VEX VRC 2022-2023 Reverse Engineering Online Challenge

Disassembly and analysis of Zero - X Titan drone

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Chapter 1 - Introduction

1.1 What is the Zero-X Titan?

The Zero-X Titan is a drone from the Zero-X band, which is based in Victoria, Australia. It has many capabilities, such as being able to take 720p video with its kit camera, and has a surprisingly long range of 120 metres. Though its design is largely outdated, with a larger body than most modern drones, the latter of which can fly faster and further, it represents the classic drone which all photographers used to dream of having.

1.2 Why the Zero-X Titan for this project?

We chose to disassemble the Zero-X Titan drone for multiple reasons. First, the members of our team, especially Justin, are very dedicated or interested in photography, so we thought that taking apart a drone, which nowadays is an almost essential component for a photographer's kit, would be both educational to us as we would learn more about the inner mechanisms of electrical components, and interesting as we would discover more about our passions and interests.

Second, we performed a large amount of research to determine a suitable device for our project. We studied past submissions, most notably the winners of the 2021 and 2020 reverse engineering/ Texas Instruments electronics online challenges, and formed a criteria to more effectively and objectively select our device. Our final criteria was that the device should be **multifunctional,** the main process should require **multiple components,** and that the device must be interesting or **educational** to tear down. Using this criteria, two of our team members, Franklin and Justin, each went to find a suitable device, ending up with a drone and multimeter respectively. In the end, after drawing up a table to compare the two options, we decided that a drone would be the superior option, as though it cost a lot more and would be a bit more lacklustre is its number of functions, it was a topic of interest for both of our team members, and we figured that it would provide for a far more interesting dissection.

Finally, the drone seemed to be the most interesting object to take apart as it was something that was very familiar to us, as we understood how a drone worked and how each organ broadly interacts with each other, yet the more precise mechanisms of the drone were foreign to us; thus, our final decision for the device became the Zero-X Titan drone.

Chapter 2 - Disassembly

2.1 Disassembly Process

Step 1 - all tools required for starting the process were laid out in a flat, open space. We wore safety glasses whilst deconstructing the drone, and had checked beforehand with our mentor to confirm that everything was perfectly safe.

Figure 2.1 - from right to left, screwdriver, tweezers, bowl, flashlight, magnifying glass

Step 2 - The two components that did not require any unscrewing, the battery and the wire connected to the camera, were taken out and put to the side.

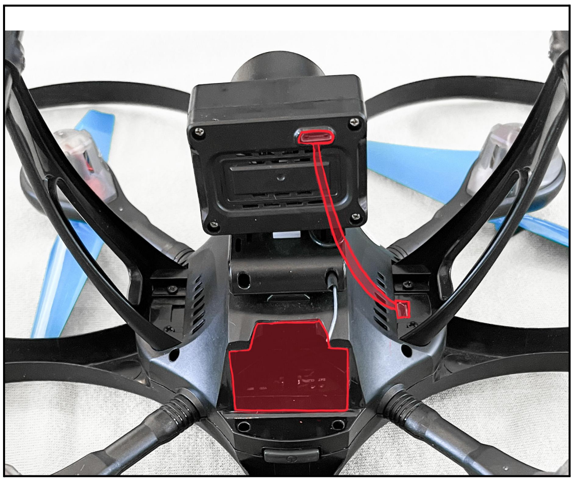


Figure 2.2 - the lower drone body, with now missing parts drawn in red

Step 3 - 8 screws were removed from the bottom casing of the drone to separate the drone from the top casing. These screws were left in a separate bowl.

