PRECISION SALINOMETER METROLOGY GRADE

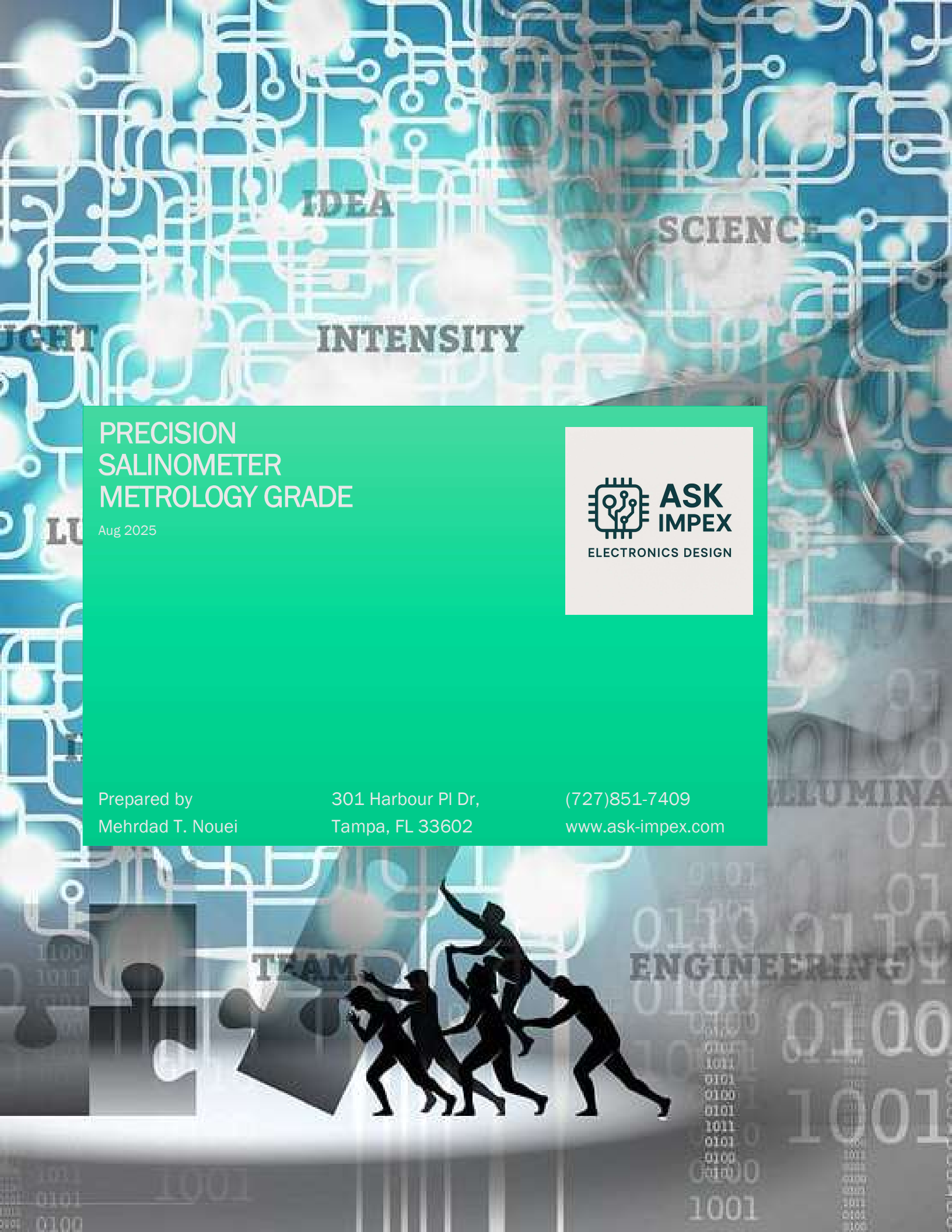
Aug 2025

ASK IMPEX
ELECTRONICS DESIGN

Prepared by
Mehrdad T. Nouei

301 Harbour Pl Dr,
Tampa, FL 33602

(727)851-7409
www.ask-impex.com



Precision Salinometer

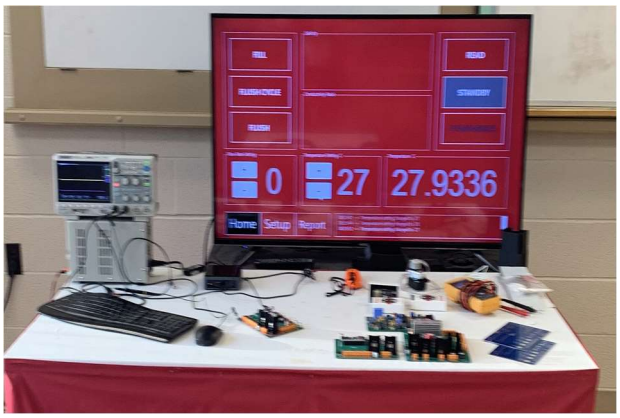
Overview:

Inspired by the proven performance of Guildline's 8400B and 8410 models, this upgraded precision temperature controller introduces advanced digital control, enhanced accuracy, and modern interfacing for calibration-grade Salinometer systems.

The Precision Temperature Calibrator module is designed to calibrate high-accuracy RTD sensors used in temperature control systems. This module enables automatic or manual calculation of Callendar–Van Dusen coefficients (A, B, and C) and supports calibration workflows based on internationally recognized standards.

ASK Impex proudly introduces High precision Salinometer instrument:

- **SalinoCore S700,** high-precision Salinometer that achieves **±0.0002 °C stability**



📌 Background & Motivation

The project is a modern reengineering of the Guildline 8400B and 8410 salinometers, considered industry standards for oceanographic and high-precision salinity measurement. Despite their performance, these legacy instruments were designed nearly 30 years ago and have seen no significant architectural updates. The goal of this project is to dramatically improve accuracy, automation, and user experience by introducing state-of-the-art electronics and control infrastructure.

🧠 Core Architecture

- **Main Controller:**
  - **ESP32-S3 dual-core microcontroller**
  - **Manages real-time control, data acquisition, and system interfacing**
  - **Chosen for its balance of performance, power efficiency, and wireless support**
- **Precision Measurement System:**
