Universidad de Costa Rica
Facultad de Ingeniería
Escuela de Ingeniería Eléctrica

`IE-0624` Laboratorio de Microcontroladores.

Laboratorio 4 - Arduino: GPIO, Timers, ADC, comunicaciones, PWM, PM, EEPROM, IoT

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1. Introducción

Para este laboratorio se desea configurar una estación meteorológica, capaz de medir diferentes variables ambientales como la temperatura que será medida con un termistor, la humedad que se lee con el sensor DHT22, la velocidad del viento que utiliza el sensor JL-FSX2 4-20MA, la intensidad de luz que se lee con un sensor LDR y para medir la lluvia se usa el sensor Hydreon RG-11. Además, esta estación debe tener la capacidad de comunicarse de manera serial y tiene una pantalla LCD (PCD8544) donde se visualizan los datos tomados por los sensores.

Para cumplir esto es necesario el uso del microcontrolador Arduino Mega (ATMega2560). Además, la estación utiliza una batería que se carga mediante paneles solares que son controlados por un par de potenciómetros, así estos se ubican en la posición deseada para captar los rayos solares.

Por otra parte, dicha estación tiene la capcidad de almacenar en memoria EEPROM los valores medidos y gracias a la pataforma IoT thingsboard es posible la comunicación por protocolo MQTT y el anvío de información.

2. Nota Teórica

En este apartado se detalla la información del microcontrolador ATMega2560. Sus características generales y eléctrica, diagramas pertinentes, periféricos utilizados y los componentes complementarios utilizados para el diseño del circuito.

2.1. Microcontolador ATMega2560

Se trabaja de la mano de la hoja de datos del Microcontrolador de 8 bit basado en en AVR y arquitectura RISC avanzada. Entre sus características generales se encuentran: [1]

Dispositivo	Memoria programa	Memoria datos		I/O	Operating Voltage	#PWM	Temp
	# Instrucciones	SRAM	EEPROM				
ATMega2560	135	8Kbytes	4Kbytes	86	1.8-5.5 V	4	-40° a 85° C

Cuadro 1: Características generales ATMega2560[1]

Si se toman sus características eléctrica se tiene:

31. Electrical Characteristics

Absolute Maximum Ratings*

Operating Temperature	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Voltage on any Pin except $\overline{RESET}$ with respect to Ground	-0.5V to V_{CC}+0.5V
Voltage on $\overline{RESET}$ with respect to Ground	-0.5V to +13.0V
Maximum Operating Voltage	6.0V
DC Current per I/O Pin	40.0mA
DC Current V_{CC} and GND Pins	200.0mA

Figura 1: Especificaciones Eléctricas microcontrolador ATMega2560 [1]

La hoja de datos nos ayuda a entender mejor cómo funciona el microcontrolador que estamos usando, una manera de hacer esto es mediante diagramas. Por ejemplo, con la siguiente imagen podemos estudiar el flujo de funcionamiento del CPU con los demás componentes.

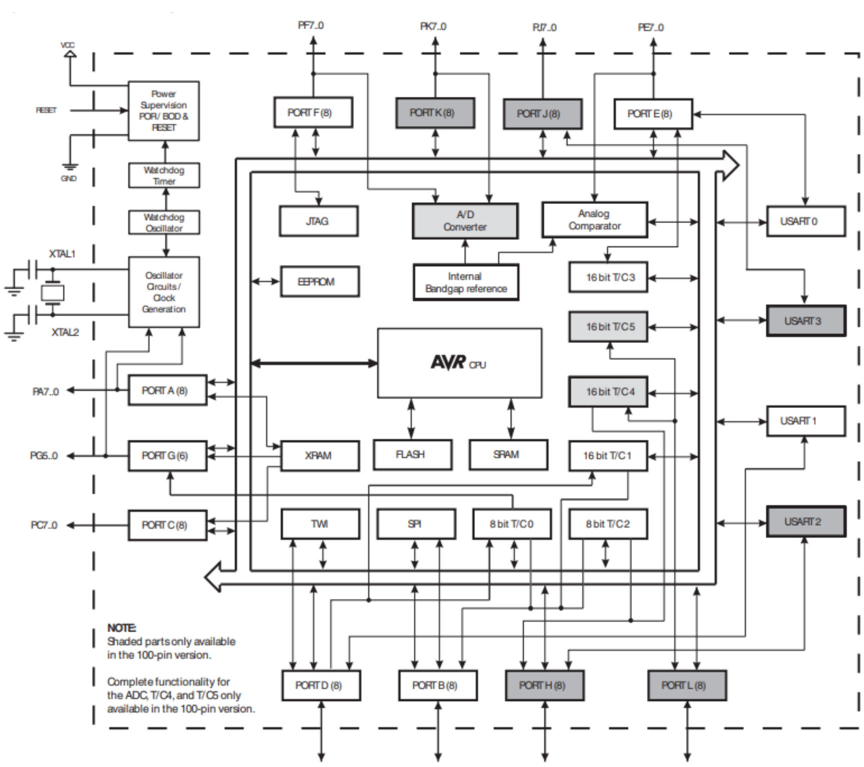


Figura 2: Diagrama de bloques microcontrolador ATMega2560 [1]

Respecto a su estructura, el microcontrolador tiene 100 pines donde cada puede cumplir diferentes funciones de acuerdo a la necesidad del usuario. El diagrama de los pines puede ser observado a continuación:

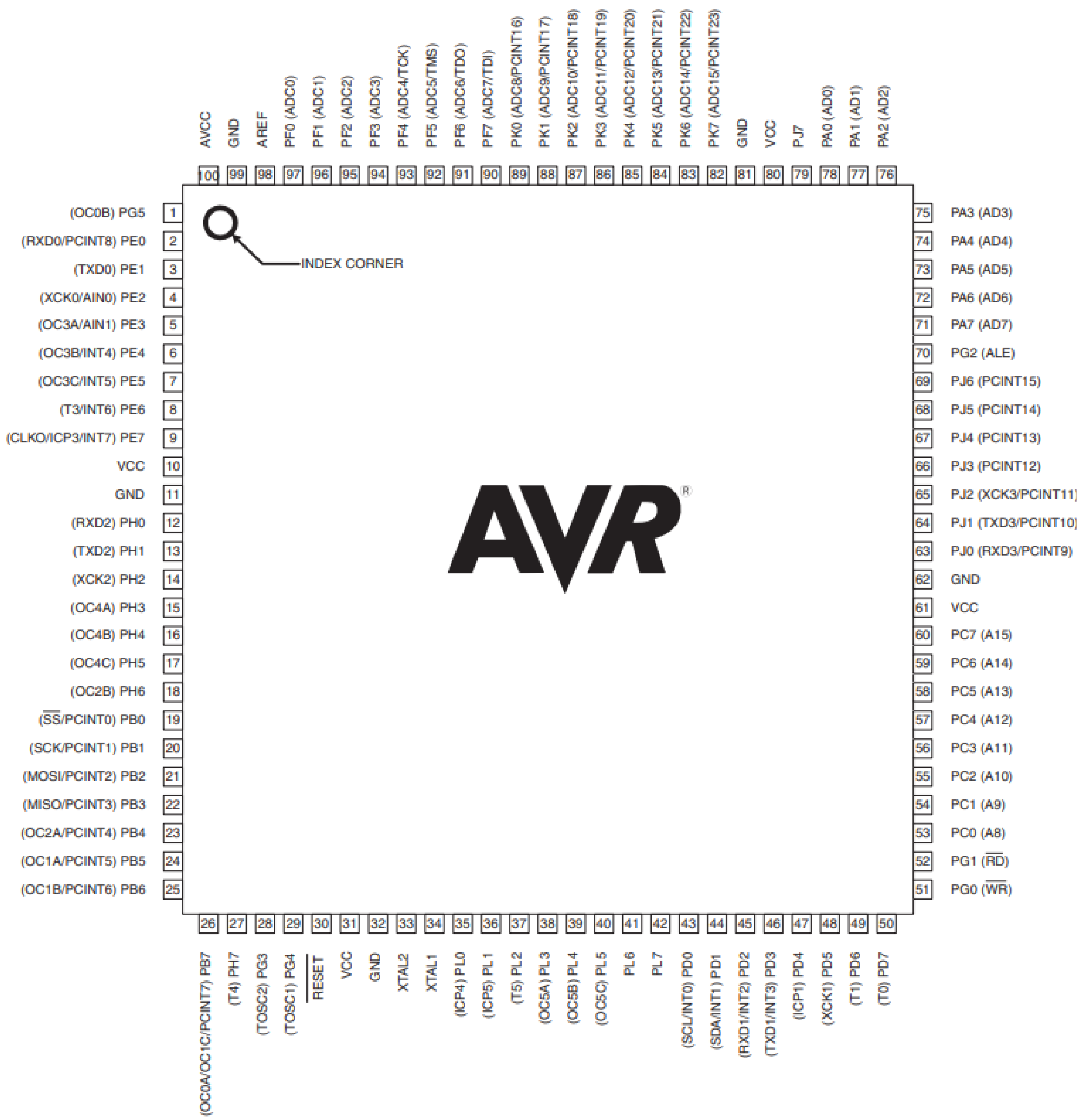


Figura 3: Diagrama de pines microcontrolador ATMega2560 [1]

En la imagen anterior podemos observar las diferentes funciones de cada pin. Las descripciones de estos se encuentran a continuación [1]:

- Puerto A (PA7..PA0): Es un puerto I/O de 8 bits bidireccional con resistencias pull-up internas. Además, este puerto tiene una función extra como dirección del byte más bajo.

- Puerto B (PB7..PB0): Es un puerto I/O de 8 bits bidireccional con resistencias pull-up internas. También, tiene mejor capacidad de conducción que otros puertos.
- Puerto C (PC7..PC0): Es un puerto I/O de 8 bits bidireccional con resistencias pull-up internas. Otra de su función es priorizar ciertas señalas.
- Puerto D (PD7..PD0): Es un puerto I/O de 8 bits bidireccional con resistencias pull-up internas. Además, es capaz de alternar funciones, puede servir como timer o contador o como medio de interrupciones.
- Puerto E (PE7..PE0): Es un puerto I/O de 8 bits bidireccional con resistencias pull-up internas. Y entre sus funciones alternas se puede encontrar pones para interrupciones externas, comparadores análogos o relojes y contadores.
- Puerto F (PF7..PF0): Este puerto sirve como una entrada analógica para el convertidos A/D. De igual manera puede ser utilizado como puerto I/O de 8 bits bidireccional.
- Puerto G (PG5..PG0): Es un puerto I/O de 6 bits bidireccional con resistencias pull-up internas.
- Puerto H (PH7..PH0): Es un puerto I/O de 8 bits bidireccional con resistencias pull-up internas. Entre sus otros usos están el comparador de salida y PWM
- Puerto J (PJ7..PJ0): Es un puerto I/O de 8 bits bidireccional con resistencias pull-up internas. Otra de sus funciones es como pin de cambio de interrupción.
- Puerto K (PK7..PK0): Este puede funcionar como entrada del canal ADC y como entrada analógica para el convertidor A/D.
- Puerto L (PL7..PL0): Es un puerto I/O de 8 bits bidireccional con resistencias pull-up internas.

Otros pines son el de reset, el XTAL1 que sirve como entrada para el oscilador amplificador invertido . Luego está XTAL2 que sirve como salida para este mismo. AVCC es la fuente de tensión para los puertos F y el convertidor y AREF es el pin de referencia analógica para el convertidor.

2.2. Periféricos

Para poder construir el sistema para la estación solicitado en el laboratorio, es necesario utilizar una serie de elementos que se conectan a los del arduino, este Arduino Mega puede presentar un costo desde los $12 hasta los $50.

Termistor NTC - MF52

Para medir la temperatura de la incubadora se utiliza un termistor, pues este componente funciona de manera que la resistencia varía según la temperatura. Pues por su composición al existir cambios en la temperatura se provocan cambios en la concentración de portadores y afecta el valor de resistividad. En este caso resulta útil utilizar el termistor de tipo NTC que tiene una resistencia inferior al aumentar la temperatura y es el más común. Además, se selecciona un termistor de la familia MF52 con una resistencia nominal de 10kΩ.[2] El precio de este componente está alrededor de $1 por unidad. La curva de funcionamiento no lineal de este se observa a continuación:

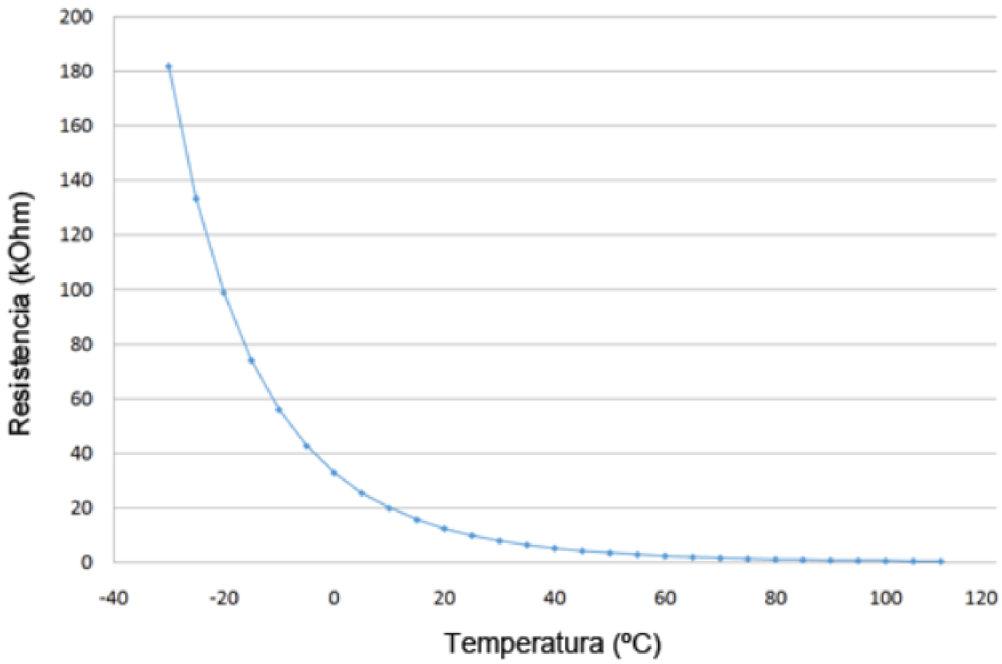


Figura 4: Comportamiento del Termistor MF52[2]

Ahora, el modelo matemático que explica el funcionamiento de este dispositivo se conoce como el Steinhart-Hart.[3]

$$T_{sh} = \frac{1}{A + B * log(R) + C(log(R))^3} \tag{1}$$

En este caso T corresponde a la temperatura, A, B y C son los coeficientes de Steinhart-Hart y R la resistencia correspondiente a esa temperatura. En nuestro caso los coeficientes utilizados corresponden a: [3]

- A: 1.009249522e-03
- B: 2.378405444e-04
- C: 2.019202697e-07

Medidor de Humedad - DHT22

El sensor DHT22 es capaz de medir la humedad y temperatura gracias a que integra un sensor capacitivo y un termistor. Este sensor solo permite obtener datos cada 2 segundos pero asegura alta estabilidad y fiabilidad. Además, es un componente donde su costo ronda los $15.

