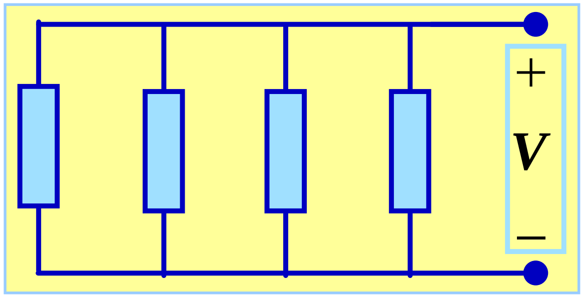
RESISTIVE CIRCUITS

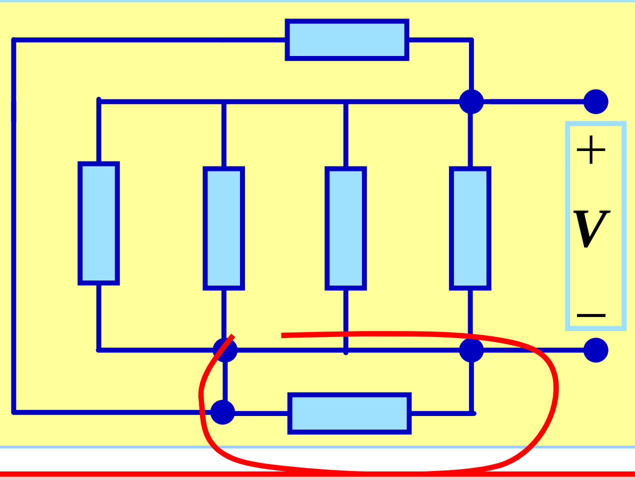
- SINGLE NODE-PAIR CIRCUIT ANALYSIS

SINGLE NODE-PAIR CIRCUITS

THESE CIRCUITS ARE CHARACTERIZED BY ALL THE ELMENTS HAVING THE SAME VOLTAGE ACROSS THEM - THEY ARE IN PARALLEL

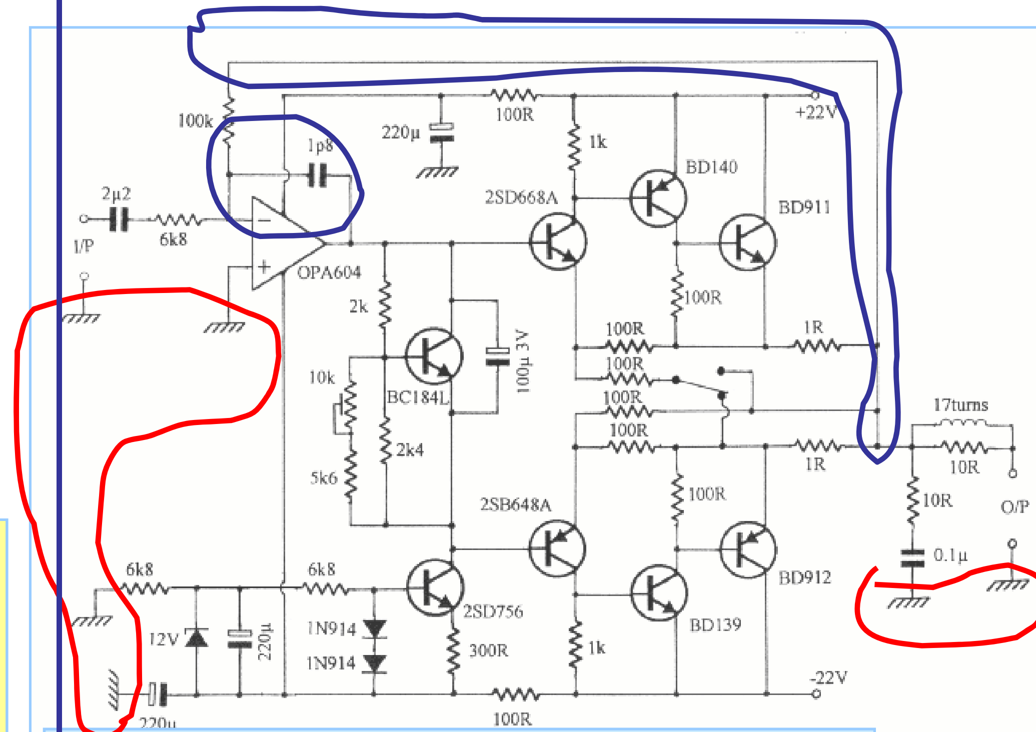


EXAMPLE OF SINGLE NODE-PAIR



THIS ELEMENT IS INACTVE (SHORT-CIRCUITED)

