Flight Control System Design: Hardware

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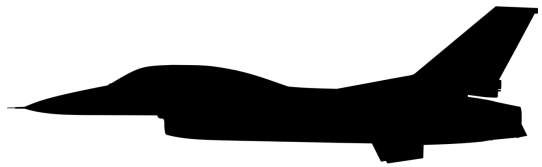
9 December 2019

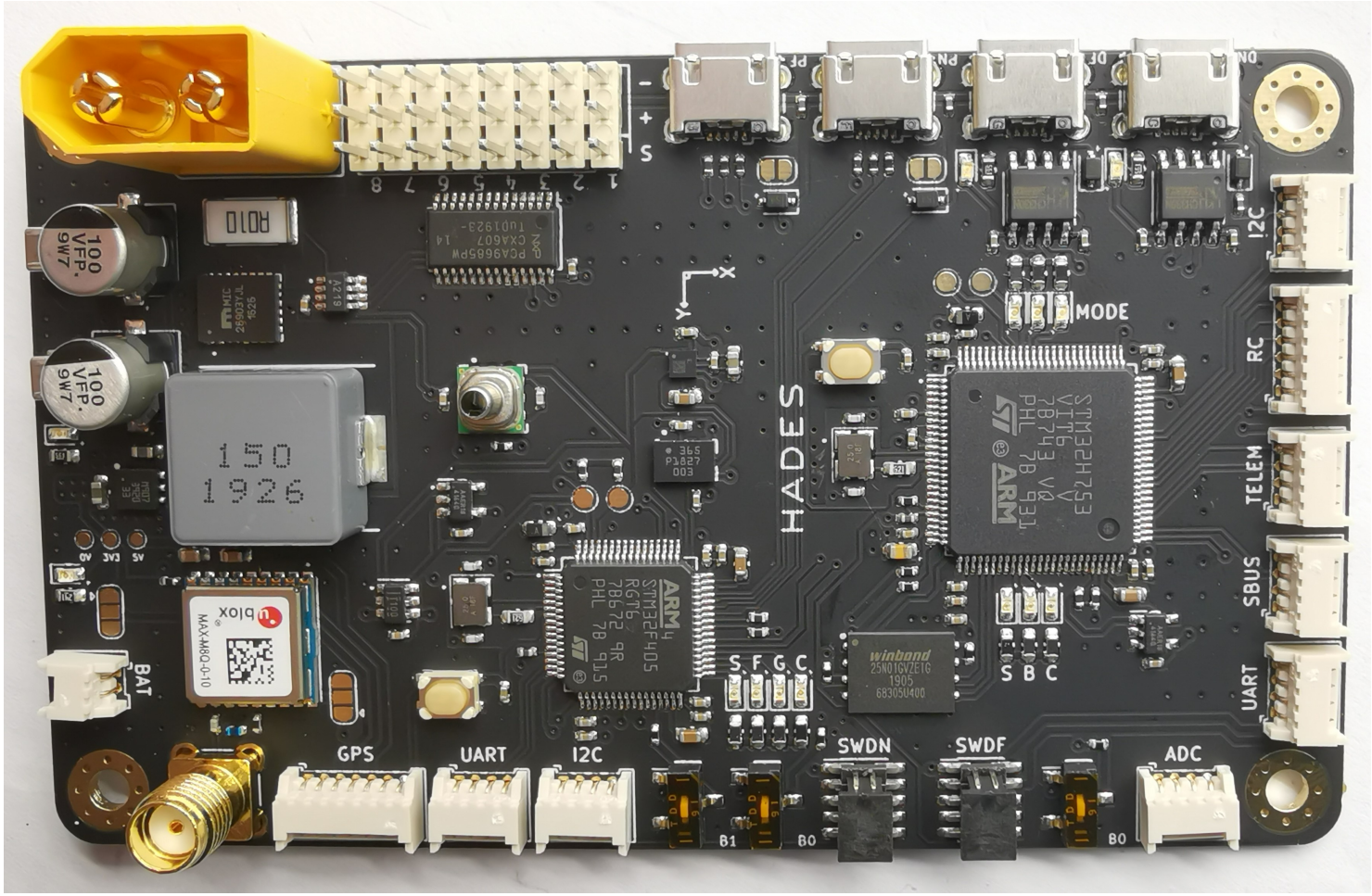


Aims

- Design a complete flight control system from scratch (hardware, software, control systems, navigation algorithms, ground control station, etc..).
- Tailored toward fixed-wing aircraft - but general enough for most other vehicles.
- Goal: Complete system consisting of standardised hardware and basic but robust software framework.

Focus on developing and testing novel algorithms - not writing boring, low-level code!

