Specifications

Item	Specifications
Baud Rate	7343 bps ~ 1 Mbps
Resolution	0.29°
Running Degree	0° ~ 300° Endless Turn
Weight	16.7g
Dimensions (W x H x D)	24mm x 36mm x 27mm
Gear Ratio	238 : 1
Stall Torque	0.39Nm @ 7.4V, 1.1A
No Load Speed	114rpm @ 7.4V, 0.18A
Operating Temperature	-5°C ~ +70°C
Input Voltage	6 ~ 8.4V (**Recommended : 7.4V**)
Command Signal	Digital Packet
Protocol Type	Half Duplex Asynchronous Serial Communication (8bit, 1stop, No Parity)
Physical Connection	TTL Level Multidrop Bus(Daisy Chain Type Connector)
ID	0 ~ 252
Feedback	Position, Temperature, Load, Input Voltage, etc
Material	Engineering Plastic

NOTE : Stall torque is the maximum instantaneous and static torque. Stable motions are possible with robots designed for loads with 1/5 or less of the stall torque.

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 polarity before wiring.

CAUTION
(May cause injury or damage to product)

- Do not operate the product at a temperature exceeding -5 ~ +70 [°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.

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.

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 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.

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(24) is cleared to '0'(Off).

Size

The Size of data varies from 1 ~ 2 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.

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.

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.

Control Table of EEPROM Area

Address	Size (Byte)	Data Name	Description	Access	Initial Value	Min	Max
0	2	Model Number	Model Number	R	350	-	-
2	1	Firmware Version	Firmware Version	R	-	-	-
3	1	ID	DYNAMIXEL ID	RW	1	0	252
4	1	Baud Rate	Communication Speed	RW	3	0	3
5	1	Return Delay Time	Response Delay Time	RW	250	0	254
6	2	CW Angle Limit	Clockwise Angle Limit	RW	0	0	1023

Address	Size (Byte)	Data Name	Description	Access	Initial Value	Min	Max
8	2	CCW Angle Limit	Counter-Clockwise Angle Limit	RW	1023	0	1023
11	1	Control Mode	Control Mode	RW	2	1	2
12	1	Temperature Limit	Maximum Internal Temperature Limit	RW	65	0	150
13	1	Min Voltage Limit	Minimum Input Voltage Limit	RW	60	50	250
14	1	Max Voltage Limit	Maximum Input Voltage Limit	RW	90	50	250
15	2	Max Torque	Maximun Torque	RW	1023	0	1023
17	1	Status Return Level	Select Types of Status Return	RW	2	0	2
18	1	Shutdown	Shutdown Error Information	RW	3	0	7

Control Table of RAM Area

Address	Size (Byte)	Data Name	Description	Access	Initial Value	Min	Max
24	1	Torque Enable	Motor Torque On/Off	RW	0	0	1
25	1	LED	Status LED On/Off	RW	0	0	7
27	1	D Gain	Derivative Gain	RW	0	0	254
28	1	I Gain	Integral Gain	RW	0	0	254
29	1	P Gain	Proportional Gain	RW	32	0	254
30	2	Goal Position	Desired Position	RW	-	0	1023

Address	Size (Byte)	Data Name	Description	Access	Initial Value	Min	Max
32	2	Moving Speed	Moving Speed(Moving Velocity)	RW	-	0	2047
35	2	Torque Limit	Torque Limit(Goal Torque)	RW	-	0	1023
37	2	Present Position	Present Position	R	-	-	-
39	2	Present Speed	Present Speed	R	-	-	-
41	2	Present Load	Present Load	R	-	-	-
45	1	Present Voltage	Present Voltage	R	-	-	-
46	1	Present Temperature	Present Temperature	R	-	-	-
47	1	Registered	If Instruction is registered	R	0	-	-
49	1	Moving	Movement Status	R	0	-	-
50	1	Hardware Error Status	Hardware Error Status	R	0	-	-
51	2	Punch	Minimum Current Threshold	RW	32	0	1023

Control Table Description

Model Number (0)

This address stores model number of the DYNAMIXEL.

Firmware Version (2)

This address stores firmware version of the DYNAMIXEL.

ID (3)

The ID is a unique value in the network to identify each DYNAMIXEL with an Instruction Packet. 0~252 (0xFC) 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 DYNAMIXELs simultaneously.

