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SINGLE-CHANNEL RTD INPUT MODULE
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SINGLE-CHANNEL RTD INPUT MODULE

Overview.

This design presents a high-precision, single-channel RTD input module that supports both Pt100 and Pt1000 sensors in a 4-wire configuration. It is optimized for modular microcontroller-based systems, enabling accurate, low-noise temperature measurements in demanding environments such as Octavia Carbon's DAC systems.

The signal acquisition chain begins with the RTD sensor connected through a 4-wire terminal block. To ensure robustness in industrial settings, the sensor input is protected against electrostatic discharge (ESD) and transients via PESD diodes. A precision current source (REF200) excites the RTD, generating a voltage drop proportional to its resistance, and hence temperature.

The voltage drop across the RTD is first filtered through an RC low-pass stage to suppress high-frequency noise, then amplified using the INA333 instrumentation amplifier. An external potentiometer sets the amplifier gain, allowing tuning for either RTD type. A second RC filter stage follows to further attenuate any amplified noise.

The conditioned signal is digitized by the ADS124S06—a high-resolution, 24-bit delta-sigma ADC with integrated multiplexer and programmable gain. A precision 5 V reference (ADR4550) provides a stable voltage reference, and analog power is cleanly regulated by the LP5907 LDO to minimize ripple and thermal drift. Digital power rails are supplied directly by the ESP32's on board 3.3 V regulator.

Communication with the ADC is handled over SPI, interfaced through fixed GPIOs on the ESP-WROOM-32 microcontroller. A USB-to-Serial bridge (CH340C) provides programming and serial debugging access via a Micro-USB connector. Reset and boot buttons are included for manual control during development.

Two GPIO-controlled tactile switches allow the user to select between Pt100 and Pt1000 operation. The firmware detects the selection and applies the appropriate scaling using the inverse Callendar–Van Dusen equation for accurate temperature computation, enabling flexible and accurate thermal sensing.

Key Features.

1. **Dual RTD Support** – Compatible with both Pt100 and Pt1000 sensors.
2. **4-Wire Configuration** – Eliminates lead resistance errors for precise measurement.
3. **Precision Current Source** – Low drift REF200 provides stable excitation current.
4. **High CMRR Amplifier** – INA333 offers noise-resistant differential amplification.
5. **24-bit ADC** – ADS124S06 enables high-resolution, low-noise digitization.
6. **Low-Noise Analog Power** – LP5907 ensures analog integrity.
7. **Stable Voltage Reference** – ADR4550 delivers accurate 5 V reference voltage.
8. **Surge & ESD Protection** – PESD devices protect against industrial transients.
9. **RTD Type Selection** – GPIO-driven tactile switches allow runtime sensor selection.
10. **USB Debug Interface** – CH340C enables easy programming and diagnostics.

Block Diagram.

