CHAPTER THREE

Near Space Avionics, Part Two
Two NearSys Central Computer/Programmable Sequencers (CC/PS)

" Alas poor Newton! Late for learning fam'd,
No more shall thy researches e're be nam'd:
For greater Newtons, now, each day shall soar,
High up to Heaven, and new worlds explore."
- Mary Alcock

Chapter Objectives

1.0 Introduction to the NearSys Flight Computers

The near spacecraft requires a set of electronics in order to complete a mission. This set of electronics can be as simple as a beacon to as complex as a flight computer. The NearSys flight computers are called the Central Computer/Programmable Sequencer, or CC/PS. As a central computer the CC/PS responds to system and environmental conditions by detecting both analog and digital inputs. After collecting and processing data, the CC/PS formats telemetry for transmission to ground stations. As a sequencer the CC/PS operates near space experiments and events in a simple, repetitive cycle.

The CC/PS functions in all phases of a near space flight from Systems Checkout, Prelaunch Activities, through Flight and Recovery. Upon power up, the CC/PS can be programmed to exercise experiments and display current GPS data. While waiting for a change in altitude, or for the launch command, the CC/PS can keep ground crews informed on capsule status. During flight, the CC/PS can operate near spacecraft equipment, collect science and status data, and send telemetry to ground stations. When balloon burst is detected, the CC/PS can terminate experiments and change its position, reporting frequency as an aid to recovery. The CC/PS is mounted inside the near spacecraft and has external connections to batteries, HT, GPS receiver, and possibly a TNC.
The CC/PS has several levels of intelligence. At the basic level, the CC/PS can monitor the status of the capsule's individual systems like power, internal temperature, and GPS position. At a higher level, the CC/PS operates experiments based on programmed conditions. In the highest level of intelligence, the CC/PS responds to system failures or ground commands during a flight.

The source of intelligence in the CC/PS is one of the BASIC Stamp 2 (BS2) microcontrollers from Parallax, Inc. The microcontroller is programmed to fetch and interpret PBASIC instructions stored in its EEPROM. EEPROM doesn't require battery power to store programs. In this way the EEPROM behaves like a hard drive, storing the program to be executed when the microcontroller starts up. While 2k of memory may not seem like a lot, it's enough memory for about 600 lines of instructions. Typically an entire mission is operated on a single 2k program. In addition to EEPROM, the BS2 has 32 bytes of internal RAM for storing variables that can be updated during program execution. The BS2 uses software UARTs, allowing any I/O pin to function as a simple serial port. This gives every I/O pin on the BS2 the ability to communicate with GPS receivers and TNCs.

Programs for the BS2p are entered on a PC using the free programming software developed by Parallax. On the PC, BS2p programs are checked for syntax and memory usage before being downloaded into EEPROM. In EEPROM the program exists in a tokenized format that the BS2p's microcontroller fetches and interprets.

1.1. Block One and Block Two CC/PS

Two flight computers are described in this chapter, the Block One CC/PS and the Block Two CC/PS. Both blocks contain a BASIC Stamp 2, MAX186 ADC, ULN 2803 Darlington pair, and Servo Controller. The difference between the two blocks is that the Block Two has a built-in TNC, whereas the Block One's TNC is external.

the Block Two CC/PS contains a TNC on the PCB (a MIM) and should be considered experimental. The Block One CC/PS depends on an external TNC. Both flight computers are capable of performing the same experiments during a mission.

1.2. Before You Begin Construction

Before you begin constructing the CC/PS, please review Section 1.2 of Chapter 2 for a refresher of recommended soldering tools and techniques. The time you invest in practicing soldering may save you time, money, and aggravation as you build your CC/PS. The soldering tools listed in that section will be necessary to complete your CC/PS.
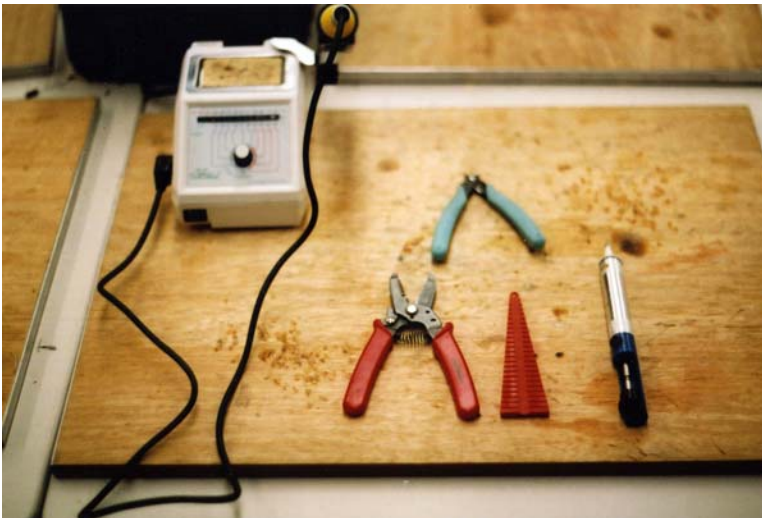
Construction – Tools for soldering the CC/PS PCB.

1.1

1.2.1. Other Tools

In addition to your soldering tools, you will need these two listed below to complete your CC/PS:
- Hot glue gun
- Jeweler's screwdrivers
- Hot air gun (heat gun)

Tools – Hot glue gun, jeweler's screwdrivers, and hot air gun.

The jeweler's screwdrivers are used to bolt the daughter boards to the CC/PS PCB. The hot air gun is used to shrink heat shrink tubing. Never use a soldering iron to shrink heat shrink tubing. Other than that, enjoy building the CC/PS for your near spacecraft and don't burn your fingers in the process.

2.0 The Block One CC/PS
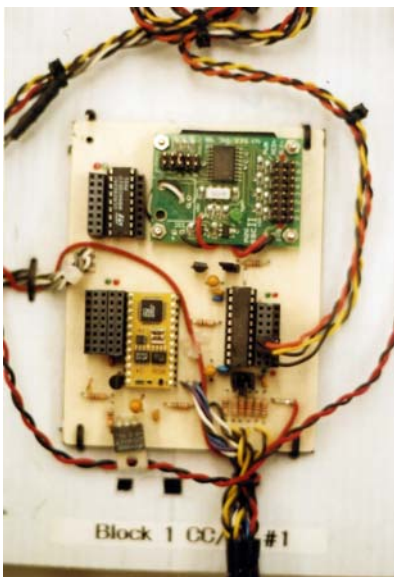
The Block One CC/PS – The completed flight computer. Detailed instruction on how to build it are given in the following sections.

The diagram below shows components and their relationships.
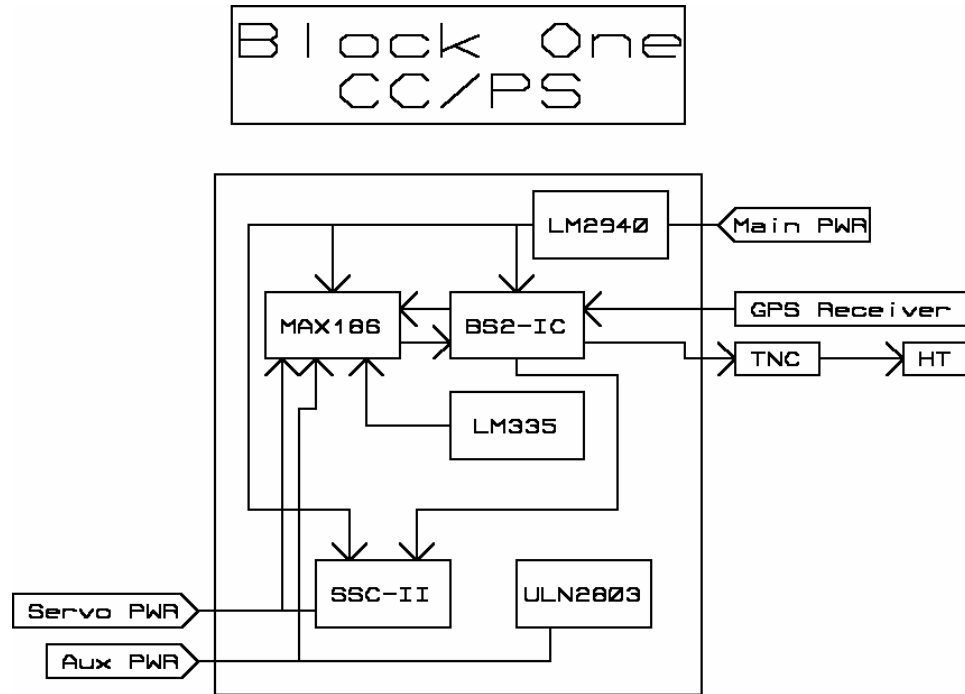
Block Diagram –*Conceptual view of Block One CC/PS.*

In the Block One CC/PS, the BS2p controls the following devices onboard the CC/PS:

- MAX186   Analog-to-Digital Converter (ADC)
- SSC II   Serial Servo Controller
- ULN2803   Darlington Pair

The MAX186 digitizes voltages from sensors which output a voltage dependent on the condition they measure. Voltages from 0 to 4.096 Volts are digitized with a resolution of 1mV. The MAX186 can digitize the voltage difference between two channels. The SSC II positions servo motors to a precision of less than one degree. A total of eight servos can be controlled during a mission. The ULN2803 switches on and off devices requiring higher voltage or current levels than the BASIC Stamp can source. A source of additional voltage, the Aux Pwr, is recommended for these devices so they cannot discharge the main battery.

The Block One CC/PS requires an external TNC, like the Kantronics KPC-3+, so there is no TNC mounted on the PCB.

GPS receivers can be connected to the Block One CC/PS in two different ways. In the first way, the GPS talks to both the BASIC Stamp and the TNC simultaneously. This configuration increases the reliability of missions by preventing a communications lock-up should the CC/PS fail. The second way is to connect the GPS receiver to only the BASIC Stamp, which requires the BASIC Stamp to forward GPS sentences to the TNC.

While any 24-pin BASIC Stamp 2 can be used in the Block One CC/PS, I recommend a BS2p because of its scratch pad RAM (SPRAM). An entire GPS sentence can be read into SPRAM for later processing.

2.1.   Theory of Operation

The following topics are covered under Theory of Operation
1. CC/PS Ports
2. Devices Internal to the CC/PS
3. External Devices Interfaced to the CC/PS
4. Function of Each Discrete Component on the CC/PS

2.1.1. CC/PS Ports

Ports provide a means to interface real world data to the BS2p. The seven ports function as either input or output, and some operate as both input and output. External devices can be connected to these ports for control instructions and/or data input.

BS2p Inputs
The following inputs are available to the BS2p:

- Eight channels of ADC, each with twelve bits of resolution
- GPS sentences from the GPS receiver
- Ground commands sent through the TNC
- Eight I/O ports

BS2p Outputs
The following outputs are available to the BS2p:

- Telemetry to the TNC
- Commands to the SSC II to position up to eight servos
- Eight channels of high power (up to 12 Volts at 1 amp) digital output
- Eight I/O ports

Now the ports in greater detail:

I/O Expansion Port
Data Type: Digital (Analog when filtered)
Data Direction: Input and Output

The CC/PS contains eight expansion ports. Each port contains its own BS2p I/O pin, +5 Volts, Ground, Clock line, and Data line. Each expansion port allows commands to be sent to devices through protocols like serial, I^2C, SPI (serial peripheral interface) and 1-Wire. Expansion ports also operate low power devices like electric switches on cameras. Each expansion port can also collect data from sensors like Geiger counters and light-to-frequency converters. With the combination of pins available at each I/O port, a single cable can power, command, and collect data from a sensor connected to the expansion port

ULN2803 High Power Port
Data Type: Digital

Data Direction: Output

The BS2p drives high power loads (up to one amp at twelve Volts) through a ULN2803, Darlington pair IC. An additional battery is required onboard the near spacecraft as the source of auxiliary voltage.

Jumper wires make the connection between BS2p I/O pins and the inputs of the ULN2803. A command to activate a ULN2803 output is made by setting the corresponding I/O pin high. When activated, auxiliary power is available to the corresponding output of the ULN2803.

SSC II Servo Port
Data Type: PWM Digital
Data Direction: Output

The SSC II allows the BS2p to position up to eight servos. The serial connection between the BS2p and SSC II is hard wired into the CC/PS PCB.

ADC Analog Port
Data Type: Analog
Data Direction: Input

The ADC ports convert analog voltages into digital values upon command from the BS2p. Analog voltages are digitized with 12 bits of resolution and the maximum input voltage is 4.096 Volts. The analog ports are typically used to record the results of sensors, but can be configured to digitize near spacecraft voltages and temperature through the use of four jumpers.

ADC Jumpers
Jumpers one through three are located above the MAX186 and jumper four is located below it. When the jumpers are shorted with a shorting block, the corresponding sensor is connected to the MAX186 through a specific ADC channel. When shorted, no external sensor can be attached to that particular ADC channel. When the shorting block is removed, that particular ADC channel can accept external sensors. The table below is a list of jumpers, sensors, and ADC channels for the four jumpers.

Jumper	Sensor	ADC
1	Main V	3
2	Aux V	2
3	Servo V	1
4	Temperature	4

GPS Port
Data Type: Digital
Data Direction: Input and Output

The BS2p receives GPS sentences through the GPS Port. In most cases the CC/PS is programmed only to read GPS sentences in order to determine the altitude at which experiments are performed. However some GPS receivers have the capability to act on commands sent to them. The Block One CC/PS is designed to allow the BS2p to send commands to a GPS receiver.

TNC Port
Data Type: Digital

Data Direction: Input and Output

The BS2p may need to send telemetry to ground stations. Ground stations may find it necessary to send commands to the CC/PS through packet radio. Depending on the TNC and how it is wired into the Block One CC/PS, the TNC Port may allow two-way digital communications between ground stations and the near spacecraft.

2.1.2. Devices Onboard and Interfaced to the CC/PS

BS2p (Programmable Microcontroller)
The CC/PS is built on a double-sided printed circuit board measuring four inches by six inches. At the heart of the CC/PS is a Parallax BS2p. The BS2p has 32 bytes of RAM and 16k bytes of EEPROM. In addition, there are 128 bytes of Scratch Pad RAM (SPRAM).   One step in configuring an near spacecraft for a mission is programming the BS2p onboard the CC/PS with the necessary flight code.

Serial Servo Controller 2 (SSC II)
The SSC II positions up to eight servos in accordance to commands from the BS2p. The servos require their own battery in the near spacecraft. The use of a separate servo battery prevents a bad servo from discharging the main battery and shutting down the CC/PS.

The BS2p sends commands to the SSC II at 2400 baud, N81. The commands specify which servo is to be placed to which position. Serial commands to the SSC II begin with a start byte 255h, followed with a servo number (1 to 8), then followed with a position byte. Some servos are capable of rotating 180 degrees while others can rotate only 90 degrees. With 255 available positions, servos can be positioned with a precision of less than one degree. After the command to position a servo is received, the SSC II maintains the servo's position without further instruction. Power to operate servos is provided by the servo battery (Servo V).

