

Command set

| <i>Command</i> | <i>Param1</i> | <i>Param2</i> | <i>Return1</i> | <i>Return2</i> | <i>Description</i> |
|----------------|---------------|---------------|----------------|----------------|-------------------------------------|
| 0..0x7F (id) | pos_high | pos_low | 0x00 | 0x00 | Set servo #id target position |
| 0xE1 | addr | 0x00 | data | 0x03 | Read EEPROM |
| 0xE2 | addr | data | 0x03 | 0x03 | Write EEPROM |
| 0xE3 | addr | 0x00 | data | 0x03 | Read memory |
| 0xE4 | addr | data | 0x03 | 0x03 | Write memory |
| 0xE5 | 0x00 | 0x00 | pos_high | pos_low | Read position |
| 0xE6 | pos_high | pos_low | 0x00 | 0x00 | Set target position |
| 0xE7 | 0x00 | 0x00 | version | id | Read version & id |
| 0xE8 | 0x00 | 0x00 | pulsewidth | voltage | Read pulsewidth & voltage |
| 0xE9 | 0..0x7F (id) | speed | pos_high | pos_low | Set servo #id speed & read position |
| 0xEA | 0x00 | 1 / 2 / 3 | 0x03 | 0x06 | Select control parameter set |
| 0xEB | 0x00 | 1 / 0 | 0x03 | 0x06 | Set go / stop |
| 0xEC | | | | | |
| 0xED | | | | | |
| 0xEE | | | | | |
| 0xEF | 0x00 | 0x00 | 0x03 | 0x06 | Release |

Command description

| | | |
|---------|---------------------|---|
| Command | 0..0x7F (id) | Set servo #id target position This allows to set the position of a single servo. Note: This command re-enables ALL released motors on the bus (see command 0xEF). |
| Param1 | pos_high | |
| Param2 | pos_low | |
| Return1 | 0x00 | |
| Return2 | 0x00 | |

| | | |
|---------|-------------|--|
| Command | 0xE1 | Read EEPROM Read one byte from the EEPROM. Readable addresses are 0..0xFF. Addresses >0x2C always read as 0x00. Known EEPROM addresses are tabulated below. |
| Param1 | addr | |
| Param2 | 0x00 | |
| Return1 | data | |
| Return2 | 0x00 | |

| | | |
|---------|-------------|---|
| Command | 0xE2 | Write EEPROM Write one byte to the EEPROM. Writable addresses are 0..0x2C. When writing addresses > 0x2C every 3 rd write attempt will fail, and return 0x00,0x00 ### ? ### |
| Param1 | addr | |
| Param2 | data | |
| Return1 | 0x03 | |
| Return2 | 0x03 | |

| | | |
|---------|-------------|--|
| Command | 0xE3 | Read memory Read one byte from the controllers volatile memory. Readable addresses are 0..0xFF. Known memory addresses are tabulated below. |
| Param1 | addr | |
| Param2 | 0x00 | |
| Return1 | data | |
| Return2 | 0x03 | |

| | | |
|---------|-------------|--|
| Command | 0xE4 | Write memory Write one byte to the controllers volatile memory. The addressable memory range is 0..0xFF, but not all addresses are writable. When a write attempt fails the controller returns 0x00,0x00. ### <i>TODO: Tabulate writable addresses.</i> ### |
| Param1 | addr | |
| Param2 | data | |
| Return1 | 0x03 | |
| Return2 | 0x03 | |

| | | |
|---------|-------------|---|
| Command | 0xE5 | Read position Read the current position. Use command 0xE9 to address multiple motors on one bus. |
| Param1 | 0x00 | |
| Param2 | 0x00 | |
| Return1 | pos_high | |
| Return2 | pos_low | |

| | | |
|---------|-------------|---|
| Command | 0xE6 | Set target position This sets the target position for all motors on the bus. Use command 0..0x7F to address multiple motors. |
| Param1 | pos_high | |
| Param2 | pos_low | |
| Return1 | 0x00 | |
| Return2 | 0x00 | |

