Development of Circuit Boards for Low-Energy Microcomputer

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Abstract

As a measure against an aging facility or detection measures for obsolete facilities with signs of fault, the market expects new services using more advanced facility data mining and data analysis.

In order to realize monitoring under circumstances which are considered difficult to monitor, we focused on technologies of low power consumption and harvesting energy.

With the progress of mobile phones, smartphones, and PC tablets, it has become easier to realize low power consumption for computer systems. As a result, energy existing in external sources can be harvested so that energy can be actively utilized as a power source for computer systems. Against such technical background, we made a prototype of monitoring equipment based on such low power consumption and energy harvesting technologies.

1 Preface

Meiden's computer products have been made to meet the specific requirements of respective industrial fields. In each industrial field, necessary information is gathered so that we can provide optimal solutions.

Presently, in some fields where automation is impossible to achieve and only human experience and intuition dominate, a demand for higher efficiencies and labor-saving is increasing. In order to meet such requirements, the market calls for new services where data collection, analysis, and visualization are performed.

In order to obtain information that was not possible to measure in the past, we need to have a way to easily gather such information. As such a method, there is talk of using a sensor information terminal that acquires power from a renewable energy resource available in particular circumstances. It does not require any construction work.

To satisfy such a requirement, we have developed an evaluation which combines the technologies of super low-power consumption microcomputers and those that harvest energy. Energy harvesting technology is the collecting of ambient energy such as heat, vibration, and light, and converting such energy into electrical power.

2 Foundation of Low-Energy Microcomputers

In order to realize highly functional characteristics, our microcomputers used in embedded computers and information system computers have been developed to be multifunctional by going through higher speeds and having a larger capacity.

For example, our industrial controllers are developed as information system products with higher speeds and a larger capacity. This is the case with our Programmable Logic Controller (PLC) with dedicated sequence functions, special relays for protection operation, and power conversion equipment such as inverters and a Power Conditioning Subsystem (PCS).

Fig. 1 shows our product lineup. Unlike conventional computers, for the development of circuit boards for low-energy microcomputers, we focused on a low-energy design. We aimed to make an autonomous monitoring system which secures power to run computers.

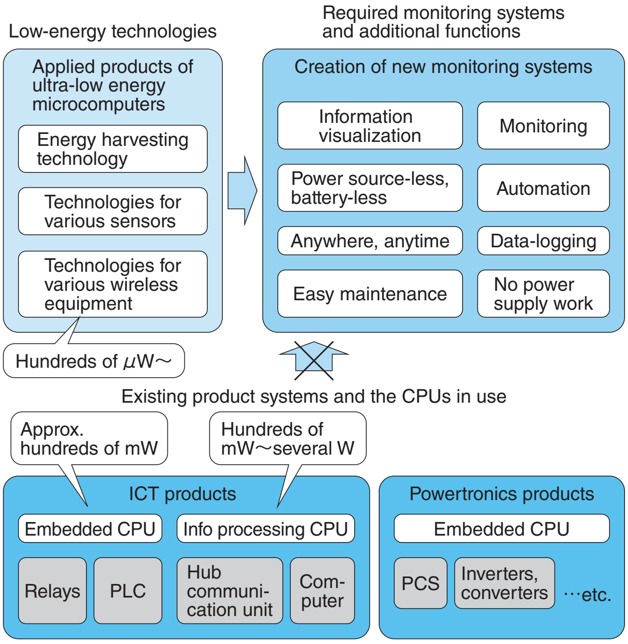

Fig. 1 **Meiden Product Lineups**

Unlike the requirements for our ICT products and Powertronics products, this graph shows how our ultra-low energy micro-computer-applied products orient towards the demands for "new products and new functions."

3 Development Concept for Evaluation Board

Fig. 2 shows the development concept for circuit boards used with low-energy microcomputers. To reduce power consumption, it is essential to realize low-energy in each component such as a microcomputer. It is also important to realize low-power in both cases of operating and non-operating period ("sleep mode"). In addition, peripheral circuits like wireless and I/O circuits installed for monitoring system functions also consume power. We investigated power circuit designs to secure power.

