

## LPC17xx

### TFT DISPLAY

Lumex's new 3.5" InfoVue™  
TFT LCD module with touch screen capability

## Digital Images and Pixels

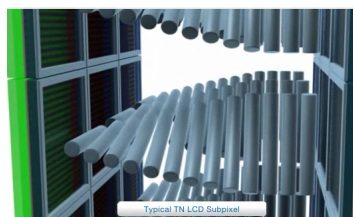
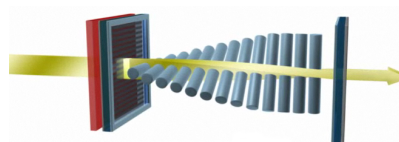
- ❑ A digital image is a binary (digital) representation of a two-dimensional pictorial data.
- ❑ Digital images may have a **raster** or **vector** representation.
- ❑ Raster Images defined over a 2D grid of picture elements, called pixels.
- ❑ A pixel is the basic items of a raster image and include intensity or color value.

Source: Computer Graphics Course. Department of Computer Science, Ben-Gurion University of the Negev, Israel

## LCD (Liquid Crystal Display)



- LCD Panel is based on
  - A light valve for each pixel that turn the light on, off, or an intermediate level.
- Grid of such light valve for the LCD display panel.
- A back light and display enhancement films create the illumination.

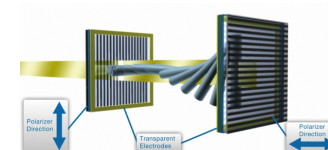
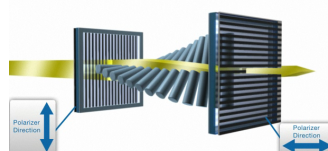
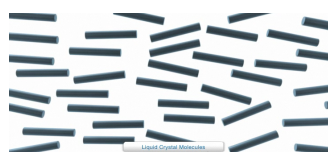


Source: Computer Graphics Course. Department of Computer Science, Ben-Gurion University of the Negev, Israel


## About Liquid Crystal




- Liquid crystal molecules can move freely while maintaining their orientation.
- It align itself to a polyimide film to the inside of a panel glass.
- When the two glass panels are not aligned the liquid crystal twists accordingly.
- The liquid crystal will also align to electric field.



Source: Computer Graphics Course. Department of Computer Science, Ben-Gurion University of the Negev, Israel



## What Does TFT Stand For?



**T** = thin

**F** = film


**T** = transistor

---


TFT stands for thin film transistor. A TFT is actually a component of an LCD designed to improve the quality and control of the LCD display. It is basically a tiny transistor linked to each individual pixel on the screen. In today's marketplace, TFT technology provides the best resolution of all the flat-panel techniques. TFT screens are sometimes called active-matrix LCDs.

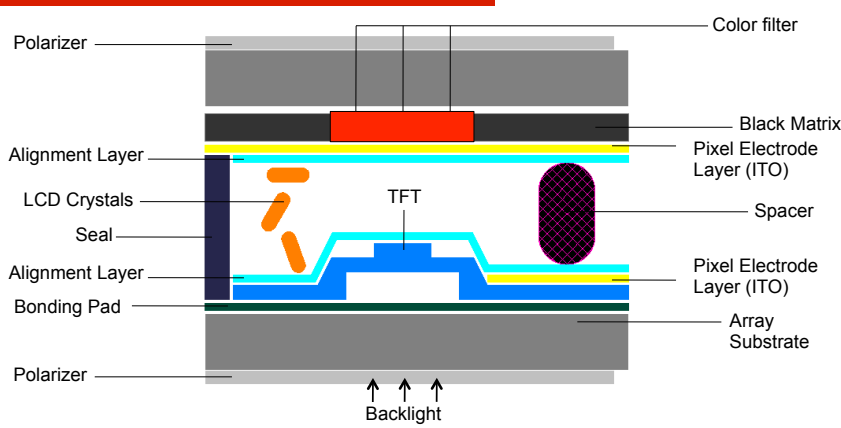
---

Source: Lumex (<http://www.lumex.com>) - LED and LCD technology



## How TFT Technology Works






The diagram illustrates the cross-section of a TFT-LCD panel. It shows two glass substrates: the top one is the Color filter, and the bottom one is the Array Substrate. Between them is a layer of LCD Crystals. The Array Substrate contains a TFT (Thin Film Transistor) and a Pixel Electrode Layer (ITO). A Black Matrix is located between the TFT and the Pixel Electrode Layer. A Spacer is used to maintain the gap between the two substrates. The entire assembly is sealed with a Seal. A Bonding Pad is located on the bottom substrate. A Backlight is shown at the bottom, with arrows indicating light passing through the panel. Polarizers are located on both the top and bottom surfaces. An Alignment Layer is also shown on the bottom substrate.

---

A TFT uses liquid crystal to control the passage of light. The basic structure of a TFT-LCD panel may be thought of as two pieces of glass with a layer of liquid crystal between them. The front glass is fitted with a color filter, while the back glass has transistors on it. When voltage is applied to a transistor, the liquid crystal is bent, allowing light to pass through to form a pixel. A light source, in many cases an LED, is located at the back of the panel and is what makes up the backlight. The front glass is fitted with a color filter, which gives each pixel its own color. The combination of these pixels in different colors forms the image on the panel.


