The Dissertation BalloonSat Flight Computer

There are 21 parts in this BalloonSat flight computer, the heart of which is the PICAXE-08M2. The PICAXE is a microcontroller; making the BalloonSat Flight Computer programmable. The PICAXE-08M2's internal memory is limited to 2 kilobytes (kb), or about 480 lines of code. The PICAXE's BASIC programming language is powerful enough that only a fraction of the memory is required to operate most near space missions. In addition to the 2kb of program memory, there is an additional 256 bytes of data storage memory. All the results from the sensors attached to your BalloonSat are stored in this memory. Power for the flight computer comes from a single nine-volt battery and the weight of the flight computer, including battery, is only 61 grams. That leaves a lot of weight available for the BalloonSat airframe and sensor suite.

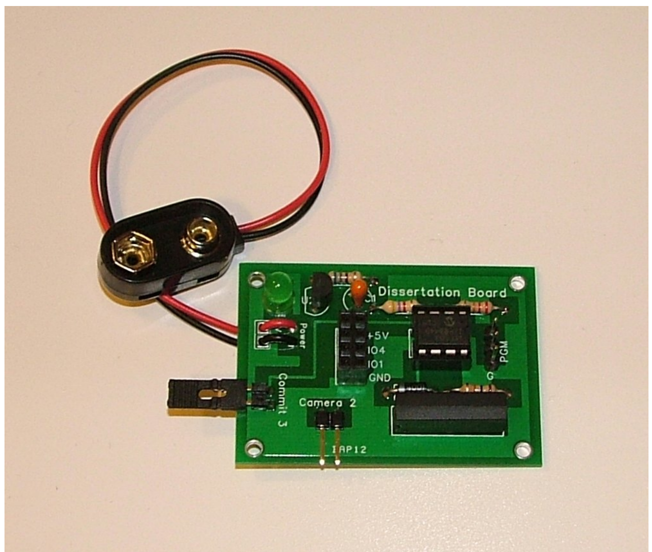

Figure 1. The BalloonSat Programmable Flight Computer.

Parts List

On the top of the printed circuit board (PCB) you will find white colored lettering that indicates the placement and orientation of individual electronic components (the lettering is called top silk). Each component has a unique and meaningful reference consisting of a letter followed by a digit. All resistors for example, have a reference beginning with the letter R. Below is a list of the components in the BalloonSat Flight computer kit and their references you'll find on the PCB.

C1 22uF tantalum capacitor
D1 Green (or red) light-emitting diode (T1-3/4)
D2 1N4001 diode
R1 680 ohm resistor (blue, gray, brown gold or blue, gray, black, black, brown)
R2 4k7 ohm resistor (yellow, violet, red, gold or yellow, violet, black, brown, brown)
R3 22k ohm resistor (red, red, orange, gold or red, red, black, red, brown)
R4 10k ohm resistor (brown, black, orange, gold or brown, black, black, red, brown)
RL 5V reed relay

U1 Eight-pin IC socket
U2 LM2950 +5 volt regulator (TO-92)
Note: Check the flat face of the LP2950 and make sure its says LP2950 and not LM335. The LM335 looks the same, but it's a temperature sensor and not a voltage regulator.

The remaining items are required to complete the BalloonSat Flight computer, but they do not have a reference on the PCB.

PICAXE-08M2
Note: Make sure the name PICAXE-08M2 is stamped on the IC and that it's not the TLC272 op-amp
Nine volt battery snap
Two-pin right angle header (2 of these)
Four-pin right angle header
Three-pin straight header
Two by three hole receptacle
Shorting block
Two printed circuit boards (PCBs)

Component Pictorials

The following pictures illustrate the physical appearance of the components you'll find in the kit. The integrated circuit and its socket are for illustration only; these parts in the BalloonSat Flight computer are smaller and have eight pins.

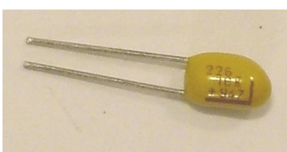

Figure 2. Capacitor

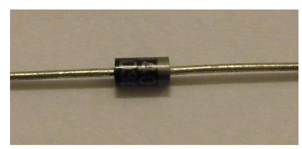

Figure 3. Diode

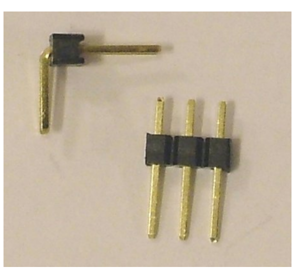

Figure 4. Headers

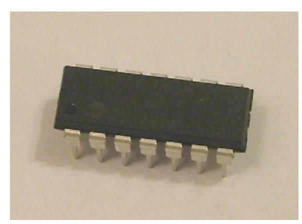

Figure 5. Integrated Circuit (IC)

