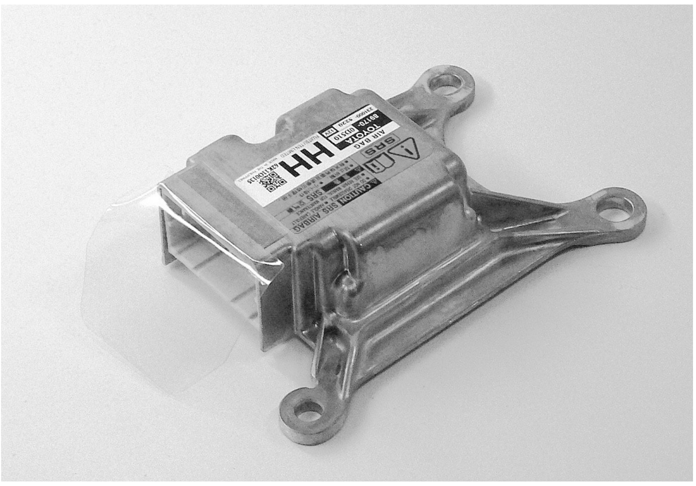
Development of Low-Cost Airbag-ECU for Emerging Markets

Junichi ENDO
Yoshiyuki HAJI
Tomoyo AZUMA
Yoshihiko MAENO



Abstract

Airbag-system markets are now greatly expanding because more vehicles are being equipped with airbag systems as standard in emerging countries such as BRICs. However, in accordance with large decline in vehicle selling prices in those areas, low-cost devices for vehicles are being highly demanded. Highly-reliable airbag systems are also demanded because they directly influence vehicle safety. Therefore, our major task is to develop a low-cost highly-reliable airbag that is as reliable as the conventional systems.

On the other hand in advanced countries where the airbag systems have already been common, the trends toward more diversification and higher functionality in airbag systems are accelerating in accordance with the increase of vehicle safety awareness.

We, at Fujitsu Ten, are now developing airbag ECUs so as to deal with these two big market trends. This paper will introduce our efforts of development of the low-cost ECUs targeting emerging countries.

1 Introduction

Almost all the current vehicles for sale in Japan and Europe are equipped with the system of airbags and seatbelt pretensioners for a driver seat and a passenger seat as a standard system as a collision safety technology has advanced and seatbelt use has spread. Therefore, the number of traffic fatalities in Japan has been decreasing year by year after peaking in 1992, according to National Police Agency data **(Fig.1)**.

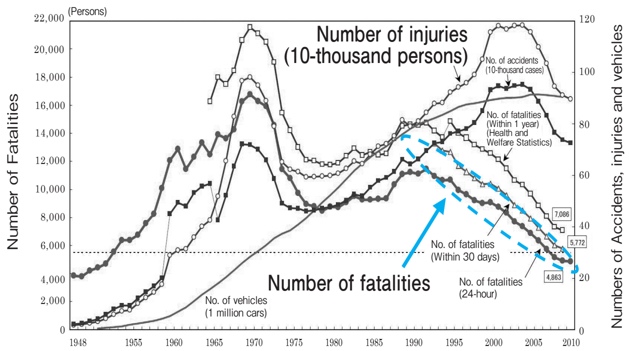


Fig.1 Transition of Number of Traffic Fatalities and Injuries

Almost all the vehicles for sale in the United States are equipped with the system of multi-level control airbags and side-collision airbags (side airbags and curtain shield airbags) based on a U.S. law, stricter than the laws of other countries, against assumed damages to passengers at the time of a side collision and an offset collision as well as a front collision. Further, a new law that aims to prevent passengers from being thrown out at the time of a roll-over will become effective in 2014. This will enhance the trend toward higher functionalities.

On the other hand in emerging countries including China, India and Brazil, traffic fatality rate has been above 20% for several years, and the fact shows that rapid spread of the airbag systems is demanded **(Fig.2)**. Toward the spread of the airbag systems, development of low-cost airbag systems is required.

