Proposed Temperature Monitor for Service Buildings

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ABSTRACT

The following is a proposal for a circuit to provide service building temperature monitoring compatible with the multiplexed analog-to-digital converter ("MADCs") infrasctructure already in place. Previous systems relied on the Nuclear Instrumentation Module ("NIM") crate and hardware standard that is becoming increasingly obsolete. The goal of this new system is to create a bare-minimum, simple to maintain, cost-effective design that makes use of parts that are easy to acquire and does not rely on outdated crates or hardware.

Overview

Monitoring the service building temperatures via the ACNET control system is vital to the continued operation of the equipment in the buildings. Alarm capabilities of ACNET allow for notification of air-conditioning or heating failures by altering operators to building temperatures that could damage electronics or power supplies. Historically, a temperature and humidity sensor combination has provided this monitoring throughout Accelerator Division buildings, but lack of expertise and available parts for this system necessitate a new solution that uses of readily-available parts. This new system must be cost-effective to scale, as well as simple and reliable to maintain.

Figure 1 shows the schematic of the new proposed temperature-measuring system, which makes use of the Analog Devices TMP36 sensor[1] and a adjustable-gain TL071[2] buffer amplifier circuit. The resulting voltage from this circuit will be digitized by the service building's MADC using a spare fan-in connection. The feedback resistor for the op-amp circuit was chosen to be adjustable to provide versatility in the output voltage range, and so the circuit can be bench-calibrated to account for variation in the actual resistance of the 1K divider resistor.

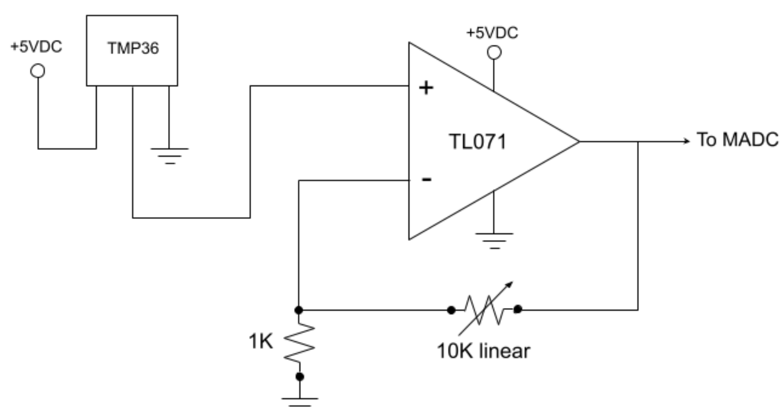

Figure 1. Circuit schematic for temperature sensor and adjustable buffer/amplifier.

Physical construction of the circuit must be unobtrusive, inexpensive, compatible with the MADC fan-in patch panels, and shield the signals from electromagnetic noise in the service buildings from the magnet power supplies. The TMP36 probe should be affixed to the end of a long cable so it can be placed precisely where the temperature needs to be monitored regardless of where the MADC is located in the building. A suggestion at physical layout and cabling is illustrated in Figure 2 that allows for versatility in temperature probe placement while shielding against electromagnetic noise.

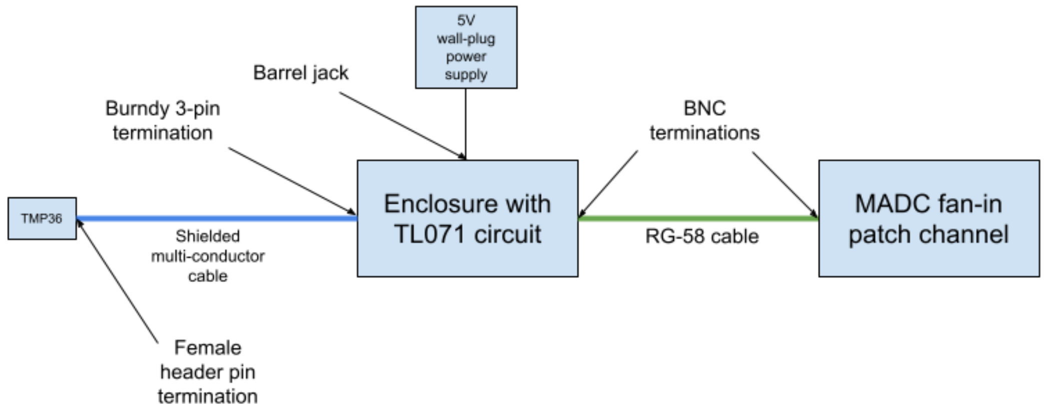

Figure 2. Proposed layout and cabling for the tempeature probe and amplifier circuit.

Digitization

To capture the temperature in the ACNET control system, the output from the circuit in Figure 1 will be digitized by an MADC in the local service building. The resolution and input voltage range of the MADCs across the lab vary depending on the which specific digitizer is used at the service building; the different specifications in operation are summarized in Table 1.[3] The lowest-resolution MADCs offer 12 bits over a total voltage range of 20.48V (± 10.24V), corresponding to a minimum-resolvable voltage step of $\frac{20.48}{2^{12}}$[V], or 5 mV per bit.

MADC type	Voltage range	Resolution
MADC-I (0828-ED-34970)	± 10.24V	12-bit
MADC-II (blue w/ keypad)	± 10.24V	12-bit
Research Division MADC	± 10.0V	14-bit

Table 1. Summary of voltage range and resolution for the various operational MADCs in Accelerator Division.

To make the best use of the MADC resolution, the gain of the amplifier circuit in Figure 1 will be bench-calibrated to a gain factor of 5.5. That corresponds to a feedback resistance for the linear trim potentiometer of about 4.5K Ohm. This widens the output voltage range of the circuit to span as much of the positive MADC input voltage range as is reasonable. The output voltage range of the TMP36 sensor is 0.01V - 1.75V; with a gain factor of 5.5, that corresponds to an output range for the entire circuit of 0.055V - 9.625V over a temperature range of -40°C to 125°C. This corresponds to a voltage-to-temperature relationship of 0.058 $\frac{V}{^\circ C}$. This means the worst temperature resolution achieved by this proposed solution is 0.086 °C per bit, which is more than sufficient for monitoring the temperatures of the service buildings.

Calibration of each corresponding ACNET temperature parameter is necessary to convert "engineering units" of volts to "common units" of °C or °F depending on preference. The above analysis shows that the total circuit will output 0.055V - 9.625V for a temperature range of -40°C to 125°C, equivalent to a Fahrenheit range of -40°F to 257°F. Therefore the conversion factor for the ACNET device database to convert MADC voltage V_{MADC} to temperature T in °F is:

$$T[^\circ F] = 31.0345 * V_{MADC}[Volts] - 41.7069 \quad (1)$$

References

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2. TL07xx Low-Noise FET-Input Operational Amplifiers. URL https://www.analog.com/media/en/technical-documentation/data-sheets/TMP35_36_37.pdf.
3. Conversation with Mike Kuplic of AD/Controls.