Drive PCB

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1 Power

1.1 Layers and Pins

- There are two power planes - **5V** and **24V**.
- 24V power plane inputs and outputs are through Dean's connectors. It's small size, secure fit and large current capacity(rated 60 A continuous) makes it a good choice for this high voltage task. Possible alternative - AMASS XT60 (not really much of a difference in capability).
- 5V power plane input is through female 2 pin Molex.
- There is no need for octocouplers as the motor drivers are supplied power directly from the power plane and the Nucleo is powered externally. This ensures that the loop never includes any power pins of the Nucleo and hence will not be affected by a back emf.

1.2 Relay

I have chosen a MOSFET based relay over a electromagnetic relay. For our task, both will do just fine as it's not really a very high voltage nor there is a constraint on reaction time. I've chosen MOSFET simply because of the lower drive current (0.3 mA), better reliability and longer lifetime as compared to the electromagnetic relay, which has moving parts. Upon operating the kill switch, it shall cut off power supplies to the 5V and 24V power planes.

2 Motor Driver : Pololu VNH5019A-E

- Contains a discrete H-bridge for powering one bidirectional DC Motor.
- PWM operation upto 20 kHz.
- Operates at max 40V/30A (continuous 12A) without a heat sink.

- **Indicator LEDs :** Increase in brightness with increase in motor speed, and color changes with direction of rotation. Works even when there is no motor attached, which is handy for testing and debugging.

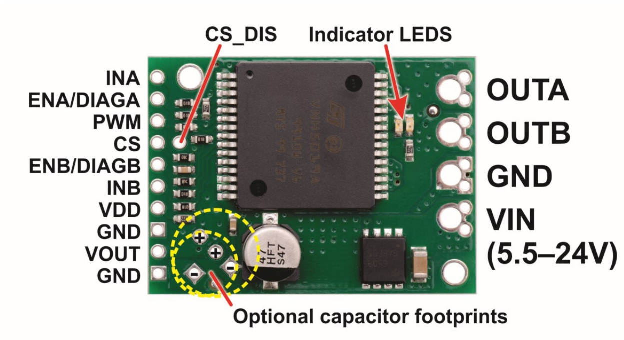

Figure 1: VNH5019A-E Pinout

2.1 Built-in Protections

- Integrated detection of common faults. Shuts down whenever these faults arise.
- Reverse voltage protection using a FET.
- Overheating protection
- Overcurrent protection.
- Active current limiting.
- Short circuit protection.

2.2 Connections

- **GND**, **OUTB**, **OUTA** and **VIN** pins are for the motor.
- **VDD pin:** Reference voltage input. I shall supply 5V from the 5V plane.
- **PWM pin:** Gets input directly from PWM pin X of Nucleo.
- **INA, INB :** Combination of inputs into these pins determine the direction of rotation. High input at INA gives clockwise input. Attached to analog pins on Nucleo.

3 STM32 Nucleo F401RE

The Nucleo series of MCUs provides us a powerful and expansive platform to handle motor driver input, Encoder data and rosserial with Xavier all at once. The large number of pins and a powerful processor allows us The Nucleo consists of two external clocks. But to take in all four encoder inputs, we need four clocks. This fact has forced me to use two STM32s in a master-slave configuration.

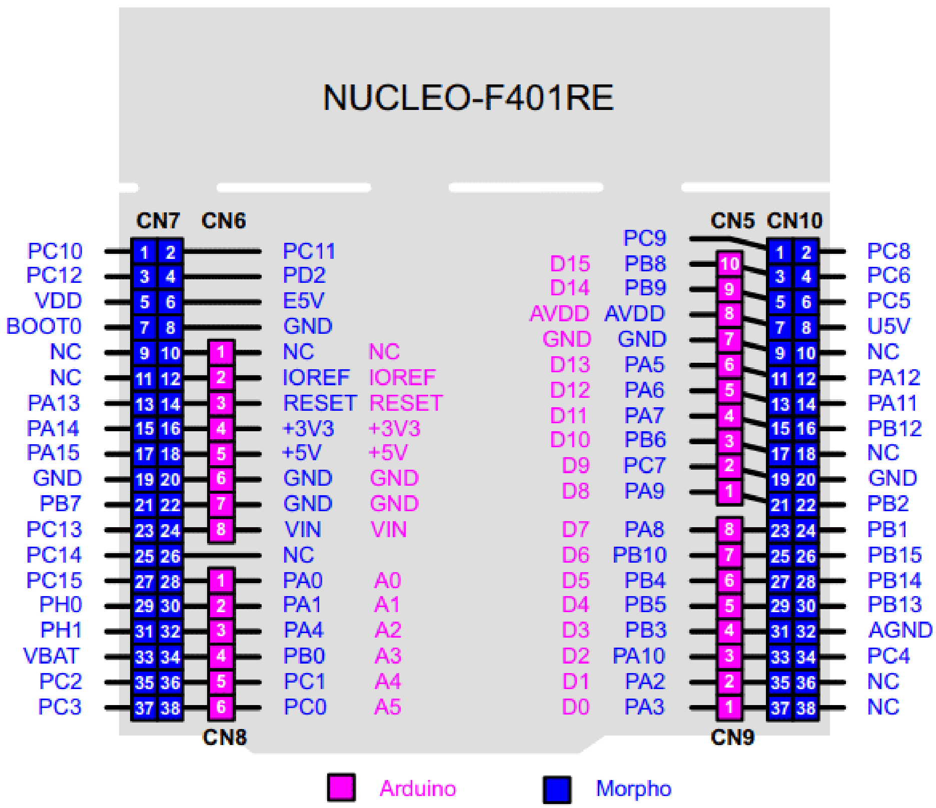

Figure 2: Nucleo Pinout

Master :

