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DO YOU REALLY NEED A LOW CURRENT AMPLIFIER TO DRIVE A LOW CURRENT MOTOR?*

O. Ivashkevych, A. Munoz, D. Poshka, BNL, Upton, NY11973, USA

Abstract

NSLS2 is standardized on Geo Brick LV 5A motor controller from Delta Tau [1], suitable to drive majority of stepper and servomotors. Standardization allows less spare inventory and common skill set to maintain. However, some applications, especially instruments in the space-confined end stations require using small, or even miniature motors. What are the limitations in customizing the 5A unit for driving low current motors?

Delta Tau Geo Brick LV (GBLV) is a turbo PMAC family motion controller [2]. It comes in different amplifier configurations: a combination of 5A, 1A, and 0.25A amplifiers. This research is focused on performance and limitations of 5A driver with low ~200 mA and very low ~40 mA current motors.

MOTIVATION

A typical photon beamline uses many motorized instruments. Some of axes are driving heavy loads and some are miniature stages. In other cases, scientific equipment is designed as a combination of big and small motors with high and low driving currents. Driving this motors usually require different controls solutions. A typical monochromator, for example, often has a combination of bigger and smaller motors with drive currents from several Amp to 100 mA. Using integrated or separate divers to control equipment is not only maintenance expensive, but in some cases impossible due to the tight spaces. In this paper, we present research data about using NSLS2 standard 5A Geo Brick LV (turbo PMAC) motor-controller of driving small current motors instead of custom solutions. The idea has presented itself when we successfully drove 125 mA stepper motor with 5A Geo Brick LV unit having no other possibilities at that moment.

EXPERIMENTAL SETUP

The following stages and motors were selected: Newport MFA-CC stage with DC servomotor UE1724SR and rotary encoder 2,048 cts/rev, rated speed 2.5 mm/s; MFA-PP stage with 2 phase stepper motor UE16PP, 1 full step = 0.485 μm, rated speed 2.5 mm/s; Faulhaber AM2224-V-12-75-10 2 phase stepper motor, AM1020-V-12-250-00 2 phase stepper motor, see Table 1.

Table 1: Motors Under Test

SUT	Motor	Current
MFA-CC stage	UE1724SR	200 mA
MFA-PP stage	UE16PP	250 mA
Faulhaber mtr	AM2224-V-12-75	125 mA
Faulhaber mtr	AM1020-V-12-250	45 mA

The motors were driven with 5A Geo Brick LV motor-controller; model BHB8-C0-442-00000000. The actual current was measured by Tektronix TCP0030A current probe and Tektronix MSO4054B oscilloscope giving 1 mA resolution. Two Faulhaber steppers were driven in the open loop mode, see Figure 1.

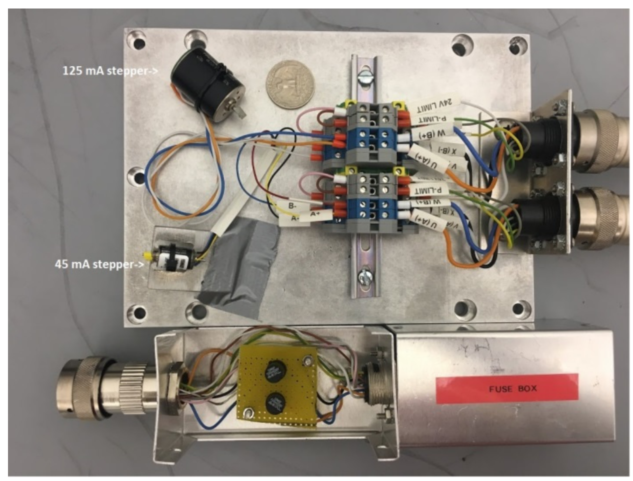

Figure 1: Low current Faulhaber steppers under test.

For current surge protection all motors were connected to Geo Brick LV via a fuse box, see Figure 1.

OPEN LOOP PERFORMANCE

Performance of a stepper motor depends on many parameters, not always analytically predicted. They are: electrical characteristics of the motor coils, such as coil resistance, inductance, back EMF, drive current, bus voltage; mechanical properties, such as generated torque, system response time, load; dynamic run conditions, such as speed and even a motor driver. Optimizing selected controller PID parameters for the experiment requirements is a mission of a control engineer.

Driving a low-current motor with an amplifier designed for high current ones is generally a poor design decision simply because the ADC count used by the PID control

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system delivers a significant change relative to the total drive current. Inability to fine-tune will certainly impede motor's best performance to the very least. However, if the best performance is not required, and space and funds are limited, using high current amplifies for driving smaller motors is justifiable.

The 15 bit ADC for BHB8-C0-442 is 33.85 A, which comes to 1mA/ct. If the feedback loop decides to increase current by 20 cts, it will be a substantial correction.