| | | |
|---------|-------------|------------------------------|
| Command | 0xE7 | Read version & id |
| Param1 | 0x00 | |
| Param2 | 0x00 | |
| Return1 | version | |
| Return2 | id | |

| | | |
|---------|-------------|--|
| Command | 0xE8 | Read pulsewidth & voltage Reads the driving pulsewidth applied to the motor and the supply voltage. Voltage scale = [0.03522 V] |
| Param1 | 0x00 | |
| Param2 | 0x00 | |
| Return1 | pulsewidth | |
| Return2 | voltage | |

| | | |
|---------|--------------|---|
| Command | 0xE9 | Set servo #id speed & read position This command sets the speed of a single servo on the bus and reads its current position. Valid speed range is 1..255. |
| Param1 | 0..0x7F (id) | |
| Param2 | speed | |
| Return1 | pos_high | |
| Return2 | pos_low | |

| | | |
|---------|-------------|--|
| Command | 0xEA | Select control parameter set This command sets the control parameters (P-gain,D-gain,Dead-band) according to the parameter sets 1-3 stored in the EEPROM. Values other than 1-3 always select parameter set 3. Parameter set 1 is loaded at power-on. |
| Param1 | 0x00 | |
| Param2 | 1 / 2 / 3 | |
| Return1 | 0x03 | |
| Return2 | 0x06 | |

| | | |
|---------|-------------|---|
| Command | 0xEB | Set go/stop Sending a 0 will suspend subsequent changes of the target position until sending a value >0. This command does NOT disable the position control. To disable the position control mechanism use command 0xEF. |
| Param1 | 1 / 0 | |
| Param2 | 0x00 | |
| Return1 | 0x03 | |
| Return2 | 0x06 | |

| | | |
|---------|-------------|---|
| Command | 0xEF | Release This command stops the servos position control mechanism. The joint can be moved by hand afterwards. Note: Any following move command on ANY servo on the bus will re-enable all servos. A re-enabled servo will move to the last set target position with highest possible speed. |
| Param1 | 0x00 | |
| Param2 | 0x00 | |
| Return1 | 0x03 | |
| Return2 | 0x06 | |

Bug: When a new target position is sent to a motor the trajectory generator uses the last trajectory set-point as starting point, which may be different from the actual position in case the joint was moved by hand after a release command(0xEF). A re-enabled motor will therefore start to move with highest speed in the direction of the old target position until it catches up with the new trajectory.

Workaround: (Single servo only!) Before sending a new target position, read the actual joint position and write it to memory location 0x07:0x06 (this is where the actual trajectory set-point is stored).

EEPROM locations

Unless otherwise stated, 2-byte values are stored most significant first.