Importante mencionar que debido a que el proyecto es simulado se utiliza una fuente de tensión variable como componente de medición de humedad.

Pantalla LCD - PCD8544

Se utiliza la pantalla PCD8544, este funciona con una tensión 5 V. Además, posee 5 pines que permiten conectar diferentes salidas del arduino para mostrar información pertinente. En este caso se conecta el CS a tierra, el RST al reset del arduino y el CLK al pin 7. Los demás, están conectados a los diferentes sensores que componen el sistema de la incubadora.

Además, los dicha pantalla posee facilidad de comunicación por puertos SPI, soporta gráficos, text, consume poca energía y es de bajo costo ($12 aprox). [4]

Por otra parte, para el uso de esta pantalla es necesario utilizar la librería **Adafruit_PCD8544**, esta se puede instalar directamente desde la aplicación de Arduino y permite el uso de la pantalla para mostrar la información necesaria. [4]

Potenciómetro

Se hace uso de este elemento para ajustar el panel solar, se tiene un potenciómetro para controlar los ejes. El costo de estos rondan los 350/400 colones.

Sensor de Luminosidad LDR VT900

El Sensor LDR, es básicamente una resistencia dependiente de la luz, es decir cambia su valor de acuerdo a la cantidad de luz que incide en la superficie. A mayor intensidad de luz menor será la resistencia. Este tipo de sensor es comúnmente utilizado en alarmas antirrobo, medidores de intensidad de luz, o en dispositivos como arduino como nuestro caso.

Es importante mencionar que el valor de esta no varía de manera rápida y al pasar de luz a oscuro no dura lo mismo que al pasar de oscuro a iluminado. En la siguiente imagen podemos observar su comportamiento:

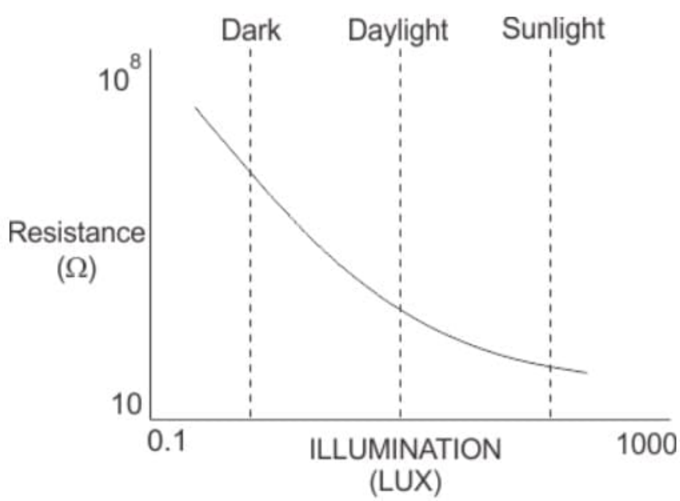


Figura 5: Curva de comportamiento del LDR [?]

Un ejemplo para este sensor sería el LDR VT90N1, este posee un costo de $3.85 y posee capacidades de 200Kohm y 80 mW

Sensor de velocidad de viento JL-FSX2 4-20MA/0-5V

Para obtener la velocidad a la que va el viento se utiliza el sensor JL-FSX2. Este posee un pequeño tamaño pero con una un rango, estabilidad y certeza bastante buenas. Su funcionabilidad va desde la toma de medidas para la protección ambiental, las estaciones del clima hasta su uso en granjas u otros ambientes de producción. En nuestro caso es parte de una estación meteorológica. Sus principales especificaciones: [5]

- Posee señales de salida, corriente, pulso y tensión.
- Su tiempo de respuesta es menor a 1 segundo
- Su rango de transmisión es menor de un 1 kilometro
- La velocidad mínima del viento para que este funcione es de 0.6 m/s

Además, su costo es aproximadamente de $56.

Sin embargo, para este laboratorio el simulador no posee este sensor por lo que se utiliza una fuente de tensión variable para representarla.

Sensor de lluvia Hydreon RG-11

El Hydreon RG-11 es un sensor de lluvia que puede ser utilizado para el control de aplicaciones y distintas variedades de monitoreo de lluvia que se pueden escoger gracias al uso de DIP switches. Entre sus características más atractivas se tiene que el sensor no requiere mantenimiento porque no tiene partes móviles y el sensor se puede orientar en cualquier dirección. Respecto a su funcionamiento, este se basa en que el sensor detecta una cantidad determinada de lluvia y según esto se provoca un cambio en un relé.

El costo de este sensor ronda los $59. [6]

Sin embargo, para este laboratorio al utilizar un simulador no es posible implementar este sensor, entonces se utiliza un circuito con un relé que permite funcionar como sensor de lluvia propuesto por el mismo enunciado del laboratorio. De esta manera, al tener el relé abierto el pin del Arduino recibe un valor alto de tensión y al estar cerrado el pin tiene una tensión de 0 V.

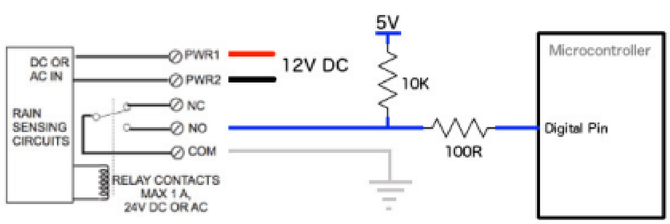


Figura 6: Circuito para el sensor de lluvia [Enunciado]

Batería de Paneles

En este caso se debe utilizar una tensión de 12 V, sin embargo, sabemos que el pin del arduino no permite valores tan altos de tensión. Por esto se utiliza una división de tensión para la conexión.

$$R_2 = \frac{V * R_1}{V_{in} - V} \tag{2}$$

Donde V_{in} es la tensión de la batería. R_1 se selecciona de manera arbitraria y V sería los 5 V máximos que acepta el pin. De esta manera las resistencias quedarían de 10k Ω y 7142.86 Ω

USART

Por último, se puede mencionar el uso de USART para manejar la conexión del circuito y sistema en arduino con la computadora. Esta función ya la trae implementada el arduino y nada más se habilita la comunicación y display de los valores mediante un pin.

Además, se hace uso de las librerías **pyserial** para leer los datos del puerto serial.

ThingsBoard
Esta es un plataforma que permite crear “Dashboards” con el circuito creado en arduino, así se logra visualizar la información de manera dinámica e inclusive controlar de manera remota el circuito. Para lograr la conexión y comunicación con esta plataforma es necesario utilizar las librerías **json** y **paho.mqtt.client**

2.3. Otros componentes

Además, de los periféricos comentados anteriormente se utiliza:

1. EEPROM: Que es una memoria volátil programable y de lectura borrable. Además, en este laboratorio se utiliza para guardar los datos leídos por el sensor e imprimirlos en la plataforma IoT. Para hacer uso de las EEPROM es necesario incluir la librería **EEPROM.h**.

2. Servomotor: Estos son motores donde sus grados o dirección puede ser controlada mediante una perillas. En este laboratorio son de gran utilidad para manera la dirección de los paneles solares. La librería necesaria para utilizar este tipo de componentes se conoce como **Servo.h**

3. Resistencias de diferentes tamaños. Algunas de protección otras como medios para disminuir la caída de tensión en el circuito. Sus precios varían según la capacidad de resistividad de cada una, pero van de los 110 colones en adelante.

4. Switch: Este habilita la comunicación con el circuito en Arduino y la computadora,

5. Fuentes de poder. Costo 800-1000 colones.

2.4. Diseño

Para el diseño del circuito se sigue paso a paso las solicitudes del enunciado.

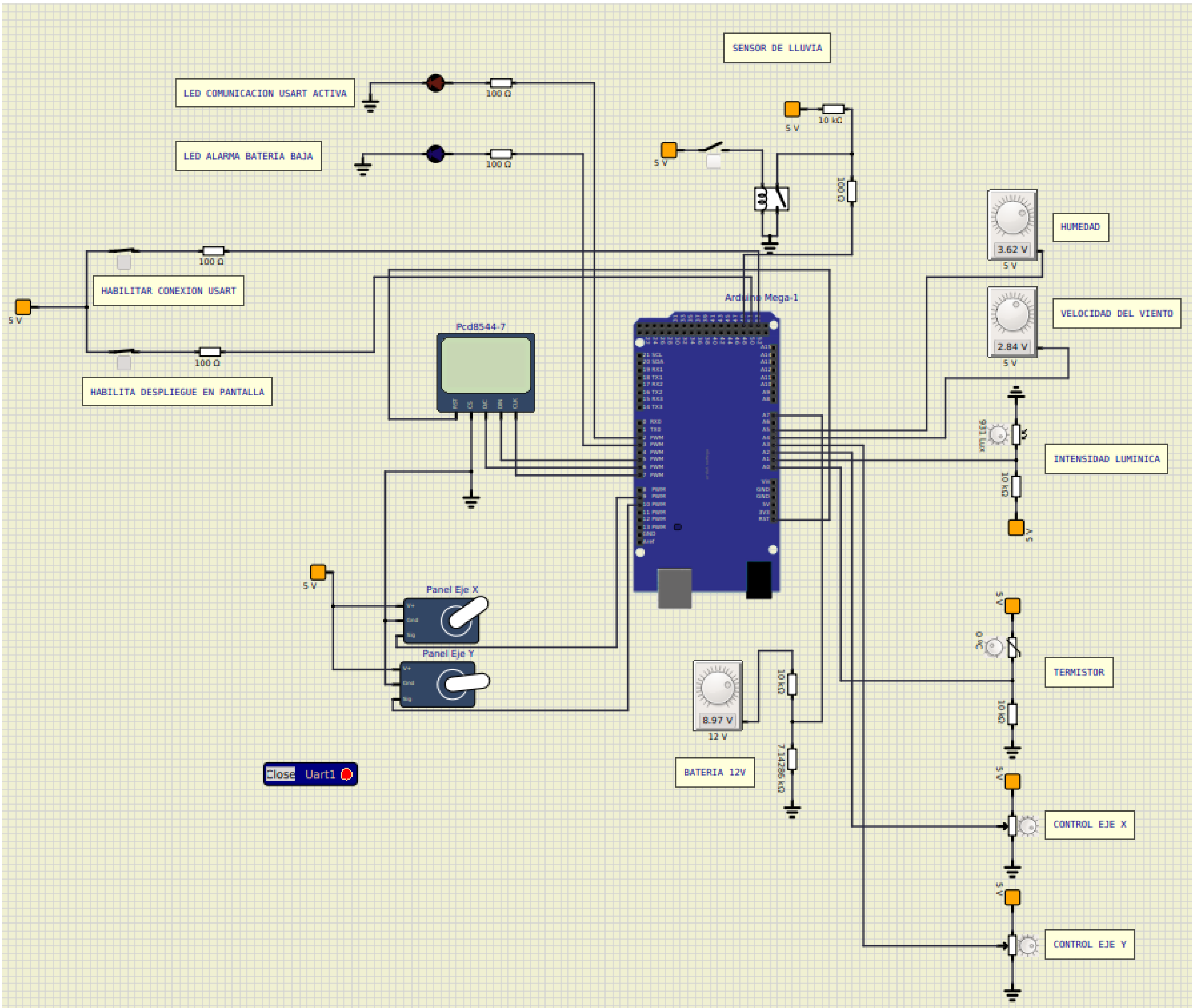


Figura 7: Diseño del circuito [Creación propia]

Primero se conecta el termistor como sensor de temperatura al pin A0, esté se encuentra conectado a una tensión fija de 5 V y un resistor de seguridad de 10k Ω. Sus parámetros corresponden a $\beta = 3455$ y una resistencia de 10000 Ω.

Seguidamente en el pin A6, se conecta lo que sería el sensor de humedad. Este se presenta como una fuente de tensión variable que presenta un rango de valores entre los [0,5] V. Esto mismo aplica para el sensor de velocidad que se conecta al pin A4.

