MEMS Approach for the Automotive Industry

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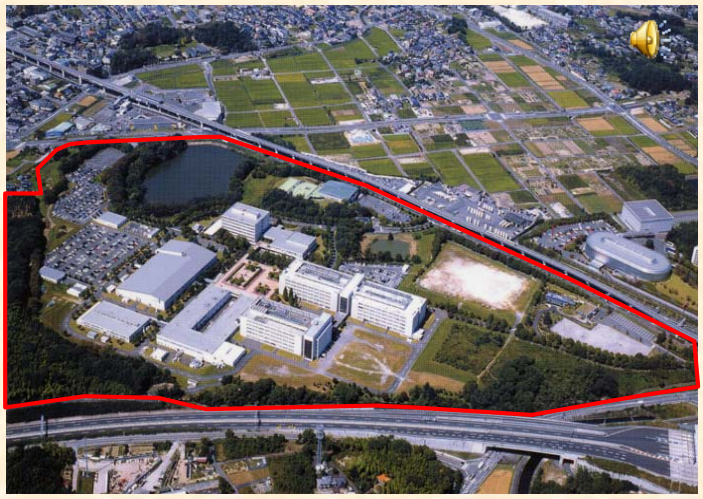
TOYOTA CENTRAL R&D LABS., Inc.

1. TOYOTA CRDL, INC

Company Outline

- Established ：November 1960
- Location ：Nagakute, Aichi, Japan
- Capital ：3 billion yen
- Number of Employees：1,045
- Ground Area ：About 300,000 m^2
- Floor Space ：About 98,000 m^2

(July 2013)



Stockholder Companies & Technical Collaboration Contractor Companies

Stockholder Companies

- Toyota Industries Corporation
- Toyota Motor Corporation
- Aichi Steel Corporation
- JTEKT Corporation
- Toyota Auto Body Co., Int.
- Toyota Tsusho Corporation
- Aisin Seiki Co., Ltd.
- Denso Corporation
- Toyota Boshoku Corporation

Technical Collaboration Contractor Companies

- Toyota Motor East Japan, Inc.
- Toyoda Gosei Go., Ltd.
- Hino Motors, Ltd.
- Daihatsu Motor Co., Ltd.

