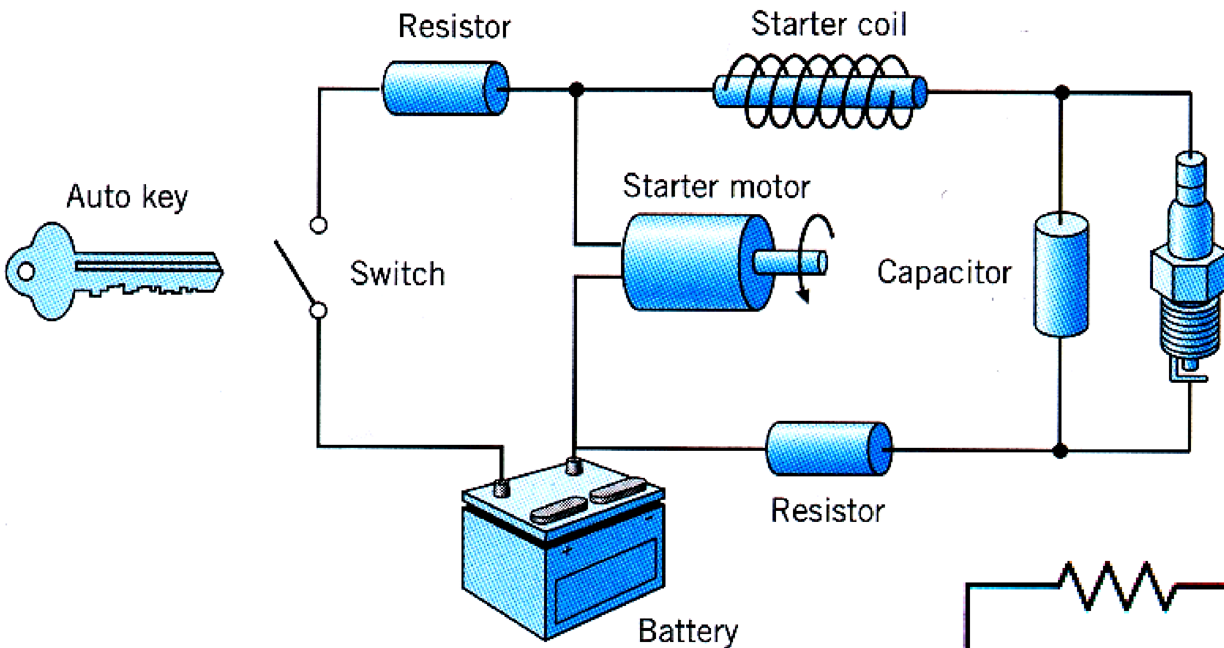
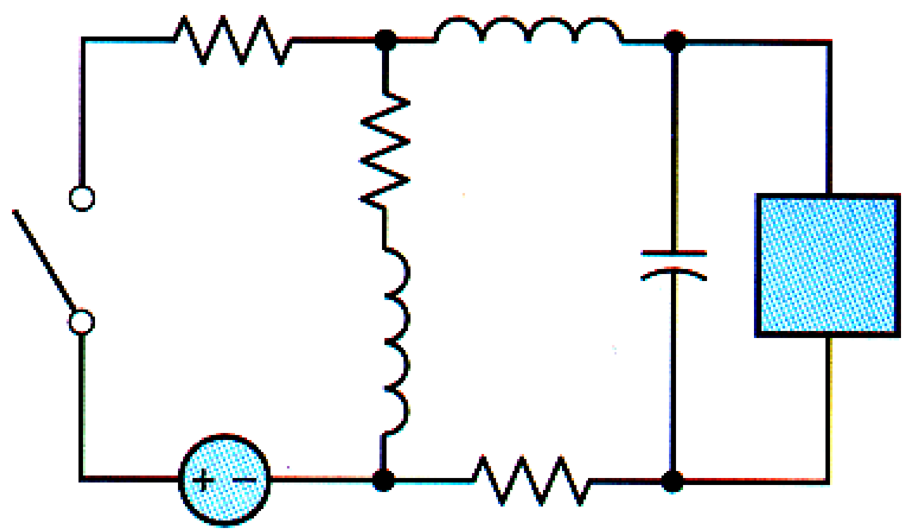
자동차 시동 모델의 회로화



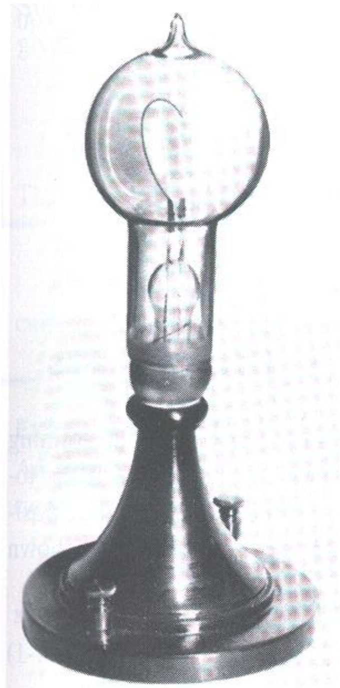
(a) An automobile ignition circuit.



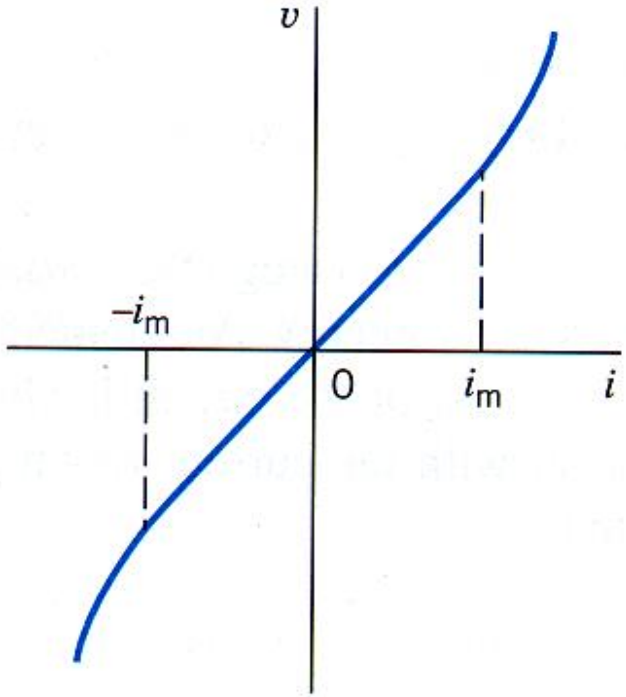
(b) Model of the ignition circuit for starting a car.

Richard C. Dorf and James A. Svoboda, Introduction to Electric Circuits, 5th edition, John Wiley and Sons, 2001

회로 이론의 선형 모델링



(a) An incandescent lamp.



(b) Voltage-current relationship for an incandescent lamp. The lamp is linear within the range $-i_m < i < i_m$.

Richard C. Dorf and James A. Svoboda, Introduction to Electric Circuits, 5th edition, John Wiley and Sons, 2001

- 선형 소자는 **superposition**과 **homogeneity**를 만족한다**.**

Superposition : i_1 의 응답이 v_1 , i_2 의 응답이 v_2 이면 $i_1 + i_2$의 응답은 $v_1 + v_2$.

Homogeneity : i 의 응답이 v 이면 ki 의 응답은 kv.

회로 이론의 가정

- 회로 이론은 전자기학의 일부.
- 가정을 통해 이론을 단순화.
- 회로 이론을 적용할 때에는 가정을 만족하는 지를 따져야 한다.

가정

(1) 전파(傳播) 효과가 무시될 만큼 계가 작다.

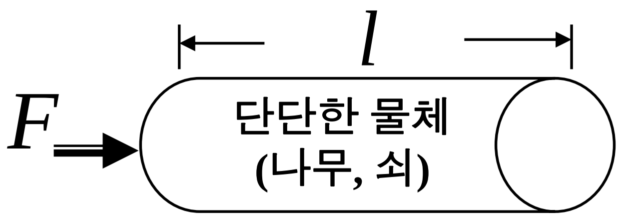
즉, 계가 순간적으로, 동시적으로 변화한다 → 집중정수 계.

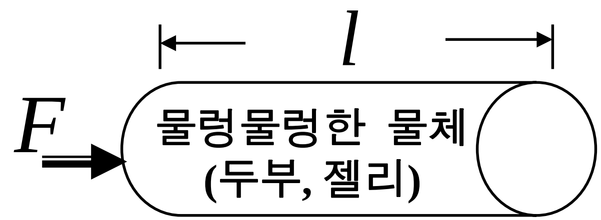
(2) 계에 알짜 전하는 없다.

(3) 계의 구성 부품 간에 자기적인 결합은 없다.

집중정수 계와 분포정수 계

- 가정 (1)은 외부에서 인가하는 물리량 (힘, 전류, 전압)이 동시에 계의 전부에 작용한다는 것을 의미.





- 물질에는 파동의 전파 속도가 있음.

$$v_p = \sqrt{E/\rho}$$

- 물체의 반대편에 신호가 전파되는 데 걸리는 시간 (지연 시간)은

$\Delta t = l/v \quad (s)$ 이다.

- 왼쪽의 단단한 물체는 전파속도가 빠르므로 계의 모든 부분이 동시적으로 외부 물리량을 느낀다.
- 오른쪽의 물렁물렁한 물체는 전파 속도가 느리므로 계의 모든 부분이 같은 시간에 같은 물리량을 갖지 못한다. 따라서, 분포 정수계의 문제로 다루어야 한다.

집중정수 계로 판단하는 기준

– 지연 시간의 외부에서 가해 주는 물리량의 주기보다 매우 작아야 한다.

$$\Delta t / T \ll 1$$

이 조건을 만족시키면 집중정수 계로 볼 수 있다.

- 전자계에서 전자파의 진행 속도는 c 이다.

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = 3 \times 10^8 \quad \text{m/s}$$

- 시스템의 특성 길이가 l 이라 하면 지연 시간은 $\Delta t = l/c$ 이 되고,

60 Hz의 상용 전원에 대해서 생각해 보면

$$\frac{\Delta t}{T} = \frac{l / 3 \times 10^8}{1/60} = \frac{l \times 2}{10^7}$$

따라서, l 이 웬만큼 (수천 km) 길지 않으면 집중정수 계로 보아도 무방하다.

– 만약, 주파수가 10^9 Hz이면 어느 정도의 시스템까지 집중정수 계로 볼 것인가?

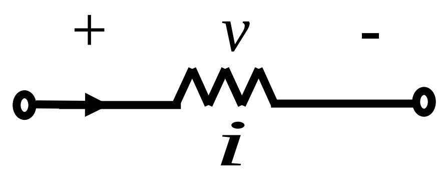
$$\frac{\Delta t}{T} = \frac{l / 3 \times 10^8}{1/10^9} = \frac{l}{0.3} \ll 1$$

0.3 m보다 매우 작아야 한다.

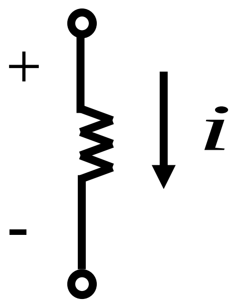
회로소자 -저항

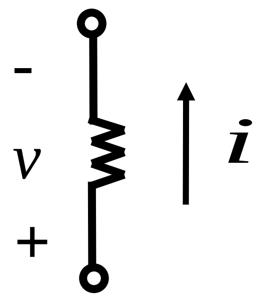
R **: resistance Ω (Ohm)**

$$R = \frac{v}{i}$$

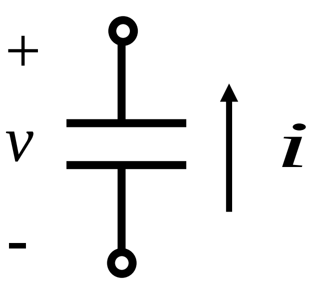


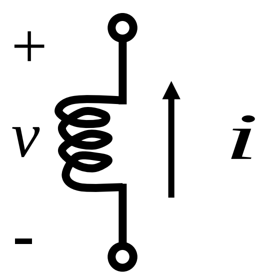
– 저항의 중요특성 : 전압의 부호에 따라 전류의 부호가 바뀜.





- **Inductor** 나 **Capacitor**는 전압의 부호에 따라 전류의 부호가 바뀌지 않음.

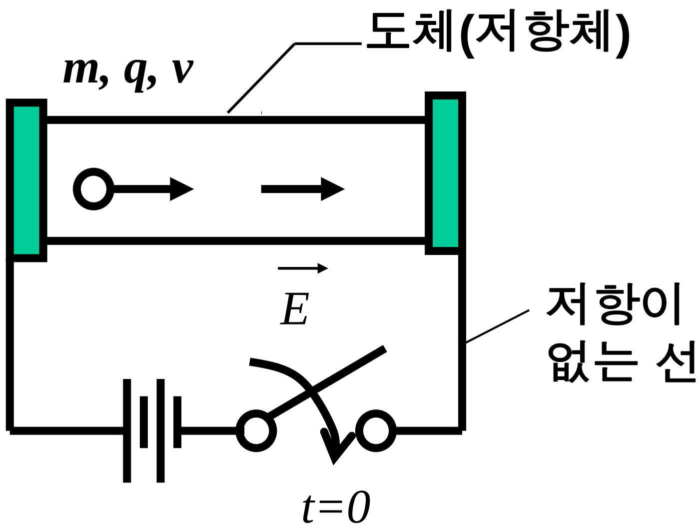




Ohm's Law (I)

- 19세기초 **George Simon Ohm** 이 확립

$\vec{J} = \sigma\vec{E}$ ($\vec{J}$: 전류밀도, σ : 도전율, $\vec{E}$: 전계)



• 전원을 연결해서 강제로 전류를 흘리면 도체(저항체) 내부에 전계가 존재.

• $t = 0$ 일 때 전류를 가하면 도체 내부의 자유전하는 전계에 의해서 가속되고, 방해하는 힘이 없다면 전하는 무한히 가속된다.

•그러나, 도체 내부에는 무수히 많은 전하가 있어서 곧 충돌하게 되며 가속 운동이 방해 받고 일정한 속도의 움직임으로 된다.

