



Ingeniate en Octave

Clase 5



Ensayo de Transferencia de Calor

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UNCUYO
UNIVERSIDAD
NACIONAL DE CUYO



FACULTAD DE
**CIENCIAS APLICADAS
A LA INDUSTRIA**

Ensayo de transferencia de calor

Mayo de 2019

Ing. Iván Ferrari

Problema planteado

- Se simula una incubadora
- Donde se usa un foco para generar calor
- Se toman mediciones de calor y humedad en función del tiempo
- Se busca controlar la temperatura en un rango fijado
- Observar transferencia de calor en estado transitorio
- Observar posibles efectos de inercia térmica

Mecanismos de transferencia de calor

- Conducción
- Convección
- Radiación

Estado transitorio

VS

Estacionario

Balances de Energía

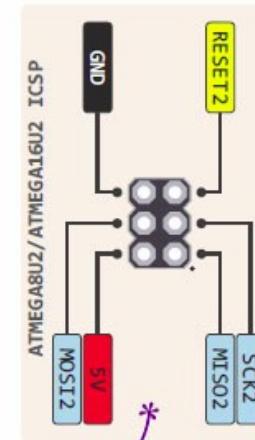
- Fuentes de calor del sistema
- Pérdidas de calor


Arduino UNO

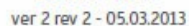
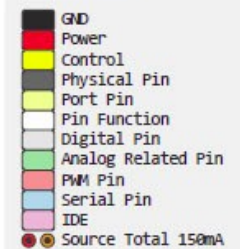


The diagram illustrates the pin configuration for the ATmega328P microcontroller. The pins are numbered 1 through 14 on the left and 28 through 15 on the right. Each pin is connected to a specific internal function, represented by a colored box. The functions are as follows:

- Pin 1:** RESET (Yellow)
- Pin 2:** PCINT14 (Yellow), PC6 (Yellow)
- Pin 3:** RXD (Blue), PCINT16 (Yellow), PD0 (Yellow)
- Pin 4:** TXD (Blue), PCINT17 (Yellow), PD1 (Yellow)
- Pin 5:** INT0 (Blue), PCINT18 (Yellow), PD2 (Yellow)
- Pin 6:** INT1 (Blue), PCINT19 (Yellow), PD3 (Yellow)
- Pin 7:** XCK (Blue), PCINT20 (Yellow), PD4 (Yellow)
- Pin 8:** VCC (Red)
- Pin 9:** GND (Black)
- Pin 10:** OSC1 (Blue), XTAL1 (Blue), PCINT6 (Yellow), PB6 (Yellow)
- Pin 11:** OSC2 (Blue), XTAL2 (Blue), PCINT7 (Yellow), PB7 (Yellow)
- Pin 12:** OC0B (Blue), PWM (Red), T1 (Blue), PCINT21 (Yellow), PD5 (Yellow)
- Pin 13:** OC0A (Blue), PWM (Red), AIN0 (Blue), PCINT22 (Yellow), PD6 (Yellow)
- Pin 14:** ICP1 (Blue), CLK0 (Blue), PCINT23 (Yellow), PD7 (Yellow)
- Pin 15:** PCINT0 (Yellow), PB0 (Yellow)
- Pin 16:** PCINT1 (Yellow), PB1 (Yellow)
- Pin 17:** PCINT2 (Yellow), PB2 (Yellow)
- Pin 18:** PCINT3 (Yellow), PB3 (Yellow)
- Pin 19:** PCINT4 (Yellow), PB4 (Yellow)
- Pin 20:** PCINT5 (Yellow), PB5 (Yellow)
- Pin 21:** AREF (Green)
- Pin 22:** GND (Black)
- Pin 23:** PCINT8 (Yellow), PC0 (Yellow)
- Pin 24:** PCINT9 (Yellow), PC1 (Yellow)
- Pin 25:** PCINT10 (Yellow), PC2 (Yellow)
- Pin 26:** PCINT11 (Yellow), PC3 (Yellow)
- Pin 27:** PCINT12 (Yellow), PC4 (Yellow)
- Pin 28:** PCINT13 (Yellow), PC5 (Yellow)
- Pin 29:** ADC5 (Green), A5 (Green)
- Pin 30:** ADC4 (Green), A4 (Green)
- Pin 31:** ADC3 (Green), A3 (Green)
- Pin 32:** ADC2 (Green), A2 (Green)
- Pin 33:** ADC1 (Green), A1 (Green)
- Pin 34:** ADC0 (Green), A0 (Green)
- Pin 35:** SCL (Blue)
- Pin 36:** SDA (Blue)
- Pin 37:** MOSI (Blue)
- Pin 38:** SS (Blue)
- Pin 39:** PWM (Red)
- Pin 40:** OC1A (Blue)
- Pin 41:** OC1B (Blue)
- Pin 42:** OC2A (Blue)
- Pin 43:** SCK (Blue)
- Pin 44:** MISO (Blue)
- Pin 45:** PB7 (Yellow)
- Pin 46:** PB6 (Yellow)
- Pin 47:** PB5 (Yellow)
- Pin 48:** PB4 (Yellow)
- Pin 49:** PB3 (Yellow)
- Pin 50:** PB2 (Yellow)
- Pin 51:** PB1 (Yellow)
- Pin 52:** PCINT1 (Yellow)
- Pin 53:** PCINT2 (Yellow)
- Pin 54:** PCINT3 (Yellow)
- Pin 55:** PCINT4 (Yellow)
- Pin 56:** PCINT5 (Yellow)
- Pin 57:** PB5 (Yellow)
- Pin 58:** PB4 (Yellow)
- Pin 59:** PB3 (Yellow)
- Pin 60:** PB2 (Yellow)
- Pin 61:** PB1 (Yellow)
- Pin 62:** PCINT0 (Yellow)
- Pin 63:** PCINT1 (Yellow)
- Pin 64:** PCINT2 (Yellow)
- Pin 65:** PCINT3 (Yellow)
- Pin 66:** PCINT4 (Yellow)
- Pin 67:** PCINT5 (Yellow)
- Pin 68:** PB6 (Yellow)
- Pin 69:** PB7 (Yellow)
- Pin 70:** PCINT6 (Yellow)
- Pin 71:** PCINT7 (Yellow)
- Pin 72:** PCINT8 (Yellow)
- Pin 73:** PCINT9 (Yellow)
- Pin 74:** PCINT10 (Yellow)
- Pin 75:** PCINT11 (Yellow)
- Pin 76:** PCINT12 (Yellow)
- Pin 77:** PCINT13 (Yellow)
- Pin 78:** PCINT14 (Yellow)
- Pin 79:** PCINT15 (Yellow)
- Pin 80:** PCINT16 (Yellow)
- Pin 81:** PCINT17 (Yellow)
- Pin 82:** PCINT18 (Yellow)
