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Real Feel Temperature

1 Abstract

On this project we want to develop an instrument, using an arduino nano and an DHT11 sensor, to measure the temperature and humidity and give us the value of the real feel temperature.

2 Instrumentation

- Sensor DHT11
- Jumpe wire (3) cable Male to mini USB
- Solderless breadboard
- Arduino nano
- resistor 4.7 kΩ

3 Introduction

3.1 Real Feel Temperature

When the body temperature is too high we produce sweat that is released through our skin make it cool down when it is evaporated. This is the process that our body uses to keep its temperature under certain values. This way, the ability of our body to keep its temperature under certain external temperatures depends on the evaporation of the sweat it produces.

When the air humidity increases, the evaporation rate reduces, making it harder for the body to achieve the comfortable values of body temperature. For this reason, we can experience different sensations of heat under the same value of air temperature.

To measure the effect of the humidity on the temperature we feel, the concept of heat index was developed. The heat index, also called real feel temperature, is an estimate of the temperature that would produce the same effect on our body for normal values of humidity.

To estimate the real feel temperature, there has to be taken into account a lot of biological mechanisms that causes the body to achieve comfortable values of temperature under different external conditions. After all the considerations we were able to produce a group of expressions that takes those mechanisms into account, and allow us to calculate the heat index for certain ranges.

To calculate the heat index, we use the following equation:

$$HI = c_1 + c_2T + c_3H + c_4TH + c_5T^2H + c_6H^2 + c_7T^2H + c_8TH^2 + c_9T^2H^2 \quad (1)$$

where T is the air temperature and H is the relative humidity. The constants taken into this equation are a result of a multivariate fit to a model of the human body and they are determined for certain ranges of temperature values and relative humidity.
For the next set of constants, we can obtain the heat index, in degrees Fahrenheit, within $\pm 1.3^oF(0.7^oC)$ with a good approximation for all the values, excluding the values at 90^oF and relative humidity of 45%/70%.

$$\begin{aligned} c_1 &= -42.379, & c_2 &= 2.049\,015\,23, & c_3 &= 10.143\,331\,27, \\ c_4 &= -0.224\,755\,41, & c_5 &= -6.837\,83 \times 10^{-3}, & c_6 &= -5.481\,717 \times 10^{-2}, \\ c_7 &= 1.228\,74 \times 10^{-3}, & c_8 &= 8.5282 \times 10^{-4}, & c_9 &= -1.99 \times 10^{-6}. \end{aligned}$$

Another alternative set of constants for the equation is the following:

$$\begin{aligned} c_1 &= 0.363\,445\,176, & c_2 &= 0.988\,622\,465, & c_3 &= 4.777\,114\,035, \\ c_4 &= -0.114\,037\,667, & c_5 &= -8.502\,08 \times 10^{-4}, & c_6 &= -2.071\,6198 \times 10^{-2}, \\ c_7 &= 6.876\,78 \times 10^{-4}, & c_8 &= 2.749\,54 \times 10^{-4}, & c_9 &= 0. \end{aligned}$$

This one gives us the heat index within $\pm 3^oF(1.7^oC)$ for all humidities from 0 to 80% and all temperatures between 70^oF and $115^oF(21\text{–}46^oC)$.

To calculate the heat index for values of temperature above 90°F (32°C) and relative humidity of 85%, the heat index is given by the formula:

$$\begin{aligned} HI = c_1 + c_2T + c_3H + c_4TH + c_5T^2H + c_6H^2 + c_7T^2H + c_8TH^2 + c_9T^2H^2 \\ + c_{10}T^3 + c_{11}R^3 + c_{12}T^3R + c_{13}TR^3 + c_{14}T^3R^2 + c_{15}T^2R^3 + c_{16}T^3R^3 \end{aligned} \quad (2)$$

with the constant values:

$$\begin{aligned} c_1 &= -42.379, & c_2 &= 2.049\,015\,23, & c_3 &= 10.143\,331\,27, \\ c_4 &= -0.224\,755\,41, & c_5 &= -6.837\,83 \times 10^{-3}, & c_6 &= -5.481\,717 \times 10^{-2}, \\ c_7 &= 1.228\,74 \times 10^{-3}, & c_8 &= 8.5282 \times 10^{-4}, & c_9 &= -1.99 \times 10^{-6}. \end{aligned}$$

3.2 Sensor

For our project we used a DHT11 sensor which is a sensor that measures the humidity and temperature. This sensor uses a resistive sensor to measure the humidity and a negative temperature coefficient(NTC) thermistor to measure the temperature.

