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AUTONOMOUS OPERATION MODE OF SENSING NODE IN TELEMETRY SYSTEM

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Abstract − Telemetry system is the wireless measuring system constructed with sensing node(s), Host system and communication device(s). The telemetry system becomes the base technology to construct the distributed measurement system to measure in geometrical wide range. Then, it is necessary to keep load balance in the local area sensing network system. In the telemetry system, autonomous operation of the sensing node enhances the effectiveness of telemetry system totally. This paper describes the investigation of operation mode and automatic sampling control in sensing node of telemetry system.

Keywords: telemetry system, sensing node, sampling control

1. INTRODUCTION

Telemetry system is a convenient and effective measuring method for the measurement at a long distance place, in a large scale area, in a danger area physically and mentally and the measurement for long time[1-5]. Mostly, the telemetry system is constructed with Sensing node(s) and a Host system. The Sensing node measures signals, analyzes them and transfers periodically to the Host system. The Sensing node has a sufficient input range for signals to changes of measuring objects and environment. The Host system reforms the data with various data processing methods according to measurement aim. In the telemetry system to stationary measuring object, the sensing node operates as a passive device for signalization and data transmission merely. In cases of telemetry system to non-stationary measuring object or distributed sensing node system, the stationary operation mode by such Sensing node brings various losses on the sampling in Analogue/Digital Converter, the operation time of circuits and the transmission rate in communication with the Host system. An effective solution to these losses is to control the sampling flexibly according to characteristics of input signal. To realize the flexible sampling control, it is necessary that the sensing node has some kinds of operation modes. The autonomous control of these operation modes brings the effective operation of the Sensing node. The autonomous sensing node will decrease the dependence to the Host system and enhance the effectiveness of telemetry system totally.

2. TRANSITIONS OF OPERATION MODE

The autonomous switching of sampling rate in the sensing node bring

1) the decrease of communication cost with the host system and other sensing nodes,
2) the avoidance of communication congestion with the host system and other sensing nodes,
3) the decrease of power consumption for signal sampling,
4) the automatic correspondence to dynamical changes of measuring object and measurement environment.

The suitable operation mode corresponding to the fluctuation of input signal is selected from four kinds of operation mode(Regular mode, Irregular mode, Event driven mode, On demand mode).

2.1. Regular mode

Regular mode is the operation mode to measure an input signal by a constant sampling time interval. The data is transmitted from the sensing node to the host system regularly. The sampling time interval is decided by the message from host system. Under the operation mode, the sensing node drives passively by static parameters not affected by external environment and condition.

2.2. Irregular mode

Irregular mode is the operation mode to measure an input signal by an irregular sampling time interval. The operation mode presumes fluctuations of measuring data and manages autonomously selections of input signal and a sampling time interval by using a stochastic process model or a static estimation model. The autonomous control realizes the effective measuring according to characteristics of input signal, the low power operation of sensing node and the decrease of communication cost without the loss of information in measuring data. The data is transmitted irregularly to host system each sampling. The operation mode saves the resource of sensing node system by the local control of the measurement to fluctuation of input signal. Under the operation mode, the sensing node drives autonomously by self control using signal/data processing.

2.3. Event driven mode

Event driven mode is the operation mode to measure an input signal by an event. The event is triggered when the input signals crossing over/down a threshold level of amplitude. Then the sensing node starts a measurement at crossing over and stop at crossing down. The operation mode saves the resource of sensing node system by the local control of the measurement. Under the operation mode, the sensing node drives passively by external trigger.

2.4. On demand mode

On demand mode is the operation mode to measure an input signal and to transmit the data by the command message from host system and other sensing nodes. Under the operation node, the sensing node drives passively as a slave of host system and other sensing nodes.

2.5. Transitions of operation mode

Fig.1 shows the transition of the operation mode in sensing node. The sensing node wakes up by Power on and Initialization of the internal parameters. And it drops into Irregular mode. If the input signal is discrete, the operation mode transfer to Event driven mode. On the other hand, if the input signal is static, the operation mode transfers to Regular mode. In Regular mode, if the input signal changes dynamically, the operation mode transfers to Irregular mode. On the other hand, if the input signal is discrete, the operation mode transfer to Event driven mode. In these cases, the sensing node knows that the input signal is static by continuing same measuring value in a constant time and also that the input signal is discrete by continuing zero in a constant time. In Event driven mode, a threshold level on amplitude monitors the discrete input signal. If the input signal crosses over the level, the operation mode transfers to Irregular mode. And the operation mode brings back to Event driven mode at that the input signal crosses down the threshold level. On demand mode is an isolate mode to other operation mode. The operation mode is driven by command messages from host system.