Para el sensor LDR se utiliza el pin A1 del arduino, este tiene un rango de funcionamiento de 0 a 1000 Lux. Además, para este sensor se crea una función que toma el valor leído por el sensor y lo multiplica por 5/1023 para tener la tensión real y utilizar está para realizar un cálculo más preciso de intensidad luminosa necesitado.

Seguidamente, se conecta el sensor de lluvia que como se explicó en la sección anterior funciona con un relé que es controlado por un switch. Al presionar el switch se cierra el relé y hay un cambio en la tensión. Al estar abierto, la tensión leída por el pin es la proviene de la fuente de 5V con las resistencias. Así cuando se lee la entrada del pin si está en alto, se hace un display de la palabra No, que implica que está lloviendo y si el pin está en bajo, se imprime la palabra sí que indica que no está lloviendo.

Además, se tiene conectada al pin A7 una batería de 12 V con conexión por divisor de tensión al arduino para alimentar los paneles solares y no quemar el arduino. Para estos paneles solares se tiene dos servomotores conectados cada uno a un potenciómetro para realizar el ajuste de dirección de los paneles.

La lectura de todos estos sensores es representada mediante un display en la pantalla PCD8544 conectada al arduino. De igual manera se habilita USART para enviar de manera serial la información obtenida. Para saber si esta está habilitada tenemos un LED de control y USART se controla mediante un switch al igual que el funcionamiento de la pantalla. Por otro lado, se tiene otro LED indicador de batería baja.

La información del USAR se programa para que se envía cada 10 minutos. Por último, se habilita guardar los datos en la memoria EEPROM cada 5 min. Para lograr esto se verifican que las direcciones de memoria estén disponibles o se limpian. Una vez que esto esté bien se escribe en memoria el dato leído por los sensores.

3. Desarrollo y Análisis

En las siguientes imágenes se podrá observar el correcto funcionamiento de la estación meteorológica según las especificaciones de diseño.

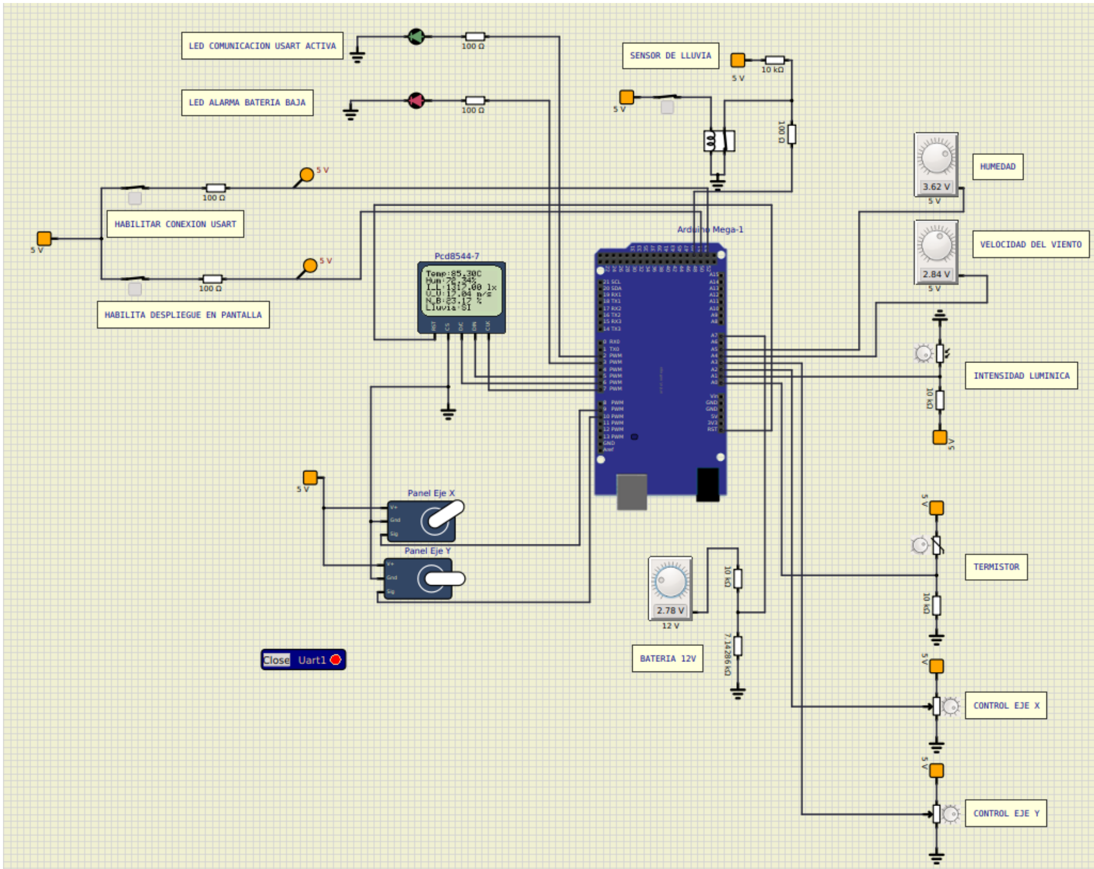


Figura 8: Funcionamiento completo del proyecto según las especificaciones requeridas [Creación propia]

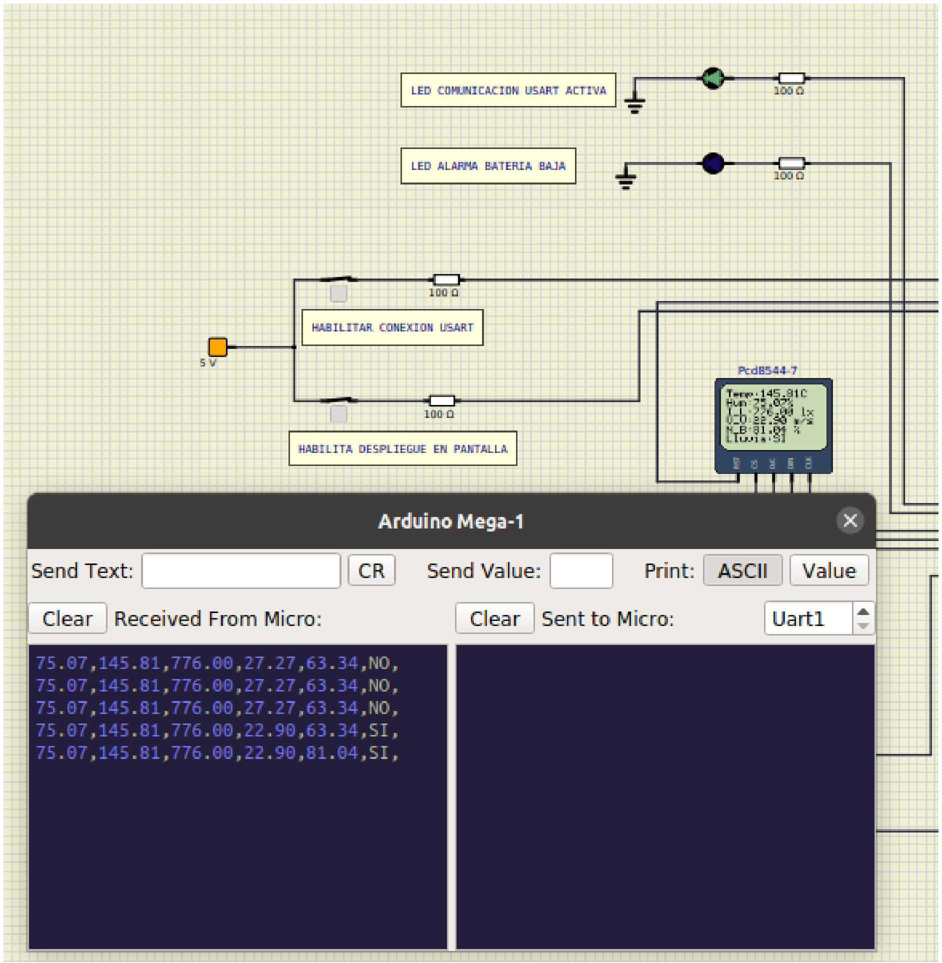


Figura 9: Funcionamiento del monitor serial [Creación propia]

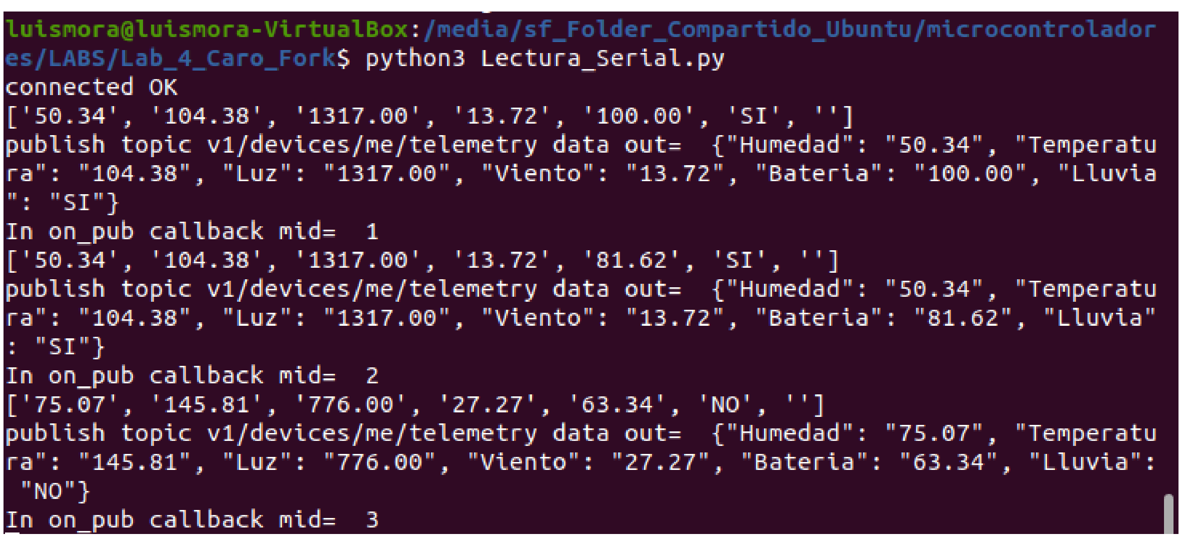


Figura 10: Funcionamiento del envío de datos a través del puerto serial [Creación propia]

Puede verse en la figura 10 como al tener una temperatura mayor a $42°C$ el led rojo se activa.

Figura 11: Dashboard desplegando correctamente la información enviada desde el Arduino [Creación propia]

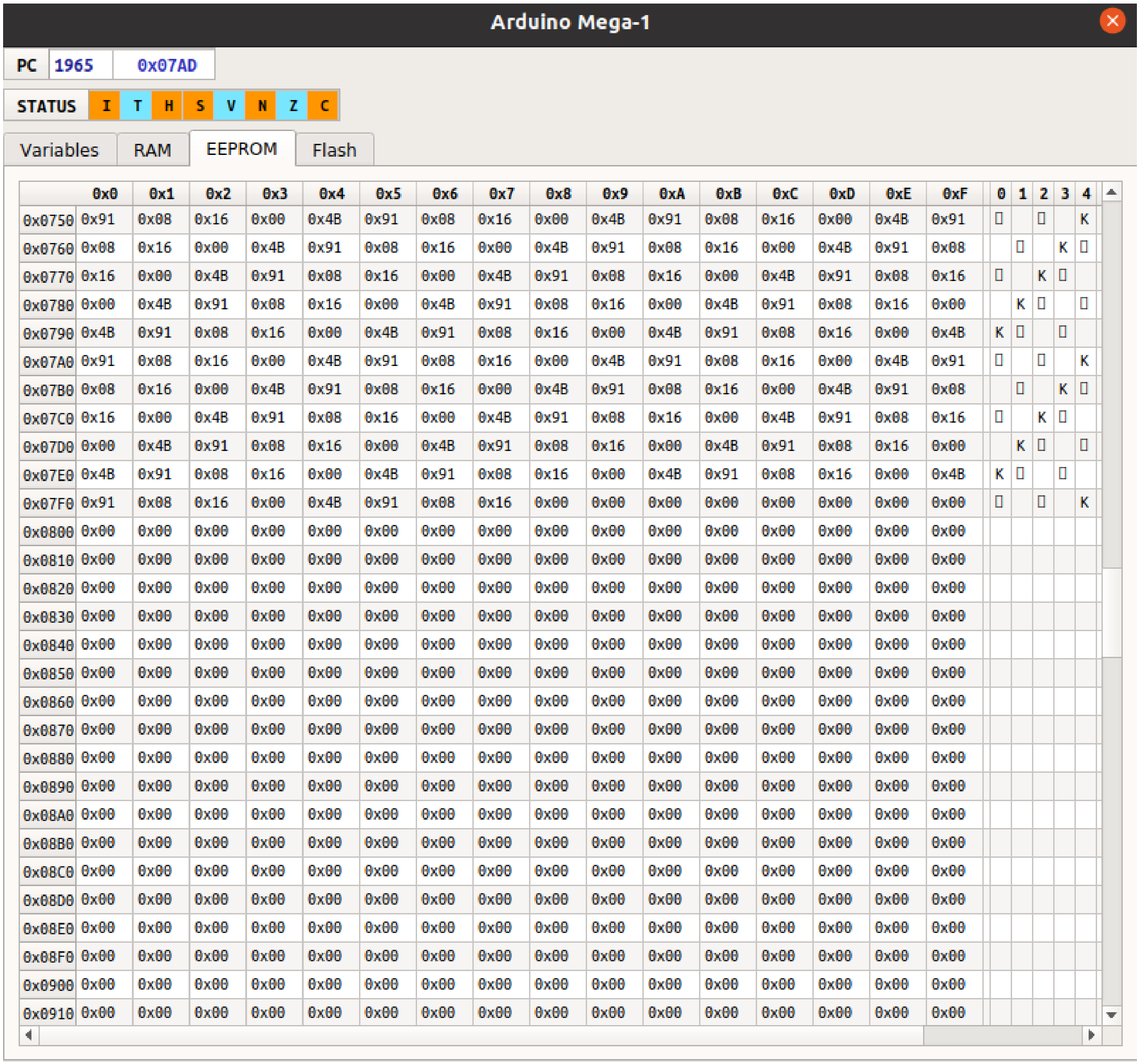


Figura 12: Llenado de memoria EEPROM [Creación propia]

