E-paper Display COG Driver Interface Timing for Wide Temperature of 1.44",2" and 2.7" EPD with G2 COG and Aurora Ma Film

Description	**Detailed information to design a timing controller for wide temperature 1.44",2" and 2.7" EPD with G2 COG and Aurora Ma film**
Date	**2015/02/16**
Doc. No.	**4P015-00**
Revision	**01**

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Revision History

Version	Date	Page (New)	Section	Description
Ver. 01	2015/02/16	All	All	First issued

Glossary of Acronyms

EPD	Electrophoretic Display (e-Paper Display)
EPD Panel	EPD
TCon	Timing Controller
FPL	Front Plane Laminate (e-Paper Film)
SPI	Serial Peripheral Interface
COG	Chip on Glass
PDI, PDi	Pervasive Displays Incorporated

1 General Description

1.1 Overview

This document explains the interface to the G2 COG Driver to operate the EPD for a Timing Controller based solution using one page of memory buffer. G2 is the most recent EPD driving technology from PDI that offers new features such as breakage detection, lower inrush current, and a lower operation voltage. This document applies to 2.0" and 2.7" EPDs.

The procedure to update display is

1. Store new pattern in memory buffer
2. Power on G2 COG Driver
3. Initialize G2 COG Driver
4. Update display stage by stage
5. Power off G2 COG Driver

Refer to the EPD controller in section 1.5 to see the complete procedure. To operate the EPDs for the best sharpness and performance, each update of the panel is divided into a series of stages before the display of the new image pattern is completed. During each stage, frame updates with intermediate image patterns are repeated for a specified period of time. The number of repeated frame during each stage is dependent on the Timing Controller speed. After the final stage, the new pattern is displayed.

Around the active area of the EPD is a 0.5mm width blank area called the border. When connected to V_{DL} (-13V ~ -14V) to keep the border white. After approximately 10,000 updates with the constant voltage, the border color may degrade to a gray level that is not as white as the active area. To prevent this phenomenon, PDI recommends turn on and off border to avoid the degradation.

Section 1 is an overview and contains supporting information such as the overall theory for updating an EPD, SPI timing for PDI's EPDs, as well as current profiles.

Section 2 describes a method to write to memory buffer. New pattern is stored in the memory buffer and update image in displays.

Section 3 describes how to power on the G2 COG Driver which consists of applying a voltage and generating the required signals for /CS and /RESET.

Section 4 describes the steps to initialize the G2 COG Driver.

Section 5 describes the details on how to update the EPD from the memory buffer, create a line of data, update in stages, and also power down housekeeping steps.

Section 6 describes how to power off the G2 COG Driver, and discharge voltage from EPD to ground, make sure there is not any voltage keep in EPD.

1.2 Input Terminal Pin Assignment

No	Signal	I/O	Connected to	Function
1	/CS	I	TCon	Chip Select. Low enable
2	BUSY	O	TCon	When BUSY = High, EPD stays in busy state that EPD ignores any input data from SPI.
3	ID	I	Ground	Set SPI interface
4	SCLK	I	TCon	Clock for SPI
5	SI	I	TCon	Serial input from host Timing Controller to EPD
6	SO	O	TCon	Serial output from EPD to host Timing Controller
7	/RESET	I	TCon	Reset signal. Low enable
8	BORDER_DRIVER or PWNON	-	BORDER or TCon	For 1.44" & 2", connect to BORDER. For 2.7", Power ON Switching Pin. Non-connected or connect to Timing Controller. This pin have a function to switch power of V_{cc} and V_{DD}. ➢ Low : Power OFF ➢ High : Power ON It has an internal pull-up resistor. It's ok to float it.
9	V_{CL}	C	Capacitor	-
10	C42P	-	NC	Not connected. These two pins are used only with G1 COG Drive IC.
11	C42M	-		
12	C41P	C	Charge-Pump Capacitor	-
13	C41M	C		-
14	C31M	C	Charge-Pump Capacitor	-
15	C31P	C		-
16	C21M	C	Charge-Pump Capacitor	-
17	C21P	C		-
18	C16M	C	Charge-Pump Capacitor	-
19	C16P	C		-
20	C15M	C	Charge-Pump Capacitor	-
21	C15P	C		-

No	Signal	I/O	Connected to	Function
22	C14M	C	Charge-Pump Capacitor	-
23	C14P	C		-
24	C13M	C	Charge-Pump Capacitor	-
25	C13P	C		-
26	C12M	C	Charge-Pump Capacitor	-
27	C12P	C		-
28	C11M	C	Charge-Pump Capacitor	-
29	C11P	C		-
30	V_{COM_DRIVER}	RC	Resistor & Capacitor	The duty cycle of V_{COM_DRIVER} can adjust V_{COM} voltage from source driver IC
31	V_{CC}	P	V_{CC}	Power supply for analog part of source driver
32	V_{DD}	P	V_{DD}	Power supply for digital part of source driver
33	V_{SS}	P	Ground	-
34	V_{GH}	C	Capacitor	-
35	V_{GL}	C	Capacitor	-
36	V_{DH}	C	Capacitor	-
37	V_{DL}	C	Capacitor	-
38	BORDER	I	-	For 1.44” & 2”, connect to BORDER_DRIVER For 2.7”, connect to V_{DL} via control circuit for white frame border
39	V_{ST}	P	V_{COM_PANEL}	-
40	V_{COM_PANEL}	C	Capacitor	V_{COM} to panel

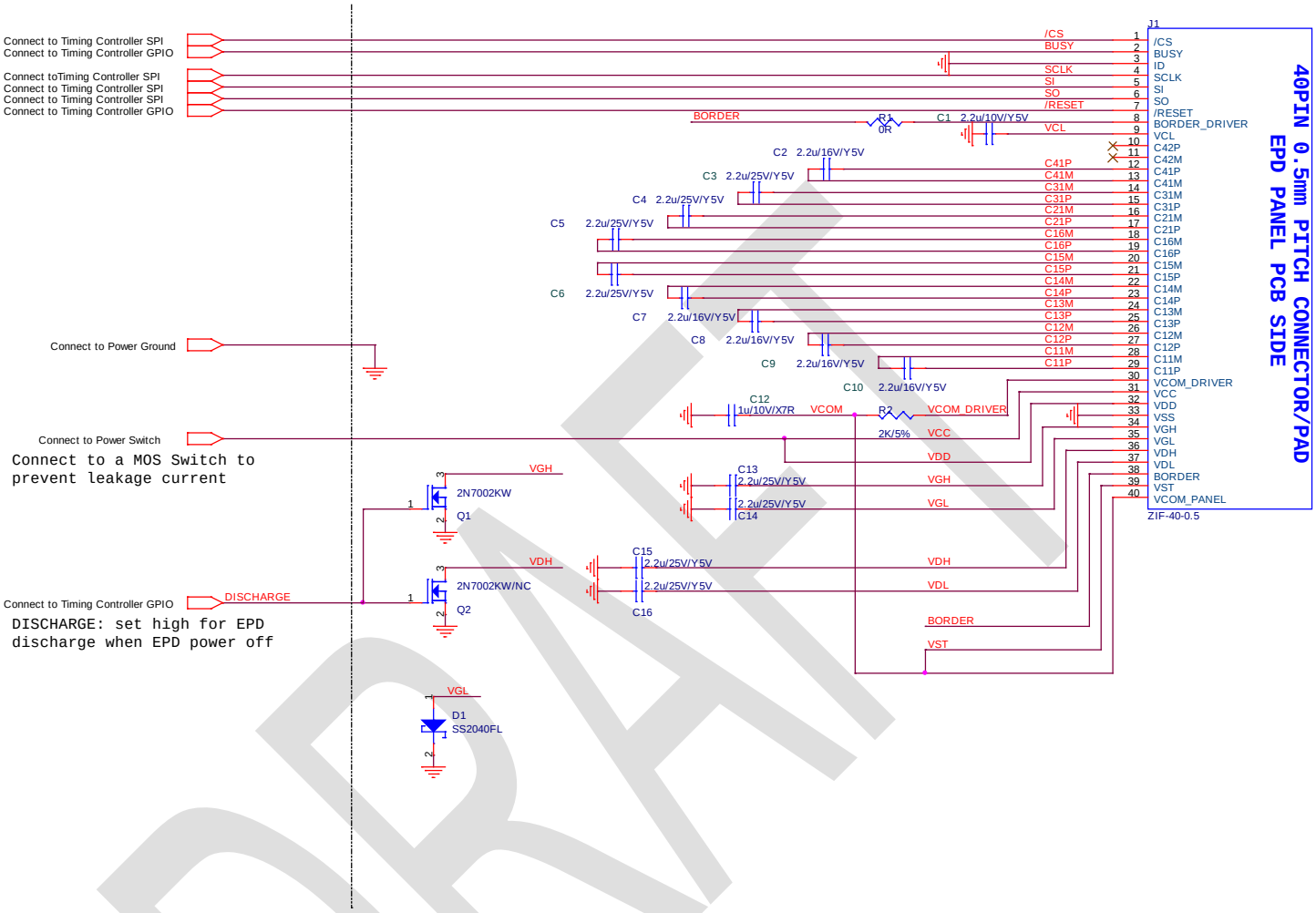
Note:

1. **I**: Input, **O**: Output, **C**: Capacitor, **RC**: Resistor and Capacitor, **P**: Power
2. Recommend to use an independent SPI bus to control the EPD.
3. Around the active area of the EPD is a 0.5mm width blank area called the BORDER. It’s connected to V_{DL} (-13V ~ -14V) to keep the border white. After EPD updates with the constant voltage, the border color may degrade to a gray level that is not as white as the active area. To prevent this phenomenon, PDI recommends turn on and off border to avoid the degradation.

1.3 Reference Circuit

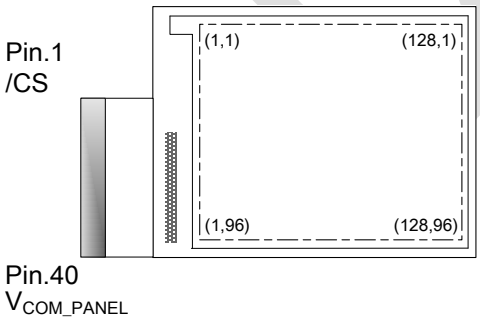
1.3.1 1.44 inch EPD Reference Circuit

INPUT



Note :

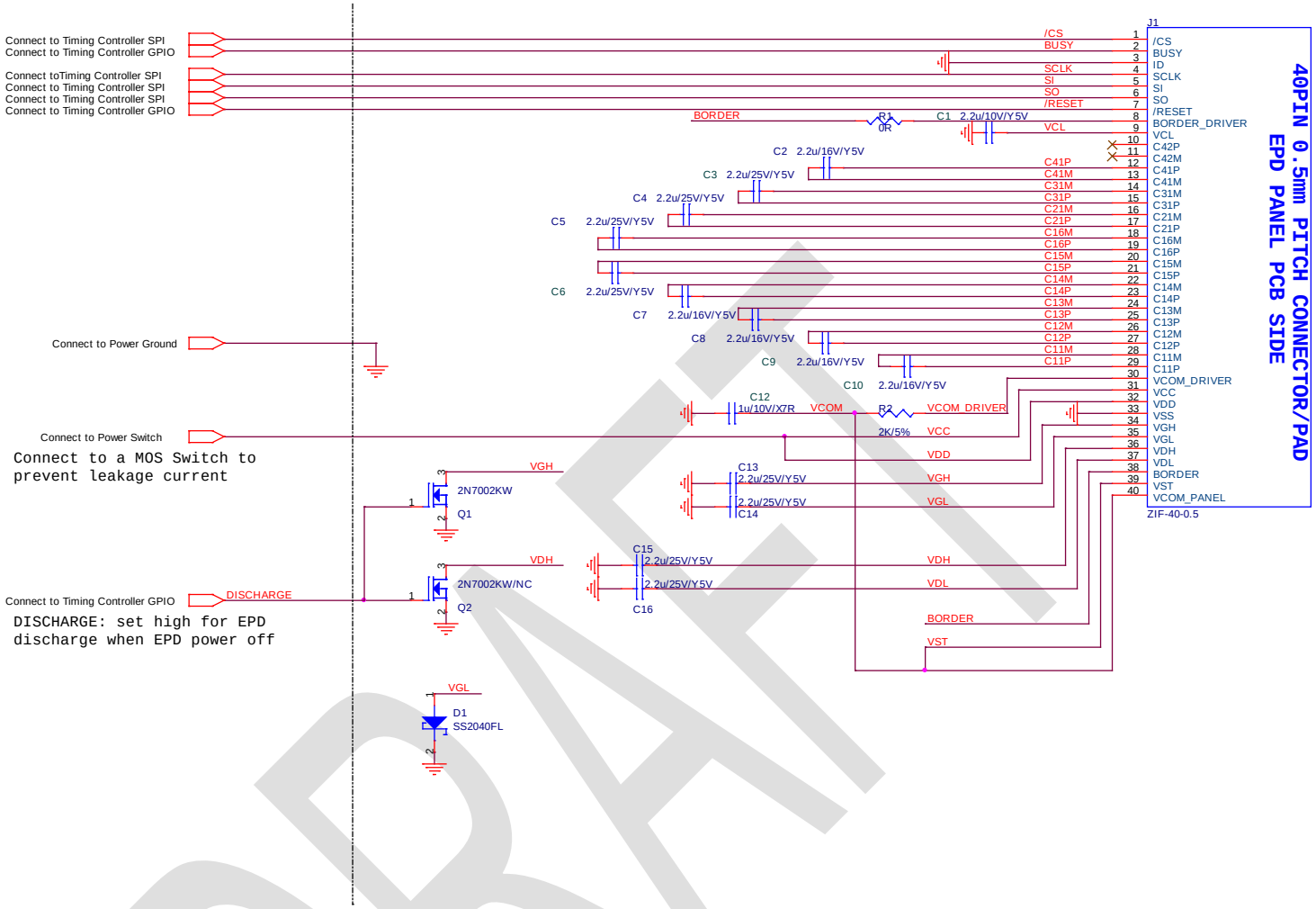
1. V_{DD} and V_{CC} must be discharged promptly after power off
2. 1.44" Pin.1 location



