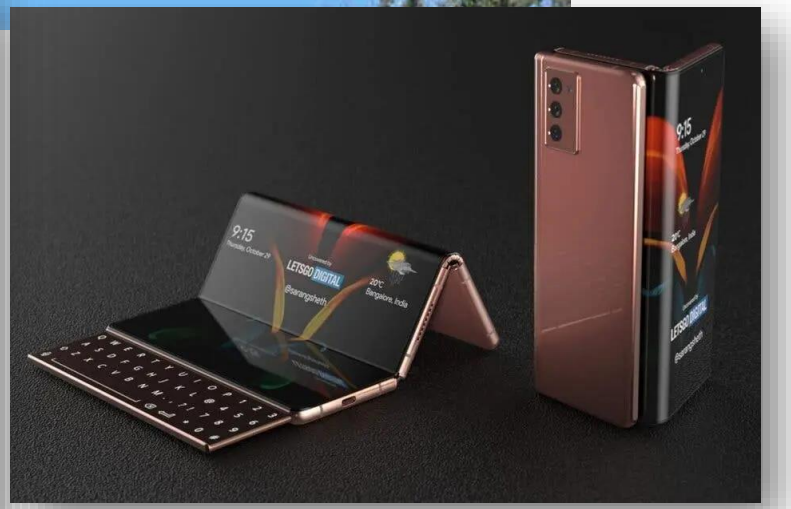
Introduction to Digital Systems

Logic Design of Digital Systems (300-1209) section 1

LECTURE 01

KRISADA PHROMSUTHIRAK

How important is this course?



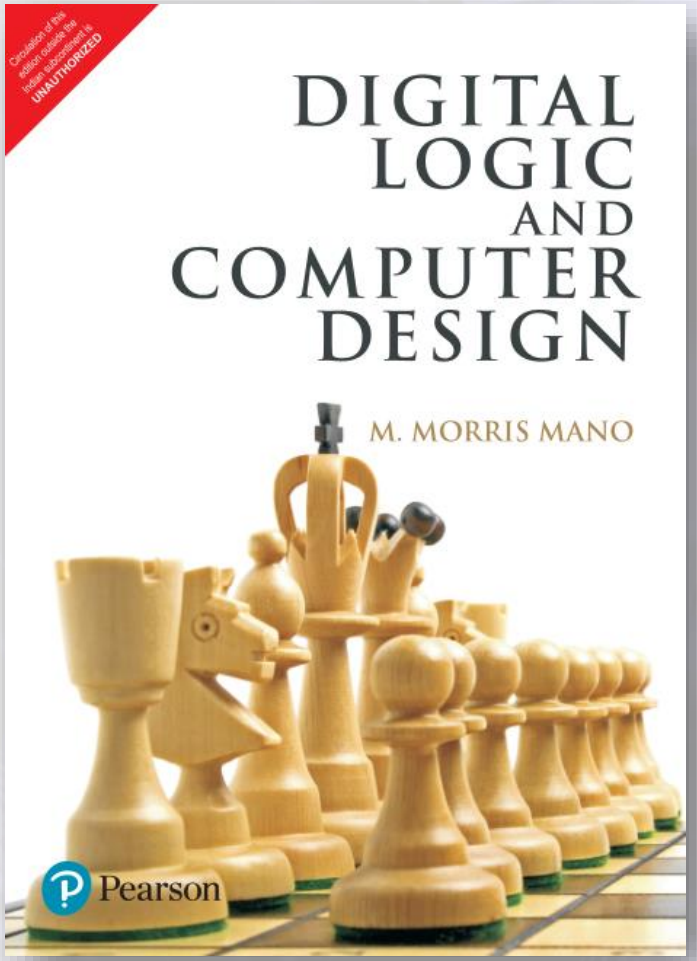
The digital is everywhere

About this class

We will cover these topics:

- Binary system
- Boolean algebra and Logic Gates and
- Simplification of Boolean Functions
- Combinational Logic
- Sequential Logic
- Registers, Counters, and the Memory Unit
- Processor Logic Design

Textbook in this class



การวัดผลสัมฤทธิ์ในการเรียน	จำนวนร้อยละ
1.) การเข้าเรียน กิจกรรมชั้นเรียน	10
2.) การบ้านและโจทย์ปัญหา	30
3.) สอบกลางภาค	30
4.) สอบปลายภาค	30

Class Materials

Students are welcome to post & ask questions.

The topic should relate to this class :)

- Handouts
- Assignment

300-1210 Practical of Digital System Design

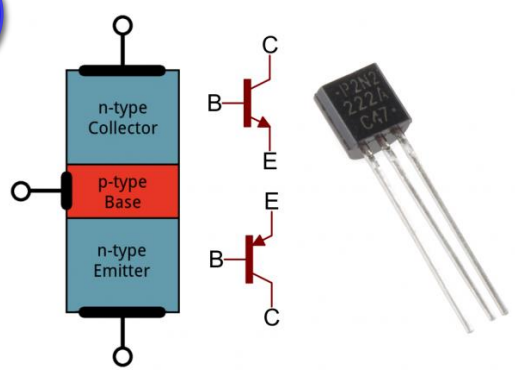
How can we learn about digital systems?

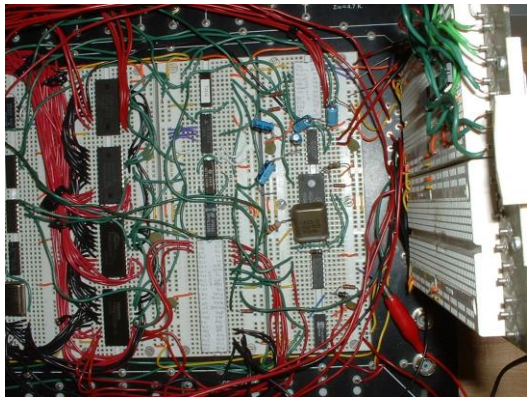
There are generally two approaches in the study of digital systems.

1. It started with the study of digital electronic representation. (All concept explained in transistor level)
2. Try to not mention any hardware representation and explain all concepts using binary representation and Boolean algebra.

1

Physical concept





2

Abstract concept

$$
\begin{aligned}
(A + B + C)' &= (A + X)' \\
&= A'\,X' \\
&= A' \bullet (B + C)' \\
&= A' \bullet (B'\,C') \\
&= A'\,B'\,C'
\end{aligned}
$$

What “Digital” really mean ?

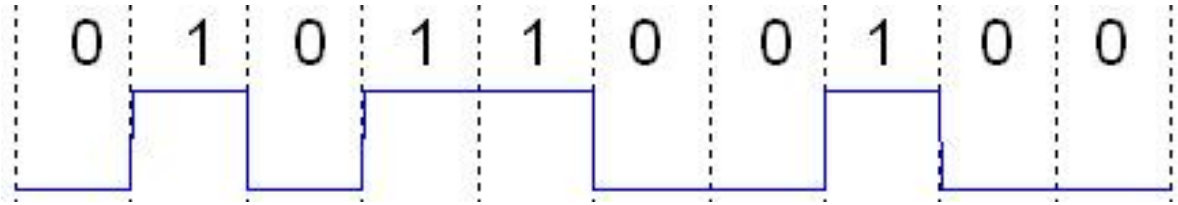
(Discrete = ไม่ต่อเนื่อง)

Digital usually refers to something using discrete digits, often binary digits.

Technology: **Digital television**

Digital television (DTV) is the transmission of television audiovisual signals using **digital encoding**.

Hardware: **Digital camera**

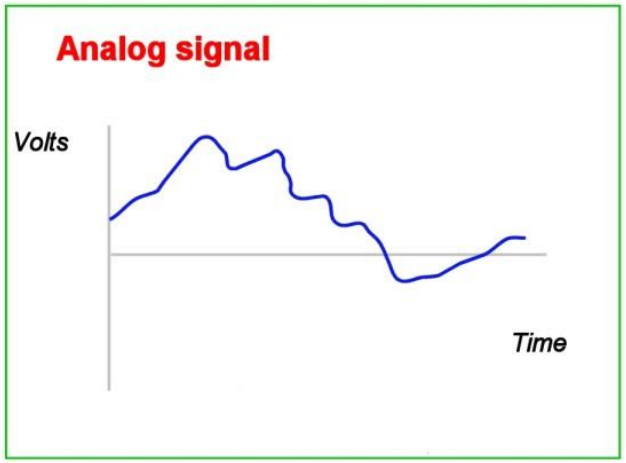


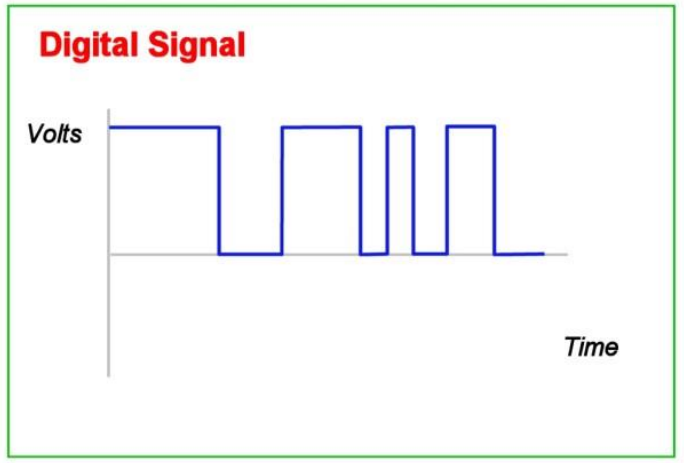
Capture information from analog world ➔ store **digital** image

คณะเทคโนโลยีดิจิทัล

Bit Values as Voltage Levels

To make it easier to learn, in this lesson we will focus on the digital aspect of electronics system.



