



Extreme Low Power LCD Driver

GENERAL DESCRIPTION

The device EM6115 is an extremely flexible, ultra-low power and low voltage LCD segment driver supporting static, Mux2, Mux3 and Mux4 addressing with $\frac{1}{2}$ and $\frac{1}{3}$ biasing.

The internally generated LCD voltage levels assure a stable display contrast over the full IC supply range.

The internal segment-mapping directory allows display updates with minimal energy by keeping the serial data transfer at a strict minimum.

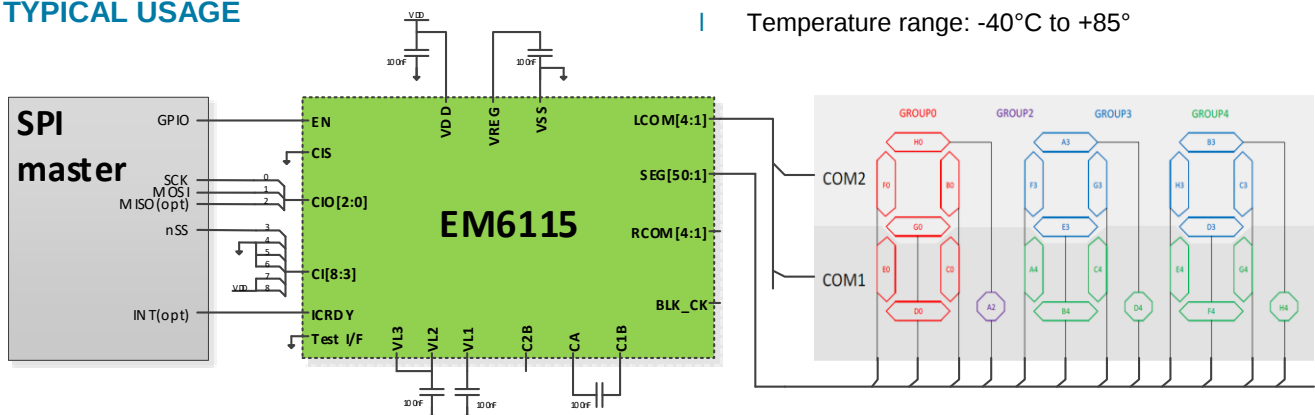
APPLICATIONS

- | Portable, battery operated devices
- | Wearables
- | IoT devices
- | Decentralized sensors
- | Always-on Displays
- | Weight scales, utility meters
- | Home appliances

AVAILABILITY

- | Naked die (for wirebonding assembly)
- | Others, please contact EM-Microelectronic-Marín

