Temperature and Humidity Measurement System Improvements

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Project Objectives

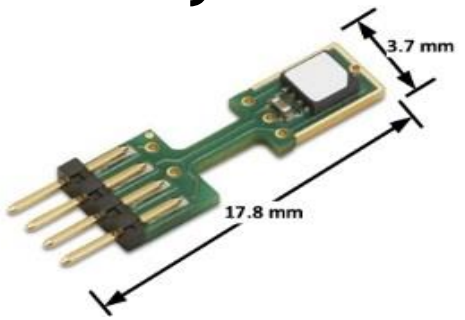
- Improve temperature and humidity slow controls measurement systems for future detectors such as the next RICH sector
  - Increase accuracy
  - Reduce size of sensor assembly
  - Reduce cables/connectors
  - Increase system reliability

Project Objectives

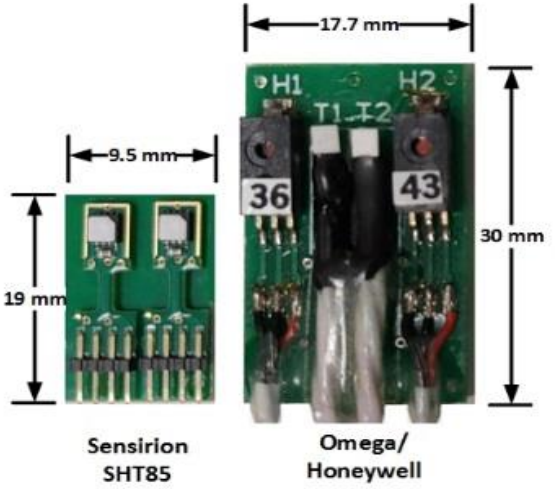
- Improve readout electronics channel density
- Compatible with existing slow controls electronics
- Compatible software support including EPICS
- Reduce costs

Conducted Sensor Research

- Sensirion SHT85 Sensor (New product released 11/2018)
  - Integrated temperature and humidity sensors
    - Both sensors in a single package



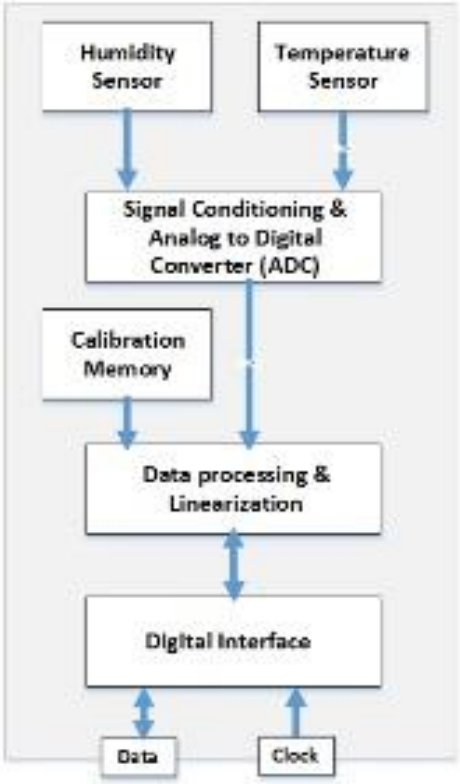
  - Increased accuracy
    - Humidity: ±1.5% RH, temperature: ±0.1°C
    - 2x RH accuracy improvement
  - Reduced size
    - 66% reduction in dual sensor board



Conducted Sensor Research

- Reduced required interconnects
  - 2x reduction in cables
  - 8 vs 14 conductors for dual sensor board
- Digital serial communication interface
  - 2-wire serial interface (I^2C industry standard)
  - Improved reliability
    - Error checking on each measurement
- Calibration
  - Each sensor is individually calibrated at factory
  - Internally programmed with calibration constants
  - Linearization and temperature compensation calculations are done internally to the sensor

Conducted Sensor Research



SHT85 Block Diagram

Parameter		Specification	Units
Humidity	Accuracy	±1.5	% RH
	Long-term drift	< 0.25	% RH/year
	Operating range	0 to 100	% RH
	Resolution	0.01	% RH
	Repeatability	0.08 [1]	% RH
Temperature	Accuracy	±0.1	°C
	Long-term drift	< 0.03	°C/year
	Operating range	-40 to 105	°C
	Resolution	0.01	°C
	Repeatability	0.04 [1]	°C
Communication interface		I^2C	N/A
Supply voltage range		2.15 - 5.5	V
Measurement duration		13	ms
Avgerage current consumption		1.7	µA

[1] The stated repeatability is 3 times the standard deviation (3σ) of multiple consecutive measurement values at constant operating conditions.

