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**MX-28T/R/AT/AR(2.0)****1. Specifications**

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MX-28AR, MX-28AT (Protocol 2.0)**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(Maxon)
Baud Rate	8,000 [bps] ~ 4.5 [Mbps]
Control Algorithm	PID control
Resolution	4096 [pulse/rev]
Backlash	20 [arcmin] (0.33 [°])
Operating Mode	Velocity Control Mode Position Control Mode(0° ~ 360°) Extended Position Ctrl Mode(Multi-turn) PWM Control Mode
Weight	MX-28AR/AT : 77 [g], MX-28R/T : 72 [g]
Dimensions (W x H x D)	35.6 x 50.6 x 35.5 [mm]
Gear Ratio	193 : 1
Stall Torque	2.3 [Nm] (at 11.1 [V], 1.3 [A]) 2.5 [Nm] (at 12 [V], 1.4 [A]) 3.1 [Nm] (at 14.8 [V], 1.7 [A])
No Load Speed	50 [rev/min] (at 11.1 [V]) 55 [rev/min] (at 12 [V]) 67 [rev/min] (at 14.8 [V])
Radial Load	① 30 [N] (10 [mm] away from the horn)
Axial Load	① 15 [N]
Operating Temperature	-5 ~ +80 [°C]
Input Voltage	10.0 ~ 14.8 [V] (Recommended : 12.0 [V])
Command Signal	Digital Packet
Protocol Type	TTL Half Duplex Asynchronous Serial Communication with 8bit, 1stop, No Parity RS485 Asynchronous Serial Communication with 8bit, 1stop, No Parity
Physcial Connection	RS485 / TTL Multidrop Bus
ID	253 ID (0 ~ 252)
Feedback	Position, Velocity, Temperature, Load, Input Voltage, Trajectory, Realtime Tick, etc

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Material	Full Metal Gear
	Engineering Plastic(Front, Middle, Back)
	① Metal(Front)
Standby Current	100 [mA]

① Applies to aluminum housing products(MX-28AR/AT, MX-64AR/AT, MX-106R/T).

**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**

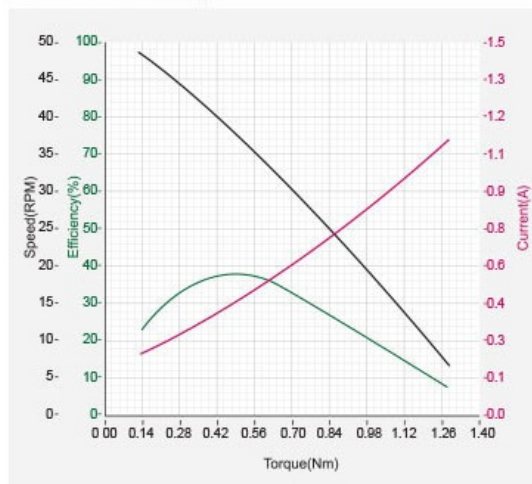
(May cause injury or damage to product)

- Do not operate the product at a temperature exceeding 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**Performance Graph**▲
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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.



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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.

CAUTION

1. MX(2.0) Firmware is different from MX series' control table and address. Please check the control table address before usage.
2. MX(2.0) Firmware inherits DYNAMIXEL-X function. Therefore, it supports [DYNAMIXEL Protocol 1.0](#) and [DYNAMIXEL Protocol 2.0](#), and various Operating Modes, Secondary ID, Drive Mode, Bus Watchdog, etc. Please refer to the control table for more details.

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](#).

