Technical Manual

Leto BLDC Intelligent Servo Motor

Product Code: OVU00243 End Stop

OVU00244 Continuous

The information in this document is subject to change without notice and should not be construed as a commitment by Overview Ltd. Overview Ltd assumes no responsibility for any errors that may appear in this document.

In no event shall Overview be liable for incidental or consequential damages arising from use of this document or the hardware and software described in this document.

This document and parts thereof must not be reproduced or copied without Overview's written permission, and contents thereof must not be imparted to a third party nor be used for any unauthorised purpose.

Leto™ and Servotorq™ are trademarks of Overview Ltd.

Overview Ltd.
Overview House, Kingswey Business Park
Forsyth Road, Woking, GU21 5SA, United Kingdom
Tel: +44 (0) 20 8875 0984
Email: info@overview.co.uk
www.overview.co.uk

Table of Contents

1. Introduction

The Leto BLDC intelligent servo motors have been designed to be integrated into a number of environments that require a combination of high positional accuracy as well as smooth and silent motion. These include video conferencing, broadcast and CCTV PTZ applications. The Leto platform creates a standalone intelligent motor with integral low-level motor control and integrated optical feedback. It is robust to external dynamic disturbances, especially impulses and vibrations.

2. Product Features

- Wide dynamic speed-range from 0.05°s^{-1} to 720°s^{-1}
- Rapid and precise positional control to 0.005° repeatability
- Near silent operation
- Integral Digital Signal Processor (DSP) based motor controller
- High level control commands via a simple, 2-wire I²C bus
- PCBA connections conveniently arranged for use in a pan/tilt camera product
- All control and drive components are contained within the 56mm by 63mm PCB
- Configurations to provide continuous or limited rotation as necessary
- Hollow shaft for slip ring integration
- User configurable PID gains and acceleration to allow tuning for the attached load
- Ability to in-field upgrade firmware

3. Precautions and Warnings

Please study this technical manual thoroughly.

- To prevent the risk of hazards such as fire or shock, do not expose this product to water.
- Do not drop or shake the carton severely. The box cannot give complete protection against heavy shocks.
- Ensure appropriate ESD preventative actions are taken when handling this product.
- Do not install the product in wet or high humidity areas without adequate protection.
- The product is guaranteed for use within temperatures of -20°C and +70°C.
- Do not disassemble the product. This will void the given warranty.
- This product is not suitable for the following environments:
  - Explosive atmospheric conditions
  - Life critical systems

4. Product Specifications

All electronic components are of industrial grade, with temperature ratings of at least -20°C and +70°C.

4.1. Motor Electrical Data

Electrical Properties

Specification	Value
Operating voltage	21.6V to 26.4V DC
Current at max torque	600mA
Initialisation current	600mA
Idle, no load, current	45mA
Max. input voltage ripple	250mV@100kHz
Resolution	0.0055°
Max Speed	720°/s
Min Speed	0.05°/s

Table 1: Motor electrical data at 24V unless otherwise specified.

Mechanical Properties

Specification	Value
Weight	96g
Rotor moment of inertia	140gcm^2
Locked Rotor/Stall/Holding Torque	90mNm
Cogging torque	4.1mNm max
Moving Torque	72mNm @ 360°/s
Perpendicularity	< +/-0.5°
Maximum radial load	102N
Maximum axial load[1]	19N
Range	Configurable between 0°-360° including continuous rotation

Table 2: Motor mechanical power and mechanical properties.

Environmental Conditions

Specification	Value
Temperature rated (standard operation)	-20°C to +70°C
Humidity range (standard operation)	5% to 90% RH at 40°C
Storage Conditions	-20°C to +70°C
Storage Humidity (%RH non-condensing)	5% - 85%

Table 3: Motor environmental capabilities.

[1] When either the axial or radial load is 0N, the other axis can be loaded more.

4.2. Performance Specifications

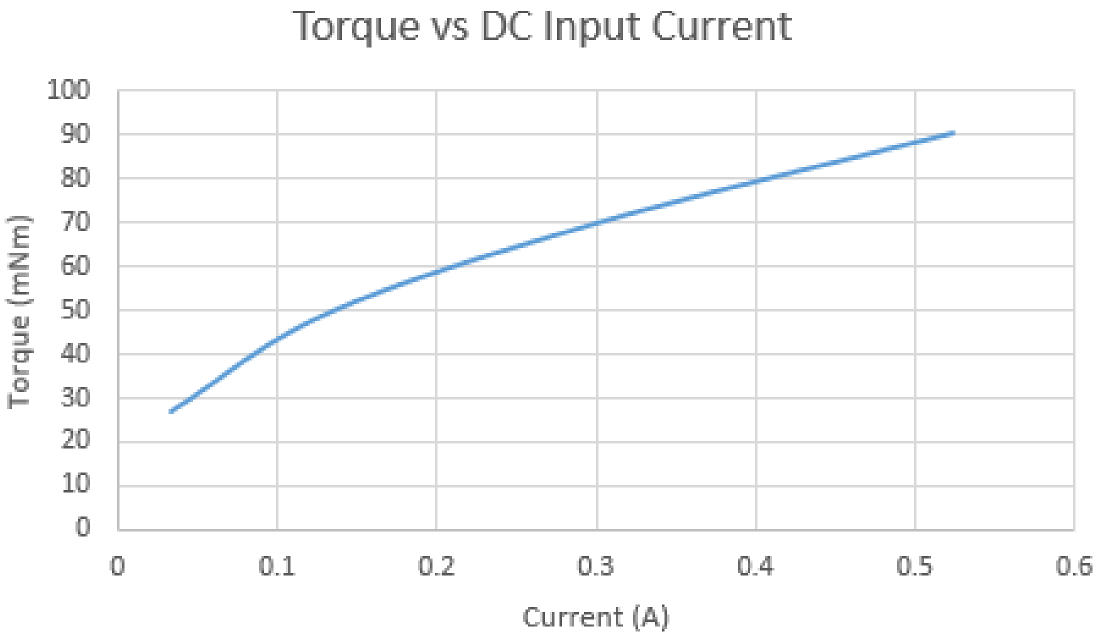
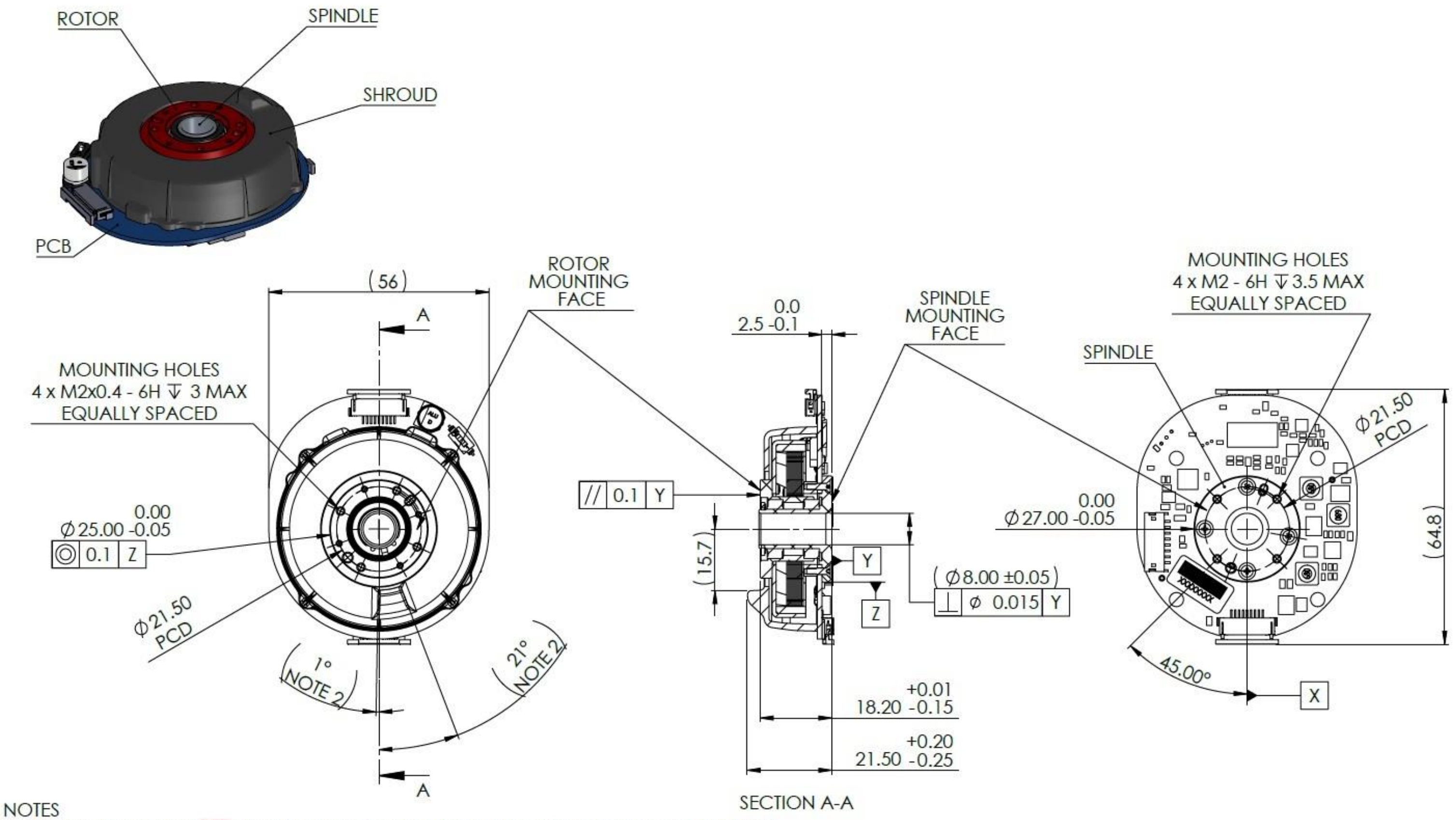


