AN13724

Stepper Motor Control on LPC55S3x

Rev. 1 — 13 November 2023 Application note

Document information

Information	Content
Keywords	AN13724, Stepper, Motor Control, LPC55S3x
Abstract	This documentation introduces basic stepper motor control on LPC55S3x MCU.

1 Introduction

This application note deals with open loop control of a bipolar stepper motor on the LPC55S36 EVK, which is equipped with two FRDM-MC-LVPMSM boards. It presents possibilities of how to set up, evaluate, and control this kind of motor.

1.1 Who should read this manual

This document is useful for people who want to understand MCU setup and basic control of a two-phase stepper motor. There is a brief introduction to stepper motors and basic control methods. AN13724SW is available with examples for MCUXpresso IDE. FreeMASTER real-time debugger is used as an application GUI.

2 Introduction to stepper motors

The stepper motor is a brushless motor that allows by its construction to divide a full rotation into some equal steps. If the motor is correctly sized to the application in respect to torque and speed, command the position of the motor to move and hold at one of these steps without any position sensor for feedback (an open-loop controller).

There are three types of stepper motors:

- Permanent magnet stepper
  A permanent magnet stepper motor uses a Permanent Magnet (PM) in the rotor and operates on the attraction between the rotor PM and the stator coils.
- Variable Reluctance (VR) stepper
  VR motors have an iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap. Therefore, attract the rotor points toward the stator magnet poles.
- Hybrid synchronous stepper
  Hybrid synchronous are a combination of the permanent magnet and variable reluctance types.

There are two basic winding arrangements for the electromagnetic coils in a two-phase stepper motor:

- Unipolar
  The unipolar stepper motor has one winding with center tap per phase. Switch on each section of the winding for each direction of the magnetic field.
- Bipolar
  Bipolar motors have a pair of single winding connections per phase. To reverse a magnetic pole, reserve the current in a winding. Therefore, perform the driving circuit with an H-bridge arrangement.

3 Application hardware setup

For evaluation of this application note, LPC55S36 EVK and two freedom low voltage power stage boards FRDM-MC_LVPMSM are required, as shown in Figure 1. Freedom power stage boards are intended for three-phase motors. However, we use only two inverter legs of each board to create an H-bridge for independent stepper motor phases.

