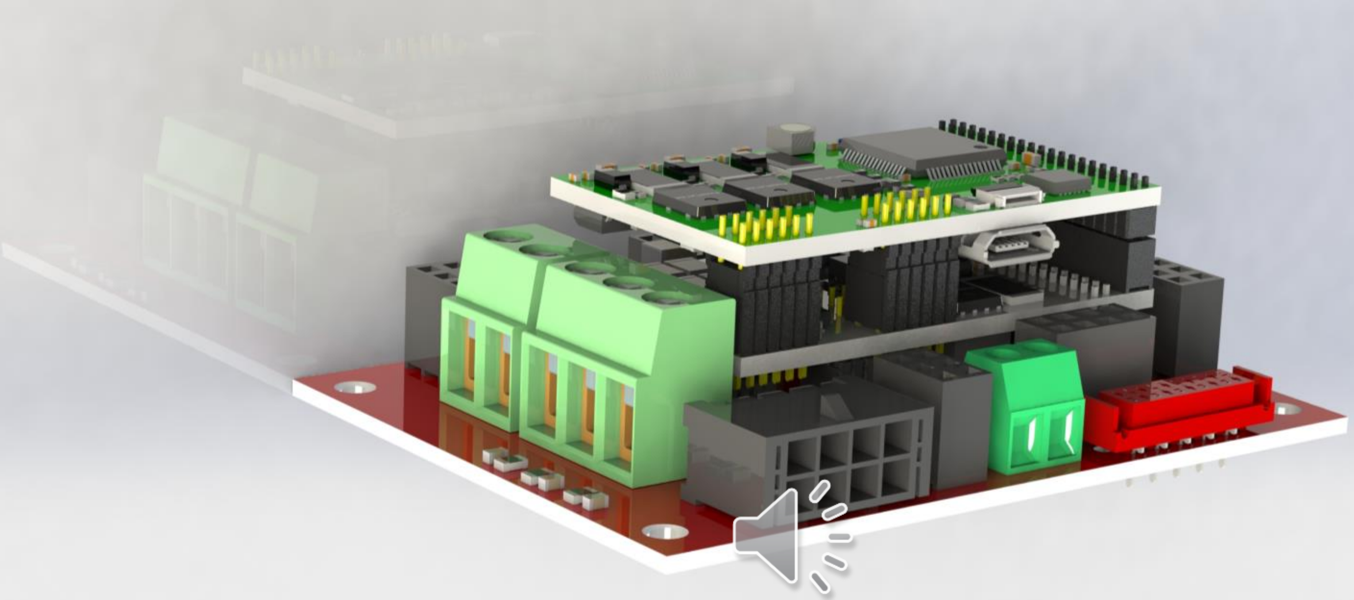


Virtual Research Presentation Conference

Polymorphic Motor Controller (PMC)

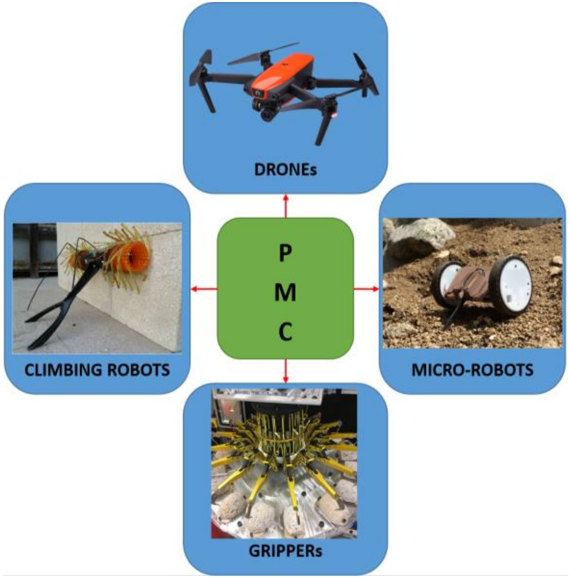
Principal Investigator: Alessandro Buscicchio (347A)
Program: Spontaneous Concept