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

Baud Rate (4)

Baud Rate determines serial communication speed between a controller and DYNAMIXELs.

Value	Baud Rate
0	9,600 bps
1	57,600 bps
2	115,200 bps
3	1 Mbps

Return Delay Time (5)

After the DYNAMIXEL receives an Instruction Packet, it delays transmitting the Status Packet for Return Delay Time (9). 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 508[µsec]

CW/CCW Angle Limit(6, 8)

The angle limit allows the motion to be restrained.
The range and the unit of the value is the same as Goal Position(Address 30, 31).

- CW Angle Limit: the minimum value of Goal Position(Address 30, 31)
- CCW Angle Limit: the maximum value of Goal Position(Address 30, 31)

Control Mode(11)

Value	Mode
1	Wheel Mode
2	Joint Mode

Temperature Limit(12)

Unit	Value Range
About 1°C	0 ~ 100

CAUTION : Do not set the temperature higher than the default value. When the temperature alarm shutdown occurs, wait 20 minutes to cool the temperature before re-use. Keep using the product when the temperature is high can cause severe damage.

Min/Max Voltage Limit(13, 14)

It is the operation range of voltage.

Unit	Value Range	Description
About 0.1V	50 ~ 250	5.0 ~ 25.0V

For example, if the value is 80, the voltage is 8V. If Present Voltage(45) is out of the range, Voltage Range Error Bit (Bit0) of Status Packet is returned as '1' and Shutdown(18) is triggered.

Max Torque(15)

It is the torque value of maximum output. 0 to 1,023 (0x3FF) can be used, and the unit is about 0.1%.
For example, Data 1,023 (0x3FF) means that Dynamixel will use 100% of the maximum torque it can produce while Data 512 (0x200) means that Dynamixel will use 50% of the maximum torque.
When the power is turned on, Torque Limit (Address 34 and 35) uses the value as the initial value.

Status Return Level(17)

This value decides how to return Status Packet when Dynamixel receives an Instruction Packet.

Value	Responding Instructions	Description
0	PING Instruction	Status Packet will not be returned for all Instructions
1	PING Instruction READ Instruction	Status Packet will be returned only for READ Instruction
2	All Instructions	Status Packet will be returned for all Instructions

NOTE : If the ID of Instruction Packet is set to Broad Cast ID(0xFE), Status Packet will not be returned for READ and WRITE Instructions regardless of Status Return Level. For more details, please refer to the `Status Packet` section for Protocol 1.0 or Protocol 2.0.

Shutdown(18)

Dynamixel can protect itself by detecting errors occur during the operation. The errors can be set are as the table below.

Bit	Item	Description
Bit 3~7	-	-
Bit 2	ERROR_INPUT_VOLTAGE	Voltage is out of operational voatage range
Bit 1	ERROR_OVER_HEATING	Temperature is out of operational temperature range
Bit 0	ERROR_OVERLOAD	Motor cannot output max load due to load being applied continouosly

It is possible to make duplicate set since the function of each bit is run by the logic of 'OR'. That is, if 0x05 (binary 00000101) is set, both Input Voltage Error and Overload Error can be detected. If errors occur, in case of Alarm LED, the LED blinks; in case of Alarm Shutdown, the motor output becomes 0 % by making the value of Torque Limit(35) to 0.

Torque Enable(24)

Value	Description
0	Turn off the torque(Free run state)
1	Turn on the torque and lock EEPROM area

LED(25)

The combination of bit changes the output color of XL-320.

Enabled Bit	Decimal Value	Output Color
NONE	0	OFF
0	1	Red
1	2	Green
2	4	Blue
0 + 1	3	Yellow
1 + 2	6	Cyan

