SpacePad™

POSITION AND ORIENTATION MEASUREMENT SYSTEM

INSTALLATION AND OPERATION GUIDE

June 28, 1996

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FCC Regulations

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

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USER MANUAL REVISIONS

Manual Date	Changes
April 28, 1995	Initial release for standalone ISA version with rev 5.07 PROM memory.
June 10, 1995	frequency, noise, metal, stream stop commands added. Alpha_min, xyz ref, group mode, transmitter interface card wiring changed. Must have at least rev 5.10 PROMS.
June 26, 1995	Antenna size command added, metal compensation command use changed. Must have at least rev 5.12 PROMS for antenna size command.
Sept. 26, 1995	Text changes to the CONFIGURATION, FREQUENCY, NOISE, and STREAM commands. Transmitter wiring changed.
Nov. 4, 1995	Board jumper settings added, transmitter wiring polarity corrected, multi-SpacePad card operation explained, Status register bit assignments changed for interrupt operation. RECEIVER OFFSET, OUTPUT BUFFER CLEAR, LOAD MAP and MAP ON/OFF commands added. Must have at least rev 5.17 PROMS to use these commands.
Nov. 24, 1995	Command Utilization, POINT, RECEIVER OFFSET, STREAM descriptions changed. Miscellaneous spelling corrections.
April 1, 1996	FCC notice added. Transmitter loop size and cable length limits added.
June 28, 1996	Miscellaneous text improvements.

1.0 INTRODUCTION

SpacePad is a six degree-of-freedom measuring device that simultaneously tracks the position and orientation of up to four receivers using up to two transmitters. SpacePad gets its name from the design of its unique magnetic field transmitting antenna. The antenna is completely flat, consisting of a loop of wire locatable in a pad near the user. When used in location-based entertainment and arcade games the transmitter loops may be located horizontally in the base of the game pod, figure 1, or vertically between adjacent pods or embedded in a sit-down module or even on a wall to create a virtual room.

SpacePad consists of a single electronics card that can drive two transmitters with four receivers. Since each transmitter is just three pieces of wire, you provide the transmitter. The electronics card is compatible with PCs and all other computers with an ISA bus slot. Additional SpacePads may be used in close proximity to one another by changing their operating frequency using a software command..

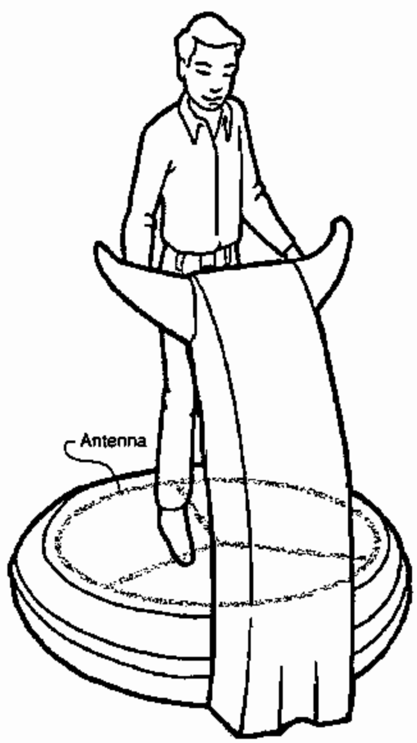


Figure 1. Transmitter in base of standup game pod

2.0 INSTALLATION

The SpacePad is shipped to you in one box containing:

1. One electronics unit.
2. One or two transmitter interface cards.
3. One or two transmitter cables.
4. One or more receivers.
5. One 5 1/4 or 3 1/2 inch DOS-formatted diskette of user software.
6. One Installation and Operation Guide.
7. If you are using multiple cards in a master/slave configuration then one of the SpacePad boxes will also contain a single multi-unit sync cable.

2.1 TRANSMITTER CONSTRUCTION.

Because the transmitter is simply three pieces of flat wire whose shape is dependent on the size of the OEMs game pod, it is the OEM who provides the transmitter. The transmitter consists of an X, Y, and Z coil of wire mounted on a flat, non-metallic surface. The shape and size of the three coils is defined in figure 2 for a coil of length "L". "L" must be 48 cm (19 in). High precision in constructing the coils is not required, 1 cm (0.4 in) accuracy is sufficient. Each coil is built using either a two wire cable shown in figure 3 or a single wire cable looped twice clockwise from the negative side to the positive side as shown in figure 4. The cable may use either solid or stranded wire of size AWG 24. The total length of the wire used in the X and Y coils must not exceed 203.2 cm (80.0 in) which includes a wire length allowance of 10.2 cm (4.0 in) from the end of the X and Y loops to the transmitter interface card. The total length of the wire used in the Z coil must not exceed 251.5 cm (99.0 in) which includes a wire length allowance of 58.4 cm (23.0 in) from the end of the Z loop to the transmitter interface card. The wires can be attached to the flat mounting surface with metal staples, glue, or plastic tie wraps. To insure long life the coils should be located such that they are not walked on by the user.

Do not change the size of the transmitter, the diameter of the wire used to make each transmitter coil, or the length or wire size of the transmitter cable without first consulting with Ascension since the transmitter interface card component values may require change and the unit will need FCC testing.

The ends of the coils are inserted into the transmitter interface card per figure 5. After inserting each wire straight into the terminal block on the interface card, tighten the wire using the screw directly opposite the wire. The transmitter interface card should be located as close to the transmitter coils as possible without exceeding the wire length restrictions above. Ideally, it would be mounted on the same surface as the coils at the point where all twelve wires from the three coils come together.

The transmitter cable is plugged into the other end of the transmitter interface card and goes to the system electronics card. If you are using only one transmitter then this cable plugs into the connector labeled "TX 1" in figure 6.

Orientation of the x, y, z measurement reference frame with respect to the transmitter coils is shown in figure 6. If you want to change the orientation of the measurement reference frame use the REFERENCE FRAME command in conjunction with the CHANGE VALUE XYZ REFERENCE FRAME command.

