User's Manual 2004-04-02

Closer to Real, ROBOTIS

Dynamixel DX-116

Contents

1. Dynamixel DX-116

1-1. Overview & Characteristics of DX-116

Dynamixel DX-116

The Dynamixel is a smart actuator which incorporates a precision servo motor and a control unit with networking functionality, all in a single unit. Despite its compact size, it can produce high torque and has been manufactured using high quality materials to provide the necessary strength and structural resilience. It can also detect and act upon internal conditions such as temperature and over-current .

The Dynamixel has many advantages over similar products:-

Precise Control Control position and speed with fine angular resolution (1024 divisions)

Compliance Driving Control the degree of elastic force in position control.

Feedback Feedback for angular position, speed and load size.

Alarm System Not only does the Dynamixel warn of a deviation from the user defined ranges (e.g. internal temperatures, torques, voltages etc), but it also automatically deals with the problems as they occur.

Communication Daisy chain connection with support for communication speeds of up to 1MBPS.

High Efficiency Motor Dynamixel uses the RE-MAX Series Coreless DC Motors from Swiss Maxon Motor which boasts high output torque and excellent acceleration.

Distributed Control The main processor requires very few resources to control multiple Dynamixels since the movement schedule requires only a single command packet.

High Quality Enclosure The high quality plastic body ensures structural integrity under all operational conditions

Metal Gears All the gear sets are made of metal to ensure extreme durability.

Axis Bearing A bearing is used on the final axis to ensure there is no loss of efficiency during heavily loaded conditions.

Status LED A LED indicates error status.

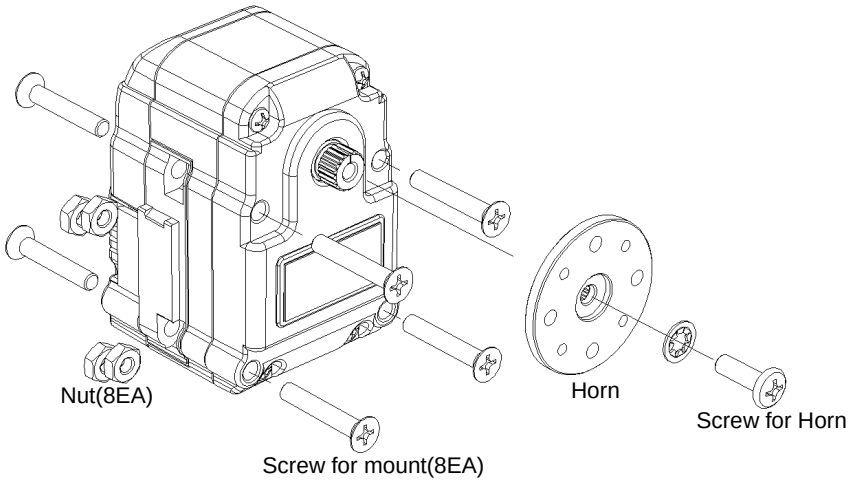
1-2. Main Specification

Holding Torque	31.5kg·cm (18V) ~ 21 kg·cm (12V)
Reduction ratio	1/140
Speed	0.084sec/60° (18V) ~ 0.125sec/60° (12V)
Resolution	0.35°
Operating Angle	300°
Voltage	12V~18V (Recommended voltage: 14~15V)
Max. Current	1200mA
Operating Temp.	-5℃ ~ +85℃
Weight	66g
Command Signal	Digital Packet
Protocol Type	Half duplex Asynchronous Serial Communication (8bit,1stop,No Parity)
Link (Physical)	RS 485 Multi Drop (daisy chain configuration)
ID	254 ID (0~253)
Communication Speed	7343bps ~ 1 Mbps
Feedback	Position, Temperature, Load, Input Voltage, etc.
Material	Full Metal Gear, Engineering Plastic Body
Motor	Swiss MAXON Motor RE-MAX (best level)

2. Installation of Dynamixel

2-1. Mechanical Parts Assembly

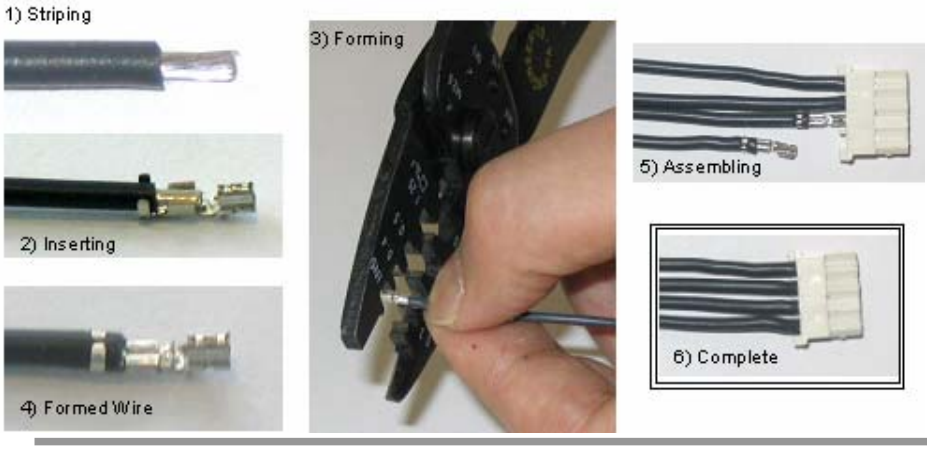
Mechanical Parts of Dynamixel are assembled as follows:



The 8 sets of Nuts & Screws are only used when a Dynamixel is mounted to other equipment.

2-2. Connector Assembly

Assemble the connectors as shown below. Attach the wires to the terminals using the correct crimping tool. If you do not have access to an appropriate crimper, solder the terminals to the wires to ensure that they do not become loose during operation.

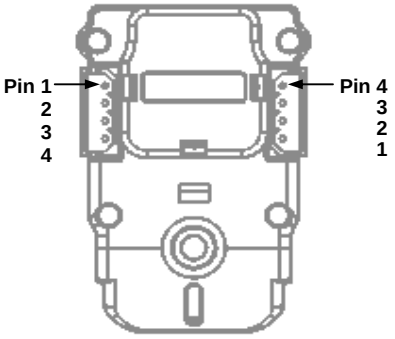


2-3. Wiring of Dynamixel

Pin Assignment

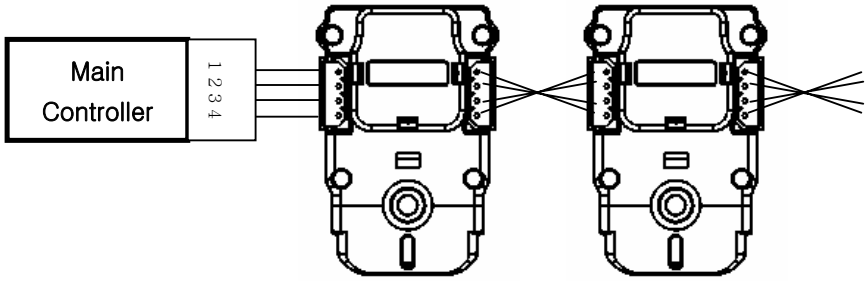
Pin assignments of the connectors are as follows:-

Pin 1: GND
Pin 2: +12V~18V
Pin 3: D+ (RS485 Signal)
Pin 4: D- (RS485 Signal)



Wire Link

Connect the same pin numbers as shown below.

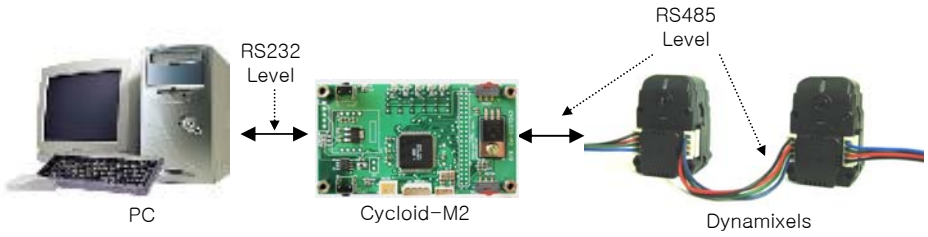


Main Controller

The Main Controller must support RS485 to control the Dynamixel. A proprietary Controller may be utilised but the Cycloid-M2 board is recommended.

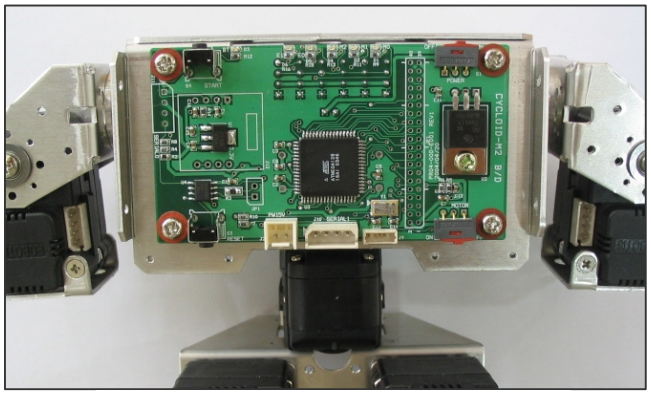
PC LIMK

A PC can be used to control the Dynamixel via the Cycloid-M2 Board.