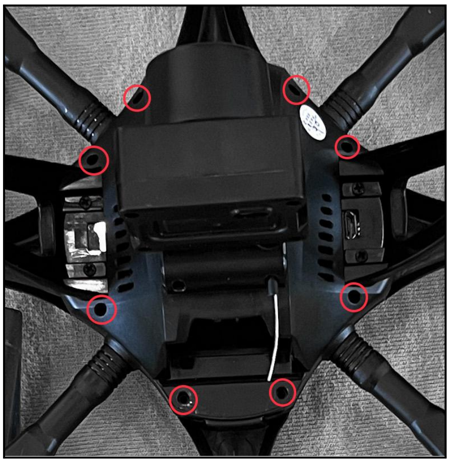


Figure 2.3 - the holes from which the screws were removed

Step 4 - to remove the circuit boards from their standoffs, the screws holding them to the standoffs were unscrewed and placed in a separate bowl. For the centre main circuit board, after the screws were removed a tweezer was used to remove the o-rings from underneath the board.

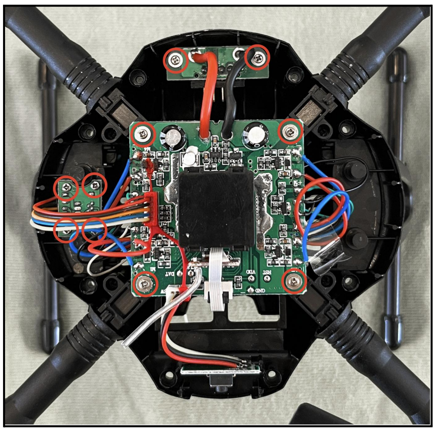


Figure 2.4 - screws which were taken off

Step 5 - to separate the circuit boards inside the main body of the drone from the wires connecting the board to the arms of the drone, we used a soldering kit (soldering iron, fan, solder sucker) to melt the solder and remove the wires from the solder.

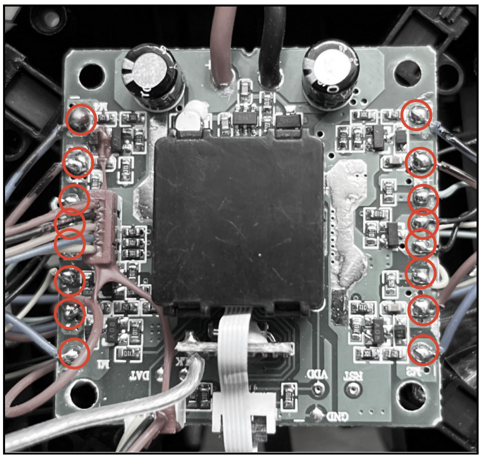


Figure 2.5 - the solders which were removed

Step 6 - Using a pair of tweezers, the lid of the black box was removed, revealing the gyroscopic organelles inside.

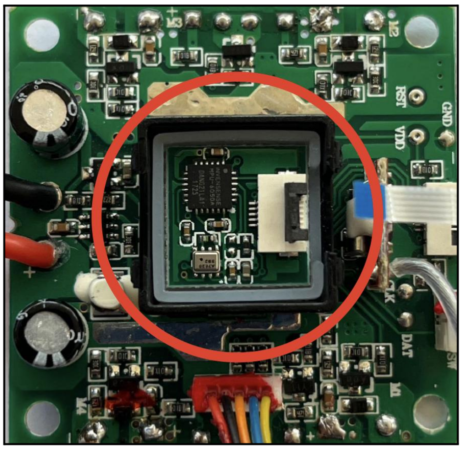


Figure 2.6 - the contents of the black box

Step 7 - To remove the black box surrounding the main processor, the wax holding the clips onto the back of the board were pulled off using tweezers, and then the box was prised off using our fingers, to reveal the main processor.

