Lecture4:
Diode circuits

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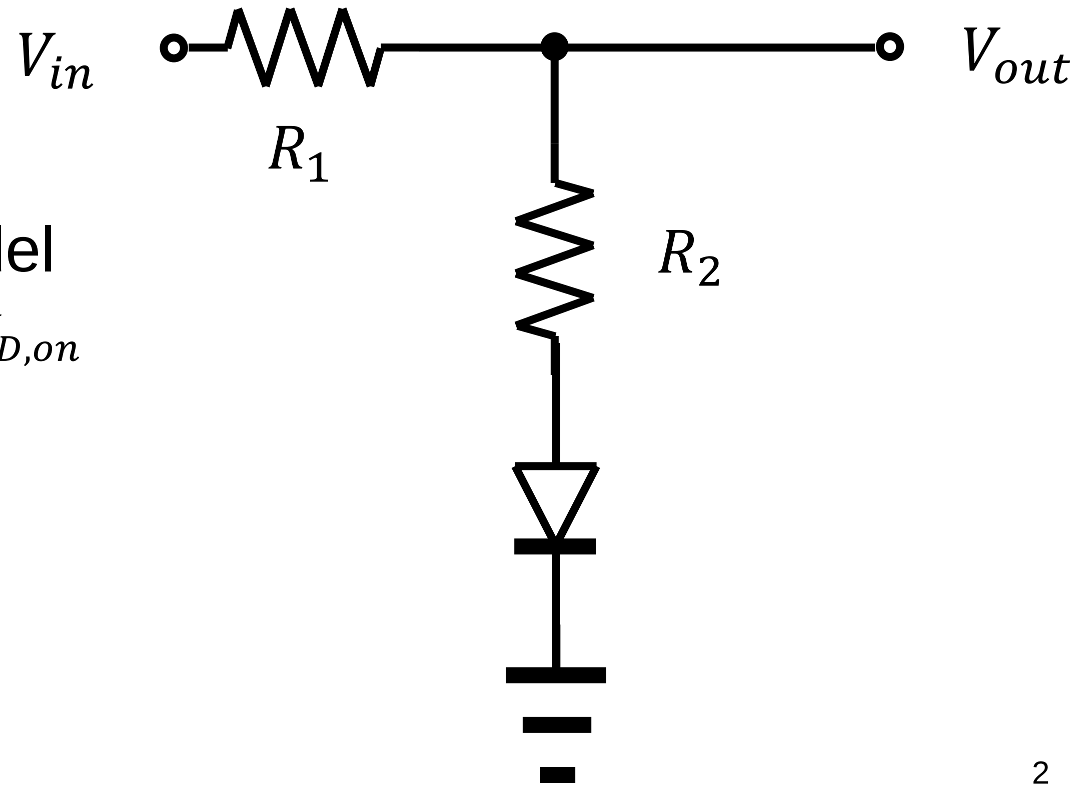
PN junction as a diode

