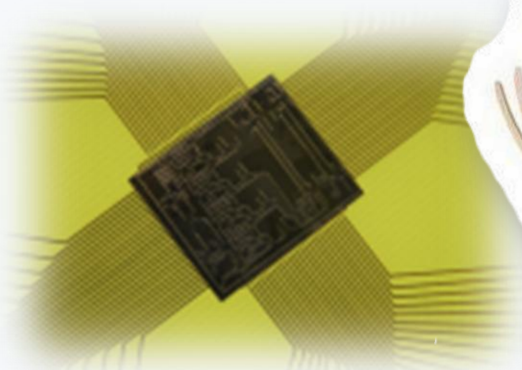
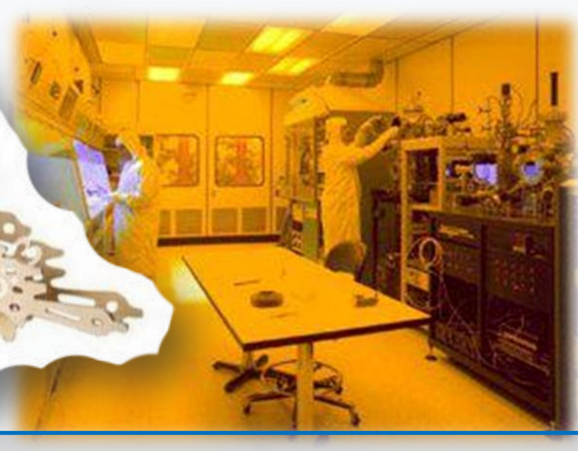
Jan 23th 2013

NKUAS *PRECEEDING*

One Day Seminar On MEMS Devices And Technology In Mechatronics 2013





國立高雄應用科技大學

PREFACE

Thank God, finally editors can completed The Journal Preceeding Student Bridging Course National Kaohsiung University of Applied Sciences (NKUAS).

The National Kaohsiung University of Applied Sciences (NKUAS) Students Bridging Course Journal Preceeding is present as report of all of student who studied in NKUAS. This journal also can be used as reading material which tells about the development in MEMS technology especially in mechatronics devices.

This journal is consisting of ten papers that made by students bridging with title namely:

1. The BMI055 6-Axis Inertial Sensor.
2. The Benefit of Mass Air Flow System PMF 2000.
3. The Function ZW Series Displacement Sensors For Ethercat.
4. Infrared Thermocopile Sensor Micro Electrical Mchanical Systems As Contactless Temperature Measurement: A Literature Review.
5. The Advantages of Model 4807A High Resolution Accelerometer.
6. Global Trend Pico Projector on Mobile Devices
7. LPS331AP Pressure Sensor With Embedded Compensation.
8. Super-Sensitive Non-Contact of the D6T Mems Thermal Sensor.
9. Energy Harvesting for Wireless Sensor System With TE-Core.

The editors also want to say thanks to:

1. Prof. Dr. Da-Chen Pang who has lectured all students bridging from Indonesia in mechatronics subject.
2. Chi-Ting Yen (staff of International Office) has helped all students bridging from Indonesia.

Kaohsiung, January 24th 2013
Sincerely,

Editors

CONTENTS

THE BMI055 6-AXIS INERTIAL SENSOR

Ahmad Kholil
Student Bridging Course National Kaohsiung University of Applied Sciences
State University of Jakarta, Indonesia
Email: ach_cholil@yahoo.com

Keywords: Inertia sensor, Acceleration, Gyroscope

Abstract: The BMI055 is a very small, 6 axis inertial sensor, consisting of: A digital, triaxial 12bit acceleration sensor and a digital, triaxial 16bit, ±2000°/s gyroscope. The BMI055 allows very low-noise measurement of angular rates and accelerations in 3 perpendicular axes and thus senses tilt, motion, shock and vibration in mobile phones, handhelds, computer peripherals, man-machine interfaces, remote and game controllers.

Introduction

The BMI055 is unique in the class of low-noise inertial measurement units. It is ultra-small footprint of only 3 mm x 4.5 mm On top, the BMI055 integrates a multitude of features that facilitate its use especially in the area of motion detection applications, such as device orientation measurement, gaming, HMI andmenu browser control.

Featuring a full operation current consumption of < 5.15mA the BMI055 is ideally suited for battery powered devices like mobile phones, remote controllers, and gaming devices. In low-power mode current consumption can be significantly reduced: the accelerometer can be operated with low current consumption at less than 10µA in order to wake-up the gyroscope only when necessary. The BMI055 is highly configurable in order to give the designer full flexibility when integrating the sensor into his system.

Depending on the programmable settings the integrated interrupt engine of the BMI055 signals the occurrence of certain events via the sensors` interrupt pins. The corresponding registers of the BMI055 can easily be set and read-out via the digital interfaces, i.e. I²C and SPI (3-wire/4-wire). Sensor parameters, like measurement ranges or lowpassfi lter settings and all interrupt engine settings can also be easily programmed via the digital interfaces.

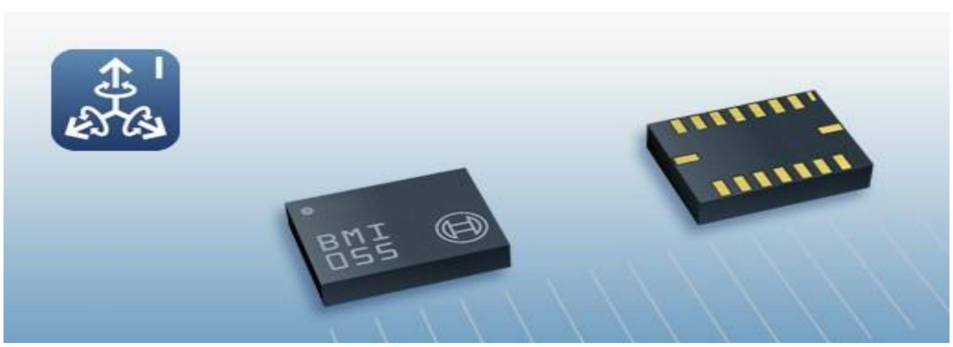


Fig 1. BMI055 6-axis inertia sensor (manufactured by Bosch)

Table 1. BMI055 Technical Data

Digital resolution	*Accelerometer (A): 12 bit* *Gyroscope (G): 16bit*
Resolution	*(A): 0.98mg (G): 0.004°/s*
Measurement ranges (programmable)	*(A): ±2 g, ±4 g, ±8 g, ±16 g* *(G): ±125°/s, ±250°/s, ±500°/s, ±1000°/s, 2000°/s*
Sensitivity (calibrated)	*(A): ±2 g 1024 LSB/g, ±4 g 512 LSB/g, ±8 g 256 LSB/g, ±16 g 128 LSB/g* *(G): ±125°/s 262.4 LSB/°/s, ±250°/s: 131.2 LSB/°/s, ±500°/s: 65.6 LSB/°/s, ±1000°/s: 32.8 LSB/°/s, ±2000°/s: 16.4 LSB/°/s*
Zero-point offset	*(A): ± 70mg, (G): ± 1°/s*
Noise density (typ.)	*(A): 150µg/√Hz (G): 0.014 °/s/√Hz*
Bandwidths (progr.)	*1000Hz … 8Hz*
Digital inputs/outputs	*SPI, I²C, 4x digital interrupts*
Supply voltage (VDD)	*2.4 … 3.6 V*
I/0 supply voltage (VDDIO)	*1.2 … 3.6 V*
Temperature range	*-40 … +85°C*
Current consumption *- Full operation* *- Accelerometer wake-up mode*	 *5.15 mA* *< 10 µA*
FIFO data buffer	*(A) 32 samples depth (G) 100 samples (each axis)*
LGA package	*3 x 4.5 x 0.95mm³*
Shock resistance	*10,000 g x 200 µs*

Integrated Interrupt Engine

One of the key elements of the BMI055 is the enhanced intelligent interrupt engine that gives the designer full control. Various motion detection scenarios can be identifi ed by the BMI055 and signaled to the system via interrupt pins. The interrupt sources can be freely mapped to the interrupt pins. Following motion detection use case scenarios are supported by the BMI055 interrupt engine.

Accelerometer interrupts:

- ✓ Data-ready (e.g. for processor synchronization)
- ✓ Any-motion detection (e.g. for wake-up)

- ✓ No-motion detection (e.g. for power saving)
- ✓ Tap sensing (e.g. for tap-sensitive UI control)
- ✓ Orientation change recognition (e.g. for portrait/landscape & face-up/face-down switching)
- ✓ Flat detection (e.g. for position sensing)
- ✓ Low-g / high-g detection (e.g. for shock and free-fall detection)

Gyroscope interrupts :

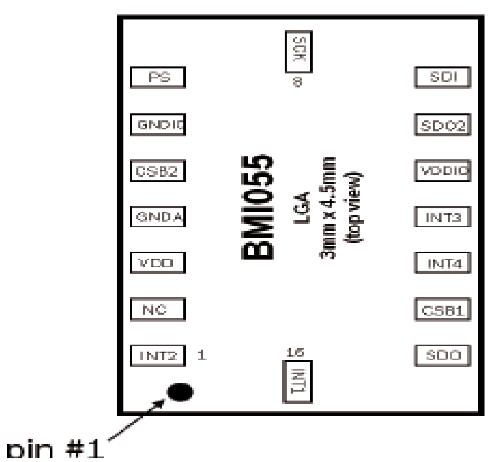
- ✓ Self-wake-up/auto-wake-up
- ✓ Auto sleep: after a predefi ned duration of no activity, switch to sleep mode and activate self-wake-up/auto-wake-up; durations: 5s/10s/15s/20s/30s/60s.

Interrupt parameters (e.g. switching angles and hysteresis settings for orientation change) can be confi gured and thus perfectly support the integration of the BMI055 into the user's system environment.

- ✓ The interrupt outputs are confi gurable as activehigh or active-low
- ✓ The interrupt source is selectable from fi ltered or unfi ltered data

System Compatibility

The BMI055 has been designed for best possible fit into modern mobile consumer electronics devices. Besides the ultra-small footprint and very low power consumption, the BMI055 has very wide ranges for VDD and VDDIO supply voltages. The BMI055 also includes a FIFO buffer with 32 samples depth for each axis for the accelerometer and a FIFO buffer with 100 samples depth for each axis of the gyroscope. An integrated self-test feature facilitates overall system reliability.



Pin no.	Signal
1	INT2 (Accelerometer)
2	NC
3	V_{DD}
4	GNDA
5	CSB2 (Gyroscope)
6	GND_{IO}
7	PS
8	SCx
9	SDx
10	SDO2 (Gyroscope)
11	V_{DDIO}
12	INT3 (Gyroscope)
13	INT4 (Gyroscope)
14	CSB1 (Accelerometer)
15	SDO1 (Accelerometer)
16	INT1 (Accelerometer)

Fig 2. Pin-number of signal BMI055

Applications

1. ***Vibration measurement, also for active damping***

A MEMS acceleration sensor detects fine movements and controls them. This can be the case to monitor the movement for saving electricity or prevent damage caused by the vibration.

2. ***Activity monitoring, step-counting***

Athletes can now practice sports while having immediate feedback on their performance. MEMS accelerometers can be placed into an easy and light portable device that can measure their status. This information can be stored and kept track of over time to keep track of progress and adjust a user's workout program.

3. ***Navigation***

A pressure sensor works as an altimeter, giving your height above sea level for hiking, biking, skiing and other outdoor sports. Check your altitude on the map and find the right trail. Monitor your daily sport acitivity. The resolution of better than +-1 meter (3 ft.) can detect smallest changes in altitude.

4. ***Six-dimensional tracking of trajectories***

Gaming applications use an accelerometer as a motion sensor that enhances the user interface of any game. Sensing the movement of the user allows for that movement to be translated into motion for a game. This provides a simpler and more interactive user interface.

5. ***Flat detection, tap sensing, menu scrolling***

An accelerometer acts as a motion or tilt sensor. A user's motion can be detected and used to orient the display, as when using a map, and to conveniently search through data such as WebPages or lengthy text. It also eliminates small or difficult buttons that are often hard to use.

6. Tilt compensation for electronic compass

A tilt-compensated compass allows for users to have a more accurate compass that can be viewed in any position that a user chooses to hold the display.

7. Shock and free-fall detection

Hard-disk-drives are included in many portable devices such as Laptops, PocketPCs, PDAs, MP3 Players and portable media centers. If these devices should be dropped, the HDD head can slide over the drive erasing the data. Using a MEMS sensor, the freefall can be measured and act as a safety feature that can signal the hard disk head to park away and protect all data.This is done using an acceleration sensor that can detect movements along all three dimensions (X, Y and Z axis).

8. Image stabilization

Today almost all mobile phones are equipped with cameras. The actions required to use the camera - especially with the reduced size of the buttons - require uncontrolled movements that can be corrected using.

Conclusions

The BMI055 is a very small, 6 axis inertial sensor for acceleration sensor and gyroscope. The BMI055 allows very low-noise measurement of angular rates and accelerations in 3 perpendicular axes and thus senses tilt, motion, shock and vibration in mobile phones, handhelds, computer peripherals, man-machine interfaces, remote and game controllers.

Refference

1. *http://www.bosch-sensortec.com/homepage/products_3/6_axis_sensors_2/geomagnetic_sensors*

THE BENEFIT OF MASS AIR FLOW SYSTEM PMF 2000

Arif Wahyudiono
Student Bridging Course National Kaohsiung University of Applied Sciences
State University of Malang
Email: arif_wahyudiono@yahoo.com, arifwahyudiono@um.ac.id

Keywords: Accelerometer, Air Flow, sensors.

