# Towards the Development and Characterization of a Torque Sensor for Volitional Control of a Pediatric Exoskeleton

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## Background

- Between 1200 and 1500 school-aged children in the U.S. are diagnosed with cerebral palsy [1], and about 400 to 600 boys are born with Muscular Dystrophy every year [2]
- Lightweight and custom exoskeletons are being developed to assist children with locomotion disabilities
- Measurement of the torque exerted at the joints of the exoskeleton will improve operation safety and allow safer human-robot interaction
- A custom torque sensor has been developed to estimate joint torques in an exoskeleton

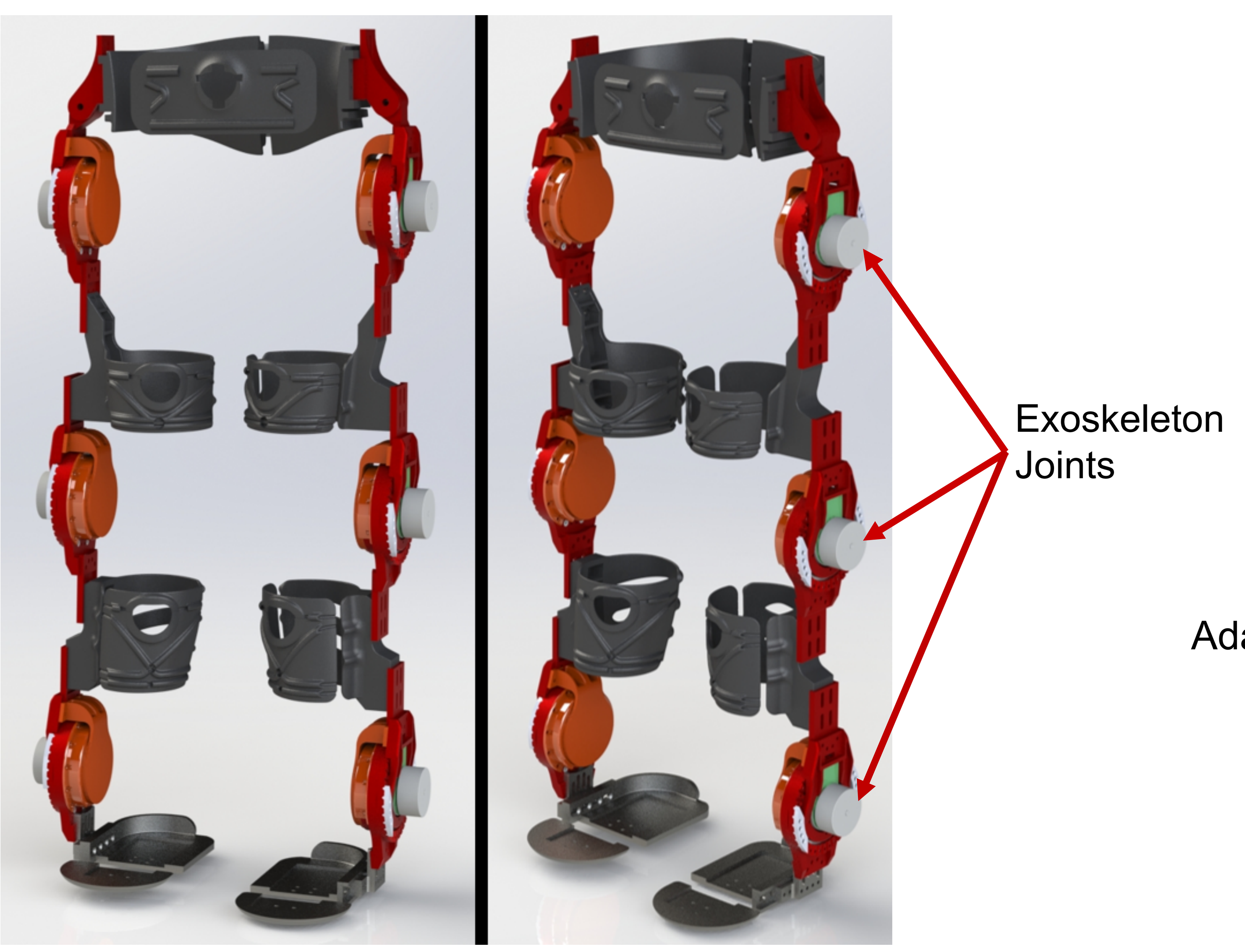


