Touch Revolution

MODEL: Fusion 4

P/N: F04B-0101

PRODUCT SPECIFICATION

Version 1.4

REVISION HISTORY

Version #	Implemented By	Revision Date	Approved By	Approval Date	Reason
1.0	Alan Dragon	October 6, 2010	Mark Hamblin	October 6, 2010	Rev 1.0 Release
1.1	Alan Dragon	October 7, 2010	Mark Hamblin	October 7, 2010	Update Reliability and Testing
1.2	Alan Dragon	October 21, 2010	Mark Hamblin	October 21, 2010	Define signals on touch panel connector
1.3	Chris Graham	May 25, 2011			Updated Mechanical DWG
1.4	Matt Rosenthal	November 1, 2011			Updated Fusion specifications

Touch Revolution is committed to continuous improvement of its product designs and performance. This specification is therefore subject to change without notice. Please contact a customer support representative to insure that you have the most current specification. Products are not intended for use in safety-critical or military/aerospace applications, and customer is responsible for all legal and regulatory requirements associated with use in such applications.

While this specification is intended to assist customers in identifying an appropriate product for their intended application, it does not constitute a warranty that the product is suitable for any specific use. It is the customer's responsibility to determine that the product is suitable for its intended application

Contents

1 INTRODUCTION

The Fusion 4 is an integrated projected capacitive touch display incorporating a 4.3”, 480 x 272 (WQVGA) LCD with a LED backlight. The touch portion of the module consists of a glass sensor optically bonded to 1.1 mm cover glass with a FPC (Flexible Printed Circuit) attached for communicating with the touch panel. The touch panel assembly (sensor plus cover glass) is bonded to the LCD frame.

Interfacing to the touch panel is done through an I2C or USB protocol communicating with the touch controller incorporated on the FPC. The touch panel can provide accurate and responsive touch performance capable of sensing up to two unambiguous points. The integrated configuration of the Fusion touch display gives the end customer the ability to develop a touch user interface with a minimum of time and design effort that is instantly recognizable by the greater public.

2 TOUCH MODULE

2.1 GENERAL SPECIFICATIONS

Table 1 - Touch Performance Specification

Parameter		Value	Unit	Remarks
Linearity	Center	1	mm	Note 1, Appendix A
	Within 5mm of the edge	2		
Touch Sensor Resolution		4096 x 4096	Detectable Resolution	
Report Rate	Single Touch	100	Serviced Interrupts/second	Note 2, Appendix A
	Dual Touch	50		
First Touch Response Time		25	ms	Note 3, Appendix A
Minimum Touch Diameter		6	mm	Note 4, Appendix A
Minimum Detectable Separation		13	mm	
Number of unique detectable concurrent touches		2		

2.2 ELECTRICAL – TOUCH PANEL

When using the I2C interface these voltages and current are applicable.

Table 2a – I2C Electrical Specification

Parameter	Symbol	Value			Unit
		Min.	Typ.	Max	
Supply voltage	VCC	3.15	3.3	3.45	V
Current (no touch)	ICC	TBD	30	TBD	mA
Current (1 touch)	ICC1	TBD	30	TBD	mA
Current (2 touch)	ICC2	TBD	30	TBD	mA

When using the USB interface these voltages and current are applicable.

Table 3b – USB Electrical Specification

Parameter	Symbol	Value			Unit
		Min.	Typ.	Max	
Supply voltage	VCC	3.15	3.3	3.45	V
Current (no touch)	ICC	TBD	45	TBD	mA
Current (1 touch)	ICC1	TBD	46	TBD	mA
Current (2 touch)	ICC2	TBD	45	TBD	mA
USB VBUS Voltage	VBUS	4.85	5.0	5.15	V
USB VBUS current	IVBUS	TBD	TBD	500	mA

2.3 ENVIRONMENTAL

Table 4 - Environmental Specification

Parameter	Value	Unit
Operating Temperature	-20 to +60	°C
Storage Temperature	-30 to +70	°C

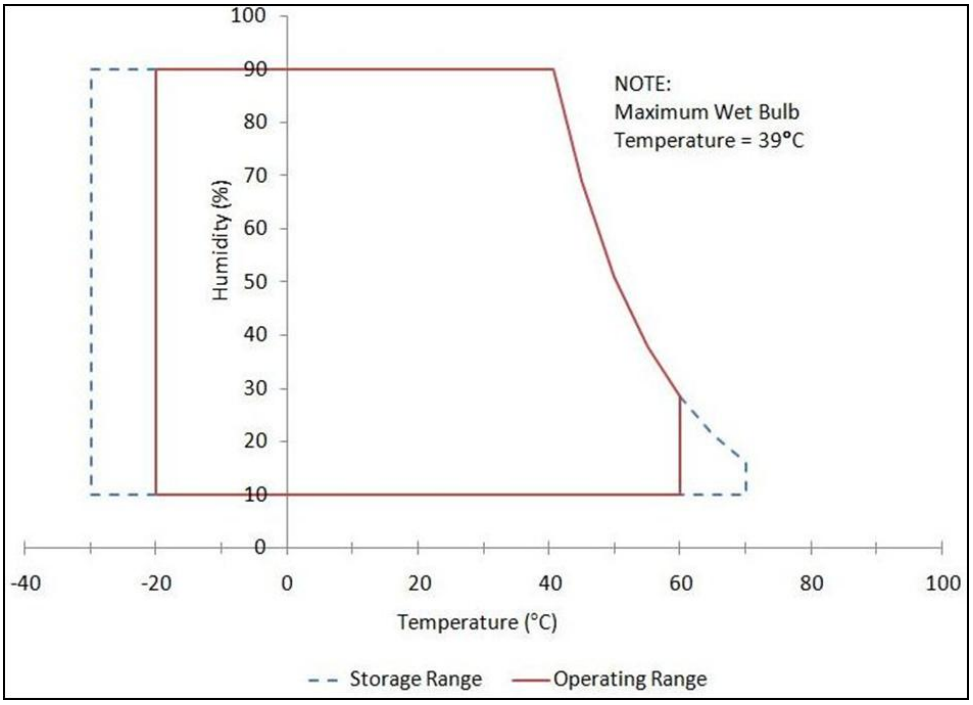


Figure 1 - Operating Temperature and Humidity Range

2.4 OPTICAL PERFORMANCE

Table 5 - Optical Performance Specification

Parameter			Value		Unit	Remarks
Optical Transmittance of Touch Panel			>89		%	Note 5, Appendix A
Light Output without touch panel			Min.=400	Typ.=500	cd/m²	Center of the Panel
Light Output with Touch Panel			Min.=355	Typ.=445	cd/m²	Center of the Panel
Viewing Angle	Hor.	θ_R	Min.=65	Typ.=75	Deg.	Note 6, Appendix A
		θ_L	Min.=65	Typ.=75		
	Vert.	Φ_T	Min.=50	Typ.=60	Deg.	
		Φ_D	Min.=60	Typ.=70		

2.5 MECHANICAL SPECIFICATIONS

Table 6 - Mechanical Specification

Parameter	Value	Unit	Remarks
Outline Dimension	117.50 x 79.20 x 5.23	mm	
Active Area	95.04(H) x 53.86 (V)	mm	LCD, Touch Sensor
Weight	80.2 (Typ)	g	
First Surface Hardness	>9H	Pencil Hardness	See Note 7, Appendix A

2.6 FPC SPECIFICATION

The flexible segment (any portion without a stiffener) of the signal FPC from the touch panel has a minimum bend radius > 1.0mm. The image below shows the FPC with the stiff areas outlined in red. Stiff areas are not designed to be bent or deformed.

