Appendices Table of Contents

DC / AC Formulae

$1\ C = 6.24 \times 10^{18}$ electrons

$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m

$\mu_0 = 1.26 \times 10^{-6}$ H/m

1 HP = 746 W

1 in. = 2.54 cm

1 mi. = 5280 ft.

1 kg = 2.2 lb.

$F = \frac{1}{4\pi\varepsilon} \times \frac{Q_1 Q_2}{d^2}$

$W = Fd = QV$

$Q = It$

$E = IR$

$P = \frac{W}{t}$

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

$\eta = \frac{P_o}{P_i}$

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

$G = \frac{1}{R}$

$R_{new} = R_{20^\circ C}\left(1 + \alpha\Delta T\right)$

$\Delta T = \left(T_{new} - 20^\circ C\right)$

$D = \frac{\Psi}{A}$

$\mathcal{E} = \frac{F}{q} = \frac{V}{d}$

$\varepsilon = \frac{D}{\mathcal{E}}$

$\varepsilon = \varepsilon_r\ \varepsilon_0$

$Q =$ [illegible]

$C = \frac{\text{[illegible]}}{d}$

$i_C = C\frac{dv}{dt}$

$W = \frac{1}{2}CV^2$

$\tau = RC = \frac{L}{R}$

$v = V_f - \left(V_f - V_i\right)e^{-t/\tau}$

$i = I_f - \left(I_f - I_i\right)e^{-t/\tau}$

$f_c = \frac{1}{2\pi\tau}$

$t_r = 2.2\ \tau$

$\mathcal{F} = NI = Hl$

$B = \frac{\phi}{A}$

$\mu = \frac{B}{H}$

$\mu = \mu_r\ \mu_0$

$L = \frac{\mu N^2 \text{[illegible]}}{\text{[illegible]}}$

$v_L = \text{[illegible]}\frac{di}{dt} = N\frac{d\phi}{dt}$

[illegible] $= -L$ [illegible]

$W = \frac{1}{2}$ [illegible]^2

$a =$ [illegible] $\sin\left(\omega t \pm \theta\right)$

[illegible] $_{(half\ cycle)} = \frac{2V_p}{\pi}$

$V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{V_{pp}}{2\sqrt{2}}$

$\omega = 2\pi f$

$T = \frac{1}{f}$

$X_L = 2\pi fL$

$X_C = \frac{1}{2\pi fC}$

$Z = R \pm j$ [illegible]

$Y = G$ [illegible]

$Y = \frac{1}{\text{[illegible]}}$ $G = \frac{1}{R}$ $B = \frac{1}{X}$

$S =$ [illegible] $\pm jQ$

[illegible] $= \cos\theta$

$Q_{coil} = \frac{X_L}{R_S}$

$Q_S = \frac{X_L \text{ or } X_C}{R_{eq}}$

[illegible] $= \frac{Q_L \text{ or } Q_C}{P}$

$Q_S = \frac{1}{R}\sqrt{\frac{L}{C}}$

$Q_P = \frac{R_{eq}}{X_L \text{ or } X_C}$

$Q_P = R\sqrt{\frac{C}{L}}$

$f_r = \frac{1}{2\pi\sqrt{LC}}$

$f_r = \sqrt{f_1 f_2}$

$BW = \frac{f_r}{Q} = \left(f_2 - f_1\right)$

$f_1 = f_r - \frac{BW}{2}$

$f_2 = f_r + \frac{BW}{2}$

$R_P = R_S\left(1 + Q^2\right)$

$X_P = X_S\left(1 + \frac{1}{Q^2}\right)$

$f_r = \frac{1}{2\pi\sqrt{LC}}\sqrt{1 - \frac{R_S^2 C}{L}}$

$a = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P} = \sqrt{\frac{Z_P}{Z_S}}$

Devices Formulae

Diode Circuits

$I_F = \frac{E - V_F}{R}$ $\quad I_R = \frac{E - V_R}{R}$

BJT Equations

$\beta = \frac{I_C}{I_B}$ $\quad \alpha = \frac{I_C}{I_E}$ $\quad \beta = \frac{\alpha}{1 - \alpha}$ $\quad \alpha = \frac{\beta}{\beta + 1}$

$I_E = I_C + I_B$ $\qquad V_{CE} = V_{CB} + V_{BE}$

$h_{ib} = \frac{26\text{ mV}}{I_E} + r_o$ $\qquad r_o = 10\ \Omega$, if not given

$h_{ie} = (h_{fe} + 1)\, h_{ib}$

r_e = external ac resistance looking **out** the emitter

r_b = external ac resistance looking **out** the base

r_c = external ac resistance looking **out** the collector

Common Emitter Amplifiers

$R_i' = (h_{fe} + 1)(h_{ib} + r_e)$

$R_i = R_1 \,//\, R_2 \,//\, R_i'$

$R_o' = \infty$

$R_o = R_C \,//\, R_o' = R_C$

$A_v = \frac{-R_C \,//\, R}{(h_{ib} + r_e)} = \frac{-r_c}{(h_{ib} + r_e)}$

$A_i = \frac{A_v\, R_i}{R}$ $\qquad A_p = A_v$ [illegible]

Emitter Follower Amplifiers

$R_i' = (h_{fe} + 1)(h$ [illegible] $)$

$R_i = R_1 \,//\, R_2$ [illegible] R_i

$R_o' = h_{ib}$ [illegible] $\frac{\text{[illegible]} \,//\, \text{[illegible]}_2 \,//\, R_E}{h_{fe} + 1}$

R_o [illegible] R_o'

A_v [illegible] $\frac{r_e}{h_{ib} + r_e}$

$A_i = \frac{A_v\, R_i}{R}$ $\qquad A_p = A_v\, A_i$

Amplifier Design Rules

$V_{R_E} = 0.1 \times V_{CC}$ $\qquad V_{CE} = 0.5 \times V_{CC}$

$R_2 = 10 \times R_E$

Decibel Relationships

$A_{P(dB)} = 10 \log\left(\frac{p_o}{p_i}\right)$

$A_{v(dB)} = 20 \log\left(\frac{v_o}{v_i}\right)$

$A_{i(dB)} = 20\ \text{l}$ [illegible]

