FEE321 – E.C.T IIA – Oct 2020

Lecture 3: Basic Concepts (2 hrs)

Lecturer: *Prof H A Ouma*

23/10/2020

Overview

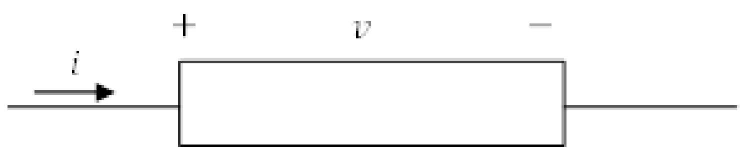
- Today's class is a continuation of the review of concepts from ECT I
- We look at
  - current and voltage conventions,
  - energy sources,
  - dot convention,
  - Kirchhoff's laws,
  - special two port circuit components

Current Convention

- The direction of flow of electrons gives the **electron current** direction
- The opposite, direction to the electron current direction, is the direction of flow of the holes. This is the **conventional current** direction
- Conventional current direction is often indicated by an arrow

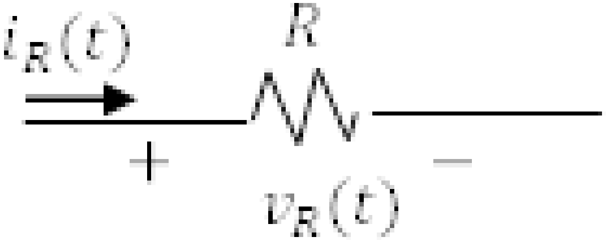
Voltage Convention[1]

- Voltage source terminals are normally indicated by a plus (+) and a minus (-)
- When a given voltage polarity **agrees** with the terminal marks, it is considered **positive**
- Otherwise the voltage is taken as **negative**
- Conventional current flows from the positive terminal to the negative terminal (high to low p.d)
- This informs the marking of passive element terminals

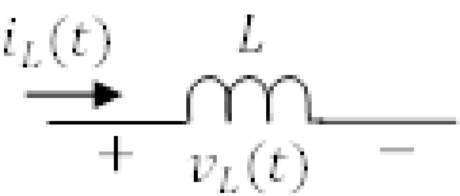


Voltage Convention[2]

- Voltage-Current relationships for the three common passive electrical elements follows the convention
- $v_R(t) = Ri_R(t)$
- $i_R(t) = Gv_R(t)$

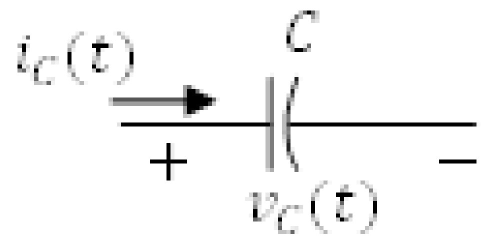


- $v_L(t) = L\frac{di_L(t)}{dt}$
- $i_L(t) = \frac{1}{L}\int_{-\infty}^{t} v_L(t)\,dt$



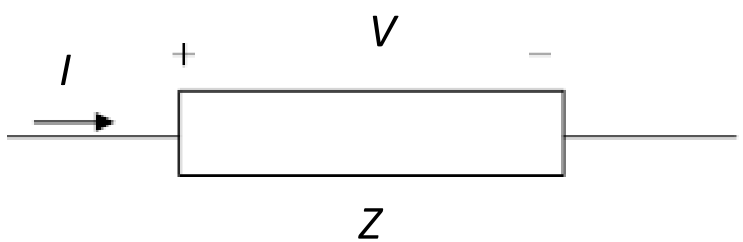
Voltage Convention[3]

- $v_C(t) = \frac{1}{C}\int_{-\infty}^{t} i_C(t)\, dt$
- $i_C(t) = C\,\frac{dv_C(t)}{dt}$



