# GPIO Protocol Specifications

*Description of the various commands and procedures*

# 1. Intro

This Gpio Protocol is used to configure, control and exchange data of GPIO elements connected to a microcontroller. It involves a host machine ( like a desktop computer) who is the **MASTER** which communicates to a microcontroller **(SLAVE).** For example, the master can tell the slave to set up an led or a button, and control it. This abstracts all the low level logic from the master, since the slave takes care of it.

## 1.1. Pin types

The slave has a set of GPIO pins which can have any number of the following type of pins:

1. **Digital input pins**
2. **Digital output pins**
3. **Analog input pins**

## 1.2. Nomenclature

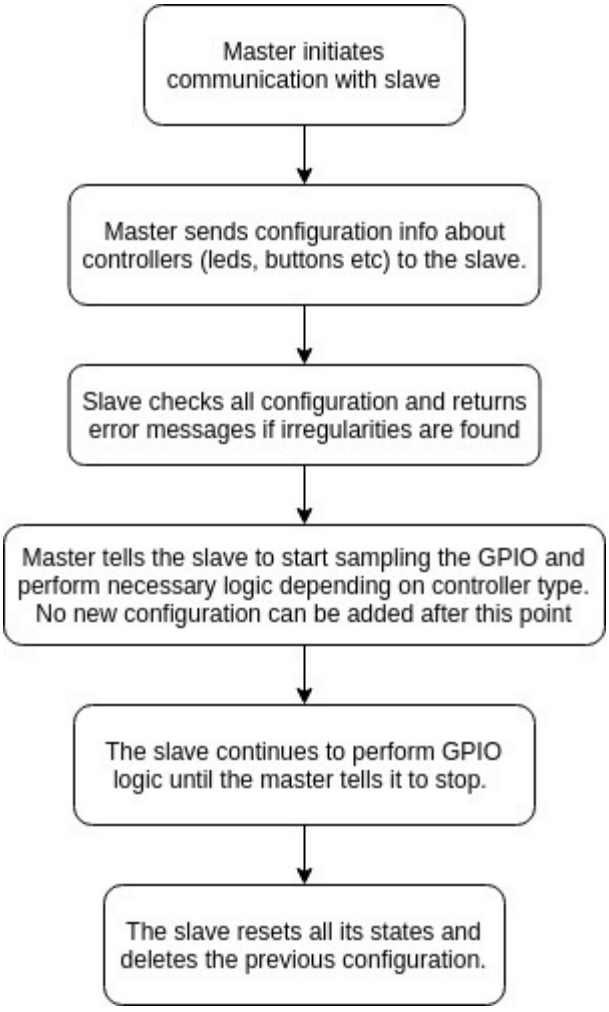
The following nomenclature and definitions are used in the document.

- **MASTER** : Used to denote the host machine (a high level computer) which initiates communication, sets up gpio elements etc.
- **SLAVE** : Used to denote the microcontroller where all the low level logic is implemented.
- **CTRL** : Abbreviation for **control** as in to control something
- **CTRLR** : Abbreviation for **controller**. A controller is a device which is connected to the GPIO pins. Eg an LED, Button, Switch etc
- **CTRLS** : Abbreviation for **controllers**. Used to denote a group of controllers.
- **HW_TYPE**: Abbreviation for hardware type. Used to denote the type of controller.
- **GPIO_NUM_DIGITAL_INPUT_PINS** : Used to denote the number of digital input pins on the SLAVE.
- **GPIO_NUM_DIGITAL_OUTPUT_PINS** : Used to denote the number of digital output pins on the SLAVE.
- **GPIO_NUM_ANALOG_INPUT_PINS** : Used to denote the number of analog input pins on the SLAVE.
- **System tick rate :** The frequency at which I/O is performed.
- **Controller tick rate :** The frequency at which I/O of a controller is performed.
- **Timestamp :** The timestamp of the system tick rate in microseconds. This is basically a counter. More on that in the later sections.
- **Configuration State:** The slave is in configuration state, where new controllers such as leds, buttons etc can be added.

- **Runtime State :** The slave has received all necessary configuration and is now in a state where it is performing IO operations with the GPIO and the necessary logic of the Controllers.

## 1.3. Control Flow Summary

The general procedure can be summarized as follows:




## 1.4. Controllers and hardware types

A **Controller** is a device that is connected to the gpio. This can be leds, buttons, analog potentiometer etc. The slave contains the low level logic to handle these controllers. Types of Controllers are specified as a hardware type (**HW_TYPE**). **It is important to note that the maximum allowed number of pins for a particular controller type is 25.** The following details the list of supported hw types for controllers.

| HW_TYPE | Pin | Num | Data range | Configur |
|---|---|---|---|---|

| | type | Pins | | able data range? |
|---|---|---|---|---|
| GPIO_BINARY_OUTPUT | Digital Output | 1 : 25 | 0 :(2^(num pins used) - 1 | NO |
| GPIO_BINARY_INPUT | Digital Input | 1 : 25 | 0 : 2^(num pins used) - 1 | NO |
| GPIO_ANALOG_INPUT | Analog Input | 1 | 0 : Resolution of ADC | YES |
| GPIO_STEPPED_OUTPUT | Digital Output | 1 : 25 | 0 : num pins used | NO |
| GPIO_MUX_OUTPUT | Digital Output | 1 : 10 | 1 : num pins used | NO |
| GPIO_N_WAY_SWITCH | Digital Input | 1 : 25 | 1 : num pins used | NO |
| GPIO_ROTARY_ENCODER | Digital Input | 2 | Configurable | YES |

### 1.4.1. Binary Outputs (HW_TYPE : GPIO_BINARY_OUTPUT)

A binary output type behaves such that its value is represented in binary form on its output pins. For eg: a single pin binary output can have values 0 or 1 in its pins. A two pin binary output can have output values 0x0 ,0x1, 0x2, 0x3 on its pins.

### 1.4.2. Binary inputs (HW_TYPE : GPIO_ BINARY_INPUT)

A binary input is a very basic controller type. Its value represents the binary data present on its pins. For eg: a single pin button can have a value 0 or 1.  A two pin dip switch can have the values 00, 01, 10, 11.