ULN2803 (Darlington Pair Transistor Switch)
The BS2p places input pins of the ULN2803 high, activating outputs. The ULN2803 is an eight pair Darlington transistor IC. A Darlington pair consists of two transistors. Energizing the base of the first transistor lets current flow into the base of the second transistor, increasing the gain of the transistor pair. Darlington pair transistors allow the BS2p to source voltages and currents in excess of the BS2p's limit of 5 Volts at 20 mA. Auxiliary Power provides voltage and current for the ULN2803. By using a separate battery for Aux V, problems with devices using it cannot drain the main battery (Main V), thus preserving flight functions in case of in-flight accidents.

MAX186 Analog to Digital Converter (ADC)
The MAX186 is the primary analog to digital converter for the CC/PS. The MAX186 digitizes eight analog inputs whose voltages do not exceed 4.096 Volts. The resolution of the MAX186 is 12 bits, yielding a precision of one millivolt. Results of the A to D conversion are either relayed to ground stations or used by the BS2p.

The MAX186 is a SPI serial device. To begin a conversion, its chip enable pin is brought low. Then the commands for which channel the MAX186 is to digitize is shifted out by the BS2p (the commands for the MAX186 are stored in a lookup table). Afterwards the results of the conversion (twelve bits) are shifted back to the BS2p

The BS2p communicates with the MAX186 via SPI, a synchronous serial protocol using either two or three wires for communication and one wire to activate the IC. The first wire sends the clock signal, which synchronizes the flow of data. The last two are data in and data out, although in the CC/PS the two data wires are shared. To begin a communication session to digitize a voltage and return the results to the BS2p, the BS2p first asserts the CE pin of the MAX186 high. Now the MAX186 is ready to receive serial data from the BS2p. Commands are sent to the DI pin of the MAX186 over the DATA_IO pin of the BS2p and clocked by the CLK pin of the BS2p. Every pulse of serial data to the MAX186 is "signaled" by the clock pulse. Eight clock pulses are required to instruct the MAX186 as to which pin to digitize. There are other options available with the MAX186, but they are not used with the CC/PS. The BS2p then clocks twelve more times, reading bits from the MAX186. The result is 12 bits, or 1.5 bytes, long. A one-word variable is required to store the result of the conversion.

2.1.3. Function of Each Component

The function of each discrete component on the CC/PS is listed in the table below.

Component	Function
R1 & R2	Voltage divider for Servo Voltage for the ADC
R3 & R4	Voltage divider for Auxiliary Voltage for the ADC
R5 & R6	Voltage divider for Main Voltage for the ADC
R7	Current limiting resistor for LED
R8	Pull-down resistor for BS2p reset
R9	Current limiting resistor for reset transistor (Q1)
R10	Current limiting resistor for ADC data-out
R11	Current limiting resistor for temperature sensor (D2)
C1	Filtering capacitor for voltage regulator (U1)
C2	Filtering capacitor for voltage regulator (U1)
C3	Filtering capacitor for ADC Port
C4 – C9	Filtering capacitors for ADC
D1	Power ON indicator of CC/PS
D2	Temperature sensor
U1	Low dropout voltage regulator
Q1	Switch to force BS2p reset

2.2.   Construction of the Block One CC/PS
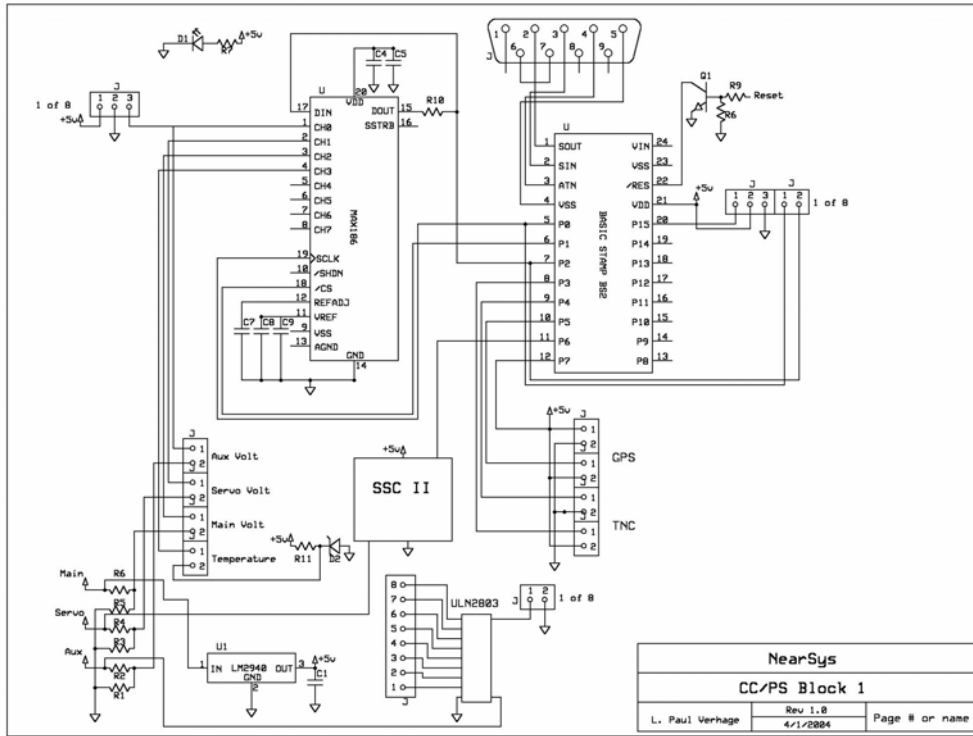
Schematic of CC/PS Block 1

First inspect the CC/PS PCB for shorted or broken traces. Then collect the following components listed in the table below.

2.2.1. Components

Part	Value	Quantity
Resistor	1k	3
Resistor	10k	6
Resistor	15k	1
Resistor	22k	1
Capacitor	0.01 uF	1
Capacitor	0.1 uF	5
Capacitor, Tantalum	4.7 uF	2
Capacitor, electrolytic	22 uF	1
Temperature sensor	LM335	1
Voltage Regulator	LM2940T-5	1
Darlington Pair IC	ULN2803	1
Transistor	2N3904	1
ADC	MAX186	1

Miscellaneous Parts

Part	Value	Quantity	Supplier	Part Number
DIP Socket	18 pins, 0.3" wide	1		
DIP Socket	20 pins 0.3" wide	1		
DIP Socket	24 pins 0.6" wide	1		
.025" female receptacles (0.1" between centers)	8 pin double row headers	4	Jameco	70720
.025" female receptacles	8 pin single row headers	3		70754
.025" male headers	8 pin double row pins	1	Jameco	160881 117196
Shorting Block		4		

2.2.2. Daughter Boards

Apart from the components, the following completed daughter boards are needed to complete the CC/PS.

| Part	Quantity
BASIC Stamp 2	1
SSC II	1

2.2.3. CC/PS Cables

Eight cables interface power and data to and from the CC/PS. The next table lists components required to make these cables.

Part	Value	Quantity	Supplier
Powerpole® Connectors[A]		3 pairs	Hobby and electronic shops
Mini Toggle Switch	SPST or SPDT	3	Jameco #26315
D-Subminiature Connector	9-Position female	1	
D-Subminiature Connector	9-Position male	1	
D-Subminiature Connector	25-Position male	1	
#24 AWG Stranded Wire	Assorted colors		
Heat Shrink Tubing	Assorted diameters		
Nylon wire ties			

2.3.   Sequence of Construction

Refer to the following diagram when placing components on the PCB.
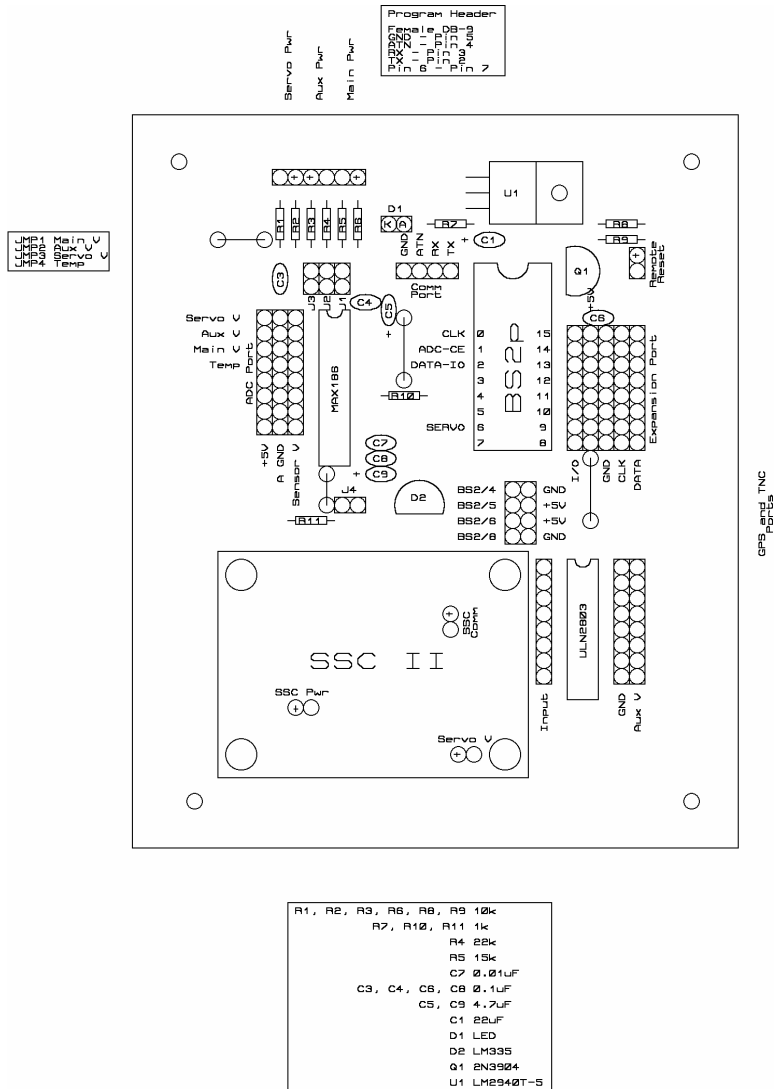
Component Placement – *Parts Placement for Block One CC/PS*

2.3.1. Jumpers

First solder the jumper wires. Jumper wires make electrical connections across copper traces without causing shorts. There are four jumper wires on the Block One CC/PS. To make a jumper wire, first cut a solid #22 or #24 AWG wire to ½" longer than the length of the jump. Strip ¼" of insulation from both ends, and then bend the ends at right angles to the wire. After soldering the wire into the via hole, snip the protruding ends of the via lead. An alternative is to use zero ohm resistors in place of jumper wires. Do not use bare wires (like cut resistor leads) to form the jumpers. Using insulated wire instead prevents dropped objects from shorting out the CC/PS, another one of those events that occurs at 100,000 feet rather than on the ground.

2.3.2. SSC II

The SSC II on the CC/PS is a daughter board that offloads some of the work from the BS2p. In this case, it is control of the servos that the SSC II takes care of, at the command of the BS2p. Four connections are needed to connect the SSC II to the CC/PS, one mechanical and three pairs of

electrical. One electrical pair is the servo battery connector and is already soldered to the SSC II. The second electrical pair is power for the SSC II. It arrives attached to the SSC II with a nine-volt battery snap at the end. The remaining pair needs to be added.

• Communication Connection
 √ Cut two 2" lengths of #24 AWG wire, one red and the other black or green.
 √ Strip ¼" of insulation from both ends of all the wires and set aside for a few minutes.
 √ Modify the SSC II by removing the RJ-11 phone jack from the board:
 √ Cut the plastic tabs holding the RJ-11 jack to the PCB.
 √ With a solder sucker and soldering iron, remove the four solder joints of the RJ-11.
 √ Carefully lift the RJ-11 as you continue to heat its solder pads.
 √ Discard the RJ-11 jack.

Beneath the former location of the RJ-11 jack you'll notice four solder pads aligned in two diagonal pairs. Two of the solder pads are connected to each other with a thin copper trace. These two pads are ground connections. The remaining two solder pads are the signal connections.

 √ Solder a wire into one of the signal solder pads.
 √ Solder the second wire into the ground solder pads.

• SSC II Power Connection
Before you begin, note which SSC II solder pad has the ground wire (black wire) of the nine-volt battery snap.

 √ Remove the red wire of the nine-volt battery snap from the SSC II with a soldering iron.
 √ Located a solder pad marked +5V.
 √ Solder the red wire to this solder pad.
 √ Cut off the nine-volt battery snap, making the wire lengths about 2" long.

• Servo Battery Power
Two wires provide voltage for servos and are located at the bottom of the SSC II. Cut these wires to a length of two inches.

After modifying the SSC II (and voiding its warranty), strip ¼" of insulation from the ends of the wires. Some wires can be passed through the holes remaining from the RJ-11 jack; however, it's not necessary to do this. Note carefully which CC/PS pads are for which electrical connection. Solder the wires to their appropriate pads in the PCB.

• Mechanical Connection
A three-millimeter thick sheet of foamed neoprene rubber is the easiest way to mount the SSC II to the CC/PS. The foam is available at craft and hobby shops and is sold under the name Foamies®. [B]They come in a variety of colors, so I suppose you can color coordinate your CC/PS. Cut the foam sheet to size then cut holes in it for the SSC II crystal and mounting holes.

Foamies® – *Foam neoprene.*

Fold the SSC II wires and place the neoprene sheet under the SSC II. Use 2-56 hardware to bolt the SSC II to the CC/PS PCB. Bolt lengths of 3/8" suffice, but I have only found ½" long bolts. I haven't needed washers, as the nuts are sufficiently large.

2.3.3. Sockets

The CC/PS has three sockets for ICs. Insert the sockets into the CC/PS as indicated on the CC/PS diagram. This means the notches of all three sockets are oriented towards the top of the PCB. Electrically it doesn't matter if the socket is placed upside down or right side up, but by correctly orienting the sockets, it's easier to properly orient their ICs, which must be placed in the correct orientation. To solder IC sockets, use this procedure: First solder the IC sockets only at two diagonally opposite pins. Press on the socket with your finger and then reheat each diagonal pin with the soldering iron. The IC socket will snap down on the PCB if it's not properly seated. Now finish soldering the socket by soldering its remaining pins.

2.3.4. Expansion Ports

The expansion ports occur in rows eight receptacles wide. The female receptacles needed are five double rows of headers eight pins long. Three single sided rows of headers eight pins long are required to build the ports. To save money, purchase longer receptacles and cut them to length.

√ Cut the receptacles to length using a sharp Exacto knife.
√ Insert all the receptacles of an entire port before soldering any of them.
√ Press the receptacle bases down firmly to the PCB.
√ Ensure the receptacles are snug to the CC/PS board and vertical to the PCB and parallel to their neighbors.
√ Solder the receptacles. Note: If the receptacles are loose, hold them down to the CC/PS with a piece of masking tape before flipping the CC/PS over on its back.
√ After soldering the receptacles, make sure no solder bridges were formed.

