NOT _drone

A NOT ED design

The NOT Engineering Design's Electronics and Hardware Design team.

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Abstract

The NOT_drone project is a brand new portfolio project developed by NOT Engineering Design; aiming to create from the ground up an ultra-compact, ultra-low power inference indoor quadcopter drone, with the specific tasks of being able to: (i) fit in the palm of the hand, (ii) safe take off and landing, and (iv) being AI capable. This paper presents and documenting the NOT ED's electronic department decision making in regards to component selection, electrical characteristics, layout, and routing architecture, as well as enriching NOT ED's documentation system.

Objectives

This is a very cool list

- Enrich NOT ED's portfolio by showcasing a full stack project.
- Demonstrate our commitment to the Open Source community by open sourcing the NOT_drone project across all engineering development areas.
- Design a compact 25x25mm avionic PCB.
- Design an AI machine vision and inference system for autonomous flight operations.
- Design an USB-C and battery powered system.

Introduction

The NOT_drone project is the brand new portfolio project developed by NOT Engineering Design; aiming to create from the ground up an ultra-compact, ultra-low power inference indoor quadcopter drone, with the specific tasks of being able to:

1. Be compact enough to fit in the palm of the hand.
2. Human recognition and image capture.
3. Safe take off and landing operations without the intervention of the user.
4. AI capable for machine vision and inference.

Zephyr RTOS is the default OS for this application given their native support for Nordic devices.

This paper has the sole objective of presenting and documenting the NOT ED's electronic department decision making in regards to component selection, electrical characteristics, layout and routing architecture.

Mechanical Restrictions

Given the nature of the project, the main board must fit within a maximum dimension restriction of 30x30mm; 25x25mm ideally. Vision and landing sensors will be designed as two separate daughter boards connected with dedicated FPC connectors or specialty wire harness and assembly. In order to not interfere with RF antenna radiated emissions, the battery will have to be housed below the board, hence, it has been determined to place and route the power management and power delivery network on the bottom layer of the board.

Preliminary Bill-of-Materials (BOM)

Being a mixed-signal, ultra-low power AI design, component selection must be kept within certain specifications to ensure proper electromagnetic compliance, signal and power integrity. It is important to note that the components are subject for change, for instance, removing the Coral tpu is being considered, as well as adding a Kendryte K210 processor to the system [9].

Core Computing and AI

- nRF5340 (QFN/WLCSP) – Main SoC with BLE + USB [12].
- STM32H747AI - Sensor fusion and AI inference [16].
- Winbond W25Q128JV – QSPI NOR Flash (128Mb) [18].
- APS6404L-3SQR – Octal PSRAM (64Mb) [1].
- W25Q32JV - QSPI Flash (32Mb) [19]

Note: Coral TPU [2] was replaced by the use of the STM747AI [16] processor which allows for AI loads and MIPI interfaces.

Power Management

- nPM1300 – PMIC for SoC + sensors [11].
- TPS62873YQWR – High-current 3.3V buck for motor rail [6].
- TPS63070 - Buck-Boost for clean camera supply [7]
- USB ESD diode or IC protection.
- Custom ⊠ filter for USB VBUS line.

RF

- Ignion NN02 mXTEND – 2.4GHz chip antenna [4].
- Murata SWF connector (MM8030-2600) – Inline RF test.
- Custom ⊠ matching network – 0402/0603 inductors + caps.

Shielding

- Würth 36103310 or Laird EIA 10x10mm – Solderable shield for RF section.
- Via stitching surrounding shield area.
- Guard copper pours (optional) – Motor driver zones.

Sensors

- BMI323 – 6-DOF IMU (gyro + accel) [13].
- BMM350 – Magnetometer (heading) [14].
- VL53L5CX – Multizone ToF sensor (downward) [17].
- BMP390 - Barometer [15].

Note: PMW 3901 optical flow sensor [10] was removed. Bosch BM390 barometer was added.

Vision

- OV7251 (USB UVC) – Forward-facing global shutter camera [5].
- VL53L5CX – Multizone ToF sensor (downward) [17].

