

# EE 351 Equation Sheet

## Test rules: (you are only one cheating event away from academic misconduct)

- ✓ Do all work on test. Use the backside if necessary. **Extra paper not allowed.**
- ✓ Equations/data are supplied as follows. You may have no other notes.
- ✓ **All sheets of the test must remain stapled – do not remove any page.**
- ✓ You may have **1** approved calculator as described in test policies. However, for some tests it is possible that no calculator will be allowed.
- ✓ All other papers, books, purses, bags, etc. must be off the desk and on the floor out of site.
- ✓ You may have no cell phones, pagers, etc. in view. Any devices you have with you must be OFF unless approved by the instructor.
- ✓ Your desk must be free of anything not approved – thus you have only three items: the test, your calculator (if permitted for the test), and your pencils/erasers – none can have any notes.
- ✓ Caps or any kind of head gear or unusual attire are not allowed.
- ✓ Nothing can be in your lap or off the desktop, even if legitimate for the test.

## General data and equations:

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

Standard C: 10 12 15 18 22 27 33 39 47 56 68 82

## Unless otherwise indicated, use the following constants for all problems:

$$V_{BE\text{nom}} \text{ at } 25\text{ C} = \underline{\hspace{2cm}} \text{ volts} \quad dV_{BE}/dT = \underline{\hspace{2cm}} \text{ mV/C}$$

$$\text{Temperatures: } T_{\text{min}} = \underline{\hspace{2cm}} \text{ C} \quad T_{\text{nom}} = \underline{\hspace{2cm}} \text{ C} \quad T_{\text{max}} = \underline{\hspace{2cm}} \text{ C}$$

$$\text{Beta: } B_{\text{min}} = \underline{\hspace{2cm}} \quad B_{\text{nom}} = \underline{\hspace{2cm}} \quad B_{\text{max}} = \underline{\hspace{2cm}}$$

$$\text{Design: } K_T = \underline{\hspace{2cm}} \quad K_B = \underline{\hspace{2cm}} \quad V_{CE\text{sat}} = \underline{\hspace{2cm}} \text{ V}$$

$$\text{JFET: } I_{DSS} = \underline{\hspace{2cm}} \text{ mA} \quad V_P = \underline{\hspace{2cm}} \text{ V}$$

$$P_{\text{gain}} = \frac{P_{\text{out}}}{P_{\text{in}}} \quad dB = 10 \log_{10} \left( \frac{P_2}{P_1} \right)$$

$$T_C = (T_F + 40) \frac{5}{9} - 40 \quad T_F = (T_C + 40) \frac{9}{5} - 40 \quad T_K = T_C + 273$$

$$I_D = I_s \left[ e^{(V_D/nV_T)} - 1 \right] \quad \text{Use } n = 1 \text{ for transistors}$$

$$V_T = kT/q \quad k = 1.38\text{E-}23 \text{ J/K, } T \text{ in kelvins, } q = 1.602\text{E-}19 \text{ coulombs} \quad r_d = \frac{nV_T}{I_D}$$

$$\% \text{ripple} \cong \frac{24}{FRC} \text{ half-wave} \quad \% \text{ripple} \cong \frac{8.6}{FRC} \text{ full-wave}$$

$$I_C = \beta I_B = \left( \frac{\beta}{\beta+1} \right) I_E \quad I_B = \frac{I_C}{\beta} = \frac{I_E}{\beta+1} \quad I_E = (\beta + 1) I_B = \left( \frac{\beta+1}{\beta} \right) I_C$$

$$I_E = \frac{V_{BB} - V_{BE} - V_{EE}}{R_E \left( 1 + \frac{R_B}{\beta+1} \right)} \quad \text{or} \quad I_E = \frac{V_{BB} - V_{BE} - V_{EE}}{R_E + \frac{R_B}{\beta+1}}$$

$$V_C = V_{CC} - I_C R_C \quad V_B = V_{BB} - I_B R_B \quad V_E = V_{EE} + I_E R_E$$

$$r_e = \frac{V_T}{I_E} \quad r_{ct} = \infty \quad r_{bt} = (\beta + 1)(r_e + R'_E) \quad r_{et} = r_e + \frac{R'_B}{\beta+1}$$

