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Ultrasonic-Flow-Converter

Data Sheet

TDC-GP21

Universal 2-Channel
Time-to-Digital Converters

March 13th 2014
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Content

1 Overview

TDC-GP21 is next generation's upgrade for TDC-GP2. It offers pin-to-pin and functional compatibility, several feature improvements and an extended functionality. Analog elements like a chopper stabilized comparator and analog switches simplify external circuits in a significant manner. In parallel, measurement quality is improved and operating current is reduced. The firepulse generator is extended, a new low-power 32 kHz oscillator driver is implemented and the temperature measuring unit is further improved. All in all, the TDC-GP21 is perfectly suited to design ultra-compact and low-cost ultrasonic flow meters and heat meters. If the integrated analog elements of the TDC-GP21 are used, the average operating current of a typical heatmeter application can be reduced to 2.2 µA.

1.1 Features

Measurement mode 2

- 1 channel with typ. 90 ps resolution
- Double resolution mode with 45 ps, Quad resolution mode with 22 ps resolution
- Measurement range 700 ns to 4 ms
- 3-fold multihit capability with automatic processing of all 3 data

Analog Input Circuit

- Chopper-stabilized low-offset comparator
- Offset programmable, -8 to 7 mV
- Integrated analog switches for input selection
- External circuit is reduced to 2 resistors and 2 capacitors

Temperature Measurement Unit

- 2 or 4 sensors, PT500/PT1000 or higher
- Schmitt trigger integrated
- 16-Bit eff. with external Schmitt trigger, 17.5-Bit eff. with integrated low noise Schmitt trigger
- Ultra low current (0.08 µA when measuring every 30 seconds)

Special Functions

- Fire pulse generator, up to 127 pulses
- Trigger to rising and/or falling edge
- Precise stop enable by windowing
- Low-power 32 kHz oscillator (500 nA)
- Clock calibration unit
- 7x32 Bit EEPROM

