

### FEATURES

- 29 measuring modes and one generator mode
- 2 identical channels
- Provides frequency (time)-to-digital conversion for many types of sensors and transducers
- Provides interfacing for resistive (including platinum (Pt), cuprum (Cu) resistors and thermistors (Ni)), capacitive sensing elements and resistive bridges
- Frequency range from 0.05 Hz up to 9 MHz without prescaling and 144 MHz with prescaling;
- Programmable accuracy (relative error) for frequency (period) conversion from 1 % to 0.0005%
- Relative quantization error is constant in all specified frequency range
- Non-redundant conversion time
- Scalable resolution
- Internal reference clock 625 kHz, 20 MHz @ 20 MHz quartz oscillator
- Quartz-accurate automated calibration
- 3-wire serial interface (SPI compatible)
- 2-wire interface (I<sup>2</sup>C compatible)
- RS-232/485 serial interface
- Master and slave communication modes
- Frequency generator mode 10 MHz with quartz crystal stability

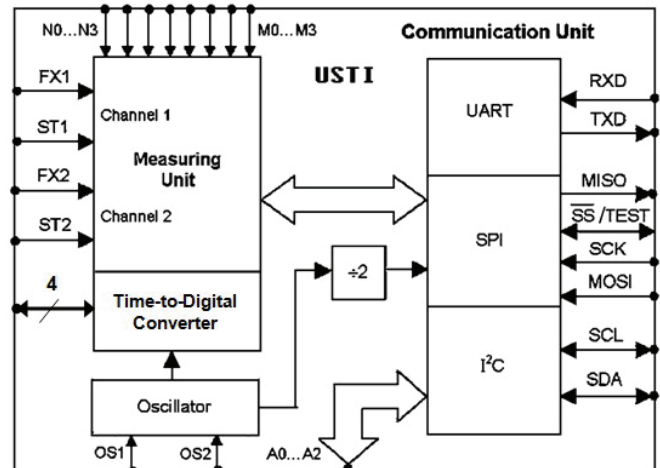
### APPLICATIONS

Physical and Chemical Sensor Systems  
Digital Sensors, SoC, SiP, BioMEMS, Lab-on-Chip  
Smart and Intelligent Sensors and Systems  
Industrial and Process Control  
Data Acquisition Systems  
Instrumentations  
Customer Electronics  
Automotive

### GENERAL DESCRIPTION

The Universal Sensors and Transducers Interface (USTI) is a fully digital CMOS integrated circuit of universal, 2-channel, high precision, multifunctional converter based on novel, advanced methods for frequency, period, its ratio, duty-cycle and phase-shift measurements. It is perfectly suited to any applications where frequency-time parameters but also sensors output signal, have to be measured with highest

### FUNCTIONAL BLOCK DIAGRAM



resolution and programmable accuracy during the non-redundant conversion time.

The USTI covers a wide range of frequencies and accuracies for modern frequency-time domain sensors. In addition, the USTI provides interfacing for resistive (including platinum, cuprum resistors and thermistors), capacitive sensing elements and resistive bridges.

By using this IC it is possible to build a wide variety of digital, smart sensors and intelligent sensor systems. The device represents a high-resolution conversion and designed to support all range of frequency-time domain and digital sensor applications. It offers high performances with flexibility and requires minimum possible number of external components.

The USTI can be easily included into digital environment, controlled by an external microcontroller (slave mode) or work independently as a separate measuring unit without an external control (master mode). The function selection can be configured in both software and hardware.

The IC converts frequency-time domain signals, resistance and capacitance of sensing elements and resistance of sensor bridges into digital and provides digital, bus interface to microcontroller, DAQ or sensor system to read these digital results. Sensing elements can be directly connected to the USTI without the need for extra electronics. Only a single reference element, of the same kind as the sensor, is required.

The USTI has 29 measuring and one generating modes. The measuring mode can be hardware-

selected by using four selection external pins M0-M2 and the relative error by using four selection pins N0-N2 (RS232 master communication mode). The mode and accuracy can be also selected by using any of three possible interfaces (slave communication mode). A communication interface type (RS232, SPI or I<sup>2</sup>C) can be automatically selected according to the circuit connection.