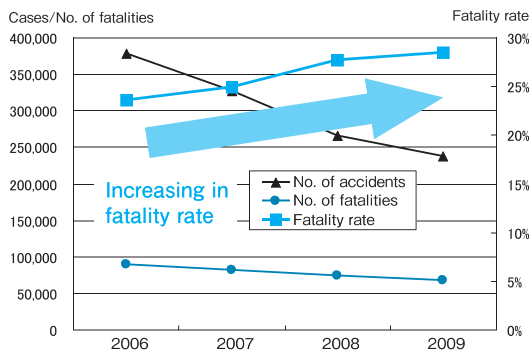


Fig.2 Traffic Fatality Rate in China

In the future, the market demands will be distinctly divided in two: one for higher-function airbag systems for advanced countries; and the other for low-cost airbag systems for emerging countries including China.

2 Overview of Airbag System

An airbag ECU controls frontal-collision multi-level airbags, seatbelt pretensioners, side airbags, curtain shield airbags, etc. for a driver seat and a passenger seat. As can be seen from the configuration example shown in **Fig.3**, the airbag ECU is set in a central forward location within the vehicle interior, and front satellite sensors and side satellite sensors are set at the vehicle front and the sides respectively. The airbag ECU and the sensors sense frontal and side impacts. Computation of such sensing is performed by a microprocessor inside the airbag ECU; if the sensed impact exceeds the impact level set for each type of a vehicle, a firing circuit is turned on to make current flow to a firing device (hereinafter referred to as squib), which ignites a gas generating agent, whereupon high pressure gas is generated and instantly inflates the airbags.

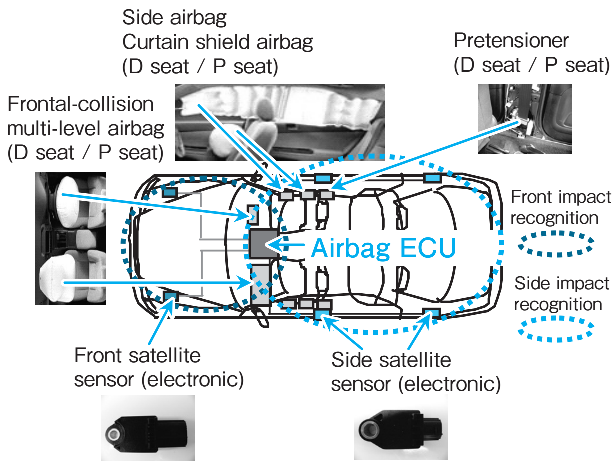


Fig.3 Example Configuration of Airbag System

3 Transition of Airbag ECU Development at FUJITSU TEN

FUJITSU TEN started delivering the airbag ECUs (1-channel specifications for only driver seat airbag system) as options to TOYOTA Motors in 1993 in which they were still expensive and low in demand, and is currently manufacturing 2 million units or more annually in total at factories in Japan, Europe, China and the Philippines.

Corresponding to collision safety standards (laws) of individual countries, squib channel number has increased year by year as shown in **Fig.4**. However, we have decided to develop a low-cost ECU based upon the specifications that are optimized for emerging markets.

The adopted system that provides 4 channels at maximum allows the airbag ECU to be much more streamlined and much lower in costs compared to the 06-model airbag ECU (frontal-collision ECU) with 8 channels that has been mass-produced since 2006.

This paper will introduce our efforts for technology development of the low-cost airbag ECU targeting the emerging markets.