- In phasor form

- $V = I \cdot Z$
- $I = V \cdot Y$



Overview

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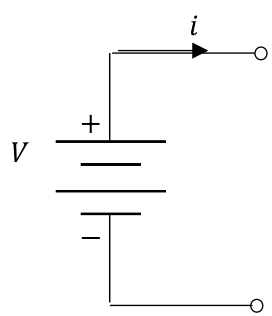
- We look at
  - current and voltage conventions,
  - **energy sources,**

Active elements

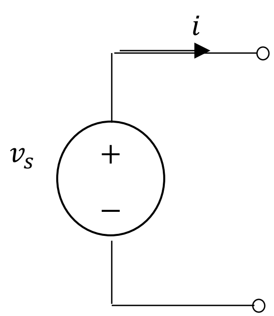
- Sources of electrical energy are modeled as active elements
- Fundamental source models may be
  – voltage sources or current sources
  – ideal or practical
  – independent or dependent (controlled)
  – constant or time varying

Voltage sources[1]

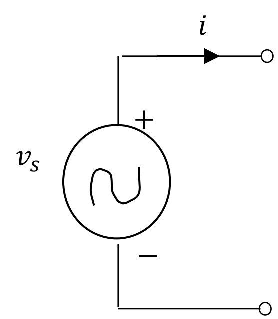
- Ideal voltage source delivers the same specified voltage at its terminals irrespective of the load across the terminals
- Symbols



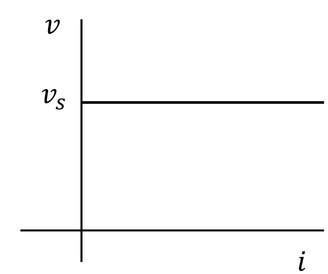
Time-invariant



Time varying



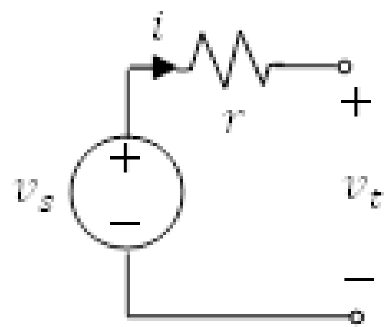
Time varying (sinusoidal)



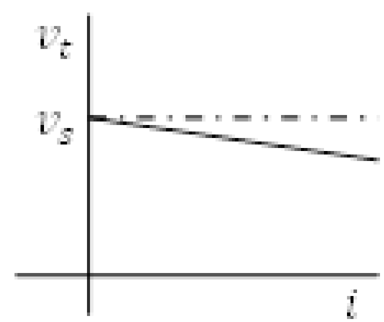
VI Characteristics

Voltage sources[2]

- Practical voltage sources show a reducing terminal voltage with increase in current drawn
- Modeled by adding *a small series resistor* to the ideal source



Practical Model



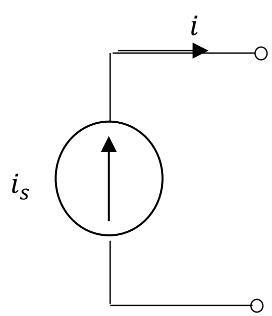
VI Characteristics

Voltage sources[3]

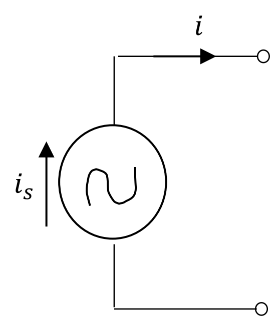
- A voltage source is *idle* when the output terminals are open, and output current is zero
- A voltage source is *turned off* when the voltage is zero
- When turned off the source is equivalent to a **short circuit**

Current sources[1]

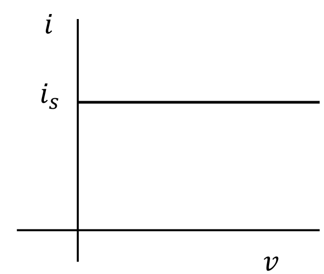
- Ideal current source delivers the same specified current at its terminals irrespective of the load across the terminals
- Symbols



