Application Note

How to Reduce Power Consumption in Stepper Motor Drivers Using Holding Torque

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ABSTRACT

This application note describes methods to reduce power consumption and improve system thermal performance using Texas Instruments' stepper motor drivers. This process is achieved by reducing the current consumption of a stepper motor during the holding mode. A manual method is proposed using the VREF reduction technique with DRV8818 as an example. This is followed by an explanation of the Standstill Power Saving Mode in advanced stepper motor drivers like the DRV8452 and DRV8462.

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1 Introduction

Optimal power consumption and heat dissipation in stepper motor drivers is important due to high motor current values. The shape of motor current in a stepper is determined by the applied voltage, speed of operation, and the motor parameters like resistance and inductance. Generally, a stepper motor works in the STEP/DIR interface with each pulse corresponding to the next step. Proper current regulation is required at every step to provide enough torque to drive the load, avoid a stall condition, and make sure that no missed steps occur. Hence, a fixed current value is determined at each step for current regulation as a percentage of full-scale current. To obtain maximum torque output from the motor, a stepper needs to be run at the maximum current value possible. This value can be limited by the stepper motor or the minimum overcurrent protection (OCP) value of the driver as specified in the data sheet. However, this causes thermal challenges in applications such as PLCs and textiles where a compact, dense PCB contains multiple motor driver ICs running simultaneously.

In many end applications, stepper motors do not require constant running operation. Steppers are used for accurate position control where the motor follows a rotate-stop-rotate pattern. During this stop condition, the motor does not move and is said to be in the holding position. During this time, the motor requires minimum torque output to maintain position. If the motor current value is reduced during this state, the device consumes significantly less power and leads to better system thermal performance.

2 Method A: Reducing VREF Manually

In low cost stepper drivers such as the DRV8818, the peak current regulation value, I_{TRIP}, in the motor current sine wave is calculated using the equation:

$$I_{TRIP} = V_{REF} \times K \quad (1)$$

Where K is a constant. For example, in DRV8818,

$$I_{TRIP} = V_{REF} \times \frac{1}{8 \times R_{SENSE}} \quad (2)$$

Where, R_{SENSE} is the value of sense resistor in ohms. This allows manual control of current regulation value at every step by the voltage on the VREF pin.

2.1 Experiment and Results

A set up was created in the lab using a DRV8818EVM and a function generator. The block diagram is shown in Figure 2-1. The function generator is used to provide a periodic voltage signal to the VREF pin with different duty cycles. The diodes prevent reverse current flow into the MCU from the function generator.

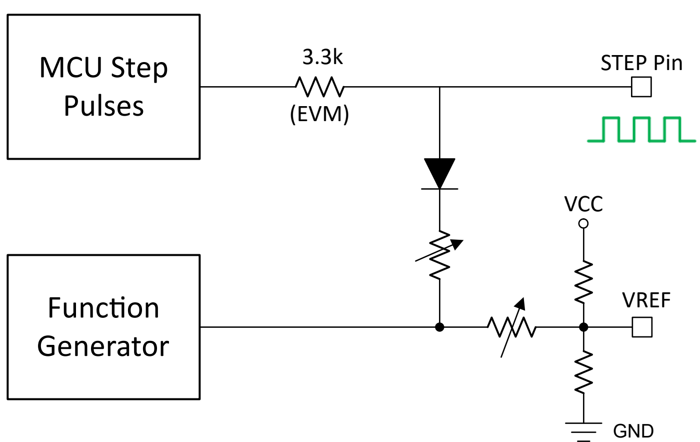

Figure 2-1. Block Diagram of Manual VREF Reduction Method

Table 2-1 summarizes the test conditions. A graphical depiction of the results is shown in Figure 2-2. Please note that 100% duty refers to the condition where a stepper motor is run constantly with a peak current value set by VREF.

