

Equations

1. $P = \frac{dW}{dt} = IV$
2. $I = \frac{dq}{dt}$
3. $V = \frac{W}{q}$
4. $R = \frac{\rho L}{A}$
5. Ohm's Law: $V = IR$
6. Coulomb's Law: $\vec{F} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$
7. Kirchhoff's Loop Law: $\sum V_i = 0$ (around a closed loop)
8. Kirchhoff's Current Law: $\sum I_i = 0$ (going into a node)
9. Conductance: $G = \frac{1}{R}$
10. Equivalent resistance: $R_{eq} = \frac{V_{test}}{I_{test}}$
11. Series capacitance: $\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$
12. Parallel capacitance: $C_{total} = C_1 + C_2 + \dots$
13. Series inductor: $L_{total} = L_1 + L_2 + \dots$
14. Parallel inductor: $\frac{1}{L_{total}} = \frac{1}{L_1} + \frac{1}{L_2} + \dots$
15. $I_{cap} = C \frac{dV}{dt}$
16. $V_{ind} = L \frac{dI}{dt}$
17. Energy stored in capacitor: $\frac{1}{2} CV^2$
18. Energy stored in inductor: $\frac{1}{2} LI^2$
19. Voltage in RC circuit:

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

20. Current in RL circuit:

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

21. Impedance of a capacitor: $\frac{-j}{\omega C}$
22. Impedance of an inductor: $j\omega L$
23. Equivalent impedance for impedances in series:

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

24. Equivalent impedance for impedances in parallel:

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

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

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

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

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

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

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

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

32. Voltage in magnetically coupled coils:

$$\begin{aligned} v_1(t) &= L_1 \frac{di_1(t)}{dt} + L_{12} \frac{di_2(t)}{dt} \\ v_2(t) &= L_1 \frac{di_2(t)}{dt} + L_{12} \frac{di_1(t)}{dt} \end{aligned}$$

33. Voltage in ideal transformer:

$$\begin{aligned} \frac{v_2(t)}{v_1(t)} &= \frac{N_2}{N_1} \\ \frac{i_2(t)}{i_1(t)} &= -\frac{N_1}{N_2} \end{aligned}$$

34. Terminated transformer circuit equations:

$$\begin{aligned} \tilde{V}_1 &= \frac{\tilde{V}_2}{n} \\ \tilde{I}_{out} &= \frac{\tilde{I}_{in}}{n} \\ \tilde{V}_{in} &= Z_{in} \tilde{I}_{in} + \tilde{V}_1 \\ \tilde{V}_2 &= Z_{out} \tilde{I}_{out} \\ \tilde{V}_2 &= Z_{out} \frac{\tilde{I}_{in}}{n} \\ \frac{\tilde{V}_{in}}{\tilde{I}_{in}} &= Z_{in} + \frac{Z_{out}}{n^2} \end{aligned}$$

35. Energy stored in magnetically coupled circuit:

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

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

37. Current in pn junction:

$$\begin{aligned} J_N &= q\mu_n n E_x + qD_n \frac{dn}{dx} \\ J_P &= -qD_p \frac{dp}{dx} + q\mu_p p E_x \end{aligned}$$

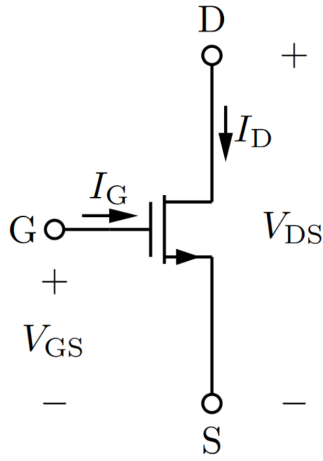
38. Width of depletion region:

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

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

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

41. Schematic of a MOSFET:



42. Transistor equations:

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

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

$$V_T = V_G - V_D$$

$$\begin{aligned}
 I_D &= \mu_n C_{ox} \left(\frac{W}{L} \right) \left[(V_{GS} - V_T) V_{DS} - \frac{1}{2} V_{DS}^2 \right] \\
 &= k \left[(V_{GS} - V_T) V_{DS} - \frac{1}{2} V_{DS}^2 \right], V_{DS} \leq V_{GS} - V_T, V_D \leq V_G - V_T \\
 I_D &= \mu_n C_{ox} \left(\frac{W}{L} \right) \left[\frac{1}{2} (V_{GS} - V_T)^2 \right] \\
 &= k \left[\frac{1}{2} (V_{GS} - V_T)^2 \right], V_{DS} \geq V_{GS} - V_T, V_D \geq V_G - V_T
 \end{aligned}$$

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

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

(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.