

## AMIS-3062x Micro-stepping Motor Driver Family

### Robust Motion Control using the AMIS-3062x



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### APPLICATION NOTE

#### Introduction

The AMIS-3062x is a family of integrated micro-stepping stepper motordriver solutions which are designed with a number of innovative features, including a position controller as well as the control/diagnostics interface. A number of devices in this product family are targeted at dedicated mechatronics applications, whereby they are coupled to a remote LIN master. Alternatively, other versions of these devices can be interfaced to an external microcontroller via an I<sup>2</sup>C bus.

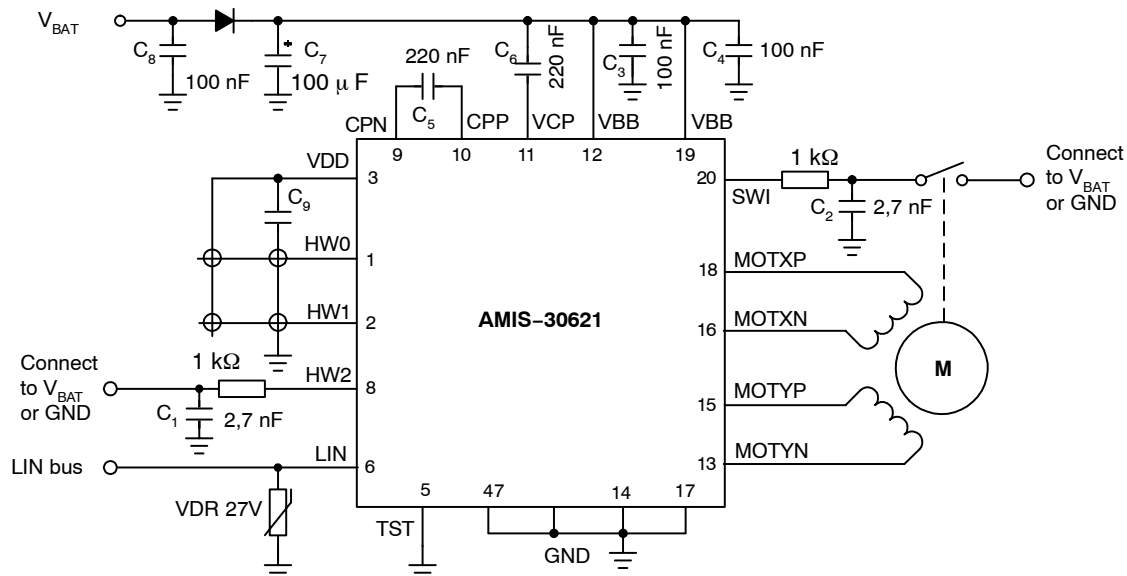
In these applications, the motor driver IC receives positioning instructions via the bus (LIN or I<sup>2</sup>C) and subsequently drives the motor coils to the desired position. The on-chip position controller is configurable (OTP) for different motor types and positioning ranges, as well as speed, acceleration and deceleration parameters, respectively. In addition, the “micro-stepping” feature allows for silent motor operation and increased positioning resolution.

The AMIS-3062x family is fully compatible with the operating voltages in industrial and automotive systems.

This article provides guidelines for arriving at a set of robust motion parameters for the AMIS-3062x stepper motordrivers. In this context, robust motion control implies reducing the occurrences of step-loss as well as false step-loss flags.

#### Typical Application

The typical application diagram for AMIS-30621 is shown in Figure 1. Here, SWI is the position switch input. If not used, Pin 20 should be left open. HW2 is an external address pin capable of withstanding high voltage transients. If not used, this pin should be connected to ground via a 1 kΩ resistor.



- Notes:
1. All resistors are 1/4 W, ±5 percent.
  2. C<sub>1</sub>, C<sub>2</sub>: Minimum value is 2.7 nF, maximum value is 10 nF.
  3. Depending on the application, the ESR value and operating voltage of C<sub>7</sub> must be carefully chosen.
  4. C<sub>3</sub> and C<sub>4</sub> must be close to Pins VBB and GND.
  5. C<sub>5</sub> and C<sub>6</sub> must be as close as possible to Pins CPN, CPP, VCP, and VBB to reduce EMC radiation.
  6. HW0 and HW1 are to be connected to VDD or GND, respectively.