2.3.5. Discrete Components

Place components into the CC/PS PCB according to Diagram 2-1. The most important items are the electrolytic capacitors. If you put them in backwards, the CC/PS will probably let you know by

exploding the caps. There are three electrolytic capacitors: C2, C5, and C9. Watch the polarity markings on the caps and the CC/PS diagram.
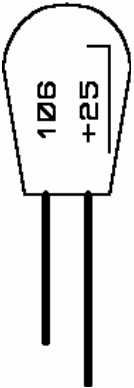
Tantalum Capacitor *– The positive lead is the one indicated – not the negative, as in an aluminum electrolytic capacitor.*

Bend resistors to a length of 0.4 inches with a lead bender, available at Radio Shack. Q1 and D2 are in identical looking TO-92 form factors. Read their faces carefully before installing them into the CC/PS. The CC/PS diagram shows their proper orientation. After soldering each component, clip the excess leads.

Lead Bender *– This tool allows component leads to be bent to the perfect length and angle.*

Component Checklist
- R1   10k
- R2   10k
- R3   10k
- R4   22k
- R5   15k
- R6   10k
- R7   1k
- R8   10k
- R9   10k
- R10   1k

- R11   1k
- C1   0.1 uF
- C2   22 uF or greater tantalum
- C3   0.1 uF
- C4   0.1 uF
- C5   4.7 uF
- C6   0.1 uF
- C7   0.01 uF
- C8   0.1 uF
- C9   4.7 uF
- D1   LED
- D2   LM335
- U1   LM2940T-5
- Q1   2N3904

2.3.6. Power Cables

Three cables are needed to provide external power to the CC/PS -- the Main Power, Servo Power, and Auxiliary Power cables. Each cable is identically constructed.
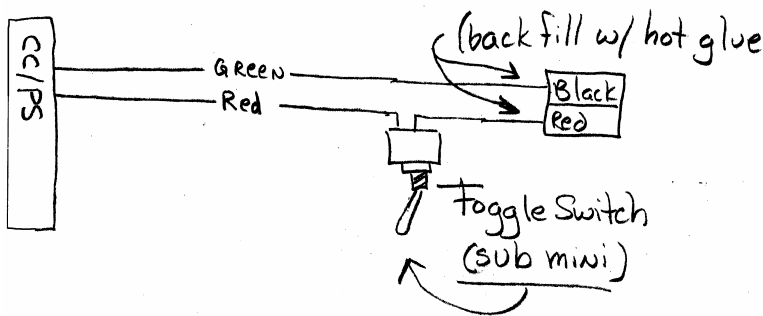
Power Cable – *The toggle switch is inline with the positive power lead (red wire).*
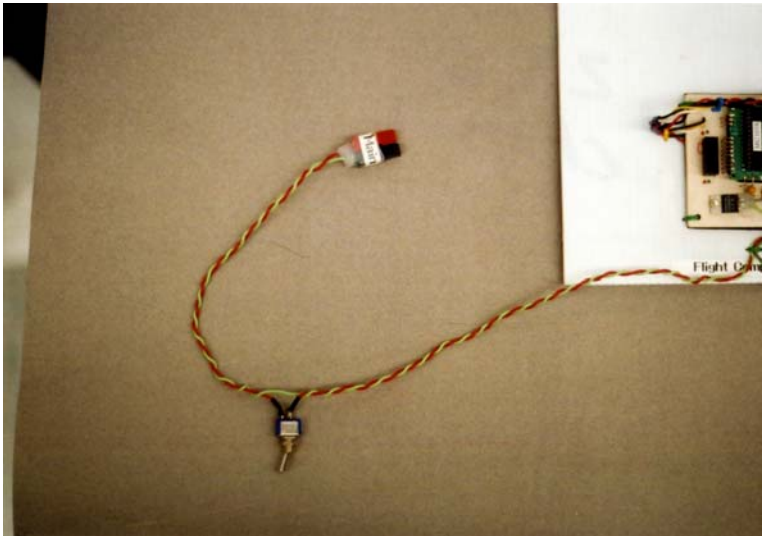
Completed Power Cable –*The toggle switch is in the positive line and Powerpole® connectors terminate the cable. The Powerpole® housings are backfilled with hot glue.*

√   Cut six red colored #24 AWG stranded wires to a length of at least 12 inches.
√   Cut three black colored #24 AWG stranded wires to a length of at least 24 inches.

√   Strip ¼" of insulation from one end of each black wire and three of the red wires. Note: this end solders to the PCB.
√   Strip one inch of insulation from the other ends of the wires. Note: This end solders to either a Powerpole® or toggle switch.
√   Solder the ¼" end of pairs of wires to the CC/PS pads marked Main Pwr, Aux Pwr, and Servo Pwr. Note: These pads are located at the top left of the CC/PS and be sure to solder the red wire to the pads marked "+".
√   Slide a short length (at least ½") of heat shrink tubing on the three red wires.
√   Twist the end of each red wire to the center terminal of the SPST or SPDT mini-toggle switches, one wire per toggle switch.
√   Solder the red wires to the toggle switches.
√   Twist one end of the remaining red wires to the outside terminal of the SPST or SPDT mini-toggle switches.
√   Solder the remaining red wires to the toggle switches.
√   Slide a short length of heat shrink tubing over the remaining red wires.
√   Cover both soldered terminals of each switch with heat shrink tubing and shrink.
√   Double over the ends of the remaining one inch stripped wires.
√   Crimp a Powerpole® terminal to the remaining ends of the red and black wires.
√   Solder the crimped terminal to the wire.
√   Slide the crimped terminal into a Powerpole® housing, being sure to match the color of the Powerpole® housings to its wire.
√   Slide the Powerpole® housings together into a unified connector. Note: There is more involved in this that it initially seems. A standard alignment must be determined so that any battery pack can attach to any power cable. Select a standard for the program, document it, and stick with it.
√   Twist pairs of the wires together to keep the power cables neat and under control.
√   Finish by back-filling the Powerpole® connector with hot glue.

2.3.7. Programming/Communication Cables

The BASIC Stamp uses a female DB-9 (D-subminiature) connector and the GPS requires a male DB-9 connector. The BS2p requires four wires connected to its DB-9 connector, and the GPS requires two wires connected to its DB-9 connector (other wires, like RX and 1 PPS are optional). Make the cables as follows:

√   Cut six stranded wires to a length of 12 inches. Note: Use different colors of wires to differentiate between them. Also, since each DB-9 needs a ground, there should be at least one black wire per DB-9.
√   Strip back ¼ inch of insulation at both ends of each wire.
√   Solder wires to the pins of the DB-9 connectors as listed below:
   o   The BS2p cable uses DB-9 (female) pins 2,3,4,5
   o   The GPS cable uses DB-9 (male) pins 2 and 5

Note: Since pin 5 on a DB-9 connector is ground, make this one a black colored wire.

√   Solder wires to the DB-9 connector pins as indicated above.
√   Slide short lengths of heat shrink tubing over the wires and cover the soldered pins.
√   Shrink the tubing down, covering the exposed solder.
√   On the BS2p DB-9 connector, short together pins 6 and 7 with a piece of resistor lead.
√   Use hot glue and cover all of the backs of the pins of the female DB-9 connectors.

√   Place the male GPS DB-9 connector into a plastic housing.

Note: If the GPS is to connect to a device (like the KPC-3+) that allows serial cables to screw to the port, then place locking screws into the DB-09 housing at this point. If the GPS is not to connect to such a device, then leave out the locking screws from the DB-9 housing.

Before closing the housing, cover the interior of the housing and the connector pins of the DB-9 with hot glue. Do this before the glue gets hot enough to melt the plastic housing.
Quickly close the housing and bolt it closed. Use more glue and seal the opened end in the back of the housing.

Connect the following pins of the BS2p programming connector to the CC/PS:
- GND to pin 5 of the BS2p DB-9
- ATN to pin 4 of the BS2p DB-9
- RX to pin 3 of the BS2p DB-9
- TX to pin 2 of the BS2p DB-9

Connect the following pins of the GPS connector to the CC/PS:
- GND to pin 5 of the GPS DB-9
- Signal to pin 2 of the GPS DB-9

Twist the programming and communication cables into three neat bundles.

DB-9 Connector – *Housing for GPS DB-9 connector. Interior volume is filled with hot glue.*

2.3.8. Power Indicator Cable
√   The two-wire cable of the LED power indicator solders to the CC/PS pads marked D1.
√   Cut the two lengths of stranded #24 AWG wire twelve inches long. Note: Use two different colors of wire, making the ground wire either black or green.
√   Strip ½ inch of insulation from one end of each wire and tin the ends.
√   Trim the leads of the LED to ½" and tin. Note: The ground wire connects to the LED lead closest to the flat spot on the LED case.
√   Press a wire and LED lead together and then heat them with a solder iron.
√   Remove the iron after the solder on both the LED lead and wire melts and flows together.

√   Do the same for the other LED lead and wire.
√   Slide one-inch lengths of heat shrink tubing over the wires, covering the exposed leads of the LED and shrink the tubing.
√   Slide a second piece of heat shrink tubing over the covered leads and shrink that down.
√   The wire soldered to the rounded side of the LED is soldered to the D1 pad marked with a +.
√   Solder the wire connected to the flat side of the LED (the black colored wire) to the other side of the D1 pad.
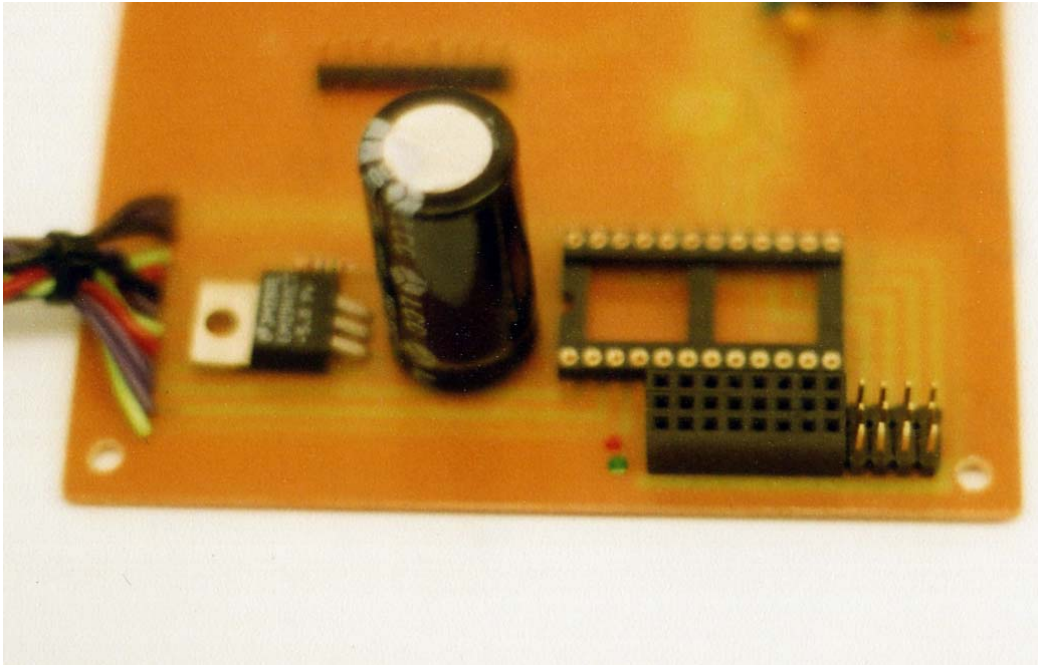
2.3.9. Labeling

Make sticky labels for the Powerpole® connectors, with each label indicating the function of the connector. Use a label maker like the Casio EZ-Label Printer to make professional looking labels. Label the connectors as Main, Servo, and Aux. Tape them around the Powerpole® connectors. Cover the labels with a short length of clear heat shrink tubing to make them more durable. One inch diameter clear heat shrink is large enough to cover the Powerpole® connectors.

Labeled Powerpole® – Cover the label with clear heat shrink (1″ diameter) to protect the label.

Using a toothpick, apply small dots of model paint to the CC/PS Expansion Ports. Place a small drop of red paint next to all the columns of pins with +5V, and a small dot of green paint next to all the columns of pins with Ground.

An alternative to painted dots is to use rub-on lettering or colored "sticky" dots. If you use rub-on lettering, cover the letters with a thin drop of clear paint applied with a toothpick.

Labeled Expansion Ports - Note the red and green dots.

3.0 The Block Two CC/PS
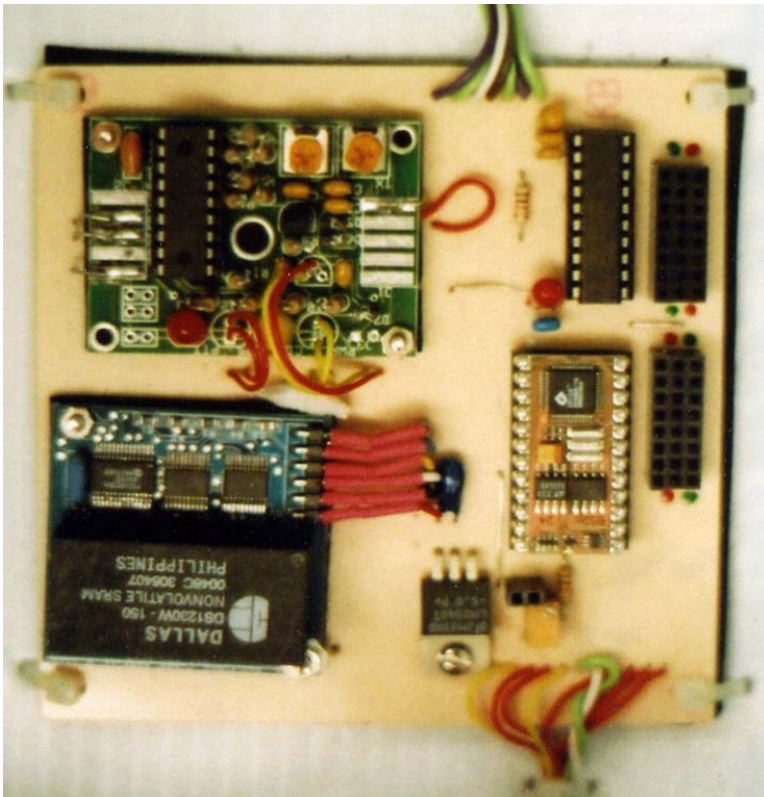
Block Two CC/PS – The completed Block Two flight computer.

The Block Two CC/PS should be considered experimental at this time since the author has only tested a variation of this flight computer on two flights before it was lost. Below is a simple block diagram of the Block Two CC/PS, showing components and their relationships.

