

Universidad de Costa Rica

Laboratorio III

Arduino: GPIO, ADC y comunicaciones

Prof. Marco Villalta

Daniela Ríos Mora B65854

José Eras Saborío B72704

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## 1. Resumen

En este laboratorio se desarrolla un voltímetro de 4 canales empleando un Arduino UNO y componentes electrónicos. Este voltímetro es capaz de leer un rango de  $[-24,24]$ V tanto en DC como en AC. Mediante implementación de software es capaz de realizar un acondicionamiento a un rango de tensión que el microcontrolador puede manejar. Además de eso, se implementa un sistema que iluminación con LEDs que se encienden en el momento que se mide una tensión menor a -20V y mayor a 20V.

## 2. Nota Teórica

En esta sección se muestran características generales del Arduino UNO, la estructura de un sketch, las entradas y salidas, tanto analógicas como digitales, las comunicaciones USART y entre el Arduino, la PC y SimulIDE, además del diseño del circuito.

### 2.1. Arduino UNO

A continuación se observan las características generales del microcontrolador Arduino UNO [?]:

- Microcontrolador AVR de 8 bits. Arquitectura RISC/Harvard.
- 23 GPIOs, interrupciones, timer/counters de 8 y 16 bits.
- 8 canales PWM, 6 canales 10-bits ADC y comparador analógico.
- Bloque USART Y Maestro/Esclavo SPI.
- TWI (2-wire), DBG, BTLDR.

Sus especificaciones eléctricas se observan en la tabla 1.

Características Eléctrica	Valor
Temperatura de Operación	40°C a +85°C
Máxima Tensión de Operación	5,5 V
DC por I/O Pin	20 mA
DC en pines $V_{CC}$ y GND	100 mA

Tabla 1: Características generales del microcontrolador Arduino UNO. [?].

El esquemático del microcontrolador se observa en la figura 1.

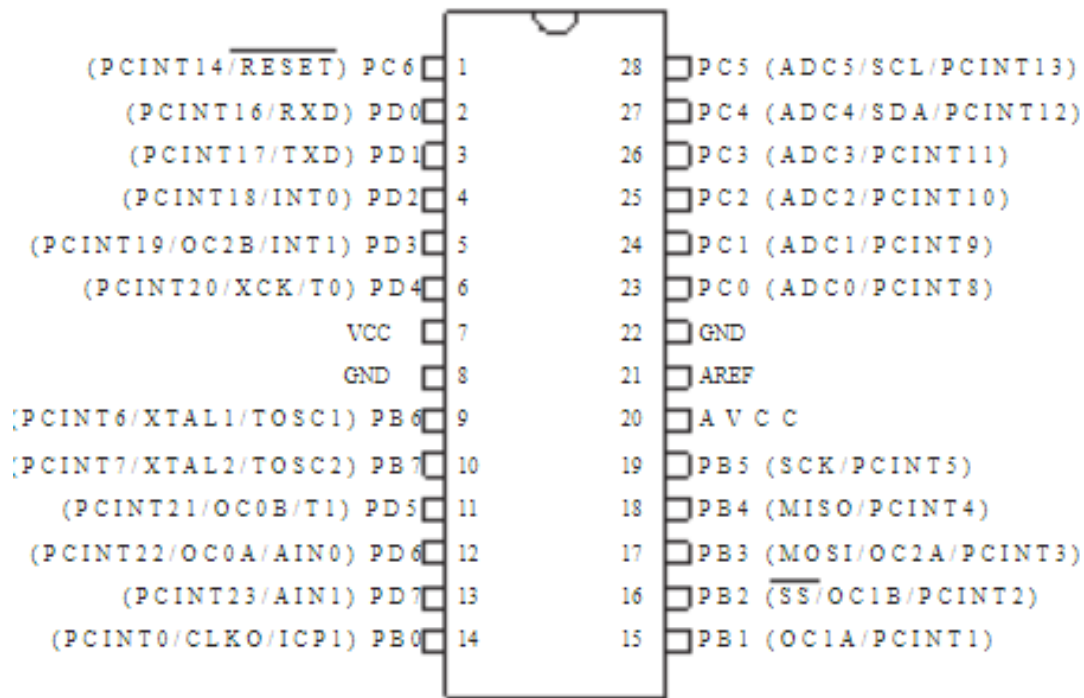


Figura 1: Esquem]’atico de Arduino UNO. [?].

El diagrama del microcontrolador se observa en la figura 2.

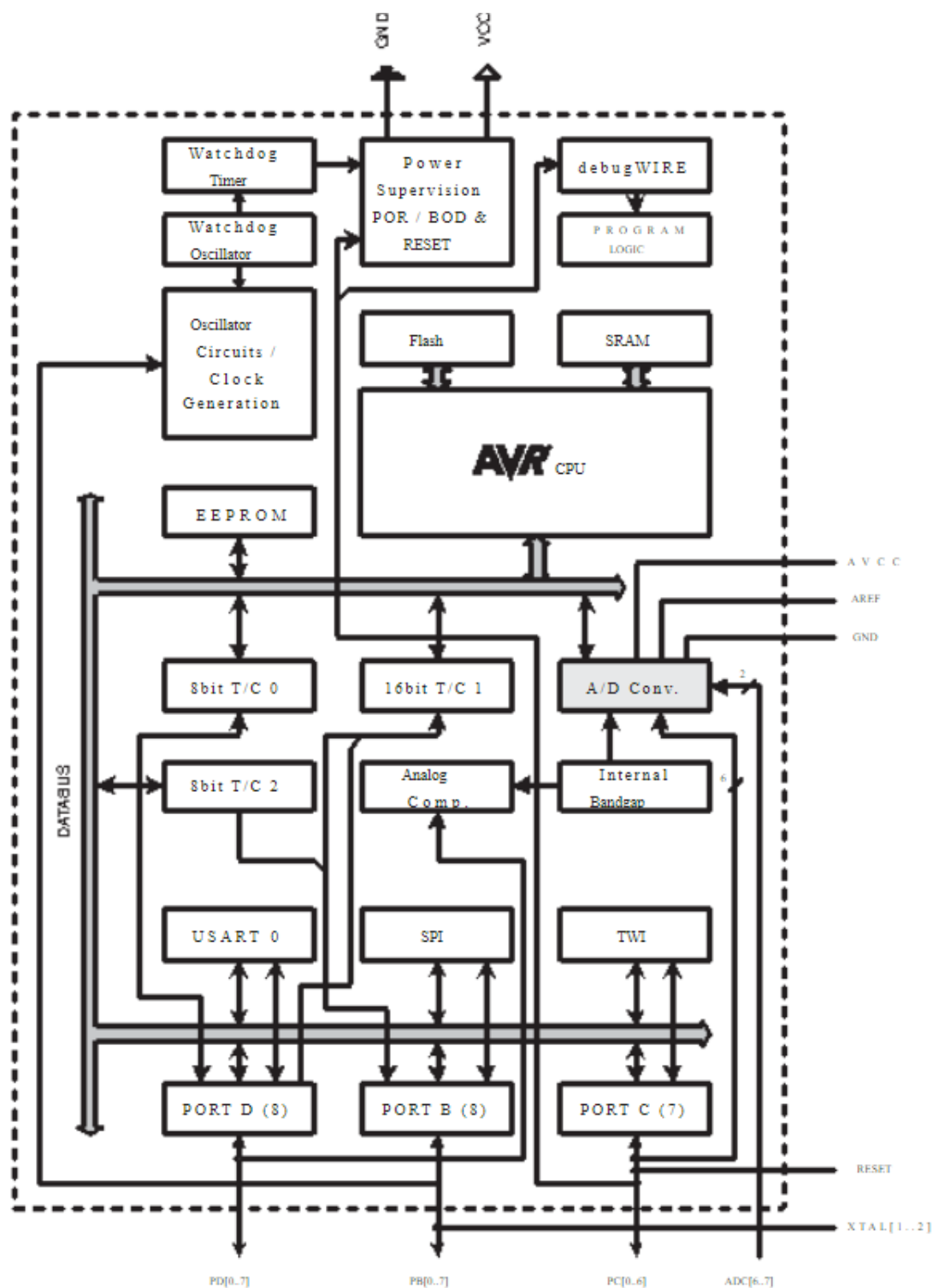


Figura 2: Diagrama de bloques de Arduino UNO . [?].

### 2.1.1. Estructura de un Sketch

Para programar un Arduino, se deben tener en cuenta tres factores:

- Declaración de variables globales y funciones a implementar.
- Configuración e inicialización de periféricos en `void_setup()`.
- La función `void_loop()`, donde se ejecuta el programa.

### 2.1.2. Entradas y Salidas Digitales

Para poder hacer uso de las entradas y salidas digitales, se utilizan las siguientes funciones [?]:

- **pin\_mode:** Se encarga de configurar el pin digital, donde su primer parámetro es el número de pin, y el segundo si es INPUT o OUTPUT.
- **digitalWrite():** Pone en HIGH o LOW el pin en cuestión como primer parámetro y el estado como segundo.
- **digitalRead():** Recibe el pin y el valor que se quiere leer para retornarlo.

Para comunicar la PC y SimulIDE, se abre el puerto serial, se renombra, lo que permite abrirlo o cerrarlo para establecer un canal de comunicación.

### 2.1.3. Entradas y Salidas Analógicas

Para poder hacer uso de las entradas y salidas analógicas, se utilizan las siguientes funciones [?]:

- **analogWrite():** Envía un byte para representar una señal PWM a un pin analógico que está configurado como OUTPUT.
- **analogRead():** Devuelve un valor leído del pin analógico configurado como INPUT.

### 2.1.4. Comunicaciones USART

Las comunicaciones MCU son seriales, lo que quiere decir que la transmisión de datos se realiza bit a bit. El bloque *USART* es el más rápido, ya que utiliza el CLK y envía mayor cantidad de datos.

### 2.1.5. Comunicaciones entre Arduino, PC y SimulIDE

Las comunicaciones entre un Arduino y la PC se realizan a una *baud rate* de 9600. Para comunicar dos dispositivos, este parámetro, el *start bit* y la paridad, deben tener el mismo valor. Para este caso, en el Arduino se utilizan los pines digitales 0 (RX) y 1 (TX) [?]. Las funciones que utilizan son:

- **Serial.begin():** Inicia la comunicación, ya que tiene como primer parámetro la velocidad.
- **Serial.print() y Serial.println():** Envían un dato de cualquier tipo y devuelven la cantidad de bytes enviados.
- **Serial.end():** Se encarga de cerrar la comunicación.

## 2.2. Componentes Electrónicos Complementarios

### 2.2.1. LCD PCD8544

El LCD PCD8544 es un controlador para pantallas LCD. utiliza una interfaz serial para poder comunicarse con el microcontrolador. Se comunican a través de la arquitectura maestro-esclavo, siendo este el esclavo. Tiene la capacidad de realizar desplazamientos, además tiene opciones de configuración, como ajuste de contraste, cambio en el modo de visualización y cambio de dirección de la pantalla [?].

Su diagrama de bloques se puede observar en la figura 3.

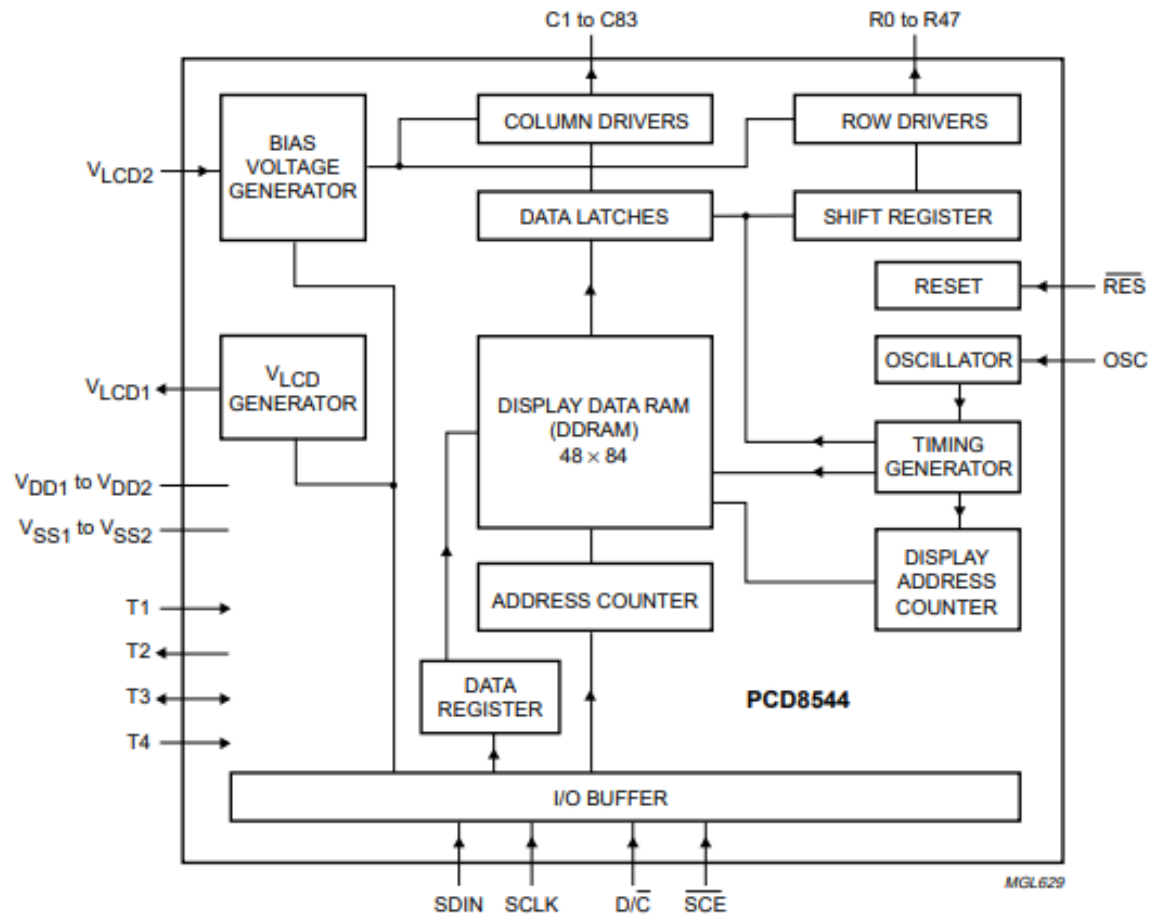


Figura 3: Diagrama de bloques de PCD8544. [?].

## 2.3. Diseño

Para poder regular la tensión generada a un rango de  $[-25; +25]$ V se utilizara un regulador de tensión como se observa en la figura 4, este regulador tambien es posible de realizar empleando amplificadores operacionales. No obstante, para este diseño se implementara de la primer forma por comodidad nuestra.

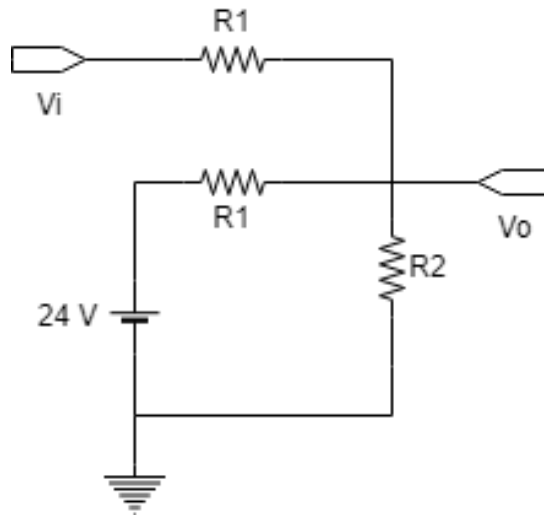


Figura 4: Regulador de tension.

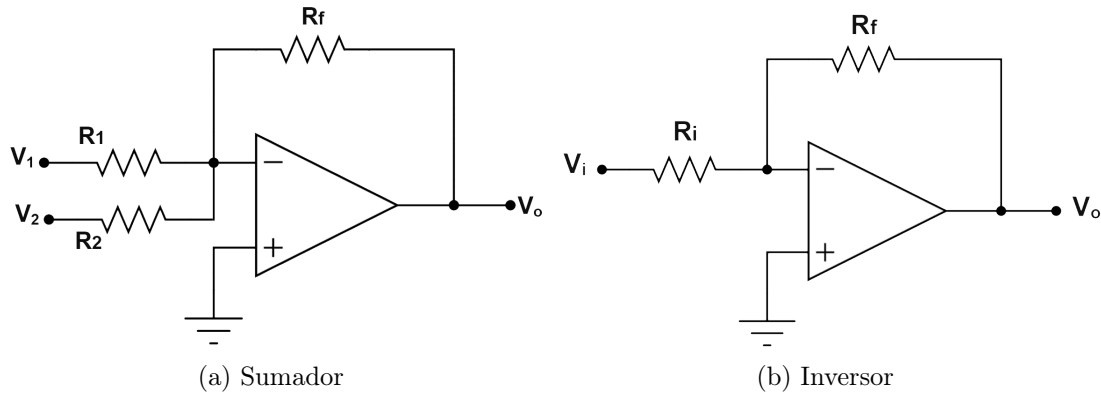


Figura 5: Aplicaciones amplificadores operacionales.

Analizando la figura 4:

$$\frac{V_o - V_i}{R_1} + \frac{V_o - 24}{R_1} + \frac{V_o}{R_2} = 0 \quad (1)$$

Despejando  $V_o$  se llega a:

$$V_o = (V_i + 24) \frac{R_2}{R_1 + 2R_2} \quad (2)$$

Usando los valores iniciales  $V_i = 24$ ,  $V_o = 5$  y  $V_i = -24$ ,  $V_o = 0$  se tiene que:

$$R_2 = \frac{5}{38} R_1 \quad (3)$$

Se toma entonces para  $R_1$  y  $R_2$  los siguientes valores:

$$R_1 = 38 \text{ M}\Omega = 22 \text{ M}\Omega + 15 \text{ M}\Omega + 1 \text{ M}\Omega \quad (4)$$

$$R_2 = 5 \text{ M}\Omega \quad (5)$$

El uso de resistencias en el orden de  $\text{M}\Omega$  es para no afectar al circuito que se está midiendo, ya que con esos valores de resistencias el voltímetro es un abierto para dicho circuito.



El circuito debe encender un LED de alarma correspondiente al canal de entrada el cual sobrepase los límites permitidos de la medición, por lo que se agrega un total de 4 LED's, uno correspondiente a cada canal. Dichos diodos deben cumplir las características de tener una tensión de polarización directa menor a 2.5 V y una corriente de polarización directa menor a 25 mA. Usando las especificaciones eléctricas de los diodos LED's ( $V_F = 2\text{ V}$  cuando  $I_F = 20\text{ mA}$ ), se calcula el valor de las resistencias de protección para los LED's usando la fórmula (6), y utilizando  $V_{DD} = 5\text{ V}$  y según la hoja de datos del fabricante la tensión de salida en alto de los pines está dada por  $V_{OH} = V_{DD} - 0,7\text{ V}$ :

$$R = \frac{V_{OH} - n \times V_F}{I_F} \quad (6)$$

Sustituyendo los valores en la ecuación anterior:

$$R = \frac{(5 - 0,7 - 2)\text{ V}}{20\text{ mA}} = 115\ \Omega \quad (7)$$

Por lo que utilizando valores comerciales, se utilizarán dos resistores conectados en serie, uno de  $100\ \Omega$  y otro de  $15\ \Omega$ . Sabemos que la fórmula de la potencia para un resistor es:

$$P_R = I^2 R = \frac{V^2}{R} \quad (8)$$

Como tenemos dos valores de resistencia, su potencia es:

$$P_{100\ \Omega} = (20\text{ mA})^2 \cdot 100\ \Omega = 0,04\text{ W} \quad (9)$$

$$P_{15\ \Omega} = (20\text{ mA})^2 \cdot 15\ \Omega = 0,006\text{ W} \quad (10)$$

Al igual que en laboratorios anteriores, para contrarrestar el rebote que genera el interruptor cuando se cierra o se abre, se debe agregar un capacitor en paralelo para que filtre el ruido que genera al pin conectado del microcontrolador. Se agrega en paralelo para que en estado estacionario el circuito RC se comporte como un circuito pull-down y evite que la corriente entre al pin y se drene a través de la resistencia. La constante de tiempo de un circuito RC es:

$$\tau = RC \quad (11)$$

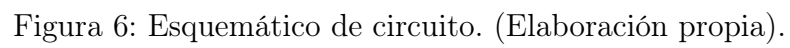
La resistencia se puede calcular también con la siguiente fórmula:

$$R = \frac{\tau}{C} \quad (12)$$

Debido a que no hay un valor específico de  $\tau$  indicado en las instrucciones del laboratorio, se escogerá arbitrariamente  $\tau = 0,1\text{ ms}$ , usando  $C = 100\text{ nF}$  entonces la resistencia es:

$$R = \frac{0,1\text{ ms}}{100\text{ nF}} = 1\text{ k}\Omega \quad (13)$$

En la figura 6 se muestra el diagrama esquemático del circuito a simular.



### 2.3.1. Costo de Componentes

Los costos de los componentes a utilizar se presentan en la tabla 2:

Componente	Cantidad	Precio (C)
Capacitores de 100nF	4	396
Resistencias de 15 $\Omega$	4	1196
Resistencias de 100 $\Omega$	4	1196
Resistencias de 1k $\Omega$	4	1196
Resistencias de 1M $\Omega$	8	2392
Resistencias de 5M $\Omega$	8	2392
Resistencias de 15M $\Omega$	8	2392
Resistencias de 22M $\Omega$	8	2392
LEDs colores	4	240
Switches	8	8800
LCD PCD8544	1	22000
Arduino UNO	1	15950

Tabla 2: Componentes y costos.

## 3. Desarrollo/Análisis de resultados

### 3.1. Diseño Lógico

El funcionamiento se da principalmente a través del archivo `voltmeter.ino`, el cual es el encargado de controlar una pantalla LCD y leer tensiones de varios pines analógicos, mostrando las mediciones en la pantalla LCD y, opcionalmente, en el puerto serie. También enciende LEDs de advertencia si las tensiones están fuera de rango.

