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XM430-W350

1. Specifications

Item	Specifications
MCU	ARM CORTEX-M3 (72 [MHz], 32Bit)
Position Sensor	Contactless absolute encoder (12Bit, 360 [°]) Maker : ams(www.ams.com), Part No : AS5045
Motor	Coreless
Baud Rate	9,600 [bps] ~ 4.5 [Mbps]
Control Algorithm	PID control
Resolution	4096 [pulse/rev]
Backlash	15 [arcmin] (0.25 [°])
Operating Modes	Current Control Mode Velocity Control Mode Position Control Mode (0 ~ 360 [°]) Extended Position Control Mode (Multi-turn) Current-based Position Control Mode PWM Control Mode (Voltage Control Mode)
Weight	82 [g]
Dimensions (W x H x D)	28.5 x 46.5 x 34 [mm]
Gear Ratio	353.5 : 1
Stall Torque	3.8 [N.m] (at 11.1 [V], 2.1 [A]) **4.1 [N.m] (at 12.0 [V], 2.3 [A])** 4.8 [N.m] (at 14.8 [V], 2.7 [A])
No Load Speed	43 [rev/min] (at 11.1 [V]) **46 [rev/min] (at 12.0 [V])** 57 [rev/min] (at 14.8 [V])
Radial Load	40 [N] (10 [mm] away from the horn)
Axial Load	20 [N]
Operating Temperature	-5 ~ +80 [°C]
Input Voltage	10.0 ~ 14.8 [V] (**Recommended : 12.0 [V]**)

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Item	Specifications
Command Signal	Digital Packet
Physical Connection	RS485 / TTL Multidrop Bus TTL Half Duplex Asynchronous Serial Communication with 8bit, 1stop, No Parity RS485 Asynchronous Serial Communication with 8bit, 1stop, No Parity
ID	253 ID (0 ~ 252)
Feedback	Position, Velocity, Current, Realtime tick, Trajectory, Temperature, Input Voltage, etc
Case Material	Metal (Front, Middle), Engineering Plastic (Back)
Gear Material	Full Metal Gear
Standby Current	40 [mA]

DANGER

(May cause serious injury or death)

- Never place items containing water, flammables, and solvents near product.
- Never place fingers, arms, toes, and other body parts near product during operation.
- Cut power off if product emits strange odors or smoke.
- Keep product out of reach of children.
- Check the power's polarity before wiring.

CAUTION

(May cause injury or damage to product)

- Do not operate the product at a temperature exceeding -5 ~ +80 [°C] range.
- Do not insert sharp blades nor pins during product operation.

ATTENTION

(May cause injury or damage to product)

- Do not disassemble or modify product.
- Do not drop or apply strong shock to product.

1. 1. Performance Graph

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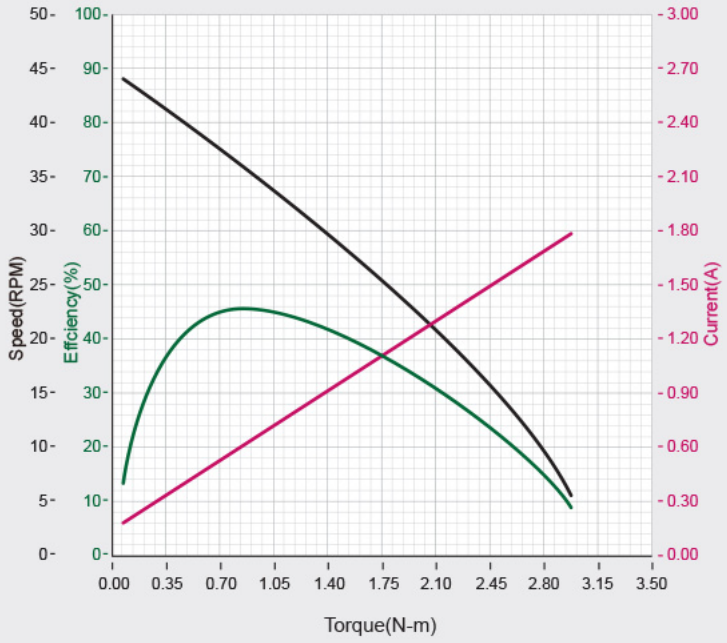

Looking for the same form factors?

NOTE : The Max Torque and the Stall Torque of Performance Graph are different in measurement methods. Stall torque is a measured value of the momentary torque that it can reach. This is generally how RC servos are measured. The Performance graph is also called as N-T curves, which is measured with the gradually increasing load. The actual motor operation environment is closer to the performance graph, not stall torque method. For this reason, the performance graph is broadly used in the industrial field. Generally, Max Torque of the Performance Graph is less than the Stall Torque.

CAUTION : When supplying power

- It is recommended using ROBOTIS controller or SMPS2DYNAMIXEL.
- Do not connect or disconnect DYNAMIXEL when power is being supplied.

2. Control Table

The Control Table is a structure of data implemented in the device. Users can read a specific Data to get status of the device with Read Instruction Packets, and modify Data as well to control the device with WRITE Instruction Packets.

2. 1. Control Table, Data, Address

The Control Table is a structure that consists of multiple Data fields to store status or to control the device. Users can check current status of the device by reading a specific Data from the Control Table with Read Instruction Packets. WRITE Instruction Packets enable users to control the device by changing specific Data in the Control Table. The Address is a unique value when accessing a specific Data in the Control Table with Instruction Packets. In order to read or write data, users

must designate a specific Address in the Instruction Packet. Please refer to DYNAMIXEL Protocol 2.0 for more details about Instruction Packets.

NOTE : Two's complement is applied for the negative value. For more information, please refer to Two's complement from Wikipedia.

2. 1. 1. Area (EEPROM, RAM)

The Control Table is divided into 2 Areas. Data in the RAM Area is reset to initial values when the power is reset(Volatile). On the other hand, data in the EEPROM Area is maintained even when the device is powered off(Non-Volatile).

Data in the EEPROM Area can only be written to if Torque Enable(64) is cleared to '0'(Torque OFF).

2. 1. 2. Size

The Size of data varies from 1 ~ 4 bytes depend on their usage. Please check the size of data when updating the data with an Instruction Packet. For data larger than 2 bytes will be saved according to Little Endian.

2. 1. 3. Access

The Control Table has two different access properties. 'RW' property stands for read and write access permission while 'R' stands for read only access permission. Data with the read only property cannot be changed by the WRITE Instruction. Read only property('R') is generally used for measuring and monitoring purpose, and read write property('RW') is used for controlling device.

2. 1. 4. Initial Value

Each data in the Control Table is restored to initial values when the device is turned on. Default values in the EEPROM area are initial values of the device (factory default settings). If any values in the EEPROM area are modified by a user, modified values will be restored as initial values when the device is turned on. Initial Values in the RAM area are restored when the device is turned on.

2. 2. Control Table of EEPROM Area

Address	Size(Byte)	Data Name	Access	Initial Value	Range	Unit
0	2	Model Number	R	1,020	-	-
2	4	Model Information	R	-	-	-
6	1	Firmware Version	R	-	-	-
7	1	ID	RW	1	0 ~ 252	-
8	1	Baud Rate	RW	1	0 ~ 7	-
9	1	Return Delay Time	RW	250	0 ~ 254	2 [µsec]
10	1	Drive Mode	RW	0	0 ~ 5	-
11	1	Operating Mode	RW	3	0 ~ 16	-
12	1	Secondary(Shadow) ID	RW	255	0 ~ 252	-
13	1	Protocol Type	RW	2	1 ~ 2	-

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Address	Size(Byte)	Data Name	Access	Initial Value	Range	Unit
20	4	Homing Offset	RW	0	-1,044,479 ~ 1,044,479	1 [pulse]
24	4	Moving Threshold	RW	10	0 ~ 1,023	0.229 [rev/min]
31	1	Temperature Limit	RW	80	0 ~ 100	1 [°C]
32	2	Max Voltage Limit	RW	160	95 ~ 160	0.1 [V]
34	2	Min Voltage Limit	RW	95	95 ~ 160	0.1 [V]
36	2	PWM Limit	RW	885	0 ~ 885	0.113 [%]
38	2	Current Limit	RW	1,193	0 ~ 1,193	2.69 [mA]
44	4	Velocity Limit	RW	200	0 ~ 1,023	0.229 [rev/min]
48	4	Max Position Limit	RW	4,095	0 ~ 4,095	1 [pulse]
52	4	Min Position Limit	RW	0	0 ~ 4,095	1 [pulse]
60	1	Startup Configuration	RW	0	3	-
63	1	Shutdown	RW	52	-	-

2. 3. Control Table of RAM Area

Address	Size(Byte)	Data Name	Access	Initial Value	Range	Unit
64	1	Torque Enable	RW	0	0 ~ 1	-
65	1	LED	RW	0	0 ~ 1	-
68	1	Status Return Level	RW	2	0 ~ 2	-
69	1	Registered Instruction	R	0	0 ~ 1	-
70	1	Hardware Error Status	R	0	-	-
76	2	Velocity I Gain	RW	1,920	0 ~ 16,383	-
78	2	Velocity P Gain	RW	100	0 ~ 16,383	-
80	2	Position D Gain	RW	0	0 ~ 16,383	-
82	2	Position I Gain	RW	0	0 ~ 16,383	-
84	2	Position P Gain	RW	800	0 ~ 16,383	-
88	2	Feedforward 2nd Gain	RW	0	0 ~ 16,383	-
90	2	Feedforward 1st Gain	RW	0	0 ~ 16,383	-
98	1	Bus Watchdog	RW	0	1 ~ 127	20 [msec]
100	2	Goal PWM	RW	-	-PWM Limit(36) ~ PWM Limit(36)	0.113 [%]
102	2	Goal Current	RW	-	-Current Limit(38) ~ Current Limit(38)	2.69 [mA]
104	4	Goal Velocity	RW	-	-Velocity Limit(44) ~ Velocity Limit(44)	0.229 [rev/min]

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Address	Size(Byte)	Data Name	Access	Initial Value	Range	Unit
108	4	Profile Acceleration	RW	0	0 ~ 32,767 0 ~ 32,737	214.577 [rev/min^2] 1 [ms]
112	4	Profile Velocity	RW	0	0 ~ 32,767	0.229 [rev/min]
116	4	Goal Position	RW	-	Min Position Limit(52) ~ Max Position Limit(48)	1 [pulse]
120	2	Realtime Tick	R	-	0 ~ 32,767	1 [msec]
122	1	Moving	R	0	0 ~ 1	-
123	1	Moving Status	R	0	-	-
124	2	Present PWM	R	-	-	-
126	2	Present Current	R	-	-	2.69 [mA]
128	4	Present Velocity	R	-	-	0.229 [rev/min]
132	4	Present Position	R	-	-	1 [pulse]
136	4	Velocity Trajectory	R	-	-	0.229 [rev/min]
140	4	Position Trajectory	R	-	-	1 [pulse]
144	2	Present Input Voltage	R	-	-	0.1 [V]
146	1	Present Temperature	R	-	-	1 [°C]
147	1	Backup Ready	R	-	0 ~ 1	-
168	2	Indirect Address 1	RW	224	64 ~ 661	-
170	2	Indirect Address 2	RW	225	64 ~ 661	-
172	2	Indirect Address 3	RW	226	64 ~ 661	-
…	…	…	…	…	-	-
218	2	Indirect Address 26	RW	249	64 ~ 661	-
220	2	Indirect Address 27	RW	250	64 ~ 661	-
222	2	Indirect Address 28	RW	251	64 ~ 661	-
224	1	Indirect Data 1	RW	0	0 ~ 255	-
225	1	Indirect Data 2	RW	0	0 ~ 255	-
226	1	Indirect Data 3	RW	0	0 ~ 255	-
…	…	…	…	…	-	-
249	1	Indirect Data 26	RW	0	0 ~ 255	-
250	1	Indirect Data 27	RW	0	0 ~ 255	-
251	1	Indirect Data 28	RW	0	0 ~ 255	-
578	2	Indirect Address 29	RW	634	64 ~ 661	-

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Address	Size(Byte)	Data Name	Access	Initial Value	Range	Unit
580	2	Indirect Address 30	RW	635	64 ~ 661	-
582	2	Indirect Address 31	RW	636	64 ~ 661	-
...	...	...	...	...	-	-
628	2	Indirect Address 54	RW	659	64 ~ 661	-
630	2	Indirect Address 55	RW	660	64 ~ 661	-
632	2	Indirect Address 56	RW	661	64 ~ 661	-
634	1	Indirect Data 29	RW	0	0 ~ 255	-
635	1	Indirect Data 30	RW	0	0 ~ 255	-
636	1	Indirect Data 31	RW	0	0 ~ 255	-
...	...	...	...	...	-	-
659	1	Indirect Data 54	RW	0	0 ~ 255	-
660	1	Indirect Data 55	RW	0	0 ~ 255	-
661	1	Indirect Data 56	RW	0	0 ~ 255	-

CAUTION : Protocol 1.0 does not support addresses greater than 256. Therefore, Indirect Address 29 ~ 56 and Indirect Data 29 ~ 56 can only be accessed with Protocol 2.0.