Figure 1: Current vs torque curves of the Leto motor showing DC input measured at 25˚C, 0 ˚/s speed

5. Product Breakdown

5.1. Product Drawing – Leto Limited Rotation Motor

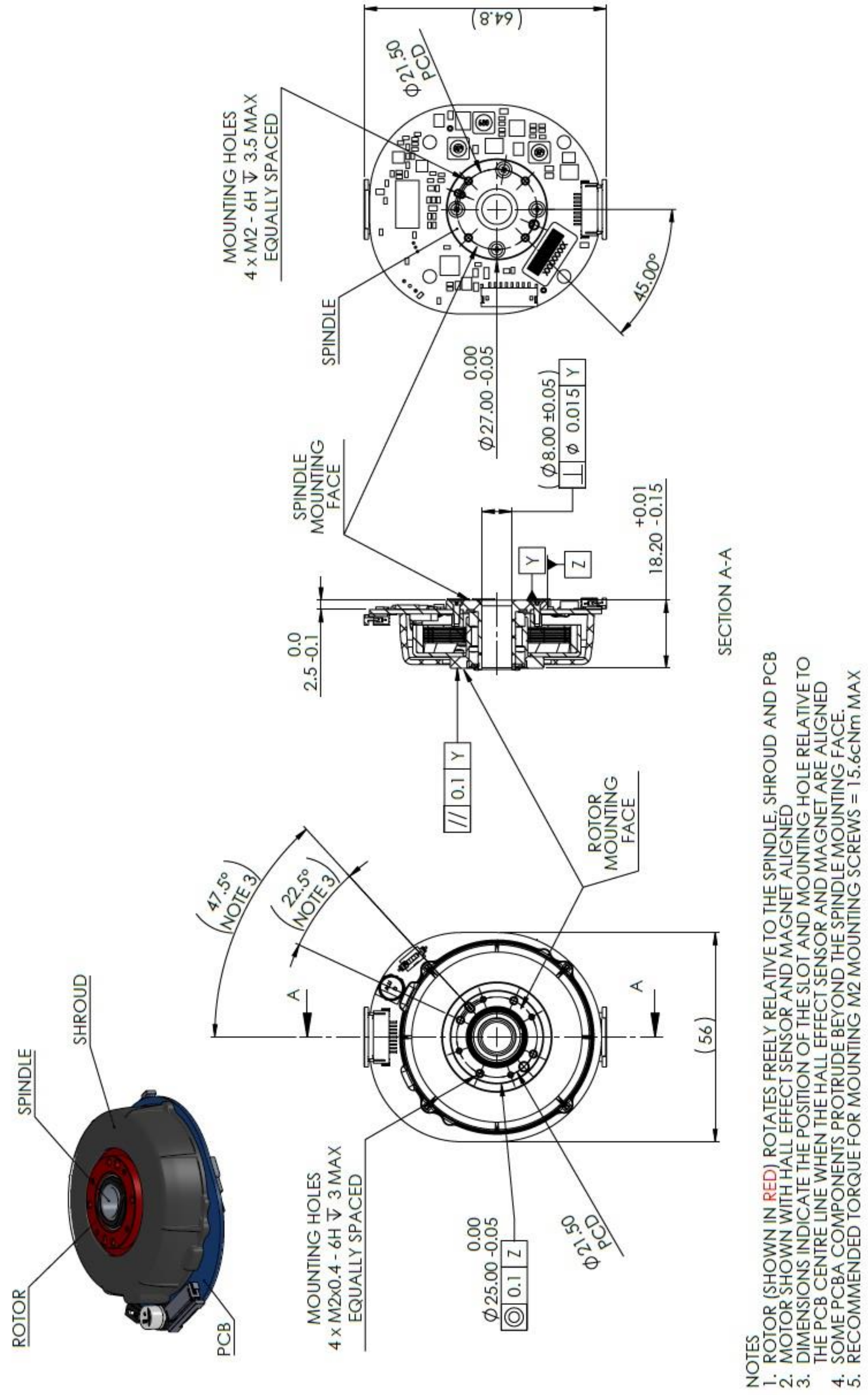


NOTES

1. ROTOR (SHOWN IN RED) ROTATES FREELY RELATIVE TO THE SPINDLE, SHROUD AND PCB
2. DIMENSION INDICATES THE POSITION OF ENDSTOP FACE COMPARED TO THE SPINDLE (DATUM X).
3. SOME PCBA COMPONENTS PROTRUDE BEYOND THE SPINDLE MOUNTING FACE.
4. RECOMMENDED TORQUE FOR MOUNTING M2 MOUNTING SCREWS = 15.6cNm MAX

