ECE 101 Lecture #1 Jan 8, 2019

Introduction to Electronic Circuits

by

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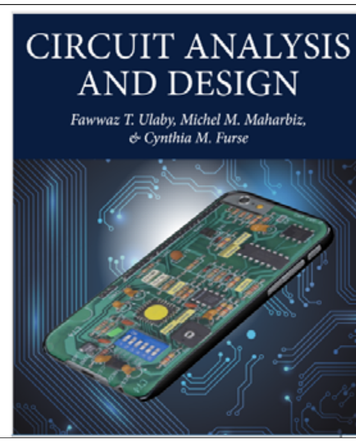
- webcast: https://webcast.ucsc.edu (ee101)

New Textbook* - eBook (This eBook can be downloaded freely from https://www.publishing.umich.edu/publications/ee/

CIRCUIT ANALYSIS AND DESIGN

Fawwaz T. Ulaby, Michel M. Maharbiz, & Cynthia M. Furse

Ref. C.K. Alexander and M.N.O. Sadiku, Fundamentals of Electric Circuits



Course Grading

- Weekly 15 min Quizzes based on Weekly HWs 20%
  (Best 7 out of 9 Quizzes
  HWs not collected.
- Mid-term Examination 30%
  (Feb 7, In class, 1 page of formulas allowed)
- Final Examination 50%
  (March 20, 8-11 a.m. 2 pages of formulas allowed)

HW #1 issued on Jan 8, 2019

(to be tested in Quiz #1 on Jan 15)

[1]. Prob. 1.13 in the eBook

[2]. Prob. 1.15

[3]. Prob. 1.25

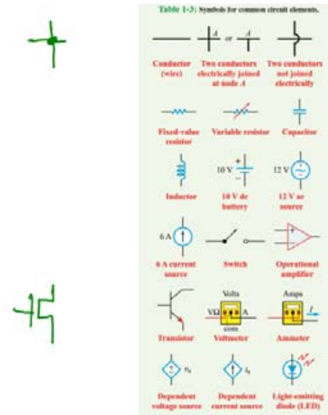
[4]. Prob. 1.28

[5]. Prob. 1.31

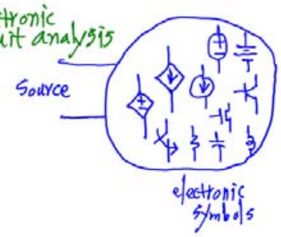
[6]. Prob. 1.40

[7]. Prob. 1.42

[8]. Prob. 2.5

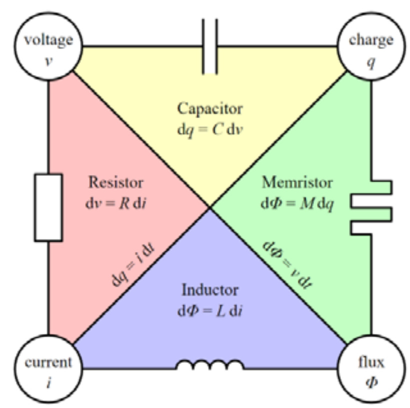


Electronic circuit analysis



1) Formulate circuit equations using model equations for elements and circuit laws (KCL, KVL)

2) solve for outputs for given inputs in terms of usually voltages, currents, power, etc.



