H28

Verson 1.5

16-Bit Analog-to-Digital Converter

- ◆ **Standby Current Consumption 0.1 µA**
- ◆ **Low Supply Current**
- ◆ **Low Power Consumption**
- ◆ **Resolution 16 Bits**
- ◆ **ENOB 14 Bits**
- ◆ **Serial Data Output (I^2C bus)**

DESCRIPTION

The **H28** is a 16 bit Analog-to-Digital Converter (ADC), which employs a delta-sigma conversion technique. With the linear input signal range of 324 mVPP ,. its resolution is 14 bits.

The **H28** is designed especially to meet the requirement for low power consumption, thus making it an ideal choice for battery powered systems. The **H28** is equipped with a standby function, i.e. the ADC is in power down between each conversion. By utilizing this and overall low power consumption, current consumption values of 1.2 µA or less can be achieved (one conversion in a second; fast mode conversion time 16 ms).

The **H28** has an on-chip second order decimator filter to process the output of the second order modulator. The ADC also has two selectable conversion ranges with two optional offset levels.

A bi-directional 2-wire I^2C bus is used for configuring conversion parameters, starting conversion and reading out the A/D conversion result.

H28 has one input channel suitable for piezo-resistive pressure sensor. In addition to pressure measurement configuration the device can be configured to temperature measurement.

FEATURES

- Low Standby Current Consumption 0.1 µA
- Low Supply Current: 0.2 µA…..1.6 µA
- Supply Voltage: 2.0 V…5.0 V
- Ratiometric Conversion
- Two Input Signal Ranges (VDD=2.35V): 405 mV_{PP} , 105 mV_{PP}
- Two Optional Offsets (VDD=2.35V): 25 mV, 33 mV
- Over Sampling Ratio: 512, 256, 128, 64
- Conversion Times 32.2 ms…2.5 ms
- In Fast Mode: Over Sampling Ratio 64, Conversion Time=2.5 ms, Resolution=10 Bits
- Good Noise Performance due to **(Δ~Σ)** Architecture
- 2-Wire I^2C Interface

APPLICATIONS

- Battery Powered Systems
- Low Frequency Measurement Applications
- Pressure and Temperature Measurement
- Current/Power Consumption Critical Systems
- Industrial and Process Control Applications in Noisy Environments

