

Real-Time Production Line Sensor Dashboard

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Project Presentation

Si-Ware System Assessment Project

Project Overview

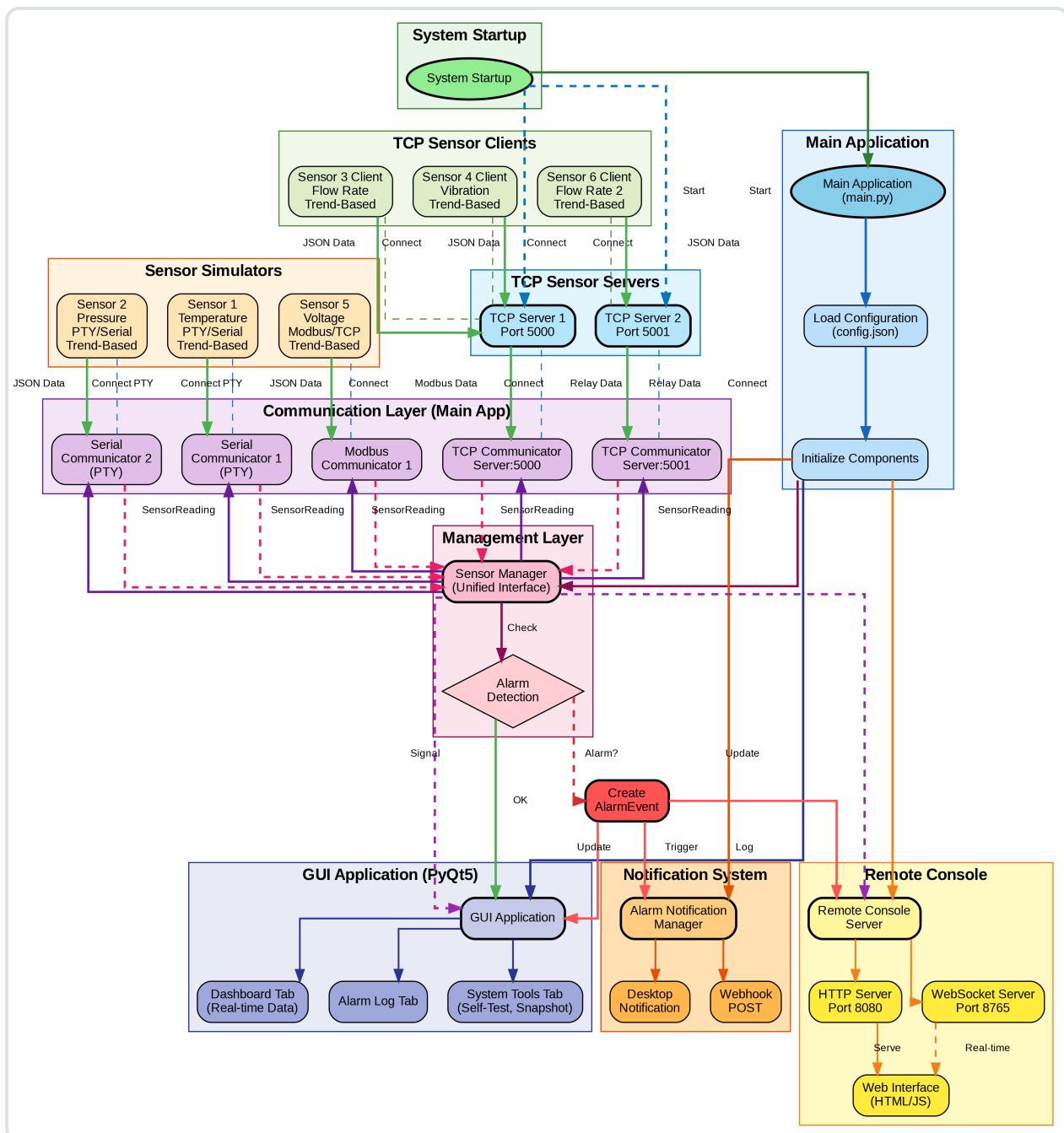
Real-Time Production Line Sensor Dashboard is a comprehensive real-time monitoring and maintenance system for industrial production lines.

This project was developed as part of the Si-Ware System Assessment, demonstrating advanced software engineering practices, multi-protocol communication, and cross-platform development capabilities.

