

# Integrated Sensor (AX-S1)

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## Part Photo

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[AX-S1]

## Product Usage

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AX-S1 is a sensor device, which plays the role of eyes and ears of robots. Distance of an object, Brightness of surroundings, heat, and sound detection functions are included; additionally, IR remote control receptor and sound-making functions are included. The configuration and the communication type of AX-S1 are equal to AX-12A's, but it is not operated by servo motor..

## How to Communicate

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The communication method and the hardware composition related to the communication of AX-S1 are the same as Dynamixel AX series.

- Please refer to [Dynamixel Communication](#) on the communication method and the packet composition.
- Please refer to [Communication Hardware Composition](#) of AX-Series on the communication hardware.

## H/W Specification

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- Weight : 37g
- Resolution : 10bit(1024)
- Working Temperature : -5℃ ~ +85℃
- Voltage : 7 ~ 10V (Recommended voltage 9.6V)
- Maximum Current : 40mA
- Command Signal : Digital Packet
- Protocol Type : Half duplex Asynchronous Serial Communication (8bit,1stop,No Parity)
- Link (Physical) : TTL Level Multi Drop (daisy chain type Connector)
- ID : 254 ID (0~253)
- Communication Speed : 7843bps ~ 1 Mbps
- Feedback : Infra-red Sensor, Internal Mic, Temperature, Input Voltage, IR Remocon Tx/Rx Data, etc.

- Material : Engineering Plastic

## Control Table

Control Table consists of data regarding the current status and operation, which exists inside of Dynamixel. The user can control Dynamixel by changing data of Control Table via Instruction Packet.

### EEPROM and RAM

Data in RAM area is reset to the initial value whenever the power is turned on while data in EEPROM area is kept once the value is set even if the power is turned off.

### Address

It represents the location of data. To read from or write data to Control Table, the user should assign the correct address in the Instruction Packet.

### Access

Dynamixel has two kinds of data: Read-only data, which is mainly used for sensing, and Read-and-Write data, which is used for driving.

### Initial Value

In case of data in the EEPROM Area, the initial values on the right side of the below Control Table are the factory default settings. In case of data in the RAM Area, the initial values on the right side of the above Control Tables are the ones when the power is turned on.

### Highest/Lowest Byte

In the Control table, some data share the same name, but they are attached with (L) or (H) at the end of each name to distinguish the address. This data requires 16bit, but it is divided into 8bit each for the addresses (low) and (high). These two addresses should be written with one Instruction Packet at the same time.

Area	Address (Hexadecimal)	Name	Description	Access	Initial Value (Hexadecimal)
EEPROM	0 (0X00)	Model Number(L)	Lowest byte of model number	R	13 (0X0D)
	1 (0X01)	Model Number(H)	Highest byte of model number	R	0 (0X00)
	2 (0X02)	Version of Firmware	Information on the version of firmware	R	-
	3 (0X03)	ID	ID of Dynamixel	RW	100 (0X64)
	4 (0X04)	Baud Rate	Baud Rate of Dynamixel	RW	1 (0X01)
	5 (0X05)	Return Delay Time	Return Delay Time	RW	250 (0XFA)
	16 (0X10)	Status Return Level	Status Return Level	RW	2 (0X02)
RAM	26 (0X1A)	IR Left Fire Data	The value of left IR Sensor	R	-
	27 (0X1B)	IR Center Fire Data	The value of central IR Sensor	R	-
	28 (0X1C)	IR Right Fire Data	The value of right IR Sensor	R	-
	29 (0X1D)	Light Left Data	The value of left Light Sensor	R	-
	30 (0X1E)	Light Center Data	The value of central Light Sensor	R	-
	31 (0X1F)	Light Right Data	The value of right Light Sensor	R	-
	32 (0X20)	IR Obstacle Detected	The object detected by IR	R	-
	33 (0X21)	Light Detected	Light Detected	R	-
	35 (0X23)	Sound Data	The value of current sound	R	-
	36 (0X24)	Sound Data Max Hold	The value of Max Sound	RW	-
	37 (0X25)	Sound Detected Count	The count of sound detected	RW	-
	38 (0X26)	Sound Detected Time(L)	Lowest byte of sound detected time	RW	-
	39 (0X27)	Sound Detected Time(H)	Highest byte of sound detected time	RW	-