En la parte inicial del código, se incluyen tres bibliotecas esenciales `Adafruit_GFX.h`, `Adafruit_PCD8544.h` y `SPI.h`. Estas bibliotecas proporcionan las herramientas necesarias para controlar la pantalla LCD y gestionar la comunicación SPI, que se utiliza para interactuar con la pantalla.

El objeto `display`, creado a partir de la clase `Adafruit_PCD8544`, se encarga de controlar la pantalla LCD. Se establecen los pines de conexión en su inicialización, lo que prepara la pantalla para mostrar los resultados de las mediciones. También se define una función de interrupción llamada `TIMER1_COMPA_vect`. Esta función se ejecuta cuando se produce una interrupción del temporizador 1 (`TIMER1`) y se utiliza para tomar muestras de voltaje en los canales habilitados. La interrupción del temporizador garantiza que las muestras se tomen con una precisión temporal constante.

El bucle principal, contenido en la función `loop()`, es el corazón del programa. Para cada uno de los cuatro canales (`V1`, `V2`, `V3` y `V4`), el código realiza una serie de pasos:

- Inicializa variables locales para almacenar los valores de tensión y otros parámetros.
- Lee el estado de los pines que determinan qué canales de entrada se deben medir.
- Habilita el temporizador para tomar muestras analógicas y espera hasta que se tomen todas las muestras
- Deshabilita el temporizador para detener la toma de muestras.

- Realiza los cálculos pertinentes de tensión.
- Imprime el valor medido en el puerto serial para su registro o monitoreo externo.
- Muestra el valor medido en la pantalla LCD para una visualización en tiempo real.

Para realizar con éxito esta comunicación, se crea un código en Python el cual tiene como objetivo principal la comunicación con un dispositivo a través de un puerto serie, COM3, y la posterior captura y almacenamiento de los datos recibidos en un archivo CSV llamado ".output.csv". En este se inicializan varias variables, como un contador, una lista llamada "valores" para almacenar los datos recibidos y se abre el archivo CSV en modo escritura. El número de datos que se espera recibir antes de cerrar el puerto (num\_datos) se establece en 100, y se crea un contador para rastrear la cantidad de datos recibidos.

Luego, el programa entra en un bucle while, que se ejecutará indefinidamente hasta que se cumpla una condición de salida. En cada iteración del bucle, el programa lee una línea de datos desde el puerto serie, la decodifica y la almacena en la lista "valores". Si la lista contiene al menos 4 valores, se procesan y escriben en el archivo CSV.

El contador de datos se incrementa en cada iteración para llevar un registro de cuántos datos se han recibido, cuando el contador de datos alcanza o supera el valor establecido en num\_datos, el programa sale del bucle principal.

### 3.2. Resultados

En esta sección se presentan los resultados obtenidos al simular el circuito. En las figuras 7 y 8 se muestran las lecturas obtenidas en DC y AC respectivamente, se logra observar que las lecturas cumplen con las especificaciones solicitadas. Para realizar el cambio entre DC y AC se deben pulsar varios botones, los cuales son fáciles de ubicar y entender.

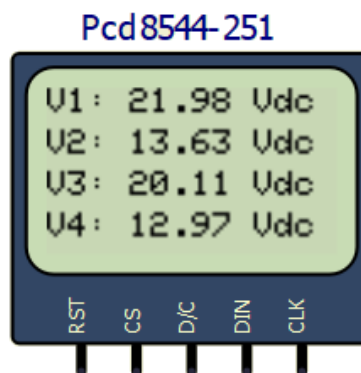


Figura 7: Lectura en DC.

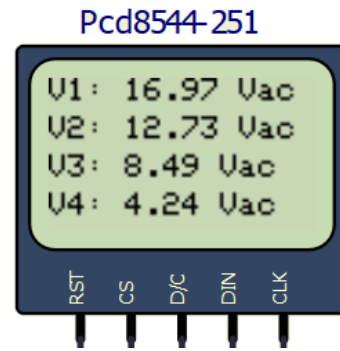


Figura 8: Lectura en AC.

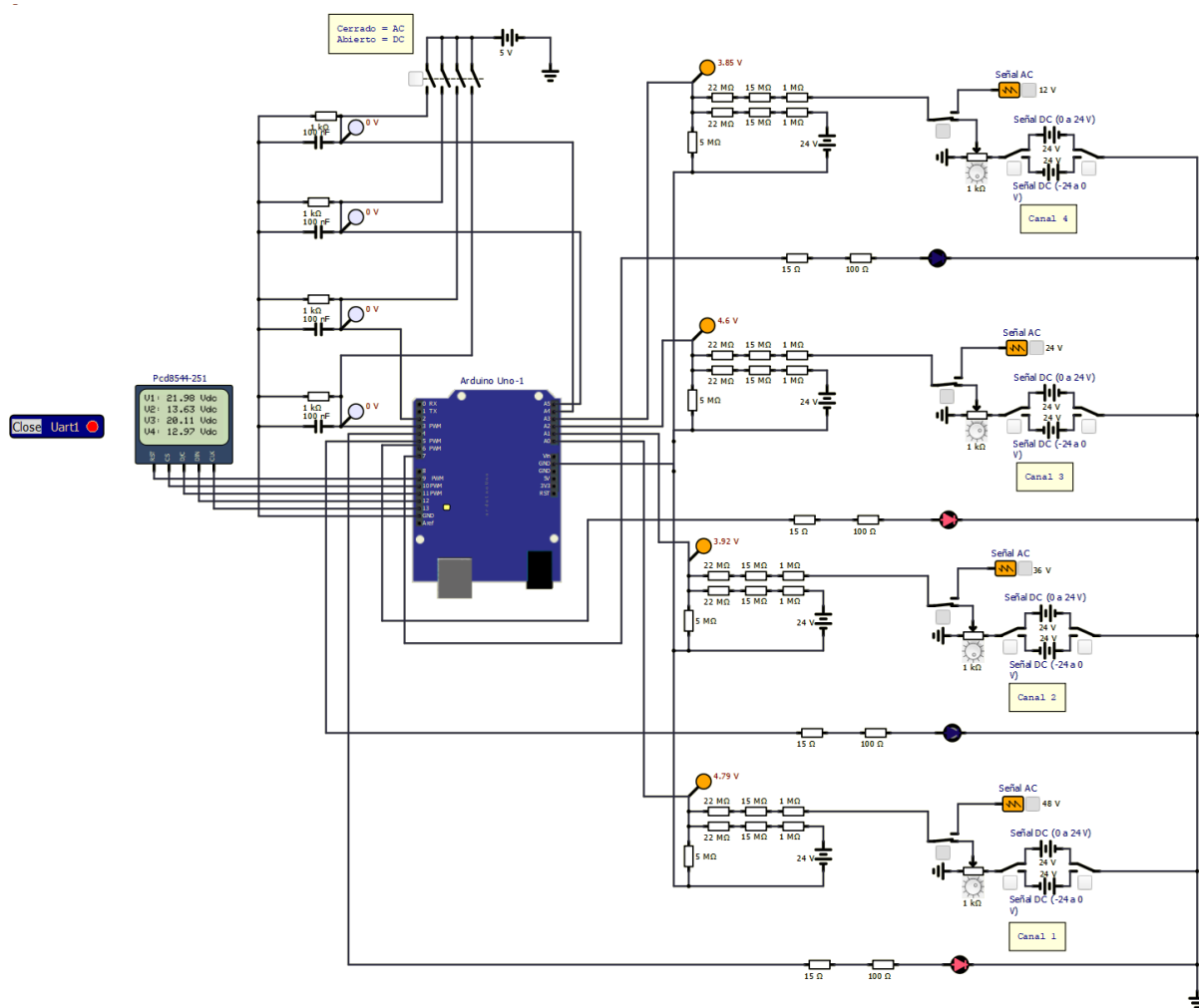


Figura 9: LED's encendidos.

```
connected to: COM3
Created file
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
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['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
['21.98Vdc', '13.63Vdc', '20.11Vdc', '12.97Vdc']
```

Figura 10: Resultados obtenidos en Python.

### 3.3. Guía de ejecución

A continuación se presenta una guía de como ejecutar el programa, cabe resaltar que esta simulación fue realizada en el sistema operativo Windows 11.

1. Clonar el repositorio .
2. Moverse a la carpeta src.  

```
cd src
```
3. Abrir manualmente el simulador SimulIDE.
4. Cargar el archivo con extensión .simu.
5. En el controlador, hacer click izquierdo y cargar el firmware, el cual tiene extensión .hex y se ubica en la carpeta build.
6. Crear los puertos seriales locales COM2 y COM3.
7. Encender
8. Correr la simulación.

## 4. Conclusiones y recomendaciones

- El Arduino Uno es un microcontrolador con una arquitectura mucho mas entendible que otros microcontroladores y con mayor cantidad de pines que permite un desarrollo mas sencillo de programas y un uso de periféricos más amplio.
- Se implemento con exito el envío de datos hacia la computadora a través de puertos seriales virtuales.

- En la carpeta se incluye un script en el cual incluye una dirección para realizar la conexión serial en sistema operativo linux.
- Se logro encender los LED's respectivos a cada canal cuando registraban tension menor a -20V o superior a 20V.

## Referencias

1. Arduino. Arduino uno.
2. Philips. Pcd8544  $48 \times 84$  pixels matrix lcd controller/driver.



## 5. Anexos



## 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
    - 32KB Flash
    - 2KB SRAM
    - 1KB 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 as a tool for education purposes or industry-related tasks, the UNO 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; Arduino 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 Arduino UNO R3 board in industries, there are a range of companies using the UNO 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

- 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.

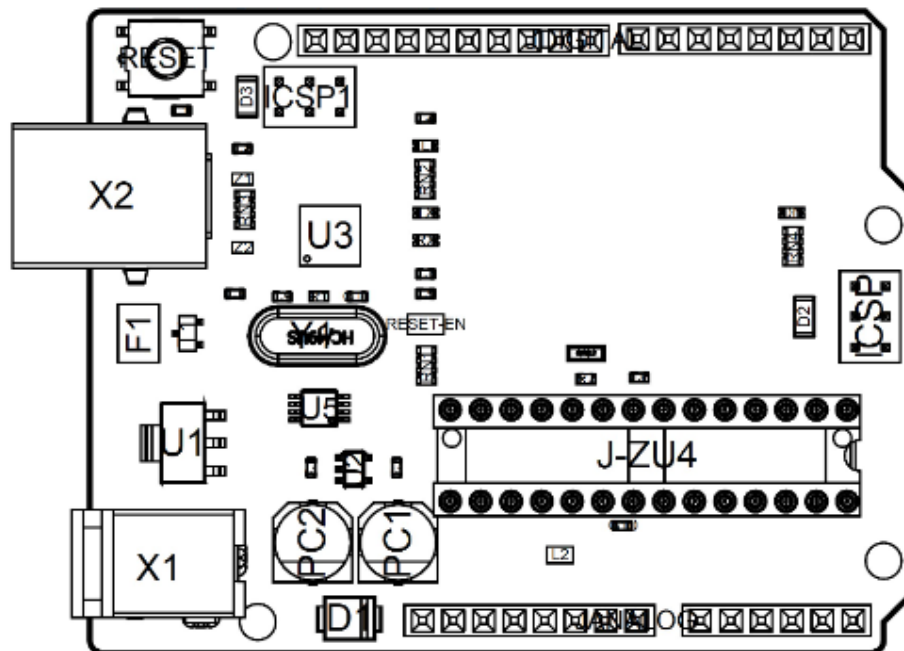
### 2.2 Power Consumption

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



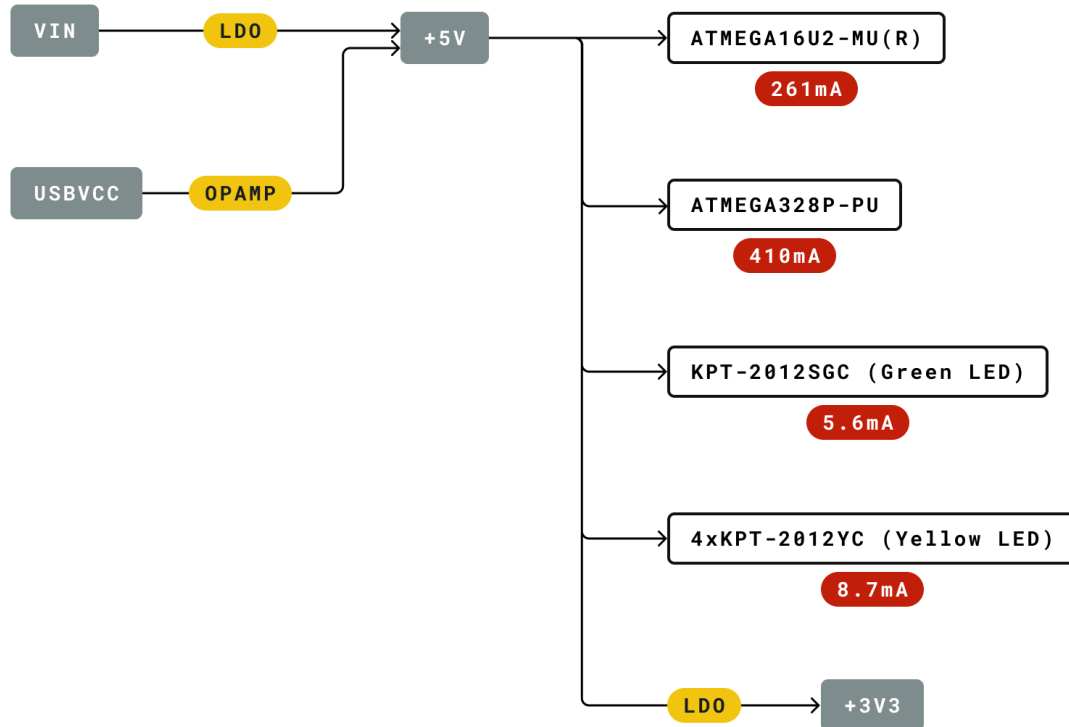
Ref.	Description	Ref.	Description
X1	Power jack 2.1x5.5mm	U1	SPX1117M3-L-5 Regulator
X2	USB B Connector	U3	ATMEGA16U2 Module
PC1	EEE-1EA470WP 25V SMD Capacitor	U5	LMV358LIST-A.9 IC
PC2	EEE-1EA470WP 25V SMD Capacitor	F1	Chip Capacitor, High Density
D1	CGRA4007-G Rectifier	ICSP	Pin header connector (through 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



#### Legend:

- |             |               |                 |
|-------------|---------------|-----------------|
| Component   | Power I/O     | Conversion Type |
| Max Current | Voltage Range |                 |

Power tree





## 4 Board Operation

### 4.1 Getting Started - IDE

If you want to program your Arduino UNO R3 while offline you need to install the Arduino Desktop IDE [1] To connect the Arduino UNO 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 Web Editor

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

The Arduino Web 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

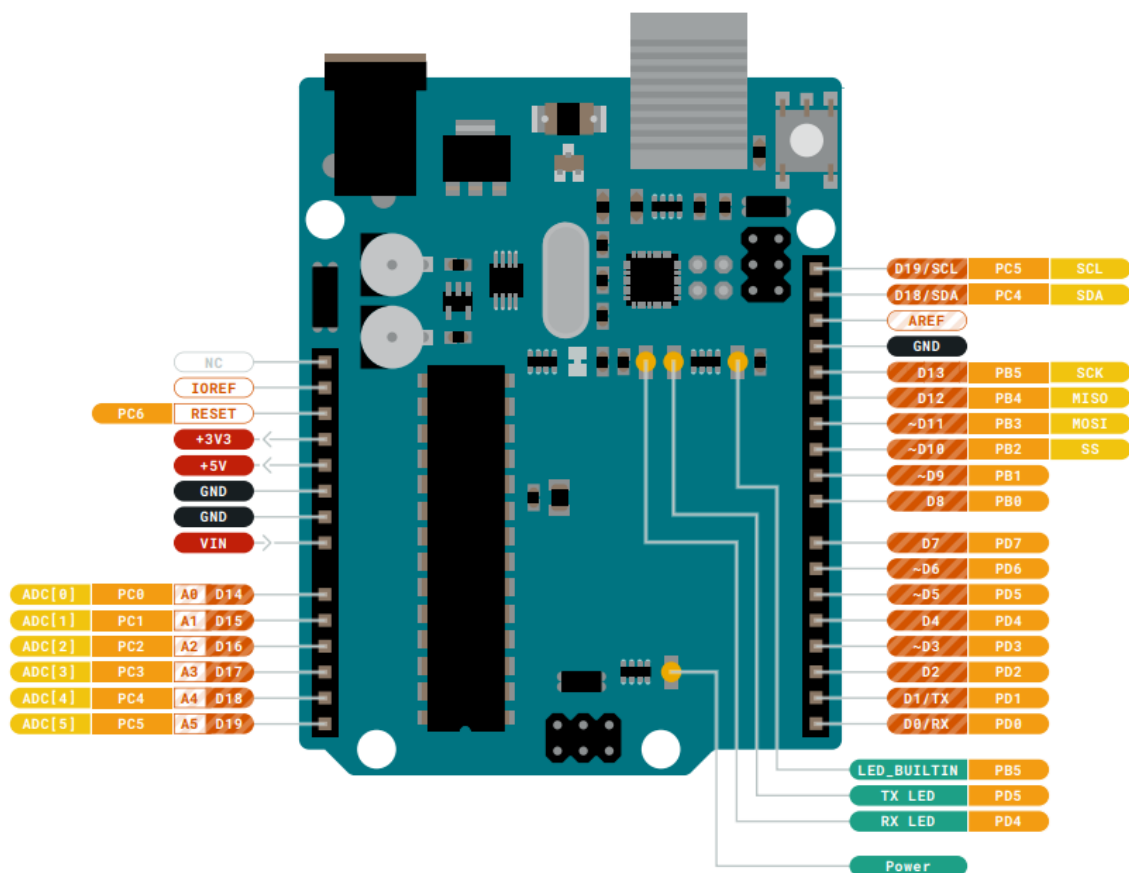
Sample sketches for the Arduino UNO R3 can be found either in the “Examples” menu in the Arduino IDE or in the “Documentation” section of the Arduino website [4]

### 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

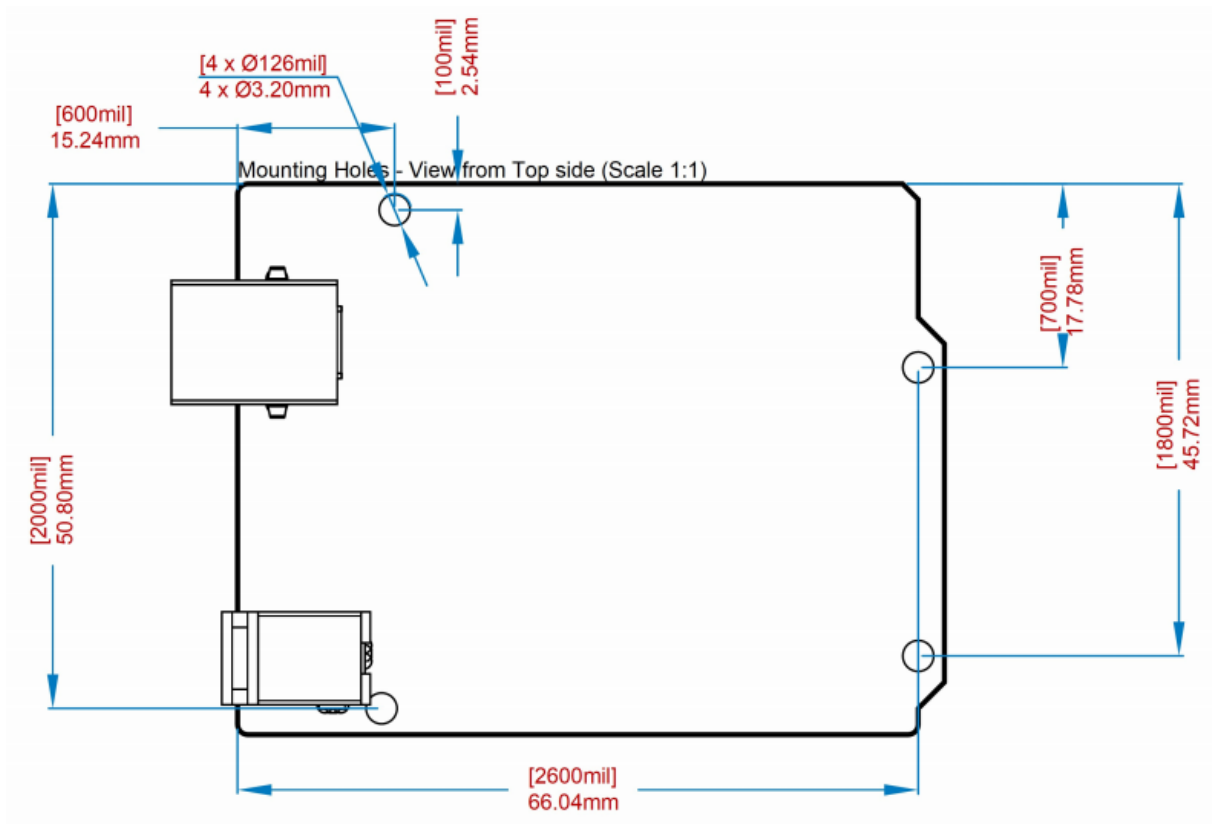
## 5.2 JDIGITAL

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).

<b>ROHS 2 Directive 2011/65/EU</b>	
Conforms to:	EN50581:2012
<b>Directive 2014/35/EU. (LVD)</b>	
Conforms to:	EN 60950-1:2006/A11:2009/A1:2010/A12:2011/AC:2011
<b>Directive 2004/40/EC &amp; 2008/46/EC &amp; 2013/35/EU, EMF</b>	
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 nedit 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°C and shouldn't be lower than -40°C.

