PERFORMANCE MOTION DEVICES
MOTION CONTROL AT ITS CORE

Step Motor Noise

Step motors controlled with a digital current loop will be significantly quieter, run faster, and have lower operating temperatures

Experiment background

Step motors are present in approximately half of all motion control solutions. As compared to servo motors, less expensive step motors are often used in lower speed applications where the dynamic loading is predictable and minimal. There is no reason to pay the higher price of a servo motor with position feedback if the application requirements can be achieved with a step motor.

If the step motor performance needs improving, sometimes a "closed-loop" stepper system will be implemented by adding a position encoder to the step motor. While this solution will increase the dynamic response of the motor, it has several disadvantages:

To increase the performance of a step motor, an alternative is to optimize the behavior of the current control method without

- Additional cost of encoder
- Additional wires for encoder
- Additional risk of component failure
- Extra time spent on system commissioning to tune the closed loop response

requiring the addition of a position feedback encoder to the system. Current control is the responsibility of the motor amplifier (drive stage) and therefore system improvements can be made by selecting an amplifier with improved winding current regulation.

Stable control of a step motor requires control of the current in the motor windings. Historically this current is controlled with a "current chopper". In this case the full supply voltage is applied to the motor windings until the current reaches a predefined comparison value. After reaching this set value the voltage is removed from the motor winding for a fixed amount of time as a result of which the current will decrease. Typically the user has some control over the comparison value and the "off" time.

Performance Motion Devices employs an improved current control algorithm which applies a proportional voltage calculated from a PI (Proportional/Integral) current control loop. The implementation of a Pulse Width Modulation (PWM) scheme means that the effective voltage being applied to the motor winding is some fraction of the bus voltage. The result is a set of current waveforms in the two motor phases which are both much closer to the desired currents and much smoother. The increase in accuracy is especially notable when the current is crossing zero, where legacy current chopper drives do a poor job of regulation.

The improvement in the current waveform has several benefits at the system level. The most noticeable will be a reduction in audible noise which is a result of reduced vibration in the motor and the load attached to the motor. Any vibration present in the system represents wasted mechanical energy and increased motor temperature. Still another benefit is that the reduction in vibration implies there is more energy available for the desired mechanical response (acceleration and deceleration) and less energy is wasted on heating the motor.

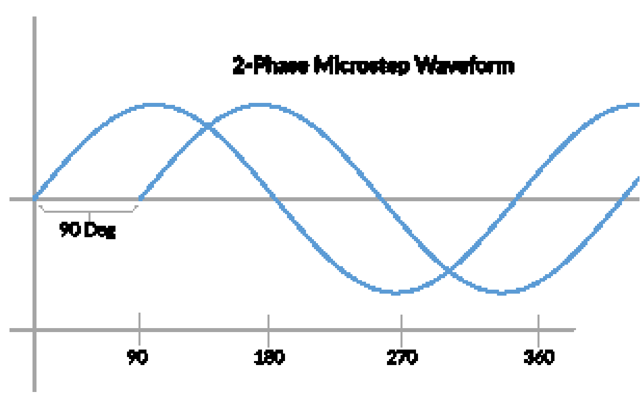


Figure 1: 2-Phase Microstep Waveform

An experimental system comprised of a step motor and an amplifier/ drive stage was created for the purposes of collecting comparative data. One setup utilized a legacy current chopper drive and another utilized Performance Motion Devices' DK58113 which uses a PI digital current loop.

One set of comparison data represents a test where the unloaded

Experimental Results

24V step motor is commanded to spin as fast as possible without losing steps (V_{max}). The other data set represents the noise and steady state temperature when running the motor at nominal speed/torque values (dB_{nom}, T_{nom}).

As can be seen from the data, the Performance Motion Devices digital current loop is able to drive the motor 20% faster with greater than 20dB lower noise and a significantly lower operating current than the conventional chopper drive. Additional data was collected using a different step motor designed for high speed operation.

Again, the digital current loop significantly outperforms the chopper drive.