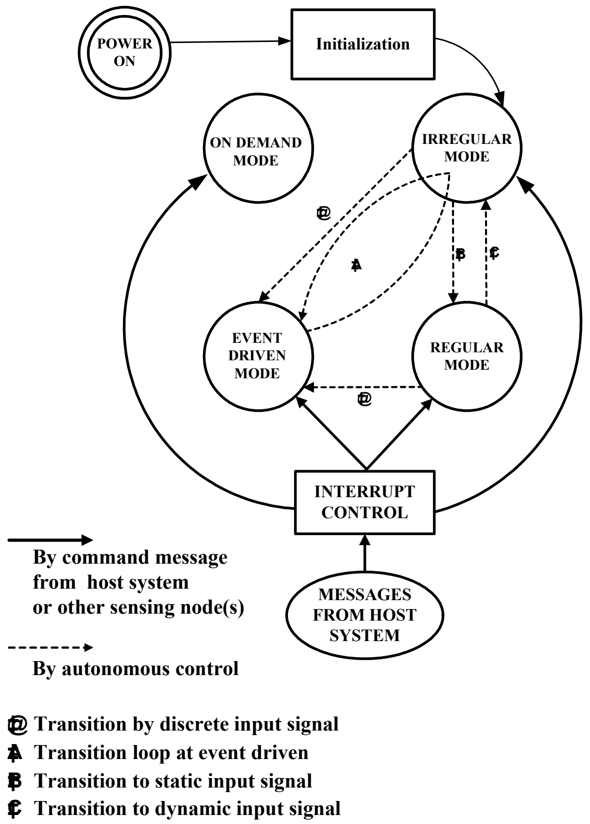

Fig.1 Transition of Operation Mode in Sensing Node

These operation modes are also transferred each other by interrupt control with the command message from Host system or other sensing node.

3. SYSTEM CONSTRUCTION

The basic components of a sensing node in telemetry system are sensor, AD converter, data converter, communication unit and power supply. To realized the autonomous operation, the sensing node needs to add some optional functions(input signal selector, sampling controller, data analyzer and so on). Fig.2 shows the system construction to manage four kinds of operation mode mentioned above. The Input Signals from Sensors go through the Input Selector and are transformed to digital signals at the Multi Channel AD Converter. Basically, these signals are transformed into a communication format and are transmitted to the Wireless Unit through the Communication Interface. Examples of Wireless Unit are PHS(Personal Handy Phone), wireless LAN(Local Area Network), Infrared transmitter and other kinds of radio transmitter. The Gate Controller switches the Input Signals individually according to an operation mode. The Input Monitor operates to monitor the amplitude level of input signal in the Event driven mode. When the signal crosses a threshold level of amplitude, the Input Monitor sends the command that

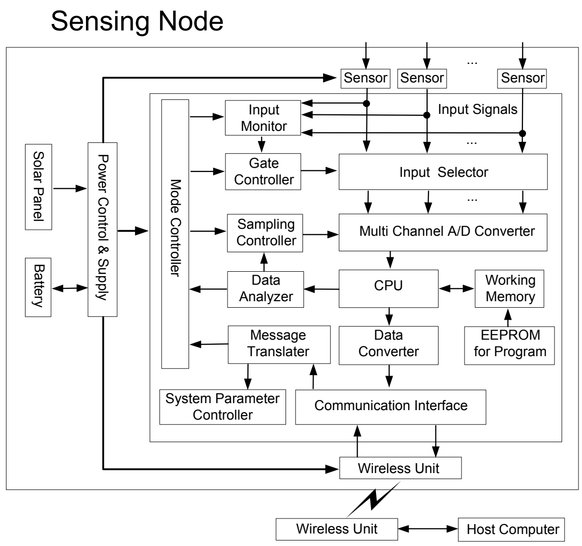

Fig.2. System Construction of Sensing Node

the signal is valid or invalid to the Gate Control. The Sampling Controller is the function to manage a sampling rate in each operation mode. The Data Analyzer indicates a sampling rate by investigating the fluctuation of a series of data in the Irregular mode. And also, it controls to change into the Event driven mode. The Message Translator sets system parameters of the sensing node and changes the operation mode by the command message from host system and other sensing nodes. To operate the sensing node autonomously, an electrical power of system is supplied by a natural resource. Generally, the Power Control & Supply unit by solar energy is used.

