

iC-MP

8-BIT HALL ANGLE ENCODER

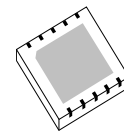
FEATURES

- ◆ Hall sensor array with automatic signal control
- ◆ Differential scanning for excellent magnetic stray field tolerance
- ◆ Realtime tracking interpolation to 256 angle steps permitting RPM speed of up to 12 000
- ◆ Selectable full scale angle of 90, 180, 270 or 360 degree
- ◆ Programmable zero/index position
- ◆ Ratiometric output with 0.5 V to 4.5 V or 0 V to 5 V
- ◆ Fast, serial absolute angle data output
- ◆ Easy daisy chaining of multiple sensors: all analog/digital outputs are bus capable
- ◆ Loss-of-magnet and excessive frequency indication via error output
- ◆ Non-volatile setup provided by reconfigurable Zap ROM
- ◆ 5 V single supply operation
- ◆ Power saving standby function
- ◆ Operational temperature range of -40 to +125 °C
- ◆ Space-saving 10-pin DFN package measuring 4 mm x 4 mm

APPLICATIONS

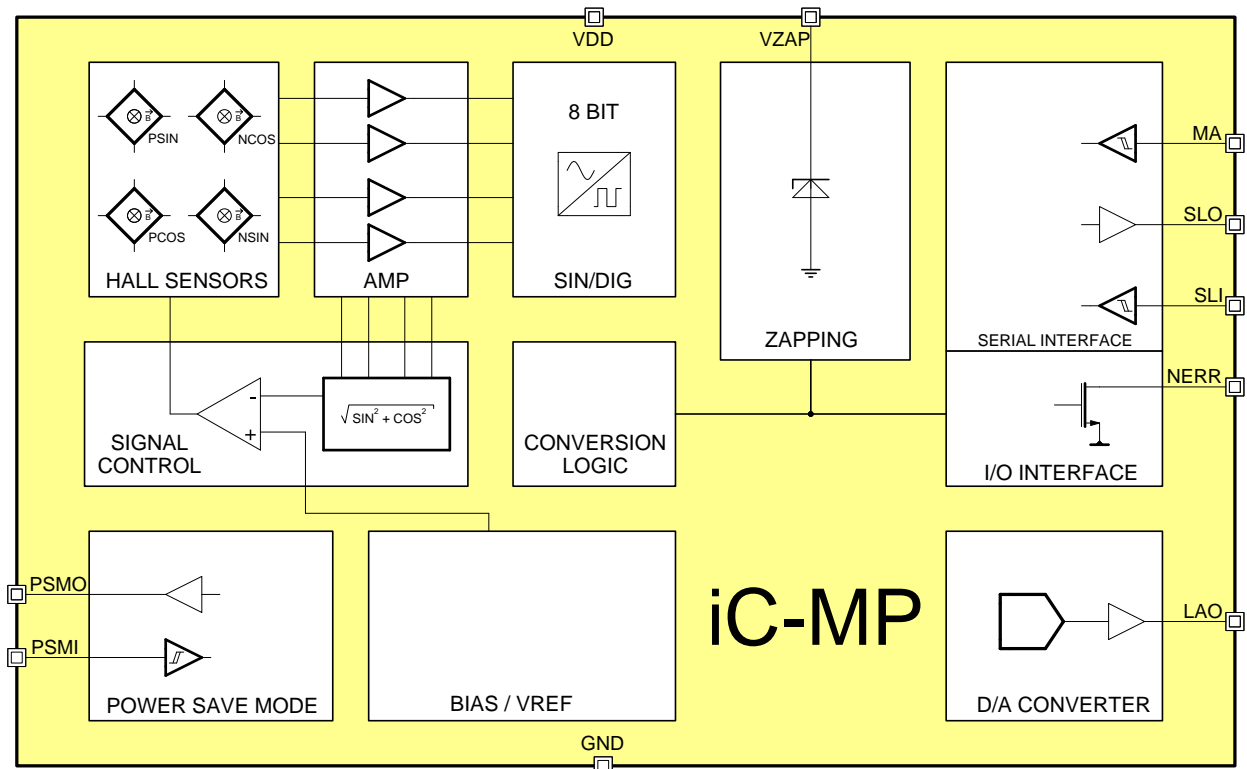
- ◆ Contactless potentiometer
- ◆ Absolute 360° angle sensor
- ◆ Magnetic rotary encoders
- ◆ Magnetic multiturn encoders

