STATE EQUATION DERIVATION

Summary of Basic Bond Graph Elements

A large class of physical systems may be described using the basic lumped parameter elements — ideal active and passive one-port elements connected by multiport junction elements. The variables and primitive elements of the energy-based formalism are summarized in the following tables.

Table 6.1 Fundamental variables

Energy and power:	$E - E_o = \int P \ dt$
Conjugate power variables:	$P = e\ f$
Conjugate energy variables:	$p - p_o = \int e \ dt$ $q - q_o = \int f \ dt$

Table 6.2 Active one-port elements (sources or boundary elements)

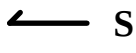
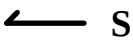
	effort source	flow source
constitutive equation	$e = e(t)$	$f = f(t)$
bond graph symbol		

Table 6.3 Passive one-port element constitutive equations

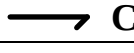
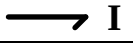
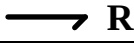
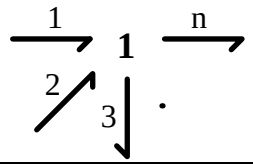
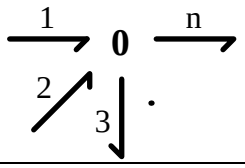
	capacitor	inertia	resistor
general form	$e = \Phi(q)$	$f = \Psi(p)$	$e = \Gamma(f)$
linear form	$e = q/C$	$f = p/I$	$e = Rf$
bond graph symbol			

Table 6.4 Symmetric multi-port junction elements

	common flow junction	common effort junction
constitutive equations	$f_i = f_j$, j = 1,n $\sum_{j=1}^{n} \sigma_j e_j = 0$	$e_i = e_j$, j = 1,n $\sum_{j=1}^{n} \sigma_j f_j = 0$
bond graph symbol		

where $\sigma_j = \begin{cases} +1 \text{ if power positive in} \\ -1 \text{ if power positive out} \end{cases}$

Table 6.5 Asymmetric two-port junction elements

	transformer	gyrator
constitutive equations	$e_i = T\, e_j$ $f_j = T\, f_i$	$e_i = G\, f_j$ $e_j = G\, f_i$
bond graph symbol		

Sign Convention

Half arrows denote the direction of positive power flow. For passive elements *power flow is positive inwards*. For active elements there is no fixed convention, though it is common to denote power flow as positive outwards. Multiport junction elements may serve to define effort or flow differences (e.g. pressure difference, relative motion). In that case the following sign convention is recommended.