Beta-Multiplier : A Step-by-Step Guide to Understanding

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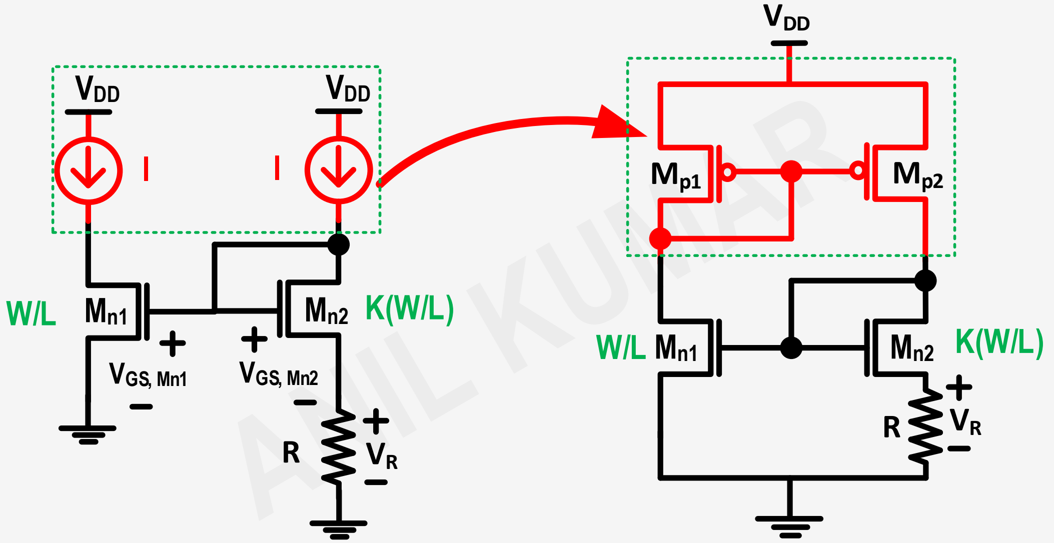
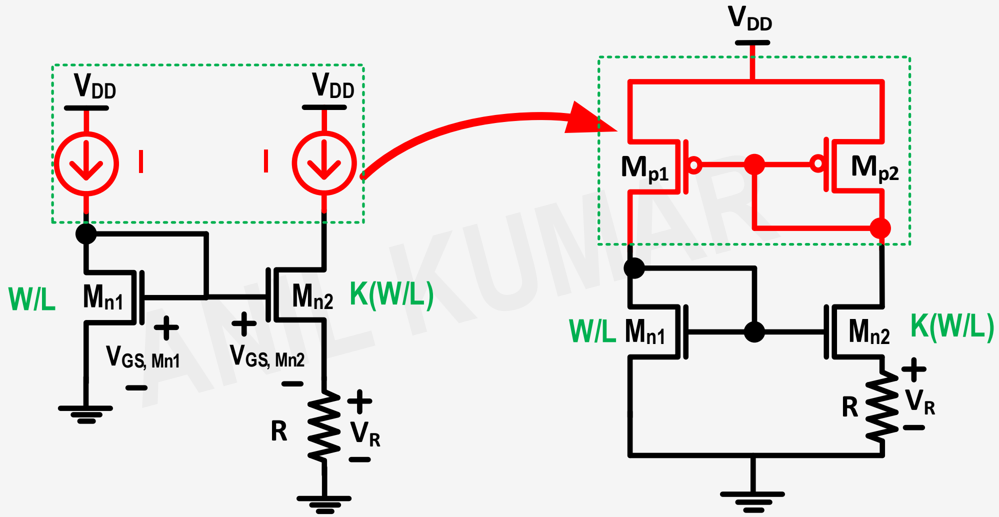
A Systematic and Simplified View of Beta-Multiplier

- One way to bias the devices M_{n1} and M_{n2} is to push the same current to both devices
- How can this be done? Use a matched current mirror (pmos in this case) as it will make sure that M_{n1} and M_{n2} carries same current
- We have two options to push same current to the devices M_{n1} and M_{n2} (shown below left and right):
  - Which option works without any problem