Constant or time varying



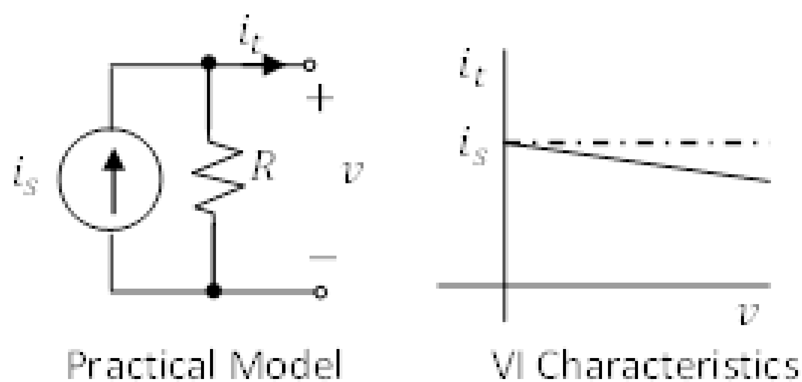
Time varying (sinusoidal)



VI Characteristics

Current sources[2]

- Practical current sources show a reducing terminal current with increase in terminal voltage
- Modeled by adding *a very large parallel resistor* to the ideal source



Current sources[3]

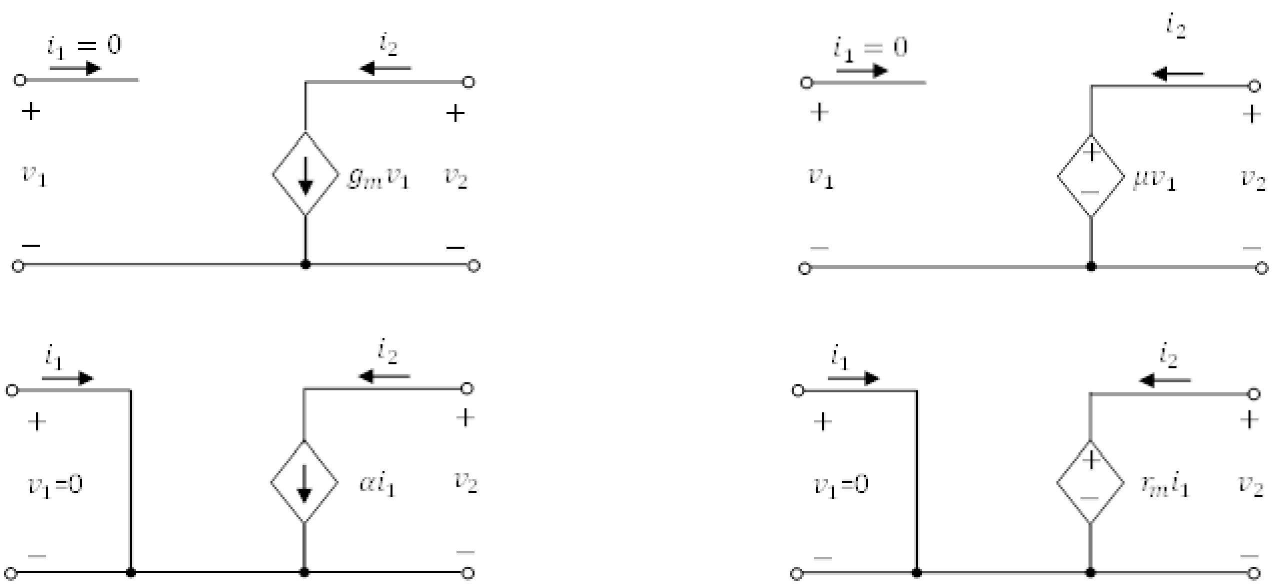
- A current source is *idle* when the terminals are shorted together, and output voltage is zero
- A current source is *turned off* when the current is zero
- When turned off the source is equivalent to an **open circuit**