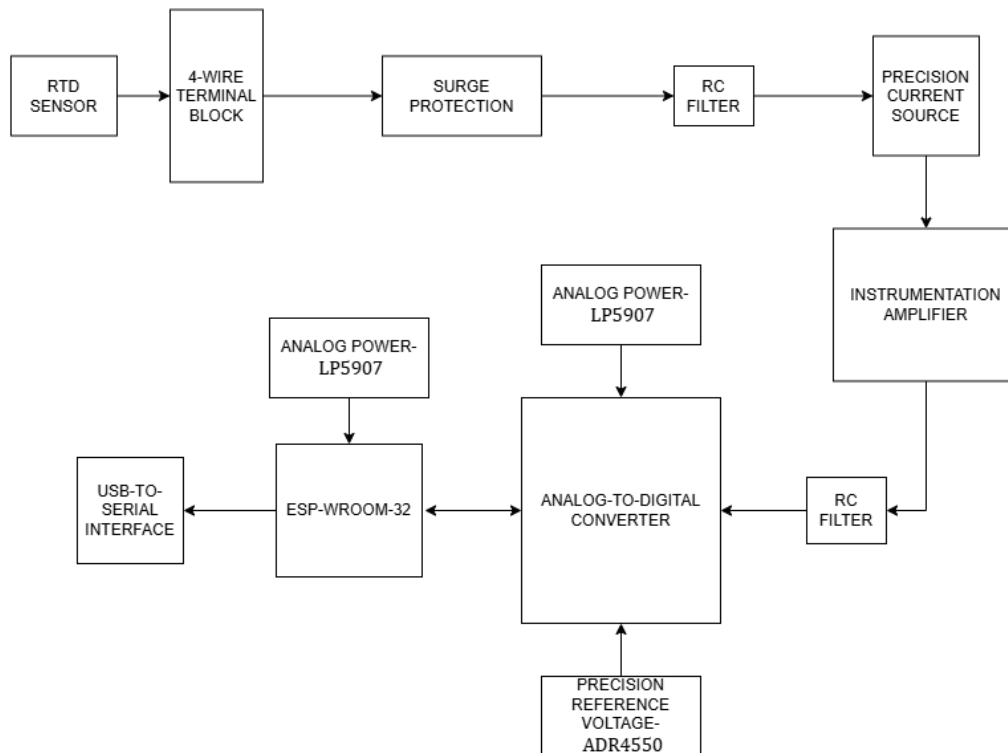


Figure 1: single-channel RTD input module block diagram

Description.

1. Support for Pt100 and Pt1000 Sensors

The RTD input module is designed to support both Pt100 and Pt1000 resistance temperature detectors using a shared, flexible analog front-end. Although these sensors differ in their nominal resistance values—100 Ω for Pt100 and 1000 Ω for Pt1000 at 0 $^{\circ}\text{C}$ —they operate on the same temperature-dependent resistance principle. This commonality enables the use of a unified signal conditioning chain comprising a precision current source (REF200), an instrumentation amplifier (INA333), and a 24-bit high-resolution ADC (ADS124S06). Together, these components accurately process signals from either RTD type without requiring any hardware modifications.

Sensor type selection is achieved via tactile switches connected to the ESP32's GPIOs. The firmware continuously monitors these inputs to detect whether a Pt100 or Pt1000 sensor is in use. Once identified, the system dynamically applies the correct scaling logic using the inverse Callendar–Van Dusen equation, ensuring accurate temperature readings. This approach offers hardware simplicity, firmware-driven flexibility, and ease of deployment in varied sensing applications.

2. Noise and Self-Heating Mitigation

Achieving reliable and accurate RTD readings requires mitigation of both electrical noise and self-heating effects. The module incorporates several analog and power-domain techniques to suppress these issues.

High-frequency noise is attenuated using two RC low-pass filter stages—one at the RTD input terminals and another after signal amplification, just before the ADC input, to minimize any residual noise. Additionally, the differential sensing configuration provided by the INA333 further enhances noise immunity by rejecting common-mode interference.

Power integrity is maintained by isolating analog and digital domains using separate LP5907 low-noise LDO regulators. These regulators deliver clean power to the ADC, reference, and amplifier, while preventing cross-domain coupling from the ESP32 or USB interface.

Self-heating is minimized by choosing low excitation currents in the range of 250 μA to 1 mA—via a precision current source (e.g., REF200). This minimizes power dissipation, maintains internal sensor temperature rise low, preserves measurement accuracy. Additionally, short ADC conversion times reduce the duty cycle of current flow through the RTD, further limiting thermal build-up within the sensor.

3. Reliable Operation at High Ambient Temperatures (up to 101 °C)

Key analog components—including the ADS124S06, INA333, ADR4550, and LP5907—are rated beyond 100 °C, ensuring reliable performance under sustained thermal load. Heat buildup is mitigated through low-power component selection and thermal isolation between analog and digital domains. Dual-stage RC filters improve signal integrity and suppress potential amplifier oscillations that may lead to excess dissipation. Precision analog components are strategically grouped into low-gradient thermal zones to minimize drift caused by localized heating.