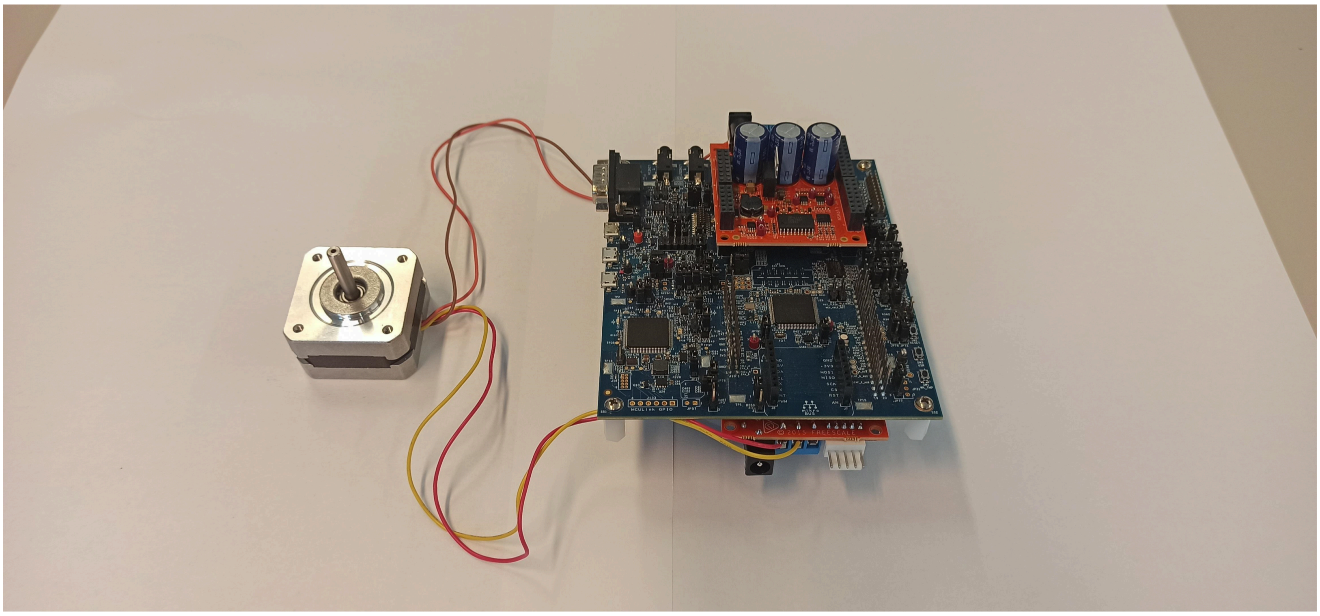

Figure 1. Hardware setup

The motor used by this application has a bipolar stepper motor Nanotec ST4118X1404-A. Connect each motor winding to Phase A and Phase B output of the FRDM board. Connect the power supply (20 V DC) to both freedom boards. Various bipolar stepper motors are possible to connect but there must be done tuning of the applied voltage.

Ideally, we can use a different board, which is more suitable for stepper drive, such as KIT33932EKEVBE. It arranges MCU PWM outputs more effectively, but some wiring must be done from this power stage to PWM, ADC, and power supply EVK headers.

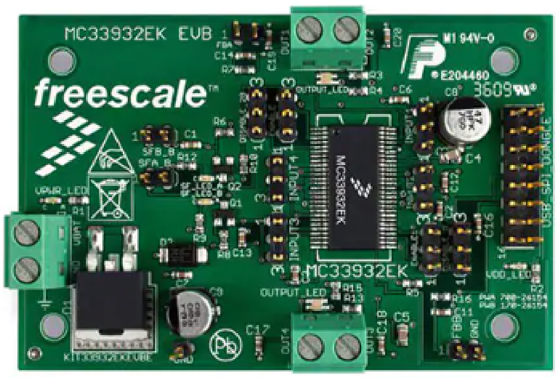

Figure 2. Alternative NXP power stage for stepper motors

4 Operational modes

This application note describes basic control of the stepper motor including the possibility to online change unipolar (soft switching) to bipolar (hard switching) and single phase, full-step to micro-step control. The software example is done as a framework to develop more complex control methods.

4.1 Switching method

Figure 3 shows the difference between unipolar switching and bipolar switching on the case of micro-step (sinusoidal) modulation. Unipolar switching applies PWM to one leg of each H-bridge and keep the second leg in a zero duty cycle. This setting enables the current to decay through the bottom transistors. For opposite sine polarity, PWM drives the second leg and the first leg has a zero duty cycle. In the bipolar mode, H-brigle PWMs of each leg switch in counter phase. When zero voltage is required, there is a 50 % duty cycle. The motor is controlled in an open loop, so there is no feedback or current control in this example.