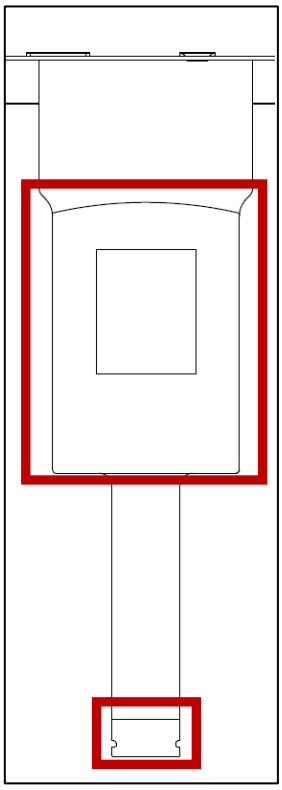


Figure 2 – Close-up View FPC Stiffener Areas (Shown from Rear View of Touch Panel Module)

3 COMMUNICATIONS INTERFACE

3.1 INTRODUCTION

The Fusion 4 Touch Module has 2 interfaces to communicate data to the host. The 2 interfaces are I2C or USB.

3.2 I2C INTERFACE

The I2C interface of the touch module is a NXP compliant I2C interface. This interface supports a protocol based on a command/response mechanism instead of an I2C register map. Please refer to document ***Fusion I2C Command Response*** for a complete overview of the protocol.

The Touch module uses 0x05 as its 7 bit I2C slave address.

The I2C interface has 4.7K Ohm resisters pulling the SDA and SCL lines up to VCC (3.3V).

3.3 USB INTERFACE

The Fusion 4 USB interface adheres to the Device Class Definition for Human Interface Devices (HID) version 1.11. The module reports as a Digitizer. It is compliant to the Windows 7 Digitizer Driver Specification[1]. The Fusion 4 is compatible to USB 2.0 FS device standards.

The Fusion 4 USB device vendor ID and product ID definition are as follows:

USB VID is: 0x1391, the PID is: 0x2112

The Fusion 4 maximum width in pixels is 4096.

The Fusion 4 maximum height in pixels is 4096.

The Fusion 4 maximum number of touches is 2.

In addition to the basic digitizer function the Fusion 4 USB interface also supports a vendor command function that can be used to configure and control the touch panel. The definition of these functions can be found in ***Fusion USB Touch Configuration Controls*** document. The basic functionality includes the ability to reset the touch panel controller, perform specific i2c transfers, and perform touch firmware upgrades.

[1] The Full Windows 7 Digitizer Driver Specification can be found online at - http://www.microsoft.com/whdc/device/input/DigitizerDrvs_touch.mspx

3.4 SWITCHING BETWEEN I2C AND USB

The touch panel can only communicate via either USB or I2C. It cannot communicate on both interfaces simultaneously.

To communicate via USB the VBUS pin must be connected to +5V. This will deactivate the I2C interface. Using the I2C pins while in USB mode will cause the device to malfunction.

To communicate via I2C the VBUS signal must not be connected. It must be left floating.

3.5 TOUCH PANEL CONNECTOR

The recommended touch panel connector is: FCI P/N SFV10R-1STE1HLF or equivalent. The pinout for the FCI connector is as noted in the following table

Table 7 - Touch Panel Connector Pinout – Refer to Mechanical Drawings for Pin 1 Orientation

Pin No.	Symbol	Description	Required for USB	Required for I2C
1	VCC	Power	NC	Yes
2	RST	Reset	No	Yes
3	INT	Interrupt	No	Yes
4	SDA	I2C Data	No	Yes
5	SCL	I2C Clock	No	Yes
6	GND	Ground	Yes	Yes
7	D+	USB Positive	Yes	No
8	D-	USB Negative	Yes	No
9	VBUS	USB Power	Yes	NC
10	GND	Ground	Yes	Yes

3.6 SIGNAL DEFINITIONS

- **VCC** 3.3V Power supply for the touch controller (required with and without USB).
- **RST** Reset for the touch controller. Should be connected to a reset line. This reset is asserted low (0V). When not asserted it should be raised to VCC.
- **INT** Interrupt from the touch controller. This should be connected to an interrupt enabled IO. This output is asserted high to VCC when touch data is ready. This interrupt should be treated as an edge sensitive signal.
- **SDA** Data line of I2C connection. This signal should be connected to the data line of an I2C bus. This I2C bus should have pull-up resistors to VCC. The touch controller does not contain pull-ups resistors
- **SCL** Clock line of I2C connection. This signal should be connected to the clock line of an I2C bus. This I2C bus should have pull-up resistors to VCC. The touch controller does not contain pull-ups resistors.
- **GND** Digital Ground
- **D+** USB Data +
- **D-** USB Data –
- **VBUS** +5 Volt for USB

4 LCD INTERFACE

4.1 INTRODUCTION

The Fusion 4 incorporates a color active matrix thin film transistor (TFT) liquid crystal display (LCD) that uses amorphous silicon TFT as a switching device. This LCD is composed of a TFT LCD panel, a driving circuit, and LED backlight system. This model has a 4.3” inch diagonally measured active display area with a 480H x 272V (WQVGA) display format that can display 16.2M colors.

4.2 FEATURES

- 4.3” inch diagonal configuration
- 480H x 272V (WQVGA) Pixel Format
- 3.3V TTL Interface
- 16.2M colors using an 8 bit R.G.B. signal input

4.3 GENERAL SPECIFICATIONS

Table 8 - LCD Specifications

Parameter	Specifications(LCD Only)	Unit
Screen Size	4.3” (Diagonal)	inch
Display Format	480 RGB(H)X 272(V)	pixels
Pixel Configuration	RGB Vertical Stripe	
Active Area	95.04 (H) x 53.86 (V)	mm
Pixel Pitch	0.198 (H) x 0.198 (V)	mm
Outline Dimension	105.50(W) x 67.20(H) x 2.90(D) Typ.	mm
Backlight	White LED	
Power Consumption	0.09W(Logic)/ 0.924W(Backlight)	Watt
Operating Temperature	-20 ~ 70	°C
Storage Temperature	-30 ~ 80	°C

4.4 ABSOLUTE MAXIMUM RATINGS

Table 9 - LCD Maximum Ratings (GND=0V)

Item	Symbol	Min.	Max.	Unit	Condition
Logic Supply Voltage	VDD	-0.3	5.0	V	Gnd=0
Logic Signal Input Level	Vi	-0.3	5.0	V	
LED-Voltage	VL		19.8	V	Note (1)(2)(3)
LED Current	IL		40	mA	Note (1)(2)(3)

Note:

1) Permanent damage may occur to the LCD module if operated beyond the absolute maximum ratings. Functional operation should be limited to the conditions described under normal operating conditions.
2) Ta = 25 ±2°C
3) Test Condition: LED current = 40mA. The LED life can decrease when operating current is greater than 40mA.

4.5 ELECTRICAL CHARACTERISTICS

4.5.1 Recommended Operating Condition

Table 10 - LCD Recommended Operating Conditions (GND=0V, Ta=25°C)

Parameter	Symbol	Rating			Unit	Condition
		Min.	Typ.	Max.		
Power Supply Voltage	VDD	3.0	3.3	3.6	V	
Input Supply Voltage	ViH	0.7VDD	-	VDD	V	Note (1)
	ViL	GND	-	0.3VDD	V	Note (1)
Power Supply Current	IDD	-	TBD	-	mA	VDD=3.3V

Note 1: HSYNC, VSYNC, DE, RGB Data

4.5.2 LED Driving Conditions

Table 11 - LED driving conditions (Ta = 25°C)

Parameter	Symbol	Min.	Typ.	Max.	Unit	Remark
LED Current	IL	-	40.0		mA	Note (2)
LED Voltage	VL		19.8		V	
LED Life	-	10,000	-	-	Hr	Note (1)(2)

The backlight uses a 12 LED edge-lighting system.

