AND8371/D

Stepper Motor Resonance Measurement Setup with the AMIS-3052x/NCV7052x Evaluation Kit

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APPLICATION NOTE

Introduction

One of the major concerns during design of a stepper motor application is the motor's resonant behavior. For stepper motor resonance characterization different methods can be followed. Most of the instruments needed for these characterizations are expensive and the measurements are time spending.

With the 52x stepper motor driver, it is possible to perform resonance characterizations of a motor by measuring the back EMF which it generates during rotation. This application note gives an explanation how to use the 52x evaluation kit to make this measurement. Furthermore, it will give some advice how to interpret the back EMF acquired data.

Application Description

The application diagram for resonance measurements with the 52x device is shown in Figure 1.

In Figure 1, the device is driving a stepper motor (DUT) as a reaction to external control signals (SPI bus, pulse generator).

The measurement technique described in this AN consists in observing the stepper motor reactions to frequency stimuli by means of the *speed and load angle* (SLA) output of the 52x. The back electromotive force (BEMF) at the stator coils is sampled by the 52x at the moment there is no current flowing through them. The amplitude of the BEMF increases linearly with speed when no load angle is affecting the rotor's movement; under these conditions, we observe a linear increase in the SLA output voltage as well.

In practice a certain load angle will be present and vary with speed. In particular, large load angle changes will be seen around speeds where the rotor is resonating. In order to obtain information on resonance states, BEMF must be analyzed in both coils when motor is running at a known speed.
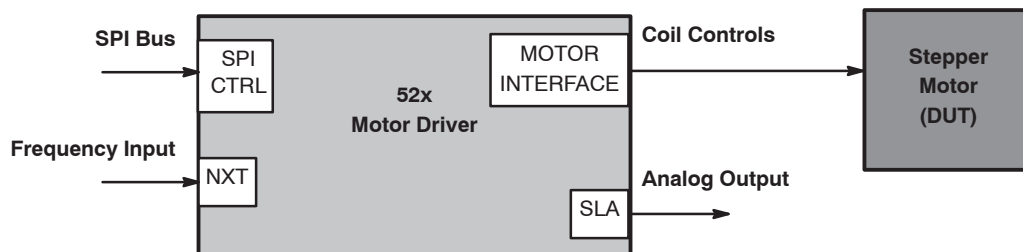

Figure 1. Resonance Measurement Application with 52x Devices – Principles

Hardware Setup Description: Block Diagram
Scope of this paragraph is to give an overview of how the intended setup is done. A logical block scheme is given below.
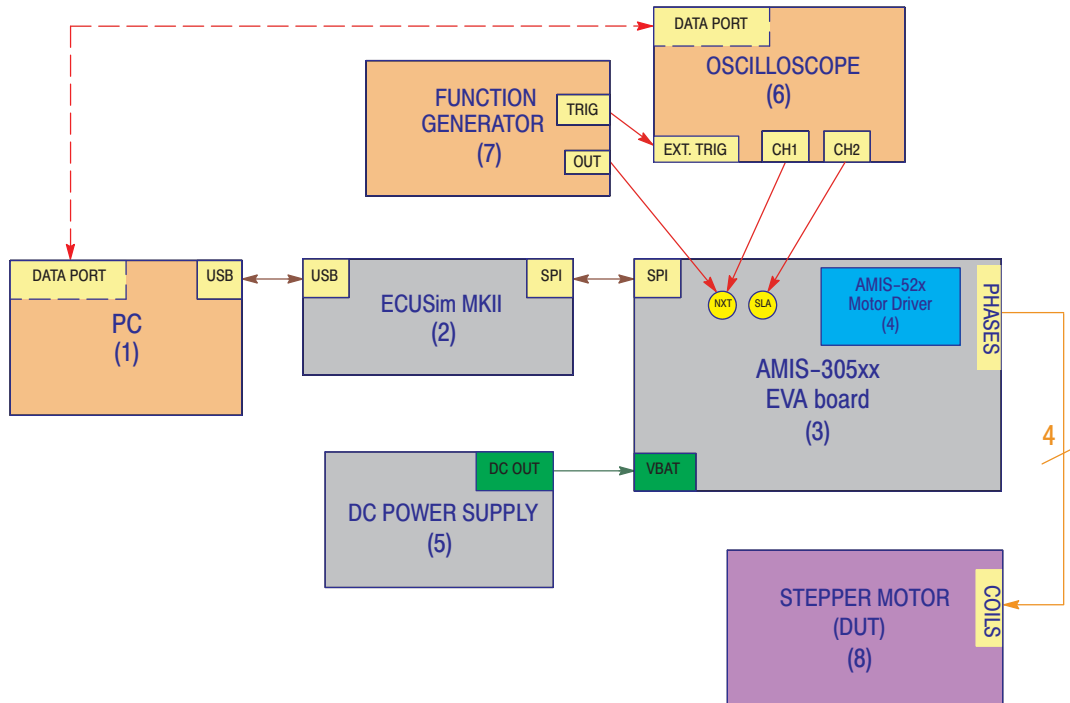

Figure 2. Resonance Study with AMIS−3052x Setup: Block Diagram

A Description of Each Block Along with its Purpose Follows:

1. **PC**: The personal computer must have a free standard USB or USB 2.0 port. The AMIS−3052x Evaluation Kit GUI software must be installed with the drivers for ECUSIM MKII (all the necessary software setup can be run from the installation CD included in the Kit).

