Grim Reefer

Payload Data Analysis.pdf Grim Reefer Manual.pdf Grim_Reefer_Schematics (1).pdf Grim Reefer L1 test flight Data.pdf fast.csv slow.csv merged (1).csv

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Attachments: Grim Reefer Schematics, Grim Reefer Manual (test and launch instructions), Payload data Analysis (data from Grim Reefer, RRC3 and Radiosondes IREC), L1 test flight data (fast.csv, slow.csv), L1 test flight data (L1 graphs), IREC data (merged.csv)

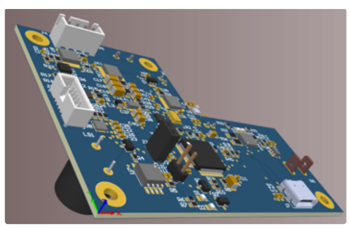
Status: Completed; successful READ THE FAILURE SECTION BEFORE YOU COPY ANYTHING!!

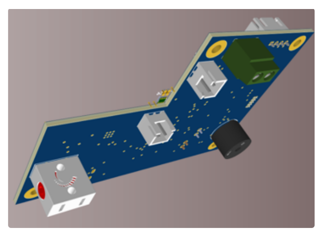
Project: IREC 2023-24 payload "Ritchie" mission was to record flight data and footage of reefing event.

Grim Reefer Requirements:

- Detect boost and landing
- Read loadcell output
- Control camera power
- Ability to arm on pad

[Component Overview] [Power Delivery] [Boost/Landing Detection] [Load Cell reading] [Control Camera Power] [Successes] [Failures]

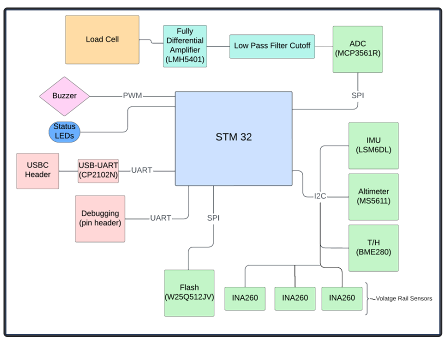




Component Overview

Requirement	Component
Processing power	STM32
USBc to UART	CP2102N
Debugging	SWD connector, reset header, debugging header
Board status indicators	LEDs and Buzzer
Store data locally	Flash mem → W25Q512JV
Voltage rail sensor	INA260
Temp and humidity	BME280
Altimeter	MS5611
IMU	LSM6DL
ADC	MCP3561R

Loadcell reading	Fully Differential Amplifier → LMH5401
Loadcell	50kg ATO Tension and Compression
7.4V Camera Power controller	Load Switch → TPS22810
3.3V rail for Grim Reefer	Buck → TPS565208DDCT
5V for load cell	LDO → TPS7B8450QWDRBRQ1
Cameras	RunCam Split v4
Camera connectors	2 pin JSTXH
Battery connector	2 pin screw terminal [Link]
Arm on pad	FingerTech screw switch and buzzer (to note if grim is flight ready)
Load cell connector	4 pin screw terminal

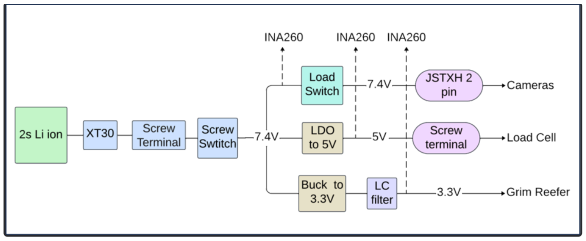


Grim Reefer High Level Wiring Diagram

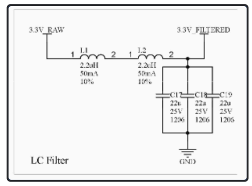
Power Delivery

Powered by a 2S Li Ion battery at 5000mAh. We needed three Voltage rails, excitation, grim reefer and cameras.

