TMC4670 Datasheet

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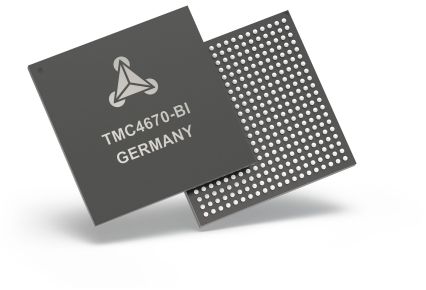
The TMC4670 is a field oriented control (FOC) servo controler for torque control, velocity control, and positioning. Integrated ADCs, position sensor interfaces, position interpolators, enables a servo controler with a couple components.



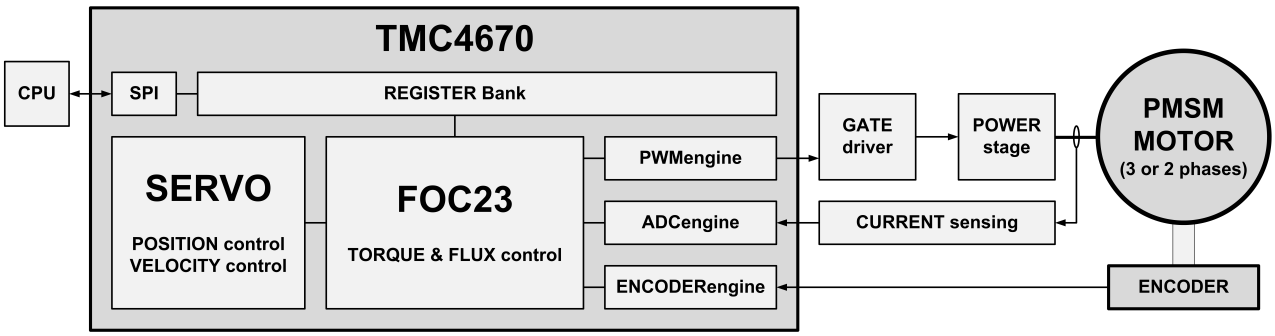
Features

- Field Oriented Control (FOC) w/ Servo Controller
- Torque Control (FOC), Velocity Control, Position Control
- Feed Forward Offsets
- Integraded ADCs
- Encoder Engine: Hall analog/digital, Encoder analog/digital, 2nd digital Encoder
- Supports 3-Phase PMSM (FOC3) and 2-Phase Stepper Motors (FOC2)
- PWM Engine including SVPWM
- SPI Communication Interface

Applications

- Robotics
- Pick and Place Machines
- Semiconductor Handling
- Factory Automation
- E-Mobility
- Laboratory Automation
- Blowers
- Pumps

Simplified Block Diagram



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TRINAMIC
MOTION CONTROL

Contents

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1 Order Codes

Order Code	Description	Size [mm^2]
TMC4670-BI	TMC4670 FOC Servo Controller IC	17 x 2.5
TMC4670-EVAL	TMC4670 Evaluation Board	85 x 79

Table 1: Order codes

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2 Functional Summary

- **Field Oriented Control (FOC) Servo Controller**
  - torque (and flux) control mode
  - velocity control mode
  - position control mode
  - update rate 200 kHz (w/ 4 kHz velocity meter sampling frequency)
- **PI Controllers**
  - programmable clipping of inputs and outputs of interim results
  - error sum (error integral over time) clipping
  - programmable target torque change in time (dTargetTorque/dt) limiter
  - programmable circular ($\sqrt{U_D^2 + U_Q^2}$) limiter
  - PI controller clipping status bit vector for real time Monitoring
  - Feed Forward Offsets for Target Values
- **Supported Motor Types**
  - FOC3 : three-phase permanent magnet synchronous motors (PMSM)
  - FOC2 : two-phase stepper motors
- **ADC Engine with Offset Correction and Scaling**
  - integrated 12 bit ADCs as analog interface for currents and analog encoders
  - interface to external AD (LTC2351, 14 bit or 12 bit)
  - ADC register to write externally sampled data via SPI communication interface
- **Encoder Engine**
  - open loop position generator (programmable [rpm], [rpm/s]) for initial setup
  - digital incremental encoder (ABN resp. ABZ, up to 5MHz)
  - secondary digital incremental encoder
  - digital hall sensor interface (H_1, H_2, H_3 resp. H_U, H_V, H_W)
  - digital hall sensor interface with interpolation of interim positions
  - analog encoder/analog hall sensor interface (SinCos (0°, 90°) or 0°, 120°, 240°)
  - position multi-turn counter (32 Bit)
- **PWM Engine including SVPWM**
  - programmable PWM frequency within range 25kHz . . . 200kHz
  - programmable Brake-Before-Make (BBM) times (high side, low side) 0ns . . . 2.5μs in 10ns steps
  - PWM auto scaling for transparent change of PWM frequency during motion
- **SPI Communication Interface**
  - 40 bit datagram length (1 ReadWrite bit + 7 address bits + 32 data bits)
  - immediate SPI read response (register read access by single datagram)
- **Supply Voltages** 3.3V, 2.5V, 1.2V
- **IO Voltage** 3.3V
- **Clock Frequency** 25MHz
- **Package** 17mm x 17mm BGA w/ 1mm ball pitch

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3 Functional Description

TMC4670 is a fully integrated controller for field-oriented control (FOC) of either one 2-phase stepper motor (FOC2) or one 3-phase brushless motor (FOC3). It contains the complete control loop core architecture (position, velocity, torque) as well as required peripheral interfaces for communication with an application controller, for feedback (digital encoder, analog interpolator encoder, digital Hall, decoder Hall position interpolator, analog inputs for current and voltage measurement), and helpful additional IO. It supports highest control loop speed and PWM frequencies.

The TMC4670 is the building block for the user application that takes care of all real time critical tasks of field oriented motor control. It decouples the real time field oriented motor control and its real sub-tasks as current measurement, real time sensor signal processing, real time PWM signal generation from the user application layer as outlined by figure 17.

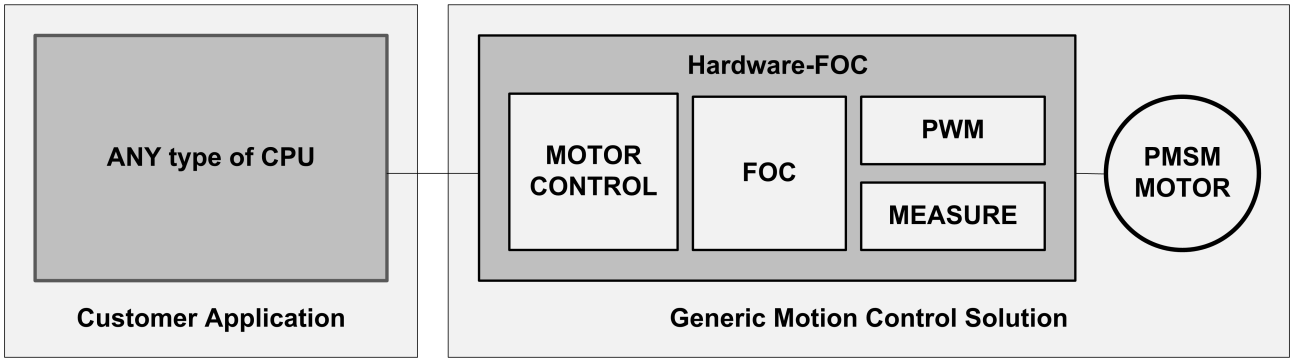

Figure 1: Hardware FOC Application Diagram

3.1 Functional Blocks

Application interface, register bank, ADC engine, encoder engine, FOC torque PI controller, velocity PI controller, position P controller, and PWM engine form the TMC4670. The TMC4670supports 3-phase PMSM motors (FOC3) and 2-phase PMSM stepper motors (FOC2).

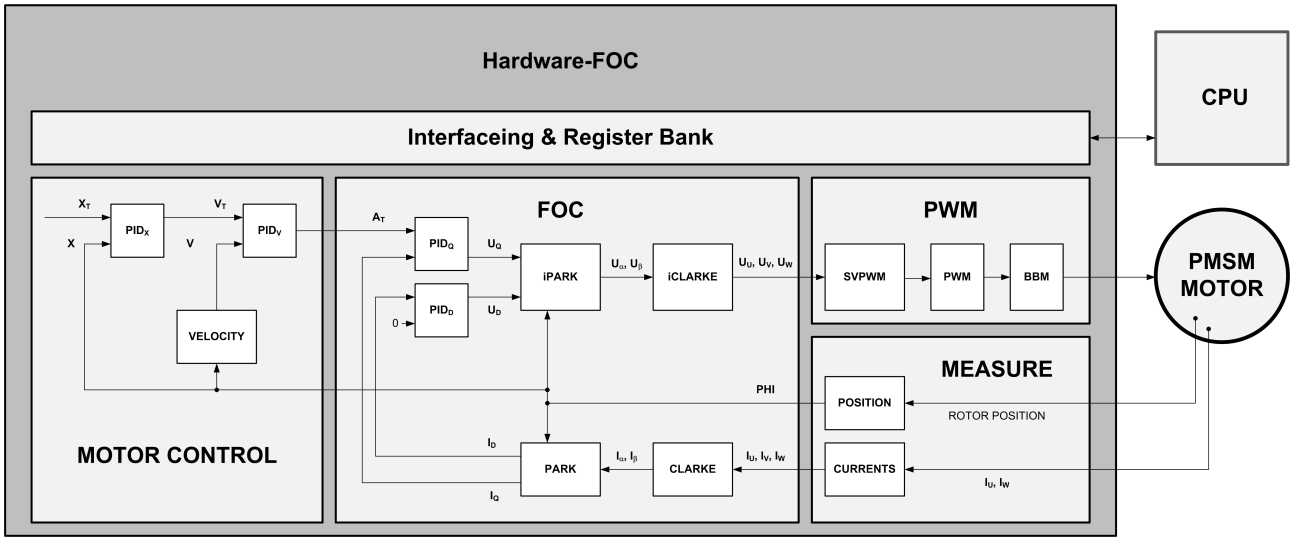

Figure 2: Hardware FOC Block Diagram

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The ADC engine interfaces integrated ADC channels and maps raw ADC values to signed 16 bit (s16) values for the inner FOC current control loop based on programmable offset and scaling factors. The FOC torque PI controller forms the inner base component including required transformations (Clark, Park, inverse Park, inverse Clark). All functional blocks are pure hardware.

3.2 Communication Interface

The TMC4670 is equipped with an SPI interface for access to all registers of the TMC4670.

3.2.1 SPI Slave User Interface

The SPI of the TMC4670 for the user application has an easy command and control structure. The TMC4670 user SPI acts as a slave. The SPI datagram length is 40 bit with up to 2Mbit/s. The MSB (bit#39) is sent first. The LSB (bit#0) is sent last. The MSB (bit#39) is the WRITE_notREAD (WRnRD) bit. The bits (bit#39 to bit#32) are the address bits (ADDR). Bits (bit#31) to (bit#0) are (up to) 32 data bits. The SPI of the TMC4670 immediately responses within the actual SPI datagram on read and write for ease-of-use communication.

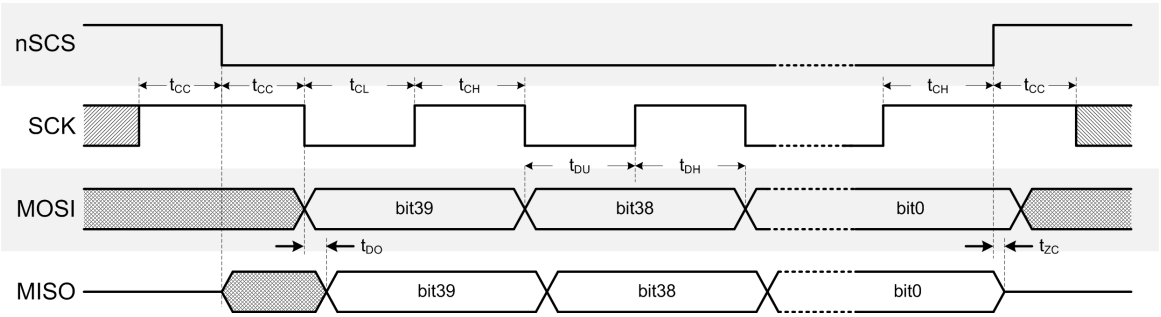

Figure 3: SPI Timing

SPI Interface Timing	Characteristics, fCLK = 25MHz					
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
SCK valid before or after change of nSCS	t_{CC}		250			ns
nSCS high time	t_{CSH}		250			ns
nSCS low time	t_{CSL}		250			ns
SCK high time	t_{CH}		250			ns
SCK low time	t_{CL}		250			ns
SCK low time	t_{CL}		250			ns
SCK frequency	f_{SCK}				2	MHz
MOSI setup time before rising edge of SCK	t_{DU}		250			ns
MOSI hold time after falling edge of SCK	t_{DH}		250			ns
MISO data valid time after falling edge of SCK	t_{DO}				10	ns

Table 2: SPI Timing Parameter

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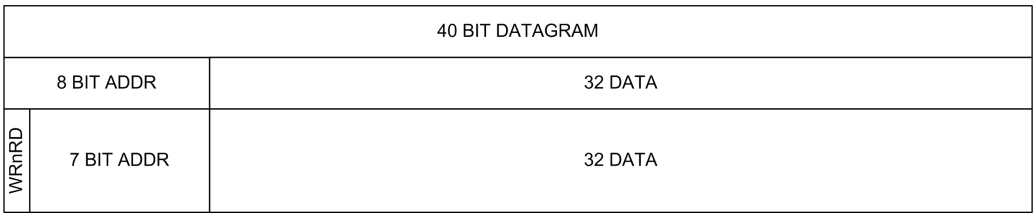

Figure 4: SPI Datagram Structure

3.3 Register Bank

Info	This section gives a functional description as an overview. The section 5 starting page 27 gives the detailed description of each register.

The register bank is the interface to the user application. Each register of the TMC4670 has 8 bit address followed by up to 32 data bits. Some addresses hold more then one data registers for simultaneous access or composed control bit vectors. Section 5 page 27 describes all registers in detail.

During initialization, the user writes parameters into associated registers. These parameters are scaling factors and offsets, sensor configuration parameters, limits for clipping, selections, P and I parameters for the FOC torque controller, P and I parameters for velocity controller, and P parameter for the position controller.

During application, the user writes application parameters into associated registers. These are - depending on the motion mode - target torque, target velocity, or target position.

The TMC4670 has direct access registers and indirect access registers. Most registers are direct access registers with read or write access by a single datagram. Some less often used registers (e.g. silicon version registers, internal values for read out) are accessed via two registers: address register and data register. The address register selects the address, the second register holds the data.

3.3.1 Register Bank - Read and Write

From the access point of view there are two kind of registers: read-only and read-write. The most significant bit (MSB) of each register access datagram defines read (=0) or write (=1). So, there are 128 read addresses ($0x00_h \ldots 0x7F_h$) and 128 write addresses ($0x80_h \ldots 0xFF_h$) available. The TMC4670 ignores write accesses to read-only registers.

- Fixed Read Only Register (e.g. SILICON_TYPE, SILICON_VERSION, SILICON_DATE, SILICON_TIME)
- Read Only Register for internal values (e.q. scaled ADC values)
- Read Only Register for external Signals (e.g. ADC raw values, ABN encoder inputs, Hall signal inputs)
- Read Write Register for configurations (e.g. P and I parameter of PI controller, clipping parameters)
- Read Write Register for target values (e.g. target torque, target velocity, target position)
- Dual Ported Read Write Register (e.g. encoder count, actual position)

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3.3.2 Register Access Datagram Examples

$0x0100000000_h$: reads data from address $0x01_h$
$0x8123456789_h$: writes data $0x23456789_h$ to address $0x01_h$

3.3.3 Identification of Silicon via Type, Version, Date, and Time

The read-only registers of silicon type, version with date and time identify the type of the silicon, the version of the silicon together with unique date stamp and time stamp. This enables the automatic identification of IC and version and enable the automatic handling of different IC and different versions.

3.3.4 Read of RAW Inputs & RAW Outputs

For ease-of-use while setting up the configuration, raw input signals and raw output signals are mapped into the register bank for user read out. With this, the user can initially check without a scope that the desired signals come into the TMC4670 as expected. Examples of readable raw input signals are digital Hall signals and incremental encoder signals.

3.4 Numerical Representation, Electrical Angle, Mechanical Angle, and Pole Pairs

The TMC4670 uses different numerical representations for different parameters, measured values, and interim results. The terms electrical angle PHI_E, mechanical angle PHI_M, and number of pole pairs (N_POLE_PAIRS) of the motor are important for setup of FOC. This section describes the different numerical representations of parameters and terms.

3.4.1 Numerical Representation

The TMC4670 uses singed and unsigned values of different length and fixed point representation for parameters that require a non-integer granularity.

Symbol	Description	Min	Max
u16	unsigned 16 bit value	0	65535
s16	signed 16 bit values, 2'th complement	-32767	32767
u32	unsigned 32 bit value	0	2^{32} = 4294967296
s32	signed 32 bit values, 2'th complement	-2147483647	2^{31} - 1 = 2147483647
q8.8	signed fix point value with 8 bit interger part and 8 bit fractional part	-32767/256	32767/256
q4.12	signed fix point value with 4 bit interger part and 12 bit fractional part	-32767/4096	-32767/4096

Table 3: Numerical Representations

Info Two's complement of n bit is $-2^{n-1} \ldots -2^{n-11} - 1$. To avoid un-wanted overflow, the range is clipped to $-2^{n-1} + 1 \ldots -2^{n-11} - 1$.

Because the zero is interpreted as a positive number for 2'th complement representation of interger n bit number, the smallest negative number is $-2^{(n-1)}$ where the largest positive number is $2^{(n-1)} - 1$. Using

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the smallest negative number $-2^{(n-1)}$ might cause critical under-flow or over-flow. Internal clipping takes this into account by mapping $-2^{(n-1)}$ to $-2^{(n-1)}+1$.