Stand Alone

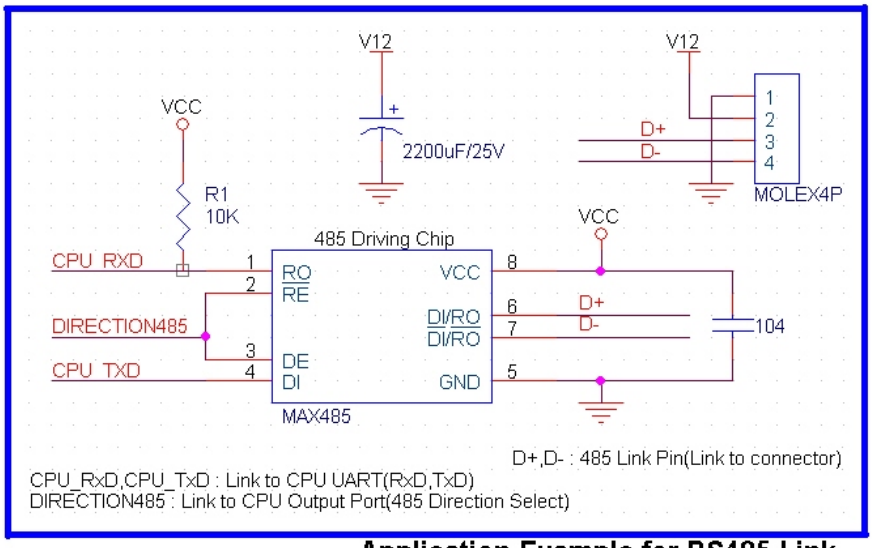
The Cycloid-M2 Board can be directly mounted on the robots.



Cycloid-M2 Board on Robot

Please refer to the Cycloid-M2 Board manual for more details.

Connection to UART To control the Dynamixel, the main Controller needs to convert the signals to RS485. The recommended schematic configuration is as follows:-

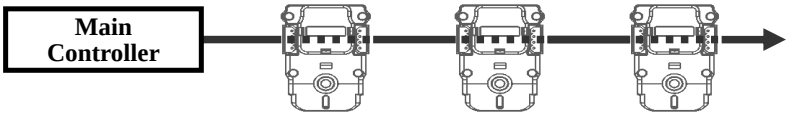


Application Example for RS485 Link

Signal DIRECTION485 determines the data direction as follows:-

- If DIRECTION485 is High: the signal TxD is output as D+ ,D-
- If DIRECTION485 is Low: signal D+ ,D- is input as RxD

RS485 A multi-dropped RS485 (IEEE485) network is established from the main controller. Data Packets are then issued through this single portal.



[RS485 Multi Drop Link]

Please note that caution should be applied when connecting the Dynamixel units to ensure that the pin assignments are correct. Always check the current consumption. The standby current consumption of a Dynamixel unit should be less than 50mA.

Connection Status When power is first applied the Dynamixel LED will blink twice to confirm its healthy status.

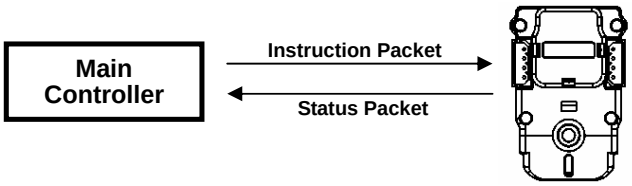
Inspection If the above operation was not successful, then check the connector pin assignment and the voltage/current limit of the power supply.

3. Communication Protocol

3-1. Communication Overview

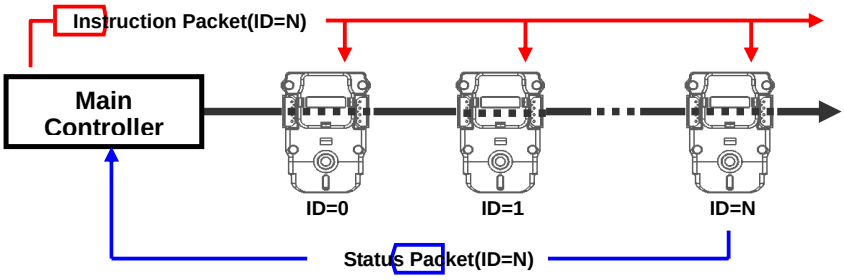
Packet

The Main Controller communicates with the Dynamixel by sending and receiving data packets. There are two types of packets, the Instruction Packet (Main Controller to Dynamixel) and the Status Packet (Dynamixel to Main Controller)



Communication

For the system connection below, if the main controller sends an instruction packet with the ID set to N, only the Dynamixel with this ID value will return its respective status packet and perform the required instruction.



Unique ID

Communication problems will arise if multiple Dynamixel's have the same ID value. This will cause multiple packets to be sent simultaneously resulting in packet collisions. It is imperative that ID values are unique within each data network.

Protocol

The Asynchronous Serial Communication word consists of 8 bits, 1 Stop bit and no parity.

3-2. Instruction Packet

The structure of the Instruction Packet is as follows:

Instruction Packet	0XFF 0XFF ID LENGTH INSTRUCTION PARAMETER1 …PARAMETER N CHECK SUM

The packet byte definitions are as follows:-

0XFF 0XFF	Two 0XFF bytes indicate the start of an incoming packet.
ID	Unique ID of a Dynamixel. The ID can range from 0X00 to 0XFD (254 IDs are available)
Broadcasting ID	ID 0XFE is the Broadcast ID which is assigned to all of the connected Dynamixel's. Status packets will not be returned with a broadcasting ID.
LENGTH	The length of the Status Packet. The value is "Parameter number (N) + 2"
INSTRUCTION	The instruction for the Dynamixel to perform.
PARAMETER0…N	Used if there is additional information to be sent other than the Instruction.
CHECK SUM	The calculation method for the 'Check Sum' is as follows: Check Sum = ~(ID + Length + Instruction + Parameter1 + … Parameter N) If the calculated value is bigger than 255, the lower byte becomes the checksum. ~ represents the Not or complement operation

3-3. Status Packet

The Status Packet is the response packet from the Dynamixel to the Main Controller after receiving an instruction packet. The structure of Status Packet is as follows:-

0XFF 0XFF ID LENGTH ERROR PARAMETER1 PARAMETER2…PARAMETER N CHECK SUM

The meaning of each byte within the packet is as follows:-

0XFF 0XFF — Two 0XFF bytes indicate the start of a packet

ID — ID of the Dynamixel which is returning the packet.

LENGTH — The length of the Status Packet. The value is "Parameter number (N) + 2".

ERROR — Dynamixel communication error flags. The meaning of each bit is as follows:

Bit	Name	Details
Bit 7	0	-
Bit 6	Instruction Error	Set to 1 if an undefined instruction is given without the reg_write instruction.
Bit 5	Overload Error	Set to 1 if the specified torque can't control the load.
Bit 4	Checksum Error	Set to 1 if the checksum of the intruction packet is incorrect
Bit 3	Range Error	Set to 1 if the intruction is out of the usage range
Bit 2	Overheating Error	Set as 1 if the internal temperature of Dynamixel is out of the operative range as set in the control table.
Bit 1	Angle Limit Error	Set as 1 if the Goal Position is set outside of the range between CW Angle Limit and CCW Angle Limit.
Bit 0	Input Voltage Error	Set to 1 if the voltage is out of the operative range set in the control table

PARAMETER0…N — Used when additional information is required.

CHECK SUM — Calculation method of 'Check Sum' is as follows:

Check Sum = ~(ID + Length + Instruction + Parameter1 + … Parameter N)

If the calculated value is bigger than 255, the lower byte becomes the checksum.