Current waveform can be a good source of information about the motor performance. The smallest current GBLV can output was measured to be ~40 mA, which worked well for the 45 mA motor, see Figure 2. The measured current value was the same for settings Ixx77=5, Ixx77=10, Ixx77=15.

Figure 2: 45 mA stepper current trace. Ixx22=5, Ixx77=10, Ixx61=0.035.

NSLS2 uses a standardized configuration file, which works well for most steppers. These settings are based on Delta Tau recommendation. This includes current loop feedback coefficients.

For the 125 mA motor, however, current trace looks distorted driven by the same configuration settings, see Figure 3.

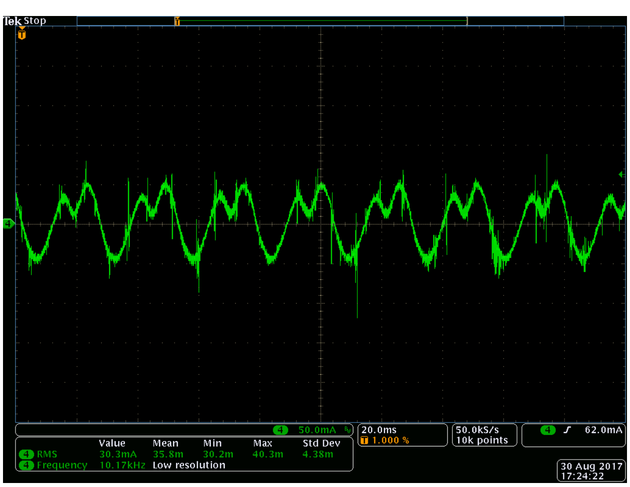

Figure 3: 125 mA stepper current trace, Ixx22=5, Ixx77=100, Ixx61=0.035.

The motor data sheets provide the necessary information to derive other important parameters [3], see Table 2.

Table 2: Faulhaber Motors' Parameters

I, mA	**45 mA**	**125 mA**
R, Ohm	250	75
L, mH	80.1	65.6
Back EMF amplitude, V/k steps/s	10.5	32.7
Holding torque at I, mNm	1.6	22
Holding torque at 2xI, mNm	2.4	37
Inductive Impedance R_L, Ohm	19.6	16.1
$R_L/R \cdot 100\%$	7%	25%

Total electric impedance is:

$$Z = R + i2\pi f L$$

$$where\ f = \frac{Ixx22 \cdot 1000 \frac{ms}{s}}{32 \frac{ct}{ms} \cdot 4 \frac{steps}{cycle}} = 39Hz$$

$$and\ R_L = 2\pi f L$$

R_L=19.6 for the first motor, and R_L=16.1 for the second.

While the inductive component for 45 mA motor is ~7% of the DC resistance, it constitutes 25% for the second. The second motor has substantially higher holding torque, and thus higher torque constant, which acts as an extra coefficient to the PID controller [4]. This causes fast current rise and the system goes into current decay mode [5]. Indeed, decreasing current integral gain improves the wave form, see Figure 4.

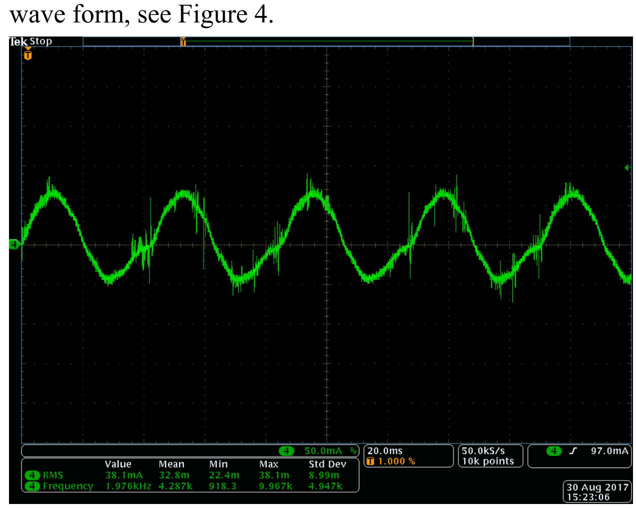

Figure 4: 125 mA stepper current trace, Ixx22=5, Ixx77=100, Ixx61=0.01.

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Increasing drive current settings makes the trace look perfect, as the motor controller does not easily overshoot, and hence does not fall into current decay mode [5], see Figure 5.

