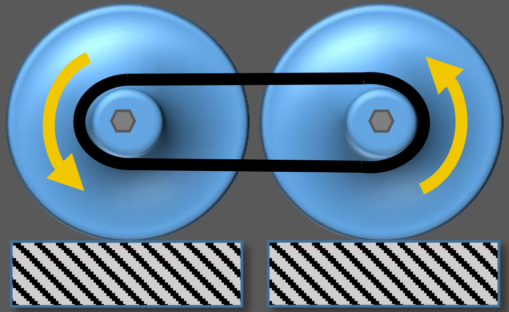
Modeling & Simulation of two DC - motors with belt connection using solidThinking *Activate*



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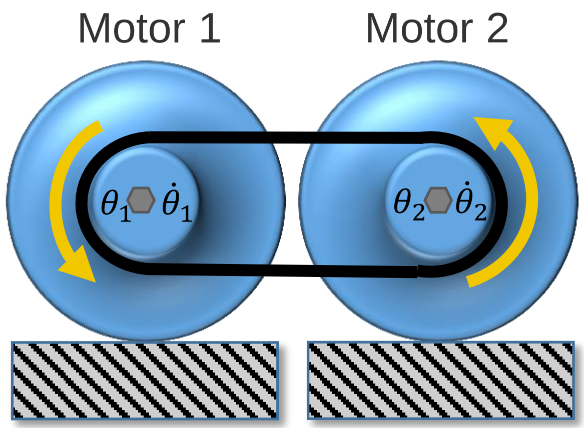
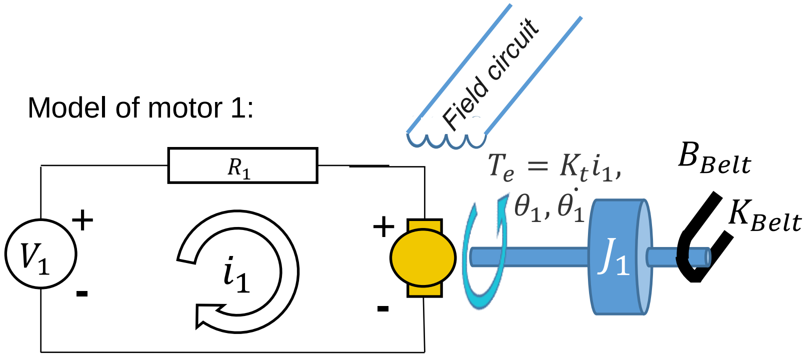
Two DC-motors with belt connection

Two armature controlled DC-motors are connected in series via a belt. The connecting belt is assumed massless with the stiffness K_{Belt} and a damping factor of B_{Belt}. Each of these DC-motors exist of a simplified armature circuit consisting a resistor, R and is controlled by application of a DC voltage V.



Model of motor 1:



$$V_{bemf} = K_{bemf}\,\dot{\theta}$$

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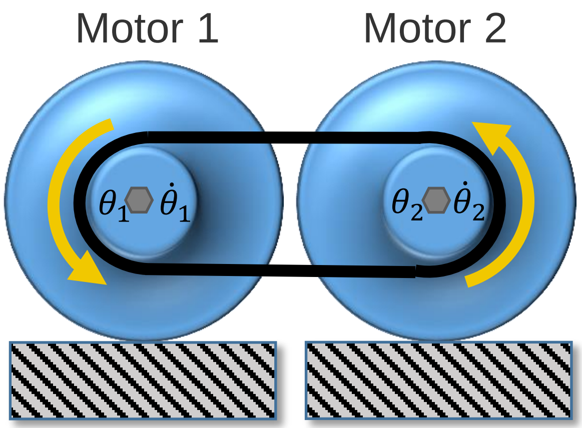
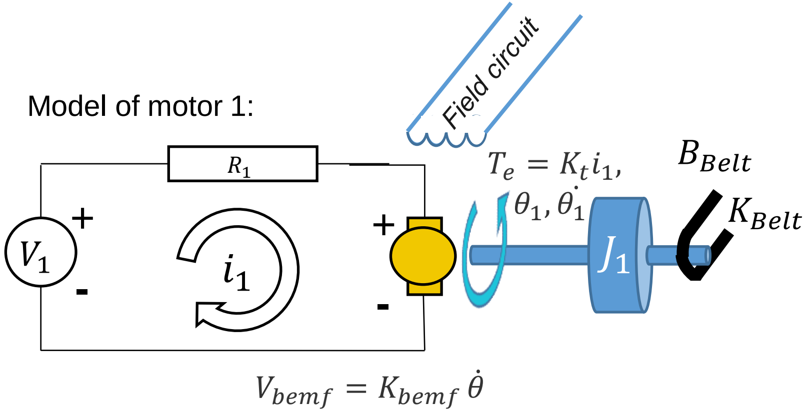
Two DC-motors with belt connection