PACKAGES



DFN10 4 x 4 mm

BLOCK DIAGRAM



iC-MP

8-BIT HALL ANGLE ENCODER

DESCRIPTION

The CMOS device iC-MP consists of a quadruple hall sensor array which has been optimized for the magnetic measurement of angles of rotation. This array permits error-tolerant adjustment of the magnet, reducing assembly efforts. The integrated signal conditioning unit provides a differential sine/cosine signal at its output. The sensor generates one sine cycle per each full rotation of the magnet, enabling the angle to be clearly determined. At the same time the internal amplitude control unit produces an regulated output amplitude of 2 Vpp regardless of variations in the magnetic field strength, supply voltage and temperature. Furthermore, signals are provided which enable the sensor amplitude to be assessed and also report any magnet loss.

With the aid of the integrated 8-bit sine/digital converter the angle of rotation is determined from the sine/cosine signals. This is output via the absolute serial interface together with a bit indicating an error.

The maximum resolution of 8-bit is maintained up to rotations of 12000 rpm.

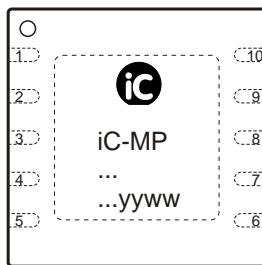
The absolute angle of rotation can be converted back to a linear analog buffered output signal using the internal D/A converter. The output voltage range can be programmed to be either rail to rail or 10% to 90% of the supply voltage. The angular output range is configurable to be 90°, 180°, 270° or 360°.

iC-MP can be easily cascaded enabling scanning of multiple axes of rotation. In fast scanning mode all devices are read consecutively. In slow scanning mode each particular device is enabled before the serial data or analog output voltage is put on the common bus.

Used in conjunction with a permanent magnet iC-MP can act as an encoder system with an integrated magnetic scanning feature.

PACKAGES

PIN CONFIGURATION DFN10



PIN FUNCTIONS

No.	Name	Function
1	PSMI	Power Save Mode Input
2	GND	Ground
3	PSMO	Power Save Mode Output
4	LAO	Linear Analog Output
5	MA	Serial Clock
6	SLO	Serial Data Output
7	SLI	Serial Data Input
8	VZAP	Zapping Voltage Input
9	VDD	+5 V Supply Voltage
10	NERR	Error Indicator, low active Output
	TP	Thermal-Pad

The *Thermal Pad* is to be connected to ground potential on the PCB. Orientation of the logo (iC MP CODE ...) is subject to alteration.

ABSOLUTE MAXIMUM RATINGS

Beyond these values damage may occur; device operation is not guaranteed.

Item No.	Symbol	Parameter	Conditions	Min. Max.		Unit
				Min.	Max.	
G001	VDD	Supply voltage		-0.3	6	V
G002	I(VDD)	Current in VDD		-20	20	mA
G003	V()	Voltage at pins PSMI, PSMO, LAO, MA, SLO, SLI, NERR		-0.3	VDD + 0.3	V
G004	Vzap()	Voltage at pin VZAP		-0.3	6.9	V
G005	I()	Current in pins PSMI, PSMO, LAO, MA, SLO, SLI, NERR		-4	4	mA
G006	Izap()	Current in pin VZAP			90	mA
G007	Vd()	ESD Susceptibility at all Pins	HBM, 100 pF discharged through 1.5 kΩ		2	kV
G008	Tj	Junction-Temperature		-40	+125	°C

THERMAL DATA

Operating conditions: VPA, VPD = 5 V ±10 %

Item No.	Symbol	Parameter	Conditions	Min. Typ. Max.			Unit
				Min.	Typ.	Max.	
T01	Ta	Ambient temperature		-40		125	°C
T02	Rthja	Thermal resistance chip/ambient	package mounted on PCB, <i>thermal pad</i> at approx. 2 cm ² cooling area		40		K/W

All voltages are referenced to ground unless otherwise stated.

All currents into the device pins are positive; all currents out of the device pins are negative.

