Let it Glow Maker Advent Calendar Day #9: Ice Cold Coding!

By The Pi Hut • Dec 9, 2023 • 0 comments

It's **day #9** of the Let it Glow Maker Advent Calendar!

Today is another control component day, and it just wouldn't be right for us not to include a **temperature sensor** considering the cold snap you usually get at this time of year (and how fun they are to play with!).

The festive season is usually a chilly one, so we'll show you how to use this sensor to keep an eye on the winter temperatures whilst using our blinky components to give us visual indication of how hot or cold it is inside.

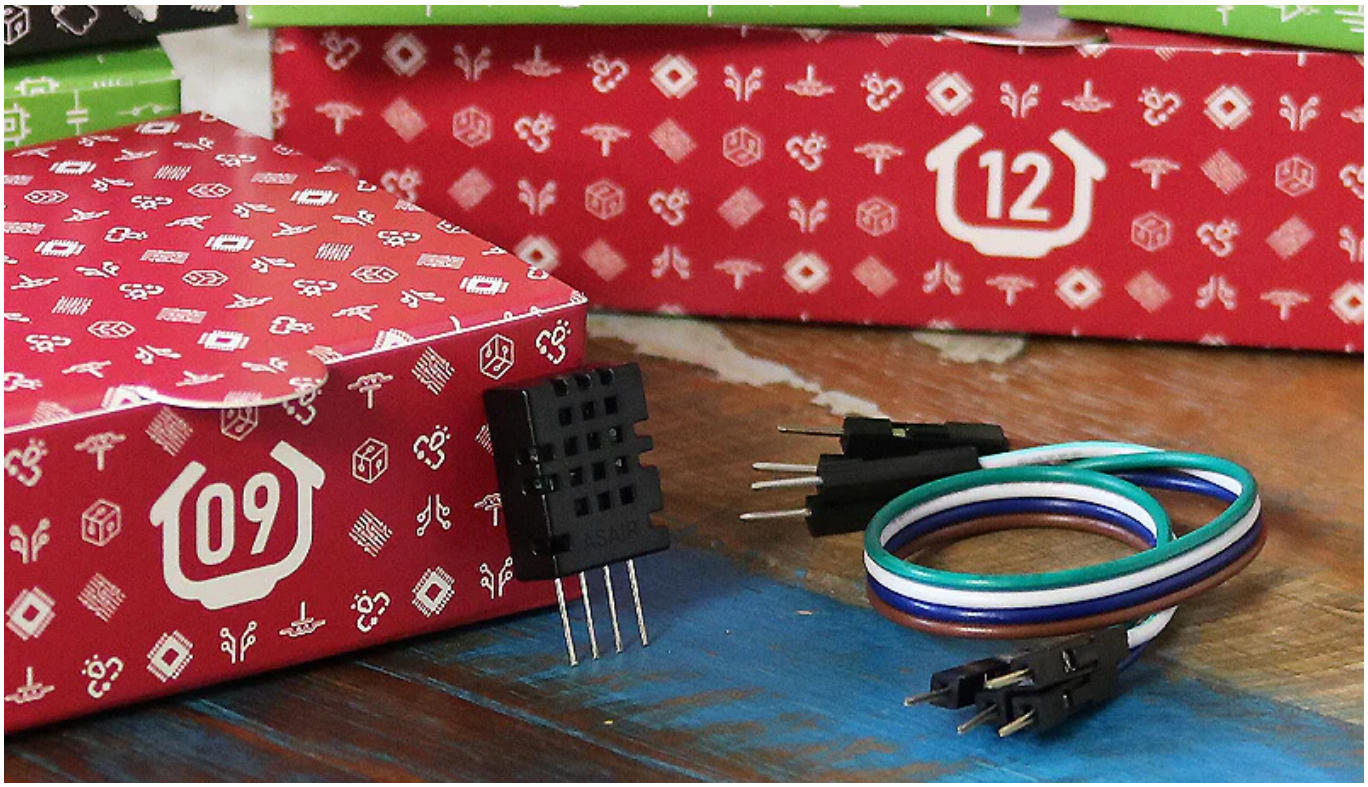
The sensor in today's box is a little smarter than some others, as **it can measure both temperature and humidity** and talks to our Pico in a different way using something called **I2C**. Don't worry, we'll explain it all!

Let's get coding...

Box #9 Contents

In this box you will find:

- 1x DHT20/AHT20 temperature and humidity sensor
- 4x Male to male jumper wires



Today's Activities

Today we're going to learn how to use this temperature sensor, using the readings in our code to

print the information and drive our RGB LEDs.