2. 4. Control Table Description

CAUTION : Data in the EEPROM Area can only be written when the value of Torque Enable(64) is cleared to '0'.

2. 4. 1. Model Number(0)

This address stores model number of DYNAMIXEL.

2. 4. 2. Firmware Version(6)

This address stores firmware version of DYNAMIXEL.

2. 4. 3. ID(7)

The ID is a unique value in the network to identify each DYNAMIXEL with an Instruction Packet. 0~253 (0xFD) values can be used as an ID, and 254(0xFE) is occupied as a broadcast ID. The Broadcast ID(254, 0xFE) can send an Instruction Packet to all connected DYNAMIXEL simultaneously.

NOTE : Please avoid using an identical ID for multiple DYNAMIXEL. You may face communication failure or may not be able to detect DYNAMIXEL with an identical ID.

NOTE : If the Instruction Packet ID is set to the Broadcast ID(0xFE), Status Packets will not be returned for READ or WRITE Instructions regardless of the set value of

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Stuatus Return Level (68). For more details, please refer to the `Status Packet` section for DYNAMIXEL Protocol 2.0

2. 4. 4. Baud Rate(8)

The Baud Rate(8) determines serial communication speed between a controller and DYNAMIXEL.

Value	Baud Rate	Margin of Error
7	4.5M [bps]	0.000 [%]
6	4M [bps]	0.000 [%]
5	3M [bps]	0.000 [%]
4	2M [bps]	0.000 [%]
3	1M [bps]	0.000 [%]
2	115,200 [bps]	0.000 [%]
1(Default)	57,600 [bps]	0.000 [%]
0	9,600 [bps]	0.000 [%]

NOTE : Less than 3% of the baud rate error margin will not affect to UART communication.

NOTE : For the stable communication with higher Baudrate using U2D2, configure USB Latency value to the lower.
USB Latency Setting

2. 4. 5. Return Delay Time(9)

If the DYNAMIXEL receives an Instruction Packet, it will return the Status Packet after the time of the set Return Delay Time(9).
Note that the range of values is 0 to 254 (0XFE) and its unit is 2 [µsec]. For instance, if the Return Delay Time(9) is set to ‘10’, the Status Packet will be returned after 20[µsec] when the Instruction Packet is received.

Unit	Value Range	Description
2[µsec]	0 ~ 254	Default value ‘250’(500[µsec]) Maximum value: ‘508’[µsec]

2. 4. 6. Drive Mode(10)

This address configures Drive Mode of DYNAMIXEL. Drive Mode is available from the **firmware V38**.

Bit	Item	Description
Bit 7(0x80)	-	Unused, always ‘0’
Bit 6(0x40)	-	Unused, always ‘0’
Bit 5(0x20)	-	Unused, always ‘0’
Bit 4(0x10)	-	Unused, always ‘0’

Bit	Item	Description
Bit 3(0x08)	Torque On by Goal Update	**[0]** Performing a given command only if the value of Torque Enable(64) is '1' **[1]** Performing a given command regardless of the set value of Torque Enable(64). If the value of Torque Enable(64) is '0' and the command is given, the Torque Enable(64) switches to '1' and perform the command.
Bit 2(0x04)	Profile Configuration	**[0]** Velocity-based Profile: Create a Profile based on Velocity **[1]** Time-based Profile: Create Profile based on time ※ See What is the Profile
Bit 1(0x02)	-	Unused, always '0'
Bit 0(0x01)	Normal/Reverse Mode	**[0]** Normal Mode: CCW(Positive), CW(Negative) **[1]** Reverse Mode: CCW(Negative), CW(Positive)

NOTE : Time-based Profile is available from **firmware V42**.

NOTE: Torque On by Goal Update is available from firmware **V45**.

NOTE : If the value of Bit 0(Normal/Reverse Mode) of the Drive Mode(10) is set to 1, rotational direction is inverted.
Thus, **Goal Position**, **Present Position** will have a inverted direction.
This feature can be very useful when configuring symmetrical joint.

2. 4. 7. Operating Mode(11)

Value	Operating Mode	Description
0	Current Control Mode	DYNAMIXEL only controls current(torque) regardless of speed and position. This mode is ideal for a gripper or a system that only uses current(torque) control or a system that has additional velocity/position controllers.
1	Velocity Control Mode	This mode controls velocity. This mode is identical to the Wheel Mode(endless) from existing DYNAMIXEL. This mode is ideal for wheel-type robots.
3(Default)	Position Control Mode	This mode controls position. This mode is identical to the Joint Mode from existing DYNAMIXEL. Operating position range is limited by the Max Position Limit(48) and the Min Position Limit(52). This mode is ideal for articulated robots that each joint rotates less than 360 degrees.
4	Extended Position Control Mode(Multi-turn)	This mode controls position. This mode is identical to the Multi-turn Position Control from existing DYNAMIXEL. 512 turns are supported(-256[rev] ~ 256[rev]). This mode is ideal for multi-turn wrists or conveyer systems or a system that requires an additional reduction gear. Note that Max Position Limit(48), Min Position Limit(52) are not used on Extended Position Control Mode.
5	Current-based Position Control Mode	This mode controls both position and current(torque). Up to 512 turns are supported(-256[rev] ~ 256[rev]). This mode is ideal for a system that requires both position and current control such as articulated robots or grippers.
16	PWM Control Mode (Voltage	This mode directly controls PWM output. (Voltage Control Mode)

Value	Operating Mode	Description
	Control Mode)	

NOTE : When the Operating Mode(11) switches to another mode, value of Gains, such as Velocity PI(76, 78); Position PID(80, 82, 84); Feedforward(88, 90), will be reset fitting to a selected Operating Mode(11). Beside, the profile generator and the data of determining the limit value will be reset either. See the next description for more details.

1. The Profile Velocity(112), Profile Acceleration(108) : Reset to '0'
2. The Goal PWM(100) and Goal Current(102) are reset to the value of PWM Limit(36) and Current Limit(38) respectively
3. When the Operating Mode(11) is **Current-based Position Control Mode**, Position PID(80, 82, 84) and PWM Limit(36) values will be reset.

Note that the changed value of Position PID(80, 82, 84) and PWM Limit(36) can be read via the Control Table.

NOTE : PWM stands for **Pulse Width Modulation** that modulates PWM Duty to control motors. It changes pulse width to control average supply voltage to the motor, and this technique is widely used in the motor control field.

1. PWM Control Mode is similar to the Wheel Mode of AX and RX series.
2. Input Goal PWM(100) value to control supply voltage for DYNAMIXEL in **PWM Control Mode**.

NOTE : Present Position(132) represents 4 byte continuous range from -2,147,483,648 to 2,147,483,647 when Torque is turned off regardless of Operating Mode(11).
However, Present Position(132) will be reset to an absolute position value within one full rotation in following cases. Note that Present Position(132) value that is reset to an absolute value can differ by the set Homing Offset(20) value.:

1. When Operating Mode(11) switches to **Position Control Mode**, Present Position(132) will be reset to an absolute position value within a full rotation.
2. When torque is turned on in **Position Control Mode**, Present Position(132) will be reset to an absolute position value within one full rotation.
3. Turning on the power supply or using Reboot Instruction.

2. 4. 8. Secondary(Shadow) ID(12)

The Secondary(Shadow) ID(12) assigns a secondary ID to the DYNAMIXEL. The Secondary ID(12) can be shared to group between DYNAMIXELs and to synchronize their movement, unlike ID(7) which must be unique and not be overlapped to use. Be aware of differences between the Secondary ID(12) and ID(7) by reading the following.

- Under the same Secondary ID(12), multiple DYNAMIXELs can be grouped.
- The ID(7) has a greater priority than the Secondary ID(12). If the data of Secondary ID(12) and ID(7) are set as same, the ID(7) will be applied at the top priority.
- The EEPROM area of the Control Table cannot be modified using Secondary ID(12).
- The RAM area can be modified using the Secondary ID(12).
- If Instruction Packet ID is the same as the Secondary ID(12), the Status Packet will not be returned.

- If the value of the Secondary ID(12) is 253 or higher, the Secondary ID function will be deactivated.

Values	Description
0 ~ 252	Activate Secondary ID function
253 ~ 255	Deactivate Secondary ID function, Default value '255'

2. 4. 8. 1. Secondary ID(12) Example

As mentioned, the Secondary ID(12) can be assigned with the same values unlike the ID(7). See the following Secondary ID(12) example to understand the address properly. Note that The assigned ID(7) on each DYNAMIXELs is '1', '2', '3', '4' or '5' and they are not overlapped to be assigned.

1. Set Secondary ID of five DYNAMIXELs (Assigned ID(7) of each is '1','2','3','4' or '5', not overlapped) to '5'.
2. Send Write Instruction Packet(ID(7) = 1, LED(65) = 1).
3. The DYNAMIXEL with ID '1' turns on its LED by the Instruction Packet, and Status Packet will be returned.
4. Send Write Instruction Packet(ID(7) = 5, LED(65) = 1).
5. All DYNAMIXELs turns on their LED, but Status Packet of ID '5' will be returned only.
6. Set the Secondary ID of all DYNAMIXELs to '100'.
7. Send Write Instruction Packet(ID(7) = 100, LED(65) = 0).
8. All DYNAMIXELs turns off their LED. As no DYNAMIXEL uses ID 100, but uses the same Secondary ID, the Status Packet will not be returned.

2. 4. 9. Protocol Type(13)

DYNAMIXEL protocol type (either DYNAMIXEL Protocol 1.0 or 2.0) can be selected using Protocol Type(13).

It is recommended to use an identical protocol type for multiple DYNAMIXEL.

Value	Description	Compatible DYNAMIXEL
1	DYNAMIXEL Protocol 1.0	AX Series, DX Series, RX Series, EX Series, MX Series with Firmware below v39
2(default)	DYNAMIXEL Protocol 2.0	MX-28/64/106 with Firmware v39 or above, X Series, PRO Series

WARNING : To modify the data of Protocol Type(13), use the DYNAMIXEL Wizard 2.0 as R+ Manager 2.0 is not compatible with the Protocol 1.0 products.

NOTE : The protocol 2.0 is more stable and safety for use than Protocol 1.0. Accessing some of the Control Table area might be denied if protocol 1.0 is selected. This manual complies with protocol 2.0. Please refer to the Protocol 1.0 and Protocol 2.0 of e-Manual for more details about the protocol.

NOTE : Please refer to the Protocol Compatibility table for product.

2. 4. 10. Homing Offset(20)

The Home Offset(20) adjusts the home position. The offest value is added to the Present Position(132).

Present Position(132) = Actual Position + Homing Offset(20)

Unit	Value Range
about 0.088 [°]	-1,044,479 ~ 1,044,479 (-255 ~ 255[rev])

NOTE : In case of the Position Control Mode(Joint Mode) that rotates less than 360 degrees, any invalid Homing Offset(20) values will be ignored(valid range : -1,024 ~ 1,024).

WARNING : Even if Drive Mode(10) is set to the Reverse Mode, the sign of Homing Offset(20) value is not reversed.

2. 4. 11. Moving Threshold(24)

The Moving Threshold(24) determines whether the DYNAMIXEL is in motion or not.
When the absolute value of Present Velocity(128) is greater than the Moving Threshold(24), Moving(122) is set to '1'. Otherwise it is cleared to '0'.