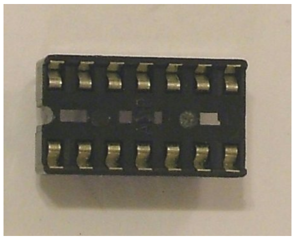

Figure 6. IC Socket

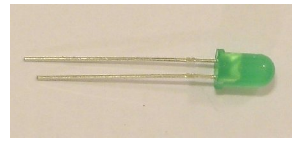

Figure 7. Light-emitting diode

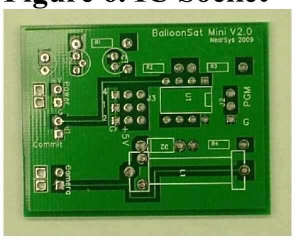

Figure 8. Printed Circuit Board (PCB)

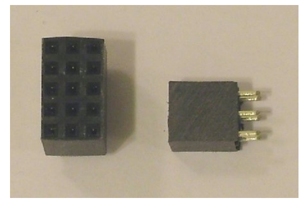

Figure 9. Receptacles

Figure 10. Resistor

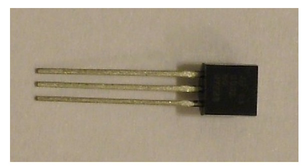

Figure 11. Voltage Regulator

Note: Don't confuse the voltage regulator for the temperature sensor. They look alike, but the voltage regulator has the name, LP2950 stamped on its face (the four temperature sensors are stamped with LM335).

Figure 12. Shorting Block

Theory of Operation

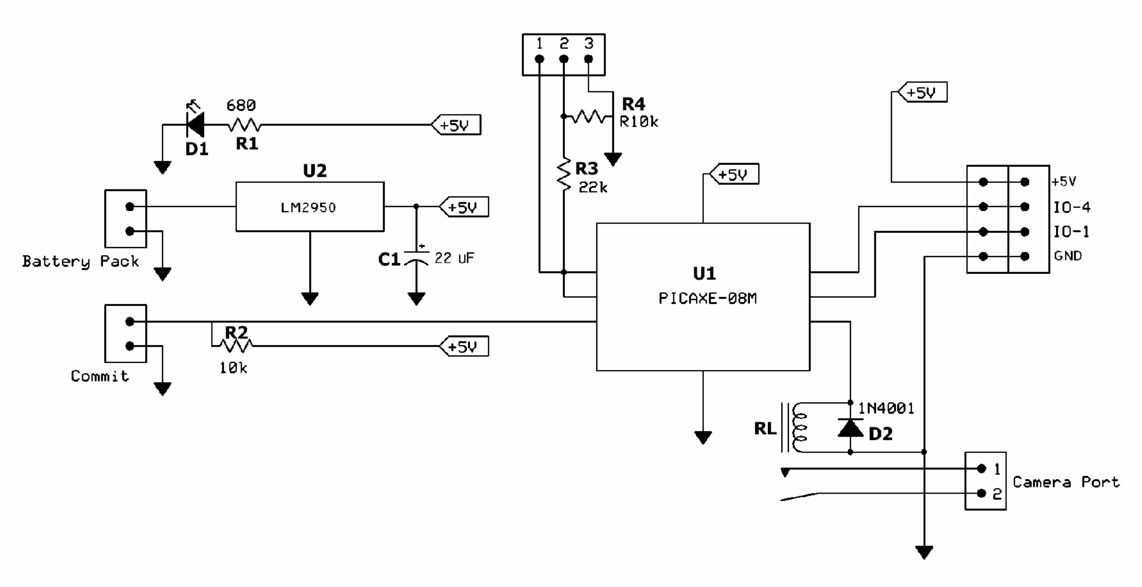

Figure 13. BalloonSat Flight Computer Schematic

The arrangement of components in the flight computer is designed to support the PICAXE-08M2 in the process of collecting and storing data. Below is a brief description of each component and how it supports the mission of the BalloonSat flight computer.

The voltage regulator (LM2950) converts the slowly declining voltage of the nine volt transistor battery into a constant five volts that the PICAXE prefers. The 22 uF capacitor next to the voltage regulator acts like a temporary battery that helps the voltage regulator maintain a more constant five volt output. If the voltage surges slightly higher, the capacitor absorbs the excess current; changing it into charge stored on its plates and bringing the voltage back down to five volts. If the voltage drops slightly lower, the capacitor dumps its stored charge; changing it into needed current and pushing the voltage back up to five volts.

The LED's only function is to light up when five volts is present. Therefore, the LED is solely a power indicator (since there are no moving parts, there is no other way to see if the BalloonSat Flight computer is operating). The 680 ohm resistor connected to the LED limits the current flowing through the LED so it and the voltage regulator are protected from excessive current.

The program header is a three straight pin header that connects to a PC so that the PICAXE Editor can download its program into the BalloonSat flight computer. The 22k resistor limits the amount of current flowing between the PC serial port and the PICAXE during the programming process. The 10k resistor is a pull down resistor that ensures then when no programming instructions are flowing between the PC and PICAXE, the PICAXE does not detect false data.