- Pin 83:** PCINT19 (Yellow)
- Pin 84:** PCINT20 (Yellow)
- Pin 85:** PCINT21 (Yellow)
- Pin 86:** PCINT22 (Yellow)
- Pin 87:** PCINT23 (Yellow)
- Pin 88:** PCINT24 (Yellow)
- Pin 89:** PCINT25 (Yellow)
- Pin 90:** PCINT26 (Yellow)
- Pin 91:** PCINT27 (Yellow)
- Pin 92:** PCINT28 (Yellow)
- Pin 93:** PCINT29 (Yellow)
- Pin 94:** PCINT30 (Yellow)
- Pin 95:** PCINT31 (Yellow)
- Pin 96:** PCINT32 (Yellow)
- Pin 97:** PCINT33 (Yellow)
- Pin 98:** PCINT34 (Yellow)
- Pin 99:** PCINT35 (Yellow)
- Pin 100:** PCINT36 (Yellow)
- Pin 101:** PCINT37 (Yellow)
- Pin 102:** PCINT38 (Yellow)
- Pin 103:** PCINT39 (Yellow)
- Pin 104:** PCINT40 (Yellow)
- Pin 105:** PCINT41 (Yellow)
- Pin 106:** PCINT42 (Yellow)
- Pin 107:** PCINT43 (Yellow)
- Pin 108:** PCINT44 (Yellow)
- Pin 109:** PCINT45 (Yellow)
- Pin 110:** PCINT46 (Yellow)
- Pin 111:** PCINT47 (Yellow)
- Pin 112:** PCINT48 (Yellow)
- Pin 113:** PCINT49 (Yellow)
- Pin 114:** PCINT50 (Yellow)
- Pin 115:** PCINT51 (Yellow)
- Pin 116:** PCINT52 (Yellow)
- Pin 117:** PCINT53 (Yellow)
- Pin 118:** PCINT54 (Yellow)
- Pin 119:** PCINT55 (Yellow)
- Pin 120:** PCINT56 (Yellow)
- Pin 121:** PCINT57 (Yellow)
- Pin 122:** PCINT58 (Yellow)
- Pin 123:** PCINT59 (Yellow)
- Pin 124:** PCINT60 (Yellow)
- Pin 125:** PCINT61 (Yellow)
- Pin 126:** PCINT62 (Yellow)
- Pin 127:** PCINT63 (Yellow)
- Pin 128:** PCINT64 (Yellow)
- Pin 129:** PCINT65 (Yellow)
- Pin 130:** PCINT66 (Yellow)
- Pin 131:** PCINT67 (Yellow)
- Pin 132:** PCINT68 (Yellow)
- Pin 133:** PCINT69 (Yellow)
- Pin 134:** PCINT70 (Yellow)
- Pin 135:** PCINT71 (Yellow)
- Pin 136:** PCINT72 (Yellow)
- Pin 137:** PCINT73 (Yellow)
- Pin 138:** PCINT74 (Yellow)
- Pin 139:** PCINT75 (Yellow)
- Pin 140:** PCINT76 (Yellow)
- Pin 141:** PCINT77 (Yellow)
- Pin 142:** PCINT78 (Yellow)
- Pin 143:** PCINT79 (Yellow)
- Pin 144:** PCINT80 (Yellow)
- Pin 145:** PCINT81 (Yellow)
- Pin 146:** PCINT82 (Yellow)
- Pin 147:** PCINT83 (Yellow)
- Pin 148:** PCINT84 (Yellow)
- Pin 149:** PCINT85 (Yellow)
- Pin 150:** PCINT86 (Yellow)
- Pin 151:** PCINT87 (Yellow)
- Pin 152:** PCINT88 (Yellow)
- Pin 153:** PCINT89 (Yellow)
- Pin 154:** PCINT90 (Yellow)
- Pin 155:** PCINT91 (Yellow)
- Pin 156:** PCINT92 (Yellow)
- Pin 157:** PCINT93 (Yellow)
- Pin 158:** PCINT94 (Yellow)
- Pin 159:** PCINT95 (Yellow)
- Pin 160:** PCINT96 (Yellow)
- Pin 161:** PCINT97 (Yellow)
- Pin 162:** PCINT98 (Yellow)
- Pin 163:** PCINT99 (Yellow)
- Pin 164:** PCINT100 (Yellow)
- Pin 165:** PCINT101 (Yellow)
- Pin 166:** PCINT102 (Yellow)
- Pin 167:** PCINT103 (Yellow)
- Pin 168:** PCINT104 (Yellow)
- Pin 169:** PCINT105 (Yellow)
- Pin 170:** PCINT106 (Yellow)
- Pin 171:** PCINT107 (Yellow)
- Pin 172:** PCINT108 (Yellow)
- Pin 173:** PCINT109 (Yellow)
- Pin 174:** PCINT110 (Yellow)
- Pin 1**