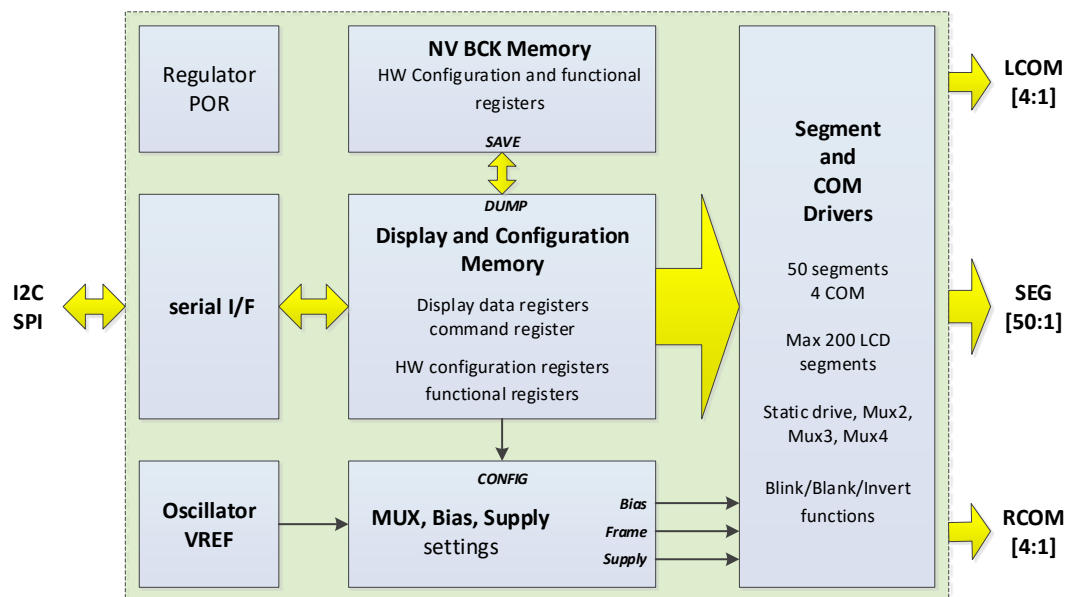
TYPICAL USAGE



FEATURES

- | Up to **50 SEG and 4 COM** physical lines, for a maximum of 200 physical segments.
- | For easier connection COM lines are provided on each side of the SEG lines (LCOM and RCOM).
- | The unused SEG and COM outputs can be disabled
- | Control of the LCD segments by 32 groups of logical segments (up to 8 bits each), configurable with a mapping dictionary.
- | Internal E²PROM for automatic configuration of operating parameters and segment mapping dictionary after reset or power-up.
- | Supported Mux rates: **Static, Mux2, Mux3, Mux4**
- | Mux2, Mux3, Mux4 can use either $\frac{1}{2}$ or $\frac{1}{3}$ biasing.
- | On-Chip generation of the LCD waveform and frame frequency.
- | **On-Chip programmable voltage reference** for the LCD Bias voltage generation (25mV steps).
- | Selectable **I²C** or **SPI** interface
- | Selectable blink behavior (global or segment-defined blink) and blink frequency
- | Blank function and Inverse function available
- | **Wide voltage range** from 1 V to 3.6 V range
- | **Ultra-low power operation**: 130 nA (at 3 V, Mux2, bias $\frac{1}{2}$ and without LCD)
- | **EN pin**, Switch-off mode below 10nA
- | Temperature range: -40°C to +85°

SIMPLIFIED BLOCKDIAGRAM





EM6115 DATASHEET

Table of Contents

1. Product Description	5
1.1. Operating modes	6
1.1.1. Block Diagram	7
1.2. Pin Description.....	8
2. Functional Description	10
2.1. LCD Addressing.....	10
2.1.1. LCD Waveforms	12
2.1.2. V _{REF} Reference.....	31
2.1.3. Static Drive	31
2.1.4. Multiplex Drive: Normal Mode.....	33
2.1.5. Multiplex Drive: Low power Mode	35
2.2. Programmable Groups of LCD Segments	37
2.2.1. Logical segments and groups.....	37
2.2.2. Dictionary.....	38
2.2.3. Example Dictionary.....	40
2.3. Communication Interface.....	44
2.3.1. I ² C Interface.....	44
2.3.2. SPI Interface.....	46
2.4. Command Set.....	49
2.5. Reset and Initialization of the LCD Segment Driver	50
2.6. Blink function with multiple Drivers	50
2.7. Internal registers.....	52
2.7.1. Command Register.....	53
2.7.2. Configuration Registers	55
2.7.3. Functional Registers	58
2.8. Engineering Mode.....	59
2.8.1. Access and functions of the engineering mode	59
2.8.2. EEPROM read operation	59
2.8.3. EEPROM write Operation.....	59
2.8.4. EEPROM correspondence to internal registers and dictionary	61
2.9. Analog System Functions	62
2.9.1. Voltage Regulator	62
2.9.2. Power on Reset	62
2.9.3. Oscillator.....	62
2.9.4. Voltage Reference.....	62
2.9.5. Voltage Generator	62
3. Electrical Specifications	64
3.1. Absolute Maximum Ratings	64
3.2. Handling Procedures	64

3.3. Operating Conditions	64
3.4. Electrical Characteristics at VDD=3V	65
3.5. Electrical Characteristics at VDD=1.55V	67
3.6. EEPROM Access – Specifications.....	69
3.7. Timing Characteristics	69
4. Typical Applications	72
5. Pad Location Diagram	75
6. PACKAGE INFORMATION	78
7. Customer delivery: Default configuration	78
8. ORDERING INFORMATION	79

1. PRODUCT DESCRIPTION

The device EM6115 is an extremely low power and low voltage LCD segment driver. The circuit includes an on-chip LCD supply voltages generator and supports static, Mux2, Mux3 and Mux4 addressing with $\frac{1}{2}$ and $\frac{1}{4}$ biasing. The internal voltage reference is adjustable in 25mV steps.

A maximum of 200 display segments can be addressed using the 50 segment lines (SEG) and the four common lines (COM). Host data interface uses either simplified I2C or SPI protocol.

To simplify the PCB all common lines are provided on the left AND the right side of the circuit. Unused COM and SEG outputs can individually be disabled to save power.

1.1. OPERATING MODES

An internal mapping directory allows easy segment grouping (32 groups of max 8 segments each). This mapping greatly reduces the complexity of the display update firmware as well as the necessary data transfer length.

Global BLINK, BLANK and INVERSE display function as well as individual BLINK bits are implemented to further reduce the display driver firmware complexity.

The internal E2PROM holds all configuration data, the operating parameters and the display mapping directory. At circuit start-up, these data are automatically copied into the local registers. Any configuration change can easily be saved in the E2PROM (Dump command).

While the EN pin is at low level, the EM6115 internal power is fully switched off while maintaining the selected I²C pull-up resistors. In this mode, the circuit consumes less than 10nA.