3. R1 is connected.

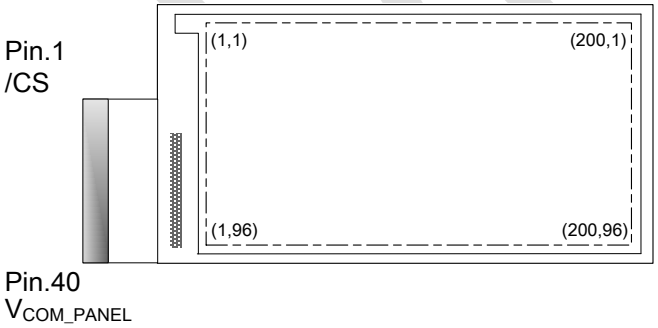
1.3.2 2 inch EPD Panel Reference Circuit

INPUT



Note :

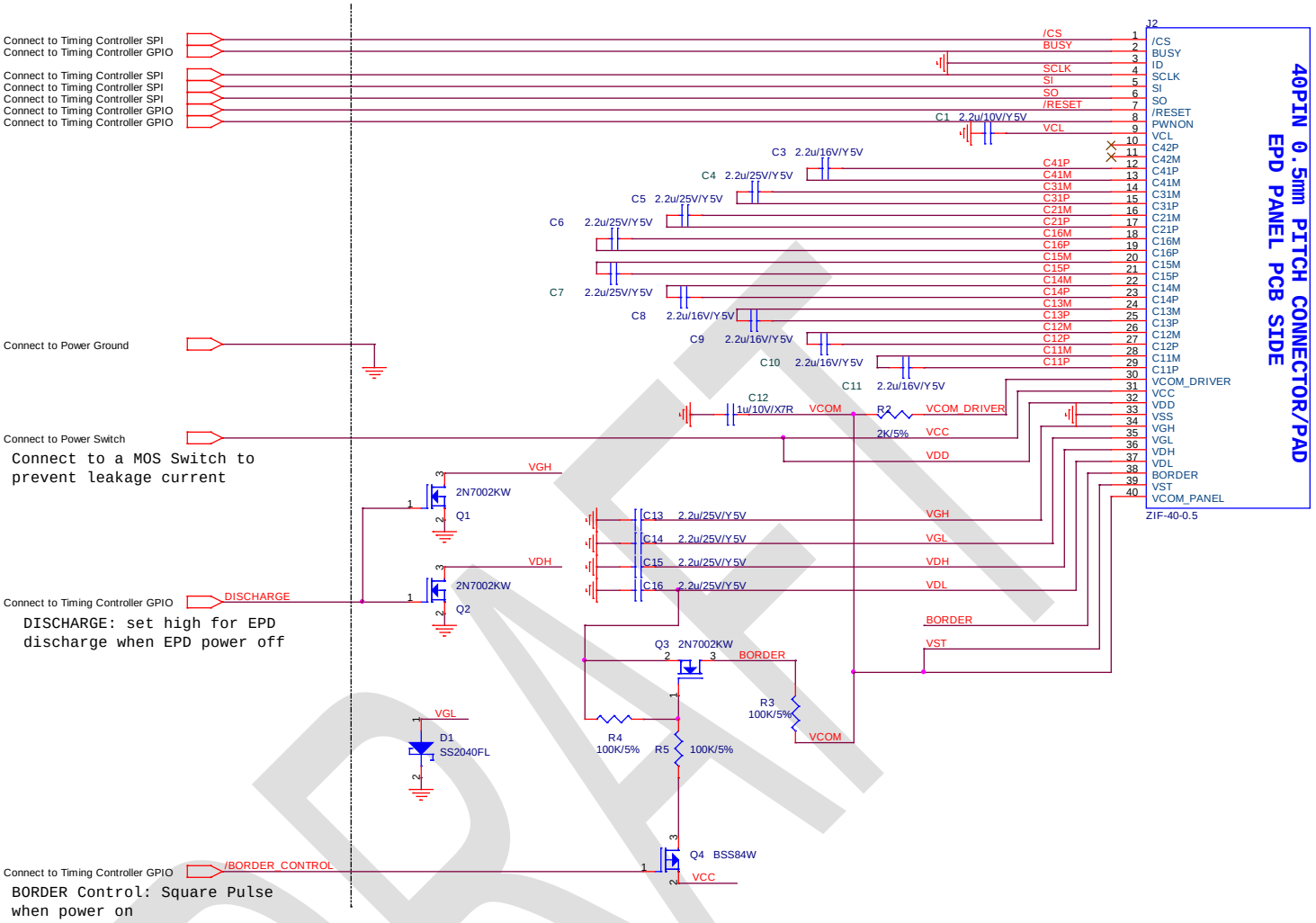
1. V_{DD} and V_{CC} must be discharged promptly after power off
2. 2" Pin.1 location



3. R1 is connected.

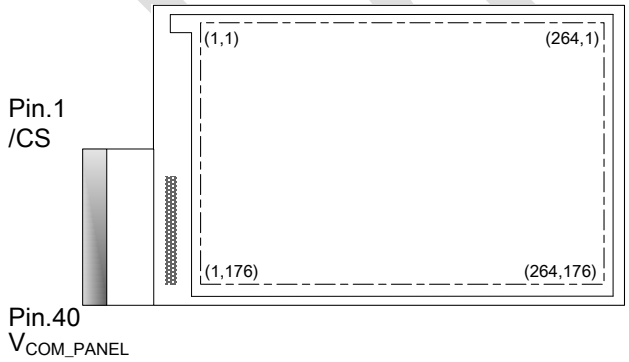
1.3.3 2.7 inch EPD Panel Reference Circuit

INPUT



Note :

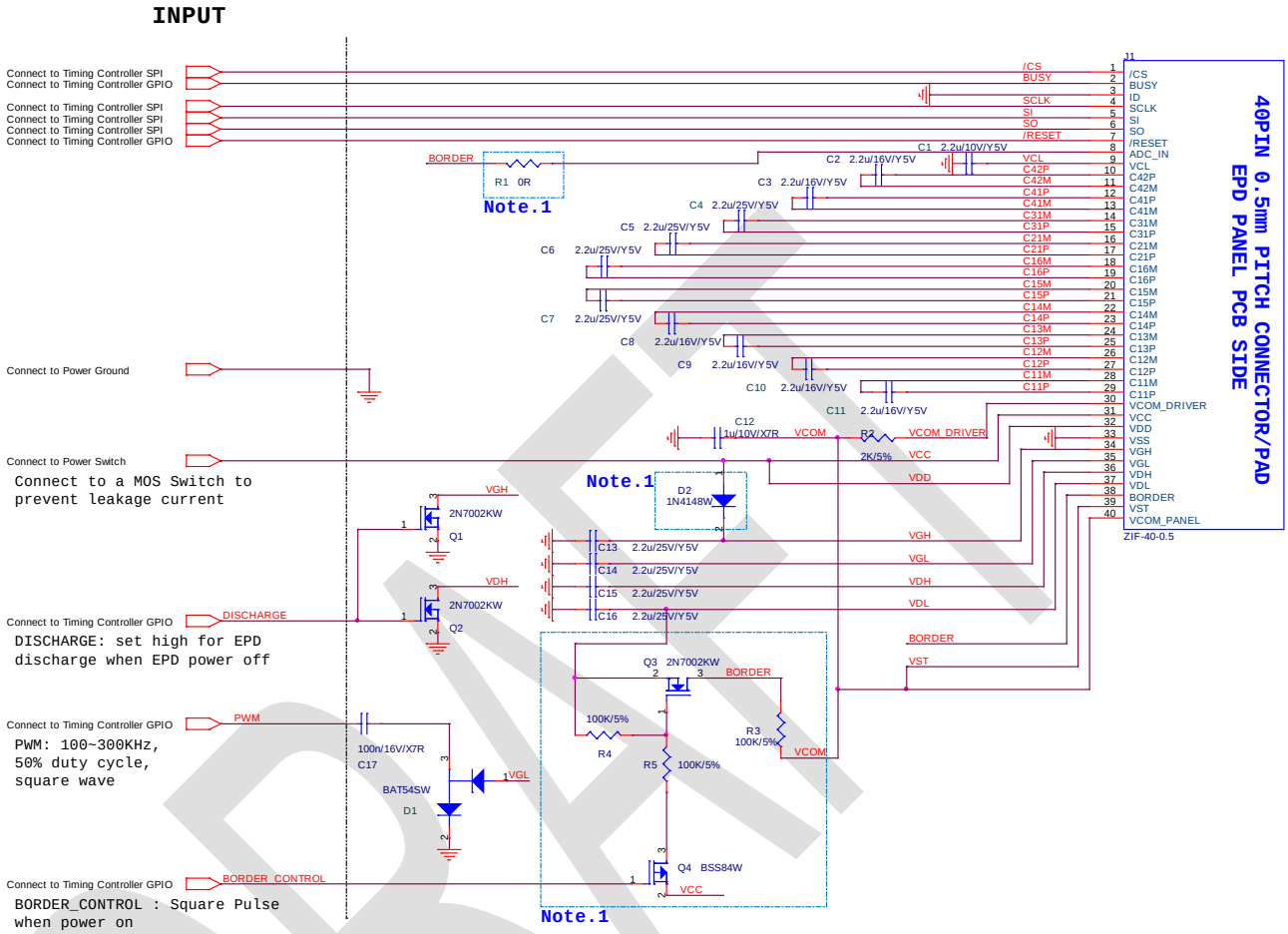
1. V_{DD} and V_{CC} must be discharged promptly after power off
2. 2.7" Pin.1 location



3. Pin. 8 (PWNON), it has an internal pull-up resistor. It's ok to float it.

1.3.4 Use G1's PCBA to drive the EPD with G2 Driver IC

Below is the reference circuit if you have arranged the PCBA that drove the EPD with G1 Driver IC already.



Note:

1. Hardware setting for different size:

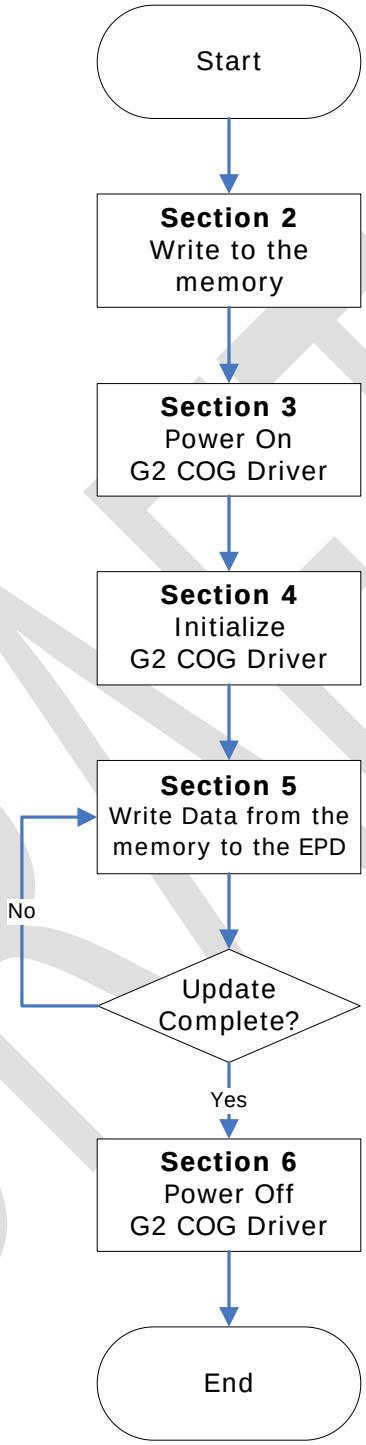
	R1	Q3,Q4,R3,R4,R5	D2
1.44 inch & 2 inch	Mounted	No Mounted	Mounted
1.9", 2.6" & 2.7 inch	No Mounted*1	Mounted	No Mounted

If users want to drive the EPD with G2 Driver IC by the current PCBA (i.e. the reference circuit above). Below items are the steps needed to do.

- Keep hardware unchanged as above.
  - Keep Resistor R1 open.
  - Keep BORDER CONTROL (Q3, Q4, R3, R4, and R5) circuit mounted.
- Modify SPI data as the following sections described.
- Disable the Timing Controller GPIO pin, PWM. Keep PWM signal as either 1 or 0.
- No matter what size EPD is, use same power off sequence as following section.

1.4 EPD Driving Flow Chart

The flowchart below provides an overview of the actions necessary to update the EPD. The steps below refer to the detailed descriptions in the respective sections.



1.5 Controller

The diagram below provides a signal control overview during an EPD update cycle. The diagram is divided into

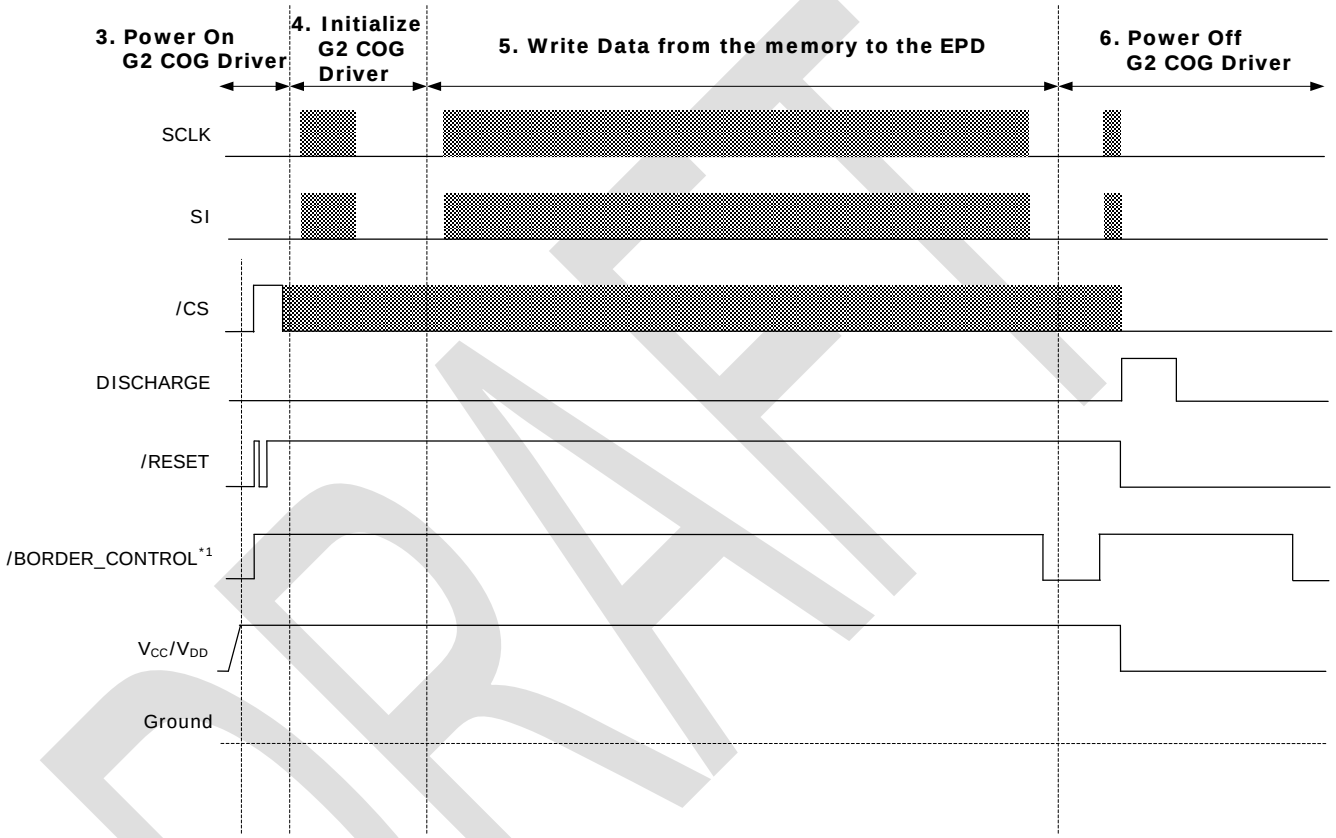
"3. Power On G2 COG Driver",

"4. Initialize G2 COG Driver",

"5. Write data from the memory to the EPD",

"6. Power Off G2 COG Driver",

The number and title matches a section title in this document.