---

Source: Lumex (<http://www.lumex.com>) - LED and LCD technology

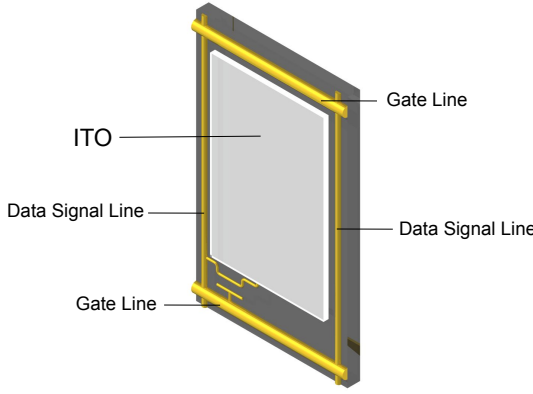


Ministry of Education and Higher Education  
of the Republic of Egypt

## How TFT Technology Works



---




---

A TFT panel array contains a specific number of pixels, often known as subpixels. Thousands or millions of these unit pixels together create an image on the display. This diagram shows the simple structure of a sub-pixel. Each unit pixel contains a TFT, a pixel electrode or ITO and microscopic storage capacitors. Each unit pixel is connected to one of the gate bus lines and one of the data bus lines in a matrix format. This allows for easy individual pixel addressing. TFT devices are switching devices, which function to turn each individual pixel on or off thereby controlling the number of electrons that flow into the ITO zone. As the number of electrons reaches the expected value, TFT turns off and these electrons can be kept within the ITO zone.


---

Source: Lumex (<http://www.lumex.com>) - LED and LCD technology

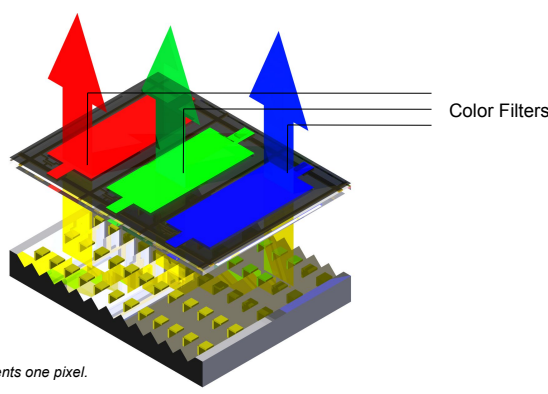


Ministry of Education and Higher Education  
of the Republic of Egypt

## How Do TFT's Generate Color?



---



---

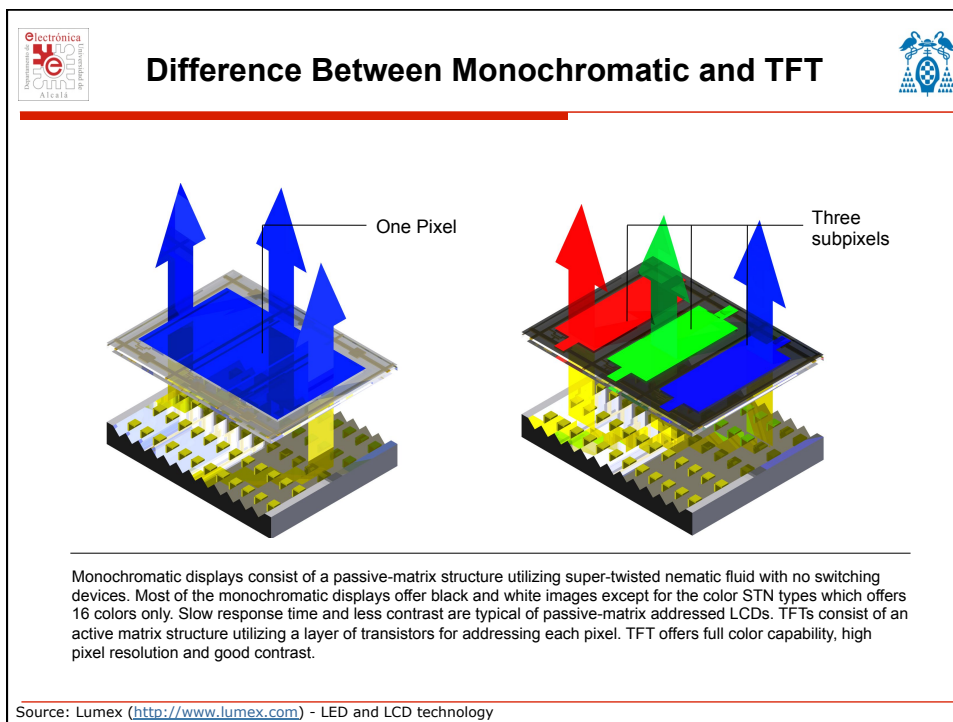
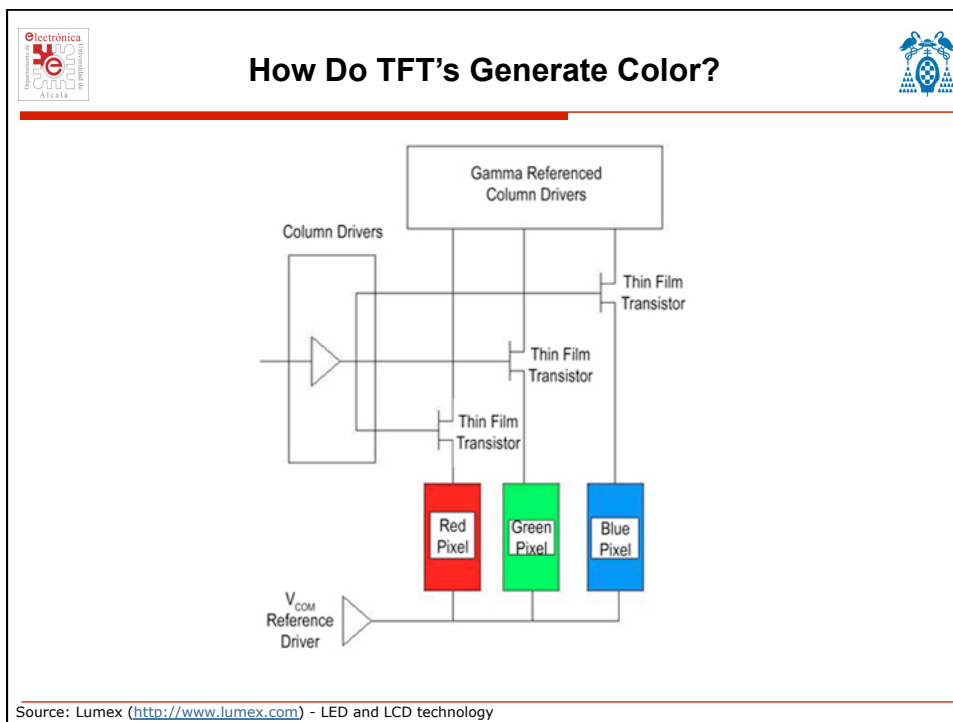
*Illustration represents one pixel.*

