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System on Chip design of Embedded Controller for Car Black Box

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***Abstract*— This paper describes the design process of Car Black Box system IC. As x by wire is introduced to the several part in vehicle, the demand of automotive semiconductors are increasing. Because it will be mandatory for every car to be equipped with Car Black Box, it is expected that many ICs for Car Black Box also will be integrated. Unlike general electronic control units (ECUs) as PCB or module, car black box implemented on a single chip can reduce its size, power consumption and the cost. So the topic of this paper is to develop the Embedded controller for Car Black Box using SoC (System on Chip) technique.**

System on Chip (SoC) is the effective method to implement embedded system like car black box, which consists of processor, memory, I/O peripheral and several interfaces.

SoC for Car Black Box system consists of 8051 processor, CAN (Controller Area Network) controller, JPEG compressor, SD controller for dumping the data from memory buffer to SD card, ROM for programming and SRAM acting as memory buffer. Describing the design process in the hardware and software, it was shown in the verification using MFC(Microsoft Foundation Class) program whether the required data such as image, location and other vehicle control status information was recorded and recovered.

I. INTRODUCTION

Like Black Box of airplane, Car Black Box (known as Event Data Recorder) is used to record information related to accidents.

Car black box records driving data, visual data, collision data and position data before and after the accidents so that it can be used to analyze the accident easily and to settle many disputes related to car accident such as crash litigation, insurance settlements. It can be used to not only reconstruct what happened before an accident by Insurance agents and police but improve vehicle design, roadway design and emergency medical service by automakers, government and hospital.

In addition to the basic function, the car black box equipped with wireless communication system can send accident location information to central emergency and disaster server in real-time, therefore drivers who want help can receive service quickly by rack car, police and hospital ambulance.

Car Black Box detects a crash automatically, and also records the motion of the vehicle and driver's actions during a predefined time period before and after the accident.

It consists of data collection devices for collecting the information about car's status and the driver's actions, a non-volatile memory device for recording, a microprocessor for controlling the unit and a wireless modem for communication. The car black box contains not only a record of what was happening in the last seconds before the impact but also the record after a collision. So it should take the most recent data values and store them in buffer with a circular sequence (RAM). When the black box senses the accident, buffer refreshing is suspended and the data before and after accident are transfer to flash memory automatically.

Figure 1 is the concept of Car Black Box.

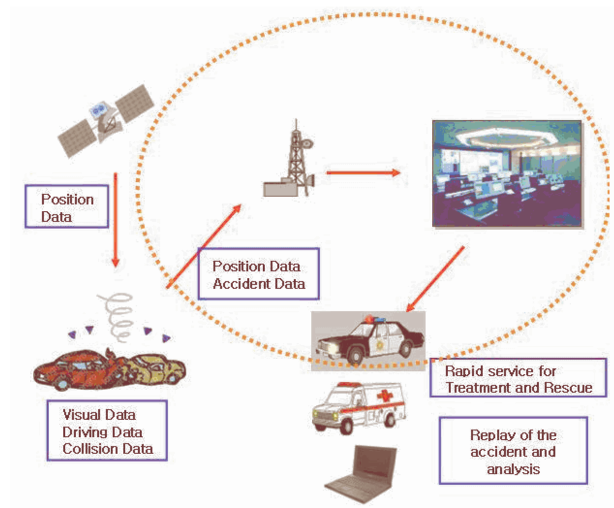

Figure 1. The concept of Car Black Box

The functions of Car Black Box follow as:

1. Data collection

- Visual data : Visual information in front and rear side during driving from camera.
- Driving data : Driving information such as speed, brake and seat belt status, steering performance.
- Collision data : Time, speed and shock power when accident from accelerometer.
- Positioning data : The car positions checked in real time by GPS.

These data are saved temporarily in RAM as memory buffer and transfer to the Flash memory like SD card.

2. Accident analysis & reconstruction

- analyze the accident easily and to handle many problems related to car accident like crash litigation, insurance settlements

3. Wireless communication

- Transmitting the all data via Wireless Network, such as CDMA and GSM/GPRS when accident to main control center.
- support rapid service for rescue and treatment of accident

In this paper, we present a SoC design of Embedded controller for Car Black Box, which integrated Car Black Box functions onto a single chip. It has several advantages with higher performance, smaller space requirements, lower power, higher system reliability, lower consumer costs.

