Brief Introduction to H/W Design

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Elements

- Passive Elements
- Resistor(R), Capacitor(C), Inductor(L)
- Active Elements
- Diode, Transistor, Op-Amp etc.

Elements

- Resistor[Ω] = $\rho \frac{l}{S}$
- Series Connection : Rtot = R1+R2+⋯+Rn
- Parallel Connection : Rtot = 1/(1/R1 + 1/R2 + ⋯+1/Rn)

Elements

- Inductor[H] = Wb/A
- 전류의 변화량에 비례해 전압을 유도 : $V = L\frac{di}{dt}$
- Series Connection : Ltot = L1 + L2 + ⋯ + Ln
- Parallel Connection : Ltot = 1/(1/L1 + 1/L2 + ⋯ + 1/Ln)

Elements

- Capacitor[F] = $\varepsilon \frac{A}{d}$
- 전압의 변화량에 따라 전류가 발생 : i= $C \frac{dV}{dt}$
- Series Connection : Ctot = 1/(1/C1 + 1/C2 + … + 1/Cn)
- Parallel Connection : Ctot = C1+ C2 + … Cn

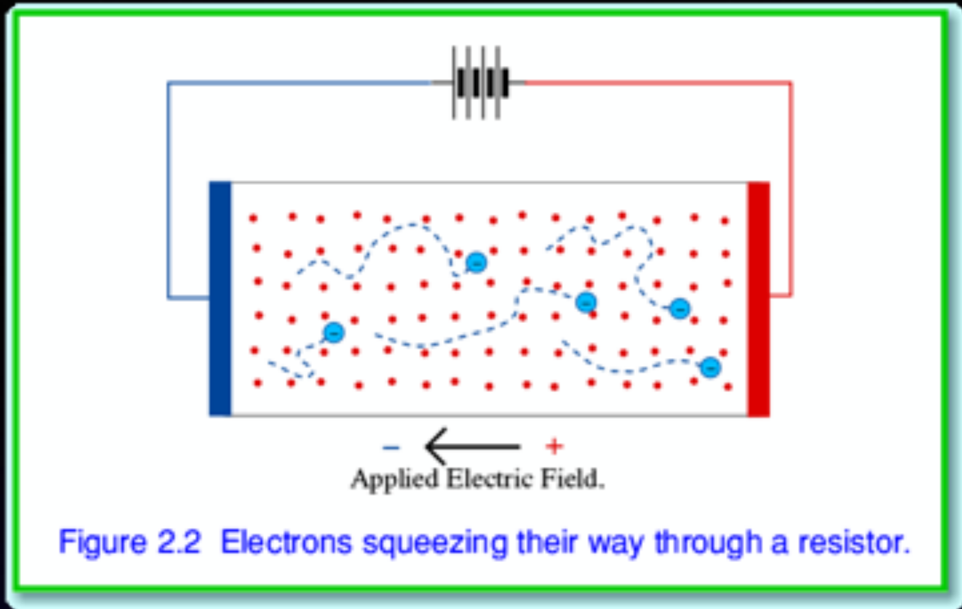
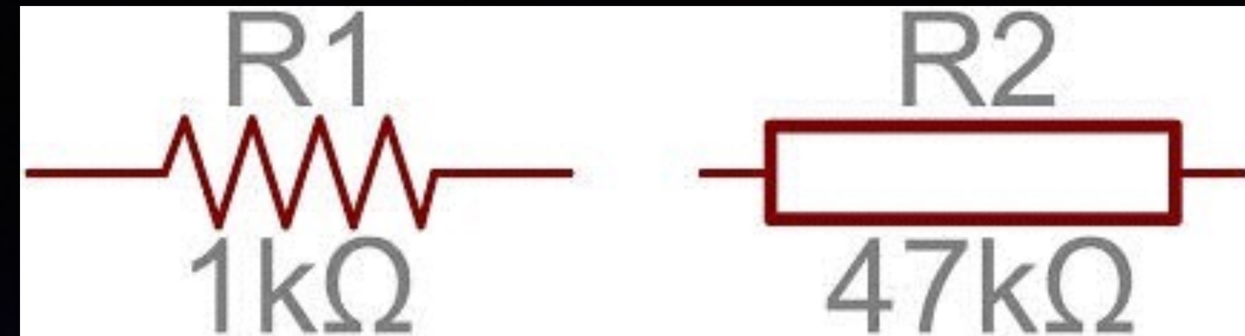
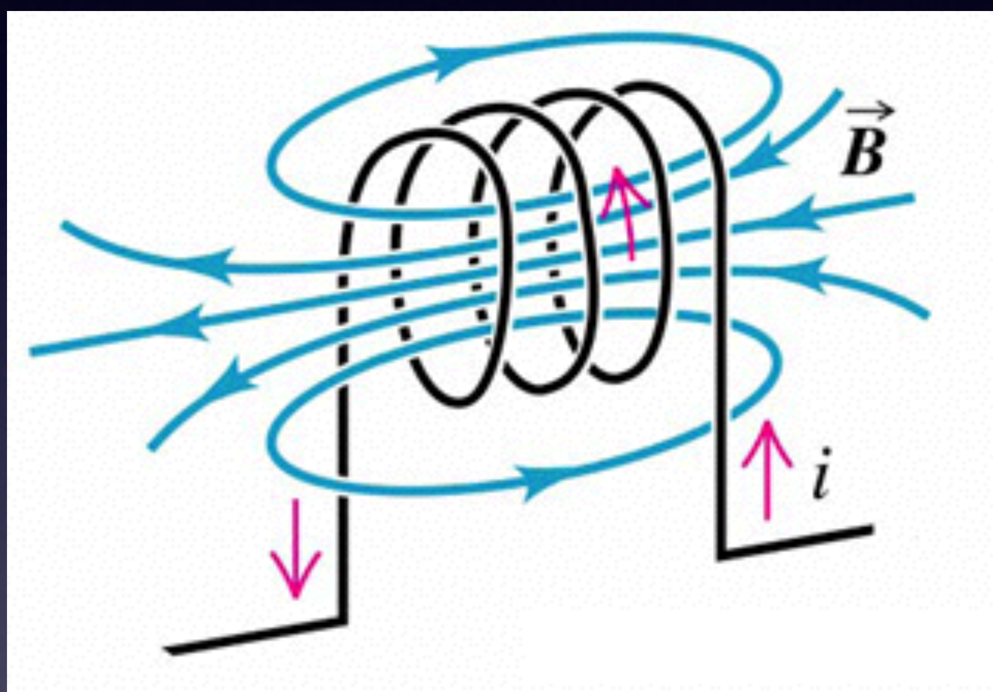
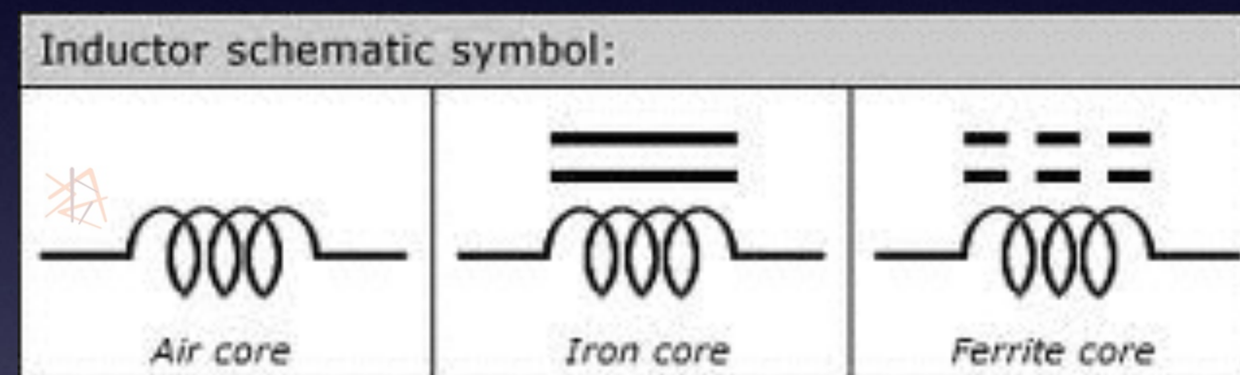
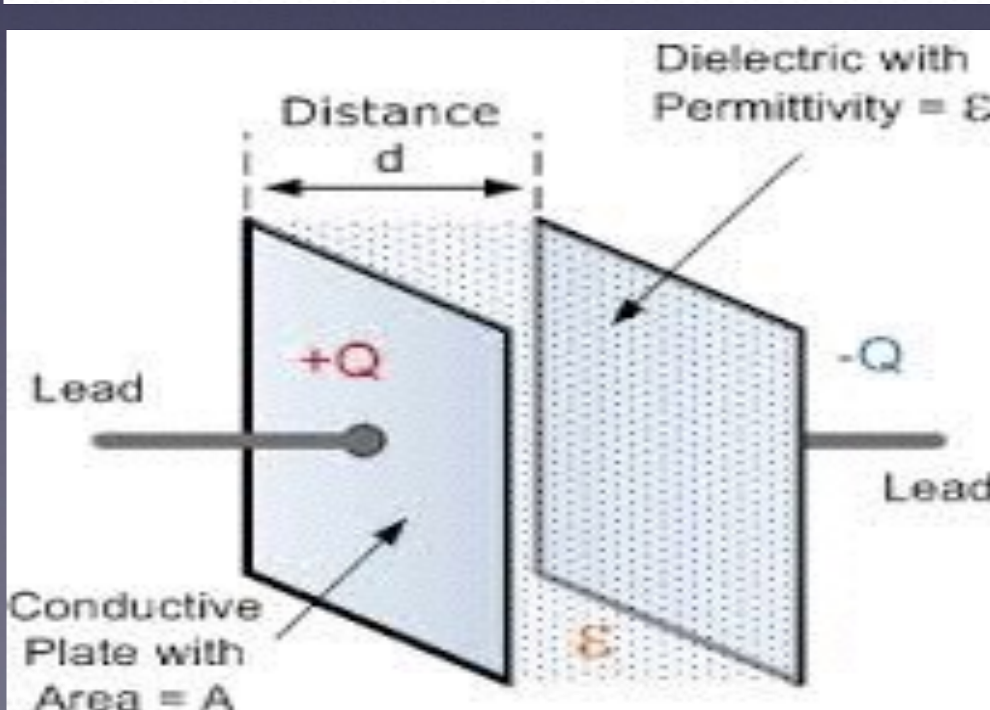


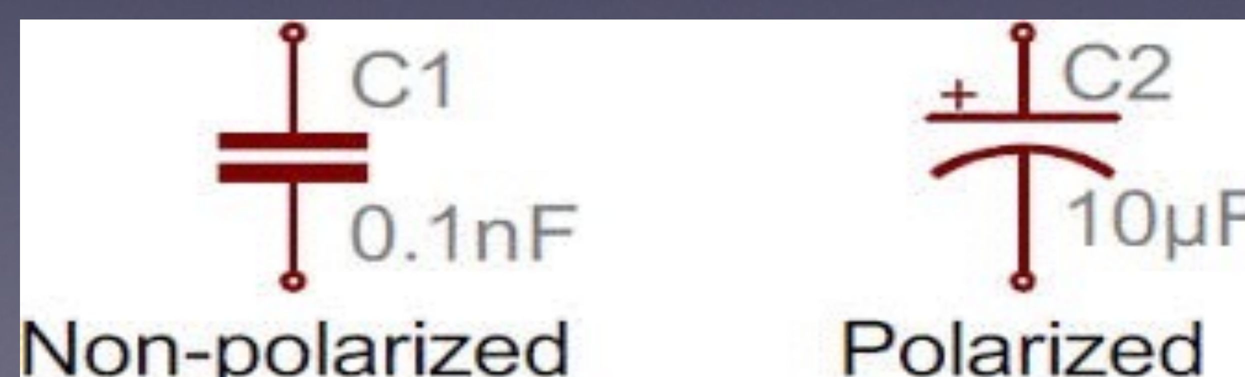
Figure 2.2 Electrons squeezing their way through a resistor.