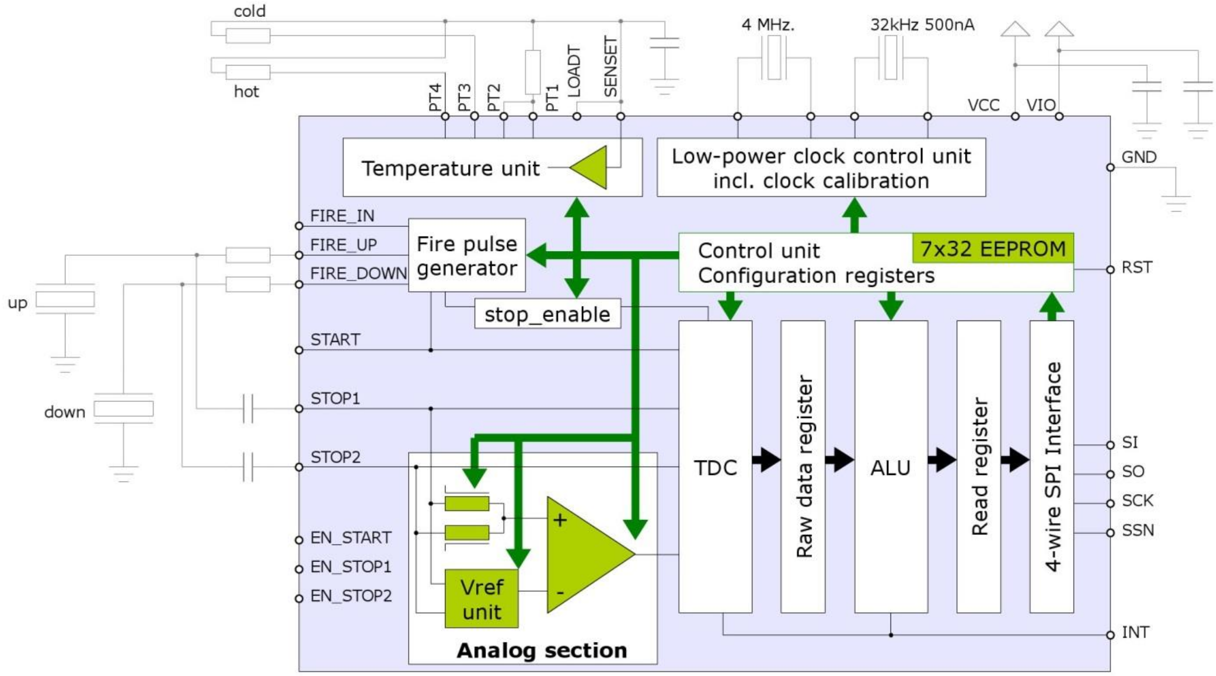
Measurement mode 1

- 2 channels with typ. 90 ps resolution
- channel double resolution with typ. 45 ps
- Range 3.5 ns (0 ns) to 2.5 µs
- 20 ns pulse-pair resolution, 4-fold multihit
- Up to 500 000 measurements per second in measurement mode 1

General

- 4-wire SPI interface
- 500 kHz continuous data rate max.
- I/O voltage 2.5 V to 3.6 V
- Core voltage 2.5 V to 3.6 V
- Temperature range – 40 °C to +85 °C
- QFN 32 Package

1.2 Blockdiagram



1.3 Ordering Numbers

Part#	Package	Package Qty; Carrier	Order number
TDC-GP21	QFN32	5000/3000; T&R	MNR 1720
TDC-GP21	QFN32	490; Tray	MNR 1839
GP21-EVA-KIT	System	1; Box	MNR 1781

This product is RoHS compliant and does not contain any Pb.

2 Characteristics & Specifications

2.1 Electrical Characteristics

Absolute Maximum Ratings

Supply voltage			
	V_{cc} vs. GND	- 0.3 to 4.0	V
	V_{io} vs. GND	- 0.3 to 4.0	V
	V_{in}	- 0.5 to V_{cc} + 0.5	V
Storage temperature (T_{stg})		- 55 to 150	°C
ESD rating (HBM), each pin		> 2	kV
Junction temperature (T_j)		max.125	°C

Recommended Operating Conditions

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{cc}	Core supply voltage[1]	V_{io} = V_{cc}	2.5		3.6	V
V_{io}	I/O supply voltage		2.5		3.6	V
t_{ri}	Normal input rising time				200	ns
t_{fa}	Normal input falling time				200	ns
t_{ri}	Schmitt trigger rising time				5	ms
t_{fa}	Schmitt trigger falling time				5	ms
T_a	Ambient temperature	T_j must not exceed 125°C	-40		125	°C
$R_{th(j-a)}$	Thermal resistance	junction-ambient		28		K/W

[1] including the oscillator pins XIN, XOUT, Clk32In, Clk32Out

DC Characteristics (V_{io} = V_{cc} = 3.0 V, T_j = -40 to +85°C)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{32}	Current 32 kHz	I_{cc} + I_{io}, only 32 kHz oscillator running		1.0		µA
I_{hs}	Current 4 MHz oscillator	V_{cc} = V_{io} = 3.6 V = 3.0 V off		200 130 < 1		µA µA nA
I_{tmu}	Current time measuring unit	only during active time measurement		4		mA
I_{ddq}	Quiescent current	all clocks off, @ 85 °C		< 0.1		µA
I_o	Operating current	TOF_UP/DOWN, 1/s Temperature average, PT1000, 1/30s		1.1 0.15		µA
V_{oh}	High level output voltage	I_{oh}= tbd mA V_{io}=Min.	0.8V_{io}			V
V_{ol}	Low level output voltage	I_{ol} = tbd mA, V_{io}=Min			0.2V_{io}	V
V_{ih}	High level input voltage	LVTTL Level, V_{io} = Max.	0.7V_{io}			V
V_{il}	Low level input voltage	LVTTL Level, V_{io} = Min.			0.3V_{io}	V
V_{th}	High level Schmitt trigger voltage		0.7Vio			V
V_{tl}	Low level Schmitt trigger voltage				0.3V_{io}	V
V_h	Schmitt trigger hysteresis			0.28		V

Terminal Capacitance

Symbol	Terminal	Condition	Rated Value			Unit
			Min.	Typ.	Max.	
C_i	Digital input	measured @ V_{cc} = V_{io}, f = 1 MHz, T_a = 25°C		7		pF
C_o	Digital output					
C_{io}	Bidirectional			9		
	PT ports			t.b.d.		
	Analog in			t.b.d.		