### 1.4.3. Analog Input  (HW_TYPE : GPIO_ ANALOG_INPUT)

This type is used to represent analog input controllers connected to any of the analog input pins. **It is important to note that each analog input controller should have only 1 pin.** The client will automatically filter these inputs with a second order filter with a time constant of 20ms. This time constant can be set to any value above 0 during configuration.

### 1.4.4. Stepped Output (HW_TYPE : GPIO_STEPPED_OUTPUT)

This type is used to represent controllers where the intended behavior is akin to an LED ring. In other words, its value represents how many of its pins are switched to ON state. For example, if a stepped output has 8 pins and its value is 5, then its 1st, 2nd, 3rd, 4rth and 5th pins are turned on.

### 1.4.5. Mux output (HW_TYPE : GPIO_MUX_OUTPUT)

This is a special type of controller, whose sole purpose is to enable/disable other controllers. Think of the logic as the output of a mux. Consider a case where there are 3 single pin binary outputs such as LEDs L1, L2 and L3 connected to the same pin on the slave, say pin number 1. Pins 2, 3, 4 of the slave are used to select which of the three leds glow. This is a common configuration when it comes to board layout as you end up using less pins.

A mux controller can be assigned to use pins 2,3,4 on the slave. It will then switch on only one pin for every tick and will iterate through its pins. So for every system tick, one of L1, L2 or L3 will be selected.

We can generalize it in the following way. If a mux has pin $MuxPin_1$ , $MuxPin_2$ ... $MuxPin_N$ where $N$ is the total number of pins assigned to It, the following state machine describes the output:

| **GPIO_MUX_OUTPUT state** | $MuxPin_1$ | $MuxPin_2$ | $MuxPin_3$ | . | . | . | $MuxPin_N$ |
|---|---|---|---|---|---|---|---|
| 0 | **ON** | OFF | OFF | OFF | OFF | OFF | OFF |
| 1 | OFF | **ON** | OFF | OFF | OFF | OFF | OFF |
| 2 | OFF | OFF | **ON** | OFF | OFF | OFF | OFF |
| . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . |
| $N-1$ | OFF | OFF | OFF | OFF | OFF | OFF | **ON** |

**The Mux Output Controller can have a maximum of 10 pins. Its state is incremented automatically and cannot be set from the MASTER.**

### 1.3.6. N way Switch (HW_TYPE : GPIO_N_WAY_SWITCH)

Its value is reflective of which of its pins is in ON state. Only one of its pins is in ON state at any given time.

### 1.4.7. Rotary Encoder (HW_TYPE : GPIO_ROTARY_ENCODER)

This type represents a rotary encoder. Since it has infinite range, the range has to be set by the MASTER. **Rotary encoders need 2 pins, not more or less.** If more pins are assigned to it, an error is thrown.

## 1.5. Communication Methodology

This protocol follows a system where the **SLAVE** sends an acknowledgement for every packet sent by the **MASTER,** but not vice versa. i.e the **MASTER** does not send any acks for a packet sent from the **SLAVE**.

Whenever the master sends a query packet ( eg “get value of this controller” or “get board info”) the slave will first send an ack packet and then respond with a packet containing info for the query. **Note that the sequence number of the packet sent from the slave will always be 0.**

## 1.6. Packet Structure

The gpio packet size of 32 bytes in length and is comprised of the following fields as shown in the layout below.

| Field | Size in bytes | Description |
|---|---|---|
| CMD | 1 | The main GPIO command field. |
| SUBCMD | 1 | For all the sub commands of the **CMD.** |
| CONTINUATION | 1 | Used in case the packet length is not enough to denote data. This field represents how many packets the data is split into. |
| RESERVED | 1 | Not used at the moment. Placed here in order to maintain word boundary alignment. |
| DATA | 20 | Contains data related to the **CMD** and **SUBCMD**. |
| TIMESTAMP | 4 | Used to denote the timestamp (in microseconds) of the packet. |
| SEQUENCE_NUMBER | 4 | denotes the sequence number of the packet, in order to ID it. This is used when replying to packets where the same sequence number is used when replying. |

| Field | Byte Offset |
|---|---|
| CMD | 0 |

| | |
|---|---|
| SUBCMD | 1 |
| CONTINUATION | 2 |
| RESERVED | 3 |
| DATA | 4 |
| | 5 |
| | 6 |
| | 7 |
| | 8 |
| | 9 |
| | 0 |
| | 10 |
| | 11 |
| | 13 |
| | 14 |
| | 15 |
| | 16 |
| | 17 |
| | 18 |
| | 19 |
| | 20 |
| | 21 |
| | 22 |
| | 23 |
| TIMESTAMP | 24 |
| | 25 |
| | 26 |

| | |
|---|---|
| | 27 |
| SEQUENCE_NUMBER | 28 |
| | 29 |
| | 30 |
| | 31 |

## 1.7. Endianness

All packets are **LITTLE ENDIAN** in nature.

## 1.8. Timestamp

The timestamp is specified in micro seconds and starts counting from when the slave gets a GPIO_START_SYSTEM command and enters the Runtime state. It is like a counter and should be updated every tick period with the tick rate specified in microseconds.

## 1.8. Configuration and Runtime States for the slave

There are two states for the slave

1. **Configuration state** where new controllers, system settings etc can be set.
2. **Runtime state** of the slave, where GPIO logic and IO is performed. No new configuration can be added when the slave is in this state. The state is changed when the slave receives **GPIO_START_SYSTEM** command i.e after all configuration info has been sent to it.

The protocol does not allow for dynamic configuration of the system. **All configuration must be done before the slave is started with a GPIO_START_SYSTEM command!** Since runtime configuration is not supported by the protocol, the system needs to be reset and reconfigured again for new configurations.

