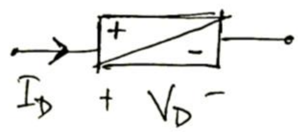
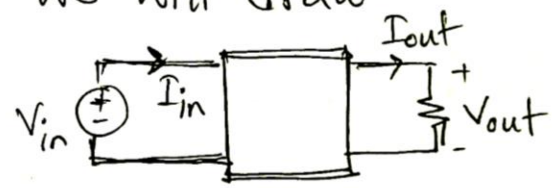
# Transfer Characteristics

Till now, we have seen the I-V characteristics of devices.
This is the graph of the current of a device vs. its voltage.




Now, we will ~~a~~ see another type of characteristics. If we plot any output parameter of a circuit (~~&~~ $V_{out}$, or, $I_{out}$) vs. any input parameter ($V_{in}$, or, $I_{in}$), the resulting graph is the transfer characteristics of that ckt.

[Note: We drew the IV of a device, but, we will draw the Transfer Char. of a ckt]



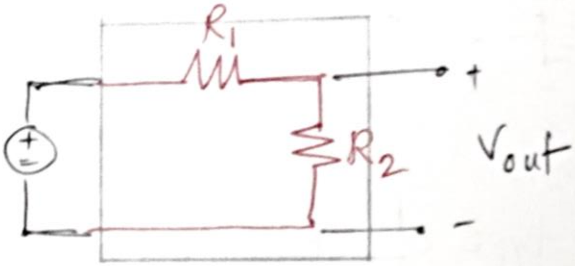

The plot of $V_{out}$ vs. $V_{in}$ is called the Voltage Transfer Characteristics (VTC) of a ckt.

The plot of $I_{out}$ vs. $I_{in}$ is called the Current Transfer Characteristics (CTC) of a ckt.

The others ($V_{out}$ vs. $I_{in}$, or, $I_{out}$ vs. $V_{in}$) don't really have a special name. They are just called Transfer characteristics.

$\boxed{1}$ We will ~~[illegible]~~ look at the VTC of some of the circuits we have studied until now.

(1) Voltage Divider:

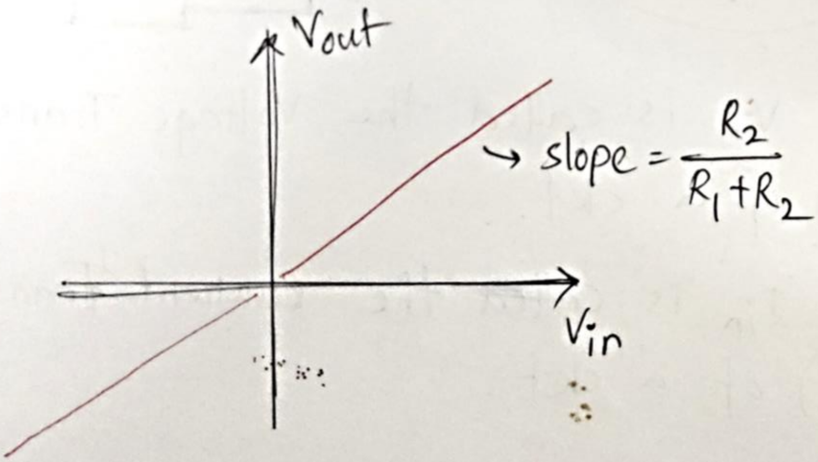



From Voltage-Division Rule, we have,

$$V_{out} = \frac{R_2}{R_1 + R_2} \cdot V_{in}$$

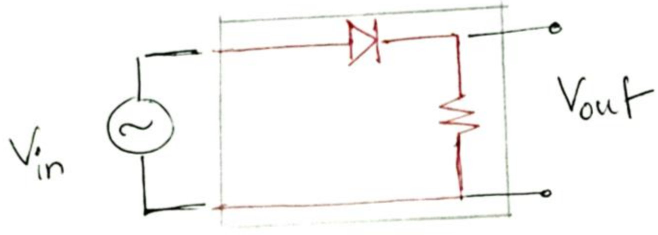
This is of the form $y = mx$ $\quad$ [If $y = V_{out}$, $x = V_{in}$]

$\therefore$ The VTC looks like this:




Note: For a Voltage Divider, slope of the VTC is less than 1. In fact, for any ckt with passive devices, the slope can be at most 1. For a slope higher than 1, (i.e, higher change in output than input, we will need an amplifier.