~ represents the Not or complement operation

3-4. Control Table

	Address	Item	Access	Initial Value
EEPROM Area	0(0X00)	Model Number(L)	RD	116(0x74)
	1(0X01)	Model Number(H)	RD	0(0x00)
	2(0X02)	Version of Firmware	RD	?
	3(0X03)	ID	RD,WR	1(0x01)
	4(0X04)	Baud Rate	RD,WR	34(0x22)
	5(0X05)	Return Delay Time	RD,WR	80(0x50)
	6(0X06)	CW Angle Limit(L)	RD,WR	0(0x00)
	7(0X07)	CW Angle Limit(H)	RD,WR	0(0x00)
	8(0X08)	CCW Angle Limit(L)	RD,WR	255(0xFF)
	9(0X09)	CCW Angle Limit(H)	RD,WR	3(0x03)
	10(0x0A)	(Reserved)	-	0(0x00)
	11(0X0B)	the Highest Limit Temperature	RD,WR	100(0x64)
	12(0X0C)	the Lowest Limit Voltage	RD,WR	60(0X3C)
	13(0X0D)	the Highest Limit Voltage	RD,WR	190(0xBE)
	14(0X0E)	Max Torque(L)	RD,WR	255(0XFF)
	15(0X0F)	Max Torque(H)	RD,WR	3(0x03)
	16(0X10)	Status Return Level	RD,WR	2(0x02)
	17(0X11)	Alarm LED	RD,WR	4(0x04)
	18(0X12)	Alarm Shutdown	RD,WR	4(0x04)
	19(0X13)	(Reserved)	RD,WR	0(0x00)
	20(0X14)	Down Calibration(L)	RD	?
	21(0X15)	Down Calibration(H)	RD	?
	22(0X16)	Up Calibration(L)	RD	?
	23(0X17)	Up Calibration(H)	RD	?
RAM Area	24(0X18)	Torque Enable	RD,WR	0(0x00)
	25(0X19)	LED	RD,WR	0(0x00)
	26(0X1A)	CW Compliance Margin	RD,WR	0(0x00)
	27(0X1B)	CCW Compliance Margin	RD,WR	0(0x00)
	28(0X1C)	CW Compliance Slope	RD,WR	32(0x20)
	29(0X1D)	CCW Compliance Slope	RD,WR	32(0x20)
	30(0X1E)	Goal Position(L)	RD,WR	[Addr36]value
	31(0X1F)	Goal Position(H)	RD,WR	[Addr37]value
	32(0X20)	Moving Speed(L)	RD,WR	0
	33(0X21)	Moving Speed(H)	RD,WR	0
	34(0X22)	Torque Limit(L)	RD,WR	[Addr14] value
	35(0X23)	Torque Limit(H)	RD,WR	[Addr15] value
	36(0X24)	Present Position(L)	RD	?
	37(0X25)	Present Position(H)	RD	?
	38(0X26)	Present Speed(L)	RD	?
	39(0X27)	Present Speed(H)	RD	?
	40(0X28)	Present Load(L)	RD	?
	41(0X29)	Present Load(H)	RD	?
	42(0X2A)	Present Voltage	RD	?
	43(0X2B)	Present Temperature	RD	?
	44(0X2C)	Registered Instruction	RD,WR	0(0x00)
	45(0X2D)	(Reserved)	-	0(0x00)
	46[0x2E)	Moving	RD	0(0x00)
	47[0x2F)	Lock	RD,WR	0(0x00)
	48[0x30)	Punch(L)	RD,WR	32(0x20)
	49[0x31)	Punch(H)	RD,WR	0(0x00)

Control Table The Control Table consists of data for conditions and movement of the Dynamixel. By writing the values in the control table, you can move the Dynamixel and detect the condition of the Dynamixel.

RAM and EEPROM The data values for the RAM Area will be set to the default initial values on power on. The data values for the EEPROM Area are non-volatile and will be available next power on.

Initial Value The Initial Value column of the control table shows the Factory Default Values for the case of EEPROM Area Data. For the RAM Area Data, the initial value column gives the power on data values.

Please note the following meanings for data assigned to each address in the control table.

Address 0x00,0x01 Model Number. In the case of the DX-116, the value is 0X0074(116).

Address 0x02 Firmware Version.

Address 0x03 ID. Unique ID number to identify the Dynamixel. Different ID's are required to be assigned to "linked" Dynamixels.

Address 0x04 Baud Rate. Determines the Communication Speed. The Calculation method is:-
Speed(BPS) = 2000000/(Address4+ 1)

Data Value as per Major Baud Rate

Address4	BPS Set	Target BPS	Error
1	1000000.0	1000000.0	0.000%
3	500000.0	500000.0	0.000%
4	400000.0	400000.0	0.000%
7	250000.0	250000.0	0.000%
9	200000.0	200000.0	0.000%
16	117647.1	115200.0	- 2.124%
34	57142.9	57600.0	0.794%
103	19230.8	19200.0	- 0.160%
207	9615.4	9600.0	- 0.160%

Note A maximum Baud Rate error of 3% is within the UART communication tolerance.

Address 0x05 Return Delay Time. The time taken after sending the Instruction Packet, to

receive the requested Status Packet. The delay time is given by 2uSec * Address5 value.

Address 0x06,0x07,0x08,0x09

Operating Angle Limit. Set the operating angle to restrict the Dynamixel's angular range. The Goal Position needs to be within the range of:-

CW Angle Limit <= Goal Position <= CCW Angle Limit

An Angle Limit Error will occur if this relationship is not satisfied.

Address 0x0B the Highest Limit Temperature. The upper limit of the Dynamixel's operative temperature. If the Dynamixel's internal temperature is higher than this value, an Over Heating Error Bit (Bit 2 of the Status Packet) will be set. An alarm will be set in Address 17,18. The values are in Degrees Celsius.

Address 0x0C,0x0D the Lowest (Highest) Limit Voltage. Setting the operative upper and lower limits of the Dynamixel's voltages.

If the present voltage (Address42) is out of the specified range, a Voltage Range Error bit will be set in the Status Packet and an alarm executed will be set in Address's 17,18. The values are 10 times the actual voltages. For example, if the Address 12 value is 80, then the lower voltage limit is set to 8V.

Address 0x0E,0x0F, 0x22,0x23

Max Torque. The max torque output for the Dynamixel. When it is set to '0', the Dynamixel enters a Torque Free Run condition. The Max Torque (Torque Limit) is assigned to EEPROM (Address 0X0E,0x0F) and RAM (Address 0x22,0x23) and a power on condition will copy EEPROM values to RAM. The torque of a Dynamixel is limited by (Address0x22,0x23) of RAM.

Address 0X10 Status Return Level. To determine whether the Dynamixel will return the Status Packet after the transmission of an Instruction Packet.

Address16	Return of Status Packet
0	Do not respond to any instruction
1	Respond only to READ_DATA instructions
2	Respond to all instructions

In the case of an instruction which uses the Broadcast ID (0XFE), regardless of the Address 0x10 value, the Status Packet will not be returned.

Address 0X11 **Alarm LED.** When an Error occurs, if the corresponding Bit is set to 1, then the LED blinks.

Bit	Function
Bit 7	0
Bit 6	If set to 1, LED blinks when Instruction Error occurs
Bit 5	If set to 1, LED blinks when Overload Error occurs
Bit 4	If set to 1, LED blinks when Checksum Error occurs
Bit 3	If set to 1, LED blinks when Range Error occurs
Bit 2	If set to 1, LED blinks when Overheating Error occurs
Bit 1	If set to 1, LED blinks when Angle Limit Error occurs
Bit 0	If set to 1, LED blinks when Input Voltage Error occurs

This function operates as the logical "OR"ing of all set bits. For example, when the register is set to 0X05, the LED will blink when a Voltage Error occurs or when an Overheating Error occurs. Upon returning to a normal condition from an error state, the LED stops blinking after 2 seconds.

Address 0X12 **Alarm Shutdown.** When an Error occurs, if the corresponding Bit is set to a 1, then the Dynamixel will shut down (Torque off).

Bit	Function
Bit 7	0
Bit 6	If set to 1, torque off when Instruction Error occurs
Bit 5	If set to 1, torque off when Overload Error occurs
Bit 4	If set to 1, torque off when Checksum Error occurs
Bit 3	If set to 1, torque off when Range Error occurs
Bit 2	If set to 1, torque off when Overheating Error occurs
Bit 1	If set to 1, torque off when Angle Limit Error occurs
Bit 0	If set to 1, torque off when Input Voltage Error occurs

This function operates as the logical "OR"ing of all set bits. However, unlike the Alarm LED, after returning to a normal condition, it maintains a torque off status. To remove this restriction, Torque Enable (Address0X18) is required to be set to 1.

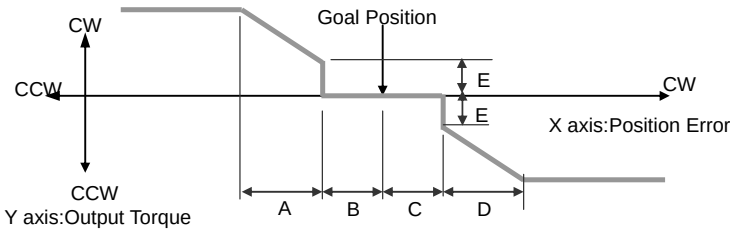
Address 0x14~0x17 **Calibration.** Data used for compensating for the differences between Robotis products. Users cannot change this area.

From Address 0x18 in the RAM area.

Address 0x18 Torque Enable. When power is first applied the Dynamixel enters the Torque Free Run condition. To allow torque to be applied Address 0x18 must be set to 1. (Torque Enabled Condition)

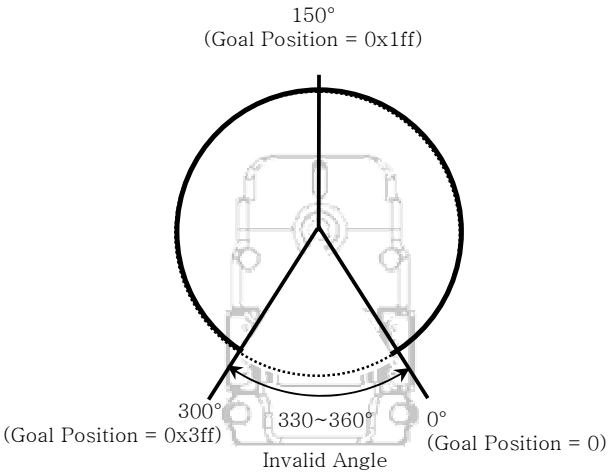
Address 0x19 LED is on when set to 1 and LED is off if set to 0.

