

iC-TW14

iC-PMX Companion Chip



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FEATURES

- ◆ Complete processing for iC-PMX-based energy-harvesting absolute multiturn encoders using Wiegand sensors¹
- ◆ SSI multiturn data output
- ◆ Interface to iC-PMX (SPI master and singleturn Hall signal I/O)
- ◆ UART Interface for calibration and diagnosis
- ◆ Adjustable synchronization offset and multiturn preset value
- ◆ Based on NXP² S9KEAZN8 microcontroller
- ◆ Extended temperature range from -40 to +125°C

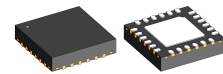
¹ Devices and processes for energy harvesting by Wiegand wire within position encoders are protected by several worldwide patents (such as EP1565755B1, US7598733, CA2506408) and require licensing by the inventors and applicants.

² NXP is a registered trademark of NXP Semiconductors

APPLICATIONS

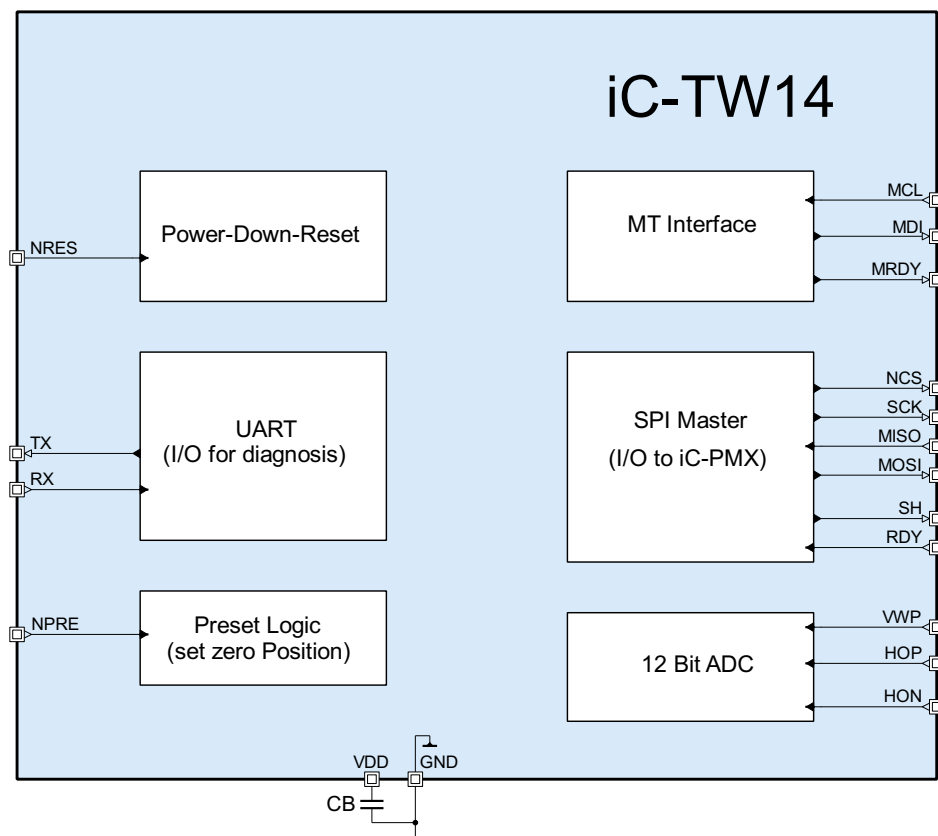
- ◆ Gearless revolution counting
- ◆ Revolution counting without batteries
- ◆ Energy harvesting multiturn encoders
- ◆ Absolute end-of-shaft encoders

PACKAGES



24-pin QFN
4 mm x 4 mm
RoHS compliant

BLOCK DIAGRAM



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iC-PMX Companion Chip



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DESCRIPTION

iC-TW14 is a companion chip for iC-PMX that performs all the functions necessary to implement an energy-harvesting multiturn absolute encoder using an external singleturn sensor system such as iC-LG, iC-MHM, iC-MU, iC-MN, etc. The iC-TW14 also provides diagnostic modes and access to iC-PMX parameters for the design, optimization, and calibration of a complete system.

Without power applied, the iC-PMX uses the attached Wiegand sensor and FRAM to count turns of the magnet autonomously by harvesting the energy of the Wiegand wire pulses. At power-on, the iC-TW14 interrogates the iC-PMX and determines the absolute position of the magnet. It provides this information via

an SSI data stream to the external singleturn sensor for start-up calibration. During powered operation, the external singleturn sensor tracks the angular position of the magnet and the number of turns, providing output to the user's system while the iC-TW14 monitors the turns counting and other operational conditions of the iC-PMX for faults.

iC-TW14 has an operating temperature range of up to 125 °C and is suitable for measuring at high speed.

Typical applications are highly-integrated energy-harvesting magnetic multiturn absolute encoders. These absolute encoders can replace existing gear or battery-buffered solutions.

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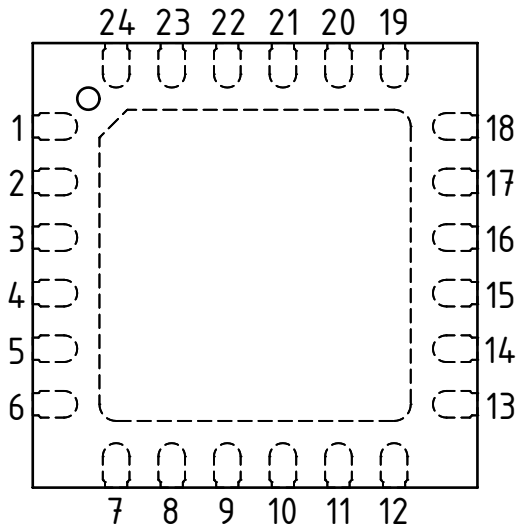
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PACKAGING INFORMATION

PIN CONFIGURATION QFN24 4mm x 4mm



PIN FUNCTIONS

No. Name Function

1	MDI	SSI Multiturn Data
2	MCL	SSI Multiturn Clock
3	VDD	Supply Voltage
4	GND	Ground
5	MRDY	SSI Multiturn Data Ready
6	NPRE	Preset Input (active low)
7	NCS	SPI to iC-PMX, Chip Select
8	MISO	SPI to iC-PMX, Master Data Input
9	SH	Interface iC-PMX, Switch Hall
10	VWP	Interface to iC-PMX, Scaled VWC
11	HOP	Interface iC-PMX, Hall Positive
12	HON	Interface iC-PMX, Hall Negative
13	MOSI	SPI to iC-PMX, Master Data Output
14	SCK	SPI to iC-PMX, Clock
15	TX	UART Serial Transmit
16	RX	UART Serial Receive
17	P17	(device test and factory calibration)
18	P18	(device test and factory calibration)
19	P19	(device test and factory calibration)
20	P20	(device test and factory calibration)
21	RDY	Interface iC-PMX, Data Ready
22	P22	(device test and factory calibration)
23	NRES	Reset Input (low active)
24	P24	(device test and factory calibration)

PIN FUNCTIONS				
No.	Name	I/O	Function	Description
1	MDI	Digital Output	SSI Multiturn Data Output	Connect to multiturn data input (MDI) pin of singleturn sensor and pull-up resistor to VDD.
2	MCL	Digital Input	SSI Multiturn Clock	Connect to multiturn clock (MCL) pin of singleturn sensor and pull-up resistor to VDD.
3	VDD	Supply	Power Input	5V power input.
4	GND	Supply common	Power Supply and Signal Common	
5	MRDY	Digital Output	SSI Multiturn Data Ready	Connect to multiturn data ready (MRDY) pin of singleturn sensor and pull-down resistor to GND.
6	NPRE	Digital Input, active low	Preset Multiturn Position	Presets internal multiturn position to zero. Can be connected to a push-button switch and pull-up resistor for easy calibration. Must be pulled up to VDD if not used.
7	NCS	Digital Output, active low	SPI Chip Select	Connect to iC-PMX NCS (pin 26) and pull-up resistor to VDD.
8	MISO	Digital Input	SPI Master Data Input	Connect to iC-PMX MISO (pin 29) and pull-down resistor to GND.
9	SH	Digital Output	Switch Hall Sensor	Connect to iC-PMX SH (pin 25) and pull-down resistor to GND.
10	VWP	Analog Input	Scaled Wiegand Pulse Voltage	Connect to iC-PMX VWC via a resistive voltage divider to allow measuring Wiegand pulse voltage without overloading the iC-TW14 ADC. Connect to GND if Wiegand pulse voltage measurement diagnostic is not required.
11	HOP	Analog Input	Hall Output Positive	Connect to iC-PMX HOP (pin 23). Connect to GND if iC-PMX singleturn sensors are not used.
12	HON	Analog Input	Hall Output Negative	Connect to iC-PMX HON (pin 24). Connect to GND if iC-PMX singleturn sensors are not used.
13	MOSI	Digital Output	SPI Master Data Output	Connect to iC-PMX MOSI (pin 28).
14	SCK	Digital Output	SPI Data Clock	Connect to iC-PMX SCK (pin 27).
15	TX	Digital Output	UART Serial Output	Serial output for communication with PC for setup and diagnostics.
16	RX	Digital Input	UART Serial Input	Serial input for communication with PC for setup and diagnostics.
17	P17		Reserved	Connect to GND via pull-down resistor.
18	P18		Reserved	Connect to GND via pull-down resistor.
19	P19		Reserved	Connect to GND via pull-down resistor.
20	P20		Reserved	Connect to GND via pull-down resistor.
21	RDY	Digital Input	iC-PMX Ready	Connect to iC-PMX RDY (pin 30) and pull-down resistor to GND.
22	P22		Reserved	Connect to GND via pull-down resistor.
23	NRES	Digital Input, active low	Reset Input	Must be connected to VDD through a pull-up resistor.
24	P24		Reserved	Connect to GND via pull-down resistor.

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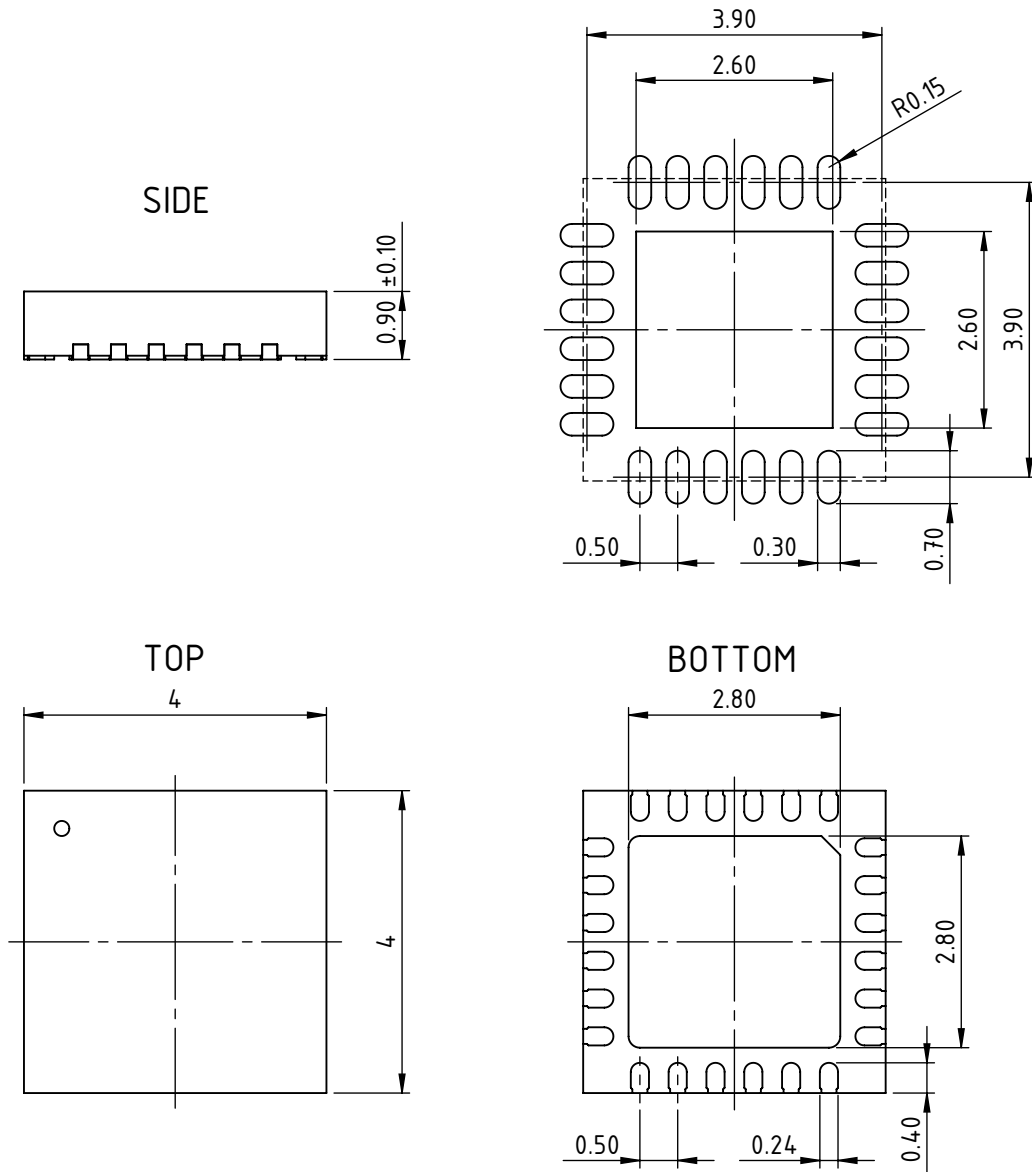
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PACKAGE DIMENSIONS

RECOMMENDED PCB-FOOTPRINT



All dimensions given in mm.
Tolerances of form and position according to JEDEC MO-220.