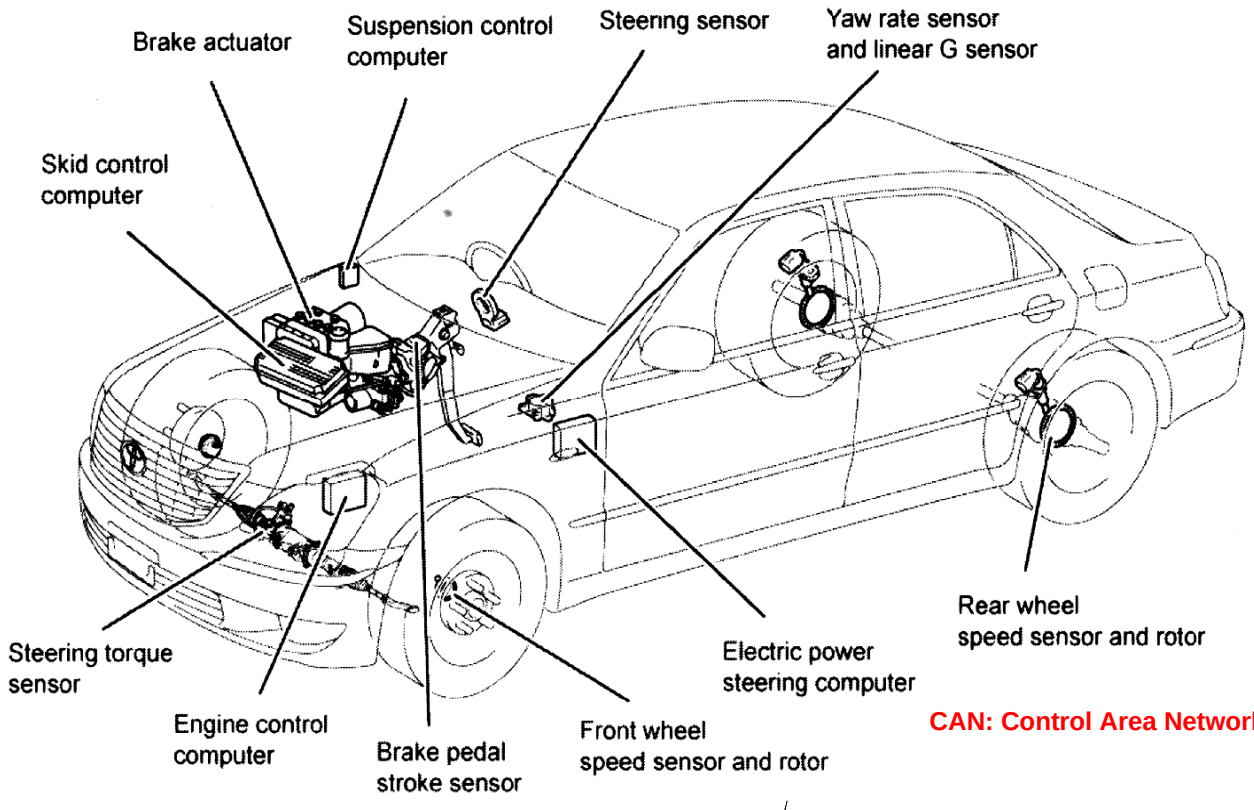
Other 39 companies

(July 2013)

2. Sensing Technology for Automobiles

Configuration of VDIM

VDIM : Vehicle Dynamics Integrated Management



CAN: Control Area Network

Sensor application comparison

	Automobile	Home Electronics	Industry	Airplane
Accuracy	1 to 5 %	5 to 20 %	0.1 to 1 %	0.1 to 1%
Temperature Range	−40 to 120 ℃	−10 to 50 ℃	0 to 60 ℃	−55 to 70 ℃
Vibration	2 to 25 G	1 to 5 G	0 to 5 G	0.5 to 10 G
Power Fluctuation	+/− 50 %	+/− 10 %	+/− 10 %	+/− 10 %
EMC	Large	Small	Medium	Small
Ambient	Water, Salt, Dirt, Erosion	Water	Water, Oil, Erosion	Water, Salt
Sensor Cost	1 to 10 $	1 to 10 $	10 to 100 $	100 to 1000 $
Whole Cost	0.01 to 0.1 M$	0.001 to 0.01 M$	0.001 to 1 M$	0.1 to 100 M$
Cost Ratio	10^2 to 10^5	10^1 to 10^4	10^1 to 10^5	10^2 to 10^5
Mass Production	Good	Good	Poor	Poor
Maintenance	Public, Professional	Public, Professional	Professional	Professional

EMC: electromagnetic compatibility

Accuracy: Middle
Working range: Wide
Life: Long

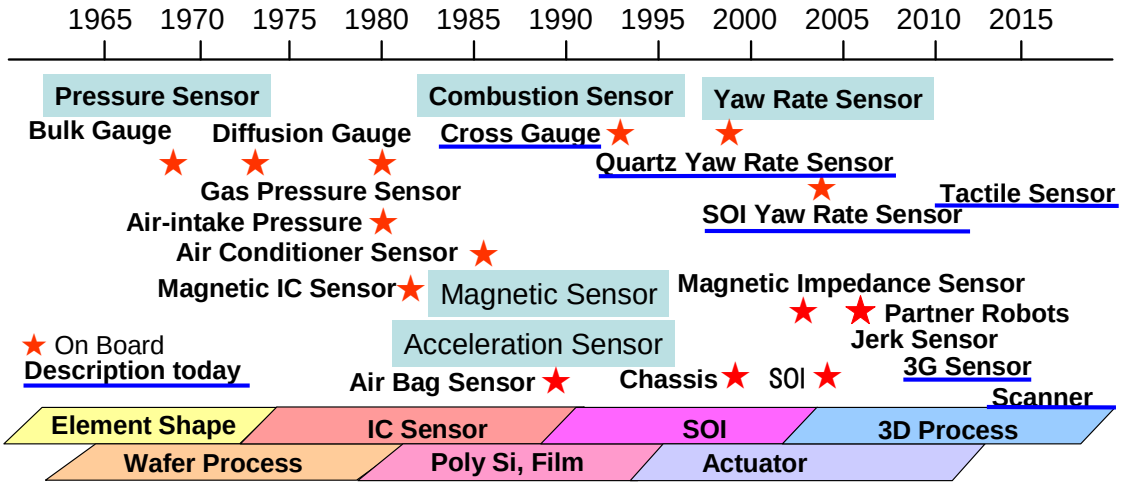
High stability
High reliability
Low cost

