南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Embedded System and Microcomputer Principle

LAB9 Film Transistor-Liquid Crystal Display (TFTLCD)

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TFTLCD Principle Description

1. TFTLCD Principle Description

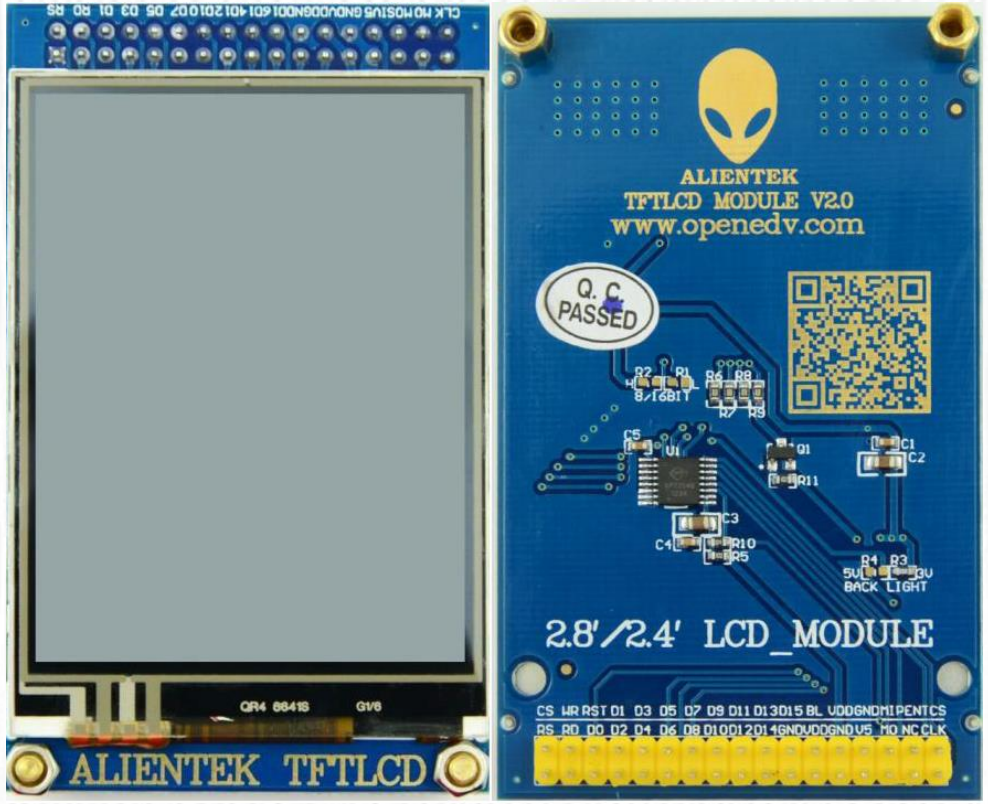
-- What is TFTLCD

- Film Transistor-Liquid Crystal Display，缩写TFTLCD，即薄膜晶体管液晶显示器
- TFT液晶为每个像素都设有一个半导体开关，每个像素都可以通过点脉冲直接控制，因而每个节点都相对独立，并可以连续控制，不仅提高了显示屏的反应速度，同时可以精确控制显示色阶，所以TFT液晶的色彩更真
- 特点：亮度好、对比度高、层次感强、颜色鲜艳等特点
- 目前最主流的LCD显示器
- 广泛应用于电视、手机、电脑、平板等各种电子产品

1. TFTLCD Principle Description

-- ALINETEK TFTLCD

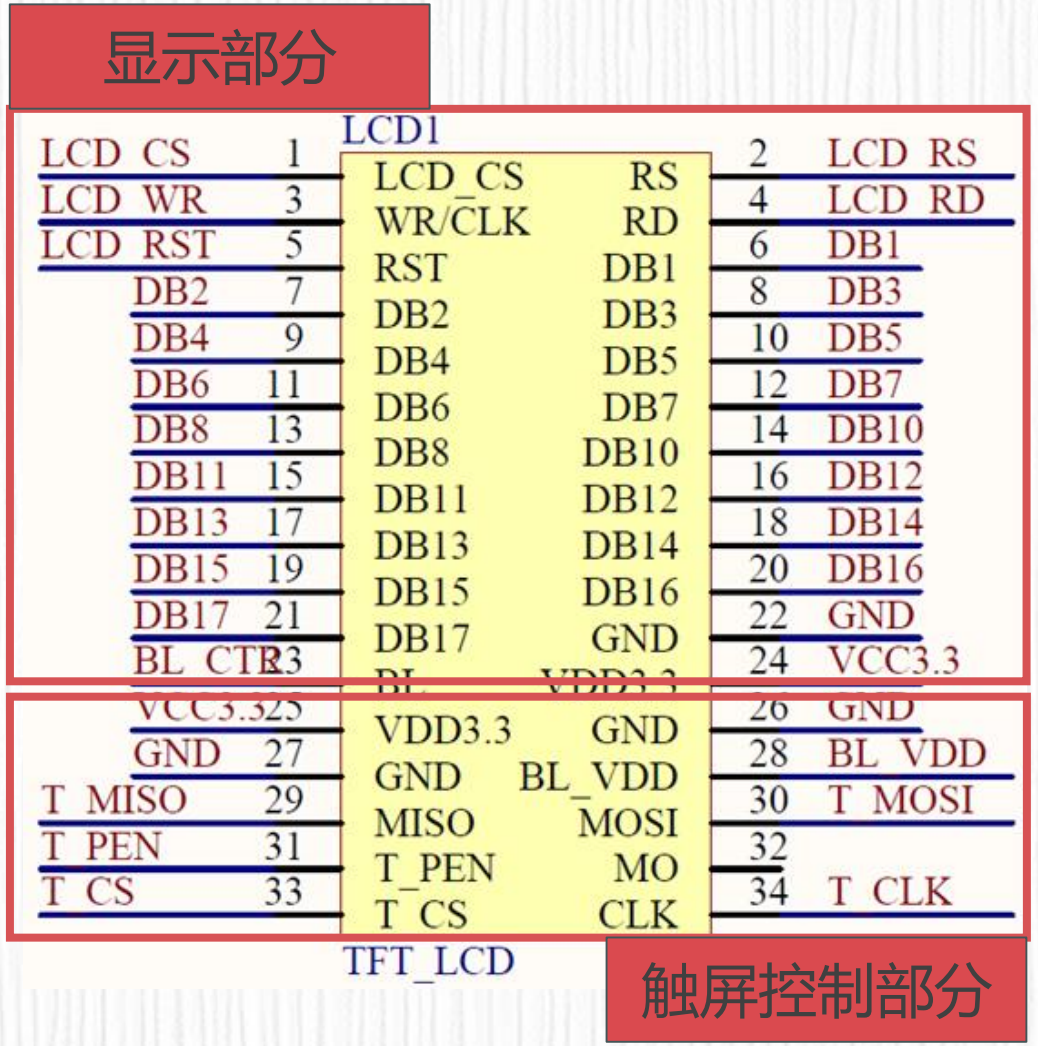
- ALINETEK 2.8寸 TFTLCD模块
- 分辨率：240*320
- 驱动IC：ILI9341
- 16位并口驱动
- 16位真彩显示（65536色）
- 自带电阻触摸屏
- 自带背光电路
- 模块是3.3V供电的，不支持5V电压的MCU，如果是5V MCU，必须在信号线串接120R电阻使用



