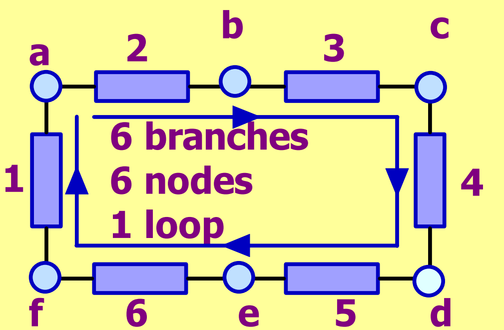
SINGLE LOOP CIRCUITS

BACKGROUND: USING KVL AND KCL WE CAN WRITE ENOUGH EQUATIONS TO ANALYZE ANY LINEAR CIRCUIT. WE NOW START THE STUDY OF SYSTEMATIC, AND EFFICIENT, WAYS OF USING THE FUNDAMENTAL CIRCUIT LAWS



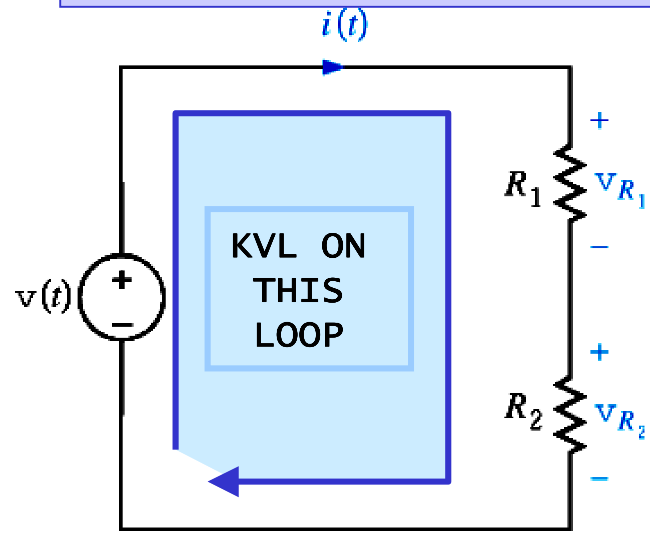
ALL ELEMENTS IN SERIES
ONLY ONE CURRENT

WRITE 5 KCL EQS OR DETERMINE THE ONLY CURRENT FLOWING

THE PLAN

- BEGIN WITH THE SIMPLEST ONE LOOP CIRCUIT
- EXTEND RESULTS TO MULTIPLE SOURCE
- AND MULTIPLE RESISTORS CIRCUITS

VOLTAGE DIVISION: THE SIMPLEST CASE



KVL $-v(t) + v_{R_1} + v_{R_2} = 0$

OHM'S LAW

$$v_{R_1} = R_1 i(t)$$

$$v_{R_2} = R_2 i(t)$$

SUBSTITUTION $v(t) = R_1 i(t) + R_2 i(t)$

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

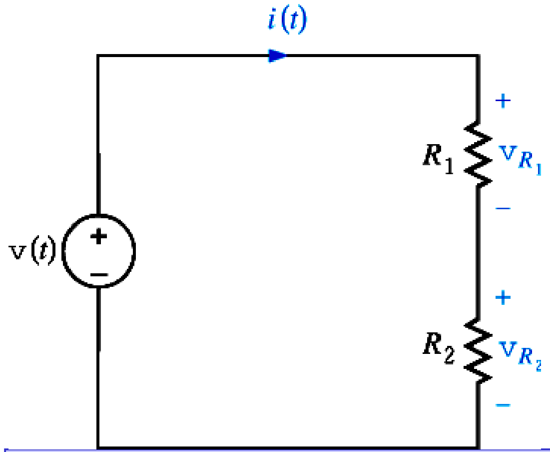
$$v_{R_1} = R_1 i(t) = R_1 \left[\frac{v(t)}{R_1 + R_2} \right] = \frac{R_1}{R_1 + R_2} v(t)$$