BLOCK DIAGRAM

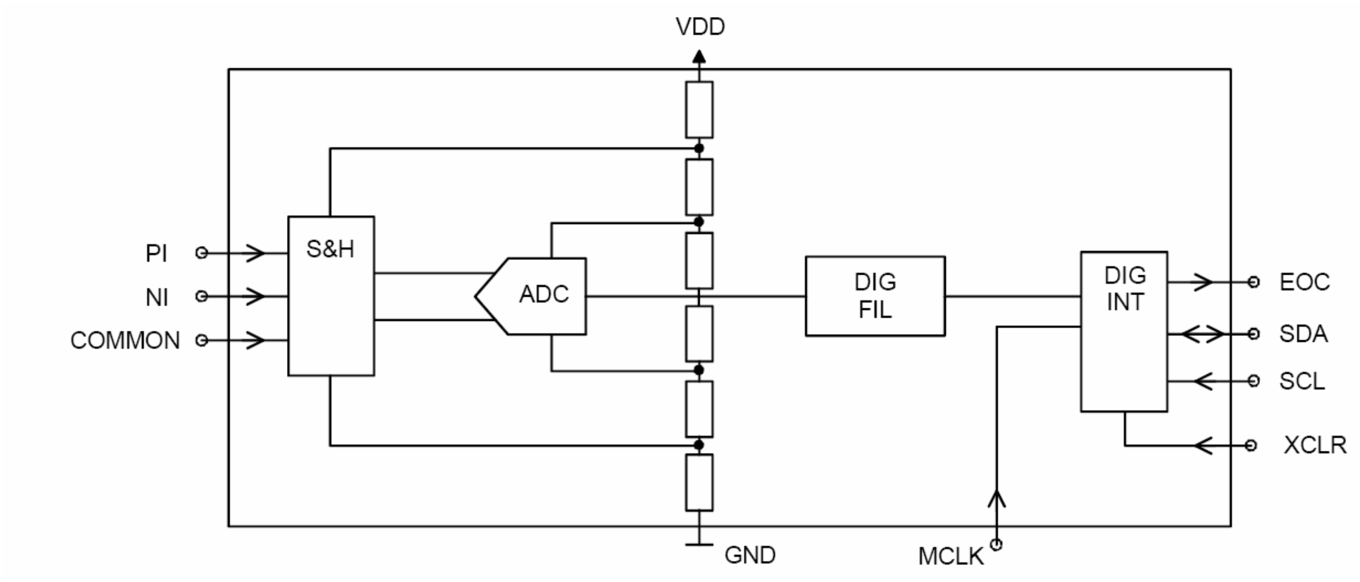


Figure 1. H28 block diagram

ABSOLUTE MAXIMUM RATINGS

All Voltages with Respect to Ground

Parameter	Symbol	Conditions	Min	Max	Unit
Supply Voltage	V_{CC}		- 0.3	6.0	V
Voltage Range for All Pins			- 0.3	V_{IN} + 0.3	V
ESD Rating	V_{ESD}	For all pins, Human Body Model (HBM), ESD Association Standard Test Method ESD-STM5.1 1998, C_{ESD} = 100 pF, Rs = 1500 :),	-2	2	kV
Latchup Current Limit	I_{LUT}	For all pins, test according to Micro Analog Systems specification ESQ0141. Note 1	- 100	+ 100	mA
Junction Temperature	T_{Jmax}			+ 135	°C
Storage Temperature	T_S		- 55	+125	°C

Stresses beyond those listed may cause permanent damage to the device. The device may not operate under these conditions, but it will not be destroyed.

Note 1. In latchup testing the supply voltages are connected normally to the tested device. Then pulsed test current is feeded to each input separately and device current consumption is observed. If the device current consumption increases suddenly due to test current pulses and the abnormally high current consumption continues after test current pulses are cut off then the device has gone to latch up. Current pulse is turned on for 10 ms and off for 20 ms.

ELECTRICAL CHARACTERISTICS

T_A = -20°C to +60°C, Typ T_A = 25°C, VDD = 2.35 V, R_{sensor} = 4.5k: unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Supply Voltage	VDD		2.0	2.35	5.0	V
Operating Temperature	T_A		-20	+25	+60	°C
Average ADC Current during Conversion Time (see Conversion Time at bottom)	I_{CONV}	VDD = 3.6 V		30	50	µA
Average ADC Current in Pressure and Temperature Measurement during Conversion Period (no sensor current included)	I_{ADC}	1 conversion/s (conversion period 1 s), XENMCLKDIV=1, R_{sensor} = 4.5 k:, Max value at VDD = 3.6 V				
		OSR=512		0.5	0.9	µA
		OSR=256		0.25	0.5	
		OSR=128		0.13	0.3	
		OSR=64		0.07	0.2	
Average Supply Current in Pressure Measurement during Conversion Period (including sensor bridge current)	I_{SAVG_P}	1 conversion/s (conversion period 1 s), XENMCLKDIV=1, R_{sensor} = 4.5 k:, Max value at VDD = 3.6 V				
		OSR=512		1.6	2.5	µA
		OS R=256		0.8	1.3	
		OSR=128		0.5	0.7	
		OSR=64		0.3	0.4	
Average Supply Current in Temperature Measurement (including sensor bridge current)	I_{SAVG_T}	1 conversion/s (conversion period 1 s), XENMCLKDIV=1, R_{sensor} = 4.5 k:, Max value at VDD = 3.6 V				
		OSR=512		0.9	1.5	µA
		OSR=256		0.5	0.8	
		OSR=128		0.3	0.4	
		OSR=64		0.2	0.3	
Peak Supply Current During Pressure Measurement	I_{SC}	VDD = 2.35 V, R_{sensor} = 4.5 k:		0.52		mA
Peak Supply Current During Temperature Measurement	I_{SC}	VDD = 2.35 V, R_{sensor} = 4.5 k:		0.19		mA
Standby Current	I_{SS}	VDD = 2.35 V		0.1	0.5	µA
Conversion Time	t_{CONV}	MCLK = 32768 Hz, XENMCLKDIV=1				
		OSR=512		16.1		ms
		OSR=256		8.3		
		OSR=128		4.4		
		OSR=64		2.5		