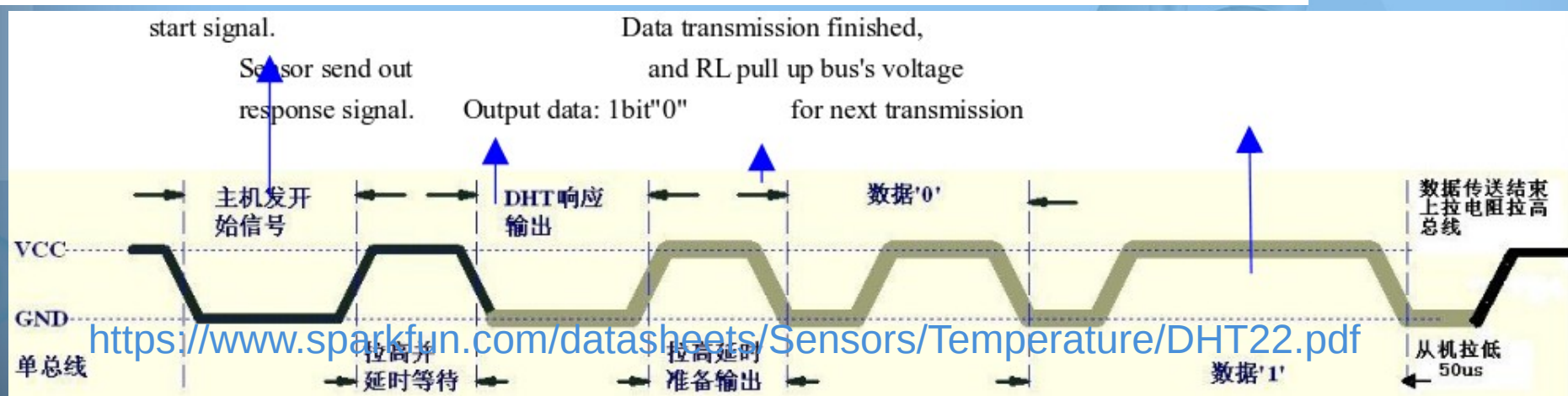


 Absolute max 200mA
for entire package



Sensor de temperatura y Humedad DHT22

Model	DHT22
Power supply	3.3-6V DC
Output signal	digital signal via single-bus
Sensing element	Polymer capacitor
Operating range	humidity 0-100%RH; temperature -40~80Celsius
Accuracy	humidity +2%RH(Max +5%RH); temperature <+-0.5C
Resolution or sensitivity	humidity 0.1%RH; temperature 0.1Celsius
Repeatability	humidity +1%RH; temperature +0.2Celsius
Humidity hysteresis	+0.3%RH
Long-term Stability	+0.5%RH/year
Sensing period	Average: 2s
Interchangeability	fully interchangeable
Dimensions	small size 14*18*5.5mm; big size 22*28*5mm



Sensor de temperatura MLX90614

Infrarojo , Pirómetro

Features and Benefits

- ☐ Small size, low cost
- ☐ Easy to integrate
- ☐ Factory calibrated in wide temperature range:
 - 40 to 125 °C for sensor temperature and
 - 70 to 380 °C for object temperature.
- ☐ High accuracy of 0.5°C over wide temperature range (0..+50 °C for both Ta and To)
- ☐ High (medical) accuracy calibration optional
- ☐ Measurement resolution of 0.02 °C
- ☐ Single and dual zone versions
- ☐ SMBus compatible digital interface
- ☐ Customizable PWM output for continuous reading
- ☐ Available in 3V and 5V versions
- ☐ Simple adaptation for 8 to 16V applications
- ☐ Power saving mode
- ☐ Different package options for applications and measurements versatility
- ☐ Automotive grade

