



Metrology for Digital Transformation

SIM - MWG - 14

# SIM WEEK 2023

#THB Development Team





# AGENDA

- 01 THB Team members
- 02 THB Objective
- 03 Scope and basic requirements
- 04 Design and development process
- 05 Description of the THB
- 06 Other considerations
- 07 THB in numbers
- 08 THB prototypes
- 09 Future improvements to the prototype
- 10 Added value
- 11 Conclusions
- 12 Acknowledgments

[ November 2023 ]

# 01 THB Team members



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Country	NMI	Team members
México	CENAM	Carlos Galván; Aldo García; Itzel Domínguez; Oscar Ramos; Susana Sainz; Hugo Gasca
Panamá	CENAMEP	Cristy Sánchez; Isaac Ruiz
Colombia	INM	Eduin Culma; Carlos Peña; Ciro Sánchez
Costa Rica	LACOMET	Olman Ramos Alfaro; Carolina Herrera
Perú	INACAL	Rubén Gil
Chile	ENAER	Marcial Espinoza; Manuel Sepulveda
Ecuador	INEN	Darwin Armijos; Alex Rocha; Wilson Naula

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## 02 THB Objective



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Development of a low cost system for remote measurement of laboratory environmental conditions (temperature, relative humidity and atmospheric pressure), including secure connectivity for data communication and management (XML) and remote verification.

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03

## THB: Scope and basic requirements



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The quantities subject to calibration and their measurement intervals are:

- **Temperature:** from 10 °C to 30 °C
- **Relative humidity:** from 20 % to 85 % at 20 °C and/or 23 °C
- **Pressure:** from 600 hPa to 1100 hPa

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# THB: Calibration results



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Reference / °C	THB-01 / °C	Correction / °C	U <sub>k=2</sub> / °C
10,00	9,67	0,33	0,25
14,97	14,73	0,24	0,25
19,95	19,93	0,02	0,25
24,97	24,89	0,08	0,25
29,96	29,99	-0,03	0,25



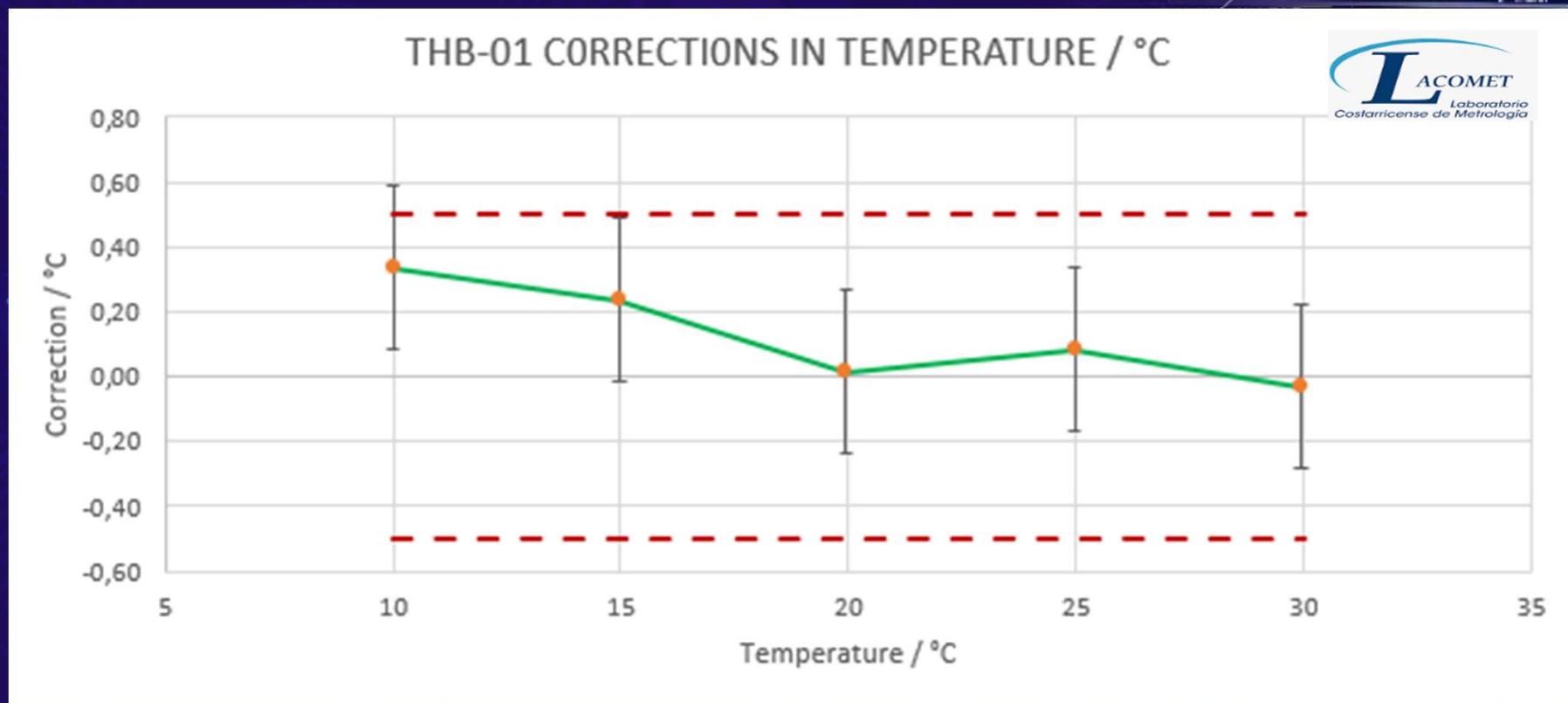
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# THB: Calibration results



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# THB: Calibration results



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Reference / %	THB-01 / %	Correction / %	$U_{k=2}$ / %
19,4	21,5	-2,1	2,3
29,5	30,7	-1,2	2,3
39,9	40,1	-0,2	2,3
50,0	49,6	0,4	2,4
60,3	58,4	1,9	2,4
70,7	67,3	3,4	2,4
80,5	75,7	4,8	2,4
85,6	80,1	5,5	2,4



