Hydra Framework Design Notebook

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| Rocket: | Gee-Force One |
| File Name: | DN-2022-AV-Hydra-Framework |
| Sub Team: | Avionics: Hardware |
| Point of Contact: | Serban, Liam, Noah |
| Purpose: | Document Hydra-level decisions that affect all Hydra boards to develop a general framework for supplemental hardware. |

Revision History:

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| --- | --- | --- |
| Revision | Description | Date |
| 0 | Baseline updated (Hydra V1) | Jan 18, 2023 |
| 1 | Updated design following first design review | Feb 11, 2023 |
| 2 | Included Hydra V3 documentation | Sep 25, 2023 |

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# Introduction

This document contains an overview of the macroscopic design requirements and considerations for the first version of uORocketry’s new avionics system, Hydra. The goal of this system is to develop a modular avionics stack in which boards can be stacked in no particular orders and swapped/upgraded over time.

# Documentation

## Hydra V1 (ignore this part of the doc)

### System Behaviour

#### Arming

The power board includes a switch that is actuated by a rod protruding from the rocket and serves to disable power delivery to the avionics stack. No further arming procedures are included since no custom hardware is in control of any controllable mechanisms/elements.

The recovery electronics are controlled by two redundant COTS RRC3 boards with individual batteries which have a similar safety mechanism. Two switches are included on the ejection board, one for each RRC3 battery, to disable power flow to the recovery systems.

#### Recovery

The recovery portion of the first version of Hydra is composed of two RRC3s with separate power sources that control the dual event recovery. The presence of the second RRC3 is due to the competition redundancy requirement. The two altimeters function completely independent from one another, and in case of failure of the primary system, the backup system guarantees a safe recovery of the rocket.

### Hardware Design

#### Board Layout

All Hydra boards intended for mounting within the avionics bay will follow a circular shape, 140mm in diameter, with three 5.3mm mounting holes spread equally along a pattern of radius of 60mm. The mounting holes are specifically located at (0, 2362.2mil), (-2045.729mil, -1181.1mil) and (2045.729mil, -1181.1mil) on the circuit board. Each stackable board in the avionics bay has two 2x15-pin headers mounted with the following Altium settings, assuming the center is at the true center of the board (Figure 2). The right header uses the same values however the X value is positive (+50mm). IMPORTANT: the location is set by selecting the header component itself, not a pin within the header.

Graphical user interface, text, application, chat or text message

Description automatically generated

Figure 1. Left header Location in Altium

Finally, a pass through cutout is included at the rear section of the board as a 15mm circular cutout, tangent to the board’s outline, and along the vertical axis in Figure 3.

Graphical user interface

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Figure 2. Hydra Board General Dimensions (all in mm)

#### Inter-board Connections

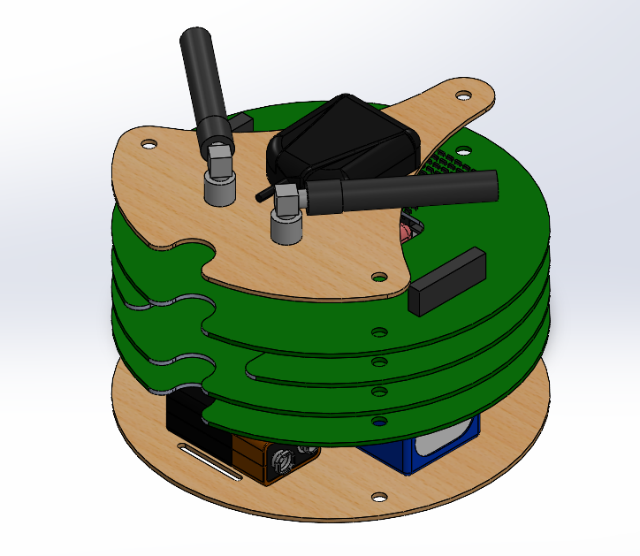
The goal of Hydra is to improve the avionics stack’s malleability and modularity thereby simplifying the process of upgrading the stack over time. As such, all Hydra boards intended to be placed in the avionics bay will have an identical connector pattern with identical pinouts such that various combinations of boards can be stacked in any order. All Hydra boards will have two sets of 2x15-pin 2.54mm pitch headers on opposing sides of the circular PCB with standardized pinouts across all boards as tabulated below:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| |  |  |  | | --- | --- | --- | | POWER | V\_BATT | V\_BATT | | V\_BATT | V\_BATT | | +5V | +5V | | +5V | +5V | | +3V3 | +3V3 | | +3V3 | +3V3 | | I2C | GND | GND | | SDA | SCL | | SPI | GND | GND | | MOSI | MISO | | SCK | CS | | UART | GND | GND | | UART\_TX | UART\_RX | | CAN | GND | GND | | CAN\_HI | CAN\_LO | | |  |  | | --- | --- | | PYRO\_PWR | PYRO\_PWR | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | |  |  | | GND | GND | |