  - **Texas Instruments 32-bit ADC for temperature and conductivity signal conversion**
  - **Enables high-resolution data acquisition critical for sub-ppm salinity accuracy**
  - **Calibration coefficients are dynamically calculated and applied using an internally developed temperature calibrator instrument**
- **Temperature Control & Stability:**
  - **Thermal system redesigned with a target stability of ±0.0002 °C**
  - **Performance improvement of 10x over legacy designs**
  - **Operates across the full 15 °C to 40 °C calibration range**

💻 User Interface & Automation

- **Display System:**
  - **Compact Mini PC with touchscreen LCD (GUI-driven)**
  - **Interface supports both lab and field operations**
- **Software & GUI:**
  - **Custom-designed for ease of use, clarity, and operator workflow**
  - **Features include:**
    - **Automated calibration and diagnostics**
    - **Real-time salinity computation and graphing**
    - **Built-in report generation and data export**
    - **Cloud-based connectivity for remote monitoring and updates**

🔧 Remaining Development Tasks

- **Custom Cell Design:**
  - **Developing a next-generation salinity sensing cell to replace legacy flow-through models**
  - **Improved thermodynamic and mechanical properties expected**
- **New Conductivity Board:**
  - **Precision analog front-end for salinity measurements**
  - **To be tightly coupled with TI ADC for optimal SNR and linearity**

🌐 Applications & Impact

This salinometer is designed for use in:

- **Oceanographic and limnological research**
- **Calibration labs**
- **Environmental monitoring**
- **Industrial and process control where trace salinity measurement is critical**

It is positioned to become the new industry benchmark, surpassing the performance, stability, and usability of the 8400B/8410 series.