Key Capabilities

- Real-time monitoring of multiple sensors across different communication protocols
 - Intelligent alarm management with automatic detection
 - Desktop and web-based interfaces for monitoring and maintenance
 - Cross-platform support (Linux and Windows)
 - Remote access via WebSocket with authentication
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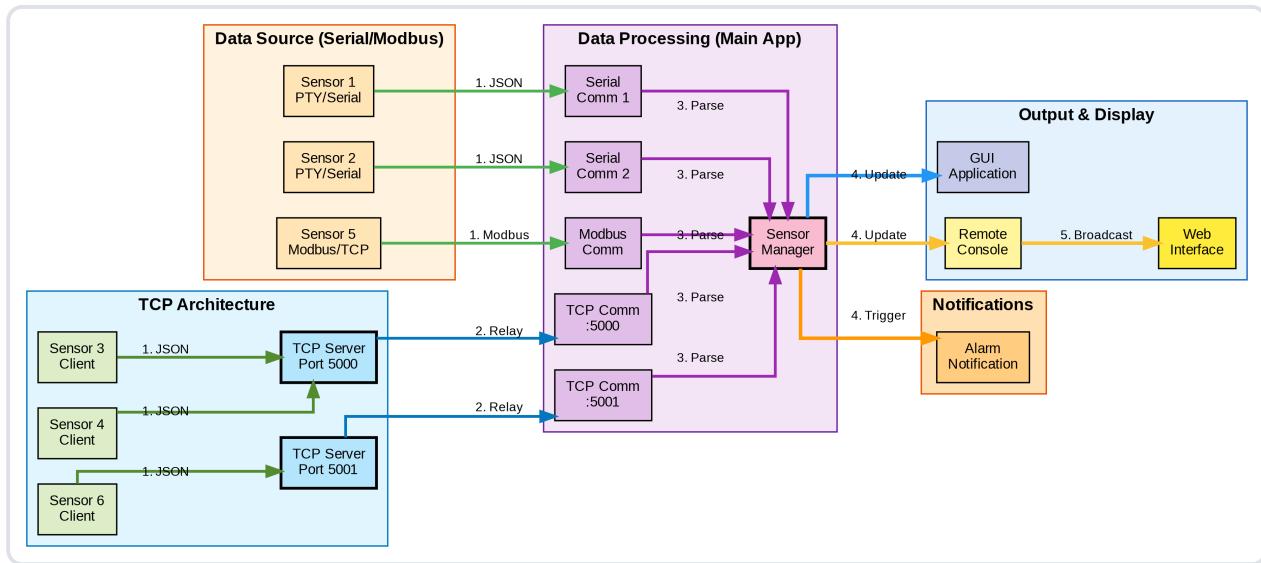
System Architecture



Complete system architecture showing:

- Sensor Simulators (Serial, TCP, Modbus)
- Communication Layer (Multi-protocol support)
- Management Layer (Sensor Manager, Alarm System)
- GUI Application (PyQt5 Desktop Interface)
- Remote Console (WebSocket Server)
- Notification System (Webhook & Desktop)

Data Flow



Data flow sequence: 1. Sensor simulators generate data 2. Communication layer receives data via multiple protocols 3. Sensor Manager processes and validates data 4. Alarm system checks limits and triggers notifications 5. GUI updates in real-time 6. Remote console provides web access

Software Flow: Sensor to GUI/Web Interface

Thread Architecture

Worker Thread Model: - One worker thread per unique communication endpoint (not per sensor) - Serial: One thread per unique port (e.g., /dev/pts/7) - TCP: One thread per unique server (e.g., localhost:5000) - Modbus: One thread per unique server (e.g., localhost:1502)

Example: - 5 sensors on 3 ports = 3 worker threads - 4 TCP sensors on 2 servers = 2 worker threads - Mixed: 3 serial (2 ports) + 4 TCP (2 servers) + 2 Modbus (1 server) = 5 total threads

Data Flow from Sensor to GUI

Step 1: Sensor Data Reception (Worker Thread)

Sensor Simulator → Physical/Network Connection → Worker Thread

- Worker thread reads data from port/socket (blocking I/O)
- Data received as bytes (Serial/TCP) or Modbus frames
- Parsed into JSON or binary format

Step 2: Data Parsing (Worker Thread)

Raw Bytes → JSON Parsing → SensorReading Object

- Serial/TCP: JSON string parsed into dictionary
- Modbus: Binary frame decoded to 16-bit integer, scaled by 10
- Creates **SensorReading** object with sensor_id, value, timestamp, status

Step 3: Thread-Safe Queue (Worker Thread)

