ECE215/S – Principles of Electronic Cyber Warfare
Equation Sheet

DC Circuit Analysis

Ohm's Law	$V = IR$
Power Law	$P = IV = \frac{V^2}{R} = I^2R$
Series	$R_{eq} = R_1 + R_2 + \ldots + R_n$
Voltage Divider	$V_x = \frac{R_x}{R_{eq}} V_{series}$
Parallel	$R_{eq} = (\frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n})^{-1}$
→ 2 resistors	$R_{eq} = \frac{R_x R_y}{R_x + R_y}$
Current Divider	$I_x = \frac{R_{eq}}{R_x} I_{parallel}$
→ 2 resistors	$I_x = \frac{R_y}{R_x + R_y} I_{parallel}$
KCL	$\sum_{In}(I) = \sum_{Out}(I)$
KVL	$\sum_{Loop}(V) = 0$
Circuit Breaker	$1.1 \times I_{nom} < CB_{value} < 1.5 \times I_{nom}$

AC Circuit Analysis

AC Equation	$v(t) = V_{bias} + V_m \cos(\omega \cdot t + \phi)$
Angular Freq	$\omega = 2\pi f$
Frequency	$f = \frac{1}{\text{period}} = \frac{1}{T}$
Phase Shift	$\phi = \omega \cdot \Delta t$, left = pos, right = neg
RMS	$V_{rms} = \frac{V_m}{\sqrt{2}} = 0.707 * V_m$
Apparent [VA]	$S = V_{rms} I_{rms} = \sqrt{P^2 + Q^2}$
Real [W]	$P = V_{rms} I_{rms} \cos(\phi_V - \phi_I)$
Reactive [VAR]	$Q = V_{rms} I_{rms} \sin(\phi_V - \phi_I)$
Power Factor	$pF = \frac{P}{S}$
$Q > 0$	lagging (I lags V)
$Q < 0$	leading (I leads V)

$P_{bus} = P_1 + P_2 + \ldots$, $Q_{bus} = Q_1 + Q_2 + \ldots$

Motors, Power Converters

Efficiency	$\eta = \frac{P_{out}}{P_{in}} = \frac{P_{useful}}{P_{useful} + P_{loss}}$
Mech Power	1 hp = 745.7 Watts
Converters	Only use REAL power, P [W]

Transformers

Turns ratio	$a = \frac{N_1}{N_2} = \frac{v_1(t)}{v_2(t)} = \frac{i_2(t)}{i_1(t)}$

Complex Math

Imag Number	$j = \sqrt{-1}$, $\frac{1}{j} = -j$
Rectangular	$Re + jIm$ $= A\cos\phi + jA\sin\phi$
Phasor	$A\angle\phi$
Amplitude	$A = \sqrt{Re^2 + Im^2}$
Phase	$\phi = \tan^{-1}\left(\frac{Im}{Re}\right)$

R-C and R-L Circuits

Resistor Impedance	$Z_R = R$
Capacitor Impedance	$Z_C = \frac{1}{j\omega C}$
Inductor Impedance	$Z_L = j\omega L$
R-C Circuit Cutoff	$f_{\text{cutoff}} = \frac{1}{2\pi RC}$
R-L Circuit Cutoff	$f_{\text{cutoff}} = \frac{R}{2\pi L}$
Bandwidth	$BW = f_{high} - f_{low}$
Gain in absolute	$G_{abs} = \left\lvert\frac{\mathrm{V_{out}}}{\mathrm{V_{in}}}\right\rvert$
Gain in decibels	$G_{dB} = 20\log_{10}(G_{abs})$

Engineering Notation

10^{12}	T (tera)
10^{9}	G (giga)
10^{6}	M (mega)
10^{3}	k (kilo)
10^{-3}	m (milli)
10^{-6}	μ (micro)
10^{-9}	n (nano)
10^{-12}	p (pico)
10^{-15}	f (femto)
10^{-18}	a (atto)