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

<b>Company name</b>	<b>Arduino S.r.l</b>
Company Address	Via Andrea Appiani 25 20900 MONZA Italy

## 9 Reference Documentation

Reference	Link
Arduino IDE (Desktop)	<a href="https://www.arduino.cc/en/Main/Software">https://www.arduino.cc/en/Main/Software</a>
Arduino IDE (Cloud)	<a href="https://create.arduino.cc/editor">https://create.arduino.cc/editor</a>
Cloud IDE Getting Started	<a href="https://create.arduino.cc/projecthub/Arduino_Genuino/getting-started-with-arduino-web-editor-4b3e4a">https://create.arduino.cc/projecthub/Arduino_Genuino/getting-started-with-arduino-web-editor-4b3e4a</a>
Arduino Website	<a href="https://www.arduino.cc/">https://www.arduino.cc/</a>
Project Hub	<a href="https://create.arduino.cc/projecthub?by=part&amp;part_id=11332&amp;sort=trending">https://create.arduino.cc/projecthub?by=part&amp;part_id=11332&amp;sort=trending</a>
Library Reference	<a href="https://www.arduino.cc/reference/en/">https://www.arduino.cc/reference/en/</a>
Online Store	<a href="https://store.arduino.cc/">https://store.arduino.cc/</a>

## 10 Revision History

Date	Revision	Changes
26/07/2023	2	General Update
06/2021	1	Datasheet release

# DATA SHEET

**PCD8544**

**48 × 84 pixels matrix LCD  
controller/driver**

Product specification  
File under Integrated Circuits, IC17

1999 Apr 12



**48 × 84 pixels matrix LCD controller/driver****PCD8544**

<b>CONTENTS</b>		<b>8</b>	<b>INSTRUCTIONS</b>
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2	GENERAL DESCRIPTION	8.2	Reset function
3	APPLICATIONS	8.3	Function set
4	ORDERING INFORMATION	8.3.1	Bit PD
5	BLOCK DIAGRAM	8.3.2	Bit V
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6.1.2	C0 to C83 column driver outputs	8.5	Set Y address of RAM
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6.1.6	T1, T2, T3 and T4: test pads	8.9	Set V <sub>OP</sub> value
6.1.7	SDIN: serial data line	9	LIMITING VALUES
6.1.8	SCLK: serial clock line	10	HANDLING
6.1.9	D/C: mode select	11	DC CHARACTERISTICS
6.1.10	SCE: chip enable	12	AC CHARACTERISTICS
6.1.11	OSC: oscillator	12.1	Serial interface
6.1.12	RES: reset	12.2	Reset
7	FUNCTIONAL DESCRIPTION	13	APPLICATION INFORMATION
7.1	Oscillator	14	BONDING PAD LOCATIONS
7.2	Address Counter (AC)	14.1	Bonding pad information
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7.5	Display address counter	16	DEFINITIONS
7.6	LCD row and column drivers	17	LIFE SUPPORT APPLICATIONS
7.7	Addressing		
7.7.1	Data structure		
7.8	Temperature compensation		

## 48 × 84 pixels matrix LCD controller/driver

## PCD8544

**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  $V_{\text{DD}}$  to  $V_{\text{SS}}$ : 2.7 to 3.3 V
- Display supply voltage range  $V_{\text{LCD}}$  to  $V_{\text{SS}}$ 
  - 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  $V_{\text{LCD}}$
- 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.

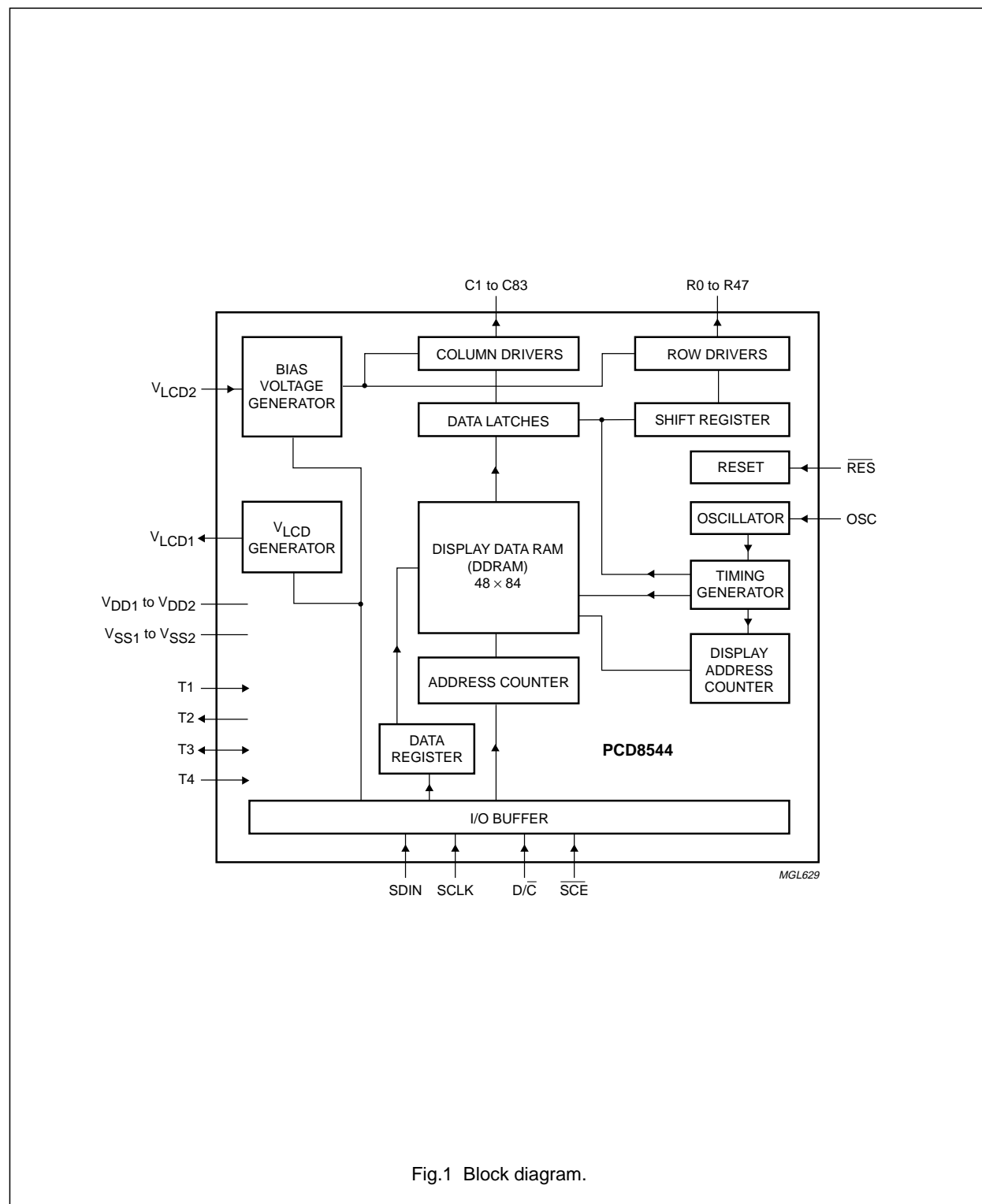
**4 ORDERING INFORMATION**

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

48 × 84 pixels matrix LCD controller/driver

PCD8544

## 5 BLOCK DIAGRAM



## 48 × 84 pixels matrix LCD controller/driver

## PCD8544

## 6 PINNING

SYMBOL	DESCRIPTION
R0 to R47	LCD row driver outputs
C0 to C83	LCD column driver outputs
V <sub>SS1</sub> , V <sub>SS2</sub>	ground
V <sub>DD1</sub> , V <sub>DD2</sub>	supply voltage
V <sub>LCD1</sub> , V <sub>LCD2</sub>	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/command
$\overline{SCE}$	chip enable
OSC	oscillator
$\overline{RES}$	external reset input
dummy1, 2, 3, 4	not connected

## Note

- 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<sub>SS1</sub>, V<sub>SS2</sub>: NEGATIVE POWER SUPPLY RAILS

Supply rails V<sub>SS1</sub> and V<sub>SS2</sub> must be connected together.

6.1.4 V<sub>DD1</sub>, V<sub>DD2</sub>: POSITIVE POWER SUPPLY RAILS

Supply rails V<sub>DD1</sub> and V<sub>DD2</sub> must be connected together.

6.1.5 V<sub>LCD1</sub>, V<sub>LCD2</sub>: LCD POWER SUPPLY

Positive power supply for the liquid crystal display. Supply rails V<sub>LCD1</sub> and V<sub>LCD2</sub> must be connected together.

## 6.1.6 T1, T2, T3 AND T4: TEST PADS

T1, T3 and T4 must be connected to V<sub>SS</sub>, 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<sub>DD</sub>. 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<sub>SS</sub>, 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.

---

**48 × 84 pixels matrix LCD controller/driver****PCD8544**

---

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

**7.4 Timing generator**

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

**7.5 Display address counter**

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

**7.6 LCD row and column drivers**

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

## 48 × 84 pixels matrix LCD controller/driver

PCD8544

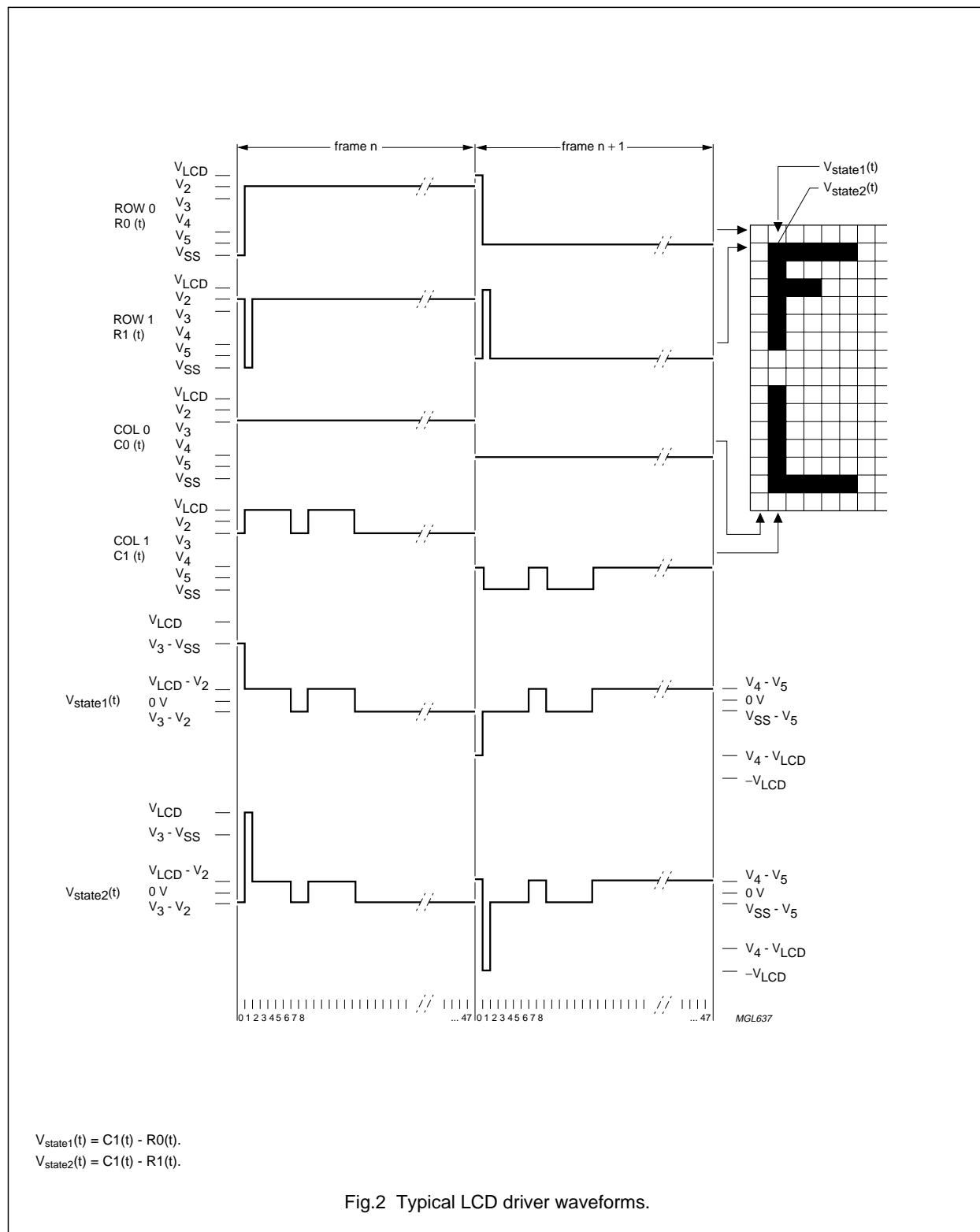


Fig.2 Typical LCD driver waveforms.

$48 \times 84$  pixels matrix LCD controller/driver

PCD8544

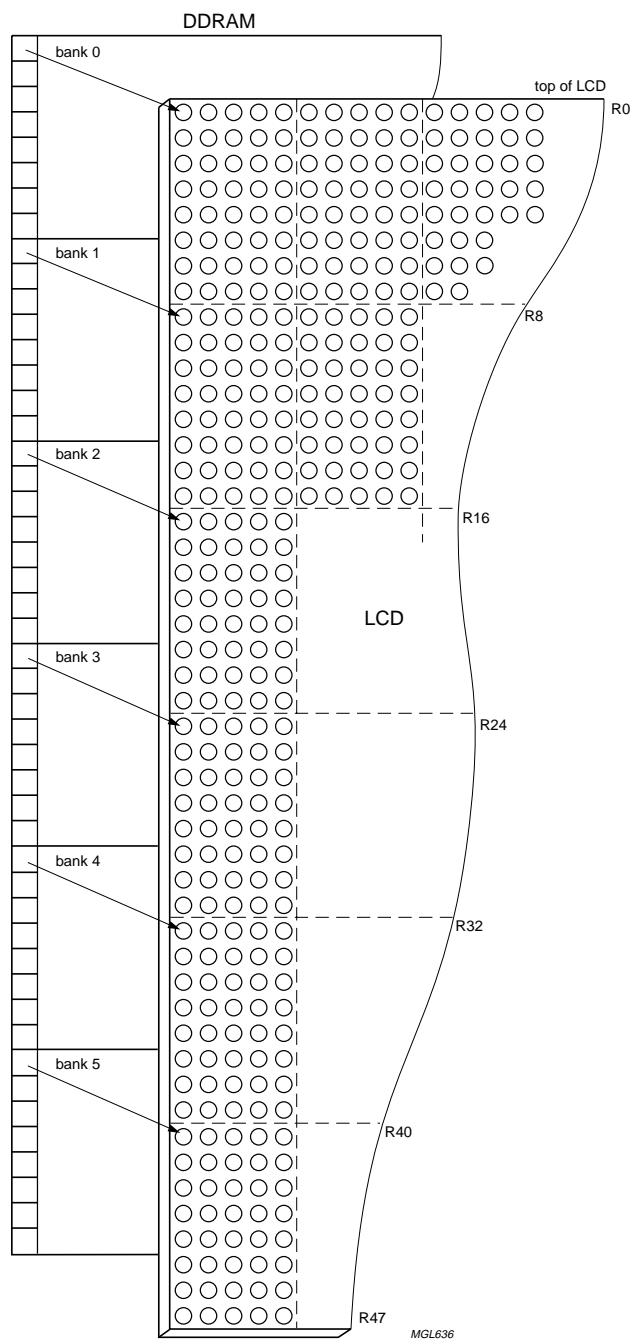


Fig.3 DDRAM to display mapping.

## 48 × 84 pixels matrix LCD controller/driver

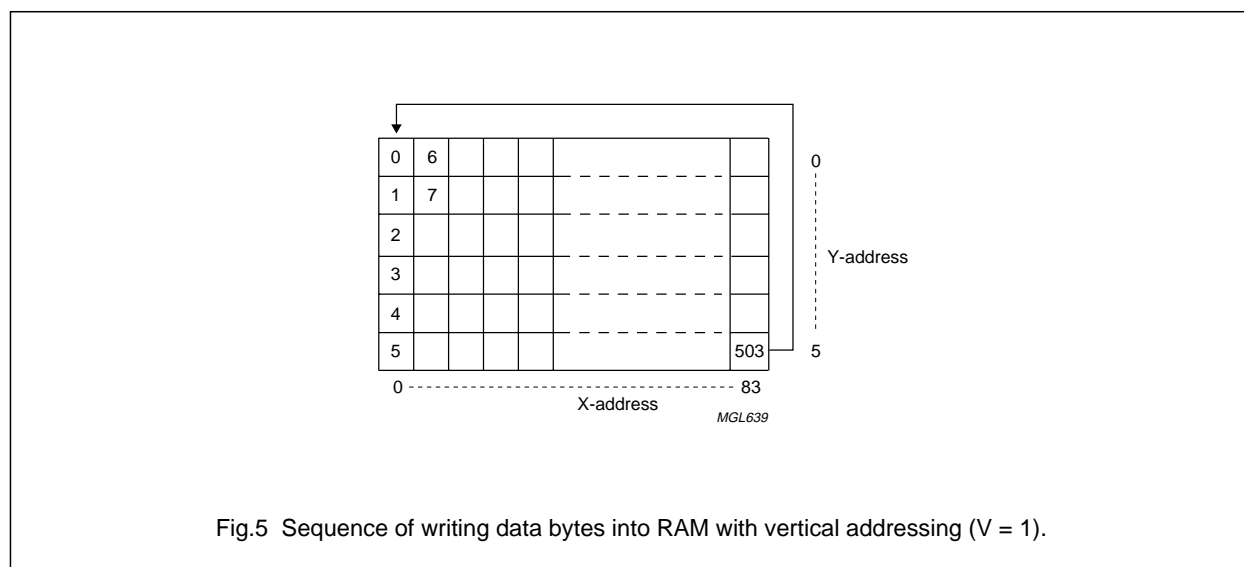
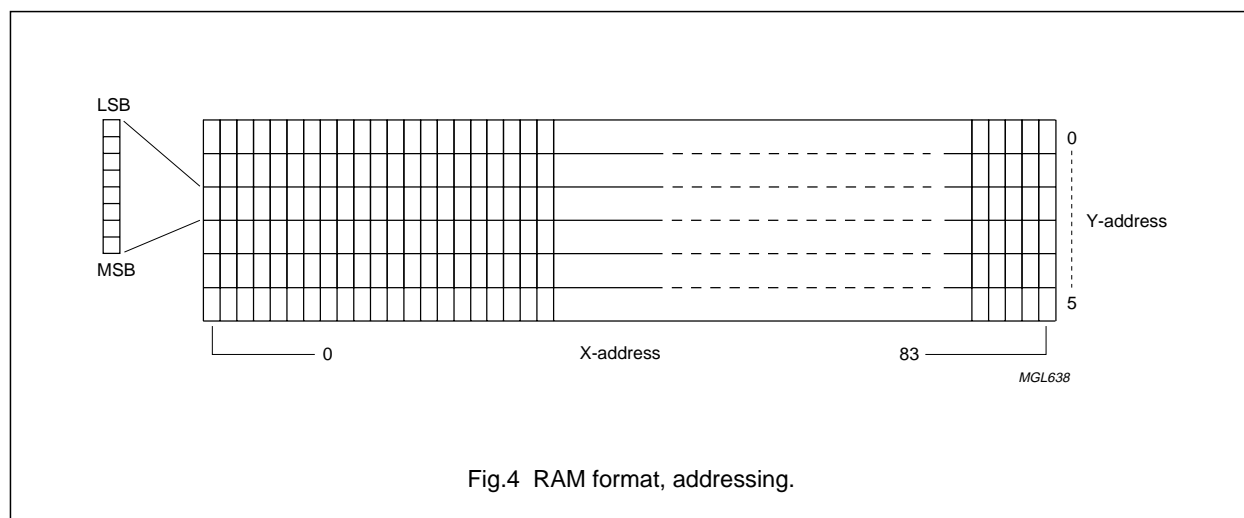
## PCD8544

## 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





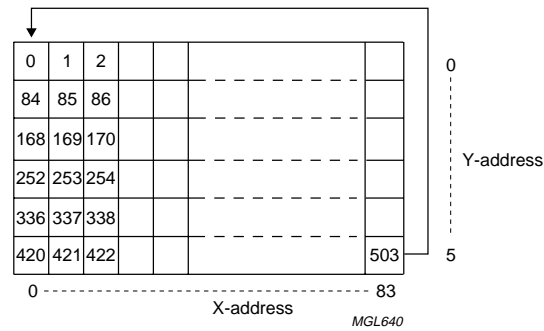
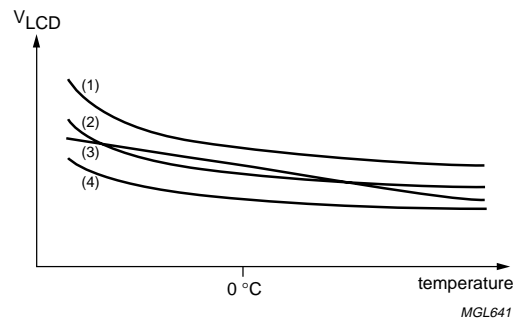
**48 × 84 pixels matrix LCD controller/driver****PCD8544**

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).

## 48 × 84 pixels matrix LCD controller/driver

## PCD8544

## 8 INSTRUCTIONS

The instruction format is divided into two modes: If  $\overline{D/\overline{C}}$  (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  $\overline{D/\overline{C}}$  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  $\overline{D/\overline{C}}$  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.

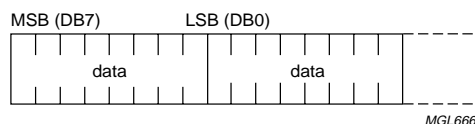


Fig.8 General format of data stream.

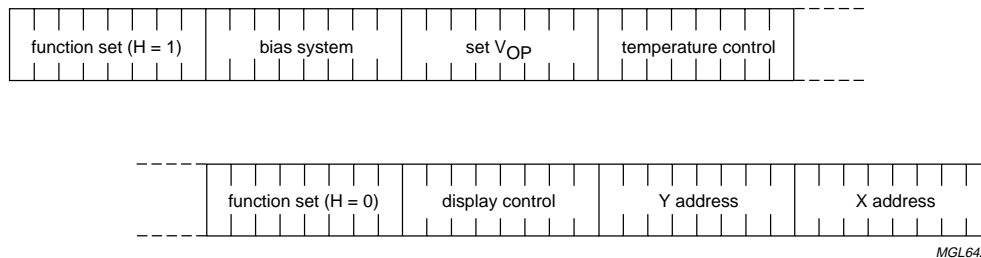


Fig.9 Serial data stream, example.