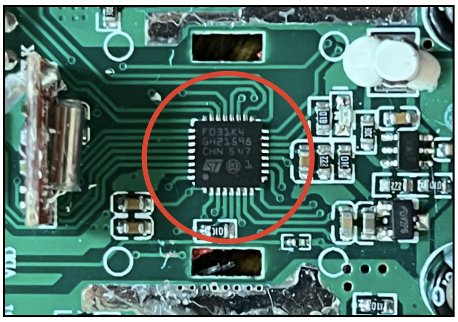


Figure 2.7 - revealed processor after black box was taken off

Step 8 - Two of the side boards connected to the main circuit board were pulled from their sockets

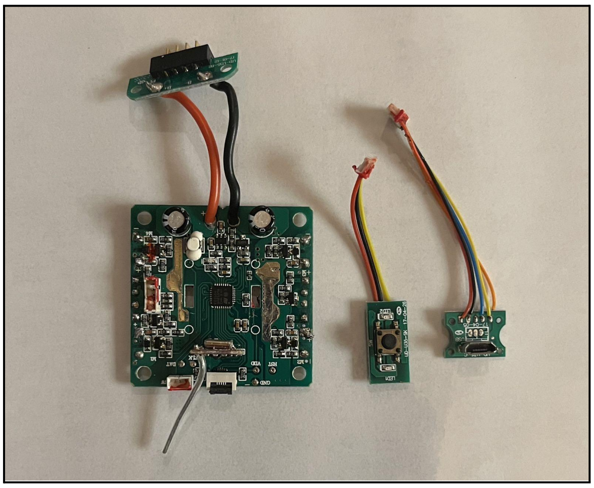
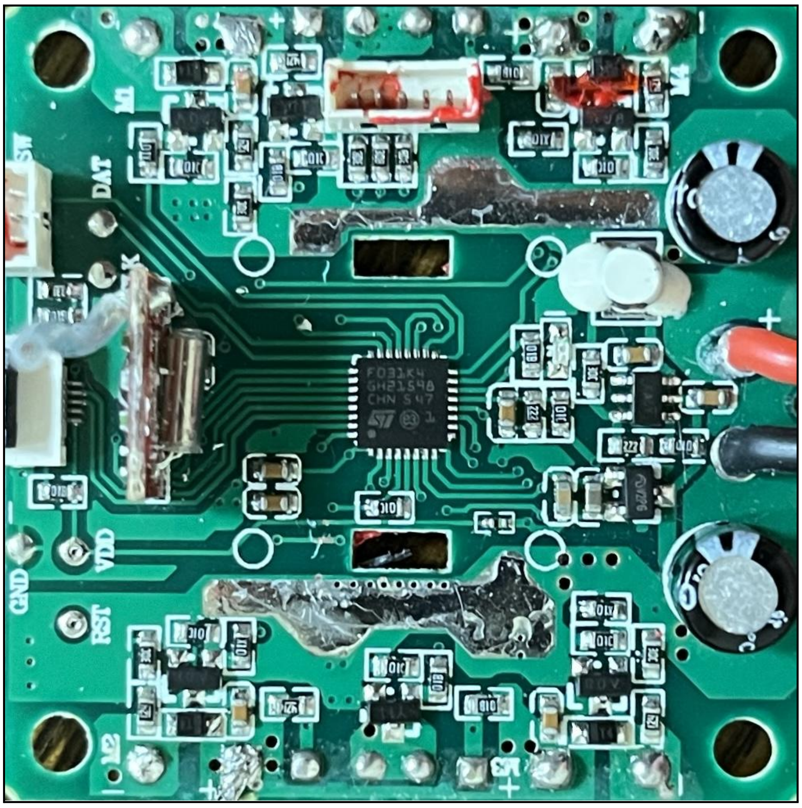


Fig 2.8 - main board with disconnected side boards

2.2 Final picture after full disassembly



Chapter 3 - Component breakdown

3.1 Power control

Smoothing capacitors:

Function - to level the voltage input of the current in case the voltage drops from a fluctuation. By providing additional power when the voltage drops, the variance of voltage decreases.