Note:

1. /BORDER_CONTROL:
   /BORDER_CONTROL is used to keep a sharp border while taking care of the electronic ink particles. For implement this function, developer needs to use a Timing Controller pin to control this signal.

   (This function is only used for 2.7" EPD Panel)

1.6 SPI Timing Format

SPI commands are used to communicate between the Timing Controller and the G2 COG Driver. The SPI format used differs from the standard in that two way communications are not used, and CS is pulled high then low between clocks. When setting up the SPI timing, PDI recommends verifying the control signals for the overall waveform in Section 1.5, next verify the SPI command format and SPI command timing both in this section.

The maximum SPI clock speed that the G2 COG Driver can accept is 20MHz.

The SPI mode is 0.

- Below is a description of the SPI Format:

  SPI (0xI, 0xD_1, 0xD_2, 0xD_3 …)

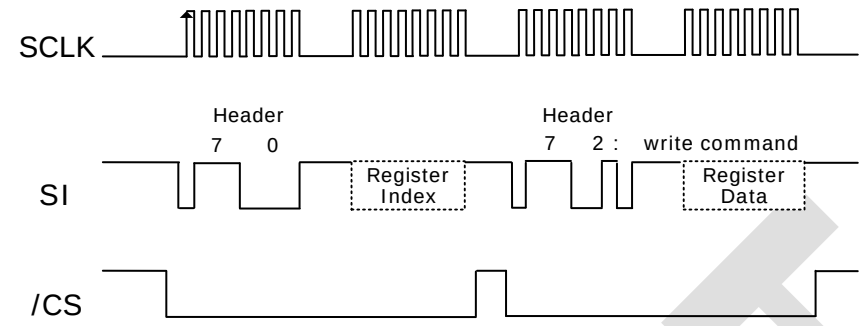
  Where:

  I is the Register Index and the length is 1 byte
  $D_{1\sim n}$ is the Register Data. The Register Data length is 1 or 110 bytes depending on which Register Index is selected.

Register Index	Number Bytes of Register Data
0x01	8
0x02	1
0x03	1
0x04	1
0x05	1
0x07	1
0x08	1
0x09	1
0x0A	< 110
0x0B	1
0x0F	1

- Before sending the Register Index, the SPI (SI) must send a 0x**70** header command.
- Likewise, the SPI (SI) must send a 0x**72** is the header command prior to the Register Data. The flow chart and detailed description can be found in the next page.
- Number Bytes of Register Index (0x0A) is depends on which panel size is used.

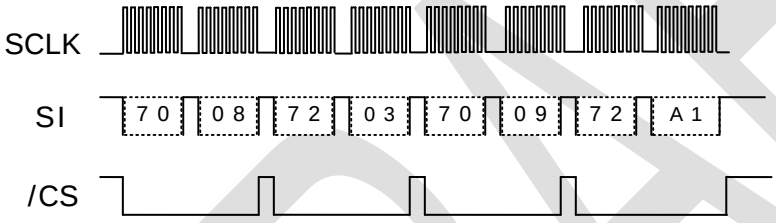
- SPI write command signals and flowchart(SPI):



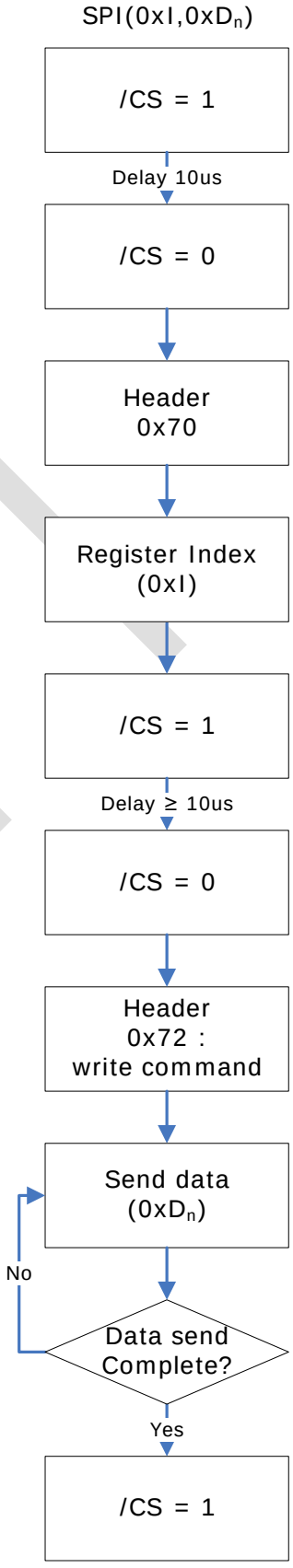
/CS must be set High then Low between Register Index and Register Data

For example:

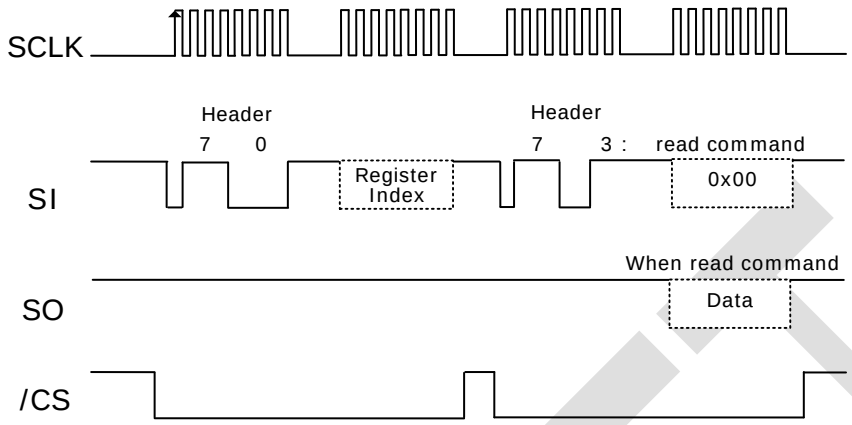
To send two continue SPI write commands:
SPI(0x08,0x03) and SPI(0x09, 0xA1)



If register data is larger than two bytes, you must input data continuously without setting Register Index again.



- SPI read command signals and flowchart(SPI_R):

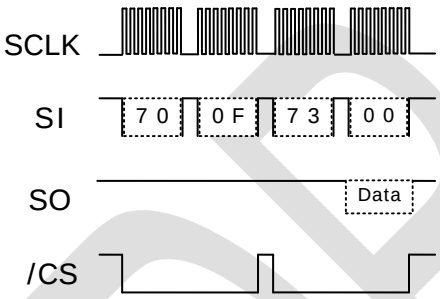


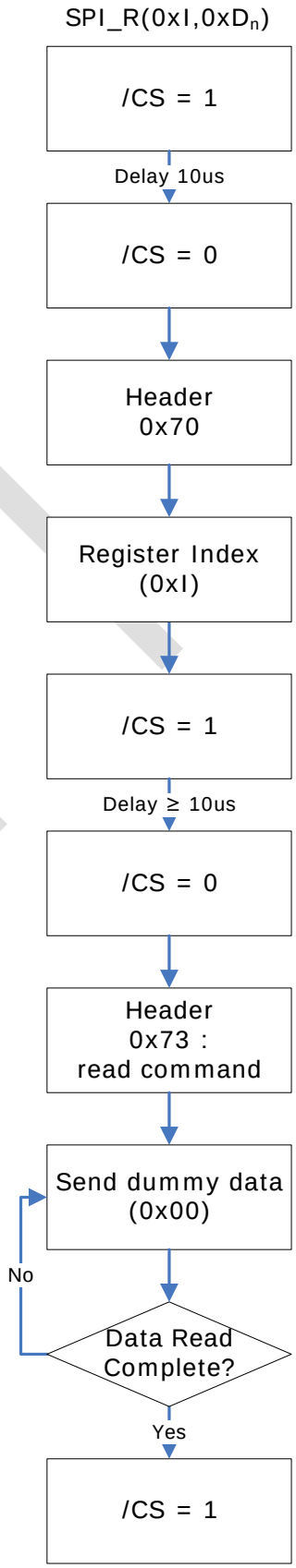
/CS must be set High then Low between Register Index and Register Data

For example:

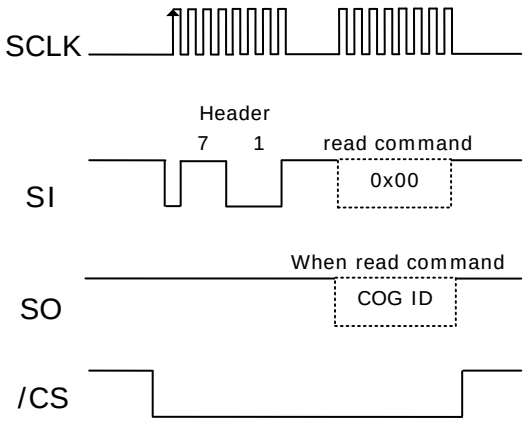
To send one SPI read command:

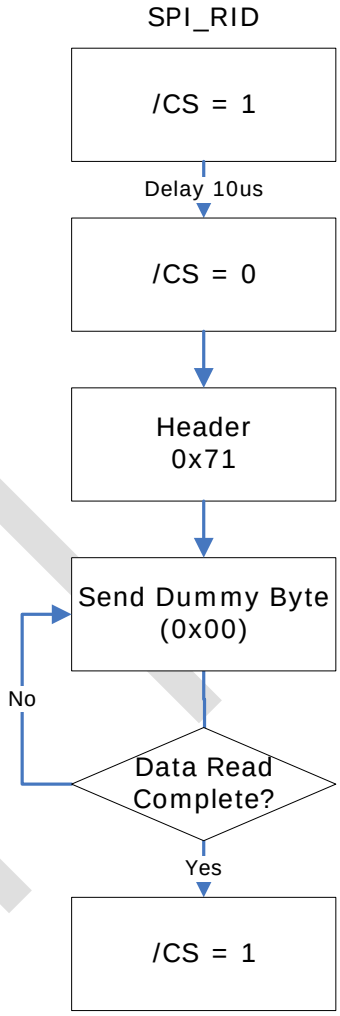
SPI_R(0x0F,0x00)





- SPI read COG ID and flowchart(SPI_RID):

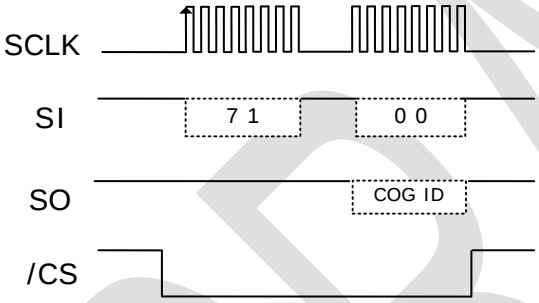




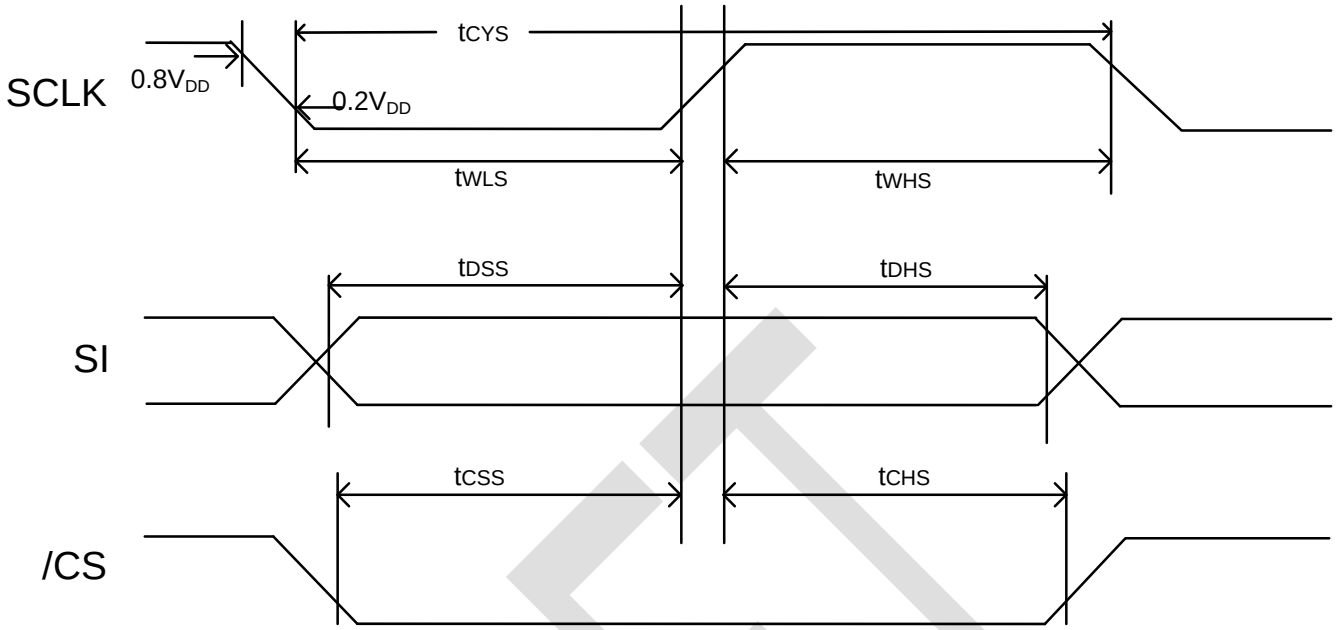
/CS must be set High then Low between Register Index and Register Data

For example:

To send one SPI read Command to COG ID(SPI_RID):



- SPI command timing (mode 0)



VCC = 2.3 to 3.6V **Temp = -25 to 50℃**

Item	Signal	Symbol	Min.	Typ.	Max.	Unit	Remark
Serial clock cycle	SCLK	tCYS	50	-	-	ns	
SCLK high pulse width	SCLK	tWHS	25	-	-	ns	
SCLK low pulse width	SCLK	tWLS	25	-	-	ns	
Data setup time	SI	tDSS	12	-	-	ns	
Data hold time	SI	tDHS	12	-	-	ns	
CSB setup time	/CS	tCSS	12	-	-	ns	
CSB hold time	/CS	tCHS	20	-	-	ns	

2 Write to the Memory

Before powering on G2 COG Driver, the Developer should write the new pattern to image buffer, either SRAM or flash memory. The image pattern must be converted to a 1 bit bitmap format (Black/White) in prior to writing.

