MECH420

Sensors and Actuators

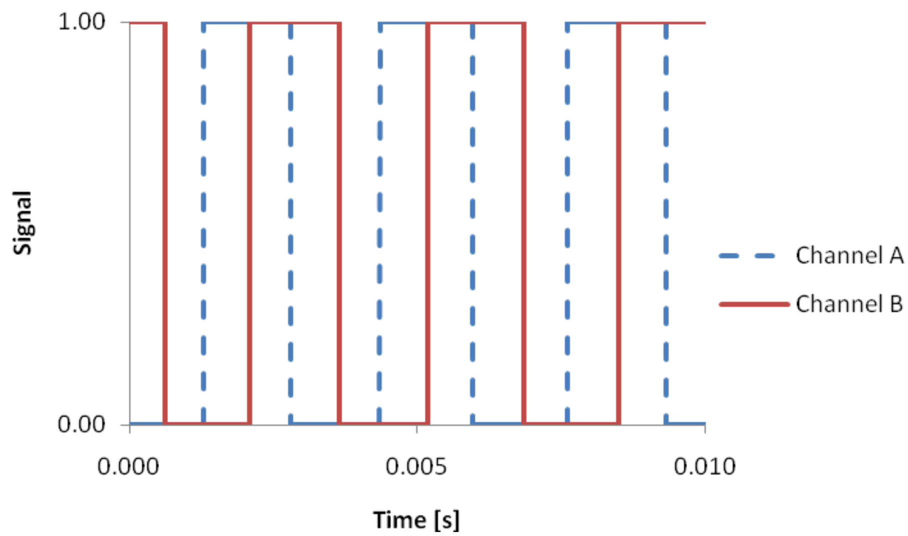
Laboratory Exercise #2:
Optical Encoder and Torque Sensor

Lab Group:	D7
Student:	A. Student
Date lab taken:	October 16, 2019
TA:	T. Assist

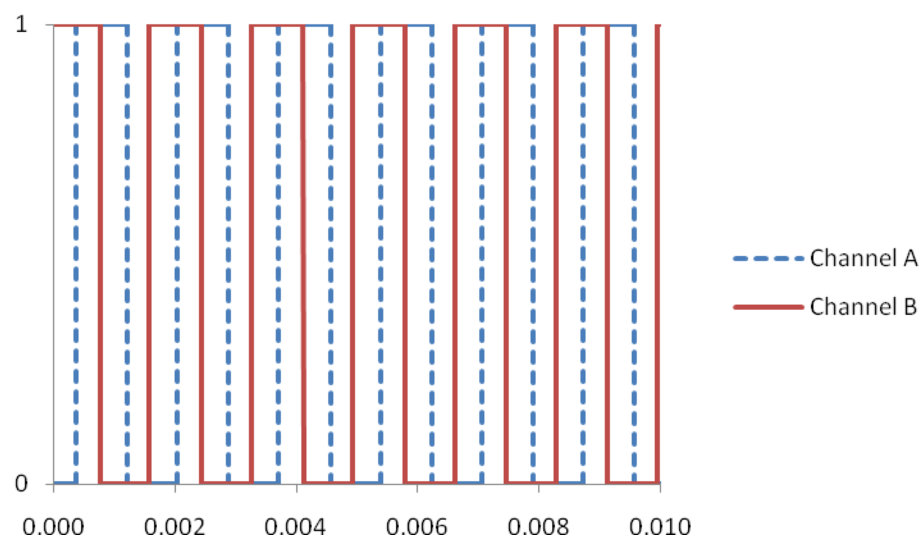
Part A: Characterization of the optical encoder signal

1. Encoder phases for the two directions of rotation:

   Clockwise rotation:



   Counter clockwise rotation:



2. Direction of rotation:

   The two signals are 90° out of phase. For clockwise rotation, the signal from channel A leads by 90°, while the signal from channel B leads by 90° for counter clockwise rotation.

3. Motor speed and resolution:

   The following table shows the number of quadrature signal pulses counted during 2.5 ms, as well as the average number of clock pulses counted per quadrature signal for the different motor excitation voltages. The corresponding motor speeds were calculated as well as the corresponding speed resolution.