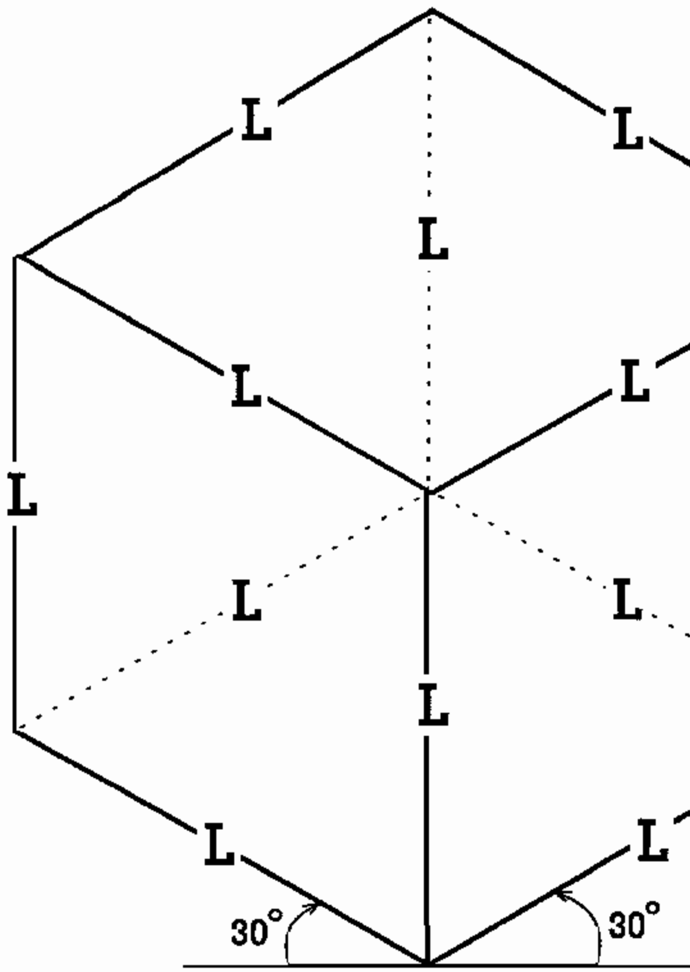


Figure 2. Transmitter Coil Dimensions

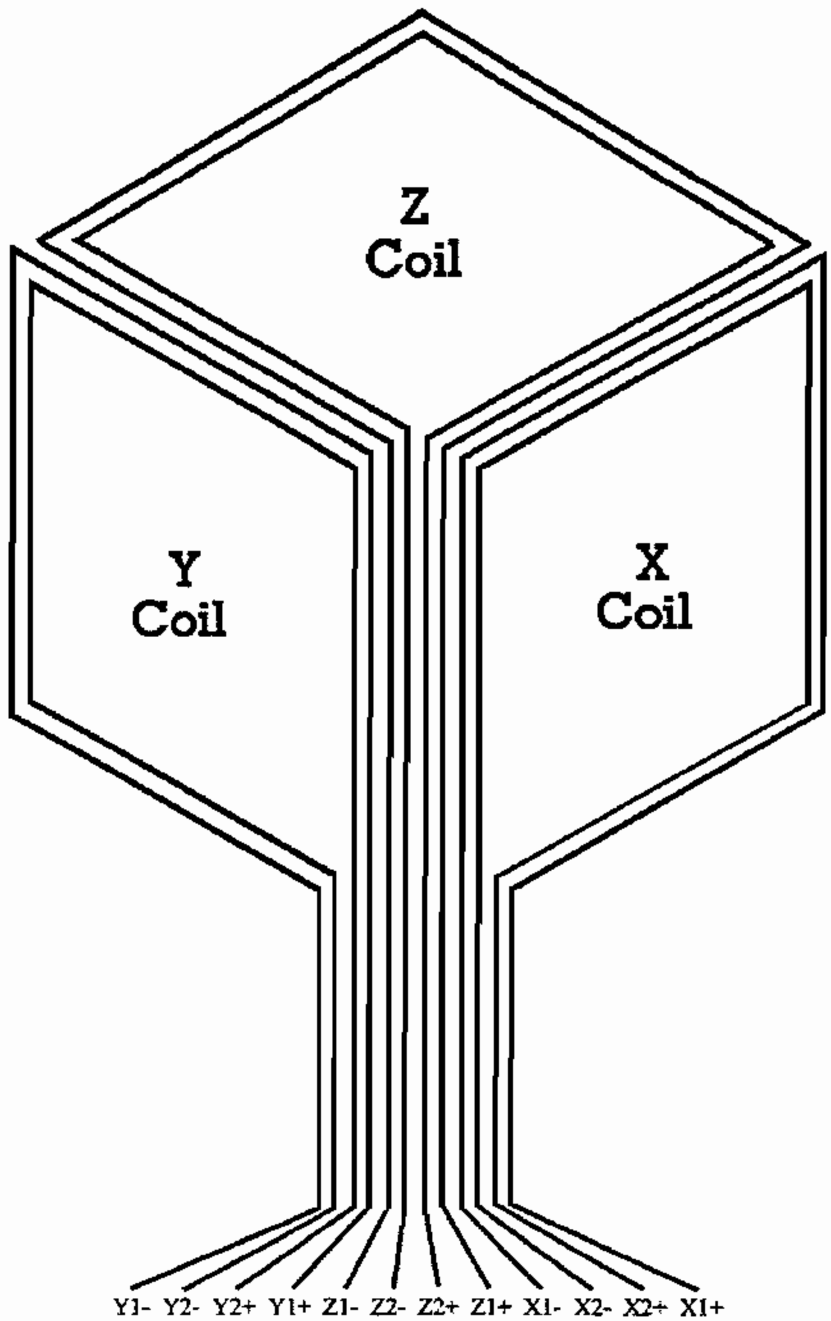


Figure 3. Two Wire Cable Transmitter Wiring

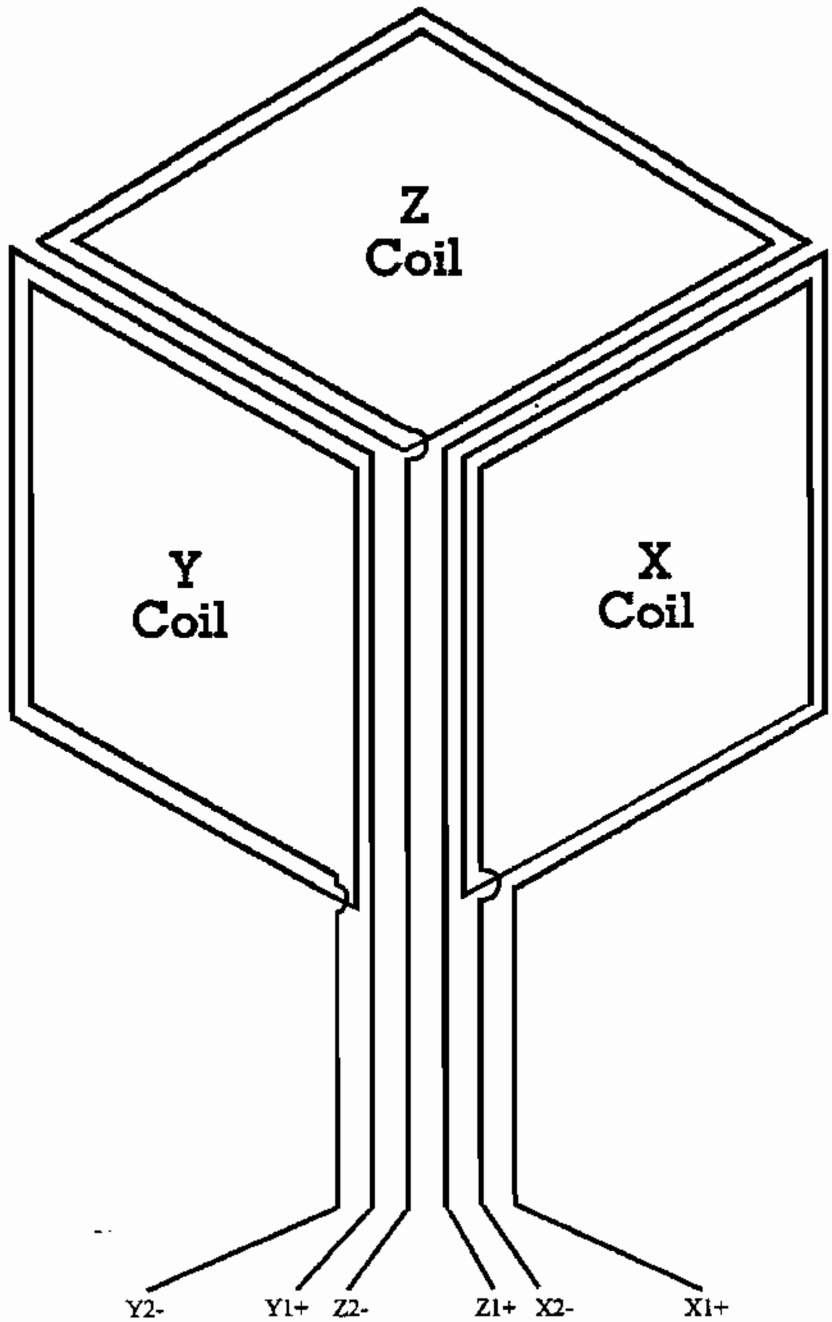


Figure 4. Single Wire Cable Transmitter Wiring

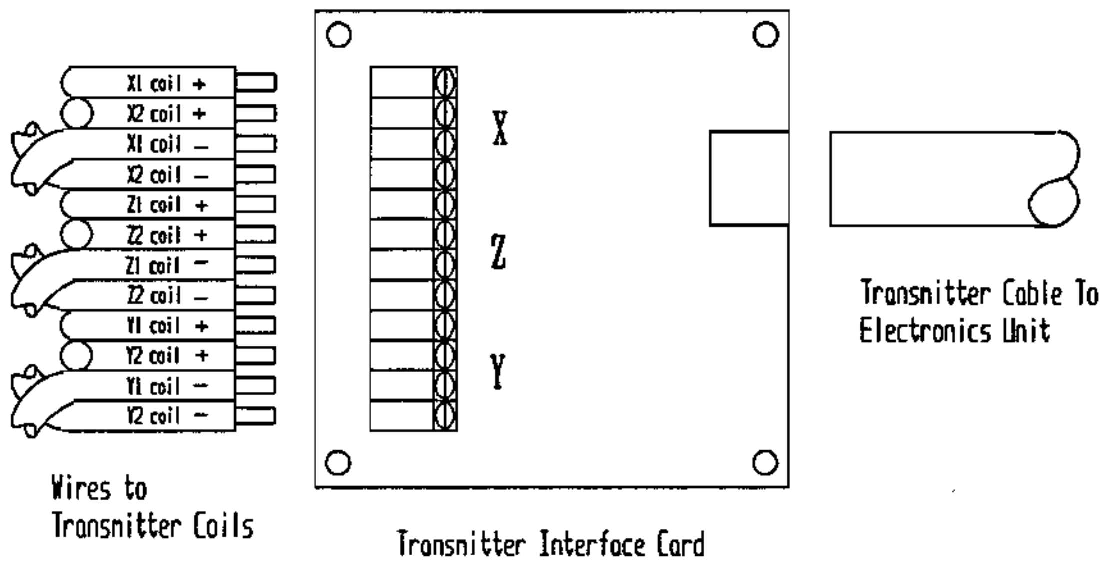


Figure 5. Transmitter interface card

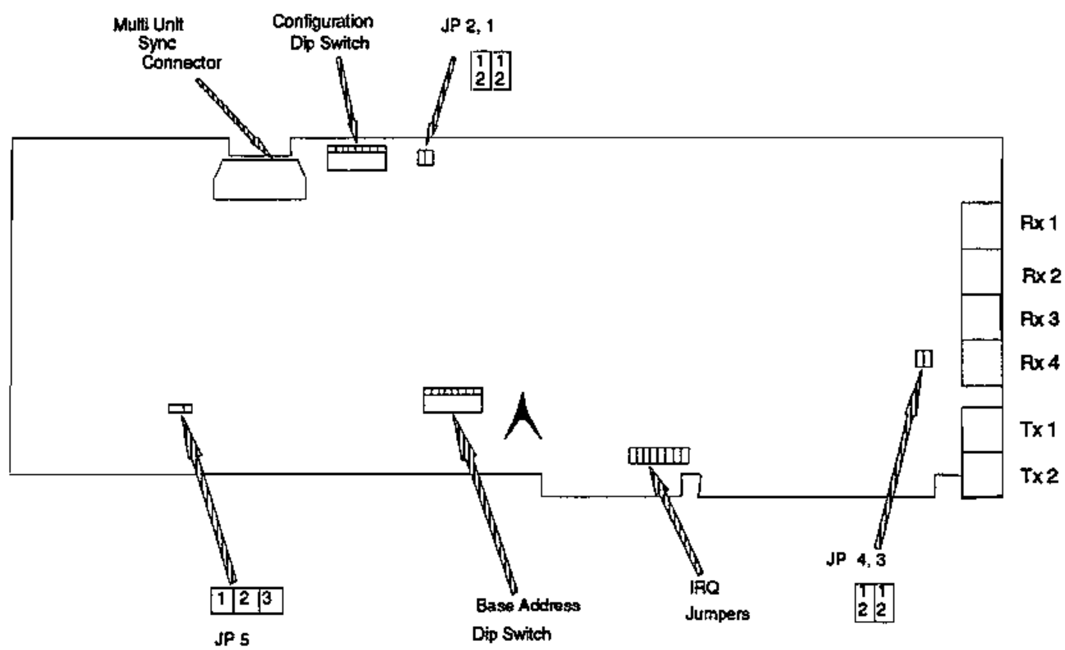


Figure 6. System Electronics Card

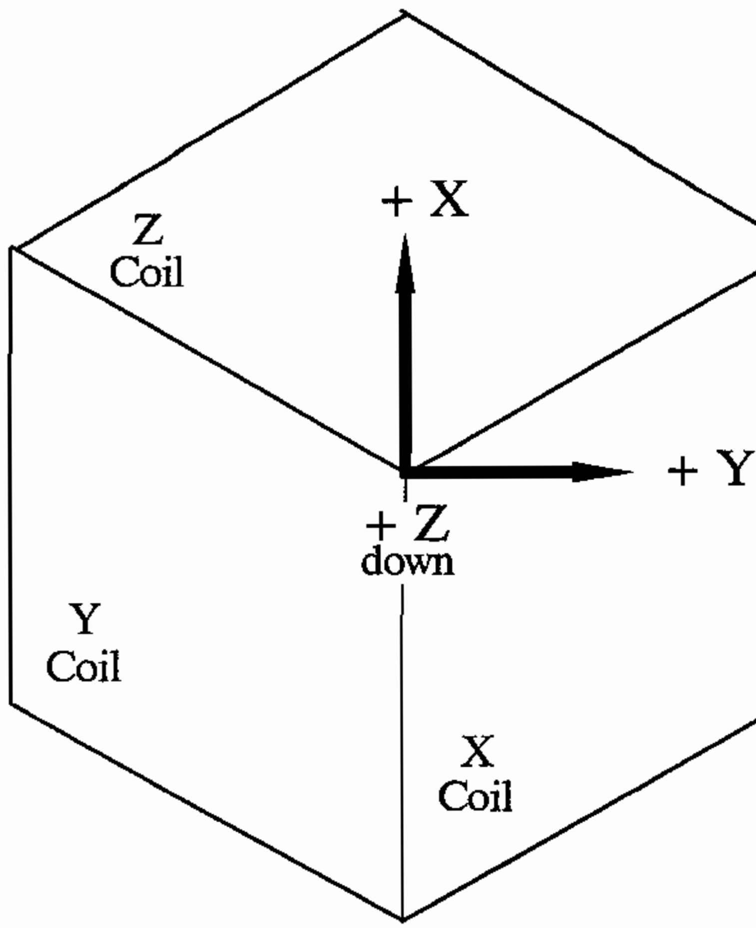


Figure 7. X, Y, Z Reference Frame (Top view of coils)

2.2 SYSTEM ELECTRONICS CARD

2.2.1 CONFIGURING THE CARD. The SpacePad card can be run in either a standalone or master/slave configuration. In the standalone configuration the SpacePad card is working independently of any other SpacePad cards that may be in the same chassis. The standalone card uses only the transmitters and receivers that are attached to the card. The standalone card can use up to two transmitters and four receivers per card. In the master/slave configuration there are two or more SpacePad cards in the same chassis that are working together and electronically attached to each other by a multi-unit sync ribbon cable running across the top of the cards. A master/slave configuration might consist of say four SpacePad cards in a single chassis. A master card with a transmitter and 2 receivers, and three slave cards each with 2 receivers. This configuration would result in 8 receivers operating from one transmitter. Each receiver making 60 measurements per second. Each card could have been configured with up to 4 receivers each but only the master can have a transmitter attached and only one transmitter. Future releases of the software will allow two transmitters on the master.

Before you install the SpacePad card in your chassis, configure the SpacePad card. To configure the card you must:

1. Set the ISA bus base address dip switch.
2. Set the IRQ number jumper block.
3. Set board jumpers 1 - 5.
4. Set the configuration dip switch if present.

The location of these switches and jumpers on the card are shown in figure 6. The switch and jumper settings are described in the ELECTRONICS CARD CONFIGURATION section 2.2.1 of this manual.

WARNING
The system electronics card contains static electricity sensitive components that may be damaged if you touch the card. As a minimum, always touch the metal chassis of the PC before touching any part of the card.

> **W A R N I N G**
>
> NEVER install or remove the electronics card when the PC's power is ON. The card and the PC may be damaged.

Once the switches and jumpers are set, the cards are plugged into the PC chassis, the transmitter cables are plugged into the connectors labeled Tx1 and Tx2 shown in figure 6 and the receivers are plugged into the connectors labeled Rx1, Rx2, Rx3, Rx4. If you have a master/slave configuration, the master/slave cards are plugged in master first, followed by a slave, if this is the only slave card then it is called the END slave because it is at one end of the multi-card sync cable. If there are multiple slave cards then all slave cards except the last slave are called the MIDDLE slaves. Attach the multi-unit sync cable to the multi-unit sync connector on the top of each card. Power can then be turned on and commands sent to the SpacePad cards.

2.2.1.1 BASE I/O ADDRESS. The base address dip switch selects the ISA bus I/O address for sending and receiving data from the SpacePad. This dip switch allows the user to select base addresses from 000 hex to 3FC hex in address steps of 4. The SpacePad uses base address+0 and base address+2. In selecting a base address for the SpacePad you must have no other devices on the ISA bus that use base address +0, +1, +2 and +3. The system is shipped with a base address of 304 hex. If your shipment also includes slave cards then they have addresses 308, 30C, etc.

Example base address settings are:

dip switch number	8	7	6	5	4	3	2	1	base address
	1	1	0	0	0	0	0	1	304 hex
	1	1	0	0	0	0	1	0	308 hex
	0	1	0	1	1	1	0	0	170 hex

where the two least significant bits to the right of the number one dip switch are fixed at zero and the two most significant bits to the left of the number eight switch are zeros.

On the base address dip switch, 0 = switch down = toward the PC card and 1 = switch up = away from the PC card = the OFF label on the switch.

2.2.1.2 IRQ JUMPERS. If interrupt driven ISA bus operation is required then you must select which interrupt number is assigned to the SpacePad card. The SpacePad can utilize interrupt numbers 3,4,5,9,10,11,12 and 15. Place a jumper plug vertically over the two pins below the interrupt number on the circuit board. If the card is not interrupt driven then remove any jumpers present. If you are using several SpacePad cards in the same chassis, all interrupt driven, then each card must use a different IRQ. The cards are shipped with no IRQ jumpers installed.

2.2.1.3 BOARD JUMPERS. There are 5 jumpers on the circuit board shown in Figure 6. Configure the jumpers per the following:

Jumper	SpacePad Hardware Configuration*			
	Standalone	Master	Middle Slave	End Slave
JP1	no jumper	no jumper	no jumper	jumper
JP2	jumper	jumper	no jumper	no jumper
JP3	jumper	jumper	no jumper	no jumper
JP4	jumper	jumper	no jumper	no jumper
JP5	no jumper	no jumper	no jumper	no jumper

* See section 2.2.1 for configuration definitions.

