Lecture2:
Circuit theory

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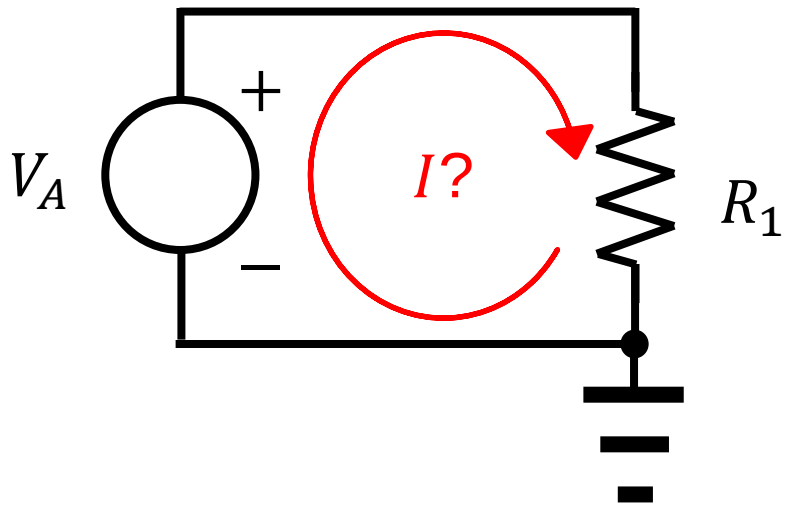
A simple problem

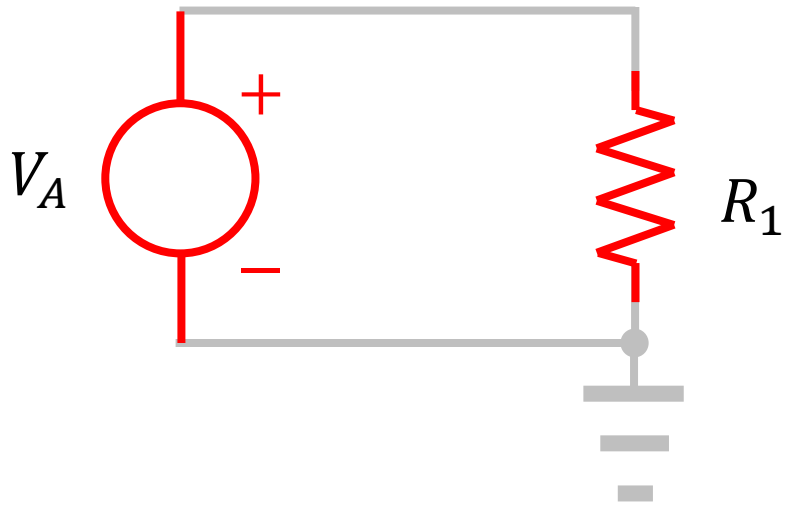
- Solve the problem.
  - What is the current?



  - It is an easy problem.

