Development of 16-bit All Flash Microcomputers "78K0R/Kx3-L" Featuring Ultralow Power Consumption

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Abstract

The NEC range of all-flash microcomputers is entirely composed of flash microcomputer products that offer our customers systems aimed at improved competitiveness. Recently there has been a rise in the awareness of the need for energy saving and a resulting focus on customers' needs for a reduction in the power consumption of microcomputers. In order to meet this trend NEC has developed the "78KOR/Kx3-L" 16-bit range of all-flash microcomputers that aim at a power consumption performance at the industry's most efficient level. The new products have been implemented by adopting a creative approach to product specifications and circuit designs that aims at reducing power consumption during the 1MHz and standby operations, which are particularly important for battery-driven equipment. These products are expected to contribute significantly to the extension of the battery life of customers' appliances.

Keywords

microcomputer, 16-bit μCOM, flash microcomputer, low power consumption
embedded equipment, battery driven equipment

1. Introduction

Various types of equipment such as home appliances and digital AV products have recently become subject to the need for energy saving, as well as for safety and comfort improvement functions. Consequently a large number of microcomputers (μCOM) are being used in the controls for such equipment. The key issues in this market have tended to become the need for the most suitable product deployment aimed at meeting the diversifying consumer needs and the need for measures to deal with fluctuations in demand.

At NEC Electronics, we have been meeting these customer requirements by releasing a series of all-flash microcomputer products that are composed exclusively of flash μCOM (microcomputers incorporating flash memory) and which feature a software rewriting capability.

2. Environmental Concern Becoming the Key to Successful Systems

The year 2008 was marked by a worldwide rise in awareness toward the environmental issues that had been announced at the Lake Toya G8 Summit held in Japan.

Nowadays, air conditioners as well as digital AV equipment are required in order to reduce the power consumption during operation as well as at standby. In addition, electronic equipment is introducing widening applications in our daily lives. For example, in home disaster prevention and security systems and in mobile equipment, competition is becoming severe in the race to extend battery operation life and to reduce the size. As seen in these examples, energy saving at the system level has now become an important issue for any system development.

In order to contribute to system energy saving we have been developing 8- to 32-bit all-flash microcomputer products with low power consumption capabilities at an industry-leading level. Among these products, the 78K0R series of 16-bit all-flash microcomputers has been developed under the concept of offering "the performance of 16-bit μCOM" with "the power consumption of 8-bit μCOM." We have thus contributed to improving the performance and to significantly reducing the power consumption from that of the previous system by means of "upward compatibility for 8-bit μCOM" and "provision of a comfortable development environment." We have already

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implemented a range of basic products in the 78K0R/Kx3 category for which we have received high praise from a wide range of users.

3. 78K0R/Kx3–L Product Outline

The 78K0R/Kx3-L 16-bit all-flash microcomputers include products for battery-driven compact systems, a field that is expected to grow in popularity in the future. The basic specifications are as shown in **Table** .

The 78K0R/Kx3-L range consists of a wide choice of products with pin counts from 44 to 100 pins and ROM capacities from 16 to 128KB while at the same time maintaining functional compatibility with the previous 78K0R/Kx3 products as well as inheriting their proven functions. Packed with features such as low power consumption at the industry’s most efficient level, three built-in oscillators, circuits required for capturing sensor output signals and a program write capability at 1.8V, these products will back up efforts aimed at size reduction and battery life extension of mobile and security equipment.

4. 78K0R/Kx3–L Development Concept

When a battery-driven compact system is used in an application aiming at capturing an intermittent output signal from a sensor, it is usually run intermittently, alternating the standby and normal operation modes from the viewpoint of battery life. It is therefore necessary to reduce the power consumption in both the standby and normal operation modes in order to extend the battery life. However, in the present case the sensor information is limited in both speed and amount and it is not required to improve the processing performance in the normal operation mode.

With the 78K0R/Kx3-L, we noticed the above point and set “ultralow power consumption during 1MHz operation” and “ultralow power consumption during standby operation” as the most important issues. We have therefore been able to develop the product targeting such performance levels by applying the industry’s top level specifications.

As a result of this strategy we have succeeded in providing the 78K0R/Kx3-L with a 1MHz operation current of 177μA@3V, which improves on the hitherto industry-top value of 200μA@3V. In order to achieve this industry leading level the current consumption in the standby mode has

Table 78K0R/Kx3-L basic specifications.