Figure 1. Typical Application Diagram

**Resonance**

Resonance phenomena in stepper motors can cause step-loss, leading to random and uncontrollable motion. The resonant frequency in stepper motor systems (with rigidly mounted ideal motor) is calculated in Ref. [1] as follows:

$$f_{res} = \sqrt{\frac{h}{8 \cdot \pi \cdot \mu \cdot S}} \quad (eq. 1)$$

Where:

- $f_{res}$  = resonant frequency of the motor with rigidly coupled load
- $h$  = holding torque
- $\mu$  = moment of inertia of the rotor and any coupled load
- $S$  = the step angle in radians

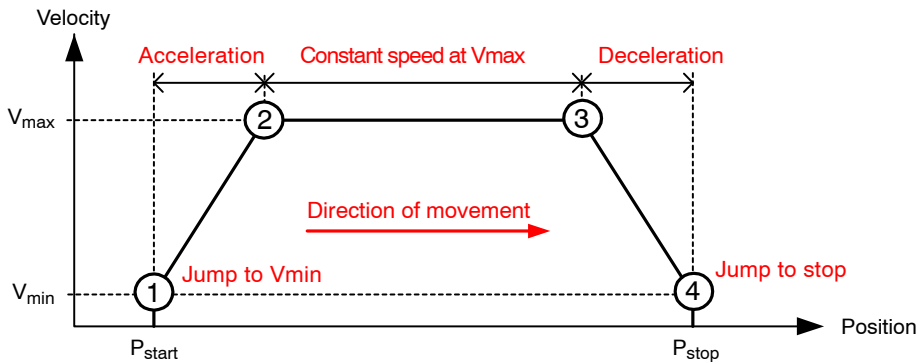
This equation indicates that for a given motor and load condition, one can affect the resonant frequency by changing the current/torque. For example, if the current in the motor coils increases, the resonant frequency will also increase. In real world systems, several resonant frequencies are generated, which are mainly due to the elastic couplings and motor non-idealities. In many of these cases, measuring the resonant frequencies rather than calculating them is the preferred technique. These frequencies can in turn be

measured by means of the step-response of a loaded motor or a velocity sweep.

**Important:** The resonant frequencies of an unloaded motor are typically different from those of a loaded motor (due to the differences in  $\mu$  and couplings). This affects the selection of robust motion control parameters in the AMIS-3062x devices. For this reason, it is essential to determine these parameters for a specific motor and load configuration. In all cases, first ensure that the selected motor matches the load requirements, and then determine the proper value of current to generate the desired torque during all conditions (“Irun[3:0]” & “Ihold[3:0]” parameters). This is key to achieving the correct set of resonant frequencies.

In conjunction with resonance effects, some degree of velocity ringing can occur following abrupt speed changes. The positioning controller of AMIS-3062x introduces four corner points (Figure 2), which will be discussed later in this application note.

NOTE: Step-loss due to resonance or velocity ringing is minimized by selecting “Vmin[3:0]”, such that the stepping frequency is at all times above  $f_{res}$  (Corners 1 and 4 in Figure 2).



**Figure 2. Speed as a Function of the Position as Implemented in the AMIS-3062x Position Controller**

**Acceleration and Deceleration**

If changes in speed (accelerations and decelerations) are not in line with certain physical constraints, an increased chance of step-loss exists. In Ref. [1], the maximum acceleration is expressed as a function of  $f_{res}$ , as follows:

$$A_{max} = \frac{8 \cdot \pi \cdot f_{res}^2}{\sqrt{2}} \quad (eq. 2)$$

Where:

- $A_{max}$  = maximum acceleration (in FS/s<sup>2</sup>)
- $f_{res}$  = resonant frequency of the motor with rigidly coupled load

This equation can be used to arrive at a good approximate value for the maximum deceleration as well.

NOTE: Measure the resonant frequencies in your application and select “Acc[3:0]” such that the resulting acceleration and deceleration are at all times below  $A_{max}$ .

Example: If  $f_{res} = 30$  Hz, then  $A_{max} = 16000$  FS/s<sup>2</sup>

Velocity ringing due to maximum acceleration and “Corner 2” (See Figure 2) can lead to false activation of the stall detection function (Ref. [3]). In order to prevent this

occurrence, a blanking period is to be introduced via the parameter “FS2StallEn[2:0]”. This parameter represents (in binary format) the count of the number of full steps to be skipped, from the onset of “Corner 2” to the instance when the stall detection function is enabled, respectively. In this case, it is necessary to first characterize the ringing in the velocity waveform beyond “Corner 2”, in order to arrive at the correct “FS2StallEn[2:0]” parameter setting. The length of the blanking period can be set according to Table 1.

**Table 1. BLANKING TIME SETTINGS TO PREVENT THE ACTIVATION OF THE STALL DETECTION CIRCUIT DURING “VELOCITY RINGING”**

Index	FS2StallEn[2:0]	Blanking Time (Full Steps)
0	000	0
1	001	1
2	010	2
3	011	3
4	100	4
5	101	5
6	110	6
7	111	7

NOTE: The parameter “FS2StallEn[2:0]” allows for reducing the risk of activation of the stall detection function due to velocity ringing beyond “Corner 2”. This parameter will blank the stall detection function during a number of full steps, at the expense of potentially losing a number of full steps in the positioner in case the motor encounters a true stall condition during this blanking time.

