Using the HT16L23 in BD Player Panel Applications

D/N：HA0291E

Introduction

The HT16L23 is an LCD driver device which has multiple display modes (Max: 52×4 or 48×8), which can drive a maximum of 8 LEDs and operate at voltages as low as 1.8V. In the device SEG44~SEG51 and LED7~LED0 are shared pins. The HT16L23 provides both I^2C and 3-wire SPI (which below will only be referred to as SPI) interface types. This example uses the HT68F40 as the master MCU to control an HT16L23 to drive a Blue-ray Disc Player Display LCD panel and 8 LEDs via the I^2C interface, showing the drive function for a 35×4 LCD and 8 LEDs. The purpose of the application is to allow users to grasp the characteristics and applications of the HT16L23 more clearly.

Operation Features

HT16L23 Features

- IC operating voltage: 1.8V~5.5V
- LCD operating voltage V_{LCD}: 2.4V~6.0V
- Internal 32kHz RC oscillator
- Supports both I^2C bus and SPI serial interface
- Four Selectable LCD frame frequencies: 64Hz/85.3Hz/128Hz/170.6Hz
- Versatile blinking modes: OFF/0.5Hz/1Hz/2Hz
- R/W address auto increment
- Internal voltage adjustment for LCD operating voltage: 3.0V, 3.2V, 3.3V, 3.4V, 4.4V, 4.5V, 4.6V, 5.0V
- Supports two output drive modes: Segment and LED drive (SEG44~SEG51/LED7~LED0)
- Internal LED driver
- 48×8 bits RAM for display data storage
- Multiple Display Patterns:
  - For 1/4 Duty: Maximum Display Dots: 52 Segments × 4 Commons
  - For 1/8 Duty: Maximum Display Dots: 48 Segments × 8 Commons
- Low power consumption
- Supplied in both and 64-pin LQFP (7x7) Package Types

Operating Principle

Display RAM Structure

The HT16L23 LCD Display RAM is used to store LCD display data. Writing a "1" means the related LCD segment is on. Writing a "0" means the related LCD segment is off.

- For 1/4 Duty:
  - SP1=0, SP0=0/1, 52 Segment × 4 Common output drive mode is selected (default mode).

Output	COM3	COM2	COM1	COM0	Output	COM3	COM2	COM1	COM0	Address
SEG1					SEG0					00H
SEG3					SEG2					01H
SEG5					SEG4					02H
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
SEG50					SEG48					18H
SEG51					SEG50					19H
	D7	D6	D5	D4		D3	D2	D1	D0	Data

52×4 Display Mode RAM Mapping

  - SP1=1, SP0=0, 48 Segmenst × 4 Commons + 4 LED output drive mode is selected.

Output	COM3	COM2	COM1	COM0	Output	COM3	COM2	COM1	COM0	Address
SEG1					SEG0					00H
SEG3					SEG2					01H
SEG5					SEG4					02H
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
SEG46					SEG44					16H
SEG47					SEG46					17H
	D7	D6	D5	D4		D3	D2	D1	D0	Data

48×4 Display Mode RAM Mapping

  - SP1=1, SP0=1, 44 Segments × 4 Commons + 8 LED output drive mode is selected.

Output	COM3	COM2	COM1	COM0	Output	COM3	COM2	COM1	COM0	Address
SEG1					SEG0					00H
SEG3					SEG2					01H
SEG5					SEG4					02H
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
SEG41					SEG40					14H
SEG43					SEG42					15H
	D7	D6	D5	D4		D3	D2	D1	D0	Data

44×4 Display Mode RAM Mapping

- For 1/8 Duty:
  - SP1=0, SP0=0/1, 48 Segment × 8 Common output drive mode is selected.

Output	COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0	Address
SEG4									00H
SEG5									01H
SEG6									02H
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
SEG50									2EH
SEG51									2FH
	D7	D6	D5	D4	D3	D2	D1	D0	Data

48×8 Display Mode RAM Mapping

  - SP1=1, SP0=0, 44 Segment × 8 Common + 4 LED output drive mode is selected

Output	COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0	Address
SEG4									00H
SEG5									01H
SEG6									02H
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
SEG46									2AH
SEG47									2BH
	D7	D6	D5	D4	D3	D2	D1	D0	Data

44×8 Display Mode RAM Mapping

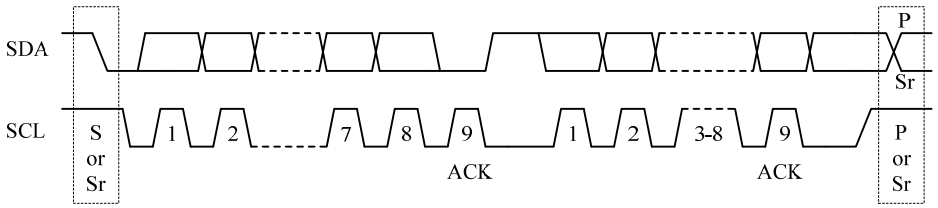
  - SP1=1, SP0=1, 40 Segment × 8 Common + 8 LED output drive mode is selected.