Abstract. The aim of this study is to review both pros and cons about mass air flow sensors PMF 2000 based on literature review. Leveraging the innovative Posifa Thermal Flow Sensor Die, Posifa's Mass Air Flow Sensors offer the inherent advantages of improved accuracy and robustness over competitive offerings. Whether improved pin-for-pin replacements to industry as standard devices, Posifa's mass air flow sensor products bring significant user benefits and economic values on applications.

Introduction

The measurement of gas and liquid flow rates is an essential requirement in many industrial and commercially application. In 1975 Hayward estimated there are more than one hundred different types of sensors with a mode of operation based on almost any physical domain [1]. Micro-electro-mechanical systems (MEMSs) Research becomes popular when auto control system is increased. The interest in research activities on MEMS area is shown by the vast scientific literature and the several hundred companies specifically worked to micro machined systems. All the growth is due to some important advantages of micro machined flow sensors compared to large-scale ones, such as better dynamic characteristics, low power consumption, reduced mass, small size, and cost-effectiveness thanks to batch-fabrication, among other attributes. The concept of micro-electro-mechanical systems (MEMSs) is still deliberated to be an emerging technology, however it was born in the early sixties [2], and almost fourteen years (1974) passed until a milestone study appeared, describing the first integrated silicon-based sensor for gas flow measurement [3]. A high growth of research works in the field of MEMS and micro machined flow sensors took place in the 1980 and about a decade need a development of the integration of many micro fluidic devices into a single chip (e.g., micro pumps, valves and flow sensors). The micro flow devices have very small volume and the result of this challenge was a new class of micro machined flow sensors that have an integrated flow micro channel [4]; which Petersen introduced for the first time into this design [5].

Theoretical Background

The Principle of main idea to measure by thermal flow sensors use transport principles from three major of physics; based on mechanical, thermal and electrical transport phenomena. It can be explain that the measurements are interaction between the measure (mechanical parameter), heated by Joule effect (electrical phenomenon), and cause a thermal exchange (thermal phenomenon).

The velocity of airflow measurement would be an essential need in many commercial and industrial applications, including environmental monitoring systems, medical instrumentation, process control, and also gas pipelines. Flow measurement applications were traditionally implemented using large-scale mechanical Flow meters of one form or another. However, the increasing sophistication of modern micro-fabrication techniques has led to the development of many MEMS-based micro-Flow meters in recent years. Reviewing the literature, it is found that the majority of these sensors can be divided as either thermal or non thermal, it is depend on their mode of operation. Furthermore, non-thermal sensors can be further classified as either differential pressure-based, lift force-based, or cantilever based.

The principles of measurement of thermal flow sensors include transport principles of three of the major branches of physics, based on mechanical-thermal-electrical transport phenomena: the interaction between the measurand (mechanical parameter) and the core of the sensing element, heated by Joule effect (electrical phenomenon), causing a thermal exchange (thermal phenomenon). Therefore, the mechanical measurand modulates, through thermal exchange, one parameter of the sensing element; the modulation produces an output voltage signal.

Description

Air Flow System Sensor which work based on the force of air flow could be a choice to be applied. The industry who called Posifa designed PMF 2000 series as a mass airflow sensors in which the ranges from 10 sccm to 2000 sccm. The sensors are fully calibrated and compensated over the temperature range of 0 to 50°C (32 to 122°F). The linear analog output (1 to 5 V) provides customers with maximum flexibility and ease-of-use. The sensors die use a pair of thermopiles, thermopiles is used to detect the changes of temperature by mass flow delivering ultra low noise to signal. The “solid state” thermal isolation on the sensor die eliminates the need for surface cavities or fragile membranes, used in competes solutions, making the sensor resistant to clogging and pressure shock.

Absolute Minimum Rating

These devices must operate in to -25 C to 85 C to get the beneficial and it would be out of recommendation if out of the range. As a special part of devices, ti can be storage between -40 C and 90 C. However it still works by 0 to 100% of RH; RH is Relative Humidity. Related to the toughness of shock pressure, the device has peak number of shock pressure 100 grams by 5 drops in the 6 axis. Also, it can still be operated until 25 Psi.

Linear Output

Flow Rate = [(Vout - 1 V) / 4 V] x Full Scale Flow Rate

For example, using the PMF2103 below, the device has a Full Scale Flow Rate of 2000 sccm. When the Output Voltage reads 2.5V, the Flow Rate will be: [(2.5V-1V)/4V x 2000 sccm] =750 sccm. It can be seen at figure 2.

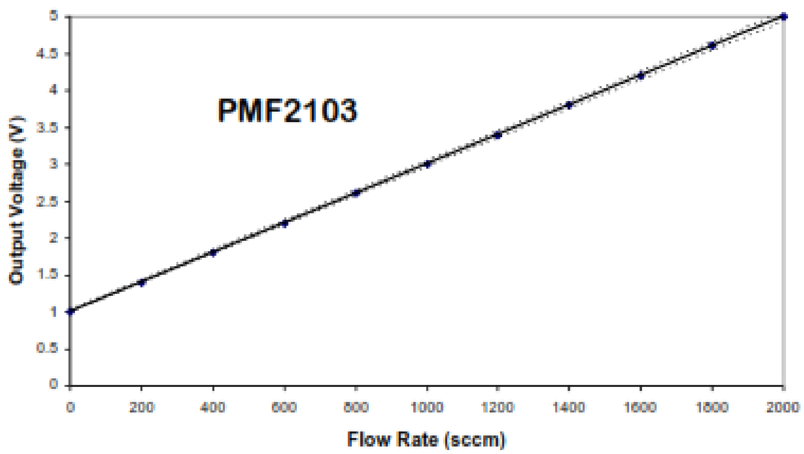


Figure 2. Flow Rate VS Out put Voltage

Performance Indicator

Table 1. Performance Indicator of Model 4807A Accelerometer

POSiFA

P

ELECTRICAL CHARACTERISTICS

Test Conditions: Vin=10±0.01VDC, Ta=25°C. Relative Humidity: 40%<RH<60%

Maximum Operating Temperature Range –25°C to +85°C

PARAMETERS	PMF2050V				CONDITIONS
	MIN	TYP	MAX	UNIT	
Flow Range[1] (Full Scale)	0		10	SCCM	
Max Output Voltage	4.94	5.00	5.02	VDC	@10 sccm
PARAMETERS	PMF2100V				CONDITIONS
	MIN	TYP	MAX	UNIT	
Flow Range[1] (Full Scale)	0		30	SCCM	
Max Output Voltage	4.94	5.00	5.02	VDC	@30 sccm
PARAMETERS	PMF2101V				CONDITIONS
	MIN	TYP	MAX	UNIT	
Flow Range[1] (Full Scale)	0		200	SCCM	
Max Output Voltage	4.94	5.00	5.02	VDC	@200 sccm
PARAMETERS	PMF2102V				CONDITIONS
	MIN	TYP	MAX	UNIT	
Flow Range[1] (Full Scale)	0		1000	SCCM	
Max Output Voltage	4.94	5.00	5.02	VDC	@1000 sccm
PARAMETERS	PMF2103V				CONDITIONS
	MIN	TYP	MAX	UNIT	
Flow Range[1] (Full Scale)	0		2000	SCCM	
Max Output Voltage	4.94	5.00	5.02	VDC	@2000 sccm
PARAMETERS	PMF2000 Series				CONDITIONS
	MIN	TYP	MAX	UNIT	
Analog Voltage Output[2]	1		5	VDC	
Null Voltage[3]	.98	1	1.02	VDC	
Null Drift		0.2		% / Year	Full Scale
Temperature Drift			4	%	0°C to +50°C
Repeatability		0.1		%	Full Scale
Load		100		KΩ	
Accuracy[4] (Full Scale)		1.5	2	%	
Response Time		1	3	mSec	
Supply Voltage	8	10	14	VDC	
Supply Current	22		23	mA	
Inrush Current[5]			550	mA	Duration: 3 ms
Wetted Materials	Silicon carbide, Epoxy, PPS, FR4, Silicone as static seal				

1. Custom ranges available between 10 and 2000 sccm
2. See Linear Output Flow Rate Calculation on Page 3
3. Null tolerance for PMF2050V is ± 0.1V
4. Accuracy for PMF2100V and PMF2050V is 2.5% F.S. Max
5. A series resistance of 5 ohms on the source supply will reduce inrush current to under 250 mA (duration: 8 ms)

Discussion

It can be seen this device has accuracy 1.5 to 2%, response time 1 to 3 msec, repeatability 0.1%, Operating Temperature: -25 °C to 85 °C, Storage Temperature: -40 °C to 90 °C, Humidity: 0 to 100% RH, Shock 100 g peak (5 drops, 6 axis), and Common Mode Pressure 25 psi.The sensor die uses a pair of thermopiles to detect changes in temperature gradient caused by mass flow, delivering ultra-low noise to-signal, and unsurpassed repeatability. The “solid state” thermal isolation on the sensor die eliminates the need for surface cavities or fragile membranes, making the sensor resistant to clogging and pressure shock.

Conclusions

The benefits of thermal flow sensors are high sensitivity and the wide measurement ranges, moreover the introduction of solutions to thermally isolate the sensing element is essential to improve some characteristics (e.g., accuracy). The drawbacks of many thermal air flow sensors are substantially related to the non-linearity of the calibration curve. Even though it able to represent a valuable characteristic that caused by the abovementioned high sensitivity at low flow rates, however, non-linearity causes an appreciable sensitivity decrease with air flow that content fluid flow. In some cases, a further issue is related to possible presence of dust or humidity in gas flow that strongly affects sensor accuracy. In the following section a detailed description of micro machined thermal flow sensors utilized in some biomedical applications is reported.

References :

[1]. Miller, R.W. Introduction to the differential producer. In *Flow Measurement Engineering Handbook*, 3rd ed.; Miller, R.W., Ed.; McGraw-Hill: New York, NY, USA, 1996; Sections 7.1–7.5.

[2].Wang, Y.H.; Chen, C.P.; Chang, C.M.; Lin, C.P.; Lin, C.H.; Fu, L.M.; Lee, C.Y. MEMS-based gas flow sensors. *Microfluid. Nanofluid.* **2009**, *6*, 333–346.

[3]. van Putten, A.F.P.; Middlehoek, S. Integrated silicon anemometer. *Electron. Lett.* **1974**, *10*, 425–426.

[4]. Nguyen, N.T. Micromachined flow sensors—A review. *Flow Meas. Instrum.* **1997**, *8*, 7–16.

[5]. Petersen, K.; Brown, J. High-Precision, High-performance mass-flow sensor with integrated laminar flow micro-channels. In *Proceedings of Technical Digest of the 3rd International Conference of Solid-State Sensors and Actuators (Transducers ’85)*, Philadelphia, PA, USA, 11–14 June 1985; pp. 361–363.

[6]. www.posifamicrosystems.com

THE FUNCTION ZW SERIES DISPLACEMENT SENSORS FOR ETHERCAT

Badaruddin Anwar
Student Bridging Course National Kaohsiung University of Applied Sciences
Makassar State University, Indonesia
Email: badaruddinanwar@yahoo.co.id

Keywords: Sensor, Ethercat, compact sensor heads

Abstract. The Excess ZW Series Displacement Sensors for EtherCAT with Compact Sensor Heads- Sysmac® Automation Platform™, Omron further expands the Sysmac lineup with the addition of new confocal fiber displacement sensors with EtherCAT interfaces to the ZW series released in February 2012. Connection with controllers and drive devices, such as servomotors, via ultra-high-speed open network EtherCAT enables flexible, high-speed machine control. The features of existing ZW series sensors that make them highly-suited to integration into devices have been retained including the following three important features; Ultra-compact and ultra-lightweight sensor head: 24 x 24 x 64 mm and only 105g, Sensor heads with low impact on operating environment: no noise or heat generation, Stable measurement from the same mounting position even for different materials. ZW series confocal fiber displacement sensors is controllers with EtherCAT and sensor heads (2 models with measuring distances of 7 mm and 30 mm). Ultra-compact sensor heads with measuring distances of 7 mm and 30 mm will also be released to enhance the sensor head lineup which currently features 20-mm and 40-mm models. With high-speed digital output through EtherCAT, it is possible to achieve a continuous output with a constant period as short as 500μs - eight times faster than Omron's previous models. This sensor head achieves separation for stable measurement of surface displacement of glass sheets as thin as 75μμm while boasting a compact size.

Indtroduction

The Sysmac automation platform 1 launch in July 2011, Omron further expands the Sysmac lineup with the addition of new confocal fiber displacement sensors with EtherCAT interfaces to the ZW series released in February 2012. Connection with controllers and drive devices, such as servomotors, via ultra-high-speed open network EtherCAT enables flexible, high-speed machine control. The Sysmac automation platform has reduced the need for wiring work and has enabled centralized management with one single EtherCAT network allowing connection of the NJ series machine automation controller with vision sensors, AC servomotors/drivers, inverters, and I/O terminals. The addition of the ZW series confocal fiber displacement sensors to the Sysmac automation platform makes machine construction more convenient than ever.