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ABSOLUTE MAXIMUM RATINGS

The following ratings are an extract - additional maximum ratings introduced by NXP's KEA8ZN8 datasheet can be relevant. Note that beyond the maximum ratings, device operation is not guaranteed and damage may occur.

Item No.	Symbol	Parameter	Conditions	Limits		Unit
				Min.	Max.	
G001	VDD	Voltage at VDD		-0.3	6	V
G002	V()	Pin Voltage	relative to GND relative to VDD	-0.3	6 +0.3	V
G003	I()	Pin Current		-25	25	mA
G004	Tj	Operating Junction Temperature		-40	125	°C
G005	Ts	Storage Temperature Range		-40	150	°C

ELECTRICAL CHARACTERISTICS

Operating Conditions: VDD = 4.5...5.5 V, Tj = -40 °C...125 °C

Item No.	Symbol	Parameter	Conditions	Limits			Unit
				Min.	Typ.	Max.	
Total Device							
101	V(VDD)	Permissible Supply Voltage		4.5	5.0	5.5	V
102	I(VDD)	Supply Current			12		mA
Bias, Power On							
201	NPORon	Power-on-Reset Threshold VDD	increasing voltage at VDD		2.65		V
202	NPORoff	Power-off Reset Threshold VDD	decreasing voltage at VDD		2.61		V
203	NPORHys	Hysteresis			40		mV
204	VBG	Bandgap Voltage			1.16		V

OPERATING REQUIREMENTS: SSI MULTITURN INTERFACE

Item No.	Symbol	Parameter	Conditions	Limits		Unit
				Min.	Max.	
I001	t _{pu} (MRDY)	Start-up Time	NRES = 0, RDY = 1, no error conditions; default startup startup with Wiegand module excitation		8 50	ms ms
I002	t _C	Permissible Clock Period		3.3	13.3	μs
I003	t _{L1} , t _{L2}	Clock Signal hi/lo Level Duration		1.2		μs
I004	t _{RQ}	Data Request Delay		1.2		μs
I005	t _d	Data Valid After Rising Edge of MCL		0.3	1.2	μs
I006	t _{out}	SSI Timeout		15	25	μs

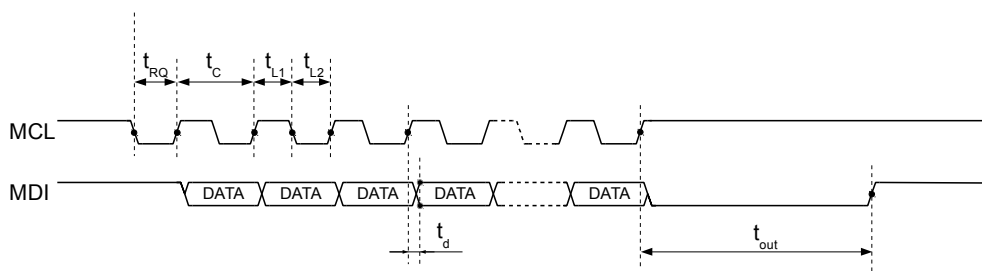


Figure 1: Multiturn (SSI) Interface timing

FUNCTIONAL BLOCK DIAGRAM

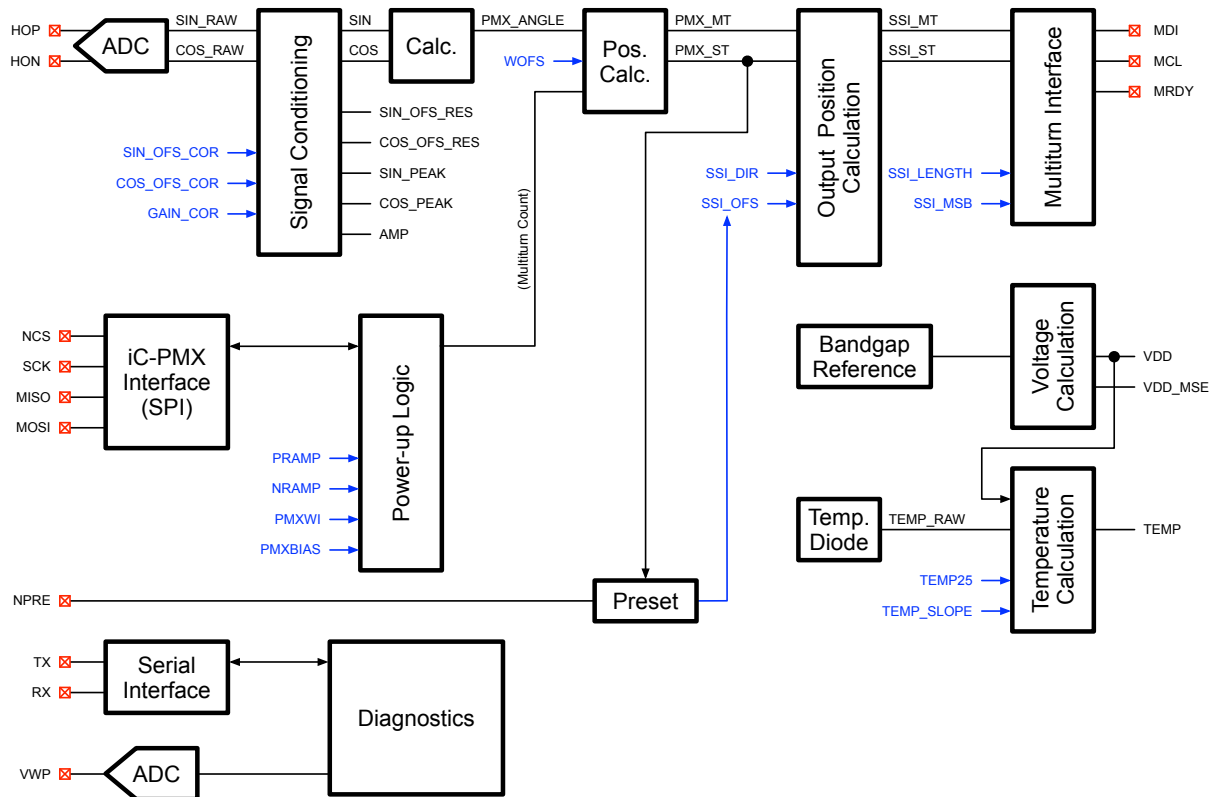


Figure 2: iC-TW14 Functional Block Diagram

The iC-TW14 performs all the functions necessary to interface the iC-PMX to a singleturn absolute sensor system such as iC-LG, iC-MHM, iC-MU, iC-MN, etc. to provide a complete energy-harvesting multiturn absolute encoder, as shown in Figure 2. At power-up, the TW14 calculates the iC-PMX magnet's absolute position and provides this information to the singleturn absolute sensor for initialization via the multiturn interface. The signal names in Figure 2 refer to iC-TW14 registers. See Register Map on page 13 for information on these registers.

At power-up, the iC-TW14 interrogates the iC-PMX and reads its multiturn count. It also reads the iC-PMX's singleturn Hall sensors (signals HOP and HON) via a built-in 12-bit ADC to determine the angle of the iC-PMX magnet. The singleturn Hall sensor readings are combined to give values proportional to the sine and cosine of the magnet angle. See Position of the Hall Sensors and the Sensor Signal Processing in the iC-PMX datasheet for more information. These values are available in registers SIN_RAW and COS_RAW respectively.

The raw sine and cosine signal values are conditioned to remove offsets and equalize amplitudes. The conditioned signal values are available in registers SIN and COS respectively.

Next, a calculation determines the iC-PMX magnet angle (PMX_ANGLE) based on the SIN and COS values. This angle is concatenated with the 32-bit multiturn count read from the iC-PMX at power-up and corrected for the Wiegand offset (WOFs) to produce the complete multiturn absolute position. This multiturn absolute position is available in registers PMX_MT and PMX_ST.

A final calculation corrects the multiturn absolute position as required for the singleturn absolute sensor zero location (SSI_OFS) and rotation direction (SSI_DIR). This corrected position is available in registers SSI_MT and SSI_ST.

Finally, the iC-TW14 assembles the SSI data packet as required for the singleturn absolute sensor. The length of the data packet (SSI_LENGTH) and the starting bit of the multiturn position (SSI_MSB) must be set to match the requirements of the singleturn absolute sensor and

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the application. When this packet is ready (MRDY high), the singleturn absolute sensor clocks the data out of the iC-TW14's multiturn SSI interface.

A serial port allows access to internal registers and diagnostics for system setup, calibration, and troubleshooting. Wiegand pulse voltage and angle, current ramp duration, Wiegand sensor misalignment, and magnetic field strength at the four iC-PMX singleturn Hall sensors can all be measured to ensure proper operation.

The NPRES pin can be connected to a push-button to allow one-button calibration of system multiturn origin (zero) position. When NPRES is active the TW14 sets SSI_OFF to the correct value so that the multiturn absolute position output to the singleturn absolute sensor (SSI_MT and SSI_ST) is zero.

A built-in temperature diode provides the die temperature of the iC-TW14 and a built-in bandgap reference provides the value of the supply voltage for diagnostics and testing.

ELECTRICAL CONNECTIONS

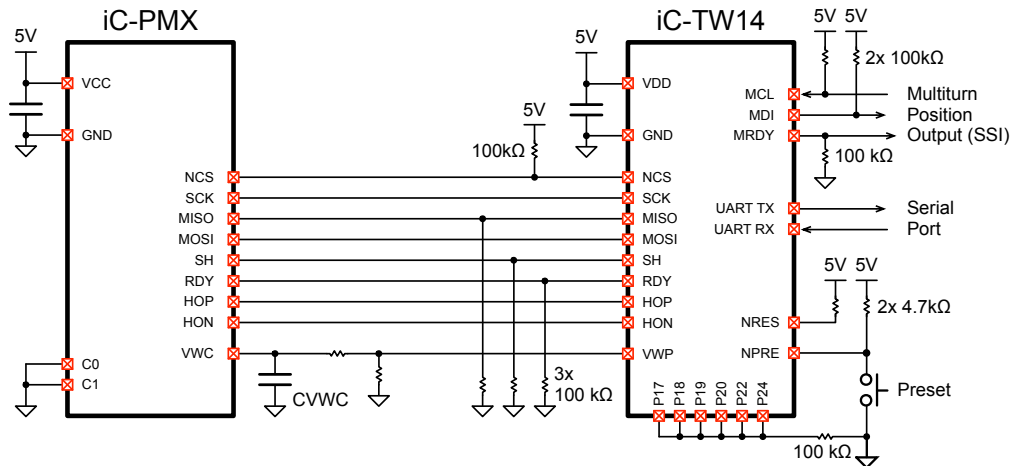


Figure 3: Typical iC-TW14 Electrical Connections

The iC-TW14 must be connected to an iC-PMX (Energy-Harvesting Multiturn Counter/Encoder) and a singleturn absolute sensor such as the iC-MHM (14-Bit Absolute Angle Hall Encoder) for proper operation. Typical connections are shown in Figure 3.

Other components required by the iC-PMX (Wiegand module, FRAM, etc.) and the singleturn sensor (EEPROM, etc.) must also be connected to make an operational system. These additional components are not shown in Figure 3.

To work properly with the iC-TW14, the iC-PMX must be configured to use an FRAM (C0 = 0) and operate in period counter mode (C1 = 0). This is accomplished by connecting iC-PMX pins C0 and C1 to ground as shown. C2 and C3 should be connected as required by the application. See Self-Sustained Operation Mode Selection in the iC-PMX datasheet for more information on the configuration inputs.

A small push-button switch can be connected to the NPRES input as shown to provide a zeroing function for system calibration. This allows the multiturn position to be set to zero during encoder installation to synchronize the encoder with the external system.

To enable the iC-TW14 to measure the Wiegand pulse voltage without overloading or damaging the ADC, a resistive voltage divider must be used. Connect this di-

vider as shown between iC-PMX pin VWC and iC-TW14 pin WWP. The resistor values should be chosen such that the voltage at iC-TW14 pin WWP never exceeds VDD. If the Wiegand pulse voltage measurement diagnostic feature of the iC-TW14 is not required, iC-TW14 pin WWP should be connected directly to GND.

Note also that the series combination of the two resistors loads CVWC which reduces the harvested energy available to the iC-PMX when external power is not available. This voltage divider is only required for diagnostics and can be removed for series production.

Connect the SSI multiturn position output of the iC-TW14 to the multiturn interface of the singleturn sensor as required by the sensor. This allows the singleturn sensor to synchronize itself with the multiturn position calculated by the iC-TW14 after power-up.

Connect the serial port to a host PC using an iC-MB3U-I2C adapter for configuration of the iC-TW14 and iC-PMX using the free graphical user interface (GUI) software.

Pull-up and pull-down resistors are recommended as shown. The six reserved pins must also be grounded using a pull-down resistor as shown. If the iC-PMX singleturn sensors are not used, HOP and HON should be connected directly to GND.

SERIAL COMMUNICATION

The iC-TW14 contains a universal asynchronous receiver/transmitter (UART) for serial communication with an external PC for configuration and diagnostics. Communication is full-duplex, 9600 baud, non-return-to-zero (NRZ) using 1 start bit, 8 data bits, and 1 stop bit.