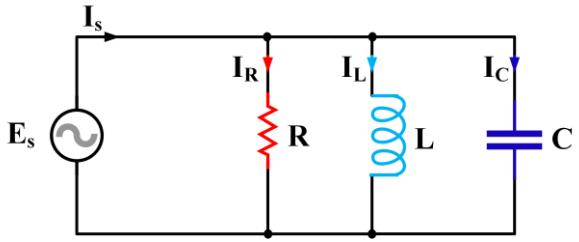


We need threshold values to decide whether it is 0 or 1

From analog to digital

Analog signal

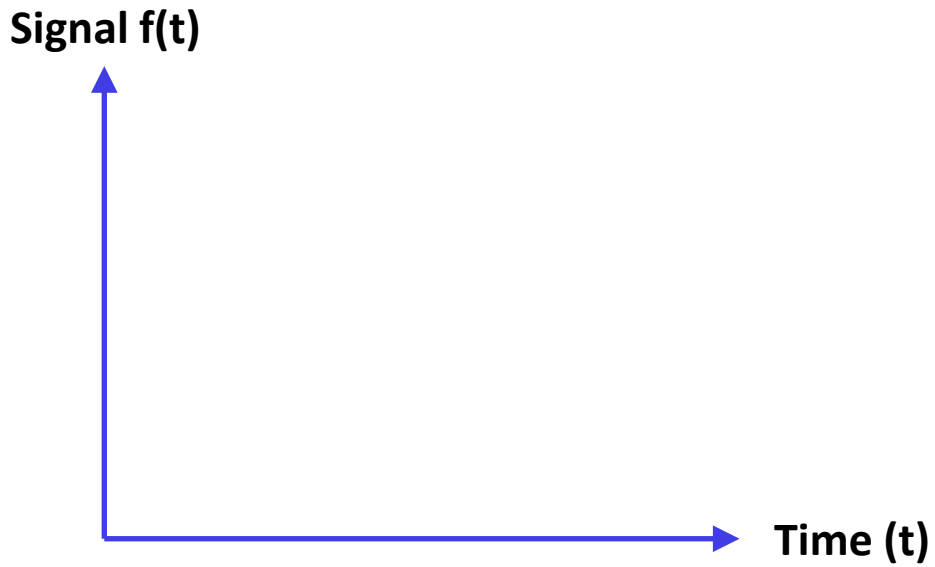
(You should already be familiar with this from previous course.)



Direct current (DC)
Alternating current (AC)

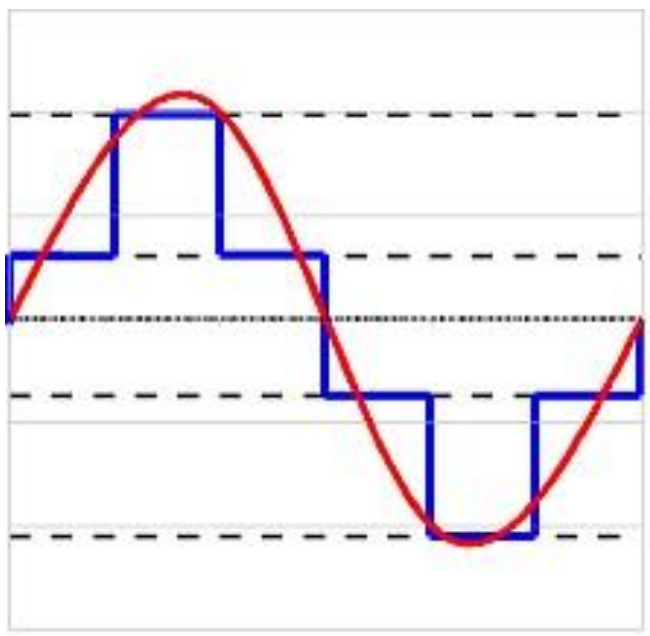
What is Signal?

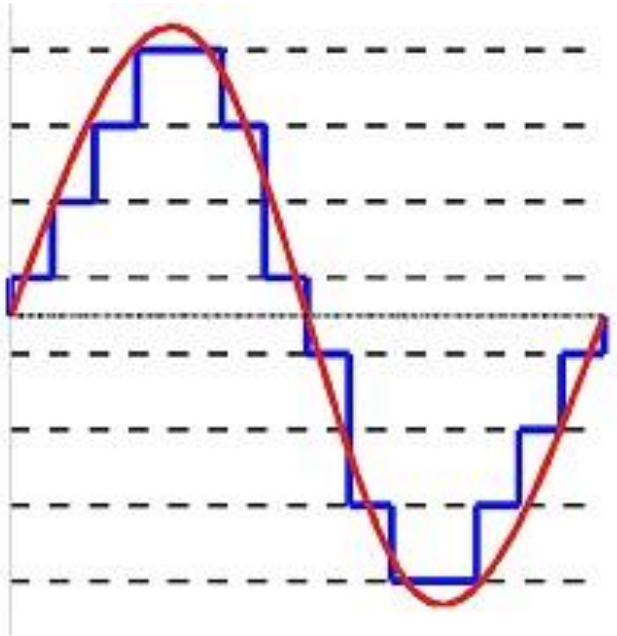
A signal is a function, that represents the variation of a physical quantity with respect to any parameter.



อะไรบ้างที่เป็นสัญญาณ?

Bit Values as Voltage Levels





Remark

Digital ≠ Binary

Bit Values as Voltage Levels

How is it possible to represent data processing in all complex digital devices (computers, tablets, smart phones, etc.) in terms of zeros and ones?

How is a binary digit (or a bit, in short) represented in a digital device?

I think you should be familiar with this in Physic class :)

Let's say if we would like to measure and record the length of a pencil.

In analog world we might have several answers of length based on our tool precision.

7.0014 Inch 7.04052900…. Inch 7 Inch

Bit Values as Voltage Levels

How is it possible to represent data processing in all complex digital devices (computers, tablets, smart phones, etc.) in terms of zeros and ones?

How is a binary digit (or a bit, in short) represented in a digital device?

In short, we make a rough estimate of the data so it's easier to store and process.

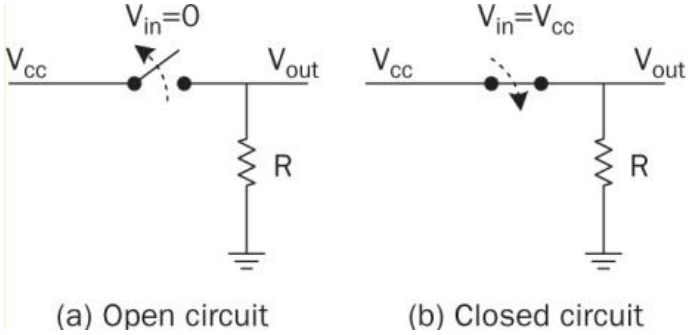
7 Inch

Data in Analog format

0	0	0	1	1	1

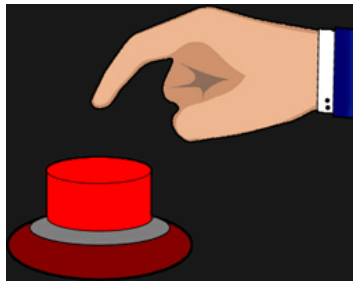
Data in Digital format

Transistor as a Switch

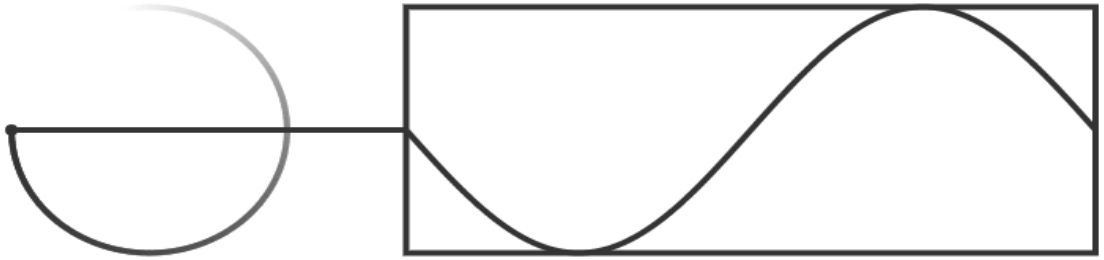


You want to convert analog data to digital data.

Use switch events as criteria



Press down ➔ [1]
Thumbs off ➔ [0]



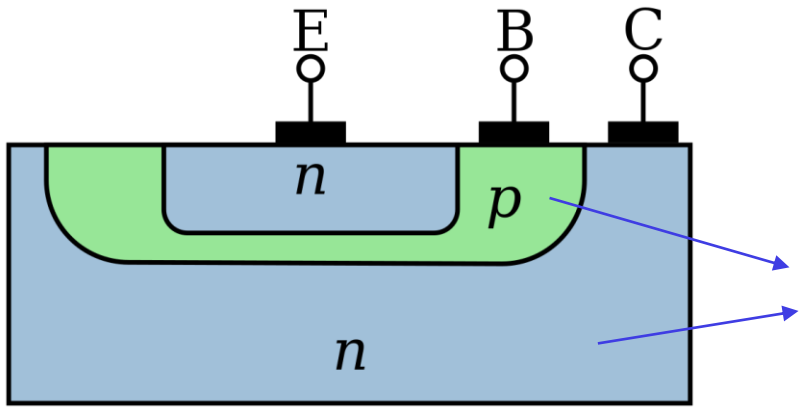
Assume this is an analog signal generator

… 0 1 1 1 0 0 0 1 1 …

Digital data stream

Transistor as a Switch

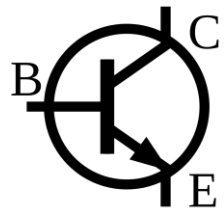
A transistor is an electronic component used in a circuit to control a large amount of current or voltage with a small amount of voltage or current.

