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Energy Technology Division

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Automotive Vehicle Sensors

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by

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ACRONYMS, SYMBOLS, AND ABBREVIATIONS

<	less than
>	greater than
λ	actual air-fuel ratio/stoichiometric air-fuel ratio
a/c	air conditioning
A/F	air to fuel ratio
ABS	antilock braking system
ACRS	air cushion restraint system
ANL	Argonne National Laboratory
$\approx$	approximately equal to
ARPA	Advanced Research Projects Administration
$^{\circ}\text{C}$	degrees Celsius
CAFE	corporate average fuel economy
CARB	California Air Resources Board
CPU	central processing unit
CVT	continuously variable transmissions
DOE	U.S. Department of Energy
DR	dead reckoning
EGO	exhaust gas oxygen
EGR	exhaust gas recirculation
EMI	electromagnetic interference
eng. mgt	engine management system
est.	estimated
$^{\circ}\text{F}$	degrees Fahrenheit
ft	feet
FOD	foreign object damage
g	acceleration of gravity, 32.17 feet per second per second
GM	General Motors Corporation
GMR	giant magnetoresistance
GPS	Global Positioning System
HE	Hall effect
HEGO	heated exhaust gas oxygen
HUD	heads-up display
HVAC	heating, ventilation, and air conditioning
Hz	Hertz (cycles/second)
in.	inch
IR	infrared
IVHS	Intelligent Vehicle Highway Systems
kHz	kilohertz
kg	kilograms
km/h	kilometers per hour
L/s	liters/second
MAF	mass air flow
MAP	manifold air pressure

MAT	manifold air temperature
mm	millimeter
MMW	millimeter wave
mi/h or mph	miles per hour
NAV	navigation system
nm	nanometer
NO _x	oxides of nitrogen
OEM	original equipment manufacturer
ORBII	on-board diagnostic regulations by CARB
PM	powdered metal
pot.	potentiometer
PVDF	polyvinylidene fluoride
RF	radio frequency
RVs	recreational vehicles
s	seconds
SAE	Society of Automotive Engineers
SAW	surface acoustic wave
TPS	throttle position sensor
UV	ultraviolet
V	volts
VR	variable reluctance
VTEC	variable timing and lift control
VVT	variable valve timing

QUOTES

"We are seeing a proliferation of sensors in automobiles due to environmental, safety, power train and engine demands for performance."

Marty Levy, Strategic Marketing Director, Motorola

"Even though we tend to think today's automotive testing and technology is state of the art, we are just breaking the edge of vehicle dynamics. We never had a way to test so many things before."

Hank Norlin, Application Engineer, DATRON

"A lot of sensors are for industrial use. We're trying to get them into more commercial products."

Craig Autio, Engineer, Whistler

"The vast majority of our sensors are engine-oriented..."

Bob Vance, Purchasing Agent, Chrysler

"We see that [engine sensors] as a market we can play in that will be worth in excess of \$600 million. For a company our size, we feel that we will do nicely if we can get a small percentage of that."

Richard Van Es, CFO, American Electronic Components (AEC)

SUMMARY

The automotive vehicle sensor market is driven by increased demand for convenience, comfort, safety, efficiency, and environmental protection. Sensors integrated with electronics, communications, and computer intelligence are poised for a growth surge. Integrated sensors with intelligence are often referred to as "smart sensors" or "intelligent sensors." They will be used in conjunction with all types of devices. The implication for the automobile industry is the advent of the "smart car."

Automotive vehicle sensor development and usage will be a dominant technology thrust over the next five to seven years. Cars are smart now but will become much smarter with the expansion of sensor technology in conjunction with microprocessor control.

The automotive market is a significant portion ($\approx 25\%$) of the total sensor market. Other large user segments are manufacturing, aerospace, medical, and heating ventilation, and, air conditioning. In 1993, the world automotive market for sensors was about \$535 million. It is forecast to be about \$1.5 billion in 2000. This is a growth rate of $\approx 18\%$ per year.

The taxonomy used to classify sensors in this report has four categories: Vehicle System, Vehicle Application, Property Sensed, and Technology Used. The primary system is engine management. There are >100 specific

vehicle sensor applications. Important properties sensed in automotive vehicles include temperature, pressure, acceleration, flow, oxides of nitrogen, oxygen, proximity, speed, and position. The most commonly used technologies are micromachined silicon, piezoresistive, variable reluctance, Hall effect, capacitive, and electromechanical.

Original equipment manufacturers (OEMs) of vehicles do not generally make or develop the sensors they use. System suppliers to the OEMs do much of the coordination on development and a significant amount of development themselves. The actual sensor manufacturers tend to be smaller companies. Some are very small and highly specialized.

There is still opportunity for individuals or small groups to make a major breakthrough in automotive vehicle sensors. There is ample room for creativity and clever applications of existing technologies to be used to new situations.

The importance of silicon and semiconductor technology and manufacturing methods in the sensor market cannot be over-emphasized. The products are cheap, reliable, fairly rugged, and can be mass produced.

In the automotive sensor market, the question is not one of making a great sensor. It is a question of making 10 million great sensors cheaply.

INTRODUCTION

In FY 1994, the U.S. Department of Energy (DOE), Office of Energy Research, under the Laboratory Technology Transfer program, funded Argonne National Laboratory to develop a national data base on sensor and control technologies. The data base will be incorporated into the DOE Integrated Technical Information System, the on-line system maintained by DOE's Office of Scientific and Technical Information. The primary use of this resource is to provide the U.S. industry base with a dial-up data base that catalogs existing sensors and control technologies, along with new and developing sensors and control technologies. Names of technical contacts will also be documented and maintained. There are two potential benefits of the data base. (1) Promoting the interaction of U.S. sensor and control companies with U.S. manufacturers, the national laboratories, and universities. This will lead to enhanced collaboration on new initiatives and development of technologies.

(2) Increase U.S. industry competitiveness through the proper identification and application of advanced sensor and control technologies.

The initial scope of this project is to develop (1) the data base structure and establish a prototype for demonstration and (2) a data base that focuses on a technology area critical to a major DOE initiative such as automotive or environmental areas. The data base structure was established in FY 1994, and an automotive vehicle sensor data base was developed in FY 1995.

This report is an introduction to the field of automotive vehicle sensors. It contains a prototype data base for companies working in automotive vehicle sensors, as well as a prototype data base for automotive vehicle sensors. A market analysis is also included.

The report was prepared primarily by Michael J. Moscyński of InTech Management Consulting, Ann Arbor, MI.

MARKET ANALYSIS

General Comments

The general market for sensors will increase as it is driven by increased demand for convenience, comfort, safety, efficiency, and environmental protection. Sensors integrated with electronics, communications, and computer intelligence are poised for a growth surge. Integrated sensors with intelligence are often referred to as "smart sensors" or "intelligent sensors" and will be used in conjunction with all types of devices. The implication for the automobile industry is the advent of the "smart car."

The automotive market needs inexpensive (\$1 or less), highly reliable (for practical purposes, 100%) sensors that lend themselves to mass production (tens of millions). The bulk of the market share in sensors currently belongs to large companies with familiar names (e.g., Motorola, Honeywell, Delco Electronic).

Sensor manufacturers generally supply to a second-tier supplier that makes an entire system for automobile OEMs. There are exceptions: a system supplier may make the individual sensor, or an OEM may make the particular subsystem, e.g., an antilock braking system (ABS). Competition is fierce at all three levels of this hierarchy. Innovations often come from small companies or even individuals, however.

Automotive Market

The automotive market is a significant portion of the total sensor market. It has been about 25% of the total market. Other

large user segments are industrial, aerospace, medical, and heating, ventilation, and air conditioning (HVAC). In 1993, the world automotive market for sensors was about \$535 million. It has been forecast to be about \$1.5 billion in 2000, for a growth rate of 18% per year. Micromachined silicon and Hall effect sensors in the world automotive market are discussed below.

Micromachined Silicon Sensors

These sensors are used in pressure and accelerometer applications. The world auto market for micromachined silicon sensors in 1993 was about \$315 million, and is expected to grow $\approx 14\%/yr$ to \$885 million in 2000. Micromachined silicon sensors can cost \$10 to \$50 each.

Hall Effect Sensors

Hall effect (HE) sensors are used extensively for angular position and speed applications. Because of their greater expense and smaller air gap compared to variable reluctance (VR) sensors, they are used for more precise applications. Camshaft and crankshaft speed and position applications are typical. The world auto market for HE sensors was about \$78 million in 1993, and has been forecast to be $\approx \$170$ million in 2000 ($\approx 12\%/year$ growth).

Giant Magnetoresistive (GMR) Sensors

GMR sensors have the potential to replace most HE sensors and increase the growth potential of sensors for position and speed.

SYSTEMS

Sensor Taxonomy and Classification

Sensors can be classified in many ways: use, technology, application, property sensed, cost, manufacturing methods, etc. The taxonomy used in this report has four categories:

1. **Vehicle System** in which a sensor is used. HVAC is an example of a vehicle system that employs several sensors.
2. **Vehicle Application** or use of the sensor. HVAC high-side refrigerant pressure is an example of a specific application for a sensor.
3. **Property Sensed** by the sensor. Fluid pressure is an example of a general property measured by a sensor.
4. **Technology**, or the basic physical phenomena that the sensor uses to do its job. An example of technologies employed in a sensor are **micro-machined silicon** and **piezoresistive** sensors.

Vehicle Systems

The following vehicle systems are used in this report:

1. air cushion restraint system (ACRS)
2. brake/traction control
3. collision avoidance
4. comfort/convenience
5. engine management (eng. mgt.)

6. HVAC
7. navigation (NAV)
8. safety
9. smart cruise control
10. suspension
11. testing
12. vehicle security

Several important vehicle systems are discussed below. They all rely heavily on one or more sensor inputs in order to function. The information from the sensor is usually sent to a system CPU for data processing and actuator movement or other action to be taken.

1. Air Cushion Restraint System (ACRS)

The air cushion restraint system must operate quickly when needed, 100% of the time, but never for a false alarm. ACRS systems decide to deploy the airbag(s), pretension seat belts, and lock seat belts. The standard application uses multiple sensors for input to the ACRS. For instance, two or three crush sensors and an accelerometer to measure g-forces typical of a crash would all be utilized before firing the airbag(s). Currently, there is an industry debate as to whether single-point crash sensor deployment is adequate.

Other important considerations in ACRS systems are the presence of occupants other than the driver and their orientation, in order to deploy the airbags and restraints to minimize injury

Children in car seats are a special problem in air bag deployment in the front seat. Sensors and systems to tell the ACRS of the presence and seating direction of a child seat are being developed. Regulation FMVSS 208 will take effect in 1998.

Side-impact crashes are another special case. Sensors to pick up lateral proximity, side crushing, and axis-oriented acceleration are used for this system.

Primary sensor inputs to the ACRS are air bag stored gas pressure (if applicable), forward and lateral acceleration, ignition switch on/off, body door closure, seat belt position or other restraint device, passenger presence and orientation, and child seat presence and orientation.

2. Braking/Traction Control

Antilock Braking System (ABS)

An ABS relies on sensors to provide input on wheel (tire) speed from all four wheels. The hydraulic oil pressure in the brake lines is needed, also. Brake pressure gives information about the driver's intent and level of braking action to be taken. To maintain straight-line travel without locking a wheel, there should be no difference in wheel speed among the four wheels. The CPU receives the wheel speeds and oil-pressure signals and individually controls the braking force applied to each wheel to avoid skidding while stopping in the minimum distance.

Primary sensor inputs to the ABS are speed of all four wheels, acceleration, and brake pedal force.

Traction Control

Traction control is similar to but the opposite of ABS. It allows power to be applied to the driving wheels without spinning. This is a very useful feature on slick roads when starting from a dead stop. Traction control requires sensor information for wheel speed. If a wheel starts to spin, braking is applied and the power is reduced by a signal to the throttle. The CPU maintains traction control automatically.

Primary sensor inputs to the traction control system are speed of all four wheels, forward acceleration, and engine power.