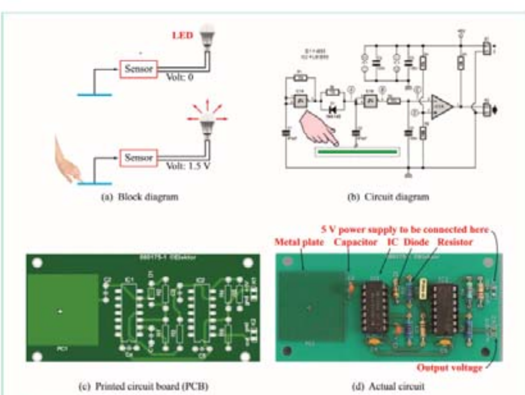
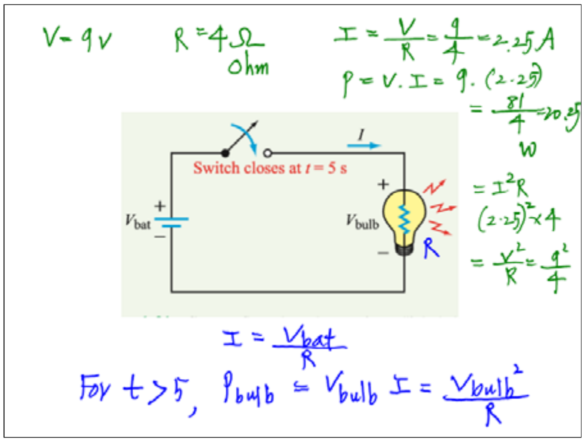
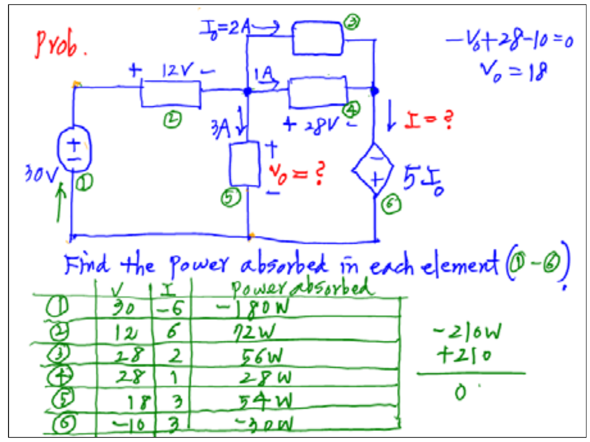


Figure 1-4: (a) Block diagram, (b) circuit diagram, (c) printed-circuit-board (PCB) layout, (d) photograph of a touch-sensor circuit.

Table 1-2: Multiple and submultiple prefixes.

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





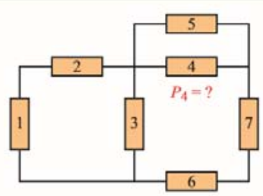


Figure P1.37: Circuit for Problem 1.37.

1.37 Apply the law of conservation of power to determine the amount of power delivered to device 4 in the circuit of **Fig. P1.37**, given that that the amounts of power delivered to the other devices are: $p_1 = -100$ W, $p_2 = 30$ W, $p_3 = 22$ W, $p_5 = 67$ W, $p_6 = -201$ W, and $p_7 = 120$ W.

Resistors

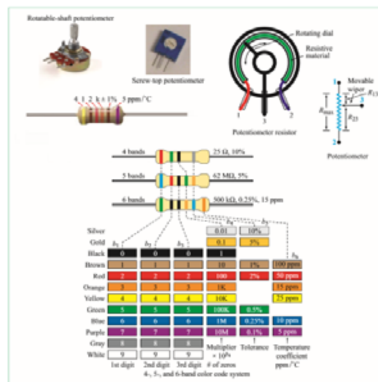


Figure 2-2: Various types of resistors. Tubular-shaped resistors usually are color-coded by 4-, 5-, or 6-band systems.

Table 2-3: Common resistor terminology.

Thermistor	R sensitive to temperature
Piezoresistor	R sensitive to pressure
Light-dependent R (LDR)	R sensitive to light intensity
Rheostat	2-terminal variable resistor
Potentiometer	3-terminal variable resistor

2-1.2 i–υ Characteristics of Ideal Resistor

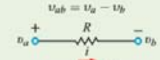
Based on the results of his experiments on the nature of conduction in circuits, German physicist Georg Simon Ohm (1787–1854) formulated in 1826 the i–υ relationship for a resistor, which has become known as ***Ohm's law***. He discovered that the voltage υ across a resistor is directly proportional to the current i flowing through it, namely

$$\upsilon = iR, \qquad (2.3)$$

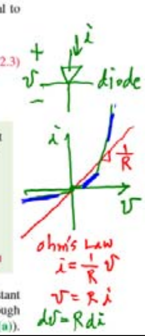
with the resistance R being the proportionality factor.

