



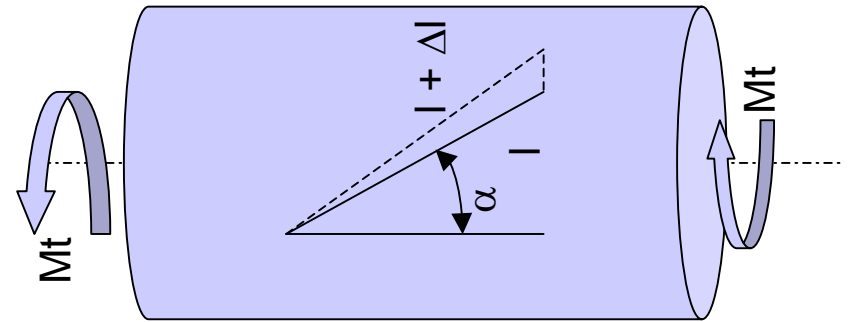
Grundlagen für DMS

Die mechanische Spannung an der Wellenoberfläche

Für die Dehnung gilt:

$$\varepsilon = \frac{\Delta l}{l} = \frac{8 \cdot Mt}{\pi \cdot G \cdot d^3} \cdot \sin 2\alpha$$

Unter $\alpha = 45^\circ$ hat ε größten Wert



Für die mechanische Spannung gilt:

$$\tau_{\max} = \frac{16 \cdot Mt}{\pi \cdot d^3}$$

Mt = Drehmoment
 d = Wellendurchmesser
 G = Schubmodul

Umwandlung der mechanischen Dehnungen in ein elektrisches Signal

$$K = \frac{\Delta R / R}{\Delta l / l} = \tan \beta \approx 2$$

Damit folgt:

$$\frac{\Delta R}{R} = K \cdot \varepsilon = K \cdot \frac{8 \cdot Mt}{\pi \cdot G \cdot d^3}$$

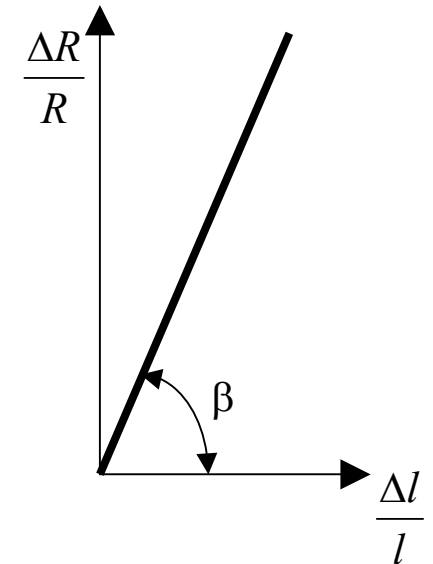
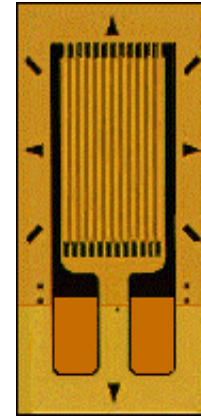
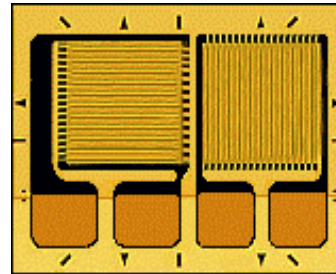