Option-1

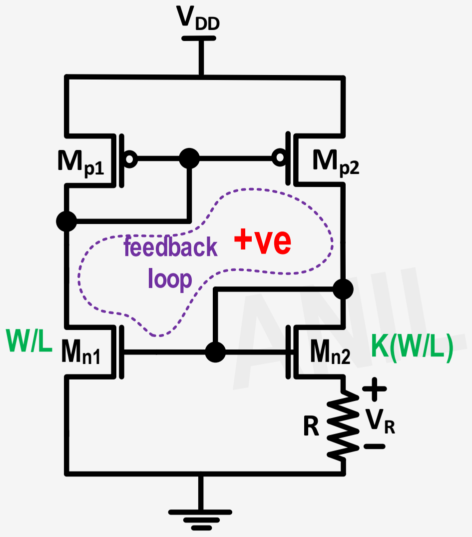


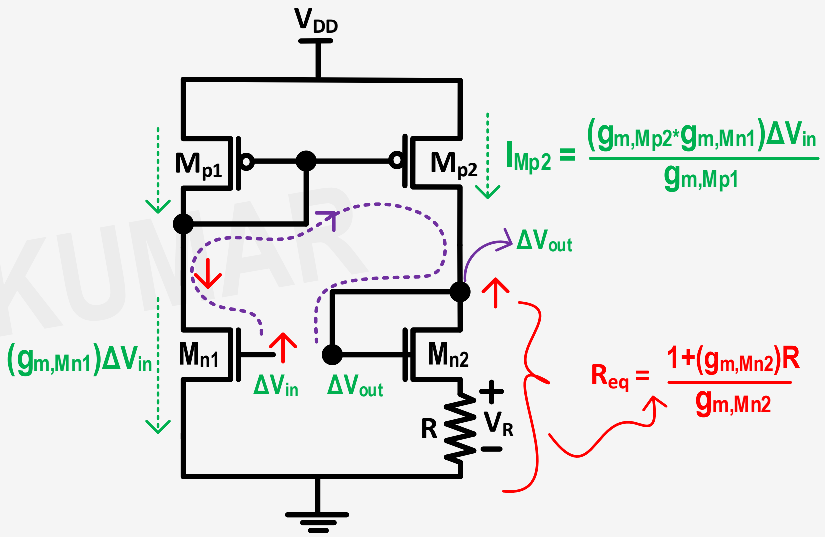
Option-2



A Systematic and Simplified View of Beta-Multiplier – Option 1

- It's a positive feedback loop. The loop gain is larger than 1.
- The loop gain and related analysis is shown below.
- The open loop gain in this case is strictly greater than 1 for any K > 1





$$\Delta V_{out} = \frac{1+(g_{m,Mn2})R}{g_{m,Mn2}} \; \frac{(g_{m,Mp2}*g_{m,Mn1})\Delta V_{in}}{g_{m,Mp1}}$$