1.1.1. BLOCK DIAGRAM

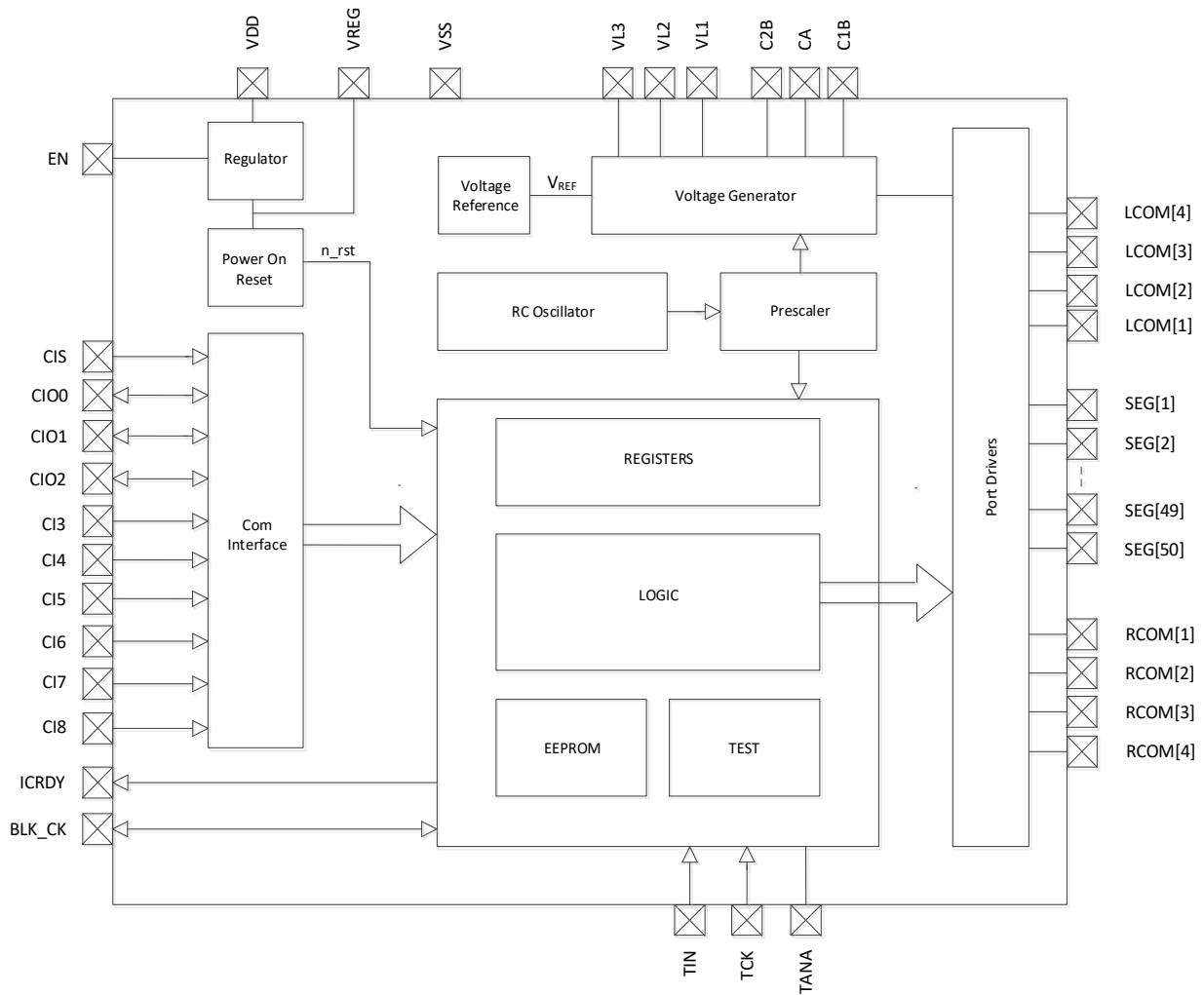


Figure 1-1 : Block diagram

1.2. PIN DESCRIPTION

#	Name	Type	Description	Remark
73	VDD	P	Power supply voltage input	
72	VSS	P	Ground	
71	VREG	P	Regulated voltage for digital part	Internal use only
57	EN	I	Device enable	It should not be left floating
56	ICRDY	O	Device ready signal	See Note ¹
58	CIS	I	I ² C/SPI COMM interface selection	See Note ²
59	CIO0/SCL/SCK	I/O	I ² C Clock or SPI Clock	It should not be left floating
60	CIO1/SDA/MOSI	I/O	I ² C Data or SPI Data In	It should not be left floating
61	CIO2/EN_IWPU/MISO	I/O	Enable I ² C internal Weak Pull-Up resistors or SPI data Output	See Note ³
62	CI3/EN_ISPU/nSS	I	Enable I ² C internal Strong Pull-Up resistors or SPI Slave Select (active low)	It should not be left floating
63	CI4/A0	I	I ² C address bit 0	It should not be left floating
64	CI5/A1/CK_POL	I	I ² C address bit 1 or SPI SCK Polarity	It should not be left floating
65	CI6/A2/CK_PHA	I	I ² C address bit 2 or SPI SCK Phase	It should not be left floating
66	CI7/A3/MSB_FIRST	I	I ² C address bit 3 or SPI MSB First selection	It should not be left floating
67	CI8/ICRDY_POL	I	ICRDY polarity	It should not be left floating
55	BLK_CK	I/O	Blink synchronization clock	See Note ⁴
69	TIN	I	Test mode input	Internal pulldown. Connect to VSS
68	TCK	I	Test Clock input	Internal pulldown. Connect to VSS
70	TANA	A	Analog test port	Internal pulldown. Connect to VSS
75	CA	A	External capacitor connector for charge pumps 1 & 2	
76	C1B	A	External capacitor connector for charge pump 1	
74	C2B	A	External capacitor connector for charge pump 2	
79	VL1	P	LCD power supply voltage	
78	VL2	P	LCD power supply voltage	
77	VL3	P	LCD power supply voltage	
51-54	RCOM[4:1]	O	Bus of COM lines located at the right of the SEG lines	They can be individually disabled
80-83	LCOM[4:1]	O	Bus of COM lines located at the left of the SEG lines	They can be individually disabled
1-50	SEG[50:1]	O	Bus of SEG lines	They can be individually disabled