1. TFTLCD Principle Description

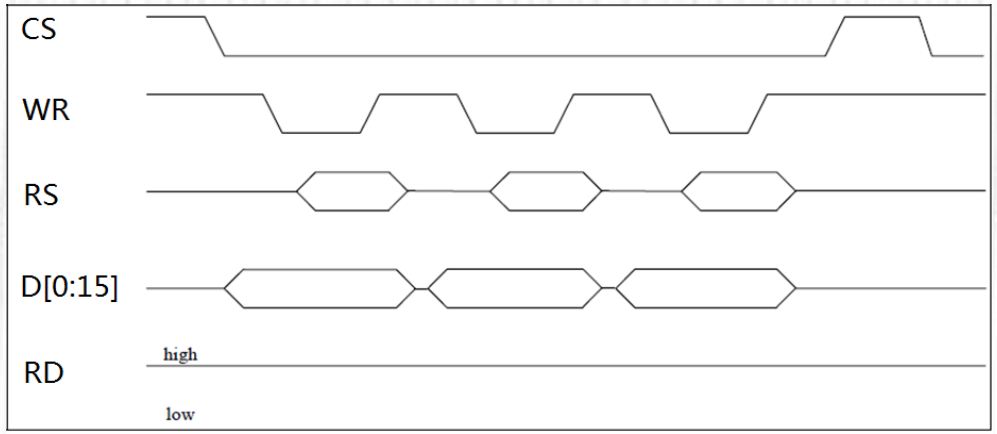
-- ATK-2.8-inch TFTLCD interface

- LCD_CS：LCD片选信号
- LCD_WR：LCD写信号
- LCD_RD：LCD读信号
- DB[17:1]：16位双向数据线
- LCD_RST：硬复位LCD信号
- LCD_RS：命令/数据标志(0:命令,1:数据)
- BL_CTR：背光控制信号
- T_MISO/T_MOSI/T_PEN/T_CS/T_CLK，触摸屏接口信号

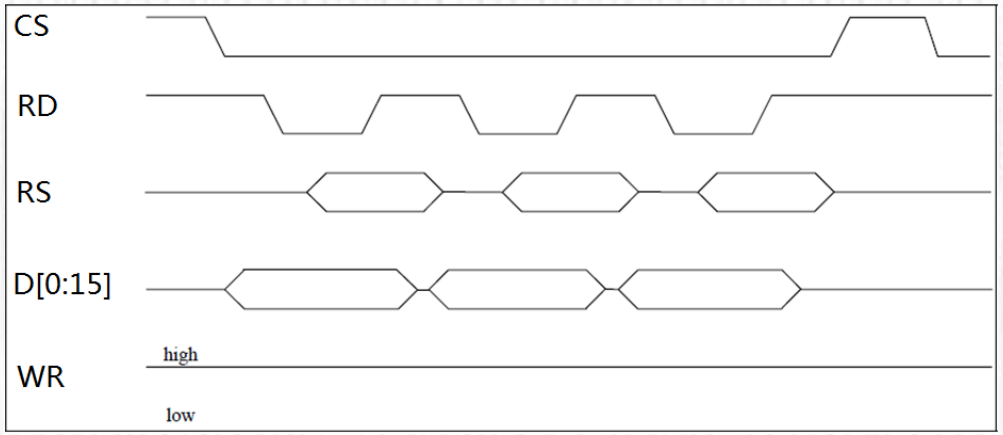


1. TFTLCD Principle Description
-- 8080 Parallel port principle

- 8080并口读/写的过程为：
- 先根据要数据类型，设置RS为高（数据）/低（命令），然后拉低片选，选中ILI9341，接着根据是读数据，还是要写数据置RD/WR为低，然后：
- 1.读数据：在RD的上升沿， 读取数据线上的数据（D[15:0]）；
- 2.写数据：在WR的上升沿，使数据写入到ILI9341里面

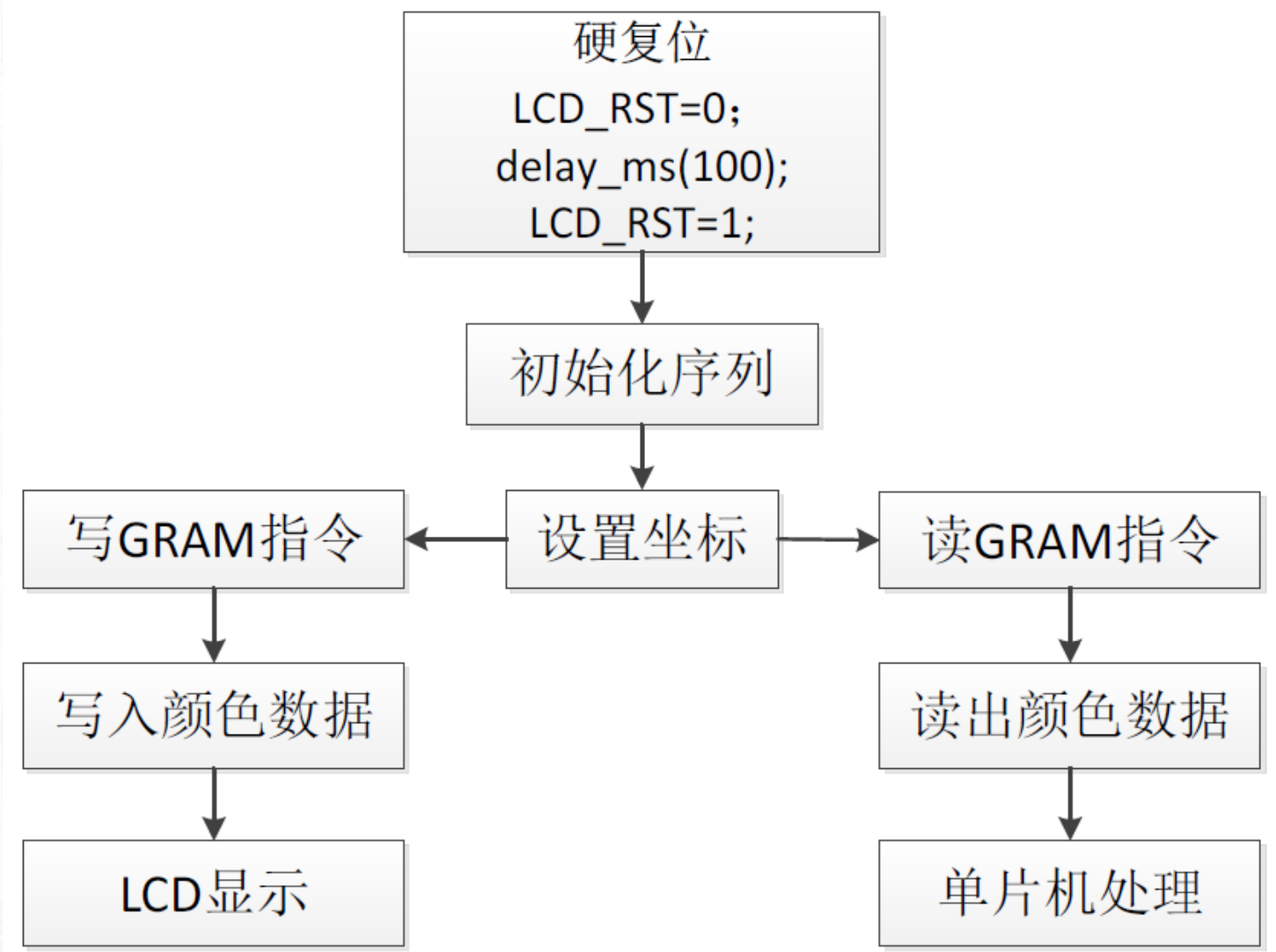


Writing timing diagram



Reading timing diagram

1. TFTLCD Principle Description
-- TFTLCD driving process



1. TFTLCD Principle Description

-- RGB565 format description

- 模块对外接口采用16位并口
- 颜色深度为16位
- 格式为RGB565

数据线	D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
LCD GRAM	R[4]	R[3]	R[2]	R[1]	R[0]	G[5]	G[4]	G[3]	G[2]	G[1]	G[0]	B[4]	B[3]	B[2]	B[1]	B[0]