**Figure 1.** Pediatric Exoskeleton Model

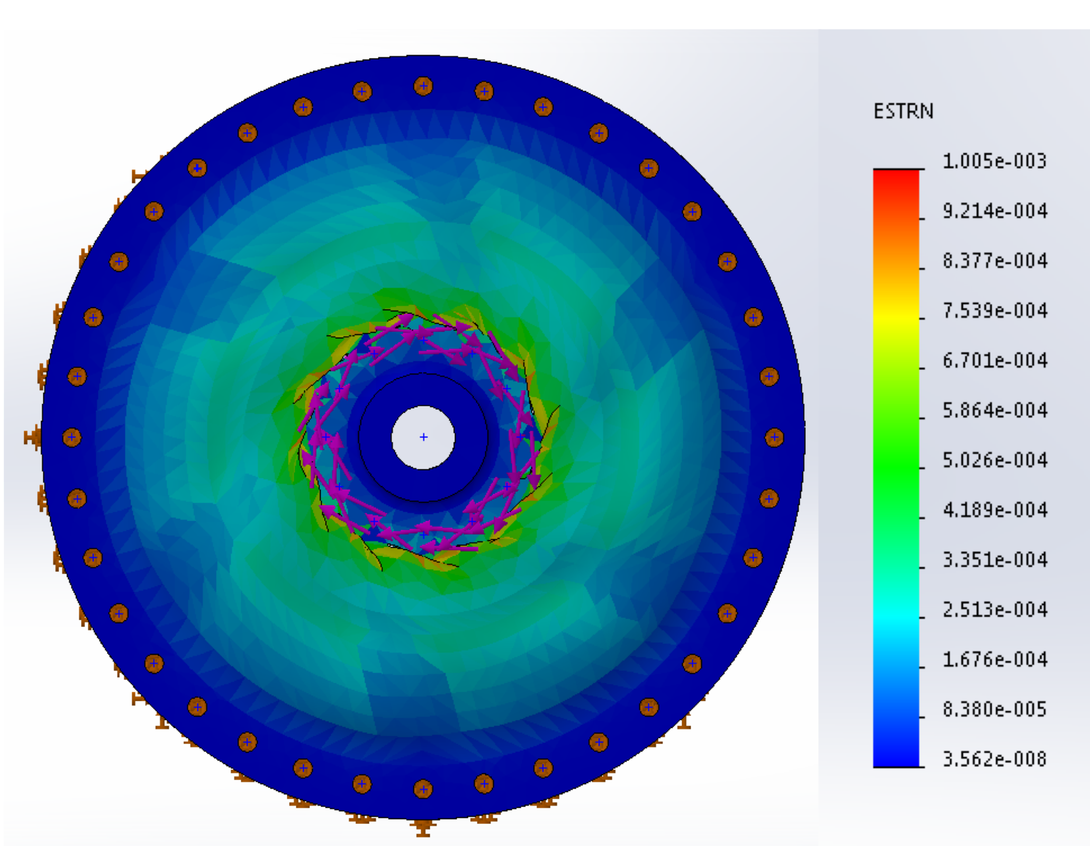


**Figure 2.** Simulated Strain when a torque of 10 [Nm] is applied

## Acknowledgements

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## Methodology

- Strain gauges are used to measure the material deformation on the output plate of the exoskeleton joint when a torque is applied
- Two Wheatstone Bridges are mounted at 90-degree angles apart from each other
- Static tests were conducted by applying known weights to the system and comparing measured output values to a reference torque transducer
- The signal was amplified and digitized for better signal resolution, and data was collected at 500 Hz

