Universidad de Costa Rica

Escuela de Ingeniería Eléctrica

IE-0624: Laboratorio de Microcontroladores

Reporte de laboratorio #3: Arduino: GPIO, ADC y comunicaciones

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I-2025

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Introducción

Los Arduinos son tarjetas de desarrollo ampliamente utilizadas por su sencillez y el nivel de abstracción que contiene, lo que permite que cualquier persona con apenas conocer sobre programación, pueda realizar proyectos directamente programados sobre un microcontrolador sin la necesidad de modificar registros, timers, interrupciones o alguna otra de las características más complejas que un dispositivo de este tipo puede poseer. Por ello en este laboratorio se desarrolla un voltímetro de 4 canales, con capacidad de medir tensión tanto en DC como en AC, además de mostrar un mensaje de advertencia cuando la tensión aumenta sobre los 20 V en DC o AC (para la tensión pico). Todo esto haciendo uso de funciones como serial.print() o analogRead(), funciones que permiten una manipulación mas sencilla de las señales. En este informa se muestran las características de el dispositivo desarrollado, la forma en la que se construyó y además la forma en la que se diseñó el programa para poder interpretar las señales de tensión medidas. El repositorio con los archivos base se puede encontrar en: https://github.com/marionabe/LabMicro

Nota teórica

Información general del Arduino

El Arduino UNO es una tarjeta de desarrollo que incorpora un microcontrolador ATMega-328P. Además, la tarjeta incluye un oscilador de cristal de 16MHz, 14 pines digitales y 6 entradas analógicas.

El Arduino Uno incluye también un controlador ADC de 10 bits, lo que permite cuantizar las entradas de tensión de entre 0V y 5V en valores de 0 a 1023.

En la figura 1 se muestra un diagrama de todos los pines del Arduino uno y del microcontrolador que posee.

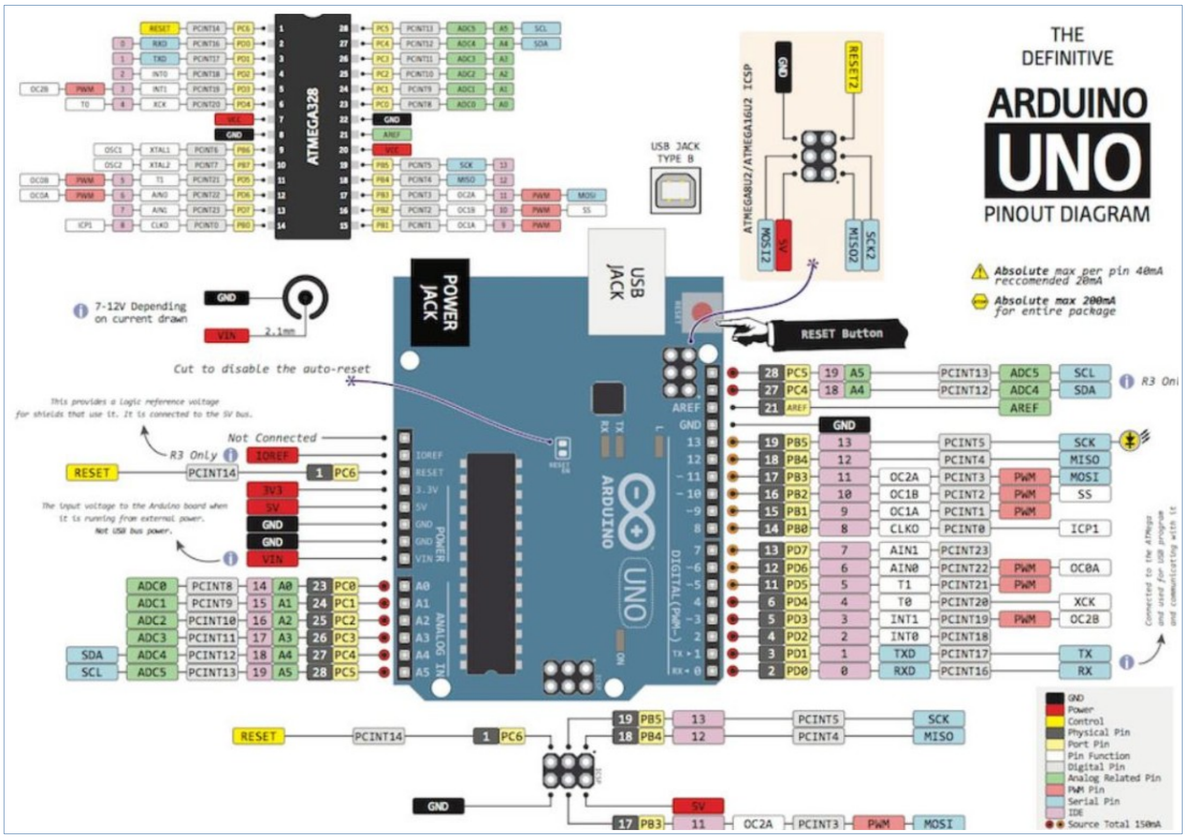


Figura 1: Diagrama de pines y funciones del Arduino Uno.

Aunque este laboratorio se desarrolló en un simulador, es importante conocer los componentes físicos de un Arduino Uno real, por ello en las figuras 2 y 3 se muestra un diagrama con los bloques que componen un tarjeta real.

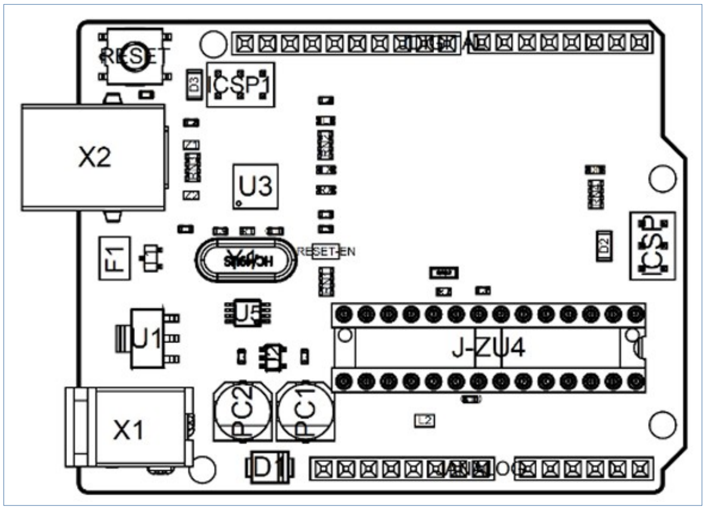


Figura 2: Diagrama de los componentes físicos de un Arduino Uno.

Ref.	Description	Ref.	Description
X1	Power jack 2.1x5.5mm	U1	SPX1117M3-L-5 Regulator
X2	USB B Connector	U3	ATMEGA16U2 Module
PC1	EEE-1EA470WP 25V SMD Capacitor	U5	LMV358LIST-A.9 IC
PC2	EEE-1EA470WP 25V SMD Capacitor	F1	Chip Capacitor, High Density
D1	CGRA4007-G Rectifier	ICSP	Pin header connector (through hole 6)
J-ZU4	ATMEGA328P Module	ICSP1	Pin header connector (through hole 6)
Y1	ECS-160-20-4X-DU Oscillator		

Figura 3: Descripción de los bloques mostrados en la figura 2.

Información general de la pantalla PCD8544.

La pantalla PCD8544 posee una resolución de 48x84 pixeles. Se comunica por una interfaz de 4 pines más la señal de CLK. En la siguiente figura se muestra una descripción de estos pines. Aunque la manipulación de esta pantalla puede resultar compleja, se utilizó una biblioteca que permitió automatizar este proceso, por lo que su utilización se simplificó bastante.

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/$\overline{C}$	data/$\overline{\text{command}}$
$\overline{SCE}$	chip enable
OSC	oscillator
$\overline{RES}$	external reset input
dummy1, 2, 3, 4	not connected

Figura 4: Descripción de los pines de la pantalla. Se marcan en amarillo los pines utilizados en el simulador.

Otros elementos utilizados

Para la implementación de este voltímetro, además del Arduino, fue necesario utilizar algunos elementos pasivos como resistencias e interruptores. Sin embargo, por su simplicidad, estos elementos no requieren de una descripción en este documento.

A continuación se muestra una lista con los elementos utilizados en este laboratorio, la cantidad y el precio aproximado de cada uno

Componente	Cantidad	Precio Total (₡)
Arduino Uno	1	18 240
Pantalla PCD-8544	1	5 800
Resistencias (varias)	21	966
Interruptores	5	950
Total	-	25 956

Diseño del circuito

Para desarrollar la implementación del circuito del voltímetro, lo que se hizo fue realizar dos etapas de divisores de tensión. Una primera etapa permite reducir la tensión de entrada o de medición en un factor de 5, lo que resulta en una tensión de entre -5V a 5V aproximadamente. Esta tensión se suma con una fuente de 5V a modo de off-set, lo que permite tener los valores entre 0V y 10V, luego de lo cual se aplica un segundo divisor de tensión que divide la tensión entre 2, lo que permite a la salida de esta etapa tener tensiones de entre 0V y 5V. A continuación, se muestra una fotografía del circuito implementado, en donde se han señalado las secciones más importantes, las cuales se describen más adelante.

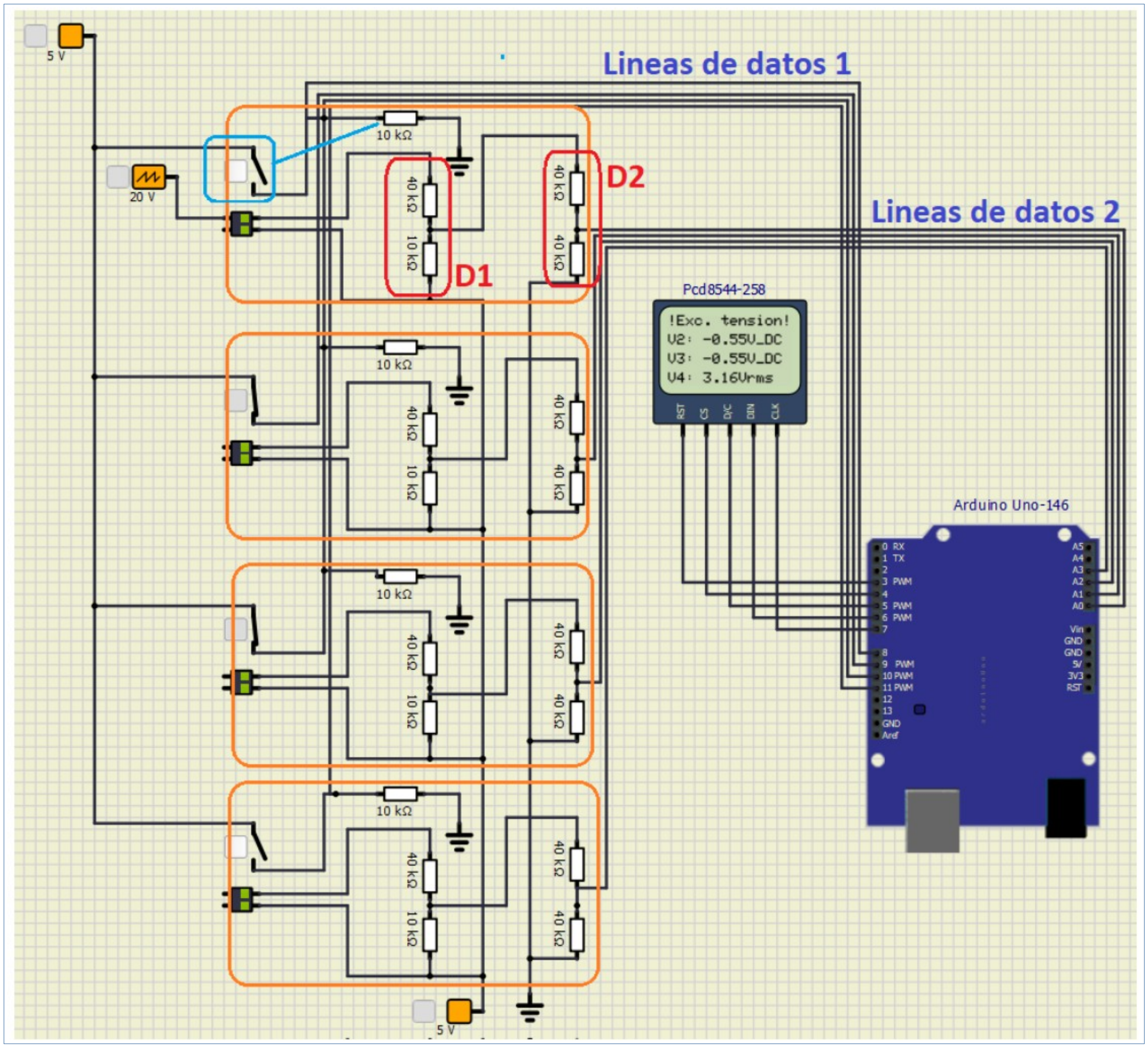


Figura 5: Diagrama del circuito implementado.

La descripción del circuito anterior es la siguiente:

- En los rectángulos anaranjados se muestran los cuatro bloques correspondientes a cada voltímetro. Todos estos rectángulos son similares, por ello solo se detalló el primer voltímetro.
- En dos bloques rojos se muestran los dos divisores de tensión. Marcado con D1 se señala el primer divisor, que reduce la tensión en aproximadamente un factor de 5. Indicado con D2 se señala el segundo divisor, que se encarga de volver a dividir la tensión (que ahora está entre

0V y 10V) en la mitad, para adaptarla a la tensión que puede medir el pin analógico del Arduino.

- Señalado con un rectángulo de color celeste se muestra el interruptor que se usa para seleccionar si la tensión medida es en DC o AC, esto permite enviar una señal de información al Arduino, por medio de los cables marcados como “Líneas de Datos 1”, para decidir cómo tratar los datos. Esto se profundizará más cuando se explique el código implementado.
- La sección marcada como “Líneas de Datos 2” corresponde a los cables que se envían al Arduino con la señal de tensión medida en cada voltímetro.
- También se muestra la pantalla utilizada, en la cual se despliega información sobre las 4 tensiones medidas, y en caso de que la tensión medida sea superior a 20 V, se muestra un mensaje de alerta.
- También se tiene un LED rojo que se activa cuando se detecta una tensión de entrada superior al limite, esta advertencia visual alerta al usuario sobre el peligro por una sobretensión que podría dañar tanto componentes como sistema completo.

