



ORIENT3D

Hardware v1.0

Firmware v1.0

USER MANUAL and SPECIFICATIONS

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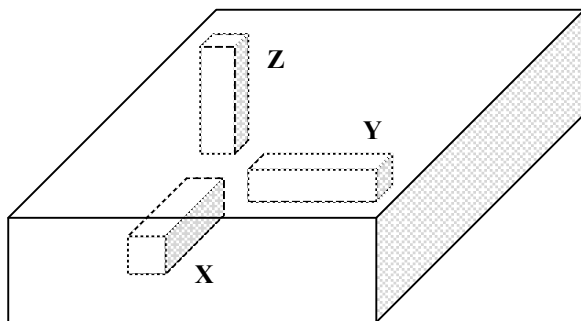
1 - Introduction

Orient3D is a 3-axis magnetic field sensing module. It uses three orthogonally placed magneto-inductive sensors to detect the earth's magnetic field.

With the data retrieved from an Orient3D, heading, pitch and roll can be computed.

The Orient3D can be used in analog mode, which consists of three 0-5V outputs; or in digital mode, through an I²C bus.

When in digital mode, you can daisy-chain up to four Orient3Ds per microDig I²C port. Since each microdig allows for four I²C ports, you could end up with sixteen Orient 3D.



Orient3D internal X, Y and Z sensor orientation

2 - How it works

Inside the Orient3D, each axis sensor outputs a 2's complement, 16bit integer (ranging from 32767 to -32768) depending on the magnetic field strength and of the axis orientation respect to the magnetic field lines.

Mathematically:

$$S_n = M * G * \cos(\theta)$$

Where S_n is the sensor output (n is either x, y or z)

M is the magnetic field strength

G is the sensor gain

θ is the angle between the sensor's axis and the magnetic field lines.

The gain might be scaled by a factor: 1/64, 1/32, 1/16, 1/8, 1/4, 1/2, 1, 2

Gain is defined as the change in the number of counts from the sensor, when the scaling factor is 1, per change in the magnetic field in μT ($G=31.24 \text{ Count}/\mu\text{T}$, see specifications section). For situations requiring higher gain and less field measurement range, the gain (and resolution) can be increased by a factor of 2, then $G = 2*31.24 = 62.48 \text{ Count}/\mu\text{T}$. For smaller gains, or when saturation occurs, the scaling factor should be set to smaller a value. Be aware that the counter can overflow if the field is strong enough drive the count beyond a signed 16-bit integer.

Internally each sensor is part of an oscillator whose frequency varies according to the magnetic field parallel to the sensor's axis. This oscillator frequency is fed into a period counter, after being divided by a user-specified divisor. The available divisor ratios are: 32, 64, 128, 256, 512, 1024, 2048 and 4096. The output from the Orient3D is the count, so the divisor is effectively the gain scaling factor. A higher divisor corresponds to a longer period, a greater high speed oscillator count (the output) and better resolution.

In I²C mode, Orient3D will return a copy of each sensor's output S_x, S_y and S_z (three integers). This mode is very useful for direction, pitch and roll angle computing:

$$\begin{aligned} \text{Heading} &= \arctan(S_x / S_y) \\ \text{Pitch} &= \arctan(S_x / S_z) \\ \text{Roll} &= \arctan(S_y / S_z) \end{aligned}$$

In analog mode, Orient3D will output three 0-5V analog signals (one per axis) based on the 10 least significant bits of above integers.

Doing the math:

$$A_n = 5V * (S_n' + 512) / 1024$$

Where A_n is the analog output and

$$S_n' = \begin{cases} -512 & \text{if } S_n < -512 \\ S_n & \text{if } -512 \leq S_n \leq 511 \\ 511 & \text{if } S_n > 511 \end{cases}$$

Note: If the analog outputs get saturated you should scale down the gain.

3 - Examples

Note 1: These examples illustrate the behaviour of the x axis only; in practice for each orientation all three axes could be computed.