## (2) Rectifier (Half-Wave):

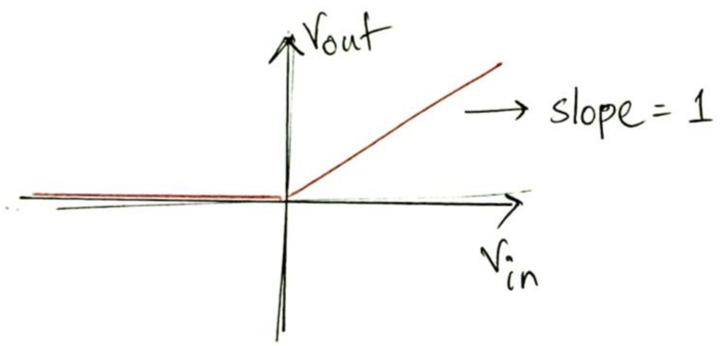



If the diode is ideal,

for +ve cycle, $(V_{in} > 0)$, we have $V_{out} = V_{in}$ [$\because$ diode is short]

for -ve cycle, $(V_{in} < 0)$, we have $V_{out} = 0$ [$\because$ diode is open].

The VTC will look like this:

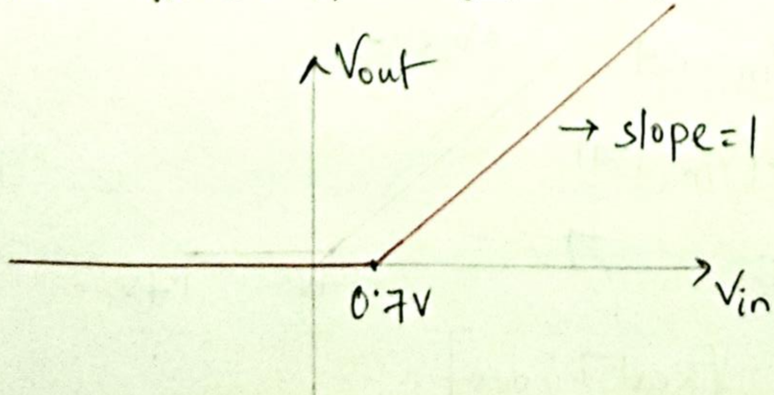



[Ideal Diode]

For real diodes, the diode will be ON, if the input ~~does~~ surpasses 0.7V. Also, the output will be 0.7V below the input.

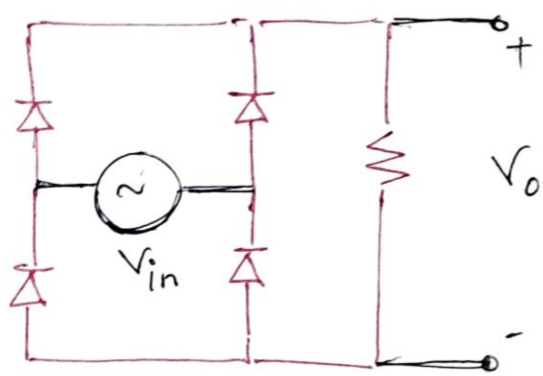
$\therefore$ For $V_{in} > 0.7$, $V_{out} = V_{in} - 0.7$

For $V_{in} < 0.7$, $V_{out} = 0$.




[Real Diode]

(3) Rectifier (Full-Wave):



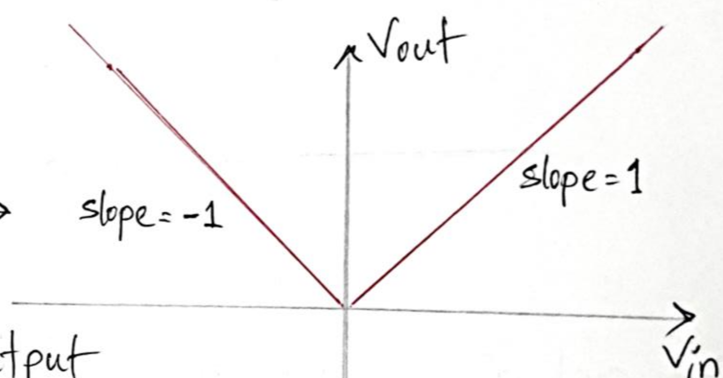

As before, for ~~the~~ ideal diodes,

For +ve cycle, ($V_{in} > 0$), $V_{out} = V_{in}$.