IN PRACTICE NODES MAY ASSUME STRANGE FORMS



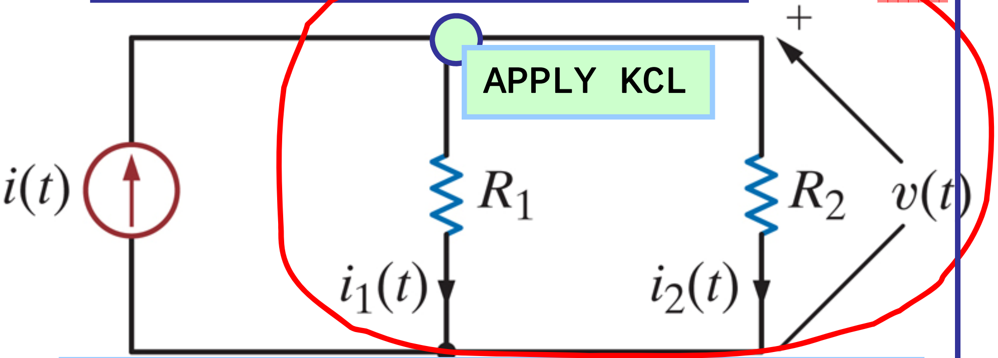
LOW DISTORTION POWER AMPLIFIER

LOW VOLTAGE POWER SUPPLY FOR CRT - PARTIAL VIEW

COMPONENT SIDE

CONNECTION SIDE

BASIC CURRENT DIVIDER



THE CURRENT *i(t)* ENTERS THE NODE AND SPLITS - IT IS DIVIDED BETWEEN THE CURRENTS *i1(t)* AND *i2(t)*

$$i(t) = i_1(t) + i_2(t)$$

USE OHM'S LAW TO REPLACE CURRENTS

$$i(t) = \frac{v(t)}{R_1} + \frac{v(t)}{R_2}$$

$$= \left(\frac{1}{R_1} + \frac{1}{R_2}\right) v(t)$$

DEFINE "PARALLEL RESISTANCE COMBINATION"

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_p = \frac{R_1 R_2}{R_1 + R_2}$$

$$i(t) = \frac{1}{R_p} v(t)$$

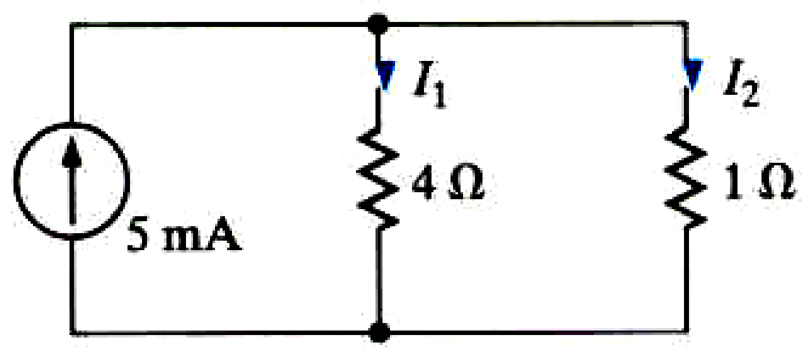
$$v(t) = \frac{R_1 R_2}{R_1 + R_2} i(t)$$

THE CURRENT DIVISION

$$i_1(t) = \frac{v(t)}{R_1} \qquad i_2(t) = \frac{v(t)}{R_2}$$

$$i_1(t) = \frac{R_2}{R_1 + R_2} i(t) \qquad = \frac{R_1}{R_1 + R_2} i(t)$$

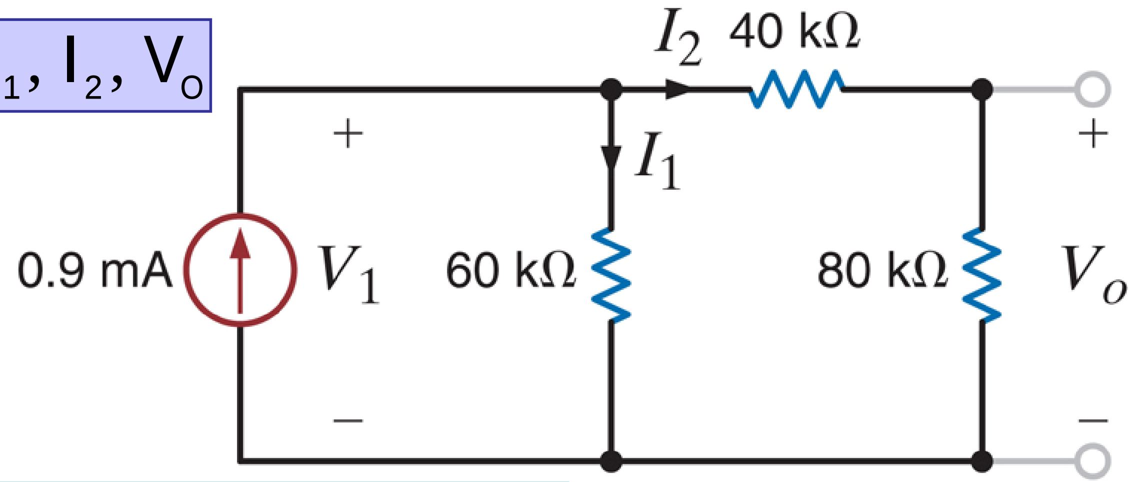
Find I_1 and I_2 in the following circuit:



$$I_1 = \frac{1}{1+4}(5) = 1mA$$

$$I_2 = I - I_1 = \frac{4}{1+4}(5)$$

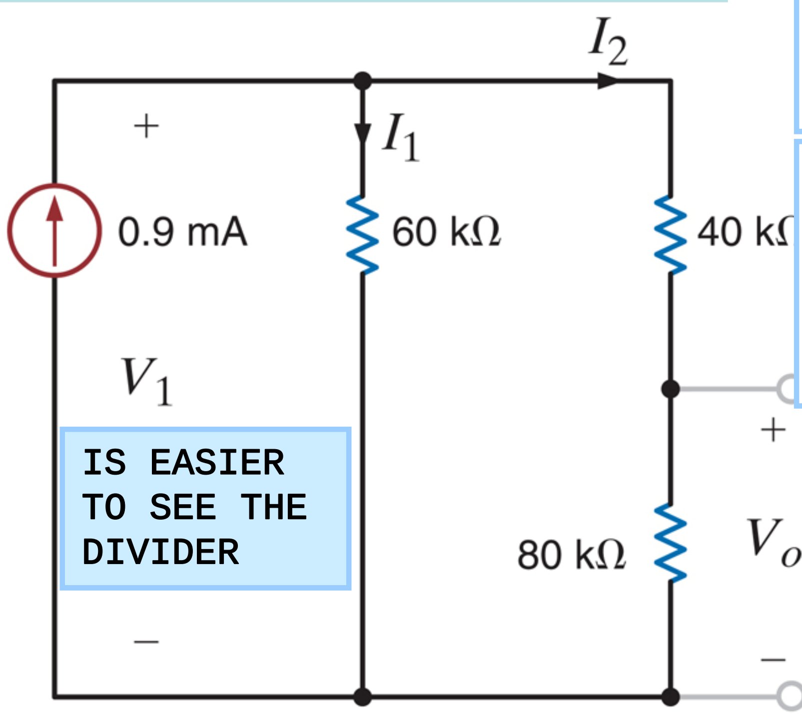
FIND I_1, I_2, V_O



WHEN IN DOUBT… REDRAW THE CIRCUIT TO HIGHLIGHT ELECTRICAL CONNECTIONS!!

$$I_1 = \left[\frac{40k + 80k}{60k + (40k + 80k)}\right](0.9 \times 10^{-3})$$
$$= 0.6 \text{ mA}$$

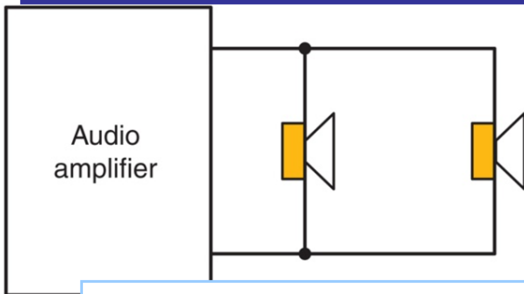
$$I_2 = \left[\frac{60k}{60k + (40k + 80k)}\right](0.9 \times 10^{-3})$$
$$= 0.3 \text{ mA}$$

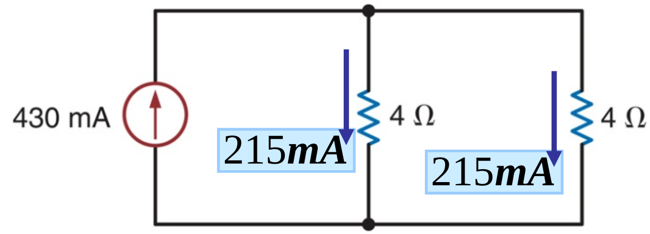


IS EASIER TO SEE THE DIVIDER

$$= 80k * I_2$$
$$24V$$

CAR STEREO AND CIRCUIT MODEL





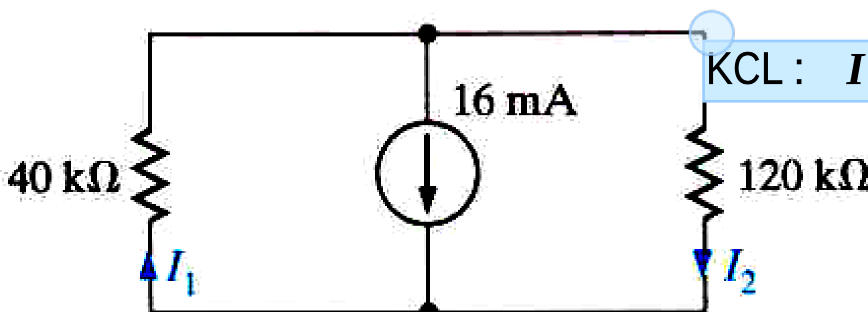
$$P = I^2R$$
$$= (215 \times 10^{-3})^2(4)$$
$$= 184.9 \text{ mW}$$