Unit	Range	Description
about 0.229 rpm	0 ~ 1,023	All velocity related Data uses the same unit

2. 4. 12. Temperature Limit(31)

The Temperature Limit(31) limits operating temperature of the DYNAMIXEL. When the Present Temperature(146) is greater than the Temperature Limit(31), the **Overheating Error Bit(0x04)** and **Alert Bit(0x80)** in the Hardware Error Status(70) will be set. If Overheating Error Bit(0x04) is configured in the Shutdown(63), Torque Enable(64) will be set to '0' (Torque OFF). See the Shutdown(63) for more detailed information.

Unit	Value Range	Description
About 1°	0 ~ 100	0 ~ 100°

CAUTION : Do not set this value higher than its default. In case that DYNAMIXEL encounters temperature warning alarm (Overheating Error Bit(0x04)), let it cool for 20 minutes or more. Otherwise, it may cause severe damage in operating.

2. 4. 13. Min/Max Voltage Limit(32, 34)

The Min Voltage Limit(32) and Max Voltage Limit(34) determine the maximum and minimum operating voltages.
When the Present Input Voltage(144) indicating the present input voltage to the device exceeds the range of Max Voltage Limit(32) and Min Voltage Limit(34), the Input Voltage error Bit(0x10) in the Hardware Error Status(70) will be set, and the Status Packet will send Alert Bit(0x80) via the Error field.
If Input Voltage Error Bit(0x10) in the Shutdown(63) is set, Torque Enable(64) will be set to '0'(Torque OFF).
For more details, please refer to the Shutdown(63) section.

Unit	Value Range	Description
About 0.1 [V]	95 ~ 160	9.5 ~ 16.0 [V]

2. 4. 14. PWM Limit(36)

The PWM Limit(36) indicates maximum PWM output. Goal PWM(100) can't be configured with any values exceeding PWM Limit(36). PWM Limit(36) is

commonly used in all operating mode as an output limit, therefore decreasing PWM output will result in decreasing torque and velocity. For more details, please refer to the Gain section of each operating modes.

Unit	Range
about 0.113 [%]	0(0 [%]) ~ 885(100 [%])

2. 4. 15. Current Limit(38)

The Current Limit(38) indicates maximum current(torque) output limit. The Goal Current(102) can't be configured with any values exceeding the Current Limit(38). The Current Limit(38) is used in Torque Control Mode and Current-based Position Control Mode, therefore decreasing the Current Limit(38) will result in decreasing torque of DYNAMIXEL. For more details, please refer to the Position PID Gain(80 ~ 84).

Unit	Value Range
about 2.69[mA]	0 ~ 1,193

NOTE : Current Limit(38) could be differ by each DYNAMIXEL so please check the Control Table.

2. 4. 16. Velocity Limit(44)

Velocity Limit(44) indicates the maximum value of Goal Velocity(104). For more details, see Goal Velocity(104).

Unit	Value Range
0.229rpm	0 ~ 1,023

NOTE: The default value of Velocity Limit(44) has been decreased since Firmware V42.

2. 4. 17. Min/Max Position Limit(48, 52)

The Min and Max Position Limit(48, 52) limit maximum and minimum desired positions for Position Control Mode(Joint Mode) within the range of 1 rotation(0 ~ 4,095).
Therefore, Goal Position(116) should be configured within the position limit range.
These values are not used in Extended Position Control Mode and Current-based Position Control Mode.

Unit	Value Range
0.088 [°]	0 ~ 4,095(1 rotation)

NOTE : Max Position Limit(48) and Min Position Limit(52) are only used in Position Control Mode with a single turn.

2. 4. 18. Startup Configuration(60)

The Startup Configuration(60) allows to set up the DYNAMIXEL with specific settings on startup.

Bit	Item	Description
Bit	-	Unused, always '0'

Bit	Item	Description
7(0x80)		
Bit 6(0x40)	-	Unused, always ‘0’
Bit 5(0x20)	-	Unused, always ‘0’
Bit 4(0x10)	-	Unused, always ‘0’
Bit 3(0x08)	-	Unused, always ‘0’
Bit 2(0x04)	-	Unused, always ‘0’
Bit 1(0x02)	RAM Restore	**[0]** Deactivate the RAM area restoration on startup. **[1]** On startup, use the backup data to restore the RAM area.
Bit 0(0x01)	Startup Torque On	**[0]** Torque Off on startup (`Torque Enable(64)` is set to `0`) **[1]** Torque On on startup (`Torque Enable(64)` is set to `1`).

NOTE: Startup Configuration is available from firmware **V45**.

NOTE: For more details about restoring the RAM area, see Restoring RAM Area.

2. 4. 19. Shutdown(63)

The DYNAMIXEL can protect itself by detecting dangerous situations that could occur during the operation. Each Bit is inclusively processed with the ‘OR’ logic, therefore, multiple options can be generated. For instance, when ‘0x05’ (binary : 00000101) is defined in Shutdown(63), DYNAMIXEL can detect both Input Voltage Error(binary : 00000001) and Overheating Error(binary : 00000100). If those errors are detected, Torque Enable(64) is cleared to ‘0’ and the motor’s output becomes 0 [%].

REBOOT is the only method to reset Torque Enable(64) to ‘1’(Torque ON) after the shutdown.

Check Alert Bit(0x80) in an error field of Status Packet or a present status via Hardware Error Status(70). The followings are detectable situations.

Bit	Item	Description
Bit 7	-	Unused, Always ‘0’
Bit 6	-	Unused, Always ‘0’
Bit 5	Overload Error(default)	Detects that persistent load that exceeds maximum output
Bit 4	Electrical Shock Error(default)	Detects electric shock on the circuit or insufficient power to operate the motor
Bit 3	Motor Encoder Error	Detects malfunction of the motor encoder
Bit 2	Overheating Error(default)	Detects that internal temperature exceeds the configured operating temperature

Bit	Item	Description
Bit 1	-	Unused, Always '0'
Bit 0	Input Voltage Error	Detects that input voltage exceeds the configured operating voltage

NOTE :

1. If Shutdown occurs, **LED will flicker every second**. (**Firmware v41 or above**)
2. If Shutdown occurs, **reboot the device**.
   - H/W REBOOT : Turn off and turn on the power again
   - S/W REBOOT : Transmit REBOOT Instruction (For more details, refer to the Reboot section of e-Manual.)

2. 4. 20. Torque Enable(64)

Torque Enable(64) determines Torque ON/OFF. Writing '1' to Torque Enable's address will turn on the Torque and all Data in the EEPROM area will be locked.

Value	Description
0(Default)	Torque Off
1	Torque On and lock EEPROM area

NOTE : Present Position(132) can be reset when Operating Mode(11) and Torque Enable(64) are updated. For more details, please refer to the Homing Offset(20) and Present Position(132).

2. 4. 21. LED(65)

The LED(65) determines LED On or Off.

Bit	Description
0(Default)	Turn OFF the LED
1	Turn ON the LED

NOTE : Check the status of DYNAMIXEL by the counts of flickering LED.

Status	LED Representation
Booting	LED flickers once
Factory Reset	LED flickers 4 times
Alarm	LED flickers
Boot Mode	LED On

2. 4. 22. Status Return Level(68)

The Stuatus Return Level (68) decides how to return Status Packet when DYNAMIXEL receives an Instruction Packet.

Value	Responding Instructions	Description
0	PING Instruction	Returns the Status Packet for PING Instruction only
1	PING Instruction	Returns the Status Packet for PING and READ

Value	Responding Instructions	Description
	READ Instruction	Instruction
2	All Instructions	Returns the Status Packet for all Instructions

NOTE : If the Instruction Packet ID is set to the Broadcast ID(0xFE), Status Packet will not be returned for READ or WRITE Instructions regardless of Stuatus Return Level (68). For more details, please refer to the `Status Packet` section for DYNAMIXEL Protocol 2.0.

2. 4. 23. Registered Instruction(69)

Indicates whether the Write Instruction is registered by Reg Write Instruction

Value	Description
0	No instruction registered by REG_WRITE.
1	Instruction registered by REG_WRITE exists.

NOTE : If ACTION instruction is executed, the Registered Instruction (69) will be changed to 0.

2. 4. 24. Hardware Error Status(70)

The Hardware Error Status(70) indicates hardware error status.

The DYNAMIXEL can protect itself by detecting dangerous situations that could occur during the operation. Each Bit is inclusively processed with the 'OR' logic, therefore, multiple options can be generated. For instance, when '0x05' (binary : 00000101) is defined in Shutdown(63), DYNAMIXEL can detect both Input Voltage Error(binary : 00000001) and Overheating Error(binary : 00000100). If those errors are detected, Torque Enable(64) is cleared to '0' and the motor's output becomes 0 [%].

REBOOT is the only method to reset Torque Enable(64) to '1'(Torque ON) after the shutdown.

Check Alert Bit(0x80) in an error field of Status Packet or a present status via Hardware Error Status(70). The followings are detectable situations.

Bit	Item	Description
Bit 7	-	Unused, Always '0'
Bit 6	-	Unused, Always '0'
Bit 5	Overload Error(default)	Detects that persistent load that exceeds maximum output
Bit 4	Electrical Shock Error(default)	Detects electric shock on the circuit or insufficient power to operate the motor
Bit 3	Motor Encoder Error	Detects malfunction of the motor encoder
Bit 2	Overheating Error(default)	Detects that internal temperature exceeds the configured operating temperature
Bit 1	-	Unused, Always '0'

Bit	Item	Description
Bit 0	Input Voltage Error	Detects that input voltage exceeds the configured operating voltage

NOTE :

1. If Shutdown occurs, **LED will flicker every second**. (**Firmware v41 or above**)
2. If Shutdown occurs, **reboot the device**.
   - H/W REBOOT : Turn off and turn on the power again
   - S/W REBOOT : Transmit REBOOT Instruction (For more details, refer to the Reboot section of e-Manual.)

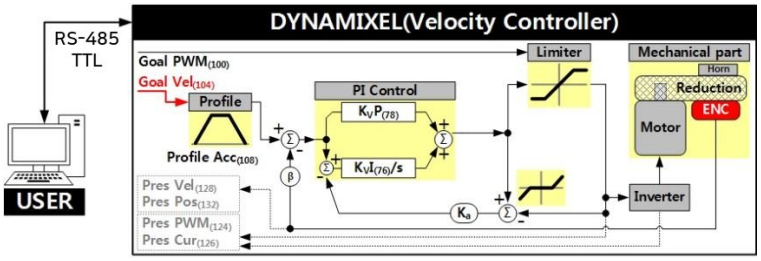
2. 4. 25. Velocity PI Gain(76, 78)

The Velocity PI Gains(76, 78) indicate gains of Velocity Control Mode. Velocity P Gain of DYNAMIXEL's internal controller is abbreviated to K_VP and that of the Control Table is abbreviated to $K_VP_{(TBL)}$.

	Controller Gain	Conversion Equations	Range	Description
Velocity I Gain(76)	K_VI	$K_VI = K_VI_{(TBL)} / 65,536$	0 ~ 16,383	I Gain
Velocity P Gain(78)	K_VP	$K_VP = K_VP_{(TBL)} / 128$	0 ~ 16,383	P Gain

Below figure is a block diagram describing the velocity controller in Velocity Control Mode. When the instruction transmitted from the user is received by DYNAMIXEL, it takes following steps until driving the horn.

1. An Instruction from the user is transmitted via DYNAMIXEL bus, then registered to Goal Velocity(104).
2. Goal Velocity(104) is converted to desired velocity trajectory by Profile Acceleration(108).
3. The desired velocity trajectory is stored at Velocity Trajectory(136).
4. PI controller calculates PWM output for the motor based on the desired velocity trajectory.
5. Goal PWM(100) sets a limit on the calculated PWM output and decides the final PWM value.
6. The final PWM value is applied to the motor through an Inverter, and the horn of DYNAMIXEL is driven.
7. Results are stored at Present Position(132), Present Velocity(128), Present PWM(124) and Present Current(126).



NOTE : K_a stands for Anti-windup Gain and β is a conversion coefficient of position and velocity that cannot be modified by users. For more details about the PID controller, please refer to the PID Controller at wikipedia.