40 (0X28)	Buzzer Data 0	Buzzer Notes	RW	-
41 (0X29)	Buzzer Data 1	Buzzer Ringing Time	RW	-
44 (0X2C)	Registered	Registration of Instruction	RW	0 (0X00)
46 (0X2E)	IR Remocon Arrived	Arrival of IR Remocon Data	R	0 (0X00)
47 (0X2F)	Lock	Locking EEPROM	RW	0 (0X00)
48 (0X30)	Remocon RX Data 0	Lowest byte of received data packet	R	-
49 (0X31)	Remocon RX Data 1	Higest byte of received data packet	R	-
50 (0X32)	Remocon TX Data 0	Lowest byte of transmitted data packet	RW	-
51 (0X33)	Remocon TX Data 1	Highest byte of transmitted data packet	RW	-
52 (0X34)	IR Obstacle Detect CompareRD	The reference value of object detected	RW	-
53 (0X35)	Light Detect CompareRD	The reference value of light detected	RW	-

## Explanation of Address Functions

### EEPROM Area

#### Model Number

It represents the Model Number.

#### Firmware Version

It represents the firmware version.

#### ID

It is a unique number to identify Dynamixel.

The range from 0 to 253 (0xFD) can be used, and, especially, 254(0xFE) is used as the Broadcast ID.

If the Broadcast ID is used to transmit Instruction Packet, we can command to all Dynamixels.

Please be careful not to duplicate the ID of connected Dynamixel.

#### Baud Rate

It represents the communication speed. 0 to 254 (0xFE) can be used for it.

This speed is calculated by using the below formula.

$$\text{Speed(BPS)} = 2000000 / (\text{Data} + 1)$$

Data	Set BPS	Target BPS	Tolerance
1	1000000.0	1000000.0	0.000 %
3	500000.0	500000.0	0.000 %
4	400000.0	400000.0	0.000 %
7	250000.0	250000.0	0.000 %
9	200000.0	200000.0	0.000 %
16	117647.1	115200.0	-2.124 %
34	57142.9	57600.0	0.794 %
103	19230.8	19200.0	-0.160 %
207	9615.4	9600.0	-0.160 %

Note : Maximum Baud Rate error of 3% is within the tolerance of UART communication.

## Return Delay Time

It is the delay time per data value that takes from the transmission of Instruction Packet until the return of Status Packet. 0 to 254 (0xFE) can be used, and the delay time per data value is 2 usec. That is to say, if the data value is 10, 20 usec is delayed. The initial value is 250 (0xFA) (i.e., 0.5 msec).

## Status Return Level

It decides how to return Status Packet. There are three ways like the below table.

Value	Return of Status Packet
0	No return against all commands (Except PING Command)
1	Return only for the READ command
2	Return for all commands

When Instruction Packet is Broadcast ID, Status Packet is not returned regardless of Status Return Level.

## IR Obstacle Detect Compare Value

The reference value is set in the estimated place where an object exists on the direction of the sensor in the IR sensor value of Dynamixel Sensor Module. If the sensor value is greater than the reference value, the bit which belongs to the sensor of IR Obstacle Detected (Address 0x20) is set to '1' because the object is located within a certain distance; if the sensor value is less than the reference value, the bit is set to '0' since the object is not located within a certain distance.

IR Obstacle Detect Compare Value is assigned to two places: ROM(Address 0x14) and RAM(Address 0x34), and when the power is turned on, the value of EEPROM is copied to RAM.

## Light Detect Compare Value

The reference value is set in the estimated place where a light is turned on in the light-brightness sensor of Dynamixel Sensor Module. If the sensor value is greater than the reference value, the bit which belongs to Light Detected is set to '1' because the light is brighter than a certain brightness; if the sensor value is less than the reference value, the bit is set to '0' since the light is not brighter than a certain brightness.

Light Detect Compare Value is assigned to two places: ROM(Address 0x15) and RAM(Address 0x35), and when the power is turned on, the value of EEPROM is copied to RAM.

## RAM Area

### IR Distance Sensor Value (Left/Center/Right)

It is the IR sensor value of Dynamixel Sensor Module for distance measurement. If the infrared rays are emitted from the IR-emitting part of AX-S1, the emitted infrared rays are reflected after hitting walls or objects. The amount of the reflected rays is measured by the IR-receiving part of AX-S1, and the higher value is acquired, the closer walls and objects are located.