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

IMPORTANT VOLTAGE DIVIDER EQUATIONS

GEAUX

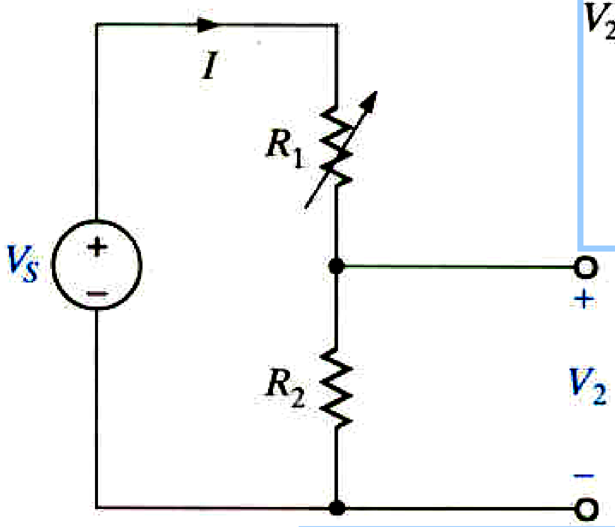
SUMMARY OF BASIC VOLTAGE DIVIDER



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

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

EXAMPLE: $V_S = 9V, R_1 = 90k\Omega, R_2 = 30k\Omega$



$$V_2 = \left[\frac{R_2}{R_1 + R_2}\right] V_S = \left[\frac{30\text{k}}{90\text{k} + 30\text{k}}\right](9) = 2.25 \text{ V}$$

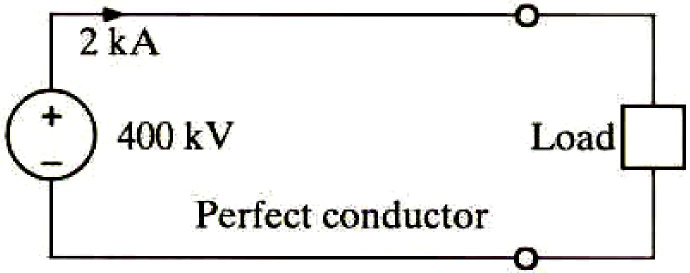
VOLUME CONTROL?

$R_1 = 15k\Omega \Rightarrow$

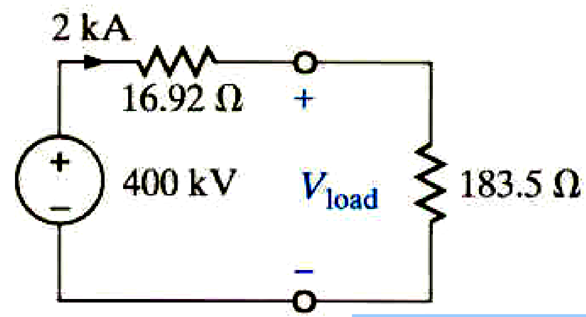
$$V_2 = \left[\frac{30\text{k}}{30\text{k} + 15\text{k}}\right] 9 = 6 \text{ V}$$

A "PRACTICAL" POWER APPLICATION

Line resistance is 0.04229 Ω/mile



400-mile transmission line



$$V_{load} = \left[\frac{183.5}{183.5 + 16.92}\right] 400\text{k} = 366.24 \text{ kV}$$

$$P_{load} = I^2 R_{load} = 734 \text{ MW}$$

$$P_{line} = P_{in} - P_{load} = I^2 R_{line} = 66 \text{ MW}$$

LOSSES!!!

HOW CAN ONE REDUCE THE LOSSES?