Desarrollo y Análisis

Procesamiento de las tensiones medidas

En los pines analógicos del Arduino, se realiza la medición de la tensión luego de la etapa de ajuste de la tensión. Aunque sería posible con base en los valores de las resistencias utilizadas poder calcular directamente la tensión medida con base en la tensión que recibe el Arduino, en la práctica esto generó algunos errores, ya que, debido a posibles imperfecciones o valores no contemplados, resultaba un poco difícil estimar la tensión solo con base en estos valores. Por ello, se hizo uso de una hoja de datos de Excel, en la cual se escribió el valor cuantizado para cada valor de tensión aplicado en las terminales del voltímetro. Esto se realizó para los 49 valores entre -24V y 24V. Con estos datos y haciendo uso de la herramienta “curva de mejor ajuste” se pudo obtener un par de ecuaciones que permiten estimar el valor de tensión en la entrada del circuito con base en el valor cuantizado. Ambas ecuaciones se muestran a continuación:

$$V_{DC\_estimada} = 0{,}0537 * (valor\_cuantizado) - 24{,}926$$

$$V_{AC\_estimada} = 0{,}0538 * (valor\_cuantizado) - 9{,}9656$$

Esta técnica también podría permitir, en una implementación real, obtener una ecuación que tome en cuenta las variaciones en los valores de las resistencias comerciales, así como comportamientos no lineales.

Análisis del programa

A continuación, se detalla el código utilizado para realizar este voltímetro. Para cada voltímetro se utilizó una copia del mismo código, por lo que igualmente se muestra el código correspondiente solo al voltímetro 1.

```
//Decidir si la tensión que se tiene es DC o AC
if (dc_2_en==1){
  //Calcular tensión con base en la fórmula obtenida
  valorMultimetro2=(0.0537*(valorMultimetro2)-24.926);

  //Desplegar info DC
  display.setCursor(0,1*espacioReglones);
  texto = "V2: "+String(valorMultimetro2)+ "V_DC";
  display.println(texto);

} else {
  //Reiniciar el medidor AC
  valorMultimetro2=0;
  // Medir varias veces para encontrar el valor máximo
  for (int i = 0; i<100; i++){
    temp=analogRead(A1);
    if (temp > valorMultimetro2){
      valorMultimetro2 = temp;
    }
  }
  //Calcular la tensión AC pico con base en la fórmula
  valorMultimetro2=0.0538*valorMultimetro2-9.9656;
  //Calcular valor rms de la tensión AC
  valorMultimetro2=0.707*valorMultimetro2-7.065;

  //Desplegar info AC
  display.setCursor(0,1*espacioReglones);
  texto = "V2: "+String(valorMultimetro2)+ "Vrms";
  display.println(texto);
}
```

Figura 6: Primera sección del código del voltímetro.

Descripción del código:

- En la linea 128 se crea un condicional IF que decide si los datos medidos deben ser tratados como en tensión AC o DC.
- En la linea 130, con base en el valor cuantizado, se calcula la tensión que se está midiendo en la entrada del circuito, haciendo uso de la ecuación antes calculada.
- En las líneas 132-135 se despliega la información en pantalla sobre la tensión medida. Para realizar esto se utiliza una biblioteca que permite simplemente indicar donde se desea posicionar el cursor, y escribir texto en esa posición.
- En la linea 137 en adelante se trata el valor cuantizado para una tensión AC.
- En esta sección, primero se reinicia el valor cuantizado, luego se pasa por un bucle en donde se obtiene la mayor tensión medida, es decir, el valor pico de la tensión de entrada. Luego de esto, se utiliza la formula antes encontrada para calcular la tensión pico AC medida, con la cual luego se obtiene el valor Vrms y luego se agrega un pequeño offset que se obtuvo con base en la prueba y error, ya que los valores de tensión medidos no correspondían con la tensión. Estas incongruencias podrían deberse al hecho de no poder separar las tierras de la etapa de medición, por lo que se generan tensiones indeseadas.
- Finalmente, la tensión se imprime, junto a un mensaje indicando que se está midiendo tensión AC.

```
//Imprimir mensaje de peligro por exceso de tensión
  if ((valorMultimetro2>20 || valorMultimetro2 < -20) && dc_2_en){
    delay(20);
    display.clearDisplay();
    texto = "!Exc. tension!";
    display.println(texto);
    delay(4);
  } else if((valorMultimetro2>14.14) && dc_2_en==0){
    delay(20);
    display.clearDisplay();
    texto = "!Exc. tension!";
    display.println(texto);
    delay(4);
  }
```

Figura 7: Segunda sección del código del voltímetro.

En esta segunda sección del código, lo que se hace es imprimir mensajes de advertencia en caso de que la tensión sea menor a -20V o mayor a 20V para DC, o que supere los 14.14Vrms para tensión AC (que corresponde a 20V pico).

En este punto es importante mencionar que el generador de ondas sinusoidales del simulador genera las tensiones sinusoidales a partir de 0, es decir, no las genera de forma simétrica con respecto a 0V, por lo que el comportamiento del voltímetro se calibró con base en este comportamiento.

Aunque era posible modificar el generador para aplicar un off-set que centrara la señal, esto resultaba un poco impráctico ya que era necesario volver a modificarlo cada vez que se cambiaba la tensión.

Análisis electrónico

Partiendo del diseño planteado, la fuente de alimentación proporciona una tensión regulada de 5V necesaria para el funcionamiento del microcontrolador y los demás componentes.

El divisor de tensión cumple la función de adaptar niveles de voltaje mayores a un rango seguro para el microcontrolador, utilizando resistencias seleccionadas para mantener la linealidad y evitar distorsiones en la lectura.

El microcontrolador procesa la señal analógica resultante y determina si el voltaje se encuentra dentro de un rango normal o en estado de alerta, en particular el LED rojo adicional actúa como señal de advertencia visual ante una condición de sobretensión.

El display de 7 segmentos recibe la información procesada y muestra los valores de tensión en tiempo real, gracias a la conversión analógico-digital realizada por el microcontrolador.

Muestra de funcionamiento

En la siguiente figura se muestra el funcionamiento de todos los voltímetros para diferentes situaciones.

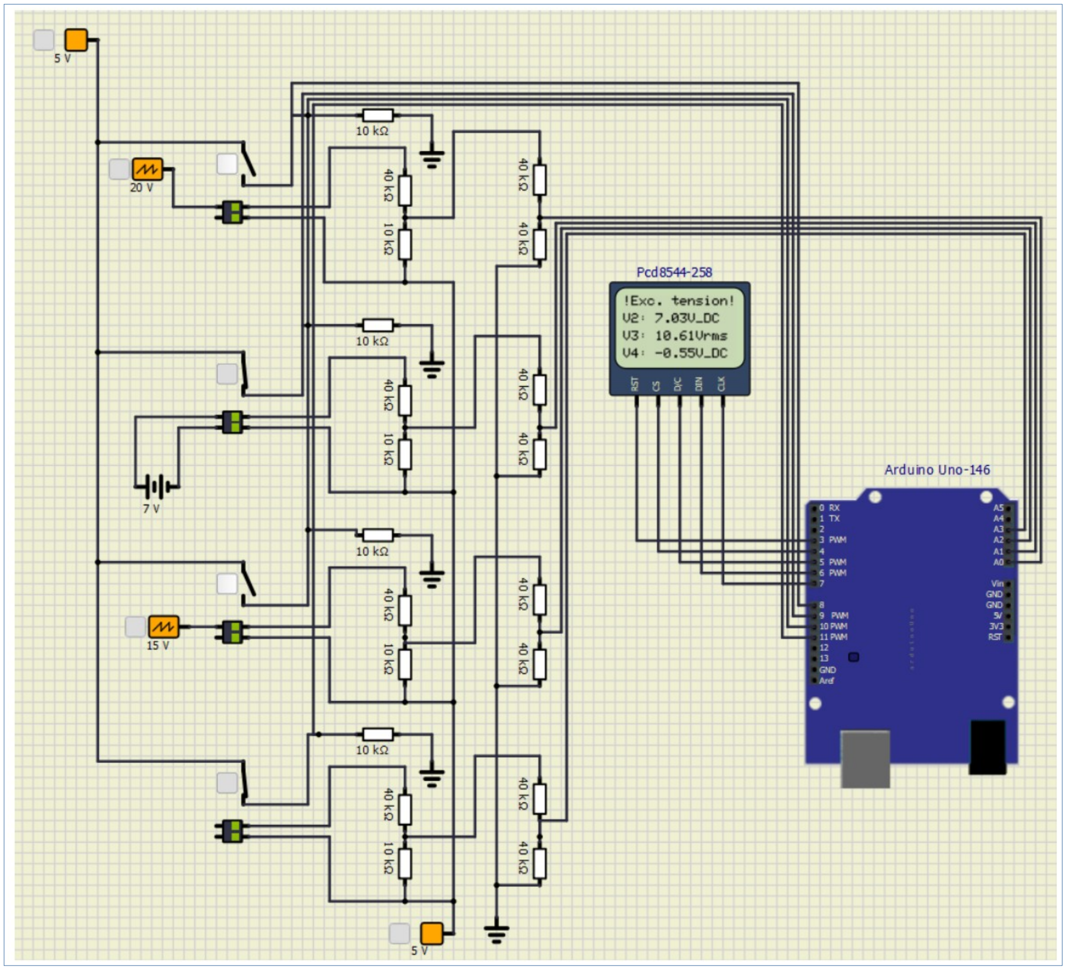


Figura 8: Muestra del funcionamiento del voltímetro

En la imagen anterior se puede observar lo siguiente:

- Para el primer voltímetro (el de la parte superior) se establece una señal sinusoidal con una frecuencia de 60 Hz y una tensión pico de 20V. Se puede observar que en la pantalla se muestra un mensaje de alerta indicando exceso de tensión. Mientras se mantenga este nivel de tensión la pantalla intercambiará entre el mensaje de advertencia y los datos de la medición.

- En el voltímetro 2 se colocó una batería con una tensión de 7V. Se puede ver en la pantalla que se muestra la tensión medida con un pequeño margen de error, además de indicar que se está midiendo en DC. Es importante observar que para este caso el switch se cerró, para indicarle al Arduino que se va a medir tensión DC.

- En el voltímetro 3, se aplicó una tensión AC, pero por debajo del umbral de peligro, por lo que se puede ver que en la pantalla se muestra el valor Vrms de la tensión correspondiente.

- Finalmente, el voltímetro 4 se dejó sin tensión, y se puede observar que en la pantalla se muestra una tensión diferente a 0, correspondiente a un pequeño margen de error de la medición, pero que se puede aproximar como 0V. Es importante mencionar que esto solo sucede cuando se deja la tensión “flotando” ya que, si se agrega una tensión muy pequeña, como 0.10V, el voltímetro igualmente es capaz de medirla, tal como se muestra en la siguiente figura.

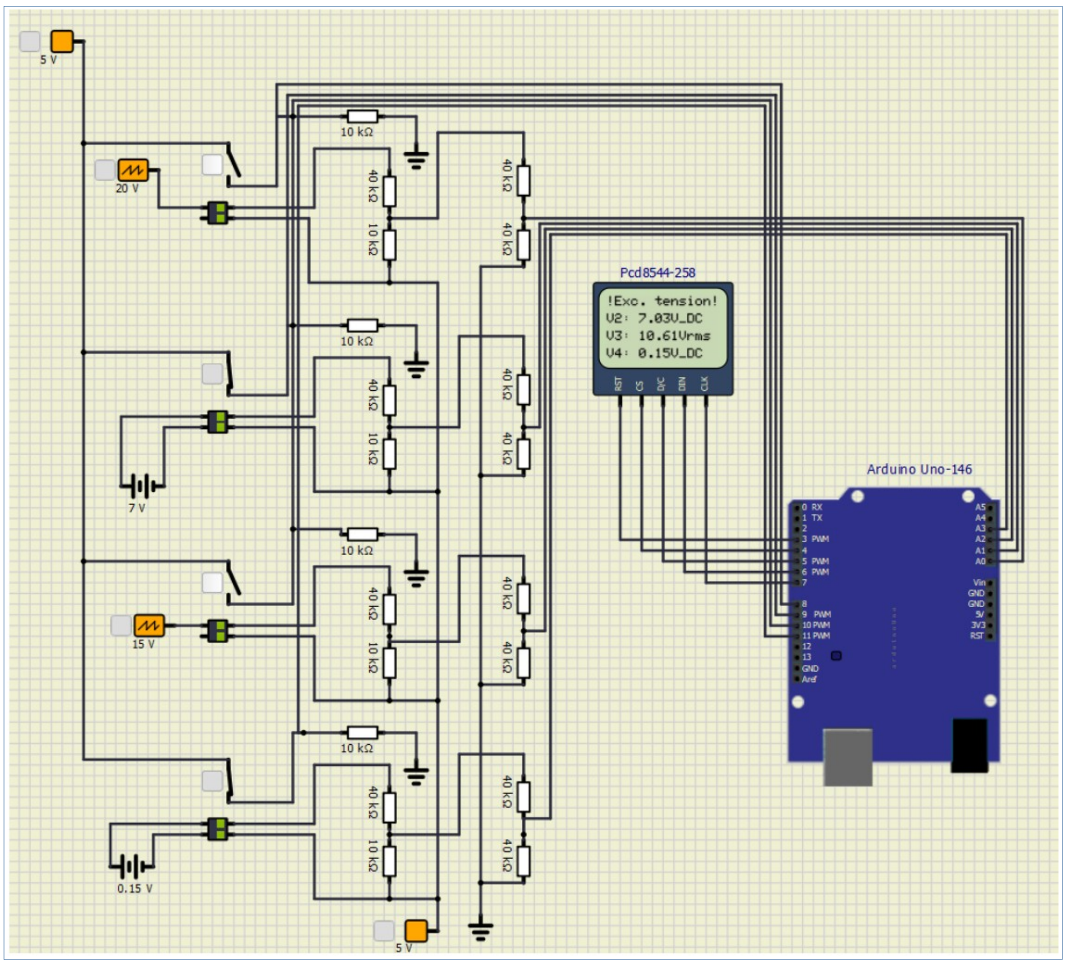


Figura 9: Muestra de que tensiones pequeñas como 0.15V son medidas de forma correcta por el Arduino.

Igualmente, el comportamiento anterior de medición se puede dar para tensiones negativas, en cuyo caso el Arduino muestra en pantalla el valor de la tensión, pero con el signo negativo. También se puede notar, que, debido a los altos valores de las resistencias, el consumo de corriente por parte del sistema del voltímetro es muy bajo, del orden de µA, lo cual es un requisito de un buen voltímetro.

Envío de datos a archivo CSV

Luego de tener todo el circuito del voltímetro completado, se procede a realizar la etapa de envío de datos desde el simulador hasta un archivo CSV, a continuación, se detalla cada parte del proceso. Lo primero que se realiza es agregar un interruptor que permite habilitar o deshabilitar el envío de datos por el puerto serial del Arduino. En la siguiente figura se muestra el switch implementado.

