# Gary Allen Skripsie – Component Proposal

## Introduction

The following proposal discussed component selection and supplier prices. This introduction first explains the initial decisions made with regards to system configuration. Although these decisions are not indicative of the final design choices, they allow for early ordering of components to begin design and testing as soon as possible.

The existing Radiosonde has a proprietary protocol that should ultimately be reverse-engineered. Since the existing Radiosonde operates on a frequency band of between 402 and 405 MHz (in 1 MHz increments) with GFSK, the ground station antenna should support this.

A literature review suggests that LoRa might be a viable option as the physical layer for the custom protocol, with a required bandwidth of less than 1 MHz. The frequency of LoRa is configurable, and the nearest range to 405 MHz begins at 410 MHz (the 433 MHz band), with a bandwidth of around 500 kHz.

To allow for maximum flexibility in the design stage, the antenna should therefore cater for both of the above. Further, the GPS tracking option will be explored, meaning GPS modules should be considered. Finally, MCUs both for the ground station and the PQ unit should be selected, as well as a motor driver and transceiver ICs.

## Antenna

Since both antennae can easily be sourced locally, their exact type and configuration can be ordered at a later date. This allows for more time to design the mechanical integration of the antenna and the existing antenna mount. However, an initial literature review suggests that even a half-wave dipole (approx. 1.2 dBi gain) for both uplink/downlink might work (Julian Fernandez Link Budget). Therefore, when selected, the antennae should have at least the following specifications:

* 404 to 411 MHz bandwidth
* 1.2 dBi gain (ideally more on uplink side)
* Low weight (not more than the existing mount can support)

## GPS

The GPS module should be chosen to suit both the ground station and PQ unit. A few popular units have been summarized in the table below.

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Availability** | **Price** | **Features** |
| NEO-6M | Make Electronics (Dev) | R110 | 2.5m accuracy  NMEA via UART  Active antenna support  47 mA current |
| ATGM336H | MicroRobotics (Dev +ant.)  JLCPCB | R275  R54 | 2.5m accuracy  NMEA via UART  Active antenna support  100 mA current (peak) |
| ATGM332D 5N31 | MicroRobotics (Dev +ant.)  JLCPBC | R198  R50 | 2.5m accuracy  NMEA via UART  Active antenna support  100 mA current (peak) |

Although the NEO-6M is the least expensive and the most popular option, there are unfortunately only 2 development board versions in stock at an external company “Make”. To simply the development, the ATGM332D will be selected, which comes with an antenna and breakout board.

## Absolute Orientation

The ground station requires absolute azimuth angle measurement data, as well as potential angle tilt data, in order to orientate itself with respect to its surroundings. A magnetometer will at least be needed to determine azimuthal rotation. An accelerometer can be used to determine tilt rotation.

Although the original PCB has 3 inclinometers, the datasheet for these are missing and they are note in integrated module. There are various simpler modules available (however potentially less accurate) that would suffice for this project.

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Availability** | **Price** | **Features** |
| BNO055 | Microrobotics | R774 | Integrated ARM Processor  100 Hz rate  0.3 uT magnetic field resolution  16 bit gyroscope  14 bit accelerometer |
| MPU-9250 | Microrobotics | R168 | Integrated Digital Motion Processor (DMP)  0.6 uT magnetic field resolution  16 bit gyroscope  16 bit accelerometer |

The MPU-9250 will be selected as it is much cheaper and has similar accuracy.

## Relative Orientation

The relative orientation of the motors will need to be measured using zero-sensing.

## Transceivers

#### Overview

Three general choices are available for transceiver systems and ICs:

* RF Front-End Module (FEM) + FPGA/MCU Software-Defined Radio (SDR)
* Dedicated Hardware RF Module with e.g. UART interface
* Custom-designed RF module using RF transceiver

#### Custom Communication

For the custom protocol, utilizing LoRa will immensely simplify the development time, and allow for long-range communication. The following is a list of popular LoRa IC modules.