2.2.1.4 CONFIGURATION DIP SWITCH. Generally, the configuration dip switch is only present on cards that are used in a master/slave configuration. The dip switch sets a sequential binary address into each card with switch 7 being the least significant bit of the address. In the case below the master, middle and end slaves represent a three card master/slave configuration. Set the dip switches per the following:

Switch	SpacePad Hardware Configuration			
	Standalone	Master	Middle Slave	End Slave
1	off	off	off	off
2	off	off	off	off
3	off	off	off	off
4	off	off	off	off
5	off	off	off	off
6	off	off	on	on
7	off	on	off	on
8	off	off	off	off

3.0 ISA HOST INTERFACE TO THE SpacePad

The ISA interface provides a 16 bit read / write data port located at base address + 0 to exchange information between the SpacePad and the user's host computer. In addition, at base address +2 the user can determine the status of the port's data availability, set the interrupt source or reset the SpacePad system.

The user's host computer initiates all command and data transactions with the SpacePad. The SpacePad card interprets the most significant byte of the first word in a record as a command. Subsequent bytes/words sent to the card by the host may contain additional data or commands.

3.1 PORT DEFINITION.

The bit definitions of the SpacePad's two ISA ports as seen by the user's host computer are defined below:

Read/Write DATA AND COMMANDS at Base address + 0

Most Significant Byte								Least Significant Byte							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0

where B0 is the least significant bit and B15 is the most significant bit of the commands and data written to or read from the SpacePad.

Read only DATA STATUS at Base address + 2

B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
X	X	X	X	X	X	X	X	X	X	X	X	X	X	RDR	TDR

RDR = Receive Data Ready
TDR = Transmit Data Ready

when B0 = 1 the user can transmit a word to the SpacePad
when B1 = 1 a word is available from SpacePad for reading
bits B2 to B15 may be any random value when STATUS is read.

Write only INTERRUPT SOURCE and RESET/RUN at Base address + 2

B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
X	X	X	X	X	X	X	X	X	X	X	X	X	X	INT	RST

```
RST = reset/run
INT = interrupt source

setting B0 = 0 holds the SpacePad in reset
setting B0 = 1 starts or continues the operation of the SpacePad

setting B1 = 0 sets the interrupt source to be the RDR status bit
setting B1 = 1 sets the interrupt source to be the TDR status bit
```

The bits associated with READ operations from the port at base address +2 will hereafter be referred to as DATA STATUS bits. The bits associated with WRITE operations to the port at base address +2 will hereafter be referred to as INTERRUPT/RESET bits.

3.2 PORT BEHAVIOR ON POWERUP.

On power up or immediately after a reset, the DATA STATUS bits are: B1 = 0, B0 = 0. Approximately two seconds after power up or reset the DATA STATUS bits will change to: B1 = 0, B0 = 1 indicating that there is no data available to read from the SpacePad (B1 = 0) but the user can send a command to the SpacePad (B0 = 1).

3.3 SENDING COMMANDS TO THE SPACEPAD.

To send a word to the SpacePad the user must first wait until the DATA STATUS bit B0 = 1. Immediately after the user sends a word, the DATA STATUS bit B0 is automatically set to zero. After the SpacePad processes this word, B0 is again set to one indicating that the user can send another command or data word. If the previous command results in the SpacePad outputting data to the user then the user must not issue a new command until the previous data is received. SpacePad operation will become faulty if the user sends a word to the SpacePad when the DATA STATUS bit B0 = 0.

3.4 RECEIVING DATA FROM THE SPACEPAD.

When the SpacePad sends a word to the user, DATA STATUS bit B1 is set to one. Immediately after the user reads the data port to get this word, DATA STATUS bit B1 is automatically reset to zero. SpacePad operation will become faulty if the user reads a data word when the DATA STATUS bit B1 = 0.

3.5 INTERRUPT OPERATION.

To send commands and read data from the SpacePad using interrupts one must insert one of the IRQ jumpers on the board. You may, however, still use polling of the DATA STATUS register when an IRQ jumper is inserted if you mask this interrupt in your host computer. Behavior of the DATA STATUS bits during interrupt operation is the same as during polled operation. When either or both of the DATA STATUS bits are = 1 an interrupt will occur. To identify the source of the interrupt the user must preset B1 in the INTERRUPT/RESET port to either a 0 or 1. When B1 has been preset = 0 then an interrupt will be generated when the RDR status bit goes to 1. If the user has preset B1 = 1 then an interrupt will be generated when the TDR status bit goes to 1. When you preset B1 to 0 or 1 be sure to keep B0 =1 to keep the card from resetting.

3.6 RESETTING SpacePad.

To initialize or re-initialize the SpacePad card using an ISA software command, write to base address +2 with B0 =0 followed immediately with a second write to base address +2 with B0 = 1. B1 can be any value when you initiate the reset. At the end of the reset, B1 is 1. The reset command can be sent at any time. If you have a master/slave configuration the slave boards must be reset before the master.

After receiving the reset sequence, SpacePad will take approximately two seconds to initialize itself. It will then indicate that it is ready to accept user commands by setting DATA STATUS B0 = 1 and generating an interrupt if interrupts are enabled. Any commands or command data sent to the SpacePad before or during the reset will be lost.

4.0 FORMAT OF ISA COMMANDS AND DATA

4.1 FORMAT OF COMMANDS AND DATA SENT.

All commands sent to the SpacePad consist of a single byte. Associated with some commands are multiple byte command data or a single byte receiver number. If you are sending only a command byte, this byte is positioned as the most significant byte in the output word. The least significant byte must be set to zero. For example, the following sends a "B" (42 hex) to request data from a single receiver system:

Most Significant Byte 42								Least Significant Byte 0							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0

To send two or more, one byte commands you must send two or more words, one command per word as defined above.

If the command uses a receiver number preface to direct the command to a particular receiver then the receiver number and command are sent in the same word. Receiver number as the most significant byte and command as the least significant byte. For example, to send a data request "B" (42 hex) to the receiver plugged into the connector labeled Rx3 you would use the RECEIVER# command preface F3 hex resulting in the following word to be sent to the SpacePad:

Most Significant Byte F3								Least Significant Byte 42							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
1	1	1	1	0	0	1	1	0	1	0	0	0	0	1	0

If you are going to send a command that has command data associated with it then the command is positioned in the most significant byte of the first word to be output and the first byte of command data is positioned in the least significant byte. Additional command data fill up additional output words. If the last output word has only one byte then the least significant byte of this word is set to zero. For example, the REFERENCE FRAME command "H" (48 hex) has 6 command data words associated with it. For this example we'll assign the following hex values to these data words, sin(A)=3618, cos(A)=7401, sin(E)=496A, cos(E)=68D9, sin(R)=7EDE, cos(R)=163A. The resulting seven words sent to the SpacePad would be as follows:

Most Significant Byte 48								Least Significant Byte 36							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
0	1	0	0	1	0	0	0	0	0	1	1	0	1	1	0

Most Significant Byte 18								Least Significant Byte 74							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	1	1	0	0	0	0	1	1	1	0	1	0	0

Most Significant Byte 01								Least Significant Byte 49							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1

Most Significant Byte 6A								Least Significant Byte 68							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
0	1	1	0	1	0	1	0	0	1	1	0	1	0	0	0

Most Significant Byte D9								Least Significant Byte 7E							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
1	1	0	1	1	0	0	1	0	1	1	1	1	1	1	0

Most Significant Byte DE								Least Significant Byte 16							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
1	1	0	1	1	1	1	0	0	0	0	1	0	1	1	0

Most Significant Byte 3A								Least Significant Byte zero pad							
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0

In general, if you are sending N bytes of command and command data, you can format the data into a single string, left justified, adding an additional zero byte onto the end if required to make the string an even number of bytes. The string is then sent a word at a time to the SpacePad.

4.2 FORMAT OF COMMANDS AND DATA RECEIVED.

Two types of binary data are returned from the SpacePad: 1) position/orientation data and, 2) change/examine value data. Position/orientation data are the data returned from The SpacePad in the ANGLES, POSITION, MATRIX, POSITION/ANGLES, POSITION/MATRIX, POSITION/QUATERNION and QUATERNION formats. All other types of data that The SpacePad returns are in the change/examine value format. Both position/orientation data and the change/examine value data return one or more 16 bit data words as detailed below.

4.2.1 POSITION/ORIENTATION DATA FORMAT. The position/orientation information generated by The SpacePad is sent in a form called a data record. The number of words in each record is dependent on the output format selected by the user (i.e. position, angles etc.). Each word in the record is in a 16 bit 2's complement binary format. The binary format consist of the 15 most significant bits (bits B15 - B1) of the data plus a least significant bit B0 used as a "phasing" bit. The phasing bit allows the host computer to identify the start of a record. This phasing bit is set to one in the first word of a record and set to zero in all other words in the output record. You can ignore the effect of the phasing bit on the magnitude of the position and orientation data since the sixteenth bit is beyond the accuracy or resolution of the tracker. When you send data in GROUP MODE an extra word containing the receiver's address is added to the record. The address is located in bits B12 - B8 of the last word, with the phasing bit in B0.

4.2.2 CHANGE / EXAMINE DATA FORMAT. The change/examine value data uses the response format described with each change/examine value command. The change/examine value data does not contain the 'phasing' bits found in the position/orientation data. All 16 bits are used for data.

5.0 COMMAND UTILIZATION

After powerup or reset the SpacePad is ready to output data to you in the POSITION/ANGLE format as soon as you send it a 'B' (POINT command). If you do not want POSITION/ANGLE formatted data then send one of the following data record select commands to the desired receiver: ANGLES, MATRIX, POSITION, QUATERNION, POSITION/ANGLES, POSITION/MATRIX, or POSITION/QUATERNION. These commands do not cause the SpacePad to transmit data to the host. For the host to receive data, it must issue a data request. Use the POINT data request each time you want one data record or use the STREAM data request once to initiate a continuous flow of data records. If you want to reduce the rate at which data STREAMs from the SpacePad, use the REPORT RATE command. All commands can be issued in any order and at any time to change SpacePad's output characteristics, however if the previous command results in the SpacePad outputting data to the user then the user must not issue a new command until the previous data is received. If you change the output format with an ANGLES, MATRIX, etc. command and immediately follow with a data request command, you will receive zero's for the data in the new format for up to 8 milliseconds if a single receiver system or up to 32 milliseconds for a four receiver system.

The following is a hypothetical command sequence, issued after power-up, which illustrates the use of some of the commands. These commands assume that the SpacePad has one receiver. If your configuration has multiple receivers use the RECEIVER# preface command to direct the command to the desired receiver.

COMMAND	ACTION
CHANGE VALUE CONFIGURATION	Tell SpacePad you only have one receiver.
ANGLES	Specify that the output record will contain angles only.
POINT	SpacePad outputs an ANGLE data record.
STREAM	ANGLE data records start streaming from SpacePad.
STREAM STOP	Stops the stream of ANGLE records.

5.1 CONFIGURING THE SYSTEM.

On power-up or upon reset The SpacePad automatically detects if there are one or two transmitters attached. If it detects that only transmitter Tx1 is attached then it assigns receivers Rx1 and Rx2 to work with this transmitter. If it detects that only transmitter Tx2 is attached then it assigns receivers Rx3 and Rx4 to work with this transmitter. If it detects two transmitters then receivers Rx1 and Rx2 are assigned to transmitter Tx1 and Rx3 and Rx4 are assigned to work with transmitter Tx2. If you have fewer than 2 receivers assigned to each transmitter and you want the maximum measurement rate possible from each receiver then you need to tell the SpacePad how many receivers you have and what transmitter they are assigned to by using the EXAMINE / CHANGE CONFIGURATION command detailed in section 9.0.

5.2 USING MULTIPLE RECEIVERS

5.2.1 RECEIVER# PREFACE. Each receiver in the system has a receiver number associated with it so that you can send commands to or receive data from a specific receiver. The receiver's number is defined by the connector number it is plugged into, see figure 6. Thus the receiver plugged into Rx1 has a receiver number of 1. The receiver plugged into Rx4 has a receiver number of 4.

To send commands to a specific receiver you must use the RECEIVER# preface command. If the RECEIVER# preface is not present the command goes to the receiver plugged into Rx1. For examples of using the RECEIVER# command see section 9.0 EXAMINE / CHANGE, ANGLE ALIGN and REFERENCE FRAME commands.

Each receiver can be individually configured for different output formats, reference frames, alignment angles, and hemispheres. See the RECEIVER# command in section 9.0 for a complete list of commands.

5.2.2 GROUP MODE. To get data output from all receivers in your system you can either use the above defined address preface method to request data from each individually or you can issue the GROUP MODE command during your initialization and then just send a single "B" with no address preface to receive data from all receivers.

5.3 MASTER/SLAVE OPERATION.

There are no special software commands to control a master/slave. You send commands and receive data from each card individually as if it were the only card in the system. On powerup or after reset you must send the CHANGE VALUE CONFIGURATION command to both the master and slave(s) assigning all receivers in use to transmitter #1. The only command restrictions are:

1. The board reset command must be sent to the slaves before being sent to the master.
2. The CHANGE/EXAMINE FREQUENCY AND NOISE STATISTICS commands must only be sent to the master.

5.4 COMMAND SUMMARY.

The following summarizes the action of each command. The details of each command are presented in Section 9.0.

Command Name	Description
ANGLES	Data record contains 3 Euler rotation angles.
ANGLE ALIGN	Aligns a receiver to a specified direction.
CHANGE VALUE	Changes the value of a selected system parameter.
EXAMINE VALUE	Reads and examines a selected system parameter.
FACTORY TEST	Enables factory test mode.
HEMISPHERE	Sets desired hemisphere of transmitter operation.
MATRIX	Data record contains 9-element rotation matrix.
LOAD MAP	Loads accuracy improvement corrections.
MAP ON/OFF	Enables/disables MAP corrections.
OUTPUT BUFFER CLEAR	Stops any data being output and clears the output buffer.
POINT	One data record is output for each B command from the selected receiver. If GROUP mode is enabled, one record is output from all configured receivers..
POSITION	Data record contains X,Y,Z position of receiver.
POSITION/ANGLES	Data record contains POSITION and ANGLES.
POSITION/MATRIX	Data record contains POSITION and MATRIX.

POSITION/QUATERNION	Data record contains POSITION and QUATERNION.
QUATERNION	Data record contains QUATERNIONs.
RECEIVER#	The number of the receiver you want to talk to.
RECEIVER OFFSET	Outputs position of a location other than the receivers.
REFERENCE FRAME	Defines new measurement reference frame.
REPORT RATE	Number of data records/second output in STREAM mode.
RUN	Starts the system running again after put to SLEEP.
SLEEP	Turns transmitter off and suspends system operation.
STREAM	Data records are transmitted continuously from the selected receiver. If GROUP mode is enabled then data records are output continuously from all configured receivers.
STREAM STOP	Stops STREAM mode.

5.4 DEFAULT VALUES.

Upon power-up or reset the SpacePad is configured per the following where all numbers are listed as base 10:

1. POINT mode
2. POSITION/ANGLE outputs selected
3. RUN activated
4. REPORT RATE = Q (maximum)
5. ANGLE ALIGN sines/cosines set for alignment angles of zero
6. REFERENCE FRAME sines/cosines set for reference angles of zero
7. FACTORY TEST commands not active
8. Maximum range scaling = 144 inches
9. Filter on/off status = filter on.
10. Filter constants ALPHA_MIN table values = 0.1

11. Filter constants ALPHA_MAX table values = 0.9
12. Filter constant Vm table values = 4
13. Hemisphere = upper (-Z)
14. Configuration: if transmitter Tx1 is present, receivers Rx1 and Rx2 assigned to transmitter Tx1 and if transmitter Tx2 is present, receivers Rx3 and Rx4 assigned to Tx2.
15. Transmitter frequency number 6.
16. Metal constants: parallel = 17192, perpendicular = 6152
17. Antenna size = 4323.
18. MAP ON/OFF = OFF
19. RECEIVER OFFSETs = 0,0,0

6.0 SOFTWARE SUPPLIED WITH THE SPACEPAD

One high density 3.25 inch DOS formatted diskette is included with your unit. This diskette contains source code written in C. One of the programs on this diskette called SPACEPAD lets you send commands to the SpacePad from a menu and read output data onto the screen or into a file. Another program is called XMTRTEST. This allows you to determine if your transmitter has been constructed correctly. Additionally, this diskette contains complete, commented source code of all the 'C' functions you'll need for talking to the SpacePad from your own program. See the file, C_FILES.TXT for a description of these functions. Additional programming notes for the 'C' user can be found in file CNOTES.TXT. Instructions for running the SPACEPAD
program are located in file OPERATEC.TXT.

Feel free to incorporate any of this software into your own application or product.

7.0 ERROR MESSAGES

The SpacePad keeps track of system errors. These errors are reported via the SYSTEM ERROR register. When an error occurs, the SYSTEM STATUS register ERROR bit is set to a '1', and the error code is put into the SYSTEM ERROR register. The user can query the SYSTEM ERROR register with EXAMINE VALUE / SYSTEM ERROR. When the user reads SYSTEM STATUS, the ERROR bit is reset to a '0' and when the user reads the SYSTEM ERROR register, all bits are reset to '0'.

The error codes are summarized below.

CODE	ERROR DESCRIPTION	TYPE
1	System Ram Failure	FATAL
2	Non-Volatile Storage Write Failure	FATAL
3	PCB Configuration Data Corrupt	WARNING
5	Receiver Calibration Data Corrupt or Not Connected	WARNING
6	Invalid Command	WARNING
10	FBB Serial Port Receive Error - Intra SpacePad Bus	WARNING
16	Invalid CPU Speed	FATAL
19	Slave Acknowledge Error	WARNING
20-27	Intel 80186 CPU Errors	FATAL
30	No transmitter attached	FATAL

7.1 ERROR MESSAGE DETAILS

For each of the error codes a possible cause and corrective action are listed. Corrective actions with an * indicate that the user should not attempt this fix but rather Ascension Technology should be called.

CODE	ERROR DESCRIPTION	TYPE
1	Ram Failure Cause: System RAM Test has did not PASS. Action: *Check for shorts or opens to the RAM chips and if OK, replace system RAM.	FATAL
2	Non-Volatile Storage Write Failure Cause: Occurs when trying to write a receiver, or PCB EEPROM but the device does not acknowledge either because it is not there or there is a circuit failure. Action: *Check the target EEPROM via a read command to verify that it is present prior to writing the device.	FATAL

CODE	ERROR DESCRIPTION	TYPE
3	PCB Configuration Data Corrupt Cause: The system was not able to read the PCB EEPROM 'Initialized Code' Action: *Verify that the error persists after removing the transmitter and the receiver.	WARNING
5	Receiver Configuration Data Corrupt Cause: The system was not able to read the Receiver EEPROM 'Initialized Code' or the Receiver is not plugged in. Action: *Insure that the Receiver is present, calibrate the receiver and set the 'Initialized Code' in the EEPROM.	WARNING
6	Invalid Command Cause: The system has received an invalid command, which can occur if the user sends down a command character that is not defined or if the data for a command does make sense (i.e., change value commands with an unknown parameter number). Action: Only send valid commands to the SpacePad.	WARNING
10	FBB Receive Error - Intra SpacePad Bus Cause: Either an overrun or framing error has been detected by the serial channel 0 UART as it received characters from another SpacePad on the internal RS-485 interface. Action: If all SpacePads have the proper crystal installed then this error should never occur.	WARNING
16	Invalid CPU Speed Cause: If the system reads an invalid CPU speed from the system EEPROM and the EEPROM is initialized the error will occur. Action: *Initialize the system EEPROM.	FATAL
20	Unused_INT4 Cause: CPU overflow. Action: *check code for INTO instruction.	FATAL
21	Unused_INT5 Cause: Array Bounds. Action: *Check code for BOUND Instruction.	FATAL
22	Unused_INT6 Cause: Unused Opcode. Action: *CPU has executed an invalid opcode. Possibly bad (or going bad) EPROM. Also, check the power supply to assure that the +5VD is not dropping below 4.75 volts even when the transmitter is running.	FATAL

CODE	ERROR DESCRIPTION	TYPE
23	Unused_INT7 Cause: ESC Opcode. Action: *Check code for the ESC Instruction.	FATAL
24	Unused_INT9 Cause: Reserved. Action: *Should never occur.	FATAL
25	Unused_INT10 Cause: Reserved. Action: *Should never occur.	FATAL
26	Unused_INT11 Cause: Reserved. Action: *Should never occur.	FATAL
27	Unused_INT16 Cause: Numeric coprocessor exception. Action: *Numeric CPU does not exists so this should never occur. Check to make sure the ERROR/ signal on the CPU is tied to +5VD.	FATAL
30	No Transmitter attached Cause: A standalone or master configured system has no transmitter or a slave has no master transmitter reference signal.. Action: Attach a transmitter, check configuration dip switches for correct configuration or check that multi-unit sync cable is connected to master and slave..	FATAL

8.0 TROUBLE SHOOTING

If you are experiencing trouble with the SpacePad try the following:

IF YOU CANNOT TALK TO THE SpacePad WITH THE ISA INTERFACE:

1) With the power off to the host computer, verify that the SpacePad card is seated into the host computer's ISA bus connectors.

2) Check that the base address dip switch is set to the correct value.

3) Verify that no other cards in your chassis use base address+0,+1,+2 or +3.

4) Check that the IRQ jumpers are set correctly. There should be no jumpers if you are using SpacePad in a polled mode.

IF YOU CAN COMMUNICATE WITH THE SpacePad BUT THE DATA IS BAD:

1) Make sure all cables are plugged in, and plugged into the correct connectors.

2) If you send commands without their proper command data bytes or the wrong number of data bytes, the system may hang. Reset the system to return you to normal operation.

3) If the data is 'noisy' use the EXAMINE VALUE NOISE STATISTICS command in conjunction with the CHANGE VALUE FREQUENCY command to locate and set a 'quiet' operating frequency.

4) If the angles and or position have the wrong polarities or are greatly in error use the program XMTRTEST.EXE to analyze if the transmitter is constructed correctly and wired correctly into the Transmitter interface card.

There are no fuse or other user-serviceable parts on the SpacePad's circuit board.

For technical assistance call Ascension Technology at 802-860-6440 between the hours of 9 AM and 5 PM Eastern Standard time or FAX us at 802-860-6439.

9.0 COMMAND REFERENCE

All commands are listed alphabetically in the following section. Each command description contains the command codes required to initiate the commands, as well as the format and scaling of the data records which the SpacePad will output to the host computer.

ANGLES

ANGLES

	ASCII	HEX	DECIMAL	BINARY
Command Byte	W	57	87	01010111

In the ANGLES mode, The SpacePad outputs the orientation angles of the receiver with respect to the transmitter. The orientation angles are defined as rotations about the Z, Y, and X axes of the receiver. These angles are called Zang, Yang, and Xang or, in Euler angle nomenclature, azimuth, elevation, and roll. The output record is in the following format for the three transmitted words:

WORD #	ANGLE
1	Zang or Azimuth
2	Yang or Elevation
3	Xang or Roll

Zang (azimuth) takes on values between the binary equivalent of +/- 180 degrees. Yang (elevation) takes on values between +/- 90 degrees, and Xang (roll) takes on values between +/- 180 degrees. As Yang (elevation) approaches +/- 90 degrees, the Zang (azimuth) and Xang (roll) become very noisy and exhibit large errors. At 90 degrees the Zang (azimuth) and Xang (roll) become undefined. This behavior is not a limitation of the SpacePad - it is an inherent characteristic of these Euler angles. If you need a stable representation of the receiver orientation at high elevation angles, use the MATRIX output mode.

The scaling of all angles is full scale = 180 degrees. That is, +179.99 deg = 7FFF hex, 0 deg = 0 hex, -180.00 deg = 8000 hex.

Angle information is output as all zeros when the receiver saturation error occurs.

ANGLE ALIGN

ANGLE ALIGN

	ASCII	HEX	DECIMAL	BINARY
Command Byte	J	4A	74	01001010

Command Data	Sin(A)	Cos(A)	Sin(E)	Cos(E)	Sin(R)	Cos(R)

By default, the angle outputs from the SpacePad receivers are measured with respect to rotations about the physical X,Y and Z axes of the receiver. The ANGLE ALIGN command allows you to mathematically change the receiver's X,Y and Z axes to an orientation which differs from that of the actual receiver. Send the ANGLE ALIGN command to the receiver you want to change by prefacing this command with the RECEIVER# command.

For example:

Suppose that during installation you find it necessary, due to physical requirements, to cock the receiver, resulting in its angle outputs reading azim = 5 deg, elev = 10 and roll = 15 when it is in its normal "resting" position. To compensate, use the ANGLE ALIGN command, passing as Command Data the sines and cosines of 5, 10 and 15 degrees. After this sequence is sent, the receiver outputs will be zero, and orientations will be computed as if the receiver were not misaligned. Note: the ANGLE ALIGN command only affects the computation of orientation - it has no effect on position.

If you immediately follow the ANGLE ALIGN command with a POINT or STREAM mode data request, you may not see the effect of the ALIGN command in the data returned. It will take at least one measurement period (i.e. 8 to 33 milliseconds) before you see the effect of the command.

The host computer must send the Command Data immediately following the Command Byte. The Command Data consists of the sines and cosines of the azimuth (A), elevation (E), and roll (R) angles that specify the amount of receiver misalignment you want to remove. The Command Data must be sent even if the angles are zero.

When used with the RECEIVER# command to direct the angles to a particular receiver, the sequence of output words to the SpacePad would take the following form:

WORD #	Most Significant Byte	Least Significant Byte
1	RECEIVER# command	ALIGN command = 4A
2	MSbyte SIN(A)	LSbyte SIN(A)
3	MSbyte COS(A)	LSbyte COS(A)
4	MSbyte SIN(E)	LSbyte SIN(E)
5	MSbyte COS(E)	LSbyte COS(E)
6	MSbyte SIN(R)	LSbyte SIN(R)
7	MSbyte COS(R)	LSbyte COS(R)

The sine and cosine elements take values between the binary equivalents of +.99996 and -1.0.

Element scaling is +.99996 = 7FFF hex, 0 = 0 hex, and -1 = 8000 hex.

CHANGE VALUE
EXAMINE VALUE

CHANGE VALUE
EXAMINE VALUE

	ASCII	HEX	DECIMAL	BINARY
CHANGE VALUE Command Byte	P	50	80	01010000

CHANGE VALUE Command Data	PARAMETERnumber	PARAMETERvalue

The CHANGE VALUE command allows you to change the value of the SpacePad system parameter defined by the PARAMETERnumber byte and the PARAMETERvalue byte(s) sent with the command.