ELECTRICAL CHARACTERISTICS

Operating conditions: VDD = 5 V ±10 %, Tj = -40 ... 125 °C, unless otherwise noted

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
General							
001	V(VDD)	Supply Voltage		4.5	5	5.5	V
002	I(VDD)	Supply current	PSMI = low, other pins open		8	12	mA
003	I(VDD)sb	Standby supply current	PSMI = high			200	µA
004	td(PSMI)dv	Time to data valid	after enabling			1	ms
005	Vc(lo)	Clamp voltage low PSMI, PS MO, LAO, MA, SLO, SLI, NERR, VDD, VZAP	I() = -4 mA	-1.5		-0.3	V
006	Vc(hi)	Clamp voltage high PSMI, PS MO, LAO, MA, SLO, SLI, NERR	VDD = GND I(PSMO, LAO, SLO) = 4 mA, I(PSMI, SLI, MA, NERR) = 1 mA	0.3		1.6	V
007	V()PDRon	Threshold Power Down Reset on		2.6			V
008	V()PDRoff	Threshold Power Down Reset off				4.1	V
Hall sensor array							
101	Hext	Required external magnetic field strength	at chip surface	20	50	100	kA/m
102	dsens	Diameter of Hall sensor array			2		mm
103	xdis	Displacement of Hall sensor array to package	DFN10 package	-0.2		0.2	mm
104	hsens	Distance chip surface to top of package	DFN10 package		400		µm
105	Aabs	Absolute angular position	Using magnet with 4 mm diameter, centered to chip, Hext = 20...100 kA/m	-3		3	DEG
106	v()	Magnetic angular velocity				12000	rpm
Linear Analog Output LAO							
201	SR(LAO)hi	Slew Rate Low/High	20 → 80%	2			V/µs
202	SR(LAO)lo	Slew Rate High/Low	80 → 20%			-2	V/µs
203	I(LAO)	Permissible output current		-1		1	mA
204	dVR1(LAO)	Delta to VDD/GND	I(LAO) = 1 mA, MODE(3) = '0' see fig. 4			170	mV
205	dVR0(LAO)	Delta to VDD/GND	I(LAO) = 0 mA, MODE(3) = '0'			75	mV
206	dV1(LAO)	Delta to VDD/GND	I(LAO) = 1 mA, MODE(3) = '1' see fig. 4			10	%VDD
207	dV0(LAO)	Delta to VDD/GND	I(LAO) = 0 mA, MODE(3) = '1'			10	%VDD
208	Res(LAO)	Resolution output voltage	CFG = 360° CFG = 270° CFG = 180° CFG = 90°		8 7.5 7 6		bit bit bit bit
209	Ilk(LAO)	Leakage current	0 ≤ V(LAO) ≤ VDD, PSMI = high	-5		5	µA
Absolute Output							
301	Res(SLO)	Resolution serial output			8		bit
302	hys	Converter hysteresis			1.4		°
303	f(MA)	Permissible serial clock frequency				12	MHz
Zapping Input VZAP							
401	Vtl(hi)	Lower threshold voltage high				2	V
402	Vtl(lo)	Lower threshold voltage low		0.8			V
403	Vtl(hys)	Lower Hysteresis	Vt(hys) = Vtl(hi) - Vtl(lo)	230		400	mV
404	Vtu(hi)	Upper threshold voltage high	Vtu(hi) = V(VDD) + V(), VDD = 5 V ±5%, Tj = 10 ... 40 °C			1.3	V
405	Vtu(lo)	Upper threshold voltage low	Vtu(lo) = V(VDD) + V(), VDD = 5 V ±5%, Tj = 10 ... 40 °C	0.7			V
406	Vtu(hys)	Upper hysteresis	Vtu(hys) = Vtu(hi) - Vtu(lo)	25		150	mV

ELECTRICAL CHARACTERISTICS

Operating conditions: VDD = 5 V ±10%, Tj = -40 ... 125 °C, unless otherwise noted