Pin type	Description
P	Power supply
A	Analog
I	Input
O	Output
I/O	Depending on the selected configuration (Bidir, Input, Output, Open-Drain)

¹ When it is active means that the start-up of the device is finished and it is ready to receive commands.

² It should not be left floating. When the pin is connected to VDD, the I²C interface is selected. When it is connected to VSS, the SPI interface is selected.

³ It should not be left floating. In SPI, the pin can be disabled through the bit "en_MISO" in the configuration registers.

⁴ It can be enabled by the bit "Blk_Share" in the configuration registers. When enabled it is either a push-pull output or an input without pulldown. When disabled or when EN = VSS, there is an internal pulldown. If it is never used, it should be connected to VSS.

2. FUNCTIONAL DESCRIPTION

2.1. LCD ADDRESSING

The LCD driver generates all necessary voltages and output signals to drive an LCD with different multiplex and bias schemes. The frame frequency is programmable, a lower frequency implies a lower consumption.

In a segment LCD, the backplanes are connected to COM lines and the electrodes are connected to SEG lines. In static addressing, one SEG line drives one LCD segment, in Mux2 it drives two, in Mux3 it drives three and in Mux4 it drives four. Therefore, static addressing needs one COM line, Mux2 needs two, Mux3 needs three and Mux4 needs four. The maximum number of addressable LCD segments as a function of the multiplex rate is:

- Static: 50 LCD segments
- Mux2: 100 LCD segments
- Mux3: 150 LCD segments
- Mux4: 200 LCD segments

The voltage difference between SEG line and COM line is the voltage across the LCD segment. This voltage has a square-wave-like waveform, its root mean square (RMS) value determines whether the segment is ON or OFF. During LCD operation, the average voltage across any LCD segment must be zero.

In Mux2, Mux3 and Mux4 two bias schemes can be chosen: $\frac{1}{2}$ and $\frac{1}{3}$. Bias $\frac{1}{2}$ uses voltages VL1 and VL2. Bias $\frac{1}{3}$ uses VL1, VL2 and VL3. In terms of power consumption, bias $\frac{1}{2}$ is recommended. In Mux3 and Mux4, bias $\frac{1}{3}$ has a bigger contrast (V_{ON}/V_{OFF}).

For $V_{DD} \geq 1.68$ V, a special low power mode is available in Mux2, Mux3 and Mux4 which reduces the overall power consumption of the LCD driver and the display. For additional information see the subsection 2.1.5.

Considering that: $VL2 = 2 \times VL1$ and $VL3 = 3 \times VL1$; the RMS voltages of the V_{ON} and V_{OFF} LCD waveforms are shown in the following table.

	Bias	V_{ON}	V_{OFF}
Static		$V_{REF}/2, V_{REF}, 2 \times V_{REF} \text{ or } 3 \times V_{REF}$	0
Mux2	$\frac{1}{2}$	$\sqrt{\frac{VL1^2 + VL2^2}{2}} = 1.581 \cdot VL1$	$\sqrt{\frac{1}{2}} \cdot VL1 = 0.707 \cdot VL1$
	$\frac{1}{3}$	$\sqrt{\frac{VL1^2 + VL3^2}{2}} = 2.236 \cdot VL1$	$VL1$
Mux3	$\frac{1}{2}$	$\sqrt{\frac{2 \cdot VL1^2 + VL2^2}{3}} = 1.414 \cdot VL1$	$\sqrt{\frac{2}{3}} \cdot VL1 = 0.816 \cdot VL1$
	$\frac{1}{3}$	$\sqrt{\frac{2 \cdot VL1^2 + VL3^2}{3}} = 1.915 \cdot VL1$	$VL1$
Mux4	$\frac{1}{2}$	$\sqrt{\frac{3 \cdot VL1^2 + VL2^2}{4}} = 1.323 \cdot VL1$	$\sqrt{\frac{3}{4}} \cdot VL1 = 0.866 \cdot VL1$
	$\frac{1}{3}$	$\sqrt{\frac{3 \cdot VL1^2 + VL3^2}{4}} = 1.732 \cdot VL1$	$VL1$

Table 2-1 : V_{ON} and V_{OFF} as a function of Mux and Bias

In static addressing all the 4 COM lines drive the same backplane signal, they can be connected together externally if high output drive is needed. In Mux2 addressing COM1 and COM3 drive the same signal, the same happens for COM2 and COM4. The COM lines can be disabled if they are not used, in that case they output VSS.

