

# Variable Stiffness Actuators: the user's point of view.

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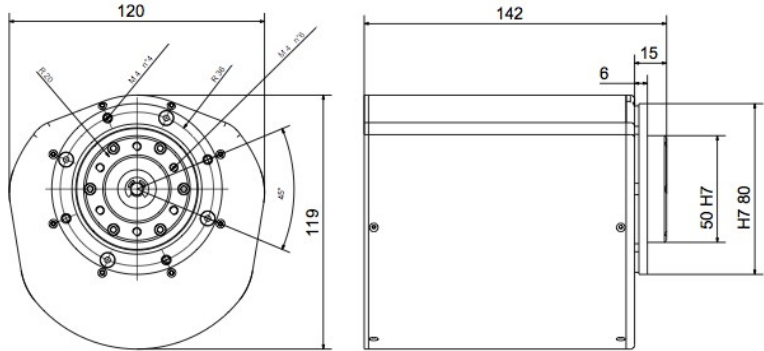
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“VSA - HD datasheet”

Multimedia Extension #5

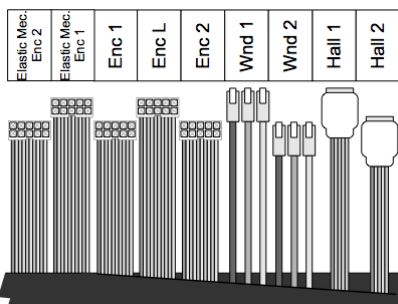
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# VSA - HD

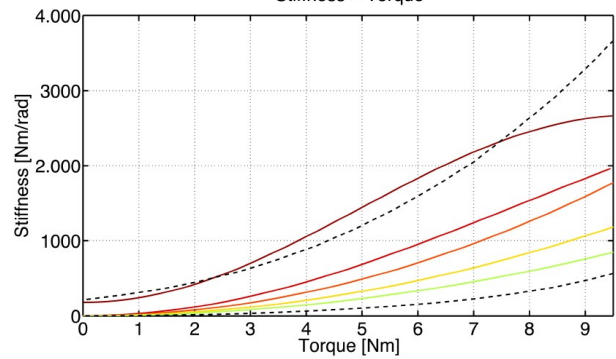


## Operating Data

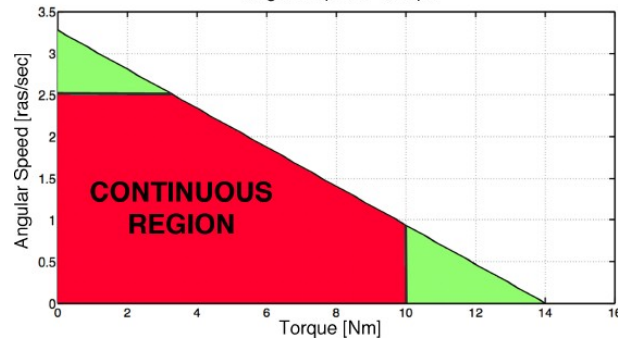
#	(quantity)	(unit)	(value)
Mechanical			
1	Continuous Output Power		[W] 25
2	Nominal Torque		[Nm] 10
3	Nominal Speed		[rad/s] 2.5
4	Nominal Stiffness Variation Time	with no load	[s] 0.4
5		with nominal torque	[s]
6	Peak (Maximum) Torque		[Nm] 14
7	Maximum Speed		[rad/s] 3.2
8	Maximum Stiffness		[Nm/rad] 8360
9	Minimum Stiffness		[Nm/rad] 0.38
10	Maximum Elastic Energy		[J] 0.12
11	Maximum Hysteresis		[°] 3
12	Maximum deflection	with max. stiffness	[°] 0.8
13		with min. stiffness	[°] 60
14	Active Rotation Angle		[°] ∞
15	Angular Resolution		[°] 0.18
16	Weight		[Kg] 1.7
Electrical			
17	Nominal Voltage		[V] 24
18	Nominal Current		[A] 1.3
19	Maximum Current		[A] 2.8
Control			
20	Voltage Supply		[V] 30
21	Nominal Current		[A] 0.25
22	I/O protocol		[] CAN