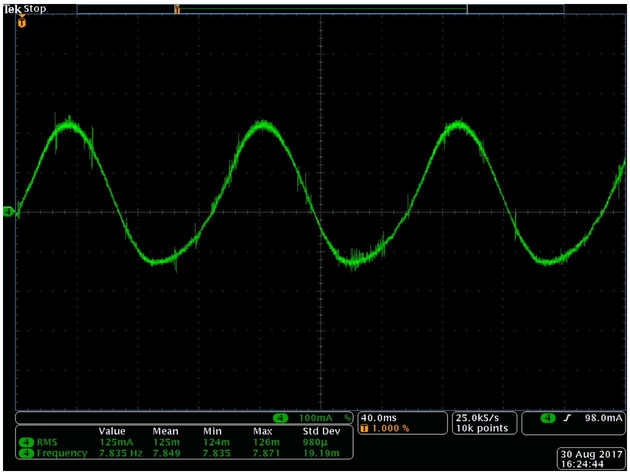

Figure 5: 125 mA stepper current trace, Ixx22=5, Ixx77=300, Ixx61=0.01.

It is worth to note, that using PMAC Tuning Pro software for current loop tuning always caused one or both fuses to blow. Fuse box with fuses is shown on Figure 1.

So far we experimented with free-running motors. What happens when the motor is loaded? Figure 6 is a current trace of MFA-PP stage. Dealing with real life friction leads to current feedback loop adjustments and causes current spikes, which, at some point can possibly burn the motor coil, if not protected by a fuse. Higher speeds add noise, as expected. See Figure 7, where The stage is moving at its rated speed.

Figure 6: MFA-PP current trace, Ixx22=2, Ixx77=200, Ixx61=0.001.

Figure 7: MFA-PP current trace, Ixx22=165 (rated speed), Ixx77=200, Ixx61=0.003; PeWin executed motion at 165 ct/ms.

CLOSE LOOP PERFORMANCE

As it was indicated earlier, driving low current motor with 1 mA/ct ADC can be a challenge for position feedback tuning. Yet, our goal is to deliver a working positioning solution to the beamline with available channels on a 5A turbo PMAC, standard at each beamline.

MFA-CC is a servo-motor stage with rotary encoder 2,048 cts/rev and 0.5 mm pitch screw. It is rated to move with the speed 2.5 mm/sec, or 10 cts/ms. We would like to report that we successfully tuned the stage to perform at its rated speed with 5A GBLV motor-controller, see Fig. 8.

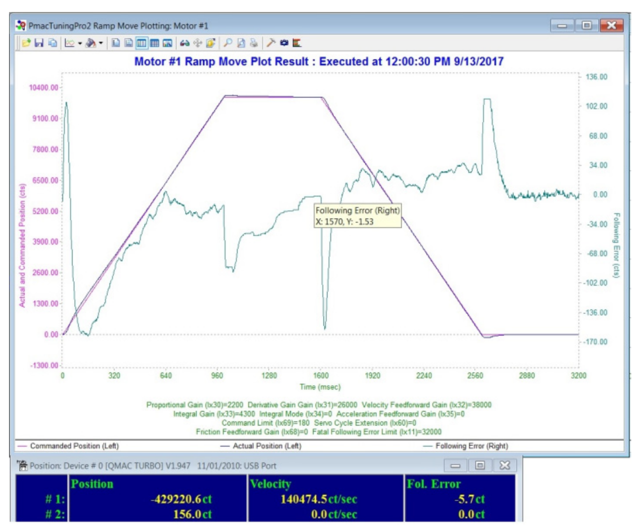

Figure 8: MFA-CC tuning ramp top, and executed motion at 140 cts/ms bottom, driven by GBLV 5A motor controller.

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CONCLUSION

It has been demonstrated that Geo Brick LV Turbo PMAC 5A Delta Tau motor controller can be used for driving motors up to 45 mA per phase in an open loop.

GBLV 5A moto controller has been successfully configured to drive Newport MFA-PP in an open loop at 2.5 mm/s, and MFA-CC stage in a closed loop at its rated speed 2.5 mm/sec.

It is recommended to use a fuse box shown on Figure 9 to protect the motor from possible current spikes. The cost of the fuse box is ~$250 including parts and labor. This investment protects the valuable, long lead motors while determining the optimal parameters for the controller.

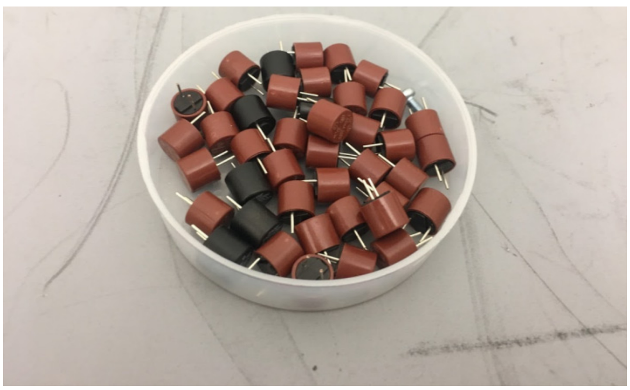

Figure 9: The number of cooked fuses during this research efforts.

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