---

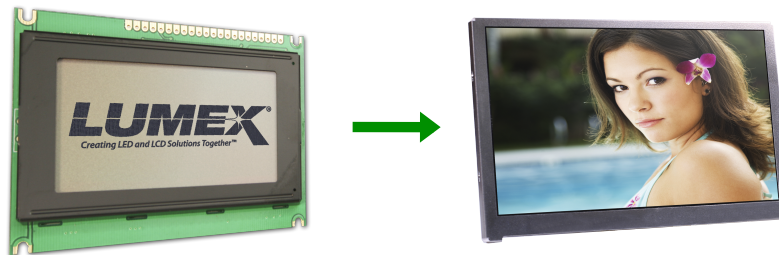
When power is applied to bend the liquid crystal, light passes through from the backlight into the color filter. How much light that passes through depends on the amount of power applied to the pixel. If there were no color filter, the output would be in the form of a grayscale. The color filter is an RGB (red, green and blue) stripe. One set of three subpixels makes up one unit pixel. The white light from the backlight passes through the color filter and outputs all three colors; the intensity of which depends on how far the liquid crystal gets bent. The human eye cannot resolve each color from a tiny pixel; instead the brain mixes the 3 colors together to give the appearance of the combined color (such as mixing red and blue to make purple).

---

Source: Lumex (<http://www.lumex.com>) - LED and LCD technology



## Transitioning from Monochromatic to TFT



Due to the simplicity in construction of a monochromatic LCD, they are ideal for text and static image on the screen with no color. TFTs are a bit more complex in construction compared to a monochromatic display, therefore TFT require more data input in order to display full color dynamic video on the screen.

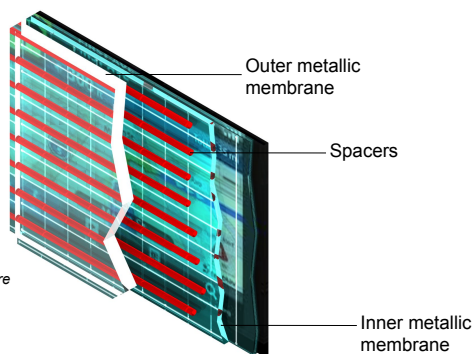
Source: Lumex (<http://www.lumex.com>) - LED and LCD technology

## Capacitive vs. Resistive TFT Technology




*Resistive touch screen displays have multiple layers that are separated by thin spacers.*

*Resistive type touch screens require more pressure to activate than capacitive touch screens.*




TFT applications are including touch screen capability in order to make the user interface more friendly. There are two primary types of touch screens: resistive and capacitive. Simply, resistive touch screens use two thin layers of a metallic membrane with a gap in between the two. A person touching the screen at a specific point compresses the outer layer until it touches the other layer. This technology is relatively inexpensive, however it can also be fragile. Environments, such as medical equipment, require resistive touch screens because they are easy to clean, maintain and do no register false readings.