Hexadecimal Value	u16	s16	q8.8	q4.12
$0x0000_h$	0	0	0.0	0.0
$0x0001_h$	1	1	1 / 256	1 / 4096
$0x0001_h$	2	2	2 / 256	2 / 4096
$0x0080_h$	128	128	0.5	0.03125
$0x0100_h$	256	256	1.0	0.0625
$0x0200_h$	512	512	2.0	0.125
$0x3FFF_h$	16383	16383	16383 / 256	16383 / 4096
$0x5A81_h$	23169	23169	23169 / 256	23169 / 4096
$0x7FFF_h$	32767	32767	32767 / 256	32767 / 4096
$0x8000_h$	32768	-32768	-32768 / 256	-32768 / 4096
$0x8001_h$	32769	-32767	-32767 / 256	-32767 / 4096
$0x8002_h$	32770	-32766	-32766 / 256	-32766 / 4096
$0xC001_h$	49153	-16383	-16383 / 256	-16383 / 4096
$0xFFFE_h$	65534	-2	-2 / 256	-2 / 4096
$0xFFFF_h$	65535	-1	-1 / 256	-1 / 4096

Table 4: Examples of u16, s16, q8.8, q4.12

The q8.8 and q4.12 are used for P and I parameters which are positive numbers but q8.8 and q4.12 are used as signed numbers. This is because theses values are multiplied with signed error values resp. error integral values.

3.4.2 N_POLE_PAIRS, PHI_E, PHI_M

The parameter N_POLE_PAIRS defines the factor between electrical angle PHI_E and mechanical angle PHI_M of a motor (pls. refer figure 5).
A motor with one (1) pole pair turns once for each electrical period. A motor with two (2) pole pairs turns once for each two electrical periods. A motor with three (3) pole pairs turns once for each three electrical periods. A motor with four pole (4) pairs turns once for each four electrical periods.

The electrical angle PHI_E is relevant for the commutation of the motor. It is relevant for the torque control of the inner FOC loop.

$$\text{PHI\_E} = \text{PHI\_M} \cdot \text{N\_POLE\_PAIRS} \tag{1}$$

The mechanical angle PHI_M is primarily relevant for velocity control and for positioning. This is because one wants to control the motor speed in terms of mechanical turns and not in terms of electrical turns.

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$$\text{PHI\_M} = \text{PHI\_E}/\text{N\_POLE\_PAIRS} \tag{2}$$

Different encoders give different kind of position angles. Analog hall sensors normally give the electrical position PHI_E that can be used for commutation. Analog encoders give - depending on their resolution - angles that have to be scaled first to mechanical angles PHI_M and to electrical angles PHI_E for commutation.

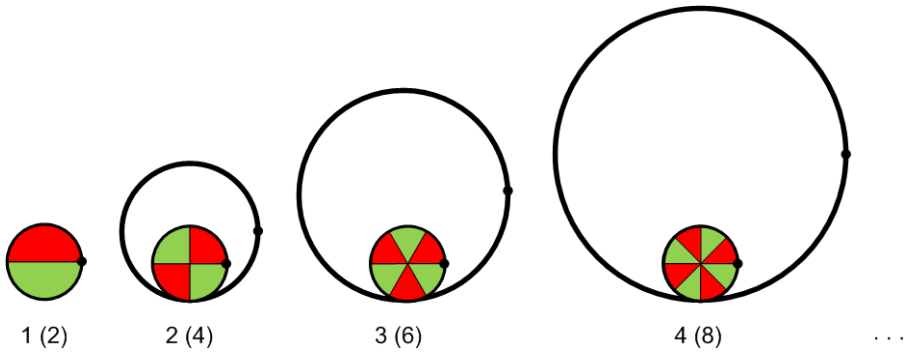

Figure 5: N_POLE_PAIRS - Number of Pole Pairs

3.4.3 Numerical Representation of Angles PHI

Electrical angels and mechanical angles are represented as 16 bit integer values. One full revolution of $360\,\text{deg}$ is equivalent to $2^{16} = 65536$ steps. Any position coming from a sensor is mapped to this interger range. Adding an offset of PHI_OFFSET causes a rotation of an angle PHI_OFFSET$/2^{16}$. Subtraction of an offset causes a rotation of an angle PHI_OFFSET in opposite direction.

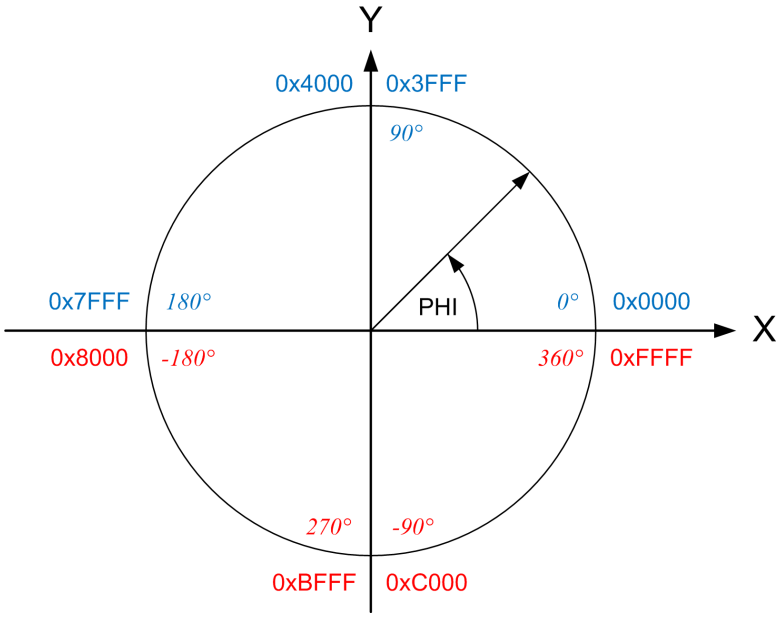

Figure 6: Integer Representation of Angles with 16 Bit as s16 resp. u16

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Hexadecimal Value	u16	s16	PHI[°]	±PHI[°]
$0x0000_h$	0	0	0.0	0.0
$0x1555_h$	5461	5461	30.0	-330.0
$0x2AAA_h$	10922	10922	60.0	-300.0
$0x4000_h$	16384	16384	90.0	-270.0
$0x5555_h$	21845	21845	120.0	-240.0
$0x6AAA_h$	27306	27768	150.0	-210.0
$0x8000_h$	32768	-32768	180.0	-180.0
$0x9555_h$	38229	-27307	210.0	-150.0
$0xAAAA_h$	43690	-21846	240.0	-120.0
$0xC000_h$	49152	-16384	270.0	-90.0
$0xD555_h$	54613	-10923	300.0	-60.0
$0xEAAA_h$	60074	-5462	330.0	-30.0

Table 5: Examples of u16, s16, q8.8

The option of adding an offset is for adjustment of angle shift between motor and stator and rotor and encoder. Finally, the relative orientations between motor and stator and rotor and encoder can be adjusted by just one offset. Alternatively, one can set the counter position of an incremental encoder to zero on initial position. For absolute encoders one needs to use the offset to set an initial position.

3.5 ADC Engine

The ADC engine controls the sampling of different available ADC channels.
The FOC engine expects offset corrected ADC values, scaled into the FOC engine 16 bit (s16) fixed point representation. The integrated scaler and offseter maps raw ADC samples of current measurement channels to 16 bit two's complement values (s16). Both, offset and scale calculations are signed. With this, the user can change the signs of current according to the application by the scaling factors.
The s16 scaled ADC values are available for read out from the register by the user. ADC samples for motor supply voltage (VM), MOSFET temperature, motor temperature, general purpose analog input (AIN) are only raw values without scaling.

- ADC samples of integrated ADC
- ADC samples from external ADC (LTC2351)
- ADC samples from external sources can be written into dedicated registers (ADC EXT)
- ADC values are for:
  - phase current measurement (most important task)
  - Supply voltage measurement (for monitoring or brake chopper)
  - Analog Hall signal measurement
  - analog Sine/Cosine encoder signal measurement
  - analog voltage input for MOS-FET temperature signal monitoring

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– analog voltage input for motor temperature signal monitoring

Info	Wrong scaling factors or wrong offsets might cause damages when the closed current regulation is active. Integrated hardware limiters allow protection especially in the setup phase when using carful limits.

3.5.1 Internal ADC

The TMC4670 is equipped with internal ADCs with input voltage range of 0V . . . 2.5V for current measurement, supply voltage measurement, analog hall signal measurement, analog encoder.

3.5.2 External ADC (LTC2351)

Alternatively to the integrated ADCs, the TMC4670 supports external SPI ADCs LTC2351 from Linear Technology for current measurements. This is intended for current sensing on separate power stages.

3.5.2.1 ADC RAW

The sampled raw ADC values are available for read out by the user. This is important during the system setup phase to determine offset and scaling factors.

3.5.2.2 ADC EXT

The user can write ADC values into the ADC EXT registers of the register bank from external ADC sources. For example it there are high precision ADC values availbale from an external ADC.

3.5.3 ADC Selector & ADC Scaler w/ Offset Correction

The ADC selector selects ADC channles for FOC. The 3-phase FOC used two of three ADC channles for measurement and calculates the third channel via Kirchhoff's Law from the scaled an offset corrected ADC values. The 2-phase FOC just used two ADC channels because for the 2-phase stepper motor the two phases are independent from each other.

Note	The Open Loop Encoder is useful for setup of ADC channel selection, scaling, and offset by turning a motor open loop.

The FOC23 Engine processes currents as 16 bit signed (s16) values. Raw ADC values are expanded to 16 bit width independent of their resolution. With this, each ADC is available for read out a a 16 bit number.
The ADC scaler w/ offset correction is for pre-processing of measured raw current values. It might be used to map to own units (e.g. A or mA). For scaling, gains of current amplifiers, reference voltages, and offsets have to be takin into account.

Info	Raw ADC values generally are of 16 bit width independent of their real resolution.

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Info The job of the ADC scaler is to map raw ADC values to the 16 bit signed (s16) range and to center the values to zero by removing of offsets.

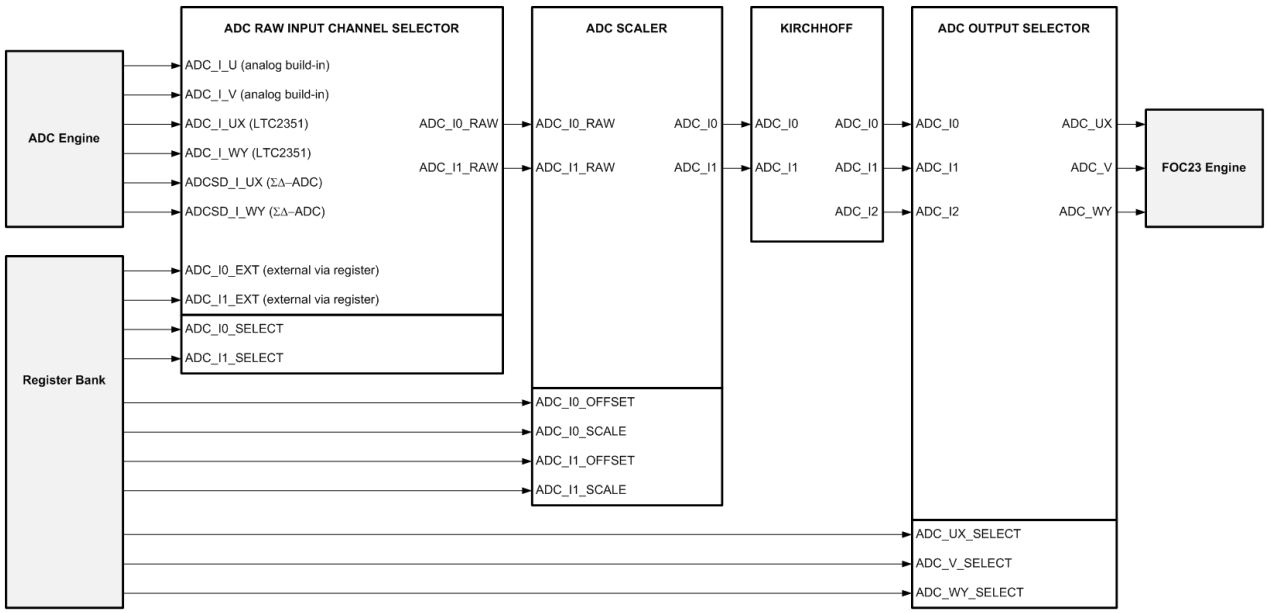

Figure 7: ADC Selector & Scaler w/ Offset Correction

ADC offsets and ADC scalers for the analog current measurement input channels need to be programmed into the associated registers. Each ADC_I_U, ADC_I_V, ADC_I_UX, ADC_I_WY, ADCSD_I_UX, ADCSD_I_WY, ADC_I0_EXT, ADC_I1_EXT is mapped either to ADC_I0_RAW or to ADC_I1_RAW by ADC_I0_SELECT and ADC_I1_SELECT.

In addition, the ADC_OFFSET is for conversion of unsigned ADC values into signed ADC values as required for the FOC.

$$\text{ADC\_I0} = (\text{ADC\_I0\_RAW} + \text{ADC\_I0\_OFFSET}) \cdot \text{ADC\_I0\_SCALE} \tag{3}$$

$$\text{ADC\_I1} = (\text{ADC\_I1\_RAW} + \text{ADC\_I1\_OFFSET}) \cdot \text{ADC\_I1\_SCALE} \tag{4}$$

For FOC3 the third current ADC_I2 is calculated via Kirchhoff's Law. This requires the correct scaling and offset correction before. For FOC2 there is no calculation of a third current.

The ADC_UX_SELECT selects one of the three ADC channels ADC_I0 ADC_I1, ADC_I2 for ADC_UX.

The ADC_V_SELECT selects one of the three ADC channels ADC_I0 ADC_I1, ADC_I2 for ADC_V.

The ADC_WY_SELECT selects one of the three ADC channels ADC_I0 ADC_I1, ADC_I2 for ADC_WY.

The For FOC3 the third current ADC_I2 is calculated via Kirchhoff's Law. This requires the correct scaling and offset correction before. For FOC2 there is no calculation of a third current.

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The ADC_UX, ADC_V, ADC_WY are for the FOC3 (U, V, W). The ADC_UX. and ADC_WY (X, Y) are for the FOC2.

Note	The Open Loop Encoder is useful for setup of ADC channel selection, scaling, and offset by turning a motor open loop.

3.6 Encoder Engine

The encoder engine is an unified position sensor interface. It maps the selected encoder position information to electrical position (phi_e) and to mechanical position (phi_e) the electrical angle. Both are 16 bit values. The encoder engine maps single turn positions from position sensors to multi-turn position. The user can overwrite the these multi-turn position for initialization.

The different position sensors are the position sources for torque and flux control via FOC, for velocity control, and for position control. The PHI_E_SELECTION selects the source of the electrical angel phi_e for the inner FOC control loop. VELOCITY_SELECTION selects the source for velocity measurement. With phi_e selected as source for velocity measurement, one gets the electrical velocity. With the mechanical angle phi_m selected as source for velocity measurement one gets the mechanical velocity taking the set number of pole pairs (N_POLE_PAIRS) of the motor into account. Nevertheless, for high precision position it might be useful to do positioning based on the electrical angel phi_e.

3.6.1 Open Loop Encoder

For initial system setup the encoder engine is equipped with an open loop position generator. With one can turn the motor open-loop by specifying speed in rpm and acceleration in rpm/s together with a voltage UD_EXT in D direction. So, the open-loop encoder it is not a real encoder, it just gives positions as an encoder does. The open-loop decoder has a direction bit to define once the direction of motion for the application.

Note	The open loop encoder is useful for initial ADC setup, encoder setup, hall signal validation, and for validation of the number of pole pairs of a motor. The open loop encoder turns a motor open with programmable velocity in unit [RPM] with programmable acceleration in unit [RPM/s].

So, with the open loop encoder one can turn a motor without any position sensor and without any current measurement as the first step of doing the system setup. With the turning motor one can adjust the ADC scales and offsets and set up positions sensors (hall, incremental encoder, . . .) according to resolution, orientation, direction of rotation.

3.6.2 Incremental ABN Encoder

The incremental encoders give two phase shifted incremental pulse signals A and B. Some incremental encoders have an additional null position signal N or zero pulse signal Z. An incremental encoder (called ABN encoder or ABZ encoder) has an individual number of incremental pulses per revolution. The number of incremental pulses define the number of positions per revolution (PPR). The PPR might mean pulses per revolution or periods per revolution. Instead of positions per revolution some incremental encoder vendors call these CPR counts per revolution.

The PPR parameter is the most important parameter of the incremental encoder interface. With that, it forms a modulo (PPR) counter, counting from 0 to (PPR-1). Depending on the direction, it counts up or

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down. The modulo PPR counter is mapped into the register bank as a dual ported register. the user can over over write it with an initial position. The ABN encoder interface provides both, the electrical position and the multi-turn position are dual-ported read-write registers.

Note	The PPR parameter must be set exactly according to the used encoder.

The N pulse from an encoder triggers either sampling of the actual encoder count to fetch the position at the N pulse or it re-writes the fetched n position on an N pulse. The N pulse can either be uses as stand alone pulse or and-ed with NAB = N and A and B. It depends on the decoder what kind of N pulse has to be used, either N or NAB. For those encoder with precise N pulse within on AB quadrat, the N pulse must be used. For those encoders with N pulse over four AB quadrants one can enhance the precision of the N pulse position detection by using NAB instead of N.

Note	Incremental encoders are available with N pulse and without N pulse.

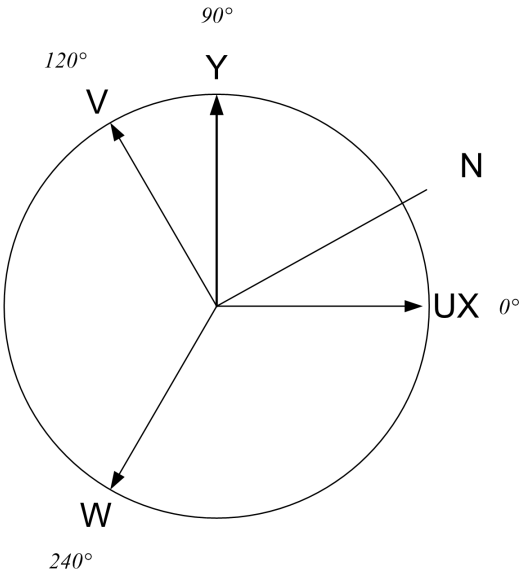

Figure 8: ABN Incremental Encoder N Pulse

The polarity of N pulse, A pulse and B pulse are programmable. The N pulse is for re-initialization with each turn of the motor. Once fetched, the ABN decoder can be configured to write back the fetched N pulse position with each N pulse.

Note	The ABN encoder interface has a direction bit to set once the direction of motion for the application.

Logical ABN = A and B and N might be useful for incremental encoders with low resolution N pulse to enhance the resolution. On the other hand, for incremental encoders with high resolution n pulse a logical abn = a and b and n might totally suppress the resulting n pulse.