Objectives

- Learn how to…
  - … model two DC-motors in series
  - … scope variables on global level
  - … link different blocks without a direct connection *(Get-/Set-Signals)*



Model of motor 1:



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Creation and Simulation of two DC-motors with belt connection

Theoretical background and how to implement it using *Activate*

Step 1: Construction of equations

- Step 1.1: Equations of the motors
- Step 1.2: Equations of the belt

Step 2: Implementation using *Activate*

Step 3: Validation of the results

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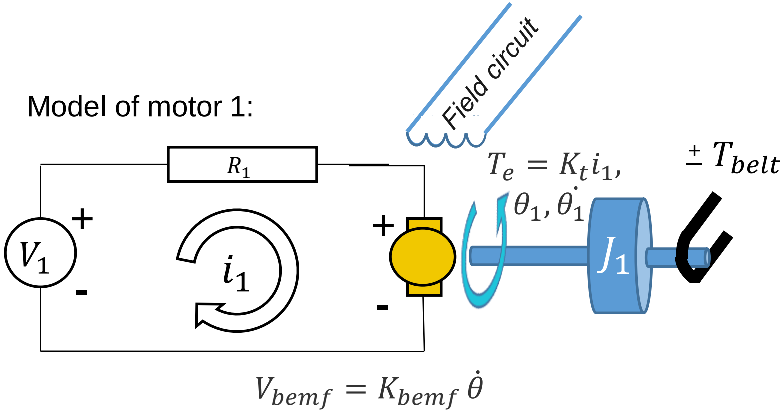
Step 1: Construction of equations

- Step 1.1: Equations of the motors
- $j = 1 \; or \; 2$
- Armature circuit:
  - $V_j = V_{r,j} + V_{bemf,j}$
  - $V_j = R_j i_j + K_{bemf} \dot{\theta}_j$
- Mechanical circuit:
  - $J_1 \ddot{\theta}_1 = T_{e,1} - T_{Belt}$
  - $J_2 \ddot{\theta}_2 = T_{e,2} + T_{Belt}$

Model of motor 1:



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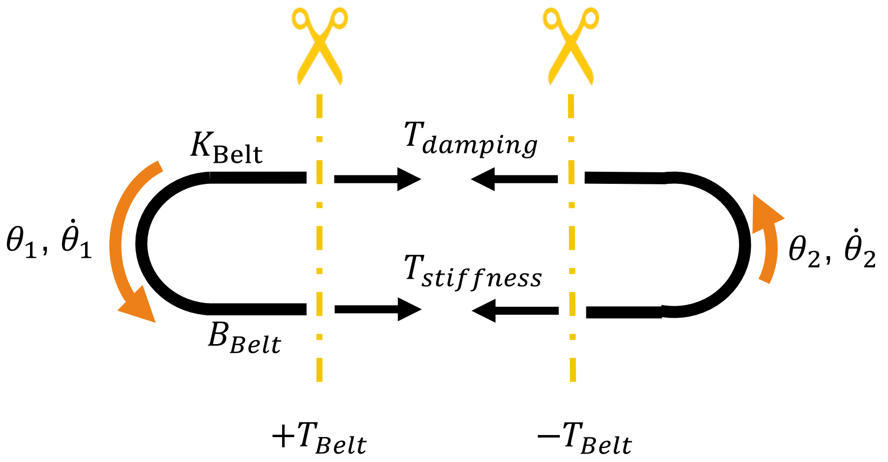
Step 1: Construction of equations

- Step 1.2: Equations of the belt

- $T_{Belt} = T_{damping} + T_{stiffness}$
- $T_{Belt} = B_{Belt}(\dot{\theta}_1 - \dot{\theta}_2) + K_{Belt}(\theta_1 - \theta_2)$



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Step 2: Implementation using *Activate*

Motor 1:

- In complex models, it is helpful to create *Superblocks* to organize models: These *Superblocks* contain an entire block diagram or could provide other subsystems. The output is defined by the number of output ports connected to their relating signal. The input is defined by the number of input ports connected to their relating blocks.