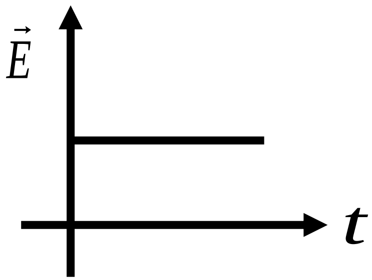
운동 방정식

$$m\frac{d\vec{v}}{dt} = q\vec{E} - m\mu\vec{v}$$

$\vec{v}$: 속도, μ : 충돌 빈도수 (실효 충돌 주파수)

Ohm's Law (II)

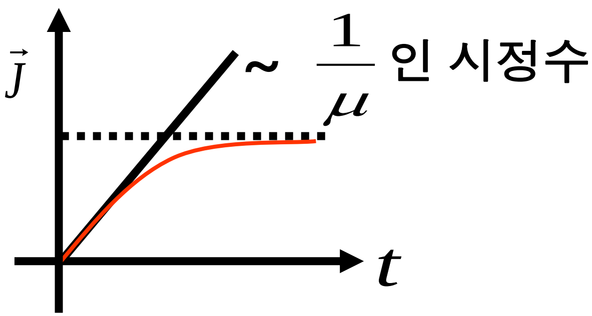
회로의 인덕턴스를 무시하고, 전계를 **step function**으로 가정하자.



$$\frac{d\vec{v}}{dt} + \mu\vec{v} = \frac{q}{m}\vec{E}$$

$$\vec{v}(t) = \frac{q}{m\mu}(1 - e^{-\mu t})\vec{E}$$

전류는 전하의 단위 시간당 흐름이므로



$$\vec{J}(t) = N \cdot q \cdot \vec{v}(t) = \frac{Nq^2}{m\mu}(1 - e^{-\mu t})\vec{E}$$

(N : 개수, q : 전하량, $\vec{v}(t)$: 속도)

$$t \to \infty \qquad \vec{J} = \frac{Nq^2}{m\mu}\vec{E} = \sigma\vec{E}$$

$\left(\sigma = \frac{Nq^2}{m\mu} \right.$,도전율 **S/m** $\left. \right)$

- **t = 0** 근처에서는 **$1/\mu$** 인 시정수로 전류가 증가하고, 충분한 시간이 흐른 후 결정.
- 구리의 경우, $\mu = 10^{14}\,\mathrm{Hz}$ 이므로, 시정수는 **10^{-14}** 초이다.
- 따라서, 과도항 $(e^{-\mu t})$ 이 무시되며, **Ohm**의 법칙이 성립.

저항율

300 K 에서의 저항율 (Ωm)

Conductors		
	Aluminum	2.73×10^{-8}
	Carbon (amorphous)	3.50×10^{-5}
	Copper	1.72×10^{-8}
	Gold	2.27×10^{-8}
	Nichrome	1.12×10^{-6}
	Silver	1.63×10^{-8}
	Tungsten	5.44×10^{-8}
Semiconductors		
	Silicon (device grade) depends on impurity concentration	10^{-5} *to* 1
Insulators		
	Fused quartz	$>10^{21}$
	Glass (typical)	1×10^{12}
	Teflon	1×10^{19}

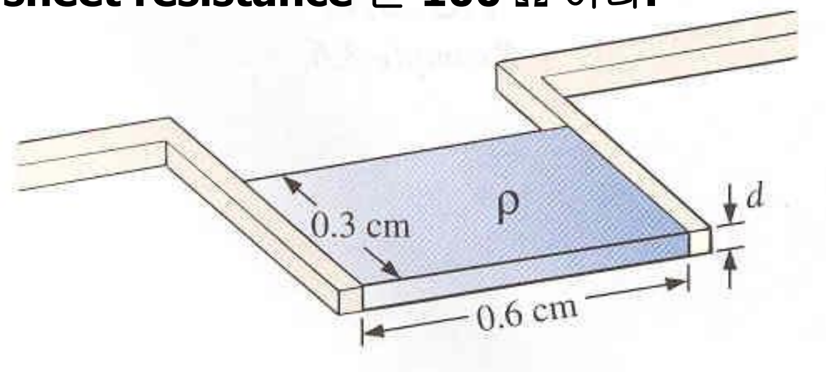
Sheet Resistance

- **Sheet resistance**

  $R_s = \rho/d \qquad (\Omega)$

- 그림과 같은 **thin film resistor**의 저항을 구하라.

  여기서**, sheet resistance** 은 **100** Ω 이다**.**



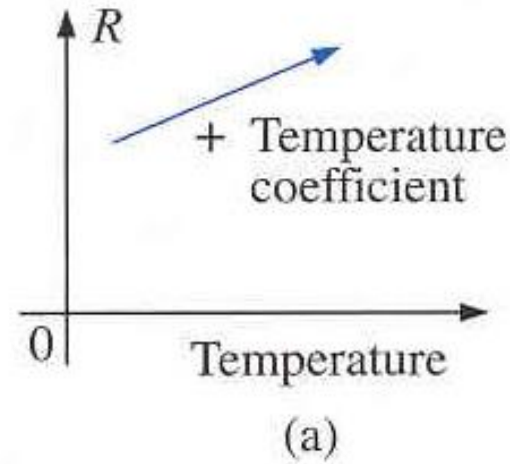
Thin film resistor

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 66, Figure 3.12

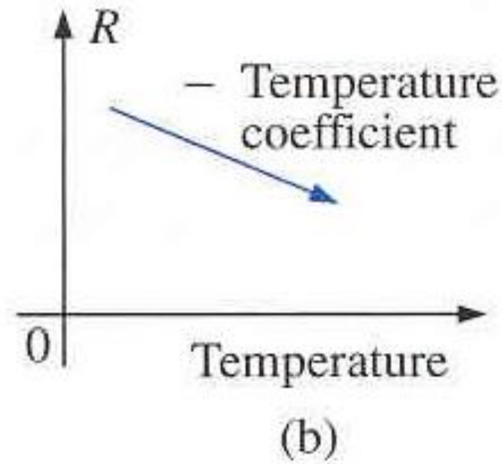
$$R = \rho\frac{l}{A} = \rho\frac{l}{dw} = \frac{\rho}{d}\frac{l}{w} = R_s\frac{l}{w}$$

Temperature Effects

- **Conductors**
  - Thermal energy increases the intensity of the random motion of the particles.
  - Positive temperature coefficient.
- **Semiconductors**
  - An increase in temperature results in an increase in the number of free carriers.
  - Negative temperature coefficient.
- **Insulators**
  - Positive temperature coefficient.



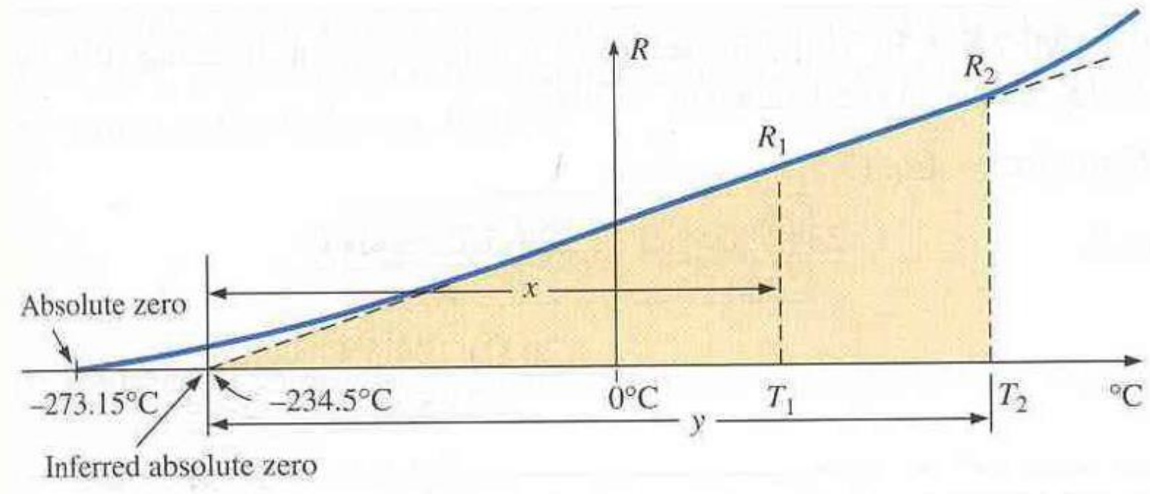
(a) Positive temperature coefficient-conductors;



(b) negative temperature coefficient-semiconductors.

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 68, Figure 3.13

Inferred Absolute Temperature



Effect of temperature on the resistance of copper.

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 69, Figure 3.14

Inferred absolute temperatures(T_i).

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 69, Table 3.5

Material	°C
Silver	−243
Copper	−234.5
Gold	−274
Aluminum	−236
Tungsten	−204
Nickel	−147
Iron	−162
Nichrome	−2,250
Constantan	−125,000

$$\frac{x}{R_1} = \frac{y}{R_2} \Rightarrow \frac{234.5 + T_1}{R_1} = \frac{234.5 + T_2}{R_2}$$

- **-234.5 °C : inferred absolute temperature of copper.**

$$\boxed{\frac{|T_i| + T_1}{R_1} = \frac{|T_i| + T_2}{R_2}}$$

Temperature Coefficients of Resistance

- α_{20} : **temperature coefficient of resistance at a temperature of 20 °C**

$$\alpha_{20} = \frac{1}{|T_i| + 20\ ^0\mathrm{C}} \qquad (\Omega/\ ^0\mathrm{C}/\Omega)$$

$$R_1 = R_{20}\left[1 + \alpha_{20}(T_1 - 20\ ^0\mathrm{C})\right]$$

- R_{20} : **resistance of the sample at 20 °C.**
- R_1 : **resistance at a temperature T_1.**

- **PPM/°C**

$$\Delta R = \frac{R_{\text{nominal}}}{10^6}(\mathrm{PPM})(\Delta T)$$

- $R_{nominal}$: **resistance at room temperature.**
- ΔT : **the change in temperature from the reference level of 20 °C.**

Temperature coefficient of resistance for various conductors at 20°C.

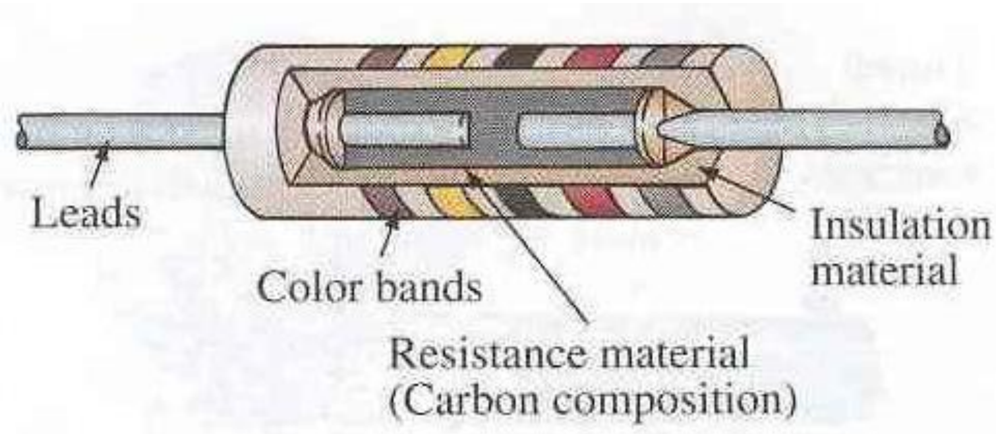
Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 70, Table 3.6

Material	Temperature Coefficient (α_{20})
Silver	0.0038
Copper	0.00393
Gold	0.0034
Aluminum	0.00391
Tungsten	0.005
Nickel	0.006
Iron	0.0055
Constantan	0.000008
Nichrome	0.00044

Types of Resistors

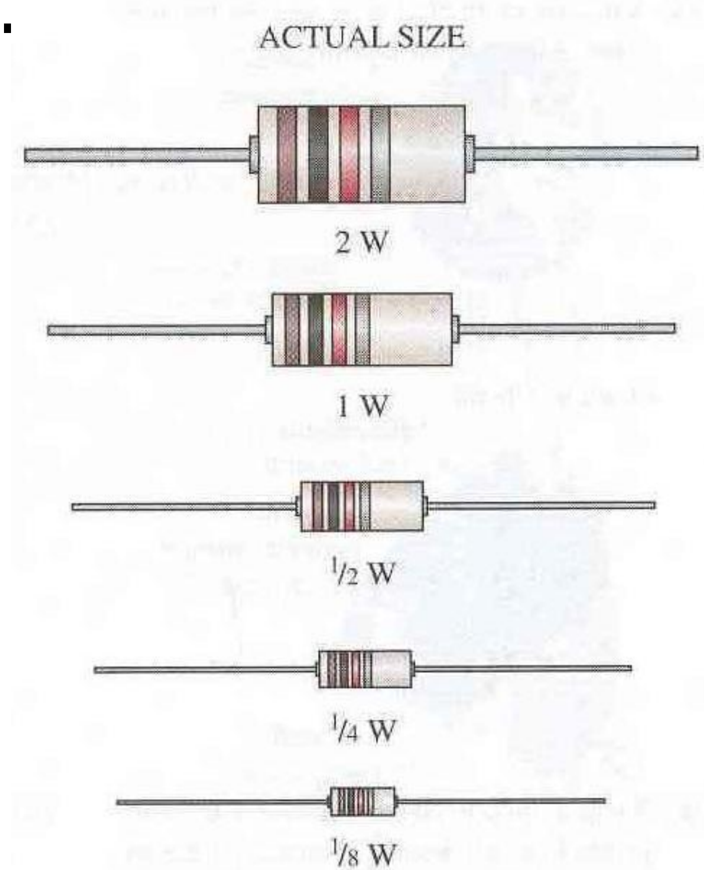
Fixed resistor 와 variable resistor 가 있다.

- ## Fixed Resistors
  - **Low-wattage.**
  - **Molded carbon composition resistor.**



Fixed composition resistor.

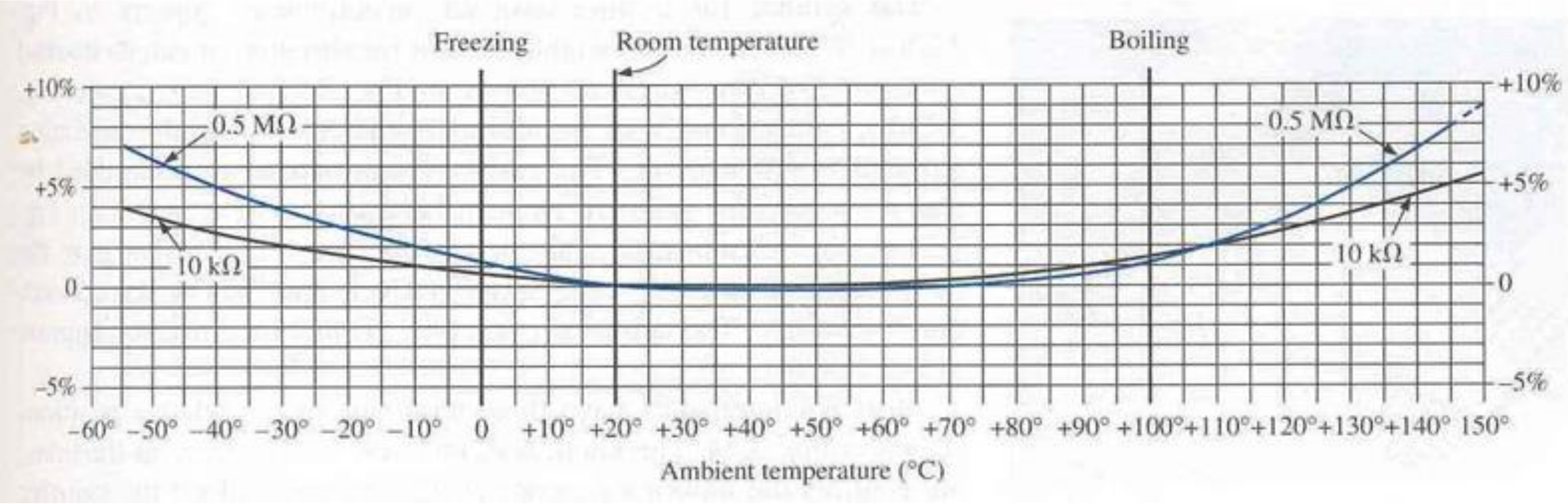
Robert L. Boylestad, Introductory Circuit Analysis, 10th edition,
Prentice Hall, 2002, p. 75, Figure 3.17



Fixed composition resistors of different wattage ratings.