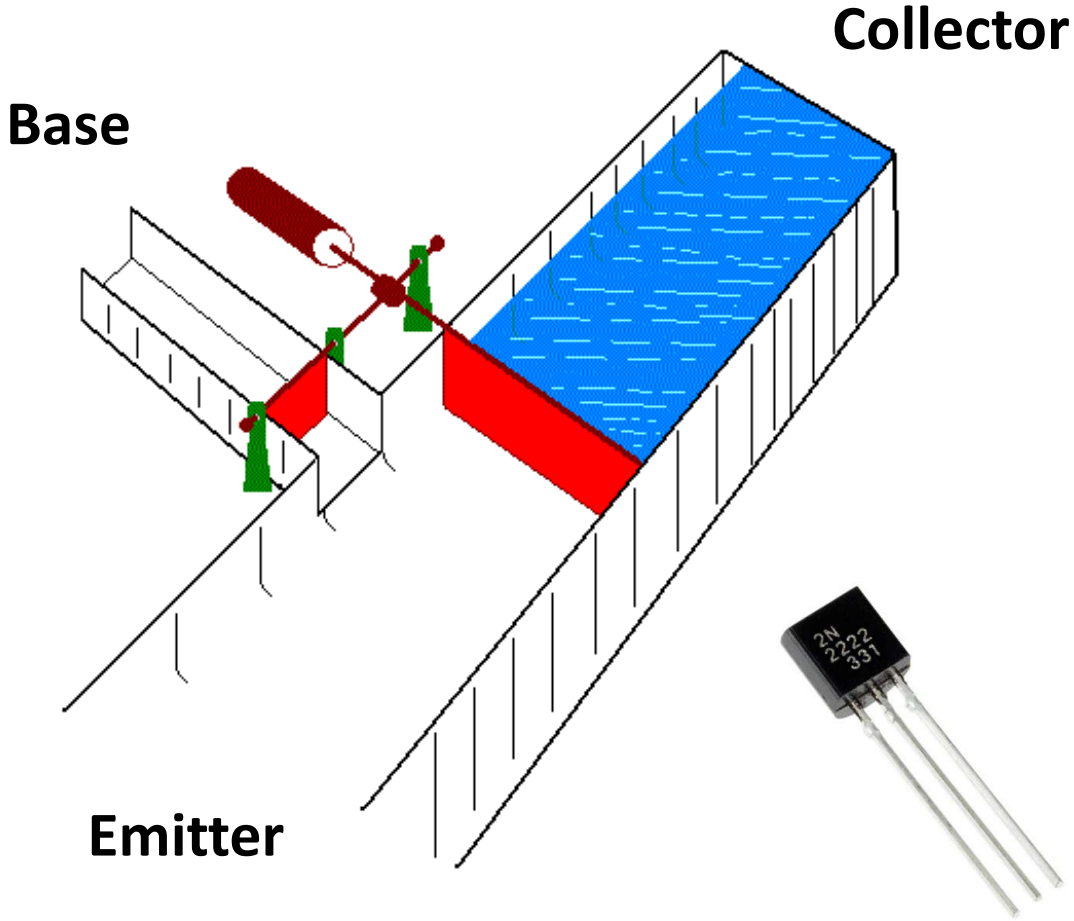


Made with semiconductor (such as **silicon**)

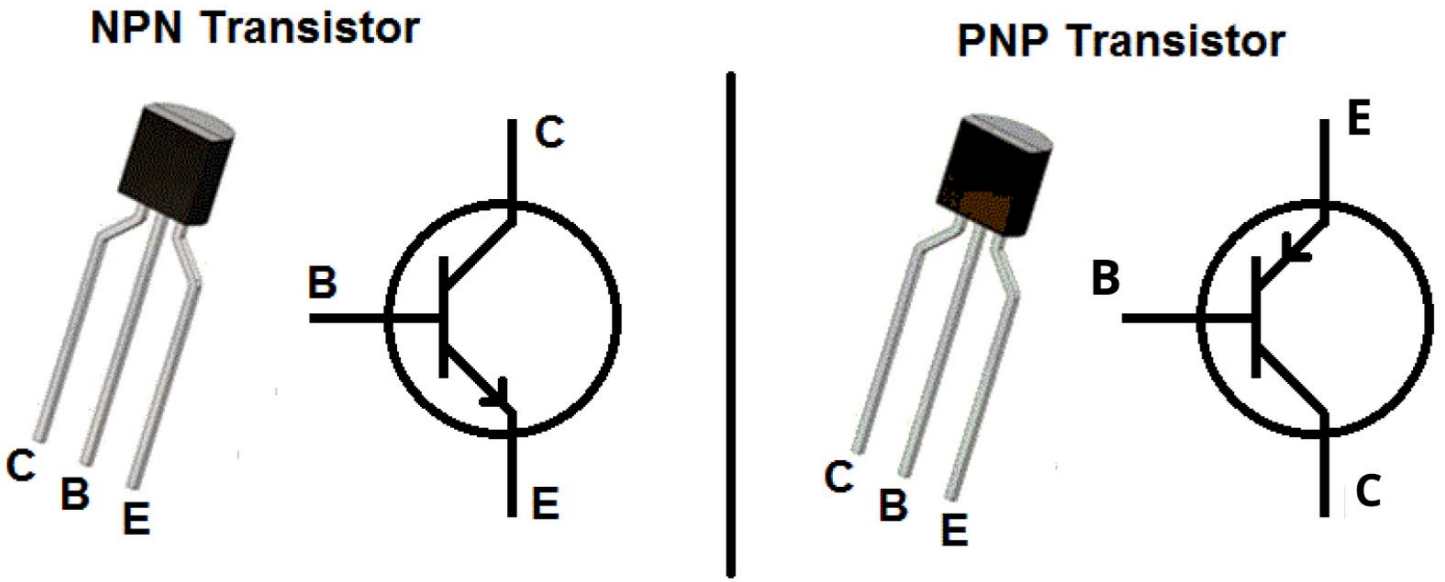
A semiconductor material has an electrical conductivity value falling between that of a conductor, such as copper, and an insulator, such as glass.

Its resistivity falls as its temperature rises.





Type of Transistor



NPN หัวลูกศร**พุ่งออก**

สถานะปกติ **ไม่มี**กระแสจาก C ไป E

ถ้ามีไฟเล็กน้อยที่ B Transistor จะทำงาน

ทำให้**ยอมปล่อย**ไฟปริมาณมากจาก C ไป E

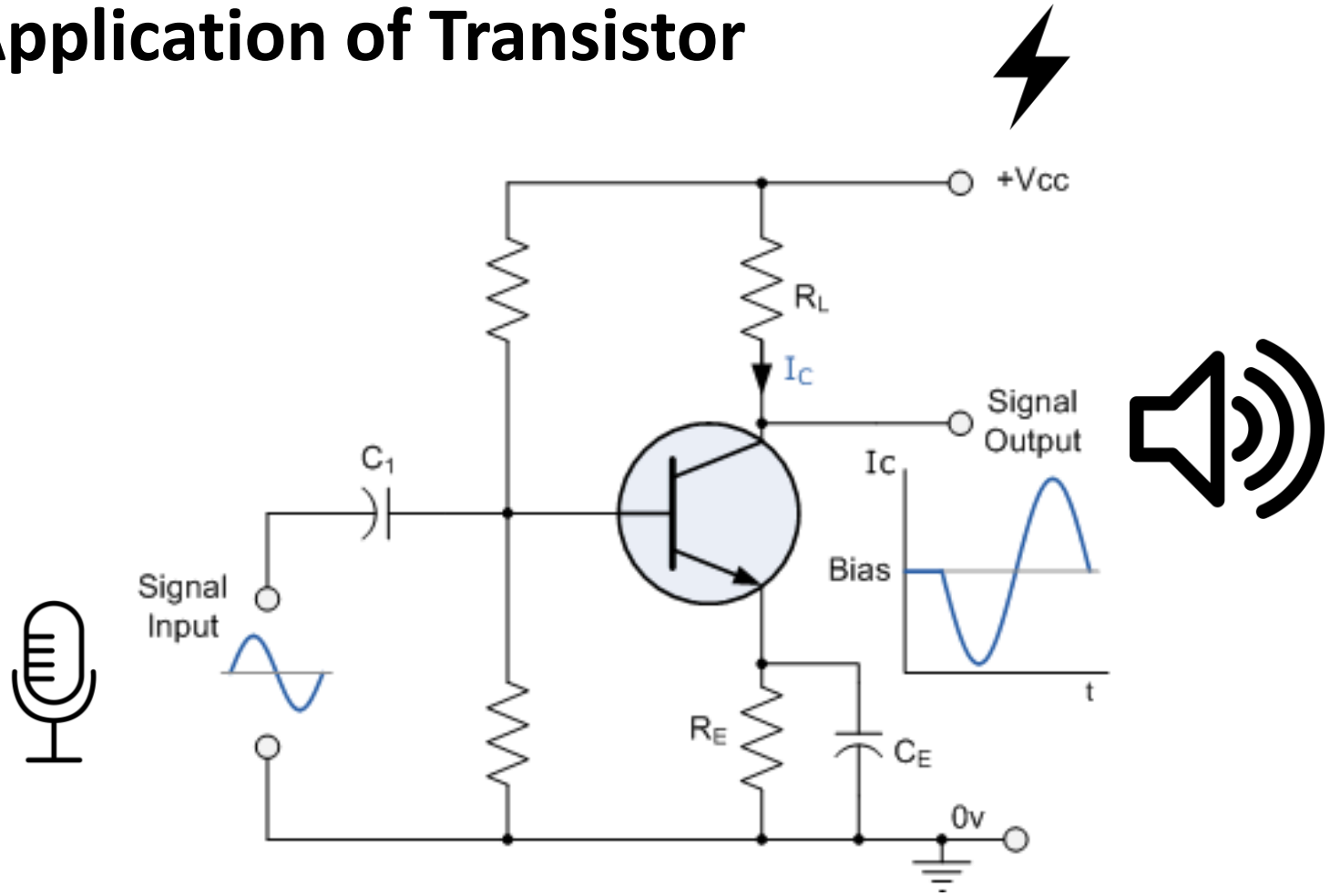
PNP หัวลูกศร**พุ่งเข้า**

สถานะปกติ **มี**กระแสจาก C ไป E

ถ้ามีไฟเล็กน้อยที่ B Transistor จะ**ไม่ยอม**ให้

กระแสไฟไหลจาก C ไป E

Application of Transistor



NPN signal amplifier circuit

Transistor as a Switch

Let's go back and look at the history a bit.