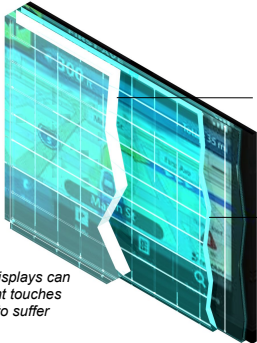
Source: Lumex (<http://www.lumex.com>) - LED and LCD technology



## Capacitive vs. Resistive TFT Technology



---



Outer metallic membrane

Inner metallic membrane


*Capacitive touch screen displays can be controlled with very light touches and are therefore subject to suffer from 'false' touches.*

---


Capacitive touch screens are similar to resistive touch screens in that they have multiple layers. With capacitive touch screen technology, the outer layer is an insulator and the inner layer is conductive. When the finger touched the outer layer, it changes the capacitance and registers a touch. Capacitive touch screens, due to their nature, require the bare finger and can register false touches, but are more impact resistant. Capacitive touch screens are generally more expensive than resistive touch screens due to their relative robustness.

---

Source: Lumex (<http://www.lumex.com>) - LED and LCD technology



## Advantages of TFT



---

- Space savings
- Finer imaging quality
- Less glare and flicker
- More vibrant color
- Increased response time

---

There are several advantages to TFT technology, including space savings, enhanced resolution and finer quality. Of all the flat panel technologies available, TFT displays offer tremendous space savings. A Lumex InfoVue TFT module, for instance, starts at an industry-leading 3mm in width. In addition, TFT displays provide a finer imaging quality with less glare and flicker for a reduction in eye strain to the end user. TFT displays also offer a more vibrant color and response time than other color LCD technologies.

---

Source: Lumex (<http://www.lumex.com>) - LED and LCD technology



## Controlador TFT SPFD5408B



### SPFD5408B

#### 720-channel 6-bit Source Driver with System-on-chip for Color Amorphous TFT-LCDs

- ❑ Características del controlador de TFT
  - Resolución de 320 x 240 pixels con 18 bits por pixel (256K colores)
  - Diferentes modos de comunicación (18 bits, 16 bits, 8 bits, SPI)
    - ❑ En el módulo HY28A - LCDA fijado el modo 16 bits por hardware
- ❑ Registros de control
  - Dispone de más de 50 registros de control
- ❑ Memoria CGRAM (Memoria gráfica)
  - Contiene la información de los 320x240 pixels con 18 bits de información por pixel
  - Representa la información que es presentada en el display.



## Controlador TFT SPFD5408B

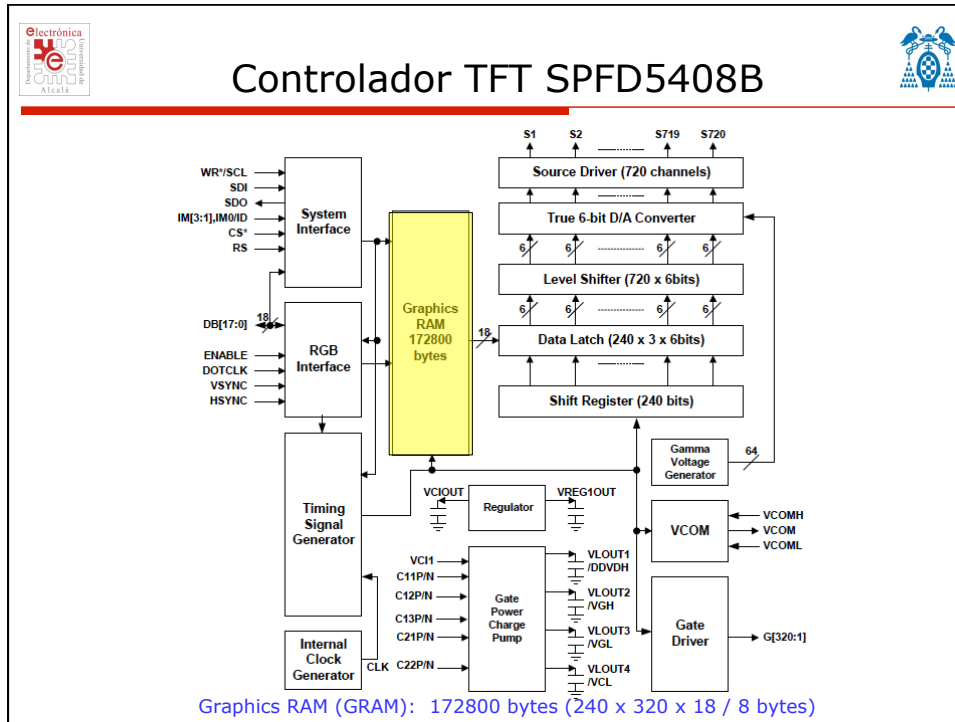



### SPFD5408B


#### 720-channel 6-bit Source Driver with System-on-chip for Color Amorphous TFT-LCDs

##### 2. FEATURE

- One-chip solution for amorphous TFT-LCD.
- Supports resolution up to 240xRGBx320, incorporating a 720-channel source driver and a 320-channel gate driver
- Outputs 64  $\gamma$ -corrected values using an internal true 6-bit resolution D/A converter to achieve 262K colors
- Built-in 172800 bytes internal RAM
- Line Inversion AC drive / frame inversion AC drive
- System interfaces
  - High-speed interfaces to 8-, 9-, 16-, and 18-bit parallel ports
  - Serial Peripheral Interface (SPI)
- Interfaces for moving picture display
  - 6-, 16-, and 18-bit RGB interfaces
- Diverse RAM accessing for functional display
  - Window address function to display at any area on the screen via a moving picture display interface
  - Window address function to limit the data rewriting area and reduce data transfer
  - Moving and still picture can display at the same time
  - Vertical scrolling function
  - Partial screen display