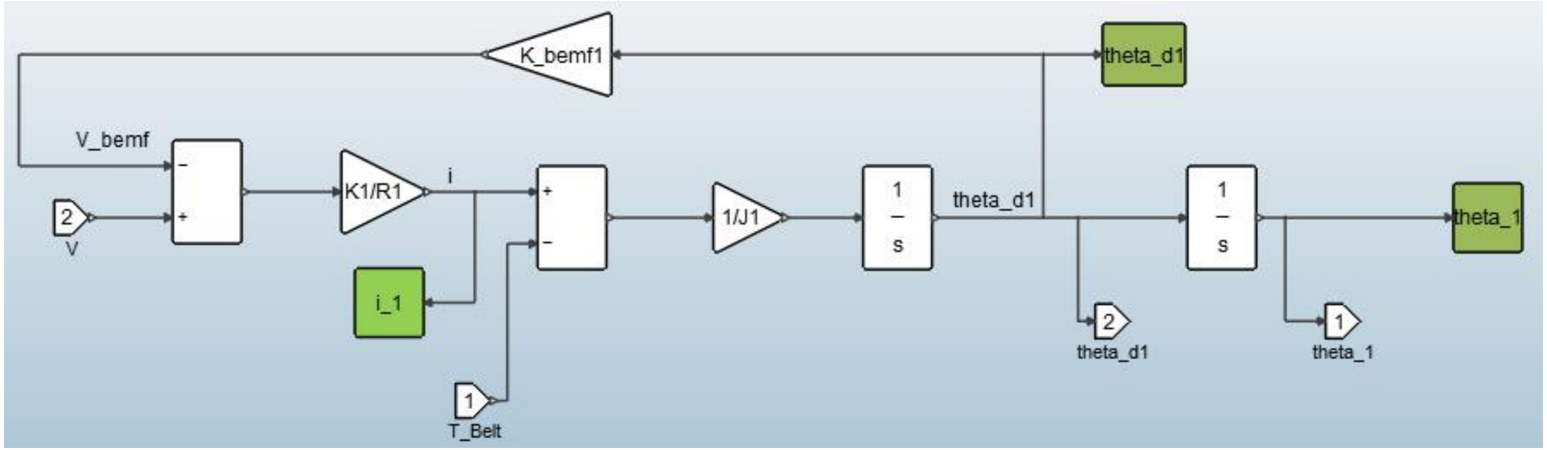

Fig. 1: Superblock of DC-motor system 1

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Step 2: Implementation using *Activate*

Motor 2:

- To scope variables in the global level implement *"Get_Signal/Set_Signal".* These blocks are set to scope signals on local level by default. By changing it to global, it's possible to compare superblock related variables.