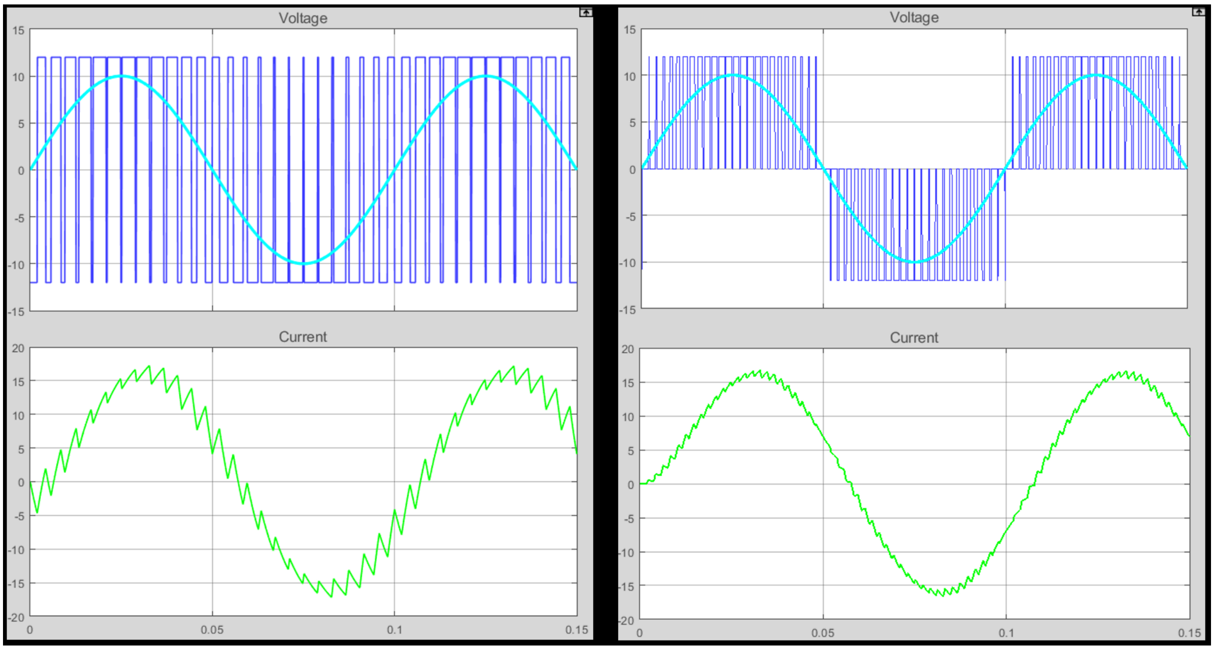

Figure 3. Switching method comparison, bipolar (left), unipolar (right)

4.2 Single phase step mode

To perform the single phase step control, apply the required voltage by fixed duty cycle to the appropriate phase according to timing in Figure 4.

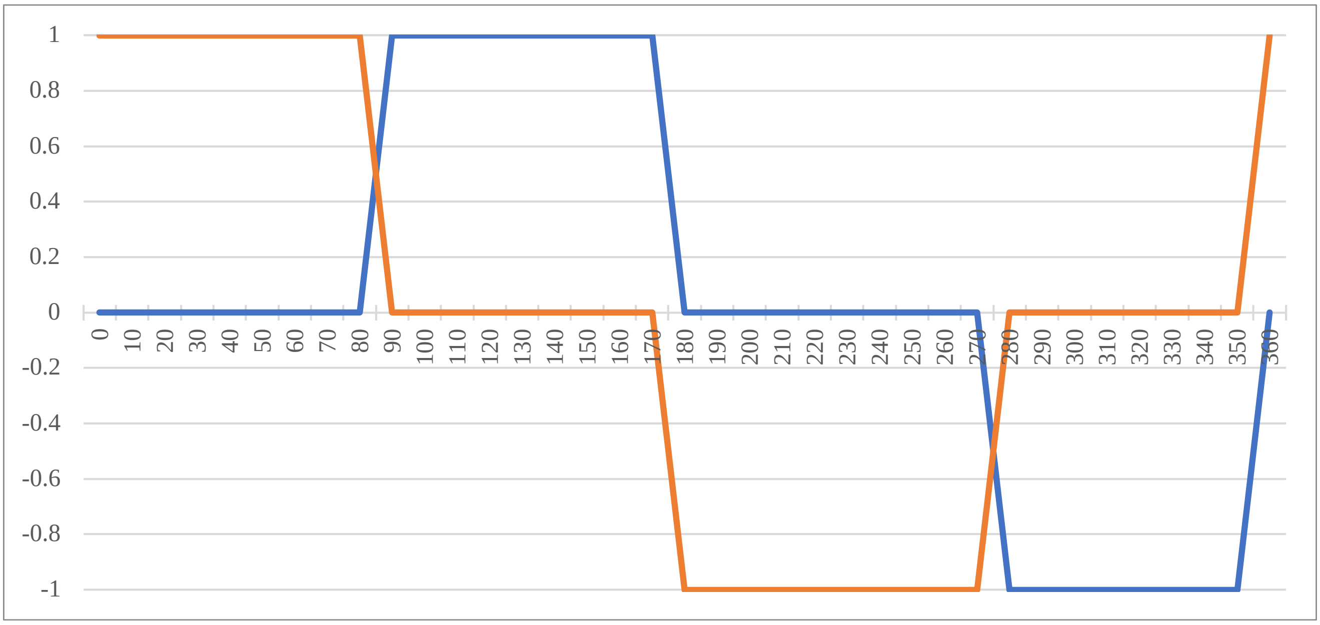

Figure 4. Single phase step control timing

[Figure 5](#) and [Figure 6](#) show real motor waveforms. On the top grid, there is Phase A voltage (yellow) and current (violet). On the bottom grid, there is Phase B voltage (blue) and current (green).