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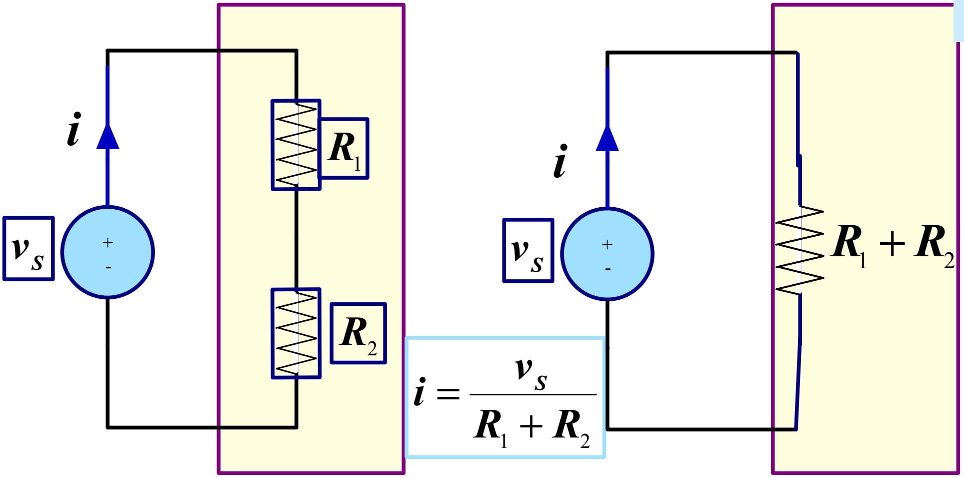
THE CONCEPT OF EQUIVALENT CIRCUIT

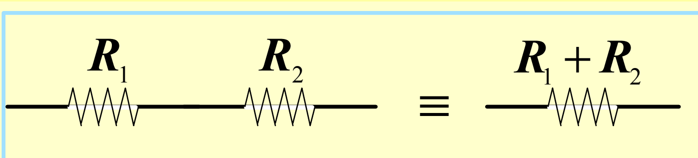
THIS CONCEPT WILL OFTEN BE USED TO SIMPLFY THE ANALYSIS OF CIRCUITS. WE INTRODUCE IT HERE WITH A VERY SIMPLE VOLTAGE DIVIDER



$$i = \frac{v_S}{R_1 + R_2}$$

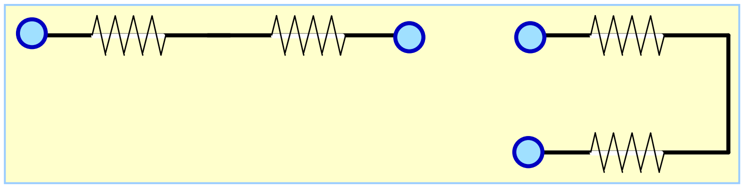
AS FAR AS THE CURRENT IS CONCERNED BOTH CIRCUITS ARE EQUIVALENT. THE ONE ON THE RIGHT HAS ONLY ONE RESISTOR

