miniBIRD-II ™

POSITION AND ORIENTATION MEASUREMENT SYSTEM

INSTALLATION AND OPERATION GUIDE

910013-A Rev A
November 22, 1999

PO Box 527
Burlington, Vermont 05402 USA
(802) 893-6657

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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.

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at the user's expense.

Canadian Regulations

This digital apparatus does not exceed the Class A limits for radio noise emissions from digital apparatus set out in the Radio Interference Regulation of the Canadian Department of Communications.

Le present appareil numerique n'emet pas de bruits radioelectriques depassant les limites applicables aux appareils numeriques de la class A prescrites dans le Reglement sur le brouillage radioelectrique edicte par le ministere des Communications du Canada.

EC Declaration of Conformity
Issued by

Ascension Technology Corporation
PO Box 527
Burlington, VT 05402 USA
802-893-6657

Equipment Description: miniBIRD-II Model
miniBIRD-II Tracking System
5V @ 1.5A, 12V @ 1.5A
No -5V or -12V

Tested With: The miniBIRD-II passed all CE directives when using a P166 Gateway computer S.N. 0009029505

Year of Manufacture: 1999

Applicable Directives: 73/23/EEC, Low Voltage Directive
89/336/EEC, EMC Directive

Applicable Standards: EN 61010-1: 1993
Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use, General Requirements

EN 50081-1: 1992
Electromagnetic Compatibility - Generic Emission Standard, Residential, Commercial and Light Industry

EN 50082-1: 1997
Electromagnetic Compatibility - Generic Immunity Standard, Residential, Commercial and Light Industry

Authorized by: ____________________ **Date:** _________
Ernie Blood
President
Ascension Technology Corporation

CE Specifications

There are no fuse or user serviceable parts on the miniBIRD-II.

Modification or use of the equipment in any way that is not specified by Ascension Technology may impair the protection and accuracy provided by the equipment.

The lightning flash arrow symbol within an equilateral triangle is intended to alert the user to the presence of uninsulated “dangerous voltage” within the product’s enclosure. That voltage may constitute a risk of electric shock to persons.

The exclamation point within an equilateral triangle is intended to alert the user to the presence of important operating and maintenance (servicing) instructions in the appliance literature.

Equipment Maintenance:

1. Do not block the ventilation holes on the PC’s casing.

2. Do not expose the miniBIRD-II to rain or condensing moisture.

3. Keep the equipment away from extreme sources of heat.

TABLE OF CONTENTS

USER MANUAL REVISIONS

Manual Date	Rev	Changes
September 2, 1999		Initial release of the miniBIRD-II with 21.09 PLD.
November 22, 1999	A	Several text changes and improvements were done to the manual.

1.0 INTRODUCTION

The miniBIRD-II is a six degrees-of-freedom measuring device that measures the position and orientation of a small body-mounted sensor when located within ± 3 feet of its transmitter. The miniBIRD-II determines position and orientation by transmitting a pulsed DC magnetic field that is measured by the sensor. From the measured magnetic field characteristics, the sensor electronics card computes its position and orientation and makes this information available to the user over the host computer's ISA bus.

The miniBIRD-II consists of a single electronics card that is compatible with PC's and other computers with an ISA bus slot. A single transmitter and up to two sensors can plug into the miniBIRD-II circuit card. An additional transmitter may be added by the addition of a daughter board.

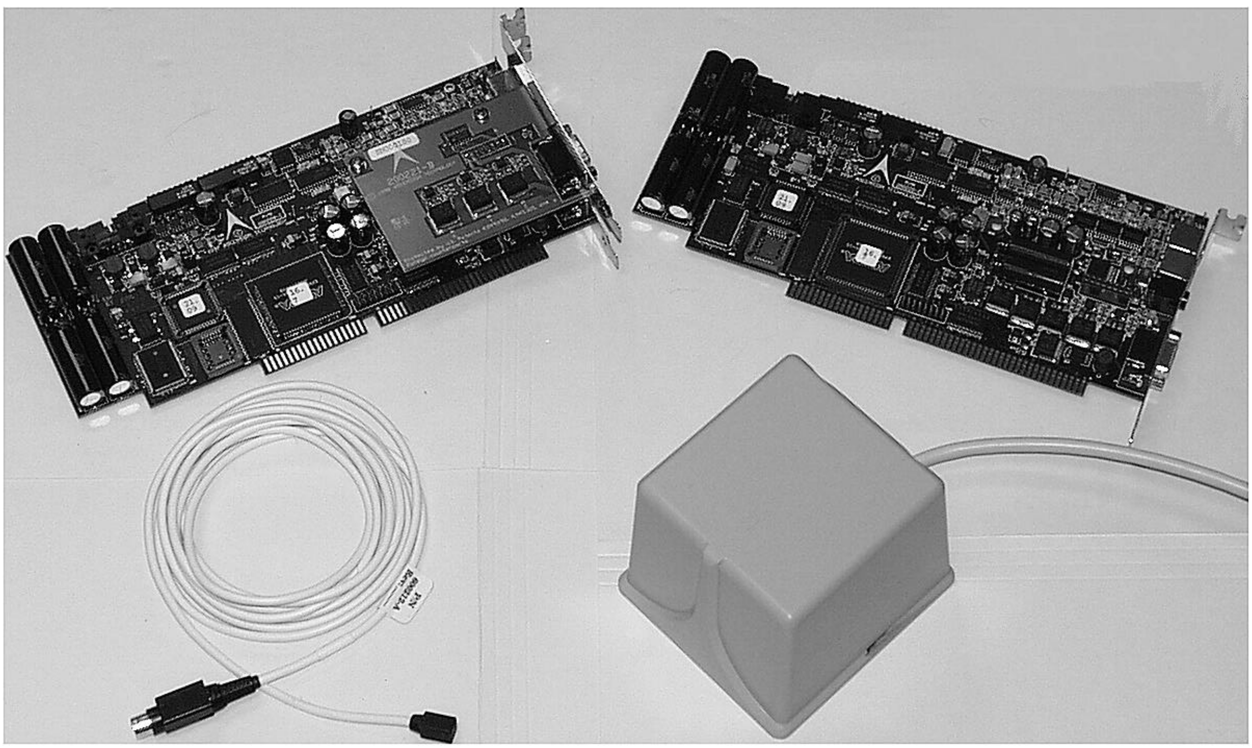
In addition to this manual the user can now receive on-line support and assistance at Ascension’s web site:

http://www.ascension-tech.com/support/troubleshoot/index.htm

2.0 INSTALLATION

The miniBIRD-II is shipped in one box containing:

1. One electronics unit
2. One or two transmitters
3. One or two sensors
4. Optional preassembled daughter board
5. One Installation and Operation Guide (This Manual)



If there are any discrepancies or the shipment is damaged, call Ascension Technology at (802) 893-6657 between the hours of 9 AM and 5 PM Eastern Standard Time or fax us at (802) 893-6659.

2.1 COMPONENT LOCATION

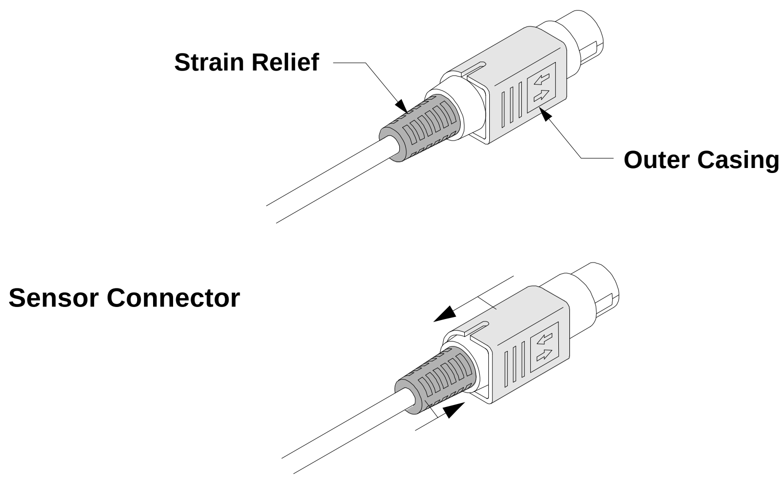
2.1.1 miniBIRD-II TRANSMITTER LOCATION. The transmitter should be mounted on a non-metallic surface such as wood or plastic, using non-metallic bolts or 300 series stainless steel bolts. If the transmitter is going to be mounted upside down, note that the two mounting holes are not strong enough to support the weight of the transmitter. Instead, the transmitter should be mounted using hardware or grooves to capture the flanges along both sides of the transmitter in addition to bolting through the two mounting holes. Do not mount the transmitter on the floor (concrete included), ceiling or walls because these all contain metal or may have large metal objects directly on their opposite side.

Because the transmitter generates magnetic fields, it may interfere with the computer's display, causing image bending, jitter or color distortion. With an unshielded commercial CRT-type display, the transmitter usually must be at least 12 inches away. With a shielded CRT, the transmitter can be closer.

2.1.2 SENSOR LOCATION. The sensor should also be mounted on a non-metallic surface such as wood or plastic, using non-metallic bolts or 300 series stainless steel bolts. It should not be located near power cords, power supplies, or other low frequency current generating devices. Their emanations will be picked up by the sensor and converted into noise on the output position and orientation measurements. The sensor will pick up noise when it is operated near a CRT-type display. The amount of noise will vary depending on the operating frequency of the CRT and the amount of shielding built into the CRT.

2.2 SENSOR INSERTION

Care must be taken when inserting or removing the sensor Mini-Din connector from the board. If the sensor connector is inserted or removed improperly, then permanent damage can occur to the mating board connector. The result is premature wear and failure of the locking ability, allowing the sensors to fall out.



When inserting the sensor Mini-Din connector the user must first pull back on the Outer Casing while holding on to the Strain Relief. Then push the sensor connector into the mating board connector. The sensor should easily slide into the board connector. If an audible click is heard when pushing the sensor in, the user did not pull back far enough on the Outer Casing.

When removing the sensor from the board, the user must pull back firmly on the Outer Casing. Then the sensor should easily slide out of the board connector.

2.3 SYSTEM ELECTRONICS CARD

2.3.1 CONFIGURING THE CARD. Before installing the miniBIRD-II card into the chassis, the user must configure the miniBIRD-II card. To configure the card do the following:

1. Set the ISA bus Base Address dip switch
2. Set the IRQ number jumper block
3. Set the configuration dip switch

The location of these switches and jumpers on the card are shown in Figure 1. The switch and jumper settings can be found in sections 2.3.1.1 through 2.3.1.3

W A R N I N G
The system electronics card contains static electricity sensitive components that may be damaged if you touch the card. As a precaution, always touch the metal chassis of the PC before touching any part of the card.