Controlled or Dependent Sources[1]

- Source voltage (or current) depends on current or voltage in another part of the circuit
- There are four types
  - voltage controlled current source (VCCS)
  - voltage controlled voltage source (VCVS)
  - current controlled current source (CCCS)
  - current controlled voltage source (CCVS)
- Other source characteristics are as for the independent sources

Controlled or Dependent Sources[2]

- Symbols for controlled sources differ from those for the independent sources
- Below presented as 2-port networks
- Not the appropriate voltage and current convention



Overview

- Today's class is a continuation of the review of concepts from ECT I
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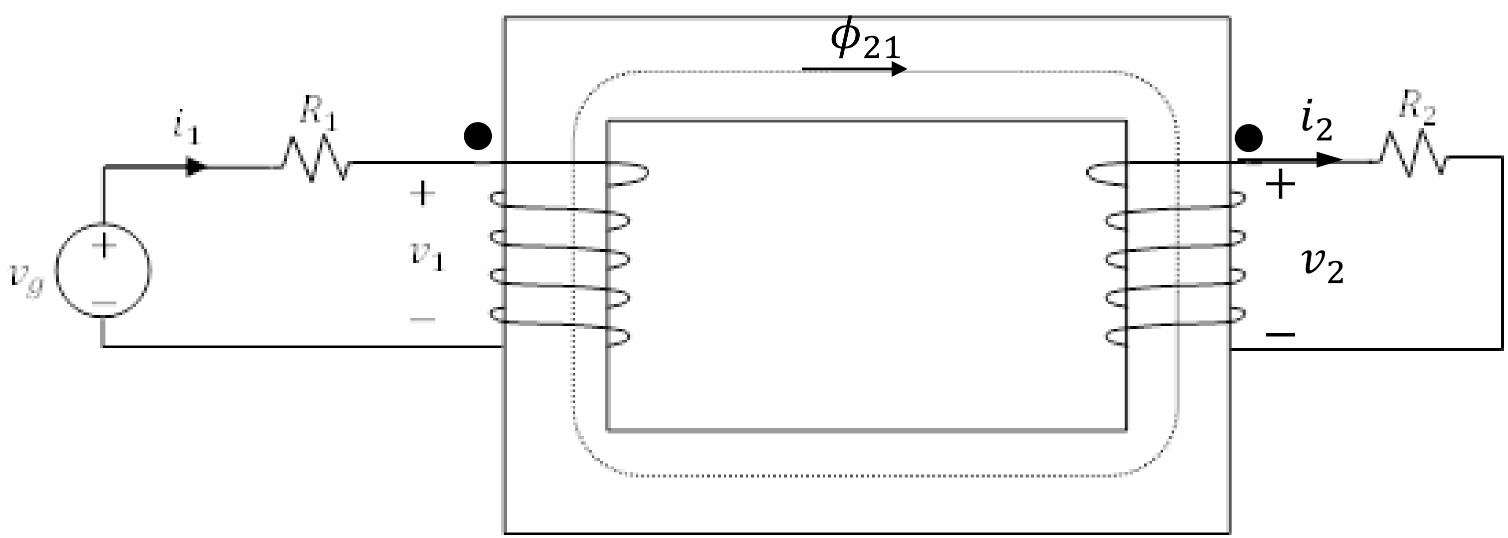
  - **dot convention,**

Dot Convention[1]

- Used in circuits with magnetic coupling, where magnetic field produced by changing current in one coil inducing voltage in other coils
- Induced effects will depend on
  - the magnitudes and directions of the currents,
  - the details of construction (turns, winding sense, core, separation etc.)
- Right-hand-grip rule is used to determine flux direction