SHT85 Specifications

Evaluated Sensor Advantages

Advantages of implementing a Sensirion SHT85 dual board sensor

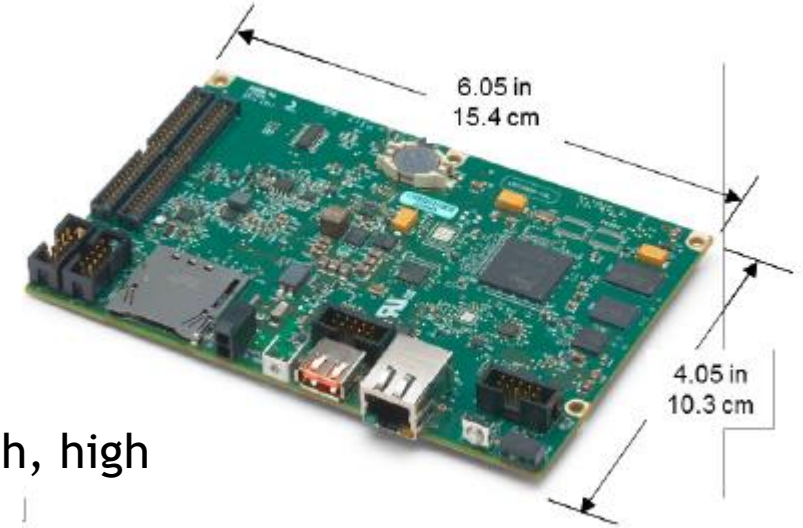
Parameter	Omega / Honeywell Dual Sensor PCB	Sensirion SHT85 Dual Sensor PCB
Accuracy	Humidity: ±3.5% RH, temperature: ±0.15°C	Humidity: ±1.5% RH, temperature: ±0.1°C
Sensor configuration	Separate temperature & humidity sensors	Integrated temperature & humidity sensor
Interface signal	Humidity: analog voltage Temperature: RTD resistance	Digital serial interface using two-wire I^2C communication protocol
Data error-detecting	None	Cyclic Redundancy Check (CRC) on each measurement (temperature & humidity)
Calibration of output	User must externally linearize and calculate temperature compensation on the analog output	Linearization and temperature compensation calculations are done internally by the sensor
Size of PCB	17.7 mm x 30 mm	9.5 mm x 19 mm (66% reduction in size)
# of Conductors	14 conductors, 4 wires	8 conductors, 2 wires (2x wire reduction)
Connector	None. Wires soldered directly to sensor and PCB	Integrated 4-pin x2 connector (easy replacement)
Sensor protection	None	Sensor opening is covered by a PTFE membrane to protect the sensor from dust and contaminants
Readout electronics	Requires two ADC channels for humidity and two RTD readout channels for temperature	2 low-cost digital serial data channels
Supply voltage	Honeywell humidity sensor: +5V, humidity measurement is dependent on the supply voltage	2.15 V to 5.5 V, humidity measurement is not dependent on the supply voltage
Cost per PCB (sensors)	$140 total for 4 sensors (2 temp, 2 humidity)	$50 total for 2 integrated sensors

Readout Research

- National Instruments sbRIO-9627
  - Purchase authorized by Dr. Rossi for detector instrumentation development

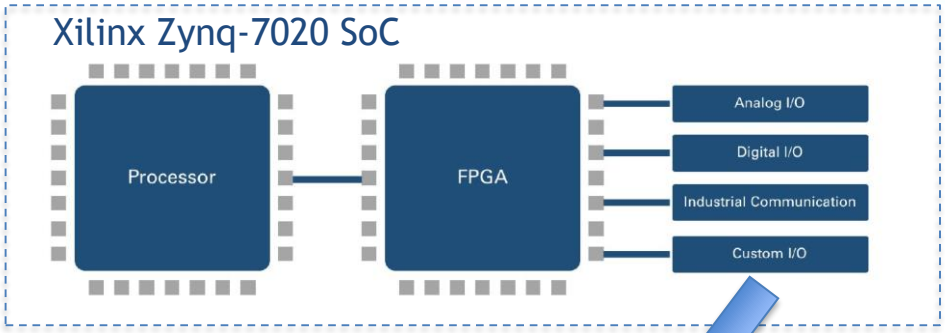
Designed for Original Equipment Manufacturers (OEM's)