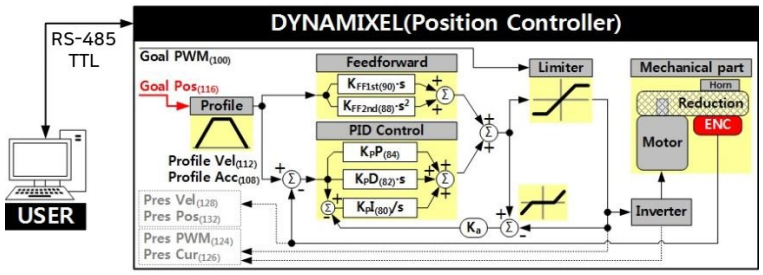
2. 4. 26. Position PID Gain(80, 82, 84), Feedforward 1st/2nd Gains(88, 90)

These Gains are used in Position Control Mode and Extended Position Control Mode. Position P Gain of DYNAMIXEL's internal controller is abbreviated to K_PP and that of the Control Table is abbreviated to $K_PP_{(TBL)}$.

	Controller Gain	Conversion Equations	Range	Description
Position D Gain(80)	K_PD	$K_PD = K_PD_{(TBL)} / 16$	0 ~ 16,383	D Gain
Position I Gain(82)	K_PI	$K_PI = K_PI_{(TBL)} / 65,536$	0 ~ 16,383	I Gain
Position P Gain(84)	K_PP	$K_PP = K_PP_{(TBL)} / 128$	0 ~ 16,383	P Gain
Feedforward 2nd Gain(88)	K_{FF2nd}	$K_{FF2nd(TBL)} / 4$	0 ~ 16,383	Feedforward Acceleration Gain
Feedforward 1st Gain(90)	K_{FF1st}	$K_{FF1st(TBL)} / 4$	0 ~ 16,383	Feedforward Velocity Gain

Below figure is a block diagram describing the position controller in Position Control Mode and Extended Position Control Mode. When the instruction from the user is received by DYNAMIXEL, it takes following steps until driving the horn.

1. An Instruction from the user is transmitted via DYNAMIXEL bus, then registered to Goal Position(116).
2. Goal Position(116) is converted to desired position trajectory and desired velocity trajectory by Profile Velocity(112) and Profile Acceleration(108).
3. The desired position trajectory and desired velocity trajectory is stored at Position Trajectory(140) and Velocity Trajectory(136) respectively.
4. Feedforward and PID controller calculate PWM output for the motor based on desired trajectories.
5. Goal PWM(100) sets a limit on the calculated PWM output and decides the final PWM value.
6. The final PWM value is applied to the motor through an Inverter, and the horn of DYNAMIXEL is driven.
7. Results are stored at Present Position(132), Present Velocity(128), Present PWM(124) and Present Current(126).



NOTE:

- In case of PWM Control Mode, both PID controller and Feedforward controller are deactivated while Goal PWM(100) value is directly controlling the motor through an inverter. In this manner, users can directly control the supplying voltage to the motor.

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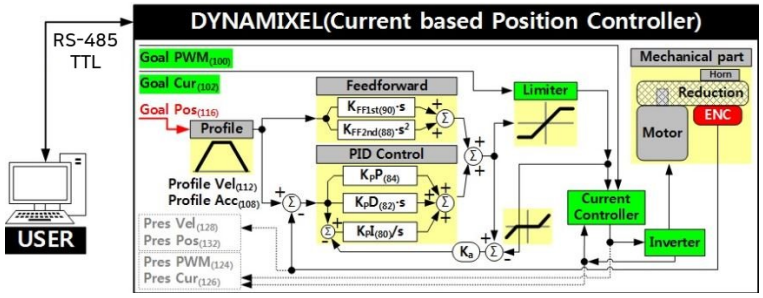
- K_a is an Anti-windup Gain that cannot be modified by users.
  For more details about the PID controller and Feedforward controller, please refer to the PID Controller and Feed Forward.

Below figure is a block diagram describing the current-based position controller in Current-based Position Control Mode. As Current-based Position Control Mode is quite similar to Position Control Mode, differences will be focused in the following steps. The differences are highlighted with a green marker in the block diagram as well.

1. Feedforward and PID controller calculates desired current based on desired trajectory.
2. Goal Current(102) decides the final desired current by setting a limit on the calculated desired current.
3. Current controller calculates PWM output for the motor based on the final desired current.
4. Goal PWM(100) sets a limit on the calculated PWM output and decides the final PWM value.
5. The final PWM value is applied to the motor through an Inverter, and the horn of DYNAMIXEL is driven.
6. Results are stored at Present Position(132), Present Velocity(128), Present PWM(124) and Present Current(126).



NOTE : K_a is an Anti-windup Gain that cannot be modified by users.

2. 4. 27. Bus Watchdog(98)

The Bus Watchdog(98) is a safety device (Fail-safe) to stops the DYNAMIXEL if the communication between the controller and DYNAMIXEL communication (RS485, TTL) is disconnected due to an unspecified error. The communication is defined as all the Instruction Packet in the DYNAMIXEL Protocol.

	Values	Description
Range	0	Deactivate Bus Watchdog Function, Clear Bus Watchdog Error
Range	1 ~ 127	Activate Bus Watchdog (Unit: 20 [msec])
Range	-1	Bus Watchdog Error Status

The Bus Watchdog function monitors the communication interval (time) between the controller and DYNAMIXEL when Torque Enable(64) is '1'(Torque ON).
If the measured communication interval (time) is larger than the set value of Bus Watchdog(98), the DYNAMIXEL will stop. Bus Watchdog(98) will be changed to '-1' (Bus Watchdog Error). If the Bus Watchdog Error screen appears, the Goal Value (Goal PWM(100), Goal Current(102), Goal

Velocity(104), Goal Position(116)) will be changed to read-only-access. Therefore, if a new value is written to the Goal Value, the Status Packet will send the Data Range Error via its Error field. If the value of Bus Watchdog(98) is changed to '0', Bus Watchdog Error will be cleared.

NOTE : For details of the Data Range Error, please refer to the Protocol 2.0

NOTE: Bus Watchdog (98) is available from firmware v38.

2. 4. 27. 1. Bus Watchdog (98) Example

The following is the example of the operation of the Bus Watchdog function.

1. After setting the Operating Mode(11) to speed control mode, change the Torque Enable(64) to '1'.
2. If '50' is written in the Goal Velocity(104), the DYNAMIXEL will rotate in CCW direction.
3. Change the value of Bus Watchdog(98) to '100' (2,000 [ms]). (Activate Bus Watchdog Function)
4. If no instruction packet is received for 2,000 [ms], the DYNAMIXEL will stop. When it stops, the Profile Acceleration(108) and Profile Velocity(112) are applied as '0'.
5. The value of Bus Watchdog(98) changes to '-1' (Bus Watchdog Error). At this time, the access to the Goal Value will be changed to read-only.
6. If '150' is written to the Goal Velocity(104), the Data Range Error will be returned via Status Packet.
7. If the value of Bus Watchdog(98) is changed to '0', Bus Watchdog Error will be cleared.
8. If "150" is written in the Goal Velocity(104), the DYNAMIXEL will rotate in CCW direction.

2. 4. 28. Goal PWM(100)

When the Operating Mode(11) is **PWM Control Mode**, both the PID and Feedforward controllers will be deactivated as the Goal PWM(100) value directly controls a motor via an inverter. But on the other Operating Mode(11), the Goal PWM(100) limits PWM value only. Read Position PID Gain(80, 82, 84), Feedforward 1st/2nd Gains(88, 90) or Velocity PI Gain(76, 78) for how Goal PWM (100) works with the gains.

Unit	Range
about 0.113 [%]	-PWM Limit(36) ~ PWM Limit(36)

NOTE: Goal PWM(100) can not exceed PWM Limit(36).

2. 4. 29. Goal Current(102)

Use Goal Current(102) to set a desired current when the Operating Mode(11) is **Torque Control Mode**. Also, the Goal Current(102) can be used to set a limit to current in Current-based Position Control Mode. Note that the Goal Current(102) can not be set larger than the Current Limit(38).

Unit	Value Range
about 2.69[mA]	-Current Limit(38) ~ Current Limit(38)

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NOTE: Goal Current(102) can not exceed Current Limit(38).

NOTE : Applying high current to the motor for long period of time might damage the motor.

2. 4. 30. Goal Velocity(104)

Use the Goal Velocity(104) to set a desired velocity when the Operating Mode(11) is **Velocity Control Mode**.

Note that the Goal Velocity(104) is not used to limit moving velocity.

Unit	Value Range
0.229 rpm	-Velocity Limit(44) ~ Velocity Limit(44)

NOTE: Goal Velocity(104) can not exceed Velocity Limit(44).

NOTE : The maximum velocity and maximum torque of DYNAMIXEL is affected by supplying voltage.
Therefore, if supplying voltage changes, so does the maximum velocity. This manual complies with recommended supply voltage(12[V]).

NOTE : If Profile Acceleration(108) and Goal Velocity(104) are modified simultaneously, modified Profile Acceleration(108) will be used to process Goal Velocity(104).

2. 4. 31. Profile Acceleration(108)

When the Drive Mode(10) is **Velocity-based Profile**, Profile Acceleration(108) sets acceleration of the Profile.
When the Drive Mode(10) is **Time-based Profile**, Profile Acceleration(108) sets acceleration time of the Profile.
The Profile Acceleration(108) is to be applied in all control mode except **Current Control Mode** or **PWM Control Mode** on the Operating Mode(11).

For more detailed information, see What is the Profile

Velocity-based Profile	Values	Description
Unit	214.577 [rev/min^2]	Sets acceleration of the Profile
Range	0 ~ 32767	'0' represents an infinite acceleration

Time-based Profile	Values	Description
Unit	1 [msec]	Sets accelerating time of the Profile
Range	0 ~ 32737	'0' represents an infinite acceleration time('0 [msec]'). Profile Acceleration(108, Acceleration time) will not exceed 50% of Profile Velocity (112, the time span to reach the velocity of the Profile) value.

NOTE : Time-based Profile is available from the firmware version 42.

2. 4. 32. Profile Velocity(112)

When the Drive Mode(10) is **Velocity-based Profile**, Profile Velocity(112) sets the maximum velocity of the Profile.
When the Drive Mode(10) is **Time-based Profile**, Profile Velocity(112) sets the time span to reach the velocity (the total time) of the Profile.
Be aware that the Profile Velocity(112) is to be only applied to **Position Control Mode**, **Extended Position Control Mode** or **Current-based Position Control Mode** on the Operating Mode(11).

For more detailed information, see What is the Profile.

NOTE: Velocity Control Mode only uses Profile Acceleration(108) without the Profile Velocity(112).

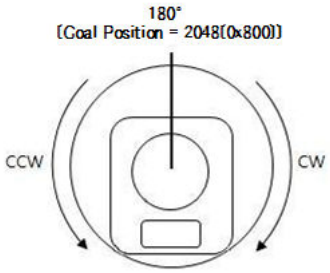
Velocity-based Profile	Values	Description
Unit	0.229 [rev/min]	Sets velocity of the Profile
Range	0 ~ 32767	'0' represents an infinite velocity

Time-based Profile	Values	Description
Unit	1 [msec]	Sets the time span for the Profile
Range	0 ~ 32737	'0' represents an infinite velocity. Profile Acceleration(108, Acceleration time) will not exceed 50% of Profile Velocity (112, the time span to reach the velocity of the Profile) value.

NOTE : Time-based Profile is available from the firmware V42.

2. 4. 33. Goal Position(116)

The Goal Position(116) sets desired position. From the front view of DYNAMIXEL, CCW is an increasing direction, whereas CW is a decreasing direction. The way of reaching the Goal Position(116) can differ by the Profile provided by DYNAMIXEL. See the What is the Profile for more details.



Mode	Values	Description
Position Control Mode	Min Position Limit(52) ~ Max Position Limit(48)	Initial Value : 0 ~ 4,095
Extended Position Control Mode	-1,048,575 ~ 1,048,575	-256[rev] ~ 256[rev]
Current-based Position Control Mode	-1,048,575 ~ 1,048,575	-256[rev] ~ 256[rev]

Unit	Description
0.088 [deg/pulse]	1[rev] : 0 ~ 4,095

NOTE : The Profile Velocity(112) and the Profile Acceleration(108) are applied in below cases.

- When the Operating Mode(11) is **Position Control Mode**, the Profile Velocity(112) and the Profile Acceleration(108) are used to create a new profile if the Goal Position(116) is updated.
- When the Operating Mode(11) is **Velocity Control Mode**, the Profile Acceleration(108) is used to create a new profile if Goal Velocity(104) is updated.