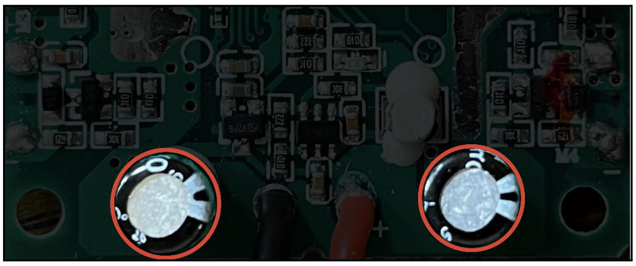


Figure 3.1 - position of smoothing capacitors on circuit board

Voltage regulator inductor:

Function - a storage for electrical power in case of a voltage drop from the battery. Also decreases the variance of the voltage due to this effect.

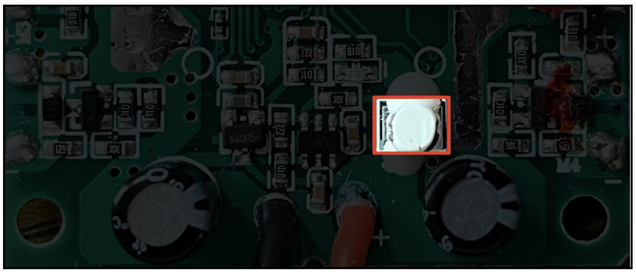


Figure 3.2 -- position of voltage regulator inductor

Battery input:

Function - to draw power from the batteries. The flow of current is from batteries -> black wire -> circuit -> red wire -> batteries. The electricity flows from negative terminal to positive terminal

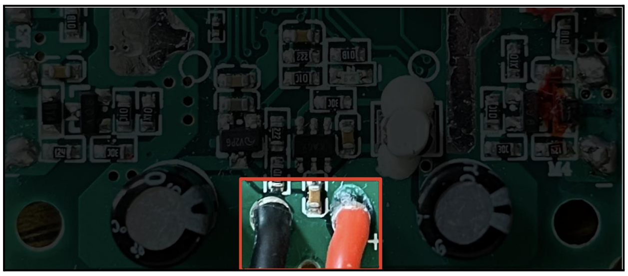


Figure 3.3 - position of battery input

Voltage regulation:

Function - capacitors and resistors lower the voltage. The battery has a voltage of 7.4, and this array of resistors and capacitors lowers this voltage to 3.3, which is the expected voltage that the gyroscope, processor and motors use.

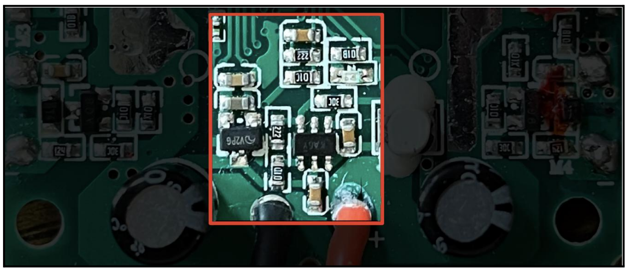


Figure 3.4 - position of voltage regulation resistors and capacitors

3.2 Drone positioning

Crystal clock:

Function - to pulse electrical signals at certain frequencies, essentially acting as a sort of digital clock. Used for timings in processor and gyrometer. This specific clock pulses in 32.768Hz, or 32,768 times per second.

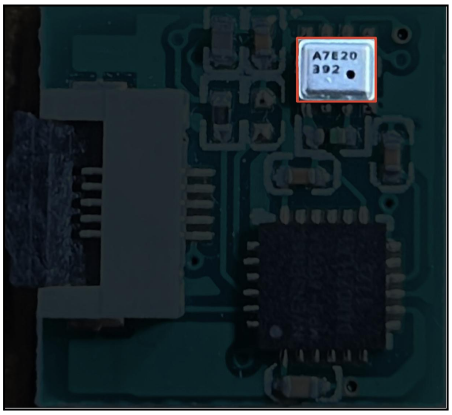


Figure 3.5 - positioning of crystal clock

I²C connector:

Function - transfers data, after it has been processed by the gyroscope / accelerometer, to motors through cable to the other connector on the circuit board.

