Lecture 4 – Design Rule or 10X rule

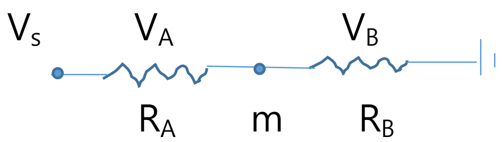
Design Rule or 10X Rule

When Device A is to drive Device B, this case can be that A is the 'Slave', B is the 'Master', because the ultimate target is to drive B, Master.

Thus Device B must have MAJOR allocation of voltage, while device A has MINOR allocation of voltage for the given voltage signal, Vs.

It can be generally accepted that 90% of Vs is allocated to V_B, while 10% of Vs is allocated to V_A.

This situation can be implemented as R_A:R_B=1:10, where R_A and R_B are resistors of device A and device B, respectively.



When $R_A/R_B=1/10$, from Ohm's law

$V_B=V_sR_B/(R_A+R_B)=V_s/(1+R_A/R_B)=0.909V_s$, $V_A=V_s-V_B=0.091V_s$

∴ 90.9% of V_s is allocated to V_B, while 9.1% of V_s is allocated to V_A

Thus R_A:R_B=1:10 or $R_A=R_B/10$ is a practical guideline for the situation "A drives B"

This is called as '10X rule', and very useful for practical circuit design

Sometimes R_A and R_B are expressed as $R_{out,A}$ and $R_{in,B}$

where $R_{out,A}$ is the resistor out of A that viewed at midpoint, m

$R_{in,B}$ is the resistor into B that viewed at the mid-point, m

Thus $R_{out,A} \leq R_{in,B}/10$ is the '10X rule' in more general form.

In more general expression

$Z_{out,A} \leq Z_{in,B}/10$ for more general AC environment

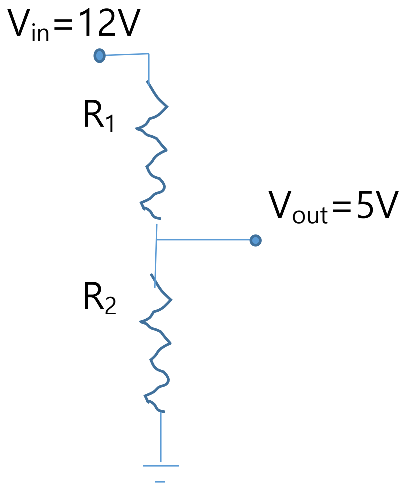
where impedance Z is used instead of R

Two Exceptions for the 10X rule

1. $Z_{out} = Z_{in}$ for "Impedance matching" in radio frequency application
2. $Z_{out}/10 \geq Z_{in}$ for current signal rather than voltage signal ("reverse situation"), and $Z_{out}=\infty$ for current source

Voltage Divider Design

Design a voltage divider: V_{in}=12V, V_{out}=5V



$V_{out}/V_{in}=R_2/(R_1+R_2)=5/12$ eq(1)

-Two unknowns R_1,R_2 with eq(1)

-Too many R_1,R_2 solutions

∴ One more eq is needed to solve

Thus, from design point of view, we need 'For what application?'

Answer can be 'To drive a A/D converter from the Vout signal'

Now we need to know the load resistor, R_L , of the A/D converter,

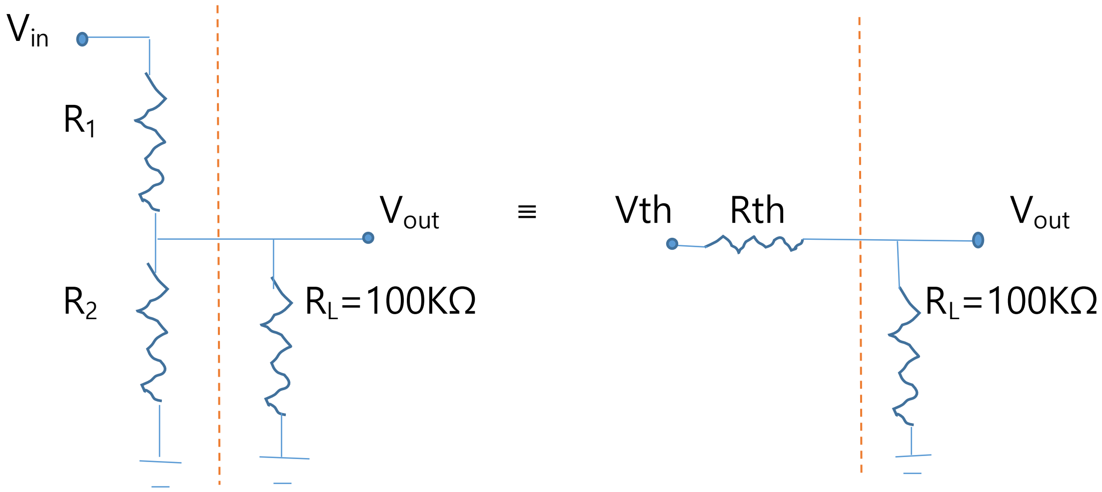
and we can obtain the R_L data from;

-Input impedance of A/D (Analog to Digital) converter

from specification sheet, or

-Direct measurement of resistor the A/D converter with multi-meter

Typical A/D's loading resistor, R_L , is 100KΩ, and it can be connected to the Vout signal as follows.