► In compliance with the passive sign convention, current enters a resistor at the "+" side of the voltage across it.

$$\upsilon_{ab} = \upsilon_a - \upsilon_b$$



$$i = \frac{\upsilon_a - \upsilon_b}{R}$$ ◄



An ideal ***linear resistor*** is one whose resistance R is constant and independent of the magnitude of the current flowing through it, in which case its ***i–υ response*** is a straight line (**Fig. 2-4(a)**).

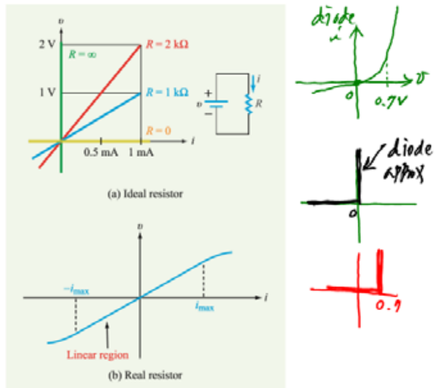
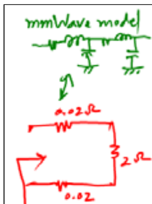


Figure 2-4: i–v responses of ideal and real resistors.



R_{total}
$= R_w + R_m$
$= 0.04 + 2$
$= 2.04\ \Omega$

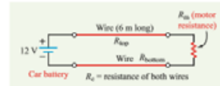
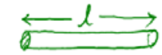


Figure 2-6: Circuit for Example 2-1.



$A = \pi r^2$
ρ = resistivity $[\Omega\text{-m}]$

(a) We need to include both the top wire and the bottom wire, as each represents a resistor through which the current flows, and therefore contributes to the resistive losses of the circuit. With $\ell = 12$ m (total for twin wires), $\rho = 1.72 \times 10^{-8}$ Ω-m for copper, $A = \pi(d/2)^2$, and $d = 2.6$ mm for AWG-10, the cable resistance R_c is

$$R_c = \rho \frac{\ell}{A} = 1.72 \times 10^{-8} \times \frac{12}{\pi(1.3 \times 10^{-3})^2} = 0.04\ \Omega.$$

(b) The total resistance in the circuit is equal to the sum of the cable and motor resistances. [In a later section, we will learn that the resistance of two resistors connected in series is simply equal to the sum of their resistances.] Hence,

$$R = R_c + R_m = 0.04 + 2 = 2.04\ \Omega.$$

Consequently, the current flowing through the circuit is

$$I = \frac{V}{R} = \frac{12}{2.04} = 5.88\ \text{A},$$

and the power contributed by the battery P and the power delivered to the motor P_m are:

$$P = IV = 5.88 \times 12 = 70.56\ \text{W}$$

and

$$P_m = I^2 R_m = (5.88)^2 \times 2 = 69.15\ \text{W}.$$

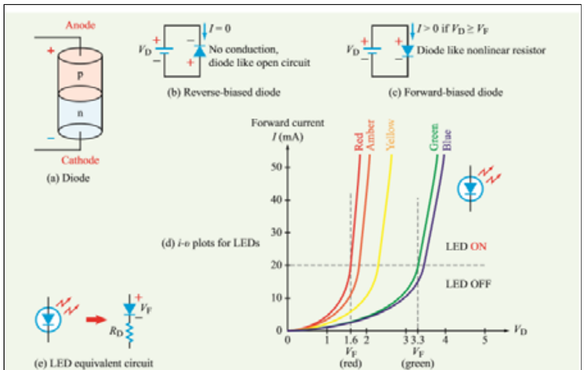


Figure 2-8: p-n junction diode (a) configuration, (b) reverse biased, (c) forward biased, (d) typical i–v plots for LEDs, and (e) LED equivalent circuit.

2-2 KIRCHHOFF'S LAWS

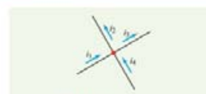


Figure 2-9: Currents at a node.

Mathematically, KCL can be expressed by the compact form:

$$\sum_{n=1}^{N} i_n = 0 \quad \text{(KCL)}, \tag{2.8}$$

where N is the total number of branches connected to the node, and i_n is the nth current.