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Availability** | **Price** | **Features** |
| RA-02 (SX1278) | MicroRobotics  Make Electronics (Dev)  DigiKey  JLCPCB | R89  R135  R135  R87 | -141 dBm sensitivity  Low power (12 mA RX, 29 mA TX @ +13 dBm)  410 to 525 MHz  SPI interface  Very commonly used  Molex connector |
| LR1121 | DigiKey | R90 | -144 dBm sensitivity  Medium power (8 mA RX, 45 mA TX @ +14 dBm)  150 to 960 MHz  SPI interface |
| STM32WLE4C8U6 | DigiKey | R117 | -148 dBm sensitivity  Very low power (8 mA RX, 22.5 mA TX @ +14 dBm)  150 to 960 MHz  SPI and I2S interface |

The SX1278 will be used in the form of the RA-02 module since it is commonly available, has good characteristics, and is inexpensive. It can also be used on both the uplink and downlink due to its power capabilities.

#### Proprietary Communication - Development

Since the proprietary communication protocol will require reverse-engineering, and the exact encoding and GFSK parameters are unknown, SDR will be utilized to allow for flexibility and rapid “hacking”.

*Universal Radio Hacker* (*URH)* (<https://github.com/jopohl/urh>) is software available to investigate wireless protocols using an SDR. For this development, an easy-to-use USB SDR can be employed to investigate the protocol. The “RTLSDR” is considered the standard, low-cost solution for this, and MicroRobotics have a variant of this for R507. An RF transceiver or module will be chosen some time in the future for potential ground station integration.

#### Proprietary Communication – Implementation

If the proprietary protocol is successfully decoded, a dedicated GFSK hardware solution can theoretically be implemented. The iMet-3100M (<https://intermet.co/wp-content/uploads/iMet-3100M-403MHz-Military-Antenna-Receiver-Brochure-V4.5.pdf>) is a receiver compatible with the iMet-54 (<https://intermet.co/wp-content/uploads/iMet-54-403MHz-GPS-Radiosonde-Brochure-V5.5.pdf>) produced by the same company.

From the datasheets, we see the following system characteristics:

* Omnidirectional (1 dBi)
* 400.15 to 406 MHz
* -118 dBm receiver sensitivity
* 4800 bps
* 4.8 kHz frequency deviation
* *Automatic frequency control* (AFC)

These are therefore minimum requirements for a new receive system to match the proprietary receiver, although *sensitivity* requirements may be relaxed slightly since a directional antenna will be used. The following table is a list of some sub-GHz GFSK receivers with AFC.

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Availability** | **Price** | **Features** |
| SI4362 | DigiKey  RS Components  Mouser | R111  R56 (x5)  R118 | 142 MHz to 1.05 GHz  -126 dBm sensitivity  13.7 mA consumption  SPI interface  GFSK parameters via GUI |
| AX5243 | RS Components | R21 | 27 to 1050 MHz  -126 dBm sensitivity @ 1 kbps  9.5 mA consumption  BT product of 0.3 or 0.5 |
| SI4355-C2A-GM | DigiKey | R80 | 284 MHz to 960 MHz  -116 dBm sensitivity  10 mA consumption  SPI interface  GFSK parameters via GUI |

The SI4362 will be used due to its high sensitivity and ease-of-us. It will, however, not yet be ordered until the protocol is successfully decoded and the parameters are determined.

## Stepper Motor Drivers

The original PCB of the previous antenna mount system contained two A3972SB ICs to drive the stepper motors. Although these could be de-soldered and used, it is favourable to use a newer supported IC with better capabilities, and in case of damage. The motors are known to be LIN Engineering 4218S 24V, 0.5A. Along with the datasheet, the following specifications can be realized:

* Dual DMOS Full-Bridge Output Configuration
* Bipolar PWM current control
* Micro-stepping (not required, higher is better)
* 0.5A, 24V

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Availability** | **Price** | **Features** |
| L6219 | RS Components | R46 | Control voltage 1.5 to 7.5V  Quarter stepping |
| LB1945H | RS Components | R54 | Control voltage 4.75 to 5.25V  Quarter stepping |
| A4970 | RS Components | R78 | Control voltage 1.5 to 7.5V  Quarter stepping |

The above drivers all have similar prices. Although the micro-stepping does not match the original A3972 (64 steps) the quarter stepping should suffice accuracy-wise for this project. For its low price and detailed datasheet, the L6219 will be chosen.

## Stepper Motor Zero Sensing

## Power Distribution

For both the PQ unit and the ground station, 3.3V and 5V power is needed for the ICs chosen. Simple linear regulators will be chosen for this as there are no specific requirements.

The GS will most likely be powered from a vehicle’s cigarette connector, and therefore a male connector for this will be needed. Since the motors require up to 24V, a boost converter module will be needed. Normal DC jack connectors will be used for initial debugging and potentially for future development. A battery for the PQ unit might be investigated in the future.