NOTE : When turning off the power supply or changing Operation Mode on Extended Position Control Mode, the value of Present Position is reset to the absolute position value of single turn .

NOTE : Present Position(132) represents 4 byte continuous range from -2,147,483,648 to 2,147,483,647 when Torque is turned off regardless of Operating Mode(11).
However, Present Position(132) will be reset to an absolute position value within one full rotation in following cases. Note that Present Position(132) value that is reset to an absolute value can differ by the set Homing Offset(20) value.:

1. When Operating Mode(11) switches to **Position Control Mode**, Present Position(132) will be reset to an absolute position value within a full rotation.
2. When torque is turned on in **Position Control Mode**, Present Position(132) will be reset to an absolute position value within one full rotation.
3. Turning on the power supply or using Reboot Instruction.

2. 4. 34. Realtime Tick(120)

The Realtime Tick(120) indicates DYNAMIXEL's time.

Unit	Value Range	Description
1 ms	0 ~ 32,767	The value resets to '0' when it exceeds 32,767

2. 4. 35. Moving(122)

The Moving(122) indicates whether DYNAMIXEL is in motion or not.
If absolute value of Present Velocity(128) is greater than Moving Threshold(24), Moving(122) is set to '1'.
Otherwise, it will be cleared to '0'.
However,the Moving(122) will always be set to '1' regardless of Present Velocity(128) while Profile is in progress with Goal Position(116) instruction.

Value	Description
0	Movement is not detected
1	Movement is detected, or Profile is in progress(Goal Position(116) instruction is being processed)

2. 4. 36. Moving Status(123)

The Moving Status(123), one byte data, provides additional information about the movement.
Following Error(0x08) and In-Position(0x01) are available under **Position**

Control Mode, **Extended Position Control Mode**, **Current-based Position Control Mode**.

For more details about the mode, see the Operating Mode(11).

Bit	Value	Information	Description
Bit 7	X	-	Reserved
Bit 6	X	-	Reserved
Bit 4 Bit 5	11 10 01 00	Velocity Profile	11 : Trapezoidal Profile 10 : Triangular Profile 01 : Rectangular Profile 00 : Profile not used(Step)
Bit 3	0 or 1	Following Error	DYNAMIXEL is following the desired position trajectory 0 : Following 1 : Not following
Bit 2	X	-	Reserved
Bit 1	0 or 1	Profile Ongoing	Profile is in progress with Goal Position(116) instruction 0 : Profile completed 1 : Profile in progress
Bit 0	0 or 1	In-Position	DYNAMIXEL has arrived to the desired position 0 : Not arrived 1 : Arrived

NOTE : The Triangular velocity profile is configured when Rectangular velocity profile cannot reach to the Profile Velocity(112).

NOTE : In-Position bit will be set when the positional deviation is smaller than a predefined value under Position related control modes.

2. 4. 37. Present PWM(124)

The Present PWM(124) value indicates current PWM. For more details, please refer to the Goal PWM(100).

2. 4. 38. Present Current(126)

This value indicates current Current. For more details, please refer to the Goal Current(102).

2. 4. 39. Present Velocity(128)

This value indicates current Velocity. For more details, please refer to the Goal Velocity(104).

2. 4. 40. Present Position(132)

The Present Position(132) indicates present Position. For more details, see the Goal Position(116).

NOTE : Present Position(132) represents 4 byte continuous range from -2,147,483,648 to 2,147,483,647 when Torque is turned off regardless of Operating Mode(11).
However, Present Position(132) will be reset to an absolute position value within one full rotation in following cases. Note that Present Position(132) value that is reset to an absolute value can differ by the set Homing Offset(20) value.:

1. When Operating Mode(11) switches to **Position Control Mode**, Present Position(132) will be reset to an absolute position value within a full rotation.

2. When torque is turned on in **Position Control Mode**, Present Position(132) will be reset to an absolute position value within one full rotation.
3. Turning on the power supply or using Reboot Instruction.

2. 4. 41. Velocity Trajectory(136)

The Velocity Trajectory(136) is a desired velocity trajectory created by Profile. Operating method can be changed based on its Operating Mode(11). For more details, see the What is the Profile.

1. **Velocity Control Mode** : When Profile reaches to the endpoint, The Velocity Trajectory(136) becomes equal to the Goal Velocity(104).
2. **Position Control Mode, Extended Position Control Mode, Current-based Position Control Mode** : Velocity Trajectory is used to create Position Trajectory(140). When Profile reaches to an endpoint, Velocity Trajectory(136) is cleared to '0'.

2. 4. 42. Position Trajectory(140)

The Position Trajectory(140) is a desired position trajectory created by the Profile.
The Position Trajectory(140) is used only when the Operating Mode(11) is **the Position Control Mode**, **Extended Position Control Mode** or **Current-based Position Control Mode**.
For more details, see What is the Profile.

2. 4. 43. Present Input Voltage(144)

The Present Input Voltage(144) indicates present voltage that is being supplied. For more details, see the Max/Min Voltage Limit(32, 34).

2. 4. 44. Present Temperature(146)

The Present Temperature(146) indicates internal temperature of DYNAMIXEL. For more details, see the Temperature Limit(31).

2. 4. 45. Backup Ready(147)

The value in this address indicates whether the backup of the control table exists after sending the Control Table Backup Packet.

Value	Description
0	The backup data doesn't exist.
1	A saved backup data exists.

NOTE
Backup Ready is available from firmware **V45**.
See Backup and Restore for more details.

2. 4. 46. Indirect Address, Indirect Data

Indirect Address and Indirect Data are useful when accessing two remote addresses in the Control Table as sequential addresses. - Sequential addresses increase Instruction Packet efficiency. Addresses that can be defined as Indirect Address is limited to RAM area(Address 64 ~ 661).

- If specific address is allocated to Indirect Address, Indirect Address inherits features and properties of the Data from the specific Address.

- Property includes Size(Byte length), value range, and Access property(Read Only, Read/Write).
- For instance, allocating 65(Address of LED) to Indirect Address 1(168), Indirect Data 1(224) can perform exactly same as LED(65).

Indirect Address Range	Description
64 ~ 661	EEPROM address can't be assigned to Indirect Address

2. 4. 46. 1. Indirect Address and Indirect Data Examples

`Example 1` Allocating Size 1 byte LED(65) to Indirect Data 1(224).

1. Indirect Address 1(168) : change the value to '65' which is the address of LED.
2. Set Indirect Data 1(224) to '1' : LED(65) also becomes '1' and LED is turned on.
3. Set Indirect Data 1(224) to '0' : LED(65) also becomes '0' and LED is turned off.

`Example 2` Allocating Size 4 byte Goal Position(116) to Indirect Data 2(225), 4 sequential bytes have to be allocated.

1. Indirect Address 2(170) : change the value to '116' which is the first address of Goal Position.
2. Indirect Address 3(172) : change the value to '117' which is the second address of Goal Position.
3. Indirect Address 4(174) : change the value to '118' which is the third address of Goal Position.
4. Indirect Address 5(176) : change the value to '119' which is the fourth address of Goal Position.
5. Set 4 byte value '1,024' to Indirect Data 2 : Goal Position(116) also becomes '1024' and DYNAMIXEL moves.

NOTE : In order to allocate Data in the Control Table longer than 2[byte] to Indirect Address, all address must be allocated to Indirect Address like the above Example 2.

NOTE : Indirect Address 29 ~ 56 and Indirect Data 29 ~ 56 can only be accessed with Protocol 2.0.

3. How to Assemble

Describes how to assemble the horn (Normal / Idler) and Frame (for Hinge / Side) of DYNAMIXEL, and how to replace the gears in DYNAMIXEL.

3. 1. Horn Assembly

3. 1. 1. Normal Horn Assembly

A normal horn is the standard horn for the DYNAMIXEL X540 series. The normal horn can be assembled to the output shaft wheel gear of a front case of DYNAMIXEL, and it can be used to connect DYNAMIXEL with frames.

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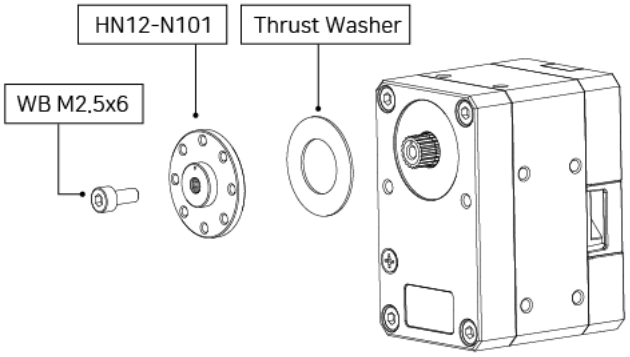
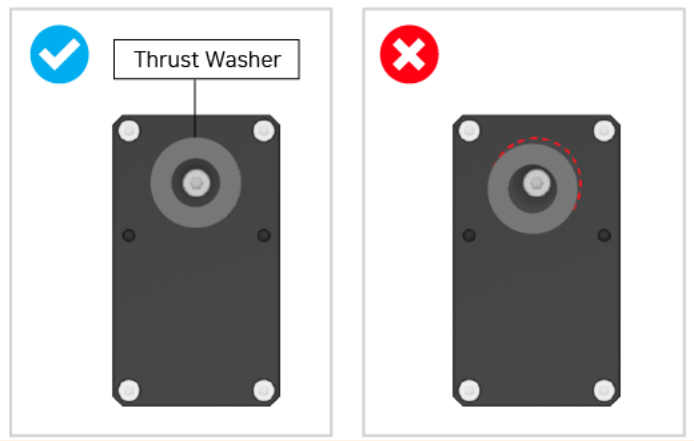
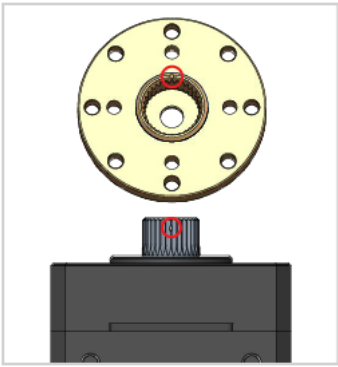


WARNNING: Be sure to align the thrust washer properly with the output shaft. Otherwise, the thrust washer can be damaged by the assembled horn.



NOTE: Note that the position of align mark of the horn should be lined to the position of the align mark of the output shaft in assembly.

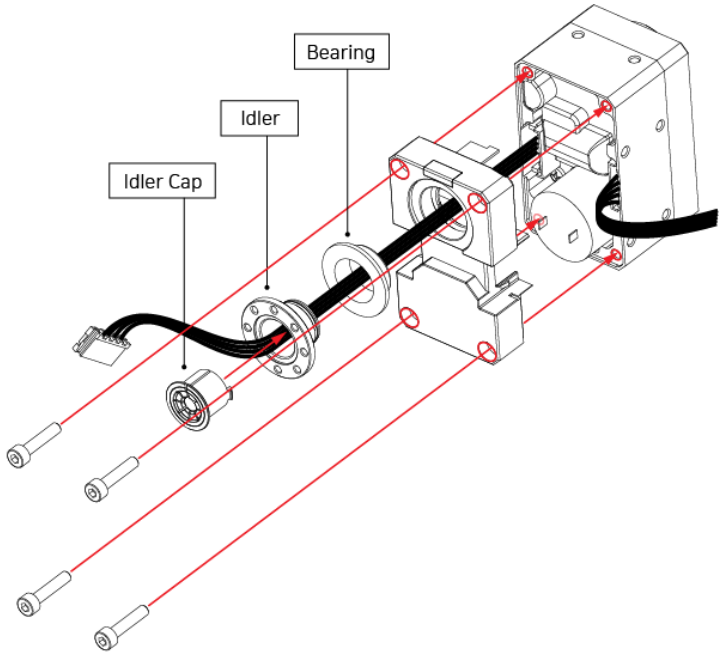


3. 1. 2. Idler Horn Assembly

The idler horn can be used for an hinge frame assembly with the DYNAMIXEL normal horn.

Additionally, utilizing the hole of the idler horn provides a neat cable wiring solution. Click the note below for how-to.