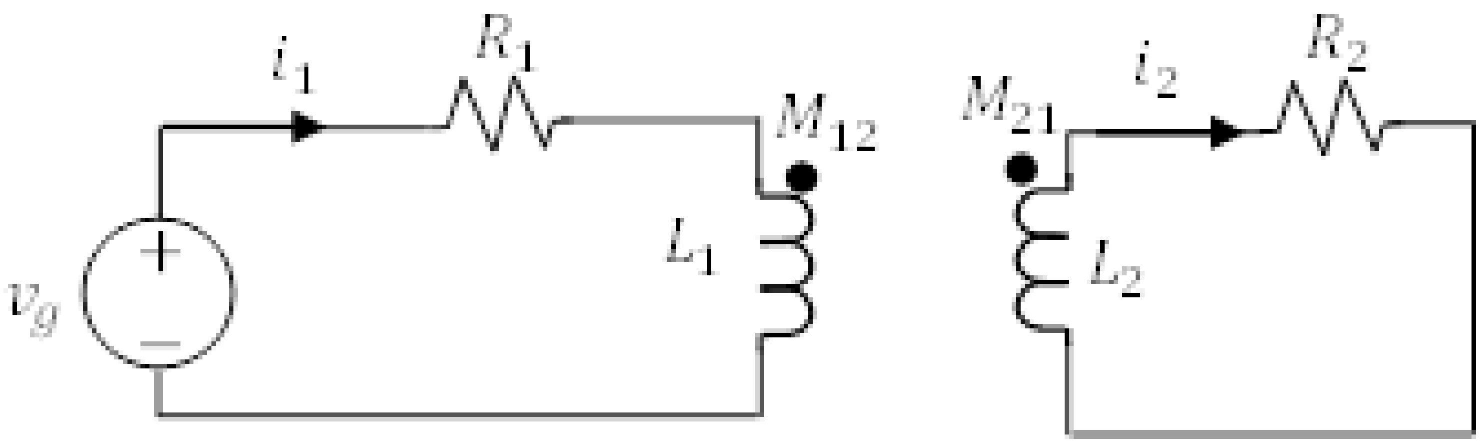
Dot Convention[2]

- Consider the magnetically coupled circuit below



Dot Convention[3]

- Equivalent electrical circuit would be



- If more than 2 coils are involved, each pair would have its unique dot relationship determined

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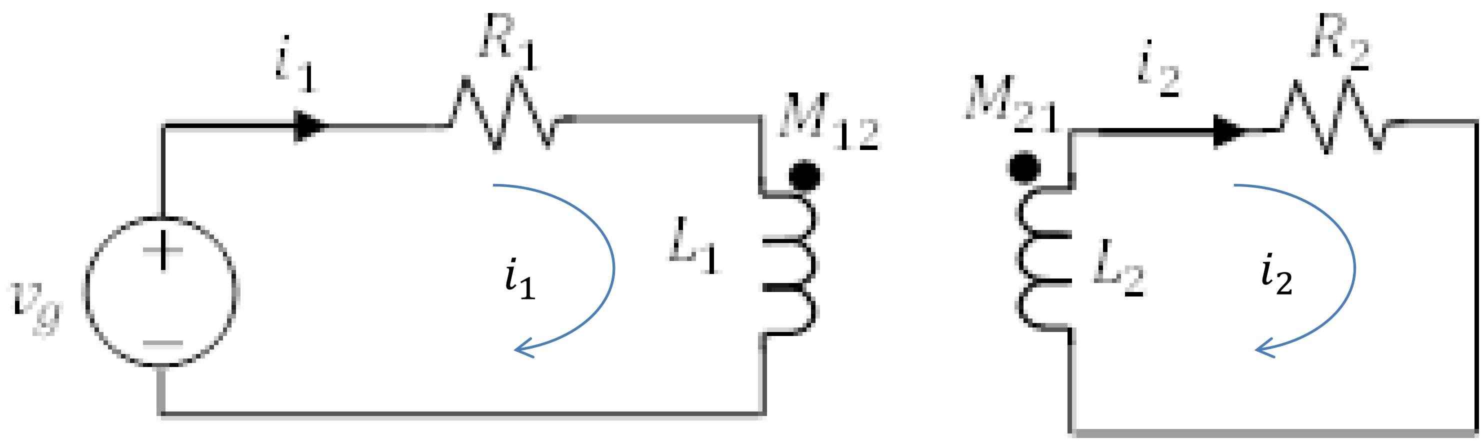
  - dot convention,
  - **Kirchhoff's laws,**

