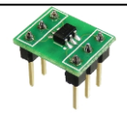
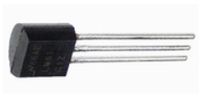
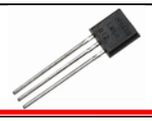
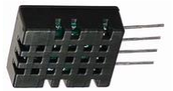
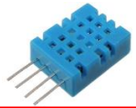
Humidity sensor survey (electronic work) [Which is the 1st place?]

- Practical data when used with ESP32
- Understand I2C basic specifications and programming

Table of contents

1. List of Humidity sensors to investigate (same list as temperature)

NO	Product	Model number	Picture	URL	Price(Yen)	I/O vol	Temperatu	Accuracy	Accuracy	Note
1	Temperature sensor IC ＭＣＰ９７００－Ｅ／ＴＯ	MCP9700-E/TO		https://akizukidenshi.com/catalog/g/gI-09692/	40	2.3~5.5V -	-40~ +125°C	±4°C (Max)	-	10.0mV/° C
2	Temperature sensor IC ＭＣＰ９７００Ａ－Ｅ／ＴＯ	MCP9700A-E/TO		https://akizukidenshi.com/catalog/g/gI-14300/	100	2.3~5.5V -	-40~ +125°C	±2°C /0~70°C Oth±4°C	-	10.0mV/° C
3	Temperature sensor IC ＴＭＰ３６ＧＴ９Ｚ	TMP36GT9Z		https://akizukidenshi.com/catalog/g/gI-14188/	200	2.3~5.7V -	-40~ +125°C	~±3°C /25°C	-	10.0mV/° C
4	Ｓ－５８５１Ａ digital temperature sensor module	S-5851AAA-M6T1U		https://akizukidenshi.com/catalog/g/gM-11575/	110	2.7~5.5V -	-40~ +125°C	±2°C/- 25~85°C Oth±3°C	-	You can purchase the sensor only [¥100]
5	Temperature sensor IC ＬＭ３３５Ｚ	LM335Z		https://akizukidenshi.com/catalog/g/gI-11158/	100	5~40V -	-40~ +100°C	±4°C (Max)	-	10.0mV/K ・Operating current: 400μA~5mA
6	Temperature sensor IC ＬＭ６１ＣＩＺ	LM61CIZ		https://akizukidenshi.com/catalog/g/gI-11160/	120	2.7~10V -	-30~ +100°C	±3°C/- 25~85°C Oth±4°C	-	10.0mV/° C Vo=(+10mV/°C×T°C)+600mV
7	Temperature sensor IC ＬＭ６０ＢＩＺ	LM60BIZ		https://akizukidenshi.com/catalog/g/gI-02490/	180	2.7~10V -	-25~ +125°C	±3°C/- 25~125°C Oth±4°C	-	6.25 mV/° C
8	Temperature and humidity sensor ＡＨＴ２５	AHT25		https://akizukidenshi.com/catalog/g/gM-16731/	350	2.2~5.5V -	-40~ +80°C	±0.3°C	±2%RH	
9	Temperature and humidity sensor ＤＨＴ２０	DHT20		https://akizukidenshi.com/catalog/g/gM-16732/	380	2.2~5.5V -	-40~ +80°C	±0.5°C	±3%RH	
10	Temperature and humidity sensor ＡＨＴ２１Ｂ	AHT21B		https://akizukidenshi.com/catalog/g/gK-17394/	400	2.2~5.5V -	-40~ +80°C	±0.5°C	±5%RH	
11	Temperature and humidity sensor ＤＨＴ１１	DHT11		https://akizukidenshi.com/catalog/g/gM-07003/	480	3.3~5.5V -	0~ +50°C	±2°C	±5%RH	
Total					**2,460**	Separate shipping fee required				

Selection criteria (IT Taro survey)
・3.3V/5V compatible
・Choose from the lowest price

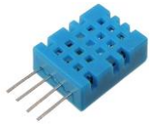
1. Humidity sensor to investigate (in specifications)

All humidity sensors are types that output data.
Sensors without libraries tend to complicate I2C programming.

<table>
<tr><th>Type</th><th>ESP32 Terminal (port)</th><th>Circuit/wiring</th><th>Programming</th><th>Note</th></tr>
<tr><td rowspan="3">Data output

Output temperature and humidity data inside the sensor</td><td rowspan="2">I2C
[AHT25,DHT20,AHT21B]

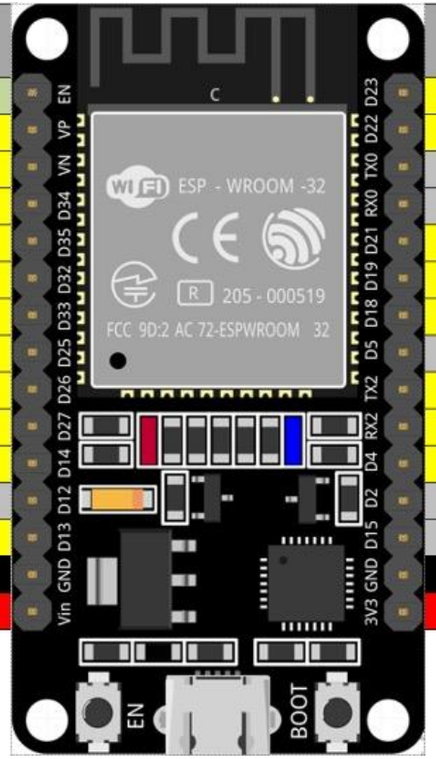
 
Fixed I2C port</td><td rowspan="2">fixed port
Need to consider address collision</td><td>I2C somewhat difficult</td><td rowspan="2">nothing special</td></tr>
<tr><td>Library
[AHT21B]</td></tr>
<tr><td>GPIO(data communication)
[DHT11]

  </td><td>high degree of freedom</td><td>Library
[DHT11]</td><td>Less accurate than I2C products
[DHT11]</td></tr>
</table>

2-1. ESP32 port

● ESP32 port configuration

Touch	SPI/ DAC	Analog (ADC)		IO
				EN
		1-0	A0	GPI 36(VP)
		1-3	A3	GPI 39(VN)
		1-6	A6	GPI 34
		1-7	A7	GPI 35
T9		1-4	A4	GPIO32
T8		1-5	A5	GPIO33
	DAC_1	2-8	A18	GPIO25
	DAC_2	2-9	A19	GPIO26
T7		2-7	A17	GPIO27
T6	HSPICLK	2-6	A16	GPIO14
T5	HSPIQ	2-5	A15	GPIO12
T4	HSPID	2-4	A14	GPIO13
				GND
				5V



IO	Analog (ADC)		SPI/ Serial	I2C/ Touch
GPIO23			VSPID	
GPIO22			VSPIWP	SCL
GPIO1			TXD0	
GPIO3			RXD0	
GPIO21			VSPIHD	SDA
GPIO19			VSPIQ	
GPIO18			VSPICLK	
GPIO5			VSPICS0	
GPIO17			TXD2	
GPIO16			RXD2	
GPIO4	A10	2-0	HSPIHD	T0
GPIO2	A12	2-2	HSPIWP	T2
GPIO15	A13	2-3	HSPICS0	T3
GND				
3.3V				

●I2C terminal

This is a method advocated by Philips, and is one of the synchronous serial communication methods. Along with SPI, it is often used for data communication between microcomputers and sensors.