Assigned Presentation #RPC-249

Jet Propulsion Laboratory
California Institute of Technology

Problem Description

Although JPL has a long heritage and expertise for flight motor controllers, no equivalent research-oriented motor controller for miniature robotics applications exists. The JPL research community is mostly relying on COTS motor controller, which has often shown to be insufficient or inadequate for the innovative technologies that JPL is continuously developing. The black-box nature of these motor controllers, from both hardware and software standpoint, presents several challenges and limitations in the integration and testing phases, thus, exposing projects to unpredictable risks. The lack of documentation and the impossibility of accessing and modify hardware and software makes it difficult, often impossible, to add new features, solve problems, and improve performance. Furthermore, the form-factor of COTS motor controllers is fixed, limiting the capability to reuse the same architecture between multiple systems that have different mechanical constraints and requirements. The JPL Polymorphic Motor Controller (PMC) can solve the gap between a ready-to-use and a custom motor controller, building new JPL capabilities and expertise. The aim is to develop a JPL in-house motor controller, targeting lightweight ground and aerial robots for the JPL research community.



Goals

The overall goal has been to develop a motor controller reference design and prototype.

Milestones:

a) Identify an ARM based microcontroller (MCU) targeting brushless motor controllers and compatible with the requirements of the PMC

b) Identify and test evaluation boards based on the selected MCU

c) Design the hardware architecture for the PMC

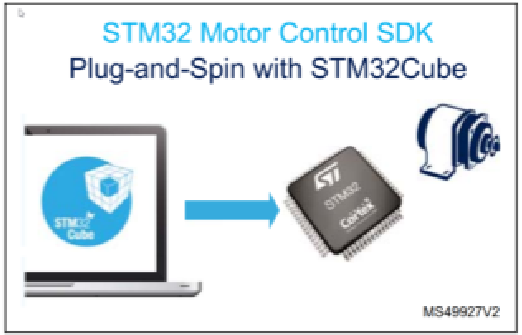
d) Design schematics and layout for the PMC

e) Fabricate prototype of the PMC

f) Test prototype

Design

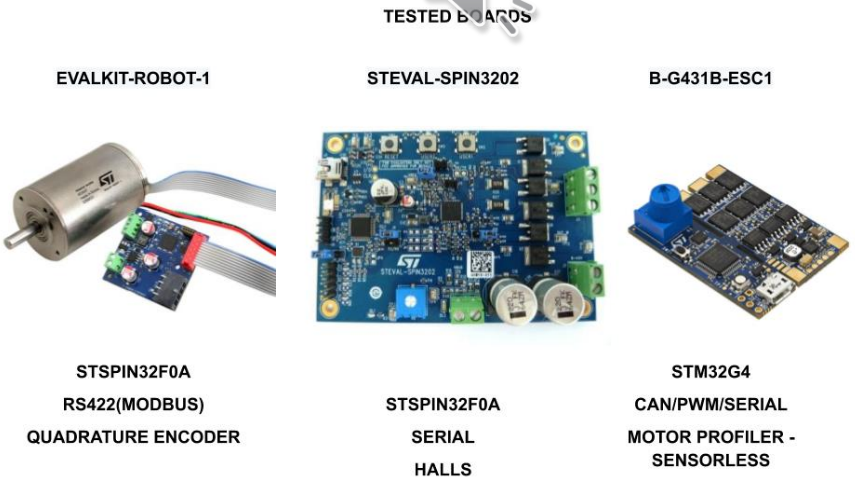
- **Identify an ARM based MUC targeting brushless motor controllers and compatible with the requirements of the PMC.** The STM32 microcontrollers have been selected, since they offer reference design, and reference software for brushless motor controller applications, see fig 1.