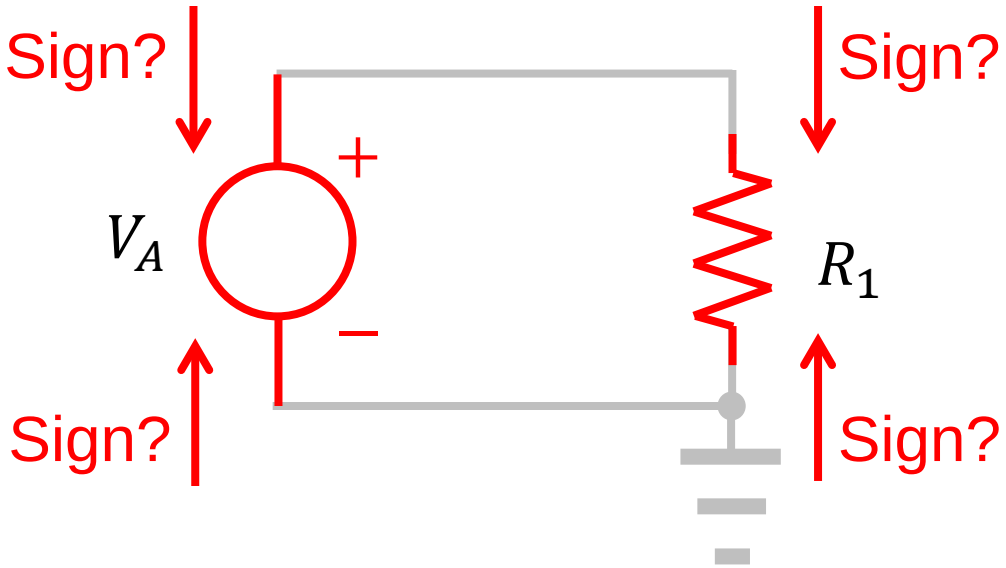
Elements

- Resistors, capacitors, etc
  - They can have multiple terminals.
  - A resistor has two terminals.
  - A diode has two terminals.
  - A MOSFET has three (or four) terminals.



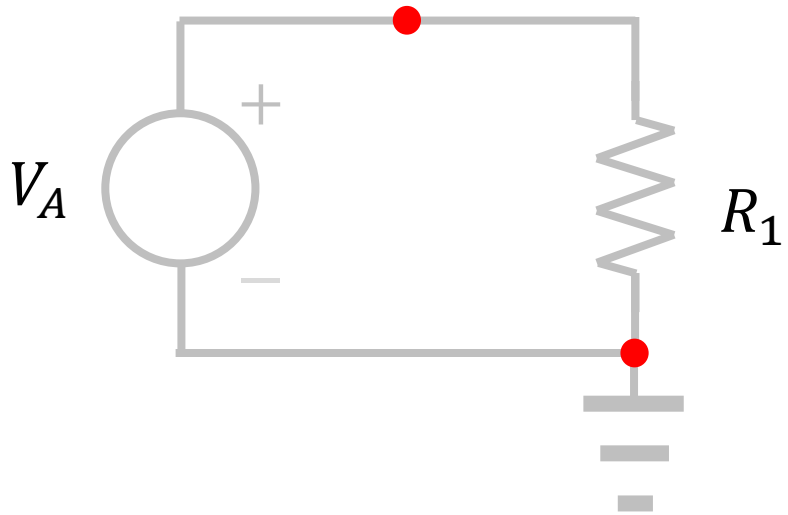
Convention for current

- Terminal current
  - Conventionally, an in-coming current is regarded as positive.



Nodes

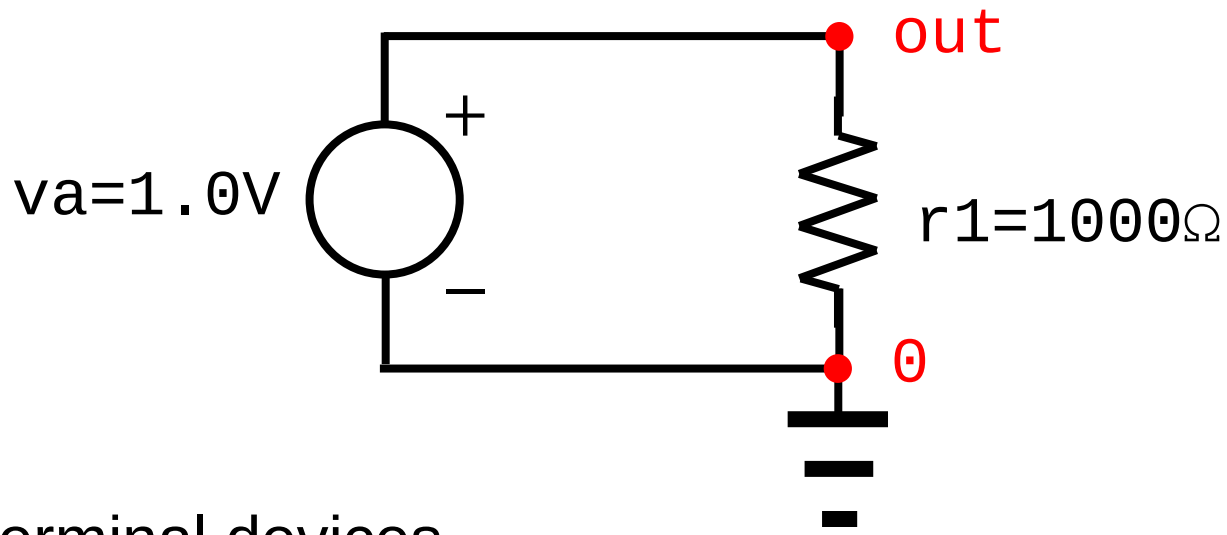
- A point to which multiple terminals are tied.
  - (Usually, a dot is used to represent a node.)
  - There is a special node, GND.



