The Proadlizer for the Next-Generation Notebook and Desktop PCs

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Abstract

A new type of decoupling device called the Proadlizer has been developed by NEC TOKIN that has been used as the decoupling capacitor in CPUs for notebook PCs. As the next-generation CPU is required to achieve a total ESR of 1mΩ, NEC TOKIN has newly developed an ultralow-ESR Proadlizer to meet this new trend. This paper is intended to introduce the Proadlizer as well as to discuss its potential for higher capacitance when used in desktop PCs with higher power consumption values.

Keywords

capacitor, notebook PC, desktop PC, CPU, one-chip implementation

1. Introduction

The CPUs (Central Processing Units) for use in PCs have been expanding in scale and functionality every year and the multi-core CPU configurations that have recently become the mainstream are promoting decreases in voltage and increases in current. Since the requirement for power saving design is regarded as being very important at the present time for notebook PCs as well as for other PCs, the CPUs vary the load frequently according to the operating conditions in order to reduce the power consumption. Due to this trend, the performance requirement for the decoupling circuitry for use in stabilizing the voltage is rapidly becoming more severe.

Another trend is the integration of multiple functions into the CPU. In ordinary PCs, the GPU (Graphics Processing Unit), memory control and various I/O hub functions are working on separate LSIs apart from the CPU. In the next-generation CPU, however, the GPU, memory controller and I/O hub functions will be integrated into a single package. This arrangement is achieved by a size reduction of the LSI. However, it will not only serve to reduce the board area but will also enable functional improvement by reducing the communication distances between LSIs. This will make it possible to reduce the size and price of PCs at the same time as improving their functions. Nevertheless, the proposed integration will also result in a concentration of various power lines at a single location, thus imposing more severe requirements for the power supply component layout and the noise environment design. In fact, it is expected that the standards recommended by LSI manufacturers will become very severe indeed.

To meet these trends in the CPUs and their power circuitry, we have improved the performance of our Proadlizer product. This paper introduces the outline of a Proadlizer featuring improvement of the ESR (Equivalent Series Resistance,) a component that exerts an important effect on the power load response as well as examples of its applications. In addition, while the Proadlizer has been used mainly in notebook PCs, the possibility of an increase in the capacitance thanks to the improvement of internal elements is opening the way to its application in the motherboards of PCs, including desktop PCs. We will also discuss this potentiality in the following sections.

2. Trends of CPUs for Notebook PCs

It was with an NEC notebook PC released in December 2005 that the Proadlizer was adopted for the first time. The CPU was Intel Pentium M (single-core) of the ultralow-voltage version, and the Proadlizer was used for the decoupling of the CPU core power supply.

Subsequently, the power control method of the CPU core was modified in 2006 in order to respond to the multi-core implementation and power saving requirements for the CPU. Here, the power control refers to the control for saving the CPU power consumption by dynamically varying the supply voltage according to the CPU operating status, and this arrangement is actually contributing greatly to the extension of the battery life of notebook PCs. The power saving control has actually improved considerably since the release of Intel Core Duo (dual-core,) which has increased the maximum current value.

Table 1 Example of capacitor configuration in the dual-core generation (2006 and after).

Item	Cap.	ESR	Quantity
Ta Polymer	330µF	6mΩ	4Pcs.
MLCC	10µF	-	32Pcs.
Total	1,640µF	1.5mΩ	36Pcs.

Table 2 Example of capacitor configuration in the integrated CPU generation (2009 and after).

Item	Cap.	ESR	Quantity
Ta Polymer	470µF	4mΩ	4Pcs.
MLCC	22µF	-	12Pcs.
MLCC	10µF	-	16Pcs.
Total	2,304µF	1.0mΩ	32Pcs.

Power saving requires optimum voltage control, and it is also important to reduce the ESR of the decoupling capacitors because this arrangement is accompanied by sudden variations in the CPU load. The ESR requirement for the CPUs of the dual core generation has hitherto been 1.5mΩ in total (**Table 1**).

In 2009, it is expected that the GPU, memory controller and I/O hub functions will be integrated in the CPU. However, integration into a single package complicates the power supply line and increases the path impedance due to the increase in the package size and pin number, so the requirement for the total ESR is expected to be 1.0mΩ (**Table 2**). In addition, concentration of multiple power supply lines at a single location also makes it necessary to choose a location for mounting the passive components including the capacitors.

3. Trends in Proadlizer Development

The concept of the Proadlizer is an "integrated passive component," and we consider it most valuable in its capability of providing integration of the passive components that used to be packaged in large quantities. The replacement of decoupling capacitors in the CPU core by a single Proadlizer is also very important in this context. Additionally, considering the low ESR requirement that is becoming more severe, as described above, it is expected that a total ESR of 1.0mΩ or less will be a mandatory condition for the next-generation CPUs.