There's a lot to learn today including some slightly more advanced stuff including **I2C**, **library installation** and **dictionaries**, so let's get cracking!

What is I2C?

I2C, sometimes referred to as **IIC**, stands for **I**nter-**I**ntegrated **C**ircuit.

It's a *communication protocol* which allows multiple I2C devices to communicate to a controller like our Pico, passing data to it for us to use in our program.

I2C requires just two wires to communicate (along with 3.3V and GND wires for our sensor) and has benefits over some other communication options - but we won't bore you with that just now as it's not going to be relevant until you're much further along on your maker journey.

You can't use just any old GPIO pin for I2C either, **you have to use the blue SDA or SCL pins**, which you'll see on the Pico pin map.

To use I2C we also need to import it in our code, which we'll show you in just two ticks!

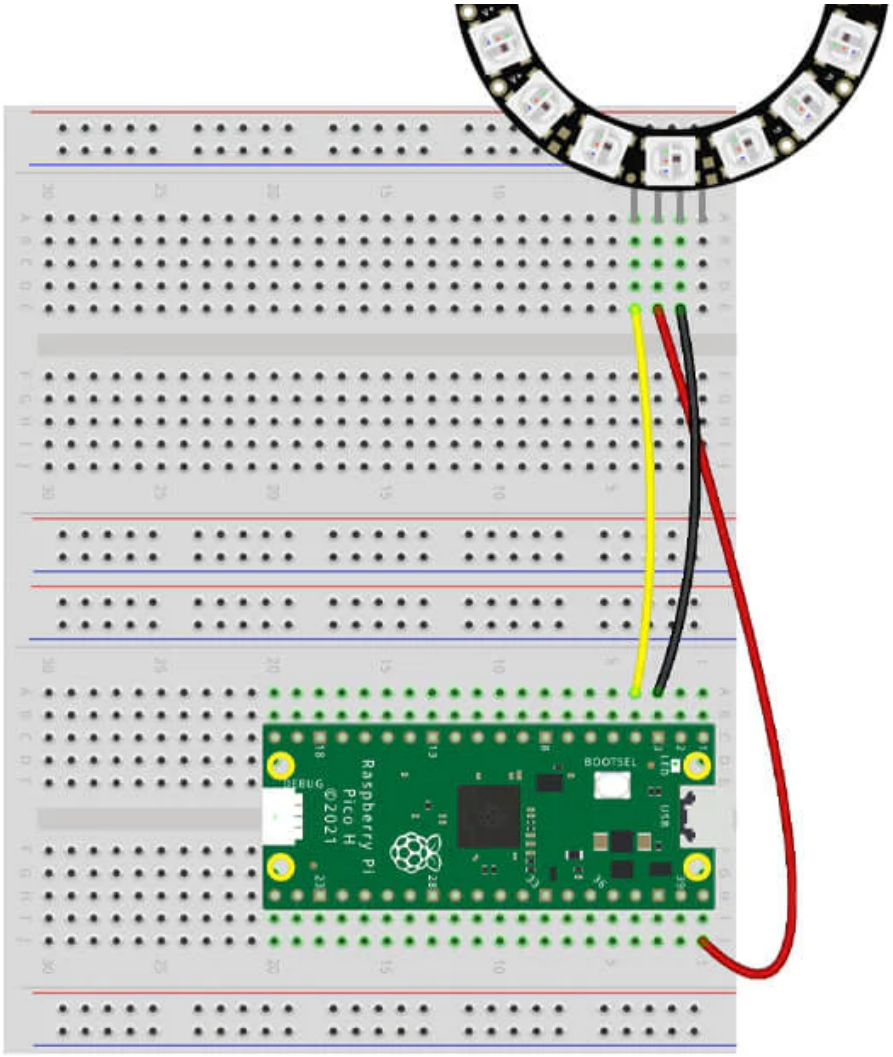
Construct the Circuit

As always, make sure your Pico is disconnected from the USB cable when working on the circuit.

Prepare the breadboard

We'll be using our LED Ring with the temperature sensor, so keep that wired up the same as yesterday, and **remove the slide potentiometer**.