Note: XENMCLKDIV refer to the I^2C serial interface control bits, see table 1 on page 5.

ELECTRICAL CHARACTERISTICS

T_A = -20°C to +60°C, Typ T_A = 25°C, VDD = 2.35 V, R_{sensor} = 4.5k: unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Resolution				16		Bit
		ISR = 405 mV ISR =105 mV		6.1 1.6		µV
Accuracy		ISRLIN =324 mV, OSR = 512 ISRLIN = 84 mV, OSR = 512		19.7 5.1		µV
Intergral Nonlinearity	INL			4		LSB
Differential Nonlinearity	DNL			3		LSB
ENOB (Effective Number of Bits)		ISRLIN = 324 mV OSR=512 OSR=256 OSR=128 OSR=64		14 13 12 10		Bit
External Clock Signal	MCLK		30000	32768	35000	Hz
Delay Between End of Conversion and ADC Result Read-Out	t_{DEL}	MCLK = 32768 Hz	0.1			ms
Duty Cycle of MCLK	DUTYC	Master Clock Division Enabled XENMCLKDIV=0	60/40	50/50	40/60	%
		Master Clock Division Disabled XENMCLKDIV=1	TBD		TBD	
Serial Data Clock	SCL				500	kHz
Input Signal Conversion Range	ISR	ISCR = 1 (Water sensor) ISCR = 0 (Air sensor)		405 105		mV
Linear Input Signal Conversion Range	ISRLIN	ISCR = 1 (Water sensor) ISCR = 0 (Air sensor)		324 84		mV
Output Code Values			0		65408	
Temperature Measurement Resistors	R_1 R_2 R_3		-10%	7710 17000 3073 17000	+10%	:
Temperature Measurement Resistors Temp Coefficient	TC_R		-400	-350	-300	ppm / °C

Note: ISCR refer to the I^2C serial interface control bits, see table 1 on page 5. TBD= To Be Defined

H28 CONTROL REGISTER

Table 1. HT2801 control register bit description

Bit Number	Bit Name	Description	Value	Function
7-6	OSRS(1:0)	Over Sampling Ratio (OSR) selection	11 01 10 00	OSR = 512 OSR = 256 OSR = 128 OSR = 64
5	SCO	Start Conversion	0 1	No Conversion Start Conversion
4	PTS	Pressure/Temperature Selection	1 0	Pressure configuration Temperature configuration
3	ISCR	Input Signal Conversion Range	1 0	Water sensor:405 mV (324 mV linear range) Air sensor: 105 mV (84 mV linear range)
2	XENMCLKDIV	Enable Master Clock Division	0 1	MCLK division enabled MCLK division disabled
1	XOSENABLE	Enable offset	0 1	Offset enabled Offset disabled
0	OSSELECT	Offset value selection	1 0	Offset for water sensor +25 mV Offset for air sensor +33 mV

H28 has one control register for configuring the measurement setup. See table 1 for control register bit definitions. Control register values are set via I2C bus.

First two **OSRS** bits of the control register define four selectable over sampling ratios. The higher over sampling ratio the better ADC accuracy, but the longer conversion time.

The **SCO** bit controls the A/D conversion. When **SCO** = 0, no A/D conversion takes place. When **SCO** = 1, the A/D converter turns on and the analog data is being converted. Then MCLK must be clocked at least until EOC pin goes high indicating that conversion has been accomplished.

