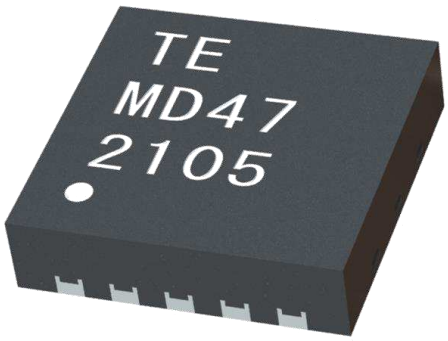


MD47 MAGNETORESISTIVE SENSOR

Optimized for switching applications and linear position measurement

Description

TE's MD47 digital sensor combines the sensitivity and precision of our MR sensor technology with our own advanced digital signal processing to create devices with unparalleled performance.

The easy-to-use digital interface enables precise magnetic sensing with shorter development cycles than ever. The sensor component can be used for non-contact position sensing or as a simple magnet switch with an adjustable, temperature-independent switch point over a wide field range.

The MD47 combines a unipolar MR sensing element with easy-to-use digital signal processing. The digital output provides magnetic field data as well as a calibration interface. The instrument is factory calibrated for temperature, and calibration coefficients are stored in internal non-volatile memory. All commands, data, and coefficients are contained in an elegant data structure that allows

rapid commissioning with minimum firmware.

Features

- SPI output
- 1-3 mT linear field range
- Up to 24-bit output resolution
- Up to 1 kHz sample rate for fast response
- 0.5 mA average supply current (@10Hz update rate)
- In-plane sensitivity perpendicular to Hall effect sensors
- Programmable offset and gain compensation

Applications

- Contactless position detection (presence, open/close)
- Industrial
- Consumer
- Automotive
- Small stroke pneumatic cylinders
- Cover positions of Notebooks and Mobiles
- Doors, windows etc.

Version	Modification	Visa	Date
0.1	Creation	AVO	15-Feb-2021
0.2	SPI Part added	OBO	28-Feb-2021
0.3	Temperature compensation added	AVO	01-Mar-2021
0.4	Change Product picture	AVO	04-Mar-2021
0.5	Update supply current, Bus structure details	AVO	12-Mar.2021
1.3	Checked in to PDM Link for promotion request	AVO	01-Apr-2021
	Add alternative configuration to ADC Update Pin6 description Update figure for Pin6 description Change HBM to Min = 4 kV (same as ASIC) Adding/correcting figure Change 24 bit SN to 40 bit SN Remove Temperature characteristics (Tout) L1 added in table for component dimensions		21-Jul-2022
	Specifications added	JMR	26-Oct-2022
2.0	40Bit SN communication for Minor SN added	OBO	03-Nov-2022
A	Small errors in		

Specification

Operating power supply range	1,6 V – 3,6 V
Operating temperature	-40 °C - +125 °C
Average Current	1,06 mA
Sleep Current	0,02 µA
Data Update Rate	0,37 ms – 18,04 ms (6 Oversampling modes available)
SPI Clock Rate	10 MHz
Digital Resolution	24 bit
Additional Features	Calibrated Component Temperature compensated output signal Scaleable Sensor chain capability Very low hysteresis,
Environmental standards	RoHS, Reach

Functional block

The MD47 encapsulates an anisotropic magnetoresistive sensor and enables a temperature measurement. Internally an AFE (analog front end) realizes digitization of the measurement data. Via the SPI interface, stored calibration data and measurement data could be obtained.

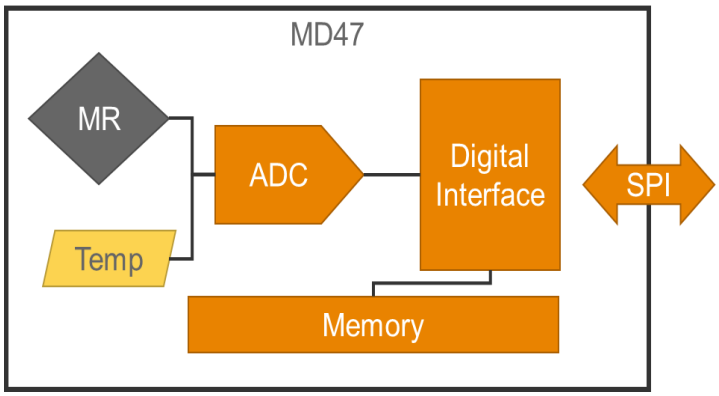


Figure 1: MD47 block diagram

Pin Assignment

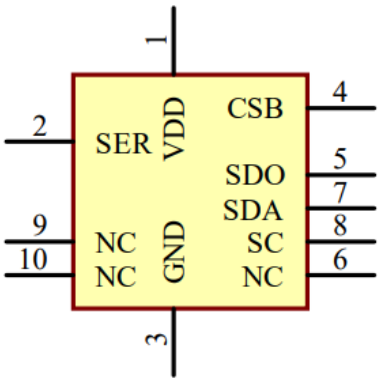


Figure 2: Pin assignment and electrical symbol

Pin number	Pin name	Pin function
1	VDD	Power supply voltage
2	SER	Set serial interface: must be connected to GND
3	GND	Ground
4	CSB	SPI chip select (active low)
5	SDO	SPI serial data output
6	NC	Do not connect
7	SDA	SPI serial data input
8	SC	SPI serial data clock
9	NC	Not connected
10	NC	Not connected

Table 1: Pin assignment

Electrical Specifications

Absolute maximum ratings

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage	VDD		**-0,3**		**3.6**	V
Operating temperature			**-40**		**125**	°C
Storage temperature			**-55**		**150**	°C

Operating conditions

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage	VDD		**1.6**	**3.3**	**3.6**	V
Standby supply Current (no conversation)	Isby_25 °C Isby_85 °C	VDD = 3.0 V T = 25 °C T= 85 °C		**0.02** **0.50**	**0.14** **1.40**	µA µA
Supply current during conversation	Ivdd	VDD = 3.0 V		**1.06**		mA
Conversation time	Tconv		**14.76**	**16.40**	**18.40**	ms
Delay after conversation	Tdel		**0**			µs
Serial Data Clock	SCL				**10**	MHz
Ambient temperature	T		**20**	**25**	**30**	°C
Applied magnetic field	Hy	|Hx| < 0.1 kA/m (*)	**-7**		**+7**	kA/m
Magnet amplitude output	Mout		**0**		**16777216**	digit
Temperature output	Tout		**0**		**16777216**	digit
Amplitude of reference curve (**)	AmplRefCurve				**10000000**	digit

(*) The magnitude of the field in the X-direction must be less than 0.1 kA/m in the application.

(**) AmplRefCurve could be set to any normalized value needed for the application. Refer to section “Theory of operation” for details.

Digital Inputs (SCL, SDI, CS, SER)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Input High Voltage	VIH	VDD = 1.6…3.6 V	0.8 VDD		VDD	V
Input Low Voltage	VIL	VDD = 1.6…3.6 V	0.0 VDD		0.2 VDD	V
Input leakage current (Vin = Vss or Vdd)	Ileak_25oC Ileak_85oC_	T = 25 °C T = 85 °C	0.01 0.25	0.01 0.25	0.14 1.40	µA µA
Input Capacitance	CIN			6		pF
CS low to first SCL rising	tCSL			21		ns
CS high from last SCL falling	tCSH			21		ns
SDI setup to first SCL rising	tDSO			6		ns
SDI hold from SCL rising	tDO			6		ns

Digital outputs (SDI, SDO, INT)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Output High Voltage	Voh	Isource = 0.5 mA	**0.8 VDD**		**VDD**	V
Output Low Voltage	Vol	Isink = 0.5 mA	**0.0 VDD**		**0.2 VDD**	V
Output Capacitance	Cout				**12**	pF
Load Capacitance	Cload				**16**	pF

ESD

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Digital Pin's		Human Body Model (HBM) pin to pin including VDD and GND	**4**			kV

Latch-up

Parameter	Symbol	Condition	Min	Typ	Max	Unit
All pins		JEDEC standard no.78	**±100**			mA