1. TFTLCD Principle Description

-- ILI9341 instruction format description

- ILI9341所有的指令都是8位的（高8位无效），且参数除了读写GRAM的时候是16位，其他操作参数，都是8位的。

Regulative command set

Command Function	D/CX	RDX	WRX	D17-8	D7	D6	D5	D4	D3	D2	D1	D0	Hex
No Operation	0	1	↑	XX	0	0	0	0	0	0	0	0	00h
Software Reset	0	1	↑	XX	0	0	0	0	0	0	0	1	01h
Read Display Identification Information	0	1	↑	XX	0	0	0	0	0	1	0	0	04h
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	ID1 [7:0]								XX
	1	↑	1	XX	ID2 [7:0]								XX
	1	↑	1	XX	ID3 [7:0]								XX
Read Display Status	0	1	↑	XX	0	0	0	0	1	0	0	1	09h
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	D [31:25]							X	00
	1	↑	1	XX	X	D [22:20]			D [19:16]				61
	1	↑	1	XX	X	X	X	X	X	D [10:8]			00
	1	↑	1	XX	D [7:5]			X	X	X	X	X	00
Read Display Power Mode	0	1	↑	XX	0	0	0	0	1	0	1	0	0Ah
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	D [7:2]						0	0	08
Read Display MADCTL	0	1	↑	XX	0	0	0	0	1	0	1	1	0Bh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	D [7:2]						0	0	00
Read Display Pixel Format	0	1	↑	XX	0	0	0	0	1	1	0	0	0Ch
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	RIM	DPI [2:0]			X	DBI [2:0]			06
Read Display Image Format	0	1	↑	XX	0	0	0	0	1	1	0	1	0Dh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	X	X	X	X	X	D [2:0]			00
Read Display Signal Mode	0	1	↑	XX	0	0	0	0	1	1	1	0	0Eh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	D [7:2]						0	0	00
Read Display Self-Diagnostic Result	0	1	↑	XX	0	0	0	0	1	1	1	1	0Fh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	D [7:6]		X	X	X	X	X	X	00

1. TFTLCD Principle Description
-- ILI9341 instruction set(continued)

Regulative command set (continued)

Enter Sleep Mode	0	1	↑	XX	0	0	0	1	0	0	0	0	10h
Sleep OUT	0	1	↑	XX	0	0	0	1	0	0	0	1	11h
Partial Mode ON	0	1	↑	XX	0	0	0	1	0	0	1	0	12h
Normal Display Mode ON	0	1	↑	XX	0	0	0	1	0	0	1	1	13h
Display Inversion OFF	0	1	↑	XX	0	0	1	0	0	0	0	0	20h
Display Inversion ON	0	1	↑	XX	0	0	1	0	0	0	0	1	21h
Gamma Set	0	1	↑	XX	0	0	1	0	0	1	1	0	26h
	1	1	↑	XX	GC [7:0]								01
Display OFF	0	1	↑	XX	0	0	1	0	1	0	0	0	28h
Display ON	0	1	↑	XX	0	0	1	0	1	0	0	1	29h
Column Address Set	0	1	↑	XX	0	0	1	0	1	0	1	0	2Ah
	1	1	↑	XX	SC [15:8]								XX
	1	1	↑	XX	SC [7:0]								XX
	1	1	↑	XX	EC [15:8]								XX
	1	1	↑	XX	EC [7:0]								XX
Page Address Set	0	1	↑	XX	0	0	1	0	1	0	1	1	2Bh
	1	1	↑	XX	SP [15:8]								XX
	1	1	↑	XX	SP [7:0]								XX
	1	1	↑	XX	EP [15:8]								XX
	1	1	↑	XX	EP [7:0]								XX

Regulative command set (continued)

Memory Write	0	1	↑	XX	0	0	1	0	1	1	0	0	2Ch
	1	1	↑	D [17:0]									XX
Color SET	0	1	↑	XX	0	0	1	0	1	1	0	1	2Dh
	1	↑	1	XX			R00 [5:0]						XX
	1	↑	1	XX			Rnn [5:0]						XX
	1	↑	1	XX			R31 [5:0]						XX
	1	↑	1	XX			G00 [5:0]						XX
	1	↑	1	XX			Gnn [5:0]						XX
	1	↑	1	XX			G64 [5:0]						XX
	1	↑	1	XX			B00 [5:0]						XX
	1	↑	1	XX			Bnn [5:0]						XX
	1	↑	1	XX			B31 [5:0]						XX
Memory Read	0	1	↑	XX	0	0	1	0	1	1	1	0	2Eh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	D [17:0]									XX
Partial Area	0	1	↑	XX	0	0	1	1	0	0	0	0	30h
	1	1	↑	XX	SR [15:8]								00
	1	1	↑	XX	SR [7:0]								00
	1	1	↑	XX	ER [15:8]								01
	1	1	↑	XX	ER [7:0]								3F
Vertical Scrolling Definition	0	1	↑	XX	0	0	1	1	0	0	1	1	33h
	1	1	↑	XX	TFA [15:8]								00
	1	1	↑	XX	TFA [7:0]								00
	1	1	↑	XX	VSA [15:8]								01
	1	1	↑	XX	VSA [7:0]								40
	1	1	↑	XX	BFA [15:8]								00
	1	1	↑	XX	BFA [7:0]								00
Tearing Effect Line OFF	0	1	↑	XX	0	0	1	1	0	1	0	0	34h
Tearing Effect Line ON	0	1	↑	XX	0	0	1	1	0	1	0	1	35h
	1	1	↑	XX	X	X	X	X	X	X	X	M	00

1. TFTLCD Principle Description
-- ILI9341 instruction set(continued)

Regulative command set (continued)

Memory Access Control	0	1	↑	XX	0	0	1	1	0	1	1	0	36h
	1	1	↑	XX	MY	MX	MV	ML	BGR	MH	X	X	00
Vertical Scrolling Start Address	0	1	↑	XX	0	0	1	1	0	1	1	1	37h
	1	1	↑	XX	VSP [15:8]								00
	1	1	↑	XX	VSP [7:0]								00
Idle Mode OFF	0	1	↑	XX	0	0	1	1	1	0	0	0	38h
Idle Mode ON	0	1	↑	XX	0	0	1	1	1	0	0	1	39h
Pixel Format Set	0	1	↑	XX	0	0	1	1	1	0	1	0	3Ah
	1	1	↑	XX	X	DPI [2:0]			X	DBI [2:0]			66
Write Memory Continue	0	1	↑	XX	0	0	1	1	1	1	0	0	3Ch
	1	1	↑	D [17:0]									XX
Read Memory Continue	0	1	↑	XX	0	0	1	1	1	1	1	0	3Eh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	D [17:0]									XX
Set Tear Scanline	0	1	↑	XX	0	1	0	0	0	1	0	0	44h
	1	1	↑	XX	X	X	X	X	X	X	X	STS [8]	00
	1	1	↑	XX	STS [7:0]								00
Get Scanline	0	1	↑	XX	0	1	0	0	0	1	0	1	45h
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	X	X	X	X	X	X	GTS [9:8]		00
	1	↑	1	XX	GTS [7:0]								00
Write Display Brightness	0	1	↑	XX	0	1	0	1	0	0	0	1	51h
	1	1	↑	XX	DBV [7:0]								00

Regulative command set (continued)

