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Electronic Control Unit for a Single-Point Sensing Airbag

● Kenichi Kinoshita ● Hiroyuki Konishi ● Tetsuhiro Mizushima

Airbags, built into a car steering wheel or dashboard, are one type of supplemental restraint system (SRS). If the car is involved in a collision, the airbag is inflated with gas and protects persons in the car. The idea of an airbag was first suggested more than 20 years ago. Recent interest in airbags has been prompted by a new law in the U.S.A. that requires airbags. In Europe and Japan, there is a growing interest in safety and reduced car insurance premiums for special safety features.

Fujitsu TEN teamed up with Siemens, and started developing an airbag system in 1989. We applied our original semiconductor technology and design and production expertise with car control equipment to the airbag system. This report outlines an electronic control unit (ECU) we developed with Toyota for a single-point sensing airbag for Toyota's Hi-Ace '93 model. The report also discusses evaluation, production and features of the airbag system.

1. Introduction

An airbag, made of cloth, is built into the steering wheel or dashboard. If the car is involved in a collision, the airbag is inflated with gas and minimizes injury to persons in the car.

A conventional system consists of a front sensor, an ECU, a bag, a gas generator, and a steering wheel with a built-in squib. A front sensor, mounted in the crushable zone at the front of the car, detects a collision. The ECU has a built-in G sensor, a self-diagnostic function, and a built-in power energy reserver that supplies power if the electrical system fails because of the collision. Figure 1 shows the configuration of the conventional airbag system.

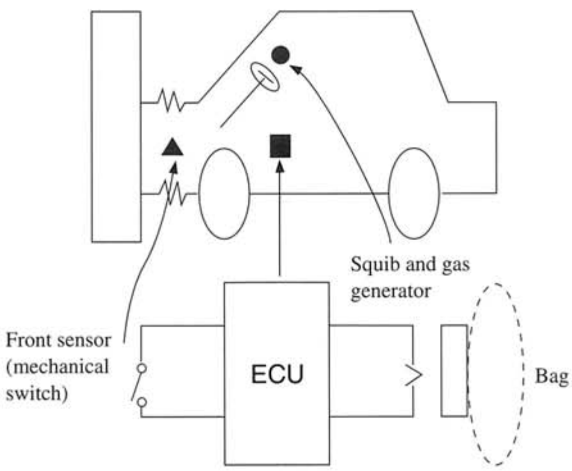

Figure 1. Conventional airbag system configuration

The front sensor positions can be optimized for collision detection. However, at least two front sensors must be placed on the right and left sides. Recently, single-point sensing airbag systems, which detect a collision using only G sensors built into the ECU, are being developed.

2. Single-point sensing airbag system

Until now, the most popular airbag systems were multiple-sensor systems with front sensors, G sensors or mechanical switches built into the ECU. Some systems being developed now have no front sensor. Other systems with single-point sensing have all of their components in the steering wheel.

By applying semiconductor technology, Fujitsu TEN has developed a single-point sensing system with built-in G sensors that has high performance and can easily be adapted for the passenger seat. In this report, we present the ECU for the Toyota Hi-Ace '93 model that we developed jointly with Toyota.

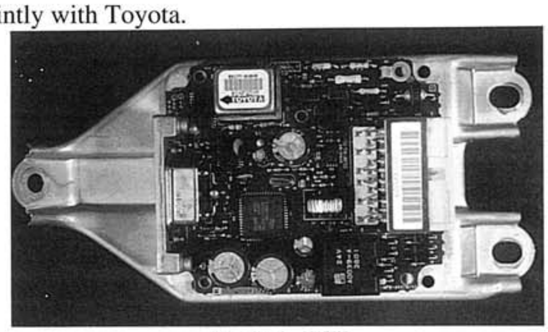

Figure 2. ECU

3. ECU

3.1 Components and functions

Figure 2 shows the appearance of the ECU, and Figure 3 is a block diagram of the ECU.

