Mini-Mapper: Motor prototype board design notes

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These notes describe the motor prototype board for the Mini-Mapper robot. This is intended as a platform to test motor driver and motor encoder setup, and to develop motor early control algorithms (particularly constant-speed PID control and soft start).

Requirements

- Power single Dagu DG01D gearmotor (4.5 V, 250 mA max.);

- PWM speed control, bidirectional, coast/brake functionality;

- Rotation measurement using optical encoder;

- Interface to STM32F767ZI Nucleo-144 board;

- Clean mechanical design for interface between motor and motor encoder disk.

Mechanical design

- Final PCB to be mounted on top chassis plate of robot: do this also for prototype motor board, to get placement right.

- Principal constraints are:

  - Access to mounting holes on top chassis plate (there is interference with the motor under some holes);

  - Clearance under PCB: both for the possibility of mounting components on the bottom of the PCB and for space for routing wires and to avoid shorts to chassis plate from THT components;

  - Alignment of photoencoder with motor encoder disk: photointerrupter slot and optical axis need to align with the holes in the motor encoder disk, there needs to be no interference between the photointerrupter and the motor body, and there needs to be little enough interference between the photointerrupter and the top chassis plate to make modifying the chassis plate easy.

- Motor encoder disk needs to be manufacturable by hand, which means a simple disk with holes, rather than slots. This leads to a strong alignment requirement in the vertical direction between the motor encoder disk and the photointerrupter optical axis.

Component choices

Motor driver: Toshiba TB67H450FNG   Chosen to match supply voltage requirements for motors, to have a standard PWM-capable control interface, internal current regulation and an easy-to-use package.

Current sense opamp: TI TLV9051   This is a low-side current sensing application, which imposes some requirements on the input range of the opamp. The TLV9051 is specifically intended for this application.

Photointerrupter: Vishay TCST1202   Phototransistor type photointerrupter, because we're not going to get a perfect transistion between full occlusion and full non-occlusion of the photointerrupter's optical aperture, so it will be useful to be able to set thresholds for occluded/non-occluded switching. The primary constraints here are mechanical, since most devices like this have similar electrical characteristics. The selected device has a 0.5 mm wide optical aperture, which matches up with some simulations I've done, and it can be mounted without interference with the motor body using reasonably sized standard hardware (i.e. 5 mm standoffs between the PCB and the top chassis plate).

Motor encoder comparator: ???   The requirements here are simple, so a jellybean comparator is a good choice. Not an LM339 though! Something more modern.

4.5 V regulator: ???   Need a linear regulator to produce 4.5 V from a 5 V input.

Power connectors   *Measure barrel plug from 5 V wall wart to select barrel jack.*

Nucleo board connectors   0.1" headers.

Schematic capture

Motor driver

- Power decoupling: following schematic in application note.

- Current sense resistor: motors run from a 4.5 V supply, and want to keep the maximum sense voltage to some small fraction of this. For a maximum

current of 250 mA, a sense resistor of 400 mΩ gives a maximum sense voltage of 100 mV.

- Current regulation: the maximum allowed motor coil current is set following the datasheet's instructions for setting the V_{ref} input.

- Current sensing: this is a simple non-inverting amplifier setup converting the 0–100 mV sense voltage to a suitable range for input to the microcontroller's ADC (0–3 V). Following a suggestion in a TI app note[1] about layout for motor drivers, the current sensing connections are highlighted to be routed as a differential pair (trying the net tie trick suggested in the app note to make the routing less confusing).

Motor encoder

- The LED side of this is simple.

- On the phototransistor side, ...

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Nucleo board interface

Connections:

- 3.3 V power and ground;

- Two GPIO outputs for motor control (PWM-capable);

- One ADC input for motor coil current sense;

- One GPIO input for photoencoder pulses (interrupt-capable).

Use 0.1" headers on motor board, and connect to Nucleo board using jumper cables, since the connections we'll want are pretty spread out.

Use	PCB	Nucleo	Conn	Pin
Power	3V3	+3V3	CN8	7
Ground	GND	GND	CN8	11
Motor control	IN1	PA6 (TIM3_CH1)	CN7	12
Motor control	IN2	PA7 (TIM3_CH2)	CN7	14
Motor current sense	Vsense	PA3 (ADC1_IN3)	CN9	1
Encoder pulses	PULSE	PC3?	CN9	5

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[1] http://www.ti.com/lit/an/slva959a/slva959a.pdf

Power

Supplies:

- Need 4.5 V (250 mA max.) for motor, and 3.3 V for logic (not sure about current requirements there).

- For prototype board, use 3.3 V supply from Nucleo board, and use external 5 V wall wart supply plus linear regulator for 4.5 V supply.

Select LDO regulator for 4.5 V supply.
Calculate current draw from 3.3 V supply and compare to 500 mA limit for supply from Nucleo board.

Layout

Mechanical board outline: photoencoder placement, mounting holes.

Assembly

Mounting hardware 5 mm spacers between PCB and top chassis plate, M2.5 bolts and nuts to secure PCB.

Power supply connections