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
- $\overline{D/\overline{C}}$  indicates whether the byte is a command ( $\overline{D/\overline{C}} = 0$ ) or RAM data ( $\overline{D/\overline{C}} = 1$ ); 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).

$48 \times 84$  pixels matrix LCD controller/driver

PCD8544

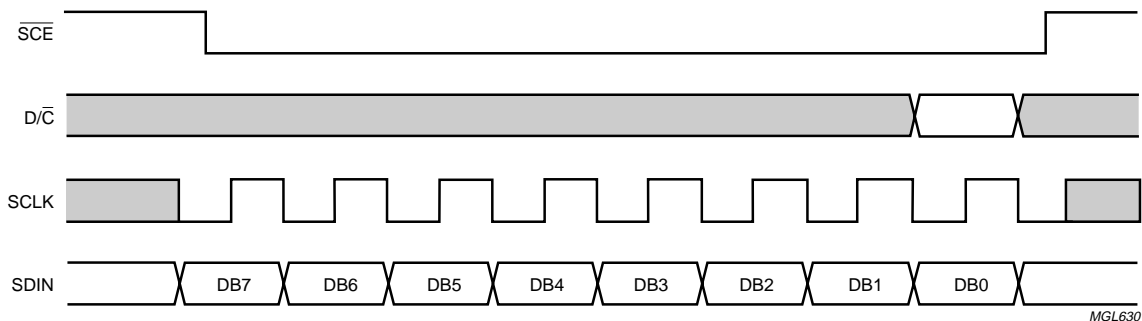


Fig.10 Serial bus protocol - transmission of one byte.

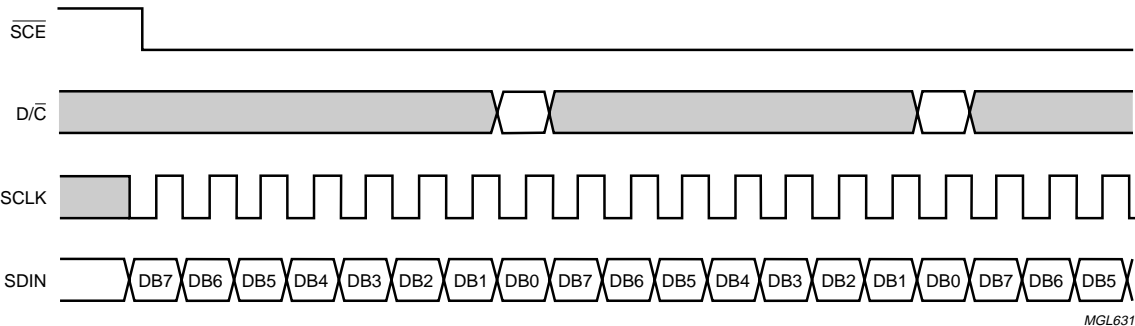
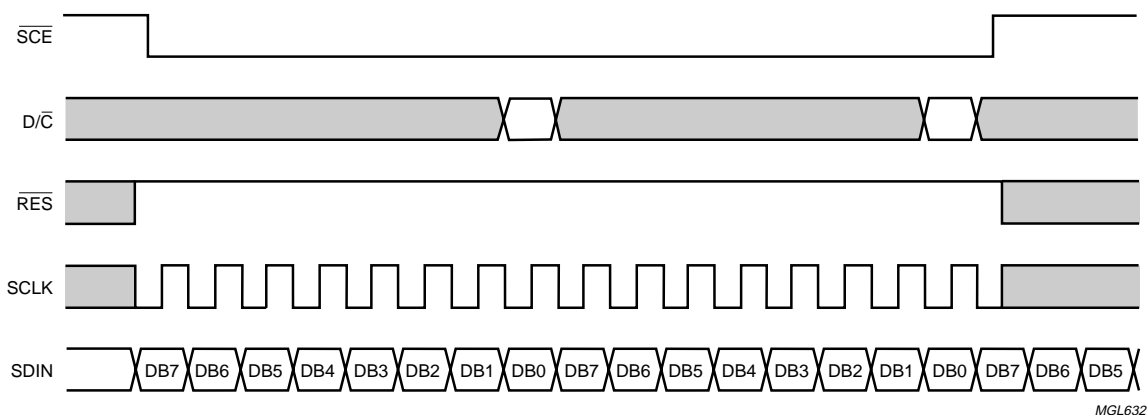
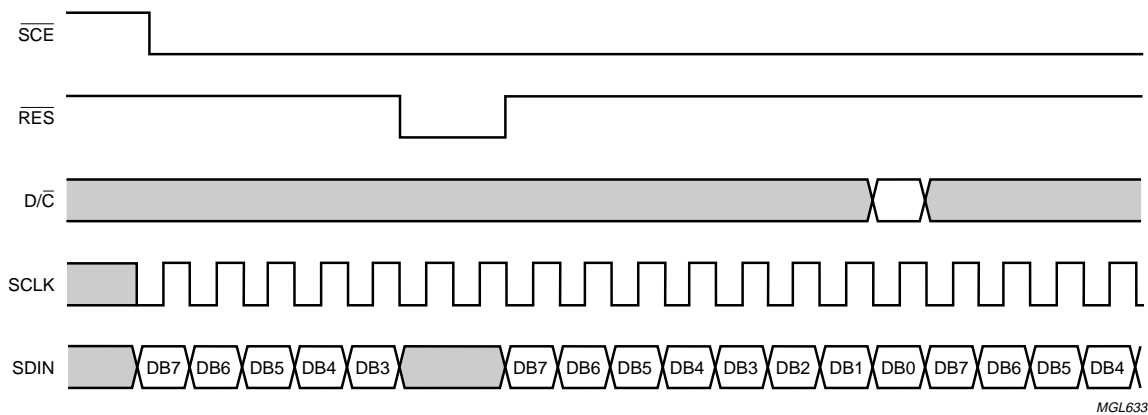


Fig.11 Serial bus protocol - transmission of several bytes.

## 48 × 84 pixels matrix LCD controller/driver

PCD8544

Fig.12 Serial bus reset function ( $\overline{\text{SCE}}$ ).Fig.13 Serial bus reset function ( $\overline{\text{RES}}$ ).

## 48 × 84 pixels matrix LCD controller/driver

## PCD8544

**Table 1** Instruction set

INSTRUCTION	D/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 <sub>7</sub>	D <sub>6</sub>	D <sub>5</sub>	D <sub>4</sub>	D <sub>3</sub>	D <sub>2</sub>	D <sub>1</sub>	D <sub>0</sub>	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 <sub>2</sub>	Y <sub>1</sub>	Y <sub>0</sub>	sets Y-address of RAM; 0 ≤ Y ≤ 5
Set X address of RAM	0	1	X <sub>6</sub>	X <sub>5</sub>	X <sub>4</sub>	X <sub>3</sub>	X <sub>2</sub>	X <sub>1</sub>	X <sub>0</sub>	sets X-address part of RAM; 0 ≤ X ≤ 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 <sub>1</sub>	TC <sub>0</sub>	set Temperature Coefficient (TC <sub>x</sub> )
Reserved	0	0	0	0	0	1	X	X	X	do not use
Bias system	0	0	0	0	1	0	BS <sub>2</sub>	BS <sub>1</sub>	BS <sub>0</sub>	set Bias System (BS <sub>x</sub> )
Reserved	0	0	1	X	X	X	X	X	X	do not use
Set V <sub>OP</sub>	0	1	V <sub>OP6</sub>	V <sub>OP5</sub>	V <sub>OP4</sub>	V <sub>OP3</sub>	V <sub>OP2</sub>	V <sub>OP1</sub>	V <sub>OP0</sub>	write V <sub>OP</sub> 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	display blank 00 normal mode 10 all display segments on 01 inverse video mode 11	
TC <sub>1</sub> and TC <sub>0</sub>	V <sub>LCD</sub> temperature coefficient 0 00 V <sub>LCD</sub> temperature coefficient 1 01 V <sub>LCD</sub> temperature coefficient 2 10 V <sub>LCD</sub> temperature coefficient 3 11	

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## 8.1 Initialization

Immediately following power-on, the contents of all internal registers and of the RAM are undefined. A **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  $\leq 0.3V_{\text{DD}}$  when  $V_{\text{DD}}$  reaches  $V_{\text{DDmin}}$  (or higher) within a maximum time of 100 ms after  $V_{\text{DD}}$  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 ( $\text{TC}_1$   $\text{TC}_0 = 0$ )
- Bias system ( $\text{BS}_2$  to  $\text{BS}_0 = 0$ )
- $V_{\text{LCD}}$  is equal to 0, the HV generator is switched off ( $V_{\text{OP6}}$  to  $V_{\text{OP0}} = 0$ )
- After power-on, the RAM contents are undefined.

## 8.3 Function set

## 8.3.1 BIT PD

- All LCD outputs at  $V_{\text{SS}}$  (display off)
- Bias generator and  $V_{\text{LCD}}$  generator off,  $V_{\text{LCD}}$  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  $V_{\text{LCD}}$  is selected by bits  $\text{TC}_1$  and  $\text{TC}_0$ .

## 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  $\text{BS}_2$  to  $\text{BS}_0$ . For Mux 1 : 48, the optimum bias value n, resulting in 1/8 bias, is given by:

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

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**Table 4** Programming the required bias system

BS <sub>2</sub>	BS <sub>1</sub>	BS <sub>0</sub>	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 1/8 BIAS
V1	V <sub>LCD</sub>	V <sub>LCD</sub>
V2	(n + 3)/(n + 4)	7/8 × V <sub>LCD</sub>
V3	(n + 2)/(n + 4)	6/8 × V <sub>LCD</sub>
V4	2/(n + 4)	2/8 × V <sub>LCD</sub>
V5	1/(n + 4)	1/8 × V <sub>LCD</sub>
V6	V <sub>SS</sub>	V <sub>SS</sub>

**8.9 Set V<sub>OP</sub> value**

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

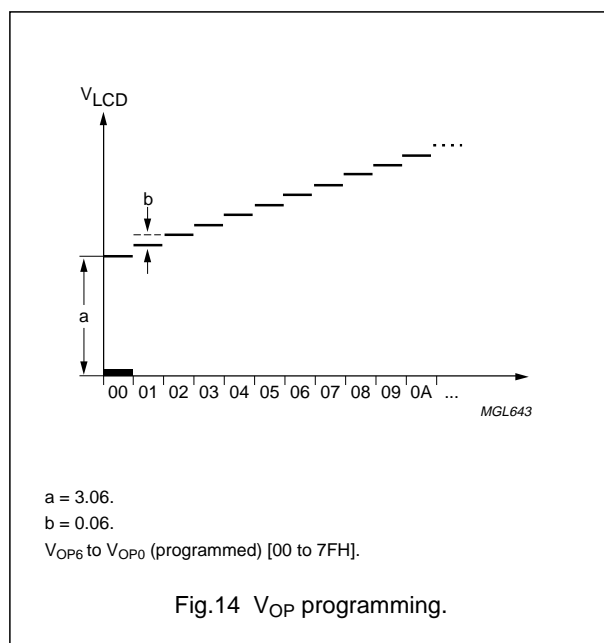
Note that the charge pump is turned off if V<sub>OP6</sub> to V<sub>OP0</sub> is set to zero.

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

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

where V<sub>th</sub> is the threshold voltage of the liquid crystal material used.

**Caution, as V<sub>OP</sub> increases with lower temperatures, care must be taken not to set a V<sub>OP</sub> that will exceed the maximum of 8.5 V when operating at –25 °C.**



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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*”).



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**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 = $10$ $\mu$ A; note 2	–	240	300	$\mu$ A
$I_{DD2}$	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 = $10$ $\mu$ A; note 2	–	–	320	$\mu$ A
$I_{DD3}$	supply current 3 (Power-down mode)	with internal or external LCD supply voltage; note 3	–	1.5	–	$\mu$ A
$I_{DD4}$	supply current external $V_{LCD}$	$V_{DD} = 2.85$ V; $V_{LCD} = 9.0$ V; $f_{SCLK} = 0$ ; notes 2 and 4	–	25	–	$\mu$ A
$I_{LCD}$	supply current external $V_{LCD}$	$V_{DD} = 2.7$ V; $V_{LCD} = 7.0$ V; $f_{SCLK} = 0$ ; $T = 25$ °C; display load = $10$ $\mu$ A; notes 2 and 4	–	42	–	$\mu$ A
<b>Logic</b>						
$V_{IL}$	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	$\mu$ A
<b>Column and row outputs</b>						
$R_{O(C)}$	column output resistance C0 to C83		–	12	20	k $\Omega$
$R_{O(R)}$	row output resistance R0 to R47		–	12	20	k $\Omega$
$V_{bias(tol)}$	bias voltage tolerance on C0 to C83 and R0 to R47		–100	0	+100	mV

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

**Notes**

1. The maximum possible V<sub>LCD</sub> 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<sub>LCD</sub>, the display load current is not transmitted to I<sub>DD</sub>.
5. Tolerance depends on the temperature (typically zero at 27 °C, maximum tolerance values are measured at the temperate range limit).

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## 12 AC CHARACTERISTICS

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

## Notes

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

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## 12.1 Serial interface

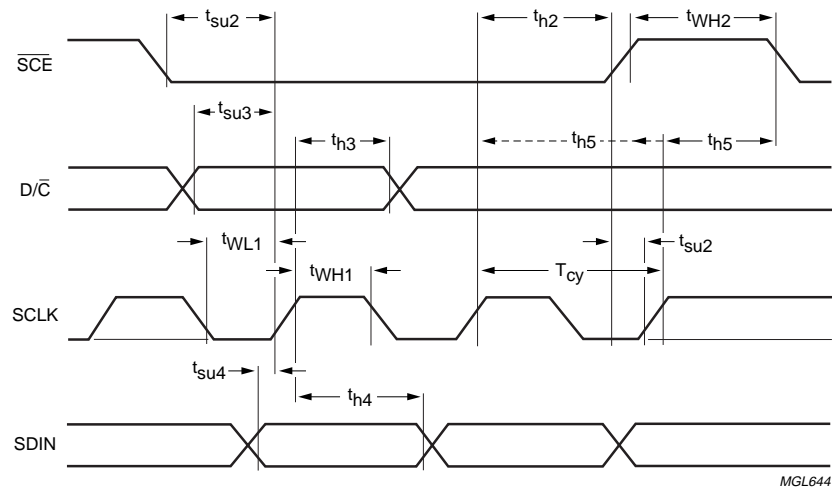


Fig.15 Serial interface timing.

## 12.2 Reset

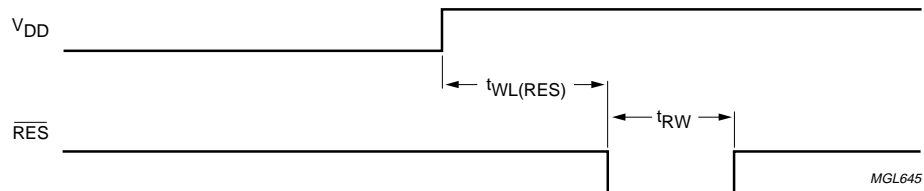


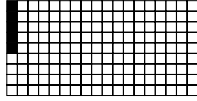
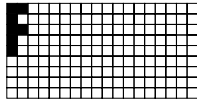
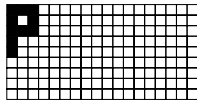
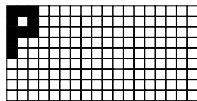
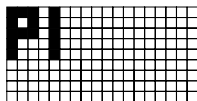
Fig.16 Reset timing.

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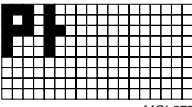
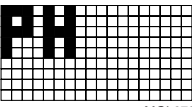
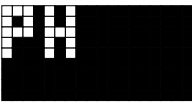
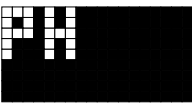
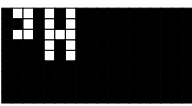
## 13 APPLICATION INFORMATION

Table 6 Programming example

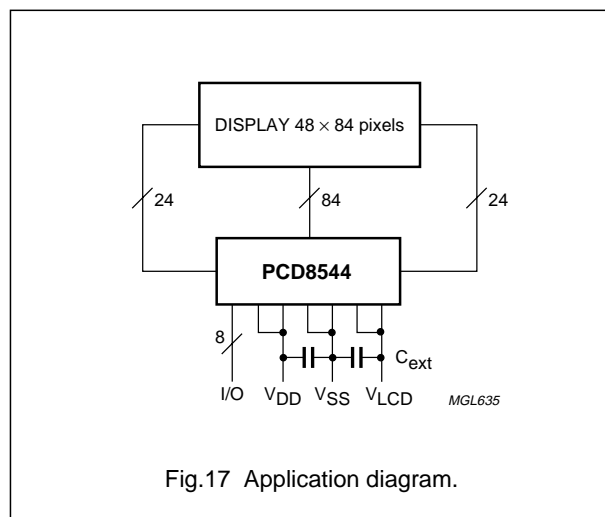
STEP	SERIAL BUS BYTE									DISPLAY	OPERATION
	D/C	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0		
1	start										$\overline{SCE}$ is going LOW
2	0	0	0	1	0	0	0	0	1		function set PD = 0 and V = 0, select extended instruction set (H = 1 mode)
3	0	1	0	0	1	0	0	0	0		set $V_{OP}$ ; $V_{OP}$ is set to a +16 × b [V]
4	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

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STEP	SERIAL BUS BYTE									DISPLAY	OPERATION
	D/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.



The required minimum value for the external capacitors is:  $C_{ext} = 1.0 \mu F$ .

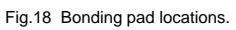
Higher capacitor values are recommended for ripple reduction.

## 14 BONDING PAD LOCATIONS

### 14.1 Bonding pad information (see Fig.18)

PARAMETER	SIZE
Pad pitch	min. 100 $\mu m$
Pad size, aluminium	80 × 100 $\mu m$
Bump dimensions	59 × 89 × 17.5 ( $\pm 5$ ) $\mu m$
Wafer thickness	max. 380 $\mu m$

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**Table 7** Bonding pad locations (dimensions in  $\mu\text{m}$ ).  
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 <sub>DD1</sub>	+4330	+1085
15	V <sub>DD1</sub>	+4230	+1085
16	V <sub>DD1</sub>	+4130	+1085
17	V <sub>DD1</sub>	+4030	+1085
18	V <sub>DD1</sub>	+3930	+1085
19	V <sub>DD2</sub>	+3750	+1085
20	V <sub>DD2</sub>	+3650	+1085
21	V <sub>DD2</sub>	+3550	+1085
22	V <sub>DD2</sub>	+3450	+1085
23	V <sub>DD2</sub>	+3350	+1085
24	V <sub>DD2</sub>	+3250	+1085
25	V <sub>DD2</sub>	+3150	+1085
26	V <sub>DD2</sub>	+3050	+1085
27	SCLK	+2590	+1085
28	SDIN	+2090	+1085
29	D/C	+1090	+1085
30	SCE	+90	+1085
31	RES	-910	+1085
32	OSC	-1410	+1085
33	T3	-1826	+1085
34	V <sub>SS2</sub>	-2068	+1085
35	V <sub>SS2</sub>	-2168	+1085
36	V <sub>SS2</sub>	-2268	+1085
37	V <sub>SS2</sub>	-2368	+1085
38	V <sub>SS2</sub>	-2468	+1085

PAD	PAD NAME	x	y
39	T4	-2709	+1085
40	V <sub>SS1</sub>	-2876	+1085
41	V <sub>SS1</sub>	-2976	+1085
42	V <sub>SS1</sub>	-3076	+1085
43	V <sub>SS1</sub>	-3176	+1085
44	T1	-3337	+1085
45	V <sub>LCD2</sub>	-3629	+1085
46	V <sub>LCD2</sub>	-3789	+1085
47	V <sub>LCD1</sub>	-4231	+1085
48	V <sub>LCD1</sub>	-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



## 48 × 84 pixels matrix LCD controller/driver

## PCD8544

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

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**48 × 84 pixels matrix LCD controller/driver****PCD8544**

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<b>PAD</b>	<b>PAD NAME</b>	<b>x</b>	<b>y</b>
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

## 48 × 84 pixels matrix LCD controller/driver

PCD8544

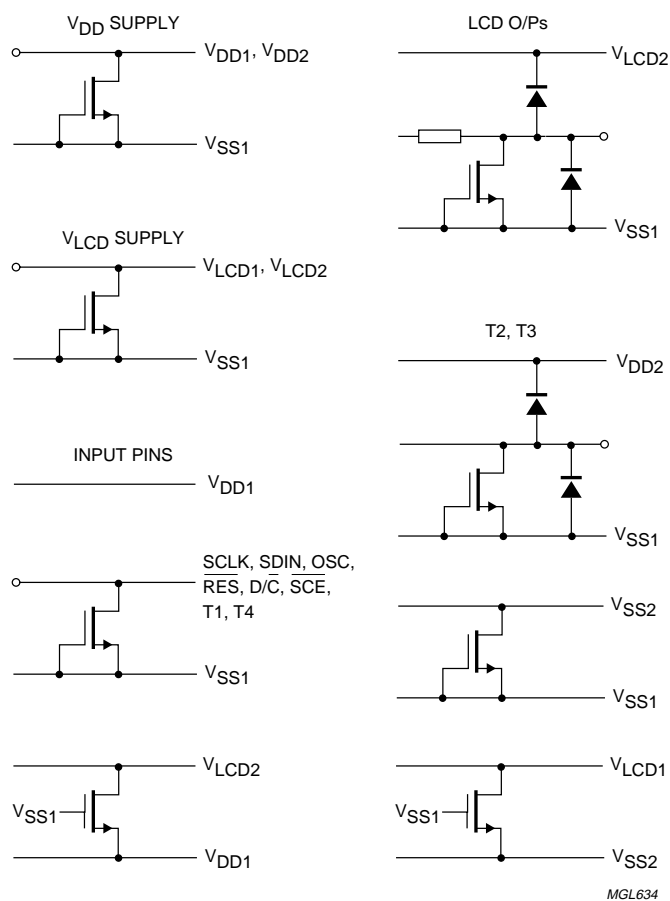
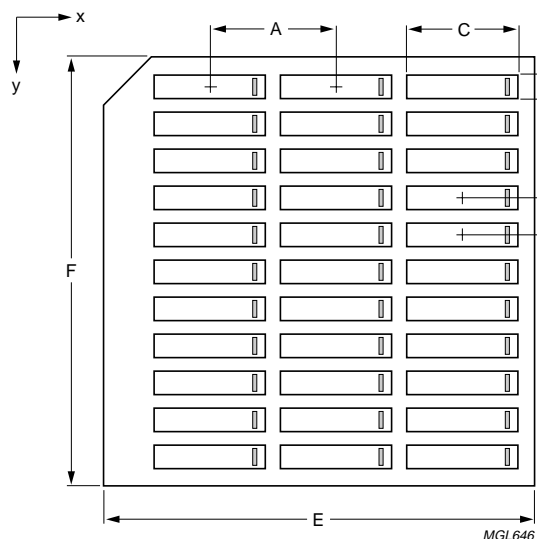


Fig.19 Device protection diagram.