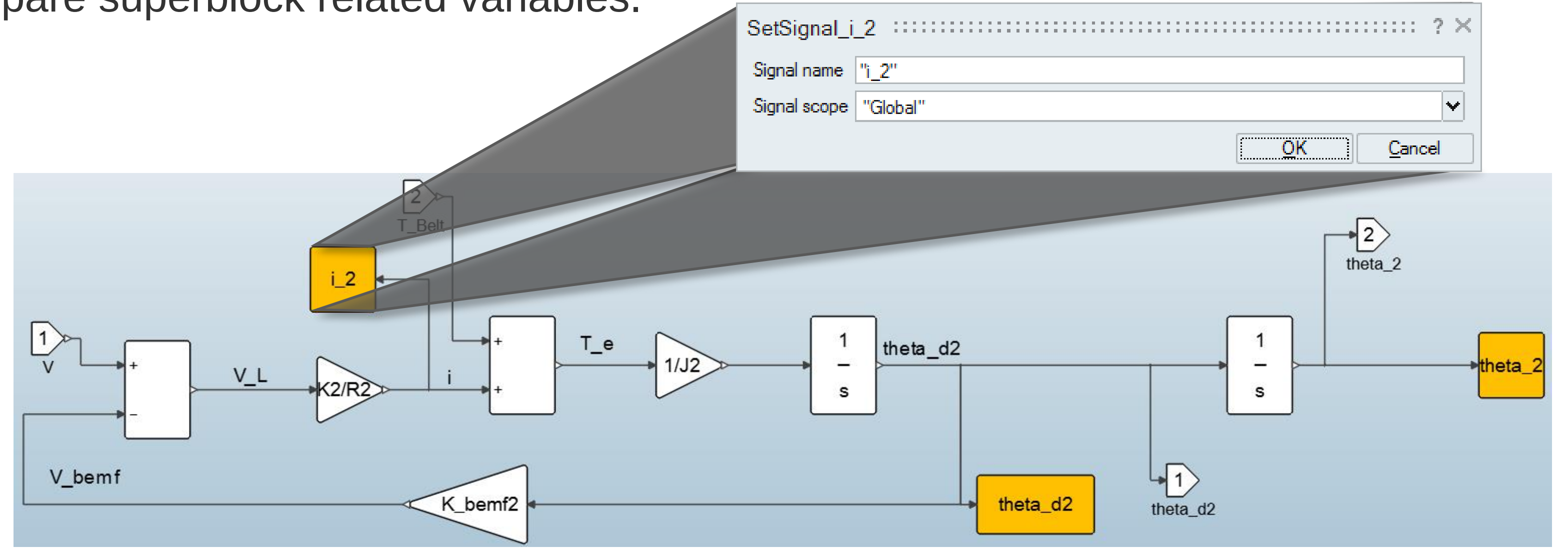

Fig. 2: Superblock of DC-motor system 2

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Step 2: Implementation using *Activate*

Belt:

- The belt torque consists of a damping and a spring behavior factor. It's a reaction torque regarding different angles $theta_j$ and angular velocities $theta_{d,j}$of both DC-motors.

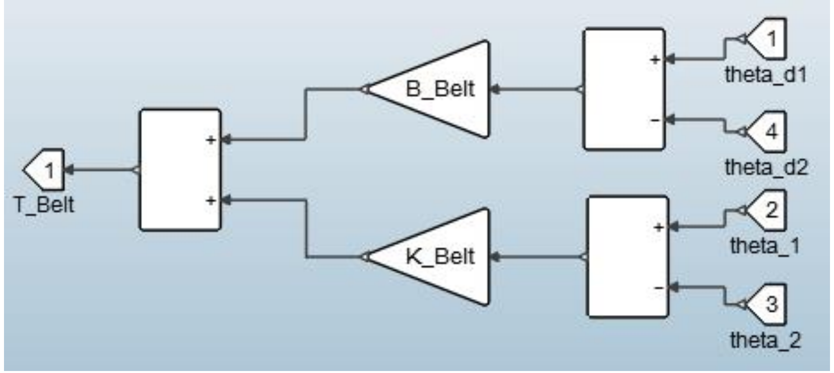

Fig. 3: Superblock of the belt

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Step 2: Implementation using *Activate*

Complete model:

- To plot the belt stretch, reduce the angular position of motor 1 by the angular position of motor 2.