2. **ECUSim MKII**: This unit acts as a translator box from USB into SPI signals. When the SPI cable is properly connected to the board, the SPI_Master LED (red) will be lit.

3. **AMIS−305xx Evaluation Board (Motherboard)**: it is the main component of the whole setup. It allows communication between the GUI and the 52x device thus controlling the motor actions. Two lines of setpoints can be found at the side of the device daughterboard. For resonance measurements we are particularly interested in two of them: "NXT" and "SLA". The "NXT" pin must be connected to the output of a function generator (**7**) and can be monitored by a oscilloscope probe. The "SLA" pin is a foremost source of data and must be probed by a scope channel. The Stepper Motor under analysis (**8**) has to be tied to the apposite connector. A DC power source must be plugged to provide V_{BAT} voltage.

4. **AMIS−3052x Motor Driver (Daughterboard)**: The 52x motor driver is placed on a small pcb that must be inserted in the indicated area.

5. **DC Power Supply**: There is a AC/DC supply provided with the kit. Its regulated output can deliver 12 V @ 2 A max, the connection is done with a standard power jack.

6. **Oscilloscope**: We recommend the use of a digital oscilloscope with data storing and transfer feature. Commonly, the first channel (CH1) can be connected to the NXT pin to check the correct generation of NEXT pulses. At the same time, channel two (CH2) must probe the SLA signal. A third connection is advised between the function generator (**7**) trigger output and a scope external trigger input: the scope acquisition should be triggered on this signal.

7. **Function Generator**: This unit must provide pulses to the NXT pin of the 52x motor driver. The frequency of this signal equals the stepping frequency of the motor. While the shape of the wave should be square, its duty cycle makes no importance as the 52x receives a step command on edges only. For proper functioning, a TTL compatible signal is recommended.
The function generator's trigger output should be connected to the oscilloscope (**5**) external trigger input.

8. **Stepper Motor**: This is the device under test (DUT), whose resonances must be evaluated. Its four wires must be connected to the motherboard (**3**) motor connector outputs. One coil will be tied between MOTXP and MOTXN pins, while the other to MOTYP and MOTYN pins. Reversing of coil connections will invert the sense of rotation of the motor.

Frequency Sweep Setup – Function Generator

The purpose of the setup described up to now is to be able to step the motor at a controlled frequency (stepping speed) and observe its behavior by means of the s*peed and load angle* (SLA) pin output.

One way is to set the input frequency manually, in order to make the motor turn at a given velocity and acquire the SLA signal, then step to the next desired speed until a full range of interest will be covered. Nevertheless, it is suggested to get information about resonance over a complete region, by using a frequency sweep and acquire the SLA output continuously during this.

First, the user should define what ranges he is interested in. For most applications, an opening range from $V_{MIN} = 0$ to $V_{MAX} = 500$ **[FS/s]** is sufficient. A second sweep, for instance from 0 to 200 [FS/s], or from 0 to 300 [FS/s], may be desired for having better resolution at lower speeds.

Please remind that motor speed values must be converted to frequency values by means of the following formula:

$$F_{DRIVE}[Hz] = V\left[\frac{FS}{s}\right] \times SM \qquad \text{(eq. 1)}$$

Where SM is the driving *step mode*. If half step mode is used, SM = 2. For instance, when $V_{MIN} = 0$ and $V_{MAX} = 500$ **[FS/s]**, the related sweep frequencies will be: $F_{MIN} = 0$ and $F_{MAX} = 1000$ **[Hz]**.

The sweep must vary linearly from F_{MIN} to F_{MAX}, with a given *sweep time*. If the motor is in *free running* configuration (no mechanical run stops are present), it is suggested to use a rather "long" sweep time, in order to keep motor acceleration low enough to observe behavior, speed by speed. A value of 10s is found to be fit in most cases. A higher value can also be selected, although a trade off with the oscilloscope maximum sampling rate at long acquisition windows and memory usage should be taken into account.

The output of the function generator must be kept inactive until the real sweep is commanded, in order to avoid starting misalignment between the rotor and stator magnetic fields when the test will effectively run.