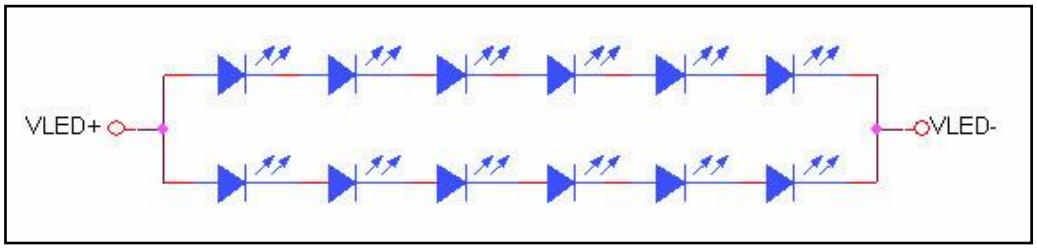


Figure 3 – LED Configuration

Note:

1) LED life is defined as the time it takes to the light output to reduce by 50% operating under the conditions of Ta=±3°C and IL=40mA.
2) LED life can decrease if the IL is operated greater than 40mA. A constant current source is recommended.
3) Schematic of suggested LED backlight driver shown below.

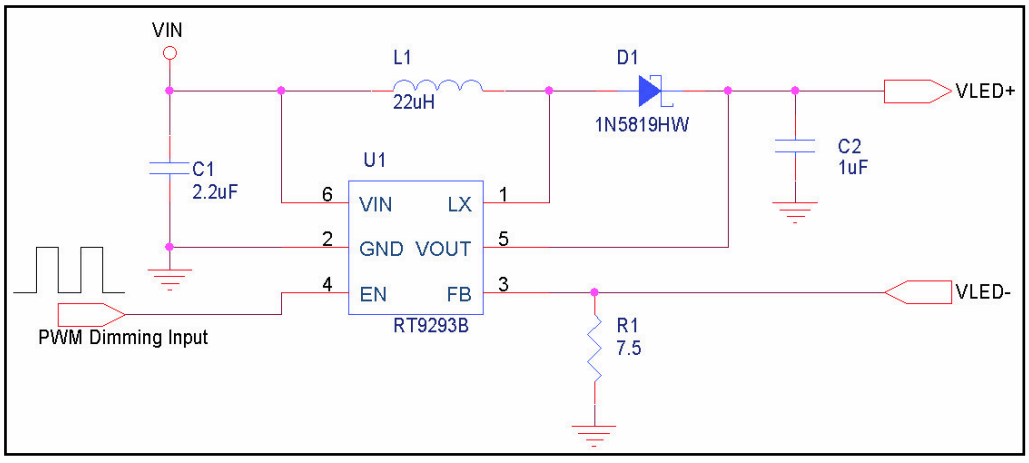


Figure 4 – LED Suggested Driver Configuration

4.6 INTERFACE

4.6.1 Timing Signal Characteristics

Table 12 - LCD Signal Timing Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units	Remark
DCLK Period Time	Tclk	83.3	111.1	200	ns	Parallel 24-bit RGB mode
		33.3	37.0	41.7	ns	Serial 8-bit RGB mode
DCLK Rising Time	Trck	-	-	9	ns	
DCLK Falling Time	Tfck	-	-	9	ns	
DCLK PulseDuty	Tcwh	40	50	60	%	
DE Setup Time	Tdesu	12	-	-	ns	
DE Hold Time	Tdehd	12	-	-	ns	
HSync Pulse Width	Thwn	1	-	-	DCLK	
HSYNC Setup Time	Thsu	12			ns	
HSYNC Hold Time	Thhd	12			ns	
VSync Pulse Width	Tvwh	1			Th	
VSYNC Setup Time	Tvsu	12			ns	
VSYNC Hold Time	Tvhd	12			ns	
Data Setup Time	Tdsu	12			ns	
Data Hold Time	Tdhd	12			ns	