A NTC thermistor is a passive sensor that uses a semiconductor material that varies its resistivity with temperature. Contrarily to the positive temperature coefficient(PTC), the NTC is a sensor in

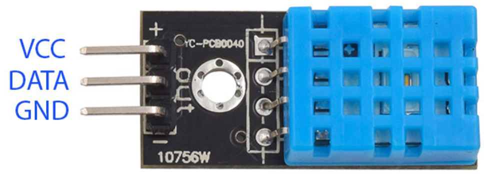

Fig. 1: DHT11

which the resistance of the material decreases as the value of the temperature increases. There are non-linear sensors, this means that the resistance of the material doesn't varies linearly with the temperature but, knowing the relation between the two variables, we can predict the temperature by measuring the resistance of the material in question.

The resistive sensor used to measure the humidity is a sensor that has an electrical resistance that varies with temperature. This sensor uses a hygroscopic material (water absorbing material) on a thin film form which ionises in the presence of water, becoming a conductor with measurable resistivity. This way, the conductivity of this kind of sensors increases with the humidity of the air and we can measure it by measuring the resistivity of the thin film.

The power supply of the DHT11 is made with a 3-5.5V DC and it is to give a certain voltage to the humidity and temperature sensors that are passive sensors.

This sensor uses a single-wire communication with a single bus for synchronization and communication between the MCU and the sensor.

On the beginning of the communication process the MCU sends a start signal for the DHT11 which changes from the low-power-consumption mode to the running-mode and waits for de MCU to complete the start signal. When the starting process is completed, DHT11 sends a response 40-bit signal with the information about humidity and temperature. After sending the data, DTH11 changes its mode to the low-power-consumption mode.

3.3 Arduino nano

The Arduino Nano is a small, complete, and breadboard-friendly board. Operating voltage for this device is equal 5V. Recommended Input Voltage for Vin pin is between 7-12V. Arduino nano contains:

- microcontroller ATmega328p- flash memory is 32KB.
- Arduino nano Pinout-main function of Pins is to be configured as input or output.
  - GND - ground pins on the board
  - 5V - regulated power supply voltage of the board.