Serial Write

The iC-TW14 serial write command contains 9 ASCII characters formatted as shown in Table 5.

Serial Write (:Waaadddd!)	
Character	Description
:	Packet Start
W	Write Command
aa	Address Byte (Hex)
dddd	Data Word (Hex)
!	Packet End

Table 5: iC-TW14 Serial Write

The address byte and data word must be specified as hexadecimal values using upper-case characters. See REGISTER MAP on page 13 for more information on available registers and addresses.

If the write was successful, the iC-TW14 responds with

:GWaaadddd!

where aa and dddd are the address byte and data word written.

For example, to set the length (number of bits) of the SSI data packet used to initialize the external singleturn sensor to 17, write 0x0011 to iC-TW14 address 0x18 by sending

:W180011!

The iC-TW14 responds with

:GW180011!

If the write command fails because aa is an undefined or non-writeable address, the iC-TW14 responds with

:FWaaadddd!

where aa and dddd are the failed address byte and data word. See REGISTER MAP on page 13 for more information on writeable registers and addresses.

Serial Read

The iC-TW14 serial read command contains 5 ASCII characters formatted as shown in Table 6.

Serial Read (:Raa!)	
Character	Description
:	Packet Start
R	Read Command
aa	Address Byte (hex)
!	Packet End

Table 6: iC-TW14 Serial Read

The address byte must be specified as a hexadecimal value using upper-case characters. See REGISTER MAP on page 13 for more information on available registers and addresses.

If the read was successful, the iC-TW14 responds with

:GRaaadddd!

where dddd is the data word read from address aa.

For example, to read the DEVICE_ID register of the iC-TW14 at address 0x00, send

:R00!

The iC-TW14 responds with its device ID (14)

:GR000E01!

If the read command fails because aa is an undefined address, the iC-TW14 responds with

:FRaa!

where aa is the undefined address. See REGISTER MAP on page 13 for more information on valid register addresses.

Serial Communication Errors

If the serial read or write command contains invalid hexadecimal digits or is the wrong length, the iC-TW14 responds with

:Exdd!

where x is R or W for a read or write command (respectively) and dd is the invalid command data (which may be any length). Valid hexadecimal digits are 1 – 9 and A – F. A valid read command contains exactly 5 characters; a valid write command contains exactly 9 characters.

If the character after the packet start character (:) is neither R nor W, or if lower-case characters are used in the command packet, the iC-TW14 responds with

:Udd!

where dd is the command data (which may be any length).

Diagnostic Mode 1

Diagnostic mode 1 is used to measure the Wiegand pulse angle, voltage, and magnetic field strength when a Wiegand pulse occurs. Diagnostic mode 1 is initiated by writing 1 to MODE/CMD (see page 20 for more information). See DIAGNOSTIC MODES on page 27 for information on using diagnostic mode 1.

With diagnostic mode 1 active, a packet containing the Wiegand pulse angle, voltage, and magnetic field strength is returned by the UART whenever a Wiegand pulse occurs.

Diagnostic Mode 1 Packet (:pvvvhhhaa!)	
Character	Description
:	Packet Start
p	Wiegand Pulse Point (J, K, L, M or F)
vvv	Wiegand Pulse Voltage (hex mV)
hhh	Magnetic Field Strength (hex units of 0.1 kA/m)
aaa	Wiegand Pulse Angle (hex degrees)
!	Packet End

Table 7: Packet of Diagnostic Mode 1

See Figure 15 and Table 8 in iC-PMX application note 2 for the definitions of the four Wiegand pulse points (J, K, L, and M). This information is acquired from the FRAM. 'F' is returned if the FRAM content is invalid.

The Wiegand pulse voltage (vvvv) is measured at iC-TW14 pin VWP, which must be connected to iC-PMX pin VWC via a voltage divider to avoid overdriving VWP. The Wiegand pulse voltage is a positive hexadecimal value in mV.

The magnetic field strength (hhh) when the Wiegand pulse occurs is measured by reading iC-PMX single-turn Hall sensors H1 and H3 since the iC-PMX phase sequence Hall sensors (H4 and H5) cannot be read directly. The magnetic field strength is a hexadecimal 16-bit 2's-complement value in units of 0.1 kA/m equal to H1 if iC-PMX configuration input C2 is low, and (H1 – H3) if C2 is high. See Self-Sustained Operation Mode Selection in the iC-PMX datasheet for more information.

The Wiegand pulse angle (aaa) is a positive hexadecimal value in degrees (0x000 – 0x167).

For example, if a Wiegand pulse M occurs at 23° with a voltage of 7.46 volts, a VWP voltage divider of 1/3, and a field strength of 10 kA/m at 27 °C, the iC-TW14 sends

:M09B60064017!

If the iC-TW14 is busy sending a diagnostic mode 1 packet when a Wiegand pulse occurs, it sends

:ED!

following the current packet. This indicates that the data from the second Wiegand pulse has been lost.

REGISTER MAP

The iC-TW14 contains a group of 16-bit registers that are used for all communication between the host processor and the TW14, as shown in Tables 8 and 9.

R/W/F access indicates iC-TW14 configuration parameters that can be stored in the FRAM connected to the iC-PMX in addition to being readable and writeable.

Address	Register Name	Description	Access
0x00	DEVICE_ID	iC-TW14 Device ID	Read
0x01	REV	iC-TW14 Revision	Read
0x02	PMXCONFIG	iC-PMX Configuration	Read
0x03	STATUS	Status of iC-TW14	Read
0x04	UID0	Unique Identifier 0	Read
0x05	UID1	Unique Identifier 1	Read
0x06	UID2	Unique Identifier 2	Read
0x07	UID3	Unique Identifier 3	Read
0x08	UID4	Unique Identifier 4	Read
0x10	PRAMP	iC-PMX Positive Current Ramp Configuration (0 – 255)	R/W/F
0x11	NRAMP	iC-PMX Negative Current Ramp Configuration (0 – 255)	R/W/F
0x12	PMXWI	WI (0 – 3)	R/W/F
0x13	PMXBIAS	iC-PMX Bias Parameter (0 – 15)	R/W/F
0x14	PMXGAIN	iC-PMX Singleturn Hall Amplifier Gain (0 – 7)	R/W/F
0x15	WOFS	Angular Offset Between iC-PMX and Wiegand Sensor in Degrees (0 – 359)	R/W/F
0x16	SSI_OFS	Angular Offset Between iC-PMX and Singleturn Sensor in Degrees (0 – 359)	R/W/F
0x17	SSI_DIR	Rotation Direction of External Singleturn Sensor (0 – 1)	R/W/F
0x18	SSI_LENGTH	SSI Data length (0 – 31)	R/W/F
0x19	SSI_MSB	MSB of the SSI Data (0 – 31)	R/W/F
0x1A	SIN_OFS_COR	Sine Calculation Offset Correction	R/W/F
0x1B	COS_OFS_COR	Cosine Calculation Offset Correction	R/W/F
0x1C	GAIN_COR	Gain Correction	R/W/F
0x1D	AUTO_GAIN	Enables Automatic Gain Control on iC-PMX Hall Gain	R/W/F
0x1E	AMP_MAG_LOSS	Hall Magnet Loss Amplitude in Units of 0.1 kA/m	R/W/F
0x1F	TEMP25	Temperature Voltage at 25°C in mV	R/W/F
0x20	TEMP_SLOPE	Slope of Temperature Voltage ($\pm 32,767$)	R/W/F
0x21	VWP_FACTOR	Voltage Divider Factor Between iC-PMX VWC and iC-TW14 VWP	R/W/F
0x22	TMODE	Test Mode	R/W/F
0x30	MODE/CMD	Mode/Command Register	R/W
0x31	FRAM_BLOCK	FRAM Data Block to Read or Write (Direct FRAM Access)	R/W
0x32	DATA.0	Data Register 0	R/W
0x33	DATA.1	Data Register 1	R/W
0x34	DATA.2	Data Register 2	R/W
0x35	DATA.3	Data Register 3	R/W
0x40	SIN_RAW	Sine Calculation Without Correction in Units of 0.1 kA/m	Read
0x41	COS_RAW	Cosine Calculation Without Correction in Units of 0.1 kA/m	Read
0x42	SIN	Sine Value After Correction in Units of 0.1 kA/m	Read
0x43	COS	Cosine Value After Correction in Units of 0.1 kA/m	Read
0x44	SIN_OFS_RES	Sine Calculation Offset Residue in Units of 0.01 kA/m	Read
0x45	COS_OFS_RES	Cosine Calculation Offset Residue in Units of 0.01 kA/m	Read
0x46	SIN_PEAK	Peak Sine Amplitude After Correction in Units of 0.01 kA/m	Read
0x47	COS_PEAK	Peak Cosine Amplitude After Correction in Units of 0.01 kA/m	Read
0x48	AMP	Singleturn Hall Sensors Amplitude $\sqrt{SIN^2 + COS^2}$ in Units of 0.1 kA/m	Read
0x49	GAIN	Actual iC-PMX Hall Sensor Gain Setting (0 – 7)	Read

Table 8: iC-TW14 Register Map

Address	Register Name	Description	Access
0x4A	HALL0_MIN	Singleturn Hall Sensor H0 Minimum Magnetic Field in Units of 0.1 kA/m	Read
0x4B	HALL1_MIN	Singleturn Hall Sensor H1 Minimum Magnetic Field in Units of 0.1 kA/m	Read
0x4C	HALL2_MIN	Singleturn Hall Sensor H2 Minimum Magnetic Field in Units of 0.1 kA/m	Read
0x4D	HALL3_MIN	Singleturn Hall Sensor H3 Minimum Magnetic Field in Units of 0.1 kA/m	Read
0x4E	HALL0_MAX	Singleturn Hall Sensor H0 Maximum Magnetic Field in Units of 0.1 kA/m	Read
0x4F	HALL1_MAX	Singleturn Hall Sensor H1 Maximum Magnetic Field in Units of 0.1 kA/m	Read
0x50	HALL2_MAX	Singleturn Hall Sensor H2 Maximum Magnetic Field in Units of 0.1 kA/m	Read
0x51	HALL3_MAX	Singleturn Hall Sensor H3 Maximum Magnetic Field in Units of 0.1 kA/m	Read
0x52	PMX_ANGLE	Calculated Hall Singleturn Angle in Degrees (0 – 359)	Read
0x53	PMX_ST	Corrected Hall Sensor Singleturn Angle in Degrees (0 – 359)	Read
0x54	PMX_MT[15:0]	iC-PMX Multiturn Count Least Significant Word (0 – 65,535)	Read
0x55	PMX_MT[31:16]	iC-PMX Multiturn Count Most Significant Word (0 – 65,535)	Read
0x60	SSI_ST	Singleturn Angle in Degrees for External Singleturn Sensor (0 – 359)	Read
0x61	SSI_MT[15:0]	Multiturn Count LSW for External Singleturn Sensor (0 – 65,535)	Read
0x62	SSI_MT[31:16]	Multiturn Count MSW for External Singleturn Sensor (0 – 65,535)	Read
0x80	DIAG2_TIME	Diagnostic Mode 2 Wiegand Pulse Time in μ s	Read
0x81	DIAG2_RAMP	Diagnostic Mode 2 Current Ramp Time in μ s	Read
0x82	DIAG2_VWP	Diagnostic Mode 2 Scaled Wiegand Pulse Voltage	Read
0x90	VDD	iC-TW14 V_{DD} in mV	Read
0x91	VDD_MSE	iC-TW14 V_{DD} Mean Squared Noise in mV^2	Read
0x92	TEMP_RAW	iC-TW14 Raw Temperature Diode Voltage	Read
0x93	TEMP	iC-TW14 Temperature in $^{\circ}C$	Read

Table 9: iC-TW14 Register Map (continued)

DEVICE_ID

DEVICE_ID is a read-only register containing the iC-TW14 device (chip) ID for identification purposes.

DEVICE_ID (0x00)	
Value	Description
0x0E00	iC-TW14 evaluation samples

Table 10: iC-TW14 Device ID

REV

REV is a read-only register containing the iC-TW14 device (chip) revision level. See page 33 for notes on chip functions.

REV (0x01)	
Value	Description
0x0001	iC-TW14 Revision
...	
0xFFFFE	

Table 11: iC-TW14 Revision

PMXCONFIG

PMXCONFIG is a read-only register containing the iC-PMX revision and the state of the four configuration pins of the iC-PMX. These values are read by the iC-TW14 from iC-PMX address 0x07 and the iC-PMX Read POS command address 0x0F (respectively) at startup.

PMXCONFIG (0x02)		
Bit	Name	Description
15:12	–	Reserved (zero)
11	C3	iC-PMX C3 pin state
10	C2	iC-PMX C2 pin state
9	C1	iC-PMX C1 pin state
8	C0	iC-PMX C0 pin state
7:0	REV	iC-PMX Revision

Table 12: iC-PMX Configuration

See Self-Sustained Operation Mode Selection and Position Data in Period Counter Mode with a Data Processing FRAM and FRAM Access in the iC-PMX datasheet for more information. See SPI Slave Interface in the iC-PMX datasheet for more information on the iC-PMX revision.

STATUS

STATUS is a read-only register containing bits that indicate the status of the iC-TW14. STATUS bits are active as long as the corresponding condition is true.

