Low Power Consumption Microcontrollers and Their Applications

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OVERVIEW: Microcontrollers can be found in a vast array of equipment and devices. Today there is a growing need for reducing the power consumption of microcontrollers, because they form a major share of the power budget of equipment, and, threrefore, to extend the life of batteries that are used to power these devices is crucial. Hitachi, Ltd. has been offering an extensive lineup of low-voltage low-power-consumption microcontrollers to meet these needs for some time. In 1999 Hitachi brought out its H8/300L super-low-power series of 8-bit microcontrollers that achieves even more drastic power savings. Besides its power-efficient design, the super-low-power series provides an on-chip liquid-crystal display (LCD) drive step-up power source and excellent resistance to electromagnetic noise thus making these MCUs easier to use than ever.

INTRODUCTION

MICROCONTROLLERS are embedded in a diverse range of equipment and devices found in the home, and used by industry, communications, and other areas affecting our everyday lives. Traditionally, there has not been much incentive or demand to reduce the power efficiency of microcontrollers that are installed in large consumer appliances and industrial equipment, because the microcontroller consumes only a tiny fraction of the overall power consumed by the

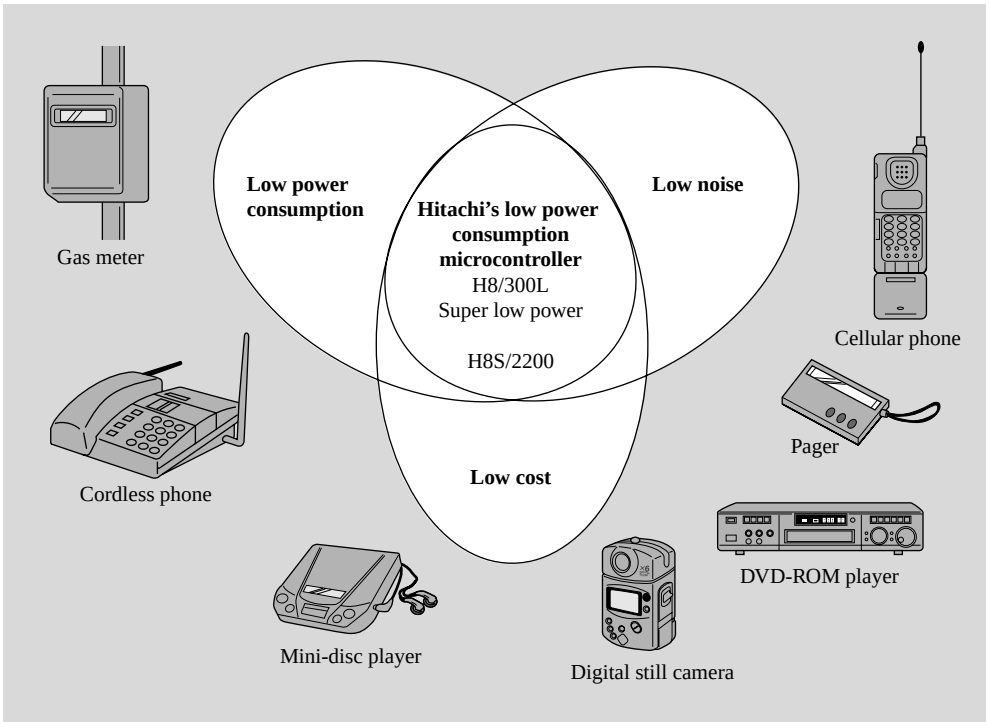


Fig. 1— Application Fields of a Low-Power-Consumption Microcontroller. Microcontrollers are embedded in a diverse range of equipment and devices. Hitachi has made a lineup of 8-bit microcontrollers—the H8/300L super-low-power series—and 16-bit microcontrollers—H8S/2200 series for meter equipment and hand-held devices.

equipment. However, in the case of battery-operated equipment such as portable phones, it is a very different story. Here there is a need to not only reduce voltage but also to minimize power requirements of microcontrollers to enable low 1.8-V operation matching the battery terminal voltage and simply to extend battery life.

