Lecture Note2: Electrical Components-Resistor

1. Resistor

:About 70% of widely used components

:To restrict/regulate/control the current

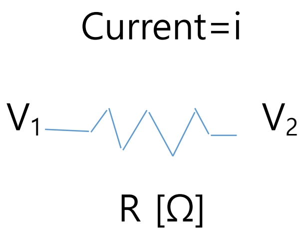
:To drop the voltage

:To divide voltage

:To dissipate energy

:To work

Symbol



<Ohm’s Law>

$i=(V_1-V_2)/R$=current through resistor

R=Resistance[Ω]=1/conductance

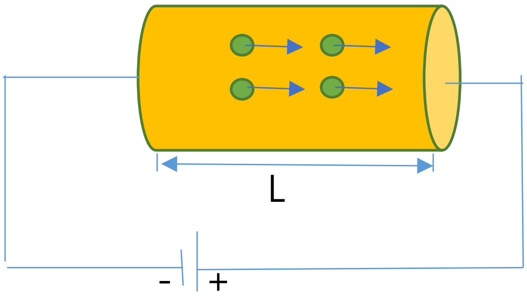
where conductance=current when 1V is applied across two points

The Ohm’s law is only applicable to elements behaving like resistors,

NA to Diode, Transistor, etc.

<Resistivity>

Voltage V, Current I



Resistance, R≡V/I=ρL/A,

where ρ=Resistivity [Ωm] and σ=1/ρ=conductivity [1/Ωm]

<u>Resistivity, ρ, for various material</u>

<Conductor>

10E-8 for Fe

2.82E-8 for Al

1.72E-8 for Cu

1.59E-8 for Ag

<Semiconductor>

0.46 for Ge

64 for Si

<Insulator>

1.0E10~1.0E14 for Glass

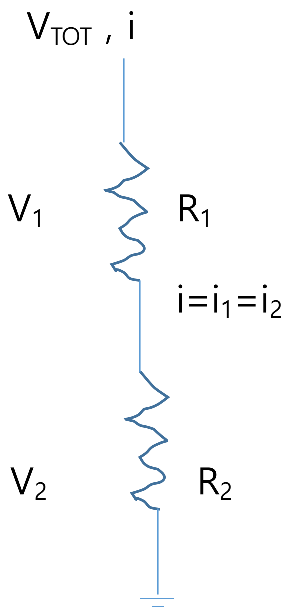
5.0E5 for Human skin

2.5E5 for water

0.2E5 for salt water

<u>Serial and Parallel Connections for Resistors</u>

1) Serial connection



Conductance=Current when 1V applied

$=1/(R_1+R_2)=1/R_{TOT}$

Thus $R_{TOT}=R_1+R_2$

From Kirchhoff's law,

$i_1=i_2=i$

$V_{TOT}=V_1+V_2=iR_1+iR_2=i(R_1+R_2)=iR_{TOT}$

Thus $R_{TOT}=R_1+R_2=R_1(1+R_2/R_1)$

If $R_1=R_2=R$, then $R_{TOT}=2R$

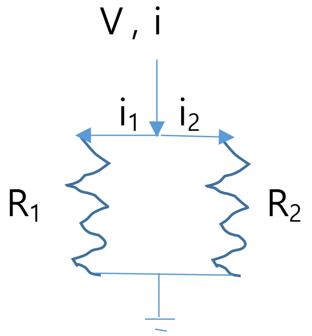
If $R_1=10R$, $R_2=R$, then $R_{TOT}=1.1R_1=11R$

If $R_1 \gg R_2$, then $R_{TOT} \fallingdotseq R_1$ ($\because R_2/R_1 \ll 1$)

<u>Thus R_1 (Larger resistor) dominates circuit in serial connection !</u>

It indicates that R_1=Master, R_2=Slave

2) Parallel connection



Kirchhoff's law,

$i=i_1+i_2=V/R_1+V/R_2=V/R_{TOT}$

$1/R_{TOT}=1/R_1+1/R_2$, thus $R_{TOT}=R_1R_2/(R_1+R_2)=R_2/(1+R_2/R_1)$

Also from Total Conductance

= Conductance1+Conductance2

$=1/R_1+1/R_2=1/R_{TOT}$

Thus $1/R_{TOT}=1/R_1+1/R_2$ and $R_{TOT}=R_1R_2/(R_1+R_2)$

If $R_1=R_2=R$, then $R_{TOT}=R/2$

If $R_1=10R$, $R_2=R$, then $R_{TOT}=10R^2/11R=R/1.1\fallingdotseq 0.909R$

If $R_1 \gg R_2$, then $R_{TOT}=R_1R_2/(R_1+R_2)=R_2/(1+R_2/R_1)\fallingdotseq R_2$ ($\because R_2/R_1 \ll 1$)

Thus R_2 (Smaller resistor) dominates circuit in parallel connection!

R_1=Slave, R_2=Master

It gives us very good understanding and insight for the circuits.

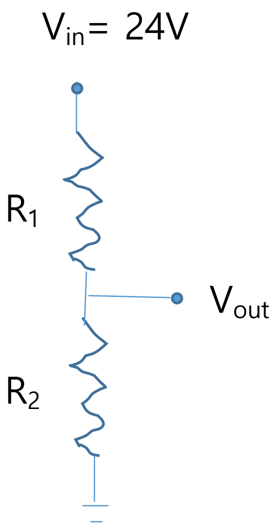
"Master and Slave" for Circuit Design

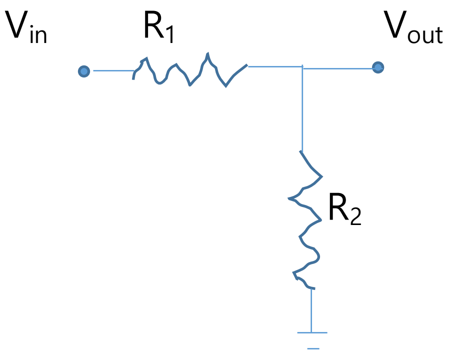
Also it leads to the "10X Rule for Circuit Design"

Voltage Divider

:To divide/drop the voltage into appropriate range

Ex) How can we get 12V from 24V voltage supply of car-battery?





From Ohm's law, the current i flowing from top to bottom,

$i=V_{in}/(R_1+R_2)$

∴ $V_{out}=iR_2=R_2V_{in}/(R_1+R_2)$ or $V_{out}/V_{in}=R_2/(R_1+R_2)=1/(1+R_1/R_2)$

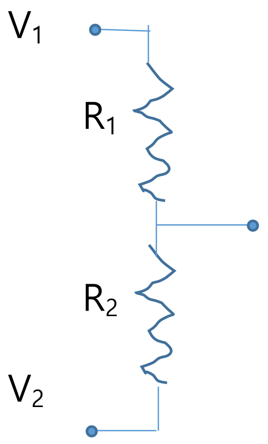
∴ V_{out}=12V when $R_1=R_2=R$ (=10K, for example)

Thus, Vout/Vin can be adjusted by changing R_1 , R_2 resistors.

There are lots of application for this.

(Q: There can be many potential R_1, R_2 combinations. Is there existing optimum one? How can we get them then? Any assumption is needed for this? Etc.)

Generalized Voltage Divider



$V_{out}=V_2+(V_1-V_2)R_2/(R_1+R_2)$

This general voltage divider becomes simple version of previous page if $V_2=0$, and it gives better understanding and meaningful insight.

Also, it is possible to set V_2 as the negative voltage, such as -5V.

Q) How can we get -5V?

HW1) Derive Vout in the above generalized voltage divider

(due in next week)