One buffer space should be allocated to store new pattern. The new pattern will be written to the EPD. The table below list the buffer space size required for each EPD size.

EPD size	Image resolution(pixels)	image Buffer (bytes)
1.44”	128 x 96	3,072
2"	200 x 96	2,400
2.7”	264 x 176	5,808

3 Power On G2 COG Driver

This flowchart describes power on sequence for the G2 COG Driver.

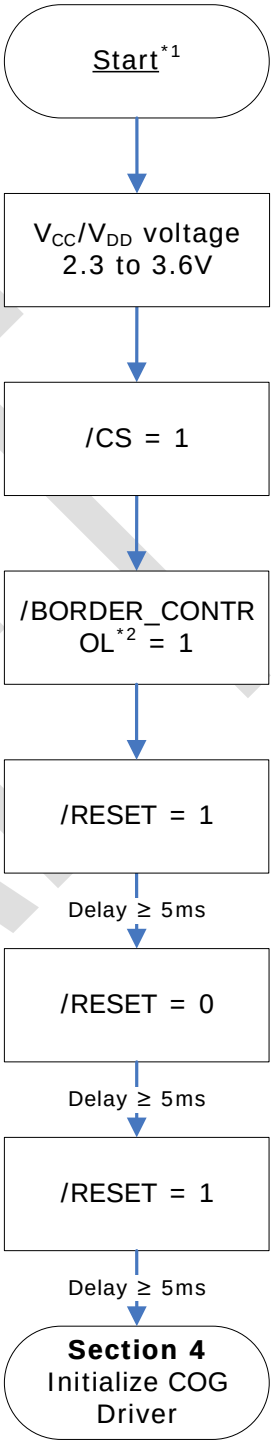
1. Start :

   Initial State:

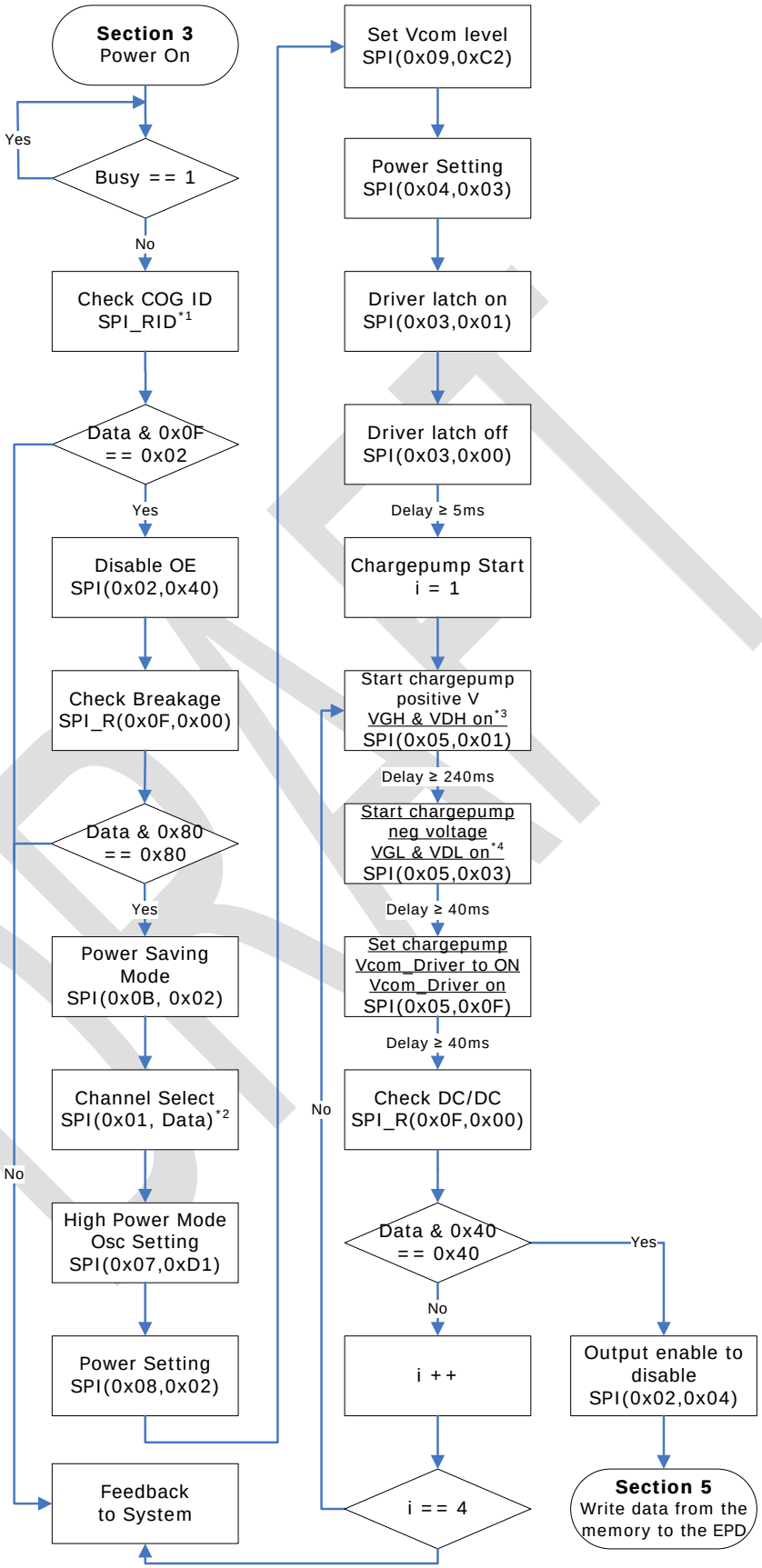
   VCC/VDD = 0

   /RESET, /CS, /BORDER_CONTROL*2, SI, SCLK = 0

2. /BORDER_CONTROL:
   /BORDER_CONTROL is used to keep a sharp border while taking care of the electronic ink particles. For implement this function, Developer needs to use a Timing Controller pin to control this signal.
   (This function is only used in 2.7" EPD Panel)



4 Initialize G2 COG Driver



Note:

1. SPI has two modes: SPI write command (SPI) and SPI read command (SPI_R), please refer"1.6 SPI Timing Format" for detail. SPI_R (0x72, 0x00) is used to check the COG Driver ID.
   - G1 COG Driver ID is 0x01.
   - G2 COG Driver ID is 0x02
2. SPI(0x01, Data):
   - Different by each size
     - 1.44": SPI(0x01, (0x0000,0000,000F,FF00))
     - 2": SPI(0x01, (0x0000,0000,01FF,E000))
     - 2.7": SPI(0x01, (0x0000,007F,FFFE,0000))
   - Take 2" for example, to send first byte protocol (0x70) before Register Index (0x01), and then send second byte protocol (0x72) before Register Data (0x0000,0000,01FF,E000).
3. Should measure VGH >12V and VDH >8V
4. Should measure VGL <-12V and VDL <-8V

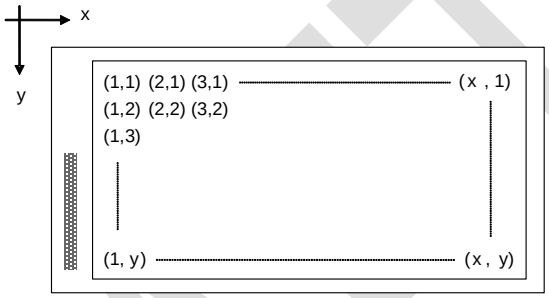
5 Write Data from the Memory to the EPD

This section describes how data should be sent to the G2 COG Driver which will update the display. The G2 COG Driver uses a buffer to store a line of data and then writes to the display.

5.1 Data Structure

- EPD Resolutions

EPD size	Image resolution(pixels)	X	Y
1.44”	128 x 96	128	96
2"	200 x 96	200	96
2.7”	264 x 176	264	176



- Data components
  - One Bit – A bit can be W (White), B (Black) or N (Nothing) bits. Using the N bit mitigates ghosting.
  - One Dot/pixel is comprised of 2 bits.
  - One line is the number of dots in a line.

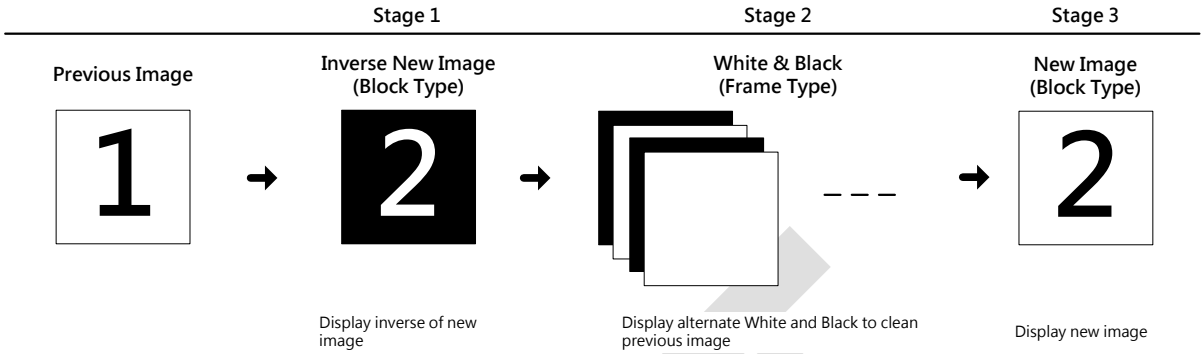
    For example:
    - The 1.44” uses 128 Dots to represent 1 Line.
    - The 2” uses 200 Dots to represent 1 Line.
    - The 2.7” uses 264 Dots to represent 1 Line.
    - The G2 COG Driver uses a buffer to write one line of data (Mapping) - interlaced

Data Bytes	Scan bytes	Data Bytes
1st – 25th (Odd)	1st - 24th	26th – 50th (Even)
2” Example: Because method to write is interlaced, write the even data bytes for a line {D(199,y),D(197,y), D(195, y), D(193, y)}…{D(7,y),D(5,y), D(3,y), D(1,y)}	2” Example: Write bytes for every scan line {S(96),S(95), S(94),S(93)}…{S(4),S(3), S(2), S(1)}	2” Example: Write the odd data bytes for a line {D(2,y),D(4,y), D(6,y), D(8,y)}…{D(194,y),D(196,y), D(198,y), D(200,y)}

  - One frame of data is the number of lines * rows. For example:
    - The 1.44” frame of data is 96 lines * 128 dots.
    - The 2” frame of data is 96 lines * 200 dots.
    - The 2.7” frame of data is 176 lines * 264 dots.

5.2 Overall Update Flow

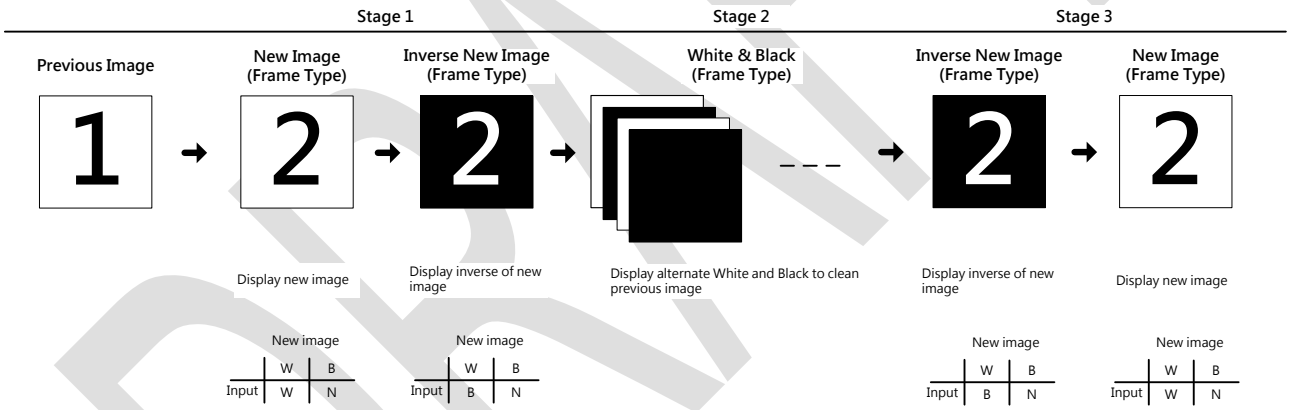
5.2.1 Room Temperature Flow (0℃≦T≦50℃)



Recommend：

(1) If the ghosting is at unacceptable level, users can increase repeat time or frame number for “White & Black” of Stage 2.

5.2.2 Low Temperature Flow (-25℃≦T＜0℃)



Recommend：

(1) If the ghosting is at unacceptable level, users can increase repeat time or frame number for “White & Black” of Stage 1 and Stage 2.

(2) Update once every 6 hours can get good ghosting level and optical performance.

5.3 Store a Line of Data in the Buffer

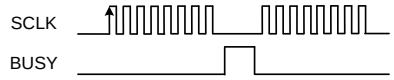
This section describes the details of how to send data to the G2 COG Driver. The G2 COG Driver uses a buffer to update the display line by line.