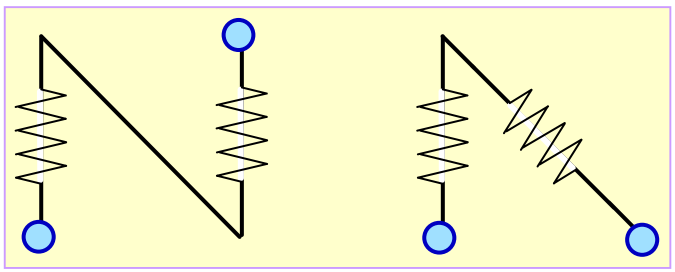
SERIES COMBINATION OF RESISTORS

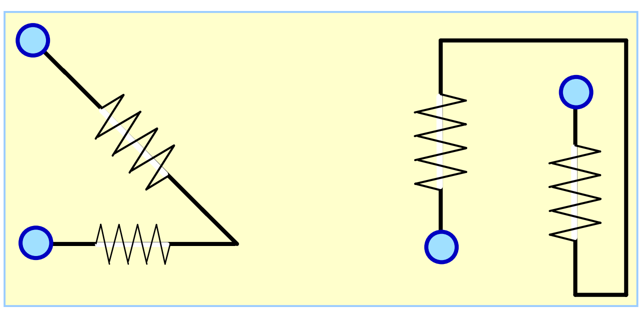


THE DIFFERENCE BETWEEN ELECTRIC CONNECTION AND PHYSICAL LAYOUT

SOMETIMES, FOR PRACTICAL CONSTRUCTION REASONS, COMPONENTS THAT ARE ELECTRICALLY CONNECTED MAY BE PHYSICALLY QUITE APART







IN ALL CASES THE RESISTORS ARE CONNECTED IN SERIES

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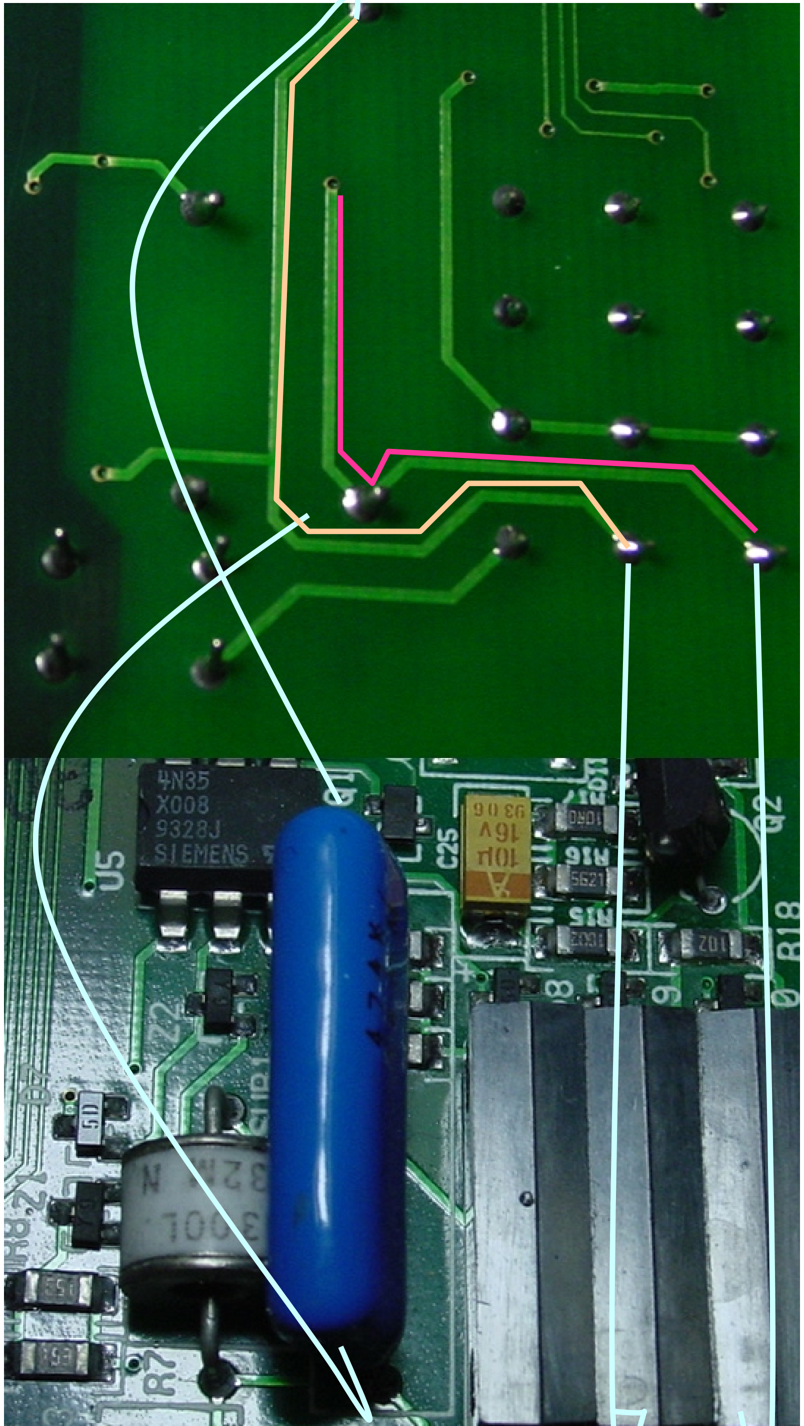
CONNECTOR SIDE