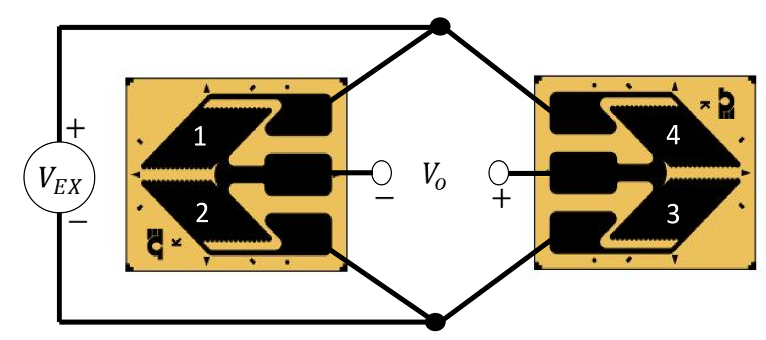


**Figure 3.** Wheatstone Bridge Sensor

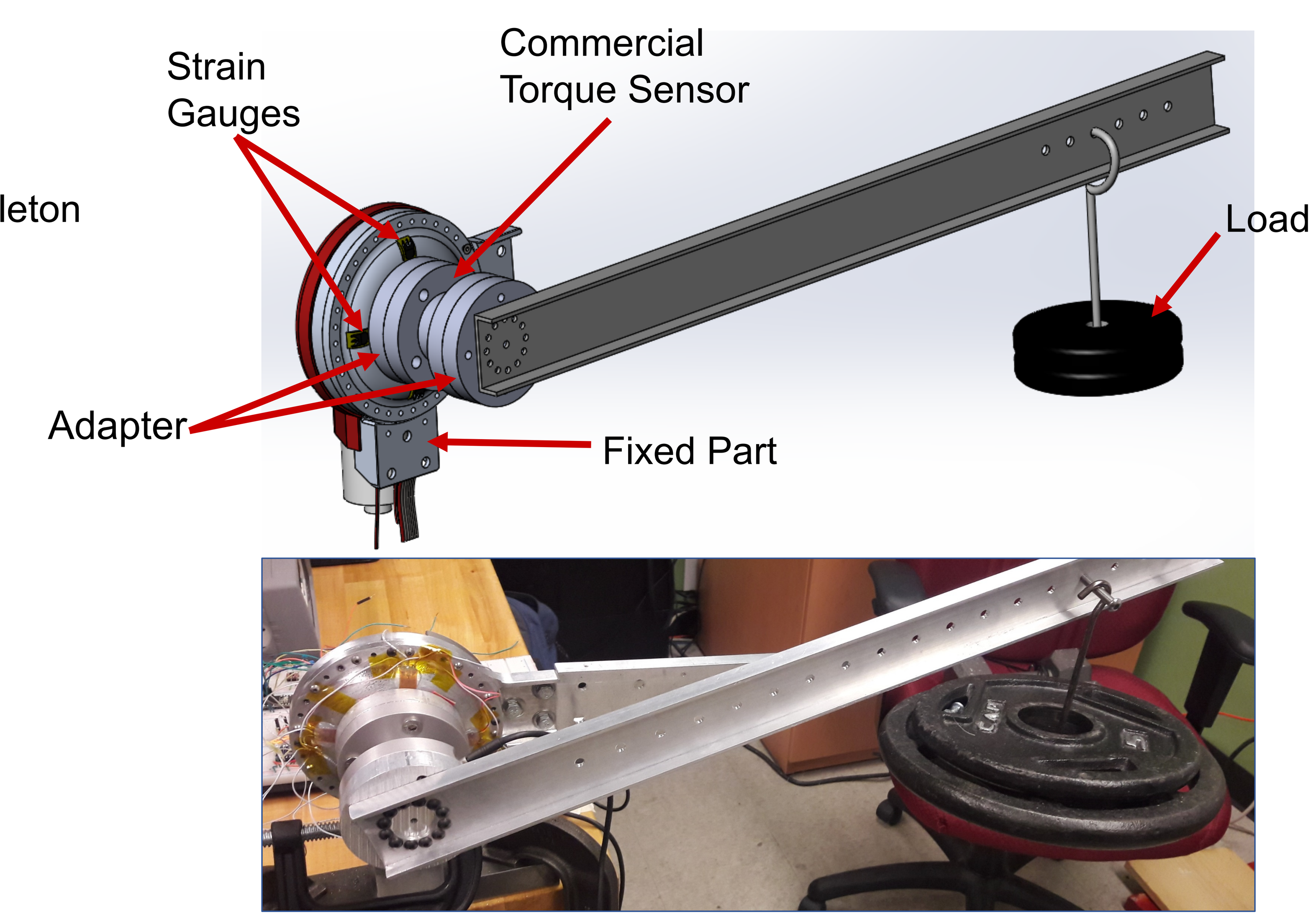


**Figure 4.** Static test setup showing the commercial torque sensor attached to the system

## Results

Similar to HBM Company methods for characterizing torque sensors [3] :