This paper will review a number of technologies for minimizing power consumption, identify key application areas for low-power microcontrollers, and introduce some of Hitachi's latest MCU products.

LOW-POWER MICROCONTROLLER APPLICATION FIELDS

The demand for low-power microcontrollers is mainly being driven by battery-operated equipment including:

(1) Industry: meter-related and safety equipment.
(2) Communications: pagers, cordless phones, cellular phones.
(3) Consumer electronics: home medical equipment, digital still cameras, car audio products, mini-disk players, other small household appliances.

Of these various applications, it is especially imperative to reduce the power requirements of remote utility metering. For example the batteries powering microcontrollers in gas meters must continue to work for up to ten years between changes. Meanwhile, portable equipment is constantly being upgraded — two-way pagers, cameras to perform digital processing, etc. — even while batteries are being made more long-lived and smaller to support smaller and lighter weight portable equipment. These contradictory developments are also fueling the demand for microcontrollers that can operate on low voltage and low power.

Hitachi offers an extensive lineup of 8-bit (H8/300L series) and 16-bit (H8S/2200 series) microcontrollers optimized for the needs of the industry, communications, and consumer electronics.

LOW-POWER DESIGN TECHNOLOGIES

Three mainstream techniques that have been used extensively to reduce the power consumption of microcontrollers are (1) reducing the power consumption of cells, (2) reducing the internal operating voltage, and (3) shutting off modules. More recently, Hitachi added a forth technique that reduces the power consumption of its microcontrollers even more: (4) reducing the oscillation stabilization time. Let us now examine each of these techniques in detail.

Reducing Power Consumption of Cells

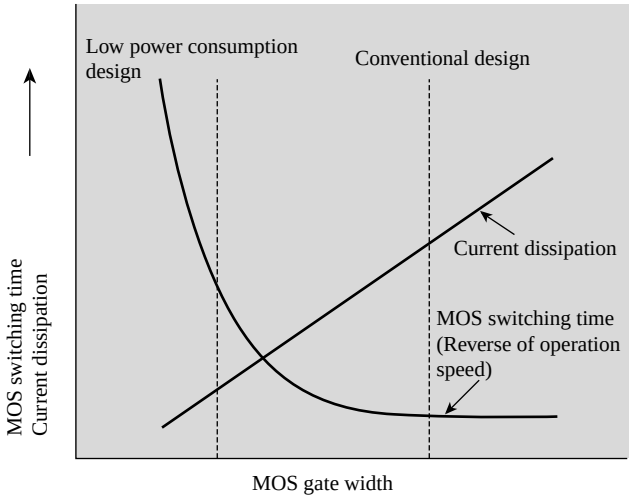
Fig. 2 shows a schematic of a simple design-optimized metal-oxide semiconductor (MOS) gate circuit. A tradeoff exists between the switching time on the one hand and the current dissipation on the other. In the past, system designers generally sought to minimize the switching time even if it meant sacrificing optimal current dissipation. The width of MOS gates for the super-low-power series has been designed to achieve the lowest possible current dissipation while at the same time meeting the operating speed requirements of our customers.

Reducing the Internal Operating Voltage

Microcontrollers operate through MOS gate switching. When switching occurs, power is consumed when the charge stored across wiring and MOS gate capacitance is discharged. Since power is reduced if the supply voltage of the microcontroller is reduced, we have minimized power consumption by incorporating a step-down circuit in the microcontroller that generates a low voltage of about 2 volts.

Shutting off Modules

Microcontrollers include a large number of on-chip modules such as controlling timers, analog-to-digital converters, and other components, but there is no need for all of these modules to be running at the same time.



MOS: metal-oxide semiconductor

Fig. 2— Relation Between MOS Switching Time/Current Dissipation and MOS Gate Width.
A tradeoff exists between switching time and current dissipation. In the past, system designers generally sought to minimize switching time. The super-low-power series has therefore been designed to use the lowest possible current while meeting the operating speed requirements of our customers.