John Bardeen, William Shockley and Walter Brattain

First working transistor, invented in 1947 @Bell Labs

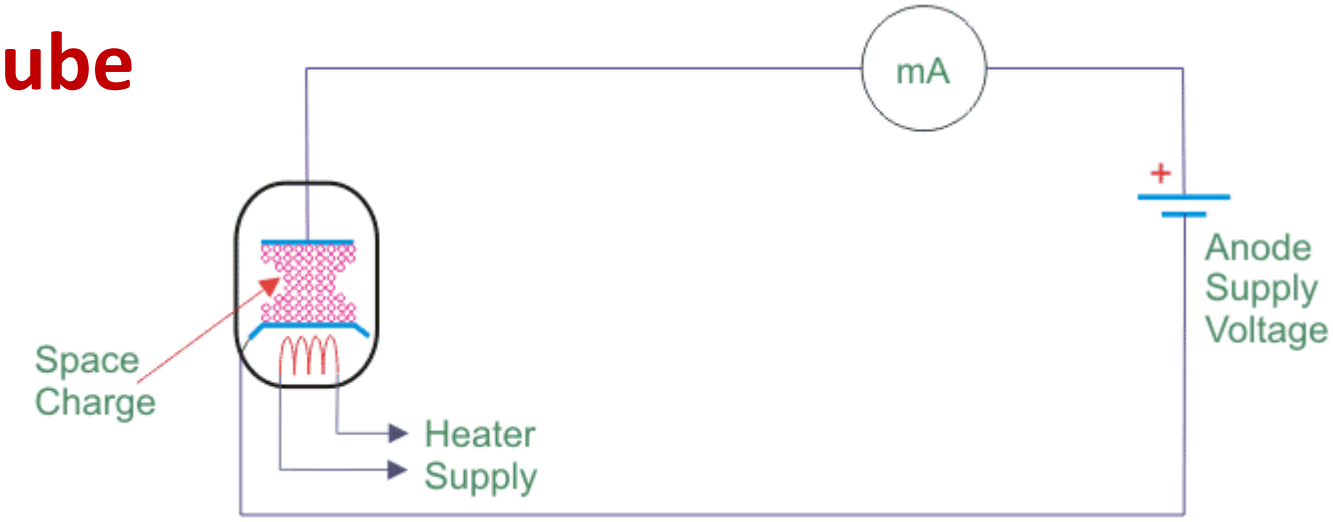
Transistor as a Switch

Before transistor… Vacuum tube

Sir John Ambrose Fleming

Invent the first vacuum tube in 1904

beginning of the electronics

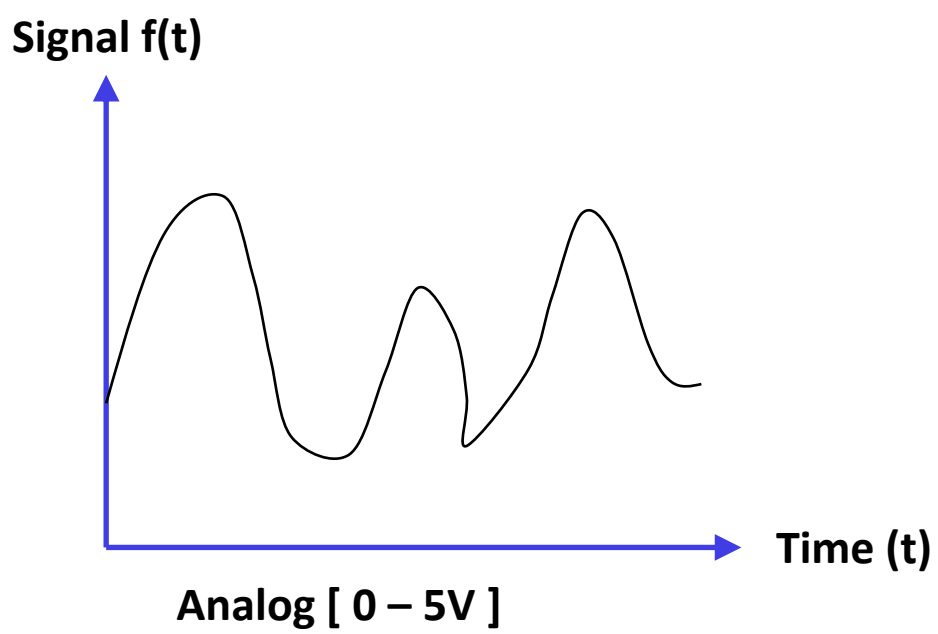


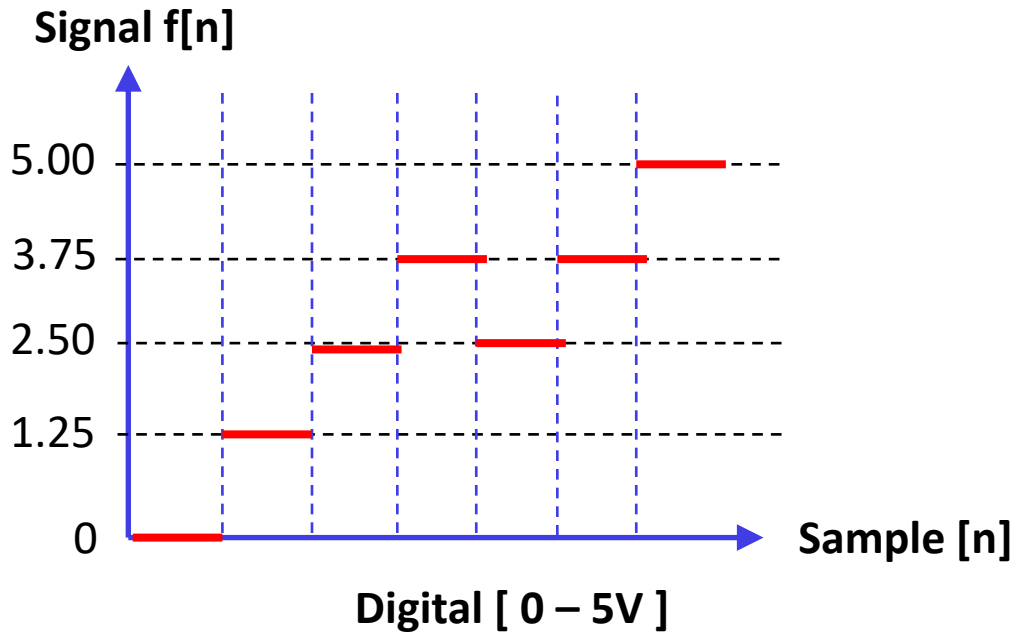
Bit of knowledge

Compared to the vacuum tubes that were used previously, the transistor was an amazing advance. Smaller in size, the transistor could easily be manufactured cheaply in large quantities.

Analog signal to Digital signal

- Sampling
- Quantization





Why we need Digital Signal?

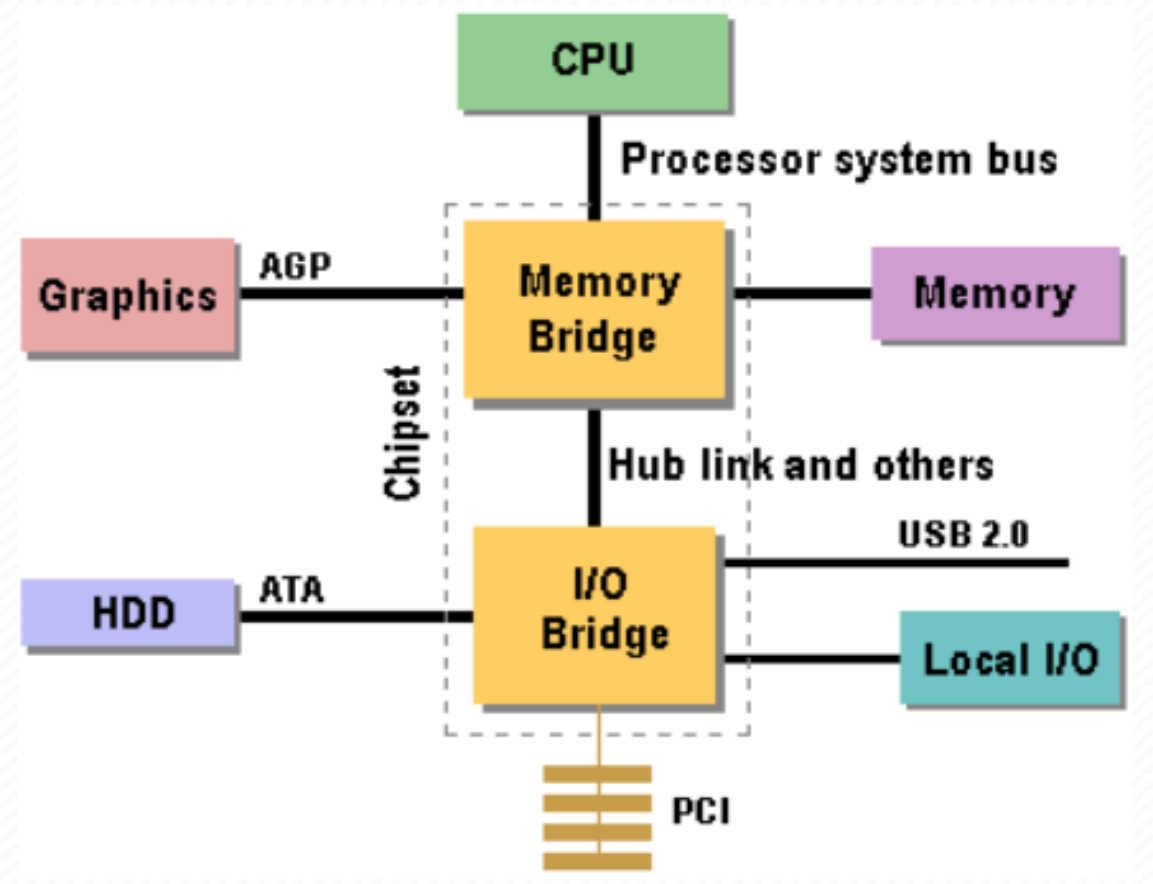
1.) All real-life signal are analog signal.

2.) Digital signal widely use in communication (minimize effect of noise)

3.) Easy to manipulate when use in large scale application.

What happens if we connect two digital systems with different sampling rates?

What happens if we connect two digital systems with different sampling rates?



Each device have difference clock.

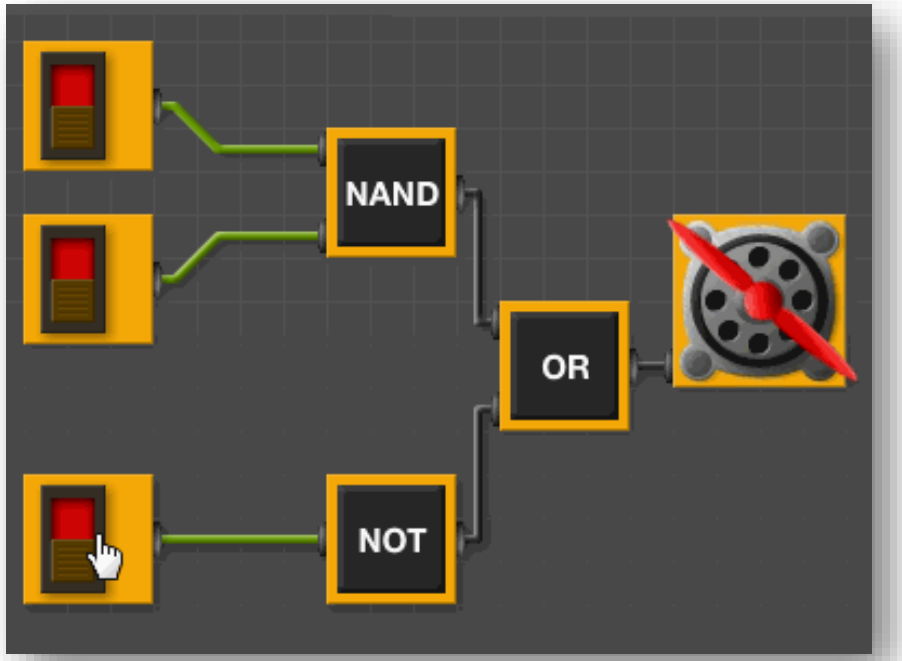
How can everything be connecting?