$A_{P(dBm)} = 10 \log\left(\frac{p_o}{1.0\ \text{[illegible]}}\right)$

Amplifier Measurement Model

[illegible] $\frac{v_g - v_i}{R_{sense}}$ [illegible] $= \frac{v_o}{R}$

$R_i = \frac{\text{[illegible]} \times R_{sense}}{v_g - v_i}$

$R_o = \frac{v_{oc} - v_o}{i_o} = \frac{(v_{oc} - v_o)\, R}{v_o}$

BJT Switching

$I_C\,(sat) = \frac{V_{CC} - V_{CE}\,(sat)}{R_C}$

$I_{B\,min}\,(sat) = \frac{I_C\,(sat)}{\beta}$

$V_o\,(sat) = V_{BE} + V_{CE}\,(sat)$

Op Amp Frequency Response

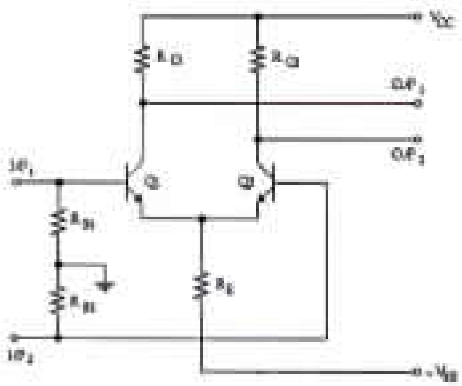
$f_c = \frac{1}{2\pi RC}$

Factor for "n" identical stages: $\sqrt{2^{1/n} - 1}$

$slope = \frac{dB_{HF} - dB_{LF}}{\log HF - \log LF} = \frac{dB_{HF} - dB_{LF}}{\log\left(\frac{HF}{LF}\right)}$

$GBP = A_{V_o} \times BW$ $\quad$ where $\quad A_{V_o} = \frac{R_f}{R_1} + 1$

Differential Amplifiers



$V_{B_1} = V_{B_2} = 0 \text{ V}$

$I_E\ (total) = \frac{V_E - V_{EE}}{R_E}$ $\qquad I_{C_1} = I_{C_2} = \frac{I_E\ (total)}{2}$

$V_{C_1} = V_{C_2} = V_{CC} - I_C R_C$

$v_{ID} = v_{i_1} - v_{i_2}$ $\qquad v_{OD} = v_{O_1} - v_{O_2}$

$v_{IC} = \frac{v_{i_1} + v_{i_2}}{2}$ $\qquad v_{OS} = v_{ID} A_{VDS} + v_{IC} A_{VCS}$

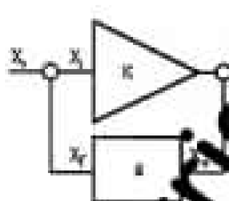
$v_{i_1} = v_{IC} + \frac{v_{ID}}{2}$ $\qquad v_{i_2} = v_{IC} - \frac{v_{ID}}{2}$

$A_{VDS} = \frac{v_{O1}}{v_{ID}}$ or $\frac{v_{O2}}{v_{ID}}$ $\qquad A_{VDD} = \frac{v_{OD}}{v_{ID}} = 2 A_{VDS}$

$A_{VCS} = \frac{v_{O1}}{v_{IC}}$ or $\frac{v_{O2}}{v_{IC}}$ $\qquad CMRS = \frac{A_{VDS}}{A_{VCS}}$

$CMRS_{(dB)} = 20 \log CMRS$

Feedback Amplifiers



$[illegible] = \frac{X_o}{X_s} = \frac{K}{1 + \beta K}$

$K = \frac{X_o}{X_i}$ $\qquad$ Heavy FB: $\beta K \geq 20$

$\beta = \frac{X_f}{X_o}$ $\qquad \beta_V = \frac{R_i}{R_1 + R_f}$

Feedback Effects on Impedance

$R_{of} = \frac{[illegible]}{(1 + \beta K)}$ $\qquad$ sampling output voltage

$R_{if} = \frac{R_i}{(1 + \beta K)}$ $\qquad$ feeding back in shunt

$R_{if} = R_i (1 + \beta K)$ $\qquad$ feeding back in series

Power Supplies

$I_{DC}\ (max) = I_{SEC}\ (max) \times Derating\ \%$

$V_{0_{avg}} = \frac{2V_p}{\pi}$ $\qquad V_{RMS} = \frac{V_p}{\sqrt{2}}$ $\qquad$ (unfiltered full-wave rectifier)

$V_{0_{avg}} = \frac{V_p}{\pi}$ $\qquad V_{RMS} = \frac{V_p}{2}$ $\qquad$ (unfiltered half-wave rectifier)

Filtering & Regulation

$V_{r_{pp}} = \frac{V_p T}{\tau} = \frac{IT}{C}$ $\qquad V_{C_{avg}} = V_{DC} = V_p - \frac{V_{r_{pp}}}{2}$

$\%\ Load\ Regulation = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\ \%$

$\%\ Line\ Regulation = [illegible] \times 100\ \%$ $\qquad V_{r_{rms}} = \frac{V_{r_{pp}}}{2\sqrt{3}}$

$P_D\ (regulator) = ([illegible] - V_o)\ I_o$

$[illegible] = V_o + V_{[illegible]}$

Op Amp Applications

Inverting Amp: $A_v = \frac{-R_f}{R_1}$ $\qquad R_i = R_1$ $\qquad R_o = 0$

Noninverting Amp: $A_v = \frac{R_f}{R_1} + 1$ $\qquad R_i = \infty$ $\qquad R_o = 0$

Summing Amp: $V_o = V_{i_1} A_{V1} + V_{i_2} A_{V2} + V_{i_3} A_{V3} + \ldots$

Difference Amp: $V_o = (V_{NON} - V_{INV}) \left(\frac{R_f}{R_1} \right)$

Butterworth Active Filters

$A_v = 3 - \alpha$ $\qquad f_c = \frac{1}{2\pi RC}$

Sampling Theorem

$f_s \geq 2 f_{i\,(max)}$ $\qquad f_{max\ (LP\ maximally\ flat)} \leq \frac{f_s}{2}$

