

Protocol of UART Bus

Summary

This protocol applies to servos using TTL level single-wire half-duplex or two-wire full-duplex interfaces, as well as RS485 interfaces with strong anti-interference capabilities using differential levels. Communication remains asynchronous, with signal transmission and reception processed asynchronously.

Communication between the controller and the servo uses a query-response method. The controller sends a command frame, and the servo returns a response frame.

Multiple servos are allowed in a single bus network, so each servo is assigned a unique ID number within the network. Instruction Pack issued by the controller include ID information; only servos matching the ID number can execute the received instruction and return a response. One byte consists of 1 start bit, 8 data bits, and 1 stop bit, with no parity bit, for a total of 10 bits.

When some parameters in the memory table use a two-byte value range, the two bytes are in Little-endian format (low byte first, high byte last). Since each servo model has slightly different functions, please refer to the specific Control Table of the model before control.

Instruction Packet

Instruction Packet is the command data sent to the Device.

Header1	Header2	Packet ID	Length	Instruction	Param 1	...	Param N	Checksum
0xFF	0xFF	Packet ID	Length	Instruction	Param 1	...	Param N	CHKSUM

• Header

The field indicates the start of the Packet.

• Packet ID

The field that indicates the ID of the Device that should receive the Instruction Packet and process it

1. Range : 0 ~ 253 (0x00 ~ 0xFD), which is a total of 254 numbers that can be used.
2. Broadcast ID : 254 (0xFE), which makes all connected devices execute the Instruction Packet.

• Length

The field indicates the Byte size of the Instruction, Parameter and Checksum field.

$$\text{Length} = \text{number of Parameters} + 2$$

• Instruction

The field that defines the type of instruction.

Value	Instructions	Description
0x01	Ping	Instruction that checks whether the Packet has arrived to a device with the same ID as Packet ID
0x02	Read	Instruction to read data from the Device
0x03	Write	Instruction to write data on the Device
0x04	Reg Write	Instruction that registers the Instruction Packet to a standby status; Packet is later executed through the Action instruction
0x05	Action	Instruction that executes the Packet that was registered beforehand using Reg Write
0x06	Factory Reset	Instruction that resets the Control Table to its initial factory default settings
0x08	Reboot	Instruction that reboots servo
0x83	Sync Write	For multiple devices, Instruction to write data on the same Address with the same length at once

• Parameters

The Parameters are the Instruction's auxiliary data field. The use of the Parameters differ depending on what Instruction is used.

• Checksum (Instruction Packet)

It is used to check if packet is damaged during communication. Checksum is calculated according to the following formula.

$$\text{Checksum} = \sim(\text{ID} + \text{Length} + \text{Instruction} + \text{Parameter1} + \dots \text{Parameter N})$$

Where “~” is the Binary Ones Complement operator. When the calculation result of the parenthesis in the above formula is larger than 255 (0xFF), use only lower bytes.

For example, when you want to use below Instruction Packet,

ID=1(0x01), Length=5(0x05), Instruction=3(0x03), Parameter1=12(0x0C), Parameter2=254(0xFE), Parameter3=0(0x05)

Checksum = ~ (ID + Length + Instruction + Parameter1 + ... Parameter 3) = ~ [0x01 + 0x05 + 0x03 + 0x0C + 0xFE + 0x05] = ~ [0x118] // Only the lower byte 0x18 executes the Not operation. = 0xE7

Thus, Instruction Packet should be 0xFF, 0xFF, 0x01, 0x05, 0x03, 0x0C, 0xFE, 0x05, 0xE7.

In the same Instruction Pack frame, if the interval between bytes is greater than 100ms, the previously received data will be discarded and the system will wait for a new valid frame header (0xFF 0xFF).

Status Packet(Return Packet)

Header1	Header2	Packet ID	Length	Error	Param 1	...	Param N	Checksum
0xFF	0xFF	ID	Length	Error	Param 1	...	Param N	CHKSUM

- **Error**

This field displays the error status occurred during the operation of servo.

