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ECE 20001 Exam II Crib Sheet

Power: $P = \frac{1}{2}\mathrm{Re}\{\hat{V}\hat{I}\}$

$P_{Load} = \frac{1}{2}\frac{R_{Load}|\hat{V}_{th}|^2}{(R_{eq}+R_{Load})^2+(X_{eq}+X_{Load})^2}$

$P_{Load\,Max} = \frac{|V_{th}|^2}{8R_{eq}} = \frac{|V_{th\,RMS}|^2}{4R_{eq}}$

$Z_{load} = Z_{eq}^*$

$\eta_{efficiency} : \frac{P_{Load}}{P_{Source}}$ max pwr η is 50°

$P_{AVG} = \frac{\hat{V}_m\hat{I}_m}{2}\cos(\theta_v - \theta_i)$

$X_{rms/eff} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} x^2(t)\,dt}$

instantaneous power: $p(t) = \underbrace{\frac{V_m I_m}{2}\cos(2\omega t+\theta_v+\theta_i)}_{a} + \underbrace{\frac{V_m I_m}{2}\cos(\theta_v-\theta_i)}_{B - AVG\ PWR}$

$P = \frac{1}{2}\mathrm{Re}(V \cdot I^*)$

Real pt of PWR - real pwr
Imaginary pt - reactive pwr

same freq: phasor
diff freq: time domain

Pavg over a full period = 0

sin → cos -90°

$I_{eff} = \sqrt{i^2(t)}$

$Z_C = \frac{1}{j\omega C} = \frac{-j}{\omega C}$

Cap: favors ↑freq, impedes ↓freq
induct: favors ↓freq, impedes ↑freq

admittance is $Y = \frac{1}{Z}$

$\frac{1}{T} = f = \frac{W}{2\pi}$

$Z_L = j\omega L$

Eulers Identity: $e^{\pm j\theta} = \cos\theta \pm \sin\theta$

Cap: I leads V by 90°
Ind: V leads I by 90°

Rectangular form: +, -, complex conjugate
Polar: *, ÷, reciprocal, ^2 or $\frac{1}{2}$, CC

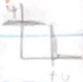
reciprocal $r\angle\theta \Rightarrow \frac{1}{r}\angle{-\theta}$

^$\frac{1}{2}$ or 2 = n
$x^n \angle n\theta$

CC: x^*
$a - jb = r\angle{-\theta}$

$u(-t)$ 1 $t<0$ 0 $t>0$

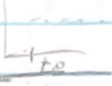
; $4u(t_0 - t)$



Cap: V is continuous
Ind: I is continuous

Step funct: $u(t) = \begin{cases} 0 & t<0 \\ 1 & t>0 \end{cases}$

; $u(t-t_0) = \begin{cases} 0 & t<t_0 \\ 1 & t>t_0 \end{cases}$



$V_C(t) = V_C(\infty) + [V_C(t_0) - V_C(\infty)]e^{\left[-\frac{1}{RC}(t-t_0)\right]}$ $\tau = R_{eq}C_{eq}$ ↑of circuit

$I_L(t) = i_L(\infty) + [i_L(t_0) - i_L(\infty)]e^{\left[-\frac{R}{L}(t-t_0)\right]}$ $\tau = \frac{L_{eq}}{R_{eq}}$

Inductors behave as RESISTORS
Capacitors behave OPP of resistor

↓ transient duration, ↓ τ

Inductance is INDEPENDENT of current

$L = \frac{\mu N^2 S}{l}$

$w(t) = \int p(t)$
$W_L = \frac{1}{2}Li^2(t)$

$Q = CV$
$C = \frac{\varepsilon A}{d}$

$i_C = C\frac{dV_c(t)}{dt}$ & $V_L = L\frac{di_L(t)}{dt}$

$W_C = \frac{1}{2}CV_C^2$

$\Phi = \int_S \vec{B}\,dS$
Inductance $(L) = \frac{N\Phi}{I} = \frac{\lambda}{I}$

flux linkage $(\lambda) = N\Phi$

Super capacitors: ↓ voltage devices

Batteries: energy dense [hold ↑ ε, ↓ space]
SC + capacitors: power dense [↑ discharge, ↓ volume]

Superposition does NOT apply to power

finding Req: 1) turn off indep. sources 2) V or I test

V_{th}: leave port open

I_N: short circuit across ports

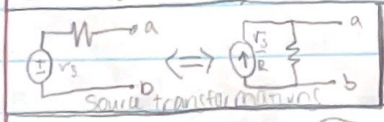
$\varepsilon = qV$
$P(t) = \frac{d\varepsilon}{dt}$

$R = \frac{\rho l}{A}$
$G = \frac{1}{R}$

"removing" source
(↑) → OPEN
(±) → Short

$L_{12} = \frac{N_2\Phi_{12}}{I_1} = \frac{\lambda}{I}$ M.I.

