## Document information

<table>
<thead>
<tr>
<th>Information</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keywords</td>
<td>Stepper, Motor Control, LPC55S3x</td>
</tr>
<tr>
<td>Abstract</td>
<td>This documentation introduces basic stepper motor control on LPC55S3x MCU.</td>
</tr>
</tbody>
</table>
1 Introduction

This application note deals with open loop control of bipolar stepper motor on LPC55S36 EVK 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 two-phase stepper motor. There is brief introduction to stepper motors and basic control methods. Software package is available with example for MCUXpresso IDE. FreeMASTER real-time debugger is used as application GUI.

2 Introduction to stepper motors

Stepper motor is a brushless motor that allows by its construction to divide a full rotation into a number of equal steps. If the motor is correctly sized to the application in respect to torque and speed, the position of the motor can be commanded 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
  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, the rotor points are attracted 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
  Unipolar stepper motor has one winding with center tap per phase. Each section of windings is switched on for each direction of magnetic field.

• Bipolar
  Bipolar motors have a pair of single winding connections per phase. To reverse a magnetic pole, the current in a winding must be reversed. Therefore, the driving circuit must be done with an H-bridge arrangement.
3 Application HW 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 H-bridge for independent stepper motor phases.

Motor used by this application is bipolar stepper motor Nanotec ST4118X1404-A. Each motor winding is connected to phase A and B output of FRDM board. Power supply (20 V DC) must be connected to both freedom boards. Various bipolar stepper motors are possible to connect but there must be done tuning of applied voltage.

Ideally, there could be used different board which is more suitable for stepper drive, such as KIT33932EKEVBE which arranges MCU PWM outputs more effectively but some wiring must be done from this power stage to PWM, ADC and power supply EVK headers.
4 Operational modes

This application note describes basic control of stepper motor including possibility to online change unipolar (soft switching) to bipolar (hard switching) and full-step to micro-step control. The software example is done as 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 second leg is kept in zero duty cycle. This setting enables the current decay through bottom transistors. For opposite sine polarity, PWM drives the second leg and the first leg has zero duty cycle. In the bipolar mode, the H-bridge PWMs of each leg switch in counter phase. When zero voltage is required, there is 50% duty cycle. The motor is controlled in open loop, so there is no feedback or current control in this example.

4.2 Full-step mode

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

Figure 5 and Figure 6 show real motor waveforms. On top grid, there is Phase A voltage (yellow) and current (violet). On bottom grid, there is Phase B voltage (blue) and current (green).
4.3 Micro-step mode

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

Figure 7. Micro step control timing

Figure 8 and Figure 9 show real motor waveforms. On top grid, there is Phase A voltage (yellow) and current (violet). On bottom grid, there is Phase B voltage (blue) and current (green).
4.4 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 inverted polarity of each submodule 1. The preprocessor pre-calculates PWM module from defined frequency. The default PWM frequency value is 20 kHz. There is enabled PWM interrupt FLEXPWM0_RELOAD0_IRQHandler. Within this interrupt, there is done everything concerning control of stepper motor. For details, see simple source code example.
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:

- \texttt{f16Amplitude} \hspace{1em} \text{applied duty cycle (sine cosine amplitude for micro-step control)}
- \texttt{ui16Switching} \hspace{1em} \text{switching mode (unipolar, bipolar)}
- \texttt{ui16Control} \hspace{1em} \text{control mode (full-step, micro-step)}
- \texttt{f16AngleInc} \hspace{1em} \text{angle increment (equivalent to speed)}

![Figure 10. FreeMASTER control page for application](image)

6 Revision history

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>05 September 2022</td>
<td>Initial release</td>
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</tbody>
</table>
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Introduction
1.1 Who should read this manual
Introduction to stepper motors
Application HW setup
Operational modes
4.1 Switching method
4.2 Full-step mode
4.3 Micro-step mode
4.4 PWM setup
Evaluation software
Revision history
Legal information