Diagramm von Kelvin

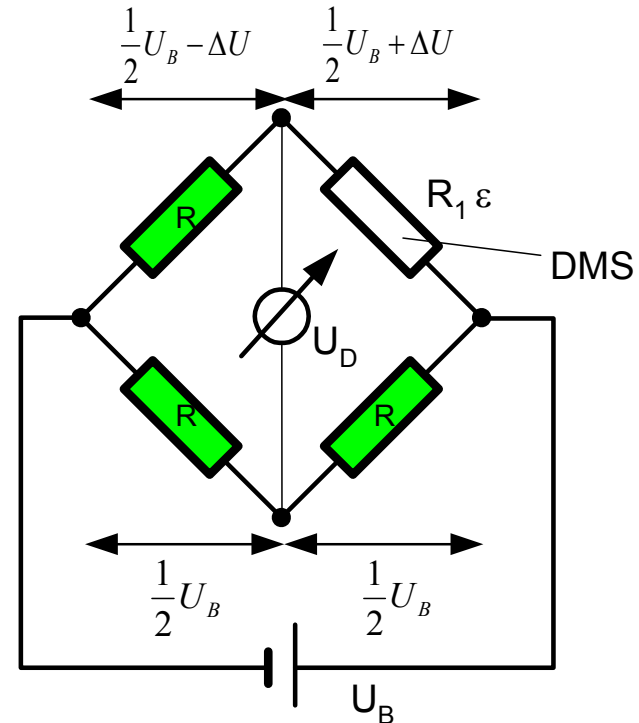
Im Sensorbau verwendete DMS



Weatston'sche Brückenschaltung Viertelbrücke

$$U_D = \frac{1}{2} \cdot U_B \cdot \varepsilon$$

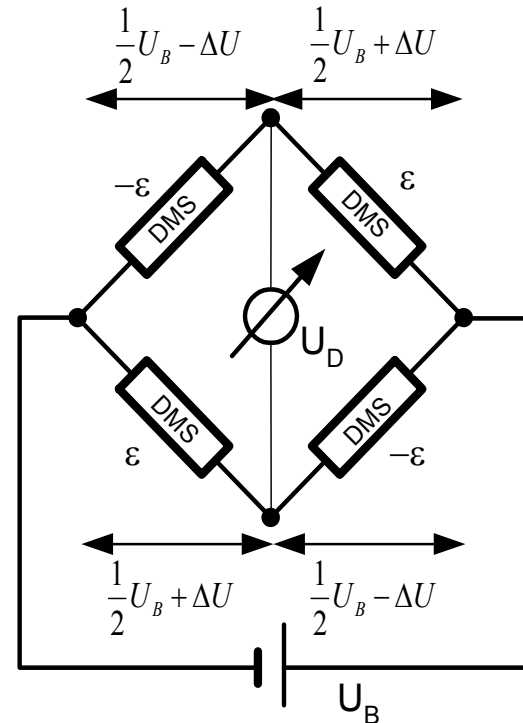
ε in mm/m



Weatston'sche Brückenschaltung Vollbrücke

$$U_D = 2 \cdot U_B \cdot \varepsilon$$

ε in mm/m





Beispiel für Vollbrücke

$$\varepsilon = 1 \frac{\text{mm}}{\text{m}} = 10^{-3}$$

Für die Vollbrücke gilt

$$U_D = 2 \cdot U_B \cdot \varepsilon$$

Für die Empfindlichkeit gilt

$$e_0 = \frac{U_D}{U_B} = 2 \cdot \varepsilon = 2 \cdot 10^{-3} = 2 \frac{\text{mV}}{\text{V}}$$

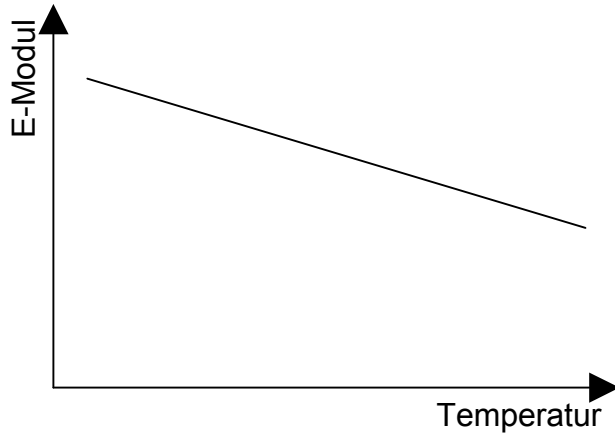
Bei $U_B = 10\text{V}$

$$U_D = U_B \cdot e_0 = 2 \cdot 10^{-3} \cdot 10\text{V} = 20 \cdot 10^{-3}\text{V}$$

$$U_D = 20\text{mV}$$

$$\frac{U_D}{U_B} = \frac{20\text{mV}}{10\text{V}} = 2 \frac{\text{mV}}{\text{V}}$$

E-Modul von Werkstoffen



E-Modul nimmt ab mit zunehmender Temperatur

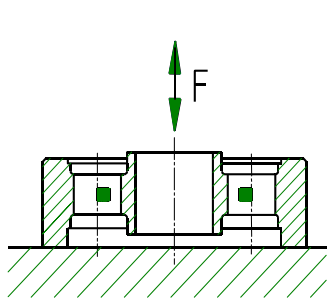
Stahl: $\frac{\Delta E}{100K} \approx (2 - 4\%) \cdot E$