The newly developed evaluation board drastically reduces current consumption during operation and in sleep mode as well. By realizing very low-energy during sleep mode, and by performing intermittent operations of a computer system, it contributes to energy saving of the overall system.

We made a prototype of a monitoring system that has low-energy computer circuits and can operate on battery power or ambient energy. **Fig. 3** shows an evaluation board developed for low-energy power consumption microcomputers.

3.1 System Configuration of Evaluation Board

Fig. 4 shows the system configuration of the newly developed evaluation board and **Table 1** shows a list of board specifications. The evaluation board is provided with a Digital Input (DI) circuit, a Digital Output (DO) circuit, and an analog input (AI) circuit so that it can be connected with various sensors in order to secure monitoring functions. It comes with an interface with due consideration to other various measuring objects.

In order to realize effective transmission of monitor data information, the board is provided with three-types of wireless communication functions.

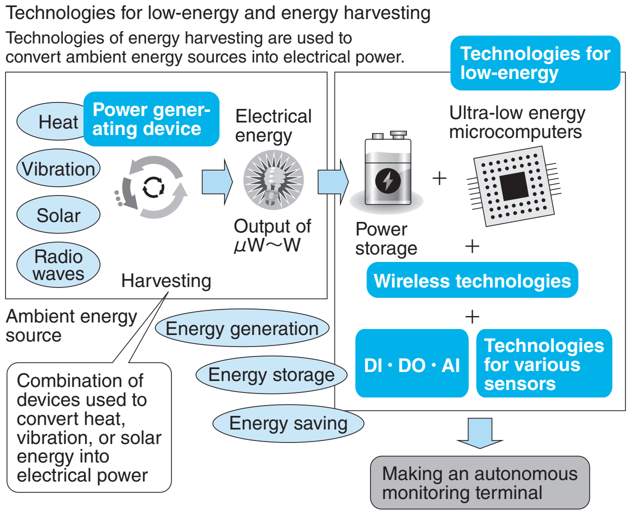

Fig. 2 **Development Concept for Circuit Boards Used in Low-Energy Microcomputers**

We are promoting the development of autonomous monitoring terminals where low-energy microcomputers are adopted as they are designed for low-energy use. I/O functions of monitoring equipment are provided, data gathering is devised by using our wireless communication expertise, and ambient energy sources are used to provide the power to the related devices.

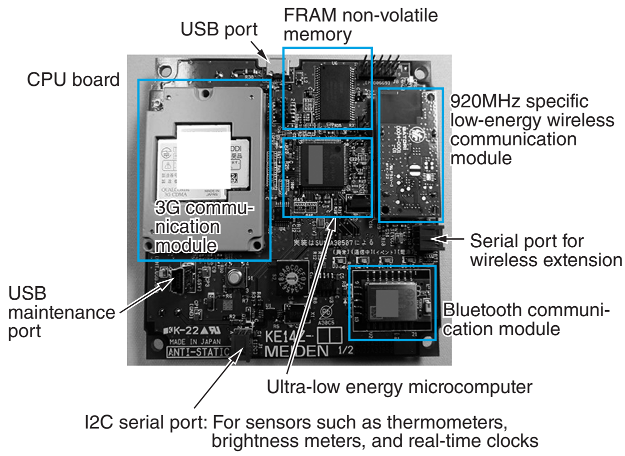

Fig. 3 **Evaluation Board Developed for Low-Energy Power Consumption Microcomputers**

The evaluation board developed for low-energy microcomputers is shown.

