NOTE

Development of Unified Power Supply IC for Car Navigation Systems

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1 Introduction

A car navigation system (hereinafter referred to as navigation system) that is a core product of Fujitsu Ten further improves its operability and convenience, and becomes increasingly highly functionalized and highly sophisticated. And, there is a requirement to reduce the size and weight of a car navigation product.

Meanwhile, the product development considering follow-up to the decline in unit prices due to the spread of portable navigation devices and smartphones, and commoditization of the navigation system has become a major issue for manufacturers.

Under such circumstances, in a power supply circuit which supports the navigation system behind the scenes, a more inexpensive configuration that enables miniaturization has been expected. We have considered the integration of power supply functions into an IC as a means for achieving such a configuration, and have developed the IC which is adoptable to various models and usable in the future.

This paper introduces some features of the developed IC in which power supplies are unified.

2 Introduction of the Developed IC

Fig. 1 shows a configuration example of the power supply for a Fujitsu Ten navigation system using this IC. Among the power supply functions normally required for the navigation system, the following circuit functions that directly handle the battery voltage have been integrated into the IC. The expensive circuit functions requiring an intermediate breakdown voltage process can be efficiently integrated into one chip, thus we have realized miniaturization and cost reduction.

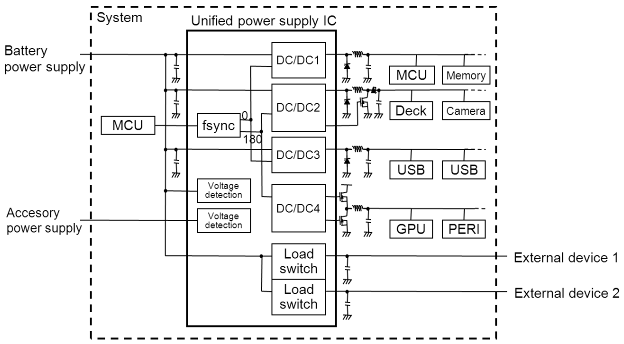

Fig.1 Example of power supply configuration with this IC

- **●Four DC/DC converters**
- **●Two voltage detecting functions (Battery power supply, Accessory power supply)**
- **●Two load switches (for feeding ON/OFF of load)**

The following sections explain the outlines of the respective functions.

2.1 Outline of DC/DC converters

DC/DC1 is designed on the assumption that it is used as a power supply which constantly supplies electric power to a microprocessor and a memory. Since the DC/DC1 supplies power even when a vehicle is not used, in order to suppress the consumption of a battery, it corresponds to the low current consumption mode that reduces an operating current by minimizing a switching frequency when a load current is small. In addition, the DC/DC1 corresponds to a low-voltage operation of 4V so as not to reset the microprocessor due to drop of the battery voltage when starting an engine.

DC/DC2 is designed on the assumption that it is mainly used as 8V power supply for driving a motor of a CD or DVD deck. In the case of no idling vehicles, for the stable 8V power supply even when the battery voltage drops in order to prevent music and video reproduction from being interrupted when restarting the engine from a state where the engine is stopped because of a traffic congestion or a intersection or the like, the DC/DC2 can be used as a step-up/step-down power supply.

DC/DC3 is designed on the assumption that it is mainly used as 5V power supply for USB bus power. While taking into consideration mounting of plural USB ports and USB charging of a tablet device, the DC/DC3 corresponds to power feeding of 2.1A.

DC/DC4 adopts a synchronous rectification method generating little heat in power supply components to supply a large current to the navigation system, peripherals, and the microprocessor for controlling them. In order to correspond even to a large scale GPU (Graphics Processing Unit) and a SoC (System On Chip), a switching FET is externally attached so that a FET can be selected according to the necessary current feeding capability.

Also, in order to ensure the radio reception performance, a switching noise of the DC/DC converter needs to avoid the frequencies of radio stations. To respond to this, a function for synchronizing the switching frequency of the DC/DC converter is added to the high-precision clock supplied from the microprocessor so that the frequency of the switching noise is controlled by the microprocessor. The DC/DC1 further judges that the navigation system has booted by a clock input, and the mode is shifted from the low current consumption mode to the PWM mode of operation at a constant frequency. Accordingly, the noise frequency may be controlled as well as other DC/DC converters.

