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DOMAIN-INDEPENDENT DESCRIPTION FORMS

In this section approaches will be described that cannot be classed as an expansion of the tools in a certain domain. The most important representatives here are bond graphs, block diagrams and modelling languages such as Modelica, Dymola or ACSL.

Bond graphs

In the analogies, currents were generally identified with forces/moments and voltages with velocities, so that an analogy in the form of an equivalent circuit has the same structure as the original system. This is true because according to Kirchhoff's laws, currents and forces add up to zero at a node and voltages and relative velocities add up to zero in a closed loop.

By contrast, in the bond graphs, the following classifications are made. Voltages are normally associated with forces/moments and called effort, currents are associated with velocities/angular velocities and called flow. The elements used in the bond graph approach can be divided into one, two and three-port networks. The one-port networks are the so-called C, I and R elements, which in electronics correspond with capacitors, inductors and resistors and in mechanics correspond with springs, masses and dampers, see Table 3.2. In addition there are sources for effort and flow. Transmission elements and gyrators are defined as two-port networks. The former transmit effort to effort or flow to flow in a fixed or variable relationship to one another; the latter put the effort, on the one hand, into a relationship with the flow, on the other (and vice versa). Transmission elements can thus be transformers, gears or levers for small deflections. A gyrator could for example describe a DC motor. The three-port networks finally represent serial or parallel junctions (s-junction, p-junction). The one, two and three-port networks are linked together by half arrows, so-called bonds, which each bear an effort and a flow. The direction of the arrow shows the direction of the positive power flow. The work done is found by the product of effort and flow. In addition to the half arrows of the bonds there are also connections with a full arrow, in which either the effort or the flow is neglected. These connections carry information, but no energy.

The calculation of bond graphs first of all requires the drawing up of a suitable system of equations, which is generally explicitly formulated. This means that the

Table 3.2 Assignment of magnitudes and elements in bond graphs

Bond graphs	Electronics	Mechanics, translational	Mechanics, rotational
Effort	Voltage	Force	Torque
Flow	Current	Velocity	Angular velocity
C element	Capacitor	Spring stiffness	Torsional spring stiffness
I element	Inductor	Mass inertia	Moment of inertia
R element	Resistor	Damping, translational	Damping, rotational
Transmission element	Transformer	Lever, pulley block	Gears

Block diagrams

Block diagrams are often used in control technology and, like bond graphs, represent a form of structural modelling, see Cellier [62]. However, this type of representation primarily shows the structure of equations, whereas the structure of the system tends to be found indirectly from the structure of the equation system. Block diagrams include blocks and directional connections between the blocks.

These connections describe signals, which are converted into other signals by the blocks. In addition there are taps and summing points, so that the important elements of block diagrams can be fully represented in Figure 3.8.

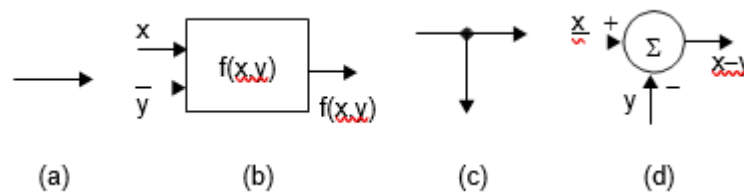
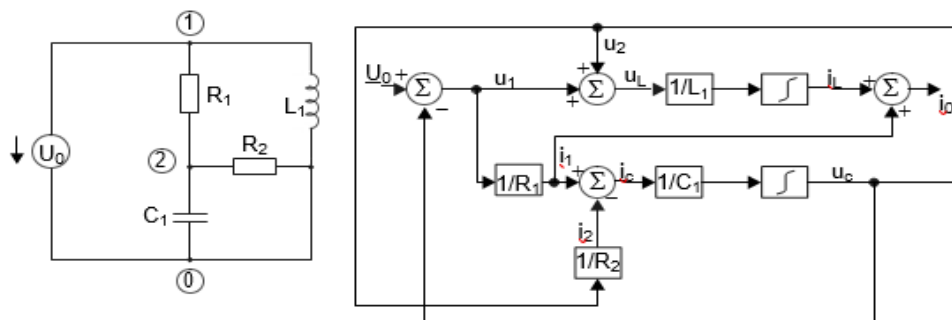


Figure 3.8 Basic elements of block diagrams: Connection (a), block (b), tap (c) and summer (d)



Block diagram of an electronic circuit

Evaluation of domain-independent description forms

From the examples shown above it is clear that bond graphs can describe both analogue electronics and mechanics (and also a range of further domains) in compact and graphic form. However, if we go beyond unidimensional mechanics and passive electronics there are significant problems to be solved. Although the modelling of transistors is also possible in principle using bond graphs, a meaningful simulation of circuits of substantial complexity remains the exclusive preserve of a dedicated circuit simulator. The same applies for three-dimensional multibody mechanics. Moreover, bond graphs are in principle limited to continuous systems, so that digital electronics and software cannot be illustrated using classical bond graphs, or at least this cannot be done efficiently. Furthermore, every element must be assigned a fixed causality prior to the simulation. This causality may alter during a simulation, for example, if an electric motor becomes a generator, so that such systems cannot be simply investigated using bond graphs. The same applies in principle for block diagrams.