Application Brief

Smart tune for quiet and smooth stepper motor operation

Texas Instruments

Almost all stepper motor drivers feature multiple decay modes, such as slow, fast and mixed decay. While mixed decay mode with fixed amount of fast decay is often a good balance between purely fast and slow decay, there are still certain issues which can arise, such as:

- Non-sinusoidal current waveforms and loss of current regulation.
- Repeated patterns in the coil current waveform often fall in the audible frequency range, resulting in a noisy motor operation.
- Conventional fixed-fast decay modes also need to be tuned by the user to identify a working solution, and the tuning is often a lengthy and time consuming process.
- Fixed-fast decay modes do not adjust themselves to variations in supply voltage, load current, motor parameters and step frequency.

Figure 1 shows a coil current waveform of a stepper using a decay mode with a fixed percentage of fast decay. This waveform distorts on the decreasing steps because the mixed decay mode does not use enough fast decay to properly regulate the current. This kind of current distortion causes an uneven torque in the motor, which will produce vibration and noise during operation.

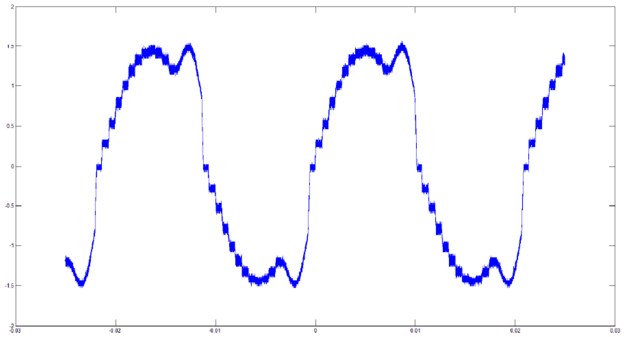

Figure 1. Coil current waveform with slow/mixed (30% fast) decay

Another source of noise in stepper motors comes from magnetostriction caused by the PWM (Pulse-width Modulation) current chopping scheme in the stepper driver. Stepper motor drivers use a PWM current chopping scheme to periodically turn ON and OFF the H bridges and regulate the coil current. Magnetostriction (mechanical deformation of the coils in changing magnetic fields) converts the PWM switching frequency into audible mechanical vibration. The impact of magnetostriction is lessened by pushing the switching frequency out of the audible range and reducing the amplitude of the ripple current.

System level designers can spend a significant amount of time trying to ensure noise free motor operation. Conventional fixed-fast decay modes try to mitigate the issue by increasing the PWM switching frequency, increasing the level of microstepping and decreasing the coil current level, whenever possible. However, none of these measures guarantee quiet and smooth operation at all operating conditions.

To ensure quiet and smooth operation, an ideal decay mode will be an adaptive decay mode that can change the percentage of fast decay as supply voltage, motor inductance and resistance, load current, motor speed and many other parameters vary during operation. No tuning will be required in such an adaptive decay scheme.

TI stepper drivers such as DRV8424, DRV8426, DRV8436, and DRV8886AT feature a smart tune decay mode, which is an adaptive decay scheme. Smart tune adapts itself to changing operating conditions and motor parameters, leading to smoother motion for the stepper motor. Smart tune also minimizes motor noise and vibration by preventing loss of current regulation.

The coil current waveform of the same motor as in Figure 1, but with smart tune decay mode, is shown in Figure 2.

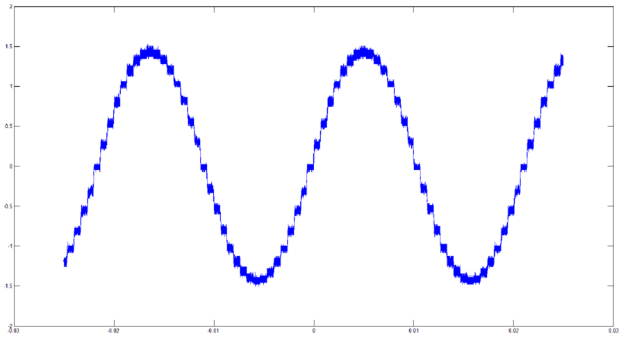

Figure 2. Coil current waveform with Smart Tune (Ripple Control)

Figure 3 and Figure 4 show in detail the differences in coil current shape between using slow/mixed decay (30% fast decay during decreasing steps) and smart tune decay modes.

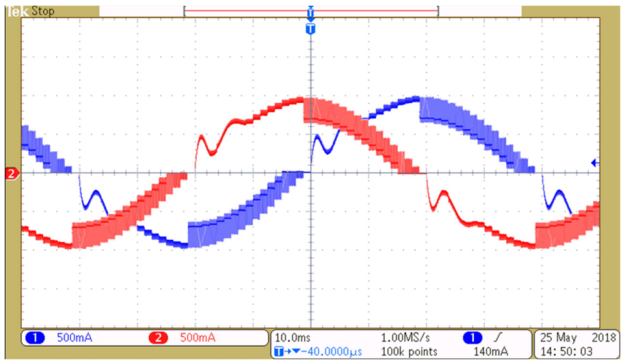

Figure 3. Coil current waveform with Slow/Mixed (30% fast)

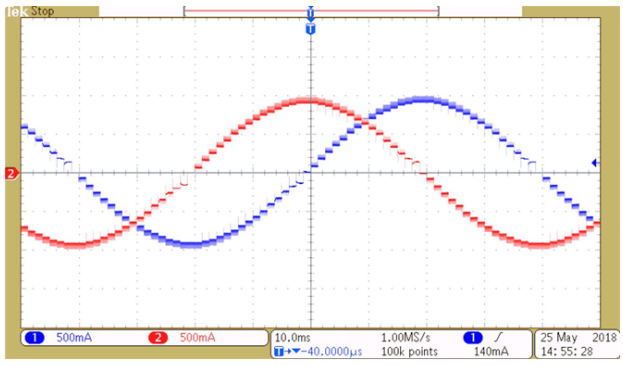

Figure 4. Coil current waveform with Smart Tune

Clearly smart tune results in smoother waveforms which results in quieter motor operation.

Figure 5 compares the power spectrum of mixed decay and smart tune in the audible frequency range. As is evident, mixed decay mode of operation generates 10 dB to 20 dB more noise than smart tune.

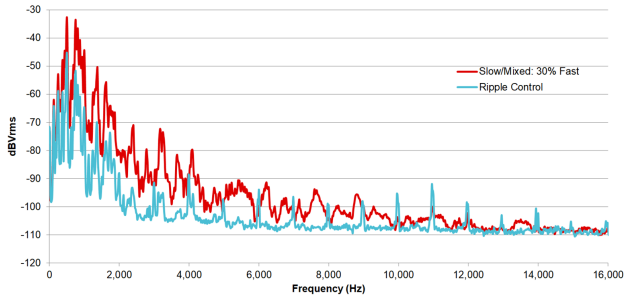

Figure 5. Power spectrum comparison

Low-frequency components are more significant for mixed decay than for smart tune – which leads to the mixed decay mode of operation causing audible noise and vibration emanating from the motor. The overall lower noise levels from smart tune operation are the result of superior automatic tuning capability of smart tune, which generates an almost ideal sinusoidal current waveform.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265