Laboratorio de Microcontroladores

IE-0624

Laboratorio #4:
Arduino: GPIO, Timers, ADC, comunicaciones, PWM, PM, EEPROM, Iot

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Índice

1. Introducción

En este laboratorio se pretende diseñar una estación meteorológica que mida y grabe varias variables ambientales, con la capacidad de comunicación serial con el fin de integrarlo a un sistema de Internet of Things (IoT).

El microcontrolador a utilizar, en este caso, será un Arduino Mega (ATMega2560), el cual es bastante sencillo de utilizar y sumamente popular a nivel mundial por su versatilidad y relativa facilidad para usuarios inexpertos en el área de la programación de microcontrolador.

Algunas de las funciones que se quieren implementar son:

- Medición de temperatura con termistor
- Medición de humedad con un sensor DHT22
- Medición de intensidad luminosa con un LDR
- Medición de velocidad de viento con un sensor JL-FSX2 4-20MA
- Detección de lluvia con un sensor Hydreon RG-11
- Visualización de datos con una pantalla PCD8544
- Almacenamiento de datos en memoria EEPROM
- Comunicación utilizando USART con una computadora
- Detección de batería baja con integración de modo low power
- Control de dirección de panel solar con servomotores
- Integración de datos a un dashboard de ThingsBoard

Se trabajo el código utilizando el repositorio GIT de la escuela de Ingeniería Eléctrica de la UCR. El código esta disponible en `https://git.eie.ucr.ac.cr/jlouzao/Lab_Microcontroladores_III-2021`

2. Nota Teórica

En esta sección se va a incluir la información del microcontrolador, periféricos utilizados, componentes electrónicos complementarios; así como también el diseño del circuito.

2.1. Características generales del microcontrolador

Arduino es una plataforma de creación de electrónica de código abierto, hecha para simplificar el desarrollo de proyectos que necesiten el uso microcontroladores. Para este proyecto, se hace uso de un Arduino Mega, el cual se muestra en la figura 1.

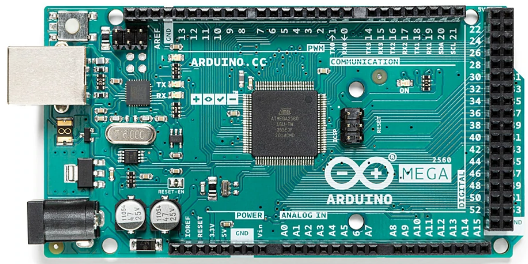


Figura 1: Arduino Mega[1]

El Arduino, como tal, es un conjunto de componentes eléctricos elegidos para realizar funciones específicas que faciliten la programación y comunicación del microcontrolador integrado dentro de la misma placa que los demás componentes, en este caso, dicho microcontrolador es un ATMega2560, el cual tiene el esquema mostrado en la figura 2.

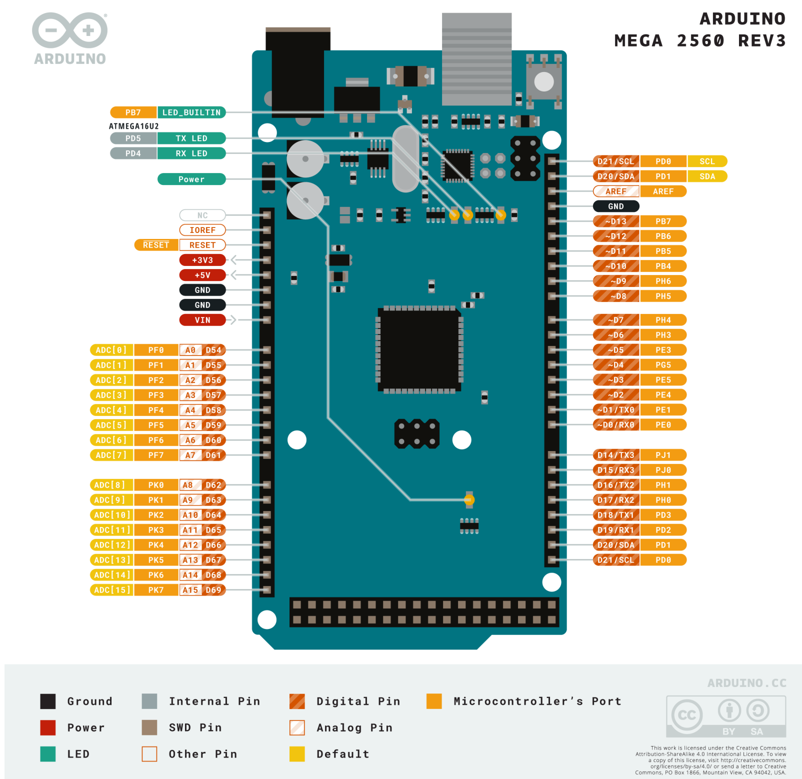


Figura 2: ATMega2560[1]

Algunas de las principales características de este microcontrolador, tomadas de la hoja del fabricante, son:

- 64/128/256 Kb Flash
- 512 Bytes/1/2K bytes de SRAM interna.
- Microcontrolador AVR de 8 bits.
- 32 GPIOS.
- Timers/Counters de 8 y 16 bits.
- Interrupciones.
- USART.
- 12 canales PWM.
- Memoria EEPROM de 4 KB

2.2. Características eléctricas

Algunas de las características eléctricas del ATMega2560 se muestran en la figura 3:

MICROCONTROLLER	ATmega2560
OPERATING VOLTAGE	5V
INPUT VOLTAGE (RECOMMENDED)	7-12V
INPUT VOLTAGE (LIMIT)	6-20V
DIGITAL I/O PINS	54 (of which 15 provide PWM output)
ANALOG INPUT PINS	16
DC CURRENT PER I/O PIN	20 mA
DC CURRENT FOR 3.3V PIN	50 mA

Figura 3: Características eléctricas del Arduino Mega[1]

2.3. Periféricos utilizados/descripción de registros e instrucciones

2.3.1. Sensor de humedad DHT22

Para el desarrollo del laboratorio se pide medir la humedad relativa del ambiente, para este fin, se elige el sensor de humedad DHT22, el cual tiene capacidad de medir la humedad relativa de un

0 % hasta un 100 %, a diferencia de su hermano menor el DHT11, el cual solamente puede medir la humedad relativa entre un 20 % y un 90 %. Este sensor es ampliamente utilizado para proyectos con Arduino y tiene la característica de que es digital, lo que lo hace más resistente a factores como el ruido.

Este útil componente integra un sensor capacitivo de humedad por medio del cual mide el aire circundante. Una vez tomada la medición, muestra los datos mediante una señal digital en el pin de datos.

2.3.2. Termistor NTC de 100k NTCG104EF104FTDSX

Por su parte, para medir la temperatura, se decide utilizar un termistor. Este es un componente electrónico que cambia su valor de resistencia nominal dependiendo de la temperatura a la que se encuentre. Por medio de un divisor de tensión, se puede hacer que la tensión de entrada en el pin analógico del Arduino lea el cambio de temperatura que se presenta en el termistor. En este caso, se utilizó un termistor de 100kΩ, con un valor de β de 4250.

Cuando se utiliza un termistor es muy importante tomar en cuenta que la relación entre la resistencia y la temperatura no es lineal, tal como se ve en la figura 4 donde el eje x horizontal representa la temperatura y el eje vertical la resistencia en Ω.

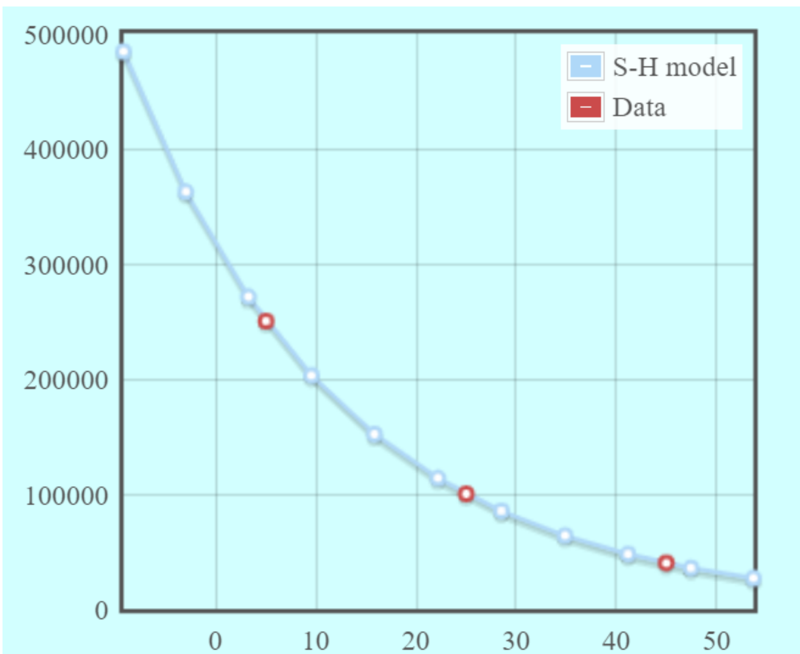


Figura 4: Curva de temperatura vs resistencia en un termistor [2].

Para realizar la estimación de la temperatura de acuerdo a la tensión medida en el pin del Arduino, se pueden emplear la ecuación de Steinhart-Hart:

$$\frac{1}{T} = A + Bln(R) + C(ln(R))^3 \tag{1}$$

Donde, T es la temperatura en kelvin, R es la resistencia en ohmios medida en el punto T. A, B y C son coeficientes de Steinhart-Hart, los cuales varían según el modelo del termistor y en este caso, van a ser calculados por medio de una página web creada por Stanford Research Systems Inc, a partir de 3 puntos del tipo (temperatura, resistencia), los cuales van a ser obtenidos de la hoja del fabricante [2].

Un ejemplo de cómo calcular los valores para los coeficientes A, B y C se muestra en la figura 5.

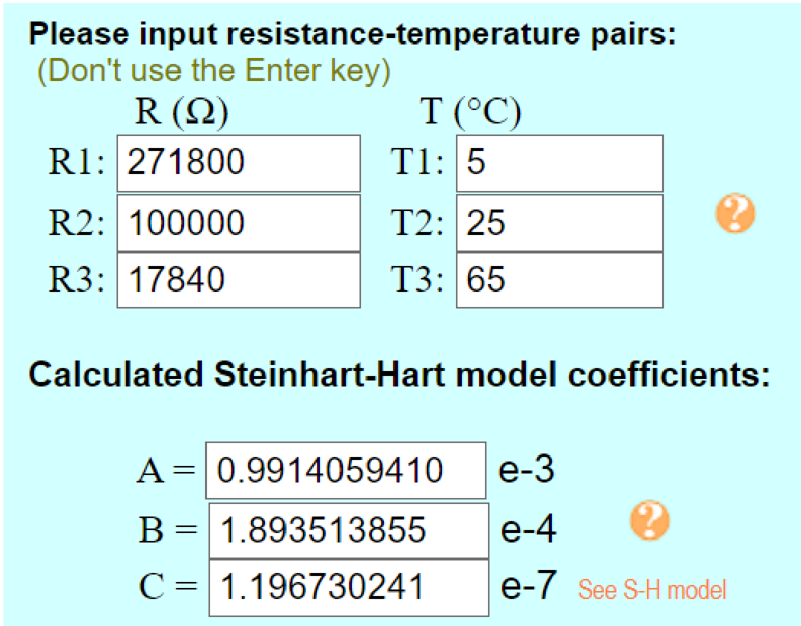


Figura 5: Coeficientes de S-H[2].

2.3.3. PCD8544-4988

La pantalla LCD PCD8544-4988, popular en teléfonos como el Nokia 5110, se utilizara para desplegar información del circuito. La pantalla posee 5 pines, además del pin de alimentación y tierra. El pin de RST se conecta al Reset del Arduino para aplicar la señal de reset cuando se inicializa el microcontrolador. El pin CS se conecta directamente a tierra, este pin normalmente funciona para realizar actualizaciones entre actualizaciones de pantalla. Este pin se conecta a tierra ya que la funcionalidad no es necesaria. El pin D/C es el selector de modo, entre comandos y datos. El pin DIN es la entrada de datos seriales. Finalmente el pin CLK recibe una señal de reloj.

2.3.4. USART

Se utiliza la funcionalidad de USART del Arduino para comunicarse con una computadora. Esto se puede lograr o con los pines 0 y 1, o en nuestro caso, con el puerto USB del Arduino. Se utiliza una taza de datos de 9600 baud. Para activar esta funcionalidad se implemento un switch con un resistor de pull up y debouncing con un filtro paso bajo RC.

El USART envía los datos a un script de Python que se comunica con ThingsBoard utilizando el protocolo de mensajes MQTT.

2.3.5. Sensor de luz LDR VT900

Para medir la cantidad de luz que hay presente en el ambiente, se utiliza un LDR, que realmente, se utiliza muy similar al termistor, con una configuración que por medio de un divisor de tensión, pero en este caso con una resistencia de 10kΩ. A diferencia del termistor, la implementación de un LDR es un poco menos precisa, debido a la forma de su curva y de que no se tienen valores tan exactos de calibración como sí lo fue en el caso del termistor con los coeficientes de Steinhart-Hart, por lo que, como recomendación, para medir la cantidad de luz en el ambiente de forma precisa, es mejor utilizar un luxómetro. Un LDR se recomiendo más para aplicaciones de umbral de luz tal y como funcionaría una fotocelda, que se enciende o se apaga dependiendo de si la luz es mayor o menor al umbral propuesto.

La curva de resistencia vs iluminación para un LDR se ve tal y como se muestra en la figura 6.

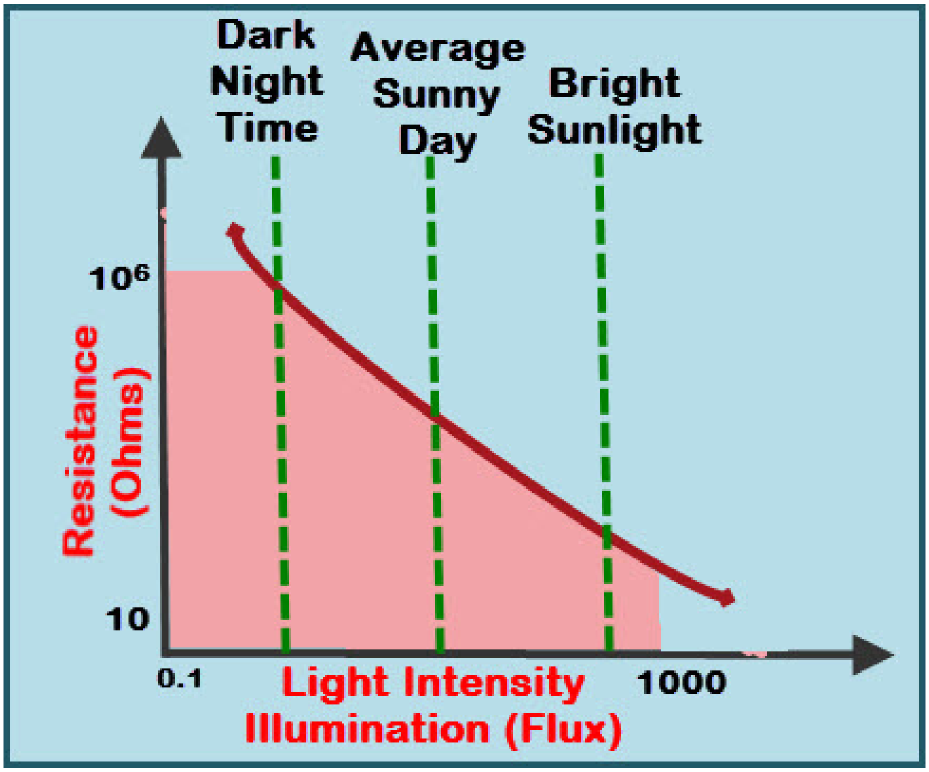


Figura 6: Curva de temperatura vs resistencia en un LDR [3].

2.3.6. Sensor de velocidad de viento JL-FSX2 4-20MA

El sensor de viento JL-FSX2 es un dispositivo muy particular, el cual, mide la velocidad del viento, tomando como referencia la velocidad a la que gira una pieza móvil que es empujada por el viento. De este modo, convierte la velocidad del viento en una señal eléctrica, la cual va de los 0 a los 5 volts, o bien de los 4mA a los 20mA [4].

Para este dispositivo no se logró encontrar una hoja de fabricante oficial, lo más cercano que se obtuvo fue la descripción del producto en uno de los sitios web en donde se puede adquirir [4].

Specification :

Signal output, Current signal, Pulse signal, Voltage signal, RS485/232 signal

Signal output way: 4 ~ 20 mA, 1.5 / M * S, 0 ~ 5 V, 1 ~ 5 V, RS485/232

Input voltage: DC24V/DC12V/DC5V

Response time: < 1 S

Transmission distance: > 1km

Measurement range: 0 ~ 5 M/S, 0 ~ 30 M/S, 0 ~ 50 M/S

Measurement accuracy: Plus or minus 3%

Start wind speed: < 0.6 M/S

Environment temperature: E: -35 ~ 85 C (often-used) L: -55 to 150 C

Level position: + 80 Rotation, with a hammer, automatically adjust the horizontal position

Potential lead: Three wire or two wire

Material: Aluminum alloy, the surface waterproof, prevent corrosion treatment.

Figura 7: Especificaciones de voltaje de salida del JL-FSX2 [4].

2.3.7. Hydreon RG-11

El Hydreon RG-11 es un sensor de lluvia el cual funciona accionando un relé cuando se detecta una cantidad específica de lluvia, es sumamente útil para detectar lluvia, por ejemplo, en una estación meteorológica, tal y como la que se diseña en este laboratorio. A modo de simulación se utiliza una configuración de pull up con 5V, lo que significa, que cuando el relé está abierto, la tensión en el pin del Arduino será de 5V, mientras que, si se cierra el relé, la tensión en el pin del Arduino será de 0. El sensor de lluvia Hydreon RG-11 realmente solo tiene dos estados, los cuales son: encendido y apagado. Tal como se mencionó anteriormente, estos estados están definidos por la posición del relé que tiene integrado.

2.3.8. EEPROM

La memoria de solo lectura borrable y programable electrónicamente o EEPROM, por sus siglas en inglés, es un tipo de memoria no volátil que permite almacenar y borrar datos a largo plazo y a gusto del usuario, normalmente la capacidad de una EEPROM es muy limitada, por lo que en este caso, lo que se hace, es escribir en le EEPROM hasta que se llene, llegado este punto, se borra completamente la memoria.

2.3.9. Servomotores

Los servomotores son un tipo de motor, los cuales pueden ser controlados para que giren una cantidad de grados específica, tiene muchas aplicaciones en la electrónica debido a su precisión y versatilidad. Normalmente estos motores tienen una capacidad de giro de entre 180 y 360 grados como máximo, por lo que no son motores convencionales, sino más bien, motores para realizar creaciones, en las cuales, se necesite girar objetos a una determinada posición de manera precisa, tal como es el caso de este laboratorio, donde se pretende girar paneles solares a una posición determinada por el usuario.

2.4. Librerías utilizadas para desarrollar el código del proyecto

2.4.1. DHT

Una de las librerías a utilizar es la de DHT, para el sensor de humedad elegido (DHT22). Esta librería no fue usada, debido a que el simulador no cuenta con este dispositivo para ser añadido al circuito, por lo que fue sustituido por una fuente de voltaje, la cual simula lo que serían los distintos valores medidos por un sensor de humedad. Sin embargo, es importante mencionar que esta librería es necesaria en caso de utilizar este dispositivo en un proyecto, ya que, como se mencionó anteriormente, este sensor tiene una salida digital que requiere de las funciones incluidas en la librería DHT para que funcione adecuadamente.

2.4.2. Adafruit_PCD8544

Se utiliza esta librería para comunicar la pantalla LCD PCD8544 con el Arduino utilizando el GPIO. Esta librería estandariza funciones para escritura de texto, actualización de la pantalla, y control de características como contraste y brillo. Hay otras librerías de apoyo que también permite mostrar figuras y otros tipos de gráficos, pero no se utilizara esto.

2.4.3. pyserial

Se utiliza la librería pyserial para leer los datos del un puerto serial utilizando Python. Esto se utiliza para leer los datos enviados del Arduino a través del puerto serial y escribirlos a un csv.

2.4.4. ThingsBoard.h

Esta librería es necesaria para poder utilizar las funciones de IoT que ofrece ThingsBoard. En el trabajo no se utiliza ya que se esta utilizando una simulación. En una aplicación con un Arduino real conectado con un shield seria necesaria.

2.4.5. Servo.h

Para controlar los servomotores, se necesita de algunas funciones que requieren el uso de la librería Servo.h.

2.4.6. EEPROM.h

Para este laboratorio se escriben y se borran datos de la memoria EEPROM, es por esto que la librería EEPROM.h es indispensable.

2.4.7. LowPower.h

Esta librería ofrece la posibilidad de que el Arduino entre en un modo de bajo consumo cuando se llama su función principal, esto es particularmente útil cuando se tienen aplicaciones que sean alimentadas por una batería y no por una fuente de alimentación directa. En este laboratorio se utiliza el mismo Arduino para medir la tensión de la batería y en base a esto, entrar en modo de bajo consumo para ahorrar el máximo de batería posible hasta que sea recargada.

2.4.8. TimerOne.h

Esta es una librería muy útil para el control de PWM o generar interrupciones de manera periódica.

2.4.9. paho.mqtt.client

Esta librería se utiliza para comunicarse utilizando con ThingsBoard utilizando el protocolo MQTT de mensajería.

2.4.10. json

Esta librería es utilizada para generar el mensaje con los datos en formato JSON para enviar a ThingsBoard.

