1 Analog Electronic

1.1 THE BJTS

1.1.1 Basic simple ones

- FIND IC
$I_C = \frac{V_{R_C}}{R_C} = \beta \cdot I_B = e^{\frac{V_{BE}}{V_T}} [A]$
- FIND IB
$I_B = \frac{I_C}{\beta} [A]$
- FIND gm
$gm = \frac{I_C}{V_T} = \frac{\beta}{R_\pi} [S][\Omega^{-1}]$
- FIND β
$\beta = gm \cdot R_\pi = \frac{I_C}{I_B} [\cdot]$
- FIND r's
$r_\pi = \frac{\beta}{gm}$; $r_e = \frac{1}{gm}$; $r_o = \frac{V_A}{I_C}$
where $V_A = 15 < V_A < 200$, Early Voltage effect.
- FIND V_{BE}
$V_{BE} = \ln\left(\frac{I_C}{I_S}\right) \cdot V_T$ [V]
- FIND Q Point
Q (I_{BQ}, I_{CQ}, V_{CEQ})
Without (RE & RB2):
$I_{BQ} = \frac{V_{BQ} - V_{BEQ}}{RB} [A]$
$I_{CQ} \approx \beta \cdot I_{BQ} [A]$
$V_{CEQ} = VCC - I_{CQ} \cdot RC [V]$
With (RE & RB2):
$V_{BQ} \approx \frac{RB2}{RB1 + RB2} \cdot VCC [V]$
$I_{CQ} \approx I_{EQ} = \frac{V_{BQ} - V_{BEQ}}{R_e} [A]$
$I_{BQ} = \frac{I_{CQ}}{\beta} [A]$
$V_{CEQ} = VCC - I_{CQ} \cdot (RC + RE) [V]$
- SMALL SIGNAL MODEL
$R_i = RB1 || RB2 || (r_\pi + (1 + \beta) \cdot RE)$
$rbe = \frac{\beta}{gm}$
$gm = \frac{I_C}{V_T}$
$A_V = \frac{\beta \cdot (R_C || R_L)}{r_\pi \cdot (R_C + R_L)}$
FOR MANY MORE SEE, BJT MAPLE DOC

1.1.2 Things you can assume

$r_\pi = r_{be}$ $V_{BE} \approx < 2.4, 3 > [V]$
$V_{BEQ} = 0.6 < V_{BEQ} < 0.8$
$V_T \approx 26 \cdot 10^{-3} [V]$ temp coef for BJT
OR
$V_T = \frac{K \cdot T_K}{q} = \frac{1.38 \cdot 10^{-23} \cdot 273 + currentTemp}{1.6 \cdot 10^{-19}} [V]$
$R_B \approx \frac{\beta \cdot R_E}{10}$
$I_C \approx I_B$ for simple model (Lec 5.3)

1.1.3 FL from values, or desired FL

- SOM BASIS R-equvilantes.
MAY NOT BE THE ONES YOU HAVE!
$R_{base} = \frac{1}{\frac{1}{RB1} + \frac{1}{RB2} + \frac{1}{r_\pi}} + R_S$
$R_{collector} = R_C + R_L$
$R_{emitter_{BBL}} = \frac{1}{gm} + \frac{\frac{1}{\frac{1}{RB1} + \frac{1}{RB2} + \frac{1}{R_S}}}{\beta + 1}$
$R_{emitter} = \frac{1}{\frac{1}{R_E} + \frac{1}{R_{emitter_{BBL}}}}$
- FIND FL FROM KNOWN C's
$FL_x = \frac{1}{2\pi} \cdot \frac{1}{C_x \cdot R_{eqX}}$
- FIND C's FROM DESIRED F-L
- We need these for later.
$f_{base} = 0.1 \cdot f_{desired}$
$f_{collector} = 0.1 \cdot f_{desired}$
$f_{emitter} = 0.8 \cdot f_{desired}$
- FOR BASE and COLLECTOR
$C_{base} = \frac{1}{2\pi \cdot f_{base} \cdot R_{base}}$
$C_{collector} = \frac{1}{2\pi \cdot f_{collector} \cdot R_{collector}}$
- FOR EMITTER
$C_{emitter} = \frac{1}{2\pi \cdot f_{emitter} \cdot R_{emitter}}$

