Universal Ground Station Receiver

For Hubsan X4

Assembly/Build Guide & Documentation

Embedded Systems Laboratory EN.525.743.91

Kyle Mercer – 2/26/2018

**RESERVED FOR TOC**

# System Description

The Universal Ground Station Receiver is a headless embedded system which will bind with compatible Bluetooth devices, listen to incoming Bluetooth control packets, and re-broadcast control packets in a format that the Hubsan X4 (H107L) Quadcopter can understand. The ultimate goal is for the system to be able to accept virtually any Bluetooth slave device as a transmitter, enabling a broad range of standard compliant devices to potentially become a quadcopter controller with minimal software setup time. Examples of devices which could communicate with the ground station include (but are not limited to):

* A Bluetooth enabled personal computer
* A smartphone
* A Bluetooth handheld classic controller (Corrie’s project)
* A glove controller with Bluetooth adapter (Corrie’s project)

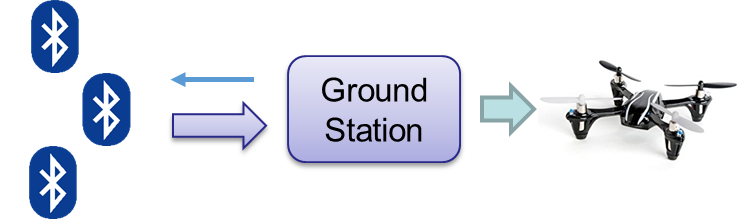


Figure 1: Top level control flow of system (Hubsan X4 pictured on right)

## Capabilities

The Ground Station Receiver supports the following capabilities:

* Perform command translation and relay communication for Quadcopter controls
* Any Bluetooth enabled device may pair
* Supports a Quadcopter over Bluetooth Universal Protocol (QoBUP) communication scheme
  + QoBUP has an accompanying developer ICD which is included in Appendix A
* Supports controlling the Hubsan Quadcopter’s onboard LEDs via a push button on the ground station

## Limitations

The Ground Station Receiver has the following limitations:

* Only the Bluetooth protocol is supported between transmitter and Ground Station
* Single Quadcopter brand supported (Hubsan X4 H107L)
* Only one quadcopter may be commanded by one transmitter
* Only the A7105 RF chip is supported for the Quadcopter RF communication

# Functional Description

## Overall System

This document describes only one half of the entire functional system. In order to fully realize the capability of the Universal Ground Station Receiver two different types of controllers have been implemented by another member of the class, Corrie Russell. She is the project partner and her half of the system is required for the full system functionality. See the documents pertaining to Corrie’s controllers for specific implementation details on the transmitter side. Each controller designed will adhere to the QoBUP standard. Each transmitter will leverage the QoBUP to send controls to the ground station.