Item No.	Symbol	Parameter	Conditions				Unit
				Min.	Typ.	Max.	
407	Vt()zap	Permissible zapping voltage	VDD = 5 V ±5%, Tj = 10 ... 40 °C	7.3	7.4	7.5	V
408	Izap()	Zapping current	VDD = 5 V ±5%, Tj = 10 ... 40 °C			90	mA
409	tzap(MA)	Permissible duration of zapping	VDD = 5 V ±5%, Tj = 10 ... 40 °C	4.5	5	5.5	µs
Input Pins PSMI, MA, SLI							
501	Vt()hi	Threshold voltage high				2	V
502	Vt()lo	Threshold voltage low		0.8			V
503	Vt()hys	Hysteresis	Vt()hys = Vt()hi - Vt()lo	230			mV
504	Ipu()	Pull-up current	V() = 0...VDD - 1 V	-240	-120	-10	µA
Output Pins SLO, PSMO							
601	Vs()hi	Saturation voltage high	Vs()hi = VDD - V(), I() = -4 mA			0.4	V
602	tr()	Rise time	CL() = 50 pF, 20 → 80%			60	ns
603	Vs()lo	Saturation voltage low	I() = 4 mA			0.4	V
604	tf()	Fall time	CL() = 50 pF, 80 → 20%			60	ns
605	Isc()hi	Short Circuit Current high		-90		-10	mA
606	Isc()low	Short Circuit Current low		10		90	mA
Output Pin NERR							
701	Vs (NERR)lo	Saturation voltage low	I() = 4 mA			0.4	V
702	Iik(NERR)	Leakage current	PSMI = high, V() = 0...VDD	-5		5	µA
703	Isc(NERR) lo			5		80	mA
Internal Signals PSIN, NSIN, PCOS, NCOS, VREF, VBG, GAIN, CLK_COM							
801	VBG	Bandgap voltage	TMODE = 3, VBG = V(NERR)	1.1	1.2	1.3	V
802	VREF	Reference voltage	TMODE = 2, VREF = V(LAO)	45	50	55	%VDD
803	V(GAIN)	Gain	TMODE = 2, V(GAIN) = V(NERR)	0.05		1.3	V
804	f (CLK_COM)	Frequency of common oscillator	TMODE = 5, CLK_COM = NERR	290	350	410	kHz
805	Vdc(PSIN)	Direct voltage of positive sinus	V(PSIN) = V(NERR), TMODE = 0		VREF		V
806	Vdc(PCOS)	Direct voltage of positive cosinus	V(PCOS) = V(LAO), TMODE = 0		VREF		V
807	Vdc(NSIN)	Direct voltage of negative sinus	V(NSIN) = V(NERR), TMODE = 1		VREF		V
808	Vdc(NCOS)	Direct voltage of negative cosinus	V(NCOS) = V(LAO), TMODE = 1		VREF		V
809	Vam(PSIN)	Amplitude of positive sinus	V(PSIN) = V(NERR), TMODE = 0		2		Vpp
810	Vam (PCOS)	Amplitude of positive cosinus	V(PCOS) = V(LAO), TMODE = 0		2		Vpp
811	Vam(NSIN)	Amplitude of negative sinus	V(NSIN) = V(NERR), TMODE = 1		2		Vpp
812	Vam (NCOS)	Amplitude of negative cosinus	V(NCOS) = V(LAO), TMODE = 1		2		Vpp
813	Voff()	Offset voltage sinus/cosinus	PSIN - NSIN, PCOS - NCOS	-50		50	mV
814	R (SIN/COS)	Ratio PSIN/PCOS, NSIN/NCOS		0.95		1.05	