Item			78K0R/Kx3-L
Number of pins			44 to 100 pins
Built-in memory		Flash memory	16KB to 128KB
		RAM	1KB to 8KB
Clocks	Main system clock	High-speed system clock	Ceramic/Crystal/External clocks, 2 to 20MHz
		High speed internal OSC clock	1MHz,8MHz,20MHz
	Sub system clock		Crystal: 32.768KHz
	Low-speed internal OSC clock		30KHz±10% (For Watch Dog timer)
Timers			-16 bit timer: 8 to 12ch - Watch Dog Timer - Real-time counter
Serial interfaces			- CSI - UART/LIN support UART - IIC/Simplified IIC
A/D converter (10-bit)			10 to 16ch
Other peripheral functions			- Multiplier/divider - Power-ON clear - Low voltage detector - Comparator: 2ch - Programmable gain amp: 1ch - Key interrupt - On-chip debugging

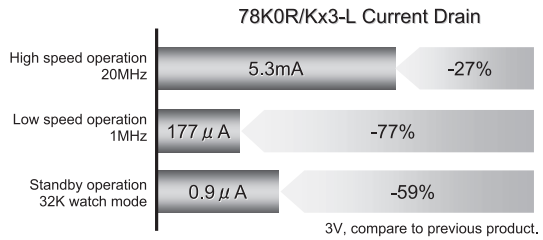

Fig. 1 Power consumption at the industry lowest level.

likewise been reduced to below 0.9μA during the watch operation, which is regarded as being the most important of the actual applications (**Fig. 1**).

5. Super Power Consumption Reduction in 1MHz Operation

5.1 New System with 1MHz Operation Mode

This section describes the means that was adopted in order to implement ultralow power consumption during the 1MHz operation mode.

(1) Internal 1MHz Oscillator

The previous product incorporated an 8MHz internal oscil-

lator that could be used as the system clock source. Meanwhile, the 78K0R/Kx3-L has newly adopted an internal 1MHz oscillator with a current consumption of less than about 20% of that of the 8MHz oscillator. In addition, the 78K0R/Kx3-L also incorporates a mechanism for selecting the internal oscillator using a function that lets the hardware perform important system setups automatically after resetting is released ("option byte" function). This function not only makes it possible to select the oscillator circuit for the system but also enables operation of the system with the internal 1MHz oscillator immediately after the resetting is released. The operation clock of the previous product had been fixed to the 1/2 division of 8MHz for a certain period after resetting was released. This also means that the current consumption can be reduced even during initialization (**Fig. 2**)

(2) Low-voltage Operation Using Internal Regulator

While the previous product regulated the internal voltage to 2.5V in order to implement a system with low power consumption optimized for 20MHz operation, the 78K0R/Kx3-L incorporates an additional internal regulator mode that can reduce the internal voltage to the minimum operation voltage of 1.8V in order to deal with 1MHz operation. This new mode makes it possible to reduce the current consumption even with a supply voltage of 3V.

(3) Addition of a New "Low Power Consumption Main Mode" for the Flash Memory

As the flash memory of the previous product was optimized for high-speed operation, its current drain occupied a large part of the chip's current consumption during low-speed operation. The 78K0R/Kx3-L has optimized the flash memory circuitry for 1MHz operation by incorporating a new "low power consumption main mode" that can reduce the current consumed by the flash memory when the system clock is 1MHz. This has reduced the self-consumed current of the flash memory by about 60% from the previous product.

5.2 Low-power CPU Architecture

For the CPU incorporated in the 78K0R/Kx3-L, we developed a low-power CPU architecture that can reduce the power consumed for operation current compared to the previous product. Low power consumption is assured at any operation current, reducing the current during 1MHz operation by 35% from that of the previous product and that during 20MHz operation by 27%.

Our typical adopted measures are as follows.

(1) Division of CPU Operators

The CPU of the previous product incorporated an address operator and data operator for use in executing one instruction per clock via a pipeline. This meant that a large operator size was always used regardless of instructions. The low-power CPU divides the operators on a per-function basis and stops the unused operator circuitry per every instruction. This has reduced the current consumed for the operators almost by a half.

(2) Stoppage of Decoder Circuit

The instruction set for the 78K0R series products includes the 1-byte instructions and 2-byte instructions. Each instruction is judged using an instruction decoder and the operation of the whole CPU including the operation units is decided accordingly.

During this mechanism, we monitored the 1-byte instructions. Since the judgment of the second byte is not required during decoding of the 1-byte instruction, the 78K0R/

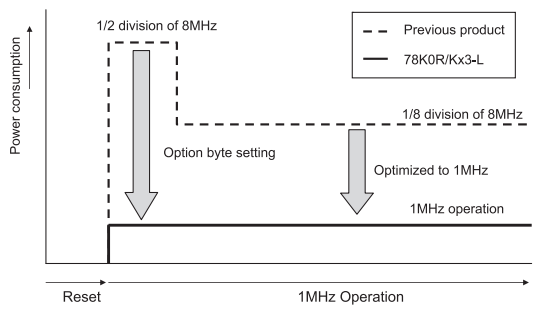

Fig. 2 1MHz operation capability immediately after reset.