Table 3 shows the low-ESR Proadlizer we have recently developed. The developed product we released achieves a very low ESR of below 1.0mΩ from the same size and capacitance as before (16.7mm × 12.1mm × 2.5mm, 900µF).

Table 3 Specifications of Proadlizer products for notebook PCs.

Product	Voltage	Cap.	ESR
PFAF250E907MCB	2.5V	900µF	1.5mΩ
PFAF250E907MCD	2.5V	900µF	1.0mΩ

We believe that the implementation of the ultralow ESR of 1mΩ without changing the traditional size is the fruit of our fabrication and development technologies at a high level.

4. Application Examples

4.1 Case of the Notebook PCs

Fig. 1 shows an example of layout of a conventional Proadlizer.

The Proadlizer is mounted at the center on the backside of the CPU. The central area of the CPU has an area of about 19mm × 19mm that does not include connection pins and it is convenient for mounting the Proadlizer at the smallest possible distance from the CPU.

The Proadlizer achieves low impedance in the high-frequency domain thanks to a unique transmission channel structure and it is fully capable of replacing the conventional capacitor configurations.

The total ESR requirement for next-generation CPUs is expected to change from the current 1.5mΩ to 1.0mΩ. The improvement of the Proadlizer according to this requirement is necessitated since the ESR performance does not derive from the structure of the Proadlizer, we had therefore to improve the

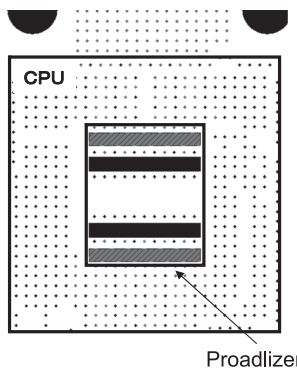

Fig. 1 Example of the conventional Proadlizer layout.

internal elements just as with the improvement of conventional polymer capacitors. However, the release of the 1.0mΩ Proadlizer has eventually allowed a single Proadlizer to be used in the decoupling of the CPU cores of next-generation CPUs.

With regard to capacitance, that of the Proadlizer (900μF) may appear to be too small compared to the 2,304μF of the conventional configuration. However, the reason that the conventional configuration used the 470μF polymer capacitors was in consideration of the provision of capacitance that could achieve a low ESR of 4.5mΩ and such a capacitance was not absolutely necessary. This is witnessed by the fact that research into a polymer capacitor that can provide equivalent ESR with smaller capacitance is currently underway. As a design using the Proadlizer can reduce the capacitor layout area by nearly 40% compared to the conventional design, the arrangement also has the potential of contributing to the reduction of board area and consequently to the reduction of the board costs. Considering that the cost requirement for notebook PCs is becoming more severe than ever, we believe that the Proadlizer can bring about great value for the notebook PCs.

With the next-generation CPU, the GPU, memory controller and I/O hub functions are integrated in the CPU, and integration of various functions at a single location means that the area reserved for each power supply should be reduced. Particularly, as the CPU core that consumes the largest power among them needs more capacitors than other functions, the reduction of the number of components by using the Proadlizer will be especially advantageous from the viewpoint of design.

4.2 Case of Desktop PCs

Table 4 shows an example of configuration of decoupling capacitors used in a CPU for desktop PCs. Usually, the desktop PCs use large cabinets and are free from height restrictions, so they use CAN type aluminum conductive polymer electrolytic (CAN type Al polymer) capacitors.

In general, desktop PCs consume more power than notebook PCs and the capacitors used in them are required to have larger capacitance values. However, considering that large-capacitance devices were adopted, aiming at decreasing the ESR as in the notebook PCs, there is a possibility that a capacitance of more than 7,000μF may not be necessary. However, in this case, it is still required to meet the total ESR value requirement.

Fig. 2 and **Fig. 3** show examples of layout using conventional capacitors and the Proadlizer respectively. The presence of the CPU heat sink does not allow the aluminum electrolytic capacitors to be placed in the proximity of the CPU. Moreover, the Proadlizer is thinner than the aluminum electrolytic capacitors and can therefore be mounted in areas where mounting is impossible in the ordinary configuration. In addition, the reduced mounting area of the Proadlizer also makes it possible to reduce the power area considerably compared to the conventional configuration.

Table 4 Example of a capacitor configuration of a CPU for a desktop PC.

Item	Cap.	ESR	Quantity
CAN type Al Polymer	820μF	7mΩ	9Pcs.
MLCC	22μF	-	24Pcs.
Total	7,088μF	0.78mmΩ	32Pcs.