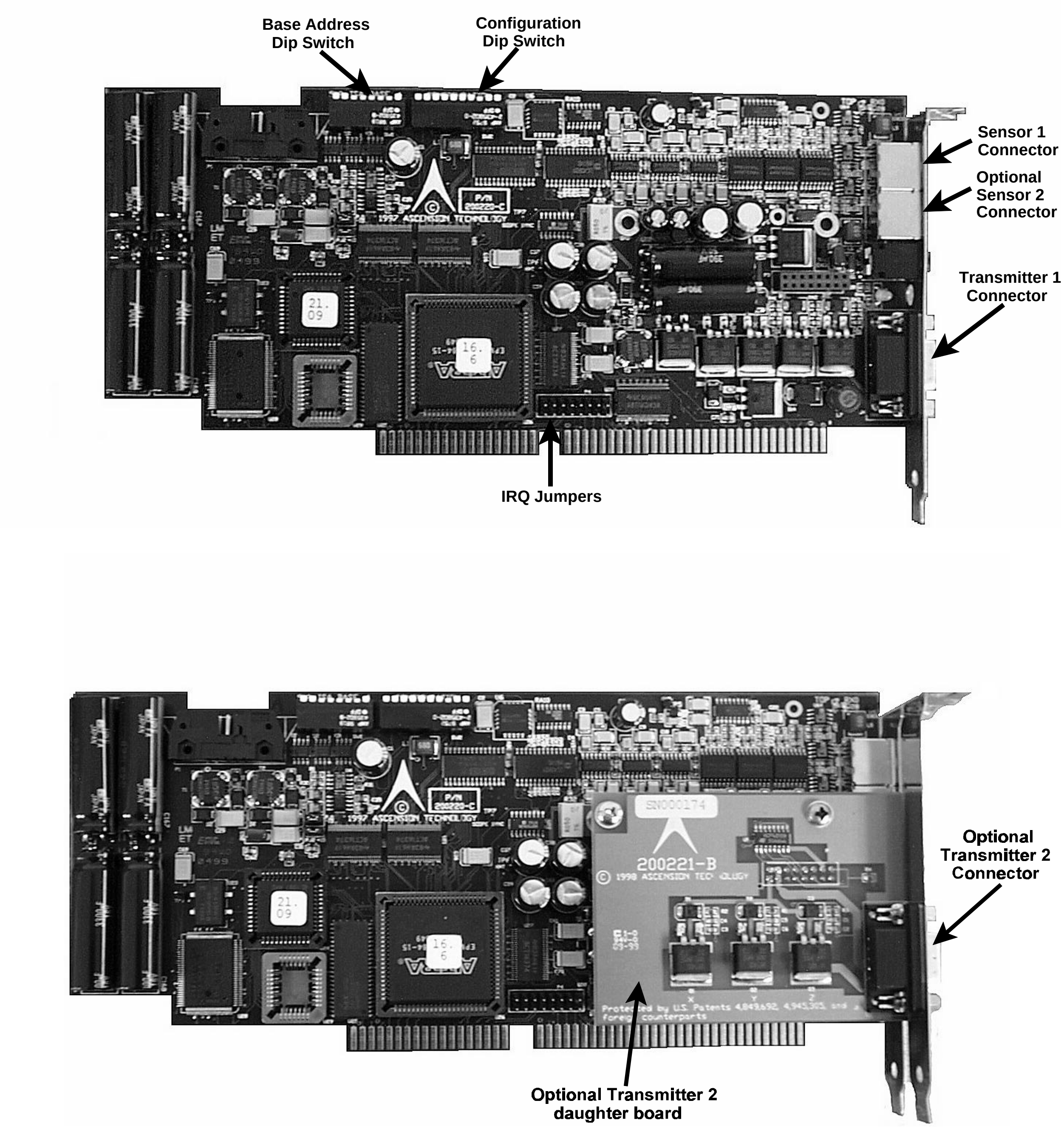


Figure 1. System Electronics Card

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.

2.3.1.1 BASE I/O ADDRESS. The Base Address dip switch selects the ISA bus I/O address for sending and receiving data from the miniBIRD-II. This dip switch allows the user to select Base Addresses from 000 Hex to 3FC Hex in address steps of 4. The miniBIRD-II uses Base Address +0 and Base Address +2. In selecting a Base Address for the miniBIRD-II, 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 200 Hex. If your shipment also includes slave cards, they have addresses 204, 208, etc.

Dip switch pins 7 and 8 determine the one hundred range (i.e. 100, 200, 300) and pins 1 through 6 determine the one and tens range (i.e. 00, 04, 08, 70, etc.).

Example Base Address settings are as follows:

dip switch number	8	7	6	5	4	3	2	1	Base Address
	0	1	0	1	1	1	0	0	170 Hex
	1	0	0	0	0	0	0	0	200 Hex
	1	0	0	0	0	0	0	1	204 Hex
	1	0	0	0	0	0	1	0	208 Hex
	1	1	0	0	0	0	0	1	304 Hex

Here 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.

If you cannot talk to the miniBIRD-II, it may be because the I/O address you have selected is the same address used by another device in your system. Try another address. In a PC, the I/O address space is usually assigned per the following table. Use this to help select a non-interfering address.

I/O Address Range	Device
1F0 - 1F8	Fixed disk
200 - 207	Game port
278 - 27F	LPT2
2E8 - 2EF	COM4
2F8 - 2FF	COM2
300 - 31F	unused or network
360 - 363	PC network low address
368 - 36B	PC network high address
378 - 3F7	LPT1
380 - 38F	SDLC, bisynchronous
3A0 - 3AF	Bisynchronous primary
3B0 - 3BF	Mono display and printer adapter
3C0 - 3CF	EGA/VGA display
3D0 - 3DF	CGA/MCGA display
3E8 - 3EF	COM3
3F0 - 3F7	Diskette
3F8 - 3FF	COM1

2.3.1.2 IRQ JUMPERS. If interrupt-driven ISA bus operation is required instead of polled operation, you must select which interrupt number is assigned to the miniBIRD-II card. The miniBIRD-II 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, remove any jumpers present. If you are using several miniBIRD-II cards in the same chassis, all interrupt-driven, each card must use a different IRQ. The cards are shipped with no IRQ jumpers installed.

If you cannot talk to the miniBIRD-II, it may be because the IRQ number you have selected is used by another device in your system. Try another IRQ. In a PC, the IRQs are usually assigned per the following table. Use this to help select a non-interfering IRQ.

IRQ	DEVICE
3	COM2, COM4
4	COM1, COM3
5	LPT2
7	LPT1

2.3.1.3 CONFIGURATION DIP SWITCH. The configuration dip switch is used for Factory Test purposes. For normal operation, all 10 switches should be OFF. The only dip switch of interest to the user is switch 10. When 10 is OFF, the system will power-up in the Sleep mode. If 10 is ON, the system will power-up Running.

ON = Towards the board
OFF = Away from the board

2.3.2 INSTALLING THE CARD. Once the switches and jumpers are set, the card is installed into a 16 bit ISA slot connector in your computer (Figure 2) by doing the following:

1. Shut the computer's power off.
2. Remove the computer's case.
3. Remove the slot cover plate from the location where you want to install the miniBIRD-II card.
4. Hold the miniBIRD-II card along the top edges and insert it vertically into the 16 bit ISA connector in your computer.
5. Wiggle the card slightly while maintaining pressure on it until it 'seats' into the connector.
6. Screw in the miniBIRD-II card using the screw removed from the slot cover plate in Step 3.
7. Install the computer's case. You may not want to screw in the case until you have verified that the miniBIRD-II is working.
8. Plug the miniBIRD-II's sensor #1 cable into the top Mini-Din connector on the card edge shown in Figure 1. The connector is self-locking. Repeat for sensor #2.
9. Plug the miniBIRD-II's transmitter cable into the bottom 9 pin D connector on the card edge. Screw in this connector.

10. If you have the optional transmitter and daughter board, then screw in the second transmitter into the 9 pin D connector on the daughter board.

Power can then be turned on and commands sent to the miniBIRD-II card.

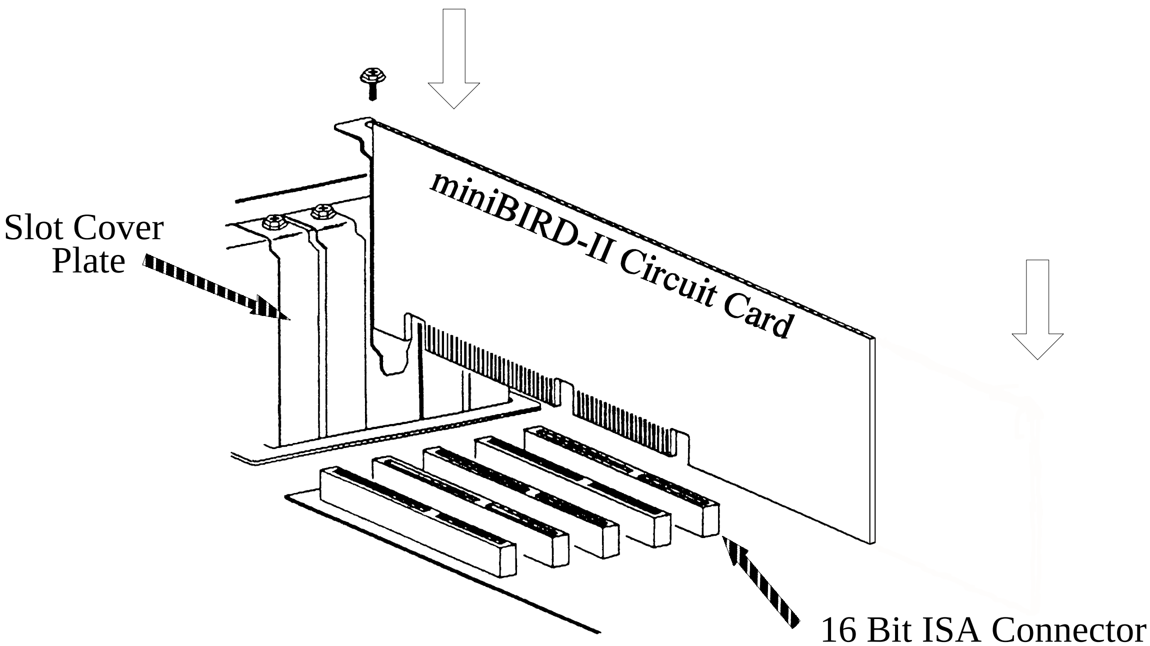


Figure 2. Installation In ISA Slot

3.0 INCLUDED SOFTWARE

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 CBIRD.EXE lets you send commands to the miniBIRD-II from a menu and read output data onto the screen or into a file. Additionally, this diskette contains complete, commented source code of all the 'C' functions you'll need for talking to the miniBIRD-II 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 miniBIRD-II program are located in file OPERATEC.TXT.

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

4.0 ISA HOST INTERFACE TO THE miniBIRD-II

The ISA interface provides a 16 bit read/write data port located at Base Address +0 to exchange information between the miniBIRD-II 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 miniBIRD-II system.

The user's host computer initiates all command and data transactions for the miniBIRD-II. The miniBIRD-II 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.

