G15 Cube Servo

User's Manual

V1.1

November 2012

Index

1. INTRODUCTION AND OVERVIEW

G15 Cube Servo is a modular smart serial servo which incorporates gear reducer, precision high torque DC motor and control circuitry with networking functionality. It is made with high quality engineering plastic to provide high necessary strength and can sustain high external force. G15 provides 360° endless turn control with resolution up to 0.33°.

The unique modular design of G15 gives very user friendly setup of desired robotics model. G15 Cube servo has an output connect (output shaft) on one surface and specially designed slide-fit latch on 5 other surfaces. With these slide-fit design on the surfaces of G15, user easily setup robotic models by just sliding the servo and joint parts together without any single screws. This slide-fit latch design also gives the flexibility for user to dismantle the parts easily and reconfigure the servo and joints for other designs with minimal effort and time.

G15 Cube Servo uses serial half duplex communication and allows daisy chain connection to multiple servos to create a servo network on a single line. G15 Cube servo comes with over temperature and over torque protection to prevent damage to the servo. It allows the use to set the servo to shutdown on several alarm factors. Besides, G15 Cube Servo has an internal LED indicator to show the status of the servo.

2. PACKING LIST

Please check the parts and components according to the packing list. If there is any part missing, please contact us at sales@cytron.com.my immediately.

Packing list:

1. G15 Cube Servo x 1
2. Inter Connect x 1
3. External Joint x 2

3. PRODUCT SPECIFICATION AND LIMITATIONS

3.1 Electrical Characteristics

Parameter	Minimum	Typical	Maximum	Unit
Current Consumption (12V)			1.5	A
Input signal, V_{IH}	2		5.5	V
Input signal, V_{IL}	0		0.8	V
Output Signal, V_{OH}	4.63	5.0	5.3	V
Output Signal, V_{OL}		0	0.33	V

3.2 Maximum Ratings

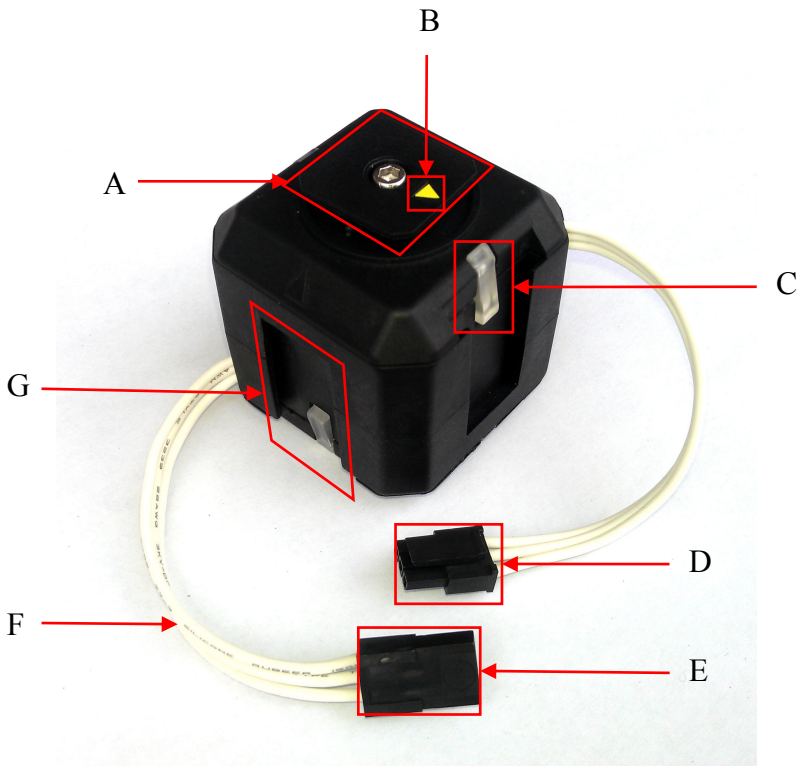
Parameter	Minimum	Typical	Maximum	Unit
Operating voltage	6.5	12	17.8	V
Maximum Current (I/O signal pins)			±35	mA
Temperature	0		80	°C
Holding Torque			15	kg.cm

3.3 Specifications

Weight	63g
Stall Torque	12kg.cm at 12V
Positioning Resolution	0.33°
Operation Angle	360° endless turn, electrical position control
Max Speed (no load)	63RPM at 12V
Gear Ratio	194:1
Communication	Half duplex asynchronous serial communication (7812.5bps-500kbps)

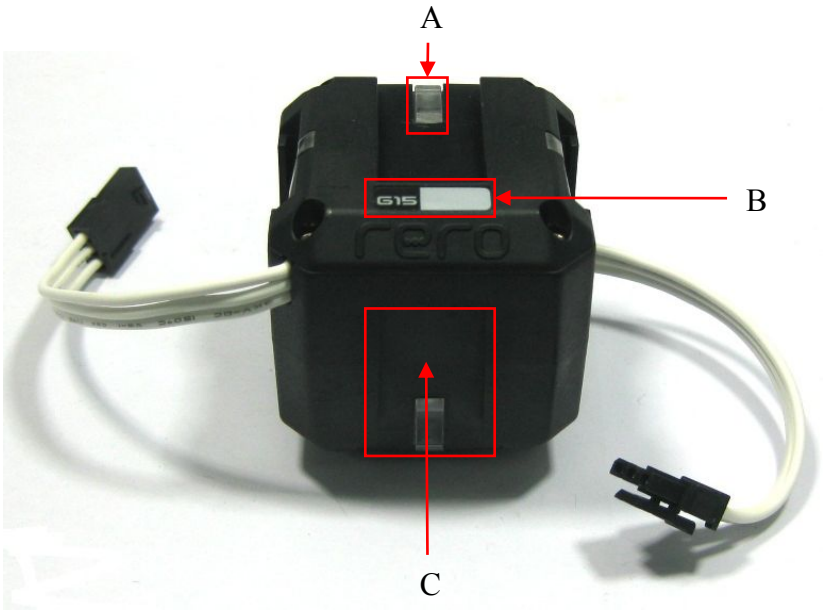
4. PRODUCT LAYOUT

4.1 Top



Label	Name	Description
A	Output Connect	Output shaft of G15 Cube Servo
B	Orientation Mark	The orientation for Output Connect to Slide into the slide fit latch mechanism
C	LED Indicator	Red LED status indicator behind the semi-transparent latch
D	Male Connector	Power and communication line with male connector.
E	Female Connector	Power and communication line with female connector
F	Wire	Power and communication line wire
G	Slide-fit Latch	Slide-fit latch mechanism on all 5 surfaces. Each Slide-fit Latch consists of sliding slot and semitransparent latch.

4.2 Bottom



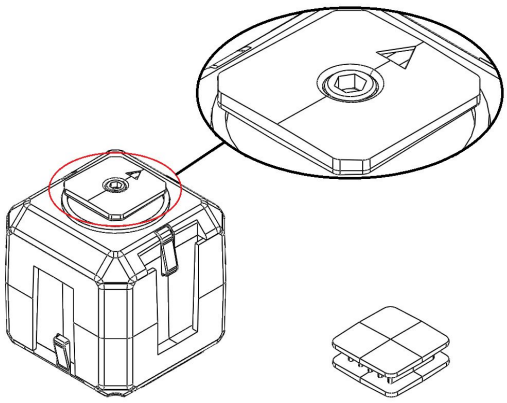
Label	Name	Description
A	Latch	Anti slide latch to hold the G15 Connects.
B	ID Sticker	ID sticker for user to write down the unique ID of servo for serial communication.
C	Sliding Slot	Sliding Slot of slide-fit mechanism for use to slide in the G15 connects.

5. INSTALLATION (HARDWARE)

5.1 G15 Cube Servo Slide Fit Latch Mechanism

5.1.1 Connectors and Joints

Connects:

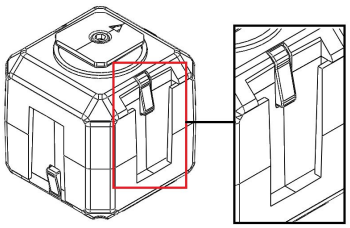


Output Connect

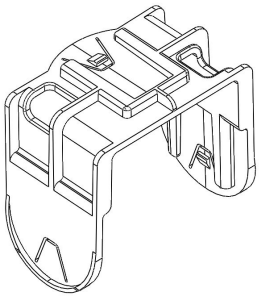
Inter Connect

Rotatable Connect

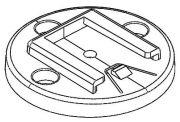
Joints:



G15 Body (5 Slots)



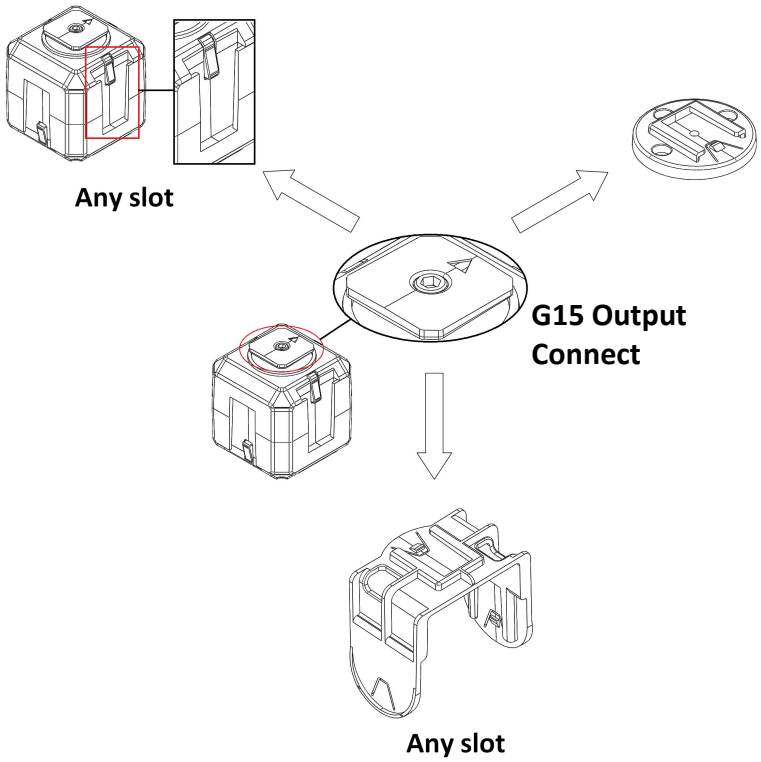
U-Joint (3 Slots)

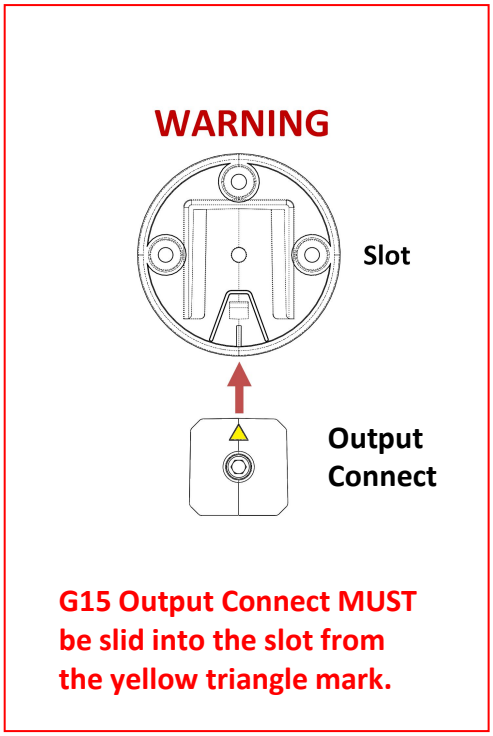


External Joint (1 Slot)