A set of COM lines is provided at each side of the SEG lines (LCOM and RCOM) to increase flexibility of LCD layout and connectivity between the LCD driver and the display.

2.1.1. LCD WAVEFORMS

2.1.1.1. STATIC MODE

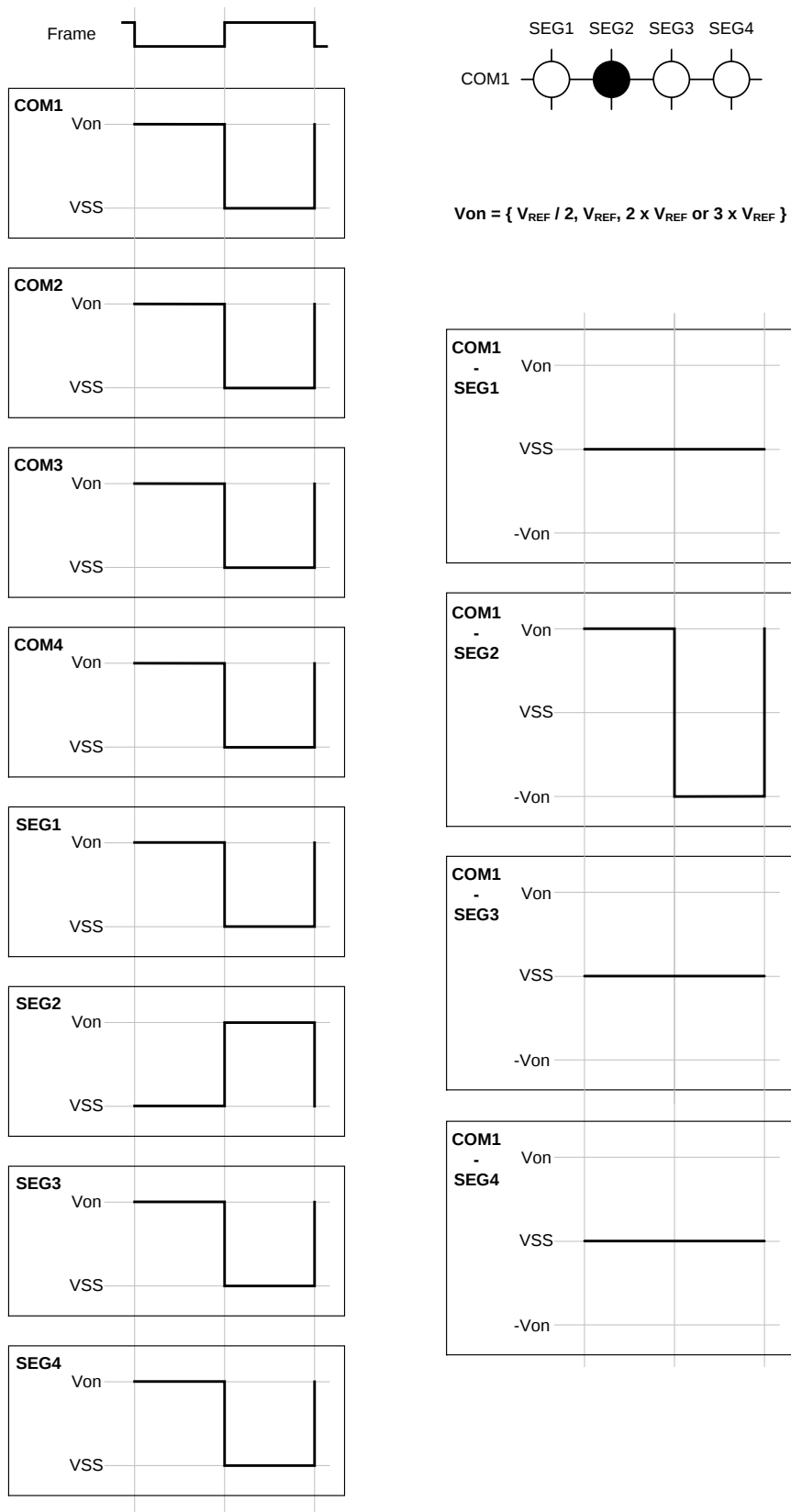


Figure 2-1 : LCD Driver Waveforms – Static mode

2.1.1.2. MUX2 & BIAS ½ MODE

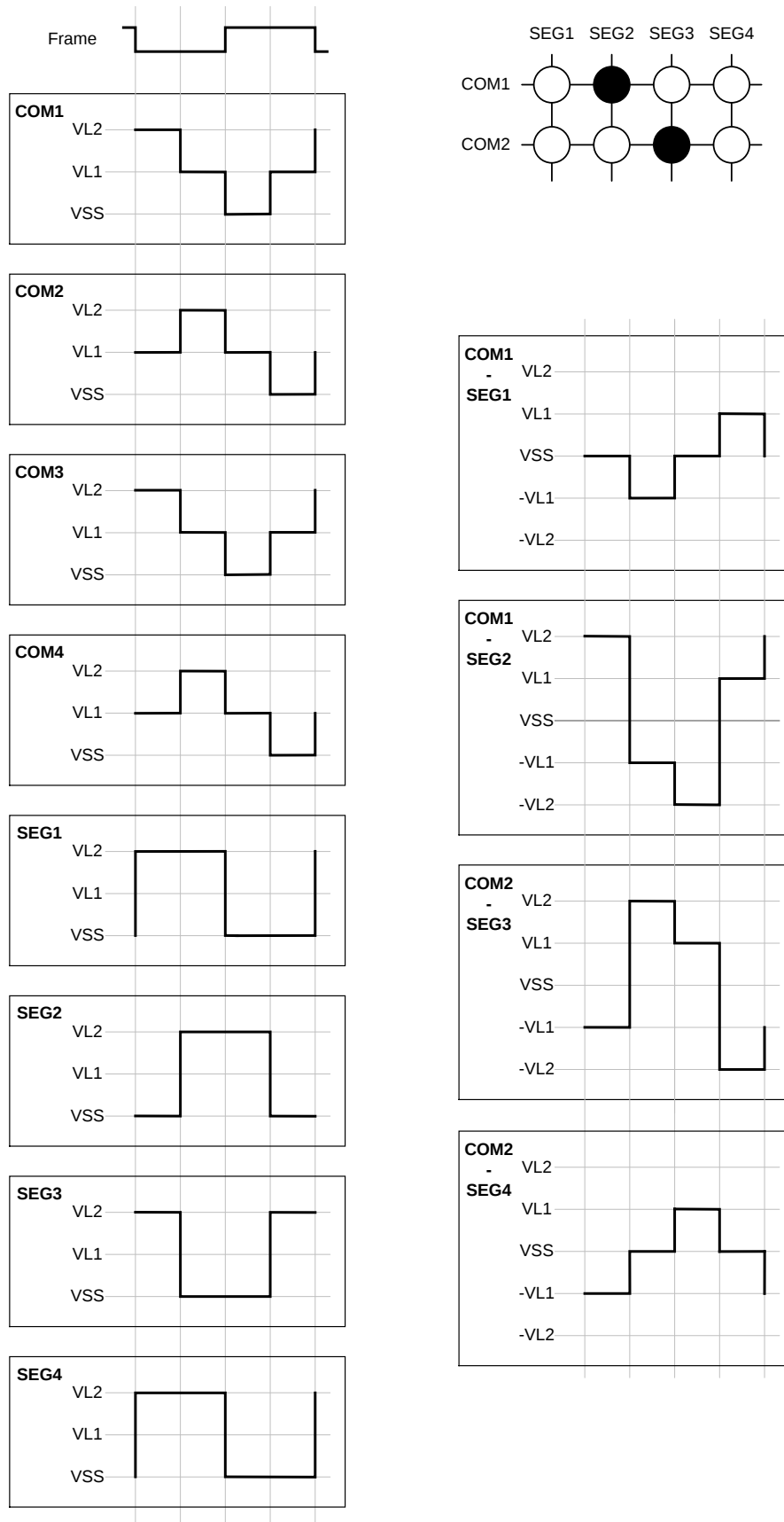


Figure 2-2 : LCD Driver Waveforms – Mux2 & Bias ½ mode