Analog Frontend

Symbol	Terminal	Condition	Rated Value			Unit
			Min.	Typ.	Max.	
	Comparator input offset voltage (chopper stabilized)			< 1	2	mV
$R_{dson(AS)}$	Switch-on resistance of analog switches at STOP1/STOP2 inputs			200		Ohm
$R_{dson(FIRE)}$	Switch-on resistance of FIRE_UP, FIRE_DOWN output buffers	Symmetrical outputs, Rdson(HIGH) = Rdson(LOW)		4		Ohm
I_{fire}	Output current FIRE_UP, FIRE_DOWN output buffers			48		mA

EEPROM

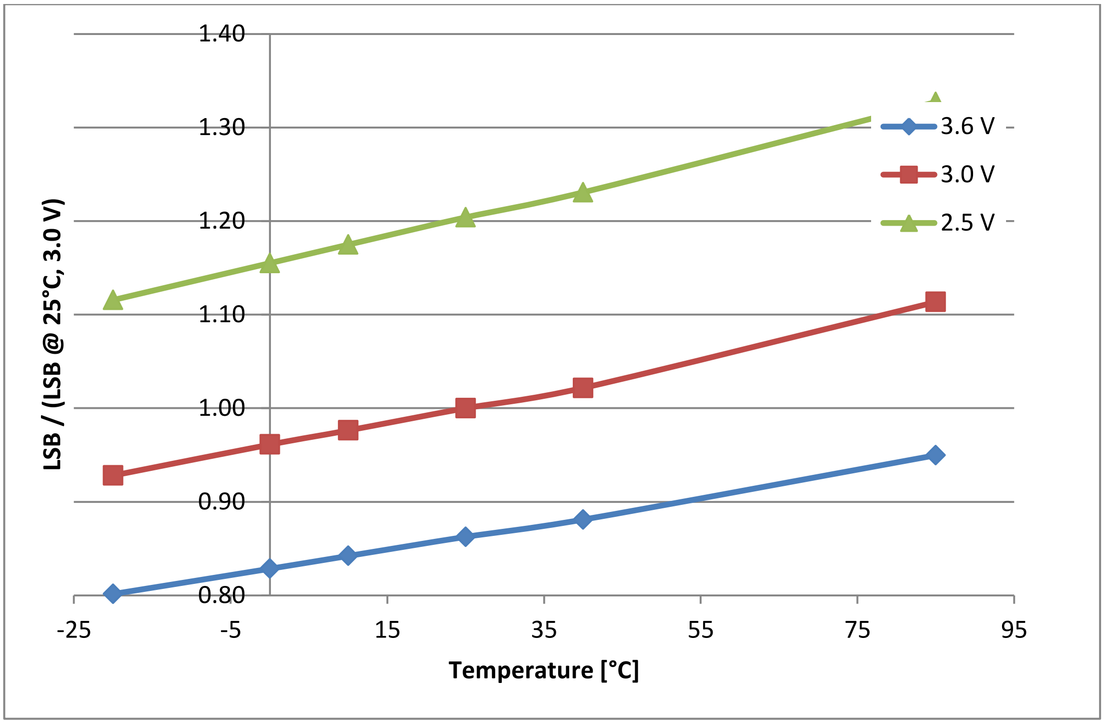
Symbol	Terminal	Condition	Minimum Value	Unit
	Data retention @ 85°C	normal	10	years
		with Error correction	practically endless	

2.2 Converter Specification

Time Measuring Unit (V_{io} = V_{cc} = 3.0 V, T_j = 25°C)

Symbol	Terminal	Condition	Rated Value			Unit
			Min.	Typ.	Max.	
LSB	Resolution (BIN-Size)	Measurement mode 1 & 2: DOUBLE_RES = 0 DOUBLE_RES = 1		90 45		ps
		Measurement mode 2: QUAD_RES = 1		22		ps
	Standard deviation Measurement Mode 1	DOUBLE_RES = 0 Delay = 200ns Delay = 1µs DOUBLE_RES = 1 Delay = 200ns		45 72 35		ps
	Standard deviation Measurement Mode 2	DOUBLE_RES = 0 Delay = 2µs Delay = 100µs DOUBLE_RES = 1 Delay = 2µs Delay = 100µs QUAD_RES = 1 Delay = 2µs Delay = 100µs		54 70 50 62 39 62		ps
t_m	Measurement range	Measurement mode 1	3.5 ns		2.4 µs =26224 *LSB	
		Measurement mode 2	700 ns		4 ms	
INL	Integral Non-linearity			< 0.1		LSB
DNL	Differential Non-linearity			< 0.8		LSB