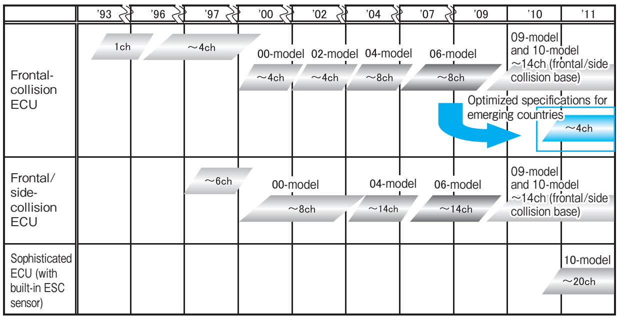


Fig.4 Transition of Airbag ECU Development at FUJITSU TEN

4 Development Objectives

4.1 Specifications of ECU under Development

Specifications	ECU under development (Low cost model)	Conventional ECU (06-model)
Squib channel number	Up to 4ch	Up to 8ch
Front satellite sensor	Up to 2ch	Up to 2ch
Side satellite sensor	NA	NA
Extended input	Up to 1ch	Up to 3ch
Extended output	Up to 1ch	Up to 1ch
P-seat indicator	OFF	ON/OFF
LA warning indicator	CAN, Direct line	CAN

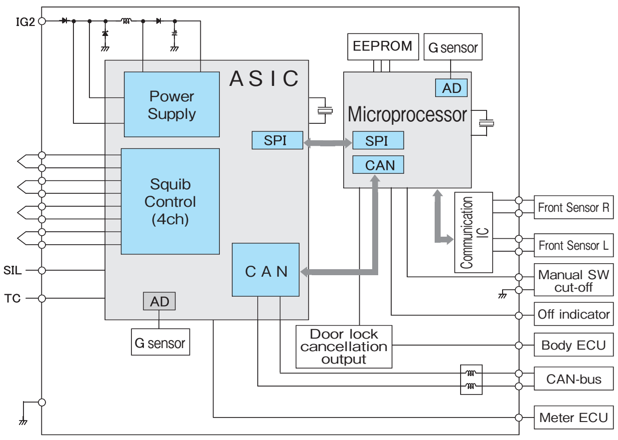


Fig.5 Circuit Diagram of ECU under Development

4.2 Development Target

We have set our development targets for a new ECU as follows: compared to the conventional ECU, 25% lower in material costs; 30% smaller in the number of applied components; and 25% lighter in weight of an ECU housing. Following three items are important for achievement of our targets. **(Fig.6)**

(1) Streamlined power circuit

Reduce the number of components by optimizing and simplifying power capability.

(2) Compact custom IC (ASIC)

Reduce costs by adopting a new process, streamlining a circuit (analog or digital) having optimized specifications, and downsizing a chip.

(3) Downsized ECU housing

Downsize the ECU housing and reduce its weight, while keeping transmission characteristics of an acceleration sensor (G sensor) inside the ECU and impact resistance at the time of a collision.

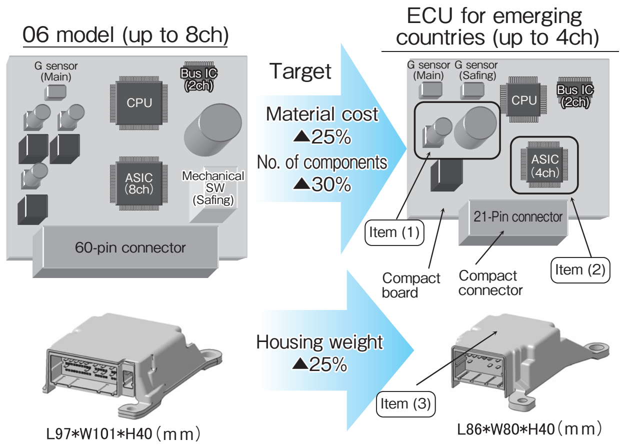


Fig.6 Development Target of Low-Cost ECU for Emerging Countries

5 Newly-Developed Technology

5.1 Streamlined Power Supply

Simplifying a power circuit is important so as to realize a wholly-streamlined ECU because the power circuit relates to many components and occupies large area on the airbag ECU. The airbag ECU (06-model) that has been mass-produced since 2006 was designed to provide the power capability enough to support 8 channels of the squib at maximum. However, the power circuit configuration of the 06-model has an excessive power capability for the low-cost ECU that covers 4 channels at maximum. Therefore, by reducing the power capability down to the appropriate specification level, we have sought to simplify the structure of the power circuit and downsize components. **(Fig.7)**