Table 2-1. Test Conditions for Manual VREF Reduction Method

Parameter	Value
VM	24V
Mode	Mixed Decay
Speed	1000 pps
Run time	5 mins

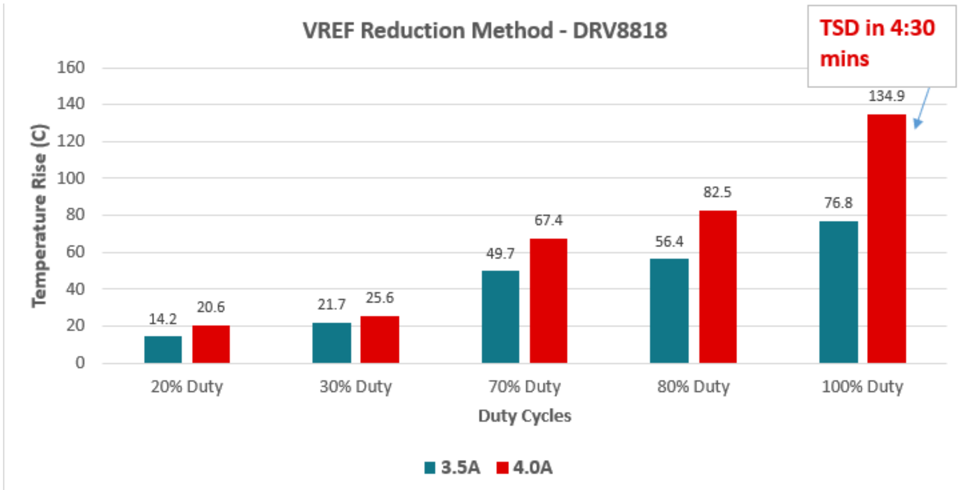

Figure 2-2. Temperature Rise While PWM-ing VREF

Thus, the manual VREF reduction method reduces power consumption and improves thermals. Furthermore, this method also allows an increased value of motor peak regulated current without hitting the thermal shutdown (TSD) temperature value.

An example waveform is shown in Figure 2-3 where the blue signal denotes the periodic VREF voltage, green signal denotes the motor current, and yellow signal denotes the step signals.

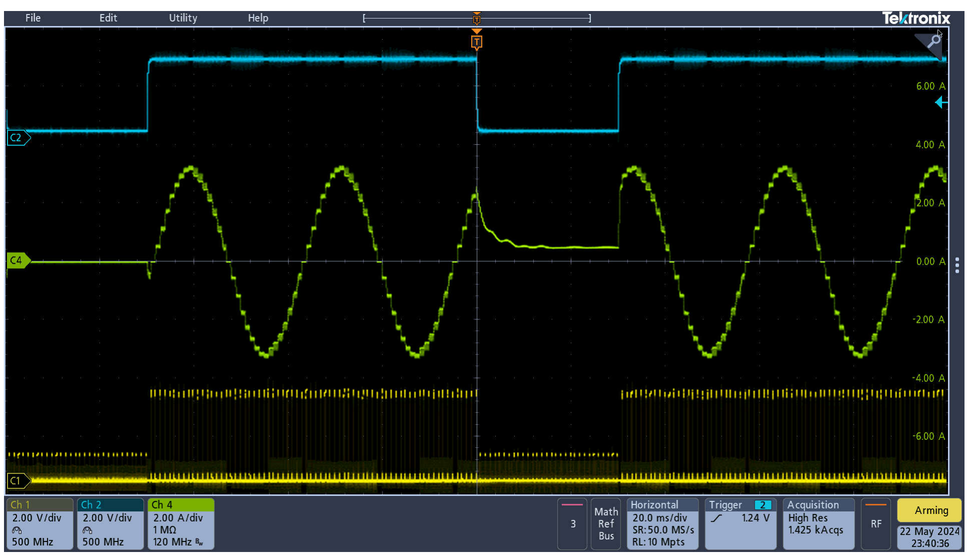

Figure 2-3. Example Waveform

3 Method B: Standstill Power Saving Mode

There are multiple ways to adjust the regulated current value at each step. As mentioned earlier, DRV8818 uses a dedicated VREF pin using Equation 2 to calculate the peak current. The VREF pin voltage in a motor driver is generally adjusted using the buffered DAC in an MCU for high accuracy.