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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	Description	Access	Initial Value
0	2	Model Number	Model Number	R	30
2	4	Model Information	Model Information	R	-
6	1	Firmware Version	Firmware Version	R	-
7	1	ID	DYNAMIXEL ID	RW	1
8	1	Baud Rate	Communication Baud Rate	RW	1
9	1	Return Delay Time	Response Delay Time	RW	250
10	1	Drive Mode	Drive Mode	RW	0
11	1	Operating Mode	Operating Mode	RW	3
12	1	Secondary(Shadow) ID	Secondary ID	RW	255
13	1	Protocol Type	Protocol Type	RW	2
20	4	Homing Offset	Home Position Offset	RW	0
24	4	Moving Threshold	Velocity Threshold for Movement Detection	RW	10
31	1	Temperature Limit	Maximum Internal Temperature Limit	RW	80
32	2	Max Voltage Limit	Maximum Input Voltage Limit	RW	160
34	2	Min Voltage Limit	Minimum Input Voltage Limit	RW	95
36	2	PWM Limit	Maximum PWM Limit	RW	885
40	4	Acceleration Limit	Maximum Acceleration Limit	RW	32767
44	4	Velocity Limit	Maximum Velocity Limit	RW	230
48	4	Max Position Limit	Maximum Position Limit	RW	4,095
52	4	Min Position Limit	Minimum Position Limit	RW	0
63	1	Shutdown	Shutdown Error Information	RW	52

2. 3. Control Table of RAM Area

Address	Size(Byte)	Data Name	Description	Access	Initial Value
64	1	Torque Enable	Motor Torque On/Off	RW	0



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Address	Size(Byte)	Data Name	Description	Access	Initial Value
65	1	LED	Status LED On/Off	RW	0
68	1	Status Return Level	Select Types of Status Return	RW	2
69	1	Registered Instruction	REG_WRITE Instruction Flag	R	0
70	1	Hardware Error Status	Hardware Error Status	R	0
76	2	Velocity I Gain	I Gain of Velocity	RW	1920
78	2	Velocity P Gain	P Gain of Velocity	RW	100
80	2	Position D Gain	D Gain of Position	RW	0
82	2	Position I Gain	I Gain of Position	RW	0
84	2	Position P Gain	P Gain of Position	RW	850
88	2	Feedforward 2nd Gain	2nd Gain of Feed-Forward	RW	0
90	2	Feedforward 1st Gain	1st Gain of Feed-Forward	RW	0
98	1	BUS Watchdog	DYNAMIXEL BUS Watchdog	RW	0
100	2	Goal PWM	Desired PWM Value	RW	-
104	4	Goal Velocity	Desired Velocity Value	RW	-
108	4	Profile Acceleration	Acceleration Value of Profile	RW	0
112	4	Profile Velocity	Velocity Value of Profile	RW	0
116	4	Goal Position	Desired Position	RW	-
120	2	Realtime Tick	Count Time in Millisecond	R	-
122	1	Moving	Movement Flag	R	0
123	1	Moving Status	Detailed Information of Movement Status	R	0
124	2	Present PWM	Present PWM Value	R	-
126	2	Present Load	Present Load Value	R	-
128	4	Present Velocity	Present Velocity Value	R	-
132	4	Present Position	Present Position Value	R	-
136	4	Velocity Trajectory	Desired Velocity Trajectory from Profile	R	-
140	4	Position Trajectory	Desired Position Trajectory from Profile	R	-
144	2	Present Input Voltage	Present Input Voltage	R	-
146	1	Present Temperature	Present Internal Temperature	R	-
168	2	Indirect Address 1	Indirect Address 1	RW	224
170	2	Indirect Address 2	Indirect Address 2	RW	225
172	2	Indirect Address 3	Indirect Address 3	RW	226
...
218	2	Indirect Address 26	Indirect Address 26	RW	249
220	2	Indirect Address 27	Indirect Address 27	RW	250
222	2	Indirect Address 28	Indirect Address 28	RW	251
224	1	Indirect Data 1	Indirect Data 1	RW	0



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Address	Size(Byte)	Data Name	Description	Access	Initial Value
225	1	Indirect Data 2	Indirect Data 2	RW	0
226	1	Indirect Data 3	Indirect Data 3	RW	0
...
249	1	Indirect Data 26	Indirect Data 26	RW	0
250	1	Indirect Data 27	Indirect Data 27	RW	0
251	1	Indirect Data 28	Indirect Data 28	RW	0
578	2	Indirect Address 29	Indirect Address 29	RW	634
580	2	Indirect Address 30	Indirect Address 30	RW	635
582	2	Indirect Address 31	Indirect Address 31	RW	636
...
628	2	Indirect Address 54	Indirect Address 54	RW	659
630	2	Indirect Address 55	Indirect Address 55	RW	660
632	2	Indirect Address 56	Indirect Address 56	RW	661
634	1	Indirect Data 29	Indirect Data 29	RW	0
635	1	Indirect Data 30	Indirect Data 30	RW	0
636	1	Indirect Data 31	Indirect Data 31	RW	0
...
659	1	Indirect Data 54	Indirect Data 54	RW	0
660	1	Indirect Data 55	Indirect Data 55	RW	0
661	1	Indirect Data 56	Indirect Data 56	RW	0

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.