- Powered directly by Xavier.
- Handles motors drivers and encoders for front wheels.
- Handles serial communications with Xavier via UART.
- Acts as a mode of communication between Xavier and slave. Has one I2C connection with slave to pass on motor inputs and recieve encoder inputs.

Slave :

- Powered via it's mini USB port, directly from PDB. (I wanted to avoid powering it directly as it poses additional problems with rebooting the memory everytime we turn it back on).
- Handles motors drivers and encoders for front wheels.

Encoder Mode :

- We run the board on encoder mode. This allows us to access the external clock on the board (attached at X2 and X3) and achieve much higher clock values.
- Clock X3 doesn't come pre-attached, we will need to place an oscillator.
- On the STM32 CubeIDE, we will have to setup the microprocessor properly. We must setup encoder mode; this enables external clocks X2 and X3 and their corresponding pins : PA0, PA1(for right wheels) and PC14, PC15(for left wheels) respectively.
- The code I have written is for a single motor/encoder; this can be easily extended to four.

4 Orange Rotary Encoder

4.1 Working

We will be using optical quadrature rotary encoders. These use light to provide a 2 phase output. Since it's an incremental encoder, we will not be able to find the absolute position. As seen in the figure, as the perforated disc spins, the light falls on the reciever behind if it's a perforation. The 2 layer track ensures that we get two square waves with a phase differnece of exactly 90 degrees. This allows us to easily find the direction of rotation (if pin A is ahead then it's clockwise).

4.2 About Orange and it's connections

- Orange provides optical quadtrature encoders.
- Has a working voltage range of 5-24 V. I shall be providing 5V from the 5V plane.
- Works at a maximum rate of 5000 RPM.
- Pin A and Pin B : Square wave outputs. Conneected to encoder mode enabled pins on Nucleo.
- 5V and GND wires are bundled and is attached to the PCB using a 2 pin molex.

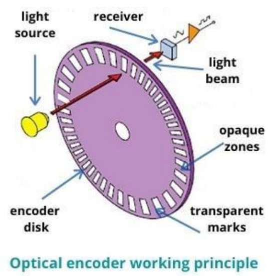

Figure 3: Standard Optical Encoder

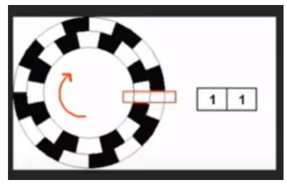

Figure 4: Tracks

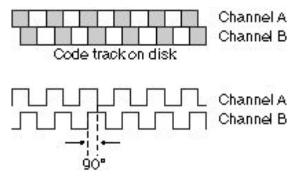

Figure 5: Track to Wave

4.3 Implementation

Direction of rotation :

- The sign of the angular velocity directly gives us direction of rotation.
- Another way would be to use if statements to see which wave is ahead. Adding a small delay helps eliminate false positives.

Angular Velocity :

- The encoder mode allows us to use the __HAL_TIM_GET_COUNTER function which gives a counter value to the rotations made to the encoder.
- The number of clicks per rotation for a particular encoder is fixed. This value can be found out manually. Lets say this value is n (in clicks per revolution).
- Hence, from here we can deduce the angular velocity :

  $$\omega = \frac{d\theta}{dt} \approx \frac{\Delta\theta}{\Delta t}$$

  we fix

  $$\Delta t = 0.1s.$$

  Therefore, in clicks per second,

  $$= \frac{10}{n}.(cur\_pos - old\_pos)$$

  in radians per second

  $$= \frac{20\pi}{n}.(cur\_pos - old\_pos)$$

5 References

5.1 Pololu

https://www.pololu.com/docs/0J44/1

5.2 Nucleo and CubeIDE

https://www.st.com/resource/en/user_manual/um1850-description-of-stm32f1-hal-and-lowlayer-
pdf

5.3 Encoder

https://deltamotion.com/support/webhelp/rmctools/Controller_Features/Transducer_Basics/Quadrature_Fundamentals.htm#:~:text=Quadrature\%20encoders\%20use\%20two\%20output,rotating\%20in\%20a\%20clockwise\%20direction.

https://robu.in/wp-content/uploads/2016/08/User-Manual-Orange-3806-OPTI-600-AB-OC-Rotary
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https://deepbluembedded.com/stm32-timer-encoder-mode-stm32-rotary-encoder-interfacing/
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https://hal.science/hal-01744934/document **An interesting advanced application**