2.5. Componentes elegidos y precios

Todos los precios en colones se obtuvieron de Steren, mientras que los precios en dolares fueron obtenidos en Mouser, a menos que se indique específicamente.

- 1 Arduino Mega -> precio aproximado de $40.30 cada uno.
- 2 LEDs de cualquier color -> precio aproximado entre 130 y 370 colones cada uno, depende del color.
- 1 resistencia de 12Ω -> precio aproximado 29 colones cada una.
- 3 resistencias de 100Ω -> precio aproximado 29 colones cada una.
- 2 resistencias de 180Ω -> precio aproximado 29 colones cada una.
- 1 resistencia de 510Ω -> precio aproximado 29 colones cada una.
- 1 resistencia de 820Ω -> precio aproximado 29 colones cada una.
- 4 resistencias de 10kΩ -> precio aproximado 29 colones cada una.
- 1 resistencia de 100kΩ -> precio aproximado 29 colones cada una.
- 2 switches de un polo -> precio aproximado 190 colones cada uno.
- 2 capacitores de 2.2μF -> precio aproximado 85 colones cada uno.
- 1 sensor de humedad DHT22 -> precio aproximado $7 cada uno.
- 1 sensor de viento JL-FSX2 4-20MA -> precio aproximado 4$5 cada uno.
- 1 batería recargable de 12V para los paneles solares -> precio aproximado 20 000 colones cada una.
- 1 pantalla LCD (PCD8544-4988) -> precio aproximado $10 cada uno.
- 1 sensor de lluvia Hydreon RG-11 -> precio aproximado $59 cada uno.
- 1 termistor de 100kΩ (NTCG104EF104FTDSX) -> precio aproximado $2 cada uno.
- 2 servomotores para los paneles solares -> precio aproximado $10 cada uno.
- 2 resistencias variables o potenciómetros de 10kΩ -> precio aproximado 370 colones cada uno.
- 1 LDR o fotoresistencia de 500kΩ -> precio aproximado $1 cada uno.

2.6. Justificación del diseño del circuito con los componentes elegidos

2.6.1. Sensor de temperatura

Para el sensor de temperatura se eligió un termistor de 100kΩ en divisor de tensión con una resistencia de 100kΩ. Al igual que en el caso anterior, lo que sucede es que en el pin, como máximo llegan 2.5V con una corriente aún más baja que en el caso del selector de temperatura deseada.

2.6.2. Sensor de humedad

Para este proyecto se necesita la implementación de un sensor de humedad, el cual sea capaz de medir la humedad relativa. Se elige un DHT22 para este objetivo, puede medir desde 0 % hasta 100 % de humedad relativa, utilizando una salida digital que lo convierte en un excelente componente por su precio. Cumple con los requerimientos del proyecto.

2.6.3. Pantalla LCD

La pantalla PCD8544 se escoge ya que es la requerida en el enunciado. Esta pantalla requiere alimentación de 3.3V, que puede ser provisto por el Arduino. Además, las señales deben ser de 3.3V, de lo que se encarga la librería Adafruit_PCD8544.

2.6.4. Servomotores y ajuste

Para el ajuste de los servomotores se eligen dos potenciómetros de 10kΩ, los cuales simplemente funcionan a modo de reguladores de la tensión que se lee en el pin correspondiente. Estos están conectados a una tensión de 5V en una de sus terminales, a tierra en la segunda y al pin en la tercera. El efecto que tiene esta configuración, es la de dividir la tensión entre el camino a tierra y el camino al pin, dejando que llegue solo una porción de la tensión al pin si así se desea. A mayor resistencia se ponga en el camino al pin, menor será la tensión.

2.6.5. Sensor de lluvia

En este caso, el sensor de lluvia que se propone en el enunciado del laboratorio es imposible de implementar en el simulador SimulIDE, ya que no existe tal parte, sin embargo, se utiliza un relé y una configuración de pull up, la cual hace que el pin del arduino lea 5V cuando el relé está abierto y 0V cuando el relé está cerrado, debido a que cuando el circuito se cierra, se conecta al pin del arduino a tierra. Simplemente se añade una resitencia de 1kΩ para limitar la corriente que llega directo desde la fuente hasta el pin a 5mA, lo cual fue calculado por ley de ohm: I $= \frac{5V}{1000\Omega} =$ 0.005A.

2.6.6. Sensor de luz

Para el sensor de luz se eligió un LDR en una configuración muy similar al divisor de tensión del termistor. En este caso se implementa el divisor con una resistencia de 10kΩ ya que esta es la resistencia aproximada del LDR cuando se encuentra en obscuridad o lo que es lo mismo, cercano a 0 LUX. De esta forma, se logra que, la tensión en el pin del Arduino varíe entre 0 y 5 V, dependiendo del nivel de luz que se esté recibiendo.

2.6.7. Sensor de viento

El JL-FSX2 es un sensor de viento, el cual tiene varios modos de operación, entre ellos uno que es el que más sencillo es para una aplicación utilizando Arduino, ya que, consta de una salida analógica de entre 0V y 5V, lo que lo hace idea para ser leído por los pines analógicos del Arduino. En este caso, no se cuenta con esta parte en el simulador Simulide, sin embargo, este se modela como una fuente de tensión variable de entre 0V y 5V, simplemente conectado a una resistencia de 1kΩ para limitar la corriente que entra al pin, como máximo, a 5mA la igual que en el sensor de lluvia.

2.6.8. Batería de alimentación

Se pide también, que se agregue un medidor de tensión para una batería de 12V, la cual es la encargada de alimentar al circuito, sin embargo, es de suma importancia la medición precisa del voltaje de la batería, ya que, no queremos que se agote nunca, por lo que se quiere que el Arduino entre en un modo de bajo consumo cuando quede poco porcentaje de batería. La implementación se realiza, creando un divisor de tensión que permita que la tensión que llega al pin del Arduino sea de 5V como máximo, ya que esta es la máxima tensión que es capáz de leer. Para esto, se utiliza la siguiente ecuación de divisor de tensión:

$$R2 = \frac{V * R1}{Vin - V} \tag{2}$$

Donde: R1 y R2 son las resistencias que conforman el divisor de tensión (se elige una de las dos y la otra se calcula para ver cual valor se necesita). V es la tensión que se quiere medir en el divisor, en este caso son 5V que es lo que necesita el pin. Y por último, Vin es la tensión de la batería.

Para hacer el cálculo se eligió para R1 una resistencia de 820Ω, así se puede calcular R2 tal que:

$$R2 = \frac{5 * 820}{12{,}84 - 5} = 522{,}96\Omega \tag{3}$$

Como R2 = 522.96Ω, entonces se decide utilizar dos resistencias en serie para acercarse lo más posible, una de 510Ω y otra de 12Ω, para un total de 522Ω, lo cual es una excelente aproximación y funciona perfecto.

3. Análisis de Resultados

Para el desarrollo del laboratorio se utilizó el software de SimulIDE para crear el esquemático del circuito, el cual se muestra en la figura 8.

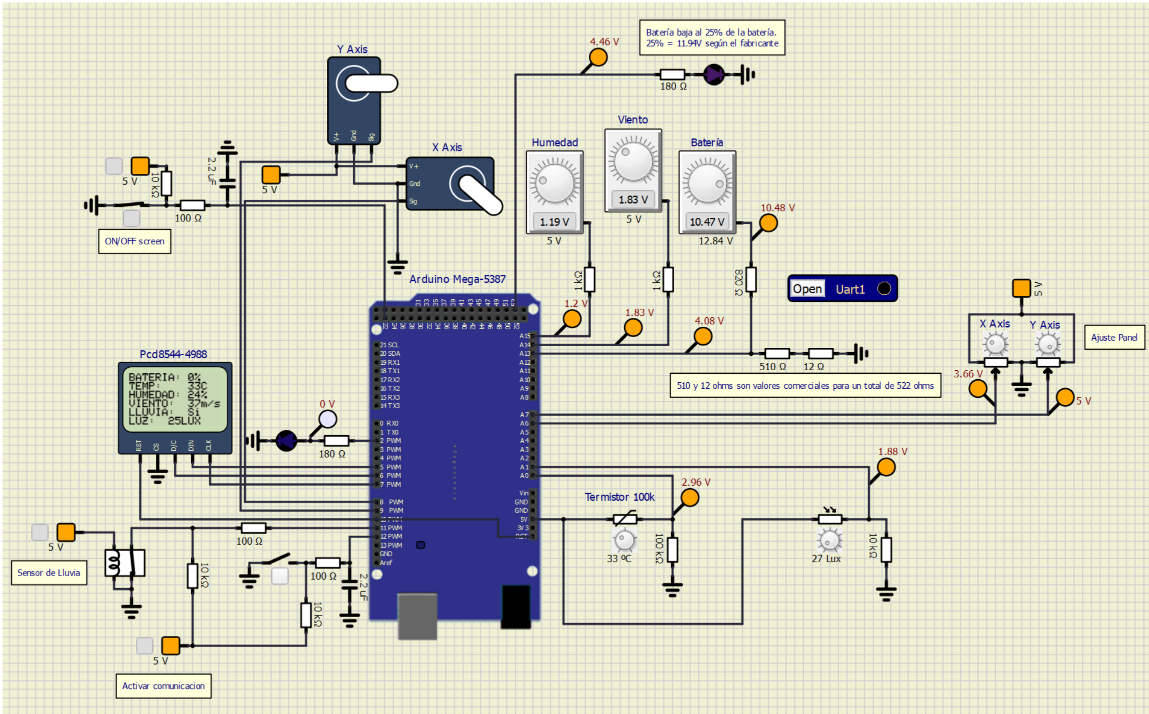


Figura 8: Circuito creado para la simulación [Elaboración propia]

Este circuito cuenta con todas las funciones que se mencionaron en la introducción, el funcionamiento del circuito se puede describir como una estación meteorológica, la cual, tiene sensores que mandan la información de sus mediciones no solo a la pantalla LCD que se integró, sino que también, a un panel de información en ThingsBoard. Cuando la transferencia de datos por medio de USART se encuentra activa, un LED parpadea con una secuencia propuesta por el enunciado del laboratorio. Se utilizaron contadores para generar un retraso que parpadea el LED.

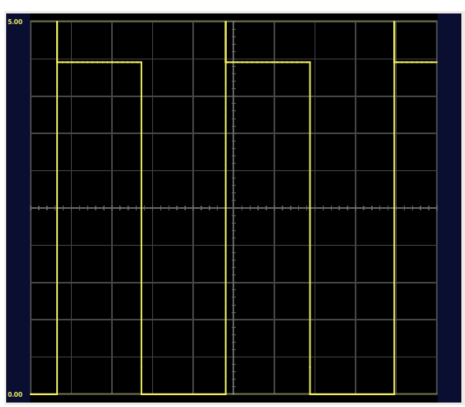


Figura 9: Respuesta en el tiempo de luz LED indicadora de comunicación serial [Elaboración propia]

Entre los sensores que se tienen, están: temperatura con termistor, humedad con un sensor DHT22, intensidad luminosa con un LDR, velocidad de viento con un sensor JL-FSX2 4-20MA, lluvia con un sensor Hydreon RG-11. Estos datos son almacenados, también en la memoria EEPROM, la cual, una vez que se llena, se borra por completo para volver a comenzar con la grabación de datos. Otra de las funciones que tiene este sistema es el de poder medir la batería restante para alimentación del circuito, de forma que, cuando se mida una tensión que indique que el nivel de la batería está por debajo del 25 % (según el fabricante), se procede a cambiar el modo de operación del Arduino a un modo de bajo consumo hasta que el nivel de batería vuelva a alcanzar un nivel aceptable. Cuando la batería está en un nivel bajo, también parpadea un LED avisando de esta situación.

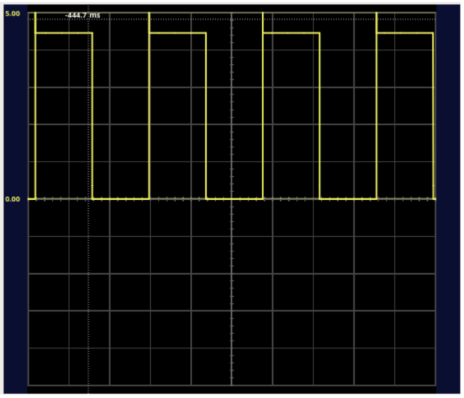


Figura 10: Respuesta en el tiempo de luz LED indicadora de baja batería [Elaboración propia]

Esta batería, se pretende cargar con paneles solares, los cuales son controlados por dos servomotores, uno para el eje vertical y otro para el eje horizontal, estos servomotores están controlados por dos potenciómetros.

Una de las principales funcionalidades, antes mencionadas, es la de poder mostrar datos del sistema en un panel en Thingsboard. Dicho panel se muestra en las figuras 11, 12, y 13.

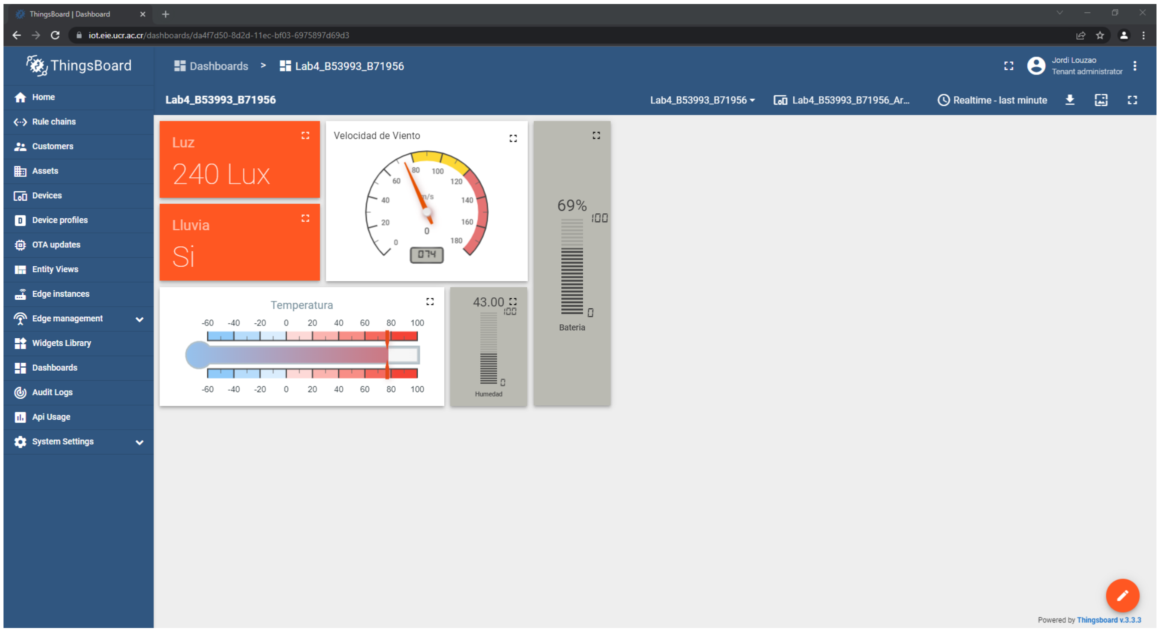


Figura 11: Panel de ThingsBoard [Elaboración propia]

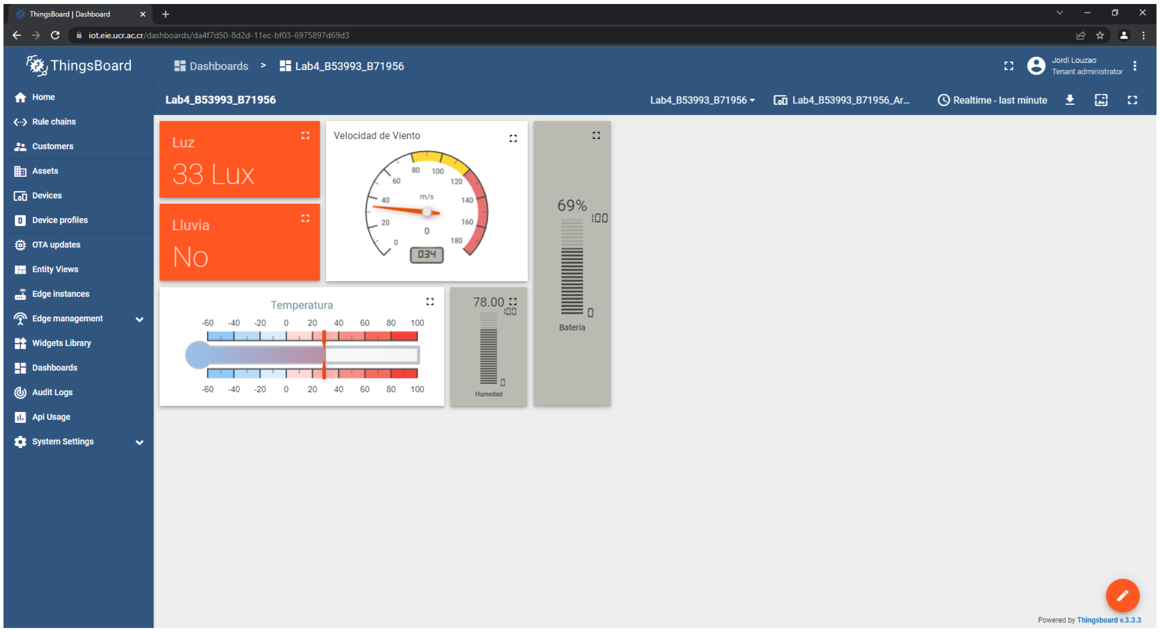


Figura 12: Panel de ThingsBoard [Elaboración propia]

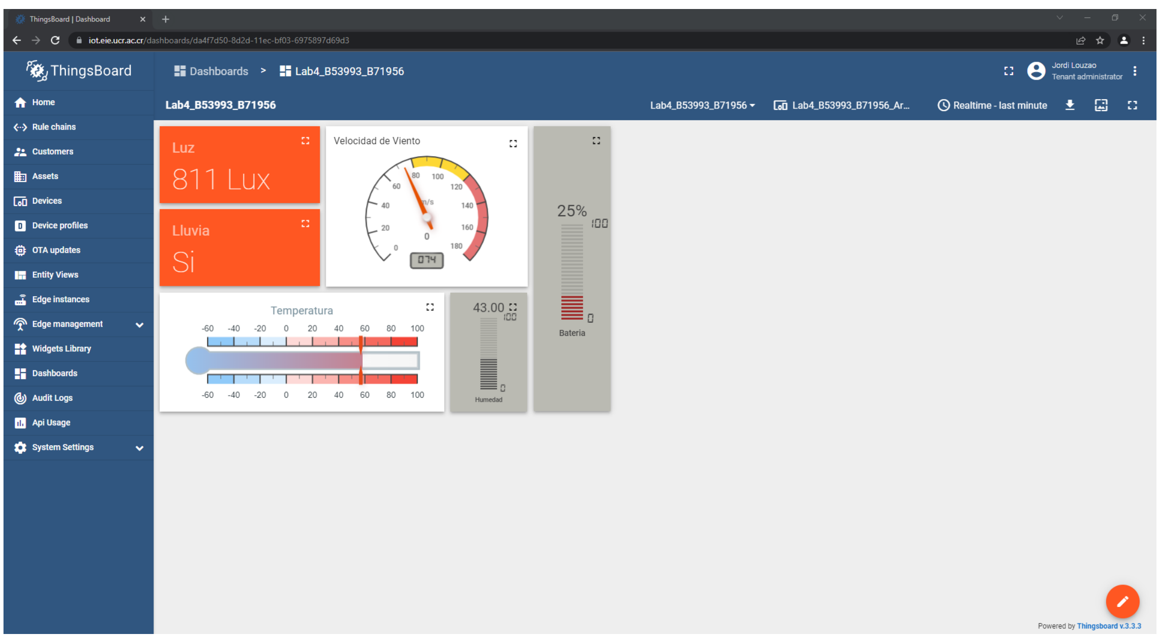


Figura 13: Panel de ThingsBoard [Elaboración propia]

La comunicación con Thingsboard se logro utilizando un script de Python que funciono como un intermediario entre el Arduino simulado y el internet en general. Este script inicia la conexión al servidor de ThingsBoard de la escuela de ingeniería eléctrica y envía los datos necesarios dentro en el formato JSON que utiliza ThingsBoard. El dashboard se configuro tomando en cuenta los diferentes tipos de datos y se escogieron los widgets mas fácilmente legibles para representarlos.

4. Diagrama de bloques

Se utiliza el siguiente diagrama de flujo para entender el funcionamiento de la estación meteorológica.