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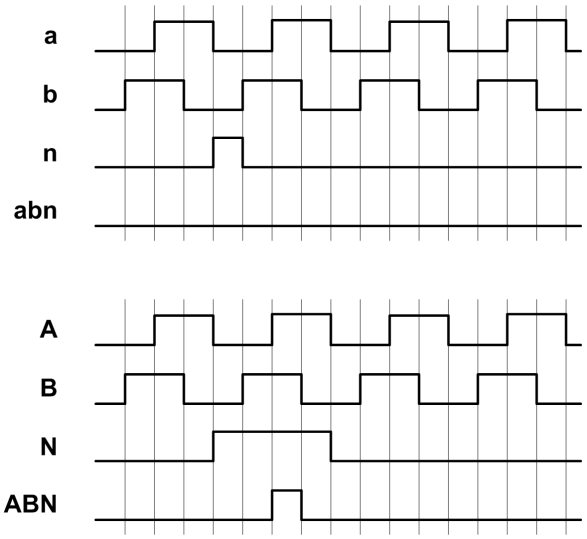

Figure 9: Encoder ABN Timing - high precise n pulse and less precise N pulse

3.6.3 Secondary Incremental ABN Encoder

For commutating a motor with FOC one selects a position sensor source (digital incremental encoder, digital hall, analog hall, analog incremental encoder, . . .) that is mounted close to the motor. The inner FOC loop control torque and flux of the motor based on the measured phase currents and the electrical angle of the rotor.

The TMC4670 is equipped with a secondary incremental encoders interface. This secondary encoder interface is available as source for velocity control or position control. This is for applications where a motor turns an object with a gear to position the object. An example is a robot arm where a motor moves an angle with a the mechanical angle of the arm as the target.

Info	The secondary incremental encoder is not available for commutation (phi_e) for the inner FOC. In others words, there is no electrical angle phi_e selectable from the secondary encoder.

3.6.4 Digital Hall Sensor Interface with optional Interim Position Interpolation

The digital hall interface is the position sensor interface for digital hall signals. The digital hall signal interface first maps the digital hall signals to an electrical position PHI_E_RAW. An offset PHI_E_OFFSET can be used to rotated the orientation of the hall signal angle. The electrical angle PHI_E is for commutation. Optionally, the default electrical positions of the Hall sensors can be adjusted by writes into the associated registers.

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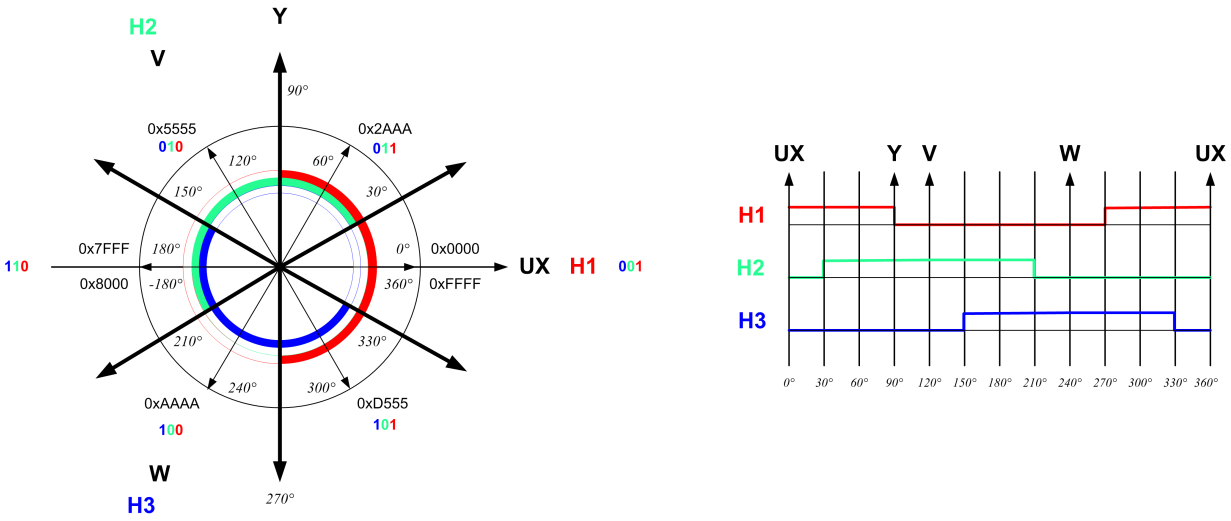

Figure 10: Hall Sensor Angles

Hall Sensors give absolute positions within an electrical period with a resolution of 60° as 16 bit positions (s16 resp. u16) PHI. With activated interim hall position interpolation one additionally gets high resolution interim positions when the motor is running at speed beyond 60 rpm.

3.6.5 Digital Hall Sensor - Interim Position Interpolation

For lower torque ripple one can switch on the position interpolation of interim hall positions. This function is useful for motors that are compatible with sine wave commutation but equipped with digital hall sensors. When the position interpolation is switched on it becomes active on speed beyond 60 rpm. For lower speed it automatically disables. This is important especially when the motor has to be at rest.
Motors that are intended for block commutation might smarter turn with hall signal interpolation but one should not expect too much for those motors.

3.6.6 Digital Hall together with Incremental Encoder

If a motor is equipped with both Hall sensors and incremental encoder, the hall sensors can be used for the initialization as a low resolution absolute position sensor and later the incermental encoder can be used a a high resolution sensor for commutation.

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3.6.7 Analog Hall and Analog Encoder Interface (SinCos of 0°90° or 0°120°240°)

An analog encoder interface is part of the decoder engine. It is able to handle analog position signals of 0° and 90° and 0° 120° 240°. The analog decoder engine adds offset and scales the raw analog encoder signals and calculates the electrical angle PHI_E from these analog position signals.

ADC offsets and ADC scalers need to be programmed into the associated registers to use analog Hall sensors or analog encoders. Each AENC_0_SELECT, AENC_1_SELECT, AENC_2_SELECT, and AENC_3_SELECT, selects one raw analog ADC input channel AENC out of AENC_UX_RAW, AENC_VN_RAW, AENC_WY_RAW, AENC_N_RAW, or one AENC register channel AENC_UX_EXT, AENC_VN_EXT, AENC_WY_EXT, AENC_NEXT.

An individual signed offset is added each associated raw ADC channel and scaled by its associated scaling factors according to

$$\text{AENC\_VALUE} = (\text{AENC\_RAW} + \text{AENC\_OFFSET}) \cdot \text{AENC\_SCALE} \tag{5}$$

In addition, the AENC_OFFSET is for conversion of unsigned ADC values into signed ADC values as required for the FOC.

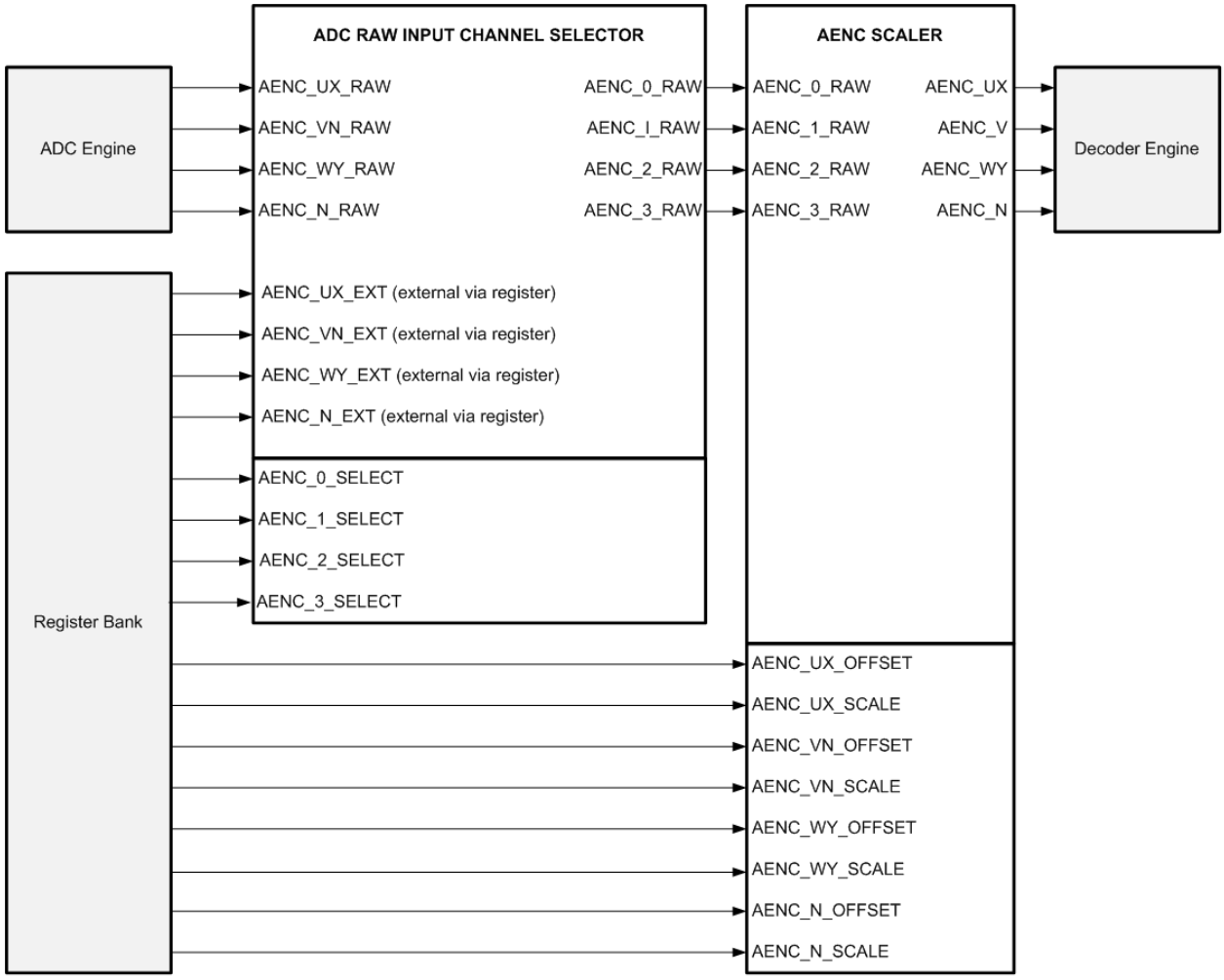

Figure 11: Analog Encoder (AENC) Selector & Scaler w/ Offset Correction

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Info	The analog N pulse is just a raw ADC value. Scaling, offset correction, hand handling of analog N pulse similar to N pulse handling of digital encoder N pulse is not implemented for analog encoder.

3.6.8 Analog Position Decoder (SinCos of 0°90° or 0°120°240°)

The extracted positions from the analog decoder are available for read out from registers.

3.6.8.1 Multi-Turn Counter

Electrical angles are mapped to a multi-turn position counter. The user can overwrite this multi-turn position for initialization purposes.

3.6.8.2 Encoder Engine Phi Selector

The angle selector select the source for the commutation angel PHI_E. That electrical angle is available for commutation.

3.6.8.3 External Position Register

A register value written vie the application interface into the register bank is available for commutation also. With this, the user can interface to any encoder by just writing positions extracted from external encoder into this regulator. From the decoder engine point of view this is just one more selectable encoder source.

3.7 FOC23 Engine

Info	Support for the TMC4670 is integrated into the TMCL-IDE including wizards for setting up. With this one can turn a motor with a few steps of setup. with the TMCL-IDE one has direct access to all registers of the TMC4670.

The FOC23 engine performs the inner current control loop for the torque current I_Q and the flux current I_D including the required transformations. Programmable limiters take care of clipping of interim results. Per default, the programmable circular limiter clips U_D and U_Q to U_D_R = $\sqrt{(2)}\cdot$ U_Q and U_R_R = $\sqrt{(2)}\cdot$ U_D. PI controllers perform the regulation tasks.

3.7.1 PI(D) Controllers

PI controllers are used for current control and velocity control. A P regulator is used for position control. The D part not yet supported, it is just a register place holder for future variants.

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3.7.2 PI(D) Controller Calculations

The PI regulators performs the calculation

$$\mathrm{dXdT} = \mathrm{P} \cdot \mathrm{e} + \mathrm{I} \cdot \int_0^t \mathrm{e(t)}\,\mathrm{d}t \tag{6}$$

with

$$\mathrm{e} = \mathrm{X\_TARGET} - \mathrm{X} \tag{7}$$

where X_TARGET stands for target flux, target torque, target velocity, or target position with error e that is the difference between target value and actual values. The time constant $\mathrm{d}t$ is $1\mu s$ with the integral part is divided by 256.

3.7.3 PI(D) Controller - Clipping

The limiting of target values for PI controllers and output values of PI controllers is programmable. Per power on default theses limiter are set to maximum values. Before one starts a motor one should set the limiters for clipping.
The target input is clipped to X_TARGET_LIMIT. The output of a PI(D) is named dXdT because it gives the desired derivative d/dt as a target value to the following stage: The position (x) controller gives velocity (dx/)
The output of the PI(D) is clipped to dXdT_LIMIT. The error integral of (6) is clipped to dXdT_LIMIT / I.

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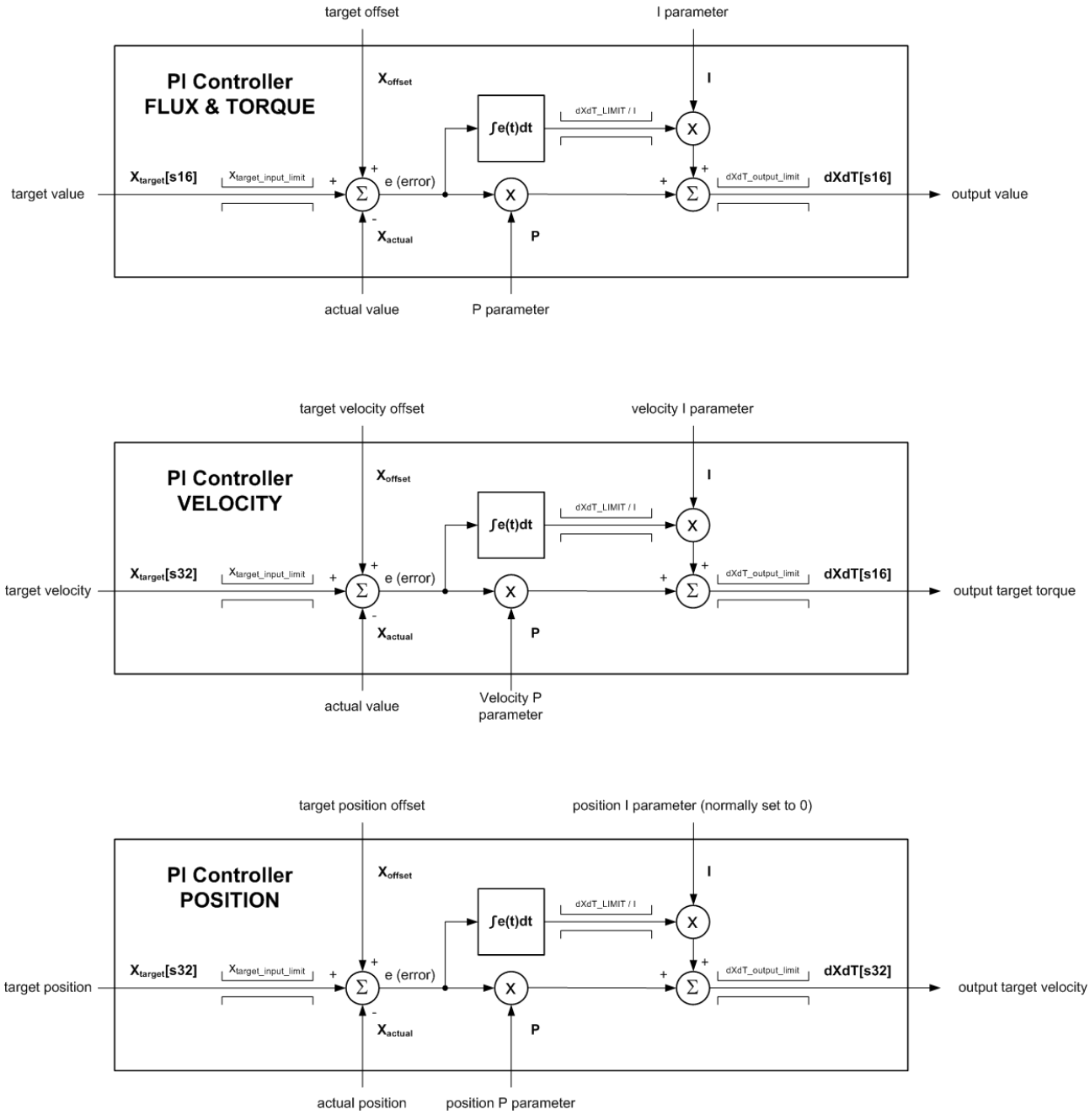

Figure 12: PID Architectures

3.7.4 PI Flux & PI Torque

The P part is represented as q8.8 and I is the I part represented as q0.15.

3.7.5 PI Velocity

The P part is represented as q8.8 and I is the I part represented as q0.15.

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3.7.6 P(I) Position

For the position regulator, the P part is represented as q4.12 to be compatible with the high resolution positions - one single rotation is handled as an s16.

This is because e = x - x_target might result in larger e[s32] for x[s32] and x_target[s32] represented as s32 for e = x - x_target for x[s16] and x_target[s16] represented as s16.

3.7.7 Inner FOC Control Loop - Flux & Torque

The inner FOC loop (figure 13) regulates the flux current to a flux target of zero and the torque current to the desired torque target. The inner FOC loop performs the desired transformations according to figure 14 for 3-phase motors (FOC3). For 2-phase motors (FOC2) both Clark (CLARK) transformation and inverse Clark (iCLARK) a by-passed.

The inner FOC control loop gets a target torque value (I_Q_TARGET) that represents acceleration, the rotor position, and the measured currents as input data. Together with the programmed P and I parameters, the inner FOC loop calculates three target voltage values as input for the PWM engine.