STATUS (0x03)		
Bit	Name	Description
15 – 14	–	Reserved (zero)
13	CF	iC-PMX configuration fault
12	NPRE	NPRE input active
11	NOSSI	SSI multiturn data not ready
10	STOP	iC-TW14 stopped
9	MTM	Multiturn position mismatch
8	HSC	Hall signals clipped
7	MLF	Magnet lost fault
6	HGW	Hall gain warning
5	FAD	FRAM access denied
4	FCF	FRAM configuration fault
3:2	EFLAG	FRAM error flag bits
1	PNR	iC-PMX not ready
0	SYNC	iC-TW14 busy synchronizing with iC-PMX

Table 13: Status Register

STATUS.CF = 1 indicates that the iC-PMX is not correctly configured for the iC-TW14. Specifically, STATUS.CF = 1 if iC-PMX pin C0 or pin C1 are high. C0 and C1 must both be low for use with the iC-TW14. STATUS.CF = 1 also sets STATUS.STOP = 1.

STATUS.NPRE = 1 indicates that the iC-TW14's NPRES input is low (active). See PRESET PIN (NPRES) on page 25 for more information.

STATUS.NOSSI = 1 indicates that the iC-TW14 is not ready to provide multiturn position data over the SSI multiturn interface. During normal operation, this bit is the logical inverse of the state of iC-TW14 pin MRDY.

STATUS.STOP = 1 indicates that the iC-TW14 has stopped working because STATUS.CF = 1, STATUS.EFLAG ≠ 0, STATUS.FCF = 1, or mode 1 or 2 (diagnostic mode 2), mode 30 (MRDY low), 31 (MRDY high), or 40 (SSI test mode) is active. To clear this condition re-synchronize the iC-TW14 using the RESYNC command (8).

STATUS.MTM = 1 indicates that the multiturn position as tracked by the iC-TW14 does not match the multiturn position stored in the FRAM.

STATUS.HSC = 1 indicates that the iC-PMX singleturn Hall signals are being clipped. This condition occurs if PMXGAIN is too large or the magnetic field is too strong.

STATUS.MLF = 1 indicates that the singleturn Hall sensor signal amplitude is too low, probably because the

magnet is too far away from the iC-PMX. Specifically, STATUS.MLF = 1 if AMP < AMP_MAG_LOSS. See AMP_MAG_LOSS on page 18 for more information

STATUS.HGW = 1 indicates that the iC-PMX Hall gain value is wrong but cannot be changed. This only occurs when the auto-gain feature is disabled and the iC-PMX Hall gain value is wrong. The current iC-PMX Hall gain value is available in the GAIN register (0x49).

STATUS.FAD = 1 indicates that a direct FRAM access command (21 – 25) failed, possibly because an illegal address was specified or the iC-PMX RDY pin indicated low VDD. See DIRECT FRAM ACCESS on page 29 for more information.

A STATUS.FAD = 1 condition can be cleared using a RESET (7) or RESYNC (8) command. See MODE/CMD on page 20 for more information.

STATUS.FCF = 1 indicates that there is a problem with the iC-TW14 configuration data stored in the FRAM and that the iC-TW14 is disabled (STATUS.STOP = 1). In this case, new configuration data must be written to the FRAM using the WRITE command (4). See MODE/CMD on page 20 for more information.

STATUS.EFLAG are the FRAM error flag bits read from iC-PMX 0x005[7:6].

STATUS.EFLAG (0x03 Bits 3:2)	
Value	Description
0	No fault
1	Counter over/underflow fault
2	Uncorrectable Error Correction Code fault
3	Incomplete write fault

Table 14: Multiturn Position Read Errors

If STATUS.EFLAG = 0, the multiturn position value read from the FRAM is valid. If STATUS.EFLAG ≠ 0, the multiturn position value read from the FRAM is invalid, the counter in the FRAM is disabled, and the iC-TW14 is stopped (STATUS.STOP = 1). A STATUS.EFLAG ≠ 0 condition can only be cleared by over-writing the FRAM contents. See DIRECT FRAM ACCESS on page 29 for more information.

STATUS.PNR = 1 indicates that the iC-PMX is not ready (iC-PMX pin RDY low). This may be because VCC is less than VDDOK (iC-PMX spec. item 705).

STATUS.SYNC = 1 indicates that the iC-TW14 is in the process of synchronizing itself with the iC-PMX. This is true right after power-up or a RESYNC (8) command. When the synchronization is complete, STA-

TUS.SYNC=0. This is the condition during normal operation of the iC-TW14.

UIDx

The read-only UIDx registers contain a unique series of numbers to identify the unique iC-TW14 device.

UIDx (0x04-0x08)	
Value	Description
0 – 65,535	Unique Identifier

Table 15: UIDx Registers

PRAMP

PRAMP is a read/write register that sets the iC-PMX ramp parameters used to activate a positive current ramp.

PRAMP (0x10)	
Bits	Description
15:8	Reserved (must be zero)
7:0	iC-PMX RAMP(7:0)

Table 16: PRAMP Register

The LSB of the PRAMP register is written to iC-PMX address 0x01 when a positive current ramp is required. See Wiegand Module Excitation in the iC-PMX datasheet for more information.

NRAMP

NRAMP is a read/write register that sets the iC-PMX ramp parameters used to activate a negative current ramp.

NRAMP (0x11)	
Bits	Description
15:8	Reserved (must be zero)
7:0	iC-PMX RAMP(7:0)

Table 17: NRAMP Register

The LSB of the NRAMP register is written to iC-PMX address 0x01 when a negative current ramp is required. See Wiegand Module Excitation in the iC-PMX datasheet for more information.

PMXWI

PMXWI is a read/write register used to set the iC-PMX WI parameter used to select the switched current ramp maximum current. The PMXWI register value is written to iC-PMX address 0x02[1:0] on startup, when diagnostic mode 2 is initiated, when a RESET or RESYNC command is executed, or when STATUS.PNR changes from 1 to 0. See SPI Slave Interface in the iC-PMX datasheet for more information.

PMXWI (0x12)	
Bits	Description
15:2	Reserved (must be zero)
1:0	iC-PMX register 0x02(1:0) (WI) value

Table 18: PMXWI Register

To change the WI value in the iC-PMX, write the desired value to PMXWI, write the configuration to FRAM using the WRITE command (4), and reset the iC-TW14 using RESET command (7). On startup, the new PMXWI value is written to the iC-PMX. See Wiegand Module Excitation in the iC-PMX datasheet for more information on WI.

PMXBIAS

PMXBIAS is a read/write register used to set the iC-PMX bias value. The least significant four bits of the PMXBIAS register are written to iC-PMX address 0x02[7:4] on startup, when diagnostic mode 2 is initiated, when a RESET or RESYNC command is executed, or when STATUS.PNR changes from 1 to 0. See SPI Slave Interface in the iC-PMX datasheet for more information.

PMXBIAS (0x13)	
Bits	Description
15:4	Reserved (must be zero)
3:0	iC-PMX Register 0x02(7:4) (BIAS) value

Table 19: PMXBIAS Register

To change the iC-PMX BIAS value, write the desired value to PMXBIAS, write the configuration to FRAM using the WRITE command (4), and reset the iC-TW14 using the RESET command (7). On startup, the new BIAS value is written to the iC-PMX. See Device Calibration and System Diagnosis in the iC-PMX datasheet for more information on BIAS.

PMXGAIN

PMXGAIN is a read/write register used to set the iC-PMX singleturn Hall amplifier gain. The gain value is written to iC-PMX address 0x00[7:5] on startup, when a RESET or RESYNC command is executed, or when STATUS.PNR changes from 1 to 0. See SPI Slave Interface in the iC-PMX datasheet for more information.

PMXGAIN (0x14)	
Bits	Description
15:3	Reserved (must be zero)
2:0	iC-PMX GAIN(2:0)

Table 20: PMXGAIN Register

WOFS

WOFS is a read/write register containing the angular offset of the Wiegand module to the iC-PMX H0/H2 axis.

WOFS (0x15)	
Value	Description
0 – 359	Wiegand module offset in degrees
360 – 65,535	Reserved (do not use)

Table 21: WOFS Register

See WIEGAND OFFSET AND MISALIGNMENT in iC-PMX Application Note 2 for more information. In general, the Wiegand module misalignment must be measured on every unit and then entered into WOFS to account for production and assembly tolerances.

SSI_OFS

SSI_OFS is a read/write register containing the angular difference (offset) between the iC-PMX 0° point and the point where the multiturn data provided over the SSI multiturn interface is expected to roll over.

SSI_OFS (0x16)	
Value	Description
0 – 359	Singleturn sensor offset in degrees
360 – 65,535	Reserved (do not use)

Table 22: SSI_OFS Register

SSI_OFS is used to calculate the multiturn position sent to the external singleturn sensor via the iC-TW14's SSI multiturn interface. In applications where the external singleturn absolute sensor uses the same magnet as the iC-PMX, SSI_OFS can be set based on the geometry of the application. In applications where the external singleturn absolute sensor is mechanically independent of the iC-PMX/iC-TW14 turns counter, use the iC-TW14 NPRES input to set SSI_OFS as explained in PRESET PIN (NPRES) on page 25.

SSI_DIR

SSI_DIR is a read/write register used to match the rotation direction of the multiturn data provided over the SSI multiturn interface to the rotation direction of the external singleturn absolute sensor.

SSI_DIR (0x17)	
Value	Description
0	Positive rotation is counterclockwise
1	Positive rotation is clockwise
2 – 65,535	Reserved (do not use)

Table 23: External Singleturn Sensor Rotation Direction

If SSI_DIR = 0, counterclockwise rotation of the magnet as viewed when looking at the top of the iC-PMX is positive (increasing SSI_MT and SSI_ST values). If SSI_DIR = 1, clockwise rotation of the magnet as viewed when looking at the top of the iC-PMX is positive. Set SSI_DIR to match the rotation direction of the external singleturn absolute system for proper initialization and synchronization.

SSI_LENGTH

SSI_LENGTH is a read/write register used to specify the length (number of bits) of the SSI data sent to the external singleturn absolute sensor using the SSI multiturn interface.

SSI_LENGTH (0x18)	
Value	Description
0 – 31	Number of bits of SSI data
32 – 65,535	Reserved (do not use)

Table 24: SSI Data Length

SSI_LENGTH must be set to match the connected singleturn absolute sensor. In general,

$$SSI_LENGTH = Multiturn\ Bits + Synchronization\ Bits$$

For example, if 16 bits of multiturn count and 1 sync bit are required, set SSI_LENGTH = 17. See SSI MULTITURN INTERFACE on page 26 for more information.

SSI_MSB

SSI_MSB is a read/write register used to specify the starting (most significant) bit of the SSI data sent to the external singleturn absolute sensor for initialization.

SSI_MSB (0x19)	
Value	Description
0 – 31	Starting bit of SSI data
32 – 65,535	Reserved (do not use)

Table 25: SSI Data MSB

SSI_MSB must be set to match the connected singleturn absolute sensor. In general,

$$SSI_MSB = Multiturn\ Bits - 1$$

For example, if 16 bits of multiturn count and 1 sync bit are required, set SSI_MSB = 15. See SSI MULTITURN INTERFACE on page 26 for more information.

SIN_OFS_COR, COS_OFS_COR

SIN_OFS_COR and COS_OFS_COR are read/write registers containing the offset correction for the sine and cosine values (respectively) calculated from reading the singleturn Hall sensors in the iC-PMX.

SIN_OFS_COR (0x1A), COS_OFS_COR (0x1B)	
Value	Description
±32,767	Sin/cos calculation offset corrections

Table 26: OFS_COR Registers

SIN_OFS_COR and COS_OFS_COR are 2's-complement numbers used to calculate SIN and COS. See SIN and COS Registers on page 21 for more information.

GAIN_COR

GAIN_COR is a read/write register containing the gain correction for the sine value calculated from reading the singleturn Hall sensors in the iC-PMX.

GAIN_COR (0x1C)	
Value	Description
±128	Sine calculation gain correction

Table 27: GAIN_COR Register

GAIN_COR is a 2's-complement number calculated as

$$GAIN_COR = INT(Desired\ Sine\ Gain \cdot 16)$$

which is used to calculate SIN and COS. See SIN and COS Registers on page 21 for more information. GAIN_COR should be adjusted so that the ratio of SIN_PEAK to COS_PEAK is as close to 1 as possible. See SIN_PEAK and COS_PEAK Registers on page 22 for more information.

Note that a negative gain correction value inverts the sine signal which reverses the rotation direction of PMX_ANGLE relative to the magnet rotation direction.

AUTO_GAIN

AUTO_GAIN is a read/write register used to enable automatic gain control on iC-PMX Hall gain.

AUTO_GAIN (0x1D)	
Value	Description
0	Automatic gain control disabled
1	Automatic gain control enabled
2 – 65,535	Reserved (not used)

Table 28: AUTO_GAIN Register

It is recommended to always enable the automatic gain control (AUTO_GAIN = 1).

AMP_MAG_LOSS

AMP_MAG_LOSS is a read/write register used to set the AMP value below which it is assumed the magnet is no longer within proper range of the iC-PMX.

AMP_MAG_LOSS (0x1E)	
Value	Description
0 – 65,535	Magnet lost amplitude in units of 0.1 kA/m

Table 29: AMP_MAG_LOSS Register

An AMP value less than AMP_MAG_LOSS generates a magnet lost fault (STATUS.MLF = 1) and an SSI multiturn data not ready condition (STATUS.NOSSI = 1). See STATUS on page 15 for more information. This condition also sets the MRDY pin low and disables the SSI multiturn interface to signal the fault to the external singleturn absolute sensor.

TEMP25

TEMP25 is a read/write register containing the voltage of the iC-TW14's temperature diode at 25°C.