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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 Status 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)

The Drive Mode(10) configures Drive Mode of DYNAMIXEL.

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 3(0x08)	-	Unused, always '0'
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



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Bit	Item	Description
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 : If the value of Bit 0(Normal/Reverse Mode) of the Drive Mode(10) is set to **1**, rotational direction is inverted.

Thus, **Position**, **Velocity**, **Current**, **PWM** will have a inverted direction.

This feature can be very useful when configuring symmetrical joint.



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2. 4. 7. Operating Mode(11)

Value	Operating Mode	Description
1	Velocity Control Mode (0° ~ 360°)	This mode controls velocity and ideal for wheel operation. This mode is identical to the Wheel Mode(endless) from existing DYNAMIXEL.
3(Default)	Position Control Mode	This mode controls position and identical to the Joint Mode. Operating position range is limited by Max Position Limit(48) and Min Position Limit(52). This mode is ideal for articulated robots that each joint rotates less than 360°.
4	Extended Position Control Mode (Multi-turn)	This mode controls position and identical to Multi-turn Mode. 512 turns are supported(-256[rev] ~ 256[rev]) and ideal for multi-turn wrists or conveyer systems or a system that requires an additional reduction gear.
16	PWM Control Mode (Voltage Control Mode)	This mode directly controls PWM output (Voltage Control Mode)

NOTE : Switching Operating Mode will reset gains(PID, Feedforward) properly to the selected Operating Mode. The profile generator and limits will also be reset.

1. [Profile Velocity\(112\)](#), [Profile Acceleration\(108\)](#) : Reset to '0'

2. [Goal PWM\(100\)](#) : Reset to [PWM Limit\(36\)](#)

NOTE : PWM is the abbreviation 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 DYNAMIXEL [AX](#) and [RX](#) series.

2. Use [Goal PWM\(100\)](#) on PWM Control Mode in order to control supply voltage for DYNAMIXEL.

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.

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- When torque is turned on in **Position Control Mode**, [Present Position\(132\)](#) will be reset to an absolute position value within one full rotation.
- 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.

- Set Secondary ID of five DYNAMIXELs (Assigned ID(7) of each is '1','2','3','4' or '5', not overlapped) to '5'.
- Send Write Instruction Packet(ID(7) = 1, [LED\(65\)](#) = 1).
- The DYNAMIXEL with ID '1' turns on its LED by the Instruction Packet, and Status Packet will be returned.
- Send Write Instruction Packet(ID(7) = 5, [LED\(65\)](#) = 1).
- All DYNAMIXELs turns on their LED, but Status Packet of ID '5' will be returned only.
- Set the Secondary ID of all DYNAMIXELs to '100'.
- Send Write Instruction Packet(ID(7) = 100, [LED\(65\)](#) = 0).
- 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



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Value	Description	Compatible DYNAMIXEL
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 offset 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°

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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. Acceleration Limit(40)

This value indicates maximum [Profile Acceleration\(108\)](#). [Profile Acceleration\(108\)](#) can't be configured with any values exceeding [Acceleration Limit\(40\)](#). [Profile Acceleration\(108\)](#) is used in all operating mode except PWM Control Mode in order to generate a desired trajectory. For more details, see [What is the Profile](#).

Unit	Value Range
214.577 Rev/min ²	0 ~ 32,767

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



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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.