2.1.1.3. MUX2 & BIAS 1/3 MODE

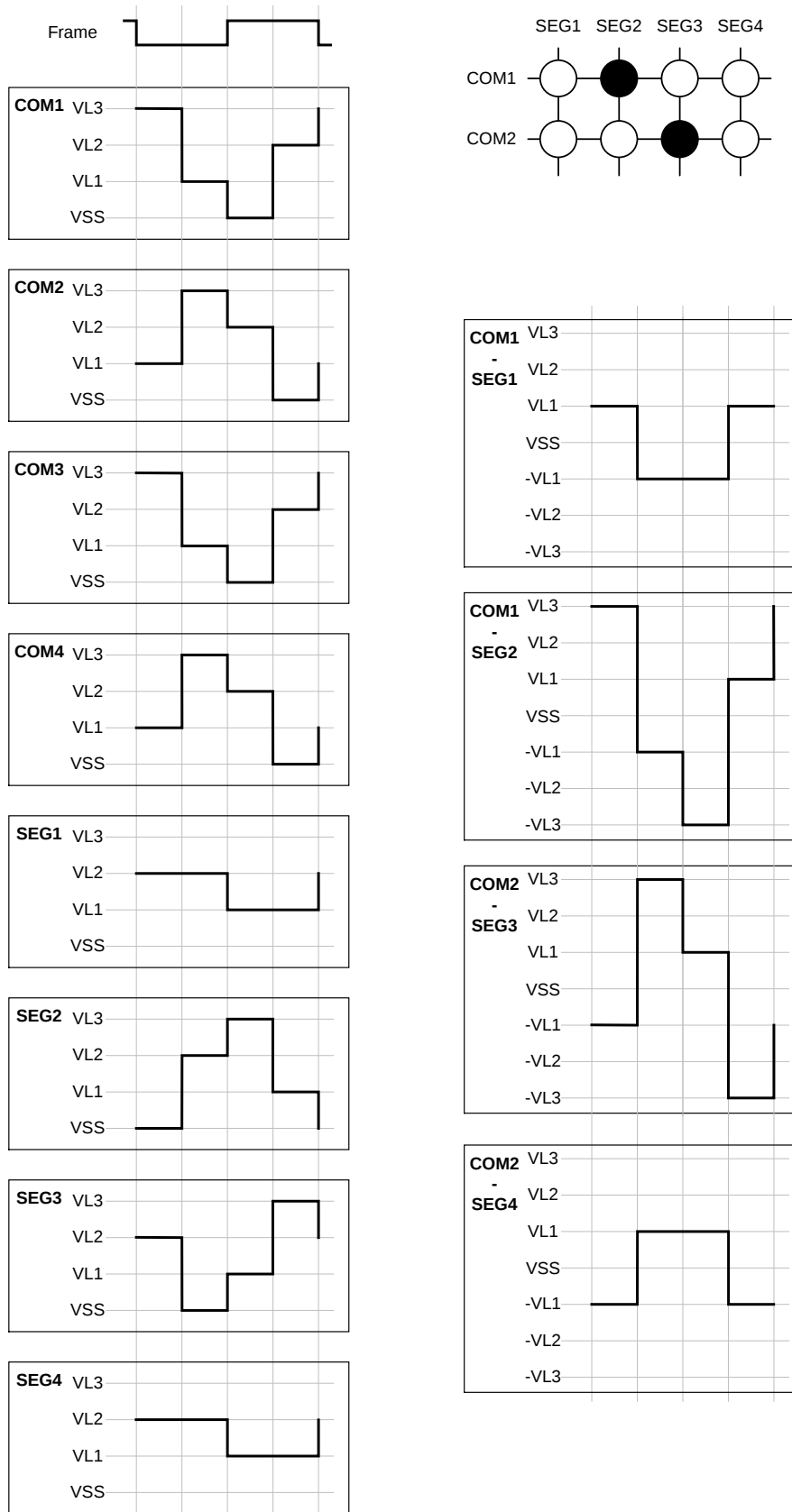


Figure 2-3 : LCD Driver Waveforms – Mux2 & Bias 1/3 mode

2.1.1.4. MUX3 & BIAS ½ MODE

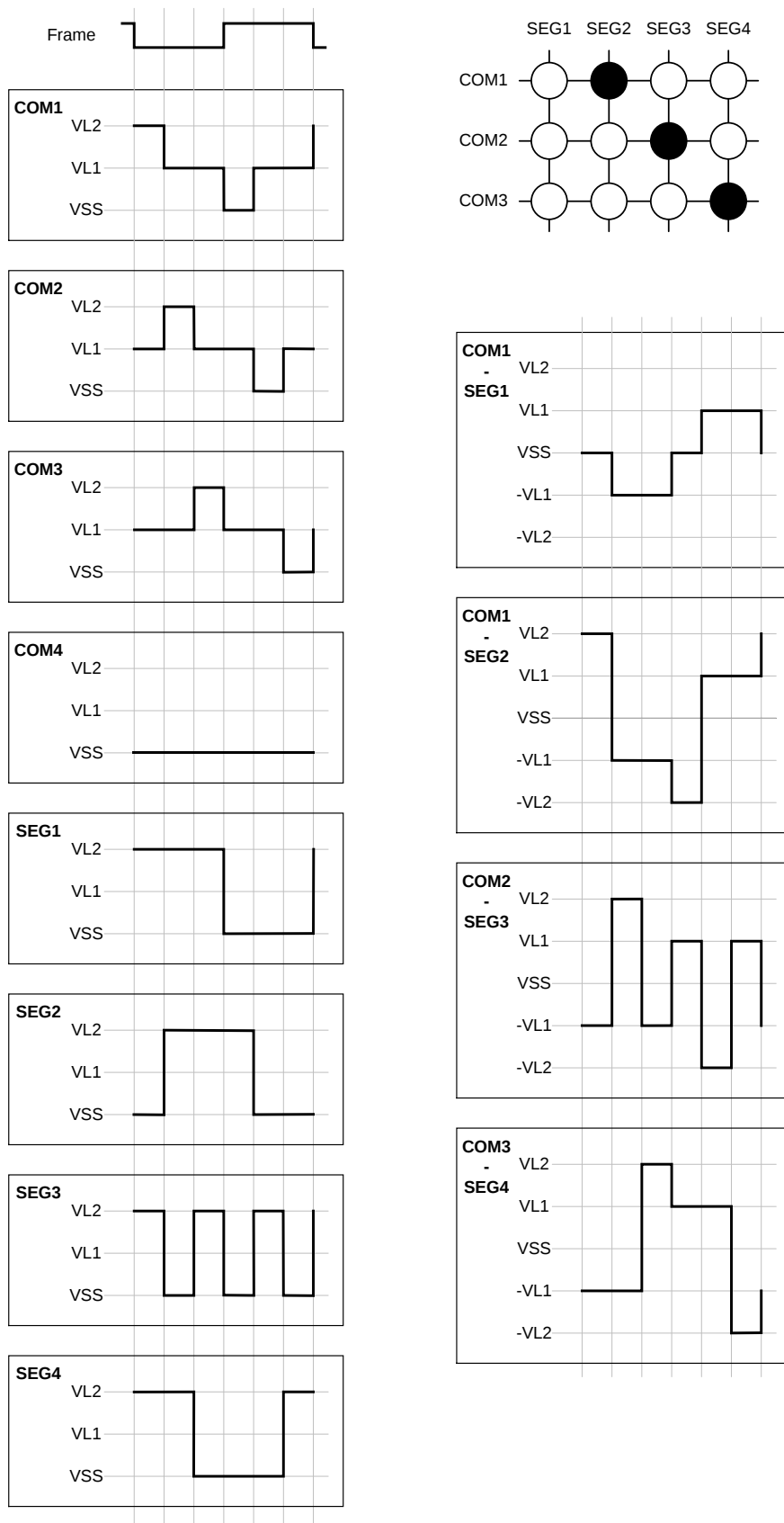