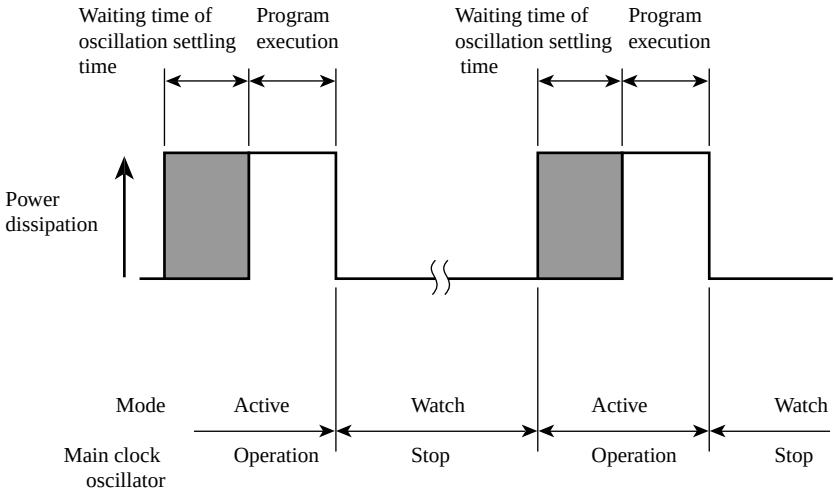


Fig. 3—Example of Operating Modes. Microcomputer alternating active mode (program execution) and watch mode (stand-by watch function only). In the wait time of oscillation settling, the microcomputer consumes the power useless. To shorten the wait time is effective on decreasing the power consumption.

Power dissipation can thus be reduced by using software to shut off the clock to modules that are not currently needed.

Reducing Oscillation Stabilization Time

Fig. 3 illustrates typical microcontroller operating modes. One can see that MCUs alternate between active and watch modes. The two modes have separate oscillators, a main oscillator for the active mode and a sub-oscillator for the watch mode. The main oscillator is shut off when the MCU is in watch mode. When transitioning from watch mode to active mode, the power dissipated during the time it takes for the frequency and amplitude of the main oscillator to get up to stable (called the *oscillation stabilization time*) is wasted. In telemetering devices such as gas meters and smoke detectors, these mode transitions can occur up to 100,000 times a day, so it is critically important from the standpoint of extending battery life to minimize the oscillation stabilization time enough that this wasted power can be ignored.

Fig. 4 shows a schematic of the main oscillator's new circuitry. A trigger generator and an amplifier circuit have been added to the oscillator's regular circuitry. When the main oscillator is started, the trigger generator forces a small amplitude. This is very quickly turned into the full swing by the amplifier. The new circuit reduces the oscillation stabilization time to about 1/1,000th that of the conventional oscillator, which is more than short enough that the power wasted in waiting for oscillation to stabilize can be ignored.

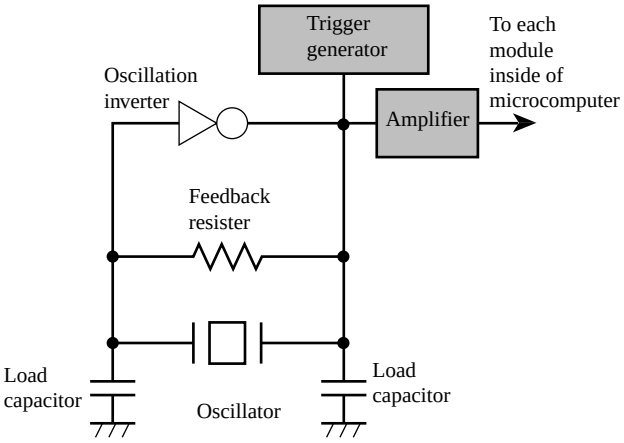


Fig. 4— Main Oscillator's New Circuitry. A trigger generator that generates a minute amplitude and an amplifier that amplifies the output of an oscillation inverter have been added to the regular circuitry. The new circuit reduces the oscillation stabilization time to about 1/1,000th that of the conventional oscillator.

LOW-POWER MICROCONTROLLERS

Fig. 5 shows representative examples of Hitachi's extensive lineup of low-power 8-bit and 16-bit microcontrollers. The 8-bit H8/300L series of MCUs features a full array of peripheral functions including an LCD driver, and the product line includes a low-power solution tailored to a wide range of applications. Current emphasis is on extending the company's family of super-low-power products for low-power applications. Exploiting the low-power design techniques described in the preceding section, we exceeded the good performance of our previous low-power H8/3837S MCU by reducing power dissipation by 50%-70% in active mode and by 50% in subactive modes (operation at 32 kHz).