## 48 × 84 pixels matrix LCD controller/driver

PCD8544

## 15 TRAY INFORMATION



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

Fig.20 Tray details.

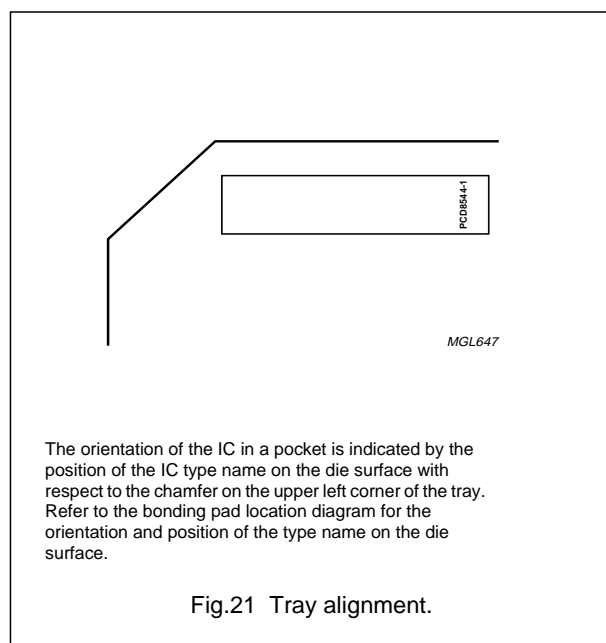


Fig.21 Tray alignment.

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

---

**48 × 84 pixels matrix LCD controller/driver****PCD8544**

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**16 DEFINITIONS**

<b>Data sheet status</b>	
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.
<b>Limiting values</b>	
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.	
<b>Application information</b>	
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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**48 × 84 pixels matrix LCD controller/driver****PCD8544**

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**NOTES**

# Philips Semiconductors – a worldwide company

**Argentina:** see South America

**Australia:** 34 Waterloo Road, NORTH RYDE, NSW 2113,  
Tel. +61 2 9805 4455, Fax. +61 2 9805 4466

**Austria:** Computerstr. 6, A-1101 WIEN, P.O. Box 213,  
Tel. +43 1 60 101 1248, Fax. +43 1 60 101 1210

**Belarus:** Hotel Minsk Business Center, Bld. 3, r. 1211, Volodarski Str. 6,  
220050 MINSK, Tel. +375 172 20 0733, Fax. +375 172 20 0773

**Belgium:** see The Netherlands

**Brazil:** see South America

**Bulgaria:** Philips Bulgaria Ltd., Energoproject, 15th floor,  
51 James Bourchier Blvd., 1407 SOFIA,  
Tel. +359 2 68 9211, Fax. +359 2 68 9102

**Canada:** PHILIPS SEMICONDUCTORS/COMPONENTS,  
Tel. +1 800 234 7381, Fax. +1 800 943 0087

**China/Hong Kong:** 501 Hong Kong Industrial Technology Centre,  
72 Tat Chee Avenue, Kowloon Tong, HONG KONG,  
Tel. +852 2319 7888, Fax. +852 2319 7700

**Colombia:** see South America

**Czech Republic:** see Austria

**Denmark:** Sydhavnsgrde 23, 1780 COPENHAGEN V,  
Tel. +45 33 29 3333, Fax. +45 33 29 3905

**Finland:** Sinikalliontie 3, FIN-02630 ESPOO,  
Tel. +358 9 615 800, Fax. +358 9 6158 0920

**France:** 51 Rue Carnot, BP317, 92156 SURESNES Cedex,  
Tel. +33 1 4099 6161, Fax. +33 1 4099 6427

**Germany:** HammerbrookstraÙe 69, D-20097 HAMBURG,  
Tel. +49 40 2353 60, Fax. +49 40 2353 6300

**Hungary:** see Austria

**India:** Philips INDIA Ltd, Band Box Building, 2nd floor,  
254-D, Dr. Annie Besant Road, Worli, MUMBAI 400 025,  
Tel. +91 22 493 8541, Fax. +91 22 493 0966

**Indonesia:** PT Philips Development Corporation, Semiconductors Division,  
Gedung Philips, Jl. Buncit Raya Kav.99-100, JAKARTA 12510,  
Tel. +62 21 794 0040 ext. 2501, Fax. +62 21 794 0080

**Ireland:** Newstead, Clonskeagh, DUBLIN 14,  
Tel. +353 1 7640 000, Fax. +353 1 7640 200

**Israel:** RAPAC Electronics, 7 Kehilat Saloniki St, PO Box 18053,  
TEL AVIV 61180, Tel. +972 3 645 0444, Fax. +972 3 649 1007

**Italy:** PHILIPS SEMICONDUCTORS, Piazza IV Novembre 3,  
20124 MILANO, Tel. +39 2 6752 2531, Fax. +39 2 6752 2557

**Japan:** Philips Bldg 13-37, Kohnan 2-chome, Minato-ku,  
TOKYO 108-8507, Tel. +81 3 3740 5130, Fax. +81 3 3740 5077

**Korea:** Philips House, 260-199 Itaewon-dong, Yongsan-ku, SEOUL,  
Tel. +82 2 709 1412, Fax. +82 2 709 1415

**Malaysia:** No. 76 Jalan Universiti, 46200 PETALING JAYA, SELANGOR,  
Tel. +60 3 750 5214, Fax. +60 3 757 4880

**Mexico:** 5900 Gateway East, Suite 200, EL PASO, TEXAS 79905,  
Tel. +9-5 800 234 7381, Fax. +9-5 800 943 0087

**Middle East:** see Italy

**Netherlands:** Postbus 90050, 5600 PB EINDHOVEN, Bldg. VB,  
Tel. +31 40 27 82785, Fax. +31 40 27 88399

**New Zealand:** 2 Wagener Place, C.P.O. Box 1041, AUCKLAND,  
Tel. +64 9 849 4160, Fax. +64 9 849 7811

**Norway:** Box 1, Manglerud 0612, OSLO,  
Tel. +47 22 74 8000, Fax. +47 22 74 8341

**Pakistan:** see Singapore

**Philippines:** Philips Semiconductors Philippines Inc.,  
106 Valero St. Salcedo Village, P.O. Box 2108 MCC, MAKATI,  
Metro MANILA, Tel. +63 2 816 6380, Fax. +63 2 817 3474

**Poland:** Ul. Lukiska 10, PL 04-123 WARSZAWA,  
Tel. +48 22 612 2831, Fax. +48 22 612 2327

**Portugal:** see Spain

**Romania:** see Italy

**Russia:** Philips Russia, Ul. Usatcheva 35A, 119048 MOSCOW,  
Tel. +7 095 755 6918, Fax. +7 095 755 6919

**Singapore:** Lorong 1, Toa Payoh, SINGAPORE 319762,  
Tel. +65 350 2538, Fax. +65 251 6500

**Slovakia:** see Austria

**Slovenia:** see Italy

**South Africa:** S.A. PHILIPS Pty Ltd., 195-215 Main Road Martindale,  
2092 JOHANNESBURG, P.O. Box 7430 Johannesburg 2000,  
Tel. +27 11 470 5911, Fax. +27 11 470 5494

**South America:** Al. Vicente Pinzon, 173, 6th floor,  
04547-130 SÃO PAULO, SP, Brazil,  
Tel. +55 11 821 2333, Fax. +55 11 821 2382

**Spain:** Balmes 22, 08007 BARCELONA,  
Tel. +34 93 301 6312, Fax. +34 93 301 4107

**Sweden:** Kottbygatan 7, Akalla, S-16485 STOCKHOLM,  
Tel. +46 8 5985 2000, Fax. +46 8 5985 2745

**Switzerland:** Allmendstrasse 140, CH-8027 ZÜRICH,  
Tel. +41 1 488 2741 Fax. +41 1 488 3263

**Taiwan:** Philips Semiconductors, 6F, No. 96, Chien Kuo N. Rd., Sec. 1,  
TAIPEI, Taiwan Tel. +886 2 2134 2886, Fax. +886 2 2134 2874

**Thailand:** PHILIPS ELECTRONICS (THAILAND) Ltd.,  
209/2 Sanpavuth-Bangna Road Prakanong, BANGKOK 10260,  
Tel. +66 2 745 4090, Fax. +66 2 398 0793

**Turkey:** Talatpasa Cad. No. 5, 80640 GÜLTEPE/ISTANBUL,  
Tel. +90 212 279 2770, Fax. +90 212 282 6707

**Ukraine:** PHILIPS UKRAINE, 4 Patrice Lumumba str., Building B, Floor 7,  
252042 KIEV, Tel. +380 44 264 2776, Fax. +380 44 268 0461

**United Kingdom:** Philips Semiconductors Ltd., 276 Bath Road, Hayes,  
MIDDLESEX UB3 5BX, Tel. +44 181 730 5000, Fax. +44 181 754 8421

**United States:** 811 East Arques Avenue, SUNNYVALE, CA 94088-3409,  
Tel. +1 800 234 7381, Fax. +1 800 943 0087

**Uruguay:** see South America

**Vietnam:** see Singapore

**Yugoslavia:** PHILIPS, Trg N. Pasica 5/v, 11000 BEOGRAD,  
Tel. +381 11 62 5344, Fax. +381 11 63 5777

**For all other countries apply to:** Philips Semiconductors,  
International Marketing & Sales Communications, Building BE-p, P.O. Box 218,  
5600 MD EINDHOVEN, The Netherlands, Fax. +31 40 27 24825

**Internet:** <http://www.semiconductors.philips.com>

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**PHILIPS**

# Radial Leaded Multilayer Ceramic Capacitors for General Purpose Class 1, Class 2 and Class 3, 50 V<sub>DC</sub>, 100 V<sub>DC</sub>, 200 V<sub>DC</sub>, 500 V<sub>DC</sub>



## FEATURES

- High capacitance with small size
- High reliability
- Crimp and straight leadstyles
- Material categorization:  
for definitions of compliance please see  
[www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)


**RoHS**  
COMPLIANT

## APPLICATIONS

- Temperature compensation
- Coupling and decoupling

## QUICK REFERENCE DATA

DESCRIPTION	VALUE									
Ceramic Class	1				2				3	
Ceramic Dielectric	C0G				X7R				Y5V	
Voltage (V <sub>DC</sub> )	50	100	200	500	50	100	200	500	50	100
Min. Capacitance (pF)	10	10	33	33	100	100	100	100	10 000	10 000
Max. Capacitance (pF)	10 000	5600	3900	1800	1 000 000	560 000	220 000	47 000	1 000 000	220 000
Mounting	Radial									

## MARKING

Marking indicates capacitance value and tolerance in accordance with "EIA 198" and voltage marks.

## OPERATING TEMPERATURE RANGE

C0G, X7R: - 55 °C to + 125 °C

Y5V: - 30 °C to + 85 °C

## TEMPERATURE CHARACTERISTICS

Class 1: C0G

Class 2: X7R

Class 3: Y5V

## SECTIONAL SPECIFICATIONS

Climatic category (acc. to EN 60058-1)

Class 1 and 2: 55/125/21

Class 3: 30/85/21

## APPROVALS

EIA 198

IEC 60384-9

## DESIGN

- The capacitors consist of a general purpose MLCC
- The lead wires are 0.5 mm and are made of 100 % tinned copper clad steel wire
- The capacitors may be supplied with straight or kinked leads having a lead spacing of 2.5 mm and 5.0 mm
- Coating is made of yellow colored flame retardant epoxy resin in accordance with UL 94 V-0

## CAPACITANCE RANGE

10 pF to 1 µF

## TOLERANCE ON CAPACITANCE

± 5 %, ± 10 %, ± 20 %, + 80 %/- 20 %

## RATED VOLTAGE

50 V<sub>DC</sub>, 100 V<sub>DC</sub>, 200 V<sub>DC</sub>, 500 V<sub>DC</sub>

## TEST VOLTAGE

- 50 V<sub>DC</sub> and 100 V<sub>DC</sub>: 250 % of rated voltage
- 200 V<sub>DC</sub>: 150 % of rated voltage + 100 V<sub>DC</sub>
- 500 V<sub>DC</sub>: 130 % of rated voltage + 100 V<sub>DC</sub>

## INSULATION RESISTANCE AT RATED VOLTAGE

- 50 V<sub>DC</sub> and 100 V<sub>DC</sub>: 100 GΩ or 1000 ΩF, whichever is less at rated voltage within 2 min of charging
- 200 V<sub>DC</sub>, 500 V<sub>DC</sub>, and size 10: 10 GΩ or 100 ΩF, whichever is less at rated voltage within 2 min of charging

## DISSIPATION FACTOR

- Class 1      0.1 % max. when C ≥ 30 pF  
(at 1 MHz; 1 V where C ≤ 1000 pF, and at 1 kHz; 1 V where C > 1000 pF)  
For C < 30 pF: DF = 100/(400 + 20 x C)  
DF = dissipation factor in %;  
C = capacitance value in pF
- Class 2      2.5 % max. (at 1 kHz; 1 V)
- Class 3      5 % max. (at 1 kHz; 1 V)



**LEAD CONFIGURATION AND DIMENSIONS** (in millimeters)

<b>L2</b>	<b>H5</b>	<b>K2</b>	<b>K5</b>				
Component outline for lead spacing 2.5 mm ± 0.8 mm (straight leads)	Component outline for lead spacing 5.0 mm ± 0.8 mm (flat bent leads)	Component outline for lead spacing 2.5 mm ± 0.8 mm (outside kink)	Component outline for lead spacing 5.0 mm ± 0.8 mm (outside kink)				
SIZE CODE	Wb <sub>MAX.</sub>	H <sub>MAX.</sub>	T <sub>MAX.</sub>	MAXIMUM SEATING HEIGHT (SH)			
				L2	H5	K2	K5
10	3.6	3.6	2.3	1.6	2.6	3.5	-
15	4.0	4.0	2.6	1.6	2.6	3.5	3.5
20	5.0	5.0	3.2	1.6	2.6	3.5	3.5

**Notes**

- Bulk packed types have a standard lead length L = 30 mm ± 5 mm
- The K5 lead style is not available for size 10
- L2 and H5 are preferred styles

**MARKING**

SIZE 10 AND 15 CAPACITANCE VALUE < 100 pF	SIZE 10 AND 15 CAPACITANCE VALUE ≥ 100 pF	SIZE 20

**Notes**

- The capacitance code indicates actual capacitance in pF when capacitance value < 100 pF
- Two significant digits followed by one digit for the multiplier as given following: 1 = \* 10, 2 = \* 100, 3 = \* 1000, 4 = \* 10 000, 5 = \* 100 000
- The tolerance codes are J = 5 %, K = 10 %, M = 20 % and Z = + 80 %/- 20 %

**ORDERING CODE INFORMATION**

K	104	K	15	X7R	F	5	3	H	5
1	2 3 4	5	6 7	8 9 10	11	12	13	14	15
Product Type	Capacitance (pF)	Capacitance Tolerance	Size Code	T.C. Code	Rated Voltage	Lead Diameter	Packaging / Lead Length	Lead Style	Lead Spacing
K = radial leaded MLCC	The first two digits are the significant figures of capacitance and the last digit is a multiplier as follows: 0 = * 1 1 = * 10 2 = * 100 3 = * 1000 4 = * 10 000 5 = * 100 000	J = ± 5 % K = ± 10 % M = ± 20 % Z = + 80 %/- 20 %	Please refer to relevant datasheet	Please refer to relevant datasheet	F = 50 V <sub>DC</sub> H = 100 V <sub>DC</sub> K = 200 V <sub>DC</sub> L = 500 V <sub>DC</sub>	5 = 0.50 mm ± 0.05 mm	3 = bulk T = tape and reel U = ammo	H = flat crimp L = straight K = outside crimp	2 = 2.5 mm 5 = 5.0 mm



## ORDERING CODES

DIELECTRIC C0G						
CAP. (pF)	50 V <sub>DC</sub>		100 V <sub>DC</sub>		200 V <sub>DC</sub>	500 V <sub>DC</sub>
	SMALLER SIZE	NORMAL SIZE	SMALLER SIZE	NORMAL SIZE	NORMAL SIZE	NORMAL SIZE
10	K100#10C0GF5###	K100#15C0GF5###	K100#10C0GH5###	K100#15C0GH5###	-	-
12	K120#10C0GF5###	K120#15C0GF5###	K120#10C0GH5###	K120#15C0GH5###	-	-
15	K150#10C0GF5###	K150#15C0GF5###	K150#10C0GH5###	K150#15C0GH5###	-	-
18	K180#10C0GF5###	K180#15C0GF5###	K180#10C0GH5###	K180#15C0GH5###	-	-
22	K220#10C0GF5###	K220#15C0GF5###	K220#10C0GH5###	K220#15C0GH5###	-	-
27	K270#10C0GF5###	K270#15C0GF5###	K270#10C0GH5###	K270#15C0GH5###	-	-
33	K330#10C0GF5###	K330#15C0GF5###	K330#10C0GH5###	K330#15C0GH5###	K330#15C0GK5###	K330#15C0GL5##5
39	K390#10C0GF5###	K390#15C0GF5###	K390#10C0GH5###	K390#15C0GH5###	K390#15C0GK5###	K390#15C0GL5##5
47	K470#10C0GF5###	K470#15C0GF5###	K470#10C0GH5###	K470#15C0GH5###	K470#15C0GK5###	K470#15C0GL5##5
56	K560#10C0GF5###	K560#15C0GF5###	K560#10C0GH5###	K560#15C0GH5###	K560#15C0GK5###	K560#15C0GL5##5
68	K680#10C0GF5###	K680#15C0GF5###	K680#10C0GH5###	K680#15C0GH5###	K680#15C0GK5###	K680#15C0GL5##5
82	K820#10C0GF5###	K820#15C0GF5###	K820#10C0GH5###	K820#15C0GH5###	K820#15C0GK5###	K820#15C0GL5##5
100	K101#10C0GF5###	K101#15C0GF5###	K101#10C0GH5###	K101#15C0GH5###	K101#15C0GK5###	K101#15C0GL5##5
120	K121#10C0GF5###	K121#15C0GF5###	K121#10C0GH5###	K121#15C0GH5###	K121#15C0GK5###	K121#15C0GL5##5
150	K151#10C0GF5###	K151#15C0GF5###	K151#10C0GH5###	K151#15C0GH5###	K151#15C0GK5###	K151#15C0GL5##5
180	K181#10C0GF5###	K181#15C0GF5###	K181#10C0GH5###	K181#15C0GH5###	K181#15C0GK5###	K181#15C0GL5##5
220	K221#10C0GF5###	K221#15C0GF5###	K221#10C0GH5###	K221#15C0GH5###	K221#15C0GK5###	K221#15C0GL5##5
270	K271#10C0GF5###	K271#15C0GF5###	K271#10C0GH5###	K271#15C0GH5###	K271#15C0GK5###	K271#15C0GL5##5
330	K331#10C0GF5###	K331#15C0GF5###	K331#10C0GH5###	K331#15C0GH5###	K331#15C0GK5###	K331#15C0GL5##5
390	K391#10C0GF5###	K391#15C0GF5###	K391#10C0GH5###	K391#15C0GH5###	K391#15C0GK5###	K391#15C0GL5##5
470	K471#10C0GF5###	K471#15C0GF5###	K471#10C0GH5###	K471#15C0GH5###	K471#15C0GK5###	K471#20C0GL5##5
560	K561#10C0GF5###	K561#15C0GF5###	K561#10C0GH5###	K561#15C0GH5###	K561#15C0GK5###	K561#20C0GL5##5
680	K681#10C0GF5###	K681#15C0GF5###	-	K681#15C0GH5###	K681#15C0GK5###	K681#20C0GL5##5
820	K821#10C0GF5###	K821#15C0GF5###	-	K821#15C0GH5###	K821#15C0GK5###	K821#20C0GL5##5
1000	K102#10C0GF5###	K102#15C0GF5###	-	K102#20C0GH5###	K102#20C0GK5###	K102#20C0GL5##5
1200	-	K122#15C0GF5###	-	K122#20C0GH5###	K122#20C0GK5###	K122#20C0GL5##5
1500	-	K152#15C0GF5###	-	K152#20C0GH5###	K152#20C0GK5###	K152#20C0GL5##5
1800	-	K182#15C0GF5###	-	K182#20C0GH5###	K182#20C0GK5###	K182#20C0GL5##5
2200	-	K222#15C0GF5###	-	K222#20C0GH5###	K222#20C0GK5###	-
2700	-	K272#20C0GF5###	-	K272#20C0GH5###	K272#20C0GK5###	-
3300	-	K332#20C0GF5###	-	K332#20C0GH5###	K332#20C0GK5###	-
3900	-	K392#20C0GF5###	-	K392#20C0GH5###	K392#20C0GK5###	-
4700	-	K472#20C0GF5###	-	K472#20C0GH5###	-	-
5600	-	K562#20C0GF5###	-	K562#20C0GH5###	-	-
6800	-	K682#20C0GF5###	-	-	-	-
8200	-	K822#20C0GF5###	-	-	-	-
10 000	-	K103#20C0GF5###	-	-	-	-