RF Spectrum

	300 GHz
EHF	
	30 GHz
SHF	
	3 GHz
UHF	
	300 MHz
VHF	
	30 MHz
HF	
	3 MHz
MF	
	300 kHz
LF	
	30 kHz
VLF	
	3 kHz

Analog/Digital Conversion

Signal Conditioning	$V_{out} = K \cdot V_{in} + B$
Nyquist Criterion	$f_s \geqslant 2f_{high}$, $T_s = \frac{1}{f_s}$
Quantization Levels	# levels $= 2^b$
Voltage Resolution	$\Delta V = \dfrac{V_{max} - V_{min}}{2^b}$
Expected Level	$EL = \dfrac{V_{in} - V_{min}}{\Delta V}$
Quantized Level	$QL = floor(EL)$
Quantized Voltage	$V_{quant} = QL \cdot \Delta V + V_{min}$
Quantization Error	$QE = V_{in} - V_{quant}$
Max QE	$QE_{max} = \Delta V$
Digital/Analog	$V_{out,DAC} = QL \cdot \Delta V + V_{min}$
(w/ $V_{min} = 0$V)	$V_{out,DAC} = \dfrac{QL}{2^b} \cdot V_{max}$

Bit Rate & Data Storage

Bit Rate	bit rate $= f_s \cdot b$
Data Storage	1 byte = 8 bits
	2^{30} bytes = 1 GiB
	2^{20} bytes = 1 MiB
	2^{10} bytes = 1 kiB

Amplitude Modulation

$A_c \cos(2\pi \cdot f_c \cdot t) \cdot [A_m \cos(2\pi \cdot f_m \cdot t) + B] = \ldots$

(diff)	$\dfrac{A_c A_m}{2} \cos[2\pi \cdot (f_c - f_m) \cdot t] + \ldots$
(sum)	$\dfrac{A_c A_m}{2} \cos[2\pi \cdot (f_c + f_m) \cdot t] + \ldots$
(bias)	$A_c B \cos(2\pi \cdot f_c \cdot t) \blacksquare$
Mod Index	$\alpha = \dfrac{A_m}{B} = \dfrac{2 \cdot Amp_{SB}}{Amp_{Carrier}}$
Efficiency	$\eta = \dfrac{\alpha^2}{\alpha^2 + 2}$

Antennas

Wavelength	$\lambda = \dfrac{c}{f}$
Speed of Light	$c = 3 \times 10^8$ m/s
Ideal Dipole	Length $= \dfrac{\lambda}{2}$, $G = 1.64$
Ideal Monopole	Length $= \dfrac{\lambda}{4}$, $G = 3.28$
Parabolic Dish	$G_{dish} = \left(\dfrac{2\pi r_{dish}}{\lambda}\right)^2$

Wireless Communication

Line of Sight	$R_{LOS,mi} = \sqrt{2 \cdot h_{ft,1}} + \sqrt{2 \cdot h_{ft,2}}$
Conversions	1mi = 1.61km, 1ft = 0.305m
Friis Equation	$P_R = P_T G_T G_R \left(\dfrac{\lambda}{4\pi R}\right)^2$
	$R = \dfrac{\lambda}{4\pi} \cdot \sqrt{\dfrac{P_T G_T G_R}{P_R}}$
Signal-to-Noise	$SNR = \dfrac{P_{signal}}{P_{noise}} = \dfrac{P_R}{k \cdot T_{sys} \cdot BW}$
	$k = 1.38 \times 10^{-23} J/K$

Radar

Radar Range Eqn	$P_R = \dfrac{P_T G_T^2 (RCS) \lambda^2}{(4\pi)^3 R^4}$
	$R = \left(\dfrac{P_T G_T^2 (RCS) \lambda^2}{(4\pi)^3 P_R}\right)^{1/4}$
Pulse Rep Freq	$PRF = \dfrac{1}{PRI}$
Unambig Range	$R_{\max,unambig} = \dfrac{c \cdot PRI}{2}$

Electronic Warfare

$$SNR_{comm} = \frac{P_{R,sig}}{P_{R,jam}} = \frac{P_{T,sig} \cdot G_{T,sig} \cdot R_{jam}^2}{P_{T,jam} \cdot G_{T,jam} \cdot R_{sig}^2}$$

$$SNR_{rad} = \frac{P_{R,rad}}{P_{R,jam}} = \frac{P_{T,rad} \cdot G_{T,rad} \cdot RCS}{P_{T,jam} \cdot G_{T,jam} \cdot 4\pi R^2}$$