Figure 2: Leo Limited Rotation Motor

5.2. Product Drawing – Leto Continuous Rotation Motor



NOTES
1. ROTOR (SHOWN IN RED) ROTATES FREELY RELATIVE TO THE SPINDLE, SHROUD AND PCB
2. MOTOR SHOWN WITH HALL EFFECT SENSOR AND MAGNET ALIGNED
3. DIMENSIONS INDICATE THE POSITION OF THE SLOT AND MOUNTING HOLE RELATIVE TO THE PCB CENTRE LINE WHEN THE HALL EFFECT SENSOR AND MAGNET ARE ALIGNED
4. SOME PCBA COMPONENTS PROTRUDE BEYOND THE SPINDLE MOUNTING FACE.
5. RECOMMENDED TORQUE FOR MOUNTING M2 MOUNTING SCREWS = 15.6cNm MAX

Figure 3: Leto Continuous Rotation Motor

6. Installation / Connection

6.1. Printed Circuit Board Assembly (PCBA)

Figure 4 and Figure 5 below highlight the position of the three sockets and one switch on the PCBA for interfacing with external systems.

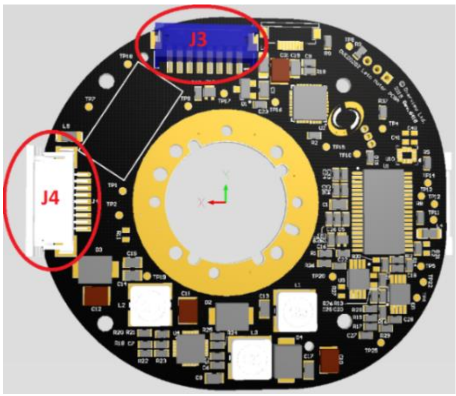


Figure 4: PCBA Rear View with J4 & J3 highlighted

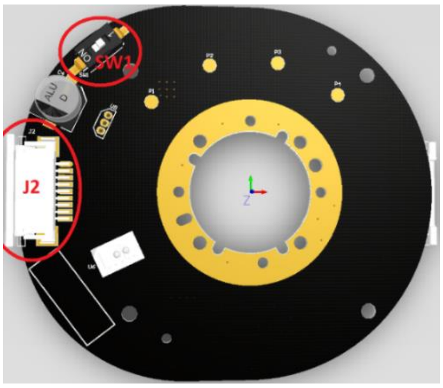


Figure 5: PCBA Front View with J2 & SW1 highlighted

J4 – Molex 0522710979	
Pin	Signal
1	V$_{in}$
2	I^{2}C SDA
3	I^{2}C SCL
4	GND
5	PASS THROUGH 1
6	PASS THROUGH 2
7	GND
8	PASS THROUGH 3
9	PASS THROUGH 4

Table 4: J4 Connector details

J2 – Molex 0522710979	
Pin	Signal
1	GND
2	GND
3	NO CONNECTION
4	NO CONNECTION
5	I^{2}C SCL
6	I^{2}C SDA
7	NO CONNECTION
8	V$_{IN}$
9	V$_{IN}$

Table 5: J2 Connector details

J3 – JST S8B-SM4A-TF (LF)(SN)	
Pin	Signal
1	V_{in}
2	I^2C SDA
3	I^2C SCL
4	PASS THROUGH 3
5	PASS THROUGH 4
6	PASS THROUGH 2
7	PASS THROUGH 1
8	GND

Table 6: J3 Connector details

SW1 - Switch		
	I^2C Address	
Position	7-bit	Left Shifted
ON	0x29	0x52
OFF	0x28	0x50

Table 7: SW1 Switch details

6.2. Mechanical

The two mounting faces of the motor have four M2 threaded holes provided for mechanical interfacing with the motor. Appropriate thread engagement calculations should be carried out to prevent stripping of threads during installation.

Use 156 mNm torque, max 3mm depth into threaded brass part.

7. Software Set-up

This section describes the use of the I^2C interface to the Servotorq Intelligent BLDC Servo family. The message protocol for devices on the bus is given, followed by a detailed description of the available motor commands. The commands listed in this document apply to firmware versions 5.5.81 and upwards.

7.1. Physical Layer

A standard two wire I^2C interface is provided by the motor consisting of a clock, SCL, and data, SDA, line. Both SDA and SCL need to be pulled up to the idle voltage. Titan and Leto BLDC motors use an I^2C high voltage of 3.3V. Atlas BLDC motors use an I^2C high voltage of 12V so a buffer chip must be used. When the bus is not busy both lines will be high. The SCL signal is always generated by the master and the BLDC motor(s) will always be slaves on the bus. SDA can be controlled by either the master or the slave being communicated to.

7.2. Communications Layer

With two exceptions all transitions of SDA will occur when SCL is low. These exceptions being start condition and the stop condition. Start condition (STX): All messages must start with this transition. SDA is set from high to low while SCL is high. Stop condition (ETX): All messages must end with this transition. SDA is set from low to high while SCL is high. Messages are of variable length but are split into 1-byte blocks, most significant bit first, after which an acknowledge bit (ACK /NACK) is required from the receiving party. An ACK bit is low and a NACK bit high.

7.3. Message Structure

There are two types of messages, a data write message and a data request message. Shading is used below to indicate whether the bus is under control of the master or slave device during message transmission:

▨	SDA under master control
	SDA under slave control

7.3.1. Data Write Message

This takes the following form

STX	Control Byte	ACK	Command Byte	ACK	Data 0	ACK 0	Data *n*	ACK *n*	ETX

Control Byte.

The control byte consists of the control code (0x5) for the BLDC motor, the address to specify which motor the message is intended for and whether the message is a data write or data request message.

Bit	**Function**
7	Control code bit 3: 0
6	Control code bit 2: 1
5	Control code bit 1: 0
4	Control code bit 0: 1
3	Address bit 2: 0
2	Address bit 1: 0
1	Address bit 0: 1/0
0	Write/Request bit: 0 (write)

Command Byte.

The command byte specifies the desired action of the message and is described in detail in section 7.5.

Data Bytes.

Depending on command byte 0, 1 or more additional data bytes will be transmitted to complete the message.

7.3.2. Data Request Message

To request data from the BLDC motor two messages are required one to setup up the request and one to deliver the requested data. This is outlined below.

Setup Request Message

STX	Control Byte	ACK	Command Byte	ACK	ETX

Control Byte.

Bit	Function
7	Control code bit 3: 0
6	Control code bit 2: 1
5	Control code bit 1: 0
4	Control code bit 0: 1
3	Address bit 2: 0
2	Address bit 1: 0
1	Address bit 0: 1/0
0	Write/Request bit: 0 (write)

Command Byte. See section 7.5. for a detailed description of request commands.

