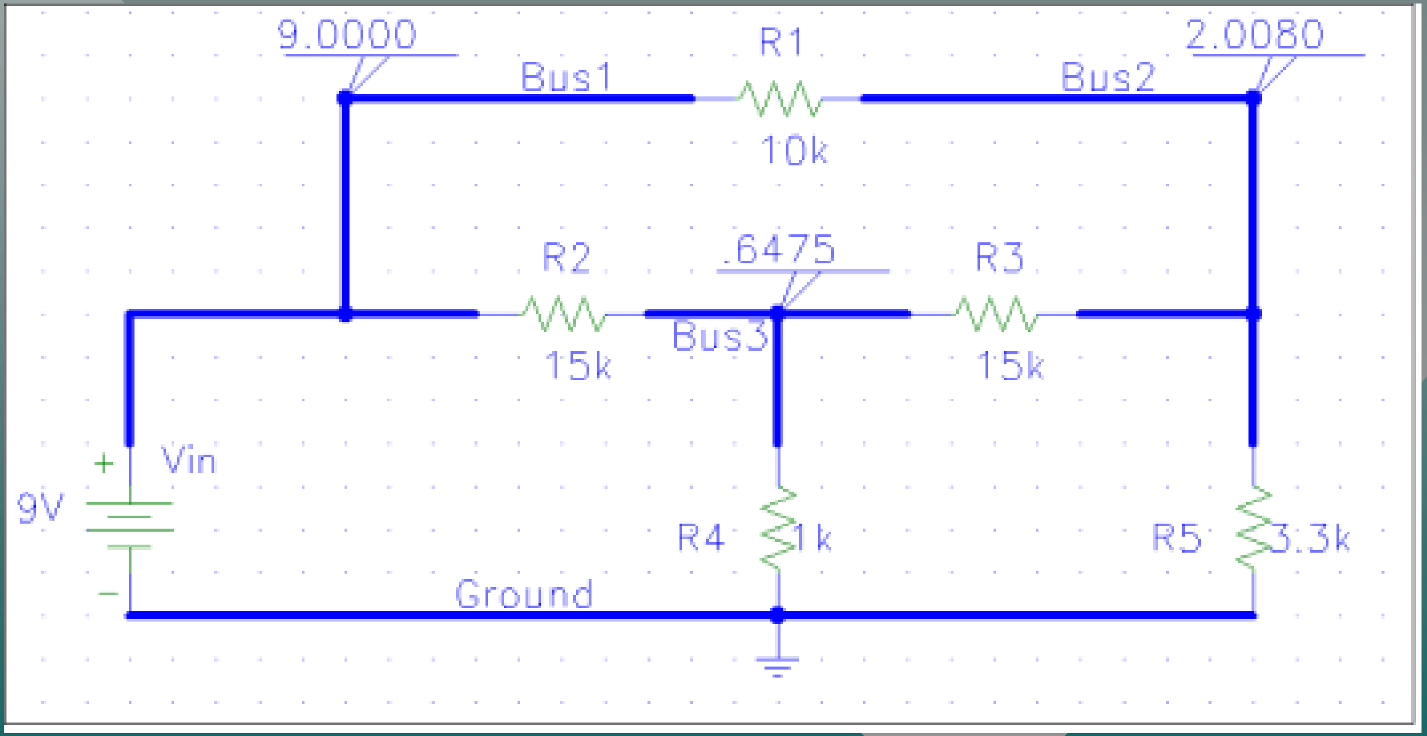
# Introduction to MatLab: Circuit Analysis



# Introduction

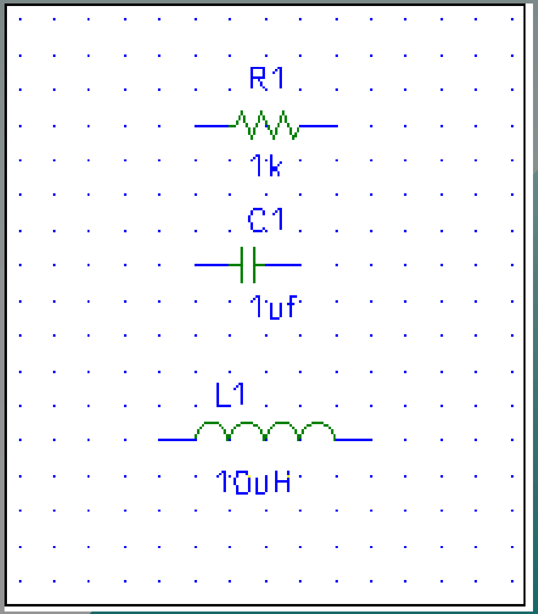
- MatLab can be a useful tool in many applications.
- We will learn how to analyze a simple electrical circuit, set the problem up as N equations in N unknowns, and transform the equations into a matrix formulation that MatLab can solve.

