



Metrology for Digital Transformation

SIM - MWG - 14

SIM WEEK 2023

#THB Development Team



AGENDA

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- 04 Design and development process
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- 11 Conclusions
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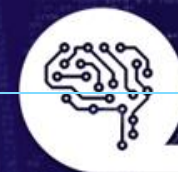


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01 THB Team members



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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	$U_{k=2}$ / °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

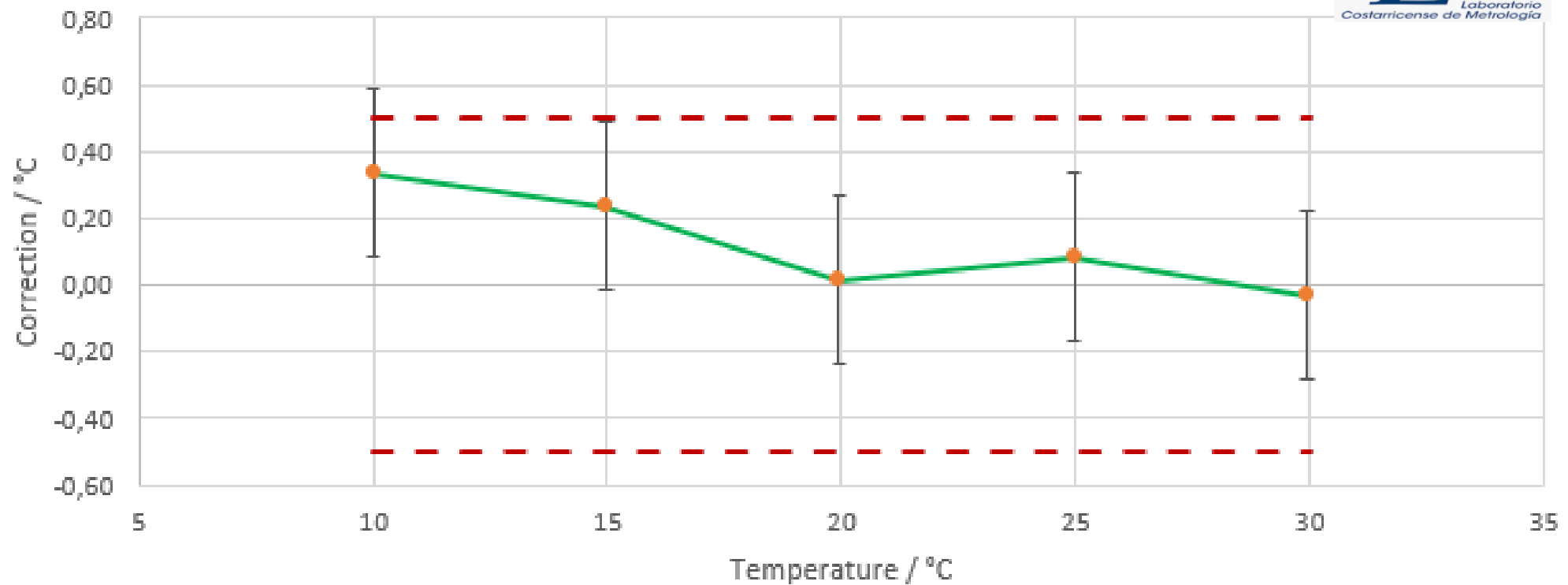


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THB: Calibration results



THB-01 CORRECTIONS IN TEMPERATURE / °C



THB: Calibration results

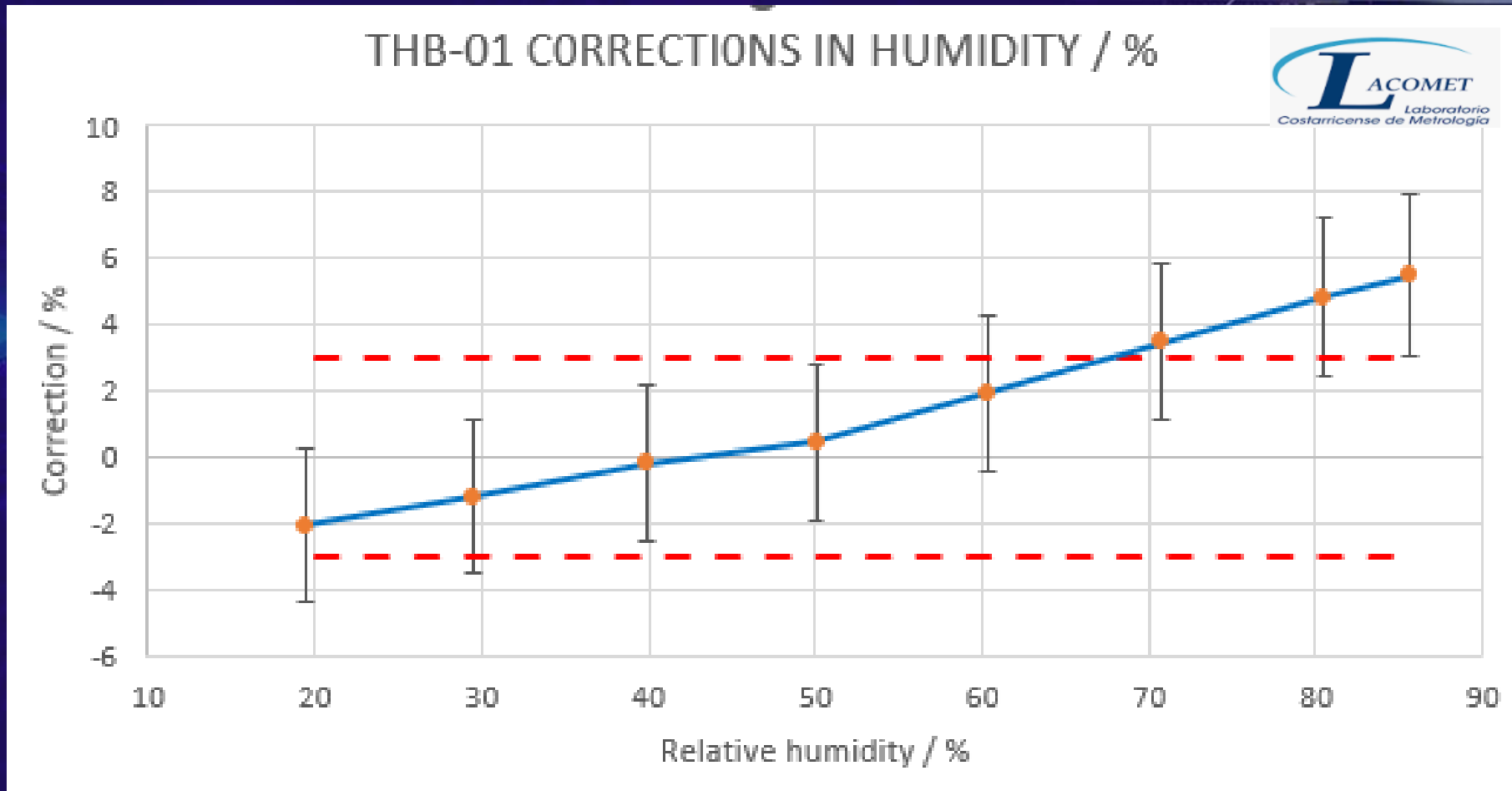


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Reference / %	THB-01 / %	Correction / %	$U_{k=2}$ / %
19,4	21,5	-2,1	2,3
29,5	30,7	-1,2	2,3
39,9	40,1	-0,2	2,3
50,0	49,6	0,5	2,4
60,3	58,4	1,9	2,4
70,7	67,3	3,5	2,4
80,5	75,7	4,8	2,4
85,6	80,1	5,5	2,4

THB: Calibration results



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

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



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.

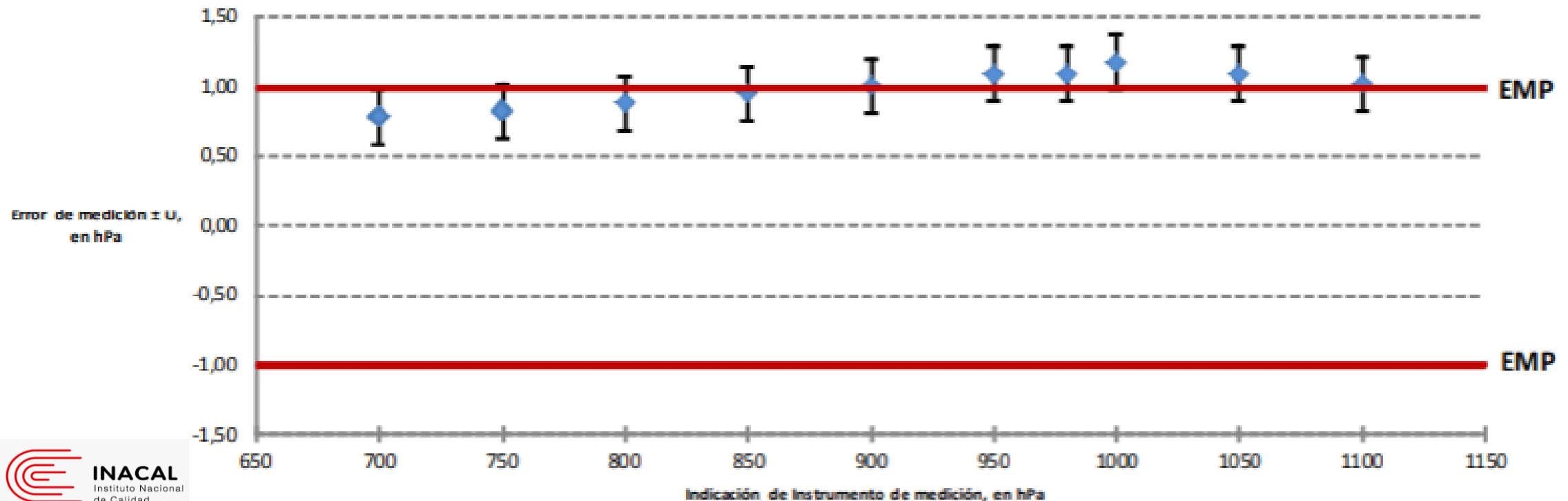
** El resultado es el promedio de cinco mediciones

*** El instrumento forma parte de un barotermohigrómetro.

THB: Calibration results