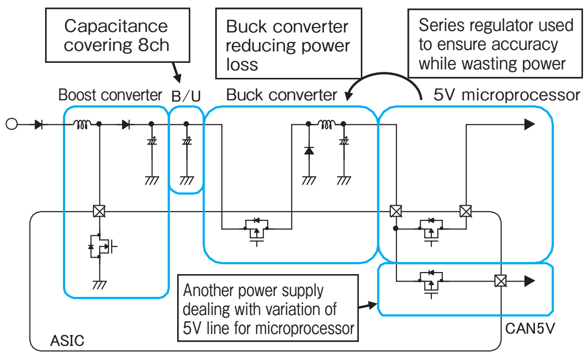


Fig.7 Power Circuit of Conventional ECU (06-model)

The following three points were studied for the simplified circuit: ① removing a buck converter, ② downsizing a back-up capacitor, and ③ sharing a 5V power supply (between a microprocessor and a CAN). **(Fig.8)**

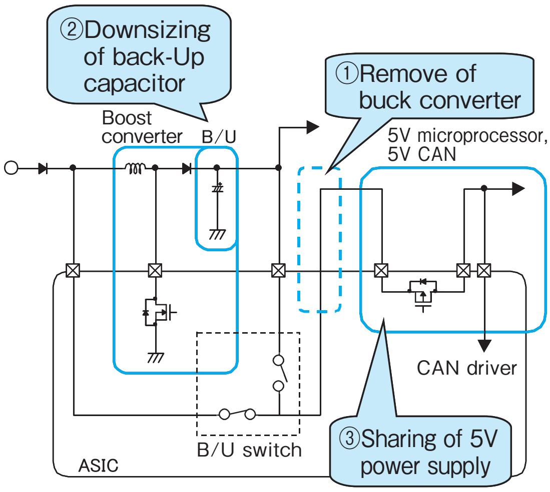


Fig.8 Power Circuit of ECU for Emerging Countries

In terms of the point ①, removing the buck converter increases the power loss of the 5V power supply that has been controlled by the buck converter, which may cause a large rise in temperature of a transistor inside the ASIC. Thus, we have sought a new structure so as to keep the temperature at an ASIC junction under 150℃ by way of thermal analyses using simulations and confirmation using actual devices.

The results revealed that the temperature exceeds 150℃ at the time of a fault such as a short circuit that allows a current to travel between a squib and a positive battery terminal due to catching of a vehicle wire harness.

Therefore, we adopted a new structure that divides the generated heat into two components: the built-in transistor in the ASIC; and an external transistor. This structure keeps the temperature at the junction in the ASIC at 150℃ or less. **(Fig.9)**

The structure based on the minimized distribution rate of the electric power to the external transistor enables minimized sizes of components and costs. **(Fig.10)**