In addition, the super-low-power series includes features that enhance its versatility and ease of adaptation. For example, the series includes an on-

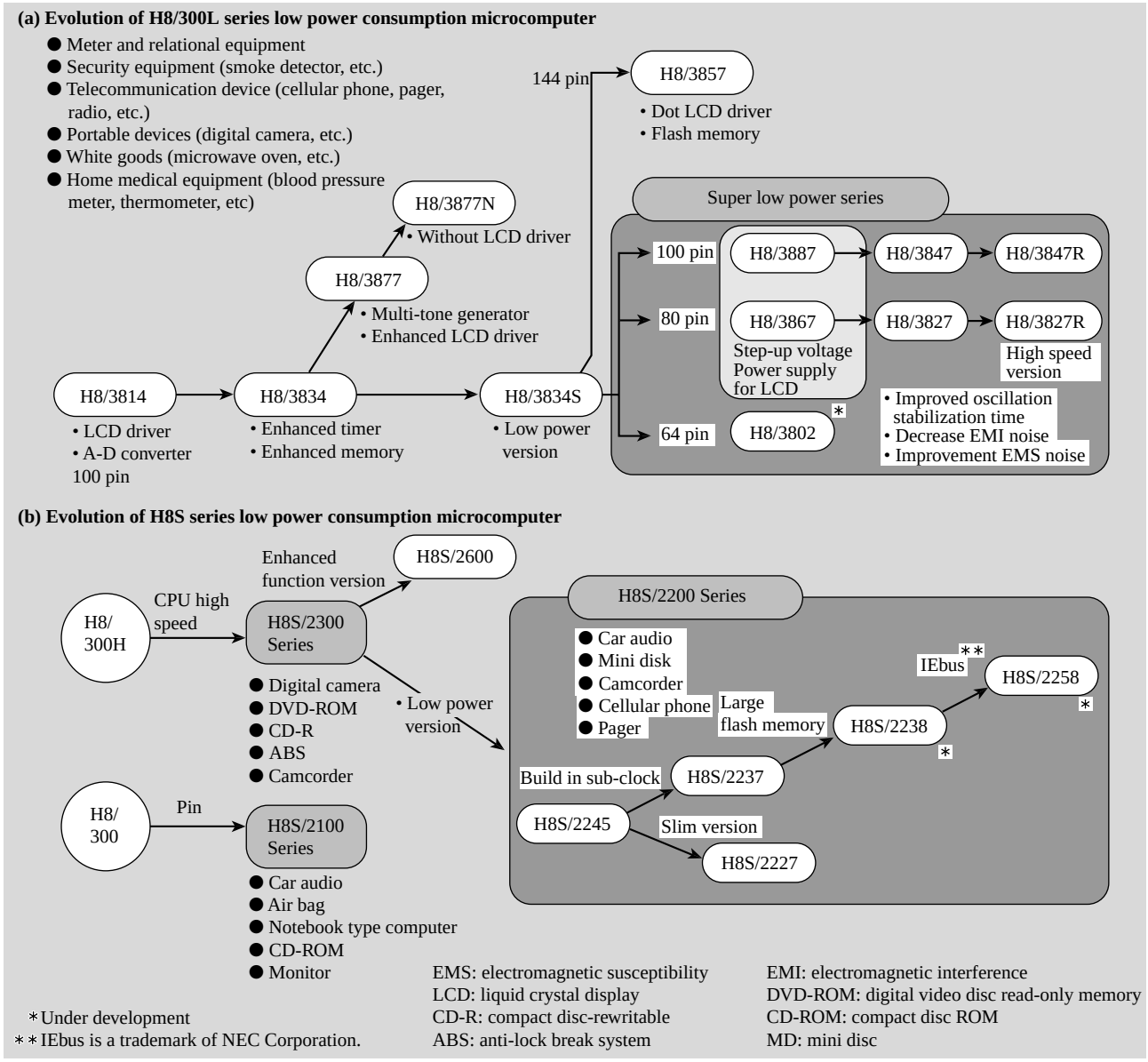


Fig. 5— Improvement of the Low Power Consumption Microcomputer.
Hitachi has launched a new lineup of super-low-power microcomputers (H8 series) which with drastically reduced power consumption compared to the previous low power series,H8/3837S. The H8S series has improved operating instructions and functions compared to the H8/300 and H8/300H series, especially Hitachi has significantly minimized the power consumption of H8S/200 series.

