# Universidad de Costa Rica
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**IE-0624 Laboratorio de Microcontroladores**

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# Laboratorio 3
## Arduino: PID, GPIO, ADC y comunicaciones

**Resumen**

En está práctica de laboratorio se desarrolló un sistema que emula una incubadora de huevos. Para ejecutar el algoritmo de control de dicho sistema se utilizó un Arduino UNO, y aparte de este dispositivo, se cuenta con un circuito compuesto por: una pantalla LCD PCD8544, un termistor, una fuente de tensión DC variable de $0\,V$ a $5\,V$, una fuente de tensión DC fija de $5\,V$, un potenciómetro, un transistor, dos LEDs (uno rojo y uno azul) y un conjunto de resistencias. Por otro lado, en el Arduino UNO se implementó un controlador PID para manipular la temperatura de la incubadora, con base en la temperatura deseada y la temperatura en tiempo real determinada por el termistor.

Link del Proyecto: https://github.com/Jams1001/IE0624/tree/main/L3

`ID del último commit hecho:e99bf4f449cf0c5db9444f61fae2838c64a5bf5a`

Figura 1: Incubadora automática.

# 1. Nota Teórica

## 1.1. Información general del MCU

En la siguiente práctica de laboratorio se utiliza el microcontrolador de ATmel ATmega328P como elemento central de la práctica. El mismo posee las siguientes características [1]:

- Microcontrolador AVR de 8 bits.
- Arquitectura RISC/Harvard.
- 4/8/16/64Kb Flash, 512b/1/2k bytes de SRAM y 256/512/1k bytes de EEPROM.
- 23 GPIOs.
- Timer/Counters de 8 y 16 bits e interrupciones.
- 8 canales PWM y comparador analogico y 6 canales 10-bit ADC.

Adicionalmente la empresa encargada de la tarjeta de desarrollo proporciona la siguiente información:

| | |
|---|---|
| Microcontroller | ATmega328P |
| Operating Voltage | 5V |
| Input Voltage (recommended) | 7-12V |
| Input Voltage (limit) | 6-20V |
| Digital I/O Pins | 14 (of which 6 provide PWM output) |
| PWM Digital I/O Pins | 6 |
| Analog Input Pins | 6 |
| DC Current per I/O Pin | 20 mA |
| DC Current for 3.3V Pin | 50 mA |
| Flash Memory | 32 KB (ATmega328P) of which 0.5 KB used by bootloader |
| SRAM | 2 KB (ATmega328P) |
| EEPROM | 1 KB (ATmega328P) |
| Clock Speed | 16 MHz |
| LED_BUILTIN | 13 |
| Length | 68.6 mm |
| Width | 53.4 mm |
| Weight | 25 g |

Tabla 1: Características generales de Arduino [2].

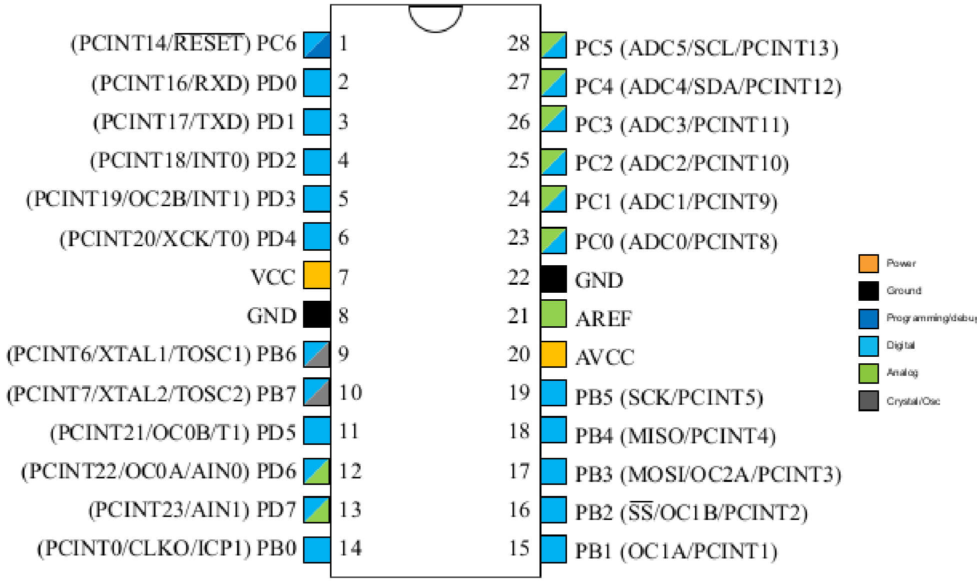


Figura 2: Diagrama de pines ATmega328P [3].

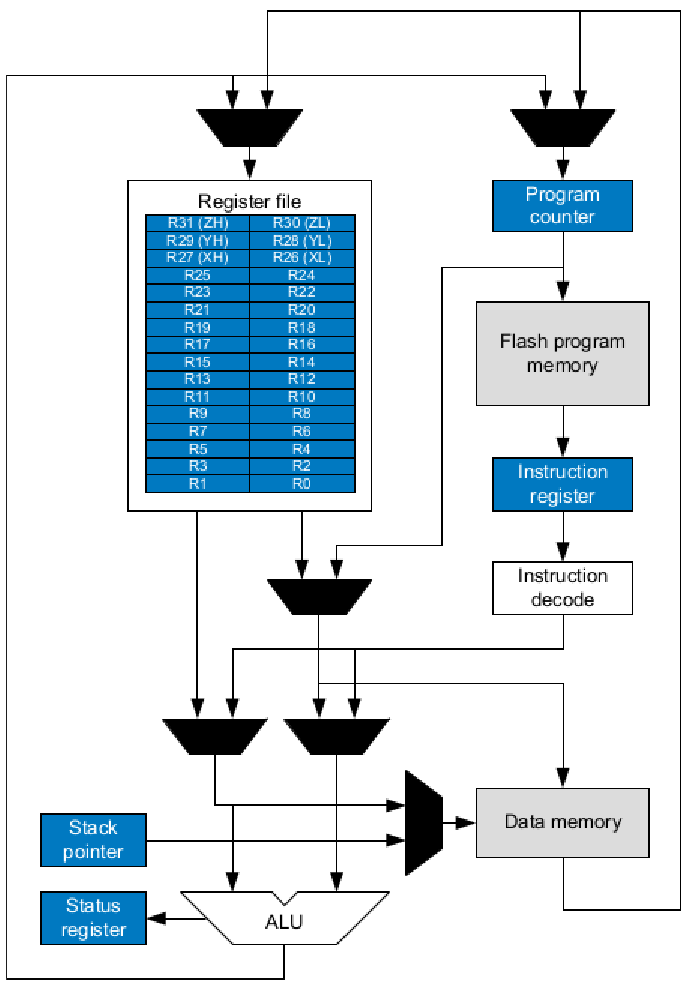


Figura 3: Diagrama de bloques ATmega328P [3].

## 1.2. Funciones de interés

- **pinMode():** Configura el pin especificado para que se comporte como una entrada o una salida [2].
- **analogRead():** Lee el valor del pin analógico especificado. Las placas Arduino contienen un convertidor analógico a digital multicanal de 10 bits. Esto significa que mapeará los voltajes de entrada entre 0 y el voltaje de funcionamiento (5 V o 3,3 V) en valores enteros entre 0 y 1023. En un Arduino UNO, por ejemplo, esto produce una resolución entre lecturas de: 5 voltios / 1024 unidades o 0,0049 voltios (4,9 mV) por unidad [2].
- **map():** Vuelve a asignar un número de un rango a otro. Es decir, un valor de fromLow se asignaría a toLow, un valor de fromHigh a toHigh, valores intermedios a valores intermedios, etc. Reasigna la escala anlógica a la escala digital en la resolución disponible [2].
- **delay():** Pausa el programa por la cantidad de tiempo (en milisegundos) especificado como parámetro. (Hay 1000 milisegundos en un segundo) [2].
- **analogWrite():** Escribe un valor analógico (onda PWM) en un pin. Se puede usar para encender un LED con diferentes brillos o impulsar un motor a varias velocidades. Después de una llamada a analogWrite(), el pin generará una onda rectangular constante del ciclo de trabajo especificado hasta la próxima llamada a analogWrite() (o una llamada a digitalRead() o digitalWrite()) en el mismo pin. Recibe como parámetros `analogWrite(pin, value)`, en donde `pin` corresponde el pin de Arduino para escribir y value al ciclo de trabajo que va entre 0 (siempre apagado) y 255 (siempre encendido) [2].

## 1.3. Diseño

La fuente de tensión variable que va de 0V a 5V representa una señal que enviaría un transductor de un sensor de humedad. La resistencia conectada al colector del transistor es la encargada de disipar la potencia (calentador) que depende de la tensión que se aplique en la base, la cuál se controla desde el microcontrolador a través del pin 9 en modo PWM. El termistor está conectado en una configuración de divisor de tensión, por otro lado por la naturaleza de un termistor, su resistencia es inversamente proporcional a su temperatura, por lo tanto a mayor temperatura menor resistencia y a menor resistencia menor tensión. El potenciometro de igual forma permite definir un punto de operación. Por último el switch utilizado permite habilitar la comunicación serial con la PCM.

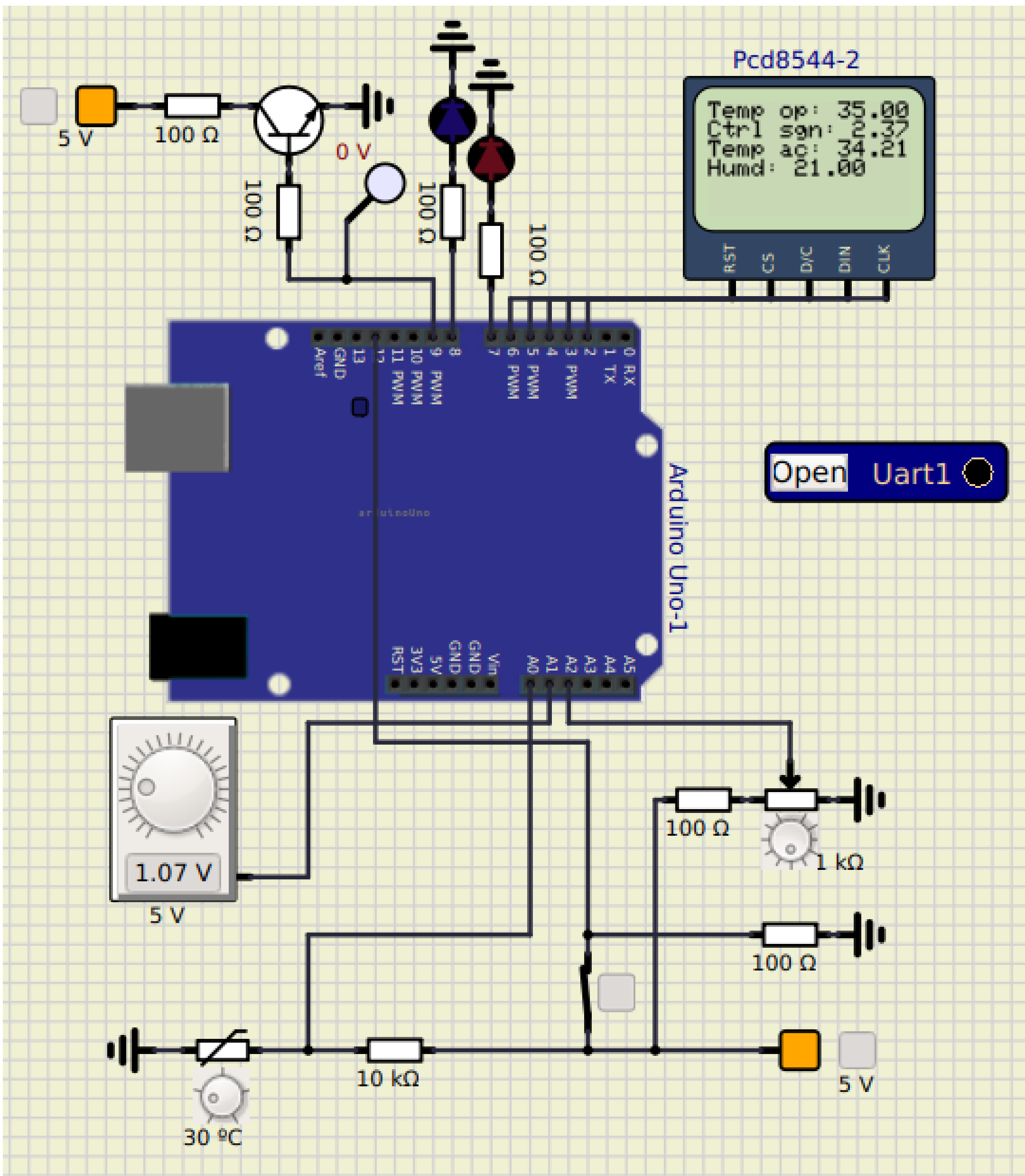


Figura 4: Esquemático final (Autoría propia).

## 1.4. Componentes complementarios

Para poder completar el proyecto se necesitó hacer uso de componentes adicionales además del MCU ATmega328P. Los mismos se detallan a continuación. Estos diseños están basados en electrónica para una parte de laboratorio, no para una implementación de uso real. Se presenta una tabla con los precios en promedio en el mercado para estos componentes. No tiene sentido especificar muy meticulosamente estos precios pues son muy variables dependiendo el tiempo y los ofertantes, sin embargo, sí tiene sentido dar una aproximación general del potencial costo probable para implementar este diseño. Estos precios no consideran envío ni impuestos.

| **Componente** | **Cantidad** | **Precio (USD)** |
|---|---|---|
| Switch | 1 | 0.26 |
| Resistencia $100\Omega$ | 6 | 2.04 |
| Resistencia $10k\Omega$ | 1 | 1.45 |
| Diodo LED | 2 | 1 |
| LCD PCD8544 | 1 | 8.95 |
| Potenciomentro 3296 $1k\Omega$ (Trimpot) | 1 | 5 |
| Sensor de humedad DHT11 | 1 | 5.66 |
| NTC THERMISTOR OF MF52-TYPE | 1 | 1.2 |
| Transistor BJT NTE123A | 1 | 1 |
| Arduino UNO | 1 | 23.27 |
| **Total** | | **49.83** |

Tabla 2: Lista de cantidad y precios de los componentes (Autoría propia).

## 1.5. Conceptos

### 1.5.1. PID

Un controlador PID es un dispositivo que permite controlar un sistema en lazo cerrado para que alcance el estado de salida deseado. Este controlador está conformado por tres bloques que dan un aporte a la señal de control [4]:

- **Proporcional:** Este bloque intenta minimizar el error del sistema. Cuando el error es grande, la acción de control es grande y tiende a minimizar este error. Aumentar la constante proporcional tiene los siguientes efectos:
  - Aumenta la velocidad de respuesta del sistema.
  - Disminuye el error del sistema en régimen permanente.
  - Aumenta la inestabilidad del sistema.
- **Integral:** Sirve para disminuir el error en régimen permanente. Aumentar la constante integral tiene los siguientes efectos:
  - Aumenta la estabilidad del sistema controlado.
  - Disminuye un poco la velocidad del sistema.
  - El error en régimen permanente permanecerá igual.