And for -ve cycle, ($V_{in} < 0$), the input will be flipped at the output. $\therefore$ $V_{out} = -V_{in}$.

The VTC will be: →

[Ideal Diodes] →




For real diodes, we will have output if the input surpasses 2 diode drops. [$\because$ 2 diodes will be active in any cycle].

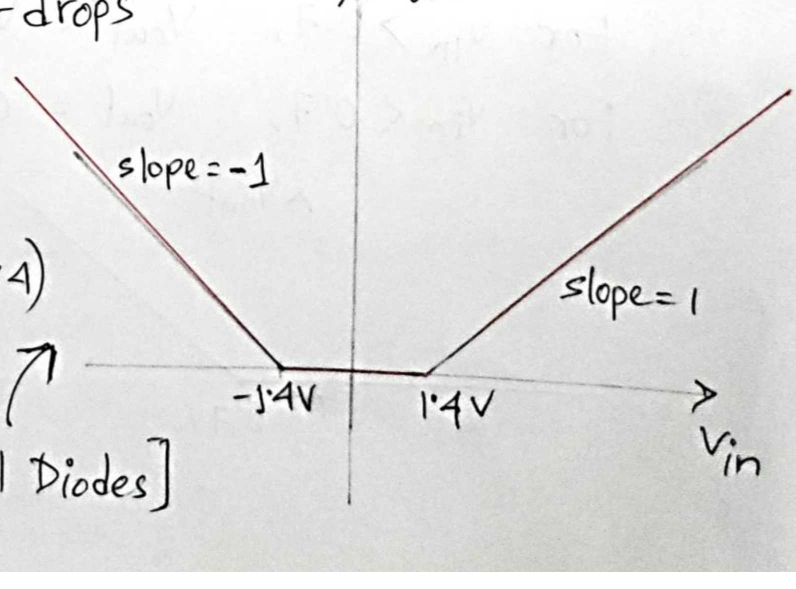
And, the output will be 2 diode-drops below the input.

$\therefore$ If $V_{in} > 1.4$, $V_{out} = V_{in} - 1.4$

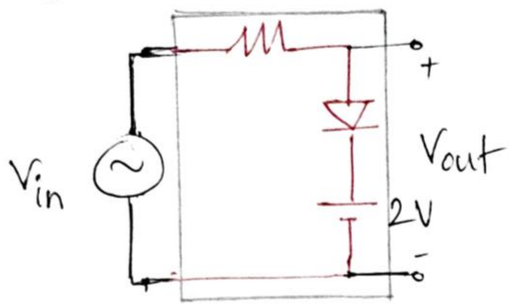
If $V_{in} < -1.4$, $V_{out} = -(V_{in} - 1.4)$

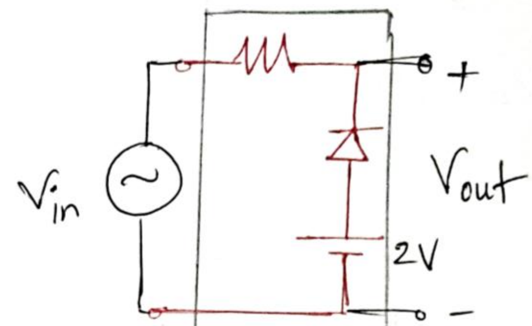
For $-1.4 < V_{in} < 1.4$ $V_{out} = 0$.

[Real Diodes]



# (4) Clipper Circuits:




This ckt will pass everything below 2V as is. ~~For~~ All voltages above 2V will be clipped at 2V.