SensorReading → Thread-Safe Queue (queue.Queue)

- Reading placed in `data_queue` (thread-safe)
- Queue prevents data loss during high-frequency updates
- Multiple sensors can share same queue if on same port/server

Step 4: Callback Registration (Worker Thread)

Queue → Callback Function → `SensorManager._on_reading_received()`

- Worker thread calls registered callbacks
- Callbacks executed with thread lock protection
- `SensorManager` receives reading in callback

Step 5: Alarm Detection (Main Thread)

SensorReading → `SensorConfig.check_alarm()` → `AlarmEvent` (if triggered)

- `SensorManager` checks value against `low_limit/high_limit`
- Creates `AlarmEvent` if alarm condition detected
- Includes `low_limit` and `high_limit` at time of alarm

Step 6: PyQt Signal Emission (Main Thread)

SensorReading → `pyqtSignal` → GUI Thread Slot `AlarmEvent` → `pyqtSignal` → GUI Thread Slot

- `sensor_reading_received.emit(reading)` - Thread-safe signal
- `alarm_triggered.emit(alarm_event)` - Thread-safe signal
- Signals are queued and processed by Qt event loop in GUI thread

Step 7: GUI Update (GUI Thread)

Signal Received → `on_sensor_reading()` → GUI Widgets Updated

- `MainWindow.on_sensor_reading()` called in GUI thread
- Updates sensor table, plots, status indicators

- Thread-safe: All GUI operations in main thread only

Data Flow to Web Interface

Step 1: WebSocket Connection

Browser → WebSocket Connection → Remote Console Server

- Client connects to ws://localhost:8765
- Authentication required before commands

Step 2: Data Request (WebSocket Thread)

Client Command → Remote Console → SensorManager.get_sensors()

- Client sends get_sensors command
- Remote Console queries SensorManager for current readings
- Data retrieved from in-memory sensor readings dictionary

Step 3: Data Serialization (WebSocket Thread)

SensorReading Objects → JSON Serialization → WebSocket Message

- Python objects converted to JSON
- Includes sensor_id, name, value, status, timestamp, unit

Step 4: WebSocket Response (WebSocket Thread)

JSON Message → WebSocket Send → Browser Client

- Message sent via WebSocket connection
- Client receives real-time updates

Thread Communication Mechanisms

1. **PyQt Signals (Thread-Safe)**
2. `pyqtSignal` objects for cross-thread communication
3. Automatically queued by Qt event loop

4. Worker threads emit signals, GUI thread receives them

5. No direct GUI access from worker threads

6. **Thread-Safe Queues**

7. queue.Queue for data buffering

8. Prevents data loss during high-frequency updates

9. Thread-safe put/get operations

10. **Thread Locks**

11. threading.Lock for shared data protection

12. Protects sensor_configs dictionary

13. Prevents race conditions

14. **Callback Mechanism**

15. Worker threads call registered callbacks

16. Callbacks executed with lock protection

17. SensorManager receives readings via callbacks

Signal Flow Diagram

```
Sensor Simulator
↓
Worker Thread (reads port/socket)
↓
Parse Data → SensorReading Object
↓
Thread-Safe Queue (data_queue.put())
↓
Callback Function (with lock)
↓
SensorManager._on_reading_received()
↓
Alarm Detection (if needed)
↓
PyQt Signal Emission (sensor_reading_received.emit())
↓
Qt Event Loop (queues signal)
↓
GUI Thread Slot (on_sensor_reading())
↓
GUI Widgets Updated (table, plots, status)
```

Web Interface Flow Diagram

```
Browser Client
↓
WebSocket Connection (ws://localhost:8765)
↓
Authentication (username/password)
↓
Command: get_sensors
↓
Remote Console Handler
↓
SensorManager.get_sensors() (reads in-memory data)
↓
JSON Serialization
↓
WebSocket Send
↓
Browser Receives & Displays
```