- Exponential model

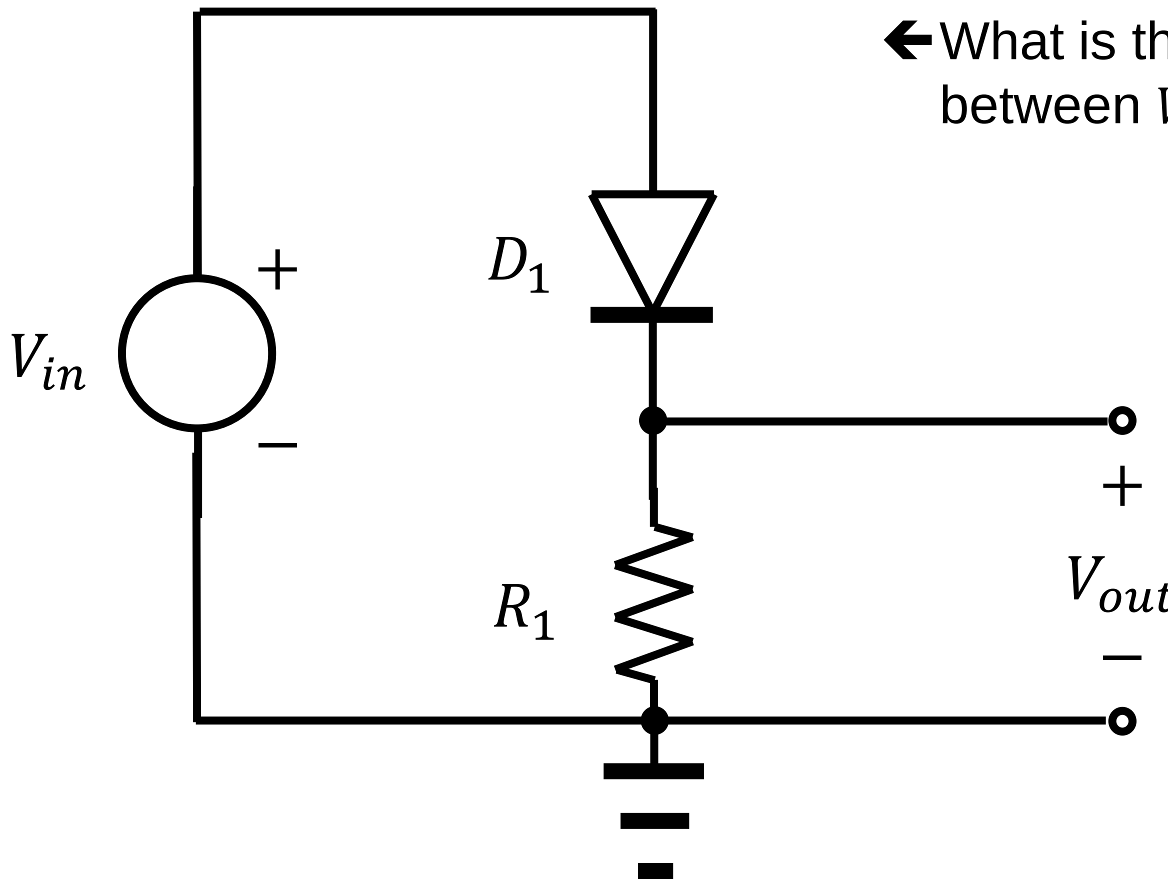
$$I_D = I_s\left(\exp\frac{V_D}{V_T} - 1\right)$$

- Constant-voltage model
  – An "offset" voltage of $V_{D,on}$



Rectifier

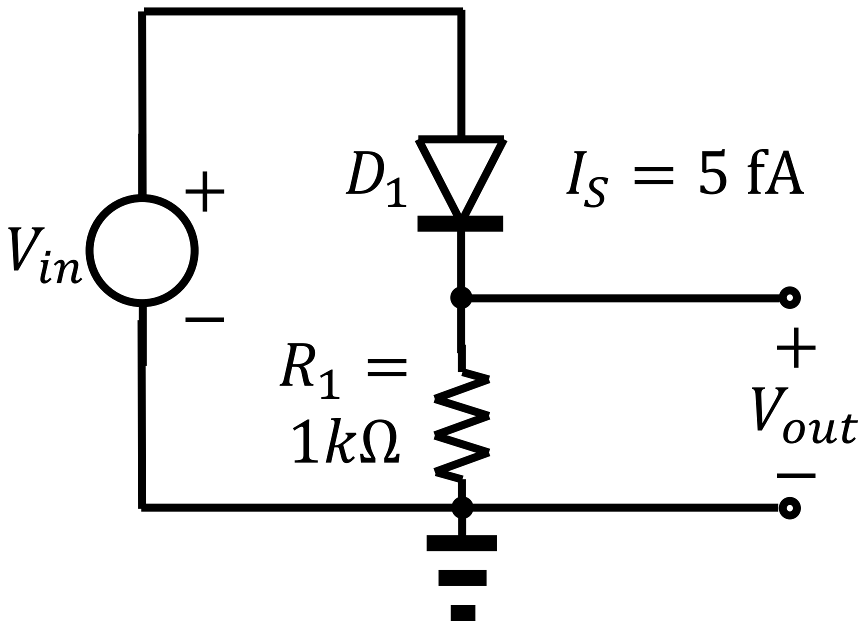
- Revisiting our first example
  - Analyze it by using the constant-voltage model

