Industrial Control Links, Inc.

Universal Inputs - Analog Measurement Techniques

as implemented in the Pinnacle Series Controllers

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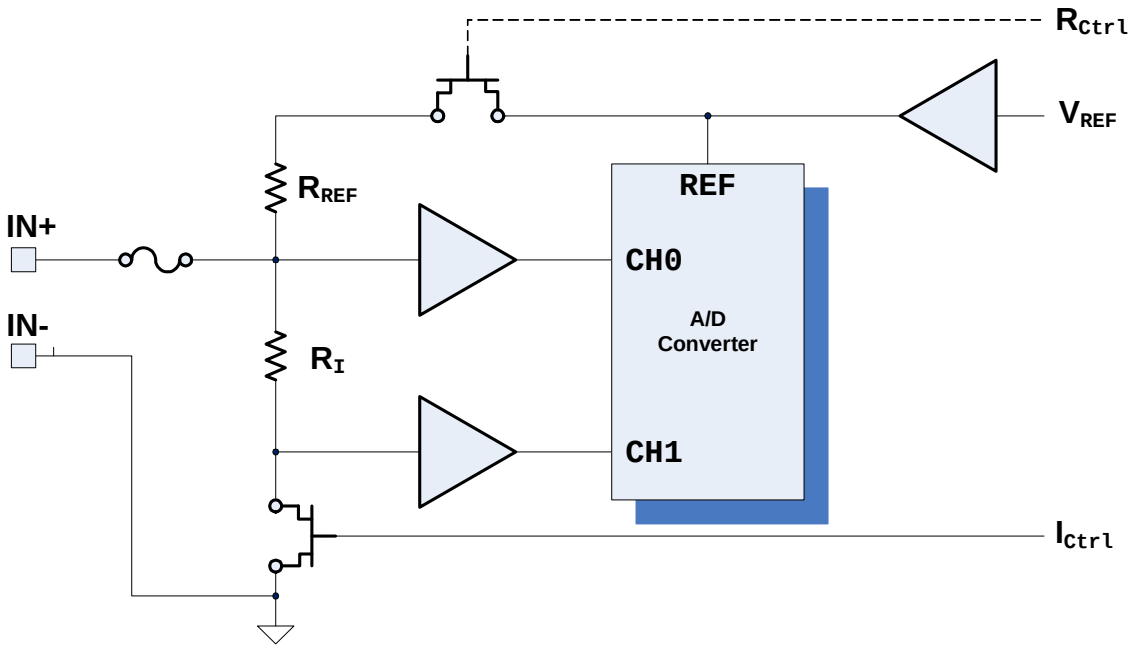
This paper describes the techniques used by the Universal Inputs of Pinnacle Series Controllers to measure analog signals and sensor readings. The Universal Inputs are capable of measuring process voltage (volts/millivolts) and current signals, resistance, and temperature (via thermistor, thermocouple and RTD resistance type sensors) as well as responding to discrete contact closure type signals.

The basic universal input circuit for a single channel is pictured below:

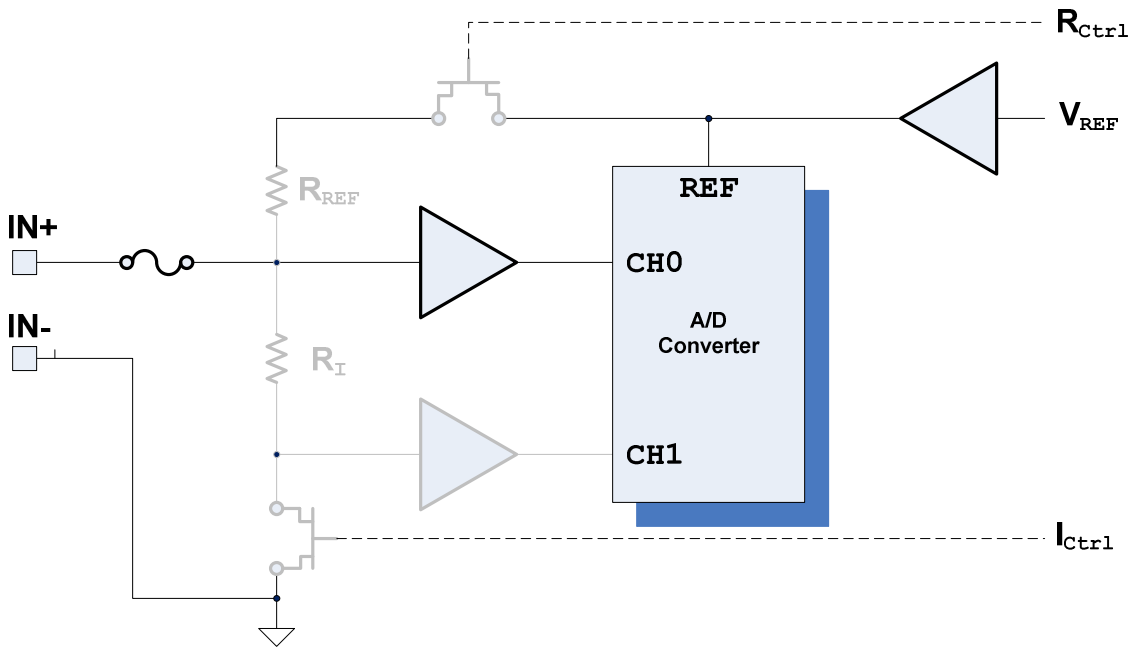


Note that this is a simplified diagram for clarity.