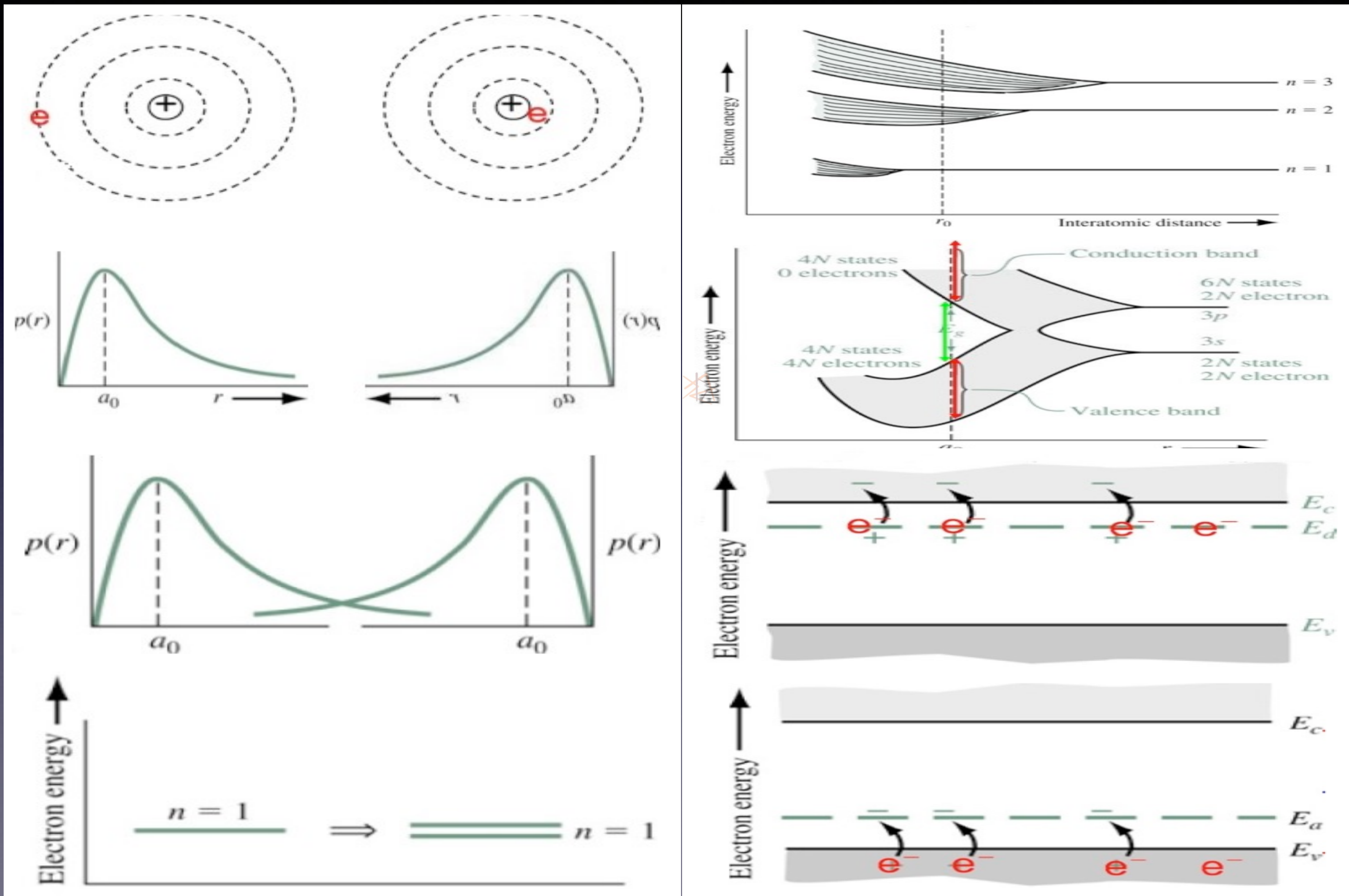




Elements

- Semiconductor
- In Periodic Table, Si is a very good element for making Semiconductors
- Semiconductors can have conductivity in specific conditions
- Si has four peripheral electrons
- 3족 원소 첨가시, P type Semiconductor 생성
- 5족 원소 첨가시, N type Semiconductor 생성