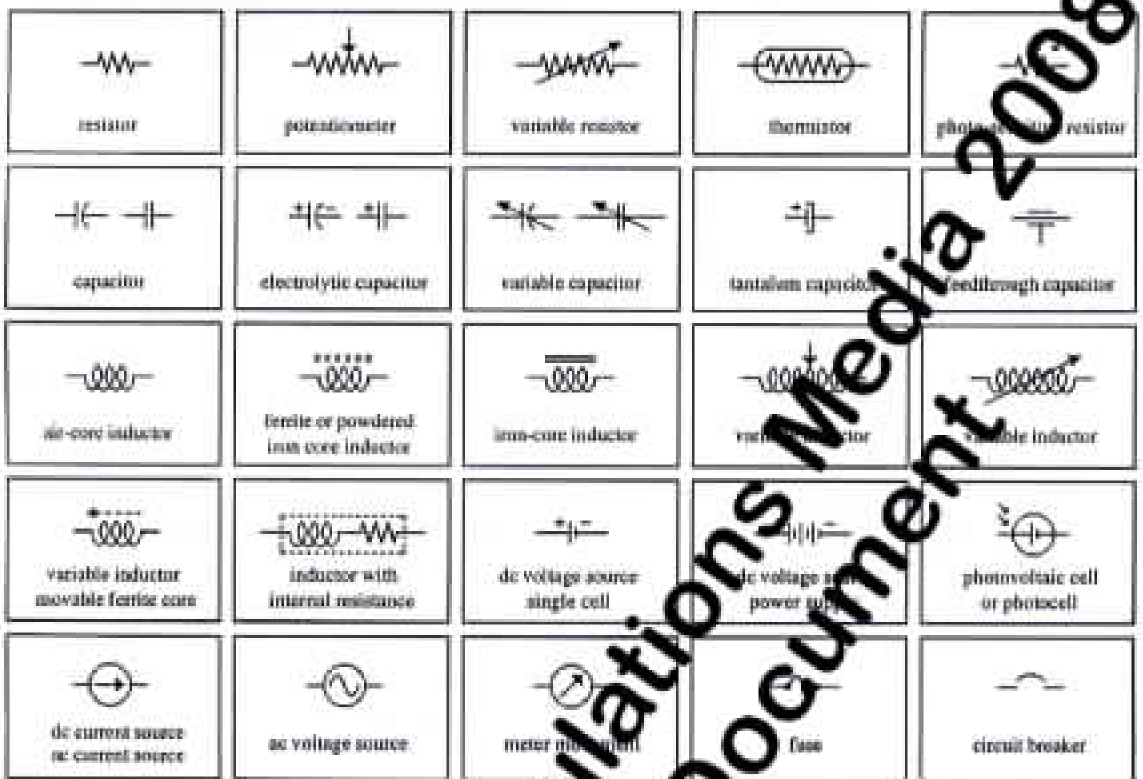
A/D & D/A Conversion

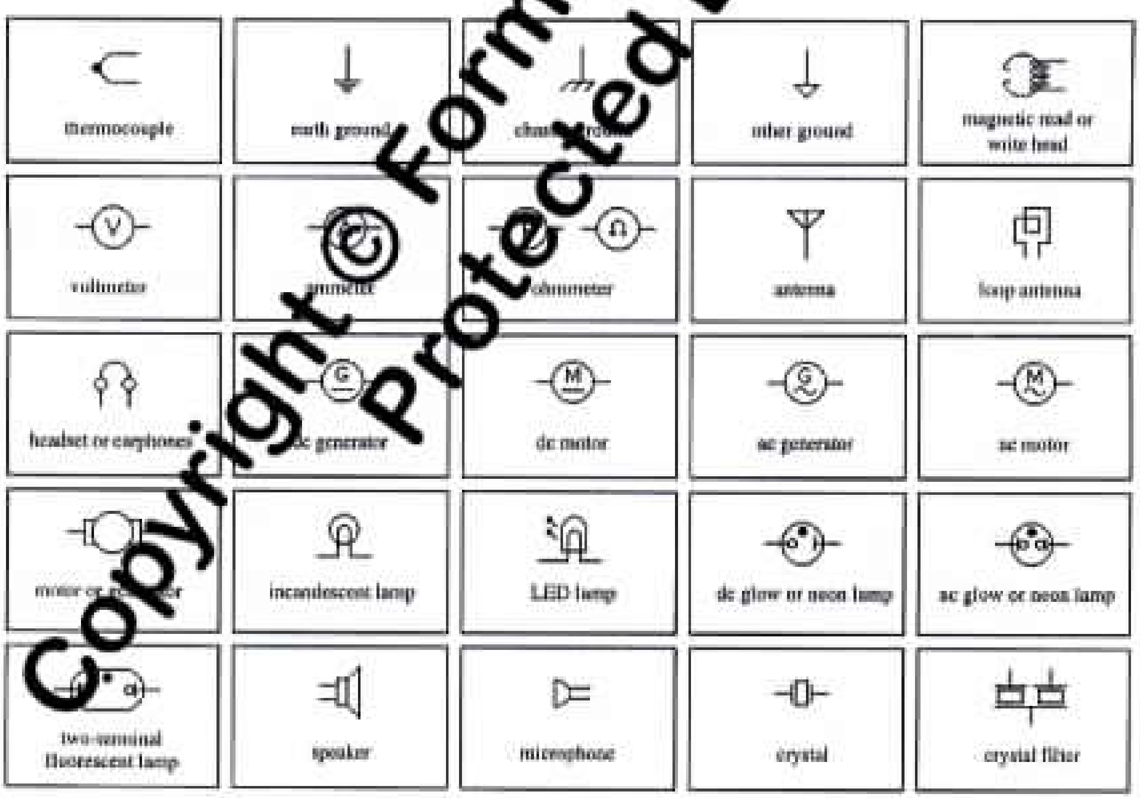
n = *number of bits*

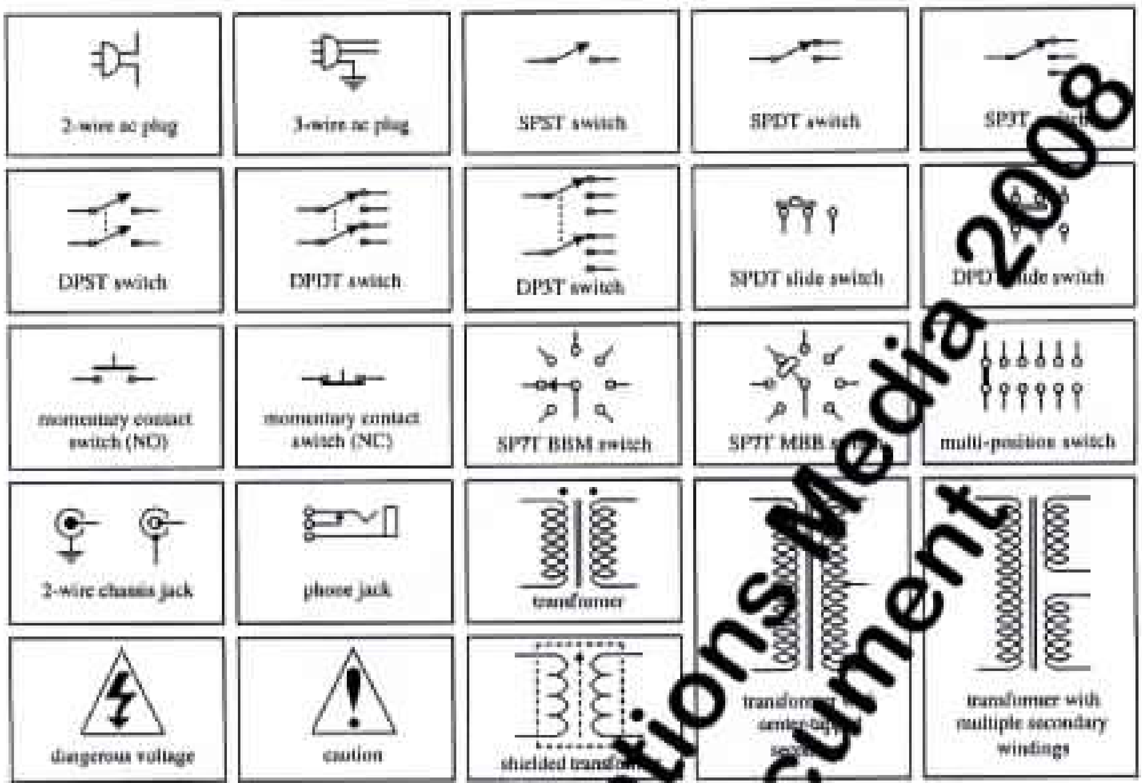