Measurement characteristics

Magnetic characteristics

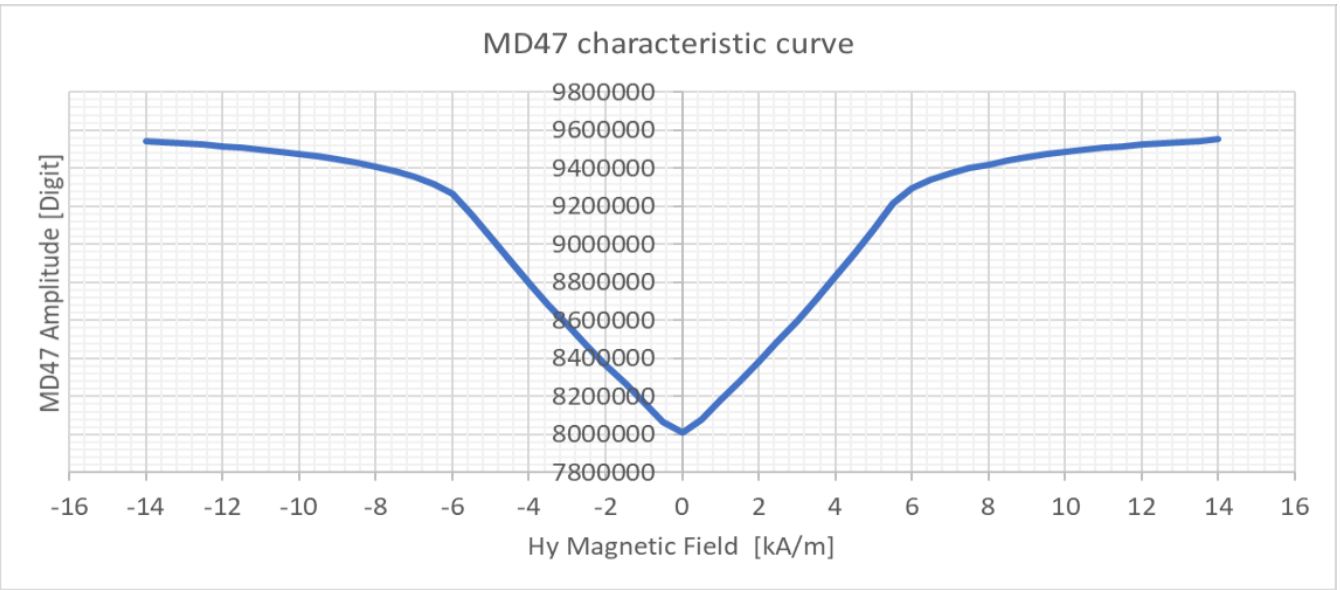


Figure 3: MD47 characteristic magnetic output curve

Due to its design, the MD47 is sensitive to a magnetic field component referred to as Hy in the following. A field sweep -14 ... + 14 kA/m results in the following characteristic output curve.

Device Parameters

The MD47 is equipped with an internal memory that contains correction values for active temperature compensation. The available parameters are listed below. The parameter set can be read out via a digital interface (see chapter "Serial digital interface").

Name	Parameter	Range	Unit	Typical value
P1	TC-Offset	16 Bit signed	Digit/K	2700
P2	TC-Amplitude	16 Bit signed	(1/32768)/K	-115
P3	TC-Flank slope	16 Bit signed	(1/32768)/K	-115
P4	Temp. sensor offset	16 Bit signed	512 Digit	16384
P5	Temp. sensor slope	16 Bit signed	Digit/(0.1 K)	5030
P6	Flank slope	16 Bit signed	32 Digit/(kA/m)	8400
P7	Offset	24-Bit unsigned A/D-C-Scale	Digit	7600000
P8	Flank intercept	24-Bit unsigned A/D-C-Scale	Digit	7500000
P9	Amplitude	24-Bit unsigned A/D-C-Scale	Digit	1900000

Table 2: MD47 description of parameter

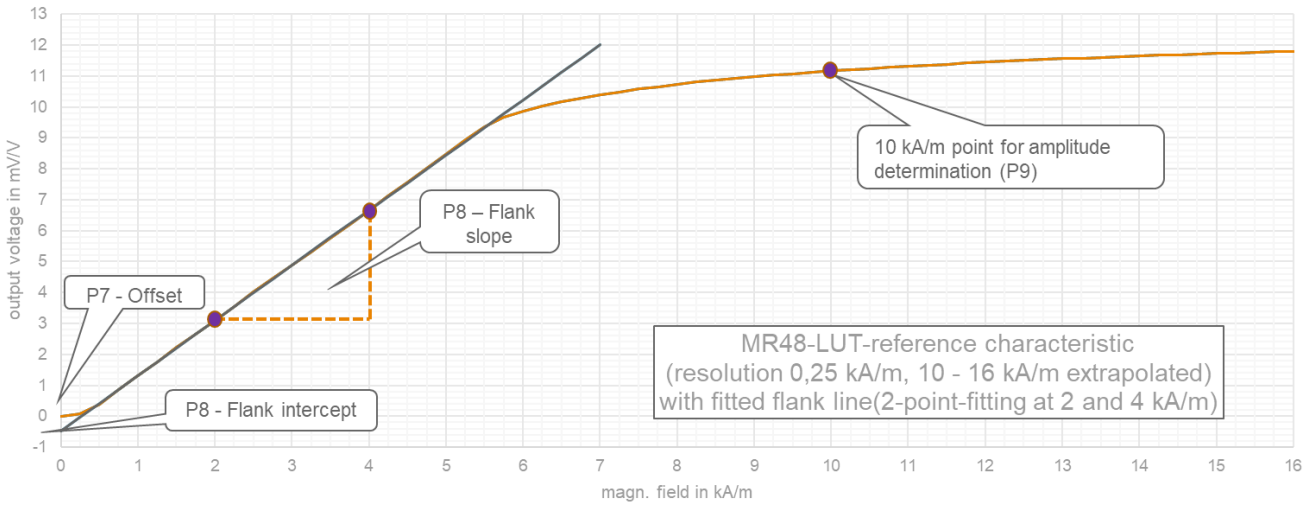


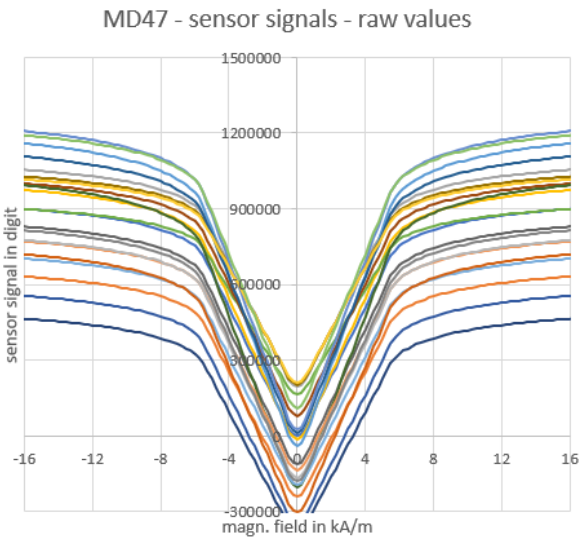
Figure 4: MR48 reference characteristic (resolution 0,25 kA/m, 10 - 16 kA/m extrapolated) with fitted flank line (2-point-fitting at 2 and 4 kA/m):

Theory of operation – Temperature compensation

The MD47 is pre-calibrated and thus provides parameters for further processing. The parameters can be read out in use, e.g., in the EOL test, and stored in the processing unit for later use. Furthermore, the MD47 is equipped with a temperature measurement option. With this additional information and the stored parameter, it is possible to subject the magnetic MD47 measurement signal to temperature compensation.

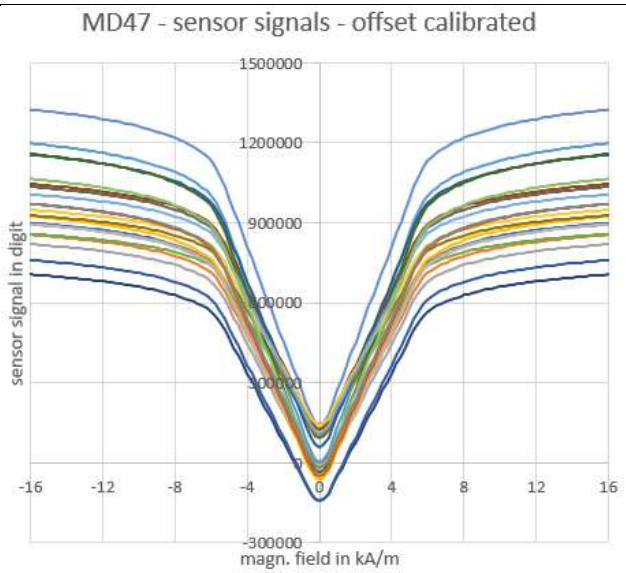
The actual magnetic measurement value (hereafter referred to as “Mout”) is compensated to a general temperature value of 25 °C. The purpose is to establish a signal processing that enables normalizing the MD47 measurement data (e.g., in an array application) to one significant signal level with a value of ***AmplRefCurve*** at 10 kA/m stimulation field strength.

After that, the signal processing consists of the following steps:

1. readout parameters and make them available in the processing unit. (Can be located once in the EOL)	
2. raw magnetic data and temperature raw data measurement (***Mout, Tout***)	
3. compensation step 1: Calculate temperature T via the measured temperature signal ***Tout*** $$T = 25° + \frac{Tout - (512 * P4)}{10 * P5}$$	