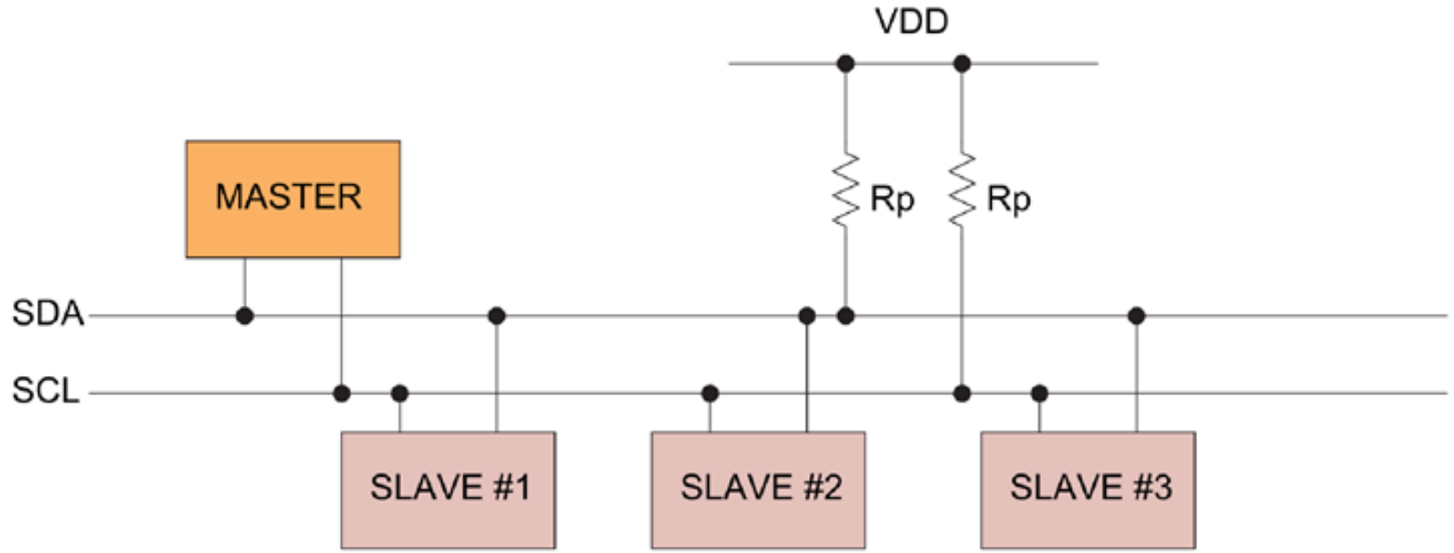
・The I2C interface is as follows.
  SCL: GPIO22
  SDA: GPIO21
・The address of the device to be connected is fixed, and multiple connections are possible.

●GPIO terminal

An abbreviation for General Purpose Input/Output, this is a general-purpose I/O port with normal terminals.
The input-only port is GPI, so the serial communication this time is Output also uses the available GPIO terminal.

2-2. I2C

I2C configuration



https://www.analog.com/jp/technical-articles/i2c-primer-what-is-i2c-part-1.html

- Connected by bus wiring (branching from main line) in a master/slave configuration
- The address of the device to be connected must be unique (cannot communicate if duplicated)
- The master sends a trigger by specifying an address, and the slave at the corresponding address responds. (All slaves receive the trigger, but only the device with the corresponding address responds)
- Communication cannot be initiated from the slave.

3-1. AHT25

[Reference URL]
https://akizukidenshi.com/download/ds/aosong/AHT25.pdf
https://qiita.com/ayakix/items/69cf14e57dec86f4415a

- Power supply voltage: 3.3V (2.2 to 5.5V)
- Current consumption: 980 μA (when measuring), 250 nA (not measuring)
- Measurement interval: Recommended every 2 seconds or more
- Humidity measurement range: 0 to 100% RH
- Humidity resolution: 0.024%
- Humidity accuracy: ±2%RH
- Temperature measurement range: -40 to 80℃
- Temperature accuracy: ±0.3℃
- Output format: **I2C** (100kHz/400kHz) **0x38** (7bit address)
- Output data: humidity 20bit, temperature 20bit

Pins	Name	Describe
1	VDD	Power supply(2.2v to 5.5v)
2	SDA	Serial Data Bidirectional port
3	GND	Ground
4	SCL	Serial clock Bidirectional port

Table 5. ATH21B pin distribution (top view)

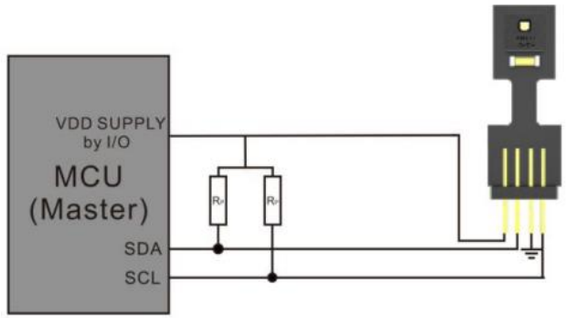
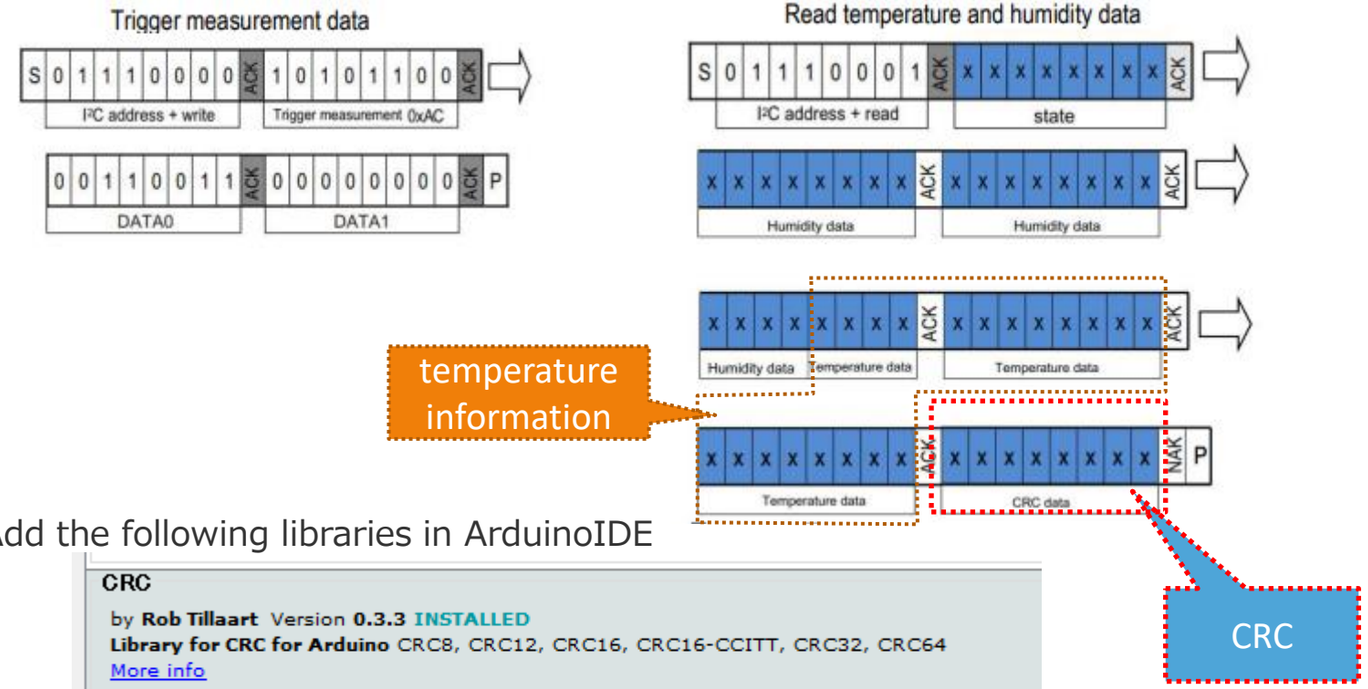