Block Diagram – *Conceptual view of Block Two CC/PS*

In the Block Two CC/PS the BS2p controls the following devices onboard the CC/PS:

- MIM   Single Board TNC
- MAX186   Analog-to-Digital Converter
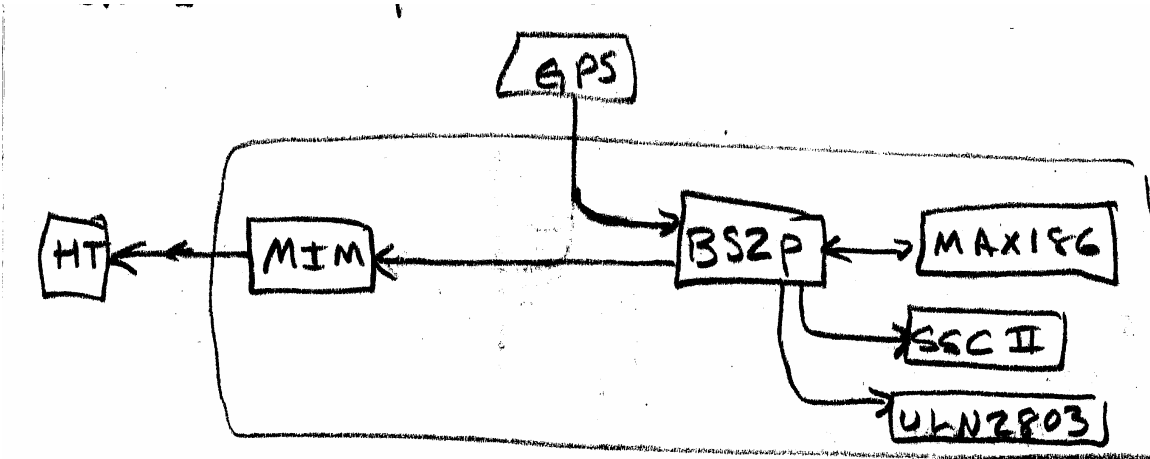- SSC II   Serial Servo Controller
- ULN2803   Darlington Pairs

The BS2p uses the MIM to generate telemetry to ground stations. The MAX186 digitizes voltages from sensors that output a voltage dependent on the condition they measure. Voltages from 0 to 4.096 Volts are digitized with a resolution of 1 mV. The MAX186 is also able to digitize the difference in voltages between two channels. The SSC II positions servo-controlled experiments with a precision of less than one degree. A total of eight servos are controllable during a mission. The ULN2803 is used to control devices requiring higher voltage and/or current levels that the BASIC Stamp can source. A source of additional voltage, the Aux Voltage, is recommended for these devices so they cannot discharge the main battery.

The Block Two CC/PS is larger than the Block One CC/PS because a TNC is mounted to the PCB; hence no external TNC is needed.

Operating the Block Two CC/PS requires the larger scratch pad RAM (SPRAM) of the BS2p microcontroller. Entire GPS sentences are read into SPRAM before going to the MIM.

3.1. Theory of Operation

The following topics are covered under Theory of Operation:

1. CC/PS Ports
2. Devices Internal to the CC/PS
3. External Devices Interfaced to the CC/PS
4. Function of Each Discrete Component on the CC/PS

3.1.1. CC/PS Ports

Ports provide a means to interface real world data to the BS2p. The seven ports can function as either input or output, and some can operate as both input and output. External devices can be connected to these ports for control instructions and/or data input. Two ports are fixed, and cannot be reconfigured.

BS2p Inputs
The following inputs are available to the BS2p on the CC/PS:

- Eight channels of ADC, each with twelve bits of resolution
- GPS sentences from a GPS receiver
- Eight I/O ports
- Main bus voltage
- Status Ports

MIM Inputs
The following inputs are available to the MIM Module on the CC/PS:

- Four channels of ADC, each with eight bits of resolution
- Eight channels of digital data
- Telemetry from the BS2p

BS2p Outputs
The following outputs are available to the BS2p on the CC/PS:

- Telemetry to the MIM Module
- Commands to the SSC II to position up to eight servos
- Eight channels of high power (up to 12 Volts at 1 amp) digital output
- Eight I/O ports

MIM Outputs
The following outputs are available to the MIM on the CC/PS:

- GPS Sentences
- Main, Servo, and Aux battery voltages
- CC/PS temperature
- Eight digital values
- CW ID

I/O Expansion Ports
The CC/PS contains eight expansion ports. Each port contains its own BS2p I/O pin, Clock line, Data line, +5 Volts, and ground. The expansion ports allow commands to be sent to serial devices using protocols such as, I^2C, SPI and 1-Wire. They also allow low power devices to be operated or

signaled, like electric switches on cameras. Each expansion port can also collect data from sensors like Geiger counters and light-to-frequency converters. With the combination of pins available at each I/O port, a single cable can power, command, and collect data from a sensor connected to the expansion port.

ULN2803 High Power Port
Data Type: Digital
Data Direction: Output

The BS2p drives high power loads (up to one amp at twelve Volts) through a ULN2803, Darlington pair IC. An additional battery is required onboard the near spacecraft as the source of auxiliary voltage.

There is a direct connection between BS2p I/O pins 8 through 15 and the inputs of the ULN2803. A command to activate a ULN2803 output also puts the corresponding BS2p pin high. If no auxiliary power is available onboard the near spacecraft, then this is not a problem. If auxiliary power is available onboard the near spacecraft, it is recommended that a BS2p I/O pin be used for only an expansion port or a high power driver on the ULN2803 but not both functions on the same mission.

SSC II Servo Port
Data Type: PWM Digital
Data Direction: Output

The SSC II allows the BS2p to position up to eight servos. The serial connection between the BS2p and SSC II is hard wired into the CC/PS PCB.

MIM Digital Ports
Input only, detects the digital status of eight inputs

ADC Analog Port
Data Type: Analog
Data Direction: Input

The ADC ports convert analog voltages into digital values upon command from the BS2p. Analog voltages are digitized with 12 bits of resolution and the maximum input voltage is 4.096 Volts. The analog ports are typically used to record the results of sensors, but can be configured to digitize near spacecraft voltages and temperature through the use of four jumpers.

MIM Analog Port
Input only, reports on three battery voltages and CC/PS board temperature. This is the first port that cannot be reconfigured.

Main Bus Voltage
This is the second BS2p I/O pin that cannot be reconfigured. A voltage divider on the CC/PS reduces the main bus voltage as input to the BS2p. This voltage divider lets the BS2p detect a low voltage condition on the main power bus as a logic low on the I/O pin.

3.1.2. Devices Onboard And Interfaced To The CC/PS

Parallax BS2p Microcontroller

The heart of the CC/PS is a Parallax BS2p-24 (BS2p for the rest of these directions). The BS2p has 32 bytes of RAM, 128 bytes of scratch pad RAM (SPRAM), and eight program slots, each with 2k bytes of EEPROM. A part of configuring an near spacecraft for a mission is programming the BS2p onboard the CC/PS with the necessary flight code.

MIM Module

The MIM Module is programmed to telemeter all serial data it receives from the BS2p. Telemetry to the MIM is sent at 4800 baud, N81. The MIM is also programmed to send four analog and eight digital values. Finally it is programmed to send a CW ID beacon as an aid to direction finding. The analog values telemetered are: Main Bus Voltage, Servo Bus Voltage, Auxiliary Bus Voltage, and CC/PS Temperature.

The MIM Module is built around a PIC microcontroller. It has the memory to store 65 characters of data. In the raw state, the MIM Module can telemeter five voltages, but as a part of the CC/PS, one of those voltages (A3) is used instead to force a transmission by bringing the A3 pin low (to ground).

There are two connections between the MIM and the BS2p. One connection is for the serial transmission of text data and the other connection is a command to transmit the data. The MIM is preprogrammed to record into RAM any text prefixed with the characters $GP and post-fixed with an *. This is the same format as NMEA standard GPS sentences. So, a direct connection between the GPS and the MIM results in the transmission of every GPS sentence from the GPS receiver (there is a limit to how fast the MIM can record data and transmit it). However, since the BS2p controls the text the MIM sees, the MIM does not transmit every sentence the GPS outputs. Telemetry sources for the MIM are GPS sentences and BS2p generated data.

To force the MIM transit, its A3 line (third analog to digital pin) must be grounded. To accomplish this, the A3 pad is connected to the collector of Q1 (a 2N3904 NPN transistor). The emitter of Q1 is connected to ground. The collector is connected to ground only when HIGHing the MIM_TX of the BS2p energizes the base of Q1. The last sentence loaded into the MIM's RAM is then transmitted as telemetry.

GPS sentences are first read into BS2p SPRAM. The GPS data is then sent one ASCII character at a time to the MIM for transmission. Since the MIM only has RAM space for 65 characters, only the first 65 characters of each sentence are sent to the MIM. After data is sent via serial to the MIM, the BS2p pulls its MIM_TX pin low. This forces the MIM to transmit its last received text.

BS2p generated text includes things like voltage levels and number of pulses from sensors. The BS2p can also be programmed to send telemetry concerning the occurrence of events.

Serial Servo Controller 2 (SSC II)

The SSC II positions up to eight servos in accordance to commands from the BS2p. The servos require their own battery in the near spacecraft.

The BS2p sends commands to the SSC II at 2400 baud, N81. The commands specify which servo is to be placed in which position. Position precisions below one degree are possible with the servos.

Commands to the SSC II are instructions to position a specific servo to a specified position. Serial commands to the SSC II begin with a start byte 255h, followed with a servo number (1 to 8), and followed with a position byte. Some servos are capable of rotating 180 degrees while others can rotate only 90 degrees. With 255 available positions, servos can be positioned with a precision of less

than one degree. After the command to position a servo is received, the SSC II maintains the servo's position without further instruction. Power to operate servos is provided by the servo battery (Servo V). By using a separate battery for the servos, a problem with the servos cannot discharge the flight battery and thereby terminate mission operations.

ULN2803 (Darlington Pair Transistor Switch)
The BS2p places input pins of the ULN2803 high, activating outputs. The ULN2803 is an eight Darlington pair transistor IC. A Darlington pair consists of two transistors. Energizing the base of the first transistor lets current flow into the base of the second transistor, increasing the gain of the transistor pair. Darlington pair transistors allow the BS2p to source voltages and currents in excess of the BS2p's limit of 5 Volts at 20 mA. Auxiliary Power provides voltage and current for the ULN2803. By using a separate battery for Aux V, problems with devices using it cannot drain the main battery (Main V), preserving flight functions.

MAX186 Analog to Digital Converter (ADC)
The MAX186 is the primary analog to digital converter for the CC/PS. The MAX186 digitizes eight analog inputs whose voltages do not exceed 4.096 Volts. The resolution of the MAX186 is 12 bits, yielding a precision of one millivolt. Results of the A to D conversion are either relayed to ground stations or used by the BS2p.

The MAX186 is a SPI serial device. To begin a conversion, its chip enable pin is brought low. Then the commands that indicate which channel the MAX186 is to digitize are shifted out by the BS2p (the commands for the MAX186 are stored in a lookup table). Afterwards the results of the conversion (twelve bits) are shifted back to the BS2p.

The BS2p communicates with the MAX186 via SPI, a serial protocol using either two or three wires for communication and one wire to activate the IC. The first wire sends the clock signal, controlling the flow of data. The last two are data in and data out, although in the CC/PS the two data wires are shared. To begin a communication session to digitize a voltage and return the results to the BS2p, the BS2p first asserts the CE pin of the MAX186 high. Now the MAX186 is ready to receive serial data from the BS2p. Commands are sent to the DI pin of the MAX186 over the DATA_IO pin of the BS2p and clocked by the CLK pin of the BS2p. Every pulse of serial data to the MAX186 is "signaled" by a clock pulse. It requires eight clock pulses to instruct the MAX186 which pin to digitize. There are other options available with the MAX186, but they are not used with the CC/PS. The BS2p then clocks twelve more times, reading bits from the MAX186. The result is 12 bits or 1.5 bytes long. A one-word variable is required to store the results of the conversion.

3.1.3. Function of Each Component

The following table lists the function of each discrete component on the CC/PS:

Component	Function
R1 & R2	Voltage divider for the Main Voltage for the MIM Module
R3	Current limiting resistor for the power indicator LED
R4	Current limiting resistor for ADC data-in pin
R5	Current limiting resistor for the base of Q1
R8	Voltage divider of Main Voltage for the BS2p
R9	Current limiting resistor for U1
R10 & R11	Voltage divider for the Auxiliary Voltage for the MIM Module
R12 & R13	Voltage divider for the Servo Voltage for the MIM Module
C1	Bypass capacitor for U2
C2 – C6	Filtering for MAX186 ADC
D1	Power ON indicator of CC/PS
U1	Temperature controlled zener (temperature sensor)
U2	Low dropout voltage regulator
Q1	Switch to force the MIM to transmit

3.2. Construction of the Block 2 CC/PS

Schematic of Block 2 CC/PS

First inspect the PCB for shorted or broken traces. Then collect the following components listed in the table below.

3.2.1. Components

Part	Value	Quantity
Resistor	0 Ohms	1
Resistor	1k	5
Resistor	10k	7
Resistor, Trimmer	10k	1
Capacitor	0.01 uF	1
Capacitor	0.1 uF	2
Capacitor, Tantalum	4.7 uF	2
Capacitor, electrolytic	22 uF	1
Temperature sensor	LM335	1
Voltage Regulator	LM2940T-5	1
Darlington Pair IC	ULN2803	1
Transistor	2N3904	1
ADC	MAX186	1

Miscellaneous Parts

Part	Value	Quantity
DIP Socket	18 pins, 0.3" wide	1
DIP Socket	20 pins 0.3" wide	1
DIP Socket	24 pins 0.6" wide	1
.025" male headers	double row headers	80 pins total
.025" male headers	single row headers	24 pins total
Female DB-9 solder connector		2
Male DB-9 solder connector		1
Shorting Block		1

Note:
The .025" male headers (0.1" between centers) are available at Jameco as part numbers 160881 and 117196. To make cables for devices connected to the expansion ports, use female crimp pins, non-polarized housings, and a pin crimper tool. They are available at Jameco as part numbers 100765, 103157, and 159265 respectively.

3.2.2. Daughter Boards

Apart from the components listed above, the following, completed, daughter boards are also a part of the CC/PS.

Part	Quantity
BASIC Stamp 2P	1
MIM Module	1
SSC II	1

3.2.3. CC/PS Cables

Eight cables interface power and data to and from the CC/PS. The table below lists the components required to make these cables.

Part	Value	Quantity
Capacitor	0.1 uF	1
Resistor	2.2k	1
Phono Jack	3.5 mm	1
Phono Jack	2.5 mm	1
DC Power Plug	4.0 X 1.7 mm	1
LED	Any color	1
Powerpole® connectors	3 pairs (red and black)	

Note:

The phono jacks are a part of a kit that allows you to solder wires to them. They are available at Radio Shack as part number 274-287A and 274-286A. The DC Power Plug is also available at Radio Shack as part number 274-1532.

3.3.   Sequence of Construction

Refer to the parts layout diagram below when placing components on the CC/PS PCB.