# 2. List of CMD and descriptions

The following table denotes all the CMDs currently supported. Detailed description of each CMD's SUB_CMD is provided in the next section.

| CMD Value | String CMD | Description |
|---|---|---|
| 1 | GPIO_CMD_SYSTEM_CTRL | Command class to denote system control functionality. Eg : start, stop, reset |

| | | |
|---|---|---|
| 100 | GPIO_CMD_CONFIG_CTRLS | Command class to denote controller configuration functionality. Eg: add controller, set pins of a controller |
| 101 | GPIO_CMD_GET_VALUE | Command class used to send data from the **SLAVE** to the **MASTER** |
| 102 | GPIO_CMD_SET_VALUE | Command class used to send data from the **MASTER** to the **SLAVE** |
| 250 | GPIO_ACK | Used to denote Acknowledgement. The **SLAVE** responds with an ACK command packet for every packet from the **MASTER** |

# 3. GPIO_ACK command description

The ack command consists of the following packet structure. Note that the **SEQ_NUM_MASTER_PACKET** corresponds to the seq num of the packet to which it is responding to. **Ack packets are only sent from the slave.**

## 3.1. Slave → Master

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | ACK |
| 1 | SUBCMD | |
| 4 | SEQ_NUM_MASTER_PACKET | The sequence number of the packet it is acknowledging to. |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | GPIO_RETURN_STATUS | A return code describing the outcome of the operation |
| 24 -> 27 | TIMESTAMP | The timestamp of the slave. **All ack packets sent before the slave is in Runtime state will have a timestamp of 0.** |

## 3.2. GPIO_RETURN_STATUS description

Below is a list of all possible error codes.

| GPIO_RETURN_STATUS Value | GPIO_RETURN_STATUS string value |
|---|---|
| 0 | GPIO_RETURN_OK |
| 1 | GPIO_RETURN_ERROR |
| 2 | GPIO_INVALID_CMD |
| 3 | GPIO_INVALID_SUB_CMD |
| 4 | GPIO_NO_CTRLS_ADDED |
| 5 | GPIO_UNINITIALIZED_CTRLS |
| 6 | GPIO_INVALID_TICK_RATE |
| 7 | GPIO_INVALID_CTRLR_ID |
| 8 | GPIO_INVALID_HW_TYPE |
| 9 | GPIO_INVALID_MUX_CTRLR |
| 10 | GPIO_INVALID_CTRLR_POLARITY |
| 11 | GPIO_NO_PINS_AVAILABLE |
| 12 | GPIO_INVALID_SHARING_OF_PINS |
| 13 | GPIO_RES_OUT_OF_RANGE |
| 14 | GPIO_UNRECOGNIZED_CMD |
| 15 | GPIO_PARAMETER_ERROR |
| 16 | GPIO_INVALID_CMD_FOR_CTRLR |
| 17 | GPIO_INVALID_RUNTIME_CONFIG |

### 3.2.1. GPIO_RETURN_OK

Denotes that the command received was executed properly and everything is OK.

### 3.2.2. GPIO_RETURN_ERROR

Denotes that the command received could not be executed due to an unknown reason. This is just used to denote any undefined error codes that have not yet been implemented.

### 3.2.3. GPIO_INVALID_CMD

Denotes that the command received is not a valid CMD.

### 3.2.4. GPIO_INVALID_SUB_CMD

Denotes that the sub command received is not a valid SUB_CMD for that particular CMD

### 3.2.5. GPIO_NO_CTRLS_ADDED

Denotes that no controllers were added or configured. This is usually sent when a GPIO_START_SYSTEM sub command is received. More info in later sections.

### 3.2.6. GPIO_UNITIALIZED_CTRLS

Denotes that one or more controllers have not been completely initialized or configured properly. This is usually sent when a GPIO_START_SYSTEM sub command is received. More info in later sections.

### 3.2.7. GPIO_INVALID_TICK_RATE

Denotes that the specified tick rate is not valid. This is used to denote an invalid tick rate for both, the system rate and controller tick rate.

### 3.2.8. GPIO_INVALID_CTRLR_ID

Denotes that the controller id mentioned in a packet is invalid because of which a command could not be executed.

### 3.2.9. GPIO_INVALID_HW_TYPE

Denotes that the packet contained an invalid or unsupported hardware type.

### 3.2.10. GPIO_INVALID_MUX_CTRLR

Denotes that a mux controller info present in the received packet is invalid.

### 3.2.11. GPIO_INVALID_CTRLR_POLARITY

Denotes that the controller’s polarity specified in the received packet is invalid.

### 3.2.12. GPIO_NO_PINS_AVAILABLE

Denotes that there are no available pins. This is a generic error type used to describe unavailability of any type of pins. For eg, Consider a system has digital output pins but no digital input pins. If a digital input controller is added and some pins are assigned to them, then this error is thrown.

### 3.2.13. GPIO_INVALID_SHARING_OF_PINS

Denotes that one or more pins of a controller are shared/duplicated with another controller. **Sharing of pins is allowed only if the controller is configured to be attached to a mux.**

### 3.2.14. GPIO_RES_OUT_OF_RANGE

Denotes that a resolution setting specified in the packet is not compatible with the controller. Usually used when the specified resolution is more than that of the ADC.

### 3.2.15. GPIO_PARAMETER_ERROR

Denotes that a value cannot be assigned to a controller. For eg, setting the value of a binary output controller type to more than its specified range.

### 3.2.16. GPIO_INVALID_CMD_FOR_CTRLR

Denotes that the specified command in the packet from the MASTER is not supported for a particular controller type.

### 3.2.16. GPIO_INVALID_RUNTIME_CONFIG

Denotes that the specified command in the packet from the MASTER is not supported as the slave has already been configured and is in Runtime State. This happens when GPIO_START_SYSTEM command has been issued by the master prior and the slave cannot receive any new configuration commands. **Runtime configuration** is not supported by the protocol and for new configurations, the system needs to be reset and reconfigured again.

# 4. GPIO_CMD_SYSTEM_CTRL description

The system control CMD has the following sub commands

| CMD | SUB_CMD value | String SUB_CMD |
|---|---|---|
| | 0 | GPIO_STOP_RESET_SYSTEM |

| | | |
|---|---|---|
| GPIO_CMD_SYSTEM_CTRL | 1 | GPIO_START_SYSTEM |
| | 2 | GPIO_SET_TICK_RATE |
| | 3 | GPIO_GET_BOARD_INFO |

## 4.1. GPIO_STOP_RESET_SYSTEM sub command

- stops the **SLAVE** from any I/O with the gpio controllers
- removes all previously configured controllers
- essentially puts the system to a **reset** state
- Can be sent when the slave is in pre or post configuration states

### 4.1.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_SYSTEM_CTRL |
| 1 | SUBCMD | GPIO_STOP_RESET_SYSTEM |
| 28→31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 4.1.2. Slave → Master GPIO_RETURN_STATUS

- This command can be sent when the slave is either Runtime or Configuration State.
- The slave sends an ack packet with a corresponding error code. **Note that the return code will always be GPIO_RETURN_OK** because nothing can go wrong, unless the slave is not responsive.