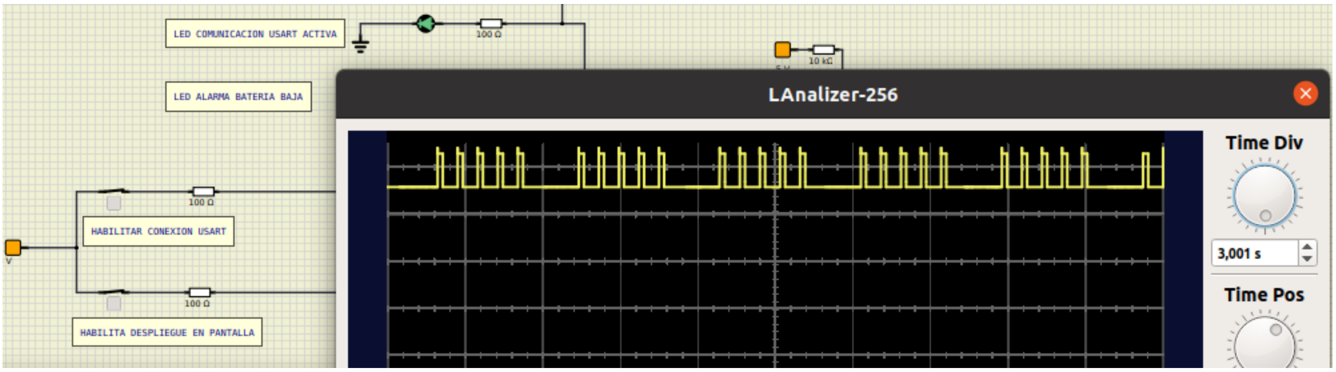


Figura 13: Parpadeo LED de comunicación funcionando según las especificaciones [Creación propia]

4. Conclusiones y Recomendaciones

Se logra diseñar y simular una estación meteorológica bastante completa, con sensores de lluvia, humedad, intensidad luminosa, temperatura y velocidad del viento. De está manera, se práctica y comprende mejor el uso del Arduino Mega. Por otro lado, se observa la importancia de tener un display de datos en el mismo circuito para comprender qué está sucediendo con la lectura de datos.

Se hace uso de la memoria EEPROM por primera vez para el guardado de datos y se utilizan componentes como servomotores para controlar otros dispositivos de gran importancia.

5. Repositorio del laboratorio

El código elaborado para realizar el laboratorio se puede consultar en la dirección:

Referencias

[1] Atmel Corporation, " 8-bit AVR Microcontrollers - ATmega328/P," 2016. [Online]. Available: https://mv1.mediacionvirtual.ucr.ac.cr/pluginfile.php/2172711/mod_resource/content/1/ATmega328-ATMEL.pdf

[2] Llamas, L, "MEDIR TEMPERATURA CON ARDUINO Y TERMISTOR (MF52)," 2015. [Online]. Available: https://www.luisllamas.es/medir-temperatura-con-arduino-y-termistor-mf52//

[3] Campbell, S. - Circuit Basics, "MAKE AN ARDUINO TEMPERATURE SENSOR (THERMISTOR TUTORIAL)," 2015. [Online]. Available: https://www.circuitbasics.com/arduino-thermistor-temperature-sensor-tutorial/

[4] V. Garcia. (2013) LCD's Gráficos PCD8544. [Online]. Available: https://www.diarioelectronicohoy.com/blog/lcds-graficos-pcd8544#:~:text=El%20controlador%20del%20PCD8544%2C%20puede,por%20lo%20que%20es%20inofensivo.

[5] MStore. (2021) JL-FSX2 4-20MA Wind Speed Sensor Wind Speed Transmitter Anemometer / 0-5V Output. [Online]. Available: https://mstore.ibda3vision.com/index.php?route=product/product&product_id=365

[6] FONDRIEST. Hydreon RG-11. [Online]. Available: https://www.fondriest.com/hydreon-rg-11.htm

6. Anexos

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 $\overline{\text{RES}}$ (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

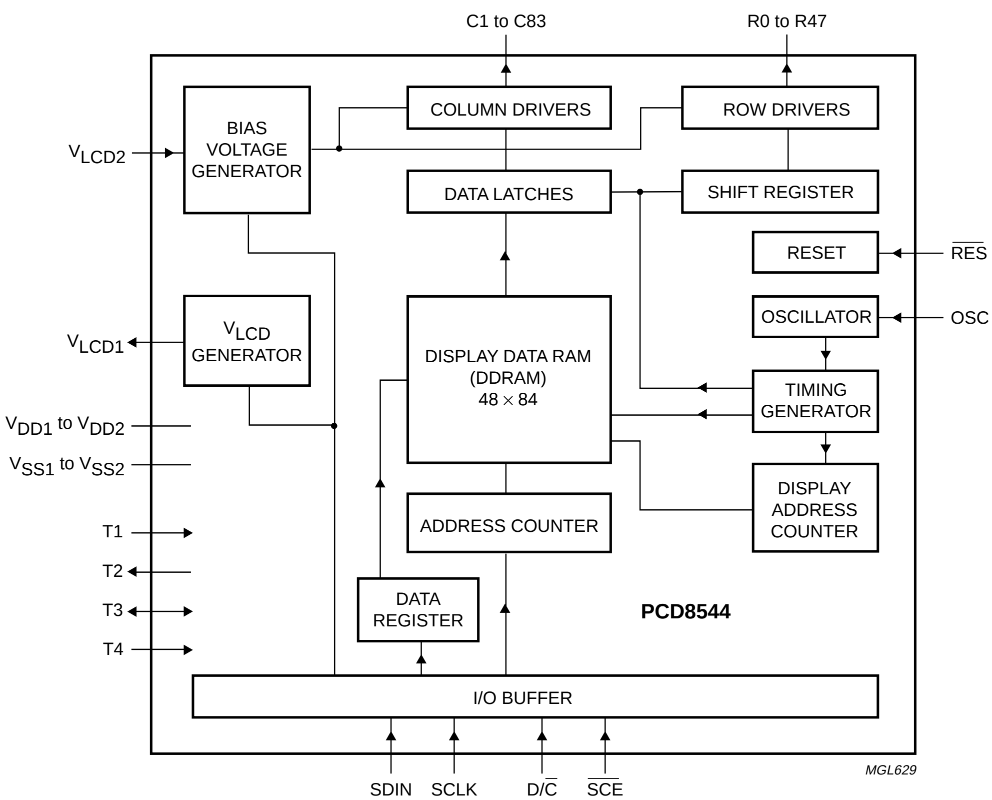


Fig.1 Block diagram.

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 × 8 × 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

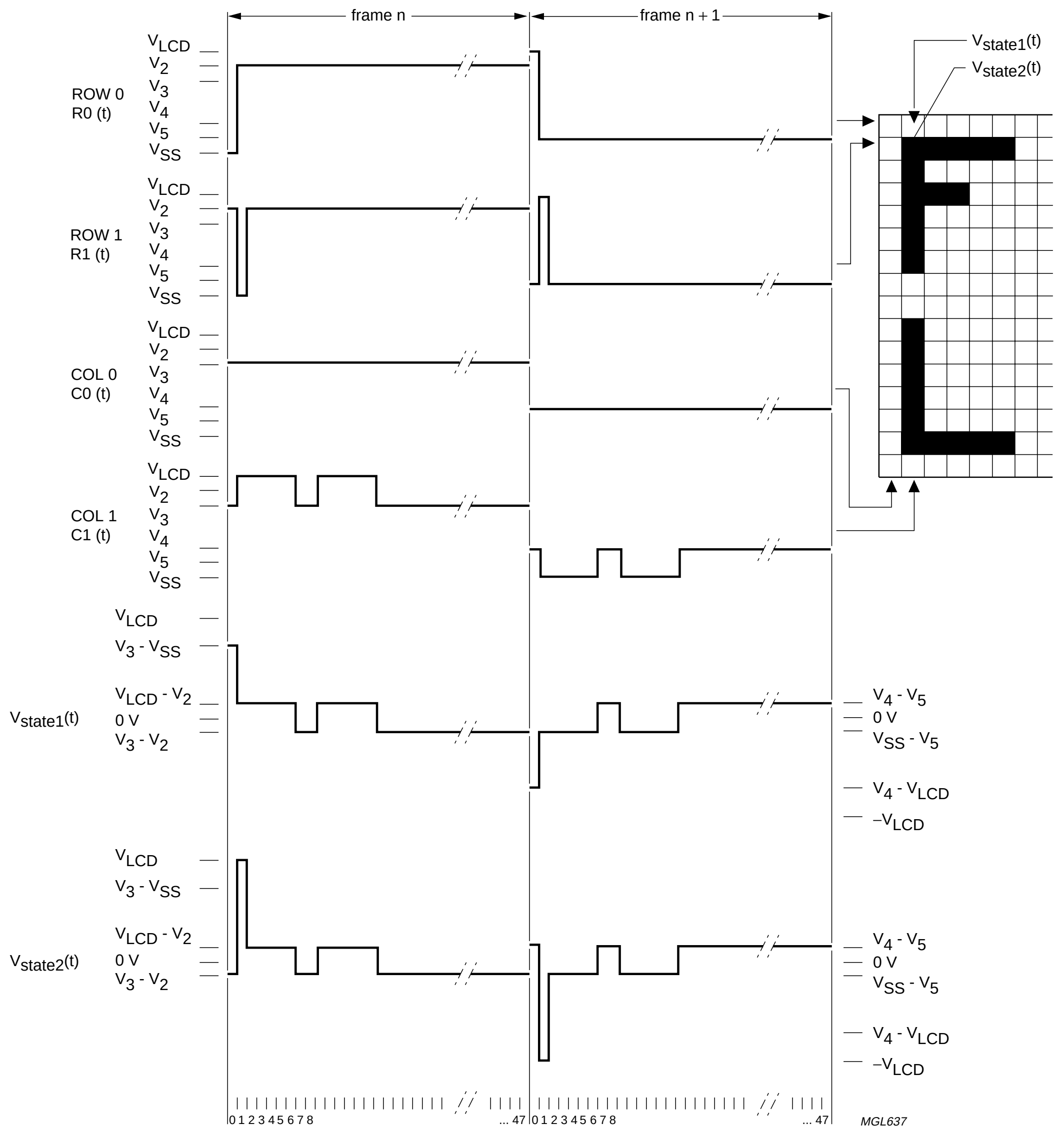
The timing generator produces the various signals required to drive the internal circuits. Internal chip operation is not affected by operations on the data buses.

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.

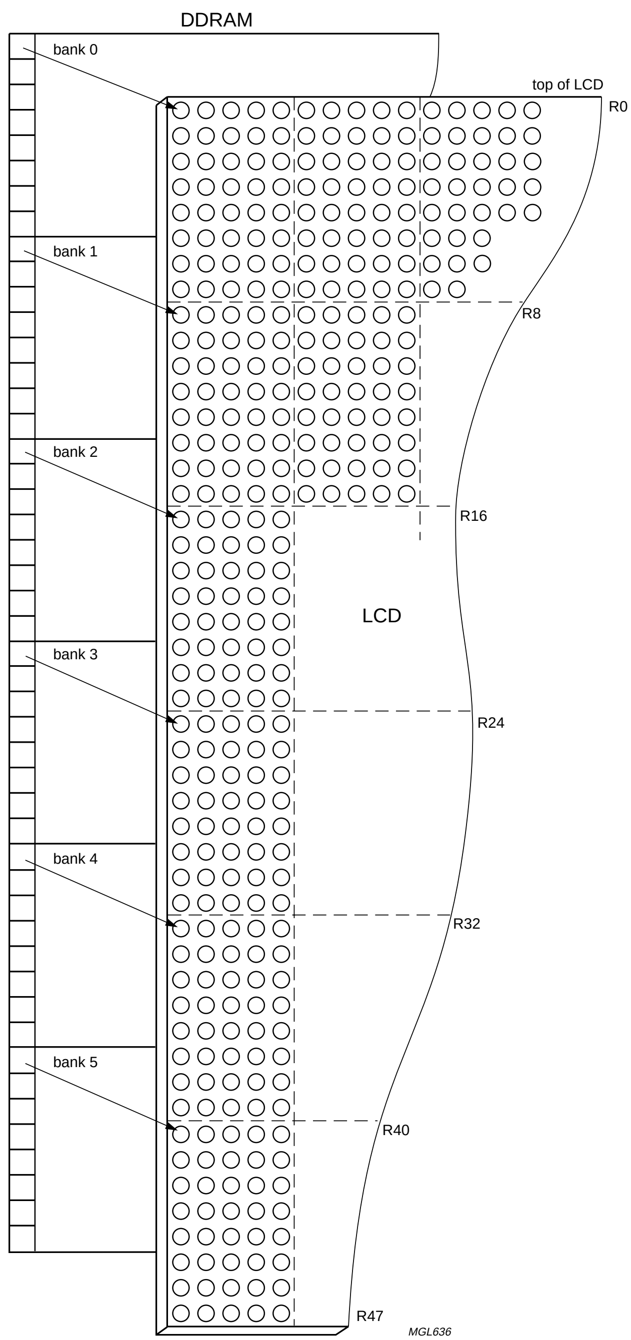


Fig.3 DDRAM to display mapping.