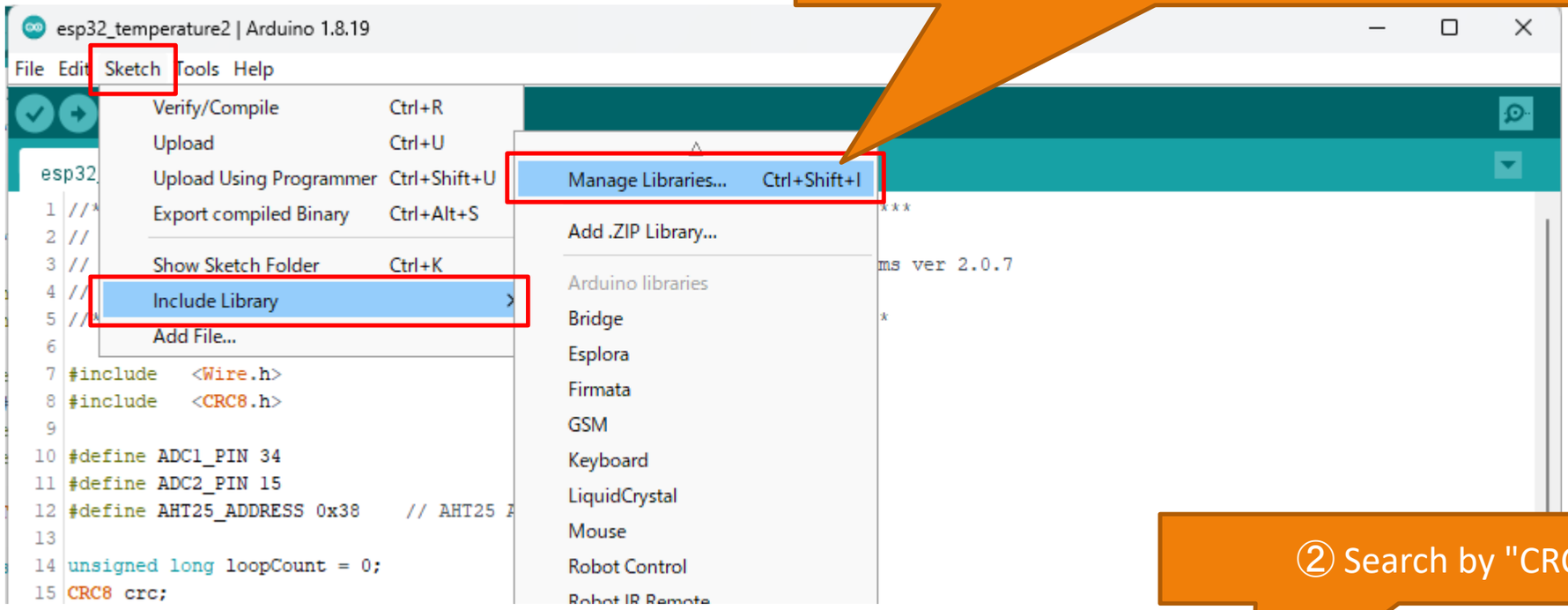
Figure 8. Typical application circuit



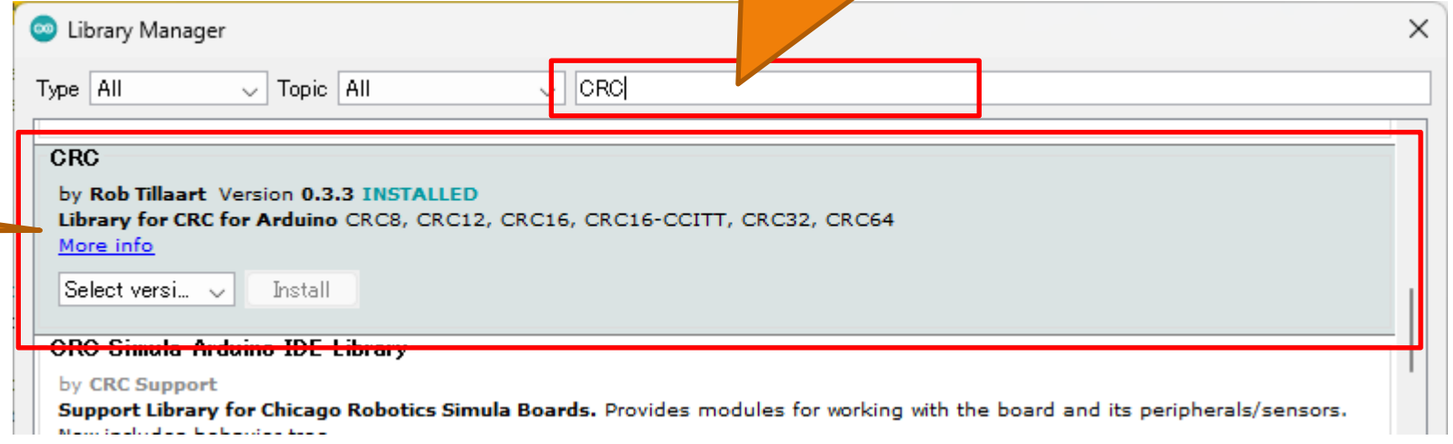
Add the following libraries in ArduinoIDE

3-1. Add “CRC” library

①Launch Library Manager
「Sketch」⇒「Include library」⇒「Manage Libraries」



② Search by "CRC"



③ Install this library

3-2. AHT21B

[Reference URL]
https://akizukidenshi.com/download/ds/aosong/AHT21B.pdf

- Power supply voltage: 3.3V (2.2 to 5.5V)
- Current consumption (when measuring): 980μA
- **Interface: I2C**
- Resolution (humidity): 0.024%RH
- Accuracy (humidity): ±3% RH
- Operating range (humidity): 0 to 100% RH
- Resolution (temperature): 0.01℃
- Accuracy (Temperature): ±0.5℃
- Operating range (temperature): -40 to +80℃

5 Interface Definition

Pins	Name	Describe
1	VDD	Power supply(2.2v to 5.5v)
2	SDA	Serial Data Bidirectional port
3	GND	Ground
4	SCL	Serial clock Bidirectional port

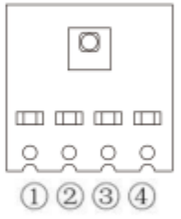


Table 5. ATH21B pin distribution (top view)

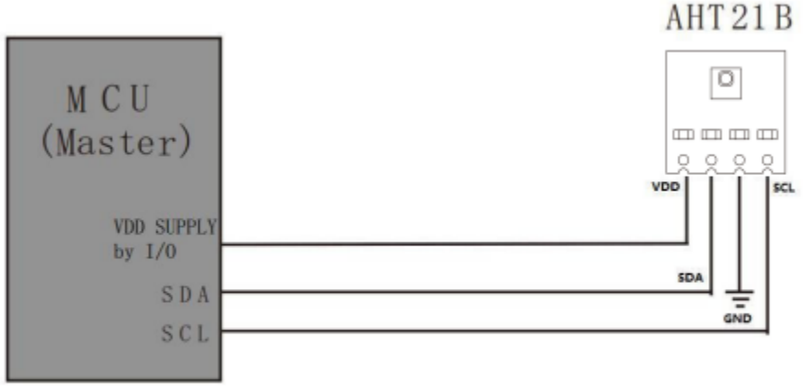
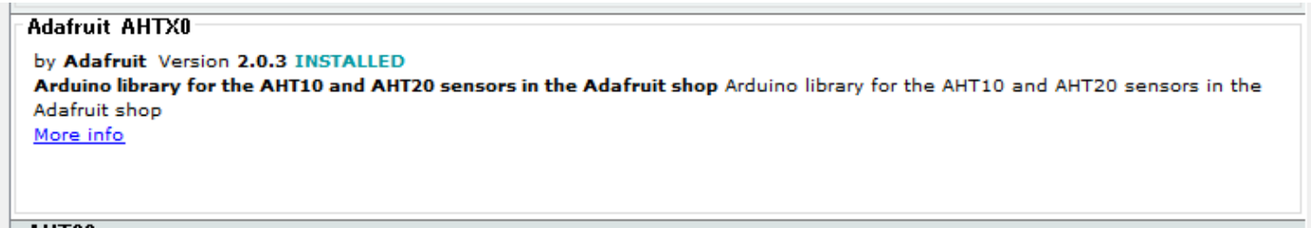


Figure 8. Typical application circuit

Add the following libraries in ArduinoIDE



3-3. DHT20

[Reference URL]
https://akizukidenshi.com/download/ds/aosong/DHT20.pdf
https://hatakekara.com/dht20-arduino/