Deliver Requested Data Message

STX	Control Byte	ACK	Data Byte 0	ACK 0	Data Byte n	NACK n	ETX

Control Byte.

Bit	Function
7	Control code bit 3: 0
6	Control code bit 2: 1
5	Control code bit 1: 0
4	Control code bit 0: 1
3	Address bit 2: 0
2	Address bit 1: 0
1	Address bit 0: 1/0
0	Write/Request bit: 1 (request)

Data Bytes. This is the relevant data as requested from the command in the setup request message. The data payload will be either one or two bytes and the last data byte will be followed by a NACK from the master.

7.4. Startup

To allow the motor firmware to be upgraded remotely, the device can be run in In-Field Programming (IFP) mode. This mode will be activated if the \HOLD LAUNCH" command (0xF0) is received in the first 500ms after power up. Figure 6 shows an outline of timings of the startup procedure. More information about the IFP mode can be found in section 7.8.

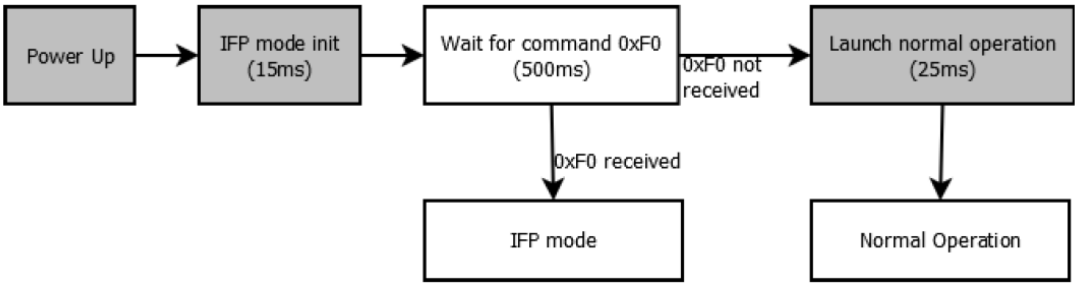


Figure 6: BLDC motor startup procedure.
Grey boxes indicate when the motor may not be guaranteed to respond to I^{2}C messages.

7.5. Commands

7.5.1.Summary

Code	Description	Message Type	# data bytes
0x01	Reset	Data write	0
0x02	Calibration complete	Data read	1
0x03	Is motor moving	Data read	1
0x04	Return current location	Data read	2
0x05	Goto absolute location	Data write	2
0x06	Goto relative location	Data write	2
0x07	Travel at velocity	Data write	2
0x08	Set acceleration	Data write	2
0x09	Goto absolute location in set time	Data write	3
0x0A	Goto relative location in set time	Data write	3
0x0B	Get acceleration	Data read	2
0x0C	Set tuning algorithm proportional gain	Data write	2
0x0D	Get tuning algorithm proportional gain	Data read	2
0x0E	Set tuning algorithm integral gain	Data write	2
0x0F	Get tuning algorithm integral gain	Data read	2
0x10	Set tuning algorithm differential gain	Data write	2
0x11	Get tuning algorithm differential gain	Data read	2
0x12	Set first endstop distance from mechanical endstop	Data write	2
0x13	Set mechanical motor range	Data write	2
0x19	Set continuous	Data write	2
0x1A	Get continuous	Data read	2
0x1B	Get firmware version	Data read	4
0x1C	Wake up	Data write	0
0x1D	Set sleep on power up mode	Data write	1
0x23	Save settings to ash	Data write	0
0x24	Reload factory defaults	Data write	0
0x2F	Get sleep on power up mode	Data read	1
0x30	Is sleeping	Data read	1
0x40	Goto relative position 360	Data write	3
0x41	Goto relative position at speed	Data write	4
0x42	Goto absolute position at speed	Data write	4
0x45	Get serial full	Data read	4
0x4A	Get first endstop distance	Data read	2
0x4B	Get mechanical motor range	Data read	2
0x4E	Set use hall sensor	Data write	1
0x4F	Get use hall sensor	Data read	1
0x53	Set use Turbo mode	Data write	1
0x54	Get use Turbo mode	Data read	1
0x5E	Goto absolute pos in time ms	Data write	4

Continued over page…….

Commands continued…..

Code	Description	Message Type	# data bytes
0x5F	Goto relative pos in time ms	Data write	5
0x99	Set Over Temperature Protection	Data write	1
0x9A	Get Over Temperature Protection	Data read	1
0X9B	Get Temperature	Data read	2
0xFE	Get Program State	Data read	1

7.5.2.Detailed Description

0x01 RESET

Purpose	Resets motor
Message Type	Data write message
Notes	Equivalent to power cycling the motor, wait 25ms before issuing new I²C commands

Command	0x01
Number of data bytes	0

0x02 CALIBRATION COMPLETE

Purpose	Checks if motor is calibrated and ready for normal operation
Message Type	Data read message
Notes	Velocity and position moves sent before calibration is complete will be ignored.

Command	0x02
Number of data bytes	1
Data 0	0x00 - calibration in progress 0x01 - calibration completed successfully 0x02 - calibration failed

0x03 IS MOTOR MOVING

Purpose	Returns movement status of motor
Message Type	Data read message

Command	0x03
Number of data bytes	1
Data 0	8bit signed value 0xff: moving anticlockwise 0x00: stopped 0x01: moving clockwise Else - Error

0x04 RETURN CURRENT LOCATION

Purpose	Returns the current target rotor location
Message Type	Data read message
Notes	Range 0 - 0xFFFF in motor counts (65536 counts per revolution) The position returned is the clockwise distance from the first mechanical endstop in motor counts. This is the controller setpoint and will differ from true location if the rotor is externally disturbed. See also 0x43. 1 degree ~ 182 motor counts Resolution ~ 0.005 degrees

Command	0x04
Number of data bytes	2
Data 0	MSB of position
Data 1	LSB of position

0x05 GOTO ABSOLUTE LOCATION

Purpose	Moves to an absolute position
Message Type	Data write message
Notes	Range 0 - 0xFFFF in motor counts (65536 counts per revolution). The position specified is the clockwise distance from the first mechanical endstop in motor counts. 1 degree ~ 182 motor counts Resolution ~ 0.005 degrees

Command	0x05
Number of data bytes	2
Data 0	MSB of position
Data 1	LSB of position

0x06 GOTO RELATIVE LOCATION

Purpose	Moves a specified number of counts in a specified direction
Message Type	Data write message
Notes	16bit signed positional accuracy in motor counts 0x8001 (180 degrees anticlockwise) 0x7FFF (180 degrees clockwise) 1 degree ~ 182 motor counts. Resolution ~ 0.005 degrees NB. The move will stop at the software endstop if the supplied range is too large to execute. The maximum relative move is ± 180 degrees. See also 0x40.

