

# Measuring Torque Ripple and its Effects on Electric Power and Noise and Vibration

## Frequently Asked Questions and Answers

### 1. How does inverter voltage effect torque ripple? Amplitude, frequency, effective voltage value?

The inverter voltage is the energy source for the system. High frequency voltages result in high frequency current, the current becomes magnetic with frequency content, which become torque that may also have frequency content. Therefore, the voltage can have a direct influence on torque.

### 2. Does inverter control type effect torque ripple and noise and vibration?

Control type dictates at what position and frequency energy is transferred to the rotor by the inverter. These interactions will often cause additional harmonics, which can be reflected in torque. Two common examples of controls that effect torque are six step control and PMSM field weakening. Manufacturers are increasingly using special inverter control algorithms to improve NVH. One of the advantages of using an HBK solution, is that it allows direct measurement of the high voltage signal to the motor synchronously with the noise and vibration signals, which provides you with a powerful troubleshooting and benchmarking tool

### 3. Do you need to account for driveline rigidity, natural modes, and overall dynamic behavior?

Yes. Test stand designers should make their driveline as short and stiff as possible. This will control the amount of torsional resonance that is experienced by the system.

### 4. How can you eliminate noise from a torque signal?

To eliminate electrical noise in the system HBK uses a digital frequency output from the torque sensor and reads the digital signal with high-end timer counter channels in the power analyzer.

### 5. What should the sampling rate of data acquisition be to catch torque ripple?

HBK measures the full frequency output of the torque sensor with a special high frequency clock and then averages the signal at the desired frequency rate.

### 6. Do you need to account for the load machine in your torque ripple measurement?

Yes. Using lower torque ripple load machines (induction machine or fly wheel in extreme cases) and characterizing them will give you the best results for your device under test.

### 7. Are there major differences between finite element models (FEM) and measured results?

There can be large differences between FEM and measured results based on control and machine types. It depends on the maturity of the modeling technology and what you are looking for. The example of switched reluctance machines and how torque ripple creates noise is currently a popular research area and does not have the most reliable models. We always advise validation with measurement.

#### **8. What bandwidth needs to be considered for doing sound and vibration measurements?**

The short answer is that we (B&K Consulting) generally use a bandwidth of 25.6 kHz when making NVH measurements. This corresponds to a sampling frequency of 65,536 samples/second for the B&K recording equipment because the upper range of human hearing is 20 kHz. Sometimes this can be relaxed if the higher frequencies are not significant for the engineering question being pursued.

#### **9. Do special considerations need to be made in regard to accelerometers and microphones?**

Regarding the effect of the powerful electromagnetic fields on the sensors, some research suggests that the EM produces some noise in the accelerometer and microphone signals. This is difficult to analyze, since the same sources produce the EM fields and noise and vibration. To our knowledge, specialized noise and vibration sensors for high EM fields are not commonly available at this time.

#### **10. Will I feel the resonant points in the car and do they have long term consequences?**

During vehicle development, these resonances are referred to as periods. They arise from many sources (driveline dynamics, tires, exhaust acoustics, exhaust structure, intake acoustics, aerodynamics, and many more). Periods are annoying and considered to be non-commercial. Eliminating periods is a major part of the vehicle NVH engineer's job.

#### **11. Can torque ripple transferred to the body of the vehicle be suppressed?**

It is very dependent on the local stiffness of the vehicle - many OEM's are evaluating nylon polymer mounts exactly for this reason, but this has other implications for durability.

Vehicle bodies are specifically designed to be less sensitive to NVH inputs from the powertrain by setting targets for attachment point stiffness, local resonances, and modal alignment. However, this must be balanced against space and weight constraints, so the vibration isolation between the powertrain (motor) and the frame is about 30 dB (0.0316 X). It is usually cheaper and lighter to address noise and vibration at the source rather than at all the paths.

Designing mounts for an automotive traction motor would seem to be easy, but the very high torques produced by traction motors and the direct attachment to the wheels via the half-shafts requires stiff engine mounts. The stiffer mounts decrease vibration isolation. The stiff motor mounts and the compact motor configuration produce higher powertrain rigid body frequencies than for an ICE which is not a good trend for NVH.

**12. Can these measurements be used for end of line validation?**

Yes, torque measurements are used to validate rotating machinery with both static and frequency-based analysis.

**13. What measurement solutions does HBK offer for Torque Ripple & NVH testing?**

HBK offers a wide range of sensors (torque, current, voltage, accelerometers, and microphones), acquisition (HBM eDrive and B&K LanXI), and software for doing torque ripple and NVH analysis.

HBK NVH solutions are comprehensive including equipment and engineering services for modal analysis, operating deflection shape analysis, spherical beamforming (acoustic camera), near field acoustic holography, source path contribution analysis (a.k.a. transfer path analysis), end-of-line testing, vehicle simulation, measurement test development, component target cascading, general troubleshooting, and sound quality analysis.

If you are new to these topics there is also a [well-qualified service group](#) that can assist you with your projects.