The left header transmits all power and data signals for the avionics stack whereas the right header is mostly free for future upgradeability. The data buses on the left header are segregated by ground pins to prevent crosstalk due to the proximity of these data lines.

The power, logic, and communication boards stack closely in this design to enable the use of inter-board connectors and minimize free wires within the avionics bay. No additional inter-board connections should be required seeing as the ejection board runs independently of Hydra and utilizes separate power supplies. The only clearance issue lies with the SBG as its 24mm height will require a hole in the communication board to maintain the close stacking of the circuit boards.

### Hydra V1 Boards

A picture containing diagram

Description automatically generated

Figure 3. Hydra V1 Preliminary Render

The flight computer is currently split into four circuit boards each having a specific role, as depicted in Figure 4 above. The two beige plates above and below the stack only serve structural purposes and are not part of the computer itself. The top beige plate serves as a mounting point for the GPS antenna and the RFD900’s antennas whereas the bottom beige board serves as a mounting point for the lithium polymer battery as well as the two 9V batteries used by the RRC3s. The material for the beige plates is not determined, however we will likely use excess unpopulated PCBs since we must order a minimum of 5 for each PCB of this flight computer. The functional flight computer PCBs, depicted in green, from bottom to top are as follows: the power board, the logic board, the communication board, and the recovery board. Their specific functionality is listed below:

#### Recovery Board

Hydra V1 does not contain any flight-critical functionality. Therefore, this board functions independently and serves solely to house two RRC3s alongside individual power sources (9V batteries) for each and the SBG’s GPS antenna. The Rocktopus airframe stores the main chute in the nose cone of the rocket (immediately above the avionics bay) and the drogue chute immediately below the avionics bay. This means that two separate sets of wires are required on either end of the avionics bay to interact with both recovery systems. Furthermore, each recovery device is actuated by a set of redundant CD3s (CO2-based deployment charges) so four independent sets of wires are required (8 total).

Beyond providing mounting locations for the components this board serves to replace the wire-to-board connectors on the RRC3s with more reliable connectors. This eliminates the risk of electrical failure due to vibration while maintaining some level of maintainability in that the avionics stack can be conveniently connected and disconnected from the airframe’s hardware.

#### Communication Board

The Hydra V1 communication board serves to provide a mounting point for the RFD900 radio as well as the Featherlight backup GPS tracker. The RFD900 radio receives power and UART from the header with no additional hardware whereas the featherlight functions independently from the avionics stack. As a result, the featherlight uses a separate LiPo battery and does not communicate with the avionics stack.

#### Logic Board

Hydra V1 contains no flight-critical logic and therefore this board serves solely as a telemetry gathering system to log rocket attitude/location data from the SBG to an SD card and transmit it using the RFD900 radio. This is the only board containing an MCU in this version of Hydra. Data is gathered from the SBG using a CMOS-TTL to RS-232 converter linked to a UART port of the MCU and data is logged onto an SD card using an SPI port of the MCU.

In addition to the electrical hardware, this board provides a mounting point for the SBG that must be at its center to ensure accurate attitude data is collected.

#### Power Board

This board contains two switching regulators providing the other boards with a 5V and 3.3V rail from the integrated avionics battery. Current version includes reverse polarity protection as well as thermal and overcurrent protection.

### Board Hardware Requirements

#### Recovery Board

Used for redundant two-stage recovery system deployment and GPS antenna mounting.

* 2 RRC3 footprints to transfer I/O from RRC3 wire-to-board connectors to locking connectors on the recovery board
* Safety disconnect switches
* Cutout in center to provide clearance for SBG
* Passthrough for RF cables throughout stack
* Two 2x15-pin headers

#### Communication Board

Used to mount RFD900 and Featherlight GPS tracker.