PTS bit selects between pressure and temperature measurement. In temperature measurement the sensor is connected in bridge configuration together with four integrated resistors (see figure 3 on page 8 and resistors R1, R2, R3 and R4).

ISCR selects between two A/D conversion ranges. Wider range is matched for water pressure sensor and narrower range for air pressure sensor.

The **XENMCLKDIV** bit controls the internal clock frequency of H28, fCLK(INT). When the bit is low, the MCLK division is enabled and the internal clock frequency fCLK(INT) = fMCLK/2, where fMCLK is the master clock frequency. When the XENMCLKDIV bit is high, the MCLK division is disabled and fCLK(INT) = fMCLK.

In the **XENMCLKDIV** = 1 mode the duty cycle should be as close to 50 % as possible. In this mode, the conversion time is made half (see page 3 conversion time values with **XENMCLKDIV** = 1) compared to clock speed division mode **XENMCLKDIV** = 0 whereas the resolution remains unchanged. In **XENMCLKDIV** = 0 mode the conversion time and also current consumption are doubled but then the external master clock signal MCLK does not need to have close to 50% duty cycle.

XOSENABLE can be used to enable input signal range offset option. At 1 value no offset is applied but at 0 value an offset value which is determined with OSSELECT bit is used.

OSSELECT selects between two offset values. Larger value is matched for water pressure sensor and smaller value is for air pressure sensor. No offset is applied if offset is disabled (**XOSENABLE**=1).

I^{2}C SERIAL INTERFACE CONTROL

Serial Interface

H28 has two wire serial I^{2}C bus type interface comprising of serial clock (SCL) and serial data (SDA) pins. I^{2}C bus is used to write configuration data to sensor interface IC and read the measurement result when A/D conversion has been finished.

Digital interface includes also master clock (MCLK), end of conversion (EOC) and master reset (XCLR) pins.

MLCK signal is needed to be clocked during conversion period. It can be stopped after EOC goes high which indicates that A/D conversion has been accomplished. MCLK signal can also be running all the time.

XCLR is used to reset the A/D converter. Reset initializes internal registers and counters. After connecting supply voltage to H28 and before starting operating the device via I2C bus it is required to reset the device with XCLR reset pin if supply voltage rise time has been longer than 400 ns. If the supply voltage rise time is shorter than this the external reset with XCLR pin is unnecessary since the device is automatically resetted by power on reset (POR) circuitry.

Device and Register Addresses

I^{2}C bus standard makes it possible to connect several I2C bus devices into same bus. The devices are distinguished from each other by unique device address codes. H28 device address is shown in table 2. The LSB bit of the device address defines whether the bus is configured to Read (1) or Write (0) operation.

Table 2. H28 device address

A7	A6	A5	A4	A3	A2	A1	W/R
1	1	1	0	1	1	1	0/1

H28 contains three 8-bit registers which are presented in table 3. Control register is used to configure the device to proper measurement setup. Control register bits are described in table 1 (page 4). Two other 8-bit registers are used to store the 16-bit A/D conversion result.

Table 3. H28 internal register addresses

A7	A6	A5	A4	A3	A2	A1	A0	Register Description
1	1	1	1	1	1	0	1	MSB A/D Conversion Result Register
1	1	1	1	1	1	1	0	LSB A/D Conversion Result Register
1	1	1	1	1	1	1	1	Control register

I^{2}C SERIAL INTERFACE CONTROL...

I^{2}C Bus Protocol Definitions

Two wire I^{2}C bus protocol has special bus signal conditions. Figure 2 shows start (S), stop (P) and binary data conditions. At start condition the SCL is high and SDA has falling edge. At stop condition the SCL is also high but SDA has rising edge. Data must be held stable in SDA pin when SCL is high. Data can change value at SDA pin only when SCL is low.