Output	COM7	COM6	COM5	COM4	COM3	COM2	COM1	COM0	Address
SEG4									00H
SEG5									01H
SEG6									02H
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
SEG42									26H
SEG43									27H
	D7	D6	D5	D4	D3	D2	D1	D0	Data

40×8 Display Mode RAM Mapping

HT16L23 Data Transmission Format

The HT68F40 MCU used in this example reads and writes data to and from the HT16L23 via the I^2C interface. The HT16L23 SCL pin, SDA pin and open-drain output must be connected to a 4.7k pull-high resisitor individually. The HT16L23 follows the general I^2C protocol, the high data bits are transmitted first, as the accompanying figure shows.

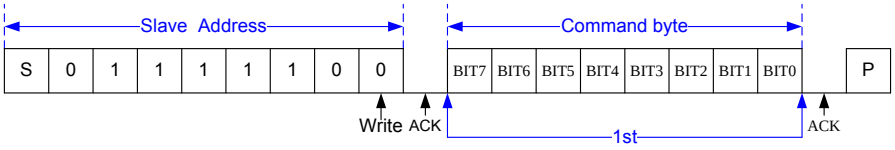


The HT16L23 slave address is 0111110, as shown below. If R/W = "1", the I^2C slave is in the read mode. If R/W = "0", the I^2C slave is in the write mode.

Write Operation

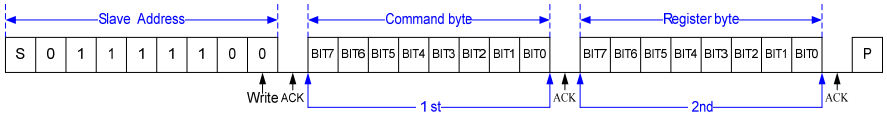
There are two ways that the controller writes data to the HT16L23. One is to write a command byte and the other is to write to the LCD Display RAM. A command byte also can be single command byte or a compound command byte.

- Write Command Byte
  - Single Command Byte
    A byte write operation requires a Start signal, a slave address, a read/write flag, a command byte and finally a stop signal.



Single Command Byte

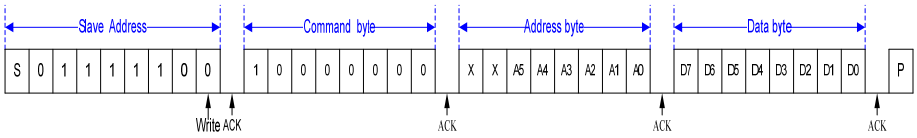
  - Compound Command Byte
    For example, when setting the HT16L23 Bias to 1/3 and the Duty to 1/8, SEG44~SEG51 as LED drivers, the controller must first send the Slave Address and 0x7c which stands for write mode, then send the Command Byte 0x82 which stands for the drive mode. Finally the command setting 0x30 must be sent.



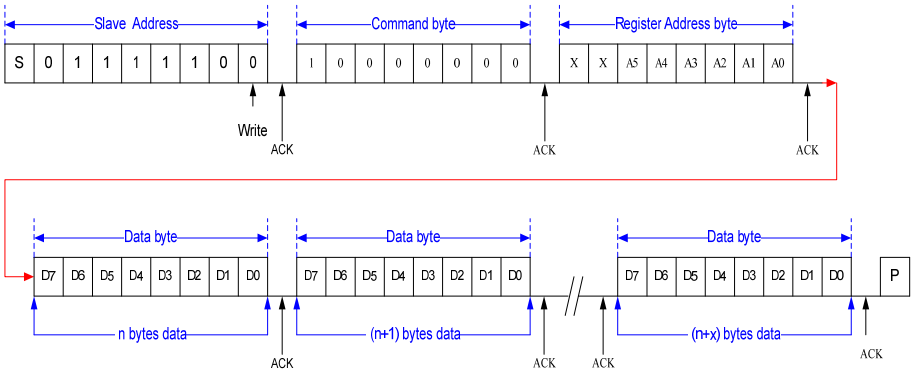
Compound Command Byte

- Writing a single data byte to the LCD Display RAM

  Writing to the LCD display RAM is implemented according to the LCD panel COM and Segment connection setup. Write a suitable value to the Display RAM to turn on the related pixel. When writing to a single location in the LCD display RAM, the controller firstly sends the slave address and then 0x7c. Then it sends the Display Data Input/Output Command 0x80, and the write address of the RAM. It then sends the data and the stop signal. After this the transmission is complete.



- Writing continuous data to the LCD Display RAM

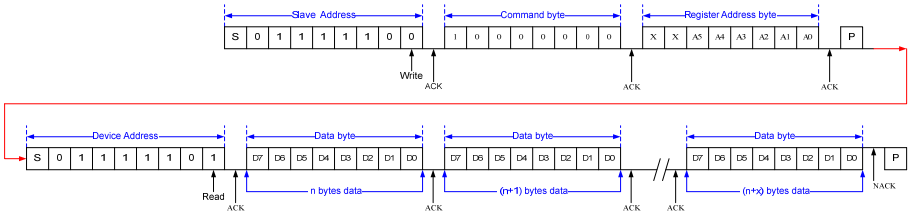


When writing continuous data to the LCD Display RAM, it firstly sends the address and then 0x7c. Then it sends the Display Input/Output Command 0x80. After sending the start address it writes to the RAM continuously. The RAM address is automatically incremented until it sends a stop signal.

