

## 02.1 graphs.intro Introduction to linear graphs

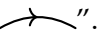
- 1 Engineers often use graphical techniques to aid in analysis and design. We will use **linear graphs** to represent the **topology** or structure of a system modeled as interconnected lumped elements.
- 2 This represents to us the essential structure of the system in a minimalist form. In this way, it is like Massimo Vignelli's famous 1972 New York

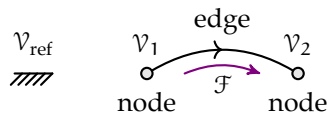


**Figure intro.1:** a modern New York subway map in the style of Vignelli (Jake Berman).

subway system “map,” which inspired widespread adoption of his style (see [Figure intro.1](#)).<sup>1</sup> Besides minimalism, the key idea in Vignelli subway maps is that the details of the tunnels’ paths are irrelevant and, in fact, distracting to the person attempting to get from one station to another.

**3** In a similar way, a linear graph represents the system in a minimalist style, with only two types of objects:

1. A set of **edges**, each of which represents an energy port associated with a system element. Each edge is drawn as an oriented line segment “”.
2. A set of **nodes**, each of which represents a point of interconnection among system elements. Each node is drawn as a dot “ $\circ$ ”.



**Figure intro.2:** an edge with nodes. The across variable is  $v = v_1 - v_2$ .

**4** All edges begin and end at nodes. The nodes represent locations in the system where distinct across-variable values may be measured. For example, wires that connect elements are actually *nodes* at which voltage may be measured. Putting an edge together with nodes, we have [Figure intro.2](#).

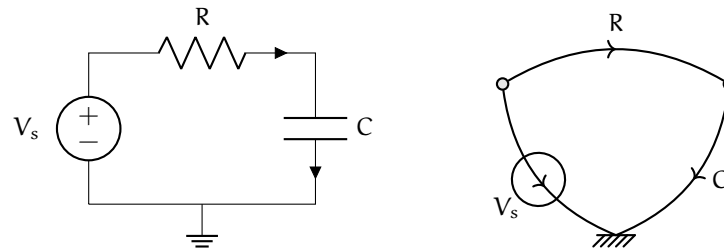
**5** It is important to note that linear graphs can represent **nonlinear** system elements—the name is a reference to the *lines* used.

**6** It is common to choose a node of the graph as the **reference node**, to which all across-variables are referenced. Due to its similarity to the electronic **ground**, we often use these terms interchangeably.

**7** [Figure intro.3](#) shows how a linear graph can be constructed for a simple RC-circuit. Note that the wires become nodes, the elements become edges, and the reference node represents the circuit ground. In a similar manner,

<sup>1</sup>Vignelli was a brilliant Minimalist designer of many products, from dishes to clothing, but he was most known for his graphic design. Great places to start studying Vignelli are the documentary *Design is One* (2012) and *The Vignelli Canon*.

we will construct linear graphs of circuits, mechanical translational systems, and mechanical rotational systems.



**Figure intro.3:** an example of a linear graph representation of an RC-circuit.