- **Derivativo:** Esta acción de control esta hecha para estabilizar una respuesta que oscile demasiado. Aumentar la constante derivativa tiene los siguientes efectos:
  - Disminuye el error en régimen permanente.
  - Aumenta la estabilidad del sistema.
  - Aumenta un poco la velocidad del sistema.

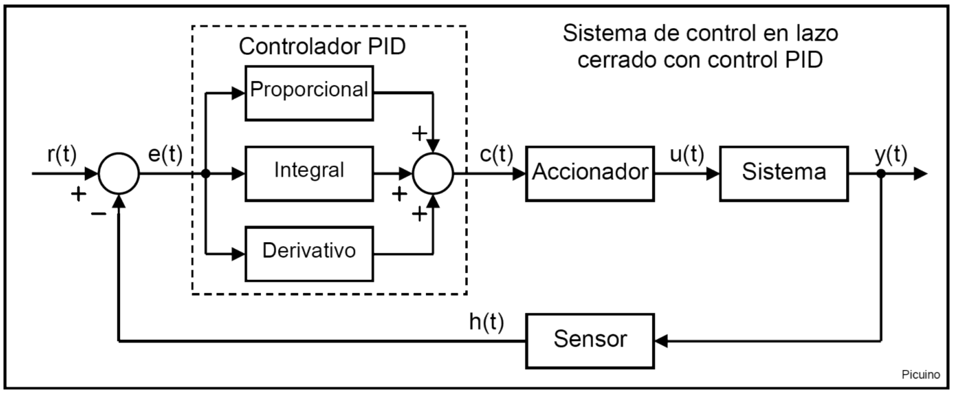


Figura 5: Representación gráfica de un controlador PID [4]

La señal r(t) se denomina referencia e indica el estado que se desea conseguir en la salida del sistema y(t). Por ejemplo, en un sistema de control de temperatura, la referencia r(t) será la temperatura deseada y la salida y(t) será la temperatura real del sistema controlado.

Como se puede observar en la figura 5, la entrada al controlador PID es la señal de error e(t). Esta señal indica al controlador la diferencia que existe entre la referencia r(t) y el estado real del sistema h(t), medido por el sensor. Si la señal de error es grande, significa que el estado del sistema se encuentra lejos del estado de referencia deseado. Si por el contrario el error es pequeño, significa que el sistema ha alcanzado el estado deseado [4].

### 1.5.2. PWM

Del inglés *Pulse width modulation* es un tipo de señal de voltaje utilizada para enviar información o para modificar la cantidad de energía que se envía a una carga. De otra forma, PWM proporciona una forma de controlar ciertas cantidades analógicas, variando el ancho de pulso de una forma de onda rectangular de frecuencia fija [5].
Las funciones relacionadas con PWM, que son controladas por hardware, utilizan los módulos Timer para generar la salida [1].

# 2. Desarrollo / Análisis de Resultados

## 2.1. Análisis de SW

### 2.1.1. Librerías utilizadas

Al principio del sketch, en el cual se desarrolló el firmware, se incluyeron las siguientes librerías para Arduino:

- **PID_v1:** Esta librería ofrece acceso a una clase PID, la cual encapsula las funciones que ejecutan el algoritmo PID. Esto facilita la comprensión del código y disminuye la complejidad que conlleva implementar un controlador de este tipo.
- **SPI:** Permite la comunicación entre un Arduino y otro dispositivo a través de SPI, con el Arduino como dispositivo controlador.
- **Adafruit_PCD8544:** Esta es una librería para un display LCD monocromático del Nokia 5110. Permite enviar mensajes desde el Arduino y desplegarlos, de forma eficiente y sencilla, en el display LCD.
- **Adafruit_GFX:** Esta se trata la librería gráfica principal para todas las pantallas de Adafruit. Proporciona un conjunto común de primitivas gráficas, sin embargo, debe utilizarse en conjunto con una librería de hardware específica para el dispositivo de visualización que vaya a utilizarse. En este caso, dicha librería es Adafruit_PCD8544.
- **math:** La librería predeterminada de Arduino para funciones matemáticas útiles que manipulan números de punto flotante.

### 2.1.2. Definición de variables globales

En esta sección primeramente se definieron los nombres con los cuales se haría referencia a los pines en el resto del código, como se muestra a continuación:

```
int CLK          = 2;
int DIN          = 3;
int DC           = 4;
int CS           = 5;
int RST          = 6;
int BLUE         = 7;
int RED          = 8;
int CALENTADOR   = 9;
int SWITCH       = 12;
int TERMISTOR    = A0;
int HUMEDAD      = A1;
int POTENCIOMETRO = A2;
```

Inmediatamente después se definieron las variables y constantes que se utilizan más adelante:

```
// Constantes de PID
int Kp = 2; // Constante proporcional
int Ki = 5; // Constante integral
int Kd = 1; // Constante derivativa
```

```
// Constantes para ecuaciones del termistor
int Resistencia = 10000;
float A = 1.11492089e-3;
float B = 2.372075385e-4;
float C = 6.954079529e-8;
float K = 2.5; //factor de disipacion en mW/C

// Definición de variables
int Temperatura_Operacion_A, Humedad_A;
double temp_ac, setPoint, ctrl_sgn, output_sgn;
float V_term, R_term, T_term, Humedad, logR;
```

Por otra parte, se declaró un objeto `PID` y otro `Adafruit_PCD8544`:

```
// Controlador PID
PID pid(&temp_ac, &ctrl_sgn, &setPoint, Kp, Ki, Kd, DIRECT);

// Objeto PCD para conectar y escribir datos al display LCD
Adafruit_PCD8544 display = Adafruit_PCD8544(CLK,DIN,DC,CS,RST);
```

El primero de estos, recibe como argumentos:

- `&temp_ac`: Dirección de memoria de la variable que guarda la temperatura sensada por el sistema.
- `&ctrl_sgn`: Dirección de memoria de la variable que guarda la señal de control generada por el PID.
- `&setPoint`: Dirección de memoria de la variable que guarda el punto de operación deseado para la temperatura.
- `Kp`: La constante proporcional.
- `Ki`: La constante integral.
- `Kd`: La constante derivativa.
- `DIRECT`: Establece la dirección en la cual va a actuar el controlador PID. DIRECT significa que la salida aumentará cuando el error, entre `temp_ac` y `setPoint`, sea positivo.

Por otra parte, el objeto `Adafruit_PCD8544 display` recibe como argumentos los números de los pines a los cuales se conectan las entradas del display LCD.

### 2.1.3. Configuración inicial

En la configuración inicial, primeramente se establece la velocidad de datos en bits por segundo (baudios) para la transmisión de datos serial. Además, se declaran cuales pines del Arduino actuarán como entradas y cuales funcionarán como salidas:

```
pinMode(CLK, OUTPUT);
pinMode(DIN, OUTPUT);
pinMode(DC, OUTPUT);
```

```
pinMode(CS, OUTPUT);
pinMode(RST, OUTPUT);
pinMode(BLUE, OUTPUT);
pinMode(RED, OUTPUT);
pinMode(SWITCH, INPUT);
```

Posteriormente, se realiza la inicialización de variables:

```
Temperatura_Operacion_A = analogRead(POTENCIOMETRO);
setPoint = map(Temperatura_Operacion_A, 0, 1023, 0, 80);

output_sgn = 0;

V_term = analogRead(TERMISTOR)*5/1023;
R_term = V_term*Resistencia/(5-V_term);
logR = log(R_term);
T_term = 1.0 /(A+B*logR+C*logR*logR*logR);
temp_ac = (T_term - V_term*V_term/(K * R_term)*1000) - 273.15;

Humedad = 0;
```

Como se puede observar en la porción de código anterior, las variables `output_sgn` y `Humedad` se inicializan en cero. Sin embargo, para `Temperatura_Operacion_A` se lee el valor analógico del pin conectado al potenciómetro y este se mapea a `setPoint`. Por otra parte, para obtener el valor de `temp_ac`, variable que representa la temperatura actual de la incubadora, primero se lee la tensión asociada a la entrada analógica conectada al termistor. Luego se utiliza la ecuación característica del termistor para determinar la resistencia asociada a dicha tensión, y consecuentemente, la temperatura. Además, como esta temperatura está dada en Kelvin, se le restan 273.15 para poder expresarla en grados Celsius.

Por último, se setea el objeto `PID` en modo automático y se inicializa el `Adafruit_PCD8544 display`:

```
pid.SetMode(AUTOMATIC);
display.begin();
```

## 2.2. Lazo de ejecución

En lazo de ejecución primeramente se realizan todas las lecturas de las entradas del Arduino. Para determinar los valores de `setPoint` y `temp_ac` se sigue el mismo procedimiento implementado en la función `setup()`. De forma similar para calcular el porcentaje de humedad, se hizo una lectura del valor analógico en un pin. Específicamente, el pin conectado a la fuente que representa el sensor. Después dicho valor se mapeo a la variable que guarda este porcentaje:

```
Humedad_A = analogRead(HUMEDAD);
Humedad = map(Humedad_A, 0, 1023, 0, 100);
```

Por otra parte, la señal de control cambia automáticamente al ejecutar la función `Compute()` del objeto `PID`. Posteriormente, el valor de esta señal se normaliza en un rango entre 0 y 100:

```
pid.Compute();
```

```
if(ctrl_sgn > 100){
ctrl_sgn = 100;
}
else if(ctrl_sgn < 0){
ctrl_sgn = 0;
}
```

A continuación, la señal de control se cuantiza para generar la salida `output_sgn`. Esta será la salida del pin analógico conectado al circuito calentador, y por lo tanto, controlará cuanta corriente circula por la resistencia que calienta la incubadora.

```
output_sgn = ctrl_sgn*255/100;
analogWrite(CALENTADOR, output_sgn);
```

En la siguiente parte del código se despliegan los valores de interés en el display LCD:

```
display.setCursor(0,0);
// Imprime temperatura de operacion en el display
display.print("Temp op: ");
display.println(setPoint);

// Imprime salida del controlador en el display
display.print("Ctrl sgn: ");
display.println(ctrl_sgn);

// Imprime temperatura actual en el display
display.print("Temp ac: ");
display.println(temp_ac);

// Imprime humedad actual en el display
display.print("Humd: ");
display.println(Humedad);

display.display();
```

Después, se procede a activar/desactivar las salidas de los LEDs, dependiendo del valor de la temperatura actual:

```
if (temp_ac <= 30){
digitalWrite(BLUE, HIGH);
}
else {
digitalWrite(BLUE, LOW);
}
if (temp_ac >= 42){
digitalWrite(RED, HIGH);
}
else {
digitalWrite(RED, LOW);
```

```
}
```

Y finalmente, se envían los datos de interés a la PC, en cada ciclo, a través de comunicación serial. No obstante, esta acción está condicionada al estado del pin 12 (SWITCH).

```
 if(digitalRead(SWITCH) == HIGH){
 Serial.print(temp_ac);
 Serial.print(",");
 Serial.print(Humedad);
 Serial.print(",");
 Serial.print(setPoint);
 Serial.print(",");
 Serial.println(ctrl_sgn);
}
else {
 Serial.print("NULL");
 Serial.print(",");
 Serial.print("NULL");
 Serial.print(",");
 Serial.print("NULL");
 Serial.print(",");
 Serial.println("NULL");
}
```

#### 2.2.1. recorder.py

Este script lee la información serial enviada por el arduino a la PC (a través de una simulación) y la decodifica escribiéndola en un archivo .csv. Consta de «4 etapas»:

1. Conexión serial: Se define el baud de la comunicación, el puerto, y «realiza» la conexión.
2. Creación del archivo: Se crea el archivo con `file = open(fileName, "w")` y se crea un array para definir el encabezado.
3. Obtención de datos: Existiendo ya la comunicación se llaman funciones como `readline()` para obtener los datos y decodificarlos.
4. Escritura de datos: Se escriben los datos ya decodificados en el array.

### 2.3. Análisis de HW

A continuación se analiza el esquemático y sus componentes medidores para verificar su funcionamiento.

En la siguiente figura se puede apreciar el sistema a 34C. Tanto la temperatura actual (`Temp ac`) como la seleccionada en el punto de operación (`Temp op`) se encuentran a una misma temperatura, y por ende la salida en la base del transistor está a 0V. No obstante, la temperatura sensada por el termistor no es de 34C sino de 22C, pues el controlador PID implementado toma en cuenta no solo la temperatura del termistor para calcular la temperatura actual, sino también la ambiente simulando aún más un prototipo “real”. En este punto la señal de control `Ctrol sgn` está calentado a un 22.04 % para tratar de mantener la temperatura estable. Adicionalmente se aprecia una Humedad `Humd` de 13 %.

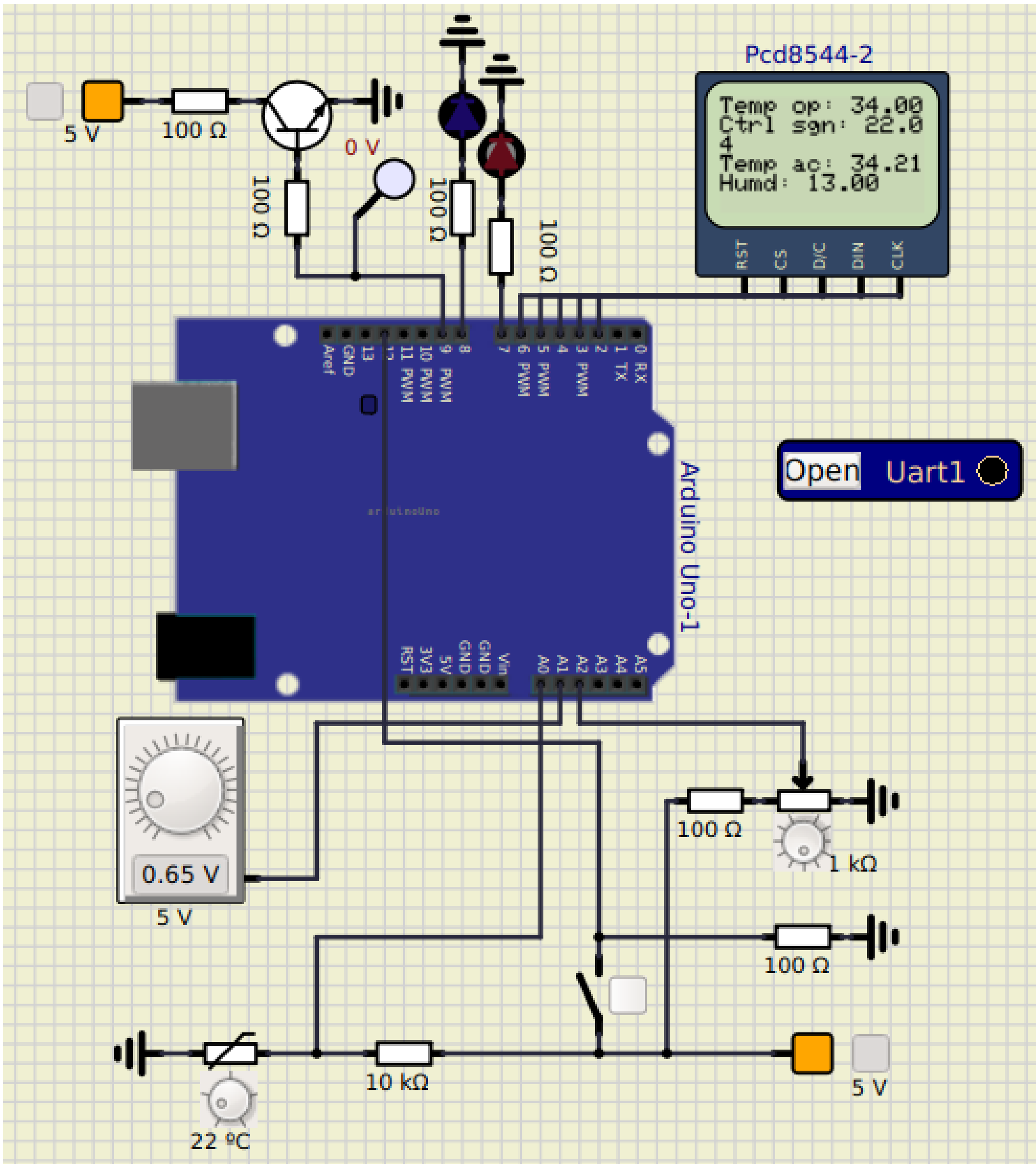


Figura 6: Incubadora a 34 grados (Autoría propia).

