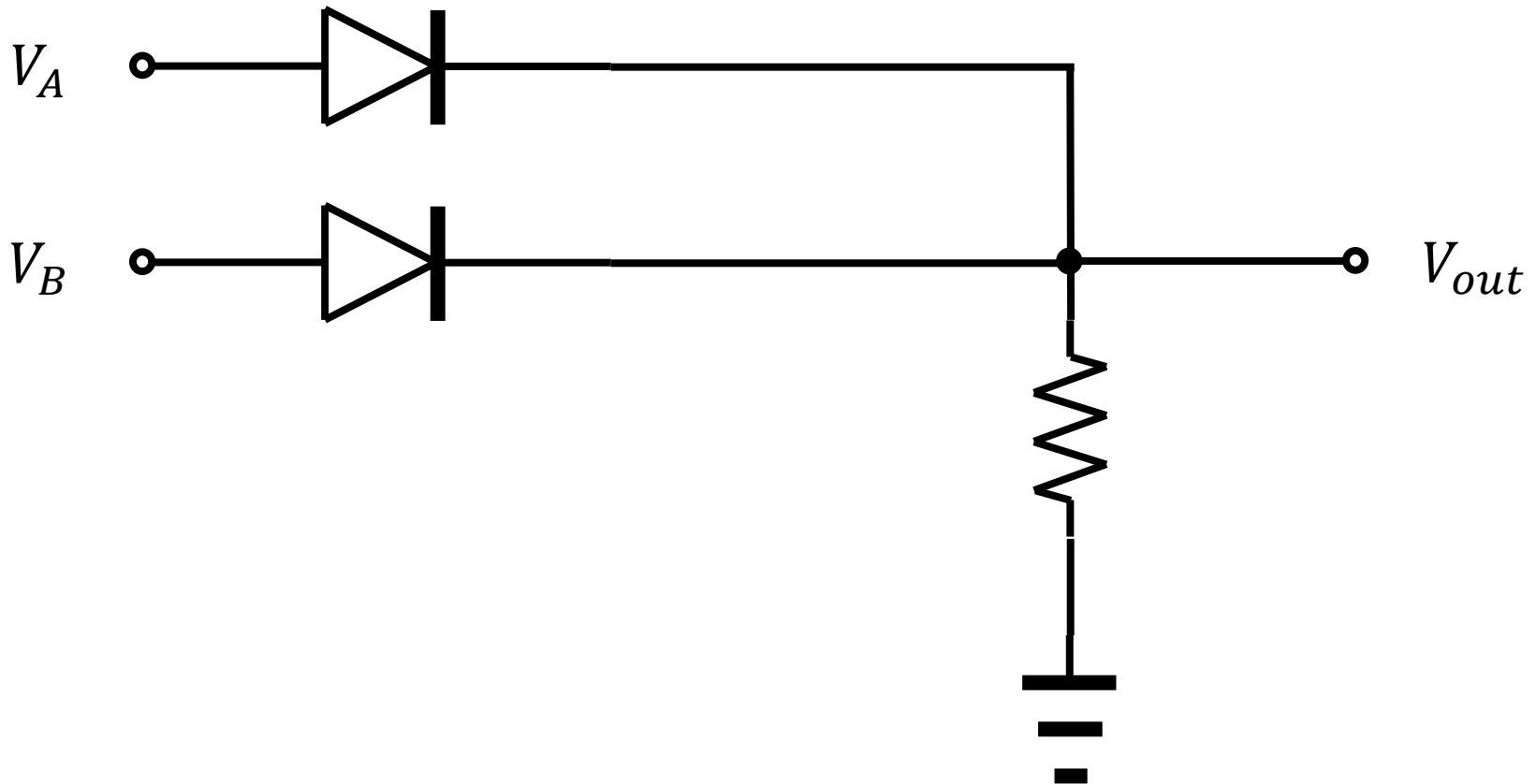

Lecture5: Small-signal analysis