Operating Modes

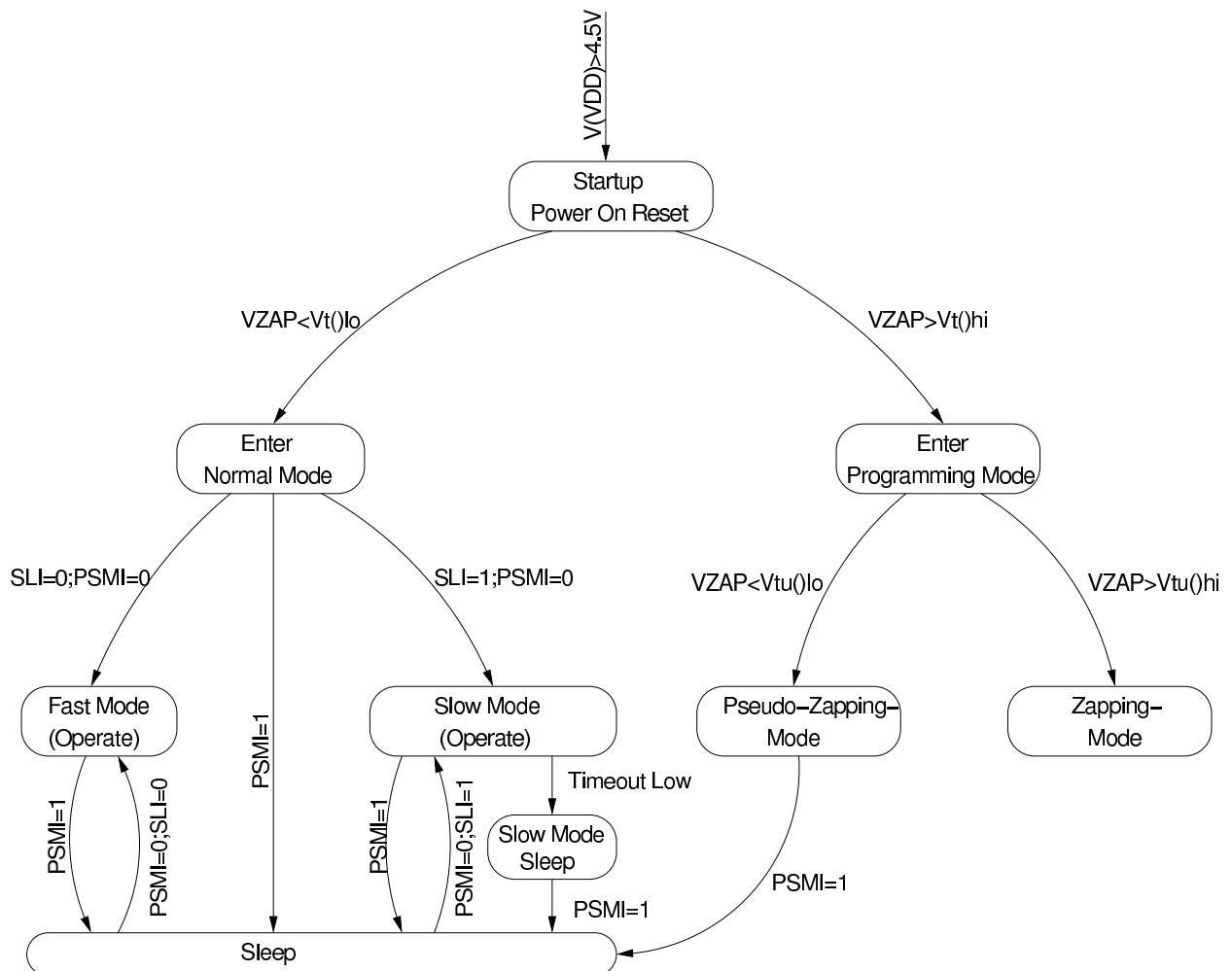


Figure 1: Modes

Figure 1 shows different modes of the iC-MP. There are two major operation modes:

- **Normal Mode:** Normal mode is divided into fast scanning mode and slow scanning mode. There are two minor operation modes:
 - **Fast Mode:** The iC-MP is always activated.
 - **Slow Mode:** The iC-MP goes to 'Slow Mode Sleep' after the first transmission of sensor-data over the serial interface.

- **Programming Mode:** In programming mode the iC-MP could be permanent configured. See Chapter 'Programming Mode' for details. There are two minor modes:

- **Pseudo-Zapping-Mode:** The internal register of iC-MP could be programmed for testing.
- **Zapping-Mode:** The zapping structure is being programmed.

Fast Scanning Mode

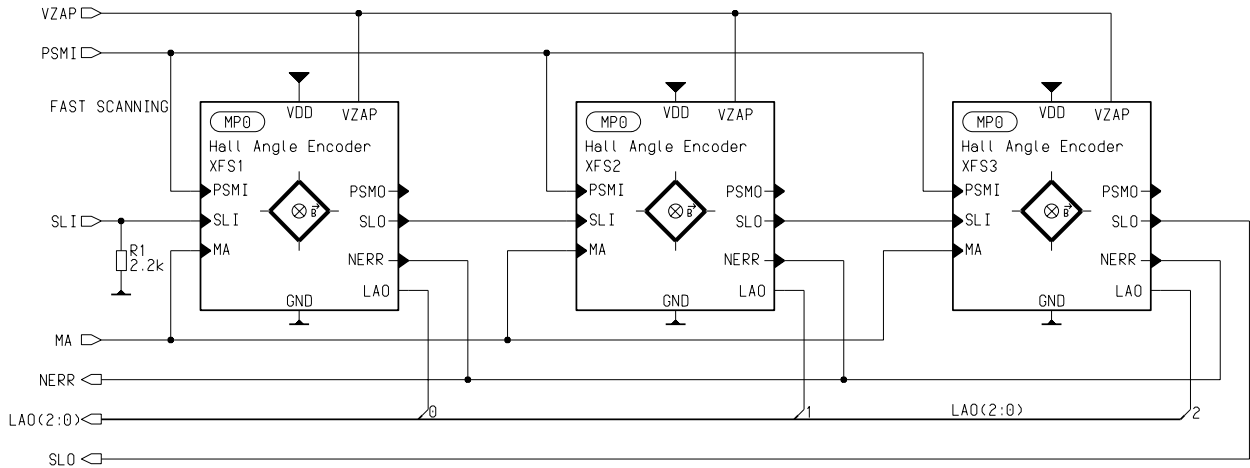


Figure 2: Fast Scanning Mode

In fast scanning mode all devices are active at the same time. With a start condition on MA the absolute position of all devices is latched and all absolute positions are transferred as one long data word.