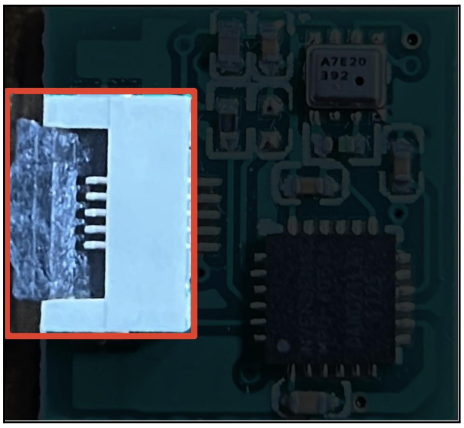


Fig 3.6 - positioning of I²C connector

IMU (gyroscope + accelerometer):

Function - gyroscope - measures the rate of change of the angle of the drone as a derivative, then integrates it to find the angle that the drone is facing. Accelerometer - measures the speed at which the drone is accelerating decelerating. Both functions work in all 3 axis. Also has own programming function to filter out background noise for cleaner readings.

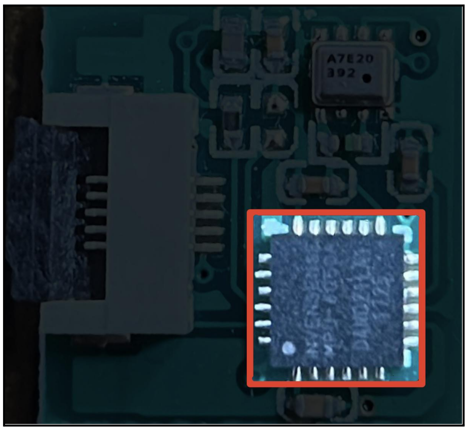


Figure 3.7 - positioning of IMU

3.3 Miscellaneous components

Radio receiver:

Function - to receive the radio signal from the controller for the drone. The antenna wire receives the radio signal which proceeds to move through the circuit board to the processor.

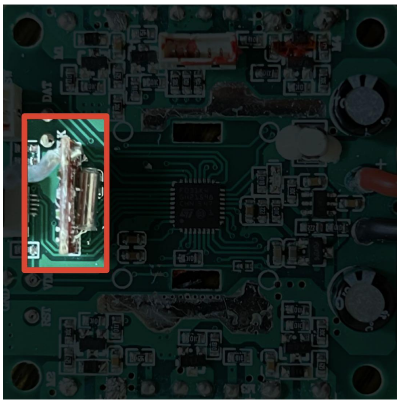


Figure 3.8 - positioning of radio receiver

Motor control resistors & capacitors:

Function - to control the voltage and signals that travel to the motors that power the rotors of the drone. An example of a resistor combination is the mosfet, a specific arrangement of resistors that affects the flow of voltage through the circuit.

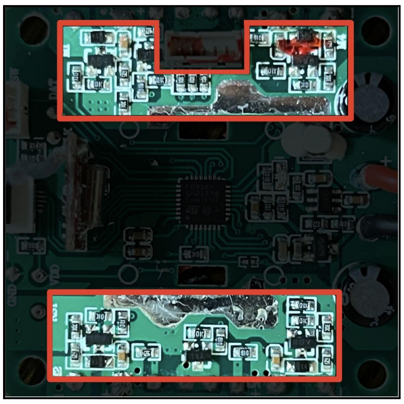


Figure 3.9 - positioning of motor control resistors

I^{2}C receiver:

Function - receives the signal from the I^{2}C connector in the "drone positioning" section through the ribbon cable and transfers that signal to the processor.