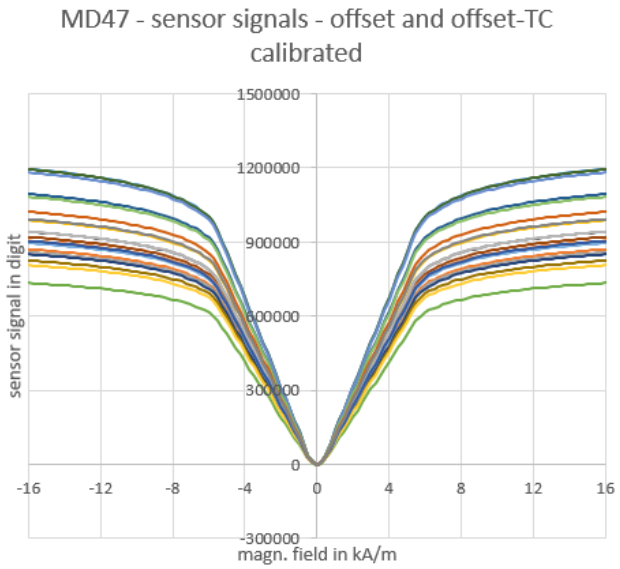
4. compensation step 2: calculate offset free magnetic signal ***CS1***

$$CS1 = M_{out} - P7$$



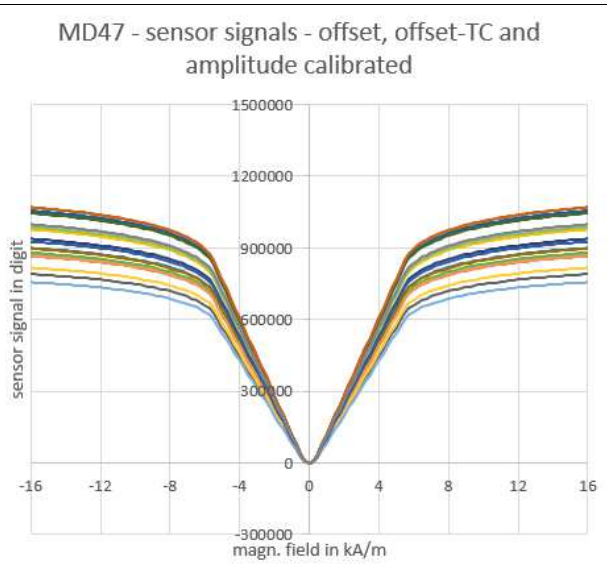
5. compensation step 3: temperature compensation of offset

$$CS2 = CS1 - (T - 25°C) * P1$$



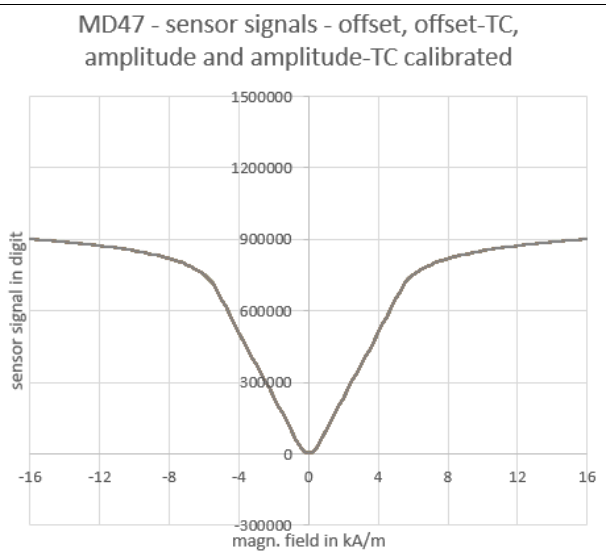
6. compensation step 4: amplitude compensation

$$CS3 = CS2 * \left(\frac{Ampl_{RefCurve}}{P9}\right)$$



7. compensation step 5: temperature compensation of amplitude

$$CS4 = \frac{CS3}{\left(1 + (T - 25°C) * \left(\frac{P2}{32768}\right)\right)}$$



Serial digital interface

SPI bus interface

MD47 has built-in an SPI serial interface. For the SPI interface to function correctly, the SER pin must be connected to ground. To keep a predictable behavior during a running conversion, the configuration cannot be changed (the digital part does not accept Write Config). A new conversion cannot be started during a conversion running (The digital part does not accept Conversion command during this time).

The MD47 SPI interface implements the SPI standard mode CPHA = 0 and CPOL = 0 and data is transmitted MSB first.

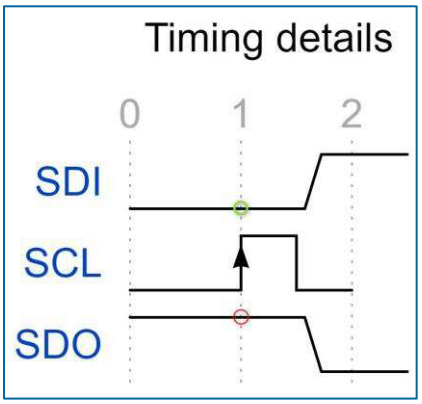
In the timing diagrams in this document, it should be noted that the dashed line defines the sampling time of the data lines. Sampling is triggered by the rising edge of the SCL line. After the rising edge of the SCL line, the data lines can be set to the state of the next bit.

Please refer the “digital inputs table” for timing details.

The example diagram shows for bit # 1:

At the sampling time (rising SCL edge):

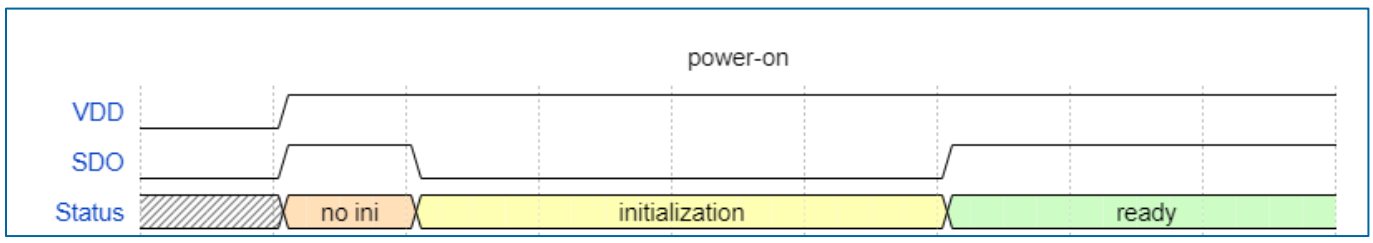
- SDI = LOW (green marking)
- SDO = HIGH (red marking)



Power on behavior

MD47 has a built-in power-on circuit. After the power-up, the digital block will be in the reset state, and the ADC is initialized. This sequence lasts about 100 to 260 µs after power-on has happened.

After power-on, but before the initialization is started, the **SDO** pin is set to high. **SDO** is set to low at the start of the initialization and reset to high when the startup sequence has finished signaling the chip is ready for operation.



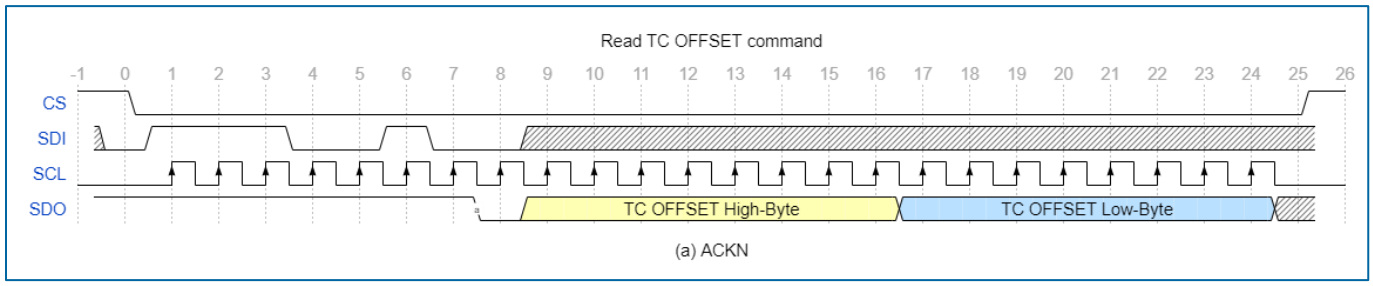
Reading calibration data: general

The MD47 has a 16-bit internal memory structure.

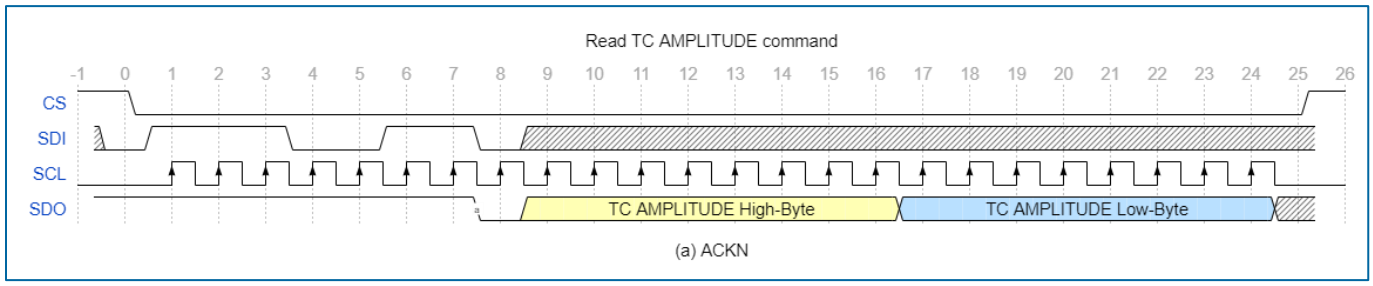
8-bit and 16-bit calibration data can be read out with a single command, while 24bit data require two commands.

After the command (Bit 1..7) is recognized by the chip, SDO goes low (Bit 8), indicating that the command has been acknowledged.

