# Control of Low Inductance ThinGap Motors

ThinGap, LLC - February 2, 2016

ThinGap motors have low inductance when compared to conventional permanent magnet motors. This feature must be addressed to ensure motor – controller compatibility. Inductance is proportional to an electric current's to change. For a fixed voltage, current changes slower if circuit inductance is increased. High motor coil inductance aids in smoothing current waveforms when using pulse width modulation (PWM) for control of motor speed. PWM is a common motor speed control method; it turns the motor controller voltage on and off in a prescribed manner to achieve speed control. The percentage that the voltage is on is called the duty cycle. High inductance can be a draw back if the operating or commutation frequency of the motor is high. As the commutation frequency increases, additional voltage is required to reach the same current level. PWM is executed at a fixed frequency, typically in the range of 20-40 kHz.

In general, ThinGap motors have low inductance. This enables the use of a larger number of magnetic poles and results in light weight motors. However, PWM frequency is not attenuated as much as desired when using off the shelf motor controllers with typical PWM frequencies. This results in system efficiency reductions. Additionally, with large current ripple in the motor at high frequencies additional power is lost due to reflexive currents in the iron and magnets, reducing the efficiency of the motor.

Figure 1 shows a typical gain and phase plot for a ThinGap motor. The gain plot shows the attenuation of the current based on the frequency. At low frequencies, the gain is 1. In other words, 100% of the voltage at low frequencies is being converted to current. At high frequencies the opposite is true with only a small percentage of the voltage being converted to current. Ideally, the commutation frequency is in the low frequency range where the gain is 1, and the PWM frequency is in the high frequency range where the gain is as small as possible.

There are two ways to alleviate losses in the motor due to PWM: 1) adding external inductance to the motor controller system, and 2) increasing the motor controller PWM frequency. For standard off the shelf controllers whose PWM frequency is in the range of 20-40 kHz ThinGap recommends the addition of external inductance of approximately 100uH per phase, depending on the speed of operation and inductance of the motor. ThinGap is currently developing a line of high frequency motor controllers to eliminate the need for external inductors and provide our customers with turnkey motor controller solutions. Please inquire for additional details.

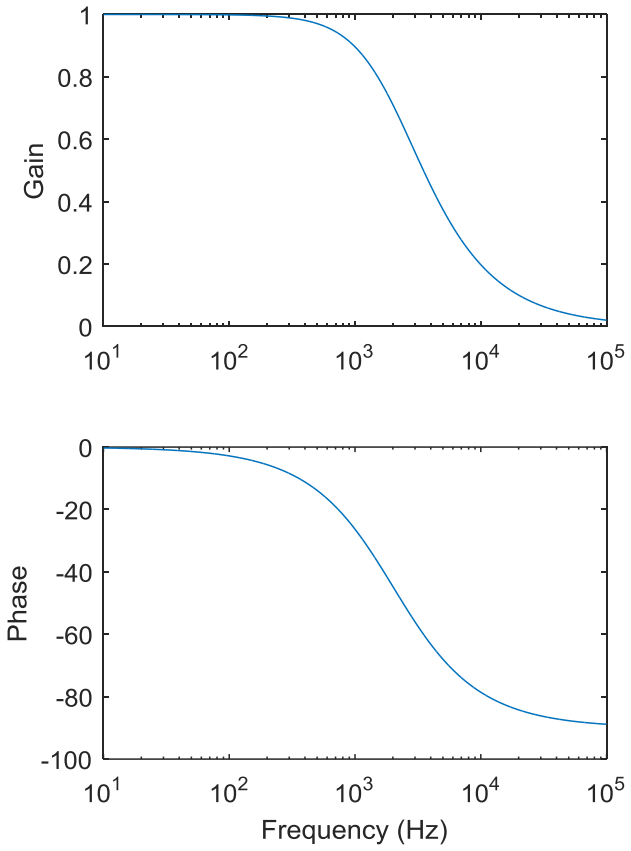


Figure 1- ThinGap motor gain and phase plots