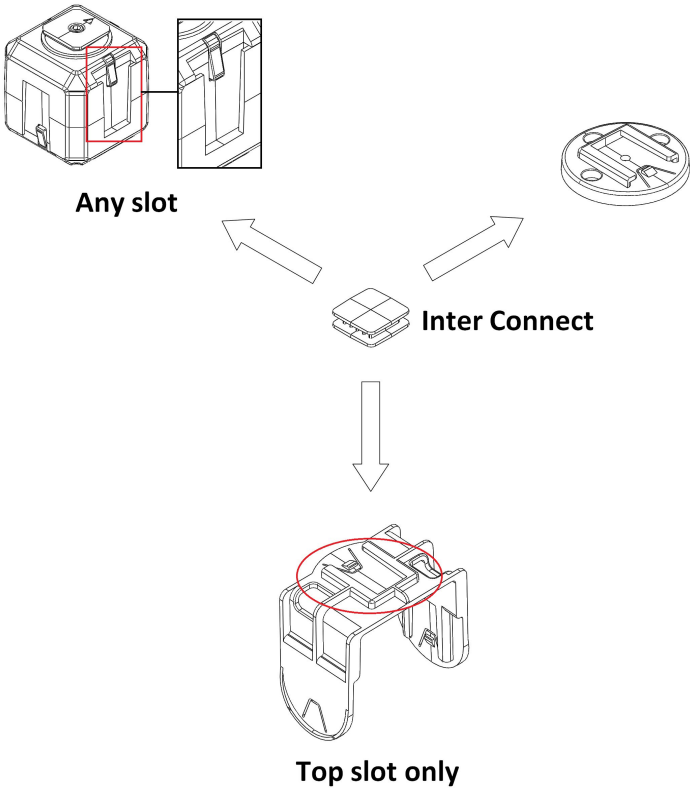
5.1.2 Slide Fit Jointing Mechanism

G15 Output Connect to Joints:

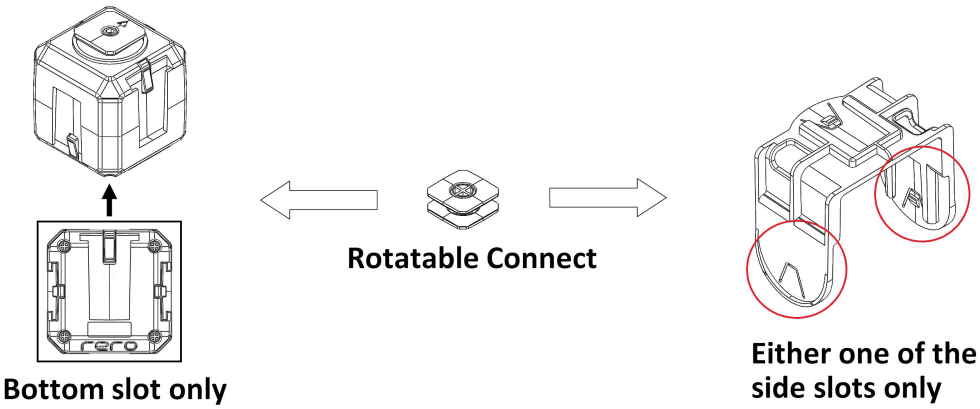




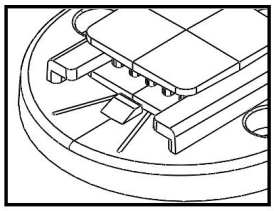
Inter Connect to Joints:

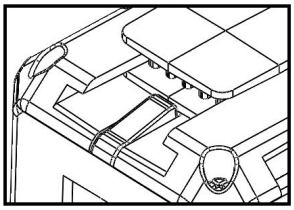


Rotatable Connect to Joints:



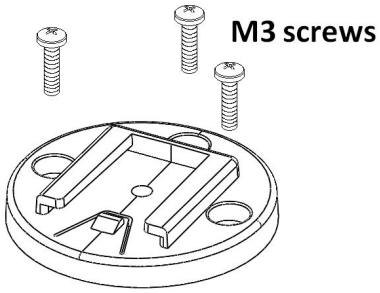
Slide Fit Latch:





Make sure all the connects are locked properly to the joint by the latch

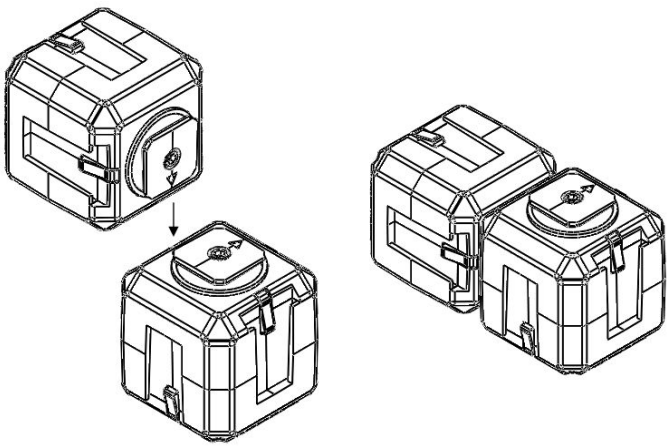
External Joint for Customized Usage:



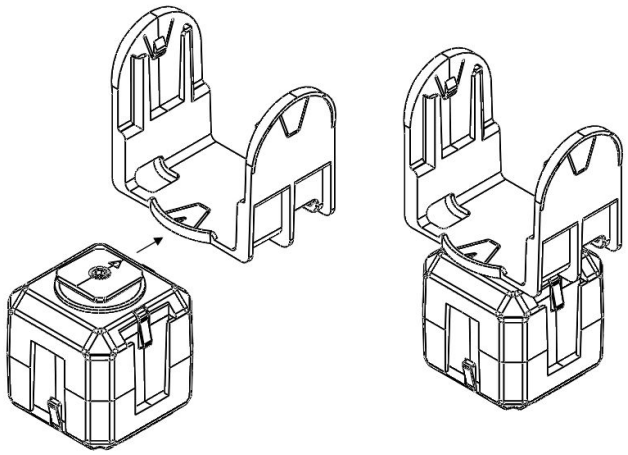
External Joint can be screwed to customized part with M3 screws.

5.1.3 Sample Connections

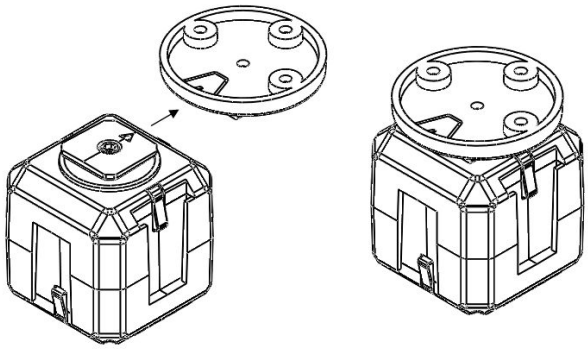
G15 Cube Servo to G15 Cube Servo:



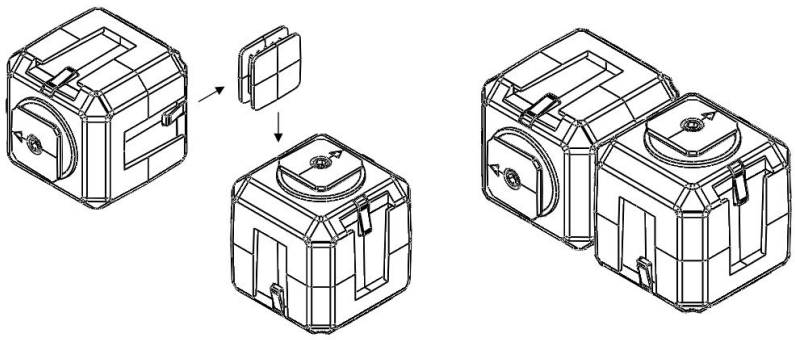
G15 Cube Servo to U-Joint



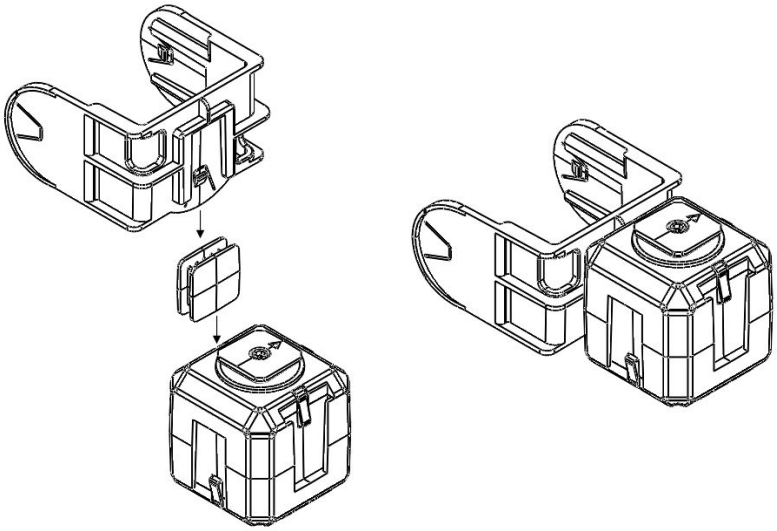
G15 Cube Servo to External Joint



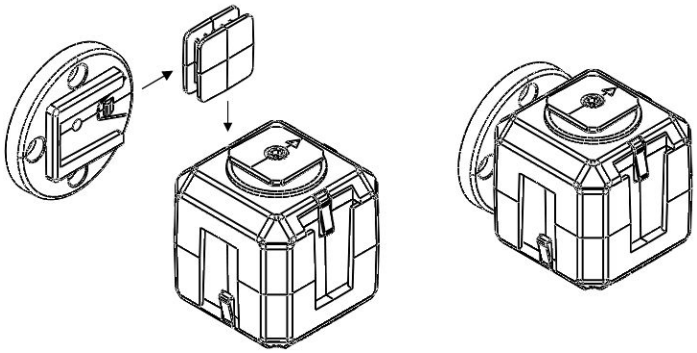
G15 – Inter Connect – G15



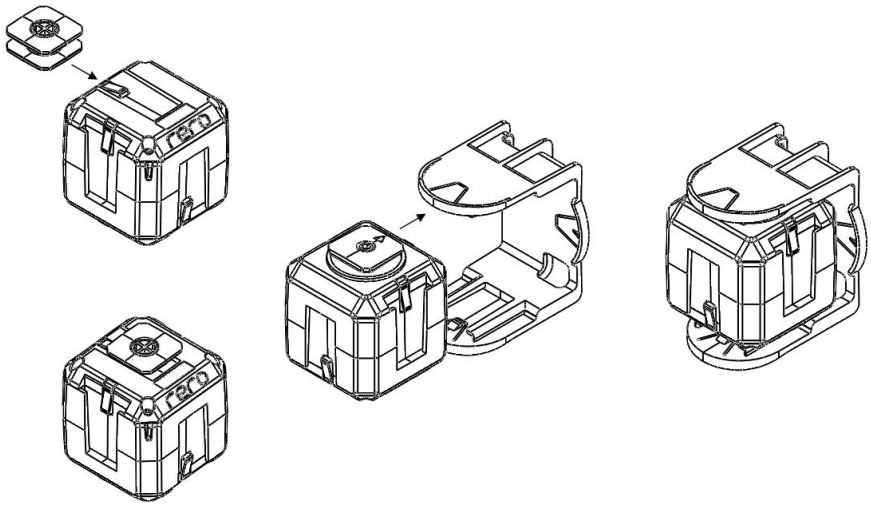
G15 – Inter Connect – U-Joint



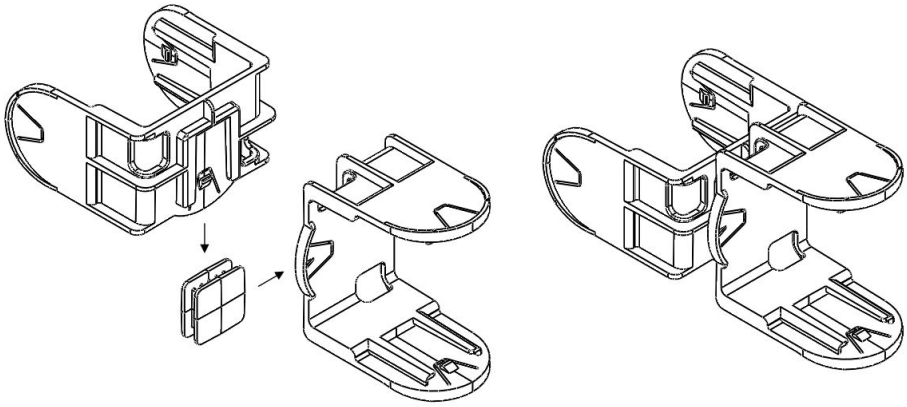
G15 – Inter Connect –External Joint



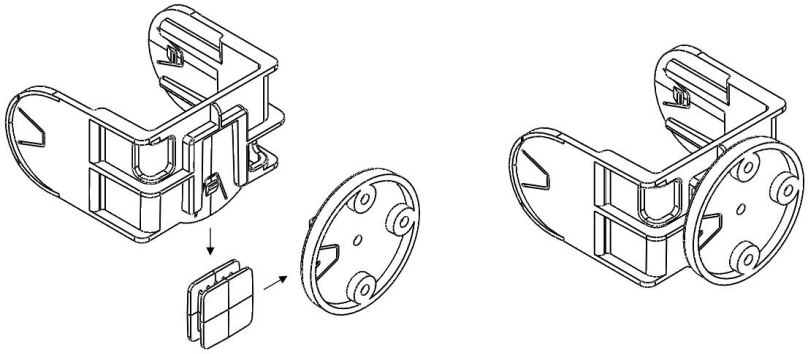
G15 – Rotatable Connect – U-Joint



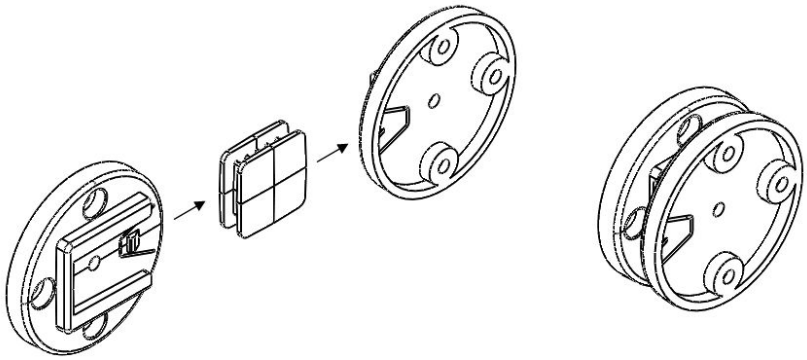
U-Joint – Inter Connect – U-Joint



U-Joint – Inter Connect – External Joint



External Connect – Inter Connect – External Connect



5.2 G15 Cube Servo Daisy Chain Connection

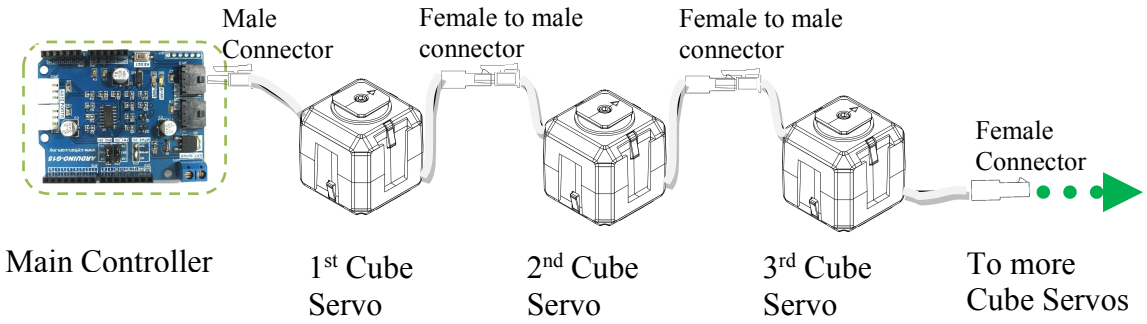
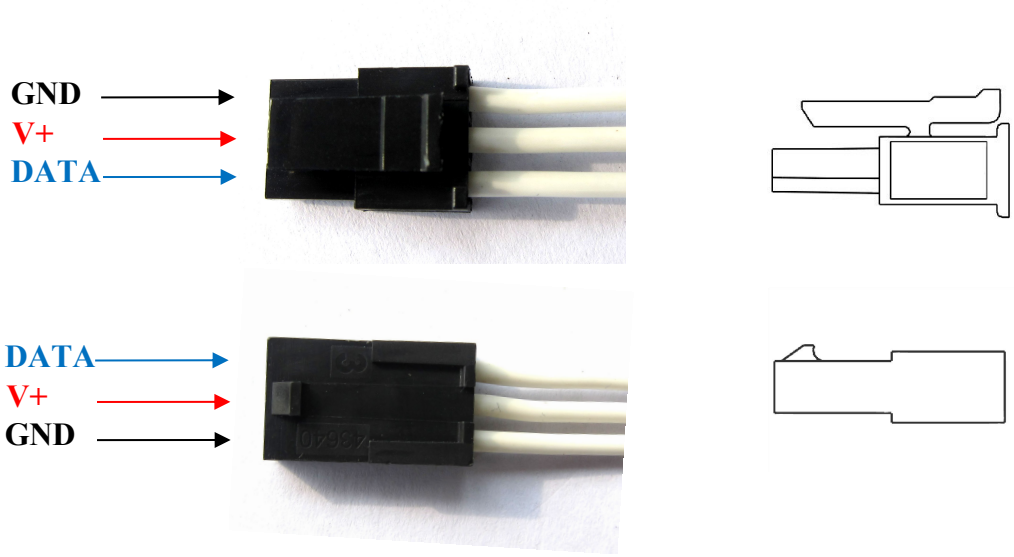
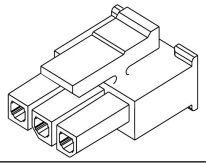
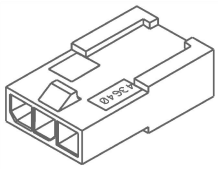
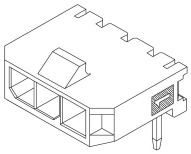
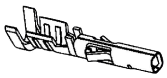


Figure above shows the daisy chain connection of G15 Cube Servo to create a servo network on a single power and communication line.

5.3 G15 Cube Servo Terminals & Polarity



G15 Cube Servo uses high quality silicone rubber wire (22AWG) and Molex Micro-Fit connector with clip for the power and data line. Types of Connector for G15 Cube Servo are listed as in table below:

Molex Micro-Fit 3.0 Order No.	Description	Picture
43645-0300	G15 Cube Servo Male connector. (Match to Female Pin Terminal -43030)	
43640-0301	G15 Cube Servo Female connector. (Match to Male Pin Terminal -43031)	
43650-0300	G15 Cube Servo Female Right angle connector. Used as connector on PCB.	
43030	Female Pin Terminal	
43031	Male Pin Terminal	

6. GETTING STARTED

6.1 G15 Cube Servo Half Duplex Serial Implementation

G15 servo use half-duplex serial communication. A normal UART module with the circuit shown below can be used to control G15.

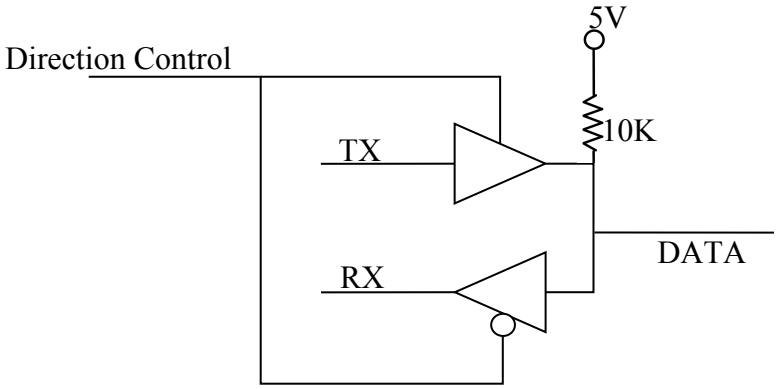
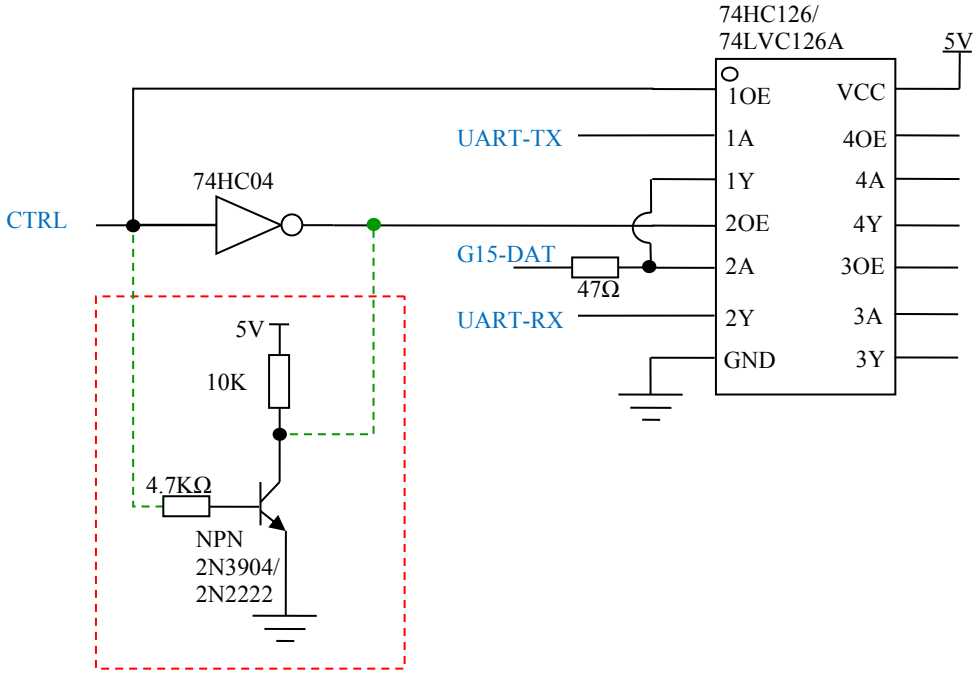
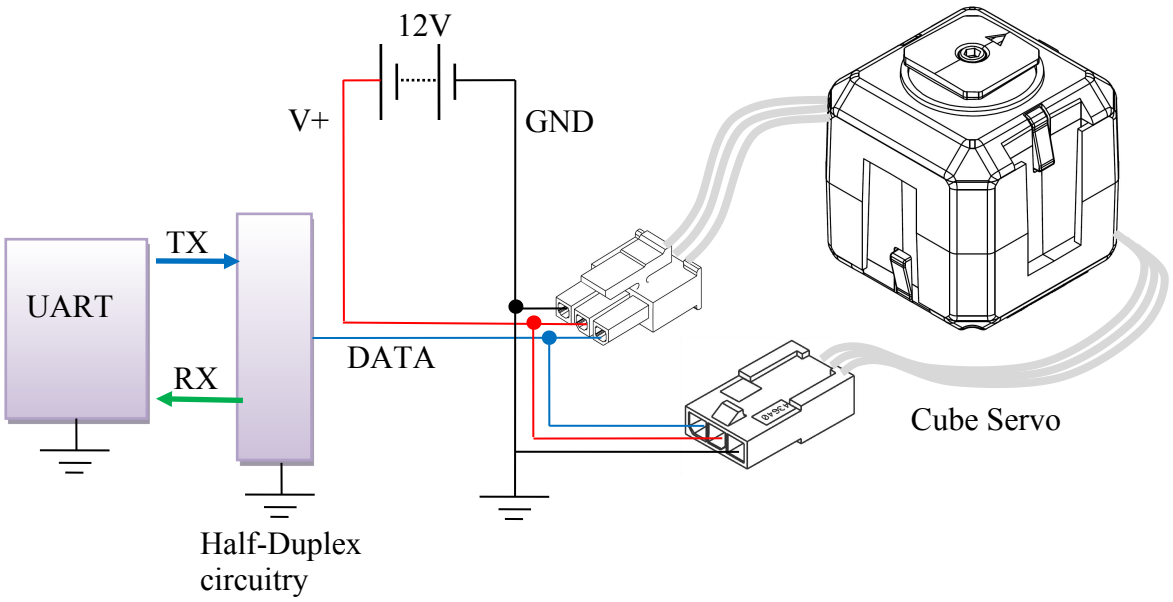


Figure below shows Half Duplex implementation with 74HC126 IC. The inverter IC, 74HC04 can be replaced with inversion transistor circuit highlighted with red dotted box as shown by the figure below. The circuit converts the UART communication lines to G15 DATA line. The UART-TX and UART-RX shown in the circuit need to be connected to controller's UART pin of TX and RX respectively. G15-DAT pin shown need to be connected to G15's DATA pin. The picture following illustrates the connection of the half-duplex circuit and power supply to the G15 Cube servo's terminals.





6.2 G15 Cube Servo Control Register

Control Register contains parameters used to control G15. The Control Register contains portion of parameters value which are saved to EEPROM and another portion which is not saved to EEPROM but stored temporary in RAM. For the parameters which are saved to EEPROM are non-volatile and the values will remain the same after a power off-on reset. However for those stored in RAM only, all value will be reset to default value after a power off-on reset.

Most of these parameters in the Control Register values can be modified to change the characteristic of G15. Table below shows all the Control Register parameters. Parameters from address of 0 to 23 are stored to EEPROM and parameters from address of 24 to 49 are stored in RAM only.

Writing to Control Registers in EEPROM area requires extra precautions. First, the power source has to be stable throughout the process to prevent corrupted data. Secondly user program has to wait for 25 ms after the EEPROM write command is sent before sending the next command. Any command sent within this period may not be processed. This is to ensure no interruption to EEPROM write process.