Aluminium: $\frac{\Delta E}{100K} \approx (7\%) \cdot E$

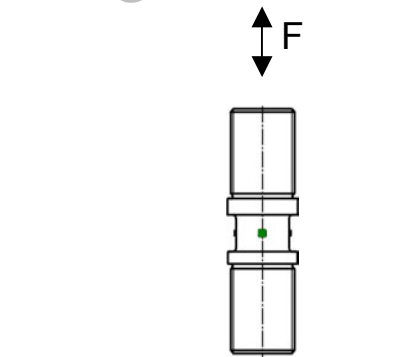
$$\varepsilon \sim \frac{K}{E} \Rightarrow E - \text{Moduländerung geht Messsignal ein}$$

Schwingungen von Kraftsensoren

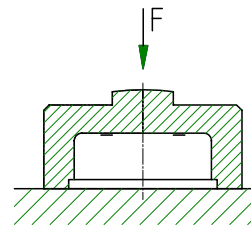
Steifigkeit von Kraftsensoren



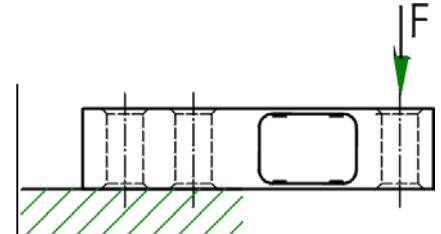
Scherkraft



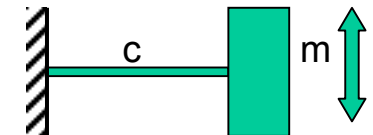
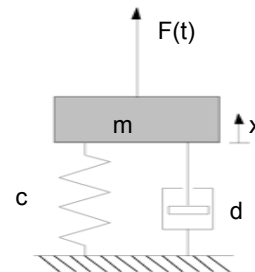
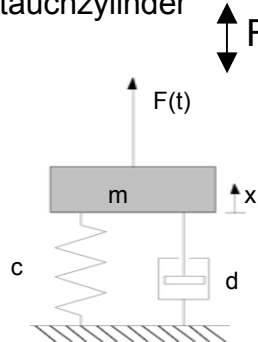
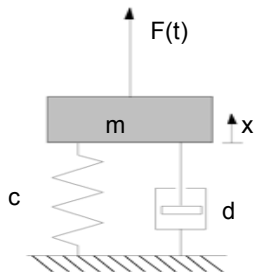
Stauchzylinder



Membrane



Biegebalken



Berechnungsformel

$$f = \frac{1}{2\pi} \sqrt{\frac{1000 \cdot c}{m}}$$

f = Eigenresonanz
c = Federkonstante in N/mm
m = Masse in kg

Steifigkeit von Scherkraftaufnehmer

Project Name: Shear Beam 0 to 10 kN		Date: 28-Jun-95	
Description: Example		ID: 14	
INPUT VARIABLES		SUGGESTED DEFAULT VALUES	
Material:	Stainless Steel 17-4PH (1.4548)	E:	2,00E+11 Pa
Load Range:	10,00 kN	v:	0,291
F= 10.000,00 N		Bridge Configuration 4 Active Gages <input checked="" type="checkbox"/> 2 Active Gages <input type="checkbox"/> 1 Active Gage <input type="checkbox"/>	
		Gage Factor: 2,00 Output-Signal: 2,3 mV/V Average ε: 1.150,00 μm/m	
The dimension "w" should as a rule of thumb be smaller than h / 8. This calculation can only give approximate value for the shear web thickness. Tests are needed to find the exact value.		Check-it! $t = \frac{1,36 * F * (1 + \nu)}{E * h * \epsilon}$	
All fields with yellow background must be filled in. Dimensions to be in millimeter (mm).			
Select a strain gage from list			
Strain Gage:	FAED-12B-35-SXE-J	Quantity:	2
Alternative:	FAED-06A-35-SXE-M	Quantity:	2