Slow Scanning Mode

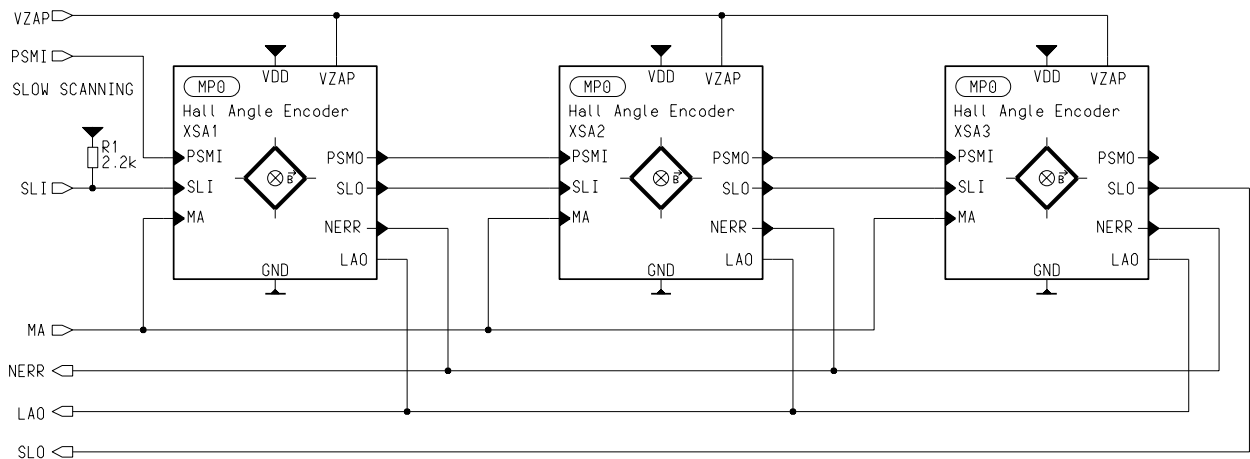


Figure 3: Slow Scanning Mode

In slow scanning mode only one device will be activated in chain. This device puts its absolute position on the SLO bus and the analog output voltage on the LAO bus. After a timeout on SLI, the next device is enabled (PSMO=high). The device needs some time after activation to find the actual position. The chain is reset by a logic high at PSMI pin.

Linear Analog Output

The LAO pin provides a linear analog output voltage representing the actual position. The output voltage can be either rail to rail or within the range of 10% to 90% of the supply voltage VDD, depending on the programmed configuration.

The zero position therefore starts at minimum voltage (either GND or 10% VDD) and ends its maximum (either VDD or 90% VDD) at the selected angular range limit (90°, 180°, 270° or 360°), depending on the chosen configuration.

LAO is tristate when the device is disabled.

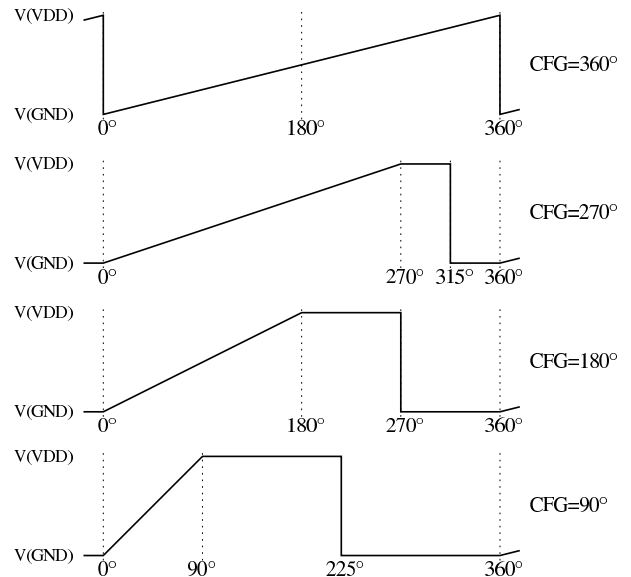


Figure 4: Linear Output Voltage

Serial Output (SLO)