- Power supply voltage: 3.3V (2.2 to 5.5V)
- Current consumption: 980μA (250nA at standby)
- Measurement interval: recommended every 2 seconds
- Dimensions: 16.1mm (not including pin length) x 12.6mm x 5.8mm
- Pin pitch: 2.54mm
- Humidity measurement range: 0 to 100% RH
- Humidity resolution: 0.024%RH
- Humidity accuracy: ±3%RH
- Humidity repeatability: 0.1%RH
- Humidity response time: within 8 seconds
- Temperature measurement range: -40 to 80℃
- Temperature resolution: 0.01℃
- Temperature accuracy: ±0.5℃
- Temperature repeatability: ±0.1℃
- Temperature response time: 5 to 30 seconds
- **Output format: I2C (100kHz/400kHz), 0x38 (7bit address)**
- **Output data: humidity 20bit, temperature 20bit**

5 Interface Definition

Pins	Name	Describe
1	VDD	Power supply(2.2v to 5.5v)
2	SDA	Serial Data Bidirectional port
3	GND	Ground
4	SCL	Serial clock Bidirectional port

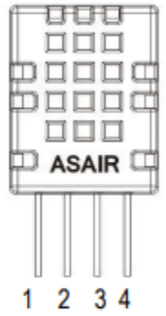


Table 5. ATH21B pin distribution (top view)

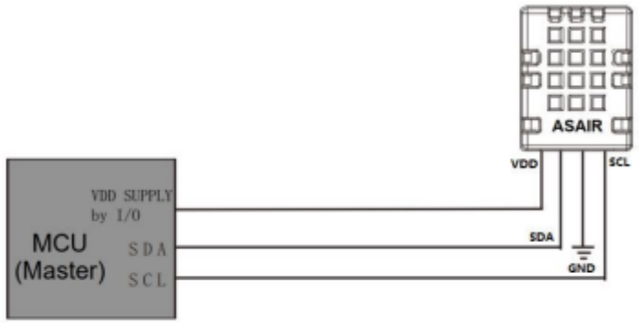


Figure 8. Typical application circuit

3-3. I2C Programing

All the programs used for the measurement are open to the public.
《Hobby-IT》 https://hobby-it.com/
(The URL is listed in the summary column.)

[参考URL]
https://akizukidenshi.com/download/ds/aosong/DHT20.pdf
https://hatakekara.com/dht20-arduino/

```
58 void updateDht20 () {
59   float hu, tp;
60   uint8_t buf[8];
61   long a;
62   int flg;
63
64   delay(500);
65   flg = 1;
66   while (flg) {
67       Wire.beginTransmission(DHT20_ADDRESS);
68       Wire.write(0xac);
69       Wire.write(0x33);
70       Wire.write(0x00);
71       Wire.endTransmission();
72       delay(100);
73
74       Wire.requestFrom(DHT20_ADDRESS, 6);
75       for (uint8_t i = 0; i < 6; i++)  buf[i] = Wire.read();
76
77       if (buf[0] & 0x80) Serial.println("Measurement not Comp");
78       else flg = 0;
79   }
80   a = buf[1];
81   a <<= 8;
82   a |= buf[2];
83   a <<= 4;
84   a |= ((buf[3] >> 4) & 0x0f);
85   hu = a / 10485.76;
86
87   a = (buf[3] & 0xf);
88   a <<= 8;
89   a |= buf[4];
90   a <<= 8;
91   a |= buf[5];
92   tp = a / 5242.88 - 50;
93
94   Serial.printf("[%ld] DHT20[I2C], temprature=%f[°], humidity=%f[%]\n", loopCount, tp, hu);
95 }
```

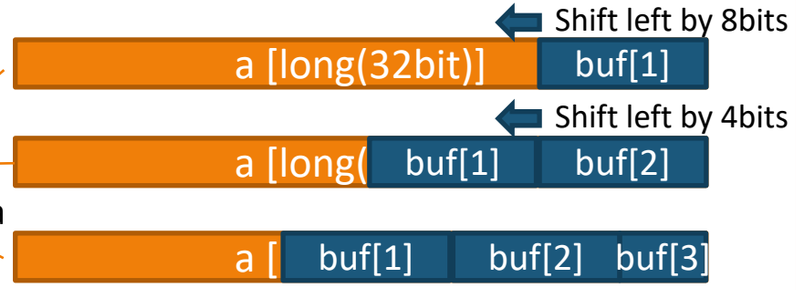
Address 0x38

Trigger 0xAC,33,00

Assign buf[1] to a, Shift left by 8 bits

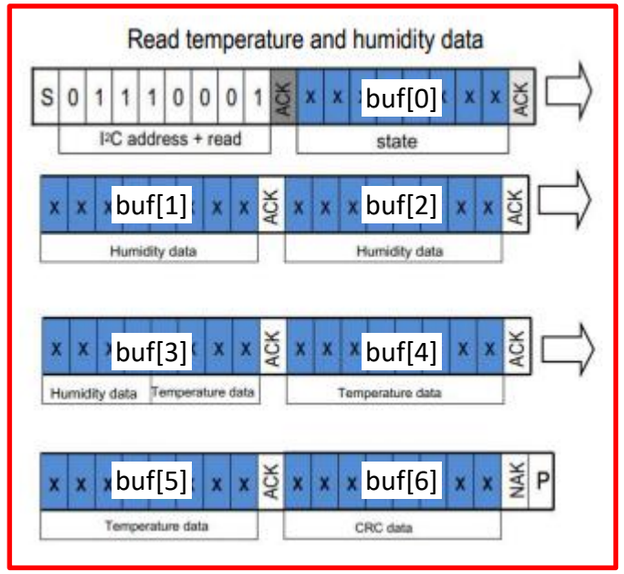
Assign buf[2] to a, Shift left by 4 bits

Assign only left 4bit of buf[3] to a



$$RH[\%] = \left(\frac{S_{RH}}{2^{20}}\right) * 100\%$$

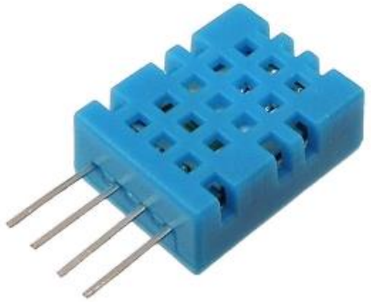
Read data



Display the calculated value on the serial monitor

3-4. DHT11

[Reference URL]
https://akizukidenshi.com/download/ds/aosong/DHT11_20180119.pdf



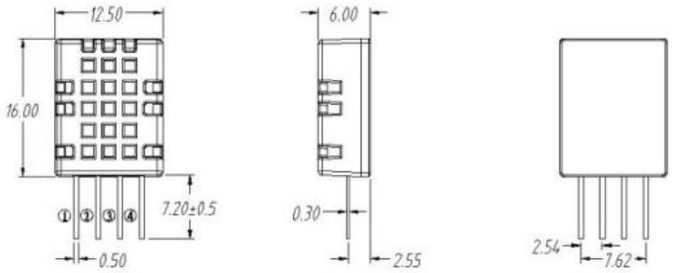


FIG. 1 product dimension diagram

Pin description

1. VDD power supply 3.3 ~ 5.5V DC
2. DATA serial DATA, single bus
3. NC empty feet
4. GND grounding, power supply negative

◆ Main specifications
・Power supply voltage: DC3.3V~5.5V
・Current consumption: 0.3mA (during measurement), 60μA (during standby)
・Sampling interval: 2 seconds or more
・Internal AD converter: 16bit each
・Size: 12 x 15.5 x 5.5mm (not including pins)
◆ Humidity sensor
・Sensor: Organic polymer
・Accuracy: ±5% RH (@25℃)
・Repeatability: ±1% RH
・Response: Within 6 seconds (1/e (63%), @25℃, wind speed 1m/s)
◆Temperature sensor
・Sensor: NTC thermistor
・Accuracy: ±2°C (@25°C)
・Repeatability: ±0.2℃
・Response: Within 10 seconds (1/e (63%))
◆**Serial communication part**
・Format: Single-wire bus (bi-directional), serial 40-bit configuration
・Output data: **Humidity 8bit** (Resolution: 1%RH), **Temperature 8bit** (Resolution: 1℃)
・Output: Open drain