1.1.4 THD

$RS_{prime} = \frac{1}{\frac{1}{RS} + \frac{1}{RB1} + \frac{1}{RB2}}$
$Re_{prime} = \frac{1}{\frac{1}{RE} + \frac{1}{Re}}$
$Av_{prime} = -\frac{\left(\frac{1}{\frac{1}{RC} + \frac{1}{RL}}\right)}{\frac{1}{gm} + Re_{prime} + \frac{RS_{prime}}{\beta}}$
$VSP_{prime} = \frac{Vop}{Av_{prime}}$
Harmonic distorion term F:
$F = 1 + gm \cdot \left(\frac{RS_{prime}}{\beta} + Re_{prime}\right) [\cdot]$
$THD = \frac{\frac{1}{4} \cdot \frac{abs(VSP_{prime})}{V_T}}{F^2} [\cdot]$

1.2 THE DIODES

1.2.1 PN diode

$V_T \approx 26 \cdot 10^{-3} [V]$ temp coef for BJT
OR
$V_T = \frac{K \cdot T_K}{q} = \frac{1.38 \cdot 10^{-23} \cdot (273 + currentTemp)}{1.6 \cdot 10^{-19}} [V]$
$I_D = I_S \cdot \left(e^{\frac{V_D}{n \cdot V_T}} - 1\right)$
$I_D \approx I_S \cdot e^{\frac{V_D}{n \cdot V_T}}$
$I_S \approx I_D \cdot e^{-\frac{V_D}{n \cdot V_T}}$
When in forward basis mode
$I_D \approx I_S \cdot e^{\frac{V_D}{v_T}}$
$I_S \approx I_D \cdot e^{-\frac{V_D}{V_T}}$
where:
I_S = reverse saturation (find in datasheet)
V_D = Voltage across junction
n = ideal factor, $1 < n < 2$, ideal = 1
V_T = Thermal voltage
See Lec 1 for example:
$n = \frac{V_{D2} - V_{D1}}{V_T \cdot ln(\frac{I_{D2}}{I_{D1}})}$
$V_{D1} = n \cdot V_T \cdot ln(\frac{I_{D1}}{I_S})$
$V_{D2} = n \cdot V_T \cdot ln(\frac{I_{D2}}{I_S})$
Get the equivalent resistance of a diode:
$r_D = \frac{V_T}{I_{DQ}} [\Omega]$

1.2.2 Rectifiers

- HALF RECTIFIER
$A_{V_{ripple}} = \frac{V_{out} - V_{D_{on}}}{f \cdot R \cdot C}$
$V_{reverse} = 2 \cdot V_{out} - V_{D_{on}}$
- FULL RECTIFIER
$A_{V_{ripple}} = \frac{V_{out} - 2V_{D_{on}}}{2 \cdot f \cdot R \cdot C}$
$V_{reverse} = V_{out} - V_{D_{on}}$
- FOR BOTH APPLIES, where:
V_{out} = output voltage
$V_{D_{on}}$ When the diode turns on ≈ 0.7
f = the frequency
R = the resistor value
C = the capacitor value