- 5V for Load Cell Excitation
  - Needs to be stable because load cell measures voltage as it undergoes compression/tension. Resistance chances during compression/tension therefore measuring a different voltage (classic V=IR) so excitation voltage for load cell must be stable throughout entire measurement to get best results.
  - For highest input to output ratio the excitation voltage should be run near max, which was recommended on the datasheet as 10V. We had concerns with the 10V supply being unstable and getting too hot. Temperature also changes resistance so we would have had to correspond what temperature the load cell was throughout flight and compensate for that in our analysis. We decided that 5V was acceptable for this application especially since we picked a 50kg loadcell instead of a 100kg loadcell.
- 7.4V for 2x Cameras (only on during flight → enables load switch once boost is detected and disables after 24 minutes)
  - Camera's voltage ranges from 5V-25V but need to be aware of power consumption and temperature. It is worth noting that these cameras were power hungry, and we would have been cutting it close with battery life if not for boost detection.
- 3.3V for Grim Reefer
  - Needs to be relatively stable to support sensor suite and STM32.
  - We have a simple LC filter on this rail see below in figure labeled 3.3V LC Filter.



Power Wiring Diagram



3.3V LC Filter

Voltage Rail	Component	Rational
7.4V (Cameras)	Load switch TPS22810	Cameras could take any voltage between 5-25V and were only going to be powered on during flight so we didn't have to worry too much about power consumption.
3.3V (Grim Reefer)	Buck from 7.4V (Battery) to 3.3V TPS565208DDCT	Grim reefer needs relatively stable voltage for sensors. LDO has lower noise floor but is less efficient - put a simple LC filter to help mitigate noise on Buck. [LDO vs Buck]
5V (load cell excitation)	LDO from 7.4V (Battery) to 5V TPS7B8450QWDRBRQ1	Load cell excitation needs to be stable - fluctuations in excitation will affect the measurement.

Boost/Landing Detection

Two ways:

- Acceleration based: **5G for 1/4 of a second**
- Altitude based: 500ft gain in altitude over 5 seconds.

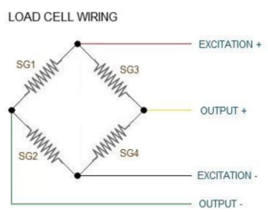
The acceleration-based boost detection was the mechanism that triggered first for the flight and the L1 test flight.

Load Cell reading

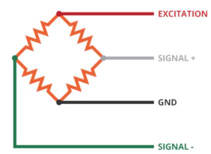
Requirement: Read a 10ms event with a CALCULATED maximum force of 27kg.

- 50kg Load Cell [Load Cell ATO Link] → we had a granularity of about 6 grams.

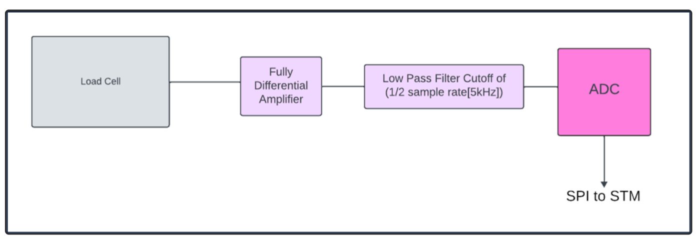
- Fully Differential Amplifier was picked was the LMH5401. This chip was definitely over speced (sorry Louis this one kinda broke da bank) but it worked well for our application. Has ability to implement certain gain - we did 12dB.
- Anti-Aliasing filter, fairly simple and standard to implement in these types of applications. If you are an EE/MicroE you will learn all about it in Linear Systems, if not read about it here [Anti-aliasing link](). Pretty much you need to filter out unwanted frequencies that you could potentially misread. Cut off frequency should be 1/2 of max sampling rate (thanks Nyquist) so ours was 5kHz because we have to sample at 10 kHz to get enough data for a 10ms event. Simulation done in LTspice (spice is life) - shown below in figure Filter Sim.
- Load cell excitation was run at 5V to GND. Usually load cells have +/- excitation voltage shown in Typical Load Cell Wiring diagram but instead of having a negative excitation we ran it to GND. You lose part of your input/output range (differential centered around 0 with +/- excitation vs differential centered around half of your excitation), but it was simpler to use GND and worked for our application.
- Load cell calibration @Richard Sommers (RIT Student) and @Mary Dertinger (RIT Student) hung a bunch of known masses on the load cell then in the same order put on, they were taken off -*hysteresis*- shown below in Load Cell Calibration/Data.