	ASCII	HEX	DECIMAL	BINARY
EXAMINE VALUE Command Byte	O	4F	79	01001111

EXAMINE VALUE Command Data	PARAMETERnumber

The EXAMINE VALUE command allows you to read the value of the SpacePad system parameter defined by the PARAMETERnumber sent with the command. Immediately after The SpacePad receives the command and command data, it will return the parameter value as a multi-word response.

Valid CHANGE VALUE and EXAMINE VALUE PARAMETERnumbers are listed in the table below. All PARAMETERnumbers are EXAMINEable but not all are CHANGEable. Similarly, not all use the RECEIVER# preface command:

PARAMETERnumber Base 10	Hex	CHANGEable	RECEIVER# preface	PARAMETER DESCRIPTION
0	0	No	Yes	SpacePad receiver/system status
1	1	No	No	Software revision number
2	2	No	No	SpacePad computer crystal speed
4	4	Yes	Yes	Filter on/off status
5	5	Yes	No	DC Filter constant table ALPHA_MIN
10	A	No	No	SpacePad error code
12	C	Yes	No	DC filter constant table Vm
13	D	Yes	No	DC filter constant table ALPHA_MAX
15	F	No	No	System model identification
17	11	Yes	Yes	XYZ reference frame
33	21	Yes	No	Configuration
35	23	Yes	No	Group mode
37	25	Yes	No	Transmitter frequency
38	26	No	Yes	Noise statistics for each frequency
39	27	Yes	Yes	Metal compensation
40	28	Yes	No	Antenna size

To send the CHANGE VALUE command, the CHANGE VALUE command is positioned in the most significant byte of the first word to be output and the PARAMETERnumber is positioned in the least significant byte. Any PARAMETERvalues required fill up additional output words. The N+1 words sent to the SpacePad are packed as follows:

WORD#	Most Significant Byte	Least Significant Byte
1	CHANGE command = 50 hex	PARAMETERnumber
2	MSbyte of PARAMETERvalue 1	LSbyte of PARAMETERvalue 1
3	MSbyte of PARAMETERvalue 2	LSbyte of PARAMETERvalue 2
.	. .	
.	. .	
N+1	MSbyte of PARAMETERvalue N	LSbyte of PARAMETERvalue N

If the PARAMETERdata is numeric, it must be in 2's complement format.

If the CHANGE VALUE applies to a specific receiver (see the RECEIVER# command for a list of commands that must be sent to a specific receiver) then the CHANGE VALUE command takes the form of:

WORD #	Most Significant Byte	Least Significant Byte
1	RECEIVER# command	CHANGE VALUE command = 50 hex
2	PARAMETERnumber	MSbyte of PARAMETERvalue 1
3	LSbyte of PARAMETERvalue 1	MSbyte of PARAMETERvalue 2
4	LSbyte of PARAMETERvalue 2	MSbyte of PARAMETERvalue 3
.	. .	
.	. .	
N+2	LSbyte of PARAMETERvalue N	0

The EXAMINE VALUE command may be issued to the SpacePad in the following one word arrangement:

WORD #	Most Significant Byte	Least Significant Byte
1	EXAMINE command = 4F hex	PARAMETERnumber

or

If you are EXAMINING a specific receiver value:

WORD #	Most Significant Byte	Least Significant Byte
1	RECEIVER# command	EXAMINE command = 4F hex
2	PARAMETERnumber	0

The PARAMETERdata returned is returned as words. If the PARAMETERdata is numeric, it is in 2's complement format. The PARAMETERdata received does not contain 'phasing' bits. If the PARAMETER data is a byte it is positioned in the MSbyte position of the word returned. The PARAMETERdata value, content and scaling depend on the particular parameter requested. See the following discussion of each parameter.

SpacePad SYSTEM/RECEIVER STATUS

When PARAMETERnumber = 0, during EXAMINE, the SpacePad returns a word which indicates the operating mode of the specified RECEIVER# and the system. The bit assignments for the one word response are:

B15	1 if SpacePad is a master SpacePad 0 if SpacePad is a slave SpacePad
B14	1 if SpacePad has been initialized 0 if SpacePad has not been initialized
B13	1 if an error has been detected 0 if no error is detected
B12	0 not used
B11,B10,B9,B8	0 not used
B7	1 if the factory test and SpacePad commands are enabled 0 if only the SpacePad commands are enabled
B6	0 not used
B5	1 if the SpacePad is in SLEEP mode 0 if the SpacePad is in RUN mode
B4,B3,B2,B1	0001 if POSITION outputs selected 0010 if ANGLE outputs selected 0011 if MATRIX outputs selected 0100 if POSITION/ANGLE outputs selected 0101 if POSITION/MATRIX outputs selected 0110 factory use only 0111 if QUATERNION outputs selected 1000 if POSITION/QUATERNION outputs selected
B0	0 if POINT mode selected 1 if STREAM mode selected

SOFTWARE REVISION NUMBER

When PARAMETERnumber = 1, during EXAMINE, the SpacePad returns one word giving the revision number of the software located in the SpacePad's PROM memory. The revision number in base 10 is expressed as III.FFF where III is the integer part of the revision number and FFF is the fractional part. For example, if the revision number is 2.13 then III=2 and FFF=13. The value of the most significant byte returned is III. The value of the least significant byte returned is FFF. Thus, in the above example the value returned in the most significant byte would have been 02 hex and the value of the least significant byte would have been 0D hex. If the revision number were 3.1 then the bytes would be 03 and 01 hex.

SpacePad COMPUTER CRYSTAL SPEED

When PARAMETERnumber = 2, during EXAMINE, the SpacePad returns one word giving the speed of its computer's crystal in megahertz (MHz). The most significant byte of the speed word is equal to zero, and the base 10 value of the least significant byte represents the speed of the crystal. For example, if the least significant byte = 28 hex, the crystal speed is 40 MHz.

FILTER ON/OFF STATUS

When PARAMETERnumber = 4, during EXAMINE, the SpacePad returns a code that tells you if the software filter is turned on or off for the specified RECEIVER#. The word returned has the following value:

Filter on/off = 0 = off, no DC filtering is being used
= 1 = on, DC filtering is being used.

To CHANGE the FILTER ON/OFF STATUS of the receiver specified by RECEIVER# send the SpacePad one word of PARAMETERdata as defined above.

The DC filter refers to an adaptive, infinite impulse response (IIR) lowpass filter applied to the receiver data to eliminate high frequency noise. Generally, this filter is always required in the system unless your application can work with noisy outputs. When the DC filter is turned on, you can modify its noise/lag characteristics by changing ALPHA_MIN, ALPHA_MAX and Vm.

DC FILTER CONSTANT TABLE ALPHA_MIN

When PARAMETERnumber = 5, during EXAMINE, the SpacePad returns 7 words which define the lower end of the adaptive range that filter constant ALPHA_MIN can assume in the DC filter as a function of receiver to transmitter separation. When ALPHA_MIN = 0 hex, the DC filter will provide an infinite amount of filtering (the outputs will never change even if you move the receiver). When ALPHA_MIN = 0.99996 = 7FFF hex, the DC filter will provide no filtering of the data.

The default values as a function of transmitter to receiver separation range are:

Range (inches)	ALPHA_MIN (decimal)
0 to 22	0.1 = 0CCC hex.
22 to 31	0.1
31 to 40	0.1
40 to 51	0.1
51 to 61	0.1
61 +	0.1
61 +	0.1

To CHANGE ALPHA_MIN, send the SpacePad seven words of PARAMETERdata corresponding to the ALPHA_MIN table defined above. At the shorter ranges you may want to increase ALPHA_MIN to obtain less lag while at longer ranges you may want to decrease ALPHA_MIN to provide more filtering (less noise/more lag). If you decrease the value below 0.008, the output noise will actually increase due to loss of mathematical precision. ALPHA_MIN must always be less than ALPHA_MAX.

ERROR CODE

When PARAMETERnumber = 10, during EXAMINE, the SpacePad will output a one word error code. The error codes are defined in section 7.0. The error code is reset to all '0's after it has been read.

DC FILTER TABLE Vm

When PARAMETERnumber=12, during EXAMINE, the SpacePad returns a 7 word table, or during CHANGE, the user sends to the SpacePad a 14 byte table representing the expected noise that the DC filter will measure. By changing the table values the user can increase or decrease the DC filter's lag as a function of receiver range from the transmitter.

The DC filter is adaptive in that it tries to reduce the amount of low pass filtering in the SpacePad as it detects translation or rotation rates in the SpacePad's receiver. Reducing the amount of filtering results in less filter lag. Unfortunately electrical noise in the environment, when measured by the receiver, also makes it look like the receiver is undergoing a translation and rotation. As the receiver moves farther and farther away from the transmitter, the amount of noise measured by the receiver appears to increase because the measured transmitted signal level is decreasing and the receiver amplifier gain is increasing. In order to decide if the amount of filtering should be reduced, the SpacePad has to know if the measured rate is a real receiver rate due to movement or a false rate due to noise. the SpacePad gets this knowledge by the user specifying what the expected noise levels are in the operating environment as a function of distance from the transmitter. These noise levels are the 7 words that form the Vm table. The Vm values can range from 1 for almost no noise to 32767 for a lot of noise.

The default values as a function of transmitter to receiver separation range are:

Range (inches)	Vm (decimal)
0 to 22	4
22 to 31	4
31 to 40	4
40 to 51	4
51 to 61	4
61 +	4
61 +	4

As Vm increases with range so does the amount of filter lag. To reduce the amount of lag reduce the larger Vm values until the noise in the SpacePad's output is too large for your application.

DC FILTER CONSTANT TABLE ALPHA_MAX

When PARAMETERnumber = 13, during EXAMINE, the SpacePad returns 7 words (14 bytes) which define the upper end of the adaptive range that filter constant ALPHA_MAX can assume in the DC filter as a function of receiver to transmitter separation. When there is a fast motion of the receiver, the adaptive filter reduces the amount of filtering by increasing the ALPHA used in the filter. It will increase ALPHA only up to the limiting ALPHA_MAX value. By doing this, the lag in the filter is reduced during fast movements. When ALPHA_MAX = 0.99996 = 7FFF hex, the DC filter will provide no filtering of the data during fast movements.

The default values as a function of transmitter to receiver separation range are:

Range (inches)	ALPHA_MAX (decimal)
0 to 22	0.9 = 7333 hex.
22 to 31	0.9
31 to 40	0.9
40 to 51	0.9
51 to 61	0.9
61 +	0.9
61 +	0.9

To CHANGE ALPHA_MAX send the SpacePad seven words of PARAMETERdata corresponding to ALPHA_MAX. During CHANGE, you may want to decrease ALPHA_MAX to increase the amount of filtering if the SpacePad's outputs are too noisy during rapid receiver movement. ALPHA_MAX must always be greater than ALPHA_MIN.

SYSTEM MODEL IDENTIFICATION

When PARAMETERnumber = 15, during EXAMINE, the SpacePad returns 10 bytes in five words which will be an ASCII string whose first 8 bytes will be "SPACEPAD". The remaining bytes may be either ASCII spaces or some additional identification numbers in ASCII code.

XYZ REFERENCE FRAME

By default, the XYZ measurement frame is the reference frame defined by the physical orientation of the transmitter's XYZ axes even when the REFERENCE FRAME command has been used to specify a new reference frame for measuring orientation angles. When PARAMETERnumber = 17, during CHANGE, if the one word of PARAMETER DATA sent to the specified RECEIVER# is equal to one then the XYZ measurement frame will also correspond to the new reference frame defined by the REFERENCE FRAME command. When the PARAMETER DATA sent is a zero then the XYZ measurement frame reverts to the orientation of the transmitter's physical XYZ axes.

During EXAMINE, the SpacePad returns a word value of 0 or 1 to indicate that the XYZ measurement frame for the specified RECEIVER# is either the transmitter's physical axes or the frame specified by the REFERENCE FRAME command.

CONFIGURATION

When PARAMETERnumber = 33, during EXAMINE, the system returns 6 bytes in three words. The information passed in BYTE 2 is the RECEIVER CONFIGURATION data. RECEIVER CONFIGURATION is used to tell the SpacePad what receivers are assigned to what transmitters.

The bit definitions of the bytes are:

BYTE 1	Not used. Value = 0
BYTE 2	RECEIVER CONFIGURATION
B7	if 1, the Rx4 operates with Tx2 if 0, the Rx4 does not operate with Tx2
B6	if 1, the Rx4 operates with Tx1 if 0, the Rx4 does not operate with Tx1
B5	if 1, the Rx3 operates with Tx2 if 0, the Rx3 does not operate with Tx2
B4	if 1, the Rx3 operates with Tx1 if 0, the Rx3 does not operate with Tx1

B3	if 1, the Rx2 operates with Tx2 if 0, the Rx2 does not operate with Tx2
B2	if 1, the Rx2 operates with Tx1 if 0, the Rx2 does not operate with Tx1
B1	if 1, the Rx1 operates with Tx2 if 0, the Rx1 does not operate with Tx2
B0	if 1, the Rx1 operates with Tx1 if 0, the Rx1 does not operate with Tx1

BYTE 3,4,5,6 Not used. All = 0

The configuration bytes are packed in the words per:

Word #	Most Significant Byte	Least Significant Byte
1	BYTE 1	BYTE 2
2	BYTE 3	BYTE 4
3	BYTE 5	BYTE 6

To CHANGE the CONFIGURATION, send to the SpacePad three words of PARAMETERdata as defined above. As an example, suppose you want to configure the SpacePad to operate all 4 receivers with transmitter 1. For this configuration the following information would be sent:

BYTE 1	=	0	
BYTE 2	=	01010101	receivers Rx1,2,3,4 assigned to transmitter Tx1
BYTE 3	=	0	
BYTE 4	=	0	
BYTE 5	=	0	
BYTE 6	=	0	

If an illegal configuration is sent to the SpacePad then the SpacePad resets the configuration for the receiver in question to the power-up configuration defaults defined in section 5.4. An illegal configuration would include assigning the same receiver to multiple transmitters.