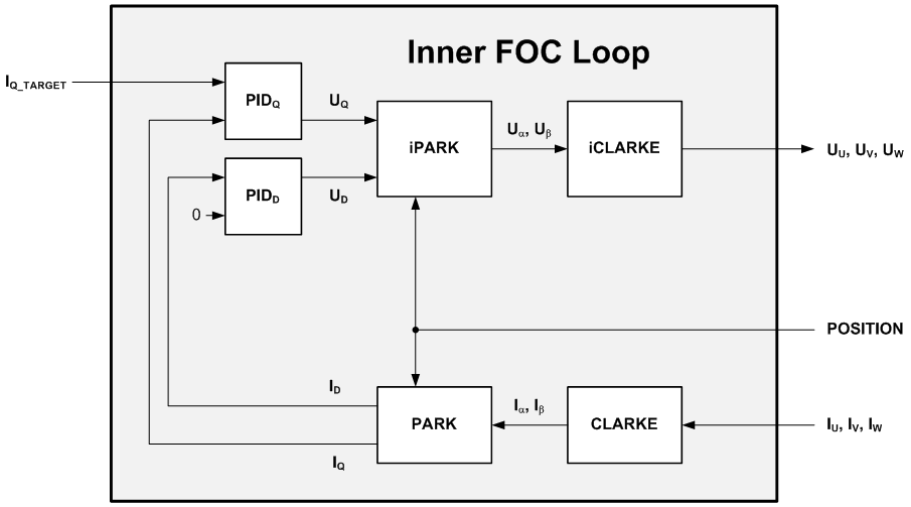

Figure 13: Inner FOC Control Loop

3.7.8 FOC Transformations and PI(D) for control of Flux & Torque

The Clark transformation (CLARKE) maps three motor phase currents (I_U, I_V, I_W) to a two dimensional coordinate system with two currents (I_α, I_β). Based on the actual rotor angel determined by an encoder or via sensorless techniques, the Park transformation (PARK) maps these two currents to a quasi-static coordinate system with two currents (I, I_Q). The current I represents flux and the current I_Q represents torque. The flux just pulls on the rotor but does not effect torque. The torque is effected by the (I_Q). Two PI controllers determine two voltages (U_D, U_Q) to drive desired currents for a target torque and a target flux of zero. The determined voltages (U_D, U_Q) are re-transformed into the stator system by the inverse Parke transformation (iPARK). The inverse Clarke Transformation (iCLARKE) transform these two currents into three voltages (U_U, U_V, U_W). Theses three voltage are the input of the PWM engine to drive the power stage.

In case of the FOC2, Clarke transformation CLARKE and inverse Clarke Transformation iCLARKE are skipped.

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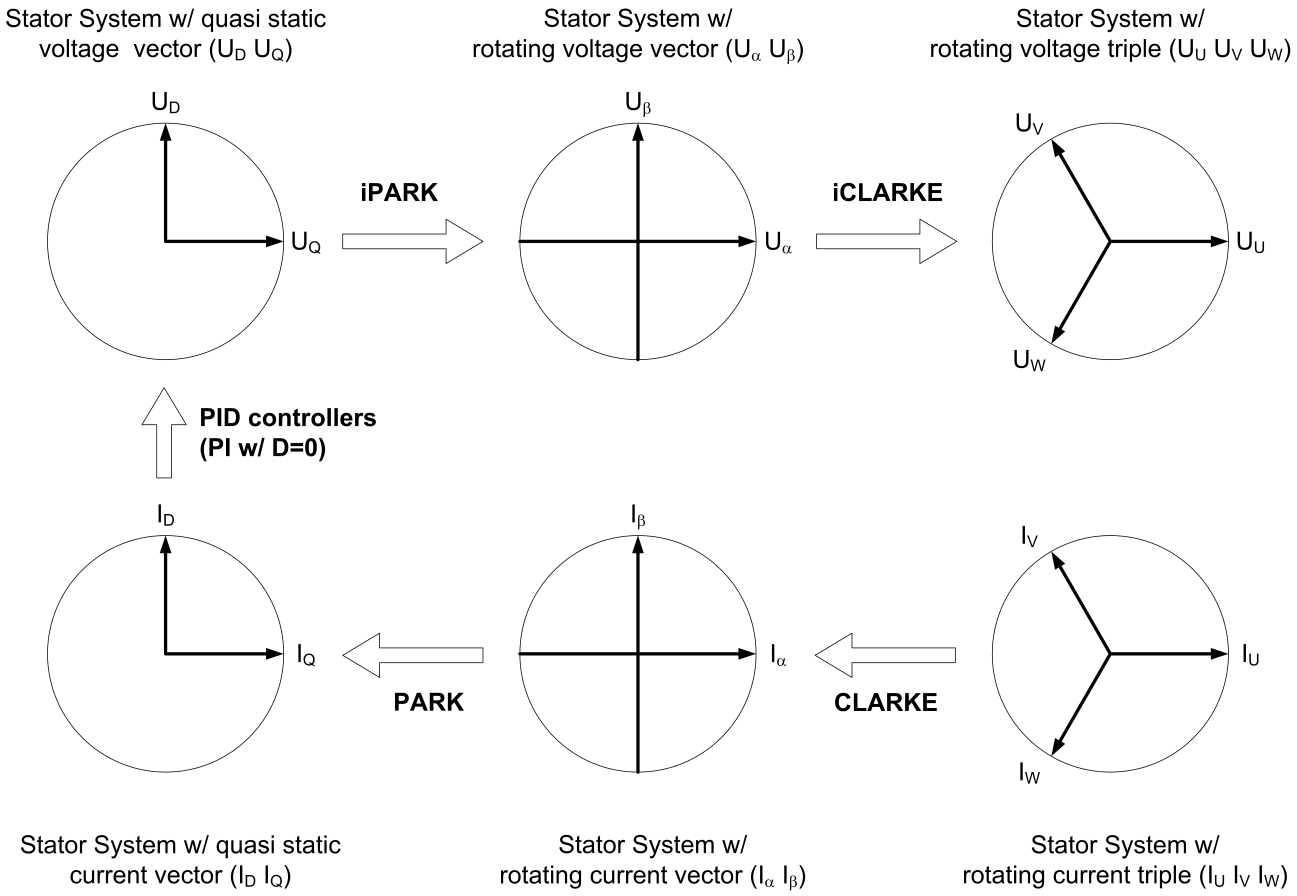

Figure 14: FOC3 Transformations (FOC2 just skips CLARKE and iCLARKE)

3.7.9 Motion Modes

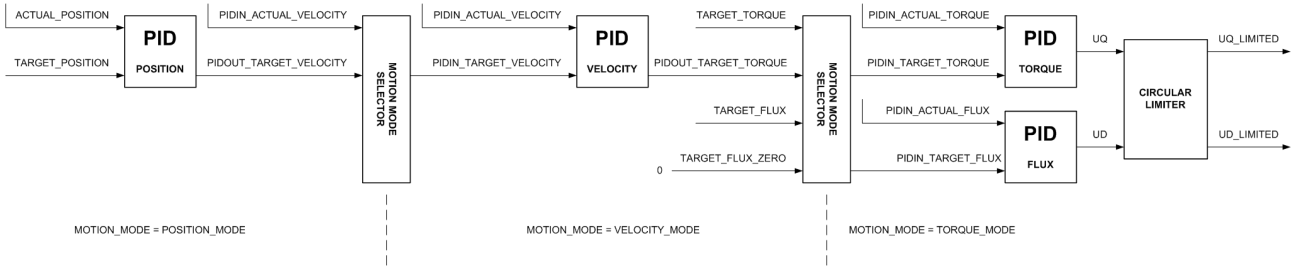

Figure 15: Motion Modes

3.8 PWM Engine

The PWM engine takes care converting voltage vectors to pulse width modulated (PWM) control signals. These digital PWM signals control the gate drivers of the power stage. For detailed description of the PWM control registers and PWM register control bits pls. refer section 5 page 27.

The ease-of-use PWM Engine requires just a couple of parameter settings. Primarily, the polarities for the gate control signal of high side and low side must be set. The power on default PWM mode is 0 that

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means PWM = OFF. For operation, the centered PWM mode must be set on by setting the PWM mode to 7. A single bit controls the Space vector PWM (SVPWM). For 3-phase PMSM the SVPWM = ON gives more effective voltage. Nevertheless, for some applications it makes sense to switch the SVPWM = OFF to keep the star point voltage of a motor almost at rest.

3.8.1 PWM Polarites

This PWM polarities register PWM_POLARITES controls the polarities of the control signals. Positive polarity for gate control means 1 represents ON and 0 represents OFF. The gate control signal polarities are individually programmable for low side gate control and for low side gate control. The PWM polarities register controls the polarity of other control signals as well.

3.8.2 PWM frequency

The PWM counter maximul length register PWM_MAXCNT controls the PWM frequency. For a clock frequency fCLK = 25MHz, the PWM frequency fPWM[Hz] = is (4.0 * fCLK[Hz]) / (PWM_MAXCNT + 1). With fCLK = 25MHz and power-on reset (POR) default of PWM_MAXCNT=3999 the PWM frequency is fPWM = 25kHz. The PWM frequency fPWM is recommended to be in the range of 25kHz to 200kHz by setting PWM_MAXCNT between 3999 to 499.

Note	The PWM frequency can be changed any time also during motion.

3.8.3 PWM Resolution

The base resolution of the PWM is 12 bit internally mapped to 16 bit range. MAX_PWMCNT=4095 gives the full resolution of 12 bit with ≈ 25kHz w/ fCLK=25MHz. MAX_PWMCNT=2047 results in 11 bit resolution but with ≈ 50kHz w/ fCLK=25MHz. So the PWM_MAXCNT defines the PWM frequency but effects the resolution of the PWM.

3.8.4 PWM Modes

The power-on reset (POR) default of the PWM is OFF. The standard PWM scheme is the centered PWM. Passive Breaking and Free Wheeling Modes are available on demand. Please refer [**?**] concerning the settings.

3.8.5 Brake-Before-Make (BBM)

One register controls BBM time for the high side. One register controls BBM time for the low side. The BBM times are programmable in 10ns steps. The BBM time can be set to zero for gate drivers that have there own integrated BBM timers.

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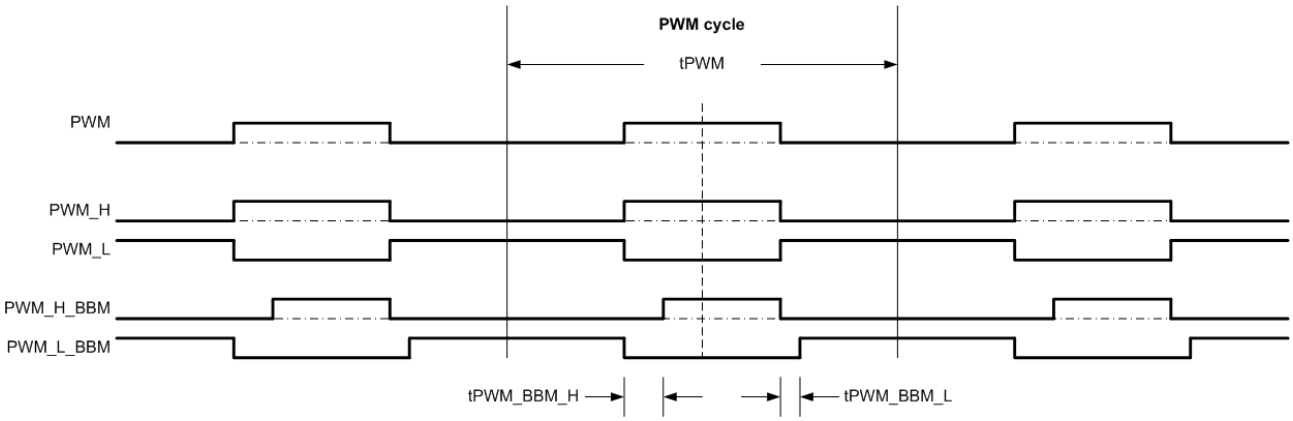

Figure 16: BBM Timing

Info	Measured BBM times at MOS-FET gates differs from programmed BBM times due to driver delays and possible additional gate driver BBM times. The programmed BBM times are for the digital control signals.

Note	Too small BBM times cause electrical short of the MOS-FET bridges - so called shoot through - that shorts the power supply and might damage the power stage and the power supply.

3.8.6 Space Vector PWM (SVPWM)

A single bit controls the internal Space vector PWM (SVPWM) enable. No further setting are required for the space vector PWM - just ON or OFF. The power on default for the SVPM is OFF.

Note	The SVPWM is for 3-phase motors only. For 2-phase motors there is no SVPWM.

4 Safety Functions

Different safety functions are integrated and mapped to status bits. Two programmable mask register select those bits for WARNING or ERROR. Warning just indicated the warning status at the WARNING output. An Error will cause programmable actions on error conditions and indicate the error status directly at ERROR output, as PWM = OFF on over current condition or ADC raw values with permanent zero or ADC raw values at maximum, . . .

Info	Programmable autonomous error handling is not implemented yet.

Internal hardware limiters for real time clipping and monitoring of interim values are available. LIMIT or LIMITS is part of register names of registers associated to internal limiters. Please refer 5.

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5 Register Map

Info This is a preliminary register map. Address mappings and register mappings might change for the release version. Names of some register addresses and names of register part might be changed for the release version.

Register Map for TMC4670					
Address	Registername				Access
$0x00_h$	CHIPINFO_DATA				R
	Variant 0				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	SI_TYPE		ASCII	
		Min	Max	Default	Unit
		0	4294967295	0	
		Hardware type (ASCII).			
	Variant 1				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	SI_VERSION		Version	
		Min	Max	Default	Unit
		0	4294967295	0	
		Hardware version (u16.u16).			
	Variant 2				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	SI_DATE		Date	
		Min	Max	Default	Unit
		0	4294967295	0	
		Hardware date (nibble wise date stamp yyyymmdd).			
	Variant 3				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	SI_TIME		Time	
		Min	Max	Default	Unit
		0	16777215	0	
		Hardware time (nibble wise time stamp –hhmmss)			
	Variant 4				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	SI_VARIANT		Unsigned	

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Address	Registername				Access
		Min	Max	Default	Unit
		0	4294967295	0	
0x01$_h$	CHIPINFO_ADDR				RW
	Mask	Name			Type
	0x000000FF$_h$	CHIP_INFO_ADDRESS			Choice
		Min	Max	Default	Unit
		0	4	0	
		0: SI_TYPE 1: SI_VERSION 2: SI_DATE 3: SI_TIME 4: SI_VARIANT			
0x02$_h$	ADC_RAW_DATA				R
	Variant 0				
	Mask	Name			Type
	0x0000FFFF$_h$	ADC_I_UX_RAW			Unsigned
		Min	Max	Default	Unit
		0	65535	0	
		Raw phase current U resp. X (LTC2351).			
	Mask	Name			Type
	0xFFFF0000$_h$	ADC_I_WY_RAW			Unsigned
		Min	Max	Default	Unit
		0	65535	0	
		Raw phase current W resp. Y (LTC2351).			
	Variant 1				
	Mask	Name			Type
	0x0000FFFF$_h$	ADC_I_U_RAW			Unsigned
		Min	Max	Default	Unit
		0	65535	0	
		Raw phase current U (ADC_I_UX analog input for FOC2).			
	Mask	Name			Type
	0xFFFF0000$_h$	ADC_I_V_RAW			Unsigned
		Min	Max	Default	Unit
		0	65535	0	
		Raw phase current V (ADC_I_WY analog input for FOC2).			

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Address	Registername				Access
	Variant 2				
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_I_B_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw phase current Bottom (analog input).			
	Variant 3				
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_VM_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw supply voltage.			
	Variant 4				
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_T_MOSFETS_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw mosfet temperature.			
	Mask	Name		Type	
	0xFFFF0000$_h$	ADC_T_MOTOR_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw motor temperature.			
	Variant 5				
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_U_UX_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw voltage terminal U resp. X.			
	Mask	Name		Type	
	0xFFFF0000$_h$	ADC_U_WY_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw voltage terminal W resp. Y.			
	Variant 6				

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Address	Registername				Access
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_U_V_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw voltage terminal V.			
	Variant 7				
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_UX_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw analog encoder voltage U resp. X.			
	Mask	Name		Type	
	0xFFFF0000$_h$	AENC_WY_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw analog encoder voltage W resp. Y.			
	Variant 8				
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_V_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw analog encoder voltage V.			
	Mask	Name		Type	
	0xFFFF0000$_h$	AENC_N_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw analog encoder zero position voltage N.			
	Variant 9				
	Mask	Name		Type	
	0x0000FFFF$_h$	ANALOG_GPI_RAW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Raw analog input voltage.			
	Variant 10				
	Mask	Name		Type	

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Address	Registername				Access
	0x0000FFFF$_h$	ADCSD_I_UX_RAW		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		SigmaDeltaADC current UX.			
	Mask	Name		Type	
	0xFFFF0000$_h$	ADCSD_I_WY_RAW		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		SigmaDeltaADC current WY.			
		Variant 11			
	Mask	Name		Type	
	0x0000FFFF$_h$	ADCSD_I_B_RAW		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		SigmaDeltaADC current at bottom (PCB S (sense) instead of B (bottom).			
0x03$_h$	ADC_RAW_ADDR				RW
	Mask	Name		Type	
	0x000000FF$_h$	ADC_RAW_ADDR		Choice	
		Min	Max	Default	Unit
		0	11	0	
		0: ADC_I_WY_RAW & ADC_I_UX_RAW			
		1: ADC_I_V_RAW & ADC_I_U_RAW			
		2: ADC_I_B_RAW			
		3: ADC_VM_RAW			
		4: ADC_T_MOSFETS_RAW & ADC_T_MOTOR_RAW			
		5: ADC_U_WY_RAW & ADC_U_UX_RAW			
		6: ADC_U_V_RAW			
		7: AENC_WY_RAW & AENC_UX_RAW			
		8: AENC_N_RAW & AENC_V_RAW			
		9: ANALOG_GPI_RAW			
		10: ADCSD_I_WY_RAW & ADCSD_I_UX_RAW			
		11: ADCSD_I_B_RAW			
0x04$_h$	ADCSD_CLKCFG				RW
	Mask	Name		Type	

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Address	Registername				Access
	0x0000FFFF$_h$	ADCSD_CLKCFG		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
0x06$_h$	ADC_I1_I0_EXT				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_I0_EXT		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Register for write of ADC_I0 value from external source (eg. CPU).			
	Mask	Name		Type	
	0xFFFF0000$_h$	ADC_I1_EXT		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Register for write of ADC_I1 value from external source (eg. CPU).			
0x08$_h$	ADC_I1_SCALE_OFFSET				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_I1_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for current ADC channel 1.			
	Mask	Name		Type	
	0xFFFF0000$_h$	ADC_I1_SCALE		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Scaling factor for current ADC channel 1.			
0x09$_h$	ADC_I0_SCALE_OFFSET				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_I0_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for current ADC channel 0.			
	Mask	Name		Type	
	0xFFFF0000$_h$	ADC_I0_SCALE		Signed	