Note 2: The strength of the field at the Earth's surface ranges from less than 30 microteslas (0.3 gauss) in an area including most of South America and South Africa to over 60 microteslas (0.6 gauss) around the magnetic poles in northern Canada and south of Australia, and in part of Siberia (Wikipedia)

Example 1: M = 15μT, G=31.24 Count/μT

1.1) θ = 0° (X sensor's axis is aligned to the magnetic field lines)

$$\begin{aligned} S_x &= M * G * \cos(\theta) = 15\mu T * 31.24 \text{ Count}/\mu T * \cos(0^\circ) = 468 \text{ (=0X01D4)} \\ A_x &= 5V * (S_x' + 512) / 1024 = 5V * (468 + 512) / 1024 = 4.785V \end{aligned}$$

1.2) θ = 60°

$$\begin{aligned} S_x &= M * G * \cos(\theta) = 15\mu T * 31.24 \text{ Count}/\mu T * \cos(60^\circ) = 234 \text{ (=0X00EA)} \\ A_x &= 5V * (S_x' + 512) / 1024 = 5V * (234 + 512) / 1024 = 3.643V \end{aligned}$$

1.3) θ = 90° (X sensor's axis perpendicular to the magnetic field lines)

$$\begin{aligned} S_x &= M * G * \cos(\theta) = 15\mu T * 31.24 \text{ Count}/\mu T * \cos(90^\circ) = 0 \text{ (=0X0000)} \\ A_x &= 5V * (S_x' + 512) / 1024 = 5V * (0 + 512) / 1024 = 2.5V \end{aligned}$$

1.4) θ = 120°

$$\begin{aligned} S_x &= M * G * \cos(\theta) = 15\mu T * 31.24 \text{ Count}/\mu T * \cos(120^\circ) = -234 \text{ (=0XFF16)} \\ A_x &= 5V * (S_x' + 512) / 1024 = 5V * (-234 + 512) / 1024 = 1.357V \end{aligned}$$

1.5) θ = 180° (X sensor's axis is aligned to the magnetic field lines but in opposite direction)

$$\begin{aligned} S_x &= M * G * \cos(\theta) = 15\mu T * 31.24 \text{ Count}/\mu T * \cos(180^\circ) = -468 \text{ (=0XFE2C)} \\ A_x &= 5V * (S_x' + 512) / 1024 = 5V * (-468 + 512) / 1024 = 0.215V \end{aligned}$$

Example 2: $M=30\mu T$, $G=62.48 \text{ Count}/\mu T$

2.1) $\theta = 60^\circ$

$$S_x = M * G * \cos(\theta) = 30\mu T * 62.48 \text{ Count}/\mu T * \cos(60^\circ) = 937 (=0X03A9)$$

$$A_x = 5V * (S_x' + 512) / 1024 = 5V * (511 + 512) / 1024 = 4.995V \text{ (saturated)}$$

Example 3: $M=30\mu T$, $G=15.62 \text{ Count}/\mu T$

3.1) $\theta = 60^\circ$

$$S_x = M * G * \cos(\theta) = 30\mu T * 15.62 \text{ Count}/\mu T * \cos(60^\circ) = 234 (=0X00EA)$$

$$A_x = 5V * (S_x' + 512) / 1024 = 5V * (234 + 512) / 1024 = 3.643V$$

4 - Hardware description

4.1- Hack cable male connectors

The Orient3D is powered through the 3D (3-channel) Hack cable. In I²C mode, only the first two channels are needed. For analog mode, all three are needed.