Min. Attn. $= 20 \log 2^n$

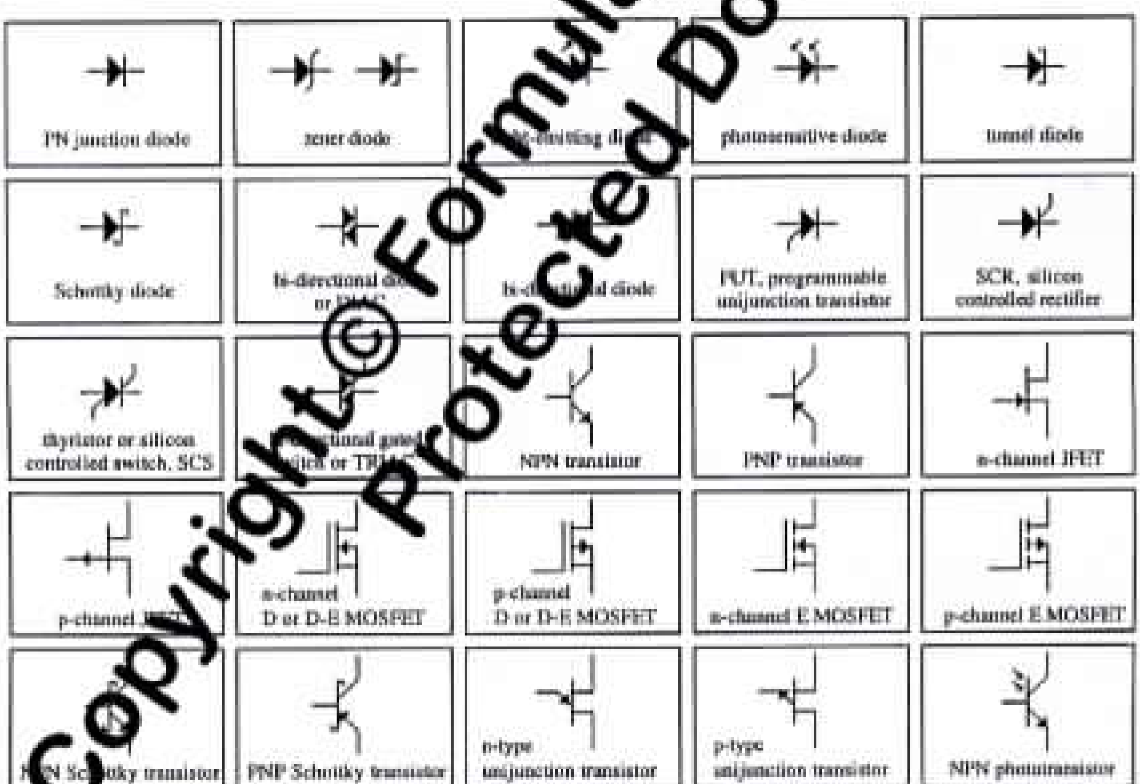
$V_{in} = \frac{decimal\ bit\ value}{2^n} \times span\ width$