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Address	Registername				Access
	Min	Max	Default	Unit	
	-32768	32767	0		
	Scaling factor for current ADC channel 0.				
0x0A$_h$	ADC_I_SELECT				RW
	Mask	Name		Type	
	0x000000FF$_h$	ADC_I0_SELECT		Choice	
	Min	Max	Default	Unit	
	0	7	0		
	Select input for raw current ADC_I0_RAW. 0: ADC_I0_RAW (analog input ADC_I_U) 1: ADC_I1_RAW (analog input ADC_I_V) 2: ADC_I0_EXT (from register) 3: ADC_I1_EXT (from register) 4: ADCSD_I0_RAW (sigma delta ADC) 5: ADCSD_I1_RAW (sigma delta ADC) 6: ADCSPI_I0_RAW (SPI ADC_I_UX) 7: ADCSPI_I1_RAW (SPI ADC_I_WY)				
	Mask	Name		Type	
	0x0000FF00$_h$	ADC_I1_SELECT		Choice	
	Min	Max	Default	Unit	
	0	7	0		
	Select input for raw current ADC_I1_RAW. 0: ADC_I0_RAW (analog input ADC_I_U) 1: ADC_I1_RAW (analog input ADC_I_V) 2: ADC_I0_EXT (from register) 3: ADC_I1_EXT (from register) 4: ADCSD_I0_RAW (sigma delta ADC) 5: ADCSD_I1_RAW (sigma delta ADC) 6: ADCSPI_I0_RAW (SPI ADC_I_UX) 7: ADCSPI_I1_RAW (SPI ADC_I_WY)				
	Mask	Name		Type	
	0x03000000$_h$	ADC_I_UX_SELECT		Choice	
	Min	Max	Default	Unit	
	0	2	0		
	0: UX = ADC_I0 (default)				

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Address	Registername				Access
		1: UX = ADC_I1 2: UX = ADC_I2			
	Mask	Name		Type	
	0x0C000000$_h$	ADC_I_V_SELECT		Choice	
		Min	Max	Default	Unit
		0	2	0	
		0: V = ADC_I0 1: V = ADC_I1 (default) 2: V = ADC_I2			
	Mask	Name		Type	
	0x30000000$_h$	ADC_I_WY_SELECT		Choice	
		Min	Max	Default	Unit
		0	2	0	
		0: WY = ADC_I0 1: WY = ADC_I1 2: WY = ADC_I2 (default)			
0x0D$_h$	AENC_0_SCALE_OFFSET				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_0_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for Analog Encoder ADC channel 0.			
	Mask	Name		Type	
	0xFFFF0000$_h$	AENC_0_SCALE		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Scaling factor for Analog Encoder ADC channel 0.			
0x0E$_h$	AENC_1_SCALE_OFFSET				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_1_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for Analog Encoder ADC channel 1.			
	Mask	Name		Type	
	0xFFFF0000$_h$	AENC_1_SCALE		Signed	

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Address	Registername				Access
		Min	Max	Default	Unit
		-32768	32767	0	
		Scaling factor for Analog Encoder ADC channel 1.			
$0x0F_h$	AENC_2_SCALE_OFFSET				RW
	Mask	Name			Type
	$0x0000FFFF_h$	AENC_2_OFFSET			Signed
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for Analog Encoder ADC channel 2.			
	Mask	Name			Type
	$0xFFFF0000_h$	AENC_2_SCALE			Signed
		Min	Max	Default	Unit
		-32768	32767	0	
		Scaling factor for Analog Encoder ADC channel 2.			
$0x10_h$	AENC_3_SCALE_OFFSET				RW
	Mask	Name			Type
	$0x0000FFFF_h$	AENC_3_OFFSET			Signed
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for Analog Encoder ADC channel 3.			
	Mask	Name			Type
	$0xFFFF0000_h$	AENC_3_SCALE			Signed
		Min	Max	Default	Unit
		-32768	32767	0	
		Scaling factor for Analog Encoder ADC channel 3.			
$0x11_h$	AENC_SELECT				RW
	Mask	Name			Type
	$0x000000FF_h$	AENC_0_SELECT			Choice
		Min	Max	Default	Unit
		0	3	0	
		Select analog encoder ADC channel for raw analog encoder signal AENC_0_RAW. 0: AENC_UX_RAW (default) 1: AENC_VN_RAW 2: AENC_WY_RAW			

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Address	Registername				Access
	3: AENC_N_RAW				
	Mask	Name		Type	
	0x0000FF00$_h$	AENC_1_SELECT		Choice	
		Min	Max	Default	Unit
		0	3	0	
	Select analog encoder ADC channel for raw analog encoder signal AENC_1_RAW. 0: AENC_UX_RAW 1: AENC_VN_RAW (default) 2: AENC_WY_RAW 3: AENC_N_RAW				
	Mask	Name		Type	
	0x00FF0000$_h$	AENC_2_SELECT		Choice	
		Min	Max	Default	Unit
		0	3	0	
	Select analog encoder ADC channel for raw analog encoder signal AENC_2_RAW. 0: AENC_UX_RAW 1: AENC_VN_RAW 2: AENC_WY_RAW (default) 3: AENC_N_RAW				
	Mask	Name		Type	
	0xFF000000$_h$	AENC_3_SELECT		Choice	
		Min	Max	Default	Unit
		0	3	0	
	Select analog encoder ADC channel for raw analog encoder signal AENC_3_RAW. 0: AENC_UX_RAW 1: AENC_VN_RAW 2: AENC_WY_RAW 3: AENC_N_RAW (default)				
0x12$_h$	ADC_IWY_IUX				R
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_IUX		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	

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Address	Registername				Access
		Register of scaled current ADC value including signed added offset as input for the FOC.			
	Mask	Name		Type	
	0xFFFF0000$_h$	ADC_IWY		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Register of scaled current ADC value including signed added offset as input for the FOC.			
0x13$_h$	ADC_IV				R
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_IV		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Register of scaled current ADC value including signed added offset as input for the FOC.			
0x15$_h$	AENC_WY_UX				R
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_UX		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Register of scaled analog encoder value including signed added offset as input for the interpolator.			
	Mask	Name		Type	
	0xFFFF0000$_h$	AENC_WY		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Register of scaled analog encoder value including signed added offset as input for the interpolator.			
0x16$_h$	AENC_N_VN				R
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_VN		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Register of scaled analog encoder value including signed added offset as input for the interpolator.			
	Mask	Name		Type	
	0xFFFF0000$_h$	AENC_N		Signed	

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Address	Registername				Access
	Min	Max	Default	Unit	
	-32768	32767	0		
	Register of scaled analog encoder value including signed added offset of analog N pulse.				
$0x17_h$	PWM_POLARITIES				RW
	Mask	Name		Type	
	$0x00000001_h$	PWM_POLARITIES[0]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	polarity of Low Side (LS) gate control signal 0: off 1: on				
	Mask	Name		Type	
	$0x00000002_h$	PWM_POLARITIES[1]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	polarity of High Side (HS) gate control signal 0: off 1: on				
	Mask	Name		Type	
	$0x00000004_h$	PWM_POLARITIES[2]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pulse AB polarity 0: off 1: on				
	Mask	Name		Type	
	$0x00000008_h$	PWM_POLARITIES[3]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pulse B polarity 0: off 1: on				
	Mask	Name		Type	
	$0x00000010_h$	PWM_POLARITIES[4]		Bool	

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Address	Registername				Access
		Min	Max	Default	Unit
		0	1	0	
		pulse C center polarity 0: off 1: on			
	Mask	Name			Type
	0x00000020$_h$	PWM_POLARITIES[5]			Bool
		Min	Max	Default	Unit
		0	1	0	
		pulse A polarity 0: off 1: on			
	Mask	Name			Type
	0x00000040$_h$	PWM_POLARITIES[6]			Bool
		Min	Max	Default	Unit
		0	1	0	
		pulse zero Z pulse polarity 0: off 1: on			
	Mask	Name			Type
	0x00000080$_h$	PWM_POLARITIES[7]			Bool
		Min	Max	Default	Unit
		0	1	0	
		over current signal polarity 0: off 1: on			
0x18$_h$	PWM_MAXCNT				RW
	Mask	Name			Type
	0x0000FFFF$_h$	PWM_MAXCNT			Unsigned
		Min	Max	Default	Unit
		0	65535	0	
		PWM maximum (count-1), PWM frequency is fPWM[Hz] = 100MHz/(PWM_MAXCNT+1)			
0x19$_h$	PWM_BBM_H_BBM_L				RW
	Mask	Name			Type

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Address	Registername				Access
	0x000000FF$_h$	PWM_BBM_L		Unsigned	
		Min	Max	Default	Unit
		0	255	0	
		Break Before Make time tBBM_L[10ns] for low side MOS-FET gate control			
	Mask	Name		Type	
	0x0000FF00$_h$	PWM_BBM_H		Unsigned	
		Min	Max	Default	Unit
		0	255	0	
		Break Before Make time tBBM_H[10ns] for high side MOS-FET gate control			
0x1A$_h$	PWM_SV_CHOP				RW
	Mask	Name		Type	
	0x000000FF$_h$	PWM_CHOP		Choice	
		Min	Max	Default	Unit
		0	7	0	
		PWM chopper mode, defining how to chopper 0: PWM = OFF, free running 1: PWM = OFF, Low Side (LS) permanent = ON 2: PWM = OFF, High Side (HS) permanent = ON 3: PWM off, free running 4: PWM off, free running 5: PWM low side (LS) chopper only, high side (HS) off; not suitable for FOC 6: PWM high side (HS) chopper only, low side (LS) off; not suitable for FOC 7: centered PWM for FOC			
	Mask	Name		Type	
	0x00000100$_h$	PWM_SV		Bool	
		Min	Max	Default	Unit
		0	1	0	
		use Space Vector PWM 0: Space Vector PWM disabled 1: Space Vector PWM enabled			
0x1B$_h$	MOTOR_TYPE_N_POLE_PAIRS				RW
	Mask	Name		Type	

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Address	Registername				Access
	0x0000FFFF$_h$	N_POLE_PAIRS		Unsigned	
		Min	Max	Default	Unit
		1	65535	1	
		Number n of pole pairs of the motor for calcualtion phi_e = phi_m / N_POLE_PAIRS.			
	Mask	Name		Type	
	0x00FF0000$_h$	MOTOR_TYPE		Choice	
		Min	Max	Default	Unit
		0	3	0	
		0: FOC2 1: FOC3 2: reserved 3: reserved			
0x1C$_h$	PHI_E_EXT				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	PHI_E_EXT		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Electrical angle phi_e_ext for external writing into this register.			
0x1D$_h$	PHI_M_EXT				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	PHI_M_EXT		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Mechanical angle phi_m_ext for external writing into this register.			
0x1E$_h$	POSITION_EXT				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	POSITION_EXT		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Mechanical (multi turn) position for external writing into this register.			
0x1F$_h$	OPENLOOP_MODE				RW
	Mask	Name		Type	
	0x00001000$_h$	OPENLOOP_PHI_DIRECTION		Bool	

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Address	Registername				Access
		Min	Max	Default	Unit
		0	1	0	
		Open loop phi direction. 0: positive 1: negative			
0x20$_h$	OPENLOOP_ACCELERATION				RW
	Mask	Name			Type
	0xFFFFFFFF$_h$	OPENLOOP_ACCELERATION			Unsigned
		Min	Max	Default	Unit
		0	4294967295	0	
		Acceleration of open loop phi.			
0x21$_h$	OPENLOOP_VELOCITY_TARGET				RW
	Mask	Name			Type
	0xFFFFFFFF$_h$	OPENLOOP_VELOCITY_TARGET			Signed
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Target velocity of open loop phi.			
0x22$_h$	OPENLOOP_VELOCITY_ACTUAL				RW
	Mask	Name			Type
	0xFFFFFFFF$_h$	OPENLOOP_VELOCITY_ACTUAL			Signed
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Actual velocity of open loop generator.			
0x23$_h$	OPENLOOP_PHI				RW
	Mask	Name			Type
	0x0000FFFF$_h$	OPENLOOP_PHI			Signed
		Min	Max	Default	Unit
		-32768	32767	0	
		Angle phi open loop (either mapped to electrical angel phi_e or mechanical angle phi_m).			
0x24$_h$	UQ_UD_EXT				RW
	Mask	Name			Type
	0x0000FFFF$_h$	UD_EXT			Signed
		Min	Max	Default	Unit
		-32768	32767	0	

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Address	Registername				Access
		External writable parameter for open loop voltage control mode, usefull during system setup, U_D component.			
	Mask	Name			Type
	0xFFFF0000$_h$	UQ_EXT			Signed
		Min	Max	Default	Unit
		-32768	32767	0	
		External writable parameter for open loop voltage control mode, usefull during system setup, U_Q component.			
0x25$_h$	ABN_DECODER_MODE				RW
	Mask	Name			Type
	0x00000001$_h$	apol			Bool
		Min	Max	Default	Unit
		0	1	0	
		Polarity of A pulse. 0: off 1: on			
	Mask	Name			Type
	0x00000002$_h$	bpol			Bool
		Min	Max	Default	Unit
		0	1	0	
		Polarity of B pulse. 0: off 1: on			
	Mask	Name			Type
	0x00000004$_h$	npol			Bool
		Min	Max	Default	Unit
		0	1	0	
		Polarity of N pulse. 0: off 1: on			
	Mask	Name			Type
	0x00000008$_h$	use_abn_as_n			Bool
		Min	Max	Default	Unit
		0	1	0	
		0: Ignore A and B polarity with Npulse = N, 1 : Npulse = N and A and B			

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Address	Registername				Access
		0: Ignore A and B polarity with Npulse = N 1: Npulse = N and A and B			
	Mask	Name		Type	
	0x00000100$_h$	cln		Bool	
		Min	Max	Default	Unit
		0	1	0	
		Clear writes ABN_DECODER_COUNT_N into decoder count at Npulse. 0: off 1: on			
	Mask	Name		Type	
	0x00001000$_h$	direction		Bool	
		Min	Max	Default	Unit
		0	1	0	
		Decoder count direction. 0: positive 1: negative			
0x26$_h$	ABN_DECODER_PPR				RW
	Mask	Name		Type	
	0x00FFFFFF$_h$	ABN_DECODER_PPR		Unsigned	
		Min	Max	Default	Unit
		0	16777215	0	
		Decoder pules per mechanical revolution.			
0x27$_h$	ABN_DECODER_COUNT				RW
	Mask	Name		Type	
	0x00FFFFFF$_h$	ABN_DECODER_COUNT		Unsigned	
		Min	Max	Default	Unit
		0	16777215	0	
		Raw decoder count; the digital decoder engine counts modulo (decoder_ppr).			
0x28$_h$	ABN_DECODER_COUNT_N				RW
	Mask	Name		Type	
	0x00FFFFFF$_h$	ABN_DECODER_COUNT_N		Unsigned	
		Min	Max	Default	Unit
		0	16777215	0	

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Address	Registername				Access
		Decoder count latched on N pulse, when N pulse clears decoder_count also decoder_count_n is 0.			
$0x29_h$	ABN_DECODER_PHI_E_PHI_M_OFFSET				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	ABN_DECODER_PHI_M_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		ABN_DECODER_PHI_M_OFFSET to shift (rotate) angle DECODER_PHI_M.			
	Mask	Name		Type	
	$0xFFFF0000_h$	ABN_DECODER_PHI_E_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		ABN_DECODER_PHI_E_OFFSET to shift (rotate) angle DECODER_PHI_E.			
$0x2A_h$	ABN_DECODER_PHI_E_PHI_M				R
	Mask	Name		Type	
	$0x0000FFFF_h$	ABN_DECODER_PHI_M		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		ABN_DECODER_PHI_M = ABN_DECODER_COUNT * 2î6 / ABN_DECODER_PPR + ABN_DECODER_PHI_M_OFFSET;			
	Mask	Name		Type	
	$0xFFFF0000_h$	ABN_DECODER_PHI_E		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		ABN_DECODER_PHI_E = (ABN_DECODER_PHI_M * N_POLE_PAIRS_) + ABN_DECODER_PHI_E_OFFSET			
$0x2C_h$	ABN_2_DECODER_MODE				RW
	Mask	Name		Type	
	$0x00000001_h$	apol		Bool	
		Min	Max	Default	Unit
		0	1	0	
		Polarity of A pulse. 0: off 1: on			

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Address	Registername				Access
	Mask	Name		Type	
	$0x00000002_h$	bpol		Bool	
		Min	Max	Default	Unit
		0	1	0	
		Polarity of B pulse. 0: off 1: on			
	Mask	Name		Type	
	$0x00000004_h$	npol		Bool	
		Min	Max	Default	Unit
		0	1	0	
		Polarity of N pulse. 0: off 1: on			
	Mask	Name		Type	
	$0x00000008_h$	use_abn_as_n		Bool	
		Min	Max	Default	Unit
		0	1	0	
		0: Ignore A and B polarity with Npulse = N, 1 : Npulse = N and A and B 0: Ignore A and B polarity with Npulse = N 1: Npulse = N and A and B			
	Mask	Name		Type	
	$0x00000100_h$	cln		Bool	
		Min	Max	Default	Unit
		0	1	0	
		Clear writes ABN_2_DECODER_COUNT_N into decoder count at Npulse. 0: off 1: on			
	Mask	Name		Type	
	$0x00001000_h$	direction		Bool	
		Min	Max	Default	Unit
		0	1	0	
		Decoder count direction. 0: positive			

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Address	Registername				Access
		1: negative			
0x2D$_h$	ABN_2_DECODER_PPR				RW
	Mask	Name		Type	
	0x00FFFFFF$_h$	ABN_2_DECODER_PPR		Unsigned	
		Min	Max	Default	Unit
		1	16777215	0	
		Decoder_2 pules per mechanical revolution. This 2nd ABN encoder interface is for positioning or velocity control but NOT for motor commutation.			
0x2E$_h$	ABN_2_DECODER_COUNT				RW
	Mask	Name		Type	
	0x00FFFFFF$_h$	ABN_2_DECODER_COUNT		Unsigned	
		Min	Max	Default	Unit
		0	16777215	0	
		Raw decoder_2 count; the digital decoder engine counts modulo (decoder_2_ppr).			
0x2F$_h$	ABN_2_DECODER_COUNT_N				RW
	Mask	Name		Type	
	0x00FFFFFF$_h$	ABN_2_DECODER_COUNT_N		Unsigned	
		Min	Max	Default	Unit
		0	16777215	0	
		Decoder_2 count latched on N pulse, when N pulse clears decoder_2_count also decoder_2_count_n is 0.			
0x30$_h$	ABN_2_DECODER_PHI_M_OFFSET				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	ABN_2_DECODER_PHI_M_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		ABN_2_DECODER_PHI_M_OFFSET to shift (rotate) angle DECODER_2_PHI_M.			
0x31$_h$	ABN_2_DECODER_PHI_M				R
	Mask	Name		Type	
	0x0000FFFF$_h$	ABN_2_DECODER_PHI_M		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	

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Address	Registername				Access
	ABN_2_DECODER_PHI_M = ABN_2_DECODER_COUNT * 2^16 / ABN_2_DECODER_PPR + ABN_2_DECODER_PHI_M_OFFSET;				
0x33$_h$	HALL_MODE				RW
	Mask	Name		Type	
	0x00000001$_h$	polarity		Bool	
		Min	Max	Default	Unit
		0	1	0	
		polarity 0: off 1: on			
	Mask	Name		Type	
	0x00000100$_h$	interpolation		Bool	
		Min	Max	Default	Unit
		0	1	0	
		interpolation 0: off 1: on			
	Mask	Name		Type	
	0x00001000$_h$	direction		Bool	
		Min	Max	Default	Unit
		0	1	0	
		direction 0: off 1: on			
0x34$_h$	HALL_POSITION_060_000				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	HALL_POSITION_000		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		s16 hall sensor position at 0°			
	Mask	Name		Type	
	0xFFFF0000$_h$	HALL_POSITION_060		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		s16 hall sensor position at 60°.			