The table shows the LCD Display RAM location limiting value. If it increases beyond this value it will return to the start value 0.

Duty	SP1	SP0	Memory Location Limit Value	Note
1/4	0	X	19H	
	1	0	17H	
	1	1	15H	
1/8	0	X	2FH	
	1	0	2BH	
	1	1	27H	

- Reading the LCD Display RAM Format



When reading the LCD Display RAM, it first sends the address and then 0x7c, the Display Data Input/Output Command 0x80 and the RAM start address. Then it sends the signal to stop the transmission. After sending the address and 0x7d which stands for the read mode, it is possible to read the RAM data from the start address until it sends a stop signal.

HT16L23 Command Summary

After the HT16L23 recieves the commands listed in the datasheet from the controller, it will execute the related operation as shown below. If the HT16L23 recieves a command not listed in the datasheet, there will be no operation executed.

- Soft Reset Setting

Function	Byte	(MSB) Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	(LSB) Bit0	Note	R/W	Def
Soft Reset	1st	1	0	0	0	0	0	0	0		W	
Note: HT16L23 soft reset command, then all registers are in default status. After sending the command, IC can execute normal operation after 1ms.												

- Display Data Address Setting

Function	Byte	(MSB) Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	(LSB) Bit0	Note	R/W	Def
Display Data address setting Command	1st	1	0	0	0	0	0	0	0	Write operation	W	
		1	0	0	0	0	0	0	1	Read operation for SPI mode only	R	
Address point	2nd	X	X	A5	A4	A3	A2	A1	A0	Display data start address of memory map	W	00H
Note: When the controller writes LCD display RAM data to the HT16L23 or reads LCD display RAM data from the HT16L23 via the I^2C interface, after sending the address, the command 0x80 must be sent before the RAM start address for reading or writing.												

- Driver Mode Setting Commands

  This group of commands is used to control the HT16L23 internal oscillator and the LCD display

Function	Byte	(MSB) Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	(LSB) Bit0	Note	R/W	Def
Driver mode setting command	1st	1	0	0	0	0	0	1	0		W	
Duty and Bias setting	2nd	X	X	SP1	SP0	X	Duty	X	Bias		W	00H

Note:

Bit0 (Bias)	Bias
0	1/3
1	1/4

Bit2 (Duty)	Duty
0	1/4
1	1/8

Bit5 (SP1)	Bit4 (SP0)	Segment / LED shared pin selected	
		Segment48~51/LED3~0	Segment44~47/LED7~4
0	X	Set as Segment pins	Set as Segment pins
1	0	Set as LED pins	Set as Segment pins
1	1	Set as LED pins	Set as LED pins

Note: This group of commands is used to set the HT16L23 driver waveform bias, duty and the Segment/LED share pin.

- System Mode Setting Command

  This group of commands is used to control the HT16L23 internal oscillator and display.

Function	Byte	(MSB) Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	(LSB) Bit0	Note	R/W	Def
System mode setting command	1st	1	0	0	0	0	1	0	0		W	
System oscillator and Display on/off Setting	2nd	X	X	X	X	X	X	S	E		W	00H

Note:

Bit1 S	Bit0 E	Internal System oscillator	LCD Display
0	X	Off	Off
1	0	On	Off
1	1	On	On

Note: This group of commands is used to control the HT16L23 internal oscillator and the LCD display.

- Frame Frequency Command

  This group of commands is used to select the LCD frame frequency

Function	Byte	(MSB) Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	(LSB) Bit0	Note	R/W	Def
Frame frequency command	1st	1	0	0	0	0	1	1	0		W	
Frame frequency	2nd	X	X	X	X	X	X	F1	F0		W	02H

Note:

Bit1 (F1)	Bit0 (F0)	Frame Frequency
0	0	85.3Hz
0	1	170.6Hz
1	0	64Hz
1	1	128Hz

Note: This group of commands is used to select the LCD frame frequency
reset status: 64Hz.

- Blinking Frequency Command

  This group of commands is used to select the LCD panel full-screen blinking frequency.

Function	Byte	(MSB) Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	(LSB) Bit0	Note	R/W	Def
Blinking Frequency command	1st	1	0	0	0	1	0	0	0		W	
Blinking Frequency setting	2nd	X	X	X	X	X	X	BK1	BK0		W	00H

Note:

Bit1 (BK1)	Bit0 (BK0)	Blinking Frequency
0	0	Blinking off
0	1	2Hz
1	0	1Hz
1	1	0.5Hz

Note: This group of commands is used to select the LCD panel full-screen blinking frequency.
reset status: Blinking off

- LED Output Control Command

Function	Byte	(MSB) Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	(LSB) Bit0	Note	R/W	Def
LED output control command	1st	1	0	0	0	1	1	0	0		W	
LED output control	2nd	X	X	X	X	LED3	LED2	LED1	LED0	When SP1 bit is set to "1" and SP0 bit is set to "0"	W	00H
		LED7	LED6	LED5	LED4	LED3	LED2	LED1	LED0	When SP1 bit is set to "1" and SP0 bit is set to "1"		

Note: This group of commands is used to control output.
reset status: output high.