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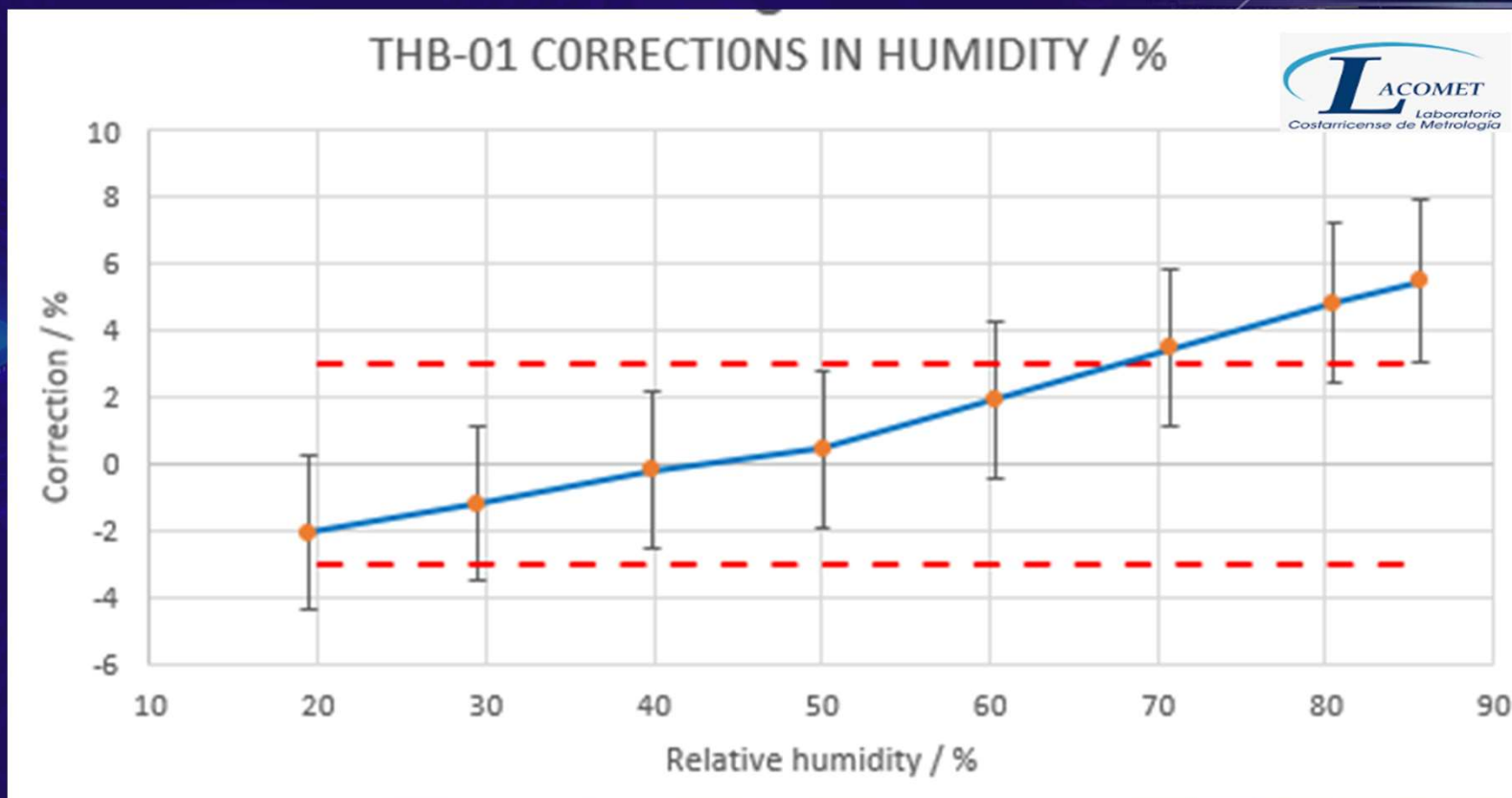


# THB: Calibration results



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# THB: Calibration results



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INDICACIÓN DEL TERMÓMETRO ( °C )	TEMPERATURA CONV. VERDADERA ( °C )	CORRECCIÓN ( °C )	INCERTIDUMBRE DE MEDICIÓN ( °C )
10,12	10,02	-0,10	0,19
15,05	14,97	-0,08	0,21
20,07	19,99	-0,08	0,20
25,05	24,99	-0,06	0,18
30,04	29,98	-0,06	0,16



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# THB: Calibration results



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INDICACIÓN DEL HIGRÓMETRO ( %hr )	HUMEDAD RELATIVA CONV. VERDADERA ( %hr )	CORRECCIÓN ( %hr )	INCERTIDUMBRE DE MEDICIÓN ( %hr )
21,26	19,96	-1,30	1,23
30,53	29,96	-0,57	1,25
39,85	39,99	0,14	1,27
49,35	49,98	0,63	1,29
58,75	60,00	1,25	1,32
67,78	69,99	2,21	1,37
76,86	80,07	3,21	1,45
81,56	85,06	3,50	1,50

# THB: Calibration results



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Indicación del Instrumento a Calibrar *** ( hPa )	Error de Medición ** ( hPa )	Incertidumbre de Medición ( hPa )	Error Máximo Permitido * ± ( hPa )
700,00	0,78	0,20	1,00
750,00	0,82	0,20	1,00
800,00	0,88	0,20	1,00
850,00	0,95	0,20	1,00
900,00	1,01	0,20	1,00
950,00	1,09	0,20	1,00
980,00	1,09	0,20	1,00
1000,00	1,18	0,20	1,00
1050,00	1,09	0,20	1,00
1100,00	1,02	0,20	1,00

\* Información tomada de su manual.

\*\* El resultado es el promedio de cinco mediciones

\*\*\* El instrumento forma parte de un barotermohigrómetro.