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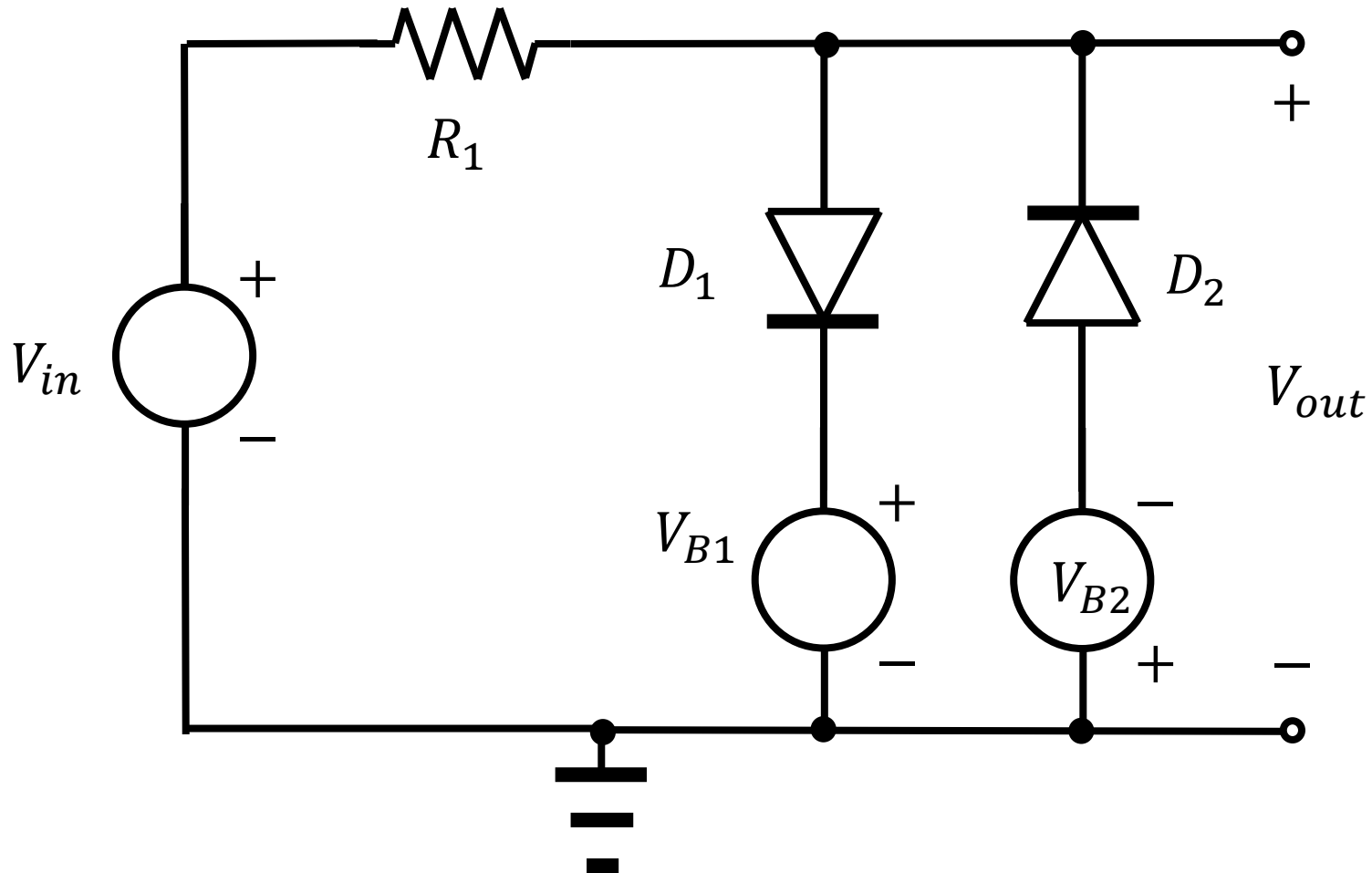
Example 3.6 (Razavi)