Theoretical Background

1. **The features of existing ZW series sensors that make them highly-suited to integration into devices have been retained including the following three important features:**
    - Ultra-compact and ultra-lightweight sensor head: 24 x 24 x 64 mm and only 105g
    - Sensor heads with low impact on operating environment: no noise or heat generation
    - Stable measurement from the same mounting position even for different materials
2. **The linking of height information and position coordinates helps to improve system productivity**

   EtherCAT can be used to connect to servo drives or encoder input slaves to quickly get the position coordinates and ZW displacement. The height information and XY position coordinates can be easily linked, which increases processing precision in machine control applications and facilitates maintenance in the inspection applications, such as helping to isolate errors or carrying out alignment-drift monitoring management.

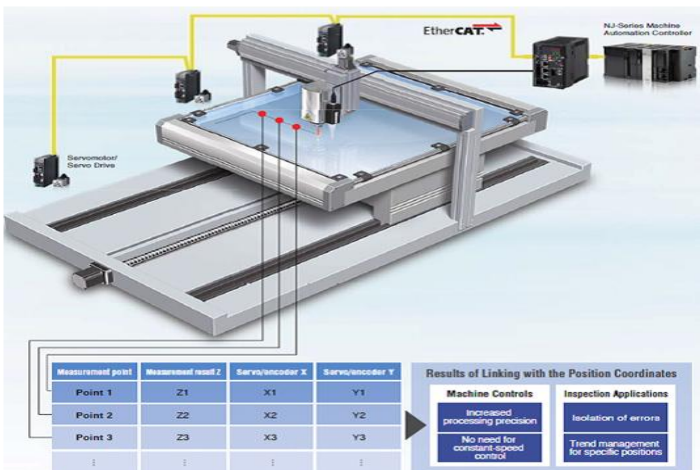


Fig 1. Information Coordinat Position

3. **Shorter machine take times with high-speed digital outputs.**

   Response times for measurement commands when using the kind of Ethernet or RS-232C generally used for digital (serial) outputs of displacement sensors are both inconsistent and slow, making them unsuitable for real-time control. With high-speed digital output through EtherCAT, it is possible to achieve a continuous output with a constant period as short as 500µs - eight times faster than Omron's previous models. Digital communications also provides great immunity to noise and this solves common problems with analog output methods, such as the inability to support long-distance transmissions and noise countermeasures.

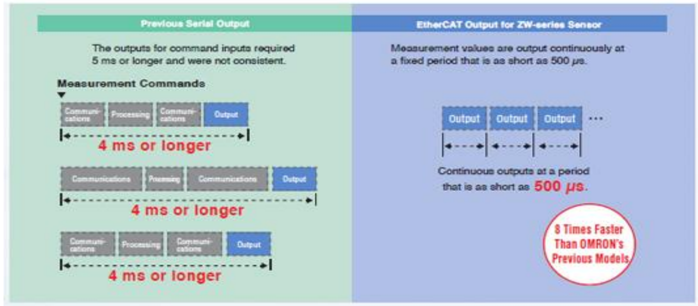


Fig 2. Output Measurement

4. **Improved measurement resolution for multipoint measurement applications** The high speed and concurrency provided by EtherCAT enable high-precision multipoint measurements with multiple sensors for displacement sensor applications. More than one sensor can perform synchronous measurements of the distance from the sensor to the target surface and the thickness of wide objects such as sheets of metal and glass by eliminating the previous time error in measurements between different sensors.

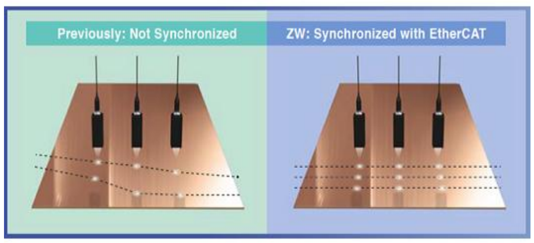


Fig 3. Measurement Resolution

5. **Tracing, adjustment, and simulation of machine movement.**
Sysmac Studio enables development, testing, and adjustment of devices connected via EtherCAT. The entire range of actions from sensing to motion control can be visually represented on screen and this reduces the man-hours required to set up systems and identify problems. There are also offline functions to debug signal control programming. It is also possible to simulate machine operation before actual installation onsite.

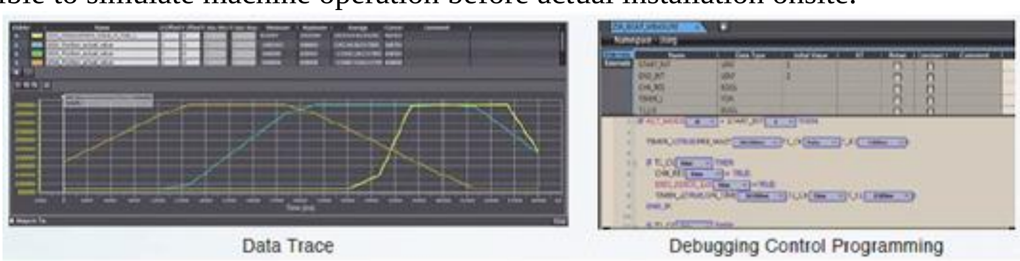


Fig 4. Tracing, adjustment, and simulation of machine movement

* As of November 2012, version 1.04 of Sysmac Studio does not have setting functions for the ZW-series Displacement Sensor and will be upgraded soon.

6. **Sensor head providing stable measurement of the thickness of thin sheets of glass** The newly-released sensor head with a measuring distance of 7 mm can stably measure the thickness of thin sheets of glass, a feat not easily achieved with conventional compact sensor

heads. To measure transparent glass, light waves received from the front and back surfaces of the glass must first be separated. This sensor head achieves separation for stable measurement of surface displacement of glass sheets as thin as 75µµm while boasting a compact size.

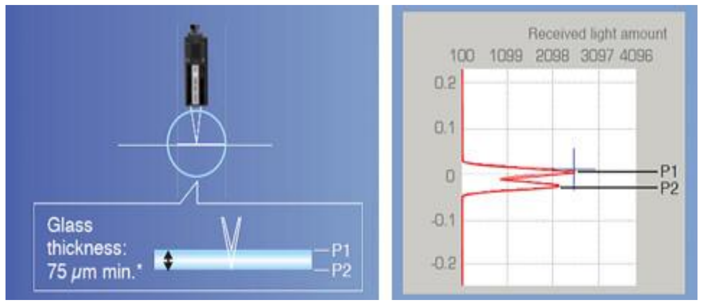


Fig 5. Sensor Head Providing Stable Measurement

ZW series confocal fiber displacement sensors is controllers with EtherCAT and sensor heads (2 models with measuring distances of 7 mm and 30 mm).

Tabel 1. Sensor Of Data

Sensor Controllers with EtherCAT				
	ZW-CE10T (New)		**ZW-CE15T (New)**	
Input/Output type	NPN		PNP	
External interface	EtherCAT, Ethernet , EtherNet/IPTM, RS-232C, Analog output, Parallel I/O			
Measurement cycle	500µs to 10ms			
Filtering	Median/average/differentiation/high pass/low pass/band pass			
Outputs	Scaling/various hold values/zero reset/logging for a measured value			
Number of configurable banks	Max. 8 banks			
Sensor Heads				
	ZW-S07 (New)	**ZW-S20**	**ZW-S30 (New)**	**ZW-S40**
Measuring range	7±0.3mm	20±1mm	30±3mm	40±6mm
Spot diameter	18 µm dia.	40 µm dia.	60 µm dia.	80 µm dia.
Static resolution	0.25µm	0.25µm	0.25µm	0.25µm
Linearity	±0.8µm	±1.2µm	±4.5µm	±7.0µm
External Dimensions	24mm x 24mm x 64mm			
Weight	Approx. 105 g			

Discussion

The newly-released sensor head with a measuring distance of 7 mm can stably measure the thickness of thin sheets of glass, a feat not easily achieved with conventional compact sensor heads, Sensor heads with low impact on operating environment: no noise or heat generation, Stable measurement from the same mounting position even for different materials.

Conclusion

ZW series confocal fiber displacement sensors is controllers with EtherCAT and sensor heads (2 models with measuring distances of 7 mm and 30 mm). Ultra-compact sensor heads with measuring distances of 7 mm and 30 mm will also be released to enhance the sensor head lineup which currently features 20-mm and 40-mm models. With high-speed digital output through EtherCAT, it is possible to achieve a continuous output with a constant period as short as 500μs - eight times faster than Omron's previous models. This sensor head achieves separation for stable measurement of surface displacement of glass sheets as thin as 75μμm while boasting a compact size.

Reference

1. http://www.omron.com/ retrieved January 13th, 2013.
2. http://www.newequipment.com/Main/Products.aspx?search=%E2%80%A2Sysmac%C2%AE%20is%20a%20trademark%20or%20registered%20trademark%20of%20OMRON%20Corporation%20in%20Japan%20and%20other%20countries%20for%20OMRON%20factory%20automation%20products. retrieved March 4th, 2013
3. http://www.omron.com/ retrieved January 12th, 2013. Headquartered in Kyoto, Japan, OMRON Corporation is a global leader in the field of automation. Established in 1933

INFRARED THERMOCOPILE SENSOR MICRO ELECTRICAL MECHANICAL SYSTEMS TMP006 AS CONTACTLESS TEMPERATURE MEASUREMENT: A LITERATURE REVIEW

M Denny Surindra
Student Bridging Course National Kaohsiung University of Applied Sciences
State Polytechnic of Semarang
Email: dennysurindra@yahoo.com.sg

Keywords: infrared, thermopile, sensor, contactless.

Abstract: This paper is aimed to inform the specification infrared thermopile sensor TMP006 as device of measurement temperature base on literature review. The model TMP006 is produced by Texas Instrument. It has advantage as measure of temperature such as non-contact temperature sensor. This model temperature measurement can be applied in many fields, such as laptops and servers to smarter home thermostats and industrial controls Monitoring, and Researches & Development.

Introduction

Add another MEMS sensor to the toolkit. Texas Instruments says it's seeing interest from a wide range of potential users in its non-contact temperature sensor, for applications ranging from better performing laptops and servers to smarter home thermostats and industrial controls. Omron has also recently introduced an IR thermopile sensor, targeted at occupancy sensing and automation control.

Seeking a product where its MEMS technology could add a disruptive advantage, TI's R&D lab came up with a CMOS-based MEMS thermopile infrared sensor that can be integrated on a single chip with the CMOS signal conditioning. Cost and size are also reduced by using very minimal wafer level chip-scale packaging, taking advantage of silicon's transparency to IR to essentially use the wafer itself as the cover window. The die with the control circuitry and the thermopile structure released over a cavity is flipped over, and the unprocessed wafer remaining below the cavity then becomes the cover window. The change in temperature of the thermopile to the IR in its field of view is converted to a change in voltage.

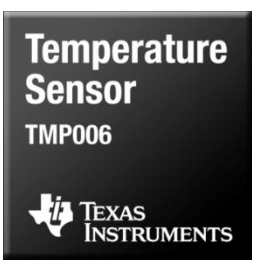
Such IR thermal sensors, which allow temperature measurement at a distance without the need for the usual direct contact with the measured surface, have typically been multichip units packaged in metal cans or relatively large surface mount packages and costing several dollars to several tens of dollars each, limiting them to industrial and automotive uses. TI's single chip solution reduces the size to 1.6mm x1.6mm, and the cost to $1.50 in 1000-unit volumes. TI says the devices also uses 90% less power than the competition. It claims +/-1°C accuracy, with a range of -40°C to +125°C.

Omron meanwhile targets first applications of its recently introduced MEMS IR thermopile sensor at occupancy sensing, as the temperature of an area can indicate more reliably if someone is in the room than motion sensors can, to switch off lights and air conditioning to save energy. The company also sees possible uses in factory automation from sensing unusual changes in temperature. Its multi die unit remains packaged in a metal can.

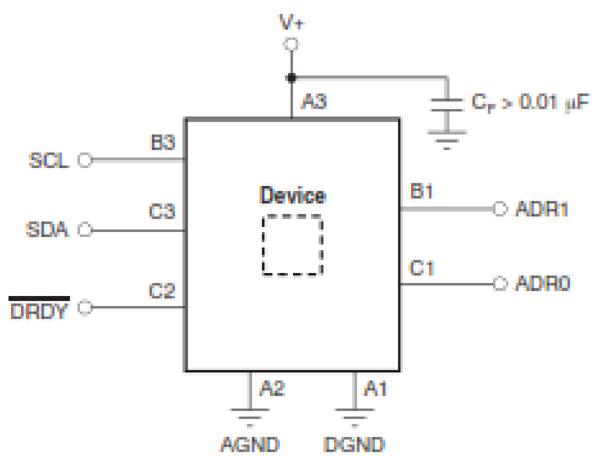
Description of model TMP006

The TMP006 is a digital temperature sensor that is optimal for thermal management and thermal protection applications where remote non-contact sensing is desired. The TMP006 is two-wire and SMBus interface compatible, and is specified over the ambient temperature range of –40°C to +125°C. The TMP006 measures object temperatures over a temperature range of –40°C to +125°C. The TMP006 contains registers for holding configuration information, temperature measurement results, and sensor voltage measurement. Ambient temperature and sensor voltage measurements are used to calculate the object temperature.

The SCL and SDA interface pins require pull-up resistors (10 kΩ, typical) as part of the communication bus, while DRDY is an open-drain output that must also use a pull-up resistor. DRDY may be shared with other devices if desired for a wired-OR implementation. A 0.01-µF power-supply bypass capacitor is recommended, as shown in Figure 4.