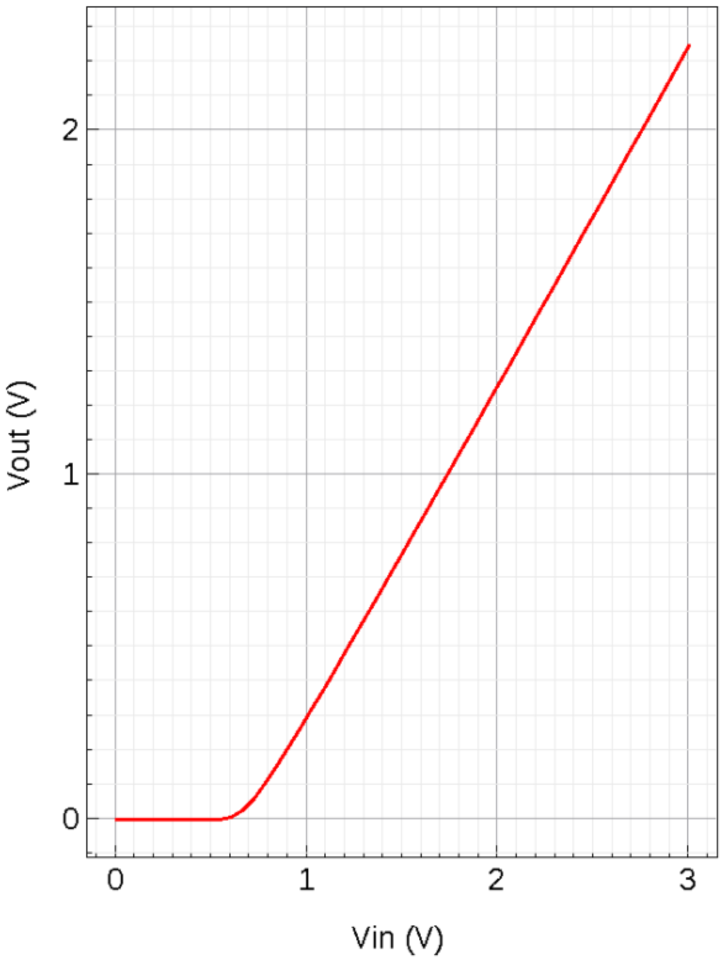


← What is the relation between V_{in} and V_{out}?

Simulation result

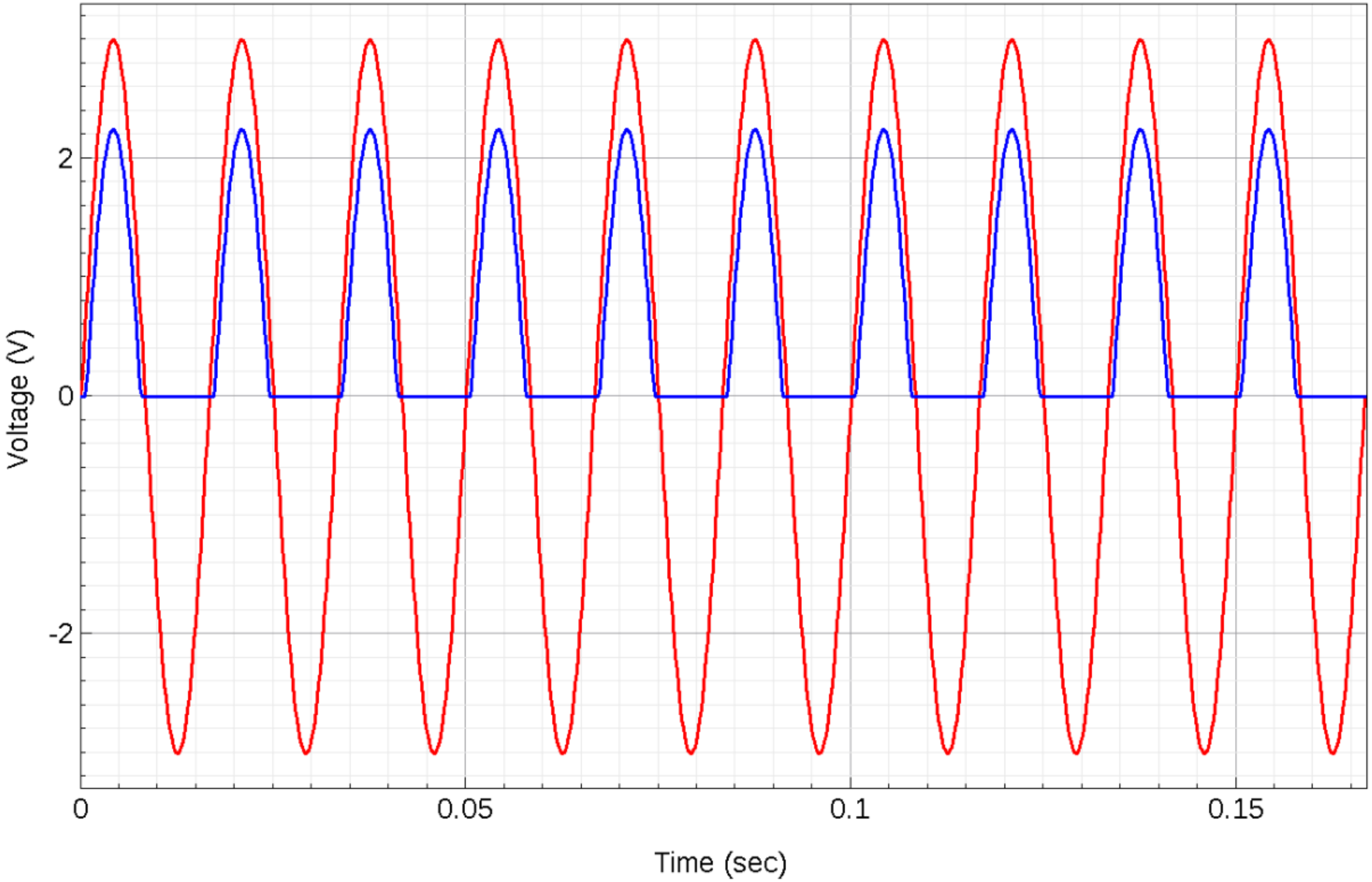
- Specific example of $I_S = 5$ fA and $R_1 = 1\ k\Omega$.