Command	0x06
Number of data bytes	2
Data 0	MSB of position
Data 1	LSB of position

0x07 TRAVEL AT VELOCITY

Purpose	Moves at a specified velocity in a given direction
Message Type	Data write message
Notes	16bit signed velocity range in motor counts per second 0x8001 - max anticlockwise (360 degrees/second) 0 - stopped 7FFF - max clockwise (360 degrees/second) 1 degree/second ~ 91 motor counts/second Resolution ~ 0.05degrees/second Min velocity 4 counts/second
Command	0x07
Number of data bytes	2
Data 0	MSB of speed
Data 1	LSB of speed

0x08 SET ACCELERATION

Purpose	Sets the maximum acceleration
Message Type	Data write message
Notes	acceleration range 1 (minimum) -256(max) default value 64 == 2746 degrees/s^2 Maximum recommended value depends on load.
Command	0x08
Number of data bytes	2
Data 0	MSB of acceleration
Data 1	LSB of acceleration

0x09 GOTO ABSOLUTE LOCATION IN SET TIME

Purpose	Moves to an absolute position in a given time
Message Type	Data write message
Notes	Range 0 - 0xFFFF in motor counts (65536 counts per revolution) The position specified is the clockwise distance from the first mechanical endstop in motor counts. 1 degree ~ 182 motor counts Resolution ~ 0.005degrees Time: 0 (as fast as possible) to 255 seconds
Command	0x09
Number of data bytes	3
Data 0	MSB of position
Data 1	LSB of position
Data 2	Time

0x0A GOTO RELATIVE LOCATION IN SET TIME

Purpose	Moves a specified number of counts in a specified direction
Message Type	Data write message
Notes	16bit signed positional accuracy in motor counts 0x8001 (180 degrees anticlockwise) 0x7FFF (180 degrees clockwise) 1 degree ~ 182 motor counts Resolution ~ 0.005degrees Time: 0 (as fast as possible) to 255 seconds NB. The move will stop at the software endstop if the supplied range is too large to execute. The maximum relative move is ± 180 degrees.

Command	0x0A
Number of data bytes	3
Data 0	MSB of position
Data 1	LSB of position
Data 2	Time

0x0B GET ACCELERATION

Purpose	Get the current maximum acceleration setting
Message Type	Data read message
Notes	

Command	0x0B
Number of data bytes	2
Data 0	MSB of acceleration
Data 1	LSB of acceleration

0x0C SET TUNING ALGORITHM PROPORTIONAL GAIN

Purpose	Set the gain level of the proportional control stage of the tuning PID loop
Message Type	Data write message
Notes	16bit unsigned fixed point (0-0xFFFE) Range $0 < x < 32$ Resolution - 0.005 Value to send - $x.2^{11}$

Command	0x0C
Number of data bytes	2
Data 0	MSB of proportional gain
Data 1	LSB of proportional gain

0x0D GET TUNING ALGORITHM PROPORTIONAL GAIN

Purpose	Get the gain level of the proportional control stage of the tuning PID loop
Message Type	Data read message
Notes	16bit unsigned fixed point (0-0xFFFE) 0xFFFF - Error Range $0 < x < 32$ Resolution - 0.005 Value to send - $x.2^{11}$
Command	0x0D
Number of data bytes	2
Data 0	MSB of proportional gain
Data 1	LSB of proportional gain

0x0E SET TUNING ALGORITHM INTEGRAL GAIN

Purpose	Set the gain level of the integral control stage of the tuning PID loop
Message Type	Data write message
Notes	16bit unsigned fixed point (0-0xFFFE) Range $0 < x < 32$ Resolution - 0.005 Value to send - $x.2^{11}$
Command	0x0E
Number of data bytes	2
Data 0	MSB of integral gain
Data 1	LSB of integral gain

0x0F GET TUNING ALGORITHM INTEGRAL GAIN

Purpose	Get the gain level of the integral control stage of the tuning PID loop
Message Type	Data read message
Notes	16bit unsigned fixed point (0-0xFFFE) 0xFFFF - Error Range $0 < x < 32$ Resolution - 0.005 Value to send - $x.2^{11}$
Command	0x0F
Number of data bytes	2
Data 0	MSB of integral gain
Data 1	LSB of integral gain

0x10 SET TUNING ALGORITHM DIFFERENTIAL GAIN

Purpose	Set the gain level of the differential control stage of the tuning PID loop
Message Type	Data write message
Notes	16bit unsigned fixed point (0-0xFFFE) Range 0 < x < 128 Resolution - 0.005 Value to send - $x.2^9$
Command	0x10
Number of data bytes	2
Data 0	MSB of differential gain
Data 1	LSB of differential gain

0x11 GET TUNING ALGORITHM DIFFERENTIAL GAIN

Purpose	Get the gain level of the differential control stage of the tuning PID loop
Message Type	Data read message
Notes	16bit unsigned fixed point (0-0xFFFE) Range 0 < x < 128 Resolution - 0.005 Value to send - $x.2^9$
Command	0x11
Number of data bytes	2
Data 0	MSB of differential gain
Data 1	LSB of differential gain

0x12 SET FIRST ENDSTOP DISTANCE FROM MECHANICAL ENDSTOP

Purpose	Inform the motor of the theoretical distance between the first mechanical endstop to the first software endstop.
Message Type	Data write message
Notes	Range 0 - 0xFFFF in motor counts (65536 counts per revolution) 1 degree ~ 182 motor steps Resolution ~ 0.005degrees Command 0x23 must be subsequently called if this value is to be saved to non-volatile memory.
Command	0x12
Number of data bytes	2
Data 0	MSB of distance
Data 1	LSB of distance

0x13 SET MECHANICAL MOTOR RANGE

Purpose	Inform the motor of the theoretical distance between the first and second mechanical endstop
Message Type	Data write message
Notes	This message is used to set the operational range of the motor. The motor will use this information to set its software endstops to ensure that the mechanical endstops are not reached during normal operation. Range 0 - 0xFFFF in motor counts (65536 counts per revolution) 1 degree ~ 182 motor steps Resolution ~ 0.005degrees If in hardware endstop mode (command 0x19 = 0x00), first endstop pos + range can't be greater than 360 degrees. This restriction does not apply in "continuous with sw endstops" mode (command 0x19 = 0x02). Command 0x23 must be subsequently called if this value is to be saved to non-volatile memory.

Command	0x13
Number of data bytes	2
Data 0	MSB of motor range
Data 1	LSB of motor range

0x19 SET CONTINUOUS

Purpose	Select whether pan motor is to perform continuous (slip ring) or limited range motion
Message Type	Data write message
Notes	16bit unsigned int Send 0x0001 for continuous motion, 0x0000 for limited motion. From firmware version 5900 onwards, send 0x0002 for continuous rotation with software endstops. When changing between limited motion and any other mode, if not in sleep mode, saves settings to flash (0x23) automatically and performs a software reset, forcing re-calibration. Wait 2000ms before issuing new I^{2}C commands. If in sleep mode, 0x23 must be called manually to save the change to non-volatile memory. Invalid input values for data1 are changed to 0x00. See also 0x30 (IS SLEEPING).