Because the new configuration sent with the CHANGE CONFIGURATION command does not take effect until the start of the next measurement cycle, any EXAMINE CONFIGURATION command issued less than 8 to 33 milliseconds after sending a CHANGE CONFIGURATION command will not return the new configuration data.

GROUP MODE

When PARAMETERnumber = 35, during EXAMINE VALUE, the SpacePad will respond with one word of data indicating if the SpacePad is in GROUP MODE. If the data is a 1 then the SpacePad is in GROUP MODE and if the data is 0 the SpacePad is not is GROUP MODE. When in GROUP MODE, in response to the POINT or STREAM commands, the SpacePad will send data records from all configured receivers. Information is output from the SpacePad with the smallest address first. The last word of the data record contains the address of the receiver. Each receiver can be in a different data output format if desired. For example, if 3 receivers are being used and the first is configured to output POSITION data only (3 data words plus 1 address word) and the other two are configured to output POSITION/ANGLES data (6 data words plus 1 address word) then the SpacePad will respond with 18 words when a data request is made.

During a CHANGE VALUE command, the host must send one word equal to a 1 to enable GROUP MODE or a 0 to disable GROUP MODE.

FREQUENCY

The frequency at which the transmitter generates magnetic fields can be examined and changed under software control. You would change the SpacePad's operating frequency to reduce the amount of noise in the receiver's position and orientation outputs. The noise may be the result of a nearby computer display or another SpacePad system. Use the NOISE STATISTICS command to select a quite operating frequency.

When PARAMETERnumber = 37, during EXAMINE VALUE, the SpacePad will respond with one word of data indicating which frequency the system is operating at. The word returned will have a value of from 1 to 8. The powerup default frequency number is 6.

When PARAMETERnumber = 37 during CHANGE VALUE, send the SpacePad one word of PARAMETERvalue data with a value ranging from 1 to 8 to select the desired frequency number. If you have a master/slave configuration, send the change frequency command only to the master. It takes approximately two seconds for the SpacePad to change frequency. During this changing period SpacePad is not computing new position and orientation data so any data requests will return data that does not change.

NOISE STATISTICS

When PARAMETERnumber = 38, during EXAMINE VALUE, the SpacePad will respond with eight words of data proportional to the amount of electromagnetic noise it senses in the operating environment at each of its eight operating frequencies. The first word returned corresponds to the noise at frequency 1, etc.. The larger the noise number, the larger the amount of noise in the receiver's position and orientation measurements. A rough indication of the amount of noise you would see in the elevation angle can be obtained by dividing the noise number by ten. The resulting number is the peak to peak noise in degrees that you would see if SpacePad was operated with its software controllable filters turned off. If you have a master/slave configuration, send the noise statistics command only to the master.

When the NOISE STATISTICS EXAMINE VALUE command is sent to the SpacePad, the transmitter is shut off and normal system operation stopped for approximately 20 seconds while receiver noise is measured. When the noise measurements are ready to be read, B1 of the data status word will be set to one. If no RECEIVER# preface command is used, noise is measured using receiver Rx1.

METAL COMPENSATION

If the SpacePad's transmitter coils are located near a large amount of metal then the resulting position and orientation measurements may have errors that are too large for the application. If the transmitter is located in a game pod the metal may take the form of steel beams used to build the pod. If the transmitter is located on the floor the metal may be the steel rebar rods used to reinforce the concrete floor when it was made. Using the RECEIVER # command with the CHANGE / EXAMINE METAL COMPENSATION command allows you to quickly and easily correct position and orientation angle errors for this metal.

When PARAMETERnumber = 39, during EXAMINE VALUE, the SpacePad will return two metal compensation words. The first word is call the parallel movement correction and the second the perpendicular movement correction. Where parallel and perpendicular refer to receiver movements parallel and perpendicular to the plane of the transmitter coil.

When PARAMETERnumber = 39 during CHANGE VALUE, send the SpacePad two words of PARAMETERvalue data. The first word being the parallel movement correction and the second the perpendicular movement correction. The parallel correction is a 2's complement positive number between 0 and 7FFF. The perpendicular correction is a 2's complement signed number between 8000 and 7FFF. The correction words are set to zero if there is no metal in the environment.

To determine the parallel movement correction, locate the receiver at a nominal usage Z distance from the transmitter. Translate the receiver at this constant Z value in the ± Y and/or ±X directions increasing the parallel movement correction until the SpacePad's Z output value is approximately constant. See figure 7 for a definition of the X,Y,Z directions. Typically, the Z value will droop off (reduce) as you move farther from the centerline of the transmitter when there is metal present. This calibration requires no fixtures, you simply hold a receiver in your hand and move it back and forth, adjusting the parallel correction until the game pod graphics image looks good.

To determine the perpendicular movement correction, locate the receiver at a nominal usage Z distance from the transmitter with X and Y approximately zero. Determine the true Z distance by using a tape measure or yard/meter stick. Increase or decrease the perpendicular correction until the SpacePad measured Z approximately agrees with the true Z location of the receiver. The perpendicular correction can be computed approximately from:

$$PC = \frac{Z_{true} - Z_{sp0}}{Z_{true}} * 32767$$

where:

PC = perpendicular correction base 10 integer
Z_{SP0}= SpacePad's Z output value when PC=0
Z_{true}= True Z distance of receiver from transmitter

The powerup default values are set to compensate for metal in a typical standup game pod.

ANTENNA SIZE

When PARAMETERnumber = 40 during EXAMINE, the SpacePad returns one word giving the antenna size L as defined in Figure 2. To convert L to inches multiply the returned word by 144. / 32767. To CHANGE the antenna size send the SpacePad one word of integer data equal to L * 32767. / 144. where L is in inches and less than or equal to 144 inches.

NOTE: IF YOU ARE CHANGING YOUR ANTENNA SIZE BY MORE THAN ±10% CONSULT WITH ASCENSION ON COMPONENT CHANGES THAT WILL BE REQUIRED ON THE TRANSMITTER INTERFACE CARD.

If you need to compensate for metal near the transmitter than use the CHANGE VALUE METAL COMPENSATION command after you have changed the ANTENNA SIZE.

FACTORY TEST

FACTORY TEST

	ASCII	HEX	DECIMAL	BINARY
Command Byte	z	7A	122	01111010

The FACTORY TEST mode is intended for factory diagnostic use only. The user should not use this command.

HEMISPHERE

HEMISPHERE

	ASCII	HEX	DECIMAL	BINARY
Command Byte	L	4C	76	01001100

Command Data word	HEMI

The shape of the magnetic field transmitted by the SpacePad is symmetrical about the plane of the transmitter. This symmetry leads to an ambiguity in determining the receiver's Z position and azimuth angle, therefore you must specify which side of the transmitter the receiver is operating on.

The HEMISPHERE command is used to tell the SpacePad on which side of the transmitter the receiver is operating. If the receiver is operating on the negative Z side (see figure 7) then specify the upper hemisphere. If operating of the positive Z side specify the lower hemisphere.

The one Command Data word, sent immediately after the HEMISPHERE command is:

Hemisphere	HEMI (hex)
Upper(-Z)	0C01
Lower(+Z)	0C00

LOAD MAP

LOAD MAP

	ASCII	HEX	DECIMAL	BINARY
Command Byte	E	45	69	01000101

Command Data words	MAP DATA

If the position and angular accuracy of the SpacePad needs to be improved over and above the improvements available from the CHANGE VALUE METAL COMPENSATION command then the LOAD MAP command allows you to load tables of position and angle corrections for each transmitter. If the corrections are the same for both transmitters then the same table must be sent to both transmitters. After loading the tables of corrections use the MAP ON command to apply the corrections to a particular receiver.

To load the tables use the following protocol:

1. The SpacePad must not be in STREAM mode during the loading.
2. Any responses from previously issued commands must be read prior to using the LOAD MAP command.
3. Follow standard ISA handshake protocol when sending each word of the table.

The data words you send to the SpacePad are:

Word #	Contents
1	4500 hex = LOAD MAP COMMAND in most significant byte
2	The transmitter number that the corrections apply to. i.e. 0001 or 0002
3	Nz = the number of mapping levels in the Z direction in the LSbyte. 0001 to 0003

4 to 3+Nz	Nz words with the values being the Z value of each mapping level.
4+Nz	Nx = the number of mapping levels in the X direction in the LSbyte. 0001 to 0007.
5+Nz to 4+Nz+Nx	Nx words with the values being the X value of each mapping level.
5+Nz+Nx	Ny = the number of mapping levels in the Y direction in the LSbyte. 0001 to 0007.
6+Nz+Nx to 5+Nz+Nx+Ny	Ny words with the values being the Y value of each mapping level.
6+Nz+Nx+Ny to 6+Nz+Nx+Ny+ 6*Nz*Nx*Ny	6 tables of corrections: dX,dY,dZ,dAZIM,dELEV,dROLL, each containing Nz*Nx*Ny words.

The correction tables are generated by:

1. Dividing the volume of space where the receivers will move into several levels in each dimension to form a three dimensional grid in the Z, X and Y directions. The number of levels can vary but can not exceed 3 levels in the Z direction and 7 levels in each of the X and Y directions.

2. Moving the SpacePad's receiver to each point in the grid work. At each of these measuring points the orientation of the SpacePad's receiver is held in the direction you want defined as azimuth =0, elevation=0 and roll=0. The SpacePad's position and angles are then output. This output is defined as the measured data.

3. At each of these points compute:

dX=Xmeasured - Xtrue
dY=Ymeasured - Ytrue
dZ= Zmeasured - Ztrue
dAZIM = AZIMmeasured
dELEV =ELEVmeasured
dROLL = ROLLmeasured

4. Scale the position data so that 144 inches represents full scale and scale the angular data so that 180 degrees represents full scale. i.e. dX scaled = dX inches * 32768/144. and dAZIM scaled = dAZIM degrees *32768/180.

5. Build 6 tables of dX,dY,dZ,dAZIM,dELEV,dROLL for sending to the SpacePad. Where each table is built with Y varying the fastest then X then Z. The dX table would look like:

dX(1) = Xmeasured at Z(1), X(1), Y(1) - Xtrue(1)
dX(2) = Xmeasured at Z(1), X(1), Y(2) - Xtrue(1)
.
.
dX(Ny) = Xmeasured at Z(1), X(1), Y(Ny) - Xtrue(1)
dX(Ny+1) = Xmeasured at Z(1), X(2), Y(1) - Xtrue(2)
.
.
dX(2*Ny) = Xmeasured at Z(1), X(2), Y(Ny) - Xtrue(2)
.
.
dX(Nx*Ny) = Xmeasured at Z(1), X(Nx), Y(Ny) - Xtrue(Nx)
dX(Nx*Ny+1) = Xmeasured at Z(2), X(1), Y(1) - Xtrue(1)
.
.
dX(Nz*Nx*Ny) = Xmeasured at Z(Nz), X(Nx), Y(Ny) - Xtrue(Nx)

MAP ON/OFF

MAP ON/OFF

	ASCII	HEX	DECIMAL	BINARY
Command Byte	D	44	68	01000100

Command Data word	ON/OFF

The MAP ON/OFF command turns ON (enables) or OFF (disables) any position and angle error correction maps that have been loaded with the LOAD MAP command.

The command data word ON/OFF has the value of 0001 hex to turn the map ON and 0000 to turn the map OFF.

This command uses the RECEIVER# preface command to direct the error corrections to a particular receiver. If no RECEIVER# preface is used the error corrections are applied to Rx1.

Do not use this command unless a map has been loaded.

When used with the RECEIVER# command to direct the MAP ON/OFF command to a particular receiver, the sequence of output words to the SpacePad takes the following form:

WORD #	Most Significant Byte	Least Significant Byte
1	RECEIVER# command	MAP ON/OFF command = 44
2	00	ON/OFF

MATRIX

MATRIX

	ASCII	HEX	DECIMAL	BINARY
Command Byte	X	58	88	01011000

The MATRIX mode outputs the 9 elements of the rotation matrix that define the orientation of the receiver's X, Y, and Z axes with respect to the transmitter's X, Y, and Z axes. If you want a three-dimensional image to follow the rotation of the receiver, you must multiply your image coordinates by this output matrix.