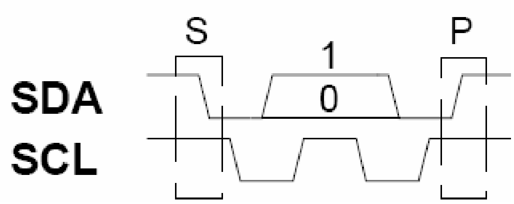


Figure 2. I^{2}C protocol definitions

I^{2}C contains also acknowledge (A) and not acknowledge (N) commands. At acknowledge the master device sends 0 bit to SDA bus (pulls down SDA for one SCL clock cycle. At not acknowledge (N) the slave device sends 0 bit to SDA (pulls down SDA) for one SCL clock cycle.

Abbreviations:
A= Acknowledge by Slave
N = Not Acknowledge by Master
S = Start
P = Stop

Conversion Starting – Write Sequence

Conversion is started by first writing measurement configuration bits into the control register. Write sequence is illustrated in Table 4.

To start conversion the control register SCO bit has to be set high (SCO=1, see control register bit description in table 1).

Table 4. H28 I2C bus write sequence bits

S	*AW*	*A*	*AC*	*A*	*DC*	*A*	*P*

Abbreviations:
AW = Device Write Address (%1110 1110)
AR = Device Read Address (%1110 1111)
AC = Control Register Address (%1111 1111)
Ax = MSB (x=M, %1111 1101) or LSB (x=L, %1111 1110) ADC Result Register Address
DC = Control Register Data
Dx = MSB (x=M) or LSB (x=L) A/D Result Register Data

Each I^{2}C bus operation like write starts with start command (see figure 2). After start the H28 device address with write bit (AW, see table 2) is sent and ended to acknowledge (A). After this control register address (AC, see table 3) is sent and ended to acknowledge (A). Next control register data (DC, see table 1) is written and ended to acknowledge (A). Finally the I2C bus operation is ended with stop command (see figure 2).

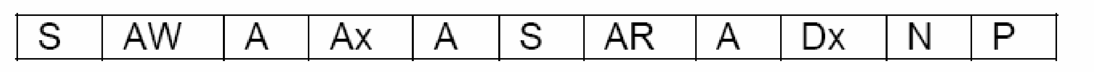
A/D Conversion

A/D conversion is progressed by running MCLK signal until EOC goes high indicating that conversion is done and data is ready for reading.

I^{2}C SERIAL INTERFACE CONTROL

Conversion Result – Read Sequence
Table 5 presents general control sequence for single register data read.

Table 5 H28 I2C bus single register (address Ax)



S	AW	A	Ax	A	S	AR	A	Dx	N	P

Table 6 presesents control sequence for reading the 16-bit A/D conversion result from both MSB and LSB data registers. LSB register data (DL) can be read right after MSB register data (DM) read since in case the read sequence is continued (not ended to stop condition P) the register address is automatically incremented to point to next register address (in this case to point to the LSB data register).

Table 6 H28 I2C bus MSB (first) and LSB (second) A/D conversion result read sequence

S	AW	A	AM	A	S	AR	A	DM	N	DL	N	P

Accuracy Improvement – Averaging

Averaging technique can be used to remove conversion error caused by noise and thus improve measurement accuracy. By accomplishing several A/D conversions and taking average of the samples, it is possible to average out noise. Theoretically noise is reduced by factor N where N is number of averaged samples. Converter non-linearities cannot be removed by averaging.