Command	0x19
Number of data bytes	2
Data 0	0x00
Data 1	0x00 or 0x01, bool on/off

0x1A GET CONTINUOUS

Purpose	Get boolean value indicating whether continuous or limited motion is default
Message Type	Data read message
Notes	16bit unsigned int 0x0000 limited range 0x0001 unlimited range (slipring) For firmware revision 5900 onwards: 0x0002 unlimited range but with software endstops
Command	0x1A
Number of data bytes	2

0x1B GET FIRMWARE VERSION

Purpose	Read firmware version
Message Type	Type Data read message
Notes	Data 0: (u8) ver major Data 1: (u8) ver middle Data 2-3: (u16) ver minor
Command	0x1B
Number of data bytes	4

0x1C WAKE UP

Purpose	Wake motor from low power state
Message Type	Data write message
Command	0x1C
Number of data bytes	0

0x1D SET SLEEP ON POWER UP MODE

Purpose	Set motor to sleep on power up, or begin calibration immediately
Message Type	Data write message
Notes	Data 0: 0 - calibrate immediately, 1 - wait for WAKE UP command. If not sleeping, saves settings to ash (0x23) automatically and performs a software reset. Wait 2000ms before issuing new I²C commands. If sleeping, 0x23 must be called to save the new setting to non-volatile memory. See also 0x30 (IS SLEEPING). All non-zero input values for data 0 are treated as 0x1.
Command	0x1D
Number of data bytes	1

0x23 SAVE SETTINGS TO FLASH

Purpose	Save the exiting PID control values, endstop and sleep mode settings to non-volatile FLASH sector
Message Type	Data write message
Notes	Motor will reset after the command, wait 2000ms before issuing new I^2C commands.

Command	0x23
Number of data bytes	0

0x24 RELOAD FACTORY DEFAULTS

Purpose	Restore default settings in non-volatile ash sector, including PID parameters, endstop range and presence, and sleep mode settings
Message Type	Data write message
Notes	Motor will reset after the command, wait 2000ms before issuing new I^2C commands.

Command	0x24
Number of data bytes	0

0x2F GET SLEEP ON POWER UP MODE

Purpose	Get whether motor sleeps on power up, or begins calibration immediately based on value currently stored in flash
Message Type	Data read message
Notes	Data 0: 0 - calibrates immediately, 1 - waits for WAKE UP command

Command	0x2F
Number of data bytes	1

0x30 IS SLEEPING

Purpose	Get current sleep state (sleeping/awake)
Message Type	Data read message
Notes	Data 0: 0 - in normal operation 1 - low power mode From firmware revision 6058: 2 - calibrated low power mode

Command	0x30
Number of data bytes	1

0x40 GOTO RELATIVE POSITION 360

Purpose	Move to relative position with input range -360 to +360 degrees
Message Type	Data write message
Notes	Range 0 - 0xFFFF in motor counts (65536 counts per revolution)

Command	0x40
Number of data bytes	3
Data 0	Sign bit: 0x00 clockwise, 0x01 anticlockwise
Data 1	MSB of move
Data 2	LSB of move

0x41 GOTO RELATIVE POSITION AT SPEED

Purpose	Move to relative position at maximum speed specified
Message Type	Data write message
Notes	Range 0 - 0xFFFF in motor counts (65536 counts per revolution) Direction set by velocity. Velocity: signed int16 0xA001 - max anticlockwise (540 degrees/second) 0 - stopped 0x5FFF - max clockwise (540 degrees/second) Velocities above 0x5FFF or below 0xA001 will be limited to 540 degrees/s 1 count/second ~ 0.022 degrees/second Min velocity 0.1 degrees/second (5 counts/second). If the requested move is beyond an endstop, move to the nearest endstop in the specified direction.

Command	0x41
Number of data bytes	4
Data 0	MSB of move
Data 1	LSB of move
Data 2	MSB of velocity
Data 3	LSB of velocity

0x42 GOTO ABSOLUTE POSITION AT SPEED

Purpose	Move to absolute position at maximum speed specified
Message Type	Data write message
Notes	Move: Range 0 - 0xFFFF in motor counts (65536 counts per revolution) Velocity: signed int16 0xA001 - max anticlockwise (540 degrees/second) 0 - stopped 0x5FFF - max clockwise (540 degrees/second) Velocities above 0x5FFF or below 0xA001 will be limited to 540 degrees/s. 1 count/second ~ 0.022 degrees/second Min velocity 0.1 degrees/second (5 counts/second). When in continuous rotation mode, the velocity sign determines the move direction. When in endstop mode, the velocity sign is ignored, and the direction required to successfully reach the destination is automatically chosen.

Command	0x42
Number of data bytes	4
Data 0	MSB of move
Data 1	LSB of move
Data 2	MSB of velocity
Data 3	LSB of velocity

0x45 GET SERIAL FULL

Purpose	Return serial number as appears on pcb barcode
Message Type	Data read message
Notes	Data 0..3 signed 32-bit integer

Command	0x45
Number of data bytes	4

0x4A GET FIRST ENDSTOP DISTANCE

Purpose	Read current setting for distance between mechanical endstop and first software endstop
Message Type	Data read message
Notes	See 0x12 for scaling

Command	0x4A
Number of data bytes	2
Data 0	MSB of distance
Data 1	LSB of distance

0x4B GET MECHANICAL MOTOR RANGE

Purpose	Read current setting for distance between first and second software end-stops
Message Type	Data read message
Notes	See 0x13 for scaling

Command	0x4B
Number of data bytes	2
Data 0	MSB of distance
Data 1	LSB of distance

0x4E SET USE HALL SENSOR

Purpose	Set whether the motor uses the hall sensor during the homing routine
Message Type	Data write message
Notes	If disabled, when in a system with endstops present, then after searching for the first mechanical endstop the motor moves to the first software end-stop position. If enabled, homing always finishes with the motor position determined by the hall effect sensor.

Command	0x4E
Number of data bytes	1
Data 0	0x00 - disabled 0x01 – enabled

0x4F GET USE HALL SENSOR

Purpose	Get whether the motor uses the hall sensor during the homing routine
Message Type	Data read message
Notes	See 0x4E

Command	0x4F
Number of data bytes	1
Data 0	0x00 - disabled 0x01 - enabled

0x53 SET USE TURBO MODE

Purpose	Set whether the motor uses turbo mode during velocity and position-at-speed moves
Message Type	Data write message
Notes	If enabled, velocity input with command 0x07 is doubled, giving max velocity of 720 deg/s. In addition, the max velocity cap of 540 deg/s for goto-pos-at-speed is changed to 720 deg/s.

Command	0x53
Number of data bytes	1
Data 0	0x00 - disabled 0x01 - enabled

0x54 GET USE TURBO MODE

Purpose	Get whether the motor uses turbo mode during velocity and position-at-speed moves
Message Type	Data read message
Notes	See 0x53.

Command	0x54
Number of data bytes	1
Data 0	0x00 - disabled 0x01 - enabled

0x5E GOTO ABSOLUTE POS IN TIME MS

Purpose	0.01 second resolution on timed absolute moves
Message Type	Data write message
Notes	Range 0 - 0xFFFF in motor counts (65536 counts per revolution) Move time in multiples of 0.01s 0 - 0xFFFF, e.g. 10.00 seconds == 0x03e8 If time/distance > 2^7, where distance is in motor counts and time in ms, a smooth trajectory cannot be guaranteed due to minimum velocity limitations.