4.1 PORT DEFINITION

The bit definitions of the miniBIRD-II'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

Here B0 is the least significant bit and B15 is the most significant bit of the commands and data written to or read from the miniBIRD-II.

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 miniBIRD-II.
When B1 = 1, a word is available from miniBIRD-II 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 miniBIRD-II in reset.
Setting B0 = 1 starts or continues the operation of the miniBIRD-II .

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.

4.2 PORT BEHAVIOR ON POWER UP

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 miniBIRD-II (B1 = 0), but the user can send a command to the miniBIRD-II (B0 = 1).

4.3 SENDING COMMANDS TO THE miniBIRD-II

To send a word to the miniBIRD-II, 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 miniBIRD-II 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 miniBIRD-II outputting data to the user, the user must not issue a new command until the previous data is received. miniBIRD-II operation will become faulty if the user sends a word to the miniBIRD-II when the DATA STATUS bit B0 = 0.

4.4 RECEIVING DATA FROM THE miniBIRD-II

When the miniBIRD-II 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. miniBIRD-II operation will become faulty if the user reads a data word when the DATA STATUS bit B1 = 0.

4.5 INTERRUPT OPERATION

To send commands and read data from the miniBIRD-II 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, 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.

4.6 RESETTING THE miniBIRD-II

To initialize or re-initialize the miniBIRD-II 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.

After receiving the reset sequence, the miniBIRD-II 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 miniBIRD-II before or during the reset will be lost.

5.0 FORMAT OF ISA COMMANDS AND DATA

5.1 FORMAT OF COMMANDS AND DATA SENT

All commands sent to the miniBIRD-II consist of a single byte packed into a word. Associated with some commands are multiple byte command data. 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:

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 you are going to send a command that has command data associated with it, 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, the least significant byte of this word is set to zero. For example, the REFERENCE FRAME1 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 miniBIRD-II 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 one word at a time to the miniBIRD-II.

5.2 FORMAT OF COMMANDS AND DATA RECEIVED

Two types of binary data are returned from the miniBIRD-II: 1) Position/Orientation data and 2) Change/Examine value data. Position/Orientation data are the data returned from the miniBIRD-II in the ANGLES, POSITION, MATRIX, POSITION/ANGLES, POSITION/MATRIX, POSITION/QUATERNION and QUATERNION formats. All other types of data that the miniBIRD-II 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.

5.2.1 POSITION/ORIENTATION DATA FORMAT. The Position/Orientation information generated by the miniBIRD-II is returned to the user 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 consists 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.

5.2.2 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.

6.0 COMMAND UTILIZATION

6.1 STAND ALONE OPERATION

After power up or reset, the miniBIRD-II 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, send one of the following data record select commands to the desired sensor: ANGLES, MATRIX, POSITION, QUATERNION, POSITION/ANGLES, POSITION/MATRIX, or POSITION/QUATERNION. These commands do not cause the miniBIRD-II 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 miniBIRD-II, use the REPORT RATE command. All commands can be issued in any order and at any time to change the miniBIRD-II's output characteristics; however, if the previous command results in the miniBIRD-II outputting data to the user, 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 until a new internal measurement cycle is started.

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 miniBIRD-II is in Stand Alone configuration.

COMMAND	ACTION
ANGLES	Specify that the output record will contain angles only.
POINT	miniBIRD-II outputs an ANGLE data record.
POINT	miniBIRD-II outputs another ANGLE data record.
STREAM	ANGLE data records start streaming from miniBIRD-II.
OUTPUT BUFFER CLEAR	Stops the stream of ANGLE records, clears the output buffer.

6.2 COMMAND SUMMARY

The following summarizes the action of each command. The details of each command are presented in Section 7.0.

Command Name	Description
ANGLES	Data record contains 3 Euler rotation angles.
ANGLE ALIGN	Aligns a sensor to a specified direction.
CHANGE VALUE	Changes the value of a selected system parameter.
EXAMINE VALUE	Reads and examines a selected system parameter.
HEMISPHERE	Sets desired hemisphere of transmitter operation.
MATRIX	Data record contains 9-element rotation matrix.
NEXT TRANSMITTER	Turns on the next transmitter.
OUTPUT BUFFER CLEAR	Stops any data being output and clears the output buffer.
PASS THROUGH	Address preface to allow access to second sensor.
POINT	One data record is output for each B command from the selected sensor. If GROUP mode is enabled, one record is output from all configured sensors.
POSITION	Data record contains X, Y, Z position of sensor.
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.
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 sensor.

6.3 DEFAULT VALUES

Upon power-up or reset the miniBIRD-II is configured as follows where all numbers are listed as base 10:

1. POINT mode
2. POSITION/ANGLE outputs selected
3. REPORT RATE = Q (maximum)
4. ANGLE ALIGN sines/cosines set for alignment angles of zero
5. REFERENCE FRAME sines/cosines set for reference angles of zero
6. Maximum range scaling = 36 inches
7. Filter on/off status = AC WIDE notch on, DC on, AC NARROW notch off
8. Filter constants ALPHA_MIN table values = 0.02
9. Filter constants ALPHA_MAX table values = 0.9
10. Filter constant Vm table values = 2, 4, 8, 32, 64, 256, 512
11. Hemisphere = forward
12. System measurement rate = 103.3 measurements/sec

7.0 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 miniBIRD-II will output to the host computer.

ANGLES

ANGLES

	ASCII	HEX	DECIMAL	BINARY
Command Byte	W	57	87	01010111

In the ANGLES mode, the miniBIRD-II outputs the orientation angles of the sensor with respect to the transmitter. The orientation angles are defined as rotations about the Z, Y, and X axes of the sensor. 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:

```
MSB                                                             LSB
 15   14   13   12   11   10   9   8   7   6   5   4   3   2   1   0

Z15  Z14  Z13  Z12  Z11  Z10  Z9  Z8  Z7  Z6  Z5  Z4  Z3  Z2  Z1   1      Zang
Y15  Y14  Y13  Y12  Y11  Y10  Y9  Y8  Y7  Y6  Y5  Y4  Y3  Y2  Y1   0      Yang
X15  X14  X13  X12  X11  X10  X9  X8  X7  X6  X5  X4  X3  X2  X1   0      Xang
```

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 miniBIRD-II -- it is an inherent characteristic of these Euler angles. If you need a stable representation of the sensor 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.

To convert the numbers into angles, first cast it into a signed integer. This will give you a number from ± 32767. Second, multiply by 180 and then divide the number by 32767 to get the angle. The equation should look something like this:

(signed int(Hex #) * 180) / 32767

ANGLE ALIGN1

ANGLE ALIGN1

	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 miniBIRD-II are measured in the coordinate frame defined by the transmitter's X, Y and Z axes, as shown in Figure 3, and are measured with respect to rotations about the physical X, Y and Z axes of the sensor. The ANGLE ALIGN1 command allows you to mathematically change the sensor's X, Y and Z axes to an orientation which differs from that of the actual sensor.

For example:

Suppose that during installation you find it necessary, due to physical requirements, to cock the sensor, 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 ALIGN1 command, passing as Command Data the sines and cosines of 5, 10 and 15 degrees. After this sequence is sent, the sensor outputs will be zero, and orientations will be computed as if the sensor were not misaligned.

Note: the ANGLE ALIGN1 command only affects the computation of orientation -- it has no effect on position.

If you immediately follow the ANGLE ALIGN1 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. 10 milliseconds if running the miniBIRD-II at 100 measurements/sec) before you see the effect of the command.

The host computer must send the Command Data immediately after 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 sensor misalignment you want to remove. Use the ANGLE ALIGN2 command for sending the angles instead of the sines and cosines of the angles. The Command Data must be sent even if the angles are zero.

The sequence of output words to the miniBIRD-II takes the following form:

WORD #	Most Significant Byte	Least Significant Byte
1	ALIGN command = 4A	MSbyte Sin (A)
2	LSbyte Sin (A)	MSbyte Cos (A)
3	LSbyte Cos (A)	MSbyte Sin (E)
4	LSbyte Sin (E)	MSbyte Cos (E)
5	LSbyte Cos (E)	MSbyte Sin (R)
6	LSbyte Sin (R)	MSbyte Cos (R)
7	LSbyte Cos (R)	0

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.

ANGLE ALIGN2

ANGLE ALIGN2

	ASCII	HEX	DECIMAL	BINARY
Command Byte	q	71	113	01110001

Command Data	A, E, R

This command is the same as the ANGLE ALIGN1 command except that the command data consists of the angles only and not the sines and cosines of the angles.

The sequence of output words to the miniBIRD-II takes the following form:

WORD #	Most Significant Byte	Least Significant Byte
1	ALIGN command = 71	MSbyte A
2	LSbyte A	MSbyte A
3	LSbyte A	MSbyte E
4	LSbyte E	MSbyte E
5	LSbyte E	MSbyte R
6	LSbyte R	MSbyte R
7	LSbyte R	0

See the ANGLES command for the format and scaling of the angle values sent.

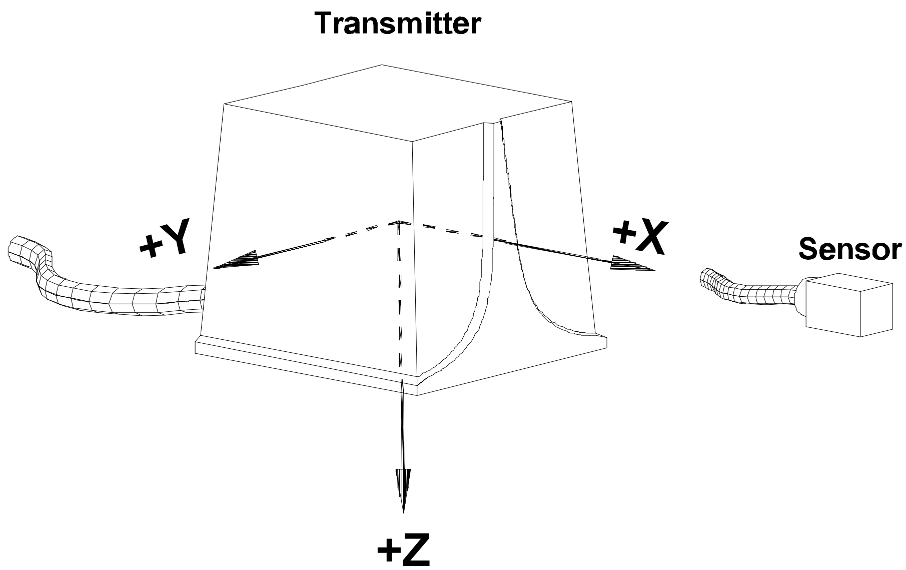


Figure 3. Measurement Reference Frame

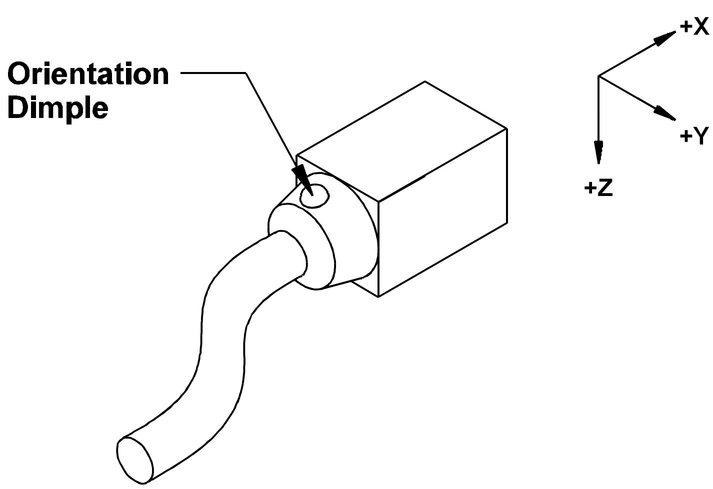


Figure 4. Receiver Zero Orientation

CHANGE VALUE
EXAMINE VALUE

CHANGE VALUE
EXAMINE VALUE

	ASCII	HEX	DECIMAL	BINARY
CHANGE VALUE Command Byte	P	50	87	0101000

CHANGE VALUE Command Byte	PARAMETERnumber	PARAMETERvalue

The CHANGE VALUE command allows you to change the value of the miniBIRD-II 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 Byte	PARAMETERnumber

The EXAMINE VALUE command allows you to read the value of the miniBIRD-II system parameter defined by the PARAMETERnumber sent with the command. Immediately after the miniBIRD-II 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. Note: not all PARAMETERnumbers are CHANGEable, but ALL are EXAMINEable.