En caso de que el termistor sense una temperatura por debajo del rango deseado, y el punto de operación esté en el punto deseado, la salida se ajusta a 3.77V para calentar la incubadora pues la temperatura actual es de 15.82C en la siguiente figura. En este punto se está fuera del margen deseado, por lo que se enciende el LED azul alertando una temperatura fría. Por la misma temperatura baja, la señal de control está al máximo, 100 %, indicándole a la señal de salida que debe calentar en lo máximo posible para establecer un punto deseado.

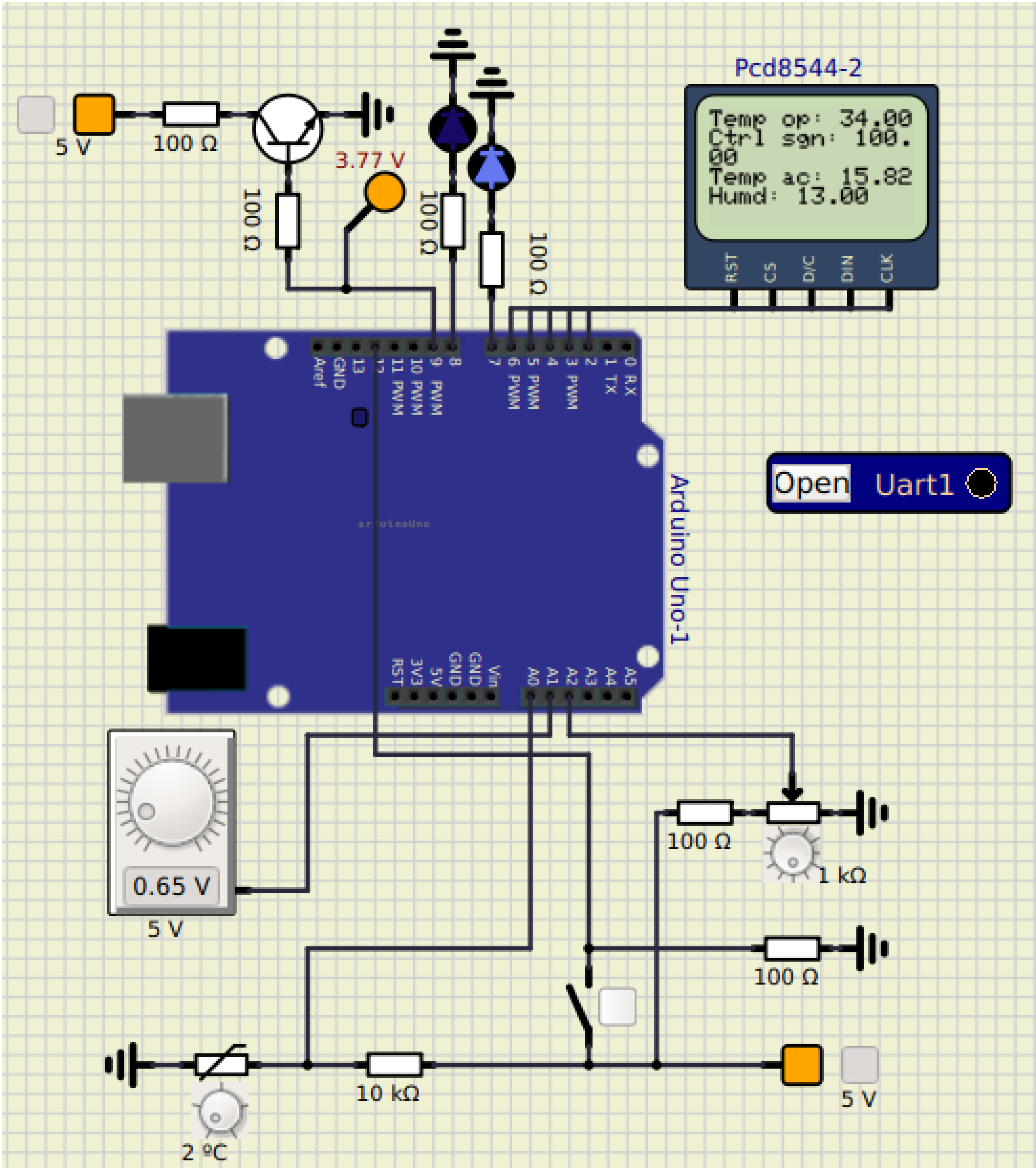


Figura 7: Incubadora a 15.82 grados (Autoría propia).

En el caso opuesto al anterior, en donde la temperatura está demasiado alta y los pollitos corren el riesgo de morir, se enciende el LED rojo para alertar alta temperatura. En la siguiente figura la temperatura actual está muy por encima de la deseada, es por esto que la señal de control está a un 0 %, indicando que la señal de salida debe ser mínima para estabilizar la temperatura.

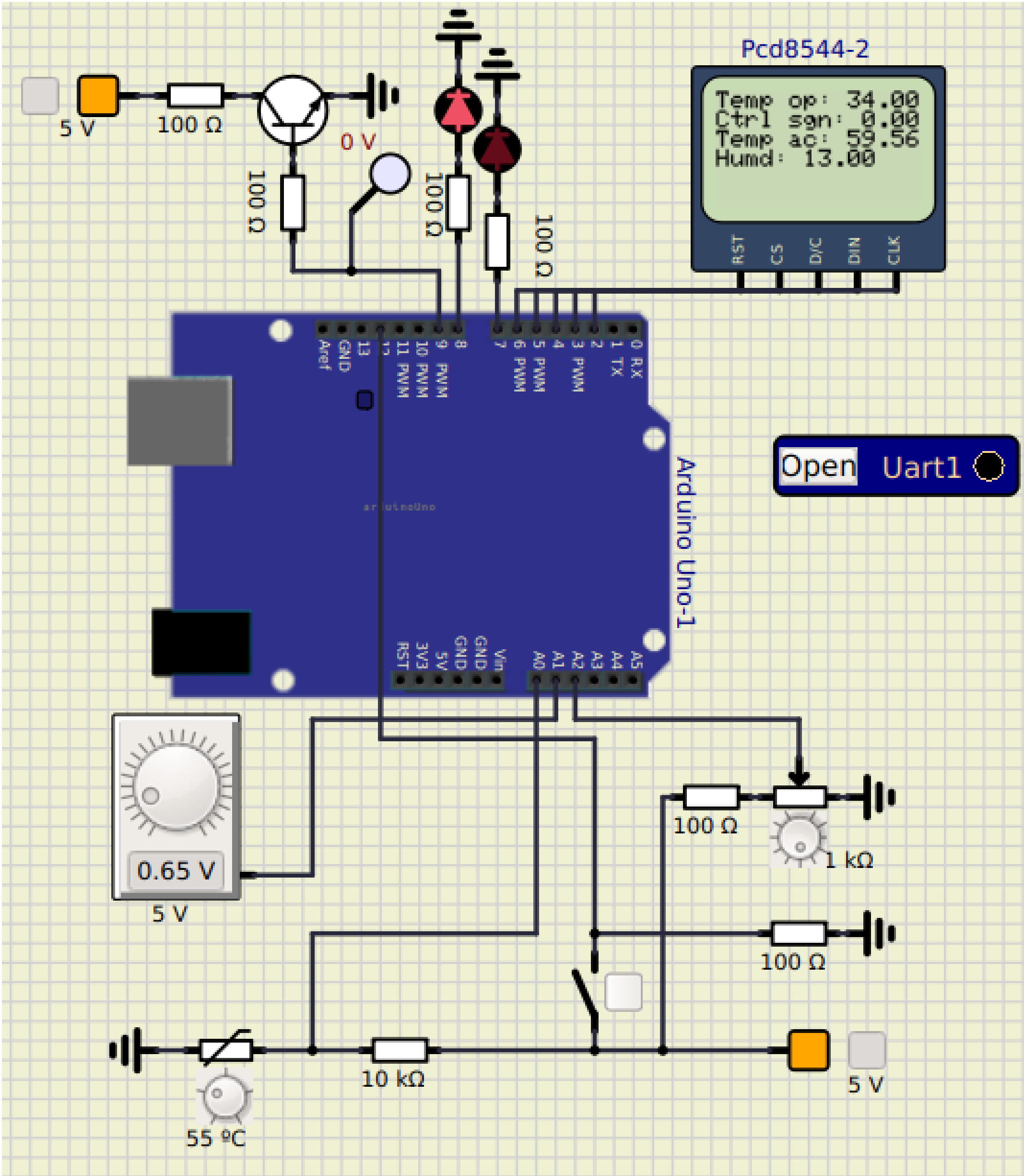


Figura 8: Incubadora a 59.56 grados (Autoría propia).

En todos los ejemplos anteriores no se ha habilitado la comunicación con la PC para registrar los datos en tiempo real en un archivo csv; esto debido a que el switch de control está abierto. En caso de cerrarlo se habilita la comunicación serial la cuál se aprecia a continuación:

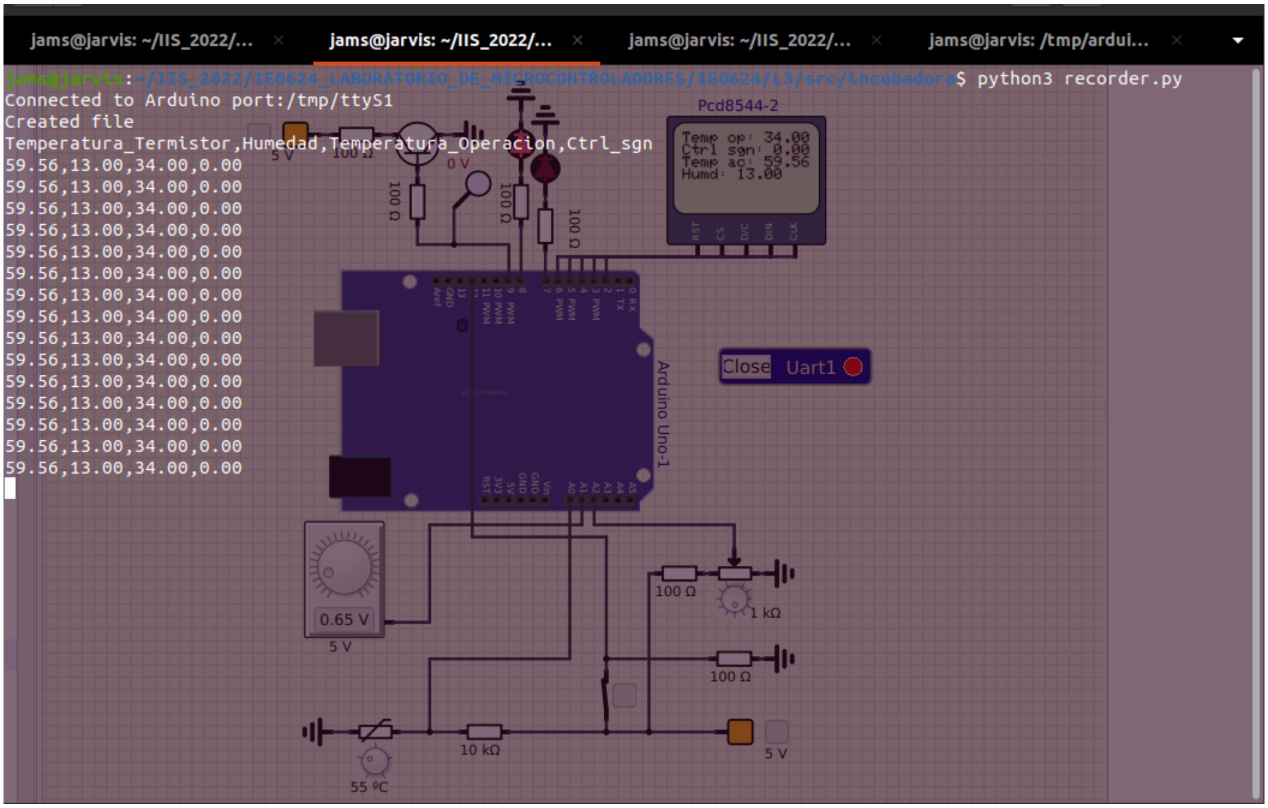


Figura 9: Incubadora a 59.56 grados. Comunicación habilitada (switch cerrado) (Autoría propia).