ILLUSTRATING THE DIFFERENCE BETWEEN PHYSICAL LAYOUT AND ELECTRICAL CONNECTIONS

PHYSICAL NODE

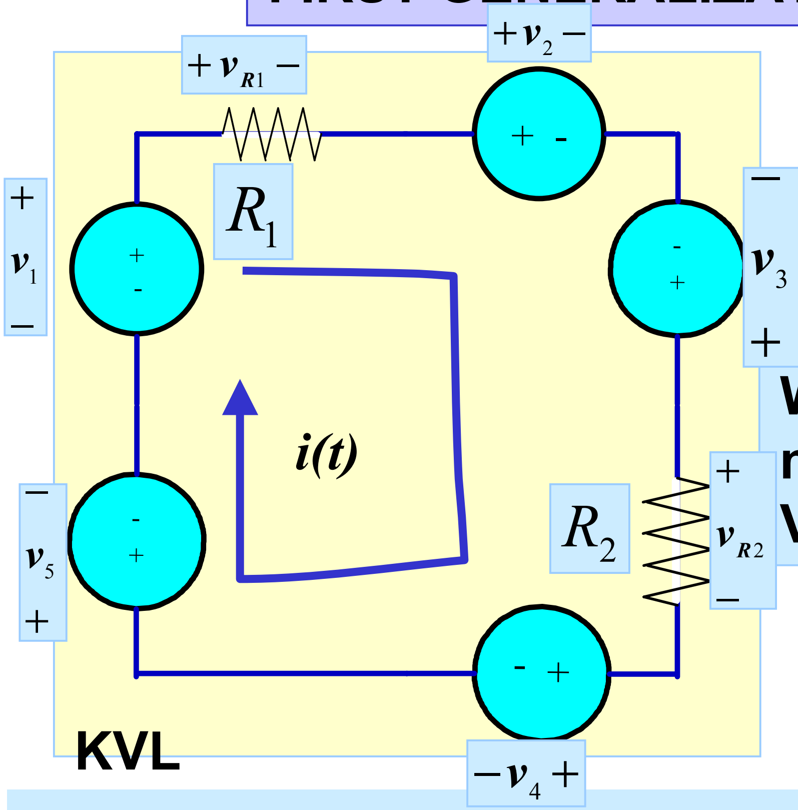
PHYSICAL NODE

SECTION OF 14.4 KB VOICE/DATA MODEM

CORRESPONDING POINTS

COMPONENT SIDE

FIRST GENERALIZATION: MULTIPLE SOURCES



Voltage sources in series can be algebraically added to form an equivalent source.

We select the reference direction to move along the path.
Voltage drops are subtracted from rises