- Three load cycles with clockwise increasing torque were recorded at unequal load steps up to a maximum applied torque of 58 [Nm]. Average results:
  - Sensitivity: 0.08 mV/V - Linearity: 2.91 %
  - Calibration constant: 6.56
- Three load cycles with clockwise torque were recorded at 0%, 33%, 66%, 100%, 66%, 33%, and 0% of a maximum applied torque of 85 [Nm]. Average results:
  - Sensitivity: 0.10 mV/V - Hysteresis: 20.6 %
  - Linearity (including Hysteresis): 11.8 %
  - Calibration constant: 7.29

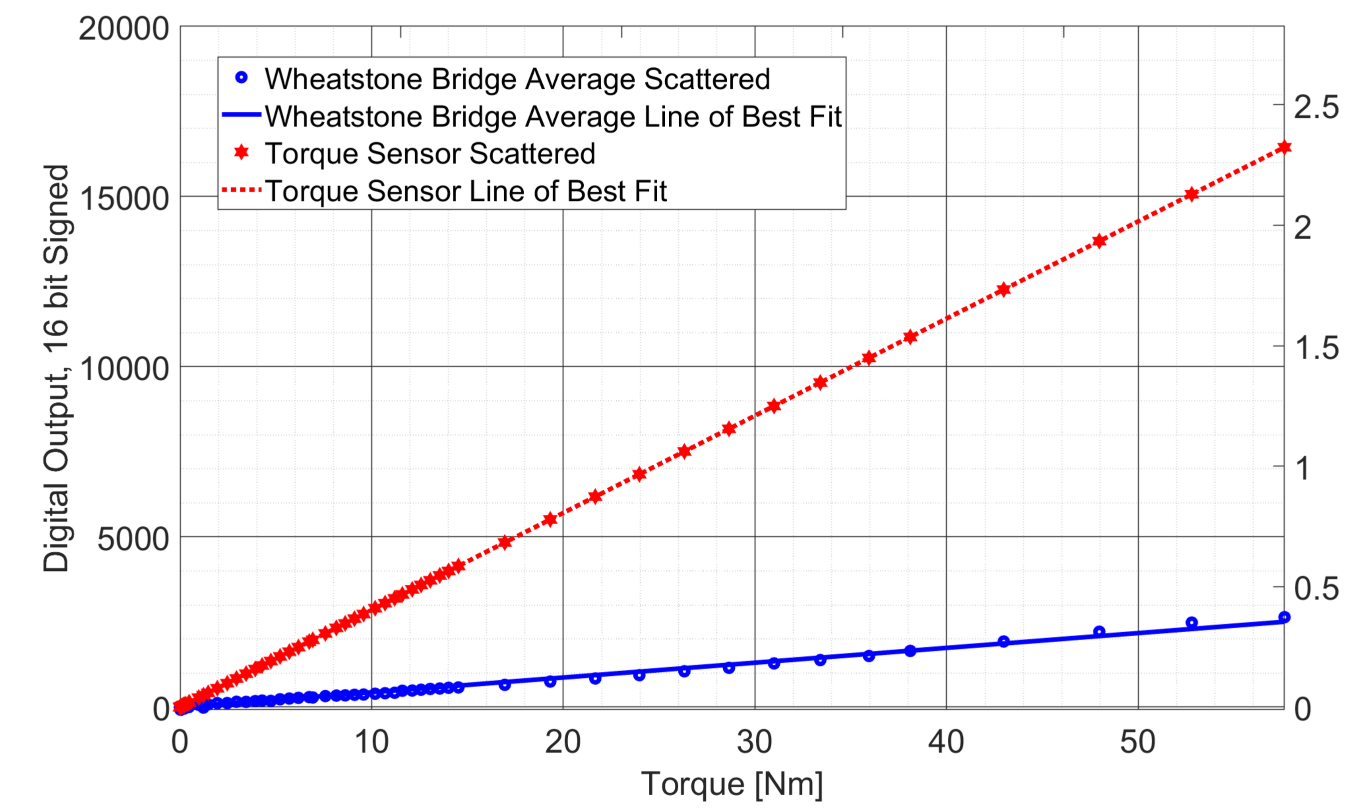


**Figure 5.** Output vs. Torque for the Commercial and Custom Torque Sensors before system calibration, for the average of 3 load cycles up to a maximum applied torque of 58 [Nm].)