Area	Address (Hex)	Parameter	Read only/ Read Write	Factory default value (Hex)	Minimum value (Hex)	Maximum value (Hex)
EEPROM	0 (0x00)	Model (L)	R	'G' (0x0F)	-	-
	1 (0x01)	Model(H)	R	15 (0x47)	-	-
	2 (0x02)	Firmware Revision	R		-	-
	3 (0x03)	ID	RW	1 (0x01)	0 (0x00)	253 (0xFD)
	4 (0x04)	Baud Rate	RW	103 (0x67)	3 (0x03)	255 (0xFF)
	5 (0x05)	Return Delay	RW	250 (0xFA)	1 (0x01)	255 (0xFF)
	6 (0x06)	CW Angle Limit (L)	RW	0 (0x0000)	0 (0x0000)	1087 (0x043F)
	7 (0x07)	CW Angle Limit (H)	RW			
	8 (0x08)	CCW Angle Limit (L)	RW	1087 (0x043F)	0 (0x0000)	1087 (0x043F)
	9 (0x09)	CCW Angle Limit (H)	RW			
	10 (0x0A)	Reserved	-	-	-	-
	11 (0x0B)	Temperature Limit	RW	70 (0x46)	0 (0x00)	120 (0x78)
	12 (0x0C)	Lowest Voltage Limit	RW	65 (0x41)	65 (0x41)	178 (0xB2)
	13 (0x0D)	Highest Voltage Limit	RW	150 (0x96)		
	14 (0x0E)	Max Torque (L)	RW	1023 (0x03FF)	0 (0x0000)	1023 (0x03FF)
	15 (0x0F)	Max Torque (H)	RW			
	16 (0x10)	Return Packet Enable	RW	2 (0x02)	0 (0x00)	2 (0x02)
	17 (0x11)	Alarm LED	RW	36 (0x24)	0 (0x00)	127 (0x7F)
	18 (0x12)	Alarm Shutdown	RW	36 (0x24)	0 (0x00)	127 (0x7F)
	19 (0x13)	Reserved	-	-	-	-
	20 (0x14)	Down Calibration (L)	R			
	21 (0x15)	Down Calibration (H)	R			
	22 (0x16)	Up Calibration (L)	R			
	23 (0x17)	Up Calibration (H)	R			
RAM	24 (0x18)	Torque Enable	RW	0 (0x00)	0 (0x00)	1 (0x01)
	25 (0x19)	LED	RW	0 (0x00)	0 (0x00)	1 (0x01)
	26 (0x1A)	CW Compliance Margin	RW	1 (0x01)	0 (0x00)	254 (0xFE)
	27 (0x1B)	CCW Compliance Margin	RW	1 (0x01)	0 (0x00)	254 (0xFE)
	28 (0x1C)	CW Compliance Slope	RW	32 (0x20)	1 (0x01)	254 (0xFE)
	29 (0x1D)	CCW Compliance Slope	RW	32 (0x20)	1 (0x01)	254 (0xFE)
	30 (0x1E)	Goal Position (L)	RW	Address 36	0 (0x0000)	1087 (0x043F)
	31 (0x1F)	Goal Position (H)	RW	Address 37		
	32 (0x020)	Moving Speed (L)	RW	0 (0x0000)	0 (0x0000)	1023 (0x03FF)
	33 (0x21)	Moving Speed (H)	RW			
	34 (0x22)	Torque Limit (L)	RW	Address 14	0 (0x0000)	1023 (0x03FF)
	35 (0x23)	Torque Limit (H)	RW	Address 15		
	36 (0x24)	Present Position (L)	R			
	37 (0x25)	Present Position (H)	R			
	38 (0x26)	Present Speed (L)	R			
	39 (0x27)	Present Speed (H)	R			
	40 (0x28)	Present Load (L)	R			
	41 (0x29)	Present Load (H)	R			
	42 (0x2A)	Present Voltage	R			
	43 (0x2B)	Present Temperature	R			
	44 (0x2C)	Registered	R	0 (0x00)	0 (0x00)	1 (0x01)
	45 (0x2D)	Reserved	-	-	-	-
	46 (0x2E)	Moving	R	0 (0x00)	0 (0x00)	1 (0x01)
	47 (0x2F)	Lock	RW	0 (0x00)	1 (0x01)	1 (0x01)
	48 (0x30)	Punch (L)	RW	32 (0x0020)	0 (0x0000)	1023 (0x03FF)
	49 (0x31)	Punch (H)	RW			

6.2.1 Description of Control Register's Parameters

Model Number (Address 0x00, 0x01)

Model Number for G15 is 0x47, 0x0F which represents 'G' in ASCII and 15 in decimal respectively.

Firmware revision (Address 0x02)

This value represents firmware revision of G15.

ID (Address 0x03)

ID is unique identification number assigned to each G15 unit. This ID is used for identification of each G15 unit on the communication network. ID needs to be unique or different for each of the G15 unit on a same network to prevent communication collisions.

Baud Rate (Address 0x04)

The serial communication speed (bps) of G15 is determined by Baud Rate register value at address 0x04. The default baudrate of G15 is 19,200bps. The Baud Rate register value corresponding to a baudrate (bps) is calculated using the equation below.

$$\text{Baud Rate Register Value} = \frac{2000000}{\text{Baudrate (bps)}} - 1$$

User need to set the Baud Rate register value (address 0x04) to the value calculated using the equation above for a desired communication speed (baudrate). For example if register value is set to 207 in decimal, then the resulting speed of the serial communication will be 9600bps.

Table below shows the register value and corresponding baudrate.

Register Value (Hex)	Baud Rate (bps)	Error (%)
3 (0x03)	500,000	0
4 (0x04)	400,000	0
7 (0x07)	250,000	0
9 (0x09)	200,000	0
16 (0x10)	115,200	2.12
34 (0x22)	57,600	-0.79
103 (0x67)	19,200	0.16
207 (0xCF)	9600	0.16

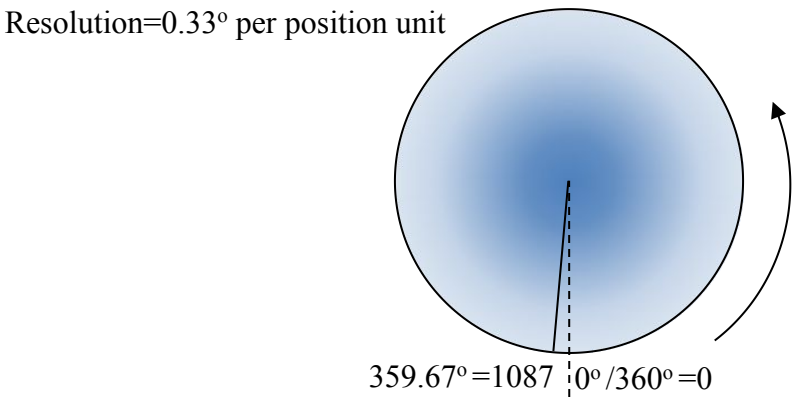
Return Delay (Address 0x05)

Return delay is the time taken for the status packet to return from G15 after an instruction packet is sent by the controller. The return delay time is calculated using the equation below.

$$\text{Return Delay Time} = 2\mu s \times \text{Return Delay register value}$$

Operation Angle Limit (Address 0x06, 0x07, 0x08, 0x09)

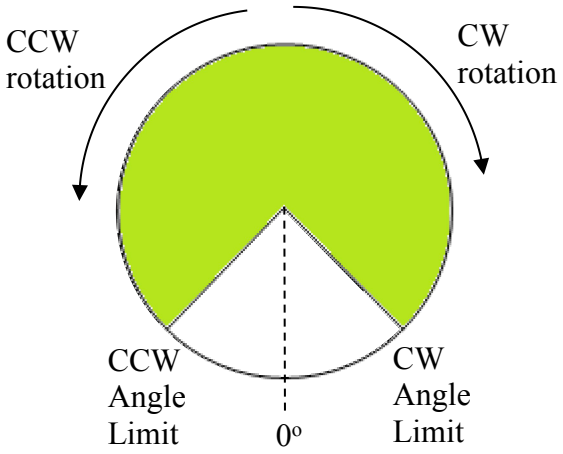
The operation angle of G15 is limited by the clock wise (CW) and counter clock wise (CCW) angle limit of the G15. The position value used for representation of angular position in G15 is from 0 to 1087.



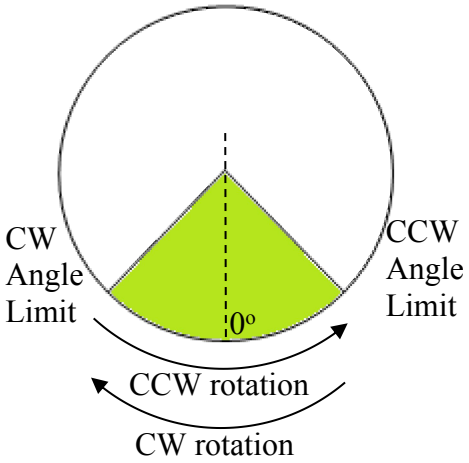
Equation below can be used for conversion between angle in degree unit and register value.

$$\text{Position} = \frac{1088}{360^{o}} \times \text{Angle}$$

If the CCW Angle Limit value is more than the CW Angle Limit value, for example CCW Angle =350° and CW Angle Limit = 10°, G15 servo will operate in shaded sector as shown in the figure below.



If the CW Angle Limit value is more than the CCW Angle Limit value, for example CW Angle =350° and CCW Angle Limit = 10°, G15 servo will operate in shaded sector as shown in the figure below.



Temperature Limit (Address 0x0B)

Temperature Limit value limits the operating temperature of G15 to prevent damage due to overheating of internal motor. If the temperature rises above this Temperature Limit value, the Over Heat Error bit (bit 2 of ERROR byte in status packet) will be set. The alarm will be set according to value of Address 17 and 18 of Control Register. Temperature Limit value is in degree Celsius unit.

Voltage Limit (Address 0x0C, 0x0D)

The Highest Voltage Limit and Lowest Voltage Limit are limiting the operating voltage of G15 Cube Servo for safety purposes. If the operating voltage is outside of the limits, the Voltage Range Error bit (bit 0 of ERROR byte in status packet) will be set. This cause G15 will respond all packets with error status. The actual operating voltage can be calculated from the Voltage Limit value by dividing the value with 10. The default operating limit range is 6.5V to 12V.

Voltage Limit (Control Register) = Voltage X 10

Maximum Torque & Torque Limit (Address 0x0E, 0x0F, 0x22, 0x23)

These values limit the maximum torque produced by G15. Maximum Torque is stored in EEPROM area and Torque Limit is stored in RAM area. When G15 is powered on, the Maximum Torque value at the address of 0x0E to 0x0F is copied to Torque Limit register located at the address of 0x22 to 0x23. G15 will produce a maximum torque corresponding to the value in Torque Limit register. The minimum and maximum value for these register are from 0 to 1023.

Return Packet Enable (Address 0x10)

Return Packet Enable value determines whether return status packet is sent out of G15 responding to the instruction from main controller according to table below.

Value	Return Status packet
0	No return status packet will be sent out
1	Only READ DATA instruction will be responded
2	Respond to all instruction

No return status packet will be sent out of G15 if **Broadcast ID** (0xFE) is used by the instruction packet.

ALARM LED (Address 0x11)

The ALARM LED byte set for the LED of G15 to blink on different occurrence of errors. Table shows function of every bit of the ALARM LED byte. If the corresponding bit is set, when the error occurs, the LED on G15 will blink. For example, if ALARM LED byte value is 0x44, the LED on G15 will blink when either Instruction Error or Overheating Error occur.

Bit	Error Indication
Bit 7	Reserved
Bit 6	Instruction Error
Bit 5	Overload Error
Bit 4	Checksum Error
Bit 3	Range Error
Bit 2	Overheating Error
Bit 1	Angle Limit Error
Bit 0	Input Voltage Error

ALARM SHUTDOWN (Address 0x12)

The ALARM SHUTDOWN register sets the G15 to shutdown or turn off its torque on several different errors. Table below shows the bits in ALARM SHUTDOWN byte which represents the several different errors. User can set these bits to turn off G15 when the particular error occurs. After an alarm shutdown, G15 will maintain in torque off condition until user manually reset the TORQUE ENABLE parameter (0x18) in Control Register to value 1.