The measured values have the range of 0~255; only 255 may be appeared if any object or wall is located within a certain distance.

Since it is an IR-measurement type, reflection ratio may vary depending on the color and the surface texture of walls and objects; the measured value can be different from the expected value.

### Light Brightness Sensor Value (Left/Center/Right)

It is the light detection sensor value of Dynamixel Sensor Module. The concept of this sensor is similar to IR sensor value's, but it is measured without turning on the IR-emitting part; it can measure only infrared rays from a light. For that reason, the light brightness sensor value can be measured from the light which emits a lot of infrared rays such as lightbulb, and also lights from a lighter or candles can be measured. The measured value has the range of 0~255.

### IR Obstacle Detected

If IR Distance Sensor value of AX-S1 is greater than the reference value, a certain bit of object detection value is set to '1', judging an object is detected.

Please refer to the table below on the bits each sensor represents.

Bit	Name
Bit 2	Object/Light are detected by the right sensor
Bit 1	Object/Light are detected by the central sensor
Bit 0	Object/Light are detected by the left sensor

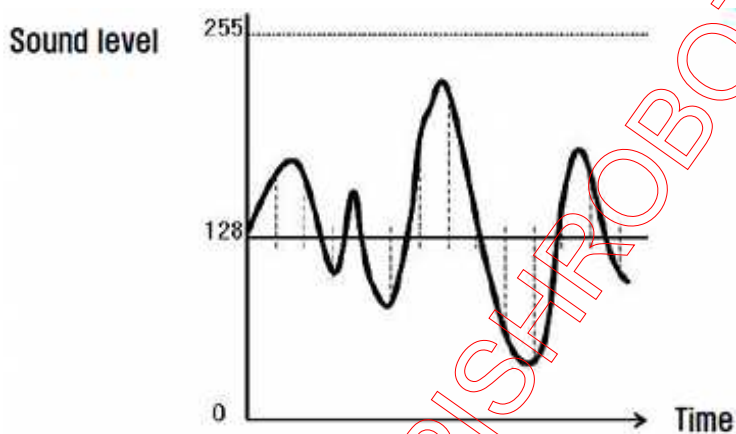
### Light Detected

If light brightness sensor value of AX-S1 is greater than the reference value, a certain bit of light detected value is set to '1', judging a light is detected.

The bit each sensor represents is equal to the object detection value. (See Address 0x20 above)

### Sound Level

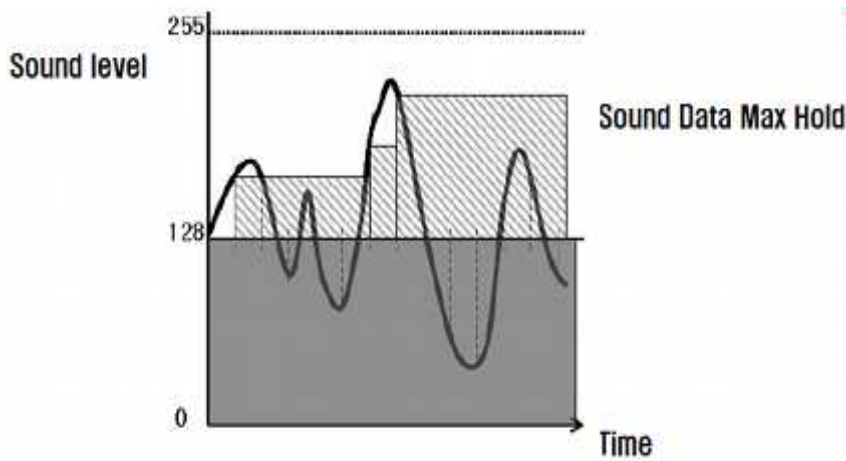
The level of the sound which is coming into the mic of AX-S1 is measured and converted into numerical value. Because the sound level is fluctuated up and down as below, if there is no sound, the numerical value of 127~128 (0x7F~0x80) is got, and it gets closer to 0 or 255 (0xFF) as the sound gets louder. The sound level is entered about 3800 times per second.



### Maximum Sound Level

The loudest sound level is saved separately among the sound levels of AX-S1. That is, if current sound level is louder than the saved maximum sound level, the current sound is copied as maximum sound level.