POWER PER SPEAKER $P = I^2R$

LEARNING EXTENSION - CURRENT DIVIDER

THERE IS MORE THAN ONE OPTION TO COMPUTE I2

I_1 and I_2 and the power absorbed by the 40-kΩ r



KCL : $I_2 + 16 - I_1 = 0$

USING CURRENT DIVIDER

$$I_2 = -\frac{40}{120+40}(16) = -4mA$$

POWER : I^2R

RESISTANCE IN kΩ,

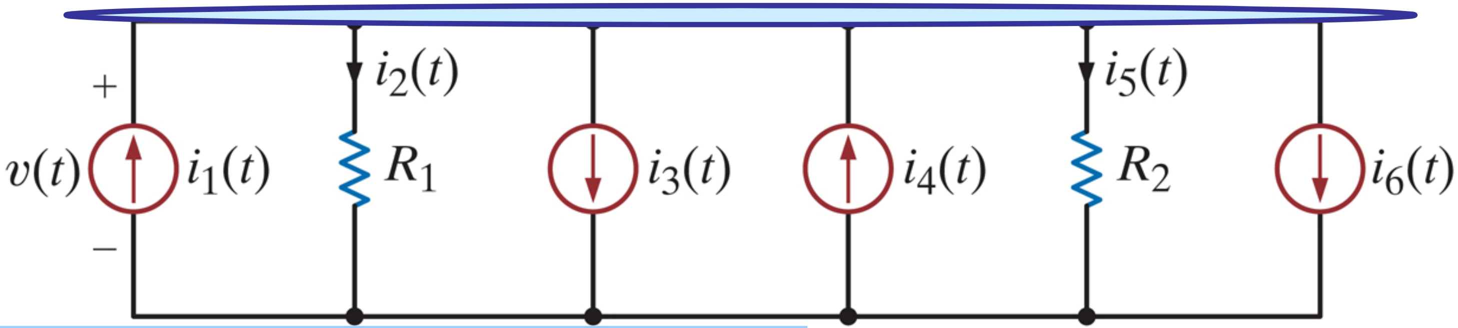
CURRENT IN mA YIELD POWER IN mW

$P = 144 * 40mW = 5.76W$

$$I_1 = \frac{120}{120+40}(16)$$ $I_1 = 12mA$

FIRST GENERALIZATION: MULTIPLE SOURCES

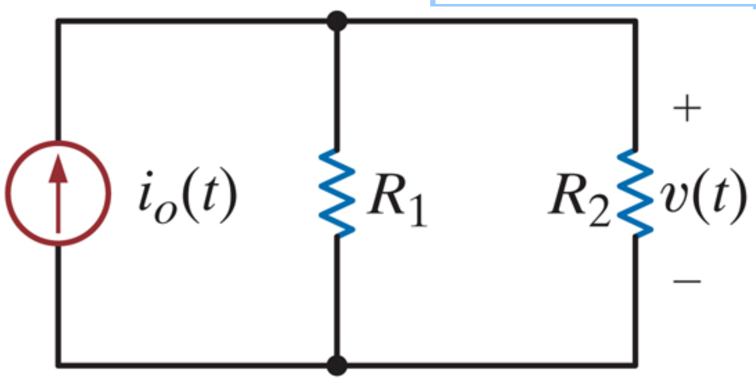
APPLY KCL TO THIS NODE



$$i_1(t) - i_2(t) - i_3(t) + i_4(t) - i_5(t) - i_6(t) = 0$$

EQUIVALENT SOURCE

$$i_o(t) = i_1(t) - i_3(t) + i_4(t) - i_6(t)$$



DEFINE "PARALLEL RESISTANCE COMBINATION"

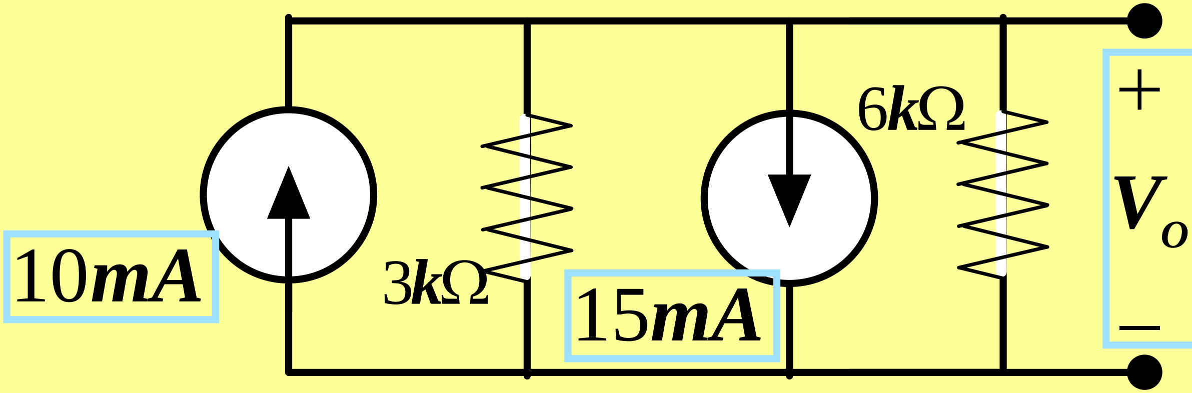
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