1) DC-to-DC converter
The DC-to-DC converter steps up the battery voltage and ensures that the bag is inflated, even if the battery voltage is low.

2) Power energy reserver
The capacitor of the energy reserver is always charged, and supplies power to the system. Even if the electrical system fails in a collision, the airbag system still works.

3) CPU monitor circuit
The CPU monitor circuit monitors CPU operation. If the CPU monitor circuit detects an abnormality, it lights an indicator.

4) Indicator driver
This driver drives indicator lamps. The indicator driver has circuits that detect indicator failures and improper mating of ECU connectors.

5) Firing driver
This driver ignites the squib. The firing driver has circuits that detect failures in the squib, wire harness, drivers, and the mechanical G sensor.

6) 5 V power supply number one
This power supply is for the CPU monitor circuit. The CPU compares 5 V supply number two and 5 V supply number one to detect a 5 V power supply failure.

7) 5 V power supply number two
This power supply is for the CPU and ceramic G sensor. To reduce the effect of power voltage variation at the sensor output, the output voltage is highly regulated.

8) Ceramic G sensor
The ceramic G sensor is a ceramic deceleration sensor containing a piezo element. It has a self-checking function and a built-in amplifier and filter circuit.

9) Mechanical G sensor
The mechanical G sensor is a deceleration sensor consists of a roller, a plate spring, a stopper and other components. Figure 4 shows its structure. If deceleration is greater than the design value, the roller rotates and the moving contact touches the stationary contact, which turns on the sensor.