Read Display Brightness	0	1	↑	XX	0	1	0	1	0	0	1	0	52h
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	DBV [7:0]								00
Write CTRL Display	0	1	↑	XX	0	1	0	1	0	0	1	1	53h
	1	1	↑	XX	X	X	BCTRL	X	DD	BL	X	X	00
Read CTRL Display	0	1	↑	XX	0	1	0	1	0	1	0	0	54h
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	X	X	BCTRL	X	DD	BL	X	X	00
Write Content Adaptive Brightness Control	0	1	↑	XX	0	1	0	1	0	1	0	1	55h
	1	1	↑	XX	X	X	X	X	X	X	C [1:0]		00
Read Content Adaptive Brightness Control	0	1	↑	XX	0	1	0	1	0	1	1	0	56h
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	X	X	X	X	X	X	C [1:0]		00
Write CABC Minimum Brightness	0	1	↑	XX	0	1	0	1	1	1	1	0	5Eh
	1	1	↑	XX	CMB [7:0]								00
Read CABC Minimum Brightness	0	1	↑	XX	0	1	0	1	0	1	1	1	5Fh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	CMB [7:0]								00
Read ID1	0	1	↑	XX	1	1	0	1	1	0	1	0	DAh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	Module's Manufacture [7:0]								XX
Read ID2	0	1	↑	XX	1	1	0	1	1	0	1	1	DBh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	LCD Module / Driver Version [7:0]								XX
Read ID3	0	1	↑	XX	1	1	0	1	1	1	0	0	DCh
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	LCD Module / Driver ID [7:0]								XX

1. TFTLCD Principle Description
-- ILI9341 instruction set(continued)

Extended command set (continued)

Command Function	D/CX	RDX	WRX	D17-8	D7	D6	D5	D4	D3	D2	D1	D0	Hex
RGB Interface Signal Control	0	1	↑	XX	1	0	1	1	0	0	0	0	B0h
	1	1	↑	XX	ByPass_MODE	RCM [1:0]		X	VSPL	HSPL	DPL	EPL	40
Frame Control (In Normal Mode)	0	1	↑	XX	1	0	1	1	0	0	0	1	B1h
	1	1	↑	XX	X	X	X	X	X	X	DIVA [1:0]		00
	1	1	↑	XX	X	X	X	RTNA [4:0]					1B
Frame Control (In Idle Mode)	0	1	↑	XX	1	0	1	1	0	0	1	0	B2h
	1	1	↑	XX	X	X	X	X	X	X	DIVB [1:0]		00
	1	1	↑	XX	X	X	X	RTNB [4:0]					1B
Frame Control (In Partial Mode)	0	1	↑	XX	1	0	1	1	0	0	1	1	B3h
	1	1	↑	XX	X	X	X	X	X	X	DIVC [1:0]		00
	1	1	↑	XX	X	X	X	RTNC [4:0]					1B
Display Inversion Control	0	1	↑	XX	1	0	1	1	0	1	0	0	B4h
	1	1	↑	XX	X	X	X	X	X	NLA	NLB	NLC	02
Blanking Porch Control	0	1	↑	XX	1	0	1	1	0	1	0	1	B5h
	1	1	↑	XX	0	VFP [6:0]							02
	1	1	↑	XX	0	VBP [6:0]							02
	1	1	↑	XX	0	0	0	HFP [4:0]					0A
	1	1	↑	XX	0	0	0	HBP [4:0]					14
Display Function Control	0	1	↑	XX	1	0	1	1	0	1	1	0	B6h
	1	1	↑	XX	X	X	X	X	PTG [1:0]		PT [1:0]		0A
	1	1	↑	XX	REV	GS	SS	SM	ISC [3:0]				82
	1	1	↑	XX	X	X	NL [5:0]						27
	1	1	↑	XX	X	X	PCDIV [5:0]						XX
Entry Mode Set	0	1	↑	XX	1	0	1	1	0	1	1	1	B7h
	1	1	↑	XX	X	X	X	X	0	GON	DTE	GAS	07

Extended command set (continued)

Backlight Control 1	0	1	↑	XX	1	0	1	1	1	0	0	0	B8h
	1	1	↑	XX	X	X	X	X	X	X	X	X	XX
	1	1	↑	XX	X	X	X	X	TH_UI [3:0]				04
Backlight Control 2	0	1	↑	XX	1	0	1	1	1	0	0	1	B9h
	1	1	↑	XX	X	X	X	X	X	X	X	X	XX
	1	1	↑	XX	TH_MV [3:0]				TH_ST [3:0]				B8
Backlight Control 3	0	1	↑	XX	1	0	1	1	1	0	1	0	BAh
	1	1	↑	XX	X	X	X	X	X	X	X	X	XX
	1	1	↑	XX	X	X	X	X	DTH_UI [3:0]				04
Backlight Control 4	0	1	↑	XX	1	0	1	1	1	0	1	1	BBh
	1	1	↑	XX	X	X	X	X	X	X	X	X	XX
	1	1	↑	XX	DTH_MV [3:0]				DTH_ST [3:0]				C9
Backlight Control 5	0	1	↑	XX	1	0	1	1	1	1	0	0	BCh
	1	1	↑	XX	X	X	X	X	X	X	X	X	XX
	1	1	↑	XX	DIM2 [3:0]				X	DIM1 [2:0]			44
Backlight Control 7	0	1	↑	XX	1	0	1	1	1	1	1	0	BEh
	1	1	↑	XX	PWM_DIV [7:0]								0F
Backlight Control 8	0	1	↑	XX	1	0	1	1	1	1	1	1	BFh
	1	1	↑	XX	X	X	X	X	X	LEDONR	LEDONPOL	LEDPWMOPL	00
Power Control 1	0	1	↑	XX	1	1	0	0	0	0	0	0	C0h
	1	1	↑	XX	X	X	VRH [5:0]						26
Power Control 2	0	1	↑	XX	1	1	0	0	0	0	0	1	C1h
	1	1	↑	XX	X	X	X	X	X	BT [2:0]			00
VCOM Control 1	0	1	↑	XX	1	1	0	0	0	1	0	1	C5h
	1	1	↑	XX	X	VMH [6:0]							31
	1	1	↑	XX	X	VML [6:0]							3C
VCOM Control 2	0	1	↑	XX	1	1	0	0	0	1	1	1	C7h
	1	1	↑	XX	nVM	VMF [6:0]							C0

1. TFTLCD Principle Description
-- ILI9341 instruction set(continued)

Extended command set (continued)

NV Memory Write	0	1	↑	XX	1	1	0	1	0	0	0	0	D0h
	1	1	↑	XX	X	X	X	X	X	PGM_ADR [2:0]			00
	1	1	↑	XX	PGM_DATA [7:0]								XX
NV Memory Protection Key	0	1	↑	XX	1	1	0	1	0	0	0	1	D1h
	1	1	↑	XX	KEY [23:16]								55
	1	1	↑	XX	KEY [15:8]								AA
	1	1	↑	XX	KEY [7:0]								66
NV Memory Status Read	0	1	↑	XX	1	1	0	1	0	0	1	0	D2h
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	X	ID2_CNT [2:0]			X	ID1_CNT [2:0]			XX
	1	↑	1	XX	BUSY	VMF_CNT [2:0]			X	ID3_CNT [2:0]			XX
Read ID4	0	↑	1	XX	1	1	0	1	0	0	1	1	D3h
	1	↑	1	XX	X	X	X	X	X	X	X	X	XX
	1	↑	1	XX	0	0	0	0	0	0	0	0	00
	1	↑	1	XX	1	0	0	1	0	0	1	1	93
	1	↑	1	XX	0	1	0	0	0	0	0	1	41
Positive Gamma Correction	0	1	↑	XX	1	1	1	0	0	0	0	0	E0h
	1	1	↑	XX	X	X	X	X	VP0 [3:0]				08
	1	1	↑	XX	X	X	VP1 [5:0]						0E
	1	1	↑	XX	X	X	VP2 [5:0]						12
	1	1	↑	XX	X	X	X	X	VP4 [3:0]				05
	1	1	↑	XX	X	X	X	VP6 [4:0]					03
	1	1	↑	XX	X	X	X	X	VP13 [3:0]				09
	1	1	↑	XX	X	VP20 [6:0]							47
	1	1	↑	XX	VP36 [3:0]				VP27 [3:0]				86
	1	1	↑	XX	X	VP43 [6:0]							2B
	1	1	↑	XX	X	X	X	X	VP50 [3:0]				0B
	1	1	↑	XX	X	X	X	VP57 [4:0]					04
	1	1	↑	XX	X	X	X	X	VP59 [3:0]				00
	1	1	↑	XX	X	X	VP61 [5:0]						00
	1	1	↑	XX	X	X	VP62 [5:0]						00
	1	1	↑	XX	X	X	X	X	VP63 [3:0]				00