- Internal Voltage Adjustment (IVA) Setting Command

  This group of commands is used to select the Segment and VLCD pin-shared function and enable/ disable the internal voltage adjustment function.

Function	Byte	(MSB) Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	(LSB) Bit0	Note	R/W	Def
Internal Voltage Adjustment (IVA) Setting	1st	1	0	0	0	1	0	1	0		W	
Internal Voltage Adjust control	2nd	X	X	X	VE	X	V2	V1	V0		W	00H

Note:

Bit4 (VE)	Regulator adjustment
0	Off (Bias voltage is supplied from VLCD pin)
1	On (Bias voltage is supplied from internal Regulator)

Bit2 (V2)	Bit1 (V1)	Bit0 (V0)	Regulator Voltage Output (V)
0	0	0	3.0V
0	0	1	3.2V
0	1	0	3.3V
0	1	1	3.4V
1	0	0	4.4V
1	0	1	4.5V
1	1	0	4.6V
1	1	1	5.0V

Note: 1. This group of commands is used to select the LCD Bias voltage.
2. Reset status: Regulator Adjustment Off.
3. When V_{LCD} <3.5V, internal Regulator is adviced to be off, the VLCD Pin is connected directly to the internal Bias voltage.
4. Note: only when Regulator output voltage < V_{LCD} - 0.5V, the Internal Voltage Adjustment can be used.

H/W Flowchart

LCD Panel

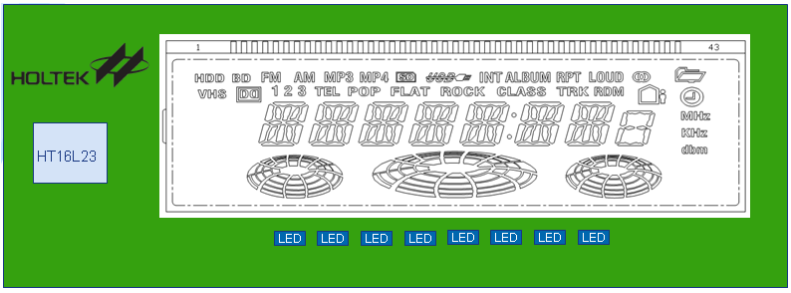


Figure 1 LCD Panel

Figure 1 shows Blue-ray Disc Player Display LCD Panel and LED display panel. The displayed contents are as follows:

1. HDD, BD, MP3, MP4, SD, USB, VHS: audio and video sources
2. POP, FLAT, ROCK, CLASS: music modes and play modes
3. TEL, 1, 2, 3: download
4. FM, AM: radio functions displayed in Mhz or KHz
5. Segment LED is used to display clock, audio and video names, play time, Dolby, radio, online download address. A Seven-Segment LED is used to display the currently playing track.
6. The disc has four display modes, to indicate if the video is playing.
7. The LEDs displays differert patterns according to different video sources.
8. The process that this example shows includes: clock, folder selection, video names, audio, Dolby value addition and subtraction, radio channel search, online download, corresponding LED display in different modes and so on. The purpose is to allow users to obtain further knowledge and understanding of the HT16L23 features and functions.

System Block Diagram

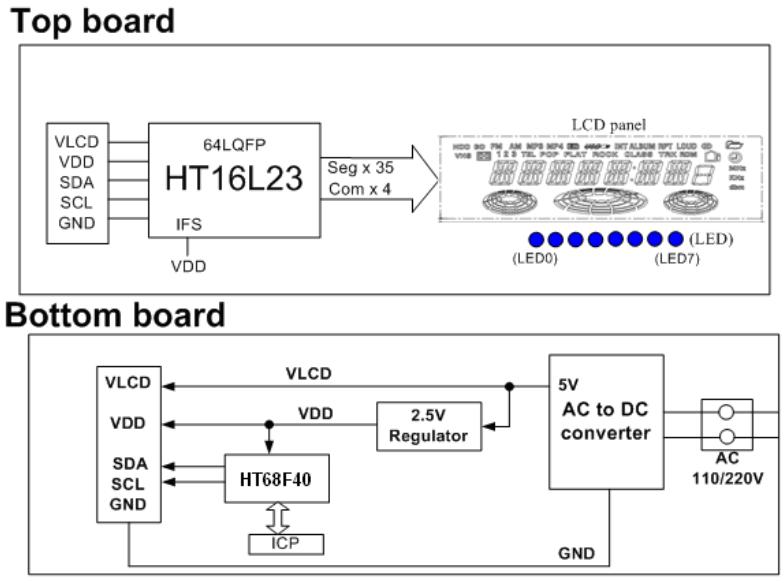


Figure 2 System Block Diagram

Block Diagram Description

As shown in Figure 2, the whole systerm consists of a Top Board and a Bottom Board.The two parts implement data transfer using I^2C communication. The Bottom Board provides 5.0V and 2.5V power supplies for the Top Board VLCD and VDD respectively.