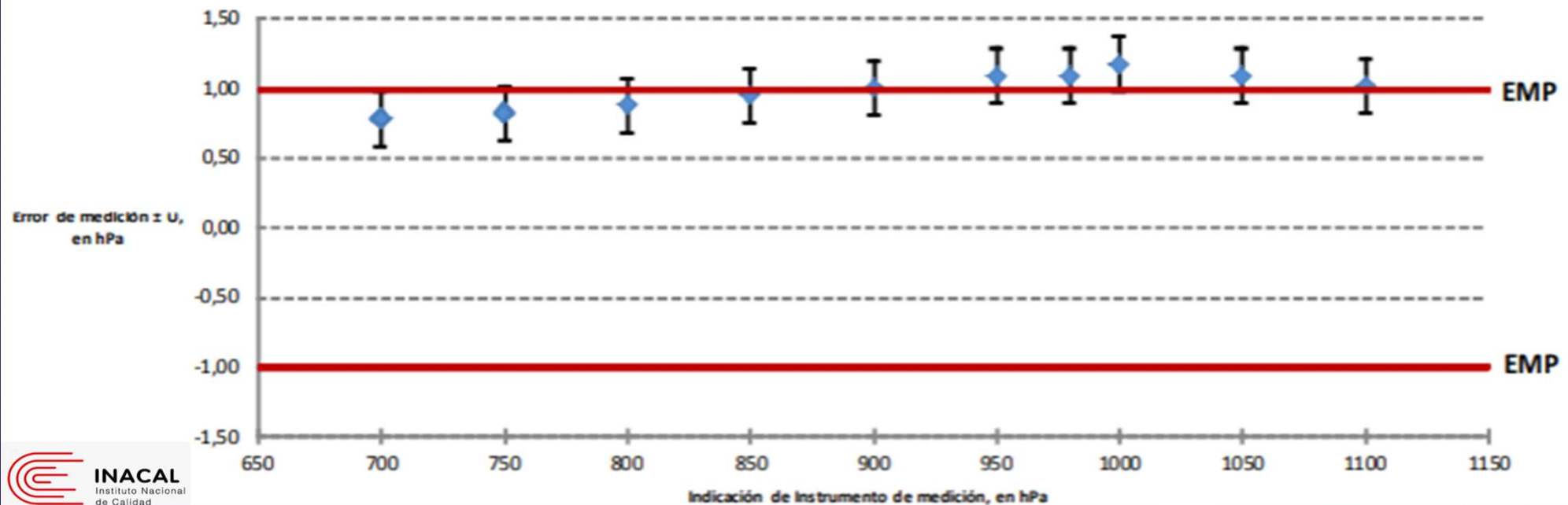
# THB: Calibration results



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## GRÁFICO INDICACIÓN VS ERROR MEDICIÓN



# THB: Calibration results



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Temperatura IBC / °C	Corrección / °C	Factor de cobertura <i>k</i>	Incertidumbre de medición / °C
9.9	0.1	1.96	0.2
19.9	0.0	1.96	0.2
30.1	0.0	1.96	0.2



Instituto Nacional de Metrología de Colombia

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# THB: Calibration results



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Lectura del patrón °C	Lectura del objeto °C	Corrección del objeto °C	Incertidumbre de calibración U (k=2) °C
10.4	11.1	-0.7	0.9
15.5	16.2	-0.7	0.9
20.2	20.9	-0.7	0.9
25.1	25.8	-0.7	0.9
30.1	30.7	-0.6	0.9



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# THB: Calibration results



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Lectura del patrón	Lectura del objeto	Corrección del objeto	Incertidumbre de calibración U (k=2)
%HR	%HR	%HR	%HR
20	19	2	3
30	27	3	3
41	35	6	3
49	44	5	3
60	54	6	3
70	63	7	3
80	74	6	3
85	78	7	3



[ November 2023 ]



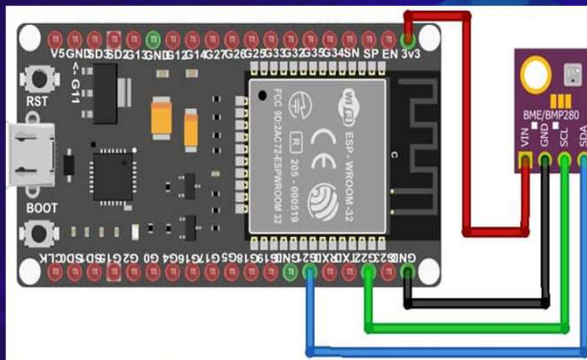
# 04 Design and development process



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Processing all the information that feeds to a frontend



## 05 Description of the THB Hardware



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Through interactive meetings and surveys to potential final users, it was defined the calibration Interval for each quantity.

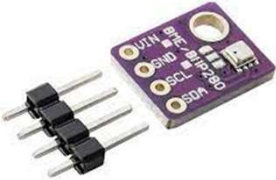






**Sensor**  
**Microcontroller**  
**Screen**  
**Batteries**  
**Charge module**  
**Case (3D printed)**  
**RTC**  
**Databases**

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# 05 Description of the THB



BME280 Sensor	Esp32 / Esp32 S3 Microcontroller	LCD Screen	Litio Batteries	PLA;resin Case
				
<ul style="list-style-type: none"><li>• Accuracy</li><li>• Lower electric consumption</li><li>• P, T and RH integrated</li></ul>	<ul style="list-style-type: none"><li>• Single or dual core, 32 bits</li><li>• Wifi compatible</li><li>• Charge module</li><li>• USB - C port</li></ul>	<ul style="list-style-type: none"><li>• Lower electric consumption</li><li>• Low cost</li></ul>	<ul style="list-style-type: none"><li>• Rechargeable</li><li>• Interchangeable</li><li>• More than 12 h of autonomy</li></ul>	<ul style="list-style-type: none"><li>• Resistant</li><li>• Low cost</li><li>• 3D impressed</li></ul>