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition,
Prentice Hall, 2002, p. 75, Figure 3.18

Temperature Effect

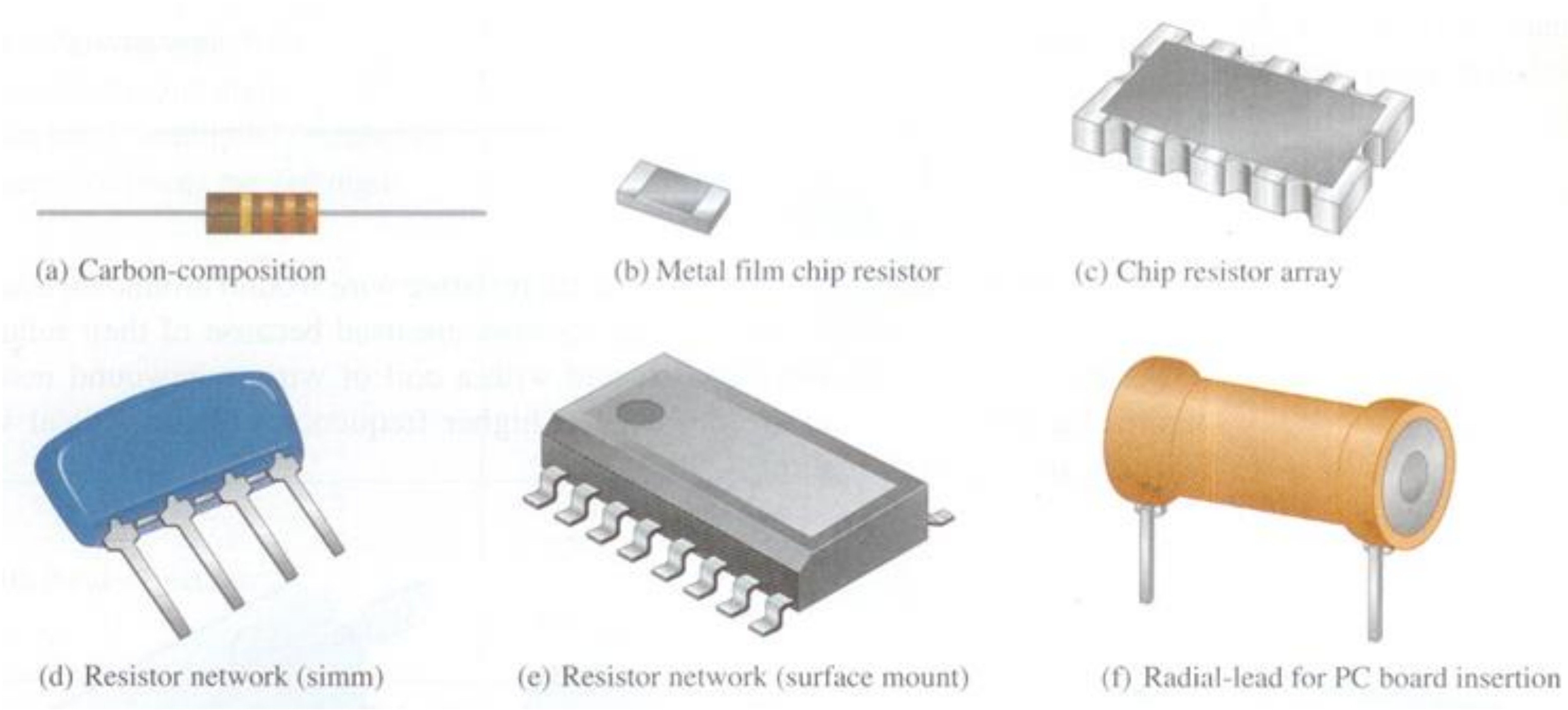


Curves showing percentage temporary resistance changes from +20°C values.

(Courtesy of Allen-Bradley Co.)

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 75, Figure 3.19

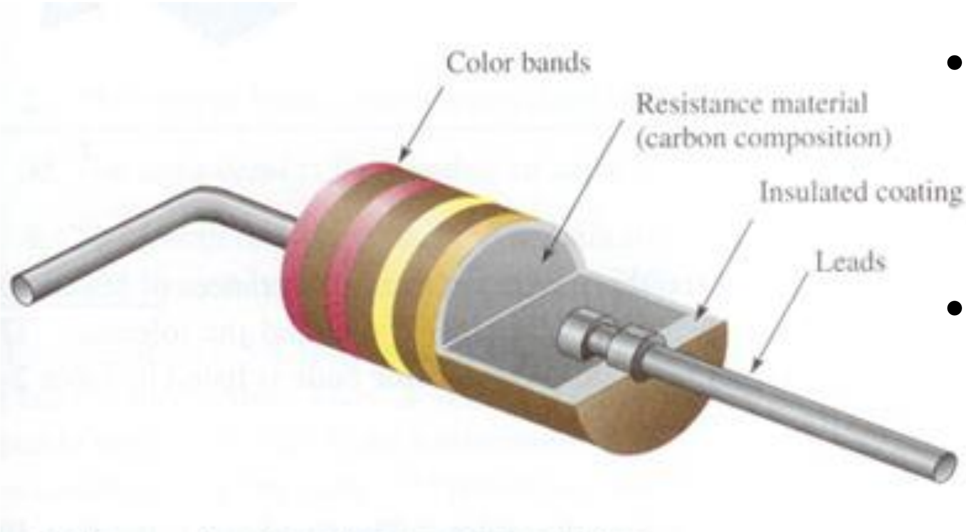
Fixed Resistors (I)



Typical fixed resistors

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 39, Figure 2.24

Fixed Resistors (II)



(a) Cutaway view of a carbon-composition resistor

- One common fixed resistor is the carbon-composition type (mixture of finely ground carbon, insulating filler, and a resin binder).
- The ratio of carbon to insulating filler sets the resistance value.

- Surface mount technology (SMT) components.
- Very small size for compact assemblies.

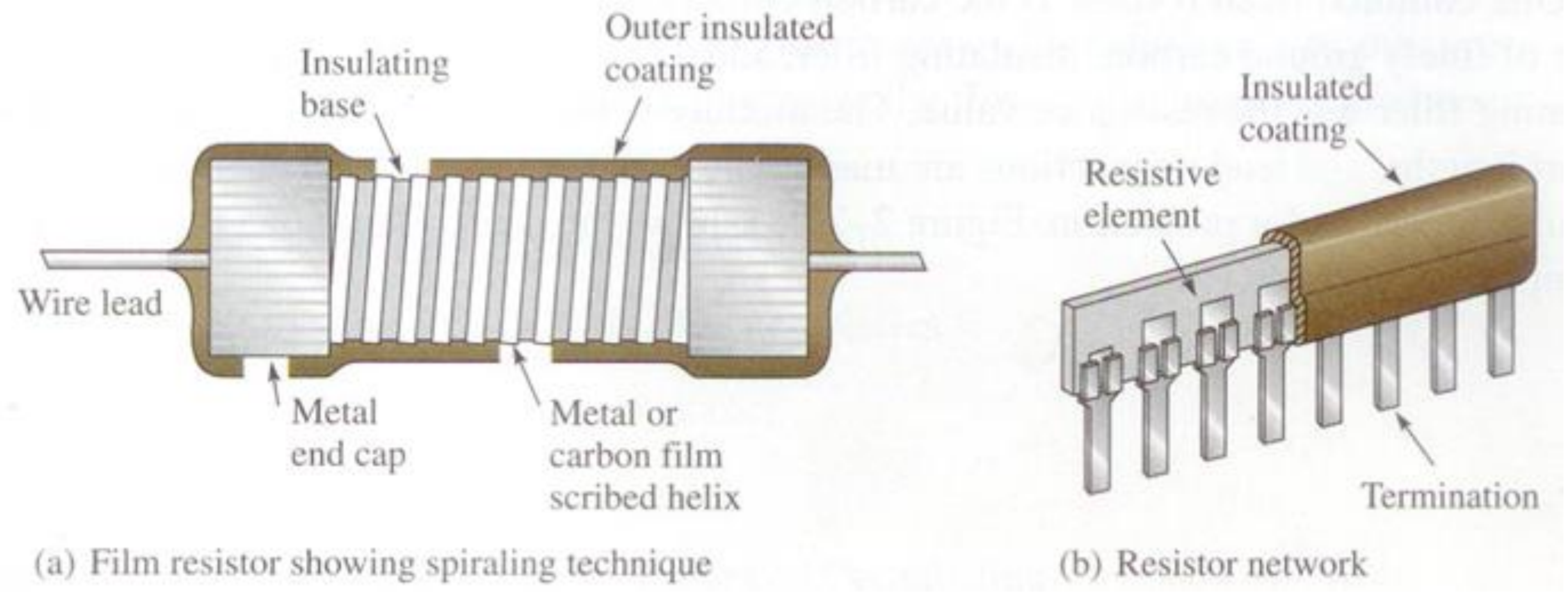
(b) Cutaway view of a tiny chip resistor

Two types of fixed resistors

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 39, Figure 2.25

Fixed Resistors – Film Resistors

- A several material is deposited evenly onto a high-grade ceramic rod.
- The resistive film is carbon film or nickel-chromium (metal film).
- The desired resistance value is obtained by removing part of the resistive material in a helical pattern along the rod.
- Very close tolerance can be achieved.



Construction views of typical film resistors

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 40, Figure 2.26

Fixed Resistors – Wirewound Resistors

- **Wirewound resistors are constructed with resistive wire wound around an insulating rod and then sealed.**
- **High power rating.**
- **Since they are constructed with a coil of wire, wirewound resistors have significant inductance.**
- **They are not used at higher frequencies.**

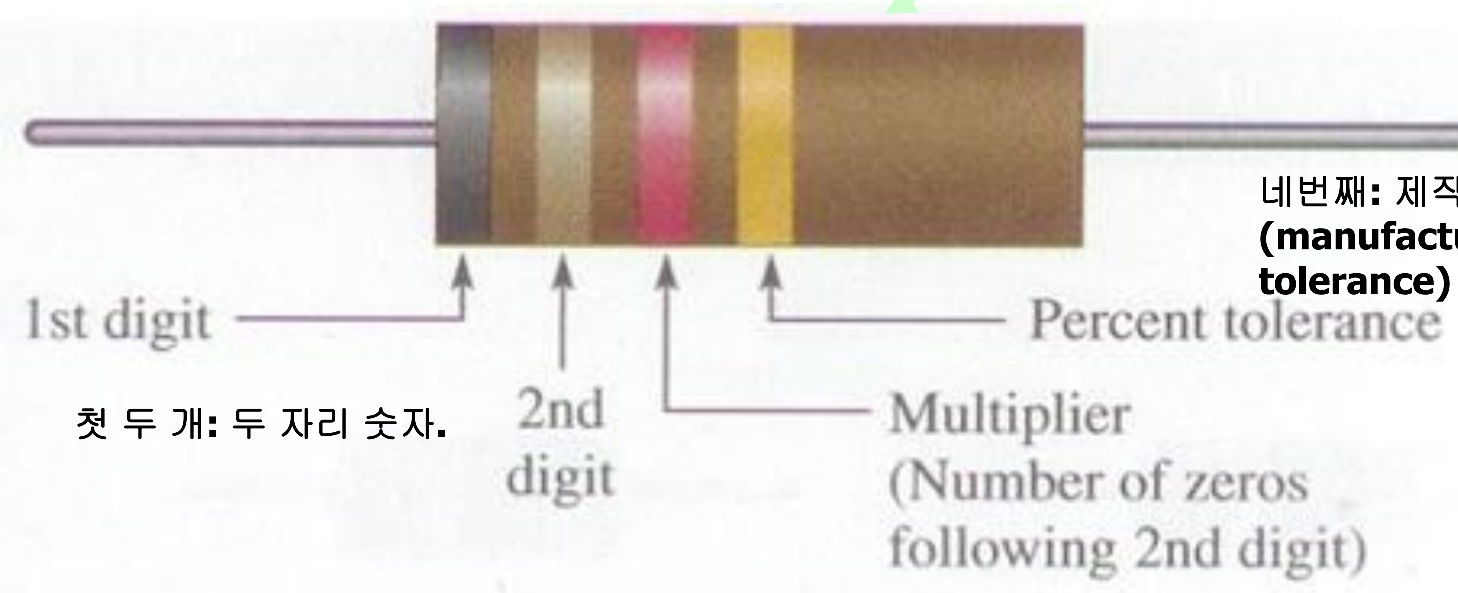
Typical wirewound power resistors

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 40, Figure 2.27

Color Coding (4-Band Resistor)

- 숫자를 쓰기에 작은 저항에는 색으로 저항 값을 나타낸다.
- **Tolerance 5 %, 10 %, 20 %** 의 저항은 **4 band** 로 나타낸다.
- 색 띠의 위치는 저항을 옆으로 놓고 보면 비 대칭적이다.
- 저항의 끝에서 가까운 쪽부터 읽는다.
- 띠의 의미

다섯번째: **1,000**시간 사용시 오동작할 확률**(extra band).**



네번째: 제작자의 허용오차 **(manufacturer's tolerance)**

첫 두 개: 두 자리 숫자.

세번째: **10**의 승수 **(power-of-ten)**

Color-code bands on a 4-band resistor.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 41, Figure 2.28

Color Code (4-Band Resistor)

4-band resistor color code.

	Digit	Color
Resistance value, first three bands: First band—1st digit; Second band—2nd digit; *Third band—multiplier (number of zeros following the 2nd digit)	0	Black
	1	Brown
	2	Red
	3	Orange
	4	Yellow
	5	Green
	6	Blue
	7	Violet
	8	Gray
	9	White
Fourth band—tolerance	±5%	Gold
	±10%	Silver

* For resistance values less than 10 Ω, the third band is either gold or silver. Gold is for a multiplier of 0.1 and silver is for a multiplier of 0.01.

흑 : 0
갈 : 1
적 : 2
등 : 3
황 : 4
록 : 5
청 : 6
자 : 7
회 : 8
백 : 9

- 세번째 색이 금색이거나 은색이면 **0.1** 또는 **0.01** 를 곱한다.
- 즉, 금색은 **-1** 승, 은색은 **-2** 승을 의미한다.