Address 0x1A~0x1D Compliance Margin and Slope. The Dynamixel controls Compliance by setting the Margin and Slope. If used well Compliance will absorb the shocks. The following graph demonstrates the use of Compliance values (length of A,B,C & D) relative to Position Error and applied torque.



A : CCW Compliance Slope(Address0x1D)
B : CCW Compliance Margin(Address0x1B)
C : CW Compliance Margin(Address0x1A)
D : CW Compliance Slope (Address0x1C)
E : Punch(Address0x30)

Address 0X1E,0x1F Goal Position. Requested Angular Position for the Dynamixel to move to. If this is set to 0x3ff, then the goal position will be 300°.



Address 0x20,0x21 **Moving Speed.** The angular speed to move to the Goal Position. If set to the maximum values of 0x3ff, it moves at 70RPM.

Address 0x24,0x25 **Present Position.** Current position of the Dynamixel.

Address 0x26,0x27 **Present Speed.** Current Speed of the Dynamixel.

Address 0x28,0x29 **Present Load.** Load size on the Dynamixel in action. Bit 10 is the direction of the load.

BIT	15~11	10	9	8	7	6	5	4	3	2	1	0
Value	0	Load Direction	Load Value									

Load Direction = 0 : CCW Load, Load Direction = 1: CW Load

Address 0x2A **Present Voltage.** The voltage applied to the Dynamixel. The value is 10 times the actual voltage. For example, 10V is read as 100(0x64).

Address 0x2B **Present Temperature.** Current internal Dynamixel temperature (Degrees Celsius).

Address 0x2C **Registered Instruction.** Set to 1 when a REG_WRITE instruction is made. After an Action instruction and an action it is reset to 0.

Address 0x2E **Moving.** Set to 1 when the Dynamixel moves by its own power.

Address 0x2F — Lock. If set to 1, only Address 0x18 ~ Address 0x23 can be written to. Other areas are not permitted. Once locked, it can only be unlocked by powering down.

Address 0x30,0x31 — Punch. Minimum current being supplied to the motor during an action. The minimum value is 0x20 and the maximum value as 0x3ff.

Range — Each Register has an operative range. Write instructions made outside of these ranges will return an error. The following table summarises the data range for each register. 16 bit data registers are indicated as (L) and (H), two bytes. Each byte of a two byte register can be written to independently.

Write Address	Writing Item	Length (bytes)	Min	Max
3(0X03)	ID	1	0	253(0xfd)
4(0X04)	Baud Rate	1	0	254(0xfe)
5(0X05)	Return Delay Time	1	0	254(0xfe)
6(0X06)	CW Angle Limit	2	0	1023(0x3ff)
8(0X08)	CCW Angle Limit	2	0	1023(0x3ff)
11(0X0B)	the Highest Limit Temperature	1	0	150(0x96)
12(0X0C)	the Lowest Limit Voltage	1	50(0x32)	250(0xfa)
13(0X0D)	the Highest Limit Voltage	1	50(0x32)	250(0xfa)
14(0X0E)	Max Torque	2	0	1023(0x3ff)
16(0X10)	Status Return Level	1	0	2
17(0X11)	Alarm LED	1	0	127(0x7f)
18(0X12)	Alarm Shutdown	1	0	127(0x7f)
19(0X13)	(Reserved)	1	0	1
24(0X18)	Torque Enable	1	0	1
25(0X19)	LED	1	0	1
26(0X1A)	CW Compliance Margin	1	0	254(0xfe)
27(0X1B)	CCW Compliance Margin	1	0	254(0xfe)
28(0X1C)	CW Compliance Slope	1	1	254(0xfe)
29(0X1D)	CCW Compliance Slope	1	1	254(0xfe)
30(0X1E)	Goal Position	2	0	1023(0x3ff)
32(0X20)	Moving Speed	2	0	1023(0x3ff)
34(0X22)	Torque Limit	2	0	1023(0x3ff)
44(0X2C)	Registered Instruction	1	0	1
47(0X2F)	Lock	1	1	1
48(0X30)	Punch	2	0	1023(0x3ff)

[Control Table Data Range and Length for Writing]

4. Instruction Set and Examples

The following Instructions are available.

Instruction Name	Function	Value	Number of Parameter
PING	No action. Used to obtain a Dynamixel Status Packet.	0x01	0
READ_DATA	Read the values in the Control Table.	0x02	2
WRITE_DATA	Write the values to the Control Table.	0x03	2 ~
REG_WRITE	Similar to WRITE_DATA, but stay in standby mode until the write upon the action instruction.	0x04	2 ~
ACTION	Start the action registered by REG_WRITE	0x05	2
RESET	Change the values of the Dynamixel in the control table back to the Factory Default Values.	0x06	0

4-1. WRITE_DATA

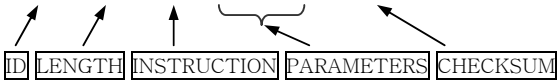
Function Write data into the control table of the Dynamixel
Length N+ 3 (Writing Data is N)
Instruction 0X03
Parameter1 Start Address of the Area to write Data
Parameter2 1st Data to write
Parameter3 2nd Data to write
Parameter N+ 1 Nth Data to write

Example 1 Set ID of connected Dynamixel as 1

Write 1 into the Address 3 of the Control Table. The ID is transmitted using

Broadcasting ID (0xFE).

Instruction Packet : 0XFF 0XFF 0XFE 0X04 0X03 0X03 0X01 0XF6`



Because it was transmitted by Broadcast ID(0XFE), no return status packet.

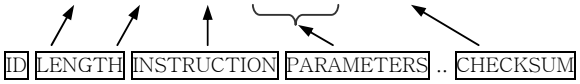
4-2. READ_DATA

Function	Read data from the Control Table of Dynamixel.
Length	0X04
Instruction	0X02
Parameter1	Starting Address of Data to Read
Parameter2	length of Data to Read

Example 2 Read the internal temperature of the Dynamixel with ID=1.

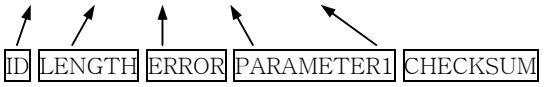
Read 1 byte from the Address 0x2B values of the Control Table.

Instruction Packet : 0XFF 0XFF 0X01 0X04 0X02 0X2B 0X01 0XCC`



The returned Status Packet will be as follows.

Status Packet : 0XFF 0XFF 0X01 0X03 0X00 0X20 0XDB



The value read is 0x20.The current Dynamixel' s internal temperature is approximately 32℃ (0X20).

4-3. REG_WRITE and ACTION

REG_WRITE

Function	REG_WRITE instruction is similar to the WRITE_DATA instruction, but the execution timing is different. When the Instruction Packet is received the values are saved into the Buffer and the Write instruction is under a standby status. The Registered Instruction register (Address 0x2C) is set to 1. After an Action Instruction Packet is received the registered Write instruction is executed.
Length	N+ 3 (The number of Write Data bytes is N)
Instruction	0X04
Parameter1	Start Address for Write Data
Parameter2	1st Data to Write
Parameter3	2nd Data to Write
Parameter N+ 1	Nth Data to Write

ACTION

Function	Execute the WRITE instruction written by REG_WRITE
Length	0X02
Instruction	0X05
Parameter	NONE

The ACTION instruction is useful when multiple Dynamixels needs to move simultaneously. When controlling multiple units, slight time delays occur between the 1st unit to receive an instruction and the last one. The Dynamixel approach fixes this problem through the use of the ACTION instruction.

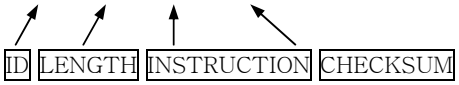
Broadcasting When sending ACTION instructions to move more than two Dynamixel units, the Broadcast ID (0XFE) should be utilised.

4-4. PING

Function	Used to request a specific Dynamixel status packet or to check the existence of a Dynamixel with a particular ID
Length	0X02
Instruction	0X01
Parameter	NONE

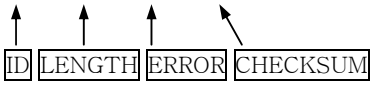
Example 3 To obtain the status packet of a Dynamixel with ID=1

Instruction Packet : 0XFF 0XFF 0X01 0X02 0X01 0XFB`



The returned Status Packet is as follow;

Status Packet : 0XFF 0XFF 0X01 0X02 0X00 0XFC



4-5. RESET

Function Restore the condition of the Control Table of the Dynamixel back to the Factory Default values.

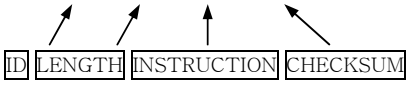
Length 0X02

Instruction 0X06

Parameter NONE

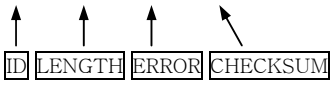
Example 4 Reset Dynamixe with ID=0

Instruction Packet : 0XFF 0XFF 0X00 0X02 0X06 0XF7`



The returned Status Packet is as follows;

Status Packet : 0XFF 0XFF 0X00 0X02 0X00 0XFD



Please note that after a RESET instruction, the ID of the Dynamixel is changed to 1.