Bit	Error
Bit 7	Reserved
Bit 6	G15 shutdown on Instruction Error
Bit 5	G15 shutdown on Overload Error
Bit 4	G15 shutdown on Checksum Error
Bit 3	G15 shutdown on Range Error
Bit 2	G15 shutdown on Overheating Error
Bit 1	G15 shutdown on Angle Limit Error
Bit 0	G15 shutdown on Input Voltage Error

CALIBRATION (Address 0x14-0x17)

These are calibration data used for compensating the position sensor difference used in G15 units. The user cannot change these values.

TORQUE ENABLE (Address 0x18)

TORQUE ENABLE sets the G15 torque to be on or off. When it is on, G15 will hold its shaft in position and when it is off, G15 shaft is under torque free condition where user can change the shaft position by turning it.

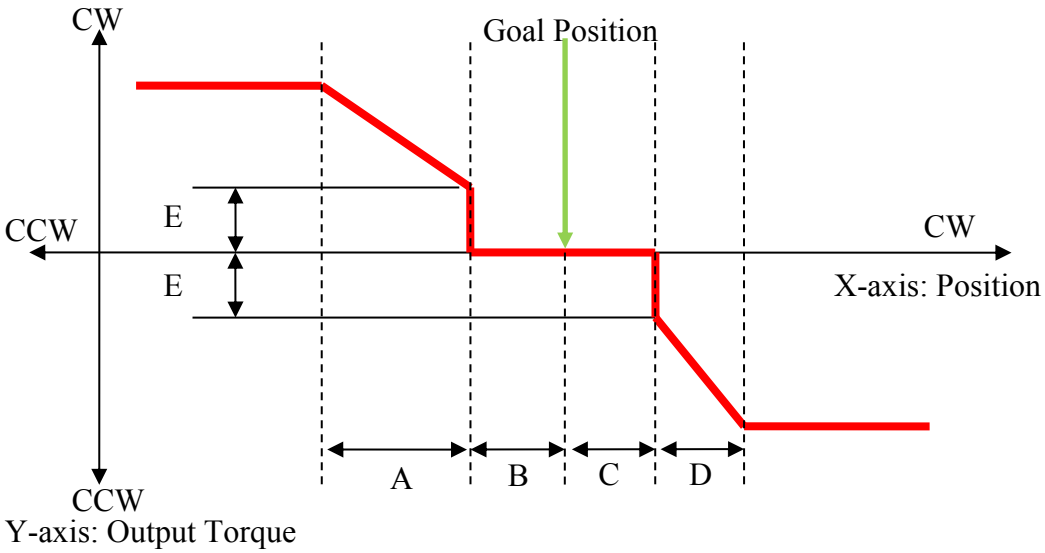
LED (Address 0x19)

LED on G15 can be turned on by setting this byte to 1 or turned off by setting this byte to 0.

COMPLIANCE MARGIN & SLOPE (Address 0x1A - 0x1D)

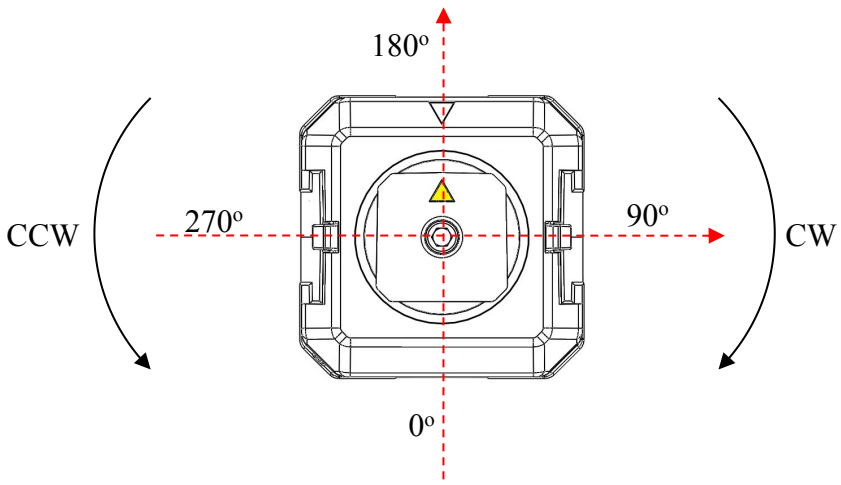
The positioning compliance margin and slope of G15 are illustrated as in the figure below. The values can be utilized for absorbing shocks at the out shaft of G15. The compliance slope will determine how fast G15 reduces its torque before reaching the goal position. The compliance margin is the allowable goal position error margin of G15 to prevent G15 shaft

start oscillating. PUNCH (0x30, 0x31) value determines the minimum torque before G15 release its torque in compliance margin.



A: CCW Compliance Slope (Address 0x1D)
B: CCW Compliance Margin (Address 0x1B)
C: CW Compliance Margin (Address 0x1A)
D: CW Compliance Slope (Address 0x1C)
E: PUNCH(Address 0x30, 0x31)

GOAL POSITION (Address 0x1E, 0x1F)



The GOAL POSITION is the destination position that G15 shaft will move to and positioned. G15 can be electrical positioned to any 360 degrees of position. The resolution of the positioning is 0.33°. The value of GOAL POSITION can be from 0 to 1087 which represent

the total 360° angular position. Equation below can be referred for the conversion between position and angle.

$$\text{Position} = \frac{1088}{360^{o}} \times \text{Angle}$$

Normal Positioning Mode:

In Normal Positioning Mode, G15 rotates to the goal position according to the OPERATION ANGLE LIMIT (0x06, 0x07, 0x08, 0x09) which set the operating sector of G15. The least significant 11 bits of GOAL position represents the desired position that G15 will move to. Table below shows the bit definition of GOAL POSITION in normal mode.

Bit	15-11	10-0
Definition	Unused	Goal position

Direction Positioning Mode:

In Direction Positioning Mode, the rotation of G15 **will not be limited** by the OPERATION ANGLE LIMIT value. The direction of rotation will be determined by the user. The least significant 11 bits of the GOAL POSITION represents the desired angular position. Bit-14 of GOAL POSITION represents the direction of rotation to the goal position. G15 can rotate CW or CCW to the goal position depending on the value of bit-14. **Bit 15 need to be set to 1** to indicate that G15 is in Direction Positioning Mode. Table below shows the bit representation.

Bit	15	14	13-11	10-0
Definition	Direction Positioning Mode = 1	Direction	Unused	Goal position

Direction=0: CCW rotation
Direction =1: CW rotation

MOVING SPEED (Address 0x20, 0x21)

MOVING SPEED parameter in Control Register can represent values for 3 different modes namely, Rotation Speed Mode, Wheel Mode and Time to Goal Position Mode. 3 different modes operate the Cube Servo differently as described below.

Positioning Mode (Speed Control):

This mode is default mode where 6 most significant bits of the MOVING SPEED are always '0' and CW Angle Limit and CCW Angle Limit are having different value to define the rotation sector of servo. The MOVING SPEED represents the angular speed of the output shaft moving to the goal position. The maximum MOVING SPEED value is 1023 (0x3FF) which is equivalent to 100RPM of the output shaft. The lowest speed is achieved by setting the MOVING SPEED value to 1. Hence, the speed control resolution is 0.098RPM. If the MOVING SPEED value is set to 0, G15 will rotate at the maximum rotational speed afforded by the power supply without speed control. If the value of MOVING SPEED is not in the range of 0 to 1023 G15 Cube Servo will respond an error.

$$\text{MOVING SPEED} = \frac{1023}{112.83} \times \text{Desired RPM}$$

Table below shows the bit definition for Rotation Speed Mode:

Bit	15-10	9-0
Definition	0	Speed

Positioning Mode (Time Control):

Time Control Mode is entered by setting the **bit-15** of MOVING SPEED register to '**1**'. The least significant 12 bits of MOVING SPEED register represents the time will be taken for G15 Cube Servo to reach the goal position. The maximum value of MOVING SPEED is 4095 which is equivalent to 409.5 seconds. The resolution of the time is 0.1 second. The minimum value of MOVING SPEED register in this mode is 1, G15 will respond an error if value '0' is loaded into the least significant 12 bits of register in this mode (bit 15 =1).

$$\text{MOVING SPEED Register value (LSB 12 bits)} = \frac{\text{Desired Time taken to Goal Position}}{0.1 \text{ second}}$$

Table below shows the bit representation of MOVING SPEED register in this mode:

Bit	15	14-13	12-0
Definition	1	unused	Time to Goal Position

Wheel Mode (Continuous Rotation):

Wheel Mode is for continuous rotation of G15 output shaft. The wheel mode is entered by **setting both CW Angle Limit and CCW Angle Limit to a same value.** In wheel mode, the MOVING SPEED register's least significant 10 bits (bit-0 to bit-9) determine the speed of the rotation. Bit-10 is used to control the rotation direction. The 16 bits value representation is shown by table below.

Bit	15-11	10	9-0
Definition	0	Direction	Speed

Direction=0: CCW rotation
Direction =1: CW rotation

In wheel mode, the 10 bits speed value represents the **torque** applied by the G15's motor to the output shaft. There is no actual speed control in this mode.

PRESENT POSITION (Address 0x24, 0x25)

PRESENT POSITION is the current angular position of G15 output shaft.

PRESENT SPEED (Address 0x26, 0x27)

PRESENT SPEED is the angular speed of the G15 output shaft.

PRESENT LOAD (Address 0x28, 0x29)

PRESENT LOAD is the magnitude of load on the operating G15. Table below shows the bit representation for the 2 bytes data. Bit 10 represent the direction of the load and bit 0 to 9 represents the load value. For the load direction, value 1 means CW direction load and vice versa.

Bit	15-11	10	9-0
Definition	-	Load direction	Load Value

PRESENT TEMPERATURE (Address 0x2B)

PRESENT TEMPERATURE gives the information of internal temperature of G15 in degree Celsius.

REGISTERED INSTRUCTION (Address 0x2C)

The value of REGISTERED INSTRUCTION is set to 1 when there is command assigned by REG_WRITE instruction. The value reset to 0 after the command is executed by the ACTION instruction.

MOVING (Address 0x2E)

The value of MOVING is set to 1 when G15 is moving to a goal position and reset to 0 when it reaches the goal position. User can check whether G15 reach the goal position by reading this address from Control Register.

LOCK (Address 0x2F)

If the LOCK value is set to 1, only register located from address 0x18 to 0x23 can be written or modified. A power off reset is need to unlock it again.

PUNCH (Address 0x30, 0x31)

PUNCH value determines the minimum current value supplied to G15's motor during the operation. This also means the minimum torque of G15 before it releases the torque when goal position is reach. Refer to previous figure of compliance margin and slope for better illustration.

6.3 G15 Cube Servo Communication Protocol, Instruction Packet & Status Return Packet

The main controller will communicate with G15 through two way communication by sending instruction packet and receiving return status packet on the half duplex line (data line). The communication is using standard UART protocol with 1 start bit, 1 stop bit, 8 data bit and no parity bit as shown in diagram below.

Start bit	D0	D1	D2	D3	D4	D5	D6	D7	Stop bit

User can choose the baudrate of the UART communication by setting the value of Baud Rate parameter of the Control Register.

6.3.1 Instruction Packet

Instruction packet is sent by main controller to G15. Instruction packet contains commands to the G15 for G15 to response and change states or status accordingly. The instruction packet format is shown as following.

0xFF	0xFF	ID	LENGTH	INSTRUCTION	PARAMETER1…PARAMETER N	CHECKSUM

0xFF of the first 2 bytes are packet headers to indicate the starting of communication packet.

> Any packet without the header or with wrong checksum will be eliminated by G15.

ID is the unique ID of the G15. Do make sure that there is no 2 units of G15 having same ID. This will cause the data line collision and communication errors. The value of ID can be from 0 (0x00) to 253 (0xFD). For broadcasting to all connected G15 units, 254 (0xFE) can be used as the ID in the packet. This will cause all G15 to receive the packet and act correspondingly. However, G15 unit will not reply any status packet if the broadcast ID is used.

LENGTH is the number of parameter added by 2, N + 2.

INSTRUCTION is the instruction to be performed by G15 (refer to the Instruction set table).

PARAMETER 1…PARAMETER N are additional data needed by the instruction (refer to description of command section).

CHECKSUM is for data sending error checking. This makes sure that there is no corruption of data during the transmission of packet. Checksum is calculated as **bitwise inversion** of summation of all bytes in the packet **excluding** the header (0xFF, 0xFF). The following formula shows the calculation of checksum:

Checksum= ~ (ID + Length + Instruction + Parameter1 + Parameter N)

6.3.2 Status Return Packet

Status Return Packet is response packet from G15 Cube Servo after receiving an instruction packet. The Status Return Packet format is shown as following.