- 1.44" Input Data Order

Note :

1. When start transfer each Data Byte, users need to check BUSY pin.

Example :



2. If users cannot check BUSY pin, use delay at least 1 usec (10^{-6} second) Between byte-byte data for transfer image data.

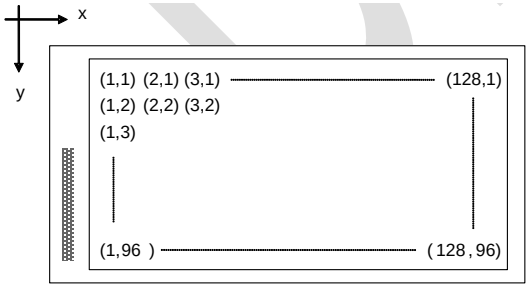
Data	bit1	bit0	Input	
D(x,y) x = 1~128 y = 1~96	1	1	Black	(B)
	1	0	White	(W)
	0	0	Nothing	(N)

Example:
D(127,y) = Black (B) = 11
D(125,y) = White (W)= 10
D(123,y) = Nothing (N) = 00
D(121,y) = Black (B) = 11
→ 1st Data Byte= 11,10,00,11

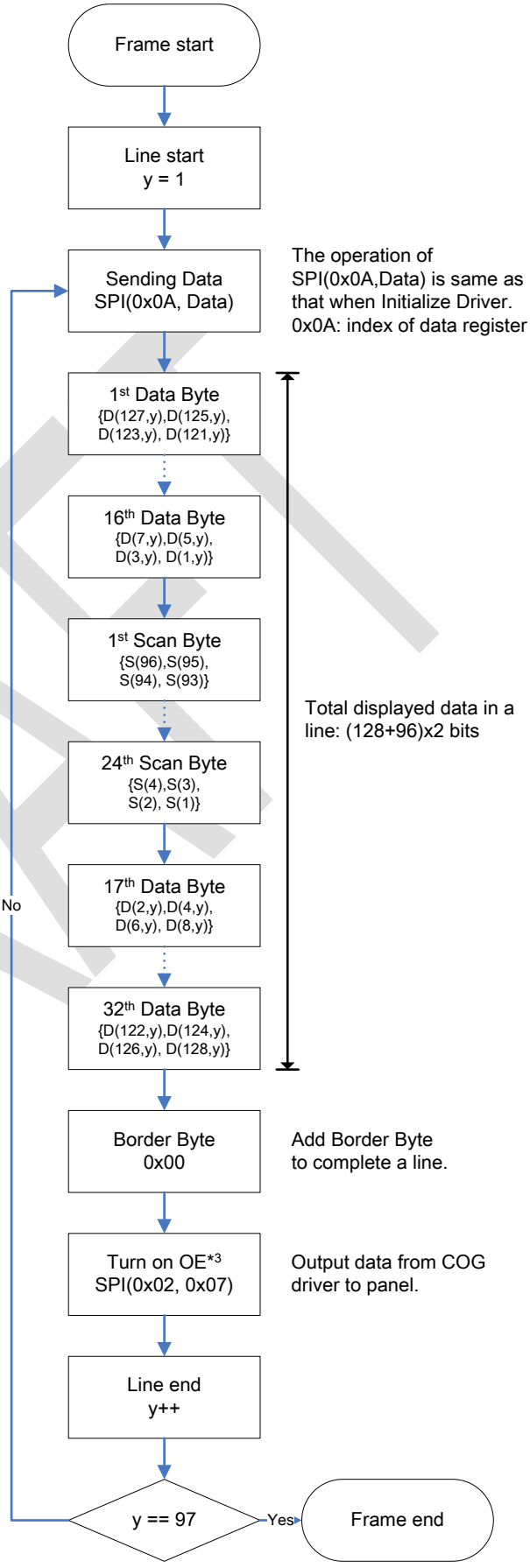
Scan	bit1	bit0	Input
S(1) ~S(96)	1	1	Scan on
	0	0	Scan off

Example:
When y = 2,
→ Only S(2) is Scan on (11) while others are Scan off (00). The image represented by Data Bytes will be displayed on 2nd horizontal line (i.e. Dot(1,2) ~ Dot(128,2)).

S(1) = Scan off = 00
S(2) = Scan on = 11
S(3) = Scan off = 00
S(4) = Scan off = 00
:
S(96) = Scan off = 00
→ 1st ~ 23rd Scan Byte = 00,00,00,00
→ 24th Scan Byte = 00,00,11,00



3. Turn on OE :
Output data from COG driver to panel.

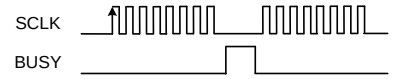


- 2” Input Data Order

Note :

1. When start transfer each Data Byte, users need to check BUSY pin.

Example :



2. If users cannot check BUSY pin, use delay at least 1 usec (10^{-6} second) Between byte-byte data for transfer image data.

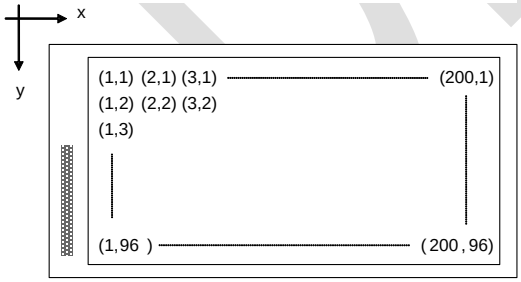
Data	bit1	bit0	Input	
D(x,y) x = 1~200 y = 1~96	1	1	Black	(B)
	1	0	White	(W)
	0	0	Nothing	(N)

Example:
D(199,y) = Black (B) = 11
D(197,y) = White (W)= 10
D(195,y) = Nothing (N) = 00
D(193,y) = Black (B) = 11
→ 1st Data Byte= 11,10,00,11

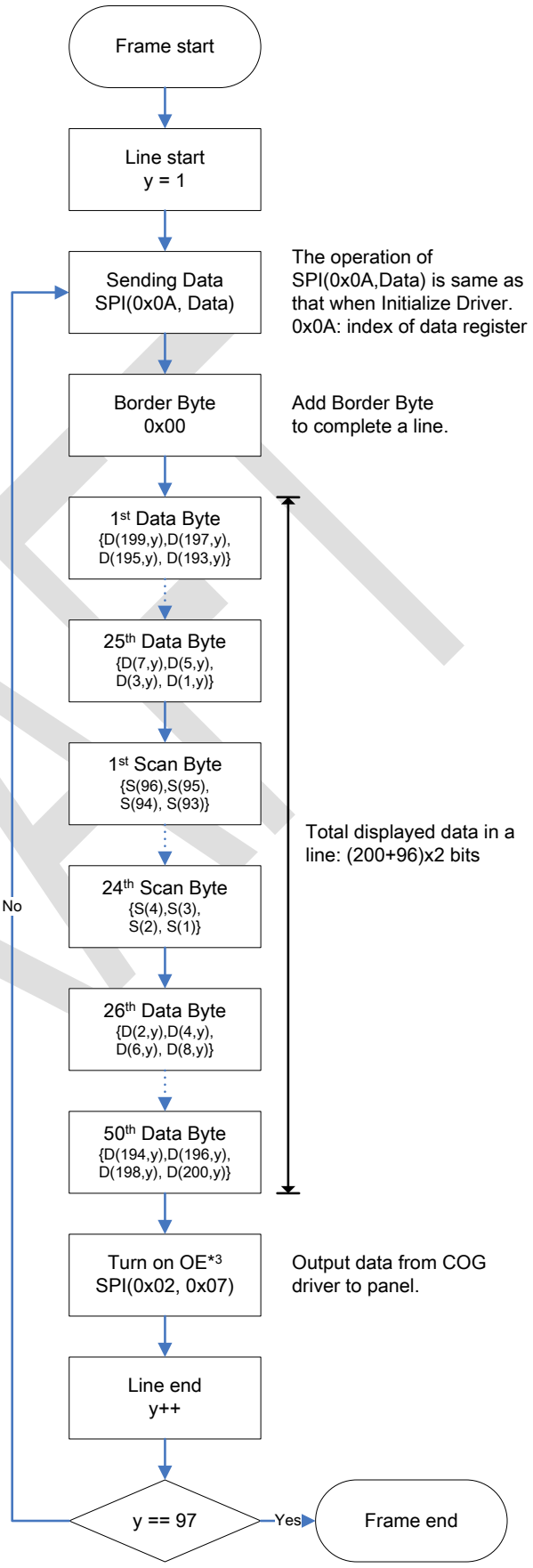
Scan	bit1	bit0	Input
S(1) ~S(96)	1	1	Scan on
	0	0	Scan off

Example:
When y = 2,
→ Only S(2) is Scan on (11) while others are Scan off (00). The image represented by Data Bytes will be displayed on 2nd horizontal line (i.e. Dot(1,2) ~ Dot(200,2)).

S(1) = Scan off = 00
S(2) = Scan on = 11
S(3) = Scan off = 00
S(4) = Scan off = 00
:
S(96) = Scan off = 00
→ 1st ~ 23rd Scan Byte = 00,00,00,00
→ 24th Scan Byte = 00,00,11,00



3. Turn on OE :
Output data from COG driver to panel.

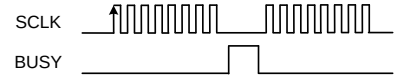


- 2.7" Input Data Order

Note :

1. When start transfer each Data Byte, users need to check BUSY pin.

Example :



2. If users cannot check BUSY pin, use delay at least 1 usec (10^{-6} second) Between byte-byte data for transfer image data.

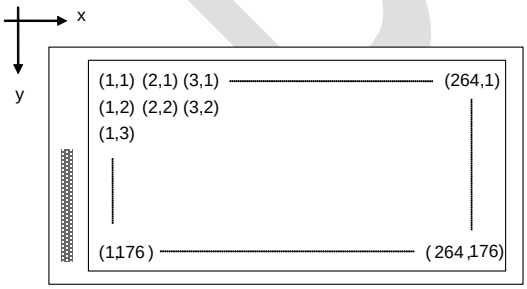
Data	bit1	bit0	Input
D(x,y) x = 1~264 y = 1~176	1	1	Black (B)
	1	0	White (W)
	0	0	Nothing (N)

Example:
D(263,y) = Black (B) = 11
D(261,y) = White (W)= 10
D(259,y) = Nothing (N) = 00
D(257,y) = Black (B) = 11
→ 1st Data Byte= 11,10,00,11

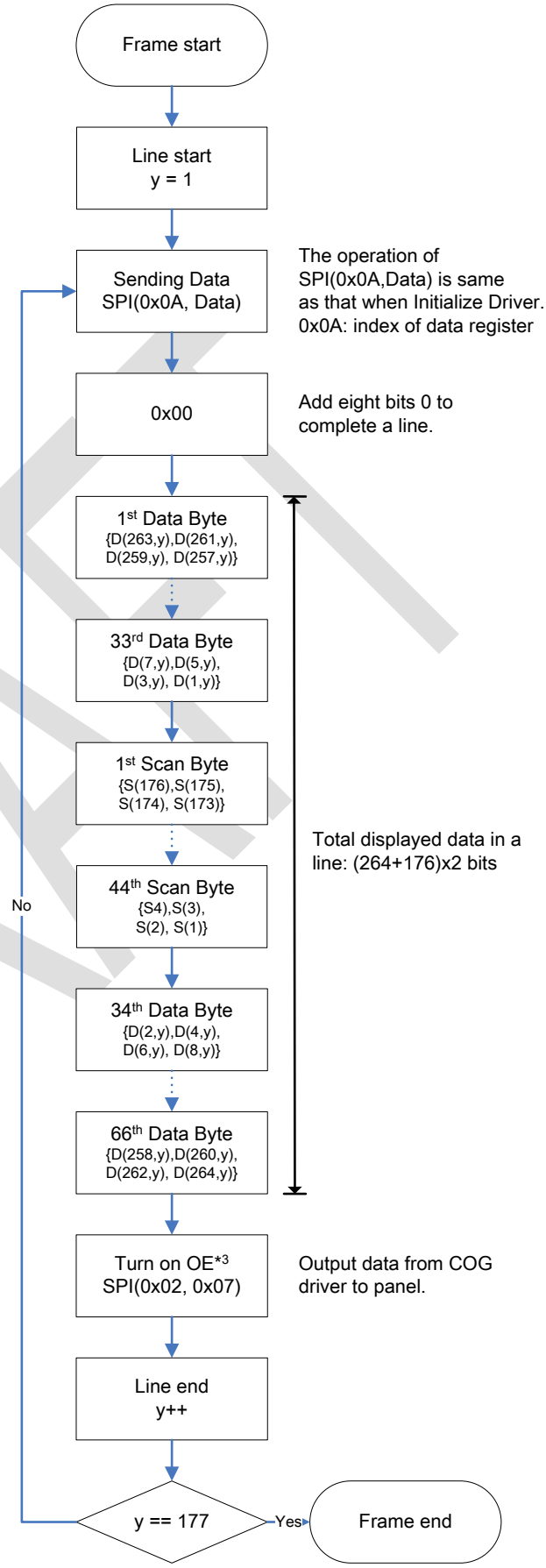
Scan	bit1	bit0	Input
S(1) ~S(176)	1	1	Scan on
	0	0	Scan off

Example:
When y = 2,
→ Only S(2) is Scan on (11) while others are Scan off (00). The image represented by Data Bytes will be displayed on 2nd horizontal line (i.e. Dot(1,2) ~ Dot(264,2)).