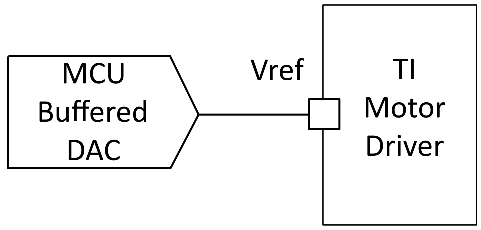

Figure 3-1. VREF Control Using MCU DAC

However, most low-cost micro-controllers have limited buffered DAC resources (usually just one). This makes them expensive to drive multiple stepper loads. Besides, the accuracy requirement for regulating current calculated by VREF is generally not too high in most use cases. As an example, a 5% error on VREF or regulated current is acceptable, without causing obvious performance differences. Thus, PWM-ing with a low pass RC filter can also be a possible option to adjust the VREF voltage. Mainstream MCUs normally provide more than 10 PWM channels making it easier to control the VREF of multiple motor drivers with a single MCU.

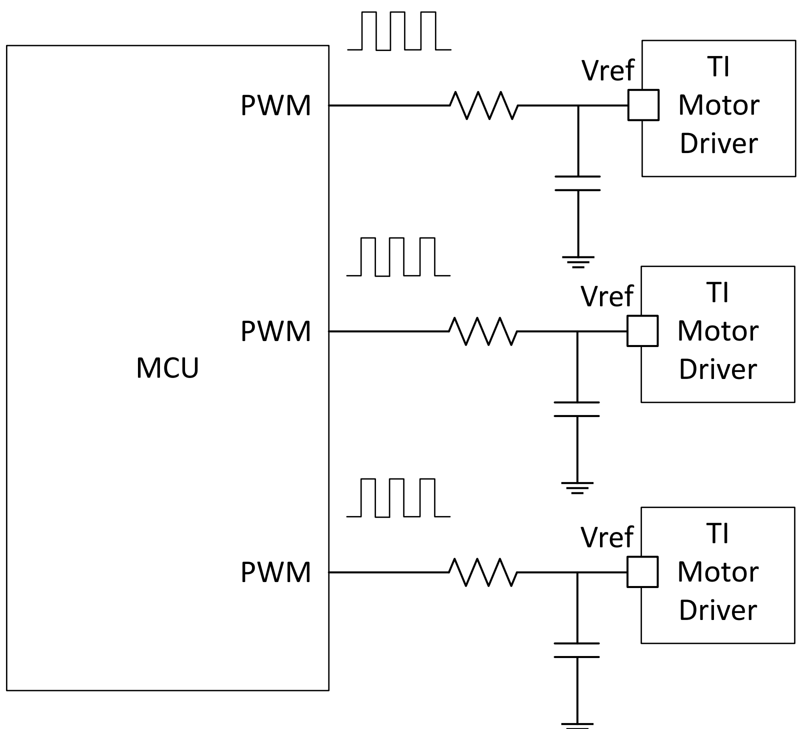

Figure 3-2. VREF control using PWM

As a further improvement, Texas Instruments' advanced motor driver series DRV8452 and DRV8462 integrate a standstill power saving feature. In this mode, the device automatically reduces the regulated current to a holding current value to reduce power loss. This eliminates the need to change the VREF pin voltage manually.

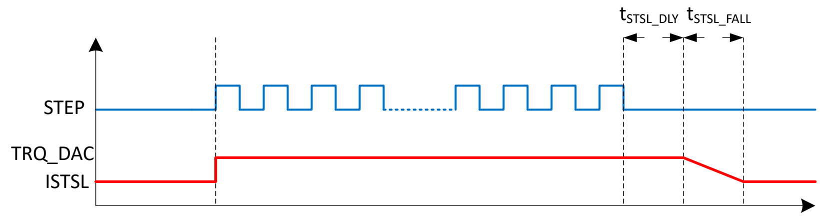

Figure 3-3. Standstill Power Saving Method

When the controller is not sending any step pulses and the motor is holding the same position, DRV8452 and DRV8462 can be configured to operate in the standstill power saving mode. When this mode is enabled by writing 1b to the EN_STSL bit, the power dissipation of the system can be reduced by lowering the coil current from run current to holding current.