Figure 2-1 Relative Variation of un-calibrated least significant bit with temperature and supply voltage, reference 3.0V/25°C



Temperature Measuring Unit[1]

Symbol	Terminal		Internal Schmitt trigger		external Schmitt trigger[2]		Unit
			PT500	PT1000	PT500	PT1000	
	Resolution RMS		17.5	17.5	16.0	16.0	Bit
	SNR		105	105	96	96	dB
	Absolute Gain[3]		0.9912	0.9931	0.9960	0.9979	
		3.6 V	0.9923	0.9940	0.9962	0.9980	
	Absolute Gain vs. V_{io}[3]	3.0 V	0.9912	0.9931	0.9960	0.9979	
		2.5 V	0.9895	0.9915	0.9956	0.9979	
	Gain-Drift vs. V_{io}		0,25	0.23	0.06	0.04	%/V

	max. Gain Error (@ dΘ = 100 K)	0,05%	0,05%	0,02%	< 0.01%	
	Gain-Drift vs. Temp	0.022	0.017	0.012	0.0082	%/10 K
	Gain-Drift vs. Vio			0,08		%/V
	Initial Zero Offset	< 20	<10	< 20	< 10	mK
	Offset Drift vs. Temp	< 0.05	< 0.03	< 0,012	< 0.0082	mK/ °C
	PSRR			>100		dB

[1] All values measured at Vio = Vcc = 3.0 V, Cload = 100 nF for PT1000 and 200 nF for PT500 (COG-type)

[2] measured with external 74AHC14 Schmitt trigger

[3] compared to an ideal gain of 1

2.3 Timings

At Vcc = 3.0 V ± 0.3 V, ambient temperature -40 °C to +85 °C unless otherwise specified

Oscillator

Symbol	Parameter	Min.	Typ.	Max.	Unit
Clk32	32 kHz reference oscillator		32,768		kHz
t_{32st}	32 kHz oscillator start-up time after power-up		250		ms
ClkHS	High-speed reference oscillator	2	4	8	MHz
t_{oszst}	Oscillator start-up time with ceramic resonator		100		µs
t_{oszst}	Oscillator start-up time with crystal oscillator		3		ms

Note:

It is strongly recommended to use a ceramic oscillator. Exactly because a quartz needs much longer to settle than a ceramic oscillator. This costs a lot current, but using a quartz oscillator has no advantage.

Serial Interface

Symbol	Parameter	Max. @ V_{io} =		Unit
		2.5 V	**3.3 V**	
f_{clk}	Serial clock frequency	15	20	MHz

Symbol	Parameter	Min. @ V_{io} =		Unit
		2.5 V	**3.3 V**	
t_{pwh}	Serial clock, pulse width high	30	25	ns
t_{pwl}	Serial clock, pulse width low	30	25	ns
t_{sussn}	SSN enable to valid latch clock	40	10	ns
t_{pwssn}	SSN pulse width between write cycles	50	40	ns
t_{hssn}	SSN hold time after SCLK falling	40	25	ns
t_{sud}	Data set-up time prior to SCLK falling	5	5	ns
t_{hd}	Data hold time before SCLK falling	5	5	ns

Symbol	Parameter	Max. @ V_{io} =		Unit
		2.5 V	3.3 V	
t_{vd}	Data valid after SCLK rising	20	16	ns