Bit	Error	Description
Bit 7	Encoder Error	When the encoder of servo is not available, It is set as 1
Bit 6	Instruction Error	In case of sending an undefined instruction or delivering the action instruction without the Reg Write instruction, it is set as 1
Bit 5	Overcurrent Error	When the current above Threshold of Overcurrent exceeds time that Threshold of OCP Judgment, it is set as 1
Bit 4	Checksum Error	When the Checksum of the transmitted Instruction Packet is incorrect, it is set as 1
Bit 3	Range Error	When an instruction is out of the range for use, it is set as 1
Bit 2	Overheating Error	When internal temperature of servo is out of the range of operating temperature set in the Control table, it is set as 1
Bit 1	Angle Limit Error	When Goal Position is written out of the range from CW Angle Limit to CCW Angle Limit , it is set as 1
Bit 0	Input Voltage Error	When the applied voltage is out of the range of operating voltage set in the Control table, it is as 1

For example, when Status Packet is returned as below

```
0xFF 0xFF 0x01 0x02 0x24 0xD8
```

It means that the error of 0x24 occurs from servo whose ID is 01. Since 0x24 is 00100100 as binary, Bit5 and Bit2 become 1. In order words, Overcurrent and Overheating Errors have occurred.

WARNING : The error types on the table above are related to actuators, and the contents may vary depending on the type of servo.

• Checksum (Status Packet)

It is used to check if packet is damaged during communication. Status Checksum is calculated according to the following formula.

Status Checksum = ~(ID + Length + Error + Parameter1 + ... Parameter N)

Instruction Details

Note that given examples use the following abbreviation to provide clear information.

- Header : H
- Reserved: RSRV
- Length: LEN
- Instruction: INST
- Error : ERR
- Param: P
- Checksum: CKSM

• Ping

This instruction is used to see if a device exists. Regardless of the Status Return Level, the Ping Instruction returns the Status Packet.

LEN	INST	P
0x02	0x01	-

- Example

Conditions

- ID 1 is connected to the PC with an identical baudrate.

Ping Instruction Packet

H1	H2	Packet ID	LEN	INST	CKSM
0xFF	0xFF	0x01	0x02	0x01	0xFB

ID 1 Status Packet

H1	H2	Packet ID	LEN	ERR	CKSM
0xFF	0xFF	0x01	0x02	0x00	0xFC

• Read

This instruction is to read data in the Control Table of servo.

LEN	INST	P1	P2
0x04	0x02	Starting Address	Length of Data

- Example

Conditions

- ID 1 : Read Present Temperature, which is located at the address 60(0x3C)

Read Instruction Packet

H1	H2	Packet ID	LEN	INST	P1	P2	CKSM
0xFF	0xFF	0x01	0x04	0x02	0x3C	0x01	0xBB

ID 1 Status Packet

H1	H2	Packet ID	LEN	ERR	P1	CKSM
0xFF	0xFF	0x01	0x03	0x00	0x20	0xDB

• Write

This instruction is to write data to the Control Table of servo

LEN	INST	P1	P2	P3	P N+1
N + 3	0x03	Starting Address	1st Byte	2nd Byte	Nth Byte

- Example

Conditions

- ID broadcast : Set the unknown servo's ID as "1" by writing 1 to ID(3)

Write Instruction Packet

H1	H2	Packet ID	LEN	INST	P1	P2	CKSM
0xFF	0xFF	0xFE	0x04	0x03	0x07	0x01	0xF2

warning

WARNING : Status Packet will not be returned if Broadcast ID(0xFE) is used.

• Reg Write

Instruction that is similar to Write Instruction, but has an improved synchronization characteristic

- Write Instruction is executed immediately when an Instruction Packet is received.
- Reg Write Instruction registers the Instruction Packet to a standby status, and sets Control table Registered Instruction to '1'.
- When an Action Instruction is received, the registered Packet is executed, and sets Control Table Registered Instruction to '0'.