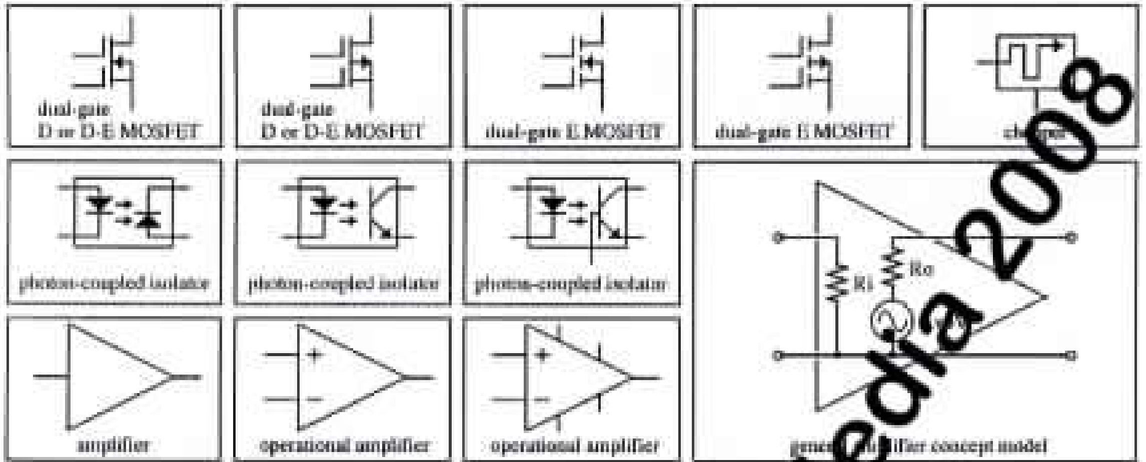
Schematic Symbols

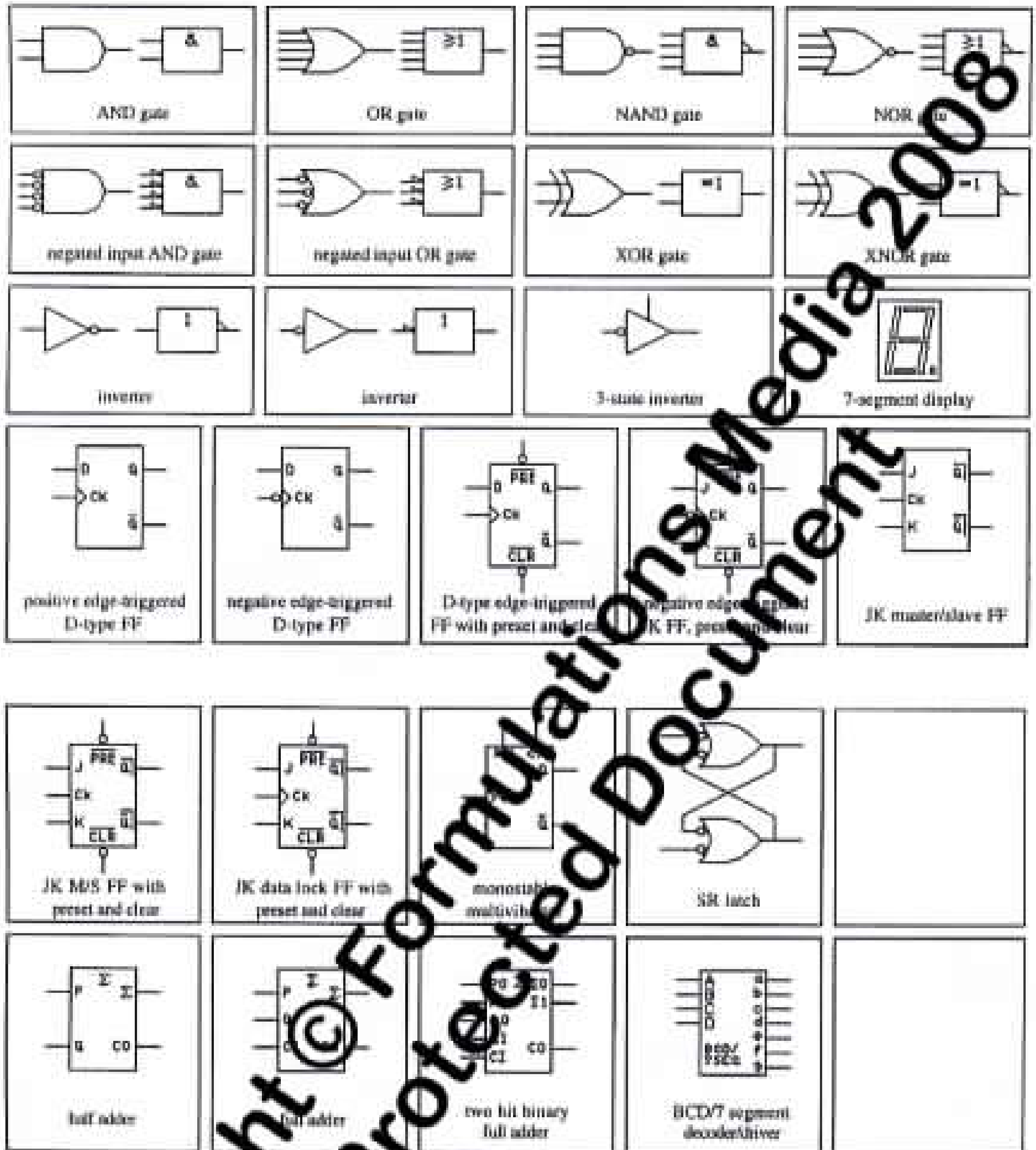





2-wire ac plug
3-wire ac plug
SPST switch
SPDT switch
SP3T
DPST switch
DPDT switch
DP3T switch
SPDT slide switch
lide switch
momentary contact switch (NO)
momentary contact switch (NC)
SP7T BBM switch
SP7T MBB
multi-position switch
2-wire chassis jack
phone jack
transformer
dangerous voltage
caution
shielded transfo
transformer with multiple secondary windings


PN junction diode
zener diode
photosensitive diode
tunnel diode
Schottky diode
bi-directional diode
PUT, programmable unijunction transistor
SCR, silicon controlled rectifier
thyristor or silicon controlled switch, SCS
NPN transistor
PNP transistor
n-channel JFET
p-channel
n-channel D or D-E MOSFET
p-channel D or D-E MOSFET
n-channel E MOSFET
p-channel E MOSFET
tky transistor
PNP Schottky transistor
n-type unijunction transistor
p-type unijunction transistor
NPN phototransistor


dual-gate D or D-E MOSFET
dual-gate D or D-E MOSFET
dual-gate E MOSFET
dual-gate E MOSFET
photon-coupled isolator
photon-coupled isolator
photon-coupled isolator
Ri
Ro
amplifier
operational amplifier
operational amplifier



Preceding symbols conform to the following standards: ANSI Y32, CSA Z99, and IEEE 315 91. Some symbols (inductor with internal resistance, general amplifier concept model, SR latch) are combined from standard symbols.

American Wire Gauge (AWG) Data Sheet

(for annealed copper at 20 °C)

Gauge	Diameter (mm)	Diameter (in.)	Resistance Ω/km	Resistance Ω/1000 ft.	Current Capacity*
0000	11.68	0.4600	0.1608	0.04901	769 A
000	10.40	0.4096	0.2028	0.06180	[illegible]
00	9.266	0.3648	0.2557	0.07793	[illegible]
0	8.252	0.3249	0.3224	0.09827	384 A
1	7.348	0.2893	0.4065	0.1239	304 A
2	6.543	0.2576	0.5128	0.1563	241 A
3	5.827	0.2294	0.6463	0.1970	191 A
4	5.189	0.2043	0.8153	[illegible]	152 A
5	4.620	0.1819	1.028	[illegible]	[illegible]
6	4.115	0.1620	1.296	[illegible]	[illegible]
7	3.665	0.1443	1.635	0.4982	[illegible]
8	3.264	0.1285	2.061	[illegible]	60.0 A
9	2.906	0.1144	2.599	0.7921	47.6 A
10	2.588	0.1019	3.277	0.9989	37.8 A
11	2.305	0.09074	4.134	1.260	29.9 A
12	2.053	0.08081	5.210	1.588	23.8 A
13	1.828	0.07196	[illegible]	[illegible]	18.8 A
14	1.628	0.06408	[illegible]	[illegible]	14.9 A
15	1.450	0.05707	[illegible]	[illegible]	11.9 A
16	1.291	0.05082	[illegible]	[illegible]	9.39 A
17	1.150	0.04526	[illegible]	[illegible]	7.45 A
18	1.024	0.04030	[illegible]	6.385	5.91 A
19	0.9116	0.03589	26.41	8.051	4.68 A
20	0.8118	0.03196	33.30	10.15	3.71 A
21	0.7229	0.02846	41.99	12.80	2.95 A
22	0.6439	0.02535	[illegible]	16.14	2.34 A
23	0.5733	[illegible]	[illegible]	20.36	1.85 A
24	0.5105	[illegible]	[illegible]	25.67	1.47 A
25	0.4547	[illegible]	[illegible]	32.37	1.17 A
26	0.4049	[illegible]	[illegible]	40.81	924 mA
27	0.3607	[illegible]	168.9	51.47	733 mA
28	0.3211	[illegible]	212.9	64.90	581 mA
29	0.2860	0.01126	268.5	81.83	461 mA
30	0.2548	0.01003	338.6	103.2	366 mA
31	0.2268	[illegible]	426.8	130.1	290 mA
32	0.2019	[illegible]	538.4	164.1	230 mA
33	[illegible]	[illegible]	678.8	206.9	182 mA
34	[illegible]	[illegible]	856.0	260.9	144 mA
35	[illegible]	0.005615	1079	329.0	115 mA
36	[illegible]	0.005000	1361	414.8	90.9 mA
37	[illegible]	0.004453	1716	523.1	72.1 mA
38	[illegible]	0.003965	2164	659.6	57.2 mA
39	0.08969	0.003531	2729	831.8	45.3 mA
40	0.07988	0.003145	3442	1049	36.0 mA