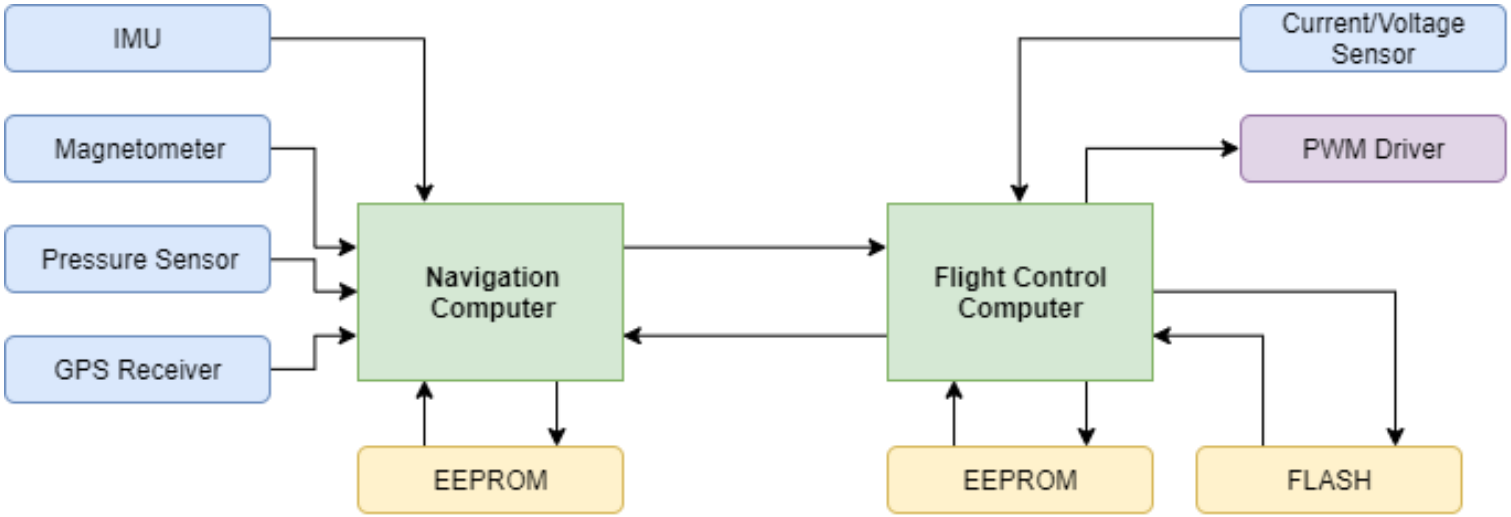
Prototype


HADES
MODE
I2C
RC
TELEM
SBUS
UART
GPS
UART
I2C
SWDN
SWDF
ADC
BAT
S F G C
S B C
B1
B0
B0

Hardware Requirements

- Standard set of sensors (e.g. IMU, magnetomer, barometer, ..).
- Expansion and interface capabilities via various IOs.
- Power distribution for servos.
- Processing power.
- Affordability.

Hardware Block Diagram



+ Power Distribution (6V < Vin < 26V, 5V (9A max.) and 3V3 (2A max.) rails)

+ Connectors (additional sensors, servos, GPS antenna)

+ Programming and Debug (SWD, DFU via USB, UART-to-USB)

Hardware Design Process I

Creating the schematic

- Choose suitable microcontroller(s) (FPU, IOs, speed, ..).
- Pick suitable sensors (cost, measurement range, noise, ..).
- Peripherals and connectors (USB, IOs, SWD, indicator LEDs, ..).
- Power distribution (required voltages, currents, ..).

Follow the manufacturer's datasheets and application notes!

Hardware Design Process II

Pick physical parts

- Consider the size of the board.
- Who's assembling the board? Sets limitations.
- Passive component sizes (0402, 0603, ..).
- IC packages (avoid BGA).
- Connectors!

Hardware Design Process III

PCB layout

- Number of layers and ordering (e.g. SIG,PWR,GND,SIG).
- PCB edge, mounting holes, and connectors.
- Divide into sections (power, RF, analog, digital).
- Special consideration: impedances, oscillators, ...
- (Rough) component placement of ICs (ideally all on one side).
- Place passives and smaller components (decoupling capacitors first).

Again: follow the manufacturer's datasheets and application notes!

Hardware Design Process IV

Routing

- Check PCB manufacturer capabilities.
- Wider tracks for higher currents. Avoid thin traces where possible.
- Route important signals first (e.g. crystal, RF, USB, ..).
- RF: use PCB manufacturer stackup specs and online impedance calculator.
- Route 'smaller' power and ground traces last - use vias to connect to PWR/GND planes.
- Final touch: copper pours and stitching vias.

Hardware Design Process V

Production

- Design rule checks (schematic and layout).
- Print out schematic and check by hand. Again, reference datasheets.
- Generate Gerbers. Check with Gerber viewer.
- Upload to manufacturer's website, fill in settings, and order!
- (For assembly: need further files, such as BOM, centroid file, ..)

Testing

Once you've received the hardware...

- Check component placement and values, check for shorts.
- Attach power supply and slowly ramp up voltage to operating voltage.
- Check voltages and current drawn.
- One-by-one: Write drivers for sensors, peripherals, etc.
- Note down errors but don't change original design files!

Next Steps

A list of a few things to come...

- Low-level firmware (e.g. device drivers and interfaces).
- Signal processing (e.g. filtering).
- Telemetry and messaging protocol.
- State estimation (via Kalman filters).
- Aircraft modelling, control system design and implementation.
- Higher-level firmware (state machine, guidance algorithms, etc.)
- Ground control station.