# 05 Description of the THB Software




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## Tools



Visual Studio Code



ARDUINO

## Technologies



JavaScript



C++ for Arduino



LabVIEW



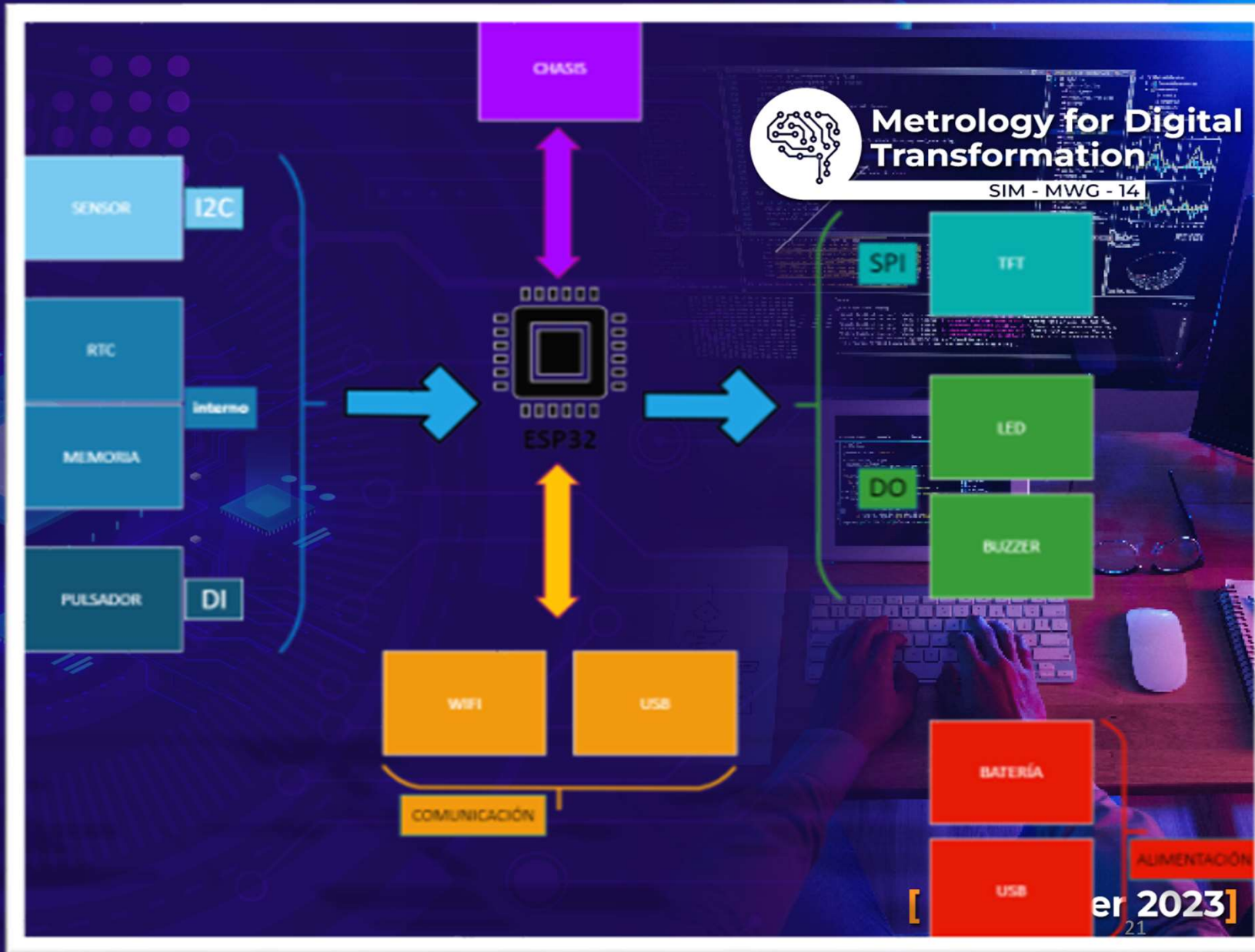
Java



python

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# Block Diagram



## 06 Other considerations



- Installed capacities of each NMI
- Type of data connection: wifi, RS232
- Equipments to perform the calibrations
- Costs are being estimated on the tangible resources: sensors, microprocessor, screen, modules and other components
- It is desirable to have access to 3D printing (additive manufacture)
- Battery autonomy: from 9 h to 12 h



	Operation Range	Accuracy	Resolution	Long term stability
<b>Temperature</b>	0 °C to 65 °C	± 0,5 °C	0,01 °C	-
<b>Humidity</b>	0 %RH to 100 %RH	±3,0 %RH	0,008 %RH	0,5 %RH/year
<b>Pressure</b>	300 hPa to 1100 hPa	± 1,0 hPa	0,18 hPa	± 1,0 hPa/year



<b>Sensor</b>	External sensor (1 m cable)
<b>Controller</b>	ESP32 30 pin
<b>Display</b>	TFT 2" 320x240
<b>Storage</b>	SPI Flash File Storage 1,5 MB
<b>Date</b>	Year-month-day Hour:Minute:Second
<b>Alarms</b>	Led, buzzer
<b>Power supply</b>	Via batteries as well as USB-Connection possible
<b>Communication</b>	Wi-fi; RS232





Display	Multi-display (calibration function)
Storage	SPI Flash File Storage 1,5 MB (Configurable save rate/enable)
Date	Year-month-day Hour: Minute: Second (Configurable)
Alarms	High/Low level Led, buzzer (Configurable)
Communication	Configurable transfer rate. RS232 (USB), WI-FI (MQTT). Optionally, mesh red.

Initial Configuration

Who are you?  
\$; Q; \*

I'm  
\$;MAC;H;Nombre; [Nombre]; EnDT; [unit]; EnWarn; [LUT;LDT;LUH;LDH;LUP;LDP; FWVersion]; \*

Are you configuring?

YES

Main Process

Parameters settings

Request Data  
\$; MAC; D; \*

\$: Inicio de trama  
 MAC: MAC del THB  
 H: Comando que recibirá el aplicativo de escritura  
 Nombre: Identificador del THB establecido por el usuario  
 AJUSTE: Coeficientes de ajuste  
 EnDT: Habilitación de data cruda o ajustada a mostrar  
 0 -> Data ajustada  
 1 -> Data cruda  
 Enwarn: Habilitación de alarmas, dependen de los límites  
 ulimados  
 0 -> Alarmas deshabilitadas  
 1 -> Alarmas habilitadas  
 LUT: Límite superior temperatura  
 LDT: Límite inferior temperatura  
 LUH: Límite superior humedad  
 LDH: Límite inferior humedad  
 LUP: Límite superior presión  
 LDP: Límite inferior presión  
 FWVersion: Versión de firmware  
 \*: Fin de trama

Example  
 \$; 3C:E9:0E:88:83:EB; m; THBv3.1; [AJUSTE]0; 10:0:24.50; 22.50; 0:80; 80; 1005; 80; 990.00; v3.1; \*