* Current carrying capacity is based upon three insulated conductors in a cable with an ambient temperature of 30°C with a [illegible] wire not to exceed 60°C, and assuming a current density of 3.64 mA/CM or 275 CM/A. Wires will get warm when operating at the maximum currents listed in this table. For cooler operation, derate to 25% of listed currents.

Resistivity & Temperature Coefficients

(for various materials all at 20 °C)

Conductive Materials	Resistivity (ρ) ($n\Omega m$)	Temp Coefficient (α) (/°C)
Alumel	333.0	1.2×10^{-3}
Aluminum	26.2	3.9×10^{-3}
Brass	39.0	2.0×10^{-3}
Carbon (graphite)	1400.0	-5.0×10^{-4}
Chromel	700.0	1.1×10^{-4}
Constantan	442.0	2.0×10^{-4}
Copper (annealed)	17.2	3.93 x 10[illegible]
Gold	24.4	3.4 x 10[illegible]
Iron	97.1	5.7 x [illegible]
Manganin	440.0	±2.0 [illegible]
Mercury (liquid)	958.0	[illegible] x 10^{-4}
Monel	420.0	[illegible] x 10^{-3}
Nichrome	1000.0	[illegible] x 10^{-4}
Nickel	69.0	[illegible].7 x 10^{-3}
Platinum	105.0	3.0 x 10[illegible]
Silicon	2300.0	−7.5 [illegible]
Silver	16.2	3.8 [illegible]
Tungsten	54.8	[illegible]5 x 10^{-3}
Zinc	60.0	[illegible] x 10^{-3}
Insulation Materials	**Resistivity (ρ)**	
Amber	500 TΩm	
Bakelite	[illegible]Ωm	
Glass	[illegible]Ωm	
Mica	100 TΩm	
Nylon	8 TΩm	
Paper	10 G[illegible]	
Paraffin Wax	50[illegible]m	
Polystyrene	10 [illegible]m	
Rubber	100 TΩm	
Teflon	1 PΩm	

G = 1×10^{9} (giga)
T = 1×10^{12} (tera)
P = 1×10^{15} (peta)
E = 1×10^{18} (exa)

Relative Permittivity & Dielectric Strength
(for various materials)

Dielectric Materials	Relative Permittivity (ε_r)	Dielectric Strength (V/μm)
dry air, or vacuum	1.00	3.15
ceramic	3300	3.61
glass	6.16	47.4
mica	6.43	96.5
oil	3.10	14.1
polyethylene	2.69	102
polypropylene	2.35	25.6
rubber	3.28	24.5
teflon	2.37	44[illegible]

Table of Prefixes

Prefix Symbol	Prefix Name	Prefix Value
E	exa	1×10^{18}
P	peta	1×10^{15}
T	tera	1×10^{12}
G	giga	1×10^{9}
M	mega	1×10^{6}
k	kilo	1×10^{3}
m	milli	1×10^{-3}
µ	micro	1×10^{-6}
n	nano	1×10^{-9}
p	pico	1×10^{-12}
f	femto	1×10^{-15}
a	atto	1×10^{-18}

Network Theorem Rules

Thévenin's Theorem

1. Determine which portion of the circuit will be classified as the load.
2. Remove the load leaving an open circuit.
3. Determine the voltage across the open-circuited load terminals. This is V_{TH}.
4. Replace each voltage source with a short circuit and each current source with an open circuit.
5. Determine the resistance looking into the load terminals. This is R_{TH}.
6. The Thévenin equivalent circuit consists of V_{TH} in series with R_{TH}.
7. Connect the original load to the Thévenin equivalent circuit and solve as required.

Norton's Theorem

1. Determine which portion of the circuit will be classified as the load.
2. Remove the load and connect a short circuit to the load terminals.
3. Determine the current through the short circuit. This is I_N.
4. Remove the short circuit from the load terminals leaving the load terminals open.
5. Replace each voltage source with a short circuit and each current source with an open circuit.
6. Determine the resistance looking into the load terminals. This is R_N.
7. The Norton equivalent circuit consists of I_N in parallel with R_N.
8. Connect the original load to the Norton equivalent circuit and solve as required.

Superposition Theorem

1. Determine the portion of the circuit, usually one resistor, to which superposition will be applied.
2. Analyze the circuit using one source only while replacing all other voltage sources with short circuits and all other current sources with open circuits.
3. Determine voltage or current for the resistor of interest due only to this one source.
4. Repeat steps 2 and 3 for each source in the circuit.
5. Sum the voltages or currents for the resistor of interest respecting voltage polarities and current directions.
6. The summation results in the correct voltage or current for the resistor in the original circuit.

Using Thévenin's or Norton's Theorems with Multiple Source Circuits

1. Apply the theorem rules until the load is removed (Thévenin's) or replaced with a short circuit (Norton's).
2. Use superposition techniques to find either V_{TH} or I_N for the circuit in its present state.
3. Return to the theorem rules to determine R_{TH} or R_N (they are the same) as required.
4. Connect the original load to the equivalent circuit and solve as required.