Parts Layout *– Block Two CC/PS*
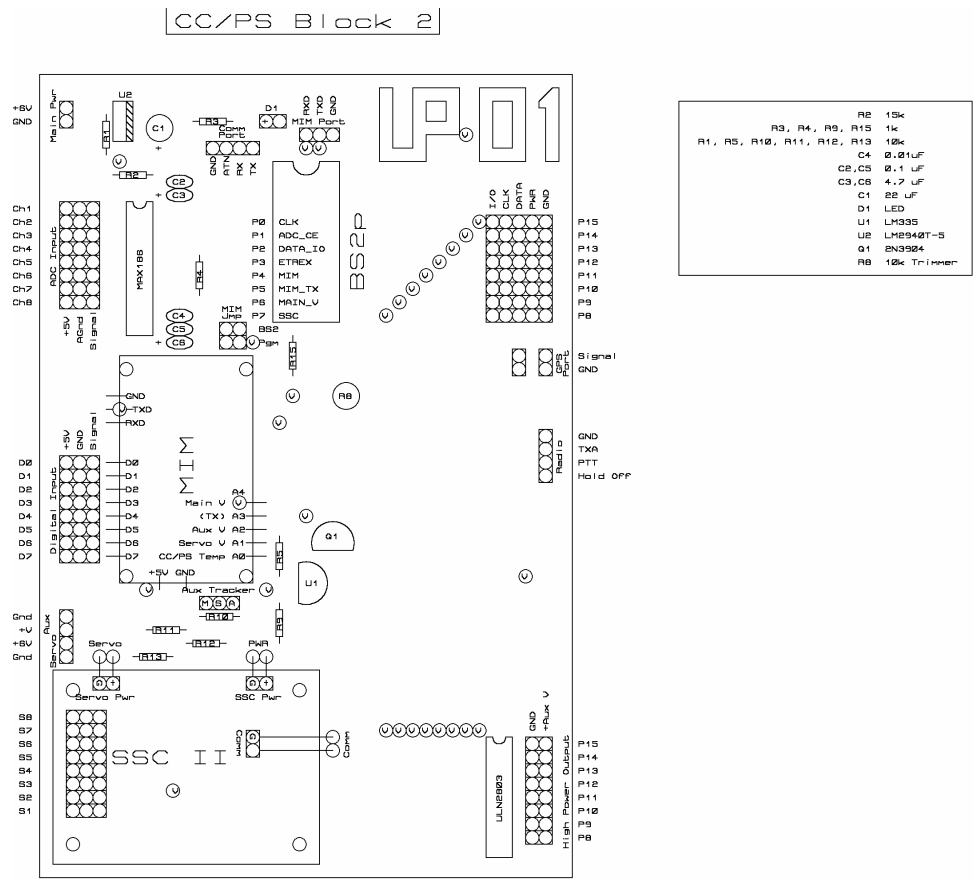
3.3.1. Vias

First solder the vias. Vias are wires that make electrical connections between copper on the top and copper on the bottom of the PCB. There are 30 vias in the CC/PS. Three of the vias unite ground planes on the top and bottom of the board. The remaining 27 vias electrically connect copper traces on the top of the CC/PS to copper traces on the bottom of the CC/PS. It is more convenient to use short lengths of resistor or capacitor leads to make the vias than to cut and strip short lengths of wire.

- √ Cut ¼" lengths from the resistors and capacitors.
- √ Stick a lead wire into a via hole, ensuring the lead protrudes from both sides of the PCB.
- √ Solder one end of the lead to the copper pad and make certain that the lead did not slip from the via hole.
- √ Flip the PCB over and solder the lead wire on the other side.
- √ After soldering the via wire, snip the protruding ends of the via lead.

3.3.2. Daughter Boards

The MIM Module and SSC II on the CC/PS are daughter boards that offload some of the work from the BS2p. Note that the MIM Module is mounted upside down in relation to the CC/PS. Either stand-offs, plastic frames, or foam pads mount the daughter boards to other PCBs. If you decide to use stand-offs, use short lengths of tubing and #2 hardware (i.e. 2-56 nuts, bolts, and washers) for the SSC II and #1 hardware for the MIM Module. Use plastic washers on the bottom of the PCB to prevent short circuits from the hardware. Thin polystyrene sheets make inexpensive washers. Use 0.010" thick polystyrene sheets, which are available from Evergreen and available at your hobby shop.

An alternative to stand-offs is to use polystyrene plastic to form a bed or platform beneath the daughter boards. If you decide to use polystyrene sheet, use two lengths of 3/8" square tubes for the MIM Module and a piece of 0.020" sheet for the SSC II. The square tubes make two rails for the MIM Module and the flat sheet makes an insulating bed for the SSC II. The MIM Module rails are 1.75" long and plastic bed has dimensions of 1.4" by 1.9". After cutting out the polystyrene, mark the placement of holes and drill them with a drill bit or Exacto knife. Test fit the plastic and the daughter boards before gluing the plastic to the PCB. Use model cement to glue polystyrene to the PCB. Then mount the daughter boards to their plastic bases with the #1 and #2 hardware (no tubes in this case). Don't forget to use plastic washers to protect the bottom of the PCB from the hardware. The square tubes and sheet are available at hobby shops. The tubes are number 90622 by Plastruct and the sheet is available as an assortment as item number 9008 by Evergreen.

The last alternative is to use stacked layers of neoprene foam beneath the daughter boards. Foamies® is the name of a brand of neoprene foam manufactured by Darice Inc. and is available at crafts stores.

3.3.3. MIM Module

- √ Cut 22 lengths of thin gauge solid (24 gauge or smaller) wire, each measuring ½ inches long.
- √ Strip 1/8 inch of insulation from both ends of all the wires.
- √ Bend each wire at the beginning of the insulation at one end to a right angle. Note: This creates 22 little "L" shaped wires.
- √ Leave the other end of the wire straight.
- √ Tin the bent end of the 22 wires. Note: An alternative is to use bare wires for the "L" shaped wires, but this does add a risk of loose washers shorting out the MIM during a mission.
- √ Carefully place a small bead of solder on each solder pad of the MIM.

√   One at a time, place a small wire into the MIM solder pads of the CC/PS, with the bent end of the wires resting on top of the MIM Module's solder pads.
√   Use a soldering iron to melt the solder on the pad and wire, connecting the pad to the wire.
√   Have fun completing the other 21 wires.
√   Flip the CC/PS on its back and solder the other ends of 22 wires to the CC/PS.

3.3.4. SSC II

The SSC II is connected to the CC/PS using three pairs of wires. One pair is the servo battery connector and is already soldered to the SSC II. The remaining two pairs need to be added.

√   Cut four pieces of a thin gauge wire (24 gauge or less), each one inch long. Note: The servo power wires in the SSC II will be reused, so you only need to prepare four additional wires.
√   Strip less than ¼" of insulation from both ends of all the wires.
√   Use these four wires are used in the next two steps.

Communication Connection
Modify the SSC II by removing the RJ-11 phone jack from the board. Beneath the former location of the jack you'll notice four solder pads aligned in two diagonal pairs. Two of the solder pads are connected to each other with a thin copper trace. These two pads are ground connections. The remaining two solder pads are the signal connections. Solder a wire into one of the signal solder pads and the second wire into the ground solder pads.

Power Connection
Note which solder pad of the SSC II has the ground wire (black wire) of the nine-volt battery snap.
√   Using a soldering iron, remove both wires of the nine-volt battery snap from the SSC II.
√   Solder one wire to the ground solder pad.
√   Solder one wire to the power solder pad.
Note: Do not solder a wire to the old solder pad of the nine-volt battery snap. Located closer to the center of the SSC II is a solder pad marked +5V. Connect the second wire to this solder pad.

Servo Battery Power
The two wires that provide voltage for servos are located at the bottom of the SSC II. Cut these wires to a length of one inch and strip less than ¼" of insulation from their ends.

Mount the SSC II to the CC/PS and solder its six wires into the CC/PS at the locations marked Servo, PWR, and Comm.

3.3.5. Sockets

The CC/PS has three sockets for ICs. Insert the sockets into the CC/PS as indicated on the CC/PS diagram. This means the notches of all three sockets are oriented towards the top of the PCB. Electrically it doesn't matter if the socket is placed upside down or right side up, but by correctly orienting the sockets, it's easier to properly orient their ICs, which must be placed in the correct orientation. Solder the IC sockets only by two diagonally opposite pins. Press on the socket with your finger and reheat each diagonal pin with the soldering iron. The IC socket will snap down on the CC/PS PCB if it's not properly seated. Now finish soldering the socket by soldering its remaining pins.

3.3.6. Expansion Ports

The expansion ports occur in rows eight receptacles wide. The female receptacles needed are five double rows of headers eight pins long. Three single sided rows of headers eight pins long are required to build the ports. To save money, purchase longer receptacles and cut them to length.

- √ Cut the receptacles to length using a sharp Exacto knife.
- √ Insert all the receptacles of an entire port before soldering any of them.
- √ Press the receptacle bases down firmly to the PCB.
- √ Ensure the receptacles are snug to the CC/PS board and vertical to the PCB and parallel
- √ to their neighbors.
- √ Solder the receptacles. Note: If the receptacles are loose, hold them down to the CC/PS with a piece of masking tape before flipping the CC/PS over on its back.
- √ After soldering the receptacles, make sure no solder bridges were formed.

3.3.7. Discrete Components

Place components into the CC/PS PCB according to Diagram 2-???. The most important items are the electrolytic capacitors. If you put them in backwards, the CC/PS will probably let you know by exploding the caps. There are three electrolytic capacitors, C1, C3, and C6. Watch the polarity markings on the caps and the CC/PS diagram.
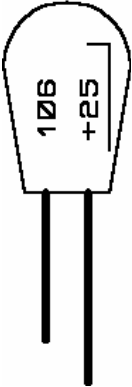
Tantalum Capacitor Markings –
The positive lead is the one
indicated – not the negative, as in
an aluminum electrolytic capacitor.

Bend resistors to a length of 0.4 inches with a lead bender, available at Radio Shack.

Lead Bender – Ensures perfect
*resistor leads every time.*

R7 has been replaced with a jumper wire, or a zero ohm resistor. After soldering R7, make sure its leads don't short out on the CC/PS board. Resistors R6 and R14 have been removed from the CC/PS design (they were not accidentally left out of the documentation). U1 and Q1 are in identical looking TO-92 form factors. Read their faces carefully before installing them into the CC/PS. The CC/PS diagram shows their proper orientation. After soldering each component, clip the excess leads.

Component Checklist
- R1   10k
- R2   10k
- R3   1k
- R4   1k
- R5   10k
- R7   0 ohm
- R8   10k trimmer potentiometer
- R9   1k
- R10   10k
- R12   10k
- R13   10k
- R15   1k
- C1   22 uF electrolytic
- C2   0.1 uF
- C3   4.7 uF electrolytic
- C4   0.01 uF
- C5   0.1 uF
- C6   4.7 uF electrolytic
- U1   LM335
- U2   LM2940T-5
- Q1   2N3904

3.3.8. Power Cables

Three cables provide external power to the CC/PS; they are the Main Power, Servo Power, and Auxiliary Power. The cables are identically constructed.
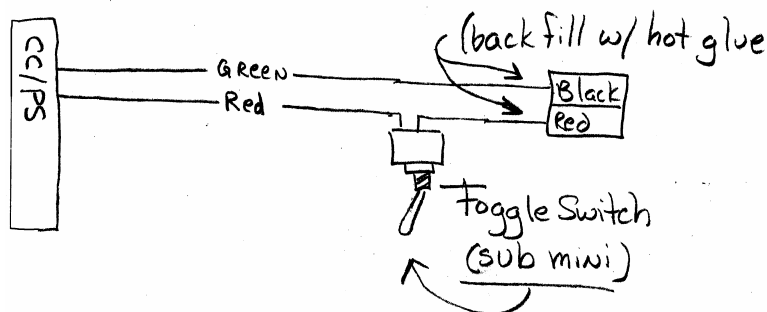
Power Cable – *The toggle switch is inline with the positive power lead (red wire).*

√   Cut six red colored #24 AWG stranded wires to a length of at least 12 inches.
√   Cut three black colored #24 AWG stranded wires to a length of at least 24 inches.
√   Strip ¼" of insulation from one end of each black wire and three of the red wires. Note: this end solders to the PCB.

√ Strip one inch of insulation from the other ends of the wires. Note: this end solders to either a Powerpole® or toggle switch.

√ Solder the ¼" end of pairs of wires to the CC/PS pads marked Main Pwr, Aux Pwr, and Servo Pwr. Note: These pads are located at the top left of the CC/PS and be sure to solder the red wire to the pads marked "+".

√ Slide a short length (at least ½") of heat shrink tubing on the three red wires.

√ Twist the end of each red wire to the center terminal of the SPST or SPDT mini-toggle switches, one wire per toggle switch.

√ Solder the red wires to the toggle switches.

√ Twist one end of the remaining red wires to the outside terminal of the SPST or SPDT mini-toggle switches.

√ Solder the remaining red wires to the toggle switches.

√ Slide a short length of heat shrink tubing over the remaining red wires.

√ Cover both soldered terminals of each switch with heat shrink tubing and shrink it.

√ Double over the ends of the remaining one inch stripped wires.

√ Crimp a Powerpole® terminal to the remaining ends of the red and black wires.

√ Solder the crimped terminal to the wire.

√ Slide the crimped terminal into a Powerpole® housing, being sure to match the color of the Powerpole® housings to its wire.

√ Slide the Powerpole® housings together into a unified connector. Note: There is more involved in this that it initially seems. A standard alignment must be determined so that any battery pack can attach to any power cable. Select a standard for the program, document it, and stick with it.

√ Twist pairs of the wires together to keep the power cables neat and under control.

√ Finish by back-filling the Powerpole®s with hot glue.

3.3.9. Programming/Communication Cables

The BASIC Stamp (and MIM) uses a female DB-9 (D-subminiature) connector and the GPS requires a male DB-9 connector. The BS2p requires four wires connected to its DB-9 connector (the MIM uses three of them) and the GPS requires two wires connected to its DB-9 connector (other wires, like RX and 1 PPS are optional). Make the cables as follows:

√ Cut six stranded wires to a length of 12 inches. Note: Use different colors of wires to differentiate between them. Since each DB-9 needs a ground, there should be at least one black wire per DB-9.

√ Strip back ¼ inch of insulation at both ends of each wire.

√ Solder wires to the pins of the DB-9 connectors as listed below:

• The BS2p cable uses DB-9 (female) pins 2,3,4,5
• The GPS cable uses DB-9 (male) pins 2 and 5

Note: Since pin 5 on a DB-9 connector is ground, make this one a black colored wire.

√ Solder wires to the DB-9 connector pins as indicated in the list above.

√ Slide short lengths of heat shrink tubing over the wires and cover the soldered pins.

√ Shrink the tubing down, covering the exposed solder.

√ On the BS2p DB-9 connector, short together pins 6 and 7 with a piece of resistor lead.

√ Use hot glue and cover all of the backs of the pins of the female DB-9 connectors.

√   Place the male GPS DB-9 connector into a plastic housing.

Note: If the GPS is to connect to a device (like the Kantronics KPC-3+) that allows serial cables to screw to the port, then place locking screws into the DB-9 housing at this point. If the GPS is not to connect to such a device, then leave out the locking screws from the DB-9 housing.