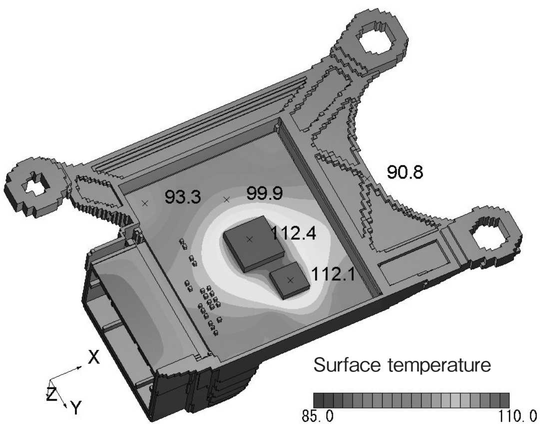


Fig.9 Thermal Analysis Simulation Result

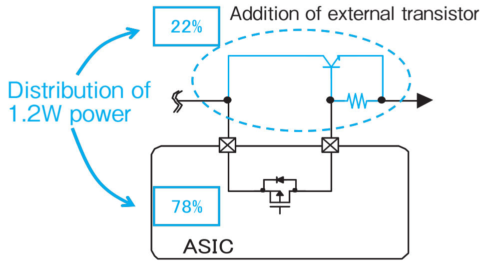


Fig.10 5V Power Distribution

In terms of the point ②, the backup capacitor is downsized / made lower in height; from a conventional $\phi 18 \times H25$ capacitor to a $\phi 18 \times H16.5$ capacitor. This was decided through the review of its capacitance required for backup performance in consideration of the reduced number of squib channels and the reduced current consumption. Besides, the circuit structure is simplified by the use of the backup capacitor as a smoothing capacitor of the boost converter as well.

In terms of the point ③, whether or not the 5V power supply can be shared (between the microprocessor and the CAN) has been studied based on the premise that airbag functions shall not be influenced even in the case of a failure occurred on a CAN bus line.

While a measure to reduce the voltage variation of the 5V power supply due to the unintended current draw occurred in the case of a failure on the CAN bus line was taken, the voltage variation actually occurred because a current limit function did not work in time due to the delayed response of the circuit. **(Fig.11)**

Since the voltage variation of the 5V power supply directly influences collision detection performance of the airbag ECU, we have decided not to share the 5V power supply on the low-cost ECU.

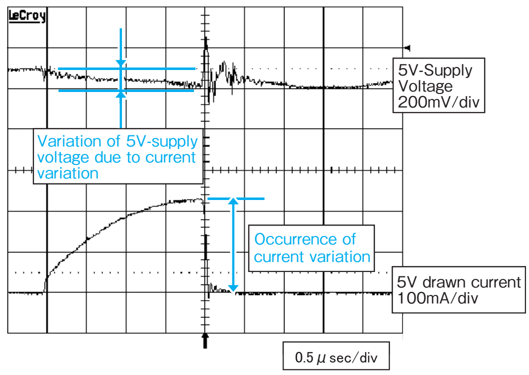


Fig.11 Verification Result of Voltage Variation of 5V Power Line on ECU

5.2 Compact Custom IC (ASIC)

The developed ECU adopts a different ASIC designed based on a different process rule, approx. 45% shrink rule, instead of the ASIC installed in the conventional ECU (06-model). The new process technology contributes to controlling parasitic actions, shortening interelement spacing, and drastically downsizing elements.

Besides, we have thoroughly studied reducing the numbers of the elements and logic gates from the aspect of simplifying IC functions and downsizing a chip in accordance with the optimized specifications of the airbag ECU.

As a result, the number of the logic gates was reduced down to 12,000 (minus 43% compared to the conventional one), the number of the analog elements was down to 3,200 (minus 18% compared to the conventional one), and the size of the chip was reduced by 22% (area) compared to the conventional one.

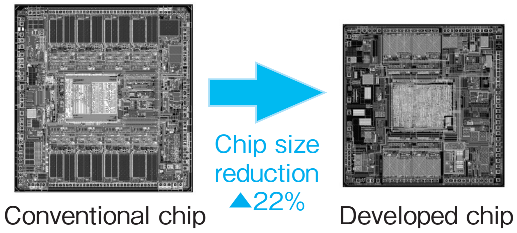


Fig.12 Chip Size Comparison of Custom ICs (ASIC)

5.3 Downsized ECU Housing

Adopting the squib having 4 channels at maximum allows connectors and a printed board of the ECU for emerging countries to be downsized. However, the connectors' points and vehicle attachment points of the ECU must be designed at the same positions as the conventional ECU (06-model) to fit standardized ECU installation positions.