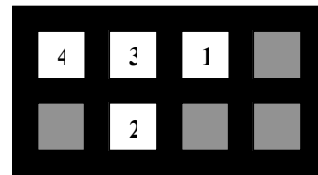
4-pin male connector

Pin assignment in I²C mode:

1- power	red	5V, 7mA per Orient3D connected in daisy chain
2- i2c_data	black	input/output, open drain, Rpullup=4k7
3- i2c_clock	white	input/output, open drain, Rpullup=4k7
4- ground	shield	0V

Pin assignment in analog mode:

1- power	red	5V, 7mA
2- analog_x	black	output 0-5V, Rout=2k2
3- analog_y	white	output 0-5V, Rout=2k2
4- ground	shield	0V



Hack cable, 4-pin male connector. Front view

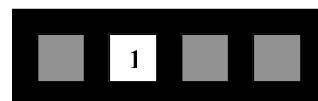
1-pin male connector

Pin assignment in I²C mode:

1- aux	grey	output, 100ms positive pulse if any axis changes more then the amount set with the I ² C command: SET DELTA
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Pins assignment in analog mode:

1- analog_z	grey	output 0-5V, Rout=2k2
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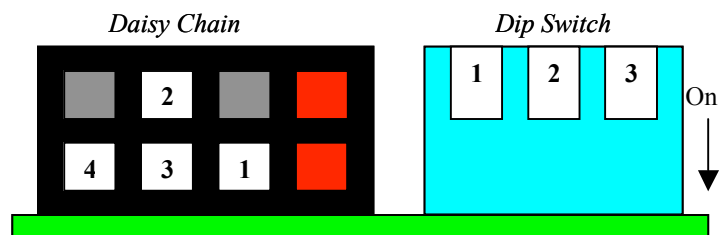
Hack cable, 1-pin male connector. Front view

4.2 - Daisy chain female connector

This connector is only used in I²C mode and allows for daisy chaining up to four Orient3D sensors.

Pins assignment:

1- power
2- i2c_data
3- i2c_clock
4- ground



Orient 3D lateral view

4.3 - Dip switch functions

Switches 1 and 2 in I²C mode:

I²C address bits 1 and 0 (the two address less significant bits)

1:off / 2:off address = xxxxx00

1:off / 2:on address = xxxxx01

1:on / 2:off address = xxxxx10

1:on / 2:on address = xxxxx11

(Where xxxxx are the five most significant bits; these may be change with the I²C command: SET ADDRESS)

Switches 1 and 2 in analog mode:

Gain scale factor (In I²C mode the scale factor is changed with a command)

1:off / 2:off scale factor = 1/4

1:off / 2:on scale factor = 1/2

1:on / 2:off scale factor = 1

1:on / 2:on scale factor = 2

Switch 3

Mode select:

3:on analog mode

3:off I²C mode

5 - I²C setup

If you are unfamiliar with the microdig's I²C commands, look up the host mode commands: "I²C PORT SET", "I²C WRITE" and "I²C READ" in the document "Wi-microdig communication protocol.pdf", before continuing.

- 1 - Set dip switch 3 to the off position; I²C mode.
- 2 - Set dip switches 1 and 2 with the I²C's address least significant bits. The five more significant bits need to be known in order to be able to send a command to the Orient3D, if you don't know which is this address, follow the next procedure to clear these five bits:
 - a- Turn off the Orient3D and set dip switch 3 to the on position (analog mode)
 - b- Turn on the Orient3D, the address five more significant bits are now 00000.
 - c- Turn off the Orient3D and set dip switch 3 to the off position (I²C mode)
- 3 - Plug the hack cable 4-pin male connector (power & I²C bus) to the microdig.
- 4 - If desired plug the hack cable 1-pin male connector (aux signal) to the microdig.
- 5 - If desired, daisy chain three more Orient3D by plugging the hack cable 4-pin male connector (power & I²C bus) of the second Orient3D into the female daisy chain connector of the first Orient3D. The aux signal can not be used in the daisy chained Orient3Ds. The daisy chained Orient3Ds should have different addresses.
- 6 - Power up the microdig.
- 7 - Reset the microdig.
- 8 - Set the microdig in host mode.
- 9 - Configure/select the microdig ports where the I²C bus has been plugged with the command "I²C PORT SET". This command should be sent each time you want to use a different I²C port before sending any command to the Orient3Ds in that I²C bus.