### 4.1.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp
- 0 if it is in Configuration State

## 4.2. GPIO_START_SYSTEM

- Informs the slave to start the GPIO I/O process.
- Done after configuration of controllers are complete.
- Can be sent only when the slave is in configuration state
- Upon success, the slave enters Runtime state

### 4.2.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_SYSTEM_CTRL |
| 1 | SUBCMD | GPIO_START_SYSTEM |
| 28→31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 4.2.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS and with a TIMESTAMP = 0.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | Start was successful |
| GPIO_NO_CTRLS_ADDED | Cannot start the system since no controllers were added during configuration. |
| GPIO_UNIITIALIZED_CTRLS | Cannot start the system since one or more controllers were not initialized/configured fully. Eg: a controller without any pins assigned to it. |
| GPIO_INVALID_SHARING_OF_PINS | Cannot start the system since one or more pins are shared between two or more controllers. Sharing is allowed only if they are attached to a mux output controller |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 4.2.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ack packet with GPIO_INVALID_RUNTIME_CONFIG return status.
- 0 if it is in Configuration State

## 4.3. GPIO_SET_TICK_RATE

Sets the system tick rate of the SLAVE. The tick rate is the frequency at which I/O is performed with the controllers. This can be only sent when the slave is in runtime state. Tick rate can be set to the following possible values:

| GPIO_SYSTEM_TICK_RATE_HZ | String Description |
|---|---|
| 100 | 100 Hz |
| 500 | 500 Hz |
| 1000 (default) | 1000 Hz |
| 5000 | 5000 Hz |

### 4.3.1. Master→Slave Packet Structure

| Byte Offset | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_SYSTEM_CTRL |
| 1 | SUBCMD | GPIO_SET_TICK_RATE |
| 4 | DATA | GPIO_SYSTEM_TICK_RATE_HZ |
| 28 →31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 4.3.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS. The TimeStamp is a unique number if this command is issued when the slave is in Runtime state. Else TimeStamp = 0.

| Possible GPIO_RETURN_STATUS | Description |
|---|---|
| GPIO_RETURN_OK | The system is configured to run with new tick rate |
| GPIO_INVALID_TICK_RATE | Specified tick rate was not valid. |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 4.3.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp
- 0 if it is in Configuration State

## 4.4. GPIO_GET_BOARD_INFO

This command is used by the master to enquire the board information of the slave, that is, the number of gpio pins it contains. This is usually done in Configuration State as to know the information of the board before configuring it, but can be sent when the slave is in Runtime state as well. This is to accommodate the fact that different boards have different numbers of pins. The slave returns the following info

1. Number of digital input pins.
2. Number of digital output pins
3. Number of analog input pins.
4. Resolution of ADC in number of bits. Eg: 10 or 8. **If no adc (and consequently no analog input pins) exist on the board, this number will be equal to 0.**

**Note:**
**The slave responds in the following sequence**

1. First it sends an ACK packet with a timestamp (as described below).
2. Then it sends a packet containing the board information containing the same timestamp.

### 4.4.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_SYSTEM_CTRL |
| 1 | SUBCMD | GPIO_GET_BOARD_INFO |
| 28→ 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 4.4.2. Slave → Master GPIO_RETURN_STATUS

1. The slave first sends an ack packet with a return status of **GPIO_RETURN_OK** and a timestamp.
2. Then it sends a packet containing the board info as shown in the packet structure below:

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_SYSTEM_CTRL |
| 1 | SUBCMD | GPIO_GET_BOARD_INFO |

| | | |
|---|---|---|
| 4 | DATA | Number of Digital input pins on the board |
| 5 | | Number of Digital output pins on the board |
| 6 | | Number of Analog input pins on the board |
| 7 | | Resolution of ADC in bits (0 if no adc or analog pins exist) |
| 24 -> 27 | TIMESTAMP | The timestamp of the slave which is the same as the ACK Packet |
| 28 → 31 | SEQUENCE_NUMBER | 0 |

### 4.4.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp
- 0 if it is in Configuration State

# 5. GPIO_CMD_CONFIG_CTRLS description

This gpio command is used to set up and configure controllers on the board. It has the following sub commands. Certain commands can be sent when the slave is in Runtime State as shown below.

| CMD | SUB_CMD value | String SUB_CMD |
|---|---|---|
| GPIO_CMD_CONFIG_CTRLS | 0 | GPIO_RESET_ALL_CTRLS |
| | 1 | GPIO_RESET_CTRLR |
| | 2 | GPIO_ADD_CTRLR |
| | 3 | GPIO_ATTACH_CTRLR_TO_MUX |
| | 4 | GPIO_SET_CTRLR_POLARITY |
| | 5 | GPIO_SET_INPUT_CTRLR_TICK_RATE |
| | 6 | GPIO_SET_INPUT_CTRLR_NOTIF_MODE |
| | 7 | GPIO_ADD_PINS_TO_CTRLR |
| | 8 | GPIO_MUTE_UNMUTE_CTRLR |

| | | |
|---|---|---|
| | 10 | GPIO_SET_ANALOG_CTRLR_RES |
| | 11 | GPIO_SET_CTRLR_RANGE |
| | 12 | GPIO_SET_CTRLR_DEBOUNCE_MODE |
| | 13 | GPIO_SET_ANALOG_CTRLR_TIME_CONSTANT |

## 5.1. GPIO_RESET_ALL_CTRLS

This sub command is used to reset data **of all configured controllers**. Note that it does not mean that it removes all configured controllers, but only resets their input/output values to the default values. This command can be sent during Runtime state **and** Configuration State.

### 5.1.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_RESET_ALL_CTRLS |
| 28 →31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.1.2. Slave → Master GPIO_RETURN_STATUS

The slave will always return **GPIO_RETURN_OK.**

### 5.1.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp
- 0 if it is in Configuration State

## 5.2. GPIO_RESET_CTRLR

This sub command is used to reset the data of a particular controller. **Note that the controller should have been already added and configured.** This command can be sent during Runtime state **and** Configuration State.