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

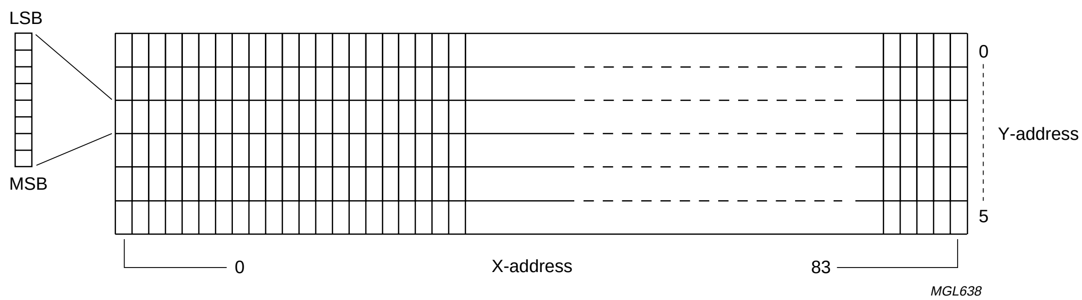


Fig.4 RAM format, addressing.

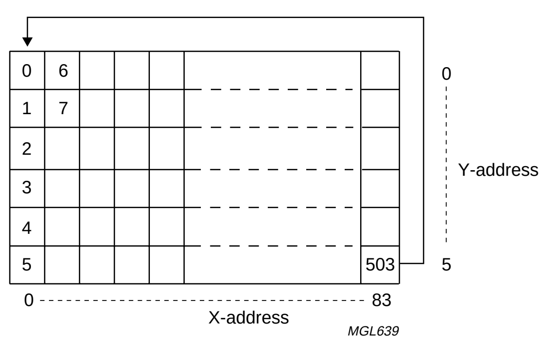


Fig.5 Sequence of writing data bytes into RAM with vertical addressing (V = 1).

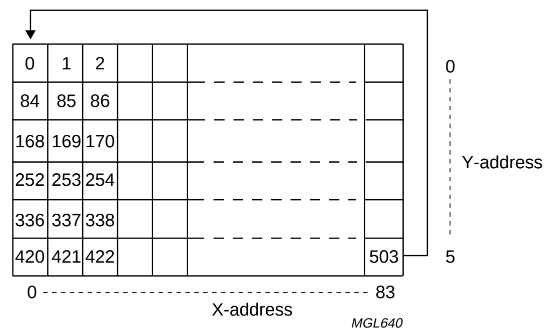
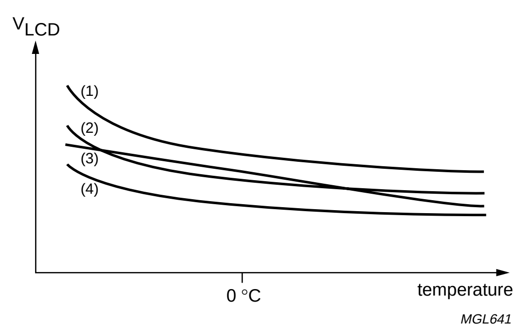


Fig.6 Sequence of writing data bytes into RAM with horizontal addressing (V = 0).

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

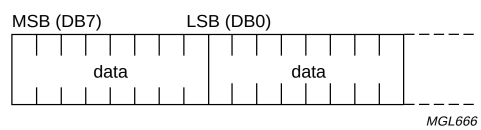


Fig.8 General format of data stream.

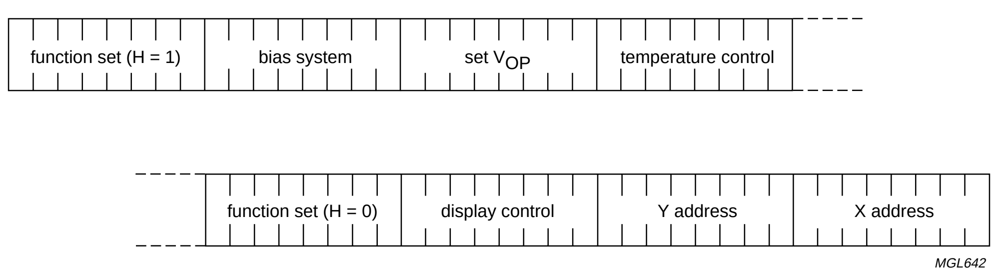


Fig.9 Serial data stream, example.

Figures 10 and 11 show the serial bus protocol.

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

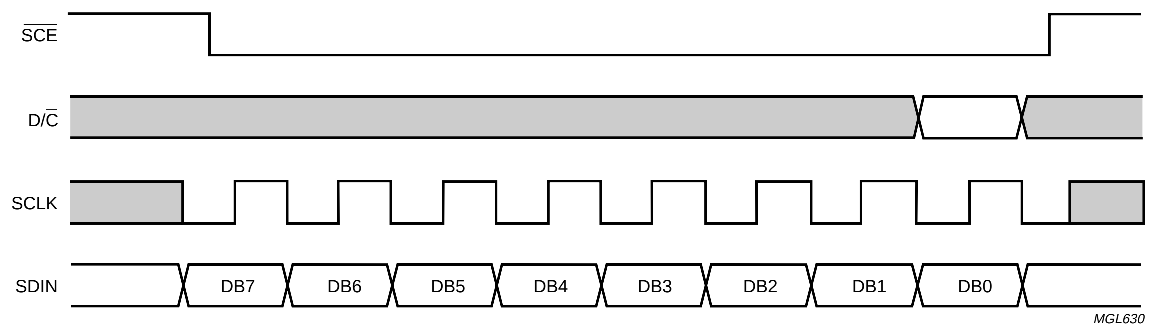


Fig.10 Serial bus protocol - transmission of one byte.

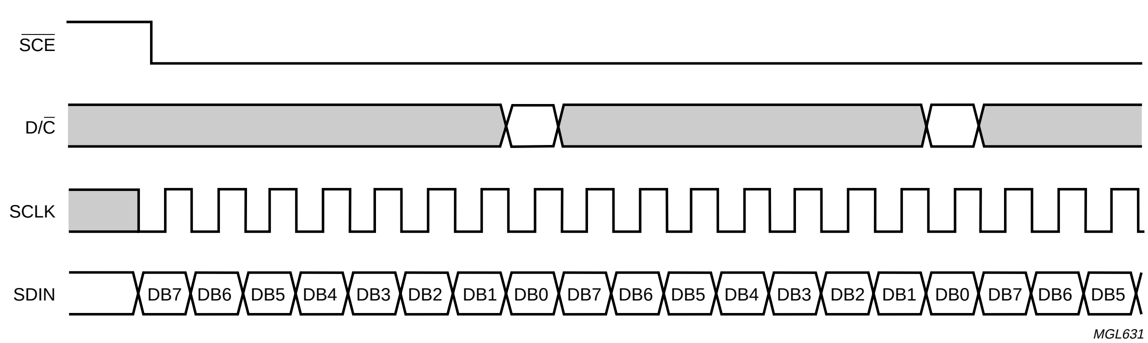


Fig.11 Serial bus protocol - transmission of several bytes.

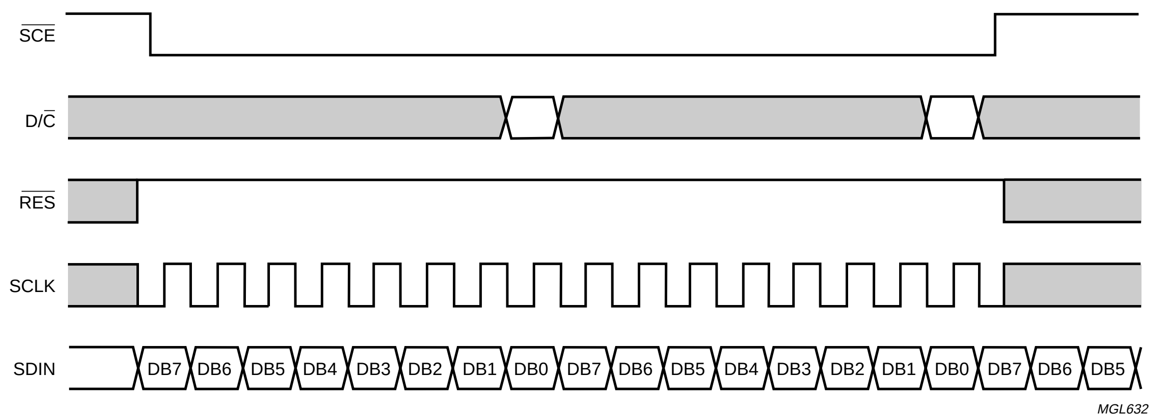


Fig.12 Serial bus reset function ($\overline{SCE}$).

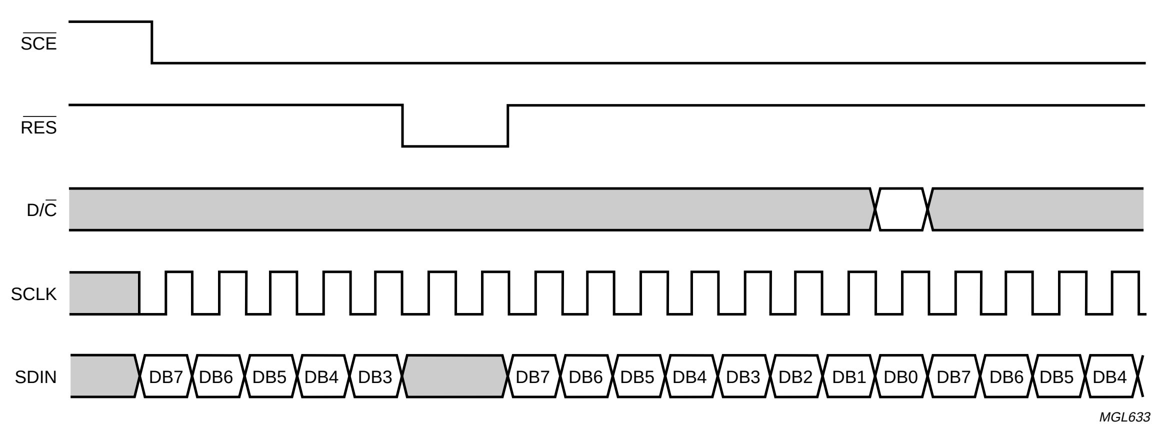


Fig.13 Serial bus reset function ($\overline{RES}$).

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 10 01 11	 display blank normal mode all display segments on inverse video mode	
TC_1 and TC_0 00 01 10 11	 V_{LCD} temperature coefficient 0 V_{LCD} temperature coefficient 1 V_{LCD} temperature coefficient 2 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 $\overline{RES}$ 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 $\overline{RES}$ 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 $\overline{RES}$ input must be ≤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:

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

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 $\frac{1}{8}$ 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.

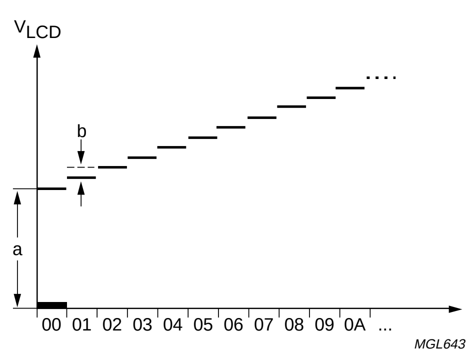
Note that the charge pump is turned off if V_{OP6} to V_{OP0} is set to zero.

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

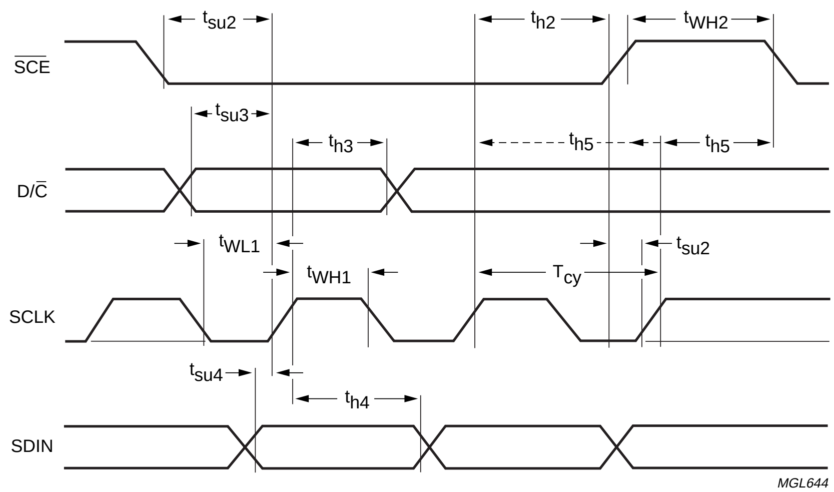


Fig.15 Serial interface timing.