TEMP25 (0x1F)	
Value	Description
0 – 65,535	Temperature voltage at 25°C in mV

Table 30: TEMP25 Register

TEMP25 is a positive number equal to the temperature diode's voltage at 25°C in millivolts. It is used by the iC-TW14 to calculate the temperature reported in the TEMP register. See TEMP on page 24 for more information.

The nominal value of TEMP25 is 1370. TEMP25 can be calibrated by measuring the die temperature of the iC-TW14 using an independent thermometer at two different temperatures, T_1 and T_2 and recording the corresponding TEMP_RAW₁ and TEMP_RAW₂ values and the VDD register value. TEMP25 is then calculated as

$$TEMP25 = \frac{VDD}{131072} \cdot \frac{(T_1 - 25) \cdot TEMP_RAW_2 - (T_2 - 25) \cdot TEMP_RAW_1}{T_1 - T_2}$$

For example, suppose that at 30°C TEMP_RAW = 0x8F3D = 36669, at 80°C TEMP_RAW = 0x7EF5 = 32501, and VDD = 4895 mV. Then TEMP25 should be set to

$$\frac{4895}{131072} \cdot \frac{(30 - 25) \cdot 32501 - (80 - 25) \cdot 36669}{30 - 80} = 1385$$

TEMP_SLOPE

TEMP_SLOPE is a read/write register containing the slope of the iC-TW14's temperature diode voltage with respect to temperature.

TEMP_SLOPE (0x20)	
Value	Description
±32,767	Temperature voltage slope

Table 31: TEMP_SLOPE Register

The TEMP_SLOPE register value is a 2's complement number calculated as

$$TEMP_SLOPE = INT(Slope[mV/°C] \cdot 192)$$

It is used by the iC-TW14 to calculate the temperature reported in the TEMP register. See TEMP on page 24 for more information.

For example, the typical temperature slope of the temperature diode is -3.266 millivolts per °C, so TEMP_SLOPE should be set to

$$INT(-3.266 \cdot 192) = -627 = 0xFD8D$$

TEMP_SLOPE can be calibrated by measuring the die temperature of the iC-TW14 using an independent thermometer at two different temperatures, T_1 and T_2 and recording the corresponding TEMP_RAW₁ and TEMP_RAW₂ values and the VDD register value. TEMP_SLOPE is then calculated as

$$TEMP_SLOPE = \frac{268,435,456}{VDD} \cdot \frac{T_1 - T_2}{TEMP_RAW_1 - TEMP_RAW_2}$$

For example, suppose that at 30°C TEMP_RAW = 0x8F3D = 36669, at 80°C TEMP_RAW = 0x7EF5 = 32501, and VDD = 4895 mV. Then TEMP_SLOPE should be set to

$$\frac{268,435,456}{4895} \cdot \frac{30 - 80}{36669 - 32501} = -658$$

This indicates an actual temperature slope of $-658/192 = -3.427$ mV/°C.

VWP_FACTOR

VWP_FACTOR is a read/write register used to record the value of the resistive voltage divider between iC-PMX pin VWC and iC-TW14 pin VWP.

VWP_FACTOR (0x21)	
Value	Description
0 – 65,535	Scaled voltage divider ratio

Table 32: VWP_FACTOR Register

VWP_FACTOR is calculated as

$$VWP_FACTOR = INT\left(\frac{256}{Voltage\ Divider\ Ratio}\right)$$

This value is not used directly by the iC-TW14, but allows a connected computer to properly calculate the Wiegand pulse voltage when using DIAG1 and DIAG2 modes. For example, if the voltage divider ratio is 1/3, VWP_FACTOR = 768 = 0x0300.

TMODE

TMODE is a read/write register used to enable test functions.

TMODE is set to 1 to enable the function *Stop on errors*. The error conditions are part of the STATUS register (see Table 13 on page 15).

The error conditions MTM, HSC, MLF and PNR are transient error conditions in normal operation (TMODE=0). This means the status bits are only active as long as the error condition is true.

If *Stop on errors* is enabled, these error conditions are latched and iC-TW14 enters the STOP state as soon as such an error condition is detected.

TMODE (0x22)	
Value	Description
0	Normal Operation
1	Stop on errors
2 – 65,535	Reserved (do not use)

Table 33: TMODE Register

MODE/CMD

MODE/CMD is a read/write register used to initiate diagnostic modes or execute commands.

MODE/CMD (0x30)		
Name	Value	Description
NORMAL	0	Normal Operation
DIAG1	1	Diagnostic Mode 1
DIAG2P	2	Diagnostic Mode 2 (Positive Ramp)
DIAG2N	3	Diagnostic Mode 2 (Negative Ramp)
WRITE	4	Write iC-TW14 Config. to FRAM
READ	5	Read iC-TW14 Config. from FRAM
–	6	Reserved (do not use)
RESET	7	Reset iC-TW14
RESYNC	8	Re-synchronize iC-TW14 to iC-PMX
CLEAR	9	Clear Min/Max Values
–	10 – 20	Reserved (do not use)
F_DATA_W	21	FRAM Data Write
F_DATA_R	22	FRAM Data Read
F_MT_W	23	FRAM Multiturn Position Write
F_MT_R	24	FRAM Multiturn Position Read
F_SET_MT	25	Set FRAM Multiturn Position
–	26 – 29	Reserved (do not use)
MRDY_LO	30	Set iC-TW14 MRDY Pin Low
MRDY_HI	31	Set iC-TW14 MRDY Pin High
–	32 – 39	Reserved (do not use)
SSI_TEST	40	SSI Test Mode
–	41 – 65,535	Reserved (do not use)

Table 34: MODE/CMD Register

At startup, MODE/CMD = 0 (normal operation). To initiate a diagnostic mode or execute a command, write the appropriate value to the Mode/Command register. To cancel a diagnostic mode and return to normal operation, re-synchronize the iC-TW14 to the iC-PMX by writing 8 to MODE/CMD. When a READ (5), WRITE (4), RESET (7), RESYNC (8), or CLEAR (9) command is complete, MODE/CMD is set to NORMAL (0) by the iC-TW14.

The DIAG1 command (1) initiates Diagnostic Mode 1, which is used to measure the Wiegand pulse angle, voltage, and magnetic field strength when a Wiegand pulse occurs. With diagnostic mode 1 active, the Hall sensor magnetic field level and the Wiegand pulse angle are returned via the UART whenever a Wiegand pulse occurs. See DIAGNOSTIC MODES on page 27 for information on using diagnostic mode 1.

To terminate diagnostic mode 1, re-synchronize the iC-TW14 to the iC-PMX by writing 8 to MODE/CMD.

The DIAG2P (2) and DIAG2N (3) commands initiate Diagnostic Mode 2, which is used to analyze current ramp operation. Initiate diagnostic mode 2 by writing 2 (for a positive ramp) or 3 (for a negative ramp) to MODE/CMD. In diagnostic mode 2, the WI and PMXBIAS values are first written to the iC-PMX, the specified

current ramp is initiated, and the Wiegand pulse time, current ramp duration time, and peak pulse voltage are measured (Wiegand pulse voltage is set to zero if no pulse occurs). These values are then available in the DIAG2_TIME (0x80), DIAG2_RAMP (0x81), and DIAG2_VWP (0x82) registers respectively. When the ramp is finished, MODE/CMD is set to NORMAL (0) by the iC-TW14. See DIAGNOSTIC MODES on page 27 for information on using diagnostic mode 2.

Diagnostic mode 2 sets STATUS.STOP and STATUS.NOSSI. To clear this condition, re-synchronize the iC-TW14 using the RESYNC command (8).

The WRITE command (4) writes the values of the iC-TW14 configuration parameters (R/W/F access registers) to FRAM using FRAM feedthrough mode in the iC-PMX. See FRAM Access in the iC-PMX datasheet and Table 8 for more information.

The READ command (5) reads the stored iC-TW14 configuration parameter values from FRAM using FRAM feedthrough mode in the iC-PMX and updates the R/W/F access registers. See FRAM Access in the iC-PMX datasheet and Table 8 for more information.

The RESET command (7) is used to reset the iC-TW14. This is equivalent to when power is applied at startup.

The RESYNC command (8) is used to re-synchronize the iC-TW14 to the iC-PMX. This is equivalent to the RESET command except that the iC-TW14 configuration parameters are not re-loaded from FRAM.

The CLEAR command (9) is used to clear the read-only HALLx_MIN and HALLx_MAX registers. When this command is executed, the value of all 8 min/max registers is set to zero.

Commands 21 – 25 provide direct access to the FRAM connected to the iC-PMX. See DIRECT FRAM ACCESS on page 29 for more information on these commands.

The MRDY_LO command (30) sets the MRDY pin of the iC-TW14 low. This indicates to the external single-turn sensor that the iC-TW14 is not ready. MRDY_LO also sets STATUS.STOP.

The MRDY_HI command (31) sets the MRDY pin of the iC-TW14 high and also sets STATUS.STOP. This command is for diagnostic use only and does not indicate that the iC-TW14 is ready to supply its absolute position.

SSI_TEST mode (40) is used to test the SSI multiturn interface by supplying a static value for transmission.

See DIAGNOSTIC MODES on page 27 for more information. To terminate SSI_TEST mode, re-synchronize the iC-TW14 to the iC-PMX using the RESYNC command (8).

FRAM_BLOCK

FRAM_BLOCK is a read/write register used with commands 21 – 25 for direct FRAM access. See MODE/CMD on page 20 and DIRECT FRAM ACCESS on page 29 for more information.

DATA Registers

DATA.0 – DATA.3 are read/write registers used with commands 21 – 25 for direct FRAM access. See MODE/CMD on page 20 and DIRECT FRAM ACCESS on page 29 for more information.

In SSI_TEST mode (MODE/CMD = 40), DATA.0 and DATA.1 contain the LSW and MSW (respectively) of the 32-bit SSI data used to test the SSI interface.

DATA.0 (0x32)	
Value	Description
0 – 65,535	SSI_TEST mode data least significant word

Table 35: DATA.0 Register in SSI_TEST Mode

DATA.1 (0x33)	
Value	Description
0 – 65,535	SSI_TEST mode data most significant word

Table 36: DATA.1 Register in SSI_TEST Mode

See DIAGNOSTIC MODES on page 27 for more information. Registers DATA.2 – DATA.3 are not used in SSI test mode.

SIN_RAW and COS_RAW Registers

SIN_RAW and COS_RAW are read-only registers containing the raw (un-corrected) sine and cosine values (respectively) calculated from reading the singleturn Hall sensors in the iC-PMX.

SIN_RAW (0x40), COS_RAW (0x41)	
Value	Description
±32,767	Raw Sin/cos calculation values in units of 0.1 kA/m

Table 37: SIN_RAW and COS_RAW Registers

SIN_RAW and COS_RAW are 2's-complement values proportional to H0–H2 and H3–H1 respectively, as explained in Position of the Hall Sensors and Sensor Signal Processing in the iC-PMX datasheet. These values are converted to units of 0.1 kA/m using the current values of the GAIN, TEMP, and VDD registers. See spec. item 801 in the iC-PMX datasheet for more information.

SIN and COS Registers

SIN and COS are read-only registers containing the corrected sine and cosine values (respectively) calculated from reading the singleturn Hall sensors in the iC-PMX.

SIN (0x42), COS (0x43)	
Value	Description
±32,767	Corrected Sin/cos calculation values in units of 0.1 kA/m

Table 38: SIN and COS Registers

SIN and COS are 2's-complement numbers calculated as

$$SIN = SIN_RAW \cdot \frac{GAIN_COR}{16} + AMP \cdot \frac{SIN_OFS_COR}{160}$$

$$COS = COS_RAW + AMP \cdot \frac{COS_OFS_COR}{160}$$

SIN_OFS_RES and COS_OFS_RES Registers

SIN_OFS_RES and COS_OFS_RES are read-only registers containing the offset residue for the SIN and COS values (respectively) calculated from reading the singleturn Hall sensors in the iC-PMX.

SIN_OFS_RES (0x44), COS_OFS_RES (0x45)	
Value	Description
±32,767	Sin/cos offset residue in units of 0.01 kA/m

Table 39: OFS_RES Registers

SIN_OFS_RES and COS_OFS_RES are 2's-complement numbers representing the remaining offset in the SIN and COS signals respectively. SIN_OFS_COR and COS_OFS_COR should be adjusted so that SIN_OFS_RES and COS_OFS_RES are as close to zero as possible.

SIN_OFS_RES and COS_OFS_RES are updated once per input cycle (magnet revolution) based on SIN and COS. This implies that changes to GAIN_COR, SIN_OFS_COR, and COS_OFS_COR do not have an immediate effect on SIN_OFS_RES and COS_OFS_RES. The effect of updated correction values occurs at the end of the input cycle following the update.

SIN_PEAK and COS_PEAK Registers

SIN_PEAK and COS_PEAK are read-only registers containing the peak amplitude of the SIN and COS values (respectively) calculated from reading the single-turn Hall sensors in the iC-PMX.

SIN_PEAK (0x46), COS_PEAK (0x47)	
Value	Description
0 – 65,535	Sin/cos peak amplitude in units of 0.01 kA/m

Table 40: SIN_PEAK and COS_PEAK Registers

SIN_PEAK and COS_PEAK are positive values calculated as

$$SIN_PEAK = Max(SIN) - Min(SIN)$$

$$COS_PEAK = Max(COS) - Min(COS)$$

over the last input cycle (magnet revolution).

GAIN_COR should be adjusted so that the ratio of SIN_PEAK to COS_PEAK is a close to 1 as possible.

AMP

AMP is a read-only register containing the vector amplitude of the signals from the singleturn Hall sensors in the iC-PMX.