How to describe a circuit

- Of course, we can draw a circuit schematic. What else?
- A netlist for this circuit looks like:

```
va out 0 1.0
r1 out 0 1000
```



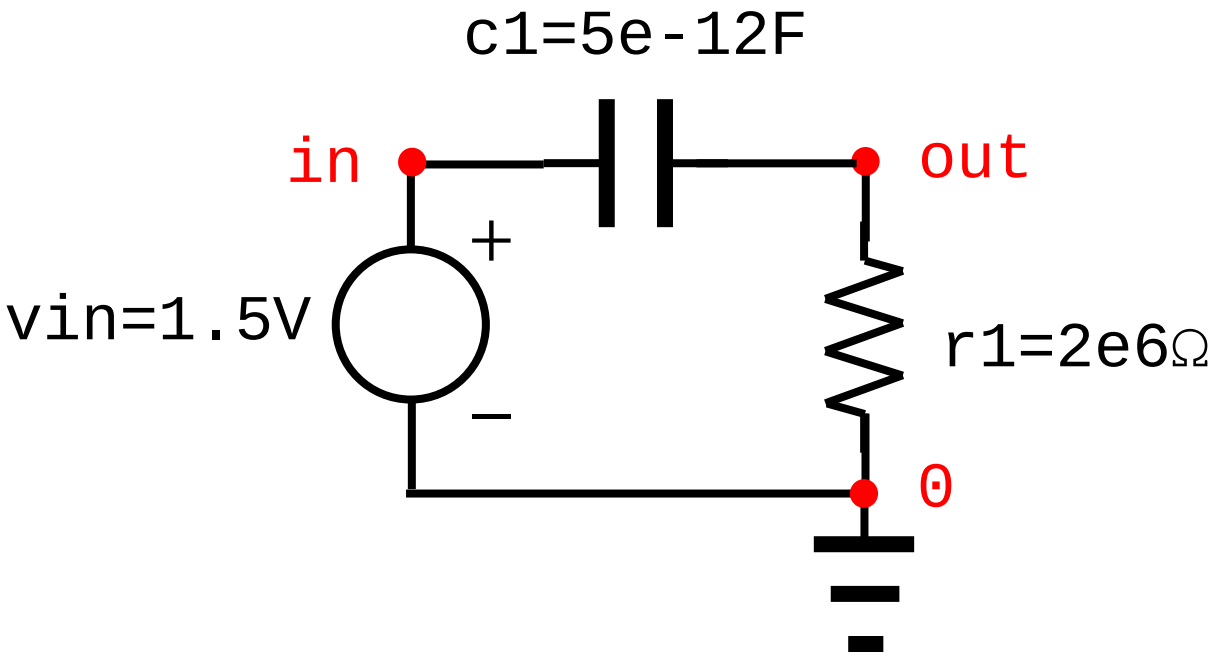
- Format for two-terminal devices

```
elementlabel node1 node2 value
```