Note: Using the typical values will give better performance

4.6.2 Clock and Data Input Timing

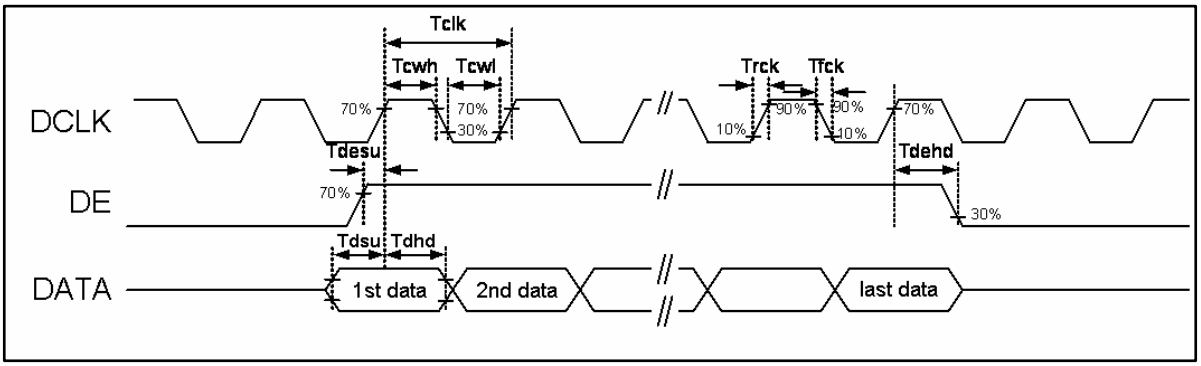


Figure 5 – LCD Interface Waveform

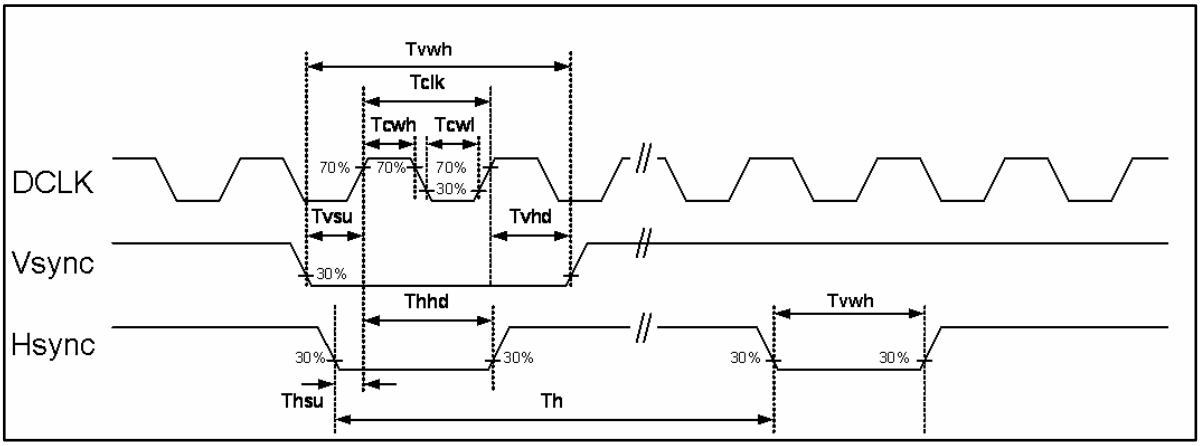


Figure 6 – LCD Interface Waveform

4.6.3 Power On/Off Sequence

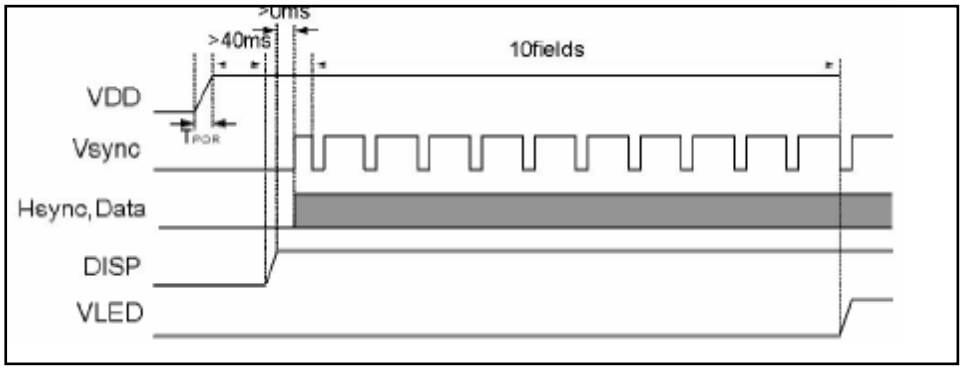


Figure 7 – LCD Power On Sequence

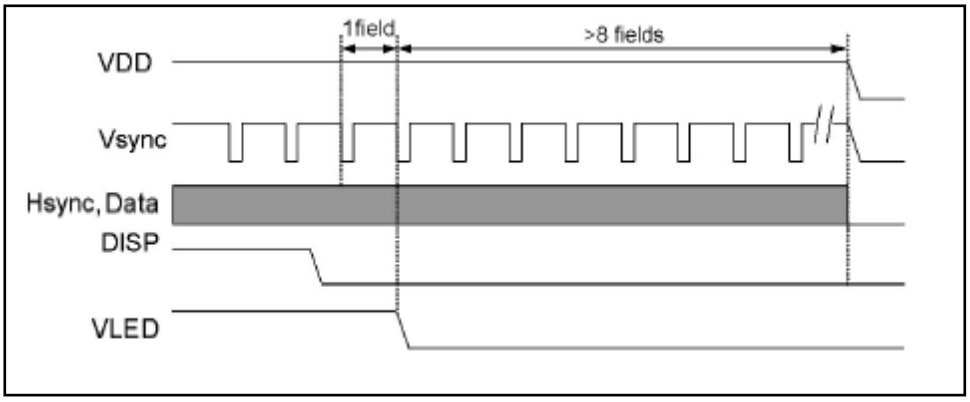


Figure 8 – LCD Power Off Sequence

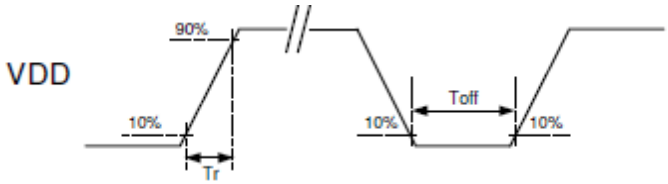


Figure 9 – VDD Power Input Timing

Notes:

- Data includes R0~R7, G0~G7, B0~B7, HSD, VSD, DCLK, DE
- Power Sequence: VDD→DISP→Data→VLED
- Power Off Sequence: DISP→VLED→Data→VDD
- VDD Power Input Timing: 0.5ms < Tr < 10ms, Toff >500ms

4.7 INTERFACE

4.7.1 Data Input Format

Table 13 - LCD Signal Timing Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
DCLK Frequency	Fclk	5	9	12	MHz	
VSYNC Period Time	Tv	277	288	400	Th	
VSYNC Display Area	Tvd		272		Th	
VSYNC Back Porch	Tvbp	3	8	31	Th	
VSYNC Front Porch	TVfp	2	8	93	Th	
HSYNC Period Time	Th	520	525	800	DCLK	
HSYNC Display Area	Thd		480		DCLK	
HSYNC Back Porch	Thbp	36	40	255	DCLK	
HSYNC Front Porch	Thfp	4	5	65	DCLK	

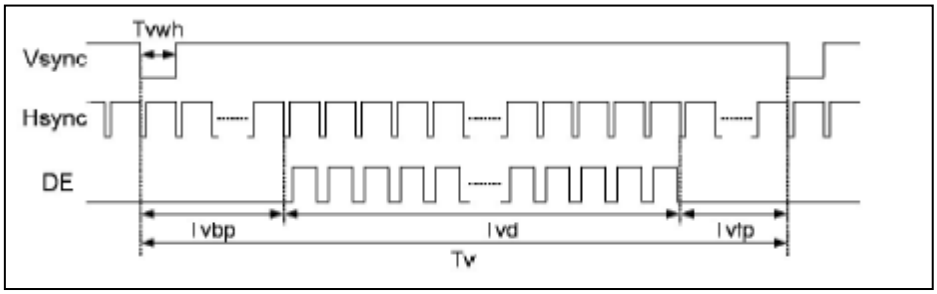


Figure 10 – Vertical Input Timing

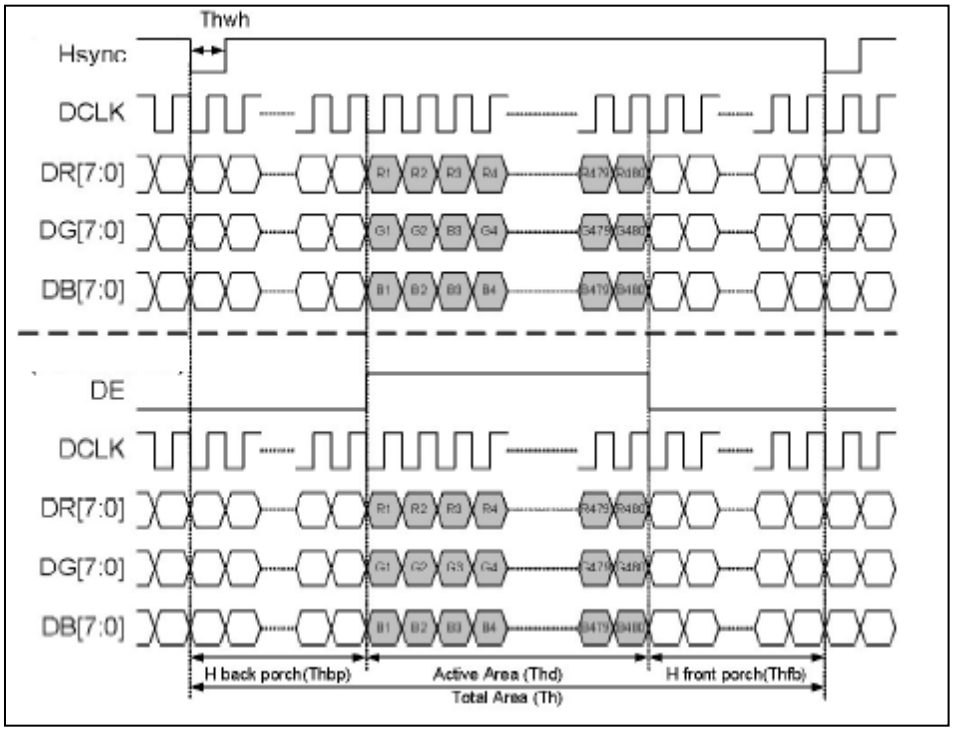


Figure 11 – Parallel 24-bit RGB Mode Data Format (DE Mode)

4.7.2 LCD Signal Cable Definition

Table 14 - LCD Signal Definition

Pin No.	Symbol	I/O	Description	Pin No.	Symbol	I/O	Description
1	VLED-	P	Power for LED Backlight Cathode	21	B0	I	Blue Data (LSB)
2	VLED+	P	Power for LED Backlight Anode	22	B1	I	Blue Data
3	GND	P	Power Ground	23	B2	I	No Connection
4	VDD	P	Power Voltage	24	B3	I	Blue Data
5	R0	I	Red Data (LSB)	25	B4	I	Blue Data
6	R1	I	Red Data	26	B5	I	Blue Data
7	R2	I	Red Data	27	B6	I	Blue Data
8	R3	I	Red Data	28	B7	I	Blue Data (MSB)
9	R4	I	Red Data	29	GND	P	Power Ground
10	R5	I	Red Data	30	DCLK	I	Pixel Clock
11	R6	I	Red Data	31	DISP	I	Display On/Off
12	R7	I	Red Data (MSB)	32	HSYNC	I	Horizontal Sync
13	G0	I	Green Data (LSB)	33	VSYNC	I	Vertical Sync
14	G1	I	Green Data	34	DE	I	Data Enable
15	G2	I	Green Data	35	NC	-	No Connect
16	G3	I	Green Data	36	GND	P	Power Ground
17	G4	I	Green Data	37	X_R	I/O	Right Electrode-Differential Analog
18	G5	I	Green Data	38	Y_B	I/O	Bottom Electrode-Differential Analog
19	G6	I	Green Data	39	X_L	I/O	Left Electrode-Differentia Analog
20	G7	I	Green Data (MSB)	40		I/O	Top Electrode-Differential Analog

4.7.2.1 LCD Signal Mating Connector

Use Hirose FPC connector**, FH19SC-40S-0.5SH** or equivalent.