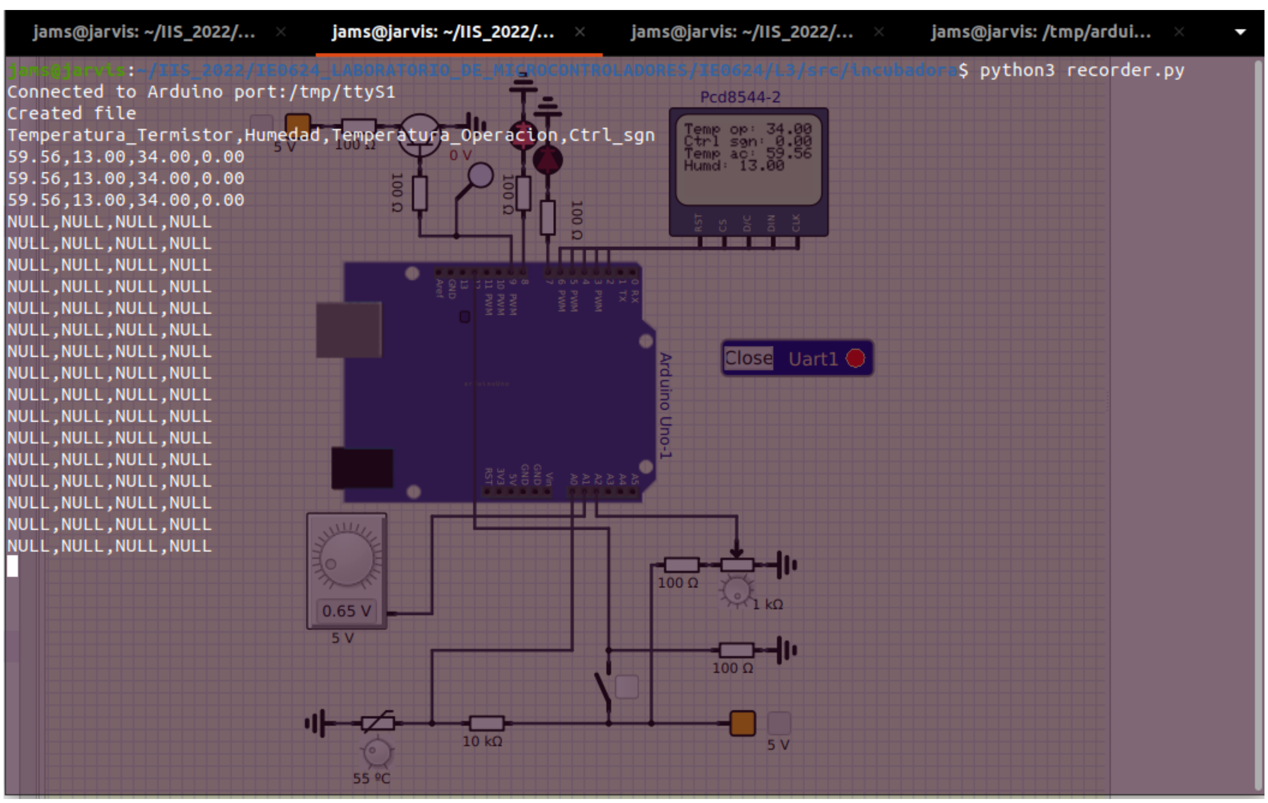


Figura 10: Incubadora a 59.56 grados. Comunicación deshabilitada (switch abierto) (Autoría propia).

Esta información se registra en un archivo de formato .csv *incubadora_data.csv*. El mismo se guarda con el siguiente estilo:

| Temperatura_Termistor | Humedad | Temperatura_Operacion | Ctrl_sgn |
|---|---|---|---|
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| NULL | NULL | NULL | NULL |
| NULL | NULL | NULL | NULL |
| NULL | NULL | NULL | NULL |
| NULL | NULL | NULL | NULL |
| NULL | NULL | NULL | NULL |
| NULL | NULL | NULL | NULL |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |
| 59.56 | 13 | 34 | 0 |

# 3. Conclusiones y Recomendaciones

- El objetivo del laboratorio se cumplió exitosamente. El controlador de temperatura es correcto y la comunicación serial de igual forma. Lo que deja al Arduino UNO como una plataforma que le permite a los usuarios, no necesariamente del campo técnico-científico, una manera simple para crear objetos interactivos que pueden tener entradas de interruptores y sensores, para controlar salidas físicas como digitales.
- Se recomienda adaptar otro entorno de desarrollo integrado para programar y compilar "Arduino", pues aunque está basado en C/C++, en primera instancia solo se permite a sí mismo trabajarse bajo su propio IDE; el cual es bastante limitado. Por esto, a través de por ejemplo Visual estudio code, se pueden descargar extensiones e instalar librerías para utilizar un entorno más profesional.
- Se recomienda crear un script de python para el registro de datos sensados más robusto a través de programación orientada a objetos haciendo uso de estructuras de tipo `class`.

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# 1. Description

The Atmel AVR® core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in a single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

The ATmega328/P provides the following features: 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 1Kbytes EEPROM, 2Kbytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, Real Time Counter (RTC), three flexible Timer/Counters with compare modes and PWM, 1 serial programmable USARTs , 1 byte-oriented 2-wire Serial Interface (I2C), a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages) , a programmable Watchdog Timer with internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption. In Extended Standby mode, both the main oscillator and the asynchronous timer continue to run.

Atmel offers the QTouch® library for embedding capacitive touch buttons, sliders and wheels functionality into AVR microcontrollers. The patented charge-transfer signal acquisition offers robust sensing and includes fully debounced reporting of touch keys and includes Adjacent Key Suppression® (AKS™) technology for unambiguous detection of key events. The easy-to-use QTouch Suite toolchain allows you to explore, develop and debug your own touch applications.

The device is manufactured using Atmel’s high density non-volatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed In-System through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. The Boot program can use any interface to download the application program in the Application Flash memory. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega328/P is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications.

The ATmega328/P is supported with a full suite of program and system development tools including: C Compilers, Macro Assemblers, Program Debugger/Simulators, In-Circuit Emulators, and Evaluation kits.

# 2. Configuration Summary

| Features | ATmega328/P |
|---|---|
| Pin Count | 28/32 |
| Flash (Bytes) | 32K |
| SRAM (Bytes) | 2K |
| EEPROM (Bytes) | 1K |
| General Purpose I/O Lines | 23 |
| SPI | 2 |
| TWI ($I^2C$) | 1 |
| USART | 1 |
| ADC | 10-bit 15kSPS |
| ADC Channels | 8 |
| 8-bit Timer/Counters | 2 |
| 16-bit Timer/Counters | 1 |

# 3. Ordering Information

## 3.1. ATmega328

| Speed [MHz][3] | Power Supply [V] | Ordering Code[2] | Package[1] | Operational Range |
|---|---|---|---|---|
| 20 | 1.8 - 5.5 | ATmega328-AU<br>ATmega328-AUR[5]<br>ATmega328-MMH[4]<br>ATmega328-MMHR[4][5]<br>ATmega328-MU<br>ATmega328-MUR[5]<br>ATmega328-PU | 32A<br>32A<br>28M1<br>28M1<br>32M1-A<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |

**Note:**

1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
3. Please refer to *Speed Grades* for Speed vs. $V_{CC}$
4. Tape & Reel.
5. NiPdAu Lead Finish.

| Package Type | |
|---|---|
| 28M1 | 28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |
| 28P3 | 28-lead, 0.300” Wide, Plastic Dual Inline Package (PDIP) |
| 32M1-A | 32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |
| 32A | 32-lead, Thin (1.0mm) Plastic Quad Flat Package (TQFP) |

## 3.2. ATmega328P

| Speed [MHz][3] | Power Supply [V] | Ordering Code[2] | Package[1] | Operational Range |
|---|---|---|---|---|
| 20 | 1.8 - 5.5 | ATmega328P-AU<br>ATmega328P-AUR[5]<br>ATmega328P-MMH[4]<br>ATmega328P-MMHR[4][5]<br>ATmega328P-MU<br>ATmega328P-MUR[5]<br>ATmega328P-PU | 32A<br>32A<br>28M1<br>28M1<br>32M1-A<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 85°C) |
| | | ATmega328P-AN<br>ATmega328P-ANR[5]<br>ATmega328P-MN<br>ATmega328P-MNR[5]<br>ATmega328P-PN | 32A<br>32A<br>32M1-A<br>32M1-A<br>28P3 | Industrial<br>(-40°C to 105°C) |

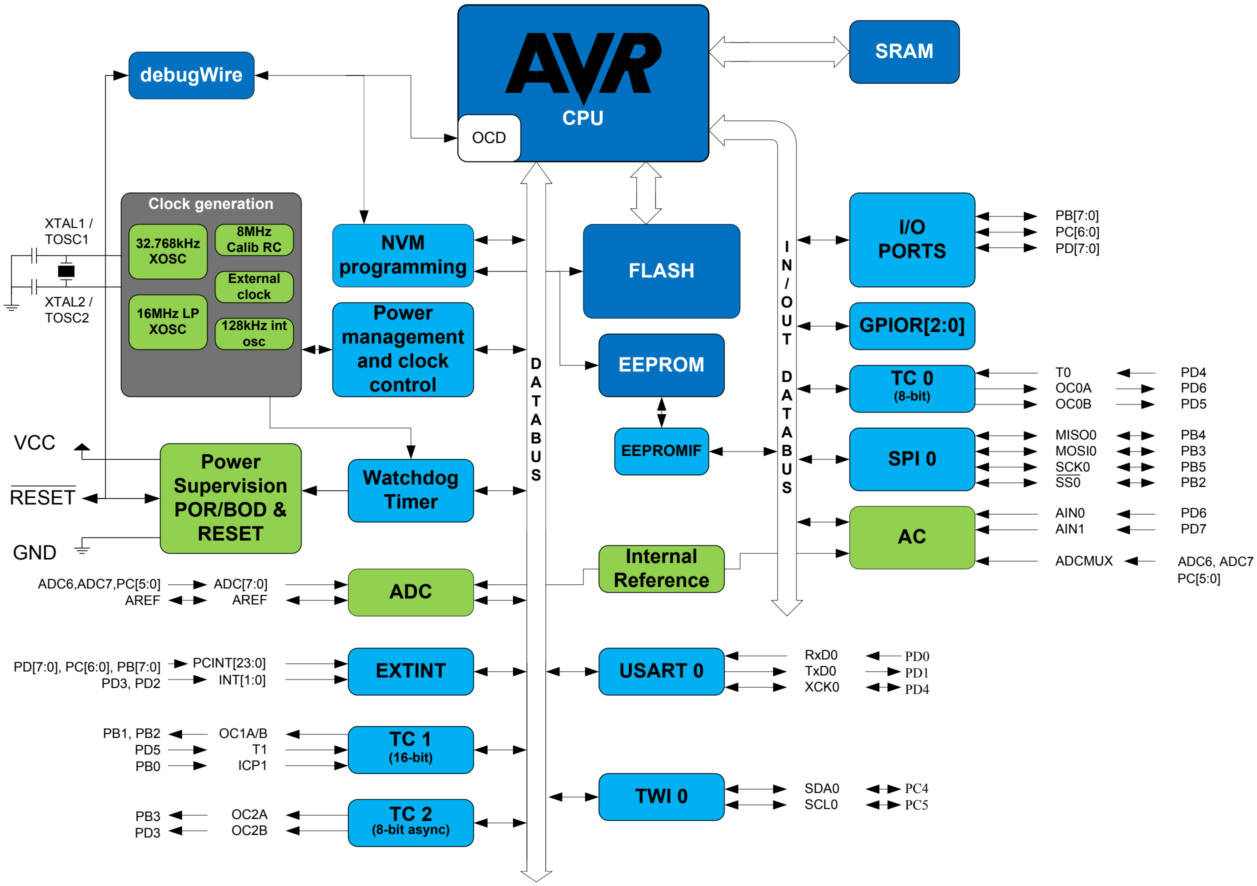
**Note:**

1. This device can also be supplied in wafer form. Please contact your local Atmel sales office for detailed ordering information and minimum quantities.
2. Pb-free packaging, complies to the European Directive for Restriction of Hazardous Substances (RoHS directive). Also Halide free and fully Green.
3. Please refer to *Speed Grades* for Speed vs. $V_{CC}$
4. Tape & Reel.
5. NiPdAu Lead Finish.

| Package Type | |
|---|---|
| 28M1 | 28-pad, 4 x 4 x 1.0 body, Lead Pitch 0.45mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |
| 28P3 | 28-lead, 0.300” Wide, Plastic Dual Inline Package (PDIP) |
| 32M1-A | 32-pad, 5 x 5 x 1.0 body, Lead Pitch 0.50mm Quad Flat No-Lead/Micro Lead Frame Package (QFN/MLF) |
| 32A | 32-lead, Thin (1.0mm) Plastic Quad Flat Package (TQFP) |

# 4. Block Diagram

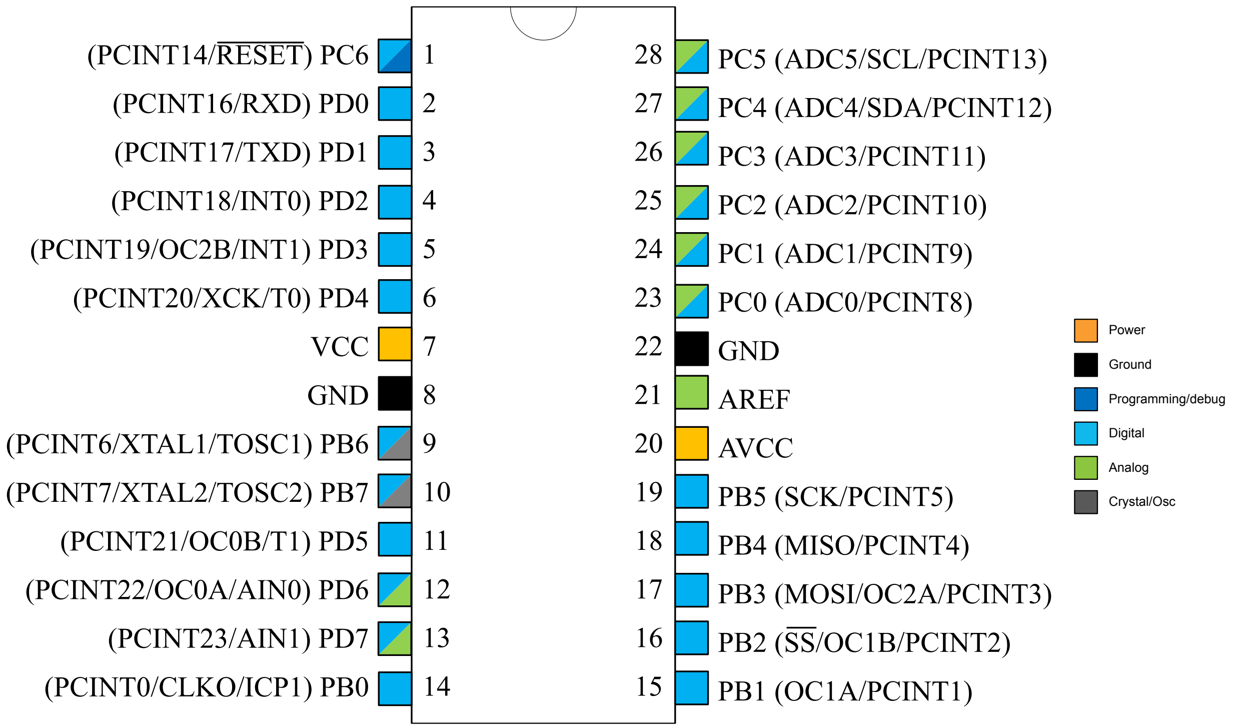
Figure 4-1. Block Diagram

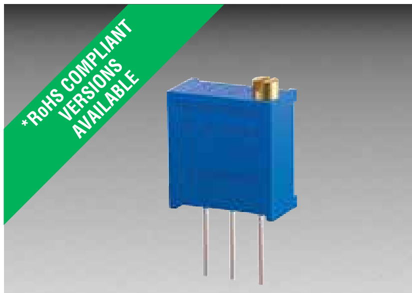


# 5. Pin Configurations

## 5.1. Pin-out

**Figure 5-1. 28-pin PDIP**






## Features

- Multiturn / Cermet / Industrial / Sealed
- 5 terminal styles
- Tape and reel packaging available
- Chevron seal design
- Listed on the QPL for style RJ24 per MIL-R-22097 and RJR24 per High-Rel Mil-R-39035
- Mounting hardware available (H-117P)
- RoHS compliant* version available
- For trimmer applications/processing guidelines, click here

# 3296 - 3/8 " Square Trimpot® Trimming Potentiometer

## Electrical Characteristics

Standard Resistance Range
......................10 ohms to 2 megohms
(see standard resistance table)
Resistance Tolerance ...........±10 % std.
(tighter tolerance available)
Absolute Minimum Resistance
........................... 1 % or 2 ohms max.
(whichever is greater)
Contact Resistance Variation
........................ 1.0 % or 3 ohms max.
(whichever is greater)
Adjustability
Voltage .................................±0.01 %
Resistance ...........................±0.05 %
Resolution .................................. Infinite
Insulation Resistance ...............500 vdc.
1,000 megohms min.
Dielectric Strength
Sea Level................................ 900 vac
70,000 Feet ............................ 350 vac
Effective Travel .................25 turns nom.