Therefore, the sound level lower than 128 is actually ignored, and it is assumed that the loudest sound level at the moment is accumulated and saved. See the following picture for better understanding.

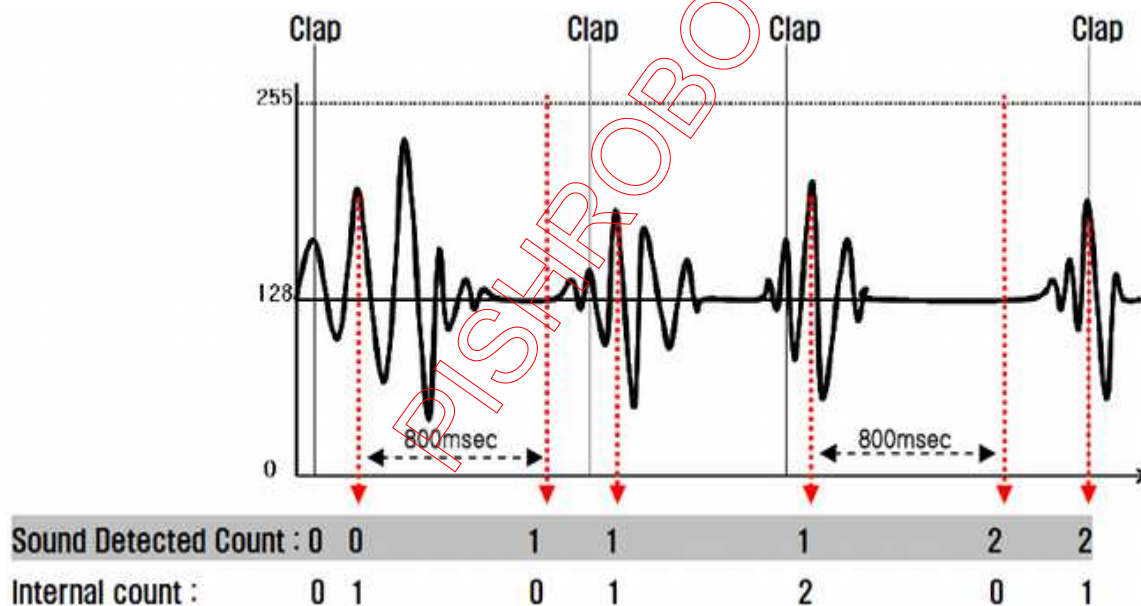


Be careful if the maximum sound level becomes 255 (0xFF) while being accumulated, the maximum sound level remains 255 because it cannot exceed 255. Therefore, '0' must be written on the maximum sound level part to measure the maximum sound level.

### Sound Detected Count

AX-S1 has a function to count 1 time if a certain level of sound is made. For instance, it is possible to count the number of claps. However, to prevent 1 clap from being counted as multiple claps, once claps are counted one time, the claps are not counted for 80msec. After the last count, the counted value is saved as sound detected count in 800msec.

To recognize the time when the sound detected count is increased, count the number internally, and then save the value in the sound detected count in 800msec while initializing the internal count as '0.' See the following picture for better understanding.