## MCUs

As discussed later, a general-purpose MCU will be needed both on the GS and the PQ. The three most popular frameworks/MCU types for this the ESP32, Arduino, and STM32.

The ATGM332D module requires a general I2C connection of 2 pins, and optionally 1 reset pin. The L6219 module requires 4 GPIO pins, and optionally 2 pins for current sensing with an ADC. The RA02 requires 6 GPIO pins, a general SPI connection of 4 pins, and optionally a pin for reset. The SI4362 also requires an SPI connection of 4 pins, 1 pin for IRQ, 1 pin for shutdown, and optionally 2 pins for GPIO. Finally, stepper zero-sensing would need two pins.

For the PQ unit, the motor and Radiosonde-related ICs are not needed, however at least an additional 3 pins are needed for the PQ interface.

Without multiplexing signals, and assuming all “optional” pins will be used, the total pin count for the ground station is:

* 2x I2C ( SCL, SDA)
* 18x GPIO
* 5x SPI (SCK, SDO, SDI, 2x CS)
* 2x ADC

The ESP32-WROOM-32 is a commonly available ESP32 variant which has 32 GPIO pins, of which several can be used as an ADC input, SPI or I2C interface. This means that there are 23x GPIO available, enough for this project. Further, the ESP32 has the added benefit of WiFi and Bluetooth connectivity, which may allow “smart” features to be added to either devices in the future.

The ATMEGA328PB is an MCU commonly used in small Arduino boards. It, however, has fewer pins than the ESP, and is also an 8-bit MCU, as opposed to the 32-bit ESP. It does, however, allow a supply voltage of as low as 1.8V.

Finally, the common STM32F411 MCU is a high-performance, ARM-Cortex board with highly accurate ADCs, up to 81 GPIOs, and a fast internal FPU.

Since the processing requirements for this project are medium, and the ESP32 is a relatively high-performance MCU which satisfies the pin requirements and has added smart capabilities, it will be selected for the GS. For the PQ unit, an ATMEGA328PB will be used, due to its exceptionally low current consumption, and many fewer pins being needed for the PQ unit.

## Final List

The following list includes both parts that are not available through JLC PCB and will need to be soldered manually to the final PCB, or those that are for development only, and therefore should be ordered already. A secondary component order might occur when the final PCB itself is to be manufactured.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **Link** | **Price (each)** | **Quantity** | **Price (Total)** |
| 3.3V Regulator | <https://www.mantech.co.za/ProductInfo.aspx?Item=35M0998> | R9 | X3 | R27 |
| 5V Regulator | <https://www.mantech.co.za/ProductInfo.aspx?Item=35M7188> | R11 | X3 | R33 |
| L6219 (Motor Driver) | <https://www.mantech.co.za/ProductInfo.aspx?Item=35M5466> | R46 | X3 | R138 |
| RA-02 (LoRa Module) | <https://www.communica.co.za/products/hkd-sx1278-lora-modul-433m-10km> | R140 | X2 | R280 |
| 24V Boost Converter | <https://www.communica.co.za/products/hkd-dc-dc-boost-adj-mod-5-35v-4a?variant=31932616409161> | R35 | X1 | R35 |
| RTL2832 (SDR) | <https://www.robotics.org.za/RTL2832U-SDR-KIT?search=sdr>). | R507 | X1 | R507 |
| Male DC Jack | <https://www.robotics.org.za/connectors/power-battery-connectors/dc-jack-connectors/JACK-2155-M> | R18 | X1 | R18 |
| Female DC Jack | <https://www.robotics.org.za/connectors/power-battery-connectors/dc-jack-connectors/DC05-05> | R10 | X1 | R10 |
| Female DC Jack (Development) | <https://www.robotics.org.za/connectors/power-battery-connectors/dc-jack-connectors/DC-2155> | R8 | X2 | R16 |
| USB to Male DC Jack | <https://www.robotics.org.za/USB-JACK55-1M> | R16 | X2 | R32 |
| ESP32 | <https://www.robotics.org.za/ESP32-DEV-CH340-C> | R125 | X1 | R125 |
| ATGM332D 5N31 (GPS module) | <https://www.robotics.org.za/MKS-ATGM332D> | R198 | X2 | R396 |
| MPU-9250 | <https://www.robotics.org.za/MPU-9250> | R168 | X1 | R168 |
| **Total** |  |  |  | **R1785** |