Elements

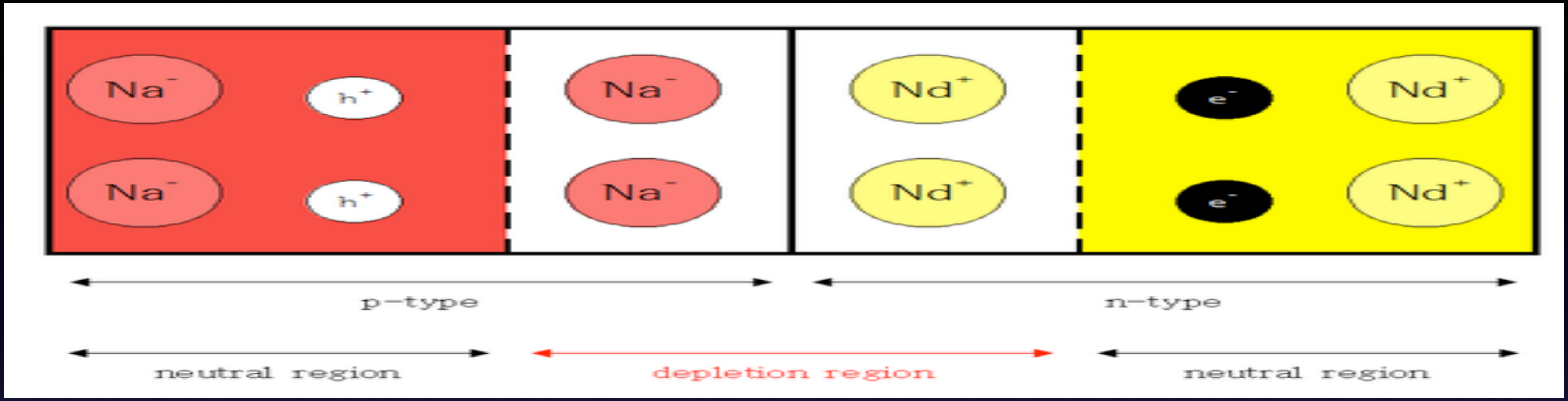


e
e
p(r)
a_0
r
p(r)
a_0
r
p(r)
p(r)
a_0
a_0
Electron energy
n = 1
n = 1
Electron energy
n = 3
n = 2
n = 1
r_0
Interatomic distance
Conduction band
4N states
0 electrons
6N states
2N electron
3p
3s
4N states
4N electrons
2N states
2N electron
Electron energy
Valence band
Electron energy
E_c
E_d
E_v
e⁻
Electron energy
E_c
E_a
E_v
e⁻

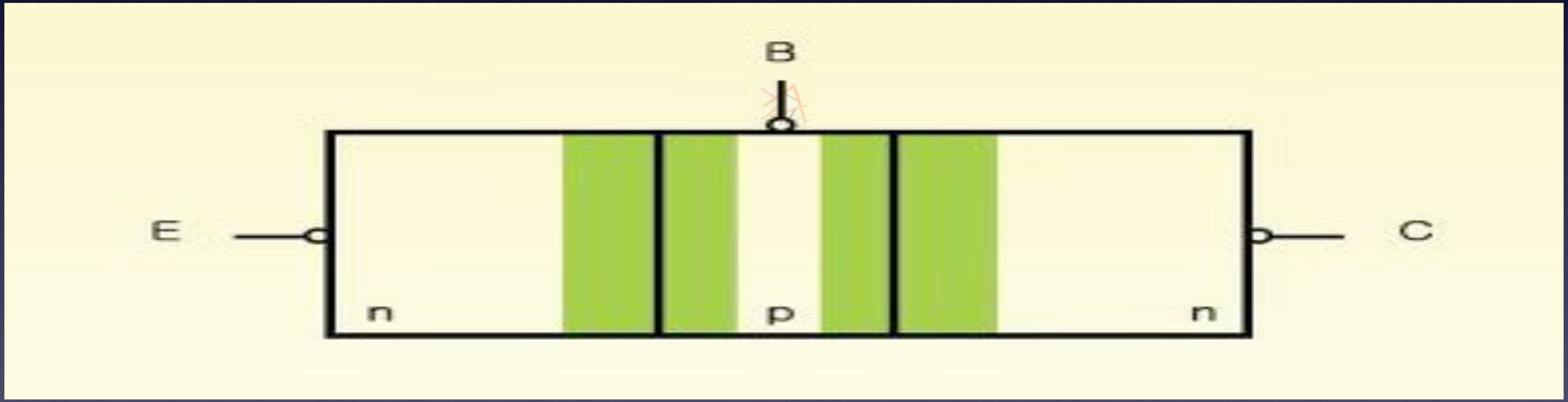
Elements

- Diode, Transistor
- By putting N-type and P-type Semiconductor together, they form a Diode(P | d | N)
- When 3 semiconductors are put together in forms of NPN or PNP, they form a Transistor (Bipolar Junction Transistor)
- MOSFET (Metal Oxide Semiconductor Field Effect Transistor) has a different structure