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



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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)
°C	°C	°C	°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



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

04 Design and development process



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Processing all the information that feeds to a frontend

Client side development

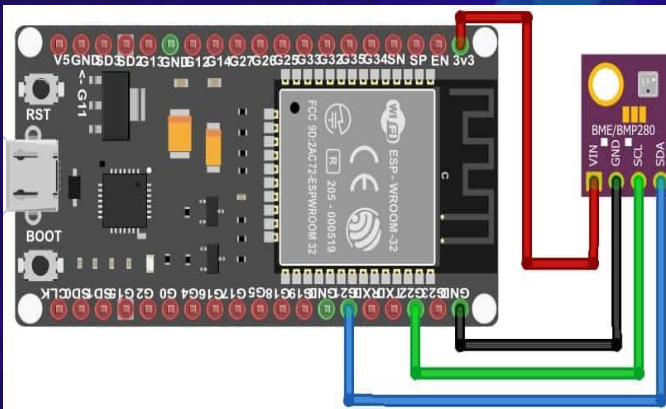
Hardware



Firmware



Software Integration



Sensor 1	100%
temperatura:	20.99 °C
Presión:	719.5 hPa
Humedad:	52.6 %HR
Estación 1 20:41 08-10-2023	

05 Description of the THB Hardware

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

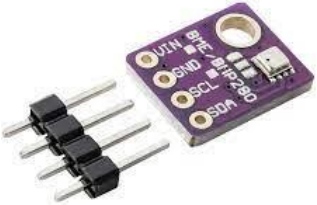


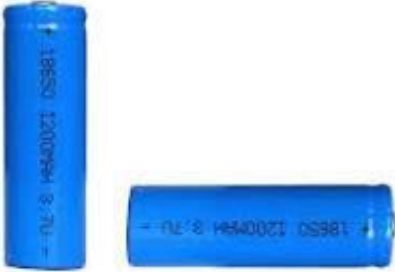



Sensor
Microcontroller
Screen
Batteries
Charge module
Case (3D printed)
RTC
Databases

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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">● Accuracy● Lower electric consumption● P, T and RH integrated	<ul style="list-style-type: none">● Single or dual core, 32 bits● Wifi compatible● Charge module● USB - C port	<ul style="list-style-type: none">● Lower electric consumption● Low cost	<ul style="list-style-type: none">● Rechargeable● Interchangeable● More than 12 h of autonomy	<ul style="list-style-type: none">● Resistant● Low cost● 3D impressed