The commit header is a two right angle pin header that sends a five volt signal to I/O #3 of the PICAXE. The five volt signal is created by the 4k7 resistor connected to the voltage regulator. The five volts appears on one of the pins of the header and the other pin in the commit header is connected to ground, or zero volts. When the commit header is shorted with the Commit Pin, current from the pull up resistor bypasses the PICAXE and travels straight to ground. In doing so, the PICAXE sees zero volts in place of the original five volts. The program you will write will monitor when the Commit Pin is removed. Only when the Commit Pin is removed will you let your program begin collecting and storing data. Note that this means the PICAXE can operate for hours on end without recording data until it's signaled to do so by the removal of the Commit Pin.

The input-output (I/O) port provides five volts, ground, and a unique connection to the PICAXE for each experiment plugged into it. The data from sensors can be either a voltage that varies by magnitude in response to a particular environmental condition, a voltage that is either on or off based on conditions, or digital data sending meaningful pulses. The program downloaded into the PICAXE analyzes the output from sensors and records the results for downloading after recovery.

The PICAXE I/O #2 operates the camera relay. The wire coil inside the relay is energized every time the PICAXE is programmed to take a picture. By energizing the coil, a magnetically activated switch inside the relay closes and triggers the camera shutter attached to the BalloonSat Flight computer. When the relay's coil is de-energized, the collapsing magnetic field of the coil induces a backwards flowing current towards the PICAXE. In a large coil this current can be great enough to damage the PICAXE. To prevent this damage, the PICAXE protected from the back current by a diode. By orienting the diode in the proper direction, this back current is safely routed to ground and away from the PICAXE. The relay used in the BalloonSat Flight computer is pretty small, so the diode is probably not needed. However, it's better to be safe than sorry at 100,000 feet. A specially modified camera connects to the two-pin right angle header on the flight computer.

Assembly Tools

You'll need the following tools to assemble the BalloonSat Flight computer (and any other PCB).

Soldering Iron

Use a low wattage, pencil style soldering iron and not a soldering gun. The tip should have a fine point or chisel. A soldering iron with temperature control would be great, but it isn't required to successfully complete the BalloonSat Flight computer. If you use a soldering iron with temperature control, set the temperature to the midpoint.

Sponge

A damp sponge cleans oxide and excess solder from the tip of the soldering iron. Don't poke the sponge with the soldering iron. Instead, quickly wipe the tip of the soldering iron against the edge of the damp sponge. This wipes off the oxide and excess solder, leaving the tip clean. After wiping the tip of the soldering iron clean, apply fresh solder to lightly coat the tip in a protective layer of molten solder. The molten solder helps heat flow from the soldering iron to the work.

Solder

Solder is an alloy, or mix of lead and tin. The alloy has a low melting point, but molten solder is still very hot – so be careful when soldering. Inside the solder is a narrow channel of flux called rosin. The flux melts first and flows out of the solder to coat the work. Flux helps remove oxide and protects the clean surface so the molten solder following the flux will more likely stick to the work. Use a narrow diameter solder, like 0.032 inches to assemble the BalloonSat Flight computer. Under no circumstances use large diameter solder or solder containing an acid flux. The acid flux will eventually corrode the electrical connections within the PCB.

Wire Cutters

Wire cutters trim wires to length. The trimming is performed before and after soldering; before to cut wires for the sensor array and after to trim excess lead length. Be aware that cut leads can fly across the room. Therefore, be safe and hold or cover the excess lead so it can't fly away when it is cut.

Wire Strippers

Wire is insulated with a plastic coating; however, wires cannot be soldered through this coating. So it must be removed without damaging the copper wire. Do not use wire cutters to strip wire as they will nick and weaken the wire. There are several different types of wire strippers to safely strip insulation. If your wire strippers have several diameter holes for stripping wire, then use the #24 gauge hole to strip the wires. In a pinch, the wire in the kit can be stripped as #22 gauge. The other type of wire strippers are automatic strippers that adjust to the diameter of the wire as they strip the insulation.

Sandpaper

To keep the cost of the BalloonSat low as possible, several components in the kit are purchased in long strips and then cut to their proper size. This includes the receptacles. The cut edges of the receptacle are rough (sorry, I can't shear the receptacles more smoothly), so you should sand them until they look nice. Place a sheet of 120 grit sand paper (or other grit close to 120) on top of a flat surface like a table top. Then briskly wipe the raw edge of the receptacle across the surface of the sandpaper. Watch that you don't sand off too much of the receptacle. The cut edge of the receptacle can be made even smoother by switching the 120 grit sandpaper with a 220 and wiping the cut edge across this sandpaper.

Multimeter

While not strictly required, it's a good idea to have access to a multimeter to test and troubleshoot the BalloonSat Flight computer. The Flight computer's PCB is design so every flight computer should work upon completion. Nevertheless, on occasion, a bad solder connection can crop up or a component can be damaged. Locating these problems is easier with a multimeter.

Forming and Soldering

The particular order that the components are installed is not really important, however, it is recommended that when soldering, you install the lowest lying components first. Before you insert the first lead of a component into a PCB, form the component by bending its leads to the proper length. Then insert the component on the top silk side of the PCB and flush to the PCB (there are a few exceptions that will be noted in the directions). Then flip over the PCB and solder the leads to the pads. To prevent the component from falling out when the PCB is flipped over, either spread the leads slightly or use a little bit of masking tape to hold the component in place.