Thevenin's equivalent circuit gives

$Rth=R_1 \parallel R_2=R_1R_2/(R_1+R_2)$, and

Vth=open voltage $=VinR_2/(R_1+R_2)$

Rth is to drive R_L , thus from 10X rule

$Rth=R_1R_2/(R_1+R_2)=R_L/10=10K\Omega$ eq(2)

Thus two unknowns, R_1, R_2 can be solved from two eqs(1) and (2)

$5R_1/12=10K\Omega$ Thus $R_1=24K\Omega$, and $R_2=5R_1/7=17.1K\Omega$

Therefore $R_1=\underline{24K\Omega}$, $R_2=\underline{17.1K\Omega}$ are uniquely determined.

Now $V_{out}=VthR_L/(Rth+R_L)=Vth(100)/(10+100)\fallingdotseq 4.5V$, while the design target is 5V.

Is it acceptable? Ans) Yes or No.

It can be generally accepted as an <u>approximate solution</u>, when R_L is sufficiently large.

What happen?

This time V_{out} is connected to R_L(=100KΩ) instead of open voltage (no-connection, and $R_L=\infty$). The current flow, i_L into R_L , gives voltage drop at Vout by the amount of $i_L Rth$ from Vth.

The smaller R_L gives the bigger voltage drop at Vout.

Here is an exact solution that keeps Vout as the design target, 5V.

Eq(1) should be modified as

$V_{out}=VthR_L/(Rth+R_L)=5V$ eq(1′), where

$Vth=VinR_2/(R_1+R_2)$ eq(3)

Three unknowns, R_1,R_2,Vth; with eq(2), eq(1′), eq(3)

From eq(1′), eq(2); $Vout=VthR_L/1.1R_L=Vth/1.1=5V$, $\therefore Vth=5.5V$

From eq(3), $R_2/(R_1+R_2)=Vth/Vin=5.5/12$

Applying to eq(2); $Rth=5.5R_1/12=10K\Omega$ $\therefore R_1=$21.8KΩ

From eq(3), $5.5(R_1+R_2)=12R_2$ $\therefore R_2=5.5R_1/6.5=$18.4KΩ

Thus we observe R_1 , R_2 are adjusted to accommodate R_L

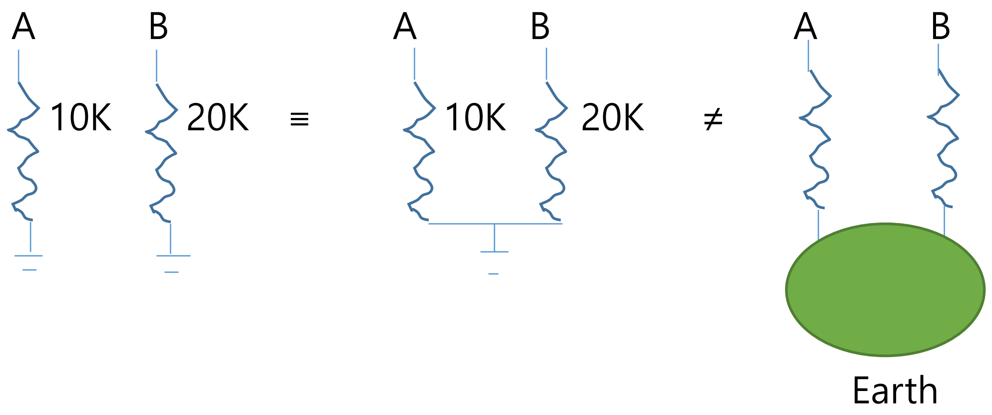
Q) What happen if AC voltage is used instead of DC voltage?

Ans) Same? or Different? It is same.

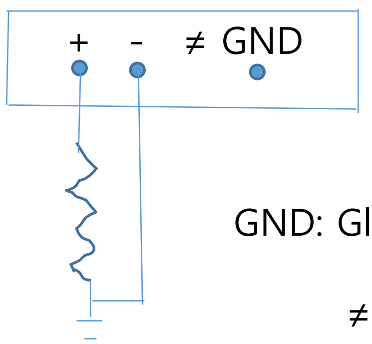
Note: Ohm's law is not influenced by whether it is DC or AC.

Local ground vs Global ground (or Earth)

Local ground or signal ground: common points in the circuit arbitrary chosen as zero volts



Power Supply



GND: Global ground or Chasis ground

≠ Local ground(-)

-Due to static electricity

or Chasis' voltage

-Better to be connected to the Earth line