Data Transmission  
 \$; MAC; H; LabelT; valueT; unitT; S8601T; LabelP; valueP; unitP; S8601; LabelH; valueH; unitH; S8601; \*

Data Transmission XML

\$: Inicio de trama  
 MAC; H: MAC del THB  
 LabelT: etiqueta de temperatura  
 valueT: valor de temperatura en kelvin  
 unitT: unidad de temperatura (platinum)  
 S8601T: Estándar de tiempo acorde a ISO8601  
 LabelP: etiqueta de temperatura  
 valueP: valor de temperatura en kelvin  
 unitP: unidad de temperatura (platinum)  
 S8601P: Estándar de tiempo acorde a ISO8601  
 LabelH: etiqueta de temperatura  
 valueH: valor de temperatura en kelvin  
 unitH: unidad de temperatura (platinum)  
 S8601H: Estándar de tiempo acorde a ISO8601  
 \*: Fin de trama

Example:  
 \$; 3C:E9:0E:88:83:EB; Temperature; 296.15; [kelvin]; 2023-07-21T19:56:38-05:00; Pressure; 99188.22; [kilogram]; [mestre]tothe[-1]; [second]tothe[-2]; 2023-07-21T19:56:38-05:00; Humidity; 54.82; [one]; 2023-07-21T19:56:38-05:00; \*





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<working modes/>

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**</Direct Mode>**



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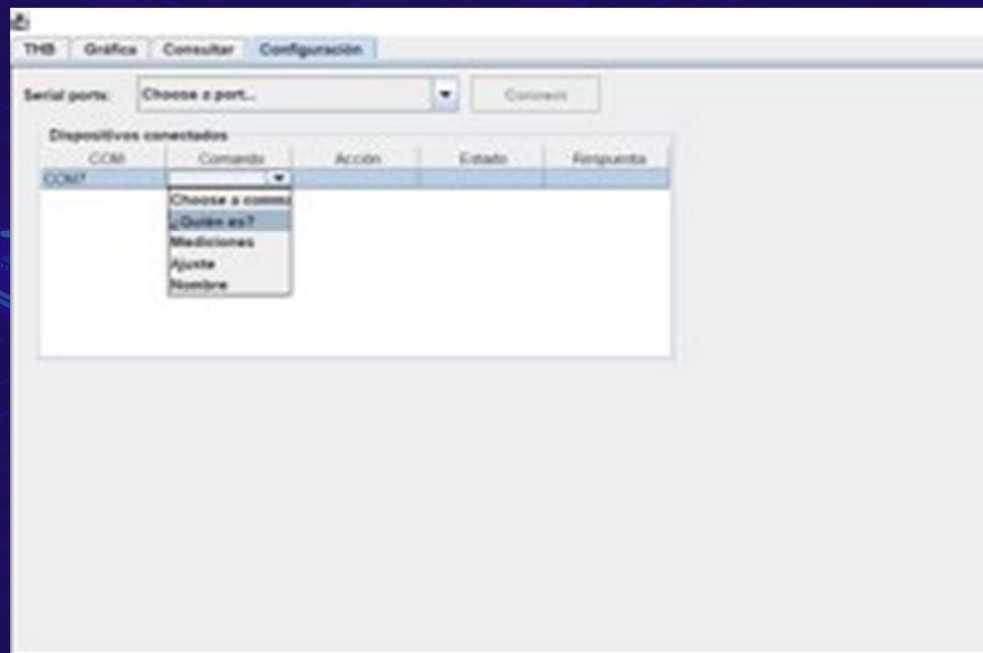
**[ November 2023 ]**

# </Reading app>



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[ November 2023 ]

# </Receptor mode>



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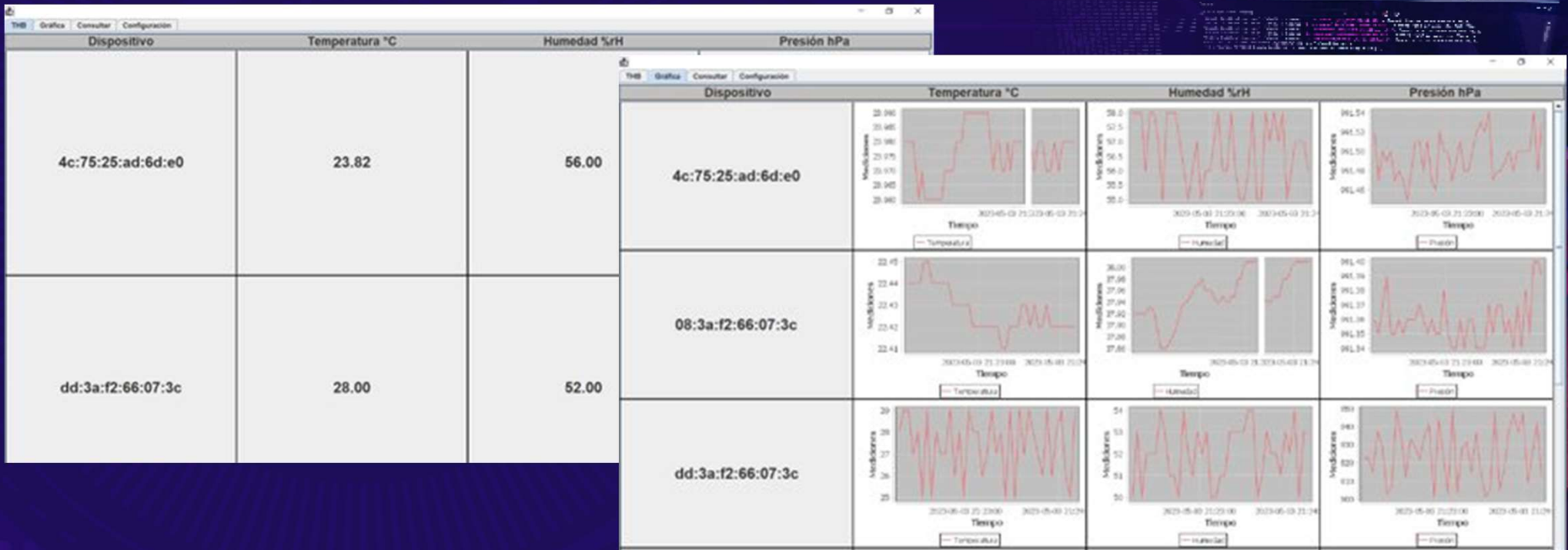
[ November 2023 ]