S(1) = Scan off = 00
S(2) = Scan on = 11
S(3) = Scan off = 00
S(4) = Scan off = 00
:
S(176) = Scan off = 00
→ 1st ~ 43rd Scan Byte = 00,00,00,00
→ 44th Scan Byte = 00,00,11,00



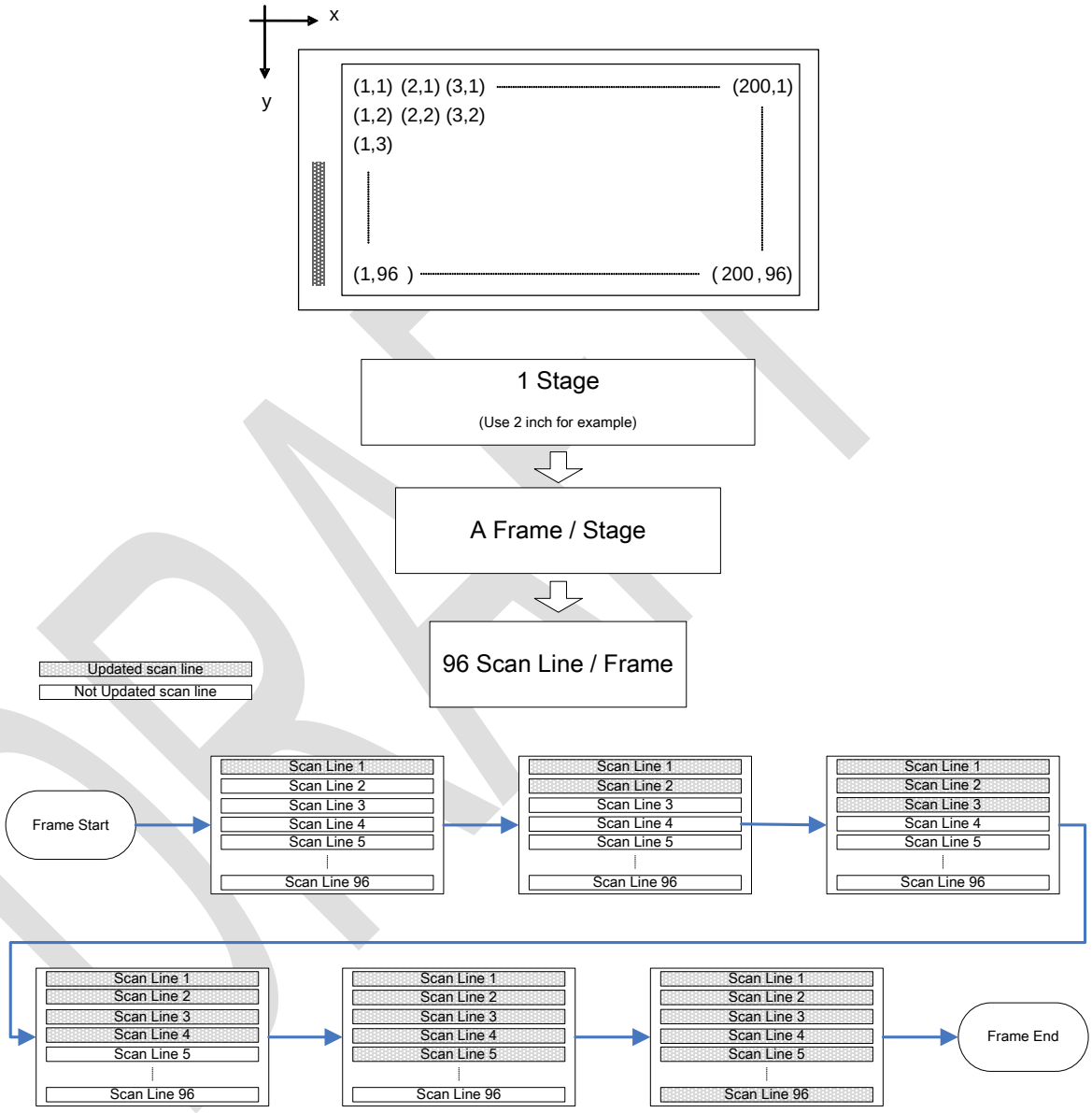
3. Turn on OE :
Output data from COG driver to panel.



5.4 Writing to the Display in Stages

This section contains the method to write to the display in stages. Rewrite the frame during each stage. There are two different ways, Block Type and Frame type, to scan the display.

5.4.1 Frame Type



Note :

Frame Type means turn on EPD scan lines line by line continuously to complete a frame. In a Frame Type Stage, you need to turn on first scan line (others scan lines are off), then turn on second scan line (the others scan lines are off) Until last scan line turn on. If you need to do more than one frame, you only do above action (i.e scanning from first line to last line) again.

- **Frame Type Flow**

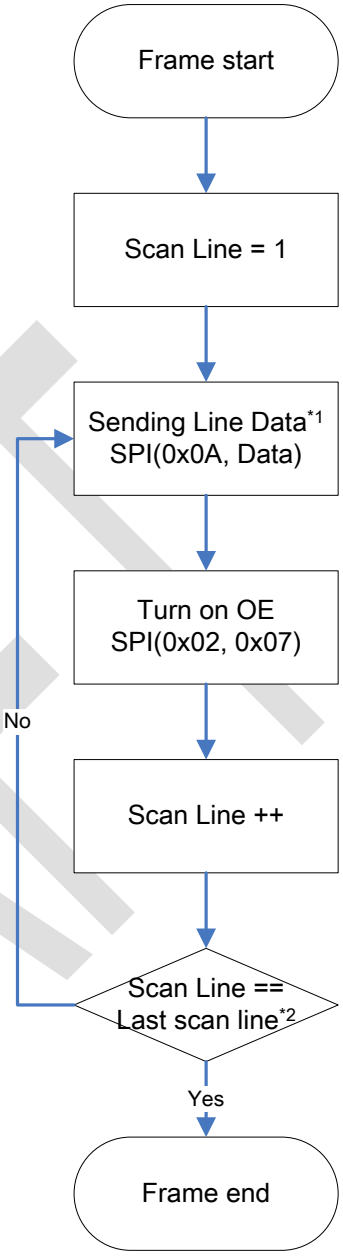
Note :

1. Line Data :
   One line data of 1.44" EPD Panel has 57 Bytes
   (include a Border Byte)

   One line data of 2" EPD Panel has 75 Bytes
   (include a Border Byte)

   One line data of 2.7" EPD Panel has 111 Bytes
   (include a Dummy Byte)

2. Last scan line :
   Total scan of 1.44" EPD Panel → 96 scan line
   Total scan of 2" EPD Panel → 96 scan line
   Total scan of 2.7" EPD Panel → 176 scan line



5.4.2 Block Type

This type drives the portion lines of an EPD. It can reduce the refresh or recharge time of the line. Therefore need to shift the portion lines (*Block*) in a fixed number of lines (*Step*) until finish all lines (*Frame number*). The last Frame needs to drive "Nothing" at the last *Step* in each *Block*. The Nothing is included in *Block*. In this type of scan, you need to decide three variables. *Frame number*, *Block* and *Step*, use these three variables to complete a stage.

***Frame number*:**

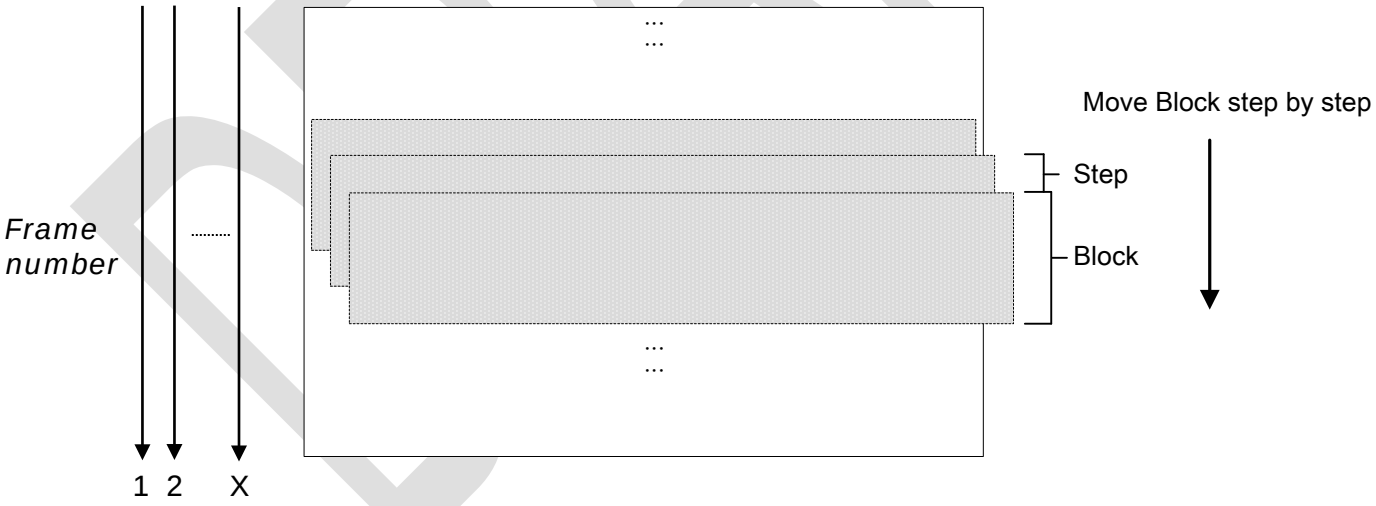
Frame number is number of *Block* moving from top to bottom of display. The last frame needs to drive nothing at the last *Step* in each *Block*.

***Block*:**

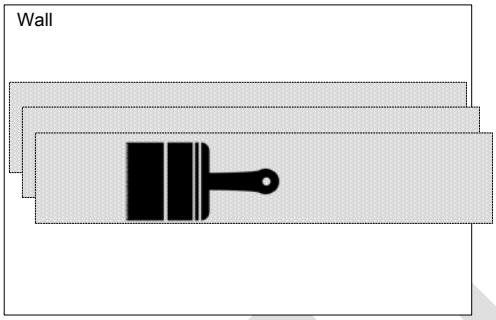
Block is a portion of total lines of EPD. It can decide the refresh or recharge time of each line. A smaller *Block* gets the fast refresh or recharge time of each line, whereas a bigger *Block* would be slower. And the number of *Block* should be divisible by the number of *Step*.

***Step*:**

Step means the *Block* will be shifted how many lines. It decides each line will be scanned how many times. A smaller *Step* gets more scan times, whereas a bigger *Step* would be less. And the number of total lines should be divisible by the number of *Step*.



Block Type update is similar to painting a wall by a brush. The width of brush is *Block*. Every time, you paint horizontally then move down certain distance, *Step.* Then paint again until finish the whole wall. If the painting is not thick enough, you will repeat above action again until getting thick enough painting. The repetition is *Frame*.



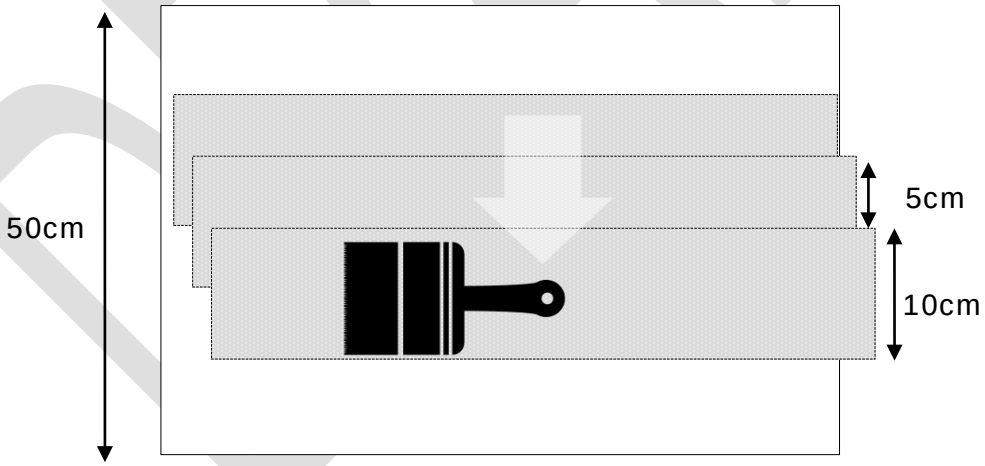
Example:

A 50cm height wall, a 10cm width brush, we move down brush in 5cm step. We must ensure the painting on the whole wall is same thickness.

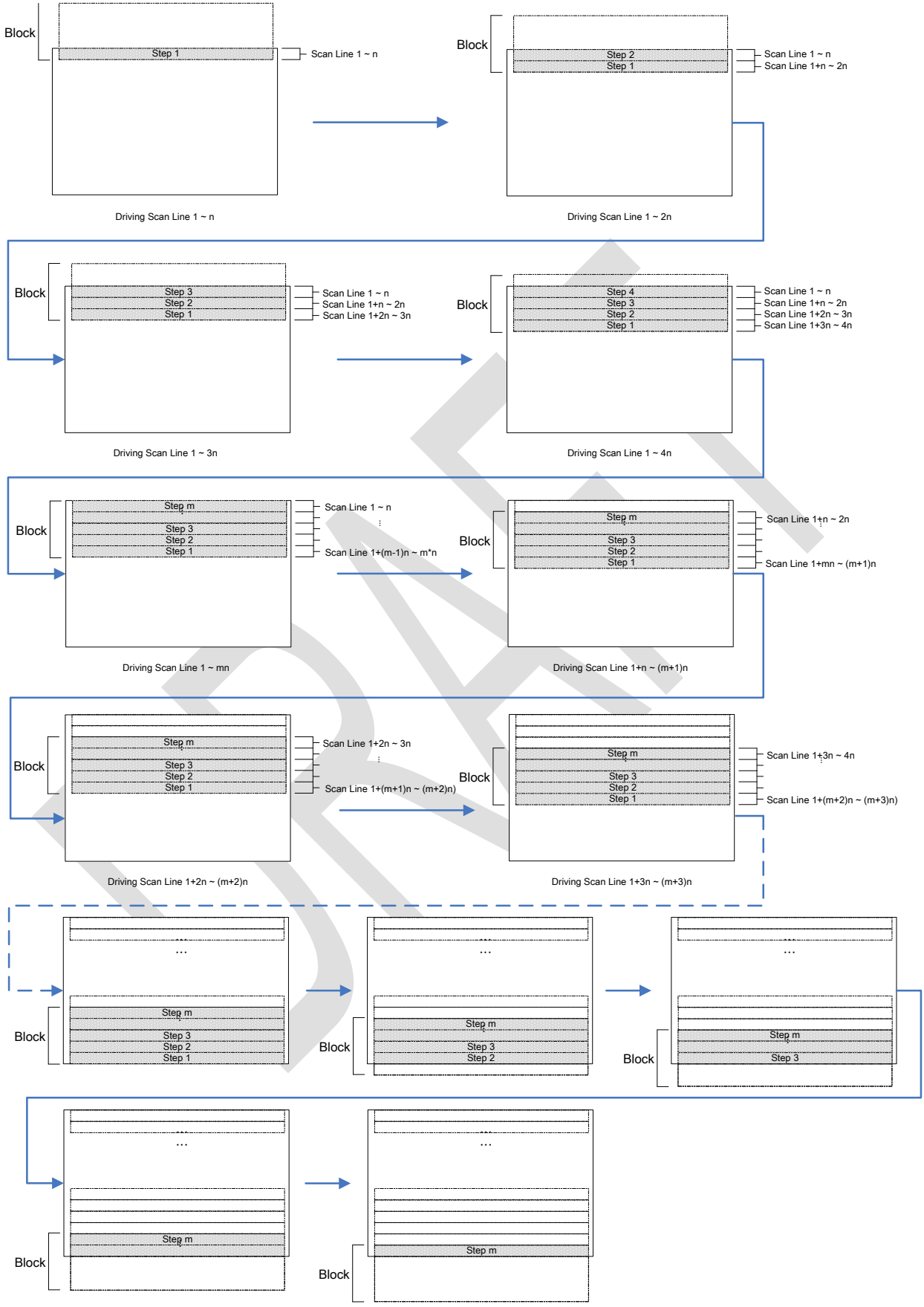
We paint the wall by this order.