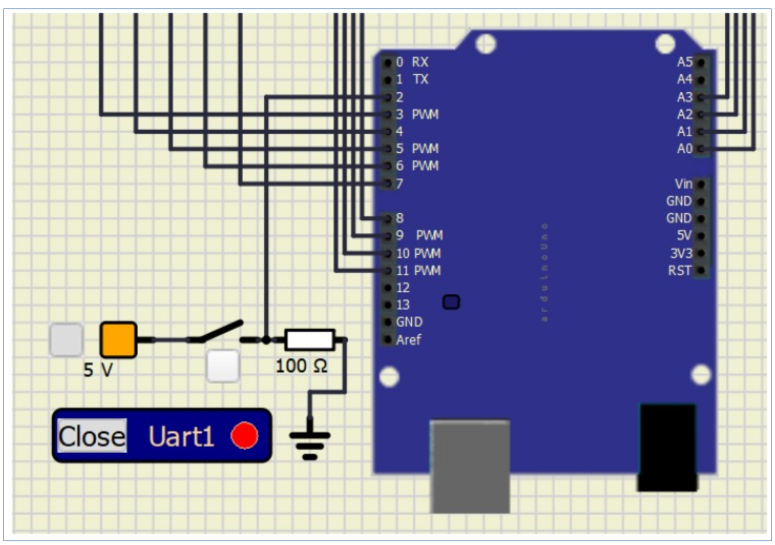


Figura 10: Switch agregado para controlar comunicaciones por UART.

Con este switch, se agrega un pequeño código en el programa del Arduino, que permite habilitar la comunicación con base en el estado del switch.

```
uart_en=digitalRead(2);
if (uart_en==1){
  //Enviar info a pc
  texto_uart=String(valorMultimetro1)+" "+String(valorMultimetro2)+" "+String(valorMultimetro3)+" "+String(valorMultimetro4);
  Serial.println(texto_uart);
}
```

Figura 11: Código del Arduino para controlar envío de datos.

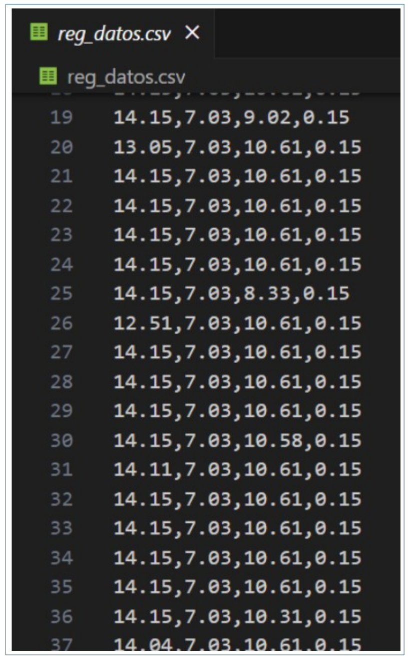
En la figura anterior se muestra el código utilizado para el envío de los datos. Básicamente lo que se realiza es crear una cadena de texto que contiene el valor de los 4 voltímetros, y este texto se envía luego por el puerto serial. Todo esto se realiza únicamente si el switch está cerrado.

Luego de esto, se crea el puerto serial virtual, tal como lo indica el profesor. Y del otro lado del puerto se crea un pequeño script en Python que se encarga de leerlo y cargar los datos a un documento CSV, tal como se muestra a continuación.

```python
import serial
import csv

puerto_serial = serial.Serial('COM3', 9600, timeout=1)

while True:
    """ if puerto_serial.in_waiting > 0:"""
    voltajes = puerto_serial.readline().decode('utf-8').rstrip()
    print(voltajes + "\n")
    voltajes = voltajes.split()

    with open('reg_datos.csv', mode='a', newline='') as reg_datos:

        writer = csv.writer(reg_datos)
        writer.writerow(voltajes)
```

Figura 12: Script de Python para el procesamiento de los datos.

En la figura anterior, se puede observar que el script es bastante sencillo. Su función es leer el puerto serial y decodificar los datos como una cadena de texto, luego esta linea de texto se separa por el símbolo espacio, para generar una lista que contiene en sus cuatro posiciones los valores de las tensiones medidas. Finalmente, el script abre el archivo “reg_datos.csv”, en donde agrega la lista que se acaba de crear. Con esto es posible guardar constantemente los valores en el documento, en donde cada columna corresponde al valor de la tensión medida.



reg_datos.csv

reg_datos.csv

```
14.15,7.03,9.02,0.15
13.05,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,8.33,0.15
12.51,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.58,0.15
14.11,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.61,0.15
14.15,7.03,10.31,0.15
14.04,7.03,10.61,0.15
```

Figura 13: Archivo CSV con los valores de la tensión medida.

Finalmente, en la figura anterior se muestra el resultado obtenido. Se puede observar que el script guarda correctamente los valores medidos, lo que permite generar un registro de los valores, para luego poder procesarlos como se desee desde el archivo creado.

Conclusiones y Recomendaciones

- Se logró crear el voltímetro de forma exitosa, solucionando problemas como los de las tierras compartidas.
- El uso de un script de Python permite llevar un registro de los datos registrados en el Arduino. Este mecanismo se pudo implementar de forma exitosa, y demostrar de forma sencilla el potencial de esta herramienta.
- Se pudo controlar de forma correcta la pantalla utilizada, esto mediante el uso de una librería que permitió un gran nivel de abstracción, permitiendo una mejor manipulación de los datos mostrados.
- La incorporación de un LED de peligro para señalizar valores de sobretensión añade un componente preventivo que mejora la seguridad operativa.

Bibliografía

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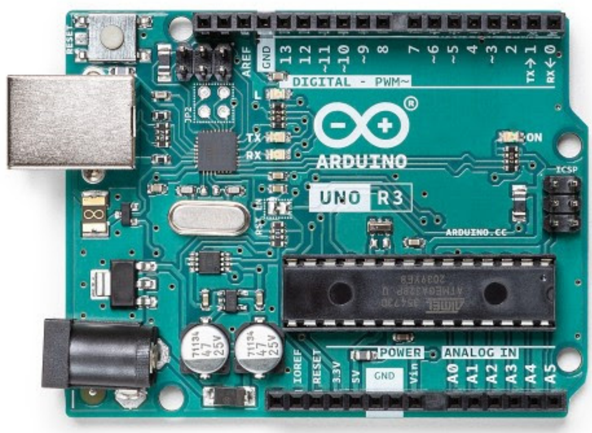
Apéndices

User Manual
SKU: A000066



Description

The Arduino® UNO R3 is the perfect board to get familiar with electronics and coding. This versatile development board is equipped with the well-known ATmega328P and the ATMega 16U2 Processor.

This board will give you a great first experience within the world of Arduino.

Target areas:

Maker, introduction, industries

Features

- **ATMega328P** Processor
  - **Memory**
    - AVR CPU at up to 16 MHz
    - 32 kB Flash
    - 2 kB SRAM
    - 1 kB EEPROM
  - **Security**
    - Power On Reset (POR)
    - Brown Out Detection (BOD)
  - **Peripherals**
    - 2x 8-bit Timer/Counter with a dedicated period register and compare channels
    - 1x 16-bit Timer/Counter with a dedicated period register, input capture and compare channels
    - 1x USART with fractional baud rate generator and start-of-frame detection
    - 1x controller/peripheral Serial Peripheral Interface (SPI)
    - 1x Dual mode controller/peripheral I2C
    - 1x Analog Comparator (AC) with a scalable reference input
    - Watchdog Timer with separate on-chip oscillator
    - Six PWM channels
    - Interrupt and wake-up on pin change
  - **ATMega16U2 Processor**
    - 8-bit AVR® RISC-based microcontroller
  - **Memory**
    - 16 kB ISP Flash
    - 512B EEPROM
    - 512B SRAM
    - debugWIRE interface for on-chip debugging and programming
  - **Power**
    - 2.7-5.5 volts

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1 The Board

1.1 Application Examples

The UNO board is the flagship product of Arduino. Regardless if you are new to the world of electronics or will use the UNO R3 as a tool for education purposes or industry-related tasks, the UNO R3 is likely to meet your needs.

First entry to electronics: If this is your first project within coding and electronics, get started with our most used and documented board; UNO. It is equipped with the well-known ATmega328P processor, 14 digital input/output pins, 6 analog inputs, USB connections, ICSP header and reset button. This board includes everything you will need for a great first experience with Arduino.

Industry-standard development board: Using the UNO R3 board in industries, there are a range of companies using the UNO R3 board as the brain for their PLC’s.

Education purposes: Although the UNO R3 board has been with us for about ten years, it is still widely used for various education purposes and scientific projects. The board's high standard and top quality performance makes it a great resource to capture real time from sensors and to trigger complex laboratory equipment to mention a few examples.

1.2 Related Products

- Arduino Starter Kit
- Arduino UNO R4 Minima
- Arduino UNO R4 WiFi
- Tinkerkit Braccio Robot

2 Ratings

2.1 Recommended Operating Conditions

Symbol	Description	Min	Max
	Conservative thermal limits for the whole board:	-40 °C (-40 °F)	85 °C (185 °F)

NOTE: In extreme temperatures, EEPROM, voltage regulator, and the crystal oscillator, might not work as expected.

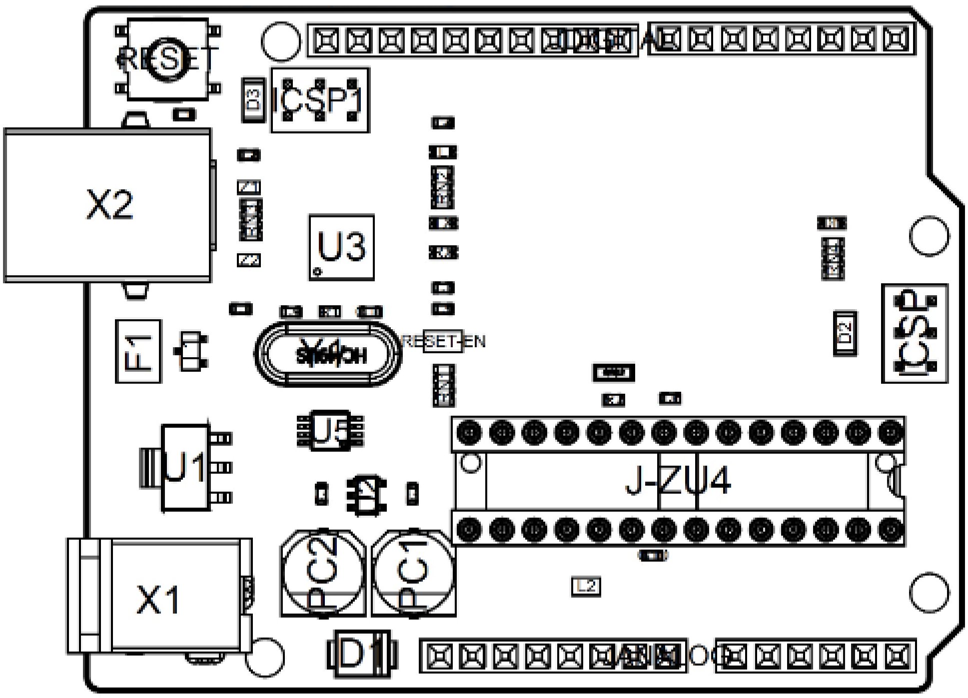
2.2 Power Consumption

Symbol	Description	Min	Typ	Max	Unit
VINMax	Maximum input voltage from VIN pad	6	-	20	V
VUSBMax	Maximum input voltage from USB connector		-	5.5	V
PMax	Maximum Power Consumption	-	-	xx	mA

3 Functional Overview

3.1 Board Topology

Top view



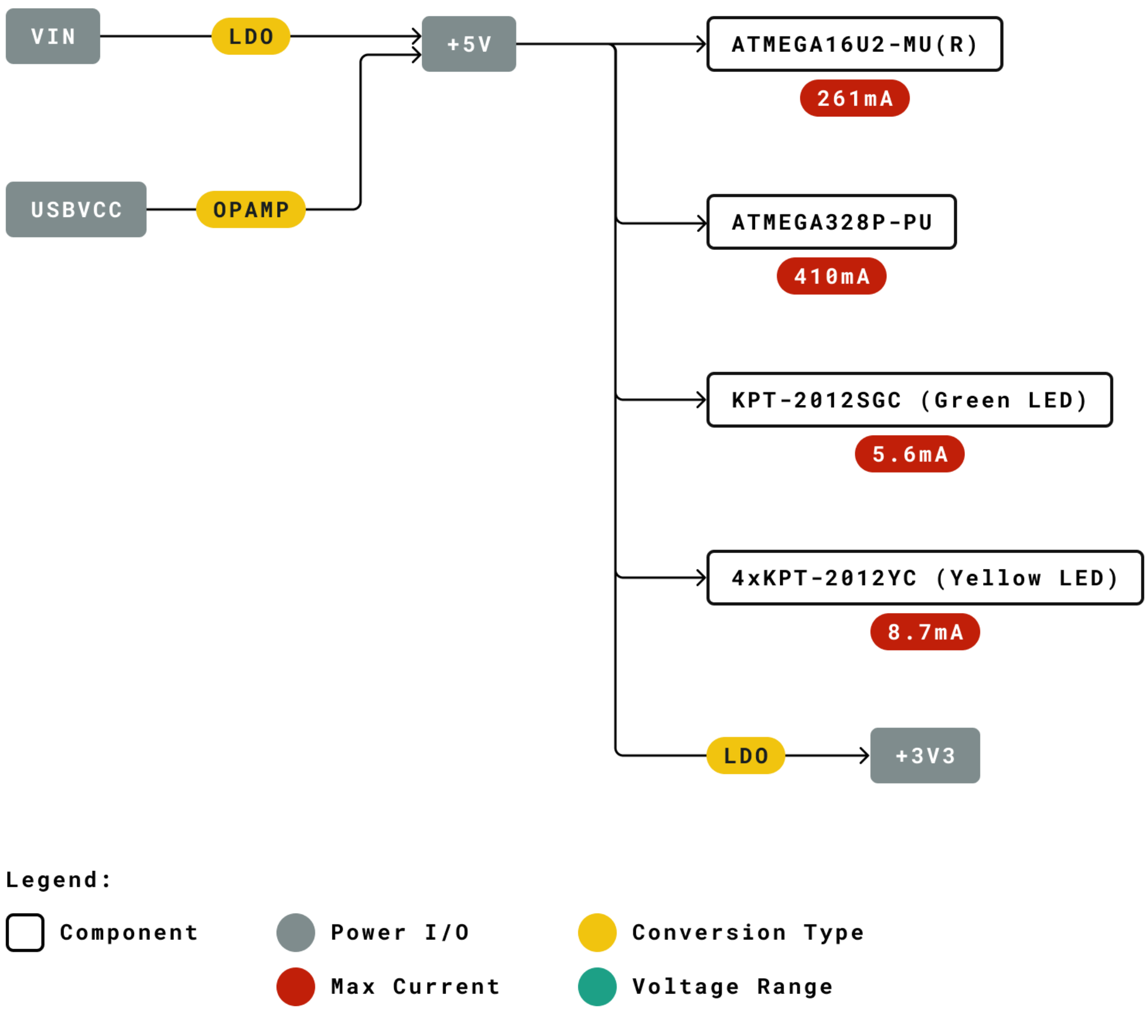
Board topology

Ref.	Description	Ref.	Description
X1	Power jack 2.1x5.5mm	U1	SPX1117M3-L-5 Regulator
X2	USB B Connector	U3	ATMEGA16U2 Module
PC1	EEE-1EA470WP 25V SMD Capacitor	U5	LMV358LIST-A.9 IC
PC2	EEE-1EA470WP 25V SMD Capacitor	F1	Chip Capacitor, High Density
D1	CGRA4007-G Rectifier	ICSP	Pin header connector (through hole 6)
J-ZU4	ATMEGA328P Module	ICSP1	Pin header connector (through hole 6)
Y1	ECS-160-20-4X-DU Oscillator		

3.2 Processor

The Main Processor is a ATmega328P running at up to 20 MHz. Most of its pins are connected to the external headers, however some are reserved for internal communication with the USB Bridge coprocessor.