chip 5-V step-up circuit for use as an LCD power source, thus eliminating the need for an LCD drive step-up circuit to be implemented externally. System designers will also find the super-low-power MCUs easier to work with, because they have been made less susceptible to EMS noise, and EMI noise has been substantially reduced.

Turning to its 16-bit offerings, Hitachi has made an aggressive effort to minimize the power consumption of the H8S/2200 series of microcontrollers for application to a wide range of products including car audio equipment, mini-disk players, cellular phones, pagers. In the H8S/2245 series, a number of techniques have been combined to optimize the MCUs for low-power applications, most notably external input frequency switching and clock gear function that enables the software to monitor the internal clock going into the CPU at full speed, 1/2, 1/4, 1/8, 1/16, or 1/32. As illustrated in Fig. 6, this permits the relative proportion of the current dissipation to be reduced to as much as 1/500th, which allows very flexible power control tailored to different systems.

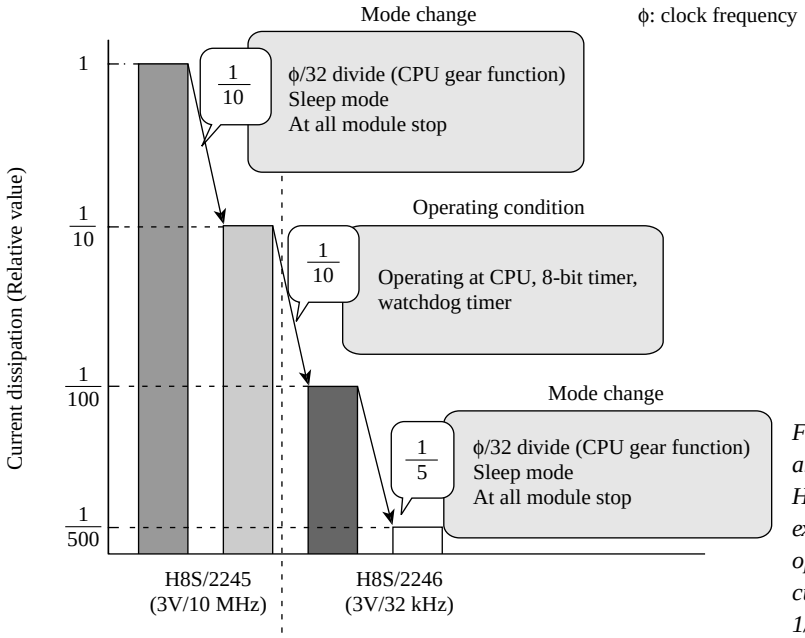


Fig. 6— Relationship Between Operating Mode and Current Dissipation.
H8S can operate at 32.3 kHz. By switching external input frequency and/or by changing the operating mode, the relative proportion of the current dissipation can be reduced to as much as 1/500th.

Finally, the H8S/2237 series is the first 16-bit H8S series to incorporate an embedded sub-oscillator (32-kHz oscillator) to push down power consumption even more. With an operating current measured in microamperes in subactive mode, devices are much easier to operate.

CONCLUSIONS

Highlighting Hitachi's H8/300L series of super-low-power microcontrollers, this paper surveyed a number of technologies for minimizing power consumption, and identified the main application areas for low-power microcontrollers.

Microcontrollers are embedded in a vast array of machines, appliances, and devices that serve us well in our everyday lives. Along with a relentless demand for more advanced functionality, there is a growing demand for more power-efficient designs in keeping with the overarching needs of society to conserve energy. Hitachi is certainly equal to the challenge, and is already working on even more power-efficient microcontroller designs.

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