 Universidad de Alicante  
 Departamento de Electrónica



# Controlador TFT SPFD5408B


## □ Líneas de control

- RS indica si se escribe en el puntero de registro o en el registro apuntado por el puntero.

Interface input Signals				
/CS	1	I	MPU	<p>Chip select signal.</p> <p>Low: the SPFD5408B is accessible</p> <p>High: the SPFD5408B is not accessible</p> <p>Must connect to the GND or IOVCC level when not used.</p> <p>This pin has weak pull high/low resistors and can be modified to high / low by metal layer change for customer's request.</p>
RS	1	I	MPU	<p>Register select signal.</p> <p>Low: Index register or internal status is selected.</p> <p>High: Control register is selected.</p> <p>Must connect to the GND or IOVCC level when not used.</p> <p>This pin has weak pull high/low resistors and can be modified to high / low by metal layer change for customer's request.</p>
(/WR) / (SCL)	1	I	MPU	<p>(A) In 80-system interface mode, a write strobe signal can be input via this pin and initializes a write operation when the signal is low.</p>
/RD	1	I	MPU	<p>In 80-system interface mode, a read strobe signal can be input via this pin and initializes a read operation when the signal is low.</p> <p>Must connect to the GND or IOVCC level when not in use.</p> <p>This pin has weak pull high/low resistors and can be modified to high / low by metal layer change for customer's request.</p>




## Controlador TFT SPFD5408B




☐ **Líneas de control**

- RS indica si se escribe en el puntero de registro o en el registro apuntado por el puntero.

DB0-DB17	1	I/O	MPU	<p>Served as an 18-bit parallel bi-directional data bus. Data bus pin assignment corresponding to different modes are summarized in the table:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Mode</th> <th>Pin Assignment</th> </tr> </thead> <tbody> <tr> <td>8-bit system interface</td> <td>DB17-DB10</td> </tr> <tr> <td>9-bit system interface</td> <td>DB17-DB9</td> </tr> <tr> <td>16-bit system interface</td> <td>DB17-DB10, DB8-DB1</td> </tr> <tr> <td>18-bit system interface</td> <td>DB17-DB0</td> </tr> <tr> <td>6-bit External (RGB) interface</td> <td>DB17-DB12</td> </tr> <tr> <td>16-bit External (RGB) interface</td> <td>DB17-13, DB11-DB1</td> </tr> <tr> <td>18-bit External (RGB) interface</td> <td>DB17-DB0</td> </tr> </tbody> </table> <p>Must connect to the GND or IOVCC level when not in use. These pins have weak pull high/low resistors and can be modified to high / low by metal layer change for customer's request.</p>	Mode	Pin Assignment	8-bit system interface	DB17-DB10	9-bit system interface	DB17-DB9	16-bit system interface	DB17-DB10, DB8-DB1	18-bit system interface	DB17-DB0	6-bit External (RGB) interface	DB17-DB12	16-bit External (RGB) interface	DB17-13, DB11-DB1	18-bit External (RGB) interface	DB17-DB0
Mode	Pin Assignment																			
8-bit system interface	DB17-DB10																			
9-bit system interface	DB17-DB9																			
16-bit system interface	DB17-DB10, DB8-DB1																			
18-bit system interface	DB17-DB0																			
6-bit External (RGB) interface	DB17-DB12																			
16-bit External (RGB) interface	DB17-13, DB11-DB1																			
18-bit External (RGB) interface	DB17-DB0																			



## Controlador TFT SPFD5408B



☐ **Configuración del modo de comunicación**

IM3	IM2	IM1	IM0/ I D	Interface Mode	DB Pin	Colors
0	0	0	0	Setting disabled	-	-
0	0	0	1	Setting disabled	-	-
0	0	1	0	80-system 16-bit interface	DB17-10, DB8-1	262,144 see Note 1
0	0	1	1	80-system 8-bit interface	DB17-10	262,144 see Note 2
0	1	0	*(ID)	Clock synchronous serial interface	-	65,536
0	1	1	0	Setting disabled	-	-
0	1	1	1	Setting disabled	-	-
1	0	0	0	Setting disabled	-	-
1	0	0	1	Setting disabled	-	-
1	0	1	0	80-system 18-bit interface	DB17-0	262,144
1	0	1	1	80-system 9-bit interface	DB17-9	262,144
1	1	0	0	Setting disabled	-	-
1	1	0	1	Setting disabled	-	-
1	1	1	0	Setting disabled	-	-
1	1	1	1	Setting disabled	-	-