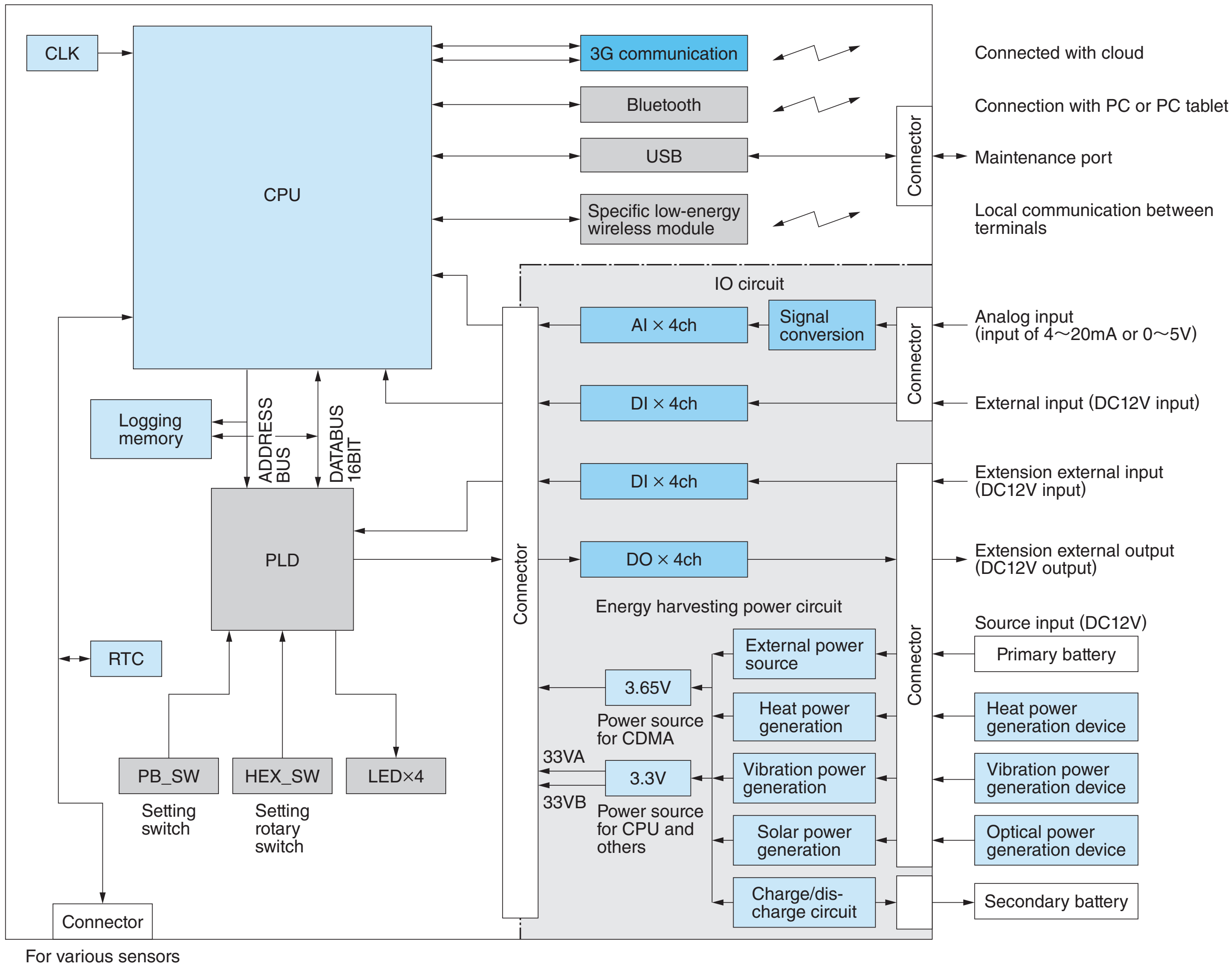

Fig. 4 **System Configuration of the Newly Developed Evaluation Board**

The monitoring system is provided with I/O functions where a low-energy microcomputer is adopted. The system is activated from a power generating device using heat, vibration, or solar energy or form the power of a primary battery.

Table 1 **List of Board Specifications**

Specifications of the evaluation board are shown, where a low power consumption microcomputer is adopted.