5. Example

Used to explain through example with the assumption that the Dynamixel has been Reset (ID = 1, Baudrate = 57142BPS)

Example 5 Read the Model Number and Firmware Version of a Dynamixel with ID=1

Instruction Packet Instruction = READ_DATA, Address = 0x00, Length = 0x03

Communication
->[Dynamixel]:FF FF 01 04 02 00 03 F5 (LEN:008)
<-[Dynamixel]:FF FF 01 05 00 74 00 08 7D (LEN:009)

Status Packet Result Model Number = 116(0x74), Firmware Version = 0x08

Example 6 Change ID number of Dynamixel from 1 to 0.

Instruction Packet Instruction = WRITE_DATA, Address = 0x03, DATA = 0x00

Communication
->[Dynamixel]:FF FF 01 04 03 03 00 F4 (LEN:008)
<-[Dynamixel]:FF FF 01 02 00 FC (LEN:006)

Status Packet Result NO ERROR

Example 7 Change Baud Rate of Dynamixel to 1M bps.

Instruction Packet Instruction = WRITE_DATA, Address = 0x04, DATA = 0x01

Communication
->[Dynamixel]:FF FF 00 04 03 04 01 F3 (LEN:008)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

Example 8 Reset Return Delay Time of Dynamixel with ID=0 to 4us.
A Return Delay Time Value of 1 corresponds to 2us.

Instruction Packet Instruction = WRITE_DATA, Address = 0x05, DATA = 0x02

Communication
->[Dynamixel]:FF FF 00 04 03 05 02 F1 (LEN:008)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

The best approach is to set the Return Delay Time to the minimum value the Main Controller will allow.

Example 9 Limit the the operative angles of a Dynamixel with ID=0 to 0~150°.
If CCW Angle Limit is 0x3ff, it is 300°, therefore the values for 150°is 0x1ff.

Instruction Packet Instruction = WRITE_DATA, Address = 0x08, DATA = 0xff, 0x01

Communication
->[Dynamixel]:FF FF 00 05 03 08 FF 01 EF (LEN:009)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

Example 10 Reset the upper limit temperature of the Dynamixel with ID=1 to 80°.

Instruction Packet Instruction = WRITE_DATA, Address = 0x0B, DATA = 0x50

Communication
->[Dynamixel]:FF FF 00 04 03 0B 50 9D (LEN:008)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

Example 11 Set the operative voltage of a Dynamixel with ID=0 to 10V ~ 17V.
10V is expressed as 100(0x64) and 17V as 170(0xAA).

Instruction Packet Instruction = WRITE_DATA, Address = 0x0C, DATA = 0x64, 0xAA

Communication
->[Dynamixel]:FF FF 00 05 03 0C 64 AA DD (LEN:009)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

Example 12 Make the Dynamixel with ID=0 perform only 50% of the maximum torque.
Set the max torque values within the EEPROM area to 50% (0x1ff) of the maximum value (0x3ff)

Instruction Packet Instruction = WRITE_DATA, Address = 0x0E, DATA = 0xff, 0x01

Communication ->[Dynamixel]:FF FF 00 05 03 0E FF 01 E9 (LEN:009)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR
After a power off and on, you can check the effect of the changes in max torque.

Example 13 Stop the Dynamixel with ID=0 from returning a Status Packet.

Instruction Packet Instruction = WRITE_DATA, Address = 0x10, DATA = 0x00

Communication ->[Dynamixel]:FF FF 00 04 03 10 00 E8 (LEN:008)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR
The Status Packet will not be returned for the next instruction.

Example 14 If temperature values are higher than those defined operative temperatures, set the alarm to make the Dynamixel blink and then shut down the Dynamixel (Torque off).
Overheating Error is Bit 2, therefore set the alarm value to 0x04.

Instruction Packet Instruction = WRITE_DATA, Address = 0x11, DATA = 0x04, 0x04

Communication ->[Dynamixel]:FF FF 00 05 03 11 04 04 DE (LEN:009)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

Example 15 Turn on the LED of the Dynamixel with ID=0 and enable the torque.

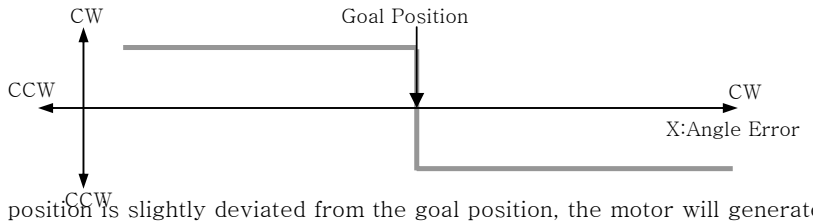
Instruction Packet Instruction = WRITE_DATA, Address = 0x18, DATA = 0x01, 0x01

Communication ->[Dynamixel]:FF FF 00 05 03 18 01 01 DD (LEN:009)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

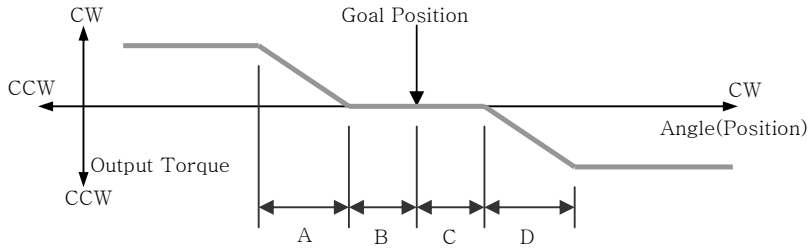
Status Packet Result NO ERROR
Physical confirmation of an enabled torque can be obtained by attempting to rotate the motor with your hand.

Example 16 Set the Dynamixel with ID=0 to have a Compliance Margin = 1 and Compliance Slope=0x40

The following graph shows the Angle Error and Torque Output.



If the position is slightly deviated from the goal position, the motor will generate a high torque to try to adjust its position to that of the goal position. The true control method is different due to the inertia. The condition provided in the above example can be shown in the graph below:-



A : CCW Compliance Slope(Address0x1D) = 0x40(Approximately 18.8°)
B : CCW Compliance Margin(Address0x1B) = 0x01 (Approximately 0.29°)
C : CW Compliance Margin(Address0x01A) = 0x01(Approximately 0.29°)
D : CW Compliance Slope(Address0x1C) = 0x40 (Approximately 18.8°)

Instruction Packet Instruction = WRITE_DATA, Address = 0x1A, DATA = 0x01, 0x01, 0x40, 0x40

Communication
->[Dynamixel]:FF FF 00 07 03 1A 01 01 40 40 59 (LEN:011)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

The effect of a Compliance Slope changes at the boundary of 2^n (n is positive

number), that is, the effect of the values of Compliance between 0x11 and 0x20 are the same.

Example 17 Position Dynamixel with ID=0 at Position 180°after moving it at the speed of 35RPM.

Set Address 0x1E(Goal Position) = 0x200, Address 0x20(Moving Speed) = 0x200

Instruction Packet Instruction = WRITE_DATA, Address = 0x1E, DATA = 0x00, 0x02, 0x00, 0x02

Communication
->[Dynamixel]:FF FF 00 07 03 1E 00 02 00 02 D3 (LEN:011)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

Example 18 Set the position of a Dynamixel (ID=0) to an angular Position of 0°and another Dynamixel (ID=1) to an angular Position of 300°. Make sure both Dynamixels start at the same time.

If you use WRITE_DATA instruction, two Dynamixel can not start at the same time, therefore use REG_WRITE and ACTION.

Instruction Packet
ID=0, Instruction = REG_WRITE, Address = 0x1E, DATA = 0x00, 0x00
ID=1, Instruction = REG_WRITE, Address = 0x1E, DATA = 0xff, 0x03
ID=0xfe(Broadcasting ID), Instruction = ACTION,

Communication
->[Dynamixel]:FF FF 00 05 04 1E 00 00 D8 (LEN:009)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)
->[Dynamixel]:FF FF 01 05 04 1E FF 03 D5 (LEN:009)
<-[Dynamixel]:FF FF 01 02 00 FC (LEN:006)
->[Dynamixel]:FF FF FE 02 05 FA (LEN:006)
<-[Dynamixel]: //No return packet against broadcasting ID

Status Packet Result NO ERROR

Example 19 Prevent the Dynamixel with ID=0 from changing values other than within the range between Address 0x18 and Address 0x23.

Set Address 0x2F(Lock) to 1.

Instruction Packet Instruction = WRITE_DATA, Address = 0x2F, DATA = 0x01

Communication ->[Dynamixel]:FF FF 00 04 03 2F 01 C8 (LEN:008)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

If Locked, it can only be unlocked by removing power.

If trying to access other data areas whilst locked, an error will be returned.

->[Dynamixel]:FF FF 00 05 03 30 40 00 87 (LEN:009)
<-[Dynamixel]:FF FF 00 02 08 F5 (LEN:006)

Range Error

Example 20 Set the minimum punch (output) in the Dynamixel with ID=0 to 0x40.

