INTERNATIONAL
BRAIN
LABORATORY

IBL Behavior Control - Device Registers

Document Version 0.1

1. Introduction

The IBL Behavior Control device uses the most recent Harp core. This means that the comunication and synchronism of the device is covered by the Harp ecosistem.

Therefore, the device uses registers to interface with the host computer. The user can use the available tools (Python and Bonsai) to communicate with the device and write & read from these registers.

The purpose of this document is to explain the functionality of each register.

If you have doubts, comments or suggestion, please provide them to filipe@open-ephys.org

2. Registers

2.1 List of Registers

Table 2-1. List of available Registers

Name	Type	Add	Brief Description
CONFIG	U16	32	Configures the device
DATA_STREAM a)	I16	33	Analog sensor, analog input, rotary encoder, and threshold events
INPUTS a)	U8	34	Contains the state of the digital inputs (IO2) (IO1) (IO0)
INPUT_IO0_CONFIG	U8	35	Configuration of port IO0 when used as digital input
INPUT_IO1_CONFIG	U8	36	Configuration of port IO0 when used as digital input
INPUT_IO2_CONFIG	U8	37	Configuration of port IO0 when used as digital input
OUTPUT_SET	U8	38	Set to logic 1 the port IO*x* according to bit mask
OUTPUT_CLEAR	U8	39	Clear to logic 0 the port IO*x* according to bit mask
OUTPUT_TOGGLE	U8	40	Toggles the current logic port IO*x* according to bit mask
OUTPUT_WRITE	U8	41	Write to the all ports (IO0, IO1 and IO1) at once
ANA_SENSOR_TH0_HIGH	U16	42	Sets the higher threshold 0 for the analog sensor
ANA_SENSOR_TH0_HIGH_MS	U16	43	Sets the number of milliseconds to consider a valid high threshold 0
ANA_SENSOR_TH0_LOW	U16	44	Sets the lower threshold 0 for the analog sensor
ANA_SENSOR_TH0_LOW_MS	U16	45	Sets the number of milliseconds to consider a valid low threshold 0
ANA_SENSOR_TH0_EVT_CONF	U8	46	Configures what to do when the thresholds 0 are crossed
ANA_SENSOR_TH1_HIGH	U16	47	Sets the higher threshold 1 for the analog sensor
ANA_SENSOR_TH1_HIGH_MS	U16	48	Sets the number of milliseconds to consider a valid high threshold 1
ANA_SENSOR_TH1_LOW	U16	49	Sets the lower threshold 1 for the analog sensor
ANA_SENSOR_TH1_LOW_MS	U16	50	Sets the number of milliseconds to consider a valid low threshold 1
ANA_SENSOR_TH1_EVT_CONF	U8	51	Configures what to do when the thresholds 1 are crossed
ANA_INPUT_TH0_HIGH	U16	52	Sets the higher threshold 0 for the analog input
ANA_INPUT_TH0_HIGH_MS	U16	53	Sets the number of milliseconds to consider a valid high threshold 0
ANA_INPUT_TH0_LOW	U16	54	Sets the lower threshold 0 for the analog input
ANA_INPUT_TH0_LOW_MS	U16	55	Sets the number of milliseconds to consider a valid low threshold 0
ANA_INPUT_TH0_EVT_CONF	U8	56	Configures what to do when the thresholds 0 are crossed
ANA_INPUT_TH1_HIGH	U16	57	Sets the higher threshold 1 for the analog input
ANA_INPUT_TH1_HIGH_MS	U16	58	Sets the number of milliseconds to consider a valid high threshold 1
ANA_INPUT_TH1_LOW	U16	59	Sets the lower threshold 1 for the analog input
ANA_INPUT_TH1_LOW_MS	U16	60	Sets the number of milliseconds to consider a valid low threshold 1
ANA_INPUT_TH1_EVT_CONF	U8	61	Configures what to do when the thresholds 1 are crossed
ENCODER_TH0_HIGH	I16	62	Sets the higher threshold 0 for the encoder
ENCODER_TH0_HIGH_MS	U16	63	Sets the number of milliseconds to consider a valid high threshold 0
ENCODER_TH0_LOW	I16	64	Sets the lower threshold 0 for the encoder
ENCODER_TH0_LOW_MS	U16	65	Sets the number of milliseconds to consider a valid low threshold 0
ENCODER_TH0_EVT_CONF	U8	66	Configures what to do when the thresholds 0 are crossed
ENCODER_TH1_HIGH	I16	67	Sets the higher threshold 1 for the encoder
ENCODER_TH1_HIGH_MS	U16	68	Sets the number of milliseconds to consider a valid high threshold 1
ENCODER_TH1_LOW	I16	69	Sets the lower threshold 1 for the encoder

ENCODER_TH1_LOW_MS	U16	70	Sets the number of milliseconds to consider a valid low threshold 1
ENCODER_TH1_EVT_CONF	U8	71	Configures what to do when the thresholds 1 are crossed
TH_ENABLE_EVENTS	U8	72	Enables each event from the thresholds
WRITE_AO	U16	73	Writes to the analog output available on port AO
ENCODER	I16	74	Value of the digital encoder (write this register to 0 to reset the encoder)

a) This register is read only. Writing to this register will issue an error.