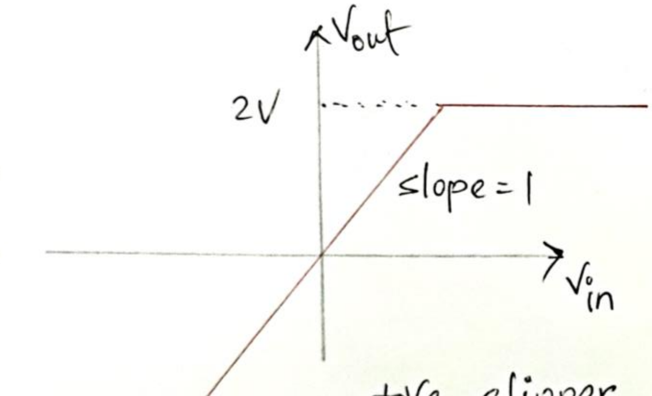
$\therefore$ If $V_{in} < 2V$, $V_{out} = V_{in}$

If $V_{in} > 2V$, $V_{out} = 2V$

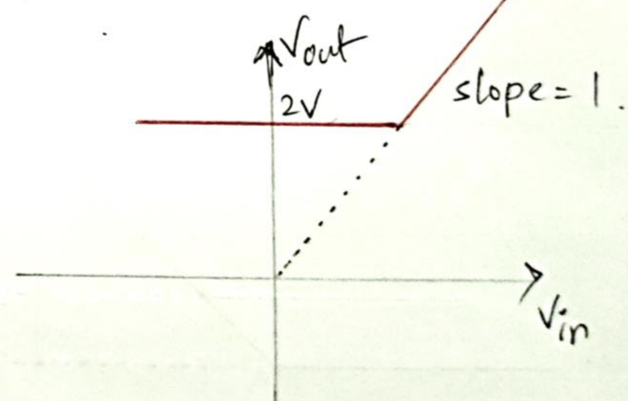
This ckt will pass everything above 2V. And, all voltages below 2V will be clipped at 2V.