► A common convention is to assign a positive "+" sign to a current if it is entering the node and a negative "−" sign if it is leaving it. ◄

For the node in Fig. 2-9, the sum of currents entering the node is

$$i_1 - i_2 - i_3 + i_4 = 0, \tag{2.9}$$

where currents i_1 and i_4 were assigned positive signs because they are labeled in the figure as entering the node, and i_2 and i_3 were assigned negative signs because they are leaving the node.

► A common convention is to assign a positive "+" sign to a current if it is entering the node and a negative "−" sign if it is leaving it. ◄

For the node in Fig. 2-9, the sum of currents entering the node is

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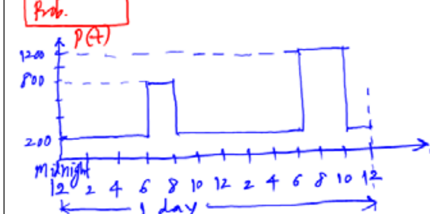
where currents i_1 and i_4 were assigned positive signs because they are labeled in the figure as entering the node, and i_2 and i_3 were assigned negative signs because they are leaving the node.

► Alternatively, the sum of currents leaving a node is zero, in which case we assign a "+" to a current leaving the node and a "−" to a current entering it. ◄

Prob.



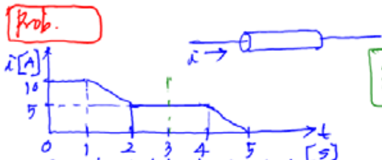
a) Total energy consumed in one day in KWh ?

$200 \times 6 + 800 \times 2 + 200 \times 10 + 1200 \times 4 + 200 \times 2$
$= 1200 + 1600 + 2000 + 4800 + 400 = 10\ \text{KWh}$

b) Average power per our over 24 hour period ?

$P_{avg} = \frac{1}{T}\int_0^T P(t)\,dt = \frac{10\ \text{KWh}}{24\ \text{h}} \simeq 0.416\ \text{KW}$

Prob.



$q(t) = \int_{-\infty}^{t} i(\tau)\,d\tau$

$q(0) = 0$

Find the total charge that passed through the element:

(a) t = 1 s, i.e. $q(t=1)$

$0 + \int_0^{t=1} i(\tau)\,d\tau = 10\ A \cdot 1\ s = 10$ Coulomb [C]

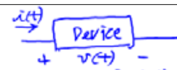
(b) t = 3 s, i.e. $q(t=3)$

$0 + \int_0^{t=3} i(\tau)\,d\tau = 10 + 7.5 + 5 = 22.5\ C$

(c) t = 5 s, i.e. $q(t=5)$

$0 + \int_0^{t=5} i(\tau)\,d\tau = 22.5 + 7.5 = 30\ C$

Prob.



For $t \geq 0$, $v(t) = 10\cos 2t\ [V]$, $i(t) = 20(1 - e^{-0.5t})\ [mA]$

a) Find the charge in the device at t = 2 s
(assume initial charge at t = 0 is zero)
$e = 2.718$, $e^{-1} = 0.368$

$0 + \int_0^{t=2} i(\tau)\,d\tau = \int_0^{2} 20(1 - e^{-0.5\tau})\,d\tau$ [mA · s]

$= 20\left[\tau - \frac{e^{-0.5\tau}}{-0.5}\right]_0^2 = 20\left[2 - \frac{e^{-1} - 1}{-0.5}\right]$

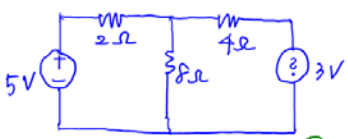
$= 20[2 + (0.368 - 1) \times 2] = 20(2 - 1.262) = 14.76$ mC

b) The power consumed by the device at t = π s
$(e^{-\frac{\pi}{2}} = 0.208)$

$p(t) = v(t)\,i(t) = 10\underbrace{\cos(2\pi)}_{=1} \times 20\overbrace{(1 - \underbrace{e^{-0.5\pi}}_{0.208})}^{0.792}$

$= 200 \times 0.792 = 158.4$ V·mA $= 0.1584$ W

Example 1.10



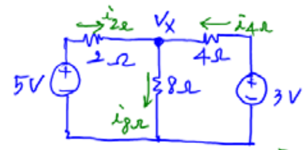
What is the polarity ?