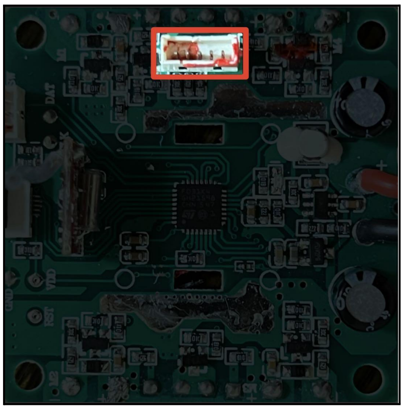


Figure 3.10 - positioning of I^{2}C receiver

Processor:

Functions - autonomous processing and manual processing

Autonomous processing - the calculations required for the drone to hover in place without any user input. For this to happen, the processor must take into account the angle at which the drone is facing, the wind speeds, and the current speed at which the rotors are spinning, and then use these values to either decrease or increase the power input that is flowing into the motors to modify the speed at which they are spinning in order to stay still.

Manual processing - the process through which a user inputs a movement on the controller and the drone moves in accordance to that input. To achieve these movements, the processor requires all of the data from the autonomous processing, and additionally needs to calculate the speed to which the motors must increase in order to move in a certain direction, and the difference between the speeds of the motors needed to change the orientation of the drone.

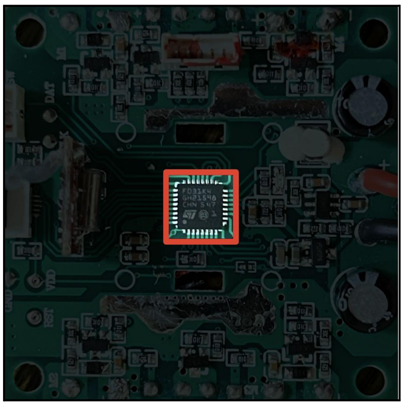


Figure 3.11 - the positioning of the main processor

Chapter 4 - Conclusion

4.1 Final Summary Report

By carrying out this project, we discovered many new functions and pieces of knowledge about both the inner workings of the drone and electrical components. For example, we went from having no knowledge in how power control worked to understanding every component required to stabilise and modify the voltage of a current, the use of the smoothing capacitors and voltage induction regulator to smooth out the voltage, and how the combination of resistors works to transform a voltage from 7.4 V to 3.3 V.

Additionally, we attained new knowledge in learning how the drone balances itself by analysing the functions of the gyroscope and accelerometer, and how they process their values. One particularly interesting discovery from this part of the research was that the initial values obtained to find the angle at which the drone is facing were rates of change - a derivative, which had to be integrated to find the actual angle that the drone was facing. Also, because we were researching how the drone positioned itself, we also learnt about how crystal clocks worked, and how the I^2C protocol transfers information through the ribbon cable,

Finally, by analysing the processor, we gained many new insights into the level of depth required to make a machine move. We learnt about the flow of information through a processor, all the steps required simply to make a drone hover still, and the sheer complexity of such a small device. The capacity and power of the processor surprised us and gave us a new appreciation for how absurdly complex these chips that inhabit our everyday electronics are.

Nevertheless, this process did not only teach us about how electrical components worked, but also how to properly manage our schedule, how to divide work among ourselves to be as productive and efficient as possible, and how to work together as a team to achieve the best results.

Some future uses of the experience and knowledge we gained from writing this paper could be found in trying to modify the drone further. Because we now understand the whole internal electrical structure of the drone, we could modify it using code or changing the components in order for it to fly faster, or maybe program code that could allow it to perform acrobatic movements in the air.

4.2 References

1. https://www.zero-x.com.au/product-titan
2. https://www.st.com/en/microcontrollers-microprocessors/stm32f031k4.html

4.3 Acknowledgements

The 3168S team at Skywalker Robotics thank Jouveer Naidoo for his work and dedication to teaching us about the complexities and intricacies of the circuit board. We also thank Annie Yeh for her watchful guidance and helping us to keep our paper on the right track.