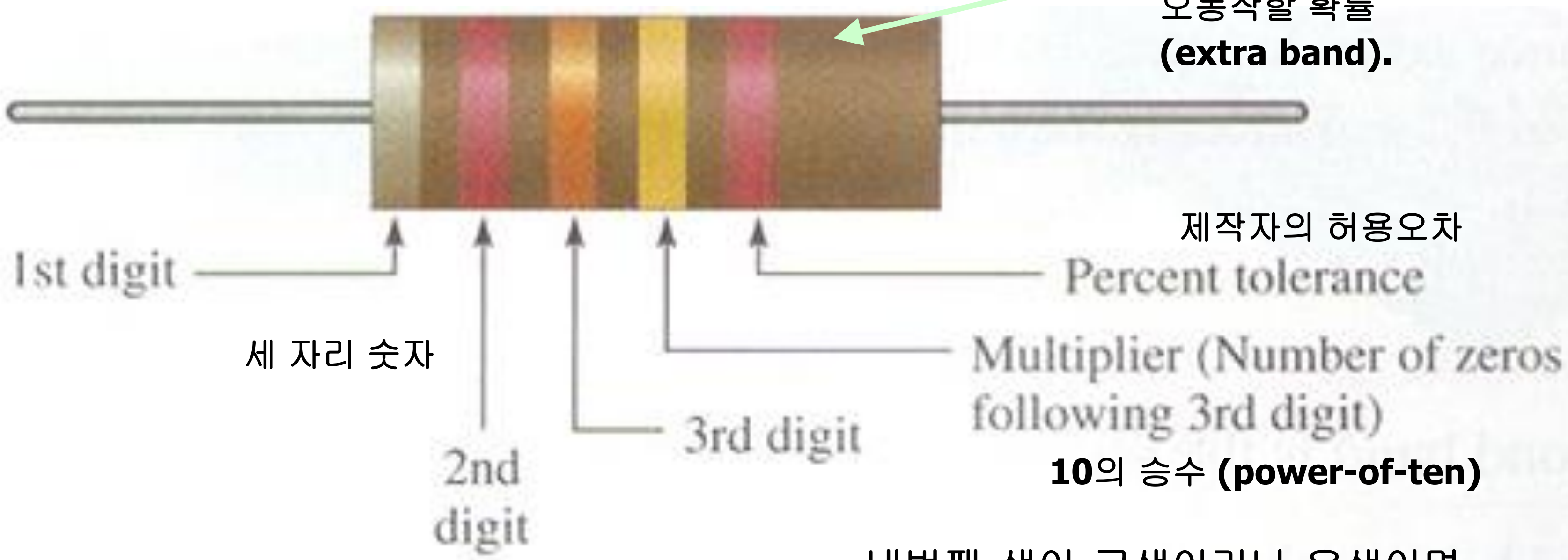
- **Failure during 1000 h of operation**
  Brown : 1.0 %
  Red : 0.1 %
  Orange : 0.01 %
  Yellow : 0.001 %

4 band resistor color code.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 41, Table 2.1

Color Coding (5-Band Resistor)

- **Tolerance 2 %, 1 % or less.**



Color-code bands on a 5-band resistor.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 42, Figure 2.30

- 네번째 색이 금색이거나 은색이면 **0.1** 또는 **0.01**를 곱한다.
- 다섯번째 – **tolerance**

± 2 % : Red

± 1 % : Brown

± 0.5 % : Green

± 0.25 % : Blue

± 0.1 % : Violet

Standard Resistors (I)

Standard values of commercially available resistors.

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 80, Table 3.8

Ohms (Ω)					Kilohms (kΩ)		Megohms (MΩ)	
0.10	1.0	10	100	1000	10	100	1.0	10.0
0.11	1.1	11	110	1100	11	110	1.1	11.0
0.12	1.2	12	120	1200	12	120	1.2	12.0
0.13	1.3	13	130	1300	13	130	1.3	13.0
0.15	1.5	15	150	1500	15	150	1.5	15.0
0.16	1.6	16	160	1600	16	160	1.6	16.0
0.18	1.8	18	180	1800	18	180	1.8	18.0
0.20	2.0	20	200	2000	20	200	2.0	20.0
0.22	2.2	22	220	2200	22	220	2.2	22.0
0.24	2.4	24	240	2400	24	240	2.4	
0.27	2.7	27	270	2700	27	270	2.7	
0.30	3.0	30	300	3000	30	300	3.0	
0.33	3.3	33	330	3300	33	330	3.3	
0.36	3.6	36	360	3600	36	360	3.6	
0.39	3.9	39	390	3900	39	390	3.9	
0.43	4.3	43	430	4300	43	430	4.3	
0.47	4.7	47	470	4700	47	470	4.7	
0.51	5.1	51	510	5100	51	510	5.1	
0.56	5.6	56	560	5600	56	560	5.6	
0.62	6.2	62	620	6200	62	620	6.2	
0.68	6.8	68	680	6800	68	680	6.8	
0.75	7.5	75	750	7500	75	750	7.5	
0.82	8.2	82	820	8200	82	820	8.2	
0.91	9.1	91	910	9100	91	910	9.1	

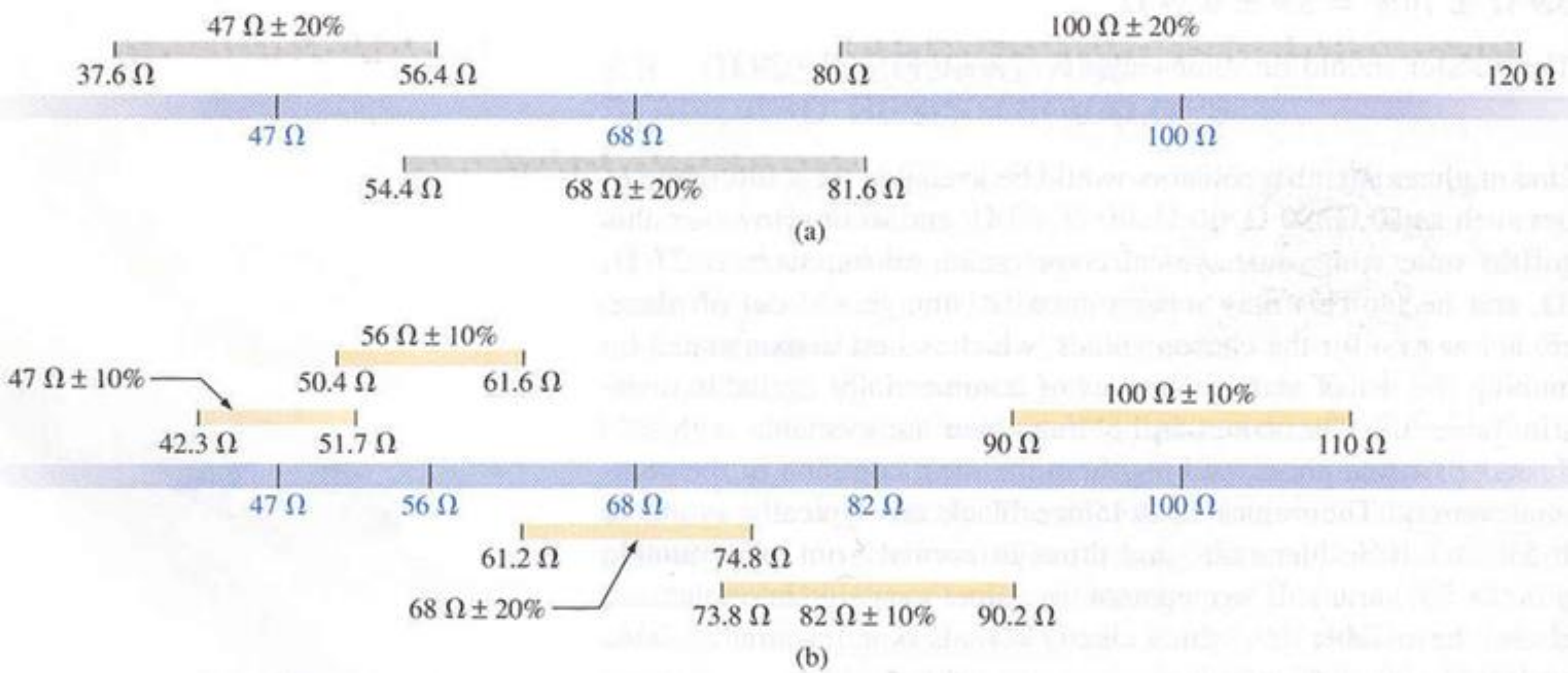
- **10 씩 증가하지 않는 이유?**

Standard values and their tolerances.

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 80, Table 3.9

±5%	±10%	±20%
10	10	10
11		
12	12	
13		
15	15	15
16		
18	18	
20		
22	22	22
24		
27	27	
30		
33	33	33
36		
39	39	
43		
47	47	47
51		
56	56	
62		
68	68	68
75		
82	82	
91		

Standard Resistors (II)



Guaranteeing the full range of resistor values for the given tolerance: (a) 20 %; (b) 10 %.

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 80, Figure 3.29

Resistor Label Codes

- **Numeric Labeling**
  - 첫째, 둘째 자리 수: 숫자
  - 셋째 자리수: 10의 승 수
  - 10 이상의 수를 표시 가능.

123	=>	$12 \times 10^3\ \Omega$
22R	=>	$22 \times 10^0\ \Omega$
2M2	=>	$2.2 \times 10^6\ \Omega$
220K	=>	$220 \times 10^3\ \Omega$

- **Alphanumeric Labeling**
  - 한 개의 알파벳 글자(R, K, M)와 두 세개의 숫자로 표시.
  - 알파벳 글자는 승수와 소수점의 위치를 의미
  R : 0, K : 3, M : 6

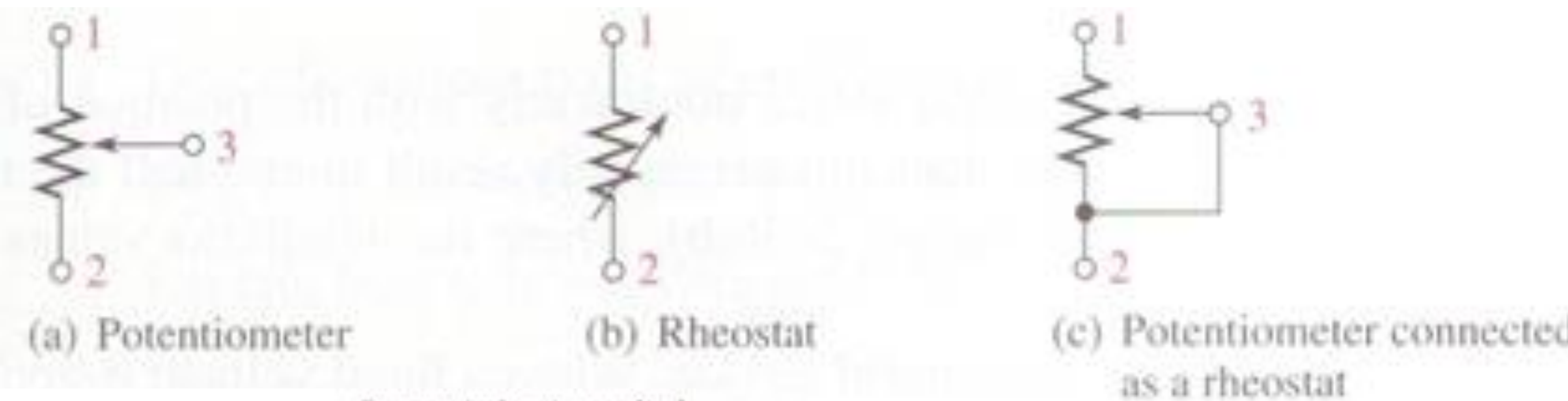
- tolerance: F, G, and J
F : ± 1 %, G : ± 2 %, J : ± 5 %

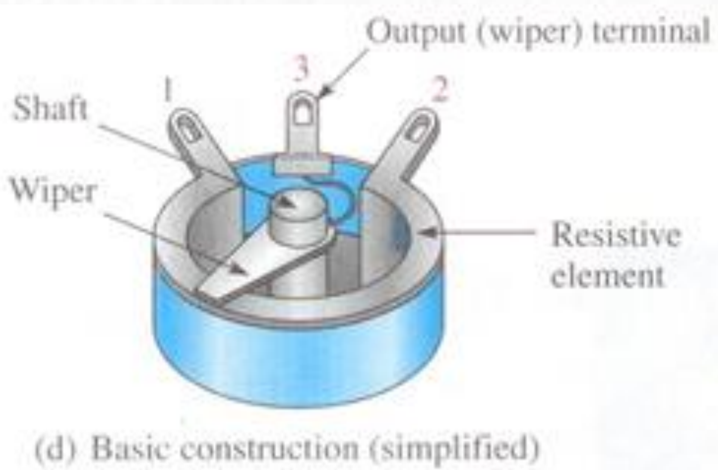
620F => $620 \pm 1\ \%\ \Omega$

4R6G => $4.6 \pm 2\ \%\ \Omega$

Variable Resistors

- 가변 저항은 전압을 조절하거나 전류 값을 조절하는 데 사용한다.
- **Potentiometer :** 전압을 조절하는 가변 저항
- **Rheostat :** 전류 값을 조절하는 가변 저항





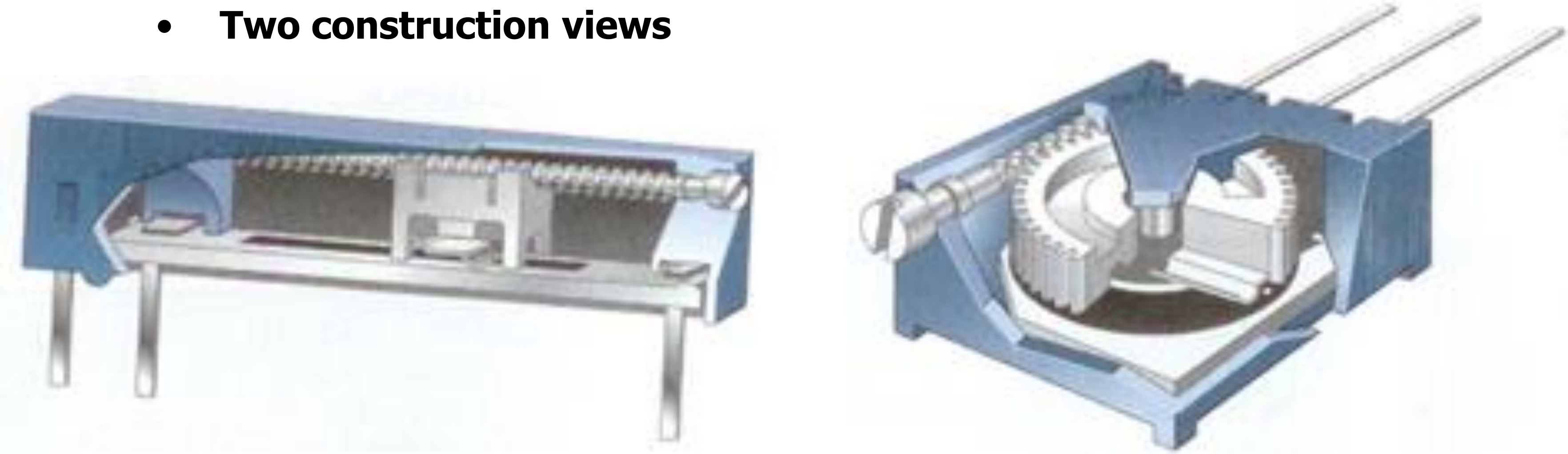
Potentiometer and rheostat symbols and basic construction of one type of potentiometer