3.3 Power Tree



Power tree

4 Board Operation

4.1 Getting Started - IDE

If you want to program your UNO R3 while offline you need to install the Arduino Desktop IDE [1] To connect the UNO R3 to your computer, you'll need a USB-B cable. This also provides power to the board, as indicated by the LED.

4.2 Getting Started - Arduino Cloud Editor

All Arduino boards, including this one, work out-of-the-box on the Arduino Cloud Editor [2], by just installing a simple plugin.

The Arduino Cloud Editor is hosted online, therefore it will always be up-to-date with the latest features and support for all boards. Follow **[3]** to start coding on the browser and upload your sketches onto your board.

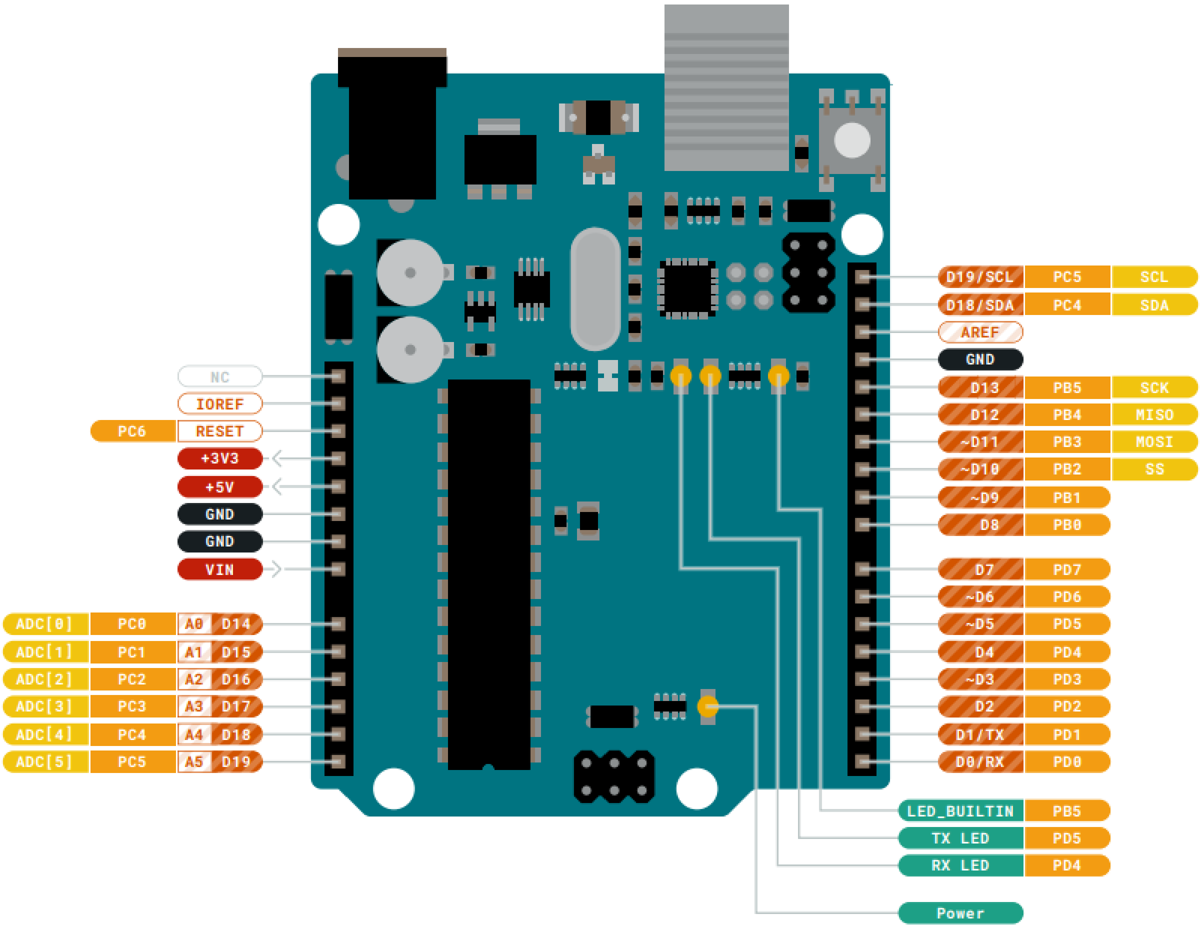
4.3 Sample Sketches

Sample sketches for the UNO R3 can be found either in the "Examples" menu in the Arduino IDE or in the "Documentation" section of the Arduino website [4].

4.4 Online Resources

Now that you have gone through the basics of what you can do with the board you can explore the endless possibilities it provides by checking exciting projects on Arduino Project Hub [5], the Arduino Library Reference [6] and the online Arduino store [7] where you will be able to complement your board with sensors, actuators and more.

5 Connector Pinouts



Pinout

5.1 JANALOG

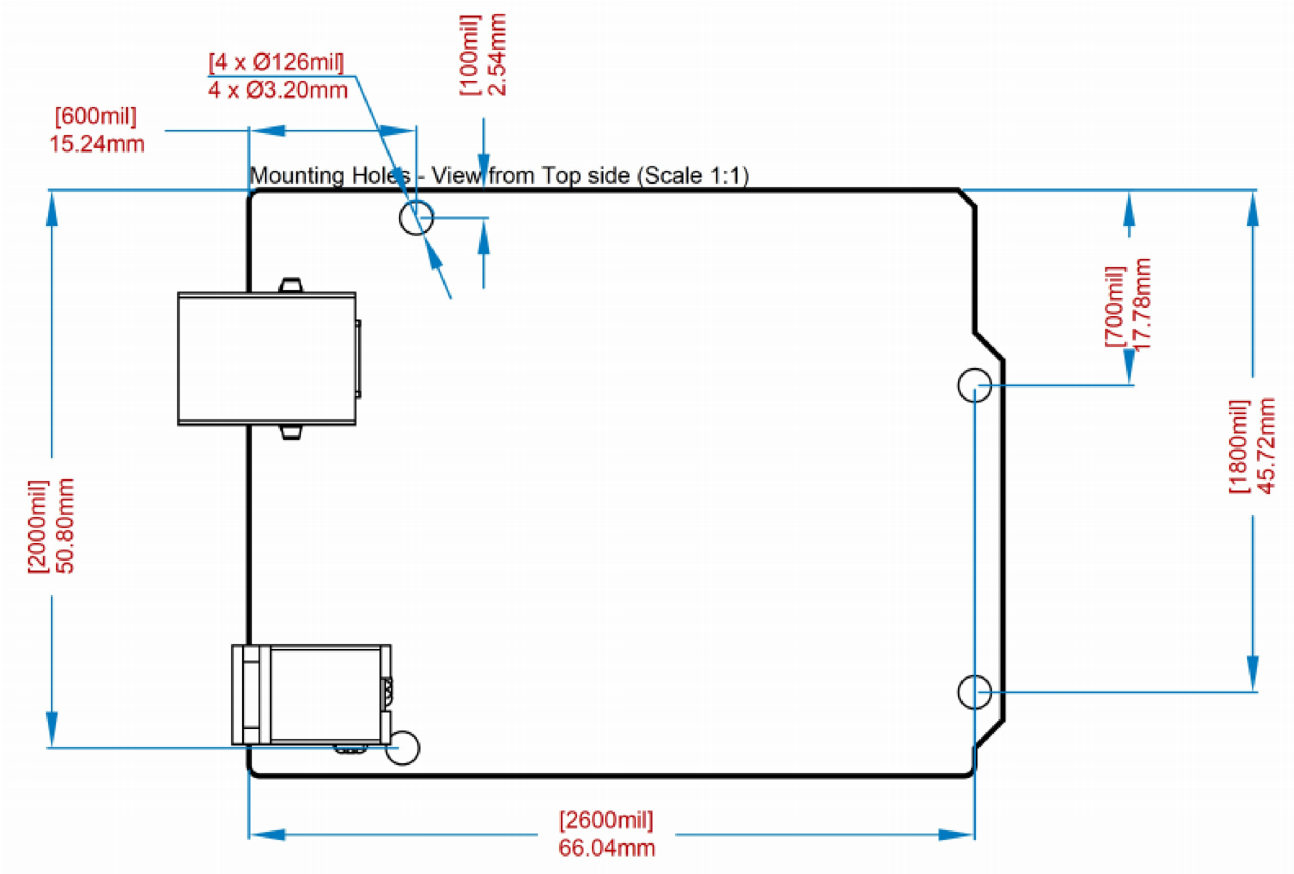
Pin	Function	Type	Description
1	NC	NC	Not connected
2	IOREF	IOREF	Reference for digital logic V - connected to 5V
3	Reset	Reset	Reset
4	+3V3	Power	+3V3 Power Rail
5	+5V	Power	+5V Power Rail
6	GND	Power	Ground
7	GND	Power	Ground
8	VIN	Power	Voltage Input
9	A0	Analog/GPIO	Analog input 0 /GPIO
10	A1	Analog/GPIO	Analog input 1 /GPIO
11	A2	Analog/GPIO	Analog input 2 /GPIO
12	A3	Analog/GPIO	Analog input 3 /GPIO
13	A4/SDA	Analog input/I2C	Analog input 4/I2C Data line
14	A5/SCL	Analog input/I2C	Analog input 5/I2C Clock line

5.2 JDIGITAL

Pin	Function	Type	Description
1	D0	Digital/GPIO	Digital pin 0/GPIO
2	D1	Digital/GPIO	Digital pin 1/GPIO
3	D2	Digital/GPIO	Digital pin 2/GPIO
4	D3	Digital/GPIO	Digital pin 3/GPIO
5	D4	Digital/GPIO	Digital pin 4/GPIO
6	D5	Digital/GPIO	Digital pin 5/GPIO
7	D6	Digital/GPIO	Digital pin 6/GPIO
8	D7	Digital/GPIO	Digital pin 7/GPIO
9	D8	Digital/GPIO	Digital pin 8/GPIO
10	D9	Digital/GPIO	Digital pin 9/GPIO
11	SS	Digital	SPI Chip Select
12	MOSI	Digital	SPI1 Main Out Secondary In
13	MISO	Digital	SPI Main In Secondary Out
14	SCK	Digital	SPI serial clock output
15	GND	Power	Ground
16	AREF	Digital	Analog reference voltage
17	A4/SD4	Digital	Analog input 4/I2C Data line (duplicated)
18	A5/SD5	Digital	Analog input 5/I2C Clock line (duplicated)

5.3 Mechanical Information

5.4 Board Outline & Mounting Holes



Board outline

6 Certifications

6.1 Declaration of Conformity CE DoC (EU)

We declare under our sole responsibility that the products above are in conformity with the essential requirements of the following EU Directives and therefore qualify for free movement within markets comprising the European Union (EU) and European Economic Area (EEA).

ROHS 2 Directive 2011/65/EU	
Conforms to:	EN50581:2012
Directive 2014/35/EU. (LVD)	
Conforms to:	EN 60950-1:2006/A11:2009/A1:2010/A12:2011/AC:2011
Directive 2004/40/EC & 2008/46/EC & 2013/35/EU, EMF	
Conforms to:	EN 62311:2008

6.2 Declaration of Conformity to EU RoHS & REACH 211 01/19/2021

Arduino boards are in compliance with RoHS 2 Directive 2011/65/EU of the European Parliament and RoHS 3 Directive 2015/863/EU of the Council of 4 June 2015 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Substance	Maximum limit (ppm)
Lead (Pb)	1000
Cadmium (Cd)	100
Mercury (Hg)	1000
Hexavalent Chromium (Cr6+)	1000
Poly Brominated Biphenyls (PBB)	1000
Poly Brominated Diphenyl ethers (PBDE)	1000
Bis(2-Ethylhexyl} phthalate (DEHP)	1000
Benzyl butyl phthalate (BBP)	1000
Dibutyl phthalate (DBP)	1000
Diisobutyl phthalate (DIBP)	1000

Exemptions: No exemptions are claimed.

Arduino Boards are fully compliant with the related requirements of European Union Regulation (EC) 1907 /2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). We declare none of the SVHCs (https://echa.europa.eu/web/guest/candidate-list-table), the Candidate List of Substances of Very High Concern for authorization currently released by ECHA, is present in all products (and also package) in quantities totaling in a concentration equal or above 0.1%. To the best of our knowledge, we also declare that our products do not contain any of the substances listed on the "Authorization List" (Annex XIV of the REACH regulations) and Substances of Very High Concern (SVHC) in any significant amounts as specified by the Annex XVII of Candidate list published by ECHA (European Chemical Agency) 1907 /2006/EC.

6.3 Conflict Minerals Declaration

As a global supplier of electronic and electrical components, Arduino is aware of our obligations with regards to laws and regulations regarding Conflict Minerals, specifically the Dodd-Frank Wall Street Reform and Consumer Protection Act, Section 1502. Arduino does not directly source or process conflict minerals such as Tin, Tantalum, Tungsten, or Gold. Conflict minerals are contained in our products in the form of solder, or as a component in metal alloys. As part of our reasonable due diligence Arduino has contacted component suppliers within our supply chain to verify their continued compliance with the regulations. Based on the information received thus far we declare that our products contain Conflict Minerals sourced from conflict-free areas.

7 FCC Caution

Any Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference

(2) this device must accept any interference received, including interference that may cause undesired operation.