12.2 Reset

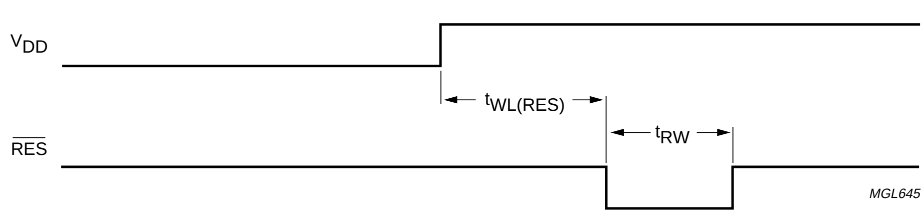
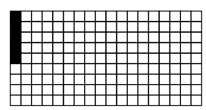
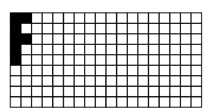
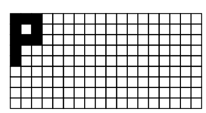
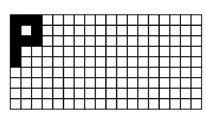
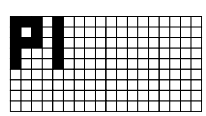
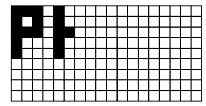
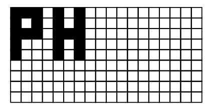
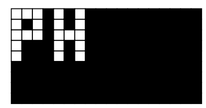
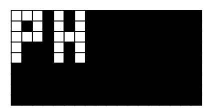
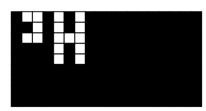


Fig.16 Reset timing.

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.

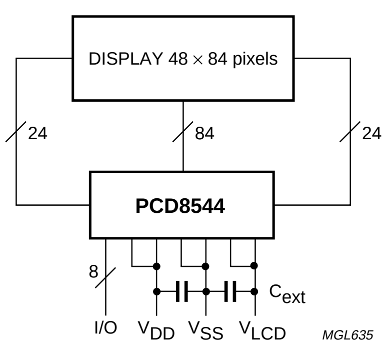


Fig.17 Application diagram.

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

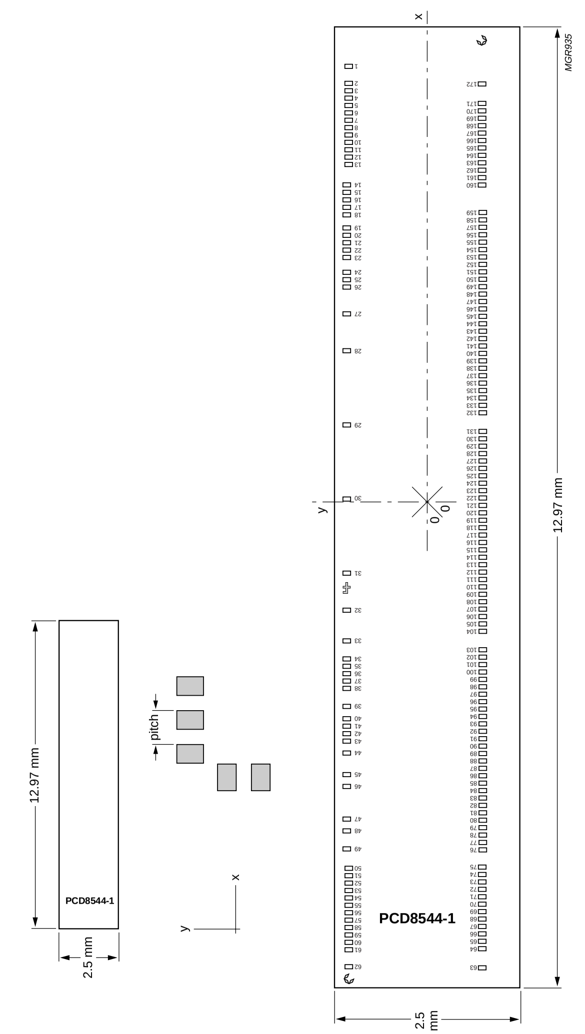


Fig.18 Bonding pad locations.

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

PAD	PAD NAME	x	y
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

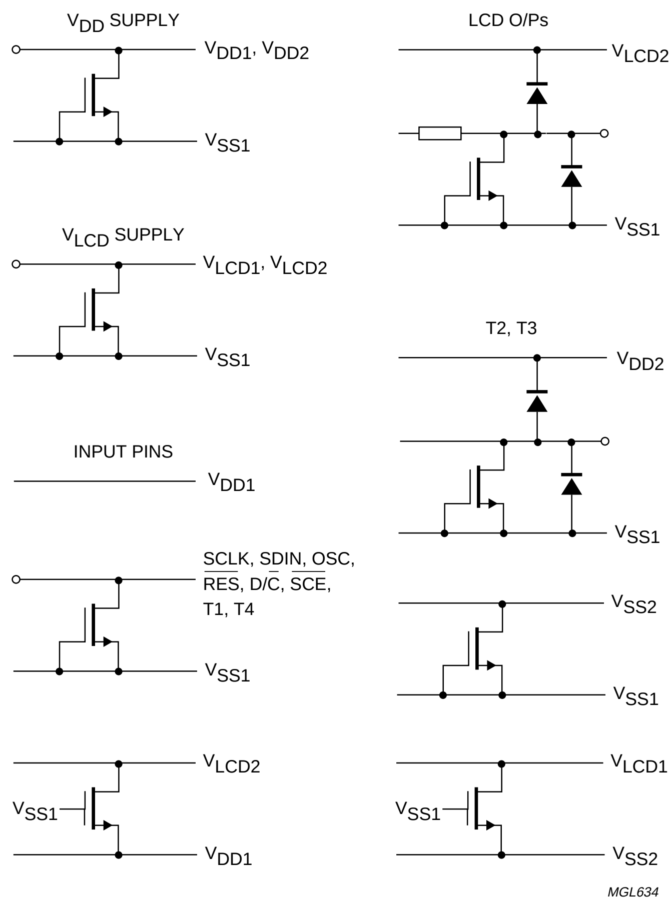
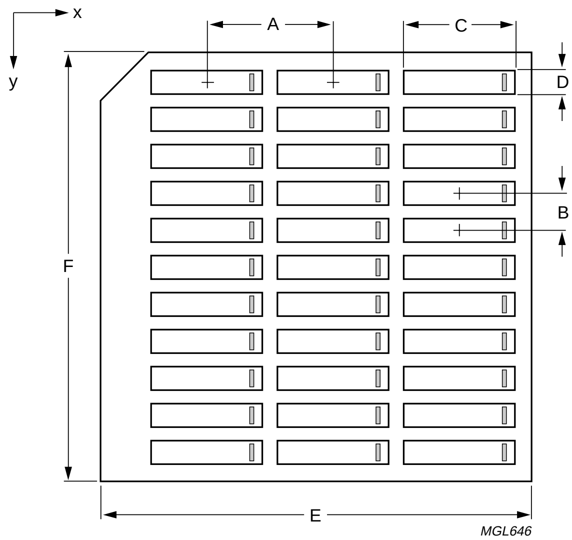


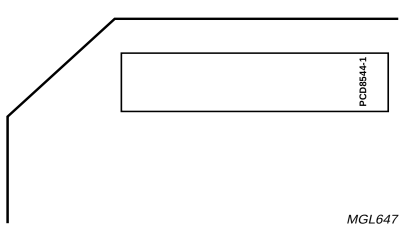
Fig.19 Device protection diagram.

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

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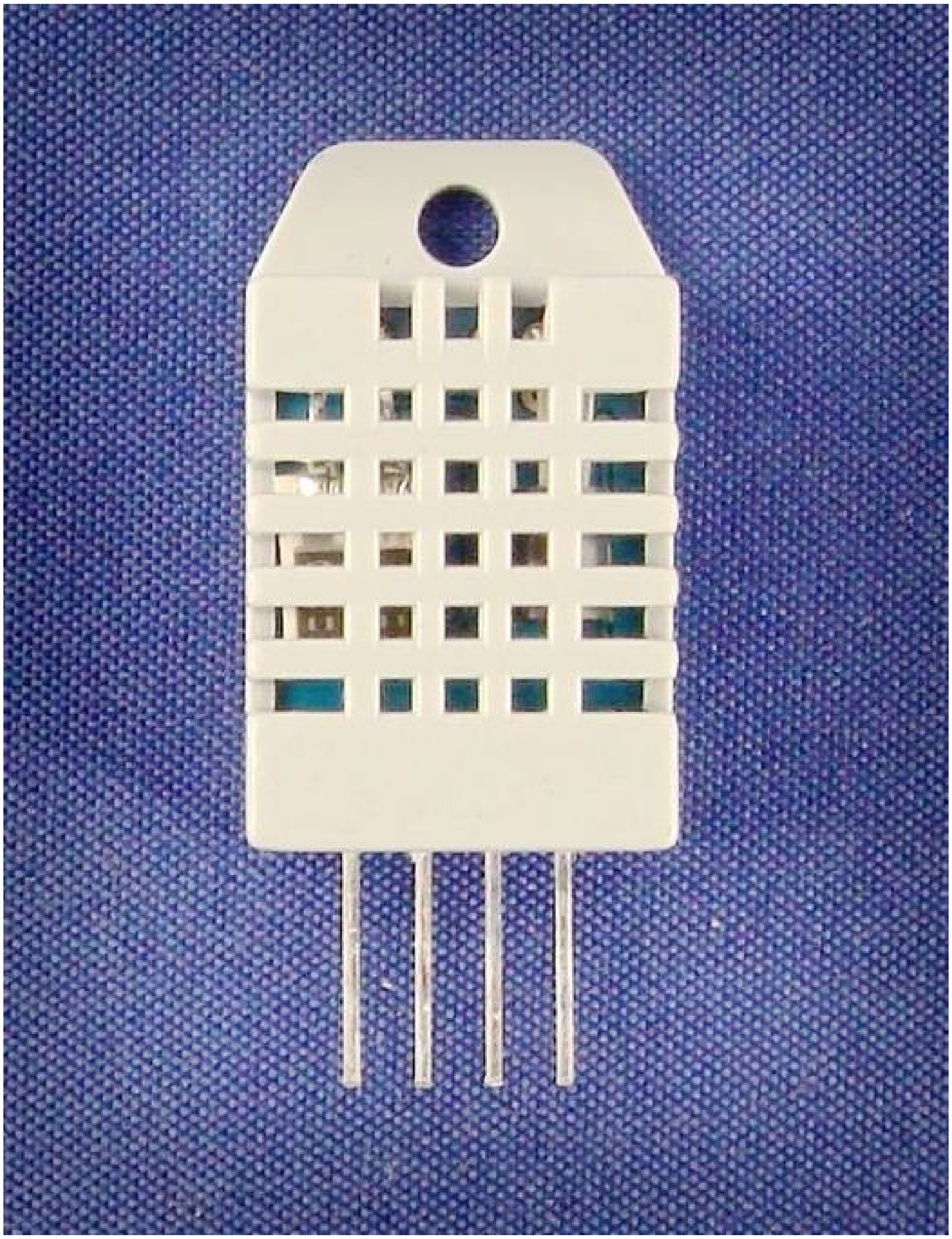
Digital-output relative humidity & temperature sensor/module

DHT22 (DHT22 also named as AM2302)



Capacitive-type humidity and temperature module/sensor

Thomas Liu (Business Manager)

Email: thomasliu198518@yahoo.com.cn

Aosong Electronics Co.,Ltd

Your specialist in innovating humidity & temperature sensors

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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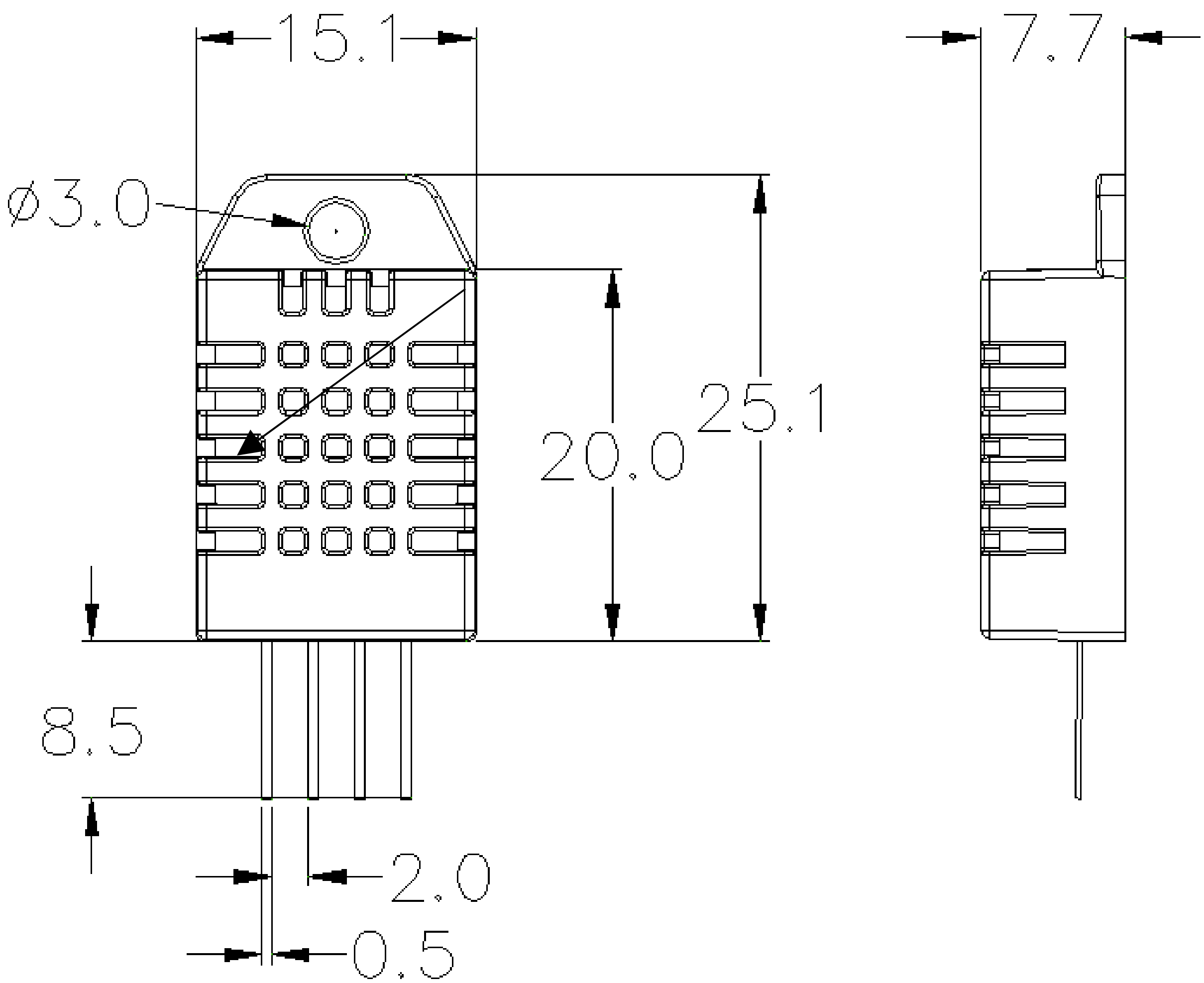

Pin sequence number: 1 2 3 4 (from left to right direction).