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2. 4. 18. 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 1	-	Unused, Always '0'
Bit 0	Input Voltage Error	Detects that input voltage exceeds the configured operating voltage

NOTE :

- If Shutdown occurs, **LED will flicker every second. (Firmware v41 or above)**
- 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. 19. Torque Enable(64)

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

Value	Description
0(Default)	Torque Off

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Value	Description
-------	-------------

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. 20. 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. 21. Status Return Level(68)

The Status 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 READ Instruction	Returns the Status Packet for PING and READ 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 Status Return Level (68). For more details, please refer to the [Status Packet](#) section for [DYNAMIXEL Protocol 2.0](#).

2. 4. 22. Registered Instruction(69)

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. 23. 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,



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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 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.**
 - o H/W REBOOT : Turn off and turn on the power again
 - o S/W REBOOT : Transmit REBOOT Instruction (For more details, refer to the [Reboot](#) section of e-Manual.)

2. 4. 24. 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

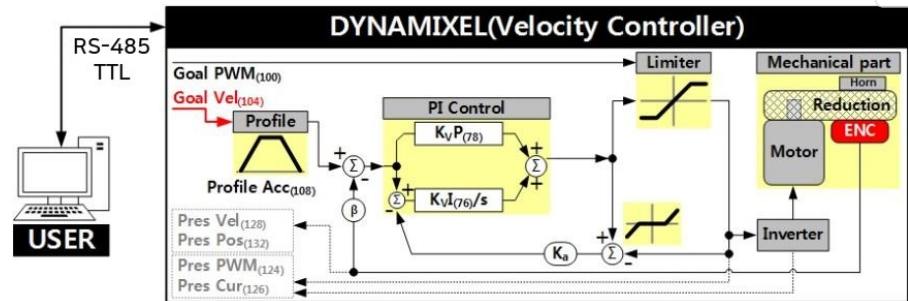
Below figure is a block diagram describing the velocity controller in Velocity Control Mode. When the instruction transmitted from the user is received by DYNAMIXEL, it takes following steps until driving the horn.

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\(136\)](#).

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- PI controller calculates PWM output for the motor based on the desired velocity trajectory.
- [Goal PWM\(100\)](#) sets a limit on the calculated PWM output and decides the final PWM value.
- The final PWM value is applied to the motor through an Inverter, and the horn of DYNAMIXEL is driven.
- Results are stored at [Present Position\(132\)](#), [Present Velocity\(128\)](#), [Present PWM\(124\)](#) and [Present Current\(126\)](#).

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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. 25. 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.

- An Instruction from the user is transmitted via DYNAMIXEL bus, then registered to [Goal Position\(116\)](#).
- [Goal Position\(116\)](#) is converted to desired position trajectory and desired velocity trajectory by [Profile Velocity\(112\)](#) and [Profile Acceleration\(108\)](#).
- The desired position trajectory and desired velocity trajectory is stored at [Position Trajectory\(140\)](#) and [Velocity Trajectory\(136\)](#) respectively.
- Feedforward and PID controller calculate PWM output for the motor based on desired trajectories.
- [Goal PWM\(100\)](#) sets a limit on the calculated PWM output and decides the final

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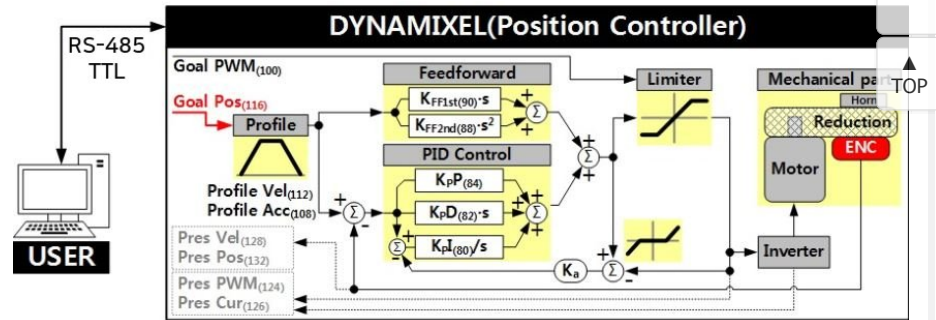
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PWM value.

- The final PWM value is applied to the motor through an Inverter, and the horn of DYNAMIXEL is driven.
- 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.
- 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](#).