After the last STEP pulse, the device waits for an amount of time programmed by the TSTSL_DLY register, after which the coil currents are ramped down from 'run' current to holding current over a time period programmed by the TSTSL_FALL register, as shown in Figure 3-3. This feature can be used to switch between a lower hold current and a higher run current by the controller thereby reducing power dissipation when the stepper is on hold for extended periods of time in an application. The STSL flag goes up to indicate that the device is in standstill power saving mode. Once the next STEP pulse is detected, the coil current immediately ramps up to the 'run' current value. The available options for TSTSL_FALL and TSTSL_DLY are mentioned in the data sheets of DRV8452 and DRV8462.

The 'run' current is programmed by the TRQ_DAC register and the holding current is programmed by the ISTSL register. In advanced motor drivers like DRV8889-Q1, DRV8899-Q1, and DRV8434S, a torque DAC is integrated which allows the host MCU to adjust motor driver current through SPI interface. Users can scale the output current by adjusting the TRQ_DAC register expressed in %. The full-scale regulation current can be calculated using the equation:

$$I_{FS} = V_{REF} \times K \times TRQ\_DAC(\%) \quad (3)$$

3.1 Experiment and Results

The DRV8452 and DRV8462 can be configured to operate in the standstill power saving (SPS) mode by setting EN_STSL to 1b when no step pulses are being sent by the MCU. Power dissipation is reduced by lowering coil current from run current to the holding current value. Further details on how to configure the device for power saving can be found in the Standstill Power Saving Mode section of the *DRV8462: 65 V, 5-10 A Stepper Motor Driver for High Efficiency and Noiseless Operation,* .data sheet.

An experiment was run with a DRV8462EVM for a comparative study in the operation of a stepper motor with and without standstill power saving mode. Test conditions are mentioned in Table 3-1.

Table 3-1. Test Conditions for Standstill Power Saving Method

Parameter	Value
VM	24V
Microstepping	1/16
ITRIP	2A
Running time	250ms
Standstill time	100ms
Holding Current	20% of Running Current

The following figures display waveforms and pictures from a thermal camera with SPS mode disabled and enabled. For images from the thermal camera, the left image shows the initial temperature while the right image shows the final temperature. The results showing temperature difference are summarized in Table 3-2.