05 Description of the THB Software



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Tools



Visual Studio Code



Technologies

JavaScript



C++ for Arduino



LabVIEW™



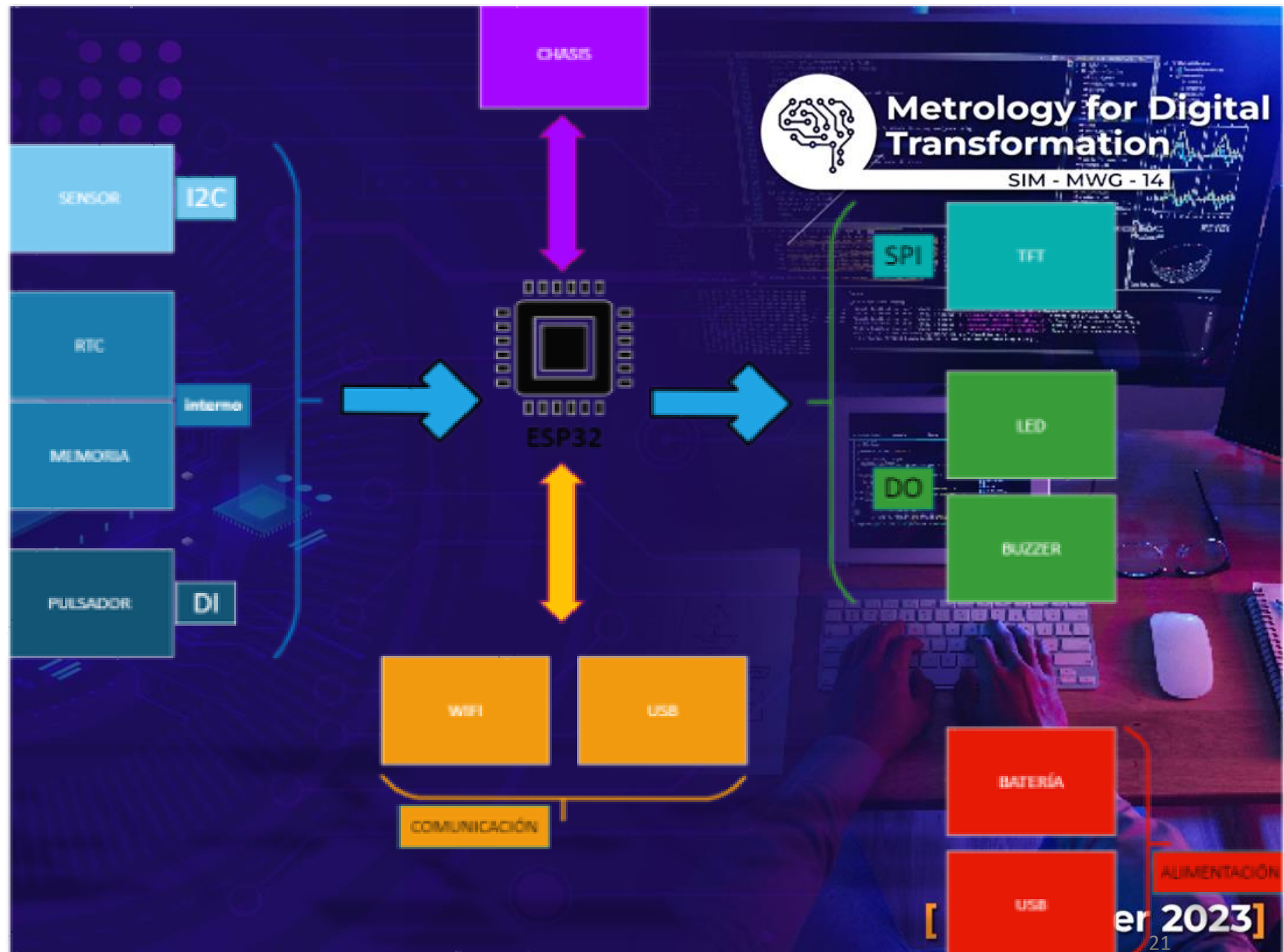
Java



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
Temperature	0 °C to 65 °C	± 0,5 °C	0,01 °C	-
Humidity	0 %RH to 100 %RH	±3,0 %RH	0,008 %RH	0,5 %RH/year
Pressure	300 hPa to 1100 hPa	± 1,0 hPa	0,18 hPa	± 1,0 hPa/year