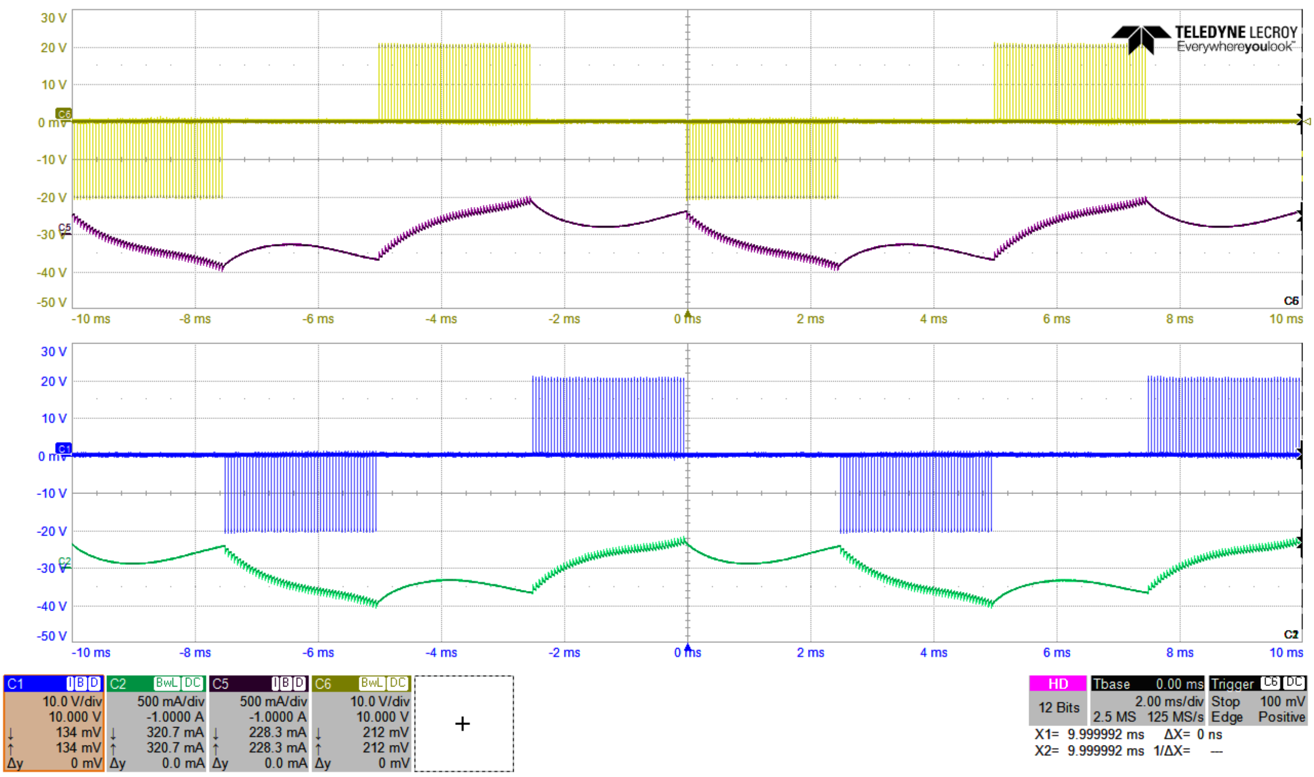

Figure 5. Single phase step control, unipolar switching

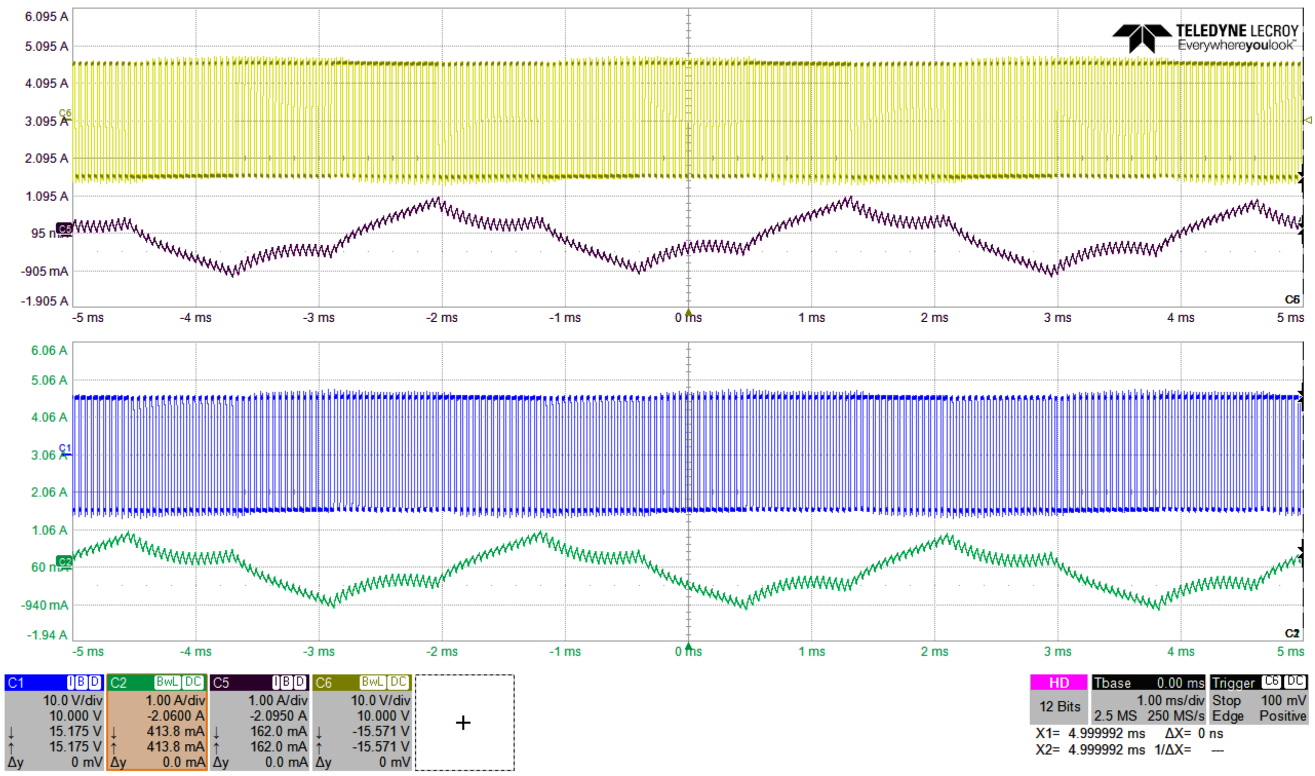

Figure 6. Single phase control, bipolar switching

4.3 Full-step mode

To perform the full step control, apply the required voltage by fixed duty cycle to the