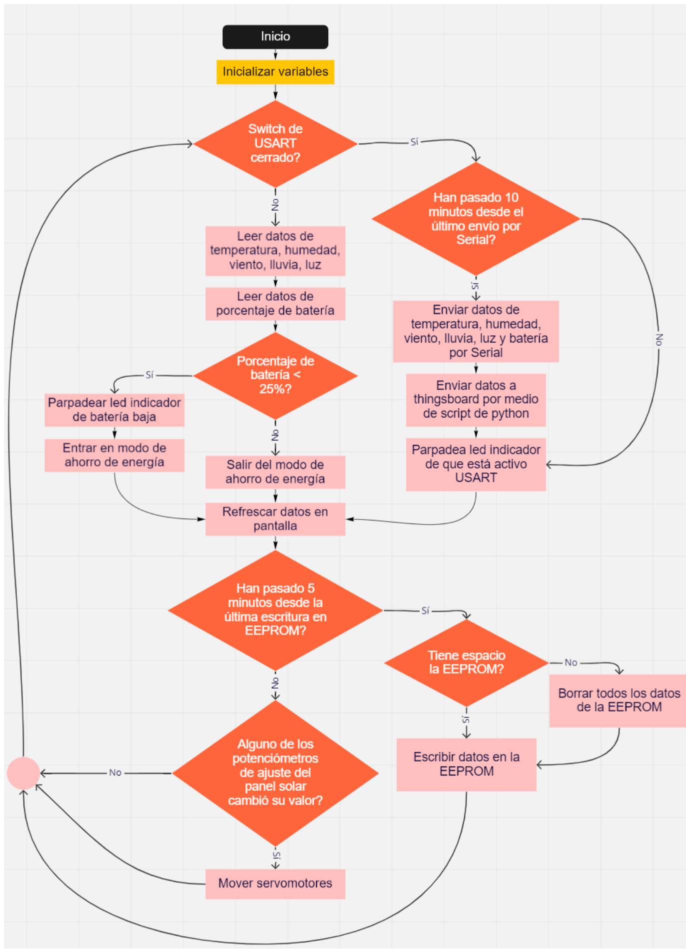


Figura 14: Diagrama de flujo del programa

5. Conclusiones y recomendaciones

- Se logró entender de una mejor forma el funcionamiento de algunos nuevos sensores, tales como el LDR VT900, el sensor de viento JL-FSX2 4-20MA y el de lluvia Hydreon RG-11.
- Se determinó el funcionamiento general de microcontrolador ATMega2560 sus registros y métodos de operación.
- Se aprendió sobre IoT y las opciones que esta ofrece cuando se trabaja con microcontroladores.
- Se logró comprender el funcionamiento de un modo de bajo consumo para el Arduino y cómo medir voltajes mayores a lo que un pin de Arduino soporta.

5.1. Recomendaciones

Una de las principales recomendaciones es utilizar algún otro dispositivo para medir la intensidad de la luz, si es que se quiere medir de manera precisa, ya que con un LDR se puede medir, pero la precisión no es tan buena como se podría esperar. Además, en un proyecto real, las variables serían aún más, y entrarían en juego factores físicos del dispositivo tales como la temperatura, que podrían hacer que las mediciones varíen aún más y sean menos precisas.

Referencias

[1] *Arduino Store*. Arduino CC. URL: https://store-usa.arduino.cc/products/arduino-mega-2560-rev3?selectedStore=us.

[2] *SRS Thermistor Calculator*. Stanford Research Systems Inc. URL: https://www.thinksrs.com/downloads/programs/Therm%5C%20Calc/NTCCalibrator/NTCcalculator.htm.

[3] *Seeed Light Sensor Selection Guide*. Seeed the IoT hardware enabler. URL: https://wiki.seeedstudio.com/Sensor_light/.

[4] *JL-FSX2 4-20MA Wind Speed Sensor Wind Speed Transmitter Anemometer / 0-5V Output*. Makers Store. URL: https://mstore.ibda3vision.com/index.php?route=product/product&product_id=365.

6. Anexos

Como parte de los anexos se adjuntan las hojas de datos del termistor de 100kΩ, del sensor de humedad DHT22, la pantalla PCD8544, la batería de 12V y el sensor LDR.

6.1. Sensor de temperatura: Termistor 100k

TDK Corporation
Piezo & Protection Device B. Grp.
3-9-1, Shibaura, Minato-ku, Tokyo,
108-0023, Japan
TEL. 03-6852-7300

NTCG

NTC Chip Thermistor

Temperature Sensing Device

PRODUCT:NTCG104EF104FTDSX

This product is compliant with the AEC-Q200 standard.

Dimensions and construction

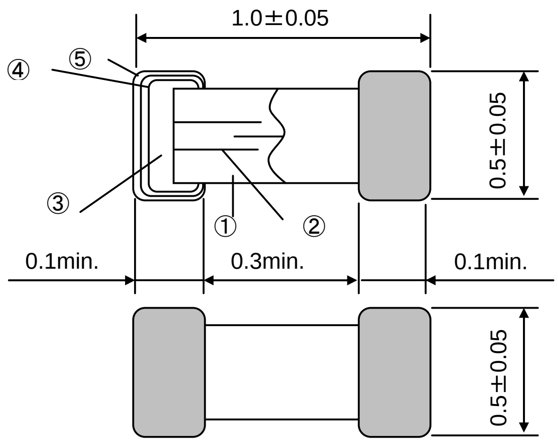


TABLE1. Parts List

	Part Name	Material
①	Element	Manganese, Nickel-oxide base Ceramics materials
②	Inner electrodes	Palladium
③	Terminal electrodes	Silver base
④		Nickel-plating
⑤		Tin-plating

Operating temperature range

-40 ~ +125°C

TABLE 2. Electric Performance:

Item	Symbol	Specification
Nominal resistance and tolerance	R25	100kΩ ± 1%
B value and tolerance	B25/50	4250K ± 1%
Maximum rated power (condition: PCB)	P25	100 mW / 25°C in still air

TABLE 3. Resistance - Temperature Characteristics (condition: chip in silicone oil)

Temp (°C)	Min (kΩ)	Nom (kΩ)	Max (kΩ)	Temp (°C)	Min (kΩ)	Nom (kΩ)	Max (kΩ)	Temp (°C)	Min (kΩ)	Nom (kΩ)	Max (kΩ)
-40.0	4054	4251	4458	20.0	125.5	127.0	128.6	80.0	10.24	10.58	10.92
-35.0	2875	3005	3140	25.0	99.00	100.0	101.0	85.0	8.587	8.887	9.195
-30.0	2063	2149	2238	30.0	78.26	79.23	80.21	90.0	7.235	7.500	7.774
-25.0	1497	1554	1613	35.0	62.26	63.18	64.10	95.0	6.122	6.357	6.600
-20.0	1097	1135	1175	40.0	49.84	50.68	51.54	100.0	5.202	5.410	5.626
-15.0	812.0	837.8	864.3	45.0	40.13	40.90	41.68	105.0	4.438	4.623	4.815
-10.0	606.6	624.1	642.0	50.0	32.50	33.19	33.90	110.0	3.801	3.966	4.137
-5.0	457.3	469.1	481.2	55.0	26.47	27.09	27.72	115.0	3.269	3.415	3.568
0.0	347.6	355.6	363.8	60.0	21.67	22.22	22.78	120.0	2.821	2.952	3.088
5.0	266.4	271.8	277.3	65.0	17.84	18.32	18.82	125.0	2.444	2.561	2.683
10.0	205.8	209.4	213.1	70.0	14.75	15.18	15.63				
15.0	160.1	162.5	164.9	75.0	12.26	12.64	13.04				

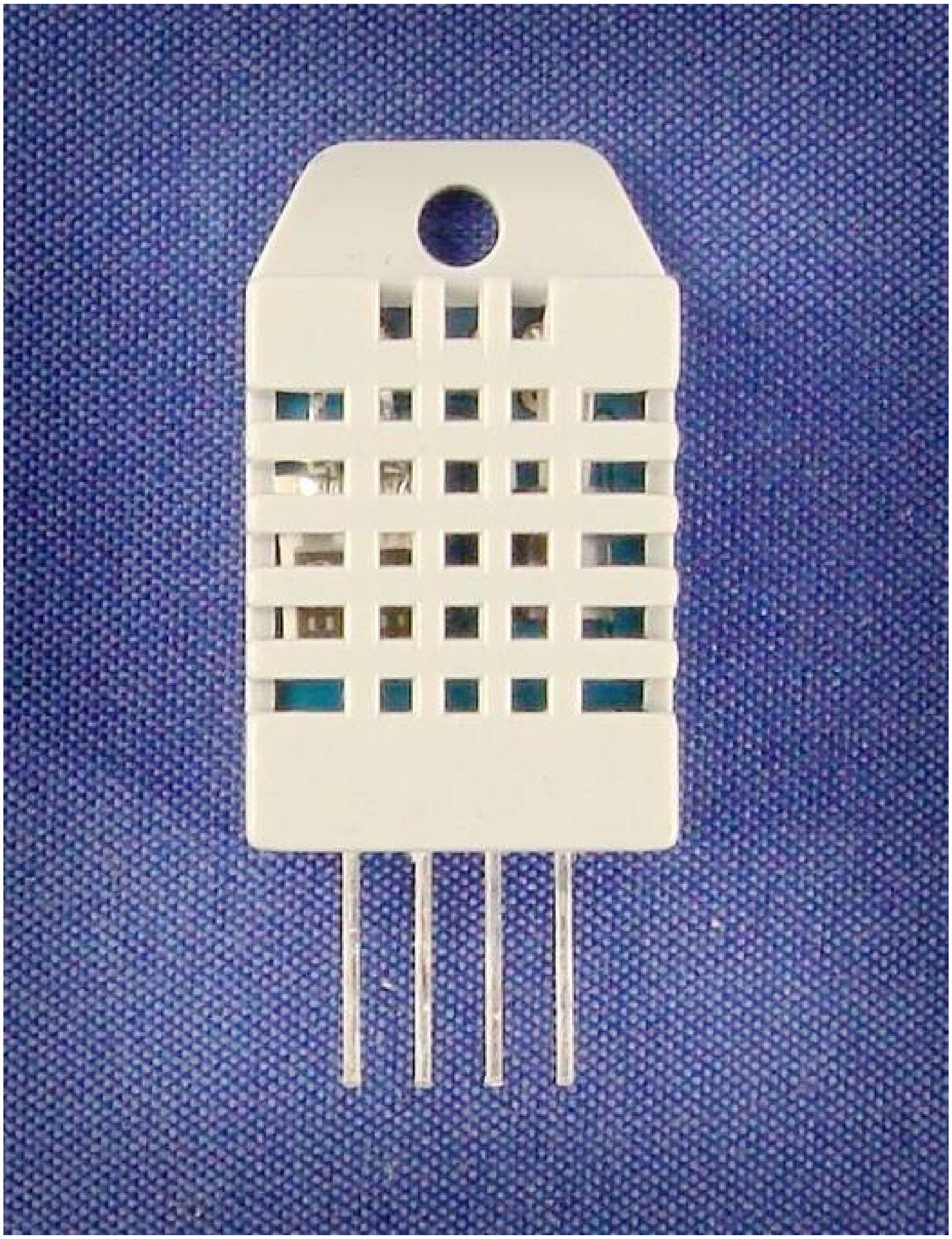
6.2. Sensor de humedad DHT22

Aosong Electronics Co.,Ltd

Your specialist in innovating humidity & temperature sensors

Digital-output relative humidity & temperature sensor/module

DHT22 (DHT22 also named as AM2302)



Capacitive-type humidity and temperature module/sensor

Thomas Liu (Business Manager)

Email: thomasliu198518@yahoo.com.cn

1. Feature & Application:

* Full range temperature compensated * Relative humidity and temperature measurement
* Calibrated digital signal *Outstanding long-term stability *Extra components not needed
* Long transmission distance * Low power consumption *4 pins packaged and fully interchangeable

2. Description:

DHT22 output calibrated digital signal. It utilizes exclusive digital-signal-collecting-technique and humidity sensing technology, assuring its reliability and stability.Its sensing elements is connected with 8-bit single-chip computer.

Every sensor of this model is temperature compensated and calibrated in accurate calibration chamber and the calibration-coefficient is saved in type of programme in OTP memory, when the sensor is detecting, it will cite coefficient from memory.

Small size & low consumption & long transmission distance(20m) enable DHT22 to be suited in all kinds of harsh application occasions.

Single-row packaged with four pins, making the connection very convenient.

3. Technical Specification:

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 <+-0.5Celsius
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

4. Dimensions: (unit----mm)

1) Small size dimensions: (unit----mm)

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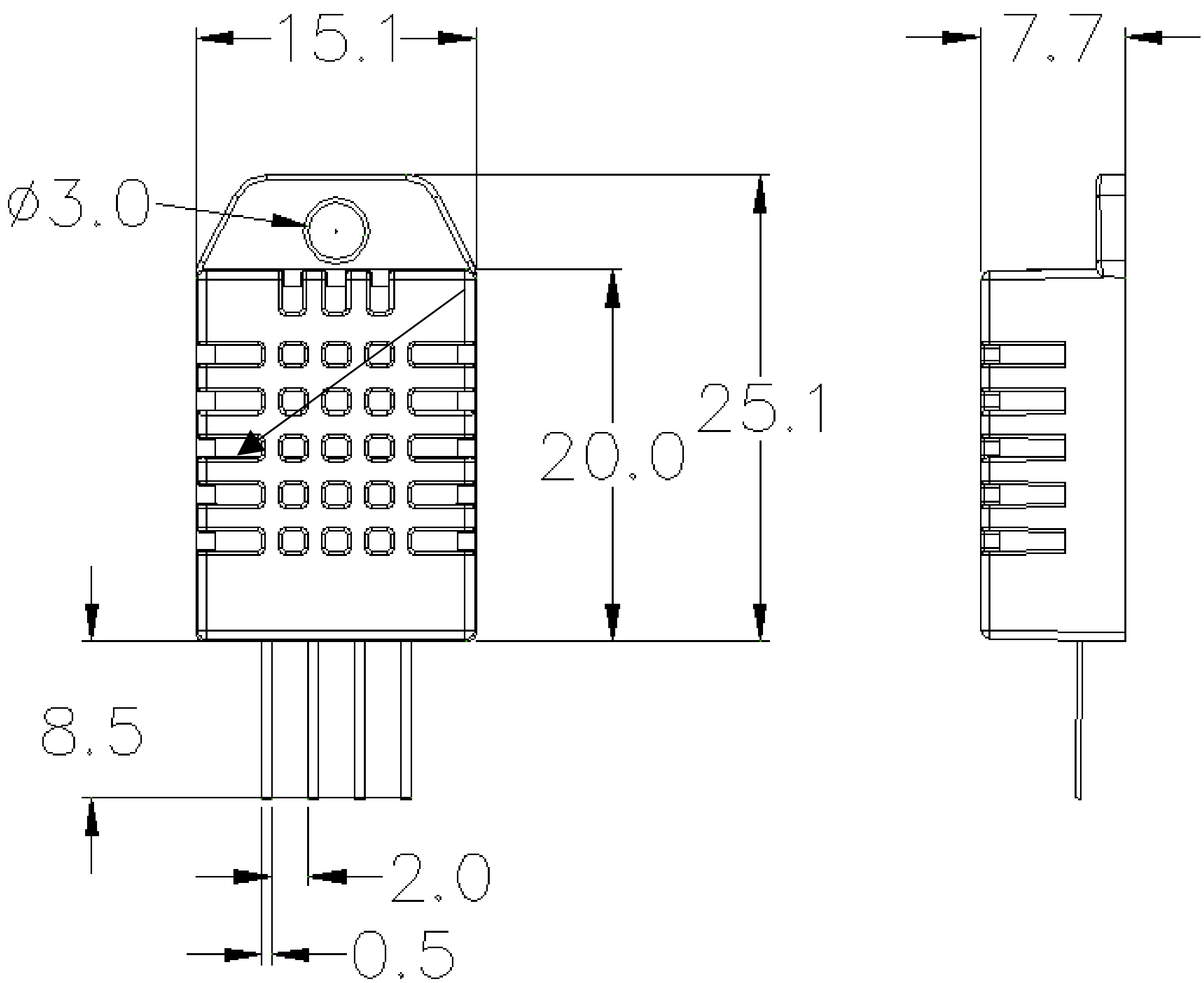

Pin sequence number: 1 2 3 4 (from left to right direction).

Pin	Function
1	VDD----power supply
2	DATA--signal
3	NULL
4	GND

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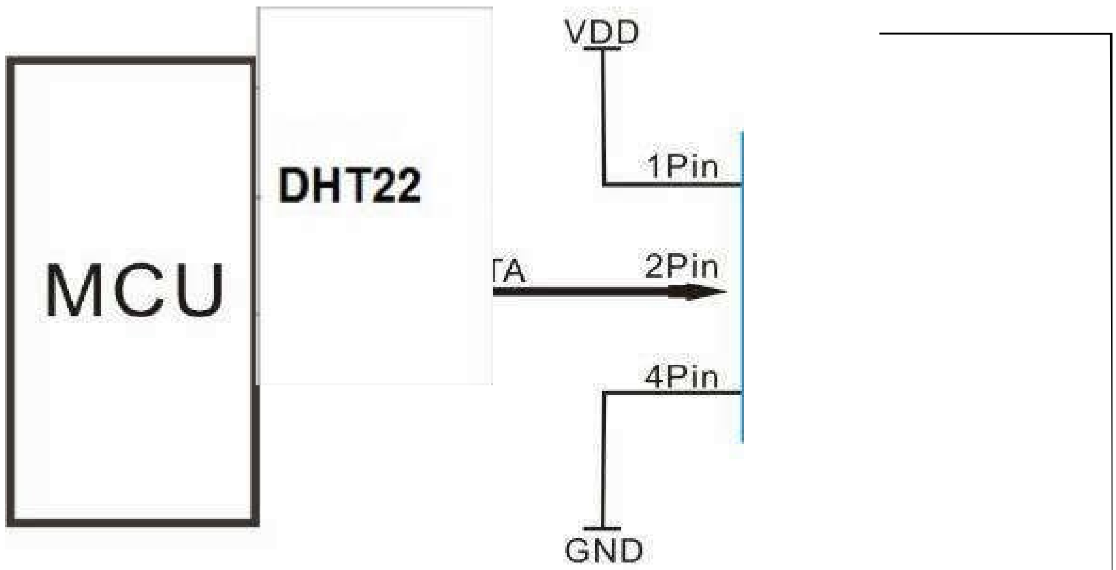
5. Electrical connection diagram:



3Pin---NC, AM2302 is another name for DHT22

6. Operating specifications:

(1) Power and Pins

Power's voltage should be 3.3-6V DC. When power is supplied to sensor, don't send any instruction to the sensor within one second to pass unstable status. One capacitor valued 100nF can be added between VDD and GND for wave filtering.

(2) Communication and signal

Single-bus data is used for communication between MCU and DHT22, it costs 5mS for single time communication.

Data is comprised of integral and decimal part, the following is the formula for data.

DHT22 send out higher data bit firstly!

DATA=8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data+8 bit check-sum

If the data transmission is right, check-sum should be the last 8 bit of "8 bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data".

When MCU send start signal, DHT22 change from low-power-consumption-mode to running-mode. When MCU finishs sending the start signal, DHT22 will send response signal of 40-bit data that reflect the relative humidity

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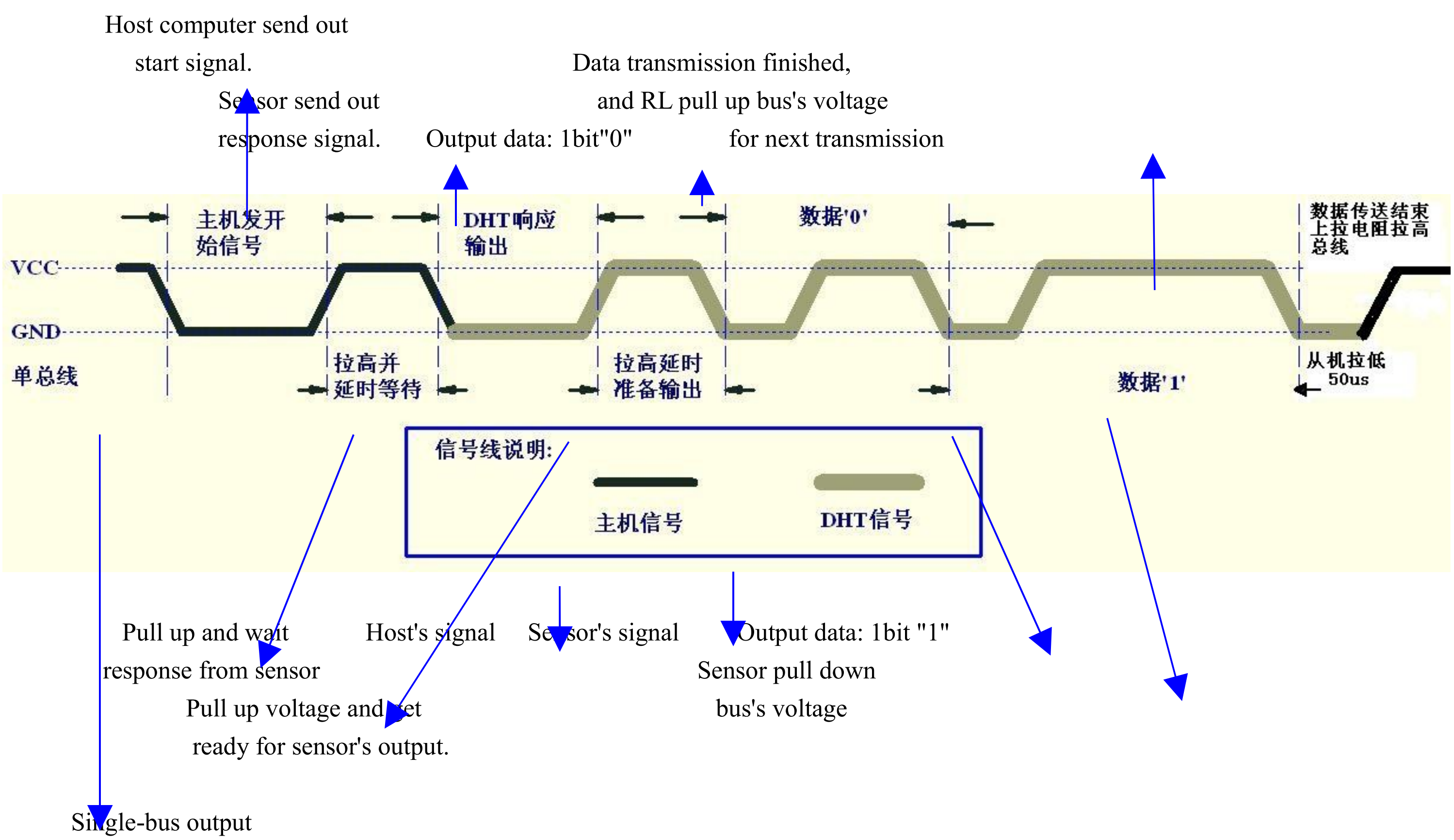
and temperature information to MCU. Without start signal from MCU, DHT22 will not give response signal to MCU. One start signal for one time's response data that reflect the relative humidity and temperature information from DHT22. DHT22 will change to low-power-consumption-mode when data collecting finish if it don't receive start signal from MCU again.