- Single-board computer (SBC)
- Linux Real-Time operating system
- Industrial-grade Xilinx Zynq-7020 System on Chip (SoC)
- Designed for long-term deployment in harsh, high temperature, high EMC environments

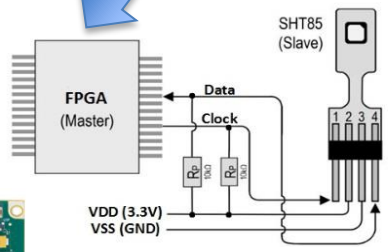


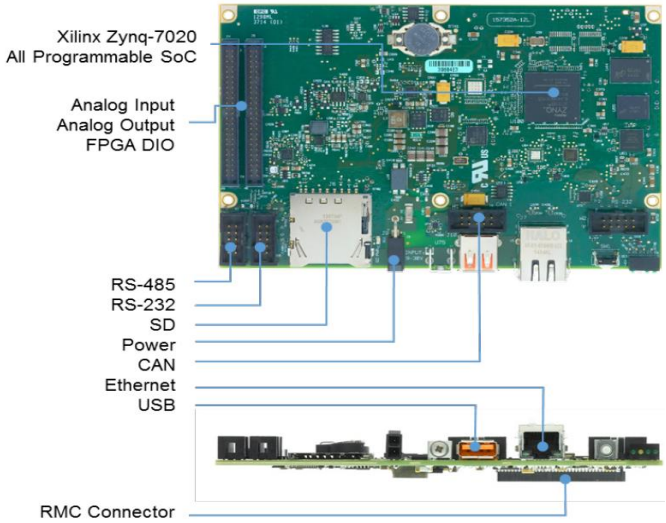
Readout Research

- Direct access to digital FGPA Ports
  - Provides support for 48 SHT85 temperature/humidity sensors
- Analog to digital converter
  - 16 input channels, 16-bit resolution
- Digital to analog converter
  - 4 output channels, 16-bit resolution
- Communication interfaces
  - Ethernet, RS232, RS485, CAN,
- SD card support



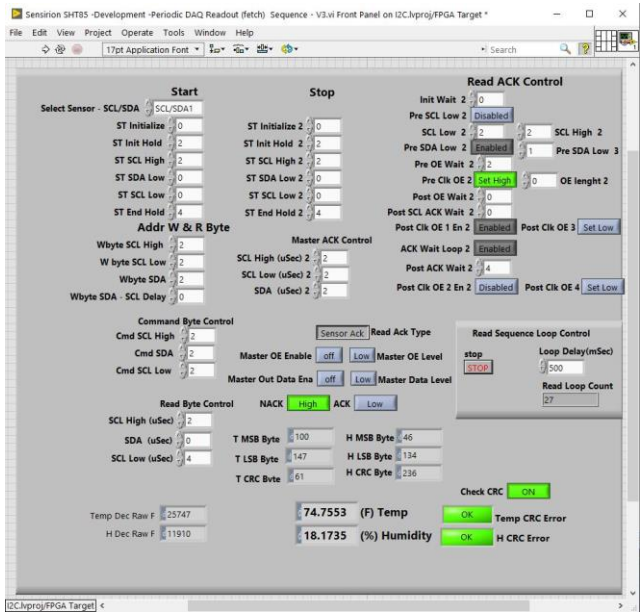
Supports 48 Sensors





Development of FPGA Programming

- I²C command library
- SHT85 sensor instruction set
- Readout mode and status readback
- Serial communication signal timing
- Development of test programs



Serial Communication Timing Test

Development of FPGA Programming

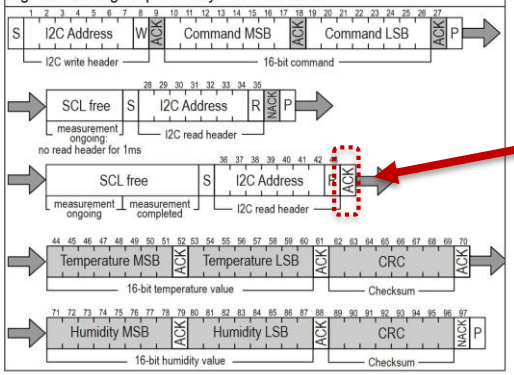
- SHT85 single shot and periodic measurement support
- Data error detection Cyclic Redundancy Check (CRC)
- Error handling routines
- Support for readout of 48 sensors with sbRIO-9627
- Support for cRIO systems with NI9402 LVTTL DIO module
- FPGA to host communication

