

ECE Essentials

Imaginary Unit: $i = \text{current, therefore } j = \pm\sqrt{-1}$ Rect/Polar: $\mathbf{Z} = a + jb = \sqrt{a^2 + b^2} \angle \tan^{-1}(\frac{b}{a})$
 Conjugate: If $\mathbf{Z} = a + jb$, $\mathbf{Z}^* = a - jb$

Resistors

$Z_R = R$ $R_{\text{series}} = R_1 + R_2 + \dots + R_N$
 $v = iR$ $R_{||} = (\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N})^{-1}$

Capacitors

$i_c = C \frac{dv_c(t)}{dt}$ $C_{\text{series}} = (\frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_N})^{-1}$ $Z_c = \frac{1}{j\omega C}$
 $v_c = \frac{1}{C} \int_0^t i_c(t) dt + v_{c,0}$ $C_{||} = C_1 + C_2 + \dots + C_N$

Inductors

$i_L = \frac{1}{L} \int_0^t v_L(t) dt + i_{L,0}$ $L_{\text{series}} = L_1 + L_2 + \dots + L_N$ $Z_L = j\omega L$
 $v_L = L \frac{di_L(t)}{dt}$ $L_{||} = (\frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_N})^{-1}$

Power

$x_{\text{rms}} = \sqrt{\frac{1}{T} \int_{t_0}^{t_0+T} x^2(t) dt}$ $P = \frac{1}{2} V_M I_M \cos(\theta_v - \theta_i) = \frac{1}{2} V_M I_M (\text{pf})$
 $\mathbf{S} = \mathbf{V}_{\text{rms}} \mathbf{I}_{\text{rms}}^* = P + jQ = I_{\text{rms}}^2 \mathbf{Z}$ $P_{\text{dc}} = IV = I^2 R = \frac{V^2}{R}$

MOS Field Effect Transistors (MOSFETs)

$$i_D = \begin{cases} k \frac{W}{L} (V_{GS} - V_t)^2 & : V_{GS} \geq V_t, V_{DS} \geq (V_{GS} - V_t) \text{ [saturation]} \\ k \frac{W}{L} [(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2] & : V_{GS} \geq V_t, V_{DS} \leq (V_{GS} - V_t) \text{ [triode]} \\ 0 & : V_{GS} < V_t \text{ [cutoff]} \end{cases}$$

$g_m = k \frac{W}{L} (V_{GS} - V_t)$

nFET	$k = k_n = \mu_n C_{ox}$	$V_t = V_{t,n} (> 0)$
pFET	$k = k_p = \mu_p C_{ox}$	$V_t = V_{t,p} (< 0)$

Ideal Op-Amps

Thévenin/Norton Equivalency

Resistor Color Codes

color:	10s:①	1s:②	multiplier:③	tolerance:④
black	0	0	1 Ω	—
brown	1	1	10 Ω	± 1%
red	2	2	100 Ω	± 2%
orange	3	3	1 kΩ	—
yellow	4	4	10 kΩ	—
green	5	5	100 kΩ	± 0.5%
blue	6	6	1 MΩ	± 0.25%
violet	7	7	10 MΩ	± 0.1%
grey	8	8	100 MΩ	± 0.05%
white	9	9	1 GΩ	—
gold	—	—	0.1 Ω	± 5%
silver	—	—	0.01 Ω	± 10%

Bipolar Junction Transistors (BJTs)

$i_c = I_S e^{\frac{v_{be}}{V_T}}$ $i_c = \beta i_b = \alpha i_e$
 $i_e = i_b + i_c$ $g_m = \frac{I_c}{V_T}$
 $i_c = g_m v_{be}$ $r_\pi = \frac{\beta}{g_m} = \frac{V_T}{I_b}$
 $r_e = \frac{\alpha}{g_m} = \frac{V_T}{I_e}$ $\alpha = \frac{\beta}{\beta + 1}$