2.1.1 CONFIG

Bit	15	14	13	12	11	10	9	8
	-	DATA_1KHz	DATA_QUIET	IO2_TO_OUTPUT	IO2_TO_INPUT	IO1_TO_OUTPUT	IO1_TO_INPUT	IO0_TO_OUTPUT
Bit	7	6	5	4	3	2	1	0
	IO0_TO_INPUT	COM_TO_TIMESTAMP	COM_TO_MAIN	EN_AI	ANA_INTERNAL_TO_A0	ANA_SENSOR_TO_A0	SYNC_TO_SLAVE	SYNC_TO_MASTER

This register is used to configure the device. As a good practice, this register should be the first one to be written.

When writing to one of these bits, the configuration will be executed, i.e., there's no need to write all the necessary bits at once.

Example: We want to configure the device to enable the Harp Timestamp output, configure the digital IO1 to output and have data streamed at 1 KHz. We have two options (the end result is exactly the same):

Option a) Write all configuration at once

```
#define B_SYNC_TO_MASTER (1<<0)
#define B_IO1_TO_OUTPUT (1<<10)
#define B_DATA_1KHz (1<<14)

write_register(R_CONFIG, B_SYNC_TO_MASTER | B_IO1_TO_OUTPUT | B_DATA_1KHz);
```

Option b) Write each configuration individually

```
write_register(R_CONFIG, B_SYNC_TO_MASTER);
write_register(R_CONFIG, B_IO1_TO_OUTPUT);
write_register(R_CONFIG, B_DATA_1KHz);
```

- **Bits 0 – SYNC_TO_MASTER**

The device outputs the internal clock sync into CLKOUT.

Another Harp device can be connected to this bus in order to share the same timestamp base.

- **Bit 1 – SYNC_TO_SLAVE**

Setting this bit to 1, the device receives the clock sync trough CLKIN and daisy chain it into CLKOUT (to synchronize another Harp device).

- **Bit 2 – ANA_SENSOR_TO_A0**

Setting this bit to 1, the analog sensor voltage value is sent to port AO. User can use this port to monitor the analog sensor.

- **Bit 3 – ANA_INTERNAL_TO_A0**

Setting this bit to 1, the internal analog generator is sent to port AO. User can use the register **WRITE_A0** to output an analog voltage on this port.

- **Bit 4 – EN_AI**

Setting this bit to 1, enables the analog input reading on port AI and disables the digital input/output circuitry.

This means that this port is used as an analog port.

- **Bit 5 – COM_TO_MAIN**

The device has two microcontrollers running internally. One is dedicated to behavior and the other to timing synchronism.

When this bit is set to logic 1, the USB communication is made with the behavior microcontroller.

This feature is used only for firmware update purposes.

- **Bit 6 – COM_TO_TIMESTAMP**

When this bit is set to logic 1, the USB communication is made with the timing synchronism microcontroller.

This feature is used only for firmware update purposes.

- **Bit 7 – IO0_TO_OUTPUT**

Setting this bit to 1, configures the port IO0 to be used as a digital output.

- **Bit 8 – IO0_TO_INPUT**

Setting this bit to 1, configures the port IO0 to be used as a digital input.

- **Bit 9 – IO1_TO_OUTPUT**

Setting this bit to 1, configures the port IO1 to be used as a digital output.

- **Bit 10 – IO1_TO_INPUT**

Setting this bit to 1, configures the port IO1 to be used as a digital input.

- **Bit 11 – IO2_TO_OUTPUT**

Setting this bit to 1, configures the port IO2 to be used as a digital output.

- **Bit 12 – IO2_TO_INPUT**

Setting this bit to 1, configures the port IO3 to be used as a digital input.

- **Bit 13 – DATA_QUIET**

The register **DATA_STREAM** can be sent to the host computer using one of two options. Sent at a frequency of 1000 samples/second or sent only when any of the thresholds is crossed (widely used to screen synchronization).

Setting this bit to 1, configures the device to send the **DATA_STREAM** register only when a threshold is crossed (on any of the two ways, rising or falling).

- **Bit 14 – DATA_1KHz**

Setting this bit to 1, configures the device to send the **DATA_STREAM** register at a frequency of 1000 samples/second.

2.1.2 DATA_STREAM

This register is an array composed of four words with 16 bits signed.

DATA_STREAM[0] Analog reading from the analog sensor input
DATA_STREAM[1] Analog reading from the AI0 input
DATA_STREAM[2] Rotary encoder's position
DATA_STREAM[3] Contains a bitmask reflecting the thresholds state

Below, is the DATA_STREAM[3] bitmask.