Fig.3 shows the exterior of sensing node(without the power supply) constructed actually. The Multi Channel AD converter has 16 channel input gates. The input signals are converted to digital signals by 12 bit resolution. The sampling rate is 6 to 100Ksamples/sec. But, by using external sampling control, the sampling time interval is able to extend to long time(ex. 1min., 10min., 30min., …). The sensing node is controlled by CPU(10MHz clock) compatible Z80. The CPU operates in cooperation with the Working Memory (SRAM 1MB) by the program stored in EEPROM(256KB). The sensing node communicates with host system and other sensing nodes through serial interface. The Wireless Unit in this sensing node is PHS.

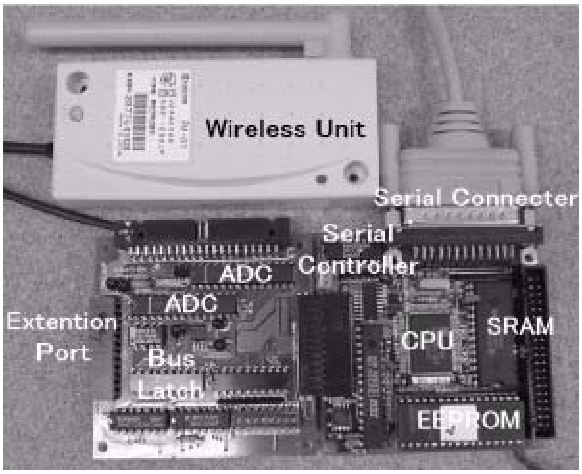

Fig.3. Sample of Sensing Node

4.SAMPLING CONTROL IN IRREGULAR MODE

Irregular mode controls the sampling time interval according to the fluctuation of input signal. The sampling time interval Δt_{i+1} is decided by the fluctuation of past data (Fig.4).

$$\Delta x_i = \left| x_i - \tilde{x}_i \right| \quad (1)$$

x_i is measured data,
$\tilde{x}_i$ is estimated value by past data

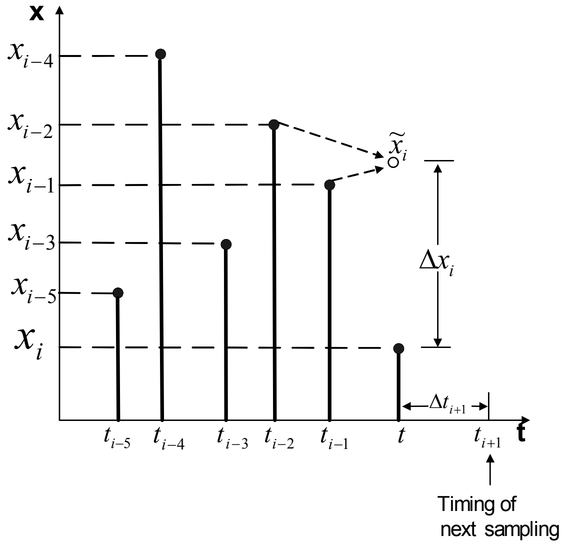

Fig.4. Estimation of Next Sampling Time Interval

If the estimation of $\tilde{x}_i$ is calculated by arithmetic mean with weight, the $\tilde{x}_i$ is got with the following equation

$$\tilde{x}_i = \frac{\sum_{j=1}^{\gamma} \alpha_{i-j} x_{i-j}}{\gamma} \quad (2)$$

ai-j is weight;
γ is order;

$$\gamma = \sum_{j=1}^{\gamma} \alpha_{i-j} \quad (3)$$

The $\alpha_{i-1}, \alpha_{i-2}, \alpha_{i-3} \cdots$ depend on past sampling time interval and gravity to past data. And the next sampling time interval Δt_{i+1} is decided with the following equation

$$\Delta t_{i+1} = \begin{Bmatrix} T_{samp\_1}\,[\mathrm{sec}] : \Delta x_i > 2A_i \\ T_{samp\_2}\,[\mathrm{sec}] : 2A_i > \Delta x_i > 1.5A_i \\ T_{samp\_3}\,[\mathrm{sec}] : \Delta x_i < 1.5A_i \end{Bmatrix} . \quad (4)$$

$$A_i = average\left(\Delta x_{i-1} \sim \Delta x_{i-k}\right)$$

$$T_{samp\_3} > T_{samp\_2} > T_{samp\_1}$$

Coefficients(2 and 1.5) of A_i are the weights given by experience of the measurement. And also k is the order given by the sampling history of past data.