$L = \frac{\Phi_{11}N_1}{I_1}$ S.I.



Source transformations

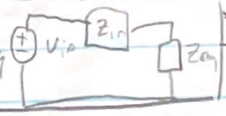
$f = \frac{1}{T} = \frac{\omega}{2\pi}$
$f_{res}\left(\begin{smallmatrix} Z\downarrow \\ I\uparrow \end{smallmatrix}\right) = \frac{1}{2\pi\sqrt{LC}}$

$V_{rms} = \frac{V_m}{\sqrt{2}}$

coupling coeff: $K = \frac{L_{12}}{\sqrt{L_1L_2}}$ ≤1 in ideal Trans

$V_1(t) = L_1\frac{di_1}{dt} + L_{12}\frac{di_2}{dt}$

Reflected impedance: $\frac{Z_{out}}{n^2} = Z_{eq}$



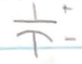
Smaller band gap higher conductivity

$np = n_i^2$

drift current density, e^- mobility

$J_{n/p\ drift} = q\mu_{p/n}\, p\, \mathcal{E}_x$

$J_{total} = J_n \cdot J_p$



capacitor

$V_{12} = R_{12} \cdot I_{opp\,loop}$

* mutual inductance

$Z_{eq} = \frac{Z_{out}}{n^2}$ → Z_{total} from secondary side

inductor

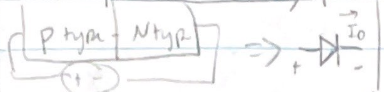
$\frac{V_2}{V_1} = \frac{N_2}{N_1} = n$ or $\frac{i_2}{i_1} = \frac{-N_1}{N_2} = \frac{-1}{n}$

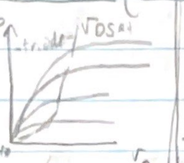
voltage devision: $V_L = V_{total} \frac{Z_L}{Z_{total}}$

$\frac{D_n}{\mu_n} = \frac{KT}{q}$ or $\frac{D_p}{\mu_p} = \frac{KT}{q}$

built in potential $V_{bi} = \frac{KT}{q} \ln\left(\frac{N_A N_D}{(n_i^2)}\right)$ ← doping concentration

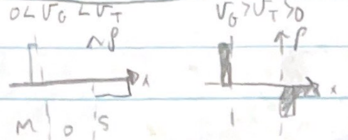
$I = I_0\left(e^{qV_A/KT} - 1\right)$





triode: $I_D = K\left[(V_{GS} - V_T)V_{DS} - \frac{1}{2}V_{DS}^2\right]$

sat: $I_D = \frac{K}{2}(V_{GS} - V_T)^2$



V_{Gate} controls I

$> $ triode
$<$ saturation

$V_{GS} - V_T = V_{DS}$

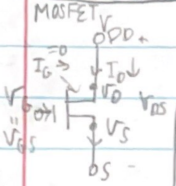
V_G fixed
ΔV_D
op. pt

↑ saturation
V_D

V_{Gate} controlls minority carriers

$V_{GS} > V_T$ to be on

cutoff: $V_G < V_T$ OFF



No I into gate no matter V.

$I_D = I_S$

onset of satration: triode → sat pt

$\vec{\mathcal{E}}_{field}$ outside DR $= 0$ $\int \mathcal{E}_x dx = V_P$

$V_{GS} = V_G - V_S$

DR width depends on doping levels

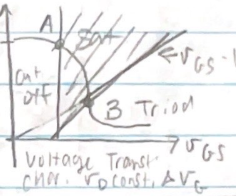
ΣQ device = 0 always $Q_P^- = Q_n^+$

$qN_A x_p = qN_D x_n$ $\frac{x_n}{x_p} = \frac{N_A}{N_D}$

$\rho = q\left(p - n + N_D^+ - N_A^-\right)$

ρ = total charge density $N_D^+ + N_A^-$ concentration of ionized donor/acceptor

$+V_A$ ⇒ PE of p side, reduces total PE between n+p

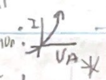


Voltage Transfer char. V_D const, ΔV_G

mosfet trans. conductance: $i_d = g_m v_{gs}$

W_{DR} @ equil. $= \left[\frac{2\varepsilon_r\varepsilon_0}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)V_{bi}\right]^{\frac{1}{2}}$

ideal PN junction diode



Anode E enters
cathod E leaves

transconductance parameter $K = \mu_n C_{ox}\left(\frac{W}{L}\right)$

Small signal condt. $\vec{v}_a \ll 2(V_G - V_T)$

Small Sig voltage Gain $A_V = -R_D K(V_G - V_T)$

*ignore +/- on capacitors treat them as resistors

If diode ON: I^+ SHORT

if looking @ ΔV off: open

* for diode to be ON ΔV = 0 across it