2.2 Outline of voltage detection and load switches

In terms of voltage detection, a function for detecting whether the battery voltage enough for navigation operations is supplied and a function for detecting ON/OFF of the accessory power supply are integrated.

Load switches are provided for feeding power to external devices linked with the navigation operations, and the two switches with overcurrent protection and overtemperature protection functions are mounted.

2.3 Selection of package

As for the package, while considering the number of required terminals, heat radiation, mountability, and cost advantage, we have selected QFP48 with a backside heat radiation pad. As a result of carrying out a thermal resistance simulation for package shown in **Fig. 2** with the PCB specifications of Fujitsu Ten, from the result indicating θ j-a=25℃/W, the size and the target specifications of the FET to be built in the IC have been determined.

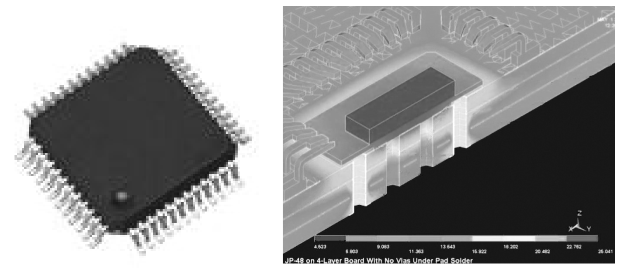

Fig.2 Simulation result of package thermal resistance

3 Challenges for Power Supply IC Integration

There are many challenges in integrating plural DC/DC converters and switches into an IC. We face some problems specific to in-vehicle devices, and three innovative points in terms of design are introduced below.

3.1 Securing of independence of each power supply

The first problem by the integration of power supplies is that the heat generated by the abnormal operation in a partial power supply spreads throughout the IC, by actuation of an overtemperature protection function for stopping before the heat reaches the high temperature state leading to a breakdown or a malfunction, all power supplies are shut off, and the whole system does not operate. For example, since it is possible that a navigation function cannot be used just because an abnormality occurs in an external device, a customer who goes out by relying on the navigation system feels inconvenience.

To solve this problem, two phases of overtemperature protection temperature are provided for this IC. By stopping the load switch which feeds power to the external device at the lower overtemperature protection temperature, and by stopping the DC/DC converters at the upper overtemperature protection temperature, as shown in **Fig. 3**, the DC/DC converters are prevented from being stopped by the abnormal operation of the external device.

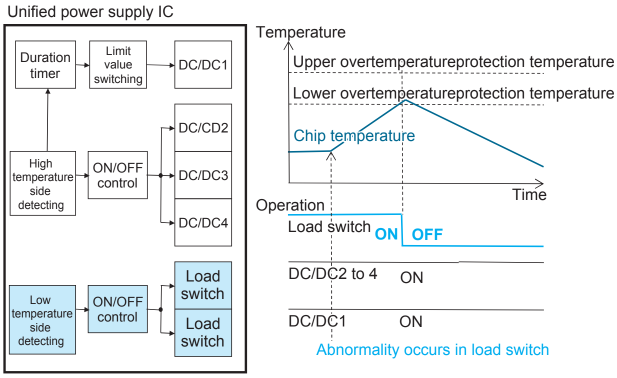

Fig.3 Operation of this IC by abnormality in load switch

Since the DC/DC1 is the power supply for the microprocessor and the memory, when the main power supply is stopped, the whole system including setting information is reset. Thus, this makes customers feel inconvenience.

To solve this problem, first of all, in order to suppress the abnormal heat generation of the DC/DC converters, the hiccup-type overcurrent protection method for switching to the intermittent switching operation when an overcurrent flows is adopted. When the temperature reaches the overtemperature protection temperature, the DC/DC converters excluding the DC/DC1 are latched off, and continuation of abnormal high temperature state is avoided. Nevertheless, if a state beyond the high temperature side overtemperature protection temperature is continued for a certain period of time, it is judged that an abnormality occurs in the DC/DC1, and the limit current level of the DC/DC1 is drastically lowered to recover from the high temperature state.

Thus, the intended independence can be ensured as shown in **Fig. 4**.

