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| International Brain Laboratory  **IBL Behavior Control - Device Registers**  **Document Version 0.1** |  |

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| **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](https://bonsai-rx.org/)) 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](mailto:filipe@open-ephys.org) |

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| **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 | | | | | | | | | | |
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| **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. | | | | | | | | | | |

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|  | **Version Control** |
|  | **V0.1**  First version released. |