RC filter

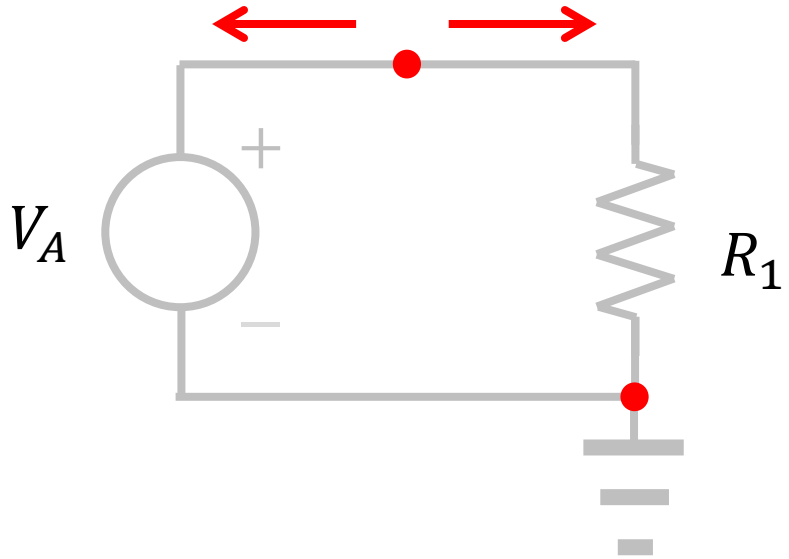
- A netlist for this circuit looks like:

```
c1 in out 5e-12
r1 out 0 2e6
vin in 0 1.5
```



Circuit analysis (1)

- The basic principle of circuit analysis is…
  - Kirchhoff's current law (KCL)!
  - At any node in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node.



Circuit analysis (2) – Optional

- Why do we have the KCL?
  - According to the Maxwell equations,
$$\nabla \cdot \mathbf{J}_{tot} = 0$$
  - Here, the total current density is a sum of the particle current density and the displacement current density:
$$\mathbf{J}_{tot} = \mathbf{J}_{particle} + \frac{\partial}{\partial t}\mathbf{D}$$
  - By integrating $\mathbf{J}_{tot}$ over a certain surface, we can calculate the current through that surface.
  - Integration over a certain volume, V, yields
$$\int_V (\nabla \cdot \mathbf{J}_{tot}) d\mathbf{r} = \oint_S \mathbf{J}_{tot} \cdot d\mathbf{a} = \sum_i I_i = 0$$
  - Here, S is the surface of V and I_i is a branch current.

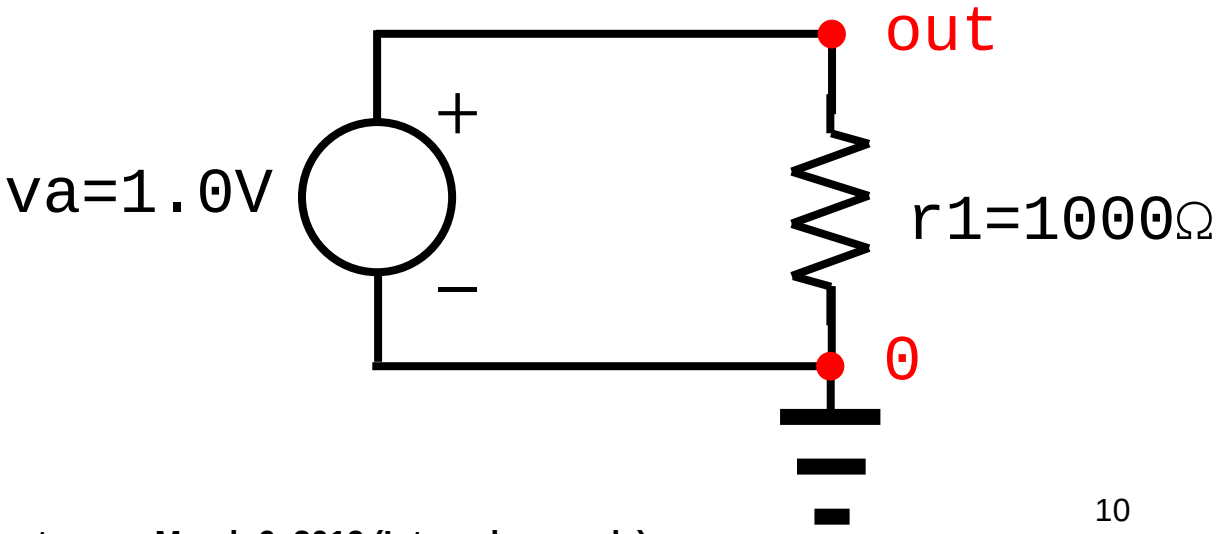
Circuit analysis (3)

- Our simple problem
  - Following equations are identified.