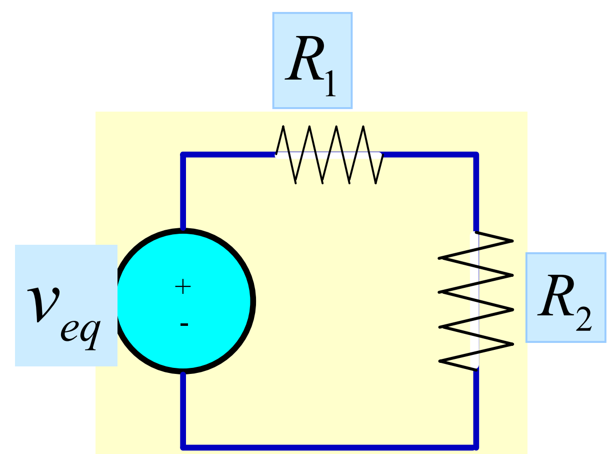
KVL

$$v_{R1} + v_2 - v_3 + v_{R2} + v_4 + v_5 - v_1 = 0$$

Collect all sources on one side

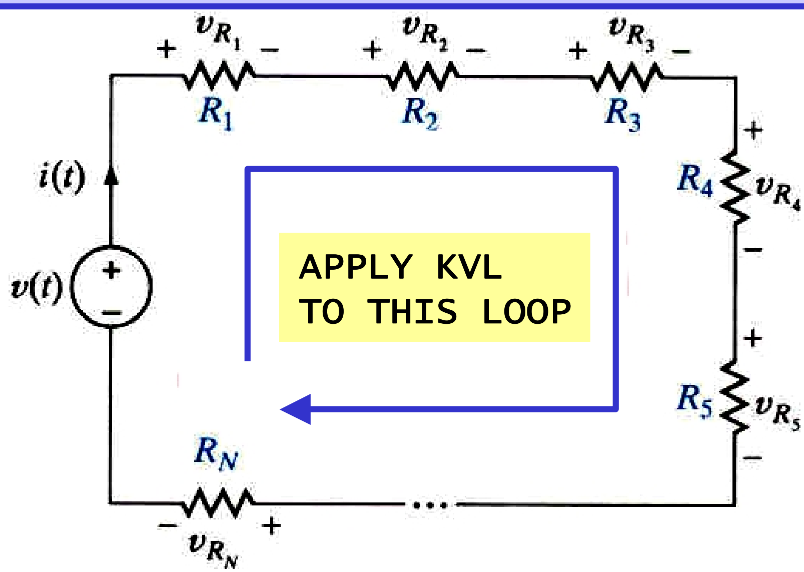
$$\left(v_1 - v_2 + v_3 - v_4 - v_5\right) = v_{R1} + v_{R2}$$

$$\left(v_{eq}\right) = v_{R1} + v_{R2}$$



GEAUX

SECOND GENERALIZATION: MULTIPLE RESISTORS



$$v(t) = v_{R_1} + v_{R_2} + \cdots + v_{R_N}$$

AND OHM'S LAW

$$= R_1 i(t) + R_2 i(t) + \cdots + R_N i(t)$$

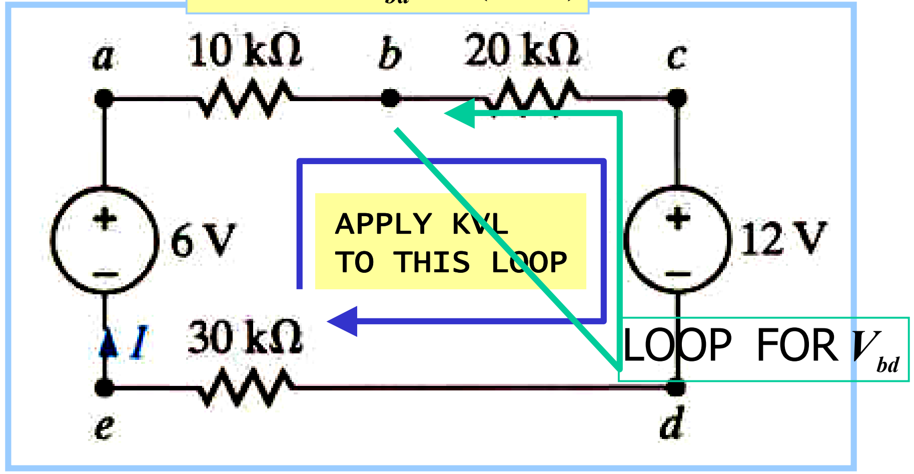
$$R_S = R_1 + R_2 + \cdots + R_N$$

$$i(t) = \frac{v(t)}{R_S}$$

$$v_{R_i} = R_i i \Rightarrow \quad v_{R_i} = \frac{R_i}{R_S} v(t)$$

VOLTAGE DIVISION FOR MULTIPLE RESISTORS

FIND $I, V_{bd}, P(30k)$



$$10kI + 20kI + 12 + 30kI - 6 = 0$$

$$I = -0.1 \text{ mA}$$

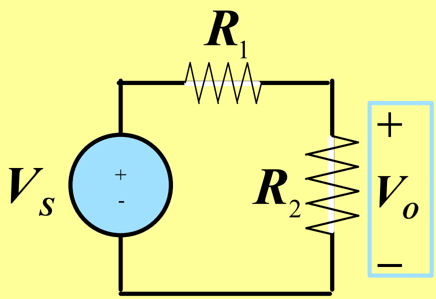
$$V_{bd} - 12 - 20[k\Omega]I = 0 \text{ (KVL)} \Rightarrow V_{bd} = 10V$$