The Universal Inputs use very high resolution (24-bit) Analog-to-Digital (A/D) converters. Each input uses two A/D channels; CH0 and CH1 in the diagram. A pair of precision resistors is connected internally to the (+) field input terminal and the first input of the A/D converter (CH0). Precision FET solid state switches are used to permit or block current flow through the resistors under microprocessor control depending on the measurement mode (Voltage/Current/Resistance or sensor type).

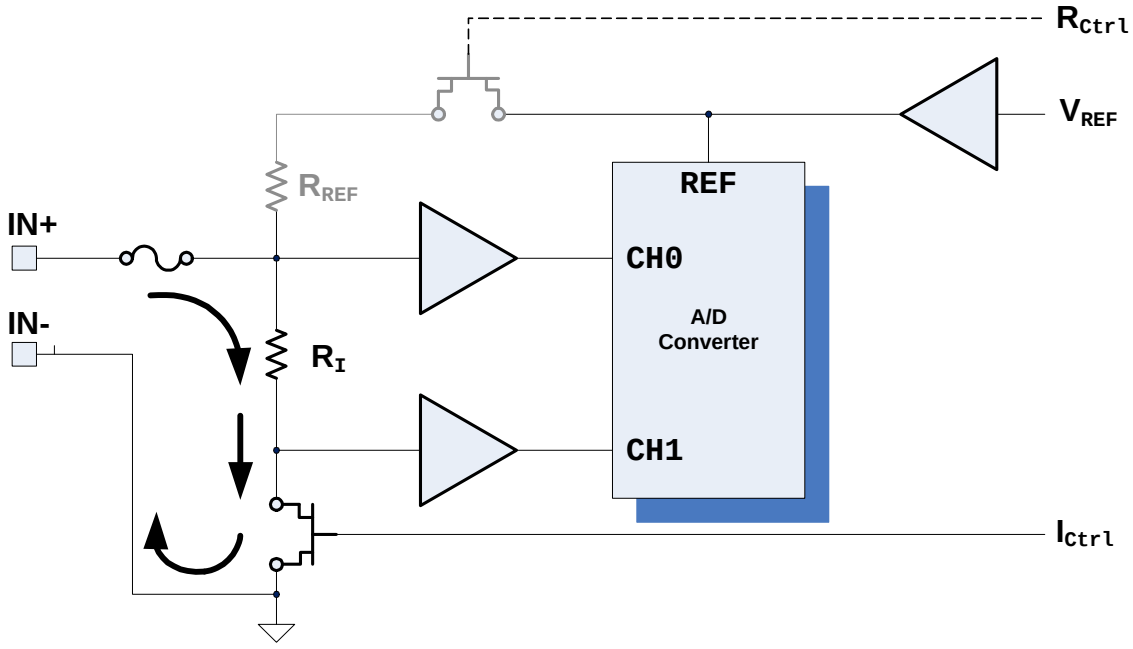
VOLTAGE AND MILLIVOLT MEASUREMENTS

With neither FET control switch enabled, a Universal Input operates as a conventional voltage (and millivolt) measurement channel. The Input Voltage is measured against the Reference Voltage, providing a digital value to the microprocessor that is proportional to the reference voltage.



CURRENT MEASUREMENTS

When the I_{CTRL} FET switch is enabled, current from the input is directed through the current reference resistor R_I.



