EVALUATION AND IMPROVEMENT OF POE-BASED TEMPERATURE MEASUREMENT MODULE

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Abstract

We developed a small temperature measurement module using Power-over-Ethernet (PoE) technology [1]. It consists of a CPU card operated by a Linux 2.6 kernel and a resistance temperature detector (RTD) card equipped with 4-channel inputs of 3-wire Pt100 RTD sensors. We installed the modules in the machine tunnel of the SCSS (SPring-8 Compact SASE Source) prototype accelerator to measure the air temperature. The measurement appears to be affected by RF nose because the noise level increases when the machine operation starts. We have, therefore, redesigned an RTD card to improve noise immunity and realize precise measurement even under RF noise. Our modifications included the use of 4-wire Pt100 sensors with shielded twisted cables and the layout of the analog ground of the RTD card onto an external connector. In addition, we have increased the number of input channels of the RTD card to 24. The new module can also be driven with PoE. We have successfully improved the noise immunity and achieved a high precision of about 0.01 degree C during the accelerator operation. Because of its compactness and PoE capability, we will apply the new module to measure the temperatures of insertion device (ID) magnets at the Japanese XFEL.

INTRODUCTION

As reported at ICAPELCS 2005 in Geneva, we successfully developed a Linux-based small (130mm ×100mm×30mm) temperature measurement module E-060 using PoE technology [1]. This module consists of a CPU card with a 240MHz SH-4 CPU [2] and a temperature measurement card with 4-channel inputs of 3-wire Pt100 RTDs. The power consumption of E-060 is less than 4.7W so that it can be powered with PoE technology. This technology can reduce the wiring required for a power line and the amount of space required for installation. The module therefore has greater freedom of deployment. We demonstrated good temperature measurement results indicating that PoE technology can also be applied to the precise measurement of analog signals.

We consider that PoE technology will be effective for the temperature measurement of ID magnets at the Japanese XFEL because it will be difficult to provide enough space for the installation of conventional measurement instruments around the IDs. The measurement requires 24 input channels of Pt100 sensors per ID and an accuracy of better than 0.1 degree C. The use of six sets of E-060 is not a cost-effective approach. Therefore, we newly developed a PoE-based temperature measurement module with 24 channel inputs of Pt100 sensors.

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DEVELOPMENT

Approach to the Development

At the design phase, we considered two possible approaches to the development. One was to expand and improve the E-060 module, the other was to apply a PC/104-plus based SH-4 CPU module and a dedicated PoE module developed at SPring-8 [3]. After consideration, we decided to expand and improve the E-060 module because this approach seemed to be more likely to enable temperature measurement at an XFEL machine tunnel. At that time, we did not have any experience of applying the PoE-based PC/104-plus module to precise analog measurement. We were able to feed back our experiences obtained from the E-060 installation into temperature measurement in the SCSS prototype accelerator.

Feedback from E-060 Experience

To measure the air and wall temperatures of the SCSS prototype accelerator, we installed the E-060 modules in the accelerator tunnel. Although E-060 showed good results under ordinary conditions [1], the measurement in the accelerator tunnel was markedly affected by RF noise from the accelerator as shown in Fig. 1. In this measurement, we used 3-wire Pt100 sensors with unshielded and untwisted lead lines.

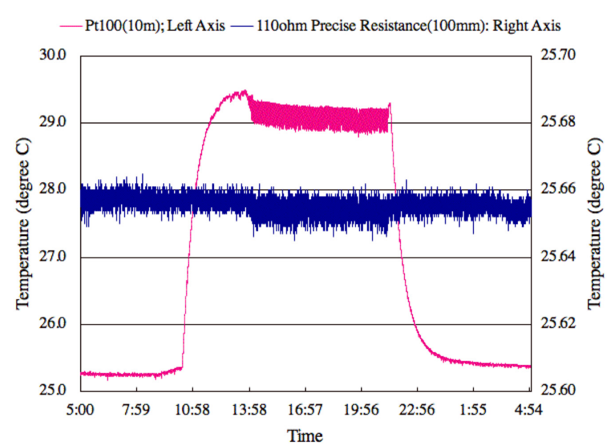

Figure 1: Measurement results of E-060.

We tried to reduce the measurement noise. We first connected a 110Ω precise resistance with short (~100mm), unshielded and untwisted lead lines under the same conditions. Although some noise was measured during the machine operation, the measurement result was satisfactory as shown in Fig. 1. Next, we connected a Pt100 sensor with a 10m unshielded but twisted lead line to E-060. As a result, the noise observed during the accelerator operation was suppressed.

These measurements indicated that the E-060 module was satisfactory and that we had to pay more attention to the lead lines of the sensors. We considered that the lead lines should be shielded and twisted cables and that using a 4-wire cable would enhance the noise immunity.

In addition, we thought of the analog ground of the E-060 module because jumps in the measured value were sometimes observed. The E-060 does not have an external terminal for its analog ground; thus, the analog ground was floating. To suppress the jumps and to stabilize the measurement, the new module should have external terminals for the analog ground. We can select an appropriate ground for each measurement.

Figures 2: Pictures of E-069. The lower picture shows a CPU card (upper side) and a temperature measurement card (lower side).

Development of the Module

We have developed a new module named E-069 by feeding back the experience we obtained from designing and using the E-060. Figs. 2 show the pictures of the new module. Since we used the same CPU card as that of E-060, only the temperature measurement card has been improved and developed. The new temperature measurement card can be connected to up to 24 four-wire Pt100 sensors, and provides an external terminal for its analog ground in its signal connector pins. E-069 employs three LTC-2428 [4] 8-channel 20-bit ΔΣ A/D converters, which are an 8-channel version of LTC-2424 [4] used in E-060. Both LTC-2428 and LTC-2424 have a 50/60Hz notch filter and a conversion time of about 133msec. The specifications of E-069 in comparison with those of E-060 are summarized in Table 1.