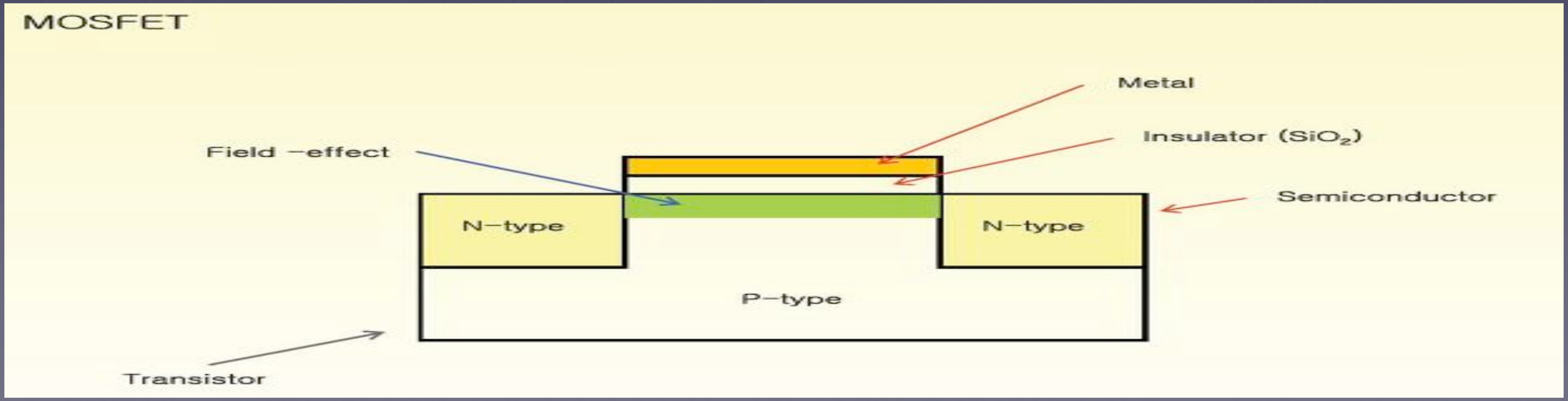
Elements



Na⁻
h⁺
Nd⁺
e⁻
p−type
n−type
neutral region
depletion region
neutral region



B
E
C
n
p
n



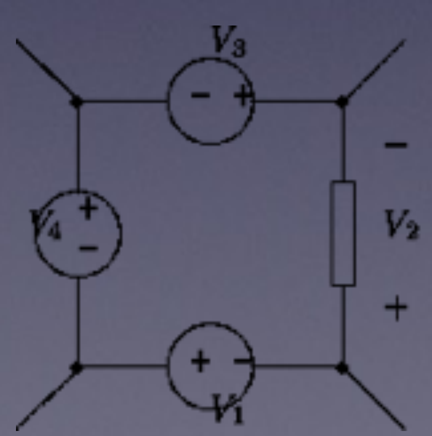
MOSFET
Metal
Insulator (SiO_2)
Field −effect
Semiconductor
N−type
N−type
P−type
Transistor

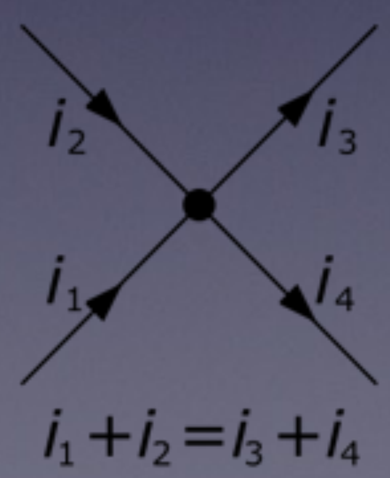
Elements

FET	BJT
낮은 전압이득	높은 전압이득
높은 전류이득	낮은 전류이득
아주 높은 입력 임피던스	낮은 입력 임피던스
높은 출력 임피던스	낮은 출력 임피던스
노이즈를 적게 발생	노이즈를 중간쯤 발생
스위칭 속도가 빠름	스위칭 속도가 중간
정전기에 약함	정전기에 강함
Gate로 0이 들어오면 ON 또는 OFF됨	Base로 0이 들어오면 OFF됨
전압에 의해 제어됨	전류에 의해서 제어됨
BJT 보다 가격이 비싸다	가격이 싸다
바이어스 설정이 어렵다	바이어스 설정이 쉽다.

Circuit Analysis

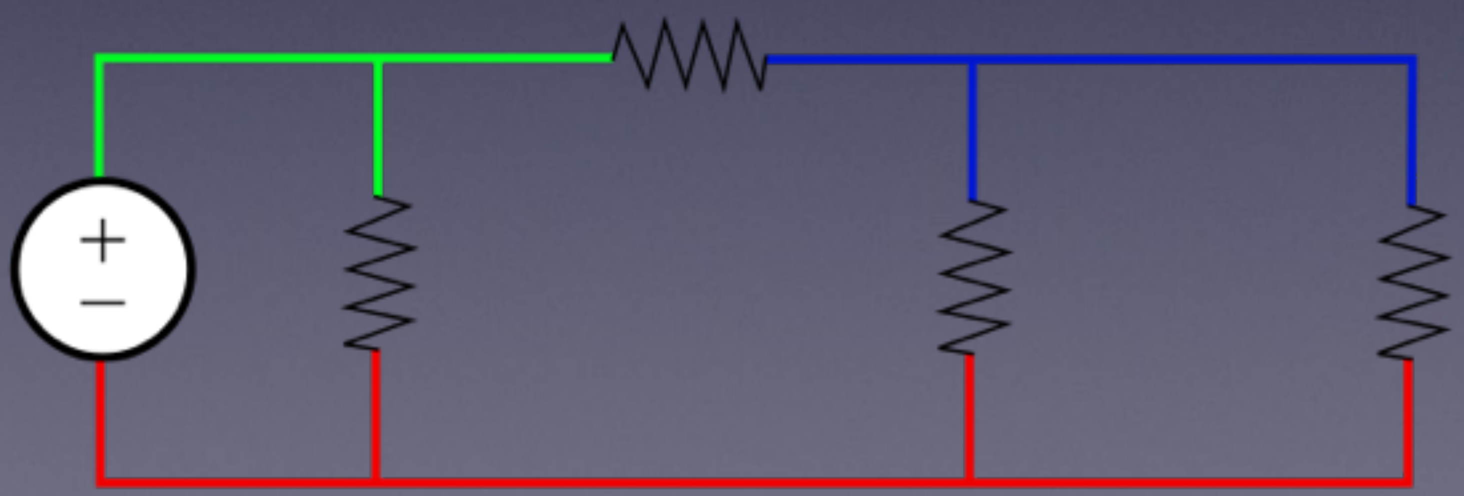
- Basic Circuit Formula
- Ohm's Law : V = IR
- Kirchhoff's Voltage/Current Law





Circuit Analysis

- Node : 두 개 이상의 회로 요소가 만나는 지점
- Mesh : 회로에서의 하나의 폐루프
- Circuit Analysis : Node Voltage, Mesh Current, Supernode, Thevenin&Norton's Equivalent Circuit