# Topics

- Electrical Devices.
- Kirchhoff's Laws.
- Analyzing a Resistor Network.
- Inverting Matrices.
- A MatLab Solution.

# Electrical Devices

- Voltage and Current.
- Sources.
- Resistors: Ohms Law.
- Capacitors: Charge Storage.
- Inductors: Current Storage.



# Voltage and Current

- Voltage - the force that pushes electrical current around a circuit.  (Sometimes called "potential" as in potential energy.)
- Current - the flow of electrical charge through a conductor.  (Electrons flow backwards)
- Conductor - the "pipe" through which an electrical current flows.

# Sources

- Voltage Source: Fixed Voltage waveform
  - Direct Current: A battery
  - Alternating Current: A generator (sine waves)
- Current Source: Fixed current waveform (AC or DC)

# Resistors

- A constriction in the flow of current
- Analogous to a small orifice in a water pipe, it takes a high pressure (voltage) to force a flow of water (current) through the resistance.
- Ohm's Law
  $V=I*R$

# Resistor Color Codes

- First two stripes: Digits
- Third stripe: Power of 10
- Fourth stripe: Precision
  (none - 20%, silver - 10%, gold - 5%)

| | |
|---|---|
| 0 - Black | 5 - Green |
| 1 - Brown | 6 - Blue |
| 2 - Red | 7 - Violet |
| 3 - Orange | 8 - Gray |
| 4 - Yellow | 9 - White |

# Capacitors

- A charge storage device
- Analogous to a water tank that is filled from the bottom.  As the water level rises (charge divided by the cross sectional area – capacitance), the pressure (voltage) rises.
- Capacitor Law
  $V=Q/C$