Typical circuits

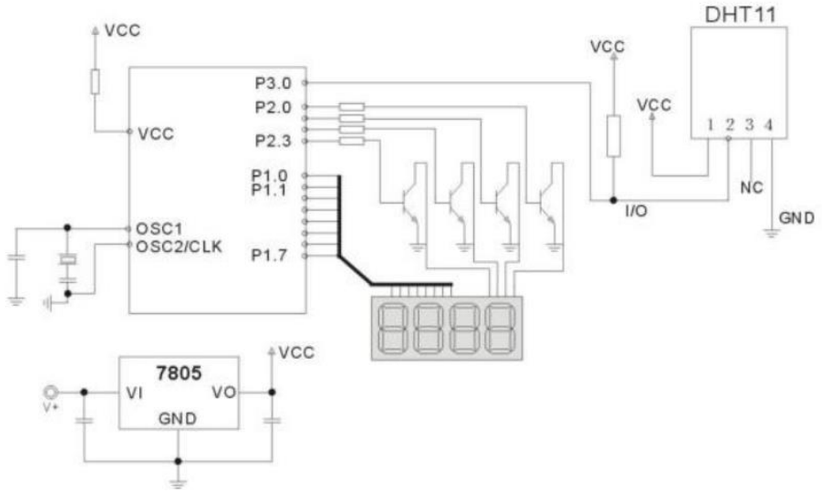
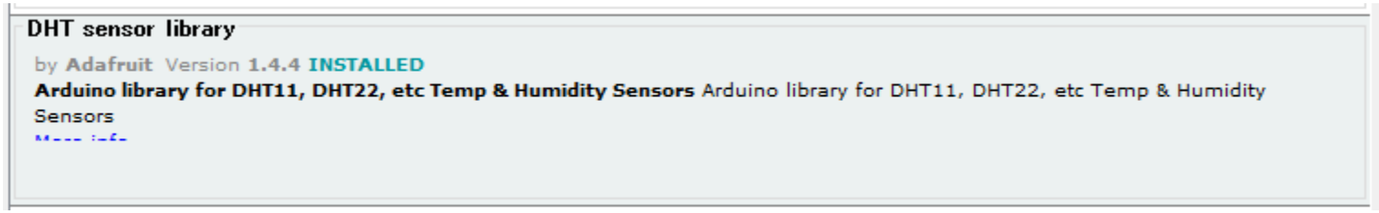


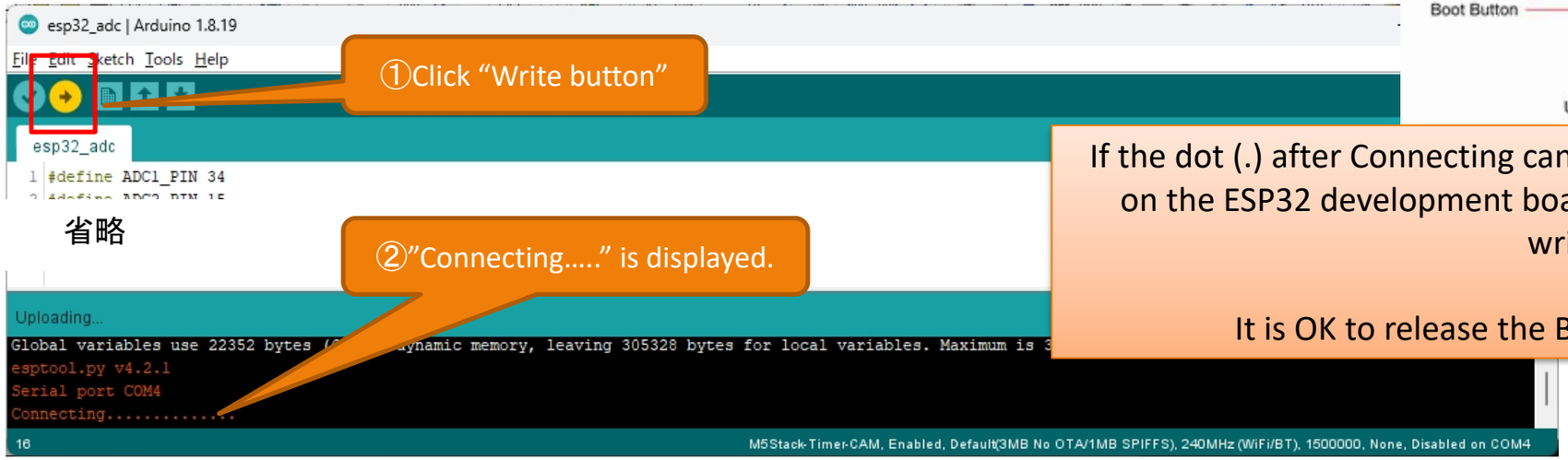
FIG. 1-2 DHT11

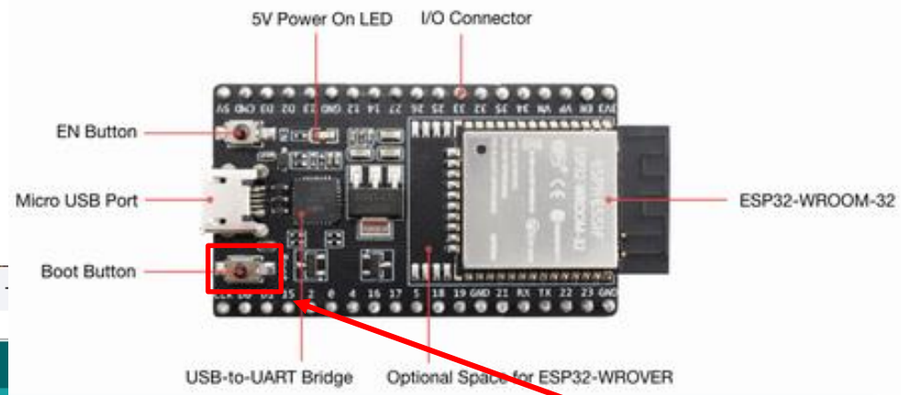
Add the following libraries in ArduinoIDE



reference. Writing to ESP32 development board

● Notes on writing to the ESP32 development board





If the dot (.) after Connecting cannot be connected, press the Boot button on the ESP32 development board (connect IO0 and GND) and check if writing starts.

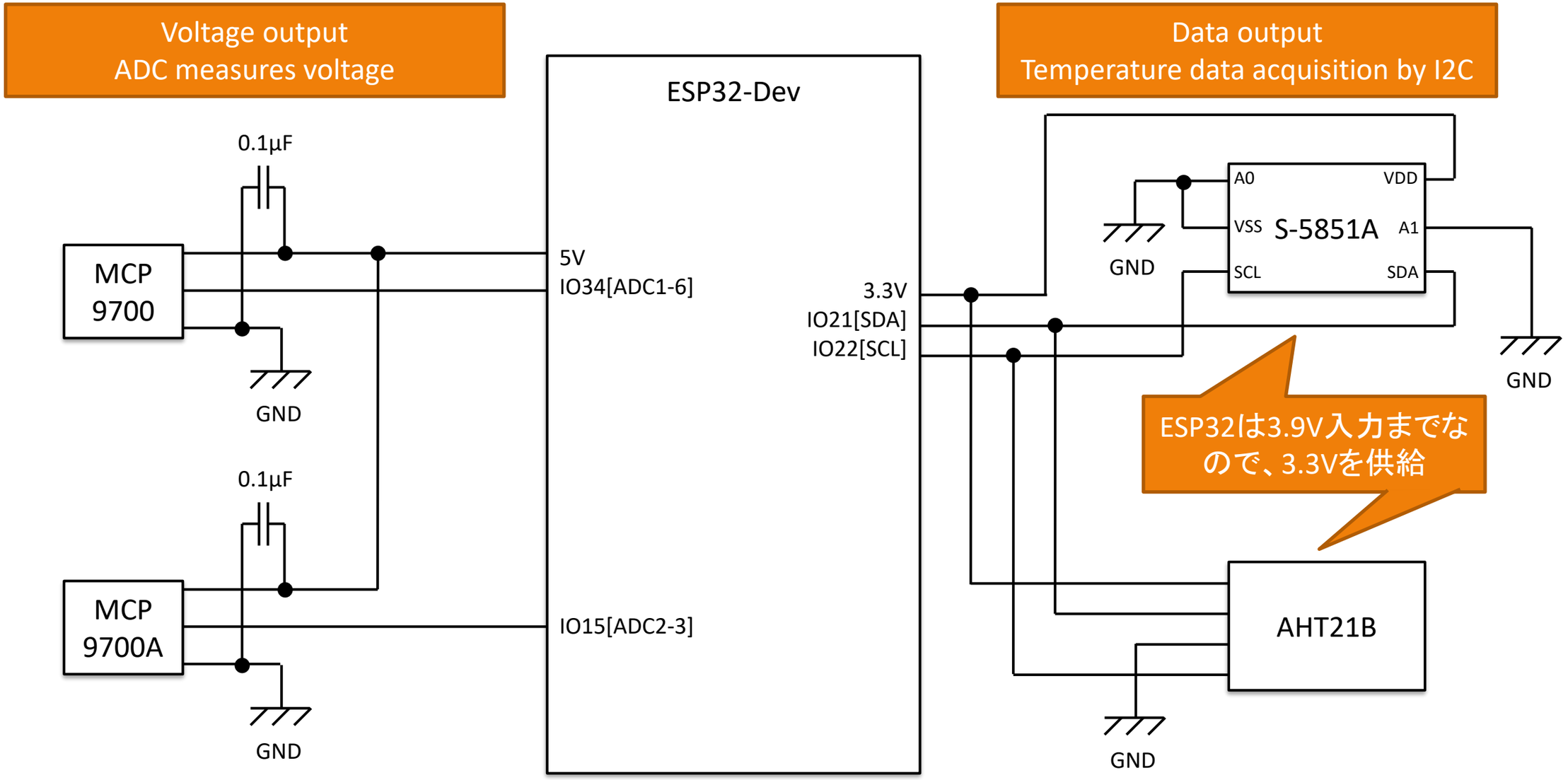
It is OK to release the Boot button when writing starts