🧭 Ask Impex Benchmarks: SalinoCore S700

- **Temperature Range**: 15 °C to +60 °C
- **Set-Point Accuracy**: ±0.0001 °C (24 hr); ±0.0002 °C (1 yr)
- **Stability**:
  - **Water**: ±0.001 K at 23 ±0.0002°C
- **Uniformity**: ±0.0002 K across chamber
- **Set & Display Resolution**: 0.0001 °C
- **Programmability**: USB, RS-232, IEEE-488, SCPI; Windows-based PID control; external touchscreen module

🧬 Adaptive PID Tuning: AI-Like Intelligence for Temperature Control

Instead of relying on static PID coefficients, our system uses **adaptive tuning algorithms** that adjust gains in real-time to optimize performance. These algorithms:

- Monitor overshoot, rise time, and steady-state error
- Dynamically adjust PID terms to maintain optimal behavior across:
  - Changing ambient conditions
  - Different thermal masses
  - Variable sensor positions or time constants

This ensures:

- **Near-zero overshoot**
- **Ultra-stable long-term regulation (±0.0002 °C class)**
- **Minimal manual tuning**—ideal for research labs, calibration benches, or field use

Temperature Calibrator (Optional Add-On)

SYSTEM COMPONENTS

Component	Description
Reference Readout	High-accuracy thermometer
Reference SPRT/PRT	ITS-90-compliant calibrated SPRT or PRT
Temperature Source	Stable temperature point (air bath or fluid bath)
UUT RTD	RTD under test (2/3/4-wire)
MUX and ADC System	TI 32-bit ADC with precision Vishay biasing resistors
EEPROM Storage	On-board non-volatile memory for storing calculated coefficients
Host Interface	USB, RS-232, and SCPI control for integration with Windows GUI
Calibration Algorithm	Based on least-squares fit to ITS-90 temperature points

FUNCTIONAL WORKFLOW

1. **Stabilization Phase:**
   - Small-Bath temperature (air or fluid) is stabilized using Peltier or compressor.
   - Dual PID loops (with adaptive tuning) ensure rapid and precise equilibrium.
2. **Measurement Phase:**
   - New RTD and reference SPRT connected to the system.
   - MUX switches between RTD and SPRT; both are read with same ADC hardware and reference voltage.
3. **Comparison Phase:**
   - The known temperature from the reference SPRT is read via the external thermometer
   - Corresponding raw data from the UUT RTD is collected.
4. **Coefficient Extraction:**
   - Using multiple temperature points, the system calculates the A, B, and C coefficients.
   - Supports 2-point (linear) or 3-point (nonlinear with C-term) calibration modes.
5. **EEPROM Storage:**
   - Once validated, the coefficients are stored in the local EEPROM.
   - System firmware and Windows GUI retrieve and use these during real-time operation.

📐 PERFORMANCE SPECIFICATIONS

Parameter	Value
Calibration Range	-5 °C to +100 °C (typical)
Accuracy (reference-limited)	±1 mK
Coefficient Storage	EEPROM, 10+ RTD profiles
RTD Bias Current	100 µA to 1 mA (user-configurable)
Coefficient Type	Callendar–Van Dusen (ITS-90)
External Readout Compatibility	SCPI-enabled precision bridges

🌐 HOST & INTERFACE SUPPORT

- **Windows GUI Software:**
  - Calibrator configuration and control
  - Live charting of RTD and reference values
  - USB connectivity
- **SCPI Protocol (Optional GPIB/RS-232):**
  - `CAL:RTD:MEAS?`, `CAL:RTD:COEF:A?`, `CAL:RTD:STORE 1`, etc.

✅ ADVANTAGES OVER TRADITIONAL METHODS

- Eliminates manual coefficient entry and wasting 300+ hours
- Uses true reference-grade readout as calibration baseline.
- Stores multiple RTD profiles for industrial fieldwork.
- Designed for interoperability with Guildline, Fluke, Isotech, and other metrology-grade equipment.