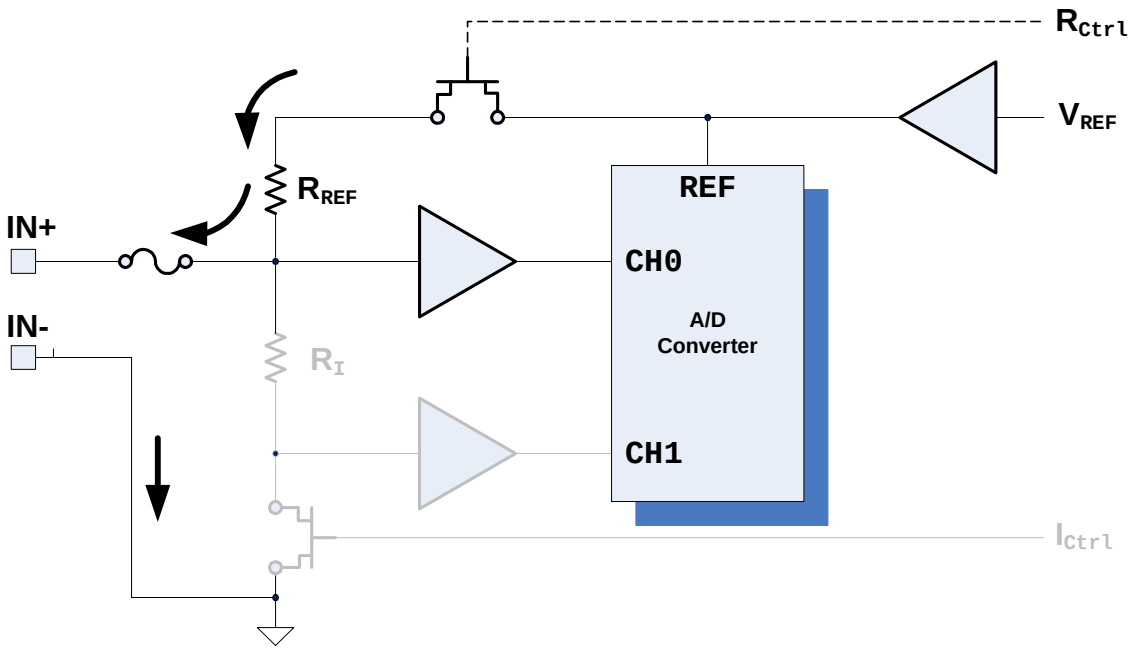
The microprocessor measures the input voltage on both A/D channels and subtracts the two (differential measurement) in order to find the true voltage drop across the current reference resistor without the effects of the voltage drop across the control FET switch. The current is calculated as:

Input Current = $(V_{CH0} – V_{CH1})/ R_I$

Note that in Pinnacle controllers, R_I is a low-drift precision 100 ohm resistor in order to minimize the voltage drop in the measured current loop, and to ensure that the input voltages on the A/D channels do not exceed the common mode rating of the A/D converter.

RESISTANCE MEASUREMENTS

When the R_{CTRL} FET switch is enabled, current from the A/D reference is directed through a precision reference resistor R_{REF} to the field input terminal.



In order to determine the resistance of the field sensor, the voltage drop across the sensor must be measured using a known current. The voltage drop across the field sensor is simply the voltage measured by the first A/D channel; CH0. The current sourced to the field sensor is the difference between the reference voltage and the CH0 input voltage divided by the known value of the precision reference resistor R_{REF}.

Measurement Current = $(V_{REF} – V_{CH0})/ R_{REF}$

The resistance of the field sensor is the Voltage measured on CH0 divided by the calculated measurement current.

$R_{SENSOR} = V_{CH0} / ((V_{REF} – V_{CH0})/ R_{REF})$

Errors introduced by internal path and component resistances (such as from the input fuse and the FET switch) are removed by calibration adjustment calculations in the controller.

In Pinnacle controllers, R_{REF} is a low-drift precision 4.99K ohm resistor in order to limit the effects of self-heating in sensitive RTD sensors by limiting the measurement current to less than 0.5mA.

TEMPERATURE SENSOR CONVERSIONS

In the case of temperature sensors (thermocouples, thermistors and RTDs), once the appropriate voltage or resistance measurements have been made, Pinnacle controllers convert the sensor readings into linear temperature measurements in Fahrenheit or Celsius degrees.

Thermocouples

For Thermocouples, Pinnacle Series controllers measure the voltage from the sensor. Since the voltage is very small (millivolts), the controller uses only the lower portion of the 24-bit A/D reading. This A/D reading is first converted to millivolt engineering units using internal calibration information. At the same time, the controller also reads the "cold junction temperature" from a precision solid state temperature sensor located near the Universal Input terminals. The cold junction temperature is converted into an "equivalent millivolt reading" for the particular thermocouple sensor being used, and then this equivalent millivolt reading is subtracted from the measured sensor millivolts. The results are converted to temperature using a polynomial equation that also linearizes the sensor reading.

Thermistors

For Thermistors, Pinnacle Series controllers measure the resistance of the sensor. Since these sensors respond to small temperature changes with relatively large changes an resistance, the controller simply converts and linearizes the resistance readings to the equivalent temperature reading by a conversion formula without further processing.

RTDs

RTDs are sensors that register very small amounts of resistance change for temperature changes (fraction of an ohm per degree). For 2-wire RTDs, Pinnacle Series controllers measure the resistance of the sensor on a single channel and ignore the errors caused by lead resistance. For 3-wire RTDs, two universal Input channels are used; one to measure the sensor resistance, and the other to measure the lead voltage drop/resistance so that the controller can compensate for external wiring resistance and improve measurement accuracy. When the sensor resistance has been determined, the controller converts the resistance reading to linear temperature using Callendar-Van Dusen calculations.

CONCLUSION

Pinnacle Series controllers are extremely flexible in measuring various types of analog signals and sensors. By eliminating the need for front-end conversion modules and transmitters, Pinnacle Series controllers can drastically reduce the cost of control equipment in a system.