(a)



(b)

Fig 1: Model TMP006 and Connection

The TMP006 provides both local temperature and thermopile sensor voltage outputs in a WCSP. The local temperature sensor in the TMP006 is integrated on-chip; the thermal path runs through the WCSP solder balls. The low thermal resistance of the solder balls provides the thermal path to maintain the chip at the temperature of the local environment. The top side of the WCSP must face the object that is being measured with an unobstructed view in order to accurately measure the temperature.

Table 1. Performance Indicator of TMP006
At TA = +25°C, V+ = 3.3 V, and conversion time = 1 sec, unless otherwise specified.

PARAMETER	TEST CONDITIONS	TMP006 MIN	TMP006 TYP	TMP006 MAX	UNIT
OUTPUT ERROR					
Ambient temperature sensor	T_A = 0°C to +60°C, V+ = 2.2 V to 5.5 V		±0.5	±1	°C
	T_A = −40°C to +125°C, V+ = 2.2 V to 5.5 V		±0.5	±1.5	°C
Power-supply rejection ratio PSRR			0.1		°C/V
Sensor voltage	T_{Object} = +40°C to +60°C, T_A = 0°C to +60°C		7		μV/°C
Calculate object temperature[1]	T_A = +20°C to +60°C, $T_{Object} - T_A$ = −10°C to +30°C		±1	±3	°C
Field of view	50% responsivity		90		Degrees
TEMPERATURE MEASUREMENT					
Conversion time	CR2 = 0, CR1 = 0, CR0 = 0		0.25		Seconds
	CR2 = 0, CR1 = 0, CR0 = 1		0.5		Seconds
	CR2 = 0, CR1 = 1, CR0 = 0		1		Seconds
	CR2 = 0, CR1 = 1, CR0 = 1		2		Seconds
	CR2 = 1, CR1 = 0, CR0 = 0		4		Seconds
Resolution					
Local temperature sensor			0.03125		°C
Thermopile sensor resolution			156.25		nV
SMBus COMPATIBLE INTERFACE					
Logic input high voltage (SCL, SDA) V_{IH}		2.1			V
Logic input low voltage (SCL, SDA) V_{IL}				0.8	V
Hysteresis			100		mV
Output low voltage (SDA) V_{OL}	I_{OUT} = 6 mA		0.15	0.4	V
Output low sink current (SDA)		6			mA
Logic input current	Forced to 0.4 V	−1		+1	µA
Input capacitance (SCL, SDA, A0, A1)			3		pF
Clock frequency		0.001		3.4	MHz
Interface timeout		25	30	35	ms
DIGITAL OUTPUTS					
Output low voltage ($\overline{DRDY}$ pin) V_{OL}	I_{OUT} = 4 mA		0.15	0.4	V
High-level output leakage current I_{OH}	$V_{OUT} = V_{DD}$		0.1	1	µA
Output low sink current ($\overline{DRDY}$)	Forced to 0.4 V	4			mA
POWER SUPPLY					
Power-on reset V+	T = −40°C to +125°C		1.6		V
Specified voltage range V+	T = −40°C to +125°C	2.2		5.5	V
Quiescent current I_Q	Continuous conversion; see Table 9		240	325	µA
	Serial bus inactive, shutdown mode		0.5	1.0	µA
	Serial bus active, f_S = 400 kHz, shutdown mode		90		µA
TEMPERATURE RANGE					
Specified range		−40		+125	°C
Storage range		−65		+150	°C

Discussion

The quiescent current is just 240 µA with a shutdown current of a typical 0.5 µA – with the serial bus inactive – and 90 µA in shutdown with the serial bus active. This is a passive sensor in that no infrared source is generated by the part and the typical accuracy of the temperature measurement is ±1ºC (the local temperature reference sensor offers a ±0.5ºC accuracy and the thermal path runs through the solder balls of the package). Communications are with a pin-programmable I2C/SMBus typically operated at 400 kHz. The supply voltage can be as low as 2.2 V for correct operation (7 V maximum).

The sensor offers an output voltage range specified from -40ºC (maximum range down to -55ºC) to +125ºC and gives a 7 µV/ºC output over a range such as +40ºC to +60ºC. The sensor resolution is 156.25 nV. The field of view of the sensor (built-in to the package window on the top) is ±45º to a 50% responsivity. Temperature measurements are held in registers together with configuration information and sensor voltage measurements.

Conclusions

Base on description and performance indicator of the model TMP006 accelerometer can be concluded as follows :

1. The TMP006 is the most highly-integrated device of its kind. It integrates an on-chip MEMS thermopile sensor, signal conditioning, a 16-bit analog-to-digital-converter (ADC), local temperature sensor and voltage references on a single 1.6-mm x 1.6-mm chip.
2. It uses 240-µA quiescent current and 1 µA in shutdown mode and supports a temperature range of −40 to +125°C with a typical accuracy of ±0.5°C on the local sensor and ±1°C for the passive IR sensor.
3. It can be applied in; hand phone, mobile device, monitoring, research & development.

References :

1. MEMS Trens, “Texas Instrument: non-contact temperature sensors come down in size and cost”, Issue no 11, page 13, Texas, July 2012.
2. Texas Instrument, “Infrared Thermopile Sensor in Chip-Scale Package”, Texas, January 2012.
3. http://www.ti.com/ww/en/analog/tmp006.
4. Texas Instrument, “Mechanical Data”, Texas, January 2012.

THE ADVANTAGES OF MODEL 4807A HIGH RESOLUTION ACCELEROMETER

Fatahul Arifin
Student Bridging Course National Kaohsiung University of Applied Sciences
Mechanical Engineering, State of Polytechnic Sriwjaya
Email: farifinus@yahoo.com, farifinus@polsri.ac.id

Keywords: Accelerometer, Ultra low noise, hermetically.

Abstract. This paper is aimed to inform the advantages of model 4807A accelerometer as device of measurement base on literature review. The model 4807A accelerometer is produced by Measurement Specialties, Inc. It has many advantages such as hermetically sealed and offers an amplified signal output covering ranges from ± 2 g to ± 200 g, and built-in mechanical overload stops for shock protection to 5,000 g. This model accelerometer can be applied in many fields, such as Vibration Isolation, Flight Testing, Trajectory Profiling, Structural Monitoring, and Researches & Development.

Introduction

An accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static, like the constant force of gravity pulling at your feet, or they could be dynamic - caused by moving or vibrating the accelerometer. An accelerometer also is a device that measures proper acceleration. The proper acceleration measured by an accelerometer is not necessarily the coordinate acceleration (rate of change of velocity). For example, an accelerometer at rest of the surface of the earth will measure an acceleration $g= 9.81\ m/s^2$ straight upwards, due to its weight. By contrast, accelerometers in free fall or at rest in outer space will measure zero. Another term for the type of acceleration that accelerometers can measure is g-force acceleration.

Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. Accelerometers are used to detect and monitor vibration in rotating machinery.

This paper is aimed to inform the advantages of model 4807A accelerometer as device of measurement. In addition this model of accelerometer has a patent pending Auto-Zero function allows the user to minimize zero offset at the output according the manual.

Theoretical Background

By measuring the amount of static acceleration due to gravity, you can find out the angle the device is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, you can analyze the way the device is moving. At first, measuring tilt and acceleration doesn't seem all that exciting. However, engineers have come up with many ways to make really useful products with them.

An accelerometer can help your project understand its surroundings better. Is it driving uphill? Is it going to fall over when it takes another step? Is it flying horizontally or is it dive bombing your professor? A good programmer can write code to answer all of these questions using the data provided by an accelerometer. An accelerometer can help analyze problems in a car engine using vibration testing, or you could even use one to make a musical instrument.

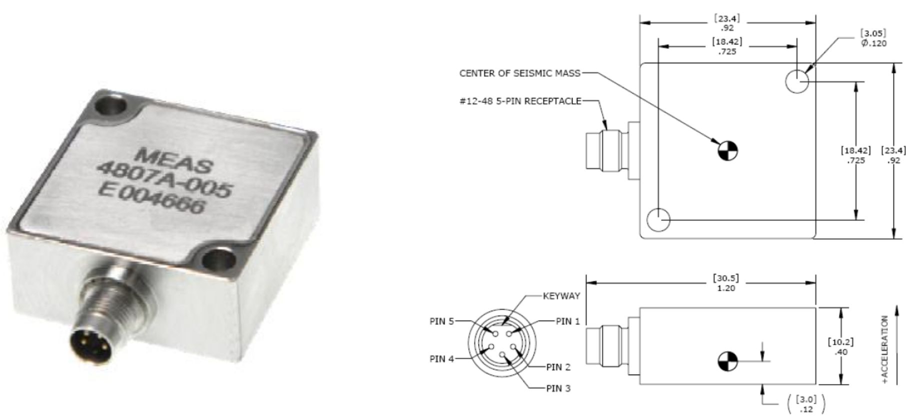
In the computing world, IBM and Apple have recently started using accelerometers in their laptops to protect hard drives from damage. If you accidentally drop the laptop, the accelerometer detects the sudden freefall, and switches the hard drive off so the heads don't crash on the platters. In a similar fashion, high g accelerometers are the industry standard way of detecting car crashes and deploying airbags at just the right time.

There are many different ways to make an accelerometer. Some accelerometers use the piezoelectric effect; they contain microscopic crystal structures that get stressed by accelerative forces, which cause a voltage to be generated. Another way to do it is by sensing changes in capacitance. If you have two microstructures next to each other, they have a certain capacitance between them. If an accelerative force moves one of the structures, then the capacitance will change. Add some circuitry to convert from capacitance to voltage, and you will get an accelerometer. There are even more methods, including use of the piezoresistive effect, hot air bubbles, and light.

The measurement specialist offers the model 4807A accelerometer that has many advantages compare another.

Description of model 4807A Accelerometer

The Model 4807A is an ultra low noise DC response accelerometer offering micro-g resolution – an order of magnitude better than the competition. The accelerometer is hermetically sealed and offers an amplified signal output covering ranges from ±2 to ±200g. The model 4807A incorporates gas damped silicon MEMS sensing elements with wide bandwidth from DC up to 1500Hz, and built-in mechanical overload stops for shock protection to 5,000g. A patent pending Auto-Zero function allows the user to minimize zero offset at the output.



(a) (b)

Fig 1: Model 4807A Accelerometer and Dimension

This model have features ; 98db dynamic range, ±2g to ±200g measurement range, 8-18vdc excitation voltage, hermetically sealed, gas damped mems element, detachable cable, remote auto-zero function.

It can be applied in; vibration isolation, flight testing, trajectory profiling, structural monitoring, research & development.

Performance Indicator

All values are typical at +24°C, 100Hz and 12Vdc excitation unless otherwise stated. Measurement Specialties reserves the right to update and change these specifications without notice. Standard product parameters are described in PSC-1004 for Plug & Play DC Accelerometers.

Table 1. Performance Indicator of Model 4807A Accelerometer

Parameters								Notes
DYNAMIC								
Range (g)	±2	±5	±10	±20	±50	±100	±200	
Sensitivity (mV/g)	1000	400	200	100	40	20	10	±2%
Frequency Response (Hz)	0-200	0-300	0-350	0-600	0-800	0-1300	0-1500	±5%
Natural Frequency (Hz)	700	800	1000	1500	4000	6000	8000	
Non-Linearity (%FSO)	±1.0	±1.0	±1.0	±1.0	±1.0	±1.0	±1.0	
Transverse Sensitivity (%)	<3	<3	<3	<3	<3	<3	<3	<1 Typical
Damping Ratio	0.7	0.7	0.7	0.7	0.6	0.5	0.4	
Shock Limit (g)	5000	5000	5000	5000	5000	5000	5000	
Residual Noise (µV RMS)	25	20	23	31	26	32	32	Passband
Residual Noise (µg/√Hz RMS)	2	3	6	12	21	41	82	Spectral
ELECTRICAL								
Zero Acceleration Output (mV)	±25 (±1.5 after auto-zero actuation)							Differential
Excitation Voltage (Vdc)	8 to 18							
Excitation Current (mA)	15							
Bias Voltage (Vdc)	2.5							
Full Scale Output Voltage (Vpk)	±2							
Output Impedance (Ω)	<100							
Insulation Resistance (MΩ)	>100							@50Vdc
Turn On Time (sec)	<2							
Ground Isolation	Isolated from Mounting Surface							
ENVIRONMENTAL								
Thermal Zero Shift (%FSO/°C)	±0.010							Typical
Thermal Sensitivity Shift (%/°C)	±0.014							Typical
Operating Temperature (°C)	-54 to 121							
Compensated Temperature (°C)	-40 to 121							
Humidity	Hermetically Sealed, IP67							
PHYSICAL								
Case Material	Stainless Steel							
Weight (grams)	20							
Mounting	2x #4 or M3 Screws							
Mounting Torque	6 lb-in (0.7 N-m)							

Discussion

It can be seen this device has range $\pm$2g to $\pm$200g, sensitivity 1000mV/g to 10 mV/g, Non-linearity $\pm$ 0.1 %, Transverse Sensitivity <3 %, Dumping ratio 0.4 to 0.7, shock limit 5000 g. All of these performances are for dynamic parameters. It can also stand on humidity environmental cause hermetically sealed. Physically is made from stainless steel and has weight only 20 gram.

Conclusions

Base on description and performance indicator of the model 4807A accelerometer can be concluded as follows :

1. The Model 4807A is an ultra low noise DC response accelerometer offering micro-g resolution – an order of magnitude better than the competition.
2. This device has range ±2g to ±200g, sensitivity 1000mV/g to 10 mV/g, Non-linearity ± 0.1%, Transverse Sensitivity <3 %, Dumping ratio 0.4 to 0.7, shock limit 5000 g. All of these performances are for dynamic parameters.
3. It can be applied in; vibration isolation, flight testing, trajectory profiling, structural monitoring, research & development.