A component lead cannot be properly soldered until both the lead and the pad on the PCB are hot. However, if the copper trace or pad on the PCB gets too hot, they will lift off the PCB damaging the circuit. Therefore, the pad and lead must be heated quickly by using a soldering iron tip that is clean of oxidation and damp with a little solder. As you are assembling the flight computer, wipe the tip of the soldering iron on a damp sponge frequently to keep it clean. After cleaning the tip, apply a little bit of fresh solder to it to keep it lightly covered in liquid solder.

When you are ready to solder, place the tip of the soldering iron where the component lead and pad meet. Then touch the tip of the solder to the iron and pad/lead to melt the solder. Quickly run the solder around the hot pad to create a shallow solder pool over the face of the pad. Then quickly remove the solder followed by the soldering iron.

The solder should form a cone around the pad and up the lead. There should be no major gaps in the solder coverage around the pad or a balling up of the solder. If the soldered connection is nearly good enough then leave it be. Trying to rework a soldered connection to make it absolutely perfect is inviting damage to the PCB.

After the solder cools, cut the excess lead at the top of the solder cone with a pair or wire cutters. Be careful not to cut deeply into the solder cone or else the connection can be damaged.

Assembling the BalloonSat Flight computer

The diagram below illustrates the placement of the components you will solder to the BalloonSat Flight computer PCB. Follow the diagram and check off each step as you complete it.

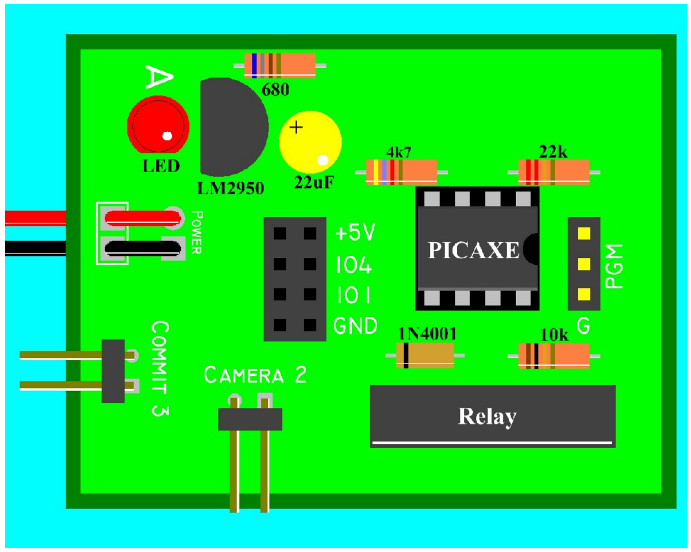

Figure 14. Parts Layout for the BalloonSat Flight computer

1. Resistors
Form (bend) the resistor leads before inserting them into the PCB. Each resistor's position is indicated by its R-number.
□ **R1 680 ohms (blue, gray, brown, gold)**
□ **R2 4.7 k-ohms (yellow, violet, red, gold)**
□ **R3 22 k-ohms (red, red, orange, gold)**
□ **R4 10 k-ohms (brown, black, orange, gold)**

2. Diode
The diode has its name, 1N4001 printed on it and a white or black stripe painted around one end. Orient the diode's stripe according to the diagram above. If it's backwards, the relay will never trigger the camera and the PICAXE could be damaged.
□ **D2 1N4001**

3. Commit/Camera Header
Insert the short leads into the PCB and leave the longer pair hanging over the edge of the PCB.
□ **2-pin right angle Commit Pin**
□ **2-pin right angle Camera Port**

4. Cable
Solder the nine volt battery snap and the camera cable to the PCB. Note that there are large diameter holes near the edge of the PCB and smaller holes inside of them. The large holes are the strain relief that will prevent normal usage from breaking the wires off the PCB. Begin with the battery snap since its wires are already stripped. Note that one wire is red and the other is black. The red wire is positive nine volts and the black is ground. These must be soldered to the proper pads in the PCB or the flight computer will not power up. Push each wire up through the strain relief hole from the underside of the PCB and then bend each wire down and into its pad. Push the wires through the pads until their

insulation is flush with the PCB and no bare wire is exposed above (or nearly no wire is exposed above). Then solder the wire.
□ **Battery Snap**

5. IC Socket
To protect the PICAXE from heat damage by the soldering iron, solder the IC socket to the PCB and not the PICAXE itself. Electrically speaking, the orientation of the IC socket doesn’t matter. However, still solder the socket with its notch aligned with the notch on the top silk graphic. The notch in the IC socket will then specify the proper orientation of the PICAXE when you install it. If the PICAXE is installed backwards, the BalloonSat Flight computer will not function. **DO NOT install the PICAXE into the socket before soldering the socket to the PCB** – this defeats the purpose of using the socket. Afterwards, do not insert the PICAXE yet, as the BalloonSat Flight computer must be tested first.
□ **U1 8-pin IC socket**

6. Capacitor
The capacitor is polarized, so look for a plus (+) mark stamped on its body. The plus marks the positive lead. Orient the capacitor according to the diagram above and solder. The capacitor will probably resist being set flush to the PCB, so don’t force it.
□ **C1 22 microfarads**