If $V_{in} < 2V$, $V_{out} = 2V$

If $V_{in} > 2V$, $V_{out} = V_{in}$

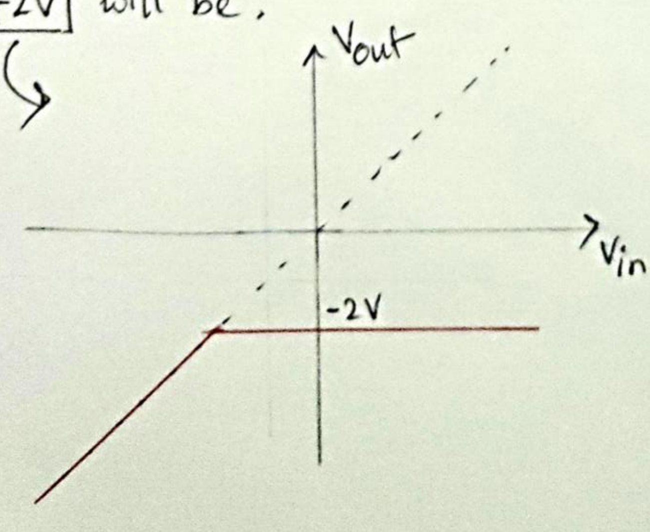



+ve clipper

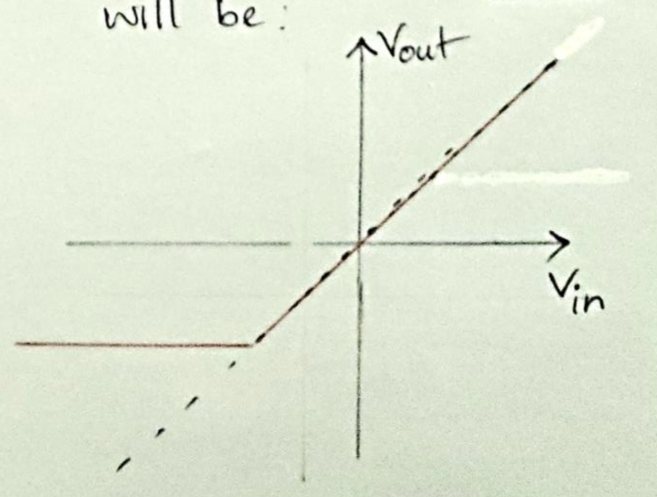



-ve clipper

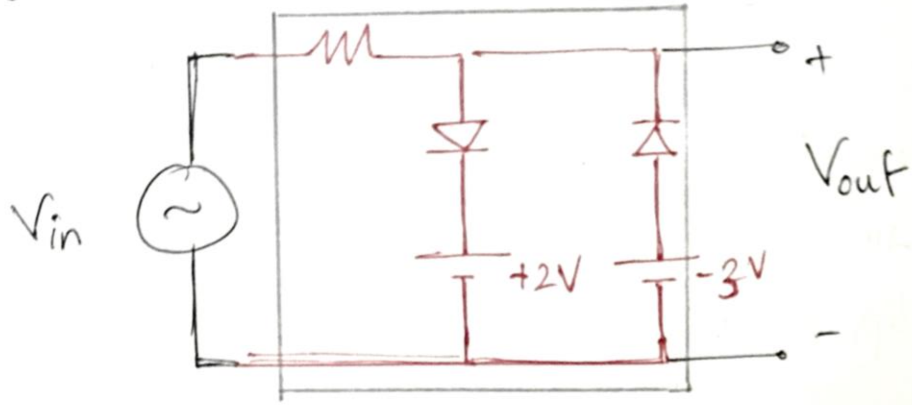
Similarly, VTC of a +ve clipper at $\boxed{-2V}$ will be:

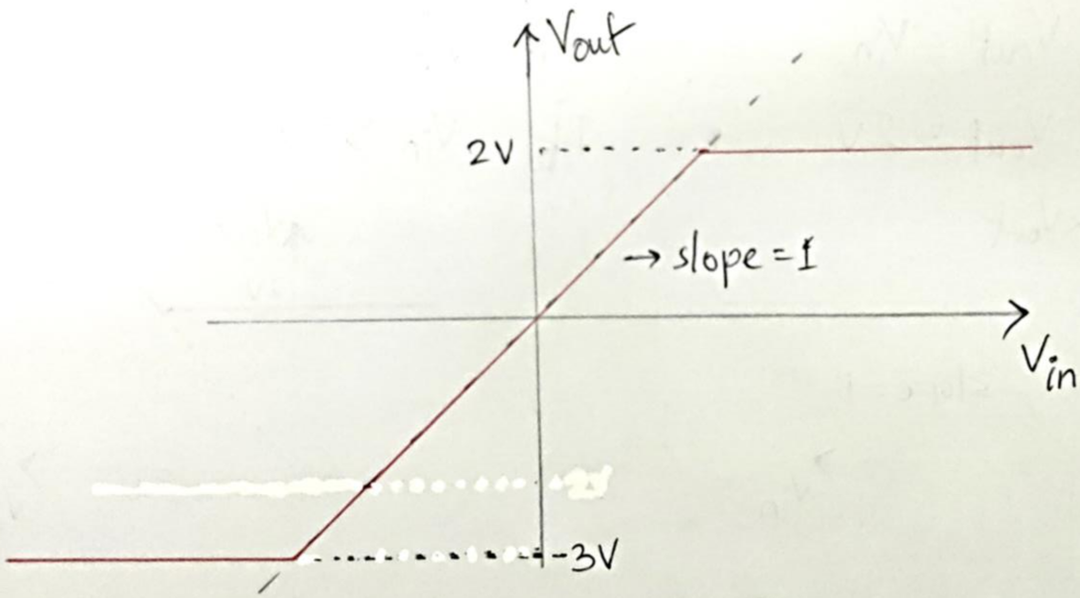



And -ve clipper at $\boxed{-2V}$ will be:



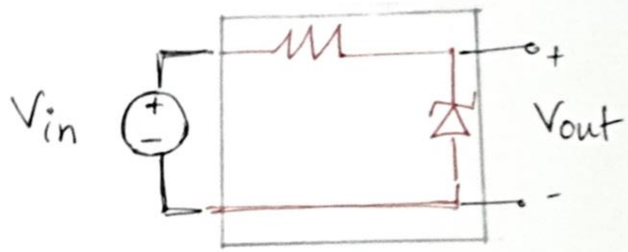
If we cascade a +ve clipper at 2V, and, a -ve clipper at -3V, we get,