Case A (?) 3V = (±) 3V (Case B (?) 3V = (∓) 3V)

is already presented using a loop analysis

Let's try to find V_X

[This is called Nodal Analysis]



Current $i_{2\Omega}[A] = \frac{[5 - V_X][V]}{2[\Omega]}$ [Ohm's Law: $v = Ri$, $i = \frac{v}{R}$]

$i_{4\Omega}[A] = \frac{3 - V_X\,[V]}{4[\Omega]}$

$i_{8\Omega}[A] = \frac{V_X[V]}{8[\Omega]}$

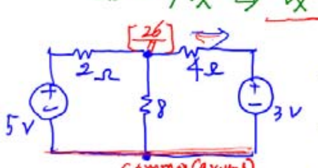
Also $i_{2\Omega} + i_{4\Omega} = i_{8\Omega}$ [Based on Kirchhoff's Current law: $\sum_k i_k = 0$ at a node]

$\frac{5 - V_X}{2} + \frac{3 - V_X}{4} = \frac{V_X}{8}$

$4(5 - V_X) + 2(3 - V_X) = V_X$

$20 + 6 - 4V_X - 2V_X = V_X$

$26 = 7V_X \Rightarrow V_X = \frac{26}{7}\ [V]$



$i_{2\Omega} = \frac{5 - \frac{26}{7}}{2} = \frac{9}{14}\ [A]$

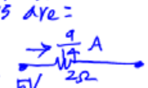
$i_{4\Omega} = \frac{3 - \frac{26}{7}}{4} = -\frac{5}{28}\ [A]$ (− means in opposite direction)

$i_{8\Omega} = \frac{\left(\frac{26}{7}\right)}{8} = \frac{13}{28}\ [A]$

$i_{8\Omega} = i_{2\Omega} + i_{4\Omega}$ (KCL ✓)

Also, Power absorbed in 2Ω, 4Ω, 8Ω resistors are:

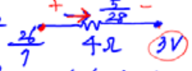
2Ω case



$P_{2\Omega} = \left[\left(5 - \frac{26}{7}\right)[V]\right]\left[\frac{9}{14}A\right]$

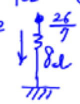
$= \frac{9}{7}[V] \times \frac{9}{14}[A] = \frac{81}{98}\ [W]$

4Ω case

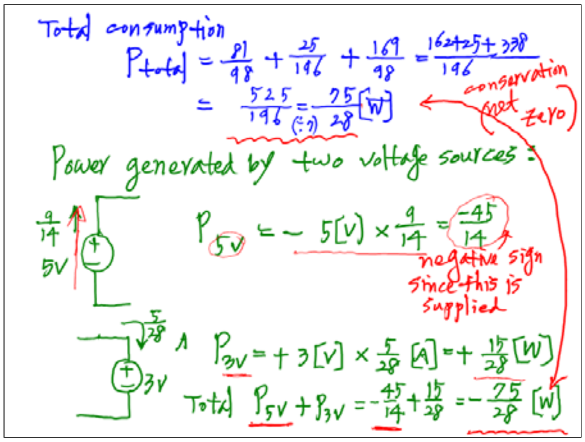


$P_{4\Omega} = \left(\frac{26}{7} - 3\right)[V] \times \frac{5}{28}[A] = \frac{5}{7} \times \frac{5}{28} = \frac{25}{196}\ [W]$

8Ω case



$P_{8\Omega} = \frac{26}{7}[V] \times \frac{13}{28}[A] = \frac{169}{98}\ [W]$


Total consumption
P total = 81/98 + 25/196 + 169/98 = (162+25+338)/196
= 525/196 = 75/28 [W]
conservation
net zero
Power generated by two voltage sources:
9/14
5V
P 5V = − 5[V] × 9/14 = −45/14
negative sign
since this is
supplied
5/28 A
3V
P 3V = + 3[V] × 5/28 [A] = + 15/28 [W]
Total P 5V + P 3V = −45/14 + 15/28 = −75/28 [W]