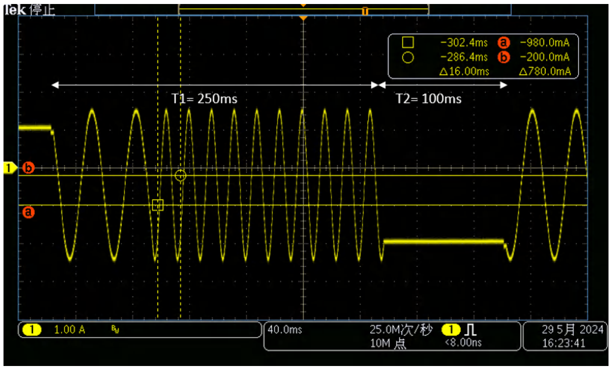

Figure 3-4. Standstill Power Saving Mode Disabled

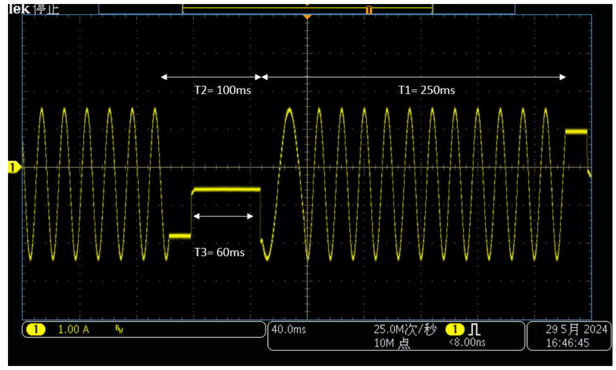

Figure 3-5. Standstill Power Saving Mode Enabled

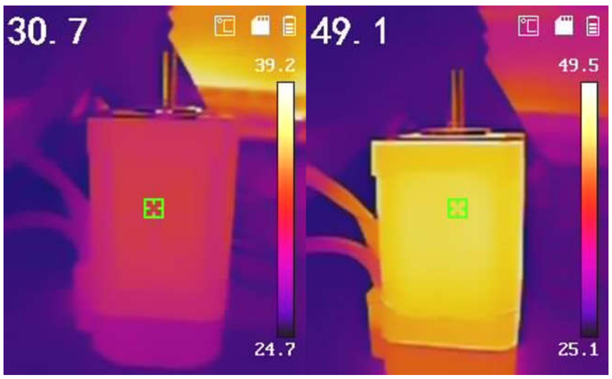

Figure 3-6. Temperature Difference in Motor - SPS Mode Disabled

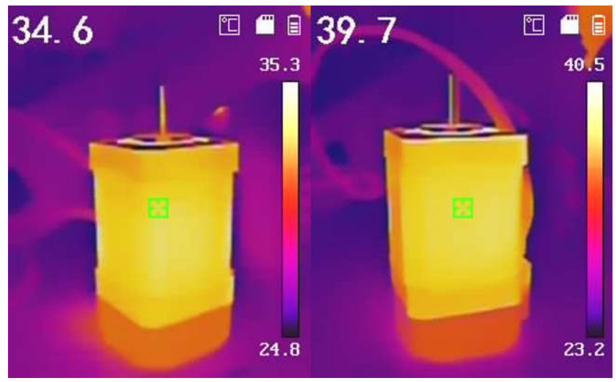

Figure 3-7. Temperature Difference in Motor - SPS Mode Enabled

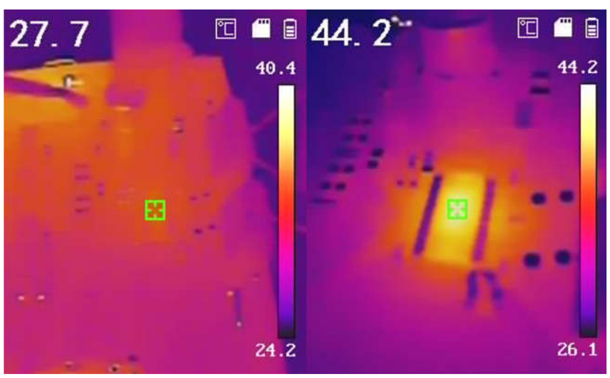

Figure 3-8. Temperature Difference in IC - SPS Mode Disabled

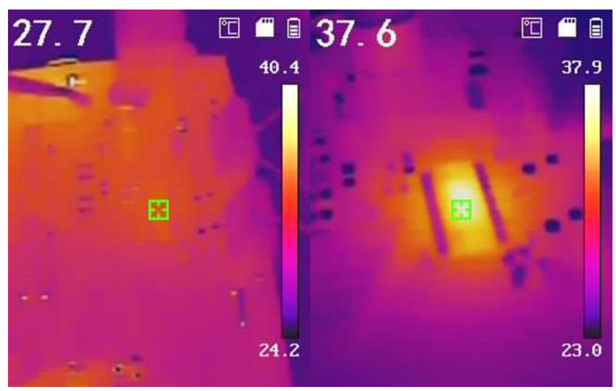

Figure 3-9. Temperature Difference in IC - SPS Mode Enabled

Table 3-2. Standstill Power Saving Mode Thermal Benefits

Standstill Power Saving Mode	Disabled	Enabled
Motor Temperature Difference	18.4°C	5.1°C
IC Temperature Difference	16.5°C	9.9°C

4 Summary

One of the methods to reduce power consumption in stepper motor drivers is using the holding torque of the motor. In simple drivers, this can be done using the VREF reduction technique to lower the regulating current during *holding mode*. In advanced stepper drivers like the DRV8452, this can be done by enabling the inbuilt Standstill Power Saving feature. Results show that significant thermal benefits can be obtained using these methods. The reduced temperatures also allow the driver to carry higher current than the full-scale value.

5 References

- Texas Instruments *DRV8818 35V, 2.5A Bipolar Stepper Motor Driver With Current Regulation and 1/8 Microstepping,* data sheet.
- Texas Instruments *DRV8452 50V, 5A, Dual H-Bridge Stepper Motor Driver With Smart Tune, Stall Detect and Auto-Torque,* data sheet.
- Texas Instruments *DRV8462 65V, 10A dual H-bridge stepper motor driver with smart tune, stall detect and auto torque,* data sheet.
- Texas Instruments *DRV8818 Evaluation Module.*
- Texas Instruments *DRV8462 Evaluation Module.*

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