4.8 BLOCK DIAGRAM

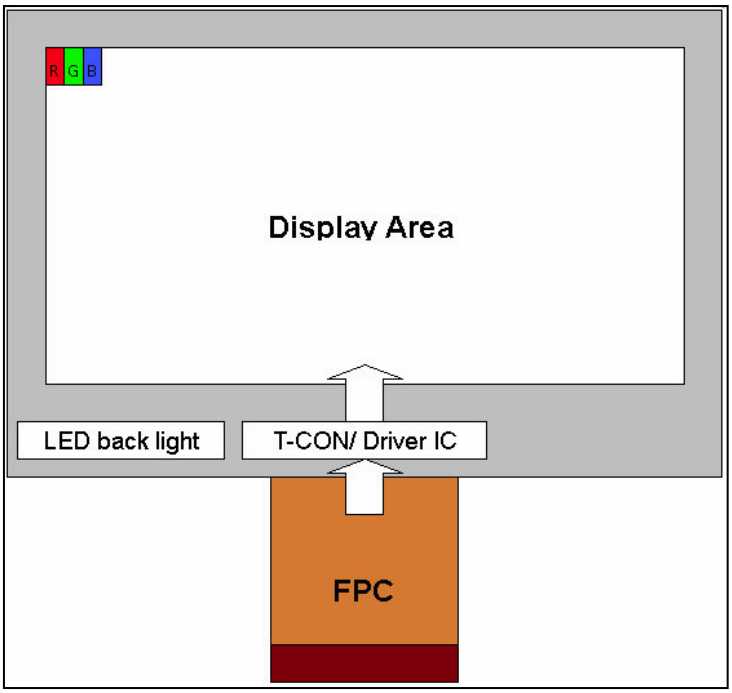


Figure 12 – LCD Block Diagram

4.9 PIXEL FORMAT

Figure 13 shows the pixel format for the Hannstar 4.3” display. The display area consists of 480 pixels arranged in 272 lines (vertical direction). Each pixel is composed of red, green and blue components.

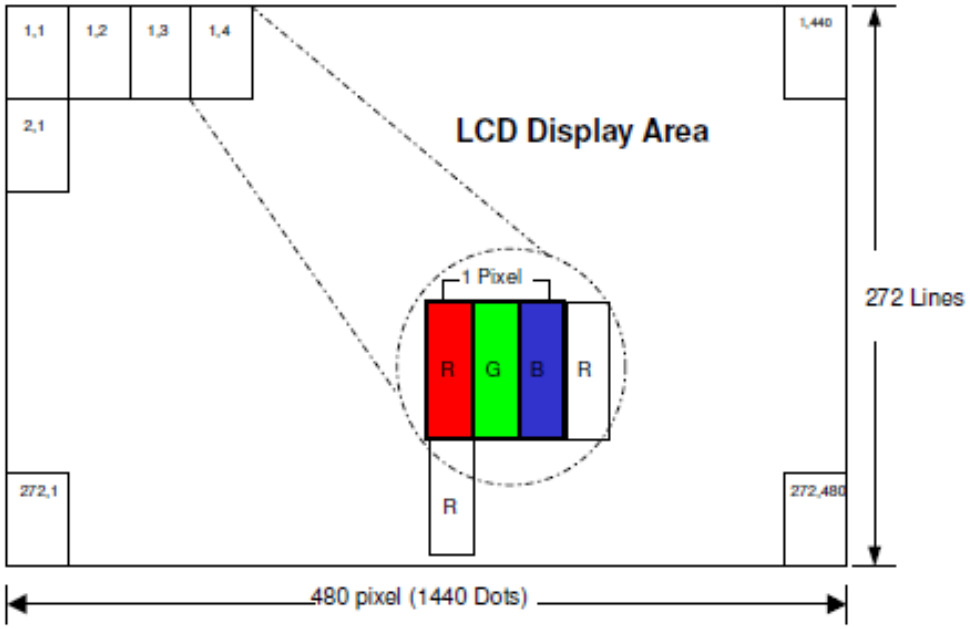


Figure 13 – LCD Pixel Format

4.10 OPTICAL PERFORMANCE

Table 15 - LCD Optical Performance

Parameter		Symbol	Condition	Min.	Typ.	Max.	Unit	Note
Contrast Ratio		CR	Viewing Normal Angle θ=0	480	600	-	-	
Response Time		Tr		-	3	6	ms	
		Tf		-	7	14	ms	
White Luminance (Center)		YL		400	500		cd/m²	IL=40ma
Color Chromaticity	White	WX		0.260	0.310	0.360		
		WY		0.280	0.330	0.380		
Viewing Angle	Hor.	θR	CR>10	65	75		Deg.	
		θL		65	75			
	Ver.	ΦT		50	60			
		ΦD		60	70			
Brightness Uniformity		BUNI	θ=0	70			%	
Optimum Viewing Direction		6 o'clock						

Note: Parameters in above table are for LCD only.

- Measured in a dark room.
- LED current (I_L) =40ma.
- Ambient Temperature: 25 ±2 °C.
- 15 minutes warm up time.

5 RELIABILITY AND TESTING

5.1 RELIABILITY TEST SPECIFICATIONS

Table 16 – Reliability Test Specifications

Item	Condition
High Temperature Storage	T_A= +70°C, 240 hrs
Low Temperature Storage	T_A= -30°C, 240 hrs
High Temperature Operation	T_A= +60°C, 240 hrs
Low Temperature Operation	T_A= -20°C, 240 hrs
Thermal cycling	-20°C (30 min) · +60°C (30 Min), 100 cycles (DRY)
Electrostatic discharge	±8kV (Contact) / ±10kV (air)

5.2 PACKAGING SPECIFICATIONS

Table 17 – Packaging Specifications

Item	Condition
Drop Test	1) Drop Sequence: 1 corner, 3 edges, 6 surfaces. 2) Drop height according to the weight of the package. 3) Inspection: sampling check, check each layer of upper and lower, 2 layers in center, total 4 layers.
Non-Operating Random Vibration	1) Truck Spectrum: (0.52G rms) and Air Spectrum: (PSD=1.46G rms), 3 axis (X/Y/Z), 20 min per axis per test. 2) Inspection: sampling check, check each layer of upper and lower, 2 layers in center, total 4 layers.

Note: All packaging tests are performed on 1 complete box of Fusion Touch Modules.

6 BARCODE

6.1 DESCRIPTION

Every Fusion touch panel contains a unique 2 dimensional barcode. This barcode is used for serial number identification and part specification.

6.2 LOCATION

The barcode is located on the flex tail as pictured below.