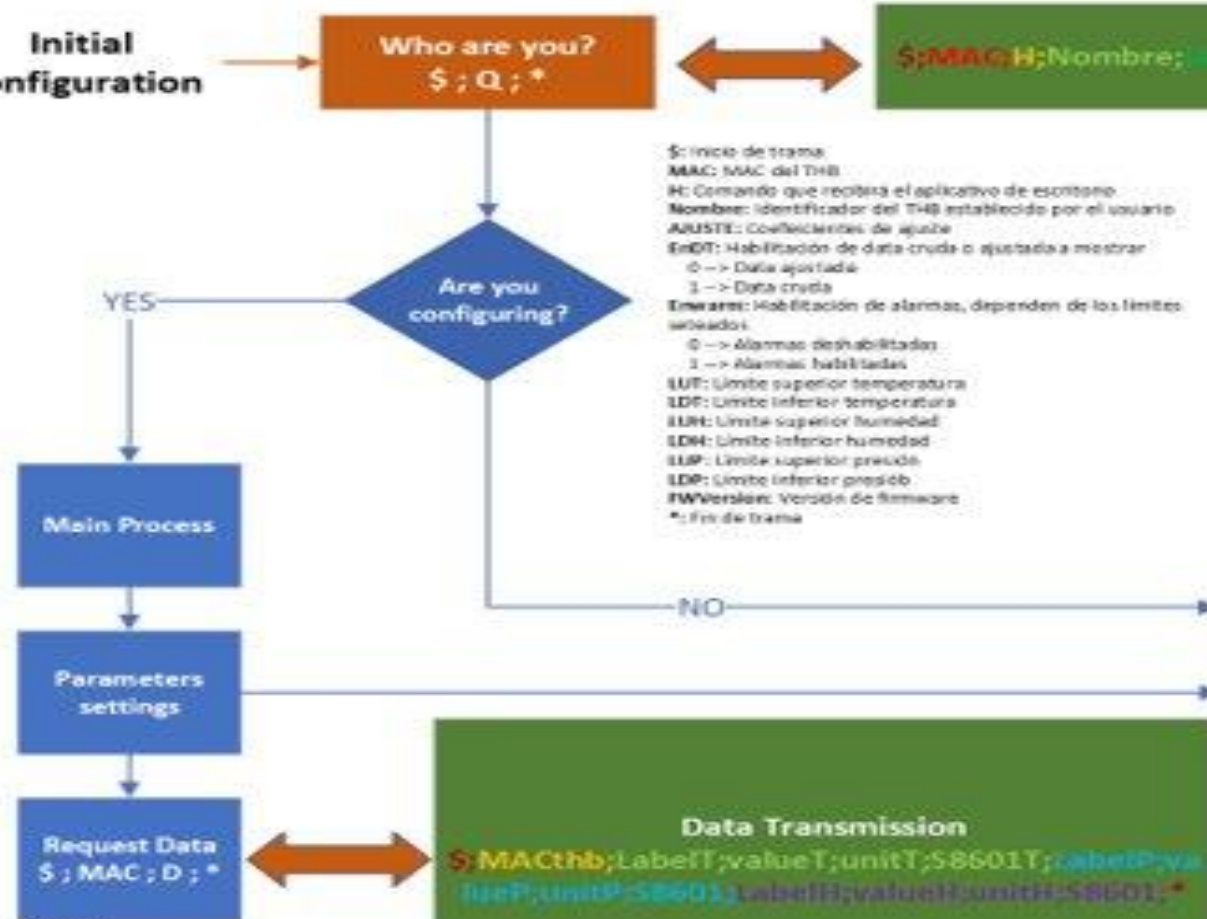


Sensor	External sensor (1 m cable)
Controller	ESP32 30 pin
Display	TFT 2" 320x240
Storage	SPI Flash File Storage 1,5 MB
Date	Year-month-day Hour:Minute:Second
Alarms	Led, buzzer
Power supply	Via batteries as well as USB-Connection possible
Communication	Wi-fi ; RS232



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



S: 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: Habilidad de data cruda o ajustada a mostrar
 0 -> Data ajustada
 1 -> Data cruda
 Enwarn: Habilidad de alarmas, dependen de los límites
 0 -> Alarmas deshabilitadas
 1 -> Alarmas habilitadas
 LUT: Límite superior temperatura
 LDT: Límite inferior temperatura
 LUN: Límite superior humedad
 LDH: Límite inferior humedad
 LUP: Límite superior presión
 LDP: Límite inferior presión
 FWVersion: Versión de firmware
 *: Fin de trama

I'm
 S;MAC;H;Nombre;EnDT;Enwarn;LUT;LDT;LUN;LDH;LUP;LDP;FWVersion*

Example
 S;3C;E9-0E-8B-83-EB;1;[AJUSTE]0;10-0;24.50;22.50;1;0;0;1005;10;0;0;0;0;0;3.1;*



S: Inicio de trama
 MAC;H: MAC del THB
 LabelT: etiqueta de temperatura
 valueT: valor de temperatura en kelvin
 unitT: unidad de temperatura [platinum]
 S8601: Estándar de tiempo acorde a ISO8601
 LabelH: etiqueta de temperatura
 valueH: valor de temperatura en kelvin
 unitH: unidad de temperatura [platinum]
 S8601: Estándar de tiempo acorde a ISO8601
 LabelP: etiqueta de temperatura
 valueP: valor de temperatura en kelvin
 unitP: unidad de presión [platinum]
 S8601: Estándar de tiempo acorde a ISO8601
 *: Fin de trama

Example:
 S;3C;E9-0E-8B-83-EB;Temperature;218.18;value;2023-07-21T19:56:38-05:00;Pressure;99188.72;Wibg-am;vestib;[1];[ajuste];[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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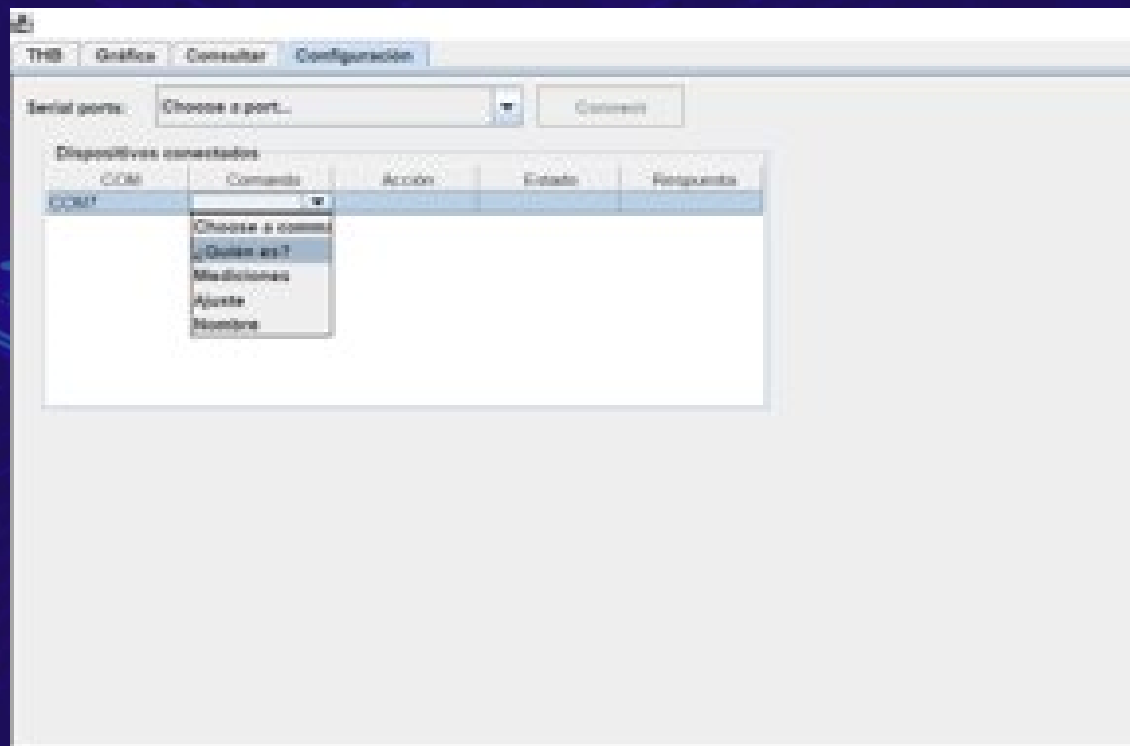
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</Reading app>