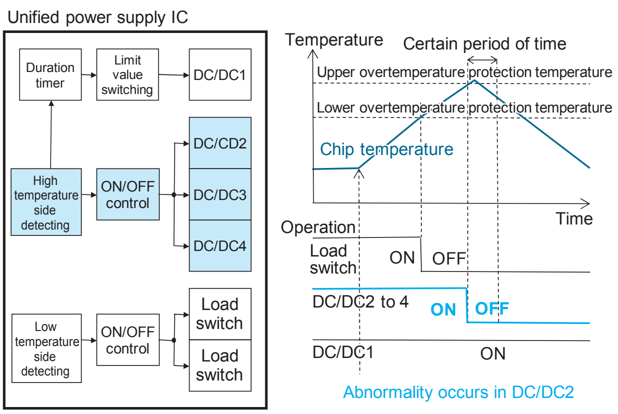

Fig.4 Operation of this IC by abnormality in DC/DC converter

3.2 Suppression of noise generation due to interference with operation between power supplies

The second problem due to the power supply integration is the interference of the switching noises between the power supplies. Since this obstructs stable PWM operations, the noise is generated in a band other than the switching frequency, and may cause the reception interference of an AM radio or a smart entry system.

The power supply block diagram in **Fig. 5** explains the mechanism for generating the noise. A switching power supply circuit is a noise source and includes a control circuit sensitive to the noise. Therefore, the noise generated when the switching FET of another power supply is turned on or turned off is superimposed on a current detection (Current Sense) signal, etc., the FET is turned off at a wrong timing, thus a subharmonic and its multiplier wave's noise is generated. This noise reduces the radio reception performance.

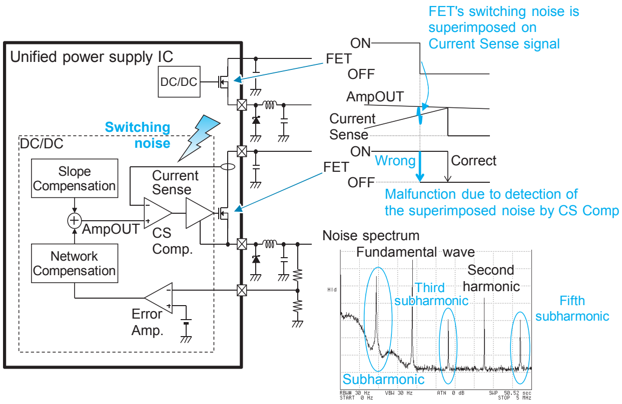

Fig.5 Power supply block diagram and generation mechanism of noise

To solve this problem, this IC includes the following countermeasures.

1) **Set the operation phase differences of the respective power supplies so that the turn-on timing and turn-off timing do not overlap each other, considering the set output voltage of each power supply (Common/Reverse phase).**
2) **Arrange the FET that becomes a noise source at a corner of the chip. Also, while reducing the GND impedance in the chip, decrease the noise mixed in the control circuit.**
3) **To make the internal power supply of IC independent between the respective power supplies, and eliminate the noise coming through the common circuit.**
4) **To suppress a ringing noise, in order to reduce the parasitic inductance, increase the number of bonding wires, and determine the terminal arrangement capable of arranging a decoupling capacitor in the shortest distance.**

Fig. 6 shows a photograph of this IC chip.

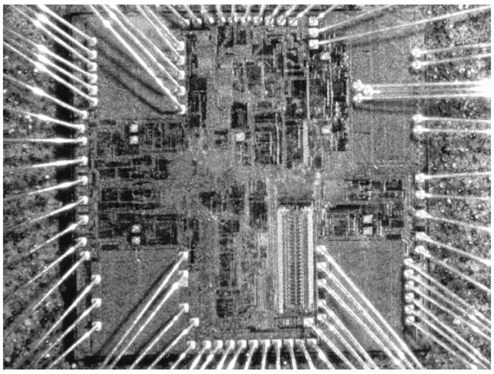

Fig.6 Photograph of developed IC chip

3.3 Supports both step-down power supply and step-up/step-down power supply

Step-up/step-down power supply is the power supply system capable of obtaining the desired output voltage even when the input voltage exceeds the output voltage or when the input voltage is lower than the output voltage. However, as necessary electronic components increase, the cost is higher than that of the step-down power supply. Since there are still many systems that satisfy the performance even in the step-down power supply configuration, this IC supports both power supply systems. As shown in **Fig. 7**, by focusing on the cost in the step-down power supply configuration, the step-down switching FET is built in the IC, and the step-up switching FET is externally attached according to the need of step-up/step-down.