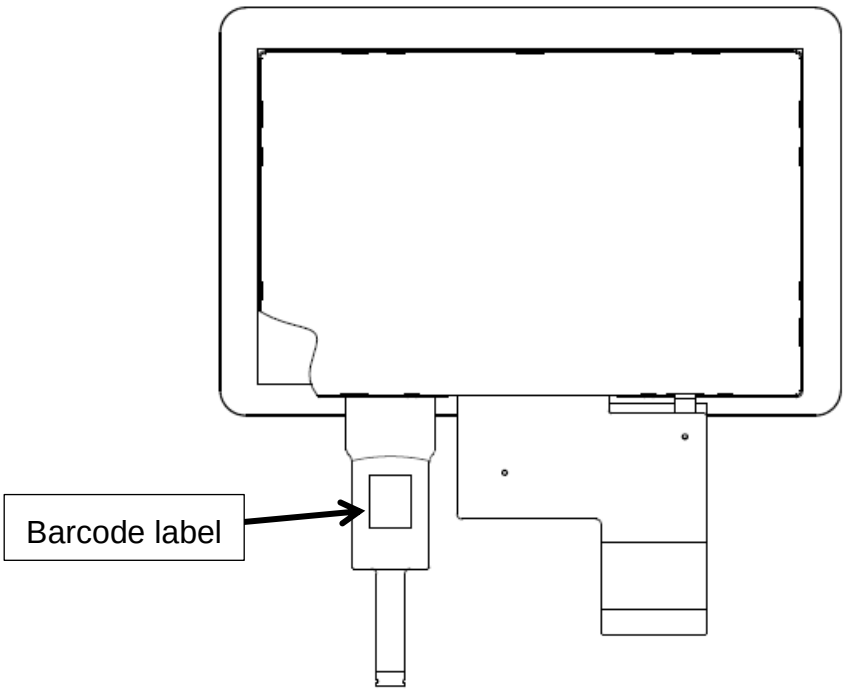


Figure 14 – Barcode Label Area (Rear View of Module Shown)

6.3 CONTENTS

The barcode contains the unit serial number, Touch Revolution part number, and touch firmware release version.

7 HANDLING AND PRECAUTIONS

7.1 DISASSEMBLY OR MODIFICATION

Do not disassemble or modify the touch display. This may cause damage to sensitive components and may cause dust or scratches between the touch sensor and LCD. Touch Revolution's warranty will be void if the unit has been disassembled or modified.

7.2 UV EXPOSURE

Long term exposure to sunlight can affect the optical performance of the LCD.

7.3 CLEANING

The cover glass should be cleaned using a soft, lint free cloth. It is recommended that either an ammonia based glass cleaner (e.g. Windex) or a 50:50 solution of isopropyl alcohol and water be used for cleaning the sensor. Apply the cleaning solution to the cloth and gently wipe the surface of the sensor. To help minimize streaking, wipe in a circular motion starting in the center and working outwards.

7.4 STATIC ELECTRICITY

Since the LCD and Touch panel use CMOS ICs, the device is susceptible to electrostatic discharge. Please use appropriate grounding when handling these modules.

7.5 ABSOLUTE MAXIMUM RATINGS

Do not exceed the absolute maximum rating values for the supply voltages and environmental conditions to prevent damage to the touch display.

7.6 BREAKAGE

If the LCD panel breaks be careful not to touch any liquid crystal material that may spill. Immediately rinse with water if liquid crystal material comes in contact with skin.

7.7 INPUT VOLTAGES

Turn off the power supply before handling and/or inserting signal or power cables to the touch module.