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Address	Registername				Access
$0x35_h$	HALL_POSITION_180_120				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	HALL_POSITION_120		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		s16 hall sensor position at 120°.			
	Mask	Name		Type	
	$0xFFFF0000_h$	HALL_POSITION_180		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		s16 hall sensor position at 180°.			
$0x36_h$	HALL_POSITION_300_240				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	HALL_POSITION_240		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		s16 hall sensor position at 240°.			
	Mask	Name		Type	
	$0xFFFF0000_h$	HALL_POSITION_300		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		s16 hall sensor position at 300°.			
$0x37_h$	HALL_PHI_E_PHI_M_OFFSET				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	HALL_PHI_M_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset of mechanical angle hall_phi_m of hall decoder.			
	Mask	Name		Type	
	$0xFFFF0000_h$	HALL_PHI_E_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for electrical angle hall_phi_e of hall decoder.			
$0x38_h$	HALL_DPHI_MAX				RW
	Mask	Name		Type	

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Address	Registername				Access
	0x0000FFFF$_h$	HALL_DPHI_MAX		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Maximum dx for interpolation (default for digital hall: u16/6).			
0x39$_h$	HALL_PHI_E_INTERPOLATED_PHI_E				R
	Mask	Name		Type	
	0x0000FFFF$_h$	HALL_PHI_E		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Raw electrical angle hall_phi_e of hall decoder, selection programmed via HALL_MODE control bit.			
	Mask	Name		Type	
	0xFFFF0000$_h$	HALL_PHI_E_INTERPOLATED		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Interpolated electrical angle hall_phi_e_interpolated, selection programmed via HALL_MODE control bit.			
0x3A$_h$	HALL_PHI_M				R
	Mask	Name		Type	
	0x0000FFFF$_h$	HALL_PHI_M		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Mechanical angle hall_phi_m of hall decoder.			
0x3B$_h$	AENC_DECODER_MODE				RW
	Mask	Name		Type	
	0x00000001$_h$	AENC_DECODER_MODE[0]		Bool	
		Min	Max	Default	Unit
		0	1	0	
		nXY_UVW : 0: SinCos Mode // 1: 0° 120° 240° Mode 0: off 1: on			
	Mask	Name		Type	
	0x00001000$_h$	AENC_DECODER_MODE[12]		Bool	
		Min	Max	Default	Unit
		0	1	0	

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Address	Registername				Access
		decoder count direction 0: positive 1: negative			
0x3C$_h$	AENC_DECODER_N_THRESHOLD				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_DECODER_N_THRESHOLD		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Threshold for generating of N pulse from analog AENC_N signal (only needed for analog SinCos encoders with analog N signal).			
0x3D$_h$	AENC_DECODER_PHI_A_RAW				R
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_DECODER_PHI_A_RAW		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Raw analog angle phi calculated from analog AENC inputs (analog hall, analog SinCos, ...).			
0x3E$_h$	AENC_DECODER_PHI_A_OFFSET				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_DECODER_PHI_A_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for angle phi from analog decoder (analog hall, analog SinCos, ...).			
0x3F$_h$	AENC_DECODER_PHI_A				R
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_DECODER_PHI_A		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Resulting phi available for the FOC (phi_e might need to be calculated from this angle via aenc_decoder_ppr, for analog hall sensors phi_a might be used directly as phi_e depends on analog hall signal type).			
0x40$_h$	AENC_DECODER_PPR				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	AENC_DECODER_PPR		Signed	
		Min	Max	Default	Unit

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Address	Registername				Access
		-32768	32767	1	
		Number of periods per revolution also called lines per revolution (different nomenclatur compared to digital ABN encoders).			
$0x41_h$	AENC_DECODER_COUNT				RW
	Mask	Name		Type	
	$0xFFFFFFFF_h$	AENC_DECODER_COUNT		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Decoder position, raw unscaled.			
$0x42_h$	AENC_DECODER_COUNT_N				RW
	Mask	Name		Type	
	$0xFFFFFFFF_h$	AENC_DECODER_COUNT_N		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Latched decoder position on analog N pulse event.			
$0x43_h$	AENC_DECODER_COUNT_N_MASK				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	AENC_DECODER_COUNT_N_MASK		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Optional position mask (position) for the analog N pulse within phi_a period to be and-ed with the digital N pulse generated via aenc_decoder_n_threshold.			
$0x45_h$	AENC_DECODER_PHI_E_PHI_M_OFFSET				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	AENC_DECODER_PHI_M_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for mechanical angle phi_m.			
	Mask	Name		Type	
	$0xFFFF0000_h$	AENC_DECODER_PHI_E_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Offset for electrical angle phi_e.			
$0x46_h$	AENC_DECODER_PHI_E_PHI_M				R
	Mask	Name		Type	

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Address	Registername				Access
	0x0000FFFF$_h$	AENC_DECODER_PHI_M			Signed
		Min	Max	Default	Unit
		-32768	32767	0	
		Resulting angle phi_m.			
	Mask	Name			Type
	0xFFFF0000$_h$	AENC_DECODER_PHI_E			Signed
		Min	Max	Default	Unit
		-32768	32767	0	
		Resulting angle phi_e.			
0x47$_h$	AENC_DECODER_POSITION				RW
	Mask	Name			Type
	0xFFFFFFFF$_h$	AENC_DECODER_POSITION			Signed
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Multi-turn position.			
0x50$_h$	VELOCITY_SELECTION				RW
	Mask	Name			Type
	0x000000FF$_h$	VELOCITY_SELECTION			Choice
		Min	Max	Default	Unit
		0	12	0	
		0: phi_e selected via PHI_E_SELECTION 1: phi_e_ext 2: phi_e_openloop 3: phi_e_abn 4: reserved 5: phi_e_hal 6: phi_e_aenc 7: phi_a_aenc 8: reserved 9: phi_m_abn 10: phi_m_abn_2 11: phi_m_aenc 12: phi_m_hal			
0x51$_h$	POSITION_SELECTION				RW
	Mask	Name			Type

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Address	Registername				Access
	0x000000FF$_h$	POSITION_SELECTION		Choice	
		Min	Max	Default	Unit
		0	12	0	
		0: phi_e selected via PHI_E_SELECTION 1: phi_e_ext 2: phi_e_openloop 3: phi_e_abn 4: reserved 5: phi_e_hal 6: phi_e_aenc 7: phi_a_aenc 8: reserved 9: phi_m_abn 10: phi_m_abn_2 11: phi_m_aenc 12: phi_m_hal			
0x52$_h$	PHI_E_SELECTION				RW
	Mask	Name		Type	
	0x000000FF$_h$	PHI_E_SELECTION		Choice	
		Min	Max	Default	Unit
		0	7	0	
		0: reserved 1: phi_e_ext 2: phi_e_openloop 3: phi_e_abn 4: reserved 5: phi_e_hal 6: phi_e_aenc 7: phi_a_aenc			
0x53$_h$	PHI_E				R
	Mask	Name		Type	
	0x0000FFFF$_h$	PHI_E		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Angle used for the inner FOC loop.			

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Address	Registername				Access
$0x54_h$	PID_FLUX_P_FLUX_I				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	PID_FLUX_I		Signed	
		Min	Max	Default	Unit
		0	32767	0	
	Mask	Name		Type	
	$0xFFFF0000_h$	PID_FLUX_P		Signed	
		Min	Max	Default	Unit
		0	32767	0	
$0x55_h$	PID_FLUX_D				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	PID_FLUX_D		Signed	
		Min	Max	Default	Unit
		0	32767	0	
$0x56_h$	PID_TORQUE_P_TORQUE_I				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	PID_TORQUE_I		Signed	
		Min	Max	Default	Unit
		0	32767	0	
	Mask	Name		Type	
	$0xFFFF0000_h$	PID_TORQUE_P		Signed	
		Min	Max	Default	Unit
		0	32767	0	
$0x57_h$	PID_TORQUE_D				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	PID_TORQUE_D		Signed	
		Min	Max	Default	Unit
		0	32767	0	
$0x58_h$	PID_VELOCITY_P_VELOCITY_I				RW
	Mask	Name		Type	
	$0x0000FFFF_h$	PID_VELOCITY_I		Signed	
		Min	Max	Default	Unit
		0	32767	0	
	Mask	Name		Type	
	$0xFFFF0000_h$	PID_VELOCITY_P		Signed	

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Address	Registername					Access
		Min	Max	Default	Unit	
		0	32767	0		
0x59$_h$	PID_VELOCITY_D					RW
	Mask	Name			Type	
	0x0000FFFF$_h$	PID_VELOCITY_D			Signed	
		Min	Max	Default	Unit	
		0	32767	0		
0x5A$_h$	PID_POSITION_P_POSITION_I					RW
	Mask	Name			Type	
	0x0000FFFF$_h$	PID_POSITION_I			Signed	
		Min	Max	Default	Unit	
		0	32767	0		
	Mask	Name			Type	
	0xFFFF0000$_h$	PID_POSITION_P			Signed	
		Min	Max	Default	Unit	
		0	32767	0		
0x5B$_h$	PID_POSITION_D					RW
	Mask	Name			Type	
	0x0000FFFF$_h$	PID_POSITION_D			Signed	
		Min	Max	Default	Unit	
		0	32767	0		
0x5C$_h$	PID_TORQUE_FLUX_TARGET_DDT_LIMITS					RW
	Mask	Name			Type	
	0xFFFFFFFF$_h$	PID_TORQUE_FLUX_TARGET_DDT_LIMITS			Unsigned	
		Min	Max	Default	Unit	
		0	32767	32767	[1/?s]	
		Limits of change in time [d/dt] of the target torque and target flux.				
0x5D$_h$	PIDOUT_UQ_UD_LIMITS					RW
	Mask	Name			Type	
	0x0000FFFF$_h$	PIDOUT_UQ_UD_LIMITS			Unsigned	
		Min	Max	Default	Unit	
		0	32767	0		
		Two dimensional circular limiter for inputs of iPark.				
0x5E$_h$	PID_TORQUE_FLUX_LIMITS					RW

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Address	Registername				Access
	Mask	Name		Type	
	0x0000FFFF$_h$	PID_TORQUE_FLUX_LIMITS		Unsigned	
		Min	Max	Default	Unit
		0	32767	0	
		PID torque limt and PID flux limit, limits the target values coming from the target registers.			
0x5F$_h$	PID_ACCELERATION_LIMIT				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_ACCELERATION_LIMIT		Unsigned	
		Min	Max	Default	Unit
		0	4294967295	0	
		Acceleration limit.			
0x60$_h$	PID_VELOCITY_LIMIT				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_VELOCITY_LIMIT		Unsigned	
		Min	Max	Default	Unit
		0	4294967295	0	
		Velocity limit.			
0x61$_h$	PID_POSITION_LIMIT_LOW				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_POSITION_LIMIT_LOW		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Position limit low, programmable positon barrier.			
0x62$_h$	PID_POSITION_LIMIT_HIGH				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_POSITION_LIMIT_HIGH		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Position limit high, programmable positon barrier.			
0x63$_h$	MODE_RAMP_MODE_MOTION				RW
	Mask	Name		Type	
	0x000000FF$_h$	MODE_MOTION		Choice	
		Min	Max	Default	Unit
		0	8	0	

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Address	Registername				Access
		0: stopped_mode 1: torque_mode 2: velocity_mode 3: position_mode 4: reserved 5: reserved 6: reserved 7: reserved 8: uq_ud_ext			
	Mask	Name		Type	
	0x0000FF00$_h$	MODE_RAMP		Choice	
		Min	Max	Default	Unit
		0	7	0	
		0: no velocity ramping 1: reserved 2: reserved 3: reserved 4: reserved 5: reserved 6: reserved 7: reserved			
0x64$_h$	PID_TORQUE_FLUX_TARGET				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	PID_FLUX_TARGET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	PID_TORQUE_TARGET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
0x65$_h$	PID_TORQUE_FLUX_OFFSET				RW
	Mask	Name		Type	
	0x0000FFFF$_h$	PID_FLUX_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	

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Address	Registername				Access
		Flux offset for feed forward control.			
	Mask	Name		Type	
	0xFFFF0000$_h$	PID_TORQUE_OFFSET		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
		Torque offset for feed forward control.			
0x66$_h$	PID_VELOCITY_TARGET				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_VELOCITY_TARGET		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Target velocity register (for velocity mode).			
0x67$_h$	PID_VELOCITY_OFFSET				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_VELOCITY_OFFSET		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Velocity offset for feed forward control.			
0x68$_h$	PID_POSITION_TARGET				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_POSITION_TARGET		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Target position register (for position mode).			
0x69$_h$	PID_TORQUE_FLUX_ACTUAL				R
	Mask	Name		Type	
	0x0000FFFF$_h$	PID_FLUX_ACTUAL		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	PID_TORQUE_ACTUAL		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
0x6A$_h$	PID_VELOCITY_ACTUAL				R
	Mask	Name		Type	

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Address	Registername				Access
	0xFFFFFFFF$_h$	PID_VELOCITY_ACTUAL		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Actual velocity.			
0x6B$_h$	PID_POSITION_ACTUAL				RW
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_POSITION_ACTUAL		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		Actual multi turn position for positioning. WRITE on PID_POSITION_ACTUAL writes same value into PID_POSITION_TARGET to avoid unwanted move.			
0x6C$_h$	PID_ERROR_DATA				R
	Variant 0				
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_TORQUE_ERROR		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PID torque error.			
	Variant 1				
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_FLUX_ERROR		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PID flux error.			
	Variant 2				
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_VELOCITY_ERROR		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PID velocity error.			
	Variant 3				
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_POSITION_ERROR		Signed	
		Min	Max	Default	Unit

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Address	Registername				Access
	-2147483648	2147483647	0		
	PID position error.				
	Variant 4				
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_TORQUE_ERROR_SUM		Signed	
	Min	Max	Default	Unit	
	-2147483648	2147483647	0		
	PID torque error.				
	Variant 5				
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_FLUX_ERROR_SUM		Signed	
	Min	Max	Default	Unit	
	-2147483648	2147483647	0		
	PID flux error sum.				
	Variant 6				
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_VELOCITY_ERROR_SUM		Signed	
	Min	Max	Default	Unit	
	-2147483648	2147483647	0		
	PID velocity error sum.				
	Variant 7				
	Mask	Name		Type	
	0xFFFFFFFF$_h$	PID_POSITION_ERROR_SUM		Signed	
	Min	Max	Default	Unit	
	-2147483648	2147483647	0		
	PID position error sum.				
0x6D$_h$	PID_ERROR_ADDR				RW
	Mask	Name		Type	
	0x000000FF$_h$	PID_ERROR_ADDR		Choice	
	Min	Max	Default	Unit	
	0	7	0		
	0: PID_TORQUE_ERROR				
	1: PID_FLUX_ERROR				
	2: PID_VELOCITY_ERROR				
	3: PID_POSITION_ERROR				

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Address	Registername				Access
	4: PID_TORQUE_ERROR_SUM 5: PID_FLUX_ERROR_SUM 6: PID_VELOCITY_ERROR_SUM 7: PID_POSITION_ERROR_SUM				
$0x6E_h$	INTERIM_DATA				RW
	Variant 0				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	PIDIN_TARGET_TORQUE		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PIDIN target torque.			
	Variant 1				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	PIDIN_TARGET_FLUX		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PIDIN target flux.			
	Variant 2				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	PIDIN_TARGET_VELOCITY		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PIDIN target velocity.			
	Variant 3				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	PIDIN_TARGET_POSITION		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PIDIN target position.			
	Variant 4				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	PIDOUT_TARGET_TORQUE		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PIDOUT target torque.			