📎 NOTES

- The performance of this calibrator is dependent on the stability and accuracy of the reference thermometer system.
- The calibrator can optionally include a **fixed-point cell interface**, or simulated point generation via ultra-stable fluid bath controlled by the internal PID system.

Calibration & Certification Compliance

To ensure high confidence and traceability in temperature measurements, the **Temperature Calibrator Module** complies with internationally recognized standards and best practices for metrological instrumentation.

✅ Accredited Calibration Lab Certification

Requirement:

All reference thermometers, probes, and calibration devices used with this system must be:

- **Calibrated by an ISO/IEC 17025-accredited laboratory**
- **Traceable to a National Metrology Institute (NMI)** such as:
  - **NIST** (National Institute of Standards and Technology, USA)
  - **NRC** (National Research Council, Canada)
  - **PTB** (Physikalisch-Technische Bundesanstalt, Germany)
  - or other signatories of the **ILAC MRA** agreement

🔍 Why This Matters

- Ensures **traceability** of all calibration points to SI units via national standards.
- Supports **audit compliance** for customers in regulated industries (pharma, aerospace, etc.).
- Confirms the accuracy and **long-term repeatability** of the system when calibrating RTDs or thermal sensors.

📦 Included Documentation (per reference probe or calibrator used):

- ISO/IEC 17025-accredited **calibration certificate**
- **Uncertainty budget** for each calibration point
- **Traceability statement** referencing the responsible national lab (e.g., NIST)

🧪 Supported Reference Devices

This calibrator is compatible with reference thermometry equipment from vendors who provide ISO/IEC 17025-certified probes or systems, such as:

- **Guildline 6622T** Digital Thermometer System
- **Fluke 1529 Chub-E4** Reference Thermometer
- **Isotech TTI series** precision thermometers

These devices are ideal for maintaining traceability and certifiable performance of your calibrator system.

1. Measurement Accuracy & Resolution

- **RTD Sensor Integration**:
  - PT100/PT1000 class A or better.
  - High-resolution, low-noise 32-bit ADC allows sub-millikelvin sensitivity.
  - RTD bias network uses ultra-precision 0.0001% Vishay resistors to ensure minimal drift and outstanding long-term stability.

🔄 2. Dual Cascade PID Control with Adaptive Tuning

- **Inner Loop**: Controls rapid response component (Peltier or heater).
- **Outer Loop**: Controls slow thermal load (air or fluid mass).
- **Adaptive Tuning**: System dynamically adjusts PID parameters in real-time based on load condition and sensor feedback, ensuring stability across environmental changes and load variations.

🌡️ 3. Temperature Calibrator Integration

- Accepts external RTD sensors for calibration.
- Supports full curve-fitting using Callendar–Van Dusen equations.
- EEPROM stores individual RTD coefficients.
- Compliant with:
  - **ISO/IEC 17025-accredited calibration labs**
  - **Traceable to NIST/NRC standards**
- **Use Case**: Enables field or lab recalibration with high confidence, ensuring metrology-grade traceability.

🛠️ 4. Modular Architecture

- **Air Bath Module**:
  - Thermally insulated chamber with PID-controlled Peltier elements.
  - Designed for rapid settling with low power usage.
- **Fluid Bath Module**:
  - Hermetically sealed tank with frequency-controlled compressor system.
  - Controlled via high-resolution 24-bit PWM.
  - Optional circulation pump for uniform temperature distribution.

📶 5. Communication & Control

- Multiple connectivity interfaces:
  - RS232/RS485 for industrial control.
  - USB for PC GUI application.
  - Optional GPIB port with SCPI protocol for automated test systems.
- **Embedded GUI Support**:
  - Touchscreen display.
  - Real-time plot of temperature, setpoint, and PID variables.

💾 6. Data Logging and Security

- Internal EEPROM + optional SD card or flash memory.
- Stores temperature history, calibration coefficients, and system logs.
- Password-protected access for configuration and calibration menus.

SalinoCore S700