FCC RF Radiation Exposure Statement:

1. This Transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.
2. This equipment complies with RF radiation exposure limits set forth for an uncontrolled environment.
3. This equipment should be installed and operated with minimum distance 20cm between the radiator & your body.

English: User manuals for license-exempt radio apparatus shall contain the following or equivalent notice in a conspicuous location in the user manual or alternatively on the device or both. This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions:

(1) this device may not cause interference

(2) this device must accept any interference, including interference that may cause undesired operation of the device.

French: Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes :

(1) l' appareil nedoit pas produire de brouillage

(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

IC SAR Warning:

English This equipment should be installed and operated with minimum distance 20 cm between the radiator and your body.

French: Lors de l' installation et de l' exploitation de ce dispositif, la distance entre le radiateur et le corps est d 'au moins 20 cm.

Important: The operating temperature of the EUT can't exceed 85℃ and shouldn't be lower than -40℃.

Hereby, Arduino S.r.l. declares that this product is in compliance with essential requirements and other relevant provisions of Directive 2014/53/EU. This product is allowed to be used in all EU member states.

8 Company Information

Company name	Arduino S.r.l
Company Address	Via Andrea Appiani 25 20900 MONZA Italy

9 Reference Documentation

Reference	Link
Arduino IDE (Desktop)	https://www.arduino.cc/en/Main/Software
Arduino Cloud Editor	https://create.arduino.cc/editor
Arduino Cloud Editor - Getting Started	https://docs.arduino.cc/arduino-cloud/guides/editor/
Arduino Website	https://www.arduino.cc/
Arduino Project Hub	https://create.arduino.cc/projecthub?by=part&part_id=11332&sort=trending
Library Reference	https://www.arduino.cc/reference/en/
Arduino Store	https://store.arduino.cc/

10 Revision History

Date	Revision	Changes
25/04/2024	3	Updated link to new Cloud Editor
26/07/2023	2	General Update
06/2021	1	Datasheet release

中文（ZH）

描述

Arduino UNO R3 是熟悉电子技术和编码的完美开发板。这款多功能开发板配备了著名的 ATmega328P 和 ATMega 16U2 处理器。该开发板将为您带来 Arduino 世界绝佳的初次体验。

目标领域：

创客、介绍、工业领域

特点

- **ATMega328P** 处理器
    - **内存**
        - AVR CPU 频率高达 16 MHz
        - 32KB 闪存
        - 2KB SRAM
        - 1KB EEPROM
    - **安全性**
        - 上电复位 (POR)
        - 欠压检测 (BOD)
    - **外设**
        - 2x 8 位定时器/计数器，带专用周期寄存器和比较通道
        - 1x 16 位定时器/计数器，带专用周期寄存器、输入捕获和比较通道
        - 1x USART，带分数波特率发生器和起始帧信号检测功能
        - 1x 控制器/外设串行外设接口 (SPI)
        - 1x 双模控制器/外设 I2C
        - 1 个模拟比较器 (AC)，带可扩展参考输入
        - 看门狗定时器，带独立的片上振荡器
        - 6 通道 PWM
        - 引脚变化时的中断和唤醒
    - **ATMega16U2 处理器**
        - 基于 AVR® RISC 的 8 位微控制器
    - **内存**
        - 16 KB ISP 闪存
        - 512B EEPROM
        - 512B SRAM

    - 用于片上调试和编程的 debugWIRE 接口
- **电源**
    - 2.7-5.5 伏特

目录

11 电路板简介

11.1 应用示例

UNO 电路板是 Arduino 的旗舰产品。无论您是初次接触电路板产品，还是将 UNO 用作教育或工业相关任务的工具，UNO 都能满足您的需求。

初次接触电子技术: 如果这是您第一次参与编码和电子技术项目，那么就从我们最常用、记录最多的电路板 Arduino UNO 开始吧。它配备了著名的 ATmega328P 处理器、14 个数字输入/输出引脚、6 个模拟输入、USB 连接、ICSP 接头和复位按钮。该电路板包含了您获得良好的 Arduino 初次体验所需的一切。

** 行业标准开发板:** 在工业领域使用 Arduino UNO R3 开发板，有许多公司使用 UNO 开发板作为其 PLC 的大脑。

教育用途: 尽管我们推出 UNO R3 电路板已有大约十年之久，但它仍被广泛用于各种教育用途和科学项目。该电路板的高标准和一流性能使其成为从传感器采集实时数据和触发复杂实验室设备等各种应用场合的绝佳资源。

11.2 相关产品

- Starter Kit
- Arduino UNO R4 Minima
- Arduino UNO R4 WiFi
- Tinkerkit Braccio Robot

12 额定值

12.1 建议运行条件

符号	描述	最小值	最大值
	整个电路板的保守温度极限值:	-40 °C (-40°F)	85 °C (185°F)

注意： 在极端温度下，EEPROM、电压调节器和晶体振荡器可能无法正常工作。

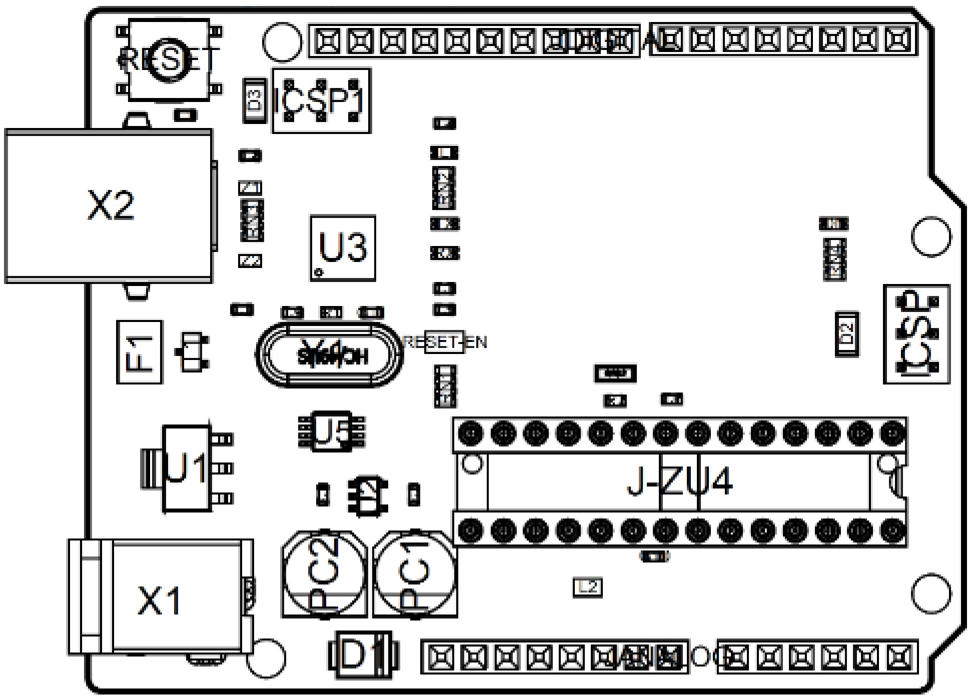
12.2 功耗

符号	描述	最小值	典型值	最大值	单位
VINMax	来自 VIN 焊盘的最大输入电压	6	-	20	V
VUSBMax	来自 USB 连接器的最大输入电压		-	5.5	V
PMax	最大功耗	-	-	xx	mA

13 功能概述

13.1 电路板拓扑结构

俯视图



电路板拓扑结构

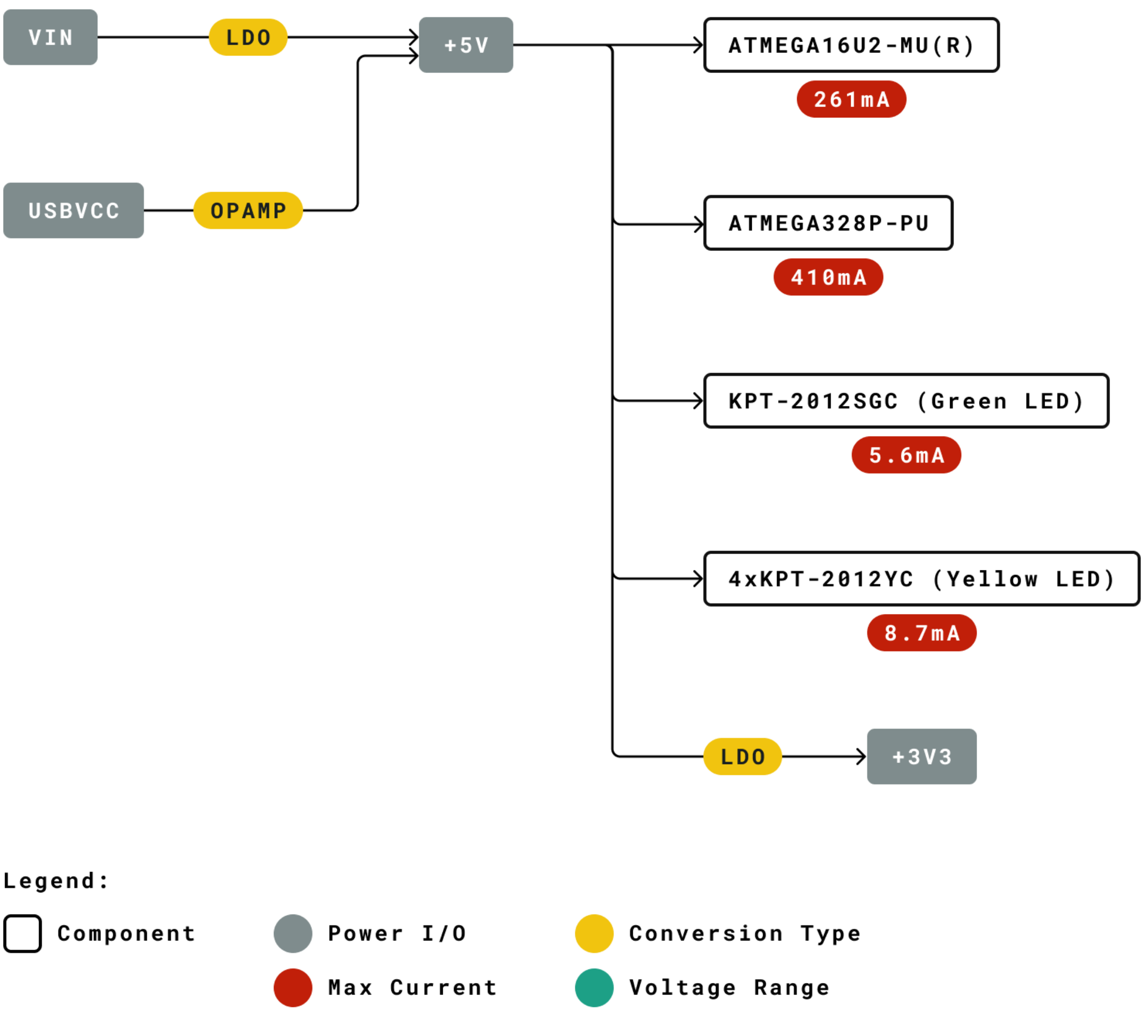
编号	描述	编号	描述
X1	电源插孔 2.1x5.5 毫米	U1	SPX1117M3-L-5 调节器

编号	描述	编号	描述
X2	USB B 连接器	U3	ATMEGA16U2 模块
PC1	EEE-1EA470WP 25V SMD 电容器	U5	LMV358LIST-A.9 IC
PC2	EEE-1EA470WP 25V SMD 电容器	F1	片式电容器，高密度
D1	CGRA4007-G 整流器	ICSP	引脚接头连接器（通过 6 号孔）
J-ZU4	ATMEGA328P 模块	ICSP1	引脚接头连接器（通过 6 号孔）
Y1	ECS-160-20-4X-DU 振荡器		

13.2 处理器

主处理器是 ATmega328P，运行频率高达 20 MHz。它的大部分引脚都与外部接头相连，但也有一些引脚用于与 USB 桥协处理器进行内部通信。

13.3 电源树



电源树

14 电路板操作

14.1 入门指南 - IDE

如需在离线状态下对 Arduino UNO R3 进行编程，则需要安装 Arduino Desktop IDE [1] 若要将 Arduino UNO 连接到计算机，需要使用 USB-B 电缆。如 LED 指示灯所示，该电缆还可以为电路板供电。

14.2 入门指南 - Arduino Cloud Editor

包括本电路板在内的所有 Arduino 电路板，都可以在 Arduino Cloud Editor [2] 上开箱即用，只需安装一个简单的插件即可。

Arduino Cloud Editor 是在线托管的，因此它将始终提供最新功能并支持所有电路板。接下来**[3]**开始在浏览器上编码并将程序上传到您的电路板上。

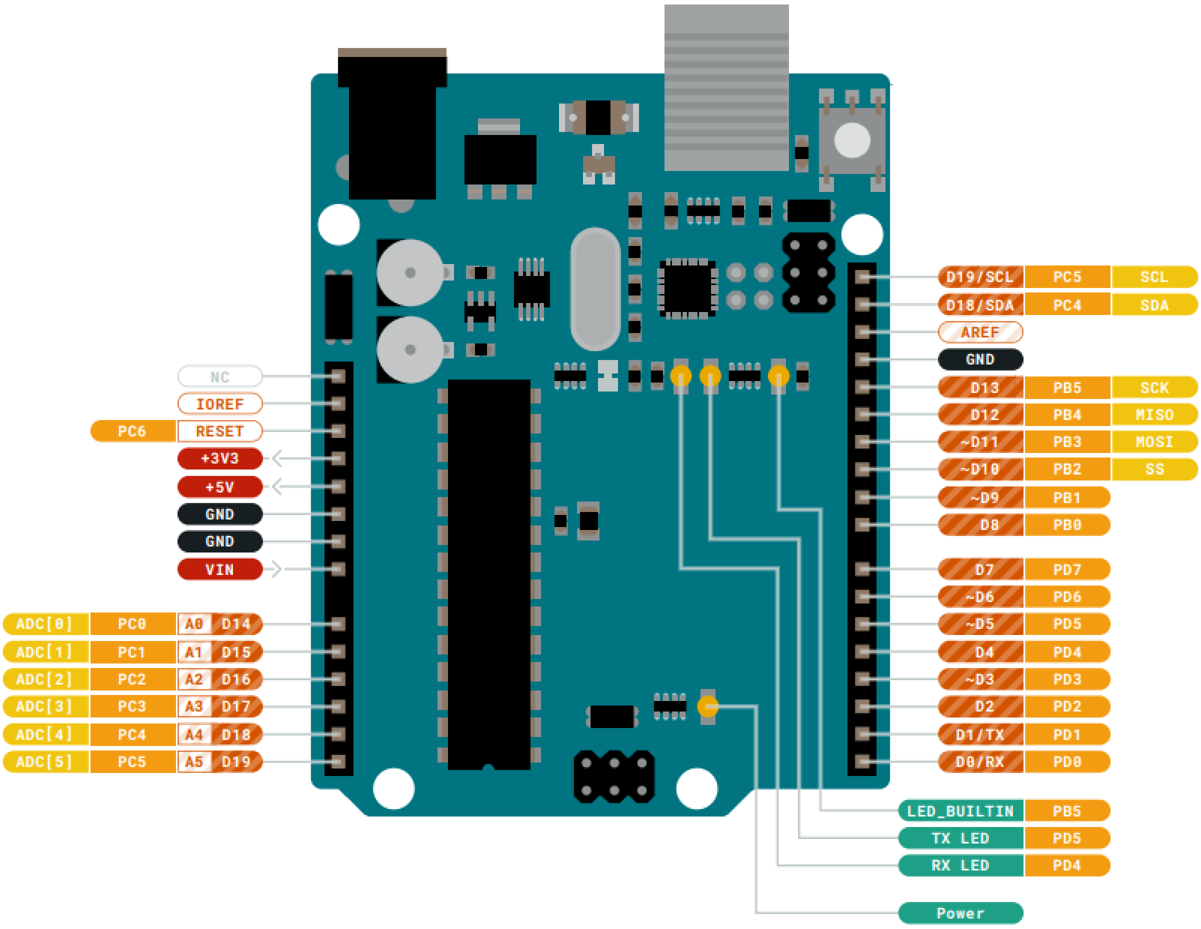
14.3 示例程序

Arduino UNO R3 的示例程序可以在 Arduino IDE 的“示例”菜单或 Arduino 网站 [4] 的“文档”部分找到

14.4 在线资源

现在，您已经了解该电路板的基本功能，就可以通过查看 Arduino Project Hub **[5]**、Arduino Library Reference **[6]** 以及在线 Arduino 商店 **[7]**上的精彩项目来探索它所提供的无限可能性；在这些项目中，您可以为电路板配备传感器、执行器等。