1.2.3 Constant voltage drop

$VCC = \frac{R1 + R2}{R2} \cdot V_{D,on}$

1.3 THE MOSFETS

1.3.1 Basics

- CONSTANTS
$V_{TH} = 0.3 < V_{TH]1}$ [V] (Voltage Threshold)
$k_n = 0.9 \cdot 10^{-3} [A/V^2]$ transconductance parameter
$V_{DD} = VCC$ [V], (kært barn, mange navne)
- FIND GM ro and AV
$gm = 2 \cdot \frac{I_{DQ}}{V_{GSQ} - V_{TH}}$
$gm = k_n \cdot (V_{GSQ} - V_{TH})$
$A_V = -gm \cdot \frac{1}{\frac{1}{R_D} \frac{1}{r_o}}$
$r_o = \frac{1}{I_{DQ} \cdot \lambda}$
$\lambda = \frac{L - L'}{V_{DS} \cdot L}$
where:
L' = actually channel length
- V's and D $V_{DS} = V_{DD} - R_D \cdot I_D$
$I_D = \frac{1}{2} k_n \cdot (V_{GS} - V_{TH})^2$
$V_{GS} = \sqrt{\frac{2 \cdot I_D}{k_n}} + V_{TH}$

1.3.2 Signal swing

- Max output swing
$V_{DS_{max}} = V_{DD} [V]$
$V_{DS_{min}} = V_{GS} - V_{TH} [V]$
$maxSwing = min(V_{DS} - V_{DS_{min}}, V_{DD} - V_{DS}) [Vpp]$
- Optimize RD for max output swing
$V_{range} = V_{DD} - V_{DS_{min}} [V]$
$V_{DSQ} = \frac{V_{range}}{2} + V_{DS_{min}} [V]$
$V_{RD} = V_{DD} - V_{DSQ} [V]$
$R_{D_{optimized}} = \frac{V_{RD}}{I_D} [\Omega]$

1.3.3 THD

$THD = HD_2 = \frac{V_{pp_{input}}}{4(V_{GS} - V_{TH})} [\%]$

1.3.4 FL from values, or desired FL

- SOME BASIS R-equvilantes.
MAY NOT BE THE ONES YOU HAVE!
$R_{gate} = R_s + \frac{1}{\frac{1}{RG1} + \frac{1}{RG2}}$
$R_{drain} = R_D + R_L$
$R_{source} = \frac{1}{\frac{1}{R_S} + gm}$
- FIND FL FROM KNOWN C's
$FL_x = \frac{1}{2\pi} \cdot \frac{1}{C_x \cdot R_{eqX}}$
- FIND C's FROM DESIRED F-L
- We need these for later.
$f_{gate} = f_{drain} = 0.1 \cdot f_{desired}$
$f_{source} = 0.8 \cdot f_{desired}$
- FOR GATE AND DRAIN
$C_{gate} = \frac{1}{2\pi \cdot f_{gate} \cdot R_{gate}}$
$C_{drain} = \frac{1}{2\pi \cdot f_{drain} \cdot R_{drain}}$
$C_{source} = \frac{1}{2\pi \cdot f_{source} \cdot R_{source}}$

1.4 Others

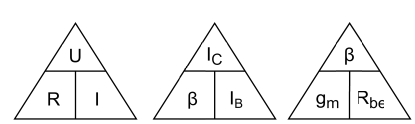
1.4.1 Miller equivalents

$C_{in_{Miller}} = C_f \cdot (1 - A_V)$ [F]
$C_{out_{Miller}} = C_f \cdot (1 - \frac{1}{A_V})$ [F]

1.4.2 Spice Commands

.op (giver værdier over komponenter)
.four <test-frequency> [Nharmonics] [-1] <outNetName> (THD directive)

1.4.3 The 3 Golden Triangles



2 HighSpeed

2.0.1 SmithCharts, LEC12

$\lambda = \frac{v}{f}, [m];$

$Z_0 = \sqrt{\frac{L}{c}}, [\Omega];$

$v = \sqrt{\frac{1}{L\cdot C}} \leftrightarrow \frac{1}{Z_0\cdot C} \leftrightarrow \frac{Z_0}{L}, [\frac{m}{s}];$