**MEASURING MODES**

- Frequency,  $f_x$  0.05 Hz – 9 MHz directly and up to 144 MHz with prescaling
- Period,  $T_x$  110 ns – 20 s
- Phase shift,  $\varphi_x$  0 - 360° at  $f_{xmax} = 625$  kHz at 50 % duty-cycle
- Time interval between start – and stop-pulse,  $\tau_x$  1.5  $\mu$ s – 250 s
- Duty-cycle, DC 0 – 1 at  $f_{xmax} \leq 625$  kHz
- Duty-off factor,  $Q_1$   $10^{-8}$  –  $8 \cdot 10^6$  at  $f_{xmax} \leq 625$  kHz
- Frequency difference,  $f_{x2} - f_{x1}$  with sign recognition, 0 – 9 MHz
- Period difference,  $T_{x1} - T_{x2}$  with sign recognition, 0 – 20 s
- Frequency ratio,  $f_{x1}/f_{x2}$   $5.5 \cdot 10^{-9}$  –  $1.8 \cdot 10^8$
- Period ratio,  $T_{x1}/T_{x2}$   $4.0 \cdot 10^{-9}$  –  $2 \cdot 10^8$
- Rotation speed,  $n_x = (f_x - 60)/Z$ , where Z is the number of encoder teeth
- Pulse width,  $t_p$  1.5  $\mu$ s – 250 s
- Space interval,  $t_s$  1.5  $\mu$ s – 250 s
- Pulse number (events) counting,  $N_x$  0 –  $4 \cdot 10^9$
- Frequency deviation absolute  $D_{A1}$ , 0-9 MHz
- Frequency deviation relative  $D_{R1}$ , 0-100 %
- Resistance,  $R_x$  10  $\Omega$  to 10 M $\Omega$  with average relative error  $\pm 0.47$  % and  $\pm 0.01$  % error at splitting of the range into sub ranges
- Capacitance,  $C_x$  50 pF to 100  $\mu$ F with average relative error  $\pm 0.036$  % and  $\pm 0.7$  % the worst case relative error
- Resistive bridges,  $B_x$  must not include any internal components other than 4 arms forming a bridge

NOTE: The USTI can also work with any voltage and current output sensors. In this case, any voltage-to-frequency converter (VFC) can be used. The accuracy of such system will be determined by sensor accuracy as well as by VFC accuracy.

**ACCURACY**

The USTI has programmable relative error from 1 to 0.0005 % in all specified range of frequencies for frequency and period measurements. This error is constant and does not depend on the measuring frequencies in all frequency ranges. The USTI has non-redundant conversion time. The higher conversion accuracy needs longer conversion time. However, it is non-redundant for any selected accuracy and frequency. For time interval, phase shift, pulse width and space measurements the relative error is determined mainly by measured and can be calculated

according to the following equation:

$$\delta_q = \frac{1}{20 \cdot 10^6 \cdot t_x} \times 100\%$$

where  $t_x$  is the appropriate measuring value of  $t_p$ ,  $t_s$  or  $\tau_x$  depending on the mode.

**COMMUNICATION MODES**

The USTI can work as an independent measuring unit (master mode), controlled by any external microcontroller (or embedded into a sensor), DAQ board or PC (slave mode). In the master mode, the conversion accuracy and measurement mode should be selected by external switches. In this mode the USTI works only through the RS232 interface in a unidirectional mode. In the slave mode (with an external microcontroller), all measuring modes and programmed accuracy can be set up by a data bus or through communication I/O ports of master microcontroller. This allows us use the USTI as a simple peripheral circuit for a microcontroller. A bidirectional data exchange is possible with any of three interfaces RS232, SPI or I<sup>2</sup>C. The USTI works as a standard element in different systems with I<sup>2</sup>C bus architecture, or can be controlled through the RS232 or SPI interfaces. The choice of interface can be performed automatically depend on the circuit connections.

