Linear amplifiers adapt the power delivered to the motor by changing the voltage or current. The power that is not delivered to the motor is dissipated (lost power, see Figure 6). As a result, a large heat sink is required to dissipate the power, increasing the amplifier size and making it more difficult to integrate in the application.

A chopper amplifier modulates the voltage (and current) by switching the power transistors on and off. The primary advantage is it saves power when the transistor is off. This helps conserve the battery life of the application, produces less heating from the electronics and allows for smaller electronics size. Most of the time, chopper amplifiers are using a PWM method.

It is important to keep the duty cycle of the PWM as far as possible from 50%, which is the worst case.

The maximum value of the ripple is obtained when the duty cycle is 50%, meaning D=0.5:

The current ripple will generate two types of losses:

1. Joules losses
2. Iron losses

The current ripple will increase the RMS (root mean square) current value, which is the value considered for Joules losses calculation. The ripple will generate additional heating, without increasing the average current, hence without increasing the torque. Notice it is a square variation in function to the RMS current.

The current ripple is proportional to the power supply voltage. Having a high supply voltage can be useful to reach extreme working points, requiring high speed or higher power. However, if the application does not require high speed or power, a lower supply voltage will be beneficial to reduce the current ripple. Operating under the same load point with a lower power supply voltage will also increase the duty cycle, which will reduce the current ripple even more. It is important to keep the duty cycle of the PWM as far as possible from 50%, which is the worst case (Figure 12).

A higher frequency will cause a shorter cycle time of the PWM; hence the current will have less time to rise. PWM frequencies not less than 50 kHz for brushless dc motors are recommended. PWM frequencies of 80 kHz or more would be even more appropriate for motors with a very small electrical time constant.

Brushless dc motors have a very small inductance value. It is a good idea to add external inductances as they will slow down the rise and fall of the current, hence reducing the current ripple. Also, the inductance value specified is given for a PWM frequency of 1 kHz. Since the motor inductance varies depending on the PWM frequency, at a typical PWM frequency of 50 kHz, the inductance may decrease to as low as 70% of the specified value. Additional inductances of several tens of µH are often added. The optimal value of the inductance is often confirmed experimentally. The additional inductances need to be added as shown in Figure 13.

Figure 13: Brushless motor with additional line inductance. Courtesy: Portescap

Figure 13: Brushless motor with additional line inductance. Courtesy: Portescap

Though this solution would solve the current ripple concern, it might not be easy to integrate additional inductances, especially when space is limited. Therefore, it is often wise to first explore the other two options.