PARAMETERnumber Dec	Hex	CHANGEable	PARAMETER DESCRIPTION
0	0	No	Bird Status
1	1	No	Software Revision Number
2	2	No	Bird Computer Crystal Speed
4	4	Yes	Filter On/Off Status
5	5	Yes	DC Filter Constant Table ALPHA_MIN
6	6	Yes	Bird Measurement Rate Count
7	7	Yes	Bird Measurement Rate
8	8	Yes	Disable/Enable Data Ready Output Character
9	9	Yes	Set Data Ready Character
10	A	No	Error Code
12	C	Yes	DC Filter Constant Table Vm
13	D	Yes	DC Filter Constant Table ALPHA_MAX
14	E	Yes	Sudden Output Change Lock
15	F	No	System Model Identification
17	11	Yes	XYZ Reference Frame
20	14	Yes	Filter Line Frequency
22	16	Yes	Change/Examine Hemisphere
23	17	Yes	Change/Examine Angle Align2
24	18	Yes	Change/Examine Reference Frame2
25	19	No	Bird Serial Number
26	1A	No	Sensor Serial Number
27	1B	No	Xmtr Serial Number
35	23	Yes	Group Mode
36	24	No	Flock System Status
50	32	Yes	Auto-Configuration - 1 Xmtr/N Snsrs

To send the CHANGE VALUE command, positionthe CHANGE VALUE command in the most significant byte of the first word to be output and the PARAMETERnumber in the least significant byte. Any PARAMETERvalues required fill up additional output words. The N + 1 words sent to the miniBIRD-II 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. You do not shift and add “phasing” bits to the data.

The EXAMINE VALUE command must be issued to the miniBIRD-II in the following one word sequence:

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

The PARAMETERdata is returned as words. If the PARAMETERdata is numeric, it is in 2's complement format. The PARAMETERdata received does not contain “phasing” bits. The PARAMETERdata value, content and scaling depend on the particular parameter requested. For further explanation, see the following discussion of each parameter.

BIRD STATUS
PARAMETERnumber = 0

When PARAMETERnumber = 0, during EXAMINE, the miniBIRD-II returns a status word to tell the user in what mode the unit is operating. The bit assignments for the two byte response are:

B15	1 if BIRD is a Master BIRD 0 if BIRD is a Slave BIRD
B14	1 if BIRD has been initialized (AUTO-CONFIGURED) 0 if BIRD has not been initialized
B13	1 if an error has been detected 0 if no error is detected
B12	1 if BIRD is RUNNING 0 if BIRD is not RUNNING
B11 - B6	NOT USED
B5	1 if BIRD is in SLEEP mode. Same as B12 0 if BIRD 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
PARAMETERnumber = 1

When PARAMETERnumber = 1, during EXAMINE, the miniBIRD-II returns the revision number of the software located in the miniBIRD-II's PROM memory. The revision number in base 10 is expressed as INT.FRA where INT is the integer part of the revision number and FRA is the fractional part. For example, if the revision number is 2.13, then INT = 2 and FRA = 13. The value of the most significant byte returned is INT. The value of the least significant byte returned is FRA. 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.

BIRD COMPUTER CRYSTAL SPEED
PARAMETERnumber = 2

When PARAMETERnumber = 2, during EXAMINE, the miniBIRD-II returns the speed of its computer's crystal in megahertz (MHz). You need to know the crystal speed if you want to determine or set the measurement rate of the miniBIRD-II or compute the vertical scan rate of your CRT. 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 = 19 Hex, the crystal speed is 25 MHz.

FILTER ON/OFF STATUS
PARAMETERnumber = 4

When PARAMETERnumber = 4, during EXAMINE, the miniBIRD-II returns a code telling you what software filters are turned on or off in the unit. The average user should not have to change the filters, but it is possible to do so. The most significant byte returned is always zero. The bits in the least significant byte are coded as follows:

BIT NUMBER	MEANING
B7-B3	0
B2	0 if the AC NARROW notch filter is ON 1 if the AC NARROW notch filter is OFF (default)
B1	0 if the AC WIDE notch filter is ON (default) 1 if the AC WIDE notch filter is OFF
B0	0 if the DC filter is ON (default) 1 if the DC filter is OFF

The AC NARROW notch filter refers to a two tap finite impulse response (FIR) notch filter applied to signals measured by the miniBIRD-II's sensor to eliminate a narrow band of noise with sinusoidal characteristics. Use this filter in place of the AC WIDE notch filter when you want to minimize the transport delay between the miniBIRD-II’s measurement of the sensor's position/orientation and the output of these measurements. The transport delay of the AC NARROW notch filter is approximately one third the delay of the AC WIDE notch filter.

The AC WIDE notch filter refers to a six tap FIR notch filter applied to the sensor data to eliminate sinusoidal signals with a frequency between 30 and 72 hertz. If your application requires minimum transport delay between measurement of the sensor's position/orientation and the output of these measurements, you may want to evaluate the effect on your application of having this filter shut off and the AC NARROW notch filter on. If you are running the miniBIRD-II synchronized to a CRT, you can usually shut this filter off without experiencing an increase in noise.

Note: For optimal notch filter performance make sure the miniBIRD-II is set for the proper Line Frequency by checking it with the FILTER LINE FREQUENCY command.

The DC filter refers to an adaptive, infinite impulse response (IIR) low pass filter applied to the sensor 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 and Vm.

To CHANGE the FILTER ON/OFF STATUS send the miniBIRD-II two bytes of PARAMETERdata with the most significant byte set to zero and the least significant set to the code in the table above.

DC FILTER CONSTANT TABLE ALPHA_MIN
PARAMETERnumber = 5

When PARAMETERnumber = 5, during EXAMINE, the miniBIRD-II returns 7 words (14 bytes) which define the lower end of the adaptive range that filter constant ALPHA_MIN can assume in the DC filter as a function of sensor-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 sensor). 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-sensor separation range for the miniBIRD-II transmitter are as follows:

miniBIRD-II Xmtr Range (inches)	ALPHA_MIN (decimal)
0 to 17	0.02 = 028F Hex.
17 to 22	0.02
22 to 27	0.02
27 to 34	0.02
34 to 42	0.02
42 to 54	0.02
54 +	0.02

To CHANGE ALPHA_MIN, send the miniBIRD-II 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.

BIRD MEASUREMENT RATE COUNT
PARAMETERnumber = 6

When PARAMETERnumber = 6, during EXAMINE, the miniBIRD-II returns a word that is used to determine the measurement rate of the unit. The word returned represents a timer count (XMTR_TIME_CNT) determining how long each of the miniBIRD-II's three transmitter antennas will be turned on/off. From this word, you can estimate the total measurement period. XMTR_TIME_CNT is returned with values from 0000 to FFFF Hex or 0 to 65535 decimal. See the miniBIRD-II MEASUREMENT RATE command below for a simpler form of this command.

The measurement rate in cycles/sec is computed from:

measurement rate = 1000 / (4.0 * XTIME + 0.3)

where XTIME in milliseconds is:

XTIME = XMTR_TIME_CNT * CLOCK / 1000

where CLOCK is the period of one computer time count in microseconds. With a crystal value equal to 40 MHz, CLOCK = 8/40. The crystal value is determined by using the command EXAMINE VALUE BIRD COMPUTER CRYSTAL SPEED.

The miniBIRD-II's measurement rate is nominally set for 103.3 measurements/sec. If, however, the unit is synchronized to your CRT (see CRT SYNC command), the measurement rate will automatically increase. If you reduce the measurement rate after you are synchronized, the miniBIRD-II will drop out of synchronization. To regain synchronization, reissue the CRT SYNC command = 2. Increasing the rate will not cause loss of synchronization nor will it result in an increased measurement rate beyond the retrace rate of the CRT.

To CHANGE the MEASUREMENT RATE COUNT send the miniBIRD-II one word of PARAMETERdata corresponding to XMTR_TIME_CNT defined above.

You can increase the miniBIRD-II's measurement rate to a maximum of 120 measurements/sec. The downside of going to rates faster than 103.3 measurements/sec is that the noise on your outputs may increase and any errors introduced by nearby metals will also increase.

You can decrease the miniBIRD-II's measurement rate to no less than 20 measurements/sec for 40 MHz BIRDs. At this value, XMTR_TIME_CNT reaches its maximum value of 65535. Decreasing the measurement rate is useful if you need to reduce errors resulting from highly conductive metals such as aluminum. If you have low-conductive, highly permeable metals in your environment such as carbon steel or iron, changing the measurement rate will not change the distortions. For low-conductive, low permeability metals such as 300 series stainless steel or nickel, speed changes will have minimal effect, since in this case, the metal is not introducing any errors into the miniBIRD-II's measurements anyway.

The downside of decreasing the miniBIRD-II's measurement rate is that dynamic performance is decreased. That is, if you move the miniBIRD-II's sensor quickly, the slow measurement rate will cause increased lag errors. Also, at slower rates, the noise will increase or decrease, depending on the rate you choose. For example, the noise will be at a maximum if you select a measurement rate equal to your power line frequency of 50 or 60 hertz.

As you change the measurement rate of the miniBIRD-II, you many want to experiment with changing the filter characteristics. For example, the AC filter is optimized for a measurement rate of 103.3 measurements/sec. At very low measurement rates, you may want to shut this filter off.