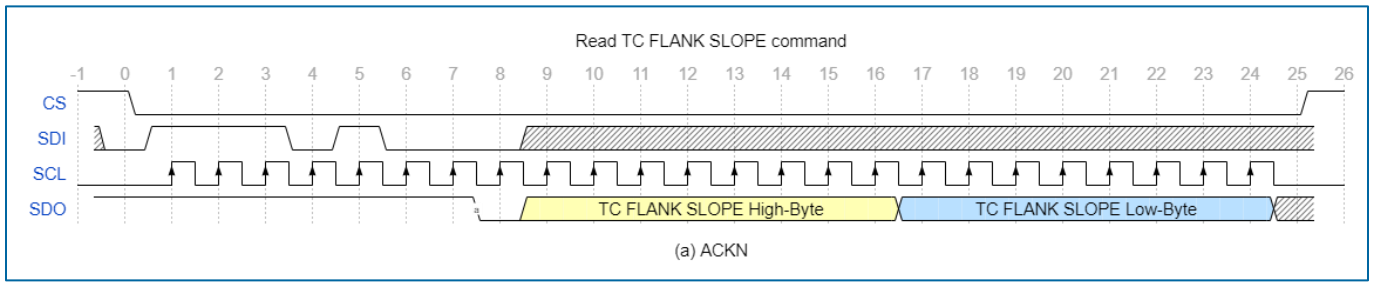
Read calibration data: TC OFFSET (SDI command: 0xE4)



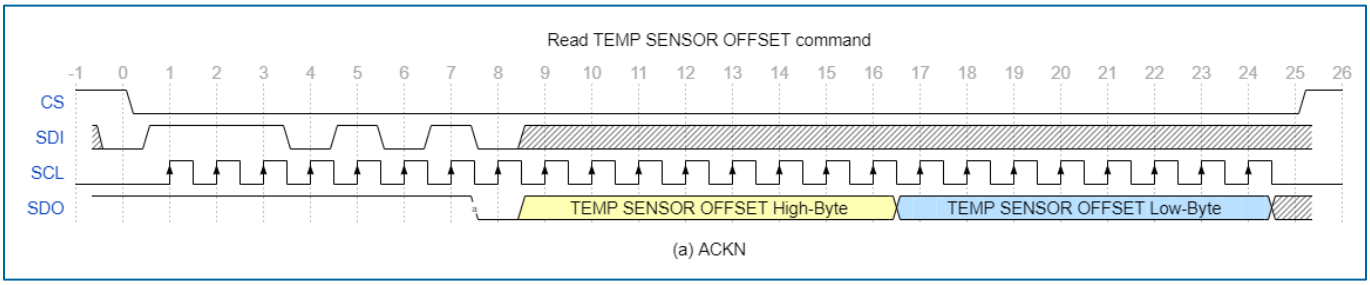
Read calibration data: TC AMPLITUDE (SDI command: 0xE6)



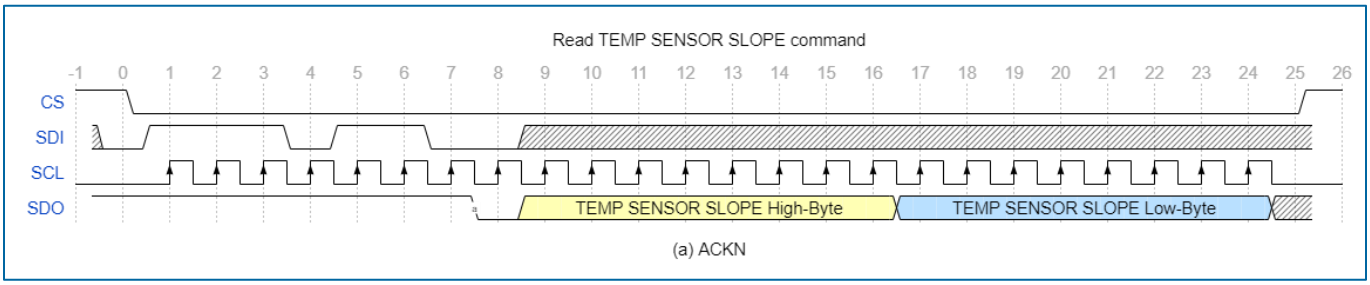
Read calibration data: TC FLANK SLOPE (SDI command: 0xE8)



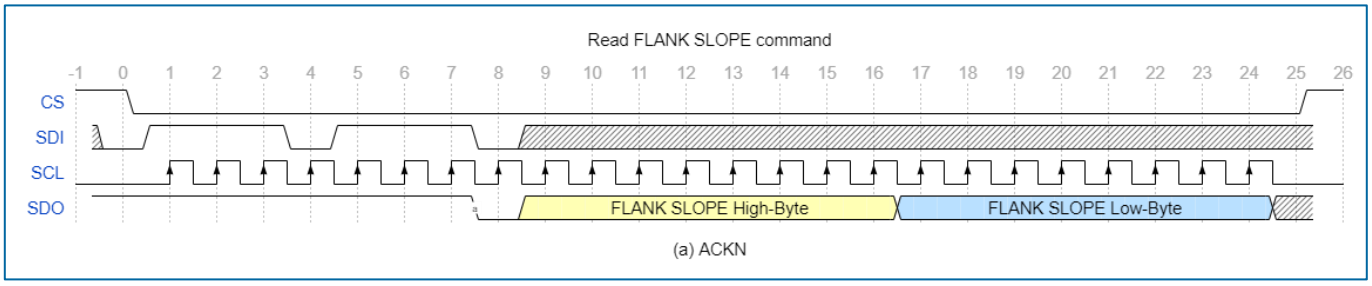
Read calibration data: TEMP SENSOR OFFSET (SDI command: 0xEA)



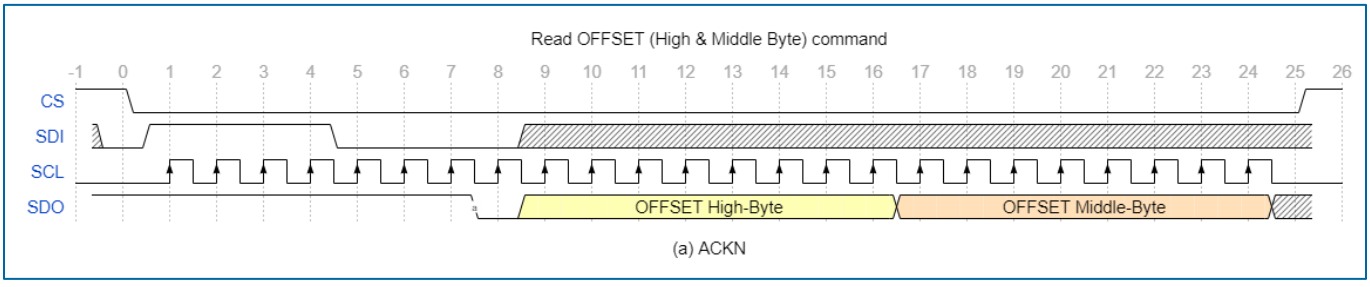
Read calibration data: TEMP SENSOR SLOPE (SDI command: 0xEC)



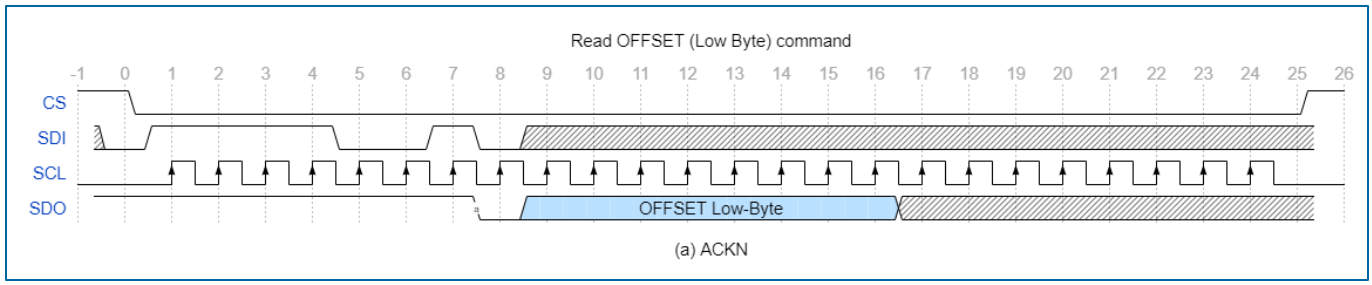
Read calibration data: FLANK SLOPE (SDI command: 0xEE)



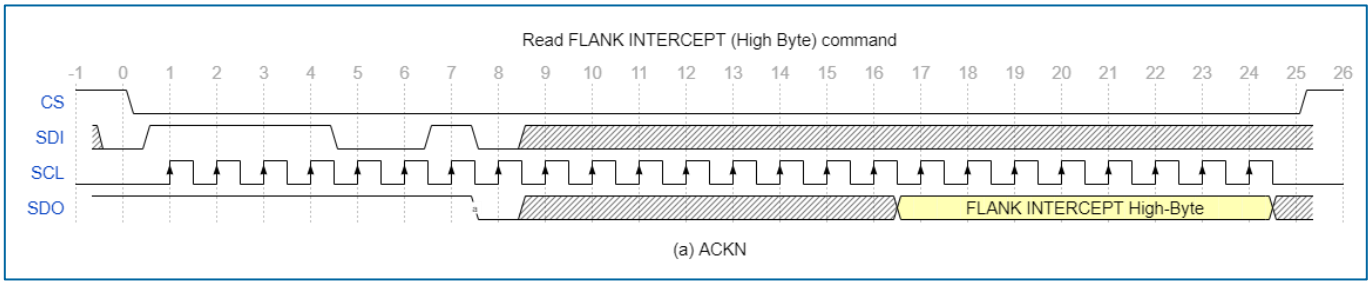
Read calibration data: OFFSET High & Middle Byte (SDI command: 0xF0)