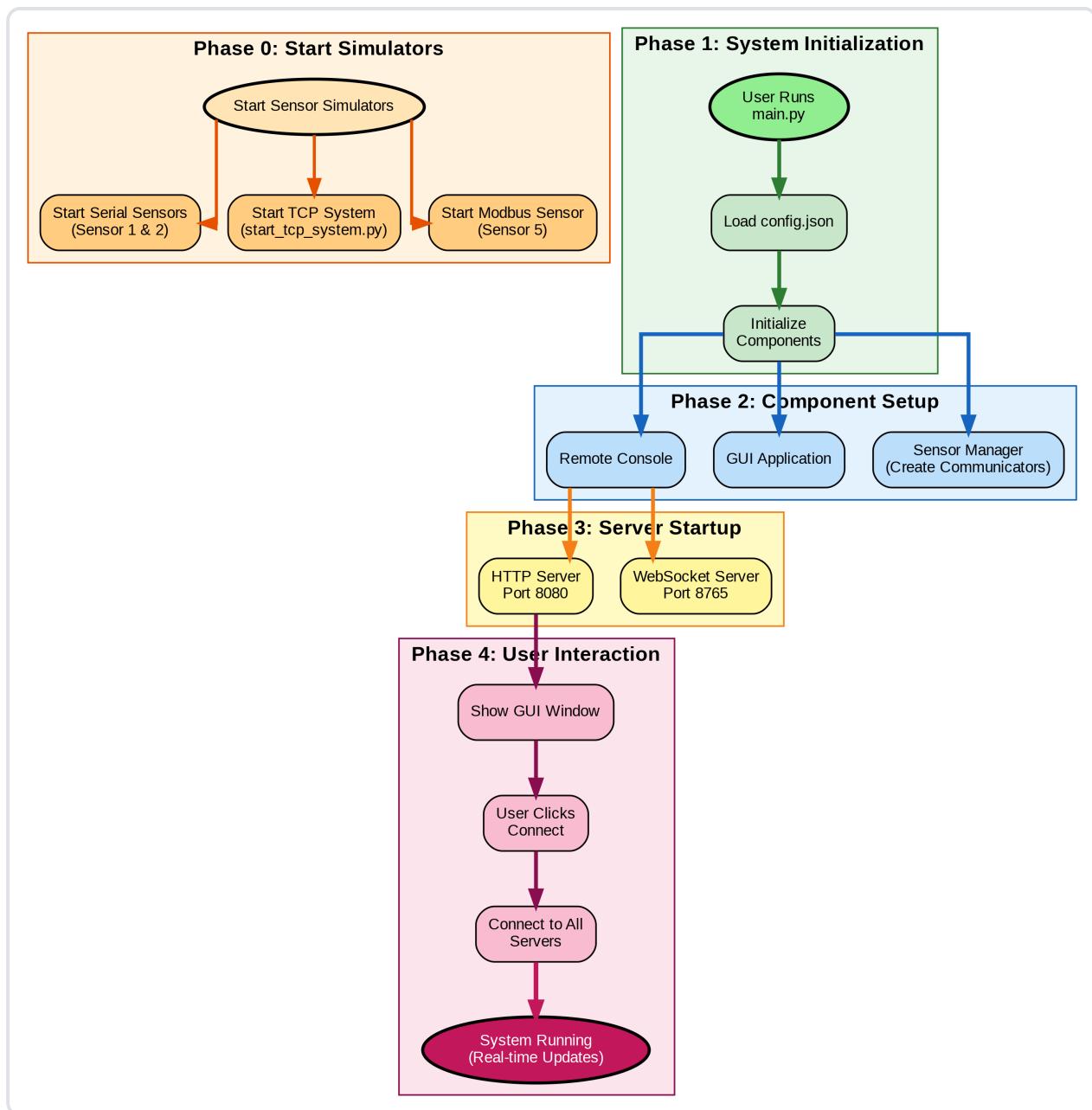
Key Thread Safety Features

1. **No Direct GUI Updates from Workers**
2. Worker threads never directly modify GUI widgets
3. All GUI updates via PyQt signals
4. Signals automatically handled in GUI thread
5. **Lock Protection**
6. Shared data structures protected with locks
7. Prevents race conditions
8. Ensures data consistency
9. **Queue-Based Buffering**
10. Thread-safe queues prevent data loss
11. Handles high-frequency sensor updates
12. Smooth data flow even under load

13. Signal Queuing

14. Qt event loop queues signals automatically
 15. Ensures signals processed in correct thread
 16. Prevents GUI freezing
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Startup Sequence



System initialization process:

- User launches application
- Configuration loading from config.json
- Sensor Manager initialization
- WebSocket and HTTP server startup
- GUI window display
- Ready for sensor connections

Supported Protocols

Serial Communication

- **Linux:** Pseudo-Terminals (PTY) - /dev/pts/X
- **Windows:** COM Ports (real or virtual via com0com)
- JSON frame format, 115200 baudrate

TCP/IP Communication

- TCP socket connections
- Multiple sensors per server
- JSON frame format

Modbus/TCP Communication

- Function Code 3 (Read Holding Registers)
 - 16-bit integer encoding (scaled by 10)
 - Configurable unit ID and register address
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Platform Support

Linux Support

- Full PTY support for serial sensors
- Desktop notifications via notify-send
- Native Python 3 support
- Automated startup scripts

Windows Support

- COM port support (real and virtual)
- Desktop notifications via win10toast
- COM port pair handling (com0com)
- Automated startup scripts

Cross-Platform Features

- Same codebase for both platforms
 - Platform detection and automatic adaptation
 - Consistent user experience
 - Thread-safe architecture
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Quick Start Guide

Step 1: Configure Sensors

Edit `config/config.json` : - Sensor IDs and names - Communication protocols
- Alarm limits (low_limit, high_limit) - Protocol-specific configurations

Step 2: Start Simulators

Modbus Sensors:

```
python3 simulators/sensor_modbus.py --config "voltage:5:localhost:1502:1:0"
```

TCP Sensors:

```
python3 simulators/start_tcp_system.py --server-ports 5000 --sensor flow:3:localhost:5000
```

Serial Sensors (Linux):

```
python3 simulators/sensor_serial.py --config "temperature:1:115200:8N1"
```

Serial Sensors (Windows):

```
python simulators\sensor_serial.py --config "temperature:1:115200:8N1" --com-port COM1
```

Step 3: Start Application

```
python3 main.py
```

Step 4: Access Features

- **Desktop:** Monitor dashboard, access maintenance console
 - **Web:** Open http://localhost:8080/remote_console_client.html
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System Components

Core Modules

- `core/sensor_data.py` - Data models (SensorReading, AlarmEvent, SensorConfig)
- `sensors/sensor_manager.py` - Unified sensor management
- `sensors/sensor_*_comm.py` - Protocol-specific communicators

GUI Application

- `gui/main_gui.py` - Main PyQt5 window
- Dashboard with real-time plots and sensor table
- Maintenance console with authentication

Services

- `services/alarm_notifications.py` - Notification system
- `services/remote_console.py` - WebSocket remote console

Simulators

- `simulators/sensor_serial.py` - Serial sensor simulator
 - `simulators/start_tcp_system.py` - TCP sensor system
 - `simulators/sensor_modbus.py` - Modbus sensor simulator
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Threading Architecture

Worker Thread Model

- One worker thread per unique communication endpoint
- Multiple sensors on same port/server share one thread
- Thread-safe communication via PyQt signals
- Non-blocking I/O operations

Example Scenarios

- 5 serial sensors on 5 ports = 5 worker threads
 - 5 serial sensors on 2 ports = 2 worker threads
 - 4 TCP sensors on 2 servers = 2 worker threads
 - Mixed setup: Optimized thread usage
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Notification System

Desktop Notifications

- **Linux:** notify-send command
- **Windows:** win10toast library
- Automatic platform detection

Webhook Notifications

- HTTP POST requests (non-blocking)
- Background thread execution
- Configurable URL in config.json
- JSON payload with alarm details

Notification Features

- All alarms trigger notifications immediately
 - No filtering or state transition checks
 - Complete alarm visibility
 - Thread-safe implementation
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Remote Console API

WebSocket Server

- Port: 8765 (configurable)
- Authentication required
- JSON message format

Available Commands

- `get_status` - System status summary
- `get_sensors` - All sensor readings
- `get_alarms` - Alarm log entries
- `clear_alarms` - Clear alarm log (requires write permission)
- `get_logs` - System log entries
- `run_self_test` - System diagnostics (requires commands permission)
- `get_snapshot` - Detailed system snapshot
- `set_limit` - Set alarm limits (requires write permission)

User Permissions

- **read:** View sensor data and alarms
 - **write:** Clear alarms, modify settings
 - **commands:** Execute system commands
-

Configuration

Sensor Configuration

```
{  
  "sensors": [  
    {  
      "name": "Temperature Sensor 1",  
      "id": 1,  
      "low_limit": 20.0,  
      "high_limit": 80.0,  
      "unit": "°C",  
      "protocol": "serial",  
      "protocol_config": {  
        "port": "/dev/pts/9",  
        "baudrate": 115200  
      }  
    }  
  ]  
}
```

Alarm Settings

```
{  
  "alarm_settings": {  
    "enable_notifications": true,  
    "enable_desktop_notifications": true,  
    "webhook_url": "http://localhost:3000/webhook"  
  }  
}
```