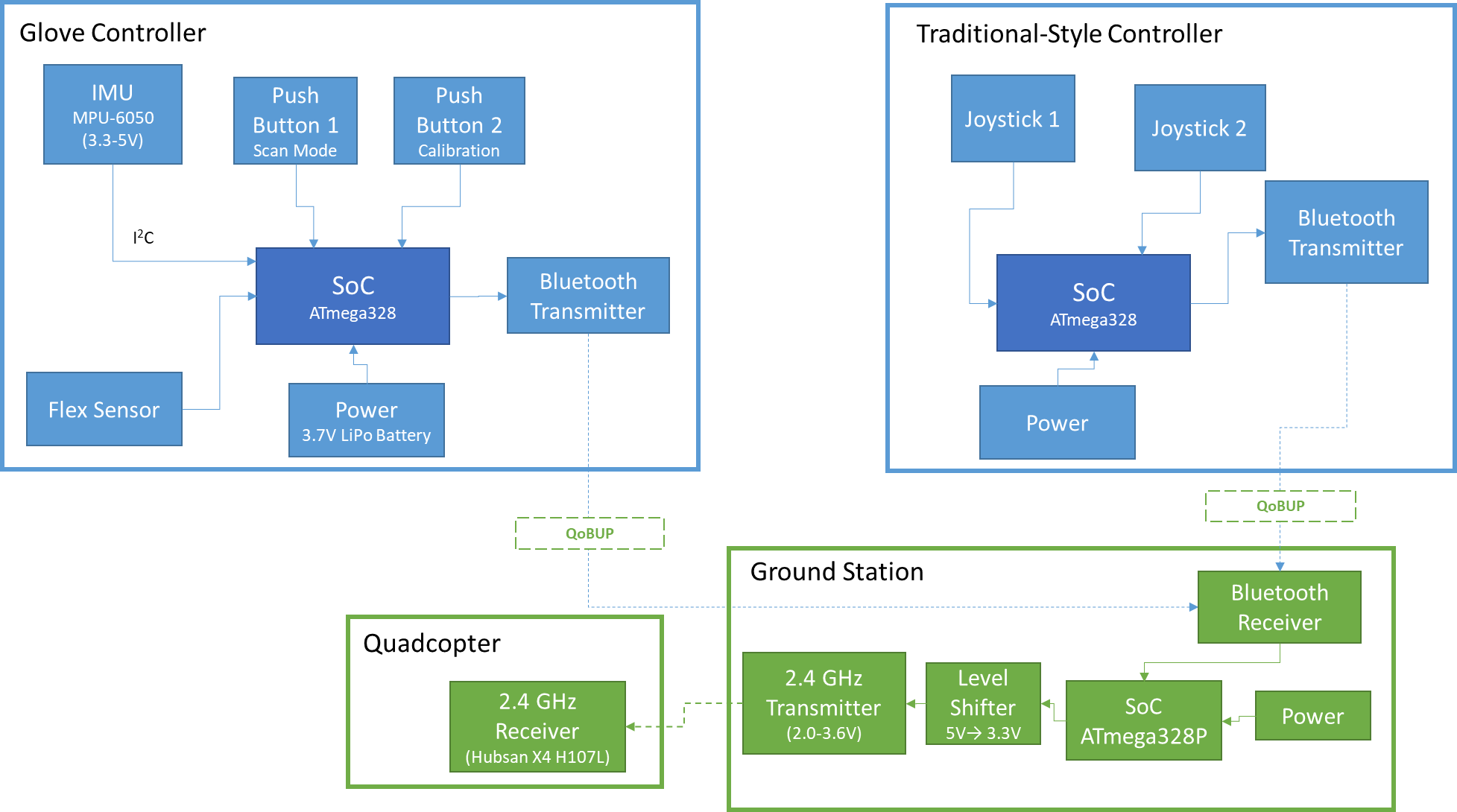


Figure 2: Overall system block diagram.

## Ground Station System

Upon reception of controls from the Bluetooth enabled transmitter the Microcontroller Unit (MCU) reads the contents of the incoming message over a standard UART interface which connects to the Bluetooth module receiver. As per the QoBUP ICD, a status message is transmitted back to the transmitter for each message received. Refer to the Quad over Bluetooth Universal Protocol (QoBUP) Developer ICD for specific details on about the QoBUP.

### MCU Software Operation

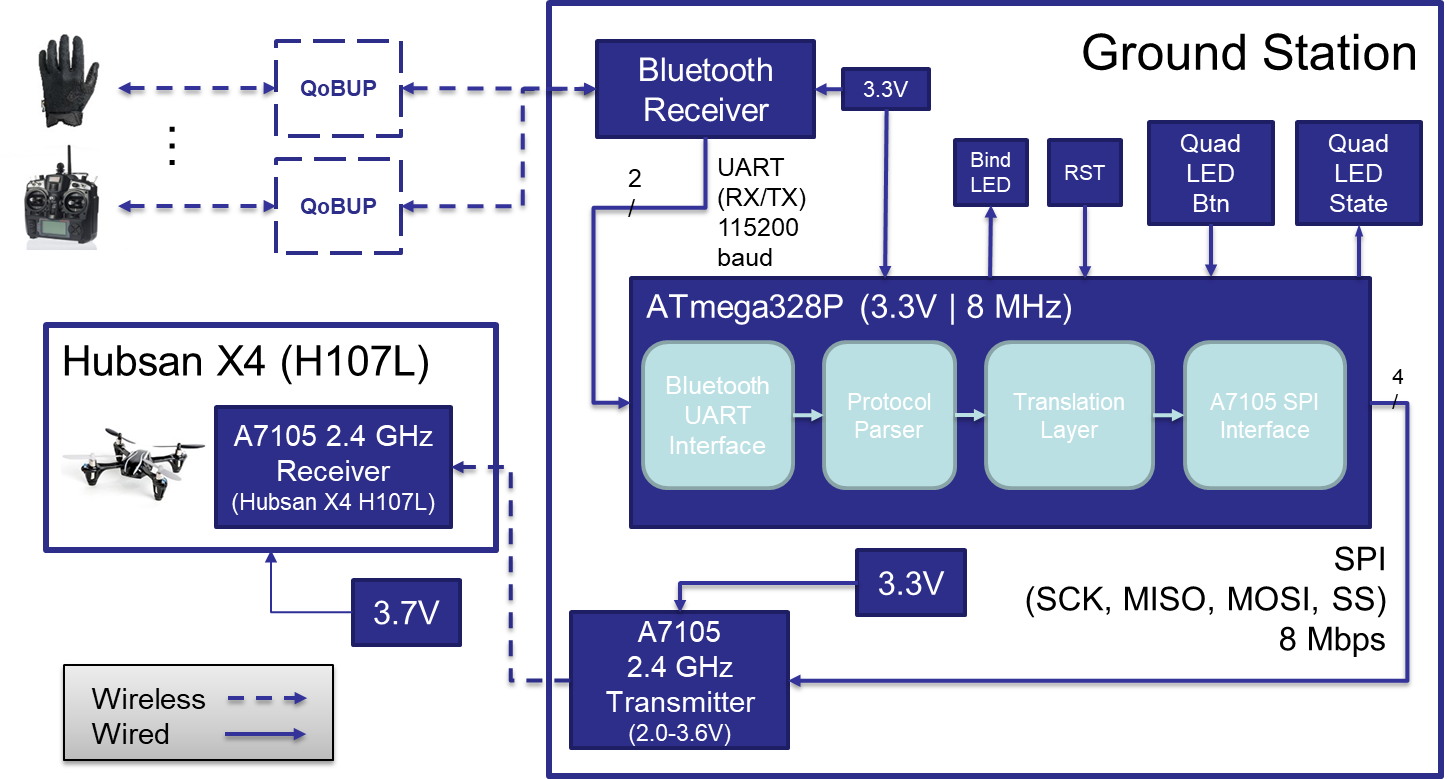
The MCU reads in control messages through the Bluetooth UART Interface into a buffer where it will get picked up by the Protocol Parsing Interface. At this stage, validation is done on the message to ensure the message adheres to the QoBUP ICD. Validation is complete once all sub-blocks are parsed out into common software structures and command processing is initiated via the Translation Layer. During this stage of software processing, the allocated structures are picked up by a translation stack which is written specifically for the target quadcopter, in this case, the Hubsan X4. The structures are then translated into a set of primitive register read/write commands which are then queued up into the A7105 SPI Interface. Controls are then dispatched to the A7105 over the SPI bus at a controlled rate dictated by the Hubsan X4 communication spec. The flight control update rate for the Hubsan X4 is 10ms (Hung, 2015). All modules including the peripheral complements and MCU operate at a common 3.3V. No level shifting is required. The overall ground station hardware/software block diagram can be seen in Figure 3.