Propulsion

- 4x TMC6300 – 3-phase BLDC drivers (QFN-16) [3].
- Motors: 0802 12000KV or 1102 10000KV (current-limited).
- 3x 0.1–0.15Ω current sense resistors per driver.

Connectivity

- USB-C connector (Amphenol 12401548E4 or similar).
- TS3USB221A [8] / FUSB340 – USB2.0 MUX for switching Coral/nRF5340
- SWD debug header.

Note: TS3USB221A MUX [8] is removed since no longer required.

To evaluate component size, classification, function, and packaging, the following table is presented:

Table 1: Tentative Component Specifications

Component	Function	Classification	Dimensions (mm)	Package
nRF5340	BLE-capable dual-core MCU	Digital	6.0 × 6.0 × 0.75	QFN/WLCSP
Coral Accelerator Module	AI inference via USB	Digital	15.0 × 10.0 × 1.5	LGA
nPM1300	Power management IC	Power	4.0 × 4.0 × 0.75	QFN-48
TPS62873YQWR	High-efficiency 3.3V buck	Power	2.0 × 2.5 × 1.0	QFN-13
USB Type-C	Power and data connector	Power/Digital	8.34 × 2.56 × 3.31	SMT
TS3USB221A	USB 2.0 MUX switch	Digital	1.8 × 1.4 × 0.5	QFN-10
W25Q128JV	Flash memory	Digital	6.0 × 5.0 × 0.9	WSON-8
APS6404L	Octal PSRAM	Digital	1.6 × 1.6 × 0.4	WLCSP
BMI323	IMU (gyro + accel)	Analog	3.0 × 4.5 × 1.0	LGA-16
BMM350	Magnetometer	Analog	2.2 × 2.2 × 0.8	LGA-12
VL53L5CX	Multizone ToF sensor	Digital	6.4 × 3.0 × 1.75	Module
PMW3901	Optical flow sensor	Digital	6.0 × 6.0 × 1.2	Module
OV7251	UVC global shutter camera	Digital	—	USB Module
TMC6300 (x4)	BLDC motor driver	Power	2.0 × 2.0 × 0.5	QFN-16
Ignion NN02 mXTEND	BLE chip antenna	RF	10.0 × 3.2 × 1.0	SMD
Murata SWF Connector	RF test connector	RF	2.0 × 2.0 × 1.0	SWF
Würth 36103310	RF shield can	RF	10.0 × 10.0 × 1.5	Can
Shunt resistors	Motor phase current sense	Analog	1.0 × 0.5 × 0.35	0402
Bypass/decoupling caps	Power filtering	Power	Various (0402–0603)	—
Ferrite bead (BLM18)	VBUS/PDN filtering	Power	1.6 × 0.8 × 0.8	0603
RF matching components	Antenna matching network	RF	0.6 × 0.3 × 0.3	0201

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Table 1 -- Continued from previous page

Component	Function	Classification	Dimensions (mm)	Package
Resistors	Pullups, feedback, etc.	Mixed	1.0 × 0.5 × 0.35	0402

Table 2: Component Count Summary by Classification

Classification	Approximate Count	Total Area (mm²)
Digital	10 major + passives	∼130
Analog	3 major + passives	∼50
Power	4 major + passives	∼65
RF	3 major + passives	∼50
Connectors	2 + test headers	∼40

Architecture

The design architecture must follow a strict order to ensure electromagnetic compliance and avoid unnecessary complications such as daughter boards or excessive FPC connections. To achieve this, the PCB architecture must follow the order depicted in **Figure 1** so that each processor and peripheral can flow freely back and forth, further reducing the complexity of trace routing.