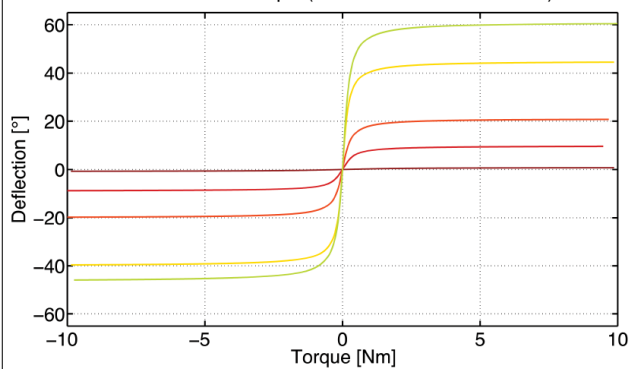
Stiffness - Torque



Angular Speed - Torque

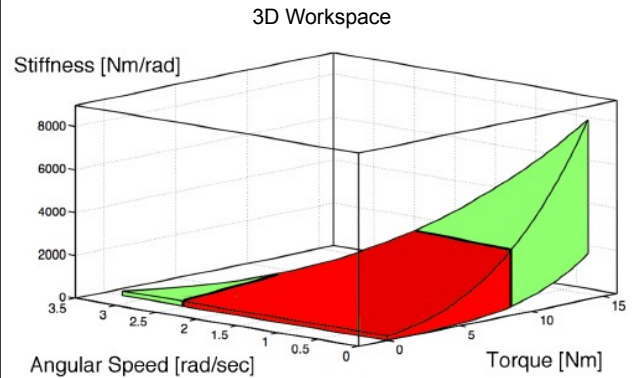
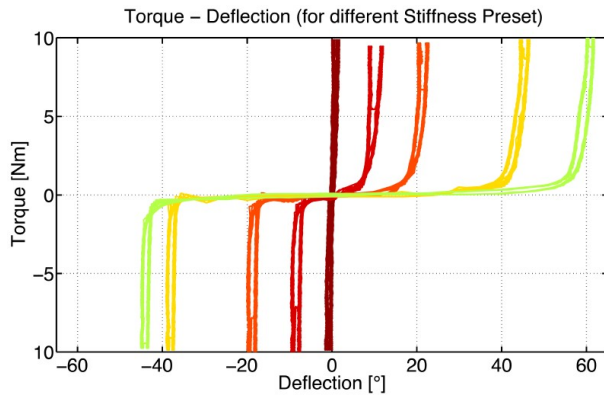


Deflection - Torque (for different Stiffness Preset)



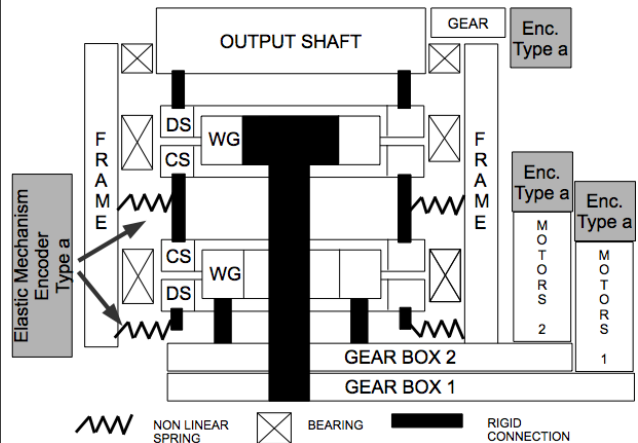
# VSA - HD

## Additional Characteristics



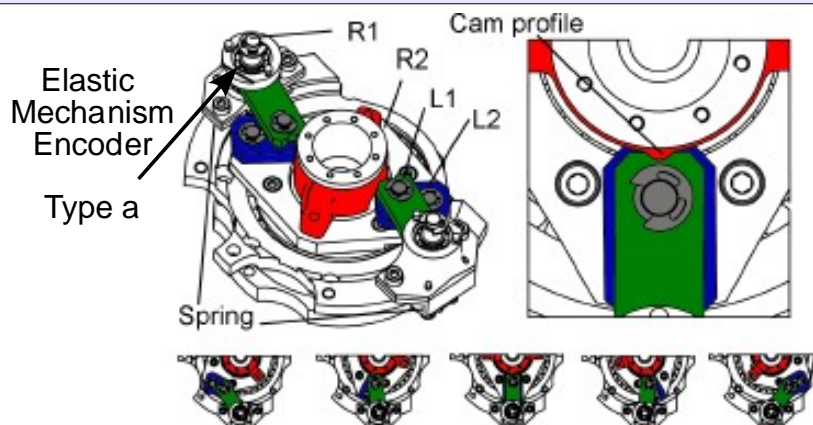
## Sensor Map

Additional sensors data			
#	(quantity)	(unit)	(value)
a0	Sensor a		
a1	Resolution	[°]	0.18
a2	Range	[°]	∞
a3	I/O protocol		Digital
ax	Voltage Supply	[V]	5