Mesh Analysis

1. Determine a minimum number of windows for the circuit so as to include all components.
2. Label the current loops within each window as I_1, I_2, I_3 and so forth. Direction does not matter.
3. There cannot be fewer loops than there are windows.
4. Label, within each window, polarities for all voltage drops caused by the indicated currents.
5. Write a Kirchhoff Voltage Law equation for each window to include all component voltages.
6. Reduce the equations to standard form and solve for the currents I_1, I_2, I_3 as required.
7. Currents which solve to be negative will actually flow opposite to the direction chosen in step 2.
8. Where two currents are defined in one component, there values are combined to yield the actual value.

Nodal Analysis (Classical Method)

1. Define a reference point in the circuit. This is usually at the bottom of the schematic diagram.
2. Label all voltage nodes in the circuit (even if they are known voltages) V_1, V_2, V_3 and so forth.
3. Develop the standard equation forms shown below for three unknowns.

$$+(\Sigma\, self\ G\ at\ 1)\ V_1 \quad -(\Sigma\, mutual\ G_{12})\ V_2 \quad -(\Sigma\, mutual\ G_{13})\ V_3 \quad = \Sigma I\ at\ 1$$
$$-(\Sigma\, mutual\ G_{21})\ V_1 \quad +(\Sigma\, self\ G\ at\ 2)\ V_2 \quad -(\Sigma\, mutual\ G_{23})\ V_3 \quad = \Sigma I\ at\ 2$$
$$-(\Sigma\, mutual\ G_{31})\ V_1 \quad -(\Sigma\, mutual\ G_{32})\ V_2 \quad +(\Sigma\, self\ G\ at\ 3)\ V_3 \quad = \Sigma I\ at\ 3$$

4. Note that "$\Sigma\, self\ G\ at\ 1$" means the sum of the self-conductances at node 1.
   Note that "$\Sigma\, mutual\ G_{21}$" means the sum of the mutual conductances between nodes 1 and 2.
   Note that self-conductance refers only to resistors which directly connect to the stated node.
   Note that mutual conductance refers only to resistors which connect between the stated nodes.
   Note that all self-conductance terms are positive and all mutual conductance terms are negative.
   Note that "$\Sigma I\ at\ 1$" means the sum of the current sources at node 1.
   Note that current sources entering a node are positive, and leaving a node are negative.
   Note the symmetry in similar terms: $\Sigma\, mutual\ G_{13} = \Sigma\, mutual\ G_{31}$.
5. Reduce the equations to standard form and solve for V_1, V_2 and V_3 as required.

SI Notation Rules

The following rules illustrate some of the commonly-seen errors in the use of the SI system of notation. These errors are often seen in technical documents to an extent inversely proportional to the length of the editing process undertaken in the creation of the document. If these errors are avoided, little else can go wrong.

1. Derived units formed through division use "per" when accompanying units are written in full or "/" when accompanying units are abbreviated.

CORRECT:	kilometres per hour km/h	WRONG:	kilometres/hour km per h

2. Quantities abbreviated by unit symbols are the same in singular or in plural. Unabbreviated quantities may be pluralized.

CORRECT:	250 km eighty kilometres	WRONG:	250 kms 80 km's

3. Periods are not used after units except at the end of a sentence.

CORRECT:	A voltage of 15 V was present. 15 V was present at the switch.	WRONG:	A voltage of 15 V. was present. 15 V. was present at the switch.
EXCEPTIONS:	Some non-SI units, still in use, use periods. Examples are: ft. in. mi. lb.		

4. Negative exponents may be used to indicate symbols in the denominator of an expression.

CORRECT:	50 kmh^{-1} 100 m/s^2 or 100 ms^{-2}	WRONG:	50 km ph 100 m/s/s

5. Leave a space between numerals and the units, but not between prefixes and units.

CORRECT:	16.8 mA	WRONG:	16.8mA 16.8m A 16.8 m A

6. The Celsius temperature scale, not an SI unit, previously known as centigrade, uses the degree sign (°). The SI unit, kelvin, does not use this symbol. Note that kelvin uses an uppercase K as its unit symbol. One Celsius degree is equal to one kelvin.

CORRECT:	0° C = 273.15 K 10° C = 283.15 K	WRONG:	0° C = 273.15 k 0°C = 273.15 K

7. When writing numbers which are less than one, a zero should precede the decimal point. This is designed to help make the decimal point more obvious to the reader.

CORRECT:	0.381	WRONG:	.381

8. Correctly use commas and decimal points for the geographical area in which you are located. For North America, except Québec, decimal points are used as the unity digit marker and commas may be used as separators. In Québec and some places in Europe, the unity digit marker is a comma. For North America:

CORRECT:	15.7 kΩ $ 13.26	WRONG:	15,7 kΩ 13,26 $

9. Use spaces to break up large blocks of numbers in groups of three in either direction from the decimal point. Commas are still widely used in North America as spacers.

CORRECT:	48 316.748 21	WRONG:	48316.74821
	48,316.748 21		4,316.748,21

10. Only one prefix may be used with a unit symbol. In the past the use of multiple prefixes, such as micro micro in place of pico was widely accepted. This is no longer the case.

CORRECT:	390 pF	WRONG:	390 μμF
	580 μm		580 mμm

11. For derived units use only one prefix and attach it to the numerator, not to the denominator. There are some exceptions to this rule which are in widespread use. The two technically wrong examples are widely used.

CORRECT:	16.3 mΩ/m	WRONG:	16.3 Ω/km
	500 kV/s		500 V/μs

12. The use of Engineering Notation where powers are always a multiple of three and the number is ≥ 1 but < 1000 is highly recommended where units are involved. Where no units are present scientific notation is preferred but only for very large or very small numbers.

CORRECT:	18.3 mA	WRONG:	0.0183 A
	1.2 kΩ		1200 Ω
	Ap = 1580		Ap = 1.58 x 10^3 (cumbersome)
	Ap = 6.50 x 10^6		Ap = 6,500,000 (cumbersome)

13. Where no units are present, it is incorrect to use a prefix. Prefixes are intended only for use alongside a unit symbol, never to stand alone. On schematic diagrams, values such as 68 k may be shown in place of 68 kΩ only where the legend indicates all resistor values are in ohms.