Here's your starting point:



Fit the temperature sensor

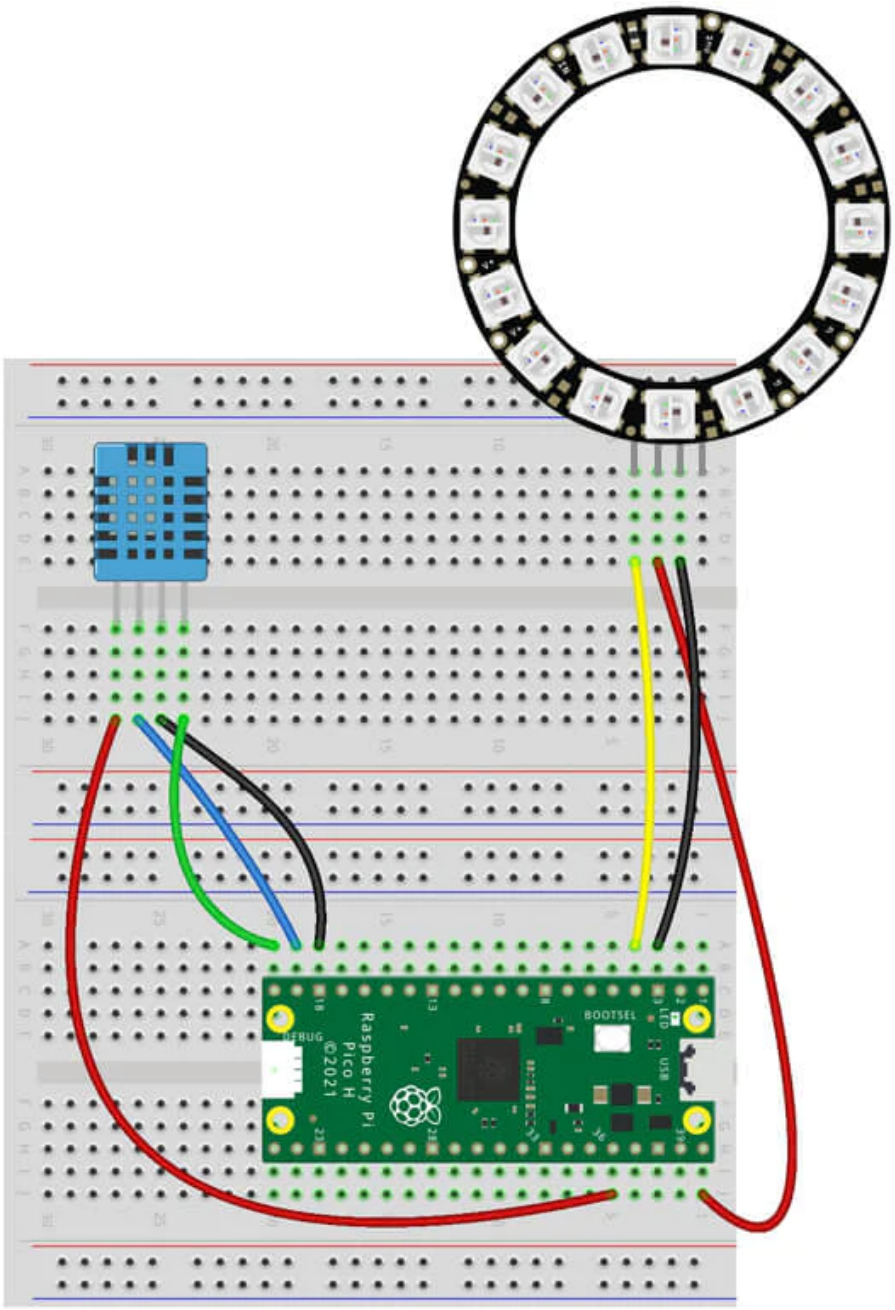
It's another easy component today, with just four pins to hook up. **Just be gentle with it**, those little legs don't like being forced!

First fit the sensor to the right-hand side of your breadboard. You need the front (the side with holes that looks a bit like a tasty waffle) to be facing you.

Then wire it up, **working from left to right** with legs 1 to 4, as follows:

- **Leg 1 (left)** connects to **3.3V (physical pin 36)**
- **Leg 2** connects to **SDA** on **GPIO 14 (physical pin 19)**
- **Leg 3** connects to **GND** (we're using **physical pin 18**)
- **Leg 4** connects to **SCL** on **GPIO15 (physical pin 20)**

Your breadboard should look like this (*your sensor will be black*):



***Tip**: We're using SDA and SCL pins on GPIO 14 and 15, but if you look at the Pico pin map, you'll see that we could have used many others, such as GPIO10 and GPIO11 for example. The Pico has lots of I2C pins to choose from!*

Install the code library

Before we can use the sensor, we need to **install** a library.

Until now we've just imported libraries that are already part of (*built in to*) MicroPython. Sometimes you'll want/need to use external libraries which require saving them on to your Pico first, then we can import them like we'd usually do at the start of a program.

DHT20 Library Installation

We're going to use be using the excellent pico-dht20 library created by GitHub user flrrth.

We're not going to ask you to navigate the scary world of GitHub - instead we've copied the library code that you need and placed it below.