To investigate that the sampling control is valid in the Irregular mode, some kinds of measuring objects

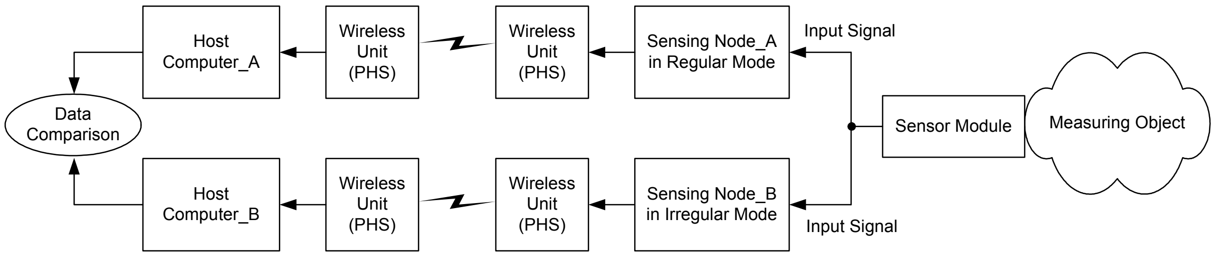

Fig.5 Comparison of Measuring Data by Regular and Irregular Mode

(room temperature, output voltage of solar cell, wind speed of electric fun) are measured by Regular mode and Irregular mode(Fig.5). These fluctuations become fast in order; room temperature, output voltage of solar cell and wind speed of electric fun. Two kinds of sensing node measured the output of same sensor module. The Sensing Node_A operates by Regular mode. The sampling time interval is fixed. The Sensing Node_B operates by Irregular mode. The sampling time interval was changed autonomously (selected from 1/6, 1/2, 1, 10 and 30 [min.]). These sensing nodes transmitted the measuring data to two different host computers through independent communication routes each other. In addition to that, the Sensing Node_B transmitted the record of sampling time interval. After the measurement, by the comparison of the data stored in the computers, the valid of measuring data by Irregular mode has been investigated with correlation coefficient, error rate and rate of data reduction.

4.1. Room Temperature Measurement

Fig.6 shows the measurement results. A capacity of room is 70[m^2]*2.7[m](height). The room is no air-conditioned. The room temperature is measured on Jan.17, 2004. The sampling time interval by Regular mode is 1/6[min.]. The sampling time interval by Irregular mode is almost 30[min.]. Two records of the room temperature by Regular mode and Irregular mode have been almost same. It is confirmed that the interval becomes less than 10[min.] when the deference of fluctuation becomes large. The correlation coefficient is 0.99 between two modes. The error rate of them is 0.657[%]. The rate of data reduction by irregular mode is 98.6[%]. These results mean that the measurement by Irregular mode has been very effective. The reason is that the fluctuation of room temperature is slow.