## Environmental Characteristics

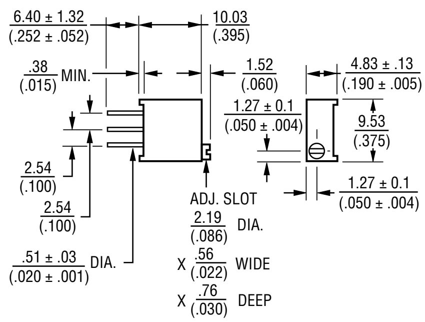
Power Rating (300 volts max.)
70 °C .....................................0.5 watt
125 °C ......................................0 watt
Temperature Range ... -55 °C to +125 °C
Temperature Coefficient ... ±100 ppm/°C
Seal Test ......................85 °C Fluorinert†
Humidity .......MIL-STD-202 Method 103
96 hours
(2 % ΔTR, 10 Megohms IR)
Vibration ....... 20 G (1 % ΔTR; 1 % ΔVR)
Shock ......... 100 G (1 % ΔTR; 1 % ΔVR)
Load Life.. 1,000 hours 0.5 watt @ 70 °C
(3 % ΔTR; 3 % or 3 ohms, whichever is greater, CRV)
Rotational Life .......................200 cycles
(4 % ΔTR; 3 % or 3 ohms, whichever is greater, CRV)

## Physical Characteristics

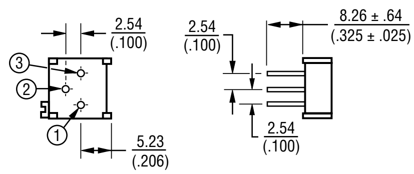
Torque............................3.0 oz-in. max.
Mechanical Stops.................Wiper idles
Terminals .......................Solderable pins
Weight ......................................0.03 oz.
Marking..........................Manufacturer's trademark, resistance code, wiring diagram, date code, manufacturer's model number and style
Wiper ...............50 % (Actual TR) ±10 %
Flammability ..........................U.L. 94V-0
Standard Packaging.....50 pcs. per tube
Adjustment Tool.............................H-90

## Product Dimensions

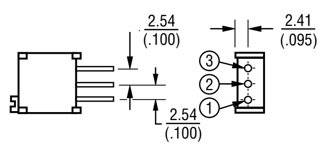
**Common Dimensions**



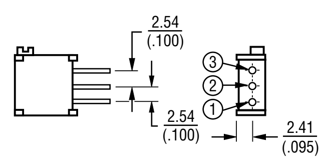

**3296P**



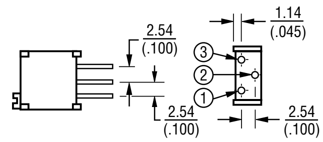

**3296W**



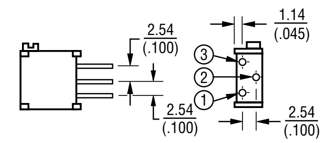

**3296X**

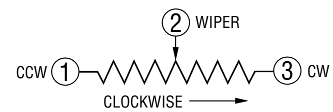



**3296Y**




**3296Z**




DIMENSIONS: $\frac{\text{MM}}{\text{(INCHES)}}$

TOLERANCES: ± $\frac{0.25}{(.010)}$ EXCEPT WHERE NOTED

## Standard Resistance Table

| Resistance (Ohms) | Resistance Code |
|---|---|
| **10** | **100** |
| **20** | **200** |
| **50** | **500** |
| **100** | **101** |
| **200** | **201** |
| **500** | **501** |
| **1,000** | **102** |
| **2,000** | **202** |
| **5,000** | **502** |
| **10,000** | **103** |
| **20,000** | **203** |
| **25,000** | **253** |
| **50,000** | **503** |
| **100,000** | **104** |
| **200,000** | **204** |
| **250,000** | **254** |
| **500,000** | **504** |
| **1,000,000** | **105** |
| **2,000,000** | **205** |

Popular values listed in boldface. Special resistances available.

## How To Order

**3296 W - 1 - 103 __ LF**

Model

Style

Standard or Modified Product Indicator
-1 = Standard Product

Resistance Code

Packaging Designator
Blank = Tube (Standard)
R = Tape and Reel (X and W Pin Styles Only)
A = Ammo Pack (X and W Pin Styles Only)

Tape and reel material meets Antistatic ANSI/ESD 5541-2003 packaging standards.

Terminations
LF = 100 % Tin-plated (RoHS compliant)
Blank = 90 % Tin / 10 % Lead-plated (Standard)

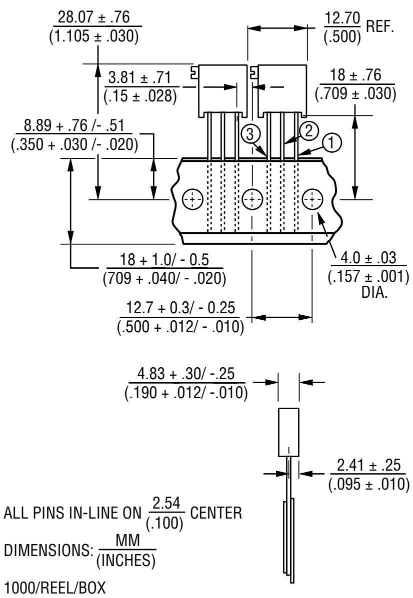
Consult factory for other available options.

†"Fluorinert" is a registered trademark of 3M Co.

*RoHS Directive 2002/95/EC Jan. 27, 2003 including annex and RoHS Recast 2011/65/EU June 8, 2011.
Specifications are subject to change without notice.
The device characteristics and parameters in this data sheet can and do vary in different applications and actual device performance may vary over time.
Users should verify actual device performance in their specific applications.

## Packaging Specifications

**SIDE ADJUST**
**3296X-1**

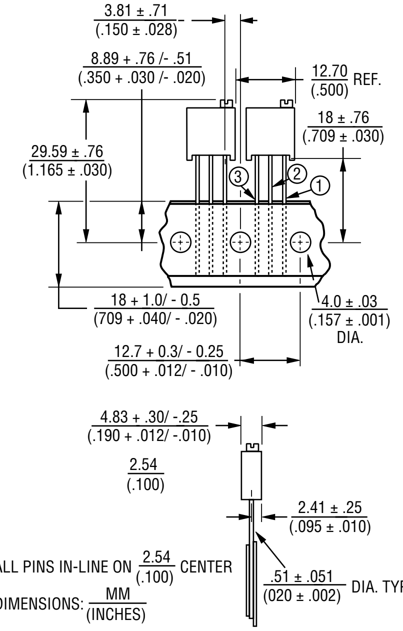



ALL PINS IN-LINE ON 2.54 (.100) CENTER

DIMENSIONS: MM (INCHES)

1000/REEL/BOX

**TOP ADJUST**
**3296W-1**




ALL PINS IN-LINE ON 2.54 (.100) CENTER

DIMENSIONS: MM (INCHES)

1000/REEL/BOX

Meets EIA Specification 468.

REV. 05/16

ELECTRONICS, INC.
44 FARRAND STREET
BLOOMFIELD, NJ 07003
(973) 748–5089

# NTE123A (NPN) & NTE159M (PNP)
# Silicon Complementary Transistors
# General Purpose

**Description:**

The NTE123A (NPN) and NTE159M (PNP) are widely used “Industry Standard” complementary transistors in a TO18 type case designed for applications such as medium–speed switching and amplifiers from audio to VHF frequencies.

**Features:**

- Low Collector Saturation Voltage: 1V (Max)
- High Current Gain–Bandwidth Product: $f_T$ = 300MHz (Min) @ $I_C$ 20mA

**Absolute Maximum Ratings:**

Collector–Emitter Voltage, $V_{CEO}$
NTE123A . . . . . . . . . . . . . . . . . . . . . . . . . . . . 40V
NTE159M . . . . . . . . . . . . . . . . . . . . . . . . . . . . 60V

Collector–Base Voltage, $V_{CBO}$
NTE123A . . . . . . . . . . . . . . . . . . . . . . . . . . . . 75V
NTE159M . . . . . . . . . . . . . . . . . . . . . . . . . . . . 60V

Emitter–Base Voltage, $V_{EBO}$
NTE123A . . . . . . . . . . . . . . . . . . . . . . . . . . . . 6V
NTE159M . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5V

Continuous Collector Current, $I_C$
NTE123A . . . . . . . . . . . . . . . . . . . . . . . . . . . . 800mA
NTE159M . . . . . . . . . . . . . . . . . . . . . . . . . . . . 600mA

Total Device Dissipation ($T_A$ = +25°C), $P_D$ . . . . . . . . . . . . . . . . 0.4W
Derate Above +25°C . . . . . . . . . . . . . . . . . . . . . 2.28mW/°C

Total Device Dissipation ($T_C$ = +25°C), $P_D$
NTE123A . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1.2W
Derate Above +25°C . . . . . . . . . . . . . . . . . . . . . 6.85mW/°C
NTE159M . . . . . . . . . . . . . . . . . . . . . . . . . . . . 1.8W
Derate Above +25°C . . . . . . . . . . . . . . . . . . . . . 10.3mW/°C

Operating Temperature Range, $T_J$ . . . . . . . . . . . . . . . . –65° to +200°C
Storage Temperature Range, $T_{stg}$ . . . . . . . . . . . . . . . . –65° to +200°C

**Electrical Characteristics:** ($T_A$ = 25°C unless otherwise specified)

| Parameter | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| **OFF Characteristics** | | | | | | | |
| Collector–Emitter Breakdown Voltage NTE123A | $V_{(BR)CEO}$ | $I_C$ = 10mA, $I_B$ = 0 | | 40 | – | – | V |
| NTE159M | | | | 60 | – | – | V |
| Collector–Base Breakdown Voltage NTE123A | $V_{(BR)CBO}$ | $I_C$ = 10μA, $I_E$ = 0 | | 75 | – | – | V |
| NTE159M | | | | 60 | – | – | V |
| Emitter–Base Breakdown Voltage NTE123A | $V_{(BR)EBO}$ | $I_E$ = 10μA, $I_C$ = 0 | | 6 | – | – | V |
| NTE159M | | | | 5 | – | – | V |
| Collector Cutoff Current NTE123A | $I_{CEX}$ | $V_{CE}$ = 60V, $V_{EB(off)}$ = 3V | | – | – | 10 | nA |
| NTE159M | | $V_{CE}$ = 30V, $V_{BE}$ = 500mV | | – | – | 50 | nA |
| Collector Cutoff Current NTE123A | $I_{CBO}$ | $V_{CB}$ = 60V, $I_E$ = 0 | | – | – | 0.01 | μA |
| | | $V_{CB}$ = 60V, $I_E$ = 0, $T_A$ = +150°C | | – | – | 10 | μA |
| NTE159M | | $V_{CB}$ = 50V, $I_E$ = 0 | | – | – | 0.01 | μA |
| | | $V_{CB}$ = 50V, $I_E$ = 0, $T_A$ = +150°C | | – | – | 10 | μA |
| Emitter Cutoff Current (NTE123A Only) | $I_{EBO}$ | $V_{EB}$ = 3V, $I_C$ = 0 | | – | – | 10 | nA |
| Base Cutoff Current NTE123A | $I_{BL}$ | $V_{CE}$ = 60V, $V_{EB(off)}$ = 3V | | – | – | 20 | nA |
| NTE159M | | $V_{CE}$ = 30V, $V_{EB(off)}$ = 500mV | | – | – | 50 | nA |
| **ON Characteristics** | | | | | | | |
| DC Current Gain NTE123A | $h_{FE}$ | $V_{CE}$ = 10V | $I_C$ = 0.1mA, Note 1 | 35 | – | – | |
| | | | $I_C$ = 1mA | 50 | – | – | |
| | | | $I_C$ = 10mA, Note 1 | 75 | – | – | |
| | | | $I_C$ = 10mA, $T_A$ = –55°C | 35 | – | – | |
| | | | $I_C$ = 150mA, Note 1 | 100 | – | 300 | |
| | | $V_{CE}$ = 1V, $I_C$ = 150mA, Note 1 | | 50 | – | – | |
| | | $V_{CE}$ = 10V | $I_C$ = 500mA, Not e 1 | 40 | – | – | |
| NTE159M | | | $I_C$ = 0.1mA | 75 | – | – | |
| | | | $I_C$ = 1mA | 100 | – | – | |
| | | | $I_C$ = 10mA | 100 | – | – | |
| | | | $I_C$ = 150mA, Note 1 | 100 | – | 300 | |
| | | | $I_C$ = 500mA, Note 1 | 50 | – | – | |
| Collector–Emitter Saturation Voltage NTE123A | $V_{CE(sat)}$ | $I_C$ = 150mA, $I_B$ = 15mA, Note 1 | | – | – | 0.3 | V |
| | | $I_C$ = 500mA, $I_B$ = 50mA, Note 1 | | – | – | 1.0 | V |
| NTE159M | | $I_C$ = 150mA, $I_B$ = 15mA, Note 1 | | – | – | 0.4 | V |
| | | $I_C$ = 500mA, $I_B$ = 50mA, Note 1 | | – | – | 1.6 | V |