# </Different devices measurements>



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# </Wi-Fi station mode>



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</Publisher>



MQTT



</subscriber>

</Publisher>



[ November 2023 ]



# </Wi-Fi station mode>



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Estado Network Servicio Otro

MAC	B4:8A:0A:BF:52:70
Access point IP	192.168.4.1
Wi-Fi Network	Ciudad de los reyes
WLAN WAN IP	192.168.4.1

Active service

**CONFIGURACION PUNTO DE ACCESO**

AP Name  
THBBF0A8AB47052

AP IP  
192.168.4.1

AP Password



THB DEMO  
SIM-IDB-THB

Acceso

admin

Contraseña

Login

Estado Network Servicio Otro

Wi-Fi Settings

les cercanas

elsol Wifi

sword

ssword

er password

Buscar redes

do

ncp

Conectar

[ November 2023 ]

# </Wi-Fi station mode>



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Conexión de cliente MQTT

**Conectar**

Servidor:

IdCliente:

Usuario:

Password:

Tiempo de vida:

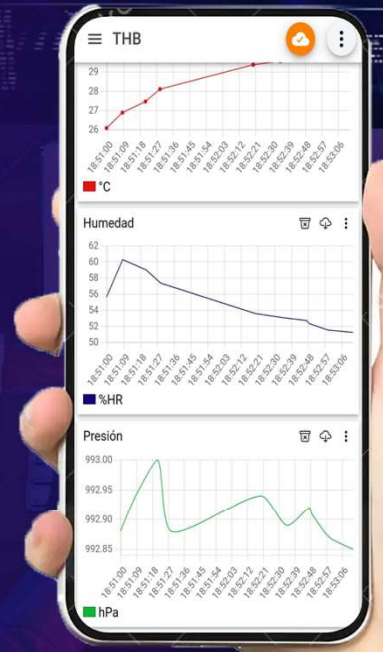
IDThb:

---

Lecturas THB

Temperatura	Humedad	Presión
20.7 °C	61.2 %Rh	991.2 hPa

Temperatura	Humedad	Presión	Hora	Fecha
Tabla sin contenido				



[ November 2023 ]



# <THB in numbers/>

**Began in March 2022**

**2 integration workshops**  
**2 surveys (for requirements planning)**

**8 prototypes:**  
**México, Ecuador, Colombia,**  
**Panamá (x2), Perú, Chile, Costa**  
**Rica**

**Handout of one prototype to SIM**

**Estimated cost of materials and components: 80 USD to 100 USD**



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**+50 technical meetings**

**5 Demos: 3 virtual and 2 in person**

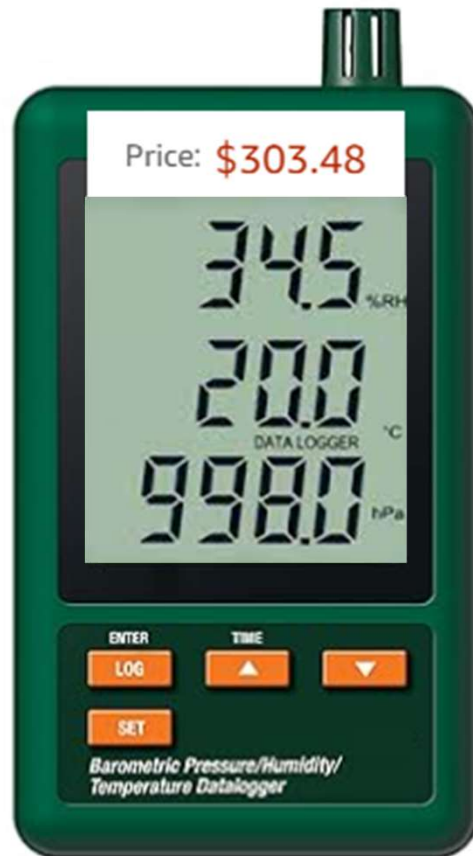
**[ November 2023 ]**

# Comercial THB



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## Pressure, Humidity and Temperature Data Logger

4.6 ★★★★★

Style:

Barometric Pressure/Humidity/Temperature... ▾

- Triple LCD simultaneously displays Barometric Pressure, Temperature, and Relative Humidity
- Datalogger date/time stamps and stores readings on an SD card in Excel format for easy transfer to a PC
- Displays Barometric Pressure in 3 units of measure: hPa, mmHg, and inHg
- Selectable data sampling rate: 5, 10, 30, 60, 120, 300, 600 seconds

[ November 2023 ]

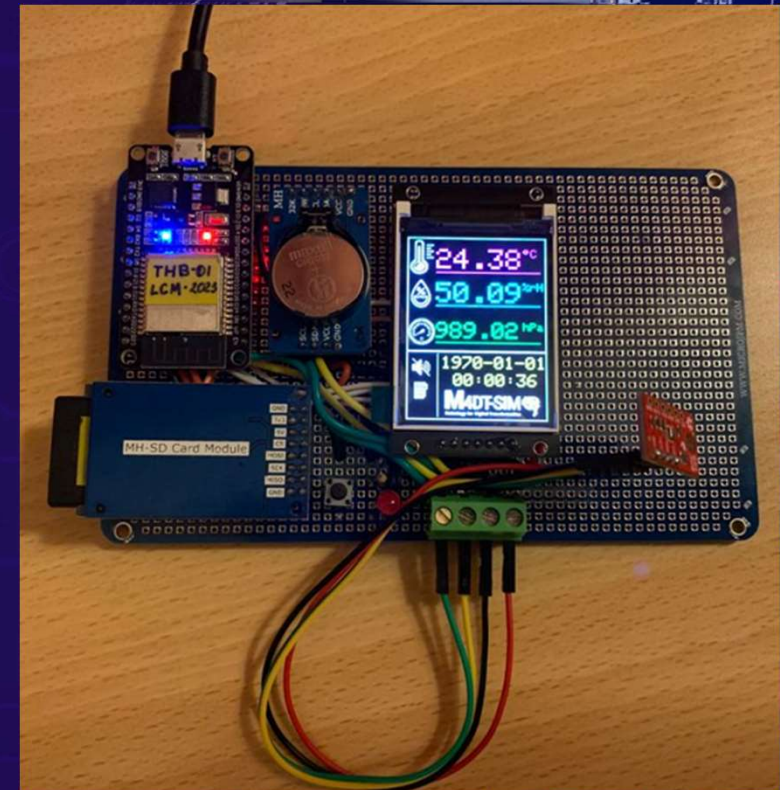
[https://www.amazon.com/Registrador-presi%C3%B3n-humedad-temperatura-SD700/dp/B005LIW57M?language=en\\_US&currency=USD&th=1](https://www.amazon.com/Registrador-presi%C3%B3n-humedad-temperatura-SD700/dp/B005LIW57M?language=en_US&currency=USD&th=1)