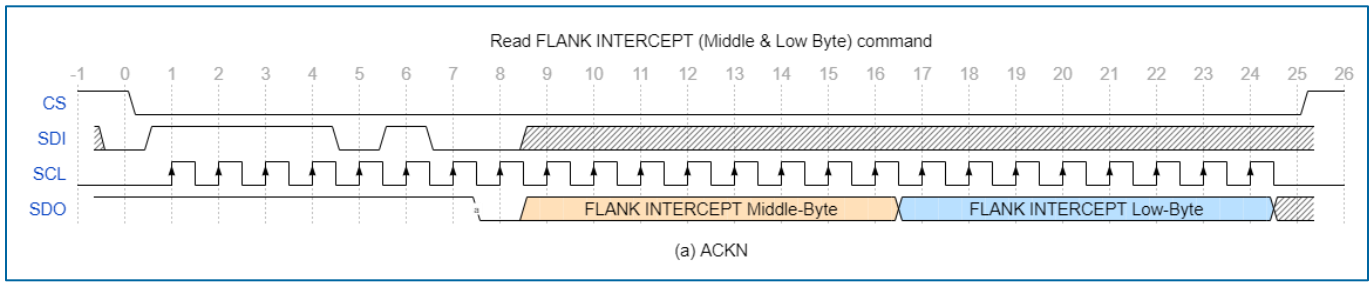
Read calibration data: OFFSET Low Byte (SDI command: 0xF2)



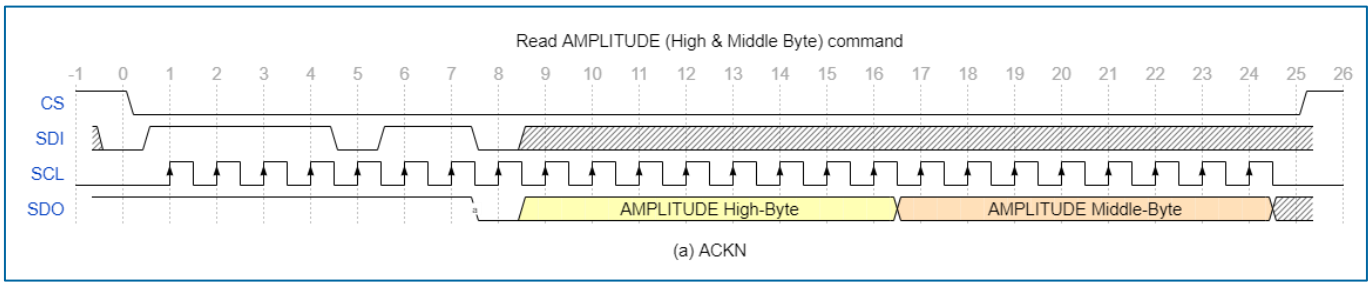
Read calibration data: FLANK INTERCEPT High Byte (SDI command: 0xF2)



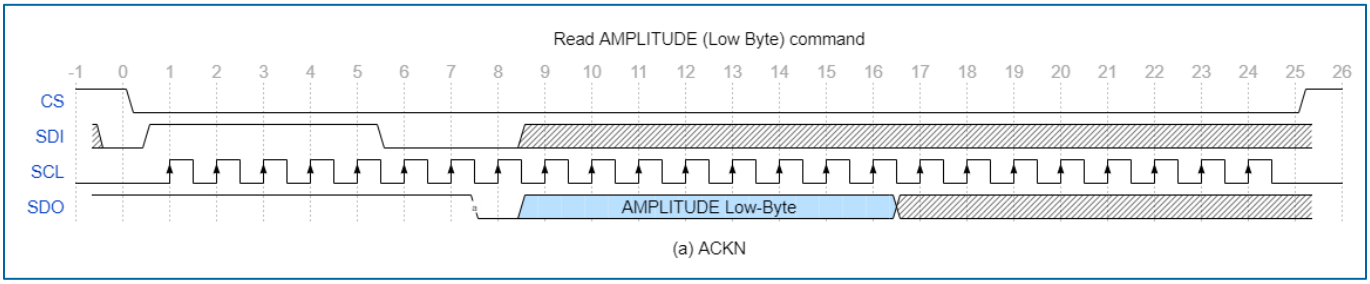
Read calibration data: FLANK INTERCEPT Middle &Low Byte (SDI command: 0xF4)



Read calibration data: AMPLITUDE High & Middle Byte (SDI command: 0xF6)



Read calibration data: AMPLITUDE Low Byte (SDI command: 0xF8)



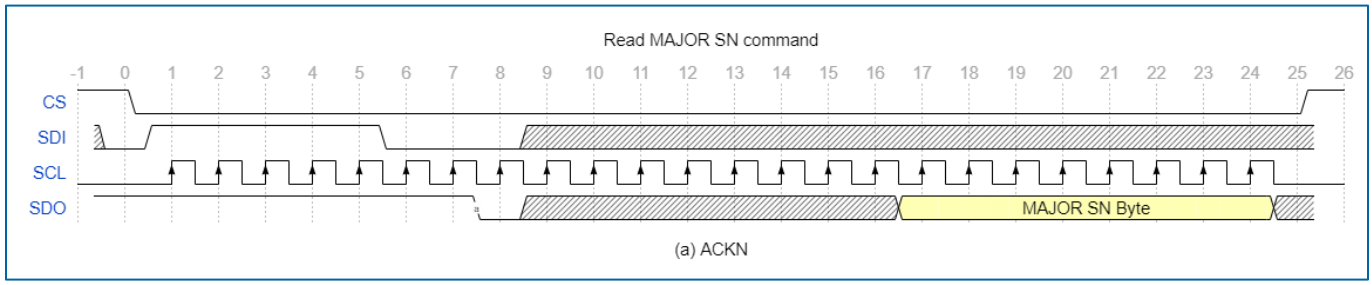
Calibration data: Serial number

The 40-bit (unsigned) serial number is divided into two parts for a better overview:

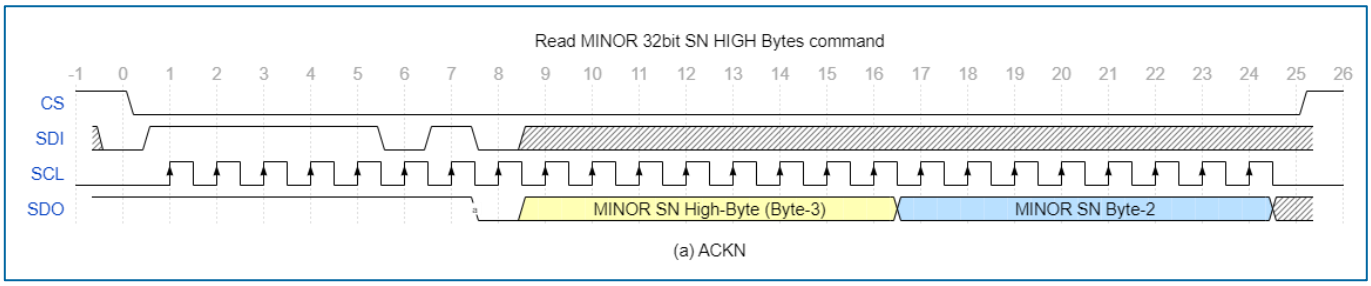
- An 8-bit MAJOR-SN part
- A 32-bit MINOR-SN part

Read as 40-bit SN	**Most-significant byte**				**Least-significant byte**
Alias name	MAJOR-SN Byte	Byte 3	Byte 2	Byte 1	Byte 0

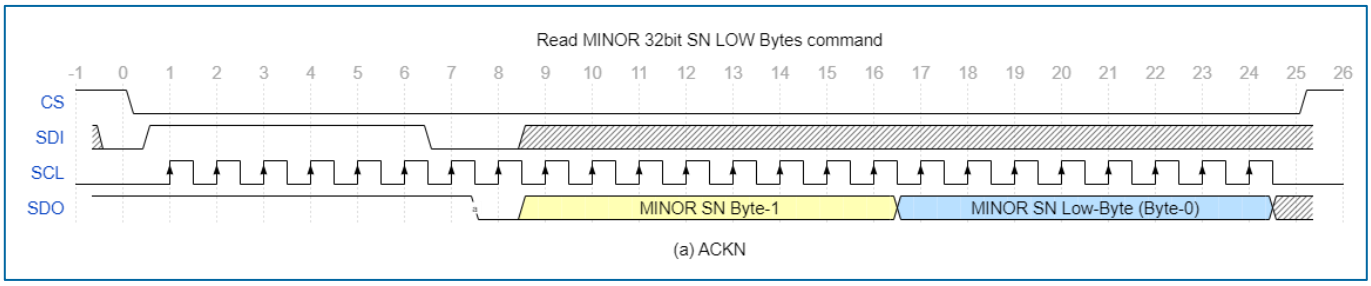
Read calibration data: MAJOR 8-bit SN (SDI command: 0xF8)



Read calibration data: MINOR 32-bit SN (High Bytes) (SDI command: 0xFA)



Read calibration data: MINOR 32-bit SN (Low Bytes) (SDI command: 0xFC)