- Top Board
  HT16L23 -- Drive Condition: 1/4 Duty & 1/3 Bias; SEG44~SEG51 are set for driving 8 LEDs. The IFS pin is connected to VDD to seleced the I^2C communication.
- Bottom Board
  MCU – The HT68F40 uses an AC 110/220V to DC 5.0V power supply module. The 5.0V supply is used as the LCD driver voltage source and is transformed to 2.5V using the HT7525 LDO. This supplies power for the master MCU HT68F40 and the HT16L23. The ICP interface is provided for users to download Code.

Note: The HT16L23 supply is named V_{DD2} and the MCU supply is named V_{DD1}. They can be provided with different levels individually. There are however restriction regarding the interfaces that must be taken into account:

- I^2C interface transmission or SPI interface transmission is bi-directional, therefore the potential difference between V_{DD1} and V_{DD2} can not exceed a Diode Forward Bias voltage (about 0.6V), otherwise the current will flow backward.
- The MCU and the HT16L23 have their own V_{IH} and V_{IL} level requirements (I^2C or SPI), therefore high level inputs must be greater than the IC transition levels ($V_{IN} \geq 0.7V_{DD1}$ or $V_{IN} \geq 0.7V_{DD2}$), otherwise there will be data transmission errors.

Application Circuit Diagram

The complete system consists of a Top Board and a Bottom Board, as shown in Figure 3 and Figure 4 respectively.

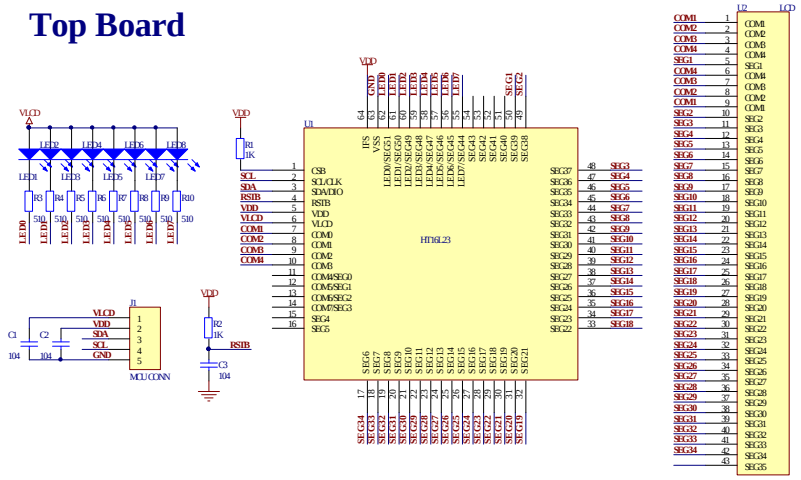


Figure 3 Top Board Application Circuit

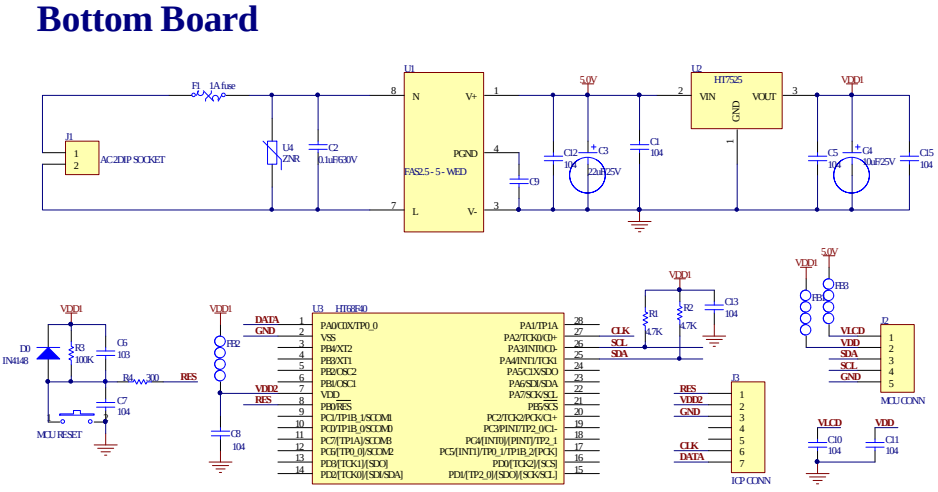


Figure 4 Bottom Board Application Circuit

Note: for circuit debug, capacitances C9, C10, C11, C13 and C15 are not required.

H/W Operating Principle

Power Supply Circuit

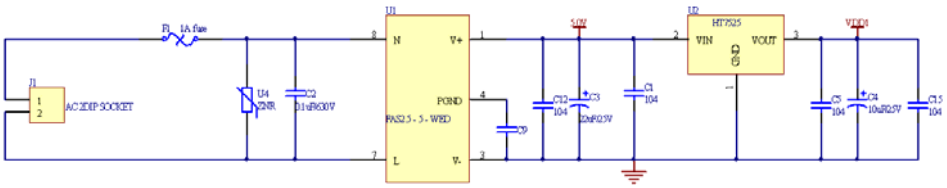


Figure 5 Power Supply Circuit

Figure 5 shows the power supply circuit. The 220V/110V AC supply is transformed into 5.0V via the fuse F1, FAS2.5-5–WED AC to DC small outline power supply module to supply power for LCD driving. It is then transformed into 2.5V via a HT7525 to supply power for the master MCU HT68F40 and the HT16L23.