LEN	INST	P1	P2	P N+1
N+3	0x04	Starting Address	1st Byte	Nth Byte

- Example

Conditions

- ID 1 : Reg Write 500(0x1F4) to Goal Position(44) and wait for Action instruction to move.

Reg Write Instruction Packet

H1	H2	Packet ID	LEN	INST	P1	P2	P3	CKSM
0xFF	0xFF	0x01	0x05	0x04	0x2C	0xF4	0x01	0xD4

ID 1 Status Packet

H1	H2	Packet ID	LEN	ERR	CKSM
0xFF	0xFF	0x01	0x02	0x00	0xFC

• Action

This instruction is to execute the registered Reg Write instruction. The Action instruction is useful when multiple servo's are required to start moving at the same time. When several devices are controlled via communication, there is a minor time difference between enabling the first and last device. Servo has resolved this problem by using Action instruction.

LEN	INST	P
0x02	0x05	-

- Example

Conditions

- All servo's have received Reg Write instructions.
- As the Packet ID is Broadcast ID (0xFE), the Status Packet is not return.

Action Instruction Packet

H1	H2	Packet ID	LEN	INST	CKSM
0xFF	0xFF	0xFE	0x02	0x05	0xFA

note

NOTE : Status Packet will not be returned if Broadcast ID(0xFE) is used.

• Factory Reset

This instruction is to reset the Control Table of servo to the factory default values.

WARNING :

- Make sure that the Factory Reset Instruction will reset the values in the FLASH that you set previously.
- Broadcast ID(0xFE) cannot be used for Factory Reset instruction.

LEN	INST	P
0x02	0x06	-

- Example

Conditions

- ID 0 : Factory Reset servo

Factory Reset Instruction Packet

H1	H2	Packet ID	LEN	INST	CKSM
0xFF	0xFF	0x00	0x02	0x06	0xF7

ID 0 Status Packet

H1	H2	Packet ID	LEN	ERR	CKSM
0xFF	0xFF	0x00	0x02	0x00	0xFD

• Reboot

This instruction restarts servo.

– Example

Conditions

- ID 1 : Reboot ID 1 servo

Reboot Instruction Packet

H1	H2	Packet ID	LEN	INST	CKSM
0xFF	0xFF	0x01	0x02	0x08	0xF4

ID 1 Status Packet

H1	H2	Packet ID	LEN	ERR	CKSM
0xFF	0xFF	0x01	0x02	0x00	0xFC

• Sync Write

This instruction is used to control multiple servo's simultaneously with a single Instruction Packet transmission. When this instruction is used, several instructions can be transmitted at once, so that the communication time is reduced when multiple servo's are connected in a single channel. However, the Sync Write Instruction can only be used to a single address with an identical length of data over connected servo's. ID should be transmitted as Broadcast ID.

Item	Description
Instruction	0x83
Length	$((L + 1) * N) + 4$, L:Data Length, N:Number of servo
Parameter 1	Starting Address
Parameter 2	Length of Data to write
Parameter 3	[1st Device] ID
Parameter 4	[1st Device] 1st Byte
Parameter 5	[1st Device] 2nd Byte
...	...
Parameter L+3	[1st Device] L-th Byte
Parameter L+4	[2nd Device] ID
Parameter L+5	[2nd Device] 1st Byte
Parameter L+6	[2nd Device] 2nd Byte
...	...
Parameter 2L+4	[2nd Device] L-th Byte

- Example

Conditions

- ID 0 : Write 0x150 to Profile Velocity(42, 0x2A) and write 0x010 to Goal Position(44, 0x2C)
- ID 1 : Write 0x360 to Profile Velocity(42, 0x2A) and write 0x220 to Goal Position(44, 0x2C)

Sync Write Instruction Packet

H1	H2	Packet ID	LEN	INST	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	CKSM
0xFF	0xFF	0xFE	0x0E	0x83	0x2A	0x04	0x00	0x50	0x01	0x10	0x00	0x01	0x60	0x03	0x20	0x02	0x5B

WARNING : Status Packet will not be returned if Broadcast ID(0xFE) is used.