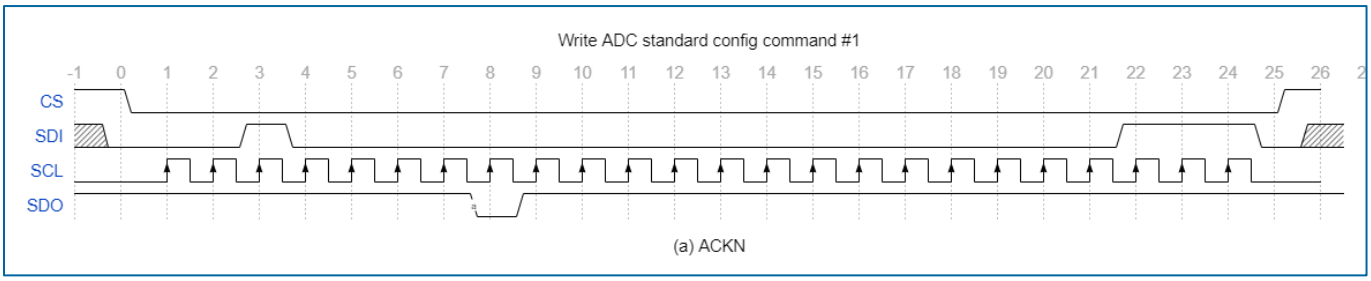


Write standard configuration to ADC

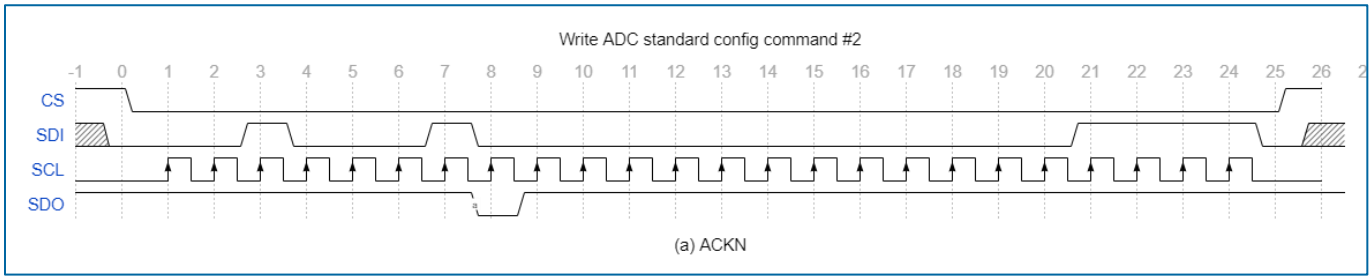
To configure the ADC, two separate commands must be sent to the MD47.

This must be done once after each power-up before the first conversion is started.

Write standard configuration to ADC command #1 (SDI command: 0x20 0x00 0x07)



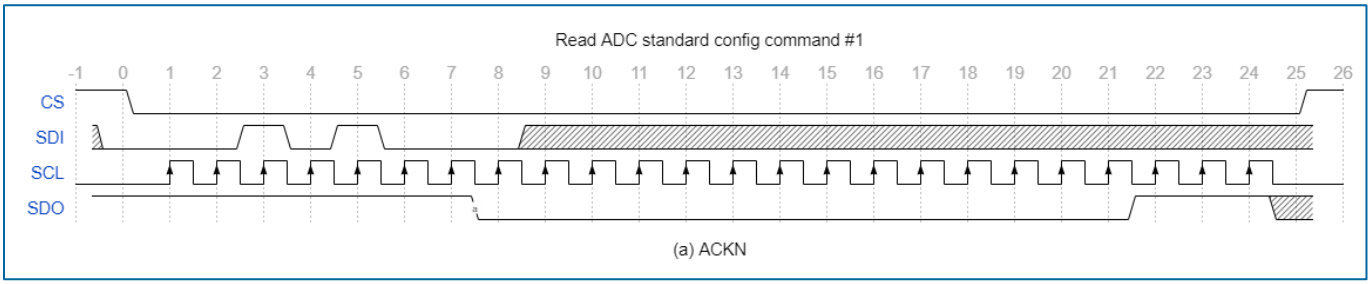
Write standard configuration to ADC command #2 (SDI command: 0x22 0x00 0x0F)



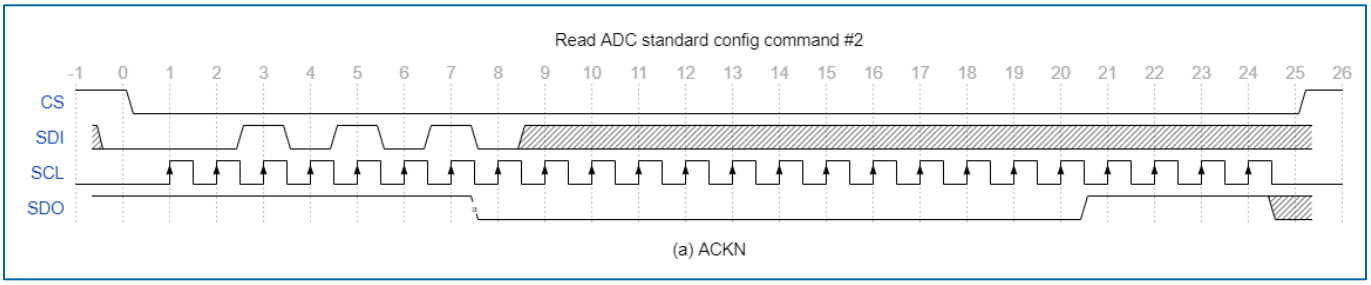
Read (Verify) configuration from ADC

Reading the configuration to verify the written configuration is recommended. Please compare the received data with the bit pattern in the figures.

Read standard configuration to ADC command #1 (SDI command: 0x28)



Read standard configuration to ADC command #2 (SDI command: 0x2A)



Write alternative configuration to ADC

To achieve higher sampling speeds, the command mentioned above, "*standard configuration to ADC command #1 (SDI command: 0x20 0x00 0x07),*" can be replaced by one of the following. These commands use lower oversampling rates than the standard configuration, resulting in more inadequate signal-to-noise ratios.

Oversampling mode	SDI command (hex)	ADC sampling time [ms]
0	0x20 0x00 0x00	0.37
1	0x20 0x00 0x01	0.65
2	0x20 0x00 0x02	1.22
3	0x20 0x00 0x03	2.34
4	0x20 0x00 0x04	4.58
5	0x20 0x00 0x05	9.07
6 (default / standard)	0x20 0x00 0x07	18.04

Table 3: Oversampling mode and ADC Sampling time

Start magnetic conversion (SDI command: 0x44)

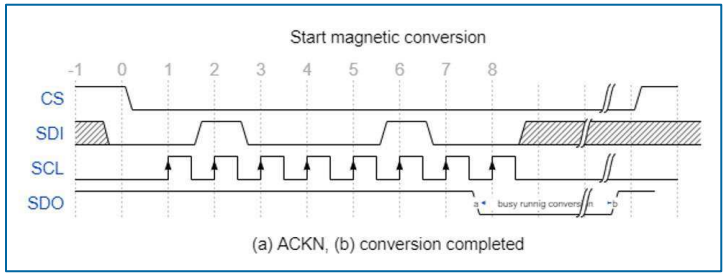
An ADC conversion of the magnetic sensor signal is started using the "Start magnetic conversion" command. This command is not accepted during an ongoing conversion.

After the command (Bit 1..7) is recognized by the chip, SDO goes low (Bit 8), indicating that the command has been acknowledged and conversion is running.

SDO goes high again when the conversion is completed.

The result of the conversion is transferred to the data register after the conversion. It is possible to trigger on the rising edge of SDO to get when the operation is finished. If the SDO pin cannot be checked, a delay of at least 18.04 ms must be implemented before the result can be read.

In this case, the CS line can be released (set to HIGH) after the transmission of the 8th bit.



(a) ACKN, (b) conversion completed

Start temperature conversion (SDI command: 0x48)

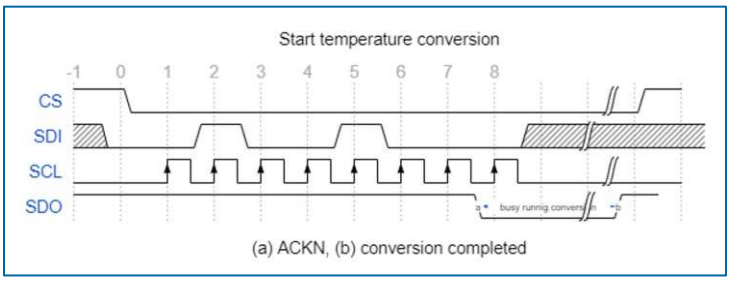
An ADC conversion of the internal temperature sensor signal is started using the "Start temperature conversion" command.

After the command (Bit 1..7) is recognized by the chip, SDO goes low (Bit 8), indicating that the command has been acknowledged and conversion is running.

SDO goes high again when the conversion is completed.

The result of the conversion is transferred to the data register after the conversion. It is possible to trigger on the rising edge of SDO to get when the operation is finished. If the SDO pin cannot be checked, a delay of at least 18.04 ms must be implemented before the result can be read.