Next section describes In Vehicle Network based Car Black Box architecture and its components. The design of hardware and software and SoC design flow is presented in section Ⅲ. Section Ⅳ shows the results of the design. The conclusions are given in Section Ⅴ.

II. In Vehicle Network Based Car Black Box Architecture

In Vehicle Network based Car Black Box consists of 8051 core that is processor of embedded system in vast range of industry, CAN (Controller Area Network) controller as standard In Vehicle network, JPEG compressor to compress image obtained through CMOS Image Sensor, SD controller dumping the data from memory buffer to SD card, collision detector, ROM for 8051 program and SRAM acting as memory buffer. These hardware modules are integrated in only one chip. We implement the whole hardware onto a single FPGA except sensor modules like CMOS Image Sensor, GPS and Accelerometer. Figure 2 shows the architecture of Car Black Box.

8051 initialize CAN controller, JPEG compressor and SD controller and also receives data from GPS and CAN controller. 8051 not only recognizes the crash through interrupt pin connected with Collision Detector when car collision is detected but also moves the data of Memory Buffer to SD card by activating SD controller.

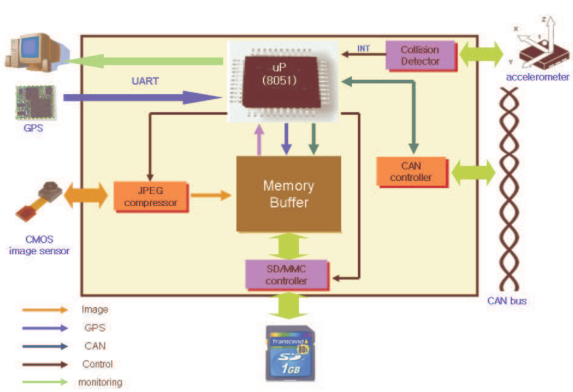

Figure 2. In Vehicle Network based Car Black Box Architecture

CMOS images sensors can offer many advantages over traditional CCD sensors as follows: no blooming, low power consumption, direct digital output, small size and little support circuit and simple design with. CIS of this black box is to obtain digital image data easily. It used to get image data of front and rear of car at regular intervals.

GPS (Global Positioning System) provides continuously record vehicle position and precise time.

An accelerometer is a device for measuring acceleration. It computes the change vehicle velocity during the impact and makes known existence of crash to car black box.

CAN (Controller Area Network) is a high-integrity serial data communications bus and connect many electronic components in modern vehicles such as electronic control units (ECUs), sensors, actuators to single wire. The driving data like car speed, engine RPM, throttle position, brake status are gathered from this CAN controller through CAN bus.

Memory buffer is the temporary storing place including GPS, image, CAN data. Because the memory of the black box is limited, it only retains the information for a few seconds. Image data is too large so image compression like JPEG is applied.

SD card is a memory card that is specifically designed to meet the security, capacity, performance and environment inherent in newly emerging audio video consumer electronic devices. It includes protection mechanism and also can support easily interface allowing a PC to be connected without special devices. In addition, If file system (FAT16 or 32) is applied, data is stored in Microsoft Access format for ease of analysis. All stored data can later be recovered using a PC equipped with appropriate software.

In this architecture was excluded wireless communication function of pre-described Car Black Box.

III. SoC Design of Car Black Box

8051 core, CAN controller, JPEG compressor, SD controller and peripheral logics, which are described by verilog HDL and VHDL are designed. These hardware blocks are integrated in a chip and are implemented by FPGA (Field Programmable Gate Array) chip. The design flow is described in Figure 3.

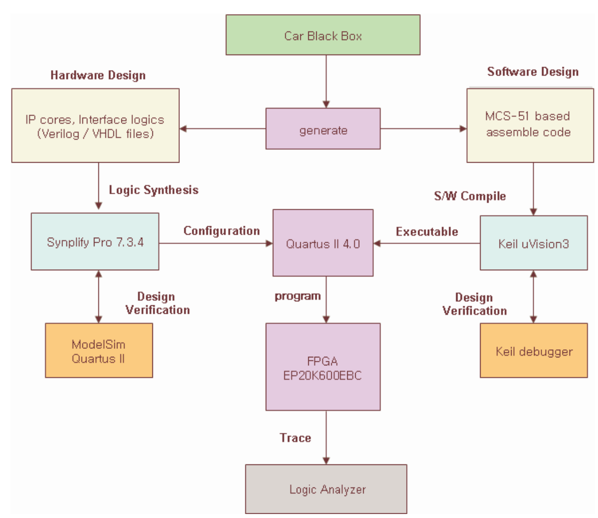

Figure 3. The SoC design flow of Car Black Box

A. Hardware

The synthesized hardware blocks by Synplify Pro 7.3.4 are placed and routed to the Altera FPGA (EP20K600EBC) by Quartus ll 4.0. The whole hardware blocks are depicted as Figure 4.