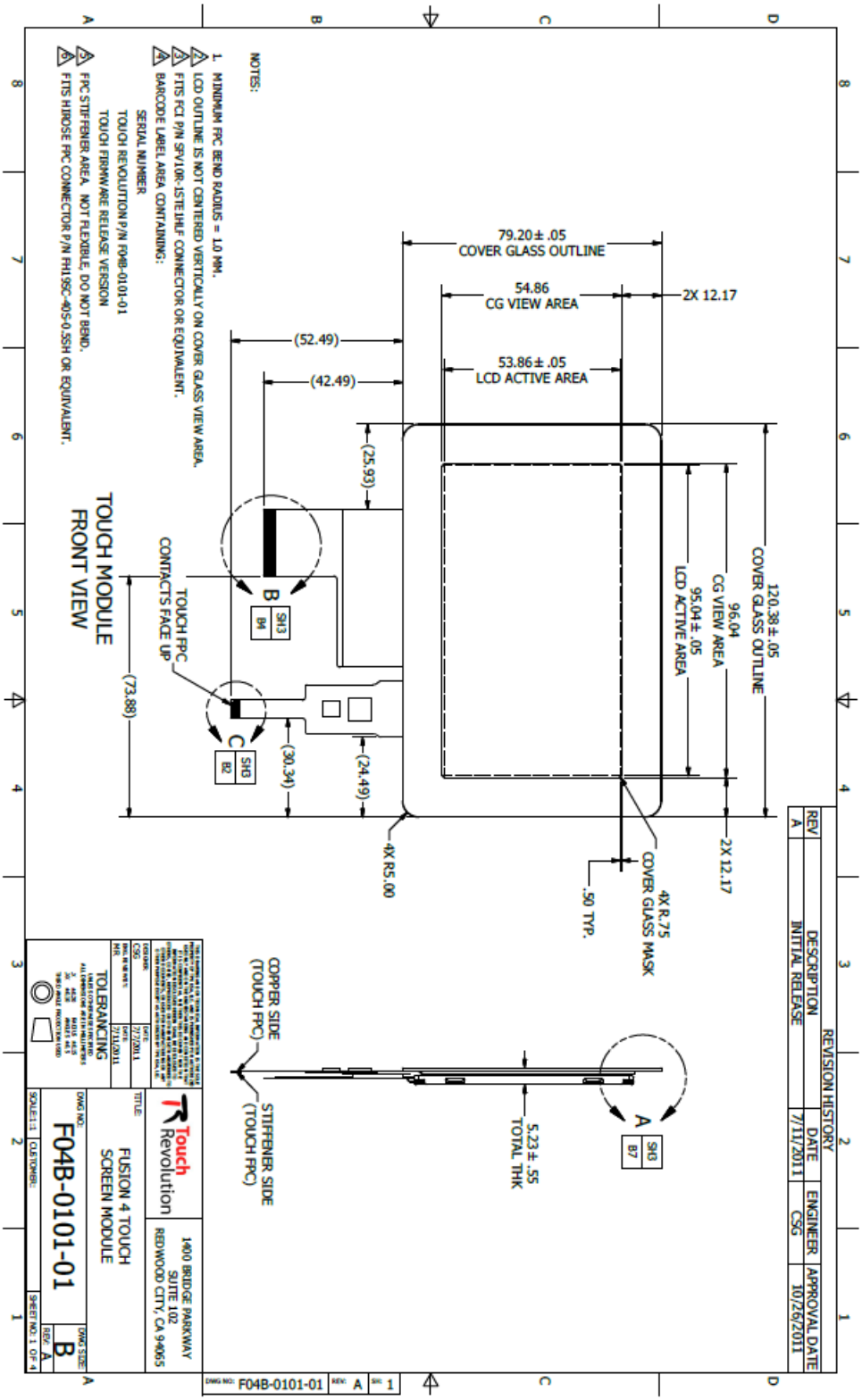
7.8 STATIC IMAGES

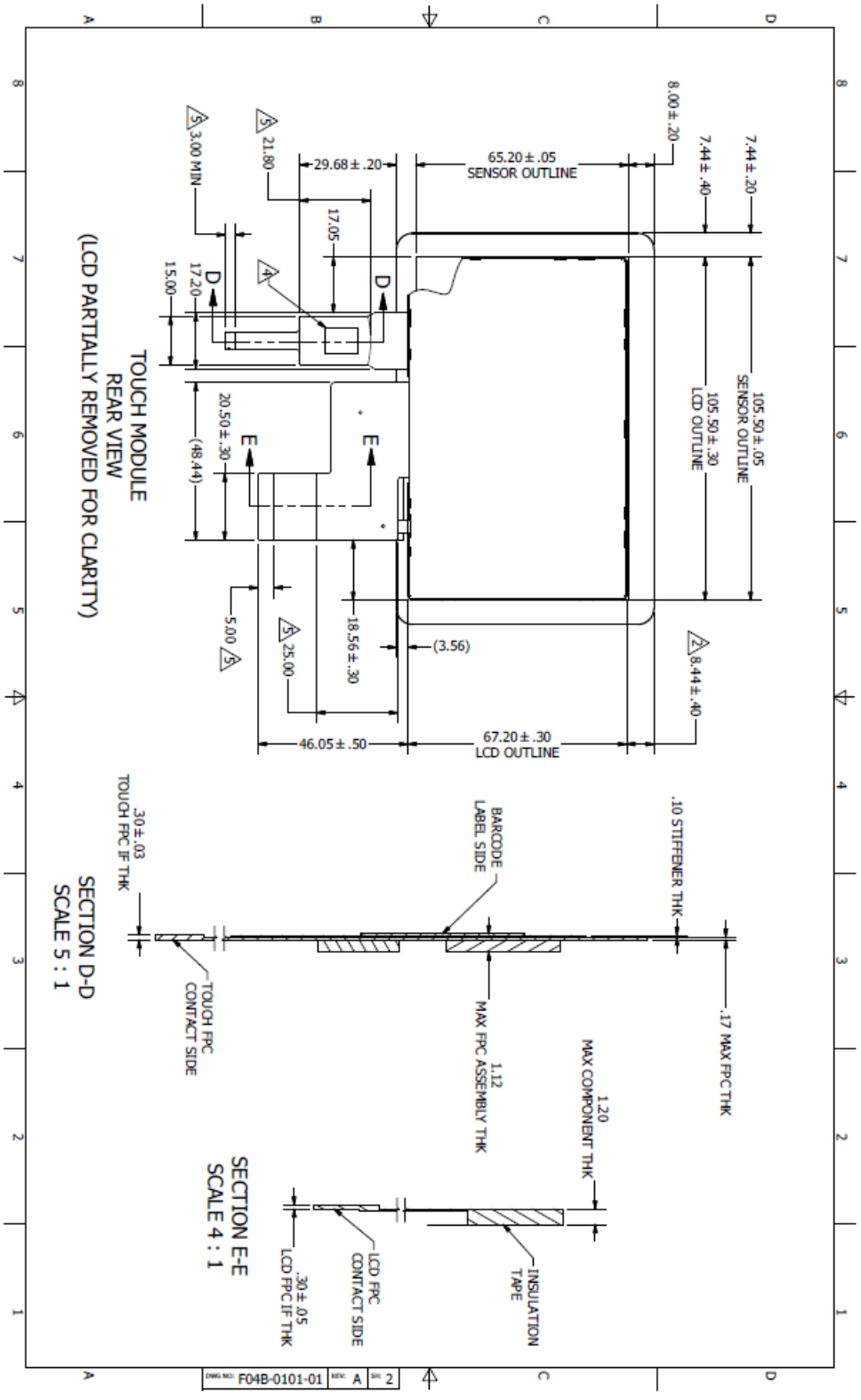
If fixed images are displayed for a long period of time, an afterimage is likely to occur.

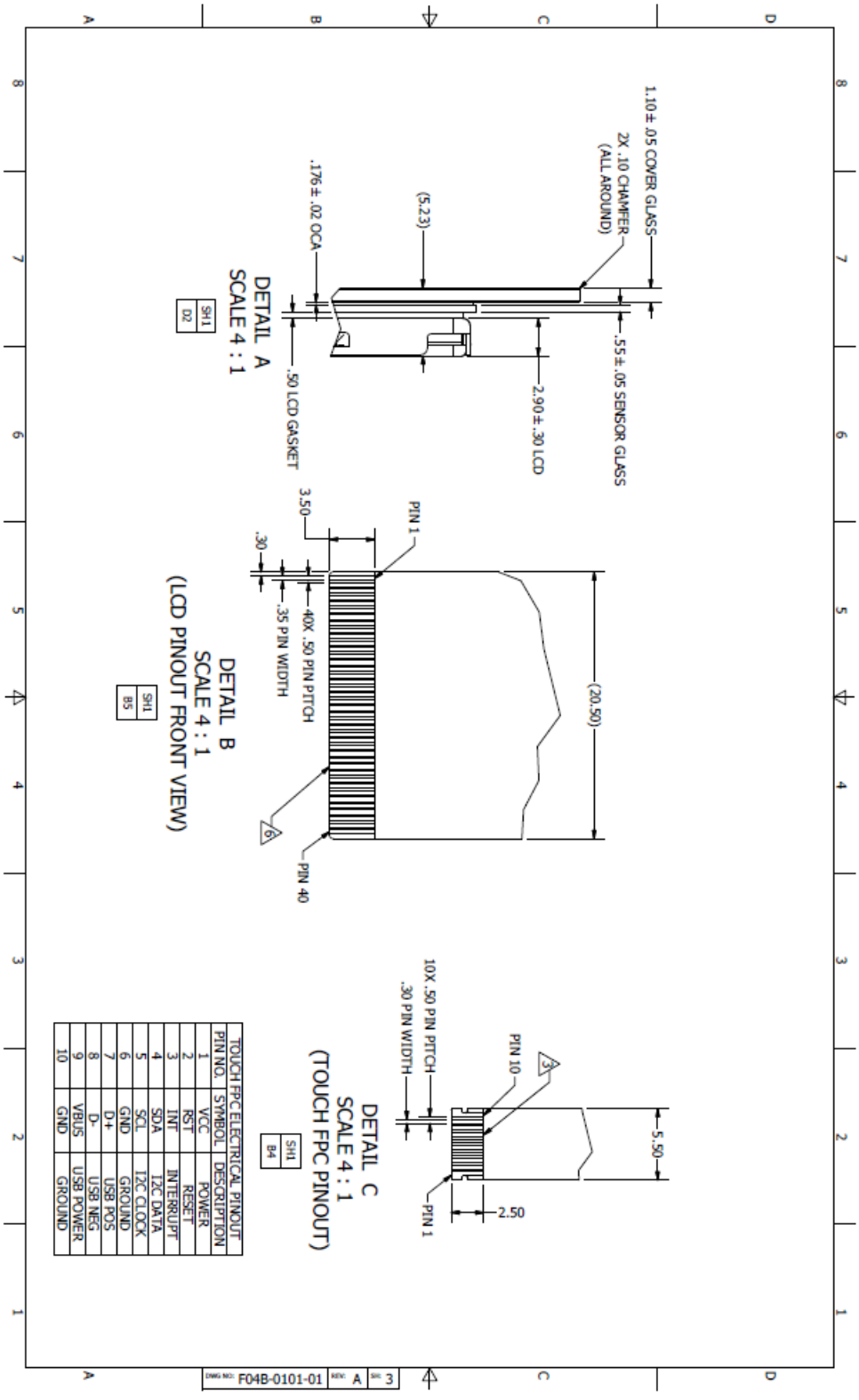
7.9 OUTGASSING

Do not store or use the touch module in an environment where caustic materials such as reagents, solvents, adhesives, and resins are present. Outgassing of these materials can damage the polarizer and ACF connections.