1) Check bellow picture for overall communication process:



2) Step 1: MCU send out start signal to DHT22

Data-bus's free status is high voltage level. When communication between MCU and DHT22 begin, program of MCU will transform data-bus's voltage level from high to low level and this process must beyond at least 1ms to ensure DHT22 could detect MCU's signal, then MCU will wait 20-40us for DHT22's response.

Check bellow picture for step 1:

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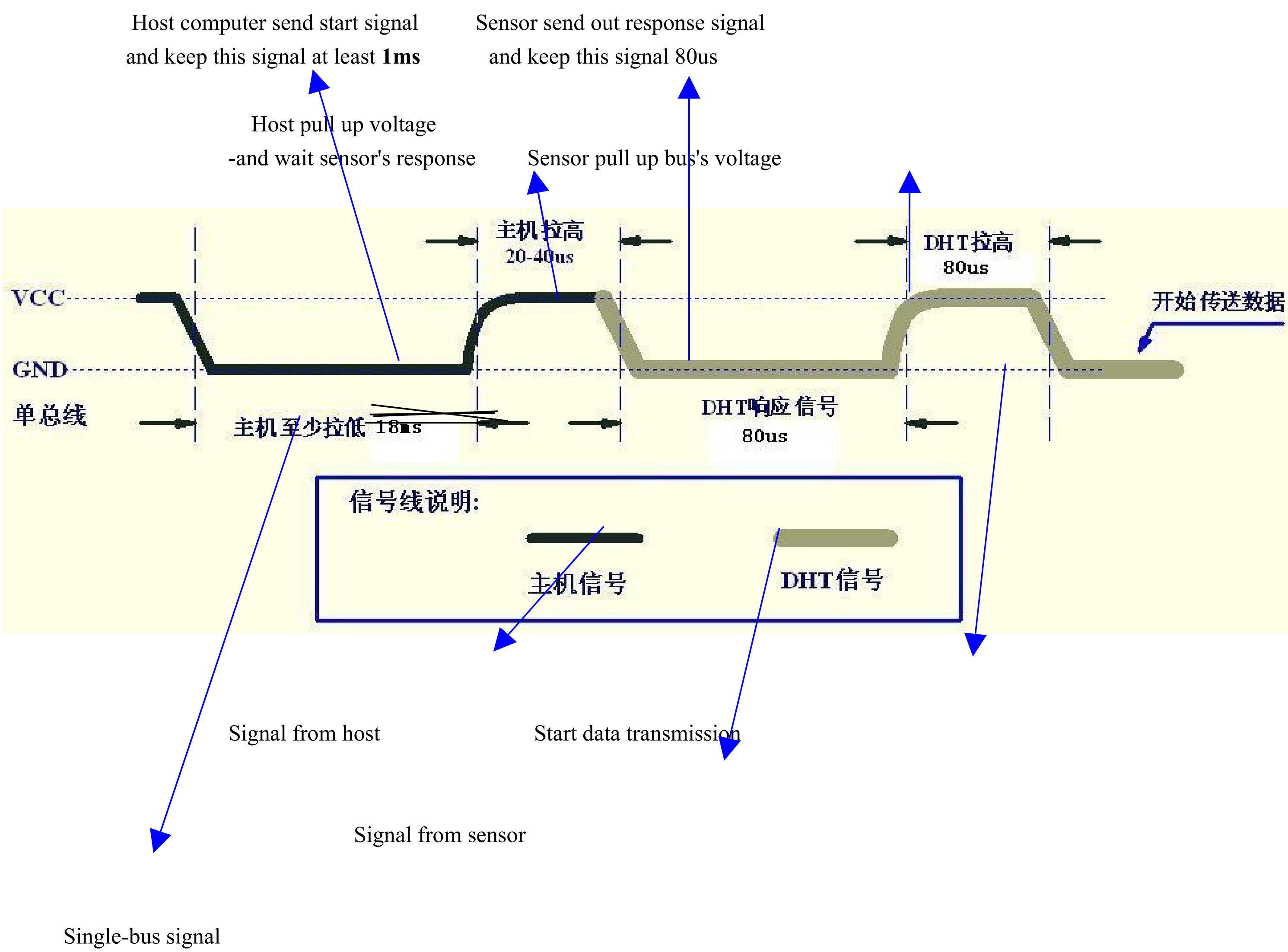

Step 2: DHT22 send response signal to MCU

When DHT22 detect the start signal, DHT22 will send out low-voltage-level signal and this signal last 80us as response signal, then program of DHT22 transform data-bus's voltage level from low to high level and last 80us for DHT22's preparation to send data.

Check bellow picture for step 2:

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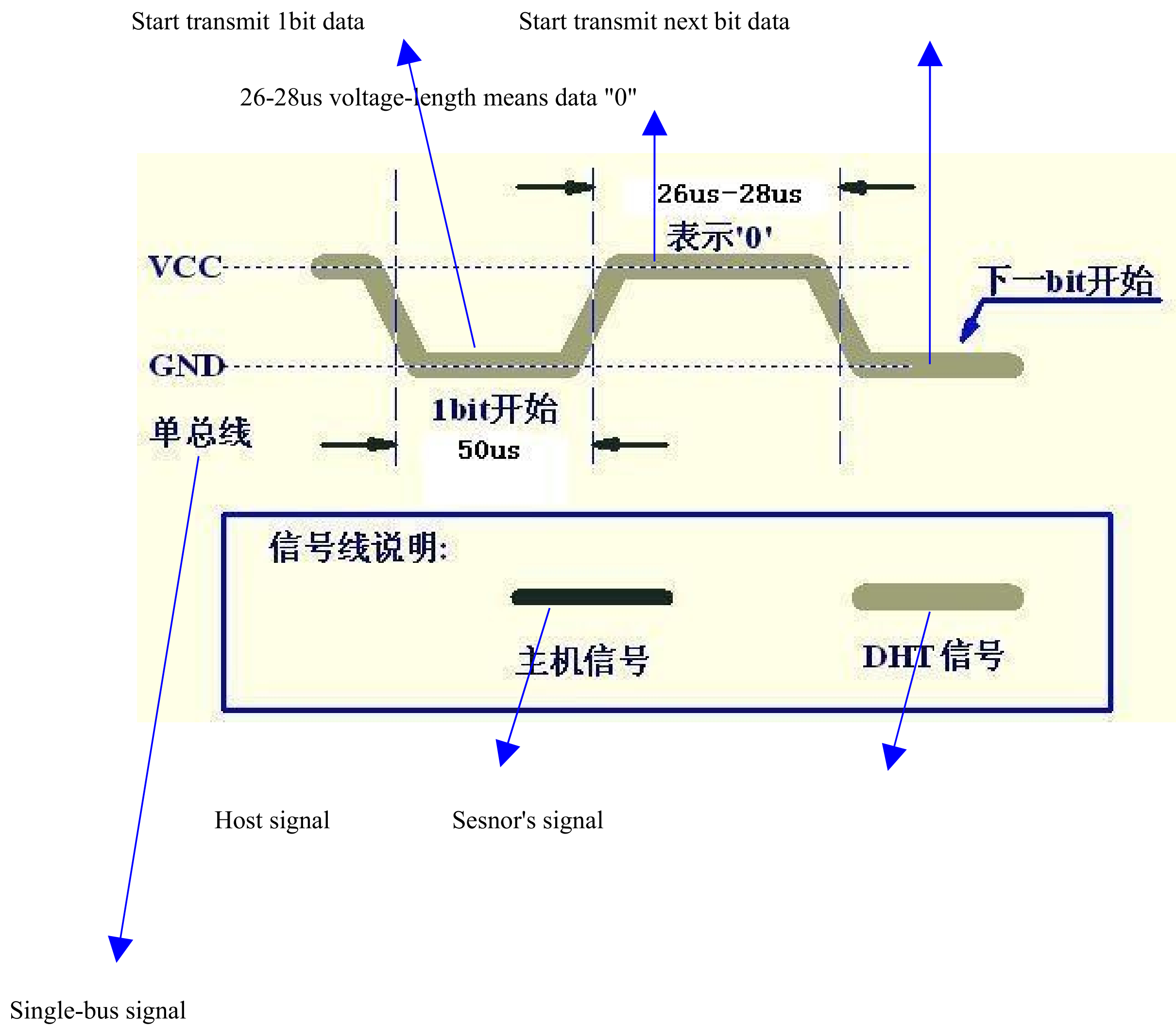

Step 3: DHT22 send data to MCU

When DHT22 is sending data to MCU, every bit's transmission begin with low-voltage-level that last 50us, the following high-voltage-level signal's length decide the bit is "1" or "0".

Check bellow picture for step 3:

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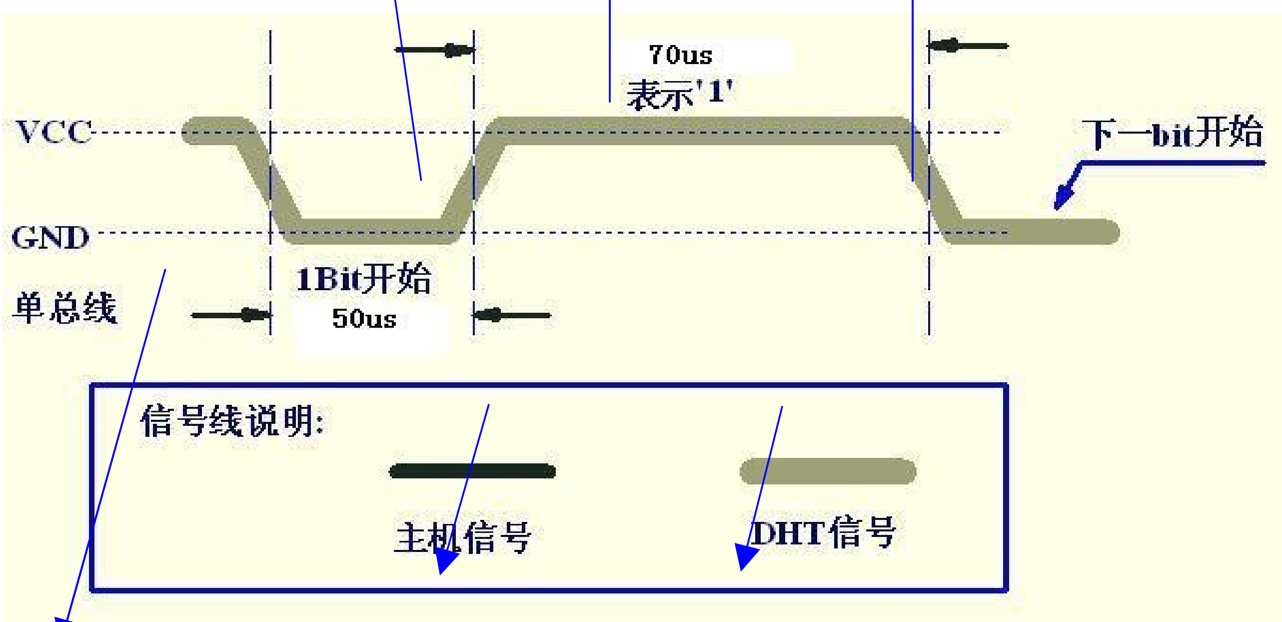
70us voltage-length means 1bit data "1"

Start transmit 1bit data

Start transmit next bit data



Host signal

Sesnor's signal

Single-bus signal

If signal from DHT22 is always high-voltage-level, it means DHT22 is not working properly, please check the electrical connection status.

7. Electrical Characteristics:

Item	Condition	Min	Typical	Max	Unit
Power supply	DC	3.3	5	6	V
Current supply	Measuring	1		1.5	mA
	Stand-by	40	Null	50	uA
Collecting period	Second		2		Second

*Collecting period should be : >2 second.

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8. Attentions of application:

(1) Operating and storage conditions

We don't recommend the applying RH-range beyond the range stated in this specification. The DHT22 sensor can recover after working in non-normal operating condition to calibrated status, but will accelerate sensors' aging.

(2) Attentions to chemical materials

Vapor from chemical materials may interfere DHT22's sensitive-elements and debase DHT22's sensitivity.

(3) Disposal when (1) & (2) happens

Step one: Keep the DHT22 sensor at condition of Temperature 50~60Celsius, humidity <10%RH for 2 hours;

Step two: After step one, keep the DHT22 sensor at condition of Temperature 20~30Celsius, humidity >70%RH for 5 hours.

(4) Attention to temperature's affection

Relative humidity strongly depend on temperature, that is why we use temperature compensation technology to ensure accurate measurement of RH. But it's still be much better to keep the sensor at same temperature when sensing.

DHT22 should be mounted at the place as far as possible from parts that may cause change to temperature.

(5) Attentions to light

Long time exposure to strong light and ultraviolet may debase DHT22's performance.

(6) Attentions to connection wires

The connection wires' quality will effect communication's quality and distance, high quality shielding-wire is recommended.

(7) Other attentions

* Welding temperature should be bellow 260Celsius.
* Avoid using the sensor under dew condition.
* Don't use this product in safety or emergency stop devices or any other occasion that failure of DHT22 may cause personal injury.

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6.3. Pantalla LCD PCD8544

INTEGRATED CIRCUITS

DATA SHEET

PCD8544

48 × 84 pixels matrix LCD controller/driver

Product specification
File under Integrated Circuits, IC17

1999 Apr 12

Philips
Semiconductors

PHILIPS

CONTENTS

1 FEATURES

- Single chip LCD controller/driver
- 48 row, 84 column outputs
- Display data RAM 48 × 84 bits
- On-chip:
  - Generation of LCD supply voltage (external supply also possible)
  - Generation of intermediate LCD bias voltages
  - Oscillator requires no external components (external clock also possible).
- External $\overline{RES}$ (reset) input pin
- Serial interface maximum 4.0 Mbits/s
- CMOS compatible inputs
- Mux rate: 48
- Logic supply voltage range V_{DD} to V_{SS}: 2.7 to 3.3 V
- Display supply voltage range V_{LCD} to V_{SS}
  - 6.0 to 8.5 V with LCD voltage internally generated (voltage generator enabled)
  - 6.0 to 9.0 V with LCD voltage externally supplied (voltage generator switched-off).
- Low power consumption, suitable for battery operated systems
- Temperature compensation of V_{LCD}
- Temperature range: –25 to +70 °C.

2 GENERAL DESCRIPTION

The PCD8544 is a low power CMOS LCD controller/driver, designed to drive a graphic display of 48 rows and 84 columns. All necessary functions for the display are provided in a single chip, including on-chip generation of LCD supply and bias voltages, resulting in a minimum of external components and low power consumption.

The PCD8544 interfaces to microcontrollers through a serial bus interface.

The PCD8544 is manufactured in n-well CMOS technology.

3 APPLICATIONS

- Telecommunications equipment.

4 ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
PCD8544U	–	chip with bumps in tray; 168 bonding pads + 4 dummy pads	–

5 BLOCK DIAGRAM

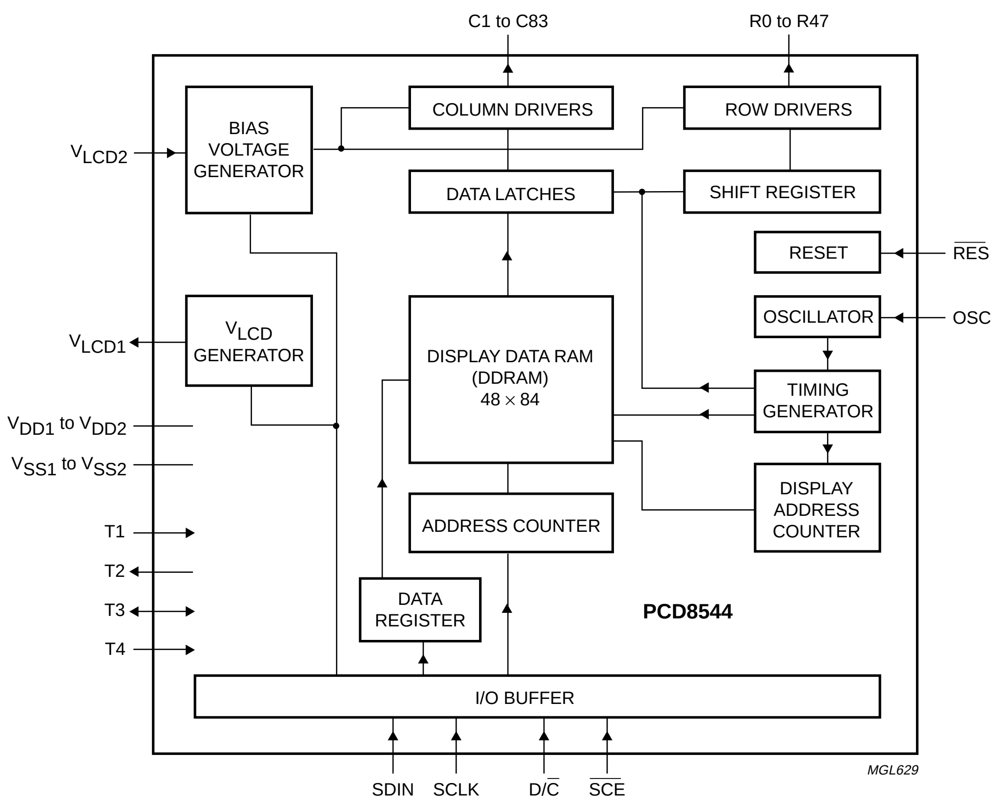


Fig.1 Block diagram.

6 PINNING

SYMBOL	DESCRIPTION
R0 to R47	LCD row driver outputs
C0 to C83	LCD column driver outputs
V_{SS1}, V_{SS2}	ground
V_{DD1}, V_{DD2}	supply voltage
V_{LCD1}, V_{LCD2}	LCD supply voltage
T1	test 1 input
T2	test 2 output
T3	test 3 input/output
T4	test 4 input
SDIN	serial data input
SCLK	serial clock input
D/$\overline{\text{C}}$	data/$\overline{\text{command}}$
$\overline{\text{SCE}}$	chip enable
OSC	oscillator
$\overline{\text{RES}}$	external reset input
dummy1, 2, 3, 4	not connected

Note

1. For further details, see Fig.18 and Table 7.

6.1 Pin functions

6.1.1 R0 TO R47 ROW DRIVER OUTPUTS

These pads output the row signals.

6.1.2 C0 TO C83 COLUMN DRIVER OUTPUTS

These pads output the column signals.

6.1.3 V_{SS1}, V_{SS2}: NEGATIVE POWER SUPPLY RAILS

Supply rails V_{SS1} and V_{SS2} must be connected together.

6.1.4 V_{DD1}, V_{DD2}: POSITIVE POWER SUPPLY RAILS

Supply rails V_{DD1} and V_{DD2} must be connected together.

6.1.5 V_{LCD1}, V_{LCD2}: LCD POWER SUPPLY

Positive power supply for the liquid crystal display. Supply rails V_{LCD1} and V_{LCD2} must be connected together.

6.1.6 T1, T2, T3 AND T4: TEST PADS

T1, T3 and T4 must be connected to V_{SS}, T2 is to be left open. Not accessible to user.

6.1.7 SDIN: SERIAL DATA LINE

Input for the data line.

6.1.8 SCLK: SERIAL CLOCK LINE

Input for the clock signal: 0.0 to 4.0 Mbits/s.

6.1.9 D/$\overline{\text{C}}$: MODE SELECT

Input to select either command/address or data input.

6.1.10 $\overline{\text{SCE}}$: CHIP ENABLE

The enable pin allows data to be clocked in. The signal is active LOW.

6.1.11 OSC: OSCILLATOR

When the on-chip oscillator is used, this input must be connected to V_{DD}. An external clock signal, if used, is connected to this input. If the oscillator and external clock are both inhibited by connecting the OSC pin to V_{SS}, the display is not clocked and may be left in a DC state.
To avoid this, the chip should always be put into Power-down mode before stopping the clock.

6.1.12 $\overline{\text{RES}}$: RESET

This signal will reset the device and must be applied to properly initialize the chip. The signal is active LOW.

7 FUNCTIONAL DESCRIPTION

7.1 Oscillator

The on-chip oscillator provides the clock signal for the display system. No external components are required and the OSC input must be connected to V_{DD}. An external clock signal, if used, is connected to this input.

7.2 Address Counter (AC)

The address counter assigns addresses to the display data RAM for writing. The X-address X_6 to X_0 and the Y-address Y_2 to Y_0 are set separately. After a write operation, the address counter is automatically incremented by 1, according to the V flag.

7.3 Display Data RAM (DDRAM)

The DDRAM is a 48×84 bit static RAM which stores the display data. The RAM is divided into six banks of 84 bytes ($6 \times 8 \times 84$ bits). During RAM access, data is transferred to the RAM through the serial interface. There is a direct correspondence between the X-address and the column output number.