Enabled Bit	Decimal Value	Output Color
0 + 2	5	Purple
0 + 1 + 2	7	White

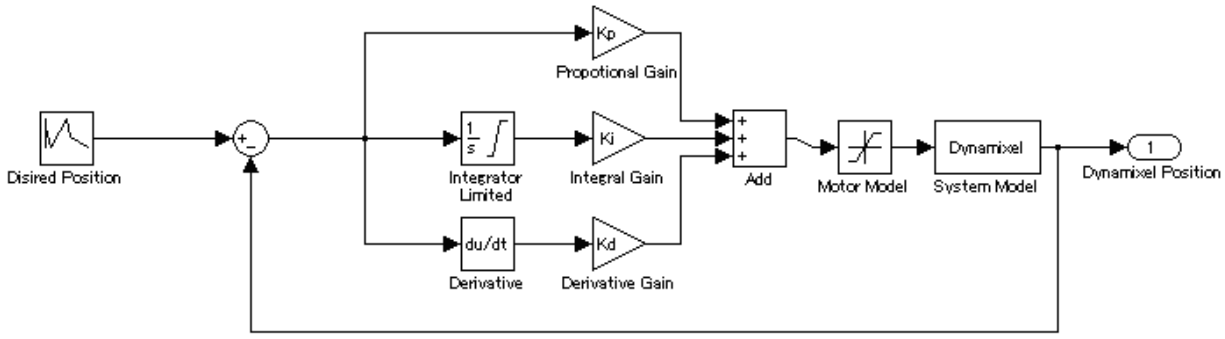
NOTE : The LED indicates present status of the device.

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

PID Gains(27, 28, 29)

MX series will use the PID controller as a main control method.

- `P gain` : value of proportional band.
- `I gain` : value of integral action.
- `D Gain` : value of derivative action. Gains values are in between 0 ~ 254.



- K_p : P Gain / 8
- K_i : I Gain * 1,000 / 2,048
- K_d : D Gain * 4 / 1,000

The relationship between Compliance Slop and PID

Slope	P Gain
8	128
16	64

Slope	P Gain
32	32
64	16
128	8

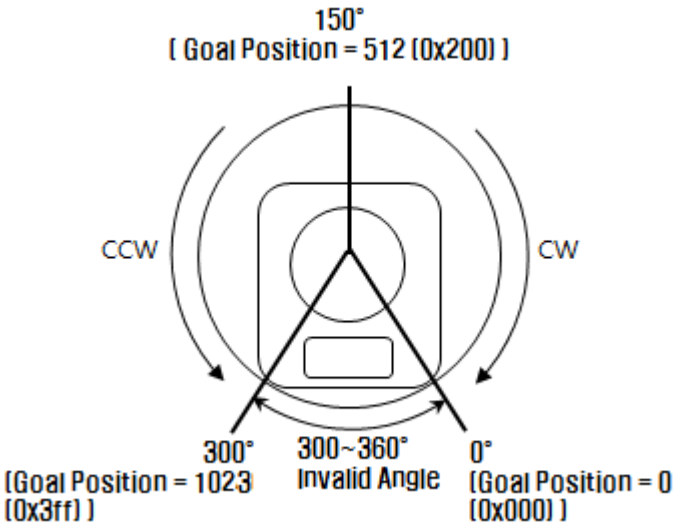
The less the P gain, The larger the back lash, and the weaker the amount of output near goal position.
At some extent, it is like a combined concept of margine and slope.
It does not exactly match the previous concept of compliance. So it is obvious if you see the difference in terms of motion.

Explanation for PID required.

For the brief explanation about general PID, please refer to the website(link) below.
http://en.wikipedia.org/wiki/PID_controller
FYI, PID control theory is not only limited to the control of motor(actuator) but is a generic theory that can be applied to all kinds of control.

Goal Position(30)

It is a position value of destination. 0 ~ 1,023 (0x3FF) is available. The unit is 0.29°. If Goal Position is out of the range, Angle Limit Error Bit (Bit 1) of Status Packet is returned as '1' and Alarm is triggered as set in Alarm LED/Shutdown.



The picture above is the front view of Dynamixel

NOTE : If it is set to Wheel Mode, Goal Position value is not used.

Moving Speed(32)

- Join Mode, Multi-Turn mode It is a moving speed to Goal Position. 0~1,023 (0x3FF) can be used, and the unit is about 0.111rpm. If it is set to 0, it means the maximum rpm of the motor is used without controlling the speed. If it is 1,023, it is about 114rpm. For example, if it is set to 300, it is about 33.3 rpm. However, the rpm will not exceed the No Load Speed.
- Wheel Mode It is a moving speed to Goal direction. 0~2,047 (0x7FF) can be used, and the unit is about 0.1%. If a value in the range of 0~1,023 is used, it is stopped by setting to 0 while rotating to CCW direction. If a value in the range of 1,024~2,047 is used, it is stopped by setting to 1,024 while rotating to CW direction. That is, the 10th bit becomes the direction bit to control the direction. For example, if it is set to 512, it means the output is controlled by 50% of the maximum output.