Remote Console Users

```
{  
  "remote_console": {  
    "enabled": true,  
    "host": "localhost",  
    "port": 8765,  
    "http_port": 8080,  
    "users": {  
      "admin": {  
        "password": "admin123",  
        "permissions": ["read", "write", "commands"]  
      }  
    }  
  }  
}
```

Testing

Unit Tests

```
python3 -m pytest tests/
```

Verification

```
python3 scripts/verify_project.py
```

Test Scripts

- `test_websocket.py` - Test WebSocket connection
 - `test_modbus.py` - Test Modbus communication
 - `test_webhook.py` - Test webhook functionality
 - `test_desktop_notifications.py` - Test desktop notifications
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Project Structure

```
RT-ProductionLine-Sensors-Dashboard/
├── main.py                      # Main entry point
├── core/                         # Core data models
├── sensors/                      # Sensor communication modules
├── gui/                          # GUI components
├── services/                     # Services (notifications, remote console)
├── simulators/                  # Sensor simulators
├── config/                       # Configuration files
├── web/                          # Web interface
├── scripts/                      # Utility scripts
├── tests/                        # Unit tests
└── docs/                         # Documentation
```

Key Benefits

For Operators

- Real-time visibility of all sensors
- Immediate alarm notifications
- Easy-to-use desktop interface
- Quick access to system status

For Administrators

- Comprehensive alarm history
- System diagnostics and snapshots
- Remote access capabilities
- Export functionality (CSV)

For Developers

- Modular, extensible architecture
- Thread-safe implementation
- Cross-platform compatibility
- Well-documented codebase

Technical Highlights

Architecture

- **Modular Design:** Clean separation of concerns
- **OOP:** Object-oriented design throughout
- **Thread-Safe:** Worker threads with PyQt signals
- **Port-Based Workers:** Efficient resource usage

Performance

- 2+ Hz refresh rate for sensor data
- Non-blocking I/O operations
- Optimized thread usage
- Real-time plot updates

Security

- Password-protected maintenance console
 - Role-based access control
 - WebSocket authentication
 - Secure remote access
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Platform-Specific Notes

Linux

- PTY devices for serial communication
- Native `notify-send` for desktop notifications
- Full feature support
- Recommended for development

Windows

- COM ports for serial communication
 - `win10toast` for desktop notifications
 - com0com support for virtual COM ports
 - Full feature parity with Linux
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Troubleshooting

Common Issues

1. **ModuleNotFoundError**
2. Solution: Run from project root or set PYTHONPATH=.
3. **Serial port not found**
4. Solution: Ensure simulators are running and ports match config.json
5. **WebSocket connection failed**
6. Solution: Check firewall settings and port availability
7. **No sensor data**
8. Solution: Click "Connect" button and verify simulators are running

Debug Tools

- System Tools → Get Snapshot
 - Maintenance Console → Live Log Viewer
 - Test scripts in `scripts/` directory
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Documentation

Available Documentation

- `README.md` - Quick overview and quick start
- `docs/Project_Documentation.md` - Complete system documentation
- `Project_Documentation.pdf` - PDF version
- `docs/SYSTEM_FLOWCHART.md` - System flowchart documentation
- `docs/WINDOWS_COMPATIBILITY.md` - Windows compatibility guide

Additional Resources

- `tests/README.md` - Unit tests documentation
 - `simulators/README.md` - Sensor simulators documentation
 - Source code comments for implementation details
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Summary

What This System Provides

- **Real-Time Monitoring** - Live sensor data with 2+ Hz refresh rate
 - **Multi-Protocol Support** - Serial, TCP/IP, and Modbus/TCP
 - **Intelligent Alarms** - Automatic detection with complete history
 - **Cross-Platform** - Full Linux and Windows support
 - **Remote Access** - Web-based interface with authentication
 - **Professional UI** - Modern desktop and web interfaces
 - **Comprehensive Logging** - System logs and alarm history
 - **Extensible Architecture** - Modular, thread-safe design
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Thank You

Real-Time Production Line Sensor Dashboard

A comprehensive solution for industrial production line monitoring and maintenance.

Developed as part of the Si-Ware System Assessment

This project demonstrates:

- Advanced multi-protocol sensor communication
- Cross-platform compatibility (Linux/Windows)
- Thread-safe architecture with real-time updates
- Professional desktop and web interfaces
- Comprehensive alarm management system

For more information, visit the project documentation.

Credits

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