Note: The data returned by the Orient3D may need to be calibrated to the working location / environment. This should be done by the system processing the data.
The available Max/MSP patch includes a calibration procedure. See the I-cubeX web page.
Also see "Calibration.pdf" for more details on calibration.

6 - Orient3D I²C commands

If you are using a microdig as I²C master, the following commands should be sent / encapsulated with the "I²C WRITE" and "I²C READ" commands.
The Orient3D I²C commands have a "get or set register" form. The register's size may vary according to the data stored in it.

6.1 - I²C Command: GET XYZ (read register 0, whose size is 6 bytes)

The data received are the three X, Y and Z, 2's complement 16 bit integers.

Example (dec):

Send: 240, 125, 0 {DEV}, 127 {I²C READ}, 0 {address of I²C device}, 0, 0 {register 16*0+0=0}, 6 {bytes to be read}, 247

Receive: 240, 125, 0 {DEV}, 127 {I²C READ}, 0 {address of I²C device}, 0, 0 {register 16*0+0=0}, 6 {bytes to be read}, 1, 2, 3, 4 {X=1234h=4660}, 15, 14, 13, 12 {Y=FEDCh=-292}, 5, 6, 7, 8 {Z=5678h=22136}, 247

Example (hex):

Send: F0h, 7Dh, 00h {DEV}, 7Fh {I²C READ}, 00h {address of I²C device}, 00h, 00h {register 16*0+0=0}, 06h {bytes to be read}, F7h

Receive: F0h, 7Dh, 00h {DEV}, 7Fh {I²C READ}, 00h {address of I²C device}, 00h, 00h {register 16*0+0=0}, 06h {bytes to be read}, 01h, 02h, 03h, 04h {X=1234h}, 0Fh, 0Eh, 0Dh, 0Ch {Y=FEDCh}, 05h, 06h, 07h, 08h {Z=5678h}, F7h

6.2 - I²C Command: GET VERSION (read register 1, whose size is 2 bytes)

The first byte received is the hardware release; the second byte is the software release.

Example (dec):

Send: 240, 125, 0 {DEV}, 127 {I²C READ}, 0 {address of I²C device}, 0, 1 {register 16*0+1=1}, 2 {bytes to be read}, 247

Receive: 240, 125, 0 {DEV}, 127 {I²C READ}, 0 {address of I²C device}, 0, 1 {register 16*0+1=1}, 2 {bytes to be read}, 0, 1 {HW rel=16*0+1=1}, 0, 1 {SW rel=16*0+1=1}, 247

Example (hex):

Send: F0h, 7Dh, 00h {DEV}, 7Fh {I²C READ}, 00h {address of I²C device}, 00h, 01h {register 16*0+1=1}, 02h {bytes to be read}, F7h

Receive: F0h, 7Dh, 00h {DEV}, 7Fh {I²C READ}, 00h {address of I²C device}, 00h, 01h {register 16*0+1=1}, 02h {bytes to be read}, 00h, 01h {HW rel = 01h}, 00h, 01h {SW rel = 01h}, F7h

6.3 - I²C Command: SET GAIN SCALING FACTOR (write register 2, whose size is 1 byte)

The value written into this register will be the gain scaling factor when working in I²C mode.
The range should be in between 0 to 7 (00h to 07h). The gain scale factor will be stored into a non volatile memory. The value received will be masked (and'ed) with 0X07, so if the value is out of range, only the three least significant bits will remain.