7.4 Timing generator

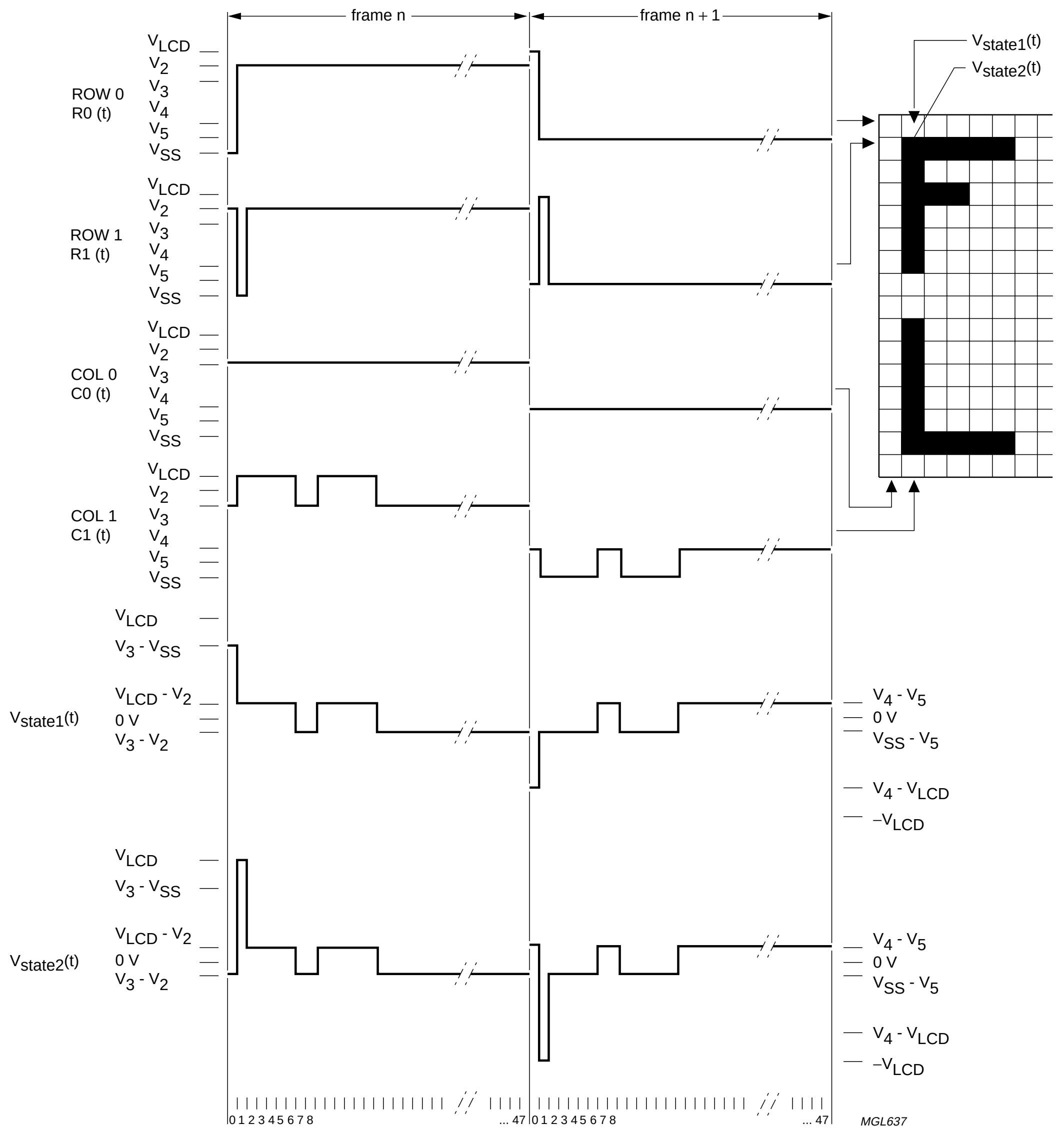
The timing generator produces the various signals required to drive the internal circuits. Internal chip operation is not affected by operations on the data buses.

7.5 Display address counter

The display is generated by continuously shifting rows of RAM data to the dot matrix LCD through the column outputs. The display status (all dots on/off and normal/inverse video) is set by bits E and D in the ‘display control’ command.

7.6 LCD row and column drivers

The PCD8544 contains 48 row and 84 column drivers, which connect the appropriate LCD bias voltages in sequence to the display in accordance with the data to be displayed. Figure 2 shows typical waveforms. Unused outputs should be left unconnected.



$V_{state1}(t) = C1(t) - R0(t)$.
$V_{state2}(t) = C1(t) - R1(t)$.

Fig.2 Typical LCD driver waveforms.

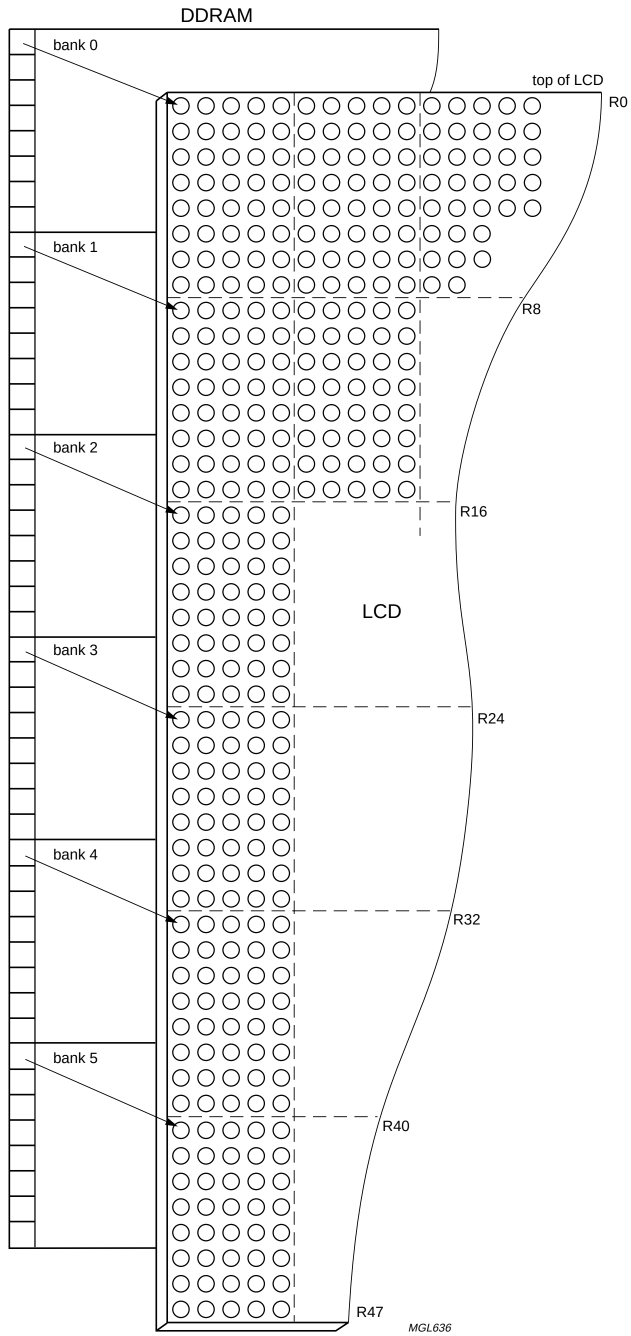


Fig.3 DDRAM to display mapping.

7.7 Addressing

Data is downloaded in bytes into the 48 by 84 bits RAM data display matrix of PCD8544, as indicated in Figs. 3, 4, 5 and 6. The columns are addressed by the address pointer. The address ranges are: X 0 to 83 (1010011), Y 0 to 5 (101). Addresses outside these ranges are not allowed. In the vertical addressing mode (V = 1), the Y address increments after each byte (see Fig.5). After the last Y address (Y = 5), Y wraps around to 0 and X increments to address the next column. In the horizontal addressing mode (V = 0), the X address increments after each byte (see Fig.6). After the last X address (X = 83), X wraps around to 0 and Y increments to address the next row. After the very last address (X = 83 and Y = 5), the address pointers wrap around to address (X = 0 and Y = 0).

7.7.1 DATA STRUCTURE

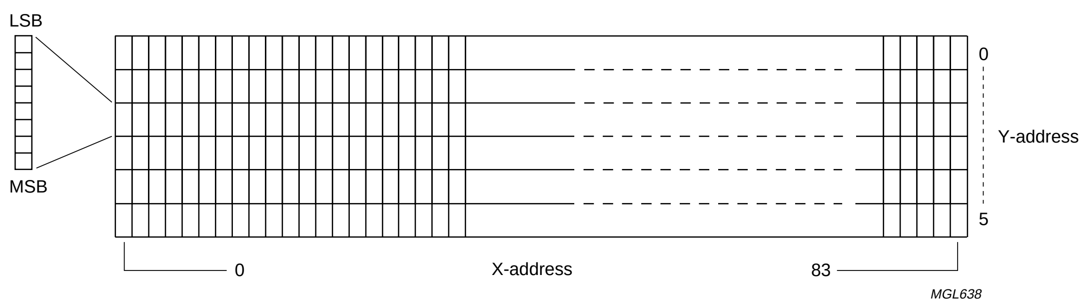


Fig.4 RAM format, addressing.

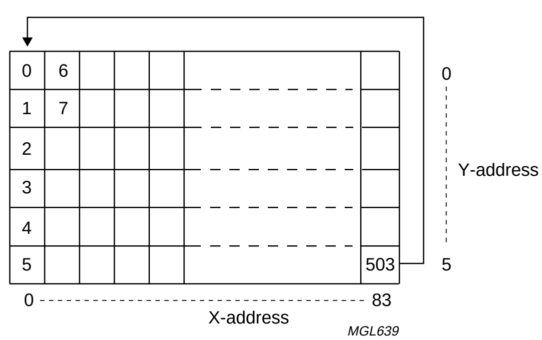


Fig.5 Sequence of writing data bytes into RAM with vertical addressing (V = 1).

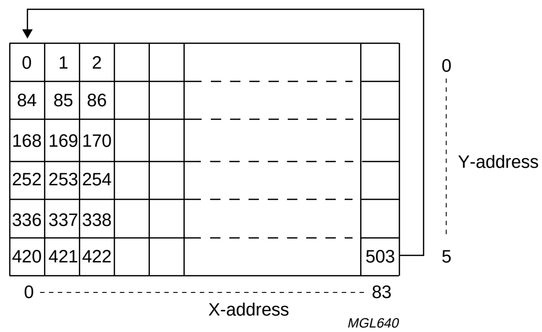
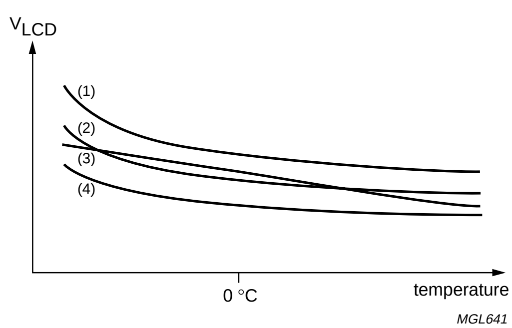


Fig.6 Sequence of writing data bytes into RAM with horizontal addressing (V = 0).

7.8 Temperature compensation

Due to the temperature dependency of the liquid crystals' viscosity, the LCD controlling voltage V_{LCD} must be increased at lower temperatures to maintain optimum contrast. Figure 7 shows V_{LCD} for high multiplex rates. In the PCD8544, the temperature coefficient of V_{LCD}, can be selected from four values (see Table 2) by setting bits TC_1 and TC_0.



(1) Upper limit.
(2) Typical curve.
(3) Temperature coefficient of IC.
(4) Lower limit.

Fig.7 V_{LCD} as function of liquid crystal temperature (typical values).

8 INSTRUCTIONS

The instruction format is divided into two modes: If $D/\overline{C}$ (mode select) is set LOW, the current byte is interpreted as command byte (see Table 1). Figure 8 shows an example of a serial data stream for initializing the chip. If $D/\overline{C}$ is set HIGH, the following bytes are stored in the display data RAM. After every data byte, the address counter is incremented automatically.

The level of the $D/\overline{C}$ signal is read during the last bit of data byte.

Each instruction can be sent in any order to the PCD8544. The MSB of a byte is transmitted first. Figure 9 shows one possible command stream, used to set up the LCD driver.

The serial interface is initialized when $\overline{SCE}$ is HIGH. In this state, SCLK clock pulses have no effect and no power is consumed by the serial interface. A negative edge on $\overline{SCE}$ enables the serial interface and indicates the start of a data transmission.

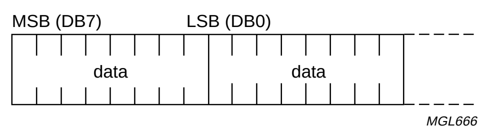


Fig.8 General format of data stream.

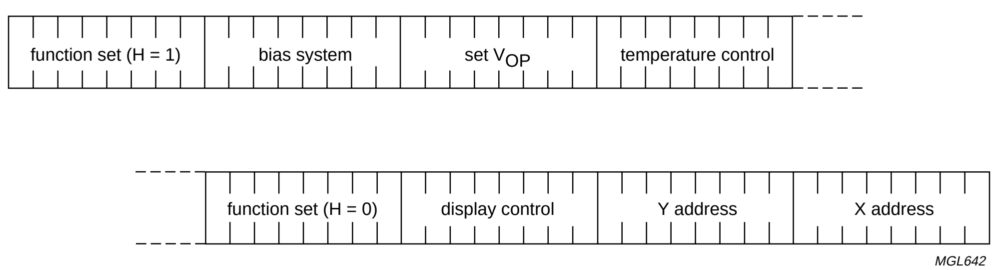


Fig.9 Serial data stream, example.

Figures 10 and 11 show the serial bus protocol.

- When $\overline{SCE}$ is HIGH, SCLK clock signals are ignored; during the HIGH time of $\overline{SCE}$, the serial interface is initialized (see Fig.12)
- SDIN is sampled at the positive edge of SCLK
- $D/\overline{C}$ indicates whether the byte is a command ($D/\overline{C}$ = 0) or RAM data ($D/\overline{C}$ = 1); it is read with the eighth SCLK pulse
- If $\overline{SCE}$ stays LOW after the last bit of a command/data byte, the serial interface expects bit 7 of the next byte at the next positive edge of SCLK (see Fig.12)
- A reset pulse with $\overline{RES}$ interrupts the transmission. No data is written into the RAM. The registers are cleared. If $\overline{SCE}$ is LOW after the positive edge of $\overline{RES}$, the serial interface is ready to receive bit 7 of a command/data byte (see Fig.13).

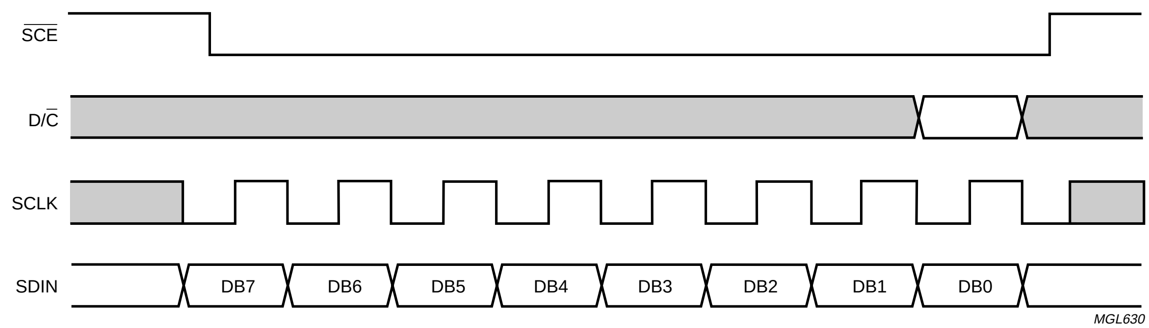


Fig.10 Serial bus protocol - transmission of one byte.

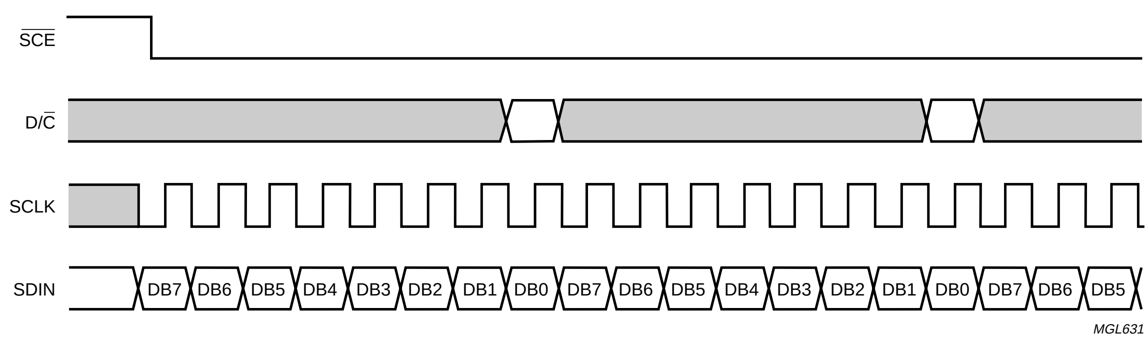


Fig.11 Serial bus protocol - transmission of several bytes.

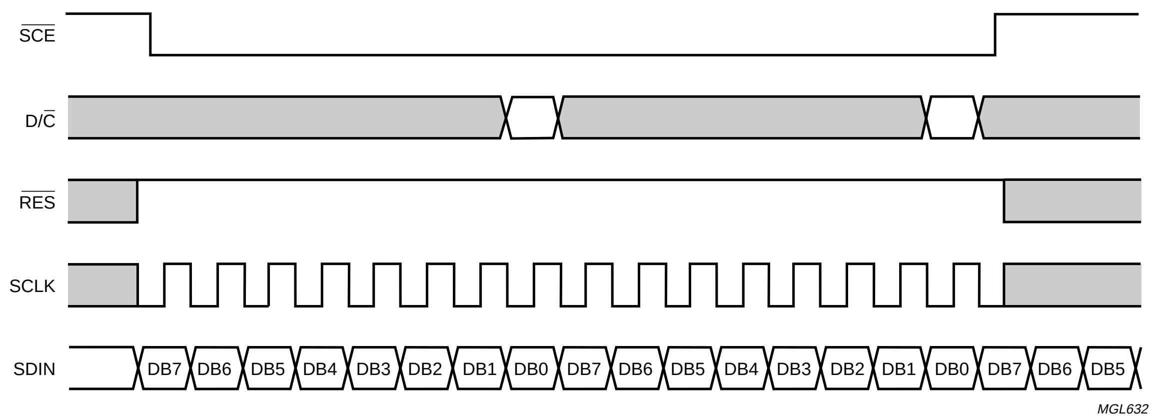


Fig.12 Serial bus reset function ($\overline{SCE}$).

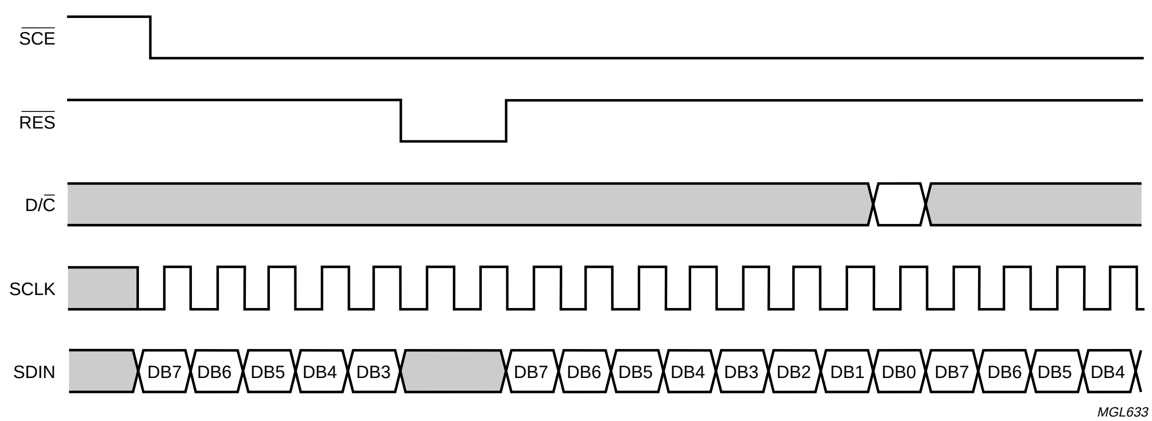


Fig.13 Serial bus reset function ($\overline{RES}$).

Table 1 Instruction set

INSTRUCTION	D/$\overline{C}$	COMMAND BYTE								DESCRIPTION
		DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
(H = 0 or 1)										
NOP	0	0	0	0	0	0	0	0	0	no operation
Function set	0	0	0	1	0	0	PD	V	H	power down control; entry mode; extended instruction set control (H)
Write data	1	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	writes data to display RAM
(H = 0)										
Reserved	0	0	0	0	0	0	1	X	X	do not use
Display control	0	0	0	0	0	1	D	0	E	sets display configuration
Reserved	0	0	0	0	1	X	X	X	X	do not use
Set Y address of RAM	0	0	1	0	0	0	Y_2	Y_1	Y_0	sets Y-address of RAM; $0 \leq Y \leq 5$
Set X address of RAM	0	1	X_6	X_5	X_4	X_3	X_2	X_1	X_0	sets X-address part of RAM; $0 \leq X \leq 83$
(H = 1)										
Reserved	0	0	0	0	0	0	0	0	1	do not use
	0	0	0	0	0	0	0	1	X	do not use
Temperature control	0	0	0	0	0	0	1	TC_1	TC_0	set Temperature Coefficient (TC_x)
Reserved	0	0	0	0	0	1	X	X	X	do not use
Bias system	0	0	0	0	1	0	BS_2	BS_1	BS_0	set Bias System (BS_x)
Reserved	0	0	1	X	X	X	X	X	X	do not use
Set V_{OP}	0	1	V_{OP6}	V_{OP5}	V_{OP4}	V_{OP3}	V_{OP2}	V_{OP1}	V_{OP0}	write V_{OP} to register

Table 2 Explanations of symbols in Table 1

BIT	0	1
PD	chip is active	chip is in Power-down mode
V	horizontal addressing	vertical addressing
H	use basic instruction set	use extended instruction set
D and E		
00	display blank	
10	normal mode	
01	all display segments on	
11	inverse video mode	
TC_1 and TC_0		
00	V_{LCD} temperature coefficient 0	
01	V_{LCD} temperature coefficient 1	
10	V_{LCD} temperature coefficient 2	
11	V_{LCD} temperature coefficient 3	

8.1 Initialization

Immediately following power-on, the contents of all internal registers and of the RAM are undefined. **A $\overline{\text{RES}}$ pulse must be applied**. Attention should be paid to the possibility that the **device may be damaged** if not properly reset.