<<Reference>> Errors that frequently occur in ESP32 and how to deal with them

	Error details (ArduinoIDE message monitor)	Workaround
at compile time (When writing file is created)	xxxxxx.h: No such file or directory	Check if the included library is added
when writing	A fatal error occurred: Failed to connect to ESP32: Timed out waiting for packet header A fatal error occurred: Failed to connect to ESP32: Invalid head of packet	① If “Connecting….” is not displayed, check the completion of compilation ② USB cable connection (Confirm connection between ESP32 development board and PC) ③ ArduinoIDE settings (including serial port settings) ④ Press the Boot button (connect IO0 to GND) when “Connecting….” is displayed. When writing starts, release the Boot button and OK. ⑤ Confirmation by sequentially replacing ESP32, USB cable, and PC
<Reference> When using SPIFFS after startup	SPIFFS: mount failed SPIFFS Failed This is displayed on the serial monitor	Write data with SPIFFS uploader (You need to write [Upload] even once to use SPIFFS)

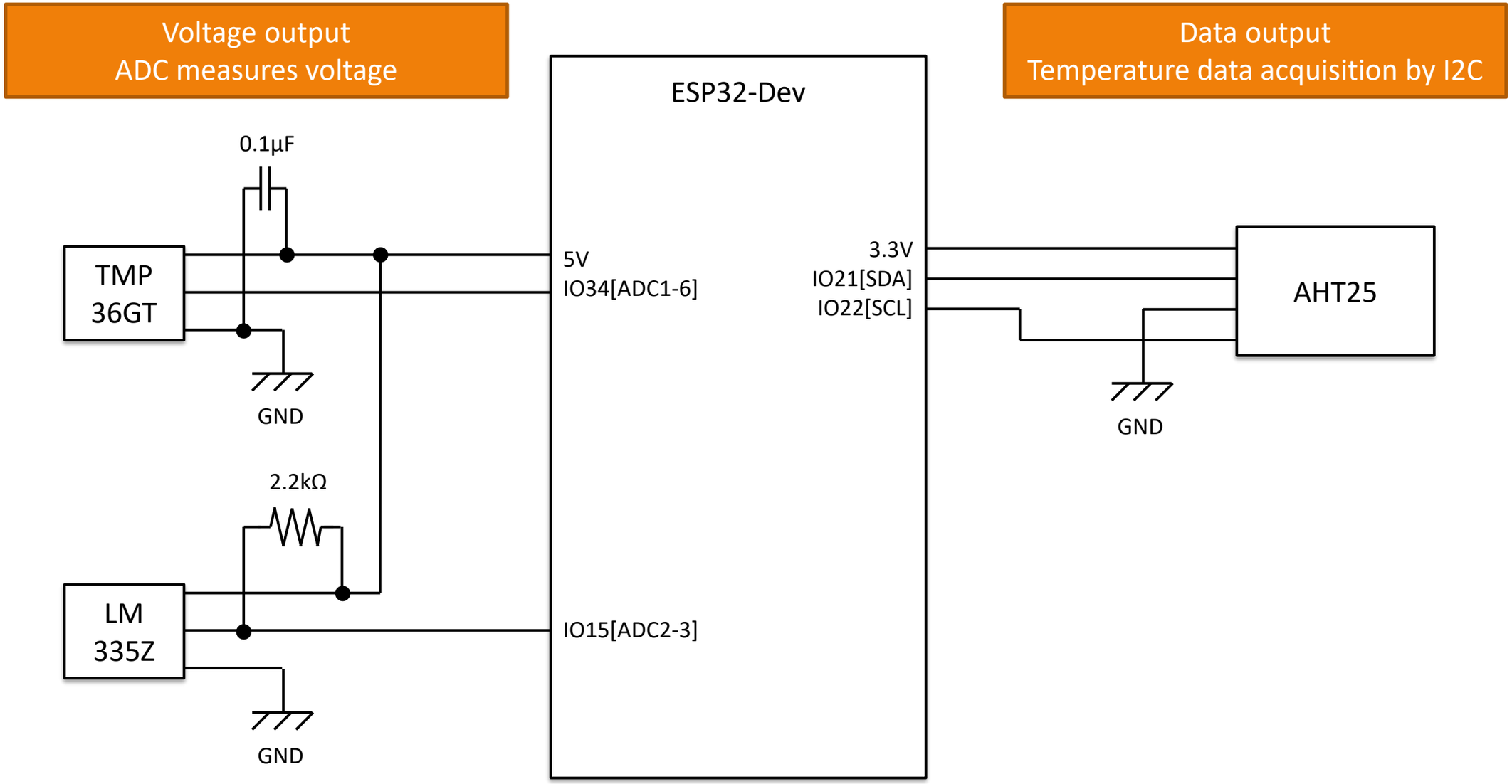
4-1. Circuit 1 (Same circuit as temperature measurement)

Measure the voltage of MCP9700/9700A with ADC1,2 and calculate the temperature.
The S-5851A and AHT21B are connected to the I2C bus to acquire temperature data.