Next-Generation ABS

Active ABS will be the next generation of ABS. GMR sensors may be used in place of variable reluctance (VR) sensors. GMR can detect zero wheel speed. A powder-metal (PM) or ferrous metal encoder ring can be embedded in a wheel bearing seal. The rotating ring is sensed by an electrical bridge circuit in the stationary part of the sensor. Use of magnetic material is discouraged near bearings because the field could result in magnetic foreign object damage (FOD) to the bearing.

Other zero-speed alternatives for active ABS include HE and magneto-optic sensors.

Active ABS may replace the need for a vehicle speedometer. It can also be used as input for dead reckoning (DR) navigation as part of a Global Positioning System (GPS). The DR system can augment the navigation system when a satellite signal is not reaching the GPS.

Primary sensor inputs to the advanced brake/traction control system are speed of all four wheels, steering wheel position and speed, brake pedal pressure, vehicle yaw (spinning) rate, lateral acceleration, forward acceleration, vehicle speed, and engine power.

3. Collision Avoidance

A number of systems can assist the driver by providing a warning or active evasion in forward, lateral, or rear collisions.

Forward-looking systems typically use Doppler radar, a laser, IR system, or a video system to "look" ahead of the vehicle.

Lateral proximity sensors can warn of vehicles or obstruction in the driver's blind spot. This is a useful feature during parking.

Rear proximity sensing is used to warn of tailgating vehicles. It is also useful during parking, particularly for obstructions below the driver's line of sight.

Primary sensor inputs to the collision avoidance system are front, lateral and rear proximity using radar, laser, millimeter wave (MMW), IR, or ultrasonic ranging, vehicle speed, brake pressure, engine power, and steering wheel position and acceleration.

4. Comfort/Convenience

Vehicle Status and Warnings

Numerous sensors provide the driver with warnings and information on vehicle status. Some of these applications are well known.

Primary sensor inputs are vehicle speed, engine speed, engine temperature, oil pressure, battery charging status, door/deck

ajar, light bulb malfunction, fuel level and others.

More advanced warnings that are or will become available include road surface condition, vehicle location, fuel quality, tire pressure, and blind-spot proximity. Detailed engine and vehicle warnings, diagnostics, and instruction systems are expected to advance in capability and usage.

Law Enforcement Radar Warning

Commercially available systems to sense the presence of microwave radar used for speed-limit law enforcement are well established. As more vehicle systems use microwave radiation for other purposes, the signal-to-noise environment for this application will degrade. Primary sensor input is microwave energy.

Two-Way Radio Receivers and Cellular Phones

Two-way radio receivers have been common in taxis and service and delivery vehicles for many years. This usage is expected to increase. There has recently been a dramatic increase in the use of vehicle cellular phones, a special application of two-way radio receivers. Use of cellular phones will continue to increase dramatically. Primary sensor input is radio frequency (RF) energy.

5. Engine Management

Sensor inputs for engine management include ambient air temperature and pressure, altitude, throttle position, manifold air pressure and temperature, camshaft and crankshaft position, coolant temperature, mass air flow, cylinder pressure, throttle position and throttle body temperature, EGR flow, oxygen sensor, engine speed, vehicle

speed, combustion quality, engine knocking, and fuel quality. The management of the engine functions is by a CPU.

Combustion Control System

The air/fuel mixture delivered to the intake manifold is important for emission control, fuel efficiency, and performance reasons.

Manifold Air Pressure (MAP)

Intake manifold pressure is an excellent indicator of engine load and performance. MAP has been historically referred to as "engine vacuum" because it is usually below atmospheric pressure to allow aspiration of air into the engine.

Exhaust Gas Oxygen (EGO)

The EGO sensor compares oxygen concentration of the outside air to the oxygen concentration in the exhaust. The purpose is to provide a signal to the CPU to optimize the fuel/air mixture for maximum economy and minimum emissions. An engine burning lean will be too hot. An engine burning too rich will waste fuel. The ideal mixture is 14.7:1 air to fuel; this is the stoichiometric ratio. The symbol for the actual air-fuel ratio/stoichiometric air-fuel ratio is λ . When $\lambda = 1$, the ratio is stoichiometric, <1.0 it is rich, and >1.0 it is lean. The EGO sensors in use today must be hot ($\approx 600^\circ\text{F}$) to operate properly. When they are working properly, carbon monoxide, hydrocarbons, and nitrogen oxides are controlled.

Exhaust Gas Recirculation (EGR)

To reduce NO_x emission, part of the exhaust gas is recirculated through the EGR valve to the intake manifold to lower the maximum combustion temperature. Sensor inputs are

engine coolant temperature and throttle position.

Fueling the Engine

Sensors are used in conjunction with delivering fuel to the engine. The quality and composition of alternative fuels and fuel mixtures is becoming increasingly important.

Accurate measurement of methanol concentration in gasoline as an alternative fuel is important for performance and emission control. Methanol sensors allow changes in spark time and fuel injection for performance optimization. One methanol sensor uses capacitance, temperature, and conductance to measure methanol concentration.

Ignition

Spark plug timing detonates the fuel/air mixture in the combustion chambers at the proper (but variable) time due to other engine parameters. This function was previously handled by mechanical cams, manifold vacuum diaphragms, and breaker points before the mid-1970s. Hall effect vane sensors can provide the signal to fire. A ferrous metal lobed wheel breaks the magnetic field pattern between the sensor and magnet. The number of lobes equals the number of cylinders.

Primary sensor inputs are engine speed, MAP, and crankshaft and camshaft position.

Transmission Control

Primary sensor inputs from the transmission are gear selection, transmission oil temperature and pressure, throttle position and throttle body, vehicle speed, and accelerator pedal position.

6. HVAC

The HVAC system provides heated or cooled and dehumidified air to the cabin. Newer systems can also sense pollutants from vehicle exhausts, pollen, and dirt, and employ filtration.

The system is locked out of operation during certain conditions. Sensors are used to deactivate the a/c system when operation could damage it. Low refrigerant, low ambient air temperature, and various combinations of heater and defroster selections will lock out the a/c system.

Typical sensor inputs to the HVAC system are high-side and low-side refrigerant pressures, fluid temperature, ambient air temperature, and cabin temperature. Advanced systems use carbon monoxide, hydrocarbon, and dust and pollen sensors. Hydrocarbons can build up during traffic jams and in parking structures.

7. Navigation (NAV)

Early navigation systems consisted of trip computers that gave various trip statistics such as fuel and range information.

Global Positioning System

NAVSTAR satellites provide signals to GPS receivers. The signals contain satellite information and time information. When three satellite signals are received, they can be used to establish a three-dimensional receiver location. GPS are being installed in some vehicles. Sophisticated systems show map overlays with vehicle position superimposed. Sensor input is RF energy.

8. Safety

A number of systems utilize sensors to increase personal safety and reduce the risk of injury to vehicle occupants.

Fuel, Electrical Fuel Pump, and Battery Cutoff

After sensing a crash, this system reduces the probability of secondary damage from fire. It can cut off one or more of the following: fuel flow, electric fuel pump, natural gas supply, and electric power (including that on all-electric vehicles). The primary sensor input is crushing or acceleration.

Emergency Door Unlock

After sensing a crash from crush sensors or acceleration sensors or both, the CPU actuates a door-unlocking system. This allows rescue workers to enter the vehicle for passenger removal more easily than if the doors were locked and the passengers were unable to help. The primary sensor input is crushing or acceleration.

Commercial Transportation

There are special cases for systems and sensors in public transportation. For instance, there are instances when a public bus or commercial coach should not move, such as during fueling and taking on passengers. A proximity sensor in the fueling door can lock out transmission engagement if the door is open. A proximity sensor or some other sensor can be used to alert the driver that a wheel chair ramp has not been stowed; the transmission can also be locked out. The primary sensor input is proximity.

9. Smart Cruise Control

Smart cruise control uses all the features and sensors of ordinary cruise control plus the addition of collision avoidance sensors. A CPU receiving input on vehicle speed and the range ahead to a leading vehicle can make speed adjustments. This prevents tailgating or inadvertently having a rear-end collision with a leading vehicle. The system can be activated for highway speeds or for stop-and-go sluggish traffic conditions. The technology is available but the decision algorithms needed to use it are still under discussion.

Primary sensor inputs are vehicle speed, brake pedal force, and forward proximity to other vehicles and closing rate.

10. Suspension

For improved vehicle handling, safety, and comfort, suspension control systems have been developed. Two basic types of suspension systems use sensors: the adaptive system and the active system.

Adaptive System

The individual stiffness of the system is varied with input from sensors for vehicle speed, steering wheel velocity, gearbox and engine speed, throttle position, and wheel attitude and position. This changes the ride characteristics considerably.

Active System

Beyond an adaptive system, the CPU receives information on vehicle-corner height above the road. The system equalizes the inclination of the vehicle by using jacks to assist the springs by air pressure, hydraulics, or electric power.

Special Load Leveling

Heavy trucks and large recreational vehicles (RVs) are other potential applications for suspension leveling systems. Motor homes can use a load-leveling auxiliary jacking system for parking on uneven ground.

11. Testing

A special use of sensors is in testing of vehicles during R&D. Today's R&D sensors and systems often become tomorrow's production option and then standard equipment later. R&D sensors incorporate all systems and applications used in production vehicles. They are generally much more sensitive and are connected to automatic and remote data-recording devices. For example, they detect:

- Complete wheel dynamics, position, and attitude.
- Very precise steering wheel information, including torque, position, velocity, and acceleration.
- Precise vehicle forward and lateral velocity (drift).

12. Security

Vehicle security includes systems and sensors to physically safeguard the vehicle when it is unattended.

Antitheft

Antitheft devices usually require several sensors. Audio sensors tuned to the frequency of breaking auto glass can warn of attempted forced entry. Simple to sophisticated sensors can be used to detect

shock or acceleration from forced entry, also. Proximity sensors can be used to give an audible warning that the vehicle is armed and alarmed. Some sensors use microwave field disturbance of the entire interior cabin and immediately adjacent outside space to detect intrusion. The primary sensor input is acceleration, shock, glass breakage acoustics, or microwave field disturbance.

Remote Locking and Unlocking

Keyless entry allows the doors and trunk of a locked vehicle to be unlocked as the driver approaches the vehicle, and locked as the driver leaves it. This saves the driver the inconvenience of using the key when carrying parcels or during inclement weather.

VEHICLE APPLICATIONS

There are more than 100 specific applications or uses for sensors on automotive vehicles. Not every sensor is found on any one automobile. In general, the more expensive the vehicle, the more sensors and the higher level of performance and comfort it will have. Below is a partial list of sensor uses.

1. a/c clutch cycling
2. accelerator pedal position
3. air/fuel mixture ratio
4. air/fuel mixture temperature
5. airbag stored gas pressure
6. ambient air pressure (barometric)
7. ambient air temperature
8. axle oil level
9. battery charging
10. battery voltage
11. brake fluid level
12. brake line pressure
13. brake pad/rotor wear
14. burned out lamps
15. cabin air quality
16. cabin carbon monoxide concentration
17. cabin temperature
18. camshaft position
19. camshaft speed
20. child seat orientation
21. child seat presence
22. combustion occurrence/quality
23. coolant level
24. coolant temperature
25. crankshaft position
26. crankshaft speed
27. crash detection
28. cylinder head temperature
29. cylinder number identification
30. cylinder pressure
31. door ajar
32. door release
33. doors locked
34. driver's eye movement
35. driver orientation
36. driver presence
37. driver size, height, weight
38. EGR carbon monoxide concentration
39. EGR flow rate
40. EGR oxygen concentration
41. engine knock
42. engine oil level
43. engine oil pressure
44. engine oil viscosity
45. engine speed
46. engine torque
47. forced entry—breaking glass
48. forced entry—shock
49. forward proximity
50. fuel injection pressure
51. fuel level
52. GPS signals
53. ground speed
54. hood tilt
55. HVAC high-side fluid pressure
56. HVAC low-side fluid pressure
57. ice
58. Lambda, λ , actual A/F : stoichio. A/F
59. lateral proximity
60. law enforcement radar
61. lumbar support position
62. manifold absolute pressure (MAP)
63. manifold air temperature (MAT)
64. mass air flow (MAF)
65. methanol/gasoline ratio
66. misfire
67. passenger orientation
68. passenger size, height, weight
69. passenger presence
70. radio entertainment
71. radio two-way communications
72. rear proximity
73. remote car-starting signal
74. remote door-opening signal
75. road surface condition
76. seat restraint fastened
77. seat tilt position
78. seat track position
79. side crash detection
80. steering wheel angle
81. steering wheel velocity

82. suspension position	94. vehicle forward acceleration
83. throttle body air temperature	95. vehicle forward speed
84. throttle position (TPS)	96. vehicle height above road
85. tire pressure	97. vehicle inclination
86. transmission oil level	98. vehicle lateral acceleration
87. transmission oil temperature	99. vehicle lateral speed
88. transmission oil viscosity	100. vehicle yaw rate
89. transmission shift position	101. wheel attitude/position
90. transmission speed	102. wheel speed
91. trunk ajar	103. windshield contamination
92. trunk tilt	104. windshield mist/water
93. turbo/supercharger boost	105. windshield washer fluid level

ENVIRONMENT

Power Supply Considerations

Power will usually be provided by the automobile battery (nominally 12 V) or through the on-board microcontroller PC board that provides a regulated 5 V.