| | Default settings (**) | | | | |
|---------|-----------------------|--------|-----------------|--|-----------------|
| Address | 8498SG | 5498SG | 5980SG / 5990TG | | |
| 0x00 | 0x50 | 0x50 | 0x14 | P-gain | Parameter set 1 |
| 0x01 | 0xB4 | 0xB4 | 0x64 | | |
| 0x02 | 0x03 | 0x04 | 0x04 | | |
| 0x03 | 0x1E | 0x0A | 0x05 | Dead-zone | |
| 0x04 | 0x01 | 0x02 | 0x02 | D-gain | |
| 0x05 | 0x01 | 0x01 | 0x01 | D-gain ? (not reloaded at parameter change) | |
| 0x06 | 0xFF | 0xFF | 0xFF | Speed | |
| 0x07 | 0x00 | 0xFF | 0x00 | Center position (**) | |
| 0x08 | 0x00 | 0xE4 | 0x00 | | |
| 0x09 | 0x02 | 0x02 | 0x02 | | |
| 0x0A | 0x26 | 0x26 | 0x26 | (550) Minimum position limit. | |
| 0x0B | 0x09 | 0x09 | 0x09 | (2450) Maximum position limit. | |
| 0x0C | 0x92 | 0x92 | 0x92 | | |
| 0x0D | 0x00 | 0x00 | 0x00 | | |
| 0x0E | 0x10 | 0x10 | 0x10 | | |
| 0x0F | 0x03 | 0x03 | 0x03 | | |
| 0x10 | 0xF0 | 0xF0 | 0xF0 | | |
| 0x11 | 0x05 | 0x05 | 0x05 | (1500) Center position ? | |
| 0x12 | 0xDC | 0xDC | 0xDC | | |
| 0x13 | 0xB4 | 0xBE | 0xB4 | Left limit (**) | |
| 0x14 | 0xB4 | 0xB9 | 0xB4 | Right limit (**) | |
| 0x15 | 0x13 | 0x13 | 0x13 | | |
| 0x16 | 0x88 | 0x88 | 0x88 | | |
| 0x17 | 0x00 | 0x00 | 0x00 | | |
| 0x18 | 0x00 | 0x00 | 0x00 | | |
| 0x19 | 0x05 | 0x05 | 0x05 | (1500) Center position ? | |
| 0x1A | 0xDC | 0xDC | 0xDC | | |
| 0x1B | 0x29 | 0x29 | 0x29 | Direction: 0x29: forward, 0x28: reverse (**) | |
| 0x1C | 0x28 | 0x28 | 0x28 | | |
| 0x1D | 0xD2 | 0xD2 | 0xD2 | | |
| 0x1E | 0x05 | 0x0A | 0x0A | | |
| 0x1F | 0x64 | 0x64 | 0x1E | P-gain | Parameter set 2 |
| 0x20 | 0xC8 | 0xC8 | 0x78 | | |
| 0x21 | 0x04 | 0x05 | 0x04 | | |
| 0x22 | 0x32 | 0x0F | 0x07 | Dead-zone | |
| 0x23 | 0x01 | 0x02 | 0x02 | D-gain | |
| 0x24 | 0x01 | 0x02 | 0x02 | D-gain ? (not reloaded at parameter change) | |
| 0x25 | 0x3C | 0x3C | 0x0A | P-gain | Parameter set 3 |
| 0x26 | 0xA0 | 0xA0 | 0x50 | | |
| 0x27 | 0x02 | 0x03 | 0x04 | | |
| 0x28 | 0x0A | 0x05 | 0x03 | Dead-zone | |
| 0x29 | 0x01 | 0x02 | 0x02 | D-gain | |
| 0x2A | 0x01 | 0x02 | 0x02 | D-gain ? (not reloaded at parameter change) | |
| 0x2B | 0x00 | 0x00 | 0x00 | ID | |
| 0x2C | 0x0A | 0x0A | 0x0A | | |
| 0x2D | 0x02 | 0x02 | 0x02 | | |
| 0x2E | 0xCF | 0x0E | 0xB3 | EEPROM Checksum (*) | |

** According to HMI-Servo programmer v 1.0.2. Not tested.

* The EEPROM Checksum adds up the location 0x00..0x2B to a multiple of 256:

$$\text{Sum}[0:0x2C] \% 256 == 0$$

$$\text{Checksum} = 256 - \text{sum}[0:0x2B] \% 256$$

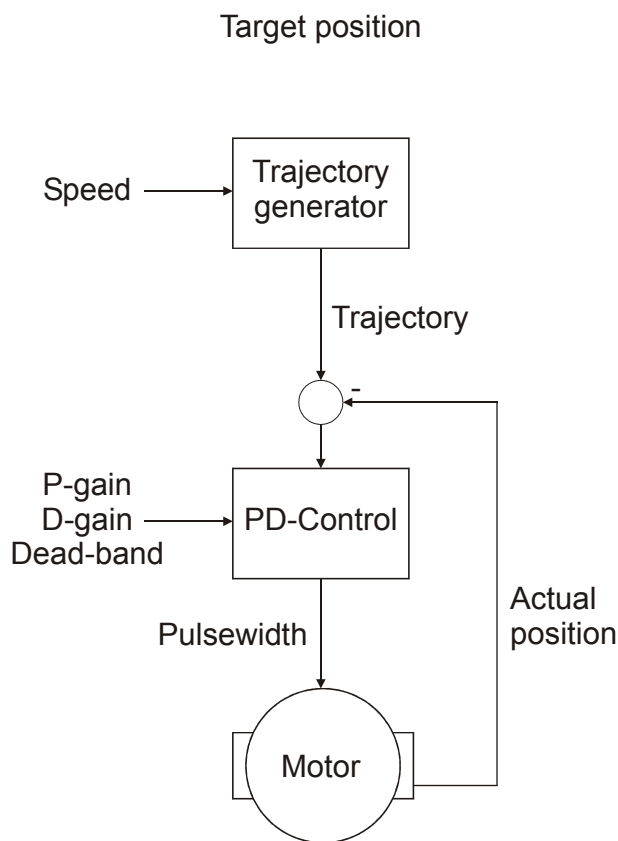
When the motor is powered on with a wrong checksum, all communication behaves normal but the motor will not move.