### 5.2.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |

| | | |
|---|---|---|
| 1 | SUBCMD | GPIO_RESET_CTRLR |
| 4 | DATA | CTRLR_ID of the controller which has to be reset |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.2.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The controller was reset successfully |
| GPIO_INVALID_CTRLR_ID | Specified controller ID was not found in the list of configured controllers. |

### 5.2.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp
- 0 if it is in Configuration State

## 5.3. GPIO_ADD_CTRLR

This sub command is used to add a new controller, of a specific hardware type. The list of hardware types is specified in section 1.3. Note that a controller of a specific hardware type can only be added if its relevant pins exist on the board. For eg, an analog controller can be only added if there are analog pins on the board.

This command cannot be sent once the slave is in RunTime state i.e a new controller cannot be added once the configuration is finished and a GPIO_START_SYSTEM command is issued by the master.

### 5.3.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_ADD_CTRLR |
| 4 | DATA | CTRLR_ID of new controller |
| 5 | | HW_TYPE of the new controller |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.3.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| Possible GPIO_RETURN_STATUS | Description |
|---|---|
| GPIO_RETURN_OK | The new controller was added successfully |
| GPIO_NO_PINS_AVAILABLE | The new controller could not be added since the pins it uses either do not exist or have been used up. |
| GPIO_INVALID_CTRLR_ID | The new controller ID specified in the master packet already exists (has already been added previously) |
| GPIO_INVALID_HW_TYPE | The specified hw type in the master's packet is invalid. |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.3.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in Configuration State

## 5.4. GPIO_ATTACH_CTRLR_TO_MUX

Attaches a controller to a mux controller of type GPIO_MUX_OUTPUT. **Do note that this command can only be sent when the slave is in Configuration State.** The following conditions have to be met

1. The mux output controller should have already been added and its pins defined.
2. The hw type of the controller which is to be attached to mux should be of compatible type. Not all hw types can be attached. This usually includes controllers such as rotary encoders, where its input signal is in the form of transitions. See the table below for supported hw types

| HW_TYPE | Can it be attached to a mux controller? |
|---|---|
| GPIO_BINARY_OUTPUT | YES |
| GPIO_BINARY_INPUT | YES |
| GPIO_ANALOG_INPUT | YES |

| | |
|---|---|
| GPIO_STEPPED_OUTPUT | YES |
| GPIO_MUX_OUTPUT | NO |
| GPIO_N_WAY_SWITCH | YES |
| GPIO_ROTARY_ENCODER | NO |

### 5.4.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_ATTACH_CTRLR_TO_MUX |
| 4 | DATA | CTRLR_ID : id of controller which has to be attached to the mux controller |
| 5 | | MUX_CTRLR_ID : id of the mux controller |
| 6 | | ASSOCIATED_MUX_PIN : the pin number which “selects” the controller that has to be attached.. |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.4.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The controller was successfully attached to the specified mux controller. |
| GPIO_INVALID_MUX_CTRLR | The specified mux was not added, or the specified associated mux pin is not part of the mux controller, or the mux pin is already associated with another controller id |
| GPIO_INVALID_CMD_FOR_CTRLR | The controller which is to be attached to the mux controller had an incompatible hw type |
| GPIO_INVALID_CTRLR_ID | The controller which is to be attached to the mux was not found. This can be attributed to the fact that the controller may not have been added or |

| | |
|---|---|
| | the controller id specified was incorrect. |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.4.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in Configuration State

## 5.5. GPIO_SET_CTRLR_POLARITY

Sets the polarity of a controller. **Do note that this command can only be sent when the slave is in Configuration State.** The polarity can be either active high or active low. This is applicable to only select hw types.

| **CTRLR_POLARITY** | **Description** |
|---|---|
| GPIO_ACTIVE_HIGH (default) | Denotes that the controller's I/O is active high in nature. **Note that all controllers by default are configured as active high** |
| GPIO_ACTIVE_LOW | Denotes that the controller's  i/O is active low in nature |

| **HW_TYPE** | **Configurable polarity?** |
|---|---|
| GPIO_BINARY_OUTPUT | YES |
| GPIO_BINARY_INPUT | YES |
| GPIO_ANALOG_INPUT | NO |
| GPIO_STEPPED_OUTPUT | YES |
| GPIO_MUX_OUTPUT | YES |
| GPIO_N_WAY_SWITCH | YES |
| GPIO_ROTARY_ENCODER | NO |

### 5.5.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_SET_CTRLR_POLARITY |
| 4 | DATA | CTRLR_ID : id of controller whose polarity has to be changed |
| 5 | | CTRLR_POLARITY : the new polarity |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.5.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The controller's polarity was successfully changed |
| GPIO_INVALID_CMD_FOR_CTRLR | The controller whose polarity was to be changed is of incompatible hw type. |
| GPIO_INVALID_CTRLR_ID | The controller whose polarity is to be changed is not found. This can be attributed to the fact that the controller may not have been added or the controller id specified was incorrect. |
| GPIO_INVALID_CTRLR_POLARITY | Invalid controller polarity |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.5.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in a Configuration State.

## 5.6. GPIO_SET_INPUT_CTRLR_TICK_RATE

Sets the tick rate of a controller whose hw type is input in nature. **Do note that this command can only be sent when the slave is in Configuration State.**

The controller tick rate is specified in multiples of the system tick rate. The default tick rate of a controller is 1.

| HW_TYPE | Configurable tick rate? |
|---|---|
| GPIO_BINARY_OUTPUT | NO |
| GPIO_BINARY_INPUT | YES |
| GPIO_ANALOG_INPUT | YES |
| GPIO_STEPPED_OUTPUT | NO |
| GPIO_MUX_OUTPUT | NO |
| GPIO_N_WAY_SWITCH | YES |
| GPIO_ROTARY_ENCODER | NO |

### 5.6.1. Master→Slave Packet Structure

| Byte Offset | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_SET_INPUT_CTRLR_TICK_RATE |
| 4 | DATA | CTRLR_ID : id of controller whose tick rate has to be changed |
| 5 | | DELTA_TICK_RATE : the new tick rate of the controller specified as multiples of the system tick rate. |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.6.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| Possible GPIO_RETURN_STATUS | Description |
|---|---|
| GPIO_RETURN_OK | The controller's tick rate was successfully changed |
| GPIO_INVALID_CMD_FOR_CTRLR | The controller whose tick rate was to be changed is of incompatible hw type. |
| GPIO_INVALID_CTRLR_ID | The controller whose tick rate is to be changed is not found amongst compatible hw types. This can |

| | |
|---|---|
| | be attributed to the fact that the controller may not have been added or the controller id specified was incorrect. |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.6.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in Configuration State