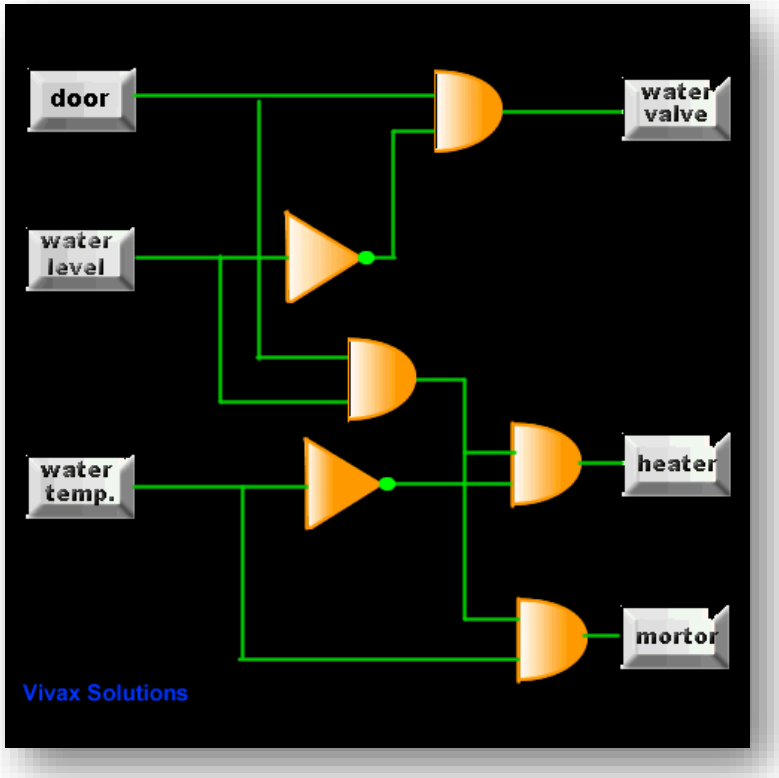
This class will give you an Idea.

If we have inputs as binary data, how can we use them?

We no longer have to worry about the sensitive value of the input.

Now, we only have just Zero (0) or One (1). **(On / Off)**



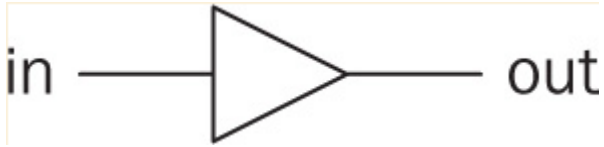


We need

“Logic Operator”

Logic Gates from Switches

[1] The Buffer



Input	Output
False	False
True	True

Truth table for a buffer

It simply passes its input, unchanged, to its output.

a buffer is mainly used to **increase propagation delay**.

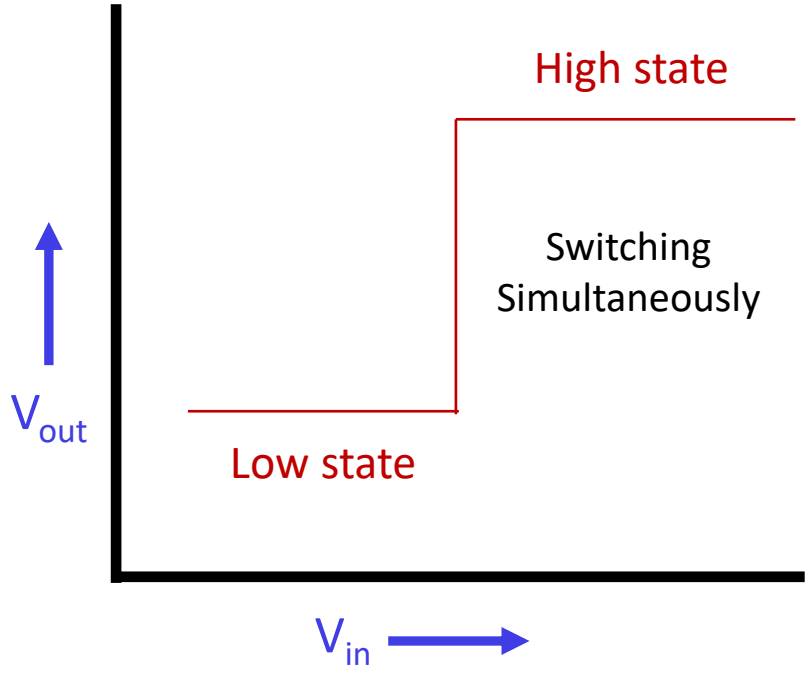
In a real-world circuit,
a buffer can be used to amplify a signal if its current is too weak.

minimize voltage loading effects between different elements.

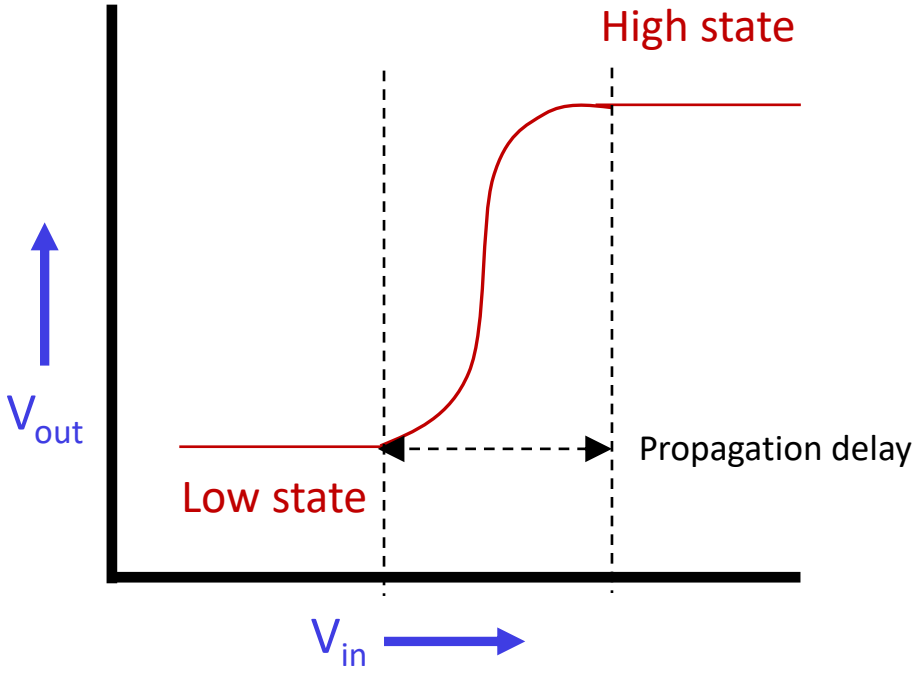
In other words, the buffer acts as a protective shield.

Logic Gates from Switches

Keep in mind that we cannot produce ideal Digital in the real world.



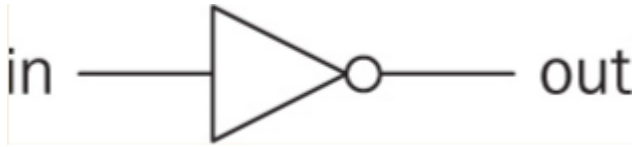
Ideal characteristic of digital system



Practical digital circuit

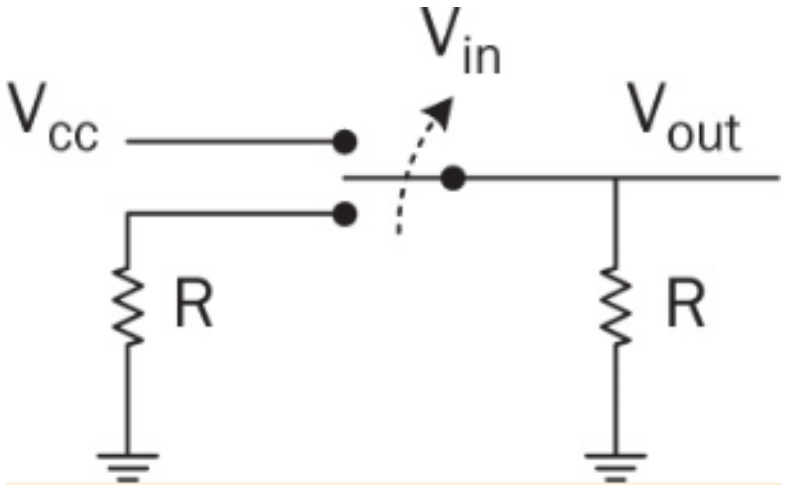
Logic Gates from Switches

[2] The NOT Gate



Input	Output
False	True
True	False

Truth table for a NOT gate

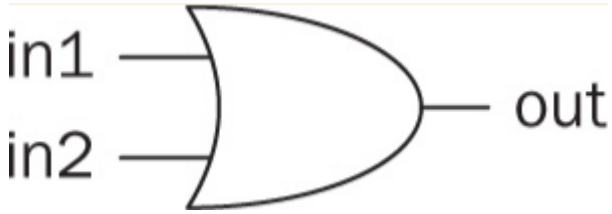


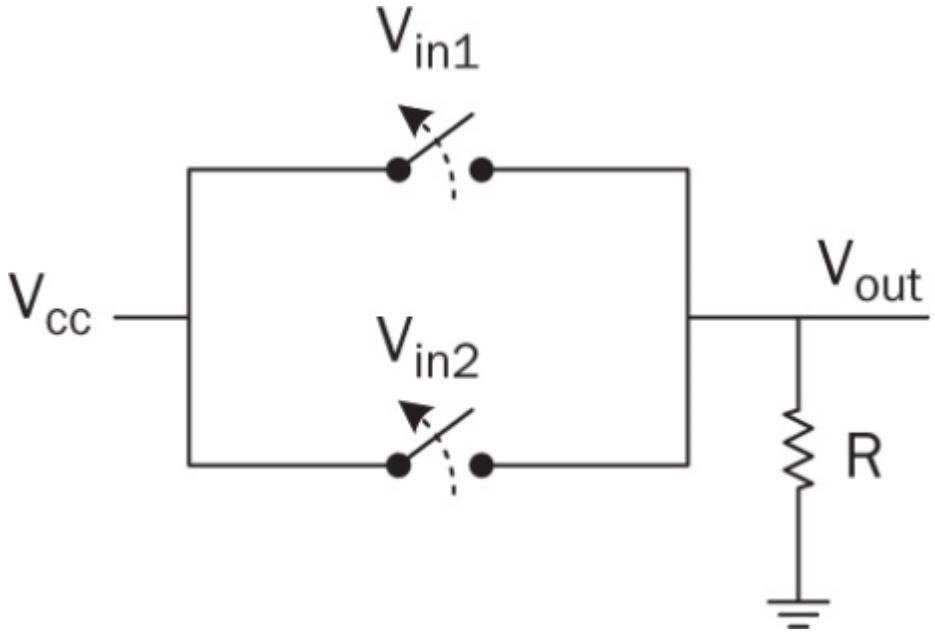
In this setup, when input is equal to supply voltage (Vin - Vcc) the switch connects ground to output. So, output voltage will be zero (Vout = 0).