Instruction Packet Instruction = WRITE_DATA, Address = 0x30, DATA = 0x40, 0x00

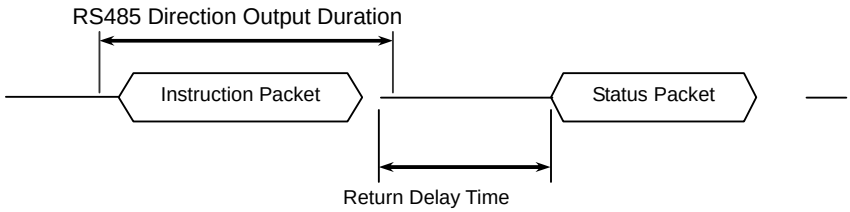
Communication ->[Dynamixel]:FF FF 00 05 03 30 40 00 87 (LEN:009)
<-[Dynamixel]:FF FF 00 02 00 FD (LEN:006)

Status Packet Result NO ERROR

Appendix

RS485 Direction

The Main Controller sets the RS485 communication direction to be an input at all times other than when specifically sending an instruction packet.



Return Delay Time

The Default Value is 160us and can be changed via the Control Table at Address 0x05. The Main Controller needs to change the RS485 communication direction after sending an instruction packet within the Return Delay time range.

485 Direction

The CPU normally indicates the UART_STATUS and the bit definitions within the register have the following meanings:-

TXD_BUFFER_READY_BIT : Transmission DATA can be loaded into the Buffer. Note that the SERIAL TX BUFFER is not necessarily completely empty.

TXD_SHIFT_REGISTER_EMPTY_BIT : Set when a Transmission byte has completed its transmission.

The TXD_BUFFER_READY_BIT is used when a byte is to be transmitted via the serial communication channel and an example is as follows:-

```
TxDByte(byte bData)
{
  while(!TXD_BUFFER_READY_BIT);   //wait until data can be loaded.
  SerialTxDBuffer = bData;          //data load to TxD buffer
}
```

When changing the RS485 Direction, check the

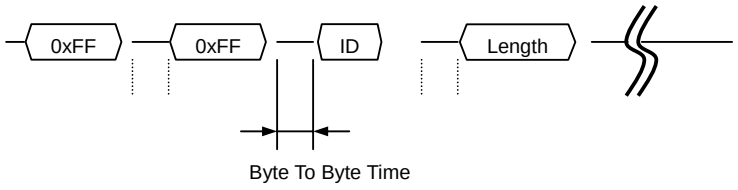
TXD_SHIFT_REGISTER_EMPTY_BIT.

An example program to send an Instruction packet:-

```
LINE 1    PORT_485_DIRECTION = TX_DIRECTION;
LINE 2    TxDByte(0xff);
LINE 3    TxDByte(0xff);
LINE 4    TxDByte(bID);
LINE 5    TxDByte(bLength);
LINE 6    TxDByte(bInstruction);
LINE 7    TxDByte(Parameter0);  TxDByte(Parameter1); …
LINE 8    DisableInterrupt(); // interrupt should be disabled
LINE 9    TxDByte(Checksum);  //last TxD
LINE 10   while(!TXD_SHIFT_REGISTER_EMPTY_BIT); //Wait till last data bit has been
            sent
LINE 11   PORT_485_DIRECTION = RX_DIRECTION; //485 direction changed to RXD
LINE 12   EnableInterrupt(); // enable interrupt again
```

Please note the important lines (LINE 8 to LINE12).
Line 8 is necessary since an interrupt here may cause a delay longer than the return delay time and corruption to the front of the status packet may occur

Byte to Byte Time The delay time between bytes when sending the instruction packet. If the delay time is over 100ms, then recognise it as a communication problem and wait for header(0xff 0xff) of the packet again.



C Language Example

```
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#include <dos.h>
#include <mem.h>

#define MCS80
#include "..\..\base.h"
#include "..\lib188es.c"

#define RS485_DIRECTION_BIT 0x2000
#define RS485_TXD (SET_PORT1(RS485_DIRECTION_BIT))
#define RS485_RXD (RESET_PORT1(RS485_DIRECTION_BIT))

#define BROADCASTING_ID             0xfe
#define MEMORY_SPARE                10

#define ADDRESS_TORQUE_ENABLE       20
#define ADDRESS_OPERATING_MODE      19
#define ADDRESS_ID                  3
#define ADDRESS_GOAL_POSITION       26

#define INST_PING                   0x01
#define INST_READ                   0x02
#define INST_WRITE                  0x03
#define INST_SET_SCHEDULE           0x04
#define INST_DO_SCHEDULE            0x05
#define INST_RESET                  0x06

#define DIGITAL_MODE                0
```

Definition area

```
//Global variable number
byte gbpInterruptRxBuffer[256+MEMORY_SPARE];    //485 RxD Data Buffer
byte gbRxBufferReadPointer,gbRxBufferWritePointer; //Pointers for access the gbpInterruptRxBuffer

void static interrupt far Serial0Interrupt(void);
void PrintBuffer(byte *bpPrintBuffer, byte bLength);
byte TxPacket(byte *bpTxBuffer, byte bID, byte bInstruction, byte *bpParameter, byte bParameterLength);
byte RxPacket(byte *bpRxBuffer);
```

Major Function

```
void main(void)
{
    byte bID,bPacketLength;
    byte bpTxBuffer[20+MEMORY_SPARE];
    byte bpRxBuffer[256+MEMORY_SPARE];
    byte bpParameter[256+MEMORY_SPARE];

    CLI; //Disable Interrupt
    //PortInitialize();
    InitPort(OUT, PDATA1, 0xe000); //Set Out(Port30,31:LED,Port29:485Direction)
    InitPort(IN,    PDATA1, 0x0004); //Set In(Port2:Push SW)
    InitPort(NORMAL_USE,    PDATA1, 0x00c0); //
    RS485_RXD;      //Set 485 Direction Select Port to 0

    //UartInitialize();
    outpw(SP0BAUD,5); //.2MBPS = 16MHz/16/5
    outpw(SP1BAUD,17); //57600
    outpw(SP0STS,0);
    outpw(SP1STS,0);

    //InterruptInitialize();
```

