Lecture22: Transient

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Calendar

- Plan for remaining lectures
  - IEDM business trip

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		[illegible]	17	18	19	20
[illegible]	22	[illegible]	24	[illegible]	26	27
28 (No lecture)	29	30 (L22)	Dec.1	2 (L23)	3	4
5 (No lecture)	6	7 (No lecture)	8	9	10	11
12 (L24)	13	14 (L25)	15	16 (Final)	17	18

Transient

- Continuity equation

$$\frac{\partial}{\partial t} n + \nabla_r \cdot \mathbf{F}_n = 0$$

- Previously, we neglected the time derivative term.
  - Mostly we are interested with the DC simulation.
  - In general cases, we must include the time derivative term.

- Direct discretization with another dimension, t?
  - A straightforward method, but it is computationally heavy.
  - Instead, in many cases, we adopt the “time-marching” method.

Implicit and explict methods

- There are two different types of the time-marching method.
  - Implicit: Time derivative is calculated by using the previous time points and the current time point.
  - For a uniform time spacing, the implicit Euler (backward Euler) reads:

$$\left.\frac{\partial n}{\partial t}\right|_t \approx \frac{n(t) - n(t - \Delta t)}{\Delta t}$$

  - Explicit: Time derivative is calculated by using the previous time points only.
  - For a uniform time spacing, the explicit Euler (forward Euler) reads:

$$\left.\frac{\partial n}{\partial t}\right|_{t+\Delta t} \approx \frac{n(t) - n(t - \Delta t)}{\Delta t}$$

In computational electronics,

- Implicit methods are adopted.
  - The reason is its stability.
  - Rule of thumb:
  - Implicit methods are stable.
  - Explicit methods are unstable.

- Exceptional cases
  - Monte Carlo
  - Finite-Difference Time-Domain (FDTD)

Implicit methods

- In practise, only implicit methods are used.
  - Backward Euler

$$\left.\frac{\partial n}{\partial t}\right|_t \approx \frac{n(t) - n(t-\Delta t)}{\Delta t}$$

  - Gear's second order method

$$\left.\frac{\partial n}{\partial t}\right|_t \approx \frac{3n(t) - 4n(t-\Delta t) + n(t-2\Delta t)}{2\Delta t}$$

  - Trapezoidal rule

$$\left.\frac{\partial n}{\partial t}\right|_{t-0.5\Delta t} \approx \frac{n(t) - n(t-\Delta t)}{\Delta t}$$

  - TRBDF (which is used in the S-device)