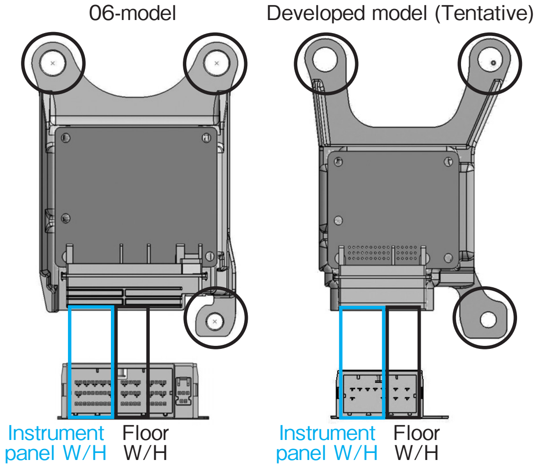


Fig.13 Standard Installation Style of Airbag ECU

As shown in **Fig.13**, bracket parts have to be extended so as to fit the standardized installation positions. However, this may increase the risk of impairing the important functions as the housing of the airbag ECU: "function for reliable transmission of collision G-force to a G-sensor on a printed board; and "function for protection of a printed board," due to less stiffness of the extended bracket parts. On the other hands, reinforcing the housing to fulfill its functions increases its weight and makes it difficult to reduce its costs.

Therefore, important points for designing the downsized housing for the low-cost ECU are ① fulfilling the functions and ② reducing the weight, with minimum reinforcement (increase of weight).

①Design for fulfilling functions

The design parameters that contribute to G-force transmission performance and strength were specified based on quality engineering through extraction of design parameters at the condition with no reinforcement.

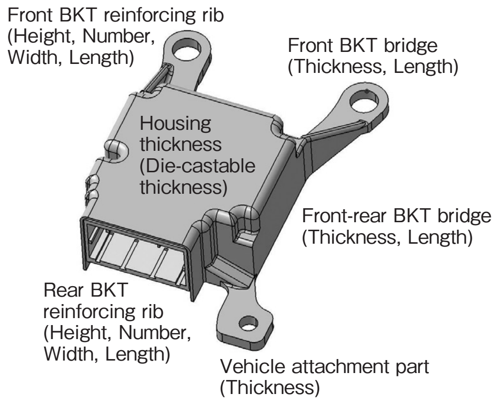


Fig.14 Housing Design Parameters

The following parameters highly contribute to the housing functions: length, height and number of front bracket and rear bracket reinforcing ribs; and thickness and length of front bracket and front-rear bracket bridges. Therefore, the housing was designed based on appropriate design factors including these parameters and the factors for contributing weight lighting as well.

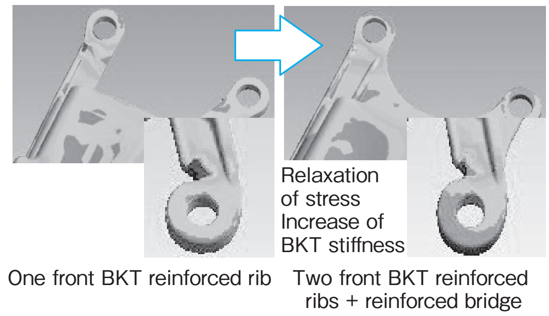


Fig.15 Example Strength Analysis

Since we verified that the vibration properties (transmission properties) and the strength fulfill the required specifications by use of the product molded in the shape studied above, we determined to adopt the shape as shown in **Fig.16**.

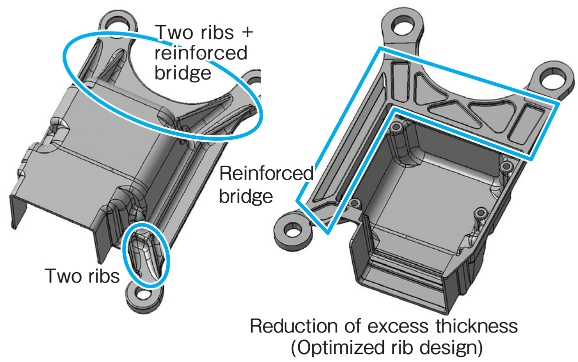


Fig.16 Determined ECU Housing Shape for Emerging Countries

②Reduction in weight

The minimum weight increase for reinforcement as studied in ① realized 25% reduction in weight of the developed housing and reduction in costs compared to the housing of the conventional ECU (06-model). Further, the developed ECU housing weighs less than or equal to the other competitors' airbag ECU housings. These facts show that we have succeeded in designing the highly-competitive airbag housing.