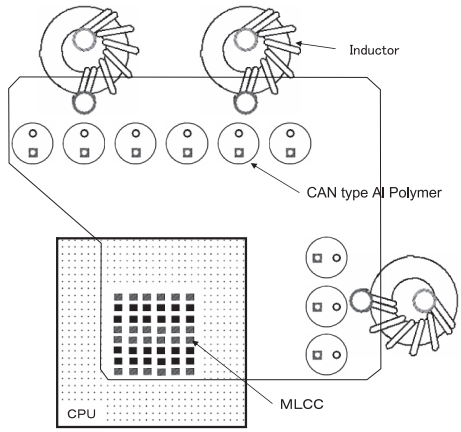

Fig. 2 Example of conventional capacitor layout.

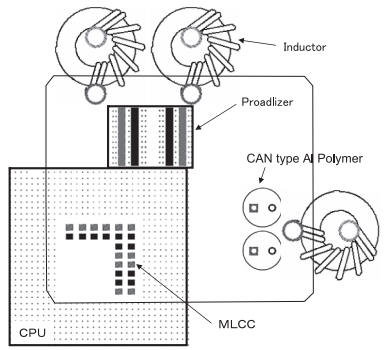

Fig. 3 Example of layout using Proadlizer.

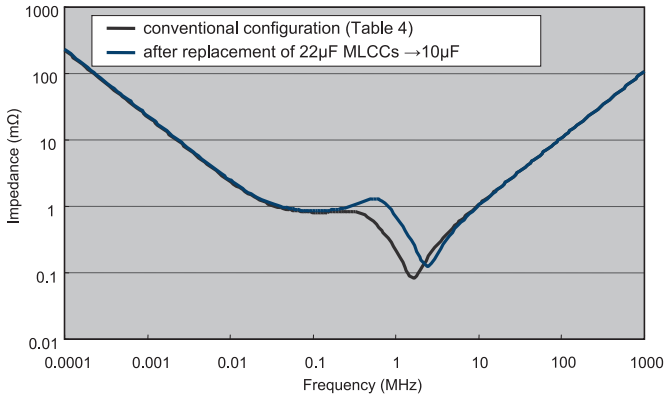

Fig. 4 Comparison of impedance (conventional configuration vs. after replacement of 22μF MLCCs → 10μF).

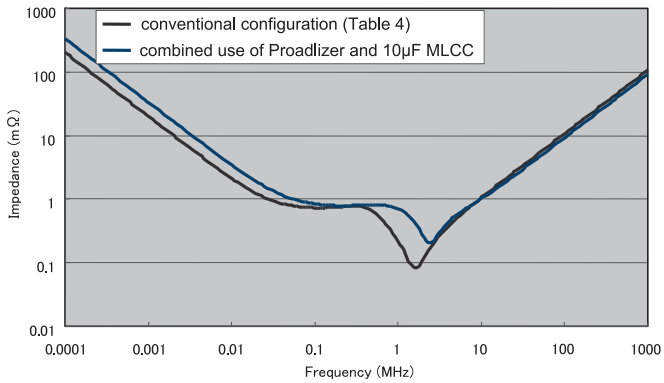

Fig. 5 Comparison of impedance (conventional configuration vs. combined use of Proadlizer and 10μF MLCC).

Furthermore, as shown in **Fig. 4** , the use of the Proadlizer has the potential of allowing replacement of the 22μF MLCCs used in the conventional configuration with 10μF MLCCs. If the 22μF MLCCs were simply replaced with 10μF MLCCs and conventional aluminum electrolytic capacitors were used in combination with them, the synthetic impedance would exceed 1mΩ at around 800kHz because of the effect of anti-resonance (Fig. 4), which has made it unavoidable to use relatively expensive 22μF MLCCs. However, when 10μF MLCCs are used in combination with the Proadlizer, it is possible to achieve ESR below 1mΩ over a wide frequency range because the Proadlizer presents a low impedance characteristic over a wide range and can therefore reduce the effect of anti-resonance (**Fig. 5**).

At present, the Proadlizer is capable of achieving capacitance up to 2,000μF from the same case size as those used in the conventional device configuration. Since the ESR of 1mΩ is already achieved, it is expected that using the Proadlizer in desktop PCs will enable integration of most of conventional capacitors.

5. Conclusion

While the increase in the scale and speed of semiconductor chips is advancing every day, the reduction in the power consumption has become a more important issue than ever. The Proadlizer is a device that is expected to offer a one-chip solution for this issue thanks to a very low impedance characteristic over a very wide range of frequencies. For our part, we will identify the new market trends adequately and contribute support to customers by offering a range of Proadlizer products that can optimally meet the market needs.

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