CORRECT:	Av = 1250	WRONG:	Av = 1.25 k

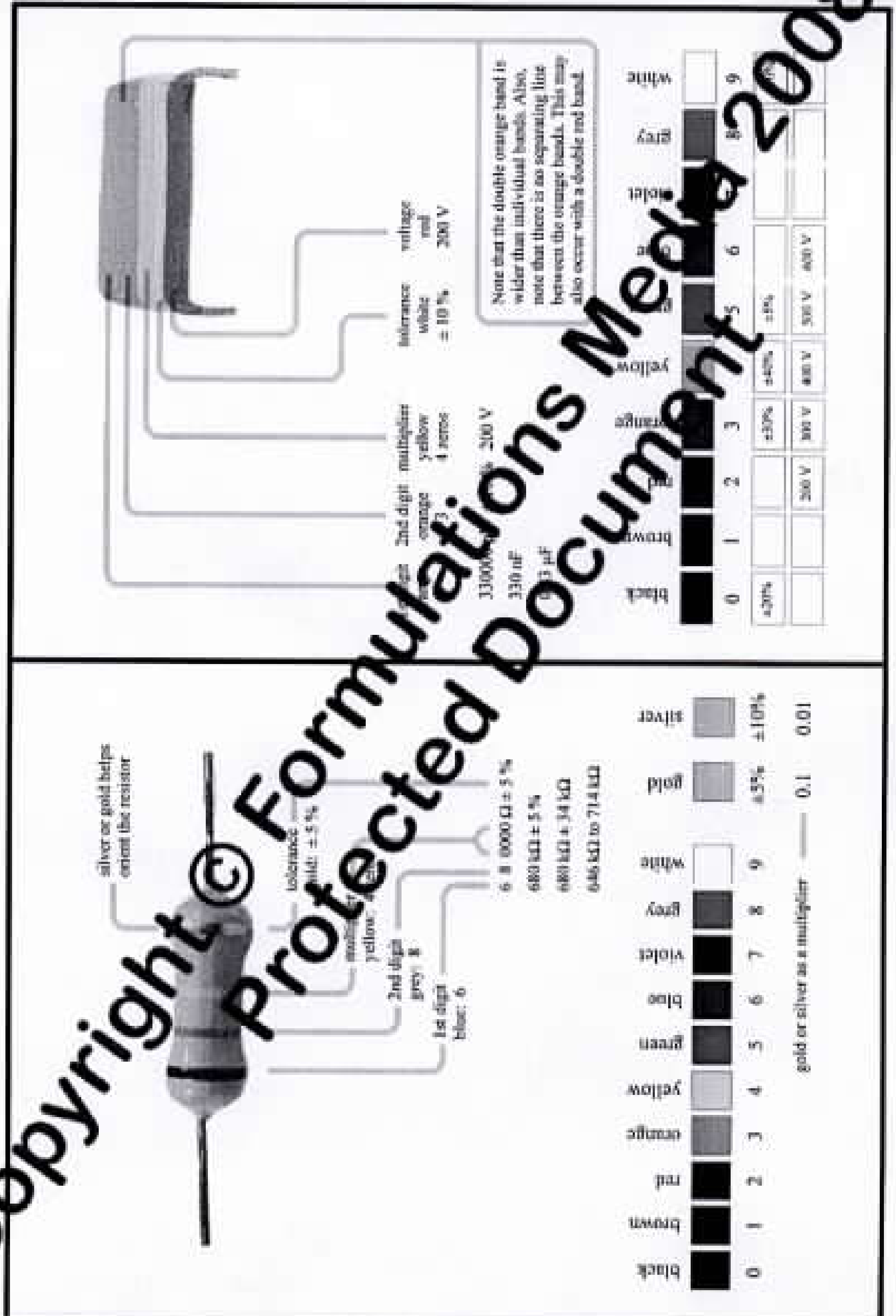
14. Values are assumed to be positive unless written with a negative sign so it is redundant to include the positive sign unless there is a valid reason to draw attention to the polarity.

CORRECT:	54.8 kV	WRONG:	+54.8 kV
	−138 V		138 V–

15. The SI system spells the word "metre" where it is used in the context of a distance and uses "meter" where an instrument is involved.

CORRECT:	The length is five metres.	WRONG:	The length is five meters.
	A voltmeter was used.		A voltmetre was used.

Color Codes


silver or gold helps
orient the resistor
tolerance
2nd digit
grey: 8
1st digit
blue: 6
680 kΩ ± 5 %
680 kΩ ± 34 kΩ
646 kΩ to 714 kΩ
black
brown
red
orange
yellow
green
blue
violet
grey
white
gold
silver
0 1 2 3 4 5 6 7 8 9
±5%
±10%
gold or silver as a multiplier
0.1
0.01
2nd digit
orange
multiplier
yellow
4 zeros
tolerance
white
± 10 %
voltage
red
200 V
330 nF
Note that the double orange band is wider than individual bands. Also, note that there is no separating line between the orange bands. This may also occur with a double red band.
±20%
±30%
±40%
200 V
300 V
400 V
500 V
600 V

Capacitor Identification

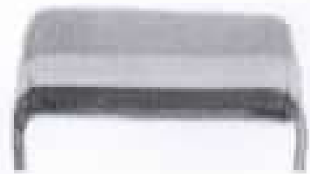
Film Capacitor – Values less than 1 are in µF. Values greater than 1 are in pF. This capacitor is 1000 pF which is 1.0 nF, and is rated for 400 V.

Ceramic Capacitor – The position of the prefix locates the decimal point. This case is 4.7 pF. One coded as [illegible] or N22 would be 0.22 nF or 220 pF.

Film Capacitor – This method of coding indicates the first two digits followed by the number of zeros, with the value being in units of pF. This case is 47000 pF or 47 nF.

Film Capacitor – This value is shown in raised relief as 0.047 and is in µF if the number is <1 or in pF if >1. This example is 0.047 µF or 47 nF.

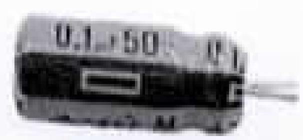
Disc Capacitor – These types are usually in pF but may be in a three-number code as above, or the actual number may be printed. This example is 18 followed by 1 zero, or 180 pF. A number such as 680 could mean 680 pF or 68 pF and should be measured to be sure of its value.



Film Capacitor – Color-coded in pF starting at the top. This case has a double orange band and is 33 followed by 0000, which is 330000 pF, or 330 nF. There may be a similar double-wide red band.

Electrolytic Capacitor – Values are generally printed on the component along with the voltage rating which is often quite important as it must not be exceeded. The circled negative points to the negative lead on the right. Some have (+) markings on the positive end. This capacitor must be connected with the correct polarity or it may explode.

Non-Polarized Capacitor – This type may be connected with either polarity even though it has a large value of capacitance.



Electrolytic Capacitor – The dark band points towards the negative lead. This example is 0.1 µF or 100 nF. It could also be coded as µ10 for the same value. A value coded 6µ8 would be 6.8 µF.