References :

1. http://www.meas-spec.com/searchresults.aspx?search=Model%204807A retrieved January 13th, 2013
2. http://en.wikipedia.org/wiki/Accelerometer retrieved January 13th, 2013
3. http://www.dimensionengineering.com/info/accelerometers retrieved January 13th, 2013
4. Measurement Specialties unveils the Model 4807A high resolution accelerometer, Micronews, The disruptive semiconductor technologies magazine, issue no. 129, May 10, 2012, Page 8.

GLOBAL TREND PICO PROJECTOR ON MOBILE DEVICES

Himawan Hadi S.
Student Bridging Course National Kaohsiung University of Applied Sciences
State University of Jakarta
Email: himawansutrisno@yahoo.com

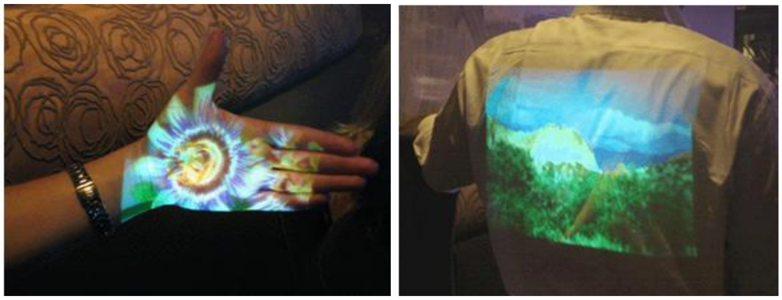
Keywords: Light source, Color management, Imagers, Lens, Screen

Abstract: Pico projector, also known as handheld projector, is an emerging technology that brings the image projector to a handheld size device. These Pico projectors provide a convenient way to quickly project the content of your portable devices onto any surface such as walls, notebooks, or airplane food trays. The advantages of Pico projector are: 1. Mobility with so small a size; 2. Convenience, able to project a clear image, regardless of the physical characteristics of the viewing surface. Mobile phone out in multiple world markets is a major start. More phones with the projectors are expected in the next six months, and major retailers will stock multiple phone-accessory projectors

Introduction

Pico projector is a handheld projector (also known as a pocket projector, mobile projector, pico projector or mini beamer) is an emerging technology that applies the use produced projected image in small device. This device can be intregated with mobile phone, dslr camera, which have sufficient storage capacity to handle presentation materials Handheld projectors involve miniaturized hardware and software that can project digital images onto any nearby viewing surface, such as many projector

The system comprises five main parts: the battery; the electronics; light sources; the combiner optic; and the scanning mirrors. First, the electronics system turns the image into an electronic signal. Next, the electronic signals drive laser light sources with different colors and intensities down different paths. In the combiner optic, the different light paths are combined into one path, defining a palette of colors. Finally, the mirrors copy the image pixel-by-pixel and can then project the image. This entire system is compacted into one very tiny chip. An important design characteristic of a handheld projector is the ability to project a clear image, regardless of the physical characteristics of the viewing surface



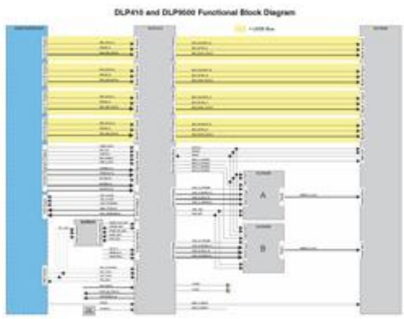
Pico projector makes it incredibly easy to share favorite moments, from photos and videos, to movies and YouTube while on the go. No cables needed, simply pop-up the built-in connector on the ipico™, slide your device into it, focus on virtually any surface, and instantly project your world to the world. Gone are the days of friends and family crowding around a small screen, the ipico™ was made to let you share your memories virtually anywhere and up to 50-inches in an optimal dimly lit room.

General Imaging (GIC) August 8, 2012 introduced pico projector as called ipico, a sleek hand-held, projector with a patented pop-up connector that turns your iPhone or iPod touch into a genuine social media tool. Made for iPhone and iPod touch, ipico makes it incredibly easy to share favorite moments Portable enough to take anywhere, ipico™ weighs only 3.35 ounces and is about two-thirds the width of an iPhone. At just over half an inch thick, the ipico's™ pop-up connector slides neatly down into the dock when not in use and easily fits inside a pocket or bag. When projecting, it conveniently holds your iPhone or iPod touch in place and in most cases does not require removing the protective case from device

Texas Instrument also build tool and advance this product wich called DLP. It contains a rectangular array of up to 2 million hinge-mounted microscopic mirrors; each of these micromirrors measures less than one-fifth the width of a human hair. More than 18 million devices have been sold worldwide into imaging applications such as HDTVs and video projectors. When integrated with a light source, optics and electronics the mirrors on the DLP® chip can reflect a binary data pattern or video image with speed, precision and efficiency far surpassing that of other spatial light modulators. A DLP chip's micromirrors are mounted on tiny hinges that enable them to tilt either toward the light source in a DLP projection system (ON) or away from it (OFF) - creating a light or dark pixel on a projection surface. The bit-streamed binary data entering the semiconductor directs each mirror to switch on and off up to several thousand times per second. When a mirror is switched on more frequently than off, it reflects a light gray pixel; a mirror that's switched off more frequently reflects a darker gray pixel.

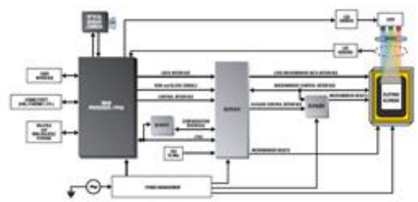
Block Diagram for DLP microcontroler

0.95 1080p Block Diagram



Enlarge

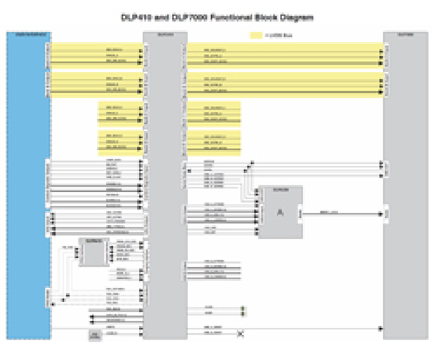
Chipset Diagram



Enlarge

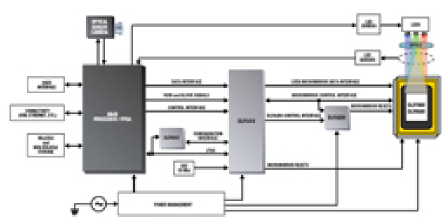
System Diagram

0.7 XGA Block Diagram



Enlarge

Chipset Diagram



Enlarge

System Diagram

DLP Chipsets consist of these optimized components to provide users fast, independent micromirror control. Utilizing the DLP Chipset components together is recommended for reliable operation. DLP Chipsets provide and easy way for integrating DLP Technology into light processing applications and help expedite product developmen

General Spesification:

General Imaging ipico Projector Specifications

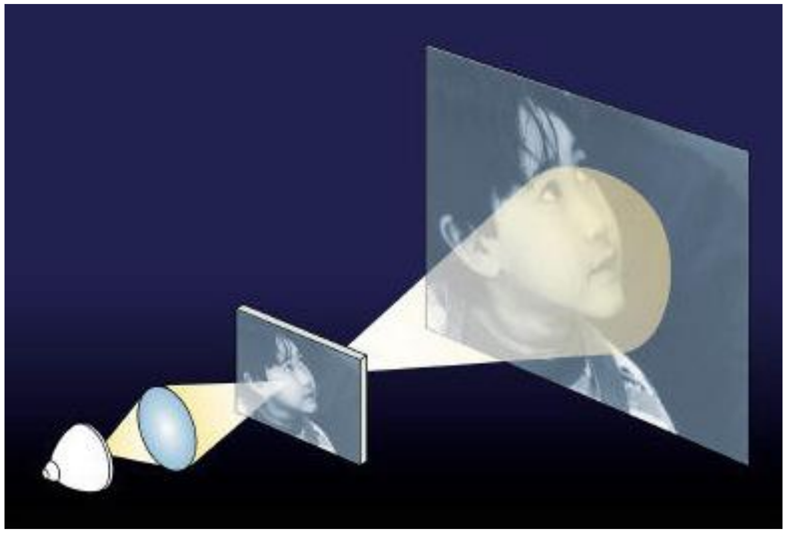
(show english units)

Press Release

MSRP (USD) **:**	$130	**Compatibility:**	
Brightness (Lumens) **:**	**	*HDTV:*	No
Color Light Output (Lumens) **:**	**	*EDTV/480p:*	No
Contrast (Full On/Off) **:**	100:1	*SDTV/480i:*	No
Variable Iris:	No	*Component Video:*	No
Audible Noise:	**	*Video:*	**
Weight:	0.1 kg	*Digital Input:*	No
Size (cm) (HxWxD) **:**	**	*Computers:*	**
Std. Lens: *Focus:*	Manual	**Display:** *Type:*	LCoS (1)
Zoom:	No	*Native:*	960x540 Pixels
Throw Dist (m) **:**	**	*Maximum:*	**
Image Size (cm) **:**	**	*Aspect Ratio:*	16:9 (WVGA)
Optional Lenses:	No	**Light Source:** *Type:*	LED
Digital Zoom:	**	*Life:*	**
Digital Keystone:	**	*Quantity:*	1
Lens Shift:	No	**Speakers:**	n/a
Warranty:	**	**Max Power:**	**
Performance:		**Voltage:**	**
H-Sync Range:	**	**FCC Class:**	**
V-Sync Range:	**	**Special:**	USB Port
		Status:	Shipping
		First Ship:	Nov 2012

The new and improved development features for pico projector:

- direct connection to a PC via an HMDI connector or HDMI-to-DVI adapter
- selectable, high speed DMD pattern timing up to 2400Hz
- sync signal output to connect to a sensor such as a camera The projection device maintains the same small form factor and contains a light engine with three solid-state color LEDs as a low power light source. The kit also includes a power supply, video cable that supports a DVI-D signal and HDMI-to-DVI adapter.



Refernce:

1. http://www.3lcd.com/explore/?rev key=&sid=&gd=&ct=633897015195606420&frm =/Default&lnkid=2
2. http://www.wikipedia.org/wiki/Handheld_projector
3. http://www.ti.com/analog/docs/memsmidmodlevel.tsp?sectionId=651&tabId=2447

LPS331AP PRESSURE SENSOR WITH EMBEDDED COMPENSATION

Imam Mahir
Student Bridging Course National Kaohsiung University of Applied Sciences
State University of Jakarta, Indonesia
Email: imammamahir@yahoo.com

Keywords: Pressure sensor, embedded compensation, quadratic compensation

Abstract: This paper is aimed to describe LPS331AP pressure sensor in terms of features, characteristics, applications, and enhanced the accuracy compensation after quadratic compensation. The LPS331AP pressure sensor is today the only type of pressure sensor among various sensors that manufactured by STMicroelectronics. The new LPS331AP is a tiny silicon pressure sensor that provides high-resolution measurements of pressure in an ultra-compact package ideal for use in many applications such as smartphones, tablet PCs, handheld GPS and other wheater station devices. The LPS331AP pressure sensor is also built SW algorithms and defined an final calibration procedure to improve quadratic compensation for the accuracy.

Introduction

Typically a pressure sensor measures pressure of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer which generates a signal as a function of the pressure imposed.

Pressure sensors are used for control and monitoring in thousands of daily applications. Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude. Pressure sensors can alternatively be called pressure transducers, pressure transmitters, pressure senders, pressure indicators and piezometers, manometers, among other names.

Today is not difficult to know the altitude of any places with our portable devices be able to pinpoint the height relative to sea level to better than one meter, using this most recent MEMS (micro-electromechanical systems) LPS331AP pressure sensors from STMicroelectronics. The LPS331AP is an ultra compact absolute piezoresistive pressure sensor. It includes a monolithic sensing element and an IC interface able to take the information from the sensing element and to provide a digital signal to the external world.

Theoretical Background

The LPS331AP is a high resolution sensor which has digital output pressure sensor packaged in an HCLGA holed package. The complete device includes a sensing element based on a piezerosistive Wheatstone bridge approach, and an IC interface able to take the information from the sensing element to the external world as a digital signal.

The sensing element consists of a suspended membrane realized inside a single mono-silicon µ-sized membrane, without requiring substrate to substrate bonding. When pressure is applied, the membrane deflection induces an imbalance in the Wheatstone bridge piezeroresistances, whose the output signal is converted by the IC interface. It is capable to detecting pressure and is manufactured using a dedicated process developed by ST, called VENSENS. The VENSENS process allows to build a mono-silicon membrane above an air cavity with controlled gap and defined pressure. The membrane is very small compared to the traditionally built silicon micromachined membranes. Membrane breakage is prevented by an intrinsic mechanical stopper.