# 08 THB prototypes



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# 08 THB prototypes



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[ November 2023 ]

# 08 THB prototypes



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# 08 THB prototypes



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[ November 2023 ]

# 08 THB prototypes



INEN



[ November 2023 ]

09

## Future improvements to the prototypes



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- Visual alarm (LED and/ or email) and/ or audible alarm (buzzer), to inform the final user about out of limits measurements.
- Possibility to read corrected by traceability values.
- Indication of low charge battery level.
- DCC.

[ November 2023 ]

## 10 Added value



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Opportunities on research, development and innovation, to advanced engineering students, to contribute actively in different tasks of the project: programming, running test, creating cases by additive manufacturing and others.



[ November 2023 ]

# 11 Conclusions



The THB could also be used in the future to:

- Monitor, record and control of ambient conditions in physical files storage applications.
- Support the air conditioning system maintenance activities and to anticipate potential failures.

## 11 Conclusions



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The main objective of the project has been met and exceeded: There are eight different designs and developments of low cost and functional thermohygrobarmeters (THB) with digitization components.

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# 11 Acknowledgments

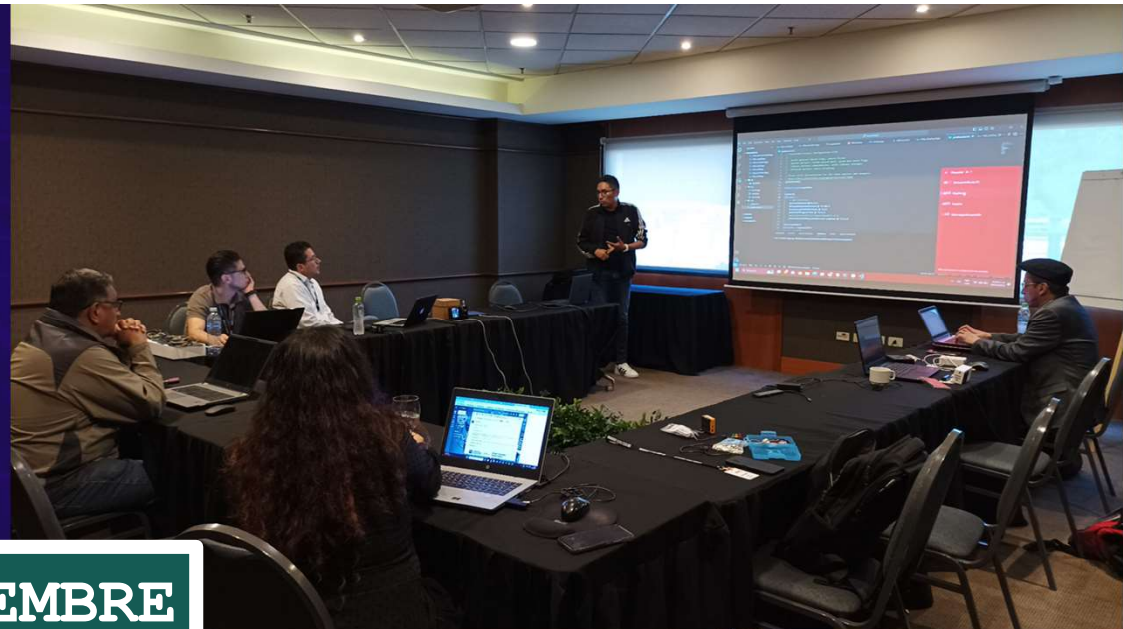
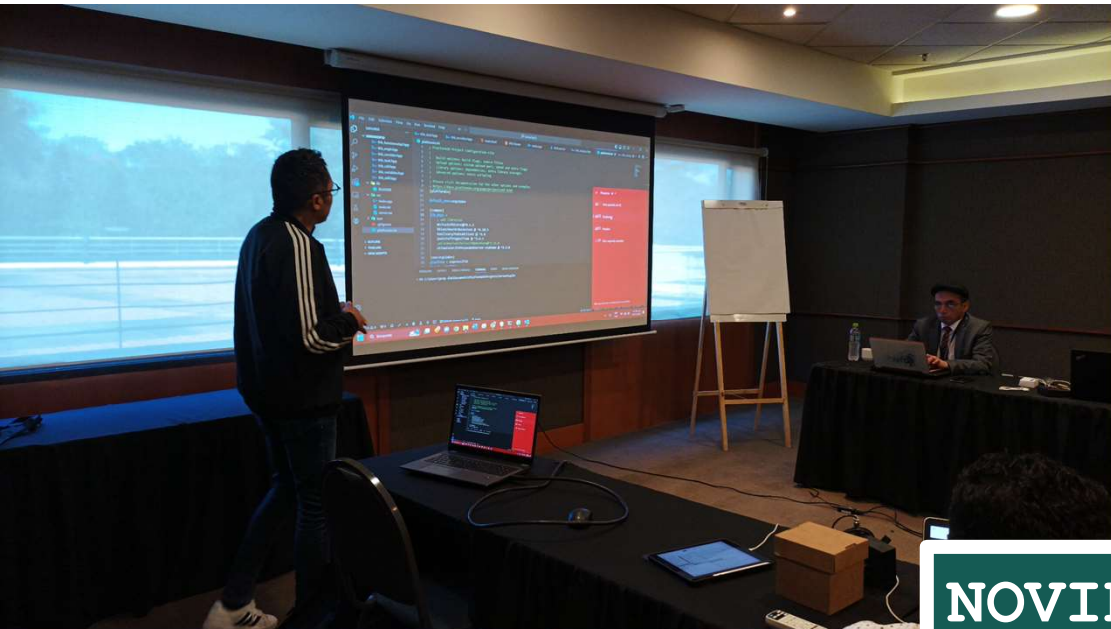