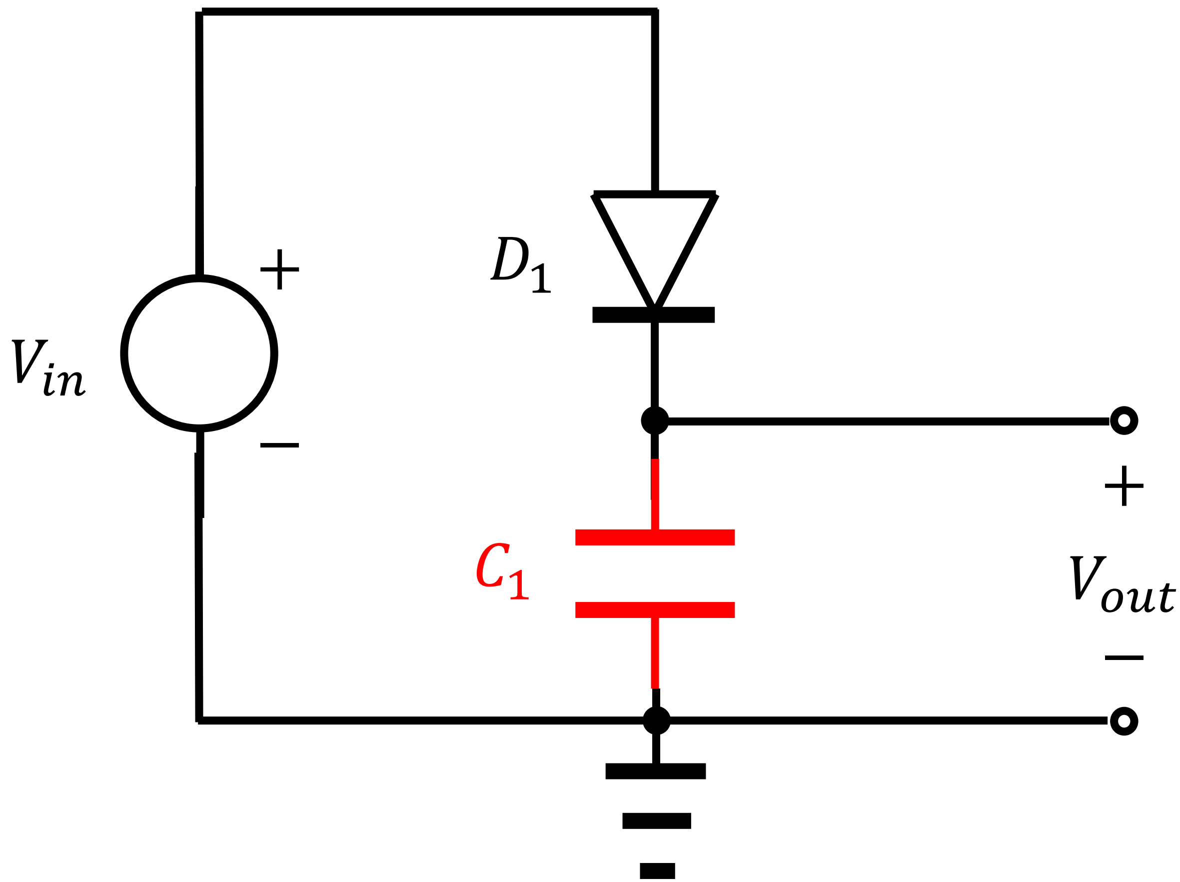
Time-varying voltage source

- For example, $V_{in}(t) = 3\sin(2\pi f t)$ V.
  - 60 Hz, 10 periods



Introducing a capacitor

- Difference from the previous one?
  - First, consider the DC case. Remember that $I_C = C_1 \frac{d}{dt} V_{out}$.