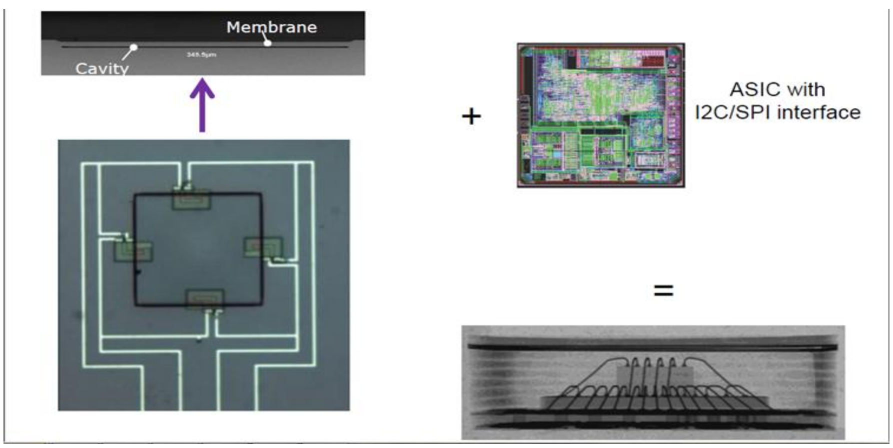


Figure 1: Visualized LPS331AP

The IC interface is manufactured using a standard CMOS process that allows a high level of integration to design a dedicated circuit which is trimmed to better match the sensing element characteristics. The LPS331AP is available in a small holed cap land grid array (HCLGA) package and it is guaranteed to operate over a temperature range extending from -40 °C to +85 °C. The package is holed to allow external pressure to reach the sensing element.

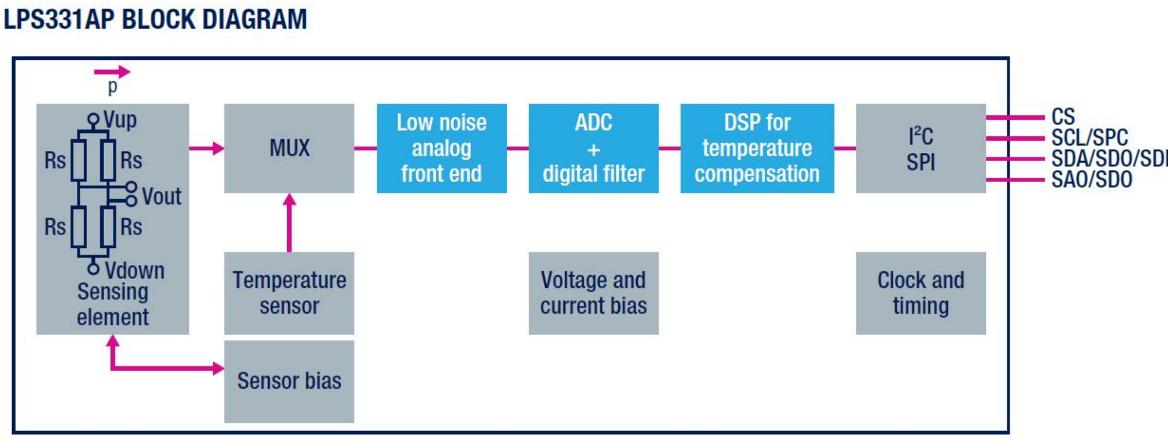


Diagram 1: LPS331AP Pressure Sensor Block Diagram

LPS331AP Pressure Sensors are supported by an evaluation kit that consists of a motherboard (STEVAL-MKI109V2) and a plug-in module (STEVAL-MKI120V1). One the adapter is plug in, the board can be connected to a host PC via USB so the device's capabilities can be easily evaluated via an intuitive graphic user interface. The STEVAL-MKI109V2 is a motherboard designed to provide users with a complete ready-to-use platform. The board features a DIL24 socket to mount all available adapters for both digital and analog output MEMS devices. The motherboard includes a high performance 32 bit microcontroller , which function as a bridge between the sensor and a PC. The STEVAL-MKI120V1 adapter board is designed to facilitate the demonstration of the LPS331AP product.

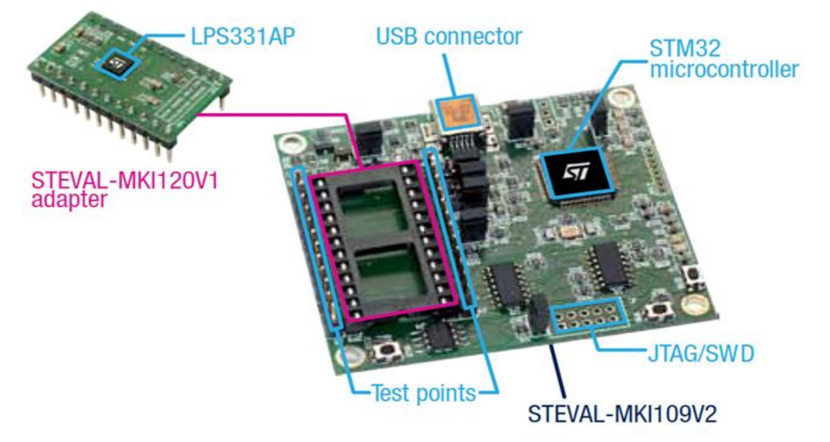


Figure 2: Evaluation Kit

The Features, Characteristics and Applications of LPS331AP Pressure Sensor

LPS331AP has mechanical data such as dimension 3x3x1 mm, pressure range 260-1260 mbar, and high overpressure capability more than 20 bar (20x full scale). This sensor also has ADC resolution 24 bits and power consumption 45 µA (high res.) with selectable ODR from 1 Hz to 25 Hz. This is also developed SW algorithms and IIR filtering to reduce the noise that pressure noise achieved at 0.020 mbar (RMS). Moreover, it is low power consumption which consume low resolution mode at 5.5 µA and high resolution mode at 30 µA. Supply voltage of the sensor can be arranged from 1.71 to 3.6 V and high shock survivability 10,000 g.

In terms of accuracy relative accuracy pressure (0÷65°C) has linear ± 2 mbar (embedded) and quadratic: ± 1 mbar (external sw). It has also performed at maximum data rate/ODR high resolution mode; selectable 1 Hz, 7 Hz, 12.5 Hz and One shot (max conversion time) = 45 msec. The two digital features are performed compensation and offset management. The compensations are linear embedded and quadratic external SW. And the offset management are autozero and one point calibration dedicated register which the value stored in the register is add/subtracted to the pressure ouput. One point calibration is a procedure to remove the soldering shift to be implemented at the end of the customers production line.

There are many applications of LPS331AP pressure sensors such as: pressure sensing, altitude sensing, and indoor navigation. Pressure sensing is where the measurement of pressure expressed as a force per unit area. This is useful in weather instrumentation, aircraft, automobiles, and any other machinery that has pressure functionality implemented. Altitude sensing is useful in many applications make use of the relationship between changes in pressure relative to the altitude. This relationship is governed by the equation $h = (1 - (P/P_{\text{ref}})^{0.190284}) \times 145366.45\text{ft}$. This equation is calibrated for an altimeter, up to 36,090 feet (11,000 m). Indoor navigation devices is usually relying on GPS to identify your general location (at the mall, at the airport), needs some other technology to get you around. LPS331AP pressure sensors is provided altitude gyroscopes that determine the position if the user is turning and in which certain direction and accelerometers that count steps.

Embedded Compensation of LPS331AP Pressure Sensor

The LPS331AP devices are trimmed at final test with a typical absolute accuracy of +/- 2mb no external S/W pressure temperature compensation over the temperature range 0^0C – 65^0C after quadratic compensation. The LPS331AP devices may have higher absolute accuracy by implementing an extra S/W pressure temperature compensation algorithm, which is called quadratic pressure compensation in temperature.

A linear pressure temperature compensation is implemented in the ASIC, using 3 embedded sensor calibration point information. A second order of accuracy can be achieved (less pressure variation when temperature changes) by implementing a quadratic compensation (second order polynomial approximation) on top of the piecewise linear (PWL) one, by S/W, using the same calibration data built-in the sensor registers.

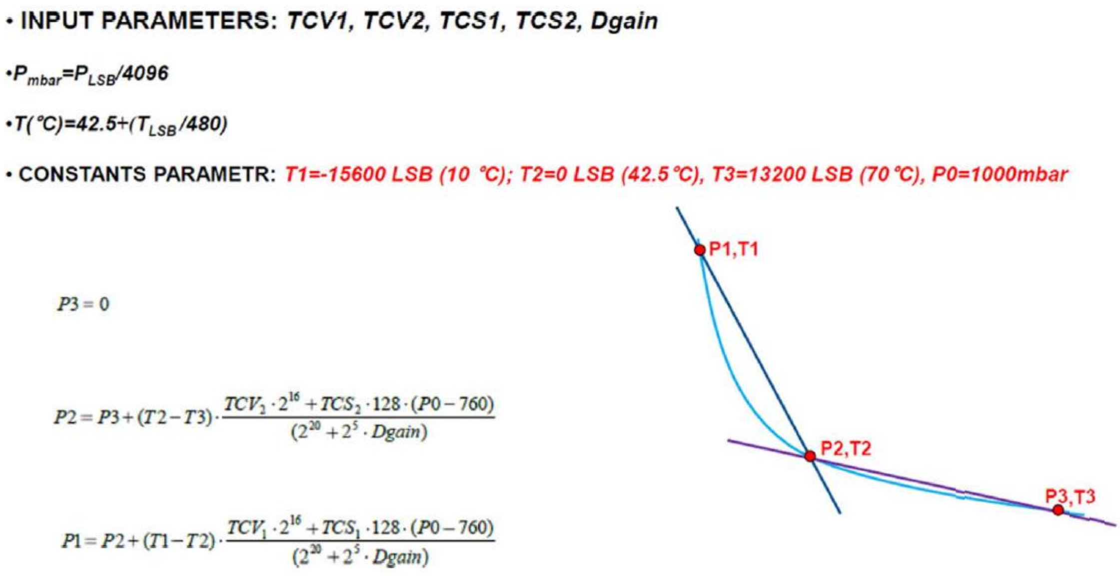


Figure 3: Overview first to second order compensation

There are some equation to determine the quadratic compensation as follows:

- Pressure calibration point calculation

$$P2 = P3 + (T2 - T3).\frac{TCV_2.2^{16} \ + TCS_2\,.128\,(P0 - 760)}{(2^{20} + \ 2^5\,Dgain)}$$

$$P1 = P2 + (T1 - T2).\frac{TCV_1.2^{16} \ + TCS_1\,.128\,(P0 - 760)}{(2^{20} + \ 2^5\,Dgain)}$$

- Linear system resolution for Quadratic law determination

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix} = \begin{bmatrix} T1^2 & T1 & 1 \\ T2^2 & T2 & 1 \\ T3^2 & T3 & 1 \end{bmatrix}^{-1} \begin{bmatrix} P1 \\ P2 \\ P3 \end{bmatrix}$$ coeficient Parabola Equation: $y=a*T^2+b*T+c$

- Linear system resolution for pwl compensation

$$\begin{bmatrix} e_1 \\ d_1 \end{bmatrix} = \begin{bmatrix} T1 & 1 \\ T1 & 1 \end{bmatrix}^{-1} \begin{bmatrix} P1 \\ P2 \end{bmatrix} \qquad \begin{bmatrix} e_2 \\ d_2 \end{bmatrix} = \begin{bmatrix} T2 & 1 \\ T3 & 1 \end{bmatrix}^{-1} \begin{bmatrix} P2 \\ P3 \end{bmatrix}$$

Coefficient straight line equation: y1=e1*T+d1; y2=e2*T+d2
Since d1=d2=c, the linear system resolution became:

$$e_1 = \frac{P1-c}{T1} \qquad e_2 = \frac{P3-c}{T3}$$

- Output pressure correction

$$Pcomp_{LSB} = \begin{cases} Pout_{LSB} + a.Tout_{LSB}{}^2 + (b-e1).Tout_{LSB} & Tout_{LSB} < 0 \\ Pout_{LSB} + a.Tout_{LSB}{}^2 + (b-e2).Tout_{LSB} & Tout_{LSB} > 0 \end{cases}$$

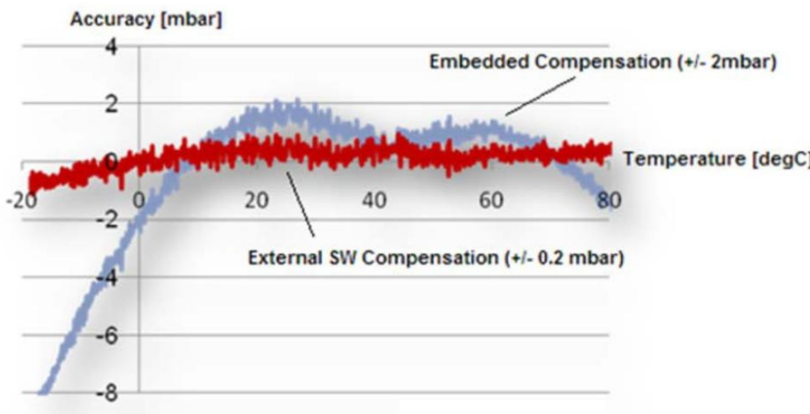


Figure 4: Comparison first to second order compensation at fixed pressure

From the Figure 4 can be seen that implementing quadratic compensation second order can achieved temperature accuracy performance of pressure sensor which is less pressure variation when the temperature change.

Conclusion

1. The LPS331AP is a high resolution sensor which has digital output pressure sensor and equiped a sensing element based on a piezerosistive Wheatstone bridge approach which is consists of a suspended a single mono-silicon μ-sized membrane.
2. The LPS331AP has a wide pressure range from 260 to 1260 mbar, high overpressure capability, low power comsumption. The relative accuracy pressure has linear embedded and quadratic external sw.
3. Some applications of LPS331AP might be performed in pressure sensing, altitude sensing, and indoor navigation.
4. The LPS331AP device has higher absolute accuracy after implementing quadratic pressure compensation in temperature.