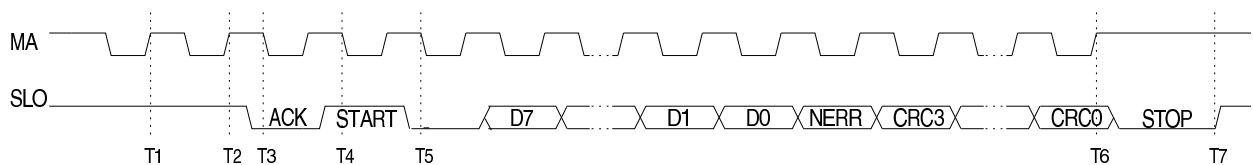


Figure 5: Timing Serial Data

D0 to D7 is the absolute position of magnet data with respect to the programmed offset (OFFSET1 xor OFFSET2 xor OFFSET3).

The absolute position is latched by a low to high transition on MA (time T1).

After the acknowledge (T3) on SLO the iC-MP requests processing time until (T4) the start condition is

being send. The processing time is needed in slow scanning mode while startup.

With the next rising edge (T4) on the clock pin the most significant bit is put on the serial data line SLO. After the 14th cycle (T6) either the controller stops clocking MA and the device is ready to latch a new position information after a time-out (T7) or by continuing clocking the previously latched position from the next device in chain is present at SLO. The data is gray-coded.

Programming Mode

When pulling the VZAP pin to a high and SLI to low during startup, the programming mode is entered. In this mode two operation categories are distinguished:

- Zapping mode (ZM)(VZAP = 6.8V): In ZM each diode is being zapped immediately with the rising edge of MA. See figure 6 for details. Zapping is only allowed for VDD = 5V ±5%, Tj = 10...40°C.

- Pseudo zapping mode (PZM)(VZAP = high): In PZM the iC-MP reacts the same as in ZM, but there is no zapping of the diodes. This mode could be used to program the iC-MP non-permanent for testing purpose.

The actual absolute position has to be read via the digital interface. The calculated offset could be clocked into the zapping diodes with SLI and MA.

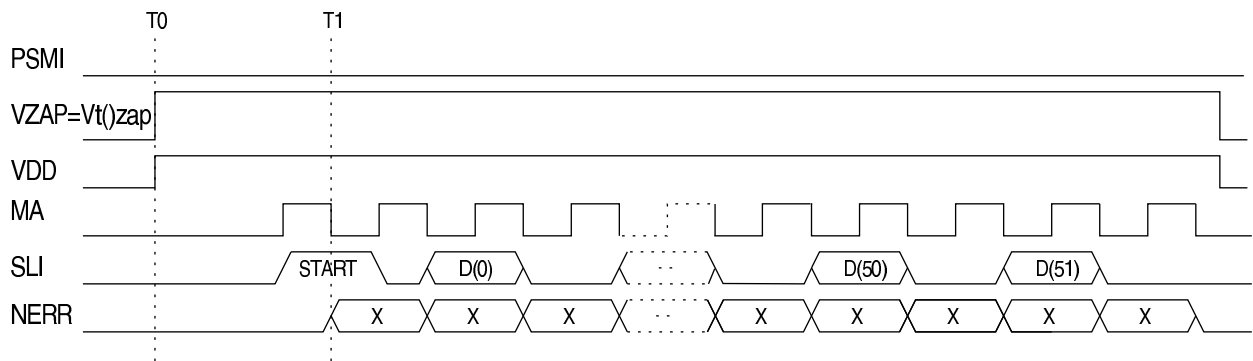


Figure 6: Serial Timing of Zapping

Figure 6 demonstrates how to program the diodes in the iC-MP. The meaning of the bits is shown in table 4. The iC-MP has the possibility to program three sets of parameter. The resulting Parameter (OFFSET, MODE) are generated by an xor-operation of the three sets of bits.

So if the first attempt to program the diodes fails, there is an possibility to try again. Because of the xor-operation the diode, which are already zapped, have to be known. On 'NERR' the programming of the Zener diodes could be read out in ZM and in PZM.