AMP (0x48)	
Value	Description
0 – 65,535	iC-PMX singleturn Hall sensor amplitude in units of 0.1 kA/m

Table 41: AMP Register

AMP is a 16-bit positive integer value proportional to $\sqrt{SIN^2 + COS^2}$ which is filtered to provide a stable value by eliminating changes less than 5%.

GAIN

GAIN is a read-only register containing the current GAIN value in the iC-PMX.

GAIN (0x49)	
Value	Description
0 – 7	Current iC-PMX Hall amplifier gain
8 – 65,535	Reserved (not used)

Table 42: GAIN Register

The GAIN value is changed by the iC-TW14 as required by application conditions when AUTO_GAIN = 1. See AUTO_GAIN on page 18 for more information.

HALLx_MIN and HALLx_MAX Registers

The iC-TW14 provides 8 read-only registers that provide the minimum and maximum magnetic field strength from the four iC-PMX singleturn Hall sensors since power-up or the last RESET (7) or CLEAR (9) command.

HALLx_MIN/MAX (0x4A – 0x51)	
Value	Description
±32,767	iC-PMX singleturn Hall magnetic field strength in units of 0.1 kA/m

Table 43: HALLx_MIN/MAX Registers

These registers are cleared (set to zero) by executing the CLEAR command (9). See MODE/CMD on page 20.

PMX_ANGLE

PMX_ANGLE is a read-only register containing the singleturn angle (in degrees) calculated from reading the singleturn Hall sensors in the iC-PMX.

PMX_ANGLE (0x52)	
Value	Description
0 – 359	iC-PMX singleturn Hall angle
360 – 65,535	Reserved (not used)

Table 44: PMX_ANGLE Register

PMX_ANGLE is calculated from SIN and COS.

PMX_ST

PMX_ST is a read-only register containing the single-turn position (angle) (in degrees) calculated from reading the singleturn Hall sensors in the iC-PMX and corrected to compensate for the offset of the Wiegand sensor to the iC-PMX.

PMX_ST (0x53)	
Value	Description
0 – 359	Corrected singleturn angle
360 – 65,535	Reserved (not used)

Table 45: PMX_ST Register

PMX_ST is calculated as

$$PMX_ST = PMX_ANGLE + WOFS$$

See WOFS on page 17 for more information on the Wiegand misalignment value WOFS.

PMX_MT

PMX_MT[15:0] is a read-only register which contains the least significant word of the 32-bit multiturn count.

PMX_MT[15:0] (0x54)	
Bits	Description
15:0	Multiturn counter LSW (bits 15:0)

Table 46: PMX_MT[15:0] Register

PMX_MT[31:16] is a read-only register which contains the most significant word of the 32-bit multiturn count.

PMX_MT[31:16] (0x55)	
Bits	Description
15:0	Multiturn counter MSW (bits 31:16)

Table 47: PMX_MT[31:16] Register

At startup, the multiturn count is read via the iC-PMX from FRAM addresses 0x000 – 0x005 and bits 31:0 are used to initialize the multiturn counter in the iC-TW14. Bits 15:0 are available in PMX_MT[15:0] and bits 31:16 are available in PMX_MT[31:16].

During operation, PMX_MT is updated by counting PMX_ST revolutions. After each update, PMX_MT[5:0] is compared to iC-PMX POS[5:0], and STATUS.MTF is set if a multiturn fault is detected. See STATUS on page 15 and Position Data in Period Counter Mode with a Data Processing FRAM in the iC-PMX datasheet for more information.

SSI_ST

SSI_ST is a read-only register containing the single-turn angle (in degrees) used with the iC-TW14's SSI multiturn interface.

SSI_ST (0x60)	
Value	Description
0 – 359	Singleturn angle
360 – 65,535	Reserved (not used)

Table 48: SSI_ST Register

SSI_ST is calculated as

$$SSI_ST = PMX_ST - SSI_OFS$$

See SSI_OFS on page 17 for more information on the external singleturn sensor offset value SSI_OFS. The number of bits of singleturn position used as sync bits over the SSI multiturn interface is determined by SSI_LENGTH and SSI_MSB. See SSI MULTITURN INTERFACE on page 26 for more information.

SSI_MT

SSI_MT[15:0] is a read-only register which contains the least significant word of the 32-bit multiturn count used with the TW14's SSI multiturn interface.

SSI_MT[15:0] (0x61)	
Bits	Description
15:0	Corrected multiturn counter LSW (bits 15:0)

Table 49: SSI_MT[15:0] Register

SSI_MT[31:16] is a read-only register which contains the most significant word of the 32-bit multiturn count.

SSI_MT[31:16] (0x62)	
Bits	Description
15:0	Corrected multiturn counter MSW (bits 31:16)

Table 50: SSI_MT[31:16] Register

At startup, the multiturn count is read via the iC-PMX from FRAM addresses 0x000 – 0x005 and bits 31:0 are used to initialize the multiturn counter in the iC-TW14. The TW14's multiturn counter value is corrected for the external singleturn sensor's offset (SSI_OFS) and rotation direction (SSI_DIR). Bits 15:0 of this value are available in SSI_MT[15:0] and bits 31:16 are available in SSI_MT[31:16].

During operation SSI_MT is updated by counting SSI_ST revolutions. The number of multiturn bits used with the SSI multiturn interface is determined by SSI_LENGTH and SSI_MSB. See SSI MULTITURN INTERFACE on page 26 for more information.

DIAG2_TIME

DIAG2_TIME is a read-only register that provides the measured time from the beginning of the current ramp to the occurrence of the Wiegand pulse. DIAG2_TIME is only valid when MODE/CMD = 2 or 3 (diagnostic mode 2 active).

DIAG2_TIME (0x80)	
Value	Description
0 – 65,535	Wiegand pulse time (t_{pulse}) in μ sec

Table 51: DIAG2_TIME Register

DIAG2_RAMP

DIAG2_RAMP is a read-only register that provides the measured length of the current ramp. DIAG2_RAMP is only valid when MODE/CMD = 2 or 3 (diagnostic mode 2 active).

DIAG2_RAMP (0x81)	
Value	Description
0 – 65,535	Current ramp duration (t_{ramp}) in μ sec

Table 52: DIAG2_RAMP Register

DIAG2_VWP

DIAG2_VWP is a read-only register that provides the scaled peak voltage of the Wiegand pulse at t_{pulse} as measured at pin VWP. DIAG2_VWP is only valid when MODE/CMD = 2 or 3 (diagnostic mode 2 active).

DIAG2_VWP (0x82)	
Value	Description
0 – 65,535	Scaled Wiegand pulse voltage (V_{WP})

Table 53: DIAG2_VWP Register

The actual Wiegand pulse voltage (VWC) is calculated as

$$VWC = VWP \cdot \frac{VWP_FACTOR}{256}$$

See VWP_FACTOR on page 19 for more information.

VDD

VDD is a read-only register that provides the calculated iC-TW14 power supply voltage (V_{DD}).

VDD (0x90)	
Value	Description
0 – 65,535	iC-TW14 V_{DD} in mV

Table 54: VDD Register

VDD is filtered to provide a stable value.

VDD_MSE

VDD_MSE is a read-only register that provides the calculated mean squared error (noise) of the iC-TW14 power supply voltage (V_{DD}).

VDD_MSE (0x91)	
Value	Description
0 – 65,535	iC-TW14 V_{DD} mean squared error in mV^2

Table 55: VDD_MSE Register

The actual RMS noise on V_{DD} is calculated as

$$Noise [mV] = \sqrt{VDD_MSE}$$

TEMP_RAW

TEMP_RAW is a read-only register that contains the raw measured ADC value of the iC-TW14's temperature diode. This value is used to calculate TEMP.

TEMP_RAW (0x92)	
Value	Description
0 – 65,535	iC-TW14 raw temperature diode ADC value

Table 56: TEMP_RAW Register

TEMP_RAW is filtered to provide a more stable value.

TEMP

TEMP is a read-only register that provides the calculated die temperature of the iC-TW14.

TEMP (0x93)	
Bits	Description
15:0	iC-TW14 die temperature in $^{\circ}C$

Table 57: TEMP Register

TEMP is calculated as

$$TEMP = 25 + \left(\frac{VDD}{4096} \cdot \frac{TEMP_RAW}{32} - TEMP_{25} \right) \cdot \frac{TEMP_SLOPE}{2048}$$

PRESET PIN (NPRES)

The iC-TW14's NPRES input pin is used to set SSI_OFS to define the 0° point of the multiturn data sent to the external singleturn absolute sensor via the SSI multiturn interface. Typically, the NPRES pin is connected to a push-button switch to provide this zeroing function. See ELECTRICAL CONNECTIONS on page 10 for more information.

To zero the SSI multiturn position, move the magnet to the desired 0° point of the SSI multiturn data (where the multiturn count should change) and activate the NPRES input for at least 50 ms. When the NPRES input is deactivated, SSI_OFS is set to the current value of PMX_ST

(see Figure 2 on page 8) and the FRAM multiturn count is set to zero. The new SSI_OFS value is then saved to FRAM (WRITE command) and the iC-TW14 is resynchronized to the iC-PMX (RESYNC command). See MODE/CMD on page 20 for more information.

The correct system 0° point is determined by the requirements of the external singleturn absolute sensor connected to the iC-TW14 based on the number of sync bits used.

STATUS.NPRES = 1 while the NPRES input is active. See STATUS on page 15 for more information.

SSI MULTITURN INTERFACE

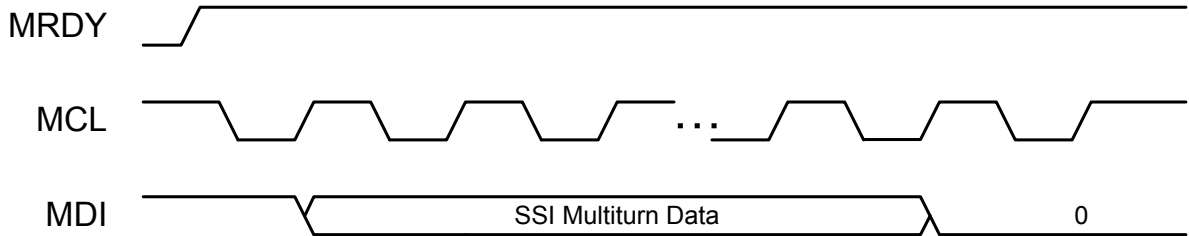


Figure 4: SSI Multiturn Interface

The SSI multiturn interface is an SSI slave port used to transmit the multiturn absolute position calculated by the iC-TW14 to a singleturn absolute sensor such as iC-LG, iC-MHM, iC-MU, iC-MN, etc. The number of multiturn and synchronization bits are programmable and must be set to match the connected singleturn absolute sensor.

Pin MRDY high and STATUS.NOSSI = 0 indicate that the iC-TW14 is ready to transmit its absolute position. Once MRDY goes high after power-up, the singleturn absolute sensor (master) sends clock pulses to pin MCL and the iC-TW14 clocks out the multiturn data on pin MDI. A single trailing 0 is provided by the iC-TW14 as shown in Figure 4. All data is binary (not Gray) coded and sent MSB first.

The iC-TW14 changes the data on pin MDI after each rising edge of MCL. After the clock pulses stop, MDI is set high after the SSI timeout delay. MRDY stays high until power-down unless a fault occurs.

The total length of the SSI data packet is specified by SSI_LENGTH and the starting bit by SSI_MSB. Up to 31 total bits of the complete multiturn position (SSI_MT.SSI_ST) can be sent.

The complete multiturn position is formed by concatenating the two SSI_MT register values with SSI_ST as shown in Figure 5. SSI_ST is first converted from degrees to a 5-bit binary number by multiplying by $\frac{32}{360}$ so that the bits represent fractions of a revolution. Thus the MSB of the converted SSI_ST value represents one half of a revolution, the next bit represents one quarter, etc. These bits can be used as synchronization bits by the external singleturn absolute sensor.

For example, to send SSI data packets containing 16 multiturn bits and one synchronization bit to the external singleturn absolute sensor, set SSI_MSB = 15 and SSI_LENGTH = 17. This case is shown in Figure 5.

If the iC-TW14 is not ready to transmit data over the SSI multiturn interface (pin MRDY low and STATUS.NOSSI = 1) and the master singleturn absolute sensor sends clock pulses to pin MCL, pin MDI stays high. In this case there is no trailing 0, but a trailing 1. This trailing 1 can be used by the singleturn absolute sensor to detect invalid multiturn position data from the iC-TW14.

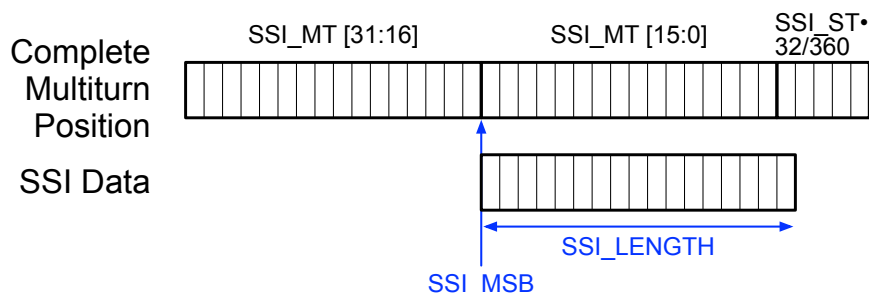


Figure 5: SSI Multiturn Data

DIAGNOSTIC MODES

SSI Test Mode

SSI test mode is used to test the SSI multiturn interface by supplying known static position data which can be verified in the external singleturn absolute sensor. To use SSI test mode, first enter the least significant word of the desired test position to DATA.0 and the most significant word to DATA.1. See Data Registers on page 21 for more information.