Before closing the housing, cover the interior of the housing and the connector pins of the DB-9 with hot glue. Do this before the glue gets hot enough to melt the plastic housing.
Quickly close the housing and bolt it closed.
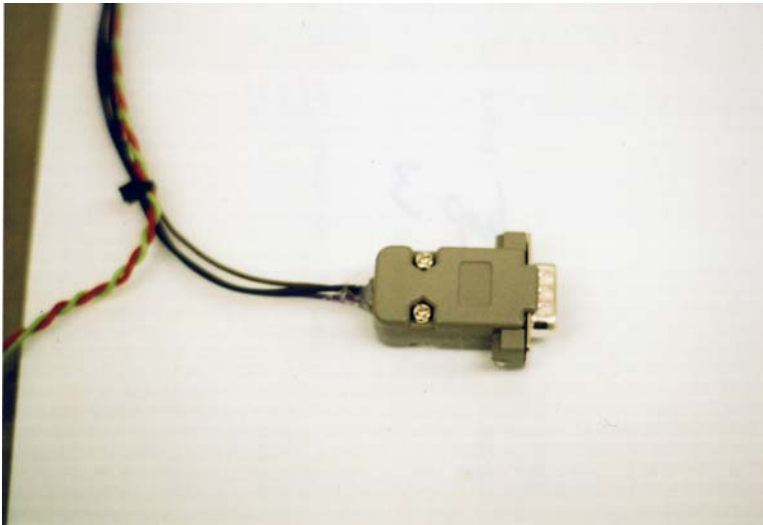Use more glue and seal the opened end in the back of the housing.

Connect the following pins of the BS2p programming connector to the CC/PS:
- GND to pin 5 of the BS2p DB-9
- ATN to pin 4 of the BS2p DB-9
- RX to pin 3 of the BS2p DB-9
- TX to pin 2 of the BS2p DB-9

Connect the following pins of the GPS connector to the CC/PS:
- GND to pin 5 of the GPS DB-9
- Signal to pin 2 of the GPS DB-9

Twist the programming and communication cables into three neat bundles.

DB-9 Connector *– Housing for GPS DB-9 connector. Interior volume is filled with hot glue.*

Note: The MIM JMP determines if the MIM is using its comm port for programming or to receive telemetry from the BS2p.

3.3.10.   HT Cable

Three wires make up the cable that connects the MIC and SPK of the Alinco DJ-S11 to the MIM Module on the CC/PS. There is a provision for a fourth connection, the Hold Off, which is not recommended. An optional second cable provides external power and switching to the HT.

MIC and SPK

√   Cut three lengths of wire twelve inches long.
√   Strip back ¼ inch of insulation from one end of all three cables.
√   Solder them into the pads labeled Radio on the CC/PS.
√   Solder to the pads marked GND, TXA, and PTT.

The HT cable has the following connections:
- GND to Base of 1/8" phono jack
- TXA to 0.1 uF capacitor to Tip of 3/16" phono jack
- PTT to 2.2k resistor to Tip of 3/16" phono jack
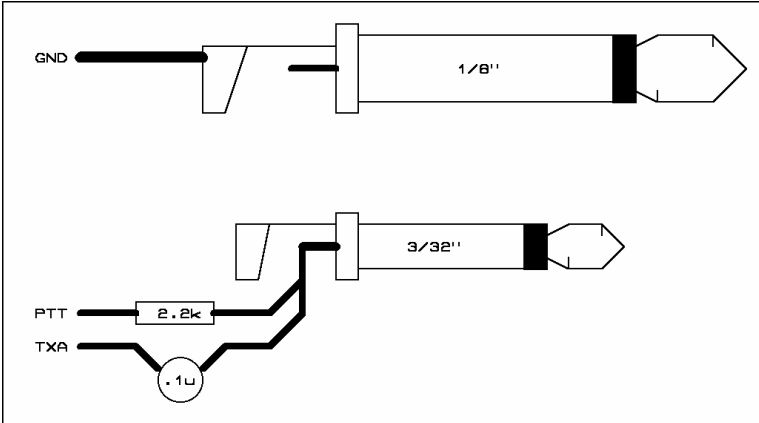
HT Cables – Close-up view of phono jacks.

√   Remove one inch of insulation from the other end of the GND wire.
√   Solder it into the Base of the 1/8" or 3.5mm phono jack.
√   Solder one lead of the capacitor and resistor on the Tip connection of the 3/16" or 2.5mm phono jack. Note: Both the resistor and capacitor are terminating at the same point of the 2.5mm jack, at its tip.
√   Slide a piece of two-inch long heat shrink tubing over the TXA and PTT wires.
√   Remove one inch of insulation from the free ends of the TXA and PTT wires.
√   Twist and solder the TXA wire to the free lead of the capacitor and the PTT wire to the open lead of the resistor.
√   Cover the exposed solder joint with the heat shrink tubing.

HT External Power
√   Cut two wires, both 24" long (use one red and one black colored wire).
√   Remove ½" of insulation from one end of both wires.
√   Solder the red wire to the center connector of DC power plug, a Coax-style DC power plug, 4.0 mm X 1.7mm (with solder tabs).
√   Solder the black wire to the ring of the connector.
√   Slide a length of heat shrink tubing over the positive wire, covering the soldered connection.
√   Squirt a drop of hot glue between the soldered connections.
√   Screw on the plastic cap and fill the interior space with a little bit of hot glue.
√   Strip 1" of insulation for the other ends of the wires.
√   Double over the exposed wire.
√   Crimp Powerpole® connectors on the wires.
√   Slide the crimps into their jackets, using the proper colored housings to indicate positive and ground.
√   Slide the Powerpole® jackets together.
√   Wrap the jackets with a label marked HT.

√   Cover the jacket and label with clear heat shrink.
√   Cut the red wire about two-thirds of the distance away from the coax power plug.
√   Strip ¼" of insulation from the ends of the wires.
√   Slide heat shrink tubing over the wires.
√   Solder the wires to the pins of a toggle switch.
√   Cover the soldered connection with heat shrink tubing.

HT Jack Housing
√   Plug the MIC and SPK jacks into the DJ-S11.
√   Plug the power connector into the DJ-S11.

Note: Do not make the external power connection a part of the jack housing. The power plug is installed only to indicate the jack housing dimensions. When the power connection is made a part of the jack housing, then the HT can never be run from internal batteries.

√   Squirt a little hot glue between the jacks, without getting any on the HT.
√   Put a thin coat of hot glue on one piece of polystyrene.
√   Press the first sheet of polystyrene onto one face of the glued connectors.
√   Put a thin coat of hot glue on the second piece of polystyrene.
√   Flip the HT over to its other side and press the second rectangle of plastic onto the combined connectors.
√   When the glue in the DJ-S11 plug has cooled, remove the plug from the HT.
√   Fill the voids in the HT plug with the warm hot glue.
√   Let the unified connector cool.
√   Trim the edges of the HT plug with a sharp Exacto knife.
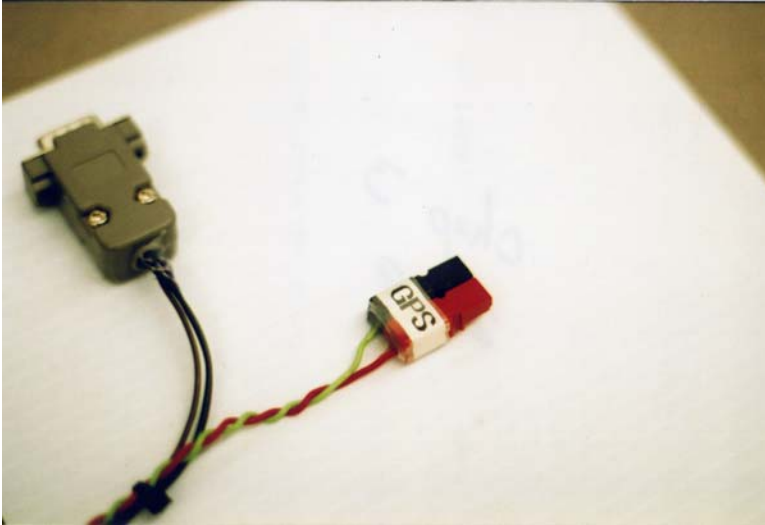√   Finish the housing by covering it with heat shrink tubing.

3.3.11. Power Indicator Cable

The two-wire cable of the LED power indicator solders to the CC/PS pads marked D1.
√   Cut the two lengths of stranded #24 AWG wire twelve inches long. Note: Use two different colors of wire, making the ground wire either black or green.
√   Strip ½ inch of insulation from one end of each wire and tin the ends.
√   Trim the leads of the LED to ½" and tin.
√   Note: The ground wire connects to the LED lead closest to the flat spot on the LED case
√   Press a wire and LED lead together and then heat them with a solder iron.
√   Remove the iron after the solder on both the LED lead and wire melts and flows together
√   Do the same for the other LED lead and wire.
√   Slide one-inch lengths of heat shrink tubing over the wires, covering the exposed leads of
√   the LED and shrink the tubing.
√   Slide a second piece of heat shrink tubing over the covered leads and shrink that down.
√   The wire soldered to the rounded side of the LED is soldered to the D1 pad marked with
√   a +.
√   Solder the wire connected to the flat side of the LED (the black colored wire) to the other side of the D1 pad.

3.3.12.   Labeling

Make sticky labels for the Powerpole® connectors, with each label indicating the function of the connector. Use a label maker like the Casio EZ-Label Printer to make professional looking labels. Label the connectors as Main, Servo, and Aux. Tape them around the Powerpole® connectors. Cover the labels with a short length of clear heat shrink tubing to make them more durable. One inch diameter clear heat shrink is large enough to cover the Powerpole® connectors.

Labeled Powerpole® – Cover the label with clear heat shrink (1″ diameter) to protect the label.

Using a toothpick, apply small dots of model paint to the CC/PS Expansion Ports. Place a small drop of red paint next to all the columns of pins with +5V, and a small dot of green paint next to all the columns of pins with Ground.

An alternative to painted dots is to use rub-on lettering or colored "sticky" dots. If you use rub-on lettering, cover the letters with a thin drop of clear paint applied with a toothpick.

4.0 Testing and Adjusting the NearSys CC/PS

DO NOT apply power to the CC/PS at this time. Place the CC/PS on a non-metallic surface to prevent short circuits when power is finally applied. You'll need a digital multimeter (DMM) to complete testing. Each test indicates whether it is for the Block One or Block Two CC/PS, or for both. The tests are for opens and shorts, polarity, setting voltage warning, voltage calibration, MIM ADC voltages, MAX186 voltages, SSC II control, ULN2803 control, and GPS.

4.1.   Short and Open Circuits

Set the DMM to test continuity and check that the meter operates properly. When you touch the DMM's leads together, the DMM will ring. If not, verify that the DMM is set properly. If it still does not ring, then use a different DMM. When it's time to test pins in IC sockets, push small wires into socket openings. This is not necessary if your test probes have very fine tips. There are ten tests of short and open circuits.

4.1.1. Test One (both)

Connect one test lead of the DMM to the +5V Powerpole® connector. Tap around the ground plane of the CC/PS with the other test lead. There should be no ringing. If there is, you have a short between power and ground that will quickly discharge the battery, possibly causing a fire.

4.1.2. Test Two (both)

Connect one test lead to ground on the expansion port. Use the other lead to tap around the CC/PS on the ground plane and other ground pins. There should be ringing on every tap.

4.1.3. Test Three (both)

Connect one test lead to a CLOCK pin on the expansion port. Use the other lead to connect to the DATA pin on the expansion port. There should be no ringing.

4.1.4. Test Four (both)

Test between pins on the DB-9 connectors. There should be no shorts anywhere. Then test between pin 5 on the DB-9 connectors and the CC/PS ground plane. There should be a ringing on this test.

4.1.5. Test Five (both)

Connect a test lead to the I/O pin in the first expansion port. Use the other lead to press into the BS2p socket. There should be a ringing for each pin that is across from the BS2p pin. There should be no ringing for all other pins. Also check between the input pins on the ULN2803 and BS2p socket. There should be ringing for the connected pins (e.g. BS2p pin 13 and ULN2803 pin 10) but not for other combinations of pins.

4.1.6. Test Six (both)

Connect a test lead to either a DATA or CLOCK pin in the expansion ports. Connect the other test lead to the proper BS2p socket pin (labeled in the CC/PS diagram). There should be a ringing. Test the other pin when done with the first.

4.1.7. Test Seven (both)

Connect a test lead to the power side of the Servo Power connector. Touch the other lead to the middle rows of pins in the servo connectors. There should be a ringing. Tap the second test lead to the bottom row of pins in the servo connectors (ground), there should be no ringing. Switch the first test lead to the ground connector in the servo power connector. There should be a ringing. Afterwards, test that there is continuity between the ground of the power connector and the CC/PS ground plane.

4.1.8. Test Eight (both)

Connect a test lead to the positive side of the Auxiliary Power connector. Check that there is no continuity between the positive power and the ground plane of the CC/PS. Leave the first test lead on the positive Aux Power connector and tap the second lead to ULN2803 pin number 10. There should

be a ringing. Next tap the bottom left pin (#9) of the ULN2803 and the ground plane of the CC/PS. You should find continuity.

4.1.9. Test Nine (Block Two only)

Connect a test lead to the GND wire at the bottom of the MIM Module. This pad is located at the top of the MIM (remember, the MIM is upside down) and labeled as GND. Check that there is continuity with the ground plane of the CC/PS. Now connect a test lead to the +5V wire at the bottom of the MIM Module. Check that there is continuity with the +5V row of pins in an expansion port. Verify there is no continuity between the +5V wire of the MIM Module and the ground plane of the CC/PS.

4.1.10.   Test Ten (both)

Press one test lead against the base of the +5V wire on the SSC II. There will only be a little bit of exposed wire, so use fine tip probe leads. Confirm continuity between the +5V wire of the SSC II and the +5V row of pins in the expansion port. Verify that there is no continuity with the +5V wire and the ground plane of the SSC II. Now press a test lead into the base of the GND wire of the SSC II and confirm continuity with the ground plane of the CC/PS.

4.2.   Proper Voltage and Polarity

At this time, no ICs are to be plugged into their sockets. Make sure the main power switch is turned off before plugging a battery into to Main Voltage. To measure voltages on each chip socket, push thin wires into the empty IC sockets. Set the DMM to the 20-volt DC scale. There are four tests of voltage and polarity.

4.2.1. Test One (both)

Switch on Main Power and observe the SSC II. The SSC II LED lights up green and there is no smoke or sparks.

4.2.2. Test Two (both)

Push wires into the BS2p socket at pins 4 and 21. Connect the black test lead to pin four and the red test lead to pin 21. Plug in the main battery. The DMM should read five Volts, give or take 0.25 Volts. Voltage measurements between pins 4 and 22 should show zero Volts.

4.2.3. Test Three (both)

Push wires into MAX186 socket pin numbers 20 and 14. Connect the black test lead to pin 14 and the red test lead to pin 20. The DMM will read within 0.25 Volts of five Volts.

4.2.4. Test Four (both)

Push wires into ULN2803 socket pin numbers 9 and 10. Connect the black test lead to pin 9 and red test lead to pin 10. Measure and record the voltage of an auxiliary battery. Connect the battery to the auxiliary power connector and the DMM will read the auxiliary voltage.

4.3.   Adjusting the Main Bus Voltage Divider (Block Two Only)

Place a wire into the BS2p socket pin number 6. This pin is marked Main V in the CC/PS components diagram. Apply power to the CC/PS and measure the voltage between this wire and the ground plane. The CC/PS voltage regulator provides the necessary five Volts for the board until the battery voltage drops to 5.25 Volts. At a battery voltage of 5.3 Volts and lower, we want the BS2p to see a logic low on its Main V pin. For the BS2p a logic low occurs at 1.4 Volts. Adjust the 10k trimmer (R8) until its voltage drop is 1.4 Volts when the main battery voltage is 5.3 Volts. There are two methods for adjusting the 10k trimmer on the CC/PS. One method involves the use of a variable power supply. The other involves using a battery and doing some math.