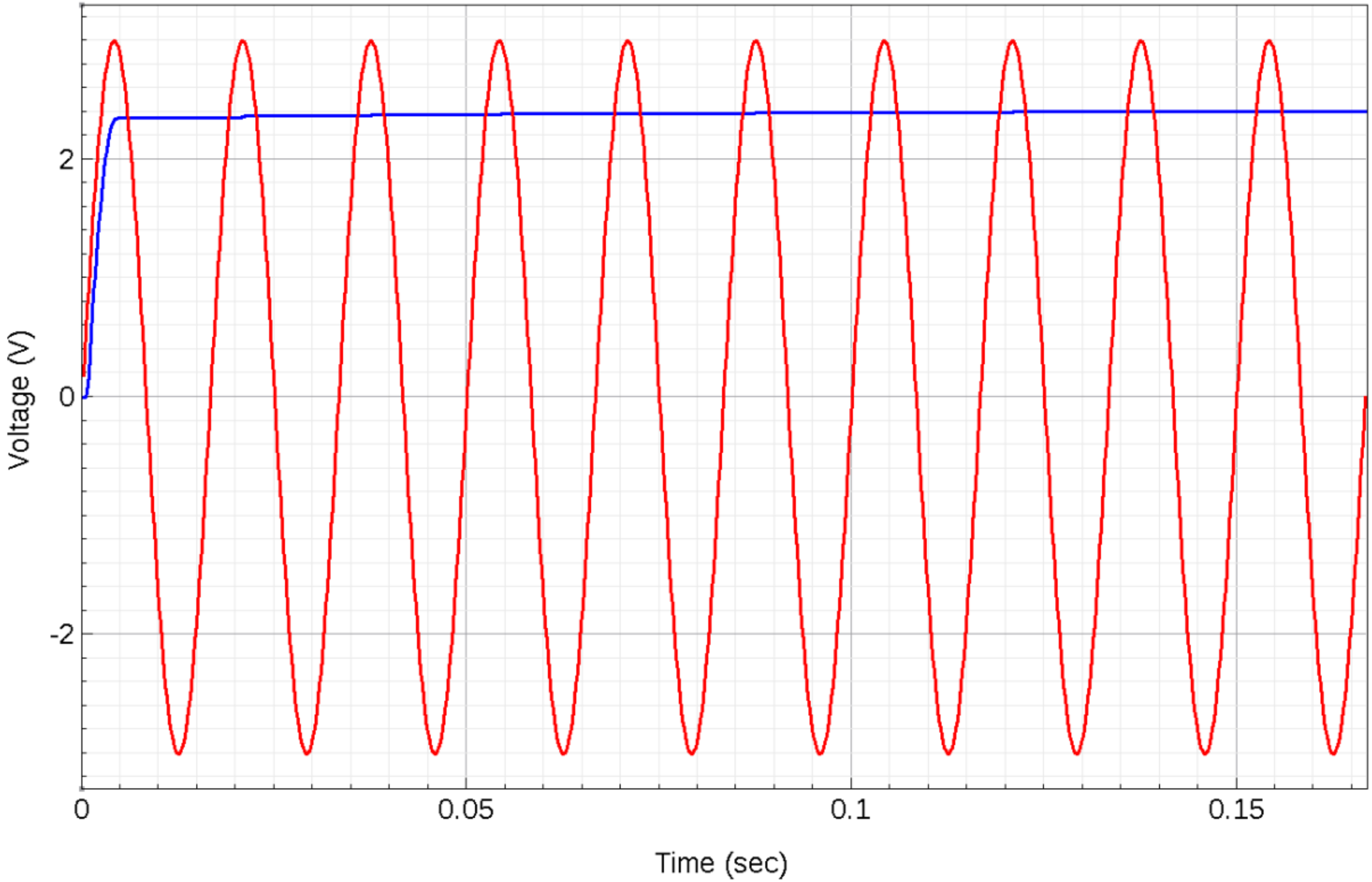


Qualitative understanding

- Consider the first period.
  - When the input voltage exceeds $V_{D,on}$, the diode is turned on.
  - The charge is stored in the capacitor. Hence, the output voltage increases.
  - When the input voltage is lower than $V_{D,on}$, the output voltage does not change. (*Why?*)