## 5.7. GPIO_SET_INPUT_CTRLR_NOTIF_MODE

Sets the notification mode of an input controller. **Do note that this command can only be sent when the slave is in Configuration State.** The notification mode describes the circumstances in which an input controller notifies the master about its value, using a GPIO_CMD_GET_VALUE packet. The following table describes the various notification modes.

| **GPIO_NOTIF_MODE** | **Description** |
|---|---|
| ON_VALUE_CHANGE (default) | A GPIO_CMD_GET_VALUE packet is sent to the master each time the controller's value changes. |
| EVERY_CTRLR_TICK | A GPIO_CMD_GET_VALUE packet is sent to the master every controller tick. This is akin to continuous mode. |
| WHEN_TOGGLED_ON | A GPIO_CMD_GET_VALUE packet is sent to the master each time the controller's value is switched from OFF → ON → OFF. What constitutes as ON or OFF depends on the controller's polarity.<br><br>Not applicable to multi pin GPIO_BINARY_INPUT, multi pin GPIO_STEPPED_OUTPUT and rotary encoders |
| WHEN_TOGGLED_OFF | A GPIO_CMD_GET_VALUE packet is sent to the master each time the controller's value is switched from ON → OFF → ON. What constitutes as ON or OFF depends on the controller's polarity. |

| | |
|---|---|
| | Not applicable to multi pin GPIO_BINARY_INPUT, multi pin GPIO_STEPPED_OUTPUT and rotary encoders |

| HW_TYPE | Configurable notification mode? |
|---|---|
| GPIO_BINARY_OUTPUT | N/A |
| GPIO_BINARY_INPUT | YES |
| GPIO_ANALOG_INPUT | YES |
| GPIO_STEPPED_OUTPUT | N/A |
| GPIO_MUX_OUTPUT | N/A |
| GPIO_N_WAY_SWITCH | YES |
| GPIO_ROTARY_ENCODER | YES |

### 5.7.1. Master→Slave Packet Structure

| Byte Offset | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_SET_INPUT_CTRLR_NOTIF_MODE |
| 4 | DATA | CTRLR_ID : id of controller whose notification mode has to be changed |
| 5 | | GPIO_NOTIF_MODE : the new notif mode of the controller. |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.7.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| Possible GPIO_RETURN_STATUS | Description |
|---|---|
| GPIO_RETURN_OK | The controller's notification mode was successfully changed |
| GPIO_INVALID_CMD_FOR_CTRLR | The controller whose notification mode was to be changed is of incompatible hw type. |
| GPIO_INVALID_CTRLR_ID | The controller whose notification mode is to be |

| | |
|---|---|
| | changed is not found amongst compatible hw types. This can be attributed to the fact that the controller may not have been added or the controller id specified was incorrect. |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.7.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in Configuration State

## 5.8. GPIO_ADD_PINS_TO_CTRLR

Adds pins to a controller. **Do note that this command can only be sent when the slave is in Configuration State.**

### 5.8.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_ADD_PINS_TO_CTRLR |
| 4 | DATA | CTRLR_ID : id of controller to which pins have to be added |
| 5 | | NUM_PINS_IN_PACKET : The number of pins **whose info is specified in this packet.** |
| 6 → 23 | | PINS : The pin numbers |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.8.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The pins have been successfully added to the controller |
| GPIO_INVALID_CTRLR_ID | The specified controller id does not exist or has not been added |

| | |
|---|---|
| GPIO_INVALID_CMD_FOR_CTRLR | The specified controller already has pins assigned to it or too many pins have been specified for this controller. |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.8.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in Configuration State

## 5.9. GPIO_MUTE_UNMUTE_CTRLR

Command to mute or unmute a controller.

If an output hw type controller is muted, then it will be in OFF state no matter what value is sent by the host to the controller. The current values are stored internally when muted and will be restored when unmuted. This also applies to new values sent when the controller is muted.

If an input hw type is muted, then it will not notify the host about its value (irrespective of its notification mode). Only certain hw types support. Can be used when the slave is in Runtime or Configuration States.

| **GPIO_CTRLR_MUTE_STATUS** | **Description** |
|---|---|
| GPIO_CTRLR_MUTED | Controller is muted |
| GPIO_CTRLR_UNMUTED (default) | Controller is unmuted. This should be the default state of all controllers. |

| **HW_TYPE** | **Can be muted/unmuted?** |
|---|---|
| GPIO_BINARY_OUTPUT | YES |
| GPIO_BINARY_INPUT | YES |
| GPIO_ANALOG_INPUT | YES |
| GPIO_STEPPED_OUTPUT | YES |
| GPIO_MUX_OUTPUT | NO |

| | |
|---|---|
| GPIO_N_WAY_SWITCH | YES |
| GPIO_ROTARY_ENCODER | YES |

### 5.9.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_MUTE_UNMUTE_CTRLR |
| 4 | DATA | CTRLR_ID : id of controller whose mute status has to be changed |
| 5 | | GPIO_CTRLR_MUTE_STATUS: the new mute status of the controller |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.9.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The controller's mute state was successfully changed |
| GPIO_INVALID_CTRLR_ID | The controller whose mute status is to be changed is not found amongst compatible hw types. This can be attributed to the fact that the controller may not have been added or the controller id specified was incorrect. |

### 5.9.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp.
- 0 if it is in Configuration State

## 5.10. GPIO_SET_ANALOG_CTRLR_RES

Set the resolution in bits of an analog input controller. The new resolution should follow the rule:

$$1 \leq AnalogController_{resolution} \leq ADC_{resolution}$$

By default, the analog input controller's resolution should be equal to that of the ADC. **Do note that this command can only be sent when the slave is in Configuration State.**