Figure 3: Overall ground station hardware/software block diagram.

### MCU Software Startup

During system initialization, the ground station will attempt to automatically bind to the Hubsan X4. The handshaking involved to complete the binding process is quite involved; however, the entire procedure has been decoded into a step-by-step process outlined on the internet (Hung, Reverse Engineering a Hubsan X4 Quadcopter, 2015).

An additional aspect of system startup will include configuration and initialization of the Bluetooth transceiver module. The Bluetooth module connected to the ground station will act as a Bluetooth master whereas all transmitters that wish to pair will act as the slave device. All communication (both configuration and controls) to and from the Bluetooth module will occur over UART connection set to an 115200 baud rate.

# Materials & Resources

## Hardware

The list of necessary hardware for the completed ground station is scoped out as follows:

* ATmega328P AVR MCU
* COTS Hubsan X4 (H107L) Quadcopter
* 9V LiPo batteries
* 5V regulator
* Capacitors/Resistors
* LEDs
* Prototyping board
* Insulated prototyping wires
* A7105 Wireless RF 2.4GHz Transceiver Module
* Bluesmirf Bluetooth modem (RN-42)
* 5V to 3.3V level shifter
* 2mm to 2.54mm pitch header adapter

The ground station will operate standalone with a 9V battery powering the entire system, including the MCU and peripherals.

## Software

The following list of development and operational software will be leveraged for the project:

* Linux (development environment)
* Arduino CLI toolchain
  + AVR compiler
  + SPI
  + UART
* Collaboration tools (to work with lab partner)
  + Git
  + Google cloud

# Implementation Guide

## Build Environment Setup

### The Arduino CLI

### Obtaining the Project Codebase

### Building the Project Codebase

## Hardware Assembly

### System Schematic

### Assembly Considerations

Mention the separation of bt and RF module

## Flashing Software to Ground Station

## Testing the Ground Station

### Without Glove Controller

### With Glove Controller

# References

The following references are critical to the success of ground station receiver.

* **Hubsan X4 reversed protocol specification:** This text document gives a breakdown of the necessary setup and binding steps required to connect to the Hubsan X4 with an A7105 RF chip. This will be used as a guide when writing the A7105 SPI interface software.
  + <http://www.jimhung.co.uk/wp-content/uploads/2014/11/HubsanX4_ProtocolSpec_v1.txt>
  + <http://www.jimhung.co.uk/?p=1349>
* **Deviation10 firmware (targets 32-bit ARM):** The Deviation10 framework is an open source, aftermarket firmware written specifically for the DEVO brand controllers (ARM-based). The controller must be hardware modded and loaded with the firmware prior to use. If loaded, the firmware essentially provides controls for a wide variety of quadcopters and small UAV planes. Since it provides support for the Hubsan quadcopters, this could be a helpful resource for reference on establishing communication with the Hubsan X4, despite the difference in target MCU architectures.
  + <https://bitbucket.org/PhracturedBlue/>
* **Bluetooth modem RN-42 AT command set:** This source provides documentation for interfacing with the Bluetooth module.
  + <https://cdn.sparkfun.com/datasheets/Wireless/Bluetooth/bluetooth_cr_UG-v1.0r.pdf>
* **Atmel’s AVR documentation:** This reference provides the necessary documentation about the MCU being using for the ground station.
  + <http://www.microchip.com/wwwproducts/en/ATmega328p>