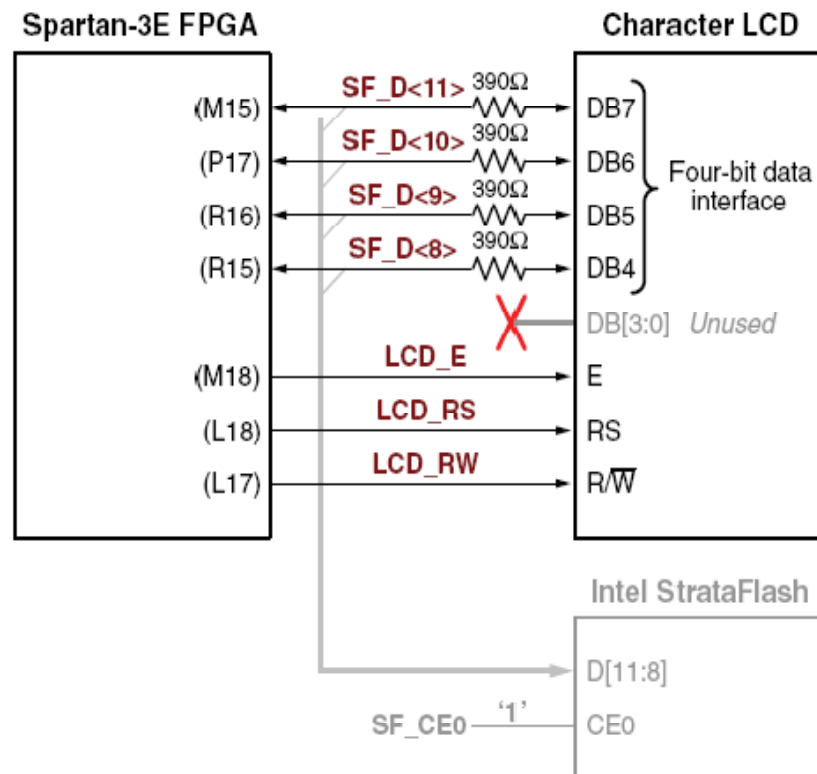


# Character 16x2 LCD

CPE166 Advance Logic Design

# Overview

- 4-bit data interface for compatibility with other Xilinx boards
- LCD\_E, LCD\_RS, LCD\_RW
- 2 line x 16 character Display
- Each character location consist of 5 dot x 8 bit display



# Interface Signals

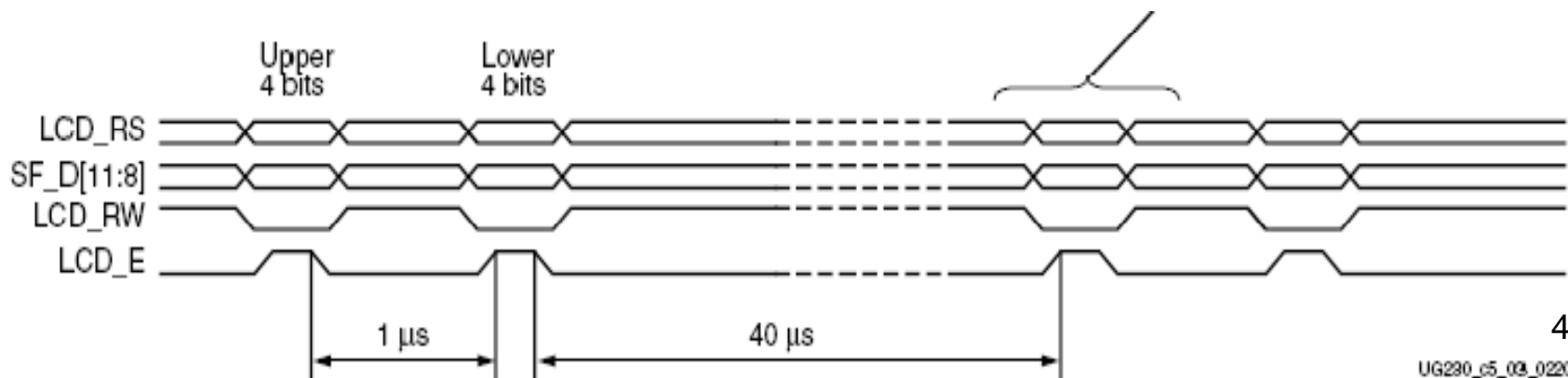
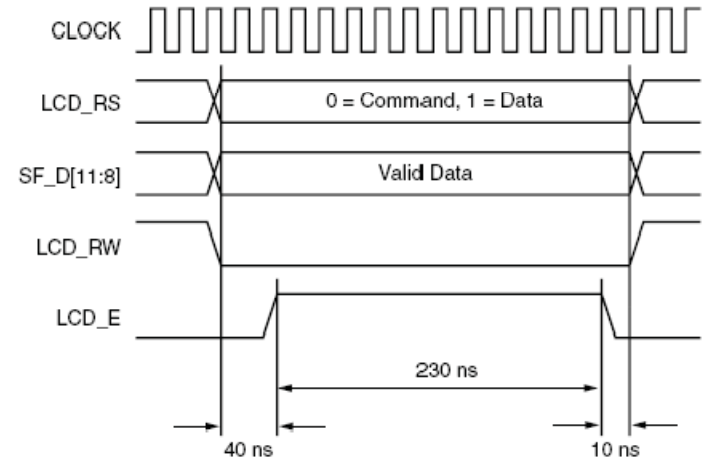
Signal Name	FPGA Pin	Function	
SF_D<11>	M15	Data bit DB7	Shared with StrataFlash pins SF_D<11:8>
SF_D<10>	P17	Data bit DB6	
SF_D<9>	R16	Data bit DB5	
SF_D<8>	R15	Data bit DB4	
LCD_E	M18	Read/Write Enable Pulse 0: Disabled 1: Read/Write operation enabled	
LCD_RS	L18	Register Select 0: Instruction register during write operations. Busy Flash during read operations 1: Data for read or write operations	
LCD_RW	L17	Read/Write Control 0: WRITE, LCD accepts data 1: READ, LCD presents data	