APPLICATION INFORMATION

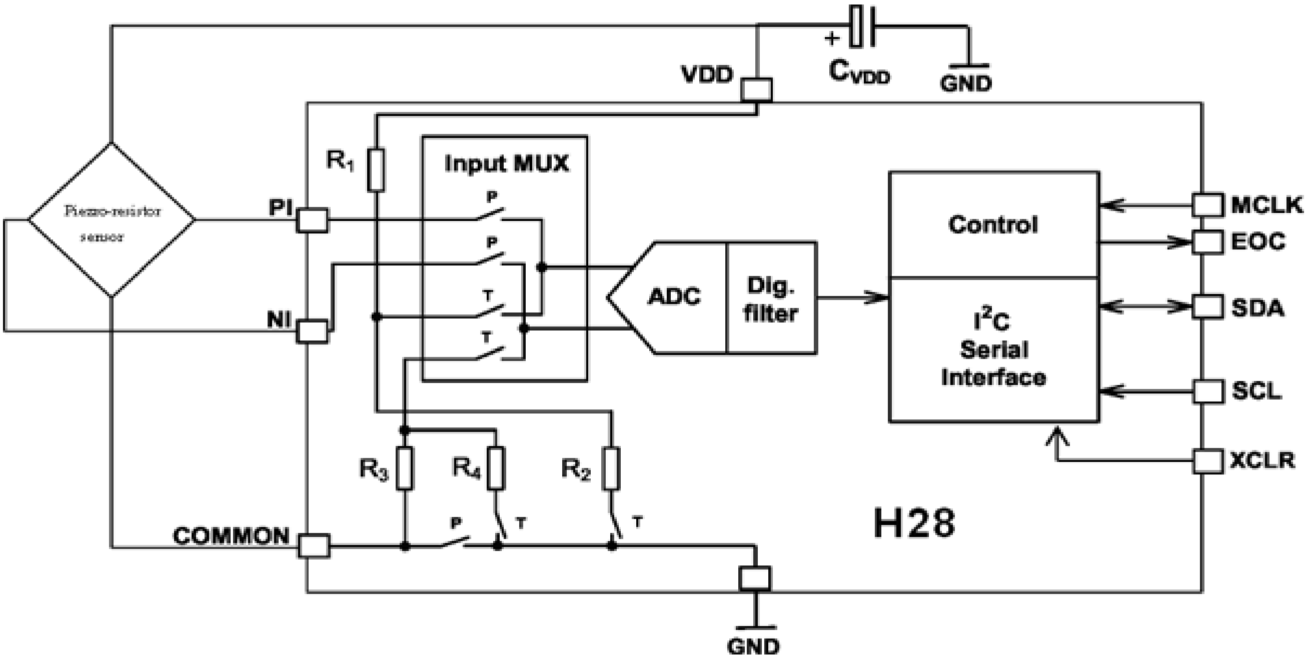


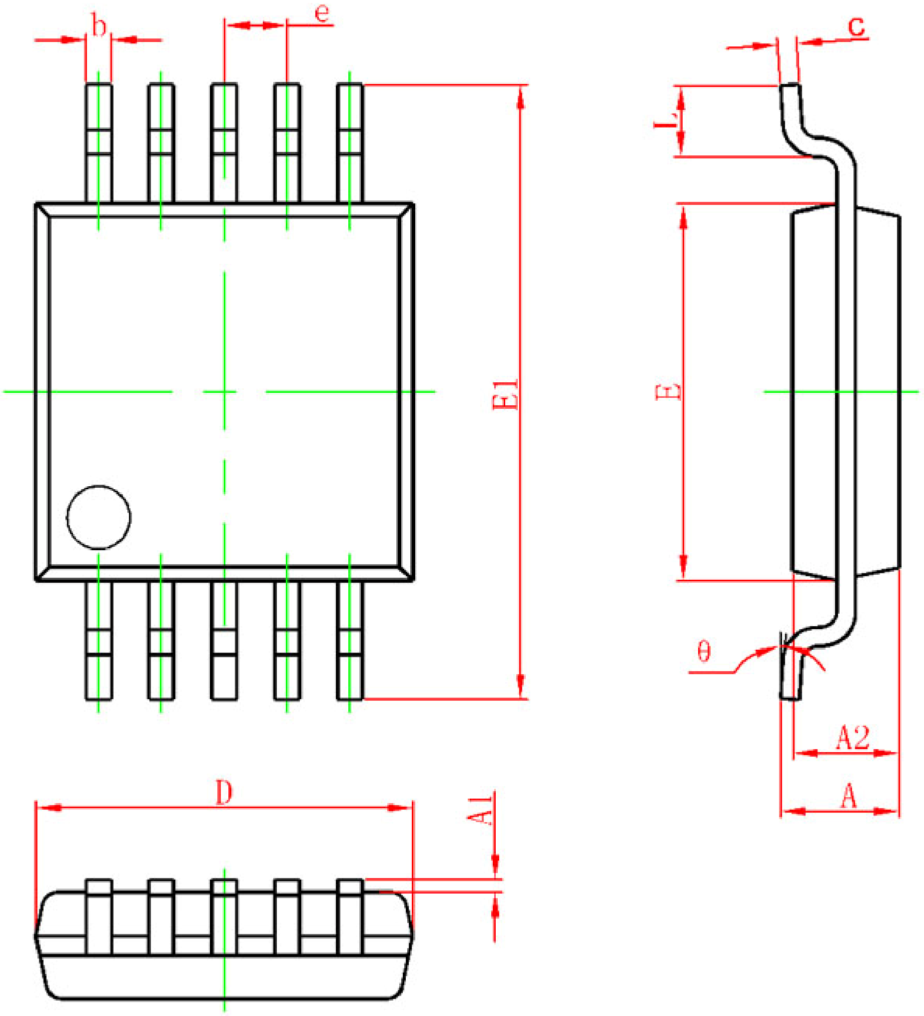
Figure 3. Resistive sensor connection circuit