Kirchhoff's laws[1]

- KVL – for any closed loop in a circuit, the algebraic sum of the branch voltages in the loop is zero (or sum of voltage drops equals sum of voltage rises), at all instants of time
- Conservation of energy law
- KCL – at any node (simple, principal or super) the sum of currents entering the node equals the sum of currents leaving the node, at all instants of time
- Conservation of charge law

Kirchhoff's laws[2]

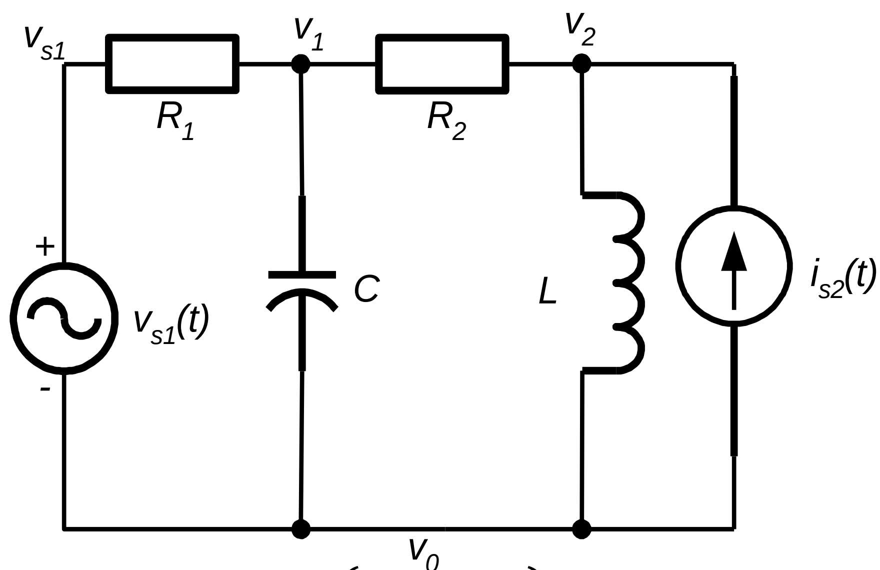
- Sample application of KVL



- Loop 1: $-v_g + i_1R_1 + L_1\frac{di_1}{dt} - M_{12}\frac{di_2}{dt} = 0$
- Loop 2: $i_2R_2 + L_2\frac{di_2}{dt} - M_{21}\frac{di_1}{dt} = 0$

Kirchhoff's laws[3]

- Sample application of KCL



- Node 1: $\frac{v_1 - v_{s1}}{R_1} + C\,\frac{d(v_1 - v_0)}{dt} + \frac{v_1 - v_2}{R_2} = 0$
- Node 2: $-i_{s2} + \frac{1}{L}\int_{-\infty}^{t}(v_2 - v_0)dt + \frac{v_2 - v_1}{R_2} = 0$