Extended command set (continued)

Negative Gamma Correction	0	1	↑	XX	1	1	1	0	0	0	0	1	E1h
	1	1	↑	XX	X	X	X	X	VN0 [3:0]				08
	1	1	↑	XX	X	X	VN1 [5:0]						1A
	1	1	↑	XX	X	X	VN2 [5:0]						20
	1	1	↑	XX	X	X	X	X	VN4 [3:0]				07
	1	1	↑	XX	X	X	X	VN6 [4:0]					0E
	1	1	↑	XX	X	X	X	X	VN13 [3:0]				05
	1	1	↑	XX	X	VN20 [6:0]							3A
	1	1	↑	XX	VN36 [3:0]				VN27 [3:0]				8A
	1	1	↑	XX	X	VN43 [6:0]							40
	1	1	↑	XX	X	X	X	X	VN50 [3:0]				04
	1	1	↑	XX	X	X	X	VN57 [4:0]					18
	1	1	↑	XX	X	X	X	X	VN59 [3:0]				0F
	1	1	↑	XX	X	X	VN61 [5:0]						3F
	1	1	↑	XX	X	X	VN62 [5:0]						3F
	1	1	↑	XX	X	X	X	X	VN63 [3:0]				0F
Digital Gamma Control 1	0	1	↑	XX	1	1	1	0	0	0	1	0	E2h
1st Parameter	1	1	↑	XX	RCA0 [3:0]				BCA0 [3:0]				XX
:	1	1	↑	XX	RCAx [3:0]				BCAx [3:0]				XX
16th Parameter	1	1	↑	XX	RCA15 [3:0]				BCA15 [3:0]				XX
Digital Gamma Control 2	0	1	↑	XX	1	1	1	0	0	0	1	1	E3h
1st Parameter	1	1	↑	XX	RFA0 [3:0]				BFA0 [3:0]				XX
:	1	1	↑	XX	RFAx [3:0]				BFAx [3:0]				XX
64th Parameter	1	1	↑	XX	RFA63 [3:0]				BFA63 [3:0]				XX
Interface Control	0	1	↑	XX	1	1	1	1	0	1	1	0	F6h
	1	1	↑	XX	MY_EOR	MX_EOR	MV_EOR	X	BGR_EOR	X	X	WEMODE	01
	1	1	↑	XX	X	X	EPF [1:0]		X	X	MDT [1:0]		00
	1	1	↑	XX	X	X	ENDIAN	X	DM [1:0]		RM	RIM	00

1. TFTLCD Principle Description

-- 0xD3 instruction

- 该指令为读ID4指令，用于读取LCD控制器的ID 。因此，同一个代码，可以根据ID的不同，执行不同的LCD驱动初始化，以兼容不同的LCD屏幕。

顺序	控制			各位描述								HEX
	RS	RD	WR	D15~D8	D7	D6	D5	D4	D3	D2	D1	D0	
指令	0	1	↑	XX	1	1	0	1	0	0	1	1	D3H
参数 1	1	↑	1	XX	X	X	X	X	X	X	X	X	X
参数 2	1	↑	1	XX	0	0	0	0	0	0	0	0	00H
参数 3	1	↑	1	XX	1	0	0	1	0	0	1	1	93H
参数 4	1	↑	1	XX	0	1	0	0	0	0	0	1	41H

1. TFTLCD Principle Description

-- 0x36 instruction

- 该指令为存储访问控制指令，可以控制ILI9341存储器的读写方向，简单的说，就是在连续写GRAM的时候，可以控制GRAM指针的增长方向，从而控制显示方式（读GRAM也是一样）。

顺序	控制			各位描述									HEX
	RS	RD	WR	D15~D8	D7	D6	D5	D4	D3	D2	D1	D0	
指令	0	1	↑	XX	0	0	1	1	0	1	1	0	36H
参数	1	1	↑	XX	MY	MX	MV	ML	BGR	MH	0	0	0

Bit	Name	Description
MY	Row Address Order	These 3 bits control MCU to memory write/read direction.
MX	Column Address Order	
MV	Row / Column Exchange	
ML	Vertical Refresh Order	LCD vertical refresh direction control.
BGR	RGB-BGR Order	Color selector switch control (0=RGB color filter panel, 1=BGR color filter panel)
MH	Horizontal Refresh ORDER	LCD horizontal refreshing direction control.

控制位			效果
MY	MX	MV	LCD 扫描方向（GRAM 自增方式）
0	0	0	从左到右, 从上到下
1	0	0	从左到右, 从下到上
0	1	0	从右到左, 从上到下
1	1	0	从右到左, 从下到上
0	0	1	从上到下, 从左到右
0	1	1	从上到下, 从右到左
1	0	1	从下到上, 从左到右
1	1	1	从下到上, 从右到左

1. TFTLCD Principle Description

-- 0x2A instruction

- 该指令是列地址设置指令，在从左到右，从上到下的扫描方式（默认）下面，该指令用于设置横坐标（x坐标）。
- 在默认扫描方式时，该指令用于设置x坐标，该指令带有4个参数，实际上是2个坐标值：SC和EC，即列地址的起始值和结束值，SC必须小于等于EC，且0≤SC/EC≤239。一般在设置x坐标的时候，我们只需要带2个参数即可，也就是设置SC即可，因为如果EC没有变化，我们只需要设置一次即可（在初始化ILI9341的时候设置），从而提高速度。

顺序	控制			各位描述									HEX
	RS	RD	WR	D15~D8	D7	D6	D5	D4	D3	D2	D1	D0	
指令	0	1	↑	XX	0	0	1	0	1	0	1	0	2AH
参数 1	1	1	↑	XX	SC15	SC14	SC13	SC12	SC11	SC10	SC9	SC8	SC
参数 2	1	1	↑	XX	SC7	SC6	SC5	SC4	SC3	SC2	SC1	SC0	
参数 3	1	1	↑	XX	EC15	EC14	EC13	EC12	EC11	EC10	EC9	EC8	EC
参数 4	1	1	↑	XX	EC7	EC6	EC5	EC4	EC3	EC2	EC1	EC0	

1. TFTLCD Principle Description

-- 0x2B instruction

- 该指令是页地址设置指令，在从左到右，从上到下的扫描方式（默认）下面，该指令用于设置纵坐标（y坐标）。
- 在默认扫描方式时，该指令用于设置y坐标，该指令带有4个参数，实际上是2个坐标值：SP和EP，即页地址的起始值和结束值，SP必须小于等于EP，且0≤SP/EP≤319。一般在设置y坐标的时候，我们只需要带2个参数即可，也就是设置SP即可，因为如果EP没有变化，我们只需要设置一次即可（在初始化ILI9341的时候设置），从而提高速度。