BIRD MEASUREMENT RATE
PARAMETERnumber = 7

When PARAMETERnumber = 7, during EXAMINE, the miniBIRD-II returns a word used to determine the measurement rate of the unit. The word returned is the measurement rate in cycles/sec times 256.

The measurement rate in cycles/sec is computed from:

measurement rate = (word returned) / 256.

To CHANGE the MEASUREMENT RATE, send the miniBIRD-II one word of PARAMETERdata corresponding to (measurement rate) * 256.

The MEASUREMENT RATE command is a simpler form of the MEASUREMENT RATE COUNT command. Refer to the MEASUREMENT RATE COUNT command regarding speed limits and metal distortion verses noise tradeoffs.

DISABLE/ENABLE DATA READY OUTPUT CHARACTER
PARAMETERnumber = 8

Enabling the DATA READY character provides a method for notifying you as soon as the newest position and orientation data has been computed. Typically, you would issue a POINT data request as soon as you receive the DATA READY command. If you are running in STREAM mode you should not use the DATA READY character since the position and orientation is sent to you automatically as soon as it is ready.

When PARAMETERnumber = 8, during EXAMINE, the miniBIRD-II outputs one word of data equal to 1 if Data Ready Output is enabled or a 0 if disabled.

Caution: When using the EXAMINE command, if DATA READY is enabled you may receive the DATA READY character itself followed by another word containing the 1, depending on when in the miniBIRD-II's computation cycle you issued the EXAMINE request. If you receive the DATA READY character first, then read the next word containing the 1 to clear the output buffer.

To CHANGE DATA READY, send the miniBIRD-II one byte of PARAMETERdata = 1 if the miniBIRD-II is to output the Data Ready Character every measurement cycle as soon as a new measurement is ready for output. The default Data Ready Character is a comma (2C Hex, 44 Dec).

SET DATA READY CHARACTER
PARAMETERnumber = 9

When PARAMETERnumber = 9, during EXAMINE, the miniBIRD-II returns one word, the current ASCII value of the Data Ready Character in the LSbyte.

To CHANGE the DATA READY CHARACTER, send the miniBIRD-II one word of PARAMETERdata equal to the character value that the unit should use as the Data Ready Character in the LSbyte.

ERROR CODE
PARAMETERnumber = 10

When PARAMETERnumber = 10, during EXAMINE, the miniBIRD-II will output a one word Error register code, defined in the Error Message Section 8.0. The error code is reset to all 0's after it has been read.

DC FILTER CONSTANT TABLE Vm
PARAMETERnumber = 12

When PARAMETERnumber = 12, during EXAMINE, the miniBIRD-II returns a 7 word table, or during CHANGE, the user sends to the miniBIRD-II a 7 word 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 sensor range from the transmitter.

The DC filter is adaptive in that it tries to reduce the amount of low pass filtering in the miniBIRD-II as it detects translation or rotation rates in the unit's sensor. Reducing the amount of filtering results in less filter lag. Unfortunately, electrical noise in the environment, when measured by the sensor, also makes it look like the sensor is undergoing a translation and rotation. As the sensor moves farther and farther away from the transmitter, the amount of noise measured by the sensor appears to increase because the measured transmitted signal level is decreasing and the sensor amplifier gain is increasing. In order to decide if the amount of filtering should be reduced, the miniBIRD-II has to know if the measured rate is a real sensor rate due to movement or a false rate due to noise. The miniBIRD-II 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-sensor separation range for the miniBIRD-II transmitter are as follows:

Std. Range Xmtr Range (inches)	Vm (integer)
0 to 17	2
17 to 22	4
22 to 27	8
27 to 34	32
34 to 42	64
42 to 54	256
54 +	512

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 miniBIRD-II's output is too large for your application.

DC FILTER CONSTANT TABLE ALPHA_MAX
PARAMETERnumber = 13

When PARAMETERnumber = 13, during EXAMINE, the miniBIRD-II returns 7 words which define the upper end of the adaptive range that filter constant ALPHA_MAX can assume in the DC filter as a function of sensor-to-transmitter separation. When there is a fast motion of the sensor, 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 sensor separation range for the miniBIRD-II transmitter are as follows:

Std. Range Xmtr Range (inches)	ALPHA_MAX (fractional)
0 to 17	0.9 = 07333 Hex.
17 to 22	0.9
22 to 27	0.9
27 to 34	0.9
34 to 42	0.9
42 to 54	0.9
54 +	0.9

To CHANGE ALPHA_MAX, send the miniBIRD-II 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 unit's outputs are too noisy during rapid sensor movement. ALPHA_MAX must always be greater than ALPHA_MIN.

SUDDEN OUTPUT CHANGE LOCK
PARAMETERnumber = 14

When PARAMETERnumber = 14, during EXAMINE, the miniBIRD-II returns a word which indicates if the position and orientation outputs will be allowed to change if the system detects a sudden large change in the outputs. Large undesirable changes may occur at large separation distances between the transmitter and sensor when the sensor undergoes a fast rotation or translation. The word returned will = 1 to indicate that the outputs will not be updated if a large change is detected. If the byte returned is zero, the outputs will change.

To change SUDDEN OUTPUT CHANGE LOCK, send the miniBIRD-II one word of PARAMETERdata = 0 to unlock the outputs or send one byte = 1 to lock the outputs.

SYSTEM MODEL IDENTIFICATION
PARAMETERnumber = 15

When PARAMETERnumber = 15, during EXAMINE, the miniBIRD-II returns 10 bytes which will represent the device that was found.

Device Description String	Device
“6DFOB “	Stand alone (SRT)
“6DERC “	Extended Range Controller
“6DBOF “	MotionStar (old name)
“6DMIN “	miniBIRD
“MINIBIRD2 “	miniBIRD-II with 1 Xmtr and 1 Snsr
“MINIBIRD2R”	miniBIRD-II with 1 Xmtr and 2 Snsrs
“MINIBIRD2X”	miniBIRD-II with 2 Xmtrs and 2 Snsrs
“PCBIRD “	pcBIRD
“SPACEPAD “	SpacePad
“MOTIONSTAR”	MotionStar (new name)
“WIRELESS “	MotionStar Wireless

XYZ REFERENCE FRAME
PARAMETERnumber = 17

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 byte of PARAMETER DATA sent to the miniBIRD-II is = 1, 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, the XYZ measurement frame reverts to the orientation of the transmitter's physical XYZ axes.

During EXAMINE, the miniBIRD-II returns a byte value of 0 or 1 to indicate that the XYZ measurement frame is either the transmitter's physical axes or the frame specified by the REFERENCE FRAME command.

FILTER LINE FREQUENCY
PARAMETERnumber = 20

When PARAMETERnumber = 20, during EXAMINE, the miniBIRD-II returns a word whose value in the LSbyte is the Line Frequency which is being used to determine the Wide Notch Filter coefficients. The default Line Frequency is 60 Hz.

To CHANGE the Line Frequency, send 1 byte of PARAMETERdata corresponding to the desired Line Frequency. The range of Line Frequencies available are 1 -> 255.

Example: To change the Line Frequency to 50Hz, you would first send a Change Value command (50 Hex), followed by a Filter Line Frequency command (14 Hex), followed by the line frequency for 50 Hz (32 Hex).

CHANGE/EXAMINE HEMISPHERE

PARAMETERnumber = 22

When PARAMETERnumber = 22, during EXAMINE, the miniBIRD-II will return one word of data defining the current Hemisphere. These are as follows:

Hemisphere	HEMI_AXIS		HEMI_SIGN	
	ASCII	HEX	ASCII	HEX
Forward	nul	00	nul	00
Aft (Rear)	nul	00	soh	01
Lower	ff	0C	nul	00
Upper	ff	0C	soh	01
Right	ack	06	nul	00
Left	ack	06	soh	01

Note: These are the same PARAMETERdata values as are used by the HEMISPHERE command 'L' (4C Hex).

To CHANGE the Hemisphere, send 2 PARAMETERdata bytes as described above.

Note: This command operates in exactly the same way as the HEMISPHERE command. The command is included in the CHANGE/EXAMINE command set in order to allow users to examine the values which were previously inaccessible.

Note: The values can only be EXAMINED with this command if they were previously CHANGED by this command.

CHANGE/EXAMINE ANGLE ALIGN2

PARAMETERnumber = 23

When PARAMETERnumber = 23, during EXAMINE, the miniBIRD-II will return 3 words of data corresponding to the Azimuth, Elevation, and Roll angles used in the ANGLE ALIGN2 command. This command differs from the ANGLE ALIGN2 command only in that it allows both reading and writing of the angles. See ANGLE ALIGN2 for a full explanation of it use.

To CHANGE the angles, send 6 bytes of PARAMETERdata after the 2 command bytes.

Note: The angles can only be read back with this command if they were previously written with this command, i.e. if the ANGLE ALIGN2 (or the ANGLE ALIGN) was used to set the angles, those angles will not be accessible with the EXAMINE ANGLE ALIGN2 command.

CHANGE/EXAMINE REFERENCE FRAME2
PARAMETERnumber = 24

When PARAMETERnumber = 24, during EXAMINE, the miniBIRD-II will return 3 words of data corresponding to the Azimuth, Elevation and Roll angles used in the REFERENCE FRAME2 command.

See REFERENCE FRAME2 command for further explanation.

To CHANGE the angles, send 6 bytes of PARAMETERdata after the 2 command bytes.

Note: These angles are only accessible with this command if they were previously written with this command.

BIRD SERIAL NUMBER
PARAMETERnumber = 25

When PARAMETERnumber = 25, during EXAMINE, the miniBIRD-II will return a 1 word value corresponding to the Serial Number of the miniBIRD-II electronic unit.

Note: This number cannot be changed.

SENSOR SERIAL NUMBER
PARAMETERnumber = 26

When PARAMETERnumber = 26, during EXAMINE, the miniBIRD-II will return a 1 word value corresponding to the Serial Number of the miniBIRD-II's sensor. You can not swap sensors while the miniBIRD-II is switched to FLY. If you do, you will get the Serial Number of the sensor that was attached to the unit when it was first turned on.

Note: This number cannot be changed.

XMTR SERIAL NUMBER
PARAMETERnumber = 27

When PARAMETERnumber = 27, during EXAMINE, the miniBIRD-II will return a 1 word value corresponding to the Serial Number of the miniBIRD-II's transmitter. You can not swap transmitters while the miniBIRD-II is switched to FLY. If you do, you will get the Serial Number of the transmitter that was attached to the unit when it was first turned on.

Note: This number cannot be changed.

GROUP MODE
PARAMETERnumber = 35

The GROUP MODE command is only used if you have multiple BIRDs working together in a Master/Slave configuration and you want to get data from all the BIRDs by talking to only the Master BIRD.