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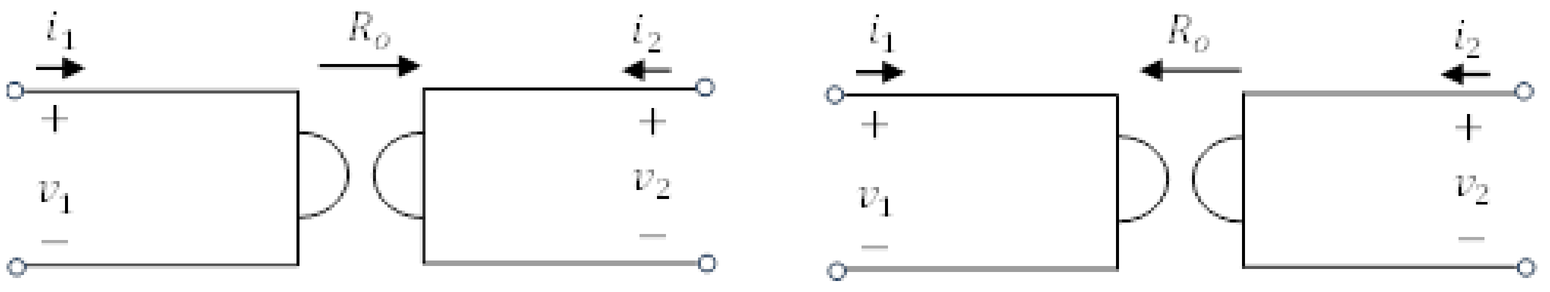
  – Kirchhoff's laws,
  – **special two port circuit components**

Special 2-port devices – Gyrator[1]

- Gyrator models electrostatic coupling in electrical circuits
- It is a non-reciprocal device
- Defined by the gyration resistance, R_o and direction of gyration
- This gives rise to one of two symbols



(a) (b)

- Defining equations
  - (a) $v_1 = -R_o i_2$ and $v_2 = R_o i_1$
  - (b) $v_1 = R_o i_2$ and $v_2 = -R_o i_1$

Special 2-port devices – Gyrator[2]

- Total energy input to the gyrator is given by

$$E(t) = \int_{-\infty}^{t} (v_1 i_1 + v_2 i_2)\, dt$$

$$= \int_{-\infty}^{t} (-R_o i_2 i_1 + R_o i_1 i_2)\, dt = 0$$

- The gyrator therefore dissipates no energy and only introduces non-reciprocity
- Result is the same for both (a) and (b) set-ups

Special 2-port devices – Gyrator[3]

- For a load R_L attached to port 2 (using set-up (a))

  $v_2 = -i_2 R_L$ and

  $$v_1 = -R_o i_2 = \frac{v_2}{R_L} R_o = \frac{R_o^2}{R_L} i_1$$

- At the gyrator input, the load R_L appears as a resistor of value $R_i = \frac{R_o^2}{R_L}$ ohm
- Thus a resistor termination is seen at the input as a resistor with value inversely proportional to the load

→ *inverting property of the gyrator*

Special 2-port devices – Gyrator[4]

- For a load C attached to port 2

  $-i_2 = C\frac{dv_2}{dt}$ and

  $$v_1 = -R_o i_2 = R_o C\frac{dv_2}{dt} = R_o^2 C\frac{di_1}{dt}$$

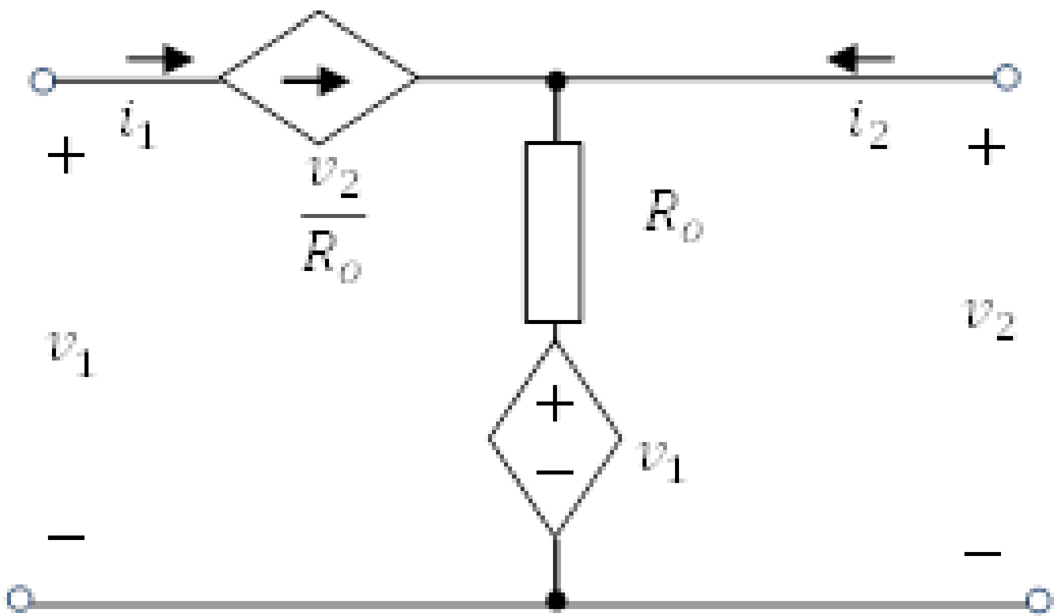
- At the gyrator input, the load appears as an inductor, of value $L_i = R_o^2 C$ henry
- Thus a capacitor termination is seen at the input as an inductor