- Inter-American Metrology System (SIM)
- Banco Internacional de Desarrollo (BID)
- Physikalisch-Technische Bundesanstalt (PTB)
- Instituto Nacional de Tecnología, Normalización y Metrología (INTN)

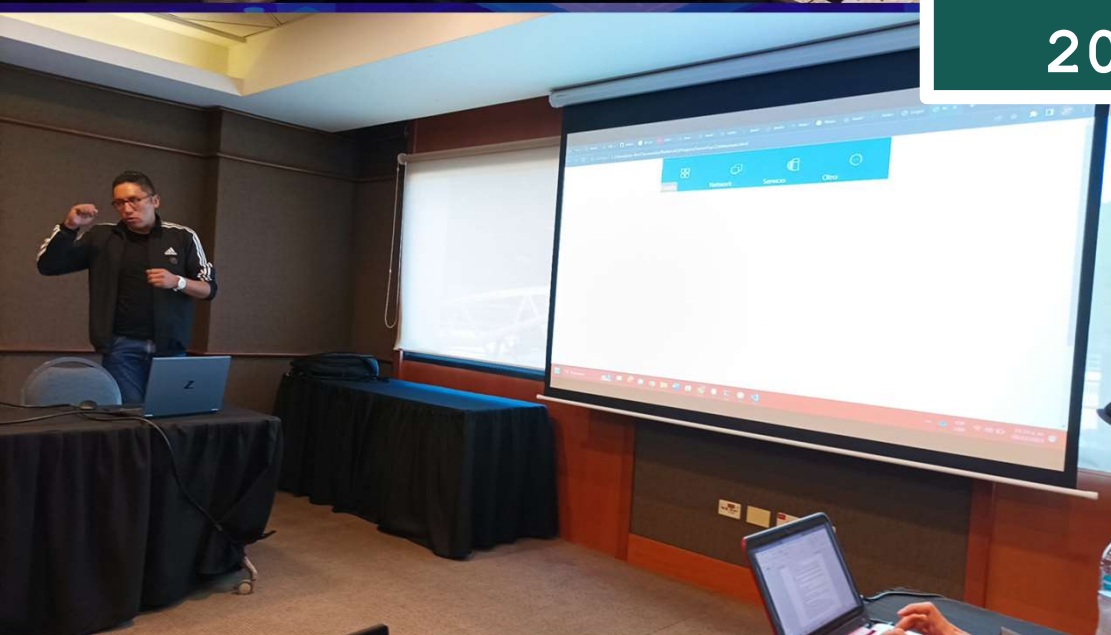
→ All participant NMIs:

- CENAM
- CENAMEP
- INM
- LACOMET
- INACAL
- ENAER
- INEN





NOVIEMBRE  
2023







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Events > SIM Digital - THB Project

# SIM Digital - THB Project

Online

THB Project  
THB Development Team



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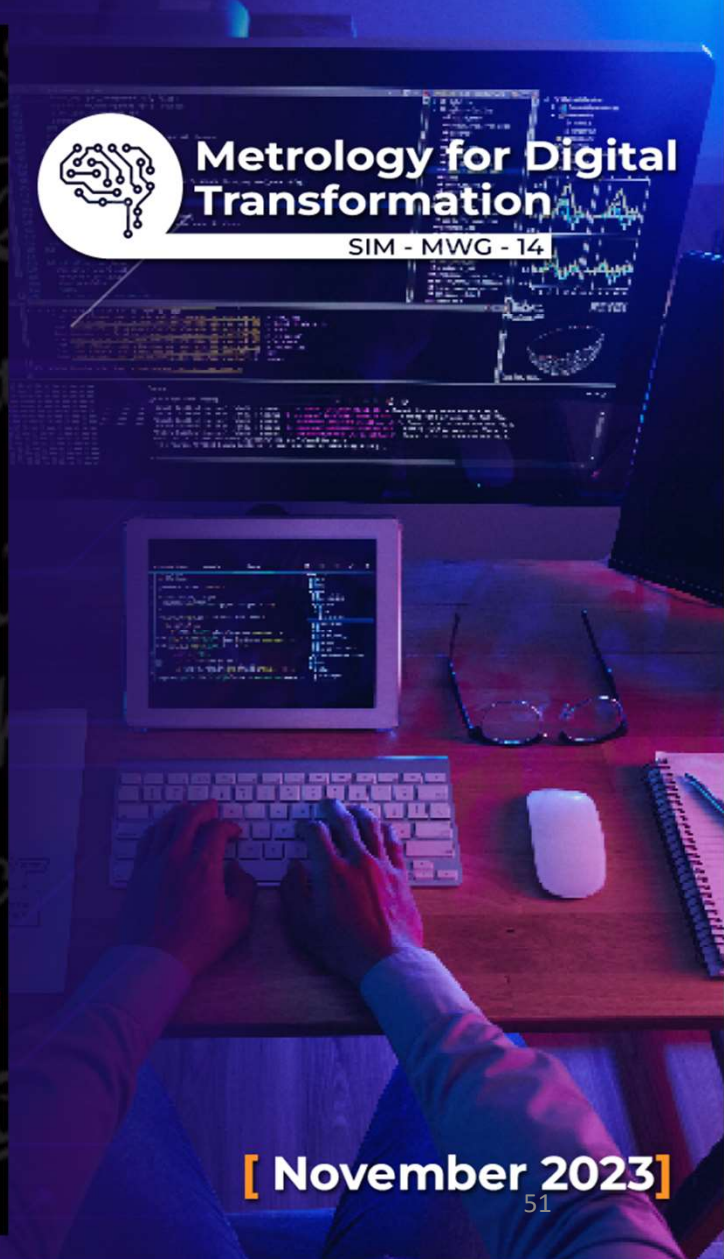


[ November 2023 ]



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