- An OR gate



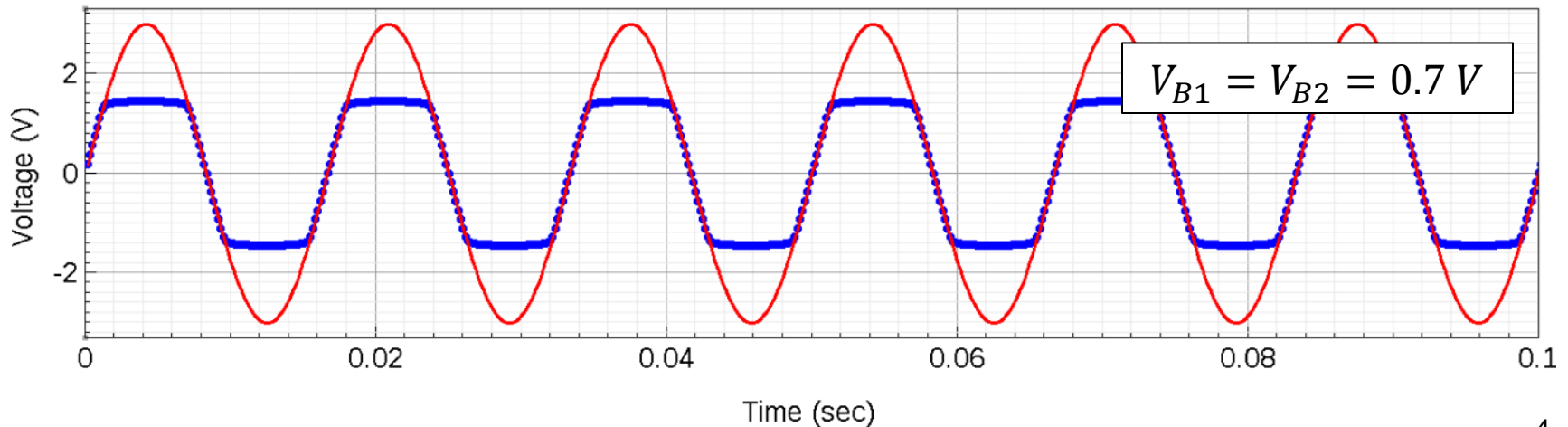
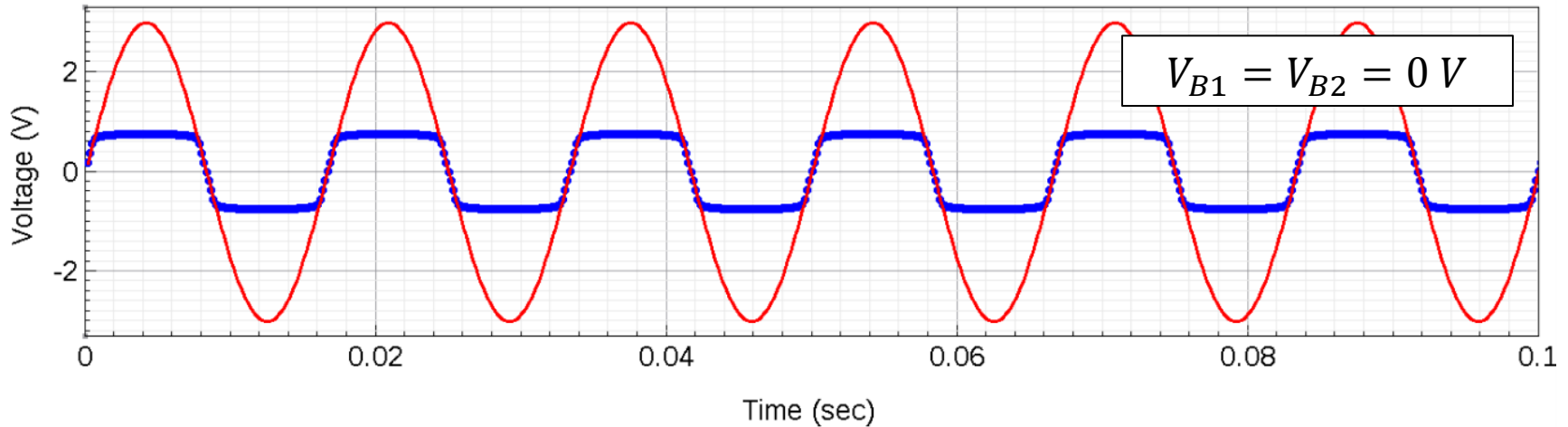
Limiter