Copy the long code below over to Thonny in the usual way, **but instead of running it**, select ***File*** from the main menu, then ***Save As***, then when a box appears asking where to save it, **select 'Raspberry Pi Pico'**, call it **dht20.py** then select '**OK**'.

```
# https://github.com/flrrth/pico-dht20

from machine import I2C
from utime import sleep_ms

class DHT20:
    """Class for the DHT20 Temperature and Humidity Sensor.

    The datasheet can be found at http://www.aosong.com/userfiles/files/medi
    """

    def __init__(self, address: int, i2c: I2C):
        self._address = address
        self._i2c = i2c
        sleep_ms(100)

        if not self.is_ready:
            self._initialize()
            sleep_ms(100)

            if not self.is_ready:
```

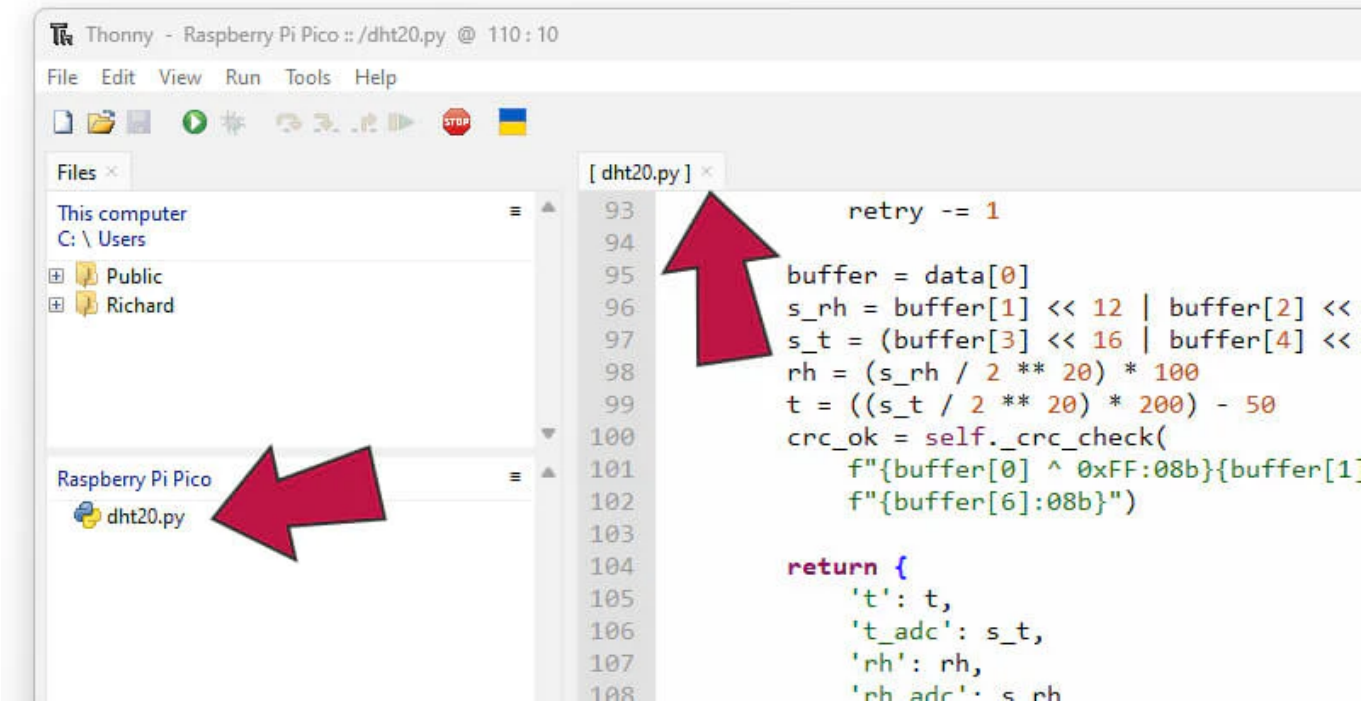
```
            raise RuntimeError("Could not initialize the DHT20.")

    @property
    def is_ready(self) -> bool:
        """Check if the DHT20 is ready."""
        self._i2c.writeto(self._address, bytearray(b'\x71'))
        return self._i2c.readfrom(self._address, 1)[0] == 0x18

    def _initialize(self):
        buffer = bytearray(b'\x00\x00')
        self._i2c.writeto_mem(self._address, 0x1B, buffer)
        self._i2c.writeto_mem(self._address, 0x1C, buffer)
        self._i2c.writeto_mem(self._address, 0x1E, buffer)

    def _trigger_measurements(self):
        self._i2c.writeto_mem(self._address, 0xAC, bytearray(b'\x33\x00'))

    def _read_measurements(self):
        buffer = self._i2c.readfrom(self._address, 7)
        return buffer, buffer[0] & 0x80 == 0

    def _crc_check(self, input_bitstring: str, check_value: str) -> bool:
        """Calculate the CRC check of a string of bits using a fixed polynom

        See https://en.wikipedia.org/wiki/Cyclic_redundancy_check
            https://xcore.github.io/doc_tips_and_tricks/crc.html#the-initial

        Keyword arguments:
        input_bitstring -- the data to verify
        check_value -- the CRC received with the data
        """

        polynomial_bitstring = "100110001"
        len_input = len(input_bitstring)
        initial_padding = check_value
        input_padded_array = list(input_bitstring + initial_padding)

        while '1' in input_padded_array[:len_input]:
            cur_shift = input_padded_array.index('1')
```

```
            for i in range(len(polynomial_bitstring)):
                input_padded_array[cur_shift + i] = \
                    str(int(polynomial_bitstring[i] != input_padded_array[cu

        return '1' not in ''.join(input_padded_array)[len_input:]

    @property
    def measurements(self) -> dict:
        """Get the temperature (°C) and relative humidity (%RH).

        Returns a dictionary with the most recent measurements.

        't': temperature (°C),
        't_adc': the 'raw' temperature as produced by the ADC,
        'rh': relative humidity (%RH),
        'rh_adc': the 'raw' relative humidity as produced by the ADC,
        'crc_ok': indicates if the data was received correctly
        """
        self._trigger_measurements()
        sleep_ms(50)

        data = self._read_measurements()
        retry = 3

        while not data[1]:
            if not retry:
                raise RuntimeError("Could not read measurements from the DHT

            sleep_ms(10)
            data = self._read_measurements()
            retry -= 1

        buffer = data[0]
        s_rh = buffer[1] << 12 | buffer[2] << 4 | buffer[3] >> 4
        s_t = (buffer[3] << 16 | buffer[4] << 8 | buffer[5]) & 0xfffff
        rh = (s_rh / 2 ** 20) * 100
        t = ((s_t / 2 ** 20) * 200) - 50
        crc_ok = self._crc_check(
            f"{buffer[0] ^ 0xFF:08b}{buffer[1]:08b}{buffer[2]:08b}{buffer[3]
            f"{buffer[6]:08b}")
```

```
        return {
            't': t,
            't_adc': s_t,
            'rh': rh,
            'rh_adc': s_rh,
            'crc_ok': crc_ok
        }
```