Top 0~5cm → 0~10cm → 5~15cm → … → 40~50cm → 45~50cm (i.e. bottom 0~5cm).

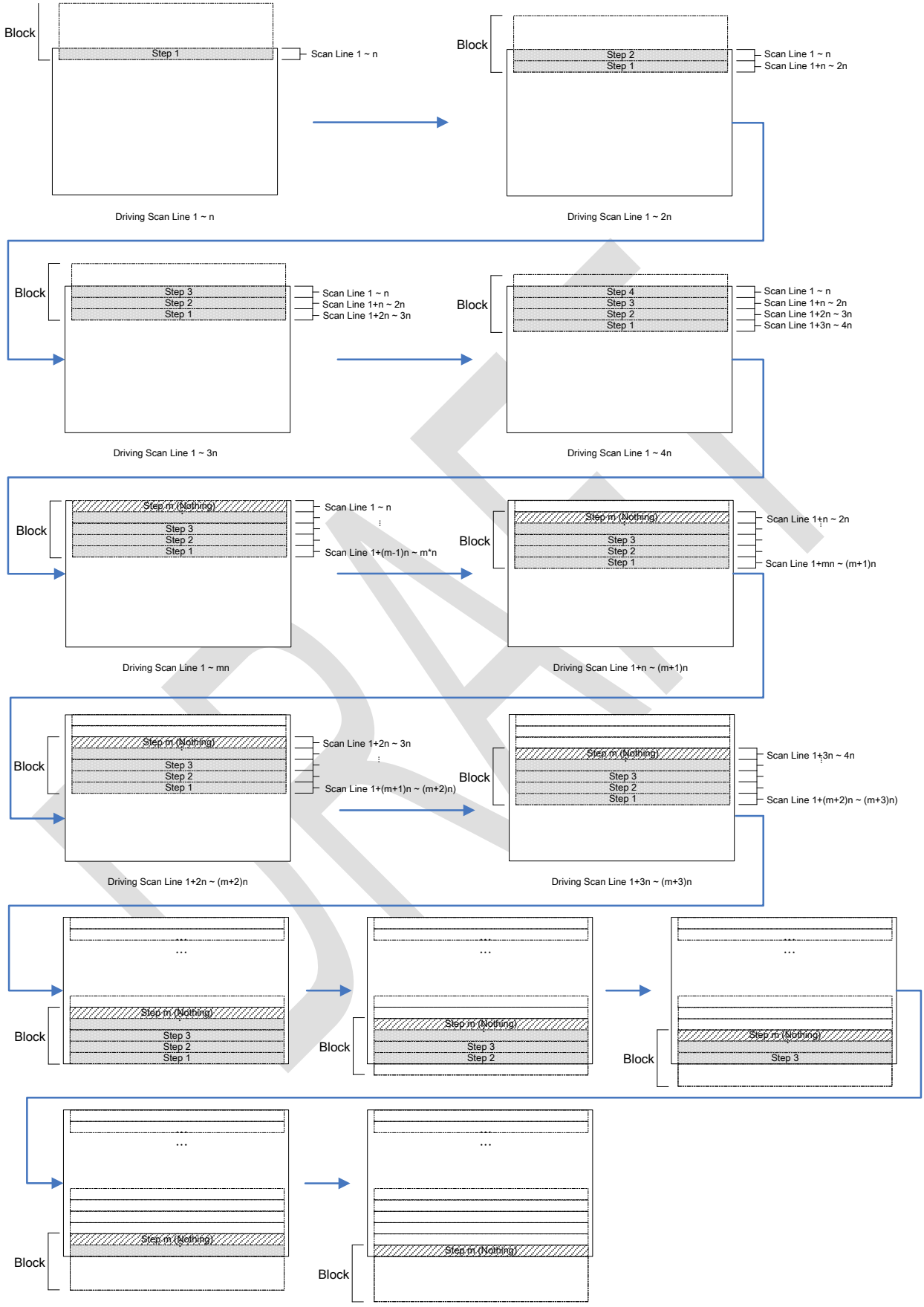
In this case, every cm of this wall is painted twice. If twice is not enough. We can repeat this top to bottom procedure one more time to get sufficient thickness.



- **Frame 1 ~ (X-1)**



- **Frame X (i.e. Last Frame)**



- **Block Type Flow**

Note :

1. Line Data :
   One line data of 1.44" EPD Panel has 57 Bytes (include a Border Byte)

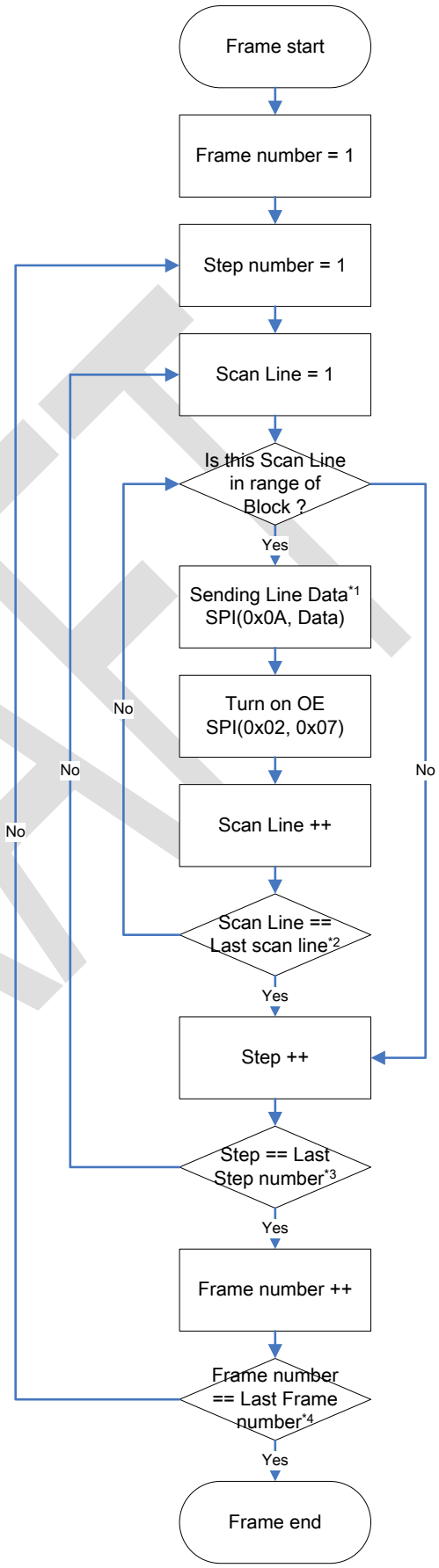
   One line data of 2" EPD Panel has 75 Bytes (include a Border Byte)

   One line data of 2.7" EPD Panel has 111 Bytes (include a Dummy Byte)

2. Last scan line :
   Total scan of 1.44" EPD Panel → 96 scan line
   Total scan of 2" EPD Panel → 96 scan line
   Total scan of 2.7" EPD Panel → 176 scan line

3. Last Step number :
   Total Step number is determine by Step and Block which user set.

4. Last Frame number :
   Total Step number is determine by user st.



- **Method to Select a suitable *Frame*/*Block*/*Step***

1. Measure Line Time of your TCon.

   Line Time: The time needed to finish the update of one scan line. i.e. The time to finish the flowchart in “Store a Line of Data in the Buffer”.

   Typically, Line Time is 0.3~1ms.

2. Determine the suitable width of *Block* (i.e. # of scan line in a *Block*)

   Width of *Block* = Block Time / Line time

   Typically, **Block Time = 5~25ms**. 10ms is suggested in most of cases.
   If Line Time = 0.5ms
   We can set
   Width of *Block* = 10ms / 0.5ms = 20 scan lines

3. Determine width of Step

   Width of *Block* is multiple of width of *Step*.
   Typically, **width of *Step* can be 2, 3 or 4 scan lines.**

4. Determine *Frame*
   In one frame, the time every scan line driven is

   Block time * Width of *Block*/ Width of *Step*

   If Block time = 10ms, Width of Block = 20, Width of Step = 2.

   10ms * 20 / 2 = 100ms

   In typical case, at room temperature, **the total time every scan line driven should be 200~400ms.** So in this example,

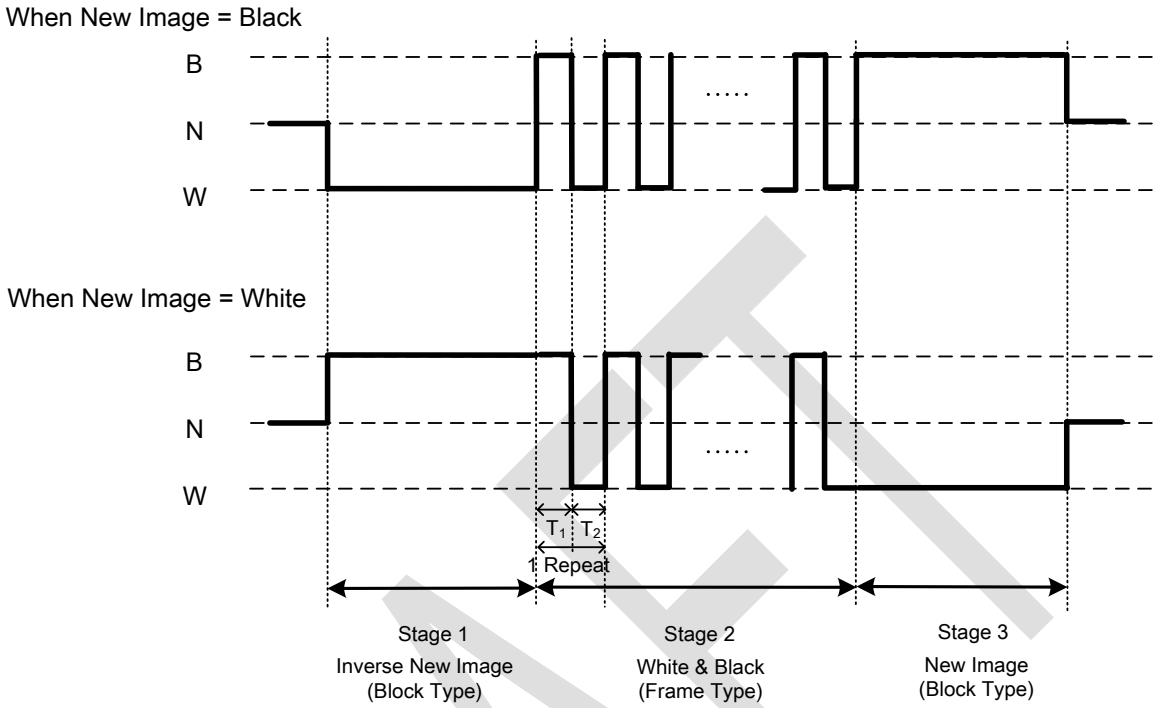
   Frame = 200~400ms / 100ms = 2~4.

   The larger *Frame*, the higher Contrast Ratio EPD has.

   Next page is the setting of PDi Jig.

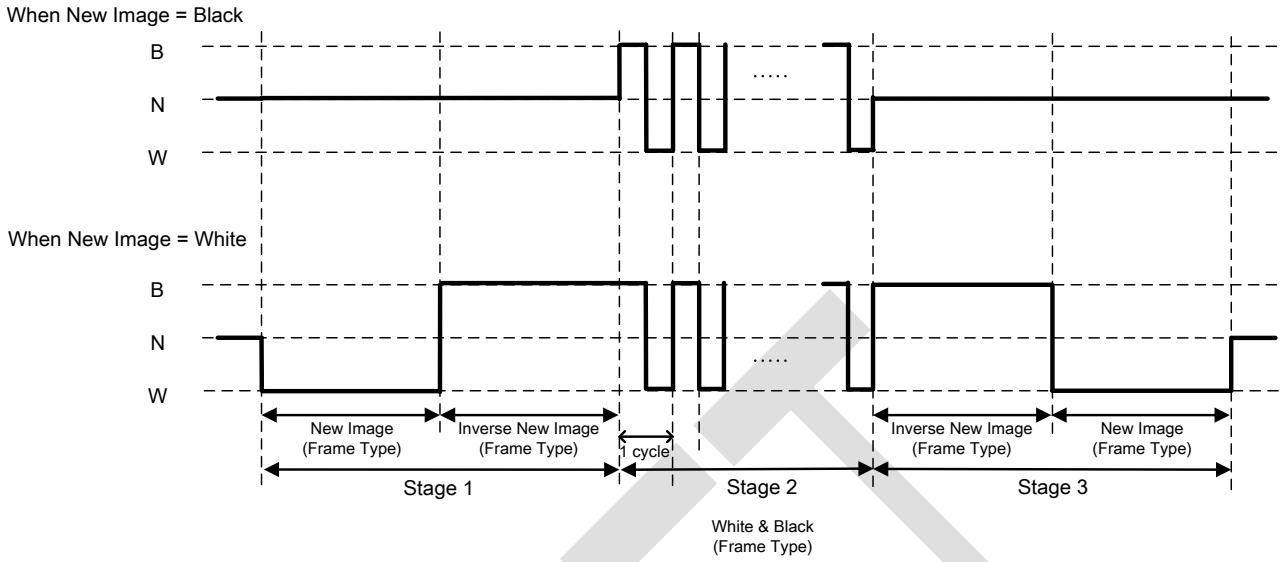
5.5 Driving Waveform and Temperature Factor in Stages

5.5.1 Room Temperature (0℃≦T≦50℃)



Temperature Range (℃)	Panel Size (inch)	Stage 1			Stage 2			Stage 3			Total time (sec)
		Frame number (frame)	Block time (ms)	Step (Scan line)	T_1 (ms)	T_2 (ms)	Repeat	Frame number (frame)	Block time (ms)	Step (Scan line)	
50 ≧ T > 40	2.7	4	16	2	155	155	4	4	16	2	7.6
	2	4	48	2	155	155	4	4	48	2	7.6
40 ≧ T > 10	2.7	2	16	2	155	155	4	2	16	2	3.8
	2	2	48	2	155	155	4	2	48	2	3.8
10 ≧ T ≧ 0	2.7	3	16	2	310	310	4	3	16	2	6.32
	2	3	48	2	310	310	4	3	48	2	6.32