Please beware such misalignments will induce a delay in the 52x analog acquisition circuit, thus resulting in a test failure or bad data. In fact, the current zero crossing measurement technique used needs the motor to start running from a known set position.

The trigger output of the function generator can activate the acquisition of the scope at a specified time instant (t = 0). The horizontal trigger of the scope can for example be positioned at the leftmost part of the screen, so that data displaying will exactly start at the beginning of the sweep itself. This simplification significantly speeds up the derivation of resonance zones, that will be performed after data acquisition.

AMIS−30521 Evaluation Kit GUI Setup

The previous paragraphs showed how to setup all hardware. In order to be able to run measurements, software must also be properly configured. The AMIS−3052x Evaluation Kit GUI must be installed on the PC used which is going to be used. An image of the GUI main panel follows.

The user has to make certain all the parameters highlighted in the picture are properly configured.

For a frequency sweep, SLA output mode must be kept in *Not Transparent* mode. The coil current should be chosen as

close as possible to the one needed in the real application. Step mode must be selected according to the application as well.

The user must also check whether the motor is enabled.

Before running the frequency sweep, all the following buttons: *Set CR0*, *Set CR1* and *Set CR2* must be clicked to update the 52x configuration.

Once the device is configured the frequency sweep can be run, starting the data acquisition.
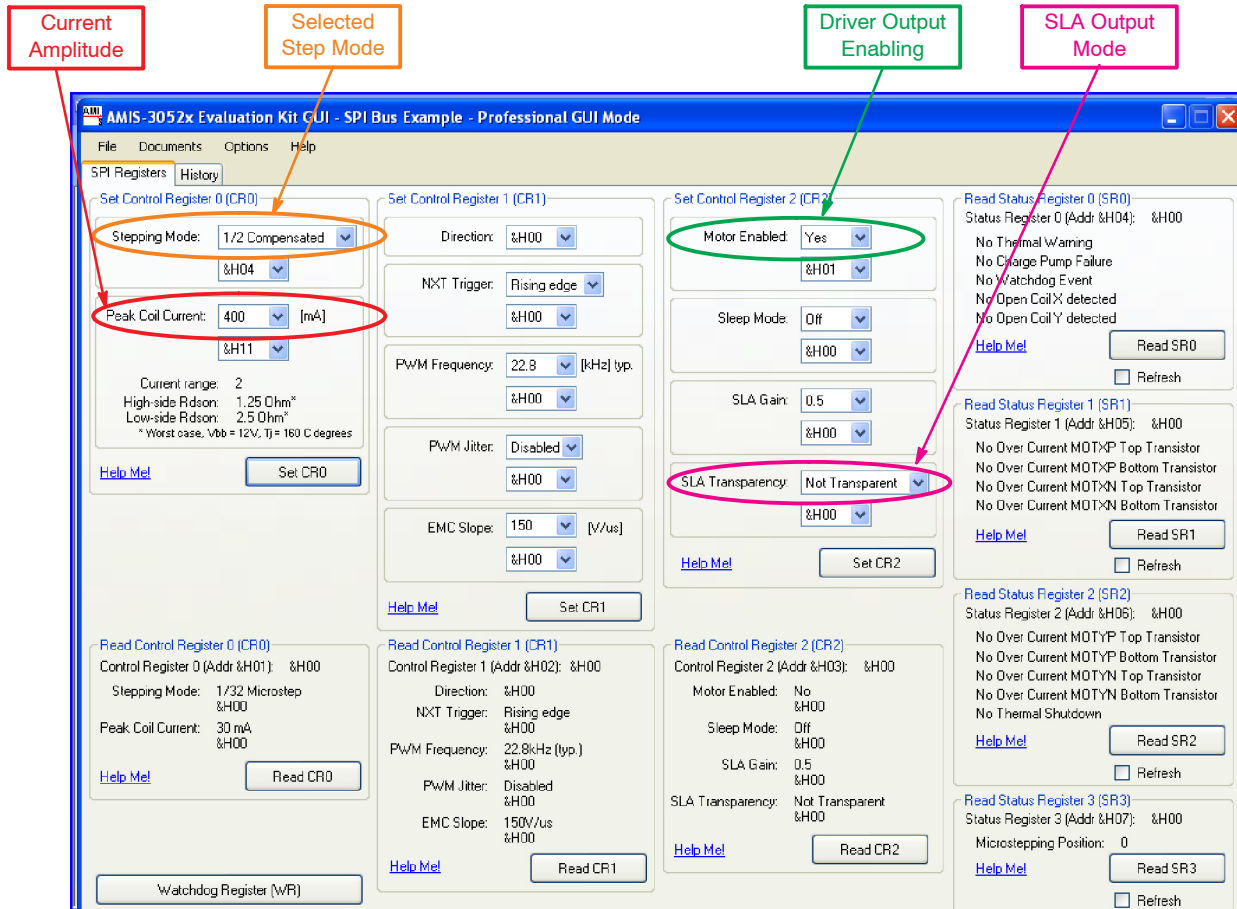
Figure 3. AMIS−3052x Evaluation Kit GUI: Main Panel Setup

Resonance Data Interpretation

Scope of this section is providing some hints on how resonance data may be analyzed. A typical waveform is given in Figure 4.