$R||L \to Z_L = \frac{1}{\frac{1}{R}+\frac{1}{j\omega L}};$

$R+L \to Z_L = R + j\omega L;$

$R||C \to Z_L = \frac{1}{\frac{1}{r}+j\omega C};$

$R+C \to Z_L = R + \frac{1}{j\omega C}, Z_L, [\Omega]$

$Z_n = \frac{Z_l}{Z_0}[\cdot];$

$Z_{stub} = j - \frac{Z_0}{B_{stub}}, [\Omega];$

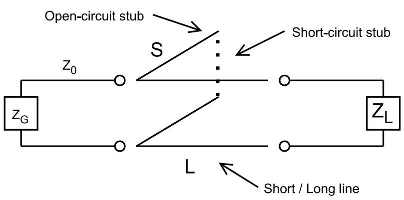
FIND DIT KOMPONENT:

$Z_{stub} = +/\text{øvre del} = \text{spole}$

$Z_{stub} = -/\text{nedre del} = \text{condensator}$

$C = \frac{-1}{\omega\cdot \mathrm{Im}(Z_{stub})}, [F];$

$L = \frac{\mathrm{Im}(Z_{stub})}{\omega}, [H];$



SmithChart: Slides MM12, slide 20-22.

2.0.2 Iron cores, LEC3&4

$\bar{B} = \mu\cdot\bar{H}, [\frac{Wb}{m^2} = \frac{V\cdot s}{m^2}];$

$\bar{H} = \frac{I}{\ell}, [\frac{A}{m}];$

$\bar{F} = \vec{\ell}\times\bar{B}, [N];$

$\mu = \mu_0\cdot\mu_r, [\frac{H}{m}]; \mu_0 = 4\pi\cdot 10^{-7};$

$\mu_{r(air)} = 1; \mu_{r(iron)} = 3000;$

$F = N\cdot I, F = I\cdot\mathscr{R}, \cdot, [A];$

$\phi = \frac{F}{\mathscr{R}}, \phi = \frac{F}{\mathscr{R}_1+\mathscr{R}_2}, \phi = \frac{|V|}{\omega\cdot N}, [Wb];$

$\omega = 2\cdot\pi\cdot f;$

$\mathscr{R} = \frac{\ell}{\mu\cdot A}, [H^{-1}, \frac{A}{Wb}];$

$I = \frac{N\cdot I}{\mathscr{R}_1+\mathscr{R}_2}, [\frac{A}{Wb}, H^{-1}];$

$A = \text{area}, [m^2];$

$\ell = \text{lengthFromThe}\textbf{CENTER!}, [m];$

2.0.3 Beam on line, LEC5

CHECK BLACKBOARDS!

$F = B\cdot I\ell, [N];$

$\bar{F} = I\cdot\bar{\ell}\times\bar{B}, [N]; a = \frac{F}{m}, [\frac{m}{s^2}];$

$v = a\cdot t, [\frac{m}{s}];$

P is the effect:

$P_{el} = \frac{v^2}{R}$

$P_{mec} = v\cdot F, [W];$

$P_{mec} = P_{el} = V\cdot I, [W];$

dot means towards us
x means away from us

2.0.4 Turning frame, LEC5

CHECK BLACKBOARDS!

$\bar{\mu} = I\cdot N\cdot A\cdot\hat{n}, [Am^2];$

$N = turns; A = Area, [m^2];$

finding $\hat{n}$:

cos = horizontal line

sin = vertical line

$\bar{\tau} = \bar{\mu}\times\bar{B}, [Nm];$

2.0.5 Reflections, LEC7&10& 13

$K_L = \frac{Z_L - Z_0}{Z_L + Z0}, [\Omega];$

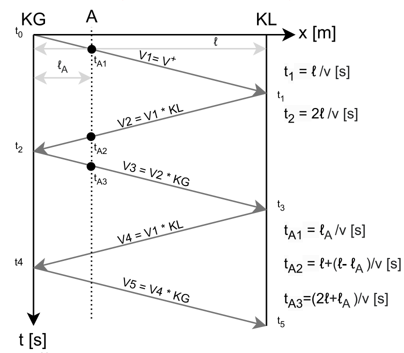
$K_G = \frac{Z_G - Z_0}{Z_G+Z_0}, [\Omega];$