### 5.10.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_SET_ANALOG_CTRLR_RES |
| 4 | DATA | CTRLR_ID : id of the analog input controller whose resolution has to be changed |
| 5 | | ANALOG_CTRLR_RES: the new resolution of the controller. |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.10.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The analog input controller's resolution has successfully changed. |
| GPIO_INVALID_CTRLR_ID | The analog input with the specified controller id is not found amongst the configured controller list or when there are no analog pins available on the board |
| GPIO_RES_OUT_OF_RANGE | The resolution specified in the master packet is more than the supported resolution of the board |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.10.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in Configuration State

## 5.11. GPIO_SET_CTRLR_RANGE

Set the range for a controller's value. **The slave will clip values higher or lower the specified range.** Only certain HW types support this feature. **It is necessary to set the controller range for rotary encoders.**

**Do note that this command can only be sent when the slave is in Configuration State.**

| HW_TYPE | Configurable range? |
|---|---|
| GPIO_BINARY_OUTPUT | NO |
| GPIO_BINARY_INPUT | NO |
| GPIO_ANALOG_INPUT | **YES (default min = 0, default max = 2^adc_res -1)** |
| GPIO_STEPPED_OUTPUT | NO |
| GPIO_MUX_OUTPUT | NO |
| GPIO_N_WAY_SWITCH | NO |
| GPIO_ROTARY_ENCODER | YES (default min = 0, default max = 0) |

### 5.11.1. Master→Slave Packet Structure

| Byte Offset | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_SET_ANALOG_CTRLR_RES |
| 4 | DATA | CTRLR_ID : id of the controller whose resolution has to be changed |
| 5 | | Empty for word alignment |
| 6 | | Empty for word alignment |
| 7 | | Empty for word alignment |
| 8→11 | | MIN_VAL : 32 bit integer representing the minimum possible value. |
| 12→15 | | MAX_VAL : 32 bit integer representing the maximum possible value. |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.11.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| Possible GPIO_RETURN_STATUS | Description |
|---|---|
| GPIO_RETURN_OK | The range of the controller was successfully set. |

| | |
|---|---|
| GPIO_INVALID_CTRLR_ID | The specified controller id is not found amongst the configured controller list. |
| GPIO_INVALID_CMD_FOR_CTRLR | Indicates that the controller specified in the master packet does not support different ranges. |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.11.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in Configuration State

## 5.12 GPIO_SET_CTRLR_DEBOUNCE_MODE

Enable or disable sw debouncing for the input pins of a digital input hw type controller. By default it is always enabled. The debounce mode is denoted by a single byte as follows. **Do note that this command can only be sent when the slave is in Configuration State.**

| **GPIO_DEBOUNCE_MODE** | **Value** |
|---|---|
| GPIO_DEBOUNCE_ENABLED | 0 |
| GPIO_DEBOUNCE_DISABLED | 1 |

| **HW_TYPE** | **Configurable Debounce?** |
|---|---|
| GPIO_BINARY_OUTPUT | NO |
| GPIO_BINARY_INPUT | **YES** |
| GPIO_ANALOG_INPUT | NO |
| GPIO_STEPPED_OUTPUT | NO |
| GPIO_MUX_OUTPUT | NO |

| | |
|---|---|
| GPIO_N_WAY_SWITCH | **YES** |
| GPIO_ROTARY_ENCODER | NO |

### 5.12.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_SET_CTRLR_DEBOUNCE_MODE |
| 4 | | CTRLR_ID : id of the controller whose debounce mode to be changed |
| 5 | | GPIO_DEBOUNCE_MODE |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.12.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The debounce of the controller was successfully enabled/dsiabled. |
| GPIO_INVALID_CTRLR_ID | The specified controller id is not found amongst the configured & compatible controller list. |
| GPIO_INVALID_CMD_FOR_CTRLR | Indicates that the controller specified in the master packet does not support debounce modes. |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

### 5.11.3. Slave → Master Timestamp

- If it is in Runtime State, the slave will send a unique timestamp in the ACK packet containing the GPIO_INVALID_RUNTIME_CONFIG gpio return status.
- 0 if it is in Configuration State

## 5.13 GPIO_SET_ANALOG_CTRLR_TIME_CONSTANT

This command is to set the time constant of the filter of an analog  controller. **By default the time constant is 0.020 seconds.** The new time constant has to be above 0. This command can only be used during configuration state.

### 5.13.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_SET_ANALOG_CTRLR_TIME_CONSTANT |
| 4 | | CTRLR_ID : id of the analog controller whose time constant has to be changed |
| 5 - 7 | | Reserved |
| 8-12 | | Time constant in seconds( Float) |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

### 5.13.2. Slave → Master GPIO_RETURN_STATUS

The slave sends an ack packet with any of the following possible GPIO_RETURN_STATUS.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The new time constant was successfully set. |
| GPIO_INVALID_CTRLR_ID | The specified controller id is not found amongst the analog controller list. |
| GPIO_INVALID_CMD_FOR_CTRLR | Indicates that the controller specified was not in the analog controller list but in another controller list. |

| | |
|---|---|
| GPIO_PARAMETER_ERROR | The time constant specified is less than or equal to 0 |
| GPIO_INVALID_RUNTIME_CONFIG | The slave has already been started since it has received a prior GPIO_START_SYSTEM command and is in Runtime State. |

# 6. GPIO_CMD_GET_VALUE description

This command is used to get controller values from the slave and can be used in two scenarios:

1. When the slave has to notify the master of a controller's value, it sends a GPIO_CMD_GET_VALUE packet.
2. The master can request the slave for a particular controller's value. **The slave responds by first sending an ACK packet with a return status.** If the controller id specified is valid, then another packet with the value of the controller is sent from the slave.

The Master can ask the value of any type of hw type except a GPIO_MUX_OUTPUT.