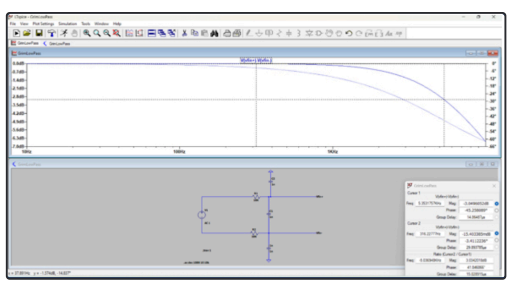
Typical Load Cell Wiring

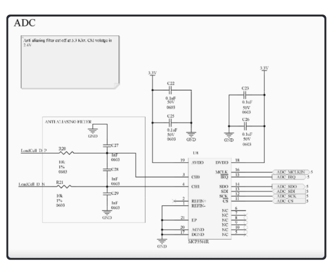


How we ran loadcell

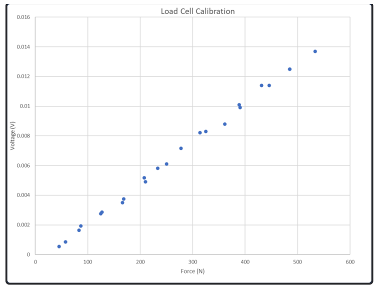


Load cell high level wiring diagram


Filter Sim



ADC with Anti-Aliasing Filter Implementation



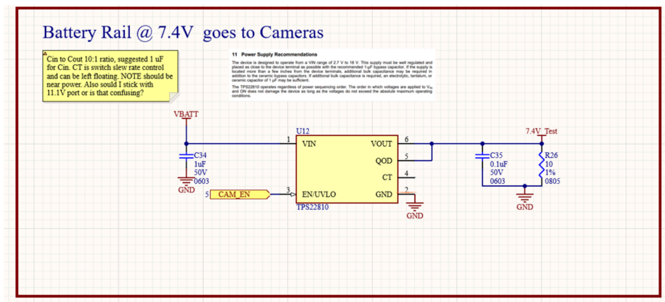
Load Cell Calibration Graph

Load Cell Calibration Data

Weight (g)	Force (N)	Voltage (V)
5855	57.43755	0.00086
8480	83.1888	0.00165
12695	124.538	0.00275
16920	165.9852	0.0035
21395	209.885	0.0049
25540	250.5474	0.0061
33150	325.2015	0.0083
36840	361.4004	0.0088
39820	390.6342	0.0099
45425	445.6193	0.0114
49410	484.7121	0.0125
54385	533.5169	0.0137
49455	485.1536	0.0125
43950	431.1495	0.0114
39600	388.476	0.0101
31980	313.7238	0.00821
28290	277.5249	0.00717
23815	233.6252	0.00582
21185	207.8249	0.00518
17195	168.683	0.00375
12970	127.2357	0.00286
8825	86.57325	0.00192
4610	45.2241	0.00055
1655	16.23555	0.00018

Control Camera Power

We used the load switch [TPS22810](#) from TI. Rated for 3A. Pretty simple implementation just don't mess up a 10 ohm for a 10 kohm resistor. CAM_EN goes to GPIO on STM. JSTXH were used to connect to cameras. Cameras must record for 12 minutes to properly save file (it will be corrupted if not) so we had the camera power run for 24 minutes to make sure we got everything. [Upward facing camera video](#) & [Scenic Camera video](#)



Load Switch

Successes

This was a successful project - it had a few hiccups, but it completed its objectives.

Success	Rationale	Would implement again?
Boosting/landing detection	Very helpful - eliminates worry for excessive power drain on pad. See Grim Reefer Instructions/github for more details on SW implementation	YES
Controlling camera power	Eliminates worry for excessive power drain on pad	YES
Load cell reading (sorta)	Mission requirements but could use schematics/grim again for similar projects	Yes - as needed
Sensor suite	Mission requirement for boost detection and helped us understand flight events especially when flight is not nominal.	Yes, but fix MS5611 mistake and I2C lockup issue. We got lots of helpful flight data for rocket and payload - see Payload Data summary attachment
L1 test flight	Wanted to test boost/landing and overall functionality of Grim.	YES, super helpful and great to add in Tech Report - see L1 test flight data attachment
Battery/power scheme (see Payload Analysis	Had to meet component voltage	Yes, would use batteries / setup again.

for voltage readings throughout flight)	supply requirements.	