0xFF	0xFF	ID	LENGTH	ERROR	PARAMETER1…PARAMETER N	CHECKSUM

0xFF of the first 2 bytes are packet headers to indicate the starting of communication packet.

ID is the unique ID of the responding G15 Cube Servo.

LENGTH is the number of parameter added by 2, N + 2.

ERROR is the error status of the G15 Cube Servo. Each bit representing different error occurred in G15 as shown by the table below.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	Instruction Error	Overload Error	Checksum Error	Range Error	Overheating Error	Angle Limit Error	Input Voltage Error

Table below shows the meaning of each bit in the ERROR status byte.

Error	Description
Instruction Error	Value is set to 1 if unknown instruction is received or Action Instruction is sent without REG_WRITE instruction being sent previously
Overload Error	Value is set to 1 if the maximum torque set is unable to handle or control the applied load.
Checksum Error	Value is set to 1 if the checksum of received instruction packet is incorrect
Range Error	Value is set to 1 if the Control Register address is incorrect or parameter is not between the defined min and max values.
Overheating Error	Value is set to 1 of the internal temperature rose above the operating Temperature Limit setting in the Control Register.
Angle Limit Error	Value is set to if the Goal Position is outside of the CW and CCW Angle Limit.
Input Voltage Error	Set 1 to if voltage is out of Voltage Limit setting in the Control Register

PARAMETER1…PARAMETER N are additional information if needed.

CHECKSUM is calculated as **bitwise inversion** of summation of all bytes in the packet **excluding** the header (0xFF, 0xFF).

Checksum= ~ (ID + Length + Instruction + Parameter1 + Parameter N)

6.3.3 Incomplete Packet Handling

G15 Cube Servo is designed to wait for a complete Instruction Packet once it received the valid header bytes (0xFF, 0xFF). Before G15 Servo Cube obtains a complete packet from user's controller, for each byte received, it will wait for another 100ms to receive the next byte. This will continue until the checksum byte arrives. Therefore if the Instruction packet received is incomplete due to connection error or any unknown reason, G15 Cube Servo only will start receiving new Instruction Packet when the 100ms wait period timeouts.

6.3.3 Instruction Sets

Instruction	Name	Description	Number of Parameter
0x01	PING	Used to obtain a status packet	0
0x02	READ DATA	Read values from Control Register	2
0x03	WRITE DATA	Write values to Control Register	2 or more
0x04	REG WRITE	Similar to WRITE_DATA instruction but pending execution until ACTION Instruction is called	2 or more
0x05	ACTION	Triggers the pending action registered by REG_WRITE instruction.	0
0x06	FACTORY RESET	Resetting the Control Register values to factory defaults.	0
0x83	SYNC WRITE	Controlling multiple G15 in one single instruction packet.	4 or more

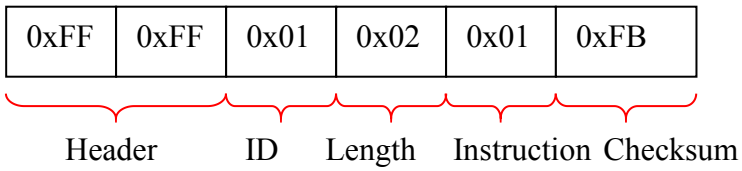
6.3.4 Description of Instructions

1. PING (0x01):

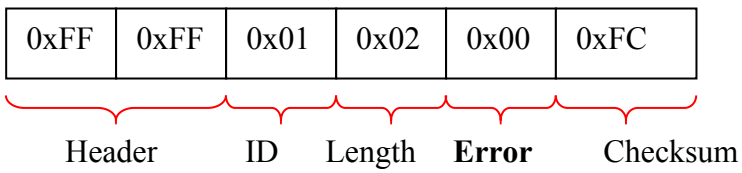
PING instruction is used to check the existence and status of G15 Cube Servo with specific ID. The instruction does not command any operation but G15 will return a status packet to the main controller. The PING instruction will always return a status packet even if the broadcast ID is used and is **regardless of Return Enable value in Control Register**. Table below describes the instruction packet:

Function	Request a status packet from G15
Length	0x02
Instruction	0x01
Parameter1	None

Example PING instruction packet:



Example PING return status packet:



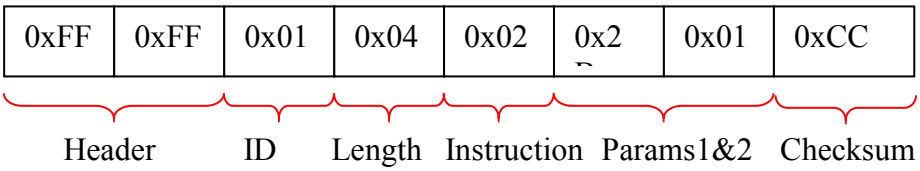
2. READ DATA (0x02):

READ DATA instruction is used to retrieve value of desired parameters from the Control Register of G15. Table below describes the instruction packet:

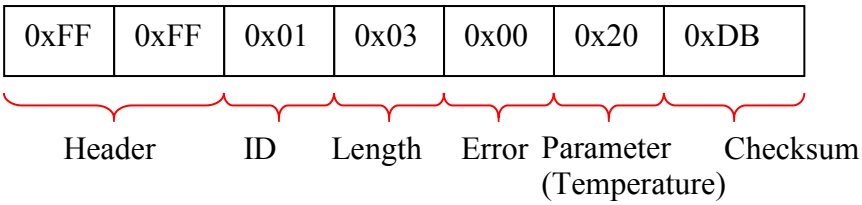
Function	Read Parameters from G15 Control Register
Length	0x04
Instruction	0x02
Parameter1	Starting address data to be read
Parameter2	Length of data in byte to be read

Example READ DATA instruction packet:

Reading internal temperature of G15 with ID 01.



Example return status packet of temperature read:



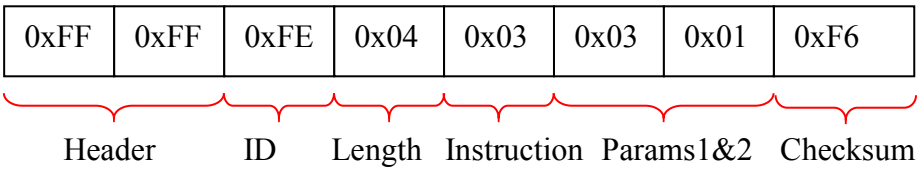
3. WRITE DATA (0x03):

WRITE DATA instruction is used to write value of desired parameters to the Control Register of G15. Writing to Control Register will cause changes of state or characteristic of G15 Cube Servo. Table below describes the instruction packet:

Function	Write to G15 Control Register's Parameters.
Length	N+3 (N is number of data to write)
Instruction	0x03
Parameter1	Starting address data to be written
Parameter2	1st data
Parameter3	2nd data
ParameterN+1	Nth data

Example of WRITE DATA instruction packet:

This example instruction packet set the ID of connected G15 to 1. The ID parameter is located at address 0x03 of Control Register. The instruction packet is transmitted using Broadcasting ID (0xFE). The broadcasted instruction will have no return status packet.



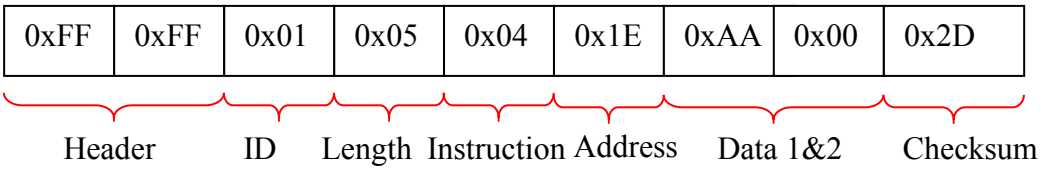
4. REG WRITE

The REG WRITE instruction is similar to WRITE DATA instruction, except that the instruction is not executed immediately. The instruction will be stored to temporary buffer and executed only when trigger by ACTION instruction. Table below describes the instruction packet.

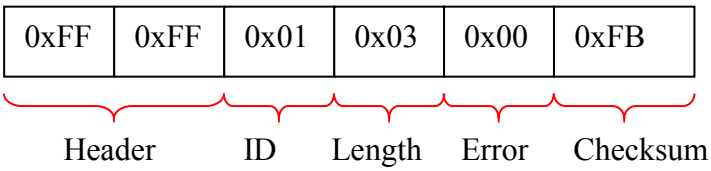
Function	Write parameters to buffer and wait ACTION instruction to trigger the write to the Control Register.
Length	N+3 (N is number of data to write)
Instruction	0x04
Parameter1	Starting address data to be written
Parameter2	1st data
Parameter3	2nd data
ParameterN+1	Nth data

Example of REG WRITE instruction packet:

This example instruction packet set the goal position of G15. The goal position is located at address of 0x1E and is two bytes parameters. The 1st parameter is the starting address of the goal position (refer to Control Register of G15) and the 2nd and 3rd parameter are the lower byte and higher byte of the goal position.



Example of return status packet:

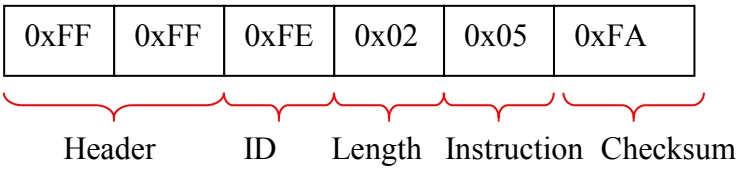


5. ACTION

The ACTION instruction triggers the pending instruction by REG WRITE to execute and change the parameter values in Control Register. This instruction is useful when multiple G15s need to act simultaneously with minimum delay time between each unit. When multiple G15s are controlled by the same main controller, there will be slight time delay between the 1st G15 unit which receives the instruction packet and last G15 unit which receive the instruction packet. Thus, REG WRITE instruction together with ACTION instruction mitigates this problem. Multiple G15s can be sent REG WRITE instructions and ACTION instruction with broadcast ID (0xFE) will trigger all the G15 units to execute the instruction at the same time. Table below describes the instruction packet.

Function	Trigger the pending instruction by REG WRITE
ID	Broadcast ID (0xFE) can be used for sending more than one G15 units
Length	0x02
Instruction	0x05
Parameter	None

Example instruction packet:



6. FACTORY RESET

The FACTORY RESET instruction is used to reset the G15 unit to factory setting. All the Control Register parameters value will be reset to factory default value. Table below describes the instruction packet

Function	Reset the G15 to factory default setting.
Length	0x02
Instruction	0x06
Parameter	None

Example instruction packet:

0xFF	0xFF	0x00	0x02	0x06	0xF7
Header		ID	Length	Instruction	Checksum

Example return status packet:

0xFF	0xFF	0x00	0x02	0x00	0xFD
Header		ID	Length	Error	Checksum

Please take note that the G15 ID will be reset to **0x01** and the communication baudrate will be reset to **19.2kbps** after FACTORY RESET instruction.