Battery voltage varies from 8.5 to 14.6 during normal operation. It can drop far below this range during cold-weather starts and climb far above if the charging system malfunctions. The possibility of reversed voltage during installation and double voltage during a jump start is a hazard. Voltage transients of ± 60 V occur, also. Electromagnetic interference (EMI) is part of the vehicle environment.

Temperature Ranges

Vehicle sensors must operate in ambient-air temperatures of $+55^{\circ}\text{C}$ in Arizona to -40°C in Alaska.

Typical temperature ranges are:

Passenger Compartment	-40 to $+85^{\circ}\text{C}$
Engine Compartment	-40 to $+125^{\circ}\text{C}$
Trunk and Chassis	-40 to $+110^{\circ}\text{C}$
Braking System	-40 to $+180^{\circ}\text{C}$

Extreme temperatures can reach 180°C in the engine compartment and 250°C in the braking system.

Chemical

Sensors may be exposed to chemicals such as gasoline, brake fluid, transmission fluid, coolant, oil, water, and windshield washer fluid.

Assembly Stress

During installation in the automobile, sensors can undergo rugged handling. One-way keyed assembly is often used to prevent improper insertion. The 48-in. drop test is standard for shock durability testing to simulate drops during assembly.

PROPERTY SENSED

There are many properties sensed in automotive vehicle applications and subsystems. **Property sensed** is a useful way to classify sensors. The following list is being used in this study.

1. acceleration—angular
2. acceleration—linear
3. altitude
4. conductivity
5. crushing
6. distance—traveled
7. distance—ranging
8. flow—fluid
9. flow—volume
10. force
11. hydrocarbons
12. ice
13. level—fluid
14. microwave radiation
15. motion
16. NO_x (oxides of nitrogen)
17. oxygen
18. position—angular
19. pressure—absolute
20. pressure—air
21. pressure—barometric
22. pressure—differential
23. pressure—fluid
24. pressure—gas
25. proximity
26. RF radiation
27. sound—intensity
28. temperature
29. tilt
30. torque
31. velocity—linear
32. velocity—angular
33. viscosity

TECHNOLOGY

Sensors make use of many technologies. Below are listed common technologies used in automotive sensors described in this report.

1. **acoustic:** sound waves.
2. **capacitive:** two electrical nonconducting surfaces, separated by a dielectric material that stores a charge.
3. **Doppler:** frequency shift due to relative motion of transmitter and receiver.
4. **electromagnetic:** coupled electrical and magnetic field flux.
5. **electromechanical:** mechanical or physical device with electrical control or actuation.
6. **giant magnetoresistance (GMR):** large magnetoresistance or change in electrical resistance due to a magnetic field.
7. **Hall effect (HE):** semiconductor carrying a current in a magnetic field normal to the current flow creates a voltage potential in the semiconductor normal to the current flow in the semiconductor.
8. **hot film/wire anemometry:** electrical resistance change with temperature change due to convective cooling of wire or film in gas flow.
9. **inductance:** oscillating circuit current caused by metallic (ferrous or nonferrous) object or another circuit.
10. **infrared (IR):** thermal radiation with longer wavelengths than visible light.
11. **laser:** natural vibration of molecules in a media to generate extremely coherent electromagnetic IR, visible, or ultra-violet (UV) light.
12. **magneto-optic:** influence of a magnetic field on light.
13. **magnetoresistive:** change in electrical resistance due to a magnetic field change.
14. **magnetostrictive:** change in dimension of a ferromagnetic body caused by a change in its state of magnetization.
15. **micromachined silicon:** machining of silicon by fine chemical etching.
16. **microwave:** electromagnetic wave between about 1 mm and 1 m in wavelength.
17. **optical:** lenses, prisms, mirrors, and light, usually in the visible wavelengths.
18. **optoelectronic:** electronic device for emitting, modulating, transmitting or sending light.
19. **piezoelectric:** material that produces electrical current or polarity when subjected to pressure.
20. **piezoresistive:** material that changes electrical resistance when subjected to pressure.
21. **potentiometric:** electromechanical device that changes voltage proportional to physical movement of a sliding arm.

- 22. **radio frequency:** electromagnetic wave frequency between audio and IR (below 3 kHz to 300 GHz).
- 23. **strain gauge:** measures minute material-length deformations or changes.
- 24. **thermal:** variety of properties that may change with temperature.
- 25. **thermistor:** semiconductor that changes electrical resistance sharply with temperature.
- 26. **thick film:** piezoresistive material sensitive to temperature or stress, applied in layers by screen printing.
- 27. **ultrasonic:** acoustic frequencies above human hearing, or >20,000 Hz.
- 28. **variable reluctance (VR):** changing material voltage corresponding to changing magnetic flux.
- 29. **vortex shedding:** vortices (Von Karman stream) generated behind a bluff body are proportional to the air flow rate; ultrasonic or pressure sensing of vortex rate is detected.
- 30. **zirconium oxide:** heated sensor ion pump to detect oxygen

Sensor Types

Selected sensor types are discussed below.

Variable-Reluctance Sensors (VR)

This is a magnetic sensor composed of a permanent magnet wrapped with a winding

of wire. It is used with a reluctance wheel, i.e., a notched or toothed wheel. Reluctance wheel rotation near the tip of the sensor changes the magnetic flux, creating an analog signal in the coil. VR sensors are reliable and need no power supply. This is the technology of choice for ABS wheel-speed sensing. VR can have a larger air gap (<2 mm) than HE (<1.5 mm) and is cheaper than HE. Two electrical wires are needed for the signal. VR provides an unreliable signal below about 3 mi/h.

Vane Hall Sensor

In this device, current flow is applied to a semiconductor in the presence of an external magnetic field. This creates a voltage proportional to the magnetic field strength. The output is a sine wave signal. Magnetic field changes, caused by a reluctor wheel or vane-type interrupters, cause the sensor to generate a digital voltage. These sensors can be used at zero and near zero speeds and are robust in noise.

Hall Effect (HE)

This is the technology of choice for engine applications. Small, well-controlled air gaps can be maintained, but cost is higher because rare-earth magnets are required. An HE device needs external power, often with three electrical wires; this can sometimes be reduced to two wires if a shunt circuit is added at additional cost. Output is a crisp square wave.

Gear-Tooth Hall Sensors

This sensor combines the Vane Hall sensor and the reluctance-sensing capability of a variable-reluctance sensor. A rotating

reluctance wheel near the face of the sensing element causes a voltage change in the Hall elements as the magnetic flux changes. Voltages from the elements are compared and converted to an accurate digital signal. Both zero and near-zero speeds can be sensed. They are accurate and robust in a noisy environment.

Magnetoresistive Sensors

Magnetoresistance is the related change in electrical resistance in the presence of a magnetic field. The operation is similar to that of gear-tooth Hall sensors. Magnetic flux changes caused by rotation of the reluctor wheel in turn causes electrical resistance changes in the magnetoresistive elements. Comparison and conversion of the resistance level differences yield an accurate digital voltage signal. Zero speed can be sensed. They have highly repeatable switch points and can be used for misfire detection.

Giant Magnetoresistance (GMR)

GMR is basically similar to HE or magnetoresistance. GMR was developed by French researchers in 1988. Thin films of conductive, nonmagnetic metals sandwiched between magnetic layers are used to produce GMR sensors. External magnetic fields cause the outer layers to align parallel, which decreases the resistance in the middle conductive layer and thereby magnifies the GMR effect. The optimal conductive copper layer is thought to be ≈ 1.5 to 2.0 nm thick, and the magnetic layer 6 to 8 nm. GMR can tolerate an air gap of up to 3.5 mm. The sensor can fit in a small package (approx. 0.036×0.036 in.); this is about one-quarter the size of a comparable HE sensor.

Micromachined Silicon Piezoresistive Pressure Sensor

A silicon chip is micromachined by chemical etching to provide a pressure-sensing function by using the piezoresistive property of silicon. An IC chip is often integrated with the pressure-sensing chip for signal conditioning, temperature compensation, and amplification.

Micromachined Silicon Accelerometer Sensor

A cantilevered sensor beam is micromachined by chemical etching in a silicon chip. The tiny inertial mass and flexure elements are machined from one piece of silicon. The seismic mass is cantilevered between two plates that act as electrodes. The capacitance changes as the cantilevered beam flexes due to acceleration. The plates shield the beam from damage during high acceleration. Entrapped air or a squeeze film damps the mass. The sensor is combined with an IC chip to produce a proportional analog output. Positive and negative accelerations can be sensed in the same device. The IC chip can provide signal conditioning, amplification, and temperature compensation. These sensors usually have a wide useful range of acceleration values.

Vortex-Shedding Mass Flow Sensor

A rapidly moving fluid passing over a bluff body in the flow produces a continuous stream of vortices known as a Von Karman vortex street. Vortex generation is proportional to flow rate. Sensing the rate of vortex formation will be proportional to the volume flow rate, usually of air. The vortex

formation rate can be sensed by a pressure sensor or an ultrasonic sensor.

Metal Beam Capacitive Accelerometer

Texas Instruments uses a metal beam capacitive device for a low-g accelerometer. The capacitive element is an etched metal blade that is welded to a substrate. The metal blade is Alloy 41, a common semiconductor material used in lead frames. The substrate is alumina ceramic. The substrate is metalized by screen printing with a thin film of gold ink. Squeeze-film air damping is used. Table 1 compares several types of low-g acceleration sensors.

Table 1 Comparison of Low-g Acceleration Sensors

Method	Cost	Durability	DC Response
Hall/MR	poorer	poorer	average
LVDT	poorer	poorer	average
Micromachined Silicon	poorer	average	good
Piezoelectric	good	average	poor
Metal Beam Capacitive	good	good	good

Information Source: Texas Instruments

SPECIFIC-USE SENSORS

Knock Detection

Knock is perceived as an unpleasant noise to drivers. It is caused by a particular detonation pattern in the combustion chamber. An accelerometer tuned to the expected frequency range can provide a signal to change engine control parameters, such as ignition timing, to avoid knock. The frequency band of knock is 7 to 17 kHz.

Tire Pressure Sensor

SSI will have a prototype remote tire-pressure sensor in November 1995. The main purpose is to eliminate the spare tire. The four tires would be run-flats with separate bladders or another technique for support when air is lost. The tire sensor would alert the driver that pressure has dropped.

In one scheme, a piezoresistive silicon pressure sensor is embedded in the metal wheel (rim). It is inductively coupled to a receiver. No external power is supplied to the sensor. The sensor gets its power inductively by rotating with the tire. A small antenna with an air gap of 20 to 30 mm picks up the signal. The reading is then sent to the CPU to alert the driver.

In another scheme, the ABS speed sensors look for changes in wheel speed among the four tires. A logic device would then infer low air pressure. All four tires would have to be the same size and have the same amount of wear.

ABS Tire Considerations

A spare tire that is a smaller than the other three tires can interfere with the normal

working of an ABS. ABS systems work to reduce the differential speed among all four tires. This is also a problem if the four tires have greatly unequal wear. It is sometimes recommended that tires for ABS-equipped cars be changed in sets of two or even four for maximum effectiveness.