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Address	Registername				Access
	Variant 5				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	PIDOUT_TARGET_FLUX		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PIDOUT target flux.			
	Variant 6				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	PIDOUT_TARGET_VELOCITY		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PIDOUT target velocity.			
	Variant 7				
	Mask	Name		Type	
	$0xFFFFFFFF_h$	PIDOUT_TARGET_POSITION		Signed	
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
		PIDOUT target position.			
	Variant 8				
	Mask	Name		Type	
	$0x0000FFFF_h$	FOC_IUX		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	$0xFFFF0000_h$	FOC_IWY		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 9				
	Mask	Name		Type	
	$0x0000FFFF_h$	FOC_IV		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 10				
	Mask	Name		Type	
	$0x0000FFFF_h$	FOC_IA		Signed	

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Address	Registername				Access
	Min	Max	Default	Unit	
	-32768	32767	0		
Mask	Name			Type	
$0xFFFF0000_h$	FOC_IB			Signed	
	Min	Max	Default	Unit	
	-32768	32767	0		
	Variant 11				
Mask	Name			Type	
$0x0000FFFF_h$	FOC_ID			Signed	
	Min	Max	Default	Unit	
	-32768	32767	0		
Mask	Name			Type	
$0xFFFF0000_h$	FOC_IQ			Signed	
	Min	Max	Default	Unit	
	-32768	32767	0		
	Variant 12				
Mask	Name			Type	
$0x0000FFFF_h$	FOC_UD			Signed	
	Min	Max	Default	Unit	
	-32768	32767	0		
Mask	Name			Type	
$0xFFFF0000_h$	FOC_UQ			Signed	
	Min	Max	Default	Unit	
	-32768	32767	0		
	Variant 13				
Mask	Name			Type	
$0x0000FFFF_h$	FOC_UD_LIMITED			Signed	
	Min	Max	Default	Unit	
	-32768	32767	0		
Mask	Name			Type	
$0xFFFF0000_h$	FOC_UQ_LIMITED			Signed	
	Min	Max	Default	Unit	
	-32768	32767	0		
	Variant 14				
Mask	Name			Type	

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Address	Registername				Access
	0x0000FFFF$_h$	FOC_UA		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	FOC_UB		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 15				
	Mask	Name		Type	
	0x0000FFFF$_h$	FOC_UUX		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	FOC_UWY		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 16				
	Mask	Name		Type	
	0x0000FFFF$_h$	FOC_UV		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 17				
	Mask	Name		Type	
	0x0000FFFF$_h$	PWM_UX		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	PWM_WY		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 18				
	Mask	Name		Type	
	0x0000FFFF$_h$	PWM_V		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	

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Address	Registername				Access
	Variant 19				
	Mask	Name		Type	
	0x0000FFFF$_h$	ADC_I_0		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	ADC_I_1		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 192				
	Mask	Name		Type	
	0x0000FFFF$_h$	DEBUG_VALUE_0		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	DEBUG_VALUE_1		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 193				
	Mask	Name		Type	
	0x0000FFFF$_h$	DEBUG_VALUE_2		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	DEBUG_VALUE_3		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 194				
	Mask	Name		Type	
	0x0000FFFF$_h$	DEBUG_VALUE_4		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	DEBUG_VALUE_5		Signed	
		Min	Max	Default	Unit

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Address	Registername				Access
		-32768	32767	0	
	Variant 195				
	Mask	Name		Type	
	0x0000FFFF$_h$	DEBUG_VALUE_6		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	DEBUG_VALUE_7		Signed	
		Min	Max	Default	Unit
		-32768	32767	0	
	Variant 196				
	Mask	Name		Type	
	0x0000FFFF$_h$	DEBUG_VALUE_8		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	DEBUG_VALUE_9		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
	Variant 197				
	Mask	Name		Type	
	0x0000FFFF$_h$	DEBUG_VALUE_10		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	DEBUG_VALUE_11		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
	Variant 198				
	Mask	Name		Type	
	0x0000FFFF$_h$	DEBUG_VALUE_12		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
	Mask	Name		Type	
	0xFFFF0000$_h$	DEBUG_VALUE_13		Unsigned	

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Address	Registername				Access
		Min	Max	Default	Unit
		0	65535	0	
	Variant 199				
	Mask	Name			Type
	0x0000FFFF$_h$	DEBUG_VALUE_14			Unsigned
		Min	Max	Default	Unit
		0	65535	0	
	Mask	Name			Type
	0xFFFF0000$_h$	DEBUG_VALUE_15			Unsigned
		Min	Max	Default	Unit
		0	65535	0	
	Variant 200				
	Mask	Name			Type
	0xFFFFFFFF$_h$	DEBUG_VALUE_16			Signed
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
	Variant 201				
	Mask	Name			Type
	0xFFFFFFFF$_h$	DEBUG_VALUE_17			Signed
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
	Variant 202				
	Mask	Name			Type
	0xFFFFFFFF$_h$	DEBUG_VALUE_18			Signed
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
	Variant 203				
	Mask	Name			Type
	0xFFFFFFFF$_h$	DEBUG_VALUE_19			Signed
		Min	Max	Default	Unit
		-2147483648	2147483647	0	
0x6F$_h$	INTERIM_ADDR				RW
	Mask	Name			Type
	0x000000FF$_h$	INTERIM_ADDR			Choice
		Min	Max	Default	Unit

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Address	Registername			Access
	0	203	0	
	0: PIDIN_TARGET_TORQUE 1: PIDIN_TARGET_FLUX 2: PIDIN_TARGET_VELOCITY 3: PIDIN_TARGET_POSITION 4: PIDOUT_TARGET_TORQUE 5: PIDOUT_TARGET_FLUX 6: PIDOUT_TARGET_VELOCITY 7: PIDOUT_TARGET_POSITION 8: FOC_IWY_IUX 9: FOC_IV 10: FOC_IB_IA 11: FOC_IQ_ID 12: FOC_UQ_UD 13: FOC_UQ_UD_LIMITED 14: FOC_UB_UA 15: FOC_UWY_UUX 16: FOC_UV 17: PWM_WY_UX 18: PWM_UV 19: ADC_I1_I0 192: DEBUG_VALUE_1_0 193: DEBUG_VALUE_3_2 194: DEBUG_VALUE_5_4 195: DEBUG_VALUE_7_6 196: DEBUG_VALUE_9_8 197: DEBUG_VALUE_11_10 198: DEBUG_VALUE_13_12 199: DEBUG_VALUE_15_14 200: DEBUG_VALUE_16 201: DEBUG_VALUE_17 202: DEBUG_VALUE_18 203: DEBUG_VALUE_19			
0x75$_h$	ADC_VM_LIMITS			RW
	Mask	Name	Type	

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Address	Registername				Access
	0x0000FFFF$_h$	ADC_VM_LIMIT_LOW		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		Low limit for brake chopper output BRAKE_OUT.			
	Mask	Name		Type	
	0xFFFF0000$_h$	ADC_VM_LIMIT_HIGH		Unsigned	
		Min	Max	Default	Unit
		0	65535	0	
		High limit for brake chopper output BRAKE_OUT.			
0x76$_h$	TMC4670_INPUTS_RAW				R
	Mask	Name		Type	
	0x00000001$_h$	TMC4670_INPUTS_RAW[0]		Bool	
		Min	Max	Default	Unit
		0	1	0	
		A of ABN_RAW 0: off 1: on			
	Mask	Name		Type	
	0x00000002$_h$	TMC4670_INPUTS_RAW[1]		Bool	
		Min	Max	Default	Unit
		0	1	0	
		B of ABN_RAW 0: off 1: on			
	Mask	Name		Type	
	0x00000004$_h$	TMC4670_INPUTS_RAW[2]		Bool	
		Min	Max	Default	Unit
		0	1	0	
		N of ABN_RAW 0: off 1: on			
	Mask	Name		Type	
	0x00000008$_h$	TMC4670_INPUTS_RAW[3]		Bool	
		Min	Max	Default	Unit
		0	1	0	

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Address	Registername			Access
	—			
	0: off			
	1: on			
Mask	Name		Type	
0x00000010$_h$	TMC4670_INPUTS_RAW[4]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	A of ABN_2_RAW			
	0: off			
	1: on			
Mask	Name		Type	
0x00000020$_h$	TMC4670_INPUTS_RAW[5]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	B of ABN_2_RAW			
	0: off			
	1: on			
Mask	Name		Type	
0x00000040$_h$	TMC4670_INPUTS_RAW[6]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	N of ABN_2_RAW			
	0: off			
	1: on			
Mask	Name		Type	
0x00000080$_h$	TMC4670_INPUTS_RAW[7]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	—			
	0: off			
	1: on			
Mask	Name		Type	
0x00000100$_h$	TMC4670_INPUTS_RAW[8]		Bool	
	Min	Max	Default	Unit
	0	1	0	

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Address	Registername			Access
	HALL_UX of HALL_RAW 0: off 1: on			
Mask	Name		Type	
0x00000200$_h$	TMC4670_INPUTS_RAW[9]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	HALL_V of HALL_RAW 0: off 1: on			
Mask	Name		Type	
0x00000400$_h$	TMC4670_INPUTS_RAW[10]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	HALL_WY of HALL_RAW 0: off 1: on			
Mask	Name		Type	
0x00000800$_h$	TMC4670_INPUTS_RAW[11]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	— 0: off 1: on			
Mask	Name		Type	
0x00001000$_h$	TMC4670_INPUTS_RAW[12]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	REF_SW_R_RAW 0: off 1: on			
Mask	Name		Type	
0x00002000$_h$	TMC4670_INPUTS_RAW[13]		Bool	
	Min	Max	Default	Unit
	0	1	0	

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Address	Registername			Access
	REF_SW_H_RAW 0: off 1: on			
	Mask	Name	Type	
	$0x00004000_h$	TMC4670_INPUTS_RAW[14]	Bool	
	Min	Max	Default	Unit
	0	1	0	
	REF_SW_L_RAW 0: off 1: on			
	Mask	Name	Type	
	$0x00008000_h$	TMC4670_INPUTS_RAW[15]	Bool	
	Min	Max	Default	Unit
	0	1	0	
	ENABLE_IN_RAW 0: off 1: on			
	Mask	Name	Type	
	$0x00010000_h$	TMC4670_INPUTS_RAW[16]	Bool	
	Min	Max	Default	Unit
	0	1	0	
	STP of DIRSTP_RAW 0: off 1: on			
	Mask	Name	Type	
	$0x00020000_h$	TMC4670_INPUTS_RAW[17]	Bool	
	Min	Max	Default	Unit
	0	1	0	
	DIR of DIRSTP_RAW 0: off 1: on			
	Mask	Name	Type	
	$0x00040000_h$	TMC4670_INPUTS_RAW[18]	Bool	
	Min	Max	Default	Unit
	0	1	0	

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Address	Registername			Access
	PWM_IN_RAW 0: off 1: on			
Mask	Name		Type	
0x00080000$_h$	TMC4670_INPUTS_RAW[19]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	— 0: off 1: on			
Mask	Name		Type	
0x00100000$_h$	TMC4670_INPUTS_RAW[20]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	ESI_0 of ESI_RAW 0: off 1: on			
Mask	Name		Type	
0x00200000$_h$	TMC4670_INPUTS_RAW[21]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	ESI_1 of ESI_RAW 0: off 1: on			
Mask	Name		Type	
0x00400000$_h$	TMC4670_INPUTS_RAW[22]		Bool	
	Min	Max	Default	Unit
	0	1	0	
	ESI_2 of ESI_RAW 0: off 1: on			
Mask	Name		Type	
0x00800000$_h$	TMC4670_INPUTS_RAW[23]		Bool	
	Min	Max	Default	Unit
	0	1	0	

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Address	Registername			Access
	—			
	0: off			
	1: on			
	Mask	Name		Type
	0x01000000$_h$	TMC4670_INPUTS_RAW[24]		Bool
	Min	Max	Default	Unit
	0	1	0	
	CFG_0 of CFG			
	0: off			
	1: on			
	Mask	Name		Type
	0x02000000$_h$	TMC4670_INPUTS_RAW[25]		Bool
	Min	Max	Default	Unit
	0	1	0	
	CFG_1 of CFG			
	0: off			
	1: on			
	Mask	Name		Type
	0x04000000$_h$	TMC4670_INPUTS_RAW[26]		Bool
	Min	Max	Default	Unit
	0	1	0	
	CFG_2 of CFG			
	0: off			
	1: on			
	Mask	Name		Type
	0x08000000$_h$	TMC4670_INPUTS_RAW[27]		Bool
	Min	Max	Default	Unit
	0	1	0	
	CFG_3 of CFG			
	0: off			
	1: on			
	Mask	Name		Type
	0x10000000$_h$	TMC4670_INPUTS_RAW[28]		Bool
	Min	Max	Default	Unit
	0	1	0	

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Address	Registername				Access
	PWM_IDLE_L_RAW 0: off 1: on				
	Mask	Name		Type	
	$0x20000000_h$	TMC4670_INPUTS_RAW[29]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	PWM_IDLE_H_RAW 0: off 1: on				
	Mask	Name		Type	
	$0x40000000_h$	TMC4670_INPUTS_RAW[30]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	DRV_ERR_IN_RAW 0: off 1: on				
	Mask	Name		Type	
	$0x80000000_h$	TMC4670_INPUTS_RAW[31]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	— 0: off 1: on				
$0x77_h$	TMC4670_OUTPUTS_RAW				R
	Mask	Name		Type	
	$0x00000001_h$	TMC4670_OUTPUTS_RAW[0]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	PWM_UX1_L 0: off 1: on				
	Mask	Name		Type	
	$0x00000002_h$	TMC4670_OUTPUTS_RAW[1]		Bool	
	Min	Max	Default	Unit	

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Address	Registername				Access
	0	1	0		
	PWM_UX1_H 0: off 1: on				
	Mask	Name		Type	
	0x00000004$_h$	TMC4670_OUTPUTS_RAW[2]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	PWM_VX2_L 0: off 1: on				
	Mask	Name		Type	
	0x00000008$_h$	TMC4670_OUTPUTS_RAW[3]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	PWM_VX2_H 0: off 1: on				
	Mask	Name		Type	
	0x00000010$_h$	TMC4670_OUTPUTS_RAW[4]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	PWM_WY1_L 0: off 1: on				
	Mask	Name		Type	
	0x00000020$_h$	TMC4670_OUTPUTS_RAW[5]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	PWM_WY1_H 0: off 1: on				
	Mask	Name		Type	
	0x00000040$_h$	TMC4670_OUTPUTS_RAW[6]		Bool	
	Min	Max	Default	Unit	

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Address	Registername				Access
		0	1	0	
		PWM_Y2_L 0: off 1: on			
	Mask	Name			Type
	0x00000080$_h$	TMC4670_OUTPUTS_RAW[7]			Bool
		Min	Max	Default	Unit
		0	1	0	
		PWM_Y2_H 0: off 1: on			
0x7C$_h$	STATUS_FLAGS				RW
	Mask	Name			Type
	0x00000001$_h$	STATUS_FLAGS[0]			Bool
		Min	Max	Default	Unit
		0	1	0	
		pid_x_target_limit 0: off 1: on			
	Mask	Name			Type
	0x00000002$_h$	STATUS_FLAGS[1]			Bool
		Min	Max	Default	Unit
		0	1	0	
		pid_x_target_ddt_limit 0: off 1: on			
	Mask	Name			Type
	0x00000004$_h$	STATUS_FLAGS[2]			Bool
		Min	Max	Default	Unit
		0	1	0	
		pid_x_errsum_limit 0: off 1: on			
	Mask	Name			Type
	0x00000008$_h$	STATUS_FLAGS[3]			Bool

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Address	Registername				Access
	Min	Max	Default	Unit	
	0	1	0		
	pid_x_output_limit 0: off 1: on				
	Mask	Name		Type	
	0x00000010$_h$	STATUS_FLAGS[4]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_v_target_limit 0: off 1: on				
	Mask	Name		Type	
	0x00000020$_h$	STATUS_FLAGS[5]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_v_target_ddt_limit 0: off 1: on				
	Mask	Name		Type	
	0x00000040$_h$	STATUS_FLAGS[6]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_v_errsum_limit 0: off 1: on				
	Mask	Name		Type	
	0x00000080$_h$	STATUS_FLAGS[7]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_v_output_limit 0: off 1: on				
	Mask	Name		Type	
	0x00000100$_h$	STATUS_FLAGS[8]		Bool	

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Address	Registername				Access
	Min	Max	Default	Unit	
	0	1	0		
	pid_id_target_limit 0: off 1: on				
	Mask	Name		Type	
	$0x00000200_h$	STATUS_FLAGS[9]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_id_target_ddt_limit 0: off 1: on				
	Mask	Name		Type	
	$0x00000400_h$	STATUS_FLAGS[10]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_id_errsum_limit 0: off 1: on				
	Mask	Name		Type	
	$0x00000800_h$	STATUS_FLAGS[11]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_id_output_limit 0: off 1: on				
	Mask	Name		Type	
	$0x00001000_h$	STATUS_FLAGS[12]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_iq_target_limit 0: off 1: on				
	Mask	Name		Type	
	$0x00002000_h$	STATUS_FLAGS[13]		Bool	

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Address	Registername				Access
	Min	Max	Default	Unit	
	0	1	0		
	pid_iq_target_ddt_limit 0: off 1: on				
	Mask	Name		Type	
	$0x00004000_h$	STATUS_FLAGS[14]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_iq_errsum_limit 0: off 1: on				
	Mask	Name		Type	
	$0x00008000_h$	STATUS_FLAGS[15]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pid_iq_output_limit 0: off 1: on				
	Mask	Name		Type	
	$0x00010000_h$	STATUS_FLAGS[16]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	ipark_cirlim_limit_u_d 0: off 1: on				
	Mask	Name		Type	
	$0x00020000_h$	STATUS_FLAGS[17]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	ipark_cirlim_limit_u_q 0: off 1: on				
	Mask	Name		Type	
	$0x00040000_h$	STATUS_FLAGS[18]		Bool	

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Address	Registername				Access
	Min	Max	Default	Unit	
	0	1	0		
	ipark_cirlim_limit_u_r 0: off 1: on				
	Mask	Name		Type	
	$0x00080000_h$	STATUS_FLAGS[19]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	— 0: off 1: on				
	Mask	Name		Type	
	$0x00100000_h$	STATUS_FLAGS[20]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	ref_sw_r 0: off 1: on				
	Mask	Name		Type	
	$0x00200000_h$	STATUS_FLAGS[21]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	ref_sw_h 0: off 1: on				
	Mask	Name		Type	
	$0x00400000_h$	STATUS_FLAGS[22]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	ref_sw_l 0: off 1: on				
	Mask	Name		Type	
	$0x00800000_h$	STATUS_FLAGS[23]		Bool	

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Address	Registername				Access
	Min	Max	Default	Unit	
	0	1	0		
	—				
	0: off				
	1: on				
	Mask	Name		Type	
	$0x01000000_h$	STATUS_FLAGS[24]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pwm_min				
	0: off				
	1: on				
	Mask	Name		Type	
	$0x02000000_h$	STATUS_FLAGS[25]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	pwm_max				
	0: off				
	1: on				
	Mask	Name		Type	
	$0x04000000_h$	STATUS_FLAGS[26]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	adc_i_clipped				
	0: off				
	1: on				
	Mask	Name		Type	
	$0x08000000_h$	STATUS_FLAGS[27]		Bool	
	Min	Max	Default	Unit	
	0	1	0		
	aenc_clipped				
	0: off				
	1: on				
	Mask	Name		Type	
	$0x10000000_h$	STATUS_FLAGS[28]		Bool	

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Address	Registername				Access
		Min	Max	Default	Unit
		0	1	0	
		enc_n 0: off 1: on			
	Mask	Name			Type
	$0x20000000_h$	STATUS_FLAGS[29]			Bool
		Min	Max	Default	Unit
		0	1	0	
		enc_2_n 0: off 1: on			
	Mask	Name			Type
	$0x40000000_h$	STATUS_FLAGS[30]			Bool
		Min	Max	Default	Unit
		0	1	0	
		aenc_n 0: off 1: on			
	Mask	Name			Type
	$0x80000000_h$	STATUS_FLAGS[31]			Bool
		Min	Max	Default	Unit
		0	1	0	
		— 0: off 1: on			
$0x7D_h$	WARNING_MASK				RW
	Mask	Name			Type
	$0xFFFFFFFF_h$	WARNING_MASK			Unsigned
		Min	Max	Default	Unit
		0	4294967295	0	
$0x7E_h$	ERROR_MASK				RW
	Mask	Name			Type
	$0xFFFFFFFF_h$	ERROR_MASK			Unsigned
		Min	Max	Default	Unit

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Address	Registername					Access
		0	4294967295	0		

Table 6: Register Map for TMC4670

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6 Pinning

Info

All power supply pins (1V2, 2V5, 3V3) must be connected.