The nine elements of the output matrix are defined generically by:

M(1,1)	M(1,2)	M(1,3)
M(2,1)	M(2,2)	M(2,3)
M(3,1)	M(3,2)	M(3,3)

Or in terms of the rotation angles about each axis
where Z=Zang, Y=Yang and X=Xang:

COS(Y)*COS(Z)	COS(Y)*SIN(Z)	-SIN(Y)
-COS(X)*SIN(Z) +SIN(X)*SIN(Y)*COS(Z)	COS(X)*COS(Z) +SIN(X)*SIN(Y)*SIN(Z)	SIN(X)*COS(Y)
SIN(X)*SIN(Z) +COS(X)*SIN(Y)*COS(Z)	-SIN(X)*COS(Z) +COS(X)*SIN(Y)*SIN(Z)	COS(X)*COS(Y)

Or in Euler angle notation, where R=roll, E=elevation, A=azimuth:

COS(E)*COS(A)	COS(E)*SIN(A)	-SIN(E)
-COS(R)*SIN(A) +SIN(R)*SIN(E)*COS(A)	COS(R)*COS(A) +SIN(R)*SIN(E)*SIN(A)	SIN(R)*COS(E)
SIN(R)*SIN(A) +COS(R)*SIN(E)*COS(A)	-SIN(R)*COS(A) +COS(R)*SIN(E)*SIN(A)	COS(R)*COS(E)

The 9 word output record is in the following order:

WORD #	MATRIX ELEMENT
1	M(1,1)
2	M(2,1)
3	M(3,1)
4	M(1,2)
5	M(2,2)
6	M(3,2)
7	M(1,3)
8	M(2,3)
9	M(3,3)

The matrix elements take values between the binary equivalents of +.99996 and -1.0. Element scaling is +.99996 = 7FFF hex, 0 = 0 hex, and -1.0 = 8000 hex.

Matrix information is 0 when receiver saturation occurs.

OUTPUT BUFFER CLEAR

OUTPUT BUFFER CLEAR

	ASCII	HEX	DECIMAL	BINARY
Command Byte	f	66	102	01100110

The OUTPUT BUFFER CLEAR command stops any data that is in the process of being output and clears any data in the output buffers. If STREAM mode is enabled this command disables STREAM mode.

To use the OUTPUT BUFFER CLEAR command:

1. Send the command.

2. Wait for the TDR bit to go high in the port at base address + 2. This wait may be as long as 20 microseconds in a standalone or master configuration. In a slave the wait could be as long as 300 microseconds.

3. Read one word from the input port at base address + 0 and throw the word away to clear the port. In reading this word you do not have to wait for the RDR bit to go high. This is the only command where you do not have to wait for the RDR bit to go high before reading a port.

The SpacePad is now ready to accept new commands from the user.

POINT

POINT

	ASCII	HEX	DECIMAL	BINARY
Command Byte	B	42	66	01000010

In the POINT mode, the SpacePad sends one data record each time it receives the B Command Byte. When in GROUP MODE, the SpacePad will output a record for each configured receiver(see EXAMINE/CHANGE parameter number 35). Remember, when GROUP MODE is enabled an extra word containing the receivers address is added to the end of each data record.

If you issue the POINT command immediately after you have changed the output format with an ANGLES, MATRIX, etc. command, you will receive zero's for the data in the new format for up to 8 milliseconds if a single receiver system or up to 32 milliseconds for a four receiver system.

POSITION

POSITION

	ASCII	HEX	DECIMAL	BINARY
Command Byte	V	56	86	01010110

In the POSITION mode, the SpacePad outputs the X, Y, and Z positional coordinates of the receiver with respect to the transmitter.

The 3 word output record is in the following order:

WORD #	POSITION ELEMENT
1	X
2	Y
3	Z

The X, Y, and Z values may vary between the binary equivalent of + / - MAX inches. By default, MAX = 144 inches. The positive X, Y, and Z directions are shown in Figure 7.

Scaling of each position coordinate is full scale = MAX inches. That is, +MAX = 7FFF hex, 0 = 0 hex, -MAX = 8000 hex. Since the maximum range (Range =square root(X**2+Y**2+Z**2)) from the transmitter to the receiver is limited to MAX inches, only one of the X, Y, or Z coordinates may reach its full scale value. Once a full scale value is reached, the positional coordinates no longer reflect the correct position of the receiver.

POSITION/ANGLES

POSITION/ANGLES

	ASCII	HEX	DECIMAL	BINARY
Command Byte	Y	59	89	01011001

In the POSITION/ANGLES mode, the outputs from the POSITION and ANGLES modes are combined into one record.

The 6 word output record is in the following order:

WORD #	PARAMETER
1	X
2	Y
3	Z
4	AZIMUTH
5	ELEVATION
6	ROLL

The scaling of all angles is full scale = 180 degrees. That is, +179.99 deg = 7FFF hex, 0 deg = 0 hex, -180.00 deg = 8000 hex.

Scaling of each position coordinate is full scale = 144 inches. That is, +144 = 7FFF hex, 0 = 0 hex, -144 = 8000 hex.

POSITION/MATRIX

POSITION/MATRIX

	ASCII	HEX	DECIMAL	BINARY
Command Byte	Z	5A	90	01011010

In the POSITION/MATRIX mode, the outputs from the POSITION and MATRIX modes are combined into one record.

The 12 word output record is in the following order:

WORD #	PARAMETER
1	X
2	Y
3	Z
4	M(1,1)
5	M(2,1)
6	M(3,1)
7	M(1,2)
8	M(2,2)
9	M(3,2)
10	M(1,3)
11	M(2,3)
12	M(3,3)

Number ranges and scaling are the same as for the POSITION mode and the MATRIX mode.

POSITION/QUATERNION

POSITION/QUATERNION

	ASCII	HEX	DECIMAL	BINARY
Command Byte	]	5D	93	01011101

In the POSITION/QUATERNION mode, the SpacePad outputs the X, Y, and Z position and the four quaternion parameters, q_0, q_1, q_2, and q_3, which describe the orientation of the receiver with respect to the transmitter.

The 7 word output record is in the following order:

WORD #	PARAMETER
1	X
2	Y
3	Z
4	q_0
5	q_1
6	q_2
7	q_3

Scaling of each position coordinate is full scale = MAX inches. That is, +MAX = 7FFF hex, 0 = 0 hex, -MAX = 8000 hex. Where MAX takes on the value of 144 inches. Scaling of the quaternions is full scale = +.99996 = 7FFF hex, 0 = 0 hex, and -1.0 = 8000 hex.

QUATERNION

QUATERNION

	ASCII	HEX	DECIMAL	BINARY
Command Byte	\	5C	92	01011100

In the QUATERNION mode, the SpacePad outputs the four quaternion parameters that describe the orientation of the receiver with respect to the transmitter. The quaternions, q_0, q_1, q_2, and q_3, where q_0 is the scalar component, have been extracted from the MATRIX output using the algorithm described in "Quaternion from Rotation Matrix" by Stanley W. Shepperd, Journal of Guidance and Control, Vol. 1, May-June 1978, pp. 223-4.

The 4 word output record is in the following order:

WORD #	PARAMETER
1	q_0
2	q_1
3	q_2
4	q_3

Scaling of the quaternions is full scale = +.99996 = 7FFF hex, 0 = 0 hex, and -1.0 = 8000 hex.

RECEIVER#

RECEIVER#

	HEX	DECIMAL	BINARY
Command Byte	F0	240	11110000 + RECEIVER ADDR

The RECEIVER# command allows the host computer to communicate with any specified receiver. The 1 byte RECEIVER# preface is always positioned in the most significant byte of the output word and has the following format: Hex command value = F0 + destination receiver address (ie. Rx2 would be F2)

Valid receiver number commands are F1, F2, F3 and F4. If F0 is sent or no RECEIVER# preface command is used, the command is sent to receiver Rx1. The RECEIVER# command is a 1 byte preface to each of the following commands:

ANGLES
ANGLE ALIGN
CHANGE / EXAMINE VALUE
- system/receiver status
- filter on/off status
- xyz reference frame
- noise statistics
- metal compensation

HEMISPHERE
MAP ON/OFF
MATRIX
POINT
POSITION
POSITION/ANGLES
POSITION/MATRIX
POSITION/QUATERNION
QUATERNION
RECEIVER OFFSET
REFERENCE FRAME
STREAM
STREAM STOP

See ANGLE ALIGN, REFERENCE FRAME and CHANGE / EXAMINE VALUE commands in this section for examples of using the RECEIVER# command.

RECEIVER OFFSET

RECEIVER OFFSET

	ASCII	HEX	DECIMAL	BINARY
Command Byte	K	4B	75	01001011

Command Data	Xoffset	Yoffset	Zoffset

By default the SpacePad's position and orientation outputs are the actual position and orientation of the receiver with respect to the transmitter. The RECEIVER OFFSET command, used in conjunction with the ANGLE ALIGN command, allows the SpacePad to output the position and orientation of an object other than the receiver. This command is useful, for example, if you have the receiver mounted say vertically in the hand grip of a gun but want your game to know the location of the end of the gun barrel and the orientation of the gun barrel with respect to the transmitter reference frame. This example is illustrated in Figure 8.

While holding the gun in the orientation that you want SpacePad to output the equivalent of zero degrees of azimuth, elevation and roll record the actual angle outputs from the SpacePad system. Using the ANGLE ALIGN command, send these values to the SpacePad. The angle outputs from the SpacePad should now be zero. If the outputs did not go to zero most likely you had some "old" ANGLE ALIGN values in the SpacePad. While holding the gun in this zero orientation, measure with a ruler the X, Y, Z distances from the center of the receiver to the location that you want SpacePad coordinates from. Make these measurements in the transmitter reference frame. These measurements are the Xoffset, Yoffset and Zoffset command data that you must send with the RECEIVER OFFSET command. For the geometry shown in this example the Xoffset will be negative and the Zoffset will be positive. Yoffset, not shown in Figure 8, is similarly defined orthogonal to the X and Z reference frame directions.

If you measured the offsets in inches, divide by 144 inches and multiply by 32768 to get the decimal integer value to send as command data with the RECEIVER OFFSET command.

When used with the RECEIVER# command to direct the offsets to a particular receiver, the sequence of output words to the SpacePad would take the following form:

WORD #	Most Significant Byte	Least Significant Byte
1	RECEIVER# command	RECEIVER OFFSET command = 4B
2	MSbyte Xoffset	LSbyte Xoffset
3	MSbyte Yoffset	LSbyte Yoffset
4	MSbyte Zoffset	LSbyte Zoffset

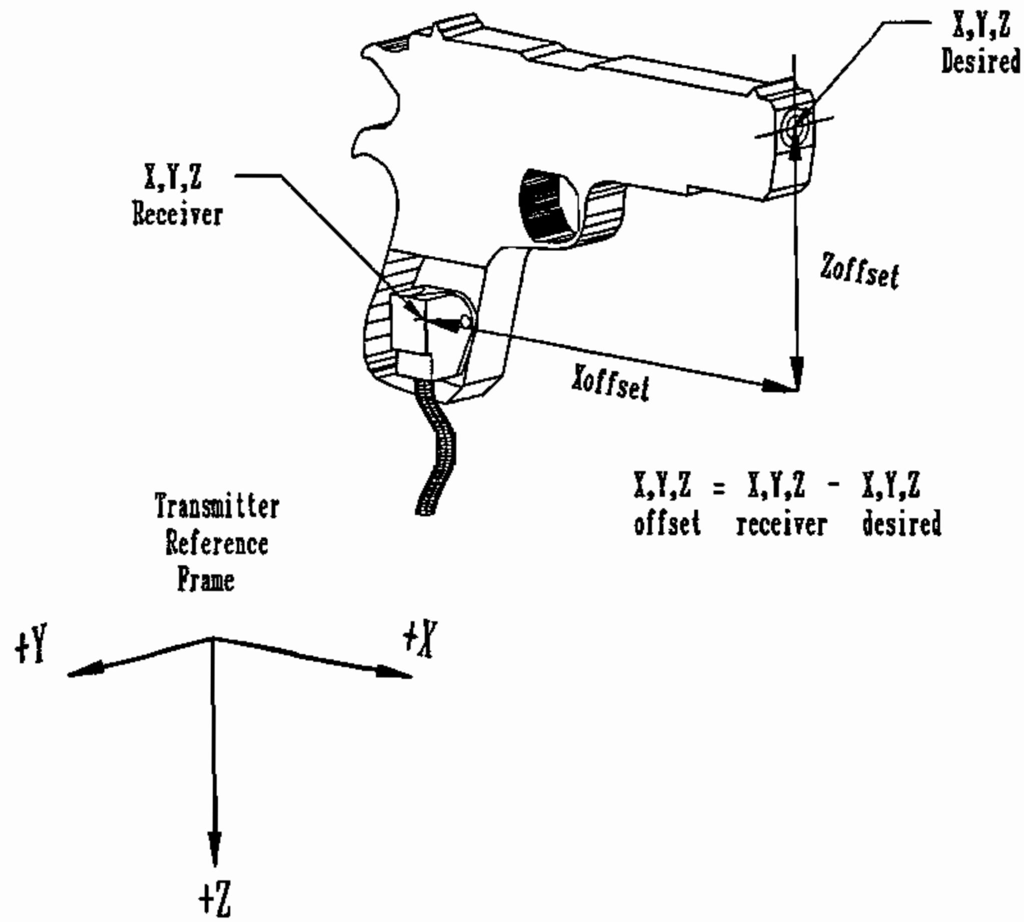


Figure 8. Receiver Offsets Defined

REFERENCE FRAME

REFERENCE FRAME

	ASCII	HEX	DECIMAL	BINARY
Command Byte	H	48	72	01001000

Command Data	Sin(Z)	Cos(Z)	Sin(Y)	Cos(Y)	Sin(X)	Cos(X)
or	Sin(A)	Cos(A)	Sin(E)	Cos(E)	Sin(R)	Cos(R)

By default, the SpacePad's reference frame is defined by the transmitter's physical X, Y, and Z axes. In some applications, it may be desirable to have the orientation measured with respect to another reference frame. The REFERENCE FRAME command permits you to define a new reference frame by inputting the angles required to align the physical axes of the transmitter to the X, Y, and Z axes of the new reference frame. The alignment angles are defined as rotations about the Z, Y, and X axes of the transmitter. These angles are called Zang, Yang, and Xang or, in Euler angle nomenclature, azimuth, elevation, and roll.