## Notes

- Lead diameter is 0.5 mm
- # 5<sup>th</sup> digit is capacitance tolerance code:  $\pm 5\%$  = J;  $\pm 10\%$  = K
- # 13<sup>th</sup> digit is packaging code: bulk = 3; reel = T; ammo = U
- # 14<sup>th</sup> digit is lead style code: L; H; K (L and H are preferred lead configuration)
- # 15<sup>th</sup> digit is lead spacing code: 2.5 mm = 2; 5.0 mm = 5



DIELECTRIC X7R						
CAP. (pF)	50 V <sub>DC</sub>		100 V <sub>DC</sub>		200 V <sub>DC</sub>	500 V <sub>DC</sub>
	SMALLER SIZE	NORMAL SIZE	SMALLER SIZE	NORMAL SIZE	NORMAL SIZE	NORMAL SIZE
100	K101#10X7RF5###	K101#15X7RF5###	K101#10X7RH5###	K101#15X7RH5###	K101#15X7RK5###	K101#15X7RL5##5
120	K121#10X7RF5###	K121#15X7RF5###	K121#10X7RH5###	K121#15X7RH5###	K121#15X7RK5###	K121#15X7RL5##5
150	K151#10X7RF5###	K151#15X7RF5###	K151#10X7RH5###	K151#15X7RH5###	K151#15X7RK5###	K151#15X7RL5##5
180	K181#10X7RF5###	K181#15X7RF5###	K181#10X7RH5###	K181#15X7RH5###	K181#15X7RK5###	K181#15X7RL5##5
220	K221#10X7RF5###	K221#15X7RF5###	K221#10X7RH5###	K221#15X7RH5###	K221#15X7RK5###	K221#15X7RL5##5
270	K271#10X7RF5###	K271#15X7RF5###	K271#10X7RH5###	K271#15X7RH5###	K271#15X7RK5###	K271#15X7RL5##5
330	K331#10X7RF5###	K331#15X7RF5###	K331#10X7RH5###	K331#15X7RH5###	K331#15X7RK5###	K331#15X7RL5##5
390	K391#10X7RF5###	K391#15X7RF5###	K391#10X7RH5###	K391#15X7RH5###	K391#15X7RK5###	K391#15X7RL5##5
470	K471#10X7RF5###	K471#15X7RF5###	K471#10X7RH5###	K471#15X7RH5###	K471#15X7RK5###	K471#15X7RL5##5
560	K561#10X7RF5###	K561#15X7RF5###	K561#10X7RH5###	K561#15X7RH5###	K561#15X7RK5###	K561#15X7RL5##5
680	K681#10X7RF5###	K681#15X7RF5###	K681#10X7RH5###	K681#15X7RH5###	K681#15X7RK5###	K681#15X7RL5##5
820	K821#10X7RF5###	K821#15X7RF5###	K821#10X7RH5###	K821#15X7RH5###	K821#15X7RK5###	K821#15X7RL5##5
1000	K102#10X7RF5###	K102#15X7RF5###	K102#10X7RH5###	K102#15X7RH5###	K102#15X7RK5###	K102#15X7RL5##5
1200	K122#10X7RF5###	K122#15X7RF5###	K122#10X7RH5###	K122#15X7RH5###	K122#15X7RK5###	K122#15X7RL5##5
1500	K152#10X7RF5###	K152#15X7RF5###	K152#10X7RH5###	K152#15X7RH5###	K152#15X7RK5###	K152#15X7RL5##5
1800	K182#10X7RF5###	K182#15X7RF5###	K182#10X7RH5###	K182#15X7RH5###	K182#15X7RK5###	K182#15X7RL5##5
2200	K222#10X7RF5###	K222#15X7RF5###	K222#10X7RH5###	K222#15X7RH5###	K222#15X7RK5###	K222#15X7RL5##5
2700	K272#10X7RF5###	K272#15X7RF5###	K272#10X7RH5###	K272#15X7RH5###	K272#15X7RK5###	K272#15X7RL5##5
3300	K332#10X7RF5###	K332#15X7RF5###	K332#10X7RH5###	K332#15X7RH5###	K332#15X7RK5###	K332#20X7RL5##5
3900	K392#10X7RF5###	K392#15X7RF5###	K392#10X7RH5###	K392#15X7RH5###	K392#15X7RK5###	K392#20X7RL5##5
4700	K472#10X7RF5###	K472#15X7RF5###	K472#10X7RH5###	K472#15X7RH5###	K472#15X7RK5###	K472#20X7RL5##5
5600	K562#10X7RF5###	K562#15X7RF5###	K562#10X7RH5###	K562#15X7RH5###	K562#15X7RK5###	K562#20X7RL5##5
6800	K682#10X7RF5###	K682#15X7RF5###	K682#10X7RH5###	K682#15X7RH5###	K682#15X7RK5###	K682#20X7RL5##5
8200	K822#10X7RF5###	K822#15X7RF5###	K822#10X7RH5###	K822#15X7RH5###	K822#15X7RK5###	K822#20X7RL5##5
10 000	K103#10X7RF5###	K103#15X7RF5###	K103#10X7RH5###	K103#15X7RH5###	K103#15X7RK5###	K103#20X7RL5##5
12 000	K123#10X7RF5###	K123#15X7RF5###	-	K123#15X7RH5###	K123#15X7RK5###	K123#20X7RL5##5
15 000	K153#10X7RF5###	K153#15X7RF5###	-	K153#15X7RH5###	K153#15X7RK5###	K153#20X7RL5##5
18 000	K183#10X7RF5###	K183#15X7RF5###	-	K183#15X7RH5###	K183#15X7RK5###	K183#20X7RL5##5
22 000	K223#10X7RF5###	K223#15X7RF5###	-	K223#15X7RH5###	K223#15X7RK5###	K223#20X7RL5##5
27 000	K273#10X7RF5###	K273#15X7RF5###	-	K273#20X7RH5###	K273#20X7RK5###	K273#20X7RL5##5
33 000	K333#10X7RF5###	K333#15X7RF5###	-	K333#20X7RH5###	K333#20X7RK5###	K333#20X7RL5##5
39 000	K393#10X7RF5###	K393#15X7RF5###	-	K393#20X7RH5###	K393#20X7RK5###	K393#20X7RL5##5
47 000	K473#10X7RF5###	K473#15X7RF5###	-	K473#20X7RH5###	K473#20X7RK5###	K473#20X7RL5##5
56 000	K563#10X7RF5###	K563#15X7RF5###	-	K563#20X7RH5###	K563#20X7RK5###	-
68 000	K683#10X7RF5###	K683#15X7RF5###	-	K683#20X7RH5###	K683#20X7RK5###	-
82 000	K823#10X7RF5###	K823#15X7RF5###	-	K823#20X7RH5###	K823#20X7RK5###	-
100 000	K104#10X7RF5###	K104#15X7RF5###	-	K104#20X7RH5###	K104#20X7RK5###	-
150 000	-	K154#20X7RF5###	-	K154#20X7RH5###	K154#20X7RK5###	-
220 000	-	K224#20X7RF5###	-	K224#20X7RH5###	K224#20X7RK5###	-
330 000	-	K334#20X7RF5###	-	K334#20X7RH5###	-	-
470 000	-	K474#20X7RF5###	-	K474#20X7RH5###	-	-
560 000	-	K564#20X7RF5###	-	K564#20X7RH5###	-	-
680 000	-	K684#20X7RF5###	-	-	-	-
1 000 000	-	K105#20X7RF5###	-	-	-	-

**Notes**

- Lead diameter is 0.5 mm
- # 5<sup>th</sup> digit is capacitance tolerance code:  $\pm 10\%$  = K;  $\pm 20\%$  = M
- # 13<sup>th</sup> digit is packaging code: bulk = 3; reel = T; ammo = U
- # 14<sup>th</sup> digit is lead style code: L; H; K (L and H are preferred lead configuration)
- # 15<sup>th</sup> digit is lead spacing code: 2.5 mm = 2; 5.0 mm = 5

DIELECTRIC Y5V			
CAP. (pF)	50 V <sub>DC</sub>		100 V <sub>DC</sub>
	SMALLER SIZE	NORMAL SIZE	NORMAL SIZE
10 000	K103Z10Y5VF5###	K103Z15Y5VF5###	K103Z15Y5VH5###
15 000	K153Z10Y5VF5###	K153Z15Y5VF5###	K153Z15Y5VH5###
22 000	K223Z10Y5VF5###	K223Z15Y5VF5###	K223Z15Y5VH5###
33 000	K333Z10Y5VF5###	K333Z15Y5VF5###	K333Z15Y5VH5###
47 000	K473Z10Y5VF5###	K473Z15Y5VF5###	K473Z15Y5VH5###
68 000	K683Z10Y5VF5###	K683Z15Y5VF5###	K683Z15Y5VH5###
100 000	K104Z10Y5VF5###	K104Z15Y5VF5###	K104Z15Y5VH5###
150 000	K154Z10Y5VF5###	K154Z15Y5VF5###	K154Z20Y5VH5###
220 000	-	K224Z15Y5VF5###	K224Z20Y5VH5###
330 000	-	K334Z20Y5VF5###	-
470 000	-	K474Z20Y5VF5###	-
680 000	-	K684Z20Y5VF5###	-
1 000 000	-	K105Z20Y5VF5###	-

### Notes

- Lead diameter is 0.5 mm
- Tolerance is + 80 %/- 20 %
- # 13<sup>th</sup> digit is packaging code: bulk = 3; reel = T; ammo = U
- # 14<sup>th</sup> digit is lead style code: L; H; K (L and H are preferred lead configuration)
- # 15<sup>th</sup> digit is lead spacing code: 2.5 mm = 2; 5.0 mm = 5

## TAPING AND PACKAGING

### LABELLING

Each reel is provided with a label showing the following details:

Manufacturer, K style, capacitance, tolerance, batch number, quantity of components, rated voltage, dielectric.

On special request other designations can be shown.

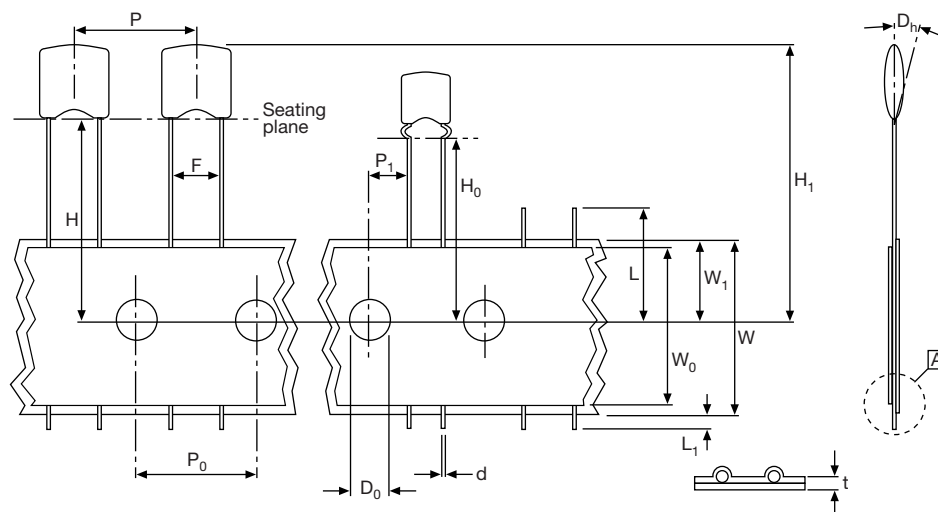
For example:



PACKAGING QUANTITIES AND BOX DIMENSIONS			
PACKAGING	SIZE CODE	SMALLEST PACKAGING QUANTITY (SPQ)	BOX DIMENSIONS L x W x H (mm)
Tape on reel	10, 15	4000	370 x 370 x 60
	20	3000	
Ammopack	10, 15, 20	2500	335 x 290 x 50
Bulk <sup>(1)</sup>	10, 15, 20	5000	245 x 120 x 65

### Note

- <sup>(1)</sup> SPQ contains one or a multiple of poly-bags, 1000 units per bag

**CAPACITORS ON TAPE**


PARAMETER	SYMBOL	DIMENSIONS	
		mm	INCH
Cut-off length	L	≤ 11.0	≤ 0.443
Lead end protrusion	L <sub>1</sub>	≤ 1.0	≤ 0.039
Height to seating plane (straight leads)	H	≥ 18.0	≥ 0.709
Height to seating plane (crimp leads)	H <sub>0</sub>	16.0 ± 0.5	0.630 ± 0.020
Top of component height	H <sub>1</sub>	≤ 32	≤ 1.26
Body inclination	Δh	0.0 ± 1.0	0.000 ± 0.039
Carrier tape width	W	18.0 + 1.0/- 0.5	0.709 + 0.039/- 0.020
Hold down tape width	W <sub>0</sub>	15.0 REF.	0.591 REF.
Sprocket hole position	W <sub>1</sub>	9.00 + 0.075/- 0.50	0.354 + 0.030/- 0.020
Lead space	F	2.50 + 0.60/- 0.40	0.100 + 0.024/- 0.016
		5.00 + 0.60/- 0.40	0.200 + 0.024/- 0.016
Sprocket hole pitch	P <sub>0</sub>	12.70 ± 0.3	0.500 ± 0.012
Sprocket hole center to lead center at F = 2.5 mm	P <sub>1</sub>	5.08 ± 0.7	0.200 ± 0.028
Sprocket hole center to lead center at F = 5 mm		3.85 ± 0.7	0.150 ± 0.028
Sprocket hole diameter	D <sub>0</sub>	4.00 ± 0.30	0.157 ± 0.012
Overall tape thickness	t	≤ 0.90	≤ 0.035
Wire lead diameter	d	0.50 ± 0.05	0.020 ± 0.002
Taping pitch	P	12.7 REF.	0.50 REF.

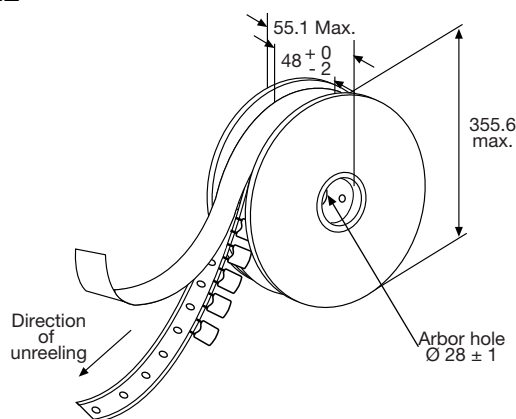
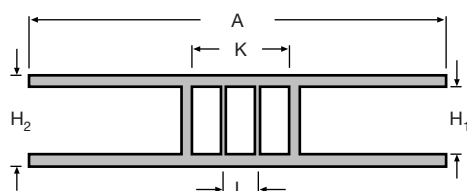
**REEL DATA**

A maximum of 0.5 % of the total number of capacitors per reel may be missing.

A maximum of 1 consecutive vacant positions is followed by 6 consecutive components.

Tape begins and ends with a minimum of 4 empty positions (50 mm tape).

Maximum of 5 splicers per reel.

**REEL**

**REEL DIMENSIONS**


REEL SIZE			(mm)
A	Outer diameter		355.6 max.
L	Hole diameter		28 ± 1.5
K	Core diameter		90
H <sub>1</sub>	Internal width		48 + 0/- 2
H <sub>2</sub>	External width		55 max.

**AMMOPACK DATA**

A maximum of 0.5 % of the total number of capacitors per box may be missing.

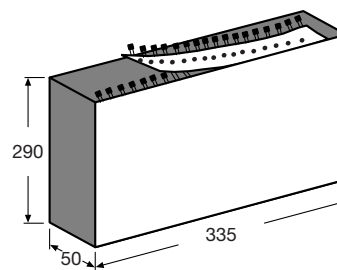
A maximum of 2 consecutive vacant positions is followed by 6 consecutive components.

Tape begins and ends with a minimum of 4 empty positions (50 mm tape).

Maximum of 5 splicers per reel.

The cumulative pitch tolerance over 20 consecutive units is not to exceed ± 1.0 mm.

Lead space (F) shall be measured at (3.6 ± 0.5) mm from the capacitor seating plane.

**AMMOPACK**

**RELATED DOCUMENTS**

General Information	<a href="http://www.vishay.com/doc?45163">www.vishay.com/doc?45163</a>
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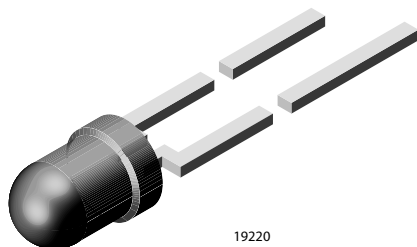
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## High Efficiency LED in Ø 3 mm Tinted Diffused Package



### DESCRIPTION

The TLH.44.. series was developed for standard applications like general indicating and lighting purposes.

It is housed in a 3 mm tinted diffused plastic package. The wide viewing angle of these devices provides a high on-off contrast.

Several selection types with different luminous intensities are offered. All LEDs are categorized in luminous intensity groups. The green and yellow LEDs are categorized additionally in wavelength groups.

That allows users to assemble LEDs with uniform appearance.

### FEATURES

- Standard Ø 3 mm (T-1) package
- Small mechanical tolerances
- Suitable for DC and high peak current
- Wide viewing angle
- Luminous intensity categorized
- Yellow and green color categorized
- Material categorization:  
for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)



**RoHS**  
COMPLIANT  
HALOGEN  
**FREE**  
**GREEN**  
(5-2008)

### APPLICATIONS

- Status lights
- Off / on indicator
- Background illumination
- Readout lights
- Maintenance lights
- Legend light

### PRODUCT GROUP AND PACKAGE DATA

- Product group: LED
- Package: 3 mm
- Product series: standard
- Angle of half intensity:  $\pm 30^\circ$

### PARTS TABLE

PART	COLOR	LUMINOUS INTENSITY (mcd)			at I <sub>F</sub> (mA)	WAVELENGTH (nm)			at I <sub>F</sub> (mA)	FORWARD VOLTAGE (V)			at I <sub>F</sub> (mA)	TECHNOLOGY
		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		
TLHR4400	Red	1.6	13	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR4400-AS12	Red	1.6	13	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR4400-AS21	Red	1.6	13	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR4400-AS12Z	Red	1.6	13	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR4400-MS12Z	Red	1.6	13	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR4401	Red	2.5	14	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR4401-AS12Z	Red	2.5	14	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHR4405	Red	6.3	15	-	10	612	-	625	10	-	2	3	20	GaAsP on GaP
TLHO4400	Soft orange	1.6	13	-	10	598	-	611	10	-	2.4	3	20	GaAsP on GaP
TLHY4400	Yellow	1.6	10	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY4400-AS12Z	Yellow	1.6	10	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY4400-MS12	Yellow	1.6	10	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY4401	Yellow	2.5	10.5	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY4405	Yellow	6.3	11	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY4405-AS12	Yellow	6.3	11	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP
TLHY4405-MS12	Yellow	6.3	11	-	10	581	-	594	10	-	2.4	3	20	GaAsP on GaP





## PARTS TABLE

PART	COLOR	LUMINOUS INTENSITY (mcd)			at $I_F$ (mA)	WAVELENGTH (nm)			at $I_F$ (mA)	FORWARD VOLTAGE (V)			at $I_F$ (mA)	TECHNOLOGY
		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		MIN.	TYP.	MAX.		
TLHG4400	Green	2.5	13	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4400-AS12	Green	2.5	13	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4400-AS12Z	Green	2.5	13	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4400-AS21	Green	2.5	13	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4400-MS12	Green	2.5	13	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4401	Green	4	14	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4401-AS12Z	Green	4	14	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4405	Green	6.3	15	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4405-AS12Z	Green	6.3	15	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP
TLHG4405-MS12	Green	6.3	15	-	10	562	-	575	10	-	2.4	3	20	GaP on GaP

ABSOLUTE MAXIMUM RATINGS ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)

## TLHR440., TLHO440., TLHY440., TLHG440.

PARAMETER	TEST CONDITION	SYMBOL	VALUE	UNIT
Reverse voltage		$V_R$	6	V
DC forward current		$I_F$	30	mA
Surge forward current	$t_p \leq 10\text{ }\mu\text{s}$	$I_{FSM}$	1	A
Power dissipation	$T_{amb} \leq 60\text{ }^{\circ}\text{C}$	$P_V$	100	mW
Junction temperature		$T_j$	100	$^{\circ}\text{C}$
Operating temperature range		$T_{amb}$	-40 to +100	$^{\circ}\text{C}$
Storage temperature range		$T_{stg}$	-55 to +100	$^{\circ}\text{C}$
Soldering temperature	$t \leq 5\text{ s}$ , 2 mm from body	$T_{sd}$	260	$^{\circ}\text{C}$
Thermal resistance junction to ambient		$R_{thJA}$	400	K/W

OPTICAL AND ELECTRICAL CHARACTERISTICS ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)

## TLHR440., RED

PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
Luminous intensity <sup>(1)</sup>	$I_F = 10\text{ mA}$	TLHR4400	$I_V$	1.6	13	-	mcd
		TLHR4401	$I_V$	2.5	14	-	mcd
		TLHR4405	$I_V$	6.3	15	-	mcd
Dominant wavelength	$I_F = 10\text{ mA}$		$\lambda_d$	612	-	625	nm
Peak wavelength	$I_F = 10\text{ mA}$		$\lambda_p$	-	635	-	nm
Angle of half intensity	$I_F = 10\text{ mA}$		$\varphi$	-	$\pm 30$	-	$^{\circ}$
Forward voltage	$I_F = 20\text{ mA}$		$V_F$	-	2	3	V
Reverse voltage	$I_R = 10\text{ }\mu\text{A}$		$V_R$	6	15	-	V
Junction capacitance	$V_R = 0\text{ V}$ , $f = 1\text{ MHz}$		$C_j$	-	50	-	pF

## Note

<sup>(1)</sup> In one packing unit  $I_{Vmin.}/I_{Vmax.} \leq 0.5$

**OPTICAL AND ELECTRICAL CHARACTERISTICS** ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)  
**TLHO440., SOFT ORANGE**

PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
Luminous intensity <sup>(1)</sup>	$I_F = 10\text{ mA}$	TLHO4400	$I_V$	1.6	13	-	mcd
Dominant wavelength	$I_F = 10\text{ mA}$		$\lambda_d$	598	-	611	nm
Peak wavelength	$I_F = 10\text{ mA}$		$\lambda_p$	-	605	-	nm
Angle of half intensity	$I_F = 10\text{ mA}$		$\phi$	-	$\pm 30$	-	$^{\circ}$
Forward voltage	$I_F = 20\text{ mA}$		$V_F$	-	2.4	3	V
Reverse voltage	$I_R = 10\text{ }\mu\text{A}$		$V_R$	6	15	-	V
Junction capacitance	$V_R = 0\text{ V}$ , $f = 1\text{ MHz}$		$C_j$	-	15	-	pF

**Note**<sup>(1)</sup> In one packing unit  $I_{Vmin.}/I_{Vmax.} \leq 0.5$ **OPTICAL AND ELECTRICAL CHARACTERISTICS** ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)  
**TLHY440., YELLOW**

PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
Luminous intensity <sup>(1)</sup>	$I_F = 10\text{ mA}$	TLHY4400	$I_V$	1.6	10	-	mcd
		TLHY4401	$I_V$	2.5	10.5	-	mcd
		TLHY4405	$I_V$	6.3	11	-	mcd
Dominant wavelength	$I_F = 10\text{ mA}$	TLHY4400	$\lambda_d$	581	-	594	nm
		TLHY4401	$\lambda_d$	581	-	594	nm
		TLHY4405	$\lambda_d$	581	-	594	nm
Peak wavelength	$I_F = 10\text{ mA}$		$\lambda_p$	-	585	-	nm
Angle of half intensity	$I_F = 10\text{ mA}$		$\phi$	-	$\pm 30$	-	$^{\circ}$
Forward voltage	$I_F = 20\text{ mA}$		$V_F$	-	2.4	3	V
Reverse voltage	$I_R = 10\text{ }\mu\text{A}$		$V_R$	6	15	-	V
Junction capacitance	$V_R = 0\text{ V}$ , $f = 1\text{ MHz}$		$C_j$	-	50	-	pF

**Note**<sup>(1)</sup> In one packing unit  $I_{Vmin.}/I_{Vmax.} \leq 0.5$ **OPTICAL AND ELECTRICAL CHARACTERISTICS** ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)  
**TLHG440., GREEN**

PARAMETER	TEST CONDITION	PART	SYMBOL	MIN.	TYP.	MAX.	UNIT
Luminous intensity <sup>(1)</sup>	$I_F = 10\text{ mA}$	TLHG4400	$I_V$	2.5	13	-	mcd
		TLHG4401	$I_V$	4	14	-	mcd
		TLHG4405	$I_V$	6.3	15	-	mcd
Dominant wavelength	$I_F = 10\text{ mA}$		$\lambda_d$	562	-	575	nm
Peak wavelength	$I_F = 10\text{ mA}$		$\lambda_p$	-	565	-	nm
Angle of half intensity	$I_F = 10\text{ mA}$		$\phi$	-	$\pm 30$	-	$^{\circ}$
Forward voltage	$I_F = 20\text{ mA}$		$V_F$	-	2.4	3	V
Reverse voltage	$I_R = 10\text{ }\mu\text{A}$		$V_R$	6	15	-	V
Junction capacitance	$V_R = 0\text{ V}$ , $f = 1\text{ MHz}$		$C_j$	-	50	-	pF

**Note**<sup>(1)</sup> In one packing unit  $I_{Vmin.}/I_{Vmax.} \leq 0.5$

**LUMINOUS INTENSITY CLASSIFICATION**

GROUP	LIGHT INTENSITY (mcd)	
	MIN.	MAX.
L	1	2
M	1.6	3.2
N	2.5	5
P	4	8
Q	6.3	12.5
R	10	20
S	16	32
T	25	50
U	40	80

**Note**

- Luminous intensity is tested at a current pulse duration of 25 ms. The above type numbers represent the order groups which include only a few brightness groups. Only one group will be shipped on each bag (there will be no mixing of two groups on each bag). In order to ensure availability, single brightness groups will not be orderable. In a similar manner for colors where wavelength groups are measured and binned, single wavelength groups will be shipped on any one bag. In order to ensure availability, single wavelength groups will not be orderable.

**COLOR CLASSIFICATION**

GROUP	DOM. WAVELENGTH (nm)			
	YELLOW		GREEN	
	MIN.	MAX.	MIN.	MAX.
0	-	-	-	-
1	581	584	-	-
2	583	586	-	-
3	585	588	562	565
4	587	590	564	567
5	589	592	566	569
6	591	594	568	571
7	-	-	570	573
8	-	-	572	575

**Note**

- Wavelengths are tested at a current pulse duration of 25 ms

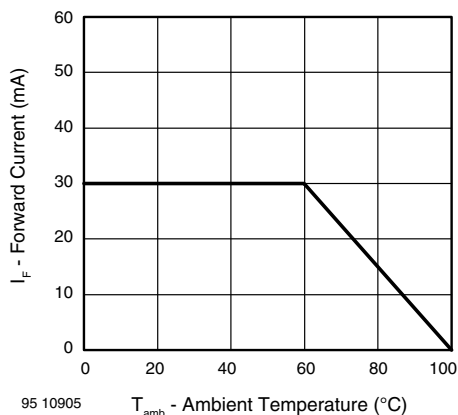
**TYPICAL CHARACTERISTICS** ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified)

Fig. 1 - Forward Current vs. Ambient Temperature

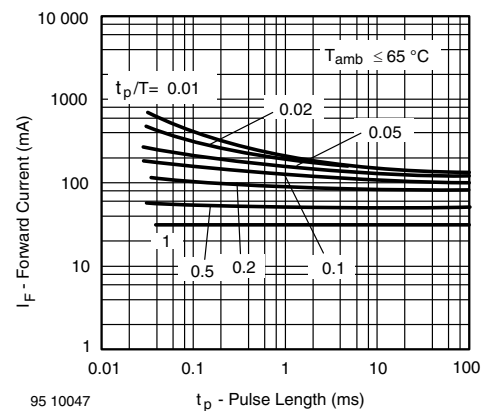


Fig. 2 - Forward Current vs. Pulse Length

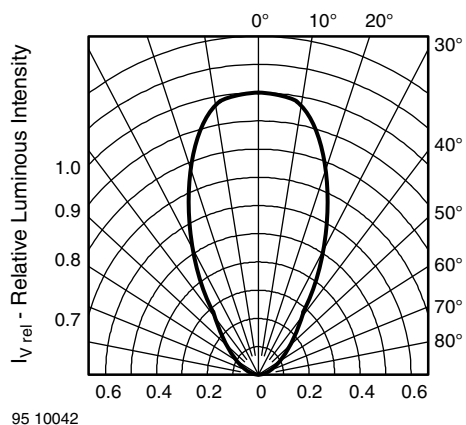


Fig. 3 - Relative Luminous Intensity vs. Angular Displacement

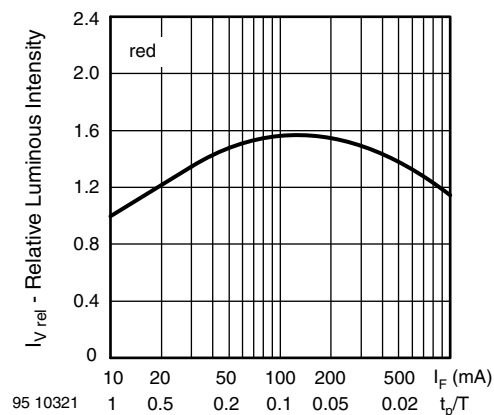


Fig. 6 - Relative Luminous Intensity vs. Forward Current/Duty Cycle

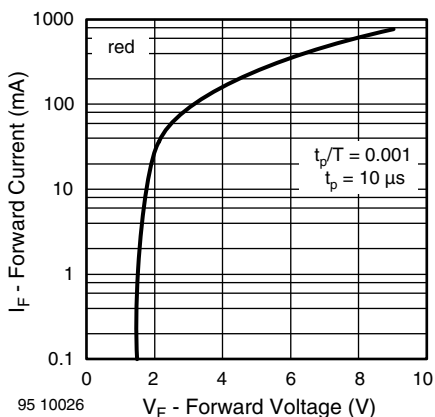


Fig. 4 - Forward Current vs. Forward Voltage

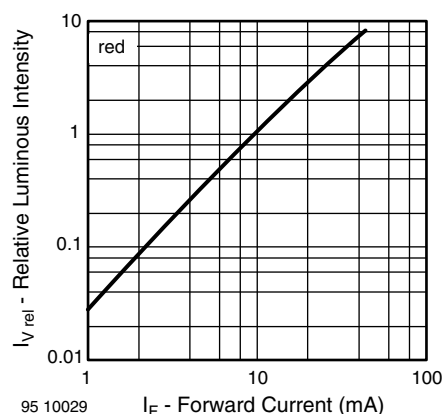


Fig. 7 - Relative Luminous Intensity vs. Forward Current

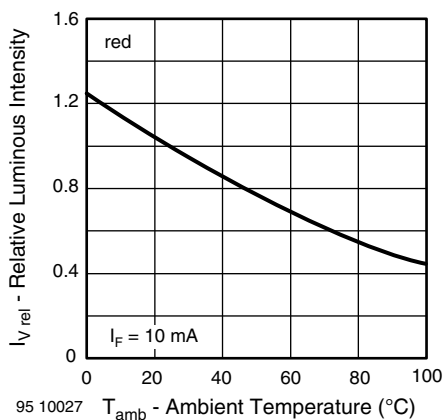


Fig. 5 - Relative Luminous Intensity vs. Ambient Temperature

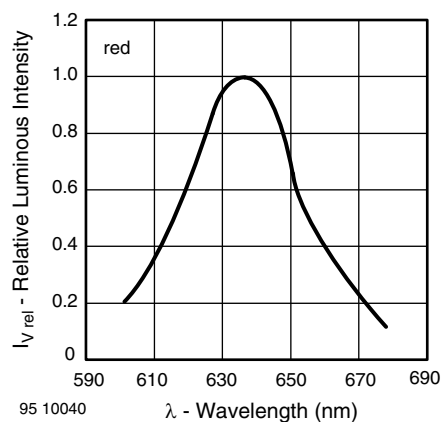


Fig. 8 - Relative Intensity vs. Wavelength

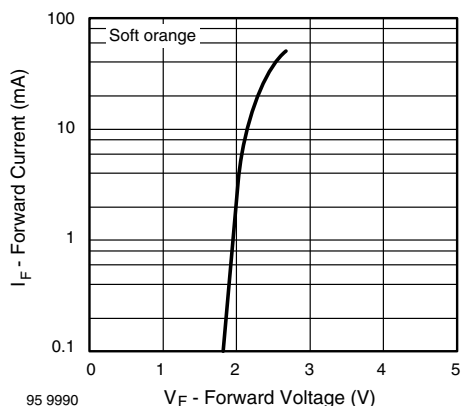


Fig. 9 - Forward Current vs. Forward Voltage

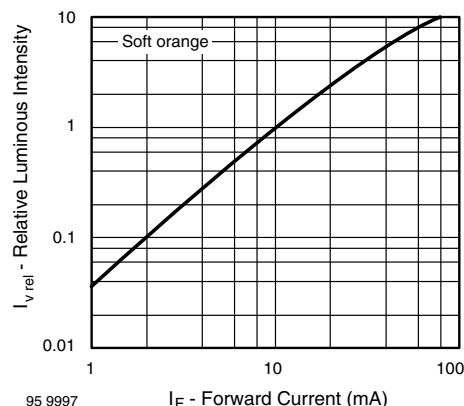


Fig. 12 - Relative Luminous Intensity vs. Forward Current

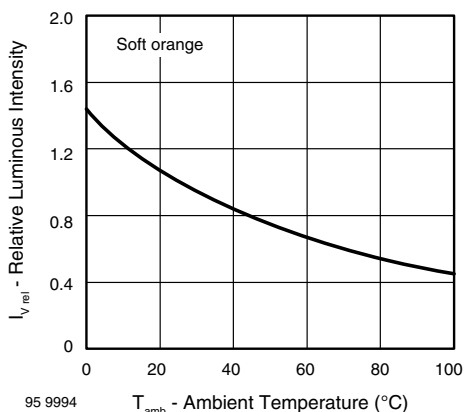


Fig. 10 - Relative Luminous Intensity vs. Ambient Temperature

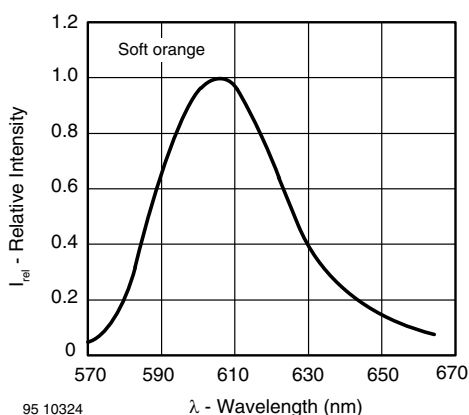


Fig. 13 - Relative Intensity vs. Wavelength

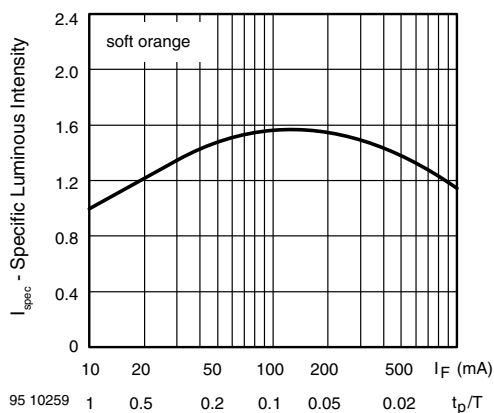


Fig. 11 - Relative Luminous Intensity vs. Forward Current/Duty Cycle

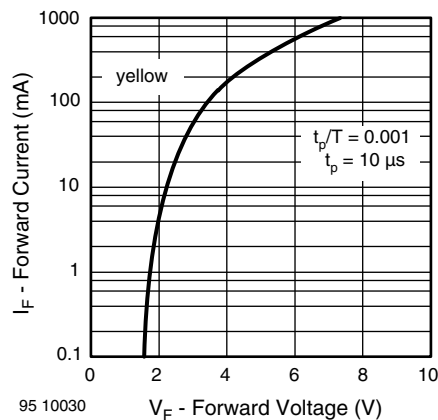


Fig. 14 - Forward Current vs. Forward Voltage

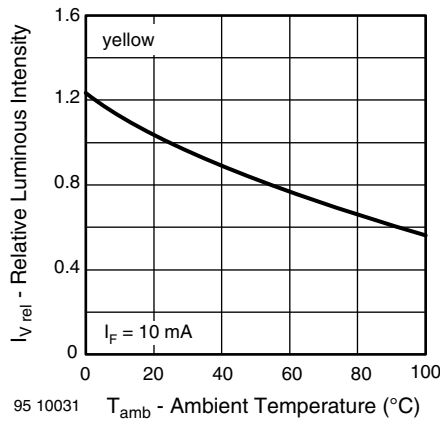


Fig. 15 - Relative Luminous Intensity vs. Ambient Temperature

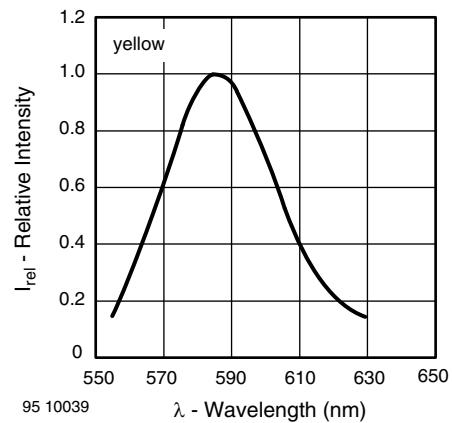


Fig. 18 - Relative Intensity vs. Wavelength

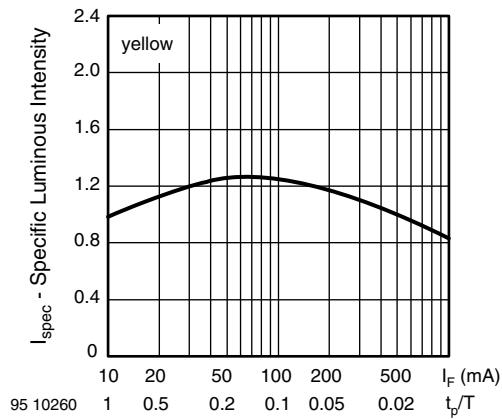


Fig. 16 - Relative Luminous Intensity vs. Forward Current/Duty Cycle

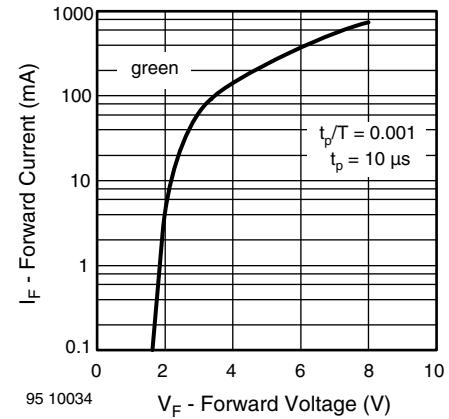


Fig. 19 - Forward Current vs. Forward Voltage

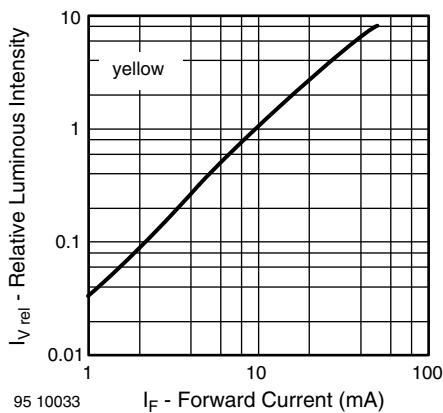


Fig. 17 - Relative Luminous Intensity vs. Forward Current

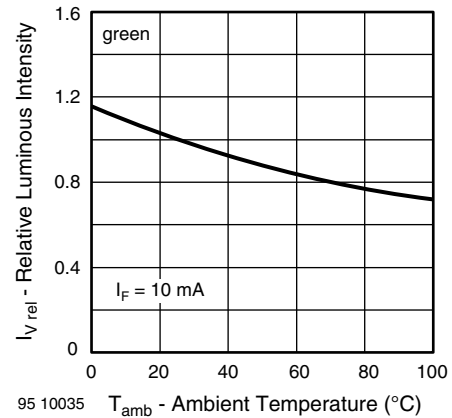


Fig. 20 - Relative Luminous Intensity vs. Ambient Temperature

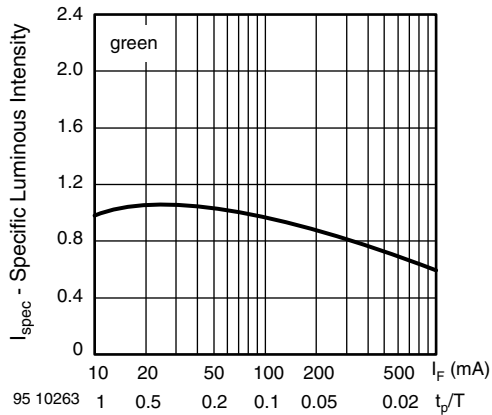


Fig. 21 - Specific Luminous Intensity vs. Forward Current

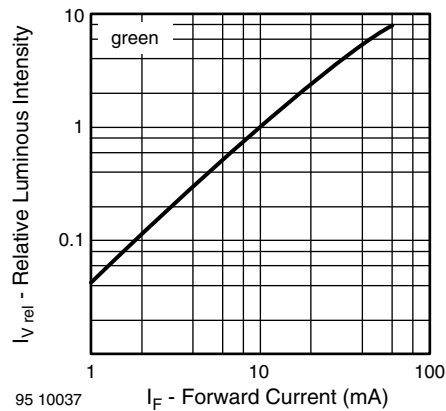


Fig. 22 - Relative Luminous Intensity vs. Forward Current

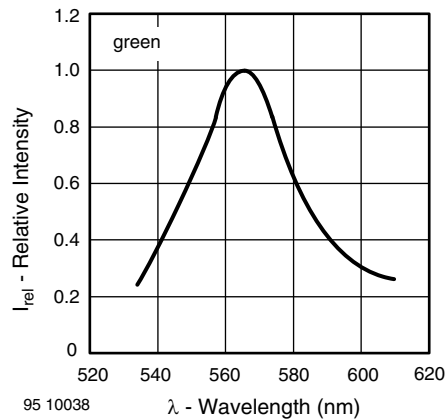
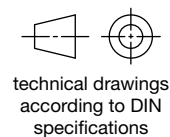
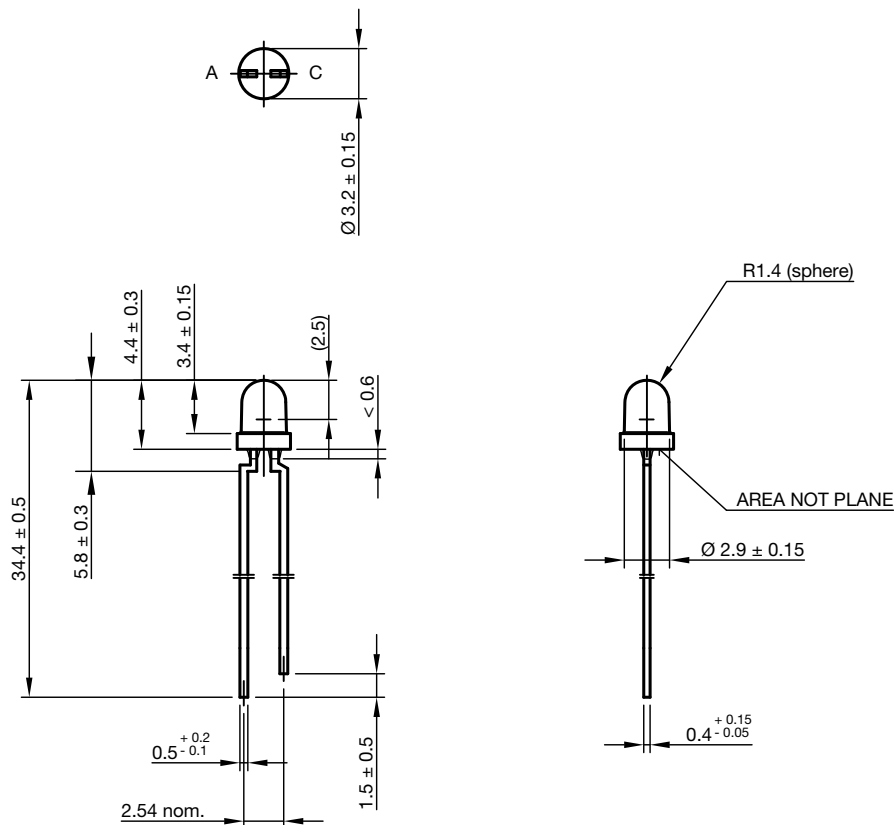