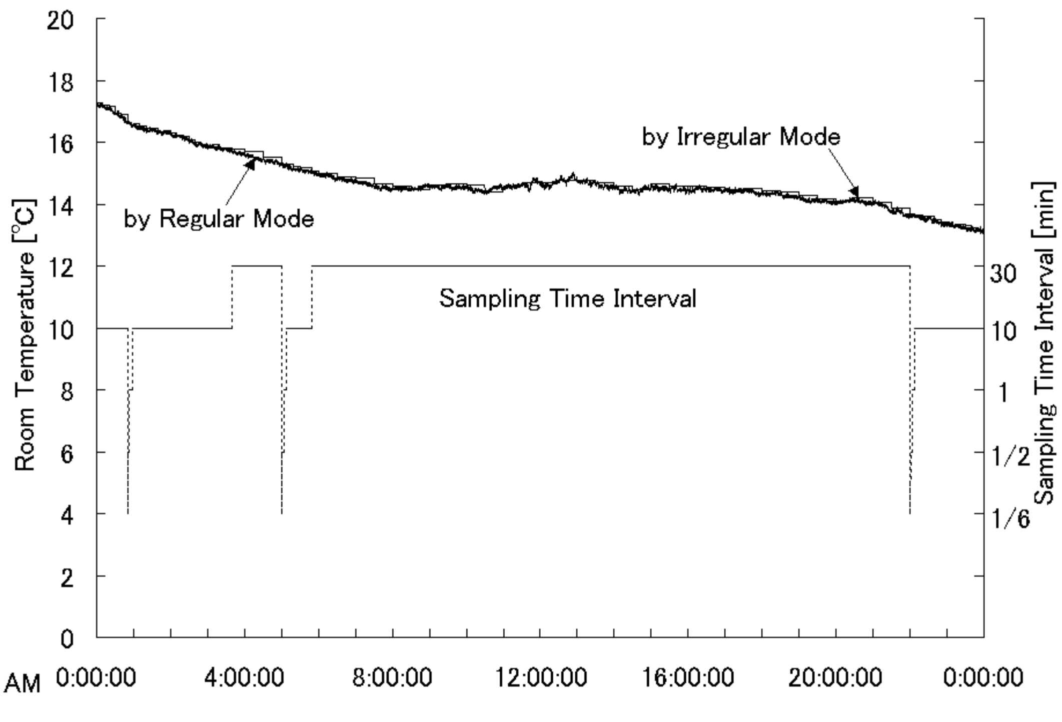

Fig.6 Measurement Result of Room Temperature

4.2. Measurement of Output Voltage of Solar Cell

Fig.7 shows the measurement result of the output voltage of solar cell in a day. As the output is nearly zero before sunrise and after sunset, the signal waveform becomes discrete totally. Then the sensing node is driven by Event driven mode. And the operation mode transfers to the Irregular mode at crossing threshold voltage level in the daytime. Two records of the output voltage by Regular mode and Irregular mode have been similar in a day. The sampling time interval by Regular mode is 1/6[min.]. The sampling time interval by Irregular mode frequently transited between 1/2[min.] and 1/6[min.]. These fluctuations are caused by the cutting off sunlight with clouds. The correlation coefficient is 0.99 between two modes. The error rate of them is 0.29[%]. The rate of data reduction in the irregular mode is 40.7[%]. The rate is lower than the room temperature measurement. The reason is on the shot sampling time interval caused by the speed of the fluctuation of sunlight.

4.3. Measurement of Wind Speed of Electric Fun

Fig.8 shows the measurement result of the Wind Speed of Electric Fun for 5[min.]. The sampling time interval by Regular mode is 1/60[min.]. The sampling time interval by Irregular mode frequently transited between 1/6[min.] and 1/60[min.]. The difference of two records of the output voltage by Regular mode and Irregular mode relates to the sampling time interval. When the sampling time interval is wide, the difference became large. The correlation coefficient is 0.74 between two modes. The error rate of them is 6.2[%]. The rate of data reduction in the irregular mode is 43.7[%]. It has been obvious that the Irregular operation mode changed automatically to narrow sampling time interval at the data loss, and to wide interval at the decrease of data loss.