- Level-shift for both half cycles



Simulation result

- An input voltage with 3 V amplitude



A simple math

- 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 :

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

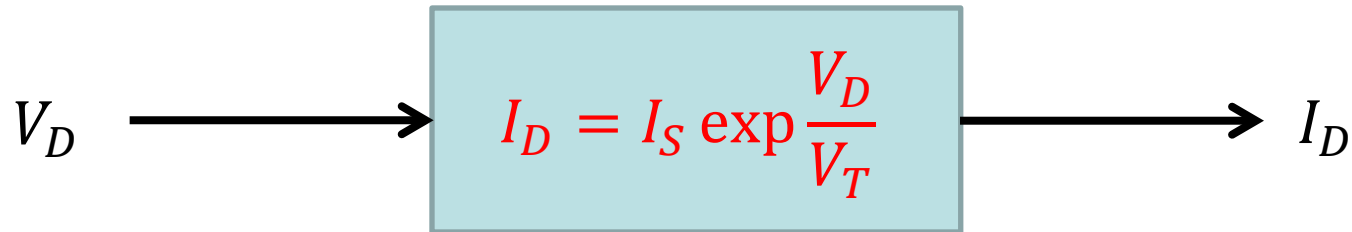
- A better approximation?

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

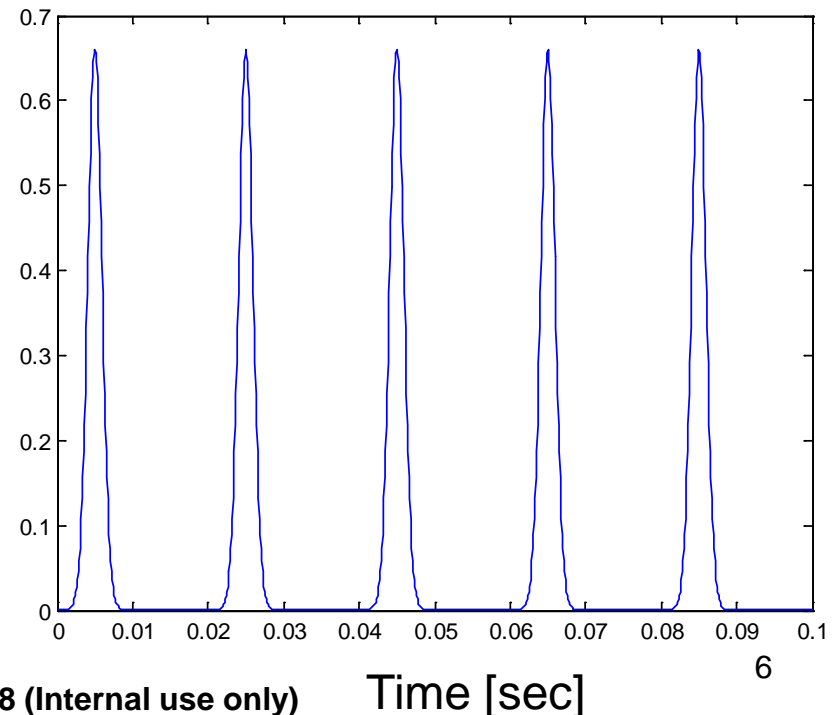
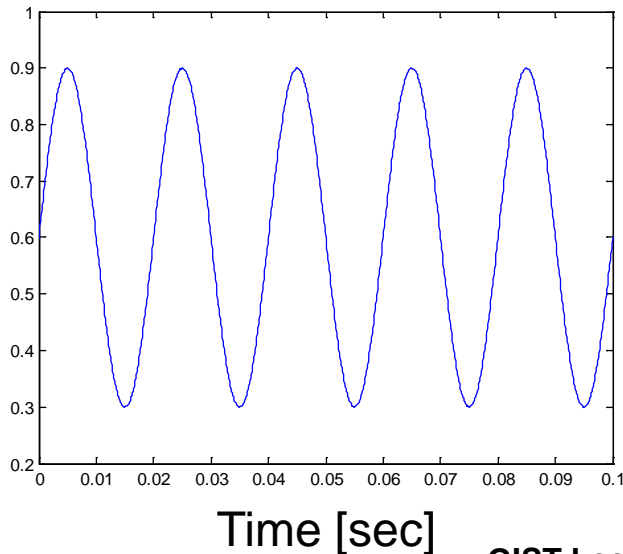
- Nonlinear function → linearly approximated!