7. SYNC WRITE

The SYNC WRITE instruction is used to control multiple G15 units using a single instruction packet. This instruction is intended to reduce the time used to send instruction packets to multiple G15 units. However, this instruction has limitation that it can only be used when the starting address of parameter and length of parameter to be written for all the G15 units are same. Broadcast address (0xFE) is used for the transmission. Table below describes the instruction packet:

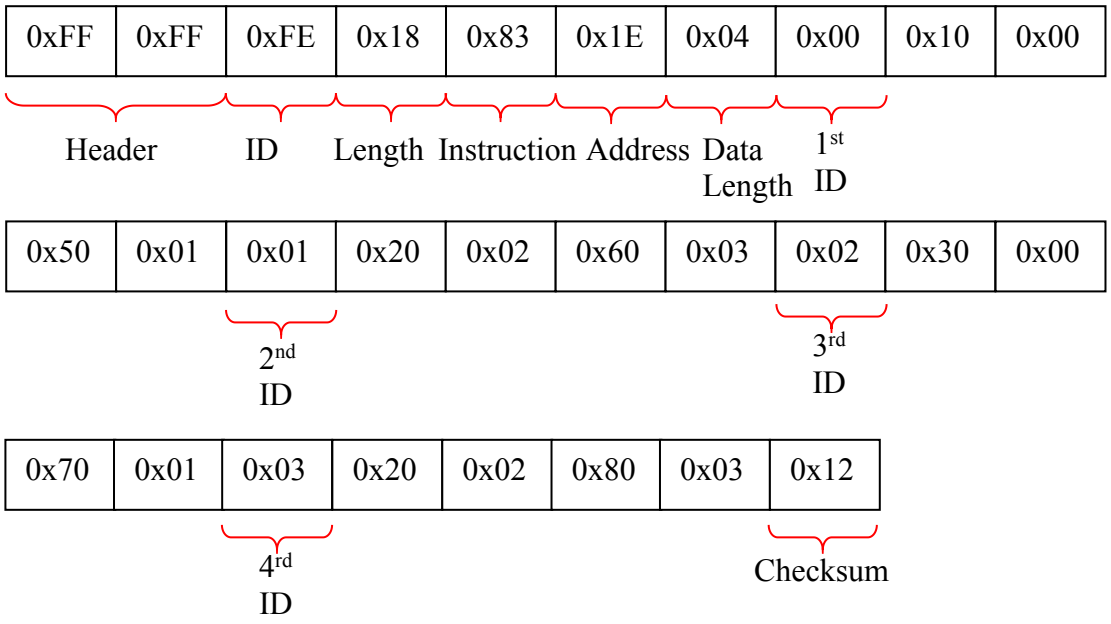
Function	Control multiple G15s using one instruction packet.
ID	0xFE
Length	(L+1)*N +4 L is the data length for each G15; N is the number of G15 unit.
Instruction	0x83
Parameter 1	Starting address of parameter to be written
Parameter 2	Length of data to be written
Parameter 3	ID of the 1st G15 unit
Parameter 4	1st data for the 1st G15 unit
Parameter 5	2nd data for the 1st G15 unit
…	
Parameter L+3	Lth data for the 1st G15 unit
Parameter L+4	ID of 2nd G15 unit
Parameter L+5	1st data for the 2nd G15 unit
Parameter L+6	2nd data for the 2nd G15 unit
…	
Parameter 2L+4	Lth data for the 2nd G15 unit
…	

Example instruction packet

The instruction packet sets the following:

1. G15 with ID of 0 to position 0x010 with speed of 0x150.
2. G15 with ID of 1to position 0x220 with speed of 0x360.
3. G15 with ID of 2 to position 0x030 with speed of 0x170.
4. G15 with ID of 3 to position 0x220 with speed of 0x380.

The instruction packet will have no return status packet because the broadcast ID is used.



7. SAMPLE INSTRUCTION PACKET

1. Read Model Number and Firmware Revision of G15 with ID of 1:

Instruction: READ DATA

Address to Read: 0x00

Length: 0x03

Send Packet: 0xFF, 0xFF, 0x01, 0x04, 0x02, 0x00, 0x03, 0xF5

Receive Packet: 0xFF, 0xFF, 0x01, 0x05, 0x00, 0x47, 0x0F, 0x00, 0x7D

Description: Model Number is 'G' 15, and Firmware revision is 0.

2. Change the ID of G15 from 1 to 0:

Instruction: WRITE DATA

Address to Write: 0x03

Data: 0x00

Send Packet: 0xFF, 0xFF, 0x01, 0x04, 0x03, 0x03, 0x00, 0xF4

Receive Packet: 0xFF, 0xFF, 0x01, 0x02, 0x00, 0xFC

Description: ID change successful if the Error byte in the return status is 0.

3. Changing the Baud Rate of G15 to 9600 bps

Instruction: WRITE DATA

Address to Write: 0x04

Data: 0xCF

Send Packet: 0xFF, 0xFF, 0x04, 0x03, 0x04, 0xCF, 0x25

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Baud Rate change successful if the Error byte in return packet is 0.

4. Setting the Return Delay Time to 4µs for G15 with ID of 0

According to the equation:

$$\text{Return Delay register value} = \frac{\text{Return Delay Time}}{2\mu s}$$

$$= \frac{30\ \mu s}{2\ \mu s}$$

$$= 15$$

Instruction: WRITE DATA

Address to Write: 0x05

Data: 0x02

Send Packet: 0xFF, 0xFF, 0x00, 0x04, 0x03, 0x05, 0x02, 0xF1

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Return Delay change successful if the Error byte in return packet is 0.

5. Change CW Angle Limit to 150º for G15 with ID 0

Instruction: WRITE DATA

Address to Write: 0x08

Data: 0xC5, 0x01

Send Packet: 0xFF, 0xFF, 0x00, 0x05, 0x03, 0x08, 0xC5, 0x01, 0x29

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Angle Limit change successful if the Error byte in return packet is 0.

6. Change the Temperature Limit to 80ºC for G15 with ID 0

Instruction: WRITE DATA

Address to Write: 0x0B

Data: 0x50

Send Packet: 0xFF, 0xFF, 0x00, 0x04, 0x03, 0x0B, 0x50, 0x9D

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Temperature Limit change successful if the Error byte in return packet is 0.

7. Setting the operating voltage to 7V to 12V for G15 with ID of 0

7 Volt =70 (0x46), 12 Volt= 120 (0x78)

Instruction: WRITE DATA

Address to Write: 0x0C

Data: 0x46, 0x78

Send Packet: 0xFF, 0xFF, 0x00, 0x05, 0x03, 0x0C, 0x46, 0x78, 0x2D

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Operating voltage change successful if the Error byte in return packet is 0.

8. Setting the Maximum Torque to 50% of maximum value for G15 with ID 0

50% of maximum torque value is 0x1FF.

Instruction: WRITE DATA

Address to Write: 0x0E

Data: 0xFF, 0x1F

Send Packet: 0xFF, 0xFF, 0x00, 0x05, 0x03, 0x0E, 0xFF, 0x01, 0xE9

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Maximum Torque change successful if the Error byte in return packet is 0.

9. Set G15 with ID 0 to not returning any status packet

Instruction: WRITE DATA

Address to Write: 0x10

Data: 0x00

Send Packet: 0xFF, 0xFF, 0x00, 0x04, 0x03, 0x10, 0x00, 0xE8

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Maximum Torque change successful if the Error byte in return packet is 0.

10. Set G15's Alarm to blink LED and shutdown for over temperature, G15 ID = 0

Alarm LED and Alarm Shutdown are located at address of 0x11 and 0x12 respectively. Alarm LED and Alarm Shutdown can be written at once with starting address of 0x11.

Instruction: WRITE DATA

Address to Write: 0x11

Data: 0x04, 0x04

Send Packet: 0xFF, 0xFF, 0x00, 0x05, 0x03, 0x11, 0x04, 0x04, 0xDE

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Setting successful if the Error byte in return packet is 0.

11. Turn on Torque and LED, G15 ID = 0

Instruction: WRITE DATA

Address to Write: 0x18

Data: 0x01, 0x01

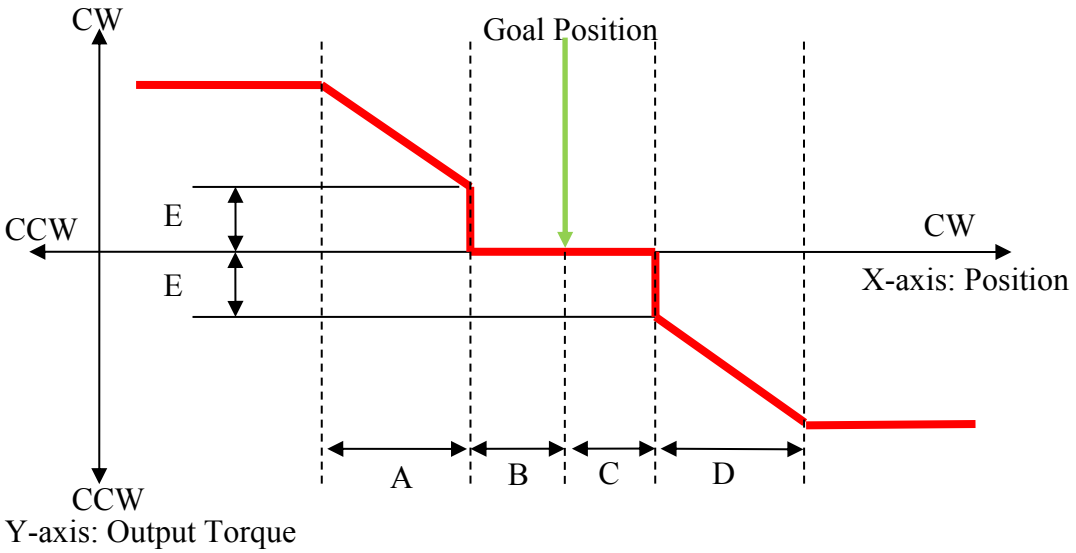
Send Packet: 0xFF, 0xFF, 0x00, 0x05, 0x03, 0x18, 0x01, 0x01, 0xDD

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Setting successful if the Error byte in return packet is 0. If Torque Enable is on, G15 shaft will hold its shaft in position and is hard to rotate the shaft with hand.

12. Setting Compliance Margin to 0x01 and Compliance Slope to 0x40, G15 ID = 0

Figure below shows the compliance margin and slope.



A: CCW Compliance Slope (Address 0x1D) =0x40 (about 21.18º)
B: CCW Compliance Margin (Address 0x1B) =0x01 (about 0.33 º)
C: CW Compliance Margin (Address 0x1A) =0x01 (about 0.33 º)
D: CW Compliance Slope (Address 0x1C) =0x40 (about 21.18º)

Instruction:	WRITE DATA
Address to Write:	0x1A
Data:	0x01, 0x01, 0x40, 0x40
Send Packet:	0xFF, 0xFF, 0x00, 0x07, 0x03, 0x1A, 0x01, 0x01,0x40,0x40, 0x59
Receive Packet:	0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD
Description:	Setting successful if the Error byte in return packet is 0. The compliance slope takes effect on discrete step of $\mathbf{2^n}$ (n is integer). Thus, value between 0x11 to 0x20 will has identical effect on positioning.

13. Position the output shaft of G15 with ID 0 to 0º and output shaft of G15 with ID 1 to 300º and initiate the movement at the same time (Normal Positioning Mode).

REG WRITE instruction together with ACTION instruction needs to be used in this case, so that both G15 units can start to move to goal position at the same time. Broadcast ID is used to send the ACTION instruction to both G15 units at the same time.

Instruction:	REG WRITE, ACTION
Address to Write:	0x1E
Data for ID 0:	0x00, 0x00
Data for ID 1:	0x8B, 0x03
Send Packet ID 0:	0xFF, 0xFF, 0x00, 0x05, 0x04, 0x1E, 0x00, 0x00, 0xD8
Receive Packet ID 0:	0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD
Send Packet ID 1:	0xFF, 0xFF, 0x01, 0x05, 0x04, 0x1E, 0x8B, 0x03, 0x49
Receive Packet ID 1:	0xFF, 0xFF, 0x01, 0x02, 0x00, 0xFC
Send Packet Broadcast ID:	0xFF, 0xFF, 0xFE, 0x02, 0x05, 0xFA
Description:	Setting successful if the Error byte in return packet is 0. The last broadcast packet will have no return status packet.

14. Set the goal position to 100º and G15 output shaft rotate CW to goal position with Direction Positioning Mode. G15 has ID 0.

Bit	15	14	13 - 11	10 - 0
Definition	Direction Positioning Mode=1	Direction	Unused	Goal position

Direction=0: CCW rotation
Direction =1: CW rotation

Goal Position 100 º=0x12E, Goal Position after add the direction=0xC12E

Instruction: WRITE DATA
Address to Write: 0x1E
Data: 0x2E, 0xC1
Send Packet: 0xFF, 0xFF, 0x00, 0x05, 0x03, 0x1E, 0x2E, 0xC1, 0xEA
Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD
Description: Setting successful if the Error byte in return packet is 0.

15. Position the output shaft of G15 with ID 0 to goal position 180º with angular speed of 57RPM (Normal Positioning Mode with speed control).

Position 180º = 0x220, 57 RPM: MOVING SPEED = 0x247

Instruction: WRITE DATA
Address to Write: 0x1E
Data: 0x20, 0x02, 0x47, 0x02
Send Packet: 0xFF, 0xFF, 0x00, 0x07, 0x03, 0x1E, 0x20, 0x02, 0x47, 0x02, 0x6C
Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD
Description: Setting successful if the Error byte in return packet is 0.

16. Move the output shaft of G15 with ID 0 to goal position 180º in 20 seconds (Normal Positioning Mode with time control)

Position 180º = 0x220, 20 seconds: MOVING SPEED = 0xC8, MOVING SPEED after setting for time control = 0x80C8

Bit	15	14-12	11-0
Definition	1	unused	Time to Goal Position

Instruction: WRITE DATA

Address to Write: 0x1E

Data: 0x20, 0x02, 0xC8, 0x80

Send Packet: 0xFF, 0xFF, 0x00, 0x07, 0x03, 0x1E, 0x20, 0x02, 0xC8, 0x80, 0x6D

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Setting successful if the Error byte in return packet is 0.