Micro-Impulse Proximity Radar

A wideband, spread-spectrum radar, Micro-Impulse, has been invented at Lawrence Livermore Laboratory. It has been licensed to Amerigon Inc. and AlliedSignal's Automotive Division. This device is expected to find applications for the driver's blind spot, providing backing-up help and as a parking aid. Cost is predicted to be under \$10.00 per unit. The transmitter emits pulses as short as 50 trillionths of a second. Range of the device is claimed to be up to 200 ft. [Lawrence Livermore National Lab press release NR 94-03-20]

Radar-Laser Proximity

Preview Distance Control (radar-laser) is being developed by Mitsubishi. The device measures the distance ahead to the next vehicle. A miniature video camera provides visual identification. [Automotive Industries, p. 86, June 1995]

Millimeter Wave (MMW) Proximity Sensor

Delco Electronics is developing a proximity sensing system called FOREWARN. It has a device that looks forward at 77 GHz and a rearward-looking device at 24 GHz. The driver is given an audible alarm and a momentary brake pulse. An EyeCue heads-up display (HUD) can be used to give a reconfigured image to the driver. [Automotive Industries, p. 86, June 1995]

FUTURE DIRECTIONS

Advanced Braking and Traction Control

A combination of braking and traction control with lateral acceleration and yaw rate sensors allows drivers to maneuver on sheet ice without spinning or losing control. Vehicles with such systems will be introduced in Europe in 1996 and in the U.S. a year or two after that.

Active Collision Avoidance

This system would not only give the driver warnings but would actually take over vehicle operation. Many issues remain to be worked out. Such a system would not be available for some years, but it is possible. It will require a wider array of sensors and more sophisticated logic than presently available, in order not to do more damage than it avoids.

Super-Smart Highways

Super-smart highways and vehicles in the future will allow unattended driving. This will increase the demand for and capability of a wide range of sensors. Each vehicle on the highway will be managed by a highway control system. On-board and stationary sensors, actuators, and communications will be needed.

U.S.A.

Intelligent Vehicle Highway System (IVHS) is a program for a very advanced future highway. The vehicles are guided to a great extent automatically. This program is jointly funded by the National Highway Traffic Safety Commission and the Advanced

Research Projects Administration (ARPA). It focuses on sensors and communications and is a \$600 million, six-year program.

Europe

The PROMETHEUS program is sponsored by European automobile manufacturers. Begun in 1986, it is a part of the larger technical research initiative, EUREKA. DRIVE is another European program that is concerned with the infrastructure to create an intelligent future highway system.

The programs are concerned with collision avoidance, cooperative driving using vehicle-to-vehicle communications, route/map guidance and driver vision enhancement. The systems provide travel and traffic information.

Exhaust Silencing

Engine exhaust noise is generated by the pulsating pressure variations related to each cylinder releasing high-pressure gas through the exhaust valve as the engine cycles. If the pulsations are matched in magnitude, but 180° out of phase, the resultant noise can be greatly reduced. Such systems are under development and will require sensors to coordinate the amplitude and phase generation of the counterwave to cancel the original muffler noise.

Oil Monitoring

Monitoring the oil quality in the engine and transmission has the potential benefit for economy, environmental improvement and damage avoidance. To protect themselves, OEMs specify fixed intervals for oil replacement with little modification except for fleet use or very dusty conditions. A great deal of oil is wasted by too-frequent oil

changes. Because engine and transmission damage can occur if the oil becomes degraded before being changed, sensors will be installed in the engine crankcase and transmission to warn the driver of the need for an oil change. The sensor will probably look for a viscosity change. This would reduce the environmental impact of recycling and disposing of automotive oils prematurely.

Variable Valve Timing (VVT)

VVT is available on a few models now and has been tried before by General Motors (GM) in a limited sense. The major impact of VVT is still to come. VVT will require sensor input for maximum effectiveness and can have several degrees of sophistication. The original GM attempt was to idle some cylinders not needed for power during cruise conditions for economy. The ultimate use will be to control each valve individually to such an extent that the throttle will not be necessary. VVT allows modification and control of the timing and of the fuel/air charge into each cylinder for maximum efficiency, sound reduction, and emission control.

Honda's 2.2 L Variable Valve Timing and Lift Control (VTEC), 4-cylinder engine was selected as one of the 10 best engines of 1995 by *Ward's Auto World magazine* [pp. 28-37, Jan. 1995]. *The VTEC engine provides different valve timing for various speed ranges.*

Smart Cruise Control

Smart cruise control uses all the features and sensors of ordinary cruise control plus the addition of collision avoidance sensors. A CPU receiving input on vehicle speed and the range ahead to a leading vehicle can

make speed adjustments. This prevents tailgating or inadvertently having a rear-end collision with a leading vehicle. The system can be activated for highway speeds or for stop-and-go sluggish traffic conditions. The technology is available but the decision algorithms needed to use it are still under discussion.

Primary sensor inputs are vehicle speed, brake pedal force, forward proximity to other vehicles, and closing rate.

Navigation System

Advanced systems that will program routes to selected destinations are coming. A corresponding electronic view of position would be given to the driver and updated rapidly. Nissan calls their development system "BirdView" because it provides a bird's-eye representation to the driver. It is updated every 1.5 to 3.0 sec.

Transmitter Headlights

New headlights could have their spectra changed to, for example, incorporate more UV in order to be more visible to other vehicles' sensors. Other "transmitters" may be added to all vehicles in order to enhance communication with other vehicles. This concept is like adding a radar reflector to enhance return echoes.

Steer-by-Wire

Steer-by-wire, like fly-by-wire, will eventually come to automobiles. Indirect sensing of the driver's intent by, say, a joystick rather than hard mechanical linkages will be developed. Speed of movement, grip pressure, etc., could be added signals from the driver to signal intent. This type of combined speed and direction, or possibly

other driving-intent functions, will have an implication for sensor development and integration.

Electric-Powered and Hybrid-Fueled Vehicles

Experts predict that by about 2005 automotive vehicles that are all-electric or hybrid-fueled will be made in significant quantities. This will change the "engine management" system a great deal from what it is today. Sensors for battery operation, charging, condition, fuel cell monitoring, kinetic energy storage, and many other parameters will need development. Driver aids to operate the vehicle efficiently and safely will still rely on sensor input to the CPU.

Data Transmission

More attention will be given to data handling and transmission in future vehicles as more

sensor information and actuator instructions are handled. Data transmission must be shielded from the electromagnetic interference (EMI) that is common in vehicles. Transmission rates from 10,000 to 125,000 baud are required today.

Smart Card for Cars

Smart cards are making their way into many aspects of daily life. They will probably also do so in automotive vehicle. Card-to-CPU and system communication could take place. The card could replace the function of keyless entry and security and remember all the drivers' preferences. Maintenance and other data from sensors may be transmitted to and stored on the smart card. Security for the card due to unauthorized use may require more sensors if the card is lost or stolen.

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APPENDIX 1: COMPANY DATA

AlliedSignal Filters and Spark Plugs Div.

28399 Cedar Park Blvd.

Perrysburg, OH 43551

Customer Service

Rose Osmena

419-661-6765

Product: oxygen sensor

Technologies: zirconium oxide, heated

Applications: exhaust gas, air/fuel ratio

Alpha Industries Inc.

20 Sylvan Rd.

Woburn, MA 01801

Earle Stewart

617-935-5150

Fax: 617-935-0159

Product: radar

Technologies: 77 GHz millimeter-wave

Applications: crash avoidance, intelligent
cruise control

AMP Inc.

P.O. Box 799

Valley Forge, PA 19482

Sales Manager

Glen MacGibbon

610-666-3505

Product: piezoelectric polyvinylidene
fluoride (PVDF) film

Technologies: piezoelectric

Applications: temp., acceleration, IR,
acoustic

Analog Devices

804 Woburn St.

Wilmington, MA 01887

Auto Marketing Manager

William Riedel

617-937-1670

Product: accelerometer, Hall Effect sensors

Technologies: micromachined polysilicon,
Hall effect

Applications: ACRS, brake/traction,
suspension

Automotive Technologies International, Inc.

37633 Schoolcraft Rd.

Livonia, MI 48150

Scott S. Turner

313-432-0444

Fax: 313-432-0062

Product: CrushSwitch

Technologies: electromechanical

Applications: ACRS, front, side, vehicle
occupant

BLD Products Ltd.

534 East 48th St.

Holland, MI 49423

Sale Manager

Terry Nyboer

616-396-1291 x5620

Fax: 616-395-5605

Product: temp., press., position sensors

Technologies: thermistor, piezoresistive,
magnetic field

Applications: eng. mgt

Breed Technologies, Inc.

5300 Old Tampa Highway

P.O. Box 33050

Lakeland, FL 33807-3050

Market Analyst

Stephanie O'Neil

941-384-6505

Product: accelerometer, crash detection

Technologies: micromachined silicon

Applications: ACRS

CTS Corp.

Automotive Products
17370 North Laurel Park Dr., Suite 400E
Livonia, MI 48152
Senior Account Manager
Gerald F. Cornetet
313-591-5475
Fax: 313-591-4523
Product: pedal position, Hall, EGR
Technologies: potentiometer, Hall
Applications: eng. mgt, suspension

DATRON Technology, Inc.

Suite 180
33533 West Twelve Mile Rd.
Farmington Hills, MI 48331
Hank Norlin
810-489-3140
Fax: 810-489-3144
Product: speed, distance, drift, steering
Technologies: optoelectronic, microwave,
Doppler
Applications: automotive testing

Delco Electronics Corp.

MS: CT10K
One Corporate Center
Kokomo, IN 46902
Business Manager
Greg Schwandt
317-451-0751
Product: pressure sensors
Technologies: piezoresistive silicon
Applications: eng. mgt.,

Delphi

Rm. 18-108
2401 Columbus Ave.
Anderson, IN 46018
Marketing Mgr. Sensors/Solenoids
Jodie Collignon
317-646-2800
Fax: 317-646-7778
Product: ignition, eng. spd., veh. spd., wheel
spd.
Technologies: variable reluct., Hall,
magneto resist.
Applications: eng. mgt., brake/traction

FASCO Controls Corp.

23800 W. Ten Mile Rd.
Southfield, MI 48034-3176
VP Sales & Marketing
Dennis M. Fedolak
810-358-3600
Fax: 810-358-3608
Product: door-ajar, pres. switches, position
Technologies: electromech., , HE
Applications: eng. mgt., safety

First Inertia Switch

G10386 North Holly Rd.
P.O. Box 704
Grand Blanc, MI 48439
Sales Administrator
Deedee Grant
810-695-8333
Fax: 810-695-0144
Product: accelerometer, crash sensors,
wheel pos.
Technologies: electromechanical,
micromachined silicon
Applications: emergency door unlock, fuel
shut-off

GE Control Products

Automotive Systems Control
West Wall St.
Morrison, IL 61270
Tim Seifert
815-772-1380
Fax: 815-772-1184
Product: pressure, temperature sensors
Technologies: thermistor, strain gauge
Applications: A/C refrigerant pressure and temperature

Hi-Stat Manufacturing Co.

Suite 200
2350 Franklin Rd.
Bloomfield Hills, MI 48302
Account Manager
Robert Melenovsky
810-332-2280
Fax: 810-332-2296
Product: pres., temp., speed, level, sensors
Technologies: capacitive, thermist., VR, Hall, electromechanical.
Applications: eng. mgt., brake/trac., HVAC

Hitachi America Ltd.

Automotive Products Division
34500 Grand River Ave.
Farmington Hills, MI 48335
Kim Postema
810-474-2800
Product: comprehensive lines
Technologies: numerous
Applications: eng. mgt., brake/trac., suspen., HVAC, NAV

Holley Automotive Division

11955 East Nine Mile Rd.
P.O. Box 2003
Warren, MI 48090-2003
Manager Market Development
Michael Magnoli
810-497-4517
Fax: 810-497-4103
Product: throttle position
Technologies: potentiometer
Applications: eng. mgt

Honeywell Micro Switch

11 West Spring St.
Freeport, IN 61032-4353
Marketing
Judy Libertain
815-235-6847
Product: comprehensive lines
Technologies: numerous
Applications: eng. mgt., comfort, safety, brake/trac., etc.,

Kavlico

14501 Los Angeles Ave.
Moorpark, CA 93021
Marketing Communications Consultant
Lori Appel
805-523-2000 x2206
Fax: 805-523-7125
Product: pres., temp
Technologies: capacitive-ceramic
Applications: eng. mgt., brake/trac., suspension

Kelsey-Hayes

11878 Hubbard
Livonia, MI 48150
Marketing
Carol L. Merritt
313-513-4854
Fax: 313-513-4457
Product: Vehicle Stability Management
System
Technologies: various
Applications: advanced brake/traction
system

Kistler Instrument Corp.