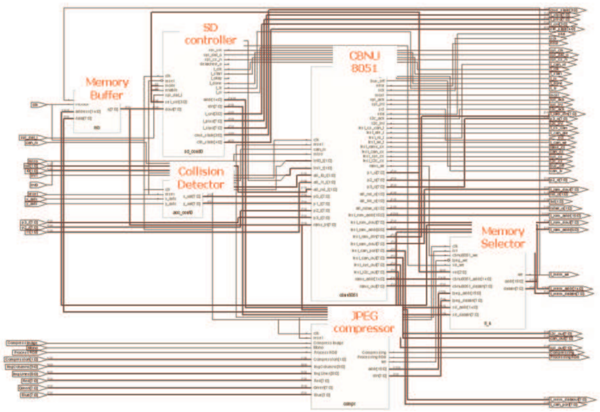

Figure 4. The synthesized hardware block

CBNU8051 has several serial interfaces like as CAN controller, SPI controller and I2C controller as well as 8051 core based MCS-51. Especially CAN controller is embedded in CBNU8051 for CAN communication. It is compatible with standard 8051 microcontroller and faster 10 times by designing new structure. Program ROM for storing executable code (HEX) and simple bus structure to interface serial logics is implemented. Figure 5 shows CNBU8051.

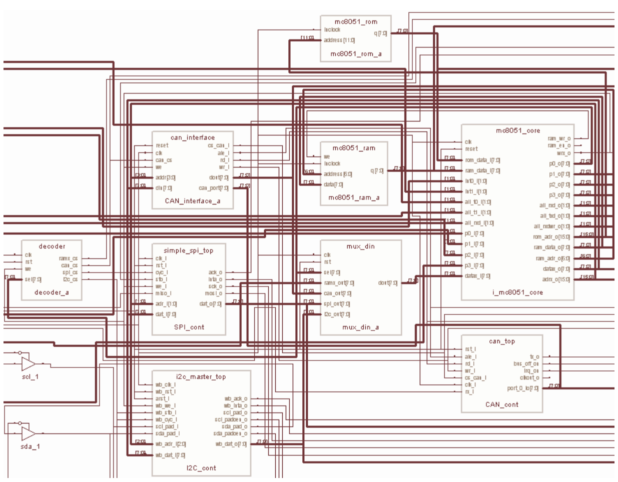

Figure 5. CBNU8051 block diagram

JPEG compressor is compliant with ISO standard (and ITU standard T-81), which makes image format of baseline DCT JPEG with JFIF header. It is able to compress at a rate of up to 24images per second (40Mhz with resolution 352x288).
This hardware consists of CIS control logic to initialize CMOS image sensor and to get output data of image sensor and JPEG logic to compress image data from image sensor. JPEG compressor is shown in Figure 6.

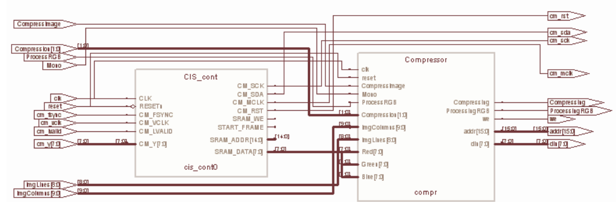

Figure 6. JPEG compressor block diagram

SD controller plays the rule of SRAM-to-SD card interface, which it transfers the data saved in SRAM to SD card in a block of 512 bytes through SPI bus.
sd_wrap block conducts to transfer data from serial to parallel and from parallel to serial between SRAM and SD interface. And sd_interface block takes charge of SD card protocol. It is described by commands and responses of SD card following SPI bus protocol. This is the block diagram.

