MDC04/MDC02
High Precision Digital Capacitance Sensor with 16bit ADC and 0.1fF resolution

Overview

MDC04/MDC02 series are highly integrated capacitance-to-digital converters by advanced mixed-signal CMOS technology. The IC drives multiple channels of capacitive sensing in a fully differential manner. By amplification , analog-to-digital conversion and digital compensation, the tiny capacitance variation can be identified in mutual capacitance structure between two ports. The sensor has a 16-bit ADC inside and can reach 0.1fF resolution and less than 0.3% linearity error. In addition, the IC integrates a temperature sensor with 0.5 ℃ accuracy for temperature sensing and compensation.

The MDC04 includes four channels of capacitance measurement and MDC02 includes two. The sensing range is 0~119pF, which is made up of programmable 0~103.5pf offset capacitance and ± 15.5pF dynamic input range. The sensing range can be configured by registers or thru an auto setting search command. The measurement mode can be flexibly set to one shot or several periodic mode. The MDC04 supports both I²C and 1-wire protocol , MDC02 supports 1-wire protocol for long cable and multiple nodes connection.

MDC04/MDC02 has a large measurement range and wide power supply voltage. It consumes little power and has flexible digital interface. It integrates internal EEPROM and temperature sensor circuit. The IC is very cost-effective with small size. The sensor can be applied to a variety of applications ranging from contact-less liquid level and moisture sensing, to dielectric recognition to material analysis, proximity and displacement sensing.

1. Features

- Total configurable measurement range: 0~119pF
- Configurable input range: ±15.5pF
- Configurable offset capacitance: 0~103.5pf
- Capacitance resolution: 0.1fF
- Linearity error: <0.3%
- Wide supply voltage range: 2.0V~5.5V
- Average power consumption: 4.5μA@1Hz
- Measurement time: 3~20ms configurable
- Temperature measurement accuracy : ± 0.5℃@0℃~50℃
- working temperature range: -55℃~125℃
- MDC04 I²C/1-wire interface
  MDC02 1-wire interface

2. Applications

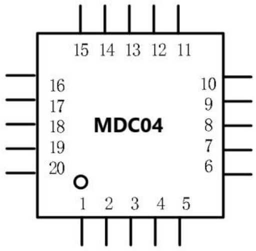
- Liquid level detection
- Moisture and humidity detection
- Oil level detection
- Water logging sensing
- Food moisture content detection
- Soil moisture content detection
- Frost and ice detection
- Displacement sensing

Type	MDC04	MDC02
Package	DFN20	SOP8
Size	3*3*0.75mm	4.9*3.9*1.6mm
#of channels	4	2
Interface	I2C, 1-wire	1-wire

3. Packaging and pin configuration

3.1 MDC04（QFN20）

Vertical view

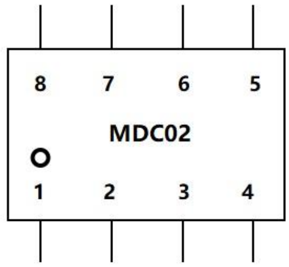


No.	Pin Name	Description
1	RSTN	Reset，digital input；low effective
2	MODE	Digital interface selection，digital input 0，PIN12 is SDA for I²C ； 1，PIN12 is DQ for 1-wire .
3	VSS	Ground
4	C4_OUT	Chanel C4 drive，analog output
5	C4_IN	Chanel C4 input，analog input
6	C1_IN	Chanel C1 input，analog input
7	C1_OUT	Chanel C1 drive，analog output
8	C2_IN	Chanel C2 input，analog input
9	C2_OUT	Chanel C2 drive，analog output
10	C3_IN	Chanel C3 input，analog input
11	C3_OUT	Chanel C3 drive，analog output
12	SDA/DQ	I²C data line/1-wire interface
13	ADDR	I²C address selection ，digital input，*cannot be floating* 0: I²C address is 0x44； 1: I²C address is 0x45。 Note：Connect to ground in 1-wire mode.
14	NC	
15	SCL	I²C clock；digital I/O，*cannot be floating* Note：Connect to ground in 1-wire mode.
16	NC	
17	NC	

18	NC	
19	NC	
20	VDD	Power supply

3.2 MDC02（SOP8）

Vertical View



No.	Pin Name	Description
1	C1_IN	Chanel C1 input，analog input
2	C1_OUT	Chanel C1 drive，analog output
3	C2_IN	Chanel C2 input，analog input
4	C2_OUT	Chanel C2 drive，analog output
5	DQ	1-wire interface
6	NC	
7	VDD	Power supply
8	VSS	Ground

Note：The C1 and C2 of MDC02 are identical to those of MDC04.

4. System Architecture

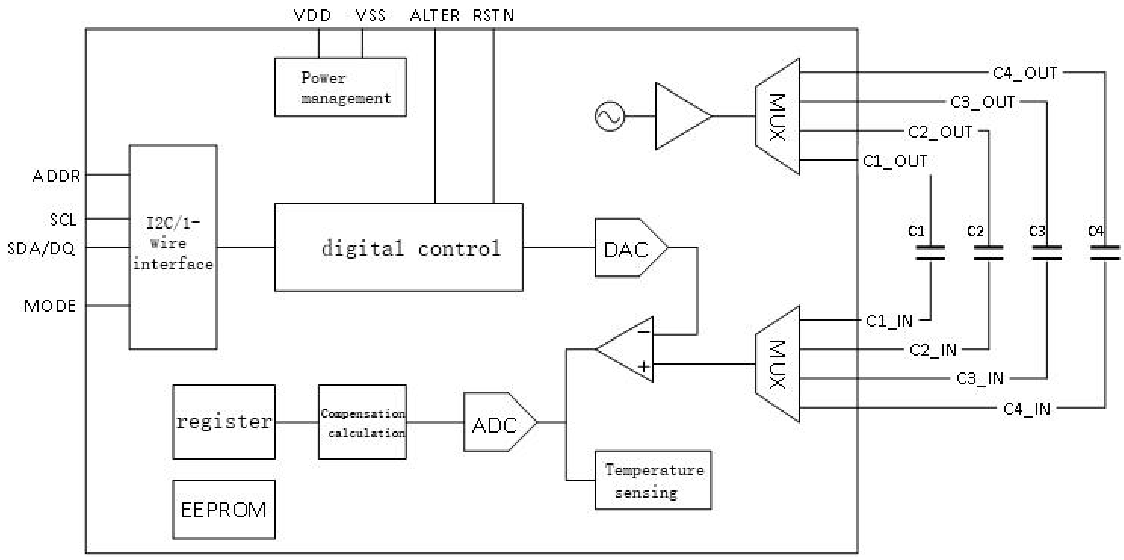


Fig. 4 MDC04 system architecture

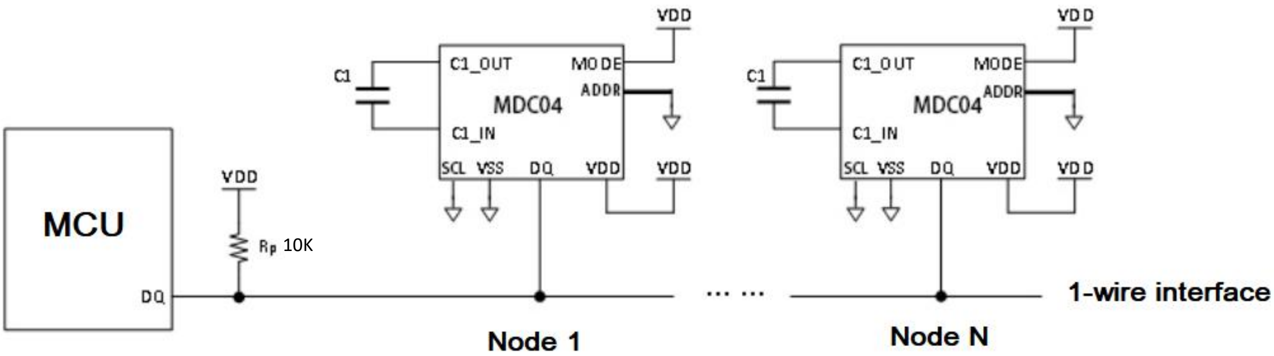
The MDC04 integrates four channels of differential capacitance measurement circuitry. Cn_OUT (n=1~4) stand for external capacitance driving port and Cn_IN (n=1~4) stands for internal capacitance measurement port. The channel selection is made by high-speed multiplexer (MUX) instead that share the signal conditioning resources on-chip. The received input signal is then amplified and the offset is subtracted by digital-to-analog converter (DAC) settings and programmable amplifier, thus the capacitance measurement offset and input ranges cannot be digital configured. Then the signal is sampled by a precise 16-bit analog-to-digital converter (ADC), the converted digital capacitance readings are further filter and compensated by digital algorithms. In addition, the IC includes temperature sensing element that can be sampled concurrently for temperature compensation.

MDC04 offers two types of digital interface: 1-wire and I²C. MDC02 offers 1-wire only interface. The digital control ASIC can recognize a variety of commands such as capacitance measurement, temperature measurement, reset, register read and write, IC settings, chip ID read and search and so on. A Low Drop-Out (LDO) power management circuit is included on chip, so that the IC can adapt wide power supply and enter idle mode automatically when there is no command on the bus and wake up by external reset command. Another differentiation of the IC is a EEPROM memory is available on chip, therefore a 64-bit unique chip ID, calibration parameters and customized information can be non-volatile stored on chip.

5. Typical Application

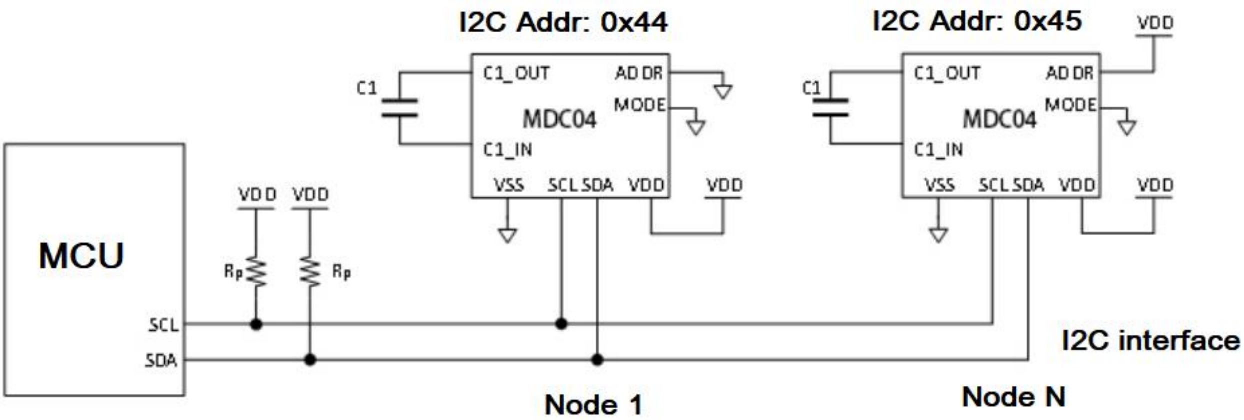
5.1 MDC04 typical application

1-wire interface



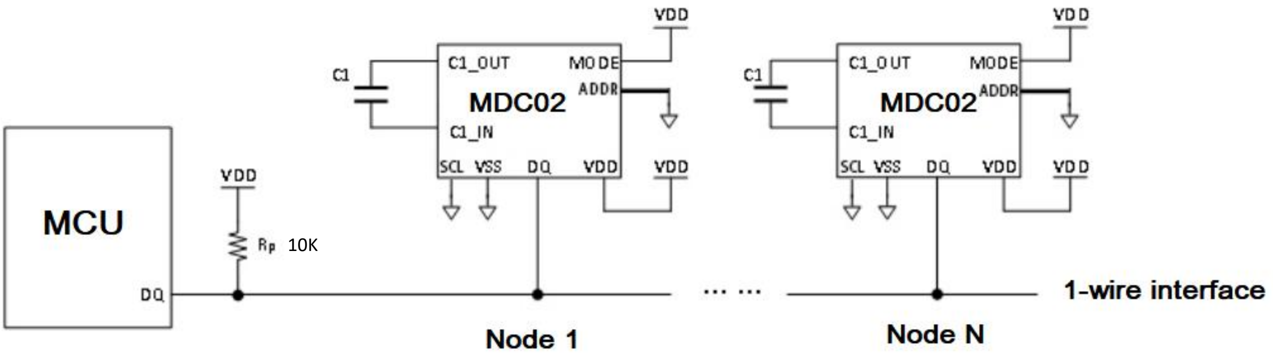
The MDC04 can be accessed by 1-wire interface as shown in the figure above. The micro controller (MCU) applies one GPIO and connects to DQ pin of each sensor。 A pull-up resistor Rp is used between DQ and VDD. In this way the MCU can read and write multiple sensor serially up to 100 node. Each sensor can be addressed by the unique chip ID； Mode pin connects to VDD in this 1-wire connection.