Memory locations

Unless otherwise stated, 2-byte values are stored most significant first.

| <i>Address</i> | |
|-----------------------|---|
| | |
| 0x06 | (low/high) Current trajectory set-point |
| 0x07 | |
| | |
| 0x80 | Correspond to EEPROM addresses 0x00..0x1E. Cells are loaded from EEPROM at power-on. |
| ... | |
| 0x9E | |
| | |
| 0xC3 | Speed (sometimes updated from 0x86) |
| | |
| 0xA5 | Target position |
| 0xA6 | |
| 0xA7 | Actual position (Not reliable if motor is released ### ? ###) |
| 0xA8 | |
| 0xA9 | Target position – actual position |
| 0xAA | |
| | |
| 0xC9 | Go / stop |
| | |

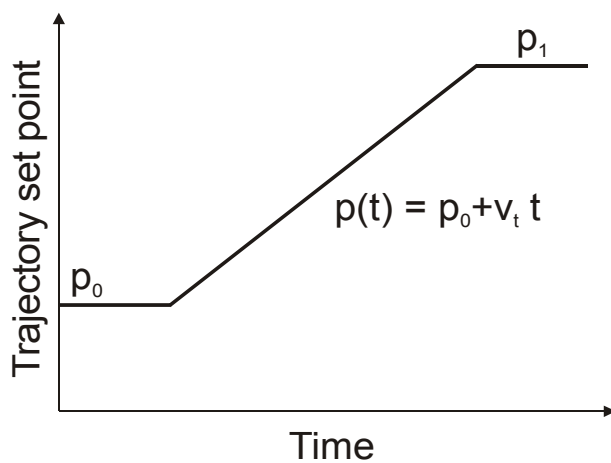
Motion control



TODO: Influence of P,D?

Trajectory generation

The trajectory generator generates a linear trajectory (constant angular velocity) starting from the last trajectory set point p_0 to the actual target position p_1 :



The current trajectory set point $p(t)$ can be read from the memory location 0x07:0x06 (least significant first!). The trajectory angular velocity v_t is proportional to the set speed parameter s . When sending commands during an ongoing motion, the addressed servo's trajectory velocity has

been found to decreases linearly with the the command frequency:

$$v_t = As (1 - Br)$$

v_t trajectory angular velocity [tics/sec]
s speed setting
r command rate [1/sec]
A = 37.46(79) tics/sec
B = 0.001106(87) sec

The velocity reduction has been measured for commands 0xE3 (read memory) and 0xE9 (set speed/read position).

TODO: Verify velocity reduction with other commands.

Note that the maximum reachable motor velocity depends on the motor type and the supply voltage.

| | <i>Voltage</i> | | <i>8498HB</i> | <i>5498SG</i> | <i>5980SG/5990TG</i> |
|---------------------------------------|-----------------------|------------|----------------------|----------------------|-----------------------------|
| Maximum Velocity * | 6V | [tics/sec] | 3000 | 2727 | 3529 |
| | 7.4V | | 3333 | 3158 | 4286 |
| Maximum possible speed setting | 6V | [speed] | 80 | 73 | 94 |
| | 7.4V | | 89 | 84 | 114 |

* According to Hitec webpage.