75 John Glenn Dr.
Amherst, NY 14228-2171
Marketing Manager
Bruce Lent
716-691-5100
Fax: 716-691-5226
Product: accelerometer, cylinder pres,
Technologies: micromach., silicon,
piezoelec., piezores.
Applications: eng. mgt, R&D

Lucas Automotive

5500 New King St.
P.O. Box 7002
Troy, MI 48007-7002
Eng. Mgr. Actuation & ABS
Patrick Hool
810-641-2500
Fax: 810-641-1905
Product: Electronic Actuation System
Technologies: various
Applications: brake/traction advanced
system

Lucas Electronics Systems Products

1000 Lucas Way
Hampton, VA 23666
Account Development Director
Malcolm Graham
804-766-4461
Fax: 804-766-2286
Product: pressure, acceleration
Technologies: micromachined silicon,
piezoresistive
Applications: eng. mgt., brake/traction,
HVAC, safety

Lucas NovaSensor

1055 Mission Court
Fremont, CA 94539
Marketing Manager
Dale Dee
510-490-9100
Fax: 510-770-0645
Product: pressure, acceleration
Technologies: micromachined silicon
Applications: Eng. mgt., tire, ACRS

Mitsubishi Electronics America, Inc.

46501 Commerce Center Dr.
Plymouth, MI 48170
Chief Engineer
William Bracken
313-453-6200
Fax: 313-453-6211
Product: temp., pres., A/f, position, motion
sensors, etc.
Technologies: laser, ultrason., hot wire/film,
thermistor, VR, Piez., etc.

Motorola

Sensor Products Division
 5005 East McDowell Rd.
 Phoenix, AZ 85008
 Strategic Marketing Manager
 Marty Levy
 602-244-3362
 Fax: 602-244-4201
 Product: pressure, accelerometer, temp.
       sensors
 Technologies: piezoresistive,
       micromachined silicon, thermistor
 Applications: MAP, altimeter, ACRS,
       air/liq. temp

Nippondenso America Inc.

24777 Denso Dr.
 P.O. Box 5133
 Southfield, MI 48086-5133
 Account Manager
 Thomas McInerney
 810-213-2344
 Fax: 810-350-7773
 Product: comprehensive lines
 Technologies: numerous
 Applications: HVAC, ACRS, brake/trac.,
       safety, comfort

Phillips Technologies (old Airpax)

Suite 308
 32605 W. Twelve Mile Rd.
 Farmington Hills, MI 48334
 Director Business Development
 Jack Obermeyer
 810-553-6030
 Fax: 810-553-6025
 Technologies: speed, position
 Applications: variable reluctance,
       magnetoresistive

Polaroid

119 Windsor St. - 2B
 Cambridge, MA 02139
 Applications Manager
 Philip W. Jackman
 617-386-3961
 Fax: 617-386-3966
 Product: Ultrasonic Ranging System
 Technologies: ultrasonic, piezo
 Applications: collision avoidance

Rathsburg Associates, Inc.

(distributor for Analog Devices, etc.)
 41100 Bridge St.
 Novi, MI 48375-1300
 Sales Engineer
 William Kittle
 810-615-4000
 Fax: 810-615-4001
 Product: auto elec. mfg. rep.
 Applications: auto sensors and actuators

Robert Bosch Corp.

Automotive Group
 3800 Hills Tech Dr.
 Farmington Hills, MI 48331-3417
 Roman Serra
 810-553-1390
 Product: tilt pres., CO, acceleration, etc.
 Technologies: thermal, PR, thick film,
       piezo-ceramic
 Applications: eng. mgt.,

Siemens

Auburn Hills, MI
 Account Manager North American Sales
 Rick Wilson
 810-252-1000
 Technologies: variable reluctance, Hall
       Effect
 Applications: NOx, MAF, wheel speed,
       trans. speed

Siemens

2400 Executive Hills Dr.
Auburn Hills, MI 48326-2980
Manager North American Sales
Richard Wilson
810-253-2874
Fax: 810-253-2998
Product: comprehensive lines
Technologies: numerous
Applications: eng. mgt., safety, comfort,
suspension, etc.

Sira Ltd.

South Hill
Chislehurst
Kent BR7 5EH,
England
Projects Manager
Mark Aston
+44 (0) 181 467 2636
Fax: +44 (0) 181 467 6515
Product: fuel flow, steer. wheel,
Applications: eng. mgt

SSI

24114 Research Dr.
Farmington Hills, MI 48335
Market Development Manager
Jeffrey A. Valdovinos
810-471-0500 x21
Fax: 810-471-0507
Product: wheel speed, ABS, pressure
Technologies: VR, Hall, magnetoresistive.
& optic, PR
Applications: braking/traction

Texas Instruments Inc.

34 Forest St.
P.O. Box 2964
Attleboro, MA 02703-0964
Product Mgr., Precision Controls
Timothy R. Spooner
508-236-3514
Fax: 508-236-1598
Product: pressure, accel, torque, liq. lev.
Technologies: capacitance- ceramic
Applications: HVAC, eng. mgt., ACRS,
brake/trac., etc.

TRW

Transportation Electronics Division
24175 Research DR.
Farmington Hills, MI 48335-2642
Dir. Marketing and New Business
Development
John T. McGowan
810-442-5391
Fax: 810-442-5172
Product: crash, occupant, child seat, sensors
Technologies: piezo-ceramic, Rolamite,
ultrasonic
Applications: front/side airbag,
occupant/child presence

Vishay Dale

2300 Riverside Blvd.
P.O. Box 74
Norfolk, NE 68702-0074
Product Manager
George Ornelas
915-771-6175 x7102
Product: thermistor, thick film resistors
Technologies: thermistors, thick film
resistors
Applications: supplier to sensor mfg., OEMs

Wabash Magnetics

1375 Swan St.

Huntington, IN 46750

Vice President

C.E. Brewer

219-356-8300

Fax: 219-356-3846

Product: VR, HE, pres., pos., fluid, elec.
cur./ sensors

Technologies: VR, HE

Applications: Eng. mgt., brake/trac.,
suspension

Whistler Corp.

16 Elizabeth Dr.

Chelmsford, MA 01824

Marketing Assistant

Pam Downey

508-244-1400

Fax: 508-244-1489

Product: broad line for vehicle security,
keyless entry, remote start

Technologies: electromagnetic, acoustic

Applications: vehicle break-in security

APPENDIX 2: SENSOR DATA

Properties sensed: acceleration, linear

Technology used: various

Application:

Vehicle system: brake/traction-advanced

Supplier: Kelsey-Hayes

Product name: Vehicle Stability System (VSM)

Description: whole system supplier to OEM mkt.

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost: \$200 est.

Development status: new 2/27/95

Comments:

Properties sensed: acceleration, linear

Technology used: thick film (KYNAR)

Application: forced entry- shock, crash detection- front, lateral

Vehicle system: security, ACRS

Supplier: AMP Inc.

Product name: General Purpose Accelerometer

Product number: ACH-01

Description: linear, single axis, low cost accelerometer

Range: +/- 150 g

Sensitivity: 10 mV/g

Accuracy: 0.1 %

Dimensions: 25.4 × 13.08 × 6.2 mm

Weight:

Thermal tolerance: - 40 to + 85°C

Benefits:

Cost: "low"

Development status: production

Comments: max. shock level
1000 g

Properties sensed: acceleration, linear

Technology used: *micromachined silicon*

Application: crash detection

Vehicle system: ACRS

Supplier: Breed Technologies Inc.

Product name: Analog Electronic Sensor

Description:

Range:

Sensitivity:

Accuracy:

Dimensions: 91 × 118.5 × 38 mm

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments: single-point sensor

Properties sensed: acceleration, linear

Technology used: *micromachined silicon*

Application: crash detection

Vehicle system: ACRS

Supplier: Breed Technologies, Inc.

Product name: Digital Electronic Sensor

Description:

Range:

Sensitivity:

Accuracy:

Dimensions: 91 × 121 × 38 mm

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments: single-point sensor

Properties sensed: acceleration, linear**Technology used:**

Application: seat restraint tension
Vehicle system: ACRS
Supplier: First Inertia Switch
Product name: Seat Belt Pre-tension
Description: 60 msec, 6 g half sine impact trigger
Range: 6 g
Sensitivity: 10 msec max. response time
Accuracy:
Dimensions: 80 × 90 × 40 mm
Weight:
Thermal tolerance: -35 to +85°C
Benefits:
Cost:
Development status: production
Comments: fires a detonator

Properties sensed: acceleration, linear**Technology used:**

Application: battery voltage (cutoff after crash)
Vehicle system: safety
Supplier: First inertia switch
Product name: Battery Cutoff Sensor
Description: 60 msec + half sine + 20 g
Range: 20 g
Sensitivity: not to operate at 12 g
Accuracy:
Dimensions: 80 × 42 × 105.8 mm
Weight:
Thermal tolerance: -40 to +125°C
Benefits:
Cost:
Development status: production
Comments:

Properties sensed: acceleration, linear

Technology used: *electromagnetic*

Application: fuel flow

Vehicle system: safety

Supplier: **First Inertia Switch**

Product name: Fuel pump shutoff

Product number: 505

Description: must operate 60 msec
+16 g

Range: 6-16 g

Sensitivity: must not operate
60 msec +6 g, 8 g, or
10 g

Accuracy:

Dimensions: 70 × 35 × 38 mm

Weight: 1.6 oz.

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: acceleration, linear

Technology used: *electromagnetic*

Application: fuel flow (shutoff:
elec., CNG or gas)

Vehicle system: safety

Supplier: **First Inertia Switch**

Product name: Fuel pump shutoff

Product number: 500

Description: must operate 60 msec
+20 g

Range: 20 g

Sensitivity: must not operate
60 msec +12 g

Accuracy:

Dimensions: 76 × 50 × 30

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: acceleration, linear

Technology used: micromachined silicon

Application: vehicle forward/lateral acceleration

Vehicle system: suspension-active/adaptive

Supplier: First Inertia Switch

Product name: Vehicle Body Accelerometer

Description: optimum vehicle handling device

Range: +/- 2 g

Sensitivity:

Accuracy: 5%

Dimensions: 85 x 46 x 35 mm

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments: single or dual axis possible in one device

Properties sensed: acceleration, linear

Technology used: electromagnetic

Application: suspension, door release

Vehicle system: suspension, safety

Supplier: First Inertia Switch

Product name: Impact-Operated Mini-sensors

Product number: 510/6, 510/0.3, 514/6, 512/6

Description: family with specific trigger/no-trigger

Range: 6-10 g

Sensitivity: 1 g

Accuracy:

Dimensions: 12 x 17 x 15 mm nominal

Weight: "about that of a dime"

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments: about size and weight of a dime

Properties sensed: acceleration, linear**Technology used:** *piezoelectric-ceramic***Application:** knock**Vehicle system:** eng. mgt**Supplier:** **Hitachi****Product name:** Knock Sensor**Description:** measures cylinder vibration**Range:****Sensitivity:****Accuracy:****Dimensions:****Weight:****Thermal tolerance:****Benefits:****Cost:****Development status:** production**Comments:** Hitachi makes numerous sensors**Properties sensed:** acceleration, linear**Technology used:** *micromachined silicon***Application:** vehicle forward acceleration**Vehicle system:** ACRS, suspension**Supplier:** **Motorola****Product name:** Micromachined Accelerometer**Product number:** XMMAS40G10D**Description:** silicon capacitive, micromachined**Range:** +/- 40 g**Sensitivity:****Accuracy:** 1 to 3%**Dimensions:****Weight:****Thermal tolerance:** -40 to +85°C**Benefits:****Cost:****Development status:** under development**Comments:** temperature compensated

Properties sensed: acceleration, linear

Technology used: *capacitive metal beam*

Application: vehicle and passenger accelerations

Vehicle system: brake/trac., suspension, safety

Supplier: **Texas Instruments Inc.**

Product name: Capacitive Low g Acceleration Sensor

Product number: families

Description: chemical etch. Alloy 42, to metalized ceramic

Range: +/- 0.4 to 10 g

Sensitivity:

Accuracy: +/- 3%; <1.5% cross axis

Dimensions: 33 x 32 x 10 mm est.