Nonlinear system

- A diode: Input V_D , output I_D

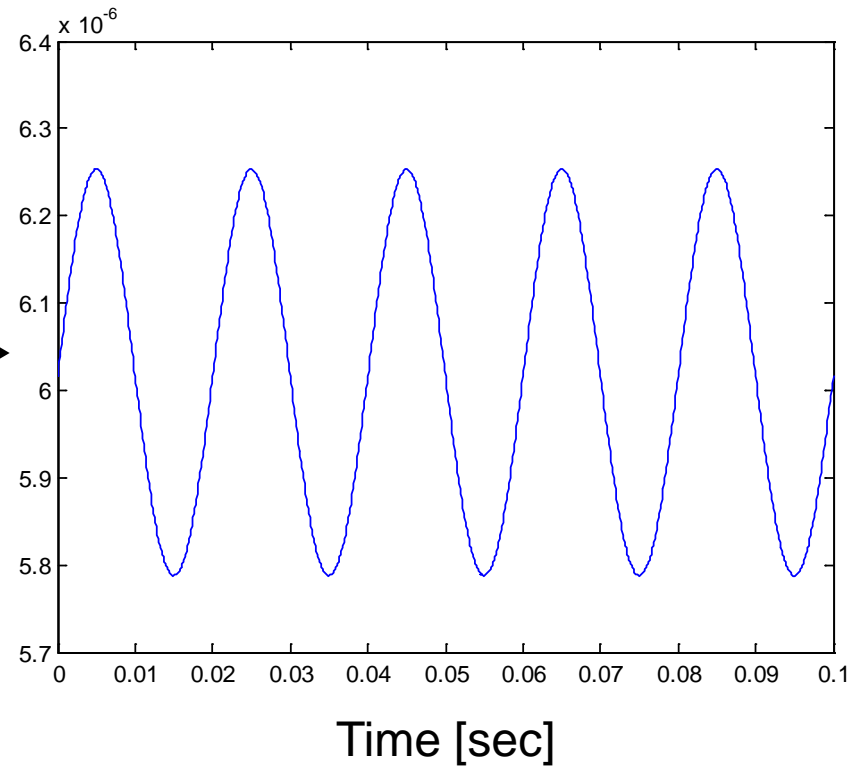
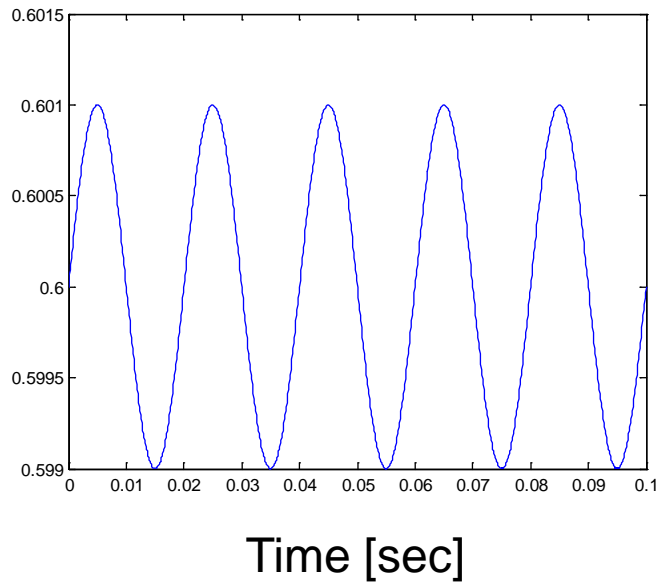


- When $V_{in} = 0.6 + 0.3 \sin 2\pi f t$,
 - I_D is not sinusoidal.