Kind of automotive sensor

Temperature	Water, Oil, Intake, Exhaust air, Fuel, Cabin
Gas	Oxygen, Lean, NO_x, HC, H_2
Pressure	Intake air, Air flow, Combustion, Supercharging, Brake, Tire, Compressor
Position	Fuel level, Cam, Vehicle height, Seat
Angle	Crankshaft, rotation, Throttle, Steering, Direction
Speed	Engine, Vehicle, Transmission, Wheel
Angular rate	Yaw rate, Rollover
Acceleration	Airbag, Chassis, Suspension
Force, Load	Brake pedal, Steering torque, Loading
Vibration	Knocking
Light, Electric wave, Sound	Laser, Microwave, Visible light, IR light, Solar irradiation, Headlight, Voice, Ultrasound
Others	Glow plug, Particle, Rain drop, Humidity, Antenna, Fingerprint, Current

Inner sensor: Pressure, Acceleration, Angular rate,
Outer sensor: Sonar, Rader, Vision

Automotive sensor & MEMS technology



Bulk Micro Machining

Integrated Micro Machining

Surface Micro Machining

SOI Micro Machining

3D Micro Machining

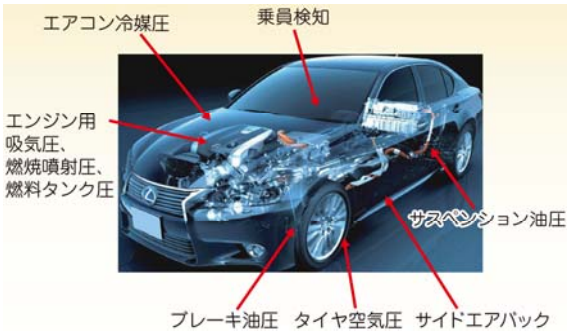
Prize of “One Step on Electro-Technology” from IEE Japan in 2013 (電気の礎)

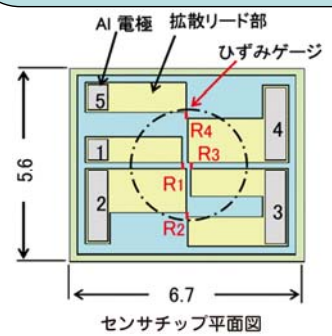
The Institute of Electrical Engineers of Japan

Piezoresistive Semiconductor Pressure Sensor

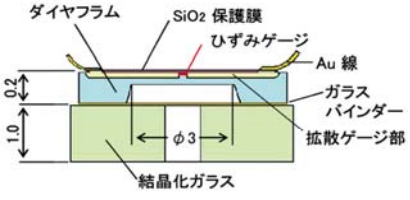
Toyota Central R&D Labs., Inc.

- Si Diaphragm with Semiconductor Strain Gauge with MEMS Technology (1970s)
- Gas Pressure Monitoring Sensor (Toyota Machine Works 1980)
- Intake Pressure Sensor for Automobile (Denso 1981)





センサチップ平面図



センサチップ断面図

(mm)