Weight:

Thermal tolerance: -40 to +125°C

Benefits: durability

Cost: lower cost

Development status: production

Comments: alumina ceramic substrate metalized

Properties sensed: acceleration, linear

Technology used: *electromechanical, micromachined silicon*

Application: crash detection

Vehicle system: ACRS

Supplier: **TRW**

Product name: Single-Point Electronic Sensor

Description:

Range:

Sensitivity:

Accuracy:

Dimensions: 85 x 95 x 49 mm

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production: old Rolamite, new: MMS

Comments: 100 msec after loss of battery OK

Properties sensed: acceleration, linear

Technology used: *micromachined
silicon, solid state
capac.*

Application: side crash detection

Vehicle system: ACRS

Supplier: TRW

Product name: Side Impact Sensor

Description: variable time-to-fire
logic

Range:

Sensitivity: can fire in less than 4
msec

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: R&D, in production
"soon"

Comments:

Properties sensed: acceleration, linear

Technology used: *electromagnetic*

Application: forced entry, shock

Vehicle system: vehicle security

Supplier: Whistler

Product name: Electromagnetic Shock
Sensor

Product number: WR-9345

Description: shock sensor detecting
forced entry

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost: \$29.95

Development status: production

Comments:

Properties sensed: acceleration, linear position, angular

Technology used: *micromachined silicon*

Application: wheel position, vehicle acceleration

Vehicle system: brake/traction, suspension

Supplier: **First Inertia Switch**

Product name: Veh. Wheel Position & Body Accel.

Description: X-axis accel. and position angle

Range: +/- 2 g

Sensitivity:

Accuracy: 2%

Dimensions: 50.0 × 48.8 × 76 mm

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: acceleration, linear temperature sound intensity

Technology used: *thick film, piezoelectric, IR, acoustic, ultrasonic*

Application: keyless entry, forced entry shock, fuel level

Vehicle system: ACRS, security, suspension, eng. mgt.

Supplier: **AMP Inc.**

Product name: Piezo Film Sensors

Product number: family

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance: to 145°C

Benefits:

Cost:

Development status: production

Comments: comprehensive thick-film line

Properties sensed: acceleration, linear

Technology used: *micromachined polysilicon*

Application: crash detection, vibration, dummies

Vehicle system: ACRS, airbag, and seat belt

Supplier: Analog Devices

Product name: Monolithic Accelerometer with Signal Conditioning

Product number: ADXL50

Description: monolithic accelerometer

Range: +/- 50 g

Sensitivity:

Accuracy: 8%

Dimensions:

Weight:

Thermal tolerance: -55 to +125°C

Benefits:

Cost:

Development status: under development

Comments:

Properties sensed: acceleration, linear

Technology used: *micromachined polysilicon*

Application: crash detection, vibration, dummies

Vehicle system: ACRS, brake/traction

Supplier: Analog Devices

Product name: Monolithic Accelerometer with Signal Conditioning

Product number: ADXL02

Description: monolithic accelerometer

Range: +/- 2 g

Sensitivity:

Accuracy: 8%

Dimensions:

Weight:

Thermal tolerance: -55 to +125°C

Benefits:

Cost:

Development status: under development

Comments: uses a capacitance measurement scheme

Properties sensed: acceleration, linear

Technology used: *piezoelec. & micromach. silicon*

Application: vehicle forward acceleration

Vehicle system: ACRS

Supplier: Kistler

Product name: Integrated K-Beam Capacitive Accel.

Product number: 8308A2 (family)

Description:

Range: +/- 2 g, 10 g, 50 g

Sensitivity:

Accuracy: +/-3%

Dimensions:

Weight: 10 g

Thermal tolerance: -20 to +85°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: Chemical, oxygen actual: stoichiometric A/F ratio

Technology used: *zirconium oxide*

Application: EGR oxygen

Vehicle system: engine management

Supplier: Allied Signal Filters and Spark plugs

Product name: XUN9401

Product number: XUN9401

Description: heated zirconium oxygen sensor

Range: air/fuel actual: air/fuel stoichiometric

Sensitivity:

Accuracy: +/- 5%

Dimensions: 1 in. diam. x 3 in.

Weight:

Thermal tolerance: 350 -900°C tip temperature

Benefits: heated sensor works on cold engine

Cost: \$18.95 ea.

Development status: commercially available

Comments: oxygen ion pumping cell and partial pres.

Properties sensed: crushing

Technology used: *electromechanical*

Application: crash detection

Vehicle system: ACRS

Supplier: Automotive Technologies Int'l (ATI)

Product name: CrushSwitch

Description: coaxial, bent tube

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits: scaleable, reduced false alarms (deer)

Cost:

Development status: under development

Comments: David S. Breed's refinement

Properties sensed: distance, ranging proximity

Technology used: *microwave*

Application: forward, rear and lateral proximity

Vehicle system: collision avoidance

Supplier: Allied Signal

Product name:

Description: pulsed in 50 trillionths of a second

Range: 0 to 200 ft

Sensitivity:

Accuracy:

Dimensions: 1 × 1 in. approx.

Weight:

Thermal tolerance:

Benefits:

Cost: target cost \$10 per unit

Development status: R&D

Comments: LLNL invented, Amerigon Inc. licensee

Properties sensed: distance, ranging proximity

Technology used: millimeter, microwave

Application: collision avoidance, smart cruise control

Vehicle system: collision avoidance

Supplier: Alpha

Product name: Forward Looking Radar

Description: MMW monolithic integrated circuit

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost: \$400 to under \$1,000

Development status: under development

Comments: 77 GHz operating frequency

Properties sensed: distance, ranging proximity

Technology used: millimeter, microwave

Application: forward proximity

Vehicle system: collision avoidance, smart cruise control

Supplier: Delco Electronics

Product name: FOREWARN

Description: system gives visual and audio driver warning

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: R&D

Comments: 77 GHz forward;
24 GHz aft

Properties sensed: distance, ranging
proximity

Technology used: laser (radar), video

Application: forward proximity

Vehicle system: collision avoidance,
smart cruise control

Supplier: Mitsubishi

Product name: Preview Distance
Control

Description: laser for distance,
video for presentation

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: R&D

Comments:

Properties sensed: fuel flow rate

Technology used: optical (Fresnel beam)

Application: navigation

Vehicle system: comfort/convenience,
eng. mgt.

Supplier: Sira Ltd.

Product name: Optical Fuel Flow
Sensor

Description: optically track
suspended particulates

Range:

Sensitivity:

Accuracy: +/- 5%

Dimensions:

Weight:

Thermal tolerance:

Benefits: no flow impedance
from obstructions

Cost: inexpensive
components

Development status: R&D

Comments: particles scatter light

Properties sensed: gas, carbon monoxide**Technology used:** *thick film resistor***Application:** EGR carbon monoxide concentration**Vehicle system:** eng. mgt.**Supplier:** Robert Bosch Corp.**Product name:** Carbon monoxide Sensor**Product number:** HS175**Description:** CO-sensitive thick film resistor**Range:** 0 to 50 ppm**Sensitivity:****Accuracy:** +/- 8 ppm**Dimensions:****Weight:****Thermal tolerance:** -40 to +125°C**Benefits:****Cost:****Development status:** production**Comments:****Properties sensed:** hydrocarbons**Technology used:** *various***Application:** methanol/gasoline fuel mixture ratio**Vehicle system:** eng. mgt.**Supplier:** Siemens**Product name:** Methanol Sensor**Description:** [dielectric], temp., and conductivity measured**Range:****Sensitivity:****Accuracy:****Dimensions:****Weight:****Thermal tolerance:****Benefits:** variety of fuels can be used efficiently**Cost:****Development status:** available**Comments:**

Properties sensed: infrared

Technology used: *infrared (IR), optoelectronic*

Application: windshield contamination/mist/water

Vehicle system: safety

Supplier: Sira Ltd.

Product name: Windscreen Contamination Sensor

Description: IR LED source in dash, detector in roof

Range:

Sensitivity: mist change 70%, rain change 3%

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: R&D

Comments: large amounts of rain are a problem (Ford)

Properties sensed: microwaves

Technology used: *microwave*

Application: law enforcement, radar detection

Vehicle system: comfort/convenience

Supplier: Whistler

Product name: Microsphere OZ/s for Banshee

Product number: WR-9338

Description: radar detector

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost: \$129.95

Development status: production

Comments:

Properties sensed: numerous

Technology used: various

Application:

Vehicle system: brake/traction-advanced

Supplier: Lucas Automotive

Product name: Electronic Actuation System (EAS)

Description: whole system supplier to OEM mkt.

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: possible 1996 offering

Comments: partner with Mercedes

Properties sensed: numerous

Technology used: various

Application: ABS

Vehicle system: brake/traction

Supplier: Nippondenso

Product name: Anti-lock Braking System

Product number: wheel speed + accelerometer

Description: complete ABS system, make sensors

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments: complete system to OEMs

Properties sensed: position, angular

Technology used: *Hall effect*

Application: crankshaft position

Vehicle system: eng. mgt.

Supplier: **BLD Products, Ltd.**

Product name: Crankshaft Position Sensor

Product number: 3906

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular

Technology used: *Hall effect*

Application: throttle position, suspension

Vehicle system: eng. mgt., suspension

Supplier: **CTS Corporation**

Product name: Electronic Non-Contacting Sensor

Description: all purpose Hall Effect sensor

Range: 110°

Sensitivity:

Accuracy: +/- 3%

Dimensions:

Weight:

Thermal tolerance: -40 to + 135°C

Benefits:

Cost:

Development status: under development

Comments:

Properties sensed: position, angular

Technology used: *Hall, gear tooth*

Application: crankshaft pos., wheel pos.

Vehicle system: eng. mgt, brake/traction

Supplier: Delphi

Product name: Gear Tooth Hall

Product number: family

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance: -40 to +165°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular

Technology used: *magnetoresistive*

Application: crankshaft pos., wheel pos.

Vehicle system: eng. mgt, brake/traction

Supplier: Delphi

Product name: Magnetoresistive Sensors

Product number: family

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance: -40 to +165°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular**Technology used:** *vane Hall***Application:** crankshaft pos., wheel pos.**Vehicle system:** eng. mgt, brake/traction**Supplier:** Delphi**Product name:** Vane Hall Sensors**Product number:** family**Description:****Range:****Sensitivity:****Accuracy:****Dimensions:****Weight:****Thermal tolerance:** -40 to +165°C**Benefits:****Cost:****Development status:** production**Comments:****Properties sensed:** position, angular**Technology used:** *Hall effect***Application:** gear position sensor (heavy truck)**Vehicle system:** eng. mgt.**Supplier:** FASCO Controls**Product name:** Position Sensor**Description:** GaAs Hall generator**Range:****Sensitivity:** 2.0-10 kHz**Accuracy:****Dimensions:****Weight:****Thermal tolerance:** -40 to +125°C**Benefits:****Cost:****Development status:** new**Comments:**

Properties sensed: position, angular

Technology used: optical

Application: steering wheel angle,
velocity, direction

Vehicle system: brake/traction-
advanced

Supplier: First Inertia Switch

Product name: Steering Wheel
Position Sensor

Description: contacts optical
sensing of steer. whl.

Range: 7 full revolutions

Sensitivity:

Accuracy: +/- 1 %

Dimensions: 82.8 × 76 × 19.5 mm

Weight:

Thermal tolerance: -40 to +85°C

Benefits:

Cost:

Development status: production

Comments: 90 pulses per 360°

Properties sensed: position, angular

Technology used: potentiometer

Application: throttle position

Vehicle system: eng. mgt.