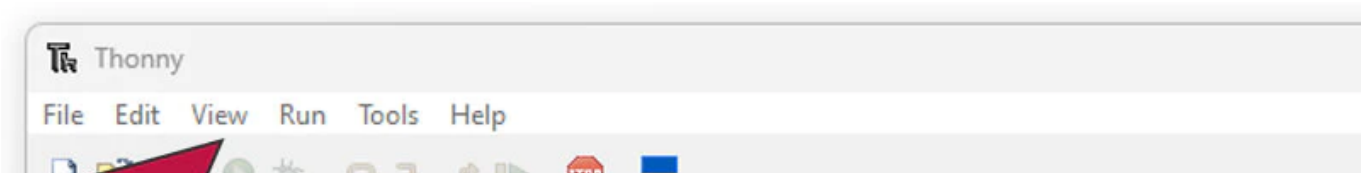
Close the library file

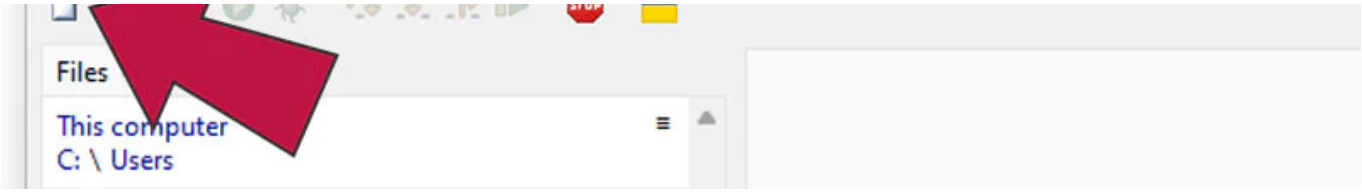
Important! Once you've saved the library to your Pico, **close the script tab down by selecting the 'X' on the tab**, shown here:



You will also see your saved library in the files sidebar, as pointed out above.