When input voltage equals to ground (Vin=0), the switch connects supply voltage to output, So, Vout = Vcc.

Logic Gates from Switches

[3] The OR Gate





Input1	Input 2	Output
True	True	True
True	False	True
False	True	True
False	False	False

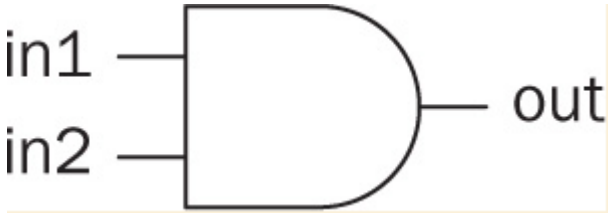
Truth table for an OR gate

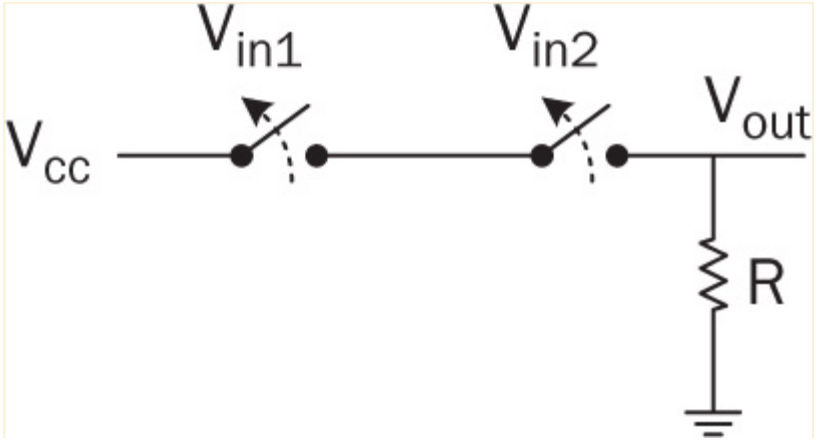
An OR gate is a digital logic gate with two or more inputs and one output that performs ***logical disjunction***.

The output of an OR gate is true when one or more of its inputs are true. If all of an OR gate's inputs are false, then the output of the OR gate is false.

Logic Gates from Switches

[4] The AND Gate





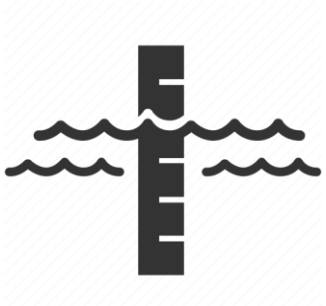
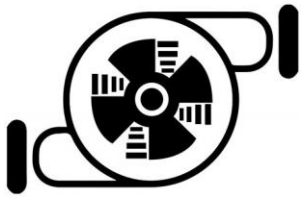
Input1	Input 2	Output
True	True	True
True	False	False
False	True	False
False	False	False

Truth table for an AND gate

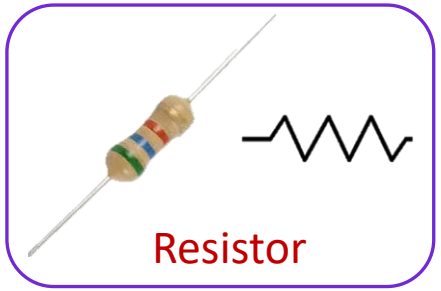
An AND gate is a digital logic gate with two or more inputs and one output that performs ***logical conjunction***.

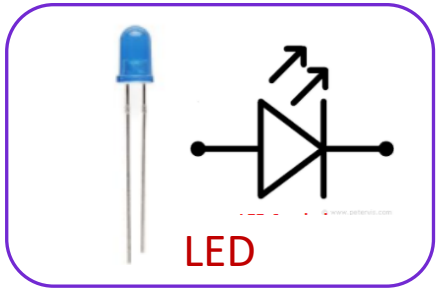
The output of an AND gate is true only when all of the inputs are true. If one or more of an AND gate's inputs are false, then the output of the AND gate is false.

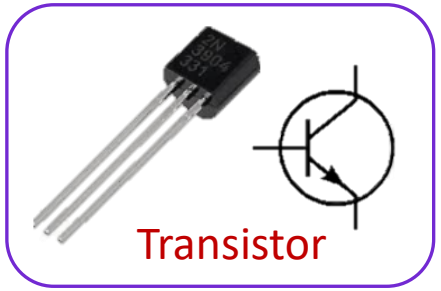
From Problem to Logic Gate Circuit

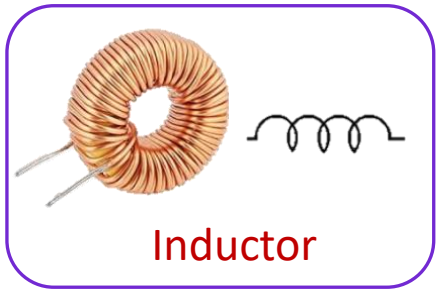
Input			Output	
				
0	0	0	0	0
0	0	1	0	1
1	1	0	1	0
1	0	1	1	1
0	1	1	0	1

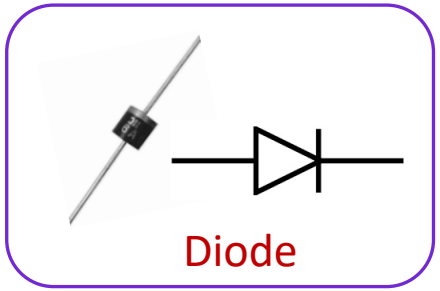
How can we make a connection between the electronic component