2. 4. 26. 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. 26. 1. Bus Watchdog (98) Example

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

- After setting the [Operating Mode\(11\)](#) to speed control mode, change the [Torque](#)

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Enable(64) to '1'.

- If '50' is written in the [Goal Velocity\(104\)](#), the DYNAMIXEL will rotate in CCW direction.
- Change the value of [Bus Watchdog\(98\)](#) to '100' (2,000 [ms]). (Activate Bus Watchdog Function)
- 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'.
- 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.
- If '150' is written to the [Goal Velocity\(104\)](#), the Data Range Error will be returned via Status Packet.
- If the value of [Bus Watchdog\(98\)](#) is changed to '0', Bus Watchdog Error will be cleared.
- If "150" is written in the [Goal Velocity\(104\)](#), the DYNAMIXEL will rotate in CCW direction.

2. 4. 27. 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. 28. 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. 29. 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

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acceleration time of the Profile.

Be aware that 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. 30. 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** or **Extended 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. 31. 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.



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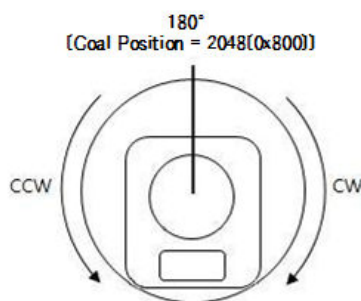
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Mode	Values	Description
Position Control Mode	Min Position Limit(52) ~ Max Position Limit(48)	Initial Value : 0 ~ 4,095
Extended Position Control Mode	-1,048,575 ~ 1,048,575	-256[rev] ~ 256[rev]

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.:

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

2. 4. 32. 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. 33. 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'.



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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)

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2. 4. 34. 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	11	Velocity Profile	11 : Trapezoidal Profile
Bit 5	10		10 : Triangular Profile
Bit 5	01		01 : Rectangular Profile
Bit 5	00		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. 35. Present PWM(124)

This value indicates present PWM. For more details, please refer to the [Goal PWM\(100\)](#).

2. 4. 36. Present Load(126)

It means currently applied load. For example, the value is 500, it means the load is detected in the direction of CCW about 50% of the maximum torque.

Unit	Value Range	Description
0.1%	-1,000 ~ 1,000	Positive(CCW Load), Negative(CW Load)

NOTE : The Present load is an inferred value based on the internal output value; not a

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measured value using torque sensor, etc. Therefore, it may be inaccurate for measuring weight or torque. It is recommended to use it for predicting the direction and size of the force being applied to the joint.

2. 4. 37. Present Velocity(128)

This value indicates present Velocity. For more details, please refer to the [Goal Velocity\(104\)](#).

2. 4. 38. 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. 39. Velocity Trajectory(136)

This is a desired velocity trajectory created by Profile. Operating method can be changed based on control mode. For more details, please refer to the Profile Velocity(112).

1. **Velocity Control Mode** : When Profile reaches to the endpoint, Velocity Trajectory(136) becomes equal to Goal Velocity(104).
2. **Position Control Mode, Extended 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. 40. Position Trajectory(140)

This is a desired position trajectory created by Profile. This value is only used in Position Control Mode, Extended Position Control Mode. For more details, please refer to the [Profile Velocity\(112\)](#).

2. 4. 41. 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. 42. Present Temperature(146)

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

2. 4. 43. 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



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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

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

2. 4. 43. 1. Indirect Address and Indirect Data Examples

Example 1 Allocating Size 1 byte [LED\(65\)](#) to Indirect Data 1(224).

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

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

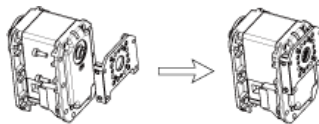
NOTE : In order to allocate Data in the Control Table longer than 2[byte] to Indirect Address, all address must be allocated to Indirect Address like the above Example 2.

NOTE : Indirect Address 29 ~ 56 and Indirect Data 29 ~ 56 can only be accessed with [Protocol 2.0](#).