7. Voltage Regulator
The voltage regulator is polarized, so install it with the flat face of the regulator aligned with its top silk illustration. This is another component that will not sit flush on the PCB, so don’t force it. **Note:** Make sure you see that the voltage regulator has LP2950 stamped on its face. The voltage regulator looks identical to the LM335 temperature sensors.
□ **U2 LM2940**

8. LED
The LED is another polarized component, but unlike the others, if it is placed backwards, the flight computer will still function; it just won’t give you a pretty green light to indicate that it’s up and running. Look for the flat edge on the LED’s plastic lens, which is usually on the side with the short lead. That flat edge indicates the negative lead of the LED, or its cathode (which is usually the short lead). The other lead is the anode and it goes into the pad marked with the letter A. Push the LED down until it is flush with the PCB and then solder.
□ **D1 Green LED**

9. Relay
The writing on the side of the relay is the side of the relay closest to the bottom of the PCB (and on the side opposite the PICAXE). The white line drawn on the relay in figure 14 represents the writing on the side of the relay. The relay sits almost flush to the PCB surface (there are small ridges on the bottom of the relay to prevent from sitting flush).
□ **RL Reed relay**

10. Receptacle
The receptacle was cut from the longer piece of receptacle. Therefore, sand the face of the receptacle flat with sandpaper to make it look more professional. The orientation of this component is unimportant, just insert it and push it flush to the PCB before soldering its leads.
□ 2 by 4 Receptacle

11. Program Header
Insert the short ends of the header's pins into the PCB and push it until its plastic base sits flush to the PCB.
□ 3-pin Straight Pin Header

Checking Your Work

That completes the assembly of the BalloonSat Flight computer. However, don't plug the PICAXE-08M2 and battery in just yet. That's because if there is an error in the assembly, the flight computer could be damaged when powered up. First perform these five checks.

1. Check the Soldering
Inspect the underside of the PCB looking for blobs of solder that may bridge across two pads. If there appears to be such a bridge, briefly apply some heat to the pads with your soldering iron and "pull" the molten solder back into two separate cones. Or you could lay solder wick across the solder and try to wick up the excess solder. Do these actions quickly as too much heat can damage copper traces on the PCB.

2. Check for Shorts
Set the multimeter to the continuity setting and tap the test leads together. The multimeter will ring or beep to indicate there is a short between the test leads. Now perform the test for real by applying the test leads to the two battery terminal contacts in the nine volt battery snap. There should be no ringing. If there is, then there's a short in the PCB that needs to be located and fixed. Pretty much the only way a short can exist in the PCB is through a solder bridge. So look over the underside of the PCB again, for a solder connection that has overflowed its pad.

3. Check the Voltage
Set the multimeter to measure DC voltage. Snap a nine volt battery into the BalloonSat Flight computer and measure the voltage across pins 1 and 8 of the IC socket. With the red lead on pin 1 and the black lead on pin 8, the multimeter will display a voltage between +4.75 and +5.25 volts.

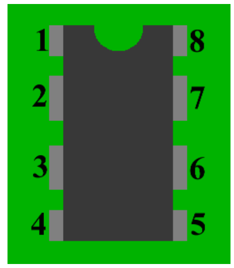

Figure 15. IC pin out.

Check the commit header voltage by leaving the black test lead on pin 8 and moving the read test lead to pin 4. The multimeter will display between +4.75 and +5.25 volts. Next place the shorting block on the commit header and repeat the same measurement. The multimeter will now display close to zero volts.

Check the voltages on the I/O ports. To make an electrical contact with the receptacle, stick cut resistor leads into the openings of the receptacle. The openings in figure 16 are marked in red are +5 volts and in green are ground, or zero volts. So insert one cut resistor lead into a +5 volt opening and a second resistor lead into a ground opening. Tap the test leads of the multimeter to the resistor leads sticking out of the openings and it should display a voltage between +4.75 and +5.25 volts.

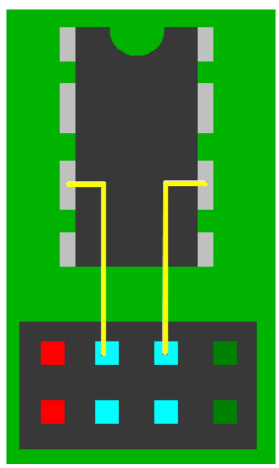

Figure 16. Receptacle connections.

4. Check I/O Continuity

The next test is a continuity test. So disconnect the battery and set the multimeter to measure continuity. The yellow lines in figure 16n indicate the connections between the openings in the receptacles and the pins in the PICAXE IC socket. Tap one test lead of the multimeter one pin in the IC socket and use a cut resistor lead to make contact with the appropriate opening in the I/O receptacle. The multimeter should ring for each connection.

5. Check the PICAXE
Insert a PICAXE-08M2 into the IC socket and plug a serial programming cable into the programming header on the BalloonSat Flight computer.

