Defining a system symbolically.

```
syms s K;
gain = K;
feedback = 1;
plant = 1/(s*(s+1)*(s+2));      % Open-loop.
sys = gain * plant + feedback; % Closed-loop.
```

Characteristic equation representation of the system.

```
coeffs = ELAB.sd2ce(sys, true);
```

```
Original expression:
```

$$\frac{K}{s\ (s+1)\ (s+2)}+1$$

```
Expanded form:
```

$$\frac{K}{s^3+3\,s^2+2\,s}+1$$

```
Set equal to 0, then simplify:
```

$$s^3+3\,s^2+2\,s+K$$

```
Collect terms of equal power:
```

$$s^3+3\,s^2+2\,s+K$$

Routh array for stability analysis.

```
RA = ELAB.routh(coeffs, true);
```

```
Routh Array
```

$$\begin{pmatrix} 1 & 2 \\ 3 & K \\ 2-\frac{K}{3} & 0 \\ K & 0 \end{pmatrix}$$

Critical points, where system transitions between stable and unstable.

```
ELAB.critical(RA,true);
```

```
Solving equations for param:
```

$$2-\frac{K}{3}=0$$

$$K=0$$

```
For stability, param (K) = ]6;0[

From s^2 auxiliary equation:
```

$$\begin{pmatrix} 3\,s^2+6=0 & 3\,s^2=0 \end{pmatrix}$$

```
Solved for s:
```

$$\begin{pmatrix} -\sqrt{2}\ \mathrm{i} & 0 \\ \sqrt{2}\ \mathrm{i} & 0 \end{pmatrix}$$

Breakaway points for root locus plot.

```
ELAB.breakaway(sys, gain, true);
```

```
Solving closed-loop for gain:
```

$$K = -s\ (s+1)\ (s+2)$$

```
Expanding expression:
```

$$K = -s^3 - 3\,s^2 - 2\,s$$

```
Derivative of gain of s:
```

$$-3\,s^2 - 6\,s - 2$$

```
Solving diff(gain) = 0 for s:
```

$$\left(s = -\frac{\sqrt{3}}{3} - 1 \quad s = \frac{\sqrt{3}}{3} - 1 \right)$$

```
Sub s in 1st equation, solving for gain.
Breakaway points [s, gain]:
   -1.5774   -0.3849
   -0.4226    0.3849
```

```
plant = ELAB.sd2tf(plant); % Convert symbolic to tf-object for rlocus.
rlocus(plant);
```