Byte received [x x x x F3 F1 F0] & Mask [0 0 0 0 1 1 1] = [0 0 0 0 F3 F1 F0]

Example (dec):

Send: 240, 125, 0 {DEV}, 126 {I²C WRITE}, 0 {address of I²C device}, 0, 2 {register 16*0+2=2}, 0, 7 {SCALE FAC=16*0+7=7}, 247

Receive: (echo of the sent data)

Example (hex):

Send: F0h, 7Dh, 00h {DEV}, 7Eh {I²C WRITE}, 00h {address of I²C device}, 00h, 02h {register 16*0+2=2}, 00h, 07h {SCALE FAC=07h}, F7h

Receive: (echo of the sent data)

6.4 - I²C Command: SET ADDRESS (write register 3, whose size is 1 byte)

This byte sets the five most significant bits of the I²C address. The value received will be masked (ANDed) with 0X7C; then if the value is out of range, the byte most significant bit and two least bits will be 0. This part of the address will be stored in non volatile memory

Byte received [x A7 A6 A5 A4 A3 x x] & Mask [0 1 1 1 1 0 0] = [0 A7 A6 A5 A4 A3 0 0]

The final I²C address is this result ORed with the values of dip switches 1 and 2.

Address = [0 A7 A6 A5 A4 A3 0 0] | [0 0 0 0 0 0 SW1 SW2] = [0 A7 A6 A5 A4 A3 SW1 SW2]

This I²C command is only available if it's the first command after power up, thus preventing any unwanted I²C address changes. You can keep sending this command as long as no other command is send in between.

Note: If this value is unknown or forgotten you won't be able to communicate by the device, follow the procedure in the "I²C setup" section to set these bits to 0.

Example (dec):

Send: 240, 125, 0 {DEV}, 126 {I²C WRITE}, 0 {address of I²C device}, 0, 3 {register 16*0+3=3}, 1, 0 {ADDRESS=16*1+0=16}, 247

Receive: (echo of the sent data)

Example (hex):

Send: F0h, 7Dh, 00h {DEV}, 7Eh {I²C WRITE}, 00h {address of I²C device}, 00h, 03h {register 16*0+3=3}, 01h, 00h {ADDRESS=10h}, F7h

Receive: (echo of the sent data)

6.5 - I²C Command: SET DELTA (write register 4, whose size is 1 byte)

When any of the axes changes more then the amount written into this register, a 100ms positive pulse will be generated at the aux pin. The range should be in between 0 to 255 (00h to FFh). The delta value will be stored in non volatile memory.

Every time a new axis is sensed, the new value is compared to the axis's latched value +/- the delta amount. If the new value is greater, the latch is updated and a pulse is generated in the aux pin.

This function could be useful to avoid constant I²C requests to the sensor if there is no significant change detected by the Orient3D. This results in less data traffic for the microdig and thus less power used for transmission.

For example (delta = 10; initial X,Y,Z latched values = 0)

t	X	Y	Z	aux
1	0	0	-127	trigger; Z<(Z latched - 10); new Z latched = -127
2	3	2	-123	no trigger
3	5	2	-118	no trigger
4	8	3	-115	trigger; Z>(Z latched + 10); new Z latched = -115
5	11	2	-115	trigger; X>(X latched + 10); new X latched = 11
6	12	1	-116	no trigger

Example (dec):

Send: 240, 125, 0 {DEV}, 126 {I²C WRITE}, 0 {address of I²C device}, 0, 4 {register 16*0+4=4}, 8, 4 {DELTA =16*8+4=132}, 247

Receive: (echo of the sent data)

Example (hex):

Send: F0h, 7Dh, 00h {DEV}, 7Eh {I²C WRITE}, 00h {address of I²C device}, 00h, 04h {register 16*0+4=4}, 08h, 04h {DELTA =84h}, F7h

Receive: (echo of the sent data)

6.6 - I²C Command: SET LED (write register 5, whose size is 1 byte)

Enable or disable the LED for I²C command: GET XYZ . Write 0 (00h) to enable the LED or write any other value to disable it. This value is not stored in non volatile memory. If the power is cycled, the register value will be 0. The range should be in between 0 to 255 (00h to FFh).