Note: Make sure the name PICAXE-08M2 is stamped on the top of the IC. The TLC272 op-amp looks identical to the PICAXE-08M2.

Start the PICAXE Editor and select the PICAXE-08M2 (the editor programs lots of different types of PICAXE's, so you have to tell it which one). Type the following program and download it into the PICAXE by clicking the Download Button. Figure 17 points to the Download button.

```
PAUSE 1000
DEBUG
```

If the PICAXE has not been damaged and the programming header is properly soldered, the debug window will open and display a single message. There will be a single debug message and circled in figure 17. The debug window will indicate that the PICAXE's memory bytes (B0 to b13) are set to zero.

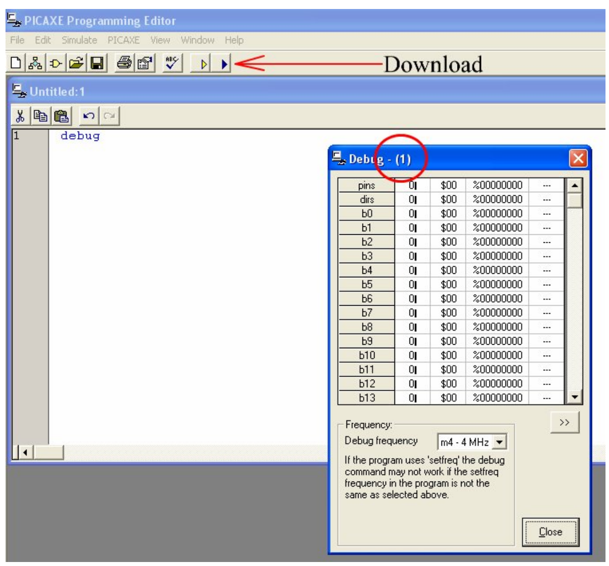

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Figure 17. Debug Screen

Protecting the BalloonSat Flight Computer from Short Circuits

Now that the BalloonSat Flight computer has checked out, it's time to protect the underside from short circuits. As long as the BalloonSat Flight computer is not placed on top of metal, like wires, the flight computer is safe from accidental short circuits. A short circuit occurs when a piece of metal (a conductor of current) bridges the gap between two solder pads that are not connected by a trace. A sheet of Foamcore or foamed neoprene rubber beneath the PCB will prevent short circuits by stray objects.

Camera Port

The camera cable terminates in a two-by-two receptacle, but notice that two of the holes are filled with a white plastic dowel. That leaves the remaining two holes in the receptacle to connect the camera to the flight computer. Just slide the two open holes in the camera cable to the flight computer's camera port. Note that the camera must be bolted to the BalloonSat airframe using the ¼ - 20 bolt and washer included in the kit.

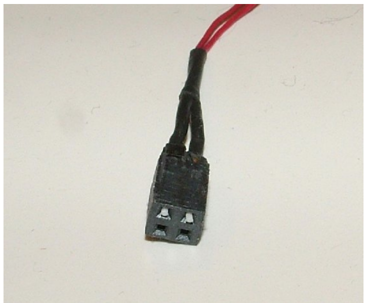


Figure 18. A camera cable terminated in a two by two receptacle.

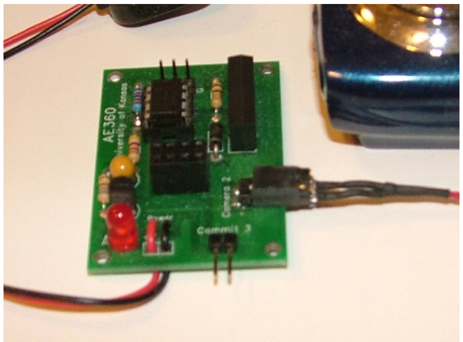
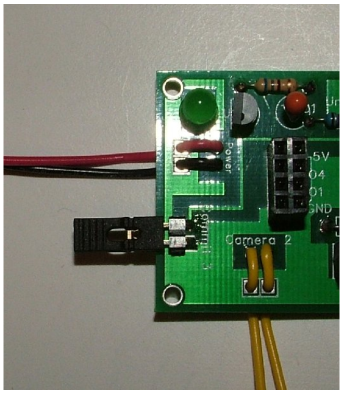


Figure 19. The camera plugged into the Flight Computer.

Commit Pin

As long as the Commit Pin (a shorting block) is on the flight computer, the PICAXE detects a logic low (zero volts or ground) on I/O pin 3 (thus the name, Commit 3). When the Commit Pin is removed, the PICAXE detects a logic high, or five volts on I/O pin 3.



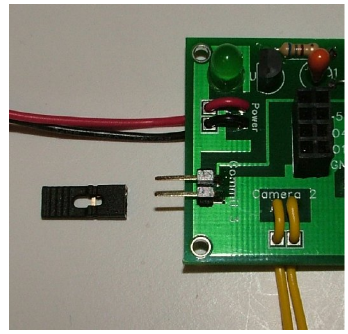


Figure 20 and 21. The Commit Pin on the flight computer and off the flight computer.