All ground pins (GND, GND_REF) must be connected.

All pins specified as n.c. (=not connected) must be left open.

Analog inputs (AI) are 2.5V single ended inputs. Voltage dividers are required to scale down higher input voltages.

Digital inputs (I) resp. (IO) are 3.3V single ended inputs. Voltage dividers are required to scale done higher input voltages.

IO	Description
AI	analog input, 2.5V
I	digital input, 3.3V
IO	digital input or digital output, direction programmable, 3.3V
O	digital output, 3.3V

Table 7: Pin Type Definition

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Name	Ball	IO	Description
nRST	B10	I	active low reset input
CLK	M3	I	clock input, 25 MHz
ENABLE_IN	T13	I	active high enable input
SPI_nSCS	R7	I	SPI active low chip select input
SPI_SCK	T7	I	SPI clock input
SPI_MOSI	T6	I	SPI master out slave input
SPI_MISO	R6	O	SPI master in sleave output
ENC_A	L1	I	A input of incremental encoder
ENC_B	L2	I	B input of incremental encoder
ENC_N	M1	I	N input of incremental encoder
ENC2_A	R1	I	A input of incremental encoder
ENC2_B	P2	I	B input of incremental encoder
ENC2_N	P4	I	N input of incremental encoder
HALL_UX	N2	I	digital hall input H1 for 3-phase (U) or 2-phase (X)
HALL_V	N1	I	digital hall input H2 for 3-phase (V)
HALL_WY	M2	I	digital hall input H3 for 3-phase (W) or 2-phase (Y)
REF_SW_L	A9	I	Left (L) reference switch
REF_SW_H	A8	I	Home (H) reference switch
REF_SW_R	A10	I	Right (R) reference switch
AENC_UX	C1	AI	analog hall or analog encoder, 3-phase (U) or 2-phase (X (cos))
AENC_V	D1	AI	analog hall or analog encoder, 3-phase (V)
AENC_WY	E1	AI	analog hall or analog encoder, 3-phase (W) or 2-phase (Y (sin))
AENC_N	B1	AI	analog encoder N pulse input
ADC_I_0	F2	AI	phase current measurement voltage input I_0 (I_U, I_X)
ADC_I_1	F4	AI	phase current measurement voltage input I_1 (I_V, I_W, I_Y)
ADC_VM	E3	AI	analog input for motor suppply voltage (VM) measurement
AGPI	G2	AI	Analog general purpose input (analog GPI)
ADC_T_MOSFETS	C3	AI	analog input for MOSFET temperature signal
ADC_T_MOTOR	C4	AI	analog input for motor temperature signal
ADC_U_UX	F1	AI	analog voltage input for terminal UX
ADC_U_V	F5	AI	analog voltage input for terminal V
ADC_U_WY	B2	A	analog voltage input for terminal WY
ADC_I_S	C2	AI	analog bottom current measurement voltage input, reserved
ADC_START	B5	O	ADC start pulse for TLC2351

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Name	Ball	IO	Description
ADC_BIP	B4	O	output driving ADC LTC2351 BIP input
ADC_nSCS	B7	O	ADC LTC2351 nSCS signal
ADC_SCK	B6	O	ADC LTC2351 SCK signal
ADC_MISO	A6	I	from ADC LTC2351 SDO output
ADC_MOSI	A7	O	reserved for ADC w/ SDI input
PWM_IDLE_H	A11	I	Idle Level of high side gate control signals
PWM_IDLE_L	B11	I	Idle Level of low side gate control signals
PWM_UX1_H	D16	O	high side gate control output U (3-phase) resp. X1 (2-phase)
PWM_UX1_L	D15	O	low side gate control output U (3-phase) resp. X1 (2-phase)
PWM_VX2_H	C16	O	high side gate control output V (3-phase) resp. X2 (2-phase)
PWM_VX2_L	D14	O	low side gate control output V (3-phase) resp. X2 (2-phase)
PWM_WY1_H	B16	O	high side gate control output W (3-phase) resp. Y1 (2-phase)
PWM_WY1_L	C15	O	low side gate control output W (3-phase) resp. Y1 (2-phase)
PWM_Y2_H	B15	O	high side gate control output Y2 (2-phase only)
PWM_Y2_L	C14	O	low side gate control output Y2 (2-phase only)
PWM_Z_OUT	L15	O	pulse, indicating start of PWM period (zero count)
PWM_C_OUT	L16	O	pulse, indicating center of PWM period
BRAKE_OUT	A13	O	brake chopper control signal
DRV_ERR_IN	A12	I	driver error input (from gate driver)

Table 8: Functional Pin Description

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Name	Ball	IO	*Description resereved IOs not supported by current version*
STP	T15	I	step input
DIR	T14	I	direction input
UART_DIR	P12	O	UART direction pin in case of RS485 usage
UART_TXD	P11	O	transmit data TXD (RS232, RS422, RS485, . . .
UART_RXD	R11	I	receive data RXD (RS232, RS422, RS485, . . .
ENC_SSI_CLK	R8	O	SSI clock (+) output
ENC_SSI_DAT	T8	I	SSI data (+) data input
SPI_DBG_CLK	P8	IO	DBG SPI master CLK
UART_RXD/SPI_DBG_MISO	T9	IO	DBG SPI master MISO
UART_TXD/SPI_DBG_MOSI	R9	IO	DBG SPI master MOSI
URAT_DIR/SPI_DBG_nSCS	P9	IO	DBG SPI mster nSCS
MCLK_UX	G16	IO	delta sigma modulator clock IO for phase current UX (programmable direction)
MDAT_UX	E16	I	delta sigma modulator data stream for phase UX
MCLK_WY	F16	IO	delta sigma modulator clock IO for phase current WY (programmable direction)
MDAT_WY	E14	I	delta sigma modulator data stream for phase WY
MCLK_S	G15	IO	delta sigma modulator clock IO for phase bottom current (programmable direction)
MDAT_S	E15	I	delta sigma modulator data stream for bottom current
CFG_0	T5	I	configuration pin#0
CFG_1	T4	I	configuration pin#1
CFG_2	T3	I	configuration pin#2
CFG_3	T2	I	configuration pin#3
ESI_0	H16	I	Emergency Switch Input #0
ESI_1	J15	I	Emergency Switch Input #1
ESI_2	J16	I	Emergency Switch Input #2
WARNING_OUT	P10	I	Maskable Warning Output
ERROR_OUT	T11	I	Maskable Error Output
ENABLE_OUT	A5	O	enable output
TRIGGER_OUT	K14	O	general purpose trigger output
GPIO_0	R5	IO	general purpose IO#0
GPIO_1	R4	IO	general purpose IO#1
GPIO_2	R3	IO	general purpose IO#2
GPIO_3	R2	IO	general purpose IO#3

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Name	Ball	IO	*Description resereved IOs not supported by current version*
DBGIO_0	P15	IO	debug IO#0
DBGIO_1	N16	IO	debug IO#1
DBGIO_2	M15	IO	debug IO#2
DBGIO_3	M16	IO	debug IO#3
PWM_IN	R10	I	PWM input, to assign target values via duty cycle
DIAG_OUT_0	T12	O	DIAG_OUT_0 diagnosis output
DIAG_OUT_1	R12	O	DIAG_OUT_1 diagnosis output

Table 9: Description of pins not supported by current version

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Name	Ball	IO	*Supply Voltage Pins and Ground Pins*
VCCIO3V3	K4	3.3V	
VCCIO3V3	L4	3.3V	
VCCIO3V3	N6	3.3V	
VCCIO3V3	N7	3.3V	
VCCIO3V3	N8	3.3V	
VCCIO3V3	N10	3.3V	
VCCIO3V3	N11	3.3V	
VCCIO3V3	K13	3.3V	
VCCIO3V3	L13	3.3V	
VCCIO3V3	M13	3.3V	
VCCIO3V3	F13	3.3V	
VCCIO3V3	G13	3.3V	
VCCIO3V3	H13	3.3V	
VCCIO3V3	J13	3.3V	
VCCIO3V3	D10	3.3V	
VCCIO3V3	D11	3.3V	
VCCIO3V3	C7	3.3V	
VCCIO3V3	D7	3.3V	
VCCIO3V3	D8	3.3V	
VCCrefR1	E8	3.3V via 10K	reference resistor to be connected to 3.3V supply voltage
VCCrefR2	F7	3.3V via 10K	reference resistor to be connected to 3.3V supply voltage
VCCrefR3	E7	3.3V via 10K	reference resistor to be connected to 3.3V supply voltage
ADCVREF2V5	E4	2.5V	
VCCA2V5	D5	2.5V	
VCCA2V5	E12	2.5V	
VCCA2V5	L5	2.5V	
VCCA2V5	M12	2.5V	
VCCA2V5	E5	2.5V	
VCCA2V5	G4	2.5V	
VCCA2V5	H4	2.5V	
VCCA2V5	J4	2.5V	
VCC1V2	G7	1.2V	
VCC1V2	G9	1.2V	
VCC1V2	H8	1.2V	

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Name	Ball	IO	*Supply Voltage Pins and Ground Pins*
VCC1V2	H9	1.2V	
VCC1V2	H10	1.2V	
VCC1V2	J7	1.2V	
VCC1V2	J8	1.2V	
VCC1V2	J9	1.2V	
VCC1V2	K8	1.2V	
VCC1V2	K10	1.2V	
VCCINT1V2	F6	1.2V	
VCCPLL1V2	D4	1.2V	
VCCPLL1V2	D13	1.2V	
VCCPLL1V2	M5	1.2V	
VCCPLL1V2	N13	1.2V	
GND	A1	0V	
GND	A16	0V	
GND	B14	0V	
GND	C8	0V	
GND	C11	0V	
GND	D2	0V	
GND	D3	0V	
GND	D6	0V	
GND	E6	0V	
GND	E13	0V	
GND	F8	0V	
GND	F15	0V	
GND	F3	0V	
GND	G3	0V	
GND	G8	0V	
GND	G10	0V	
GND	H7	0V	
GND	H14	0V	
GND	J10	0V	
GND	K1	0V	
GND	K3	0V	
GND	K7	0V	

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Name	Ball	IO	*Supply Voltage Pins and Ground Pins*
GND	K9	0V	
GND	K16	0V	
GND	L14	0V	
GND	M4	0V	
GND	N9	0V	
GND	N12	0V	
GND	N15	0V	
GND	P3	0V	
GND	P7	0V	
GND	R13	0V	
GND	T1	0V	
GND	T10	0V	
GND	T16	0V	
REFGND	E2	0V	

Table 10: Supply Voltage Pins and Ground Pins

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Name	Ball	IO	*Not Connected (n.c.) Pins*
n.c.	A2	-	not connected
n.c.	A3	-	not connected
n.c.	A4	-	not connected
n.c.	A14	-	not connected
n.c.	A15	-	not connected
n.c.	B3	-	not connected
n.c.	B8	-	not connected
n.c.	B9	-	not connected
n.c.	B12	-	not connected
n.c.	B13	-	not connected
n.c.	C5	-	not connected
n.c.	C6	-	not connected
n.c.	C9	-	not connected
n.c.	C10	-	not connected
n.c.	C12	-	not connected
n.c.	C13	-	not connected
n.c.	D9	-	not connected
n.c.	D12	-	not connected
n.c.	E9	-	not connected
n.c.	E10	-	not connected
n.c.	E11	-	not connected
n.c.	F9	-	not connected
n.c.	F10	-	not connected
n.c.	F11	-	not connected
n.c.	F12	-	not connected
n.c.	F14	-	not connected
n.c.	G5	-	not connected
n.c.	G1	-	not connected
n.c.	G11	-	not connected
n.c.	G12	-	not connected
n.c.	G14	-	not connected
n.c.	G6	-	not connected
n.c.	H5	-	not connected
n.c.	H6	-	not connected

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Name	Ball	IO	*Not Connected (n.c.) Pins*
n.c.	H1	-	not connected
n.c.	H11	-	not connected
n.c.	H12	-	not connected
n.c.	H15	-	not connected
n.c.	H2	-	not connected
n.c.	H3	-	not connected
n.c.	J1	-	not connected
n.c.	J2	-	not connected
n.c.	J3	-	not connected
n.c.	J5	-	not connected
n.c.	J6	-	not connected
n.c.	J11	-	not connected
n.c.	J12	-	not connected
n.c.	J14	-	not connected
n.c.	K2	-	not connected
n.c.	K5	-	not connected
n.c.	K6	-	not connected
n.c.	K11	-	not connected
n.c.	K12	-	not connected
n.c.	K15	-	not connected
n.c.	L3	-	not connected
n.c.	L6	-	not connected
n.c.	L7	-	not connected
n.c.	L8	-	not connected
n.c.	L9	-	not connected
n.c.	L10	-	not connected
n.c.	L11	-	not connected
n.c.	L12	-	not connected
n.c.	M6	-	not connected
n.c.	M7	-	not connected
n.c.	M8	-	not connected
n.c.	M9	-	not connected
n.c.	M10	-	not connected
n.c.	M11	-	not connected

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Name	Ball	IO	*Not Connected (n.c.) Pins*
n.c.	M14	-	not connected
n.c.	N3	-	not connected
n.c.	N4	-	not connected
n.c.	N5	-	not connected
n.c.	N14	-	not connected
n.c.	P1	-	not connected
n.c.	P5	-	not connected
n.c.	P6	-	not connected
n.c.	P13	-	not connected
n.c.	P14	-	not connected
n.c.	P16	-	not connected
n.c.	R14	-	not connected
n.c.	R15	-	not connected
n.c.	R16	-	not connected

Table 11: Pin Description of not connceted Pins

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7 Package Dimensions

Package: FBGA 256 balls, 1.0mm pitch, size 17mm x 17mm,
industrial temperature range 0°C . . . 85°C, RoHS compliant.

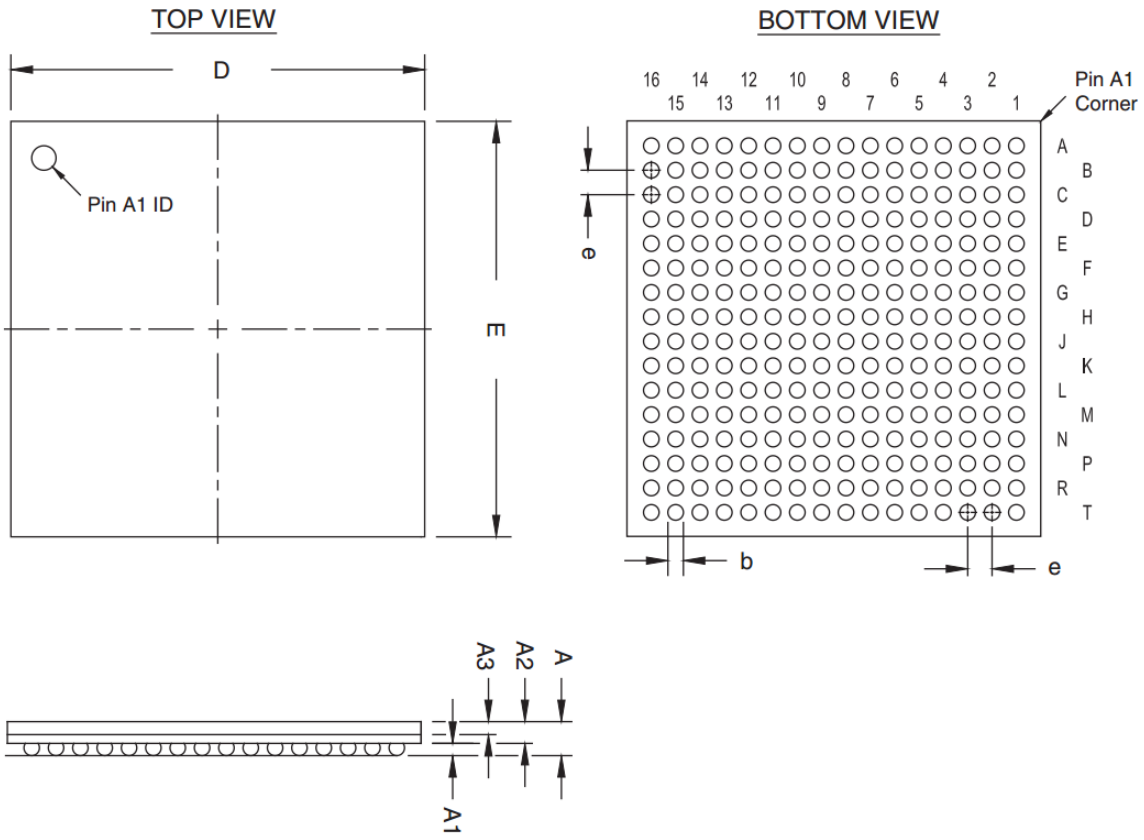

Figure 17: FBGA256 Package Outline

FBGA256 Package Dimensions in mm			
	min.	typ.	max.
A	-	-	2.20
A1	0.30	-	-
A2	-	-	1.80
A3		0.70 REF	
D		17.00 BSC	
E		17.00 BSC	
b	0.50	0.60	0.70
e		1.00 BSC	
JEDEC MS-034, Variation: AAF-1			

Table 12: Package Outline Dimensions

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8 Supplemental Directives

8.1 Producer Information

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The documentation provided here, is for programmers and engineers only, who are equipped with the necessary skills and have been trained to work with this type of product.

The Target User knows how to responsibly make use of this product without causing harm to himself or others, and without causing damage to systems or devices, in which the user incorporates the product.

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This product documentation is related and/or associated with additional tool kits, firmware and other items, as provided on the product page at: www.trinamic.com.

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9 Figures Index

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10 Tables Index

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11 Revision History

11.1 IC Revision

Version	Date	Description
V0.90	2016-JUN-30	Preliminary release.
V0.99	2016-SEP-30	Engineiring Sample Release.

Table 13: IC Revision

11.2 Document Revision

Version	Date	Description
V0.9	2016-MAY-23, LL	Initial version.
V0.9	2016-JUL-29, LL	First draft committed.
V0.91	2016-OCT-13, LL	Functional summary added, updated register set of TMC4670 0v99, ADC selector with scaling and offset correction added, Analog Encoder (AENC) selector with scaling and offset correction added,
V0.91	2016-OCT-19, LL	Pinning updated.
V0.91	2016-MOV-02, LL	Short Spec Block Diagram added.
V0.91	2016-MOV-04, LL	PID architecture and PID motion mode drawings added
V0.91	2016-MOV-07, LL	Functional description hierachies updated
V0.91	2016-MOV-08, LL	First version for www.trinamic.com

Table 14: Document Revision

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