I2C interface



As given in the figure above, the MDC04 can also communicate with MCU by I²C interface，The SDA and SCL pin are connected to the MCU I2C port, and are pulled up by Rp to VDD. Two sensors can be accessed by two different I2C address. The sensor’s ADDR pin connects to low and high voltage respectively for 0X44 and 0X45 I2C address. Mode pin connects to the ground in this I2C connection.

5.2 MDC02 typical application



Similar to MDC04, the MDC02 can be accessed by 1-wire interface as shown in the figure above. The micro controller (MCU) applies one GPIO and connects to DQ pin of each sensor。 A pull-up resistor Rp is used between DQ and VDD. In this way the MCU can read and write multiple sensor serially up to 100 node. Each sensor can be addressed by the unique chip ID； Mode pin connects to VDD in this 1-wire connection.

6. Technical Specifications

6.1 DC Electrical Characteristics

Table 6.1 DC Electrical Characteristics

Parameter	Symbol	Condition	Min	Typ	Max	Unit	Note
Supply voltage	VDD		2.0	3.3	5.5	V	
Supply current	IDD	Standby (Single measurement mode) T=25°C	-	0.2	2.0	uA	The current when idle
		Standby(Single measurement mode) T=125°C	-	-	6.0	uA	
		Standby(periodic measurement mode)	-	36	-	uA	The current when idle
		measurement	-	400	1500	uA	
		Average	-	2.5	-	uA	
Single channel conversion time	t_{CONV}	Low repeatability	-	3.24	-	ms	
		Medium repeatability	-	-	-		
		High repeatability	-	10.5	-	ms	

Auto calibration duration	t_{AUTO}	Low repeatability	-	19.0	-	ms	Auto calibration duration is the IIC auto configuration bias capacitor command duration
		Medium repeatability	-	-	-		
		High repeatability	-	62.8	-	ms	
Waiting time after powered-up	t_{PU}	-	-	2	-	ms	
Digital input/output							
Input logic low	VIL	SCL, DQ/SDA	0	—	0.3*VDD	V	
Input logic high	VIH	SCL, DQ/SDA	0.7*VDD	—	1*VDD	V	
Output low level voltage	VOL	IOL = -3 mA	—	—	0.4	V	
Input leakage current	IIN	—	-0.1	—	0.1	uA	
Pull up resistor	Rup	—	1	10	100	kΩ	

6.1.1. Absolute maximum rating

Parameter	Value	Unit
Supply voltage	-0.3 to 6	V
Pin-to-ground voltage	-0.3 to VDD +0.3	V
Input current	±100	mA
Working temperature	-40 to 125	℃
Storage temperature	-40 to 150	℃
Welding temperature	Refer to IPC/JEDEC J-STD-020 Spec.	
ESD HBM(Human body discharge mode)	8	kV

6.1.2. AC Electrical Characteristics - Non-Volatile Memory

-55℃ to +125℃; V_{DD}=1.8V to 5.5V

Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Non-volatile write period	t_{WR}	—	—	—	40	ms
EEPROM endurance	N_{EEWR}	-55°C to +55°C	50000	—	—	times
EEPROM data retention	t_{EEDR}	-55°C to +55°C	—	10	—	year

6.2. Temperature measurement performance

Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**

Range	—	—	-70℃	—	+150℃
Accuracy tolerance	t_{ERR}	0℃ to +50℃	—	±0.5℃	
		-55°C to +125°	—	±1.5℃	—
		-70°C to +150°C	—	±2℃	—
Repeatability	—	Low repeatability setting	—	0.07℃	—
		Medium repeatability setting	—	0.05℃	—
		High repeatability setting	—	0.03℃	—
Resolution	—	—	—	0.004℃	—
Long-term drift	—	—	—	—	0.03°C/Y

Note: different output accuracy can be achieved by configuring different filter bandwidth.

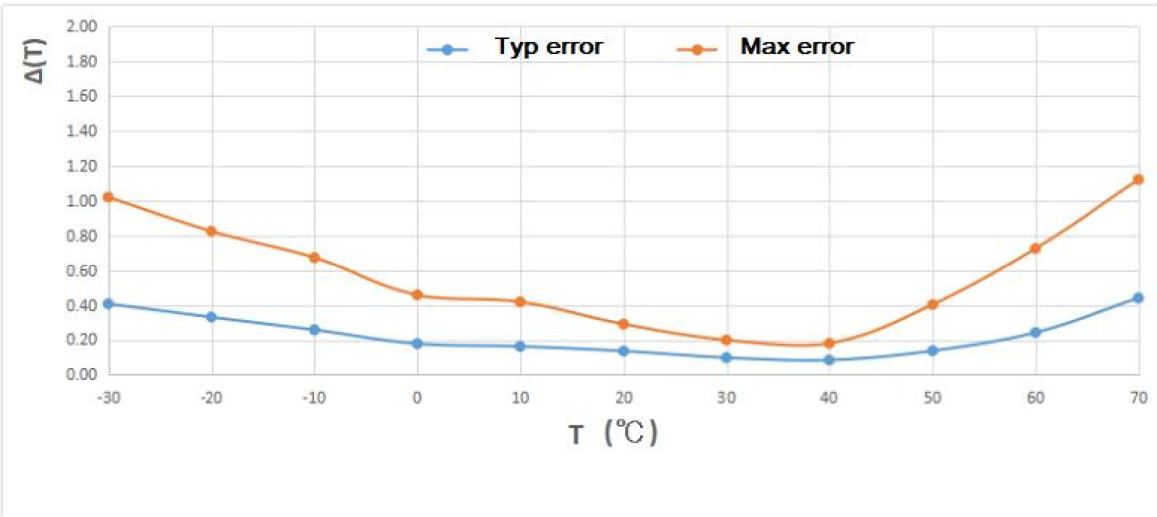


Fig. 6-2 Temperature measurement accuracy curve

6.3. 1-wire interface timing sequence

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Slot length	t_{SLOT}	See Fig.7.3	60		120	μs
Recovery time	t_{REC}	See Fig.7.3	1	5		μs
Write 0 low level time	t_{LOW0}	See Fig.7.3	60	60	120	μs
Write 1 low level time	t_{LOW1}	See Fig.7.3	1	5	15	μs
Read data effective time	t_{RDV}	See Fig.7.3		5	15	μs
Reset low level time	t_{RSTL}	See Fig.7.3	480	960		μs

Exist detection high level time	t_{PDHIGH}	See Fig.7.3	15	30	60	μs
Exist detection low level time	t_{PDLOW}	See Fig.7.3	60	115	240	μs

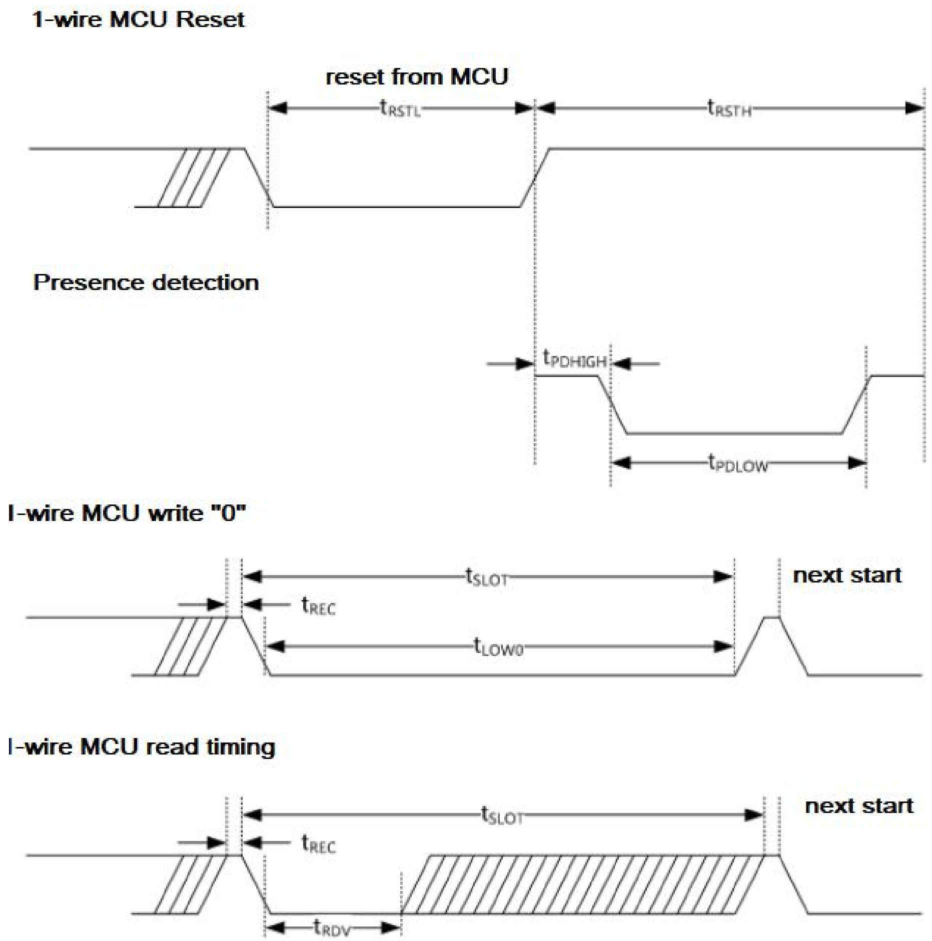


Fig. 6.3 1-wire interface sequence

6.4. I2C Interface Sequence

Table 6.4 I2C Timing (1)

Parameter	Symbol	Standard mode		Fast mode		Unit
		Min	Max	Min	Max	
SCL frequency	f_{SCL}	0	100	0	400	kHz
SCL low level time	t_{LOW}	4.7(7)	—	1.3(7)	—	μs
SCL high level time	t_{HIGH}	4.0	—	0.6	—	μs
Time interval from SCL pull down to SDA data change	$t_{HD;STA}$	4.0 30(6)	—	0.6 30(6)	—	μs
Time interval from SDA data stabilization to SCL pull up	$t_{HD;DAT}$	5.0 0(2)	— 3.45(3)	— 0(2)	— 0.9(3)	μs μs

High level holding time of SDA and SCL at the beginning of restart	$t_{SU;DAT}$	250	—	100(4)	—	ns
High level holding time of SDA and SCL at the beginning of restart	$t_{SU;STA}$	4.7	—	0.6	—	μs
Time interval from SCL pull to SDA pull during stop	$t_{SU;STO}$	4.0	—	0.6	—	μs
Interval between start and stop	t_{BUF}	4.7	—	1.3	—	μs
Time required for rising edge of SCL / SDA	t_r	—	1000	$20+0.1C_b$(5)	—	ns
Time required for falling edge of SCL / SDA	t_r	2.5	300	$20+0.1C_b$(5)	—	ns

Note 1：all values are based on VIHmin and VILmax.
Note 2：the device must increase the holding time of at least 300ns internally to SDA.
Note 3：the maximum tHD; DAT must be met only when the SCL low level cycle (TLOW) is not stretched.
Note 4：fast device mode I2C device can work in standard mode, but the requirements of tSU;DAT= 250ns must be met.
Note 5：Cb = total capacitance of I2C bus.
Note 6 : For application with sleep-mode enable, to guarantee the device can be waked-up successfully, the minimum value of $t_{HD;STA}$ is reverse proportional to VDD level. The minimum value of $t_{HD;STA}$ is 30us when VDD=5V, 50us when VDD=3V, and 150us when VDD=1.8V, respectively. The details are described in FAQ.
Note 7: For application with sleep-mode enable, if the master uses hardware-based I2C and the parameter $t_{HD;STA}$ cannot be changed, to guarantee the device can be waked-up successfully, the minimum value of the first t_{LOW} (the time from SCL first pull-low to SCL first pull-high after I2C start) is reverse proportional to VDD level. The minimum value of t_{LOW} is 30us when VDD=5V, 50us when VDD=3V, and 150us when VDD=1.8V, respectively. The details are described in FAQ.