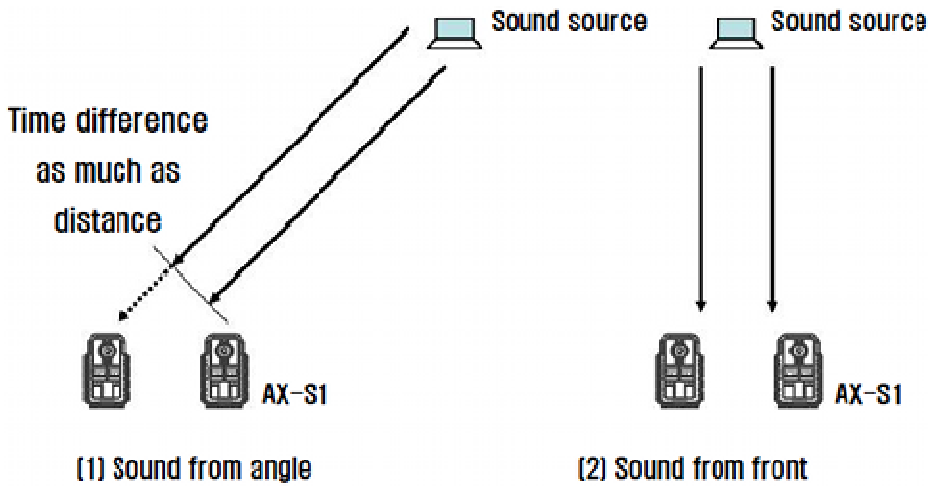
### Sound Detected Time

AX-S1 has a function to save the time of the moment whenever sound detected count is done. The function is provided to detect the direction of sounds, and at least 2 units of AX-S1 are necessary. The function is based on the difference of sound-incoming time to each of AX-S1 Mics using the speed of sound (The speed of sound is about 343m/sec at 20 degrees of Celsius).

Sound detected time is counted internally (Repeating the count of 0~65535), and the currently counted value is saved when sound detected count is increased. Thus, after initializing sound detected time simultaneously to '0' using Broadcasting command by separating 2 units of AX-S1 properly from each other, if sounds are made, the time difference between the two AX-S1s occurs pursuant to the directions of sounds.

If the sound source is in the front, the sound is detected almost at the same time, but if the sound source is not in the front, the time difference occurs pursuant to the apart distance of AX-S1. The direction of sound sources can be roughly estimated

using the principle above. See the following picture for better understanding.



The sound counted time of AX-S1 is counted about every 4.096 msec and it is counted again from '0.' Therefore, calculating by the speed of sound, the sound moves about 0.02mm per count, and the distance between two AX-S1s must be within 70cm. For example, if the two AX-S1s are 10cm apart, in case of using the method above, the difference of sound detected time between two AX-S1s may vary up to 5000. (If the difference is about 5000, it means the sound source is located at 90 degrees left or right of the two AX-S1s)

### Buzzer Notes

A buzzer is installed in AX-S1, and simple beep sounds can be made. Total 52 musical notes can be made in Buzzer Notes, and various notes can be made because there are whole tones and halftones in each octave. The values of Buzzer Notes are assigned as the table below.

Buzzer index	Melody notes	Buzzer index	Melody notes	Buzzer index	Melody notes	Buzzer index	Melody notes
0	la	13	la#	26	si	39	do
1	la#	14	si	27	do	40	do#
2	si	15	do	28	do#	41	re
3	do	16	do#	29	re	42	re#
4	do#	17	re	30	re#	43	mi
5	re	18	re#	31	mi	44	fa
6	re#	19	mi	32	fa	45	fa#
7	mi	20	fa	33	fa#	46	sol
8	fa	21	fa#	34	sol	47	sol#
9	fa#	22	sol	35	sol#	48	la
10	sol	23	sol#	36	la	49	la#
11	sol#	24	la	37	la#	50	si
12	la	25	la#	38	si	51	do

### Buzzer Ringing Time

AX-S1 has a function to control the buzzer alarming time. It is possible to control by the unit of 0.1 second, and the minimum length is set to 0.3 seconds; the time can be extended up to maximum 5 seconds. That is, if 0~3 is entered, the buzzer rings for 0.3 seconds; if the value over 50 is entered, the buzzer rings only for 5 seconds regardless of the value. Moreover, if the ringing is finished, the buzzer ringing time is automatically initialized to '0.'

There are 2 special buzzer ringing time functions for AX-S1. Firstly, the buzzer can be ringing without stopping. If 254 is entered in buzzer ringing time, and the number of desired musical notes is entered, the buzzer rings without stopping. To stop the ringing, '0' is entered in buzzer ringing time.

Secondly, the buzzer can play special melodies. If 255 is entered in buzzer ringing time, and then the value 0~26 is entered

in buzzer notes, 27 melodies corresponding to each number can be played. If the ringing is finished, the buzzer ringing time is automatically initialized to '0.'

### Registered Instruction

Value	Meaning
0	There are no commands transmitted by REG_WRITE
1	There are commands transmitted by REG_WRITE.

Notes: If ACTION command is executed, the value is changed into 0.

### Arrival of New Remocon Data

IR remote controller communication is possible among other AX-S1s since IR remote controller sensor is installed on the front of AX-S1. The data can be transmitted by 2 byte unit.