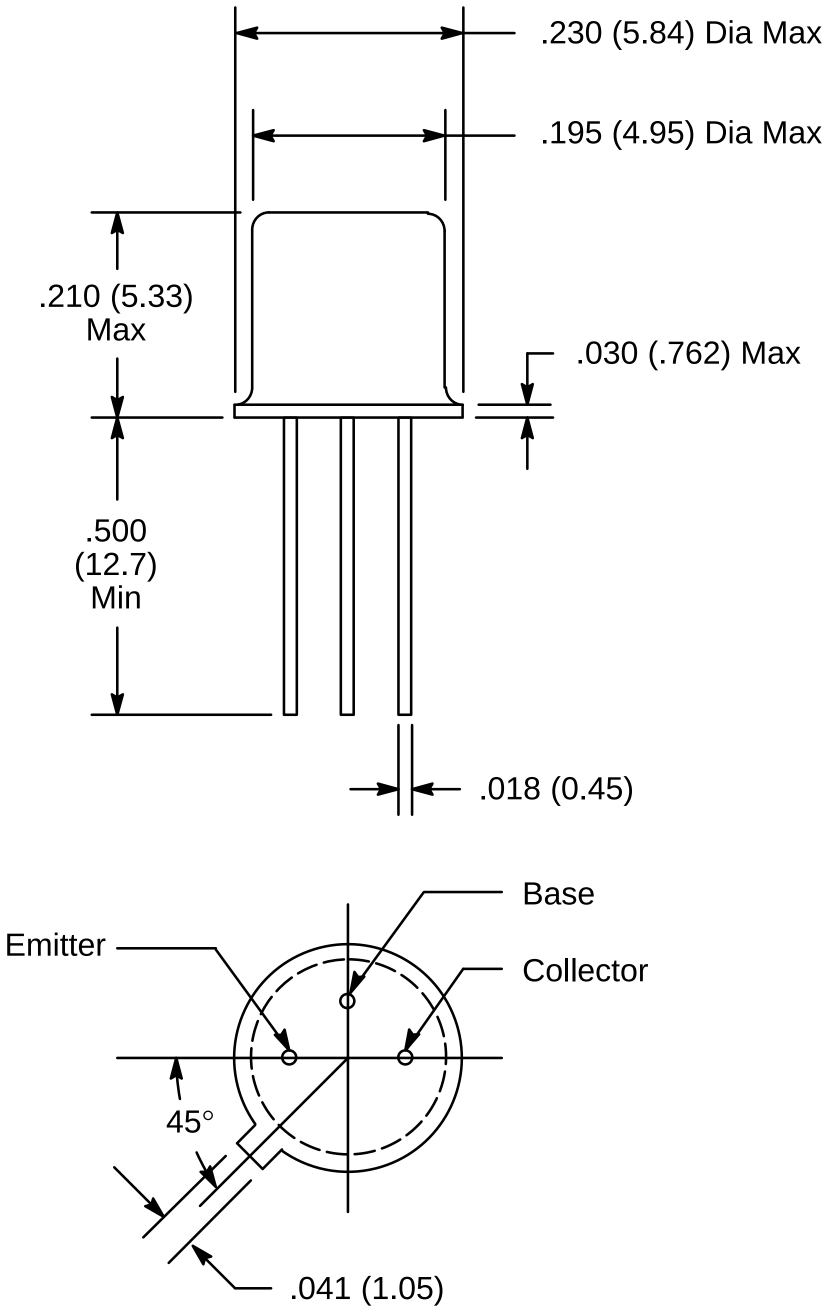
Note 1. Pulse Test: Pulse Width ≤ 300μs, Duty Cycle ≤ 2%.

**Electrical Characteristics (Cont'd):** ($T_A$ = 25°C unless otherwise specified)

| Parameter | Symbol | Test Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| **ON Characteristics (Cont'd)** | | | | | | | |
| Base–Emitter Saturation Voltage NTE123A | $V_{BE(sat)}$ | $I_C$ = 150mA, $I_B$ = 15mA, Note 1 | | 0.6 | – | 1.2 | V |
| | | $I_C$ = 500mA, $I_B$ = 50mA, Note 1 | | – | – | 2.0 | V |
| NTE159M | | $I_C$ = 150mA, $I_B$ = 15mA, Note 1 | | – | – | 1.3 | V |
| | | $I_C$ = 500mA, $I_B$ = 50mA | | – | – | 2.6 | V |
| **Small–Signal Characteristics** | | | | | | | |
| Current Gain–Bandwidth Product NTE123A | $f_T$ | $I_C$ = 20mA | $V_{CE}$ = 20V, f = 100MHz, Note 2 | 300 | – | – | MHz |
| NTE159M | | $I_C$ = 50mA | | 200 | – | – | MHz |
| Output Capacitance | $C_{obo}$ | $V_{CB}$ = 10V, $I_E$ = 0, f = 100kHz | | – | – | 8 | pF |
| Input Capactiance NTE123A | $C_{ibo}$ | $V_{BE}$ = 0.5V | $I_C$ = 0, f = 100kHz | – | – | 25 | pF |
| NTE159M | | $V_{BE}$ = 2V | | – | – | 30 | pF |
| Input Impedance (NTE123A Only) | $h_{ie}$ | $I_C$ = 1mA | $V_{CE}$ = 10V, f = 1kHz | 2.0 | – | 8.0 | kΩ |
| | | $I_C$ = 10mA | | 0.25 | – | 1.25 | kΩ |
| Voltage Feedback Ratio (NTE123A Only) | $h_{re}$ | $I_C$ = 1mA | $V_{CE}$ = 10V, f = 1kHz | – | – | 8 | x $10^{-4}$ |
| | | $I_C$ = 10mA | | – | – | 4 | x $10^{-4}$ |
| Small–Signal Current Gain (NTE123A Only) | $h_{fe}$ | $I_C$ = 1mA | $V_{CE}$ = 10V, f = 1kHz | 50 | – | 300 | |
| | | $I_C$ = 10mA | | 75 | – | 375 | |
| Output Admittance (NTE123A Only) | $h_{oe}$ | $I_C$ = 1mA | $V_{CE}$ = 10V, f = 1kHz | 5 | – | 35 | µmhos |
| | | $I_C$ = 10mA | | 25 | – | 200 | µmhos |
| Collector–Base Time Constant (NTE123A Only) | $rb'C_c$ | $I_E$ = 20mA, $V_{CB}$ = 20V, f = 31.8MHz | | – | – | 150 | ps |
| Noise Figure (NTE123A Only) | NF | $I_C$ = 100µA, $V_{CE}$ = 10V, $R_S$ = 1kΩ, f = 1kHz | | – | – | 4 | dB |
| Real Part of Common–Emitter High Frequency Input Impedance (NTE123A Only) | $Re(h_{ie})$ | $I_C$ = 20mA, $V_{CE}$ = 20V, f = 300MHz | | – | – | 60 | Ω |
| **Switching Characteristics** | | | | | | | |
| NTE123A Delay Time | $t_d$ | $V_{CC}$ = 30V, $V_{BE(off)}$ = 500mV, $I_C$ = 150mA, $I_{B1}$ =– 15mA | | – | – | 10 | ns |
| Rise Time | $t_r$ | | | – | – | 25 | ns |
| Storage Time | $t_s$ | $V_{CC}$ = 30V, $I_C$ = 150mA, $I_{B1}$ = $I_{B2}$ = 15mA | | – | – | 225 | ns |
| Fall Time | $t_f$ | | | – | – | 60 | ns |
| NTE159M Turn–On Time | $t_{on}$ | $V_{CC}$ = 30V, $I_C$ = 150mA, $I_{B1}$ = 15mA | | – | 26 | 45 | ns |
| Delay Time | $t_d$ | | | – | 6 | 10 | ns |
| Rise Time | $t_r$ | | | – | 20 | 40 | ns |
| Turn–Off Time | $t_{off}$ | $V_{CC}$ = 6V, $I_C$ = 150mA, $I_{B1}$ = $I_{B2}$ = 15mA | | – | 70 | 100 | ns |
| Storage Time | $t_s$ | | | – | 50 | 80 | ns |
| Fall Time | $t_f$ | | | – | 20 | 30 | ns |

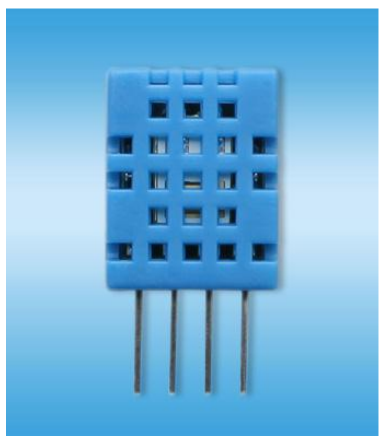
Note 1. Pulse Test: Pulse Width ≤ 300µs, Duty Cycle ≤ 2%.

Note 2. $f_T$ is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.


.230 (5.84) Dia Max
.195 (4.95) Dia Max
.210 (5.33)
Max
.030 (.762) Max
.500
(12.7)
Min
.018 (0.45)
Base
Emitter
Collector
45°
.041 (1.05)

AOSONG

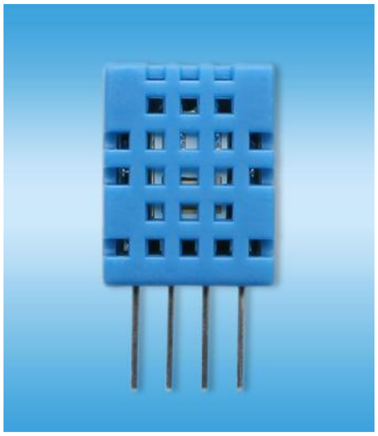
# Temperature and Humidity Module
## DHT11 Product Manual



For more information, please visit：www.aosong.com

## 1. Product Overview

DHT11 digital temperature and humidity sensor is a calibrated digital signal output of the temperature and humidity combined sensor. It uses a dedicated digital modules capture technology and the temperature and humidity sensor technology to ensure that products with high reliability and excellent long-term stability. Sensor includes a resistive element and a sense of wet NTC temperature measurement devices, and with a high-performance 8-bit microcontroller connected .



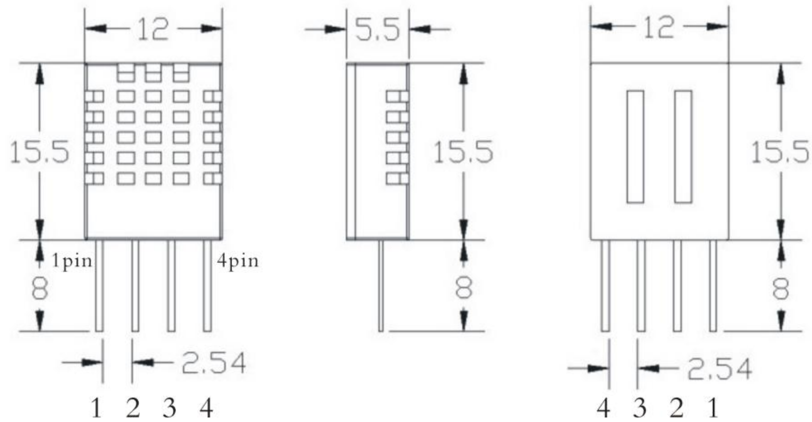
## 2. Applications

HVAC, dehumidifiers, testing and inspection equipment, consumer goods, automotive, automation, data loggers, weather stations, home appliances, humidity regulator, medical and other relevant humidity measurement and control.

## 3. Product Highlights

Low-cost, long-term stability, relative humidity and temperature measurement, excellent quality, fast response, anti-interference ability, long distance signal transmission, the digital signal output, precise calibration.

## 4. Dimensions（Unit：mm）




## 5. Parameters

### Relative Humidity

Resolution：16Bit

Repeatability： ±1%RH

Accuracy：25℃ ±5%RH

Interchangeability：Fully interchangeable

Response time：1/e (63%)25℃ 6s

1m/s Air 6s

Hysteresis：<±0.3%RH

Long-term stability：<±0.5%RH/yr

### Temperature

Resolution：16Bit

Repeatability： ±1℃

Accuracy：25℃ ±2℃

Response time：1/e (63%) 10S

### Electrical Characteristics

Power supply：DC 3.3～5.5V

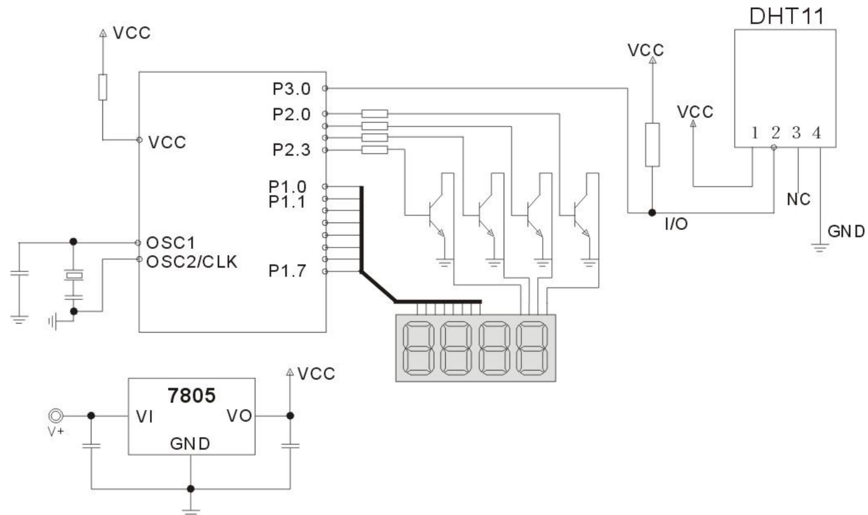
Supply current：Measure 0.3mA Standby 60µA

Sampling period：Secondary Greater than 2 seconds

Pin Description

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

## 6. Typical circuit




Connecting the typical application circuit shown above the microprocessor and DHT11, DATA pull-up and microprocessor I/O port.

1. A typical application circuit recommended cable length shorter than 20 meters with a 5.1K pull-up resistor when greater than 20 meters when the pull-up resistor to reduce the actual situation.

2. When using a 3.3V voltage supply cable length must not be greater than 100cm. Otherwise it will lead to lack of line drop sensor supply, causing measurement bias.

3. Temperature and humidity values are read out every last measurement result, want to get real-time data, to be read twice in a row, but not recommended repeatedly read sensors, each sensor reading interval of more than 5 seconds to obtain accurate data.

## 7. Serial Communications Description (single-wire bidirectional)

◎Single Bus Description

DHT11 device uses a simplified single-bus communication. Single bus that only one data line, the data exchange system, are controlled by a single bus is complete. Device (master or slave) through an open-drain or tri-state port is connected to the data line to allow the device to send data when not able to release the bus, and let other devices use the bus; single bus usually requires an external approximately 5.1kΩ pull up resistor, so that when the bus is idle, the state is high. Because they are master-slave structure, only the host calls a slave, a slave to answer, so the host access devices must strictly follow the sequence of a single bus, if there is a sequence of confusion, the device will not respond to the host.

◎Single bus transfer data bit definition

DATA is used for communication between the microprocessor and DHT11 and synchronization, single-bus data format, a 40-bit data transfer, high first-out.

Data formats:

8bit humidity integer data + 8bit decimal data +8 bit temperature and humidity data + 8bit temperature decimal integer data +8 bit parity bit.

Note: The fractional portion wherein the temperature and humidity of 0.

◎Parity bit data definition

"8bit humidity decimal integer data + 8bit humidity temperature data +8 bit decimal integer data + 8bit temperature data" 8bit parity bit is equal to the result of the end of eight.