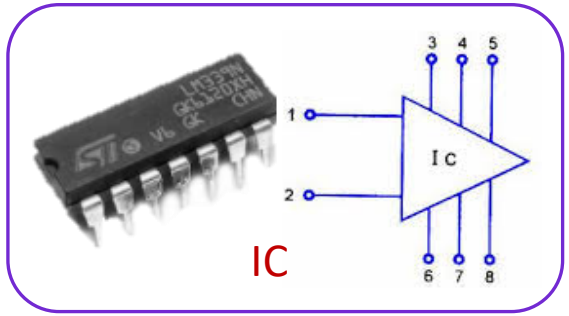


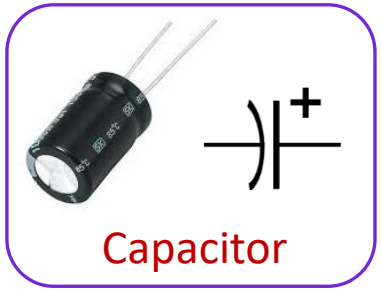


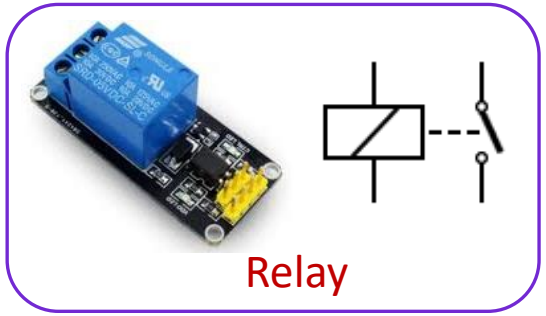


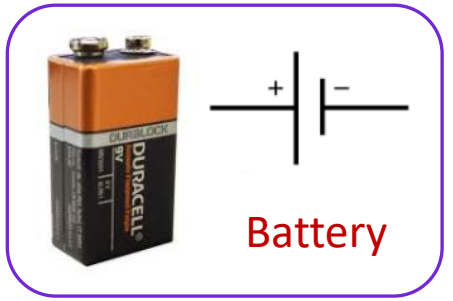




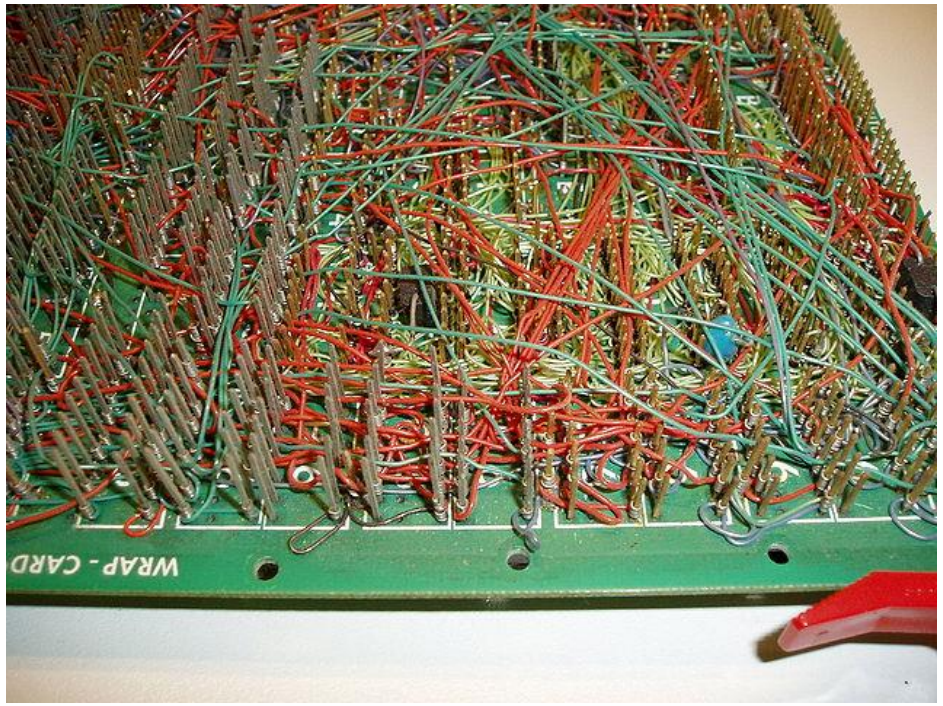




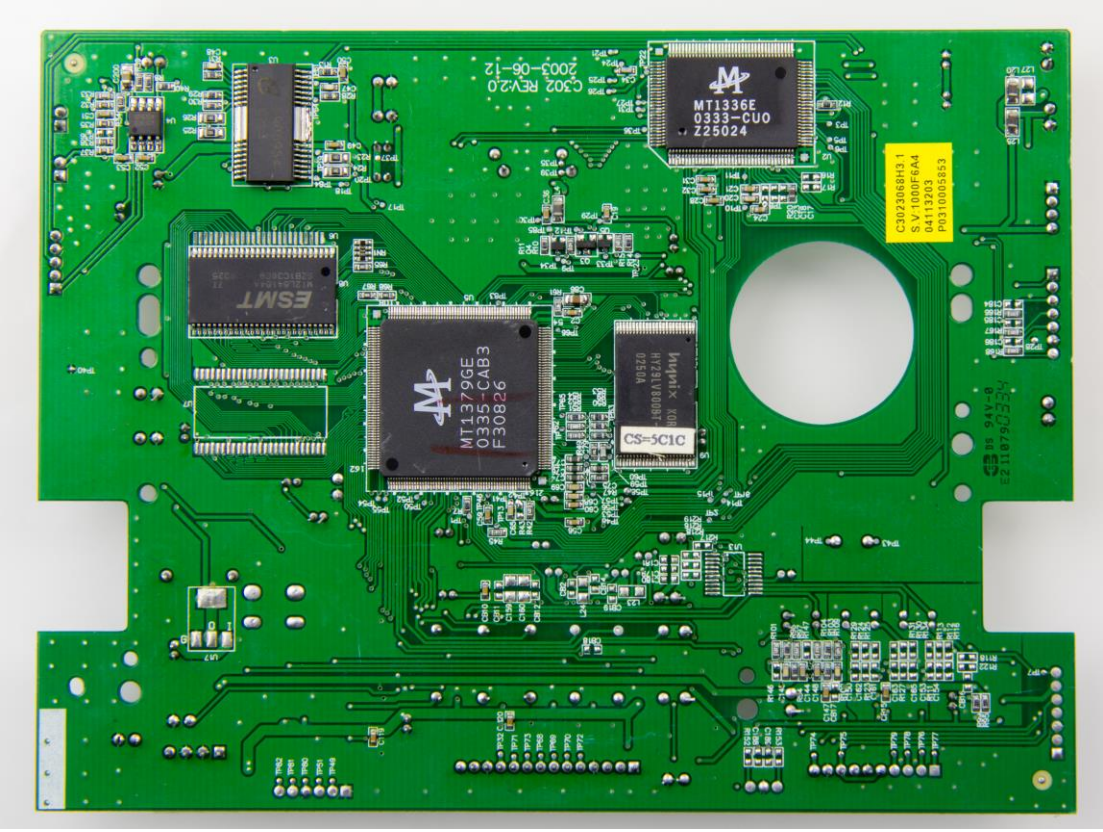




Printed Circuit Board (PCB)



Point-to-point wiring

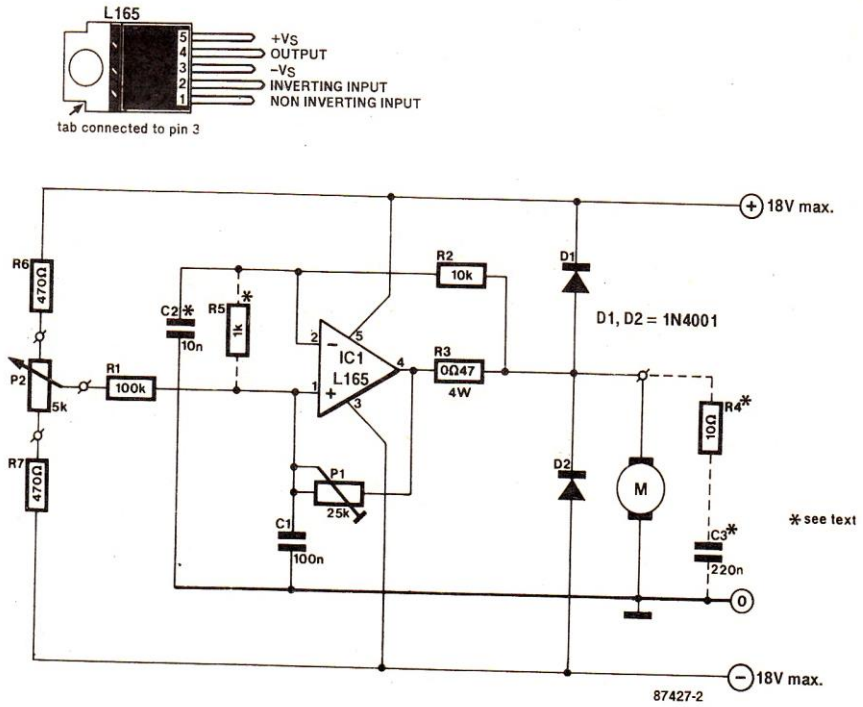


PCB

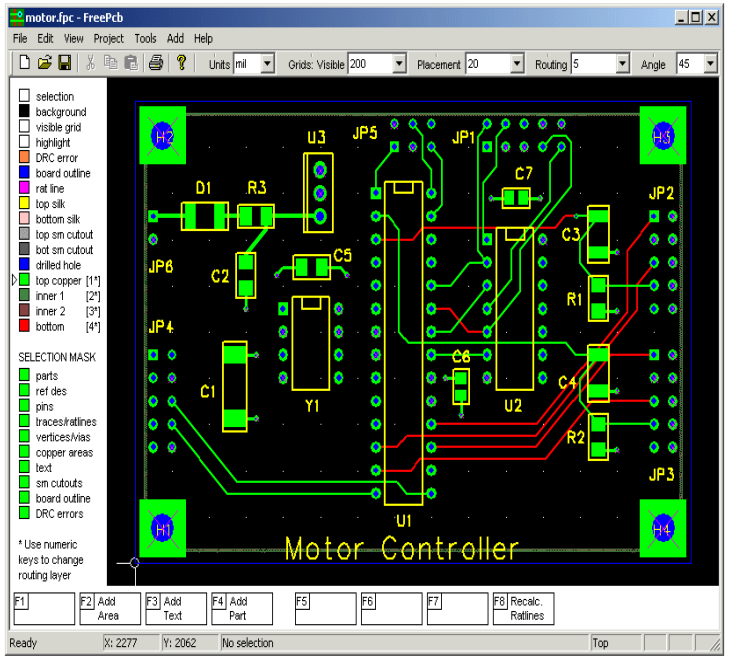
Printed circuit board is the most common name but may also be called "printed wiring boards" or "printed wiring cards". Before the advent of the PCB circuits were constructed through a laborious process of point-to-point wiring. This led to frequent failures at wire junctions and short circuits when wire insulation began to age and crack.