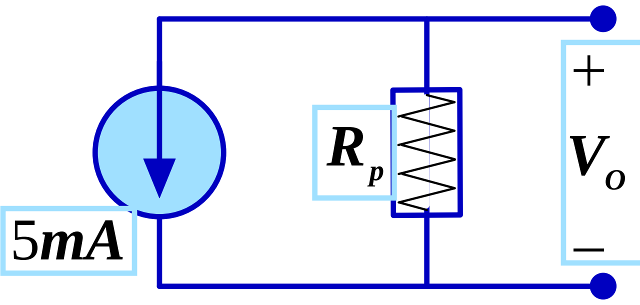
$$R_p = \frac{R_1 R_2}{R_1 + R_2}$$

$$i_o(t) = \frac{1}{R_p} v(t)$$

$$v(t) = \frac{R_1 R_2}{R_1 + R_2} i_o(t)$$

FIND V_o AND THE POWER SUPPLIED BY THE SOURCES





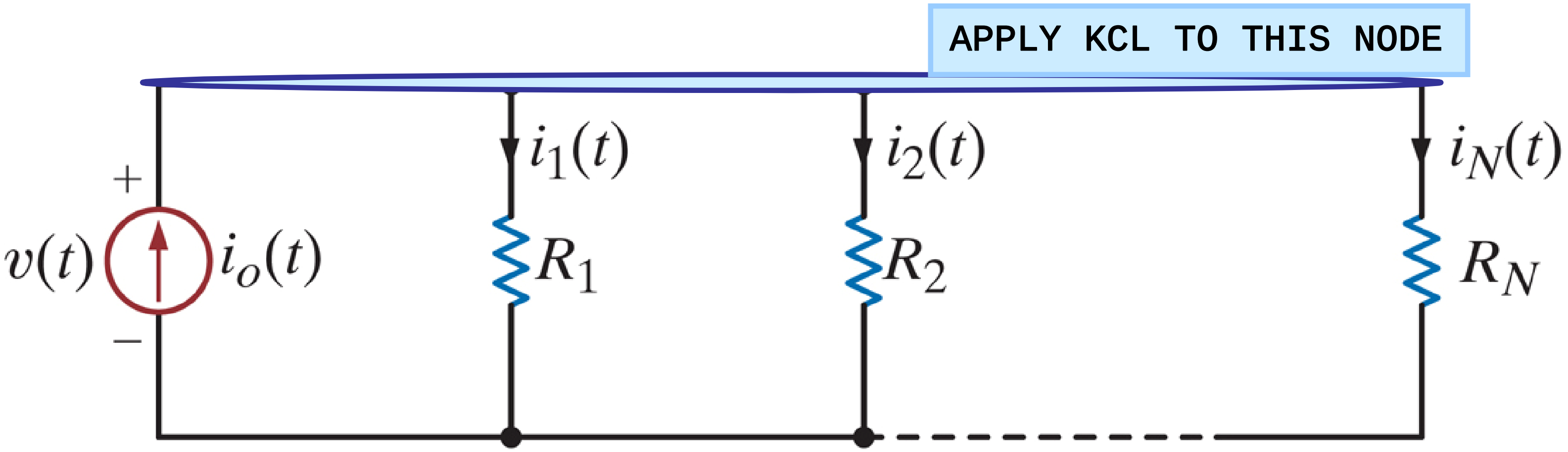
$$R_p = \frac{6k * 3k}{6k + 3k} = 2k\Omega$$

$$V_O = -10V$$

$$P_{15mA} = V_O(15mA) = -150mW$$

$$P_{10mA} = V_O(-10mA) = 100mW$$

SECOND GENERALIZATION: MULTIPLE RESISTORS



$$i_o(t) = i_1(t) + i_2(t) + \cdots + i_N(t)$$
$$= \left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}\right) v(t)$$

Ohm's Law at every resistor

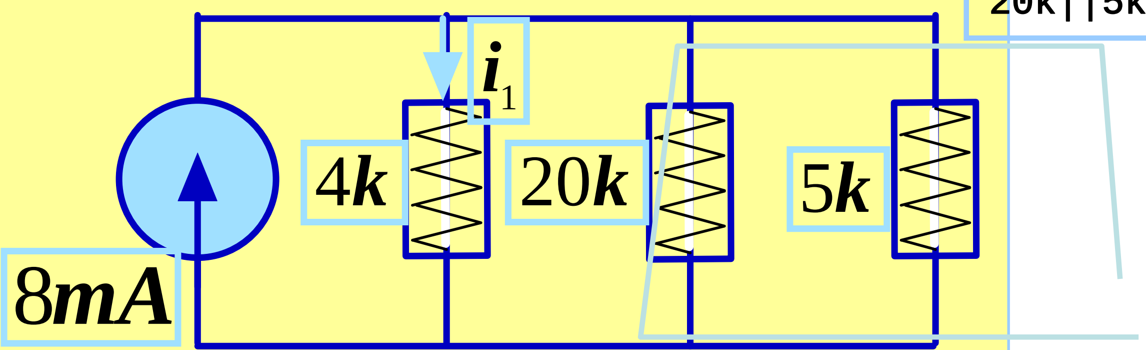
$$\frac{1}{R_p} = \sum_{i=1}^{N} \frac{1}{R_i}$$

$$i_o(t) = \frac{v(t)}{R_p}$$

$$\left.\begin{array}{l} v(t) = R_p i_O(t) \\ i_k(t) = \dfrac{v(t)}{R_k} \end{array}\right\} \Rightarrow i_K(t) = \frac{R_p}{R_k} i_O(t)$$