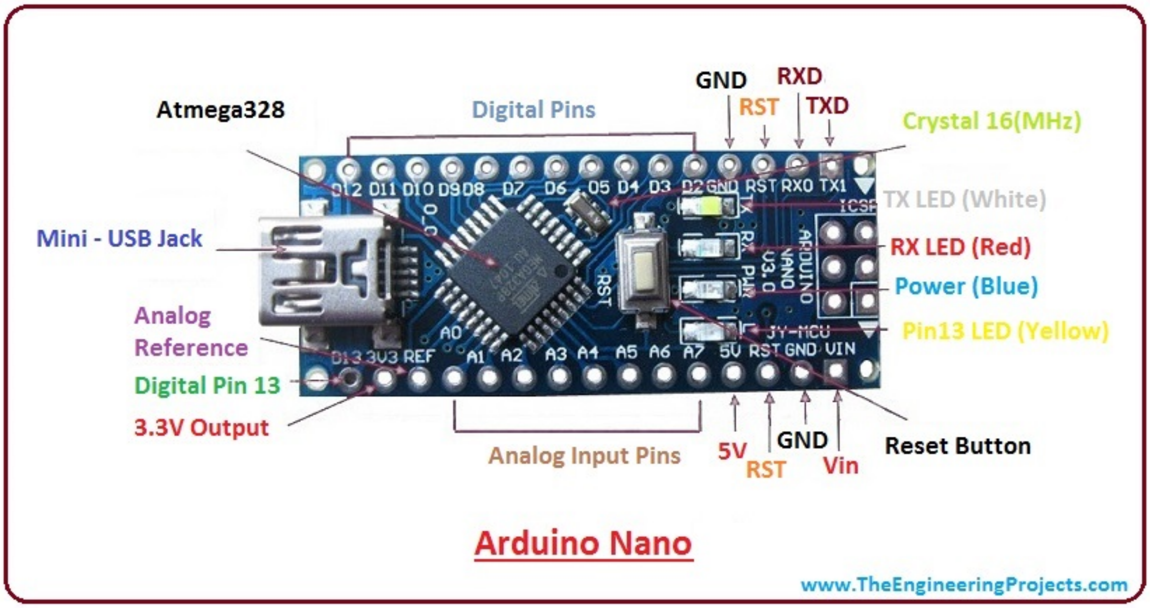

Fig. 2: Arduino nano
source:https://www.theengineeringprojects.com/2018/06/introduction-to-arduino-nano.html

  - 14 digital Pins -each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. Can be used as input or output pins. 0V (low) and 5V (high).
  - 8 analog Pins - with a total resolution of 10bits which measure the value from zero to 5V.
  - 2 Reset Pins - resets the board. It is very helpful when running program goes too complex and hangs up the board.
  - another - which we didn't use in our project

- crystal oscillator - frequency 16 MHz

The difference between Arduino Nano and Arduion UNO is that the first doesn't come with DC power jack, means you can not supply external power source through a battery. Tiny size and breadboard friendly nature make this device an ideal choice for most of the applications where a size of the electronic components are of great concern.

4 Implementation

The implementation of the circuit of the instrument is really simple, it consists on connecting the pins of the sensors with the power sources of the Arduino and with the digital pin for the acquisition of the data using a breadboard to establish the connection. This way, we proceeded as shown in figure.

On the implementation we used a $5k\Omega$ pull-up resistor. Pull-up resistors are used when we are dealing with microcontrollers. They ensure a known state for a signal.

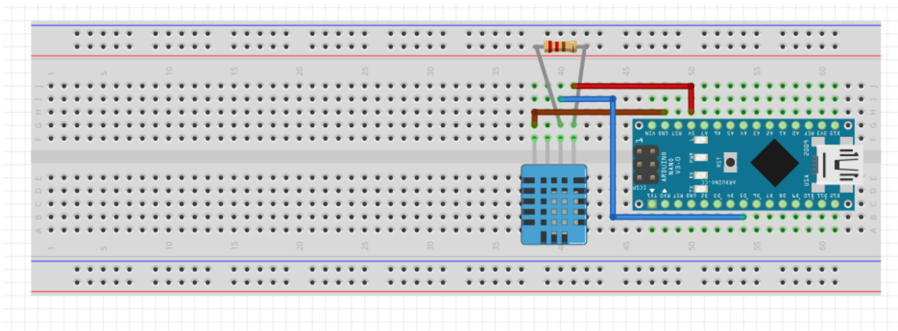

Fig. 3: Breadboard our circuit

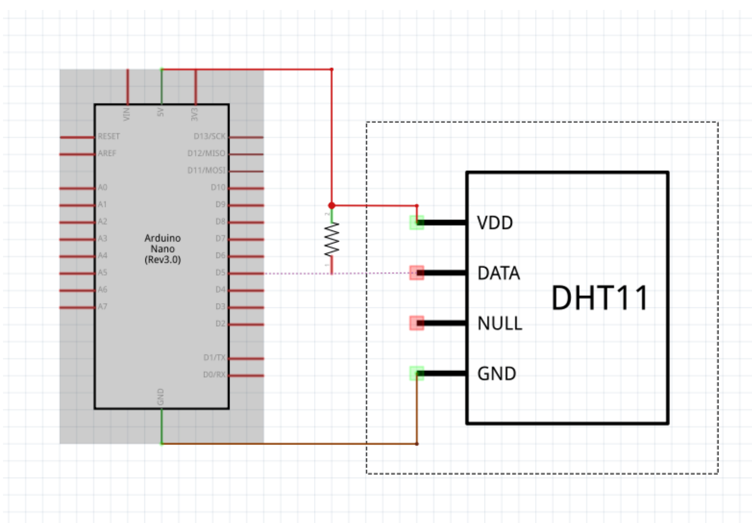

Fig. 4: Sketch our circuit

5 Code

For the code we used the language C++ which is associate with the Arduino. We started by initializing the variables associated with the temperature and humidity values.