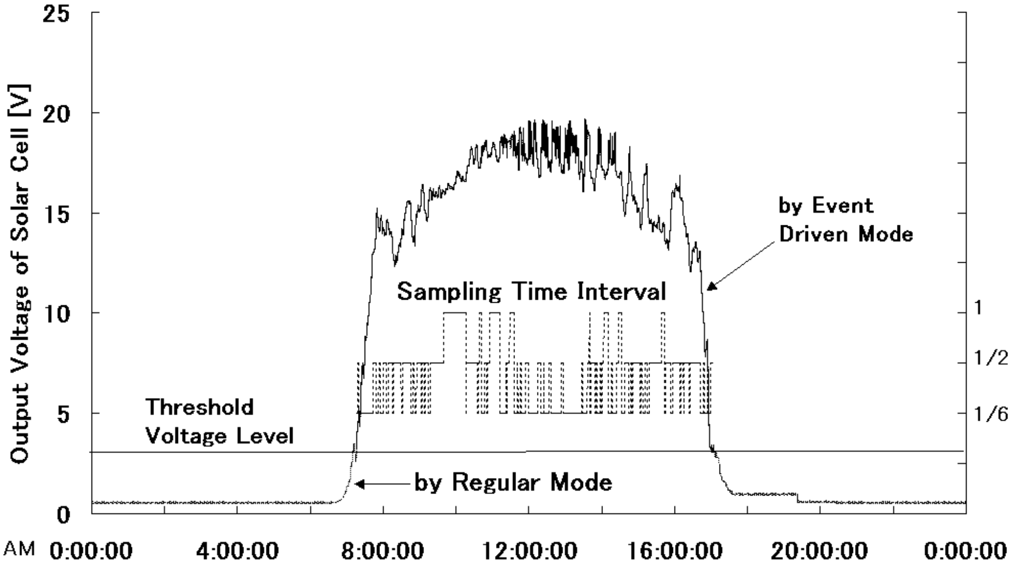

Fig.7 Measurement Result of Output Voltage of Solar Cell in a Day

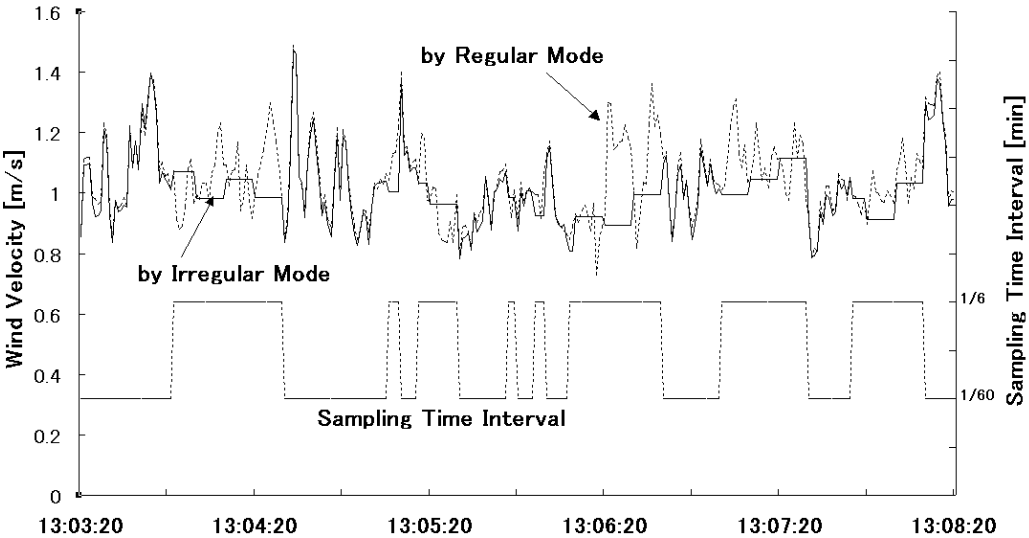

Fig.8 Measurement Result of Wind Speed of Electric Fun

Table1 Relation of Estimation Parameters of Measurement Results

	Room Temperature	Output Voltage of Solar Cell	Wind Velocity of Electric Fan
Speed of fluctuation	slow	medium	high
Correlation coefficient	0.999	0.999	0.738
Error rate [%]	0.657	0.29	6.2
Rate of data reduction [%]	98.6	40.7	43.7

Table 1 shows the relation of the estimation parameters(correlation coefficient, error rate, rate of data reduction) of measurement Results each measuring object. In proportion to the speed of fluctuation, the correlation coefficient and the rate of data reduction become low. The tendency is obvious on the rate of data reduction.

5. CONCLUSION

In environment measurement, plant monitoring, navigation system and security system, the development of wireless networked sensing system(WNSS) is expected strongly. Telemetry system is the key technology. The autonomous sensing node becomes the telemetry system more flexible and effective. The autonomous sensing system is realized by controlling operation mode automatically. This paper shows the classification of operation modes(Regular mode, Irregular mode, Event driven mode, On demand mode) and the transition of them. The essential of operation mode is the sampling control to input signal. By measurement results to three kinds of measuring objects, it has been confirmed that high correlation coefficient and high rate of data reduction are realized keeping low error rate in Irregular mode. Future subjects are on

1) transition condition among operation modes,
2) irregular sampling control.

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