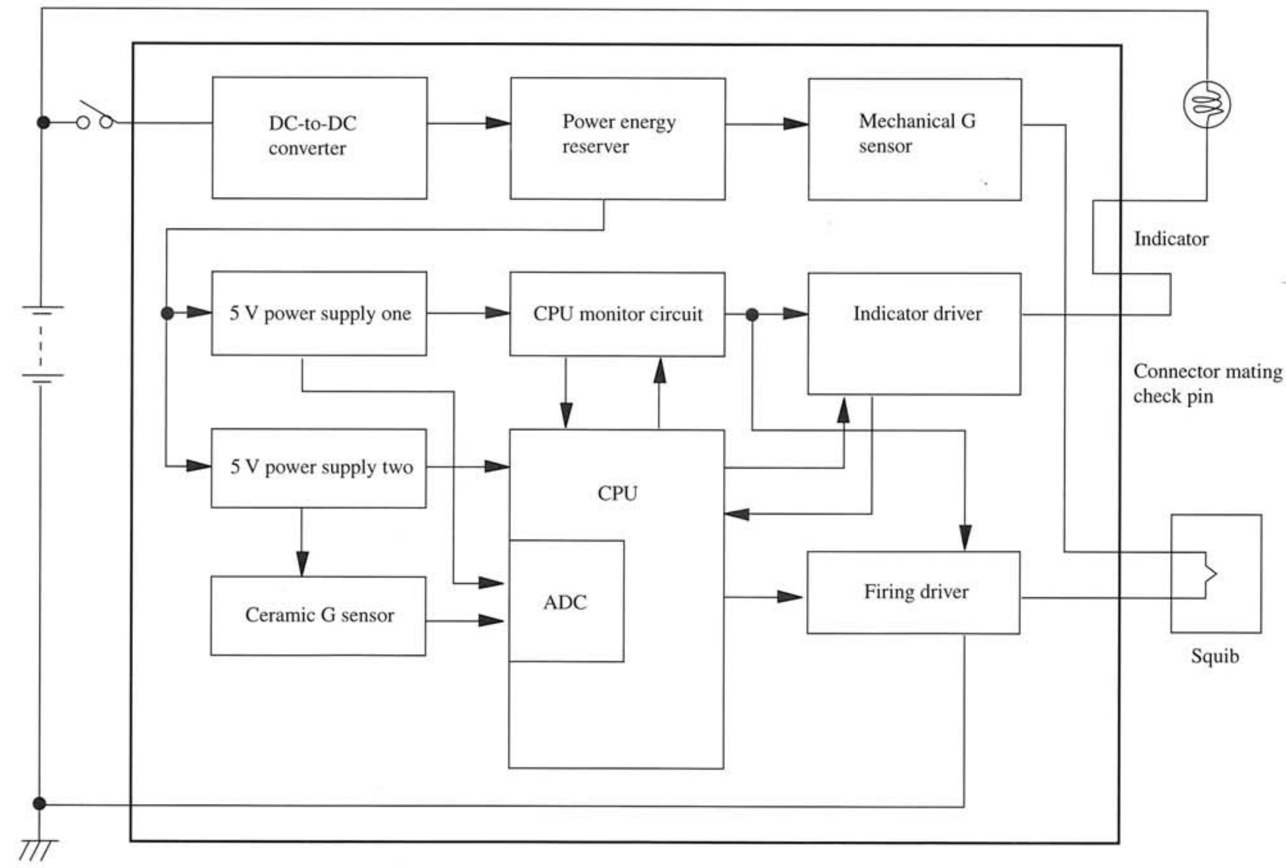

Figure 3. ECU block diagram

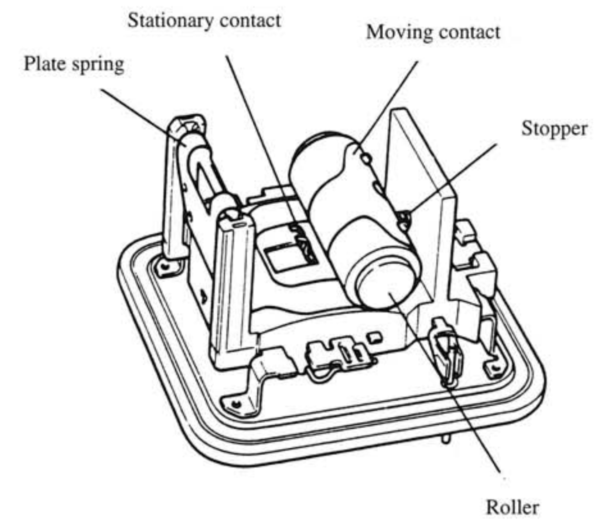

Figure 4. Mechanical G sensor

3.2 Diagnostic function

The airbag ECU performs fault diagnosis in two stages. A primary check is made for about 6 seconds after the ignition switch is turned on. An indicator is lit and all checks are made during this period. The mode then switches to the regular check, and operation to detect collision starts. Table 1 lists the diagnostic checks for these two stages.

If a failure is detected, an indicator is turned on to issue an alarm to the driver.

Even a failure in the airbag system is easy to pinpoint using the diagnostic function.

Table 1 . Diagnostic checks

Item	Primary	Regular
Power supply voltage drop	⊙	⊙
Firing device wireharness short circuit (ground)	⊙	⊙
Regular on state of airbag ECU	⊙	⊙
Firing device wireharness short circuit (power supply)	⊙	⊙
Firing device short circuit	⊙	⊙
Firing device open circuit	⊙	⊙
Airbag indicator system error	⊙	⊙
Airbag ECU failure	⊙	△

Note:
A circle indicates a diagnostic item.

A triangle indicates a limited diagnostic item.

3.3 Collision detection algorithm

We introduced multiple algorithms to produce a single-point sensing airbag that has excellent collision detection performance. Figure 5 shows the firing logic, which is outlined below.

1 Q value: The ceramic G sensor output is fed to a band pass filter, and then to the CPU, which calculates shock and detects a collision.