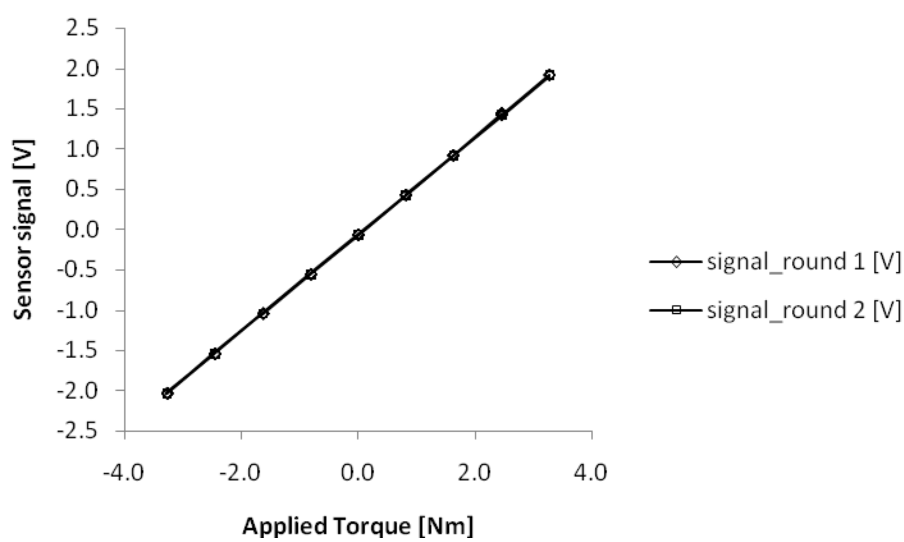
The angular velocities calculated according to both methods are fairly similar. The velocity resolution for the pulse counting method is better for most of the velocity range considered, while the resolution of the pulse timing method is better at lower velocities. The approximation for the resolution of the angular velocity for the pulse timing method is closer to the exact value for low velocities (large values for *m*).

	pulse counting method				pulse timing method				
Voltage [V]	number of pulses	time [s]	angular velocity [rad / s]	angular velocity resolution [rad / s]	clock counts per Q: m	time per Q [s]	angular velocity [rad/s]	angular velocity resolution (exact.) [rad/s]	angular velocity resolution (approx.) [rad/s]
0.25	30	0.0025	52.4	1.75	32	8.00E-05	54.5	1.7	1.7
0.3	46	0.0025	80.3	1.75	21	5.25E-05	83.1	3.8	4.0
0.35	68	0.0025	118.7	1.75	15	3.75E-05	116.4	7.3	7.8
0.4	86	0.0025	150.1	1.75	11	2.75E-05	158.7	13.2	14.4
0.45	108	0.0025	188.5	1.75	9	2.25E-05	193.9	19.4	21.5
0.5	130	0.0025	226.9	1.75	7.5	1.88E-05	232.7	27.4	31.0

[Only 3 voltages necessary]

Part B: Characterization of the Torque Sensor

1. Torque sensor signal:



The torque was calculated from the mass of the weights *m*, the gravitational accelaration g = 9.81 m/s^2, and the length of the torque arm L_W as