VTC of a Cascaded Clipper

## (5) Voltage Regulator:



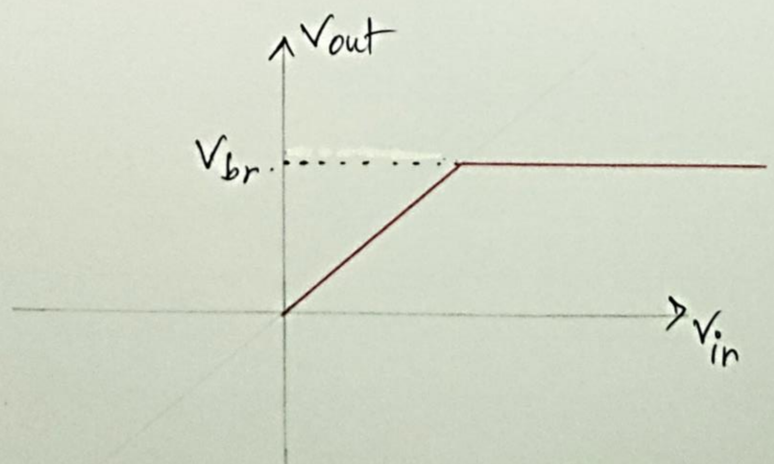

If the zener-diode is ideal, the IV of it is completely Vertical during breakdown, So, as long as the input is above the breakdown voltage, the zener voltage will be fixed (at the breakdown voltage).

$\therefore$ If $V_{in} > V_{breakdown}$, $V_{out} = V_{breakdown}$

If the input is below the breakdown voltage, the zener will be open-circuited. So, the output voltage will be equal to the input.

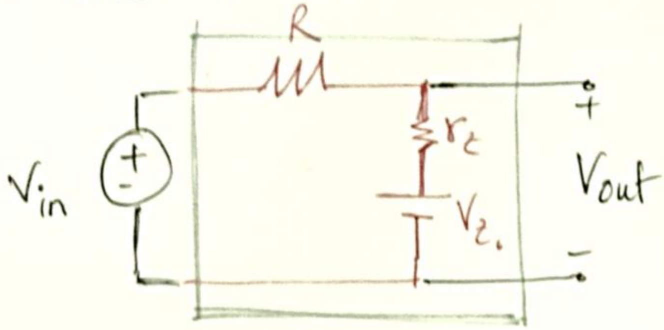
$\therefore$ If $V_{in} < V_{breakdown}$, $V_{out} = V_{in}$

The VTC looks like this,

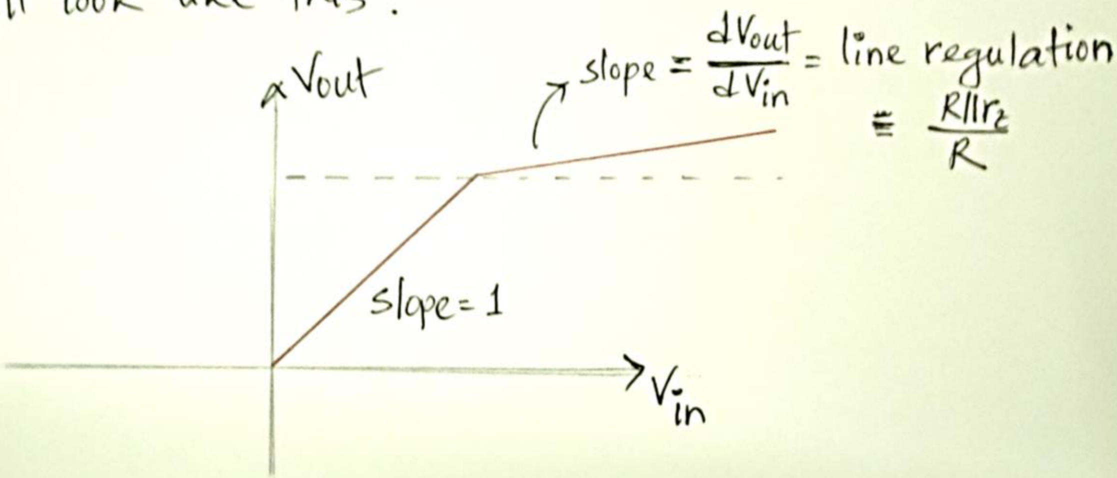



Note the similarity in VTC with that of a clipper circuit. So, a clipper is kind of like a voltage regulator as well.

If the zener is non-ideal (i.e, there is a slope in the IV characteristics during breakdown), the VTC won't be completely flat. In that case, we have to use the Voltage Source + Series Resistance model of the zener diode while in breakdown.




The VTC will look like this:




Note that the VTC has a slope in the breakdown region. The slope is equal to $\frac{dV_{out}}{dV_{in}}$, which is the line-regulation.

So, this is just a graphical representation of the non-ideality of a zener regulator we saw before.