

# Electronics Key Equations

## Basic Electricity

Ohm's Law

$$V = IR$$

Charge

$$Q = It$$

Power

$$P = IV$$

$$P = I^2R$$

$$P = \frac{V^2}{R}$$

Resistors in Series

$$R = R_1 + R_2 + \dots$$

Resistors in Parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

Resistivity

$$R = \frac{\rho L}{A}$$

## Waveforms

Sinusoidal Waves

$$v = V \sin(\omega t)$$

$$v = V \cos(\omega t)$$

Angular Frequency

$$\omega = \frac{2\pi}{t}$$

Converting between  
rad/s and rpm

$$\text{rad s}^{-1} = \frac{\pi}{30} (\text{rpm})$$

Phase difference

$$v = V \cos(\omega t + \phi)$$

## Capacitors & Capacitance

Capacitance

$$C = \frac{Q}{V}$$

$$C = \frac{\epsilon_0 A}{d}$$

$$C = 4\pi\epsilon_0 R$$

Time Constant

$$\tau = CR$$

$Q$  &  $V$  when Charging

$$x = x_0 \left(1 - e^{-\frac{t}{\tau}}\right)$$

$I$  when Charging

$$I = I_0 e^{-\frac{t}{\tau}}$$

$Q$ ,  $I$  &  $V$  when

$$x = x_0 e^{-\frac{t}{\tau}}$$

Discharging

Work Done

$$W = QV$$

$$W = VIt$$

Current

$$I = nAve$$

Internal Resistance

$$\epsilon = I(R + r)$$

$$\epsilon = V + Ir$$

Potential Divider

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2}$$

Sinusoidal RMS

$$V_{eff} = \sqrt{\frac{1}{T} \int_0^T \frac{v^2}{R} dt}$$

Piecewise RMS

$$V_{rms} = \sqrt{\frac{1}{N} \sum v_n^2}$$

Pulse Width  
Modulation

$$\alpha = \frac{\text{on time}}{\text{off time}}$$

$$V_{rms} = V_{max} \sqrt{\alpha}$$

$$I_{rms} = I_{max} \sqrt{\alpha}$$

Capacitors in Series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

Capacitors in Parallel

$$C = C_1 + C_2 + \dots$$

Energy Stored

$$W = \frac{1}{2} QV$$

$$W = \frac{1}{2} \frac{Q^2}{C}$$

$$W = \frac{1}{2} V^2 C$$

### Rectification & Smoothing

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

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

Ripple Voltage  $V_{rpp} = V_{max} - V_{min}$   
 $V_{rpp} = V_{max} \frac{T}{\tau}$

DC Output Voltage

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

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 1.0, 2.2, 4.7, 10, 22, 47, 100 ...

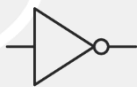
E6 1.0, 1.5, 2.2, 3.3, 4.7, 6.8, 10, 15, 22, 33, 47, 68, 100 ...

E12 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 ...

### Logic Gates

#### NOT Gate

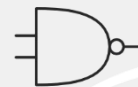
$$M = \bar{A}$$



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
emf	V
Current, $I$	A
Resistance, $R$	$\Omega$
Resistivity, $\rho$	

## Magnetic Equivalent

Magnetic Equivalent	Units
mmf	A. turns
Flux, $\phi$	Wb
Reluctance, $S$	A. turns $Wb^{-1}$
1 / Permeability	

## Encoders

Rotary Resolution	$resolution = \frac{range}{2^M}$
Linear Resolution	$resolution = \frac{range}{2^M - 1}$

## Absolute Uncertainty

$$\Delta = \pm r \text{ resolution}$$

## 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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