CPU dependent Initialize

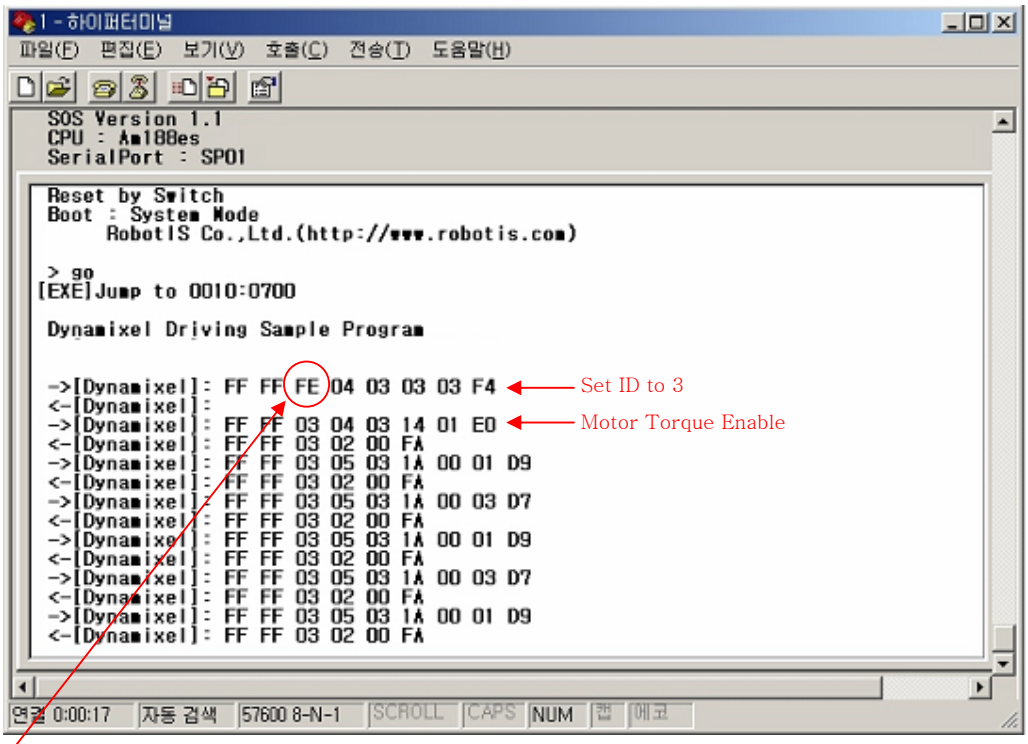
```
    SetInterrupt(INUM_SERIAL0,Serial0Interrupt,INT_ENABLE|INT_RX, 7/*Priority*/);

    //Memory Initialize
    gbRxBufferReadPointer = gbRxBufferWritePointer = 0;
    STI; //Interrupt Enable

    /*
     *
     *   Example For Driving Dynamixel DX-116
     *
     */
    TxDString("\r\n\n Dynamixel Driving Sample Program");


    //Set ID to 3
    bpParameter[0] = ADDRESS_ID;
    bpParameter[1] = 3;
    bPacketLength = TxPacket(bpTxBuffer, BROADCASTING_ID, INST_WRITE, bpParameter, 2/*Length of Parameter*/);
    bID = 3;
    TxDString("\r\n ->[Dynamixel]: "); PrintBuffer(bpTxBuffer,bPacketLength);
    bPacketLength = RxPacket(bpRxBuffer);
    TxDString("\r\n <-[Dynamixel]: "); PrintBuffer(bpRxBuffer,bPacketLength);

    //Set Motor Torque Enable
    bpParameter[0] = ADDRESS_TORQUE_ENABLE;
    bpParameter[1] = 1;
    bPacketLength = TxPacket(bpTxBuffer, bID, INST_WRITE, bpParameter, 2/*Length of Parameter*/);
    TxDString("\r\n ->[Dynamixel]: "); PrintBuffer(bpTxBuffer,bPacketLength);
    bPacketLength = RxPacket(bpRxBuffer);
    TxDString("\r\n <-[Dynamixel]: "); PrintBuffer(bpRxBuffer,bPacketLength);

    //Move to Position 0x0100 <-> 0x300
    while(1)
    {
        bpParameter[0] = ADDRESS_GOAL_POSITION;
        bpParameter[1] = 0x00; bpParameter[2] = 0x01;
        bPacketLength = TxPacket(bpTxBuffer, bID, INST_WRITE, bpParameter, 3/*Length of Parameter*/);
        TxDString("\r\n ->[Dynamixel]: "); PrintBuffer(bpTxBuffer,bPacketLength);
        bPacketLength = RxPacket(bpRxBuffer);
        TxDString("\r\n <-[Dynamixel]: "); PrintBuffer(bpRxBuffer,bPacketLength);
        MiliSec(1000);

        bpParameter[0] = ADDRESS_GOAL_POSITION;
        bpParameter[1] = 0x00; bpParameter[2] = 0x03;
        bPacketLength = TxPacket(bpTxBuffer, bID, INST_WRITE, bpParameter, 3/*Length of Parameter*/);
        TxDString("\r\n ->[Dynamixel]: "); PrintBuffer(bpTxBuffer,bPacketLength);
        bPacketLength = RxPacket(bpRxBuffer);
        TxDString("\r\n <-[Dynamixel]: "); PrintBuffer(bpRxBuffer,bPacketLength);
        MiliSec(1000);
    }

    //while(1);
}

void static interrupt far Serial0Interrupt(void)     //Serial RxD Interrupt routine
{
    STI; //Enable Interrupt
    gbpInterruptRxBuffer[gbRxBufferWritePointer++] = RXD_DATA0;    //Reading Arrival Data
    outpw(EOI, 0x14); //End of Interrupt
}


byte RxPacket(byte *bpRxBuffer)
{
```

```
    #define RX_TIMEOUT_COUNT2     10000L    //10mSec
    #define RX_TIMEOUT_COUNT1    (RX_TIMEOUT_COUNT2*10L)    //1Sec

    unsigned long ulCounter;
    byte bCount;

    ulCounter = 0;
    while(gbRxBufferReadPointer == gbRxBufferWritePointer)
    {
        if(ulCounter++ > RX_TIMEOUT_COUNT1)
        {
            return 0;
        }
    }
    bCount = 0;
    for(bCount = 0; bCount < 254; bCount++) //Maximum Data Length Limit : 255
    {
        ulCounter = 0;
        while(gbRxBufferReadPointer == gbRxBufferWritePointer)
        {
            if(ulCounter++ > RX_TIMEOUT_COUNT2)
            {
                return bCount;
            }
        }
        bpRxBuffer[bCount] = gbpInterruptRxBuffer[gbRxBufferReadPointer++];
    }
    return bCount;
}

byte TxPacket(byte *bpTxBuffer, byte bID, byte bInstruction, byte *bpParameter, byte bParameterLength)
{
    byte bCount,bCheckSum,bPacketLength;

    bpTxBuffer[0] = 0xff;
    bpTxBuffer[1] = 0xff;
    bpTxBuffer[2] = bID;
    bpTxBuffer[3] = bParameterLength+2; //Length(Paramter,Instruction,Checksum)
    bpTxBuffer[4] = bInstruction;
    for(bCount = 0; bCount < bParameterLength; bCount++)
    {
        bpTxBuffer[bCount+5] = bpParameter[bCount];
    }
    bCheckSum = 0;
    bPacketLength = bParameterLength+4+2;
    for(bCount = 2; bCount < bPacketLength-1; bCount++) //except 0xff,checksum
    {
        bCheckSum += bpTxBuffer[bCount];
    }
    bpTxBuffer[bCount] = ~bCheckSum; //Writing Checksum with Bit Inversion

    RS485_TXD; //Change 485 Direction to Transmission
    for(bCount = 0; bCount < bPacketLength; bCount++)
    {
        TxD80(bpTxBuffer[bCount]);
    }
    while(!TXD_FINISH0); //Wait until TXD Shift register empty
    RS485_RXD;
    return(bPacketLength);
}

void PrintBuffer(byte *bpPrintBuffer, byte bLength)
{
    byte bCount;
    for(bCount = 0; bCount < bLength; bCount++)
```

Should wait until last data bit transmission is completed.
Note.: 'Shift register empty' is differ from 'Tx Ready'. Tx Ready just means you can load the data to CPU UART TxD Register. There can be several Tx Buffering registers as what kind of CPU

```
    {
        TxD8Hex(bpPrintBuffer[bCount]);
        TxD8(' ');
    }
}
```

Result



0xFE is BROADCAST_ID, so Dynamixel does not return status packet.(First 2 Instruction Packet)

Connector

Company Name : Molex

Pin Number: 4

Model Number

	Molex Part Number	Old Part Number
Male	22-03-5045	5267-04
Female	50-37-5043	5264-04

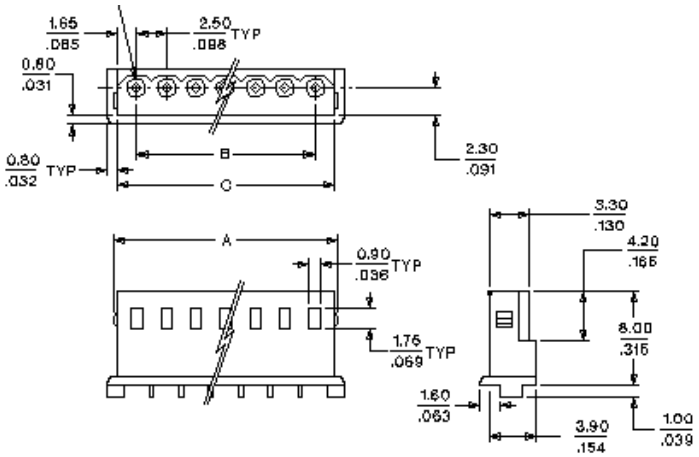
Temperature range : -40°C to + 105°C

Contact Insertion Force-max : 14.7N (3.30 lb)

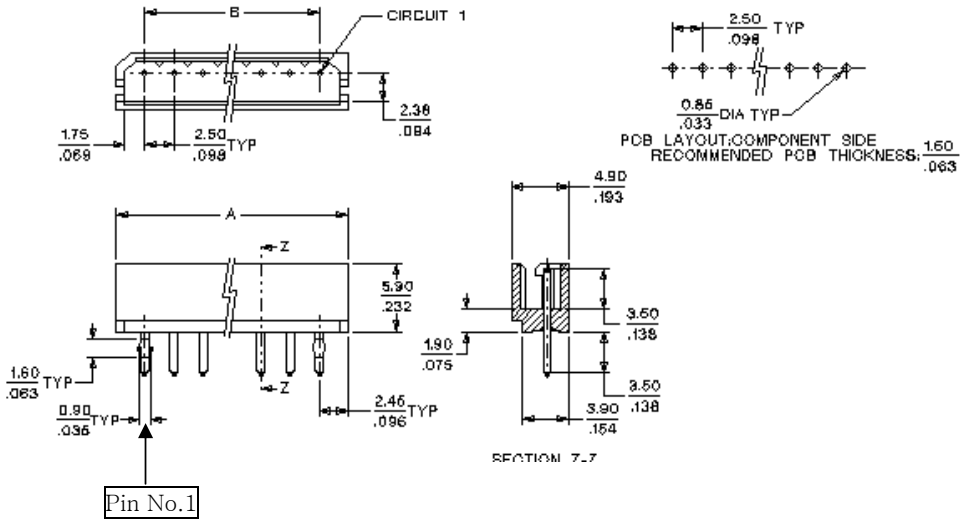
Contact Retention Force-min : 14.7N (3.30 lb)