It is easier to pull the pin off than it is to push it back on. Therefore, the flight computer is programmed (by you) to wait for the removal of the pin before it begins recording data. The shorting block used for the Commit Pin is small enough that chances are that it will be lost or forgotten. To prevent this and to ensure the flight computer knows when to begin recording data, attach a brightly colored ribbon to the handle of the shorting block.

Figure 22. A shorting block sporting a brightly colored ribbon for enhanced visibility.

Connecting Sensors

The BalloonSat Flight computer collects data from a sensor array consisting of two sensors. The sensor array terminates at a PCB with a four-pin header on one end. Each pin has one of the following functions, ground (zero volts or the negative terminal of a battery), two input channels, and +5 volts. The pins of the header are soldered to a printed circuit board and have a spacing of 0.1 inch between pins. The pins are 0.025 inches across.

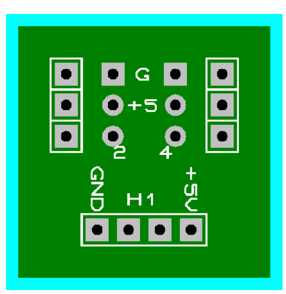


Figure 23. The four pin header, how the BalloonSat's sensor array terminates.

The benefit of using four-pin header is that sensors can be plugged into any I/O channel. And as soon as the header is plugged in, the sensor array receives power and communications with the PICAXE. The output from sensors plugged into the BalloonSat Flight computer can be either an analog voltage, a series of voltage pulses (on and off), or an on-off state.

To make the sensor terminator, solder the four-pin right angle header to the four pads marked H1. Solder the short ends of the header; leave the long pins free.
□ **4-Pin Right Angle Header**

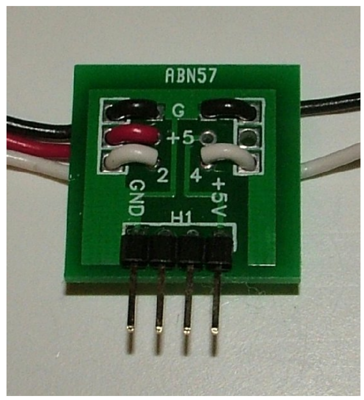


Figure 24. The terminator for a sensor array. The wires on the left and right sides connect to sensor PCBs. These will be added later.

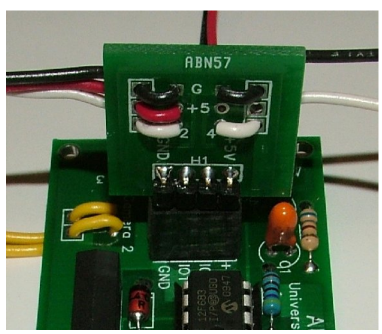


Figure 25. A sensor array plugged into a flight computer.

Programming the BalloonSat Flight Computer

Download and install the latest version of the PICAXE Editor on a PC. The editor is similar to a word processor in that you'll write text and have the editor check it for syntax. Syntax is another word for rules. The program you will create for the flight computer uses a computer language called BASIC. The rules of BASIC are its syntax.

If your code follows the rules, then the editor will download it into the PICAXE-08M2 on the flight computer. Note that just because the syntax is correct doesn't mean the program will work. You must test the program by observing the flight computer and the way it collects and downloads data. Always save a copy of your program on the PC. It's much easier to modify old code than it is to create new code from scratch. When a program is downloaded into the PICAXE, it is stored in EEPROM memory. In EEPROM it will be remembered for at least ten years without power or a battery. When I receive your BalloonSat, you will have tested the code and make sure the latest version is currently in memory. I'll snap in a battery and your BalloonSat will start running your program.

The flight computer is programmed over a serial port on the PC. If your PC does not have a serial port, then purchase a USB to Serial adapter. The serial port ends in a male DB-9 connector. However, the BalloonSat flight is programmed through a three-pin header. In your BalloonSat kit is an adapter cable made of three wires (two white wires and one purple). The purple wire is the ground wire and it must connect to the pin with the letter **G** next to it (they're the ground connection).

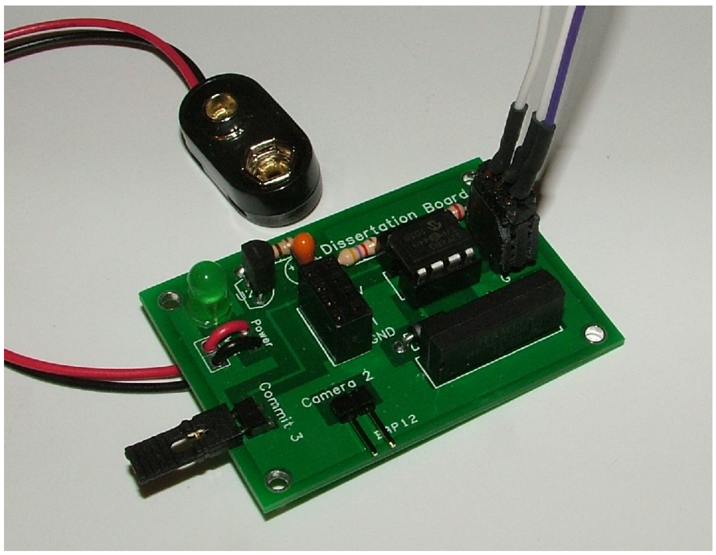


Figure 26. The white and purple programming adapter plugged into the BalloonSat flight computer's programming port. The purple wire is the ground wire and must be connected to the pin with the letter G next to it.