MCU Control Circuit

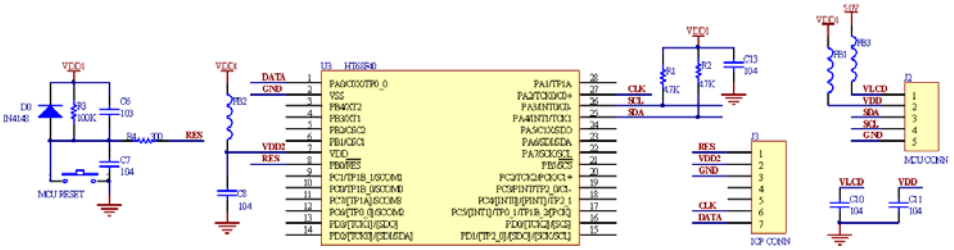


Figure 6 MCU Control Circuit

Figure 6 shows the MCU control circuit. The master MCU is a HT68F40 which uses PA3 and PA4 to simulate the I^2C master mode to transmit data to the HT16L23, so as to control the LCD display screen. J3 is used for the ICP interface for users to download code and J2 is used for the I^2C communication interface.

Display Circuit

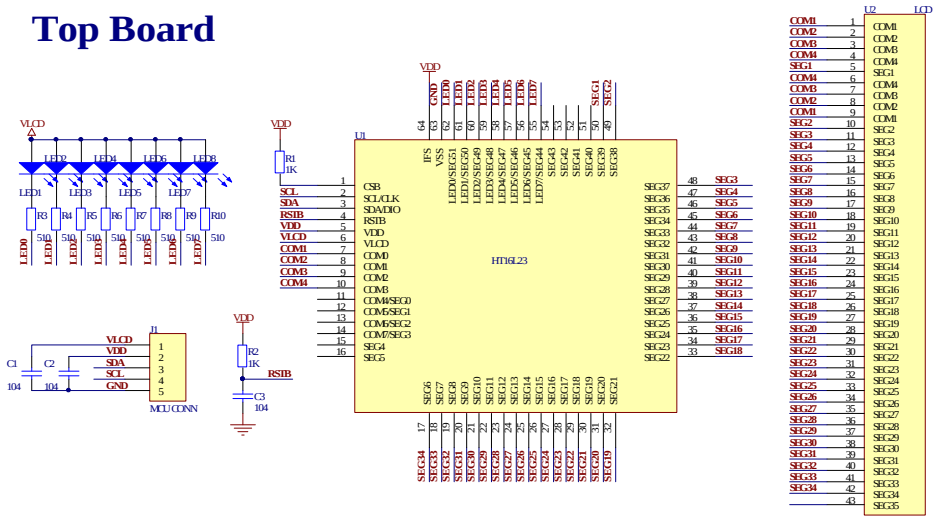


Figure 7 Display Circuit

Figure 7 shows the display circuit, showing the Segment and Common connections from the HT16L23 to the LCD Panel. There are 35 SEGs but only 34 SEGs are actually used, because SEG35 and SEG1 are internally connected together inside the LCD. IFS is connected to VDD to select the I^2C communication type or IFS is connected to VSS to select the SPI communication type. In this case as the I^2C type is used, IFS is connected to VDD. The CSB pin which is used for SPI communication is connected to VDD through a 1K pull-up resistor. The RSTB pin must be connected to a Reset Circuit and is active low. Because of the 5V drive voltage, this example chooses an external VLCD drive mode. The LED drive circuit is a common anode type. A current limiting resistor can be selected as required and in this case a value of 510Ω is selected. J1 is used for the I^2C communication interface.

