The BalloonSat Flight Computer

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Good afternoon, I'm Paul Verhage. I teach electronics at the Dehyrl A. Dennis Professional Technical Center and write for Nuts and Volts and Amateur Television Quarterly magazine.

I started flying near spacecraft almost eleven years ago and to date, I have flown 63 near space missions. The near spacecraft flown in those missions have all carried trackers and flight computers that I've developed.

One of my latest developments is a flight computer for BalloonSats. And I'd like to take this opportunity to describe it and its capabilities.

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The BalloonSat that most high school and college students are familiar with is a foamcore box covered in aluminum tape. Its avionics consists of a Hobo data logger and 555 timer driven relay that operates an APS film camera. This BalloonSat design lets students concentrate on developing the airframe. As far as avionics go, this design only needs its 555 timer trimmer pot adjusted and its Hobo programmed to collect data at a specified interval.

It's a good project for a first time flyer and gets experiments into near space quickly and easily. After recovery the student will have photographs taken in near space and charts showing the variations of temperature and relative humidity during the mission.

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The flight computer I've designed replaces the camera timer and Hobo data logger. It's an advanced form of avionics that's programmed with more detailed instructions than the traditional 555 timer and Hobo data logger. But the flight computer is still simple enough for first time BalloonSat students. It really shows its power though in the hands of more advanced students, students who are ready to run more complex experiments and cameras.

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The BalloonSat Flight Computer, or BFC, is simple in design and inexpensive to construct. Its construction can in fact be incorporated into the BalloonSat curriculum. The BFC uses a Parallax BASIC Stamp 1 as its microcontroller, so it's easy to program. Sensor voltages are digitized with an ADC0834 A to D converter. That gives it four analog channels with 8 bits of resolution. Sensor data is stored in EEPROM. Therefore data remains stored in memory even after the power is shut down. The serial EEPROMs are the Microchip 93C66's with 512 bytes of storage each. The voltage regulator is a low voltage drop out LM2940. So the BFC can run from six volts and source up to one amp of current. That current is available to the BASIC Stamp and to devices plugged into the digital and analog channels.

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The BFC is superior to a Hobo and 555 timer in most comparisons. Since the BFC is programmed, its rate of data collection can be varied during a mission. For example, some sensor data could be collected only during ascent, near maximum altitude, or at rates that differ for different sensors. One real world example is collecting environmental data. Since ascent is slower than descent, altitude resolution is finer while collecting data during ascent than during descent.

Both the Hobo and '834 have 8-bits of resolution. The Hobo makes the most of its resolution by limiting its voltage inputs to 2.5 volts. That gives it a precision of 10 millivolts. Of course you lose some of that precision if the voltage span of the sensor is greater than 2.5 volts and it must be divided down. The '834 in the BFC has a voltage span of five volts and a precision of 19 millivolts.

A Hobo shines in its data storage capability while the BFC is limited to only one kilobyte, or 1,024 one-byte records. However this is not as bad as it might at first appear. One thousand records collected equally in time from four channels during an ascent of 1,200 feet per minute to an altitude of 85,000 feet yields an altitude resolution of 330 feet. A dataset of 1,000 records is easier to mentally grasp than a dataset one hundred times larger. And in most cases the chart from the larger dataset is not be significantly more informative than a chart from a smaller dataset.

Depending on the model of Hobo, the traditional BalloonSat is limited to four sensors. Usually though, only two sensors are flown. And unless a Hobo is measuring events like switch closures, only analog sensor data can be recorded. The BFC on the other hand can record data from up to six sensors and two of those sensors can produce a digital output.

A simple 555 driven relay operates a camera shutter at a fixed rate unless something like a photocell varies the rate. Because of the BFC's programmability, it can operate cameras at a rate that varies controllably during a mission. This can be important when a BalloonSat's camera is pointed downwards. At high altitudes the ground span of a photograph is so great that there is very little difference between two photographs taken five minutes apart. When it comes to complete ground coverage it's better if the camera records photographs more frequently at the start of a mission and less frequently at high altitudes. This change in photography rate is easily programmed into the BFC.