For example, to test the SSI multiturn interface using the 32-bit multiturn data 0x76543210, set

DATA.0 = 0x3210
DATA.1 = 0x7654

Initiate SSI test mode using the SSI_TEST command (40). See MODE/CMD on page 20 for more information. The external singleturn absolute sensor will then clock in as many of these multiturn bits as it is configured to use starting with the most significant bit of DATA.1.

Because the SSI multiturn protocol requires a trailing zero after all bits are sent, it is important that the test position in DATA.0 and DATA.1 provide a zero bit at the proper position. For example, if the external singleturn absolute sensor is programmed to require 16 multiturn bits and 1 sync bit, the 18th bit of the SSI data packet (bit 14 of DATA.0 in this example) must be zero, as shown in Figure 6.

Care must be taken to ensure that this requirement is fulfilled, otherwise the SSI multiturn communication will fail.

Note that SSI test mode sets STATUS.STOP (see STATUS on page 15 for more information). To end SSI test mode and clear STATUS.STOP, re-synchronize the iC-TW14 to the iC-PMX using the RESYNC command (8).

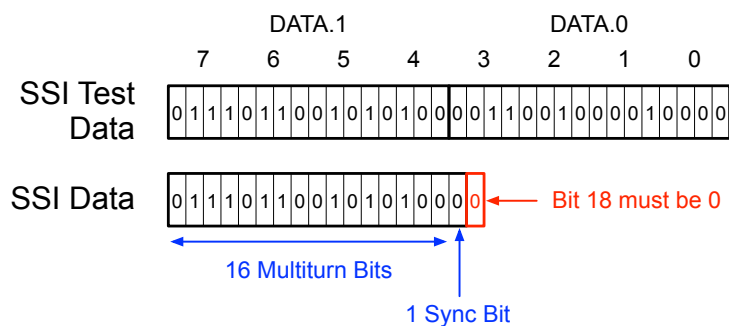


Figure 6: SSI Test Example

Diagnostic Mode 1

Diagnostic mode 1 is used to measure the Wiegand pulse angle, voltage, and magnetic field strength when a Wiegand pulse occurs. Diagnostic mode 1 is initiated using the DIAG1 command (1). See MODE/CMD on page 20 for more information. See Diagnostic Mode 1 on page 12 for information on the serial data packet used by diagnostic mode 1.

Diagnostic mode 1 is most easily used via the Wiegand Pulse Stream tab in the free iC-TW14 GUI software as shown in Figure 7.

See chapter MAGNET ALIGNMENT AND AIRGAP in iC-PMX application note 2 for more information on using diagnostic mode 1.

The magnetic field strength during Wiegand pulses is calculated with the following approximation formula:

$$H_4 = H_1 + \frac{H_3 - H_1 + H_2 - H_0}{28}$$

$$H_5 = H_3 - \frac{H_3 - H_1 + H_2 - H_0}{28}$$

Care must be taken when using diagnostic mode 1 to ensure that the rotational speed of the magnet is low enough that all pulses are measured. Since each character in a serial packet uses 10 bits, there are 14 characters in each packet, and there are 2 Wiegand pulses per revolution, the theoretical maximum speed for using diagnostic mode 1 can be calculated as

$$\frac{9600 \text{ bits}}{\text{sec}} \cdot \frac{1 \text{ char}}{10 \text{ bits}} \cdot \frac{1 \text{ packet}}{14 \text{ chars}} \cdot \frac{1 \text{ rev}}{2 \text{ packets}} \cdot \frac{60 \text{ sec}}{\text{min}} = 2057 \text{ RPM}$$

It is recommended to use a speed well below this value for best results.

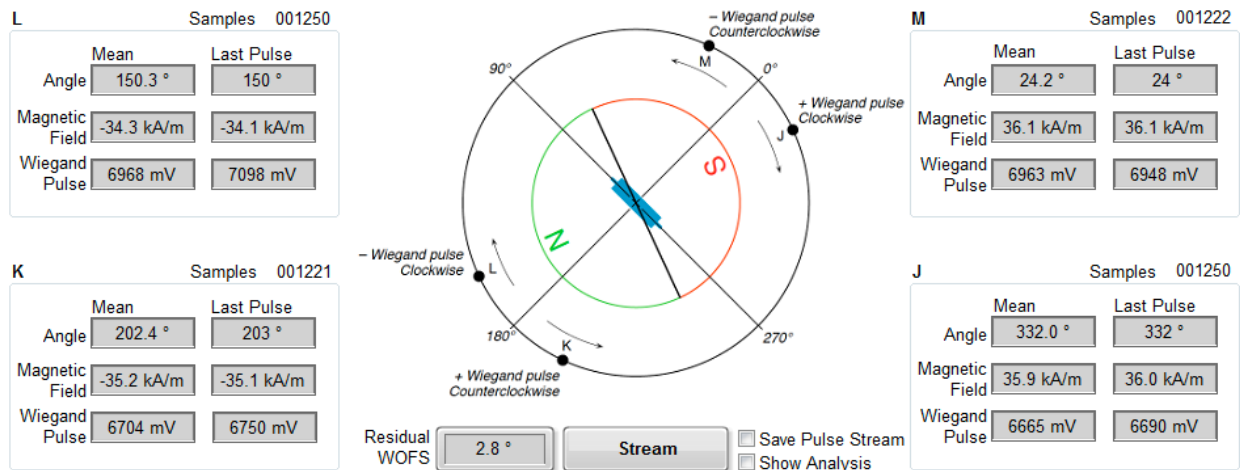


Figure 7: Typical Wiegand Pulse Data

Diagnostic Mode 2

Diagnostic mode 2 (MODE/CMD = 2 or 3) is used to analyze current ramp operation and set the PMXBIAS value. Initiate diagnostic mode 2 using the DIAG2P (2) or DIAG2N (3) commands. See MODE/CMD on page 20 for more information.

Diagnostic mode 2 is most easily used via the Current Ramp tab in the free iC-TW14 GUI software as shown in Figure 8.

See PMX BIAS and CURRENT RAMP PARAMETERS in iC-PMX application note 2 for more information on using diagnostic mode 2.

Diagnostic mode 2 sets STATUS.STOP. To clear this condition, re-synchronize the iC-TW14 using the RESYNC command (8).

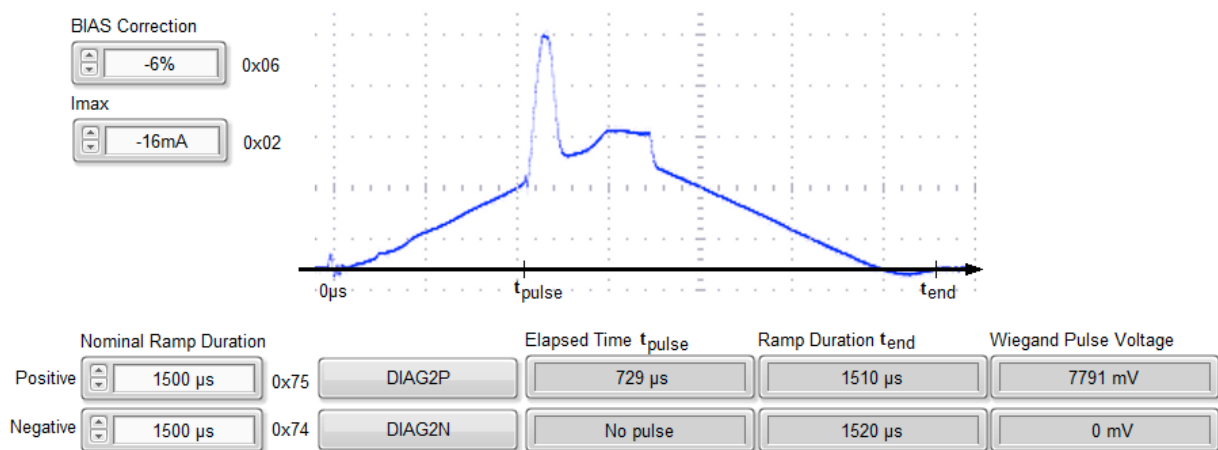


Figure 8: Typical Wiegand Pulse Data

DIRECT FRAM ACCESS

The iC-TW14 contains an FRAM block address register, four FRAM data registers, and five additional commands which are used to directly access the FRAM connected to the iC-PMX for diagnostics or storage of user data.

FRAM_BLOCK

FRAM_BLOCK is a read/write register used to specify the block address for reading data from or writing data to the FRAM using the F_DATA_W (21) and F_DATA_R (22) commands. See Direct FRAM Access Commands on page 30 for more information.

FRAM_BLOCK (0x31)	
Bits	Description
15:8	Reserved (must be 0)
7:0	FRAM Address/ 8

Table 58: FRAM Block Address Register

Data in the FRAM is accessed in 8-byte blocks. This provides efficient use of the iC-PMX to FRAM commu-

nication channel while still permitting Wiegand pulse processing. FRAM_BLOCK specifies the starting location of the desired data block and is calculated as

$$FRAM_BLOCK = \frac{FRAM\ Address}{8}$$

For example, to access the block of FRAM data starting at address 0x40, set FRAM_BLOCK = 0x0008.

DATA Registers

DATA.0 – DATA.3 are read/write registers used to hold the data being written to or read from the FRAM using commands 21 – 25. The data stored in these registers is different depending on the specific command used. See Direct FRAM Access Commands on page 30 for more information.

The 8 byte block of FRAM data used by the F_DATA_W (21) and F_DATA_R (22) commands is stored in DATA.0 – DATA.3 as shown in Table 59.

DATA.0 – DATA.3 (0x32 – 0x35)		
Register	Bits	Description
DATA.0	15:8 7:0	DATA to or from (8·FRAM_BLOCK + 1) DATA to or from (8·FRAM_BLOCK)
DATA.1	15:8 7:0	DATA to or from (8·FRAM_BLOCK + 3) DATA to or from (8·FRAM_BLOCK + 2)
DATA.2	15:8 7:0	DATA to or from (8·FRAM_BLOCK + 5) DATA to or from (8·FRAM_BLOCK + 4)
DATA.3	15:8 7:0	DATA to or from (8·FRAM_BLOCK + 7) DATA to or from (8·FRAM_BLOCK + 6)

Table 59: Registers DATA.0 – DATA.3 as FRAM Data Registers

The 6 bytes of FRAM multiturn position data used by the F_MT_W (23) and F_MT_R (24) commands are stored in DATA.0 – DATA.2 as shown in Table 60.

DATA.0 – DATA.2 (0x32 – 0x34)		
Register	Bits	Description
DATA.0	15:8 7:0	Data to or from FRAM address 0x001 Data to or from FRAM address 0x000
DATA.1	15:8 7:0	Data to or from FRAM address 0x003 Data to or from FRAM address 0x002
DATA.2	15:8 7:0	Data to or from FRAM address 0x005 Data to or from FRAM address 0x004

Table 60: Registers DATA.0 – DATA.2 as FRAM Multiturn Position Registers

Registers FRAM_BLOCK and DATA.3 are not used with the F_MT_W (23) and F_MT_R (24) commands.

The 32-bit multiturn position used to set the FRAM multiturn position using the F_SET_MT command (25) is stored in these registers as shown in Table 61.

DATA.0 – DATA.1 (0x32 – 0x33)		
Register	Bits	Description
DATA.0	15:8 7:0	FRAM Counter(15) – Counter(8) FRAM Counter(7) – Counter(0)
DATA.1	15:8 7:0	FRAM Counter(31) – Counter(24) FRAM Counter(23) – Counter(16)

Table 61: Registers DATA.0 – DATA.1 as FRAM Multiturn Position Set Registers

See MEMORY MAP for POS0/1/2/3 in the FRAM datasheet for more information on the FRAM Counter registers. Registers FRAM_BLOCK, DATA.2, and DATA.3 are not used with the F_SET_MT command.

Direct FRAM Access Commands

The five additional commands used for direct FRAM access, along with the FRAM address range that can be accessed with each command, are shown in Table 62.

MODE/CMD (0x30)		
Command	Value	FRAM Addresses
F_DATA_W	21	0x008 – 0x7FF
F_DATA_R	22	0x008 – 0x7FF
F_MT_W	23	0x000 – 0x005
F_MT_R	24	0x000 – 0x005
F_SET_MT	25	0x000 – 0x005

Table 62: MODE/CMD Register

To execute a command, write the appropriate value to the Mode/Command register. When any of the FRAM read or write commands is complete, MODE/CMD is set to NORMAL (0) by the iC-TW14.

The F_DATA_W command (21) is used to write configuration or user data to the FRAM as shown in Table 63.