Item		Specifications
CPU	CPU	32bitRISC　48MHz
	Embedded flash memory	1024KB
	Embedded SRAM	128KB
	SRAM	512KB
	FRAM	256KB
	A/D converter	12bit 8ch
Wireless/wired	3G communi-cation	Cloud connection
	920MHz communication	Local communication between terminals
	Bluetooth com-munication	PC, PC tablet communication
	USB	Serial port for maintenance
Monitor and control	AI	4ch (0～5V or 4～20mA), Source voltage※1

Item		Specifications
Monitor and control	DI	8ch※2
	DO	4ch
	I2C	1ch
Source circuit		3.3VA, 3.3VB, 3.65V, 24V※3
Energy harvesting source	Heat power	30～500mV
	Vibration power	2.6～23V
	Optical power	0.3～4.75V, 2.6～23V
	Solar power	Various types of batteries
Primary power source	14.4V, 5V	4-series pack of 3.6V lithium batteries
OS		μT-Kernel 2.0
Protocol stacks		TCP, UDP, IP, FTP, FILEsystem, 6LoWPAN

Notes: ※1. Partial wakeup possible　※2. Partial wakeup possible　※3. Partial power supply shutdown possible

The power circuit comes with energy harvesting technology and it comes with a configuration that realizes the low-energy by shutting down by circuit partitioning inside the evaluation board. The power circuit selects an energy source from three energy sources, i.e. heat, vibration, and solar power, and stores the energy in a secondary battery.

3.2 Low-Energy Microcomputers

We adopted a 32-bit RISC microcomputer. This type of microcomputer is designed for ultra-low energy application. The low-energy microcomputer is designed to work on a supply of 10mA during operation and it can lower its power consumption as low as approximately 1μA in sleep mode.

The evaluation board is provided with a variety of useful startup conditions to enable the application to monitor systems, such as a startup from sleep mode caused by a status change in DI, a startup due to deviation of an analog value in AI exceeding the preset threshold level, and a periodic startup according to signals from a built-in calendar IC.

3.3 Wireless Communication Function

Here we introduce an example of an application of the evaluation board to communications. The board is used for communication with our cloud-computing system by using the TELEMOT communication protocol. For this purpose, a function of 3G communication is incorporated, which works in the mobile phone network of KDDI CORPORATION.

In order to make a wireless local network among evaluation boards, a specific 920MHz low-power wireless unit is adopted. Bluetooth is also adopted to secure a function of wireless communication with a PC and a PC tablet at the workplace.

3.4 Software System

Fig. 5 shows the software system of low-power energy microcomputers. Considering portability from the embedded real-time OS μITRON having long been used for the Meiden TELEMOT as an OS of the embedded type, the real-time OS μT-Kernel 2.0 has been adopted because it is rich in compatibility, scalability, and energy-saving properties.

Since μT-Kernel 2.0 is adopted, general-purpose IP protocol stacks and the 6LoWPAN (IPv6 over Low-power Wireless Personal Area Networks) protocol stacks are used to build our local communication systems.

For 3G communications, IP communication is maintained through a connection with the internet via a base station of mobile phones. It is possible to realize IPv6-based communication over a local network via a 920MHz wireless module. In a network where power resources and system reliability are limited, IPv6 packets are efficiently transmitted.

3.5 Energy-Harvesting Technologies and Power Source Circuits

For a power source circuit, a synchronous rectification step-down regulator (wide input voltage range of 2.7～17V) is adopted. The self-loss of the