To open a new file ready for today's examples, select the 'New' icon (or select **File > New**):





Using the DHT20 library and dictionary

This particular library creates a **dictionary** of stored values from the sensor for us to use in our code, but what is a dictionary in MicroPython?

We covered **lists** previously, which were handy for storing data or variables and allowing us to quickly referencing them, using the list **index**, as and when we need to.

Dictionaries are also used to store information, and they also allow us to retrieve that information quickly, but they can be more useful when handling lots of data as each value is paired with a name (***key***) rather than an index number.

Confusing? You bet! Let's go off on a complete tangent and make it clearer with an example.

Dictionary vs List

Imagine we're keeping a record of every Christmas song we like. Our records for each track might include:

- Title
- Artist
- Supporting artist
- Album
- Year
- Label
- Rating

We *could* make a **list** for this data, the format would lay out like this:

```
song1 = [title, artist, supportingartist, album, year, label, rating]
```

...and a working example might be:

```
song1 = ["I Wish It Could Be Christmas Everyday", "Wizzard", "none", "none",
```

That works...but it's going to be tricky remembering which index in that list relates to which field, and longer lists would be even more unmanageable!

A **dictionary** might be a better option, and would look like this:

```
song1 = {
  "title": "I Wish It Could Be Christmas Everyday",
  "artist": "Wizzard",
  "supportingartist": "none",
  "album": "none",
  "year": "1973",
  "label": "Warner Bro",
  "rating": 5,
}
```

Dictionary Key = handy!

Where the dictionary really shows its power, compared to a list, is when you want to grab data from it. You can use the **name/key** instead of a random **index** number that you're never going to remember!

Using our examples above, let's print the release year of our song.

First, using a **list**:

```
print(song1[4])
```

Now with a **dictionary**:

```
print(song1["year"])
```

See! The dictionary makes it a lot easier to grab the data you want as the key has a sensible,

memorable name rather than an index.

Our only advice is ***don't force it***. Lists are perfectly fine for lots of tasks, but now you have the dictionary option up your sleeve if you need it for a project.

Now, where were we...

Activity 1: Simple sensor reading test

Now that we understand dictionaries in MicroPython, let's start simple and run some code to grab readings from the sensor dictionary every five seconds, and print these to Thonny.

Double-check - did you close the library file tab down? *If not, this is where things can go wrong, as you may accidentally overwrite the library if you try to run your script in the same tab. You need a new tab for your code.*

The Code

To use our library, we need to import it, so we use **from dht20 import DHT20** to do that.

Our code then sets up the I2C pins we're using, which isn't a lot different to how we've set up GPIO pins previously, however we then have a couple of lines setting up I2C and our I2C device (the sensor).

Every I2C device has an **address** - our sensor uses **0x38**. You don't really need to worry about that just now, but just try to remember that if you ever want to run more than one I2C device in the future, you may need to check that the devices don't have the same address.

Our while loop then grabs data from the sensor by bringing the dictionary in, using **measurements = dht20.measurements**. Now we can access that data!

We then proceed to **print** each value from the dictionary by using the names (**key**) of each available item. Here's a list of the data available in the dictionary, taken from the library GitHub page:

Key	Description
t	The temperature (°C)
t_adc	The 'raw' temperature value as produced by the sensor
rh	The relative humidity (%RH)
rh_adc	The 'raw' humidity value as produced by the sensor
crc_ok	The result of the Cyclic Redundancy Check (True or False)

Run the code below and grab your first readings:

```
from machine import Pin, I2C
import time
from dht20 import DHT20

# Set up I2C pins
i2c1_sda = Pin(14)
i2c1_scl = Pin(15)

# Set up I2C
i2c1 = I2C(1, sda=i2c1_sda, scl=i2c1_scl)

# Set up DHT20 device with I2C address
dht20 = DHT20(0x38, i2c1)

while True:

    # Grab data from the sensor dictionary
    measurements = dht20.measurements

    # Print the data
```

```
print(measurements['t'])
print(measurements['t_adc'])
print(measurements['rh'])
print(measurements['rh_adc'])
print(measurements['crc_ok'])

# Wait 5 seconds
time.sleep(5)
```

Activity 2: Readable readings!

Now that we know we can grab data from our library, let's format that data and add some other text to make it more useful/readable.

We'll add **strings** to our print statement readings to help identify what each number relates to, as well as rounding the readings to sensible values using the **round function** that we used previously.

We won't include the **crc_ok** (Cyclic Redundancy Check) line as we don't want to check for errors in our simple example *(it's a simple True/False value to see if the data has gone whoopsie!)*.

We're also going to introduce **formatted string literals** to make our prints even fancier than before, so let's cover that quickly...

What are formatted string literals?