# Operation

- LCD uses 4-bit interface
- Data = 8 bit
- Upper nibble is transferred first, followed by lower nibble

## Timings:

- LCD\_RW, LCD RS and Data must be set 40 ns before asserting of LCD\_E
- LCD\_RW, LCD RS and Data must be hold 10 ns after de-asserting LCD\_E
- 1 usec time between transfer of upper and lower nibble
- 40 usec time between transfer of two 8-bit data



# Memory Map

It consist of:

- 1) DD RAM
- 2) CG ROM
- 3) CG RAM

1) DD RAM : Display Data RAM

- Stores the character code for each character of LCD Display
- Extra locations are used during shifting operations

Character Display Addresses																Undisplayed Addresses			
1	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	10	...	27
2	40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F	50	...	67
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	...	40

# Memory Map

## 2) CG ROM : Character Generator ROM

- Contains font bitmap for predefined characters that LCD can display
- Character code in DD RAM equates to a location in CG ROM
- e.g. 48H location refers to character 'H' (also 48 is ASCII value of H)
- Contains English ASCII characters and Japanese Characters

## 3) CG RAM : Character Generator RAM

- Provides space for 8 custom characters

		Upper Data Nibble													
		DB7	DB6	DB5	DB4										
Lower Data Nibble	XXXX0000		0	0	0	0	0	0	0	0	1	1	1	1	1
	XXXX0001	!	1	A	Q	a	q	。	ア	チ	△	△	△	△	△
	XXXX0010	"	2	B	R	b	r	「	イ	ツ	×	×	×	×	×
	XXXX0011	#	3	C	S	c	s	」	ウ	テ	ε	ε	ε	ε	ε
	XXXX0100	\$	4	D	T	d	t	、	エ	ト	μ	μ	μ	μ	μ
	XXXX0101	%	5	E	U	e	u	・	オ	ナ	1	1	1	1	1
	XXXX0110	&	6	F	V	f	v	ヲ	カ	ニ	ヨ	ρ	ρ	ρ	ρ
	XXXX0111	'	7	G	W	g	w	フ	キ	ヲ	ラ	q	π	π	π
	XXXX1000	<	8	H	X	h	x	イ	ク	ネ	リ	フ	フ	フ	フ
	XXXX1001	>	9	I	Y	i	y	ウ	ケ	ル	”	”	”	”	”
	XXXX1010	*	:	J	Z	j	z	エ	コ	ハ	レ	i	千	千	千
	XXXX1011	+	;	K	[	k	[	オ	サ	ヒ	ロ	×	万	万	万
	XXXX1100	,	<	L	¥	l	l	ハ	シ	フ	フ	φ	円	円	円
	XXXX1101	-	=	M	]M	]M	]M	ユ	ズ	ヘ	ン	も	÷	÷	÷
	XXXX1110	.	>	N	^n	^n	^n	ヨ	セ	ホ	°	ん			
	XXXX1111	/	?	O	_	o	←	ッ	ッ	マ	°	○	■	■	■
		DB3	DB2	DB1	DB0										