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

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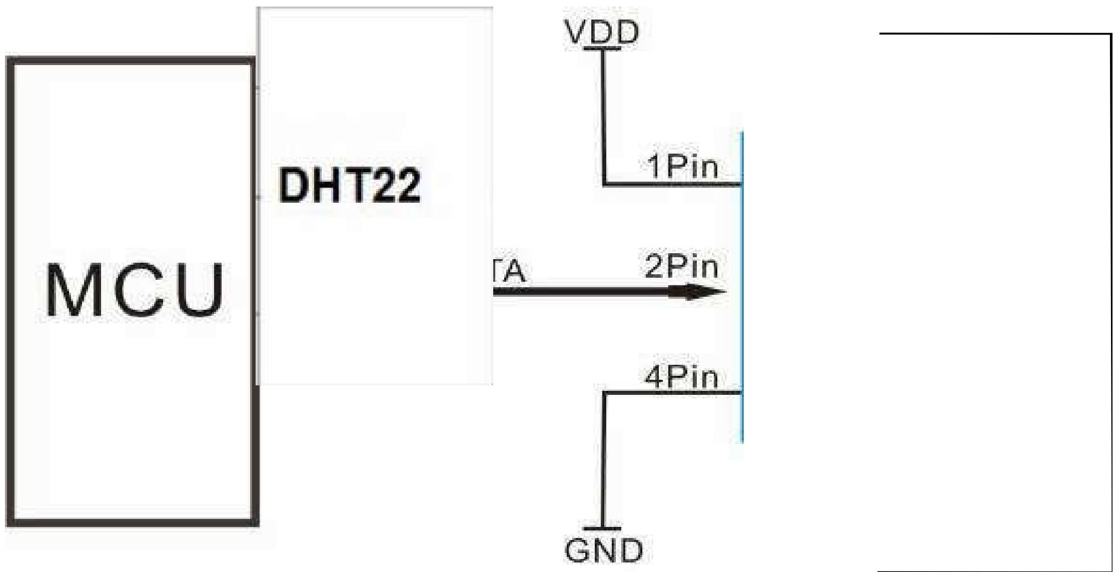
5. Electrical connection diagram:



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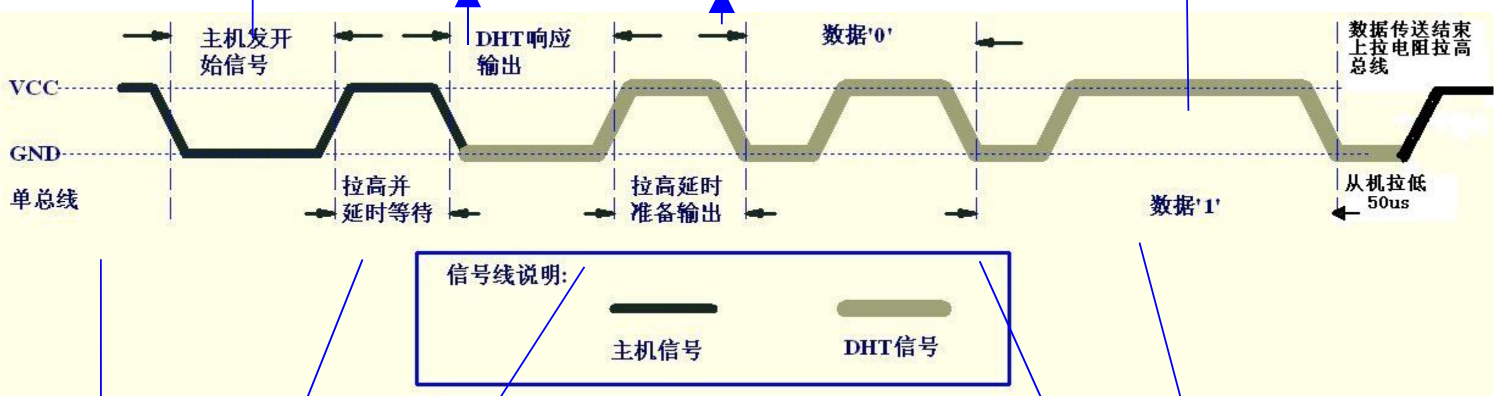
and temperature information to MCU. Without start signal from MCU, DHT22 will not give response signal to MCU. One start signal for one time's response data that reflect the relative humidity and temperature information from DHT22. DHT22 will change to low-power-consumption-mode when data collecting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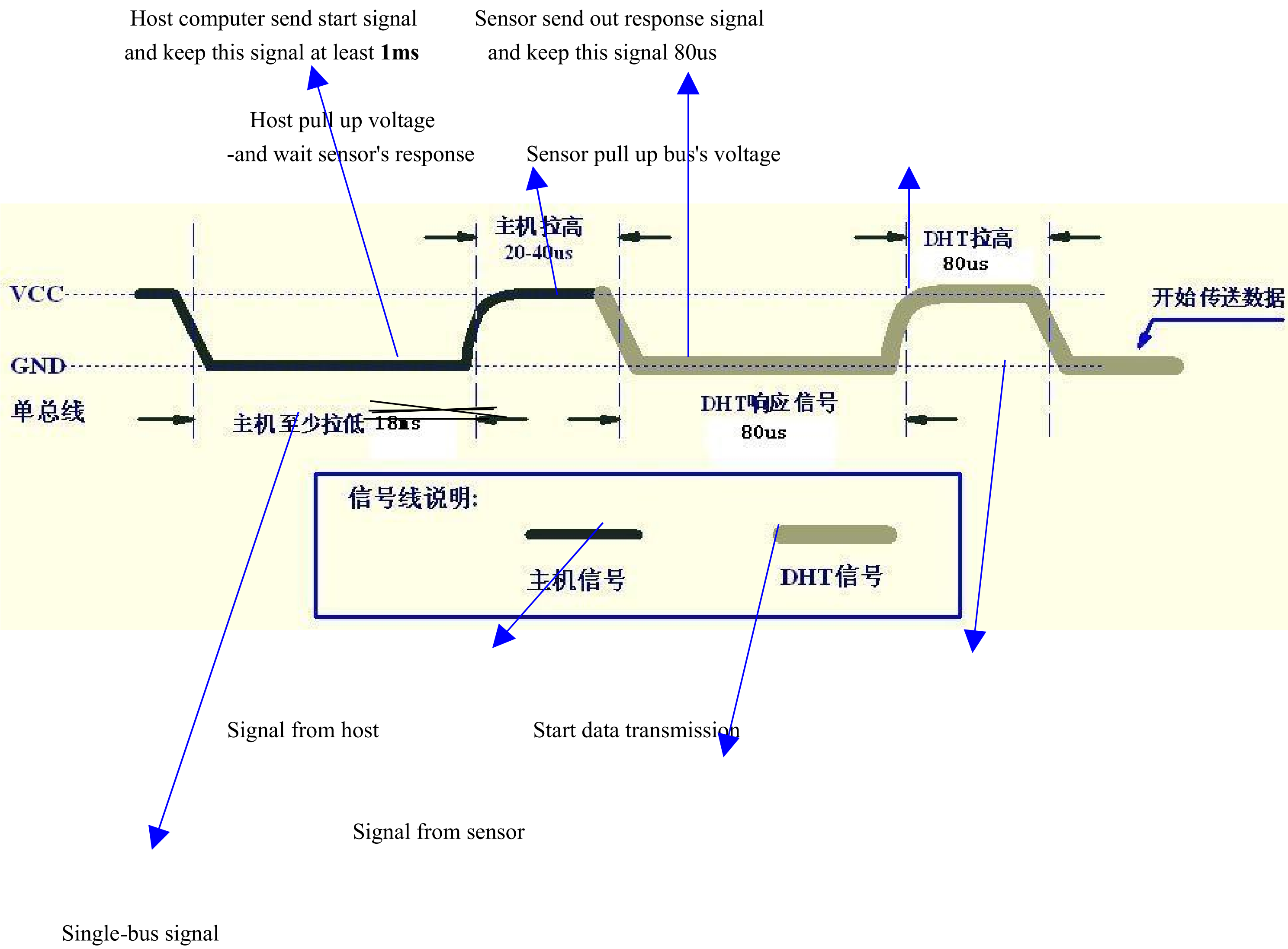

Step 2: DHT22 send response signal to MCU

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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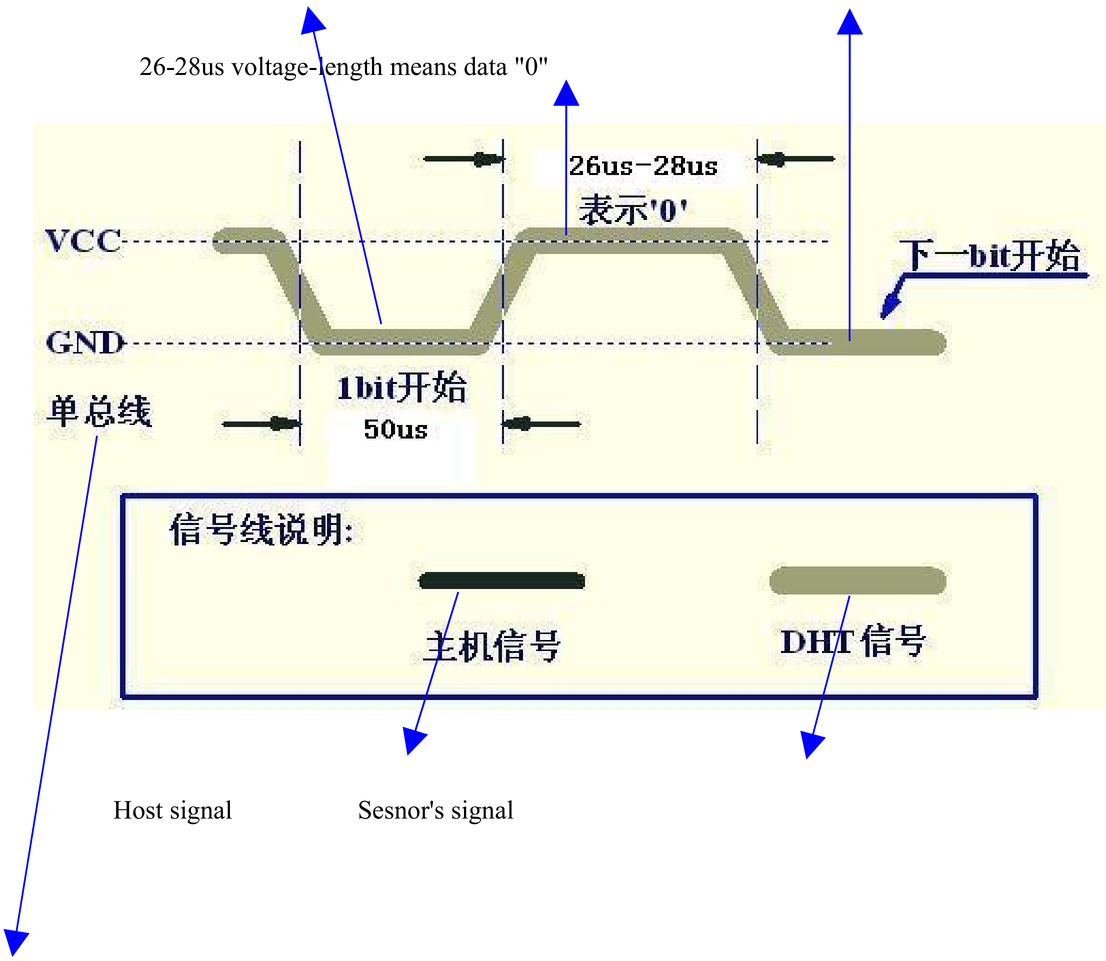
Start transmit 1bit data

Start transmit next bit data

26-28us voltage-length means data "0"



Host signal

Sesnor's signal

Single-bus signal

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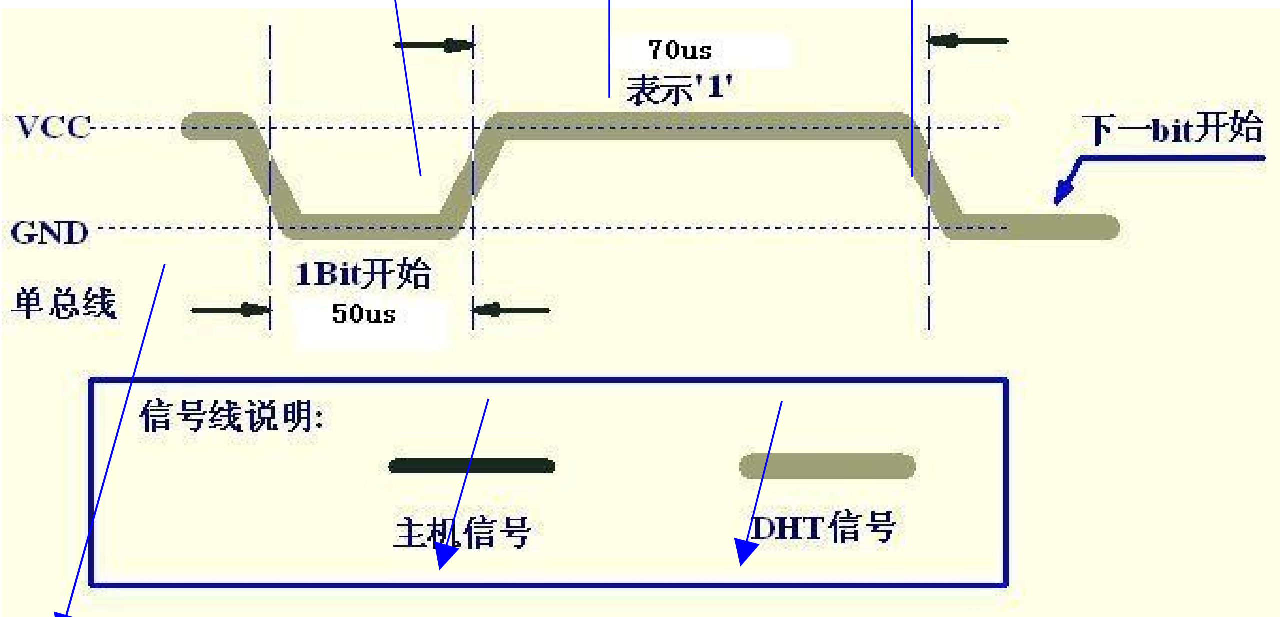
70us voltage-length means 1bit data "1"

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.