Control board	Vmax (rps)	Vnom (rps)	dBnom	Tnom (ºC)
DK58113 from PMD	10.25	7.0	52.8	34.6
Current Chopper	8.1	7.0	73.2	42

The experiments above represent operational behavior during continuous rotation. Many times the step motor will drive a linear load within a fixed positional range. The rotary-to-linear translation is typically achieved with a belt drive or a lead screw in higher end applications. The video below demonstrates a linear stage driven with a lead screw and step motor. In the first video segment a conventional current chopping drive is being used and in the next segment, a PMD DK58113 drive with Proportional Integral

Control Board	V_{max} (rps)
DK58113 from PMD	42.9
Current Chopper	38.2

(PI) digital current loop control is utilized.

The reason the current loop operation outperforms the current chopper, is related to the shape of the current waveform in the motor winding. Two specific properties of the waveform can be analyzed in order to understand where the relevant differences are between the current loop and current chopper waveforms.

The smoothest operation of a step motor results from generating a sinusoidal current waveform in the windings. A smoother sinusoid will result in smoother motion. Both drive techniques employ the use of a “switching” voltage on the motor windings.

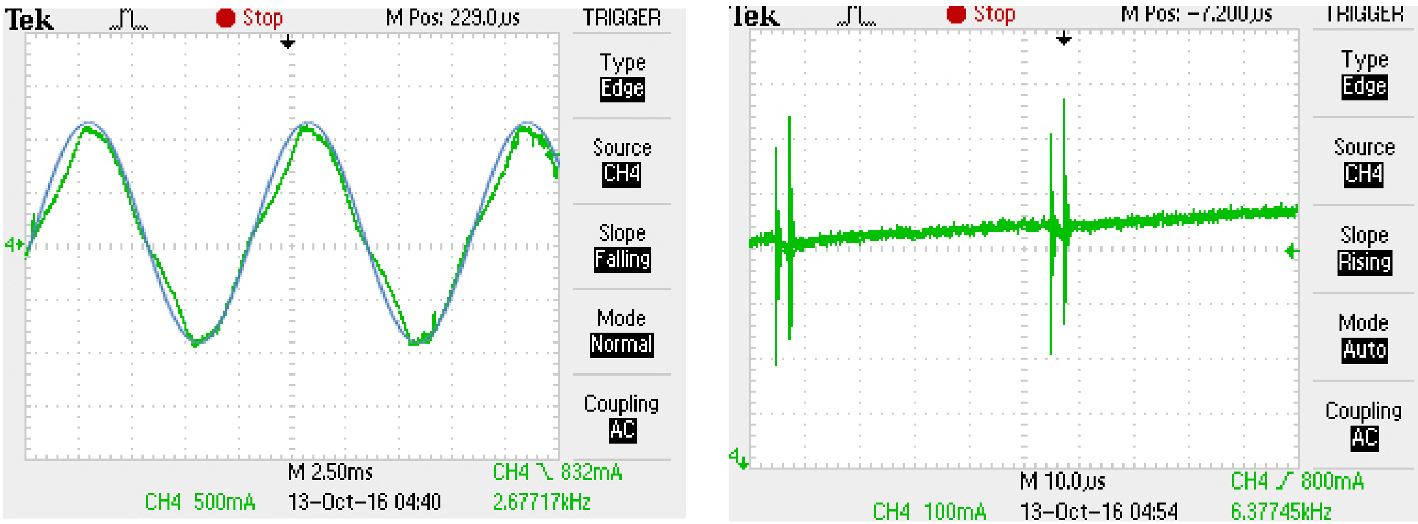
The switching event produces a “ringing” or “ripple” in the current waveform which is a deviation from the desired shape. This deviation is wasted energy which causes excessive motor heating. The amount of wasted energy scales with the amplitude of the ringing.

Experimental Results (cont.)

Figure 2 demonstrates the shape and current ripple resulting from the use of the current chopper drive. In figures 2a and 3a, a sine wave has been over-laid onto the waveforms so as to better show how the waveform approaches a pure sine function. Figure 2b is generated by zooming on a small section of the waveform in 2a.

Figure 3 demonstrates the waveform when running the same motor under the same kinematic conditions using Perfromance Motion Devices' PI current loop technology.