All internal registers are reset by applying an external $\overline{\text{RES}}$ pulse (active LOW) at pad 31, within the specified time. However, the RAM contents are still undefined. The state after reset is described in Section 8.2.

The $\overline{\text{RES}}$ input must be $\leq 0.3V_{DD}$ when V_{DD} reaches V_{DDmin} (or higher) within a maximum time of 100 ms after V_{DD} goes HIGH (see Fig.16).

8.2 Reset function

After reset, the LCD driver has the following state:

- Power-down mode (bit PD = 1)
- Horizontal addressing (bit V = 0) normal instruction set (bit H = 0)
- Display blank (bit E = D = 0)
- Address counter X_6 to X_0 = 0; Y_2 to Y_0 = 0
- Temperature control mode (TC_1 TC_0 = 0)
- Bias system (BS_2 to BS_0 = 0)
- V_{LCD} is equal to 0, the HV generator is switched off (V_{OP6} to V_{OP0} = 0)
- After power-on, the RAM contents are undefined.

8.3 Function set

8.3.1 BIT PD

- All LCD outputs at V_{SS} (display off)
- Bias generator and V_{LCD} generator off, V_{LCD} can be disconnected
- Oscillator off (external clock possible)
- Serial bus, command, etc. function
- Before entering Power-down mode, the RAM needs to be filled with ‘0’s to ensure the specified current consumption.

8.3.2 BIT V

When V = 0, the horizontal addressing is selected. The data is written into the DDRAM as shown in Fig.6. When V = 1, the vertical addressing is selected. The data is written into the DDRAM, as shown in Fig.5.

8.3.3 BIT H

When H = 0 the commands ‘display control’, ‘set Y address’ and ‘set X address’ can be performed; when H = 1, the others can be executed. The ‘write data’ and ‘function set’ commands can be executed in both cases.

8.4 Display control

8.4.1 BITS D AND E

Bits D and E select the display mode (see Table 2).

8.5 Set Y address of RAM

Y_n defines the Y vector addressing of the display RAM.

Table 3 Y vector addressing

Y_2	Y_1	Y_0	BANK
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5

8.6 Set X address of RAM

The X address points to the columns. The range of X is 0 to 83 (53H).

8.7 Temperature control

The temperature coefficient of V_{LCD} is selected by bits TC_1 and TC_0.

8.8 Bias value

The bias voltage levels are set in the ratio of R - R - nR - R - R, giving a 1/(n + 4) bias system. Different multiplex rates require different factors n (see Table 4). This is programmed by BS_2 to BS_0. For Mux 1 : 48, the optimum bias value n, resulting in 1/8 bias, is given by:

$$n = \sqrt{48} - 3 = 3.928 = 4 \quad (1)$$

Table 4 Programming the required bias system

BS_2	BS_1	BS_0	n	RECOMMENDED MUX RATE
0	0	0	7	1 : 100
0	0	1	6	1 : 80
0	1	0	5	1 : 65/1 : 65
0	1	1	4	1 : 48
1	0	0	3	1 : 40/1 : 34
1	0	1	2	1 : 24
1	1	0	1	1 : 18/1 : 16
1	1	1	0	1 : 10/1 : 9/1 : 8

Table 5 LCD bias voltage

SYMBOL	BIAS VOLTAGES	BIAS VOLTAGE FOR ⅛ BIAS
V1	V_{LCD}	V_{LCD}
V2	(n + 3)/(n + 4)	$\frac{7}{8} \times V_{LCD}$
V3	(n + 2)/(n + 4)	$\frac{6}{8} \times V_{LCD}$
V4	2/(n + 4)	$\frac{2}{8} \times V_{LCD}$
V5	1/(n + 4)	$\frac{1}{8} \times V_{LCD}$
V6	V_{SS}	V_{SS}

8.9 Set V_{OP} value

The operation voltage V_{LCD} can be set by software. The values are dependent on the liquid crystal selected. $V_{LCD} = a + (V_{OP6}$ to $V_{OP0}) \times b$ [V]. In the PCD8544, a = 3.06 and b = 0.06 giving a program range of 3.00 to 10.68 at room temperature.

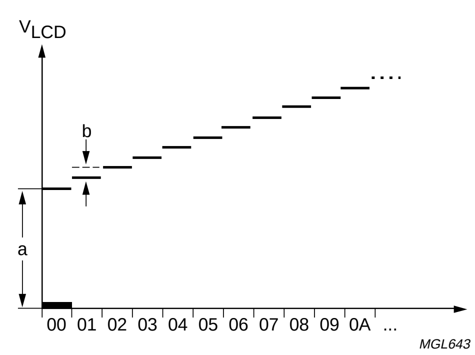
Note that the charge pump is turned off if V_{OP6} to V_{OP0} is set to zero.

For Mux 1 : 48, the optimum operation voltage of the liquid can be calculated as:

$$V_{LCD} = \frac{1 + \sqrt{48}}{\sqrt{2 \cdot \left(1 - \frac{1}{\sqrt{48}}\right)}} \cdot V_{th} = 6.06 \cdot V_{th} \qquad (2)$$

where V_{th} is the threshold voltage of the liquid crystal material used.

Caution, as V_{OP} increases with lower temperatures, care must be taken not to set a V_{OP} that will exceed the maximum of 8.5 V when operating at −25 °C.



a = 3.06.
b = 0.06.
V_{OP6} to V_{OP0} (programmed) [00 to 7FH].

Fig.14 V_{OP} programming.

9 LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134); see notes 1 and 2.

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{DD}	supply voltage	note 3	–0.5	+7	V
V_{LCD}	supply voltage LCD	note 4	–0.5	+10	V
V_i	all input voltages		–0.5	V_{DD} + 0.5	V
I_{SS}	ground supply current		–50	+50	mA
I_I, I_O	DC input or output current		–10	+10	mA
P_{tot}	total power dissipation		–	300	mW
P_O	power dissipation per output		–	30	mW
T_{amb}	operating ambient temperature		–25	+70	°C
T_j	operating junction temperature		–65	+150	°C
T_{stg}	storage temperature		–65	+150	°C

Notes

1. Stresses above those listed under limiting values may cause permanent damage to the device.
2. Parameters are valid over operating temperature range unless otherwise specified. All voltages are with respect to V_{SS} unless otherwise noted.
3. With external LCD supply voltage externally supplied (voltage generator disabled). V_{DDmax} = 5 V if LCD supply voltage is internally generated (voltage generator enabled).
4. When setting V_{LCD} by software, take care not to set a V_{OP} that will exceed the maximum of 8.5 V when operating at –25 °C, see Caution in Section 8.9.

10 HANDLING

Inputs and outputs are protected against electrostatic discharge in normal handling. However, to be totally safe, it is desirable to take normal precautions appropriate to handling MOS devices (see *“Handling MOS devices”*).

11 DC CHARACTERISTICS

V_{DD} = 2.7 to 3.3 V; V_{SS} = 0 V; V_{LCD} = 6.0 to 9.0 V; T_{amb} = –25 to +70 °C; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
V_{DD1}	supply voltage 1	LCD voltage externally supplied (voltage generator disabled)	2.7	–	3.3	V
V_{DD2}	supply voltage 2	LCD voltage internally generated (voltage generator enabled)	2.7	–	3.3	V
V_{LCD1}	LCD supply voltage	LCD voltage externally supplied (voltage generator disabled)	6.0	–	9.0	V
V_{LCD2}	LCD supply voltage	LCD voltage internally generated (voltage generator enabled); note 1	6.0	–	8.5	V
I_{DD1}	supply current 1 (normal mode) for internal V_{LCD}	V_{DD} = 2.85 V; V_{LCD} = 7.0 V; f_{SCLK} = 0; T_{amb} = 25 °C; display load = 10 µA; note 2	–	240	300	µA
I_{DD2}	supply current 2 (normal mode) for internal V_{LCD}	V_{DD} = 2.70 V; V_{LCD} = 7.0 V; f_{SCLK} = 0; T_{amb} = 25 °C; display load = 10 µA; note 2	–	–	320	µA
I_{DD3}	supply current 3 (Power-down mode)	with internal or external LCD supply voltage; note 3	–	1.5	–	µA
I_{DD4}	supply current external V_{LCD}	V_{DD} = 2.85 V; V_{LCD} = 9.0 V; f_{SCLK} = 0; notes 2 and 4	–	25	–	µA
I_{LCD}	supply current external V_{LCD}	V_{DD} = 2.7 V; V_{LCD} = 7.0 V; f_{SCLK} = 0; T = 25 °C; display load = 10 µA; notes 2 and 4	–	42	–	µA
Logic						
V_{IL}	LOW level input voltage		V_{SS}	–	$0.3V_{DD}$	V
V_{IH}	HIGH level input voltage		$0.7V_{DD}$	–	V_{DD}	V
I_L	leakage current	$V_I = V_{DD}$ or V_{SS}	–1	–	+1	µA
Column and row outputs						
$R_{o(C)}$	column output resistance C0 to C83		–	12	20	kΩ
$R_{o(R)}$	row output resistance R0 to R47		–	12	20	kΩ
$V_{bias(tol)}$	bias voltage tolerance on C0 to C83 and R0 to R47		–100	0	+100	mV

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
LCD supply voltage generator						
V_{LCD}	V_{LCD} tolerance internally generated	V_{DD} = 2.85 V; V_{LCD} = 7.0 V; f_{SCLK} = 0; display load = 10 μA; note 5	–	0	300	mV
TC0	V_{LCD} temperature coefficient 0	V_{DD} = 2.85 V; V_{LCD} = 7.0 V; f_{SCLK} = 0; display load = 10 μA	–	1	–	mV/K
TC1	V_{LCD} temperature coefficient 1	V_{DD} = 2.85 V; V_{LCD} = 7.0 V; f_{SCLK} = 0; display load = 10 μA	–	9	–	mV/K
TC2	V_{LCD} temperature coefficient 2	V_{DD} = 2.85 V; V_{LCD} = 7.0 V; f_{SCLK} = 0; display load = 10 μA	–	17	–	mV/K
TC3	V_{LCD} temperature coefficient 3	V_{DD} = 2.85 V; V_{LCD} = 7.0 V; f_{SCLK} = 0; display load = 10 μA	–	24	–	mV/K

Notes

1. The maximum possible V_{LCD} voltage that may be generated is dependent on voltage, temperature and (display) load.
2. Internal clock.
3. RAM contents equal ‘0’. During power-down, all static currents are switched off.
4. If external V_{LCD}, the display load current is not transmitted to I_{DD}.
5. Tolerance depends on the temperature (typically zero at 27 °C, maximum tolerance values are measured at the temperate range limit).

12 AC CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
f_{OSC}	oscillator frequency		20	34	65	kHz
$f_{clk(ext)}$	external clock frequency		10	32	100	kHz
f_{frame}	frame frequency	f_{OSC} or $f_{clk(ext)}$ = 32 kHz; note 1	–	67	–	Hz
t_{VHRL}	V_{DD} to $\overline{RES}$ LOW	Fig.16	0[2]	–	30	ms
$t_{WL(RES)}$	$\overline{RES}$ LOW pulse width	Fig.16	100	–	–	ns
Serial bus timing characteristics						
f_{SCLK}	clock frequency	V_{DD} = 3.0 V ±10%	0	–	4.00	MHz
T_{cy}	clock cycle SCLK	All signal timing is based on 20% to 80% of V_{DD} and maximum rise and fall times of 10 ns	250	–	–	ns
t_{WH1}	SCLK pulse width HIGH		100	–	–	ns
t_{WL1}	SCLK pulse width LOW		100	–	–	ns
t_{su2}	$\overline{SCE}$ set-up time		60	–	–	ns
t_{h2}	$\overline{SCE}$ hold time		100	–	–	ns
t_{WH2}	$\overline{SCE}$ min. HIGH time		100	–	–	ns
t_{h5}	$\overline{SCE}$ start hold time; note 3		100	–	–	ns
t_{su3}	D/$\overline{C}$ set-up time		100	–	–	ns
t_{h3}	D/$\overline{C}$ hold time		100	–	–	ns
t_{su4}	SDIN set-up time		100	–	–	ns
t_{h4}	SDIN hold time		100	–	–	ns

Notes

1. $T_{frame} = \frac{f_{clk(ext)}}{480}$
2. $\overline{RES}$ may be LOW before V_{DD} goes HIGH.
3. t_{h5} is the time from the previous SCLK positive edge (irrespective of the state of $\overline{SCE}$) to the negative edge of $\overline{SCE}$ (see Fig.15).

12.1 Serial interface

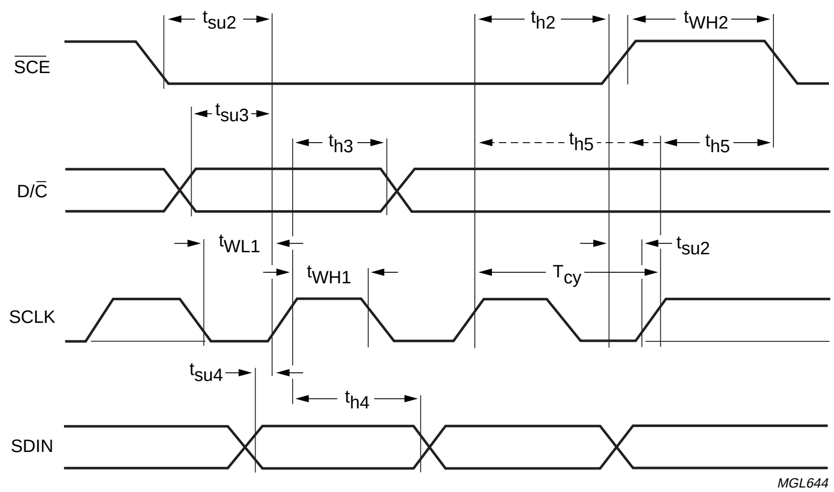


Fig.15 Serial interface timing.

12.2 Reset

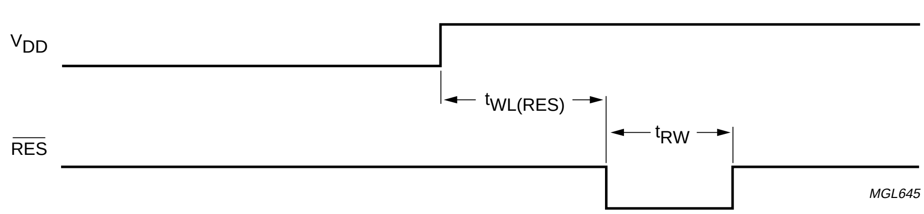
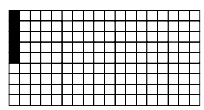
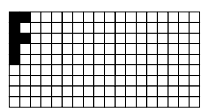
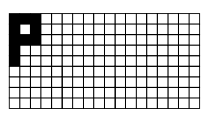
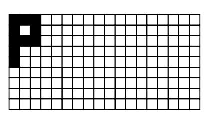
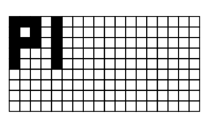
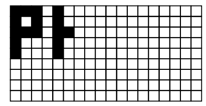
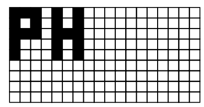
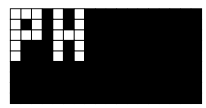
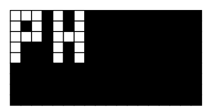
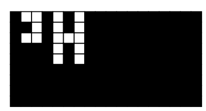


Fig.16 Reset timing.

13 APPLICATION INFORMATION

Table 6 Programming example

STEP	SERIAL BUS BYTE									DISPLAY	OPERATION
	$D/\overline{C}$	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
1	start										$\overline{SCE}$ is going LOW
2	0	0	0	1	0	0	0	0	1		function set PD = 0 and V = 0, select extended instruction set (H = 1 mode)
3	0	1	0	0	1	0	0	0	0		set V_{OP}; V_{OP} is set to a $+16 \times b$ [V]
4	0	0	0	1	0	0	0	0	0		function set PD = 0 and V = 0, select normal instruction set (H = 0 mode)
5	0	0	0	0	0	1	1	0	0		display control set normal mode (D = 1 and E = 0)
6	1	0	0	0	1	1	1	1	1	 MGL673	data write Y and X are initialized to 0 by default, so they are not set here
7	1	0	0	0	0	0	1	0	1	 MGL674	data write
8	1	0	0	0	0	0	1	1	1	 MGL675	data write
9	1	0	0	0	0	0	0	0	0	 MGL675	data write
10	1	0	0	0	1	1	1	1	1	 MGL676	data write

STEP	SERIAL BUS BYTE									DISPLAY	OPERATION
	D/$\overline{C}$	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
11	1	0	0	0	0	0	1	0	0	 MGL677	data write
12	1	0	0	0	1	1	1	1	1	 MGL678	data write
13	0	0	0	0	0	1	1	0	1	 MGL679	display control; set inverse video mode (D = 1 and E = 1)
14	0	1	0	0	0	0	0	0	0	 MGL679	set X address of RAM; set address to ‘0000000’
15	1	0	0	0	0	0	0	0	0	 MGL680	data write

The pinning is optimized for single plane wiring e.g. for chip-on-glass display modules. Display size: 48 × 84 pixels.

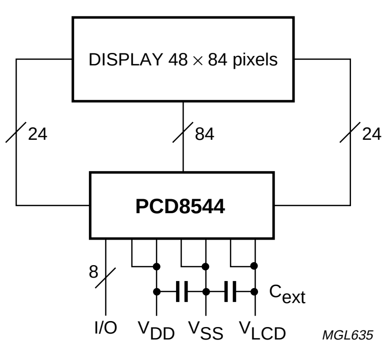


Fig.17 Application diagram.

The required minimum value for the external capacitors is: C_{ext} = 1.0 µF.

Higher capacitor values are recommended for ripple reduction.

14 BONDING PAD LOCATIONS

14.1 Bonding pad information (see Fig.18)

PARAMETER	SIZE
Pad pitch	min. 100 µm
Pad size, aluminium	80 × 100 µm
Bump dimensions	59 × 89 × 17.5 (±5) µm
Wafer thickness	max. 380 µm

14.2 Bonding pad location

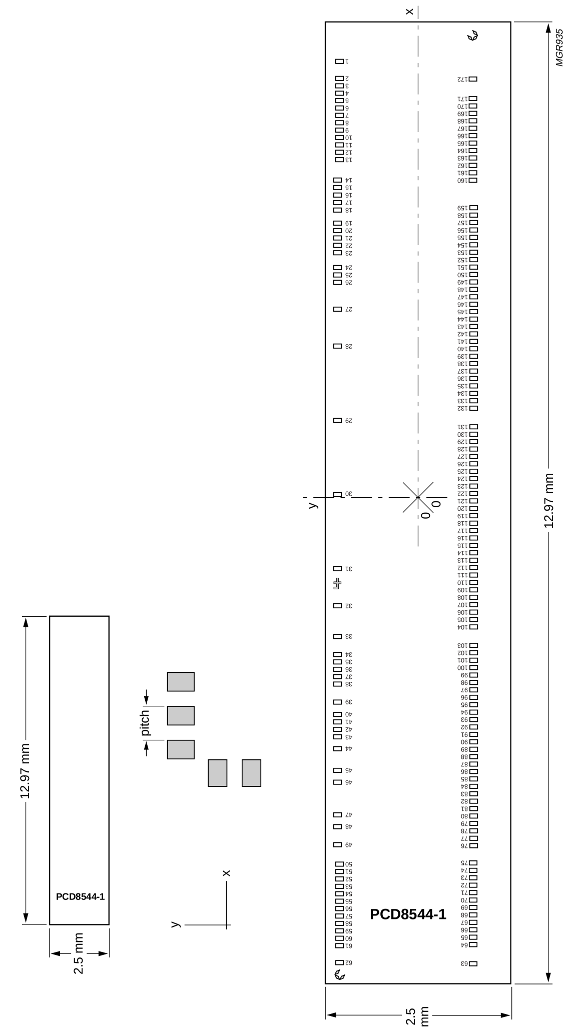


Fig.18 Bonding pad locations.