Formatted string literals, in simple terms, allow us to mix strings with Python variables (and any manipulation of those variables), and this all joins up at the end to make one very useful string (great for print lines!).

"But you already showed us how to add text next to a variable" we hear you cry! Yes we did, however formatted string literals are more powerful, as we're about to show you.

Here's an example

We want a print line which looks something like this: **Temperature: 56.1°C**.

That doesn't seem complicated until you realise what the code needs to do to achieve that. It

would need to:

- Start with a string of "Temperature: "
- Grab the temperature reading from the dictionary
- Round the reading to 1 decimal place
- Inject the reading variable into the string
- Add "°C" to the end

Here's the line of code that can achieve that, using formatted string literals:

```
print(f"Temperature: {round(measurements['t'],1)}°C")
```

Let's break it down into pieces:

- **print(f** - string literals need an **f** after the first bracket
- **"Temperature:** - we start the string with simple text, inside the first inverted comma
- **{round(measurements['t'],1)}** - any data we want to inject into our string must go inside **braces {}**. Inside those braces we use the **round function** on our measurement temperature data **['t']**, setting decimal places to **1**.
- **°C")** - we end the line with the °C symbol and close the brackets and inverted commas

If that's a bit too busy for your liking, you could choose to round the data separately into a new variable beforehand. This causes an extra line of code, but makes things a bit more readable:

```
temperature = round(measurements['t'],1)
print(f"Temperature: {temperature}°C")
```

The Code

Now that we've covered formatted string literals, you should be able to see what's going on in the code example below.

We've added some print lines using formatted string literals for temperature and humidity, along with additional print lines for headings, blank spaces and dividers to display our data clearly. We also add some large gaps in some of our strings to align everything nicely.

Give it a try!

```
from machine import Pin, I2C
import time
from dht20 import DHT20

# Set up I2C pins
i2c1_sda = Pin(14)
i2c1_scl = Pin(15)

# Set up I2C
i2c1 = I2C(1, sda=i2c1_sda, scl=i2c1_scl)

# Set up DHT20 device with I2C address
dht20 = DHT20(0x38, i2c1)

while True:

    # Grab data from the sensor dictionary
    measurements = dht20.measurements

    # Print the data
    print("-- Environment ---------") # Heading
    print(f"Temperature:      {round(measurements['t'],1)}°C")
    print(f"Humidity:         {round(measurements['rh'],1)}%")
    print("------------------------") # Divider
    print("                        ") # Empty line

    # Wait 5 seconds
    time.sleep(5)
```

Activity 3: Temperature Indication Ring

Let's bring our LED ring back into the project and use it to show where temperature is on a scale.

Find your ambient temperature

The first thing you need to do is get a rough idea of the ambient temperature in your room, as this

will be the mid-point in our scale.

Run the previous example and keep an eye on the temperature for a few minutes and make a note of where the temperature usually sits. Ours sat at around 20°C. We'll come back to this in a moment.

Temperature LED Index

We're going to create a simple variable for the temperature reading using **temp = round(measurements['t'])**. Notice we don't use a number at the end to specify the decimal places? That's because we only want to deal with round numbers (**integers**) here.

This variable will drive our LED ring. Our rings have 12 LEDs, so we'll create a temperature **dictionary** with 12 **keys** (for each LED on our ring), placing our ambient temperature in position **6** (the **index** for the **7th** LED at the top of the ring).

Here's an example using our **ambient temperature of 20°C**:

Temperature	LED Index
14	0
15	1
16	2
17	3
18	4
19	5
20 *(our average temp)*	**6** *(middle LED)*

21	7
22	8
23	9
24	10
25	11

Working from this example and table above, when the temperature is **14°C**, the **1st** LED (**index 0**) will be lit. When the temperature is **23°C**, the **10th** LED (**index 9**) will be lit.

Now grab a pen and **make your own scale based on your average temperature**. Start by entering your ambient temperature next to index **6**, then fill the rest of the table.

Code Breakdown

Now we need to put this all together! We'll split this one out as it's a bit more complicated.

The example below brings our **neopixel library** and associated setup lines back in.