General current divider

FIND i_1 AND THE POWER SUPPLIED BY THE SOURCE



$$\frac{1}{R_p} = \frac{1}{4k} + \frac{1}{20k} + \frac{1}{5k} = \frac{5+1+4}{20k} = \frac{1}{2k} \Rightarrow R_p = 2k$$

$$i_1 = \frac{2k}{4k}(8) = 4mA$$

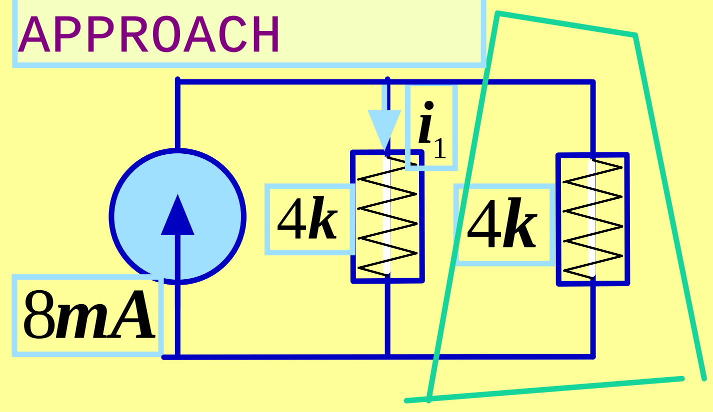
$$v = 4k * i_1 = 16V$$

$$P = v(-8mA) = -128mW$$

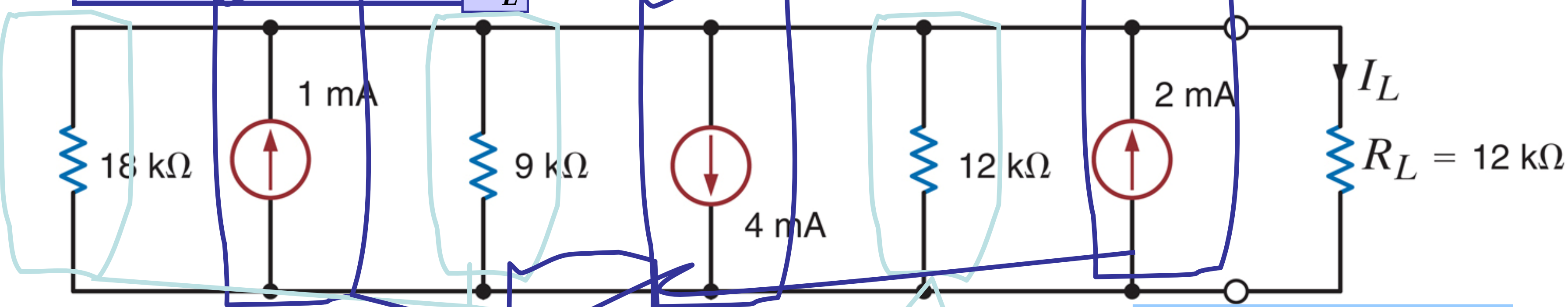
$$\left.\begin{aligned} v(t) &= R_P i_O(t) \\ i_k(t) &= \frac{v(t)}{R_k} \end{aligned}\right\} \Rightarrow i_K(t) = \frac{R_p}{R_k} i_O(t)$$

General current divider

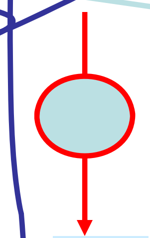
AN ALTERNATIVE APPROACH



FIND THE CURRENT I_L



COMBINE THE SOURCES

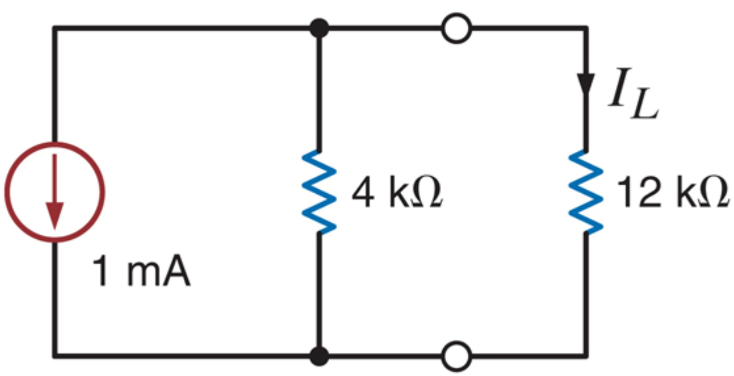


1mA

COMBINE RESISTORS

$$\frac{1}{R_p} = \frac{1}{18k} + \frac{1}{9k} + \frac{1}{12k}$$

$$R_p = 4\ k\Omega$$

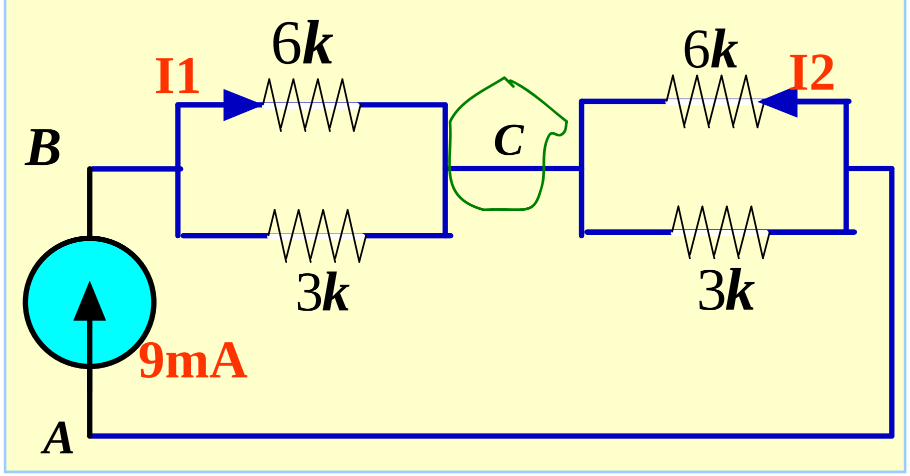


STRATEGY: CONVERT THE PROBLEM INTO A BASIC CURRENT DIVIDER BY COMBINING SOURCES AND RESISTORS.
THE NEXT SECTION EXPLORES IN MORE DETAIL THE IDEA OF COMBINING RESISTORS