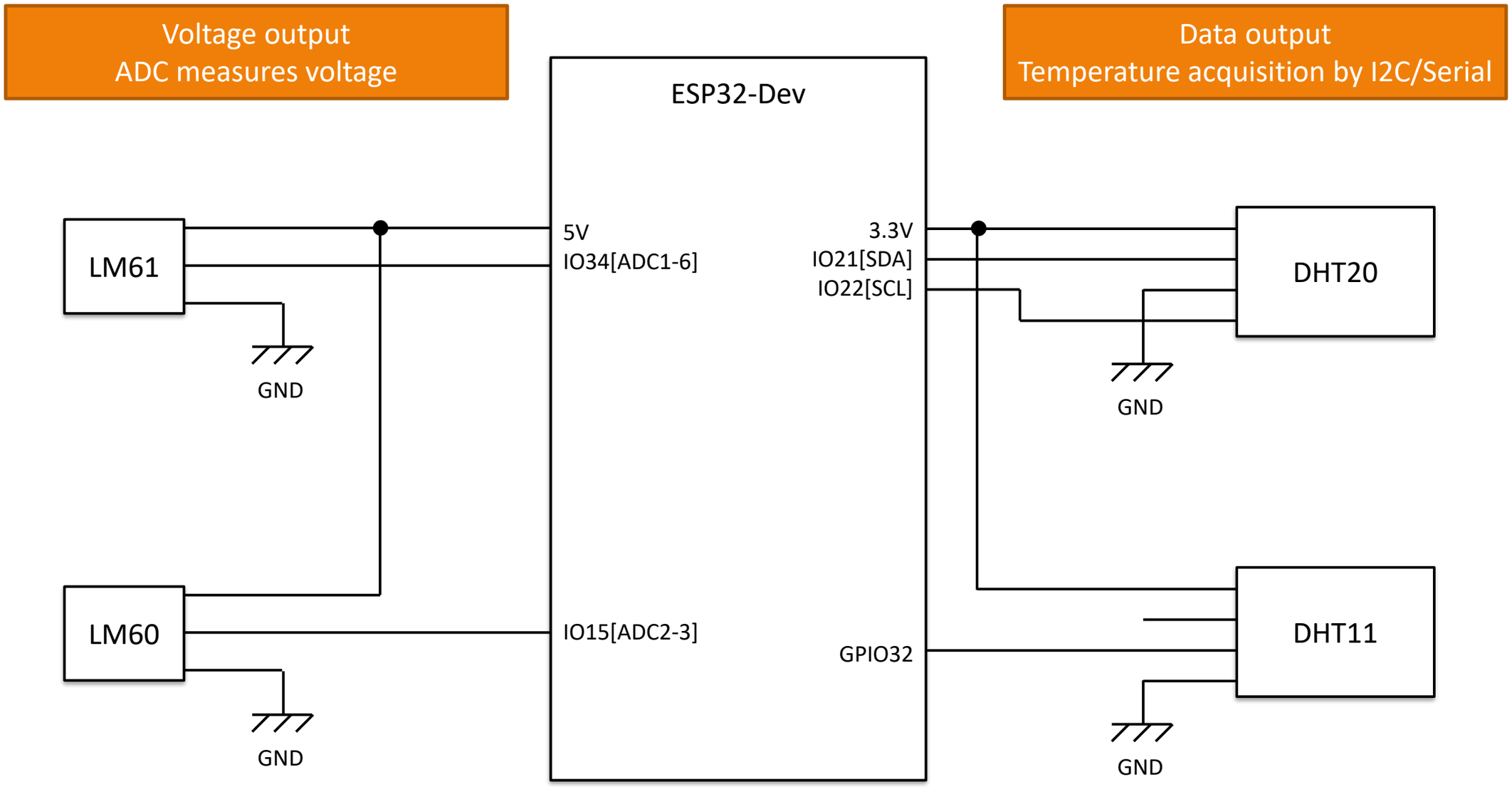
4-2. Circuit 2 (Same circuit as temperature measurement)

Calculate the temperature by measuring the voltage of the TMP36GT with ADC1 and the LM335 with ADC2.
AHT25 uses I2C to acquire temperature data.



4-3. Circuit 3 (Same circuit as temperature measurement)

Measure the voltage of LM60/LM61 with ADC1,2 and calculate the temperature.
DHT20 uses I2C and DHT11 uses GPIO32 to acquire temperature data.



5. Measuring instrument (hygrometer)

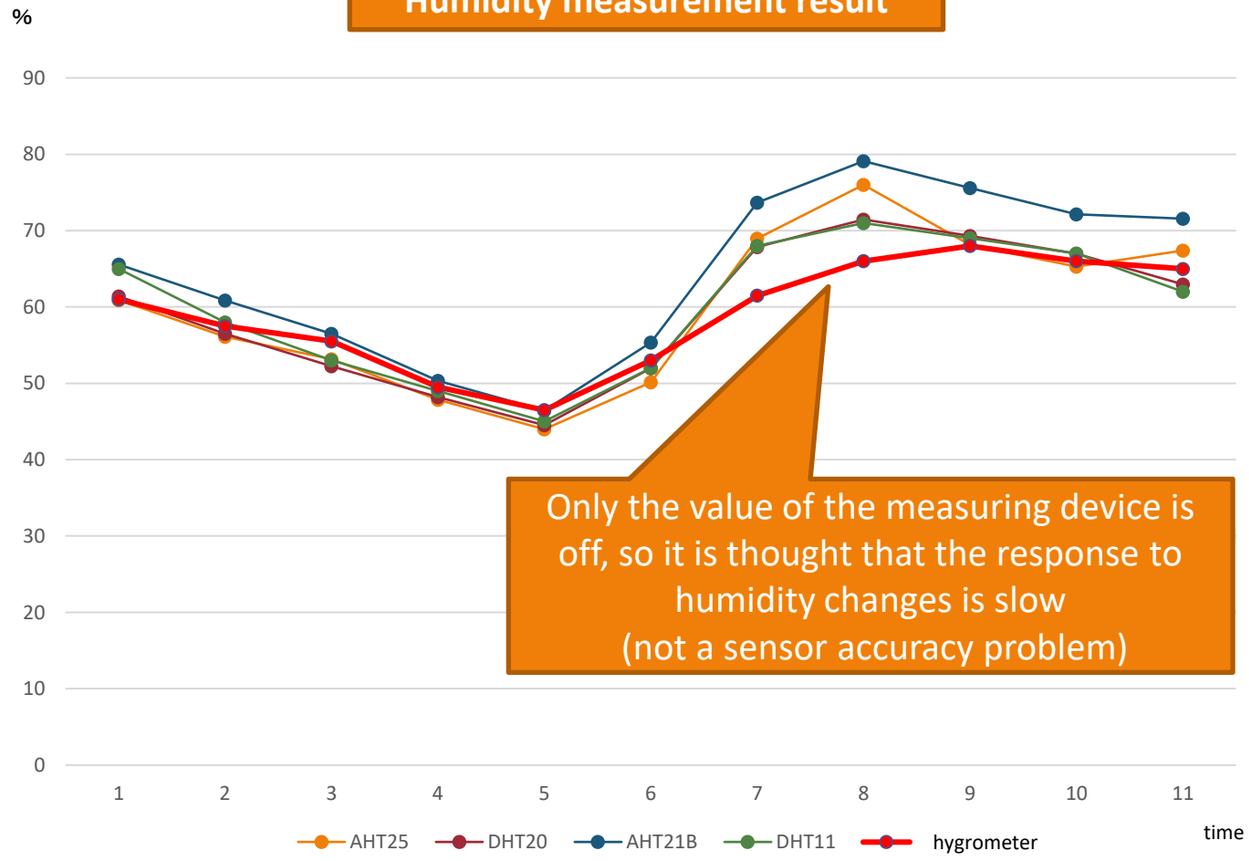
In order to measure the temperature as accurately as possible, four thermometers are prepared, and the average value is used by excluding the specific values that deviate greatly.

	Manufacturer	Model number		Measurement range (temperature humidity)	Accuracy (temperature humidity)
1	TANITA	Digital thermohygrometer TT-558		-5～50℃ 20～95%	0～40℃ ±1℃ （Other ±2℃） 35～75% ±5% （Other ±10%）
2					
3		Digital thermohygrometer TT-585		-5～50℃ 20～95%	0～40℃ ±2℃ （Other ±3℃） 35～75% ±5% （Other ±10%）
4	Shinwa measurement	72669 Thermo-hygrometer U-3(Round 6.5cm)		-24～50℃ 10～90%	-20～40℃ ±2℃ （Other ±4℃） 35～75% ±5% （Other ±10%）