Circuit Analysis

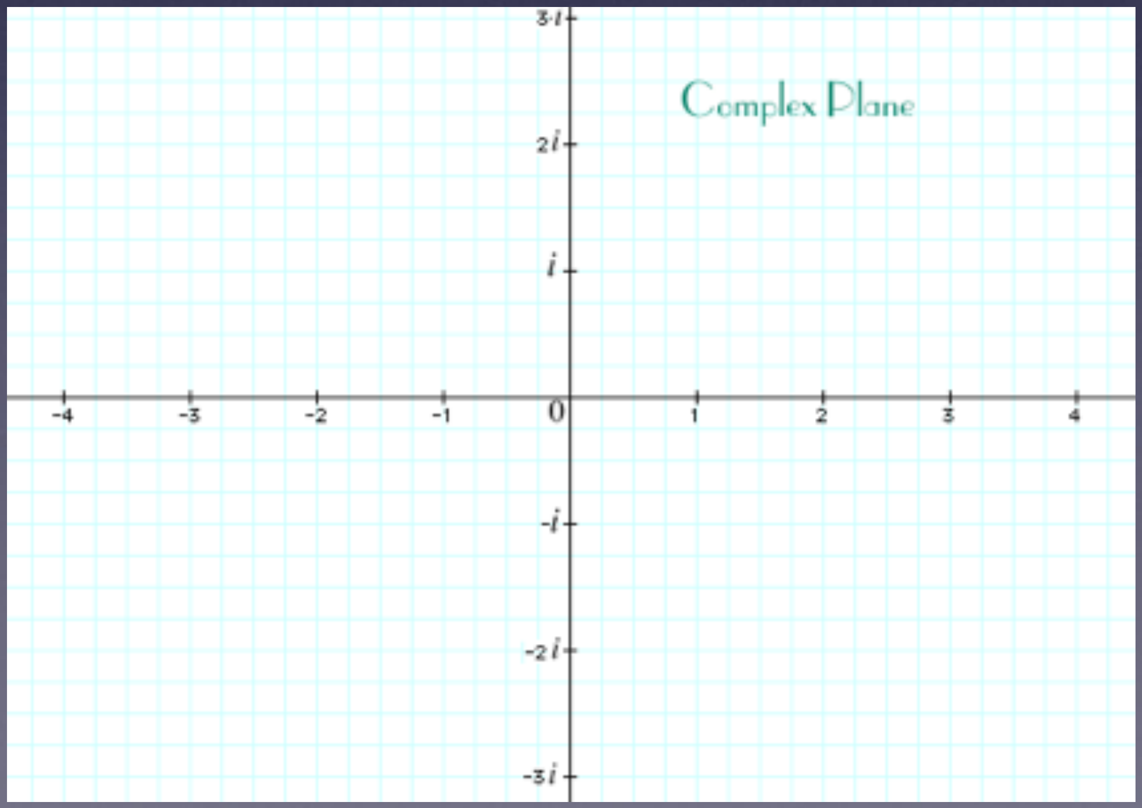
- In RLC Series Circuit, Let V=VCos(wt+θ), i = iCos(wt+θ) (w = 2 · pi · f)
- In Inductor , V= L · d(iCos(wt+θ))/dt = −wLisin(wt+θ) = −wLicos(wt+θ−90)
- By Euler Formula($e^{\pm j\theta}=cos\theta \pm jsin\theta$)
- $V=-wLie^{j(\theta-90)}=jwLie^{j\theta}$ (∵ cos90 = 0, sin90=1)
- Thus, **V**= jwL · **i** (ie^jθ = **i)**

Circuit Analysis

- In Capacitor i = C · d(Vcos(wt+θ))/dt = −C · wVsin(wt+θ) =−wCVcos(wt+θ−90)
- By Euler Formular, $i=-wCVe^{j(\theta-90)}=jwCVe^{j\theta}$
- Thus, $V=\frac{1}{jwC}i$

Circuit Analysis

- For each Elements
- Resistor : V=Ri
- Inductor : V= (jwL) ▪ i
- Capacitor : V = (1/jwC) ▪ i
- Why Complex Number? : Phase!



Circuit Analysis

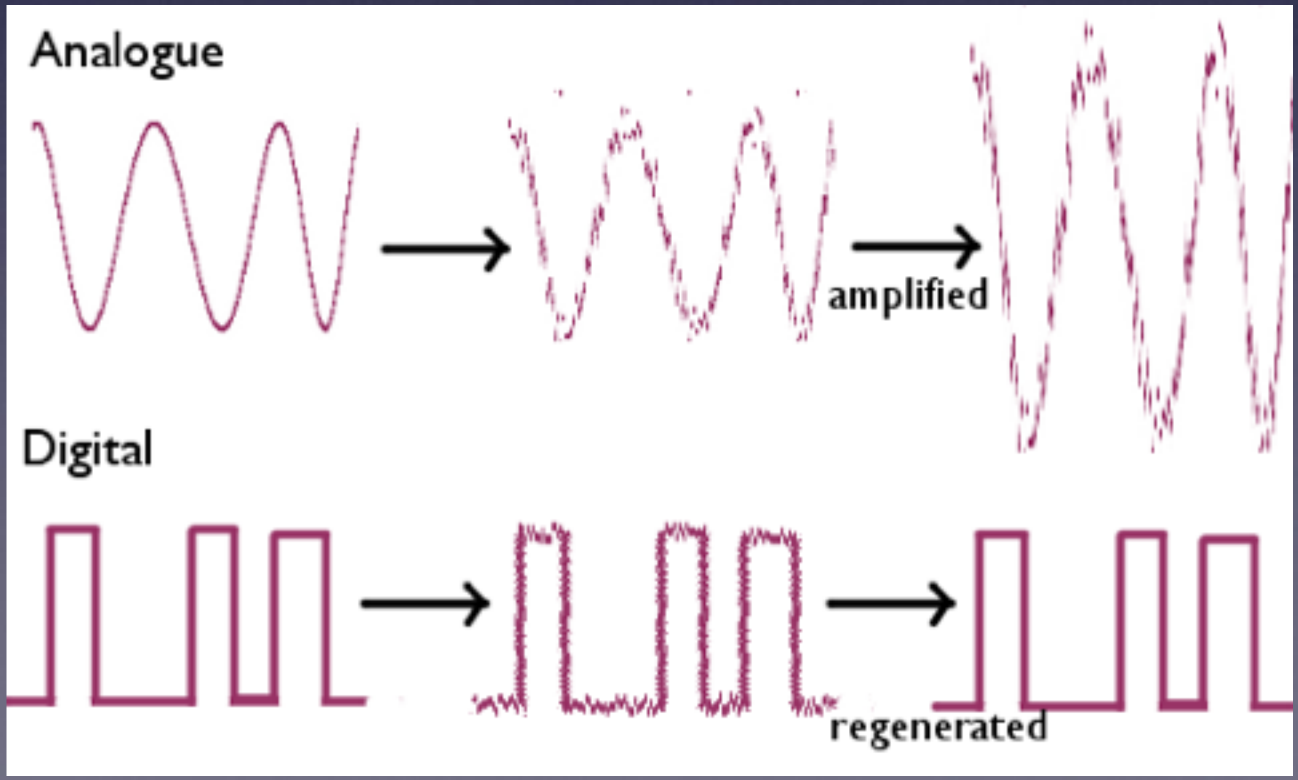
	Impedence(Z)	Reactance(X)
Resistor	R	R
Inductor	jwL	wL
Capacitor	1/jwC	1/wC