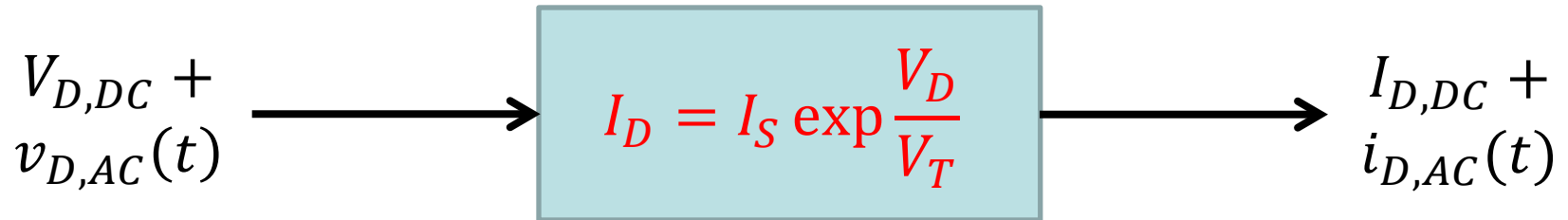
Smaller amplitude of input

- When $V_{in} = 0.6 + 0.001 \sin 2\pi f t$,
 - I_D is almost sinusoidal.



Small-signal analysis

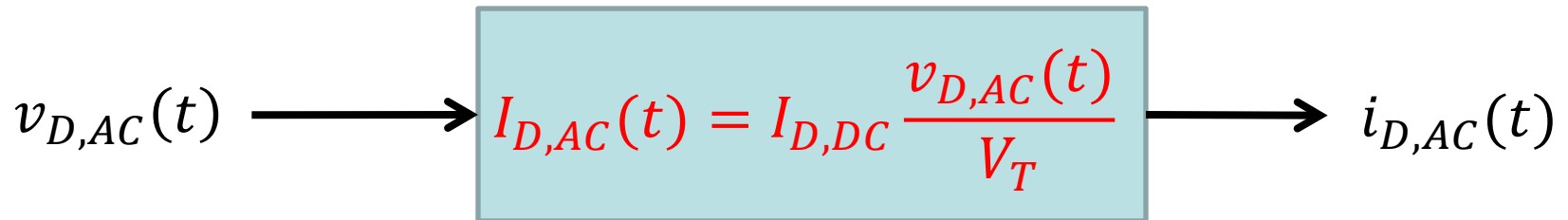
- General case



- “Small-signal” case

– When $v_{D,AC}(t)$ is small, then, the AC current is given by

$$i_{D,AC}(t) \approx I_{D,DC} \frac{v_{D,AC}(t)}{V_T}$$



Example 3.18 (Razavi)

- A diode is biased at a current of 1 mA.
 - Determine the current change if V_D changes by 1 mV.

$$i_D = \frac{I_D}{V_T} v_D \approx 40 \mu\text{A}$$

- Small-signal resistance
 - As far as small changes in the diode current and voltage are concerned, the device behaves as a linear resistor.

$$r_d = \frac{V_T}{I_D}$$

Example 3.19 (Razavi)

- When the small change in the diode voltage is time-varying,
 - What happens?

$$I_D(t) = I_s \exp \frac{V_{D,DC} + \Delta V \cos \omega t}{V_T} = I_s \exp \frac{V_{D,DC}}{V_T} \exp \frac{\Delta V \cos \omega t}{V_T}$$

$$I_D(t) \approx I_{D,DC} \left(1 + \frac{\Delta V \cos \omega t}{V_T} \right)$$

- The output current has the same frequency!

Homework#3 (1)

- Due: 09:00, March 26
- Write another program, which reads two input files.
 - One represents a square matrix, A . The first line shows the size. It is followed by triplets: a row index, a column index, and an entry. If not specified otherwise, the entry is assumed to be zero. For example, a 2x2 identity matrix is given by
2
1 1 1.0
2 2 1.0
 - The other represents a vector, b . The first line shows the size. The rest of the file specifies the entries.
 - The program calculates a vector, $x = A^{-1}b$.
 - Data files (`A.dat` and `b.dat`) will be uploaded.

Homework#3 (2)

- Solve the following problems of the mid-term exam in 2017.
 - P1
 - P2
 - P3
 - P4
 - P5
 - P7
 - P8
 - P9