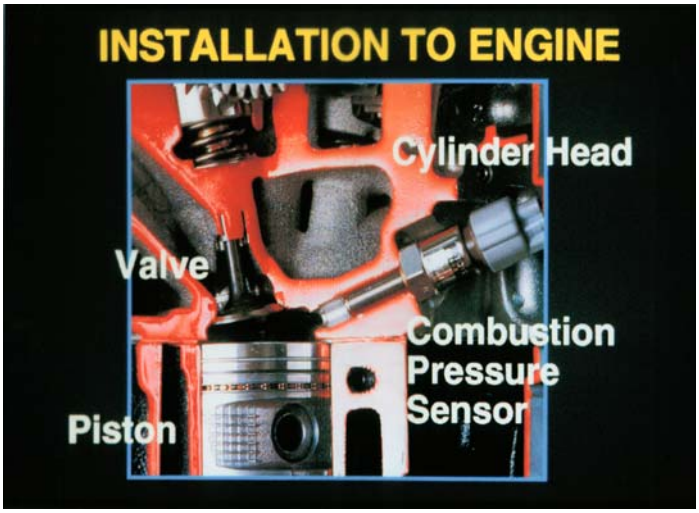
3. Sensors for Automobiles

3.1 Combustion Pressure Sensor

Combustion Pressure Sensor

Low exhaust emission

Low-fuel consumption

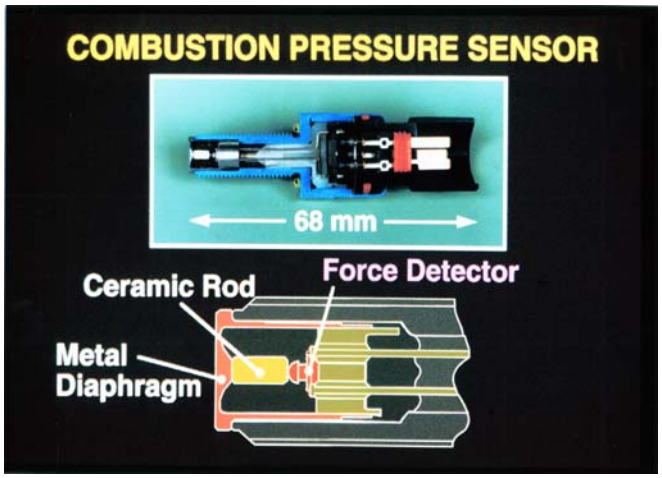


Lean Burn Engine (TOYOTA)