Übliche Werte für Durchbiegung: $y = 0,01$ bis $0,1$ mm

$$y = 1,15(\text{mm/m}) \times 20\text{mm} = 23\mu\text{m}$$

$$c = 10000\text{N} / 0,023\text{mm} = 4,3 \times 10^5 \text{N/mm}$$

Steifigkeit von Stauchzylinder

INPUT VARIABLES		SUGGESTED DEFAULT VALUES	
Material:	Stainless Steel 17-4PH (1.4548)	E:	2,00E+11 Pa
Load Range:	10.000,00 N	v:	0,291
<p>F= 10.000,00 N</p> <p>For square cross-section the width is: <input type="text" value="8,03"/></p> <p>For rectangular cross-section enter the width. <input type="text" value="10,00"/></p> <p><input type="text" value="6,46"/> <input type="text" value="10,00"/></p>		<p>Strain ?</p> <p><input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/></p> <p>For solid shaft enter diameter ϕ <input type="text" value="0"/></p>	
<p>The column should be made long enough so that a uniform strain field is established at the gage locations. As a rule of thumb the column should be 5 times as long as the widest cross sectional dimension.</p>		<p>Check-it! $A = \frac{F}{E \cdot \epsilon}$</p> <p>Cross Sectional Area (A): <input type="text" value="64,550"/> mm²</p> <p>ϵ transversal <input type="text" value="225"/> $\mu\text{m/m}$</p> <p>Longitudinal deflection for a given basis length:</p> <p><input type="text" value="100,00"/> L: <input type="text" value="0,08"/> Delta-L: mm</p>	
<p>Select a strain gage from list</p> <p>Strain Gage: FAET-A6194N-35-SXE <input type="text"/> Quantity: <input type="text" value="2"/></p> <p>Alternative: FAE-12S-35-SXE-J <input type="text"/> Quantity: <input type="text"/></p>			

Übliche Werte für Durchbiegung: $y = 0,01$ bis $0,1\text{mm}$

$$c = 10000\text{N}/0,08\text{mm} = 1,25 \times 10^5 \text{N/mm}$$

Steifigkeit von Membrankraftaufnehmer

Übliche Werte für Durchbiegung: $y = 0,1$ bis $0,3\text{mm}$

$$F = 1000\text{N}$$

$$y = 0,1\text{mm}$$

$$c = 1000\text{N}/0,1\text{mm} = 1 \times 10^4\text{N/mm}$$

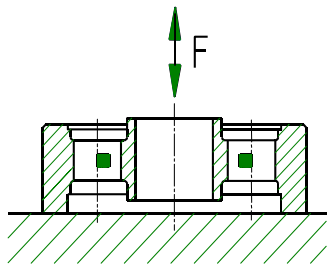
Steifigkeit von Doppelbiegebalken

INPUT VARIABLES		SUGGESTED DEFAULT VALUES	
Material:	Stainless Steel 17-4PH (1.4548)	E:	2,00E+11 Pa
Load Range:	100,00 N	v:	0,291
F= 100,00 N		Bridge Configuration 4 Active Gages <input checked="" type="checkbox"/> 2 Active Gages <input type="checkbox"/> 1 Active Gage <input type="checkbox"/>	
		Gage Factor: 2,00 Output-Signal: 2,2 mV/V Average ε: 1.100,00 μm/m	
Grid center line: 25,00 33,00 10,00		Check-it! $t = \sqrt{\frac{1,4 * F * l_1}{E * \epsilon * W}}$ $Y = \frac{F * l_2^3}{2 * E * W * t^3}$	
Deflection[Y]: 0,45 mm		Select a strain gage from list	
All fields with yellow background must be filled in. Dimensions to be in millimeter (mm).		Strain Gage:	FAE2-A6174J-35-SXE
		Quantity:	2
		Alternative:	FAE-12S-35-SXE-J
		Quantity:	

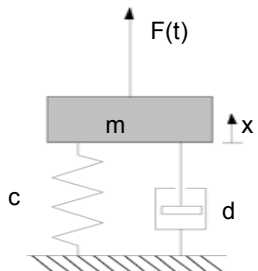
Übliche Werte für Durchbiegung: $y = 0,5$ bis 1 mm