The command sequence consists of a Command Byte and 12 Command Data bytes. The Command Data consists of the sines and cosines of the Zang (Z), Yang (Y), and Xang (X) alignment angles or, in Euler angle nomenclature, the azimuth (A), elevation (E), and roll (R) alignment angles.

Although the REFERENCE FRAME command will cause the SpacePad's output angles to change, it has no effect on the position outputs. If you want the SpacePad's XYZ position reference frame to also change with this command then you must first use the CHANGE / EXAMINE VALUE XYZ REFERENCE FRAME command.

If you immediately follow the REFERENCE FRAME command with a POINT or STREAM mode data request you may not see the effect of this command in the data returned for at least one measurement period (i.e. 8 to 33 milliseconds).

When used with the RECEIVER# command to direct the REFERENCE FRAME command to a particular receiver, the sequence of output words to the SpacePad would take the following form:

WORD #	Most Significant Byte	Least Significant Byte
1	RECEIVER# command	REFERENCE FRAME command = 48
2	MSbyte SIN(A)	LSbyte SIN(A)
3	MSbyte COS(A)	LSbyte COS(A)
4	MSbyte SIN(E)	LSbyte SIN(E)
5	MSbyte COS(E)	LSbyte COS(E)
6	MSbyte SIN(R)	LSbyte SIN(R)
7	MSbyte COS(R)	LSbyte COS(R)

The sine and cosine elements take values between the binary equivalents of +.99996 and -1.0.

Element scaling is +.99996 = 7FFF hex, 0 = 0 hex, and -1.0 = 8000 hex.

REPORT RATE

REPORT RATE

Measurement Rate Divisor Command	ASCII	HEX	DECIMAL	BINARY
1	Q	51	81	01010001
2	R	52	82	01010010
8	S	53	83	01010011
32	T	54	84	01010100

If you do not want a SpacePad data record output to your host computer every SpacePad measurement cycle when in STREAM mode then use the REPORT RATE command to change the output rate to every other cycle (R), every eight cycles (S) or every thirty-two cycles (T). If no REPORT RATE command is issued, transmission proceeds at the measurement rate by default.

RUN

RUN

	ASCII	HEX	DECIMAL	BINARY
Command Byte	F	46	70	01000110

The RUN command is issued to the SpacePad to restart the system after the SpacePad has been put to sleep with the SLEEP command. RUN does not reinitialize the system RAM memory, so any configuration or alignment data entered before the system went to SLEEP will be retained.

SLEEP SLEEP

	ASCII	HEX	DECIMAL	BINARY
Command Byte	G	47	71	01000111

The SLEEP command turns the transmitter off and halts the system. While asleep, the SpacePad will respond to data requests and mode changes but the data output will not change. To resume normal system operation, issue the RUN command.

STREAM

STREAM

	ASCII	HEX	DECIMAL	BINARY
Command Byte	@	40	64	01000000

In the STREAM mode, the SpacePad sends a data record to the host computer once every measurement cycle starting as soon as SpacePad has computed the position and orientation of the selected receiver. Data records will continue to be sent automatically until the host sends the STREAM STOP, POINT or OUTPUT BUFFER CLEAR commands. If you use the POINT command to stop the streaming then you will receive an additional data record in response to the POINT command. It is the user's responsibility to clear the SpacePad's data output port of any unread words after issuing the POINT command.

You can use the STREAM command to get streaming data from either one of the receivers or all of the receivers configured.

To get streaming data from one of the receivers use the STREAM command prefaced with the RECEIVER# command.

To get streaming data from all of the configured receivers first enable GROUP MODE then send the STREAM command with no RECEIVER# preface. Remember, when GROUP MODE is enabled an extra word containing the receiver's address is added to the end of each data record.

The SpacePad will output a single receiver record or group all records every 1/120 sec if one receiver is configured, every 1/60 sec if two receivers are configured, every 1/30 sec if four receivers are configured.

See REPORT RATE to change the rate at which records are transmitted during STREAM.

STREAM STOP

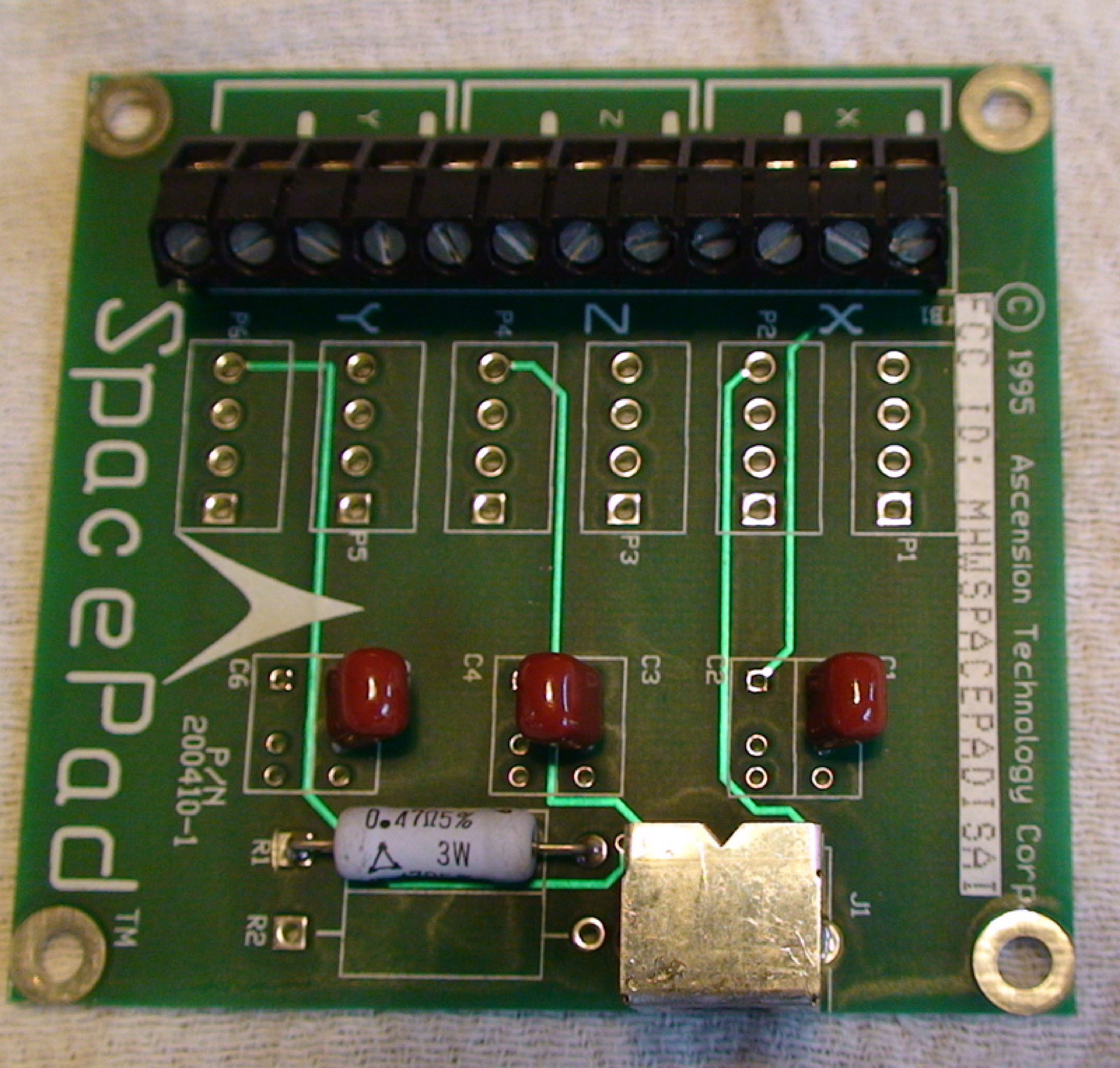
STREAM STOP

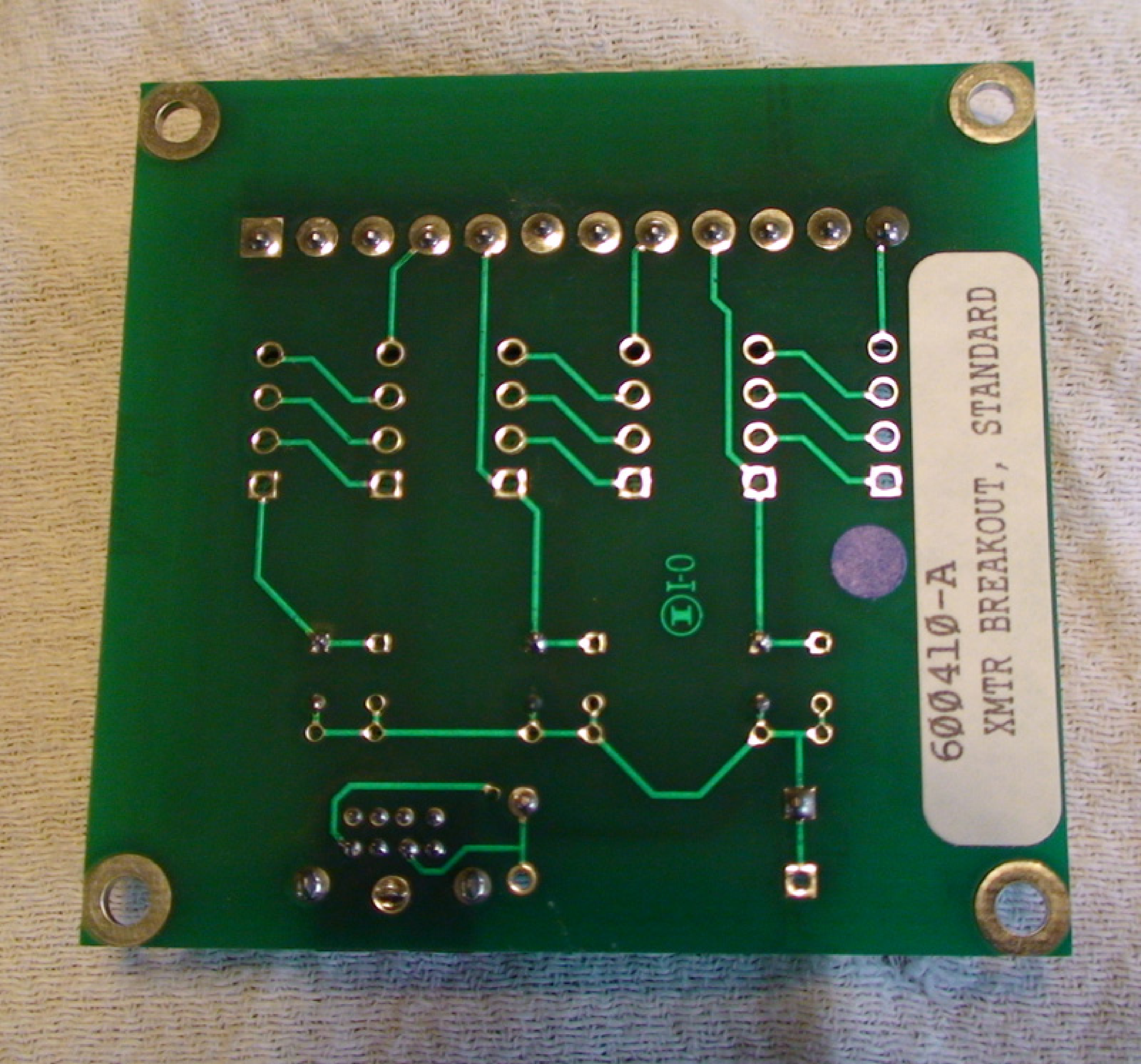
	ASCII	HEX	DECIMAL	BINARY
Command Byte	?	3F	63	00111111

STREAM STOP turns STREAM mode off after it completes the output of any in progress data record outputs.

It is the user's responsibility to clear the SpacePad's data output port of any unread words after issuing the STREAM STOP command. Even if the STREAM STOP command is issued after the last record is read you should still check the output port to make sure it is empty in case the next stream record started while you were sending the STREAM STOP command.

STREAM STOP is used with the RECEIVER# preface command to stop the streaming from a single receiver. STREAM STOP does not use the RECEIVER# command to stop GROUP streaming.


SpacePad
TM
Y
Z
X
P6
P5
P4
P3
P2
P1
TB1
C1
C2
C3
C4
C6
P/N
200410-1
0.47Ω5%
3W
R1
R2
J1
© 1995 Ascension Technology Corp.


600410-A
XMTR BREAKOUT, STANDARD