The selection of communication interface is performed automatically based on the state of IS1 and IS2 inputs at the power switch on:

IS1	IS2	Communication Interface
0	0	SPI slave
0	1	I2C slave
1	0	RS232 master
1	1	RS232 slave

**CHARACTERISTICS**

- Single power supply, V: 4.5 – 5.5
- External reference frequency, MHz: 20
- Internal reference frequency, kHz: 625
- Conversion time, s: 0.00016 to 0.32
- Supply current (at 20 MHz, 4.5V, 25°C), mA: < 9.5
- Operating temperature range -40°C to +85°C
- Storage temperature range -65°C to +150°C

**PIN-OUT AND HOUSING**

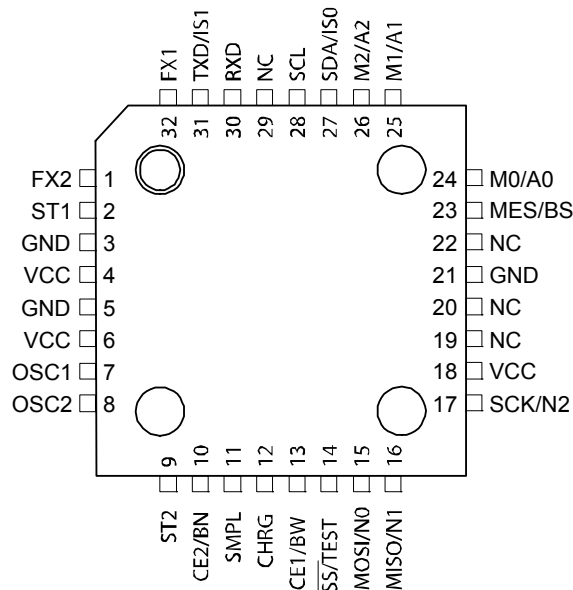
The USTI is available in a 28-lead (0.300"/7.62 mm Wide) Plastic Dual Inline Package (PDIP); 32-lead 7 x 7 mm Body Size, 1.0 mm Body Thickness, 0.8 mm Lead Pitch small Thin Profile Plastic Quad Flat Package (TQFP); and 32-pad, 5 x 5 x 1.0 mm Body,

Lead Pitch 0.50 mm, 3.10 mm Exposed Pad, Micro Lead Frame Package (MLF).

## TQFP/MLF TOP VIEW

### PIN FUNCTION DESCRIPTIONS

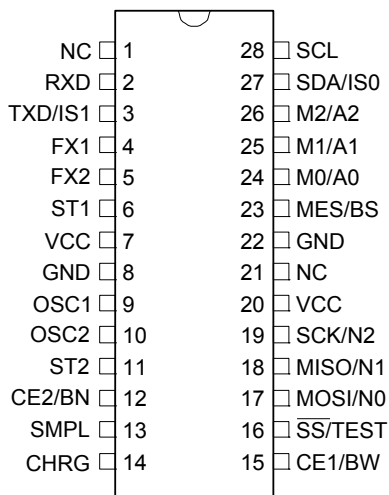
Name	Pin Descriptions
VCC	Supply voltage
GND	Ground
FX1, ST1	Input channel 1
FX2, ST2	Input channel 2
OSC1, OSC2	Oscillator
M0, M1, M2	Mode selection (see table)
N0, N1, N2	Accuracy selection (see table)
A0, A1, A2	Address of I <sup>2</sup> C slave (for I <sup>2</sup> C bus communication)
TEST	Calibration signal
SCK	SPI Bus Master clock Input
MISO	SPI Bus Master Input/Slave Output
MOSI	SPI Bus Master Output/Slave Input
SS	SPI Bus Master Slave select
SCL	Two-wire (I <sup>2</sup> C compatible) Serial Bus Clock Line
SDA	Two-wire (I <sup>2</sup> C compatible) Serial Bus Data Input/Output Line
RXD	UART Input
TXD	UART Output
IS0,IS1	Interface mode selection
BN	North port of bridge
BW	West port of bridge
BS	South port of bridge
CE1	Calibration element 1
CE2	Calibration element 2
CHRG, MES, SMPL	R <sub>x</sub> and C <sub>x</sub> measurement pins



NOTE: Bottom Pad for MLF Package Should be Soldered to Ground.

This device can also be supplied in wafer form. Please contact Technology Assistance BCNA 2010 S. L. sales office for detailed ordering information and minimum quantities.

### PDIP



For more detailed information, specifications and application notes the following document are strongly recommended: *Universal Sensors and Transducers Interface (USTI): Specification and Application Note*



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