顺序	控制			各位描述									HEX
	RS	RD	WR	D15~D8	D7	D6	D5	D4	D3	D2	D1	D0	
指令	0	1	↑	XX	0	0	1	0	1	0	1	0	2BH
参数 1	1	1	↑	XX	SP15	SP14	SP13	SP12	SP11	SP10	SP9	SP8	SP
参数 2	1	1	↑	XX	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0	
参数 3	1	1	↑	XX	EP15	EP14	EP13	EP12	EP11	EP10	EP9	EP8	EP
参数 4	1	1	↑	XX	EP7	EP6	EP5	EP4	EP3	EP2	EP1	EP0	

1. TFTLCD Principle Description

-- 0x2C instruction

- 该指令是写GRAM指令，在发送该指令之后，我们便可以往LCD的GRAM里面写入颜色数据了，该指令支持连续写 (地址自动递增)。
- 在收到指令0X2C之后，数据有效位宽变为16位，我们可以连续写入LCD GRAM值，而GRAM的地址将根据MY/MX/MV设置的扫描方向进行自增。例如：假设设置的是从左到右，从上到下的扫描方式，那么设置好起始坐标（通过SC，SP设置）后，每写入一个颜色值，GRAM地址将会自动自增1（SC++），如果碰到EC，则回到SC，同时SP++，一直到坐标：EC，EP结束，其间无需再次设置的坐标，从而大大提高写入速度。

顺序	控制			各位描述									HEX
	RS	RD	WR	D15~D8	D7	D6	D5	D4	D3	D2	D1	D0	
指令	0	1	↑	XX	0	0	1	0	1	1	0	0	2CH
参数 1	1	1	↑	D1[15：0]									XX
……	1	1	↑	D2[15：0]									XX
参数 n	1	1	↑	Dn[15：0]									XX

1. TFTLCD Principle Description

-- 0x2E instruction

- 该指令是读GRAM指令，用于读取ILI9341的显存（GRAM），同0X2C指令一样，该指令支持连续读 (地址自动递增)。
- ILI9341收到该指令后，第一次输出的是dummy数据（无效），第二次开始，读取到的才是有效的GRAM数据（从坐标：SC，SP开始），输出规律为：每个颜色分量占8bit，一次输出2个颜色分量。比如：第一次输出是R1G1，随后的规律为：B1R2→G2B2→R3G3→B3R4→G4B4→R5G5... 依此类推。

顺序	控制			各位描述												HEX
	RS	RD	WR	D15~D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	
指令	0	1	↑	XX				0	0	1	0	1	1	1	0	2EH
参数 1	1	↑	1	XX												dummy
参数 2	1	↑	1	R1[4:0]			XX		G1[5:0]						XX	R1G1
参数 3	1	↑	1	B1[4:0]			XX		R2[4:0]					XX		B1R2
参数 4	1	↑	1	G2[5:0]			XX		B2[4:0]					XX		G2B2
参数 5	1	↑	1	R3[4:0]			XX		G3[5:0]						XX	R3G3
参数 N	1	↑	1	按以上规律输出												

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02

TFTLCD Function Description

2. TFTLCD Function Description

-- _lcd_dev structure

```
typedef struct {
        u16 width;          //LCD 宽度
        u16 height;         //LCD 高度
        u16 id;             //LCD ID
        u8  dir;            //横屏还是竖屏控制：0，竖屏；1，横屏。
        u16   wramcmd;      //开始写GRAM指令
        u16  setxcmd;           //设置x坐标指令
        u16  setycmd;           //设置y坐标指令
}_lcd_dev;
//LCD参数 in lcd.h
extern _lcd_dev lcddev;     //管理LCD重要参数
```

1. TFTLCD Principle Description

-- Some functions

- LCD初始化函数：void LCD_Init(void)
- 写寄存器值函数(通过 8080 并口向 LCD 模块写入寄存器命令)：void LCD_WR_REG(u16 regval)
- 写数据函数(写入16位的数据)：void LCD_WR_DATA(u16 data)
- 读数据函数：u16 LCD_RD_DATA(void)
- 写寄存器内容函数： void LCD_WriteReg(u16 LCD_Reg, u16 LCD_RegValue)
- 读寄存器内容函数： u16 LCD_ReadReg(u16 LCD_Reg)
- 开始写GRAM函数： void LCD_WriteRAM_Prepare(void)
- 写GRAM函数：void LCD_WriteRAM(u16 RGB_Code)
- 坐标设置函数：void LCD_SetCursor(u16 Xpos, u16 Ypos)
- 画点函数：void LCD_DrawPoint(u16 x,u16 y)
- LCD读点函数：u16 LCD_ReadPoint(u16 x, u16 y)

1. TFTLCD Principle Description
-- Some functions(continued)

- LCD字符显示函数：void LCD_ShowChar(u16 x, u16 y, u8 num, u8 size, u8 mode)
- void LCD_Clear(uint16_t Color); // Clear the screen with specific color
- void LCD_DrawLine(uint16_t x1, uint16_t y1, uint16_t x2, uint16_t y2); // Draw a line
- void LCD_DrawRectangle(uint16_t x1, uint16_t y1, uint16_t x2, uint16_t y2); // Draw a rectangle
- void LCD_Fill(uint16_t sx,uint16_t sy,uint16_t ex,uint16_t ey,uint16_t color); // Fill the area with color
- void LCD_ShowNum(uint16_t x,uint16_t y,uint32_t num,uint8_t len,uint8_t size); // Display number without the leading zeros
- void LCD_ShowString(uint16_t x, uint16_t y, uint16_t width, uint16_t height, uint8_t size, uint8_t *p); // Display a string

1. TFTLCD Principle Description -- Character code table

- //PC2LCD2002取模方式设置：阴码+逐列式+顺向+C51格式
- //总共：3个字符集（12*12、16*16和24*24）in font.h
- //每个字符所占用的字节数为:(size/8+((size%8)?1:0))*(size/2),其中size是字库生成时的点阵大小(12/16/24...)