8 MECHANICAL DRAWINGS

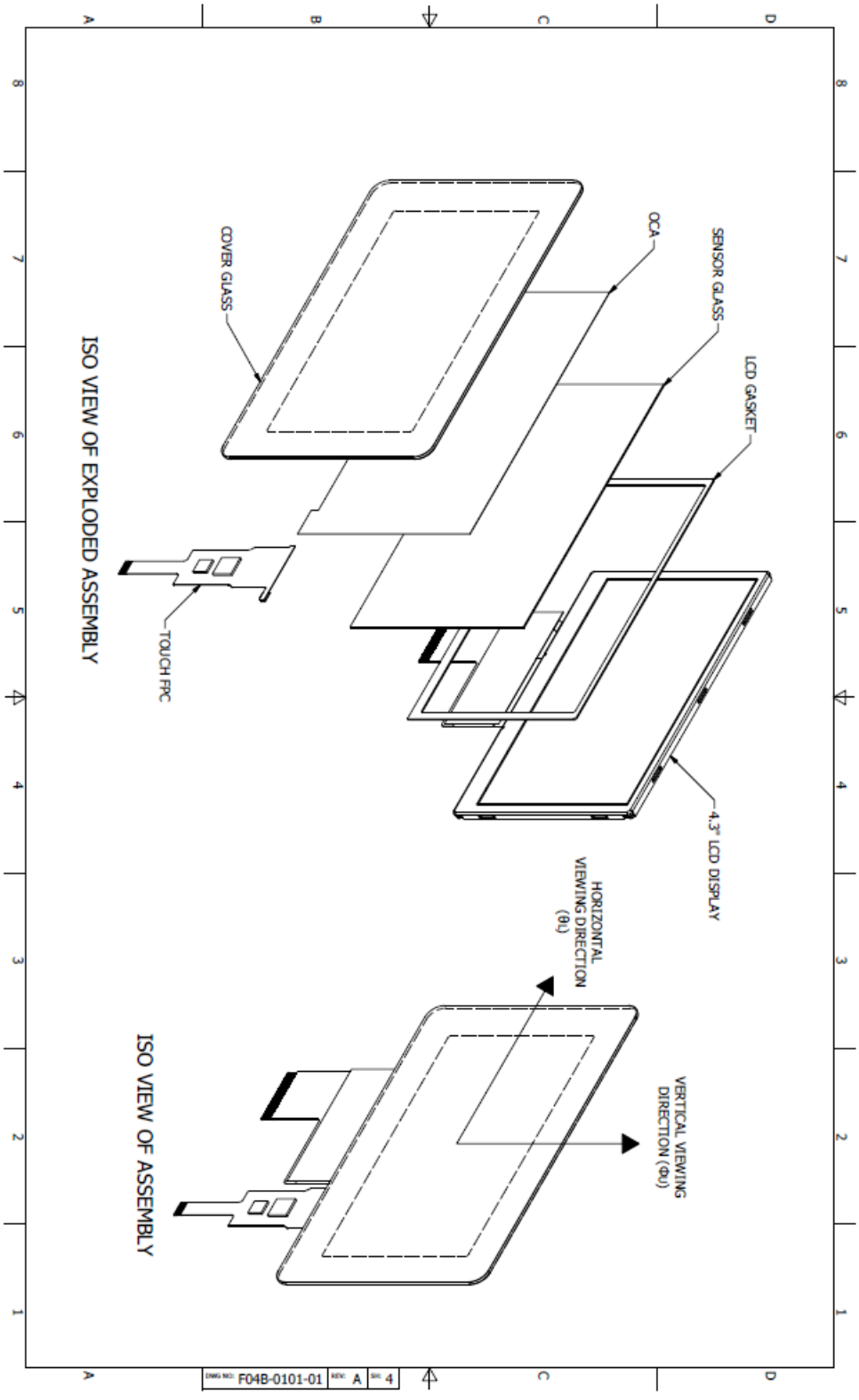



TOUCH MODULE
REAR VIEW
(LCD PARTIALLY REMOVED FOR CLARITY)
3.00 MIN
21.80
29.68 ± .20
65.20 ± .05
SENSOR OUTLINE
8.00 ± .20
7.44 ± .40
7.44 ± .20
17.05
15.00
17.20
105.50 ± .05
SENSOR OUTLINE
105.50 ± .30
LCD OUTLINE
20.50 ± .30
(48.44)
5.00
25.00
18.56 ± .30
(3.56)
8.44 ± .40
46.05 ± .50
67.20 ± .30
LCD OUTLINE
SECTION D-D
SCALE 5 : 1
.30 ± .03
TOUCH FPC I/F THK
BARCODE
LABEL SIDE
.10 STIFFENER THK
TOUCH FPC
CONTACT SIDE
MAX FPC ASSEMBLY THK
1.12
MAX COMPONENT THK
1.20
.17 MAX FPC THK
SECTION E-E
SCALE 4 : 1
.30 ± .05
LCD FPC I/F THK
LCD FPC
CONTACT SIDE
INSULATION
TAPE
DWG NO: F04B-0101-01
REV: A
SH: 2



TOUCH FPC ELECTRICAL PINOUT

PIN NO.	SYMBOL	DESCRIPTION
1	VCC	POWER
2	RST	RESET
3	INT	INTERRUPT
4	SDA	I2C DATA
5	SCL	I2C CLOCK
6	GND	GROUND
7	D+	USB POS
8	D-	USB NEG
9	VBUS	USB POWER
10	GND	GROUND


ISO VIEW OF EXPLODED ASSEMBLY
COVER GLASS
OCA
SENSOR GLASS
LCD GASKET
TOUCH FPC
4.3" LCD DISPLAY
ISO VIEW OF ASSEMBLY
HORIZONTAL VIEWING DIRECTION (θ)
VERTICAL VIEWING DIRECTION (Φ)
F04B-0101-01
A
4

APPENDIX A

Note 1: **Linearity Test Definition**

The linearity of the sensor is tested by dragging a 6mm copper slug in a line across the first surface of the touch sensor. The distance between the actual location of the center of the slug and the reported location shall be less than or equal to the maximum specified error.

Note 2: **Report Rate**

Report rate is the maximum rate at which touch data is returned to the host PC. The report rate may drop to 30 interrupts/second for some unique two finger touch combinations.

Note 3: **Response Time**

Response time is the time elapsed between the first touch and interrupt assuming touch is in active mode

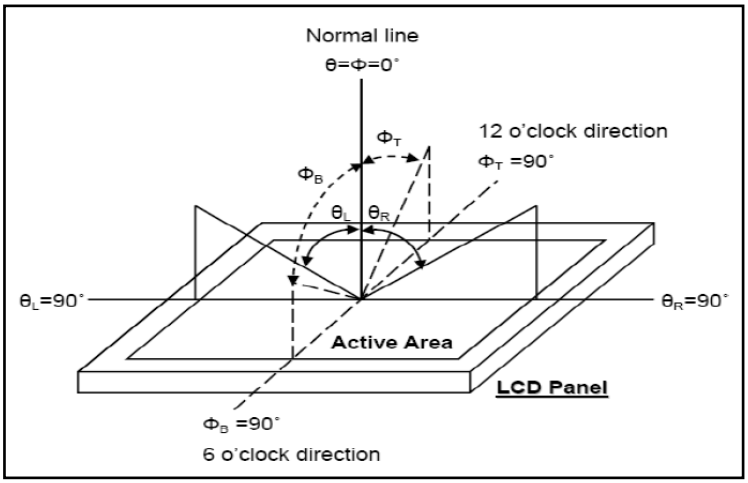
Note 4: **Minimum Touch Diameter**

The minimum touch diameter is the minimum diameter of a copper slug that is needed to record a touch.

Note 5: **Optical Transmittance**

Measured Per ASTM D1003

Note 6: **Viewing Angle**



Note 7: **First Surface Hardness**

Measured Per ASTM D3363