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$$\text{CE: } A_V = \frac{-\left(\frac{\beta}{\beta+1}\right)R_C}{r_e + R'_E} \quad \text{CC: } A_{VL} = \frac{R_E || R_L}{r_e + R_E || R_L} \quad \text{CB: } A_V = \frac{\left(\frac{\beta}{\beta+1}\right)R_C}{r_e}$$

$$V_{BEmin} = V_{BE_{Tref}} + \frac{dV_{BE}}{dT}(T_{max} - T_{ref}) \quad V_{BEmax} = V_{BE_{Tref}} - \frac{dV_{BE}}{dT}(T_{ref} - T_{min})$$

$$K_T = \frac{I_{Cmax}}{I_{Cmin}} \quad V_{BBmin} = \frac{K_T V_{BEmax} - V_{BEmin}}{K_T - 1} \quad V_{BEnom} = \frac{V_{BEmax} + V_{BEmin}}{2}$$

$$K_B = \frac{I_{Cmax}}{I_{Cmin}} \quad \left(\frac{R_B}{R_E}\right)_{max} = \frac{K_B \left(\frac{\beta_{max} + 1}{\beta_{max}}\right) - \left(\frac{\beta_{min} + 1}{\beta_{min}}\right)}{\left(\frac{1}{\beta_{min}}\right) - \left(\frac{K_B}{\beta_{max}}\right)} \quad \beta_{nom} = \sqrt{\beta_{min} \beta_{max}}$$

$$\text{Bias Design: } R_{B1} = R_B \left(\frac{V_{CC}}{V_{BB}}\right) \quad R_{B2} = \frac{R_{B1}}{\left(\frac{V_{CC}}{V_{BB}}\right) - 1}$$

$$\text{CE large signal design: } V_{CQopt} \cong \frac{2\left(\frac{R_C}{R_L} + 1\right)(V_{BB} + V_{CBmin}) + K V_{CC}}{2\left(\frac{R_C}{R_L} + 1\right) + K} \quad \text{where } K \sim 0.2 \text{ to } 0.5$$

$$R'_E = \left(\frac{\beta}{\beta+1}\right)\left(\frac{R_C}{A_V}\right) - r_e \quad R_{E1} = \frac{R_E R'_E}{R_E - R'_E}$$

$$\text{CC large signal design: } V_{EQopt} = \frac{(V_{CC} - V_{CEsat})\left(1 + \frac{R_E}{R_L}\right)}{2 + \frac{R_E}{R_L}}$$

$$I_D = I_{DSS} \left(1 - \left(\frac{V_{GS}}{V_P}\right)\right)^2 \quad V_{GS} = V_P \left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right) \quad g_m = \left|\frac{2\sqrt{I_D I_{DSS}}}{V_P}\right|$$

$$V_K = V_{GG} - V_{SS} - V_P \quad V_R = \frac{V_P^2}{I_{DSS}} \quad X = \left|\frac{2V_K R_S}{V_R}\right| \quad I_D = \left(\frac{V_R}{2R_S^2}\right)(X + 1 - \sqrt{2X + 1})$$

$$\begin{array}{ccc} \text{n-channel:} & \text{n-channel:} & \\ V_D > (V_G - V_P) & V_{DS} > (V_{GS} - V_P) & r_{dt} = \infty \quad r_{gt} = \infty \quad r_{st} = \frac{1}{g_m} \end{array}$$

$$\text{CS: } A_V = \frac{-g_m R_D}{1 + g_m R'_S} \quad \text{CD: } A_V = \frac{g_m R_S}{1 + g_m R'_S} \quad \text{CG: } A_V = g_m R_D$$

$$\text{Bias design: } V_{GG} = V_{SS} + I_D R_S + V_{GS} \quad R_S = \frac{V_{GG} - V_{GS} - V_{SS}}{I_D}$$

$$F_{CH} = \frac{1}{2\pi R_{shunt} C_{shunt}} \quad F_{CHnet} \cong \frac{1}{\sqrt{\frac{1}{F_{CH1}^2} + \frac{1}{F_{CH2}^2} + \dots}} \quad C_{Miller} = C_f [|A_{VL}| + 1]$$

$$F_{CL} = \frac{1}{2\pi R_{series} C_{series}} \quad F_{CLnet} \cong \sqrt{F_{CL1}^2 + F_{CL2}^2 + \dots}$$

$$\text{Cascade factors: } 2: \underline{0.664}, \quad 3: \underline{0.510}, \quad 4: \underline{0.435}, \quad 5: \underline{0.386}, \quad 6: \underline{0.350}$$