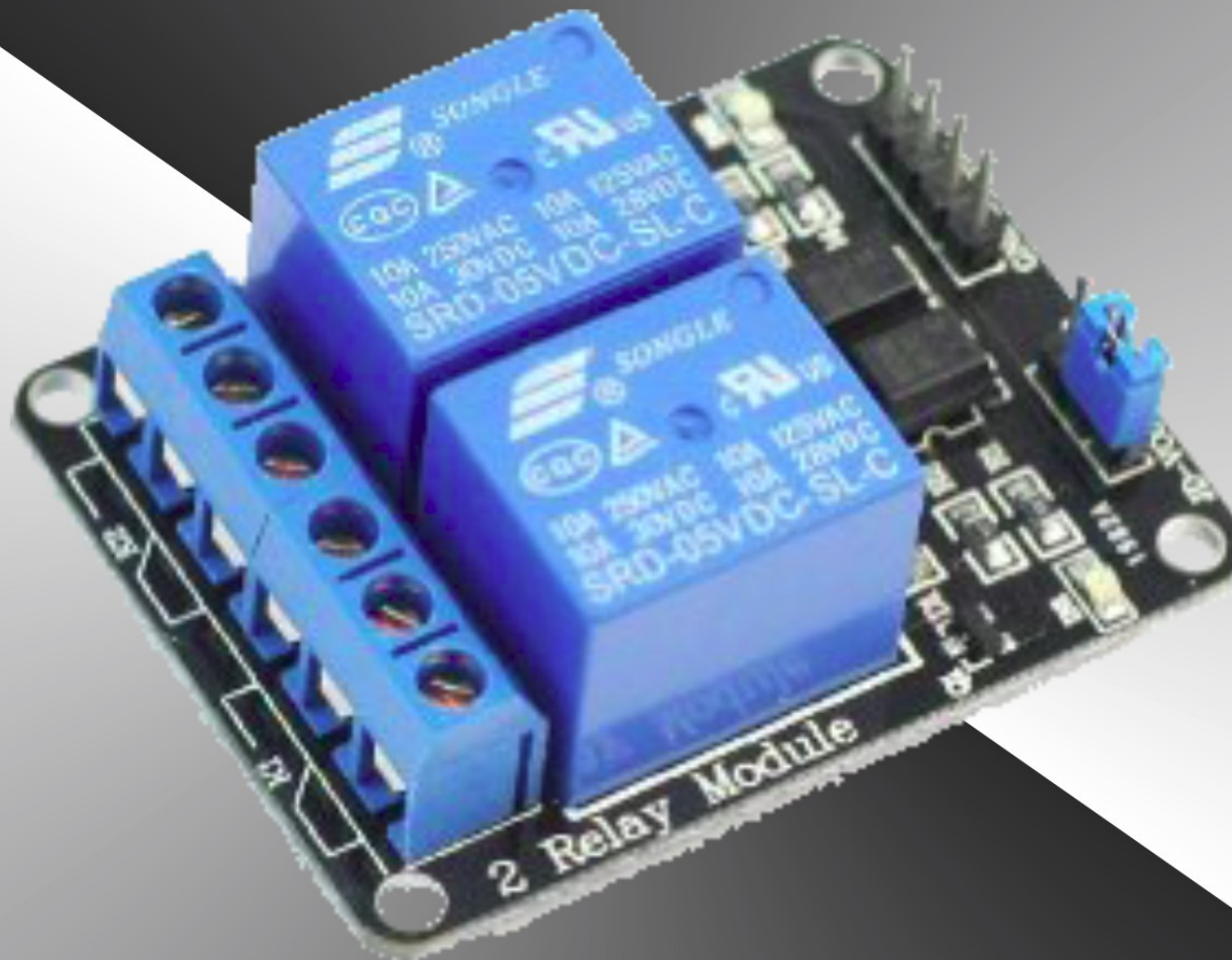
Applications Examples

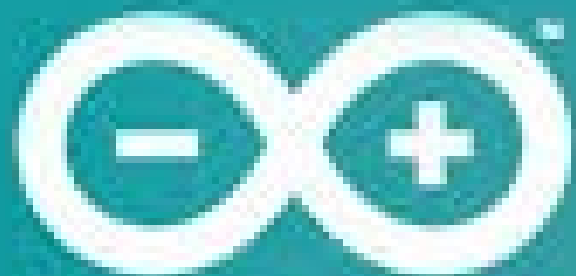
- ☐ High precision non-contact temperature measurements;
- ☐ Thermal Comfort sensor for Mobile Air Conditioning control system;
- ☐ Temperature sensing element for residential, commercial and industrial building air conditioning;
- ☐ Windshield defogging;
- ☐ Automotive blind angle detection;
- ☐ Industrial temperature control of moving parts;
- ☐ Temperature control in printers and copiers;
- ☐ Home appliances with temperature control;
- ☐ Healthcare;
- ☐ Livestock monitoring;
- ☐ Movement detection;
- ☐ Multiple zone temperature control – up to 100 sensors can be read via common 2 wires
- ☐ Thermal relay/alert
- ☐ Body temperature measurement