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

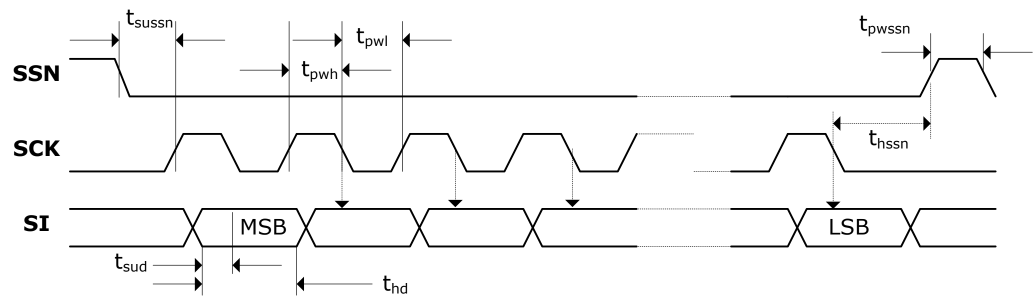


Figure 2-2 SPI Write

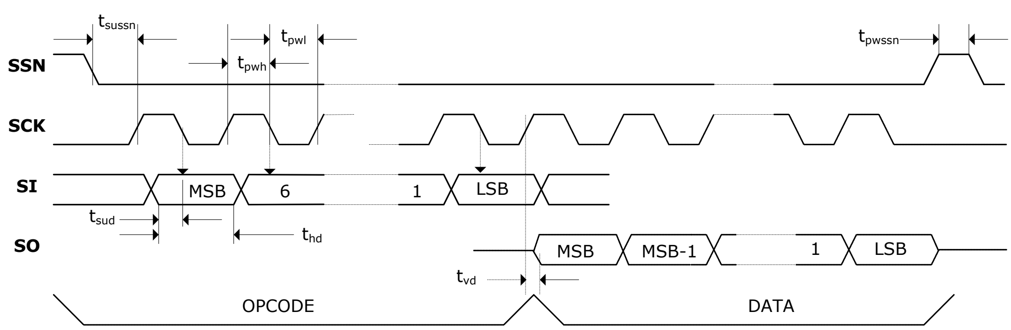


Figure 2-3 SPI Read

Disable Timings

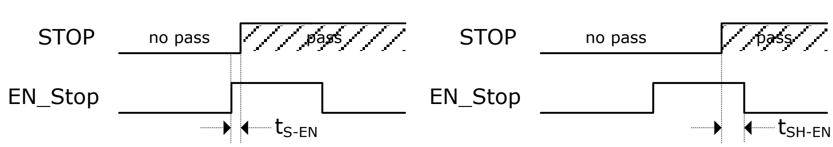


Figure 2-4 Disable Timings

Spec	Description	Measurement mode 1	Measurement mode 2
t_{S-EN}	Enable Setup Time	0 ns	0 ns
t_{SH-EN}	Enable Hold Time	1.5 ns	3.0 ns

Reset Timings

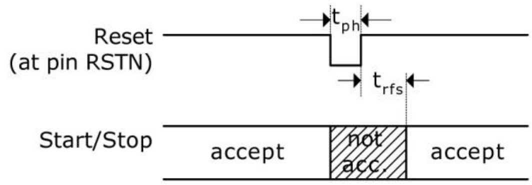


Figure 2-5 Reset Timings

Spec	Description	Typ. Min
t_{ph}	Reset pulse width	50 ns
t_{rfs}	Time after rising edge of reset pulse before further communication	200 ns
	Time after rising edge of reset pulse before analog section is ready	500 µs