Table 1: Specifications of E-069 and E-060

	E-069	E-060
Channels	24	4
Sensors	4-wire Pt100/JPt100	3-wire Pt100/JPt100
Size (H×D×W)	200×130×32mm	130×100×30mm
Power Consumption	~6.3W	~4.7W
Resolution	0.0001 degree C	0.001 degree C
Sampling Rate	~0.9Hz	~1.8Hz

EVALUATION

To verify the feasibility of the E-069 module for the temperature measurement of XFEL ID magnets, we installed it in the SCSS prototype accelerator tunnel and measured the air temperature. We connected 4-wire Pt100 sensors with 10m shielded and twisted lead lines for the measurement. The shields of the lead lines were connected to the analog ground of the module.

For comparison, we also installed a Keithley 2701 6½-digit digital multimeter (DMM) [5] into the machine tunnel and connected the same sensors to the DMM. The integration time of the DMM was set to one-power line cycle.

The measurement results are illustrated in Fig. 3. E-069 showed good results even during the accelerator operation and successfully realized almost the same measurement precision as the DMM of about 0.01 degree C. We consider that this result shows the feasibility of E-069 for the temperature measurement of XFEL ID magnets.

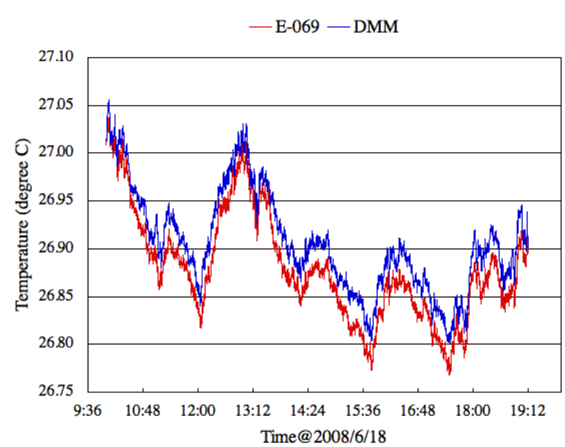

Figure 3: Measurement results of E-069 in comparison with DMM.

Fig. 4 shows the difference between the measurement values obtained from E-069 and DMM. The differences appears to be rather large (0.03 - 0.04 degree C) during the machine operation. At present, we do not know whether this is due to RF noise or the variation of the air temperature. We will investigate the reason by connecting and measuring a precise resistance.

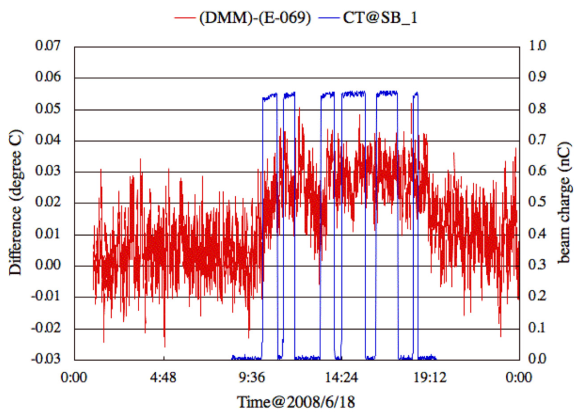

Figure 4: Differences between the measured values obtained from E-060 and DMM.

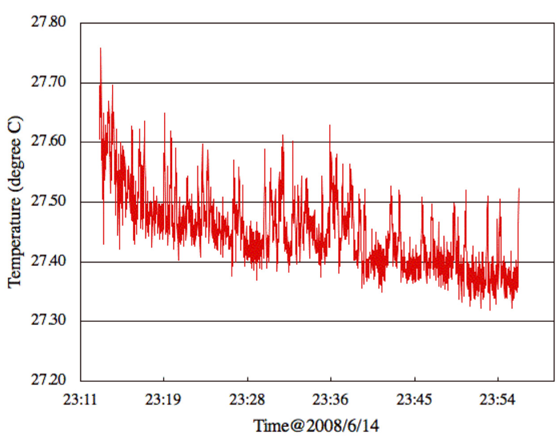

Figure 5: Measurement result of E-069 without connecting the shields of the lead lines to the E-069 analog ground.

We found that the external terminal of the E-069 analog ground was very important. When we did not connect the shields of the lead lines of the Pt100 sensors, the measured noise became worse as shown in Fig. 5. Although the accelerator was not in operation during this period, the noise level was markedly large in comparison with that of the Fig. 3. Connecting the shields to the analog ground of the module improves the precision of measurement.

SUMMARY

We have successfully developed E-069, a PoE-based temperature measurement module, by expanding and improving E-060. Since the new module is designed to have the same CPU card as E-060, we only developed the temperature measurement card, which has 24 four-wire Pt100 RTD inputs.

The new module has been installed in the machine tunnel of the SCSS prototype accelerator to measure the air temperature. By connecting shielded and twisted lead lines to the Pt100 sensors, the module showed good results with an precision of about 0.01 degree C even during machine operation. We consider that the new module is feasible for the measurement of XFEL ID magnets.

Since E-069 can be powered though PoE, we can obtain the benefit of greater freedom of module deployment. We can reduce deployment space owing to its compactness, and can reduce the wiring of RTD sensors. These features are advantageous for the temperature measurement of IDs because there will be little installation space around the IDs.

REFERENCES

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