Development of FPGA Programming

- Issue with single-shot device readout sequence
  - No data returned after command sequence issued
  - Isolated error using logic analyzer
    - Sensor read sensor command acknowledge
  - **Incorrect documentation**

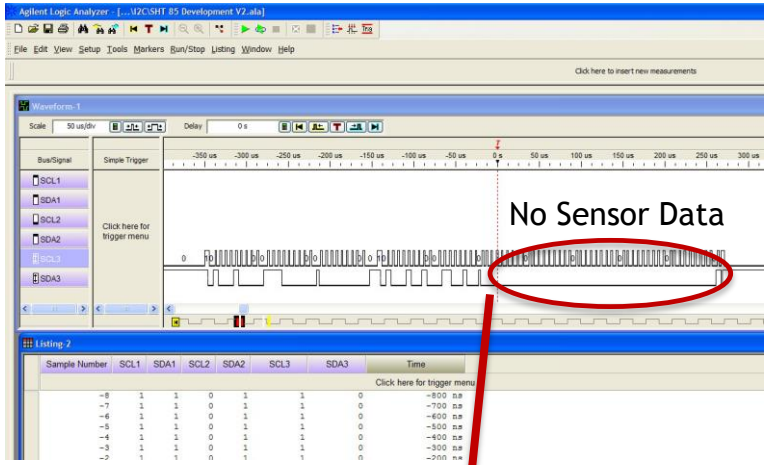
Condition	Hex. code	
Repeatability	MSB	LSB
High	0x24	00
Medium		0B
Low		16

e.g. 0x2400: high repeatability measurement.

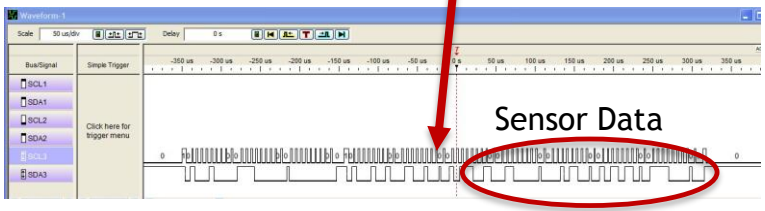


Incorrect Sensor Acknowledge

Grey Block = Data passed from sensor to FPGA
Clear Block = Data passed from FPGA to sensor



Corrected acknowledge



Next Development Steps

- Data integrity testing at extended cable lengths
  - LVTTL line driver may be required at sbRIO
- Sensor accuracy studies
- FPGA code optimization
- Host communication
- System auto-recovery after reboot

RICH System Cost Comparison

Model	Item	Qty	Cost	Total
NI-9035	8-Slot cRio Controller	1	$3838	$3838
NI-9216	8-Channel PT100 RTD Module	3	$1017	$3051
NI-9217	4-Channel RTD Module	2	$621	$1242
NI-9205	16-Channel 16-bit ADC Module	2	$899	$1798
NI-9485	8-Channel SSR Relay Module	2	$394	$788
NI-9329	4-Channel isolated 24-Bit ADC	1	$1199	$1199
NI-9203	8-Channel Current Input Module	1	$601	$601
NI-9219	4-Channel Universal Input Module	1	$1199	$1199
H & T PCB	Dual Sensor Omega/Honeywell PCB	16	$145	$2320
				$16036

$16,036 Cost of duplicating existing Hardware Interlock System for next RICH Sector (Readout Electronics)

Model	Item	Qty	Cost	Total
NI-9627	sbRIO Embedded Controller	1	$1800	$1800
NI-9694	Digital I/O Breakout Card	1	$177	$177
NI-9485	8-Channel SSR Relay Module	1	$394	$394
NI-9329	4-Channel isolated 24-Bit ADC	1	$1199	$1199
NI-9203	8-Channel Current Input Module	1	$601	$601
NI-9219	4-Channel Universal Input Module	1	$1199	$1199
SHT85 PCB	Sensirion SHT85 Dual Sensor PCB	16	$55	$880
				$6250

$6,250 Cost of Sensirion SHT85 Hardware Interlock System for next RICH Sector (Readout Electronics)

- Additional savings for SHT85 System: Uses ½ the cable & connectors

Total savings for SHT85 System: $10K+

Conclusion

- Based on research and analysis, a DSG-designed measurement system with the Sensirion SHT85 temperature and humidity sensors:
  - Increases accuracy
  - Reduces size of sensor assembly
  - Reduces cables/connectors
  - Increases system reliability
  - Improves readout electronics channel density
  - Is compatible with existing slow controls electronics & software
  - Reduces costs