ss.graph2nt Normal trees

1 Before we introduce the algorithm for constructing the state-space model in Lecture ss.nt2ss, we introduce the first step from the system graph to the state-space model: the normal tree. It is a subgraph of the system's linear graph.

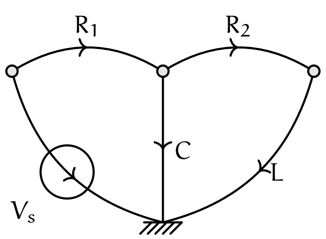
normal tree
subgraph

2 In the following, we will consider a connected graph with E edges, of which S are sources. There are $2E - S$ unknown across- and through-variables, so that's how many equations we need. We have $E - S$ elemental equations and for the rest we will write continuity and compatibility equations. N is the number of nodes.

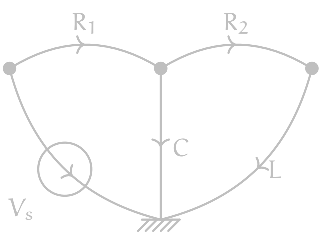
3 The following rules must be respected.

R1. There can be no loops.
R2. Every node must be connected.

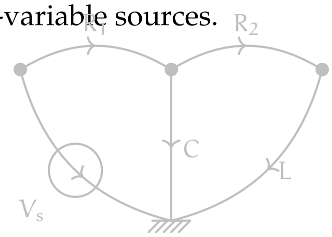
Form a normal tree with the following steps. For an inline example, we will construct a normal tree from the linear graph for an electronic system, shown at right.



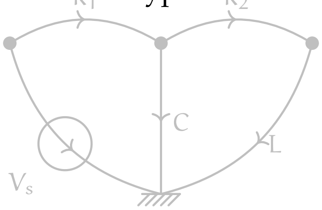
1. Include all nodes.



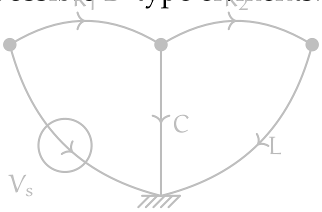
2. Include all across-variable sources.



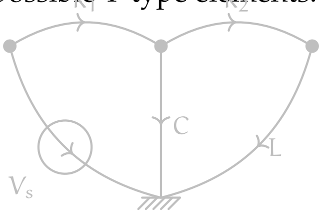
3. Select as many as possible A-type elements.



4. Select as many as possible D-type elements.



5. Select as many as possible T-type elements.



4 We call those edges in the normal tree its branches and those not, the links.

branches
links

5 A-type elements not in and T-type elements in the normal tree are called dependent energy storage elements. All other A- and T-types are independent energy storage elements. The energy in these can be independently controlled.

dependent energy storage elements
independent energy storage elements

6 In order to avoid an artificial excess in state variables and construct what is called a controllable model, whenever A-types in series (sharing one node) or T-types in parallel (sharing two nodes) appear, we should combine them to form equivalent elements in accordance with the formulas

controllable
A−types in series
T−types in parallel

$$C_e = \frac{1}{\sum_i 1/C_i} \quad \text{or} \tag{1a}$$

$$L_e = \frac{1}{\sum_i 1/L_i}. \tag{1b}$$

7 There are special names for power-flow variables associated with an element, depending on whether the element is a branch or link. Primary variables are: across-variables on branches and through-variables on links.

Primary variables

Secondary variables are: through-variables on branches and across-variables on links.

Secondary variables