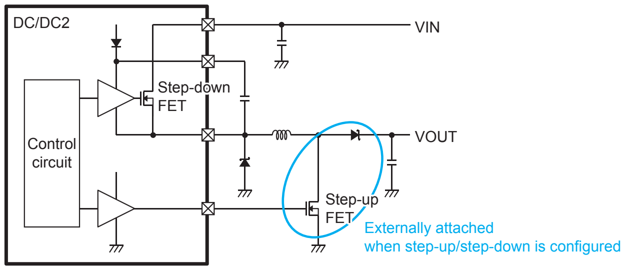

Fig.7 Circuit block diagram of buck-boost converter

The third problem here is to have the step-down switching FET built in the IC by suppressing the current flowing through the FET. Since the step-up/step-down power supply simultaneously performs a step-down operation and a step-up operation, both the input power and the output power are intermittently supplied, and the inductor current is increased as a result. However, since it is intended to reduce the cost for the step-down power supply configuration, the FET cannot be enlarged for the step-up/step-down power supply.

To solve this problem, an improvement is needed so as to minimize the overlap between the step-down operation and the step-up operation. Consequently, this IC adopts the control circuit that eliminates the overlapping period and seamlessly switches the step-down operation and the step-up operation. **Fig. 8** shows the current waveform in the case of input voltage: 7V, output voltage: 8V, 5.6A of the flowing current before the countermeasure can be reduced to 2.7A of current after the countermeasure, and integration of the step-down FET into the IC has been realized.

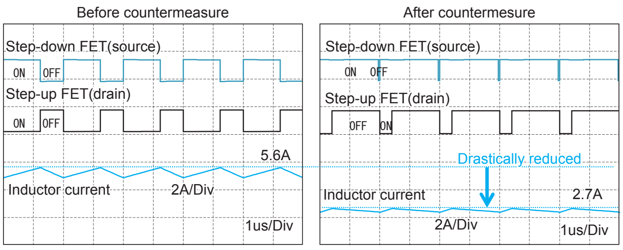

Fig.8 Inductor current waveform before and after countermeasure

4 Outcome of Development

The IC developed this time has been mounted on AVN for Japanese market released in autumn 2013, dealer option navigation systems, and some factory-installed options. Compared with our conventional products, the power supply circuit has been downsized by about 30%, reducing the cost by about 20%. In addition, we have ensured the independence of the power supply as intended, and have solved the technical problems to the integration such as suppression of an unwanted noise due to the interference with an operation. **Fig. 9** shows an example of the IC mounted on a product.

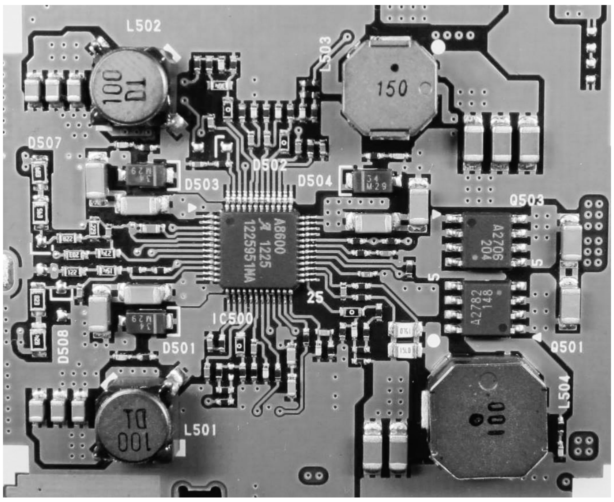

Fig.9 Example of this IC mounted on our product

5 Prospects and Challenges for the Future

In this IC development, we have solved the technical problems to the integration, and the IC which can be miniaturized while having performance and quality adoptable to products has been completed. However, further miniaturization may be required in the future. We will consider various measures toward the practical use of the IC, including a technology of reducing heat generation and noise, minimum arrangement and wiring of components, reduction of a required space by the built-in IC, and miniaturization of components by high-frequency switching, and we will continue to make efforts so as to release the attractive products.

6 Acknowledgment

Lastly, we would like to express our cordial appreciation to Sanken Electric Co., Ltd. and Allegro Microsystems, LLC, which have provided significant cooperation for developing this IC from the step of planning specifications.

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