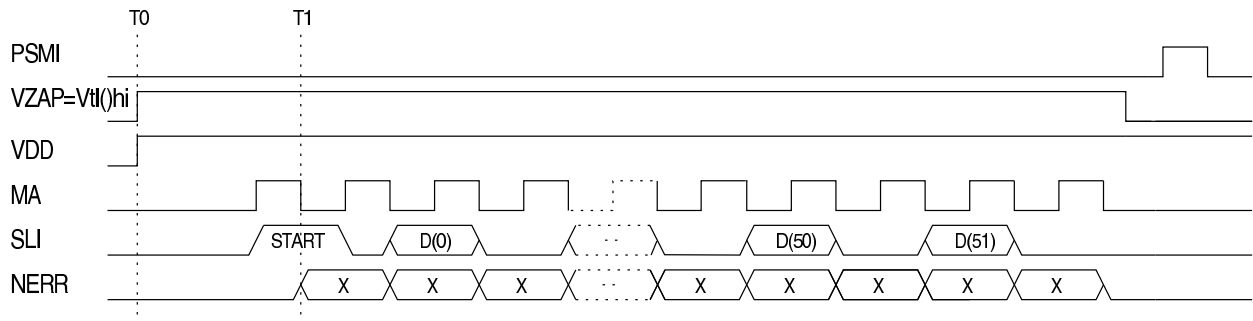


Figure 7: Serial Timing of Pseudo Zapping

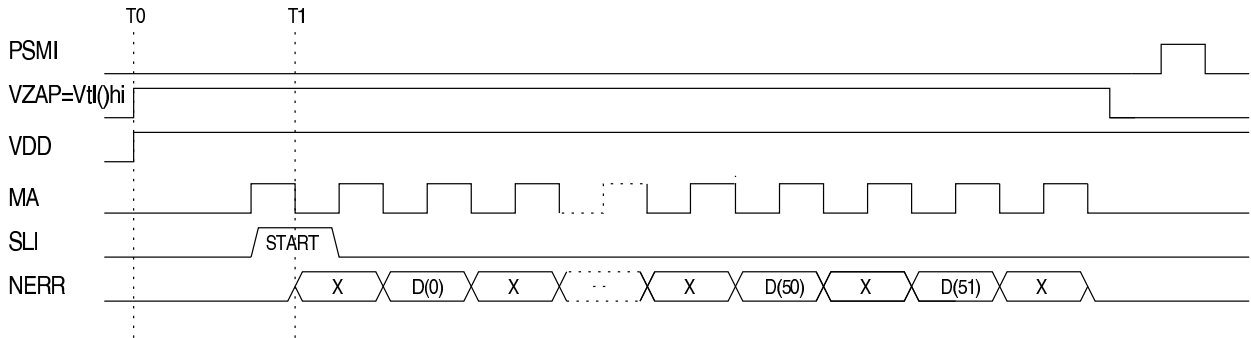


Figure 8: Serial Timing of Reading

D(53:0)	Parameter	Legend
7:0	OFFSET1(7:0)	Offset of the first set
11:8	MODE1(3:0)	Mode of the first set, see table 5
13:12	ENERR1(1:0)	Error Mask of the first set, see table 7
21:14	OFFSET2(7:0)	Offset of the second set
25:22	MODE2(3:0)	Mode of the second set, see table 5
27:26	ENERR2(1:0)	Error Mask of the second set, see table 7
35:28	OFFSET3(7:0)	Offset of the third set
39:36	MODE3(3:0)	Mode of the third set, see table 5
41:40	ENERR3(1:0)	Error Mask of the third set, see table 7
45:42	CRCID(3:0)	CRC ID
47:46	ZTEST(1:0)	Zappingdiodes for testing
51:48	TEST(3:0)	Test

Table 4: Programming Datastream

Table 5 illustrates the 'MODE'-bits. With two combinations of the rotation (CW, CCW) and four of the range (360°, 270°, 180°, 90°) eight codes are needed.

MODE(2:0)	Range	Rotation
"000"	360°	CW
"001"	270°	CW
"010"	180°	CW
"011"	90°	CW
"100"	360°	CCW
"101"	270°	CCW
"110"	180°	CCW
"111"	90°	CCW

Table 5: Operating Modes

MODE(3)	Range V(LAO)
"0"	0-100
"1"	10-90

Table 6: Operating Modes 3

ENERR(1:0)	Digital error	Loss of magnet
"00"	no	no
"01"	no	yes
"10"	yes	no
"11"	yes	yes

Table 7: Errormasks

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We understand suitable application of our published designs to be state-of-the-art technology which can no longer be classed as inventive under the stipulations of patent law. Our explicit application notes are to be treated only as mere examples of the many possible and extremely advantageous uses our products can be put to.

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8-BIT HALL ANGLE ENCODER

preliminary



Rev A1, Page 12/12

ORDERING INFORMATION

Type	Package	Order Designation
iC-MP	DFN10	iC-MP DFN10

For technical support, information about prices and terms of delivery please contact:

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