  NOTE : Wheel mode allows to check max rpm. Any values higher than max rpm will not take effect.

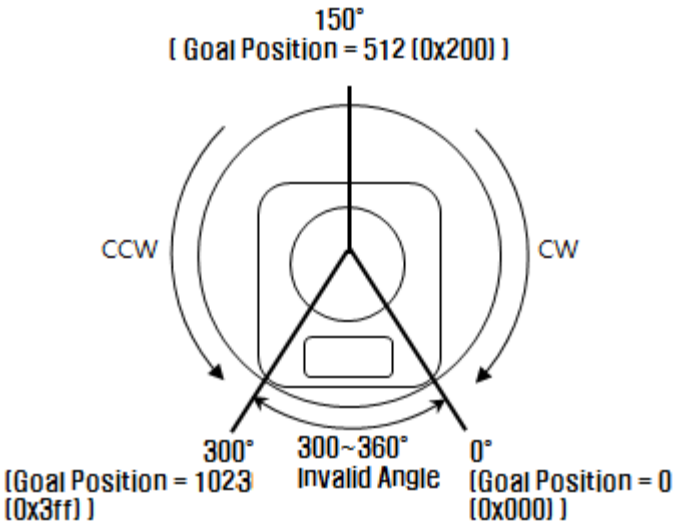
Torque Limit(35)

It is the value of the maximum torque limit. 0 ~ 1,023(0x3FF) is available, and the unit is about 0.1%. For example, if the value is 512, it is about 50%; that means only 50% of the maximum torque will be used. If the power is turned on, the value of Max Torque (Address 14, 15) is used as the initial value.

NOTE : If the function of Alarm Shutdown is triggered, the motor loses its torque because the value becomes 0. Once error conditions are resolved and this value is changed to the value other than 0, the motor can be operated again.

Present Position(37)

It is the present position value of Dynamixel. The range of the value is 0 ~ 1,023 (0x3FF), and the unit is 0.29 [°].



The picture above is the front view of Dynamixel.

CAUTION : If it is set to Wheel Mode, the value cannot be used to measure the moving distance and the rotation frequency.

Present Speed(39)

Is the present moving speed. 0~2,047 (0x000 ~ 0x7FF) can be used. If a value is in the rage of 0~1,023 then the motor rotates to the CCW direction. If a value is in the rage of 1,024~2,047 then the motor rotates to the CW direction. The 10th bit becomes the direction bit to control the direction; 0 and 1,024 are equal. The unit of this value varies depending on operation mode.

- Joint Mode The unit is about 0.111rpm. For example, if it is set to 300, it means that the motor is moving to the CCW direction at a rate of about 33.3rpm.
- Wheel Mode The unit is about 0.1%. For example, if it is set to 512, it means that the torque is controlled by 50% of the maximum torque to the CCW direction.

Present Load(41)

It means currently applied load. The range of the value is 0~2047, and the unit is about 0.1%. If the value is 0~1,023, it means the load works to the CCW direction. If the value is 1,024~2,047, it means the load works to the CW direction. That is, the 10th bit becomes the direction bit to control the direction, and 1,024 is equal to 0. For example, the value is 512, it means the load is detected in the direction of CCW about 50% of the maximum torque.

Bit	15 ~ 11	10	9 ~ 0
Value	0	Load Direction	Data (Load Ratio)

NOTE : CCW Load : Load Direction = 0, CW Load : Load Direction = 1
NOTE : Present load is an inferred value based on the internal output value; not a 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.

Present Voltage(45)

It is the size of the present voltage supplied. This value is 10 times larger than the actual voltage. For example, when 10V is supplied, the data value is 100 (0x64) If Present Voltage(45) value is out of range, Voltage Range Error Bit (Bit0) of Status Packet is returned as '1' and Shutdown(18) is triggered by setting 1 to the Bit 0 of the address 18.

Present Temperature(46)

It is the internal temperature of Dynamixel in Celsius.
Data value is identical to the actual temperature in Celsius. For example, if the data value is 85 (0x55), the current internal temperature is 85°C.

Registered Instruction(47)

Value	Description
0	REG_WRITE instruction is not received
1	REG_WRITE instruction is received

NOTE : If ACTION instruction is executed, the value will be changed to 0.