Circuit Analysis

- 기타 회로해석 기법
- Laplace Transformation(s-domain Circuit Analysis)
- Fourier Transformation(f-domain Circuit Analysis)
- s-domain -> Transfer function for Circuit Stability
- f-domain -> Frequency Response

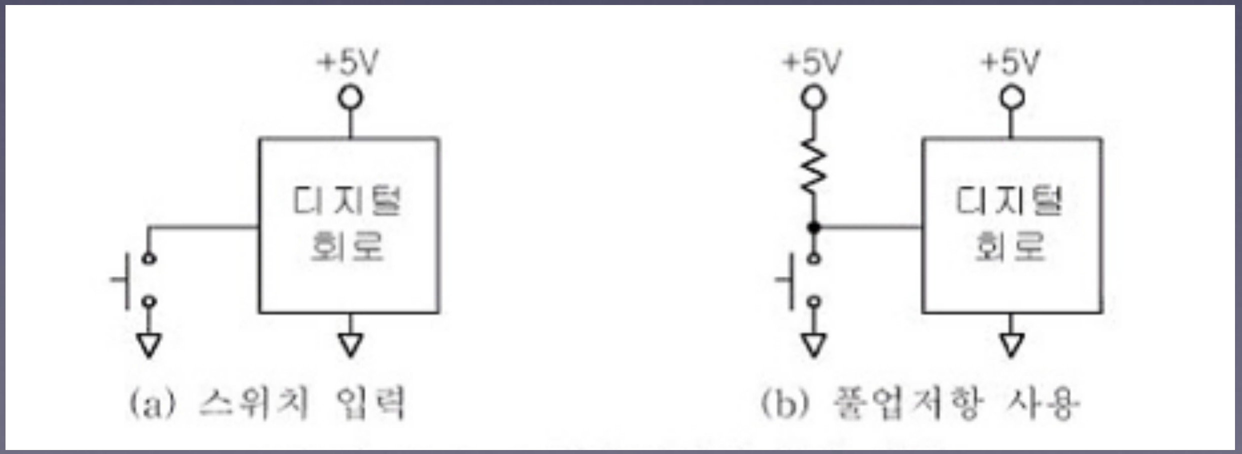
Analog VS Digital

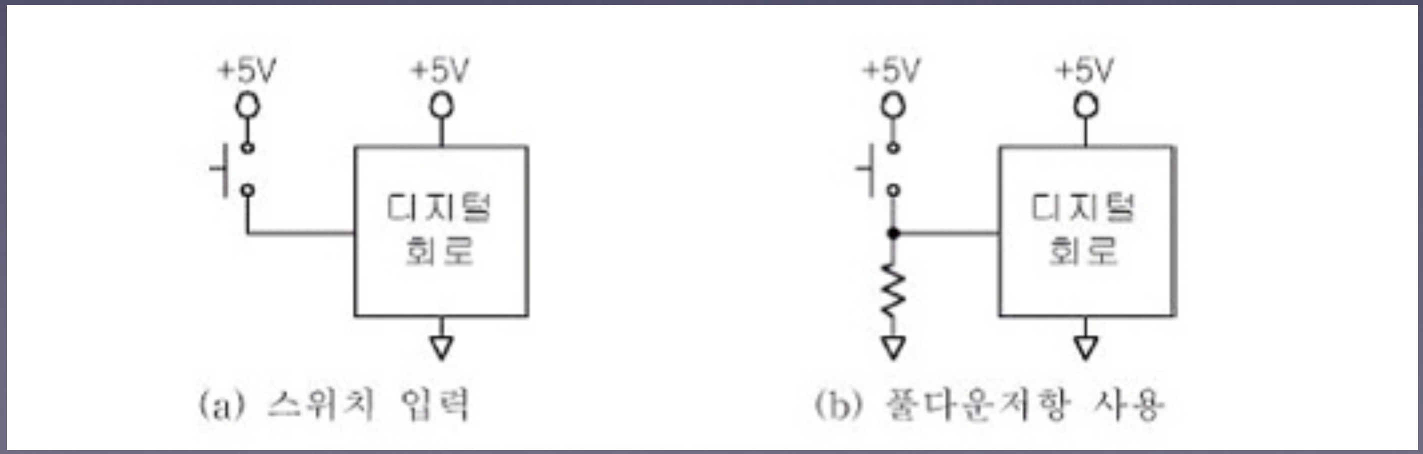
- Analog : Continuous
- Digital : Discontinuous
- Main difference : Noise Immunity