S/W Flowchart

- HT16L23 initialisation flow chart

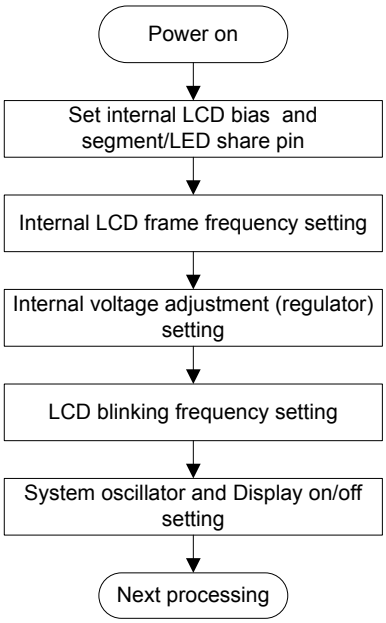


Figure 8 HT16L23 initialisation flow chart

- HT16L23 Demo Board main flowchart

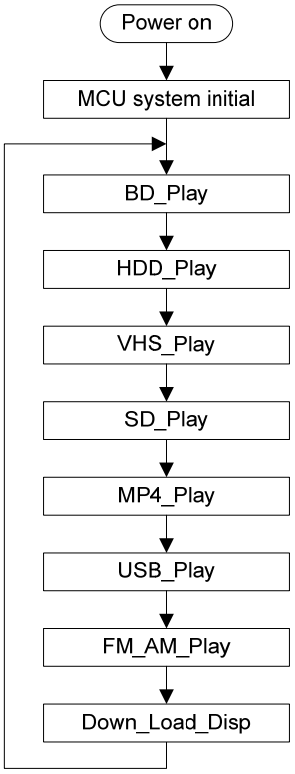


Figure 9 Main Flowchart

- HT16L23 Demo Board Interrupt Subroutine Flowchart

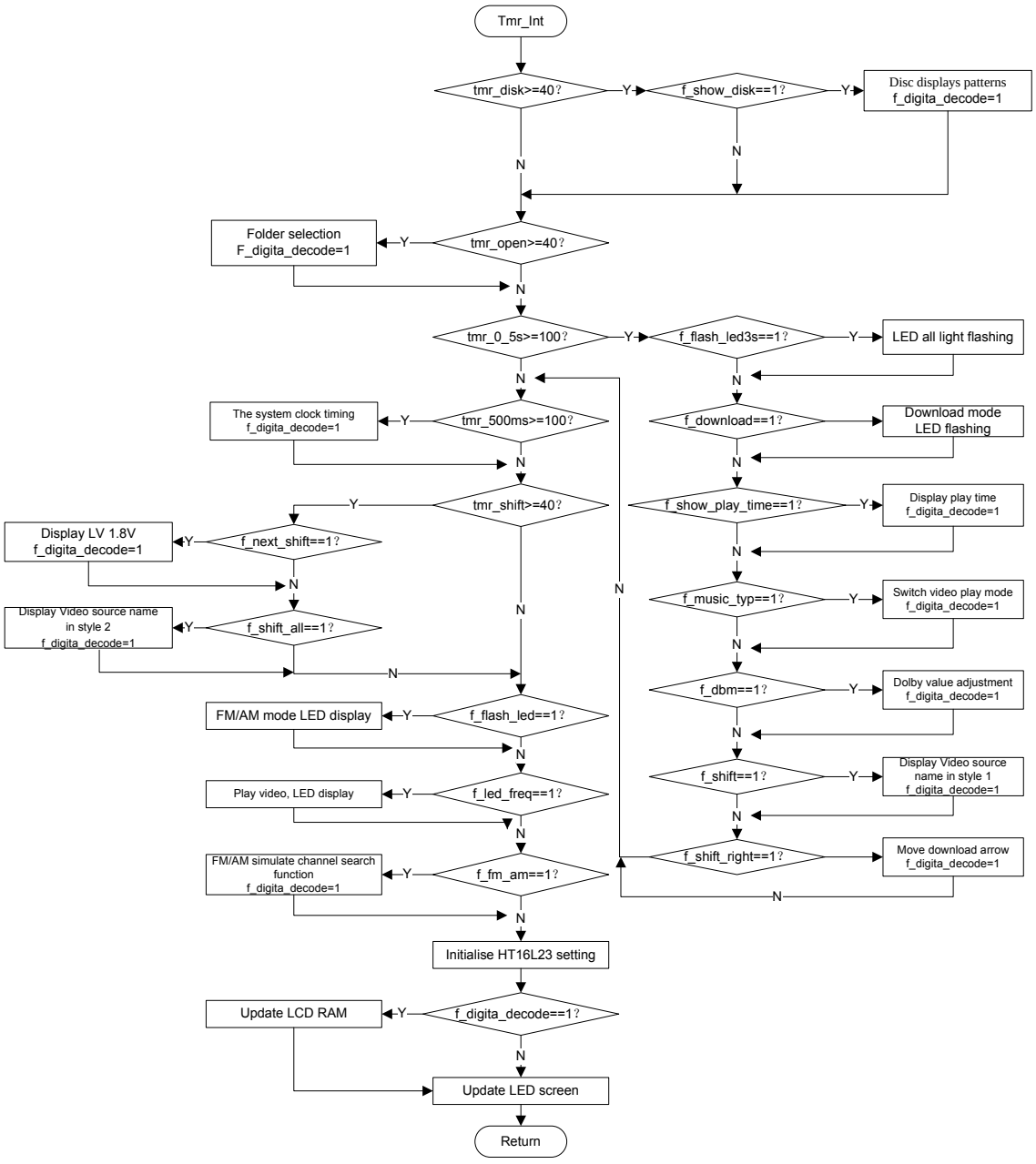


Figure 10 Interrupt Subroutine Flowchart

Main Flowchart Diagram Description

The master MCU HT68F40 uses two general I/O ports to simulate the I^2C host. The slave HT16L23 implements data transmission using I^2C comminunication to implement the analog BD player display function.

For program power-on reset, firstly, initialise. This mainly means clearing the MCU RAM, setting the parameters used in the program, setting the comparator, I/Os, TMn, interrupt enable and so on.

The main loop is mainly used to for the processing of various play modes.

Interrupt Subroutine Description

Enable a timer setting of 5ms as a time base for a variety of timing operations. With this many types of LCD screen and LED pattern displays can be implemented using the timer interrupt.