POWER ON 30kΩ RESISTOR

$$P = I^2 R = (-10^{-4} A)^2 (30 * 10^3 \Omega) = 30mW$$

GEAUX

THE "INVERSE" VOLTAGE DIVIDER



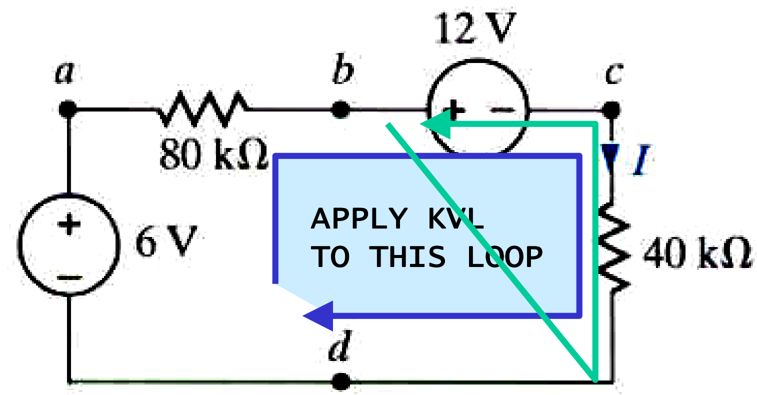
VOLTAGE DIVIDER

$$V_O = \frac{R_2}{R_1 + R_2} V_S$$

"INVERSE" DIVIDER

$$V_S = \frac{R_1 + R_2}{R_2} V_O$$

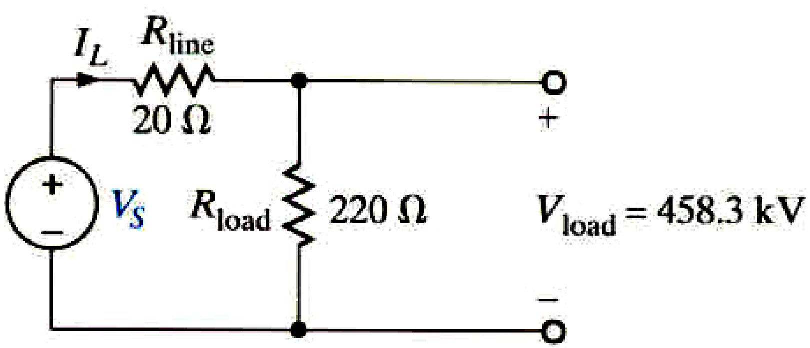
Find I and V_{bd} in the circuit



$$-6 + 80kI + 12 + 40kI = 0 \Rightarrow I = -0.05mA$$

$$V_{bd} = -40kI - 12V = 0 \Rightarrow V_{bd} = 10V$$

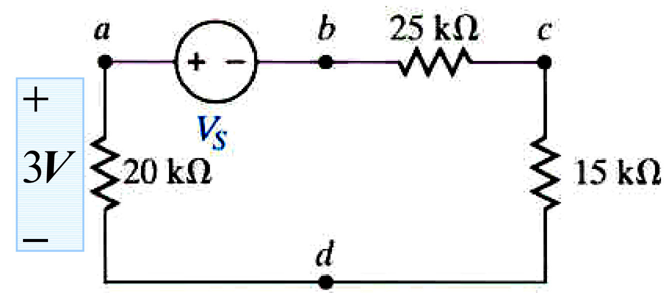
COMPUTE V_S



"INVERSE" DIVIDER

$$V_S = \frac{220 + 20}{220} 458.3 = 500k\Omega$$

In the network in Fig. E2.11, if V_{ad} is 3 V, find V_S.