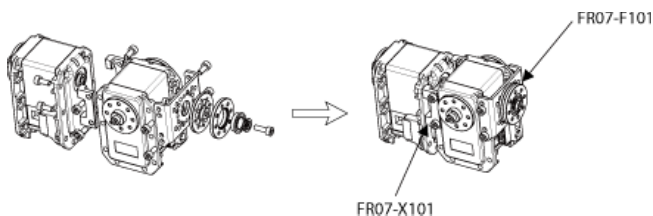
3. How to Assemble

3. 1. Frames

- FR07-B101 Option Frame



- FR07-F101_FR07-X101 Option Frame



- FR07-H101 Option Frame



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2. 2. EEPROM Area

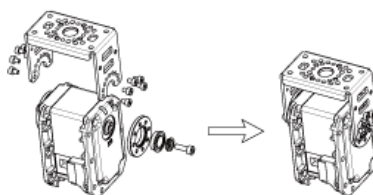
2. 3. RAM Area

2. 4. Control Table Description

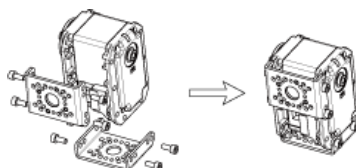
3. How to Assemble

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5. Reference

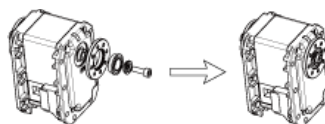


• FR07-S101 Option Frame



3. 2. Horns

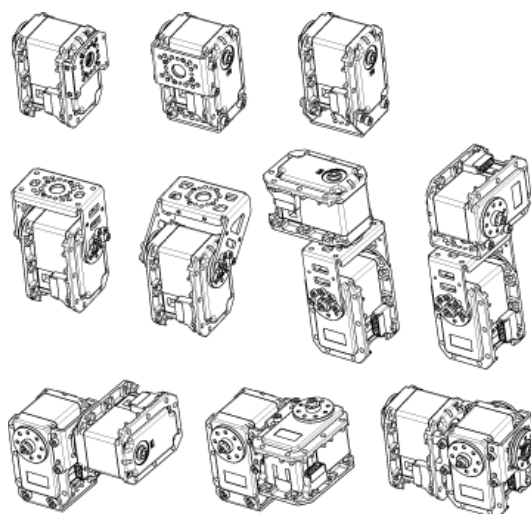
• HN07-I101



• HN07-N101



3. 3. Combination Structures



4. Maintenance

4. 1. Horn and Bearing Replacement

The horn is installed on the front wheel gear serration of the DYNAMIXEL whereas the bearing set is installed on the back.



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2. 2. EEPROM Area

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4. 1. 1. Installing the Horn

Place the thrust horn washer into the actuator before inserting the horn. You must carefully align the horn to the wheel gear serration by aligning dots.



Once alignment is properly done, gently push the center of the horn toward the actuator. Make sure that the horn washer is in place as you tighten the bolt.

4. 1. 2. Installing the Bearing Set

You may need to remove the bearing set from the previous actuator and reinstall it into the new actuator. The bearing set can also be purchased separately. As bearing set is rotating freely, therefore alignment is not required when assembling to DYNAMIXEL.



4. 2. 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.



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- *Access*

- *Initial Value*

2. 2. EEPROM Area

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ROBOTIS FAQ-DXL Gear Replacement (MX-28) ENG



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4. 3. 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.

ROBOTIS FAQ-DXL Gear Calibration (MX-28) ENG (RoboPlus 1.0)



NOTE:

- As the USB2Dynamixel has been discontinued, a [U2D2](#) is required to communicate 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.

5. Reference

NOTE

[Compatibility Guide](#)

[Harness Compatibility](#)

5. 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

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2. 4. Control Table Description

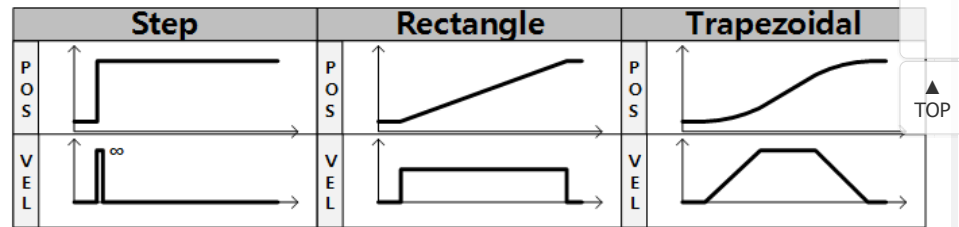
3. How to Assemble

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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'.

