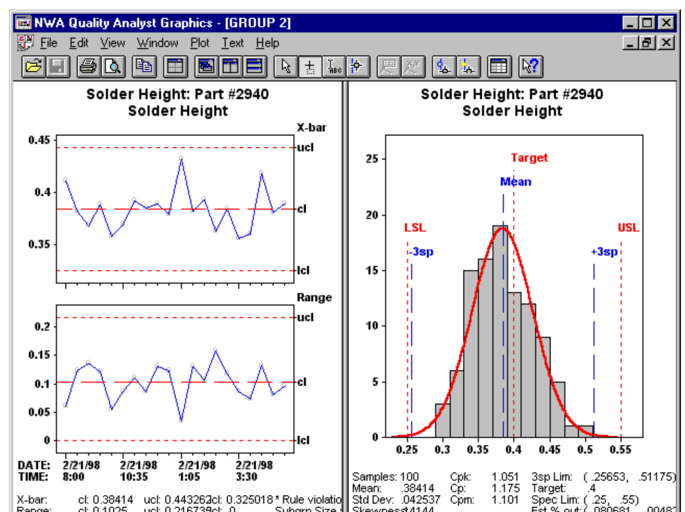
- Entertainment
  - Audio/video
  - Digital assistants
  - Cable/satellite TV
  - WiFi, networking
  - Data coding and compression hardware and software
  - DRM – digital rights management
  - Gaming
  - Special effects



# Sample Careers in Electronics

- Manufacturing
  - Robotics
  - Process controls, PLCs
  - Quality control
  - Reliability analysis
  - Networking



# Future Careers in Electronics

- Let's dream a little…

- "Rocket Man" - backup pilot for pilotless Mars tourist flights
- Medical drone pilot - directs swallowable repair device to cancer location, "zaps" it
- Materials farm supervisor - monitors growth, directs harvest of new materials on Alpha Centauri planet
- Smart Grid load balancing software developer
- Cyber warfare "soldier" - counters enemy attacks, perhaps initiates…

Your ideas??

  - Job title: ______________________
  - Salary: ________________________
  - Description/duties: _____________

# Preparing for Careers in Electronics

- High School
  - Math Classes
  - Science Classes
  - Tech Ed Classes
- College - 4 year Bachelor of Science (BS) EE degree in Electronics Engineering
  - Math
  - Physics
  - Chemistry
  - Material Science
  - Thermodynamics / Fluid
  - Mechanics
  - Mechanics - Statics and Dynamics
  - Computer Aided Design
  - Computers
  - Analog, Digital circuits, Digital Signal Processing
  - IC Design, Signal/Power Integrity
  - Control systems
  - Power generation/distribution
  - English / Humanities / Social Studies / Business / Economics electives
- Summer jobs / internships
- "Soft skills" – communications, public speaking, writing, collaboration, teamwork

# Electronics Career Resources

- Institute of Electrical and Electronics Engineers (IEEE), www.ieee.org
  - Over 430,000 members worldwide
  - 39 societies dealing with many aspects of Electrical Engineering, from Aerospace & Electronic Systems to Vehicular Technology
  - Sponsors conferences, publishes technical journals
  - Standards development – Aerospace, Components, Computers, Devices, EMC, Instr./Measurement, Nanotech, Networking (Ethernet, WiFi), Nuclear, Power/Energy, Robotics, Signal Processing, Vehicular Tech., etc.

# Electronics Career Resources

- TryEngineering
- TryComputing
- TryNano
- IEEE Spark
- Coursera
- edX
- American Radio Relay League (ARRL)
- IEEE emeritbadges Project
- IEEE Teacher In-Service Program
- FIRST
- Engineer Your Life
- IEEE REACH
- Engineering and Technology History Wiki
- Maker Faire

# Electronics Merit Badge

## Class 3