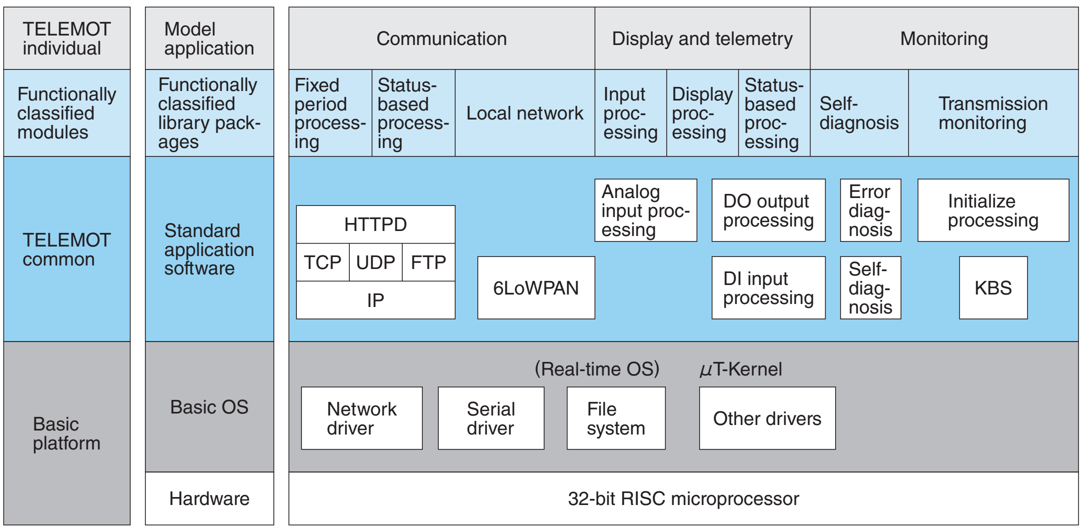

Fig. 5 Software System of Low-Power Energy Microcomputers

As a software system of the developed low-energy microcomputers, the hierarchical diagram of software for real-time OS is shown.

circuit is minimal throughout the operation range from hundreds of mA during operation to approximately 1mA in sleep mode. As a power source supplies 24V power to the monitoring system from a battery cell, a battery-driven power circuit with a rated voltage of 14.4V is provided. The battery is composed of four 3.6V lithium battery cells connected in a series.

Harvesting energy for the evaluation board is realized by an energy-autonomous system that is provided with a source circuit, a charger circuit, and a power storage circuit. The board is capable of power generation in combination with power-generating devices using heat, vibration, and light.

The aforementioned power generating devices are, for example, the piezo vibration power generation element, the thermoelectric conversion module, the microfiber composite, and the dye sensitized indoor optical power generation module. They are used in combination for power generation.

4 Operation in Low Power Consumption

4.1 Example of Intermittent Operation

During intermittent operation, switching over between sleep mode and working mode is accomplished in 2μs. If the working time is dramatically shortened and power consumption in sleep mode is decreased, the amount of energy consumption can be reduced to the least possible minimum.

When limited energy obtained by using an energy harvesting technique, any effort to complete active processing in a short time is an important factor when effective use of limited energy is intended.

Fig. 6 shows an example of intermittent operation of the evaluation board. In sleep mode, almost no current consumption occurs (approx. 1mA). It is designed so that operation can be maintained with minimal current consumption when the power circuit necessary for processing is made active after starting up.

4.2 Example of Energy Harvesting Application

Table 2 shows an example of an application of energy-harvesting technologies. Using an indoor optical power generation module (sensitized type of dye made by Fujikura Ltd.), power generation was made indoors (by the window side) with the brightness of 2000lux. When the load is operated for 10 seconds (20mA in operation mode and 0.1mA in sleep mode), intermittent operation is possible at the intervals of 3.5min. Similarly, in the case of a thermoelectric power generation module (made by YAMAHA CORPORATION), it is possible to perform intermittent operation at the intervals of 2.5min under the circumstances where a temperature difference of about 60℃ is maintained.

When circuit design is made to realize the conditions where intermittent operation is possible with a total of power consumption for both operation

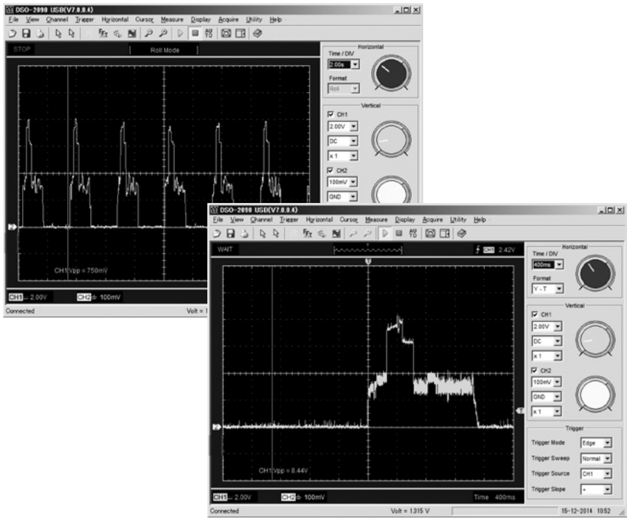

Fig. 6 Example of Intermittent Operation of Evaluation Board

The behavior of current consumption in the evaluation board is shown; observed in operation mode and sleep mode.