Memory Map for F_DATA_W and F_DATA_R Commands			
Name	iC-TW14 Address	FRAM Addresses	FRAM_BLOCK
FRAM MT pos.	–	0x000 – 0x007	0
User Data	–	0x008 – 0x01F	1 – 3
PRAMP	0x10	0x020 – 0x021	4
NRAMP	0x11	0x022 – 0x023	
PMXWI	0x12	0x024 – 0x025	
PMXBIAS	0x13	0x026 – 0x027	
PMXGAIN	0x14	0x028 – 0x029	5
WOFS	0x15	0x02A – 0x02B	
SSI_OFS	0x16	0x02C – 0x02D	
SSI_DIR	0x17	0x02E – 0x02F	
SSI_LENGTH	0x18	0x030 – 0x031	6
SSI_MSB	0x19	0x032 – 0x033	
SIN_OFS_COR	0x1A	0x034 – 0x035	
COS_OFS_COR	0x1B	0x036 – 0x037	
GAIN_COR	0x1C	0x038 – 0x039	7
AUTO_GAIN	0x1D	0x03A – 0x03B	
AMP_MAG_LOSS	0x1E	0x03C – 0x03D	
TEMP25	0x1F	0x03E – 0x03F	
TEMP_SLOPE	0x20	0x040 – 0x041	8
VWP_FACTOR	0x21	0x042 – 0x043	
Reserved	–	0x044 – 0x045	
Reserved	–	0x046 – 0x047	
User Data	–	0x048 – 0x7FF	9 – 0xFF

Table 63: Memory Map for FRAM Data Read/Write Commands

This command writes the 8 bytes of data in DATA.0 – DATA.3 directly to the FRAM starting at address FRAM_BLOCK · 8 using FRAM feedthrough mode in the iC-PMX and the FRAM WRITE command (op-code 0x02). See FRAM Access in the iC-PMX datasheet and COMMAND • WRITE in the FRAM datasheet for more information. When the write is complete, the iC-TW14 sets MODE/CMD to NORMAL (0).

For example, to write the 8 bytes 0x1F, 0x2E, 0x3D, 0x4C, 0x5B, 0x6A, 0x79, and 0x88 to FRAM addresses

0x050 – 0x057, set FRAM_BLOCK = 0x000A (0x050/8), set the DATA registers as shown in Table 64, and write 0x0015 (21) to the MODE/CMD register.

F_DATA_W Example			
Register	Bits	Data	FRAM Address
DATA.0	15:8	0x2E	0x051
	7:0	0x1F	0x050
DATA.1	1:8	0x4C	0x053
	7:0	0x3D	0x052
DATA.2	15:8	0x6A	0x055
	7:0	0x5B	0x054
DATA.3	15:8	0x88	0x057
	7:0	0x79	0x056

Table 64: FRAM Data Write Example

When the write is complete, the iC-TW14 sets MODE/CMD to NORMAL (0) and the contents of FRAM addresses 0x0050 – 0x057 are as shown in Table 64.

If the F_DATA_W command cannot be executed, possibly due to an illegal address specified in FRAM_BLOCK, STATUS.FAD is set. See STATUS on page 15 for more information.

Do not use this command to write the multiturn position (FRAM addresses 0x000 – 0x007). The multiturn position is specially encoded, please use the F_MT_W command instead.

The F_DATA_R command (22) is used to read iC-TW14 configuration and user data from the FRAM as shown in Table 63.

This command reads the 8 byte block of data starting from FRAM address 8 · FRAM_BLOCK and stores the results in DATA.0 – DATA.3 using FRAM feedthrough mode in the iC-PMX and the FRAM READ command (op-code 0x03). See FRAM Access in the iC-PMX datasheet and COMMAND • READ in the FRAM datasheet for more information. When the read is complete, the iC-TW14 sets MODE/CMD to 0 (Normal Operation).

For example, to read the 8 bytes of data from FRAM addresses 0x050 – 0x057, set FRAM_BLOCK = 0x000A (0x050/8) and write 0x0016 (22) to the MODE/CMD register. When MODE/CMD = 0, the FRAM access is done and the data is available in DATA.0 – DATA.3 as shown in Table 65 (assuming that the FRAM data write command example shown earlier had been previously executed).

F_DATA_R Example			
FRAM Address	Data	Register	Bits
0x051 0x050	0x2E	DATA.0	15:8
	0x1F		7:0
0x053 0x052	0x4C	DATA.1	15:8
	0x3D		7:0
0x055 0x054	0x6A	DATA.2	15:8
	0x5B		7:0
0x057 0x056	0x88	DATA.3	15:8
	0x79		7:0

Table 65: FRAM Data Read Example

If the F_DATA_R command cannot be executed, possibly due to an illegal address specified in FRAM_BLOCK, STATUS.FAD is set. See STATUS on page 15 for more information.

Do not use this command to read the multiturn position (FRAM addresses 0x000 – 0x007). The multiturn position is specially encoded, please use the F_MT_R command instead.

The F_MT_W command (23) is used to directly write the FRAM multiturn position, which is specially encoded in the FRAM. This command writes the 6 bytes of data in DATA.0 – DATA.2 to FRAM addresses 0x000 – 0x005 with special encoding using FRAM feedthrough mode in the iC-PMX and the FRAM WRTSs command (op-code 0x3F). See FRAM Access in the iC-PMX datasheet and COMMAND • WRTSs in the FRAM datasheet for more information. When the write is complete, the iC-TW14 sets MODE/CMD to 0 (Normal Operation).

For example, to write the value 0x0123,4567,89AB to FRAM addresses 0x00 – 0x05, set DATA.0 – DATA.2 as shown in Table 66 and write 0x0017 (23) to the MODE/CMD register. When the write is complete, the iC-TW14 sets MODE/CMD to NORMAL (0).

F_MT_W Example			
Register	Bits	Data	FRAM Address
DATA.0	15:8	0x89	0x001
	7:0	0xAB	0x000
DATA.1	15:8	0x45	0x003
	7:0	0x67	0x002
DATA.2	15:8	0x01	0x005
	7:0	0x23	0x004

Table 66: FRAM Multiturn Position Write Example

The F_MT_R command (24) is used to directly read the FRAM multiturn position, which is specially encoded in the FRAM. This command reads the 6 bytes of data at FRAM addresses 0x000 – 0x005 with special encoding using FRAM feedthrough mode in the iC-PMX and the FRAM RDTs command (op-code 0x38) and stores the result in DATA.0 – DATA.2. See FRAM Access

in the iC-PMX datasheet and COMMAND • RDTs in the FRAM datasheet for more information. When the read is complete, the iC-TW14 sets MODE/CMD to 0 (Normal Operation).

For example, to read the 6 bytes of multiturn position data from the FRAM, write 0x0018 (24) to the MODE/CMD register. When MODE/CMD = 0, the FRAM access is done and the data is available in DATA.0 – DATA.2 as shown in Table 67 (assuming that the FRAM multiturn position write command example shown earlier had been previously executed and no Wiegand pulses have occurred in the meantime).

F_MT_R Example			
FRAM Address	Data	Register	Bits
0x001 0x000	0x89 0xAB	DATA.0	15:8 7:0
0x003 0x002	0x45 0x67	DATA.1	15:8 7:0
0x005 0x004	0x01 0x23	DATA.2	15:8 7:0

Table 67: FRAM Multiturn Position Read Example

The **F_SET_MT** command (25) is used to set the FRAM multiturn position to a specific value. This command writes the 32-bit multiturn position in DATA.0 – DATA.1 to FRAM addresses 0x000 – 0x005 with special encoding using FRAM feedthrough mode in the iC-PMX

and the FRAM WRTs command (op-code 0x3F). The existing values of PP (FRAM address 0x000 Bit 0) and DIR (FRAM address 0x000 Bit 1) are preserved (not affected) and DIR' (FRAM address 0x005 Bit 5) is made equal to DIR (FRAM address 0x000 Bit 1). EFLAG (FRAM address 0x005 Bits 7:6) and FRAM counter bits 32:42 (FRAM address 0x004 Bit 2 – FRAM address 0x005 Bit 4) are reset to zero. See FRAM Access in the iC-PMX datasheet and MEMORY MAP for POS0/1/2/3 in the FRAM datasheet for more information. When the command is complete, the iC-TW14 sets MODE/CMD to NORMAL (0).

For example, to set the FRAM multiturn position to 0x0123,4567, set DATA.0 – DATA.1 as shown Table 68 and write 0x0019 (25) to the MODE/CMD register. This sets the multiturn position without affecting the PP and DIR bits to allow proper turns counting after setting the multiturn position. When the command is complete, the iC-TW14 sets MODE/CMD to NORMAL (0).

F_SET_MT Example			
Register	Bits	Data	FRAM Bits
DATA.0	15:8	0x45	Counter(15:8)
	7:0	0x67	Counter(7:0)
DATA.1	15:8	0x01	Counter(31:24)
	7:0	0x23	Counter(23:16)

Table 68: Set FRAM Multiturn Position Example

DESIGN REVIEW: Notes on Chip Functions

iC-TW14_1 (Rev. 0x20B4)		
No.	Function, Parameter/Code	Description and Application Hints
1	UID0 - UID4	Register values not available
2	TMODE	Test mode functions not available
3	STATUS.MTM	Reading the FRAM multiturn position can fail when iC-PMX simultaneously updates the position data. Thus a multiturn mismatch might be reported temporarily by iC-TW14 due to missing exception handling for this case.
4	STATUS.MTM	The allowed mismatch between the tracked multiturn position of iC-TW14 and the multiturn position stored in the FRAM can be too low. STATUS.MTM is activated when the mismatch is too large and the multiturn data output is halted as long as this condition is true.
5	PMXCONFIG	The value of PMXCONFIG is set to 0 when STATUS.FCF is active.
6	SSI Multiturn Interface	If the iC-TW14 is not ready to transmit data over the SSI multiturn interface and the master sends clock pulses to pin MCL, pin MDI stays high for 32 clock cycles. (Pin MDI switches to low after 32 clock cycles.)
7	SSI Multiturn Interface	iC-TW14 needs a delay of 25 us after the rising edge of MRDY before the SSI multiturn data is requested. (Otherwise, the first multiturn data transmission might be faulty.)
8	Conversion to magnetic field strength	The temperature compensated conversion of the iC-PMX singleturn voltages to magnetic field strength is imprecise for very low and very high temperatures. (deviation approx. 10%)
9	Diagnostic Mode 1	The value for the Wiegand pulse point is the FRAM's value, even if the FRAM content is invalid.
10	Diagnostic Mode 1	The magnetic field strength during Wiegand pulses is calculated based on the assumption H4=H1 and H5=H3.
11	Diagnostic Mode 1	It may happen that an additional 'diagnostic mode 1 packet' is sent after terminating the diagnostic mode 1 with the RESYNC command.
12	Test Mode MRDY_HI	The command MRDY_HI does not set Pin MRDY Pin high.

Table 69: Notes on chip functions regarding device revision 0x20B4

iC-TW14_2 (Rev. 0x2309)		
No.	Function, Parameter/Code	Description and Application Hints
1	UID0 - UID4	Register values not available
2	TMODE	Test mode functions not available
3	STATUS.MTM	Reading the FRAM multiturn position can fail when iC-PMX simultaneously updates the position data. Thus a multiturn mismatch might be reported temporarily by iC-TW14 due to missing exception handling for this case.
4	STATUS.MTM	The allowed mismatch between the tracked multiturn position of iC-TW14 and the multiturn position stored in the FRAM can be too low. STATUS.MTM is activated when the mismatch is too large and the multiturn data output is halted as long as this condition is true.
5	PMXCONFIG	The value of PMXCONFIG is set to 0 when STATUS.FCF is active.

Table 70: Notes on chip functions regarding device revision 0x2309

iC-TW14_3 (Rev. 0x2555)		
No.	Function, Parameter/Code	Description and Application Hints
1	UID0 - UID4	Register values not available
2	TMODE	Test mode functions not available
3	STATUS.MTM	Reading the FRAM multiturn position can fail when iC-PMX simultaneously updates the position data. Thus a multiturn mismatch might be reported temporarily by iC-TW14 due to missing exception handling for this case.

Table 71: Notes on chip functions regarding device revision 0x2555

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iC-TW14_4 (Rev. 0x2705)		
No.	Function, Parameter/Code	Description and Application Hints
		No further notes at time of printing.

Table 72: Notes on chip functions regarding device revision 0x2705

REVISION HISTORY

Rel.	Rel. Date*	Chapter	Modification	Page
A1	2016-06-17		Confidential release of the target specification	

Rel.	Rel. Date*	Chapter	Modification	Page
A2	2017-11-15	ABSOLUTE MAXIMUM RATINGS	Chapter added	7
		SERIAL COMMUNICATION	New Wiegand pulse point value 'F'	12
		SSI MULTITURN INTERFACE	Added information that MDI stays high when TW14 is not ready	26
		DIAGNOSTIC MODES	Add calculation formula for the magnetic field strength during diagnostic mode 1	28
		DIRECT FRAM ACCESS	Table 63: added FRAM MT pos.	30
		DESIGN REVIEW: Notes on Chip Functions	Chapter added	33

Rel.	Rel. Date*	Chapter	Modification	Page
A3	2019-01-07	SERIAL COMMUNICATION	Removed the duplicated '!' in line ":Gwaadddd!"	11
		SSI MULTITURN INTERFACE	Removed the incorrect statement that after the complete data packet is sent, MDI stays low until the clock pulses on MCL stop. (iC-TW14 provides a trailing 0, but may sent arbitrary data if the master sends additional clock pulses.)	26
		DESIGN REVIEW: Notes on Chip Functions	Added notes on iC-TW14_2, iC-TW14_3	33

Rel.	Rel. Date*	Chapter	Modification	Page
A4	2019-09-25	REGISTER MAP	Added documentation for the new registers UID0, UID1, UID2, UID3, UID4 and TMODE	13-19
		DESIGN REVIEW: Notes on Chip Functions	Added notes on iC-TW14_1, iC-TW14_2, iC-TW14_3 and iC-TW14_4	33

Rel.	Rel. Date*	Chapter	Modification	Page
A5	2019-11-15		Preliminary marking removed.	

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iC-TW14

iC-PMX Companion Chip



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Type	Package	Order Designation
iC-TW14	QFN24	iC-TW14 QFN24-4x4

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