https://www.sparkfun.com/datasheets/Sensors/Temperature/MLX90614_rev001.pdf

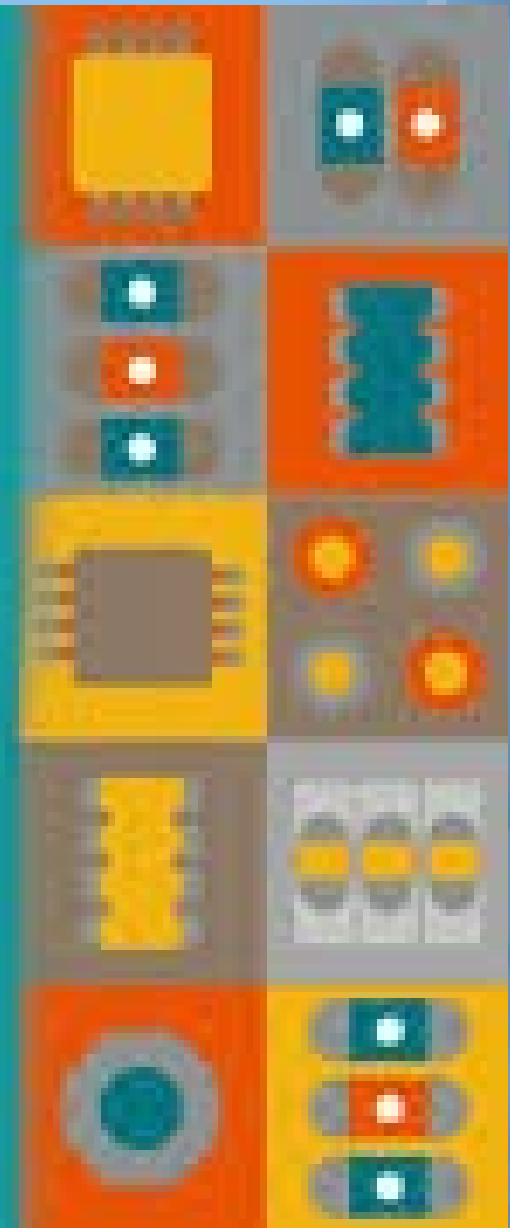
Módulo relay





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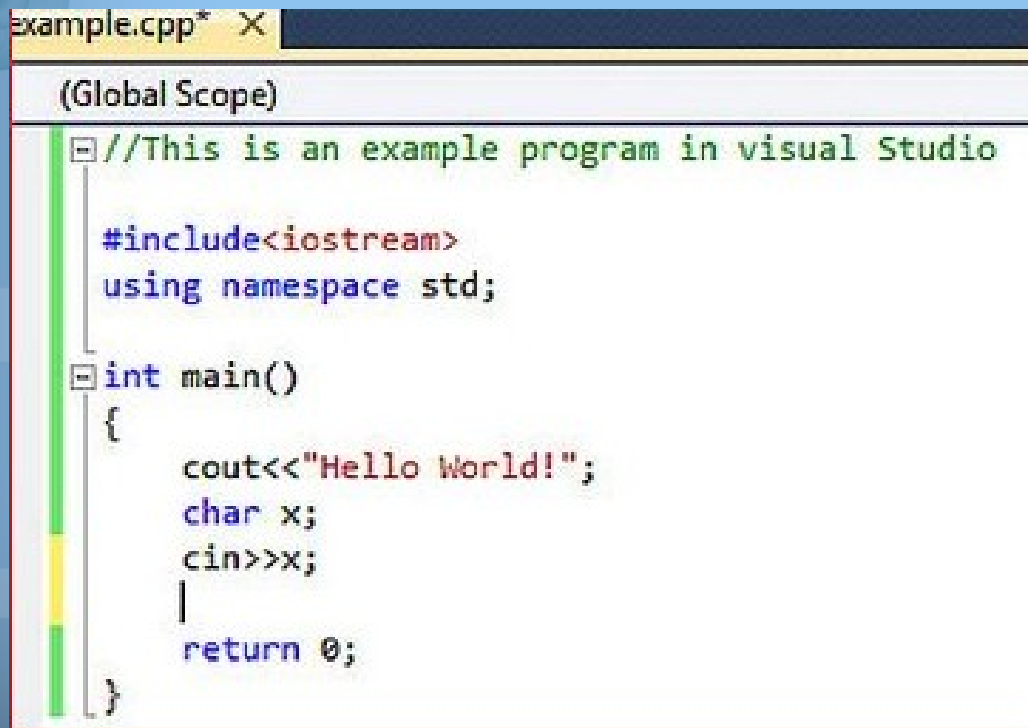
Programming Languages



El lenguaje de programación Arduino

- Es simplemente un conjunto de funciones en C/C++ que pueden ser llamadas desde el código fuente, sketch
- El sketch pasa luego a un compilador C/C++ (avr-g++).
- Todos los constructores estándar de C y C++ soportados por avr-g++ deberían funcionar en arduino