In this case, the CS line can be released (set to HIGH) after the transmission of the 8th bit

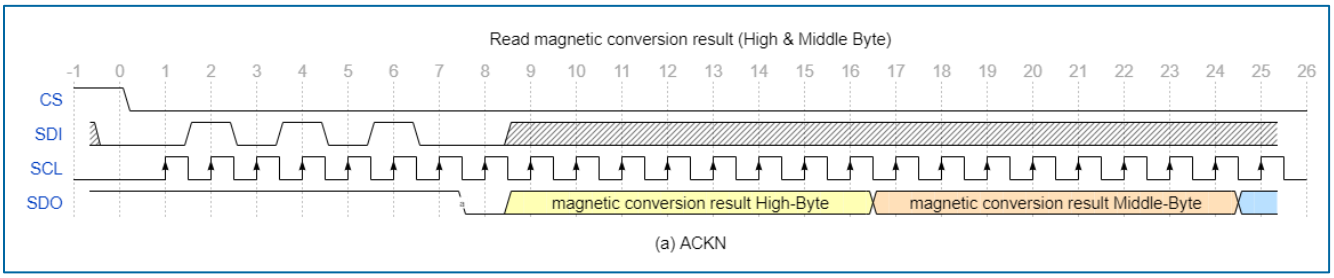


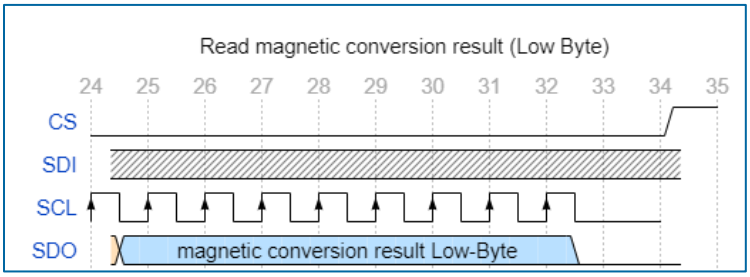
Read magnetic conversion result (SDI command: 0x54)

After the magnetic signal conversion, the ADC result is read using the “Read magnetic conversion result” command.

After the command (Bit 1..7) is recognized by the chip, SDO goes low (Bit 8), indicating that the command has been acknowledged.

The 24-bit result is read out by clocking three more bytes.

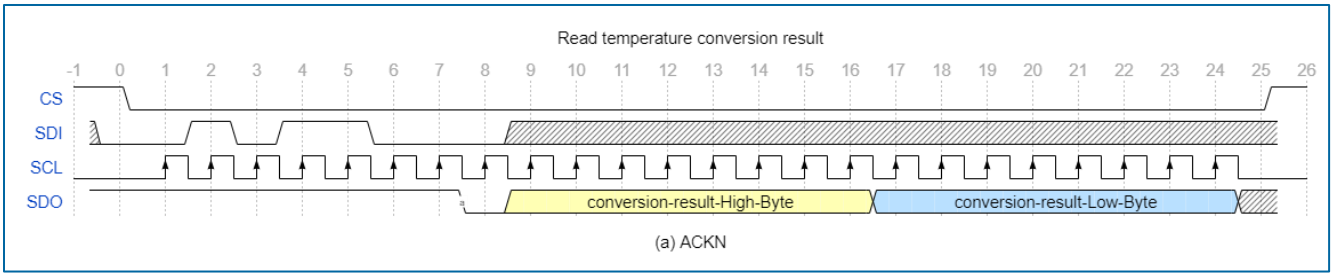




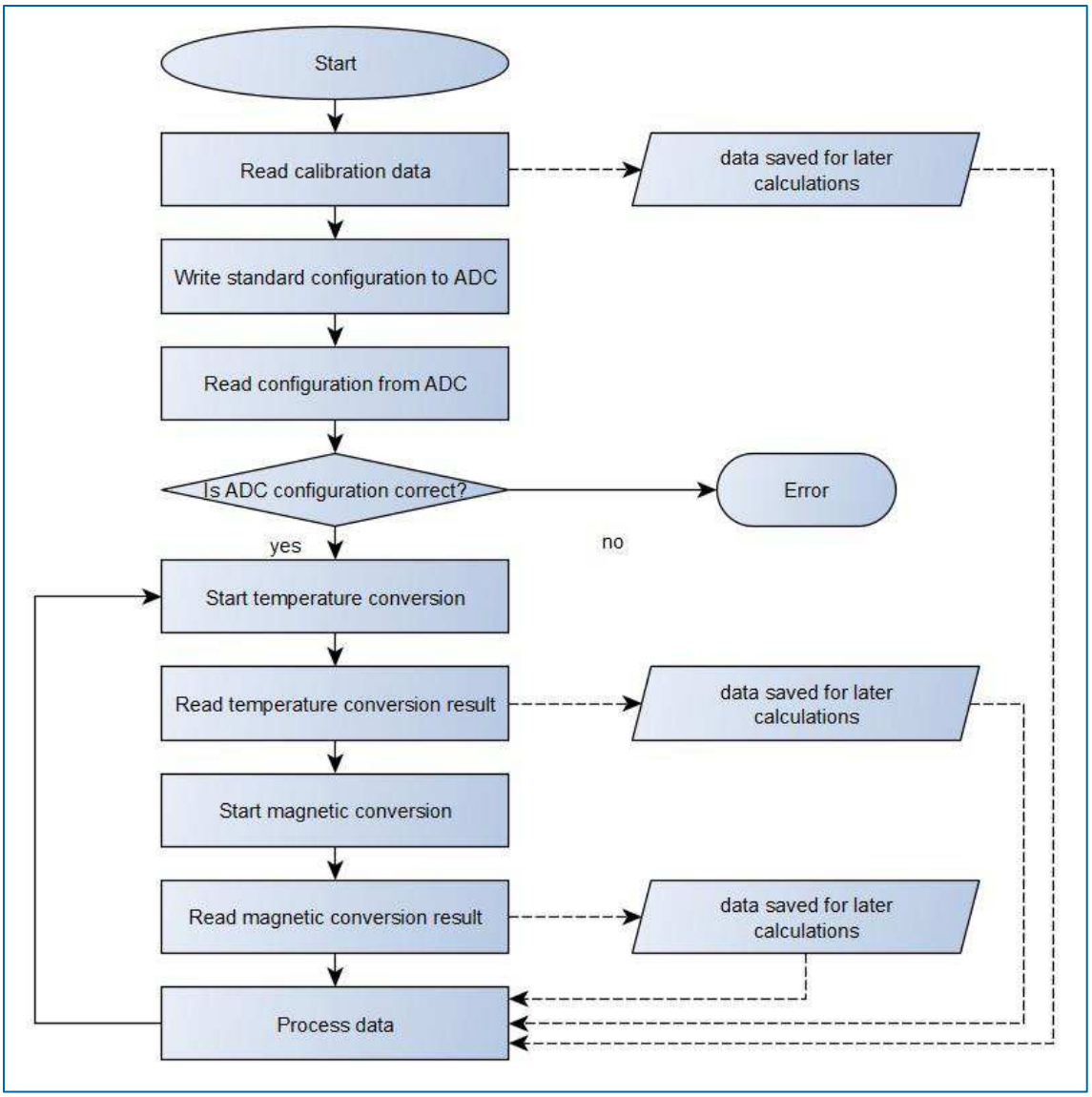
Read temperature conversion result (SDI command: 0x58)

After the temperature signal conversion, the ADC result is read using the “Read temperature conversion result” command.

After the command (Bit 1..7) is recognized by the chip, SDO goes low (Bit 8), indicating that the command has been acknowledged. The 16-bit result is read out by clocking two more bytes.



Typical Sequence



Typical application

Electrical Circuit

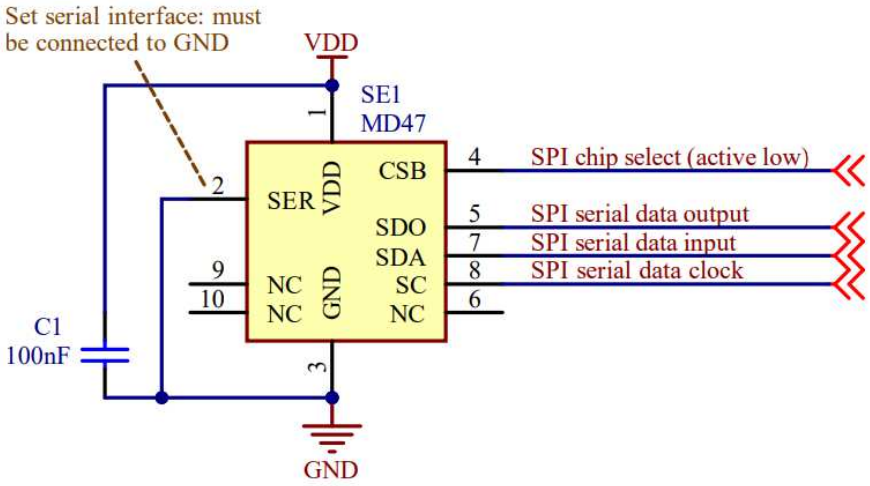


Figure 5: Typical electrical circuit

Bus structure – reference design

A generic array of MD47 could be chained together by the help of digital flip flops, which represent a shift register for the CS of each MD47. In that way each MD47 could be addressed, and a SPI communication could be done with the specific sensor node.