2.4 Pin Description

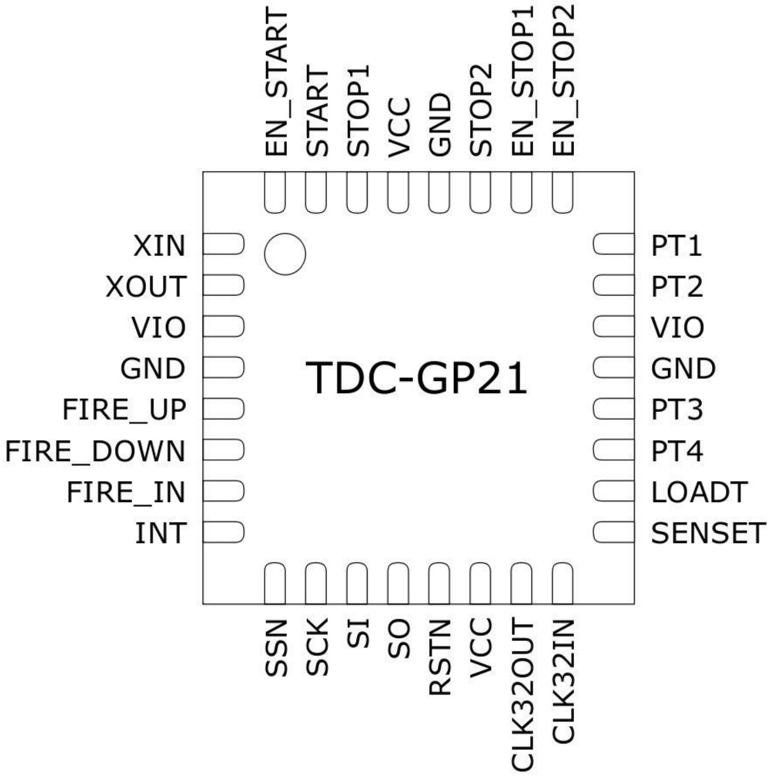


Figure 2-6 TDC-GP21 Pinout

No.	Name	Description	Buffer type	Value	If not used
1	XIN	Oscillator driver in			GND
2	XOUT	Oscillator driver out			
3	VIO	I/O – supply voltage			
4	GND	Ground			
5	FIRE_UP	Fire pulse generator output 1	48 mA		
6	FIRE_DOWN	Fire pulse generator output 2	48 mA		
7	FIRE_IN	Diagnostics output			GND
8	INTN	Interrupt flag	4 mA	LOW active	
9	SSN	Slave select		LOW active	
10	SCK	Clock serial interface			

No.	Name	Description	Buffer type	Value	If not used
11	SI	Data input serial interface			
12	SO	Data output serial interface	4 mA tristate		
13	RSTN	Reset input		LOW active	
14	VCC	Core supply voltage			
15	CLK32OUT	Output 32 kHz clock generator			n. c.
16	CLK32IN	Input 32 kHz clock generator			GND
17	SENSET	Sense input temperature measurement	Schmitt trigger		GND
18	LOADT	Load output temperature measurement	24 mA		n.c.
19	PT4*	Port 4 temperature measurement	> 96 mA open drain		
20	PT3*	Port 3 temperature measurement	> 96 mA open drain		
21	GND	Ground			
22	VIO	I/O – supply voltage			
23	PT2*	Port 2 temperature measurement	> 96 mA open drain		
24	PT1*	Port 1 temperature measurement	> 96 mA open drain		
25	EN_STOP2	Enable pin stop input 2		HIGH active	VIO
26	EN_STOP1	Enable pin stop input 1		HIGH active	VIO
27	STOP2	Stop input 2			GND
28	GND	Ground			
29	VCC	Core supply voltage			
30	STOP1	Stop input 1			GND
31	START	Start input			
32	EN_START	Enable pin start input		HIGH active	VIO