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(t_1) 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

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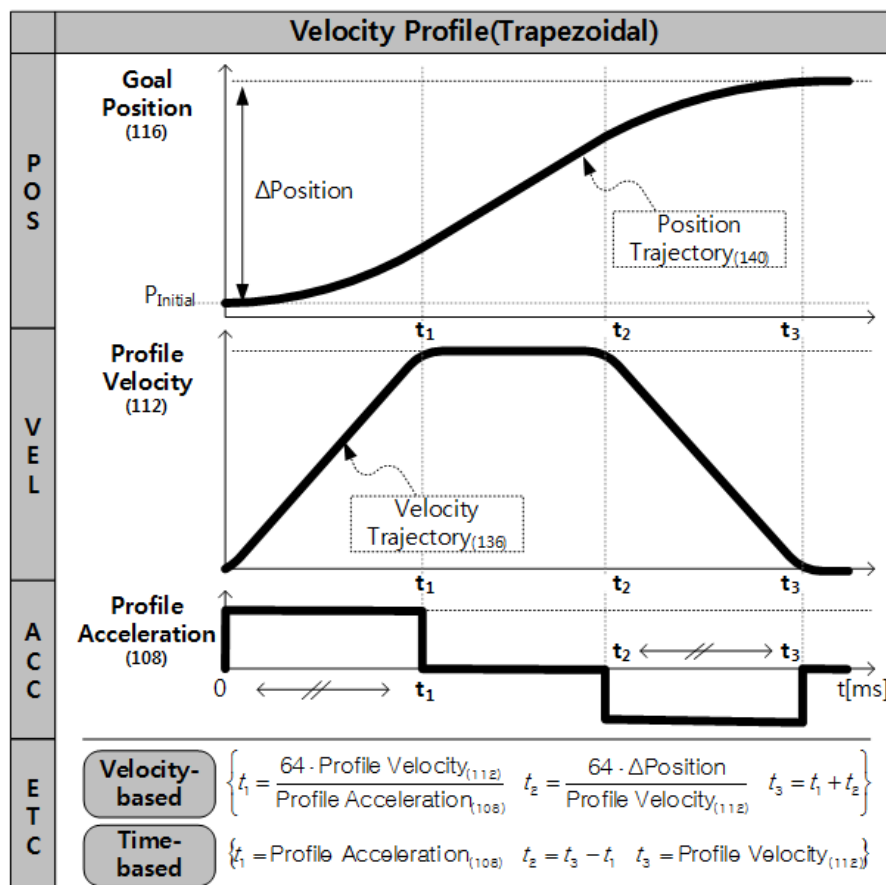
2. 3. RAM Area

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NOTE : Velocity Control Mode only uses [Profile Acceleration\(108\)](#). Step and Trapezoidal Profiles are supported. Velocity Override are supported as well. Acceleration time(t_1) can be calculated as below equation.

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

Time-based Profile : $t_1 = \text{Profile Acceleration}(108)$

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.

5. 2. Certifications

Please inquire us for information regarding unlisted certifications.

5. 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.

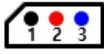
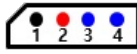
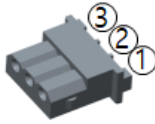
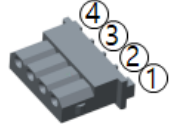


WARNING

Any changes or modifications not expressly approved by the manufacturer could void the

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user's authority to operate the equipment.

5. 3. Connector Information

Item	TTL	RS-485
Pinout	<div> <div>1</div> GND <div>2</div> VDD <div>3</div> DATA </div>	<div> <div>1</div> GND <div>2</div> VDD <div>3</div> DATA+ <div>4</div> DATA- </div>
Diagram		
Housing	 MOLEX 50-37-5033	 MOLEX 50-37-5043
PCB Header	 MOLEX 22-03-5035	 MOLEX 22-03-5045
Crimp Terminal	MOLEX 08-70-1039	MOLEX 08-70-1039
Wire Gauge for DYNAMIXEL	21 AWG	21 AWG

WARNING: To enhance user safety and to prevent proprietary risk or damage, **be sure to check the pinout installed on DYNAMIXEL and the board.** The Pinout of DYNAMIXEL may differ depending on a manufacturer of connector.