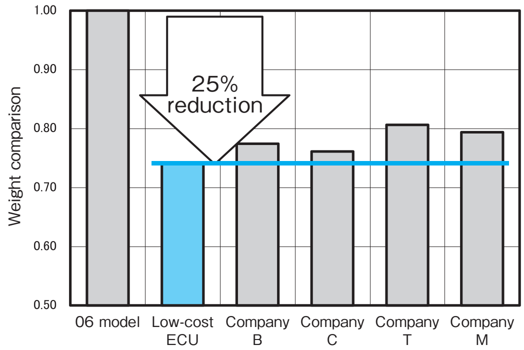


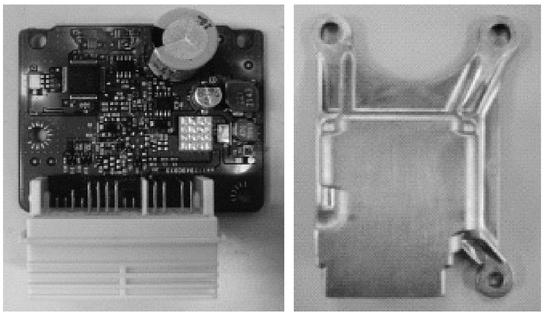
Fig.17 Housing Weight Comparison with Competitors

6 Development Results

The table below shows development results.

	Development target	Results	Judgment
Material costs	▲25%	▲30%	Achieved
No. of components	▲30%	▲31%	Achieved
Housing size (Weight)	▲25%	▲26%	Achieved

We have made intense and consecutive efforts to develop low-cost products, which led to achieve the initial development targets: 25% lower in material costs; 30% smaller in the number of components; and 25% smaller in housing size.



ECU board ECU housing

Fig.18 Low-Cost Airbag ECU

7 Future Engineering Development

In the future of the emerging markets, we predict that upgrade systems such as a 6-channel system and an 8-channel system will increase in demand based on the increase of vehicle safety awareness especially in China, instead of this frontal-collision-specialized system that has 4 channels at maximum.

To meet the future market demands, we will further develop a low-cost ECU that is activated in a frontal and a side collisions and is packed in the small housing size developed this time.

8 Conclusion

The newly-developed ECU has been mass produced since December 2010 at the factory of FUJITSU TEN PHILIPPINES as the ECU for emerging countries, and has significantly contributed to price reduction of airbag systems.

Lastly, we would like to express our heartfelt thanks to everyone involved for their cooperation and guidance for this development.

References:
"Traffic accidents situation -- yearly 2010"
National Police Agency (Jan. 27, 2011)

Profiles of Writers

Junichi ENDO

Entered the company in 1991. By way of manufacturing of automotive electronics, has engaged in the hardware development of airbag ECUs since 2002. Currently in AE Engineering Dept 1, AE Engineering Div, AE Engineering Grp.

Yoshiyuki HAJI

Entered the company in 2002. Since then, has engaged in the structural design of AE products (airbag ECUs mainly). Currently in Development Dept 2, Common Technology Div, ITS Engineering Grp.

Tomoyo AZUMA

Entered the company in 2006. Since then, has engaged in the box design and element development for airbag ECUs. Currently in Engineering Dept 1, Fujitsu Ten Technology Limited.

Yoshihiko MAENO

Entered the company in 1984. Since then, has engaged in the development of automotive electronics. Currently the Department Manager of AE Engineering Dept 1, AE Engineering Div, AE Engineering Grp.