5.5.2 Low Temperature (-25℃≦T＜0℃)



1.44” Temperature Factor

Temperature Range (℃)	Stage 1		Stage 2			Stage 3		Total Time (Sec)
	New Image (ms)	Inverse New Image (ms)	White (ms)	Black (ms)	Cycle	Inverse New Image (ms)	New Image (ms)	
0 ≧ T ＞ -5	245	1960	950	950	12	245	1960	27.2
-5 ≧ T ＞ -10	445	3560	1250	1250	9	445	3560	30.5
-10 ≧ T ＞ -15	745	5960	1650	1650	12	745	5960	53
-15 ≧ T ＞ -20	1045	8360	2250	2250	12	1045	8360	72.8
≦ -20	1345	10760	2540	2540	13	1345	10760	90.2

2.0” Temperature Factor

Temperature Range (℃)	Stage 1		Stage 2			Stage 3		Total Time (Sec)
	New Image (ms)	Inverse New Image (ms)	White (ms)	Black (ms)	Cycle	Inverse New Image (ms)	New Image (ms)	
0 ≧ T > -5	245	1960	950	950	12	245	1960	27.2
-5 ≧ T > -10	445	3560	1250	1250	9	445	3560	30.5
-10 ≧ T > -15	745	5960	1650	1650	12	745	5960	53
-15 ≧ T > -20	1045	8360	2250	2250	12	1045	8360	72.8
≦ -20	1345	10760	2540	2540	13	1345	10760	90.2

2.7” Temperature Factor

Temperature Range (℃)	Stage 1		Stage 2			Stage 3		Total Time (Sec)
	New Image (ms)	Inverse New Image (ms)	White (ms)	Black (ms)	Cycle	Inverse New Image (ms)	New Image (ms)	
0 ≧ T > -5	545	4360	1080	1080	10	545	4360	31
-5 ≧ T > -10	745	5960	1580	1580	9	745	5960	41.8
-10 ≧ T > -15	1045	8360	2180	2180	10	1045	8360	62.4
-15 ≧ T > -20	1345	10760	2580	2580	9	1345	10760	70.6
≦ -20	1680	13440	2680	2680	11	1680	13440	89.2

Note:

1. Line time of PDi Jig is 0.462ms. (@2.7 inch EPD Panel)
2. Detailed temperature guaranteed operation range is listed in PDI EPD datasheets. The temperature range listed in this document is only for timing controller programming reference.
3. This table is tested with PDI jig.
4. If the ghosting is at unacceptable level, the EPD can be rewritten.

5.5.3 The Structure of the stage

- **Room Temperature** (0℃≦T≦50℃)

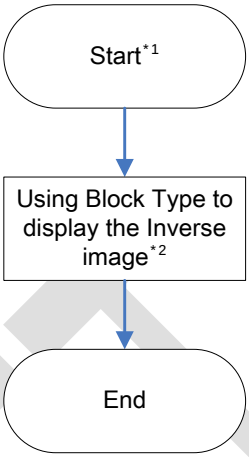
Stage 1 Inverse New Image

Note :

1. Start :
   Follow the end of COG initial sequence.

2. Inverse image :
   Input the inverse image of the new pattern.

3. New :
   The "New" mean the image that user want to show on EPD.



Inverse	Data		Border
New*3	B	W	
Input	W	B	N

Stage 2 White & Black

Note :

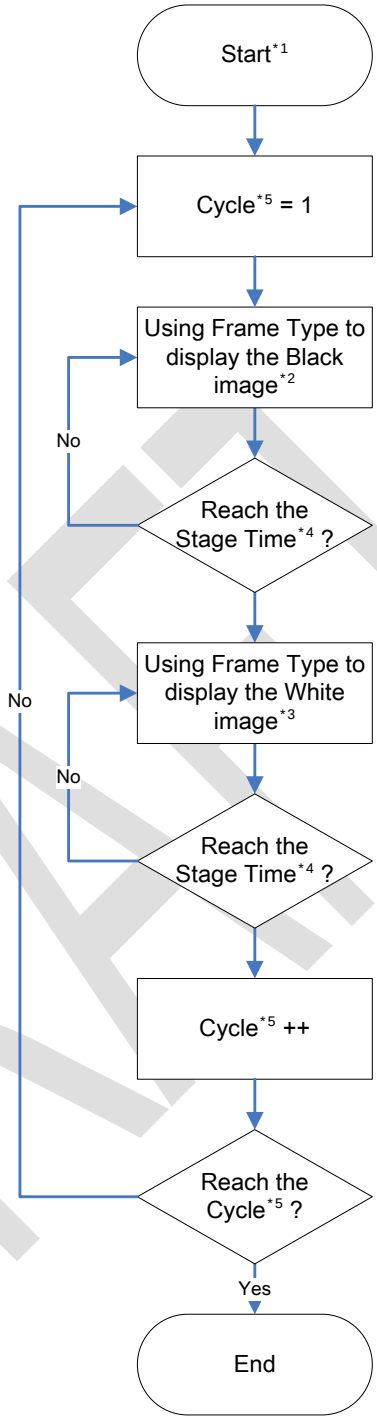
1. Start :
   Follow the end of the Stage 1.

2. Black image :
   Input the Black image by Frame Type. The Stage Time is different at different temperature.

3. White image :
   Input the White image by Frame Type. The Stage Time is different at different temperature.

4. Stage Time :
   Total display time for White image and Black image.

5. Cycle :
   White image and Black image repeat times. The repeat times is different at different temperature.



Black	Data		Border
Input	B	B	N

White	Data		Border
Input	W	W	N

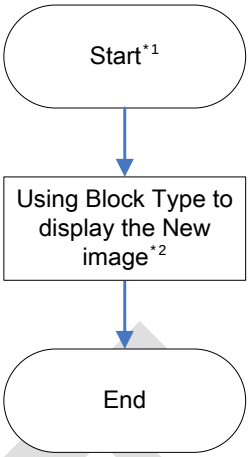
Stage 3 New Image

Note :

1. Start :
   Follow the end of the Stage 2.

2. New image :
   Input the New image of the new pattern.

3. New :
   The "New" mean the image that user want to show on EPD.



Inverse	Data		Border
New*3	B	W	
Input	B	W	N

- **Low Temperature** (-25℃≦T＜0℃)

Stage 1

• New Image

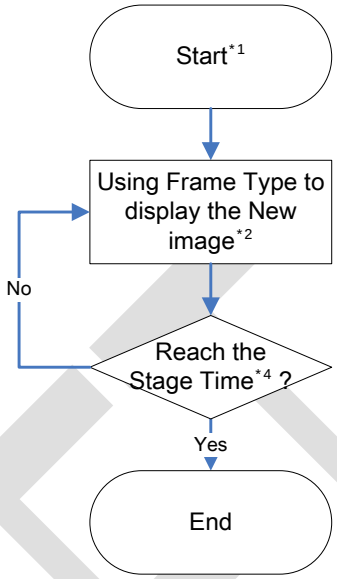
Note :

1. Start :
   Follow the end of COG initial sequence.

2. New image :
   Input the New image of the new pattern.

3. New :
   The "New" mean the image that user want to show on EPD.

4. Stage Time :
   The New image display times.



	Data		Border
New*3	B	W	
Input	N	W	N

• Inverse New Image

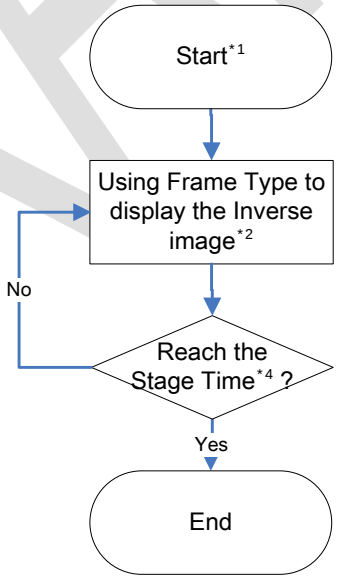
Note :

1. Start :
   Follow the end of New Image at Stage 1.

2. Inverse image :
   Input the inverse image of the new pattern.

3. New :
   The "New" mean the image that user want to show on EPD.

4. Stage Time :
   The Inverse image display times.



Inverse	Data		Border
New*3	B	W	
Input	N	B	N

Stage 2 White & Black

Note :

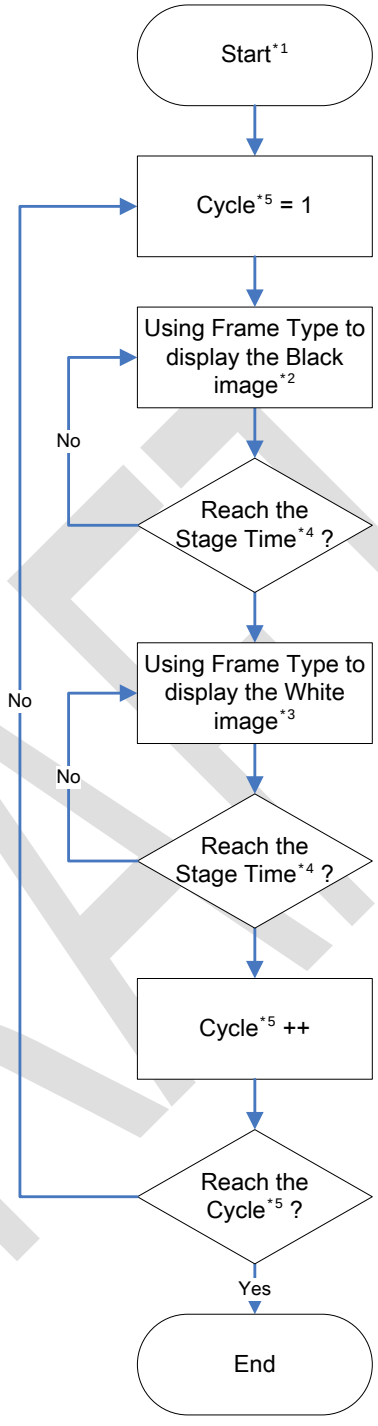
1. Start :
   Follow the end of the Stage 1.

2. Black image :
   Input the Black image by Frame Type. The Stage Time is different at different temperature.

3. White image :
   Input the White image by Frame Type. The Stage Time is different at different temperature.

4. Stage Time :
   Total display time for White image and Black image.

5. Cycle :
   White image and Black image repeat times. The repeat times is different at different temperature.



Black	Data		Border
Input	B	B	N

White	Data		Border
Input	W	W	N

Stage 3

• Inverse New Image

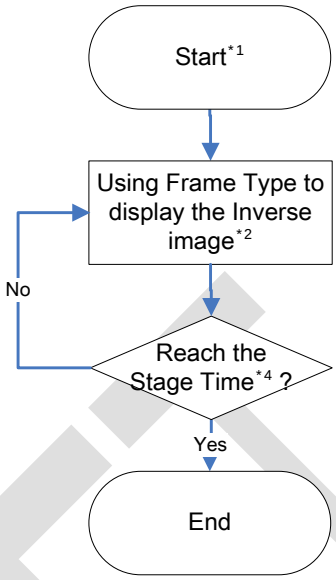
Note :

1. Start :
   Follow the end of Stage 2.

2. Inverse image :
   Input the inverse image of the new pattern.

3. New :
   The "New" mean the image that user want to show on EPD.

4. Stage Time :
   The Inverse image display times.



Inverse	Data		Border
New*3	B	W	
Input	N	B	N

• New Image

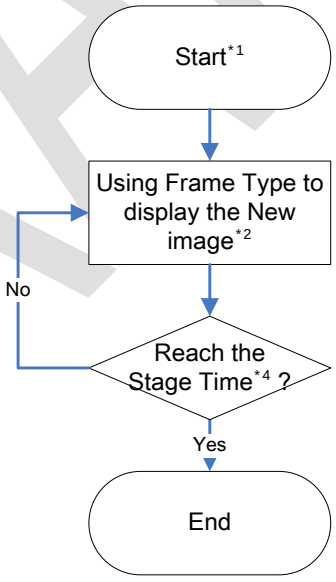
Note :

1. Start :
   Follow the end of Inverse New Image at Stage 3.

2. New image :
   Input the New image of the new pattern.

3. New :
   The "New" mean the image that user want to show on EPD.

4. Stage Time :
   The New image display times.



	Data		Border
New*3	B	W	
Input	N	W	N

6 Power off G2 COG Driver

1. Nothing Frame :
   Write a frame data

Panel size	Scan Line
1.44"	96
2"	96
2.7"	176

   Whose all D(x,y) are N(00). Scan Bytes operate normally.
   Scan lines are still turned on sequentially. This frame will make the image more uniform. Turn on OE SPI(0x02, 0x07) at the end of each line.
   For 1.44" & 2", need to set Border Byte before 1st Data Byte.
   Border Byte = 0x00 for 1.44" & 2".

2. Dummy Line :
   A line whose all Data Bytes are 0x00 and Scan Bytes are 0x00. Turning on OE SPI(0x02, 0x07) to complete this Dummy Line. Clear the register data before power off. Detail of data input is on page 29 ~ page 33.
   (This function is only used in 2.7")

3. /BORDER_CONTROL :
   For implement this function, users need to use a pin to control from microcontroller. When = 0, the /BORDER_CONTROL is ON and write to white. When = 1,the /BORDER_CONTROL is OFF. The reason for using /BORDER_CONTROL is to keep a sharp border and not have a charge on the particles of FPL. Voltage too long on these will produce a gray effect which is the optimal for long term operation.
   (This function is only used in 2.7")

4. External Discharge :
   For implement this function, users need to use a pin from microcontroller to control. This is important to avoid vertical lines.

5. If you use the flash memory for pattern store, please recheck flash in this phase and verify the old image flash is erased.

6. BORDER Dummy Line :
   Set Border Byte = 0xAA and write to white. A line whose a Border Byte is before 1st Data Byte and all Data Bytes are 0x55 and Scan Bytes are 0x00. Then must to set SPI(0x02,0x07) in the end of line for turn on output enable by COG control border and clear the register data before power off. Detail of data input is on page 29 ~ page 33.
   (This function is only used in 1.44" & 2")