* RFD900 footprint
  + UART and power traces
* Featherlight tracker footprint
  + Independent battery so no traces needed whatsoever
* Passthrough for RF cables throughout stack
* Two 2x15-pin headers

#### Logic Board

Used for data logging and ground station communication.

* Micro SD card holder
* 1 external crystal 32KHz
* 1 external crystal 8MHz
* Microcontroller ATSAME51J18A
* SBG mounting point
* UART link to SBG
  + CMOS-TTL to UART adapter
* LEDs:
  + Green: connected to power
  + Red: connected to chip, error
  + Yellow: connected to chip, communication
* SWD debugging port (<https://www.segger.com/products/debug-probes/j-link/models/j-link-edu-mini/>)
* Two 2x15-pin headers
  + UART link for RFD900
  + CAN link for future avionics boards
  + I2C link for future avionics boards
  + SPI link for future avionics boards?

#### Power Board

Used to step down battery voltage to 5V and 3.3V rails.

* 5V regulator
* 3.3V regulator
* LEDs to indicate operational state of each power rail
* Battery connector
* Safety power-disconnect switch
* Two 2x15-pin headers

## Hydra V2

### System Behaviour

#### Arming

The arming system is identical to Hydra V1 (see Section 2.1.1.1) and uses two arming rods: one for power and another for pyrotechnics. The power safety interacts with the power board and mechanically disconnects battery power from the avionics system whereas the pyrotechnics safety rod interacts with the recovery board and mechanically disconnects power from the pyrotechnics channels.

#### Recovery

Hydra V2 uses SRAD and COTS recovery systems in parallel for redundancy. The SRAD system is in the form of the recovery board which also houses a RRC3 to use as its COTS backup.

### Hardware Design

Hardware design is highly similar to V1 and was not documented since so few people worked on the boards that there was no need.

### Hydra V2 Boards

A green and black device

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Figure 3. Hydra V1 Preliminary Render

The flight computer is currently split into four circuit boards each having a specific role, as depicted in Figure 4 above. The two beige plates above and below the stack only serve structural purposes and are not part of the computer itself. The top beige plate serves as a mounting point for the GPS antenna and the RFD900’s antennas whereas the bottom beige board serves as a mounting point for the lithium polymer battery as well as the two 9V batteries used by the RRC3s. The functional flight computer PCBs, depicted in green, from bottom to top are as follows: the power board, the logic board, the communication board, and the recovery board. Their specific functionality is listed below:

#### HYDRA\_V2\_POWER

The V2 power board uses identical regulators to the V1 power board albeit in parallel for redundancy. Each power rail (5V and 3V3) has two regulators whose outputs go through a load-sharing circuit based on the LTC4353IDE#PBF load-sharing controller. This ensures we have 5A of redundant current delivery per rail with a possibility of peaking up to 10A.

From a macroscopic perspective, the power is received through a Molex connector (J1) and passed through two cutoff switches before entering the global power protection circuit. This circuit handles reverse polarity protection as well as overcurrent and overvoltage protection (in this order). Finally, the power protection circuit provides the MCU with input voltage and current data. Following the protection circuit, power passes through two similar regulator circuits which power the 5V and 3V3 rails of the avionics stack. Both circuits consist of two identical regulators who largely share input and output capacitors and are combined using a load-sharing circuit. Finally, an MCU is included to manage the board and communicate with the remainder of the avionics. The MCU has its own internal regulators such that it remains online even in the case of a power failure on the main hydra power rails.

#### HYDRA\_V2\_LOGIC

This board is relatively identical to the V1 logic board with the exception of some added voltage sensing, a new MOSFET switch to turn the SBG on/off, and a secondary CAN network which enables us to interface with CAN devices without exposing the flight-critical avionics CAN network. Its purpose is to interface with the SBG, log data from the SBG to an onboard SD card and publish navigational data to the avionics CAN bus. This board is also intended for future use in a hybrid vehicle where it could interact with satellite PCBs throughout the vehicle to receive sensor data or control actuators.

#### HYDRA\_V3\_COMMUNICATION

The purpose of this board is to act as a black box with respect to all content going across the avionics CAN network, and to provide a radio link between Hydra and the ground station. Additionally, this version of the communication board contains a set of internal regulators which it can use in the event of a power failure on the main Hydra power buses. At that point, the communication board can revert to using pyrotechnics power and its own internal regulators which ensures that we can maintain a telemetry link with the avionics in the event of an accidental short circuit or other non-critical power failure.