1 Create a logic circuit with physical concept

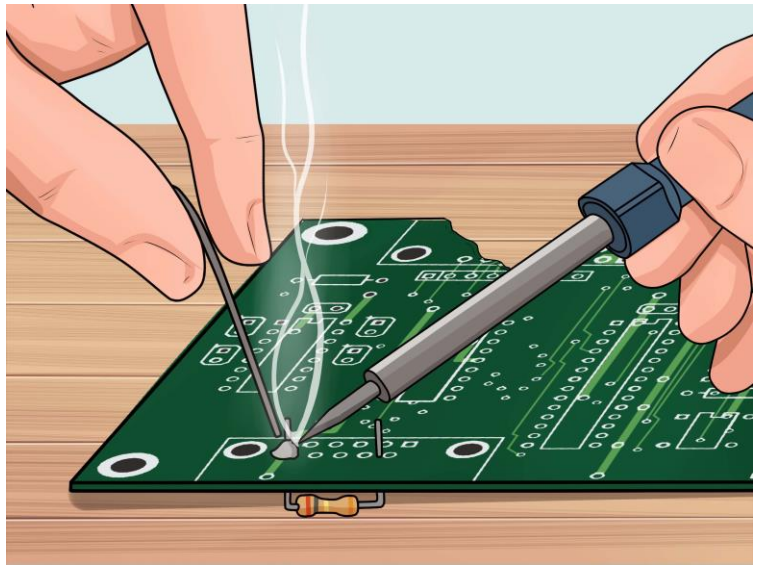
Step-by-step



Design Circuit



Design PCB

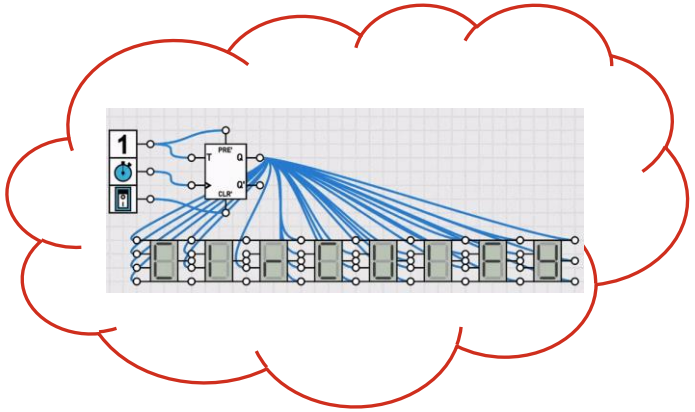


Soldering electrical components into printed circuit boards

https://www.wikihow.com/Build-a-Circuit-Board

2 Create a logic circuit with programming

Abstract concept



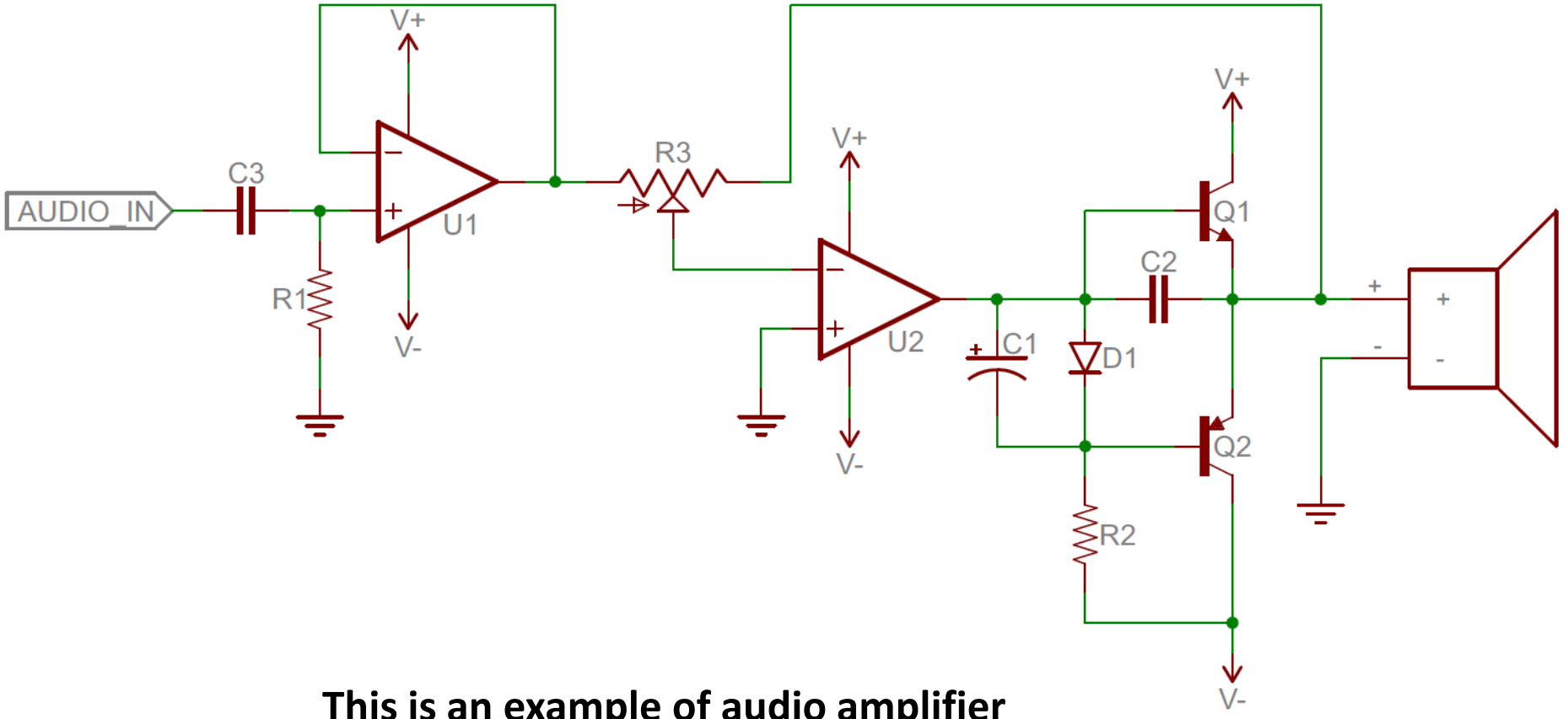
Make a logical idea to do something

```
1  library ieee;
2  use ieee.std_logic_1164.all;
3  use ieee.numeric_std.all;
4
5  entity signed_adder is
6    port
7    (
8      aclr : in   std_logic;
9      clk  : in   std_logic;
10     a    : in   std_logic_vector;
11     b    : in   std_logic_vector;
12     q    : out  std_logic_vector
13   );
14 end signed_adder;
15
16 architecture signed_adder_arch of signed_adder is
17   signal q_s : signed(a'high+1 downto 0); -- extra bit wide
18
19 begin -- architecture
20   assert(a'length >= b'length)
21     report "Port A must be the longer vector if different sizes!"
22     severity FAILURE;
23   q <= std_logic_vector(q_s);
24
25   adding_proc:
26   process (aclr, clk)
27     begin
28       if (aclr = '1') then
29         q_s <= (others => '0');
30       elsif rising_edge(clk) then
31         q_s <= ('0'&signed(a)) + ('0'&signed(b));
32       end if; -- clk'd
33     end process;
34
35 end signed adder arch;
```

Write a program

Load programs into board

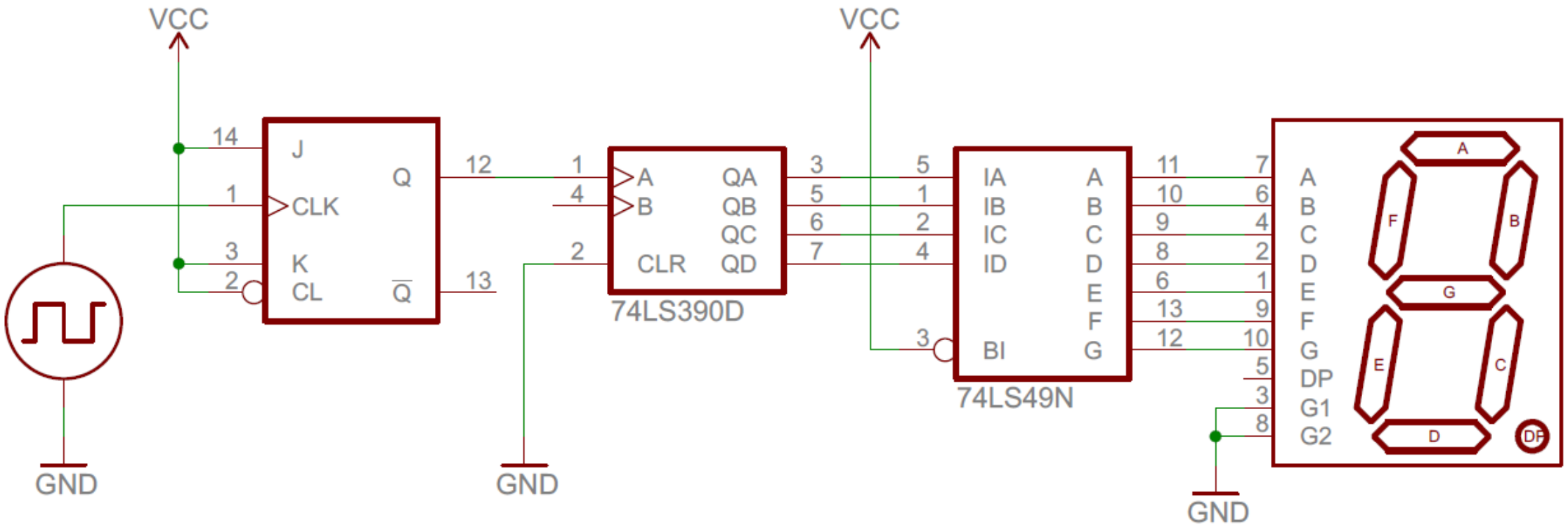
Example of Analog Circuit



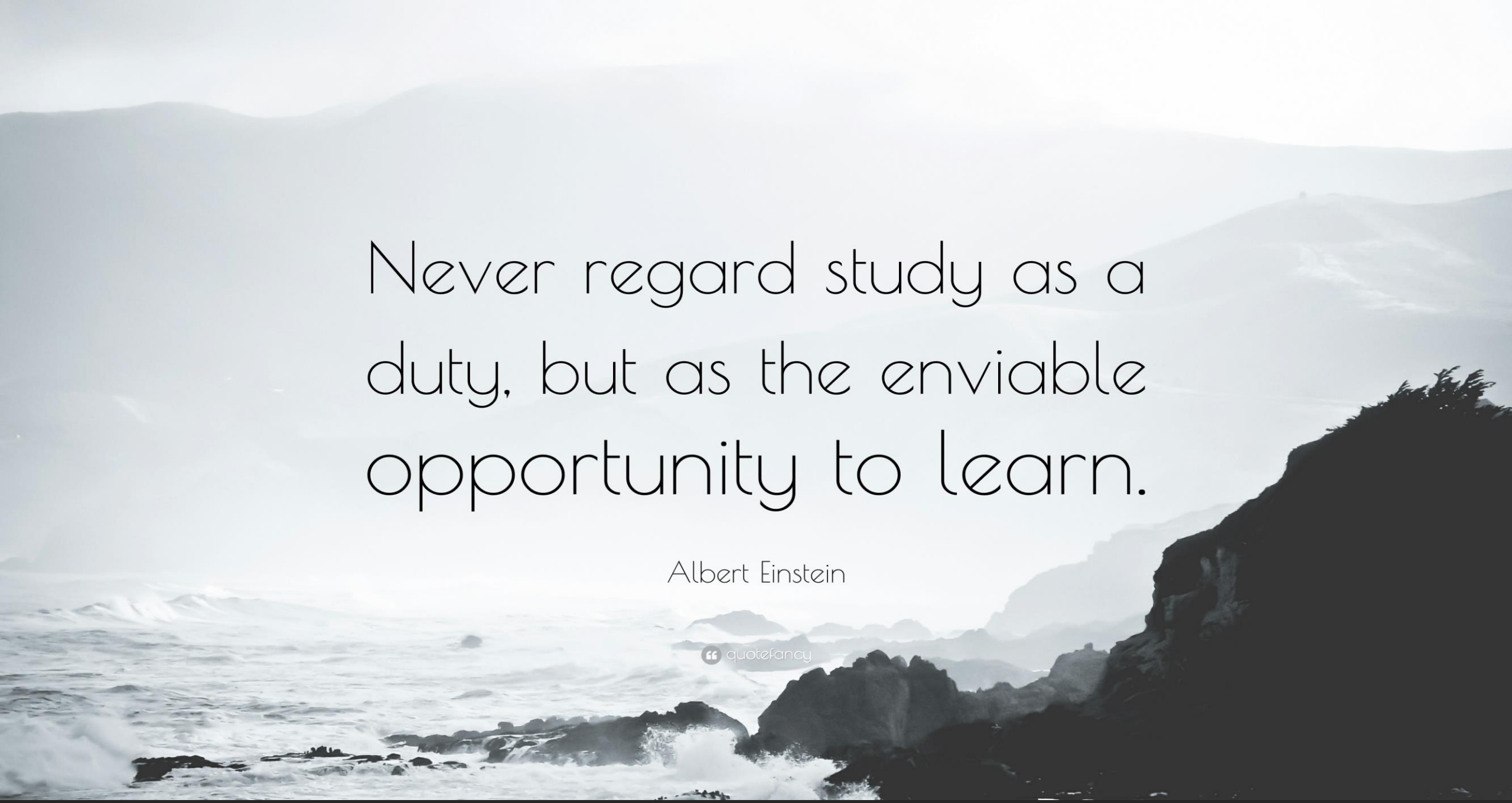
This is an example of audio amplifier

Analog circuits are usually complex combinations of op amps, resistors, caps, and other foundational electronic components.

Example of Digital Circuit



Digital circuits make use of components like logic gates, or more complicated digital ICs (usually represented by rectangles with labeled pins extending from them)


Never regard study as a duty, but as the enviable opportunity to learn.
Albert Einstein
quotefancy