However, when the time between exposures is too great, a camera with a power save feature will shut down from its lack of use. The second digital channel of the BFC is designed to start up and shut down cameras like these. The camera's state is fully controllable during the mission. Alternatively, one digital channel can command a servo that either rotates a mirror or the camera itself before the second digital channel commands the camera to record an image. This lets one camera do the work of three cameras, saving weight. If a camera is not part of the BalloonSat's payload, then the two digital channels can operate experiments. Say for example, at altitude releasing a bag of cockroaches.

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The BalloonSat Flight Computer is programmed in PBASIC. Parallax has done a great job in developing this programming language and its teaching materials. Free BASIC Stamp books can be downloaded from Parallax at their website, www.parallax.com. If you give BalloonSat teams a set of prewritten subroutines then programming the BFC is further simplified.

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Here's an image of a BFC connected to a miniature weather station and a two channel digital camera. The sensors and camera cables terminate in three pin male headers. Headers and receptacles make interfacing cameras and sensors as easy as plugging in a cable. In this example four triple A cells power the BFC and three triple A cells power the camera. Two reed relays are used to operate the camera in this image, but transistor switches can be substituted for the relays.

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To ensure positive control before launch, the BalloonSat Flight Computer incorporates a launch commit pin and LED. After being powered on, the BFC indicates it's readiness by blinking its LED indictor. However, the mission is not started nor is data collected until the launch commit pin is first removed. This way the BalloonSat can remained sealed after its assembly and testing the night before. There's no need to open the BalloonSat at the launch site to load a battery or to begin recording data. Even if the balloon is not launched on schedule, the BFC does not begin its mission. This is not necessarily true with a 555 camera timer and Hobo data logger. The 555 timer begins operating the camera once its battery is in place and the Hobo begins recording data at the time programmed into it the night before.

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I recommend using ½ inch thick Styrofoam and polyester tape to make the BalloonSat airframe. The Styrofoam's thickness keeps the interior of the BalloonSat warmer than thinner and heavier foamcore. By replacing the 555 timer and Hobo datalogger with a BalloonSat Flight Computer, a very capable BalloonSat can be constructed under the traditional one pound limit.

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Here are some of the projects I'm currently developing for the BalloonSat Flight Computer.

Photometers are used to measure the brightness of light. Many affordable photometers are based on a photodiode, a semiconductor device that produces a current in proportion to light intensity. As Forest Mims has described, an LED can be used as a color specific photodiode. I'm working on a design that is not sensitive to its pointing direction. If this project is successful then BalloonSats can determine the brightness of the sky as a function of color and altitude.

Since 1996 I've measured cosmic ray flux in near space. Those missions used the BASIC Stamp 2 and an Aware RM-60 Geiger counter. In development now is a simple Geiger counter interface for the BASIC Stamp 1. When completed, a BalloonSat can record the cosmic ray flux as a function of altitude.

A data synergy exists if the measurements of multiple BalloonSats can be coordinated. So I'm beginning experiments with radio communications between a string of BalloonSats and their tracking module. If successful, this will create a BalloonSat constellation. A BalloonSat doesn't have to be maxed out in weight to be productive as long as each BalloonSat in the constellation carries unique and complementary sensors and their measurements are coordinated. Here's how I envision this working. At the moment that the near spacecraft's time and position are recorded, every BalloonSat in the constellation records their complementary sensor data. The resulting dataset is combined after recovery and incorporated into charts. Another example is to have one BalloonSat activate an experiment for a second BalloonSat to record.

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I have copies of my last column in Nuts and Volts and two printed circuit boards of the BalloonSat Flight Computer to give to anyone interested. Also being passed around is one of my BalloonSats with a flight computer. Now I'd like to take a little time to answer any questions you might have.

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Meanwhile here's a list of articles I've written for Nuts and Volts magazine that you may find useful in your BalloonSat program.