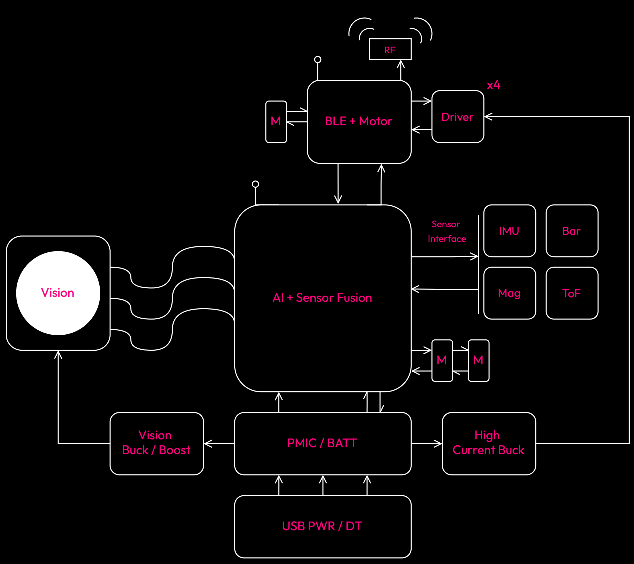

Figure 1: Component Block Diagram. Naime, R. [Diagram] Own authorship diagram.

In the figure above we can observe certain design decisions; starting from the bottom, we can see that power rails will be divided into three sections:

1. IC, battery charge and sensor supply from the PMIC.

2. Vision buck/boost converter, to provide a clean power source to the vision module.

3. Driver supply through a high current buck converter given the power specifications of the motor drivers [3].

Layer Stack and Routing Architecture

Based on Rick Hartley's recommendations on PCB design and grounding techniques, the layer count is designed to keep the EMI at the lowest possible level without the need of excessive ground vias; therefore, adapting Rick's preferred 12-layer stack, the proposed layer stack for this high-density design is reduced to 8 layers with careful consideration of signal return paths and power planes. The following diagram shows a better view of the design of the layer stack, via the types and placement of the components, as well as the proposed thickness of the board.

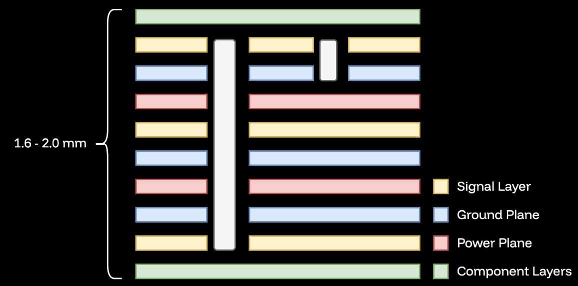

Figure 2: Layer Stack Architecture Diagram. Naime, R. [Diagram] Own authorship diagram.

As depicted above, the proposed stack counts 8 layers; 3 signal layers, 3 continuous ground planes, and 2 power planes. Represented as grey vertical rectangles are the via types, in this case, we will be using both through and blind via types. The routing strategy will be as follows:

- **Layer 1:** Component placement, signal and power lines routing.
- **Layer 2:** Continuous ground plane.
- **Layer 3:** Power plane with different supply voltages.
- **Layer 4:** Signal routing and partial ground copper pour.
- **Layer 5:** Continuous ground plane.
- **Layer 6:** Power plane with different supply voltages.
- **Layer 7:** Continuous ground plane.
- **Layer 8:** Component placement, signal and power line routing.

Inner signal layers can be poured with partial GND copper to further contain EM fields of the different signals. The rationale behind the use of two separate power planes is given by proximity; we need to avoid unnecessary EMI and deliver power efficiently to ICs, hence the close distance of the power planes to each component layer. Return paths for both power and signal lines are ensured by placing ground planes between each layer.

Ground pours in Layer 1 and Layer 8 can be considered instead of power routing to ensure proper audio design practices.

Controlled Impedance

Calculations for the impedance profiles will be carried out later with a dedicated impedance calculator, although three routing profiles are desired:

- 50 ohm RF feeding line.
- 90 ohm differential lines.
- A variable width profile to route power and signal lines.

To ensure impedance globally, the use of grounded micro-strip and coplanar strip-line transmission lines will be used as part of the calculations for the impedance profiles. Additionally, to maintain such impedance profiles across layer jumps, via propagation delay will be simulated in OpenEMS.

Power Analysis and Battery

Table 3: Processing & Connectivity Power Requirements

Component	Supply Voltage	Current Draw	Power Consumption	Operating Mode
STM32H747AI	3.3V	300mA / 900mA	1.0W / 3.0W	Dual-core processing
nRF5340	3.3V	50mA / 150mA	0.16W / 0.5W	Wireless + motor control

Recommended Battery: 2S LiPo 1300mAh 75C.