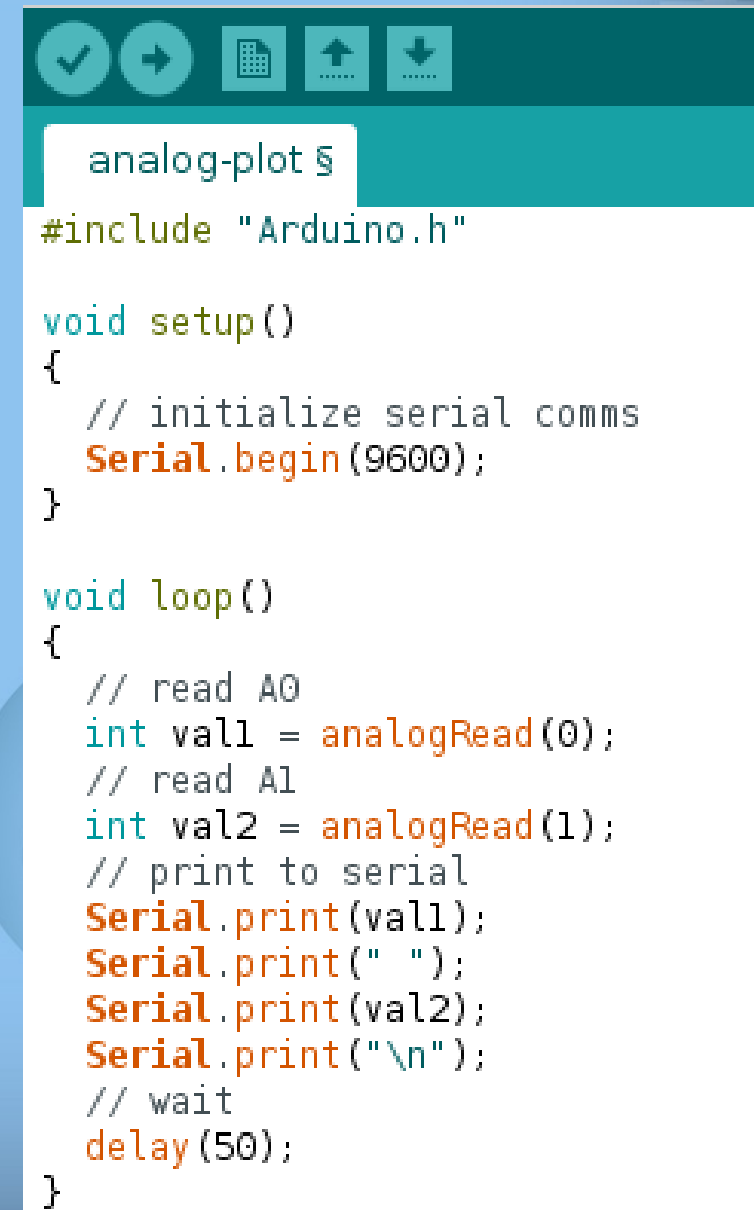
- Vamos a trabajar con una versión simplificada de C/C++
- Con igual sintáxis, manejo de flujos y variables
- Diferente estructura del programa



```
example.cpp* X
(Global Scope)
//This is an example program in visual Studio

#include<iostream>
using namespace std;

int main()
{
    cout<<"Hello World!";
    char x;
    cin>>x;
    |
    return 0;
}
```



```
analog-plot $
#include "Arduino.h"

void setup()
{
    // initialize serial comms
    Serial.begin(9600);
}

void loop()
{
    // read A0
    int val1 = analogRead(0);
    // read A1
    int val2 = analogRead(1);
    // print to serial
    Serial.print(val1);
    Serial.print(" ");
    Serial.print(val2);
    Serial.print("\n");
    // wait
    delay(50);
}
```

Sintaxis básica en C/C++ y Arduino

- `/*... */` bloque de comentarios
- `//` línea de comentario Pulse para añadir texto
- `{}` uso de llaves para delimitar bloques por ejemplo al llamar a funciones
- `;` punto y coma se colocan al final de cada instrucción

```
/*
 * Este es un bloque
 * de comentario
 */

//esta es una línea de comentario

void setup() {
  pinMode(13, OUTPUT);
  pinMode(2, INPUT); //cada instrucción termina con ";"
}

//las llaves {} delimitan bloques
//en este caso de la función void setup()

void loop() {
  digitalWrite(13, HIGH);
  delay(1000);
  digitalWrite(13, LOW);
  delay(1000);
}
```