appropriate phase according to timing in Figure 7.

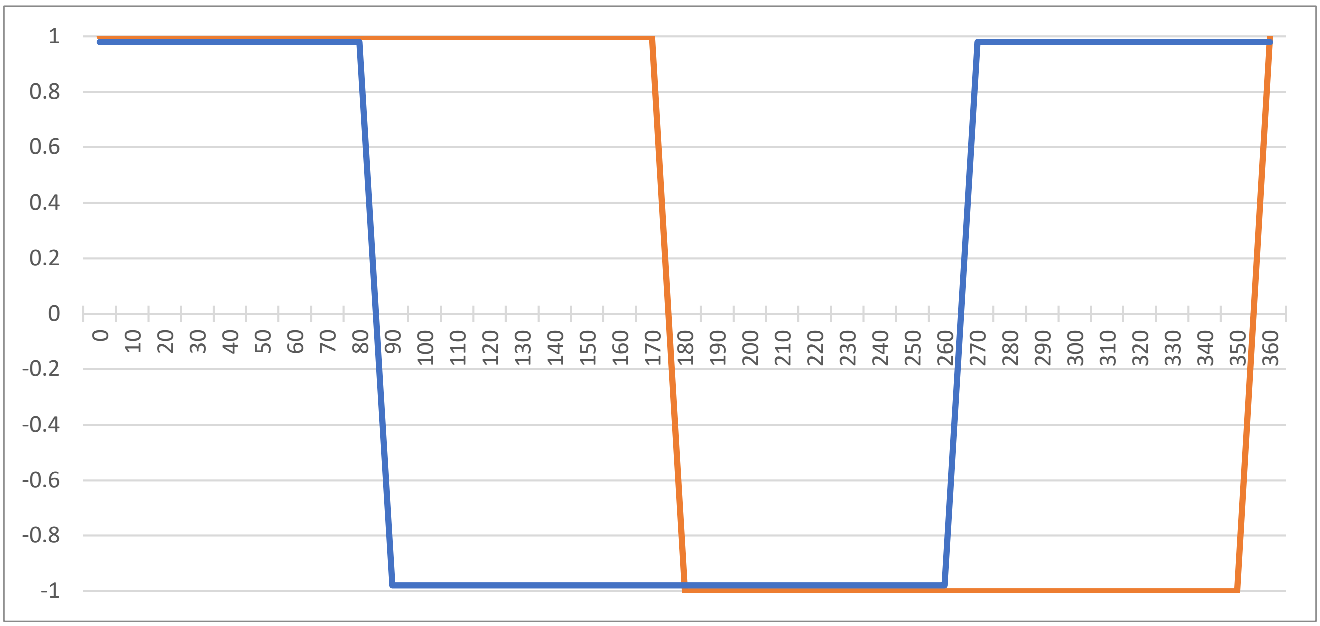

Figure 7. Full step control timing

4.4 Micro-step mode

To perform the micro-step mode, apply a sin/cos rotating system to motor phases with defined angle increment (equal to speed) and sin/cos amplitude.