15 连接器引脚布局



布局

15.1 JANALOG

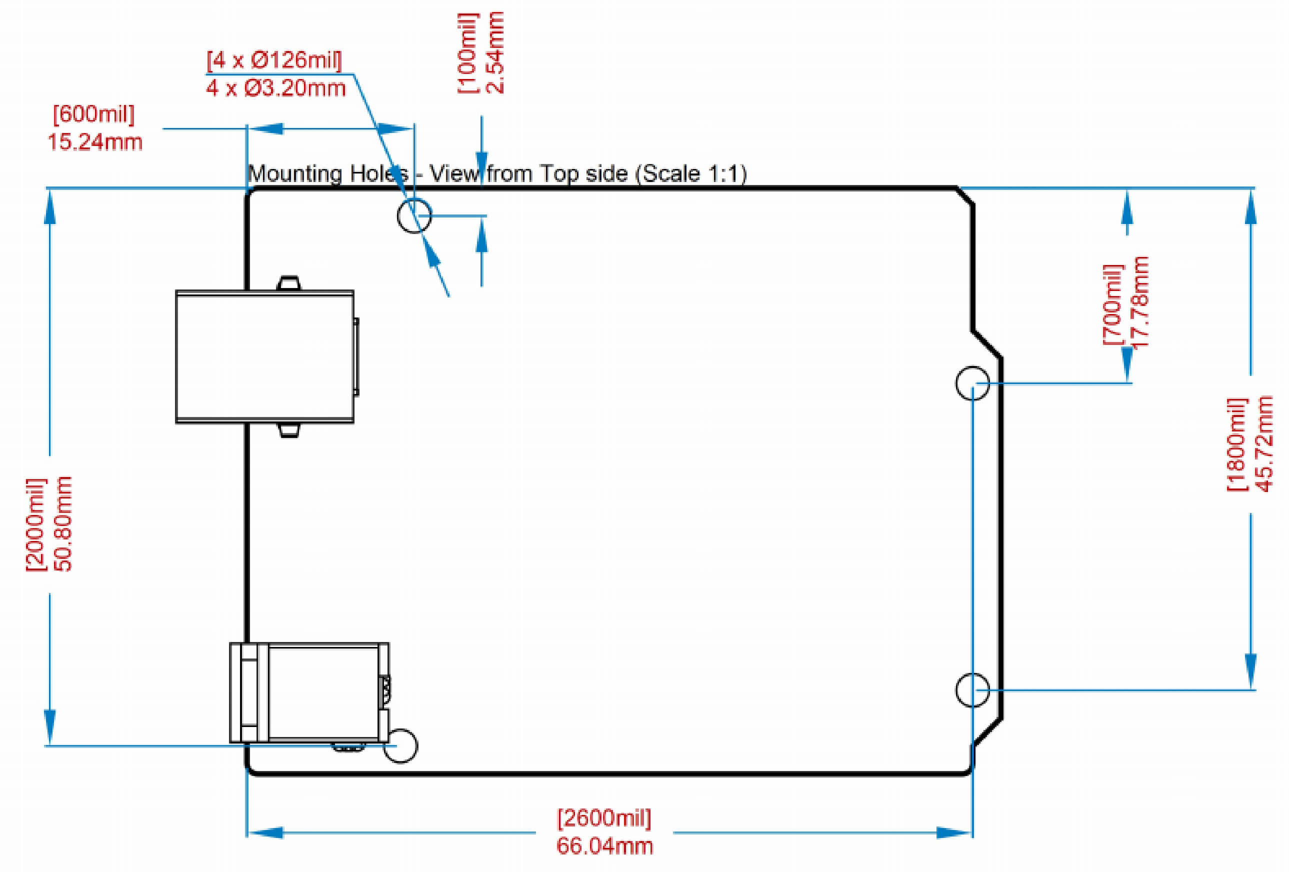
引脚	功能	类型	描述
1	NC	NC	未连接
2	IOREF	IOREF	数字逻辑参考电压 V - 连接至 5V
3	复位	复位	复位
4	+3V3	电源	+3V3 电源轨
5	+5V	电源	+5V 电源轨
6	GND	电源	接地
7	GND	电源	接地
8	VIN	电源	电压输入
9	A0	模拟/GPIO	模拟输入0 / GPIO
10	A1	模拟/GPIO	模拟输入1 / GPIO
11	A2	模拟/GPIO	模拟输入2 / GPIO
12	A3	模拟/GPIO	模拟输入3 / GPIO
13	A4/SDA	模拟输入/I2C	模拟输入 4/I2C 数据线
14	A5/SCL	模拟输入/I2C	模拟输入 5/I2C 时钟线

15.2 JDIGITAL

引脚	功能	类型	描述
1	D0	数字引脚/GPIO	数字引脚 0/GPIO
2	D1	数字引脚/GPIO	数字引脚 1/GPIO
3	D2	数字引脚/GPIO	数字引脚 2/GPIO
4	D3	数字引脚/GPIO	数字引脚 3/GPIO
5	D4	数字引脚/GPIO	数字引脚 4/GPIO
6	D5	数字引脚/GPIO	数字引脚 5/GPIO
7	D6	数字引脚/GPIO	数字引脚 6/GPIO
8	D7	数字引脚/GPIO	数字引脚 7/GPIO
9	D8	数字引脚/GPIO	数字引脚 8/GPIO
10	D9	数字引脚/GPIO	数字引脚 9/GPIO
11	SS	数字	SPI 芯片选择
12	MOSI	数字	SPI1 主输出副输入
13	MISO	数字	SPI 主输入副输出
14	SCK	数字	SPI 串行时钟输出
15	GND	电源	接地
16	AREF	数字	模拟参考电压
17	A4/SD4	数字	模拟输入 4/I2C 数据线（重复）
18	A5/SD5	数字	模拟输入 5/I2C 时钟线（重复）

15.3 机械层信息

15.4 电路板外形图和安装孔



电路板外形图

16 认证

16.1 符合性声明 CE DoC（欧盟）

我们在此郑重声明，上述产品符合以下欧盟指令的基本要求，因此有资格在包括欧盟（EU）和欧洲经济区（EEA）在内的市场内自由流通。

RoHS 2 指令 2011/65/EU	
符合：	EN50581:2012
指令 2014/35/EU。（LVD)	
符合：	EN 60950-1:2006/A11:2009/A1:2010/A12:2011/AC:2011
指令 2004/40/EC & 2008/46/EC & 2013/35/EU, EMF	
符合：	EN 62311:2008

16.2 声明符合欧盟 RoHS 和 REACH 211 01/19/2021

Arduino 电路板符合欧洲议会关于限制在电子电气设备中使用某些有害物质的 RoHS 2 指令 2011/65/EU 和欧盟理事会于 2015 年 6 月 4 日颁布的关于限制在电子电气设备中使用某些有害物质的 RoHS 3 指令 2015/863/EU。

物质	最大限值 (ppm)
铅 (Pb)	1000
镉 (Cd)	100
汞 (Hg)	1000
六价铬（Cr6+）	1000
多溴联苯（PBB）	1000
多溴联苯醚（PBDE）	1000
邻苯二甲酸二(2-乙基己)酯 (DEHP)	1000
邻苯二甲酸丁苄酯 (BBP)	1000
邻苯二甲酸二丁酯（DBP）	1000
邻苯二甲酸二异丁酯（DIBP）	1000

豁免：未申请任何豁免。

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18 公司信息

公司名称	Arduino S.r.l
公司地址	Via Andrea Appiani 25 20900 MONZA Italy

19 参考资料

参考资料	链接
Arduino IDE (Desktop)	https://www.arduino.cc/en/Main/Software
Arduino IDE (Cloud)	https://create.arduino.cc/editor
Cloud IDE 入门指南	https://create.arduino.cc/projecthub/Arduino_Genuino/getting-started-with-arduino-web-editor-4b3e4a
Arduino 网站	https://www.arduino.cc/
Arduino Project Hub	https://create.arduino.cc/projecthub?by=part&part_id=11332&sort=trending
库参考	https://www.arduino.cc/reference/en/
在线商店	https://store.arduino.cc/

20 修订记录

日期	版次	变更
2023/07/26	2	一般更新
2021/06	1	数据表发布

DATA SHEET

PCD8544
48 × 84 pixels matrix LCD controller/driver

Product specification
File under Integrated Circuits, IC17

1999 Apr 12

Philips Semiconductors

PHILIPS

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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

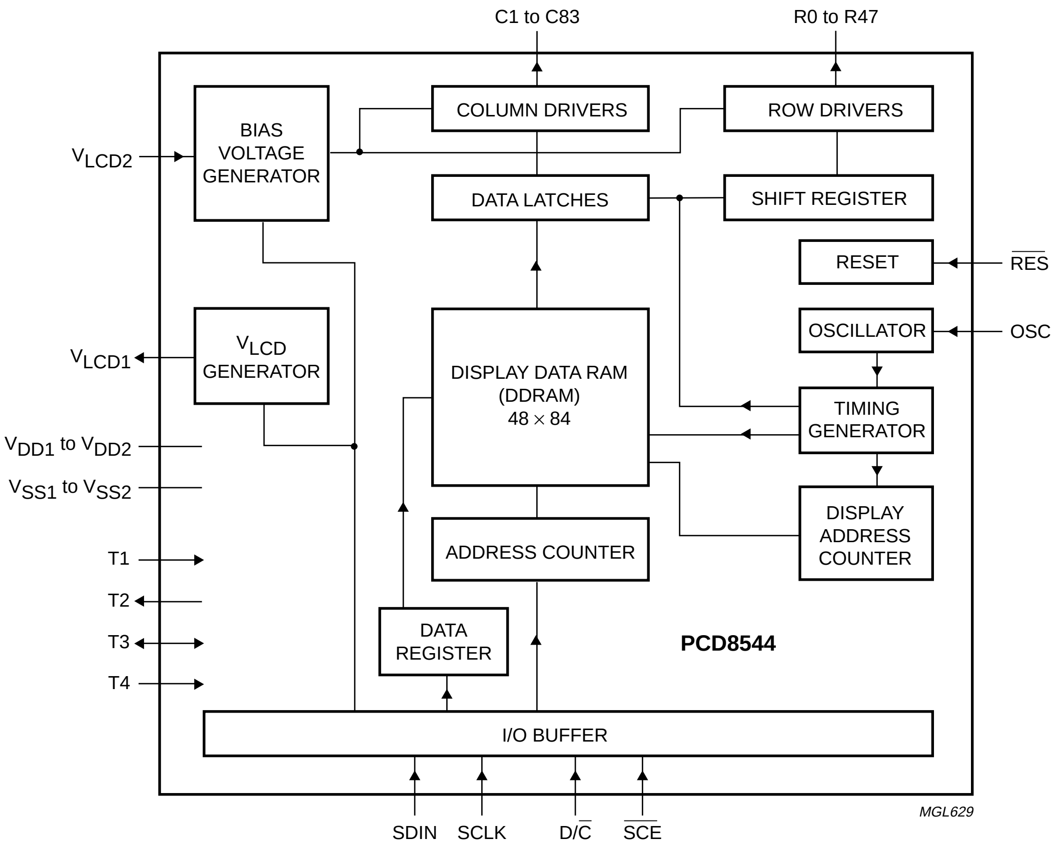


Fig.1 Block diagram.

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
$D/\overline{C}$	data/$\overline{\text{command}}$
$\overline{SCE}$	chip enable
OSC	oscillator
$\overline{RES}$	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 $D/\overline{C}$: MODE SELECT

Input to select either command/address or data input.