Bit	15-6	5	4	3	2	1	0
	-	**ENCTH1**	**ENCTH0**	**AITH1**	**AITH0**	**ASTH1**	**ASTH0**

- **Bits ASTH*x***

If this bit is set to 1, it means that the reading of analog sensor input is above the threshold **ANA_SENSOR_TH*x*_HIGH** for the time configured in **ANA_SENSOR_TH*x*_HIGH**.

If this bit is clear to 0, it means that the reading of analog sensor input is below the threshold **ANA_SENSOR_TH*x*_LOW** for the time configured in **ANA_SENSOR_TH*x*_LOW**.

This bit is always read as 0.

- **Bits AITH*x***

If this bit is set to 1, it means that the reading of analog input is above the threshold **ANA_INPUT_TH*x*_HIGH** for the time configured in **ANA_INPUT_TH*x*_HIGH**.

If this bit is clear to 0, it means that the reading of analog input is below the threshold **ANA_INPUT_TH*x*_LOW** for the time configured in **ANA_INPUT_TH*x*_LOW**.

- **Bits ENCTH*x***

If this bit is set to 1, it means that the reading of the encoder is above the threshold **ENCODER_TH*x*_HIGH** for the time configured in **ENCODER_TH*x*_HIGH**.

If this bit is clear to 0, it means that the reading of the encoder is below the threshold **ENCODER_TH*x*_LOW** for the time configured in **ENCODER_TH*x*_LOW**.

2.1.3 INPUTS

This register is sent to the host computer according to registers **INPUT_IO*x*_CONFIG**.

Bit	7	6	5	4	3	2	1	0
	-	-	-	-	-	**IO2**	**IO1**	**IO0**

- **Bits 0 – IO0**

Contains the digital state of the port IO0.

- **Bits 1 – IO1**

Contains the digital state of the port IO1.

- **Bits 2 – IO2**

Contains the digital state of the port IO2.

2.1.4 INPUT_IO*x*_CONFIG

It is good practices to keep the bandwidth of the device as low as possible.

If what matters is the transition from logic 0 to logic 1 (a camera's strobe, for instance), the option **1** should be used, and the device will ignore the logic 1 to logic 0 transition.

Bit	7	6	5	4	3	2	1	0
	-	-	-	-	-	-	**INPUT_OPTIONS [1:0]**	

- **Bits 1:0 – INPUT_OPTIONS [1:0]**

INPUT_OPTIONS [1:0]	Configuration
0	Port IO*x* input is not used
1	Port IO*x* input is sensitive to both edges
2	Reserved
3	Reserved

2.1.5 OUTPUT_SET
OUTPUT_CLEAR
OUTPUT_TOGGLE
OUTPUT_WRITE

Bit	7	6	5	4	3	2	1	0
	-	-	-	-	-	**IO2**	**IO1**	**IO0**

The action is taking according to the bit mask.

Examples:

Set only Port IO0 to logic 1: `OUTPUT_SET = (1<<0)`

Set only Port IO2 to logic 1: `OUTPUT_SET = (1<<2)`

Set both Port IO1 and IO2 to logic 1: `OUTPUT_SET = (1<<1) | (1<<2)`

Clear only Port IO1 to logic 0: `OUTPUT_CLEAR = (1<<1)`

Toggle the current logic state of Port IO1: `OUTPUT_TOGGLE = (1<<1)`

Write IO0 to logic 0, IO1 to logic 1 and IO2 to logic 1 (all at the same time): `OUTPUT_WRITE = (1<<1) | (1<<2)`

2.1.6 ANA_SENSOR_TH*x*_EVT_CONF
ANA_INPUT_TH*x*_EVT_CONF
ECNODER_TH*x*_EVT_CONF

This register configures if the threshold result is show in the digital outputs.

Bit	7	6	5	4	3	2	1	0
	-	-	-	-	-	-	**TH_OPTIONS [1:0]**	

- **Bits 1:0 – TH_OPTIONS [1:0]**

TH_OPTIONS [1:0]	Configuration
0	Don't output the threshold
1 a)	Threshold result on IO0
2	Threshold result on IO1
3	Threshold result on IO2

a) This option is not valid when used on registers **ANA_INPUT_TH*x*_EVT_CONF**.

2.1.7 TH_ENABLE_EVENTS

This register allows the user to disable the non-used thresholds. It is recommended to disable the nonused ones!

Bit	7	6	5	4	3	2	1	0
	-	-	**ENCTH1**	**ENCTH0**	**AITH1**	**AITH0**	**ASTH1**	**ASTH0**

- **Bits 5:0**

Writing to logic 0 disables the correspondent threshold.

Writing to logic 1 enables the correspondent threshold.

Version Control

V0.1
First version released.