

Equations

1. Constants:

$$\epsilon_0 = 8.85 * 10^{-14} \frac{F}{cm}$$

$$k = 1.386 * 10^{-23}$$

2. $P = \frac{dW}{dt} = IV$

3. $I = \frac{dq}{dt}$

4. $V = \frac{W}{q}$

5. $R = \frac{\rho L}{A}$

6. Ohm's Law: $V = IR$

7. Coulomb's Law: $\vec{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$

8. Kirchhoff's Loop Law: $\sum V_i = 0$ (around a closed loop)

9. Kirchhoff's Current Law: $\sum I_i = 0$ (going into a node)

10. Conductance: $G = \frac{1}{R}$

11. Equivalent resistance: $R_{eq} = \frac{V_{test}}{I_{test}}$

12. Series capacitance: $\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$

13. Parallel capacitance: $C_{total} = C_1 + C_2 + \dots$

14. Series inductor: $L_{total} = L_1 + L_2 + \dots$

15. Parallel inductor: $\frac{1}{L_{total}} = \frac{1}{L_1} + \frac{1}{L_2} + \dots$

16. $I_{cap} = C \frac{dV}{dt}$

17. $V_{ind} = L \frac{dI}{dt}$

18. Energy stored in capacitor: $\frac{1}{2} CV^2$

19. Energy stored in inductor: $\frac{1}{2} LI^2$

20. Voltage in RC circuit:

$$v_c(\infty) + (v_c(t_0) - v_c(\infty)) e^{(\frac{-1}{RC})(t-t_0)}$$

21. Current in RL circuit:

$$I_L(\infty) + (I_L(t_0) - I_L(\infty)) e^{(\frac{-R}{L})(t-t_0)}$$

22. Impedance of a capacitor: $\frac{-j}{\omega C}$

23. Impedance of an inductor: $j\omega L$

24. Equivalent impedance for impedances in series:

$$Z_{eq} = \sum_i^n Z_i$$

25. Equivalent impedance for impedances in parallel:

$$\frac{1}{Z_{eq}} = \sum_i^n \frac{1}{Z_i}$$

26. RMS value of signal: $S_{rms} = \sqrt{\frac{1}{T} \int_{t_0}^{t_0+T} s^2(t) dt}$

27. Maximum power extracted in DC circuits: $\frac{V_{th}^2}{4R_{th}}$

28. Maximum power extracted in AC circuits: $\frac{|\tilde{V}_{th}|^2}{8R_{th}}$

29. Average power: $P_{avg} = \frac{V_m I_m}{2} \cos(\theta_v - \theta_i)$

30. Reactive power: $V_{ar} = Im(\frac{1}{2} \tilde{V} \tilde{I}^*)$

31. Apparent power: $P_{app} = \frac{|V_{rms}|^2}{|z|}$

32. Coupling coefficient in coupled circuit: $k = \frac{L_{12}}{\sqrt{L_1 L_2}}$

33. Voltage in magnetically coupled coils:

$$v_1(t) = L_1 \frac{di_1(t)}{dt} + L_{12} \frac{di_2(t)}{dt}$$

$$v_2(t) = L_1 \frac{di_2(t)}{dt} + L_{12} \frac{di_1(t)}{dt}$$

34. Voltage in ideal transformer:

$$\frac{v_2(t)}{v_1(t)} = \frac{N_2}{N_1}$$

$$\frac{i_2(t)}{i_1(t)} = -\frac{N_1}{N_2}$$

35. Terminated transformer circuit equations:

$$\tilde{V}_1 = \frac{\tilde{V}_2}{n}$$

$$\tilde{I}_{out} = \frac{\tilde{I}_{in}}{n}$$

$$\tilde{V}_{in} = Z_{in} \tilde{I}_{in} + \tilde{V}_1$$

$$\tilde{V}_2 = Z_{out} \tilde{I}_{out}$$

$$\tilde{V}_2 = Z_{out} \frac{\tilde{I}_{in}}{n}$$

$$\frac{\tilde{V}_{in}}{\tilde{I}_{in}} = Z_{in} + \frac{Z_{out}}{n^2}$$

36. Energy stored in magnetically coupled circuit:

$$E = \frac{1}{2} L_1 i_1^2 + \frac{1}{2} L_2 i_2^2 + L_{12} i_1 i_2$$

37. Equilibrium in pn junction: $pn = n_i^2$

38. Current in pn junction:

$$J_N = q\mu_n n E_x + qD_n \frac{dn}{dx}$$

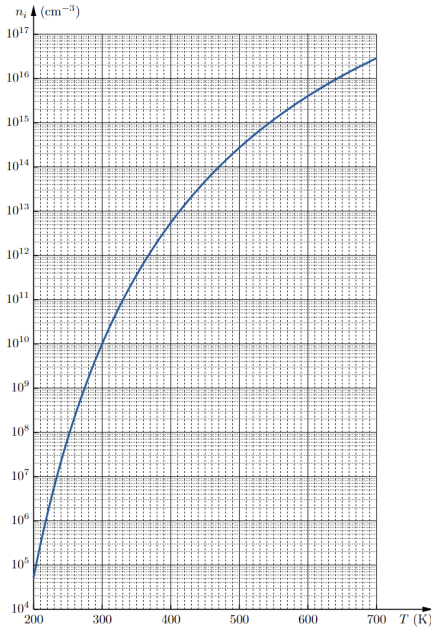
$$J_P = -qD_p \frac{dp}{dx} + q\mu_p p E_x$$

39. Width of depletion region:

$$W = \left[\frac{2\epsilon_r \epsilon_0}{q} \left(\frac{N_A + N_D}{N_A N_D} \right) V_{bi} \right]^{1/2}$$

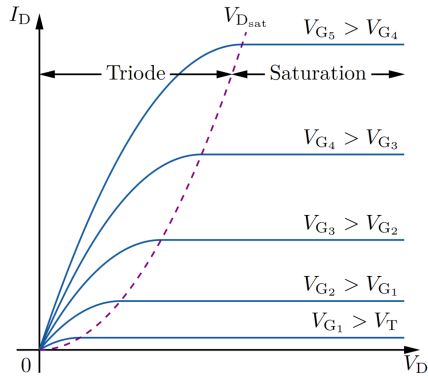
40. Built-in potential: $V_{bi} = \frac{kT}{q} \ln \left(\frac{N_A N_D}{n_i^2} \right)$

41. Intrinsic carrier density at given temperature:



42. Current through an ideal diode: $I = I_0(e^{qV_A/kT} - 1)$

43. $I_D - V_D$ characteristic graph:



44. Transistor equations:

$$V_{DS} = V_D - V_S$$

$$V_{GS} = V_G - V_S$$

$$I_D = \mu_n C_{ox} \left(\frac{W}{L} \right) \left[(V_{GS} - V_T) V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

$$= k \left[(V_{GS} - V_T) V_{DS} - \frac{1}{2} V_{DS}^2 \right], V_{DS} \leq V_{GS} - V_T, V_D \leq V_G - V_T$$

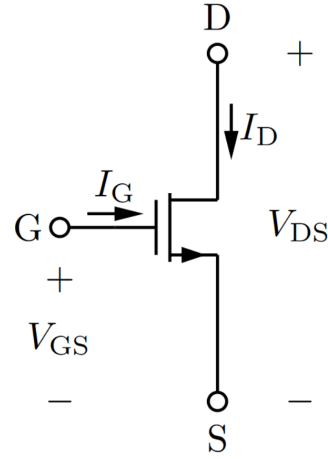
$$I_D = \mu_n C_{ox} \left(\frac{W}{L} \right) \left[\frac{1}{2} (V_{GS} - V_T)^2 \right]$$

$$= k \left[\frac{1}{2} (V_{GS} - V_T)^2 \right], V_{DS} \geq V_{GS} - V_T, V_D \geq V_G - V_T$$

45. Condition for CSA distortion less than 10%: $V_G < 0.2(V_G - V_T)$

46. Gain of a CSA: $A = -R_D k (V_G - V_T) = -g_m R_D$

47. Schematic of a MOSFET:



To find Thevenin voltage and Norton current:

(R_{eq}) Turn off all independent sources (dependent sources remain unchanged) and calculate the resulting resistance at the desired port. Notice that you may have to apply the i-v test if resistors cannot be combined through series and parallel connections, or if the circuit includes dependent sources.

(V_{th}) Leave the desired port open-circuited (i.e. no load connected) and find the voltage across it.

(I_N) Short-circuit the desired port (i.e. connect a short circuit across the port) and find the current through it.