

Electronics Key Equations

Basic Electricity

Ohm's Law	$V = IR$	Work Done	$W = QV$
Charge	$Q = It$		$W = VIt$
Power	$P = IV$	Current	$I = nAve$
	$P = I^2R$	Internal Resistance	$\varepsilon = I(R + r)$
	$P = \frac{V^2}{R}$	Potential Divider	$\varepsilon = V + Ir$
Resistors in Series	$R = R_1 + R_2 + \dots$		$\frac{V_1}{V_2} = \frac{R_1}{R_2}$
Resistors in Parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$		$V_{out} = V_{in} \frac{R_2}{R_1 + R_2}$
Resistivity	$R = \frac{\rho L}{A}$		

Waveforms

Sinusoidal Waves	$v = V \sin(\omega t)$ $v = V \cos(\omega t)$	Sinusoidal RMS	$V_{eff} = \sqrt{\frac{1}{T} \int_0^T \frac{v^2}{R} dr}$
Angular Frequency	$\omega = \frac{2\pi}{t}$	Piecewise RMS	$V_{rms} = \sqrt{\frac{1}{N} \sum v_n^2}$
Converting between rad/s and rpm	$rad \ s^{-1} = \frac{\pi}{30} (rpm)$	Pulse Width Modulation	$\alpha = \frac{on \ time}{off \ time}$
Phase difference	$v = V \cos(\omega t + \phi)$		$V_{rms} = V_{max} \sqrt{\alpha}$
			$I_{rms} = I_{max} \sqrt{\alpha}$

Capacitors & Capacitance

Capacitance	$C = \frac{Q}{V}$ $C = \frac{\epsilon_0 A}{d}$ $C = 4\pi\epsilon_0 R$	Capacitors in Series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$
Time Constant	$\tau = CR$	Capacitors in Parallel	$C = C_1 + C_2 + \dots$
Q & V when Charging	$x = x_0 \left(1 - e^{-\frac{t}{\tau}}\right)$	Energy Stored	$W = \frac{1}{2} QV$
I when Charging	$I = I_0 e^{-\frac{t}{\tau}}$		$W = \frac{1}{2} \frac{Q^2}{C}$
Q , I & V when Discharging	$x = x_0 e^{-\frac{t}{\tau}}$		$W = \frac{1}{2} V^2 C$

Rectification & Smoothing

$$\text{Maximum DC Voltage} \quad V_{max} = \sqrt{2} \times V_{rms,AC}$$

$$\text{Minimum DC Voltage} \quad V_{min} = V_{max} \left(1 - \frac{T}{\tau}\right)$$

$$V_{min} = V_{max} \left(1 - \frac{1}{f\tau}\right)$$

$$\text{Ripple Voltage} \quad V_{rpp} = V_{max} - V_{min}$$

$$V_{rpp} = V_{max} \frac{T}{\tau}$$

$$\text{DC Output Voltage}$$

$$V_{DC} = V_{max} - \frac{1}{2}V_{rpp}$$

$$\text{Assuming } V_{DC} \approx V_{rpp}$$

$$V_{rpp} = V_{DC} \frac{T}{\tau}$$

$$V_{rpp} = V_{DC} \frac{1}{f\tau}$$

Note: When a bridge rectifier is used, the rectified frequency is double the AC frequency, and the ripple voltage is half what it would be if a half-bridge rectifier were used.

Resistor Series

$$E3 \quad 1.0, 2.2, 4.7, 10, 22, 47, 100 \dots$$

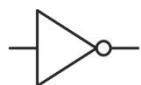
$$E6 \quad 1.0, 1.5, 2.2, 3.3, 4.7, 6.8, 10, 15, 22, 33, 47, 68, 100 \dots$$

$$E12 \quad 1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2, 10, 12, 15 \dots$$

Logic Gates

NOT Gate

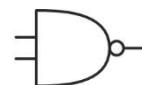
$$M = \bar{A}$$



A	M
0	1
1	0

NAND Gate

$$M = \overline{A \cdot B}$$



A	B	M
0	0	1
1	0	1
0	1	1
1	1	0

AND Gate

$$M = A \cdot B$$



A	B	M
0	0	0
1	0	0
0	1	0
1	1	1

NOR Gate

$$M = \overline{A + B}$$



A	B	M
0	0	1
1	0	0
0	1	0
1	1	0

OR Gate

$$M = A + B$$



A	B	M
0	0	0
1	0	1
0	1	1
1	1	1

XOR Gate (exclusive OR)

$$M = A \oplus B$$



A	B	M
0	0	0
1	0	1
0	1	1
1	1	0

Boolean Identities

$$A + B = \overline{(\bar{A} \cdot \bar{B})}$$

$$\overline{A + B} = (\bar{A} \cdot \bar{B})$$

$$A + \bar{A} = 1$$

$$A \cdot \bar{A} = 0$$

DC Generator

Induced emf	$E = K_e \omega$
Generator Power	$V_a I = T_i \omega - R_a I^2$
Mechanical Torque	$T_i = K_e I$ $T_i = T - T_f$

DC Motor

Induced emf	$E = K_e \omega$
Generator Power	$V_a I = T_0 \omega + R_a I^2$
Mechanical Torque	$T_0 = K_e I$ $T_0 = T + T_f$

Magnetic Fields & Induction

Magnetic Flux	$\phi = BA \cos \theta$
Flux Linkage	$N\phi = BAN \cos \theta$
Lorentz Force	$F = BIL \sin \theta$
	$F = BQv$

Faraday's Law

$$E = N \frac{d\phi}{dt}$$
$$E = \frac{d}{dt} (BAN \cos \theta)$$

Electromagnetism

Magnetomotive Force	$mmf = NI$
Reluctance	$S = \frac{mmf}{\phi}$ $S = \frac{L}{\mu_r \mu_0 A}$
Reluctance in Series	$S_{total} = S_1 + S_2 + \dots$
Reluctance in Parallel	$\frac{1}{S_{total}} = \frac{1}{S_1} + \frac{1}{S_2} + \dots$
Flux	$\phi = Ni \frac{\mu_r \mu_0 A}{L}$

Flux Density

$$B = Ni \frac{\mu_r \mu_0}{L}$$
$$B = \frac{NI}{SA}$$

Energy

$$energy = N^2 I^2 A \frac{\mu_r \mu_0}{2L}$$
$$energy = \frac{1}{2} \frac{N^2 I^2}{S}$$
$$energy = \frac{1}{2} \phi^2 S$$

Force

$$F = \frac{AB^2}{2\mu_0}$$

Electrical & Magnetic Quantities

Electrical Quantity	Units	Magnetic Equivalent	Units
emf	V	mmf	A. turns
Current, I	A	Flux, ϕ	Wb
Resistance, R	Ω	Reluctance, S	$A. turns Wb^{-1}$
Resistivity, ρ		1 / Permeability	

Encoders

Rotary Resolution	$resolution = \frac{range}{2^M}$	Absolute Uncertainty	$\Delta = \pm r esolution$
Linear Resolution	$resolution = \frac{range}{2^M - 1}$		

Strain Gauges

Change in Resistance	$\frac{dR}{R} = G \frac{dI}{I} = G\varepsilon$ $\ln \frac{R_1}{R_2} = G \ln \frac{I_1}{I_2}$
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Load Cells

Output Voltage (when $G\varepsilon$ is small)	$V_{out} = \frac{1}{4} V_{in} G\varepsilon$
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