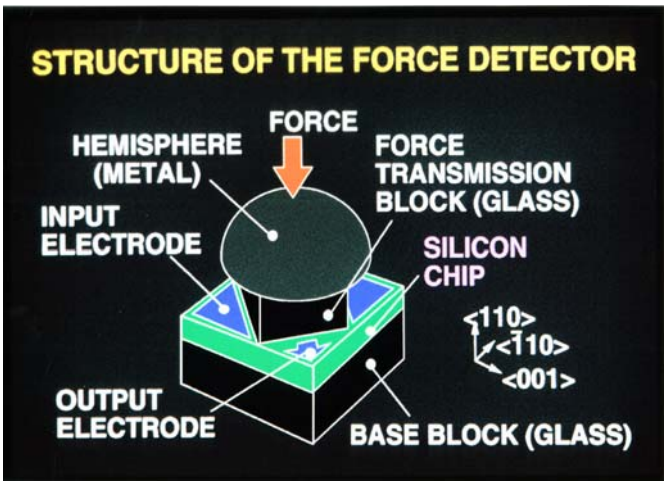
1993

Combustion Pressure Sensor

Installed on TOYOTA Lean Burn engine in 1993



Cross Section View

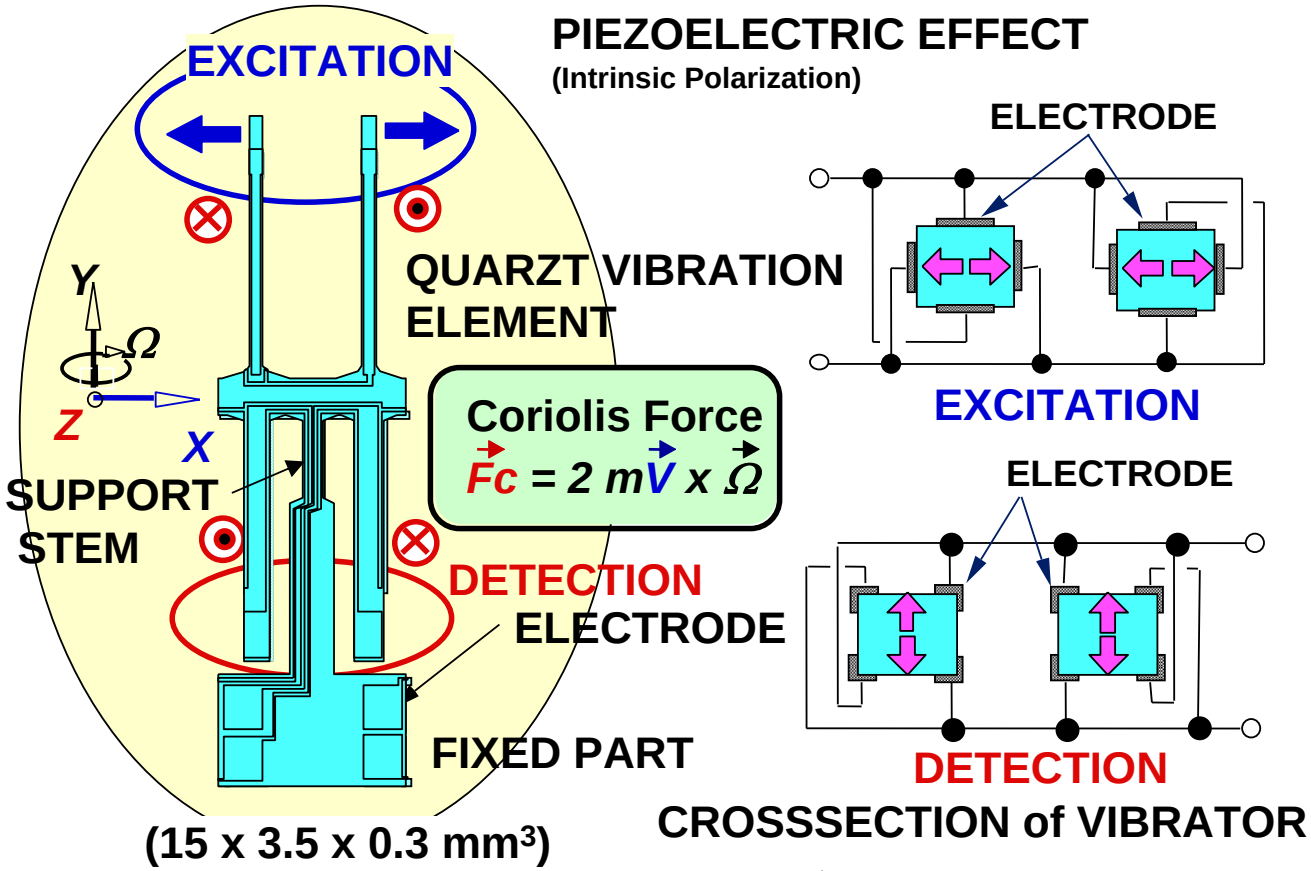


Cross Gauge Type

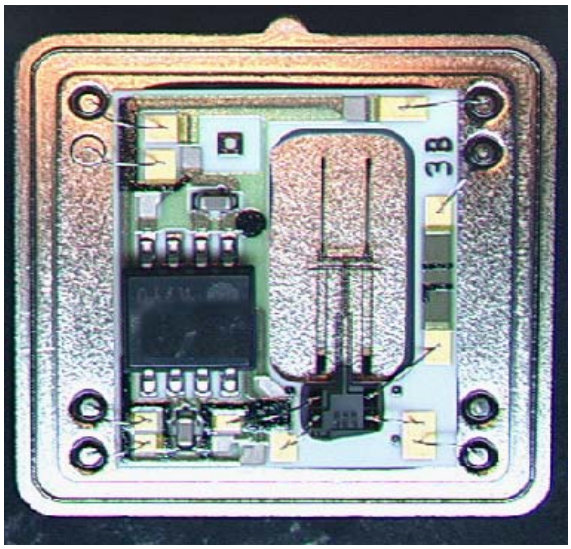
3. Sensors for Automobiles

3.2 Quartz Yaw Rate Sensor

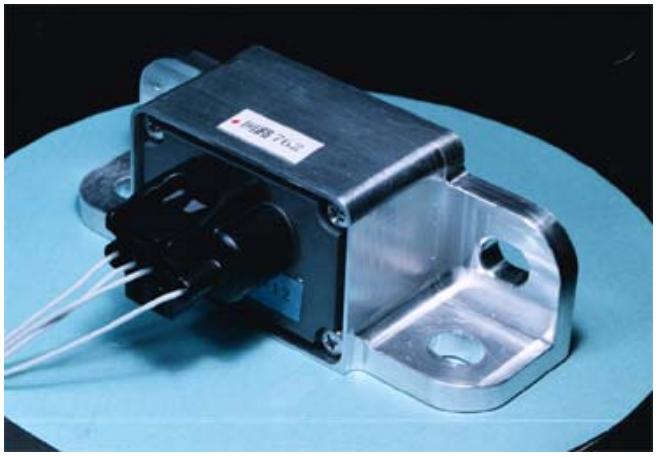
Structure of Quartz Sensor



Quartz Yaw Rate Sensor



Installed on TOYOTA VSC System in 1998
VSC: Vehicle Stability Control



SENSOR ELEMENT
15 x 3.5 x 0.3 mm^3

IC PACKAGE SIZE
25 x 25 x 5 mm^3

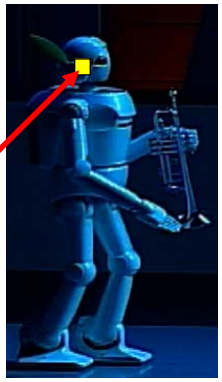
HOUSING
107 x 48 x 37 mm^3

4. Sensors for Robots

4.1 Robot Use of Automotive Sensors

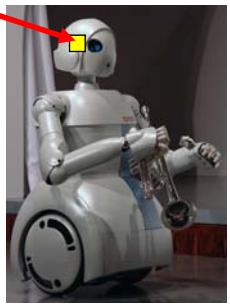
Role of the Artificial Three Semicircular Canal

Walk on stilts
with keeping balance



Biped-type Robot

Artificial
Three Semicircular Canal
(Gyro)



Rolling-type Robot

Ride on wheel
with keeping balance

TOYOTA CRDL., INC.

Robots with the Inertial Force Sensing System

Parson Carrier Biped-type Robot

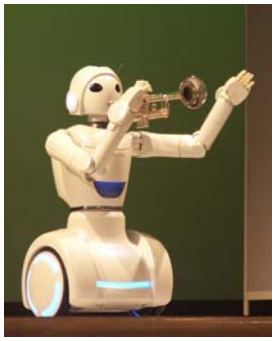