**Stalled Motor**

If a motor is mechanically blocked or is accelerated into a physical end-stop, then step-loss will occur (see description of “AbsThr[3:0]” and flag <AbsStall> in Ref. [3]). The maximum number of lost full steps (#LFS<sub>max</sub>) is the sum of following:

$$\{ \text{number of full steps in FS2StallEn[2:0]} \} + \{ \text{number of full steps in acceleration ramp} \}$$

or:

$$\#LFS_{max} = FS2StallEn[2:0] + \frac{(V_{max}^2 - V_{min}^2)}{2 \cdot A_{CC}} \quad (eq. 3)$$

Where:

- # LFS<sub>max</sub> = maximum number of lost full steps (FS)
- FS2StallEn[2:0] = 0 to 7 FS
- V<sub>max</sub> = selected maximum speed (FS/s)
- V<sub>min</sub> = selected minimum speed (FS/s)
- ACC = selected acceleration (FS/s<sup>2</sup>)

In this case, the actual position in the device’s position register can be updated (through the master command) to correct for the lost steps.

NOTE: The parameter “AbsThr[3:0]” helps to detect an indefinitely blocked motor.

NOTE: “AbsThr[3:0]nom” is obtained upon conducting certain motion tests on blocked motors and observing the flag <AbsStall> Ref. [x3]. A robust rule of thumb estimate for the “AbsThr[3:0]” parameter setting is “AbsThr[3:0]nom” minus 0.5 V.

**Hitting a Mechanical Obstruction at V<sub>max</sub>**

In this case, the maximum number of lost full steps is only related to FS2StallEn[2:0]. Please refer to the description of “DelThr[3:0]” and “DelStallLo” and “DelStallHi” in Ref. [3].

NOTE: To verify “DelThr[3:0]” operation, it is important for velocity-ringing (parameter “FS2StallEn[2:0]”) to be under control. A robust rule of thumb estimate for the “DelThr[3:0]” parameter setting is “AbsThr[3:0]”/2 (in volts).

**Torque Reduction at Elevated Speeds**

The inductance in the motor windings limits the rate of rise in motor current. At slow speeds this is hardly noticeable. However, at elevated speeds, with the rise and fall times of the current being of the same order of magnitude as the step time, this results in a reduction in the effective current in the motor phases, with a consequent reduction of the torque. Another contributor to the decline of torque is the “back-emf” or “counter EMF” Ref. [1]. The AMIS–3062x stepper drivers have a PWM current control system. When a motor with high back-emf is operated at high speeds and low supply voltages, the PWM duty cycle can be as high as 100 percent. This indicates that the supply voltage is too low to generate the required torque. This situation may also result in erroneous triggering of the stall detection function (Table 2). As a precaution, the stall detection function is automatically disabled when the PWM duty cycle approaches ~100 percent, while some degree of control is possible via the parameters “DC100StEn” and “MinSamples[2:0]”.

Finally, the parameter “MinSamples[2:0]” provides for a timing function for sampling of the back-emf voltage, according to Table 3.

Example: When running at 5000 micro-steps/s, the duration per micro-step is 200 μs and MinSamples[2:0] should be set to “010”.

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**Table 2. AVOIDING FALSE STALL DETECTION IN CASE OF 100 PERCENT DUTY CYCLE**

Case	DC100StEn	PWM Duty Cycle	Stall Detection Enabled?	Risk for False Stall Detection?
1	0	< 100 %	Yes	No
2	0	100 %	No	No
3	1	< 100 %	Yes	No
4	1	100 %	Yes	High

NOTES: Set "DC100StEn" = 0 for normal use.

It is possible (if "DC100StEn" = 1) to verify the safe operating range (max. speed, min. supply voltage). The "false stall-detection (case 4)" will indicate 100 percent PWM duty cycle and torque reduction.


**Table 3. RELATION BETWEEN "MINSAMPLES[2:0]" VALUE AND THE SAMPLING TIME OF THE BACK-EMF**

MinSamples[2:0]	Timing (μs)
000	87.7
001	131.6
010	175.4
011	219.3
100	263.2
101	307.0
110	350.9
111	394.7

NOTE: Set "MinSamples[2:0]" to the next smaller value that best corresponds to the duration of one micro-step when running at  $V_{max}$ .

## References

- [1] "Stepping Motor Physics": Part 2 of "Stepping Motors" by Douglas W. Jones, [www.cs.uiowa.edu/~jones/step/](http://www.cs.uiowa.edu/~jones/step/)
- [2] ON Semiconductor Data Sheets [AMIS-30621](#), [AMIS-30622](#)
- [3] ON Semiconductor Data Sheets [AMIS-30623](#), [AMIS-30624](#)

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