5. 4. Drawings

- [Download MX-28AT_AR DWG](#)
- [Download MX-28AT_AR PDF](#)
- [Download MX-28AT_AR STEP](#)
- [Download MX-28T DWG](#)
- [Download MX-28T PDF](#)
- [Download MX-28T STEP](#)
- [Download MX-28T IGES](#)
- [Download MX-28R DWG](#)
- [Download MX-28R PDF](#)
- [Download MX-28R STEP](#)
- [Download MX-28R IGES](#)

Please also checkout [ROBOTIS Download Center](#) for software applications, 3D/2D CAD, and other useful resources!

5. 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.

5. 5. 1. TTL Communication

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2. 3. RAM Area

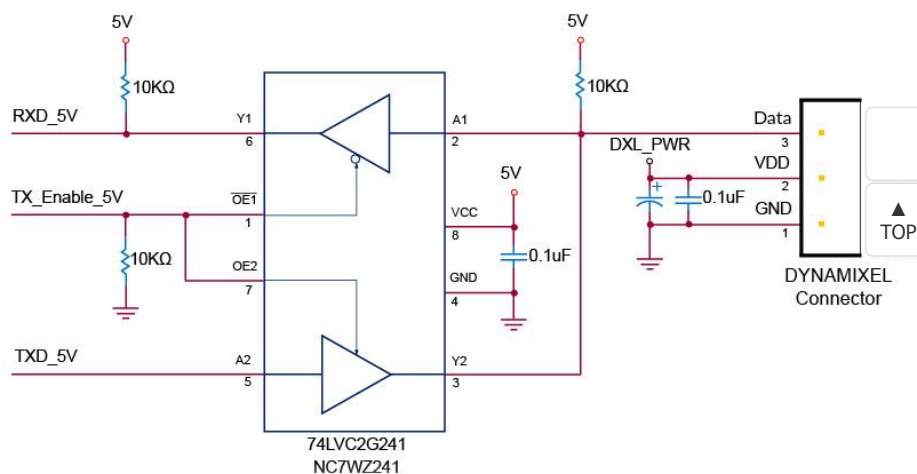
2. 4. Control Table Description

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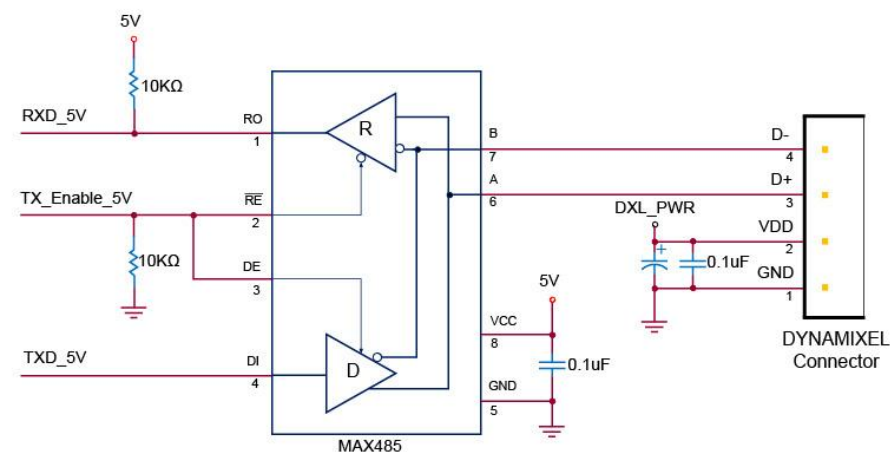
TTL Communication Circuit



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

5. 5. 2. RS-485 Communication

RS485 Communication Circuit



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 TX_Enable_5V as follows:

In case of TX_Enable_5V = High: The signal of TxD is output to D+ and D-

In case of TX_Enable_5V = Low: The signal of D+ and D- is output to RxD