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 45, Figure 2.34

Potentiometers and Construction

- **Potentiometers**

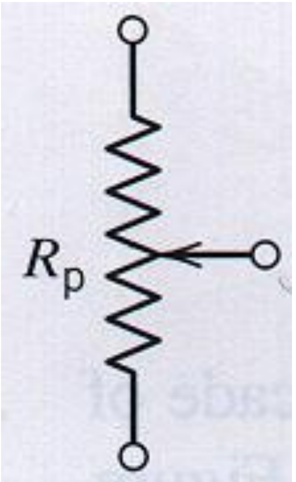
- **Two construction views**



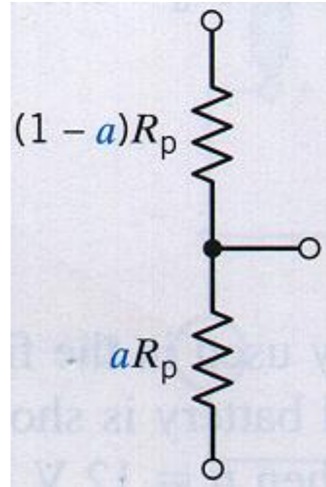
Typical potentiometers and two construction views

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 45, Figure 2.35

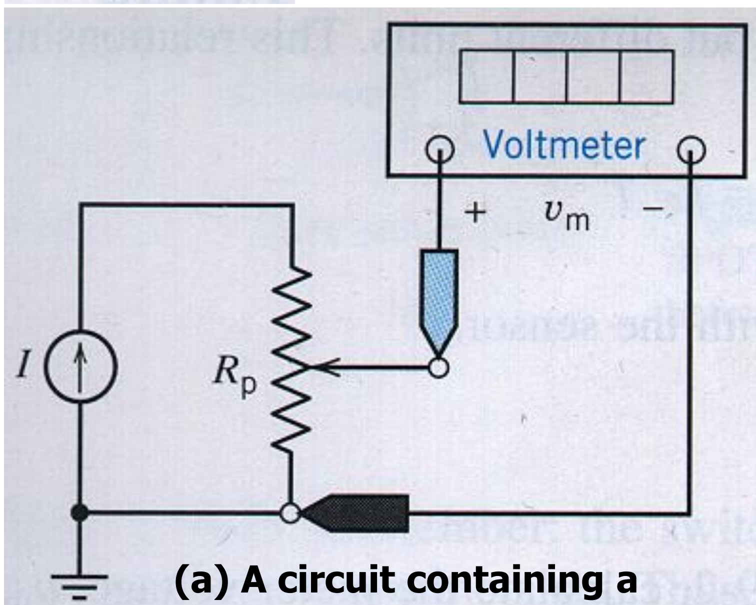
Potentiometer as Voltage-Control Device



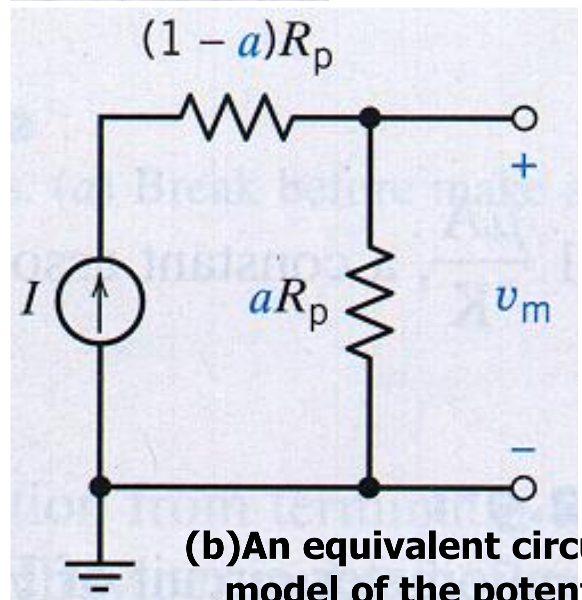
(a) The symbol



(b) A model for the potentiometer



(a) A circuit containing a potentiometer

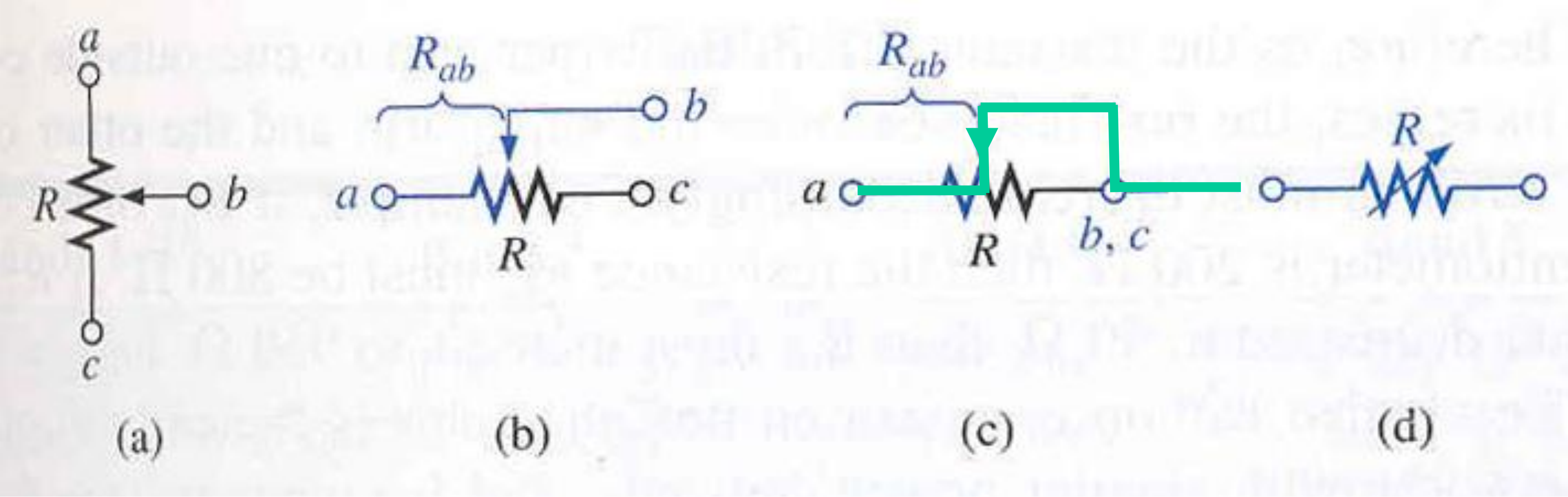


(b)An equivalent circuit containing a model of the potentiometer

Richard C. Dorf and James A. Svoboda, Introduction to Electric Circuits, 9th edition, John Wiley and Sons, 2010, p. 38

Potentiometer as Rheostat

- **Current-control device**

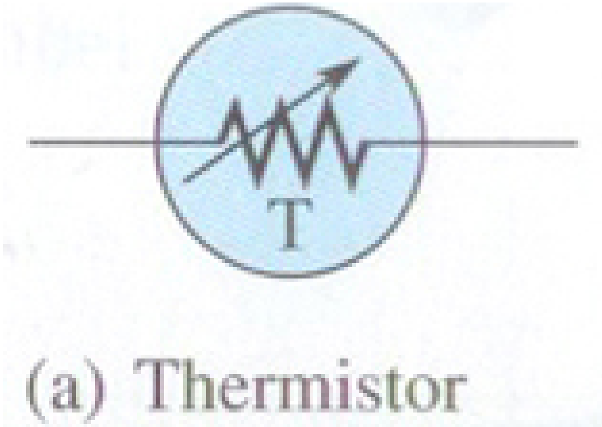


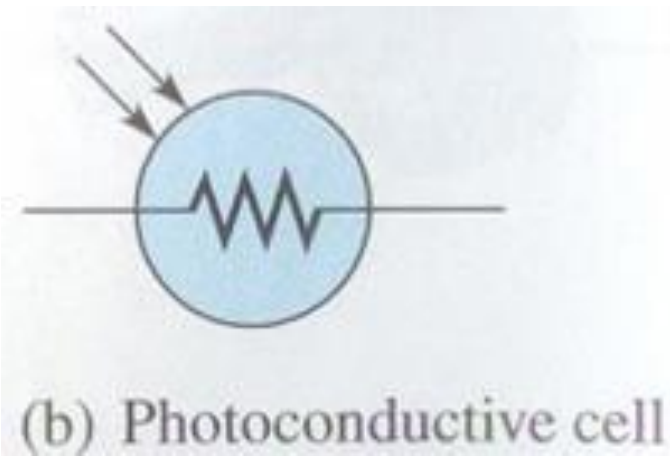
Potentiometer: (a) symbol; (b) and (c) rheostat connections; (d) rheostat symbol.

Robert L. Boylestad, Introductory Circuit Analysis, 10th edition, Prentice Hall, 2002, p. 77, Figure 3.23

$$
\begin{aligned}
R_{ac} &= R_{ab} + 0 \\
&= R_{ab}
\end{aligned}
$$

Automatically Variable Resistors





- **Thermistor : temperature sensitive variable resistors**

  - temperature coefficient :

  negative => resistance decreases

  positive => resistance increases

- **Photoconductive cell : light intensity sensitive variable resistors**

  - light intensity coefficient :

  negative => resistance decreases

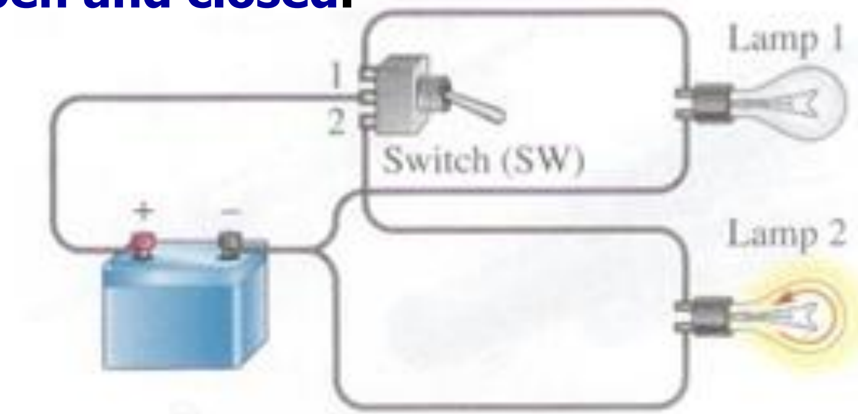
  - Sometimes the Greek letter lamda (λ) is used with photoconductive cell symbol.

Symbols for resistive devices with sensitivities to temperature and light

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 46, Figure 2.37

Circuit Current Control : Switches

Switches have two distinct states : open and closed.



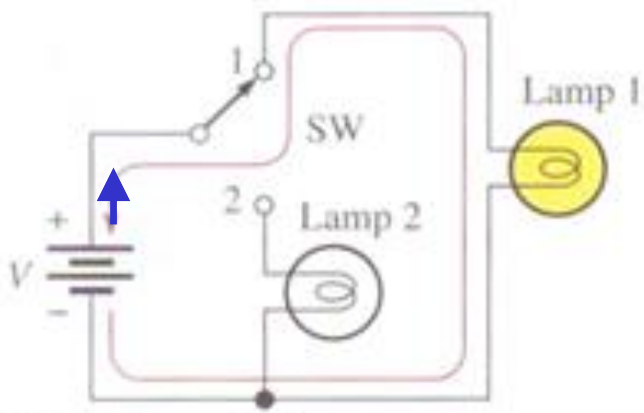
(a) Pictorial

- **Mechanical switches**

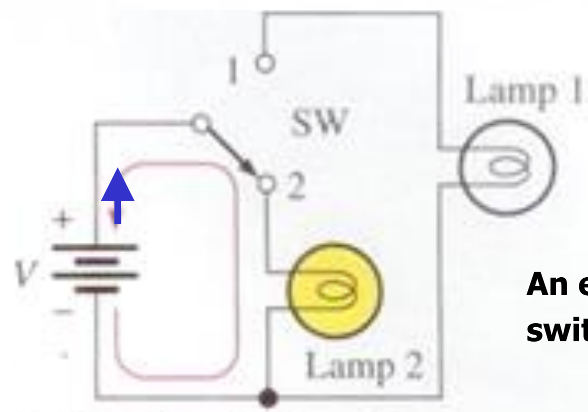
  SPDT : Single-Pole, Double-Throw

  Pole: movable arm

  Throw: number of contacts



(b) A schematic showing Lamp 1 on and Lamp 2 off

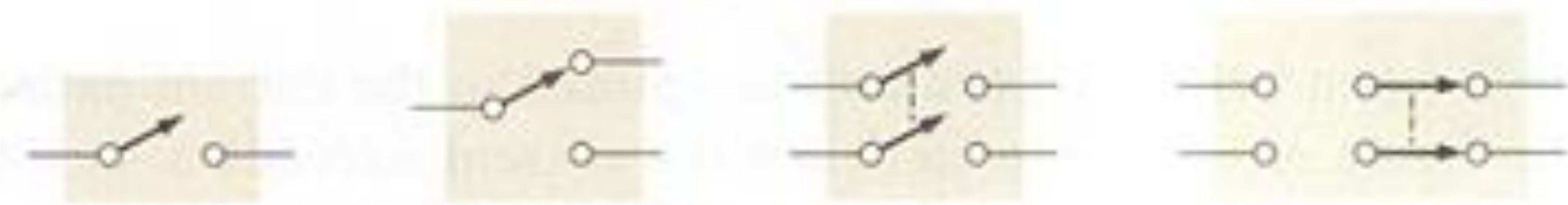


(c) A schematic showing Lamp 2 on and Lamp 1 off

An example of an SPDT switch controlling two lamps

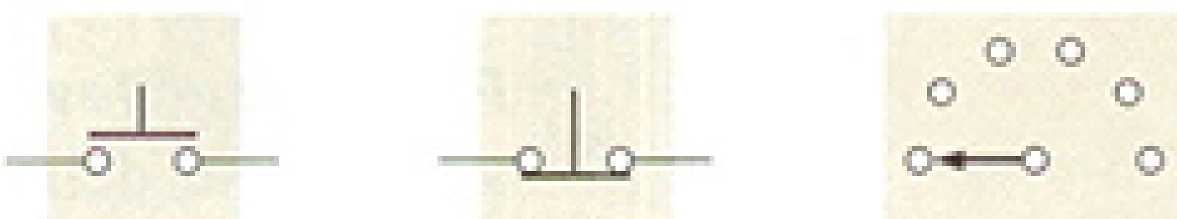
Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 49, Figure 2.41