* R_{DSON} temperature ports: typ. 1.8 Ω @ 3.0 V

2.5 Package Drawings

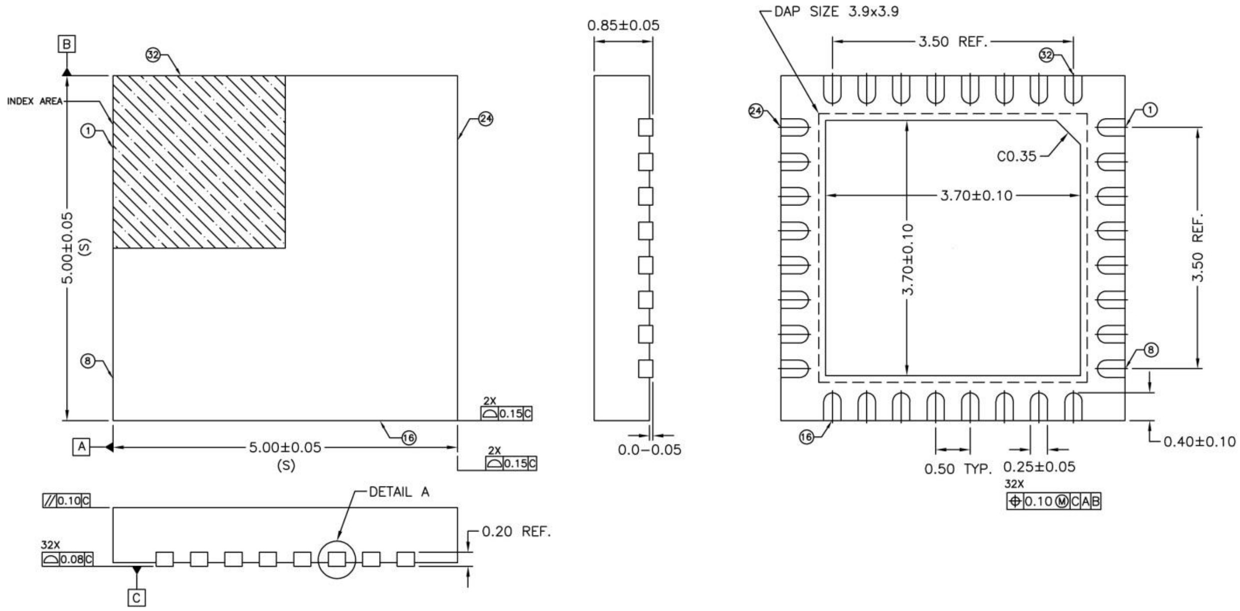


Figure 2-7 QFN-32 package outline, 5 x 5 x 0.9 mm³, 0.5 mm lead pitch

Caution: Center pad, 3.70 * 3.70 mm², is internally connected to GND. No wires other than GND are allowed underneath. It is not necessary to connect the center pad to GND.

Suitable socket: Plastronics 32QN50S15050D

Landing Pattern:

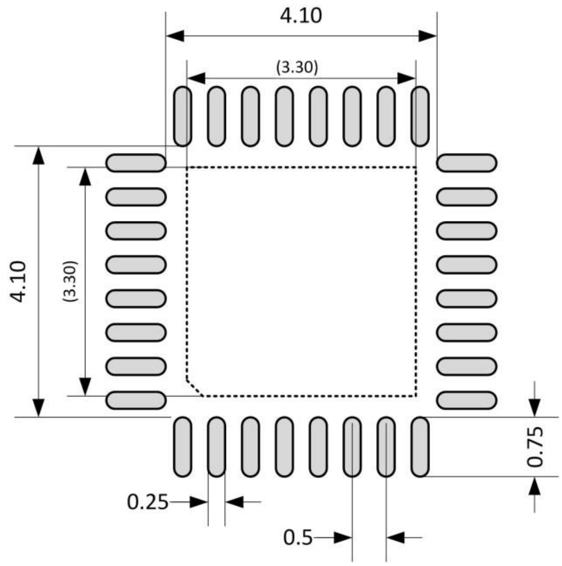


Figure 2-8

Thermal resistance: Roughly 28 K/W (value just for reference).

Environmental: The package is RoHS compliant and does not contain any Pb.

Moisture Sensitive Level (MSL)

Based on JEDEC 020 Moisture Sensitivity Level definition the TDC-GP21 is classified as MSL 1.

Soldering Temperature Profile

The temperature profile for infrared reflow furnace (in which the temperature is the resin's surface temperature) should be maintained within the range described below.

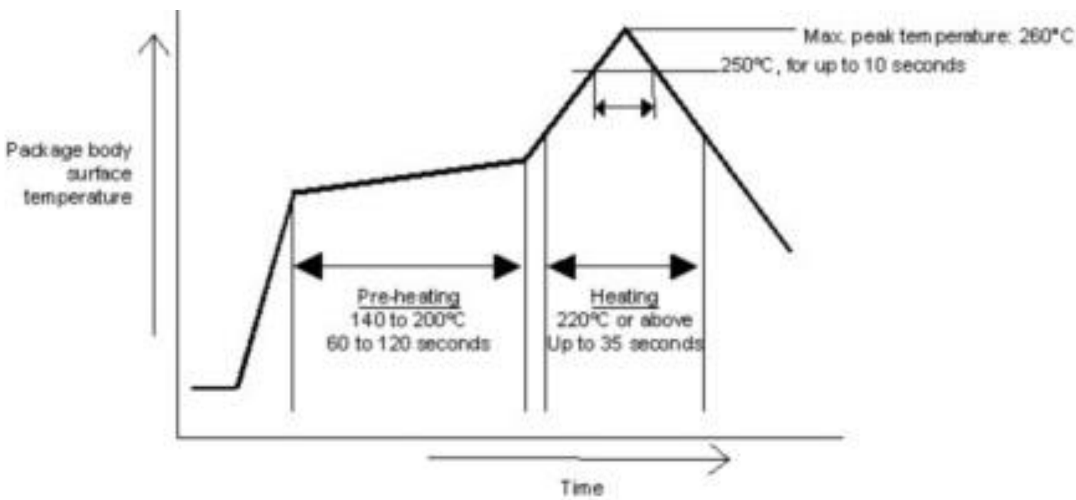


Figure 2-9 Soldering profile

Maximum temperature

The maximum temperature requirement for the resin surface, given 260°C as the peak temperature of the package body's surface, is that the resin surface temperature must not exceed 250°C for more than 10 seconds. This temperature should be kept as low as possible to reduce the load caused by thermal stress on the package, which is why soldering for short periods only is recommended. In addition to using a suitable temperature profile, we also recommend that you check carefully to confirm good soldering results.