4. Schematic Diagram

The schematic integrates a precision analog signal chain tailored for RTD sensing using either Pt100 or Pt1000 sensors. It includes a REF200 precision current source for RTD excitation, an INA333 instrumentation amplifier for differential signal acquisition, and an ADS124S06 24-bit ADC for high-resolution digital conversion. Key support components—such as the ADR4550 voltage reference, dual-stage RC filters, and LP5907 LDO regulators—ensure signal integrity, thermal resilience, and power domain isolation. Sensor type selection is managed through GPIO-interfaced switches on the ESP32, with SPI-based data acquisition and scaling logic handled in firmware.

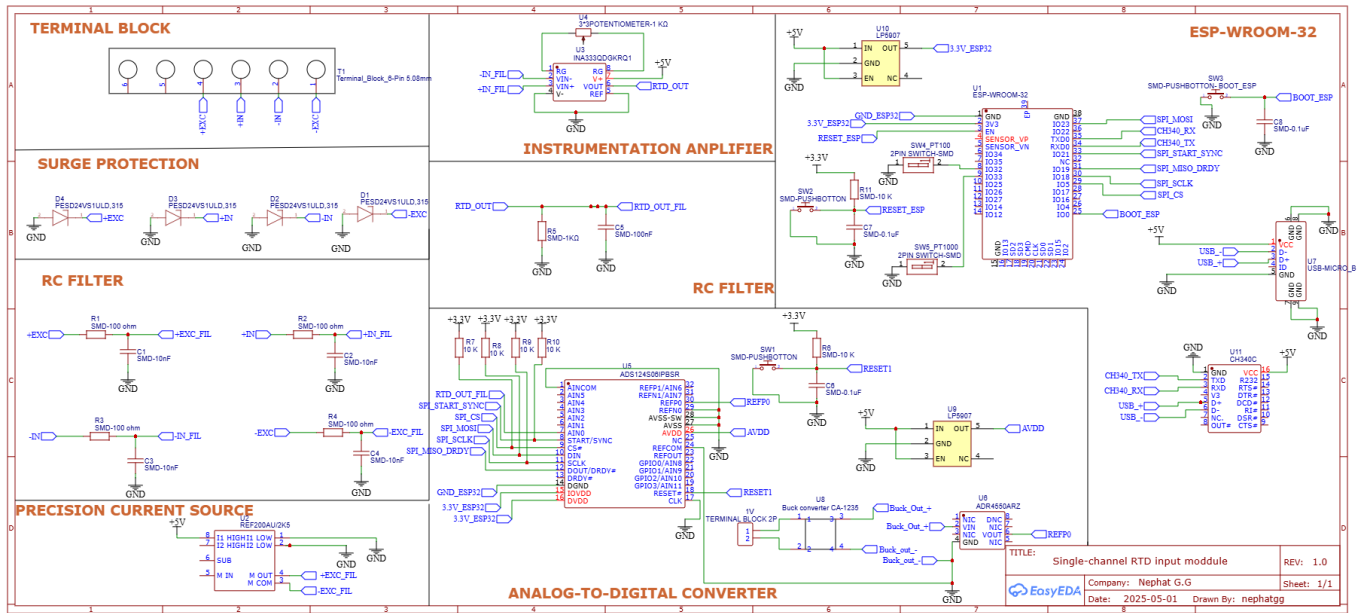


Figure 2: Schematic diagram

Conclusion.

The RTD input module demonstrates a robust and scalable approach to precision temperature sensing in demanding environments. By combining high-resolution ADCs, low-noise analog front-ends, clean power delivery, and software-selectable RTD compatibility, the design achieves accurate, low-drift performance across a wide temperature range. Careful layout practices and thermal management further enhance reliability, making the system suitable for field-deployable DAC or industrial monitoring applications.

Link.

Github: [Single-Channel_RTd_Input_Module](https://github.com/NGGithua1/Single-Channel_RTd_Input_Module)

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