Example One：40 receives the data to:

| 0011 0101 | 0000 0000 | 0001 1000 | 0000 0000 | 0100 1101 |
|---|---|---|---|---|
| High humidity 8 | Low humidity 8 | High temperature 8 | Low temperature 8 | Parity bit |

Calculated as follows:

0011 0101+0000 0000+0001 1000+0000 0000= 0100 1101

Receive data is correct:

Humidity: 0011 0101=35H=53%RH

Temperature:0001 1000=18H=24℃

Example Two: The received data is 40:

| 0011 0101 | 0000 0000 | 0001 1000 | 0000 0000 | 0100 1001 |
|---|---|---|---|---|
| High humidity 8 | High humidity 8 | High temperature 8 | High temperature 8 | Parity bit |

Calculated as follows:

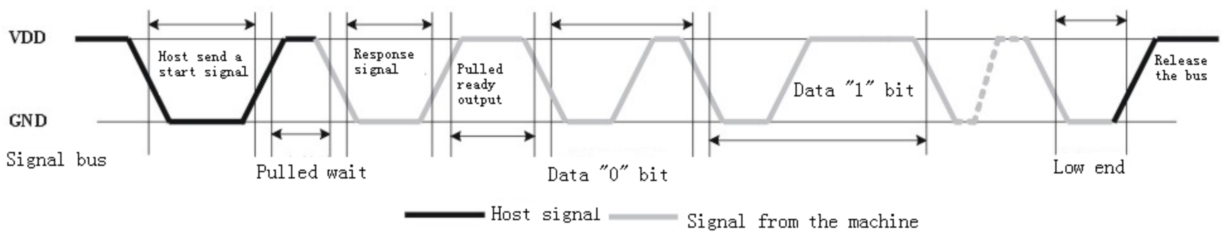
0011 0101+0000 0000+0001 1000+0000 0000 = 0100 1101

01001001 is not equal to 01001101

The received data is not correct, give up, again receiving data.

◎Data Timing Diagram

Hosts (MCU) after sending a start signal, DHT11 transition from a low-power mode to high-speed mode, the host until after the end of the start signal, DHT11 send a response signal, send 40bit data acquisition and trigger a letter. Signal transmission shown in fig.




Data Timing Diagram

Note: The host reads temperature and humidity data from DHT11 always previous measurements, such as the two measured time interval is long, please read twice in a row is the second time in real time temperature and humidity values.

◎Peripheral reading step

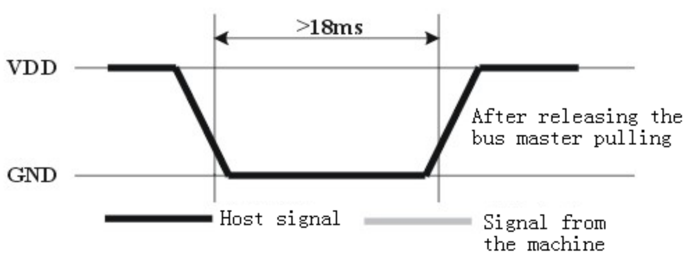
Communication between master and slave can be completed by the following steps (peripherals (such as a microprocessor) to read step DHT11 data).

Step one:

DHT11 after power (power after DHT11 1S to wait to cross the unstable state during this period can't send any commands), test environment temperature and humidity data, and record data while the data lines DATA DHT11 pulled by a pull-up resistor remains high; DHT11 this time the DATA pin is the input state, always detect external signals.

Step two:

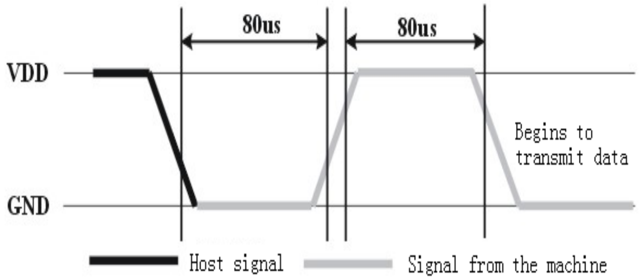
Microprocessor I / O output while the output is set to low, and low retention time can't be less than 18ms, then the microprocessor I / O is set to enter the state, due to the pull-up resistor, the microprocessor I / O that the data lines DHT11 also will go high, waiting to answer DHT11 signals transmitted signal as shown:




**The host sends a start signal**

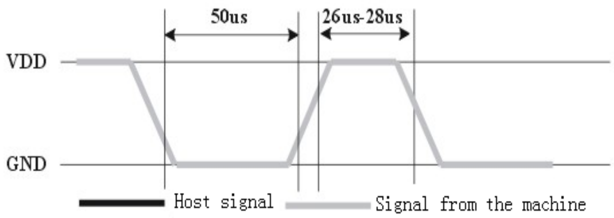
Step three:

DHT11 the DATA pin when external signals detected low, waiting for the external signal low end, after a delay DHT11 the DATA pin is an output, the output low as 80 microseconds response signal, followed by the output of 80 micro-notify the second high peripheral is ready to receive data, the microprocessor I / O at this time in the input state detecting I / O with low (DHT11 echo signal) to the wait for 80 microseconds high data receiving and sending signals as shown:

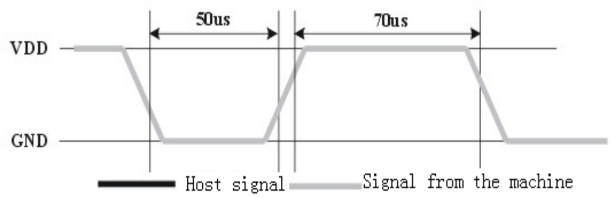



Step four:

The 40 bit data output by the DHT11 DATA pin, the microprocessor according to the change of I/O level receive 40 bits of data, a data format of "0": high level and low level of 50 microseconds and 26-28 microsecond, format data "1": low level 50 microsecond plus 70 microsecond high. Bit data "0", "1" format signal as shown in fig:



Bit data ″0″ format



Bit data ″1″ format

End signal:

DHT11 the DATA pin output 40-bit data, the continued output low 50 microseconds after the entry into the state, due to the pull-up resistor attendant goes high. But DHT11 temperature and humidity inside the test-retest data, and record the data, awaiting the arrival of an external signal.

## 8. Application Information

1. Working and storage conditions

The proposed scope of work may result in up to 3% RH temporary drift of the signal. Return to normal working conditions, the sensor calibration status will slowly recover. To speed up the recovery process can be found in "recovery process." The use of the product will accelerate the aging process for a long time under abnormal operating conditions.

Avoid placing components on a long-term condensation and dry conditions and the following environments.

A. smoke

B. Acid or oxidizing gases such as sulfur dioxide, hydrochloric acid

Recommended Storage Environment

Temperature：10~40℃　　　Humidity：60% RH or less

2. Effects of exposure to chemical substances

Sensing resistive humidity sensor will be disturbed chemical vapor layer, the diffusion layer in the induction of chemicals may cause drift and measurement sensitivity. In a clean environment, slowly release contaminants out. The recovery process described below to accelerate the process.

High concentrations of chemical pollution can cause damage to the sensor sensing layer completely.

3. Temperature Effect

Relative humidity of the gas is largely dependent on temperature. Therefore, when measuring the humidity should be possible to ensure that the humidity sensor works at the same temperature. If you share a printed circuit board with electronic components heat released in the sensor should be installed as far as possible away from the electronic components, and installed at the bottom of the heat source, while maintaining a well-ventilated enclosure. To reduce the thermal conductivity sensor and a copper plating layer of the printed circuit board should be as minimal other portions, and leaving a gap between them.

4. Light effects

Prolonged exposure to sunlight or strong ultraviolet radiation, will reduce performance.

5. Recovery process

Placed under extreme operating conditions or chemical vapor sensors, through the following process, you can return it to the state calibration. <2 hours (drying) under 10% RH humidity conditions; then at 20-30 ℃ and> 45 ℃ and humidity under 70% RH conditions were maintained for more than 5 hours.

6. Wiring Precautions

DATA signal wire quality will affect the communication distance and communication quality, we recommend using a high-quality shielded cable.

7. Soldering Information

Manual welding, at a temperature of 300 ℃ maximum contact time must be less than 10 seconds.

8. Product upgrades

For details, please consult our technical department。

## 9. License Agreement

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Do not use this product as safety or emergency stop devices, as well as due to the failure of the product could result in personal injuries to any of the other applications. The product shall not apply unless there is a particular purpose or use authorization. Before installation, handling, use or maintenance of the product to the reference product data sheets and application notes. Failure to comply with this recommendation could result in death or serious injury. The resulting company will not be liable for all damages in personal injury and death, and thus exempt from any claims against the company managers and employees and affiliated agents, distributors, etc. that may arise, including: a variety of costs, damages costs, attorney fees, and so on.

## 11. Quality Assurance

The company offers a three-month quality assurance (calculated from the date of shipment from) their direct purchasers of the product. Data sheet of the company published the technical specifications of the product shall prevail. If the warranty period, the product is proved to be defective quality, the company will provide free repair or replacement. Users must satisfy the following conditions:

① Product is found defective within 14 days written notice to the Company;

② Product should be returned to the purchaser to pay the company;

③ Shelf life of the product should be.

The company only to those used in compliance with the technical condition and defects of products is responsible for. Company for its products used in those special applications without any warranty, guarantee or written statement. The company applied to the product or its products reliability of the circuit does not make any promises.

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CHINA YUNSUN LED LIGHTING CO., LTD.
TEL: (86) 755-28079401 28079402 28079403 28079404 28079405
FAX: (86) 755-28079407 E-mail: info@100LED.com Web: www.100LED.com

# Model No.: YSL-R1047R3D-D2

## Applications:

- Decorations
- Illuminations
- Advertising Sign
- Traffic Lights
- Indicators
- Flashlights

## Absolute Maximum Ratings: (Ta=25℃) .

| ITEMS | Symbol | Absolute Maximum Rating | Unit |
|---|---|---|---|
| Forward Current | $I_F$ | 20 | mA |
| Peak Forward Current | $I_{FP}$ | 30 | mA |
| Suggestion Using Current | $I_{su}$ | 16-18 | mA |
| Reverse Current (V$_R$=5V) | $I_R$ | 10 | uA |
| Power Dissipation | $P_D$ | 105 | mW |
| Operation Temperature | $T_{OPR}$ | -40 ~ 85 | ℃ |
| Storage Temperature | $T_{STG}$ | -40 ~ 100 | ℃ |
| Lead Soldering Temperature | $T_{SOL}$ | Max. 260℃ for 3 Sec. Max. (3mm from the base of the expoxy bulb) | |

## Absolute Maximum Ratings: (Ta=25℃)

| ITEMS | Symbol | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| Forward Voltage | $V_F$ | $I_F$=20mA | 1.8 | --- | 2.2 | V |
| Wavelength (nm) or TC(k) | $\Delta\lambda$ | $I_F$=20mA | 620 | --- | 625 | nm |
| *Luminous intensity | $I_V$ | $I_F$=20mA | 100 | --- | 150 | mcd |
| 50% Viewing Angle | $2\theta 1/2$ | $I_F$=20mA | 40 | | 60 | deg |

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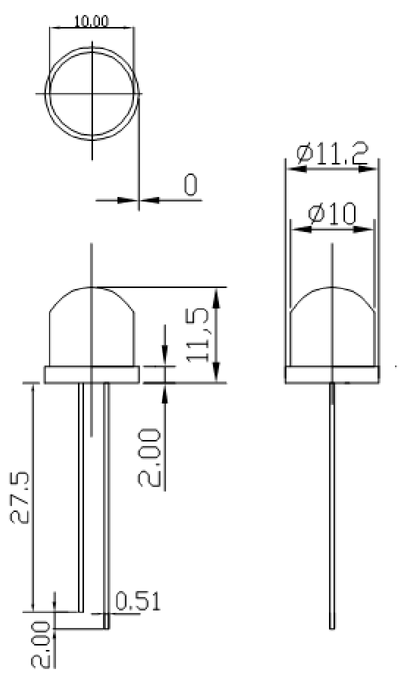
## Light Degradation in mcd: ($I_F$=20mA)

| Hours / Colors | Light Degradation in mcd after Different Hours | | | | | |
|---|---|---|---|---|---|---|
| | 216 Hrs | 360 Hrs | 792 Hrs | 1104 Hrs | 1992 Hrs | 2328 Hrs |
| Red | 1.52% | -1.22% | -3.10% | -4.68% | -5.72% | -8.27% |
| Yellow | -1.71% | -2.97% | -5.93% | -8.13% | -8.90% | -11.10% |
| Blue | 3.13% | -0.33% | -3.84% | -8.23% | -21.32% | -24.92% |
| Green | -8.02% | -9.78% | -14.25% | -17.37% | -20.79% | -22.30% |
| Hours | 48 Hrs | 168 Hrs | 336 Hrs | 360Hrs | 720 Hrs | 1008 Hrs |
| Cool White | 10.56% | 6.72% | -2.29% | -7.68% | -17.32% | -22.48% |
| Pure White | 13.66% | 8.22% | -1.45% | -8.50% | -19.52% | -25.26% |
| Warm White | 3.02% | -4.38% | -15.18% | -21.15% | -27.19% | -29.97% |

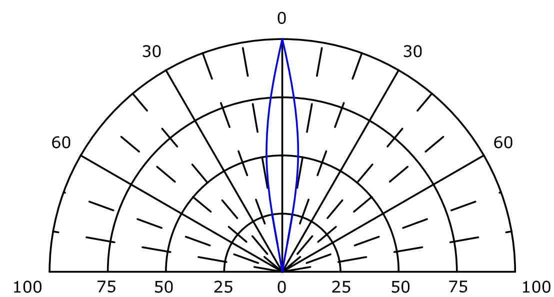
## Mechanical Dimensions:

- All dimension are in mm, tolerance is ±0.2mm unless otherwise noted
- An epoxy meniscus may extend about 1.5mm down the leads.
- Burr around bottom of epoxy may be 0.5mm Maximum

Unit: mm

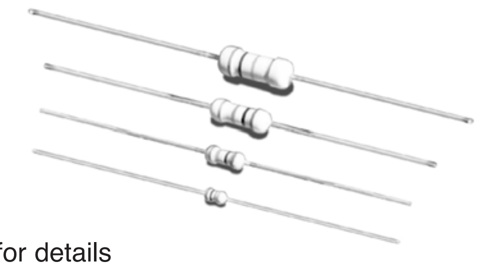



Viewing Angle Drawing




Address: 5/F, Building B, Anzhilong Indl., Qinghua East Road., Longhua Town, Shenzhen CHINA. 518109

# Carbon Film Fixed Resistors (RoHS Compliant) CF-RC Series



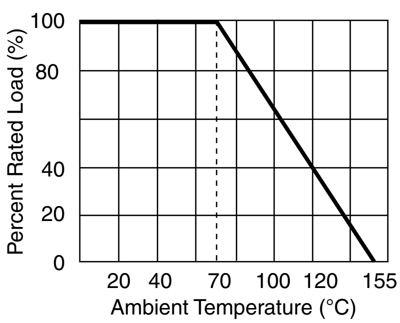
## FEATURES

- Temperature Range -55°C ~ +155°C
- ±5% tolerance
- High quality performance at economical prices
- Compatible with automatic insertion equipment
- Flame retardant type available
- Tin coated annealed copper wire
- Values below 1Ω or above 10MΩ are available by special request, please ask for details