References

1. http://www.st.com/internet/analog/product/251601.jsp retrieved January 14th, 2013.
2. http://en.wikipedia.org/wiki/Pressuresensor retrieved January 14th, 2013.
3. DeHennis, Andrew and Chae, Junseok. 2008. Pressure Sensor. Comprehensive Microsystems, Pages 101–133

SUPER-SENSITIVE NON-CONTACT OF THE D6T MEMS THERMAL SENSOR

Yusuf Dewantoro Herlambang
Student Bridging Course National Kaohsiung University of Applied Sciences
State Polytechnic of Semarang, Indonesia
Email: masyusufdh@yahoo.com, yusuf.dewantoro@polines.ac.id

Keywords: MEMS, Non-contact, Super-sensitive, Thermal Sensor

Abstract: The D6T non-contact MEMS thermal sensor, a super-sensitive infrared temperature sensor of an entire area contactlessly. Thermal sensors are able to measure temperature by receiving energy radiated from target objects on thermopile elements. Through the use of ASICs (Application Specific Integrated Circuits) and thermopile elements fabricated with MEMS technology. The D6T MEMS thermal sensors have two model are the first D6T 44L-06 with 4 x 4 element type, 18 x 14 x 8.8 mm. The second, D6T 8L-06 and 1 x 8 element type, 18 x 14 x 10.7 mm. The D6T have object temperature range 5 to 45^0 and temperatur resolution (NETD) is 0.14^0C. It has an accuracy ±1.5^0C max at 5 V_{cc} and 5 mA type. This model MEMS non-contact thermal can be applied in many field such as security, electronic hardware, military, chemistry, saving energy household, robotic industrial.

Introduction

The D6T MEMS Thermal sensors are able to measure temperature by receiving energy radiated from target objects on thermopile elements. Through the use of ASICs (Application Specific Integrated Circuits) and thermopile elements fabricated with MEMS technology, Omron has been able to create a miniature non-contact thermal sensor. Unlike typical pyroelectric human presence sensors that rely on motion detection, the D6T thermal sensor is able to detect the presence of stationary humans by detecting body heat, and can therefore be used to automatically switch off unnecessary lighting, air conditioning, etc. when people are not present (regardless of whether they move or not). As the D6T sensor is also able to monitor the temperature of a room, they can also be used to continually maintain optimal room temperature levels, instantly sense unusual changes in temperature thereby detecting factory line stoppages, or discover areas of overheating for early prevention of fire outbreaks, etc. While standard thermal sensors are only able to measure temperature at one certain contact point, the D6T can measure the temperature of an entire area contactlessly. Signals generated by infrared rays are usually extremely weak, and high-sensitivity detection is therefore very difficult to achieve.

Theoritical Background

The thermal sensor measurement principle that thermal sensors utilize the Seebeck effect in which thermoelectric force is generated due to the temperature difference at the contact points between two different kinds of metal. A thermopile is created by serially connecting thermocouples consisting of N + poly Si, P + poly Si, and Al. By creating hot junctions on highly heat-resistant dielectric membranes, and cold junctions on highly heat-conductive silicon. Itis possible to achieve high-speed response and high-energy conversion efficiency (infrared rays-temperature-thermoelectric force).

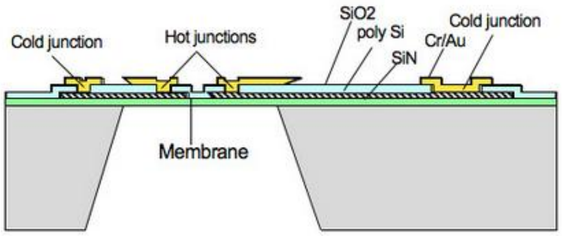


Fig 1: Sensor chip cross-section

Description of Model D6T MEMS Thermal Sensor

The D6T MEMS thermal sensors have two model are the first D6T 44L-06 model with 4 x 4 element type, dimensions is 18 x 14 x 8.8 mm. The second, D6T 8L-06 model and 1 x 8 element type, dimensions is 18 x 14 x 10.7 mm. The view angle is the maximum sensor output as reference, the angular range where the sensor output is 50% or higher when the angle of the sensor is changed is defined as the view angle.

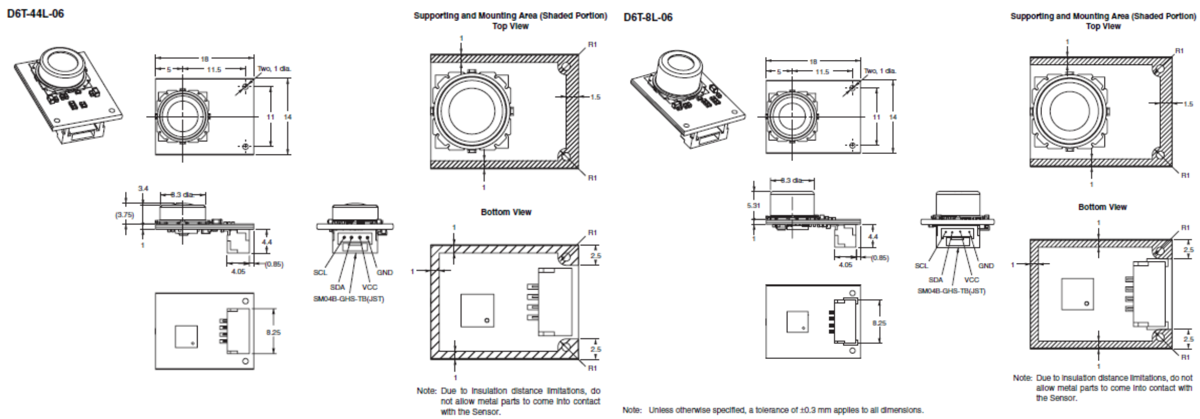


Fig 2: D6T 44L-06 and D6T 8L-06 model

The D6T MEMS thermal sensors is a super-sensitive sensor for non-contact thermal measurement that showed in ratings. It has 4.5 to 5.5 VDC power supply, storage temperature with no icing or condensation is -10 to 60^{0}C and operating temperature range is 0 to 50^{0}C, 85% max. of storage humidity and 20% to 85 % for operating humidity. The view angle is the maximum sensor output as reference, the angular range where the sensor output is 50% or higher when the angle of the sensor is changed is defined as the view angle.

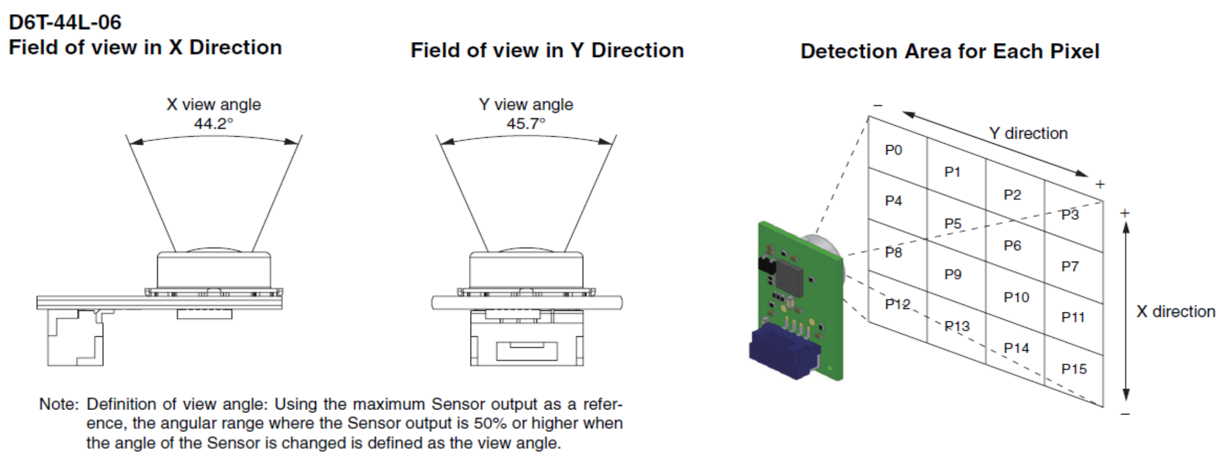


Fig 3: Field of view characteristics D6T 44L-06 and D6T 8L-06 MEMS

Performance and Characteristics

The D6T MEMS use ASIC technology achieve a high SNR and superior noise immunity with a digital output also high-precision area temperature detection with low cross-talk field of view characteristics. Performance characteristics is shown by object temperature detection range that have view angle X-Y direction. Measurement reserves the right object temperatur output accuracy. An accuracy 1 has conditions 5.0V_{cc} ±1.5^{0}C max and an accuracy 2 has conditions 5.0V_{cc} ±3.0^{0}C max. with 5 mA current consumption.

Table 1. Characteristics D6T MEMS thermal sensors

Item		D6T-44L-06	D6T-8L-06
View angle *1	X direction	44.2°	62.8°
	Y direction	45.7°	6.0°
Object temperature output accuracy *2	Accuracy 1	±1.5°C max. Measurement conditions: Vcc = 5.0 V (1) Tx = 25°C, Ta = 25°C (2) Tx = 45°C, Ta = 25°C (3) Tx = 45°C, Ta = 45°C	
	Accuracy 2	±3.0°C max. Measurement conditions: Vcc = 5.0 V (4) Tx = 25°C, Ta = 45°C	
Current consumption		5 mA typical	

*1. Refer to *Field of View Characteristics.*
*2. Refer to *Object Temperature Detection Range.*

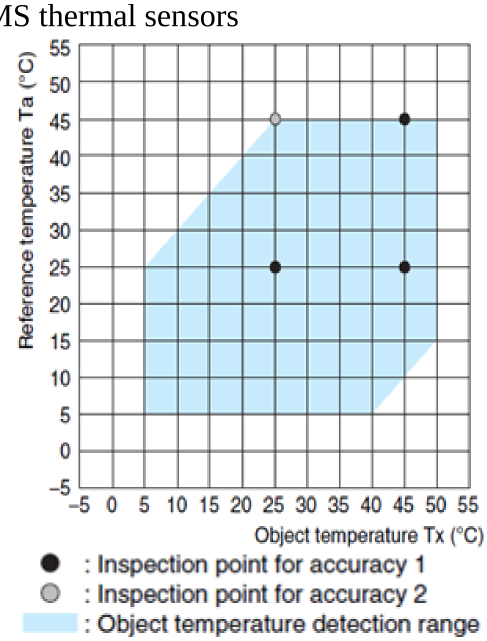
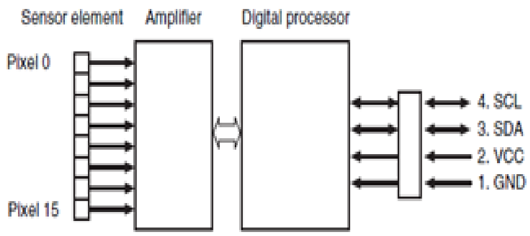


Fig 4: The Performance and Characteristics D6T MEMS Thermal Sensor

Connections

The D6T MEMS thermal sensor configuration diagram and terminal arrangement is shown at belows.



Terminal	Name	Function	Remarks
1	GND	Ground	
2	VCC	Positive power supply voltage input	
3	SDA	Serial data I/O line	Connect the open-drain SDA terminal to a pull-up resistor.
4	SCL	Serial clock input	Connect the open-drain SCL terminal to a pull-up resistor.

Fig 5: The Terminal Arrangement

Discussions

The D6T MEMS thermal sensor has temperature resolution 0.14^0C, the object yemperature detection range ± 5 to 50^0C, Reference temperature detection range ± 5 to 45^0C. It has output digital value that correspond to the object temperature, T_x and reference temperature, T_a are output from a serial communication port. The output form has binary code 10 times the detected temperature, communications form using I2C compliant. It has some functions such as the object temperature detection range for D6T MEMS thermal sensors have been unique characteristics. The temperature detection range is showed in inspection point area for accuracy 1 that have been given black round. Then white round is inspection point for accuracy 2. In the inspection area 1 and 2 have a maximum temperature range 45^0C to reference temperature Ta, and the object temperature, Tx at 50^0C. The lowest temperature range is achieved at a temperature, Ta is 5^0C and the reference point object temperature, Tx is also 5^0C.

Conclusions

Base on description and characteristis performance of the D6T 44L-06 and D6T 8L-06 MEMS thermal sensors above it can be concluded as follows :

1. The D6Ts 44L-06 has view angle 44.2^0 X-direction and 45.7^0 Y-direction. The D6T 8L-06 model has view angle 62.8^0 X-direction and 6.0^0 Y-direction.
2. The object temperature output accuracy has an accuracy 1 with conditions $5.0V_{cc}$ $\pm 1.5^0$C max. and an accuracy 2 has conditions $5.0V_{cc}$ $\pm 3.0^0$C max. with 5 mA current consumption.
3. This device has high sensitivity and superior noise immunity, low visual field crosstalk characteristics enable high-precision area temperature detection.
4. It can be applied in security, electronic hardware, military, chemistry, saving energy household, robotic industrial.

References

1. New Super-Sensitive Sensor for Non-Contact Thermal Measurement, Micronews, The disruptive semiconductor technologies magazine, issue no. 134 2012.10.10.pdf page 1.
2. http://www.omron.com/ecb/products/sensor/11/d6t.html.
3. http://www.siliconsemiconductor.net/article/75474-Omron-Reveals-Non-Contact-D6T-MEMS-Thermal-Sensor.php.