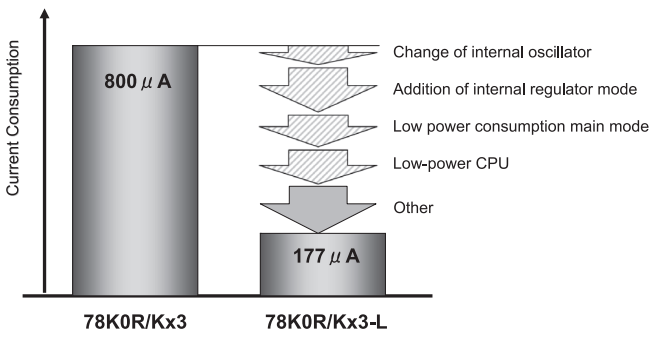

Fig. 3 Reduction of 1MHz operation current.

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Kx3-L confirms the first byte using the judgment circuit and stops the circuit for decoding the second byte when the instruction is judged as a 1-byte one. This procedure has reduced the current used for decoding by about 25%.

As described above, we have succeeded in achieving current consumption of 177µA@3V, which is even better than the target value of 200µA, thanks to the measures taken for the new 1MHz operation mode and the low-power CPU architecture (**Fig. 3**).

6. Super Power Consumption Reduction in Standby Operation

6.1 Addition of Watch Mode

The 78K0R series products incorporate a real-time clock (RTC)/calendar function that can update the date and time automatically without the need to start the CPU until the year 2099, so the watch operation can be continued.

In consideration of its importance when a battery-driven compact system is in standby mode the 78K0R/Kx3-L watch mode was set as one of our targets in order to enable a reduction in power consumption and the “watch mode” with which only the RTC is run in the standby mode was added.

With the previous product, the sub-clock is input to the system clock selection circuit and the peripheral functions even when the CPU and peripheral functions are halted. In the case of the 78K0R/Kx3-L, however, when the “watch mode” is set and the RTC operation is enabled before the standby mode is entered, the system clock selector circuit and the clock supply circuit for the peripheral functions are halted and the clock is supplied only to the RTC in the standby mode (**Fig. 4**). This design aimed at running the minimum required circuitry has enabled a reduction in the current consumption.

6.2 Current–saving Sub–oscillator with a 3–step Gain Switching Capability

The operation clock of the RTC running in the standby mode is supplied from the sub-oscillator. The sub-oscillator used in the previous product is known to have a large self-consuming current, thereby making it one of the big issues for the new product to reduce the self-consuming current while maintaining the requisite oscillation characteristics.

The configuration of the sub-oscillator has not been changed

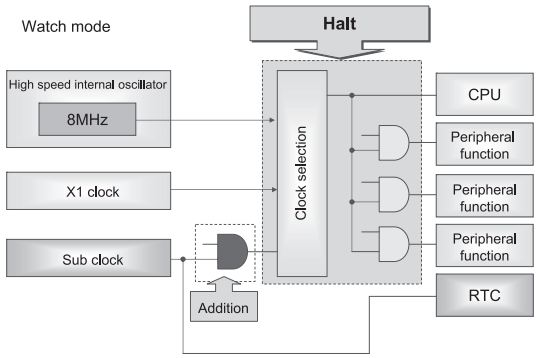

Fig. 4 Watch Mode.

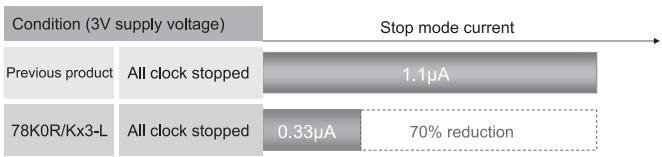

Fig. 5 Stop mode current.

for a long time but with the 78K0R/Kx3-L, we implemented a radical review of the circuit configuration and decided to make the gain of the amp built into the sub-oscillator switchable. This strategy reduced the self-consumed current of the sub-oscillator when the minimum gain was set to less than a half that of the previous product, thus achieving a current consumption including the RTC operation current of 0.6µA.

6.3 Reduction of the Current Consumption of the Regulator and POC

The previous product incorporates a regulator and a power-ON clear (POC) circuit, both of which run permanently in the standby mode. We have optimized these circuits and reduced the total current consumption of the regulator and POC circuit to 0.33µA.

This value is the current consumed by this product in the stop mode and the reduction effect as compared to the previous product is 70% (**Fig. 5**).

Thanks to the above measures, the current in the watch mode has been reduced from 2.2A for the previous product to 0.9µA for the new product, which is lower than the 1µA target current that was set at the beginning of the development program.

7. Conclusion

As described above, we have significantly improved the power performance of the 78K0R/Kx3-L range and have succeeded in achieving low power consumption at the industry's most efficient level of 177μA@3V 1MHz operation current and 0.9μA@3V standby current, which is a much lower value than that of previous products. This advance has made it possible for us to contribute significantly to the improvement of the battery driven equipment performance of customers' systems.

In the future, we intend to deploy all-flash microcomputer products that meet customers' needs by further reducing power consumption performances, increasing the number of accommodated peripheral functions and by offering a wider range of products.

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