$$T = m\, g\, L_{W.}$$

2. Torque sensor calibration

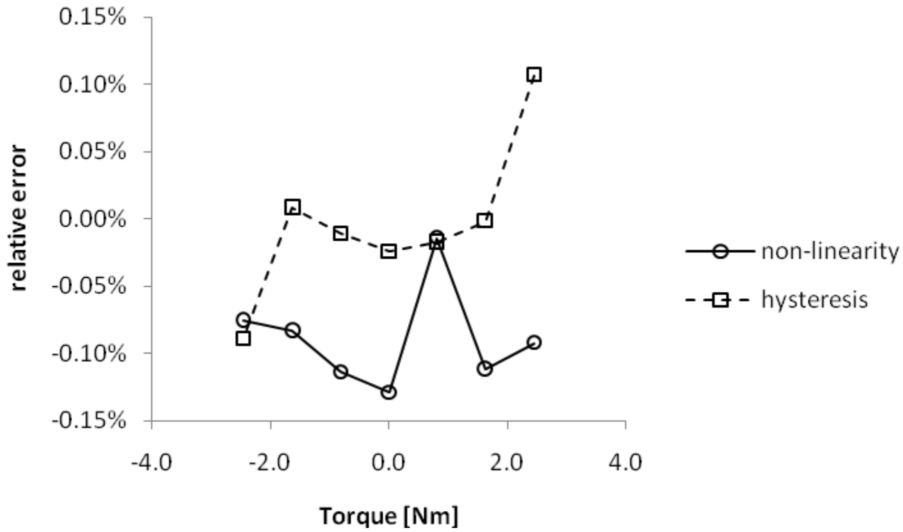
   The calibration equation for the torque sensor

$$V(T) = V_0 + T \cdot 0.604 \text{ V/Nm}, \; V_0 = -0.085 \text{ V}$$

   was calculated from the average voltage readings in the following table:

***T* [Nm]**	***V* [V]**
- 3.273	- 2.037
3.273	1.914

3. non-linearity and hysteresis error (should be absolute errors!)



The non-linearity error (elin) and the hysteresis error (eH) are both below 0.15% (should be absolute!).

4. Comparison of theoretical and measured sensor transfer characteristics

The theoretical sensitivity S = 0.553 V / Nm is very close to the measured value of 0.604 V / Nm.

The maximum theoretical offset of 130 mV is above the measured 66 mV offset of the torque sensor, which indicates that the system offset can be fully explained by the offset of the load cells.

The theoretical maximum non-linearity error and the hysteresis error are much lower than the measured non-linearity error of 5.1 mV and the measured hysteresis error of 4.2 mV, which both might therefore be dominated by the other components of the torque sensor setup.

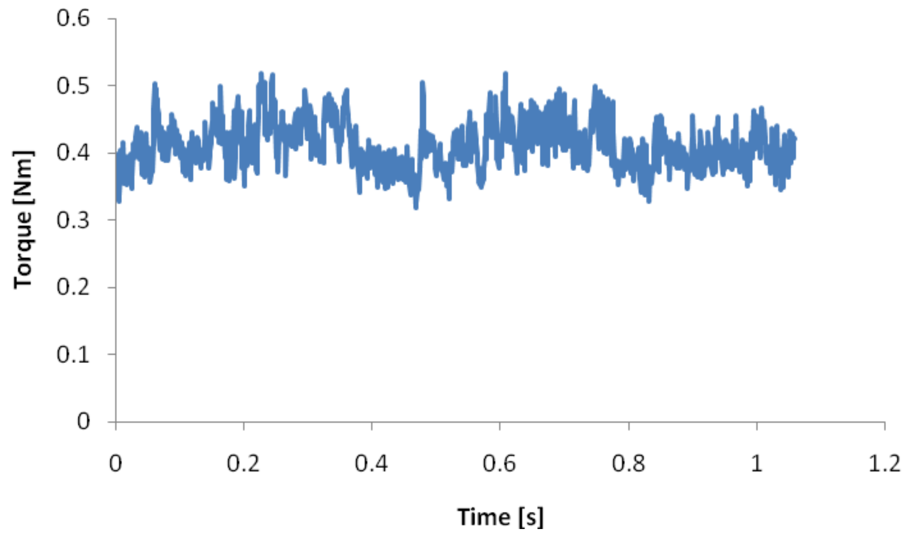
Part C: Measurement of the Required Torque to run the Conveyor

To determine the torque

$$T = \{V(T) - V_0\} / 0.604 \text{ V/Nm}$$

from the voltage signal, the previously derived calibration equation for the torque sensor needs to be rearranged.

The following figure shows the torque sensor signal over one cycle of the conveyor system for a motor speed of 30 RPM.



The average torque measurement is xy Nm with a standard variation of zy Nm.