//12*12 ASCII字符集点阵

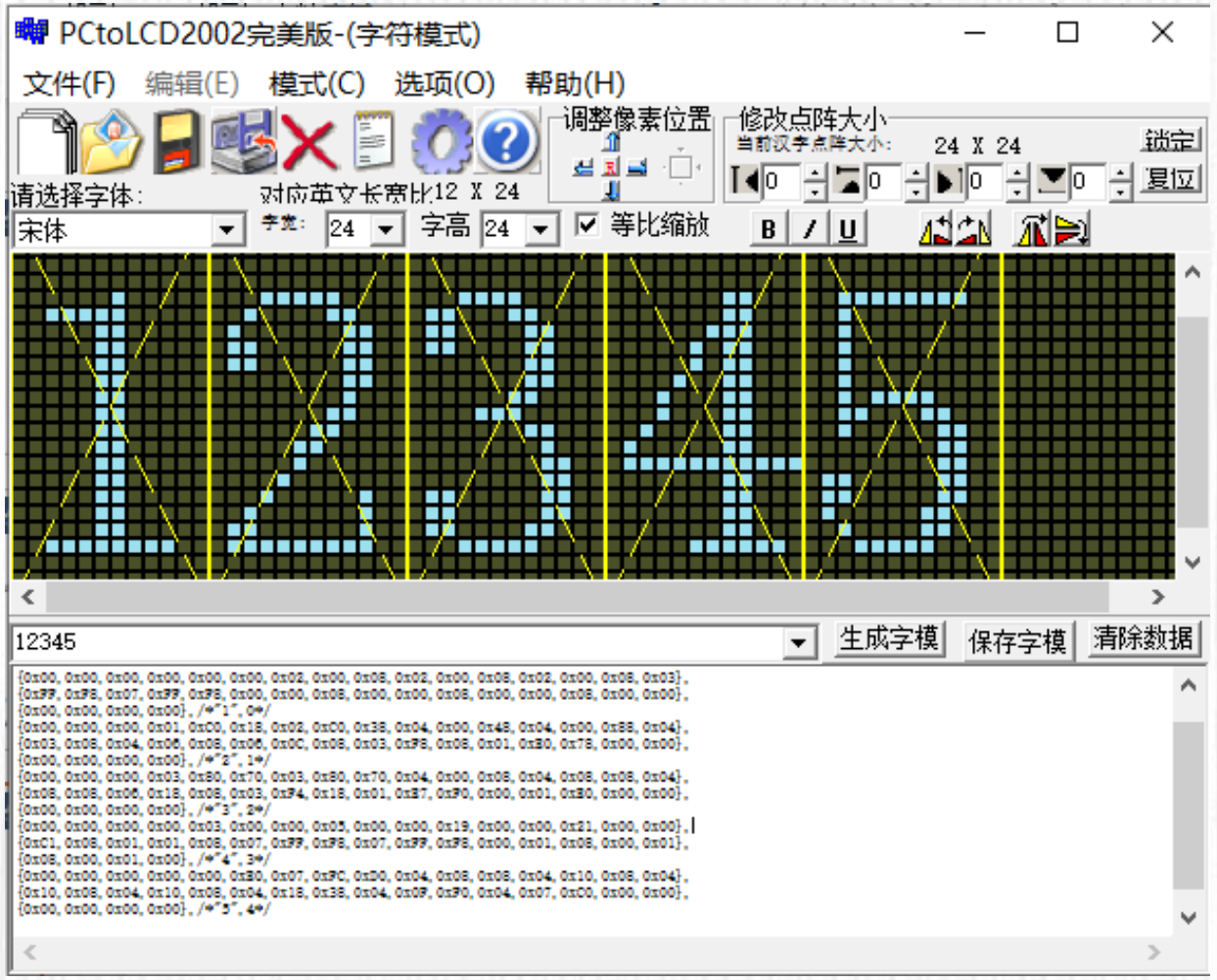
```
const unsigned char asc2_1206[95][12]={
{0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00},/*" ",0*/
{0x00,0x00,0x00,0x00,0x3F,0x40,0x00,0x00,0x00,0x00,0x00,0x00},/*"!",1*/
……
{0x40,0x00,0x80,0x00,0x40,0x00,0x20,0x00,0x20,0x00,0x40,0x00},/*"~",94*/};
```

//16*16 ASCII字符集点阵

```
const unsigned char asc2_1608[95][16]={
{0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00,0x00},/*" ",0*/
......
{0x00,0x00,0x60,0x00,0x80,0x00,0x80,0x00,0x40,0x00,0x40,0x00,0x20,0x00,0x20,0x00},/*"~",94*/};
```

//24*24 ASICII字符集点阵 .....

1. TFTLCD Principle Description
-- PCtoLCD2002



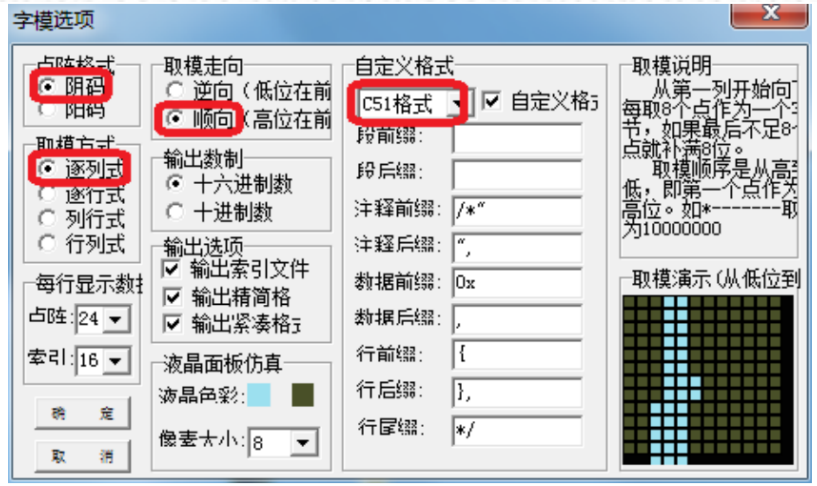
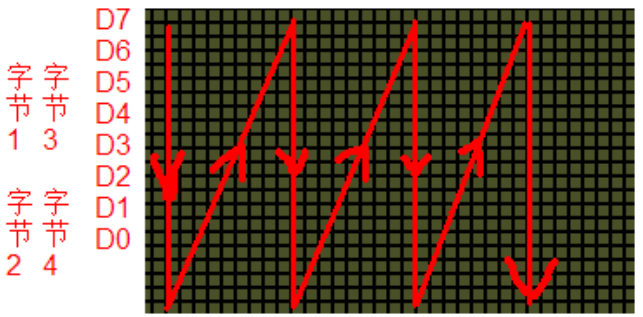


图 17.3.2 设置取模方式

上图设置的取模方式，在右上角的取模说明里面有，即：从第一列开始向下每取 8 个点作为一个字节，如果最后不足 8 个点就补满 8 位。取模顺序是从高到低，即第一个点作为最高位。如*-------取为 10000000。其实就是按如图 17.3.3 所示的这种方式：



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03

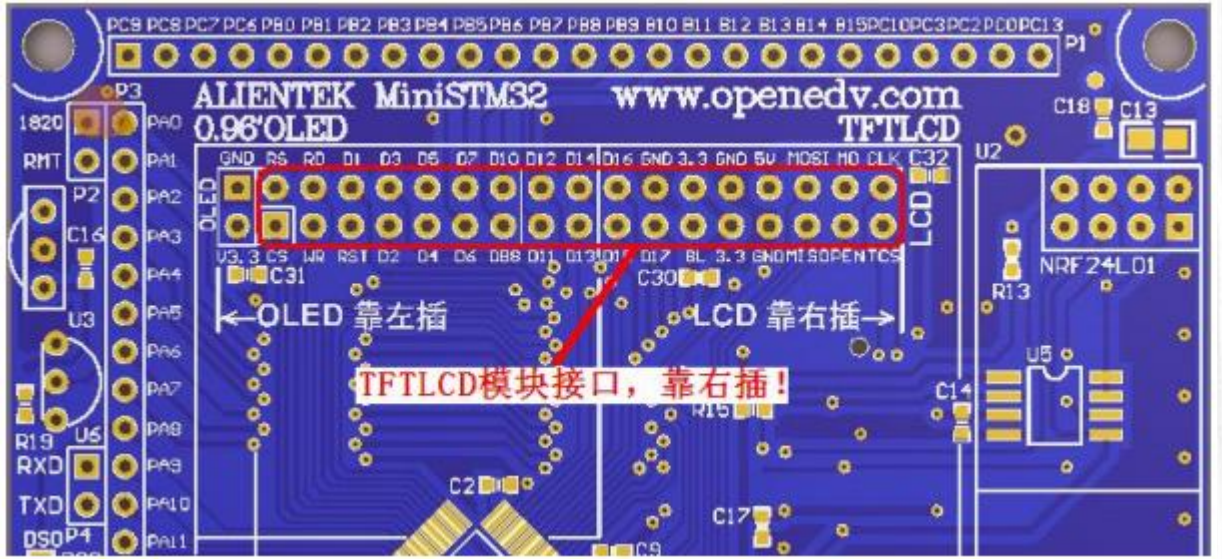
How to Program

3. How to Program

- Our Goal
  - Show charactes on TFTLCD

3. How to Program

- Hardware connection
  - MiniSTM32 开发板底板的 LCD 接口和 ALIENTEK TFTLCD 模块直接可以对插（靠右插！）
  - 多出的 2 个口是给 OLED 用的
  - TFTLCD 模块与 MiniSTM32 开发板的 IO口对应关系如下:
    - LCD_LED 对应 PC10
    - LCD_CS 对应 PC9
    - LCD _RS 对应 PC8
    - LCD _WR 对应 PC7
    - LCD _RD 对应 PC6
    - LCD _D[17:1]对应 PB[15:0]