Mecanismo de control

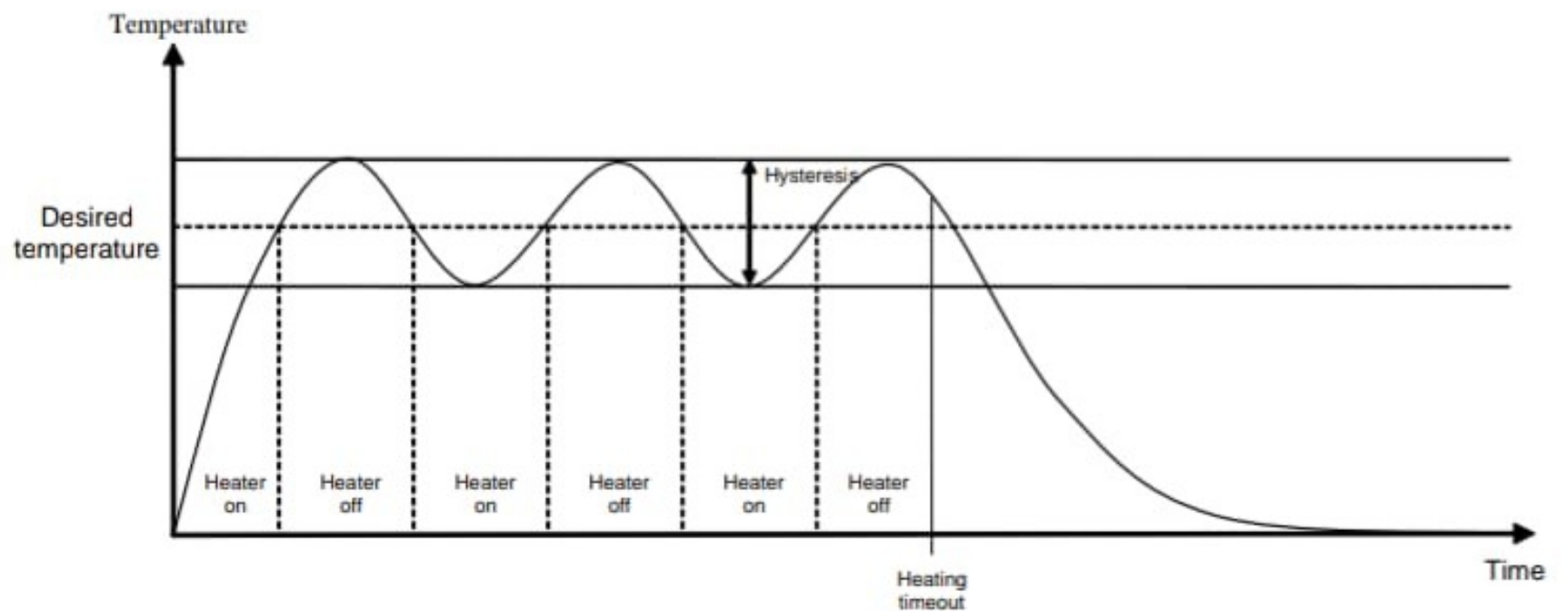


Figure 3. On-off System Behavior

- ¿Por qué se usan dos valores para una controlar una única temperatura objetivo?
- Plantee el pseudo-código del sistema de control

```
boolean banda=false;
// banda entre 29 y 30,apaga en 30 enciende en 29
#define tsup 27
#define tinf 26
```

```
if(!banda){ //todavía no entre en la banda
    if (promedio <= tsup) { //no llegué a tsup
        digitalWrite(7, LOW); //enciendo luz
    }
}

if(promedio>=tsup){ //paso la temp superior
    banda=true; //active la entrada a la banda
    digitalWrite(7,HIGH); //apaga la luz
}

if(banda){ //estoy en la banda
    if(promedio<=tinf){ //bajé de la tinf
        digitalWrite(7,LOW); // enciendo la luz
    }
}

}
```

```
void medir() {
    humedad = dht1.readHumidity();
    temp1 = dht1.readTemperature();
    t2 = dht2.readTemperature();
    temp2=-0.0016035*t2*t2+0.9323968*t2+2.4405110;
    t3 = mlx.readAmbientTempC();
    temp3=0.042397*t3*t3-1.460512*t3+33.876647;
    promedio = (temp1 + temp2 + temp3) / 3.0;

    Serial.print(humedad);
    Serial.print(",");
    Serial.print(temp1);
    Serial.print(",");
    Serial.print(temp2);
    Serial.print(",");
    Serial.print(temp3);
    Serial.println("");
}
}
```

Efectos de la inercia Térmica

- ¿Cuáles son las posibles variables del sistema que afectan a la transferencia del calor la inercia térmica?