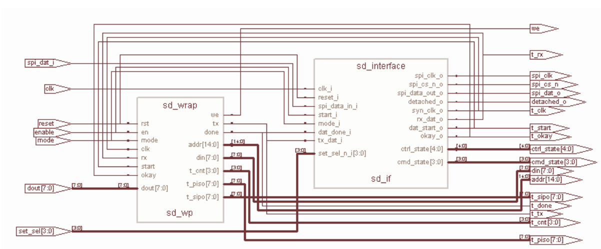

Figure 7. SD controller block diagram

The last collision detector is the logic to detect collision by estimating accelerometer data.
The total logic elements and memory for implementation are shown table 1. Target FPGA is Altera EP20K600E.

	Car Black Box
Total Logic elements	7,641/24,320 (31%)
Total Memory bits	298,816/311,296 (95%)

Table 1. Synthesis result in Quartus ll

B. Software

Embedded software in car black box is executed by 8051. The software is designed in assembler using Keil software and then input in ROM of ALTERA as initialize file formatting HEX.
CAN and GPS data are collected through CAN controller and UART of CBNU8051 and saved to designated address of SRAM. To get useful data from CAN bus the code is described to set baud rate, message filtering and to input identifier of CAN remote frame. When collision detected by interrupt pin of 8051 SD controller is enable by 8051 and then stored car black box data to external memory (SD card) automatically.
In addition to that, the software for UART transfer is described to debug that valid data is recorded in SD card. This is the software design flow.
The external interrupt 0 indicates collision detection and interrupt 1 indicates the end of SD card read/write operation. All data of Car Black Box are updated per 1 sec.

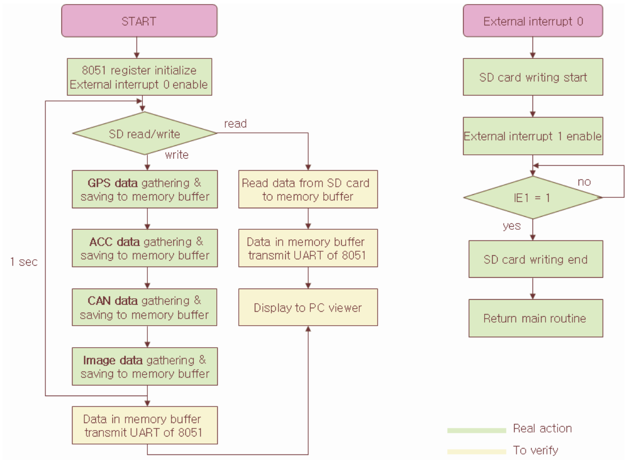

Figure 8. Software Design Flow

IV. TEST AND VERIFICATION

To verify that correct data of car black box is recorded in SD card, we use serial port. Stored data in SD card are transferred by UART of 8051 and displayed serial monitor in PC. Next is the monitored result of car black box's data for the data saved memory buffer and the data stored in SD card.

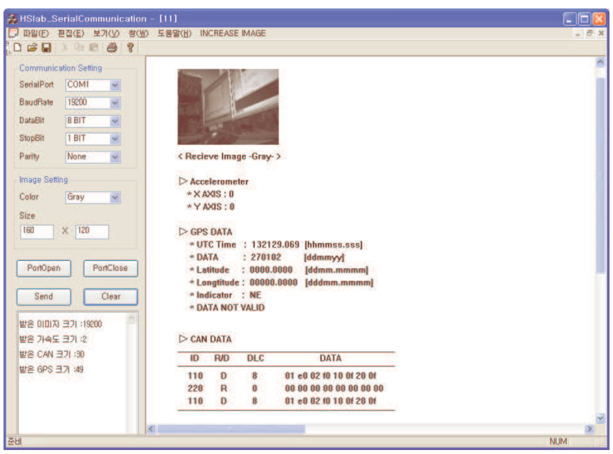

Figure 8. The monitored result of Car Black Box data

We can monitor image data, acceleration data, GPS data and CAN data from three CAN node. One frame of Images was shown because image size is large and serial baud rate is slow. And the antenna of GPS can not receive GPS data properly from GPS satellite so GPS data is not valid.

V. CONCLUSIONS

In this paper, we present the design of Embedded controller for Car Black Box. We made a System on Chip design for Car Black Box through integrating and verifying each IP of 8051 core, CAN controller, SD controller, JPEG compressor and other components. The design result for Car Black Box system IC is implemented into FPGA and is verified in the test board system for demonstration.

ACKNOWLEDGMENT

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