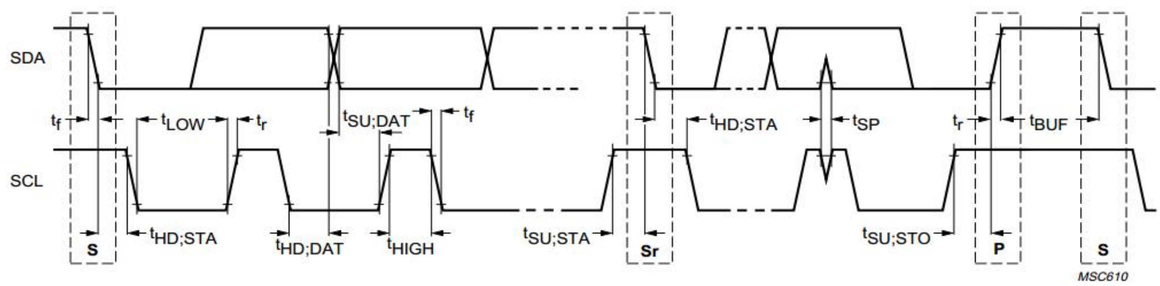


Fig. 6.4 I2C sequence

7. Circuit description

7.1. Capacitance conversion

MDC04/MDC02 series are highly integrated capacitance-to-digital converters by advanced mixed-signal CMOS technology. The IC drives multiple channels of capacitive sensing in a fully differential manner. By amplification，analog-to-digital conversion and digital compensation, the tiny capacitance variation can be identified in mutual capacitance structure between two ports. The sensor has a 16-bit ADC inside and can reach 0.1fF resolution and less than 0.3% linearity error.

The capacitance value C_D directly output is an unsigned 16 bit binary number, as shown in the table below:

Table7.1 Capacitance output register format

Capacitance value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
LSB	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Capacitance value	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
MSB	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8

The capacitance value C_X is calculated by the following formula:

$$C_x = 2\left(\frac{C_D}{2^{16}-1} - \frac{1}{2}\right)C_r + C_o$$

In the formula, Cr is the measurement range and C_O is the value of offset capacitance.

Therefore, the measurable range of the measured capacitance C_X is [Co-Cr， Co+Cr]. The capacitance measurement range Cr and the fixed offset capacitance Co are configured through registers C_{FB} and C_{OS} to achieve the best measurement range of C_X.

7.1.1.Offset capacitance configuration register - Cos

Reset value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0x00	COS_SEL [7]	COS_SEL [6]	COS_SEL [5]	COS_SEL [4]	COS_SEL [3]	COS_SEL [2]	COS_SEL [1]	COS_SEL [0]
Description	COS_SEL[7:0]：Offset capacitance selection							

The 8-bit COS_SEL[7:0] value in register Cos<7:0> combine with the 2-bit COS_RANGE[1:0] value in register Cfb<7:6> are used to configure C_{OFFSET} value. Appropriate COS_RANGE is selected according to the desired value of offset capacitance and the excitation frequency. The numerical relationship between offset capacitance and Cos register is as follows:

$$\text{Coffset} = 20\bullet q[7]+16\bullet q[6]+8\bullet q[5]+4\bullet q[4]+2\bullet q[3]+1\bullet q[2]+0.5\bullet q[1]+0.25\bullet q[0]+51.75\ (\text{pF})$$

$$q[i] = \begin{cases} 1, & Cos < i >= 1 \\ -1, & Cos < i >= 0 \end{cases} \quad i=0\sim7$$

For the specific configuration of offset capacitance Co, please refer to the configuration table of offset capacitance C_O under the condition of COS_RANGE[1:0]=0x11 in Appendix.

Cfb<7:6> Configuration selection	COS_RANGE[1:0] =0x00	COS_RANGE[1:0] =0x01	COS_RANGE[1:0] =0x10	COS_RANGE[1:0] =0x11

Cos<7:0> effective bits	Cos<4:0>	Cos<5:0>	Cos<6:0>	Cos<7:0>
Offset capacitance configurable range	0 ~ 15.5 pF	0 ~ 31.5 pF	0 ~ 63.5 pF	0 ~ 103.5 pF
Noise performance	Best	Better	Good	Normal

7.1.2. Feedback capacitance configuration register - Cfb

Reset value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0x00	COS_ RANGE[1]	COS_ RANGE[0]	CFB_SEL[5]	CFB_SEL[4]	CFB_SEL[3]	CFB_SEL[2]	CFB_SEL[1]	CFB_SEL[0]
Description	COS_RANGE[1:0]: For the configuration of offset capacitance range, please see the introduction of offset capacitance register		CFB_SEL[5:0]: Feedback capacitance selection					

The 6-bit CFB_SEL<5:0> value in register Cfb<5:0> is used to configure $C_{FEEDBACK}$ value, which therefore can change the measurement range, C_{RANGE} value. The relationship between feedback capacitance value and Cfb register value is as follows:

$$\text{Cfeedback} = 46\bullet\text{bit5} + 32\bullet\text{bit4} + 16\bullet\text{bit3} + 8\bullet\text{bit2} + 4\bullet\text{bit1} + 2\bullet\text{bit0} + 2 \text{ (pf)}$$

The measurement range Cr is calculated by the following formula:

$$Cr = \pm\, 0.1408 \times Cfeedback$$

Cfb Configuration range	0x00~0x3f
Feedback capacitance range CFEEDBACK	2 ~ 110 pF
Capacitance measurement range Cr	±0.281 ~ ±15.462 pF

For the specific configuration of measurement range Cr, please refer to the configuration table of capacitance measurement range Cr in Appendix.

7.1.3. Capacitance channel selection register Ch_sel

The channel selection register is used to select the specific channels converted at the same time.

Reset value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0x00	Reserved	Reserved	Reserved	Reserved	Reserved	CH_SEL[2]	CH_SEL[1]	CH_SEL[0]
Description	The value is reserved and cannot be changed.					CH_SEL[2:0]: Select capacitance channel 000/001: channel 1, 010: channel 2, 011: channel 3, 100: channel 4, 101: channel 1&2, 110: channel 1&2&3, 111: channel 1&2&3&4 (For MDC02, only channel 1 and channel 2 need to be configured)		

7.1.4.System configuration register - Config

Reset value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0X00	Reserved	Reserved	Clk_stretch	MPS[2]	MPS[1]	MPS[0]	Repeatability[1]	Repeatability[0]
Description	The value is reserved and cannot be changed.		I2C clock stretching control: 0: Clock stretching is not allowed 1: Clock stretching is allowed	Periodic measurement frequency configuration MPS (Note 1) 000: Single measurement 001: 0.5 times per second 010: 1 time per second 011: 2 times per second 100: 4 times per second 101: 10 times per second			Repeatability setting: (Note 2) 00: Low 01: Medium 10: High	

Note1: The default periodic measurement configuration is single measurement, and the measurement frequency can be configured as required. The fastest speed is about 133 samples/second under low repeatability, 111 samples/second under medium repeatability and 70 samples/second under high repeatability.

Another way to achieve the periodic measurement is to use the single measurement in a cyclical control function, the steps are shown as follows:

i. Calculate the duration of each measurement under the required measurement frequency

ii. Use duration of each measurement minus the combination of conversion time and one-wire command time, to get the delay value

iii. Put the delay value at the end of the cyclical function to achieve the required measurement frequency.

Note 2: Repeatability and conversion time are a direct compromise relationship. The higher the repeatability, the longer the conversion time; The lower the repeatability, the shorter the conversion time.

7.1.5.System status register - Status

Reset value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0X08	Measure[1]	Reserved	Write_data_checksum	Command_status	Sys_reset_detected	Reserved	Reserved	Measure[0]
Description	Measure[1:0]: Periodic measurement mode (MPS>=001) 00: No measurement; 01: Measuring temperature; 10: Measuring capacitance; 11: Measuring temperature and capacitance Write_data_checksum: 0: right; 1: wrong Command_status: 0: right; 1: wrong Sys_reset_detected: 0: not detected; 1: detected							

7.2. Temperature conversion

The temperature sensing principle is based on the characteristic relationship between the semiconductor PN-junction temperature and voltage, through small signal amplification, analog to digital conversion, digital calibration, output digital temperature. It has strength of high accuracy, outstanding consistency, long lifetime, low power consumption, programmable configuration flexibility.

The digital output of temperature is 16 bit signed binary complement, the resolution of the lowest LSB is 1/256℃, and S is the sign bit, as shown in the table below:

Table 7.2 Temperature register format

Temperature value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
LSB	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}	2^{-8}
Temperature value	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
MSB	S	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

The conversion relationship between output temperature data and Celsius is:

$$T\left[℃\right] = \frac{S_T}{256} + 40$$

The following table shows the corresponding relationship between different temperature values and output temperature data.

Temperature value（℃)	Register value
40	0x0000
40.5	0x0080
125	0x5500
-54.5	0xA180
-55	0xA100

8. 1-wire Interface

The 1-wire bus MDC02 is exactly the same as MDC04, so this chapter will take MDC04 as an example.

8.1. 1-wire bus register mapping

Name	Addr offset	Read	Write	EEPROM 映射	Copy	Recall	Reset Value

<table>
<tr><td>Temp_lsb</td><td>0</td><td rowspan="4">Read TC1 (0xbd)</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>H' 01</td></tr>
<tr><td>Temp_msb</td><td>1</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>H' F1</td></tr>
<tr><td>Cap1_lsb</td><td>2</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>H' 00</td></tr>
<tr><td>Cap1_msb</td><td>3</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>H' 80</td></tr>
<tr><td>Reserved</td><td>4</td><td rowspan="5">Read Scratchpad (0xbe)</td><td rowspan="3">Write scratchpad (0x4e)</td><td>0</td><td rowspan="12">Copy Page0 (0x48)</td><td rowspan="3">Recall EE (0xb8)</td><td>H' 00</td></tr>
<tr><td>Reserved</td><td>5</td><td>1</td><td>H' 00</td></tr>
<tr><td>Config</td><td>6</td><td>2</td><td>H' 00</td></tr>
<tr><td>Status</td><td>7</td><td>NA</td><td>3</td><td rowspan="9">Recall Page0 (0xbb)</td><td>NA</td></tr>
<tr><td>Crc_scr</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Reserved</td><td>8-13</td><td>Read Scratchpad_ext (0xdd)</td><td>Write Scratchpad_ext (0x77)</td><td>4-9</td><td>H' 00</td></tr>
<tr><td>Cap2_lsb</td><td>14</td><td rowspan="6">Read C2-4 (0xdc)</td><td>NA</td><td>10</td><td>H' 00</td></tr>
<tr><td>Cap2_msb</td><td>15</td><td>NA</td><td>11</td><td>H' 00</td></tr>
<tr><td>Cap3_lsb</td><td>16</td><td>NA</td><td>12</td><td>H' 00</td></tr>
<tr><td>Cap3_msb</td><td>17</td><td>NA</td><td>13</td><td>H' 00</td></tr>
<tr><td>Cap4_lsb</td><td>18</td><td>NA</td><td>14</td><td>H' 00</td></tr>
<tr><td>Cap4_msb</td><td>19</td><td>NA</td><td>15</td><td>H' 00</td></tr>
<tr><td>Crc_scr_ext</td><td>NA</td><td></td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Romcode</td><td>20-24</td><td>Read Romcode (0x33)</td><td>NA</td><td>16-20</td><td rowspan="8">NA</td><td rowspan="8">Recall Page1 (0xba)</td><td>H' 00</td></tr>
<tr><td>NA</td><td>25-27</td><td></td><td rowspan="2">Write Ch_sel 0xaa</td><td>21-23</td><td>H' 00</td></tr>
<tr><td>Ch_sel</td><td>28</td><td rowspan="2">Read Ch_sel 0x8a</td><td>24</td><td>H' 00</td></tr>
<tr><td>Cos</td><td>29</td><td rowspan="5">Write Parameters (0xab)</td><td>25</td><td>H' 00</td></tr>
<tr><td>NA</td><td>30</td><td rowspan="5">Read Parameters (0x8b)</td><td>26</td><td>H' 00</td></tr>
<tr><td>NA</td><td>31-33</td><td>27-29</td><td>H' 00</td></tr>
<tr><td>Cfb</td><td>34</td><td>30</td><td>H' 00</td></tr>
<tr><td>NA</td><td>35-38</td><td>31</td><td>H' 00</td></tr>
<tr><td>Crc_para</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
</table>

8.2. Reset

All communication with the thermometer begins with an initialization sequence that contains a reset pulse from the host followed by a presence pulse from the thermometer. Figure 8.2-1 illustrates this sequence. When the thermometer sends a presence pulse in response to the reset pulse, it indicates to the host that the device is connected on the bus and is ready to run. During the initialization sequence, the master issues a reset pulse by pulling the 1-wire low for at least 480 μs. The host then releases the bus into receive mode. When the bus is released, pull-up resistor pulls the bus high. When the thermometer detects this rising edge, it waits for 15μs to 60 μs and then issues a presence pulse by pulling the 1-wire down 60μs to 240μs.

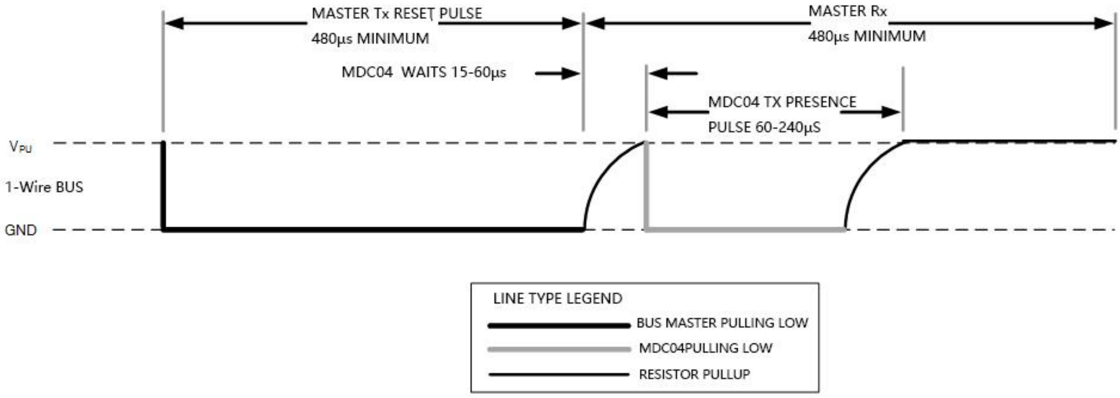


Fig.8.2-1 Initialization

Read/Write Time Slot

The host writes data to thermometer in the write time slot and reads data from thermometer in the read time slot. Each time slot transmits one bit on 1-wire.

Write Time Slot

There are two types of write time slots: "write 1" time slot and "write 0" time slot. The host writes a logic 1 to thermometer by writing 1 time slot and writes a logic 0 to thermometer by writing 0 time slot. All write time slots must last at least 60 μs and there is at least a 1 μs recovery time between the two write time slots. Both write time slots are initiated by the host pulling the 1-wire low (see Figure 8.2-2).
To generate a write 1 time slot, after the 1-wire is pulled low, the host must release the 1-wire within 15 μs. After the bus is released, pull-up resistor pulls the bus high. To generate a write 0 time slot, after pulling the 1-wire low, the host must keep the bus low at least 60 μs throughout the time slot.
After the host initiates a write time slot, the thermometer samples the 1-wire for a time window of at least 15μs to 60μs. If the bus is high during this sampling time window, a 1 is written to thermometer. If the bus is low, a 0 will be written to thermometer.

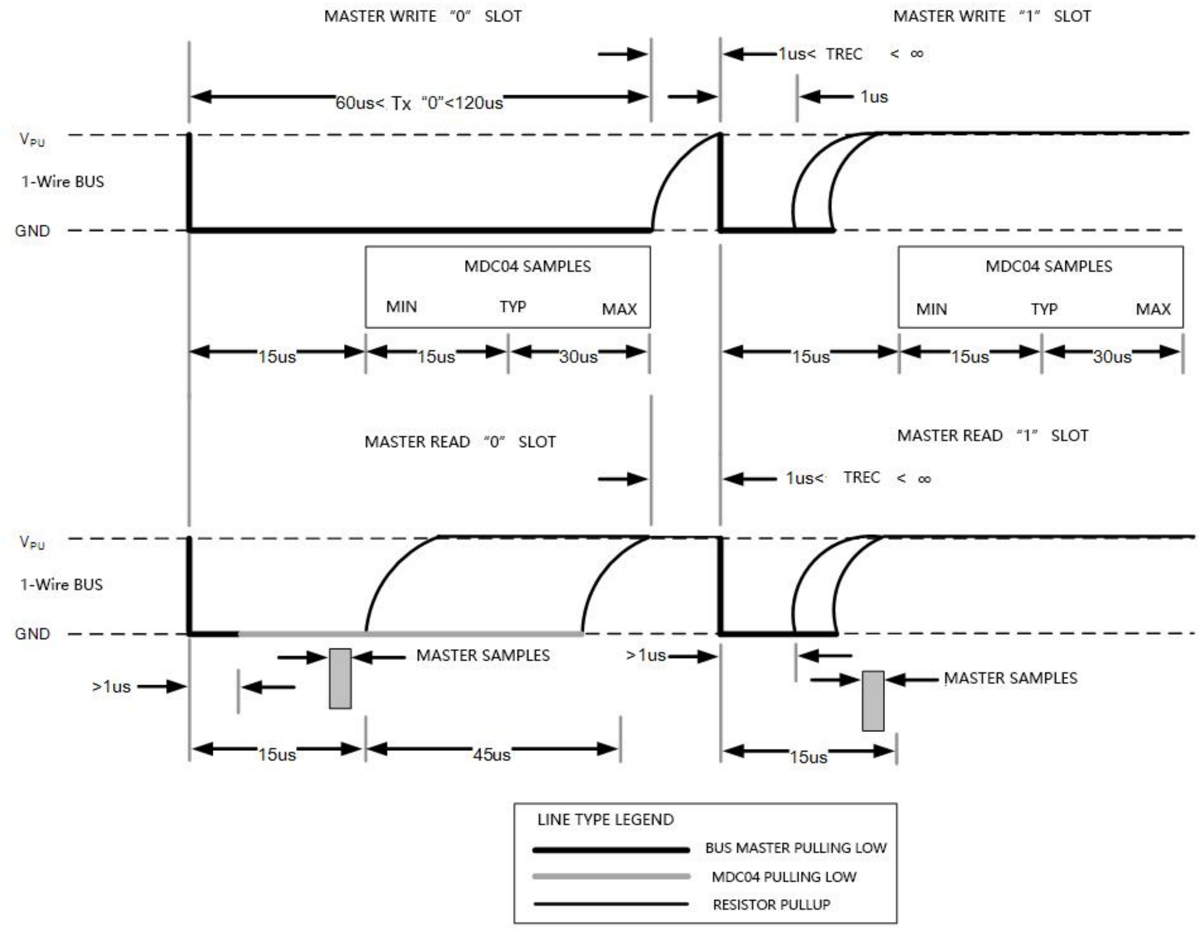


图 8.2-2 Read/Write time slot

Read Time Slot

The thermometer can only transfer data to the host during the host's issues the read time slot. After the host issues the Read Scratchpad [BEh] command, the read time slot must be generated immediately so that the thermometer can provide the requested data. In addition, the host can generate a read time slot after issue the Convert T[44h] or Recall E^2 [B8h] command to get the operating status. This part of the mechanism is explained in detail in the thermometer functional commands section. All read time slots must last at least 60 μs and the recovery time between the two write time slots is not less than 1 μs. The generation of the read time slot is achieved by the host pulling the 1-wire low for at least 1 μs and then releasing the bus (see Figure 8.2-3). After the host initiates a read time slot, the thermometer will start transmitting 1 or 0 on the bus. The thermometer sends a 1 by holding the bus high and sends a 0 by pulling the bus low. When transmitting 0, thermometer will release the bus at the end of the time slot, after which the bus will be pulled back to the high idle state by the pull-up resistor. The output data of the thermometer is valid for 15μs after the falling edge of the start time slot. Therefore, the host must release the bus and sample the bus state within 15 μs after the time slot is started. Figure 8.2-3 illustrates that the sum of T_{INIT}, T_{RC} and T_{SAMPLE} must be less than 15 μs in a read time slot. Figure 8.2-4 shows that the time margin of the system can be maximized by keeping T_{INT} and T_{RC} as short as possible and placing the host sample time at the end of the 15 μs period of the read time slot.

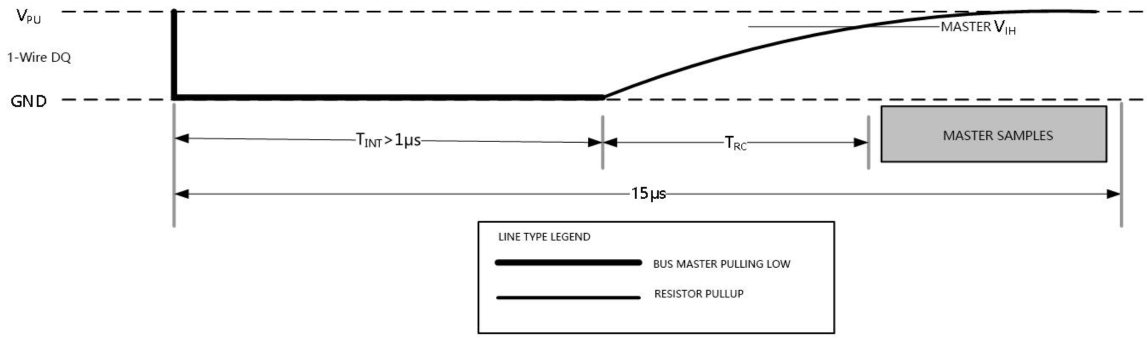


Fig.8.2-3 Detailed MCU Read “1” Timing

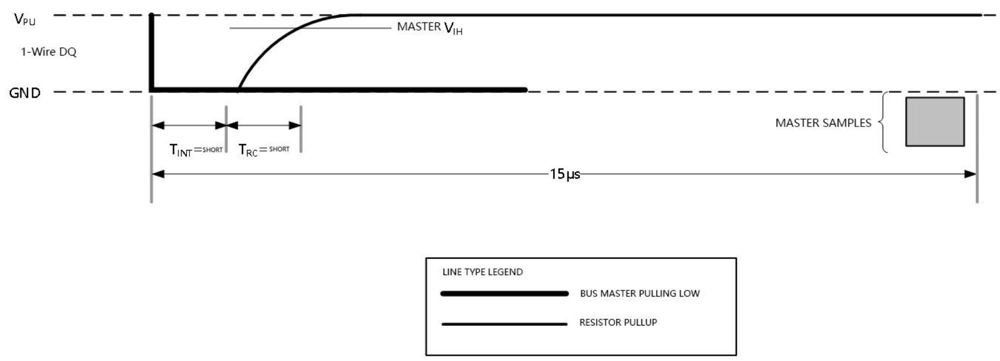


Fig.8.2-4 Recommended MCU Read “1” Timing

8.3. ROM Commands

When the host detects the presence pulse, it can issue a ROM command. These commands operate on a unique 64-bit ROM code for each slave device and if multiple slave devices are attached to a 1-wire, the host can specify the individually device. These commands also allow the host to determine what type of device is on the bus and if any device meets the alarm condition. There are 5 ROM commands, each 8 bits long. The master device must issue a suitable ROM command before issuing the thermometer function commands.

SEARCH ROM [F0h]

When a system is initialized and powered up, the host must identify the ROM encoding of all slave devices on the bus so that the host can determine the number and type of slave devices. The host recognizes the ROM code by the exclusion process, which requires the host to perform a Search ROM loop (eg, the Search ROM command follows the data exchange) repeatedly until all slave devices are identified. If there is only one slave on the bus, you can use a simple Read ROM (see below) instead of the Search ROM. After each Search ROM cycle, the host can return to step 1 (initial state) of the transfer sequence or follow a function command.

Read ROM [33h]

This command allows the host to read the 64-bit ROM code of MDC04. This command can only be used if there is a single MDC04 on the bus. If there is more than one MDC04 on the bus, a data collision occurs when all slaves attempt to respond at the same time.

Match ROM [55h]

Matches the ROM command followed by a 64-bit ROM encoding sequence that allows the host to address a specified thermometer on a multipoint or single-point bus. Only the thermometer with exact 64-bit ROM code will respond to the function command issued by the host. Other slaves will be in idle state and wait for a reset pulse.

Skip ROM [CCh]

It is possible for the host to simultaneously address all devices on the bus without sending any ROM code. For example, the host can perform temperature conversion on all thermometeron the bus at the same time, just by issuing a Skip ROM command followed by a Convert T [44h] command.

Note that the Read Scratchpad [BEh] command can only follow the Skip ROM command when a single slave device is attached to the bus. In this case, time can be saved by allowing the host to read the slave without sending a 64-bit device ROM code. If there is more than one slave on the bus, a Skip ROM command following a Read Scratchpad command will cause a data collision because multiple devices will attempt to transmit data at the same time.

8.4. Function commands

After the host uses a ROM command to address a desirable MDC04, the host can issue one of the MDC04 function commands. These commands write or read data from the MDC04 scratchpad, initiate temperature conversion, and understand the power mode. The functional commands of MDC04 as described below, are summarized in the flowing Table.

Command	Description	Value	Events after command	Remarks
Convert T	Initialize temperature conversion	44h	MDC04 transmits conversion status to master	
Convert C	Start capacitance conversion	66h		
Read TC1	Read temperature and capacitance channel 1	BDh	MDC04 transmits CRC and two bytes of temperature and C1	
Read C2-4	Read capacitance channels 2, 3 and 4	DCh	MDC04 transmits CRC and two bytes of C2, C3 and C4	
Read Scratchpad	Read the contents of all Scratchpad including the configuration register	BEh	MDC04 transmits up to 9 data bytes to master	1
Write Scratchpad	Write 3 bytes including the	4Eh	Mater transfer scratchpad	2

	configuration register to bytes 4, 5, and 6 of the register (0x00, 0x00, configuration register)		bytes 2，3, and 4 transfers to MDC04	
Read Scratchpad_ext	Read the contents of all scratchpad_ext including capacitance channels 2, 3 and 4	DDh		
Write Scratchpad_ext	Write Bytes 8, 9, 10, 11, 12, 13 of the register	77h		
Read Ch_sel	Read Ch_sel of parameter register	8Ah	MDC04 transmits 1 byte to master	
Write Ch_sel	Write Ch_sel of parameter register	AAh	Master transmits 1 byte to MDC04	
Read Parameter	Read parameter area （ttrim，Cos，Cfb）	8Bh		
Write Parameters	Set parameter area (Ch_sel，Cos，Cfb)	ABh		
Copy Page0	Copy 00h and configuration register data from register to EEPROM	48h	Write EEPROM time 40ms	
Recall EE	Call configuration register to register from EEPROM	B8h	MDC04 transmits call status to Master	
Recall Page1	Call Ch_sel, COS and CFB to parameter register from EEPROM	BAh	MDC04 transmits call status to Master	

CONVERT T [44h]

This command initiates a temperature conversion. After the conversion, the acquired thermal data is stored in the 2-byte temperature register in the scratchpad and then thermometer returns to the low-power idle state. The host can issue a read time slot after the Convert T command, and then thermometer will return 0 or 1 to indicate that the temperature conversion is in progress or completed.

CONVERT C [66h]

This command initiates a simultaneous conversion of the selected capacitance channel. After conversion, the collected capacitance data is stored in the corresponding result register, and then returns to the low-power free state.The host can issue the read timeslot after the convert C command, and then MDC04 will reply 0 or 1, indicating that the temperature conversion is in progress or has been completed.

READ TC1 [BDh]

This command allows the host to read the temperature and capacitance outputs in the register. MDC04 is transmitted in the order of temperature LSB, temperature MSB, capacitance channel 1 LSB and capacitance channel 1 MSB, followed by the CRC checksum byte of the previous 4 bytes. If only part of the data in the register is required, the host can issue a reset signal to terminate the reading at any time.

READ C2-4 [DCh]

This command allows the host to read the outputs of capacitance channels 2, 3 and 4 in the extended register. MDC04 is transmitted in the order of channel 3 LSB, channel 3 MSB, capacitance channel 3 LSB, capacitance channel 3 MSB, capacitance channel 4 LSB and capacitance channel 4 MSB, followed by the CRC checksum byte of the previous 6 bytes. If only part of the data in the register is required, the host can issue a reset signal to terminate the reading at any time.

READ CH_SEL [8Ah]

This command allows the host to read the contents of Ch_sel in the parameter register.

WRITE CH_SEL [AAh]

This command allows the host to write 1 byte data to Ch_sel in the parameter register.

READ PARAMETERS [8Bh]

This command allows the host to read the contents of the parameter register. Data transmission starts from the lowest bit of byte 0 and continues to traverse the register until the 14th byte (byte 3 is Ch_sel, byte 4 is COS, byte 9 is CFB, byte 13 is transmission A5h, and byte 14 is CRC code) is read. If only part of the data in the register is required, the host can issue a reset signal to terminate the reading at any time.

WRITE PARAMETERS [ABh]

This command allows the host to write 13 bytes of data to MDC04 parameter register. The 3rd byte is written into Ch_sel of the parameter register, the 4th byte is written into COS of the parameter register, and the 9th byte is written into CFB of the parameter register. the lowest bit of data must be sent first. All 13 bytes must be written before the host sends a reset signal, otherwise the data may be damaged(This means that the host can abort writing at any time by resetting).

WRITE SCRATCHPAD [4Eh]

This command allows the host to write up to 3 data to the MDC04 register. The first byte is written to the TH register (storage byte 2) and the second byte is written to the TL register (storage byte 3),the third byte is written to the configuration register (register byte 4). Data must be sent the lowest bit first. All 3 bytes must be written before the host issues a reset signal, otherwise the data may be corrupted(meaning that the host can abort writing by resetting at any time).

READ SCRATCHPAD [BEh]

This command allows the host to read the contents of the scratchpad. The data transfer begins at the lowest bit of byte 0 through the ninth byte (byte 8, CRC byte). If only part of the data in the scratchpad is needed, the host can issue a reset signal to terminate the read at any time.

COPY PAGE0 [48h]

This command copies the data in the register (including the configuration register) to the EEPROM.

RECALL EE [B8h]

This command calls data from the EEPROM and replaces the corresponding data in bytes 4,5,6 in the register. The host issue a read slot after following the Recall EE command, and then MDC04 will indicate the call status. Transmitting 0 means that the call is in progress and transmitting 1 means that the call has ended. The calling operation is automatically executed when the IC is powered on, so there is valid data in the register immediately after the device is powered on.

RECALL PAGE1 [BAh]

This command calls data from EEPROM and replaces the data of parameter register. The host can continuously issue read timeslots after following the RECALL PAGE1 command, and then MDC04 will indicate the loading status. Transmitting 0 means that the loading is in progress, and transmitting 1 means that the call has ended. The loading operation is automatically executed when the IC is powered on, so there is valid data in the extended register immediately after the device is powered on.

8.5. Cyclic redundancy check（CRC）

The 8-bit CRC checksum sents after each data are generated by the CRC algorithm. Its properties are shown in the following table.

Parameter	Value
Name	CRC-8/MAXIM
Bit width	8-bit
Data Protect	W/R
Polynomial	0x31 ($x^8 + x^5 + x^4 + 1$)
Initial value	0x00
Whether each byte of the test data reversed by bit	Yes
After calculation and before exclusive or output, whether the whole data is reversed by bit	Yes
The calculation result is exclusive or to this parameter	0x00
Example	CRC (0xBEEF) = 0x76

Note：ROM ID last two bytes are 0x00 without CRC. CRC can be generated by Maxim CRC-8 polynomial above in MCU software.

8.6. MDC04 Example

8.6.1. Example Conditions 1

In this condition, for the middle cable, there will be several MDC04. The host will read a specific MDC04 scratchpad after temperature conversion and then recalculates the CRC to verify the data.

Host	Data（LSB first)	Command
Send	Reset pulse	Host send reset pulse
Receive	Presence pulse	MY605+ respond presence pulse
Send	55h	Host send Match ROM command
Send	64bit ROM ID	Host send Match ROM command
Send	44h	Host send Convert T command
	DQ keep high	Host keep DQ high during temperature conversion
Receive	Reset pulse	Host send reset pulse
Receive	Presence pulse	MY605+ respond presence pulse
Send	55h	Host send Match ROM command
Send	64bit ROM ID	Host send Match ROM command
Send	BEh	Host send Read Scratchpad command
receive	9 bytes data	Host read all scratchpad data, include CRC byte.Then host calculate CRC byte for the first 8 bytes locally, and compare with the CRC code read back. Host continues if CRC match, otherwise, host repeat above steps.

8.6.2. Example Conditions 2

In this example there is only one MDC04 on the main cable. The host reads the parameter register and modifies the values of Ch_sel，COS and CFB, then write them back to the parameter register of MDC04. The host then copies the contents of the scratchpad to the EEPROM.

Host	Data（LSB first)	Command
Send	Reset pulse	Host send reset pulse
Receive	Presence pulse	thermometer respond presence pulse
Send	CCh	Host send Skip ROM command
Send	8Bh	Host send Read Parameter command
Send	15 bytes data	MDC04 send 15 bytes data to host
Send	Reset pulse	Host send reset pulse
Receive	Presence pulse	MDC04 respond presence pulse
Send	CCh	Host send Skip ROM command
Send	ABh	Host send Write Parameter command

Receive	13 bytes data	Host send read/modified 13 bytes in turn
Send	Reset pulse	Host send reset pulse
Receive	Presence pulse	MDC04 respond presence pulse
Send	CCh	Host send Skip ROM command
Send	DQ keep high	Host keep DQ high for at least 40 ms during Copying Command.

9. I2C Interface

9.1. I2C register access

Register name	address	reset value	note	Read/Write command	EEPROM write/read
Temp_lsb	0	0x90	Temperature output low byte	Read one byte/ ReadT	-
Temp_msb	1	0x01	Temperature output high byte	Read one byte/ ReadT	-
Cap1_lsb	2	0x00	Cap1 output low byte	Read one byte/ ReadC1	-
Cap1_msb	3	0x00	Cap1 output high byte	Read one byte/ ReadC1	-
Config	6	0x00	Working Configuration register	ReadStatusConfig/Read one byte/Write one byte	Copy_Page 0/Recall EE
Status	7	0x08	System status register	ReadStatusConfig/Read one byte/Clear Status	-
Cap2_lsb	14	0x00	Cap2 output low byte	Read one byte	-
Cap2_msb	15	0x00	Cap2 output high byte	Read one byte	-
Cap3_lsb	16	0x00	Cap3 output low byte	Read one byte	-
Cap3_msb	17	0x00	Cap3 output high byte	Read one byte	-
Cap4_lsb	18	0x00	Cap4 output low byte	Read one byte	-
Cap4_msb	19	0x00	Cap4 output high byte	Read one byte	-
Ch_sel	28	0x00	Channel selection register	Read one byte/Write one byte	Recall Page1
Cos	29	0x00	Bias capacitor configuration register	Read one byte/Write one byte	
Cfb	34	0x00	Bias capacitance range and feedback capacitance configuration register	Read one byte/Write one byte	

9.2. I2C Command

Command	Function	Code	Note
Measuring temperature	IIC_ConvertT	0xCC44	

Measuring capacitance	IIC_ConvertC	0xCC66	
Read temperature and C1	IIC_READ_TC1	-	
Read register single byte	read one byte	0xD2XX	IIC read register single byte，(XX is SCR logical address)
Write register single byte	write one byte	0x52XX	IIC write register single byte，(XX is SCR logical address)
Write configuration register	IIC_CONFIG	0x5206 *	Write configuration register
Read status and configuration registers	IIC_READ_STATUSCONFIG	0xf32d	
Clear status register	IIC_CLEAR_STATUS	0x3041	
Stop periodic measurement	IIC_BREAK	0x3093	
Bias capacitance automatic configuration	IIC_AUTO_CALIBRATION	0xa187	Automatically configure the best Cos
Software reset	IIC_SOFT_RST	0x30a2	Clear the register to the initial value and re execute EEPROM
Save Page0 to EEPROM	IIC_COPY_PAGE0	0xcc48	
Restore EE area	IIC_RECALL_EE	0xccb8	
Restore page1	IIC_RECALL_PAGE1	0xccba	

9.3. Operation and communication

MDC04 supports I2C fast mode (up to 400 kHz). Clock stretch can be enabled and disabled by the corresponding user command. After sending a command to the sensor, a minimum waiting time of 1ms is required before the sensor receives another command. All MDC04’ s commands and data are mapped to a 16 bit address space. In addition, data and commands include CRC verification, which improves communication reliability. The data sent and received by the sensor always follows the 8-bit CRC checksum. In the write operation, the host must send the checksum to the slave, and MDC04 can only accept the data after receiving the correct checksum. During the read operation, the main device reads and processes the checksum.

9.3.1. Power on and communication starts

The sensor starts to power on after reaching the power on threshold voltage vpor. When the threshold voltage is reached, the sensor needs time for TPU to enter idle state. Once idle, commands can be received from the main device (microcontroller). Each transmission sequence starts with a start condition (s) and ends with a stop condition (P), as described in the I2C bus specification. Whenever the sensor is powered up but no measurement or communication is performed, it automatically goes into an idle state to save energy. The idle state cannot be controlled by the user.

9.3.2. Start measurement

The measurement communication sequence includes start condition, I2C writing head (7-Bit I2C device address plus 0 as the writing bit) and 16 bit measurement command. The sensor indicates the correct reception of each byte. It pulls the SDA pin down (ACK bit) after the falling edge of the 8th SCL clock to indicate reception. The complete measurement cycle is described in section 12.8. By confirming the measurement command, the sensor begins to measure the temperature. In addition, measurement repeatability and single / continuous measurement mode are set by corresponding control bits of configuration register.

9.3.3. Single byte read and write command

The single byte read register command is 0xD2xx , where XX, that is, the second byte of the command is the address of the register. The first byte of reading is the value of the specified register, and the second byte is the concatenated 0xff, the third byte is the checksum of the first two bytes.

Command	Hex Code
Single byte read	0xD2XX

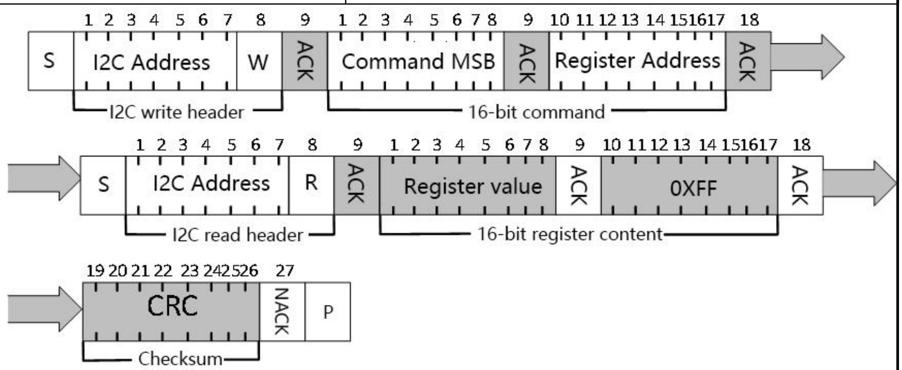


Fig.9.3-1 Single byte read command(the white block is controlled by the micro controller, and the sensor response is gray block)

The single byte write register command is 0x52xx, where XX, that is, the second byte of the command is the register address. The first byte of writing is the value of the specified register and the second byte is 0xFF, and the third byte is the checksum of the first two bytes.

Command	Hex Code
Set configuration register	0x52XX

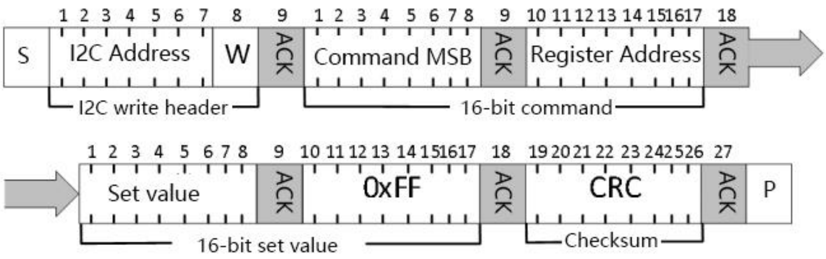


Fig.9.3-2 Single byte write command (the white block is controlled by the micro controller, and the sensor response is gray block)

9.3.4. Set configuration register instruction

Command	**Hex Code**
Set configuration register	0x5206

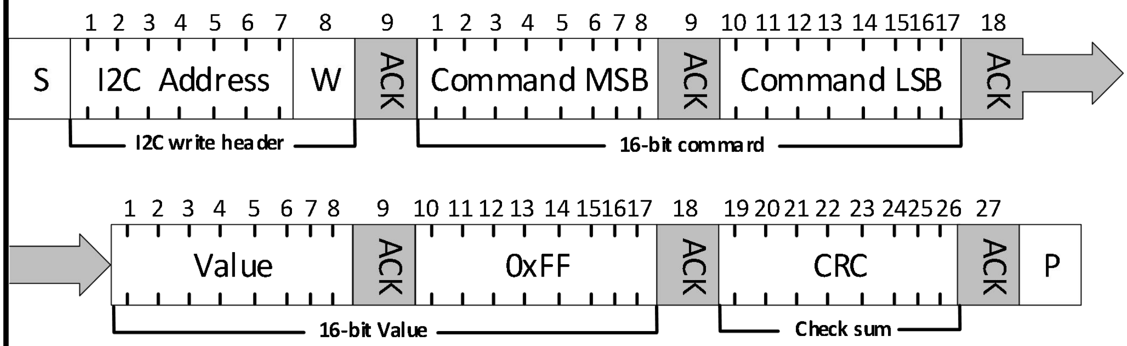


Fig.9.3-3 Set configuration register instruction(the white block is controlled by the micro controller, and the sensor response is gray block)

9.3.5. Read status register and configuration register instructions

The commands to read the status register and configuration register are shown in the following Fig.

Command	Hex Code
Read status and config register	0xF32D

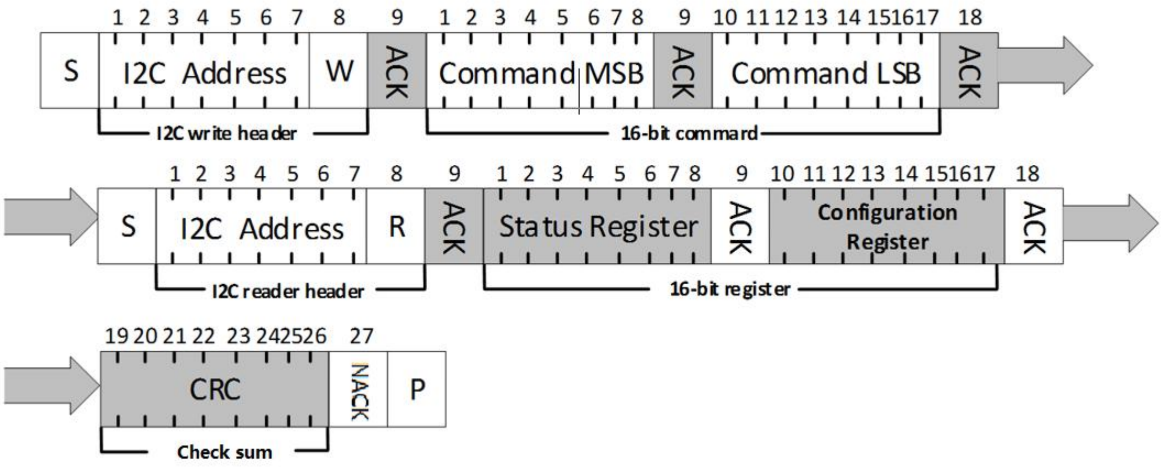


Fig.9.3-4 Read status register and configuration register instructions(the white block is controlled by the micro controller, and the sensor response is gray block)

9.3.6. Reset status register instruction

The flag (bits 3,2,1) in the status register can be cleared (set to zero) by sending the command shown in the following table.

Command	Hex Code
Reset status register	0x3041

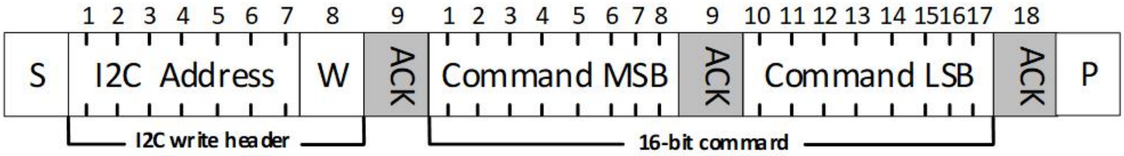


Fig. 9.3-5 Reset status register instruction(the white block is controlled by the microcontroller, and the sensor response is gray block)

9.3.7. Bias capacitance, feedback capacitance and channel selection register access

The write and read of the bias capacitance register is the single byte write and read command.

9.3.8. Single measurement mode command

In this mode one issued measurement command Convert C or Convert T triggers the acquisition of one capacitance or temperature data. During transmission each data value is always followed by the CRC checksum. The 16 bit commands are shown in the following table. Repeatability (low, medium and high) and clock stretching (enabled or disabled) can be achieved by modifying the configuration register. The repeatability setting influences the measurement duration and thus the overall energy consumption of the sensor.

Command	Hex Code
Measure temperature	0xCC44
Measure capacitance	0xCC66

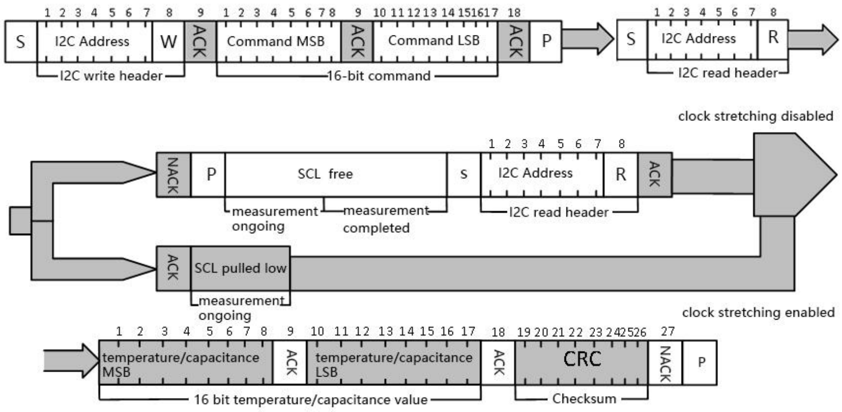


Fig.9.3-6 Temperature / capacitance measurement command in single measurement mode. “SCL free” block Indicates the single channel conversion time. (the white block is controlled by the microcontroller, and the sensor response is gray block)

9.3.9. Continuous measurement mode

MDCO4 continuous measurement mode is enabled by setting bits 2, 3 and 4 of the configuration register. They differ in repeatability (low, medium, and high) and data acquisition frequency (0.5, 1, 2, 4, and 10 measurements per second). Clock Stretching cannot be selected in this mode.

Data acquisition frequency and repeatability settings affect the measurement duration and current consumption of the sensor. This is explained in Section 2.

9.3.10. Read data in single and continuous measurement mode

Read temperature and capacitance channel 1

After the sensor completes the measurement, the host send the START condition and then send the I2C read header to read the measurement results. After the read temperature command is issued, the sensor will confirm the reception of the read header and send two bytes of data (temperature), followed by one byte of CRC checksum. Each byte must be acknowledged by the microcontroller and have an ACK condition for the sensor to continue sending data. If the sensor does not receive an ACK from the host after any data bytes, it will not continue to send data.

NOTE: Please close capacitor channel 2, channel 3 and channel 4 when using this command

After receiving the checksum of temperature data, the non reply (NACK) and stop conditions should be sent（See Fig. 9.3-7）。

If you are not interested in subsequent data, the I2C master device can abort the read transmission in a non acknowledge (NACK) condition after any data byte. For example, the second byte or CRC byte of the measurement result is not read to save time.

Command	Hex Code
Measure temperature and capacitance channel 1	0x2C10

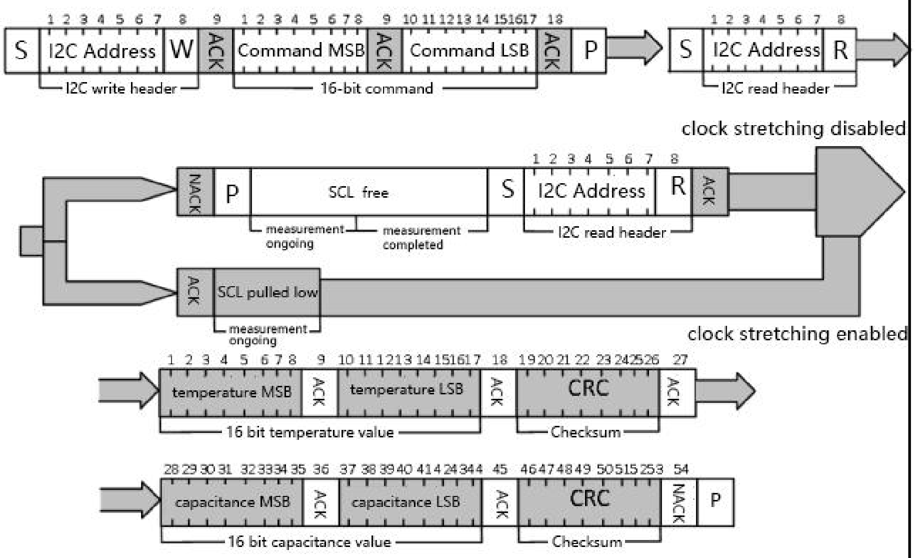


Fig. 9.3-7 Temperature capacitance channel 1 measurement command in single measurement mode. "SCL free" block indicates the required conversion time of temperature and capacitance（Table7.1） .(the white block is controlled by the microcontroller, and the sensor response is gray block)

No Clock Stretching

When the clock stretching is turned off, after the measurement command is issued, if the temperature measurement has not finished, the sensor will respond to a read header with a not acknowledge (NACK).

Clock Stretching

The clock stretching mode is enabled by setting the bit 5 of configuration register to 1. When the clock stretching is turned on, after the measurement command is issued, the sensor responds to the read header through an ACK, and then pulls down the SCL line until the measurement is completed. Once the measurement is completed, the sensor releases the SCL line and sends the measurement result.

9.3.11. Stop continuous measurement mode command

The stop command shown in the following table to stop the continuous measurement mode. After receiving the stop command, the sensor will stop the measurement in progress but will not enter the single measurement mode. After sending the measurement command again, it will enter the continuous measurement mode again. If you want to switch to the single measurement mode, you need to set the control bits related to the configuration register.

Command	**Hex Code**
Stop continuous measurement	0x3093

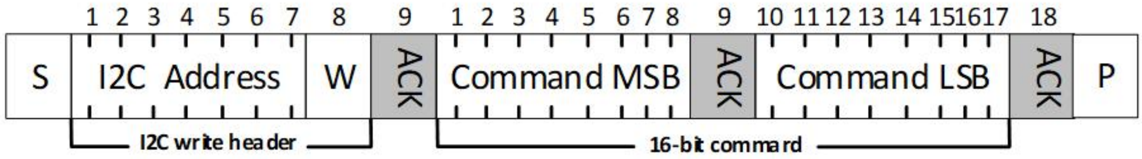


Fig.9.3-8 Stop continuous measurement mode command(the white block is controlled by the micro controller, and the sensor response is gray block)

9.3.12. Reset

The system reset signal of the sensor can be generated externally by issuing a command (soft reset) or by sending a pulse to the special reset pin (nREEST pin). In addition, during power on, the chip internal generation system is reset. During reset, the sensor does not process commands.In order to fully reset the sensor under the condition of continuous power supply, it is recommended to use the nRESET pin of MDC04

Reset interface

If the communication with the device is abnormal, the following signal sequence will reset the serial interface: switch the SCL nine or more times when the SDA remains high. This method must follow the transfer start sequence before the next command. This sequence only resets the interface and the status register retains its contents.

Soft reset/Re-initialization

MDC04 provides a soft reset mechanism, which forces the system to enter a clearly defined state under the condition of continuous power supply. When the system is idle, the soft reset command can be sent to MDC04. This triggers the sensor to reset its system controller and reload calibration data from memory. In order to start the soft reset process, the commands shown in the following table should be sent.

Command	Hex Code
Software reset	0x30a2

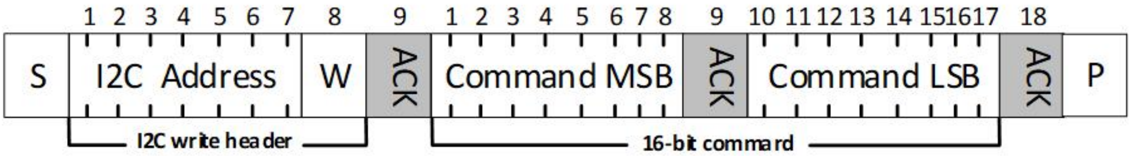


Fig.9.3-9 Soft reset(the white block is controlled by the microcontroller, and the sensor response is gray block)

Hard reset

Pulling the nReset pin down will produce a reset similar to the hard reset. The nReset pin is internally connected to VDD through pull-up resistor, so it is effective for low level. The nReset pin must be pulled down for at least 1µs to generate the sensor reset.

9.3.13. Register store and recovery commands

All data written to the register (working configuration and alarm threshold) is temporary. If you want these settings to stay permanently, that is, they can still be saved after power failure, you need to use the copy command to store these data in E2PROM.

When hard reset or soft reset, the system automatically loads E2PROM data into the register. In addition, data can be recovered from E2PROM to register with recovery instruction.

Command	HEX Code
Copy to E^2PROM	0xcc48
Restore E^2PROM area	0xccb8
Restore the rest area	0xccba

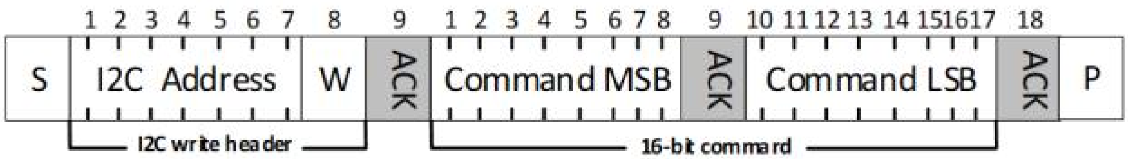


Fig.9.3-10 Register store and recovery commands (the white block is controlled by the microcontroller, and the sensor response is gray block)

9.3.14. Auto configure bias capacitor command

By calling the IIC command, the automatic configuration of the measured capacitance offset can be realized. After connected by the measured capacitance, and set the highest two bits of cfb[7:6] of Cfb register to "11" and apply this instruction, the sensor will automatically search for the best bias capacitance Co, and write it into the bias capacitance register Cos according to the currently measured stable capacitance value. If the measured capacitance exceeds the maximum range, Cos will stop at FF.

Command	HEX Code
Automatically configure capacitance range	0xA187

Fig.9.3-11 Auto configuration range command (the white block is controlled by the microcontroller, and the sensor response is gray block)

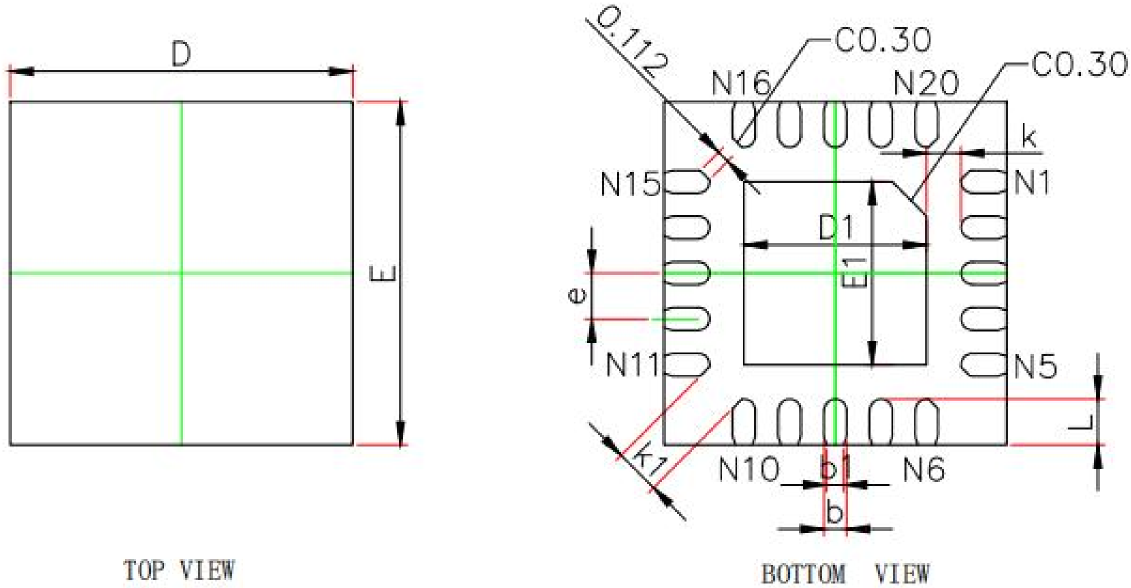
9.4. Cyclic redundancy check（CRC)

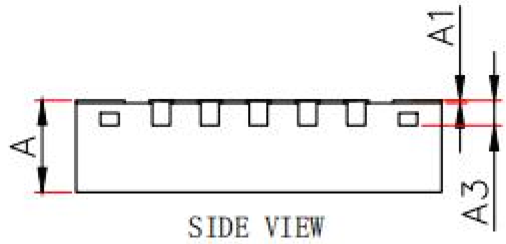
The 8-bit CRC checksum is sent after each data are generated by the CRC algorithm. Its properties are shown in the following table.

Parameter	**Value**
Name	CRC-8
Width	8-bit
Data Protect	W/R
Polynomial	0x31 ($x^8 + x^5 + x^4 + 1$)
Initial Value	0xFF
Whether each byte of the test data reversed by bit	No
After calculation and before exclusive or output, whether the whole data is reversed by bit	No
The calculation result is exclusive or to this parameter	0x00
Example	CRC (0xBEEF) = 0x92

10. Packaging information

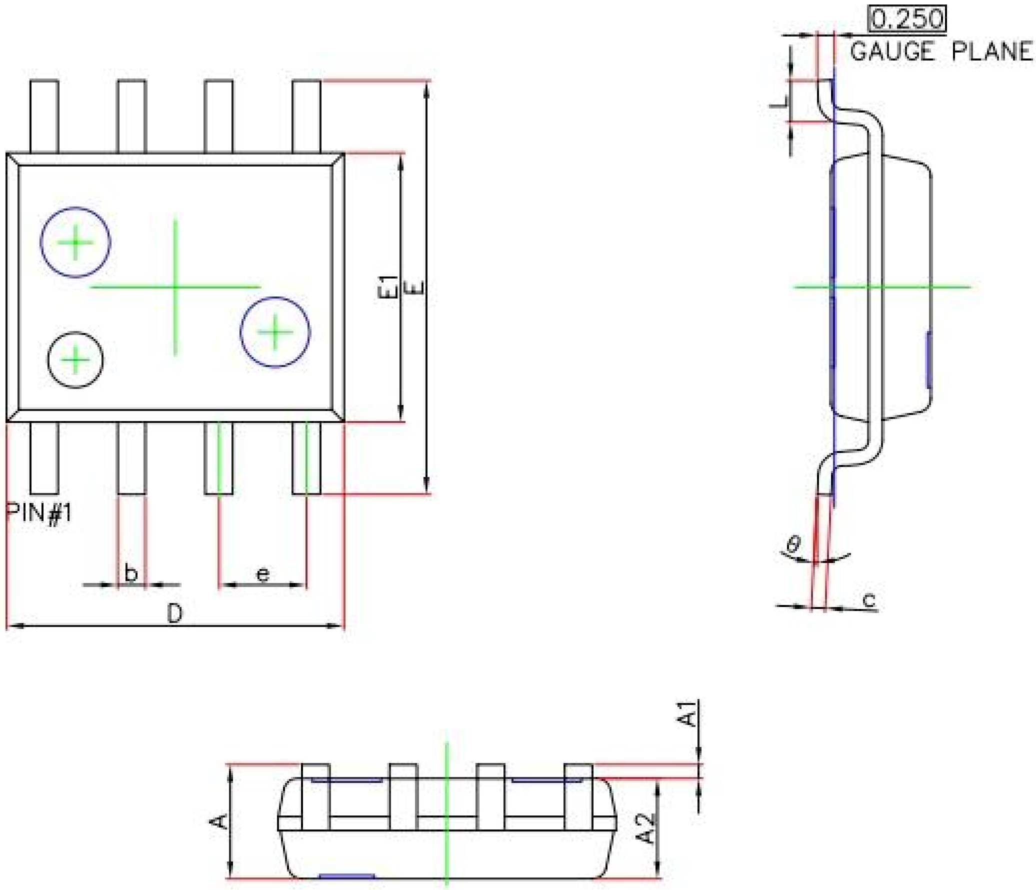
10.1. MDC04 QFN20 3*3*0.75mm





Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	2.950	3.050	0.116	0.120
E	2.950	3.050	0.116	0.120
D1	1.550	1.650	0.061	0.065
E1	1.550	1.650	0.061	0.065
k	0.300REF.		0.012REF.	
k1	0.400REF.		0.016REF.	
b	0.150	0.250	0.006	0.010
b1	0.150REF.		0.006REF.	
e	0.400BSC.		0.016BSC.	
L	0.300	0.500	0.012	0.020

10.2. MDC02 SOP8 4.9*3.9*1.6mm



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	1.450	1.750	0.057	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

Appendix: Capacitance offset and input ranges configuration

Configure the measuring range of the measured capacitance C_X by accessing the registers Cfb and Cos in Chapter 7.1. The fixed offset capacitance Co and the capacitance measurement range Cr, make the measured Cx range from Co-Cr to Co+Cr. For more methods of configuring registers, please refer to the development board routine. Here are configuration tables of Cr and Co in hex, under the condition of COS_RANGE[1:0]=0x11, respectively:

Table1 Measurement range Cr configuration

Cfb[7:0]	Cr (pf)	Cfb[7:0]	Cr (pf)	Cfb[7:0]	Cr (pf)	Cfb[7:0]	Cr (pf)
C0	0.282	D0	4.788	E0	6.760	F0	11.267
C1	0.563	D1	5.070	E1	7.042	F1	11.548
C2	0.845	D2	5.352	E2	7.323	F2	11.830
C3	1.127	D3	5.633	E3	7.605	F3	12.112
C4	1.408	D4	5.915	E4	7.887	F4	12.393
C5	1.690	D5	6.197	E5	8.168	F5	12.675
C6	1.972	D6	6.478	E6	8.450	F6	12.957
C7	2.253	D7	6.760	E7	8.732	F7	13.238
C8	2.535	D8	7.042	E8	9.013	F8	13.520
C9	2.817	D9	7.323	E9	9.295	F9	13.802
CA	3.098	DA	7.605	EA	9.577	FA	14.083
CB	3.380	DB	7.887	EB	9.858	FB	14.365
CC	3.662	DC	8.168	EC	10.140	FC	14.647
CD	3.943	DD	8.450	ED	10.422	FD	14.928
CE	4.225	DE	8.732	EE	10.703	FE	15.210
CF	4.507	DF	9.013	EF	10.985	FF	15.492

Table2 Offset capacitor Co configuration

Cos[7:0]	Co (pf)	Cos[7:0]	Co (pf)	Cos[7:0]	Co (pf)	Cos[7:0]	Co (pf)
00	0.00	40	32.00	80	40.00	C0	72.00
01	0.50	41	32.50	81	40.50	C1	72.50
02	1.00	42	33.00	82	41.00	C2	73.00
03	1.50	43	33.50	83	41.50	C3	73.50
04	2.00	44	34.00	84	42.00	C4	74.00
05	2.50	45	34.50	85	42.50	C5	74.50
06	3.00	46	35.00	86	43.00	C6	75.00
07	3.50	47	35.50	87	43.50	C7	75.50
08	4.00	48	36.00	88	44.00	C8	76.00

09	4.50	49	36.50	89	44.50	C9	76.50
0A	5.00	4A	37.00	8A	45.00	CA	77.00
0B	5.50	4B	37.50	8B	45.50	CB	77.50
0C	6.00	4C	38.00	8C	46.00	CC	78.00
0D	6.50	4D	38.50	8D	46.50	CD	78.50
0E	7.00	4E	39.00	8E	47.00	CE	79.00
0F	7.50	4F	39.50	8F	47.50	CF	79.50
10	8.00	50	40.00	90	48.00	D0	80.00
11	8.50	51	40.50	91	48.50	D1	80.50
12	9.00	52	41.00	92	49.00	D2	81.00
13	9.50	53	41.50	93	49.50	D3	81.50
14	10.00	54	42.00	94	50.00	D4	82.00
15	10.50	55	42.50	95	50.50	D5	82.50
16	11.00	56	43.00	96	51.00	D6	83.00
17	11.50	57	43.50	97	51.50	D7	83.50
18	12.00	58	44.00	98	52.00	D8	84.00
19	12.50	59	44.50	99	52.50	D9	84.50
1A	13.00	5A	45.00	9A	53.00	DA	85.00
1B	13.50	5B	45.50	9B	53.50	DB	85.50
1C	14.00	5C	46.00	9C	54.00	DC	86.00
1D	14.50	5D	46.50	9D	54.50	DD	86.50
1E	15.00	5E	47.00	9E	55.00	DE	87.00
1F	15.50	5F	47.50	9F	55.50	DF	87.50
20	16.00	60	48.00	A0	56.00	E0	88.00
21	16.50	61	48.50	A1	56.50	E1	88.50
22	17.00	62	49.00	A2	57.00	E2	89.00
23	17.50	63	49.50	A3	57.50	E3	89.50
24	18.00	64	50.00	A4	58.00	E4	90.00
25	18.50	65	50.50	A5	58.50	E5	90.50
26	19.00	66	51.00	A6	59.00	E6	91.00
27	19.50	67	51.50	A7	59.50	E7	91.50
28	20.00	68	52.00	A8	60.00	E8	92.00
29	20.50	69	52.50	A9	60.50	E9	92.50
2A	21.00	6A	53.00	AA	61.00	EA	93.00
2B	21.50	6B	53.50	AB	61.50	EB	93.50
2C	22.00	6C	54.00	AC	62.00	EC	94.00
2D	22.50	6D	54.50	AD	62.50	ED	94.50
2E	23.00	6E	55.00	AE	63.00	EE	95.00
2F	23.50	6F	55.50	AF	63.50	EF	95.50
30	24.00	70	56.00	B0	64.00	F0	96.00
31	24.50	71	56.50	B1	64.50	F1	96.50
32	25.00	72	57.00	B2	65.00	F2	97.00

33	25.50	73	57.50	B3	65.50	F3	97.50
34	26.00	74	58.00	B4	66.00	F4	98.00
35	26.50	75	58.50	B5	66.50	F5	98.50
36	27.00	76	59.00	B6	67.00	F6	99.00
37	27.50	77	59.50	B7	67.50	F7	99.50
38	28.00	78	60.00	B8	68.00	F8	100.00
39	28.50	79	60.50	B9	68.50	F9	100.50
3A	29.00	7A	61.00	BA	69.00	FA	101.00
3B	29.50	7B	61.50	BB	69.50	FB	101.50
3C	30.00	7C	62.00	BC	70.00	FC	102.00
3D	30.50	7D	62.50	BD	70.50	FD	102.50
3E	31.00	7E	63.00	BE	71.00	FE	103.00
3F	31.50	7F	63.50	BF	71.50	FF	103.50