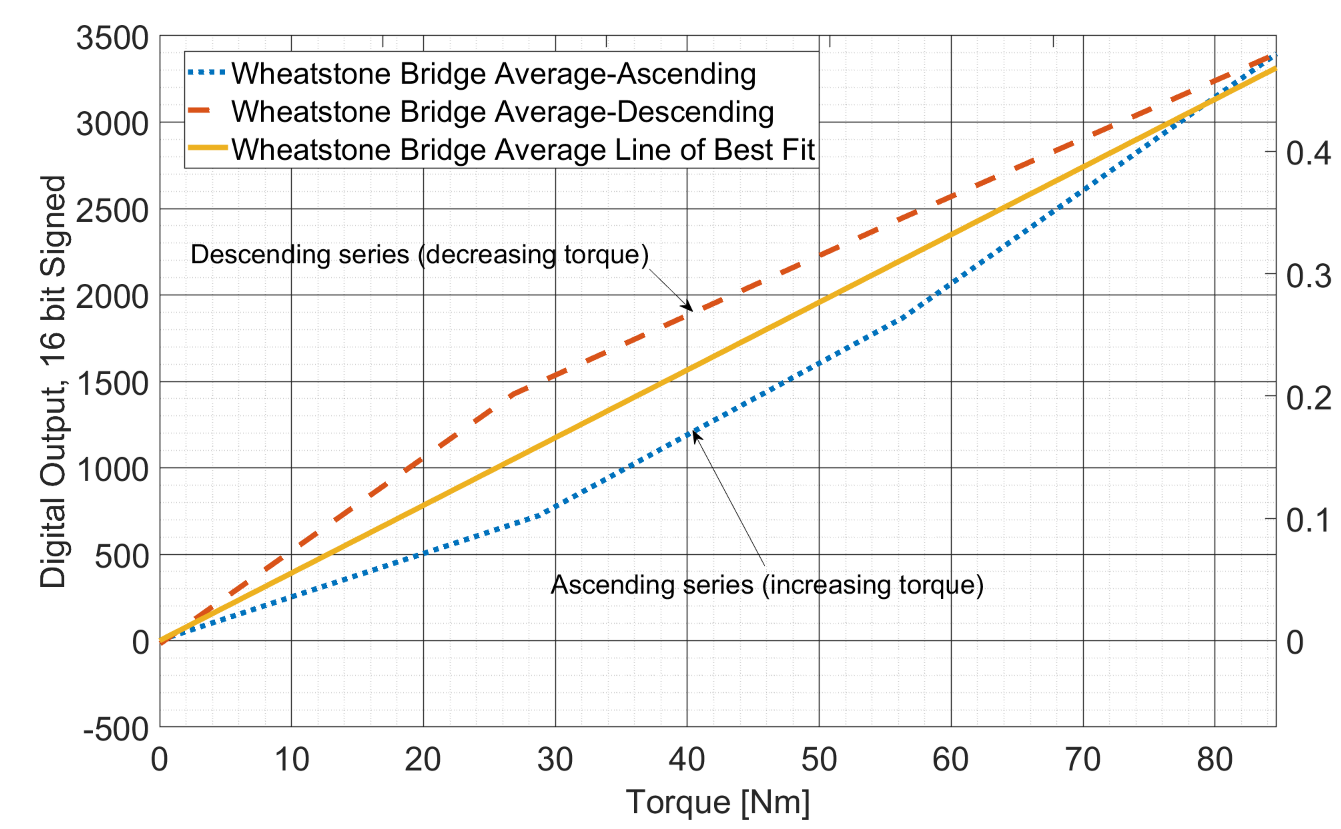


**Figure 6.** Output vs. Torque for the Custom Torque Sensor showing hysteresis curve, for the average of 3 load cycles up to a maximum applied torque of 85 [Nm].)

## Conclusions

- A custom torque sensor was developed and characterized to be used in a pediatric exoskeleton
- Preliminary results show the system is capable of detecting increasing and decreasing loads, indicating the system can be used for volitional control
- Future work includes:
  - Testing the system at other angle configurations
  - Determine how to reduce the large hysteresis if caused by the shape of the joint plate or the system installation
  - Perform tests on a new joint with better ground support
  - Perform dynamic tests

## References

[1] *Cerebral Palsy Facts and Statistics.* (2018). Retrieved from Cerebral Palsy Guidance: https://www.cerebralpalsyguidance.com/cerebral-palsy/research/facts-and-statistics/
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[3] Schicker, R., & Wegener, G. (n.d.). Measuring Torque Correctly. Retrieved from HBM: https://www.hbm.com/fileadmin/mediapool/files/torque-book/HBM_Measuring-Torque-Correctly_COMPLETE-EDITION.pdf