Lecture19

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Importance of S-G scheme

- “The equation that started it all”
  - M. Lundstrom, SISPAD 2015 presentation

SISPAD 2015, September 9-11, 2015, Washington, DC, USA

Drift-Diffusion and computational electronics – Still going strong after 40 years!

Reflections on computational electronics and the equation that started it all

Our naïve approach

- Re-arrangement
  - The current density was discretized as

$$\frac{J_{n,i+0.5}}{-q\mu_n} = \frac{n_{i+1} + n_i}{2}\frac{\phi_{i+1} - \phi_i}{\Delta x} - V_T \frac{n_{i+1} - n_i}{\Delta x}$$

  - Simple manipulation gives

$$\frac{J_{n,i+0.5}}{qD_n}\Delta x = -\frac{n_{i+1} + n_i}{2}\frac{\phi_{i+1} - \phi_i}{V_T} + n_{i+1} - n_i$$

  - In terms of n_{i+1} and n_i,

$$\frac{J_{n,i+0.5}}{qD_n}\Delta x = n_{i+1}\left(1 - \frac{\phi_{i+1} - \phi_i}{2V_T}\right) - n_i\left(1 + \frac{\phi_{i+1} - \phi_i}{2V_T}\right)$$

Scharfetter-Gummel

- What happens if $|\phi_{i+1} - \phi_i| > 2V_T$?
  - One of two coefficients for the electron densities becomes negative. Unphysical!

$$\frac{J_{n,i+0.5}}{qD_n}\Delta x = n_{i+1}\left(1 - \frac{\phi_{i+1} - \phi_i}{2V_T}\right) - n_i\left(1 + \frac{\phi_{i+1} - \phi_i}{2V_T}\right)$$

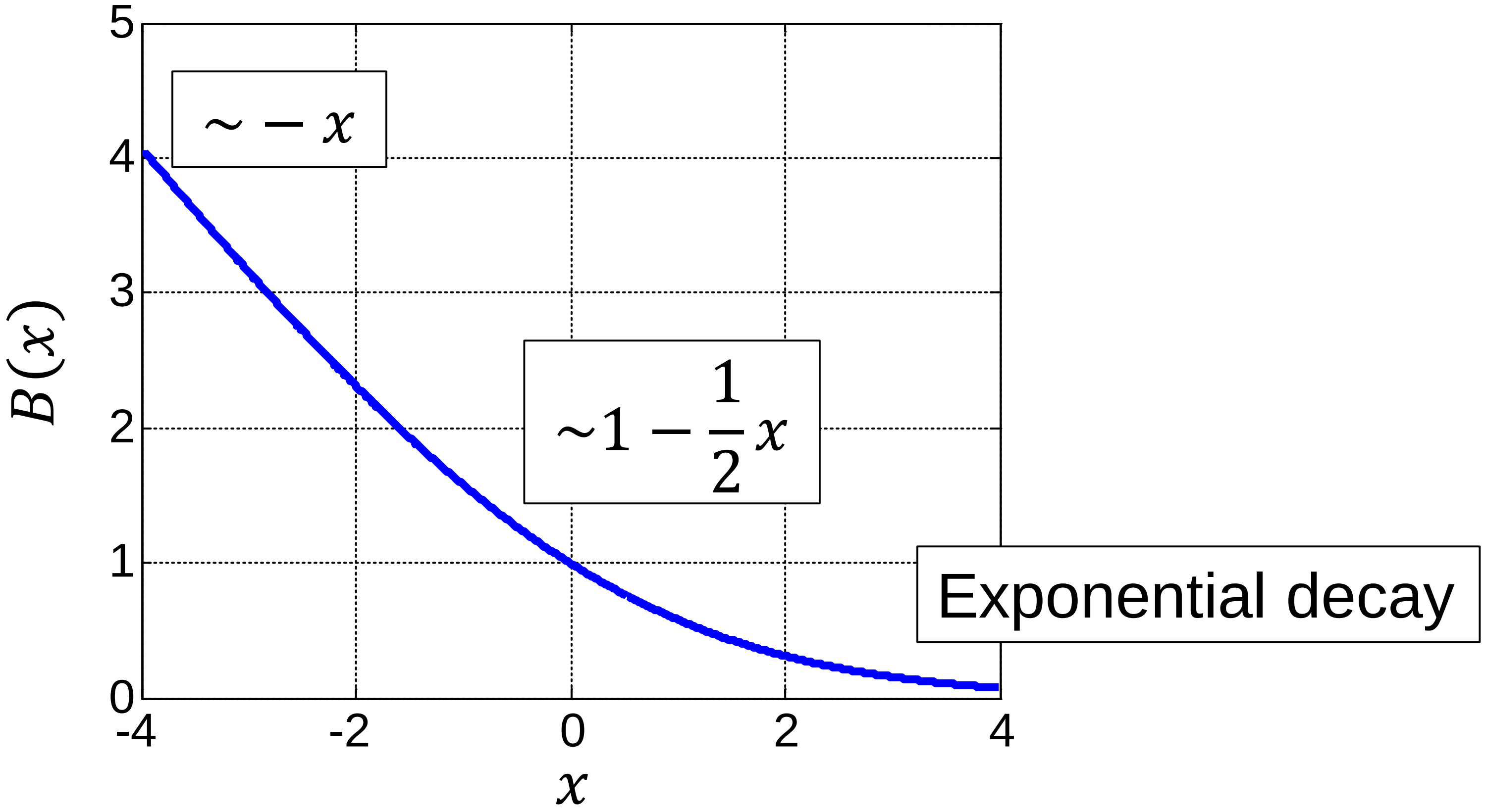
  - The Scharfetter-Gummel scheme

$$\frac{J_{n,i+0.5}}{qD_n}\Delta x = n_{i+1}B\left(\frac{\phi_{i+1} - \phi_i}{V_T}\right) - n_i B\left(\frac{\phi_i - \phi_{i+1}}{V_T}\right)$$

  - Here, the Bernoulli function is

$$B(x) = \frac{x}{e^x - 1}$$

Bernoulli function



Two limits

- When $|\phi_{i+1} - \phi_i| \approx 0$,
  - Our original scheme is obtained.

$$\frac{J_{n,i+0.5}}{qD_n}\Delta x = n_{i+1}\left(1 - \frac{\phi_{i+1} - \phi_i}{2V_T}\right) - n_i\left(1 + \frac{\phi_{i+1} - \phi_i}{2V_T}\right)$$

- When $|\phi_{i+1} - \phi_i| \gg 0$,
  - (Without loss of generality) when $\phi_{i+1} - \phi_i \gg 0$,

$$\frac{J_{n,i+0.5}}{qD_n}\Delta x = -n_i\frac{\phi_{i+1} - \phi_i}{V_T}$$

$$J_{n,i+0.5} = -q\mu_n n_i\frac{\phi_{i+1} - \phi_i}{\Delta x}$$