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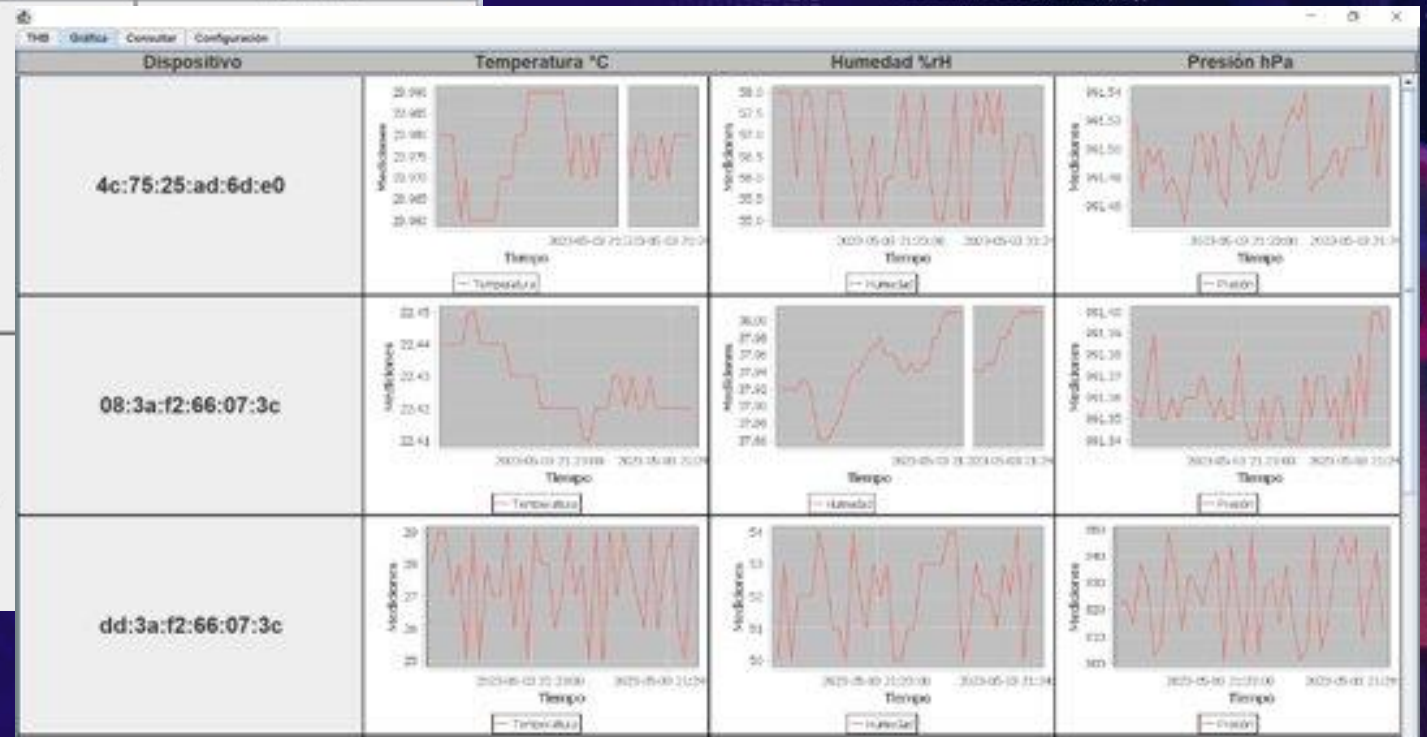
</Receptor mode>



</Different devices measurements>



Dispositivo	Temperatura °C	Humedad %rH	Presión hPa
4c:75:25:ad:6d:e0	23.82	56.00	
dd:3a:f2:66:07:3c	28.00	52.00	



</Wi-Fi station mode>



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MQTT



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</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

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

Redes cercanas

Seleccionar Wifi

Nombre de la red

Contraseña

Seguridad

Mostrar contraseña

Buscar redes

Seleccionar red

Conectar

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</Wi-Fi station mode>



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Conexión de cliente MQTT

Conectar

Servidor:

IdCliente:

Usuario:

Password:

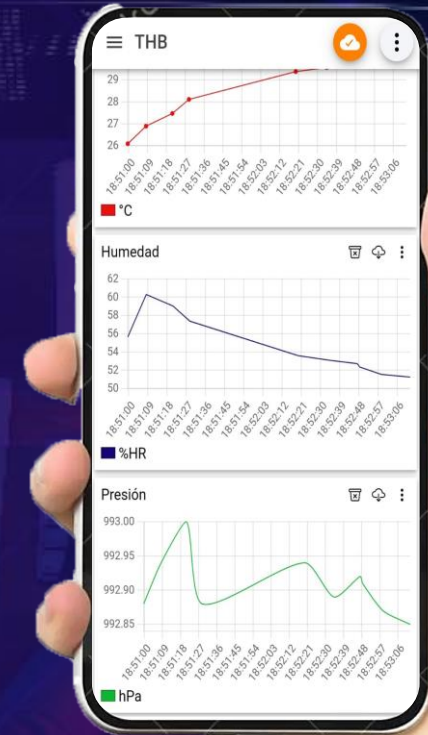
Tiempo de vida:

IDThb:

Lecturas THB

Temperatura	Humedad	Presión	Hora	Fecha
20.7 °C	61.2 %Rh	991.2 hPa		

Tabla sin contenido



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<THB in numbers/>

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Began in March 2022

2 integration workshops
2 surveys (for requirements planning)

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

+50 technical meetings

5 Demos: 3 virtual and 2 in person

Handout of one prototype to SIM

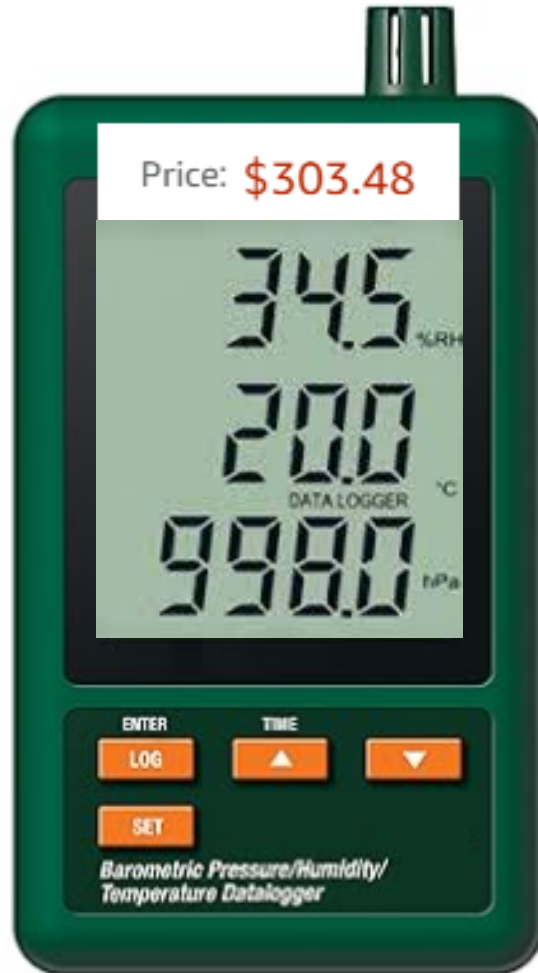
Estimated cost of materials and components: 80 USD to 100 USD

