Application Brief

MCx8316x for Vacuum Robot Applications

Introduction

The vacuum robot industry is continuing to expand as more consumers are updating appliances in their homes to be automated and hands free. In vacuum robots, the current motor drivers that are being use are brushed and brushless. More customers are switching to brushless DC motors (BLDC) due to the longevity of the device and efficiency. The MCx8316x devices are a fully integrated brushless DC motor (that includes control, gate drivers, and integrated FETs. This brief includes discussion on how the MCx devices can be implemented in a vacuum robot system for the vacuum suction motor, brushed bar, and mop motor with a market analysis.

Vacuum Robots

Vacuum robot structure varies depending on what features different vendors offer however the basic motors are standard across the market. Brushless DC motors are primarily being implemented in the vacuum suction motor, brushed bar, and mop motor. Some customers use BLDC in the wheels of vacuum robots with hall sensors due to the quiet operation and longer motor life compared to brushed. The control algorithms in the MCx devices make them competitive. Control refers to the algorithms that are integrated in the device that make each MCx8316x applicable to different motors.

MCx8316x

All three devices have the operating voltage of 4.5-V to 35-V with a 40-V abs max and 8-A peak current. The package size of these devices are 7 mm x 5 mm with a height of 1 mm allowing customers to choose what device they need based on the sub-system they are implementing the motor driver in.

MCT8316A and MCF8316A

The MCT8316A and MCF8316A are a code-free sensorless BLDC motor drivers. MCT8316A provides code-free sensorless trapezoidal control solution while MCF8316A provides code-free sensorless Field oriented control (FOC) solution. Rotor position in MCF8316A is estimated using BEMF observers. Rotor position in MCT8316A is measured through Back EMF zero crossings. The trapezoidal solution is typically used for customers that require high speed operations (up to 3 kHz electrical speed) and quick startup times (<50 ms). The FOC solution is used for customers that want to drive speed-controlled applications and lessen the audible noise generated due to motor commutation.

MCT8316Z

The MCT8316Z provides a single-chip code-free sensored trapezoidal solution. MCT8316Z is used by customers in applications that require high startup torque and precise speed control.

Applications

For Vacuum robots, there are three primary sub-systems to consider for MCx8316x devices: the vacuum suction, brushed bar, and mop motor. The brushed bar and mop can be seen in Figure 1. Suctions motors are inside the vacuum robot and are not visibly seen on the outside of the robot.

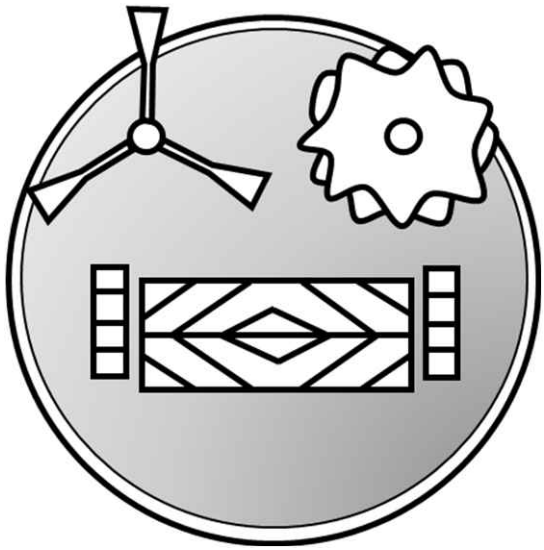

Figure 1. Vacuum Robot

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Suction Motor

The suction motor of a vacuum robot picks up the dirt and debris while going over different surfaces. This means that the motor will encounter varying levels of dirt and must suction debris over different floor types (carpet, hardwood, or tile). Because of this the MCT8316A and MCF8316A are highly recommended to customers. The MCF8316A and MCT8316A both can achieve high speeds of 1.5 kHz (90 kRPM for 2 pole motor) and 3 kHz (180 kRPM for 2 pole motor), respectively. These high motor speeds translate to faster suction power, which makes picking up dense areas of dirt easy to do. Both devices have a constant speed feature regulating the speed when encountering dynamic load conditions. For the use case of the suction motor this can be present when the vacuum robot moves from hardwood flooring to carpet. The higher resistance from the carpet will not affect the speed of the suction due the constant speed feature.

Reliable Motor Startup

The MCF8316A and MCT8316A devices share common startup features. With align or initial position detection (IPD) the rotor position of the motor is accurately sensed ensuring reliable motor startup

On-the-Fly-Startup

On the fly startup is a feature that allows smooth forward and reverse syncs when the vacuum robot is turned on and off repeatedly. For example, if the vacuum robot needs to be turned off to move an obstruction out of its way and immediately turned.

Power Limit

The MCF8316A and MCT8316A have a power limit featue that prevents power surge on the battery. The use case for this feature would be when the vacuum robot goes over an area with larger portions of debris and dirt. The sudden load change causes the motor to draw more power and will spike. The power limit feature sets a threshold for the power to avoid spikes from occurring. This lengthens the longevity of the battery that prevents the consumer from having to replace the part.

Automatic Deadtime Compensation

The MCF8316A device has another key feature that minimizes audible noise. The integrated FOC algorithm optimizes acoustics by smoothing out the phase current waveform. Figure 2 shows the MCF8316A phase current waveform.