Switch Symbols



(a) SPST (b) SPDT (c) DPST (d) DPDT

- **SPST** : **Single-Pole, Single-Throw**
- **SPDT** : **Single-Pole, Double-Throw**
- **DPST** : **Double-Pole, Single-Throw**
- **DPDT** : **Double-Pole, Double-Throw**



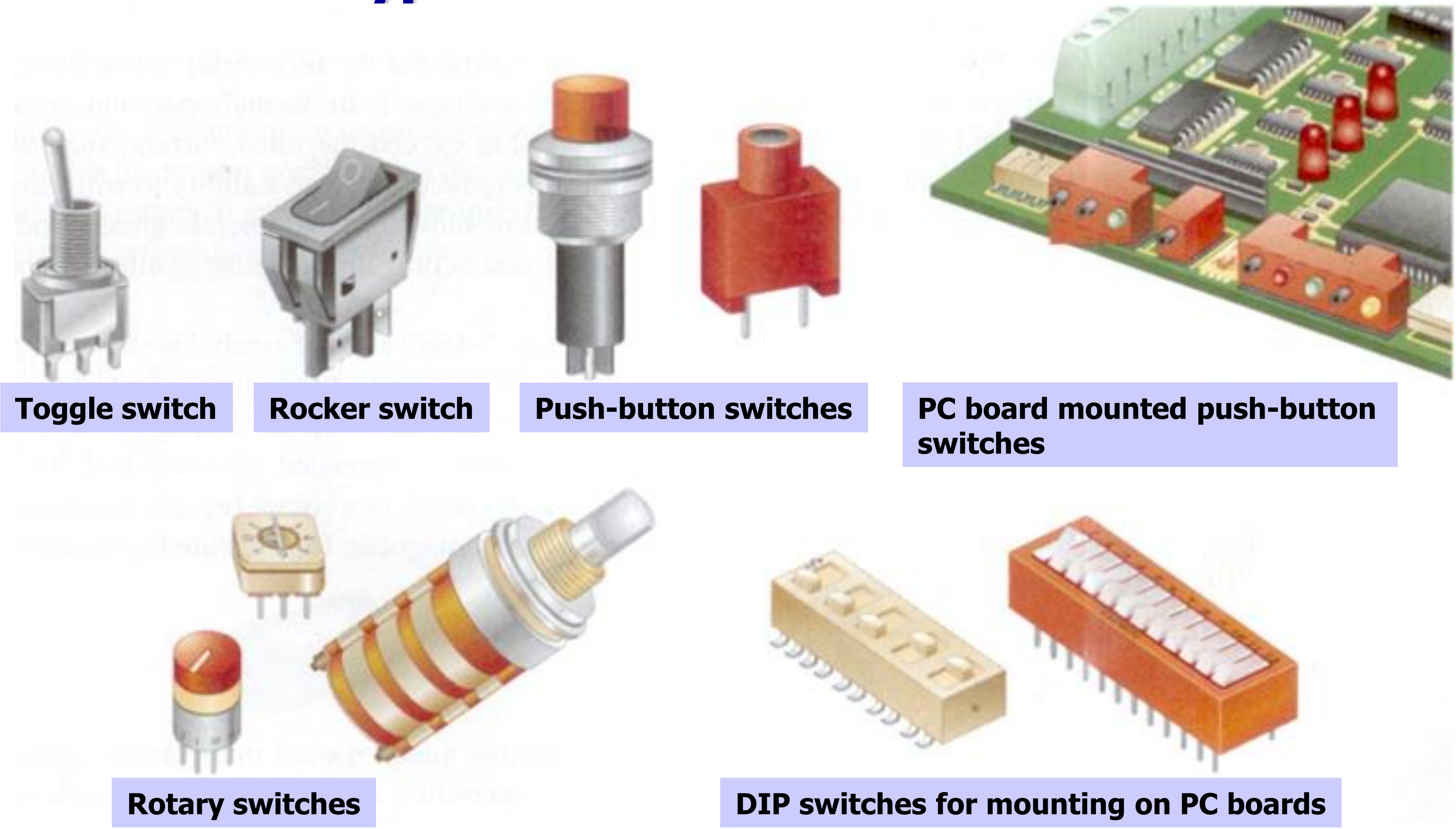
Switch symbols

(e) NOPB (f) NCPB (g) Single-pole rotary (6-position)

- **NOPB** : **Normally Open Push-Button**
- **NCPB** : **Normally Closed Push-Button**

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 49, Figure 2.42

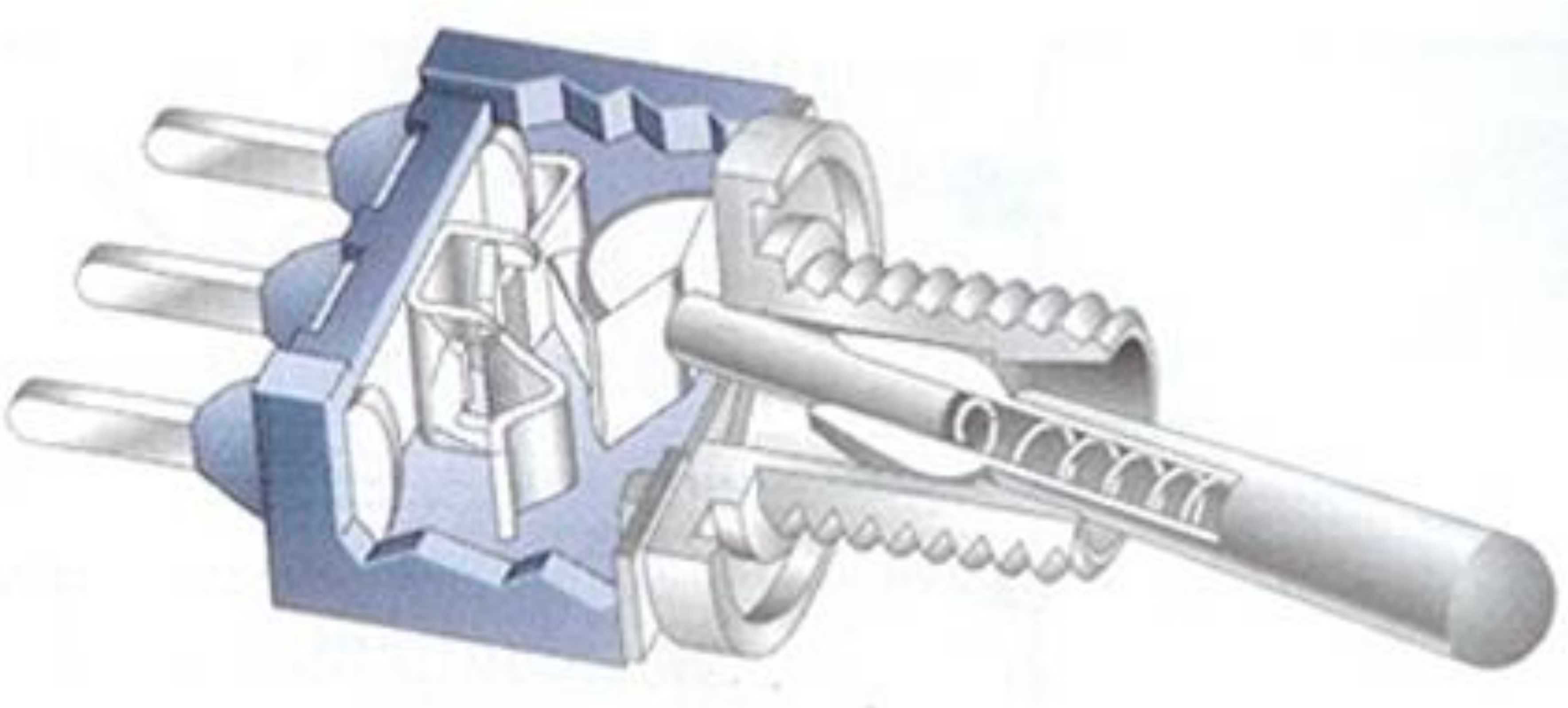
Typical Mechanical Switches



Typical mechanical switches

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 49, Figure 2.43

Toggle Switch



Construction view of a typical toggle switch

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 50, Figure 2.44

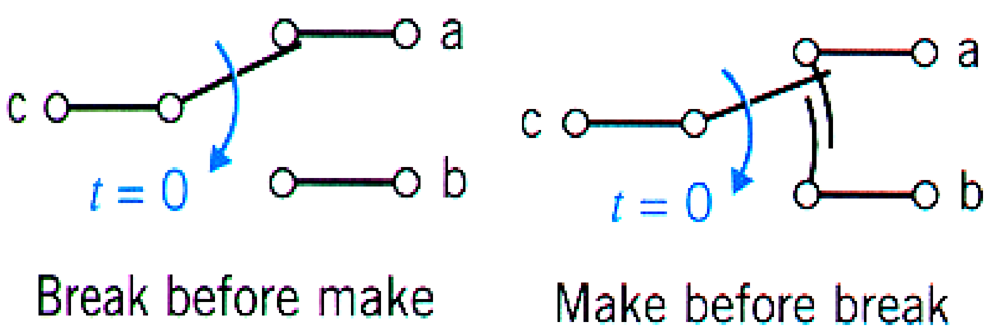
SPST and SPDT

A transistor can be used as the equivalent of a SPST switch in certain applications.

SPST : Single-Pole, Single-Throw

(a) **Initially open.** (b) **Initially closed.**

SPDT : Single-Pole, Double-Throw

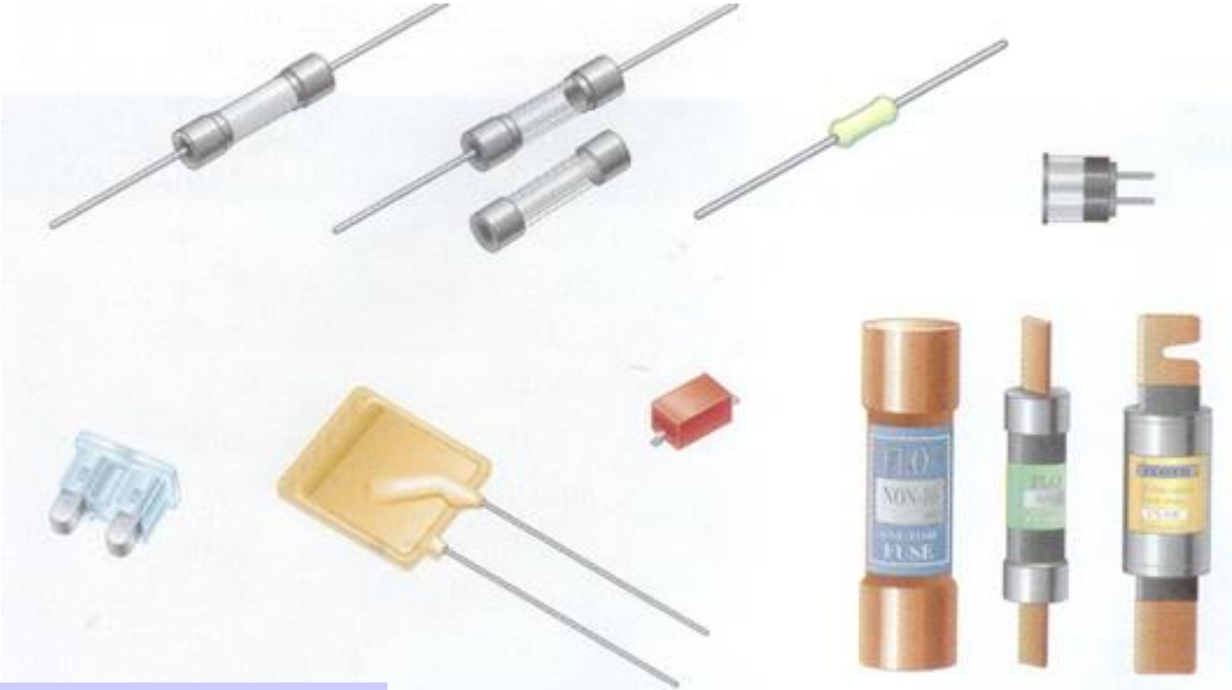


스위칭은 아주 짧은 시간 내에 이루어지고,
회로의 응답시간에 비해 아주 빠르게 스위칭한다.

Richard C. Dorf and James A. Svoboda, Introduction to Electric Circuits, 8th edition, John Wiley and Sons, 2010, p. 39

Protective Devices : Fuses

- 전류 통로에 배치해서 과도한 전류가 흐르면 녹아 내림. 따라서, 재사용이 불가.
- 빠른 반응이 필요한 경우, 예를 들면 전자회로를 보호할 때 사용.
- **Type F : fast-acting fuses. Type T : time-delay fuses.**
- 전원 투입 시 정격 전류 이상이 흘러서 휴즈의 성능을 저하시킴. 이럴 때 **T** 타입을 사용.



(a) Cartridge fuses

(b) Plug fuse

(c) Fuse symbol

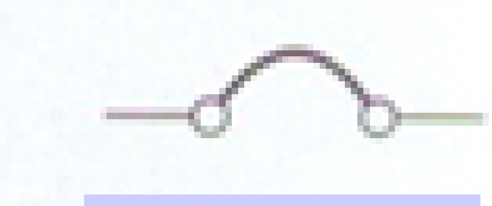
Typical fuses and symbol.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 51, Figure 2.45

Protective Devices : Circuit Breakers

- 과도한 전류가 흐르면 전류에 의한 가열 효과나 전류에 의한 자기장에 의해서 동작.
- 재사용이 가능.
- 가열 효과를 이용하는 회로 차단기의 경우, 바이메탈 스프링이 회로를 차단.
  회로가 차단되면 수동적으로 리셋할 때까지 차단기는 개방(open) 되어 있다.
- 자기장에 의해 동작하는 회로 차단기의 경우, 전자력이 회로를 개방시킴.
  기계적으로 리셋해주어야 한다.

(d) Circuit breakers



(e) Circuit breaker symbol

Typical fuses and symbol.