## 6.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_GET_VALUE |
| 1 | SUBCMD | 0x00 |
| 4 | DATA | CTRLR_ID : The id of the controller whose value is requested. |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

## 6.2. Slave→Master Packet Structure

If the master has requested for the value, then the slave first sends an ack packet with the following possible gpio return status and a timestamp.

| **Possible GPIO_RETURN_STATUS** | **Description** |
|---|---|
| GPIO_RETURN_OK | The controller id specified in the master packet is valid and its value will be sent in the **next** packet. |
| GPIO_INVALID_CTRLR_ID | The specified controller id is not found amongst |

| | |
|---|---|
| | the configured and compatible controller list. |

After sending an ack packet with GPIO_RETURN_OK, the slave sends a packet containing the controller value as shown in the packet structure below, and with the same timestamp as that of the ack packet. **Note that this packet structure is the same when the slave sends the value of a controller without the master requesting it.**

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_GET_VALUE |
| 1 | SUBCMD | 0x00 |
| 4 | DATA | CTRLR_ID : The id of the controller whose value is requested or has to be sent in order to notify the master. |
| 5→7 | | RESERVED : Empty bytes in order to preserve word boundary |
| 8→11 | | CTRLR_VALUE : The value of the controller |
| 24→ 27 | TIMESTAMP | The timestamp of the slave. |
| 28→31 | SEQUENCE_NUMBER | 0x00 |

# 7. GPIO_CMD_SET_VALUE description

This command is used by the master to set a value of a particular controller.

- If this command is sent during Configuration state, then this value is the default start value of the controller. This will be supported by all hw types with the exception of GPIO_MUX_OUTPUT.
- If this command is sent Runtime state, only hardware types of digital output will support this command.

## 7.1. Master→Slave Packet Structure

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_SET_VALUE |
| 1 | SUBCMD | 0x00 |
| 4 | DATA | CTRLR_ID : The id of the controller whose value is has to be set. |

| | | |
|---|---|---|
| 5→7 | | RESERVED : Empty bytes in order to preserve word boundary |
| 8→11 | | CTRLR_VALUE : The value of the controller |
| 28→31 | SEQUENCE_NUMBER | The sequence number of the packet. |

## 7.2. Slave→Master Packet Structure

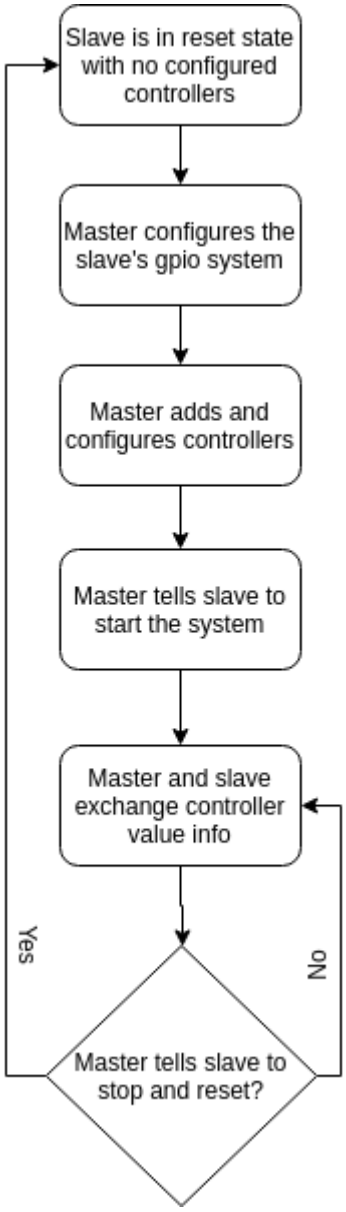
The slave sends an ack packet with the following possible gpio return status and a unique timestamp.

| Possible GPIO_RETURN_STATUS | Description |
|---|---|
| GPIO_RETURN_OK | The controller id specified in the master packet is valid and its value is set to the new one. |
| GPIO_INVALID_CTRLR_ID | The specified controller id is not found amongst the configured controller list. |
| GPIO_PARAMETER_ERROR | The value sent is not in the range of the controller or is not compatible with it. |

# 8. Command Sequence with Example

The setup sequence is divided into three main stages:

1. System configuration
2. Controller configuration
3. Exchanging controller value information between master and slave. This is similar to a runtime stage.




For example, consider a setup where the following controllers that have to be configured:

1. A simple LED (binary output) having an ID of 1 connected on a digital output pin 1.
2. Two LED rings of IDs 2 and 3. Each has 5 LEDs (stepped output) connected to the same digital output pins 2,3,4,5 and 6. The individual LED ring is selected using digital output pins 7 and 8.
3. A simple button having ID 4 on digital input pin 1
4. A four way switch having ID 5 on digital input pins 2,3,4 and 5

## 8.1. System setup

### 8.1.1. Stop and reset the system

First the Master should stop and reset any previous configuration to ensure that the slave is in reset state. This is done by sending a **GPIO_STOP_RESET_SYSTEM** packet. The slave sends an ack packet with the return status **GPIO_RETURN_OK**.

### 8.1.2. Get board information

The master queries the slave for the board information by sending a **GPIO_GET_BOARD_INFO** packet. The slave responds by first sending an ack packet with return status **GPIO_RETURN_OK** followed by the packet containing board info. The master can use this information to validate the configuration requirements and see if it can be supported on the slave's gpio capabilities.

### 8.1.3. Set System Tick Rate:

By default, the tick rate of the slave's system at reset will be 1000Hz. You can change the system tick if needed by using the GPIO_SET_TICK_RATE command.

## 8.2. Controller configuration

### 8.2.1. Adding the single LED (ID = 1)

The LED is of hw type GPIO_BINARY_OUTPUT. First the controller is added using the **GPIO_ADD_CTRLR** command. The slave responds with return status **GPIO_RETURN_OK.**

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |
| 1 | SUBCMD | GPIO_ADD_CTRLR |
| 4 | DATA | CTRLR_ID : 0x01 |
| 5 | | HW_TYPE : 0x01 |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

Then the master adds pins to this controller using **GPIO_ADD_PINS_TO_CTRLR** command.The slave responds with return status **GPIO_RETURN_OK.**

| **Byte Offset** | | |
|---|---|---|
| 0 | CMD | GPIO_CMD_CONFIG_CTRLS |

| | | |
|---|---|---|
| 1 | SUBCMD | GPIO_ADD_PINS_TO_CTRLR |
| 4 | DATA | CTRLR_ID : 0x01 |
| 5 | | NUM_PINS_IN_PACKET : 0x01 |
| 6 | | PINS : 0x01 |
| 28 → 31 | SEQUENCE_NUMBER | The sequence number of the packet |

After this the master can then configure other parameters of the controller such as its mute status etc.

## 8.3. Starting the gpio client

The master then sends a  GPIO_START_SYSTEM command to the slave to start the gpio client.