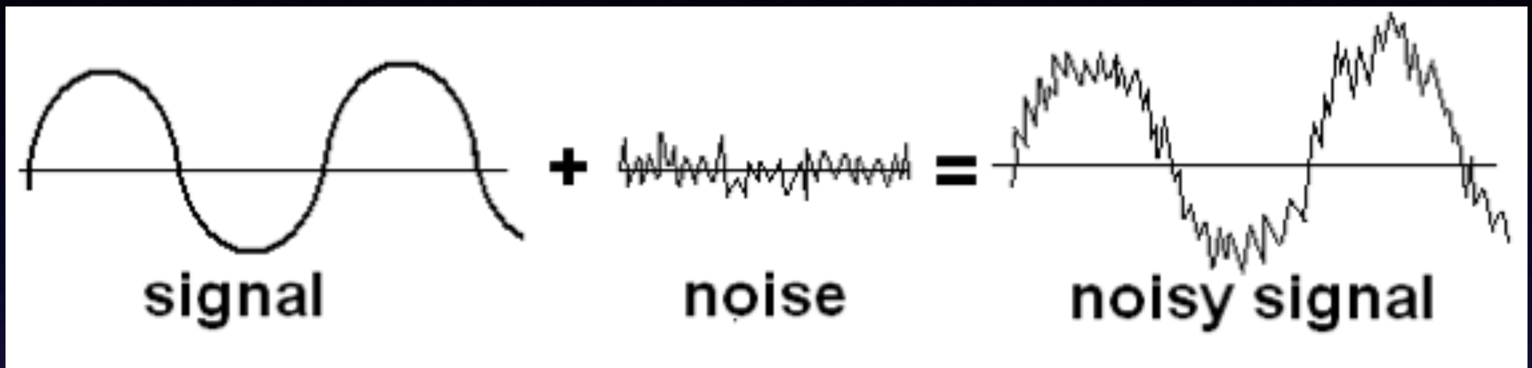
Application Of Element

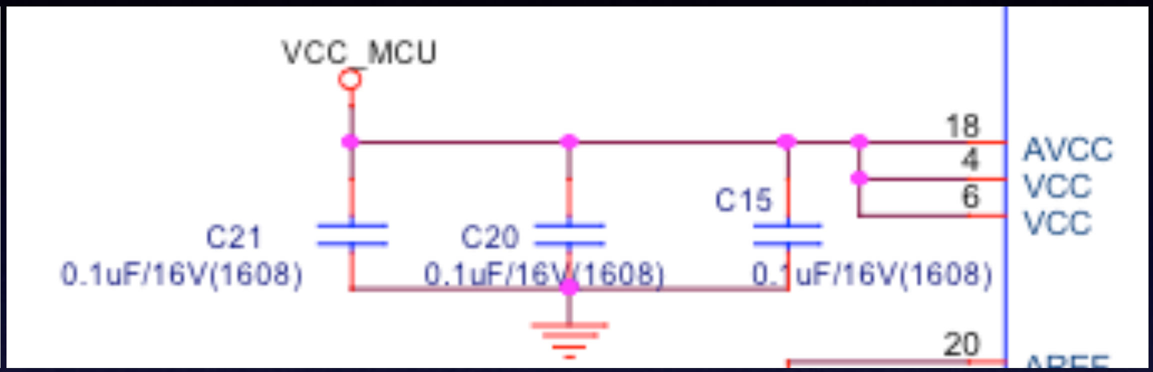
- Pull Up/Down Resistor
- Current Flow to Low Resistor
- Digital Signal has two condition : High / Low
- With Pull up or Pull down Resistor, We can easily define Digital Signal Condition





Application Of Element





- Bypass Capacitor
- In Capacitor, Xc is 1/wC
- if frequency goes high -> Xc goes to zero
- All high frequency signals easily pass Capacitor

Application of Element

- Bead(Not Inductor, But Very Similar)
- Digital Signal has a very high frequency when compared to Analog Signal
- In Inductor, Reactance is wL
- High frequency cannot pass Inductor(Reactance goes to infinity)
- Easily Separate Analog and Digital Signal

Application of Element

	Reactance	High Frequency	Low Frequency
Resistor	R	-	-
Capacitor	1/wC	Short	Open
Inductor	wL	Open	Short

Open : Signals cannot flow / Short : Flow with no obstacle

Application of Element

- TTL(Transistor-Transistor Logic)
- CMOS (Complementary Metal Oxide Semiconductor)
- 논리 게이트(AND, OR, NOT, NAND, NOR) 제작에 응용
- TTL 동작 전압 : 5V, 출력전류 20mA(Typ.)
- CMOS 동작 전압 : 3.3V, 출력전류 10mA(Typ.)
- BJT Collector Current : $I_c = AJ_s[e^{V_{BE}/V_t} - 1]$
- MOSFET Drain Current : $I_D = \mu C_{ox} \frac{W}{L} (V_{GS} - V_T) V_{DS}$

Block Diagram

- H/W System has a typical structure

Block Diagram

- Input : Sensor, Switch, MIC, etc
- Control : MCU, DSP, MPU
- Output : LCD, Speaker, LED, etc
- Determine How to Connect/Control each device

Design H/W System

- Datasheet : All device/element have datasheet
- Datasheet has all information about its device/element
- Absolute Maximum Ratings, DC/AC Characteristics, Pin Assignment, Resister Map, Reference Design
- Design H/W System <=> 데이터시트 분석

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