Table 7 Bonding pad locations (dimensions in µm). All X/Y coordinates are referenced to the centre of chip (see Fig.18)

PAD	PAD NAME	x	y
1	dummy1	+5932	+1060
2	R36	+5704	+1060
3	R37	+5604	+1060
4	R38	+5504	+1060
5	R39	+5404	+1060
6	R40	+5304	+1060
7	R41	+5204	+1060
8	R42	+5104	+1060
9	R43	+5004	+1060
10	R44	+4904	+1060
11	R45	+4804	+1060
12	R46	+4704	+1060
13	R47	+4604	+1060
14	V_{DD1}	+4330	+1085
15	V_{DD1}	+4230	+1085
16	V_{DD1}	+4130	+1085
17	V_{DD1}	+4030	+1085
18	V_{DD1}	+3930	+1085
19	V_{DD2}	+3750	+1085
20	V_{DD2}	+3650	+1085
21	V_{DD2}	+3550	+1085
22	V_{DD2}	+3450	+1085
23	V_{DD2}	+3350	+1085
24	V_{DD2}	+3250	+1085
25	V_{DD2}	+3150	+1085
26	V_{DD2}	+3050	+1085
27	SCLK	+2590	+1085
28	SDIN	+2090	+1085
29	D/$\overline{C}$	+1090	+1085
30	$\overline{SCE}$	+90	+1085
31	$\overline{RES}$	–910	+1085
32	OSC	–1410	+1085
33	T3	–1826	+1085
34	V_{SS2}	–2068	+1085
35	V_{SS2}	–2168	+1085
36	V_{SS2}	–2268	+1085
37	V_{SS2}	–2368	+1085
38	V_{SS2}	–2468	+1085
39	T4	–2709	+1085
40	V_{SS1}	–2876	+1085
41	V_{SS1}	–2976	+1085
42	V_{SS1}	–3076	+1085
43	V_{SS1}	–3176	+1085
44	T1	–3337	+1085
45	V_{LCD2}	–3629	+1085
46	V_{LCD2}	–3789	+1085
47	V_{LCD1}	–4231	+1085
48	V_{LCD1}	–4391	+1085
49	T2	–4633	+1085
50	R23	–4894	+1060
51	R22	–4994	+1060
52	R21	–5094	+1060
53	R20	–5194	+1060
54	R19	–5294	+1060
55	R18	–5394	+1060
56	R17	–5494	+1060
57	R16	–5594	+1060
58	R15	–5694	+1060
59	R14	–5794	+1060
60	R13	–5894	+1060
61	R12	–5994	+1060
62	dummy2	–6222	+1060
63	dummy3	–6238	–738
64	R0	–5979	–738
65	R1	–5879	–738
66	R2	–5779	–738
67	R3	–5679	–738
68	R4	–5579	–738
69	R5	–5479	–738
70	R6	–5379	–738
71	R7	–5279	–738
72	R8	–5179	–738
73	R9	–5079	–738
74	R10	–4979	–738
75	R11	–4879	–738
76	C0	–4646	–746

PAD	PAD NAME	x	y
77	C1	–4546	–746
78	C2	–4446	–746
79	C3	–4346	–746
80	C4	–4246	–746
81	C5	–4146	–746
82	C6	–4046	–746
83	C7	–3946	–746
84	C8	–3846	–746
85	C9	–3746	–746
86	C10	–3646	–746
87	C11	–3546	–746
88	C12	–3446	–746
89	C13	–3346	–746
90	C14	–3246	–746
91	C15	–3146	–746
92	C16	–3046	–746
93	C17	–2946	–746
94	C18	–2846	–746
95	C19	–2746	–746
96	C20	–2646	–746
97	C21	–2546	–746
98	C22	–2446	–746
99	C23	–2346	–746
100	C24	–2246	–746
101	C25	–2146	–746
102	C26	–2046	–746
103	C27	–1946	–746
104	C28	–1696	–746
105	C29	–1596	–746
106	C30	–1496	–746
107	C31	–1396	–746
108	C32	–1296	–746
109	C33	–1196	–746
110	C34	–1096	–746
111	C35	–996	–746
112	C36	–896	–746
113	C37	–796	–746
114	C38	–696	–746
115	C39	–596	–746
116	C40	–496	–746
117	C41	–396	–746

PAD	PAD NAME	x	y
118	C42	–296	–746
119	C43	–196	–746
120	C44	–96	–746
121	C45	+4	–746
122	C46	+104	–746
123	C47	+204	–746
124	C48	+304	–746
125	C49	+404	–746
126	C50	+504	–746
127	C51	+604	–746
128	C52	+704	–746
139	C53	+804	–746
130	C54	+904	–746
131	C55	+1004	–746
132	C56	+1254	–746
133	C57	+1354	–746
134	C58	+1454	–746
135	C59	+1554	–746
136	C60	+1654	–746
137	C61	+1754	–746
138	C62	+1854	–746
139	C63	+1954	–746
140	C64	+2054	–746
141	C65	+2154	–746
142	C66	+2254	–746
143	C67	+2354	–746
144	C68	+2454	–746
145	C69	+2554	–746
146	C70	+2654	–746
147	C71	+2754	–746
148	C72	+2854	–746
149	C73	+2954	–746
150	C74	+3054	–746
151	C75	+3154	–746
152	C76	+3254	–746
153	C77	+3354	–746
154	C78	+3454	–746
155	C79	+3554	–746
156	C80	+3654	–746
157	C81	+3754	–746
158	C82	+3854	–746

PAD	PAD NAME	x	y
159	C83	+3954	–746
160	R35	+4328	–738
161	R34	+4428	–738
162	R33	+4528	–738
163	R32	+4628	–738
164	R31	+4728	–738
165	R30	+4828	–738
166	R29	+4928	–738
167	R28	+5028	–738
168	R27	+5128	–738
169	R26	+5228	–738
170	R25	+5328	–738
171	R24	+5428	–738
172	dummy4	+5694	–738

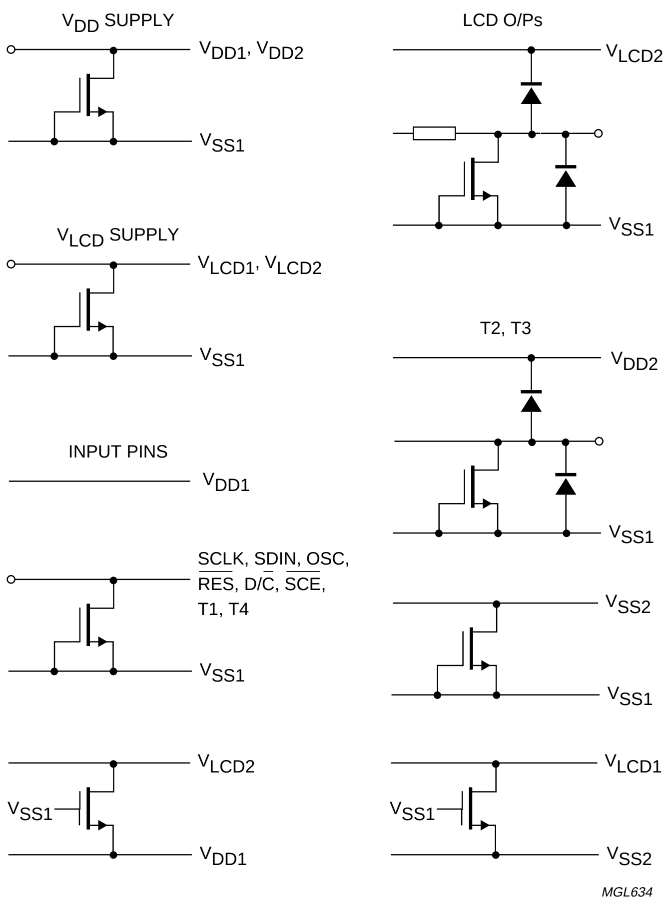
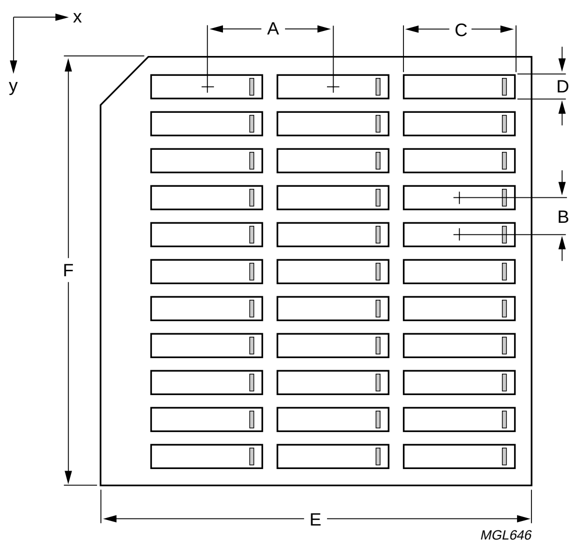


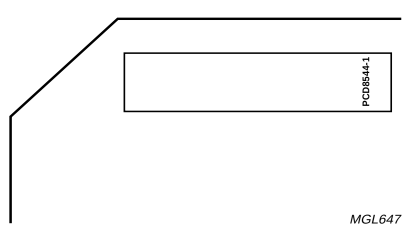
Fig.19 Device protection diagram.

15 TRAY INFORMATION



For the dimensions of x, y and A to F, see Table 8.

Fig.20 Tray details.



The orientation of the IC in a pocket is indicated by the position of the IC type name on the die surface with respect to the chamfer on the upper left corner of the tray. Refer to the bonding pad location diagram for the orientation and position of the type name on the die surface.

Fig.21 Tray alignment.

Table 8 Dimensions

DIM.	DESCRIPTION	VALUE
A	pocket pitch, in the x direction	14.82 mm
B	pocket pitch, in the y direction	4.39 mm
C	pocket width, in the x direction	13.27 mm
D	pocket width, in the y direction	2.8 mm
E	tray width, in the x direction	50.67 mm
F	tray width, in the y direction	50.67 mm
x	no. of pockets in the x direction	3
y	no. of pockets in the y direction	11

16 DEFINITIONS

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

17 LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

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PHILIPS

6.4. Batería de 12 volts

TROJAN BATTERY COMPANY

DATA SHEET

SOLAR SAGM 12 135

MODEL	**SAGM 12 135**
VOLTAGE	**12**
CAPACITY	**135Ah @ 20Hr**
MATERIAL	**Polypropylene**
BATTERY	**VRLA AGM / Non-Spillable / Maintenance-Free**
COLOR	**Maroon**
WATERING	**No Watering Required**
IEC 61427	**8+ Years Life**

12 VOLT

PHYSICAL SPECIFICATIONS

MODEL NAME	TERMINAL TYPE	DIMENSIONS [B] INCHES (mm)			WEIGHT [F] LBS. (kg)	HANDLES	INSTALLATION ORIENTATION
		LENGTH	WIDTH	HEIGHT [C]			
SAGM 12 135	M8/LT	12.96 (329)	7.06 (179)	10.96 (278)	83 (38)	Embedded	Horizontal and Vertical

ELECTRICAL SPECIFICATIONS

VOLTAGE	CAPACITY [A] AMP-HOURS (Ah)					ENERGY (kWh)	INTERNAL RESISTANCE (mΩ)	SHORT CIRCUIT CURRENT (amps)
	10-Hr	20-Hr	48-Hr	72-Hr	100-Hr	20-Hr		
12	131	135	136	137	137	1.62	4.3	2920

CHARGING INSTRUCTIONS

CHARGER VOLTAGE SETTINGS (AT 77°F/25°C)				
SYSTEM VOLTAGE	**12V**	**24V**	**36V**	**48V**
Maximum Charge Current (A)	20% of C_{20}			
Absorption Voltage (2.40 V/cell)	14.40	28.80	43.20	57.60
Float Voltage (2.25 V/cell)	13.50	27.00	40.50	54.00

Do not install or charge batteries in a sealed or non-ventilated compartment. Constant under or overcharging will damage the battery and shorten its life as with any battery.

CHARGING TEMPERATURE COMPENSATION

ADD	SUBTRACT
0.005 volt per cell for every 1°C below 25°C 0.0028 volt per cell for every 1°F below 77°F	0.005 volt per cell for every 1°C above 25°C 0.0028 volt per cell for every 1°F above 77°F

OPERATIONAL DATA

OPERATING TEMPERATURE	SELF DISCHARGE
-4°F to 122°F (-20°C to +50°C). At temperatures below 32°F (0°C) maintain a state of charge greater than 60%.	Less than 3% per month depending on storage temperature conditions.

RECYCLE RESPONSIBLY

99% RECYCLABLE		12V AGM

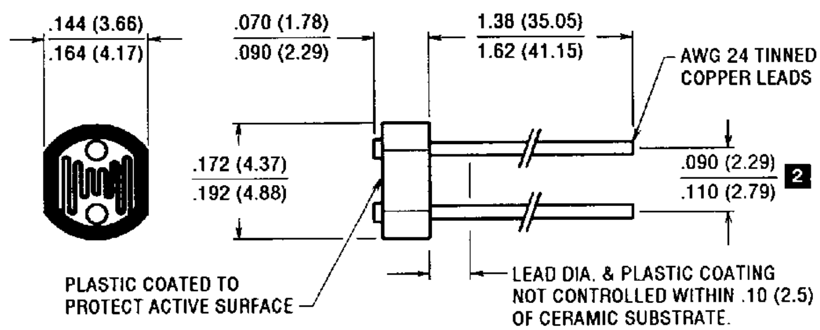
STATE OF CHARGE MEASURE OF OPEN-CIRCUIT VOLTAGE

PERCENTAGE CHARGE	CELL	12 VOLT
100	2.14	12.84
75	2.09	12.54
50	2.04	12.24
25	1.99	11.94
0	1.94	11.64

6.5. Sensor de luz: LDR

PHOTOCONDUCTIVE CELL — VT900 Series

PACKAGE DIMENSIONS inch (mm)



ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	RATING	UNITS
CONTINUOUS POWER DISSIPATION	P_D	80	mW
DERATE ABOVE 25° C	$\Delta P_D / \Delta T$	1.6	mW/°C
TEMPERATURE RANGE OPERATING AND STORAGE	T_A	– 40 to +75	°C

ELECTRO-OPTICAL CHARACTERISTICS @ 25° C (16 HRS. LIGHT ADAPT, MIN.) [4]

Part Number *	Resistance (Ohms) [3]						Material Type	Sensitivity (γ, typ.) $\frac{\text{LOG (R10/R100)}}{\text{LOG (100/10)}}$	Maximum Voltage (V, pk)	Response Time @ 1 fc (ms, typ.)	
	10 lux 2850 K			2 fc 2850 K	DARK					Rise (1-1/e)	Fall (1/e)
	Min.	Typ.	Max.	Typ.	Min.	sec.					
VT9ØN1	6.0 k	12 k	18 k	6.0 k	200 k	5	Ø	0.80	100	78	8
VT9ØN2	12 k	24 k	36 k	14 k	500 k	5	Ø	0.80	100	78	8
VT9ØN3	25 k	50 k	75 k	34 k	1.0 M	5	Ø	0.85	100	78	8
VT9ØN4	50 k	100 k	150 k	80 k	2.0 M	5	Ø	0.90	100	78	8
VT9Ø5G [1]											
GROUP A	8.0 k	14 k	20 k	4.5 k	200 k	5	Ø	0.70	100	78	8
GROUP B	14 k	25 k	36 k	7.0 k	200 k	5	Ø	0.70	100	78	8
GROUP C	24 k	42 k	60 k	11.5 k	200 k	5	Ø	0.70	100	78	8
VT93N1	12 k	24 k	36 k	12 k	300 k	5	3	0.90	100	35	5
VT93N2	24 k	48 k	72 k	30 k	500 k	5	3	0.90	100	35	5
VT93N3	50 k	100 k	150 k	70 k	500 k	5	3	0.90	100	35	5
VT93N4	100 k	200 k	300 k	168 k	500 k	5	3	0.90	100	35	5
VT935G [1]											
GROUP A	10 k	18.5 k	27 k	9.3 k	1.0 M	5	3	0.90	100	35	5
GROUP B	20 k	29 k	38 k	15 k	1.0 M	5	3	0.90	100	35	5
GROUP C	31 k	40.5 k	50 k	20 k	1.0 M	5	3	0.90	100	35	5

* See page 11 for notes.

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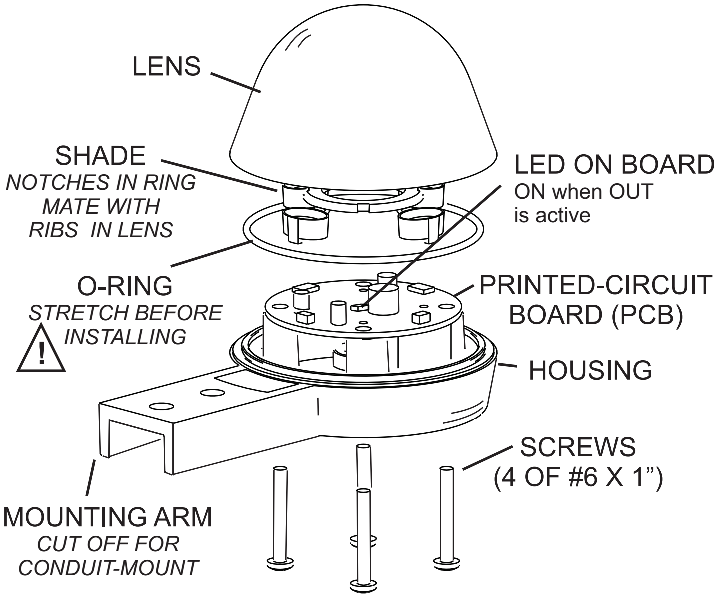
6.6. Sensor de lluvia

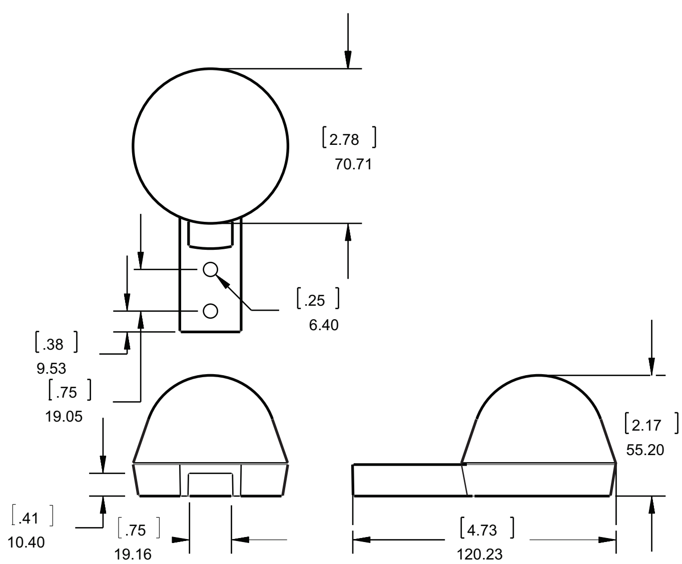
HYDREON

HYDREON CORPORATION

MODEL RG-11
OPTICAL RAIN GAUGE



EXPLODED VIEW



DIMENSIONAL VIEW

INSTALLING THE RAIN SENSOR

1. Determine the Mode / Set DIP switches
You must set the DIP switches so that the RG-11 behaves the right way for your application. The pages that follow describe each of the possible modes, and how to set the DIP switches.

2. Mount the Rain Gauge
Mount the rain Gauge where it gets a clear measurement of precipitation– away from overhangs, etc.

The mounting arm is designed to fit over a strap 0.75” (19 mm) wide. Two 0.25” (holes 6.35 mm) are placed 0.75” (19 mm) part.

The gland style connector goes in the bottom hole. Be sure to use wire rated for outdoor (high-UV) use.

For conduit applications, the mounting arm may be removed, and the wiring hole drilled out using a step drill to accommodate a ½” EMT compression connector or similar style of conduit connector.

3. Assemble the Rain Gauge as shown.
The silicone O-ring fits nicely in the lens groove, but it can fall or slip out during assembly. After the unit is assembled, verify that the O-ring is properly seated by confirming that you can see it through the lens, all the way around.

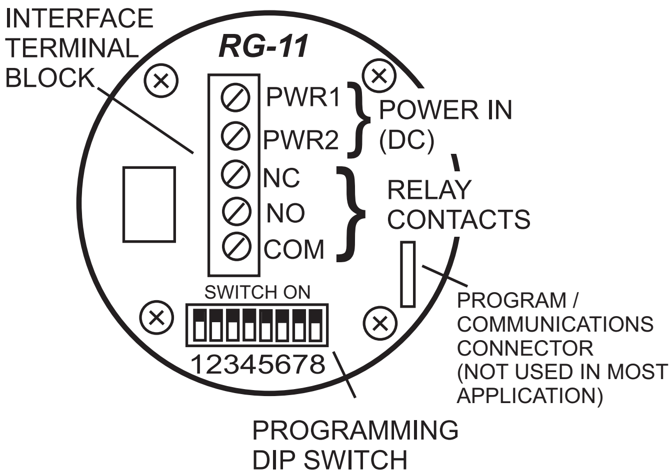
The Rain Gauge must be assembled when dry. Any water trapped inside can condense and cause corrosion. You may optionally add extra desiccant packets (not supplied). If the Rain Gauge is not subject to splashing or sprayed water, you may optionally vent the enclosure by drilling a 1/8” (3 mm) hole in the bottom of the case.

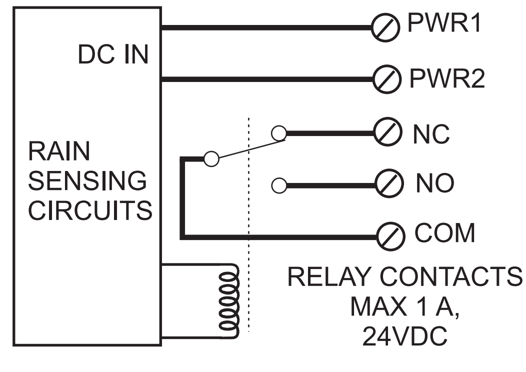
⚠

- APPLICATION WARNING -
Do not use the RG-11 in any application where the false indication of water or a missed valid detection of water could cause damage to life or property. It is the responsibility of the system designer / integrator to design redundancy into the system so that the failure of any one component, including the RG-11 or other sensor, does not result in disaster. The manufacturer of the RG-11, Hydreon Corporation, will in no way be liable for consequential damages due to the failure or false indication of one of its sensors.