- After the first period…
  - In the second period, the diode current is smaller than the one in the first period. (*Why?*)
  - After some periods, the diode current vanishes.
  - A DC output voltage is established.

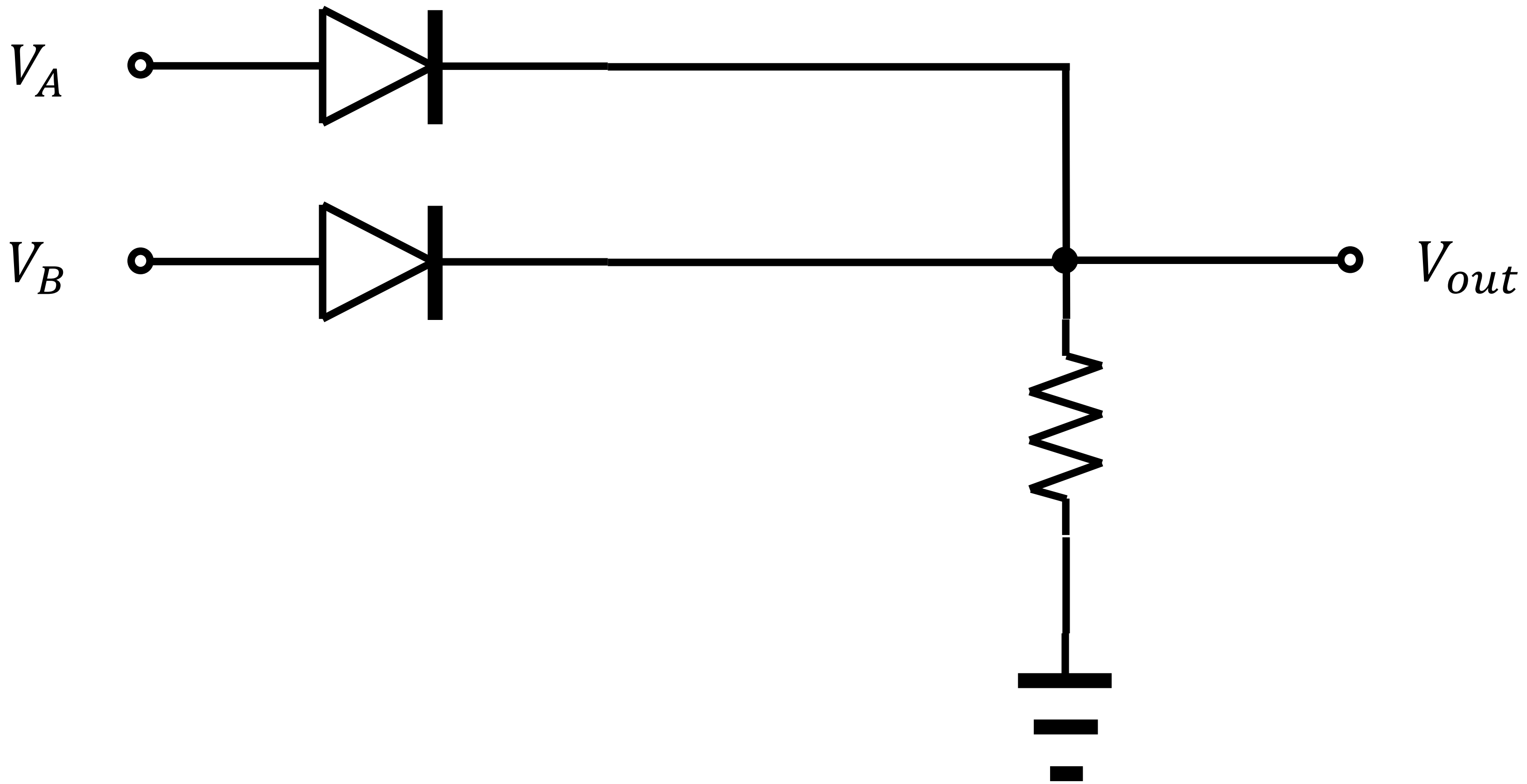
Simulation result

- The capacitance, $C_1 = 1\ \mu\mathrm{F}$.