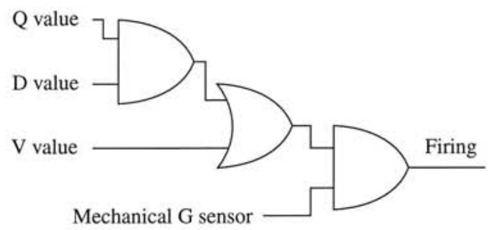

Figure. 5. Firing logic

2 D value: The CPU estimates the displacement of a free mass when a collision occurs, and determines the optimum firing time.

3 V value: A change in car speed is calculated from the ceramic G sensor signal, and the firing time is determined from this change.

The firing output of the ECU is determined from the three parameters above and the mechanical G sensor output. This logic prevents inadvertent deployment of the bag and no deployment of the bag, ensuring high reliability.

4. Collision detection algorithm evaluation device

To evaluate the collision detection algorithm for our airbag ECU, we developed an airbag simulator and installed a shock test system. This setup is outlined below.

4.1 Airbag simulator

The airbag simulator runs on a personal computer. The simulator consists of a processing circuit for the ceramic G sensor signal and a collision detection algorithm section. Both programs are written in C. Figure 6 is a flowchart of our simulator.

4.1.1 Signal processing circuit for the ceramic G sensor

G data taken from a collision test is used as the input. All ceramic G sensor processing circuits are simulated, and

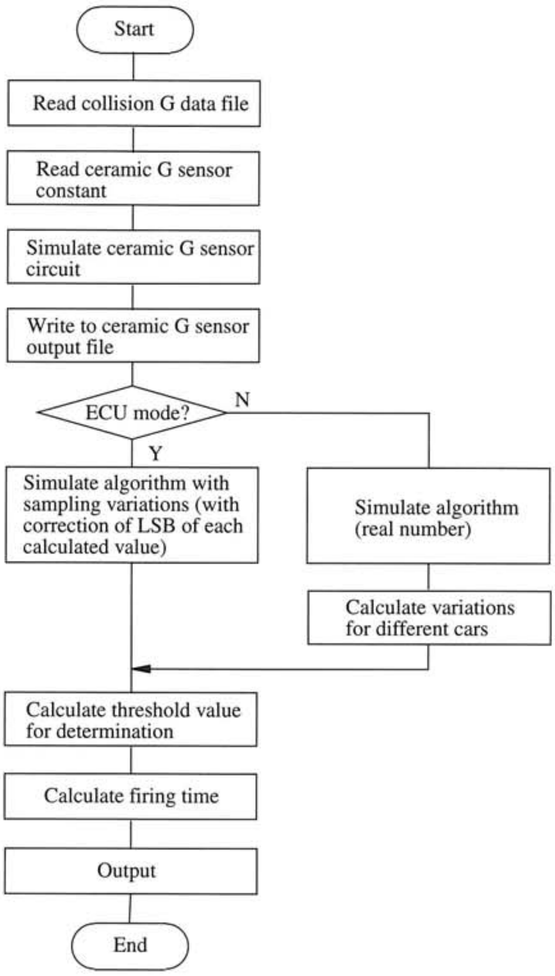

Figure 6. Simulatory flowchart

the ceramic G sensor output voltage is calculated. This simulation also tests for variations in processing circuit components, temperature, and voltage characteristics, and calculates variations in the ceramic G sensor output signal.

4.1.2 Collision detection algorithm section

The result of ceramic G sensor simulation is used as the input to simulate the collision detection algorithm. There are two modes. In real number mode, the sampling interval is the same as for G data and real numbers are used in calculations. ECU mode simulates calculation by the CPU in the ECU. The sampling interval in ECU mode is longer than that in real number mode. This difference is sampling variations and corrected. The real number mode is used to evaluate variations with different cars in the same collision mode. The ECU mode is used to develop and evaluate algorithms.

4.2 Shock test system

Figure 7 shows the shock test system, and Figure 8 is a block diagram of the system. Controller signals are fed to the power amplifier that drives the drive coil of the shock generator and the DC power supply for the exciting coil, and a shock is generated.