HYDREON CORPORATION

RAIN GAUGE CONNECTIONS

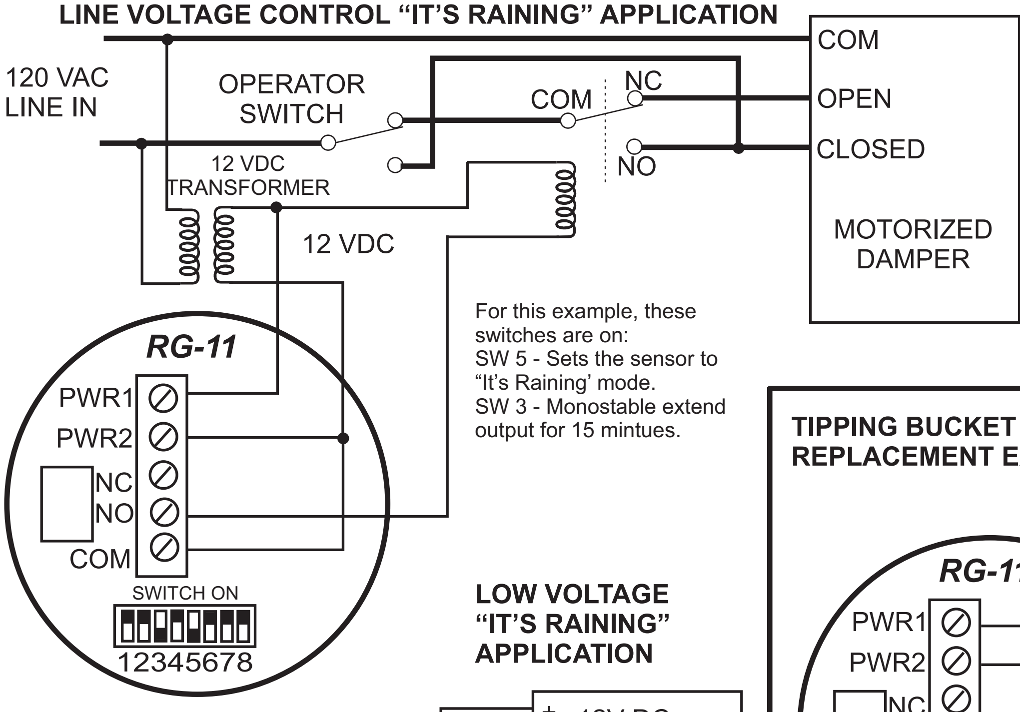




EQUIVALENT SCHEMATIC

RAIN GAUGE WIRING EXAMPLES

LINE VOLTAGE CONTROL "IT'S RAINING" APPLICATION

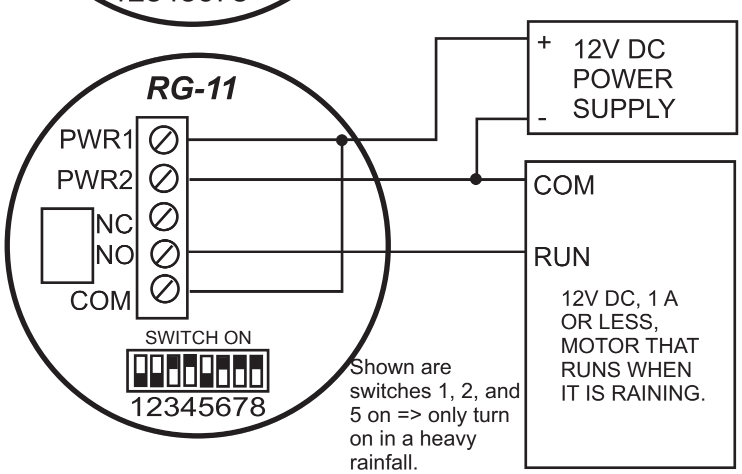


For this example, these switches are on:
SW 5 - Sets the sensor to "It's Raining' mode.
SW 3 - Monostable extend output for 15 mintues.

The relay output of the RG-11 is rated for 24VDC, at 1 A. Thus, the RG-11 cannot drive a line voltage (120 VAC) load without an external relay.

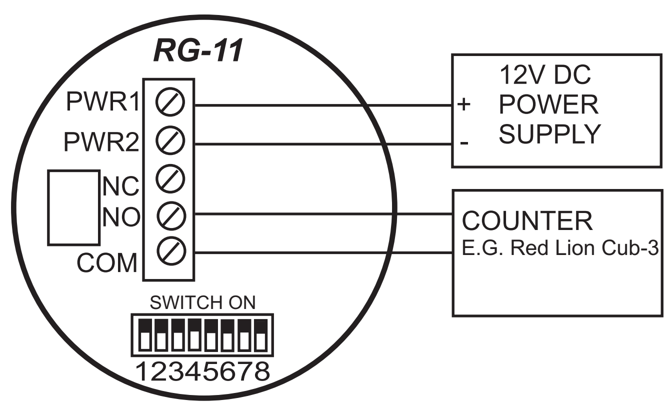
The RG-11 requires a DC supply and may not be directly powered from the 120 VAC line.

LOW VOLTAGE "IT'S RAINING" APPLICATION



Shown are switches 1, 2, and 5 on => only turn on in a heavy rainfall.

TIPPING BUCKET REPLACEMENT EXAMPLE



In many cases, the RG-11 may directly replace tipping buckets in existing systems.
The switch settings shown here- all off– will emulate a tipping bucket of 0.01"

Specifications

Parameter	Value
Input Voltage	Nominal 12 VDC (Range 10 -15 VDC) 50V surge Reverse polarity protected to 50V
Current Drain	15 mA nominal. (No outputs on, not raining, no heater) about 1.5 mA in micro-power sleep mode. 50 mA with output on. 55 mA - With heater on, 12V DC input.
Output	Relay closure, Normally Open and Normally Closed contacts. Max load 1A, 24 VDC.
Operating Temperature range	-40 C to +60C

DIP Switches
Set the DIP switches for the application according to the tables below. Generally, a few switch positions (5, 6, and 7) set the overall mode of operation, and others (1, 2, 3, 4) adjust the behavior within the modes.
In the tables, 1 = Switch on, 0 = Switch off, X = switch in either position.

Software Revision
This manual corresponds to software revision 016. The software revision is printed on a sticker place on the connector block. See www.rainsensors.com (click on “support”) for information about differences in software revisions. Differences are generally minor.

Switch 8 is Enable Micro-power Sleep Mode in most applications.
Most applications will use SW 8 off. If micro-power is enabled, the low-power heater is disabled. In micro-power mode, if a long time (about 20 min) has elapsed since the last rain was detected, the unit will enter a less sensitive sleep mode. A large drop will cause it to exit sleep mode and resume normal operation. This is for battery or solar powered applications. Micro-power mode is disabled in Condensation sensing mode and in irrigation mode. Switch 8 must be off for First Flush Controller. The unit will not read the DIP switches during sleep.

OUT LED
The LED in the center of the circuit board turns on when OUT is on, as an aid to debugging.

Condensation
Generally, the RG-11 will sense condensation as if it were rainfall, but this seldom amounts to a significant accumulation of water. The built-in low power heater (DIP SW 8 off) will tend to reduce condensation.

Ambient Light Interference
The RG-11 is almost completely immune to the effects of ambient light, and may freely be mounted in direct sunlight.

Heater Notes
A built-in low power (0.25W) heater extends operation of the device to freezing (32 F or 0C). This is disabled if the micro-power (SW 8) is enabled. Note that this is a very modest amount of power; it will tend to drive off a modest amount of frost, but will not melt ice.

Dark Sensing
Turns output on when it is dusk-- nominally less than 2000 lux. This is for applications such as retracting sun-shields in the evening, when they are not needed. (Only in Mode 1, “It's Raining” applications.)

LED Flicker / Relay Buzz
If the relay and LED remain on for a long period of time (seconds), the LED may flicker, and the relay may make a barely audible buzz. This is because the RG-11 pulse-width modulates the relay drive signal to reduce current consumption. It does this to prevent excessive heat in the RG-11. This does not affect functionality in any way.

J2 Connector

J2 is a pin-field on 0.1” centers, used for programming, development, and testing of the RG-11. Most applications do not connect to J2, and we make this information available only for special applications.

Connector field is 0.025” square pins on 0.1” centers. An example compatible connector is Molex part number 22-01-3067. This is available from Digi-Key as part number WM2004-ND. The necessary crimp-on wire terminals are Molex 08-55-0131 / DigiKey WM4591-ND.

J2 Pin assignments
J2 - 1 GND
J2 - 2 +5V OUT
J2 - 3 SW4
J2 - 4 SW1
J2 - 5 SW2
J2 - 6 RS232 and SW 5.

Remote Switching
These connections may be used to remotely operate the corresponding switches, by grounding the connections. This can be used for operator-accessible sensitivity adjustment in wiper control applications.

RS-232 communications
Requires an external resistor. See the “support” link on www.rainsensors.com. Modes that require SW 5 on (It's Raining, Wiper Control and First Flush) cannot use RS-232.

Mode 0: Tipping Bucket

Rain Gauge emulates a tipping bucket of the specified size.

Switch							Behavior
7	6	5	4	3	2	1	
0	0	0	X	0	0	0	Bucket Size = 0.01”
				0	0	1	Bucket Size = 0.001” (Sensitive)
				0	1	0	Bucket Size = 0.0001” (Very sensitive)
				1	0	0	Bucket Size = 0.2 mm
				1	0	1	Bucket Size = 0.01 mm (sensitive)
				1	1	0	Bucket Size = 0.001 mm (Very sensitive)
			1	1	1	1	Reserved for system test

In tipping bucket mode, the Rain Gauge effectively emulates a tipping bucket of the specified size. For example, if the DIP switches are set to a tipping bucket mode with a bucket size of 0.01", then the output will pulse ON for 50mS each time 0.01" of water accumulates, just as a tipping bucket would. This can be externally totalized, and used to measure rainfall rates. Bucket sizes of 0.001" and 0.0001" are similar, generating pulses at accumulations of one one-thousandth, and one ten-thousands of an inch, respectively. These emulate what a tipping bucket would do if it were possible to make one that small. Metric bucket sizes are available as well, or the Inch unit scales may be scaled with external equipment.

Accuracy

We do not claim an accuracy spec for the RG-11. For more information see the “Tipping Bucket” link on www.rainsensors.com.

Mode 1: It's Raining

Rain Gauge turns on the relay to indicate that it is raining when the rainfall has reached a given intensity.

Switch							Function
7	6	5	4	3	2	1	
0	0	1	X	X	0	0	Very sensitive-- first detected raindrop.
					0	1	Sensitive-- turn on with very light rainfall (0.1” per hour).
					1	0	Medium Sensitivity-- turn on with medium rain (0.25” per hour. You would want your car's wipers on steady slow)
					1	1	Low Sensitivity-- turn on in heavy rainfall. (1” per hour. You would want your car's wipers on high)
			X	0	X	X	Output off when rain stops.
				1			Output Monostable Extended by 15 minutes
			0	X	X	X	No Dark-Detect - Normal operation
			1				Dark Detect

Use this mode to control equipment that should be controlled, enabled, open, closed, and so forth depending on whether or not it is raining. The output turns on when a given rate of rainfall is detected, and turns off after it has dropped below a threshold.

Each of the sensitivity levels (set by switches 1 and 2) provides different trip and release points. There is much hysteresis built in, but real rain fall rates typically fluctuate, even in what you may perceive as a “steady rain”, so expect the output to turn on and off. The output will remain on for between about 30 seconds and 5 minutes after the last detected rain drop, depending on sensitivity setting and actual conditions.

Monostable Extend = Switch 3 ON

To prevent some piece of equipment from turning constantly on and off (or opening / closing, etc.) you can enable the Monostable extend (Switch 3). That will hold the output on for 15 minutes after the rain has ceased.

Dark Detect = Switch 4 ON

If this enabled, the output will also turn on when the ambient light drops below about 2000 lux. This feature may be used to retract a sun-shade awning when it is dark.

Mode 2: Condensation Sensor

Rain Gauge detects condensation or frost formation on the surface.

Switch							Behavior
7	6	5	4	3	2	1	
0	1	0	0	0	0	0	Very Sensitive- first sign of condensation
					0	1	Sensitive
					1	0	Medium Low
					1	1	Low

The rain sensor senses condensation by detecting a shift from the "clear" condition. The relay closes when the condensation occurs, and opens when the condensation goes away. The rain sensor is set to very gradually adapt the clear condition, so that very gradual build up of dirt or other contaminants do not cause a false trip.

Condensation sensing mode disables the heater and micro-power mode.

Mode 3: Wiper Control

Rain sensing wiper control from off through intermittent and steady slow speeds.

Switch							Behavior
7	6	5	4	3	2	1	
0	1	1	0	x	0	0	Normal Wiper Control
			0		0	1	Wipe More
			0		1	0	Wipe a Lot More
			0		1	1	Wipe a Whole Lot More
			1		0	0	Wipe Less
			1		0	1	Wipe a Lot Less
			1		1	0	Wipe a Whole Lot Less
			1		1	1	Wipe hardly at all
			x	0	x	x	Normal Slow Cycle Time (1.2 to 3 sec.)
				1			Long Slow Cycle Time (3 – 8 sec.)

See rainsensors.com for instructions that are just for wiper control applications. (Click on “Wiper Control”).

The RG-11 may be used to control a wiper system. The output relay turns on when the slow motor winding should be engaged. This will typically be used to drive an external relay, which will, in turn, drive the wiper motor windings. This may be used for the wipers for a boat, ship, locomotive, observation window, or many other applications. The RG-11 does not care what the wipers are wiping.

WARNING: The relay contacts of the RG-11 can control only a 1A load, and wiper systems generally require many times that current. The RG-11 MUST be used with a suitable external relay in wiper control applications.

The nominal wiper control is set so that it properly controls the wipers of a passenger car. It is optimized for wiper systems that require between 1.2 and 3 seconds to make a single complete actuation of the wipers. A long cycle time is provide (Switch 4 on) for systems with a wiper actuation cycle time between 3 and 8 seconds. In all cases, the RG-11 provides a pulse to initiate the wiper actuation. Most wiper system will include some sort of cam feedback mechanism that causes the wipers to keep running until they reach a home position.

Mount the RG-11 so that it generally gets the same rainfall as the surface to be wiped. Usually, this means about a 45 degree angle. The RG-11 does not need to be within the actual field of view of the window. Adjust the sensitivity control DIP switches (3, 2, and 1) to set the system to wipe more or less, depending on the needs of the installation.

Mode 4: Irrigation Control
Rain Gauge output on means inhibit watering.

Switch 8	7	6	5	4	3	2	1	Behavior
X	1	0	X	X	0	0	0	Typical Water Control. Inhibit watering for up to 5 days.
					0	0	1	Water More
					0	1	0	Water a lot more
					1	0	0	Water Less
					1	0	1	Water a lot less
				0	X	X	X	Inhibit irrigation during a storm
				1				Allow irrigation during a storm
			0	X	X	X	X	Inhibit irrigation during freeze
			1					Allow irrigation during freeze
0								Normal Evaporation Rate
1								Hi Evaporation Rate

See rainsensors.com for instructions that are just for irrigation control applications. (Click on "Irrigation Control")

The RG-11 may be set to provide precise control of an irrigation system. Typically, the installation will connect to the COM and NC relay contacts to interrupt the valves when watering should be inhibited. Note that the RG-11 also requires 24 VAC (or other suitable supply.)

The nominal irrigation profile is set so that the ground receives an inch of water per week. It will inhibit watering upon the accumulation of 0.2 inches of water, and re-enable the system after that water has evaporated. This can be a short as less than a day, or as long as six days, depending on rainfall. Additional DIP switch settings are provided for allowing more or less watering, as shown in the table below.

Nominally (Switch 4 off), the RG-11 will inhibit watering during a storm, even if not much water has accumulated. The reasoning is that if it is raining hard now, the rainfall is likely to deliver enough accumulation to justify inhibiting at least the current cycle of watering. This prevents the "it's pouring, but my sprinklers are still running" objection from the customer, and the accompanying excessive runoff and muddy ground. The feature may be defeated by turning switch 4 on.

Normally, the RG-11 will inhibit irrigation if the temperature drops below freezing, or nominally about 34 degrees. If SW 5 is on, the RG-11 will allow irrigation below 34 degrees. Micro-power mode is disabled in irrigation control.

Evaporation Rate
Normal Evaporation Rate = 0.11 inches per day
Hi Evaporation Rate = 0.22 inches per day
In irrigation mode, if Switch 8 is on, the control assumes a high evaporation (or transpiration rate). Set this switch to ON for sandy soil or other conditions where the soil tends to dry out quickly. The system will re-enable the irrigation sooner.

Mode 6: Drop Detector

Switch 7	6	5	4	3	2	1	Behavior
1	1	0	0	X	0	0	Normal drop threshold
					0	1	Sensitive Drop threshold. Expect rare false trips.
					1	0	Hi drop threshold. Trip only with large drops.
				0	X	X	One pulse per drop, longer pulses for bigger drops
				1			Multiple pulses per larger drop

The RG-11 may also provide drop detection. Use this if you want to do your own, external data interpretation. The output will pulse once with each detected drop. Normally, it will produce longer pulses (in multiples of 200 mS) for larger drops. If set to multiple pulses per drop (SW 3 ON), each detected drop will generate one or more 100 mS pulses, depending on drop size.

In sensitive mode, the threshold for drop detection is lowered to below the normal level. This makes the system more sensitive, but raises the possibility of false detections. It is up to the system designer to determine the proper tradeoff. Similarly, the Hi drop threshold will provide an output only for large drops, making false detections unlikely, for installations were a false detection is especially objectionable.

Mode 7: First Flush / Rain Water Harvest
Rain Gauge output on means rain water is being harvested and first flush has occurred.

Switch								Behavior		
8	7	6	5	4	3	2	1	Level (in)	Gallons	Clean Time (days)
0	1	1	1	X	0	0	0	0.02	12	3
					0	0	1	0.04	25	5
					0	1	0	0.08	50	9
					0	1	1	0.16	100	13
					1	0	0	0.20	125	15
					1	0	1	0.24	150	17
					1	1	0	0.28	175	19
					1	1	1	0.32	200	21
				0	X	X	X	Normal Clean Time		
				1				Gets Dirty Fast		

Note: Switch 8 must be off for this mode.

The RG-11 can be used in a Rain Water Harvest / First Flush application. In this mode, the RG-11 will not change the relay state until a certain amount of water has fallen. After a certain amount of water has been detected, the relay opens, diverting the water to a proper holding tank. So configured, the output relay acts as an "Enable Harvest" control, indicating that at least the desired amount of rainfall has accumulated.

Level
The amount of water that will accumulate before the relay closes.

Gallons
The number of gallons per thousand square feet of collected area that are diverted. Note that a conventional first flush diverter system totalizes water after it has made it through the collection system. The RG-11 enables the system as soon as the threshold has fallen, which may be substantially sooner. Take this into account when designing your system.

Clean Time
After the rainstorm is over and the relay of the RG-11 is once again open, it will take some time for the collecting surface to become dirty again, and once again require a complete first flush. Clean time means how many days, after the water stopped, it takes for the system to require a full flush. Up to that time, the system will flush less. For example, a system is set to flush 0.08 of accumulation, and thus the clean time is 8 days. If a storm comes after only 4 days, the system will flush only half as much water before enabling harvest again.

Gets Dirty Fast = Switch 4 ON
If switch 4 is on, the system remains enabled for only 12 hours after the rain storm stops. Also, the Clean Time is halved. Use this setting if the surface becomes contaminated especially quickly.

SAFETY, LIMITS OF RAIN GAUGE LIABILITY, AND WARRANTY

Only the rain sensor is covered-- absolutely no consequential damages. If this policy is unacceptable in your installation, do not use the RG-11.

It is the responsibility of the systems integrator and purchaser of the Rain Gauge to insure a safe installation. Any mechanical system, including one that incorporates a Rain Gauge, requires appropriate safety interlocks. Hydreon Corporation (Hydreon) warrants only the actual cost of the sensor, and only that it is free from defects in workmanship.

The Rain Gauge is warranted to be free from defects for a period of one year from date of purchase. Under no circumstances will Hydreon be liable for any consequential damages due to failure or any other mishap involving a Rain Gauge. Hydreon's liability in the event of a failure, or inability to sense a condition, is limited to the actual cost of the particular sensor. Explicitly, if other objects are destroyed due to water damage, or if any object is destroyed because of a false indication of water, Hydreon is in no way whatsoever liable for anything other than the cost of the Rain Gauge, and then only if the Rain Gauge is shown to have some defect in materials or workmanship. Limitations and imperfections of the Rain Gauge do not constitute a defect. Further, if some valuable data is not gathered because an erroneous indication of any sort due to the Rain Gauge, Hydreon is liable only for the cost of the Rain Gauge.

It is the responsibility of the system designer and purchasers of the Rain Gauge to insure that a failure of the Rain Gauge will not cause consequential damages. If a failure in Rain Gauge would cause disaster, we recommend against deployment of the Rain Gauge, or against the system in which the Rain Gauge is deployed. If a failure of a Rain Gauge would cause great expense, Hydreon recommends redundant Rain Gauges, and even in that case do not assume any liability for consequential damages. It is the responsibility of the system designer and purchasers of the Rain Gauge to be aware of performance limitations of the device. If a Rain Gauge fails for any reason Hydreon will not be responsible for the labor of servicing and or installing and/or removing the Rain Gauge. Labor is NOT COVERED. Transportation of the suspected failed Rain Gauge to Hydreon is the responsibility of the purchaser. Hydreon recommends that the system designer perform a Failure-Mode Effects Analysis that includes the possibility of Rain Gauge failure. If a potential purchaser of the Rain Gauge does not agree with these terms, we ask that the potential purchaser not buy the Rain Gauge. Deployment of the Rain Gauge implies understanding and agreeing to these limits of liability.

Apply engineering judgment: Hydreon does not claim the RG-11 is a perfect rain sensor. It is what it is, and senses what it senses.

CASE and COSMETIC POLICY
Some amount of yellowing or discoloration of the case is considered normal cosmetic aging of the device, and sensors so affect will not be replaced under warranty. Tiny cracks or crazing within the lens is also considered cosmetic, and units so affected will be replaced only if they are deemed by Hydreon corporation to be considered to be of a functional nature.