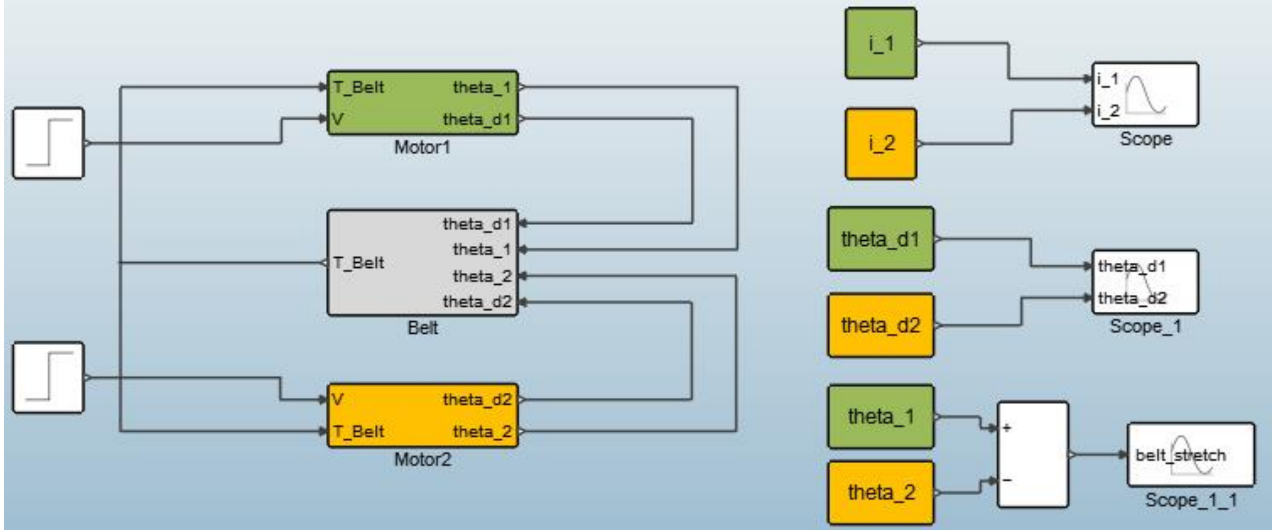

Fig. 4: Complete model of double DC-motor with belt

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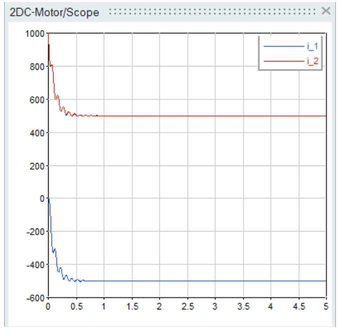
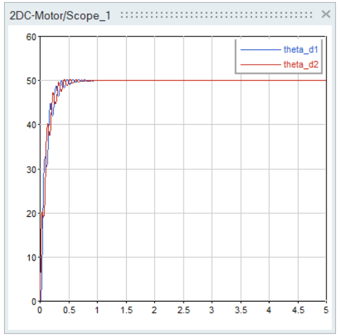
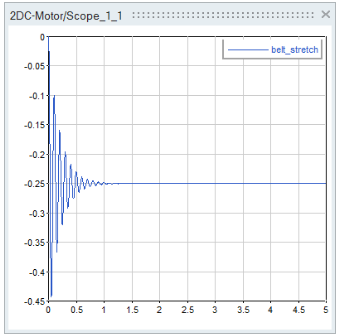
Step 3: Validation of the results

- Simulation time: $5\ sec.$
- Case 1: $V_1 = 0\ Volts, V_2 = 10\ Volts$
- The initial current of motor 2 to is $\frac{K_2}{R_2} V_2 = 1000A$. Motor 1 is powerless at that time. Due to the belt connection this motor works as a generator. It uses the mechanical torque of the motor 2 and the belt to produce current. Thus, the current of motor 2 is reduced by the same amount. In this case both motors run at $5\ Volts$ at steady state.







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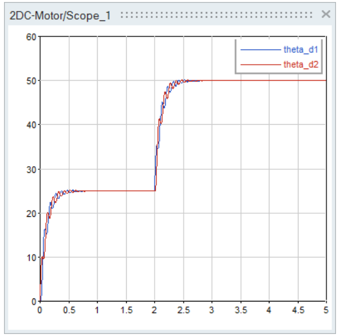
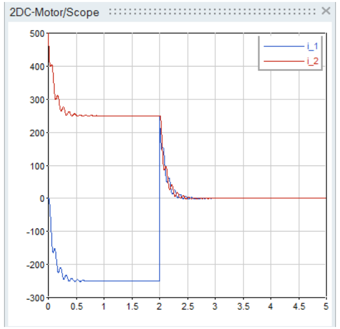
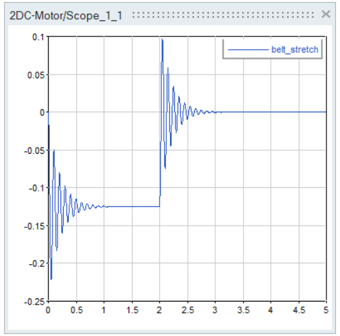
Step 3: Validation of the results

- Simulation time: $5\ sec.$
- Case 2: $V_1 = 5\,Volts_{\,(Start\ time=2\ sec.)}, V_2 = 5\,Volts$
- The initial current of motor 2 to is $\frac{K_2}{R_2}V_2 = 500A$. Motor 1 is powerless and behaves like a generator again at that time. The switch up of motor 1 after two seconds causes an increase of the angular velocity up to $50\,\frac{rad}{s}$ and a maximum stretch of the belt.
- After reaching the steady state ($\dot{\theta}_1 = \dot{\theta}_2$) both motors don't produce current ($i = 0$).







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Step 3: Validation of the results

- Simulation time: $5\ sec.$
- Case 3: $V_1 = 3\ Volts_{(Start\ time=2\ sec.)}, V_2 = 7\ Volts$
- The initial current of motor 2 to is $\frac{K_2}{R_2}V_2 = 700A$. The switch up of motor 1 after two seconds causes an increase of the angular velocity up to $50\frac{rad}{s}$ again.
- After reaching the steady state $(\dot{\theta}_1 = \dot{\theta}_2)$ motor 2 runs with a current of $200\ A$ and motor 1 stays in generator mode and produces $200\ A$.