First we've determined all constants needed for calculation. Next used setup() function defined the data rate to 9600 bpsI and delay to let system boot. In function loop we read humidity and temperature and after calculate heat index for uncertainty equal 0.7°C and 1.7°C.

Read the Pin, humidity in % and temperature. We calculate temperature from Fahrenheit to Celsius:

```
void loop(){
    //read the PIN
    DHT.read11(DHTPIN);

    //Reead Humidity in % and temperature which is calculate from Fahrenheit
     to Celsius
    R=DHT.humidity;
    T=(DHT.temperature *9/5)+32;

    //Print Humidity in \% and Celsiusz
    Serial.print("Current humidity: ");
    Serial.print(DHT.humidity);
    Serial.print("%  ");

    Serial.print("temperature: ");
    Serial.print(DHT.temperature);
    Serial.println("C  ");
```

Calculate temperature for heat index in Celsius:

```
    //Calculate heat index in Celsiusz,
     when uncertantity heat index is 0.7C
    HI0=((c01 + c02*T+c03*R +c04*T*R+c05*T*T+c06*R*R
    +c07*T*T*R+c08*T*R*R+c09*T*T*R*R)-32)*5/9;

    //Print Feel temperature in Celsiusz,
     when uncertantity heat index is 0.7C
    Serial.print("Temperature feel by people,
    when uncertainty heat index is 0.7C:");
    Serial.print(HI0);
    Serial.println("C  ");


    //Calculate heat index in Celsiusz,
     when uncertainty heat index is 1.7C
    if(R<=80 or (T>=21 and T<=46)){
    HI1=((c1 + c2*T+c3*R +c4*T*R+c5*T*T+c6*R*R
    +c7*T*T*R+c8*T*R*R+c9*T*T*R*R)-32)*5/9;
    }
    else{
    HI1=((c21 + c22*T+c23*R +c24*T*R+c25*T*T+c26*R*R
    +c27*T*T*R+c28*T*R*R+c29*T*T*R*R+c210*pow(T,3)+c211*pow(R,3)+
    c212*pow(T,3)*R+c213*T*pow(R,3)+c214*pow(T,3)*pow(R,2)
    +c215*pow(T,2)*pow(R,3)+c216*pow(T,3)*pow(R,3))-32)*5/9;
    }

    //Print Feel temperature in Celsiusz,
     when uncertainty heat index is 1.7C
    Serial.print("Temperature feel people,
     when uncertainty heat index is 1.7C: ");
    Serial.print(HI1);
    Serial.println("C  ");
    delay(5000);          //Wait 5 seconds before accessing sensor again.

}
```

6 Results

We compare our results with calculator heat index from website (https://www.wpc.ncep.noaa.gov/html/heatindex.shtml). Accuracy on the website is to 1°C, our accuracy is calculate to 0.01°C.

Temperature (C)	Humidity (%)	HI (C) $\pm 0.7^oC$	HI (C) $\pm 1.7^oC$	website ^oC
22	38	23.92	22.84	21
26	95	27.82	25.88	28
28	95	34.67	33.75	34
24	28	24.92	23.94	23
24	32	25.08	24.25	23
27	95	31.27	32.02	32

Tab. 1: Result for different humidity and temperature

7 Conclusions

The aim of project was very well achieved.

Our measure data confirm theory that with higher humidity the temperature which people feel is also higher. This phenomenon we can see the best for our data, where temperature is equal 24°C and humidity in one case is equal 28% and in the second case 32%, the difference between this two data is equal only 0.31°C. It is not a lot of but also the difference in humidity is not big.

In internet is a lot of website where can calculate heat index using first calculate formula. We tried compare our results with score from this websites. Heat index calculate by our device from 26°C give similar outcom as this from this website, but for lower temperature we see deviation between two outcomes. This is due to the fact that heat index should be calculate for temperature higher than 27°C. So we concluded that there is a problem with the formula we used, that is not suitable for this range of temperatures, only for lower temperatures.