$$c = 100\text{ N} / 0,45\text{ mm} = 2,2 \times 10^3 \text{ N/mm}$$

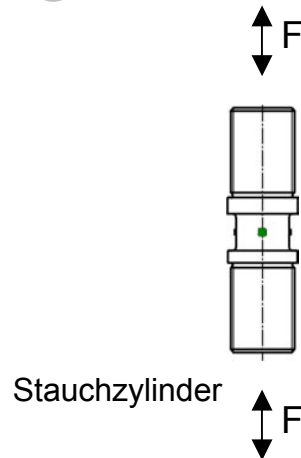
Eigenresonanz bei $m = 1\text{kg}$



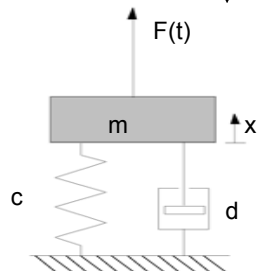
Scherkraft



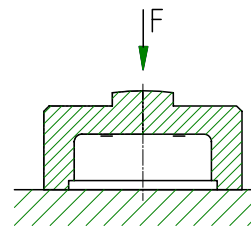
$m = 1\text{ kg}$
 $c = 4,3 \times 10^5 \text{ N/mm}$
 $f = 3280\text{ Hz}$



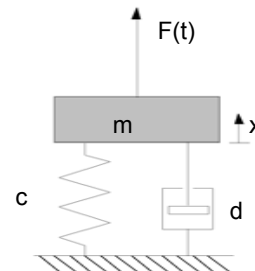
Stauchzylinder



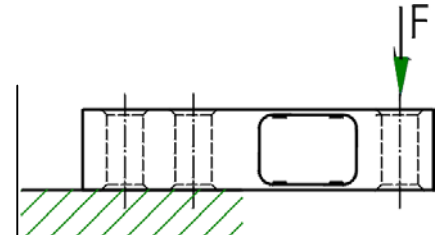
$m = 1\text{ kg}$
 $c = 1,25 \times 10^5 \text{ N/mm}$
 $f = 1768\text{ Hz}$