6. Measurement result

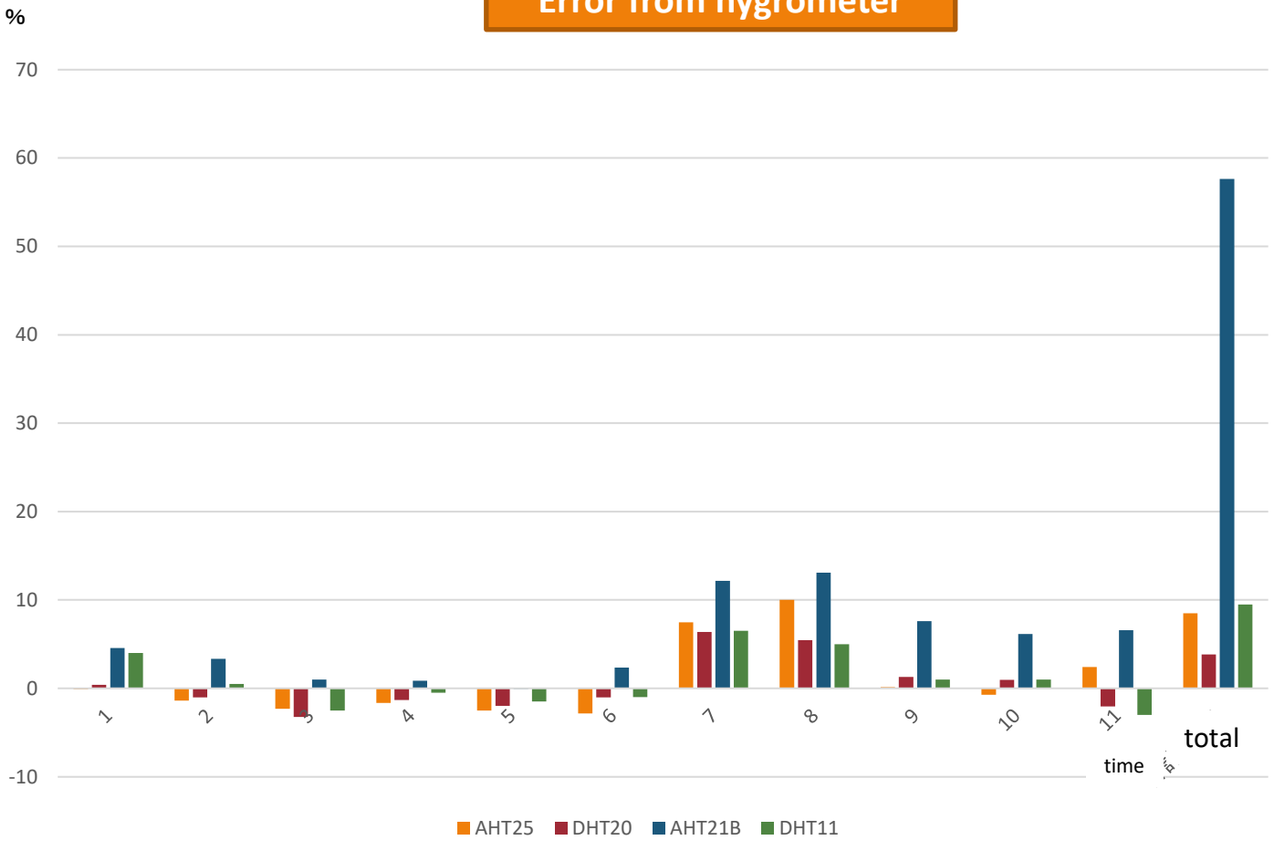
- High-precision measurements require advanced measuring instruments, but in normal use, any sensor can measure humidity changes.
- This time, the error is the least 1st place: DHT20 2nd place: AHT25 3rd place: DHT11

Humidity measurement result



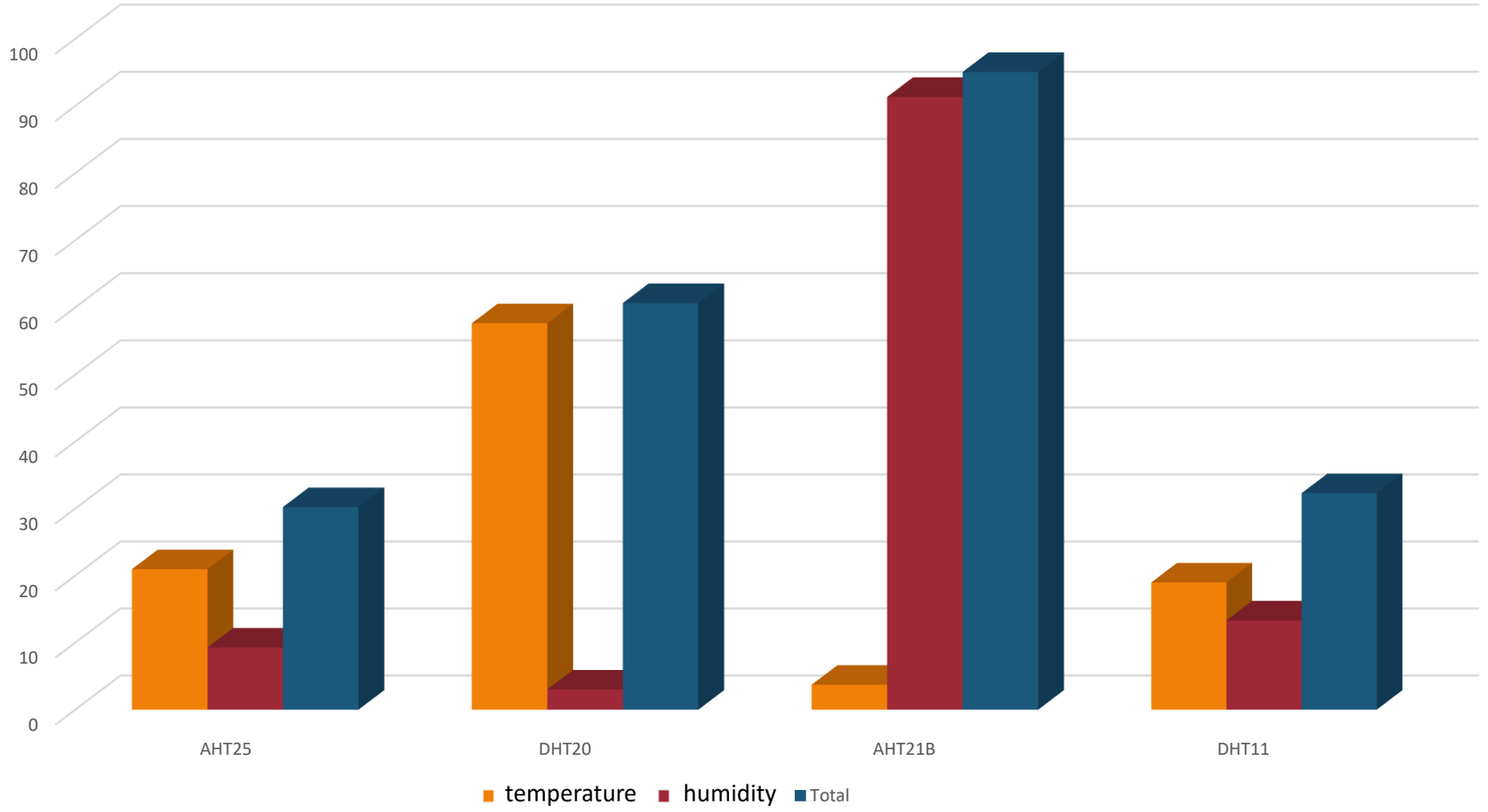
Only the value of the measuring device is off, so it is thought that the response to humidity changes is slow
(not a sensor accuracy problem)

Error from hygrometer



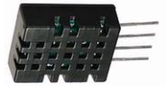
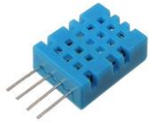
6. Measurement result (temperature and humidity error rate)

- Calculate the error rate for all measurements of temperature and humidity (10% if there is an error of 2℃ at 20℃) and total
- Least error rate　1st place: AHT25 2nd place: DHT11 3rd place: DHT20



7. Summary (Consideration: temperature and humidity sensor)

If you use it for electronic work, I felt that "DHT20" is the best in terms of accuracy, ease of work, price, etc.
However, I2C programming is somewhat complicated, so if you want to make programming easier, "DHT11"

Type	Product	Price	Accuracy	Ease of work	Programming	Note
I2C	[AHT25] 	○ 350 yen	○ Available	△ Cable required for use on a breadboard	△ I2C somewhat complicated	nothing special
	[AHT21B] 	△ 400 yen	○ Available	○ Easy	○ Library available [AHT21B]	
	[DHT20] 	○ 380 yen	○ Available	○ Easy	△ I2C somewhat complicated	
Serial communication	[DHT11] 	△ 480 yen	○ Available	○ Easy	○ Library available [DHT11]	△ Decimal numbers cannot be measured