When PARAMETERnumber = 35, during EXAMINE VALUE, the miniBIRD-II will respond with one byte of data indicating if the unit is in GROUP MODE. If the data is a 1, the miniBIRD-II is in GROUP MODE and if the data is 0, the miniBIRD-II is not in GROUP MODE. When in GROUP MODE, in response to the POINT or STREAM commands, the Master BIRD will send data records from all running BIRDs with sensors. Information is output from the BIRD with the smallest address first. The last byte of the data record from each BIRD contains the address of that BIRD. This address byte contains no "phasing" bits. Each BIRD can be in a different data output format if desired. For example, if the first sensor is configured to output POSITION data only (6 data bytes plus 1 address byte) and the other sensor is configured to output POSITION/ANGLES data (12 data bytes plus 1 address byte), the Master BIRD will respond with 20 bytes when a data request is made.

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

FLOCK SYSTEM STATUS

PARAMETERnumber = 36

When PARAMETERnumber = 36, during EXAMINE, the Master BIRD returns to the host computer 14 bytes defining the physical configuration of each BIRD on the bus. This command can be sent to the Master either before or after the Flock is running. The response has the following format, where one byte is returned for each possible sensor address:

BYTE 0	- address 1 configuration
BYTE 1	- address 2 configuration
.	.
.	.
.	.
BYTE 13	- address 14 configuration

Each byte has the following format:

BIT 7	If 1, device is accessible. If 0, device is not accessible. A device is accessible when its fly switch is on. It may or may not be running.
BIT 6	If 1, device is running. If 0, device is not running. A device is running when the power switch is on, it has been AUTO-CONFIGed and it is AWAKE. A device is not running when the power switch is on and it has not been AUTO-CONFIGed or it has been AUTO-CONFIGed and it is ASLEEP.
BIT 5	If 1, device has a sensor. If 0, device does not have a sensor.
BIT 4	If 1, transmitter is an ERT. If 0, transmitter is standard range.
BIT 3	If 1, ERT #3 is present. If 0, ERT #3 is not present
BIT 2	If 1, ERT #2 is present. If 0, ERT #2 is not present
BIT 1	If 1, ERT #1 is present. If 0, ERT #1 is not present
BIT 0	If 1, ERT #0 or standard range transmitter is present. If 0, ERT #0 or standard range transmitter is not present

AUTO-CONFIGURATION
PARAMETERnumber = 50

The AUTO-CONFIGURATION command is used to start running multiple BIRDs working together in a Master/Slave configuration.

When PARAMETERnumber = 50, during an CHANGE VALUE command, the Master BIRD will perform all the necessary configurations of the Slaves and itself for a one transmitter/multiple sensor configuration. The Master BIRD expects one word of data corresponding to the number of BIRD electronic units that will be used in the 1 transmitter/multiple sensor mode. For example, if the one word = 2 then the BIRD at address = 1 (the default Master) will assume that there is also a BIRD at address 2. The two BIRD units will then start running.

The AUTO-CONFIGURATION command sequence would look like in Hex:

WORD #	Most Significant Byte	Least Significant Byte
1	50	32
2	0	2

Once the Flock is running, the AUTO-CONFIGURATION command can also be used to reconfigure the Flock. For example, if the Flock is currently AUTO-CONFIGURED with 2 BIRD units, you can reconfigure it with 1 BIRD unit by sending the AUTO-CONFIGURATION command with 1 as the data while the Flock is in operation.

Resending AUTO-CONFIGURATION to the Master after an error develops in the Flock will many times clear the error and restart the system.

If you have GROUP STREAM mode running, you must first terminate STREAM mode before sending another AUTO-CONFIGURATION command.

Before sending the AUTO-CONFIGURATION command, you must wait at least 600 milliseconds to allow any previous commands to complete. After sending the AUTO-CONFIGURATION command, you must also wait at least 600 milliseconds before sending another command.

HEMISPHERE

HEMISPHERE

	ASCII	HEX	DECIMAL	BINARY
Command Byte	L	4C	76	01001100

Command Data	HEMI_AXIS	HEMI_SIGN

The shape of the magnetic field transmitted by the miniBIRD-II is symmetrical about each of the axes of the transmitter. This symmetry leads to an ambiguity in determining the sensor's X, Y, Z position. The amplitudes will always be correct, but the signs (±) may all be wrong, depending upon the hemisphere of operation. In many applications, this will not be relevant, but if you desire an unambiguous measure of position, operation must be either confined to a defined hemisphere, or your host computer must ‘track’ the location of the sensor.

There is no ambiguity in the sensor's orientation angles as output by the ANGLES command, or in the rotation matrix as output by the MATRIX command.

The HEMISPHERE command is used to tell the miniBIRD-II in which hemisphere, centered about the transmitter, the sensor will be operating. There are six hemispheres from which you may choose: the forward, aft (rear), upper, lower, left, and the right. If no HEMISPHERE command is issued, the forward is used by default.

The two Command Data bytes, sent immediately after the HEMISPHERE command, are to be selected from the following:

Hemisphere	HEMI_AXIS		HEMI_SIGN	
	ASCII	HEX	ASCII	HEX
Forward	nul	00	nul	00
Aft (Rear)	nul	00	soh	01
Upper	ff	0C	soh	01
Lower	ff	0C	nul	00
Left	ack	06	soh	01
Right	ack	06	nul	00

The HEMISPHERE command sequence sent to each BIRD with a receiver would look like this:

WORD #	Most Significant Byte	Least Significant Byte
1	command = 4C	HEMI_AXIS
2	HEMI_SIGN	0

The ambiguity in position determination can be eliminated if your host computer's software continuously 'tracks' the sensor location. In order to implement tracking, you must understand the behavior of the signs (±) of the X, Y, and Z position outputs when the sensor crosses a hemisphere boundary. When you select a given hemisphere of operation, the sign on the position axes that defines the hemisphere direction is forced to positive, even when the sensor moves into another hemisphere. For example, the power-up default hemisphere is the forward hemisphere. This forces X position outputs to always be positive. The signs on Y and Z will vary between plus and minus depending on where you are within this hemisphere. If you had selected the lower hemisphere, the sign of Z would always be positive, and the signs on X and Y would vary between plus and minus. If you had selected the left hemisphere, the sign of Y would always be negative, etc.

Using the default forward hemisphere, if the sensor moved into the aft hemisphere, the signs on Y and Z would instantaneously change to opposite polarities while the sign on X remained positive. To 'track' the sensor, your host software, on detecting this sign change, would reverse the signs on the miniBIRD-II's X, Y, and Z outputs. In order to 'track' correctly you must start 'tracking' in the selected hemisphere so the signs on the outputs are initially correct, and you must guard against having the sensor legally cross the Y = 0, Z = 0 axes simultaneously without having crossed the X = 0 axes into the other hemisphere.

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 sensor'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 sensor, you must multiply your image coordinates by this output matrix.

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

```
*                                                                 *
*         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)            COS(X)*COS(Z)                          *
*+SIN(X)*SIN(Y)*COS(Z)    +SIN(X)*SIN(Y)*SIN(Z)    SIN(X)*COS(Y)*
*                                                                 *
*                                                                 *
* SIN(X)*SIN(Z)           -SIN(X)*COS(Z)                          *
*+COS(X)*SIN(Y)*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)            COS(R)*COS(A)                            *
*+SIN(R)*SIN(E)*COS(A)    +SIN(R)*SIN(E)*SIN(A)    SIN(R)*COS(E)*
*                                                                   *
*                                                                   *
* SIN(R)*SIN(A)           -SIN(R)*COS(A)                            *
*+COS(R)*SIN(E)*COS(A)    +COS(R)*SIN(E)*SIN(A)    COS(R)*COS(E)*
*                                                                   *
```

The 9 word output record is in the following order:

```
MSB                                                                   LSB
 15   14   13   12   11   10   9    8    7    6    5    4    3    2    1    0

M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   1       M(1,1)
M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   0       M(2,1)
M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   0       M(3,1)

M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   0       M(1,2)
M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   0       M(2,2)
M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   0       M(3,2)

M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   0       M(1,3)
M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   0       M(2,3)
M15  M14  M13  M12  M11  M10  M9   M8   M7   M6   M5   M4   M3   M2   M1   0       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.

NEXT TRANSMITTER

NEXT TRANSMITTER

	HEX	DECIMAL	BINARY
Command Byte	30	48	00110000

Command Data	TRANSMITTER ADDR

If you have multiple transmitters in your Flock and you want to turn on a transmitter other than the transmitter at address 1, use the NEXT TRANSMITTER command. This command is sent to the current Master with a single byte of command data containing the transmitter address (1 or 2). At the end of its current measurement cycle (1 to 10 milliseconds after the command is received), the addressed BIRD starts its transmitter.

Next Transmitter command data format:

```
MSB                                                 LSB
7     6     5     4     3     2     1     0
A3    A2    A1    A0    0     0     0     0
```

where A1-A0 is the address of the Next Transmitter,

A3	A2	A1	A0	
0	0	0	1	- Address 1
0	0	1	0	- Address 2

Therefore, to turn on transmitter 2, the command byte is 30H followed by a command data byte of 20H.

Notes:

1) With multiple transmitters, the measurement reference frame is defined with respect to the location and orientation of the transmitter that is currently turned on. Thus, unless each transmitter is aligned perfectly to each other, you will get a jump in the measured orientation of the sensor when the next transmitter is turned on. To overcome the angular misalignments, you can use the REFERENCE FRAME command directed to each transmitter after you power up the Flock but before you do the transmitter switching.

2) If you select a transmitter that is not available, the Master will indicate error 29, 'transmitter not accessible'.

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, OUTPUT BUFFER CLEAR disables STREAM mode.

To use the OUTPUT BUFFER CLEAR command, do the following:

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.

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 miniBIRD-II is now ready to accept new commands from the user.

PASS THROUGH

PASS THROUGH

	HEX	DECIMAL	BINARY
Command Byte	F0	240	11110000 + Sensor #

In order to talk to the second sensor/transmitter, you need to use the PASS THROUGH command. The PASS THROUGH command is a 1 Byte preface to each of the user commands.

The command looks like the following:
Command Byte = F0 + destination sensor # in Hex
(i.e. Sensor 1 (1 Hex) would be F1
Sensor 2 (2 Hex) would be F2)

Example: There are two sensors in the Flock configured for the 1 transmitter/2 sensor mode.

To get Position/Angle data from sensor 1, the host would either send:

- a 2 byte command consisting of the PASS THROUGH command, F1 (Hex), followed by the POINT command, 42 (Hex)
- or the 1 byte POINT command 42 (Hex)

To get Position/Angle data from sensor 2, the host would send:

- a 2 byte command consisting of the PASS THROUGH command, F2 (Hex), followed by the POINT command, 42 (Hex)

Notes:

1) To use STREAM mode with multiple BIRDs, first send the GROUP MODE command to the Master before sending the STREAM command to the Master.

2) Data output from the Master may be delayed up to 2 milliseconds (when running at 100 measurements/second) from the time the PASS THROUGH command is issued.

POINT

POINT

	ASCII	HEX	DECIMAL	BINARY
Command Byte	B	42	66	01000010

In the POINT mode, the miniBIRD-II sends one data record each time it receives the B Command Byte. When in GROUP MODE, the Master BIRD will output a record for each running BIRD in the Flock (see EXAMINE/CHANGE parameter number 35). Remember, when GROUP MODE is enabled, an extra byte containing the sensor number 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.

POSITION

POSITION

	ASCII	HEX	DECIMAL	BINARY
Command Byte	V	56	86	01010110

In the POSITION mode, the miniBIRD-II outputs the X, Y, and Z positional coordinates of the sensor with respect to the transmitter. The output record is in the following format for the three transmitted words:

```
MSB                                                               LSB
 15   14   13   12   11   10   9    8    7    6    5    4    3    2    1    0

X15  X14  X13  X12  X11  X10  X9   X8   X7   X6   X5   X4   X3   X2   X1   1      X
Y15  Y14  Y13  Y12  Y11  Y10  Y9   Y8   Y7   Y6   Y5   Y4   Y3   Y2   Y1   0      Y
Z15  Z14  Z13  Z12  Z11  Z10  Z9   Z8   Z7   Z6   Z5   Z4   Z3   Z2   Z1   0      Z
```

The X, Y, and Z values vary between the binary equivalent of ± MAX inches, where MAX = 36". The positive X, Y, and Z directions are shown in Figure 3.

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 sensor 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 sensor.

To convert the numbers into inches, first cast it into a signed integer. This will give you a number from ± 32767. Second, multiply by 36. Finally, divide the number by 32767 to get the position in inches. The equation should look something like this:

(signed int(Hex #) * 36) / 32767

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 containing the following six words:

```
MSB                                                             LSB
 15   14   13   12   11   10   9   8   7   6   5   4   3   2   1   0

X15  X14  X13  X12  X11  X10  X9  X8  X7  X6  X5  X4  X3  X2  X1   1       X
Y15  Y14  Y13  Y12  Y11  Y10  Y9  Y8  Y7  Y6  Y5  Y4  Y3  Y2  Y1   0       Y
Z15  Z14  Z13  Z12  Z11  Z10  Z9  Z8  Z7  Z6  Z5  Z4  Z3  Z2  Z1   0       Z