This board is named the V3 power board since it integrates a blackbox and the internal regulator feature which was provisioned for V3 and not V2.

#### HYDRA\_V2\_RECOVERY

The Hydra V2 recovery board contains SRAD ejection circuitry in parallel with an RRC3 recovery device for redundancy. This version of the board uses a SAME51 MCU though this will be updated in the future since functions that rely on the ADC are unusable due to an issue with the chip’s clocks on the software side. The SRAD circuitry also contains a barometer and IMU that can be utilized in the event that no navigational data is available on the avionics CAN bus from the SBG.

## Hydra V3

Hydra V3 is the expansion of Hydra V2 that allows the avionics system to completely integrate with a hybrid rocket engine. Both the V2 and V3 systems are capable of this though hybrid hardware was not included in V2 seeing as the purpose of V2 was to test the avionics stack’s functionality.

Hydra V3 consists of revised and miniaturized Hydra V2 boards as well as two additional non-stackable ‘satellite’ boards: one for sensors external to the avionics stack and another for actuators external to the avionics stack. The stackable boards have many design constraints all of which are detailed in Section 2.2.2. Satellite boards have far less design constraints and their standard can be found in Section 2.2.3.

### System Behaviour

#### Arming

Hydra V3 uses a MOSFET-based switch on the power board which is actuated by some sort of external source such as a key switch. This is due to problems we faced with the arming rods and paddle switches used by Hydra V1 and V2. The arming rods failed to reliably interact with the switches which allowed devices to be powered with the rods inserted. Additionally, we believe the switches to have actuated due to vibrations in the airframe thereby resetting the stack mid-flight.

The MOSFET-based switch consists of two back-to-back MOSFET assemblies in parallel for redundancy and lowered resistance. These MOSFETs circuits are driven directly from battery power by an external switch and contain as little circuitry as possible to ensure reliability. This circuit is entirely analog and cannot be influenced in any way by any programmable hardware.

#### Recovery

Unlike Hydra V1 and V2, this system is too small to house an RRC3 recovery device and cannot therefore use our current COTS-based redundant recovery system. For this reason, Hydra V3 can only be redundant with the inclusion of two recovery boards within the stack running individual recovery algorithms and wired to independent initiators within the parachute deployment mechanisms. A redundant COTS solution can be included external to the stack itself if needed.

### Stackable Board Design

#### General Outline

The Hydra V3 ecosystem maintains the physiology of V1/V2 though at a much smaller scale such that it can fit smaller airframes. The wire cutout at the rear of the PCBs is also maintained though it is no longer circular to enable board-to-wire connectors to sit flush with the backside of the PCB making it easy to mate/unmate connectors without disassembling the stack. A sketch of the updated PCB layout is included below. Fundamentally, the system now has boards which are 50mm in diameter (roughly 2 inches), have a similar set of stacking connectors on all PCBs, and have the aft end of the PCB flattened for board-to-wire connectors.

A blue circle with a blue line drawing

Description automatically generated with medium confidence

Figure 4. Hydra V3 Stackable PCB Layout

No mounting provisions are made for Hydra V3 to maximize usable board space for electronics. Instead, the system will be held in place using braces at the top and bottom of the stack which fix it to the airframe.

#### Inter-PCB Connectors

Hydra V3 uses Samtec TigerEye locking connectors between the PCBs (see part numbers below). The locking behaviour is important since Hydra V3 does not include any mounting provisions on the PCBs and therefore relies partly on the connectors to hold itself together. The set of connectors listed below mates together and provides 40 pins of combined I/O between all PCBs. Each pin is rated to 3.2A and the connectors themselves are rated for various data transfer protocols all of which far exceed our needs.

1. SFML-110-02-L-D-A
2. TFML-110-02-L-D-A

The SFML connector is the female variant and is placed on the bottom size of the PCB. Conversely, the TFML connector is the male variant and is placed on the top side of the PCB. This choice was made to mitigate the risk of short circuits by not having exposed pins on the bottom end of the stack which will be placed on various surfaces during testing. The left set of headers is placed at (X: -20mm, Y: 0mm) whereas the right set of headers is placed at (X: 20mm, Y: 0mm). Both these dimensions are given with the center of the PCB’s radius (not the center of its area since it’s not a circle) as the reference (X: 0mm, Y: 0mm) and the connector footprints should have centers which perfectly align the pads. **A 0.7mm/0.5mm (via diameter/hole diameter) via must be included on each connector pad.** These connect the pads from the top and bottom connectors.