The yellow signal represents the NEXT pulse frequency, linearly varied by the sweep generator. The SLA output is in presented in *blue*. The sweep was performed over 2 seconds,

with an oscilloscope time division of 200 ms. The speed of the motor is varied from $V_{MIN} = 0$ to $V_{MAX} = 500$ [FS/s].

To obtain the motor speed at any specific time instant, it is sufficient to apply a proportional law.

As an example: $V_1 = (400 ms/2s)$ x $V_{MAX} = 100$ [FS/s], while the center of *resonance region 2* is calculated to be about 170 [FS/s].
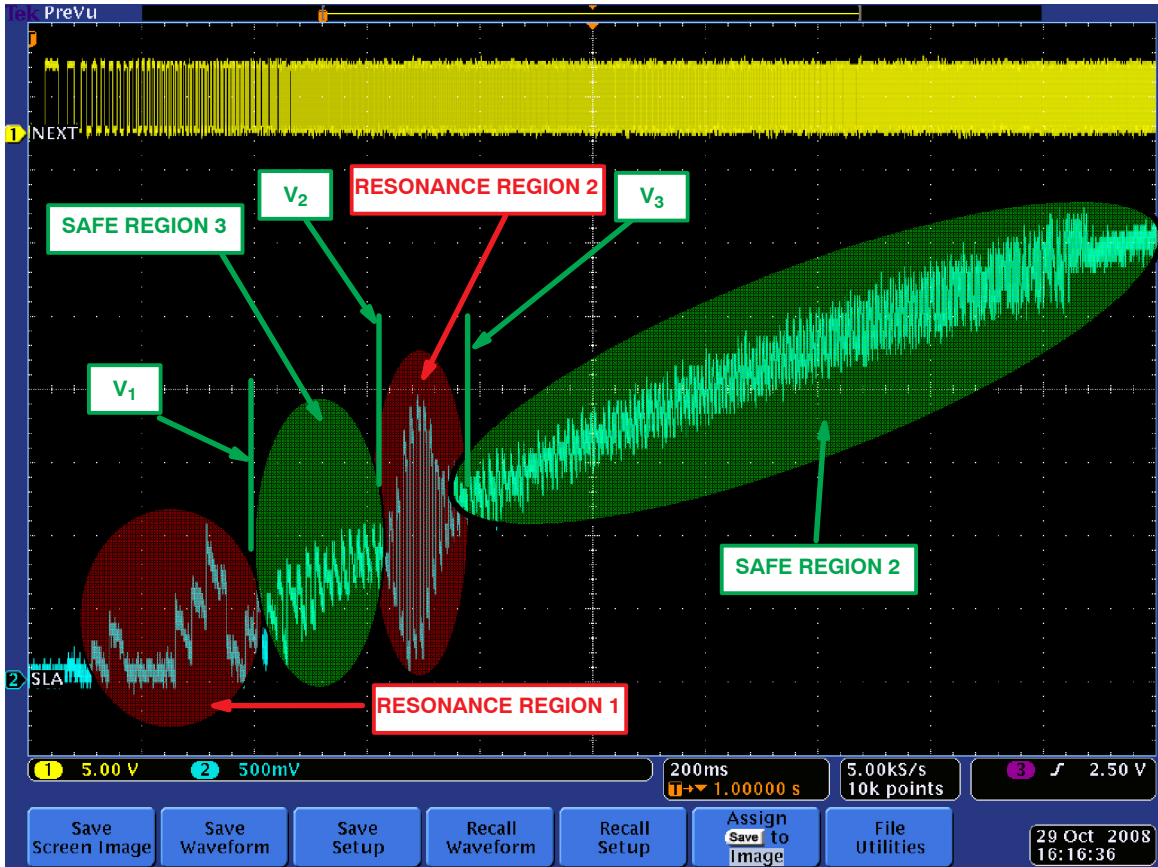
Figure 4. Resonance Data Acquired During a Frequency Sweep with 52x Devices

References

1. "Stepping Motor Physics" : Part 2 of "Stepping Motors" by Douglas W. Jones, Internet

2. Datasheet AMIS−30521/NCV70521 & AMIS−30522/NCV70522 products, http://www.onsemi.com