Table 2 Example of Application of Energy Harvesting Technologies

An empirical result is shown in regard to energy harvesting technologies using indoor solar power and heat power.

Confirm the charging operation:
Power generating element → Source IC → Secondary battery

Item	Evaluation item	Charging operation	Charging current
1	Indoor solar power generation	OK	Approx. 1.1mA (Approx. 2000lux)
2	Heat power generation	OK	Approx. 1.4mA (Temperature difference: Approx. 60℃)

Attainment of operation with intermittent operation sensor terminal combined with secondary battery + power generating device

Current consumption		Operating time	Period of intermittent operation	
Operation	Standby		Indoor solar power generation	Heat power generation
20mA	0.1mA	10s	Intervals of 3.5min	Intervals of 2.5min

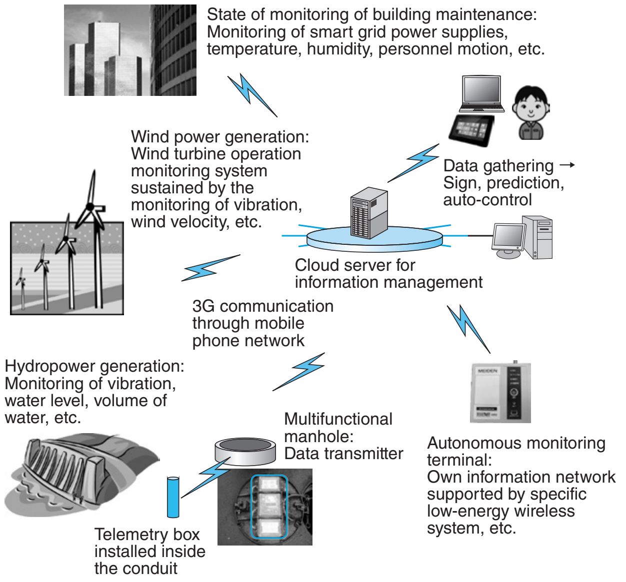

Fig. 7 Making Applied Products

An example of an application is shown in regard to telemetry and monitoring performed by autonomous monitoring terminals to which low-energy microcomputers are applied. In this case, installation work for power supply and communications equipment can be omitted. As a result, the system can be operated shortly after installation.

mode and sleep mode kept within the amount of energy resulting from indoor optical power generation, remote object monitoring is possible without using any grid power.

5 Making Some Applied Products

Fig. 7 shows our products where low-energy microcomputer technologies are applied.

5.1 Multifunctional Manhole Monitoring Unit

When a manhole is equipped with a low-energy monitoring unit that is combined with a lithium battery, automatic measurement becomes possible to obtain data of the water level, amount of hydrogen sulfide, pH values, and other necessary values prevailing inside the conduit. This equipment performs the start-ups at a predetermined cycle and the obtained data are gathered and transmitted to our cloud-computing system by 3G communication. These data can be monitored in any place by using an internet browser. If the number of objects to be monitored inside the manhole is increased, information can be collected by the using multiple units that are combined through a specific low power radio station.

5.2 Wind Turbine Operation Monitoring System

Vibrational components of a wind turbine tower are analyzed in order to examine the operational conditions of the wind turbine system. Operational data are collected by means of a specific low-power wireless communication.

6 Postscript

Technologies of circuit boards for low-energy microcomputers are indispensable factors in the future in order to realize products requiring energy generation, energy storage, and energy saving. In this connection, we introduce such circuit board technologies.

These technologies are applicable to monitoring equipment and data transmission terminals that make it possible to perform monitoring and measurements without requiring power source-related work in a location where such work was needed in the past. Further development of these technologies is expected.

We will continue to promote the development of products to meet the new market demands by combining technologies on ultra-low energy and energy harvesting.