The updated connector pinout is as follows:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| |  |  |  | | --- | --- | --- | | POWER | V\_BATT | V\_BATT | | +5V | +5V | | +5V | +5V | | +3V3 | +3V3 | | +3V3 | +3V3 | | GND | GND | | CAN | GND | GND | | CAN0\_HI | CAN0\_LO | | GND | GND | | CAN1\_HI | CAN1\_LO | | |  |  | | --- | --- | | PYRO\_PWR | PYRO\_PWR | | PYRO\_PWR | PYRO\_PWR | | PYRO\_PWR | PYRO\_PWR | | PYRO\_PWR | PYRO\_PWR | | GND | GND | | GND | GND | | GND | GND | | GND | GND | | GND | GND | | GND | GND | |
|  |  |

The left table represents the pinout for the left Hydra V3 connector (based on a top-down view of the PCB) where V\_BATT is the top left pin of the connector. **This is important because Altium inserts the connectors upside down and they must be rotated 180 degrees.** Likewise, the right table represents the pinout for the right Hydra V3 connector where the PYRO\_PWR pins are on the top half of the connector. Eight PYRO\_PWR pins are included to allow for enough ground pins such that there is a ground pin for every power pin (regulated or not).

Only two V\_BATT pins are included since V\_BATT was seldom used by Hydra V2 boards though it may be useful in the future and should therefore not be fully omitted. Hydra V2 boards sometimes tapped into the PYRO\_PWR rail for things like the logic board’s buzzer but **this should no longer be a thing**. The PYRO\_PWR rail should only be used by power boards, pyrotechnics channels, and the communication board to ensure that it remains a highly reliable power rail for the entire system.

The regulated 5V and 3V3 rails of the avionics system maintain 4 power pins each, providing each rail with a theoretical 12.8A current capacity (based on 3.2A/pin). The left header of the avionics stack also contains two separate CAN buses. This is for two reasons: firstly, the software team had issues sending commands over CAN as those packets would get drowned in sensor data and would not be received by target boards. Furthermore, this provides redundant CAN buses allowing Hydra V3 to persist in the case that one CAN bus fails. Of the two new CAN buses, one is reserved for sending time-critical command data and the other is reserved for sending non-time-critical sensor data.

#### Wire-to-board Connectors

Hydra V3 uses Molex PicoBlade connectors between its PCBs and external devices such as batteries and the SBG. These connectors are used for their small size, locking ability, and high current capacity. All connectors to external I/O will be located at the back end of the PCB (flat part of sketch in Section 3.2.1) and **must be labelled on the opposite silk mask**. The individual pinouts can be omitted from the silk mask on a case-by-case basis, but the general function of the connector should be clearly visible without needing to disassemble the stack. All wire-to-board connectors located at the rear of Hydra V3 PCBs should be located at a Y value of -16.25mm. Therefore:

* + - Wire-to-board connectors (general) 🡪 (X: varies, Y: -16.25mm)

#### Debugging Interface

The Samtec TigerEye connectors severely limit the vertical clearance available between Hydra V3 PCBs. This, in combination with the small size of the PCBs prevents the use of a dedicated full-scale J-Link connector. Instead, the Hydra V3 PCBs use a 6-pin Molex PicoBlade connector for debugging which is located on the top layer of the PCB as follows:

* + - Debug connector à (X: 0.0mm, Y: 19.0mm)
      * Label 1 🡪 (X: -7.0mm, Y: 21.0mm)
      * Label 2 🡪 (X: 7.0mm, Y: 23.299mm)
    - Reset switch à (X: 10.0mm, Y: 18.7mm)
      * Label 🡪 (X: 8.9mm, Y: 20.8mm)

The pinout for the debugging interface (based on the Molex 0532610671 part available in our Altium cloud) is as follows:

1. SWO
2. SWDIO
3. SWCLK
4. RESET
5. VREF
6. GND

And both shield pins of the connector are also grounded.