Notes: 1. 65,536 colors in one transfer mode  
2. 65,536 colors in two transfers mode


16 bits

8 bits


SPI

18 bits

9 bits



## Controlador TFT SPFD5408B



☐ Acceso los Registros de Configuración

- Hay más de 50 registros de configuración de 16 bits
- Para escribir en un registro primero hay que escribir un puntero que apunte al registro
- La escritura en el puntero al registro (Index Register) o en el registro apuntado por el puntero se controla con el pin RS
  - ☐ RS = 0 → El dato se escribe en el Index Register (Puntero)
  - ☐ RS = 1 → El dato se escribe en el registro apuntado por el Index Register


**6.2.1. Index Register (IR)**

RW	RS	CB15	CB14	CB13	CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1	CB0
W	0	*	*	*	*	*	*	*	*	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0


The index register specifies the index (R00h ~ RFFh) of a control register. The index range is from "000\_0000" to "111\_1111" in binary format.

**6.2.5. Entry Mode (R03h)**

RW	RS	CB15	CB14	CB13	CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1	CB0
W	1	TRIR	DFM	0	BGR	0	0	0	0	ORG	0	I/D1	I/D0	AM	0	0	0
		EG															



## Controlador TFT SPFD5408B




☐ Ejemplo de registro de control: R03h – Entry Mode

- Entre otras cosas permite configurar la orientación de la visualización.

	I/D[1:0] = 00 Horizontal : decrement Vertical : decrement	I/D[1:0] = 01 Horizontal : increment Vertical : decrement	I/D[1:0] = 10 Horizontal : decrement Vertical : increment	I/D[1:0] = 11 Horizontal : increment Vertical : increment
AM = 0 Horizontal				
AM = 1 Vertical				


**6.2.5. Entry Mode (R03h)**

RW	RS	CB15	CB14	CB13	CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1	CB0
W	1	TRIR	DFM	0	BGR	0	0	0	0	ORG	0	I/D1	I/D0	AM	0	0	0
		EG															



Universidad de Cuenca

## Controlador TFT SPFD5408B



---

☐ Acceso a la CGRAM

- Se debe especificar el puntero de acceso a la CGRAM (R20h y R21h) y luego escribir o leer
- Con cada lectura o escritura se autoincrementa el puntero
- Cada fila sólo tiene útiles 240 (0x0000-0x00EF) (0x0100-0x01EF)...

**6.2.18. GRAM Address Set (Horizontal Address) (R20h)**

R/W	RS	CB15	CB14	CB13	CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1	CB0
W	1	0	0	0	0	0	0	0	0	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0

**6.2.19. GRAM Address Set (Vertical Address) (R21h)**


R/W	RS	CB15	CB14	CB13	CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1	CB0
W	1	0	0	0	0	0	0	0	AD16	AD15	AD14	AD13	AD12	AD11	AD10	AD9	AD8

**6.2.20. Write Data to GRAM (R22h)**

R/W	RS	CB15	CB14	CB13	CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1	CB0
W	1	RAM write data (WD17-0) The DB17-0 pin assignment is different in different interface modes.															


**6.2.21. Read Data Read from GRAM (R22h)**

R/W	RS	CB15	CB14	CB13	CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1	CB0
R	1	RAM Read data (RD17-0) The DB17-0 pin assignment is different in different interface modes.															



Universidad de Cuenca

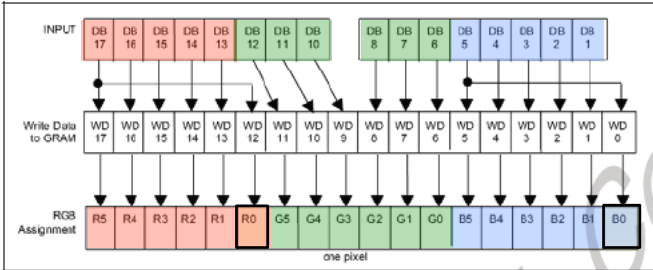
## Controlador TFT SPFD5408B



---

☐ Acceso mediante un bus paralelo de 16 bits

- Modo 64K colores → 16 bits por pixel
  - ☐ Cada pixel necesita una palabra de 16 bits
  - ☐ Se pierde la resolución del bit menos significativo del R y del B
- El modo se controla con la información del registro "Entry Mode (R03h)"



one pixel

**Figure 6-9 16-bit interface (65,536 colors) TRIREG= 0, DFM=x**

**6.2.5. Entry Mode (R03h)**

R/W	RS	CB15	CB14	CB13	CB12	CB11	CB10	CB9	CB8	CB7	CB6	CB5	CB4	CB3	CB2	CB1	CB0
W	1	TRIR	DFM	0	BGR	0	0	0	0	ORG	0	ID1	ID0	AM	0	0	0
		EG															

## Controlador TFT SPFD5408B

- Acceso mediante un bus paralelo de 16 bits
  - Modo 256K colores → 18 bits por pixel
    - Cada pixel necesita dos transferencias de 16 bits
    - Hay dos modos de distribuir la información en las dos palabras