Date Code: YYWWA: YY = Year, WW = week, A = Assembly site code

2.6 Power Supply

Supply voltage

TDC-GP21 is a high end mixed analog/digital device. To reach full performance of the chip a good power supply is mandatory. It should be high capacitive and of low inductance.

The TDC-GP21 provides two pairs of power supply terminals:

Vio - I/O supply voltage

Vcc - Core supply voltage

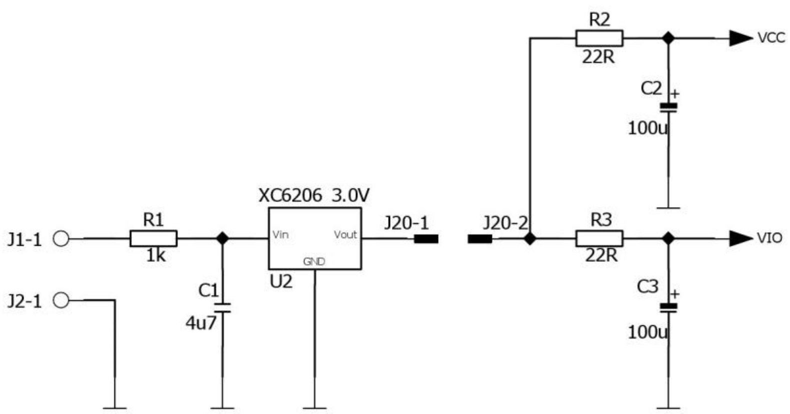


Figure 2-10

Both voltages should be applied with low series resistance from the same source. On the chip there are connected, but a separate external connection is recommended for good measurement quality. 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.

Vio and Vcc are connected internally on the chip. The resistance between both is in the range of several Ohms. However, Vio is connected to the pads with significantly lower impedance and therefore can provide this better than Vcc.

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 to 100 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 switch mode power supplies.

Current consumption

The current consumption is the sum from different parties (all data for Vio = Vcc = 3.0V):

I_{ddq}	< 5 nA typ.@3.0V, 25°C	Quiescent current, no 32 kHz oscillator running
I_{32}	typ. 1.0 µA	Standby current with active 32 kHz oscillator (GP21 waiting for command).
I_{hs}	typ. 130 µA/s * (active runtime)	Current into the high speed oscillator at 3.0 V Vio. Example: In ultrasonic flow-meters the high-speed oscillator is on for about 2ms only. The average current consumption is 130 µA/s * 2 ms = 0.26 µA
I_{tmu}	typ. 4 mA/s * (active measuring time)	Current into the time measuring unit, In measurement mode 1 The time measuring unit is active for the start-stop time interval plus the calibration time interval of 2 periods of the reference clock per measurement. In measurement mode 2 the time measuring unit is on for average 4 periods of the reference clock per measurement, two for the time measurement and two for calibration. Example: With 10 measurements per second in measurement mode 2 and a 4 MHz reference clock the time measuring unit is active for

		only about 10 µs. The average current is 4 mA/s * 10 µs = 0.040 µA.
I_{ALU}	typ. 7 nA per calculation	Current into ALU during data proccesing including a calibration calculation. Example: At 1000 measurements per second with 3 stops per start the ALU average current is 7 nA * 3000 = 21 µA.
I_T	typ. 2.5 µAs * measure rate	The current for a full temperature measurement is typ.2.5µAs. In heat-meters the temperature is measured typically once every 30 seconds. The average current is about 0.085 µA
I_{ana}	typ. 0.8 mA	Current consumption of the integrated analog part of TDC-GP21 during a Time-of-flight (ToF) measurement. The analog part is active for a duration of 250 µs + ToF.