Moving(49)

Value	Description
0	Goal position command execution is completed
1	Goal position command execution is in progress

Hardware Error Status(50)

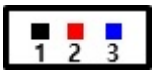
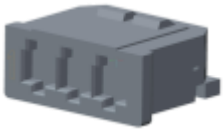
Present hardware error staus. Alarm shutdown error value.

Punch(51)

Minimum current to drive motor. This value ranges from 0x20 to 0x3FF.

Reference

NOTE
Compatibility Guide
Harness Compatibility
Connector Information

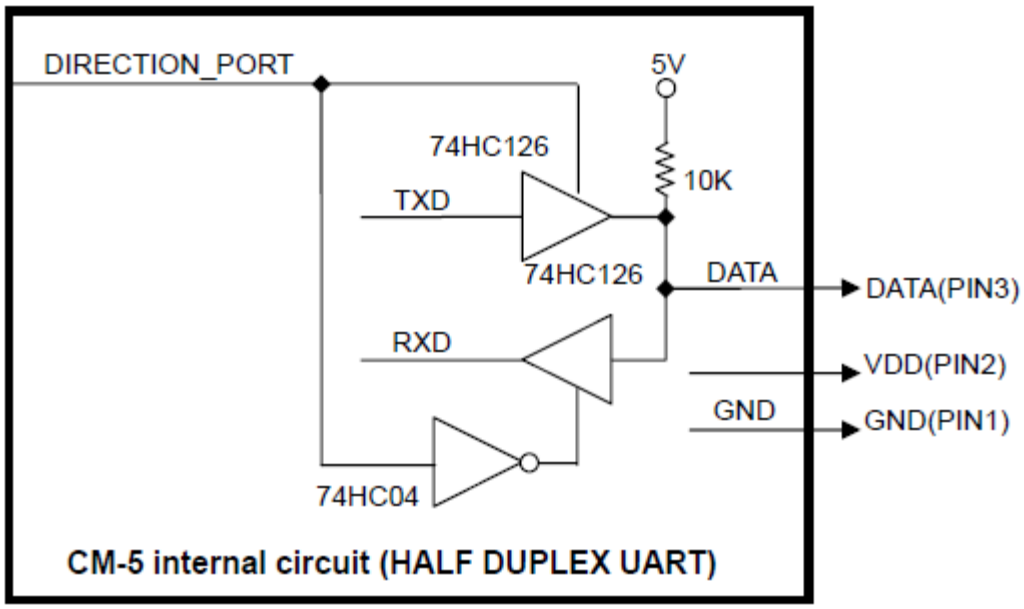
Item	TTL
Pinout	1 GND 2 VDD 3 DATA
Diagram	
Housing	 MOLEX 51065-0300
PCB Header	 MOLEX 53253-0370
Crimp Terminal	MOLEX 50212-8000
Wire Gauge	24 AWG

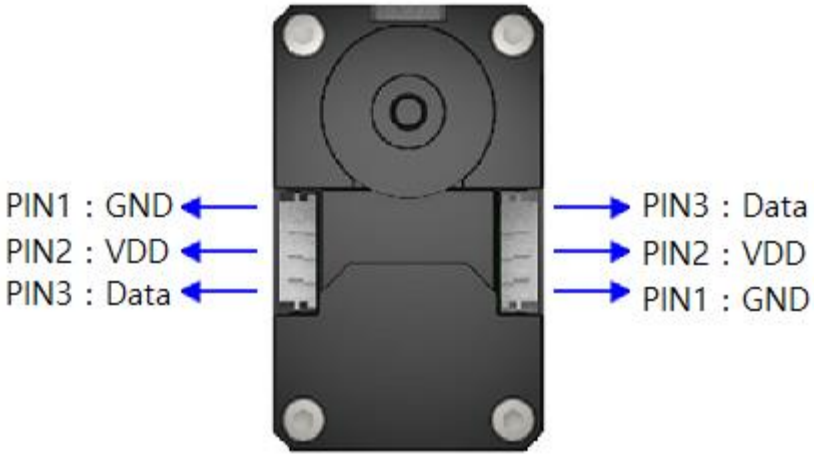
WARNING: **Check the pinout!** The pinout of Dynamixel can differ from the pinout of connector manufacturer.

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.

TTL Communication





WARNING: **Check the pinout!** The pinout of Dynamixel can differ from the pinout of connector manufacturer.