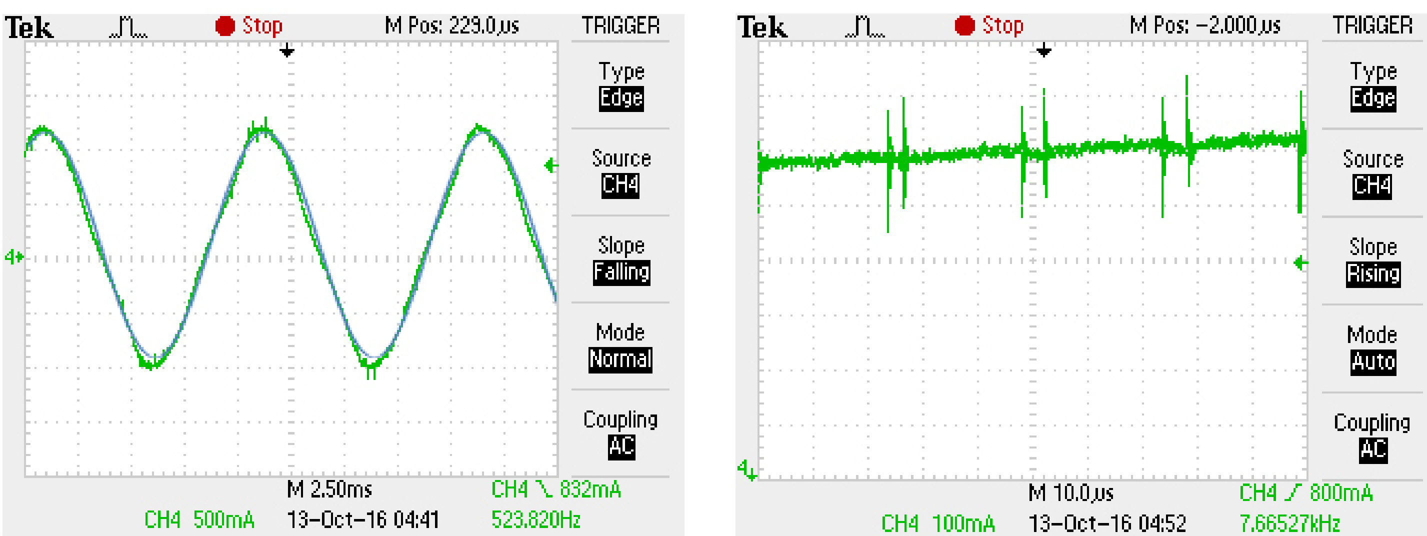
When comparing Figure 2a to 3a it can be observed that the waveform in Figure 3a has a much smoother sinusoid. A comparison to a sine wave in Figure 2a shows a much poorer correlation of the actual wave form to the sine wave form, particularly during the latter half of the rise and fall of the motor current, whereas the correlation to a sine wave in Figure 3a shows that the PMD current



2a. 2b.

Figure 2: Current Chopper Waveform

loop approach is a significantly better match to the ideal sine wave function. Furthermore, the amplitude of current ripple in Figure 3b is half that of Figure 2b. The frequency of the ripple is faster in Figure 2b since the PMD digital current loop, running at 20 kHz, will



3a. 3b.

Figure 3: PMD Current Loop Waveform

Experimental Results (cont.)

switch the voltage faster and more periodically. The switching frequency of the current chopper varies, as it depends on how quickly the current transient reaches the comparison value.

In conclusion, it is clear that conventional step "current chopper" drives result in a large amount of step motor noise, needless motor heating, and consume more current. A digital current loop will result in significantly quieter and lower temperature motor operation which is beneficial in many applications such as laboratory instruments, medical equipment, security camera operation and 3D printers.

About Perfromance Motion Devices

Performance Motion Devices provides reliable multi-axis motion solutions and unparalleled technical support such as; motor set-up and tuning, motion board design, electrical schematic review and custom software/hardware development services. We offer a full line of ICs, modules, digital drives, and boards, plus easy-to-use software which will bring your system to life. Our intuitive development tools and common motion architecture make design, development, and validation of your motion system fast, predictable and low-risk.

Performance Motion Devices' ensemble of industry-leading customers provide us with extensive experience across a wide range of applications: including; lab automation, liquid handling, precision fluid pumping, centrifuge control, sample handling, robotics, 3D printing, packaging, semiconductor manufacturing, and more.

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