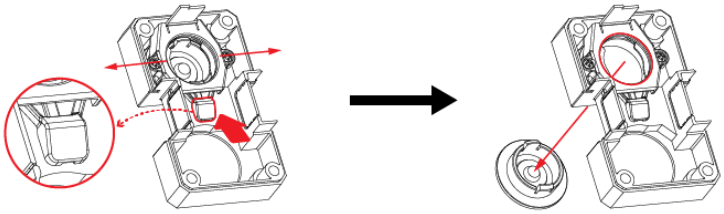
XM430-W350-T/R



Find Cable Wiring Throuh a Back Case Here

3. 1. 2. 1. Idler Horn Disassembly

To disassemble the attached idler horn, push the button located on the reverse side of a back case and pull a hook to disconnect.

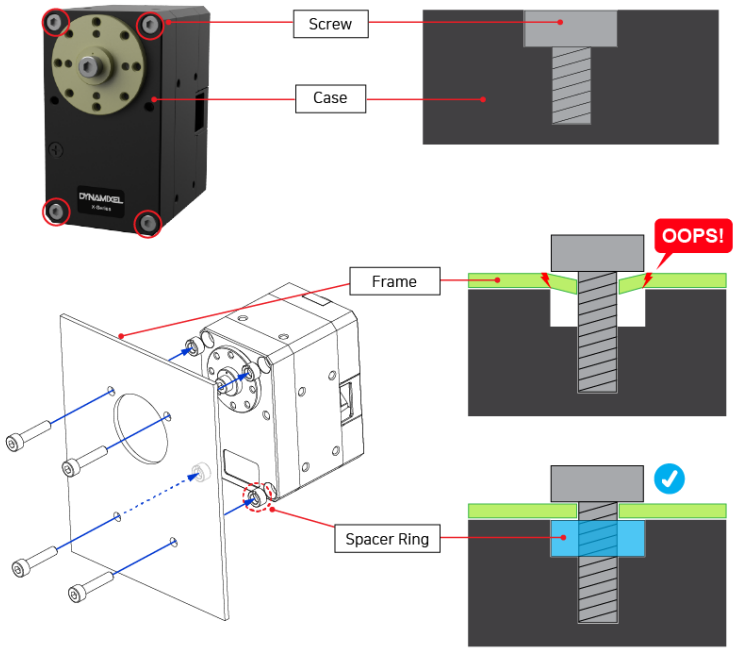


3. 2. Frame Assembly

3. 2. 1. How To Use Spacer Ring

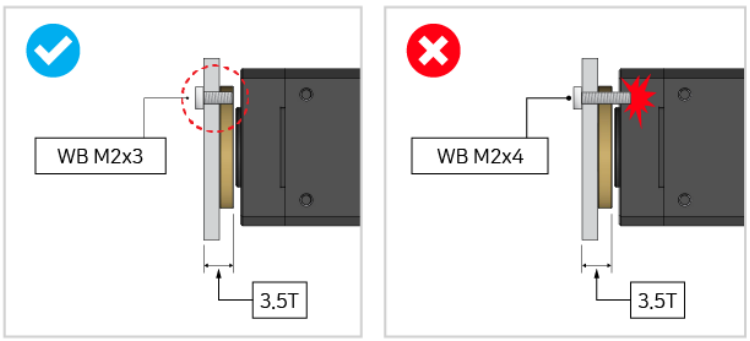
To protect your assembled frame, use the spacer rings which fills the gap between assembled frame and DYNAMIXEL case.

XM430-W350-T/R



3. 2. 2. Precaution of Frame and Horn Assembly

Be sure to use screws in proper length by considering the depth of the thickness of frame plus thickness (T) of DYNAMIXEL horn.
If the length of screw is longer than the depth of them, it may cause a damage to the DYNAMIXEL during work.

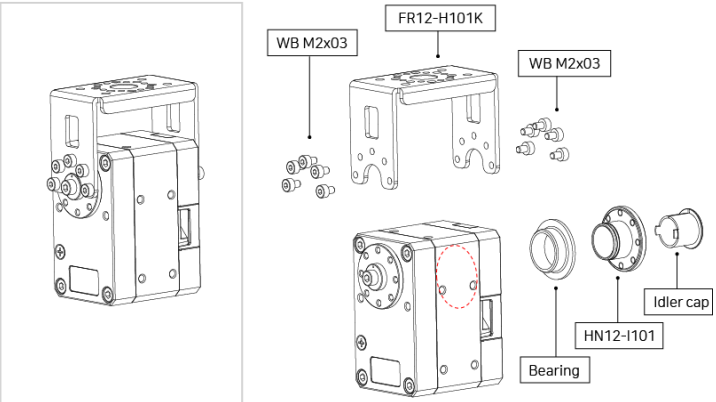


NOTE: Find useful data (Size, Depth and etc) for your horn or frame assembly from Drawings.

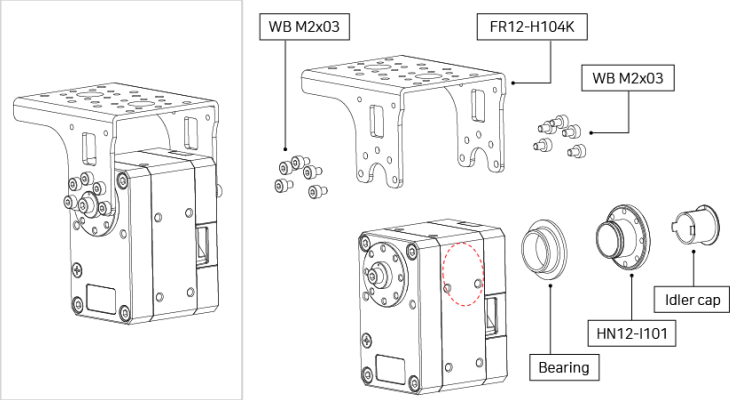
3. 2. 3. Hinge Frame Assembly

A hinge frame can be assembled to the output shaft wheel gear of DYNAMIXEL.

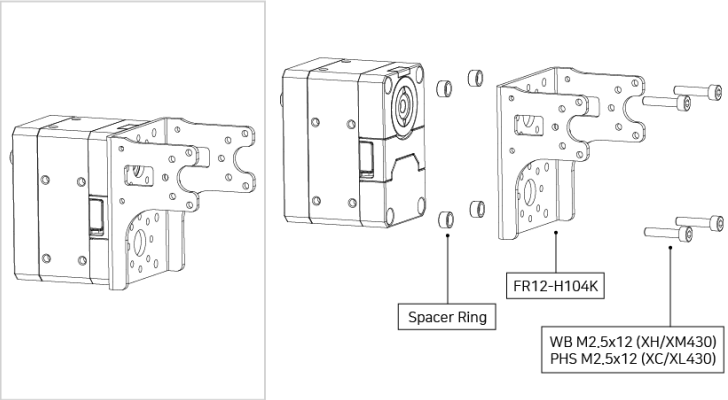
XM430-W350-T/R



FR12-H101K

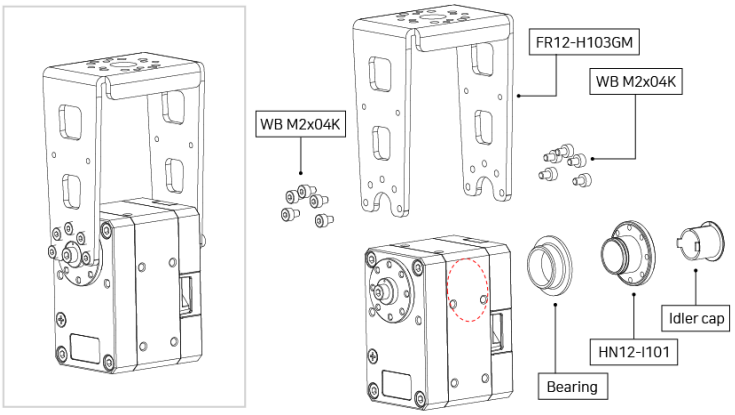


FR12-H104K



FR12-H104K (Back Mount, compatible with DYNAMIXEL XL & XC Series)

XM430-W350-T/R



FR12-H103GM

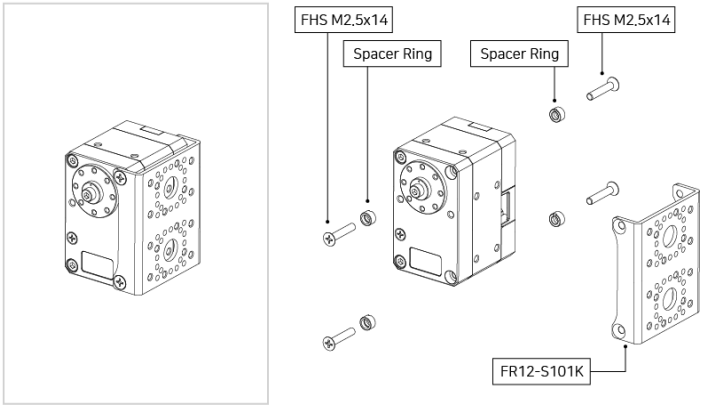
NOTE: Find useful data (Size, Depth and etc) for your horn or frame assembly from Drawings.

NOTE: In hinge assembly, the idler horn should be assembled to the back case of DYNAMIXEL. See Idler Horn Assembly.

WARNNING: In hinge assembly, make sure to use the proper screw. See Precaution of Frame and Horn Assembly.

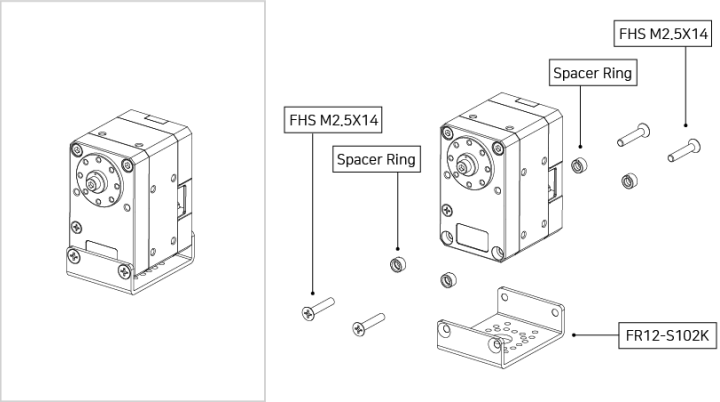
3. 2. 4. Side Frame Assembly

A side frame can be assembled to the side and bottom of case of DYNAMIXEL.



FR12-S101K

XM430-W350-T/R

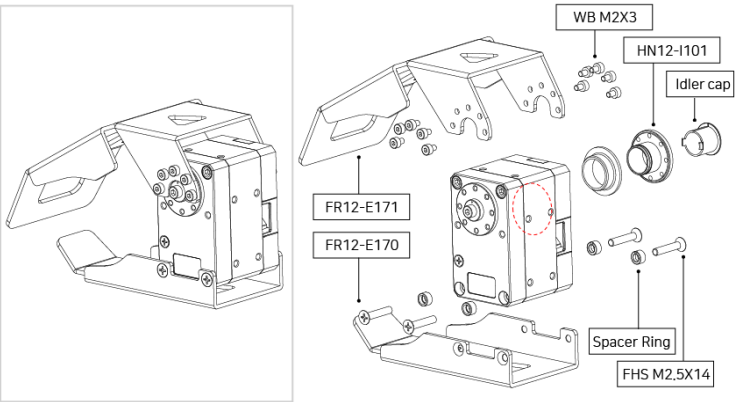


FR12-S102K

NOTE: Find useful data (Size, Depth and etc) for your horn or frame assembly from Drawings.

NOTE: Use spacer rings to protect assembled frame. See How To Use Spacer Ring.

3. 2. 5. Gripper Assembly



FR12-G101GM (FR12-E170 + FR12-E171)

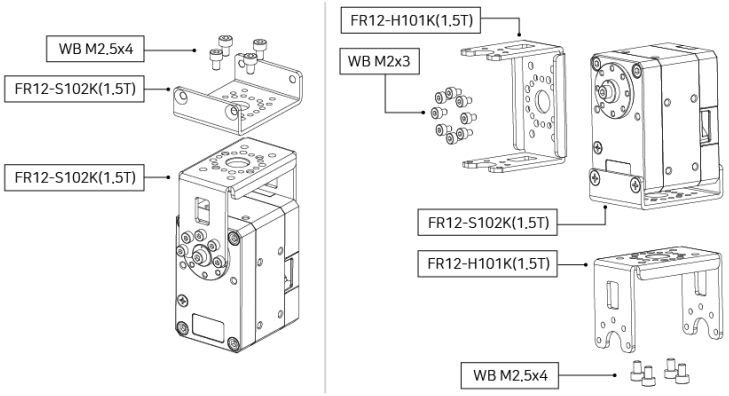
NOTE: Find useful data (Size, Depth and etc) for your horn or frame assembly from Drawings.