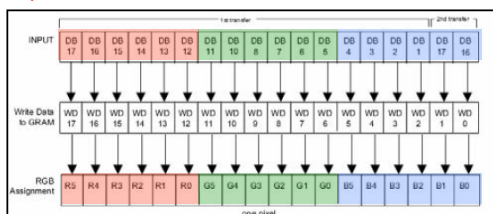


Figure 6-10 16-bit interface (262,144 colors) TRIREG = 1, DFM = 0

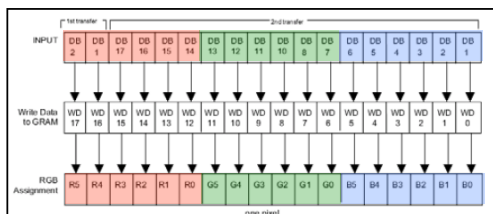
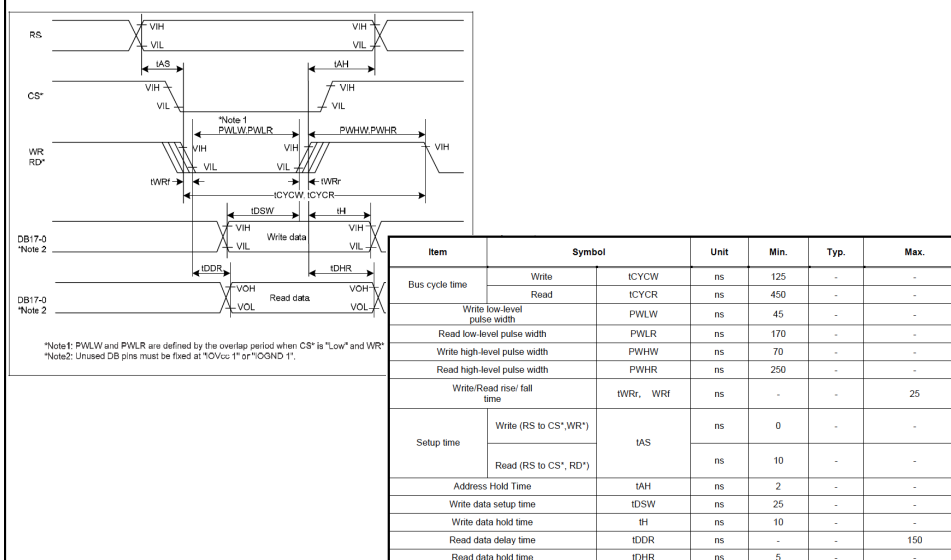



Figure 6-11 16-bit interface (262,144 colors) TRIREG = 1, DFM = 1

## Conexión Controlador TFT SPFD5408B


- Temporización de lectura y escritura del bus paralelo





Electrónica  
Departamento de Ingeniería de Electrónica

## Controlador TFT SPFD5408B

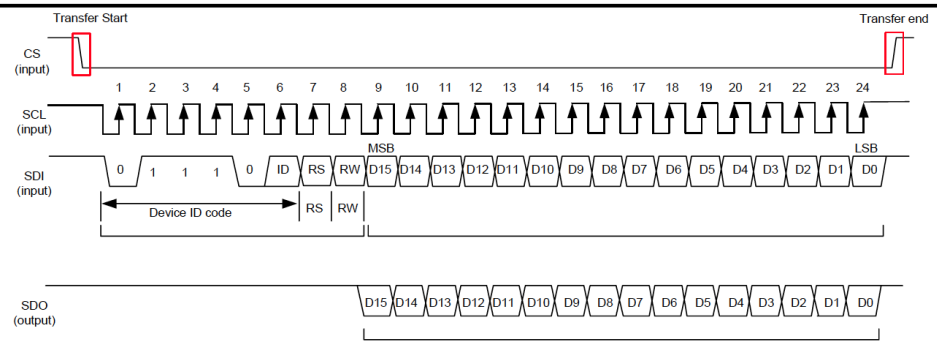


□ Acceso mediante SPI


- Transferencia de 24 bits (3 bytes)
  - (6 bits) Identificador de dispositivo
  - Bit RS
  - Bit RW
  - Dato de 16 bits

RS	R/W	Function
0	0	Set an index register
0	1	Read a status
1	0	Write an instruction or RAM data
1	1	Read an instruction or RAM data