Supplier: Holley Automotive
Division

Product name: Throttle Position
Sensor

Description: slide and conductive
plastic resistive

Range: 0 to 118°

Sensitivity:

Accuracy: +/- 2%

Dimensions: 41.1 × 44.0 × 36.8 mm

Weight:

Thermal tolerance: -40 to +135°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular

Technology used: *Hall effect*

Application: cam and crankshaft pos., speed

Vehicle system: eng. mgt.

Supplier: Honeywell Micro Switch

Product name: Hall Effect Gear Tooth Sensor

Product number: 1GT101DC

Description:

Range: 3600 rpm, 0.080 in. gap

Sensitivity:

Accuracy: +/- 1.25°

Dimensions: 12 × 41.6 × 36.4 mm

Weight:

Thermal tolerance: -30 to +150°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular

Technology used: *magnetoresistive*

Application: cam, crankshaft, wheel, position

Vehicle system: eng. mgt., brake/trac.

Supplier: Phillips Technologies (old Airpax)

Product name: Active Magnetic Sensor

Product number: 70087-3040-001 (family)

Description: Zero velocity with 3-pin connector

Range: air gap 0.005 to 0.050 in.

Sensitivity: 0 to 10,000 Hz

Accuracy:

Dimensions: 97.1 × 25.4 (approx. diam.) mm

Weight:

Thermal tolerance: -25 to +70°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular
5-axis wheel
movement

Technology used: potentiometer,
(LVDT)

Application: wheel attitude/position

Vehicle system: testing

Supplier: DATRON
Technology, Inc.

Product name: Wheel Vector
Transducer

Product number: WVT

Description: wheel attitude in 5 axes
during test

Range: +/- 30°, 150 mm

Sensitivity:

Accuracy: 2 arc minutes

Dimensions:

Weight:

Thermal tolerance: -50 to +70°C

Benefits:

Cost:

Development status: production

Comments: can program through a
PC

Properties sensed: position, angular
velocity, angular

Technology used: Hall Effect

Application: cam, crankshaft, wheel
speed/position

Vehicle system: eng. mgt.,
brake/traction

Supplier: Wabash Magnetics

Product name: Hall Effect Sensors

Product number: family

Description: wide assortment
offered

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, incremental

Technology used: *potentiometer*

Application: throttle position (TPS)

Vehicle system: eng. mgt

Supplier: BLD Products, Ltd.

Product name: Throttle Position
Sensor

Product number: 3500 series

Description: wide open, closed or
normal positions

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, incremental

Technology used: *potentiometer*

Application: throttle position

Vehicle system: eng. mgt.

Supplier: CTS Corporation

Product name: Throttle Position
Sensor

Description: for EFI engines

Range: 3 K to 12 K Ω

Sensitivity:

Accuracy: +/- 3%

Dimensions:

Weight:

Thermal tolerance: -40 to +150°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, incremental

Technology used: potentiometer

Application: pedal position

Vehicle system: eng. mgt.

Supplier: CTS Corporation

Product name: Pedal Position Sensor

Description:

Range: 1 K to 5 K Ω

Sensitivity:

Accuracy: +/- 3%

Dimensions:

Weight:

Thermal tolerance: -40 to +100°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, incremental

Technology used: potentiometer

Application: suspension position
(height and attitude)

Vehicle system: suspension

Supplier: CTS Corporation

Product name:

Description: can add built-in
accelerometer

Range:

Sensitivity:

Accuracy: +/- 2% pos,
+/- 0.2% g,
<4% X-axis

Dimensions:

Weight:

Thermal tolerance: -40 to +105°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, linear
position, angular

Technology used: *GMR or capacitance*

Application: throttle pos., steering
pos., accel. pedal

Vehicle system: eng. mgt,
brake/traction

Supplier: **First Inertia Switch**

Product name: Non-Contact. Rotary
Pos. Sensor

Description: versatile position
sensor: angular or
linear

Range: +/- 45° GMR; +/- 80°
(cap.)

Sensitivity:

Accuracy: 3% GMR; 5% cap.

Dimensions: 38 diam. × 54 mm

Weight:

Thermal tolerance: -40 to +125°C GMR,
-40 to + 85°C cap.

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular

Technology used: *variable reluctance*

Application: crankshaft pos., wheel
pos.

Vehicle system: eng. mgt,
brake/traction

Supplier: **Delphi**

Product name: Variable reluctance
Sensors

Product number: family

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance: -40 to +165°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular

Technology used: *optoelectronic*

Application: steering wheel angle

Vehicle system: brake/trac., suspension, safety

Supplier: **Sira Ltd.**

Product name: Steering Wheel Position Sensor

Description: simple optics with counter-rot. choppers

Range:

Sensitivity:

Accuracy: 2 to 0.3°

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: R&D

Comments: for advanced driver-assist steering

Properties sensed: position, angular velocity, angular

Technology used: *variable reluctance*

Application: cam, crankshaft, wheel speed/position

Vehicle system: eng. mgt., brake/trac,

Supplier: **Wabash Magnetics**

Product name: Variable Reluctance Sensors

Product number: family

Description: wide assortment offered

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: position, angular velocity, angular

Technology used: *Hall Effect*

Application: wheel position and speed

Vehicle system: ABS, traction control

Supplier: Analog Devices

Product name: Hall Effect Sensor With Signal Conditioning

Product number: AD22150

Description: senses change in magnetic field

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance: -40°C to +150°C

Benefits:

Cost:

Development status: patents pending

Comments: hysteresis built into output

Properties sensed: position, incremental

Technology used: *potentiometer*

Application: EGR flow rate

Vehicle system: eng. mgt.

Supplier: CTS Corporation

Product name: Exhaust Gas Recirculation Sensor

Description:

Range:

Sensitivity:

Accuracy: +/- 2%

Dimensions:

Weight:

Thermal tolerance: -40 to +150°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure and temperature

Technology used: capacitance- ceramic

Application: transmission, oil, MAT, fuel rail temp./pres.

Vehicle system: eng. mgt

Supplier: Kavlico

Product name: Dual pressure & Temperature Sensor

Description:

Range: 0 to 350 psi, -40 to +150°C

Sensitivity:

Accuracy: +/- 4%

Dimensions:

Weight:

Thermal tolerance: -40 to +150°C

Benefits: two-in-one sensor

Cost:

Development status: production, new

Comments: 4-pin connection

Properties sensed: pressure, absolute

Technology used: piezoresistive

Application: manifold absolute pressure (MAP)

Vehicle system: eng. mgt.

Supplier: BLD Products, Ltd.

Product name: Manifold Absolute Pressure

Product number: 3300 series

Description: input to CPU related to changing eng. load

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, absolute

Technology used: *piezoresistive*

Application: manifold air pressure (MAP)

Vehicle system: eng. mgt

Supplier: Motorola

Product name: Manifold Absolute Pressure Sensor

Product number: MPX4100D

Description:

Range: 20 to 105 kPa

Sensitivity: 54 mV/Pa

Accuracy: +/- 1.8%

Dimensions: 0.01 in.³

Weight: 4.0 g

Thermal tolerance: -40/+125°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, absolute, barometer,

Technology used: *piezoresistive silicon*

Application: MAP, barometric pressure

Vehicle system: eng. mgt.

Supplier: Delco Electronics Corp.

Product name:

Product number: DPS/SL

Description: family of sensors, temperature-compensated

Range: 15 to 105 kPa

Sensitivity:

Accuracy: 1.5%

Dimensions: 15 × 39.2 × 15.8 mm

Weight:

Thermal tolerance: -40 to +125°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, absolute,
barometer,
differential

Technology used: *piezoresistive silicon*

Application: manifold air pressure
(MAP)

Vehicle system: eng. mgt.

Supplier: Delco Electronics
Corp.

Product name:

Product number: DPS/SA

Description: family of sensors

Range: 15 to 300 kPa

Sensitivity:

Accuracy: 1.0%

Dimensions: 69 × 79 × 27.25 mm

Weight:

Thermal tolerance: -40 to +125°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, air

Technology used: *piezoresistive silicon*

Application: tire pressure (remote)

Vehicle system: brake/traction,
suspension

Supplier: SSI

Product name:

Description: driver warning for run-
flat tires

Range:

Sensitivity:

Accuracy:

Dimensions: 1 mm square est.

Weight: 22 g est.

Thermal tolerance:

Benefits: allows use of run-flat
tires

Cost:

Development status: under development
1996?

Comments:

Properties sensed: pressure, barometric

Technology used: *piezoresistive*

Application: air/fuel mixture

Vehicle system: eng. mgt

Supplier: BLD Products Ltd.

Product name: Barometric Pressure Sensor

Product number: 3364

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, barometric, absolute

Technology used: *piezoresistive*

Application: ambient air pressure

Vehicle system: eng. mgt.

Supplier: Motorola

Product name: Altimeter/Barometer Pressure

Product number: MPX4115

Description: compensates A/F mixture for altitude

Range: 15 to 115 kPa

Sensitivity: 45.9 mV/kPa

Accuracy: +/- 1.5%

Dimensions: 0.01 in.³

Weight: 4.0 g

Thermal tolerance: -40/+125°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, fluid

Technology used: strain gauge

Application: HVAC high-side fluid pressure

Vehicle system: HVAC

Supplier: GE

Product name: Solid State Strain Gage Pres. Transducer

Description: stainless steel disk. electromechanical

Range: 0- 500 psi est.

Sensitivity:

Accuracy: 1%

Dimensions:

Weight:

Thermal tolerance: under-hood typical

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, fluid

Technology used: capacitance (ceramic)

Application: a/c refrig., hydraulic, brake, trans. pres.

Vehicle system: HVAC, brake/trac., eng. mgt.

Supplier: Texas Instruments Inc.

Product name: Solid State Pressure Sensor

Product number: family

Description: ceramic capacitance with microelectronics

Range: 0-100 psi; 0-450 psi; 0-3500 psi

Sensitivity:

Accuracy: +/- 3%

Dimensions: 23.04 diam. x 35.81 mm nominal

Weight:

Thermal tolerance: -40 to +135°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, gas

Technology used: *piezoelectric*

Application: combustion, knock, misfire, cam position

Vehicle system: eng. mgt.

Supplier: Delphi

Product name: Combustion Sensors

Product number: family

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance: -40 to +150°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: pressure, gas

Technology used: *piezoresistive-ceramic*

Application: tire pressure, engine oil pres., et al

Vehicle system: brake/traction, eng. mgt

Supplier: Lucas NovaSensor

Product name: Silicon Pres. Sensors in Ceramic Surf. Mt.

Product number: NPC-103 (series)Series

Description: miniature piezoresistive sensor

Range: 0 to 15; 0 to 30; 0 to 100 psi

Sensitivity:

Accuracy: 0.20%

Dimensions: 0.3 × 0.3 in.

Weight: 0.25 g

Thermal tolerance: -40 to +125°C

Benefits:

Cost:

Development status: new

Comments: uses an electric bridge

Properties sensed: pressure, absolute

Technology used: *piezoresistive silicon*

Application: eng., HVAC, airbag
gas, brake, pres.

Vehicle system: eng. mgt,
brake/traction, ACRS

Supplier: SSI

Product name: Solid State integrated
Pressure Sensors

Product number: family, 40 to 2,500 psi

Description:

Range: 40 to 2,500 psi (family)

Sensitivity:

Accuracy: 0.8%

Dimensions:

Weight:

Thermal tolerance: -40 to +150°C

Benefits:

Cost:

Development status: production

Comments: 2.5 mm square die

Properties sensed: pressure, liquid and
gas

Technology used: *micromachined
silicon, piezoresistive*

Application: brake line, trans. oil,
eng. oil, HVAC pres.

Vehicle system: eng. mgt, brake/trac.,
HVAC

Supplier: Lucas Electronics
Systems Products

Product name: High Pressure Media
Isolated Pres. Sens.