Table 4: Memory Power Requirements

Component	Supply Voltage	Current Draw	Power Consumption	Notes
W25Q128JV (nRF Flash)	3.3V	15mA / 1μA	0.05W / 0.003mW	SPI flash
W25Q32JV (STM32 Flash)	3.3V	15mA / 1μA	0.05W / 0.003mW	QSPI flash
APS6404L PSRAM	3.3V	50mA / 10mA	0.16W / 0.033W	Image buffering

Table 5: Sensor Power Requirements

Component	Supply Voltage	Current Draw	Power Consumption	Notes
BMI088 IMU	3.3V	5mA	0.016W	Continuous operation
BMM150 Magnetometer	3.3V	0.17mA	0.0006W	Low power mode available
VL53L5CX ToF	3.3V	20mA	0.066W	Active ranging
BMP390 Barometer	3.3V	0.7mA	0.002W	Continuous monitoring

Table 6: Camera & Motor Control Power Requirements

Component	Supply Voltage	Current Draw	Power Consumption	Notes
OV7251 Camera	2.8V/1.8V	120mA	0.42W	During image capture
TMC6300 (4x drivers)	3.3V	40mA total	0.13W	Quiescent current
0802 Motors (4x)	7.4V	500mA each	14.8W	Normal flight
0802 Motors (4x)	7.4V	2A each	59.2W	Takeoff/landing

Table 7: Power Management Efficiency

Component	Input Voltage	Output Voltage	Efficiency	Quiescent Current
nPM1300	7.4V	3.3V/1.8V	90%	50μA
TPS62873	7.4V	7.4V (pass-through)	95%	17μA
TPS63070	7.4V	2.8V	92%	55μA

Table 8: Standby Mode Power Consumption

Component Group	Power Consumption	Notes
STM32H747AI	1.0W	Reduced clock, peripherals off
nRF5340	0.16W	Idle, radio off
Sensors	0.08W	Continuous monitoring
Memory	0.04W	Standby modes
Camera	0W	Powered down
Motor drivers	0.13W	Quiescent current
PMIC losses	0.15W	Efficiency losses
Total Standby	**1.56W**	95% of time

Table 9: Active Flight Mode Power Consumption

Flight Phase	Duration	Power Consumption	Energy per Phase
Takeoff	5 seconds	65W	90.3Wh
Positioning/Photo	10 seconds	8W	22.2Wh
Landing	5 seconds	65W	90.3Wh
Total per Mission	20 seconds	--	**202.8Wh**

Table 10: Battery Specifications

Specification	Value	Notes
Nominal Voltage	7.4V	2S configuration
Capacity	1300mAh	9.62Wh total energy
Discharge Rate	75C	97.5A maximum current
Weight	~55g	Lightweight for drone
Charge Rate	2C max	2.6A via USB-C PD

Table 11: Mission Energy Calculations

Parameter	Value	Calculation
Energy per Mission	202.8Wh	20 seconds active flight
Standby Energy	0.43Wh/min	Between missions
Missions per Charge	15--20	Depending on standby time
Total Flight Time	5--7 minutes	Spread over 2--3 hours
Expo Session Time	2--3 hours	With standby between shots

Table 12: Battery Life Scenarios

Scenario	Missions	Standby Time	Total Session	Battery Usage
Rapid Fire	15 missions	2 min between	45 minutes	85%
Casual Expo	12 missions	5 min between	1.5 hours	80%
Full Day	20 missions	8 min between	3 hours	95%

Table 13: Charging Analysis

Parameter	Value	Notes
Charge Time (0--80%)	25 minutes	2C rate via USB-C PD
Charge Time (80--100%)	15 minutes	Reduced rate for safety
Full Charge Time	40 minutes	Complete cycle
Portable Charging	Yes	Power bank compatible

Safety Margins

- **Current Capacity**: 75C battery provides 20× safety margin for peak motor current
- **Energy Reserve**: 15% minimum battery level maintained
- **Thermal Management**: Short mission cycles prevent overheating
- **Voltage Sag**: Buck-boost converters maintain stable power delivery

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