4.3.1. Method One

If you have a variable power supply, set it to 5.3 Volts then connect it to the main battery connector. Monitor the voltage between Main V and ground while adjusting the trimmer. Set the trimmer to the one extreme that gives a voltage above 1.4 Volts. Slowly adjust the trimmer back with a jeweler's screwdriver until the voltage drops to 1.4 Volts.

4.3.2. Method Two

The voltage drop of a resistor is a linear function of the resistors in the chain from positive voltage to ground. If you know the current voltage of the battery, then you can calculate the voltage that will appear at a low main bus voltage condition. Measure the voltage of the battery and call this voltage V0. Divide V0 by 5.3 to get a ratio. Multiply this ratio by 1.4 to get the proper current voltage at the Main V pin. Adjust the trimmer until the calculated voltage appears at Main V.

4.4.   Voltages to the ADC of the MIM Module

4.4.1. Test One

Apply power to the Main Power connector and set the DMM to the 20 volt scale. For these tests, leave the black test lead connected to the ground plane of the CC/PS. Measure and record the voltages on the MIM Module at its Main V and Temp wires. The Main V wire connects to the main power through a voltage divider and will read approximately half of the main power voltage. Divide the Main V voltage by the main battery voltage. Keep the result as a conversion factor. The Temperature voltage from the LM335 measures approximately 2.90 Volts. The voltage is the temperature of the CC/PS in units of hundreds of kelvins. Room temperature is around 293 kelvins, so the voltage at the MIM Module's Temp wire should measure 2.93 Volts.

4.4.2. Test Two

Measure and record the voltage of a battery attached to Powerpole® connectors. Connect the battery to the Servo power connector then measure and record the voltage at the MIM Module's Servo V wire. Next, connect the same battery to the Auxiliary power connector then measure and record the voltage at the MIM Module's Aux V wire. Divide the battery's voltage by the measured voltage at the MIM Module to determine the proper conversion factor.

4.4.3. Test Three

Calibrating the MIM telemetry output is performed in Test 4.9.

4.5.   Voltages on the CC/PS ADC (MAX186) (Both)

Insert the MAX186 into its IC socket.

4.5.1. Test One

Leave the DMM set to the 20-volt, DC scale. Short all the ADC inputs to ground with a wire jumper. One at a time, remove the jumper wire and connect a 1.5-volt battery to the inputs of the MAX186. Connect the black lead of the DMM to the ground plane of the CC/PS PCB or to a ground pin in the expansion port. Use the red DMM probe lead to measure the voltage at each MAX186 input pin by placing the probe in contact with the exposed IC lead.

4.5.2. Test Two

Calibrating the digitized value from the MAX186 is performed in Test 4.9.

4.6.   SSC II Test (Both)

Have a servo, servo battery, and main battery at hand to perform this test.

4.6.1. Test One

Switch Main Voltage and Servo Voltage to off on the CC/PS.
Connect a servo horn to a servo and rotate the servo horn to one extreme. Plug the servo into the first SSC II port. Apply servo power before the main power. Observe the servo and verify the servo is rotating to its mid position.

4.6.2. Test Two

Sending commands to the SSC II is performed in Test 4.9.

4.7.   ULN2803 Test (Both)

Insert the ULN2803 into its IC socket. Have both a main and auxiliary battery handy.

4.7.1. Test One

For the Block One CC/PS, make a jumper wire that connects +5V from the Expansion Ports to an Input Port of the ULN2803 (the jumper wire is not required to test the ULN2803 in the Block Two CC/PS). Apply both main and auxiliary power to the CC/PS. Set the DMM to the 20-volt DC scale and connect its probes across the ground and power of the first ULN2803 Output Port. Connect one end of the jumper wire to the +5V. There should be no voltage at the Auxiliary Output Port at this time. Now connect the open lead of the jumper to the first Input Port of ULN2803 and observe that auxiliary power is now only available to the first Auxiliary Output Port and none other. Test the remaining ports in the same fashion.

4.7.2. Test Two

Sending commands to the ULN2803 is performed in Test 4.9.

4.8.   Reading GPS Sentences (Both)

Insert the BS2p into its IC socket and connect a completed GPS receiver to the CC/PS.

4.8.1. Test One

Power up the CC/PS and GPS receiver, then write and download the following GPS program:

```
'GPS Test
gpschar        var  byte
gpsloop        var  byte
'gps_rx        con 3                   'block two cc/ps
'gps_rx        con 7                   'block one cc/ps
I4800          con 16884

GPS:
GPGGA:
serin gps_rx,I4800,[wait ("GGA"),spstr 70]
for exploop = 0 to 70
get gpsloop,gpschar
debug gpschar
next
end
```

The debug screen should display the GPGGA sentence starting with the comma after GGA.

4.9.   Live Test and Dropped Packets

This is the full up test of the flight computer. Perform this test when an APRS station is available and the owner knows how to save a log. The goal is to program the CC/PS to exercise all its features as if it were going on a mission. Write down the packets that are expected then compared your notes to the log recorded by the APRS station. Expect to see some records dropped. Carry this test out as a part of qualification testing; see Chapter Five, Section Four.

5.0 Programming the NearSys Flight Computers

The following code snippets are broken into functional blocks. Use them to write subroutines for the flight computers. One of the first flight codes you write should be to test telemetry from the flight computer in conjunction with Test 4.9.

5.1.   Block One CC/PS

The first step is to program the TNC connected to the flight computer. Consult Chapter Two for information on programming TNCs for near space flights. The code below assumes a KPC-3+ is connected to the CC/PS. If a different TNC is connected, then some of the tests must be performed with debug commands of a flight data recorder (see Chapter Four, Section Five).

5.1.1. BS2p I/O Definitions

```
clock              con  0
adc_ce             con  1
data_io            con  2
tnc_tx             con  3
tnc_rx             con  4
gps_tx             con  5
servo              con  6
gps_rx             con  7

n1200              con  2063           '1200 baud n81 true
n2400              con  1021           '2400 baud n81 true
i4800              con  16884          '4800 baud n81 inverted
i2400              con  17405          '2400 baud n81 inverted
```

5.1.2. GPS

```
alt_curr           var  word     'current gps alt (m)
gpschar            var  byte     'individual character in gps sentence
gpsloop            var  byte     'looping control

gps_rx             con  7
i4800              con  16884    '4800 baud n81 inverted

SPRAM_GPGGA:
serin gps_rx,I4800,10000,NoGPS,[wait ("GGA"),spstr 56]

SPRAM_ALTITUDE:
for gpsloop = 42 to 46
get gpsloop,gpschar
debug gpschar
next

VAR_GPGGA:
serin gps_rx,I4800,10000,BadGPS,[wait ("$GPGGA"),skip 42, dec alt_curr]
debug "Alt:", dec alt_curr
end
```

5.1.3. TNC

This code assumes a KPC 3+ is connected to the flight computer, and LT buffer four is programmed to accept text and telemeter it.

```
tnc_tx        con 3
I4800         con 18664

serout tnc_tx,I4800,["lt 4 >Testing, 1,2,3", cr]
end
```

5.1.4. MAX186

The following code snippet tells the MAX186 to digitize each of its analog ports and return the value.

```
clock         con    0
adc_ce        con    1
data_io       con    2
exploop       var    nib
adc_code      var    byte
```

```
Exp_Value    var    word

for exploop = 0 to 7                              '8 channels on tv02f
lookup exploop,[$8C,$CC,$9C,$DC,$AC,$EC,$BC,$FC],adc_code
low adc_ce                                  'activate ihu adc
pause 10
shiftout data_io,clock,1,[adc_code]         'shift out instructions
shiftin data_io,clock,2,[Exp_Value\12]      'shift in the data
high adc_ce
pause 10
debug "CH:", dec exploop, "/", dec Exp_Value, cr
next
end
```

5.1.5. SSC II

```
servo        con    6
i2400        con    17405                        '2400 baud n81 inverted

serout Servo,i2400,[255,0,0]
```

5.1.6. ULN2803

The ULN2803 is activated by HIGHing the BS2p I/O pin connected to one of its inputs. Make a jumper wire to connect the BS2p and ULN2803.

```
high 12
pause 1000
low 12
```

5.1.7. Main Bus Voltage

The third channel to the MAX186 can be jumpered for Main Power. When done, the following code returns the digitized value of the main bus voltage.

```
clock        con    0
adc_ce       con    1
data_io      con    2
adc_code     var    byte
Exp_Value    var    word
MainV        var    bit

GetMainV:
MainV = 0                                         'good until proven bad
adc_code = $9C
low adc_ce                                        'activate ihu adc
pause 10
shiftout data_io,clock,1,[adc_code]               'shift out instructions
shiftin data_io,clock,2,[Exp_Value\12]            'shift in the data
high adc_ce
pause 10
if Exp_Value > 2750 then MainVOkay
MainV = 1                                         'low main voltage
```

5.2. Block Two CC/PS

First step is to program the MIM Module. To program the MIM Module, the MIM JMP jumper (a shorting block) must be set to Pgm. The MIM JMP is located near the center of the CC/PS. Consult the CC/PS diagram to locate it. Once the jumper is set to Pgm then the MIM Module can be programmed through its DB-9 connector. Program the MIM to send all position reports beginning with a string of $GP???. The period, or amount of time selected for position transmissions is irrelevant, since the BS2p forces transmissions from the MIM Module. To take advantage of the digital inputs of the MIM, program the MIM to send telemetry. Finally, as a back up to GPS failure, program the MIM to beacon every minute or two. For the Alinco DJ-S11, leave PTT at 0, or active low. To get mission data into an Igate, select WIDE 3-3 for a path. Refer to the documentation you receive with your MIM Module for more complete information on programming the MIM Module. After programming the MIM Module, reset the MIM JMP to BS2p. If this is not done, then the MIM Module will not hear data from the BS2p.

The last section gives snippets of code needed to operate all features of the CC/PS.

5.2.1. BS2p Definitions

```
CLK           CON    0
ADC_CE        CON    1
DATA_IO       CON    2
ETREX         CON    3
MIM           CON    4
MIM_TX        CON    5
MAIN_V        CON    6
SSC           CON    7
```

5.2.2. GPS

```
I4800        con  16884                     '4800 inverted baud
alt_curr     var  word                      'current gps alt (m)
alt_max      var  word                      'highest alt so far
gpsqual      var  Status_Flag.bit0          '0=poor qual, 1=good quality
gpsreply     var  Status_Flag.bit1          '0=no gps response, 1=gps ok
gpschar      var  byte
gpsloop      var  byte

GPS:
GPGGA:
serin etrex,I4800,10000,NoGPS,[wait ("GGA"),spstr 70]
gpsreply = 1
for exploop = 0 to 70
get gpsloop,gpschar
if gpschar = "*" then ShiftGGA
next
ShiftGGA:
for gpsloop = exploop to 0
get gpsloop,gpschar
put gpsloop+6,gpschar
next
put 0,"$"
put 1,"G"
put 2,"P"
put 3,"G"
put 4,"G"
put 5,"A"
SendGGA:
```

```
for gpsloop = 0 to exploop+6
get gpsloop,gpschar
serout mim,n4800i,[gpschar]
next
gosub KeyMIM                                    'send telemetry

get 33,gpschar
gpsqual = gpschar - 48

gpsloop = 42
alt_curr = 0
GetAlt:
get gpsloop,gpschar
if gpschar = "." then DoneAlt
alt_curr = alt_curr * 10
gpschar = gpschar - 48
alt_curr = alt_curr + gpschar
gpsloop = gpsloop + 1
goto GetAlt
DoneAlt:
get gpsloop+1,gpschar
gpschar = gpschar - 48
serout mim,n4800i,["$GPGLL,,,,,,",cr,dec alt_curr,".",dec gpschar," M*"]
gosub KeyMIM                                    'send telemetry

GPRMC:
serin etrex,N4800I,10000,NoGPS,[wait ("RMC"),spstr 70]
gpsreply = 1
for exploop = 0 to 70
get gpsloop,gpschar
if gpschar = "*" then ShiftRMC
next
ShiftRMC:
for gpsloop = exploop to 0
get gpsloop,gpschar
put gpsloop+6,gpschar
next
put 0,"$"
put 1,"G"
put 2,"P"
put 3,"R"
put 4,"M"
put 5,"C"
SendRMC:
for gpsloop = 0 to exploop+6
get gpsloop,gpschar
serout mim,n4800i,[gpschar]
next
gosub KeyMIM                                    'send telemetry

goto GPSEnd

NoGPS:
gpsreply = 0

GPSEnd:
return

DeadGPS:
for gpsloop = 1 to 10
serout mim,n4800i,["$GPGLL,,,,,,",cr,">Dead GPS*"]
gosub KeyMIM                                    'send telemetry
next
```

```
return

NoSat:
for gpsloop = 1 to 5
serout mim,n4800i,["$GPGLL,,,,,,",cr,">No GPS Lock*"]
gosub KeyMIM                                       'send telemetry
return
```

5.2.3. MIM Module

```
n4800i        con  16884

serout mim,n4800i,["$GPGLL,,,,,,",cr,">Text*"]
gosub KeyMIM                                       'send telemetry

KeyMIM:
pause 1000
high mim_tx
pause 250
low mim_tx
pause 5000
return
```

5.2.4. MAX186

```
exp_value     var  word                  '# of pulses from experiments
                                          'result of adc conversion
exp_high      var  exp_value.highbyte
exp_low       var  exp_value.lowbyte
adc_code      var  byte                   'instructions to adc
exploop       var  byte

ADC:                                      'measure ihu adc
for exploop = 0 to 7                      '3 channels on tv01h
lookup exploop,[$8C,$CC,$9C,$DC,$AC,$EC,$BC,$FC],adc_code
low adc_ce                                'activate ihu adc
pause 10
shiftout data_io,clock,1,[adc_code]       'shift out instructions
shiftin data_io,clock,2,[exp_value\12]    'shift in the data
high adc_ce
pause 10
put (exploop*2),exp_low
put ((exploop*2)+1),exp_high
next
serout mim,n4800i,["$GPGLL,,,,,,",cr,">EXP-",dec data_rep,","]
for exploop = 0 to 7
get (exploop*2),exp_low
get ((exploop*2)+1),exp_high
serout mim,n4800i,[dec exp_value]
serout mim,n4800i,["/"]
next
serout mim,n4800i,["*"]
gosub KeyMIM                                       'send telemetry
return
```

5.2.5. SSC II

```
n2400i        con  17405                  '2400 baud, inverted

serout SSC,n2400i,[255,0,127]             'rotate servo # 0 to position 127
```

5.2.6. ULN2803

```
high 8                              'turn on  8
pause 1000                          'wait one second
low 8                               'turn off  8
```

5.2.7. Main Bus Voltage

```
if MainV = 0 then EndFlight
```

Congratulations, I now pronounce your CC/PS flight computer healthy! Ask about Parallax's educational discount on selected items if you are associated with a school. A project board is not required, as the BS2p is programmed in the CC/PS. While you are at the Parallax website, download the programming software, their BS2p Documentation Guide, and app notes for sample projects. You can learn a lot about designing your experiments by looking at these project descriptions. In the Documentation Guide you'll find all the information you need to know about programming the BS2p.

