$$V_{\text{amplitude}} = \sqrt{2}\, V_{RMS} \tag{1}$$

$$A_V = \frac{V_{out}}{V_{in}} \tag{2}$$

$$A_V(\text{ideal}) = \frac{V_{out,\text{OC}}}{V_{in}} \tag{3}$$

$$V = IR \tag{4}$$

$$R_{Th} = R_N = \frac{V_{\text{OC}}}{I_{\text{SC}}} \tag{5}$$

$$\text{Gain (dB)} = 10\log_{10}\frac{P_2}{P_1} \stackrel{*}{=} 20\log_{10}\frac{V_2}{V_1} \tag{6}$$

$$Z_R = R \tag{7}$$

$$Z_C = (j\omega C)^{-1} \tag{8}$$

$$Z_L = j\omega L \tag{9}$$

$$\text{Gain (closed-loop)} = \frac{A}{1+AB} \tag{10}$$

$$f_{\text{3dB}} = (2\pi RC)^{-1} = (2\pi\tau)^{-1} \tag{11}$$

$$\text{Gain (non-inverting)} = \frac{R_1+R_2}{R_2}\ \text{, (R_1 connected to the output)} \tag{12}$$

$$\text{Gain (inverting)} = -\frac{R_1}{R_2}\ \text{, (R_1 connected to the output)} \tag{13}$$

$$V_{out}(t) = -\frac{1}{RC}\int_0^t dt'\, V_{in}(t') + \text{constant} \tag{14}$$

$$V_{out} = -RC\,\frac{dV_{in}(t)}{dt} \tag{15}$$

$$V_{out} = -(V_1+V_2)\frac{R_1}{R_2}\ \text{, (R_1 connected to the output)} \tag{16}$$

$$V_{out} = -(V_1-V_2)\frac{R_1}{R_2}\ \text{, (R_1 connected to output and ground)} \tag{17}$$

$$\text{(Gain)(Bandwidth)} \sim \text{(unity gain bandwidth)} \tag{18}$$

$$\frac{S}{N}\text{ratio} = 20\log_{10}\left(\frac{V_S}{V_N}\right) \tag{19}$$

$$V_N(\text{rms}) = (4k_BTBR)^{1/2} \tag{20}$$

$$\vec{J} = \sigma\vec{E} \tag{21}$$

$$\sigma = e(n\mu_e + p\mu_h) \tag{22}$$

$$np = 4\left(\frac{k_BT}{2\pi\hbar^2}\right)^3 (m_em_h)^{3/2}\exp\left(-\frac{E_g}{k_BT}\right) \tag{23}$$

$$n_i = p_i \tag{24}$$

$$I = C\exp\left(-\frac{e(V_0-V)}{k_BT}\right) - I_S = I_S\left\{\exp\left(-\frac{e(V_0-V)}{k_BT}\right) - 1\right\} \approx I_S\exp(40\,V) \tag{25}$$

$$I_C = h_{FE}I_B \tag{26}$$

$$I_C \approx -I_E \tag{27}$$

$$h_{fe} \approx h_{FE} = \beta \tag{28}$$

$$\alpha = \frac{h_{FE}}{h_{FE}+1} \tag{29}$$

$$g_m = \frac{dI_C}{dV_{BE}} \approx 40I_C = \frac{1}{r_e} \tag{30}$$

$$h_{ie} \approx \frac{1}{40I_B} = \frac{h_{fe}}{g_m} \tag{31}$$

$$dI_C = \left(\frac{\partial I_C}{\partial I_B}\right)_{V_{CE}} dI_B + \left(\frac{\partial I_C}{\partial V_{CE}}\right)_{I_B} dV_{CE} = h_{fe}\, dI_B + h_{oe}\, dV_{CE} \tag{32}$$

$$dV_{BE} = \left(\frac{\partial V_{BE}}{\partial I_B}\right)_{V_{CE}} dI_B + \left(\frac{\partial V_{BE}}{\partial V_{CE}}\right)_{I_B} dV_{CE} = h_{ie}\, dI_B + h_{re}\, dV_{CE} \tag{33}$$

$$A_V \approx -\frac{R_C}{R_E + r_e} \text{ (feedback config)} \tag{34}$$

$$A_V \approx -\frac{R_C}{r_e} \text{ (common emmitter or decoup. cap.)} \tag{35}$$

$$r_i = R_1 // R_2 // r_b \tag{36}$$

$$r_b = h_{ie} + (h_{fe}+1)R_E \text{ (common emmitter)} \tag{37}$$

$$r_o = R_C \left(\frac{1 + h_{oe}R_E}{1 + h_{oe}(R_E + R_C)}\right) \tag{38}$$

$$f_c = \{2\pi C_{in}(R_{\text{source}} + r_i)\}^{-1} \text{ (coupling capacitor)} \tag{39}$$

$$f_{co} = \{2\pi C_E (R_E // r_e)\}^{-1} \text{ (decoupling capacitor)} \tag{40}$$

$$f_\beta = \{2\pi (C_{b'e} + C_{b'c}) r_{b'e}\}^{-1} \text{ (high-f hybrid-}\pi\text{)} \tag{41}$$

$$f_\beta \approx \frac{40I_E}{2\pi h_{fe(0)} C_{b'e}} \tag{42}$$

$$f_T \approx \frac{40I_E}{2\pi C_{b'e}} \tag{43}$$

$$\frac{V_o}{V_i} = \left\{1 - \frac{5}{(\omega CR)^2} - j\left(\frac{6}{\omega CR} - \frac{1}{(\omega CR)^3}\right)\right\}^{-1} \tag{44}$$

$$f = \frac{1}{2\pi CR\sqrt{6}} \text{ (phase-shift oscillator)} \tag{45}$$

$$A_V = -\frac{1}{29} \text{ (feedback } B \text{ of phase-shift oscillator)} \tag{46}$$

$$\frac{V_o}{V_i} = \left\{3 - j\left(\frac{1 - \omega^2 R^2 C^2}{\omega CR}\right)\right\}^{-1} \text{ (Wein-bridge oscillator)} \tag{47}$$