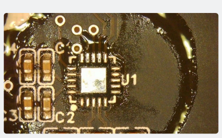
Failures

Every project has its failures… here is a comprehensive list of ours (any figure/schematic explicitly mentioned are in the Failure Figure expand below)

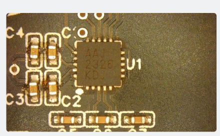
Failure	Solution	Future Mitigation
Wrong transistor on buzzer which was copied off of Auto Pilot Module (Q1 on schematics). Originally used AO3400A, a N channel mosfet see schematic below, Buzzer Schematic Failure. Need a resistor on this implementation.	Removed and replaced with a digital npn but could also have replaced with a sub-logic mosfet. Digital transistor is not a discrete transistor, it has a pull-down resistor and a current limiting resistor built in. It is simpler but can be either fully on or fully off, hence digital. This is ideal for our buzzer application.	Check schematics that are copied from other boards, especially when they have not been fully tested. We need a deeper level schematic check.
MS5611 Schematics issue - SCK wired in I2C mode which was copied off of Sensor Module (U1 on schematics, see MS5611 Schematic Failure below)	Remove MS5611 and use BME280 for altitude (slower refresh rate but still suitable).	Check schematics that are copied from other boards, especially when they have not been fully tested. We need a deeper level schematic check.
10 ohm resistor from 7.4 V → GND on load switch (R26 on schematics, see 10 ohm Resistor Schematic Failure)	Took off resistor - several had already completely popped off	We need a deeper level schematic check.
MCP3561R was oriented wrong on breakout (See MCP3561R Incorrect Orientation Photo)	De-soldered and re-soldered chip with help from @Jim Heaney (See MCP3561R Correct Orientation Photo)	May have been JLC issue but if not - always check the component on JLC especially the ones we import components that are not made ourselves.
I2C lock up issue	WIP (same as sensor mod)	WIP

Issue with INA260 on camera rail ?	WIP	WIP
Load cell sensor breaking - load cell underwent excess forces, but it read the initial snatch force then -8000 for rest of flight - see payload analysis attachment	Still determining failure mode (Likely due to ~7.5 sec free fall after deployment causing an unexpectedly high snatch force) so unable to pinpoint exact solution. We could have gone up to a 100kg load cell, but issue would have likely still occurred.	Likely more of a recovery failure, but make sure the static line to the parachute bag is strong enough, and assume there will be very high forces, and it's better to have less sensitive data than none at all.
Camera Exposure adjustment caused the first few seconds of video to be very overexposed, giving us less information immediately following separation (Minor, not sure if this belongs here)	None taken	Add some bright LED's next to the cameras to lessen the difference between the inside of the tube and the sky.
Measuring the acceleration of the buzzer (LOL see graph - Buzzer Accel - below. For more detail see Payload Analysis pdf.	WIP	WIP

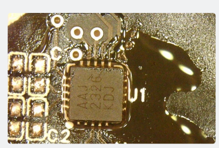
Failure Figures (there are a lot so buckle up)



MCP3561R Footprint

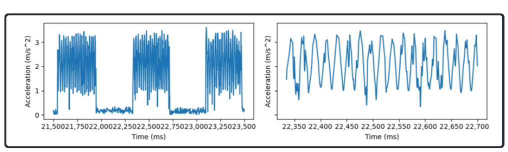


MCP3561R Incorrect Orientation

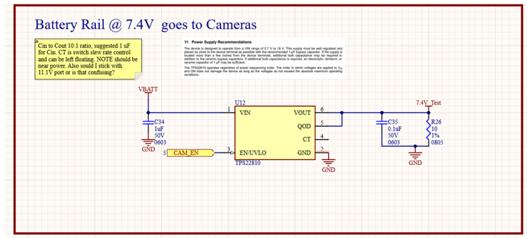


MCP3561R Correct Orientation

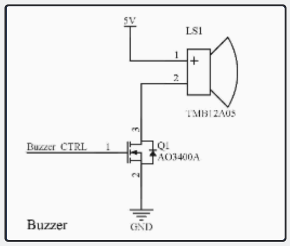
Behind the Scenes



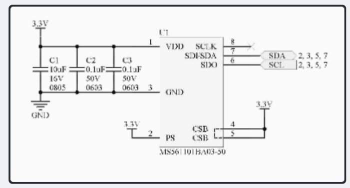
Buzzer Accel



10 ohm Resistor Schematic Failure



Buzzer Schematic Failure



MS5611 Schematic Failure