# Command Set

Function	LCD_RS	LCD_RW	Upper Nibble				Lower Nibble			
			DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
Clear Display	0	0	0	0	0	0	0	0	0	1
Return Cursor Home	0	0	0	0	0	0	0	0	1	-
Entry Mode Set	0	0	0	0	0	0	0	1	I/D	S
Display ON/OFF	0	0	0	0	0	0	1	D	C	B
Cursor and Display Shift	0	0	0	0	0	1	S/C	R/L	-	-
Function Set	0	0	0	0	1	0	1	0	-	-
Set CG RAM Address	0	0	0	1	A5	A4	A3	A2	A1	A0
Set DD RAM Address	0	0	1	A6	A5	A4	A3	A2	A1	A0
Read Busy Flag and Address	0	1	BF	A6	A5	A4	A3	A2	A1	A0
Write Data to CG RAM/DD RAM	1	0	D7	D6	D5	D4	D3	D2	D1	D0
Read from CG RAM/DD RAM	1	1	D7	D6	D5	D4	D3	D2	D1	D0



# Command Set

- Disabled:  $LCD\_E = 0 \Rightarrow$  All other inputs are ignored
- Clear Display:
  - Clears the Display
  - Returns cursor to top-left position
  - Writes a blank space to all DD RAM Location
  - Address counter is reset to 0
  - Clears all optional setting
- Return Cursor Home:
  - Returns cursor to top-left position
  - DD RAM content remains unchanged
  - Address counter is reset to 0
  - Display is returned to original status, if shifted

# Command Set

- Entry Mode Set
  - Set cursor move direction
  - Specify whether or not to shift the display

Bit DB1 – I/D (Increment/Decrement)

0 - Auto Increment the address counter. Cursor blink/move to left

1 - Auto Decrement the address counter. Cursor blink/move to right

Bit DB0 – Shift

0 – Shifting Disabled

1 – During a DD RAM write operation, shift the entire display value in the direction controlled by Bit DB1 (I/D). Appears as though the cursor position remains constant and the display moves

# Command Set

- Display ON/OFF: Display is turned on/off

Bit DB2 (D) Display on/off

0 – No character displayed. Data stored in DD RAM is retained

1 – Display character stored in DD RAM

Bit DB1 (C) Cursor on/off

0 – No cursor

1 – Display cursor

Bit DB0 (B) Cursor blink on/off

0 – No cursor blinking

1 – Cursor blinks on/off approx. every half second

# Command Set

- **Cursor and Display Shift:** Moves cursor and shifts display without changing the DD RAM contents

<b>DB3 (S/C)</b>	<b>DB2 (R/L)</b>	<b>Operation</b>
0	0	Shift cursor left. Add. Counter decrement by 1
0	1	Shift cursor right. Add. Counter increment by 1
1	0	Shift entire display to left. Add. Counter remains unchanged
1	1	Shift entire display to the right. Add. Counter remains unchanged

# Command Set

- Function Set:
  - Sets interface data length
  - Number of display lines
  - Character font
  - Starter kit – Value = 28h
- Set CG RAM Address:
  - Sets initial CG RAM Address
  - Subsequent data read/write is performed from CG RAM
- Set DD RAM Address:
  - Sets initial DD RAM Address
  - Subsequent data read/write is performed from DD RAM
- Read Busy Flag and Address:
  - BF = 1 => Some internal operation is in progress. Next instruction is not accepted until the flag clears
  - Returns present value of the Address Counter

# Command Set

- Write Data to CG RAM or DD RAM:
  - Writes data to CG RAM / DDRAM if followed by Set CG RAM / DD RAM Address respectively
  - Add. Counter automatically inc. or dec. depending upon I/D bit
- Read Data from CG RAM or DD RAM:
  - Reads data from CG RAM / DDRAM if followed by Set CG RAM / DD RAM Address respectively
  - Add. Counter automatically inc. or dec. depending upon I/D bit

# Initializing Display

- Power-On Initialization:
  - Wait 15 msec, write SF\_D<11:8> = 03h, for 12 clock
  - Wait 4.1 msec, write SF\_D<11:8> = 03h, for 12 clock
  - Wait 100 usec, write SF\_D<11:8> = 03h, for 12 clock
  - Wait 40 usec, write SF\_D<11:8> = 02h, for 12 clock
  - Wait 20 usec
  - Timings are as per the given specs for this LCD
- Display Configuration:
  - Function Set
  - Entry Mode set
  - Display On/Off
  - Clear Display
  - Write data to Display
  - Disable unused LCD (LCD\_E = low, LCD\_RW = low)

# References

- Spartan 3E Starter Kit User Guide, UG230 (V 1.0), March 9 '06