6.1.10 $\overline{SCE}$: 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 $\overline{RES}$: 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

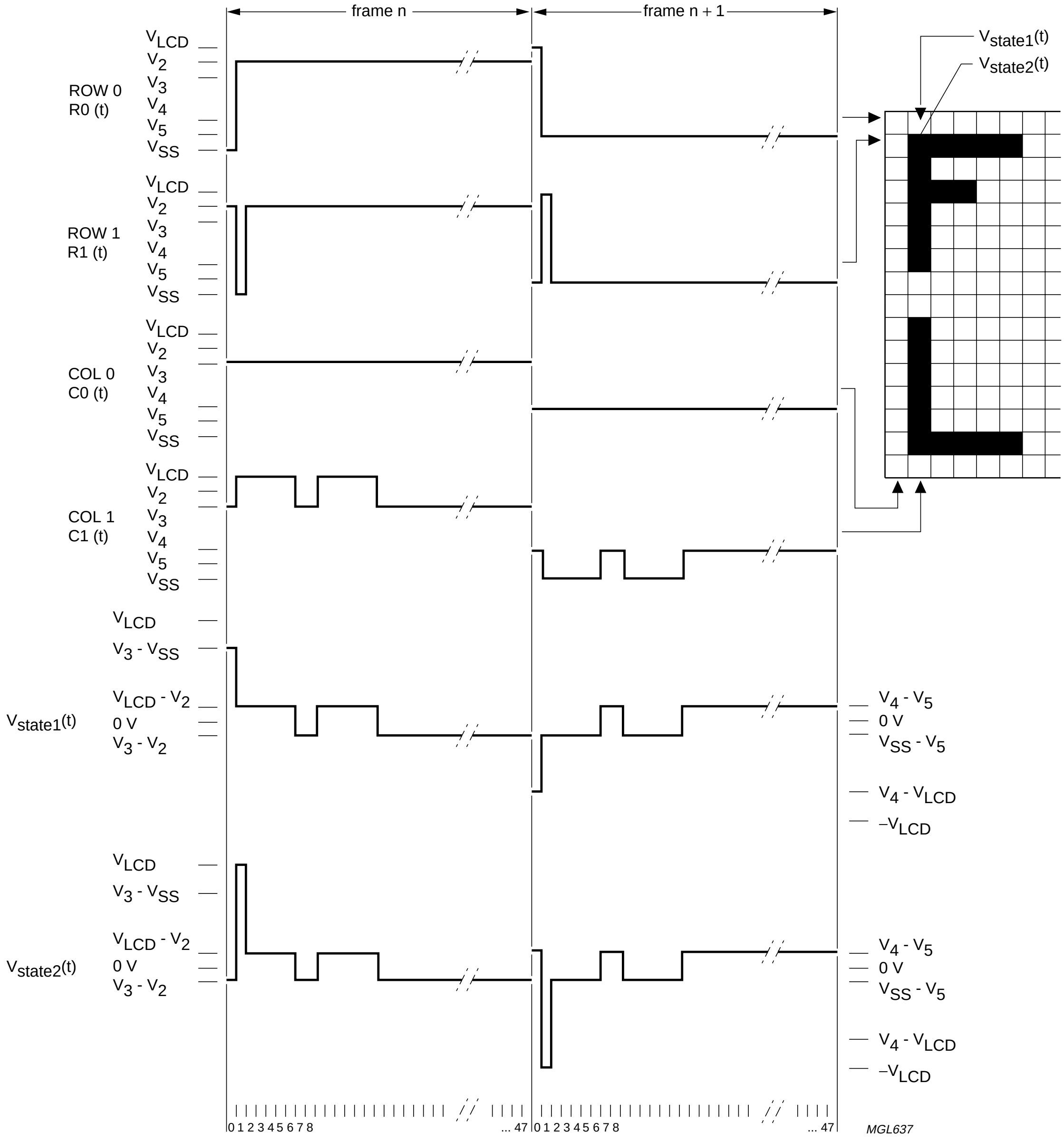
The timing generator produces the various signals required to drive the internal circuits. Internal chip operation is not affected by operations on the data buses.

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.

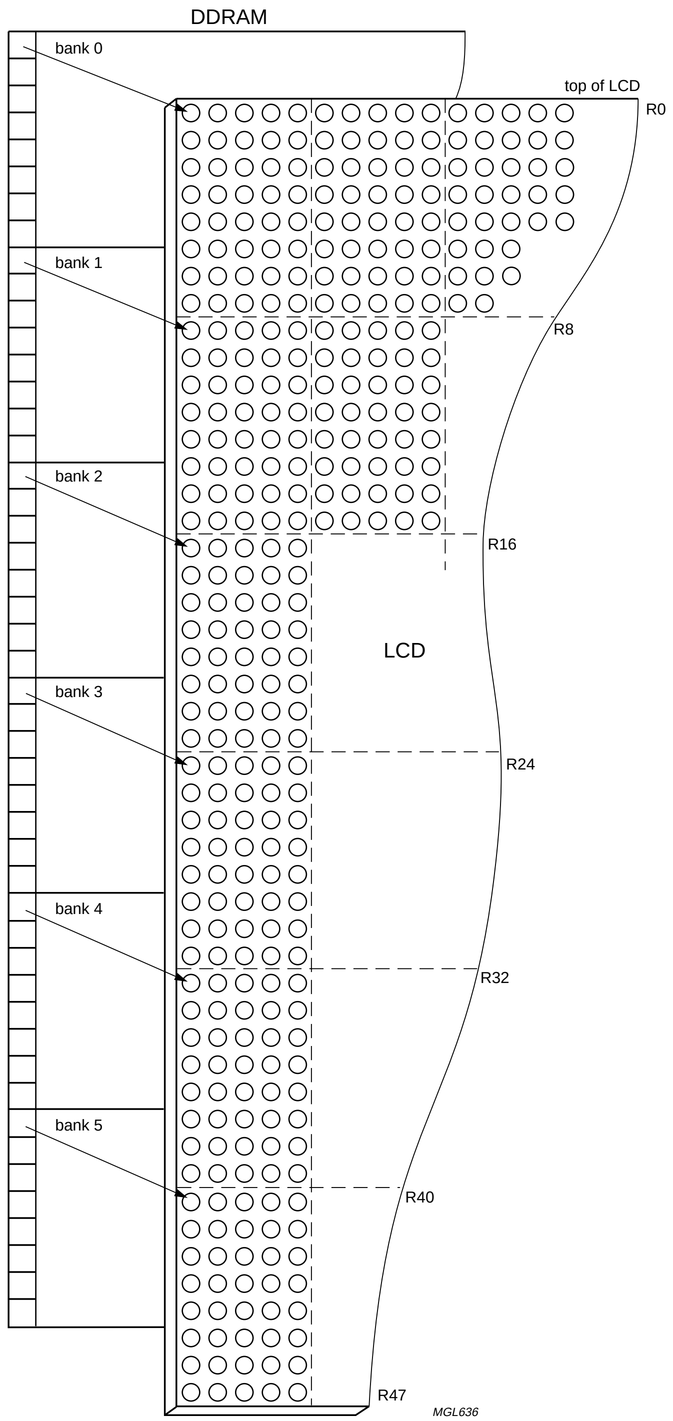


Fig.3 DDRAM to display mapping.

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

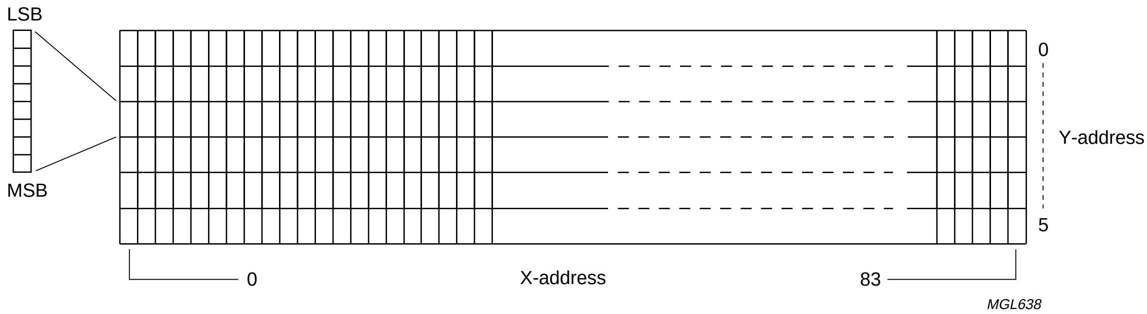


Fig.4 RAM format, addressing.

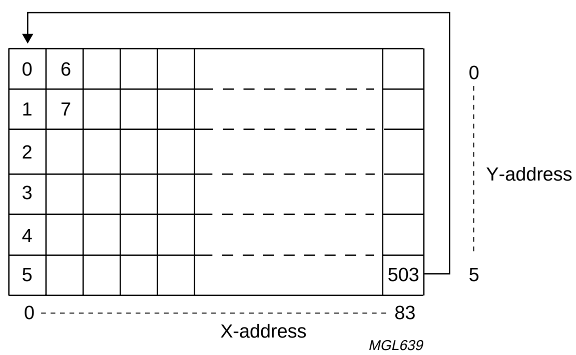


Fig.5 Sequence of writing data bytes into RAM with vertical addressing (V = 1).

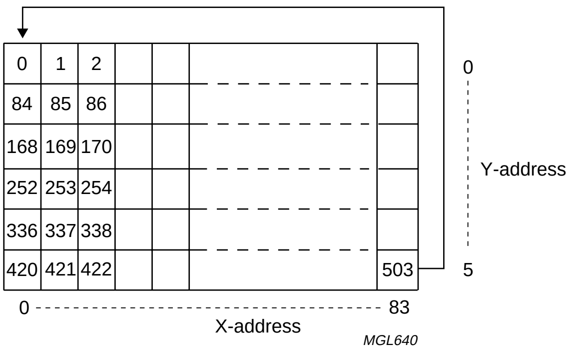
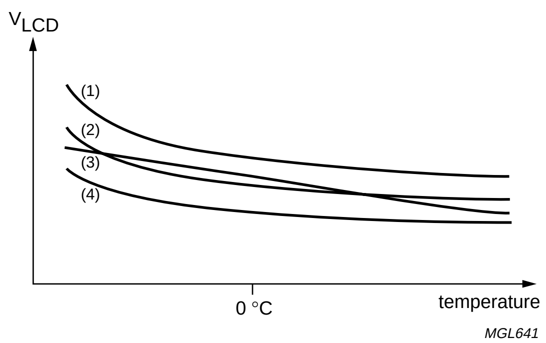


Fig.6 Sequence of writing data bytes into RAM with horizontal addressing (V = 0).

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 $D/\overline{C}$ (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.

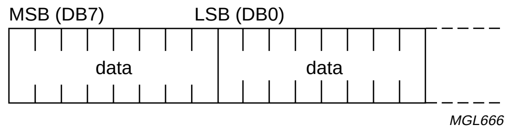


Fig.8 General format of data stream.

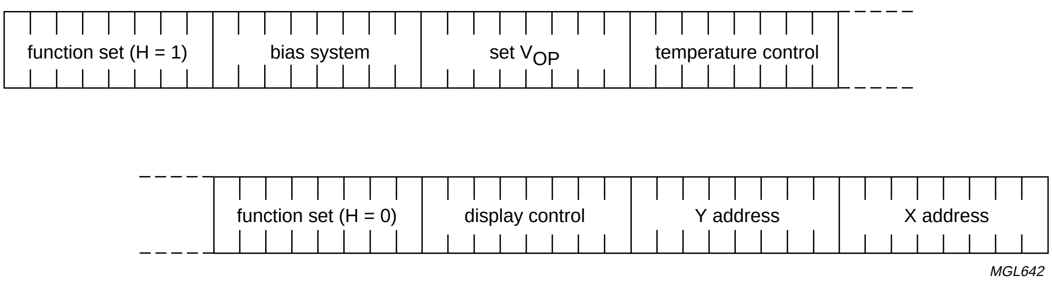


Fig.9 Serial data stream, example.

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).

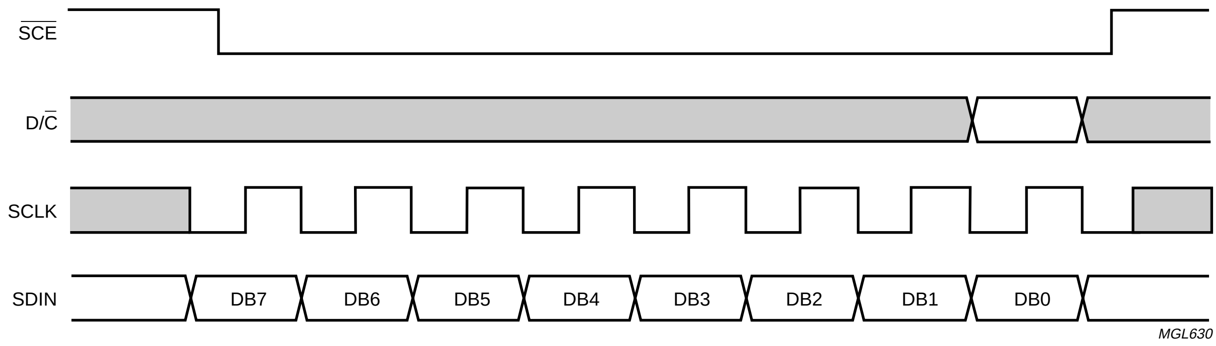


Fig.10 Serial bus protocol - transmission of one byte.

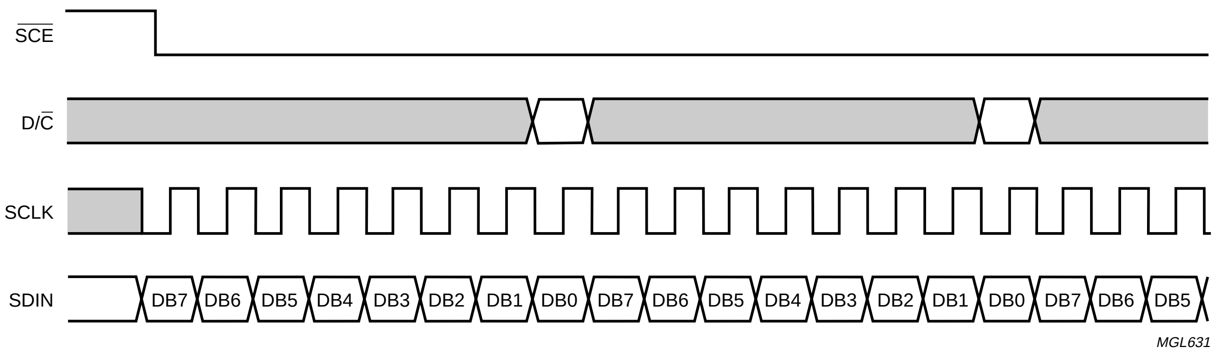


Fig.11 Serial bus protocol - transmission of several bytes.

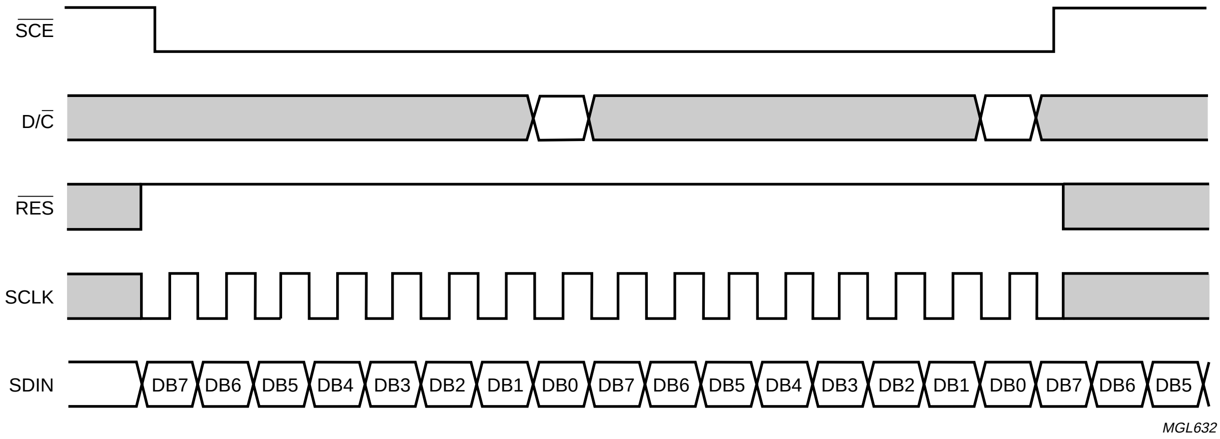


Fig.12 Serial bus reset function ($\overline{SCE}$).