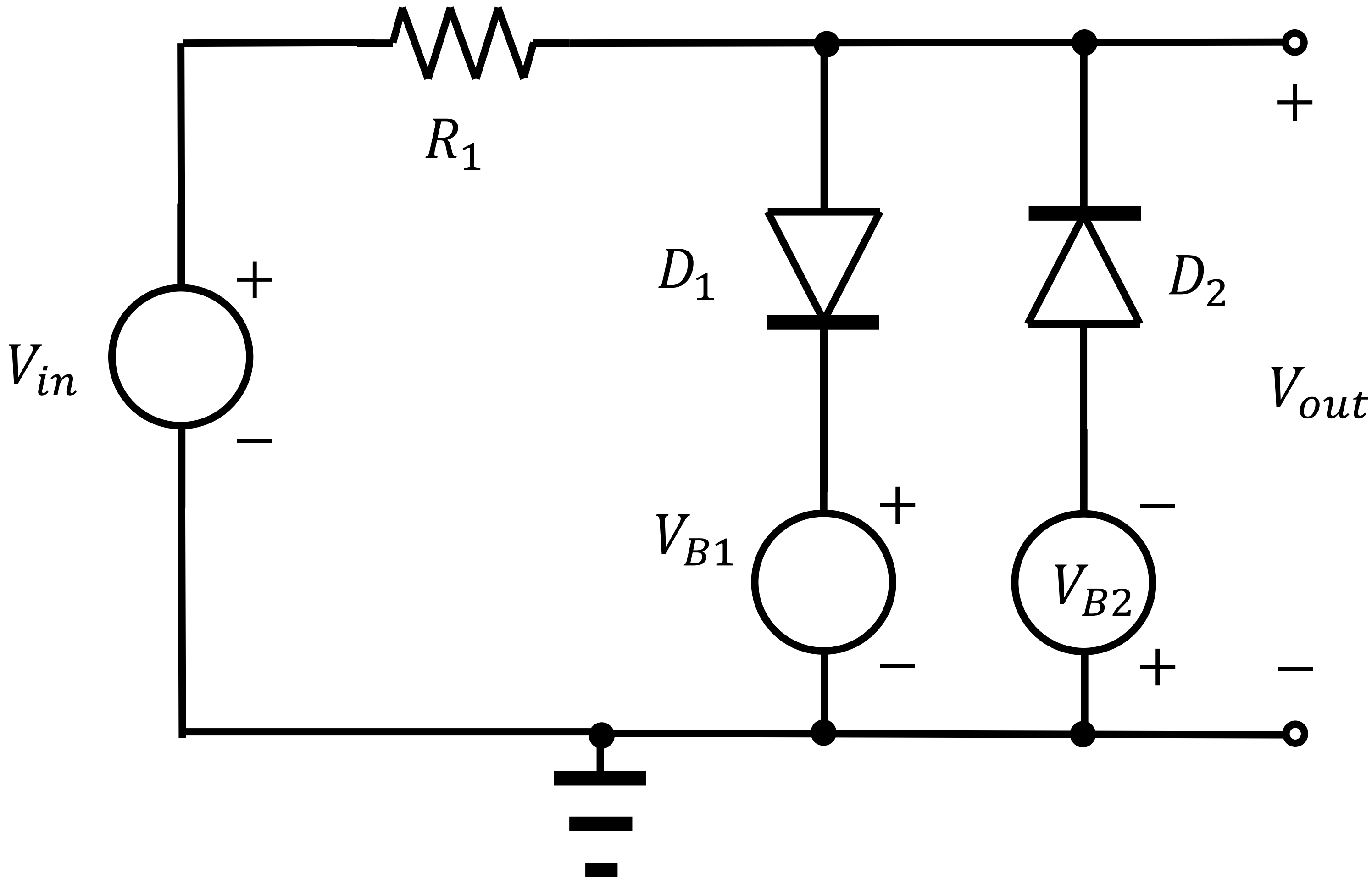
Example 3.6 (Razavi)

