not held at a particular temperature but rather the cold junction temperature is measured and used to provide for "cold junction compensation." The temperature at the thermocouple is determined by combining the absolute temperature of the terminal where the thermocouple is connected (i.e. cold junction temperature) with the relative temperature measurement of the thermocouple. Thus, a thermocouple requires a temperature measuring device which measures an absolute cold junction temperature.

[0006] Cold junction temperatures may be determined by temperature measuring devices (also known as cold junction compensators or CJCs). For example, a thermistor or RTD is attached to terminals near the thermocouples to provide a measurement of the temperature in the proximity of those terminals. This cold junction temperature measurement is used for the cold junction compensation of the nearby thermocouple by the I/O module through a cold junction compensation computation typically performed by a processor internal to the I/O module. This compensation process may use a function stored in a lookup table or expressed as a polynomial equation.

SUMMARY OF THE INVENTION

[0007] The present inventors have recognized that a significant source of error in thermocouple measurements by I/O modules is minor temperature variations among the terminals of the terminal block. This error is corrected in the present invention by an empirical model providing temperature differences as a function of ambient temperature. One or more actual terminal measurements are used to adjust them all appropriately. Underlying at least one embodiment of the invention is a recognition that empirically derived temperature differences tend to be constant in a variety of installations of the I/O modules.

[0008] ~~Specifically,~~A first aspect of the present invention provides an I/O circuit for use with an industrial control system. The I/O circuit provides a housing supporting a terminal block having a plurality of terminals arranged in rows and columns to provide terminals displaced from each other in at least two perpendicular directions, the terminals releasably receiving thermocouple leads to obtain a temperature at a temperature measurement location. A processor executes a stored program to read at least one cold junction compensation temperature from at least one terminal and to determine effective cold junction compensation temperatures at other terminals based on a stored empirically derived model.

[0008a] A second aspect of the present invention provides a method of measuring temperatures in an I/O circuit in a terminal block having a plurality of terminals arranged in rows and columns to provide terminals displaced from each other in at least two perpendicular directions, the terminals releasably receiving thermocouple leads to obtain a temperature at a temperature measurement location, the method comprising the steps of:

(a) reading at least one cold junction compensation temperature from at least one terminal; and

(b) determining effective cold junction compensation temperatures at other terminals based on a stored empirically derived model.

[0008b] A third aspect of the present invention provides an I/O circuit for use with an industrial control system comprising:

an I/O circuit housing supporting a terminal block having a plurality of terminals arranged in rows and columns to provide terminals displaced from each other in at least two perpendicular directions, the terminals releasably receiving thermocouple leads to obtain a temperature at a temperature measurement location;

a processor executing a stored program to read at least two cold junction compensation temperatures from at least two terminals and to determine effective cold junction compensation temperatures at other terminals based on an interpolation between at least two cold junction compensation temperatures and to further read at least one temperature signal from a thermocouple at one other terminal and apply a cold junction compensation correction to the temperature signal based on the determined effective cold junction compensation temperatures at the other terminal and to output the corrected temperature signal.

[0018] ~~The~~ Embodiments of the invention may provide input circuitry between the processor and the terminals adapted to receive a temperature transducer from a group consisting of a resistance temperature detector (RTD), thermistor, a thermocouple, and a solid-state temperature sensor.

[0019] It is thus a feature of a least one embodiment of the invention to provide an I/O module suitable for a variety of different temperature sensors.

[0020] The I/O circuit housing may include a mounting slot configured for a DIN mounting rail controlling orientation of the I/O circuit housing.

[0021] It is thus a feature of a least one embodiment of the invention to enforce an orientation of the housing that may improve the accuracy of the empirical model.

[0022] The I/O circuit may have a plurality of terminals arranged in rows and columns and heights to provide terminals displaced from each other in at least three perpendicular directions.

[0023] It is thus a feature of a least one embodiment of the invention to provide up to three dimensions of temperature correction.

[0024] The housing may hold heat-producing electronic circuitry in a fixed location with respect to the terminal block.

[0025] It is thus a feature of a least one embodiment of the invention to compensate for temperature gradients produced by the I/O module itself.

[0026] The described aspects and objects of the present invention will be better appreciated and understood when considered in conjunction with the following description and the accompanying drawings. It should be understood, however, that the following description while indicating preferred embodiments of the present invention is given by way of illustration and not of limitation. Particular objects and advantages may apply to only some embodiments falling within the claims and thus do not define the scope of the invention. Many changes and modifications may be made within the scope of the present invention without departing from the spirit thereof, and the invention includes all such modifications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Fig. 1 is a block diagram of an I/O module showing a thermocouple and two cold junction compensation devices attached to a terminal block of the I/O module for temperature measurement;

[0028] Fig. 2 is a perspective view of an I/O module and its terminal block showing the terminals arranged in rows of different heights;