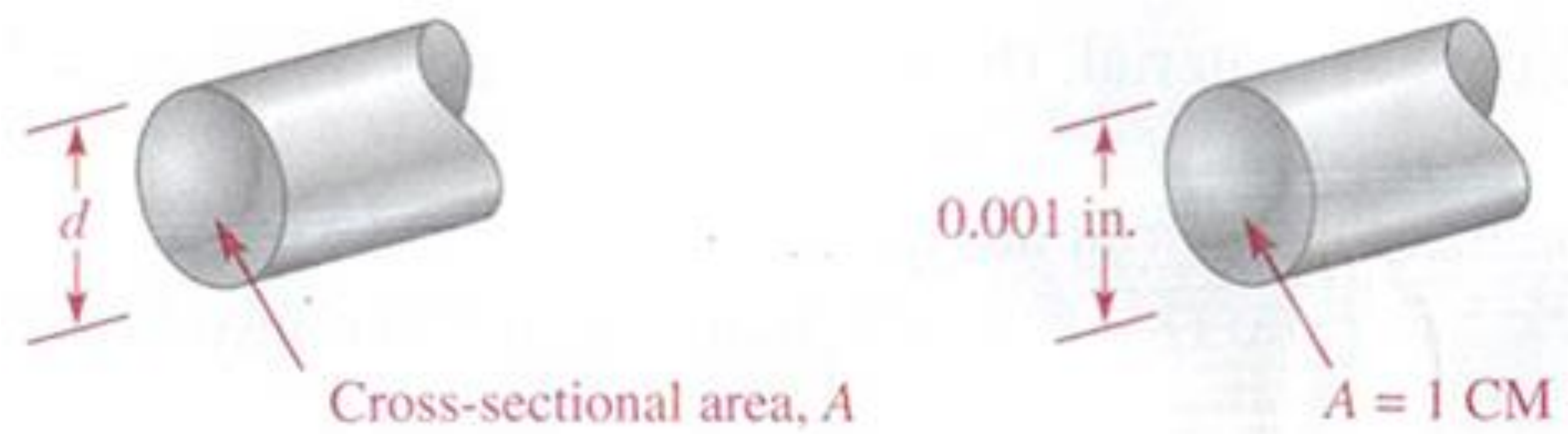
Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 51, Figure 2.45

Wires : AWG

- **American Wire Gauge (AWG) :**
  gauge number가 커지면**,** 도체 직경은 감소한다**.**
  도체의 크기는 단면적으로 정의하는데**,** 단면적의 단위는 **circular mil (CM)** 이다**.**

  1 CM = 직경이 **1 mil(1/1000 inch)** 일 때의 단면적 **=** $\pi \times (5 \times 10^{-4})^2 \text{ in}^2$

$A = d^2$, A 의 단위 **CM,** d 의 단위 **mil**



Cross-sectional area of a wire.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 51, Figure 2.46

AWG Sizes and Resistances for Solid Round Copper

AWG #	A (CM)	R (Ω/1000 ft @ 20⁰C)	AWG #	A (CM)	R (Ω/1000 ft @ 20⁰C)
0000	221,600	0.0490	19	1,288.1	8.051
000	167,810	0.0618	20	1,021.5	10.15
00	133,080	0.0780	21	810.10	12.80
0	105,530	0.0983	22	642.40	16.14
1	83,694	0.1240	23	509.45	20.36
2	66,373	0.1563	24	404.01	25.67
3	52,634	0.1970	25	320.40	32.37
4	41,742	0.2485	26	254.10	40.81
5	33,102	0.3133	27	201.50	51.47
6	26,250	0.3951	28	159.79	64.90
7	20,816	0.4982	29	126.72	81.83
8	16,509	0.6282	30	100.50	103.2
9	13,094	0.7921	31	79.70	130.1
10	10,381	0.9989	32	63.21	164.1
11	8,234.0	1.260	33	50.13	206.9
12	6,529.0	1.588	34	39.75	260.9
13	5,178.4	2.003	35	31.52	329.0
14	4,106.8	2.525	36	25.00	414.8
15	3,256.7	3.184	37	19.83	523.1
16	2,582.9	4.016	38	15.72	659.6
17	2,048.2	5.064	39	12.47	831.8
18	1,624.3	6.385	40	9.89	1049.0

예제 1
d = 5 mil 이면
A = 25
=> AWG # = 36

예제 2
d = 20.1 mil 이면
A = 404.001
=> AWG # = 24

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 52, Table 2.4

Wire Resistance

도선도 저항을 갖고 있다.
저항율, 길이, 단면적에 의해 결정되고,
온도 영향을 받는다.

$$R = \rho l / A \;\; \Omega$$

예제 1 A = **810.1 CM** 이고 **100 ft** 인 도선 **(20°C)**의 저항은? $\rho = 10.37$ **CM-Ω/ft.**

$$R = \rho l / A = 10.37 \times 100 / 810.1$$
$$= 1.28 \; \Omega$$

예제 2 A = **810.1 CM** 이고 **100 ft** 인 도선 **(20°C)**의 저항은?

$$R = 12.80 \times 100 / 1000 = 1.28 \; \Omega$$

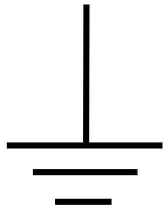
예제 3 **AWG # 14** 인 도선 **1000 ft** 의 저항은?
2.525 Ω

예제 4 **AWG # 22** 인 도선 **1000 ft** 의 저항은?
16.14 Ω

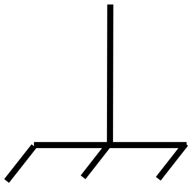
AWG #	A (CM)	R (Ω/1000 ft @ 20°C)
19	1,288.1	8.051
20	1,021.5	10.15
21	810.10	12.80
22	642.40	16.14
23	509.45	20.36
24	404.01	25.67
25	320.40	32.37
26	254.10	40.81
27	201.50	51.47
28	159.79	64.90
29	126.72	81.83
30	100.50	103.2
31	79.70	130.1
32	63.21	164.1
33	50.13	206.9
34	39.75	260.9
35	31.52	329.0
36	25.00	414.8
37	19.83	523.1
38	15.72	659.6
39	12.47	831.8
40	9.89	1049.0

Ground

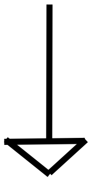
- **Ground :** Reference point in an electric circuit.
- **Earth Ground :** Originated from the fact that one conductor of a circuit was typically connected with an 8-foot long metal rod driven into the earth itself.
- **Reference Ground :** Reference ground defines 0 V for the circuit. Reference ground is called common and labeled **COM** or **COMM** because it represents a common conductor.
  When you are wiring a protoboard in the laboratory, you will normally reserve one of the bus strip (a long line along the length of the board) for this common conductor.



(a) An earth ground or a reference ground

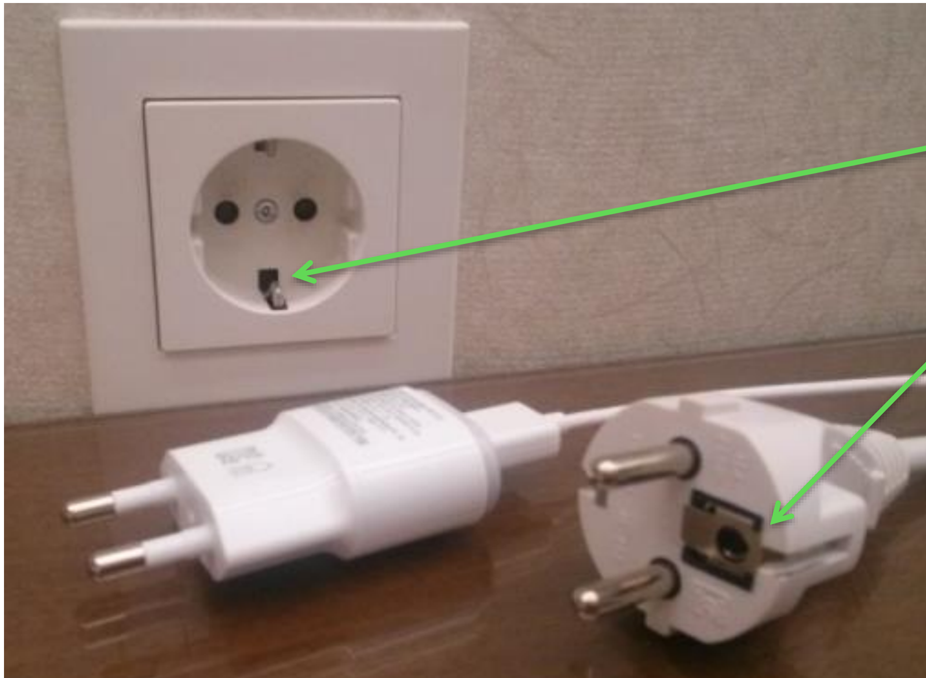


(b) A chassis ground



(c) An alternate reference symbol typically used when there is more than one common connection (such as analog and digital ground in the same circuit).

Ground and Plug

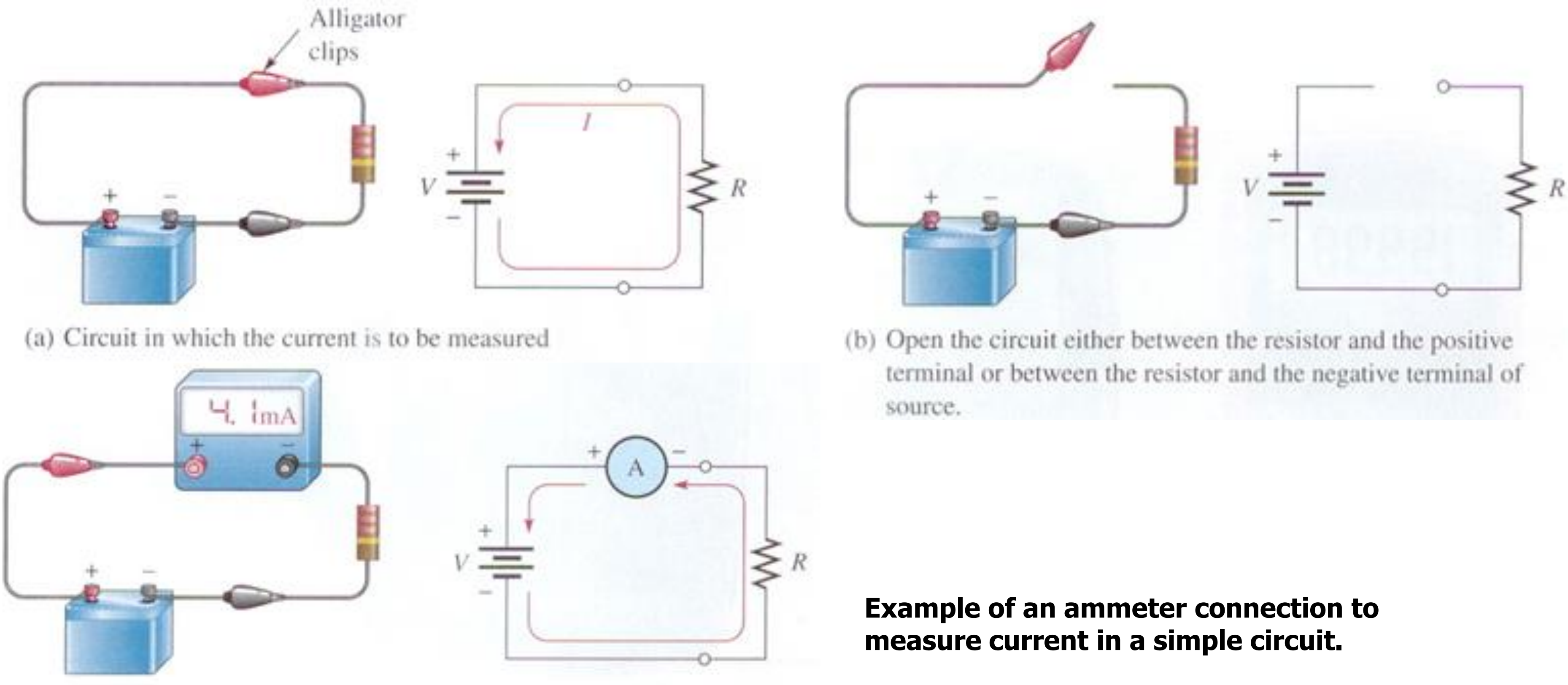


접지단자

개별 스위치와 접지단자가 있는 멀티탭

Measuring Current

- **Ammeter, Series**
- **Ideal ammeter: internal resistance = 0.**



(a) Circuit in which the current is to be measured

(b) Open the circuit either between the resistor and the positive terminal or between the resistor and the negative terminal of source.

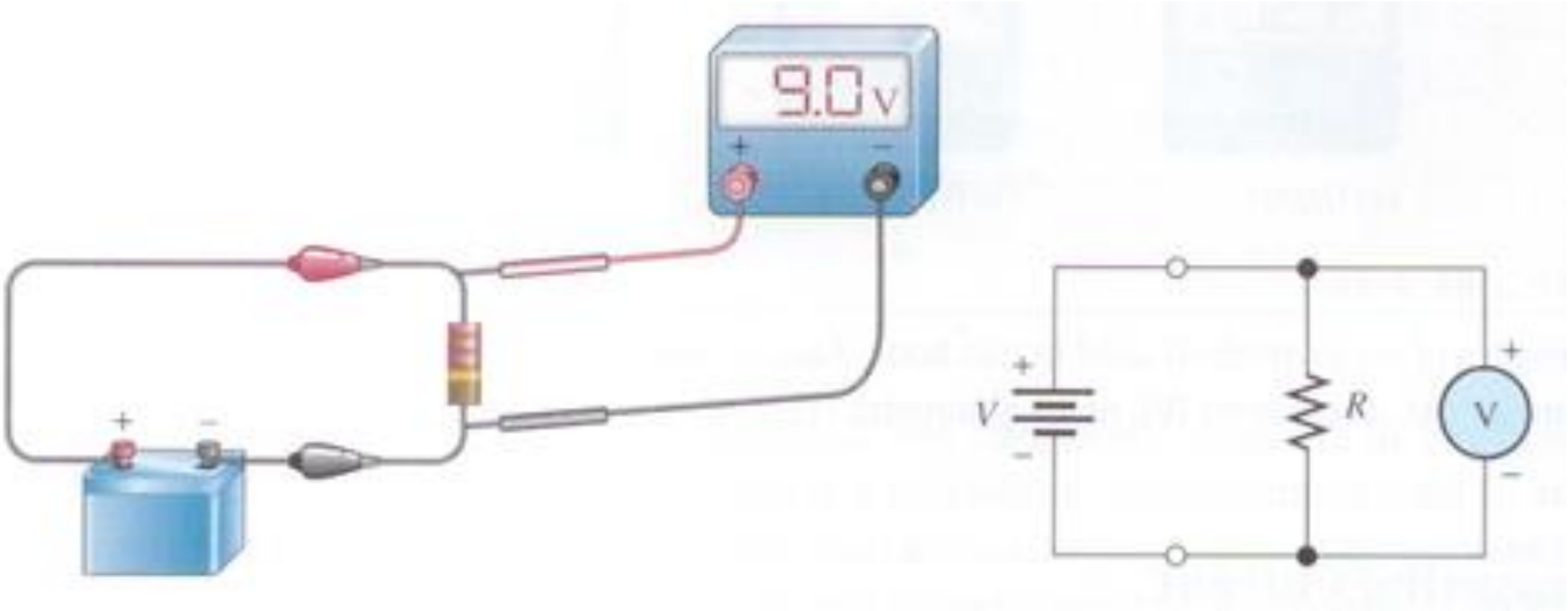
(c) Install the ammeter in the current path with polarity as shown (negative to negative, positive to positive).