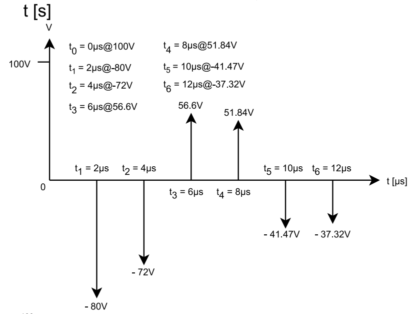
$V_+ = V_G\cdot\frac{Z_0}{Z_0+Z_G}, [V]$

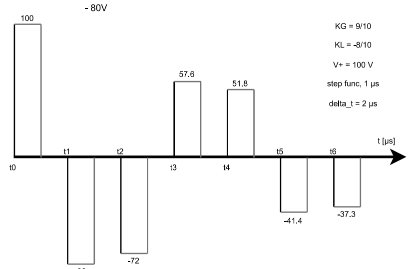
$\Delta T = \frac{\ell}{v}, [s];$

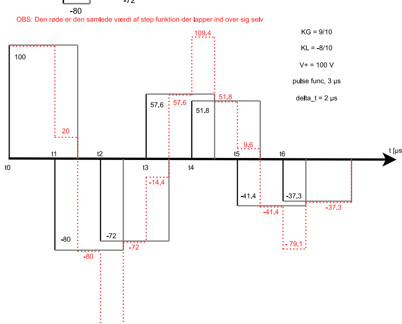
$V_\infty = V_G\cdot\frac{Z_L}{Z_G+Z_L}, [V];$

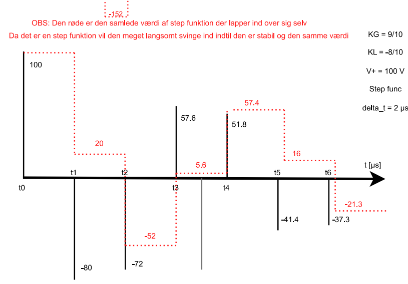
If it is current flip the sign on KG and KL otherwise, carry on.











Important note to the figures. They are made each of the reflections. If asked to do at the GENERATOR, it would be $V_1\cdot V^+, (V_2+V_3)\cdot V^+, (V_4+V_5)\cdot V^+$ and so on. If it is at the LOAD it would be $(V_1+V_2)\cdot V^+, (V_3+V_4)\cdot V^+$ and so on. If it is on the middle it would be for each seperat.

2.0.6 Standing waves, LEC11

$\omega = 2\cdot\pi\cdot f, [\frac{rad}{s}]; \gamma = \alpha - j\beta, [m^{-1}];$

$\beta = \omega\sqrt{L\cdot C}, [\frac{rad}{m}]; \alpha = 0, [\frac{Np}{m}]$

$\lambda = \frac{2\cdot\pi}{\beta} = \frac{v}{f}, [m]; v = \frac{1}{\sqrt{LC}} = \frac{\omega}{\beta}, [\frac{m}{s}]$

$SWR = \frac{max}{min};$

$K(x) = \frac{Z(x) i Z_0}{Z(x)+Z_0}[\cdot]; Z(x) = Z_0\frac{1+K(x)}{1-K(x)}, [\Omega];$

$K_L = \frac{Z_L-Z_0}{Z_L+Z_0}, [\Omega]; K_L = -(\frac{Z_0-Z_L}{Z_0+Z_L}), [\cdot];$