Biped-type Robot
(Plays the Trumpet)

2005
AICHI EXPO

Three Semicircular Canal

Rolling Type
(2 + 1 wheels)
<i-Swing>
2006
Motor Show

Biped-type Robot with Wire Drive

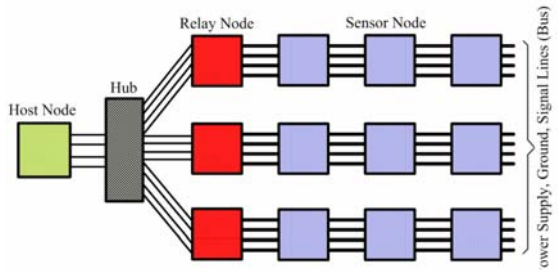


Rolling Type (2 wheels) Robot
(Inverted Pendulum)

4. Sensors for Robots

4.2 Tactile Sensor with Nerve Network

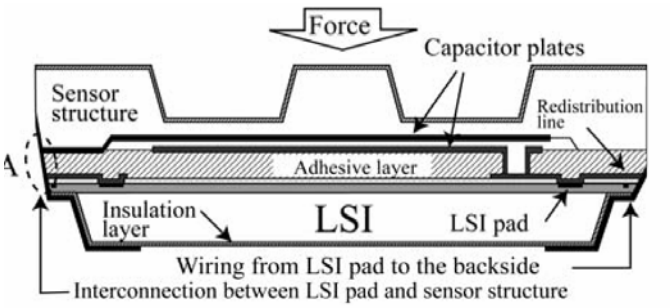
Nerve Net Type Tactile Sensor



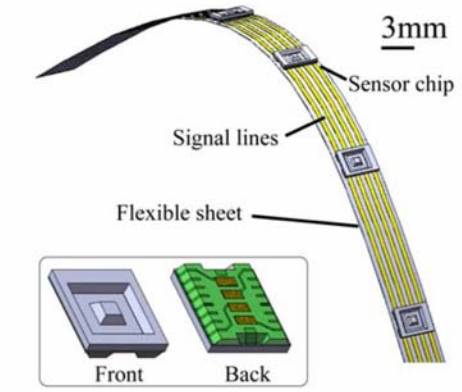
<POINTS>
Serial bus, Event driven against congestion
Sensor chip on signal processor
Signal outputs when force changes
Nerve like relay node

Transducers2011

Robina, TOYOTA



Tactile sensor chip



Tactile sensor chip and signal line

5. Summary

- The sensors for the automobiles have been advanced with the MEMS technology.
- New sensors and devices are created with new MEMS technology, and that will continue to grow.
- The needs and applications of the sensors and devices are expanding.
- The sensors and devices of the automobiles should be integrated with LSI for high performance and communication systems.