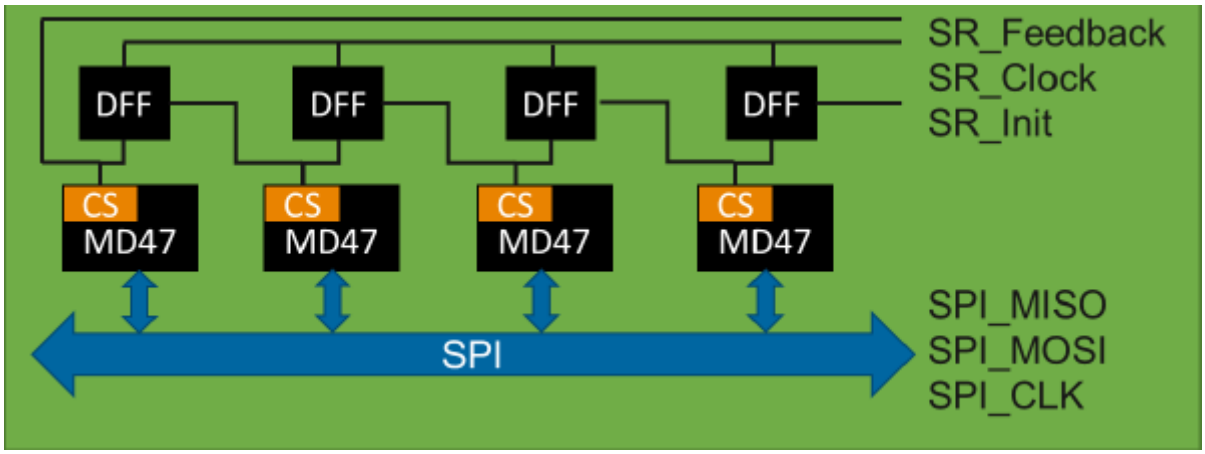


Figure 6: Block diagramm of SPI Communication example

Controlled by the master MCU, the sensor chain could be read out in the following way:

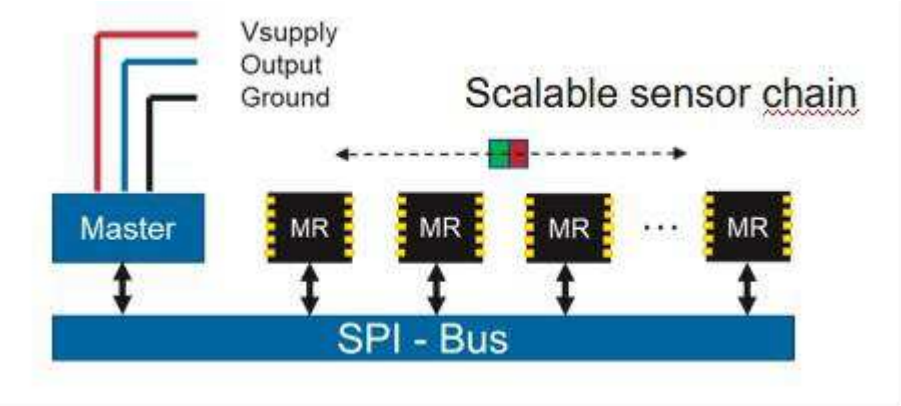
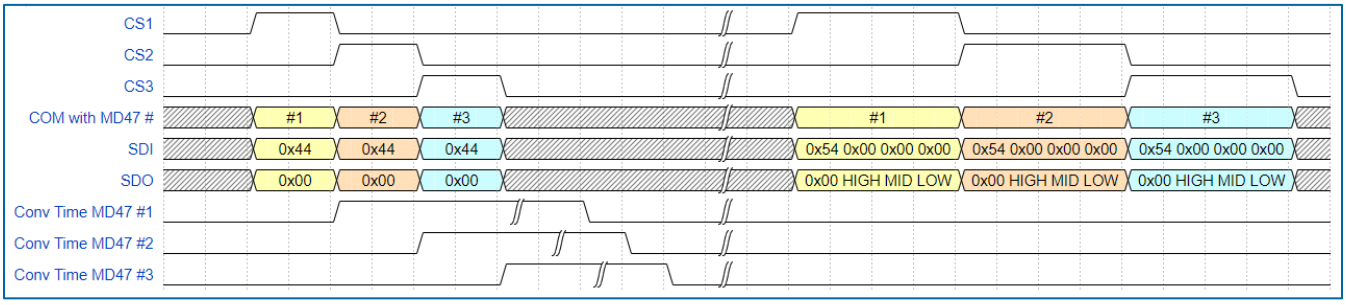


Figure 7: Scaleable Sensor Chain controlled by maste MCU

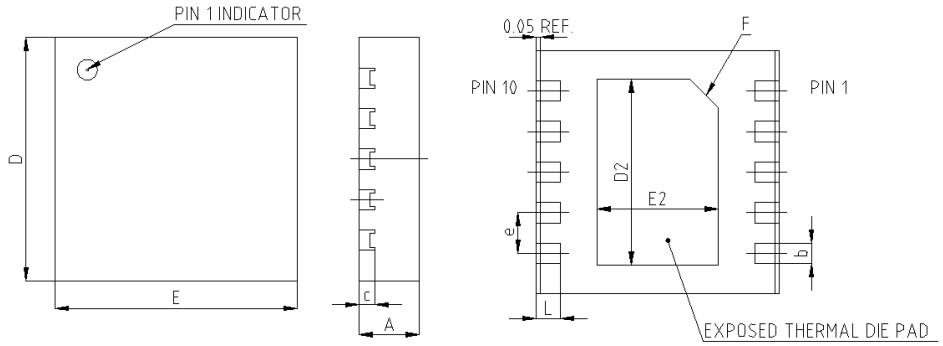
A combination of “Start Conversion” and “Read out” leads to an optimized flow in terms of array update rate as the conversion time of each sensor could be used to communicate with the other sensors of the array in parallel.

1. Start conversation for each sensor node.
2. Wait conversation time for sensor #1 → read out result.



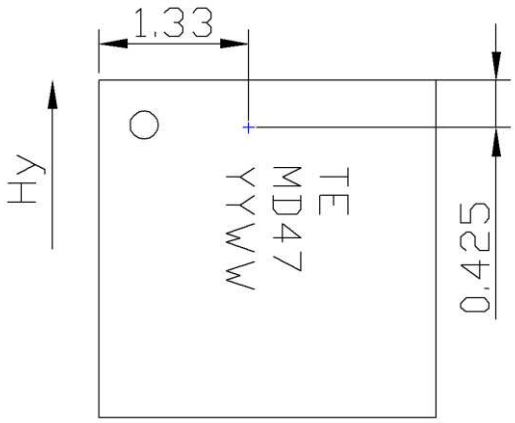
Package Information

Package Outline Dimensions and Pinout

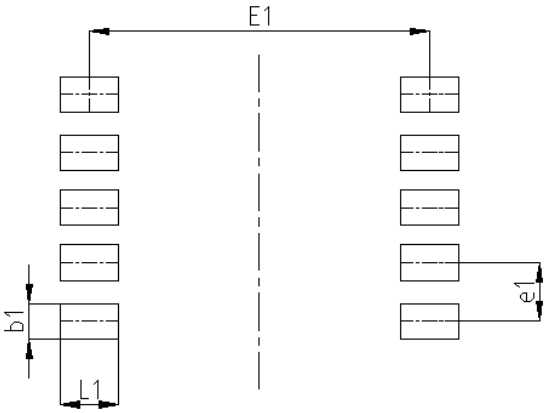


	Millimeter		
DIM	min.	typ.	max.
A	0.70	0.75	0.80
b		0.25	
c		0.20	
D	2.95	3.00	3.05
D2	2.20	2.30	2.40
E	2.95	3.00	3.05
E2	1.40	1.50	1.60
e		0.50	
F		0.35 x 45°	
L		0.30	

Magnetic center and field direction

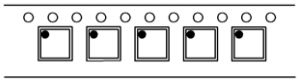


Recommended Land Pattern

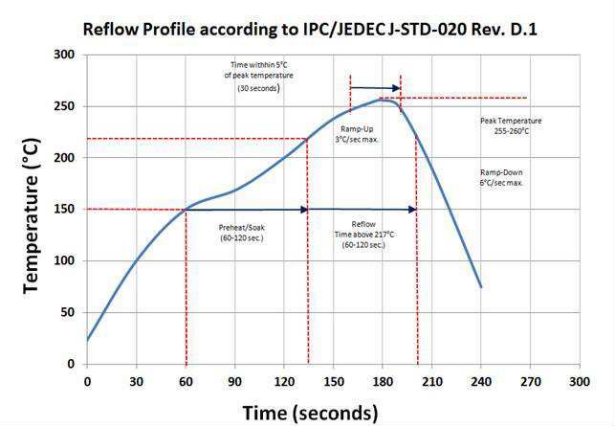


	Millimeter		
DIM	min.	typ.	max.
b1		0.25	
E1		2.90	
e1		0.50	
L1		0.50	
Thermal pad not contacted			

Tape and Reel Information

Description	Size/Quantity/Note	
Reel	330 mm (13”)	
Tape width	12 mm	
Units/reel	6,000 pcs.	
Minimum empty cavities	Start of Reel:100 / End of Reel: 40	
Peel Back Force	20-80 grams	
Pin 1 orientation on tape	Top-left of sprocket hole side	
Label	Affix on reel	
Secondary packaging	Anti-static shielding bag, Dry pack with desiccant and humidity-indicator-strip, Bubble sheet	
Pizza-Box	Dimension: 370 x 345 x 60 mm³	

Soldering Information



Moisture Sensitivity Level for MD47: MSL1 @ 260°C

Ordering Information

Description	Part Number	Alias Part Number
CO MD47 parabel DFN3x3 digital SPI	23100001-00	MD47