The following items are evaluated by selective half-sine excitation of the shock test system.

- Ceramic and mechanical G sensors
- Basic firing performance of ECU

The following items are also evaluated, using the real shock wave reproduction function:

- Effect of resonance of ECU bracket mechanism
- Matching of the behavior of the CPU in the ECU and the results of algorithm simulation
- Performance of new algorithm and firing of new ECU
- Performance of ECU before collision test using an actual car

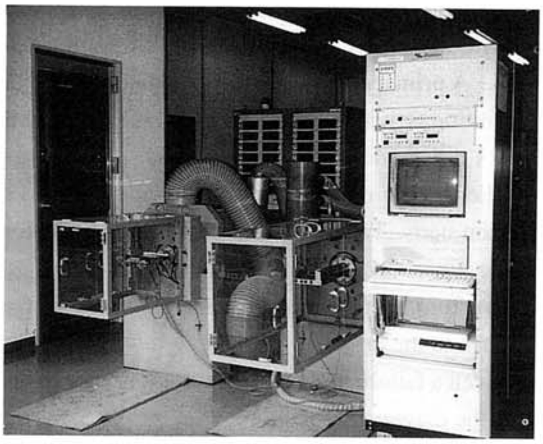

Figure 7. Shock test system

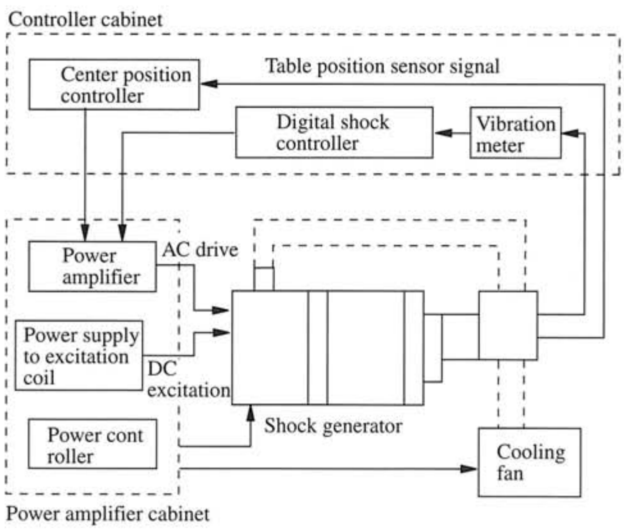

Figure 8. Block diagram of shock test system

5. Data storage in production process

Data is stored at each process of ECU production for the following two purposes:

1 Checking the status of the ECU during production and at shipment

2 Identifying the production lot of faulty components (if any) of the ECU

Table 2 shows production of the airbag ECU.

Table 2. Production of airbag ECU

Process flow	Process
▽ ◇	Reception inspection
○	Automatic part insertion
○	Manual part insertion
○	Soldering
◇	Measurement
○	Coating
○	Assembly
◇	Aging
◇	Shock test
◇	Shipment inspection
○ ▽	Shipment

6. Conclusion

Jointly with Toyota, we developed an ECU for a single-point sensing airbag. ECUs for airbags are rapidly becoming smaller and less expensive. We will develop a smaller ECU at lower cost and improve collision detection performance and quality.

7. Acknowledgments

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Kenichi Kinoshita

Employed by Fujitsu TEN since 1979. Engaged in developing electronic equipment for automobiles. Currently in the System Research & Development Department, Vehicle Electronics Division.

Hiroyuki Konishi

Employed by Fujitsu TEN since 1980. Engaged in developing electronic equipment for automobiles. Currently in the System Research & Development Department, Vehicle Electronics Division.

Tetsuhiro Mizushima

Employed by Fujitsu TEN since 1982. Engaged in quality control for manufacturing electronic equipment for automobiles. Currently in the Quality Control Department, Vehicle Electronics Division.