Peace, Love, and Rockets!

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Abstract

My son and I enjoy building and flying model rockets. But when we went looking for an electronic altimeter to measure how high our flights were going, the products we found provided limited features, and required the use of proprietary software for configuration and to extract the data recorded. . . and that's no fun!

This paper gives a brief overview of the resulting work to develop open hardware and associated open source software to satisfy our altitude curiosity, and provides pointers to sources of more information. The live conference presentation will include a more detailed report on our progress and plans for more sophisticated payloads for our higher-powered rocket projects, punctuated with photos and video clips.

This material should be interesting to anyone curious about open small embedded systems. The hardware is ARM-based, licensed under the TAPR Open Hardware License, and implemented entirely using open source design tools. The software is built on FreeRTOS using GNU tools and a variety of open source libraries.

1 The Basic Idea

Model rocketry is a popular hobby in which rocket-shaped models are built, launched, and recovered by a variety of means to be flown again. One of the first questions people ask about model rockets is: "How high did it go?" This question can be answered by visual observations and some fairly simple math, but modern electronics and miniature sensors also make it possible (and more fun!) to measure altitude and other flight parameters directly.

A number of commercial model rocket avionics systems exist, are reasonably priced, and work well. The problem is that they really aren't "hackable" to add new features, or try out different approaches. In some cases, even the serial protocol used to speak to the units from a PC is explicitly proprietary and only useful with provided software for Windows or Mac systems. And that's just no fun!

2 Role of Avionics

Beyond the simple "how high did it go?" question, there are a number of other dynamic parameters that can be interesting to measure in flight. This is particularly true at the more advanced end of the hobby, where flights may exceed the speed of sound, or where experimental propellants, motor casings, and nozzle designs may be under evaluation.

Another significant role of avionics in many model rockets is to control the recovery system, firing ejection charges to deploy parachutes or streamers. If the rocket is moving too fast when the recovery system deploys, it can cause damage to the vehicle or recovery system due to the sudden changes of velocity and resulting energy transfers at ejection. The objective is therefore usually to cause ejection to happen as close to the flight apogee as possible, because that's where the rocket is moving at minimum speed. Simple models accomplish this by flying with a motor that includes a delay element that burns through in a predictable time before firing an ejection charge. But with active electronics, apogee can be directly sensed, eliminating variations due to weather conditions, exact takeoff weights due to payload changes, etc.

For very high flights, particularly on windy days, an additional feature that active on-board electronics can enable is "dual deployment" in which a small drogue chute or streamer is ejected at apogee, followed by deployment of the main recovery parachute at a pre-determined altitude much closer to the ground. This allows the rocket to return towards earth in a controlled but rapid descent to minimize how far down-range it drifts, yet touch down at a safe speed once the main parachute deploys.

Even more sophisticated systems include a radio downlink to the ground for live updates, video from on-board cameras, or even live position information if the rocket is equipped with a GPS receiver. A radio uplink could even be used to command events on board from the ground.

3 What We Built

The Altus Metrum project intends to deliver a completely open (hardware and software) recording altimeter for model rockets. Sized to fit airframes as small as 24mm in diameter, with flexible battery choices, the design bases most operations on a barometric pressure sensor, but also includes a three-axis accelerometer and temperature sensor. Enough non-volatile memory is included to support data logging through the entire flight, and a USB interface allows easy programming, data recovery, and operational power when not in flight. Other features include two serial ports to support an on-board GPS receiver and RF downlink, and support for firing two ejection charges using "electric match" low-current igniters to support dual-deploy or staging activities.

The hardware design is based around the single-chip LPC-2148 microcontroller from NXP, which is an ARM7TDMI-S core with 512k of flash memory, 32k of RAM, USB, and lots of analog, digital, and serial I/O on-board. Non-volatile storage of flight data is provided in a Microchip 24FC1025 CMOS serial EEPROM, which is 128k by 8 bits with an I2C interface. The sensor complement in the initial prototype includes the Freescale MP3H6115A pressure sensor, Freescale MMA7260QT 3-axis accelerometer, and Microchip MCP9700A linear temperature sensor. A Honeywell 2-axis magnetic sensor was evaluated but not included because of the large circuit board area required for supporting circuitry.

The hardware was designed entirely using open source tools, including `gschem` and `pcb` from the gEDA suite, the features of `digikey.com` for parts selection and data sheet access, `gerbv` and the service of `freedfm.com` for circuit board verification, and the services of barebonespcb.com for quick and cheap circuit board fabrication. An Olimex ARM-USB-OCD JTAG interface is used with `gdb` via `openocd` for hardware testing and firmware development and debugging.

The firmware is written mostly in C with some ARM assembler, runs from the on-chip flash using the on-chip RAM, and stores flight data to the serial EEPROM. USB serial emulation provides a console interface for interaction with the software during ground testing and to retrieve data after flight. Software development uses GCC, newlib, FreeRTOS, and the LPCUSB packages, and is derived from a FreeRTOS demo package written for the Olimex LPC-P2148 evaluation board by J.C. Wren.

The hardware design carries the TAPR Open Hardware License (OHL), which was created to be "GPL-like" for hardware designs. The software is licensed GPL "v2 or later."

4 Current Status

First article prototypes are completely assembled and mostly tested. Enough problems were found and fixed that more v0.1 boards are unlikely to be assembled, a revision of the circuit board design is called for instead. The weather in Colorado has been mostly unsuitable for flight testing since the hardware was developed, and the flight software is not quite finished, so there have been no flight tests yet as of the time of talk submission.

By the time of the conference, we hope to have completed testing and evaluation of the initial hardware including some amount of flight testing. The design will then be updated and a new circuit board revision released, with work to integrate a GPS receiver core and RF downlink continuing in parallel.

5 For Further Information

This project can be found at `http://altusmetrum.org`, with more information on our hobby rocketry activities appearing at `http://gag.com/rockets`.

Information about the TAPR Open Hardware License may be found at `http://tapr.org/ohl`.

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