#### Status LED Locations

Hydra V3 implements a standardized LED layout which enables all LEDs to be aligned across the entire stack. The V3 PCB layout provides space for 4 bicolor LEDs to provide status information about the board. From top to bottom the LEDs are as follows: power status, MCU status, custom status 1, custom status 2. The latter two LEDs are board-specific and do not need to be included on all PCBs. The LEDs are the Wurth Electronics 150066RG54050 and their locations are standardized as follows:

* + - Power status LED 🡪 X:13.6mm, Y:18.4mm
      * Label à X: 11.5mm, Y: 19.3mm
    - MCU status LED 🡪 X:16.5mm, Y:15.5mm
      * Label à X: 15.0mm, Y: 16.4mm
    - Custom status 1 LED 🡪 X: 19.0mm, Y:12.5mm
      * Label 🡪 X: varies, Y: 13.4mm
    - Custom status 2 LED 🡪 X: 20.5mm, Y: 9.5mm
      * Label 🡪 X: varies, Y: 10.4mm

All LEDs **must be labelled** as per the label locations provided in the list above. The X coordinate of the label may be adjusted depending on the length of the label’s text though the text must be kept as close as possible to the PCB’s edge. The dimensions above are provided with the center of the Hydra V3 PCB as the origin (X: 0mm, Y: 0mm).

#### Silk Mask Layout

All Hydra V3 boards must contain the name of the board (HYDRA\_V3\_NAV, for example), the uORocketry logo, and the name of whoever designed the board. The uORocketry logo is standardized across all PCBs and is located at (X: 19.5mm, Y: -9mm. Furthermore, the PCB’s name should be located at (X: 0mm, Y: -12mm) whereas the designer’s name should be located at (X: 0mm, Y: -13mm). All the dimensions above are provided with the center of the PCB’s curvature being the origin (X: 0mm, Y: 0mm)

All text on Hydra V3 PCBs, with the exception of the designer’s name, has a text height of 0.75mm and a stroke width of 0.15mm. The designer’s name has a text height of 0.5mm and a stroke width of 0.1mm. To summarize:

* + - **Must include:**
      * uORocketry logo at (X: 19.5mm, Y: -9mm)
      * Board name at (X: 0mm, Y: -12mm)
      * Designer’s name at (X: 0mm, Y: -13mm)
    - All text except designer’s name:
      * Text height 🡪 0.75mm
      * Stroke width 🡪 0.15mm
    - Designer’s name text:
      * Text height 🡪 0.5mm
      * Stroke width 🡪 0.1mm

#### Component Identifiers

Individual component identifiers may be excluded from Hydra V3 boards as they were in Hydra V2 boards. This is to maintain clean-looking high density PCBs and should not be a concern seeing as Hydra V3 PCBs are solely for internal use by people with Altium access.

#### Component Sizing

Hydra V2 followed strict guidelines with regards to component sizing in which all resistors were 0603 and all capacitors were 0805. Due to the size limitations of Hydra V3 and the general pain that is soldering 0402 components, Hydra V3 will use 0603 for all resistors and capacitors unless PCB constraints require the components to be smaller. Decoupling caps will remain 0402s because they are universally used by all ICs on Hydra PCBs and are therefore used in large numbers on all boards. To summarize:

* + - Resistors and capacitors 🡪 0603 unless larger size is required.
    - Decoupling capacitors 🡪 0402

#### Vertical Clearance

The Samtec TigerEye connectors provide 5-7mm of clearance between two mated PCBs which is assumed to be exactly 5mm for design purposes. Therefore, no components with a height greater than 5mm can be used on Hydra V3 PCBs. Additionally, some high-density PCBs may benefit from locating components on the bottom side of the board; this should generally be avoided as it may prevent the system from truly being stackable in any order/combination thereby compromising Hydra’s design philosophy. Some exceptions may be made to this rule in which case no component with a height greater than 1.5mm (solder included) should be included on the bottom side of the PCB.

### Satellite Board Design

I’ve got no idea what’s gonna happen with these yet, ignore for now.

#### General Outline

#### Wire-to-board Connectors

#### Debugging Interface

Hydra V3 satellite boards are not affected by the limitations of the stackable boards and will therefore maintain the debugging interface of V2 with a dedicated J-Link-style SWD connector.

#### Status LED Locations

#### Silk Mask Layout

#### Component Identifiers

#### Component Sizing

### Hydra V3 Boards

The Hydra V3 ecosystem will be identical to the Hydra V2 ecosystem albeit with the inclusion of two new satellite PCBs (not part of the avionics stack) for interfacing with external avionics hardware. The satellite PCBs do not have many size constraints and will therefore be built as small as possible while also maintaining reasonable mounting provisions.