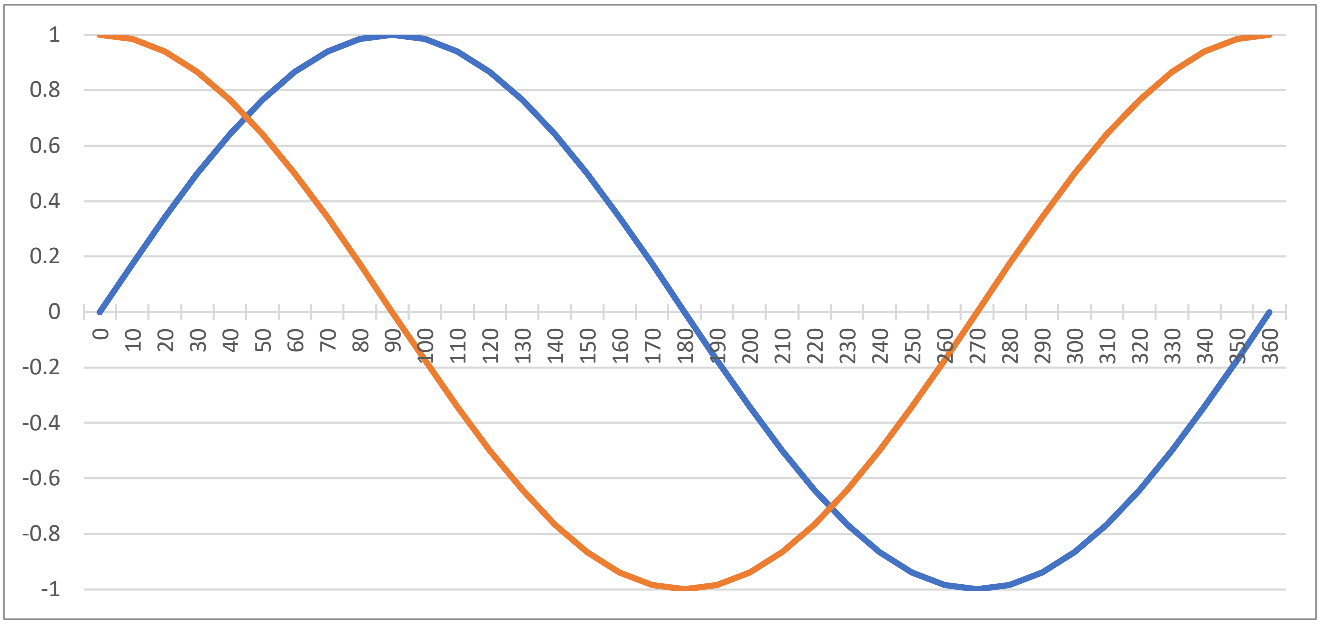

Figure 8. Micro step control timing

Figure 9 and Figure 10 show real motor waveforms. On the top grid, there is Phase A voltage (yellow) and current (violet). On the bottom grid, there is Phase B voltage (blue) and current (green).