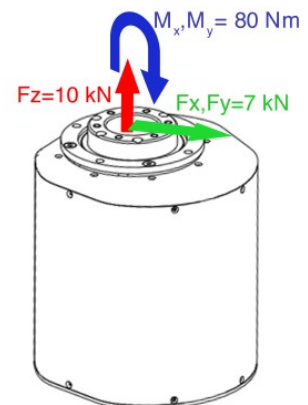


## Mechanical Details

### Non linear mechanism and cam profile

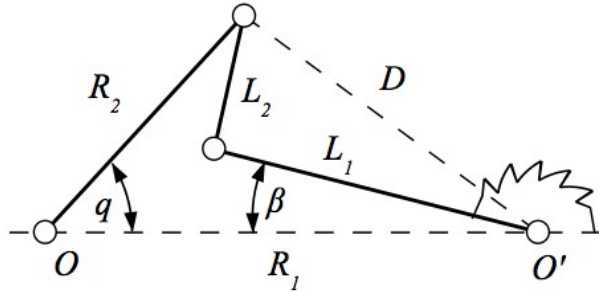
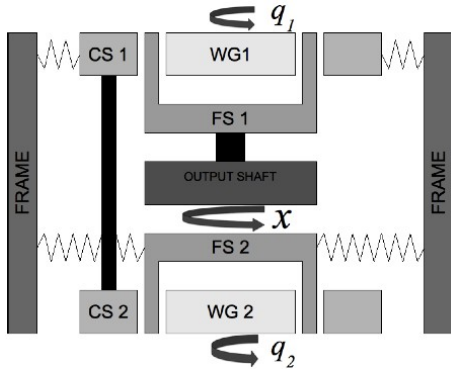


## Structural Load



# VSA - HD

## Model



## Mathematical model

101	Recoil Point Function	$q_L = \frac{1}{100} \left( q_1 - \frac{1}{2} q_2 \right)$
102	Energy Function	$H(q, x) = 0.03 \left( 0.0649 + 3,21 \cdot 10^{-13} C_4^6 - 4,74 \cdot 10^{-17} C_4^8 + 2,01 \cdot 10^{-21} C_4^{10} \right) C_3^2$ $+ 0.03 \left( 0.0649 + 3,41 \cdot 10^{-13} C_5^6 - 5,13 \cdot 10^{-17} C_5^8 + 2,22 \cdot 10^{-21} C_5^{10} \right) C_2^2$
103	Output Torque Function	$\tau(q, x) = -0.03 \left( -1,28 \cdot 10^{-3} q_1 + 1,28 \cdot 10^{-3} q_2 - 2,54 \cdot 10^{-14} C_4^7 + 4,70 \cdot 10^{-18} C_4^9 - 2,39 \cdot 10^{-22} C_4^{11} \right.$ $\left. + 0,13x \right) - 0.03 \left( -1,31 \cdot 10^{-3} q_1 + 0,13x + 2,75 \cdot 10^{-14} C_6^7 - 5,19 \cdot 10^{-18} C_6^9 + 2,69 \cdot 10^{-22} C_6^{11} \right)$
104	Output Stiffness Function	$\sigma(q, x) = -0.03 \left( 0,13 + 1,95 \cdot 10^{-11} C_5^6 - 4,71 \cdot 10^{-15} C_5^8 + 2,99 \cdot 10^{-19} C_5^{10} \right)$ $- 0.03 \left( 0,13 + 1,80 \cdot 10^{-11} C_4^6 - 4,27 \cdot 10^{-15} C_4^8 + 2,65 \cdot 10^{-19} C_4^{10} \right)$
105	Spring Torque Function	$e_s(q, x) = \begin{bmatrix} -0.03 (0,13C_2 + 2,72C_2^7 - 5,14C_2^9 + 2,66C_2^{11}) \\ -0.03 (0,13C_3 + 2,72C_3^7 - 5,14C_3^9 + 2,66C_3^{11}) \end{bmatrix}$
106	Springs to Motors Transmission Ratio	$A(q, x) = \begin{bmatrix} \frac{1,30 \cdot 10^{-3} C_1 - 2,72 \cdot 10^{-2} C_2^7 + 5,14 \cdot 10^{-2} C_2^9 - 2,66 \cdot 10^{-2} C_2^{11}}{2\sqrt{6,49 \cdot 10^{-2} C_2^2 + 0,34 C_2^8 - 0,51 C_2^{10} + 0,22 C_2^{12}}} & 0 \\ C_7 & -C_7 \end{bmatrix}$
107	Springs to Output Transmission Ratio	$B(q, x) = \begin{bmatrix} \frac{0,13C_2 + 2,75C_2^7 - 5,19C_2^9 + 2,69C_2^{11}}{2\sqrt{0,06C_2^2 + 0,34C_2^8 - 0,51C_2^{10} + 0,22C_2^{12}}} \\ \frac{0,13C_3 + 2,72C_3^7 - 5,135C_3^9 + 2,66C_3^{11}}{2\sqrt{0,06C_3^2 + 0,34C_3^8 - 0,51C_3^{10} + 0,22C_3^{12}}} \end{bmatrix}$
$\frac{q_1 - x}{100} - x = C_1; x + \frac{-q_1 + x}{100} = C_2; \frac{-q_1 + q_2}{101} + x = C_3; q_1 - q_2 - 101x = C_4;$ $q_1 - 101x = C_5; -q_1 + 101x = C_6;$ $\frac{-1,28 \cdot 10^{-3} C_3 - 2,70 \cdot 10^{-2} C_3^7 + 5,08 \cdot 10^{-2} C_3^9 - 2,64 \cdot 10^{-2} C_3^{11}}{2\sqrt{6,49 \cdot 10^{-2} C_3^2 + 0,34 C_3^8 - 0,51 C_3^{10} + 0,22 C_3^{12}}} = C_7$		