Implemnting MCU and HT16L23 communication:

The RAM Buffer is used for storing the LCD Display data. To renew the screen, first update the data into the RAM Buffer, then write the data to the HT16L23 via the I^2C interface. To improve the system ESD and EFT abilities, repeat the HT16L23 initialisation operation within the interrupt subroutine.

Demo Code interrupt subroutine variables and signs description:

variable	function
tmr_disk	Disc patterns show the timer variables
tmr_open	Simulate the folder selection function display timer variable
tmr_0_5s	0.5s Timer for 0.5s timer variable
tmr_500ms	0.5s Timer for the system clock timing variable
tmr_shift	The playing video file name moving display timing variable
sign	**funcion**
f_show_disk	The sign of playing the disc patterns display
f_flash_led3s	The sign for the completed download then LED flashes 3s in download mode
f_download	The sign for LED flashing in download mode
f_show_play_time	The sign for displaying the audio and video play time
f_music_typ	The sign for displaying the audio and video play style
f_dbm	The sign for adjusting the Dolby value
f_shift	The sign for displaying the audio and video file name in moving mode 1
f_shift_right	The sign for moving the arrow in the download mode
f_flash_led	The sign for LED flashing when the video is playing
f_fm_am	The sign for searching FM/AM
f_digita_decode	The sign for updating the LCD RAM data

Demo Code Interrupt Subroutine Description

- In different modes, through the corresponding time variables and signs, a different complete display screen is required for different play modes. As long as there is an update of the page then f_digita_decode=1, calling digita_decode subroutine to code. Through the write_lcd_data routine, update the LCD RAM data
- Within the subinterrupt routine, repeat HT16L23 initialisation actions to improve the system ESD & EFT. In this example every 5ms implement a HT16L23 initialisation. HT16L23 initialisation:
  - Internal Voltage Adjustment (regulator) Setting (Bias voltage is supplied from VLCD pin)
  - Internal LCD bias and duty setting (1/3 bias, 1/4 duty)
  - Internal LCD frame frequency setting (Frame frequency: 64Hz)
  - LCD blinking frequency setting (Blinking off)
  - System oscillator and Display on/off setting (LCD Display on , internal system clock on)

Display Steps Description

- Step0: initialisation after power on
  - After booting, the screen lights up for 3 seconds, flashes 3 times and enters the next stage.
- Step1: BD_Play
  - The file name which is playing moves left
  - Switch video sources
  - Display Dolby value and adjust the Dolby value
  - LED moves right with one light
  - Disc displays patterns
- Step2: HDD_Play
  - Simulate the folder selection function
  - The file name which is playing moves left
  - Switch video sources
  - Display Dolby value and adjust the Dolby value
  - LED moves right with two light
  - Disc displays patterns
- Step3: VHS_Play
  - The file name which is playing moves left
  - Switch video sources
  - Display Dolby value and adjust the Dolby value
  - LED moves right with one light
  - Disc displays patterns
- Step4: SD_Play
  - Simulation the folder selection function
  - The file name which is playing moves left
  - Switch video sources
  - Display Dolby value and adjust the Dolby value
  - LED moves right with two light
  - Disc displays patterns
- Step5: MP4_Play
  - The file name which is playing moves left
  - Switch video sources
  - Display Dolby value and adjust the Dolby value
  - LED moves right with one light
  - Disc displays patterns
- Step6: USB_Play
  - Simulation the folder selection function
  - The file name which is playing moves left
  - Switch video sources
  - Display Dolby value and adjust the Dolby value
  - LED moves right with two light
  - Disc displays patterns

- Step7: MP3_Play
  - Simulation the folder selection function
  - The file name which is playing moves left
  - Switch video sources
  - Display Dolby value and adjust the Dolby value
  - LED moves right with two light
  - Disc displays patterns
- Step8: FM_AM_Play
  - Display the current FM/AM channels
  - FM/AM up search or down search
  - LED one by one off from left to right during the search process
  - Disc does not show
- Step9: Down_Load_Disp
  - Display the address to download online
  - Display HOLTEK HT16L23 LV 1.8V
  - LED one by one lit from left to right during the download process
  - Disc does not show

Conclusions

This application uses the HT68F40 as the master MCU to control the HT16L23 to drive Blue-ray Disc Player LCD displays. It has introduced the Demo Board circuit and related program. The application also gives some advices for programming so that users can have a better understanding of how to master the applications of the HT16L23, and improve the system ESD and EFT capabilities.

Accessory

Source Code File

HT16L23_BD_Player_Demo.zip

PCB Figure File

pcb & sch.zip

Demo Board Specification

HT16L23 BD player Controller Specification-V00.ZIP

Demo Board Display Flowchart

HT16L23 BD player Display Flowchart .ZIP

Revision History

Revision: V1.10

Updated Date: 2011/11/23

Revision History:

- The LCD operating voltage (V_{LCD}) was modified.
- A Dice type was added.
- In the Command Summart section, the Display Data Adress Setting table was modified.
- In the H/W Flowchart section, the LCD Panel description was modified.
- The Conclusions section was modified.