Lecture 8

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- PN-Junction Diodes
  - Shockley Equation ("Diode Equation")
    - More realistic model for the I-V characteristics (for FB and RB regions)
    - Based on semiconductor physics

$$i_D = I_s e^{V_D/(nV_T)} + 1$$

  - I_s is the saturation current (10^{-6} to 10^{-18}[A])
  - n = diode ideality factor, also called emissions coefficient, and can range from 1 to 2
  - $V_T = (kT)/q$ is the thermal voltage (≈ 26[mV] at $T = 300$[K] room temperature)
    - k = Boltzmann's constant ($1.38 \cdot 10^{-23}$[J/K]), q = electron charge ($1.6 \cdot 10^{-19}$[C])
- Temperature Dependence
  - At a constant current, the voltage drop decreases approximately 2[mV] for every 1[°C] increase in temperature
- Solving Circuits using the Junction Diode Model
  - Iterative Approach
    - Pro: accurate hand calculations
    - Con: tedious (time-consuming)
  - Graphical Approach
    - Pro: fast
    - Con: inaccurate (unless done numerically with a computer program)
  - Simulation

    * Pro: most accurate
    * Con: limited insights into the trade-offs

- Constant Voltage Drop (CVD) Model
  - Diode approximation with an open-circuit (RB) or with a DC voltage source of V_{dc} ($\approx .7$[V]) to model the forward voltage drop (FB)
  - With the Resistance Model
    * The diode is modeled with an open-circuit (RB), or with a DC voltage source and series resistance (FB), where $V_{do} \approx .7$[V]
    * Dynamic resistance: $r_d = (nV_T)/I_{DQ}$
      · Approximated around the operating point Q (quiescent point)
      · A small-signal parameter (represents the diode's resistance associated with small changes of i_d and V_d)

- Zener Diode Modeling
  - Forward Bias (FB): $I_D > 0$
  - Reverse Bias (RB): $-V_{zo} < V_d < V_{do}$
  - Breakdown (BD): $I_z = -I_D > 0$, $V_D = -V_{zo} - I_z r_z$
  - Voltage Regulation:
    * Voltage regulator quality indicators:
      · Source regulation: $\dfrac{\Delta V_{load}}{\Delta V_{SS}} \cdot 100\%$
      · Load regulation: $\dfrac{V_{NOload} - V_{FULLload}}{V_{FULLload}} \cdot 100\%$