Example (dec):

Send: 240, 125, 0 {DEV}, 126 {I²C WRITE}, 0 {address of I²C device}, 0, 5 {register 16*0+5=5}, 0, 1 {LED =16*0+1=1}, 247

Receive: (echo of the sent data)

Example (hex):

Send: F0h, 7Dh, 00h {DEV}, 7Eh {I²C WRITE}, 00h {address of I²C device}, 00h, 05h {register 16*0+5=5}, 00h, 01h {LED =01h}, F7h

Receive: (echo of the sent data)

7 - Analog setup

- 1 - Set dip switch 3 to the on position; analog mode (Please note that after doing this and powering the sensor, the five most significant bits of the I²C address will be set to 00000)
- 2 - Set dip switches 1 and 2 with the desired gain scaling factor (this can be done at any time)
- 3 - Plug the hack cable 4-pin male connector (x & y) to the microdig.
- 4 - Plug the hack cable 1-pin male connector (z) to the microdig.
- 5 - Power up the microdig.
- 6 - Reset the microdig.
- 7 - Set the microdig in stand alone mode.

8 - Configure the microdig ports as analog inputs with the desired resolution. Use Pitch Bend for 12-bit resolution.

8- Analog calibration

The following describes using the editor to calibrate the microDig to give a full-scale reading for each axis.

Set the scale factor dip switches to the highest value (2)

Repeat the following procedure for all three axes.

1 - Align the sensor's axis to the north, keeping it tangent to the earth surface (ie horizontally flat), looking for the maximum reading (the closest to 5V), if the reading gets saturated scale down the gain with the dip switches. If necessary invert the signal.

2- Without changing the direction away from north, adjust the sensor's axis pitch, looking for the maximum reading (the closest to 5V), if the reading gets saturated scale down the gain with the dip switches.

3- The sensor is now aligned to the earth's magnetic lines.

4- Without moving the Orient3D set the high threshold to get the maximum reading.

5- Align the sensor axis to the south, looking for the minimum reading (the closest to 0V), if the reading gets saturated scale down the gain with the dip switches.

6- Without moving the Orient3D set the low threshold to get the minimum reading.

Now, you will get a value from 0 to 127 (0 to 16383 in high resolution) for each Orient3D axis according to their orientation in the earth magnetic field lines.

You can also do this in the Max/MSP patch from the website. If you are using the patch, then simply use the editor to set the microdig to standalone mode, and enable 3 inputs and set each one to output pitch-bend messages (0 – 16383).

9 - Specifications

Sensors Parameters	min	typical	max
Measurement range	-1100 μ T		+1100 μ T
Accuracy		0.015 μ T	
Gain Scale factor = 1 Scale factor = 2		31.24 Count/ μ T 62.48 Count/ μ T	
Resolution		1/Gain μ T	
Linearity (Error from best fit straight line at \pm 300 μ T)		0.6%	1%

Electrical Parameters	min	typical	max
Supply voltage	4.75V	5V	5.25V
Supply Current	7mA	8mA	9mA
I ² C input, high voltage threshold	3V		5.25V
I ² C input, low voltage threshold	-0.5V		1.5V
I ² C pullup resistors		4K7 ohm	
I ² C output, low voltage level (Io 20mA)			0.7V
I ² C output, sink current (Vo 0.7V)			20mA
Analog output, voltage range	0V		5V
Analog output, DC equivalent resistance		2K2 ohm	

Timing	min	typical	max
I ² C clock frequency			50kHz
I ² C inter command time	10ms		
Analog output, response time (10 to 90%)		50ms	
Internal three axis sensors sample time Scale factor = 2 Scale factor = 1 Scale factor = 1/2 Scale factor = 1/4 Scale factor = 1/8 Scale factor = 1/16 Scale factor = 1/32 Scale factor = 1/64			180ms 106.5ms 45ms 22.50ms 12ms 6ms 3ms 1.5ms