3. How to Program

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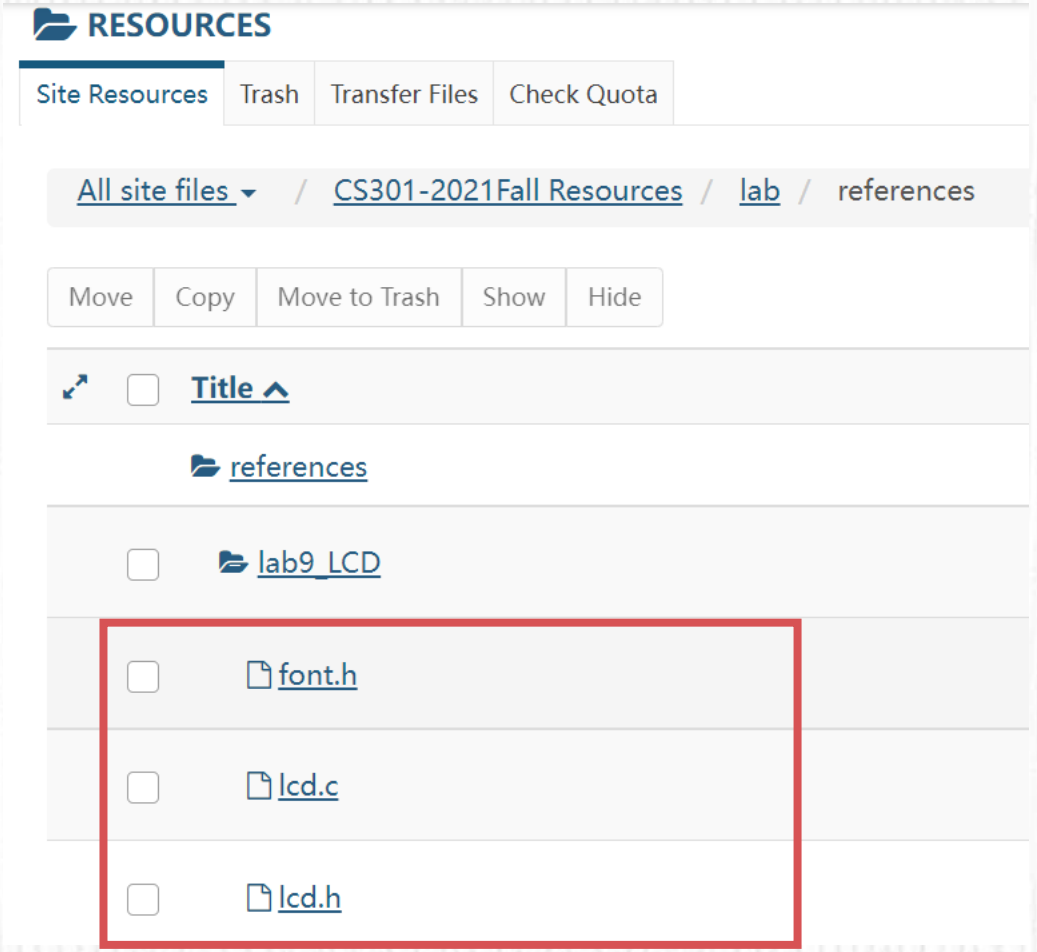
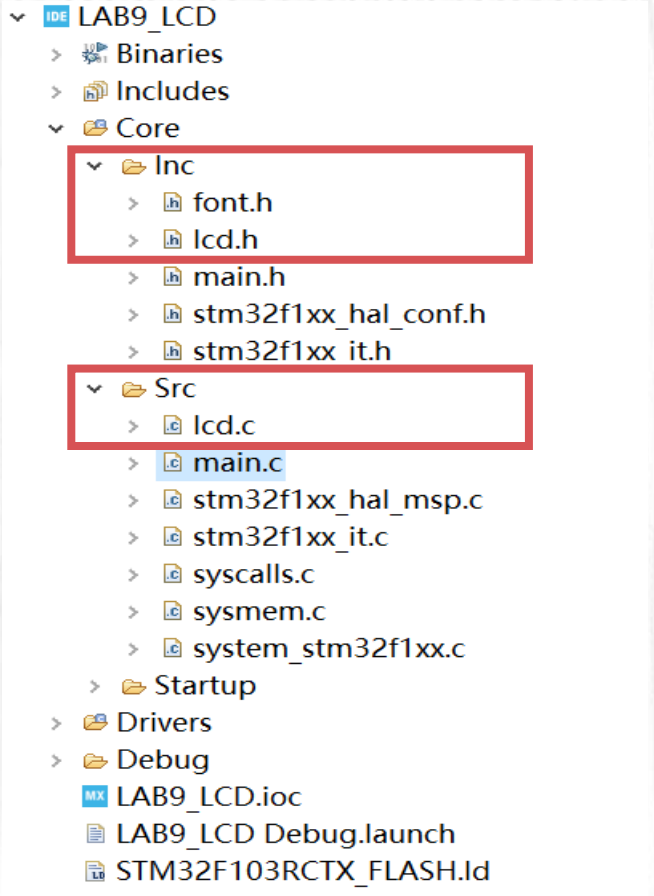
- Download lcd.c, lcd.h and font.h from Sakai site



3. How to Program

- Add the files in your STM32Cube project. Source files should be in Src folder, while header files should be in Inc folder.



3. How to Program

- Add the following codes in main.c

```
// ......
/* USER CODE BEGIN Includes */
#include "lcd.h"
/* USER CODE END Includes */
int main(void)
{
        // ... ...
        /* USER CODE BEGIN SysInit */
        LCD_Init();
        /* USER CODE END SysInit */
        // ......
        /* Infinite loop */
        /* USER CODE BEGIN WHILE */
        uint8_t x = 0;
        while (1) {
        /* USER CODE END WHILE */
```

```
/* USER CODE BEGIN 3 */

switch (x) {
case 0: LCD_Clear(WHITE); BACK_COLOR = WHITE; break;
case 1: LCD_Clear(BLACK); BACK_COLOR = BLACK; break;
case 2: LCD_Clear(BLUE); BACK_COLOR = BLUE; break;
case 3: LCD_Clear(RED); BACK_COLOR = RED; break;
case 4: LCD_Clear(MAGENTA); BACK_COLOR = MAGENTA; break;
case 5: LCD_Clear(GREEN); BACK_COLOR = GREEN; break;
case 6: LCD_Clear(CYAN); BACK_COLOR = CYAN; break;
case 7: LCD_Clear(YELLOW); BACK_COLOR = YELLOW; break;
case 8: LCD_Clear(BRRED); BACK_COLOR = BRRED; break;
case 9: LCD_Clear(GRAY); BACK_COLOR = GRAY; break;
case 10: LCD_Clear(LGRAY); BACK_COLOR = LGRAY; break;
case 11: LCD_Clear(BROWN); BACK_COLOR = BROWN; break;
}//end of switch
```

3. How to Program

- Add the following codes in main.c

```
            POINT_COLOR = RED;
            LCD_ShowString(30, 40, 200, 24, 24, (uint8_t*) "Mini STM32 ^_^");
            LCD_ShowString(30, 70, 200, 16, 16, (uint8_t*) "TFTLCD TEST");

            POINT_COLOR = BLACK;
            LCD_DrawRectangle(30, 150, 210, 190);
            LCD_Fill(31, 151, 209, 189, YELLOW);

            x++;

            if (x == 12)
                        x = 0;

            HAL_Delay(2000);
            } //end of while(1)
} //end of main
```

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04

Practice

4. Practice

- Run the demo on MiniSTM32 board
- Complete assignment 2 on Sakai site(would be released on weekend)