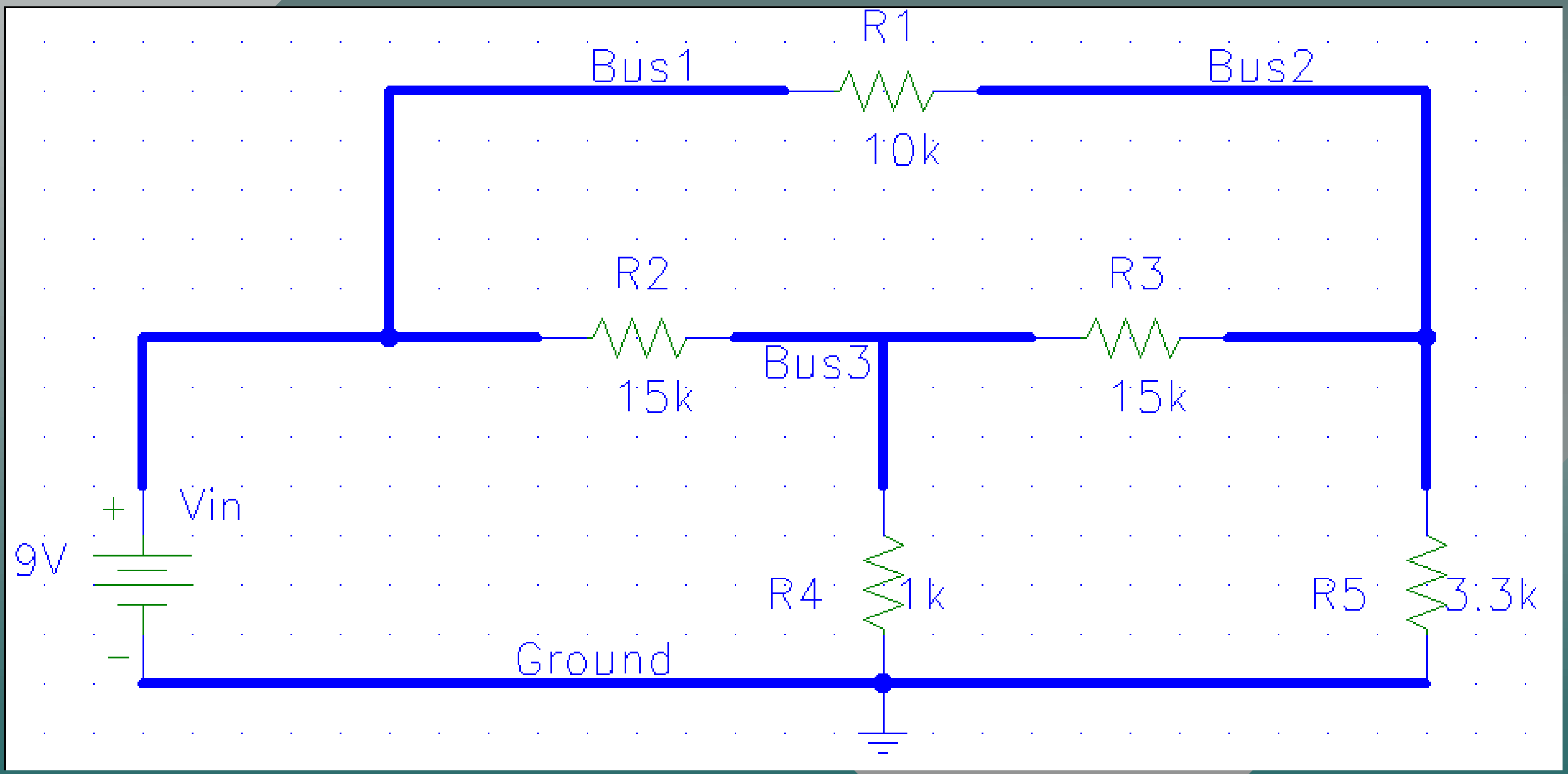
# Inductors

- A current storage device
- Analogous to the inertial effect of the flow of a fluid. The inductance is the mass that is moving.
- Inductor Law
  V=L*dI/dt (dI/dt is the "rate of change" in the current. This is analogous to velocity.)

# Kirchhoff's Laws

- Conservation of Current:
  The sum of all currents into a "node" equals zero.
- Loop Law:
  The sum of all voltages around a loop equals zero.

# A Resistor Network



# Measurements

- Multimeter (Analog and Digital)
- Voltage - measured relative to a reference, usually electrical ground.
- Resistance - meter puts a small current through the resistor and uses Ohm's law.
- Current - careful, the meter can be destroyed by an over-current.

# Loop Equations

- Establish Independent Loop Currents
- Write Equation for Each Loop
  - Determine voltages in terms of the loop currents.
  - Sum to zero

(note: Alternative, use a set of "Node" equations)

# Our Circuit – First Step

$9v = 15k*(I_1-I_2) + 1k*(I_1-I_3)$

$0 = 10k*I_2 + 15k*(I_2-I_1) + 15k*(I_2-I_3)$

$0 = 1k*(I_3-I_1) + 15k*(I_3-I_2) + 3.3k*I_3$

# Our Circuit – Collecting Terms

$$9v = 16k*I_1 - 15k*I_2 - 1k*I_3$$

$$0 = -15k*I_1 + 40k*I_2 - 15k*I_3$$

$$0 = -1k*I_1 - 15k*I_2 + 19.3k*I_3$$

# Vectorizing N Equations

- Rewrite, ordering variables
- Formulate equivalent as an input column vector equals a coefficient matrix times an “unknowns” vector
- Solution: pre-multiply both sides by the inverse of the coefficient matrix.

# Our Circuit – Vector Equation

$$\begin{bmatrix} 9v \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 16k & -15k & -1k \\ -15k & 40k & -15k \\ -1k & -15k & 19.3k \end{bmatrix} * \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

# Inverting Matrices

- The inverse of a square matrix is that matrix which, when multiplied by the original matrix yields the Identity matrix
- In MatLab use “inv()”.

# Our Circuit – Inverse Matrix

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 0.1396 & 0.0777 & 0.0676 \\ 0.0777 & 0.0785 & 0.0651 \\ 0.0676 & 0.0651 & 0.1059 \end{bmatrix} * \begin{bmatrix} 9 \\ 0 \\ 0 \end{bmatrix} * 10^{-3}$$

# Our Circuit – Currents

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 1.256 \\ 0.6992 \\ 0.6085 \end{bmatrix} * 10^{-3} \text{ amps}$$

# Intro To PSpice

- Originally from Microsim, now part of OrCad.
- Demo/student CDROM is free at www.orcad.com, current version is 9.2, Limited to small circuits and part library.
- Graphical simulation of circuits and automated Printed Circuit board layout.

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