www.molex.com or www.molex.co.jp for more detail information

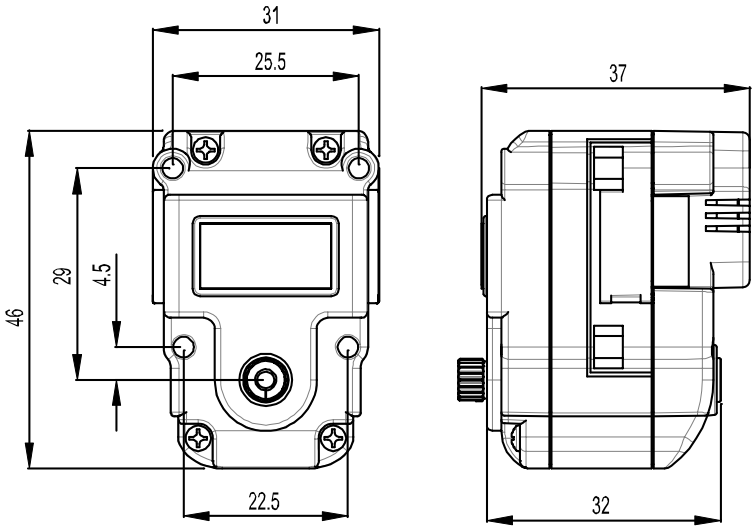
Female Connector



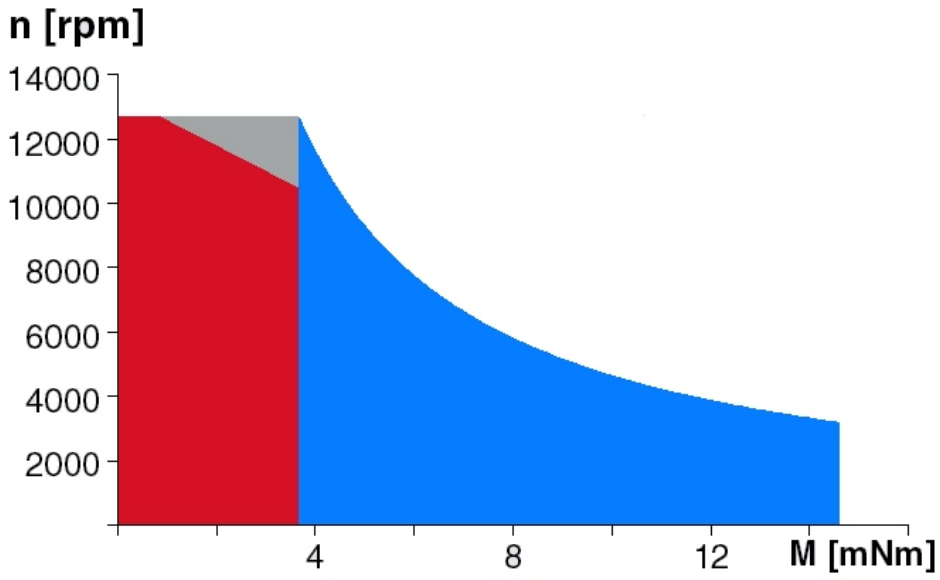
Male Connector



Dimension

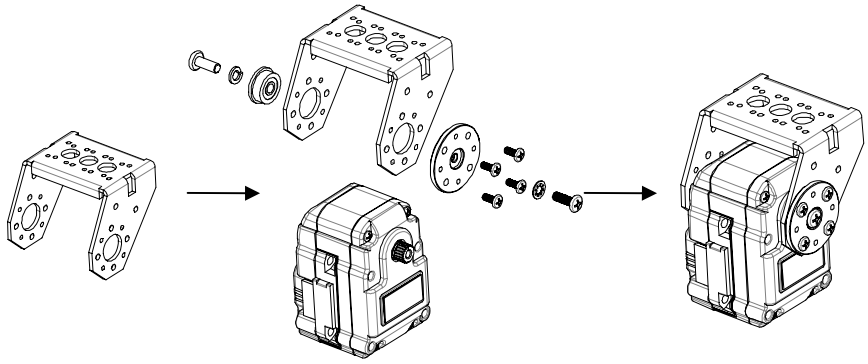


Motor Curve(No reduction gear state)

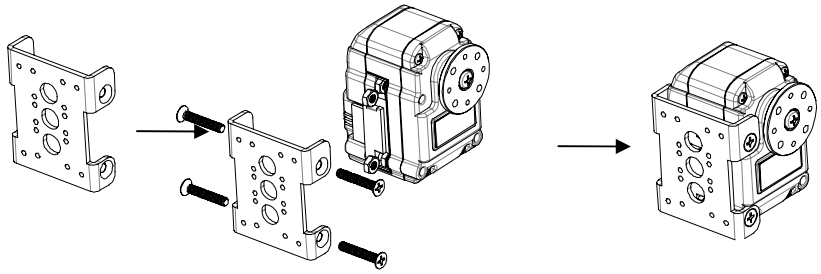


Optional Frame Application Example

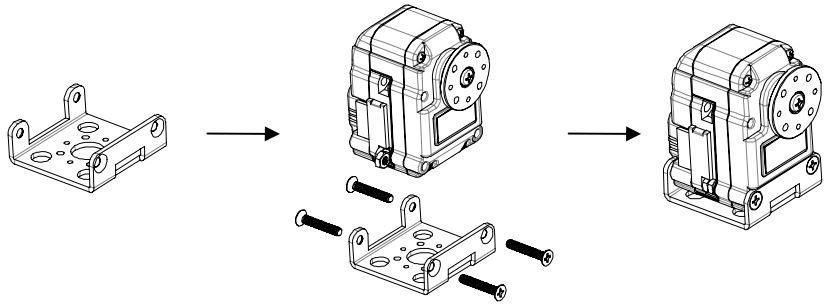
OF116H



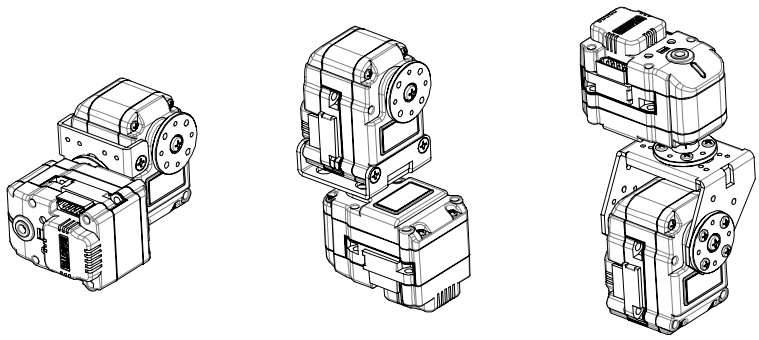
OF116S



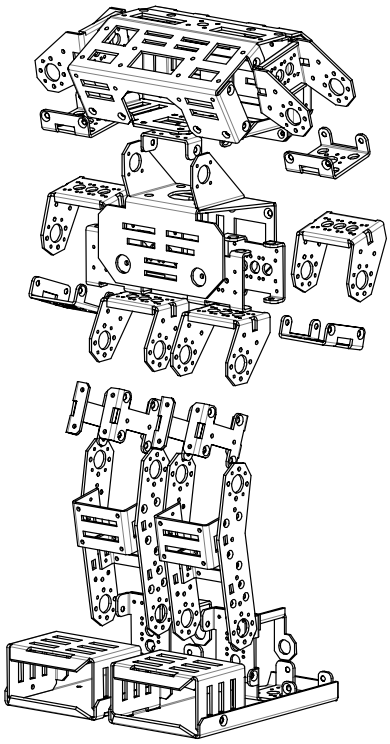
OF116B

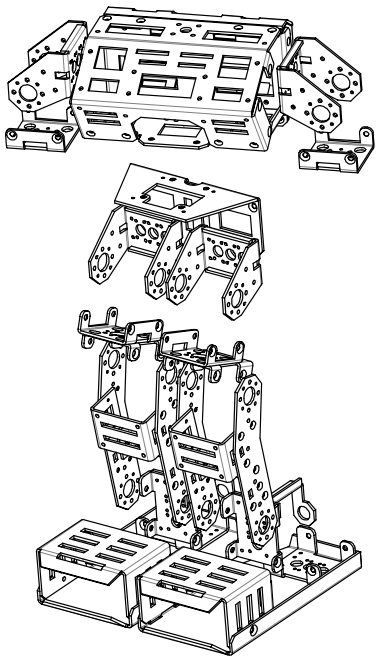


Body to Body Mount



Full Option frame



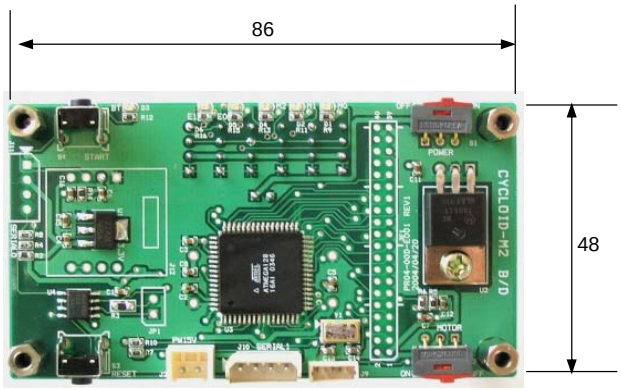


23Axis frame full Set **15Axis frame full set**

Helmet and hands plastic is not included in frame set

Cycloid M2 Board

- The Custom-Built Controller for Dynamixel
- Optional Part : Blue-tooth module, RS232 UART, and 6-button blue-tooth remocon.
- Can be adapted multi-axis robot directly.



Application Example