



# ThinGap Torque Ripple Brief

Torque ripple in 3-phase brushless motors is caused by any deviation of the back emf voltage or current waveforms from a perfect sinusoidal signal. Therefore, providing a sinusoidal current and voltage waveform is the best way to minimize torque ripple on 3-phase brushless motors. Other control methods that involve switching or commutation of the motor current do not perform as well. ThinGap motors have an inherently low harmonic distortion of the back emf waveform due to their unique construction and configuration. **The ThinGap NEMA 23 brushless motor has a torque ripple less than +/- 0.045%**, as shown in the bottom right chart. The following illustrates the benefits of using the ThinGap motor.

The typical ThinGap back emf waveforms have the following frequency components:

### BACK EMF HARMONICS

ORDER OF HARMONIC	AMPLITUDE %
1	100.0000
3	0.0040
5	0.045
7	0.003
9	0.007
11	0.003

$$\text{SHAFT POWER} = V_a \cdot I_a + V_b \cdot I_b + V_c \cdot I_c$$

$$\text{SHAFT TORQUE} = (\text{SHAFT POWER}) / (\text{SPEED})$$

With perfectly sinusoidal back emf and current waveforms,

$$\text{Shaft Power} = 1.5 = \sin^2(\theta) + \sin^2(120+\theta) + \sin^2(240+\theta)$$

With harmonics on the back emf waveform, the Torque is as shown below

The ABC phase waveforms are superimposed onto the sum total chart

The detail of the sum torque output is the waveform in the circle

To calculate the torque ripple from these harmonics, we need to consider the current and back emf voltage product. By calculating this product for a single phase, we get the following:

