

High-precision Time-to-Digital-Converter

PRODUCT DESCRIPTION

The MS1030 is a high-precision TDC circuit. It has the characteristics of high accuracy, high stability, and high efficiency. It has measurement accuracy of 15ps and a measurement range from 500ns to 4ms @ 4MHz. In the first wave mode, the offset range of the internal comparator is $\pm 127\text{mV}$, and a comparison bias voltage of $-128\sim 124\text{mV}$ is also added; The measurement echo can be up to 8 echo pulses. The package pins of this circuit is completely compatible with the MS1022, making it easy for the customer to replace.



QFN32

FEATURES

Flow Measurement Unit

- Measurement Accuracy of 15ps, 3.8ps at 1LSB
- Measurement Range from 500ns to 4ms @ 4MHz
- 8 Echo Signals can be Measured, Accumulated and Stored in the Result Register
- High-precision Pulse Width Detection Unit

Analog Input Circuit

- Built-in Stable Low-drift Precision Comparator, 1mV (TYP) Offset Voltage
- Built-in Programmable Comparator Bias Voltage, $-128\sim 124\text{mV}$ Programming Voltage
- Built-in First-wave Detection Function with Programmable Bias Voltage up to $\pm 127\text{mV}$
- Analog Section is Disabled during Non-measurement Time, Power Dissipation less than 50nA

Pulse Generation Unit

- Built-in Two Pulse Generators, Generate up to 127 Pulse Singularly
- Pulse Generator Sends Pulse Frequency: 62.5kHz~2MHz @4MHz
- Pulse Generator Output 48mA Current Singularly
- Two Pulse Output Pins with a Single Reverse Function

Temperature Measurement Unit

- Two or Four Temperature Sensors, PT500/PT100
- Built-in Schmitter Trigger
- Extra-low Power Dissipation (Perform a Measurement Every 30s, 0.08 μA)

Other Functions

- Rising or/and Falling Edge Trigger Measurement
- High-precision STOP Shielding Window
- 32kHz Oscillator with Low Power Dissipation(7 μA)
- Four-wire SPI Communication Interface
- 2.5V to 3.6V Operating Voltage
- $-40^{\circ}\text{C}\sim +125^{\circ}\text{C}$ Operating Temperature
- QFN32

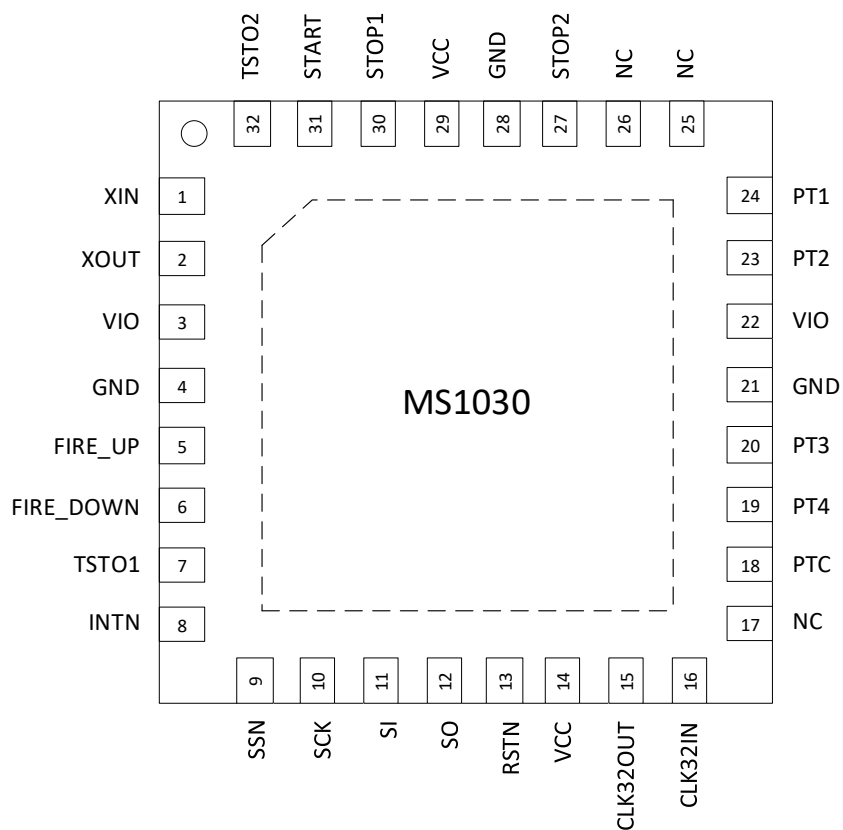
APPLICATION

- Ultrasonic Water Meter
- Ultrasonic Heat Meter
- Ultrasonic Gas Meter
- Ultrasonic Flowmeter
- Ultrasonic Anemometer

PRODUCT SPECIFICATION

Part Number	Package	Marking
MS1030	QFN32	MS1030

PIN CONFIGURATION

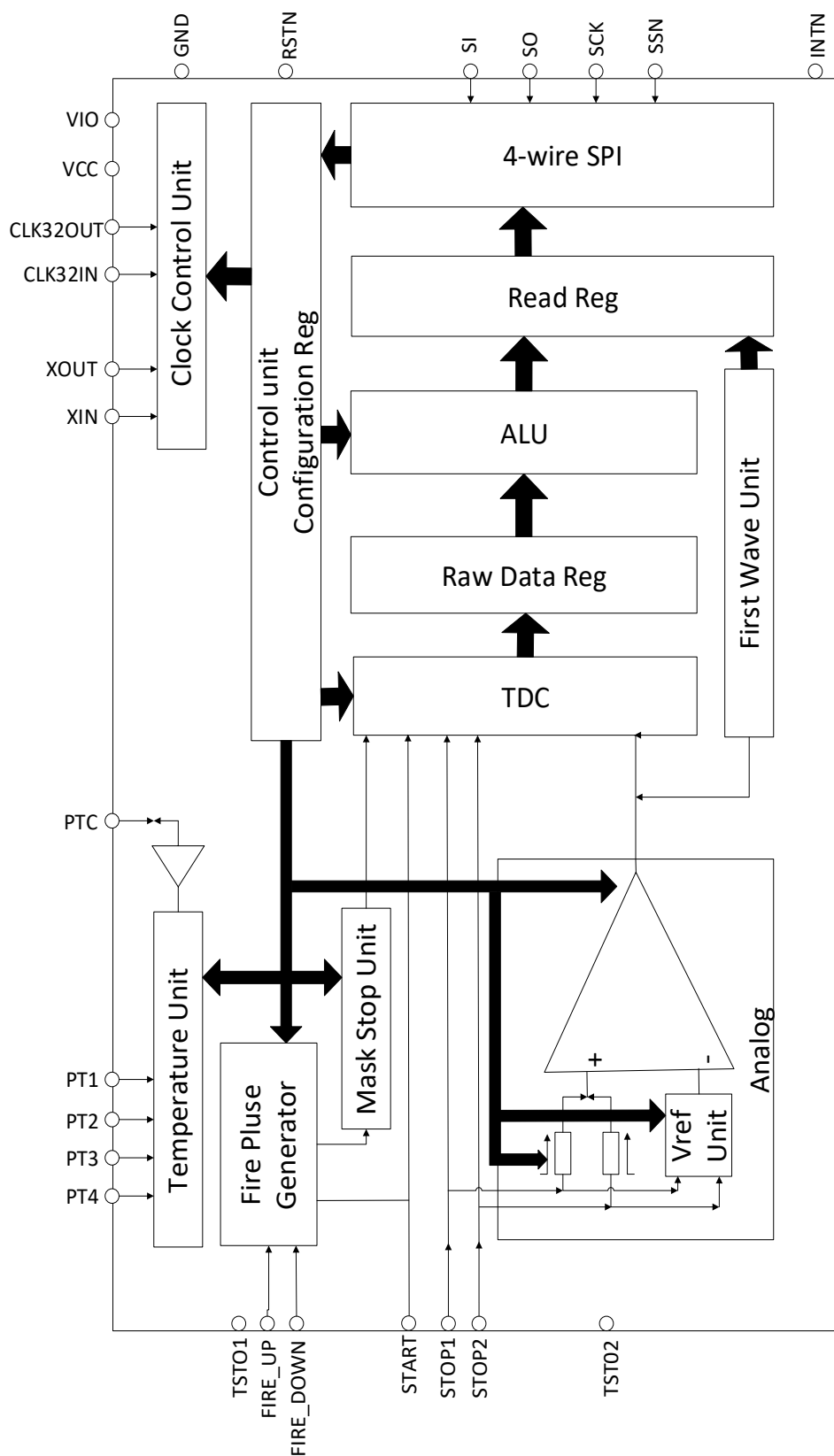


PIN DESCRIPTION

Pin	Name	I/O	Buffer Type	Description	Unused
1	XIN	I		High-speed Crystal Input	GND
2	XOUT	O		High-speed Crystal Output	
3	VIO	-		I/O Supply Voltage	
4	GND	-		Ground	
5	FIRE_UP	O	48mA	Fire Pulse Generator Output 1	
6	FIRE_DOWN	O	48mA	Fire Pulse Generator Output 2	
7	TSTO1	O		Test Output Pin 1	
8	INTN	O	4mA	Interrupt Flag, Active Low	
9	SSN	I		Slave Select, Active Low	GND
10	SCK	I		Clock Serial Interface	GND
11	SI	I		Data Input Serial Interface	GND
12	SO	O	4mA Tri-state	Data Output Serial Interface	
13	RSTN	I		Reset Input, Active Low	VIO
14	VCC	-		Core Supply Voltage	
15	CLK32OUT	O		32kHz Clock Output	
16	CLK32IN	I		32kHz Clock Input	GND
17	NC	-		No Connection	
18	PTC	-		Temperature Measurement Capacitor Terminal	
19	PT4	O	>96mA Open Drain	Temperature Measurement Port 4	
20	PT3	O		Temperature Measurement Port 3	
21	GND	-		Ground	
22	VIO	-		I/O Supply Voltage	
23	PT2	O	>96mA Open Drain	Temperature Measurement Port 2	
24	PT1	O		Temperature Measurement Port 1	
25	NC	-		No Connection	
26	NC	-		No Connection	
27	STOP2	I		STOP Channel 2(Analog Only)	GND
28	GND	-		Ground	
29	VCC	-		Core Supply Voltage	
30	STOP1	I		STOP Channel 1(Digital or Analog)	GND
31	START	I		START Input (Digital)	GND
32	TSTO2	O		Test Output Pin 2	

Note: If the user does not use the above pins, please set the unused pins according to the connection in the "Unused" column above.

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Any exceeding absolute maximum rating application causes permanent damage to device. Because long-time absolute operation state affects device reliability. Absolute ratings just conclude from a series of extreme tests. It doesn't represent chip can operate normally in these extreme conditions.

Parameter	Symbol	Range	Unit
Core Supply Voltage	V_{CC}	-0.3 ~ 4	V
I/O Supply Voltage	V_{IO}	-0.3 ~ 4	V
Input Voltage	V_{IN}	-0.5 ~ $V_{CC}+0.5$	V
Storage Temperature	T_{STG}	-65 ~ 150	°C
Maximum Junction Temperature	T_{JMAX}	150	°C
ESD (HBM)	V_{ESD}	>4000	V

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Core Supply Voltage ¹	V_{CC}	$V_{CC}=V_{IO}$	2.5		3.6	V
I/O Supply Voltage	V_{IO}		2.5		3.6	V
Input Signal Rising Time	t_{RI}				200	ns
Input Signal Falling time	t_{FA}				200	ns
Schmitt Trigger Rising Time	t_{RI}				5	ms
Schmitt Trigger Falling Time	t_{FA}				5	ms
Operating Temperature	T_A	T_J must not exceed 125°C	-40		125	°C
Thermal Resistance	$R_{TH(J-)}$	Junction-ambient		28		k/W

Note 1: Including the oscillator pins XIN, XOUT, CLK32IN, CLK32OUT

ELECTRICAL CHARACTERISTICS

DC Characteristics

 $V_{IO} = V_{CC} = 3V$, $T_A = -40 \sim +85^{\circ}C$, 32kHz External Input

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
32kHz Crystal Current	I_{32}	$I_{CC} + I_{IO}$, Only 32kHz		7	15	μA
4MHz Crystal Current	I_{HS}	$V_{CC} = V_{IO} = 3.3V$	100	180	300	μA
		Disabled		<1		μA
Current of Time Measurement Unit	I_{TMU}	Only Time Measurement		2		mA
Quiescent Current	I_{DDQ}	All Clock Disabled, $85^{\circ}C$		<0.1		μA
Operating Current	I_O	TOF-UP/DOWN, 1/s,		1.1		μA
		PT1000, 1/30s		0.15		
Current of Temperature Measurement Unit	I_T	Every 30 Seconds		0.085		μA
Current of Analog Part	I_{ANA}	Only Analog Part		0.8		mA
Total Current	I_{TOTAL}	Time is measured twice per second. Temperature is measured every 30 seconds.		2.3		μA
High-level Output Voltage	V_{OH}	$I_{OH} = tbd$ mA, $V_{IO} = Min$	$0.8 \times V_{IO}$			V
Low-level Output Voltage	V_{OL}	$I_{OL} = tbd$ mA, $V_{IO} = Min$			$0.2 \times V_{IO}$	V
High-level Input Voltage	V_{IH}	LVTTL, $V_{IO} = Max$	$0.7 \times V_{IO}$			V
Low-level Input Voltage	V_{IL}	LVTTL, $V_{IO} = Min$			$0.3 \times V_{IO}$	V
High-level Schmitt Trigger Voltage	V_{TH}		$0.7 \times V_{IO}$			V
Low-level Schmitt Trigger Voltage	V_{TL}				$0.3 \times V_{IO}$	V
Schmitt Trigger Hysteresis	V_H			0.28		V

Terminal Capacitance

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Digital Input Capacitance	C_{IN}	$V_{CC} = V_{IO}$, $f = 1MHz$, $T_A = 25^{\circ}C$		7		pF
Digital Output Capacitance	C_O			3		
Bidirectional Capacitance	C_{IO}			9		

Analog Front-end

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Comparator Input Offset Voltage (Chopper Stabilized)	V_{OFFSET}			1	2	mV
Switch-on Resistance of Analog Switches at STOP1/STOP2 Inputs	$R_{\text{DSON(AS)}}$			300		Ω
Switch-on Resistance of FIRE_UP, FIRE_DOWN Output Buffers	$R_{\text{DSON(FIRE)}}$	Symmetrical Outputs, $R_{\text{DSON (HIGH)}} = R_{\text{DSON (LOW)}}$		4		Ω
Output Current of FIRE_UP, FIRE_DOWN Output Buffers	I_{FIRE}			48		mA
Analog Input Voltage	V_{ANA}		50	500		mVpp
STOP Bias Voltage				$V_{\text{CC}} \times 1/3$		V
Comparator Transmission Delay	t_{PD}			100		ns

Time Measuring Unit

$V_{\text{IO}} = V_{\text{CC}} = 3.0\text{V}$, $T_{\text{J}} = 25^\circ\text{C}$

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Time Measurement Accuracy	T_{ACC}	$V_{\text{CC}} = 3.0$		15		ps
Measurement Resolution	T_{RES}	$V_{\text{CC}} = 3.0$		3.8		ps
Measuring Range ²	T_{M}	$V_{\text{CC}} = 3.0$	0.0005		4	ms

Note 2: @4MHz

Temperature Measuring Unit³

Parameter		Conditions		Unit
Sensor		PT500	PT1000	
Resolution RMS		16.5	16.5	Bit
SNR		75	75	dB
Absolute Gain VS. V_{IO}	3.6V	0.9922	0.9958	
	3.0V	0.9901	0.9932	
	2.5V	0.9892	0.9926	
Gain Drift VS. V_{IO}		0.2117	0.2611	%/V
Maximum Gain Error @ $d\theta = 100\text{k}$		0.04%	0.04%	

Note 3: All values measured at $V_{\text{IO}} = V_{\text{CC}} = 3.0\text{V}$, $C_{\text{LOAD}} = 100\text{nF}$ for PT1000 and 200nF for PT500 (COG-type).

TIMING

The following parameters are measured at $V_{CC} = 3.0V \pm 0.3V$, ambient temperature: $-40^{\circ}C$ to $+85^{\circ}C$, unless otherwise specified.

Oscillator

Parameter	Symbol	Min	Typ	Max	Unit
32kHz Reference Oscillator	CLK32		32.768		kHz
32kHz Oscillator Start-up Time after Power-up	t_{32ST}		3		s
High-speed Reference Oscillator	CLKHS	1	4	8	MHz
Oscillator Start-up Time with Ceramic Resonator	t_{OSZST}		100		μs
Oscillator Start-up Time with Crystal Oscillator	t_{OSZST}		1		ms

Serial Interface

Parameter	Symbol	$V_{IO}=2.5V$	$V_{IO}=3.3V$	Unit
Serial Clock Frequency	f_{clk}	15(Max)	20(Max)	MHz
Serial Clock, Pulse Width High	t_{pwh}	30(Min)	25(Min)	ns
Serial Clock, Pulse Width Low	t_{pwl}	30(Min)	25(Min)	ns
SSN Enable to Valid Latch Clock	t_{sussn}	40(Min)	10(Min)	ns
SSN Pulse Width between Write Cycles	t_{pwssn}	50(Min)	40(Min)	ns
SSN Hold Time after SCK Falling Edge	t_{hssn}	40(Min)	25(Min)	ns
Time from Data Valid to SCK Falling Edge	t_{sud}	5(Min)	5(Min)	ns
Data Hold Time after SCK Falling Edge	t_{hd}	5(Min)	5(Min)	ns
Time from SCK Rising Edge to Data Valid	t_{vd}	20(Min)	16(Min)	ns

Serial Interface (SPI compatible, Clock Phase Bit =1, Clock Polarity Bit =0):

The serial interface is compatible with the 4-wire SPI. It requires a SerialSelectNot (SSN) signal, so it can't work in the 3-wire SPI interface.

The falling edge of the SSN or the first rising edge of the SCK would reset the state of INTN pin (interrupt pin).

The transmission starts from the most significant bit (MSB) and ends with the least significant bit (LSB). The transfer is done in bytes. Data transfer can stop after each byte by sending a LOW-HIGH-LOW level to the SSN.

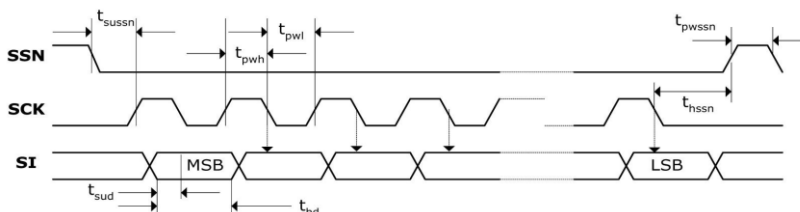


Figure1. SPI Write

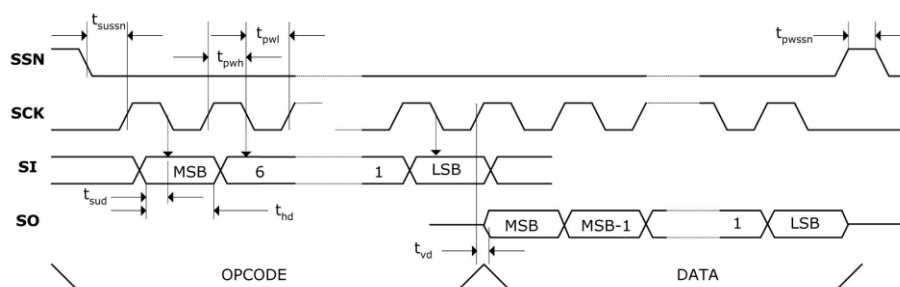


Figure2. SPI Read

Reset Timing

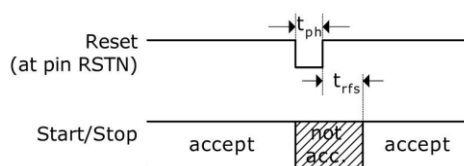


Figure3. Reset Timing

Parameter	Symbol	Min	Max	Unit
Reset Pulse Width	tph	30	-	ns
Time after rising edge of reset pulse before hits are accepted	trfs	30	-	ns

Note: After power-on reset, it is necessary to wait minimum 500μs to settle the analog part.

POWER SUPPLY

The MS1030 is a high-end mixed analog/digital device. To reach full performance of the chip, a good power supply is mandatory. It should be featured with high capacitance and of low inductance.

The MS1030 provides two pairs of power supply terminals:

VIO - I/O supply voltage

VCC - Core supply voltage

All ground pins should be connected to a ground plane on the printed circuit board. VIO and VCC should be provided by a battery or fixed linear voltage regulator. Do not use switched regulators to avoid disturbances caused by the I/O supply.

The measurement quality of a time-to-digital converter depends on a good power supply. The chip sees mainly pulsed current and therefore a sufficient bypassing is mandatory:

VCC 47 μF (minimum 22 μF)

VIO 100 μF (minimum 22 μF)

The supply voltage should be provided through analog regulators. We strongly recommend not to use switched power supplies.

REGISTER DESCRIPTION

OP CODE & Registers

1. OP Code

The operation code is used to read or write registers or execute operation commands.

The specific commands are as follows:

Name	Code	Description
Write_REG0	0x80	Write configuration register 0
Write_REG1	0x81	Write configuration register 1
Write_REG2	0x82	Write configuration register 2
Write_REG3	0x83	Write configuration register 3
Write_REG4	0x84	Write configuration register 4
Read_TOF_UP_STOP1	0xb0	Read the Upstream 1st STOP result register
Read_TOF_UP_STOP2	0xb1	Read the Upstream 2nd STOP result register
Read_TOF_UP_STOP3	0xb2	Read the Upstream 3rd STOP result register
Read_TOF_UP_STOP4	0xb3	Read the Upstream 4th STOP result register
Read_TOF_UP_STOP5	0xb4	Read the Upstream 5th STOP result register
Read_TOF_UP_STOP6	0xb5	Read the Upstream 6th STOP result register
Read_TOF_UP_STOP7	0xb6	Read the Upstream 7th STOP result register
Read_TOF_UP_STOP8	0xb7	Read the Upstream 8th STOP result register
Read_TOF_UP_SUM	0xb8	Read 8 STOP accumulation result in the forward direction
Read_Temp_PT1	0xc2	Read temperature measurement PT1 port result register
Read_Temp_PT2	0xc3	Read temperature measurement PT2 port result register
Read_Temp_PT3	0xc4	Read temperature measurement PT3 port result register
Read_Temp_PT4	0xc5	Read temperature measurement PT4 port result register
Read_PW_First	0xd0	Read the first wave pulse width result register
Read_PW_Stop1	0xd1	Read the first STOP pulse width result register
Read_Status_REG	0xd2	Read status register
Read_Comm_REG	0xd3	Read communication detection register (low 8 bits in register 0)
Read_CAL_REG	0xd4	Read clock calibration register
INITIAL	0x70	Initialization, only the result and status registers are initialized
POR	0x50	Software reset to initialize all registers
START_TOF_UP	0x01	unidirectional measurement, sending pulse and receiving channel according to register configuration
START_TEMP	0x04	Temperature measurement, perform temperature test
START_TEMP_RESTART	0x05	Two temperature measurements, perform two temperature tests
START_CAL_RESONATOR	0x06	high-speed clock calibration, perform high-speed clock calibration test

2. Registers

Registers can store configuration parameters, measurement results, and detection status, which are executed by different operation codes. The specific register names and operation codes are as follows:

Name	Code	Description
Write_REG0	0x80	Configuration register 0: 32 bits, write-only, not readable
Write_REG1	0x81	Configuration register 1: 32 bits, write-only, not readable
Write_REG2	0x82	Configuration register 2: 32 bits, write-only, not readable
Write_REG3	0x83	Configuration register 3: 32 bits, write-only, not readable
Write_REG4	0x84	Configuration register 4: 32 bits, write-only, not readable
TOF_UP_STOP1_REG	0xb0	Upstream 1st STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP2_REG	0xb1	Upstream 2nd STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP3_REG	0xb2	Upstream 3rd STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP4_REG	0xb3	Upstream 4th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP5_REG	0xb4	Upstream 5th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP6_REG	0xb5	Upstream 6th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP7_REG	0xb6	Upstream 7th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP8_REG	0xb7	Upstream 8th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_SUM_REG	0xb8	Upstream 8 STOP accumulation result registers: 16-bit integer, 16-bit decimal
Temp_PT1_REG	0xc2	Temperature measurement PT1 result register: 16-bit integer, 16-bit decimal
Temp_PT2_REG	0xc3	Temperature measurement PT2 result register: 16-bit integer, 16-bit decimal
Temp_PT3_REG	0xc4	Temperature measurement PT3 result register: 16-bit integer, 16-bit decimal
Temp_PT4_REG	0xc5	Temperature measurement PT4 result register: 16-bit integer, 16-bit decimal
PW_First_REG	0xd0	First wave pulse width result register: 11-bit integer
PW_Stop1_REG	0xd1	First STOP pulse width result register: 11-bit integer
Status_REG	0xd2	Status register: 16-bit integer
Comm_REG	0xd3	Communication register: 8-bit integer (low 8 bits in write register 0)
CAL_REG	0xd4	Clock check register: 16-bit integer, 16-bit decimal

3. Configuration Register

The configuration register is set by the user according to the characteristics of the product.

This type of register can only write but not read, as follows:

3.1. Write_REG0(Code: 0x80)

Bit	Defaults	Parameter	Description	Settings
31	0	ANZ_FIRE	Set the number of pulses transmitted by the fire port.	0 = disabled 1 = 1 pulse ... 127 = 127 pulses
30	0			
29	0			
28	0			
27	0			
26	1			
25	0			
24	0	DIV_FIRE	Sets the division factor of the pulses generated by the internal clock signal	0 = divided by 2 1 = divided by 2 ... 63 = divided by 64
23	0			
22	0			
21	0			
20	1			
19	0			
18	0	DIV_CLKHS	Sets division factor for CLKHS high-speed reference clock	0 = no division 1 = divided by 2 2 = divided by 4 3 = divided by 4
17	0			
16	0	START_CLKHS	Set the crystal start time interval after the crystal is turned on and before the measurement starts	0 = Oscillator disabled; 1 = Oscillator always enabled; 2 = starting of oscillation delay time 480 μ s 3 = starting of oscillation delay time 1.46 ms 4 = starting of oscillation delay time 2.44 ms 5 to 7 = starting of oscillation delay time 5.14 ms
15	0			
14	1			
13	0	NEG_START	Negation start channel	0 = non-inverted input signal-rising edge 1 = inverted input signal-falling edge
12	0	NEG_STOP	Negation stop channel 1	0 = non-inverted input signal-rising edge 1 = inverted input signal-falling edge
11	0	HITIN	Set the expected number of pulses for the stop channel	0 = disabled 1 = START 2 = 1 pulse 3 = 2 pulses 4 = 3 pulses 5 = 4 pulses 6 = 5 pulses 7 = 6 pulses 8 = 7 pulses 9 = 8 pulses A = Not allowed
10	0			
9	0			
8	0			
7	0	K.D		
6	0	SEL_TIMO_MB	Set overflow time	0 = 64 μ s 1 = 128 μ s 2 = 256 μ s 3 = 512 μ s 4 = 1024 μ s 5 = 2048 μ s 6 = 4096 μ s @ 4 MHz ClkHS
5	1			
4	1			
3	0	SEL_TST02 ⁴	Set TST02 pin function	0 = High_Z 1 = START output 2 = STOP1 output 3 = 4 kHz output
2	0			
1	0	SEL_TST01 ⁴	Set TST01 pin function	0 = High_Z 1 = START output 2 = STOP1 output 3 = 32 kHz output
0	0			

Note 4: When these two pins are set to "high impedance" and connected to the input of the rear stage, the pins should be connected to VIO or GND through a large resistor to avoid causing large current.

3.2. Write_REG1(Code: 0x81)

Bit	Defaults	Parameter	Description	Settings
31	0	EN_INT_TO	Timeout Interrupt trigger	1=enabled 0=disabled
30	0	EN_INT_HIT	End Hits Interrupt trigger	1=enabled 0=disabled
29	1	EN_INT_ALU	ALU Interrupt trigger	1=enabled 0=disabled
28	0	RFEDGE	Edge sensitivity	0 = rising or falling edge 1 = rising and falling edge
27	0	DELVAL1	The first STOP pulse or the first wave masking window: when EN_FIRST_WAVE=0, the first STOP pulse masking window is performed, when EN_FIRST_WAVE=1, the first wave masking window is performed. Unit time is in multiples of Tref with 16 integer digits.	DELVAL1 = 0 to 65535 Delay_time:750ns~4ms @4MHz
26	0			
25	0			
24	0			
23	0			
22	0			
21	0			
20	0			
19	0			
18	0			
17	0			
16	0			
15	0			
14	0			
13	0			
12	0			
11	0			
10	0			
9	0			
8	0			
7	0			
6	0	K.D		
5	0	offset	Set built-in comparator offset voltage, From 124mV to -128 mV	0 = 0 mV
4	0			1 = 4 mV
3	0			...
2	0			31 = 124 mV
1	0			32 = -128 mV
0	0			... 63 = -4 mV

3.3. Write_REG2(Code: 0x82)

EN_FIRST_WAVE=0

Bit	Defaults	Parameter	Description	Settings
31	0	EN_FIRST_WAVE	Enables the automatic first hit detection. In this case, new meaning will be generated in registers 2 and 3.	0 = disabled 1 = enabled
30-0	0	K.D		

EN_FIRST_WAVE=1

Bit	Defaults	Parameter	Description	Settings
31	0	EN_FIRST_WAVE	Enables the automatic first hit detection. In this case, new meaning will be generated in registers 2 and 3.	0 = disabled 1 = enabled
30	0	EDGE_FW	Sets the edge sensitivity for the first wave.	0=rising edge 1=falling edge
29	0	DELREL1	Sets the number of the periods after the first hit for the 1st stop	3 to 64
28	0			
27	0			
26	0			
25	0			
24	0			
23	0	DELREL2	Sets the number of the periods after the first hit for the 2nd stop	4 to 64
22	0			
21	0			
20	0			
19	0			
18	0			
17	0	DELREL3	Sets the number of the periods after the first hit for the 3rd stop	5 to 64
16	0			
15	0			
14	0			
13	0			
12	0			
11	0	DELREL4	Sets the number of the periods after the first hit for the 4th stop	6 to 64
10	0			
9	0			
8	0			
7	0			
6	0			
5	0	DELREL5	Sets the number of the periods after the first hit for the 5th stop	7 to 64
4	0			
3	0			
2	0			
1	0			
0	0			

3.4. Write_REG3(Code: 0x83)

EN_FIRST_WAVE=0

Bit	Defaults	Parameter	Description	Settings
31-0	0	K.D		

EN_FIRST_WAVE=1

Bit	Defaults	Parameter	Description	Settings
31	0	DELREL6	Sets the number of the periods after the first hit for the 6th stop	8 to 64
30	0			
29	0			
28	0			
27	0			
26	0			
25	0	DELREL7	Sets the number of the periods after the first hit for the 7th stop	9 to 64
24	0			
23	0			
22	0			
21	0			
20	0			
19	0	DELREL8	Sets the number of the periods after the first hit for the 8th stop	10 to 64
18	0			
17	0			
16	0			
15	0			
14	0			
13	0	DIS_PW	Disable pulse width measurement	0= pulse width measurement enabled 1= pulse width measurement disabled
12	0	wave_offs	The first wave enables the comparator bias voltage: -128mV~126mV(After receiving the first wave, the bias voltage returns to the offset setting voltage)	0 = 0 mV
11	0			1 = 2 mV
10	0			...
9	0			63 = 126 mV
8	0			64 = -128 mV
7	0			...
6	0			127 = -2 mV
5-0	0	K.D		

3.5. Write_REG4(Code: 0x84)

Bit	Defaults	Parameter	Description	Settings
31	0	CONF_FIRE	Output configuration for pulse generator 3'b 011 is not allowed	Bit 31 = 1: FIRE_BOTH (inverts FIRE_DOWN) Bit 30 = 1: enable output FIRE_UP Bit 29 = 1: enable output FIRE_DOWN
30	0			
29	0			
28	0	PHASE_FIREUP	FIREUP Inverted	0 = no inversion 1 = inversion
27	0	PHASE_FIREDOWN	FIREDOWN Inverted	0 = no inversion 1 = inversion
26	0	SEL_START_FIRE	Fire pulse is used as TDC start	0 = External input START 1 = Use FIRE as Start
25	0	EN_ANALOG	Enable analog measurement section. If it is enabled, it is only powered on to save power when in measurement. STOP1 and STOP2 are analog inputs now and automatically selected by the internal multiplexer.	0 = STOP1 and STOP2 are digital inputs 1 = analog section is enabled, STOP1 and STOP2 are analog inputs
24	0	ANZ_PORT	Set the number of ports for temperature measurement	0 = 2 ports (PT1 and PT2) 1 = 4 ports
23	0	TCYCLE	Sets cycle time for temperature measurement	0 = 128 μ s @ 4 MHz 1 = 512 μ s @ 4 MHz (recommended)
22	0	ANZ_FAKE	Fake measurements before temperature measurement	0 = 2 Fake measurements 1 = 7 Fake measurements
21	1	SEL_ECLK_TMP	Select reference signal for internal cycle clock for temperature measurement	0 = use 32.768 kHz as cycle clock 1 = use 128 \times CLKHS as period for cycle clock
20	0	TEMP_PORTDIR	Ports for temperature measurement are measured in the opposite order	0 = PT1 > PT2 > PT3 > PT4 1 = PT4 > PT3 > PT2 > PT1
19	0	TW2	Timer to charge up the capacitor of the recommend RC network when the internal analog part is enabled.	Charge time: 0 = 90 μ s 1 = 120 μ s 2 = 150 μ s 3 = 300 μ s
18	0			

Bit	Defaults	Parameter	Description	Settings
17	0	HZ60	Make complete up and down flow measurement and two temperature measurements in series.	0 = based on 50 Hz, 20ms 1 = based on 60 Hz, 16.67ms
16	0	CYCLE_TEMP	During two automatic temperature tests, trigger the second temperature measurement in multiples of 50/60Hz	0=0.25 (5ms) 1=0.5 (10ms) 2=0.75 (15ms) 3=1.0 (20ms) 4=1.25 (25ms) 5=1.5 (30ms) 6=1.75 (35ms) 7=2.0 (40ms) @50Hz
15	0			
14	0			
13	0	K.D		
12	0			
11	0			
10	0	EN_ERR_VAL	Timeout forces ALU to write 0xFFFFFFFF into the output register	0 = disabled 1 = enabled
9	0	K.D		
8	0	FIRE0_DEF	Default State of FIRE channel in non-operational mode	0 = High-Z(digital mode) 1 = LOW(analog enabling mode)
7-0	0	K.D		

4. Result Register

The result registers mainly include: a time measurement result register, a temperature measurement result register, a first wave pulse width measurement result register, and a clock check coefficient result register.

4.1. Flow Measurement Result Register

Name	Code	Description
TOF_UP_STOP1_REG	0xb0	Upstream 1st STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP2_REG	0xb1	Upstream 2nd STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP3_REG	0xb2	Upstream 3rd STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP4_REG	0xb3	Upstream 4th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP5_REG	0xb4	Upstream 5th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP6_REG	0xb5	Upstream 6th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP7_REG	0xb6	Upstream 7th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_STOP8_REG	0xb7	Upstream 8th STOP result register: 16-bit integer, 16-bit decimal
TOF_UP_SUM_REG	0xb8	Upstream 8 STOP accumulation result registers: 16-bit integer, 16-bit decimal

There are 9 registers in the flow measurement result register, the operation code 0xb0~0xb8 corresponds to the upstream result register. When using START_TOF_UP (0x01) measurement instruction, the test result is always stored in the corresponding result register 0xb0~0xb8 no matter which FIRE channel is sent.

The flow measurement result is a multiple of the internal reference clock period. The internal reference clock is equal to the external reference clock divided by DIV_CLKHS (DIV_CLKHS = 1, 2, 4). The calibration value is a 32-bit fixed-point number consisting of a 16-bit integer and a 16-bit decimal. Therefore, a calibration value occupies a result register. The serial output starts from the most significant bit(2^{15}), ends with the least significant bit(2^{-16}), and exists in complement form of 2.

$$\text{Time} = \text{RES}_X \times \text{Tref} \times N, \text{ with } N = 1, 2 \text{ or } 4$$

4.2. Temperature Measurement Result Register

Name	Code	Description
Temp_PT1_REG	0xc2	Temperature measurement PT1 result register: 16-bit integer, 16-bit decimal
Temp_PT2_REG	0xc3	Temperature measurement PT2 result register: 16-bit integer, 16-bit decimal
Temp_PT3_REG	0xc4	Temperature measurement PT3 result register: 16-bit integer, 16-bit decimal
Temp_PT4_REG	0xc5	Temperature measurement PT4 result register: 16-bit integer, 16-bit decimal

Temperature measurement is a measurement of discharge time, and has the same structure as flow measurement. The ratio of discharge time is the same as the ratio of resistance:

$$RT = R_{\text{ref}} \times \tau_T / \tau_{\text{ref}}$$

When taking two consecutive temperature measurements, only the last measurement result is retained.

4.3. First Wave Pulse Width Measurement Result Register

Name	Code	Description
PW_First_REG	0xd0	First wave pulse width result register: 11-bit integer, 11 bits high
PW_Stop1_REG	0xd1	First STOP pulse width result register: 11-bit integer, 11 bits high

The first wave pulse width measurement result has the same structure as the time measurement, and is only used for the ratio between the two data. The absolute value has no reference value.

4.4. Clock Check Coefficient Result Register

Name	Code	Description
CAL_REG	0xd4	Clock check register: 16-bit integer, 16-bit decimal

This register counts based on the standard clock and measurement clock values, and then stores this value in Read_CAL_REG. It's a 32-bit fixed floating-point number, where 16 bits are integers and 16 bits are decimal.

4.5. Status Register

Bit	Name	Description	Setting
15-13			
12	Temp_short	Temperature sensor short circuit	1=Short circuit
11	Temp_open	Temperature sensor open circuit	1= Open circuit
10	Counter_Flood	Coarse value counter overflow	1= Overflow
9	TDC-Flood	TDC overflow	1= Overflow
8			
7	Stop_num	Number of obtained HIT	
6			
5			
4			
3	Register	Result address pointer	
2			
1			
0			

FUNCTION DESCRIPTION

1. Flow Measurement Overview

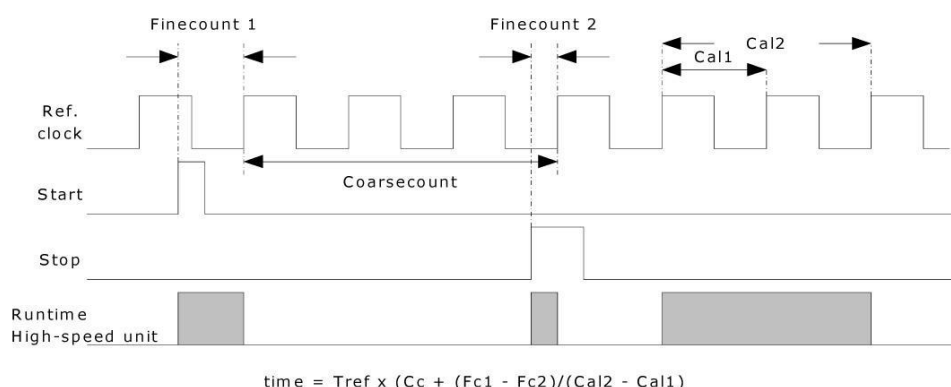
1.1. Overview

Flow measurement is composed of analog front end, digital TDC, and arithmetic unit (ALU). The analog front end is mainly responsible for signal conversion and transmission to digital TDC. Digital TDC is composed of precision counter and coarse value counter, responsible for converting valid signals on the front end to unit time, the calculator calibrates the unit time stored by the digital TDC to the standard time related to the reference clock and stores it in the corresponding result register. The brief description is as follows:

- Measurement accuracy up to 15ps, minimum resolution up to 3.8ps (1LSB)
- Maximum measurement range up to 500ns~4ms @ 4MHz
- The capability of 8 STOP samplings and accumulates 8 STOPs
- The measurement results are stored in independent result registers
- In analog mode, the first wave mode and non-first wave mode measurement can be selected
- Optional rising / falling edge trigger
- An adjustable window with 250ns accuracy for stop signal, providing accurate stop enabling.

1.2. Digital TDC

The digital TDC is composed of a precision counter and a coarse value counter. The precision of the precision counter can reach 15ps, the minimum resolution is 3.8ps (1LSB), the count range of precision counter is 0 ~ 2 μ s; And count range of the coarse counter is 500ns ~ 4ms @ 4MHz. TDC's high-speed unit does not measure the entire time interval, it only measures the interval time (precision counter) from the START or STOP signal to the rising edge of the adjacent reference clock. Between two precision measurements, the TDC counts the number of cycles of the reference clock (coarse value counter). So, the flow measurement result is the sum of precision measurement value and rough measurement value. Digital TDC has 8 STOP sampling capabilities, but each STOP interval is not less than 2 \times Tref.

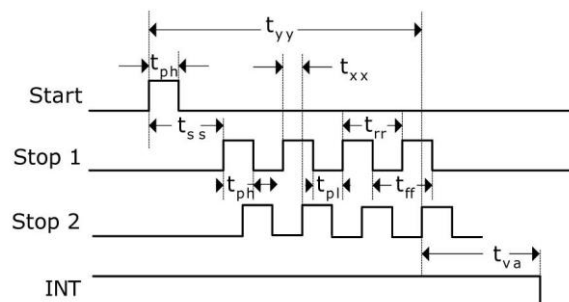


The measurement range is limited by the size of the coarse counter:

$$t_{yy} = T_{ref} \times 2^{14} \approx 4.1\text{ms @ 4MHz}$$

The time difference between Start and Stop is calculated within a 26-bit measurement range.

	Time (Condition)	Description
t _{ph}	2.5 ns (min.)	Minimum pulse width
t _{pl}	2.5 ns (min.)	Minimum pulse width
t _{ss}	2×Tref	Start to Stop @ Dis_PhaseNoise=1
t _{rr}	2×Tref	Rising edge to rising edge
t _{ff}	2×Tref	Falling edge to falling edge
t _{va}	4.6μs(max)	Last hit to data valid
t _{yy}	4ms (max) @ 4MHz	Maximum measuring range = Tref × 2 ¹⁴



Each input can be individually set to be active on rising or falling edge, Bit12-13 (NEG_START, NEG_STOP1) of register 0 can be used to select the trigger edge.

In addition, all START / STOP input ports support high-level activation.

Note: If the time difference between Start-Stop is less than the minimum time limit t_{zz}, TDC will ignore all time difference pulses less than t_{zz}, and error will not occur under any circumstances.

1.3. ALU

The function of the ALU is to process the value of the digital TDC count. It mainly calibrates the value of the digital TDC, saves the calibrated value to the corresponding result register and sends the status register, and also accumulates the expected STOP sum. And store the accumulated value in the corresponding result register, The following matters should be noted when using the ALU:

- When setting the "DIV_CLKHS" (17 ~ 18BIT of Register 0) reference clock: 2× Tref < 2μs;
- If Timeout overflow occurs, ALU will not calculate the content of digital TDC;
- ALU calculation takes some time. If EN_INT_HIT = 1, please wait for a period of time to read the result register after the interrupt.

1.4. Analog Front End

The AFE is mainly responsible for signal conversion and transmission to the digital TDC. The AFE is composed of a precision comparator, a programmable bias voltage generator, a first wave processor, and a high-speed switch. The AFE can use digital and analog signals:

- When EN_ANALOG = 0, the AFE can only collect digital signals, the START signal enters from START (PIN31), and the STOP signal enters from STOP1 (PIN30). Input signals:

Parameter	Symbol	Condition	Min	Typ	Max	Unit
High-level input voltage	V _{IH}	LVTTL, V _{IO} = Max	0.7×V _{IO}			V
Low-level input voltage	V _{IL}	LVTTL, V _{IO} = Min			0.3×V _{IO}	V

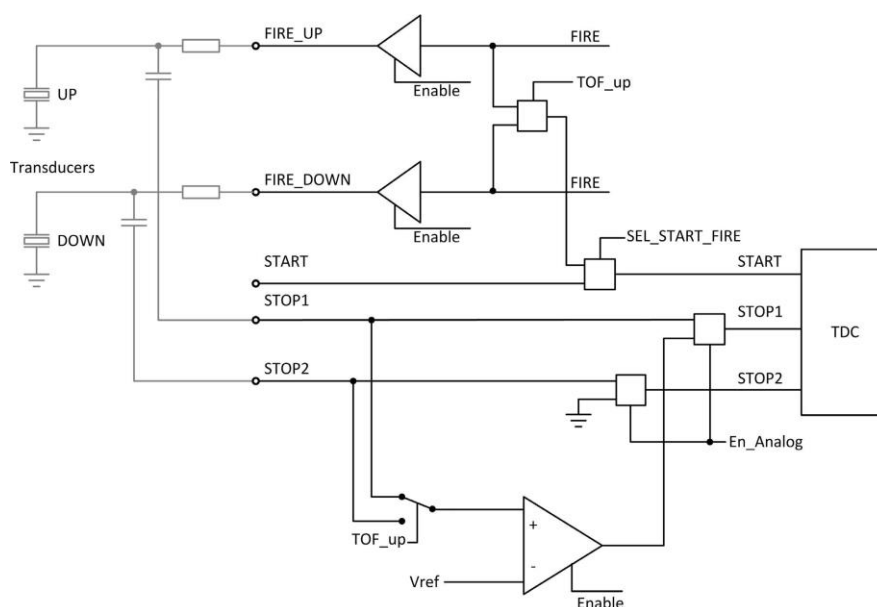
- When EN_ANALOG = 1, the internal integrated analog circuit input section is enabled. This section can be used as an alternative input for the digital input section. Especially when designing ultrasonic heat flow measurement, this function will greatly simplify the design of the entire circuit. The signal will be coupled to the input through a high-pass filter. The analog signal inputs from the two ports STOP1 and STOP2. Because the internal comparator cannot trigger with zero, the trigger voltage of the comparator is set to 1/3 VCC. The analog selector will select

different measurement inputs based on the direction of measurement. The chopper-stabilized comparator will ensure lower voltage zero drift (less than 2mV), which is a prerequisite for high-quality measurements. The comparator's voltage zero drift will be corrected very frequently internally by a chopper circuit. If the temperature or voltage changes with time, the voltage zero drift will be automatically adjusted to less than 2 mV.

All components are controlled by the control unit of the MS1030. They are turned on only during the measurement process to reduce overall measurement power.

The comparator offset voltage: offset can be set on a 4mV basis, from -128mV to +124 mV. This setting is set by the parameter offset, Bit 0-5 in register 1, and is given in complement form of 2.

When the first wave mode is applied, the bias voltage recognized by the first wave can be additionally set. The setting can be performed on the basis of 2mV, from -128mV to +126 mV. This setting is set by the parameter wave_offs, Bit 6-12 in register 3, and is given in complement form of 2.



2. Flow Measurement Mode

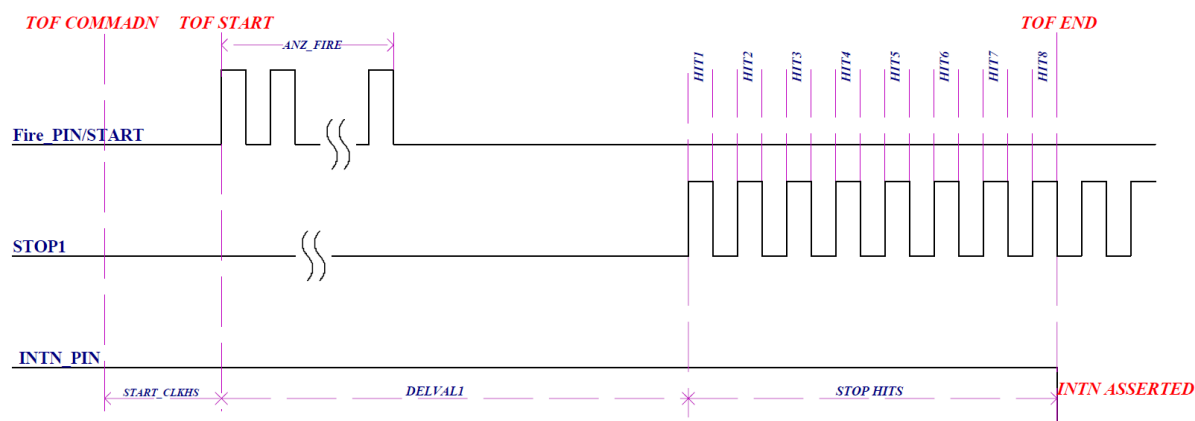
The flow measurement mode is divided into: digital measurement mode, analog measurement mode, first wave measurement mode. The three measurement modes are introduced below.

2.1. Digital Measurement Mode

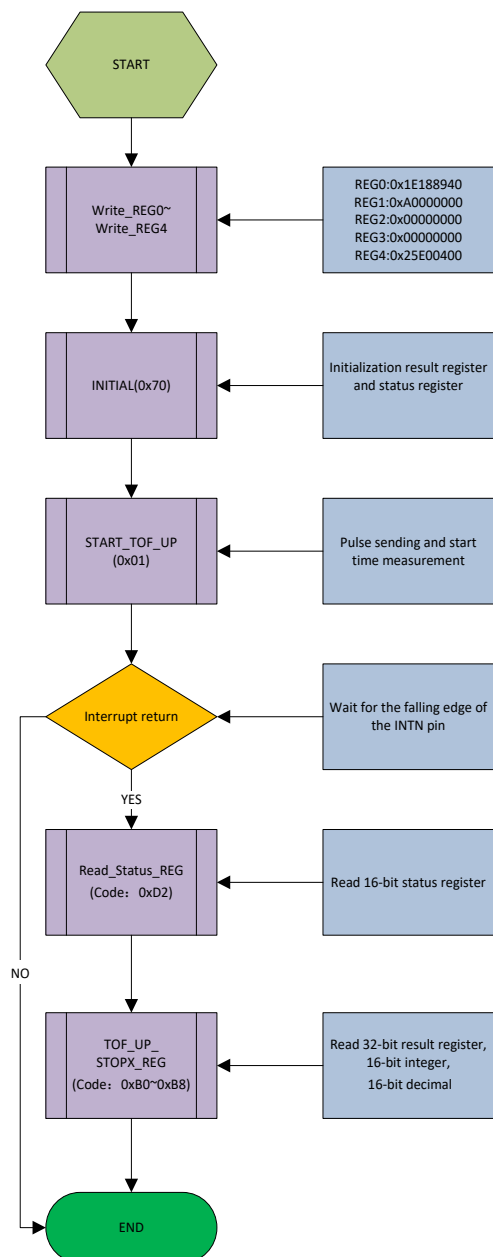
2.1.1. Digital Measurement Overview

When "EN_ANALOG = 0", select digital measurement mode. In this measurement mode, the start signal inputs from the START pin, the end signal inputs from the STOP1 pin, the STOP2 pin is invalid. START and STOP1 input signals are all digital signals. The figure below shows the digital measurement waveform. The measurement process is as follows:

- Send "TOF COMMADN" command 0x01;
- "START_CLKHS" is the high-speed crystal oscillator delay. This delay is for the high-speed crystal oscillator to switch from off mode to stable start-up time;
- Send a pulse or an external signal to trigger the START signal. At this time, the measurement starts;
- "DELVAL1" is a STOP shielding window. The setting time is set according to the user process. The setting time should not exceed the echo return time to avoid overflow;
- When the "DELVAL1" masking time is completed, the STOP signal is started to be received, until the "HITIN" setting is expected, and no more echo signals are received. At this time, the ALU performs calibration and saves the data to the corresponding result register. A maximum of 8 Wave signal can be received, and store the sum of 8 echoes in the result register to complete the test;
- When the entire test is completed, a falling edge is generated on the "INTN" pin to notify the MCU to process the data.



2.1.2. Digital Measurement Software Process

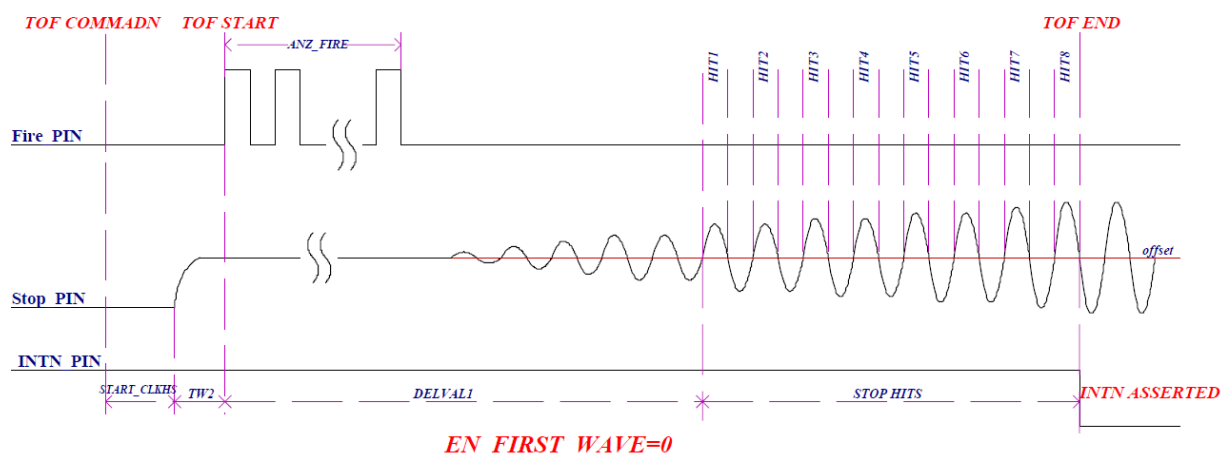


2.2. Analog Measurement Mode

2.2.1. Analog Measurement Overview

When "EN_ANALOG = 1" and "EN_FIRST_WAVE = 0", select the analog measurement mode. In this measurement mode, the internal analog part is enabled. The main functions are as follows:

- Built-in high-precision analog comparator, which is enabled during measurement is performed and automatically disabled after measurement is completed, thus achieving low power consumption.
- The echo signal can input from STOP1 and STOP2 through capacitive coupling. When Fire_UP sends a pulse, the echo signal inputs from STOP2 pin. When Fire_DOWN sends a pulse, the echo signal inputs from STOP1 pin.
- Built-in programmable bias voltage, which can be set through register "offset", voltage ranges from -128~124mV.

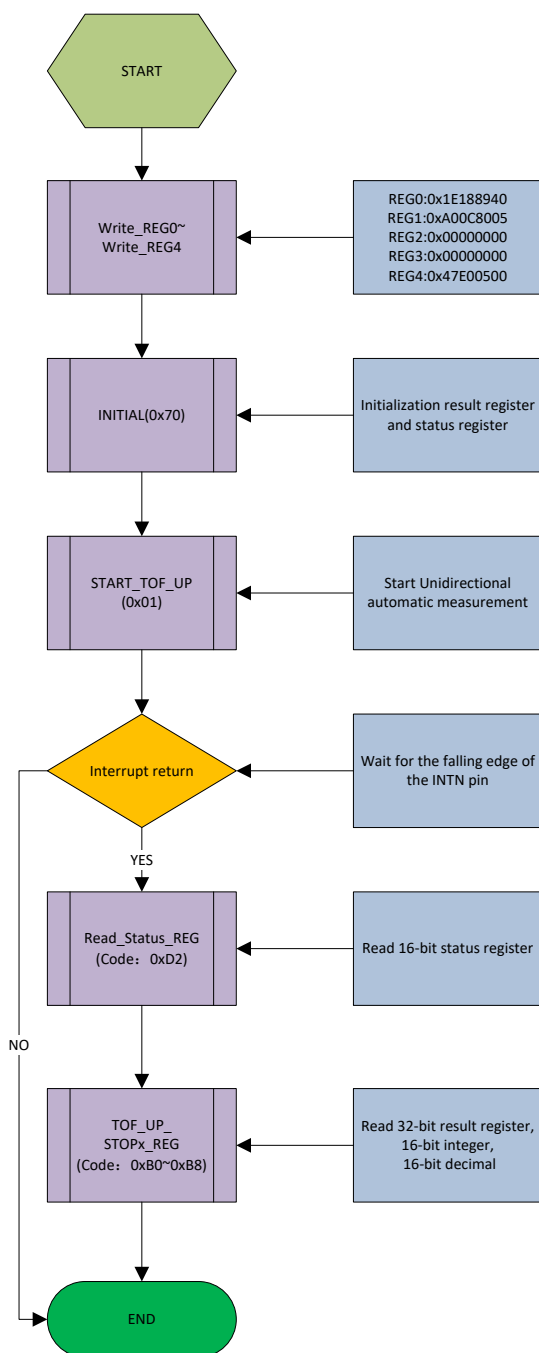


The figure above is an analog measurement waveform. The measurement process is as follows:

- Send "TOF COMMANDN" command 0x01;
- "START_CLKHS" is the high-speed crystal oscillator delay. This delay is for the high-speed crystal oscillator to switch from off mode to stable start-up time;
- "TW2" is the charging time of the STOP sampling capacitor, so that the STOP terminal charges the sampling capacitor to 1/3VCC;
- Send pulses, set the number of sent pulses according to "ANZ_FIRE", and trigger the START signal with the first pulse sent at this time;
- "DELVAL1" is an echo shielding window. The setting time is set according to the user process. The setting time should not exceed the echo return time to avoid overflow;
- offset is the programmable comparator bias voltage, the voltage range is from -128mV ~ 124mV;
- When the "DELVAL1" masking time has elapsed, the comparator starts to receive the echo signal. When the amplitude of the echo signal exceeds the "offset" bias voltage, STOP receives the echo signals in turn, and it stops receiving echo signals until the "HITIN" expected pulse returns. At this time, the ALU performs calibration and saves the data to the corresponding result register. A maximum of 8 echo signals can be received, and the 8 echoes are accumulated and placed in the result register to complete a test;
- When the entire test is completed, a falling edge is generated on the "INTN" pin to notify the MCU to process the data.

2.2.2. Analog Measurement Software Process

Unidirectional Measurement Process

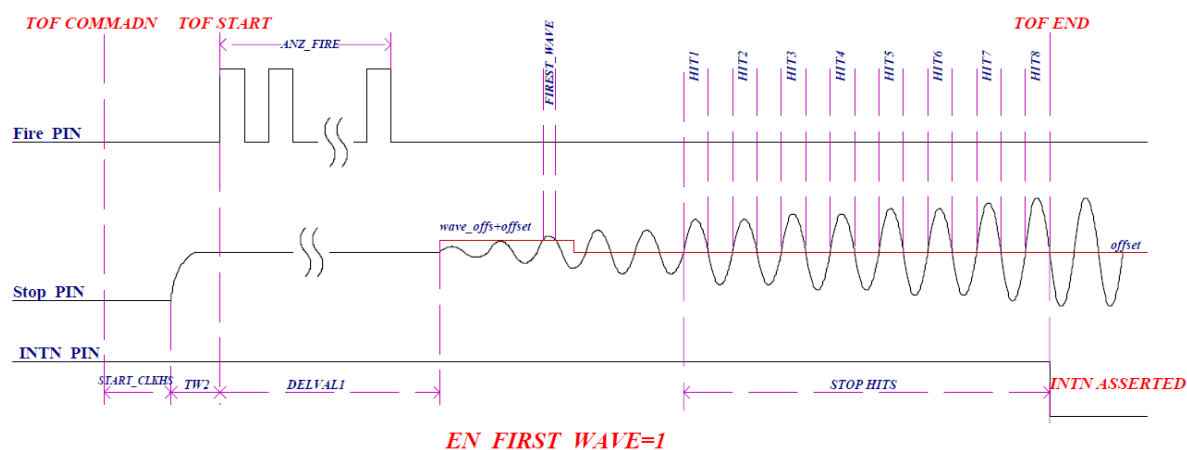


2.3. First Wave Measurement Mode

2.3.1. First Wave Measurement Overview

When “EN_ANALOG = 1” and “EN_FIRST_WAVE = 1”, the simulation first wave measurement mode is selected. At this time, the “Write_REG2” and “Write_REG3” registers have a new meaning. The offset is automatically controlled to detect the first safety echo pulse. Then, the ToF flight time of the required echo is measured according to the position of the first wave. In high dynamic applications (such as ultrasonic water meter), it is not possible to determine whether the change of flight time is greater than a driving period only through a fixed stop shield window (fixed DALVAL value), thus measurement error is occurred, so using the first wave measurement mode has the following advantages:

- Safe first wave detection, allowing highly dynamic applications such as ultrasonic water meter;
- Can receive up to 8 echo signals;
- Water backflow can also be identified and treated(have great impact on the ultrasonic water meter)
- Pulse width measurement can help detect received echo signals, and can issue alarm signals based on triggered amplitude levels;
- Offset voltage offset low noise, can give empty pipe signal;
- Measure the ToF time of flight with the first wave so that the temperature can be estimated.



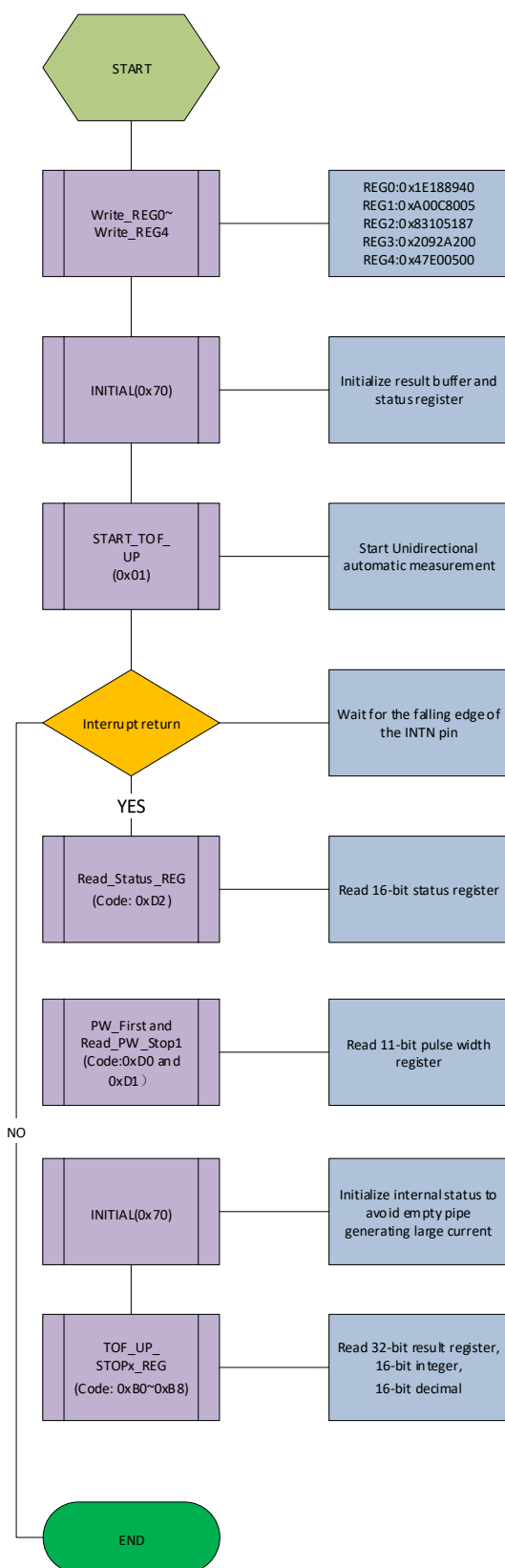
The picture above is the first wave measurement waveform, the measurement process is as follows:

- A. Send "TOF COMMADN" command 0x01.
- B. "START_CLKHS" is the high-speed crystal oscillator delay. This delay is for the high-speed crystal oscillator to switch from off mode to stable start-up time.
- C. "TW2" is the charging time of the STOP sampling capacitor, so that the STOP terminal charges the sampling capacitor to $1/3VCC$.
- D. Send pulses, set the number of sent pulses according to "ANZ_FIRE", and trigger the START signal with the first pulse sent at this time.
- E. "DELVAL1" is an echo shielding window. The setting time is set according to the user process. The setting time should not exceed the echo return time to avoid overflow.
- F. "Wave_offs" and "offset" are the first wave bias voltage setting and the comparator bias voltage setting, and adding these two voltages together is the threshold voltage of the first wave; Voltage ranges from $-256mV \sim 250mV$.

- G. The first wave is triggered when the echo signal exceeds the threshold voltage detection of the first wave, and when "DIS_PW = 0", the first wave pulse width "FIREST_WAVE" is saved to the "PW_First" first wave pulse width result register ; At the same time, the threshold voltage of the first wave is returned to the "offset" comparator bias voltage, and the subsequent echo signals are detected. According to "DELREL1" setting, detect first STOP pulse width and save it to the "Read_PW_Stop1" first STOP pulse width result register. Then calculate whether the first wave threshold voltage is reasonable according to the values of PW_First and Read_PW_Stop1.
- H. Note: when "DIS_PW = 0", if no echo generates (empty pipe or no transducer), internal TDC would wait echo and cannot enter low power dissipation state. At this time, after flow measurement is completed, writing "INITIAL(0x70)" and disabling pulse width detection function.
- I. The first and second echoes detected after the first wave are not regarded as valid signals for STOP. The echo signals are received in sequence from the start of the third echo, and echo signal will not be received until all the "HITIN" expected pulses return. At this time, the ALU performs calibration and saves the data to the corresponding result register. It can receive up to 8 echo signals, add and accumulate 8 echoes into the result register to complete one test.
- J. When the entire test is completed, a falling edge is generated on the "INTN" pin to notify the MCU to process the data.

2.3.2. First Wave Measurement Software Flow

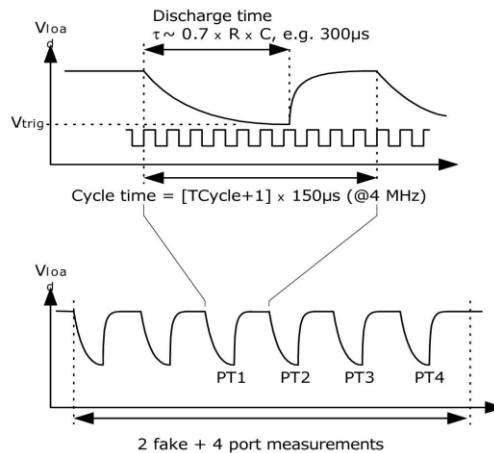
Unidirectional Measurement Process



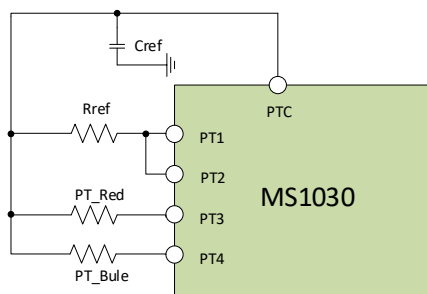
3. Temperature Measurement Mode

3.1. Temperature Measurement Overview

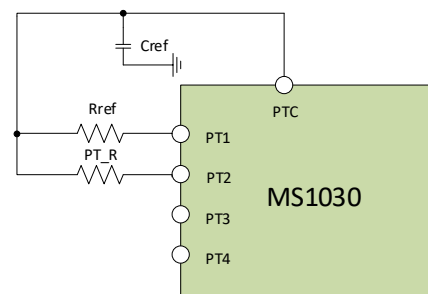
The MS1030 integrates a high-precision temperature measurement unit. The measurement principle is based on the measurement of the discharge time of the capacitor based on the resistance. The capacitor will discharge the reference resistance and the temperature sensor resistance separately, and then convert the resistance value of the temperature sensor through resistance to accurately calculate the temperature.



The temperature measurement unit has 4 resistance measurement ports. For heat meter, 4 ports can be selected by "ANZ_PORT=1", two are used as the temperature sensor measurement terminal for hot water(upstream) and cold water(downstream), and the others are used to connect the reference resistance. Generally, only one reference resistance is needed to be connected to two ports. For water meter, two ports can be selected by "ANZ_PORT=0", one is used as temperature sensor measurement terminal, the other is used for connecting reference resistance.



Heat Meter Connection Diagram



Water Meter Connection Diagram

The M1030 can only measure two-wire sensors, not be applied to four-wire sensors. The accuracy of temperature measurement using PT500 or PT1000 fully meets the requirements specified by the heat meter. When using PT500 or PT1000 sensors, two reference resistors can be omitted. It also supports the measurement of PT100 sensor, but the stability of the measurement will be reduced. In this case, it is recommended to connect both reference resistors instead of just one. This will help compensate the temperature sensor's gain offset across the temperature range with a two-point temperature calibration.

Temperature measurement is done completely automatically. Through the microcontroller, send the opcode START_TEMP or START_TEMP_RESTART. Send START_TEMP_RESTART and the MS1030 will measure temperature twice, with a time delay between multiples of 50 Hz/60Hz. This helps to reduce 50Hz/60Hz noise.

For one temperature measurement, the MS1030 first performs 2 or 7 warm-up pseudo measurements on the PT1 port, and then performs temperature measurement in the order of PT1> PT2 > PT3> PT4 port. After the measurement of the four ports is completed, the interrupt flag will be set. The MS1030 can also perform

temperature measurement in the opposite port order. In this case, the warm-up measurement will start from the PT4 port.

The four measurement results will be stored in the temperature result registers Temp_PT1_REG ~ Temp_PT4_REG. The ratio of Rtemp/Rref can then be calculated based on the ratio of the result registers. By querying the temperature table, the temperature value currently measured by the sensor can be obtained.

3.2. Configuration Register Description

The 22th bit of the Write_REG4 register, ANZ_FAKE, sets the number of warm-up measurements for temperature measurement. This setting is to avoid mechanical effects during capacitor charging and discharging.

ANZ_FAKE = 0 2 warm-up measurements

ANZ_FAKE = 1 7 warm-up measurements

The 23rd bit TCYCLE of the Write_REG4 register sets the cycle time of the temperature measurement. Note that the setting time must be less than the register Write_REG0 "SEL_TIMO_MB" to avoid overflow measurement abnormality.

TCYCLE = 0 128 μ s cycle time @ 4MHz

TCYCLE = 1 512 μ s cycle time @ 4MHz

The 24rd bit ANZ_PORTS of the Write_REG4 register sets how many temperature measurement ports will be used. 4 ports are normally set in heat meter, and 2 ports are set in water meter. When set to 4 ports, all 4 ports must be connected with resistors or sensors to prevent the status register from reporting an "open circuit" exception.

ANZ_PORTS = 0 2 ports = 1 sensor

ANZ_PORTS = 1 4 ports = 2 sensors

The 20th bit TEMP_PORTDIR in the Write_REG4 register measures the order of the ports. When "TEMP_PORTDIR = 0", PT1 warms up and starts measurement from PT1. When "TEMP_PORTDIR = 1", PT4 warms up and then starts measurement from PT4:

TEMP_PORTDIR = 0 PT1 > PT2 > PT3 > PT4

TEMP_PORTDIR = 1 PT4 > PT3 > PT2 > PT1

The 14th ~ 17th bits HZ60 and CYCLE_TEMP of the Write_REG4 register are set. When using the "START_TEMP_RESTART" command, the interval between two temperature measurements:

HZ60 = 0 50 Hz base

HZ60 = 1 60 Hz base

CYCLE_TEMP 0 = 0.25 (5ms @50Hz) 1 = 0.5 (10ms @50Hz)

2 = 0.75 (15ms @50Hz) 3 = 1.0 (20ms @50Hz)

4 = 1.25 (25ms @50Hz) 5 = 1.5 (30ms @50Hz)

6 = 1.75 (35ms @50Hz) 7 = 2.0 (40ms @50Hz)

3.3. Recommended Capacitor

In order to achieve accurate measurement results, we recommend using very low dC / dU capacitors. We recommend using COG series capacitors or CfCap series capacitors.

The discharge time is about 150 μ s. Therefore, the following values should be selected for the capacitor:

PT500: 220 nF

PT1000: 100 nF

Set Tcycle = 1 to avoid overflow errors

Do not use X7R or similar capacitor materials in heat meter applications.

3.4. Current Consumption

The current consumption of the temperature measurement with the MS1030 is extremely low compared to that of the A / D converter.

Take a complete temperature measurement (2 sensors, 2 reference), including all calculations, and its consumption is less than 2.5 μ A/s. If a temperature measurement is performed every 30 seconds (typical measurement frequency of a heat meter), the average current consumption is 0.08 μ A, which is less than 1/50 of the power consumption of other measurement methods. The PT500 sensor will double the current.

3.5. Error Detection

Additionally, the temperature measurement unit checks the availability of the results. It is able to detect a sensor is short-circuited or open-circuited. The MS1030 sets the 11th or 12th bit of the status register to 1 and writes an error code to the equivalent result register.

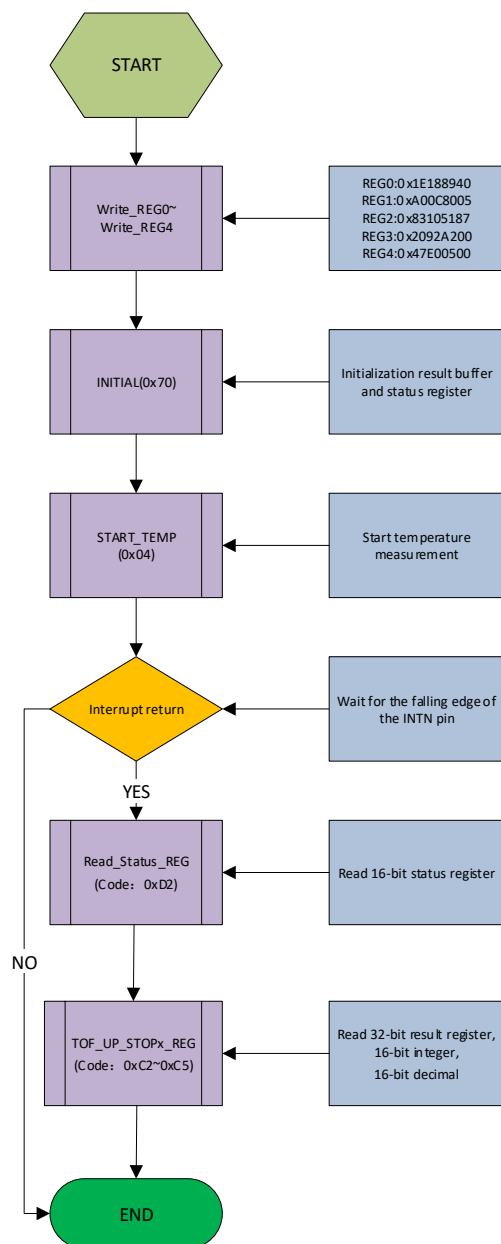
- Short circuit between lines: equivalent to a very short time interval ($< 8 \times T_{ref} = 2 \mu s$ @ 4 MHz).

The MS1030 writes a 0x00h to the result register.

- sensor open circuit: equivalent to no stop signal or timeout. The MS1030 writes a 0xFFFFFFFFh into the output register.

Note: When the cycle time of temperature measurement is selected as 512 μs ($T_{cycle} = 1$), SEL_TIMO_MB2 must be greater than 512 μs . Otherwise, the interrupt flag obtained may be an overflow result.

3.6. Temperature Measurement Software Flow

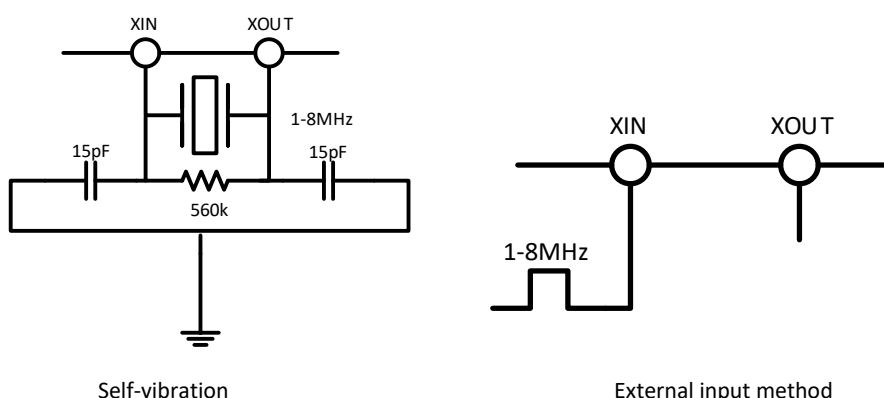


4. Oscillator

The MS1030 has two external oscillators, a high-speed oscillator and a 32.768kHz oscillator. The high-speed clock is used as a coarse value counter for the TDC measurement unit. The 32kHz clock is used as the calibration clock for the high-speed clock and the delay clock for the analog part.

4.1. High-speed Oscillator

The high-speed oscillator of the MS1030 mainly provides the basic clock for time measurement, pulse frequency, and temperature measurement. The frequency range is 1-8MHz. Users can choose the frequency of the oscillator according to their application conditions. The recommended high-speed clock frequency is 4MHz. High-speed oscillator can be connected to passive or active oscillator, connection is as shown below:



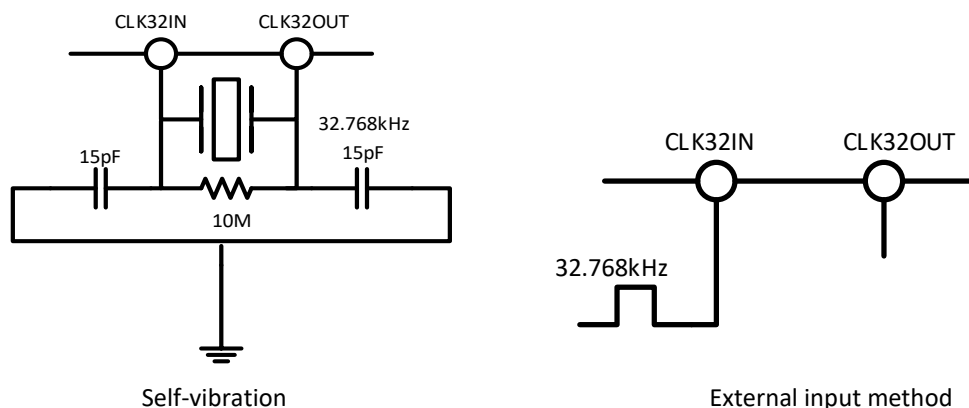
The high-speed oscillator is started by default, and the average operating current is 260μA in the state of constant start-up. However, the crystal oscillator only needs to be turned on when measuring time, so the high-speed oscillator can control the turn-on time through the internal circuit. This is achieved by setting the parameter START_CLKHS. When setting START_CLKHS > 1, the crystal oscillator will be turned on in the measurement after sending Start_TOF, Start_TEMP or START_TEMP_RESTART command. Set a delay between turning on the crystal and measuring to ensure that the crystal has enough time to oscillate to full amplitude. The user sets the start time according to the crystal used. For the specific start time of the crystal, see the previous parameter table.

START_CLKHS = 0	Oscillation disabled
= 1	Oscillation continues to be enabled
= 2	Delay 480 μs
= 3	Delay 1.46 ms
= 4	Delay 2.44 ms
= 5 to 7	Delay 5.14 ms

The delay set above can ensure the crystal has fully reached its full amplitude before the measurement starts. A delay of 480 μs is sufficient for a ceramic crystal. In this way, the current consumption can be greatly reduced.

4.2. 32.768kHz Oscillator

The MS1030 has a built-in 32.768kHz reference clock that cannot be closed, which can be used to control high-speed clock start-up and clock calibration. It can also be used as a clock driver. Set SEL_TSTO1 and SEL_TSTO2 through register 0 to output the clock from TSTO1 and TSTO2. If the 32.768kHz oscillator is always working, the current consumption at 3.3V is about 7μA. Input mode the current consumption of using external low-frequency is about 0.5μA. The specific connection method is as follows:



This low-power clock can be output to an external microcontroller as a clock source through the pin. The setting of the register is:

SEL_TSTO1 = 3: 32kHz at TSTO1 pin output

SEL_TSTO2 = 3: 4kHz (32kHz / 8) at TSTO2 pin output

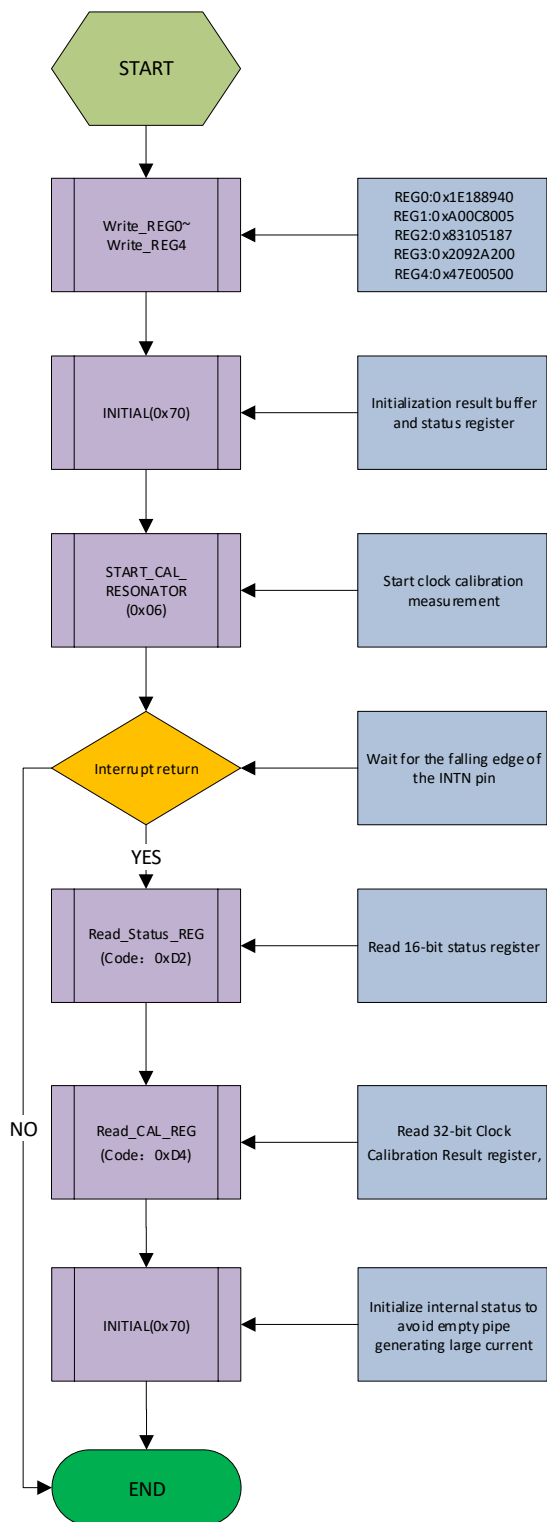
4.3. Calibrating High-Speed Ceramic Oscillators

Due to the low cost and fast start-up of 1-8MHz ceramic oscillators, this oscillator is still very popular for low power consumption products, but it has large error (0.3-0.5%) and has obvious temperature drift. Therefore, the MS1030 will perform clock calibration measurements to compensate errors caused by the ceramic oscillator. The measurement is based on an accurate 32.768kHz clock. The MS1030 draws the Star / Stop pulse from the 32.768kHz clock and starts the TDC unit to measure the time difference. The result is stored in the Read_CAL_REG result register and the interrupt flag is set. The microcontroller can read this result and calculate the frequency error of the ceramic oscillator.

In the MS1030 clock calibration, 8 cycles of 32.768kHz clock are used as the calibration time, then the 8 cycle time is $1 / 32.768\text{kHz} \times 8 = 244.140625\mu\text{s}$. If a high-speed clock of 4MHz is used, the theoretical result should be $244.140625\mu\text{s} / 250\text{ns} = 976.5625$, and then compare the value of the Read_CAL_REG (high 16-bit integer, low 16-bit decimal) register with the theoretical value, and the coefficient obtained is the clock calibration coefficient.

In an ultrasonic flowmeter, the measurement result consists of two one-way propagation time measurements of ultrasonic wave propagation in the cocurrent and countercurrent propagation. The flow rate of the fluid can be calculated according to the time difference between the ultrasonic countercurrent propagation and the cocurrent propagation. In order to avoid the influence of the calibration clock jitter on the measurement result, the same calibration value must be used when measuring the forward flow time and the reverse flow time. Only in this way, the time difference between ultrasonic wave cocurrent propagation and countercurrent propagation cannot be influenced by calibration clock jitter. Clock calibration must be performed between cocurrent propagation and countercurrent propagation and occurs before they are subtracted.

4.4. Clock Calibration Process

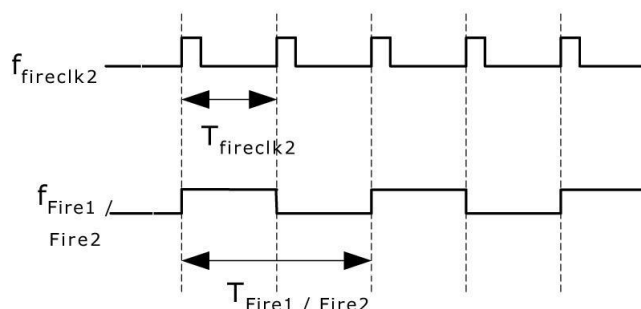


5. Pulse Generator

5.1. Pulse Generator Overview

The MS1030 pulse generator generates pulse sequences whose frequency and pulses can be adjusted. The high-speed oscillator frequency is used as a fundamental clock. This frequency is divided internally, and it can also be divided by a factor of 2-64 freely. It can generate 1-127 pulse sequences and activate the trigger pulse generator by sending the code START_TOF_UP.

The pulse generator provides two output ports, FIRE_UP and FIRE_DOWN. The driving capability of each output is 3.3mA at 3.3V. In addition, each output signal can be inverted to double the signal amplitude. The output pins can be individually set to high impedance. In addition, the default inactive buffer can be set to GND.



5.2. Register Configuration

Number of Pulses:

ANZ_FIRE = 0 Disable the pulse generator
 = 1 1 pulse
 = 2 2 pulses

 = 127 127 pulses

SEL_START_FIRE = 1 Fire pulse directly to TDC START signal

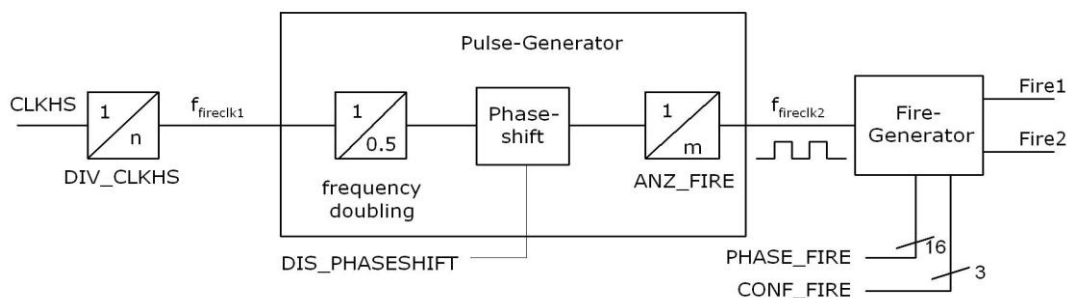
FIREO_DEF = 0 The default status is High_Z (compatible with the MS1002)

= 1 The default state is GND. If you use the internal analog part, you must set it in this way.

The application recommends an external circuit with R and C.

Frequency of Pulse Emission:

The input signal fireclk1 of the pulse generator is derived from the high-speed clock CLKHS and the selected division factor DIV_CLKHS.



The frequency of the reference clock is first doubled internally, and then divided by DIV_FIRE. The lowest frequency is divided to 64, which can meet some low-frequency transducers such as gas.

DIV_FIRE = 0 Divide by 2
 = 1 Divide by 2

 = 63 Divide by 64

Output Driver:

The output driver can be set in Bits 29-31 (CONF_FIRE) in Register 4:

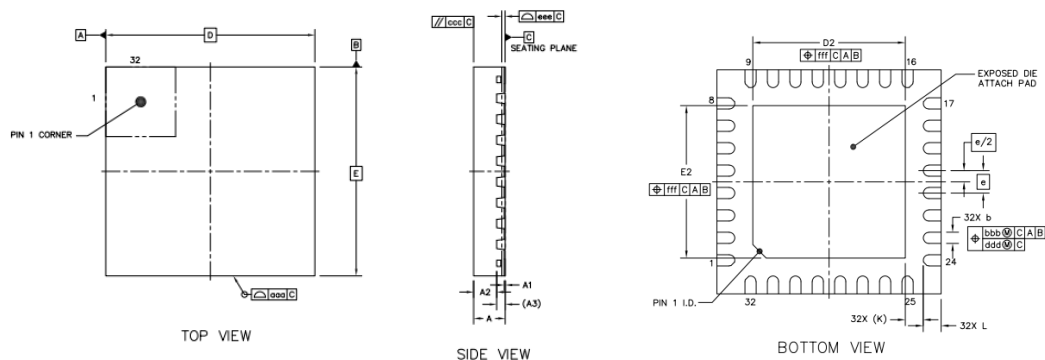
Bit 31 = 1 FIRE_BOTH (Reverse on FIRE_DOWN signal)

Bit 30 = 1 FIRE_Up Enabled

Bit 29 = 2 FIRE_Down Enabled

PACKAGE OUTLINE DIMENSIONS

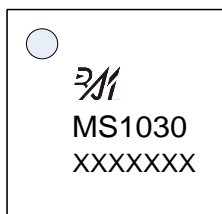
QFN32



Symbol	Dimensions in Millimeters		
	Min	Typ	Max
A	0.7	0.75	0.8
A1	0	0.02	0.05
A2	-	0.55	-
A3	0.203 REF		
b	0.2	0.25	0.3
D	5 BSC		
E	5 BSC		
e	0.5 BSC		
D2	3.3	3.4	3.5
E2	3.3	3.4	3.5
L	0.3	0.4	0.5
K	0.4REF		
aaa	0.1		
ccc	0.1		
eee	0.08		
bbb	0.1		
ddd	0.05		
fff	0.1		

MARKING and PACKAGING SPECIFICATIONS

1. Marking Drawing Description



Product Name: MS1030

Product Code: XXXXXXX

2. Marking Drawing Demand

Laser printing, contents in the middle, font type Arial.

3. Packaging Specification

Device	Package	Piece/Reel	Reel/Box	Piece /Box	Box/Carton	Piece/Carton
MS1030	QFN32	1000	8	8000	4	32000

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**MOS CIRCUIT OPERATION PRECAUTIONS**

Static electricity can be generated in many places. The following precautions can be taken to effectively prevent the damage of MOS circuit caused by electrostatic discharge:

1. The operator shall ground through the anti-static wristband.
2. The equipment shell must be grounded.
3. The tools used in the assembly process must be grounded.
4. Must use conductor packaging or anti-static materials packaging or transportation.



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