Command	0x5E
Number of data bytes	4
Data 0	Move MSB
Data 1	Move LSB
Data 2	Time MSB
Data 3	Time LSB

0x5F GOTO RELATIVE POS IN TIME MS

Purpose	0.01 second resolution on timed relative moves
Message Type	Data write message
Notes	Range 0 - 0xFFFF in motor counts (65536 counts per revolution) Move time in multiples of 0.01s 0 - 0xFFFF, e.g. 10.00 seconds == 0x03e8 Direction 0x00 clockwise, 0x01 anti-clockwise If time/distance > 2^7, where distance is in motor counts and time in ms, a smooth trajectory cannot be guaranteed due to minimum velocity limitations.
Command	0x5F
Number of data bytes	5
Data 0	Move MSB
Data 1	Move LSB
Data 2	Time MSB
Data 3	Time LSB
Data 4	Direction

0x99 SET OVER TEMPERATURE PROTECTION

Purpose	Set or turn off Over Temperature Protection mode, which sends the motor to sleep to prevent overheating
Message Type	Data write message
Notes	Data 0: (uint8) 0x0 – Over Temperature Protection off 0x1 – Over Temperature protection on – motor will sleep if the temperature is over the max limit (80°C). All non-zero input values for data 0 are treated as 1.
Command	0x99
Number of data bytes	1

0x9A GET OVER TEMPERATURE PROTECTION

Purpose	Get status of Over Temperature Protection mode
Message Type	Data read message
Notes	Data 0: (uint8) 0x0 – Over Temperature Protection off 0x1 – Over Temperature protection on – motor will sleep if the temperature is over the max limit (80°C).
Command	0x9A
Number of data bytes	1

0x9B GET TEMPERATURE

Purpose	Get temperature from the sensor
Message Type	Data read message
Notes	Data 0+1: data read back from the temperature sensor via ADC

Command	0x9B
Number of data bytes	2

0xFE GET PROGRAM STATE

Purpose	Query run status of motor firmware
Message Type	Data read message
Notes	This command will produce a response in both IFP and normal running modes.

Command	0xFE
Number of data bytes	1
Data 0	0x00 - Motor drive system started 0x01 - Infield programming mode, launch timeout active 0x02 - Infield programming mode, launch timeout halted, device will stay in IFP mode until launched by user

7.6. Recommended Configurations

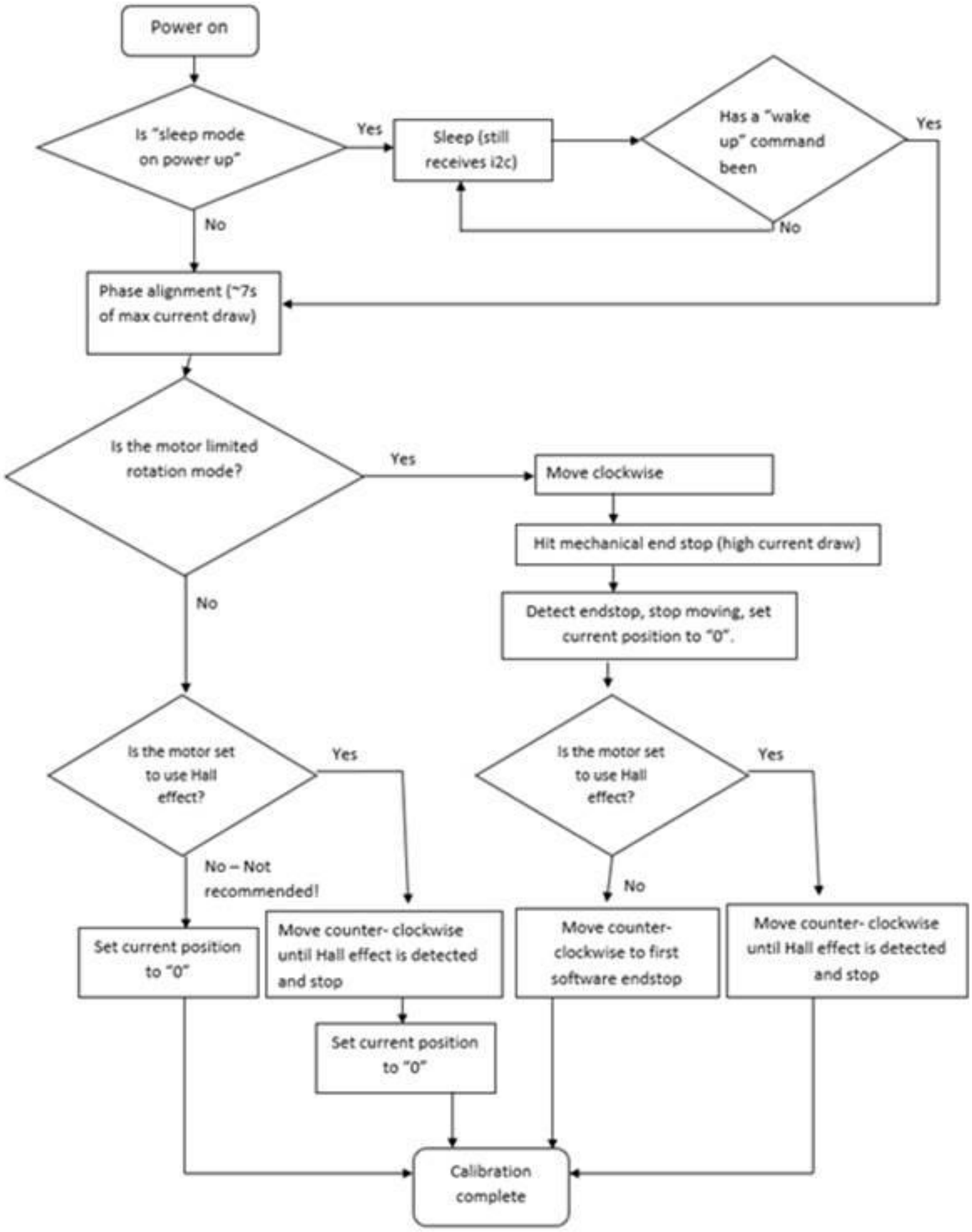
Setup	Parameter	I^2C command	I^2C data
Unloaded	Kp	0x0C	0x03FB
	Ki	0x0E	0x0005
	Kd	0x10	0x0400
	acc	0x08	0x0080
Rated Load	Kp	0x0C	0x0800
	Ki	0x0E	0x0025
	Kd	0x10	0x1500
	acc	0x08	0x0080
Above Rated Load	Kp	0x0C	0x08CD
	Ki	0x0E	0x0025
	Kd	0x10	0x1800
	acc	0x08	0x0040
Max Disturbance Rejection	Kp	0x0C	0x0DB8
	Ki	0x0E	0x000A
	Kd	0x10	0x1100
	Kc	0x46	0x044E
	Ud	0x4C	0x01
	LPF	0x43	0x01
	Control method	0x48	0x01

7.7. Motor Start-up and homing

The motor start-up and homing routine is controlled by 3 settings for each motor:

- “Sleep on power up” mode
- “Continuous” mode
- “Use hall effect” mode.