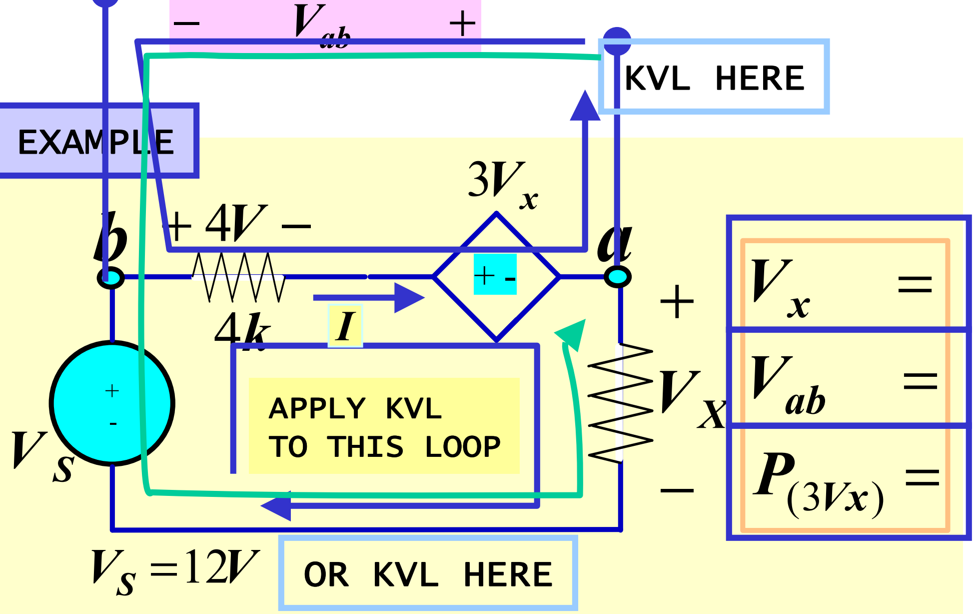


INVERSE DIVIDER PROBLEM

$$V_S = \frac{25 + 15 + 20}{20} 3 = 9V$$

GEAUX

EXAMPLE



$P_{(3Vx)}$ is the power absorbed or supplied by the dependent source

KVL: $-12 + 4 + 3V_X + V_X = 0 \Rightarrow$ $V_X = 2V$

KVL: $V_{ab} + 4 + 3V_X = 0 \Rightarrow$ $V_{ab} = -10V$

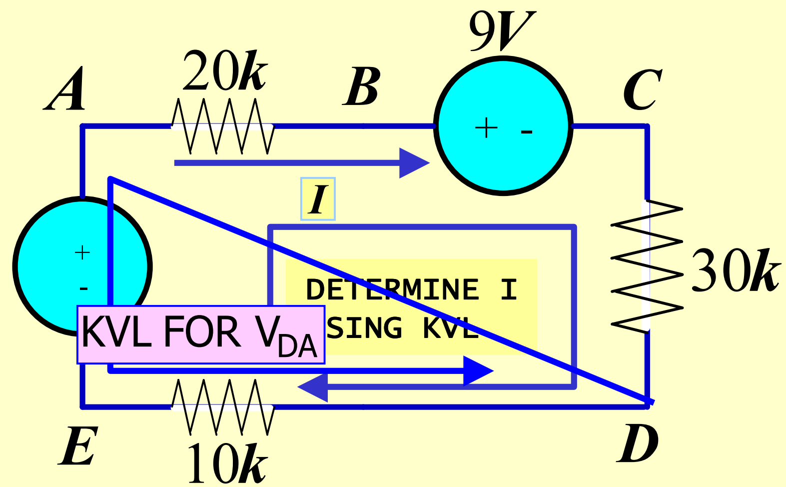
KVL: $V_{ab} + V_S - V_X = 0$

$P_{(3V_x)} = 3V_X I$ (PASSIVE SIGN CONVENTION)

OHMS' LAW: $I = \frac{4V}{4k} = 1mA$

$P_{(3V_x)} = 2[V]*1[mA] = 2mW$

EXAMPLE



$V_{DA} =$

$V_{CD} =$ $30k * I = 1.5V$

$I_{DE} =$ $0.05mA$

KVL: $-12 + 20k*I + 9 + 30k*I + 10k*I = 0$

$I = \frac{3V}{60k\Omega} = 0.05mA$

KVL: $V_{DA} + 12 - 10k*I = 0$

$V_{DA} = -11.5V$

STOP