NOTE: Use spacer rings to protect assembled frame. See How To Use Spacer Ring.

3. 2. 6. Frame Combination

Make various combination with hinge and side frames.

XM430-W350-T/R

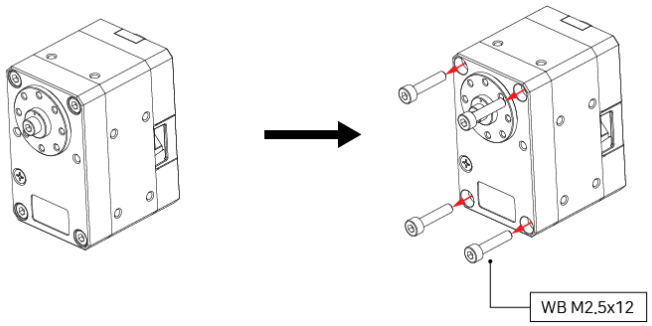


3. 2. 7. Custom Frame Assembly

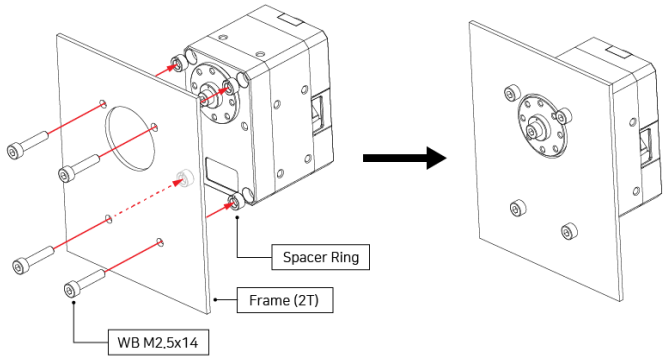
If you make custom frames for your application, see the next assembly example.

3. 2. 7. 1. Front (Wrench Bolt)

1. Step 1



2. Step 2



NOTE: Note that the frame in the image is not for sale.

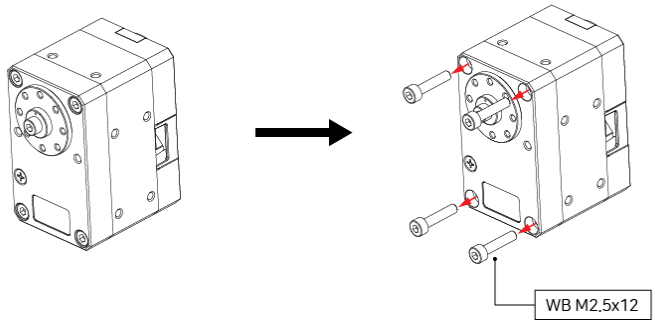
NOTE: Use spacer rings to protect assembled frame. See How To Use Spacer Ring.

XM430-W350-T/R

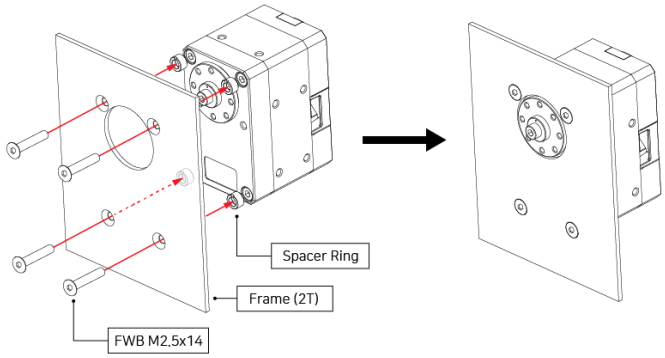
NOTE: Find useful data (Size, Depth and etc) for your horn or frame assembly from Drawings.

3. 2. 7. 2. Front (Flat Head Wrench Bolt)

1. Step 1



2. Step 2



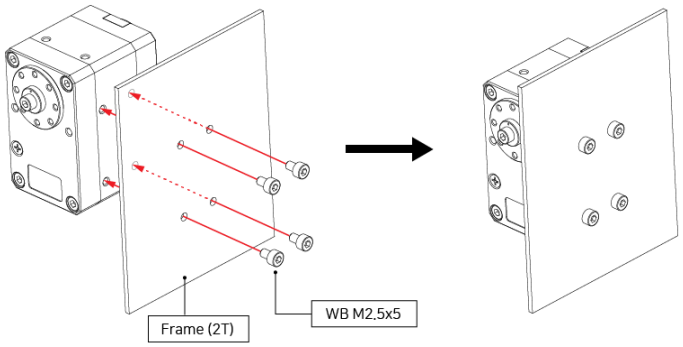
NOTE: Note that the frame in the image is not for sale.

NOTE: Use spacer rings to protect assembled frame. See How To Use Spacer Ring.

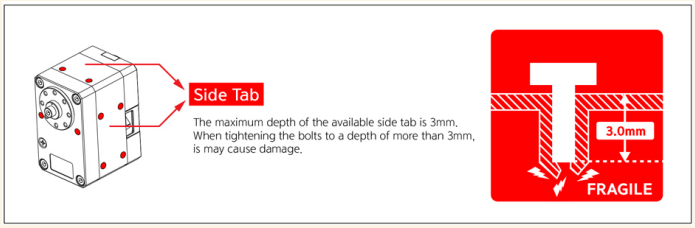
NOTE: Find useful data (Size, Depth and etc) for your horn or frame assembly from Drawings.

3. 2. 7. 3. Side

XM430-W350-T/R



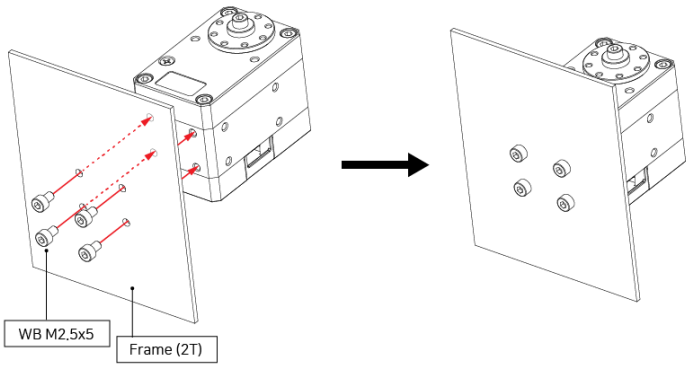
WARNNING: Be sure to use the proper length of screws when assembling a frame to the side tab.



NOTE: Note that the frame in the image is not for sale.

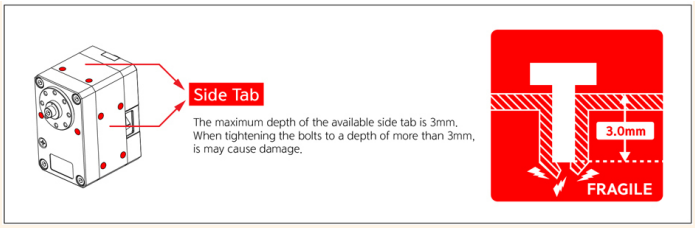
NOTE: Find useful data (Size, Depth and etc) for your horn or frame assembly from Drawings.

3. 2. 7. 4. Bottom



WARNNING: Be sure to use the proper length of screws when assembling a frame to the side tab.

XM430-W350-T/R



NOTE: Note that the frame in the image is not for sale.

NOTE: Use spacer rings to protect assembled frame. See How To Use Spacer Ring.

NOTE: Find useful data (Size, Depth and etc) for your horn or frame assembly from Drawings.

3. 3. Gear Replacement

When gears inside DYNAMIXEL are damaged or worn out, replace the gears in DYNAMIXEL to maintain the good condition.

See the following video on how to replace the gears properly.

Gear Replacement Procedure for DYNAMIXEL XH430 & XM430

3. 3. 1. DYNAMIXEL Calibration

Calibrate the DYNAMIXEL after the gear replacement to arrange the gears in the right position.

See the following video on how to calibrate the DYNAMIXEL properly using software.

XM430-W350-T/R

How to calibrate the DYNAMIXEL XH430 & XM430

NOTE:

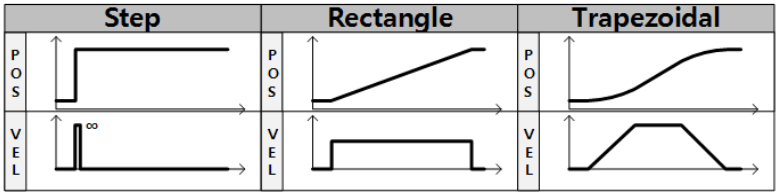
- As the USB2Dynamixel has been discontinued, a U2D2 is required to comunicate with DYNAMIXEL via PC using the software in the video.
- Alternatively, you can calibrate the DYNAMIXEL (X / MX only) using the DYNAMIXEL Wizard 2.0 instead of using the R+ Manager 2.0 used in the video.

4. Reference

NOTE
Compatibility Guide
Harness Compatibility

4. 1. What is the Profile

The Profile is an acceleration/deceleration control method to reduce vibration, noise and load of the motor by controlling dramatically changing velocity and acceleration.
It is also called Velocity Profile as it controls acceleration and deceleration based on velocity.
DYNAMIXEL provides 3 different types of Profile. The following explains 3 Profiles.
Profiles are usually selected by the combination of Profile Velocity(112) and Profile Acceleration(108).



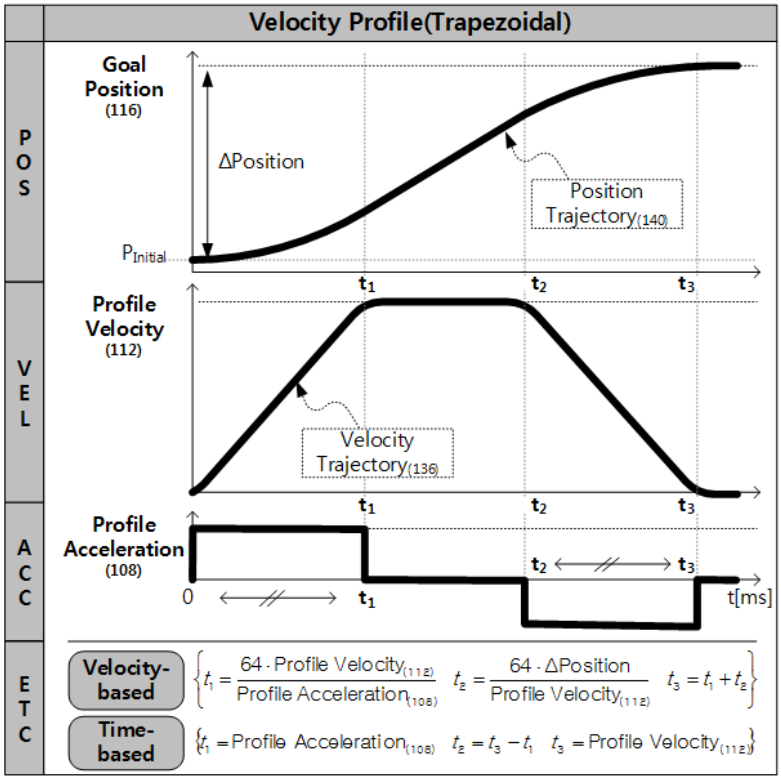
When given Goal Position(116), DYNAMIXEL's profile creates desired velocity trajectory based on present velocity(initial velocity of the Profile).
When DYNAMIXEL receives updated desired position from a new Goal Position(116) while it is moving toward the previous Goal Position(116), velocity smoothly varies for the new desired velocity trajectory.
Maintaining velocity continuity while updating desired velocity trajectory is called Velocity Override.
For a simple calculation, let's assume that the initial velocity of the Profile is '0'.