17. Lock all Control Register address except address 0x18-0x23 for G15 with ID 0

Instruction: WRITE DATA

Address to Write: 0x2F

Data: 0x01

Send Packet: 0xFF, 0xFF, 0x00, 0x04, 0x03, 0x2F, 0x01, 0xC8

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

Description: Locking successful if the Error byte in return packet is 0.

If any attempt to access locked address, status packet with error is returned.

Example:

Send Packet: 0xFF, 0xFF, 0x00, 0x05, 0x03, 0x30, 0x40, 0x00, 0x87

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x08, 0xF5

(Range Error)

18. Set Minimum torque (PUNCH) to 0x40 for G15 with ID 0

Instruction: WRITE DATA

Address to Write: 0x30

Data: 0x40, 0x00

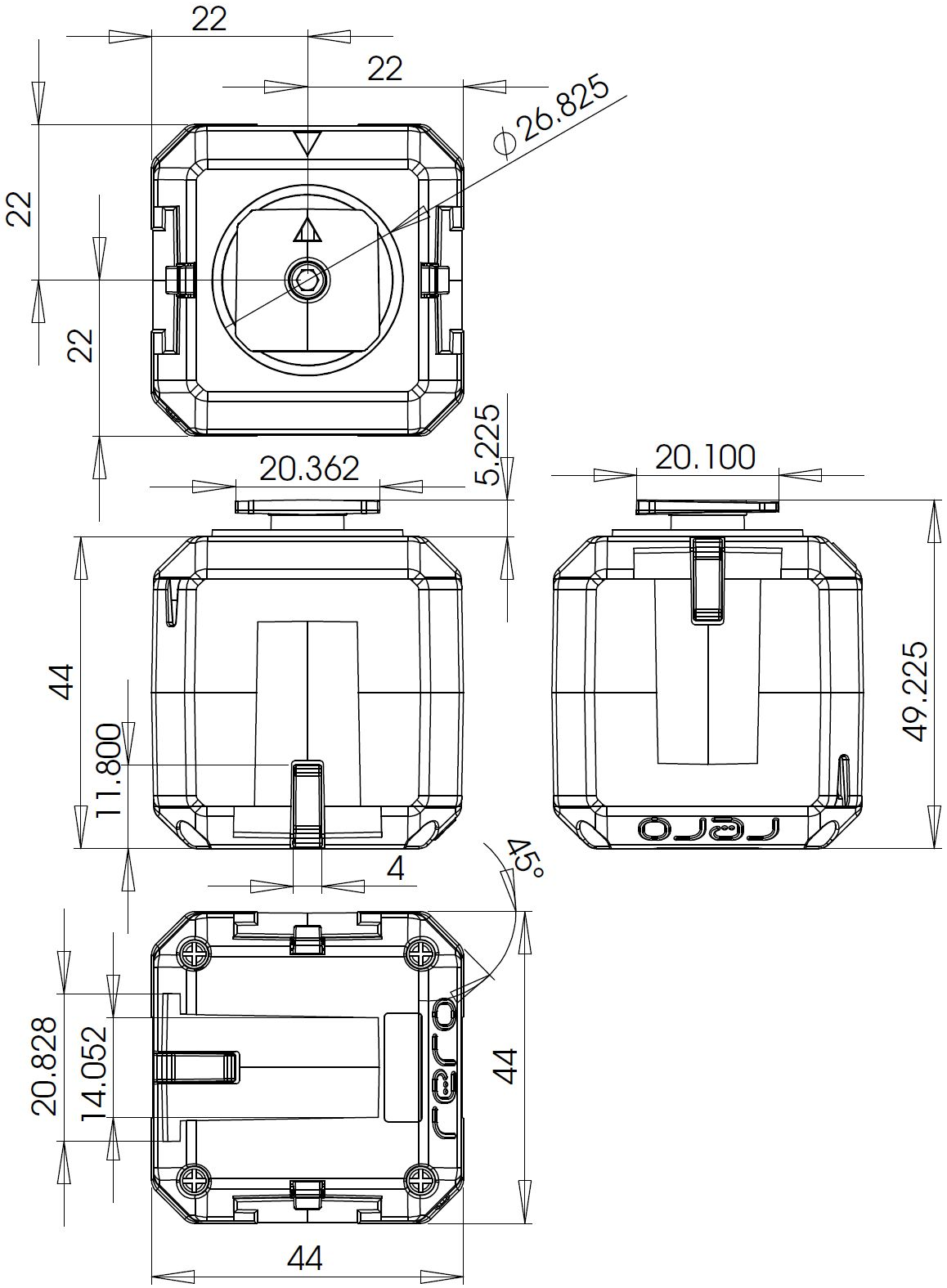
Send Packet: 0xFF, 0xFF, 0x00, 0x05, 0x03, 0x30, 0x40, 0x00, 0x87

Receive Packet: 0xFF, 0xFF, 0x00, 0x02, 0x00, 0xFD

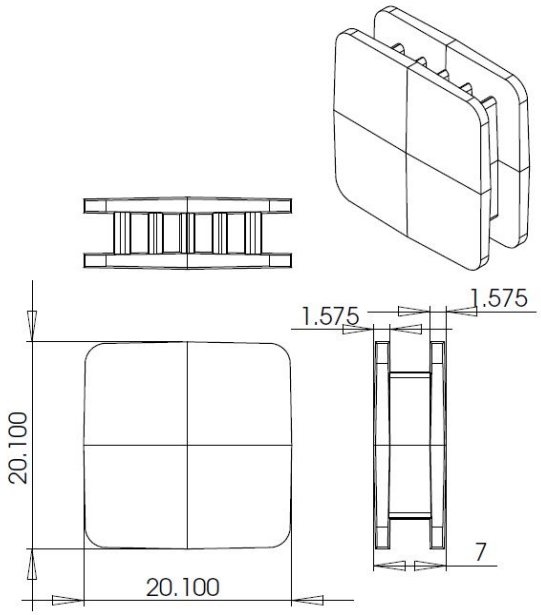
Description: Setting successful if the Error byte in return packet is 0.

8. DIMENSIONS

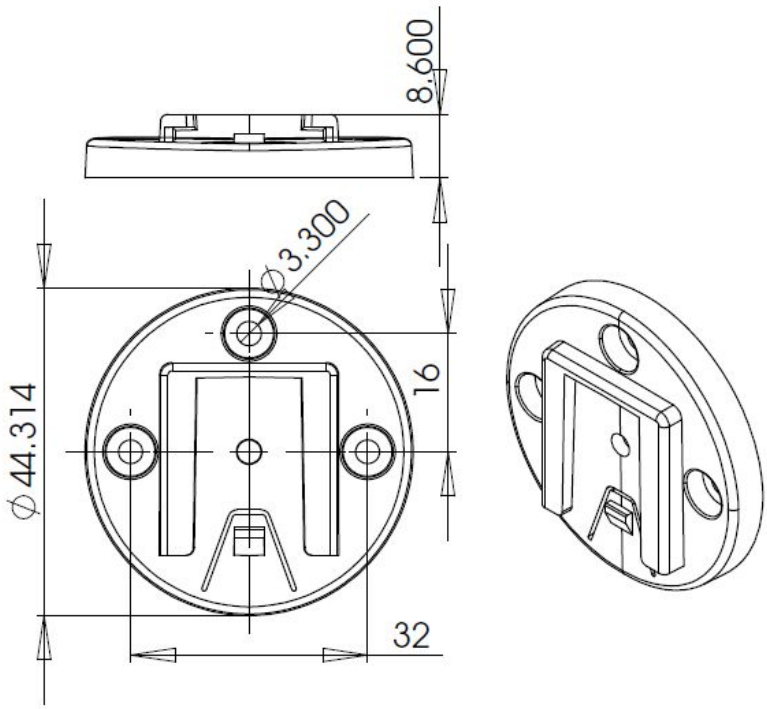
8.1 G15 Cube Servo Dimensions (mm):



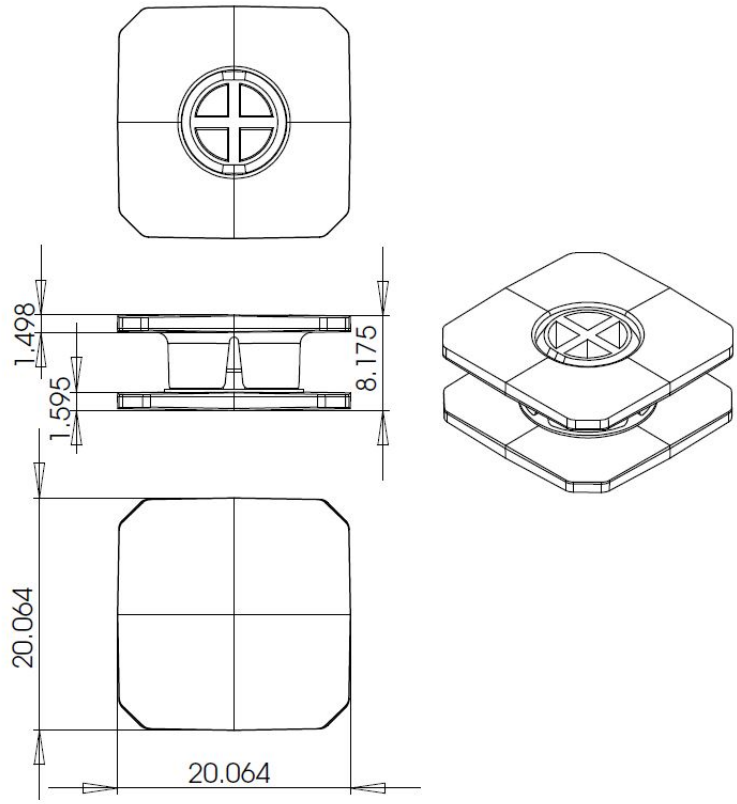
8.2 G15 Inter Connect Dimensions (mm):



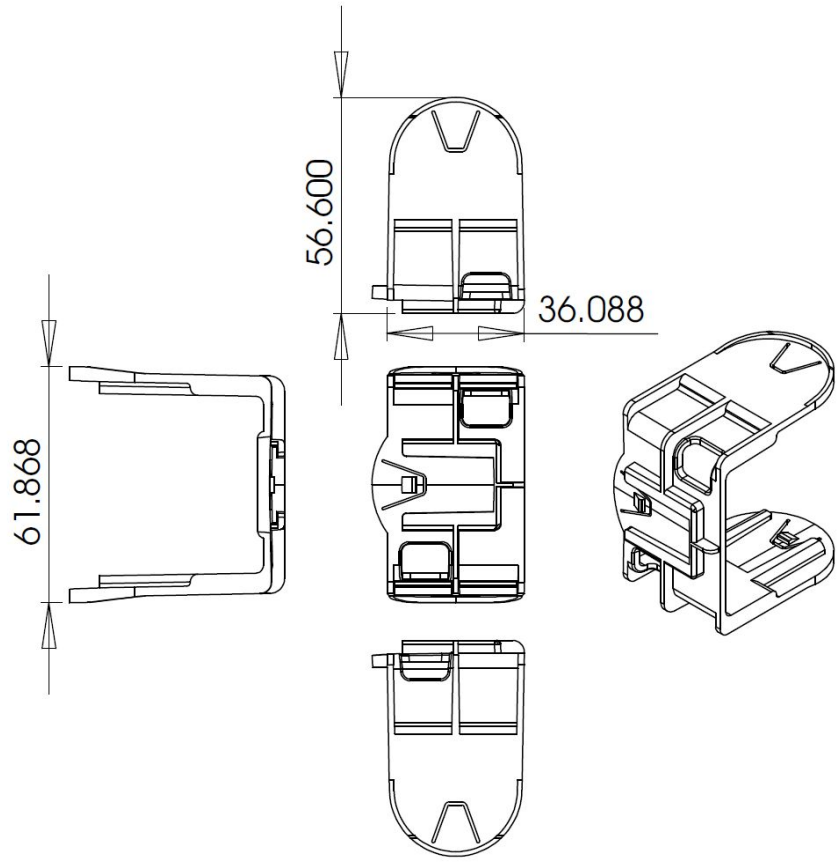
8.3 G15 External Joint Dimensions (mm):



8.4 G15 Rotatable Connect Dimensions (mm):



8.5 G15 U-Joint Dimensions (mm):



9. WARRANTY

- Product warranty is valid for 6 months.
- Warranty only applies to manufacturing defect.
- Damage caused by misuse is not covered under warranty.
- Warranty does not cover freight cost for both ways.

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