$I_{va} + I_{r1} = 0$ KCL

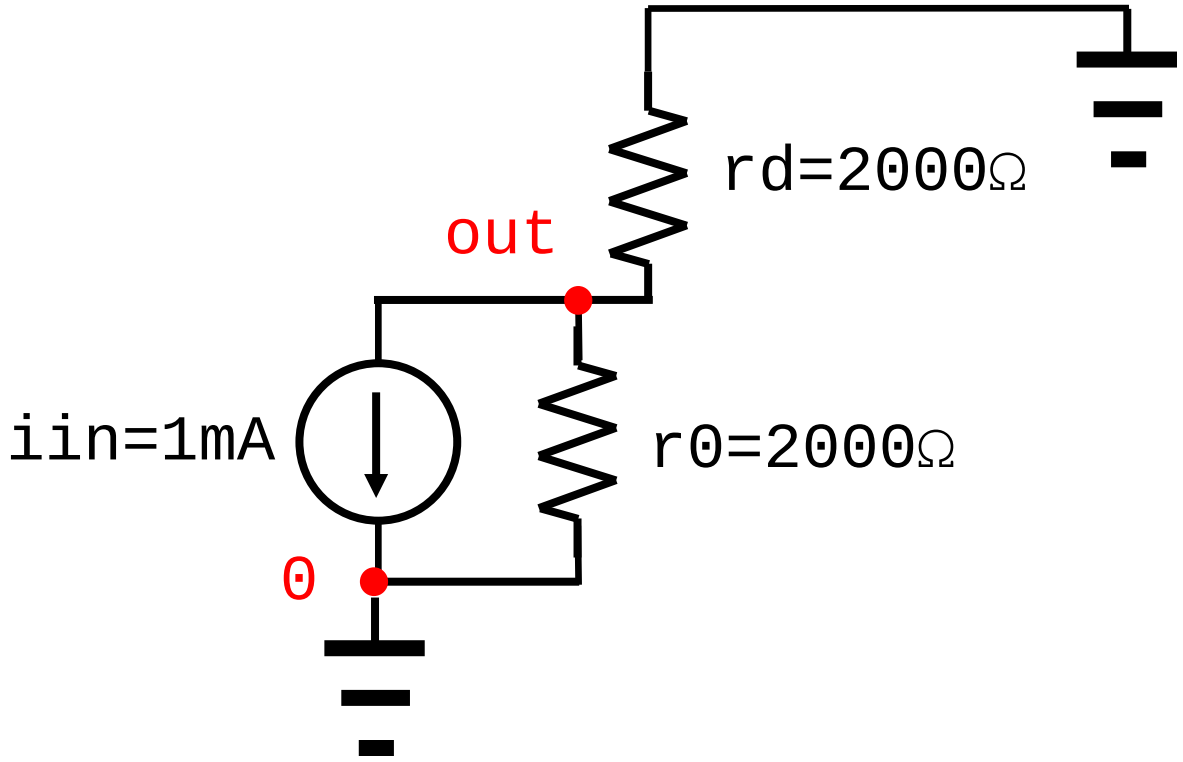
$V(out) - 0.0 = 1.0$ Voltage source

$I_{r1} = \frac{V(out)}{1000}$ Resistor



Circuit analysis (4)

- Our real-world example
  - Write a netlist.
  - Calculate the node voltage of `out`.



Homework#1

- Due: 09:00, March 11
  - Submit your Homework answer sheet (hardcopy) directly to Mr. Suhyeong Cha, our TA.
  - His office: EECS building C-411

- Draw a circuit schematic of the following netlist.

```
v1 batt 0 1.5
rchar batt anode 1e6
cchar anode 0 1e-9
rpcss anode cathode 21
rload cathode 0 50
```