Z15  Z14  Z13  Z12  Z11  Z10  Z9  Z8  Z7  Z6  Z5  Z4  Z3  Z2  Z1   0       Zang
Y15  Y14  Y13  Y12  Y11  Y10  Y9  Y8  Y7  Y6  Y5  Y4  Y3  Y2  Y1   0       Yang
X15  X14  X13  X12  X11  X10  X9  X8  X7  X6  X5  X4  X3  X2  X1   0       Xang
```

See POSITION mode and ANGLE mode for number ranges and scaling.

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 containing the following twelve words:

MSB 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	LSB 0	
X15	X14	X13	X12	X11	X10	X9	X8	X7	X6	X5	X4	X3	X2	X1	1	X
Y15	Y14	Y13	Y12	Y11	Y10	Y9	Y8	Y7	Y6	Y5	Y4	Y3	Y2	Y1	0	Y
Z15	Z14	Z13	Z12	Z11	Z10	Z9	Z8	Z7	Z6	Z5	Z4	Z3	Z2	Z1	0	Z
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(1,1)
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(2,1)
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(3,1)
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(1,2)
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(2,2)
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(3,2)
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(1,3)
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(2,3)
M15	M14	M13	M12	M11	M10	M9	M8	M7	M6	M5	M4	M3	M2	M1	0	M(3,3)

See POSITION mode and MATRIX mode for number ranges and scaling.

POSITION/QUATERNION

POSITION/QUATERNION

	ASCII	HEX	DECIMAL	BINARY
Command Byte	]	5D	93	01011101

In the POSITION/QUATERNION mode, the miniBIRD-II 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 sensor with respect to the transmitter. The output record is in the following format for the seven transmitted words:

MSB 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	LSB 0	
X15	X14	X13	X12	X11	X10	X9	X8	X7	X6	X5	X4	X3	X2	X1	1	X
Y15	Y14	Y13	Y12	Y11	Y10	Y9	Y8	Y7	Y6	Y5	Y4	Y3	Y2	Y1	0	Y
Z15	Z14	Z13	Z12	Z11	Z10	Z9	Z8	Z7	Z6	Z5	Z4	Z3	Z2	Z1	0	Z
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	0	q_0
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	0	q_1
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	0	q_2
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	0	q_3

See POSITION mode and QUATERNION mode for number ranges and scaling.

QUATERNION

QUATERNION

	ASCII	HEX	DECIMAL	BINARY
Command Byte	\	5C	92	01011100

In the QUATERNION mode, the miniBIRD-II outputs the four quaternion parameters that describe the orientation of the sensor 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 output record is in the following format for the eight transmitted bytes:

MSB 15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	LSB 0	
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	1	q_0
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	0	q_1
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	0	q_2
B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1	0	q_3

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

REFERENCE FRAME1

REFERENCE FRAME1

	ASCII	HEX	DECIMAL	BINARY
Command Byte	H	48	72	01001000

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

By default, the miniBIRD-II'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 the, Azimuth, Elevation, and Roll angles.

The command sequence consists of a Command Byte and 12 Command Data bytes. The Command Data consists of the sines and cosines of the alignment angles Azimuth (A), Elevation (E), and Roll (R). See the REFERENCE FRAME2 command if you want to send only the angles and not the sines and cosines of the angles.

Although the REFERENCE FRAME1 command will cause the miniBIRD-II's output angles to change, it has no effect on the position outputs. If you want the unit's XYZ position reference frame to also change with this command, you must first use the EXAMINE/CHANGE VALUE XYZ REFERENCE FRAME command.

If you immediately follow the REFERENCE FRAME1 command with a POINT or STREAM mode data request, you may not see the effect of this command in the data returned. It will take at least one measurement period (i.e. 10 milliseconds if running the miniBIRD-II at 100 measurements/sec) before you see the effect of the command.

If the command is sent to the Master, then all accessible BIRDs in the Flock are updated. If the command is sent to the Slave, then only the Slave is updated.

The sequence of output words to the miniBIRD-II takes the following form:

WORD #	Most Significant Byte	Least Significant Byte
1	REF command = 48	MSbyte SIN(A)
2	LSbyte SIN(A)	MSbyte COS(A)
3	LSbyte COS(A)	MSbyte SIN(E)
4	LSbyte SIN(E)	MSbyte COS(E)
5	LSbyte COS(E)	MSbyte SIN(R)
6	LSbyte SIN(R)	MSbyte COS(R)
7	LSbyte COS(R)	0

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.

REFERENCE FRAME2

REFERENCE FRAME2

	ASCII	HEX	DECIMAL	BINARY
Command Byte	r	72	114	01110010

Command Data	A, E, R

This is the same as the REFERENCE FRAME1 command except that the command data consists of the angles only and not the sines and cosines of the angles.

The Command Byte and Command Data must be transmitted to the miniBIRD-II in the following four word format:

WORD #	Most Significant Byte	Least Significant Byte
1	REF command = 72	MSbyte A
2	LSbyte A	MSbyte E
3	LSbyte E	MSbyte R
4	LSbyte R	0

See the ANGLES command for the format and scaling of the angle values sent.

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 BIRD data record output to your host computer every BIRD measurement cycle when in STREAM mode, 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 Master BIRD, but not to the Slave BIRD, to start the BIRDs FLYing or to the standalone BIRD to restart normal system operation after it 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. The command is issued to the Master BIRD or the standalone BIRD but not to the Slave BIRD. While asleep, the BIRD 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 miniBIRD-II starts sending continuous data records to the host computer as soon as the @ Command Byte is received. Data records will continue to be sent until the host sends the POINT or OUTPUT BUFFER CLEAR commands. If you use the POINT command to stop the streaming, you will receive an additional data record in response to the POINT command. It is the user’s responsibility to clear the BIRD’s output port of any unread words after issuing the POINT command.

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

8.0 ERROR MESSAGES

The miniBIRD-II keeps track of system errors. When an error occurs, the SYSTEM STATUS register ERROR bit is set to a '1', and the error code is put into the ERROR CODE register. The user can query the SYSTEM STATUS register by using the EXAMINE VALUE SYSTEM STATUS command. The ERROR CODE register can be read by using the EXAMINE VALUE ERROR CODE command. When the user reads SYSTEM STATUS, the ERROR bit is reset to a '0', and when the user reads the ERROR CODE register, all bits are reset to '0'.

CODE	ERROR DESCRIPTION	TYPE
1	System Ram Failure	FATAL
2	Non-Volatile Storage Write Failure	FATAL
3	PCB Configuration Data Corrupt	WARNING
4	BIRD Transmitter Calibration Data Corrupt or Not Connected	WARNING
5	BIRD Sensor Calibration Data Corrupt or Not Connected	WARNING
6	Invalid Command	WARNING
9	BIRD is Not Initialized	WARNING
16	Invalid CPU Speed	FATAL
20-27	Intel 80186 CPU Errors	FATAL
29	Transmitter Not accessible	WARNING
31	CPU Time Overflow	WARNING
32	Sensor Saturated	WARNING

MESSAGE TYPE	DESCRIPTION
FATAL	Error is posted in system status, panel light continuously blinks the error code, the BIRDs stops running.
WARNING	Error is posted in the system status, the BIRDs continues to run.

8.1 ERROR MESSAGE DETAILS

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

CODE	ERROR DESCRIPTION	TYPE
1	RAM Failure Cause: System RAM Test 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 transmitter, sensor, 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
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 sensor.	WARNING
4	Transmitter Configuration Data Corrupt Cause: The system was not able to read the Transmitter EEPROM 'Initialized Code' or the Transmitter is not plugged in. Action: *Insure that the Transmitter is present, calibrate the transmitter, and set the 'Initialized Code' in the EEPROM.	WARNING
5	Sensor Configuration Data Corrupt Cause: The system was not able to read the Sensor EEPROM 'Initialized Code' or the Sensor is not plugged in. Action: *Insure that the Sensor is present, calibrate the sensor, 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 not make sense (i.e., change value commands with an unknown parameter number). Action: Only send valid commands to the miniBIRD-II.	WARNING
9	BIRD is Not Initialized Cause: The Master BIRD is sent the Run command, but it has not been initialized via the Auto-Configuration command. Action: Send the Auto-Configuration command prior to sending the Run command.	WARNING

CODE	ERROR DESCRIPTION	TYPE
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
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 exist, so this should never occur. Check to make sure the ERROR/signal on the CPU is tied to +5VD.	FATAL
29	Transmitter Not accessible Error Cause: This error occurs when the host starts the system FLYing via the Auto-Configuration command, and a BIRD which should have a transmitter does not have a transmitter. Action: Assure that the specified BIRD has a transmitter.	WARNING

CODE	ERROR DESCRIPTION	TYPE
31	CPU Time Overflow Error Cause: This error occurs if the CPU in the miniBIRD-II runs out of CPU time. This can occur if the host overburdens the miniBIRD-II with multiple commands in a measurement cycle. Action: The host can either slow down the measurement rate or decrease the number of commands sent to the miniBIRD-II.	WARNING
32	Sensor Saturated Error Cause: This error occurs if the sensor is saturated during power-up. This will occur if the sensor is not connected, the sensor or cable is damaged, a large magnetic field is present, or the sensor is sitting on a steel table. Action: The User should check that the sensor is attached to the miniBIRD-II (screw in the connector) and that none of the other above-mentioned conditions exist.	WARNING

9.0 TROUBLE SHOOTING

In addition to this manual you can now receive on-line support and assistance at the Ascension's web site:

http://www.ascension-tech.com/support/troubleshoot/index.htm

If you are experiencing trouble with the miniBIRD-II, try the following:

IF YOU CANNOT TALK TO THE miniBIRD-II WITH THE ISA INTERFACE:

1) With the power off to the host computer, verify that the miniBIRD-II 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 miniBIRD-II in a polled mode.

IF YOU CAN COMMUNICATE WITH THE miniBIRD-II 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.

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

For technical assistance call Ascension Technology at 802-893-6657 between the hours of 9 AM and 5 PM Eastern Standard Time or fax us at 802-893-6659.

APPENDIX I - NOMENCLATURE

FLOCK	A Flock is one or more sensors and/or transmitters that are connected together to make a single system.
MASTER	The Master miniBIRD-II is the electronic unit that controls and coordinates the operation of all the sensors and transmitters. The Master controls the sequencing and synchronizing of Flock transmitters and dictates when to measure the transmitted magnetic fields. The user's host computer communicates with the Master to start and stop the Flock and perform other master specific control functions.
SLAVE	This is the second sensor in the Flock with possibly a transmitter that receives operating instructions from the Master.
NOISE	Noise is when you place a sensor in a stable location and the sensor still looks like it is moving. Noise can come from many places in your environment including, but not limited to: power lines, monitors, transformers, overhead lights, fuse boxes, etc.
CRT	The CRT (Cathode Ray Tube) is the monitor that connects to the host computer.
ISA BUS	The ISA bus is the interface that the computer uses to talk to the miniBIRD-II.
I/O ADDRESS	Is the dip switch assigned address that the user selects for communication with the miniBIRD-II. Each electronic unit must have a unique I/O address.
EULER ANGLE	These are the rotations about the axes. The Azimuth is the rotation about the Z axis, the Elevation is the rotation about the Y axis, and the Roll is the rotation about the X axis.
FLYING	This is the state that the miniBIRD-II is in immediately after power on. This is the running state.

APPENDIX II - miniBIRD-II SPECIFICATIONS

Physical

Transmitter:	3.75" cube with 10' cable.
Sensor:	0.71" x 0.32" x 0.32" with 10' cable.
PC Board:	Half size PC board (one per sensor pair to be tracked)

Technical

Positional range:	± 3' in any direction
Angular range:	± 180^o Azimuth & Roll ± 90^o Elevation
Static positional accuracy:	0.07" RMS @ 12" with miniBIRD-II Transmitter
Positional resolution:	0.02" RMS @ 12" with miniBIRD-II Transmitter
Static angular accuracy:	0.5^o RMS @ 12" with miniBIRD-II Transmitter
Angular resolution:	0.1^o RMS @ 12" with miniBIRD-II Transmitter
Update rate:	30-120 measurements/sec
Outputs:	X, Y, Z positional coordinates and orientation angles: rotation, matrix, or quaternions
Interface:	ISA-Bus
Format:	Binary
Modes:	Point or Stream

Electrical

miniBIRD-II Power requirements:	Uses PC’s power supply (+5V @ 1.5A, +12V @ 1.5A No -5V or -12V)

Environment	All specifications are valid at 30^o C ± 10^o in an environment void of large metal objects and electromagnetic frequencies, other than the power line.

APPENDIX III - APPLICATION NOTES

Application Note #1

Computing the Coordinates of a Stylus Tip

Some applications need to measure the X, Y, Z coordinates that describe the physical shape of an object such as a plastic model or a person's face. This measurement can be accomplished by moving the miniBIRD-II's sensor over the object and recording the X, Y, Z positional outputs. Because of the sensor's size, it is sometimes more convenient to mount the miniBIRD-II's sensor onto a pencil or pen or some other device with a pointed tip (generically called a stylus) and then trace the object with the stylus tip to record its shape. Since the positional outputs of the miniBIRD-II are in relation to the center of the sensor, one needs to find the corresponding X, Y, Z coordinates at the tip of the stylus. This translation of coordinates is easily accomplished with the application of some elementary trigonometry given the POSITION/MATRIX outputs and the X, Y, Z offset distances from the miniBIRD-II's sensor center to the tip of the attached stylus.

Notation: X_B, Y_B, Z_B are the X, Y, Z position outputs from the miniBIRD-II, that is, the location of the sensor's center with respect to the transmitter's center.

X_O, Y_O, Z_O are the offset distances from the sensor's center to the tip of the stylus.

X_S, Y_S, Z_S are the coordinates of the stylus's tip with respect to the transmitter's center.

M(i, j) are the elements of the rotation matrix returned to the user when the user requests POSITION/MATRIX outputs. Definition of the individual matrix elements can be found in the User's manual under the heading MATRIX.

Math: The stylus coordinates can be computed from the following:

$$X_S = X_B + X_O * M(1,1) + Y_O * M(2,1) + Z_O * M(3,1)$$

$$Y_S = Y_B + X_O * M(1,2) + Y_O * M(2,2) + Z_O * M(3,2)$$

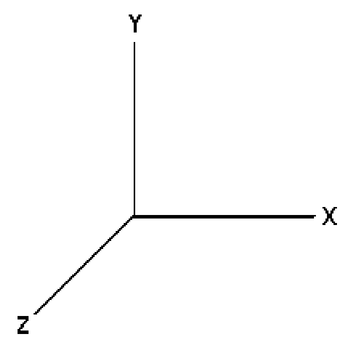
$$Z_S = Z_B + X_O * M(1,3) + Y_O * M(2,3) + Z_O * M(3,3)$$

Application Note #2

Converting the miniBIRD-II's Output to a Graphics Modeling Matrix

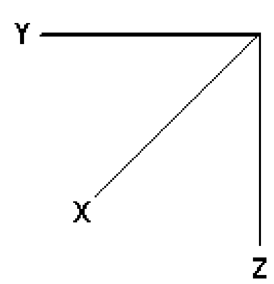
Purpose: Build the 12 elements of a standard computer graphics modeling matrix, MM(i, j), given the 9 matrix output elements from the miniBIRD-II, MB(i, j), and the miniBIRD-II's X, Y, Z position outputs Xpos, Ypos, and Zpos.

The standard computer graphics XYZ coordinate system is: positive X axis points to the right, positive Y axis points up, and positive Z points towards you.



Standard Graphic Mode

When the transmitter is between you and the graphics screen and the transmitter's power cord extends in the direction toward the screen the miniBIRD-II's XYZ coordinate system is: positive X axis points out of the screen, positive Y axis points to the left, positive Z axis points down.



Ascension's Graphic Mode

To have the screen image follow the rotations and translations of the miniBIRD-II's sensor with movement of the sensor toward the screen causing the image to move toward the front of the graphics screen, the following transformations from BIRD coordinates to modeling matrix elements are required:

MM(1,1) = MB(2,2)
MM(1,2) = MB(2,3)
MM(1,3) = - MB(2,1)
MM(1,4) = 0.
MM(2,1) = MB(3,2)
MM(2,2) = MB(3,3)
MM(2,3) = - MB(3,1)
MM(2,4) = 0.
MM(3,1) = - MB(1,2)
MM(3,2) = - MB(1,3)
MM(3,3) = MB(1,1)
MM(3,4) = 0.
MM(4,1) = - Ypos
MM(4,2) = - Zpos
MM(4,3) = Xpos
MM(4,4) = 1.0

Application Note #3

Configuring the miniBIRD-II for Minimum Lag

1. Use STREAM mode not POINT mode for collecting data. STREAM mode gives you data every BIRD measurement cycle as soon as it has been computed. If you used POINT mode, the data request would come at some random point in the miniBIRD-II's measurement cycle resulting in a random variation of up to 10 milliseconds in the 'age' of the unit’s measured data.

2. Select an output format that transmits the minimum amount of data required. For example, if you only want to measure angles, then select ANGLE mode and not POSITION/ANGLE mode.

3. Unlock the outputs if you are going to be making sudden movements by setting the CHANGE VALUE, SUDDEN OUTPUT CHANGE LOCK command to zero.

4. Minimize the number of filters applied to the miniBIRD-II data. To determine which filters you can remove: 1) Set the miniBIRD-II's sensor at the maximum distance from the transmitter that you will be using in your application. 2) Use the CHANGE VALUE, FILTER ON/OFF STATUS command to remove one filter at a time. Observe the noise on the outputs of your measurements as you remove each filter. If the amount of noise is acceptable, leave the selected filter out. The DC filter will have the largest impact on noise and usually cannot be eliminated unless you are going to be running with the sensor close to the transmitter or you are going to filter your own data.

5. Minimize the amount of steady state filtering applied by the DC filter. Use the CHANGE VALUE, DC FILTER CONSTANT TABLE ALPHA_MIN command and increase ALPHA_MIN until the noise level is unsatisfactory. The closer the sensor is to the transmitter, the larger ALPHA_MIN can be.

6. Run the miniBIRD-II at a higher measurement rate. Use the CHANGE VALUE, BIRD MEASUREMENT RATE command and increase the unit's measurement rate from its default speed of approximately 103.3 measurements/second. You can increase the speed up to a maximum of approximately 120 measurements/seconds. As you increase the speed, you will note that the amount of noise in the miniBIRD-II’s measurements may be higher than or less than the amount of noise at the power-up default speed. The noise can increase or decrease rapidly with a speed change of just a few cycles/sec and then increase or decrease again as you continue to change the speed.

7. Reduce the amount of noise that the miniBIRD-II thinks is in the local environment by using the CHANGE VALUE, DC FILTER TABLE Vm command. Set the sensor at various distances from the transmitter and reduce the Vm value for this range until the noise is unacceptable. The biggest gain in dynamic performance, other than elimination of the DC filter, comes from reducing Vm.

8. Reduce the amount of filtering during the steady state part of fast movements by using the CHANGE VALUE, DC FILTER CONSTANT TABLE ALPHA_MAX. Set ALPHA_MAX as close to 0.999 as possible. The larger ALPHA_MAX is, the less lag there will be during fast motions. But note, the larger ALPHA_MAX is, the larger the noise will be during the movement.

At Ascension Technology when we want a 'snappy' response with good noise characteristics we use all system defaults except for the following overrides:

a). Stream mode
b). Sudden output change lock = 0
c). DC filter ON, AC narrow notch filter ON, AC wide notch OFF
d). Vm table = 2, 2, 2, 10, 10, 40, 200

where most of the 'snap' comes from the Vm table.

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