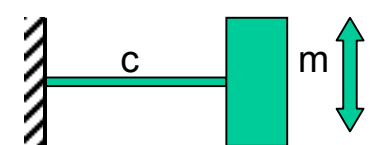
Membrane



$m = 1\text{ kg}$
 $c = 1 \times 10^4 \text{ N/mm}$
 $f = 500\text{ Hz}$

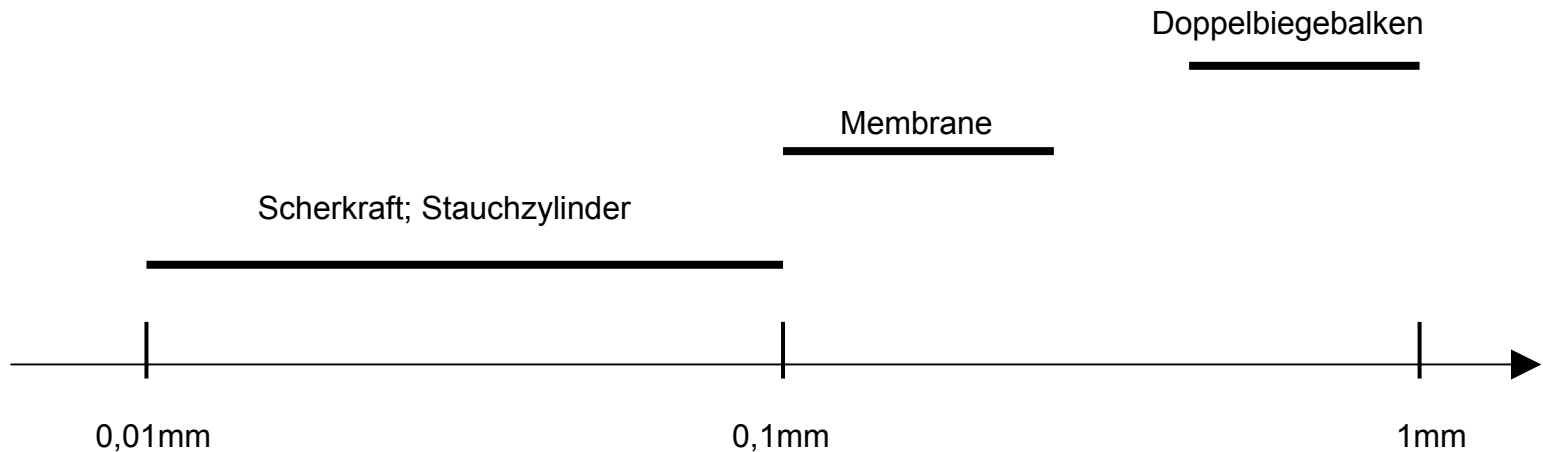


Biegebalken

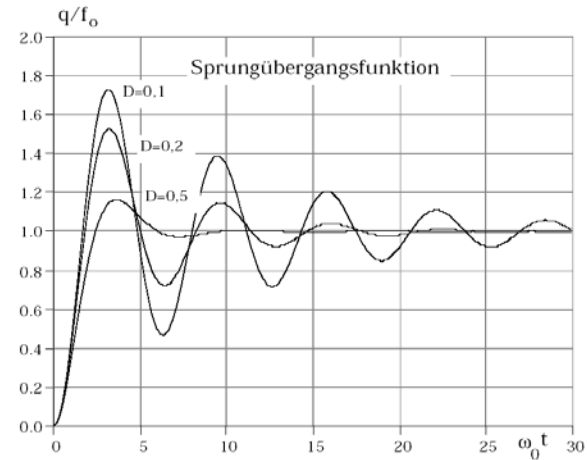
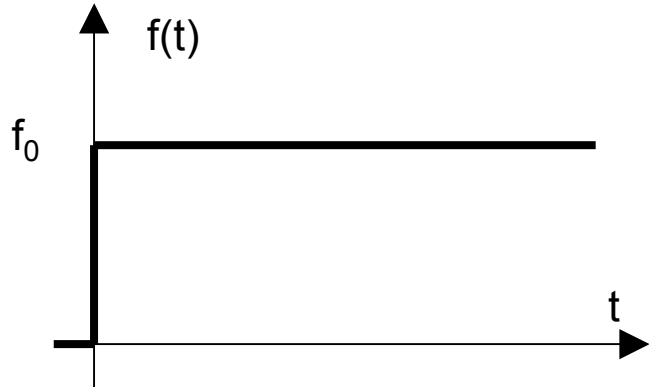


$m = 1\text{ kg}$
 $c = 2,2 \times 10^3 \text{ N/mm}$
 $f = 235\text{ Hz}$

Durchbiegung bzw. Messweg der Sensoren

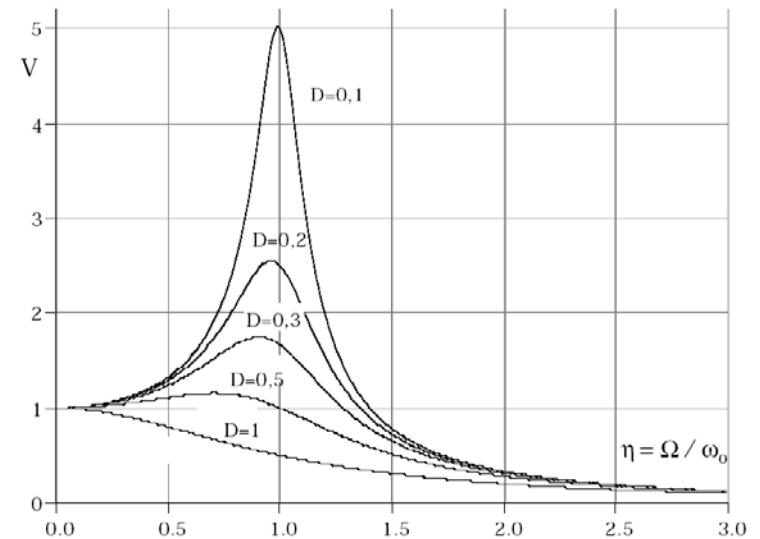
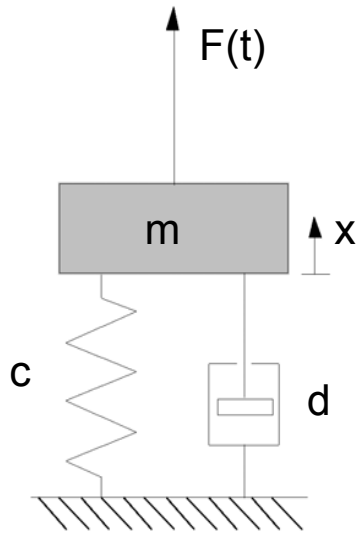


Die Sprungfunktion



Maximale Sprungantwort:
2x Sprunghöhe
abhängig von der Dämpfung

Die Eigenresonanz



Amplitude je nach Dämpfung 5 - 10x Eingangsamplitude

Anregung der Eigenschwingung