→*inverting property of the gyrator*

- Repeat for other loads

Special 2-port devices – Gyrator[5]

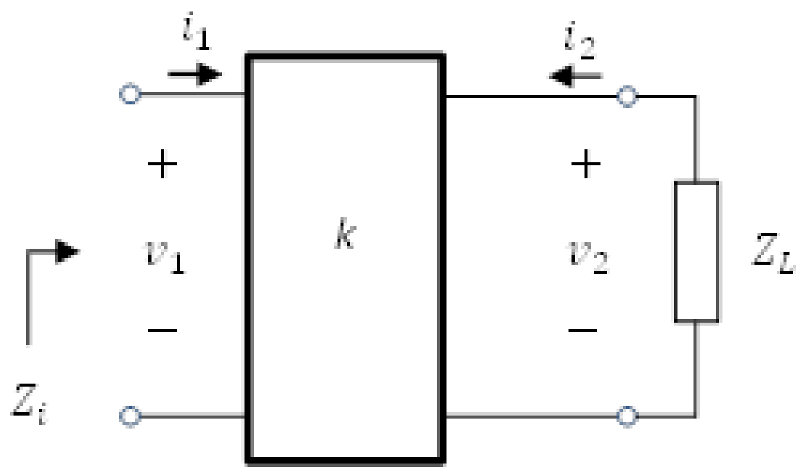
- Equivalent circuit of the gyrator



- KVL may be used to confirm the equivalence

Special 2-port devices – NIC[1]

- Negative Impedance Converter
- Another non-reciprocal device used in circuit and systems modeling
- Symbol



- Here: $Z_i = -kZ_L$, where *k* is the conversion ratio

Special 2-port devices – NIC[2]

- As before $v_2 = -i_2 Z_L$ and $Z_i = \frac{v_1}{i_1} = k\,\frac{v_2}{i_2}$
- Two possible cases for the equations to hold, resulting in two different types of NIC
- Case 1: $v_1 = -k_1 v_2$, $i_1 = \frac{-i_2}{k_2}$, and $k = k_1 k_2$
  - Voltage inversion type NIC (VNIC)results
- Case 2: $v_1 = k_1 v_2$, $i_1 = \frac{i_2}{k_2}$, and $k = k_1 k_2$
  - Current inversion type NIC (CNIC) results

Special 2-port devices – NIC[3]

- NIC can simulate inductance using C components due to the negative impedance
- A parallel RC load would appear as a series RL at the input of the device
- $Y_L = G + j\omega C$ and

$$Y_i = -\frac{1}{k} Y_L$$
$$= -\frac{1}{k}(G + j\omega C\ )$$

$$Z_i = \frac{-k}{G + j\omega C} = \frac{-k(G - j\omega C)}{G^2 + \omega^2 C^2} = \left[\frac{k}{G^2 + \omega^2 C^2}\right](-G + j\omega C)$$

- Series (negative) resistance and inductor of value $L_i = \frac{kC}{G^2+\omega^2 C^2}$ henry

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QUESTIONS?