ENERGY HARVESTING FOR WIRELESS SENSOR SYSTEM WITH TE-CORE

Zulhaji
Student Bridging Course National Kaohsiung University of Applied Sciences
Makassar State University
Email: adjie_oto@yahoo.co.id/zulhaji.otomotif@unm.ac.id

Keywords: Energy Harvesting, Wireless, TE-Core

Abstract: Sensor is the right equipment in a wide range of applications that can be used in a difficult place. It would be a better way to provide electricity by collecting energy for wireless purposes. "Energy harvesting" is a technology that converts the excess energy available in the environment into energy that can be used for low-power electronics. A lot of ambient energy sources have been considered for this purpose as the incident light, vibration, electromagnetism, radio frequency (RF), the function of the human body, the temperature gradient and others. Based on the literature, different energy sources and techniques of collecting energy to power MEMS sensors used TE-Core.

Introduction

Energy harvesting (also known as power harvesting or energy scavenging), or “Micro-Generators” in the literature, is a process performed by a conversion mechanism for generating electric power from available ambient energy sources. Incident light, thermal gradients, machine vibrations and human body functions are the well known examples of ambient energy sources receiving the attention of many researchers. Since energy harvesting systems offer maintenance-free, long-lasting, green power supply for many portable, low-powered electronic devices, they are likely to become an essential part of power management systems.

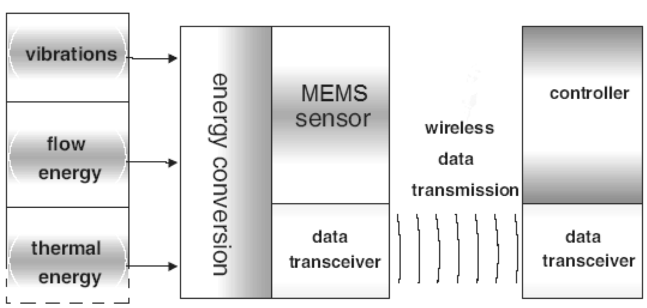


Figure 1. Wireless Self-powered Sensor Nodes

The growing interest in the field of energy harvesting systems is also due to great developments in related technologies such as micro-electromechanical-system (MEMS) technology, wireless sensor network (WSN) technology, very large scale integration (VLSI) design technology, and complementary metal oxide semiconductor (CMOS) fabrication technology. Sensors emerge as a promising application of energy harvesting techniques where these state of the art technologies work together as shown in figure 1.

Energy harvesting from ambient energy sources for MEMS sensors and low-power electronic devices is an active research topic with growing application areas such as wireless sensor networks and wearable devices. As the power consumptions of the electronic devices are decreased by the advancements in micro fabrication techniques, various energy sources including incident light, thermal gradient, human body functions and vibrating industrial machinery which are available in the environment have aroused the interest of many researchers as ambient energy sources convertible into electric energy. However, ambient vibrations stand out as a promising and convenient energy source for many applications among others, since they are usually available continuously and abundantly in the surroundings of the energy harvesting systems.

Energy Harvesting for Wireless Sensor Network

The concept of energy harvesting in relation to wireless sensor network (WSN) entails the idea of scavenging energy from mechanical, vibrational, rotational, solar or thermal means rather than relying on mains power or alkaline/rechargeable batteries to power the sensor nodes in the WSN. For instance, power can be harvested from the mechanical force of a conventional mechanical ON and OFF switch being turned on or off. Alternately, power can be derived from the difference in temperature between the human body and the surrounding ambient environment. Energy harvesting is increasingly gaining notice in the WSN research as well as industry market because it is a very potential solution to extend the lifetime of the sensor node's operation.

"The industrial market will be the second key area for energy harvesters, again with applications in wireless sensors that are used to monitor machines and processes", announces Antoine Bonnabel, Technology & Market Analyst, MEMS Devices & Technologies at Yole Développement. Energy harvesters increase the autonomy of the battery and thus the measurement data rates which are today limited with batteries. Maintenance free is also a great argument for EH in those applications where accessibility is sometimes critical (oil & gas industry for instance). "*Today, sales are limited because there is no real agreement on a low power radio protocol, as in buildings, but this will soon change and will allow significant price reduction and production ramp-up to several hundred thousand units in 2017*", pursues Antoine Bonnabel.

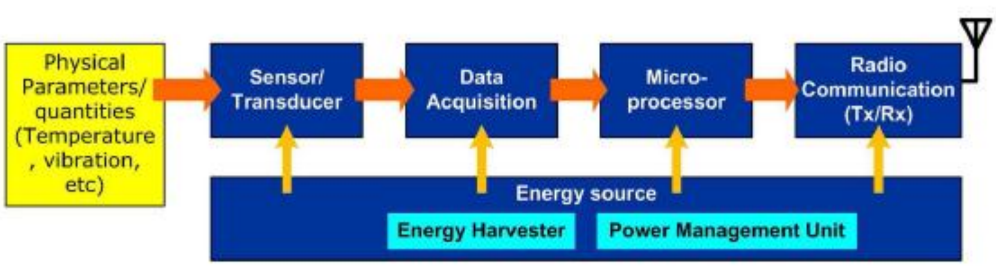


Figure 2. Block diagram of energy-hungry wireless sensor node

To ensure continuity in the load operation even when the external power source is temporarily unavailable, the excess energy harnessed has to be stored either in a rechargeable battery or electrochemical double layer capacitors, also known as supercapacitors/ultracapacitors. The power conditioning electronic circuits in the energy harvesting system are designed based on the energy harvesting input energy sources and the connected output loads, hence different types of power conditioning circuit designs have been proposed to bridge between the source and the load. It is worth noting that the design of the energy harvesting system to power the sensor node in the WSN may differ from one application to another application because of the variations in the load requirements and the differences in the condition of the deployment area.

TE-CORE

The TE-CORE is a complete thermo-powered, self sufficient wireless sensor node system (WSN). The TE-CORE thermoharvesting module converts locally available waste heat thermoelectrically to indefinite free electric energy-as long as the heat flows through the thermogenerator (TEG). The integral power conversion and management circuit steps up the ‘gradient–analog’ output voltage of the TEG at a fixed voltage (2.4 V by default). The harvested energy is being buffered in an extendable capacitor and controlled by a configurable hysteresis.

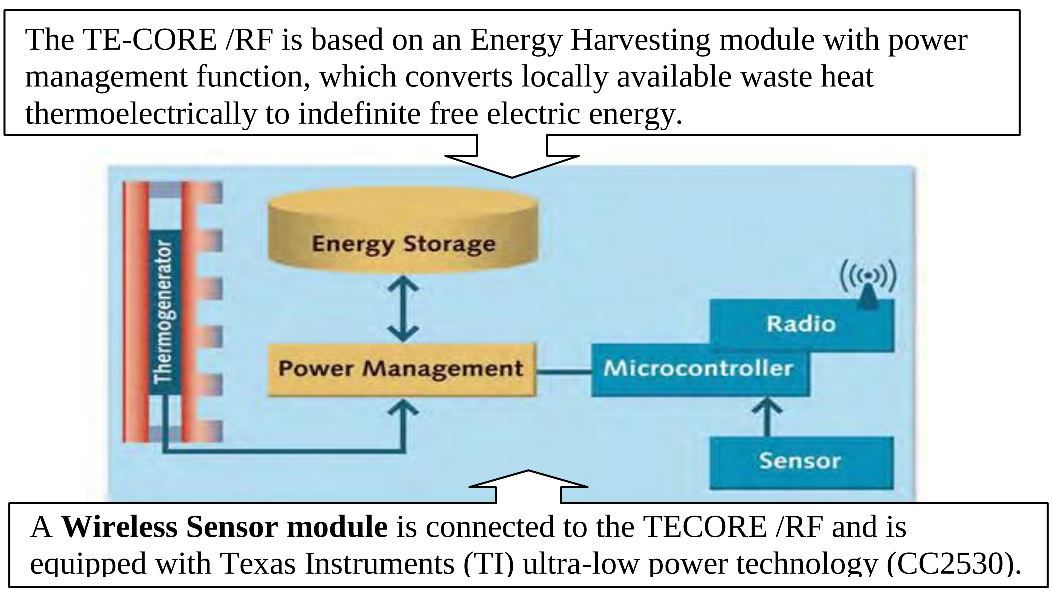


Figure 3. based on an Energy Harvesting module.

Design TE-CORE

The **Energy Harvesting module** of the TE-CORE /RF operates from a heat (or cold) thermal energy source. The TGP’s aluminum top side, its thermal input, is supposed to be attached to the heat source. The thickness of the thermal input acts as a spacer to protect the PCB and to ensure a thermal separation between the hot and cold sides; i.e. optimizing energy harvesting performance through suppression of thermal ‘cross talk’

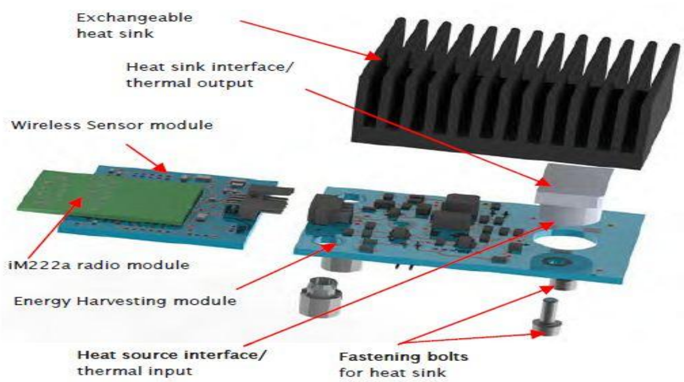


Figure 4. Component TE-CORE

Absolute Maximum Ratings

Please ensure that during operation of the TE-CORE /RF system the below maximum ratings, see below, are not exceeded:

	min	TYP	max
Hot side temperature	+10 °C	-	+ 100 °C
Operating temp	0 °C		+ 70 °C
Storage temp	+5 °C		+ 35 °C
ESD sensitivity	-	-	9000 V

The TE-CORE/RF ThermoHarvesting Wireless Sensor System is available in two variations, differentiated by two thermal generator types:

1. TE-CORE7 /RF: TGP-751 (thin-film TEG MPG-D751)
2. TE-CORE6 /RF: TGP-651 (thin-film TEG MPG-D651)

TGP Properties

Properties of TGPs	TGP-751	TGP-651
TEG chip inside	MPG-D751	MPG-D651
Electrical resistance R_i	200 - 350 Ω	150 - 230 Ω
Thermal resistance R_{th}	18 K/W	28 K/W
Thermovoltage S	110 mV/K	60 mV/K
Footprint (l x w x h)	15 x 10 x 9.3 mm	

TGP Electrical Performance without DC-DC Booster

The direct output performance of the TGP devices are measured at an ambient temperature of 25 ºC with heat sink fins in vertical orientation for best natural convection.

The diagrams provide the output- voltages and power of TGP-751 and TGP-651, each integrated in a standard TE-CORE module. DC-DC Booster is not used. Between the heat source and thermal input of the TGP, thermal paste is used for a good thermal connection.

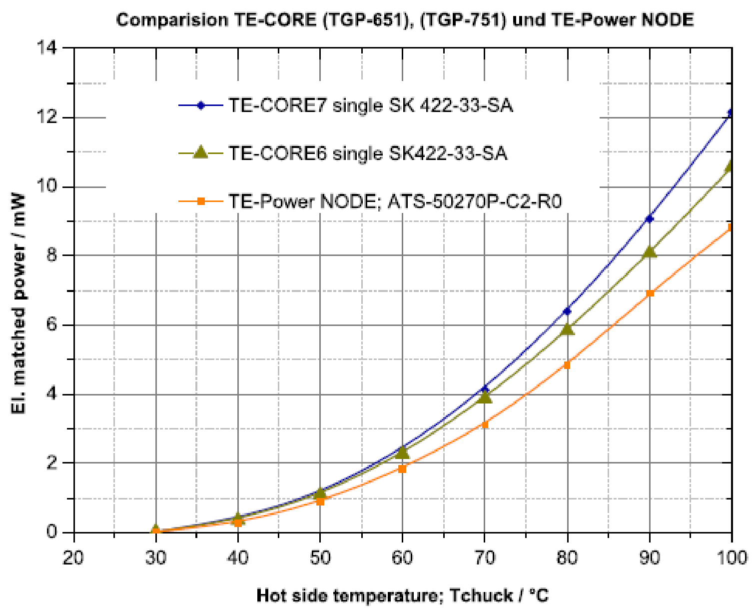


Figure 5. Graphic of Comparison TE-Core

Reference:

1. Yen Kheng Tan and Sanjib Kumar Panda (2010). Review of Energy Harvesting Technologies for Sustainable WSN, Sustainable Wireless Sensor Networks, Yen Kheng Tan (Ed.), ISBN: 978-953-307-297-5, InTech.
2. Gurkan Erdogan Energy harvesting for Micro-electromechanical-systems (mems).
3. Lyon, France – October 31, 2012 – Yole Développement announces its new analysis "Emerging Energy Harvesting Devices". In this report, Yole Développement analysts describe why and how emerging energy harvesting devices will be increasingly used in the dynamic wireless sensor business.
4. Micronews No.127 2012.04.12 Micropelt's thin fi lm thermoelectric technology
5. Datasheet TE-CORE http://www.micropelt.com/applications/te_core.php