SELECTIVE FORMULAE IN ANALOGUE ELECTRONICS

Op Amp Circuits

Operational Amplifier

$$A_{DM} = \frac{R_2}{R_1}\left[1 - \frac{\in (R_1+2R_2)}{2(R_1+R_2)}\right] \qquad A_{CM} = \frac{R_2 \in}{(R_1 + R_2)}$$

$$CMRR = 20\log\left|\frac{A_{DM}}{A_{CM}}\right|$$

Inverting Amplifier

$$V_{out} = -\left(\frac{R_2}{R_1}\right)V_{in}$$

Non-Inverting Amplifier

$$V_{out} = \left(1 + \frac{R_2}{R_1}\right)V_{in}$$

Summing Amplifier

$$V_{out} = \left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3 + \cdots\right)$$

Differential Amplifier

$$v_{out} = \frac{R_2}{R_1}\left[\left(\frac{1 + \frac{R_1}{R_2}}{1 + \frac{R_3}{R_4}}\right)v_2 - v_1\right]$$

Instrumentation Amplifier

$$v_{out} = \left(\frac{R_2}{R_1}\right)\left(1 + \frac{2R_3}{R_G}\right)(v_1 - v_2)$$

Comparator

$$\Delta V_t = V_{TH} - V_{TL}$$

$$\Delta V_T = \left(\frac{R_1}{R_1 + R_2}\right) \times (V_{OH} - V_{OL})$$

Oscillator (Wien-Bridge)

$$\frac{V_o}{V_i} = \frac{j\omega C_1 R_2}{1 + j\omega(C_1R_2 + C_2R_2 + C_1R_1) - \omega^2(C_1C_2R_1R_2)}$$

$$\omega^2 = \frac{1}{C_1C_2R_1R_2}$$

Phase-Shift Oscillator

$$\omega = 2\pi f = \frac{1.732}{RC} \qquad (\text{e.g. } \tan 60° = 1.732) \qquad \beta = \left(\frac{1}{sRC + 1}\right)^3$$

Low-/High-Pass Filter

$$F_c = \frac{1}{\omega RC}$$

Sallen-Key Filter

$$\omega_0 = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} \qquad Q = \frac{1}{R_1 + R_2}\sqrt{R_1 R_2 \left(\frac{C_1}{C_2}\right)}$$

State-Variable Filter

$$f_o = \frac{1}{2\pi C R_F} \qquad Q = \frac{1}{2}\left(1 + R/R_Q\right) \qquad A_{BP} = \frac{R}{R_G}$$

Power Amplifiers

$v_{ce(\text{p-p})} = 2V_{CC}$

$P_{dc} = V_{CC} I_C = I_C^2 R_L'$

$R_L' = n^2 R_L$

$P_{o(\max)} = \dfrac{v_{ce(\text{p-p})} \times i_{c(\text{p-p})}}{8}$

$V_{out} = V_{REF}\left(1 + \dfrac{R_2}{R_1}\right) + I_{ADJ} R_2$

$f_s = \dfrac{1}{2\pi\sqrt{LC}}$

$f_p = \dfrac{1}{2\pi\sqrt{LC_T}}$

$I_{R_s} = I_{Z(\min)} + I_{B(\max)}$

$R_s = \dfrac{V_{in(\min)} - V_Z}{I_{R_s}}$

$I_{C(\text{sat})} = \dfrac{V_{CC}}{R_C + R_E}$ or $I_{C(\text{sat})} = \dfrac{V_{CEQ}}{R_L}$

$V_{CE(\text{off})} = V_{CC}$

$V_B = \left(\dfrac{R_2}{R_1 + R_2}\right) V_{CC}$

$V_E = V_B - 0.7\ \text{V}$

$I_E = \dfrac{V_E}{R_E}$

$V_{CEQ} = V_{CC} - I_C(R_C + R_E)$

$I_{C(\text{sat})} = I_{CQ} + \dfrac{v_{CEQ}}{r_C}$

$$V_{CE(\text{off})} = V_{CEQ} + I_{CQ} r_C$$

$$V_{PP} = 2 I_{CQ} r_C$$

$$I_{bias} = \frac{V_{CC} - 2V_{BE}}{2R}$$

$$I_{ave} = \frac{I_{C(sat)}}{\pi}$$

$$P_{out(\max)} = \frac{MPP^2}{8R_L}$$

$$V_Z = V_{Z0} + r_Z I_Z$$

$$\Delta V_O = r_Z \Delta I_Z$$

Power Supplies

$$\text{Line Regulation} = \frac{\Delta V_o}{\Delta V_i}$$

$$\text{Load Regulation} = \frac{\Delta V_o}{\Delta I_L}$$

Thermal Analysis

$$R_{\theta ja} = R_{\theta jc} + R_{\theta cs} + R_{\theta sa}$$

$$T_j = P_d * \theta_{ja} + T_a$$

$$\theta_{cs} = \frac{\rho \times t}{A}$$

Noise Analysis

Electron charge, $q = 1.6 \times 10^{-19}$ Coulomb

Boltzman's constant, $k = 1.38 \times 10^{-23}$ Joule/Kelvin

Johnson noise spectral density, $e_n = \sqrt{4ktR}$ V/$\sqrt{\text{Hz}}$

Johnson noise voltage, $E_n = e_n \sqrt{f_H - f_L}$ V

Shot noise spectral density, $i_n = \sqrt{2qI}$ A/$\sqrt{\text{Hz}}$

Thermal voltage, $V_T \approx 25$ mV for $T = 20°C$

E24 Resistor Value Standards

10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91.