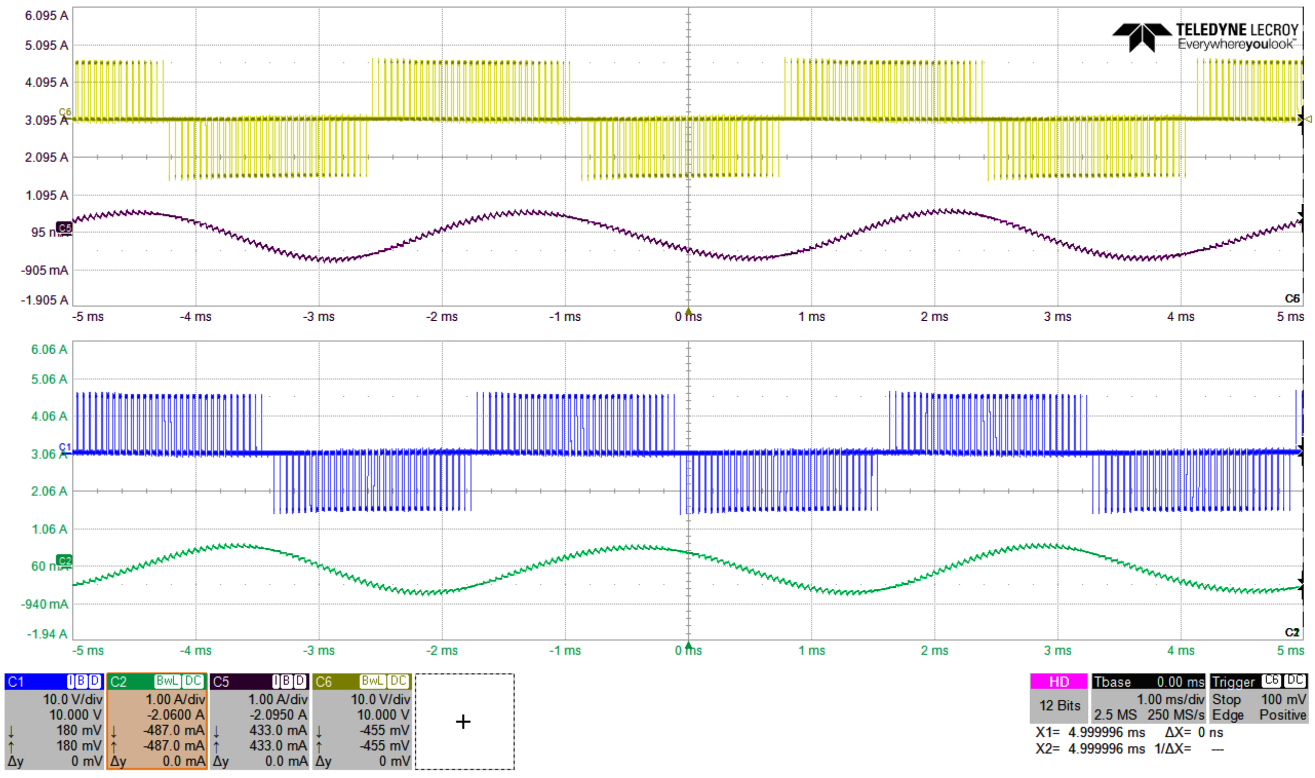

Figure 9. Micro step control, unipolar switching

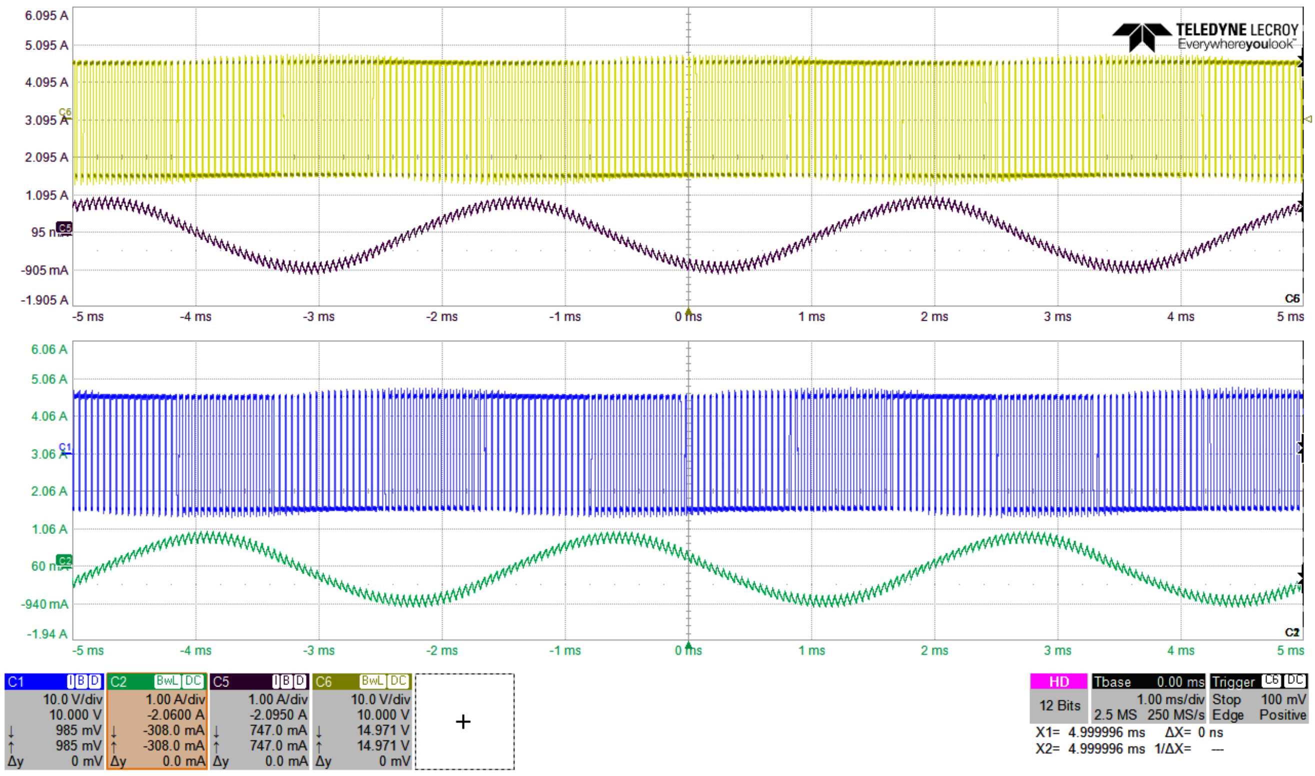

Figure 10. Micro step control, bipolar switching

4.5 PWM setup

On MCU, there are two eFlexPWM modules: PWM0 and PWM1. To create PWM signals for H-bridges with defined dead time, two submodules (0,1) are used for each PWM module. For bipolar mode, there is an inverted polarity of each submodule 1. The preprocessor pre-calculates PWM module from a defined frequency. The default PWM frequency value is 20 kHz. There is an enabled PWM interrupt `FLEXPWM0_RELOAD0_IRQHandler`. Within this interrupt, there is done everything concerning control of the stepper motor. For details, see the simple source code example.

5 Evaluation software

MCUXpresso, LPC553x/LPC55S3x SDK package, and the FreeMASTER tool must be installed.

To run the example, perform the following steps:

1. Unzip the examples to your hard drive location.
2. Import the example into the MCUXpresso IDE.
3. Build the example.
4. Flash the example. The motor runs immediately.
5. Start the FreeMASTER project.
6. Click the FreeMASTER **Run** button.
7. Play with variables such as:

`f16Amplitude`	applied duty cycle (sine cosine amplitude for micro-step control)
`ui16Switching`	switching mode (unipolar, bipolar)
`ui16Control`	control mode (full-step, micro-step)
`f16AngleInc`	angle increment (equivalent to speed)

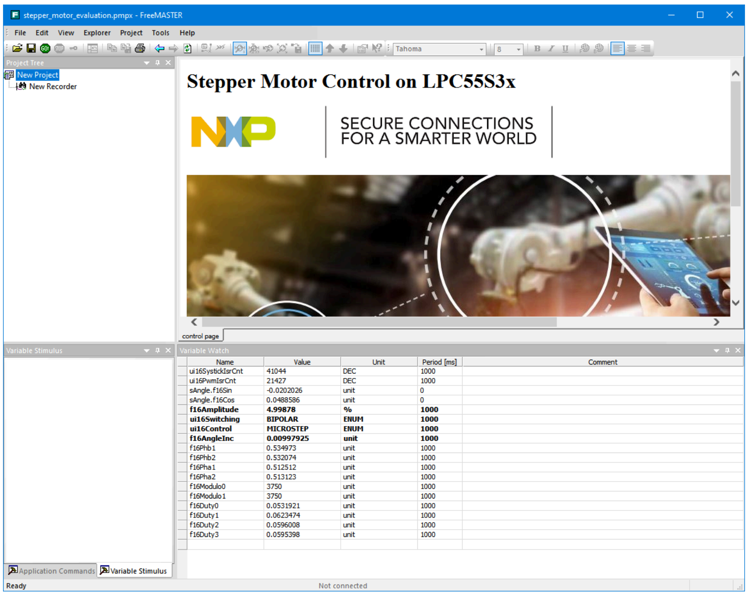

Figure 11. FreeMASTER control page for application

6 Revision history

Table 1 summarizes the revisions to this document.

Table 1. Revision history

Revision number	Release date	Description
1	13 November 2023	• Updated Section 4
0	05 September 2022	Initial public release

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