Example of an ammeter connection to measure current in a simple circuit.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 56, Figure 2.51

Measuring Voltage

- Voltmeter, Parallel
- Ideal voltmeter: internal resistance = ∞.

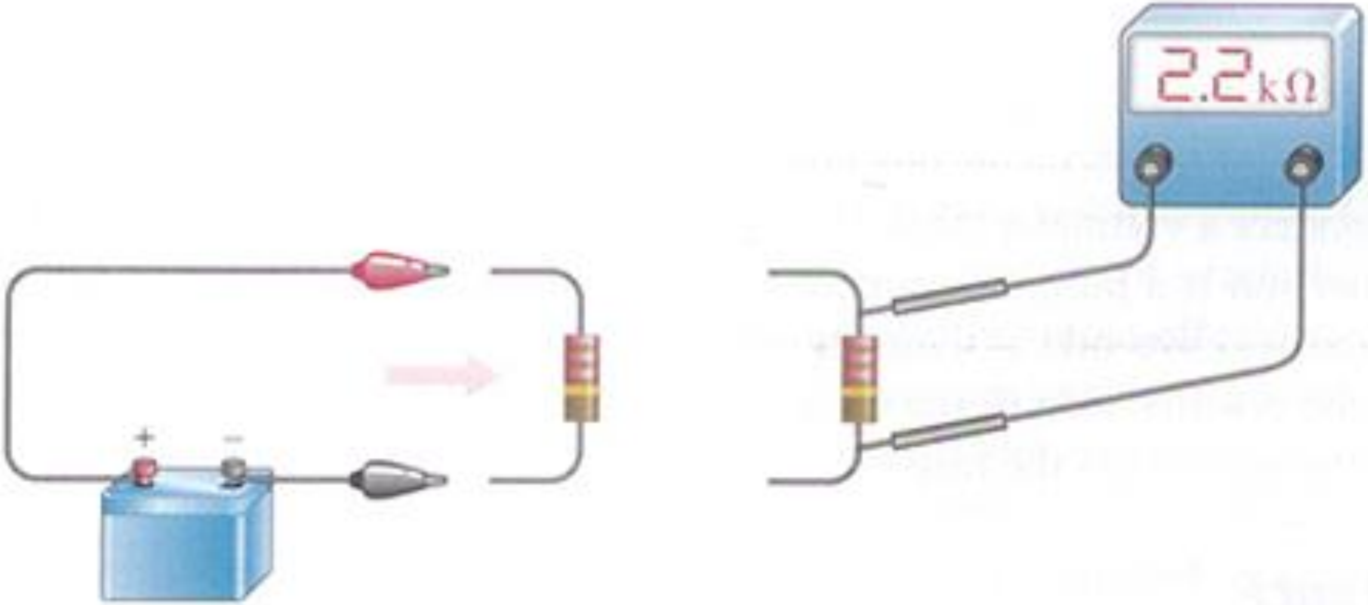


Example of a voltmeter connection to measure voltage in a simple circuit.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 56, Figure 2.52

Measuring Resistance

- The resistor must first be removed or disconnected from the circuit.



(a) Disconnect the resistor from the circuit to avoid damage to the meter and/or incorrect measurement.

(b) Measure the resistance. (Polarity is not important.)

Example of a using an ohmmeter to measure resistance.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 56, Figure 2.53

Digital Mutimeters (DMMs)

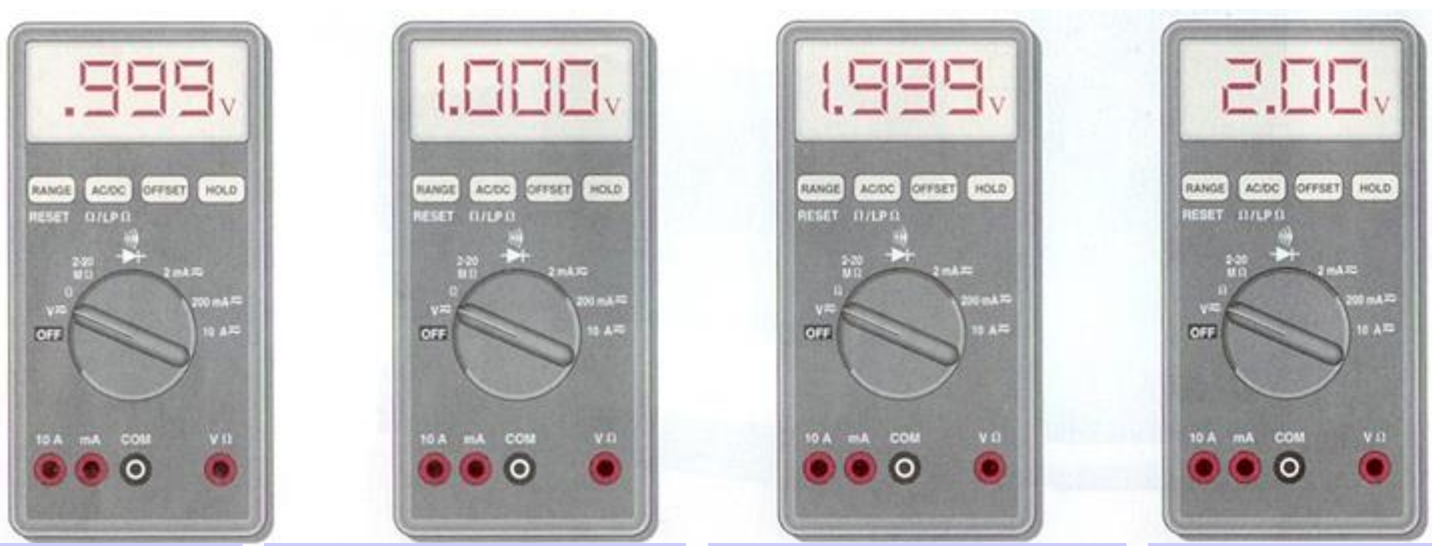
- **DMMs** provide more functions, better accuracy, greater ease of reading, and greater reliability than do analog meters.
- Many DMMs are autoranging types in which the proper range is automatically selected by internal circuitry.
- **DMM functions**

  Ohms, DC voltages and current, AC voltage and current.
- **DMM display : LCD or LED** readouts are available.

  A typical battery-powered DMM with **an LCD readout** operates on a 9 V battery that will last from a few hundred hours to **2,000 hours and more**. The disadvantages of LCD readouts are that (a) they are difficult or **impossible to see in low-light conditions** and (b) they are relatively **slow to respond to measurement changes.**
- **LED** can be **seen in the dark and respond quickly to changes** in measured values. LED displays require much more current than LCD displays; and therefore **battery life is shortened** when LEDs are used in portable equipment.

3½ Digits in Display of DMMs

- The resolution of a DMM is the smallest increment of a quantity that the DMM can measure.
- The smaller the increment, the better the resolution.
- One factor that determines the resolution of a meter is the number of digits in the display.
- Many DMMs have 3½ digits in their display.



(a) Resolution: 0.001 V (b) Resolution: 0.001 V (c) Resolution: 0.001 V (d) Resolution: 0.01 V

A 3½-digit DMM illustrates how the resolution changes with the number of digits in use.

Thomas L. Floyd and David M. Buchla, Electronics Fundamentals: Circuits, Devices, and Applications, Prentice Hall, p. 58, Figure 2.56

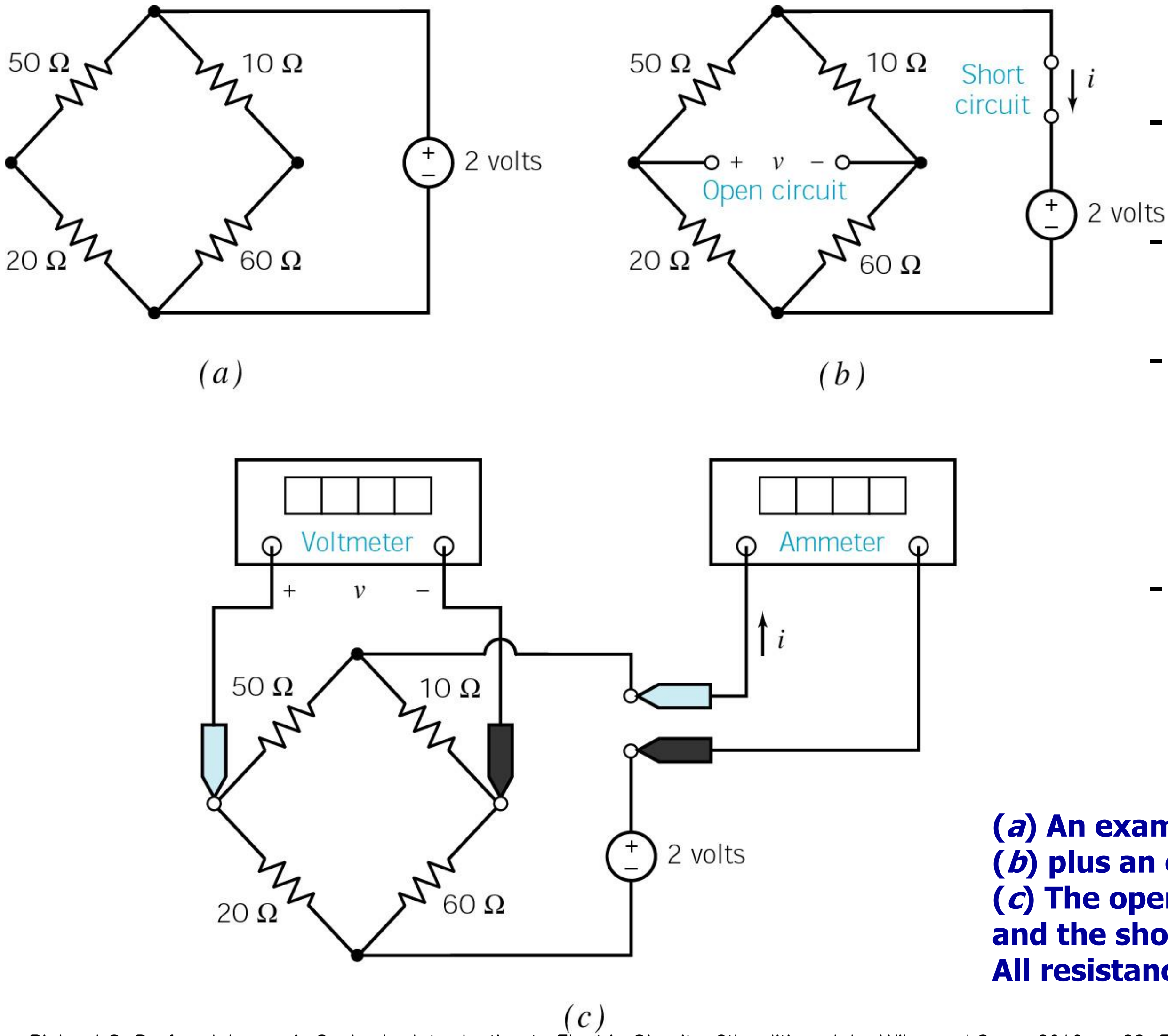
Resolution and Accuracy of DMMs

- **Resolution**
- **1.999 V** 까지 **resolution** 은 **0.001 V** 이다.
- **2.000 V**로 표시가 되지 않고 **2.00 V**로 표시되므로 **resolution** 은 **0.01 V**가 된다.
- **19.99 V** 까지 **resolution** 은 **0.01 V** 이다.
- 다시 **0.01 V** 가 증가되면 **20.0 V** 로 표시되고 **resolution** 은 **0.1 V** 가 된다.

- **DMMs with displays of 4½ through 8½ digits are also available.**

- **Accuracy**
- **Accuracy is an indication, usually expressed in percentage, of the range of error which is the difference in the measured and true or accepted value of quantity.**
- **For typical meters, accuracies range from 0.01 % to 0.5 %, with some precision laboratory-grade meters going to 0.002 %.**

An Example Circuit



- **Ideal ammeter: short circuits.**
- **Ideal voltmeter: open circuits.**
- **Ideally, adding the voltmeter and ammeter does not disturb the circuit.**
- **The reference direction is important.**

(*a*) An example circuit,
(*b*) plus an open circuit and a short circuit.
(*c*) The open circuit is replaced by a voltmeter, and the short circuit is replaced by an ammeter. All resistances are in ohms.

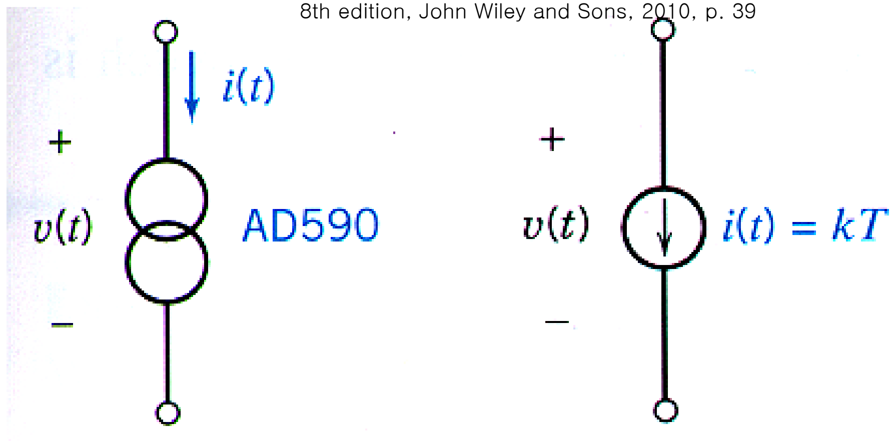
Richard C. Dorf and James A. Svoboda, Introduction to Electric Circuits, 8th edition, John Wiley and Sons, 2010, p. 39, Figure 2.7-3

Transducer - Temperature Sensor

Transducer : Devices that convert physical quantities to electrical quantities.

- **Analog Device** 사의 **AD590** 은 온도를 전류로 바꾸어서 온도를 측정하는 소자이다.
- 소자는 그림과 같이 표시한다.
- 이 센서를 적절히 동작시키려면 전압은 **4** V 에서 **30** V 사이에 있어야 한다.
- 이런 조건에서 전류는 온도 **1** K 의 변화에 **1** μA의 전류가 흐르게 된다.

Richard C. Dorf and James A. Svoboda, Introduction to Electric Circuits, 8th edition, John Wiley and Sons, 2010, p. 39



(a) The symbol and (b) a model for the temperature sensor

$$i = k \cdot T \quad \text{where} \quad k = 1\,\mu\text{A}/^{\text{o}}\text{K}$$

- **AD590** 을 이용하여 수조의 물 온도를 측정하는 회로를 설계하라.

  AD590, 전류계**,** 저항**,** 전압원**(10, 12, 15, 18, 24 V)**이 사용 가능하다.

  300 K 이면 전류는 얼마가 흐르는가?

  이상적인 전류계와 실제적인 전류계를 사용했을 때 어떤 변화가 있는가?

  여러 전원 중 어떤 전원을 사용해야 하는가? 그 이유는?