XM430-W350-T/R

The following explains how Profile processes Goal Position(116) instruction in Position Control mode, Extended Position Control Mode, Current-based Position Control Mode.

1. An Instruction from the user is transmitted via DYNAMIXEL bus, then registered to Goal Position(116) (If Velocity-based Profile is selected).
2. Acceleration time(t1) is calculated from Profile Velocity(112) and Profile Acceleration(108).
3. Types of Profile is decided based on Profile Velocity(112), Profile Acceleration(108) and total travel distance(ΔPos, the distance difference between desired position and present position).
4. Selected Profile type is stored at Moving Status(123).
5. DYNAMIXEL is driven by the calculated desired trajectory from Profile.
6. desired velocity trajectory and desired position trajectory from Profile are stored at Velocity Trajectory(136) and Position Trajectory(140) respectively.

Condition	Types of Profile
$V_{PRFL}(112) = 0$	Profile not used (Step Instruction)
$(V_{PRFL}(112) \neq 0)$ & $(A_{PRF}(108) = 0)$	Rectangular Profile
$(V_{PRFL}(112) \neq 0)$ & $(A_{PRF}(108) \neq 0)$	Trapezoidal Profile



NOTE : Velocity Control Mode only uses Profile Acceleration(108). Step and Trapezoidal Profiles are supported. Velocity Override are supported as well. Acceleration time(t1) can be calculated as below equation.

Velocity-based Profile : t_1 = 64 * {Profile Velocity(112) / Profile Acceleration(108)}

Time-based Profile : t_1 = Profile Acceleration(108)

[redacted]

XM430-W350-T/R

NOTE : If Time-based Profile is selected, Profile Velocity(112) is used to set the time span of the Profile(t_3), while Profile Acceleration(108) sets accelerating time(t_1) in millisecond[ms]. Profile Acceleration(108) will not exceed 50% of Profile Velocity(112) value.

4. 2. Certifications

Please inquire us for information regarding unlisted certifications.

4. 2. 1. FCC

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

WARNING
Any changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment.

4. 3. Quick Start

4. 3. 1. Prerequisites

- Power supply to DYNAMIXEL(12V SMPS / Controllers, compatible with DYNAMIXEL or LB-020 battery)
  - See Compatibility Table
- PC with Windows, Linux or MacOS.
- Connection between PC and DYNAMIXEL (U2D2, USB2Dynamixel)
- Compatible Software with DYNAMIXEL

WARNING:

- USB2Dynamixel has been discontinued.
- Some software may not support OS which you use. Be sure to read e-Manual of software you use to check the supported OS for right use of software.

NOTE:

- U2D2 is a small size USB communication converter that enables to control and operate DYNAMIXEL with PC.
- U2D2 Power Hub which combines with U2D2 supplies a variety external power source with a stable power supply to DYNAMIXEL.

4. 3. 2. Compatible Software with DYNAMIXEL

You can use exclusive software for DYNAMIXEL. See the software compatibility on the next table and choose a desired software for your project.

XM430-W350-T/R

Model	AX Series	DX Series	RX Series	EX Series	MX Series	X-Series	PRO Series	P Series
R+ Manager 2.0	X	X	X	X	O	O	O	O
DYNAMIXEL Wizard	O	X	X	O	O	X (XL320 can be used)	O	X
DYNAMIXEL Wizard 2.0	O	O	O	O	O	O	O	O
DYNAMIXEL SDK	O	O	O	O	O	O	O	O
DYNAMIXEL Workbench	O	O	O	O	O	O	O	O

NOTE: You can also use more variety of software. For more information, see the following to check software provided by ROBOTIS.

- DYNAMIXEL to software Compatibility Table
- Controller to software Compatibility Table

4. 3. 2. 1. R+ Manager

R+ Manager is used to handle devices used by a robot. Major functions of this program are as follows.

- Manage controller firmware. (Update and Restore)
- Inspect the status of the controller and peripheral devices. (Test)
- Set the required modes. (Settings)

NOTE: R+ Manager 2.0 or DYNAMIXEL Wizard 2.0 provides diverse features compared to R+ Manager.

4. 3. 2. 2. R+ Manager 2.0

The R+ Manager 2.0 manages a controller and DYNAMIXEL devices that comprise the robot. By connecting the product, you can update the product to the latest version and test Control Table. The functions that were previously provided in RoboPlus Manager 1.0 and Wizard 1.0 have been combined in RoboPlus Manager 2.0.

WARNING: R+ Manager 2.0 is not compatible with DYNAMIXEL using protocol 1.0.
DYNAMIXEL Wizard 2.0 supports all DYNAMIXEL for Firmware Recovery, Firmware Update, and change data of Control Table of DYNAMIXEL.

4. 3. 2. 3. DYNAMIXEL Wizard 2.0

DYNAMIXEL Wizard 2.0 is an optimized tool for managing DYNAMIXEL's from various operating systems.

The following features are provided with DYNAMIXEL Wizard 2.0.

- DYNAMIXEL Firmware Update
- DYNAMIXEL Diagnosis
- DYNAMIXEL Configuration and Test
- DYNAMIXEL Data Plotting in Real-Time
- Generate & Monitor DYNAMIXEL Packets

XM430-W350-T/R

4. 3. 2. 4. DYNAMIXEL SDK

DYNAMIXEL SDK is a software development kit that provides DYNAMIXEL control functions using packet communication. The API of DYNAMIXEL SDK is designed for DYNAMIXEL actuators and DYNAMIXEL-based platforms. You need to be familiar with C/C++ programming language for right use of the software. This e-Manual provides comprehensive information on ROBOTIS products and applications.

Supported Programming Laguanges and Features:

- C, C++, C#, Python, Java, MATLAB, LabVIEW
- Windows, Mac, Linux.
- ROS
- Arduino

4. 3. 2. 5. DYNAMIXEL Workbench

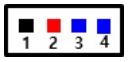
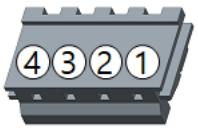
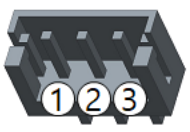
DYNAMIXEL Workbench, based on DYNAMIXEL SDK, is library which provides simple and easier method to use DYNAMIXEL.

Supported Programming Laguanges and Features:

- C++
- Linux, MacOS
- ROS
- Arduino

NOTE: DYNAMIXEL Workbench may provide lack of contents or features compared to DYNAMIXEL SDK. In order to use DYNAMIXEL with sufficient contents, use DYNAMIXEL SDK.

4. 4. Connector Information

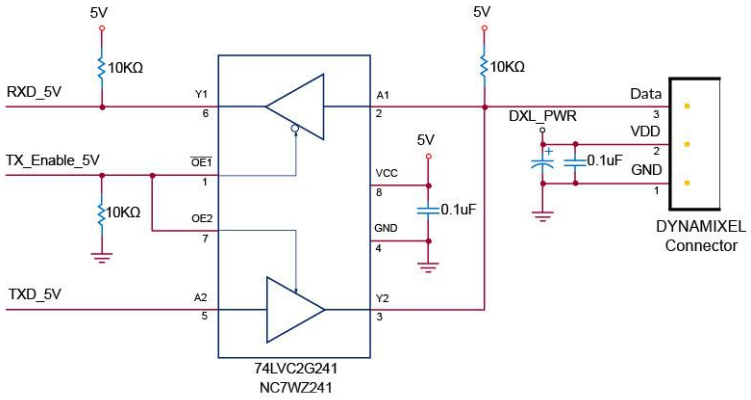
Item	TTL	RS-485
Pinout	1 GND 2 VDD 3 DATA	1 GND 2 VDD 3 DATA+ 4 DATA-
Diagram		
Housing	 JST EHR-03	 JST EHR-04
PCB Header	 JST B3B-EH-A	 JST B4B-EH-A
Crimp Terminal	JST SEH-001T-P0.6	JST SEH-001T-P0.6
Wire Gauge for DYNAMIXEL	21 AWG	21 AWG

4. 5. Communication Circuit

To control the DYNAMIXEL actuators, the main controller needs to convert its UART signals to the half duplex type. The recommended circuit diagram for this is shown below.

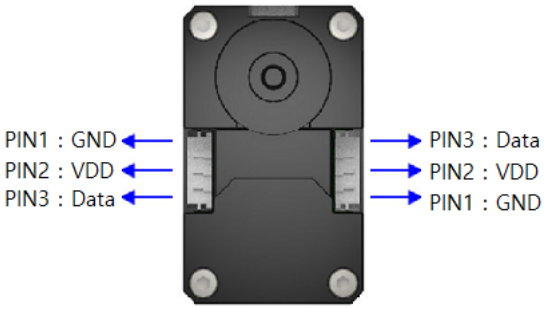
4. 5. 1. TTL Communication

TTL Communication Circuit



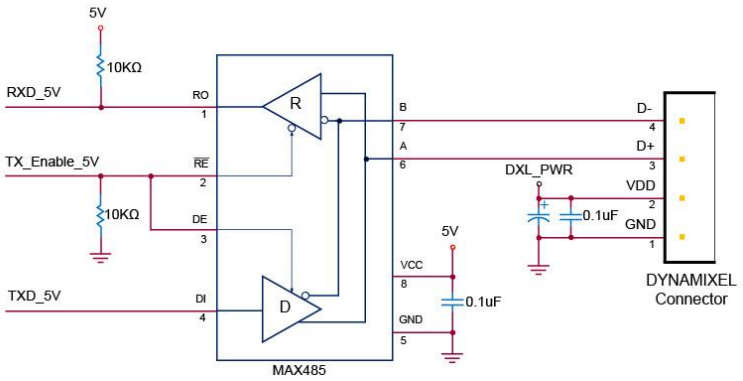
TTL Circuit

NOTE: Above circuit is designed for 5V or 5V tolerant MCU. Otherwise, use a Level Shifter to match the voltage of MCU.



4. 5. 2. RS-485 Communication

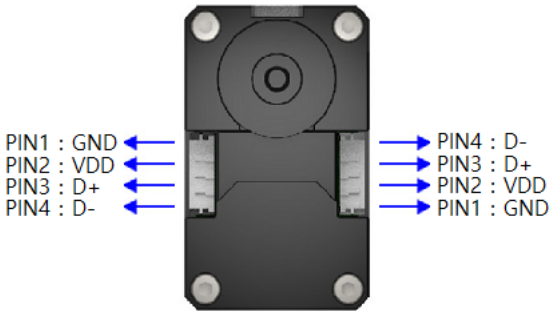
RS485 Communication Circuit



RS-485 Circuit

XM430-W350-T/R

NOTE: Above circuit is designed for 5V or 5V tolerant MCU. Otherwise, use a Level Shifter to match the voltage of MCU.



The power of DYNAMIXEL is supplied via Pin1(-), Pin2(+).
(The above circuit is built into DYNAMIXEL's controller only)
In the above circuit diagram, the direction of data signal of TxD and RxD in the TTL Level is determined according to the level of DIRECTION 485 as follows:
In case of DIRECTION485 Level = High: The signal of TxD is output to D+ and D-
In case of DIRECTION485 Level = Low: The signal of D+ and D- is output to RxD

4. 6. Drawings

4. 6. 1. X430

- Download X_430_idle_ref.pdf
- Download X-430_idle_ref.dwg
- Download x-430_idle.stp

4. 6. 2. FR12-H101K

- Download fr12_h101_ref.dwg
- Download fr12_h101_ref.pdf
- Download fr12_h101.stp

4. 6. 3. FR12-H103GM

- Download fr12-h103.dwg
- Download fr12-h103.pdf
- Download fr12-h103.stp

4. 6. 4. FR12-H104K

- Download fr12-h104.dwg
- Download fr12-h104.pdf
- Download fr12-h104.stp

4. 6. 5. FR12-S101K

- Download fr12_s101_ref.dwg
- Download fr12_s101_ref.pdf
- Download fr12_s101.stp

4. 6. 6. FR12-S102K

- Download fr12_s102_ref.dwg

- Download fr12_s102_ref.pdf
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4. 6. 7. FR12-G101GM

NOTE: FR12-G101GM is a gripper frame set that include a FR12-E170 and FR12-E171.

4. 6. 7. 1. FR12-E170

- Download fr12-e170.dwg
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4. 6. 7. 2. FR12-E171

- Download fr12-e171.dwg
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4. 7. Moment of Inertia

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