The behaviour of the motor and impact of each of the settings can be seen in this flow chart:


Power on
Is “sleep mode on power up”
Yes
Sleep (still receives i2c)
Has a “wake up” command been
Yes
No
No
Phase alignment (~7s of max current draw)
Is the motor limited rotation mode?
Yes
Move clockwise
Hit mechanical end stop (high current draw)
Detect endstop, stop moving, set current position to “0”.
No
Is the motor set to use Hall effect?
Yes
Is the motor set to use Hall effect?
Yes
No – Not recommended!
No
Set current position to “0”
Move counter- clockwise until Hall effect is detected and stop
Move counter-clockwise to first software endstop
Move counter- clockwise until Hall effect is detected and stop
Set current position to “0”
Calibration complete

Note that the “clockwise” and “counter-clockwise” directions describe the movement of the rotor relative to the PCBA, when viewed from the side of the motor which the rotor is mounted on.
For use in a standard pan-tilt gimbal system with a slipring + continuous motion in pan, and no slipring + mechanical end stop in tilt, the recommended settings are:

Pan: Continuous and Use hall effect.
Tilt: Not continuous and Not use hall effect.

During the “phase alignment” process the motor will draw max current. The “sleep on power up” setting can be used along with staggered “wake up” I^{2}C commands to ensure that only one motor is in this process at a time, in situations where power supply limitations apply.

7.8. Firmware Update Mode

In this section we describe the ability to update the motor firmware remotely using the Infield Programming (IFP) mode. When in IFP mode the same protocol applies for I^{2}C data read and write messages as in section 7.4, except the commands used are in the range 0xF0 upwards.

7.8.1.Firmware Image File

BLDC motor firmware is distributed as a 32KB binary file. The layout of the file is as follows:

Byte Address	Contents
0x0000 - 0x0001	Magic Number 0xA5A5
0x0002 - 0x0003	Uint16 Major version
0x0004 - 0x0005	Uint16 Middle version
0x0006 - 0x0007	Uint16 Minor version
0x0008 - 0x7FFB	Program data
0x7FFC - 0x7FFD	Magic Number 0xA5A5
0x7FFE - 0x7FFF	16-bit LRC

7.8.2.Programming Procedure

Below is pseudo-code that would be run on a host to program the BLDC motor using the I^{2}C bus.

```
void I2C_write (u8 command , u8* tx_data , u8 n_data_bytes );
void I2C_read (u8 command , u8* rx_data , u8 n_data_bytes );
int fw_upgrade ()
{
u8 rx_data [4];
u8 tx_data [4];
// reset ( if already powered on ), otherwise power on , then interrupt launch
I2C_write (0 x01 , tx_data , 0);
delay_ms (250) ; // max wait 500 ms , min wait 15 ms
//" hold " command
I2C_read (0 xF0 , rx_data , 1);
if( rx_data [0] != 0) return -1;
//" prepare to send " command
I2C_read (0 xF1 , rx_data , 1);
if( rx_data [0] != 0) return -1;
// send data chunk by chunk
{
int i_c = 0;
u8 * p_d = BLDC_Drive_APP ; // application image data
const int chunk_size = 4;
int chunks = BLDC_Drive_APP_ARRAY_LEN / chunk_size ;
for ( i_c =0; i_c < chunks ; i_c ++)
{
I2C_write (0 xF2 , p_d , chunk_size ); // load chunk to device ram
I2C_read (0 xF3 , rx_data , 1); // save chunk to device flash
if( rx_data [0] != 0) return -1;
p_d += chunk_size ;
}
}
// check image integrity in device memory
I2C_read (0 xF4 , rx_data , 1);
if( rx_data [0] != 0) return -1;
// finished , now launch
I2C_write (0 xF5 , tx_data , 0);
return 0;
}
```

Important points to note:

- The "prepare to send" command (0xF1) must be sent before the application is written to the device. This erases the current application, and the device holds the SCL line low while this operation is in progress.
- Data is transferred to the device in 4-byte chunks with command 0xF2
- Command 0xF3 is used to save each chunk to non-volatile memory. The device holds the SCL line low until this is completed (5ms).
- The whole update procedure takes approximately 5 seconds from start to finish.

7.8.3.IFP Commands Summary

Code	Description	Message type	# data bytes
0xF0	Hold launch	Data read	1
0xF1	Prepare to send	Data read	1
0xF2	Send data chunk	Data write	4
0xF3	Save data chunk	Data read	1
0xF4	Verify program	Data read	1
0xF5	Launch	Data write	1
0xF6	Get ifp mode version	Data read	2
0xFE	Get program state	Data read	1

7.8.4.IFP Commands in Detail

0xF0 HOLD LAUNCH

Purpose	Hold in IFP mode
Message Type	Data read message
Notes	If received within 500ms following power on or a firmware reset, halt launch and stay in reprogramming mode

Command	0xF0
Number of data bytes	1
Data 0	0x00 - hold successful

0xF1 PREPARE TO SEND

Purpose	Prepare device to receive new firmware image
Message Type	Data read message
Notes	This erases the current firmware from ash memory. The device will hold SCL low during this operation (approximately 3 seconds) and only return the status byte once this process is finished.

Command	0xF1
Number of data bytes	1
Data 0	0x00 - device ready

0xF2 SEND DATA CHUNK

Purpose	Send next data chunk to device
Message Type	Data write message
Notes	Send the next 4 bytes of the firmware image to the device.

Command	0xF2
Number of data bytes	4

0xF3 SAVE DATA CHUNK

Purpose	Commit last data chunk sent to flash memory
Message Type	Data read message
Notes	Writes the last data sent to the device to non-volatile memory. The device will hold SCL low until the write operation is finished.

Command	0xF3
Number of data bytes	1
Data 0	0x00 - Write successful 0xFF - Write failed

0xF4 VERIFY PROGRAM

Purpose	Verify image currently stored in the device flash memory
Message Type	Data read message
Notes	

Command	0xF4
Number of data bytes	1
Data 0	0x00 - Image verification OK 0x01 - LRC failed 0x02 - Image not a valid program

0xF5 LAUNCH

Purpose	Launch into normal operation
Message Type	Data write message
Notes	

Command	0xF5
Number of data bytes	1

0xF6 GET IFP MODE VERSION

Purpose	Read the version of the infield update program currently running
Message Type	Data read message
Notes	NB this is NOT the same as 0x1B \Get firmware version".

Command	0xF6
Number of data bytes	2
Data 0	Uint8 Major version
Data 1	Uint8 Minor version

0xFE GET PROGRAM STATE

Purpose	Query run status of motor firmware
Message Type	Data read message
Notes	

Command	0xFE
Number of data bytes	1
Data 0	0x00 - Motor drive system started 0x01 - Infield programming mode, launch timeout active 0x02 - Infield programming mode, launch timeout halted, device will stay in IFP mode until launched by user