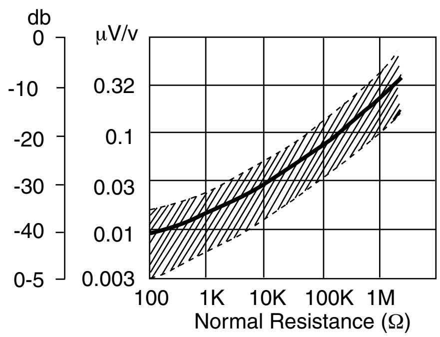
LEAD-FREE

Environmental Commitment

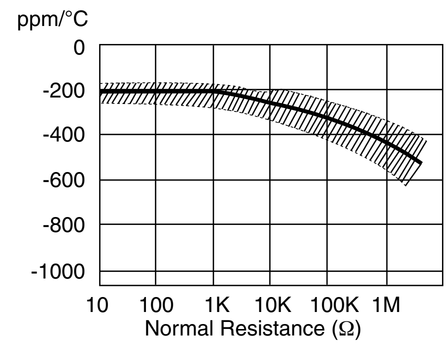
## DERATING CURVE




## CURRENT NOISE



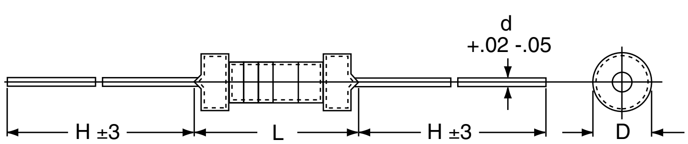

## TEMPERATURE COEFFICIENT




## PART NUMBERING SYSTEM

| 2 | 9 | 1 | – | 1 | 0 | K | / | R | E | E | L | - | R | C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Series | | | | Ohms | | | | Package Code | | | | | Suffix (RoHS Compliant) | |

## SERIES, WATTAGE, SIZE, VOLTAGE, DIMENSIONS, AND AVAILABLE PACKAGING




| Code: | Package: |
|---|---|
| | Bulk |
| /REEL | Tape and Reel |
| /AP | Ammo Pack |

| Series | Watts | Size | Voltage (max.) | | Dimensions (mm) | | | | Standard Quantities Available | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W.V. | O.V. | L max. | D max. | H | d | Bulk | Tape and Reel | Ammo Pack |
| **294** | 1W | Small | 500 | 1,000 | 12 | 5.0 | 28 | 0.7 | 1,000 | 3,000 | 1,000 |
| **299** | 1/8W | Standard | 200 | 400 | 3.5 | 1.85 | 28 | 0.45 | 1,000 | 5,000 | 2,000 |
| **291** | 1/4W | Standard | 250 | 500 | 6.8 | 2.5 | 28 | 0.54 | 1,000 | 5,000 | 1,000 |
| **293** | 1/2W | Standard | 350 | 700 | 10 | 3.5 | 28 | 0.54 | 1,000 | 3,000 | 1,000 |

## STANDARD VALUES (Ω)

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 2.0 | 4.3 | 9.1 | 20 | 43 | 91 | 200 | 430 | 910 | 2K | 3.9K | 8.2K | 18K | 39K | 82K | 180K | 390K | 820K | 1.8M | 3.9M | 8.2M |
| 1.0 | 2.2 | 4.7 | 10 | 22 | 47 | 100 | 220 | 470 | 1K | 2.2K | 4.3K | 9.1K | 20K | 43K | 91K | 200K | 430K | 910K | 2M | 4.3M | 9.1M |
| 1.1 | 2.4 | 5.1 | 11 | 24 | 51 | 110 | 240 | 510 | 1.1K | 2.4K | 4.7K | 10K | 22K | 47K | 100K | 220K | 470K | 1M | 2.2M | 4.7M | 10M |
| 1.2 | 2.7 | 5.6 | 12 | 27 | 56 | 120 | 270 | 560 | 1.2K | 2.7K | 5.1K | 11K | 24 K | 51K | 110K | 240K | 510K | 1.1M | 2.4M | 5.1M | 15M |
| 1.3 | 3.0 | 6.2 | 13 | 30 | 62 | 130 | 300 | 620 | 1.3K | 3K | 5.6K | 12K | 27K | 56K | 120K | 270K | 560K | 1.2M | 2.7M | 5.6M | 22M |
| 1.5 | 3.3 | 6.8 | 15 | 33 | 68 | 150 | 330 | 680 | 1.5K | 3.2K | 6.2K | 13K | 30K | 62K | 130K | 300K | 620K | 1.3M | 3M | 6.2M | |
| 1.6 | 3.6 | 7.5 | 16 | 36 | 75 | 160 | 360 | 750 | 1.6K | 3.3K | 6.8K | 15K | 33K | 68K | 150K | 330K | 680K | 1.5M | 3.3M | 6.8M | |
| 1.8 | 3.9 | 8.2 | 18 | 39 | 82 | 180 | 390 | 820 | 1.8K | 3.6K | 7.5K | 16K | 36K | 75K | 160K | 360K | 750K | 1.6M | 3.6M | 7.5M | |

# Carbon Film Fixed Resistors (RoHS Compliant) CF-RC Series

## CHARACTERISTICS

| Characteristics | Limits | Test Methods ( JIS C 5201-1 ) |
|---|---|---|
| DC. Resistance | Must be within the specified tolerance. | 5.1 The limit of error of measuring apparatus shall not exceed allowable range or 5% of resistance tolerance |
| Temperature coefficient | Resist. Range / T.C.R. (PPM / °C)<br>< 10 Ω : 0 ~ ±350<br>11Ω ~ 99K : 0 ~ -450<br>100K ~ 1M : 0 ~ -700<br>1.1M ~ 10M : 0 ~ -1500 | 5.2 Natural resistance change per temp. degree centigrade.<br>$\frac{R_2-R_1}{R_1(t_2-t_1)}$ x106 (PPM/°C)<br>$R_1$: Resistance value at room temperature ($t_1$)<br>$R_2$: Resistance value at room temp.plus 100°C ($t_2$) |
| Short time overload | Resistance change rate is ± (1 % + 0.05Ω) Max. with no evidence of mechanical damage | 5.5 Permanent resistance change after the application of a potential of 2.5 times RCWV for 5 seconds. |
| Insulation Resistance | Insulation resistance is 10,000 MΩ Min | 5.6 Resistors shall be clamped in the trough of a 90° metallic V-block and shall be tested at DC potential respectively specified in the above list for 60 +10/ -0 seconds. |
| Dielectric withstanding voltage | No evidence of flashover mechanical damage,arcing or insulation break down. | 5.7 Resistors shall be clamped in the trough of a 90° metallic V-block and shall be tested at AC potential respectively specified in the table 1 for 60 + 10/-0 seconds. |
| Terminal strength | No evidence of mechanical damage. | 6.1 **Direct load**<br>Resistance to a 2.5 kgs direct load for 10 secs. in the direction of the longitudinal axis of the terminal leads.<br>**Twist test :**<br>Terminal leads shall be bent through 90° at a point of about 6mm from the body of the resistor and shall be rotated through 360° about the original axis of the bent terminal in alternating direction for a total of 3 rotations. |
| Resistance to soldering heat | Resistance change rate is ± (1% + 0.05Ω) Max. with no evidence of mechanical damage. | 6.4 Permanent resistance change when leads immersed to 3.2 to 4.8 mm from the body in 350 °C ± 10°C solder for 3 ± 0.5 seconds |
| Solderability | 95 % coverage Min. | 6.5 The area covered with a new , smooth clean , shiny and continuous surface free from concentrated pinholes.<br>Test temp. of solder : 245°C ± 3°C<br>Dwell time in solder : 2 ~ 3 seconds |
| Temperature cycling | Resistance change rate is ± (1% + 0.05Ω) Max. with no evidence of mechanical damage. | 7.4 Resistance change after continuous 5 cycles for duty shown below:<br>**Step / Temperature / Time**<br>1 / -55°C ±3°C / 30 mins<br>2 / Room temp. / 10~15 mins<br>3 / +155°C ±2°C / 30 mins<br>4 / Room temp. / 10~15 mins |
| Load life in humidity | Resistance value / ΔR/R<br>Normal Type: < than 100KΩ : ± 3 %<br>Normal Type: >100KΩ : ± 5 % | 7.9 Resistance change after 1,000 hours operating at RCWV with duty cycle of (1.5 hours "on", 0.5 hour "off") in a humidity test chamber controlled at 40°C ± 2°C and 90 to 95 % relative humidity |
| Load life | Resistance value / ΔR/R<br>Normal Type: < than 56KΩ : ± 2 %<br>Normal Type: > 56KΩ : ± 3 % | 7.10 Permanent resistance change after 1,000 hours operating at RCWV with duty cycle of ( 1.5 hours "on", 0.5 hour "off" ) at 70°C ± 2°C ambient |

# NTC THERMISTOR OF MF52-TYPE SERIES SPECIFICATION

*** Outline：**

The MF52 thermistor is a small-sized,epoxy-resin coated NTC resistor made from new-type material with new craftsmanship.It is featured with advantages including high precision and quick reaction

*** Application：**

Air conditioners, heating facilitied,electronic thermometers ,fluid level sensors,automobile electronics and electronic table-calendars.

*** Features：**

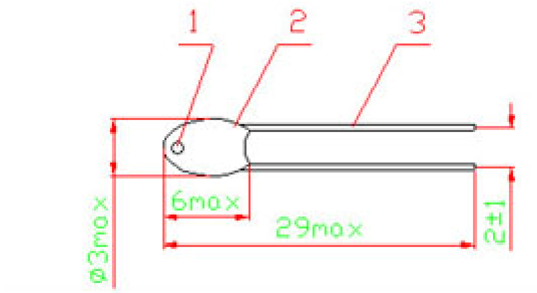
1.High testing precision;
2.Small and quick in reaction;
3.Long and good service;
4.Good interconvertibility and consistency.

*** Part NO.：**

| MF52 | E | 103 | H | L | 347 |
|---|---|---|---|---|---|
| ① | ② | ③ | ④ | ⑤ | ⑥ |

① Drop-like NTC thermistor
② E：Epoxy-resin coated package S：Silicone coated package
③ R25: 10KΩ-103
④ Tolerance: F：±1% G：±2% H：±30% J：±5% K：±10%
⑤ L：B25/50 H：B25/85 T：Special
⑥ B-value：347：3470 338：3380 we adopted the former three digits

*** Dimensions(mm) :**




*** Specification**

| Model | R25 | B value | Dissipation | Time Constant | Temperature Range |
|---|---|---|---|---|---|
| MF52 | 100Ω-10KΩ | 3100K | | | |
| MF52 | 200Ω-10KΩ | 3270K | | | |
| MF52 | 500Ω-15KΩ | 3470K | | | |
| MF52 | 1KΩ-50KΩ | 3600K | ≥2.5mW/℃ in static air | ≤7S in static air | -40℃~+120℃ |
| MF52 | 5KΩ-50KΩ | 3950K | | | |
| MF52 | 10KΩ-100KΩ | 4050K | | | |
| MF52 | 10KΩ-100KΩ | 4150K | | | |
| MF52 | 20KΩ-500KΩ | 4300K | | | |

**Remarks:**

1) Tolerance of the resistance: F：±1% G：±2% H：±3% J：±5% K：±10% .
2) The Tolerance of the B-value is ±1% in response with a rated resistance for which the precision is ±1%,　The tolerance of B-value is±2% under other circumstances.
3) Products with specifications unmentioned in the table above are available upon customers' request.

*** Cautions :**

1) The two ends of the lead is not supposed to be loaded with excess pulling stress,owing to the small size and small welding spot of MF52-srs products.
2) Soldering is supposed to be done 5mm away from the root of the lead,and only for a brief moment.
3) Thermistor of MF52-srs are not supposed to be exposed directly in water while working.

## Normal specification Resistance & Temperature Table of MF52-type (Unit：KΩ)

| $R_{25}$ / B / T(℃) Rt | 10 KΩ | 50 KΩ | 100 KΩ | 50 KΩ | 50 KΩ | 100 KΩ | 100 KΩ | 150 KΩ |
|---|---|---|---|---|---|---|---|---|
| | 3950 | 3950 | 4000 | 4050 | 4150 | 4150 | 4300 | 4500 |
| -30 | 181.70 | 908.30 | 1790.00 | | | | | |
| -25 | 133.30 | 666.50 | 1321.00 | | | | | |
| -20 | 98.88 | 494.50 | 984.70 | | | | | |
| -15 | 74.10 | 370.50 | 740.80 | | | | | |
| -10 | 56.06 | 280.30 | 562.30 | | | | | |
| -5 | 42.80 | 214.00 | 430.50 | | | | | |
| 0 | 98.96 | 164.80 | 332.30 | 168.80 | 172.00 | 344.10 | 352.40 | 576.70 |
| 5 | 25.58 | 127.90 | 257.50 | 131.30 | 132.20 | 264.30 | 270.00 | 433.20 |
| 10 | 20.00 | 99.98 | 201.10 | 101.00 | 102.40 | 204.80 | 208.30 | 328.40 |
| 15 | 15.76 | 78.79 | 158.20 | 79.28 | 80.03 | 160.10 | 161.90 | 250.90 |
| 20 | 12.51 | 62.55 | 125.40 | 62.78 | 63.00 | 125.00 | 136.70 | 193.30 |
| 25 | 10.00 | 50.00 | 100.00 | 50.00 | 50.00 | 100.00 | 100.00 | 150.00 |
| 30 | 8.048 | 40.24 | 80.29 | 39.98 | 39.76 | 79.51 | 78.35 | 117.30 |
| 35 | 6.518 | 32.59 | 64.87 | 32.16 | 31.89 | 63.77 | 62.37 | 92.28 |
| 40 | 5.312 | 26.56 | 57.72 | 26.10 | 25.73 | 51.45 | 49.94 | 73.11 |
| 45 | 4.354 | 21.77 | 43.10 | 21.35 | 20.88 | 41.76 | 40.22 | 58.28 |
| 50 | 3.588 | 17.94 | 35.42 | 17.72 | 17.04 | 34.08 | 32.56 | 46.74 |
| 55 | 2.974 | 14.87 | 29.26 | 14.36 | 13.99 | 27.97 | 26.40 | 37.71 |
| 60 | 2.476 | 12.38 | 24.30 | 11.92 | 11.53 | 23.06 | 21.53 | 30.58 |
| 65 | 2.072 | 10.36 | 20.27 | 9.938 | 9.541 | 19.08 | 17.69 | 24.94 |
| 70 | 1.743 | 8.717 | 16.99 | 8.317 | 7.929 | 15.86 | 14.62 | 20.45 |
| 75 | 1.473 | 7.364 | 14.31 | 6.991 | 6.621 | 13.24 | 12.20 | 16.85 |
| 80 | 1.250 | 6.248 | 12.10 | 5.906 | 5.552 | 11.10 | 10.05 | 13.94 |
| 85 | 1.065 | 5.324 | 10.27 | 5.012 | 4.674 | 9.348 | 8.376 | 11.60 |
| 90 | 0.911 | 4.555 | 8.758 | 4.271 | 3.950 | 7.900 | 7.004 | 9.680 |
| 95 | 0.7824 | 3.912 | 7.495 | 3.654 | 3.349 | 6.698 | 5.894 | 8.118 |
| 100 | 0.6744 | 3.372 | 6.438 | 3.316 | 2.849 | 5.698 | 4.978 | 6.836 |
| 105 | 0.5836 | 2.918 | 5.550 | 2.701 | 2.438 | 4.875 | 4.215 | 5.780 |
| 110 | 0.5066 | 2.533 | 4.801 | 2.336 | 2.093 | 4.186 | 3.580 | 4.904 |