- Single/Dual simultaneous field-oriented control (FOC)
- Simplified firmware architecture based on the STM32Cube HAL/LL libraries
- Current reading topologies supported:
  - – 1 shunt resistor
  - – 3 shunt resistors
  - – 2 ICS (Isolated Current Sensor)
- Speed/position sensors (Encoder and Hall) as well as sensor-less operation (state observer) supported
- On-the-fly startup for fans
- Speed and torque control
- Motor control algorithms implemented for specific applications, among them MTPA (maximum torque per ampere), Flux weakening, Feed forward and Start-on-the-fly

Design

- **Identify and test evaluation boards based on the STM32 MCU.** Three boards have been tested, see fig 2:
  - EVALKIT-ROBOT-1, based on the STM32 STSPIN32F0 MCU, targeting brushless motors with position feedbacks (encoder).
  - STEVAL-SPIN3202, based on the STM32 STSPIN32F0 MCU, targeting brushless motors with velocity feedbacks (hall sensors).
  - B-G431B-ESC1. Based on the STM32G4 MCU, targeting senseless brushless motor (such as drones).

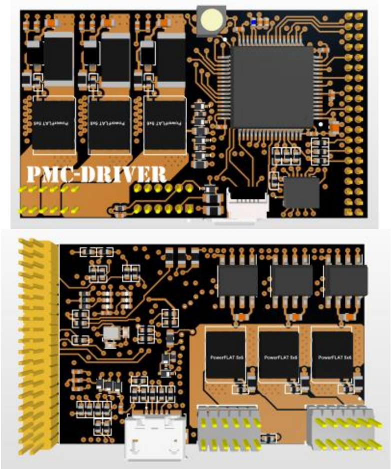


Design

- **Design the hardware architecture for the PMC, with the following features:**
  - Custom brushless motor controller rated for 100V and 20A.
  - The core of the motor controller is the STM32G4 micro-controller and the STM MotorControl Workbench. It features Field Oriented Control, Block commutation, and both sensored/sensorless commutation methods. Although the developed board is targeting robots in the class of EELS (sensored, high power, high voltage), the architecture is very versatile, and it is suitable for lightweight robots such as PUFFER and drones.
  - Sensors:
    - Hall sensors
    - Absolute Encoder (PWM and BiSS-RS422)
    - Relative Encoder (Quadrature)
  - Communication:
    - RS485 (for daisy chain configuration and distributed motor controller)
    - Serial/SPI/I2C/CAN
    - PWM (common in drones application)
    - EtherCAT (Requires an EtherCat adapter board through SPI port)
  - Brake Driver:
    - 1 Brake driver
  - Safety Feature:
    - ESTOP. Rather than be implemented in software, it is mapped directly to the timer generating the PWM. This ensures robustness since it acts on a hardware level rather than software.

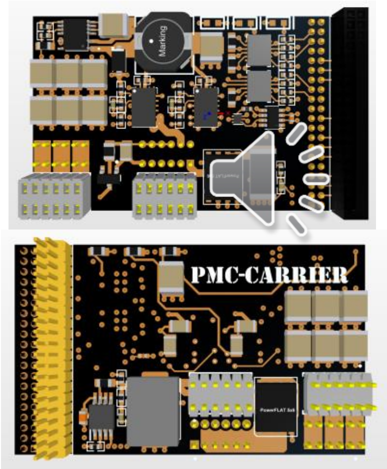
Prototype

Driver Board



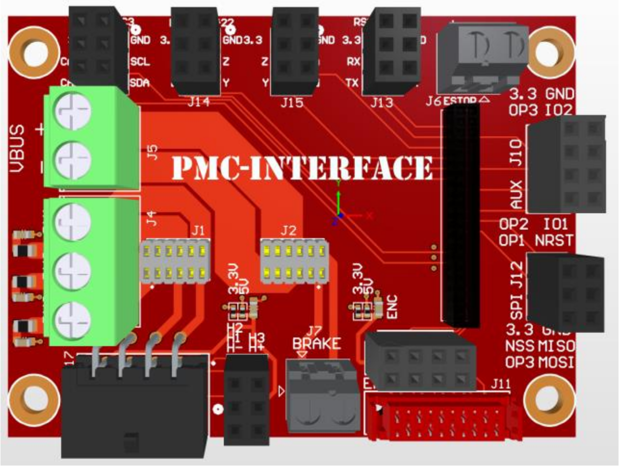
Dimensions:
25.5 x 42.8 mm

Carrier Board



Dimensions:
25.5 x 42.8 mm

Interface Board



Dimensions:
25.5 x 42.8 mm

Prototype