Comercial THB



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Pressure, Humidity and Temperature Data Logger

4.6 ★★★★★

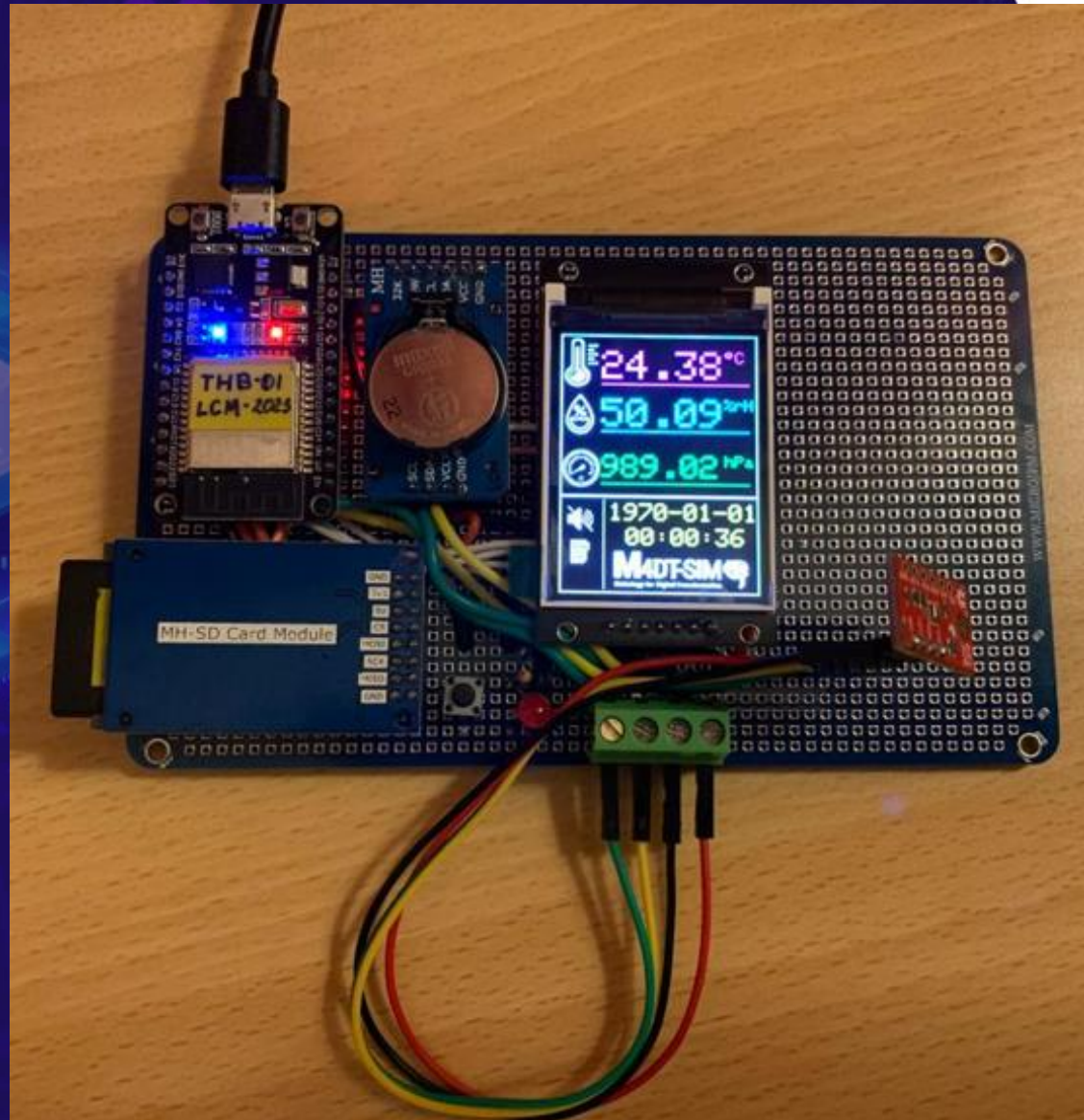
Style:

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

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08 THB prototypes



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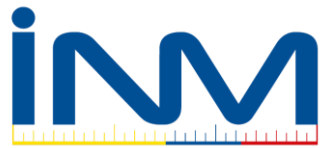
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08 THB prototypes



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Instituto Nacional de Metrología de Colombia



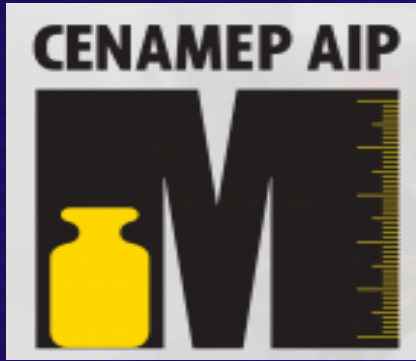
[November 2023]