$\text{abs}(K_L) = \frac{SWR-1}{SWR+1}, [\cdot];$

$V_{min}/I_{max} = V^+/I^+\cdot 1 + \text{abs}(K_L), [VorA];$

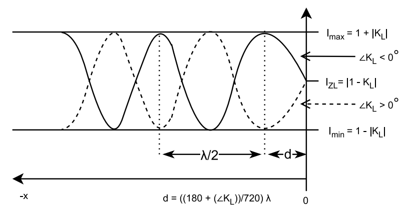
$V_{min}/I_{min} = V^+/I^+\cdot 1 - \text{abs}(K_L), [VorA];$

$V_{Z_L} = V^+\cdot\text{abs}(1+K_L), [V]$

$I_{ZL} = I_{(0)} = I^+\cdot\text{abs}(1-K_L), [A];$

$d = \lambda\frac{\varphi}{720\deg}; \varphi = 180\deg + \angle(K_L);$

$Abs(K_L) = |K_l|$



2.0.7 Point charges, LEC1

$Q_1 = -F < x,y,z >; \hat{d} = \frac{\bar{d}}{|\bar{d}|}, [\cdot];$

$\bar{d} =< x,y,z >, [m]; |\bar{d}| = d = \sqrt{x^2+y^2+z^2}, [m];$

$\vec{AB} =< X_b - X_a, Y_b - Y_a >, [m];$

$\epsilon_0 = \frac{10^{-9}}{36\pi}[\frac{F}{m}];$

$\bar{E}_{QP} = \frac{Q_b}{4\pi\epsilon_0\cdot d^2}\cdot\hat{d}, [\frac{V}{m}];$

$\bar{D} = \epsilon\cdot\bar{E}, [\frac{C}{m^2}];$

$\bar{E}_{QP(FULL)} = \bar{E}_{QP(1)} + \bar{E}_{QP(2)} + \bar{E}_{QP(3)}, [\frac{V}{m}];$

$V_{pot} = \frac{Q_b}{4\pi\epsilon_0\cdot x}, [V]; x = dist, [m];$

$V_{pot(FULL)} = V_{pot(1)} + V_{pot(2)} + V_{pot(3)}, [V];$

$\bar{F} = Q_a\cdot -\bar{E}_{QP(FULL)}, [N];$

$\bar{a} = \frac{\bar{F}}{m}, [\frac{m}{s^2}]; m = mass, [kg];$

$\bar{F} := \frac{Q_1\cdot Q_2}{4\cdot\pi\epsilon d}\cdot\hat{d};$

2.0.8 DETRIMENTAL formulas

$A_r + jB_r;$

$A_p = \sqrt{A_r^2+B_r^2}; B_p = \angle = \arctan(\frac{b}{a})\cdot\frac{360}{2\cdot\pi};$

HUSK FOR GUDS SKYLD: Cos og Sin med stort i MAPLE! og med with(Gym):

$\circ\cdot\frac{\pi}{180} = rad; rad\cdot\frac{180}{\pi} = \circ;$

$A_p\angle B_p \leftrightarrow A_r + jB_r = A_p\cdot(\cos(B_p) + j\sin(B_p));$

$$\begin{bmatrix} x_1 \\ y_1 \\ z_1 \end{bmatrix} \times \begin{bmatrix} x_2 \\ y_2 \\ z_2 \end{bmatrix} = \begin{bmatrix} X = (y_1 z_2) - (z_1 y_2) \\ Y = (x_1 z_2) - (z_1 x_2) \\ Z = (x_1 y_2) - (y_1 x_2) \end{bmatrix};$$

Tera, T $= 10^{12}$; Giga, G $= 10^9$; Mega, M $= 10^6$;
Kilo, k $= 10^3$;
Milli, m $= 10^{-3}$; micro, $\mu = 10^{-6}$; Nano, n $= 10^{-9}$;
Pico, p $= 10^{-12}$
For more prefixes see slides "ISQ"(mm8) slide 14.