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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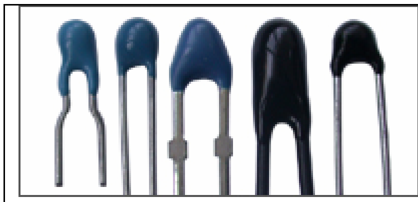


NTC THERMISTOR OF MF52-TYPE SERIES SPECIFICATION

*** Outline：**

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

*** Application：**

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

*** Features：**

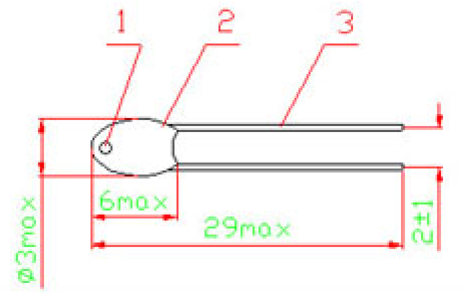
1.High testing precision;
2.Small and quick in reaction;
3.Long and good service;
4.Good interconvertibility and consistency.

*** Part NO.：**

MF52	E	103	H	L	347
①	②	③	④	⑤	⑥

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

*** Dimensions(mm) :**



*** Specification**

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

Remarks:

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

*** Cautions :**

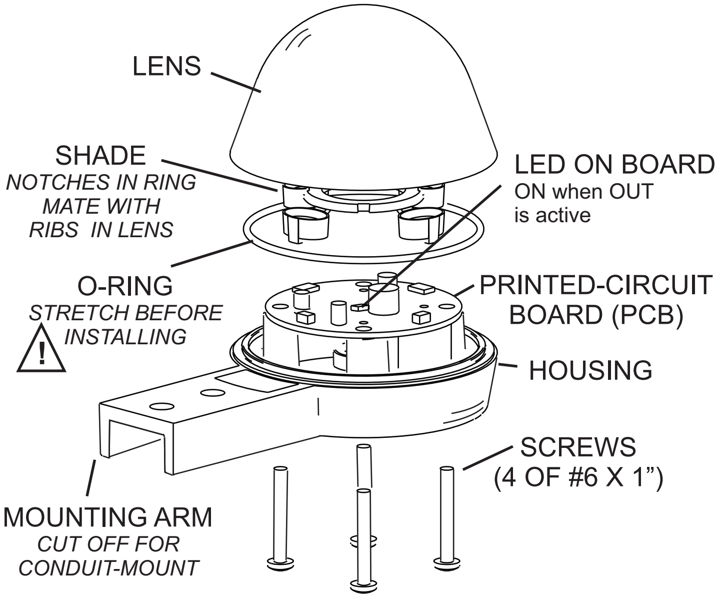
1) The two ends of the lead is not supposed to be loaded with excess pulling stress,owing to the small size and small welding spot of MF52-srs products.
2) Soldering is supposed to be done 5mm away from the root of the lead,and only for a brief moment.
3) Thermistor of MF52-srs are not supposed to be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

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

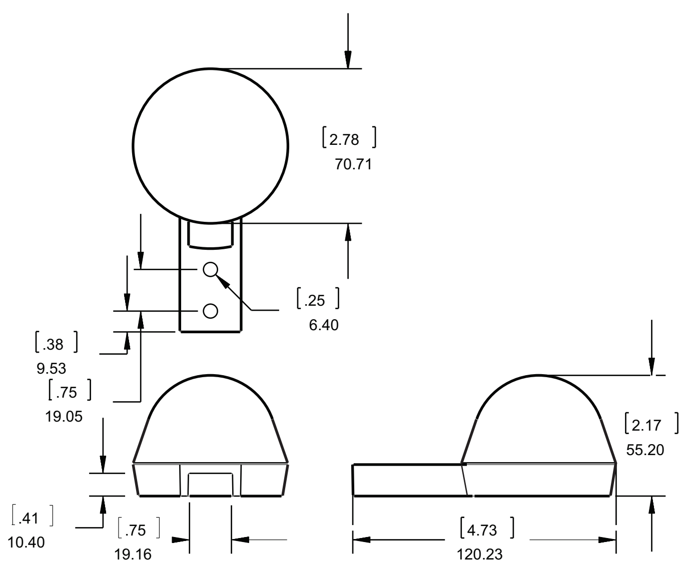
R_{25} / B / T(℃) Rt	10 KΩ	50 KΩ	100 KΩ	50 KΩ	50 KΩ	100 KΩ	100 KΩ	150 KΩ
	3950	3950	4000	4050	4150	4150	4300	4500
-30	181.70	908.30	1790.00					
-25	133.30	666.50	1321.00					
-20	98.88	494.50	984.70					
-15	74.10	370.50	740.80					
-10	56.06	280.30	562.30					
-5	42.80	214.00	430.50					
0	98.96	164.80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

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.

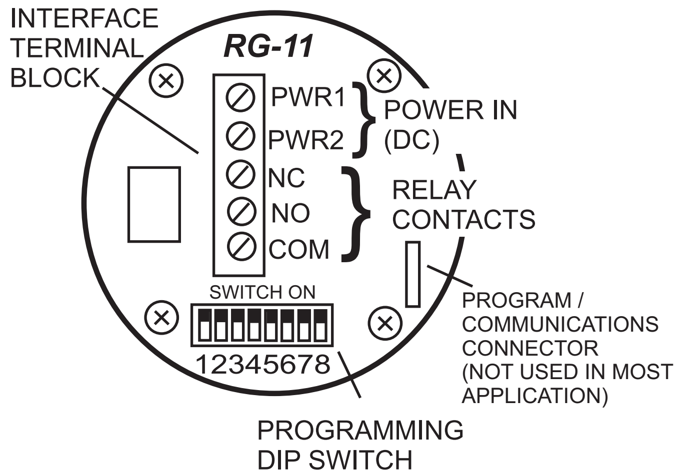
3. Assemble the Rain Gauge as shown.
The silicone O-ring fits nicely in the lens groove, but it can fall or slip out during assembly. After the unit is assembled, verify that the O-ring is properly seated by confirming that you can see it through the lens, all the way around.

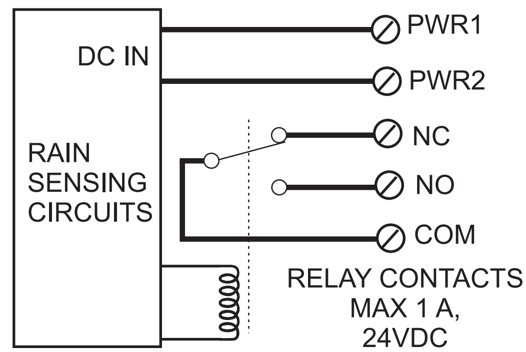
The Rain Gauge must be assembled when dry. Any water trapped inside can condense and cause corrosion. You may optionally add extra desiccant packets (not supplied). If the Rain Gauge is not subject to splashing or sprayed water, you may optionally vent the enclosure by drilling a 1/8” (3 mm) hole in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

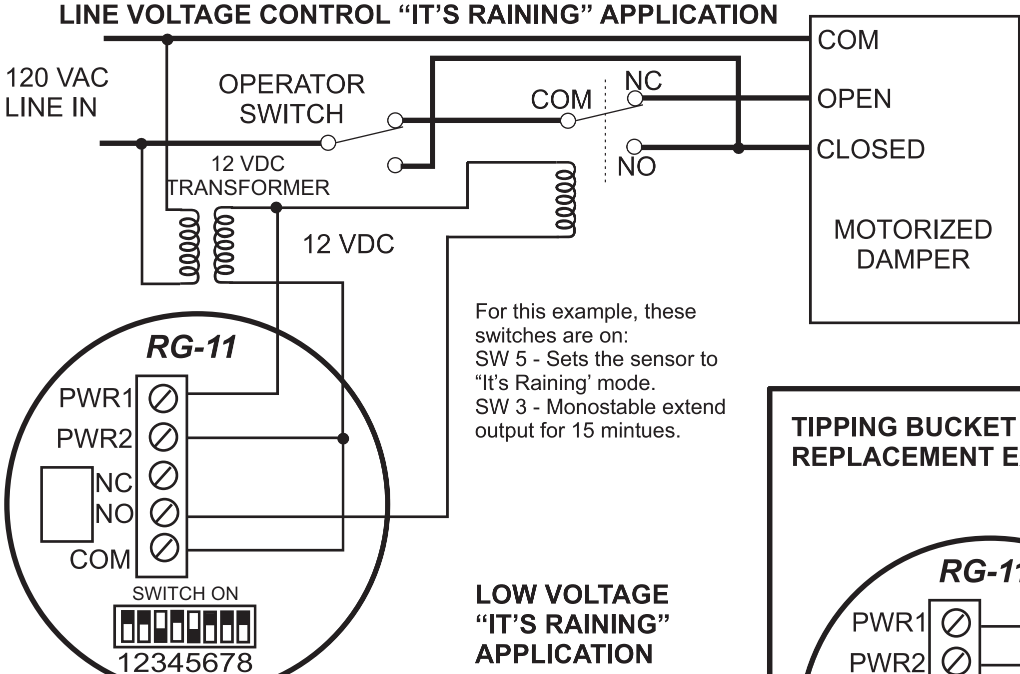




EQUIVALENT SCHEMATIC

RAIN GAUGE WIRING EXAMPLES

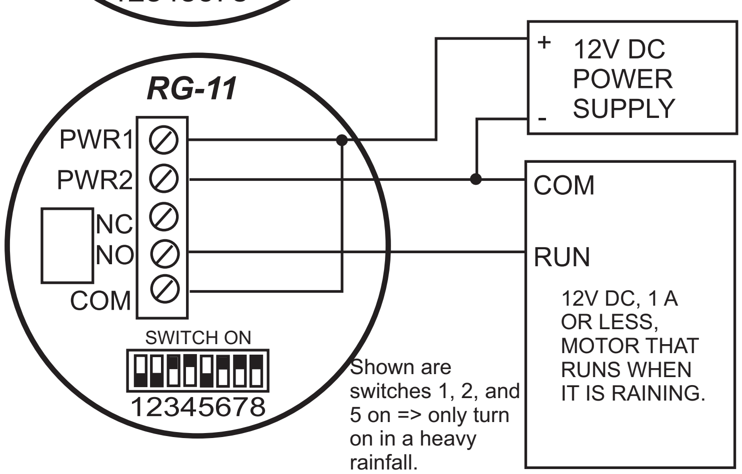
LINE VOLTAGE CONTROL "IT'S RAINING" APPLICATION



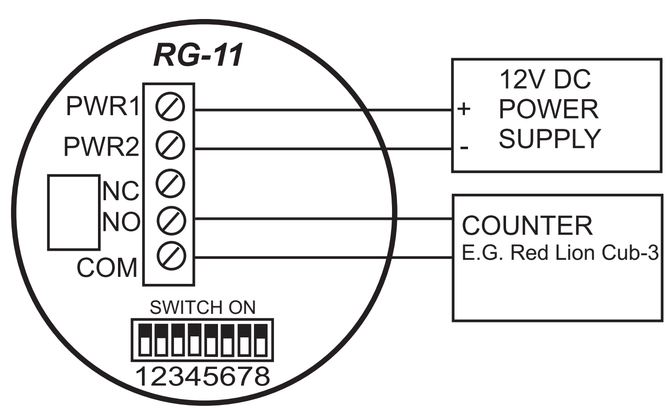
The relay output of the RG-11 is rated for 24VDC, at 1 A. Thus, the RG-11 cannot drive a line voltage (120 VAC) load without an external relay.

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

LOW VOLTAGE "IT'S RAINING" APPLICATION



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								Behavior
8	7	6	5	4	3	2	1	
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							Behavior
7	6	5	4	3	2	1	
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.