08 THB prototypes



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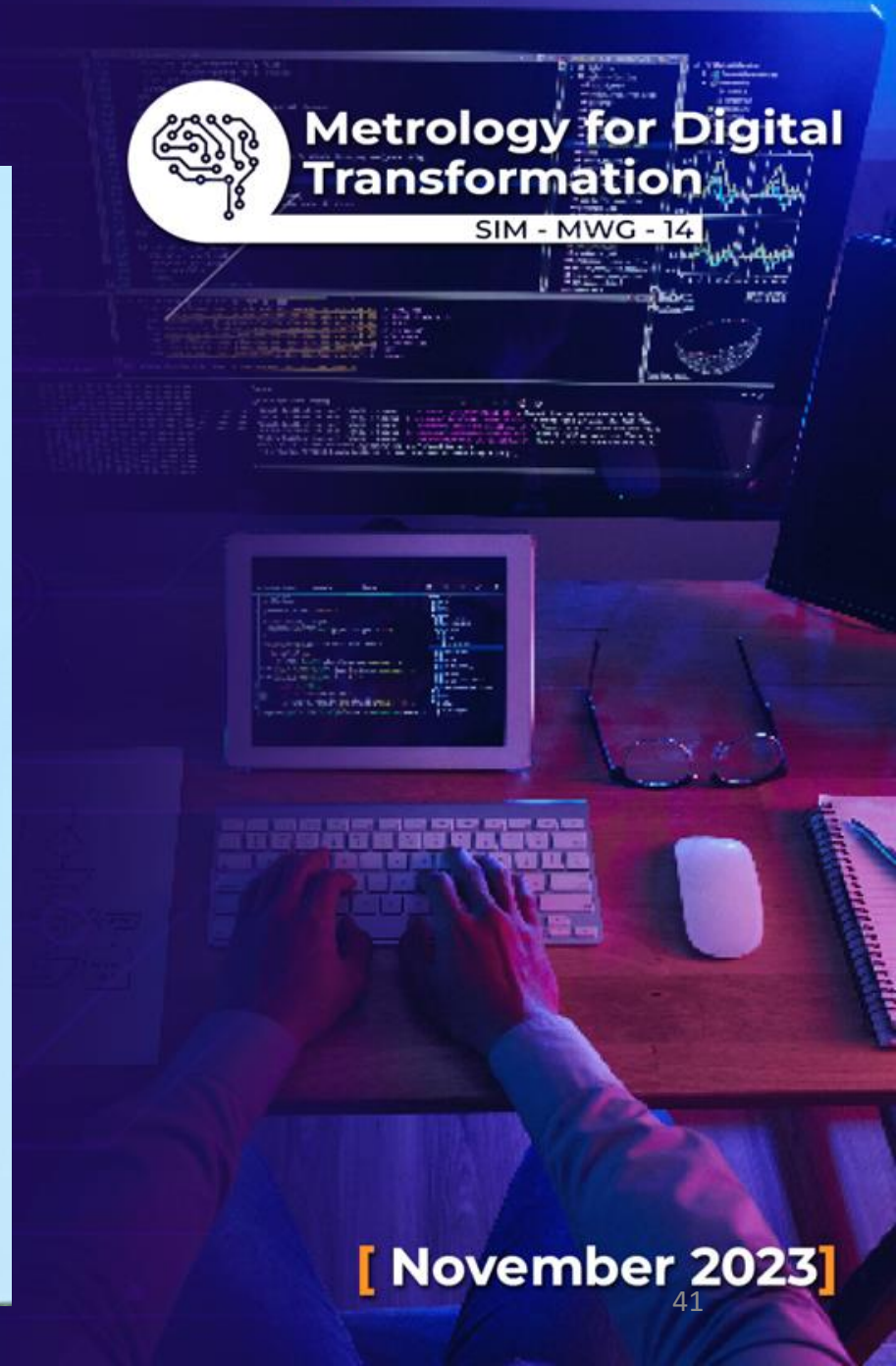


08 THB prototypes



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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.

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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



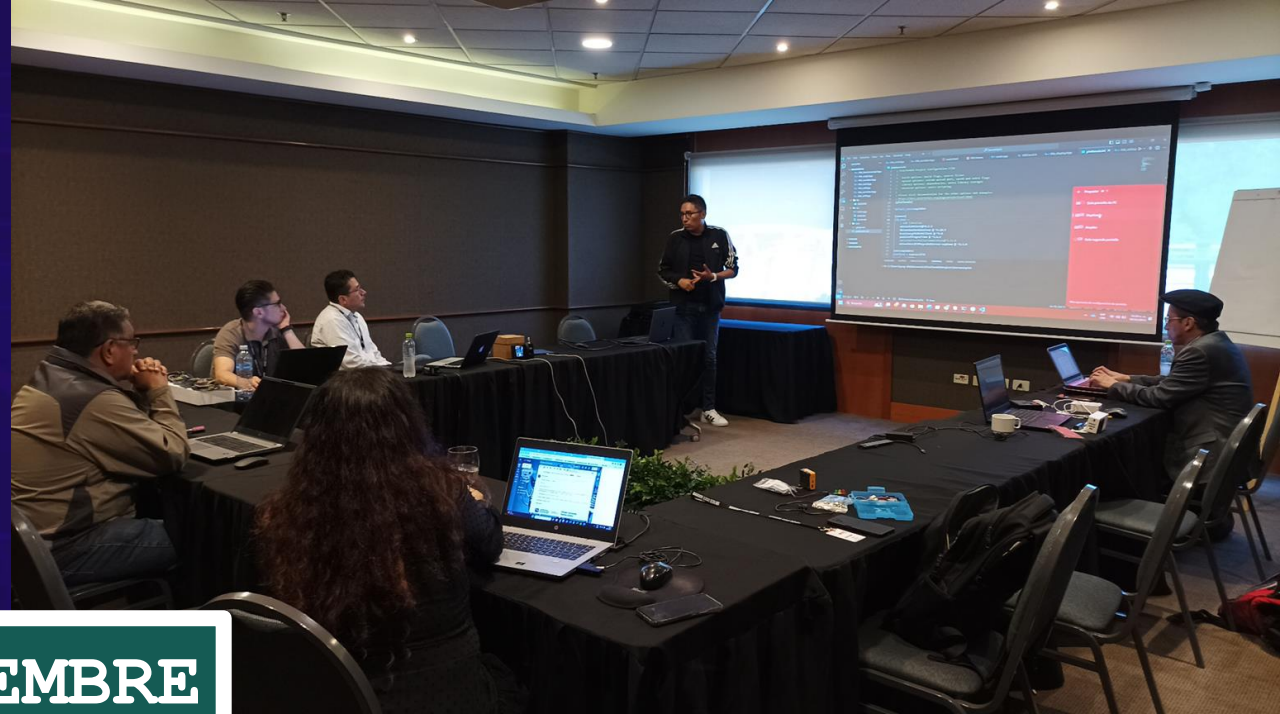
Technology Transform
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- Inter-American Metrology System (SIM)
- Banco Internacional de Desarrollo (BID)
- Physikalisch-Technische Bundesanstalt (PTB)
- Instituto Nacional de Tecnología, Normalización y Metrología (INTN)