Together with a resistive pressure sensor, H28 can be used in pressure measurement applications. Control can be performed with a micro-controller through the I^{2}C serial interface.

The sensor is connected between the power supply voltage (VDD) and H28 signal ground (COMMON) which can be internally (switch inside of **H28**) connected to ground (GND). Sensor output is read as a differential signal through PI (positive input) and NI (negative input) to the converter in H28.
In the pressure measurement mode, the switches marked “P” are closed and the sensor output is fed through to the ADC. In the temperature measurement mode, the switches marked “T” are closed and the voltage at the ADC input is determined by the internal resistor array and the temperature-dependent resistance of the sensor. In this configuration the sensor bridge is connected as part of single four resistor bridge circuit where other four resistors (R1, R2, R3, R4) are inside the IC.

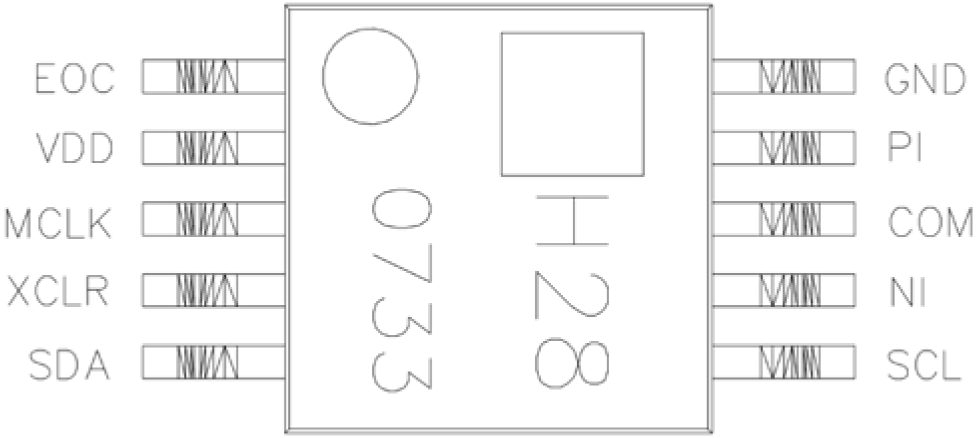
To guarantee conversion accuracy a supply voltage decoupling capacitor of 4.7 µF or more should be placed between VDD and GND of **H28** (see C_{VDD} in figure 3).

H28 PAD LAYOUT



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.180	0.280	0.007	0.011
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
e	0.50(BSC)		0.020(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

PIN LAYOUT



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