Fig. 23 - Relative Intensity vs. Wavelength



**PACKAGE DIMENSIONS** in millimeters



Drawing-No.: 6.544-5255.01-4  
Issue: 9; 28.07.14

**REEL DIMENSIONS** in millimeters

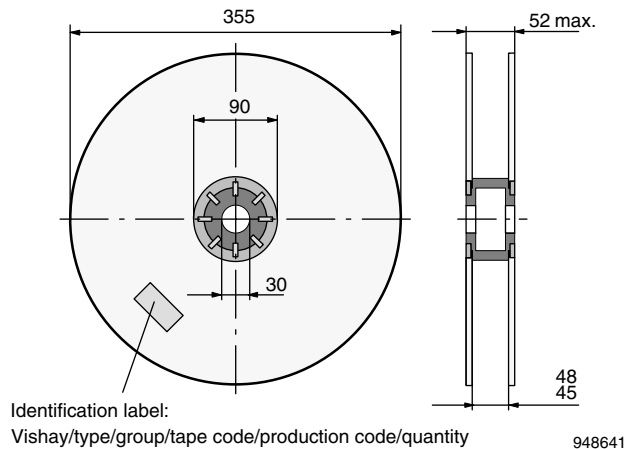


Fig. 24 - Reel

**TAPE**

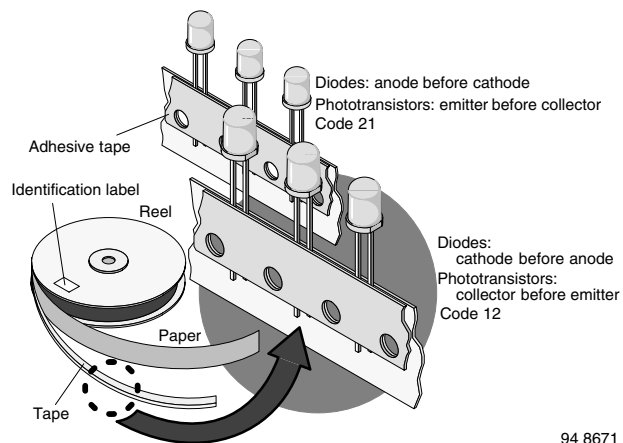


Fig. 25 - LED in Tape

94 8671



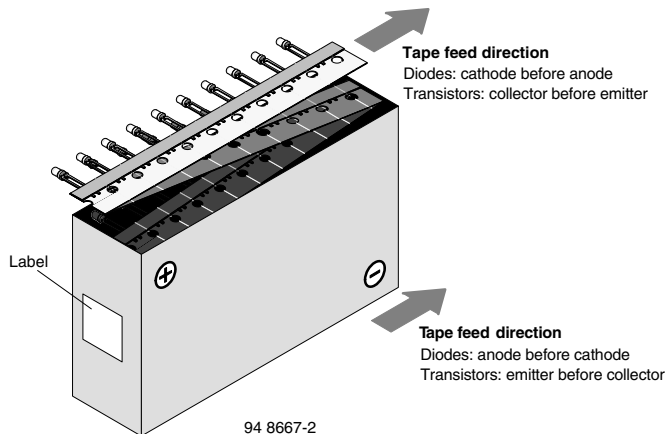
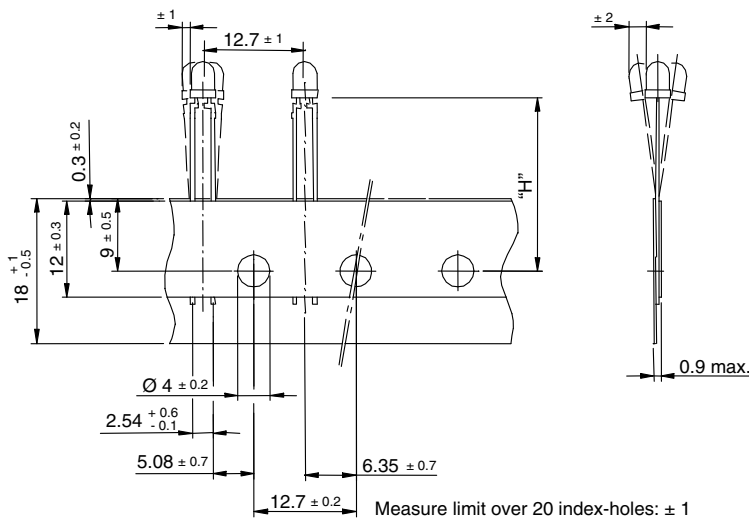
**AMMOPACK** (ending: Z)


Fig. 26 - Tape Direction

**Note**

- The new nomenclature for ammpack is e.g. ASZ only, without suffix for the LED orientation. The carton box has to be turned to the desired position: "+" for anode first, or "-" for cathode first. AS12Z and AS21Z are still valid for already existing types, BUT NOT FOR NEW DESIGN

**TAPE DIMENSIONS** in millimeters


Quantity per:	Reel
	(Mat. - No. 1764)
	2000

94 8171

OPTION	DIMENSION "H" ± 0.5 mm	DIMENSION "X" ± 0.5 mm
AS	17.3	-
MS	25.5	-



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# Metal Film Resistors, Axial, Industrial, Precision



## FEATURES

- Small size - conformal coated
- Flame retardant epoxy coating
- Controlled temperature coefficient
- Excellent high frequency characteristics
- Exceptionally low noise; typically 0.10  $\mu\text{V/V}$
- Low voltage coefficient to  $\pm 5$  ppm/V
- Special tolerance and or TC matching available on request
- Material categorization: for definitions of compliance please see [www.vishay.com/doc?99912](http://www.vishay.com/doc?99912)


**RoHS\***  
Available

## Note

\* This datasheet provides information about parts that are RoHS-compliant and/or parts that are non RoHS-compliant. For example, parts with lead (Pb) terminations are not RoHS-compliant. Please see the information / tables in this datasheet for details

Vishay Dale Model CMF is also available as Military Qualified Styles RN and RL. See Vishay Dale's CMF (Military RN and RL) datasheet ([www.vishay.com/doc?31027](http://www.vishay.com/doc?31027)) for the MIL-SPEC ratings / attributes. (Except for marking, the Industrial and Military versions are exactly the same).

## STANDARD ELECTRICAL SPECIFICATIONS

GLOBAL MODEL	HISTORICAL MODEL	MAXIMUM WORKING VOLTAGE <sup>(1)</sup> V	POWER RATING $P_{70^{\circ}\text{C}}$ <sup>(2)</sup> W	POWER RATING $P_{125^{\circ}\text{C}}$ <sup>(2)</sup> W	RESISTANCE RANGE $\Omega$	TOLERANCE $\pm \%$	TEMPERATURE COEFFICIENT $\pm \text{ppm}/^{\circ}\text{C}$
CMF50	CMF-50	200	0.25	0.125	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5, 1, 2, 5	50
					10 to 2.5M	1, 2, 5	100
					10 to 22M	1, 2, 5	150, 200
CMF55	CMF-55	250	0.5	0.25	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 5M	1, 2, 5	50
					1 to 22.1M	1, 2, 5	100
					0.5 to 50M	1, 2, 5	150
					0.5 to 50M	1	200
					0.1 to 50M	2, 5	300
					0.2 to 50M	2, 5	200
CMF60	CMF-60	500	1	0.5	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 10M	1, 2, 5	100
					0.5 to 10M	1, 2, 5	150
					0.5 to 10M	1	200
					0.1 to 10M	2, 5	300
					0.2 to 50M	2, 5	200
CMF65	CMF-65	500	1.5	1	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 15M	1, 2, 5	100
					0.5 to 22M	1, 2, 5	150
					0.5 to 22M	1	200
					0.1 to 22M	2, 5	300
					0.2 to 50M	2, 5	200
CMF70	CMF-70	500	1.75	1.25	10 to 2.5M	0.1, 0.25, 0.5, 1	25
					10 to 2.5M	0.1, 0.25, 0.5	50
					10 to 10M	1, 2, 5	50
					1 to 15M	1, 2, 5	100
					1 to 22M	1, 2, 5	150, 200
CMF07	CMF-07	250	0.5	-	5 to 5M	2, 5	100
					1 to 5M	2, 5	150, 200
CMF20	CMF-20	500	1	-	5 to 10M	2, 5	100
					1 to 10M	2, 5	150, 200

## Notes

<sup>(1)</sup> Continuous working voltage shall be  $\sqrt{P \times R}$  or maximum working voltage, whichever is less

<sup>(2)</sup> See the load life shift due to power and derating table for a summary of the more common combinations of power rating, case size and ambient operating temperature that prevail in various industrial and military resistor specifications. The "performance" table quantifies the load life stability under these combinations

## GLOBAL PART NUMBER INFORMATION

New Global Part Numbering: CMF55301R00FKRE (preferred part numbering format)

GLOBAL MODEL	RESISTANCE VALUE	TOLERANCE CODE	TEMPERATURE COEFFICIENT <sup>(1)</sup>	PACKAGING	SPECIAL
(See Standard Electrical Specifications table)	<b>R</b> = Ω <b>K</b> = kΩ <b>M</b> = MΩ <b>R10000</b> = 0.1 Ω <b>680K00</b> = 680 kΩ <b>1M0000</b> = 1.0 MΩ	<b>B</b> = ± 0.1 % <b>C</b> = ± 0.25 % <b>D</b> = ± 0.5 % <b>F</b> = ± 1 % <b>G</b> = ± 2 % <b>J</b> = ± 5 %	<b>E</b> = 25 ppm <b>H</b> = 50 ppm <b>K</b> = 100 ppm <b>L</b> = 150 ppm <b>N</b> = 200 ppm <b>M</b> = 300 ppm	<b>EK</b> = lead (Pb)-free, bulk <b>EA</b> = lead (Pb)-free, T/R (full) <b>EB</b> = lead (Pb)-free, T/R (1000 pieces) <b>BF</b> = tin / lead, bulk <b>RE</b> = tin / lead, T/R (full) <b>R6</b> = tin / lead, T/R (1000 pieces)	Blank = standard (Dash number) (Up to 3 digits) From <b>1</b> to <b>999</b> as applicable <b>70</b> = color banded, 5 bands (≤ 1 %) <b>80</b> = color banded, 4 bands (≥ 2 %) <b>88</b> = hot solder dip

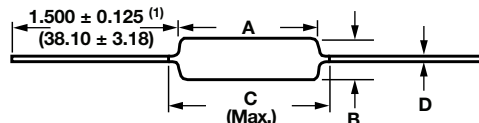
Historical Part Number Example: CMF-553010FT-1 (will continue to be accepted)

CMF-55	3010	F	T-1	R36
HISTORICAL MODEL	RESISTANCE VALUE	TOLERANCE CODE	TEMPERATURE COEFFICIENT	PACKAGING

### Notes

- For additional information on packaging, refer to the Through-Hole Resistor Packaging document ([www.vishay.com/doc?31544](http://www.vishay.com/doc?31544))
- <sup>(1)</sup> Tolerances of ± 0.5 % (D), ± 0.25 % (C) and ± 0.1 % (B) are available only in 50 ppm and 25 ppm temperature coefficients

## DIMENSIONS in inches (millimeters)



GLOBAL MODEL	A	B	C (Max.)	D
CMF50	0.150 ± 0.020 (3.81 ± 0.51)	0.065 ± 0.015 (1.65 ± 0.38)	0.187 (4.75)	0.016 ± 0.002 <sup>(2)</sup> (0.41 ± 0.05)
CMF55	0.240 ± 0.020 <sup>(3)</sup> (6.10 ± 0.51)	0.090 ± 0.008 (2.29 ± 0.20)	0.290 (7.37)	0.025 ± 0.002 (0.64 ± 0.05)
CMF60	0.344 ± 0.031 (8.74 ± 0.79)	0.145 ± 0.015 (3.68 ± 0.38)	0.425 (10.80)	0.025 ± 0.002 <sup>(4)</sup> (0.64 ± 0.05)
CMF65	0.562 ± 0.031 (14.27 ± 0.79)	0.180 ± 0.015 (4.57 ± 0.38)	0.687 (17.45)	0.025 ± 0.002 (0.64 ± 0.05)
CMF70	0.562 ± 0.031 (14.27 ± 0.79)	0.180 ± 0.015 (4.57 ± 0.38)	0.687 (17.45)	0.032 ± 0.002 (0.81 ± 0.05)
CMF07	0.240 ± 0.020 (6.10 ± 0.51)	0.090 ± 0.008 (2.29 ± 0.20)	0.290 (7.37)	0.025 ± 0.002 (0.64 ± 0.05)
CMF20	0.375 ± 0.040 (9.53 ± 1.02)	0.145 ± 0.015 (3.68 ± 0.38)	0.425 (10.80)	0.032 ± 0.002 (0.81 ± 0.05)

### Notes

- Lead length for product in bulk pack. For product supplied in tape and reel, the actual lead length would be based on the body size, tape spacing and lead trim.
- Available with 0.020" (0.51 mm) lead [CMF50..38]
- 0.260" ± 0.020" (6.60 mm ± 0.51 mm) for values > 5 MΩ
- Available with 0.032" (0.813 mm) lead [CMF60..95]

## TECHNICAL SPECIFICATIONS

PARAMETER	UNIT	CMF50	CMF55	CMF07	CMF60	CMF20	CMF65	CMF70
Maximum Working Voltage	V <sub>≡</sub>	≤ 200	≤ 250	≤ 250	≤ 500	≤ 500	≤ 500	≤ 500
Insulation Voltage (1 Min)	V <sub>eff</sub>	> 500						
Voltage Coefficient (Max.)	ppm/V	± 5 (measured between 10 % and full rated voltage)						
Dielectric Strength	V <sub>AC</sub>	450	450	450	750	750	900	900
Insulation Resistance	Ω	≥ 10 <sup>11</sup>						
Operating Temperature Range	°C	-55 to +175						
Terminal Strength (Pull Test)	lb	2	2	5	2	5	2	5
Noise	dB	0.10 μV/V over a decade of frequency, with low and intermediate resistance values typically below 0.05 μV/V						
Weight (Max.)	g	0.12	0.28	0.28	0.50	0.60	1.00	1.10

**TEMPERATURE COEFFICIENT CODES**

GLOBAL TC CODE	HISTORICAL TC CODE	TEMPERATURE COEFFICIENT
E	T-9	25 ppm/°C
H	T-2	50 ppm/°C
K	T-1	100 ppm/°C
L	T-0	150 ppm/°C
N	T-00	200 ppm/°C
M	M	300 ppm/°C

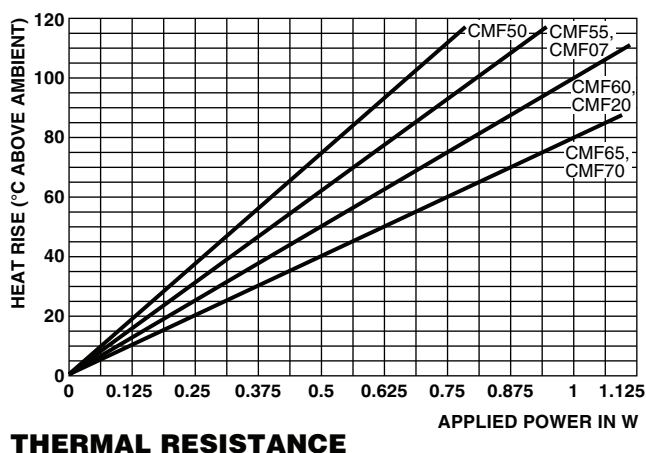
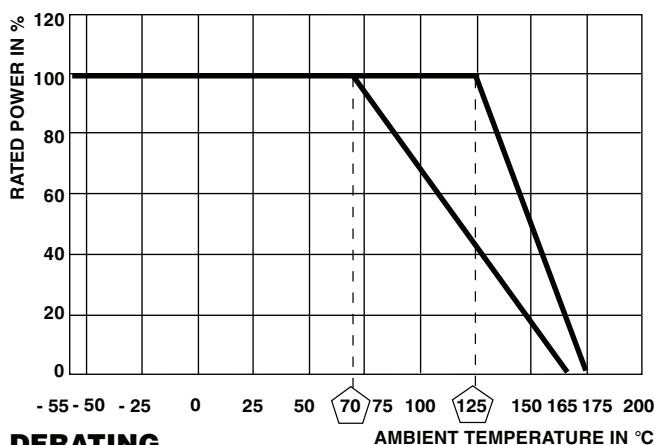
**LOAD LIFE SHIFT DUE TO POWER AND DERATING (AT +70 °C AND AT +125 °C)**

The power rating for the CMF parts is tied to the derating temperature, the heat rise of the parts, and the  $\Delta R$  for the load life performance. When the tables/graphs below are used together they show that when the parts are run at their higher power ratings, the parts will run hotter, which has the potential of causing the resistance of the parts to shift more over the life of the part.

**LOAD LIFE SHIFT VS. POWER RATING**

LOAD LIFE	MAXIMUM $\Delta R$ (TYPICAL TEST LOTS)					
	$\pm 0.15\%$	$\pm 0.5\%$	$\pm 1.0\%$	$\pm 0.15\%$	$\pm 0.5\%$	$\pm 1.0\%$
MODEL	POWER RATING AT +70 °C			POWER RATING AT +125 °C		
CMF50	1/20 W and 1/10 W	1/8 W	1/4 W	1/20 W	1/10 W	1/8 W
CMF55, CMF07	1/10 W and 1/8 W	1/4 W	1/2 W	1/10 W	1/8 W	1/4 W
CMF60, CMF20	1/8 W and 1/4 W	1/2 W	3/4 W and 1 W	1/8 W	1/4 W	1/2 W
CMF65	1/4 W and 1/2 W	3/4 W	1 W and 1-1/2 W	1/4 W	1/2 W	3/4 W and 1 W
CMF70	1/4 W and 1/2 W	3/4 W	1 W and 1-3/4 W	1/4 W	1/2 W	3/4 W and 1-1/4 W

CMF resistors have an operating temperature range of -55 °C to +175 °C. They must be derated at high ambient temperatures according to the derating curve.

**Example:**

When a CMF55 part is run at 1/8 W in a 70 °C ambient environment, the resistor will generate enough heat that the surface temperature of the part will reach about 19 °C over the ambient temperature, and over the life of the part this could cause the resistance value to shift up to  $\pm 0.15\%$ .

If the same resistor was instead run at 1/4 W in a 70 °C environment, the element will heat up to about 30 °C over ambient, and over the life of the part the resistance value could shift roughly  $\pm 0.5\%$ .

And if the resistor was run at its maximum power rating of 1/2 W in a 70 °C environment, it will heat up to about 58 °C over ambient, and you could see the resistance value shift roughly  $\pm 1\%$  over the life of the part.

**MATERIAL SPECIFICATIONS**

<b>Element</b>	Vacuum-deposited nickel-chrome alloy	<b>Coating</b>	Flame retardant epoxy, formulated for superior moisture protection
<b>Core</b>	Fire-cleaned high purity ceramic	<b>Solderability</b>	Continuous satisfactory coverage when tested in accordance with MIL-R-10509

**SPECIAL MODIFICATIONS**

1. Terminals may be supplied in any commercial material with several type finishes.
2. Special pre-conditioning (power aging, temperature cycling, etc.) to customer specifications.
3. Non-helixed resistors can be supplied for critical high frequency applications.
4. Fusible, flameproof versions available.

**MARKING**

Temperature coefficient: T00 = 200 ppm, T0 = 150 ppm, T1 = 100 ppm, T2 = 50 ppm, T9 = 25 ppm, M = 300 ppm

CMF50: (3 lines)

CMF55, CMF60, CMF65, CMF70: (5 lines)

3.01 Value  
K 1 % Ohm, K or M sign and Tolerance  
1208 4-digit date code

DALE Manufacturer's name  
CMF55 Style and size  
49.9 k $\Omega$  Value  
1 % T2 Tolerance and TC  
1208 4-digit date code

**Note**

- CMF07 and CMF20 parts are marked with color bands, either per MIL-PRF-22684 (with a wide white band) or using commercial color bands. CMFxx..70 and CMFxx..80 parts are marked using commercial color bands

**PERFORMANCE**

TEST (TEST METHODS - MIL-STD-202)	AT +70 °C	AT +125 °C
	MAXIMUM $\Delta R$ (TYPICAL TEST LOTS)	
Short Time Overload	$\pm 0.05$ %	$\pm 0.05$ %
Low Temperature Operation	$\pm 0.05$ %	$\pm 0.05$ %
Moisture Resistance	$\pm 0.05$ %	$\pm 0.05$ %
Shock	$\pm 0.01$ %	$\pm 0.01$ %
Vibration	$\pm 0.04$ %	$\pm 0.04$ %
Temperature Cycling	$\pm 0.15$ %	$\pm 0.15$ %
Load Life	Varies based on power rating used; see load life shift due to power and derating table	
Dielectric Withstanding Voltage	$\pm 0.01$ %	$\pm 0.01$ %
Effect of Solder	$\pm 0.03$ %	$\pm 0.03$ %



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