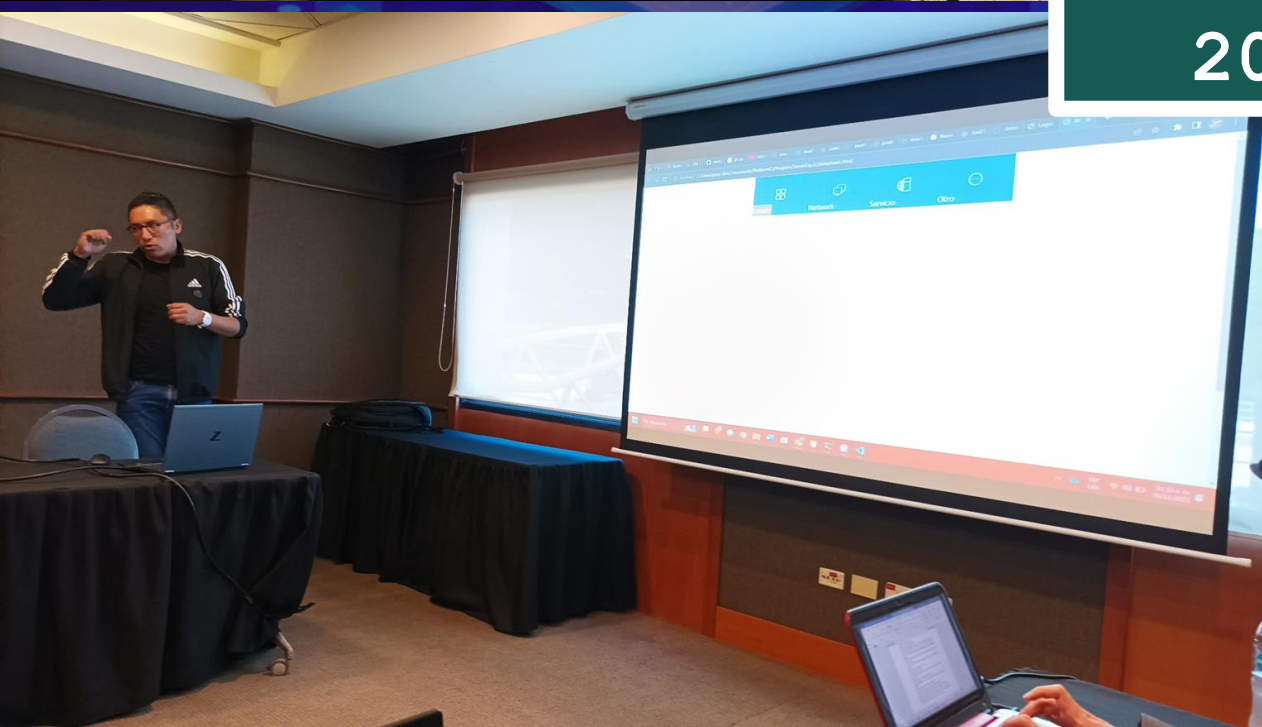
→ All participant NMIs:

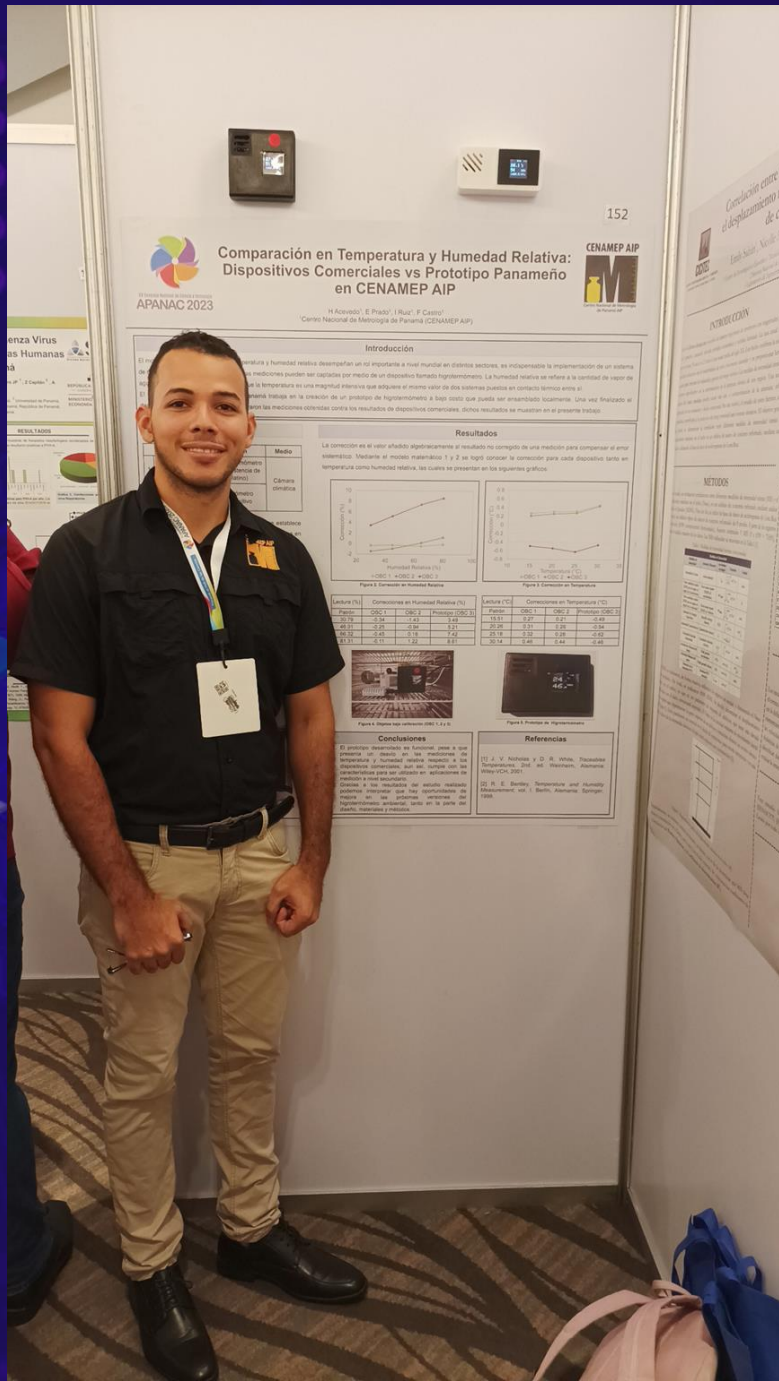
- CENAM
- CENAMEP
- INM
- LACOMET
- INACAL
- ENAER
- INEN





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