- An OR gate



Limiter

- Level-shift for both half cycles



A simple math, again

- Taylor series expansion
  - Consider a function, $f(x)$.
  - Then, at $x_0 + \Delta x$ (Δx is small.), the function value would be similar to that at x_0:

$$f(x_0 + \Delta x) \approx f(x_0)$$

  - A better approximation?

$$f(x_0 + \Delta x) \approx f(x_0) + \left.\frac{df(x)}{dx}\right|_{x=x_0} \Delta x$$

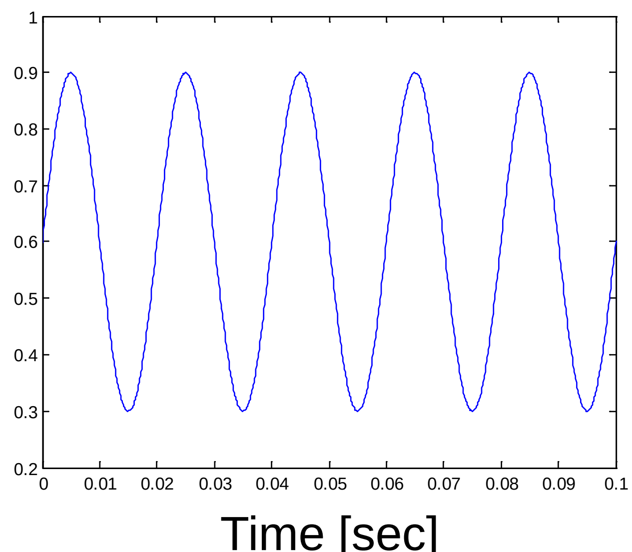
  - Nonlinear function ➔ linearly approximated!

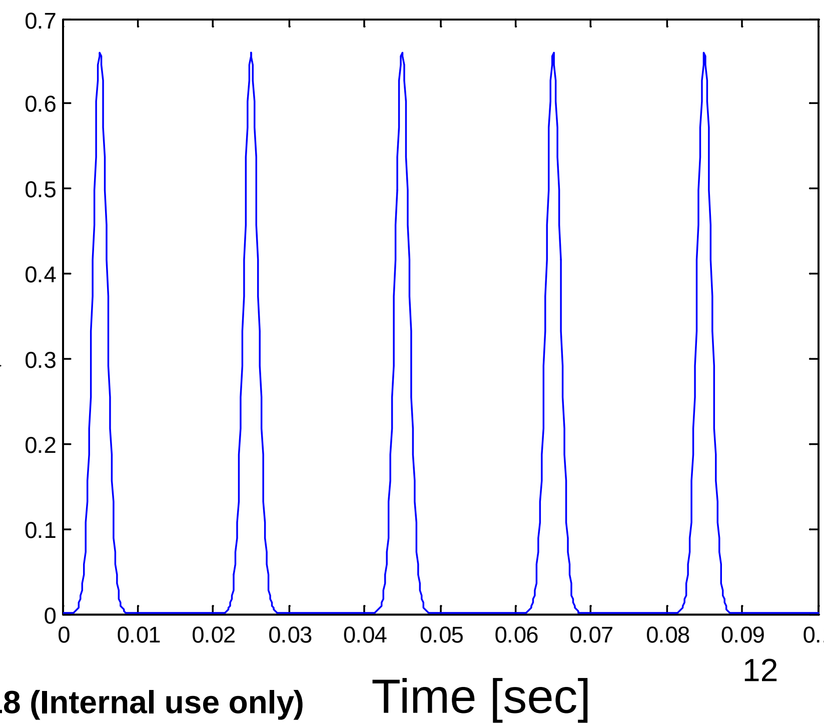
A system

- A system (You know what it actually represents.)

$$V_{in} \longrightarrow \boxed{I_{out} = I_s \exp\frac{V_{in}}{V_T}} \longrightarrow I_{out}$$

- When $V_{in} = 0.6 + 0.3\sin 2\pi f t$,
  - Certainly, nonlinear!





Smaller amplitude?

- When $V_{in} = 0.6 + 0.001 \sin 2\pi f t$,
  - Nonlinear?