Transfer Start




Transfer end



Electrónica  
Departamento de Ingeniería de Electrónica

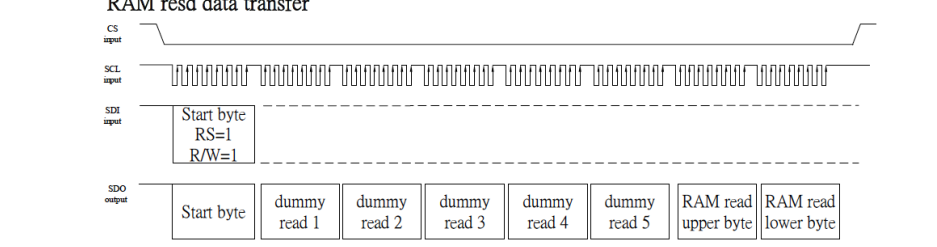
## Controlador TFT SPFD5408B



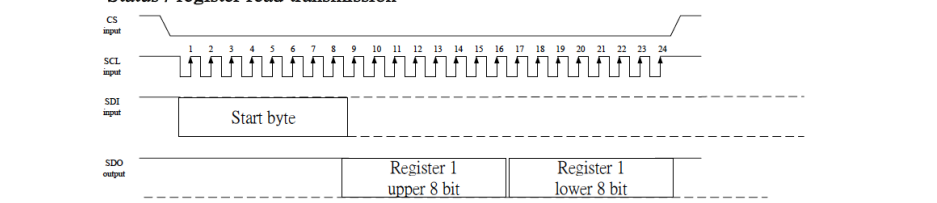
□ Acceso mediante SPI


- La lectura de los registros está disponible en el segundo byte
- La lectura de la RAM está disponible en el séptimo byte

RAM read data transfer




Status / register read transmission





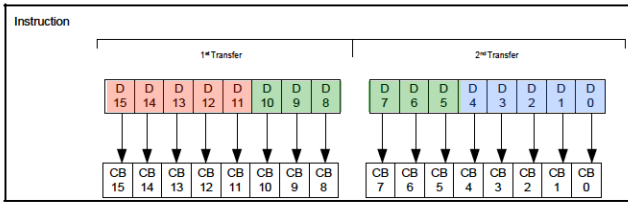
## Controlador TFT SPFD5408B



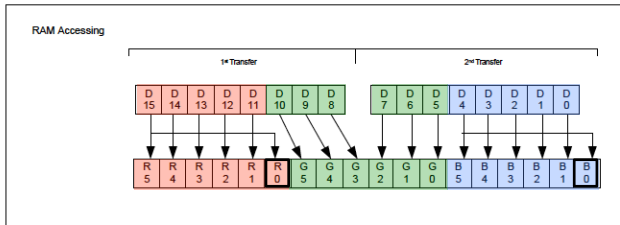
---

□ Acceso mediante SPI


■ Formato de los bits de Datos




**Figure 8-10**



**Figure 8-11**



## Controlador TFT SPFD5408B



---

□ Acceso mediante SPI

■ Escritura y Lectura de un Byte


```

unsigned char LPC17xx_SPI_SendRecvByte (unsigned char byte_s)
{
    /* wait for current SSP activity complete */
    while (SSP_GetStatus(LPC_SSP0, SSP_STAT_BUSY) == SET);


    SSP_SendData(LPC_SSP0, (unsigned short) byte_s);

    while (SSP_GetStatus(LPC_SSP0, SSP_STAT_RXFIFO_NOTEMPTY) == RESET);
    return (SSP_ReceiveData(LPC_SSP0));
}

```



## Controlador TFT SPFD5408B



---

☐ Acceso mediante SPI

- Escritura del "Index Register" (RS=0, RW=0)
  - ☐ El "Index Register" es de 8 bits

```

void LCD_WriteIndex(unsigned char index)
{
    SPI_CS_LOW;

    /* SPI write data */
    LPC17xx_SPI_SendRecvByte(SPI_START | SPI_WR | SPI_INDEX); /* Write : RS = 0, RW = 0 */
    LPC17xx_SPI_SendRecvByte(0);
    LPC17xx_SPI_SendRecvByte(index);

    SPI_CS_HIGH;
}
  
```

■ Escritura del un datos donde apunta "Index Register" (RS=1, RW=0)


- ☐ El contenido de los registros es de 16 bits

```


void LCD_WriteData( unsigned short data)
{
    SPI_CS_LOW;

    LPC17xx_SPI_SendRecvByte(SPI_START | SPI_WR | SPI_DATA); /* Write : RS = 1, RW = 0 */
    LPC17xx_SPI_SendRecvByte((data >> 8)); /* Write D8..D15 */
    LPC17xx_SPI_SendRecvByte((data & 0xFF)); /* Write D0..D7 */

    SPI_CS_HIGH;
}
  
```



## Controlador TFT SPFD5408B



---

☐ Acceso mediante SPI

- Escritura en un registro

```

void LCD_WriteReg( unsigned short LCD_Reg, unsigned short LCD_RegValue)
{
    /* Write 16-bit Index, then Write Reg */
    LCD_WriteIndex(LCD_Reg);
    /* Write 16-bit Reg */
    LCD_WriteData(LCD_RegValue);
}
  
```

■ Lectura de un registro (RS=1, RW=0)

- ☐ Los registros son de 16 bits

```

unsigned short LCD_ReadData(void)
{
    unsigned short value;

    SPI_CS_LOW;

    LPC17xx_SPI_SendRecvByte(SPI_START | SPI_RD | SPI_DATA); /* Read: RS = 1, RW = 1 */
    LPC17xx_SPI_SendRecvByte(0); /* Dummy read 1 */
    value = LPC17xx_SPI_SendRecvByte(0); /* Read D8..D15 */
    value <<= 8;
    value |= LPC17xx_SPI_SendRecvByte(0); /* Read D0..D7 */

    SPI_CS_HIGH;

    return value;
}
  
```