Go to the Maxim website and ask for a sample of the MAX186, 12 bit, 8 channel Analog to Digital converter.   You can purchase the MAX186, but they cost about $20 a piece. Maxim does send out free samples however, so ask for one (you'll probably receive two of them).

Websites for Parts

Parallax has a website at http://www.parallax.com.
Maxim's website is located at http://www.maxim-ic.com

Good to Know – The Great Plains Super Launch (GPSL)

This article is derived from an article I wrote for Mr. Harlan, the publisher of ATV Quarterly.

One reason for the great success at GPSL 2002 is because of the great help and support I had. Without the help of my mother Erma Verhage, Mark Conner (N9XTN), and Ralph Wallio (WØRPK), GPSL 2002 would not have been the success it was. One other thing that helped was the fact there was a history behind GPSL 2002.

Pre-GPSL
Two years ago, in June 2000, I made a trip to Manhattan, Kansas (from Idaho where I teach) to visit my parents. I still had email addresses from my balloon buddies in Kansas and Nebraska, so I proposed we launch a balloon during my visit. We launched our balloon from the Johnson Near Space Center, about ten miles south of the town of Manhattan. This is the same location from which I launched balloons when I was the program manager of KNSP, the Kansas Near Space Program. I had lost my main tracking capsule back in Idaho, so my science capsule hitched a ride with Mark Conner's (N9XTN) tracking capsule. My capsule carried a BASIC Stamp and was programmed to position a 35mm camera and take pictures at fixed intervals. Launch day was covered with dreary overcast skies. Because of the clouds, the photographs looking downwards were pretty much useless. That is, except for one or two that showed Mark's capsule below my capsule and a jet contrail still thousands of feet lower. There were other photographs taken that showed the balloon expanding as it ascended to over 90,000 feet. The chase of this flight went well and chase crews were about ½ mile

away from the capsules as they dropped out of the low cloudbank. I suppose this launch could be considered the first Great Plains Space Launch.

GPSL 2001

In the spring of 2001, when we were considering another balloon launch during my annual visit to my parents, it was decided we should try for a record number of launches that summer. When planning to break a near space record, there's only one source to go to, and that's Ralph Wallio (WØRPK). He informed us that the greatest number of known simultaneous launches was two. So Mark Conner (N9XTN), Bill All (N3KKM), Don Pfister (KAØJLF), and I (KD4STH) began planning for at least three simultaneous launches.

GPSL 2001 – Launch crews.

The near space programs involved were the Treasure Valley Near Space Program (TVNSP) from Idaho, the High Altitude Balloon Investigation Testing And Tracking (HABITAT) group, the Near Space Balloon Group (NSBG) from the Kansas City area, and the Nebraska Stratospheric Amateur Radio (NSTAR) group from Nebraska. This time we determined we needed a name for the launches because Kimbra Cutlip of Weatherwise magazine asked to cover the launches. It was Bill All (N3KKM) who came up with the name Great Plains Super Launch, or GPSL, because of the number of balloons we were attempting to launch. GPSL 2001 was a wonderful success; with three balloons being launched and two being immediately recovered (Bill's was recovered a few days later).

GPSL 2001 – On the launch line, L to R, NSTAR, NSBG, TVNSP.

HABITAT and NSBG shared a ride on a balloon while NSTAR and TVNSP each took their own ride on a balloon. During its descent, Bill and Don's capsules ran into a problem and stopped sending us packets. Mark's capsule was the first one capsule recovered. The owner and his family of the wheat field that the capsule landed in were fascinated by what had happened. My capsule was recovered second in another cut wheat field.

GPSL 2001 – Recovery of the author's near spacecraft. L to R, Paul, Dan, Paul, Mark, & Sheri.

This time however, the landowner didn't care one bit about what we were doing. So we retrieved the capsule and left the field to find Bill. Bill searched for a couple hours in the area we predicted the capsule would land based on its last known altitude and descent. Sometimes we get lucky making this kind of prediction, as when Mark predicted a capsule's recovery location to within less than a mile of its actual landing location. This time however, we were unsuccessful. We met Bill on the road after his search and headed off to lunch, and to have our film processed. Midwestern farmers tend to be a friendly bunch, and when one farmer found a capsule in his field a few days later, he called Bill. Bill had the foresight to leave a phone card and a phone number on his capsule, in case something like this should happen. A few days later Bill made arrangements to pick up his capsule. Ms. Cutlip wrote an excellent article on GPSL 2001. See Weatherwise, November/December 2001, pp. 14 – 23.

GPSL 2002

I wanted GPSL 2002 to be better than GPSL 2001 in every measurement. Since GPSL 2001 saw the launch of three balloons on one day, we planned GPSL 2002 to launch more balloons and occur over more days. We tried for twice as many launches and added an extra day for a symposium. My mother arranged for GPSL 2002 to use the Hemisphere Room at the Kansas State Library (the Hale Library). Ralph maintained the webpage for GPSL 2002 so that everyone could keep up to date on the plans for GPSL. He also kept me on my toes, so I didn't forget anything. Mark started the Yahoo Groups email list and researched things like available motels and rates that guests could use. By the time I left for my summer vacation, everything for GPSL 2002 had been arranged except for food trays.

Officially, GPSL 2002 started on Friday morning, 5 July 2002. Unofficially it began Thursday evening when several of us met for dinner in Manhattan, Kansas. Present at dinner was Bill Brown (WB8ELK), probably the first person to launch a balloon carrying amateur radio gear. Since his flight in 1987, a lot has changed in ham radio. Now we send GPS receivers and TNCs on our balloons to make tracking and recovery easier. But in the early days, it was all done with direction finding. This can be tough when you consider that a balloon may reach altitudes in excess of 90,000 feet and land over 100 miles away.

Friday morning began with several near space programs setting up displays about their programs. The variation in the design and construction of near space capsules is amazing. What these programs are planning and accomplishing is even more amazing. Ralph Wallio (WØRPK) MC'd the symposium. He began with introductions by the 25 attendees of GPSL 2002. Next the near space programs present discussed what they were currently working on. Several videotapes were shown. Some videos were of near space launches; some were of newscasts about launches; while others were actual videos taken from near space. After the morning presentations, we headed over to the Ramada Inn's restaurant, the Gold Fork. They couldn't seat all of us at one table, so we occupied four tables in one corner of the restaurant.

The afternoon presentations were more technical. Presentations covered the range of topics from, Early History, Meteorology, Tracking and Recovery Procedures, Advanced Projects, and Airframes and Avionics. I'm currently putting together proceedings from the GPSL 2002 symposium. So if you'd like more information on the presentations, please email the author. At the close of the presentations, attendees decided the launch time for Saturday morning. The author is accustomed to launching balloons at the break of dawn, before the sun has a chance to create surface winds too high to safely launch balloons. This meant a launch at 6:00 AM, which means we had to arrive at the launch site before 5:00 AM. This was fine with the author (and probably others), but not with the majority of the attendees. So it was decided to arrive at the launch site at 7:00 AM and try to launch by 9:00 AM. Because of winds aloft that were not cooperating with a launch from the traditional Johnson Near Space Center, it had been decided several days earlier to move the launch site out to the Herington Municipal Airport. This required we drive more than an hour from Manhattan to get to the launch site. No doubt that added to the desire to launch later in the morning.

After Friday afternoon's presentations, GPSL 2002 attendees drove to the Sirloin Stockade in Manhattan for dinner. At dinner Bill Brown (WB8ELK) was presented a plaque declaring him the Father of Amateur Radio High Altitude Ballooning. Bill's first flight occurred on his birthday in August 1987. Since his first launch, Bill has launched over 200 balloons carrying some form of amateur radio. And here I thought I was doing pretty well at 33 launches in five and a half years!

Saturday morning couldn't have been much better. There was a little haze in the sky that would limit our ability to see the balloons at high altitudes, but other than that, the morning was perfect. The

surface winds were light enough that we were able to safely fill the balloons outdoors. Almost everyone arrived by 7:00 a.m., but we didn't start filling the balloons until much later. Only the Herington Times covered the launch. Other local newspapers and television stations didn't even try to cover the launch. I'm sorry Mr. Harlan wasn't able to make it out to the launch. But unlike other media, Mr. Harlan did make the effort to cover the launch.

The only problem to occur that morning was when Mike Bogard's (KDØFW) balloon burst. His balloon was twenty years old and had begun to bulge oddly during the filling. Eventually the bulge burst with a pop. Bill Brown (WB8ELK) must have been covered in latex, as he was beneath the balloon, holding it by the neck at the time it burst. Fortunately Zack Clobes (WØZC) brought an extra balloon with him. It wasn't until after 9:00 AM that all the balloons were finally filled and sealed. After conferring with the balloon crews, we decided we were all ready for launch. A total of eight weather balloons were carried out to the grassy field near the tarmac. Once safely spread out, we formed a line about 200 feet long.

GPSL 2002 – Six balloons on the launch line, a record.

The size of this launch made communications with all the balloon crews difficult. Before launch, every balloon crew manager indicated his readiness to launch by calling out either a GO or NO GO. There was only one NO GO, but it only took a few minutes to correct their lanyard problem.

After a countdown from five, the balloons simultaneously took to the hazy Kansas skies. It was impressive to see all these balloons lift off at once! With the low winds aloft, we were in no hurry to start chasing after the balloons. After getting pictures of the launch crews, we headed out to the Herington Dairy Queen for refreshments and waited there for the first balloon to burst. Zacks' balloon was the first to burst, after having reached an altitude greater than 72,000 feet. Zack used a 600-gram balloon, so it's not surprising his balloon burst first and at the lowest altitude. EOSS's and TVNSP's balloons were 1200 grams each, so these two flights reached altitudes above 87,000 feet before bursting. Ascent times were only about ninety minutes and it took the capsules another hour to land. With APRS on the balloons and Kansas roads arranged in a grid with roads every one mile, the recovery of capsules went very well and fast. The capsule that took the longest to recover was Mike Bogard's (KDØFW) capsule. He didn't fly an APRS tracker; instead Mike flew amateur television (ATV) and a 6m repeater on his balloon. So recovering his balloon required fox hunting skills. Talk about the ultimate foxhunt! By 3:00 PM, all the capsules had been successfully recovered.

After recovery, most balloon crews headed to lunch at the Cracker Barrel restaurant in Junction City, Kansas, located almost one hour north of Herington.

GPSL 2002 – *A well deserved, but late, lunch.*

 With over 20 people present, we swamped the restaurant. Stories and photographs were traded during lunch. Everyone agreed this had been a great GPSL and were looking forward to next year's.

GPSL 2003

GPSL 2003 was held in conjunction with the Space Grant's BalloonSat program. Five missions took to the sky, each carrying two BalloonSats.

GPSL 2003 – *Filling five balloons. In forefront, TVNSP's baloon will carry Scrat and Team Ohio's BalloonSats.*

Students from schools across the U.S. met at the Colorado University – Boulder campus to design and build BalloonSats. GPSL 2003 was the first in Colorado and was sponsored by EOSS. Students attached their BalloonSats to one of five stacks, then helped with the prep, launch, chase, and recovery. For the latest information on GPSL, join the GPSL email list on Yahoo Groups.

GPSL 2003 – About ready to launch one of TVNSP's near spacecraft. This flight will carry Team Alabama's BalloonSats.

GPSL 2003 – Five balloons on their way to near space.

Near Space Humor

Balloon Talk
With Phil and Pop, The Helium Brothers

Phil: Hello and welcome to Nation Public Radio! You're listening to Phil and Pop, the Helium Brothers on Balloon Talk. We're here to discuss near space and your near space problems. If you have a question about your balloon, or anything else, the number to call is 888-Balloon Junk.

Hello, you're on Balloon Talk.

Caller: This is Barbara from Burlington. I only have 600-gram balloons and I need to get a 12-pound capsule above 90,000 feet.
Phil: I'm going to take a guess here.
Pop: I like it already.
Phil: Duct tape two 600-gram balloons together!
Phil: See you Barbara, good luck!

Phil: 888, BALLOON JUNK. That's 888-123-1234, hello, you're on Balloon Talk.
Caller: Hi guys, this is Tim from Tulsa.
Pop: So what's up man?
Caller: I can't get my TNC settings right. I'm always missing packets from the balloon.
Phil: Are you using a KPC-3+ with version 8 EEPROM?
Caller: Yes and no, it's a KPC-3+ with version 6 EEPROM.
Pop: Try duct tape.
Phil: Thanks Tim, see you.

Caller: Hi, I'm a first time caller.
Pop: Okay, so what's going on?
Caller: I ran into trouble when filling a 1200 gram balloon with helium. While we were filling it, my crew noticed there was a hole in it, so we just threw out the balloon and used a new one. One of my balloon crew thought we could have saved the balloon. What should we have done?
Phil: Next time try duct tape.
Pop: I love it!
Phil: Good luck!

Caller: This is Fred from Fresno. After our last near space capsule recovery, we noticed a rip in our recovery system. How can we fix this?
Phil: What kind of recovery system are you using?
Caller: It's a seven foot diameter, ripstop parachute.
Pop: Did you buy it or make it?
Caller: We made it ourselves.
Phil: Then I suggest you use duct tape.
Pop: Man, duct tape fixes everything!

Caller: Hi guys, this is Alan from Atlanta. The BASIC Stamp 2 in my flight computer keeps coming out of its socket when the capsule lands. What am I doing wrong?
Pop: Did you try duct taping the Stamp to the IC socket in your flight computer?
Caller: Ah, no, I hadn't tried that.
Phil: Give that a try.

Caller: I will, thanks guys!
Pop: No problem man!

Pop: Did you notice how easy it is to solve these problems?
Phil: Sure, but our callers don't know this.

Caller: Howdy, I'm Deb, I'm calling from Dallas. I can never get my car started on time in the morning to go on balloon chases.
Pop: Wrong show, try Car Talk!

Caller: My husband always complains about the time I spend chasing near space capsules. What can I do?
Phil: I'll let my brother answer that one.
Pop: Have you tried duct tape?
Phil: Ummm….
Pop: Duct tape will fix everything.
Caller: Okay, I'll give it a try. Thanks!

Pop: Do you know what time it is?
Phil: Time to pay that rental fee on our helium tank?
Pop: No, it's time to play, Stump the Chumps! This is the time in our show when we find out if our advice was insightful….
Phil: Or just criminal!
Phil: Whom do we have on the phone?
Pop: Do you remember a call last year from Paul of Payette asking about getting near space capsules out of power lines?
Phil: Is he the one we recommended bring big wire cutters so he could cut the power lines himself?
Pop: That's the one.
Phil: Before we hear your answer Paul, we need to confirm that we have not talked since your last call.
Caller: No we haven't.
Pop: Or that you weren't influenced by the staff of NPR, by Balloon Talk, or by that 500 cubic feet of helium we sent you.
Caller: Nope
Pop: So did the wire cutters work?
Caller: I don't know. All I remember seeing is a bright flash of light. Now I get an occasional buzzing sound in my ears.
Pop: I wish you the very best!

Phil: Well it's happened again, you've wasted another perfectly good hour listening to Balloon Talk!

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