We then create a temperature dictionary, which we're just going to use to convert temperatures into LED index values (there are other ways to do this, but we figure some dictionary practice makes sense today):

```
# Create a temperature/LED dictionary for our scale
# Temperature is the key (left), LED index is the value (right)
LEDdict = {
  14: 0,
  15: 1,
  16: 2,
  17: 3,
  18: 4,
  19: 5,
```

```
    20: 6, # Top-middle LED (index 6 / LED #7) for 20°C
    21: 7,
    22: 8,
    23: 9,
    24: 10,
    25: 11,
}
```

Our **while loop** grabs the temperature data from the dht20 dictionary, and we round this to a whole number in a new variable called **temperature**:

```
# Grab data from the sensor dictionary
measurements = dht20.measurements

# Create a rounded variable for the temperature
temperature = round(measurements['t'])
```

Then we start an if statement that checks if the temperature reading is **not in** our dictionary (**14 to 25**). If we don't do this, when the temperature goes so high or low that it takes our LED index outside of the possible range of our LED ring, the program will fall over!

```
if temperature not in LEDdict:

    pass
    print("*** Out of temperature range ***")
```

If the temperature is within our dictionary range, the **else statement** will trigger instead.

We then say *"take that temperature value as a key, and use it with our dictionary to find what LED index should be used for that temperature"*. This creates a new variable **LEDindex** with the index value from the dictionary.

```
# Use our temperature variable with our dictionary
# To convert it from the temperature to the LED index
LEDindex = (LEDdict[temperature])
```

We fire out a few print lines to allow us to check the data and variables:

```
# Print the temperature and index
print("Temperature:",temperature)
print("LED index:  ",LEDindex)
print("----------------")
```

We then clear the LEDs quickly, before proceeding to light the LED that matches the index:

```
# Clear the ring
ring.fill((0,0,0))
ring.write()

ring[LEDindex] = (10,0,0) # Light the index LED
ring.write() # Write the LED data
```

Full program

That was a LOT to take in, so we suggest running the full example below, watching it work and having a few additional reads through the script and description above.

Try opening a window or gently blowing a hair dryer over the sensor (from at least ~45cm away) and watch the values and LEDs change.

```
from machine import Pin, I2C
import time
from dht20 import DHT20
from neopixel import NeoPixel

# Set up I2C pins
i2c1_sda = Pin(14)
i2c1_scl = Pin(15)

# Set up I2C
i2c1 = I2C(1, sda=i2c1_sda, scl=i2c1_scl)

# Set up DHT20 device with I2C address
dht20 = DHT20(0x38, i2c1)
```

```
# Define the ring pin number (2) and number of LEDs (12)
ring = NeoPixel(Pin(2), 12)

# Create a temperature/LED dictionary for our scale
# Temperature is the key (left), LED index is the value (right)
LEDdict = {
  14: 0,
  15: 1,
  16: 2,
  17: 3,
  18: 4,
  19: 5,
  20: 6, # Top-middle LED (index 6 / LED #7) for 20°C
  21: 7,
  22: 8,
  23: 9,
  24: 10,
  25: 11,
}

while True:

    # Grab data from the sensor dictionary
    measurements = dht20.measurements

    # Create a rounded variable for the temperature
    temperature = round(measurements['t'])

    if temperature not in LEDdict:

        pass
        print("*** Out of temperature range ***")

    else:

        # Use our temperature variable with our dictionary
        # To convert it from the temperature to the LED index
        LEDindex = (LEDdict[temperature])

        # Print the temperature and index
```

```
        print("Temperature:",temperature)
        print("LED index:  ",LEDindex)
        print("-----------------")

        # Clear the ring
        ring.fill((0,0,0))
        ring.write()

        ring[LEDindex] = (10,0,0) # Light the index LED
        ring.write() # Write the LED data

    # Wait 2 second before looping again
    time.sleep(2)
```

Day #9 Complete!

We'll end it there today as we've probably exhausted your brains with those final activities!

There you have it, now you can keep an eye on your internal environment when that snow starts to fall (*fingers crossed*), and see how humid different rooms get when you close windows or hang the washing indoors!

We ran some examples with the LED ring, but there's lots of ways you can use your growing stash of components with these sensors:

- Use with the bar graph display for a 5-stage humidity indicator
- Use with the blocky LED as a general warning light if the temperature or humidity goes over or under a certain value
- Change RGB LED colours based on temperature ranges
- Use it with...*something in one of the future boxes (shh!)*

Recap time – What did we cover today?

- Wiring a temperature sensor
- What I2C is and how it works
- SDA and SCL I2C pins on the Pico

- Installing libraries
- Using and creating a dictionary
- Dictionaries vs Lists
- Formatted string literals

Keep everything as it is until the morning, where we'll unwrap the next blinky component. See you then!

We used Fritzing to create the breadboard wiring diagram images for this page.

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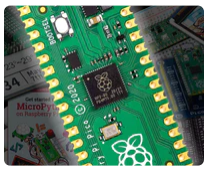

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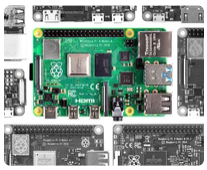

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