$$g_{m,Mn2} = \sqrt{K}*g_{m,Mn1}$$

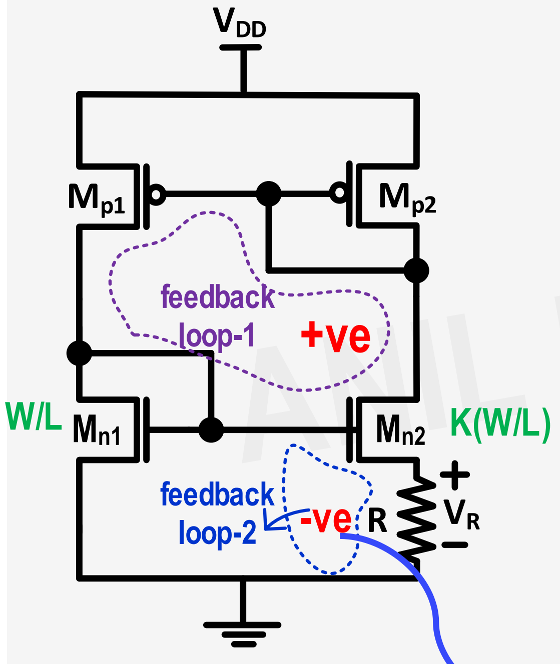
perfectly matched current mirror yield,

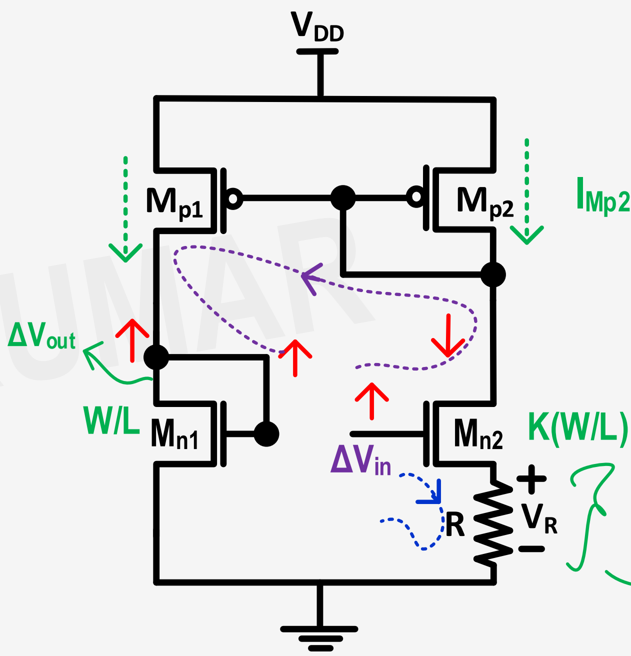
$$\Delta V_{out} = \frac{[1+(g_{m,Mn2})R](g_{m,Mn1})\Delta V_{in}}{g_{m,Mn2}}$$

$$\Delta V_{out} = \frac{[1+(g_{m,Mn2})R]\;\Delta V_{in}}{\sqrt{K}}$$

A Systematic and Simplified View of Beta-Multiplier – Option 2

- It's a positive feedback loop. But the loop gain is smaller than 1.
- The loop gain and related analysis is shown below.
- The open loop gain in this case is strictly less than 1 for any K > 1





$$I_{Mp2} = \frac{g_{m,Mn2}\Delta V_{in}}{(1+R^*g_{m,Mn2})}$$

$$I_{Mp2} = V_R / R$$

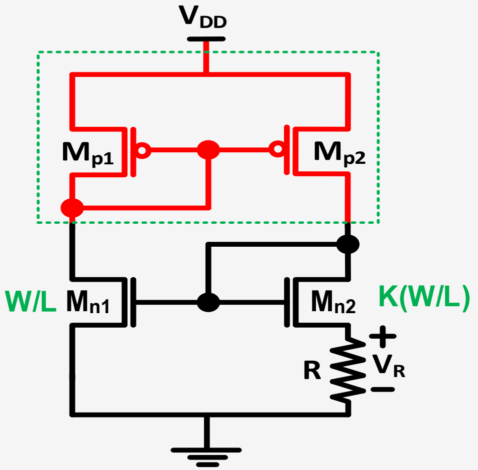
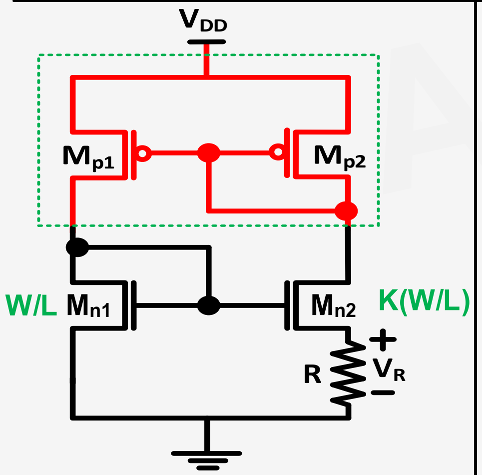
$$V_R = \frac{R^*g_{m,Mn2}\Delta V_{in}}{(1+R^*g_{m,Mn2})}$$

$$\Delta V_{out} = \frac{g_{m,Mn2}\Delta V_{in}}{(1+R^*g_{m,Mn2})}\frac{1}{g_{m,Mn1}}$$

$$\boxed{\Delta V_{out} = \frac{\sqrt{K}\Delta V_{in}}{(1+R^*g_{m,Mn2})}}$$

This loop effectively helps in keeping loop gain less than 1

Beta-Multiplier at a Glance

	feedback	DC Loop Gain	stability	gm
	**positive**	$\Delta V_{out} = \frac{2\sqrt{K}-1}{\sqrt{K}} \Delta V_{in}$ Loop gain is greater than 1 **> 1**	**unstable**	**gm is not stabilized**
	**positive**	$\Delta V_{out} = \frac{\sqrt{K}}{2\sqrt{K}-1} \Delta V_{in}$ Loop gain is less than 1 **< 1**	**stable**	$g_{m,Mn1}R = \frac{2(\sqrt{K}-1)}{\sqrt{K}}$ **(constant)**