Examples of Code

This section contains examples of the commands used most often in a BalloonSat Flight computer flight program. These notes **<u>are not</u>** meant as a replacement for the PICAXE BASIC Commands Guide. You'll find the manual under the HELP option of the programming editor.

FOR

This command instructs the PICAXE to begin a loop of program. The program loop is typically a sequence of commands that collects sensor values and stores them into memory. By using a program loop, the program only needs to be written once since it can be repeated ad infinitum. The FOR command is combined with a NEXT command to create a block of program that is repeated a fixed number of times during a near space mission.

HIGH
The HIGH command energizes the camera relay onboard the flight computer. When the relay's electromagnet is energized, its magnetic field closes the relay's switch. The relay switch has replaced the shutter switch in the camera, so by using the HIGH 2 command, the camera is commanded to take a picture.

IF PIN3 =
This command instructs the PICAXE to check the voltage on the Commit Header (the input pin 3 of the PICAXE-08M2). If the value of this pin is 1 (five volts) then the Commit Pin has been removed.

LOW
The LOW command releases the shutter switch; however, the camera needs time to focus and record an image before releasing the shutter switch. Therefore, so use the PAUSE command after triggering the shutter, but before releasing the shutter.

NEXT
This command instructs the PICAXE that this the end of the program loop. The sequence of commands between the FOR and NEXT statement will be repeated during the mission until an event specified in the FOR statement is met.

PAUSE
The PAUSE command halts the program for a specified length of time. The time is given in units of milliseconds, or in 1/1000 of a second. The largest number that can be used with the PAUSE command is 65,535, or about 65.5 seconds. Use this command to add a pause between collecting data and taking pictures. Remember, your flight program needs to collect data for at least 95 minutes, so there needs to be a pause after each time the camera records data (including taking a picture). Without a pause, the entire mission will run in a few minutes at most.

READ
This command instructs the PICAXE to read a value out of its 256 bytes of memory. The command when part of a FOR-NEXT loop will read out all the data collected during the BalloonSat's mission. To display the data on a PC, use the SERTXD command and the PICAXE Editor's built-in terminal program.

READADC
This command instructs the PICAXE to digitize the voltage on a particular input pin. The voltage is digitized to an eight-bit level. This means the voltage, from 0 to 5 volts, is divided into 8-bits, or 256 units. Five volts divided by 256 units means each unit or count is equal to 0.0195 volts.

SERTXD
This statement instructs the PICAXE to send text and data to a PC over the serial port from the flight computer's programming port. This means the same programming cable and connection to the flight computer used to program it also downloads its data. The Terminal program is an option under the PICAXE option of the menu. Be sure the terminal speed is set to 4800 baud or else the data will look like gibberish.

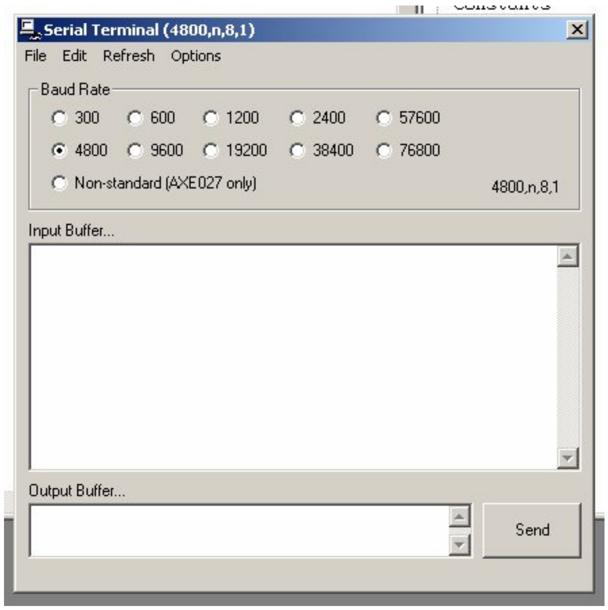


Figure 27. The Terminal program in the PICAXE Editor. Under the Edit option, you'll find the Copy Input Buffer option. Use it to copy the data displayed in the terminal program into a text file. The text file is then copied into a spreadsheet for processing.

The SERTXD command does not know to display the data as a number or a text character. Therefore, you must precede the data to display with the pound sign or hash mark (#). Also, if you just SERTXD each memory location, the data will be displayed as a long string of numbers. Unfortunately, this means you won't be able to tell where one memory value ends and the next one begins. Therefore, add a comma after each time your program displays the number stored in a memory location. The final SERTXD command will look something like this, SERTXD (#B0,",").

WRITE
This command instructs the PICAXE to store a number, usually a sensor value, into memory. After the recovery of the BalloonSat Flight computer flight computer, the READ command retrieves the stored value.

L. Paul Verhage
University of Kansas
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