#### HYDRA\_V3\_POWER

The Hydra V3 power board is a revamped version of the Hydra V2 power board which allows multiple power boards to be stacked within the avionics system. Each power board contains a single regulator per voltage rail alongside a load sharing circuit which allows all power boards to share the load of the avionics system. Furthermore, the Hydra V3 power boards are based around a 3-way MOSFET junction which allows the MCU to actively rewire the PCB as it sees fit. A basic system diagram of the Hydra V3 power board is included below.

A group of squares with text

Description automatically generated

Figure 5. HYDRA\_V3\_POWER System Diagram

The 3-way MOSFET junction allows the board to connect any combination of its power input, the avionics-wide pyrotechnics power rail, and the board’s internal regulators. Furthermore, a battery balance connector is included on each power board to monitor the status of the battery as the 3-way MOSFET junction now provides us with the ability to charge the avionics battery.

The hardware requirements for this board are as follows:

* + - MCU
    - Voltage sense on all rails and temperature sense on regulators as well as current sense wherever possible (at least have current sense at board input but maybe also at regulated rail outputs and on pyrotechnics power rail)
    - Separate regulators for the onboard MCU and CAN transceiver
    - Battery cell voltage sensing circuit
    - Fuse at input
    - MOSFET-based reverse polarity protection
    - MOSFET-based safety switch mechanism
      * Prevent bidirectional current flow à back-to-back MOSFETs
    - Large 5V and 3V3 switching regulators (ideally 2+ amps)
    - Two load sharing circuits, one for each of the regulators mentioned above
      * Load sharing circuits should enable regulators to share the load on the Hydra 5V and 3V3 rails
    - One bi-color status LED per regulator
    - 3-way MOSFET junction
    - Resettable OC and OV protection between 3-way MOSFET junction and regulators
    - **Very important:** have very sensitive OC protection on V\_BATT rail since no other hydra boards have protection on these pins and a short on this rail will kill the system

#### HYDRA\_V3\_NAV

The Hydra V3 navigation board is very similar to the Hydra V2 logic board albeit with an upgraded MCU and solder-on eMMc memory. The upgraded MCU provides the board with more processing power in hopes of it keeping up with the high data rate emanating from the SBG Ellipse2-N-G4A3-B1 sensor. The solder-on eMMc memory is included since mechanically affixing the SD card onboard the PCB has proven to not be reliable enough for our application. Lastly, the V3 logic board does not include the buzzer from Hydra V2 since it is a large through hole component that is difficult to add and was not used at all by Hydra V2.

The hardware requirements for this board are as follows:

* + - MCU
    - Voltage sense on all rails
    - eMMc memory
    - RS-232 to TTL converter
    - MOSFET-based switch to turn off SBG power
    - Outward-facing CAN network
    - Two status LEDs
      * One for UART to SBG
        + Green means Rx
        + Red means Tx
      * Second for outward-facing CAN network
        + Green means Rx
        + Red means Tx

#### HYDRA\_V3\_LINK

The Hydra V3 link board is highly similar to the Hydra V2 communication but contains fixed regulator logic, so the board no longer relies primarily on its internal regulators to power itself. Instead, the board will use the avionics power rails until they fail and will only switch to internal regulators at that point. Furthermore, the RFD900 is no longer mounted on the communication board due to its small size and therefore interfaces with the board using a connector at the rear of the PCB.

The hardware requirements for this board are as follows:

* + - MCU
    - Voltage sense on all rails
    - Onboard regulators with failover logic
    - RFD900 interface
    - eMMc memory?
      * Maintain SD card for first iteration
    - Two status LEDs on this board
      * One for UART activity
        + Green is Rx
        + Red is Tx
      * Second for regulator status
        + Green means using Hydra power
        + Red means using internal regulators

#### HYDRA\_V3\_RECOVERY

The Hydra V3 recovery board is virtually identical to the Hydra V2 recovery board albeit with an updated sensor package that should hopefully be more functional. This board contains both an IMU and a barometer such that it can fully replace the navigational data provided by the SBG with the exception of the SBG’s GPS data. The sensors chosen for the Hydra V3 recovery board are as follows:

* IMU: TDK InvSense ICM-40609-D
* BARO: TE MS561101BA03-50

The hardware requirements for this board are as follows:

* + - MCU
    - Voltage sense on all rails
    - Separate SPI links to each of the two sensors listed above
      * **IMU must be centered on the PCB**
    - MOSFET-based pyro switches
      * Continuity and detonation detection
        + Go with current-based detection
        + Voltage-based continuity detection is great but doesn’t provide feedback on whether the charge drew enough current to ignite. We can detect both continuity and successful ignition by just measuring current going through the pyro channel.
    - Two status LEDs for pyro channels
      * One bi-color per pyro channel
        + Green means continuity
        + Red means ignition

#### HYDRA\_V3\_SENSOR

The Hydra V3 sensor board is a satellite board designed to interface with pressure transducers and temperature sensors throughout the hybrid engine. The propulsion team only wanted pressure transducers within the flight-ready engine, but this board is designed to be compatible with many more sensors such that it can be used for other things such as future strain gauges throughout the airframe. This board only takes battery power and CAN; all additional voltage regulation must happen internally.

#### HYDRA\_V3\_ACTUATOR

The Hydar V3 actuator board is used to interact with servos and solenoid valves within the flight-ready hybrid rocket engine. It contains a high current 5V regulator to power large servos and a MOSFET-based switch which can be used to interface with solenoid valves. This board only takes battery power and CAN; all additional voltage regulation must happen internally.

# Software Design

Enjoy, cutie

# EMI/RF Considerations

Four antennas are used for the avionics stack’s various RF components: two quarter-wave 900MHz dipoles for the RFD900, one 900MHz dipole for the Featherweight tracker, and a GPS antenna for the SBG. The avionics stack may be surrounded with non-conductive RF isolating material depending on future testing which will be done once the boards are manufactured. A potential concern is the proximity of the RFD900’s antennas to the ejection circuitry though the RRC3s are likely perfectly capable of withstanding the radiation induced by the RFD900’s relatively low 1W transmission power.

The RFD900’s two dipoles will be placed orthogonally and perpendicular to the rocket’s axis above the avionics stack alongside the GPS antenna. The Featherweight’s antenna is placed at the top of the payload bay to limit interference since it transmits on the same band as the RFD900. As previously mentioned, the entire Featherweight unit may be transferred to the top of the payload bay pending testing.

# Arming and Safety Considerations

The power board has a cutoff switch that interacts with a rod protruding from the rocket’s fuselage which must be removed to allow power to flow from the battery to the voltage regulators. Furthermore, the ejection board has two separate switches, one for each RRC3, that utilize a similar mechanism to disconnect the 9V batteries from their accompanying RRC3 prior to flight. Both of these rods will protrude out of both sides of the rocket through holes drilled along a centerline of the fuselage. Additionally, each rod intended to be removed before flight will have a Clevis pin to ensure it cannot be removed accidentally. A sample photo of the proposed locking pin design is included below in Figure 5.

Text, whiteboard

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Figure 6. Clevis Pin

3D-printed rod guides will be attached to any PCB containing safety cutoff switches such that a dummy rod can be inserted during assembly to maintain the switches in an open position. Once the rocket has been fully assembled, the real rod will be inserted into the fuselage hole consequently pushing out the dummy rod without ever closing any safety cutoff switches. These 3D-printed rod guides will also contain O-rings to provide additional friction for maintaining the safety rods in place.

# Battery and SBG Considerations

As depicted in Figure 4, the battery is placed horizontally below the PCB stack. The avionics battery will be a 3S 2200mAh lithium polymer pack as we found this to be lighter than using lithium-ion cells of a similar capacity while also providing plenty of battery life. Two additional 9V batteries are included for each RRC3. All batteries are attached using a combination of double-sided adhesive and straps going through slits in the battery mounting plate.

The SBG was included in this section as it lies on the second board from the bottom of the stack and is relatively large. As a result, the communication and ejection boards will have cutouts in the middle to allow the SBG’s body to protrude through their center thereby providing the required clearance. Due to the relative simplicity of the hardware, this cutout does not deprive us of any required PCB space. A few additional cutouts are included on the rear of the stack to allow RF and power cables to pass through the boards since clearance around the avionics stack is limited. These cutouts allow RF cables to pass from the RFD900 to the two antennas above the stack and the GPS antenna’s cable to connect with the SBG. Additionally, they allow power cables from the two 9V batteries on the bottom plate to pass through to the RRC3s on the recovery board.