Description: 316 stainless steel
isolating diaphragm

Range: 0 to 2900 psi

Sensitivity:

Accuracy: +/- 25

Dimensions:

Weight:

Thermal tolerance: -40 to +125°C

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: proximity

Technology used: inductive

Application: door ajar (bus fuel door)

Vehicle system: safety

Supplier: Honeywell Micro Switch

Product name: MM DC inductive Proximity Sensor

Product number: 922AA2xm-A9N-L12

Description: used to lock out trans during fueling

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status:

Comments: lock out on commercial transportation

Properties sensed: proximity

Technology used: ultrasonic (piezo)

Application: lateral proximity

Vehicle system: collision avoidance

Supplier: Polaroid

Product name: 9000 series Piezo Transducer

Product number: 618416

Description: 40 to 50 kHz air ultrasonic transducer

Range: 1 in. to 50 ft

Sensitivity: 108 dB min. Trans. -75 dB min. rec.

Accuracy: +/- 1%

Dimensions: 1.44 x 1.04 x 0.50 in.

Weight:

Thermal tolerance: -40 to +185°F

Benefits:

Cost: sample kit \$299.00

Development status: prototype

Comments: driver blind-spot warning

Properties sensed: proximity

Technology used: *magnetostrictive*

Application: child seat presence, orientation

Vehicle system: ACRS

Supplier: TRW

Product name: Child Seat Sensing

Description: amorphous metal at front of child seat

Range:

Sensitivity: presence, front or back facing

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits: 1998 regulation FMVSS 208

Cost:

Development status: R&D

Comments: controls air bag deployment go/no-go

Properties sensed: proximity

Technology used: *ultrasonic (piezo-ceramic 75 to 200 kHz)*

Application: passenger, driver presence

Vehicle system: ACRS

Supplier: TRW

Product name: Occupant Sensing

Description: adjust ACRS system for each occupant

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits: better crash safety

Cost:

Development status: R&D

Comments: ultrasound and potentiometers in seat track

Properties sensed: RF radiation

Technology used: *radio frequency (305 to 418 MHz)*

Application: keyless door opening

Vehicle system: comfort/convenience, security, safety

Supplier: Whistler

Product name: Keyless Entry System

Product number: WR-9666

Description: remote control door lock

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost: \$149.95

Development status: production

Comments: transmitter in ignition key

Properties sensed: RF radiation

Technology used: *radio frequency (305 to 418 MHz)*

Application: remote car starting

Vehicle system: comfort/convenience

Supplier: Whistler

Product name: Car Starter with Onboard Relays

Product number: WR-9642

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost: \$179.95

Development status: production

Comments:

Properties sensed: sound intensity

Technology used: *acoustic*

Application: forced entry-breaking
glass

Vehicle system: vehicle security

Supplier: Whistler

Product name: Acoustic Glass Break
Sensor

Product number: WR-2210

Description: discriminates glass
break from noise

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost: \$29.95

Development status: production

Comments:

Properties sensed: speed, angular

Technology used: *VR, Hall, magneto-
optics*

Application: transmission speed,
wheel speed

Vehicle system: brake/traction

Supplier: SSI

Product name: various

Product number: family

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: temperature

Technology used: *thermistor*

Application: ambient air or fluid temperatures

Vehicle system: eng. mgt

Supplier: Motorola

Product name: Silicon Temperature Sensor

Product number: MTS 102

Description: automotive temperature sensor

Range: -40 to +150°C

Sensitivity:

Accuracy: +/- 2°C

Dimensions:

Weight: 87 g

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments: air 8 sec., liq. 3 sec.

Properties sensed: temperature

Technology used: *hot-film anemometry*

Application: ambient air temperature

Vehicle system: eng. mgt.

Supplier: Siemens

Product name: Hot-Film AirFlow Sensor-

Description:

Range:

Sensitivity: "fast" response time

Accuracy: +/- 3%

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: available

Comments:

Properties sensed: temperature

Technology used: *thick film*

Application: various temperature applications

Vehicle system: eng. mgt., HVAC

Supplier: Vishay Dale

Product name: Thick Film Chip Resistors

Product number: CRCW 1206 (family)

Description: thick film chip resistor component

Range: -55 to +150°C

Sensitivity:

Accuracy: +/- 1%

Dimensions: 3.2 × 1.6 × 0.56 mm

Weight:

Thermal tolerance: -55 to + 150°C

Benefits:

Cost:

Development status: production commodity item

Comments:

Properties sensed: temperature, air

Technology used: *thermistor*

Application: manifold air temperature (MAT) for EFI

Vehicle system: eng. mgt

Supplier: BLD Products Ltd.

Product name: Air Cleaner Air Temperature Sensor

Product number: 3086

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: temperature, air

Technology used: *thermistor*

Application: air/fuel mixture temperature

Vehicle system: eng. mgt, EFI

Supplier: **BLD Products Ltd.**

Product name: Air Charge Temperature Sensor

Product number: 3013

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: temperature, air

Technology used: *thermistor*

Application: throttle body air temperature

Vehicle system: eng. mgt

Supplier: **BLD Products, Ltd.**

Product name: Air Temperature Sensor

Product number: 3041

Description: air temp. in TB for hot restarts

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: temperature, air
Technology used: *thermistor*
Application: ambient air temp.
(before a/c condenser)
Vehicle system: HVAC
Supplier: BLD Products, Ltd.
Product name: Air Temperature
Sensor
Product number: 3041
Description: input to control a/c
Range:
Sensitivity:
Accuracy:
Dimensions:
Weight:
Thermal tolerance:
Benefits:
Cost:
Development status: production
Comments:

Properties sensed: temperature, air
Technology used: *thermistor*
Application: air/fuel temperature
(intake manifold)
Vehicle system: eng. mgt
Supplier: BLD Products, Ltd.
Product name: Charge Temperature
Sensor
Product number: 3071
Description: backup to coolant
sensor for eng. mgt.
Range:
Sensitivity:
Accuracy:
Dimensions:
Weight:
Thermal tolerance:
Benefits:
Cost:
Development status: production
Comments:

Properties sensed: temperature, air

Technology used: *thermistor*

Application: MAT, (adjust throttle and air/fuel)

Vehicle system: eng. mgt

Supplier: **BLD Products, Ltd.**

Product name: Manifold Air Temperature Sensor

Product number: 3000 series

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: temperature, liquid

Technology used: *thermistor*

Application: engine oil temperature

Vehicle system: eng. mgt.

Supplier: **BLD Products Ltd.**

Product name: Engine Oil Temperature Sensor

Product number: 3034

Description:

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: temperature, liquid

Technology used: *thermistor*

Application: coolant temperature

Vehicle system: eng. mgt.

Supplier: **BLD Products, Ltd.**

Product name: Coolant Temperature Sensor

Product number: 3087

Description: input to fuel metering

Range:

Sensitivity:

Accuracy:

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: temperature, air
temperature, liquid

Technology used: *thermistor (inferred)*

Application: temperature, coolant,
oil, air

Vehicle system: engine management

Supplier: **Analog Devices**

Product name: Monolithic
Temperature Sensor
with Signal
Conditioning

Product number: AD 22100

Description: air and liquid
temperature

Range: -50/+125°C

Sensitivity: 2%

Accuracy: 2%

Dimensions:

Weight:

Thermal tolerance: -50/+150°C

Benefits: wide power supply
range

Cost:

Development status: under development

Comments:

Properties sensed: thermistor
temperature

Technology used: thermistor

Application: a/c clutch cycling

Vehicle system: HVAC

Supplier: GE

Product name: A/C Refrigerant
Temperature Sensor

Description: neg. temp coef.
thermistor

Range: 0-100°C nominal

Sensitivity:

Accuracy: +/- 2.0°C

Dimensions:

Weight:

Thermal tolerance: under-hood typical

Benefits:

Cost:

Development status: production

Comments: 20 sec response time

Properties sensed: tilt

Technology used: electromechanical

Application: seat restraint fast., liq.
level, trunk tilt

Vehicle system: ACRS,
comfort/convenience

Supplier: First Inertia Switch

Product name: Tilt Sensor

Description: rolling ball and ramp

Range: 0.3 to 0.7 g

Sensitivity: 10 msec response

Accuracy:

Dimensions: 56.0 × 85.5 × 39.0 mm

Weight:

Thermal tolerance: -40 to +85°C

Benefits:

Cost:

Development status: design/prototype

Comments:

Properties sensed: tilt

Technology used: *thermal*

Application: vehicle inclination,
trunk tilt

Vehicle system: suspension, ABS.

Supplier: **Robert Bosch Corp.**

Product name: Inclination Sensor

Product number: HS46

Description: gas bubble causes
platinum resistor
change

Range: $>21^{\circ}$ or not

Sensitivity: digital, over threshold
or not

Accuracy: $\pm 3^{\circ}$

Dimensions:

Weight:

Thermal tolerance: -40 to $+95^{\circ}\text{C}$

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: torque; position,
angular; velocity,
angular

Technology used: *strain gauge,
optoelectronic*

Application: steering wheel torque,
angle, velocity

Vehicle system: testing

Supplier: **DATRON
Technology, Inc.**

Product name: Measurement Steering
Wheel

Product number: MSW

Description:

Range: $\pm (200 \text{ Nm}, 360^{\circ},$
 $400^{\circ}/\text{sec})$

Sensitivity:

Accuracy: 0.2% , 0.1% , $1^{\circ}/\text{sec}$

Dimensions:

Weight:

Thermal tolerance:

Benefits:

Cost:

Development status: production

Comments:

Properties sensed: velocity, linear;
distance traveled

Technology used: *microwave, Doppler*

Application: vehicle forward speed,
location

Vehicle system: testing

Supplier: **DATRON
Technology, Inc.**

Product name: Non-Contact Optical
Smart Sensor

Product number: DLS-3

Description: 24 GHz, dual-beam
Doppler

Range: 2.5 to 300 km/h

Sensitivity:

Accuracy: +/- 0.5%

Dimensions: 1 x 4 x 6 in.

Weight:

Thermal tolerance: -40 to +85°C

Benefits: can be used on off-
road terrain

Cost:

Development status: production

Comments:

Properties sensed: velocity, linear;
distance traveled

Technology used: *optical, halogen
source, IR detector*

Application: vehicle forward speed,
distance

Vehicle system: testing

Supplier: **DATRON
Technology, Inc.**

Product name: Non-Contact Optical
Smart Sensor

Product number: DLS-1

Description: forward vehicle speed
and dist. traveled

Range: 0.5 to 400 km/h, 200
to 400 mm

Sensitivity:

Accuracy: +/- 0.2%

Dimensions:

Weight:

Thermal tolerance: -35 to +55°C

Benefits: looks at surface
changes

Cost:

Development status: production

Comments: can program through a
PC

Properties sensed: velocity, linear
distance traveled

Technology used: *optical, halogen
source, IR detector*

Application: vehicle forward speed,
distance

Vehicle system: testing

Supplier: **DATRON
Technology, Inc.**

Product name: Non-Contact Optical
Smart Sensor

Product number: DLS-2

Description: forward vehicle speed
and dist. traveled

Range: 1.0 to 260 km/h, 200
to 400 mm

Sensitivity:

Accuracy: +/- 1.0%

Dimensions:

Weight:

Thermal tolerance: -35 to +55°C

Benefits: looks at surface
changes

Cost:

Development status: production

Comments: can program through a
PC

Properties sensed: velocity, linear;
distance traveled

Technology used: *optical, halogen
source, IR detector*

Application: vehicle forward speed,
distance

Vehicle system: testing

Supplier: **DATRON
Technology, Inc.**

Product name: Non-Contact Optical
Smart Sensor

Product number: DLS-3

Description: forward vehicle speed
and dist. traveled

Range: 0.3 to 400 km/h

Sensitivity:

Accuracy: +/- 0.2%

Dimensions:

Weight:

Thermal tolerance: -40 to 55°C

Benefits: looks at surface
changes

Cost:

Development status: production

Comments: 4 potentiometers,
1 LVDT

Properties sensed: velocity, vector; drift angle

Technology used: *optical, halogen source, IR detector*

Application: vehicle forward/lateral speed

Vehicle system: testing

Supplier: **DATRON Technology, Inc.**

Product name: V-Sensor

Product number: DV1

Description: halogen illumination

Range: +/- 25°, 0.5 to 310 km/h

Sensitivity:

Accuracy: 0.1°

Dimensions:

Weight: 2.0 kg

Thermal tolerance: -25 to +80°C

Benefits: looks at surface changes

Cost:

Development status: production

Comments: can program through a PC

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