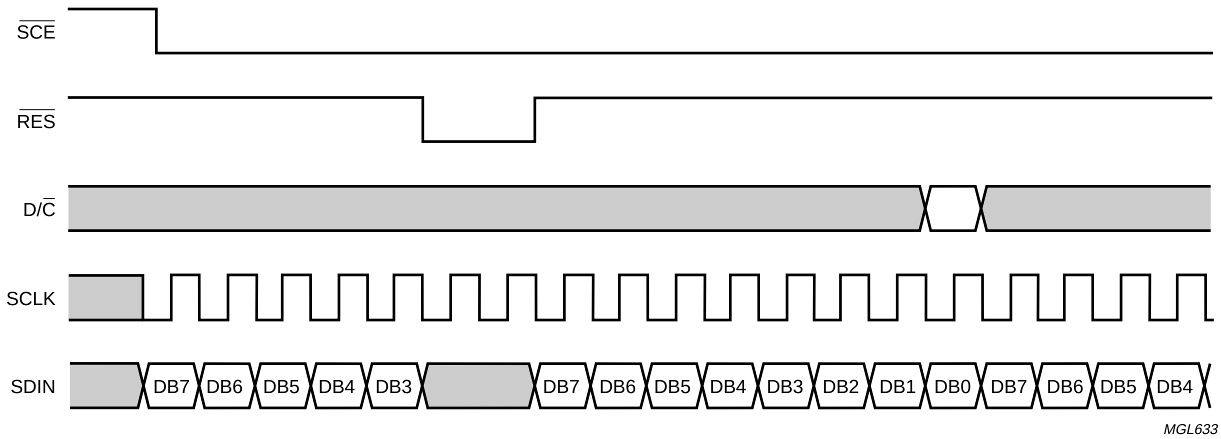


Fig.13 Serial bus reset function ($\overline{RES}$).

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 $\frac{1}{8}$ 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.

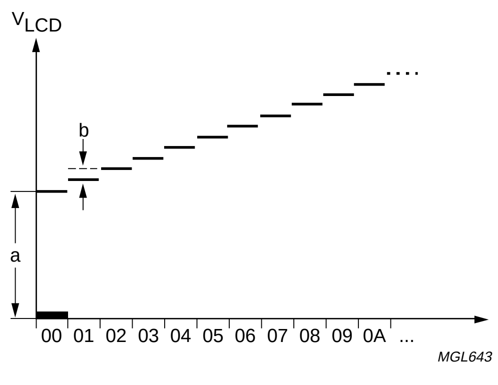
Note that the charge pump is turned off if V_{OP6} to V_{OP0} is set to zero.

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

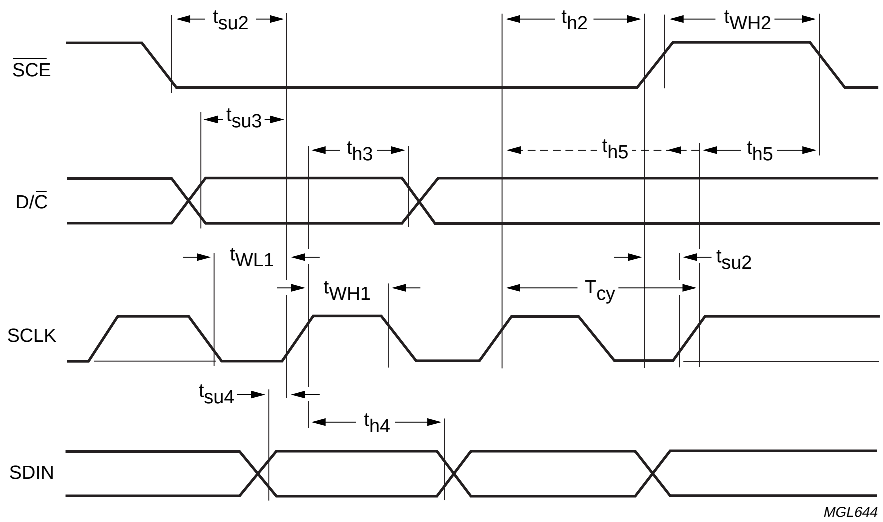


Fig.15 Serial interface timing.

12.2 Reset

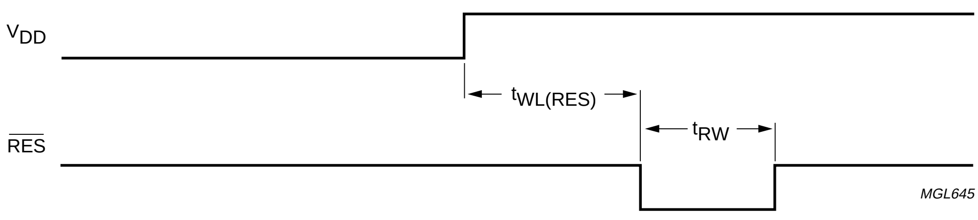
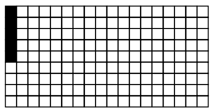
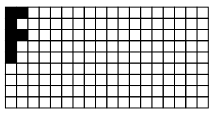
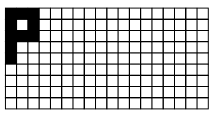
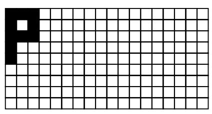
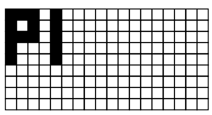
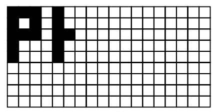
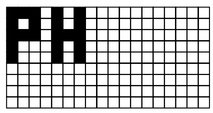
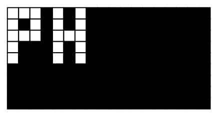
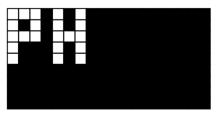
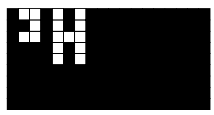


Fig.16 Reset timing.

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 × 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.

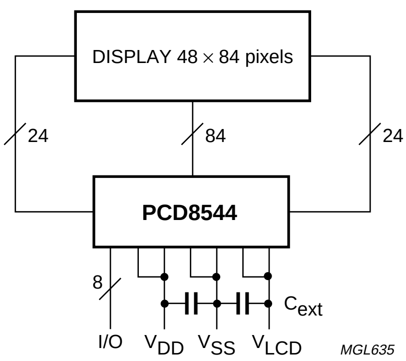


Fig.17 Application diagram.

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

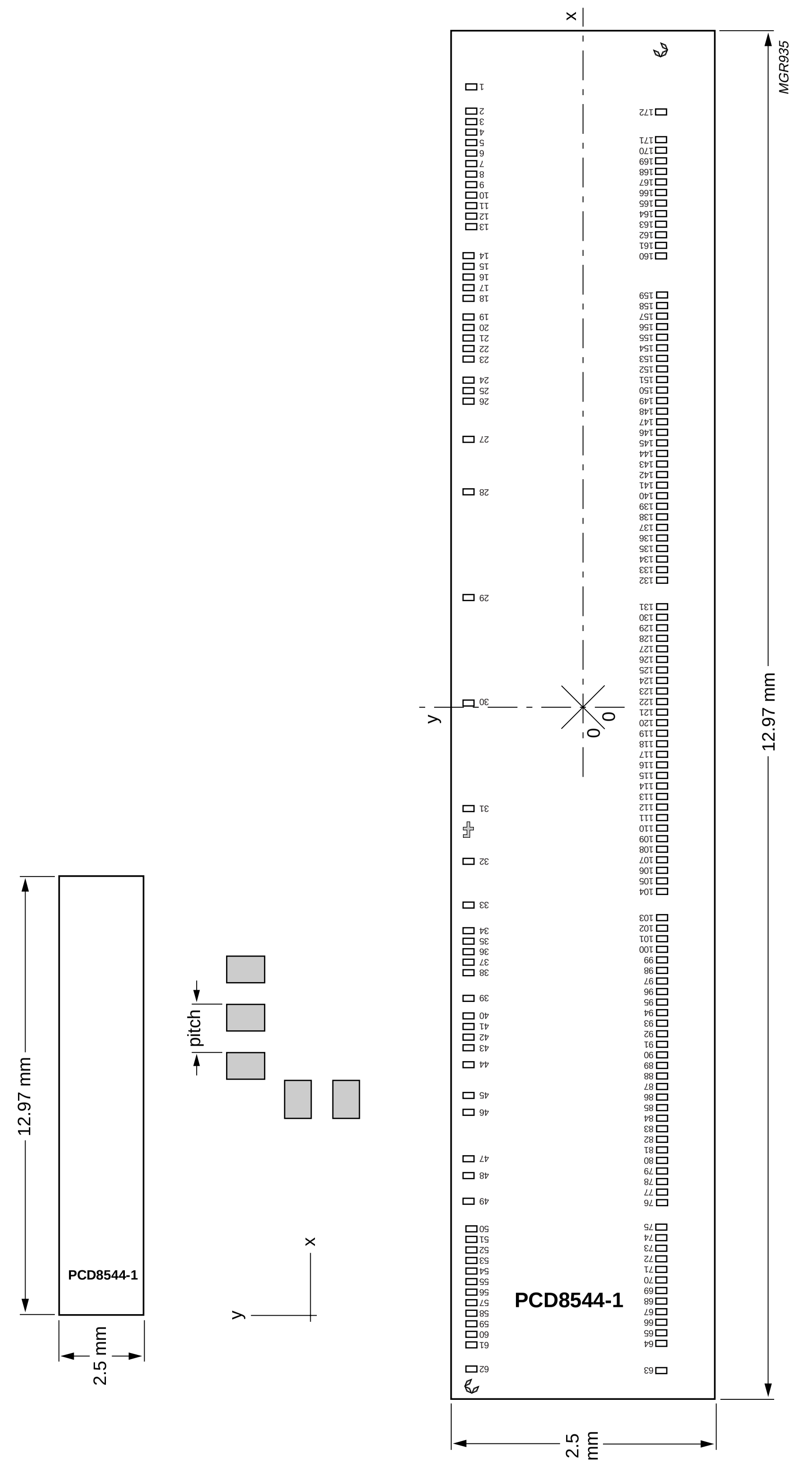


Fig.18 Bonding pad locations.

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

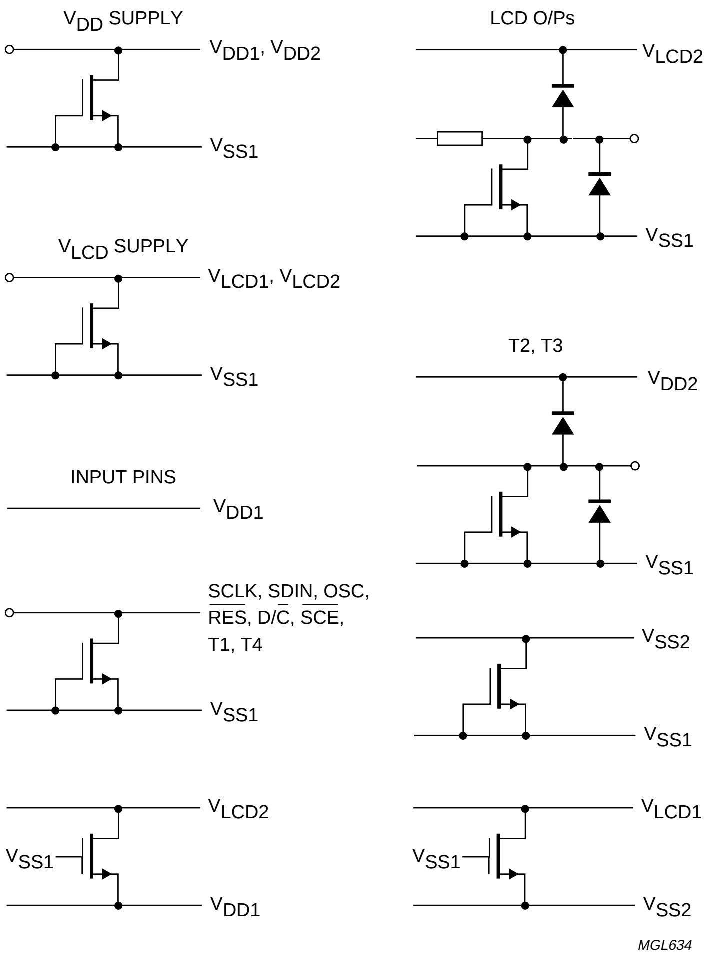
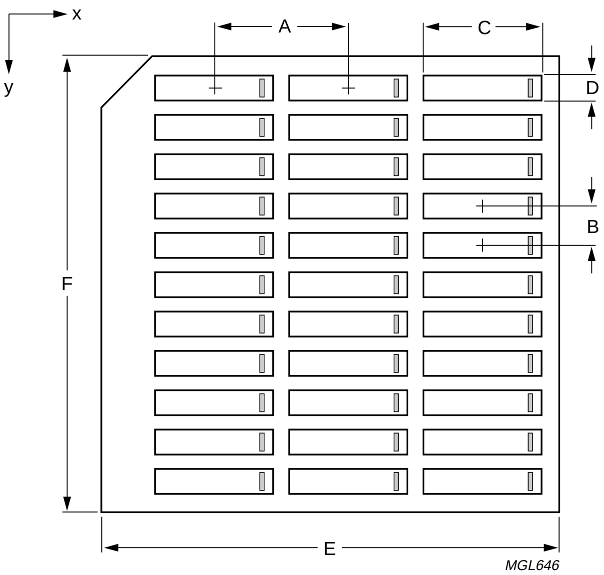


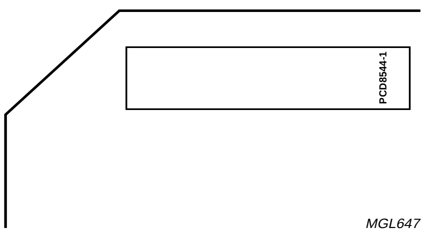
Fig.19 Device protection diagram.

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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Printed in The Netherlands 465008/750/01/pp32 Date of release: 1999 Apr 12 Document order number: 9397 750 05024

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