$$I_L = -\left[\frac{4k}{4k + 12k}\right](1 \times 10^{-3})$$

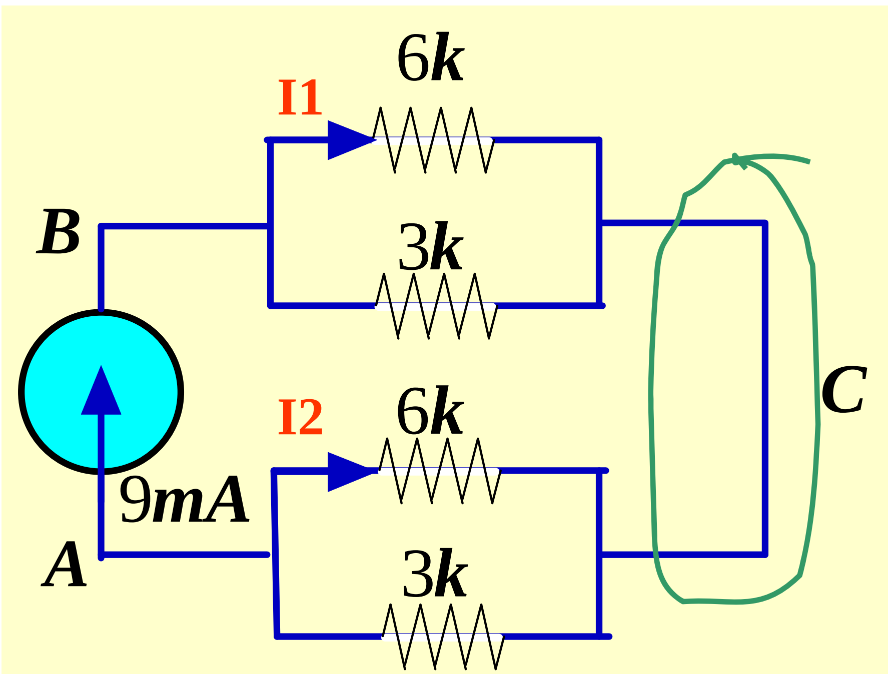
$$= -0.25\ mA$$

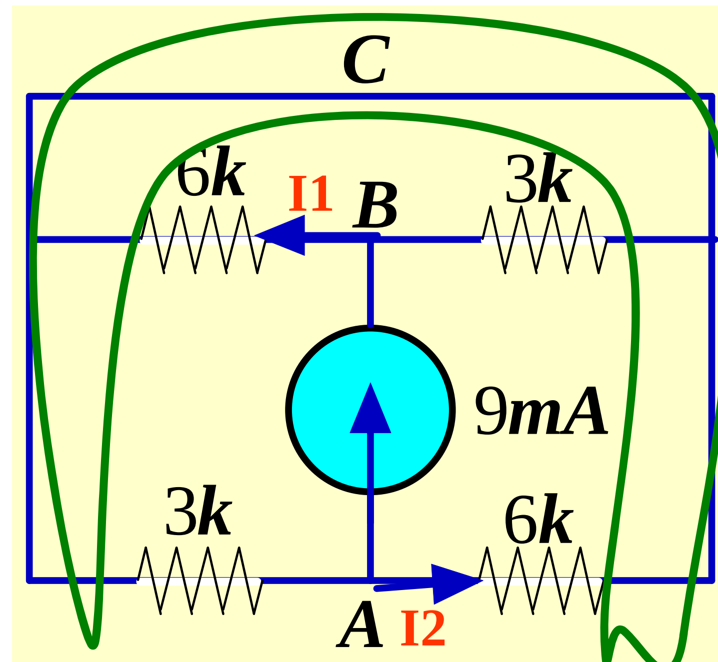
NOTICE THE MINUS SIGN



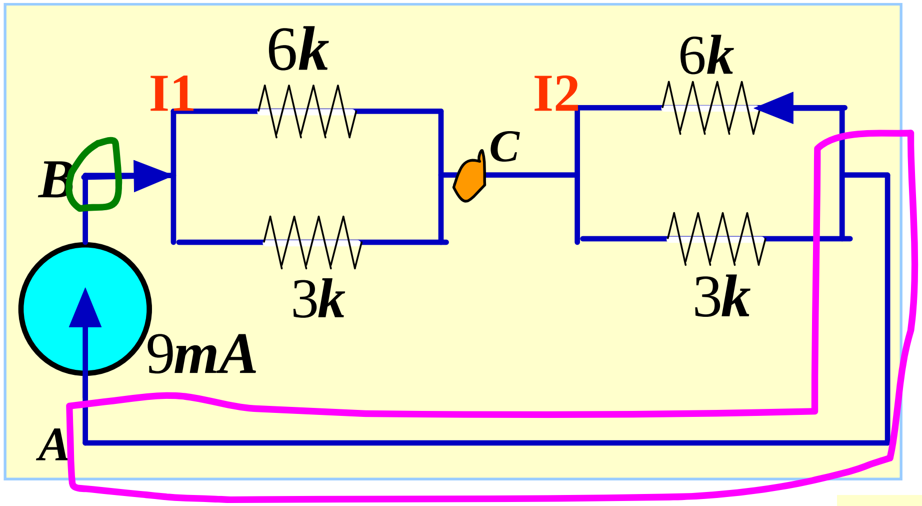
$$I_1 = \frac{3}{9} 9[mA] = 3mA$$

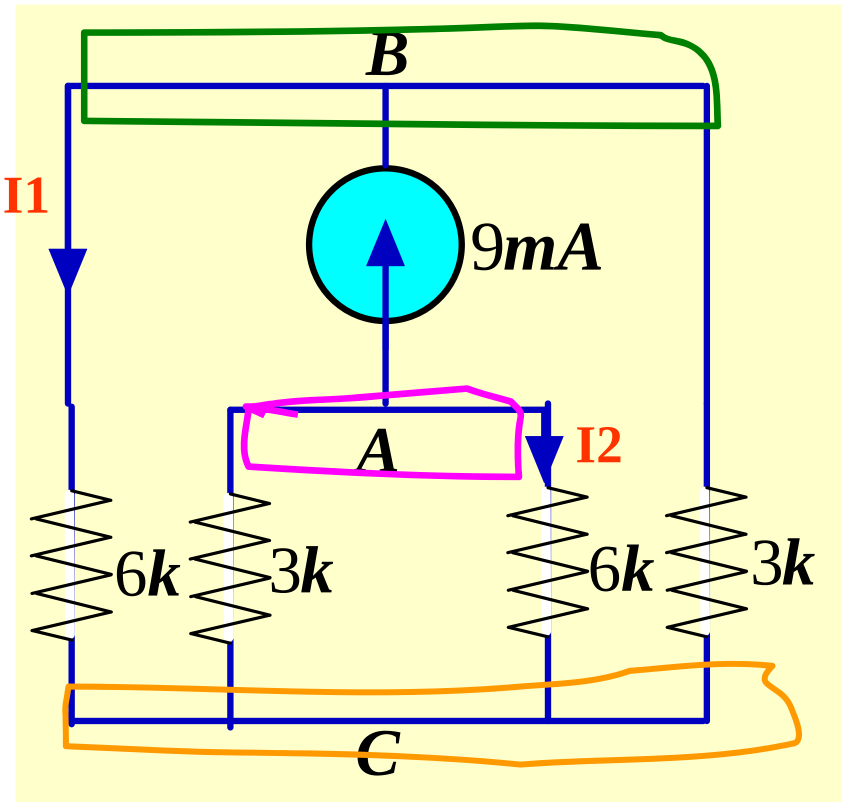
$$I_2 = -I_1$$



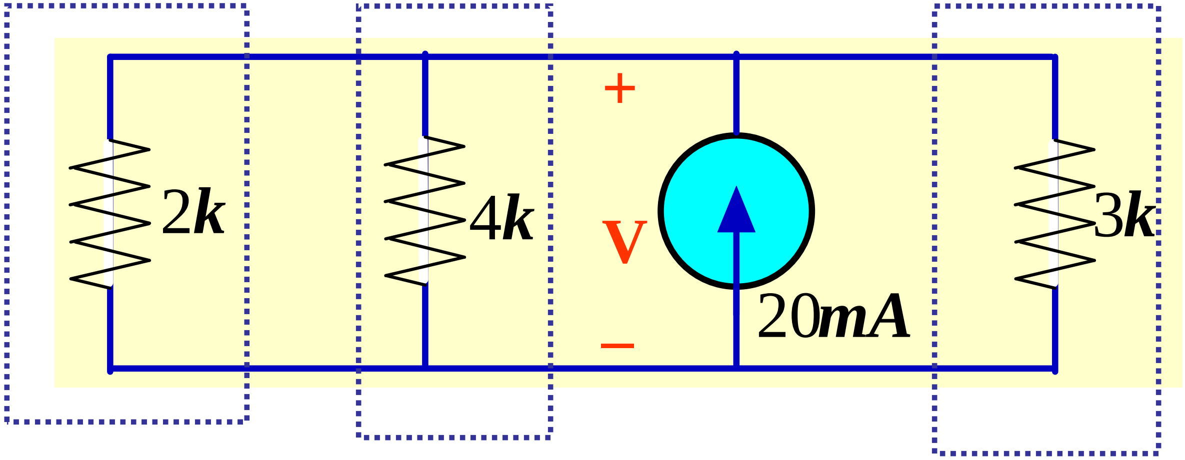


DIFFERENT LOOKS FOR THE SAME ELECTRIC CIRCUIT





REDRAWING A CIRCUIT MAY, SOMETIMES, HELP TO VISUALIZE BETTER THE ELECTRICAL CONNECTIONS



Determine power delivered by source

$$P = Rp * (20mA)^2$$

$$\frac{1}{Rp} = \frac{1}{2k} + \frac{1}{4k} + \frac{1}{3k} = \frac{6+3+4}{12k}$$

$$Rp = \frac{12}{13}k$$

$$\boldsymbol{P} = \frac{12}{13} * 10^3 \Omega * (20 * 10^{-3})^2 [\boldsymbol{A}]$$

$$\boldsymbol{P} = \frac{4.800}{13} \boldsymbol{W}$$