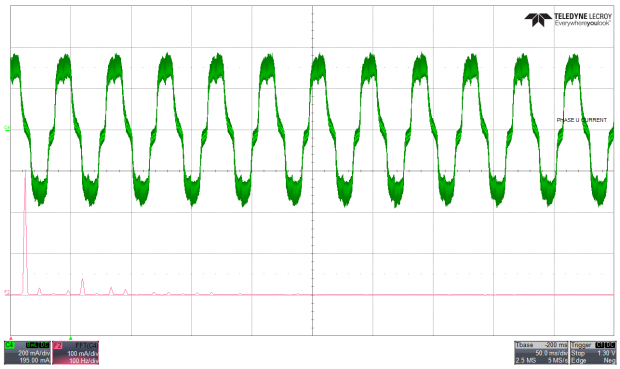

Figure 2. Phase Current Waveform and FFT - Dead Time Compensation Disabled

The sinusoidal shape is optimal to lower acoustics. The smoother the waveform, the lower the generated noise. In order to further smooth sinusoidal shape, the customer can enable dead time compensation. Figure 3 shows the MCF8316A phase current waveform after enabling dead time.

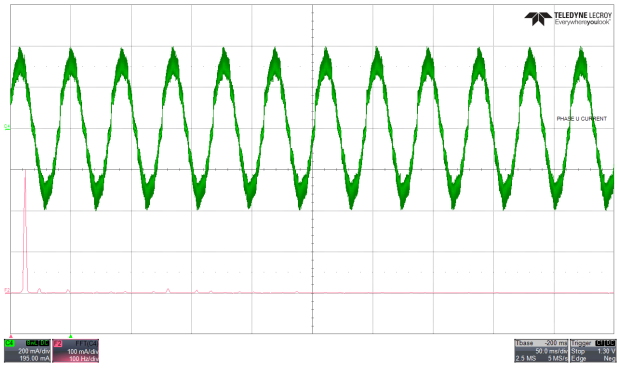

Figure 3. Phase Current Waveform and FFT - Dead Time Compensation Enabled

An experiment was performed using a hand-held sound level meter showing the noise levels at different motor electrical speeds before and after optimizing acoustics.

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Figure 4 shows the chart comparing audible noise with MCF8316A before and after optimizing acoustics in MCF8316A.

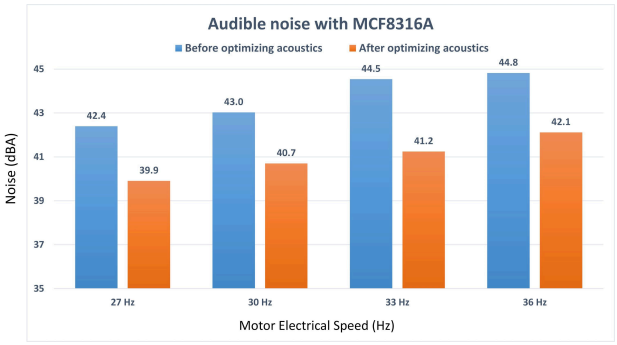

Figure 4. Audible Noise Comparison With MCF8316A

The MCT8316A has the ability to use 120° and 150° commutation. MCT8316A provides better acoustics with 150° commutation. Figure 5shows the chart comparing the acoustics between 120° and 150° commutation in MCT8316A.

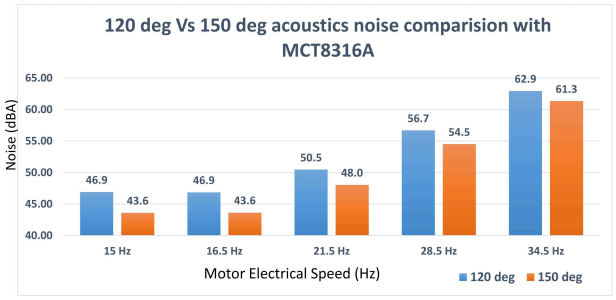

Figure 5. Audible Noise Comparison Between 120° Commutation and 150° Commutation

Vacuum robots are used as a multitasking device. Consumers start the robot and plan to do other things around the house while the robot is cleaning. Improving acoustics from the motor is a valuable quality to promote to consumers and both MCF8316A and MCT8316A have the ability to improve audible noise.

Brushed Bar and Mop Motor

For the brushed bar and mop motor, the MCT8316A and MCT8316Z is recommended. The MCT8316Z has the same qualities as the MCT8316A mentioned above including a few more features. The brushed bar and mop motor require higher torque and acceleration capabilities. This is due to the bar and mop directly interacting with the flooring and obstacles that the robot may encounter while running. For example, the brush bar runs over carpet and debris that could make the brushes get stuck such as food, hair, and even a sock. The higher torque that the MCT devices are able to reach makes the vacuum robot be able to run consistently during the dynamic load conditions.

Fast acceleration is another important feature that the MCT devices are able to achieve. Fast acceleration allows the device to easily reach variable speeds fast when moving from tight corners to larger areas of the rooms that are being cleaned.

Minimizing power loss is important in vacuum robots since this loss translates to thermal dissipation. Due to the varying loads that the device is encountering ensuring that the robot does not overheat is important. The MCT devices have the features Automatic Synchronous Rectification (ASR) and Automatic Asynchronous Rectification (AAR) coupled with the low $R_{DS(ON)}$ of 95 mΩ prevents high power losses and heat from being dissipated.

Table 1. Device Family Features

Device	High Speeds	Constant Speed	Reliable Motor Start Up	On the Fly Start Up	Power Limit	Fast Acceleration	ASR & AAR
MCT8316A	✓	✓	✓	✓		✓	✓
MCT8316Z	✓	✓	✓	✓		✓	✓
MCF8316A	✓	✓	✓	✓	✓		

Conclusion

The MCx8316x driver selection for vacuum robots covers varying levels of features that customers may require from their robot. The versatility being able to choose any of these integrated drivers for the use of a suction, brushed bar, and mop motor make these devices very valuable for a customer to implement in their design. The market continues to grow as more consumers are switching to smart devices and finding ways to make their homes more efficient. The MCx8316x is an all in one solution to incorporate the features consumers need.

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