

$$V_{\text{amplitude}} = \sqrt{2} V_{RMS} \quad (1)$$

$$A_V = \frac{V_{out}}{V_{in}} \quad (2)$$

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

$$V = IR \quad (4)$$

$$R_{Th} = R_N = \frac{V_{OC}}{I_{SC}} \quad (5)$$

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

$$Z_R = R \quad (7)$$

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

$$Z_L = j\omega L \quad (9)$$

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

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

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

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

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

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

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

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

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

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

$$\vec{J} = \sigma \vec{E} \quad (20)$$

$$\sigma = e(n\mu_e + p\mu_h) \quad (21)$$

$$np = 4 \left(\frac{k_B T}{2\pi\hbar^2} \right)^3 (m_e m_h)^{3/2} \exp \left(-\frac{E_g}{k_B T} \right) \quad (22)$$

$$n_i = p_i \quad (23)$$

$$I(V) = I_S \exp \left(\frac{eV}{k_B T} \right) - I_S = I_S \left\{ \exp \left(\frac{eV}{k_B T} \right) - 1 \right\} \approx I_S \exp(40V) \quad (24)$$

$$I_C = h_{FE} I_B \quad (25)$$

$$I_C \approx -I_E \quad (26)$$

$$h_{fe} \approx h_{FE} \quad (27)$$

$$g_m = \frac{dI_C}{dV_{BE}} \approx 40I_C = \frac{1}{r_e} \quad (28)$$

$$h_{ie} \approx \frac{1}{40I_B} = \frac{h_{fe}}{g_m} \quad (29)$$

$$dI_C = \left(\frac{\partial I_C}{\partial I_B} \right)_{V_{CE}} dI_B + \left(\frac{\partial I_C}{\partial V_{CE}} \right)_{I_B} dV_{CE} = h_{fe} dI_B + h_{oe} dV_{CE} \quad (30)$$

$$dV_{BE} = \left(\frac{\partial V_{BE}}{\partial I_B} \right)_{V_{CE}} dI_B + \left(\frac{\partial V_{BE}}{\partial V_{CE}} \right)_{I_B} dV_{CE} = h_{ie} dI_B + h_{re} dV_{CE} \quad (31)$$

$$A_V \approx -\frac{R_C}{R_E + r_e} = -\frac{g_m R_C}{g_m R_E + 1} \text{ (feedback config)} \quad (32)$$

$$A_V \approx -\frac{R_C}{r_e} \text{ (common emitter or decoupl. cap.)} \quad (33)$$

$$r_i = R_1 // R_2 // r_b \quad (34)$$

$$r_b = h_{ie} + (h_{fe} + 1)R_E \text{ (common emitter)} \quad (35)$$

$$r_o = R_C \left(\frac{1 + h_{oe}R_E}{1 + h_{oe}(R_E + R_C)} \right) \quad (36)$$

$$f_c = \{2\pi C_{in}(R_{source} + r_i)\}^{-1} \text{ (coupling capacitor)} \quad (37)$$

$$f_{co} = \{2\pi C_E(R_E // r_e)\}^{-1} \text{ (decoupling capacitor)} \quad (38)$$

$$f_\beta = \{2\pi(C_{b'e} + C_{b'c})r_{b'e}\}^{-1} \text{ (high-f hybrid-}\pi\text{)} \quad (39)$$

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

$$f_T \approx \frac{40I_E}{2\pi C_{b'e}} \quad (41)$$

$$\frac{V_o}{V_i} = \left\{ 1 - \frac{5}{(\omega CR)^2} - j \left(\frac{6}{\omega CR} - \frac{1}{(\omega CR)^3} \right) \right\}^{-1} \quad (42)$$

$$f = \frac{1}{2\pi CR\sqrt{6}} \text{ (phase-shift oscillator)} \quad (43)$$

$$A_V = -\frac{1}{29} \text{ (feedback } B \text{ of phase-shift oscillator)} \quad (44)$$

$$\frac{V_o}{V_i} = \left\{ 3 - j \left(\frac{1 - \omega^2 R^2 C^2}{\omega CR} \right) \right\}^{-1} \text{ (Wein-bridge oscillator)} \quad (45)$$

$$I_{DSS} = I_{DSS0} \left(1 - \frac{V_{GS}}{V_P} \right)^2 \quad (46)$$