IR remocon data can be transmitted to any direction since IR-emitting parts are installed in 3 directions: front/left/right, but the IR remocon data can be received only in limited angle because IR remocon sensor is installed only on the front.

If IR remocon data is received on the sensor, the new remocon data arrival value is changed into '2'; it means 2 byte is received. If the received remocon data are read, it is automatically initialized to '0.'

### Lock

Value	Meaning
0	EEPROM area can be modified.
1	EEPROM area cannot be modified.

Caution: If Lock is set to 1, the power must be turned off and then turned on again to change into 0.

### Received Remocon Data

The received data is saved in IR remocon sensor. If this value is read, the new remocon data arrival value is automatically initialized to '0.'

### Remocon Data To Be Transmitted

The remocon data to be transmitted through the IR-emitting part is written. The remocon data is transmitted as soon as the value of 2 bytes is written.

### IR Obstacle Detect Compare Value

IR Obstacle Detect Compare Value of Address 0x14 is saved in RAM area of Control Table.

Currently, it is not possible to detect normally in short distance(e.g. within 5cm distance, the maximum value is always acquired) since, in case of IR Sensor of AX-S1, infrared rays are emitted strongly to detect in long distance.

Therefore, AX-S1 supports low-sensitive mode for accurate detection in short distance: if '0' is entered in IR Obstacle Detect Compare Value, it is converted to low-sensitive mode. In low-sensitive mode, the long distance sensor performance is not satisfactory, but accurate and sensitive detection is possible in short distance because it is not saturated to the maximum value.

### Light Detect Compare Value

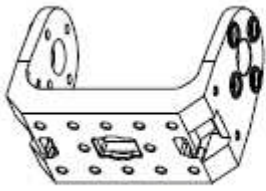
Light Detect Compare Value of Address 0x15 is saved in RAM Area of Control Table.



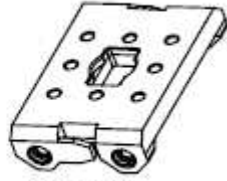
## Option Frame

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The types of AX-S1 option frames are as follows. The frame of AX-S1 is compatible with the frame of AX-12/12+.

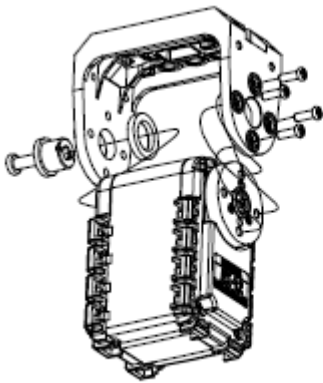


OF-12SH

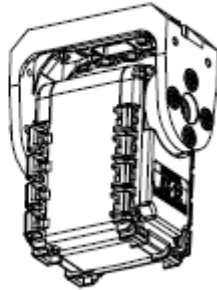


OF-12S

### How to Assemble



*Exploded view*

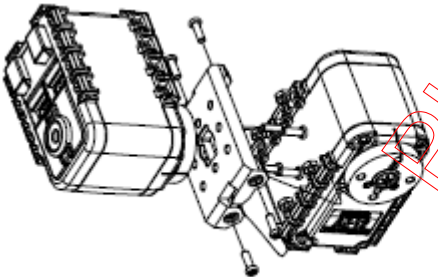


*Assembled*

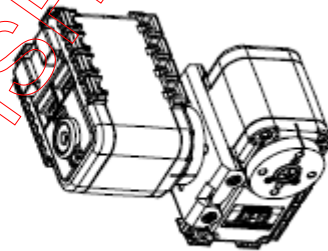
## Combination

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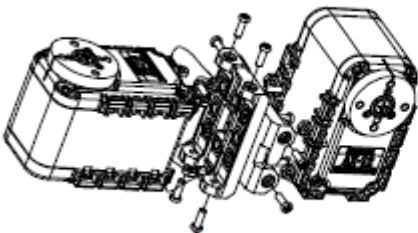
The following example shows the combination structure of option frames and horns.



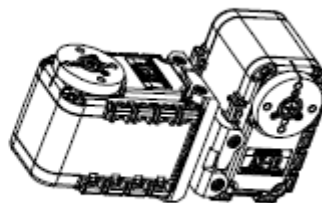
*Exploded view*



*Assembled*



*Exploded view*



*Assembled*

## Dimension

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