Figure 2-4 : LCD Driver Waveforms – Mux3 & Bias ½ mode

2.1.1.5. MUX3 & BIAS 1/3 MODE

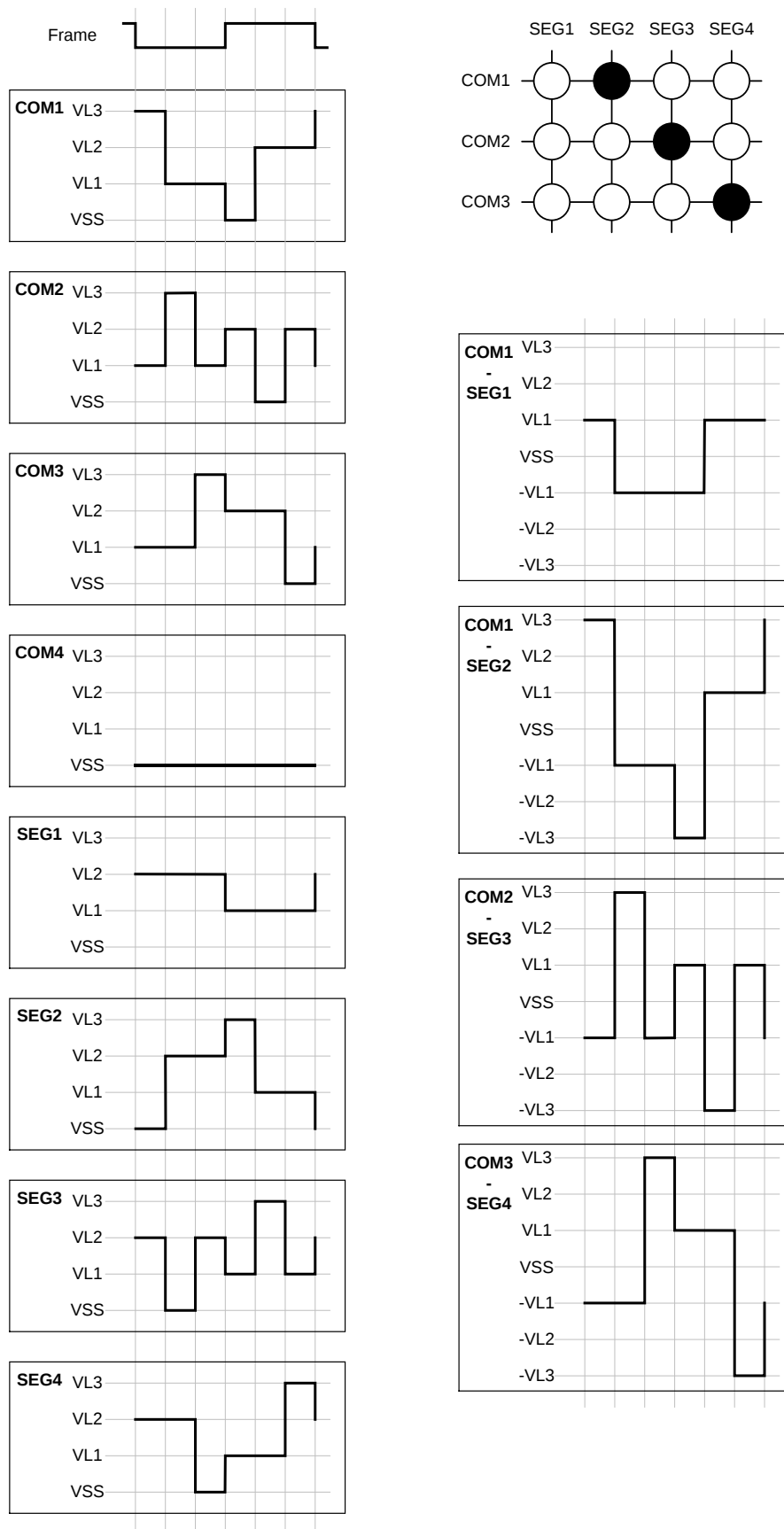


Figure 2-5 : LCD Driver Waveforms – Mux3 & Bias 1/3 mode

2.1.1.6. MUX4 & BIAS ½ MODE

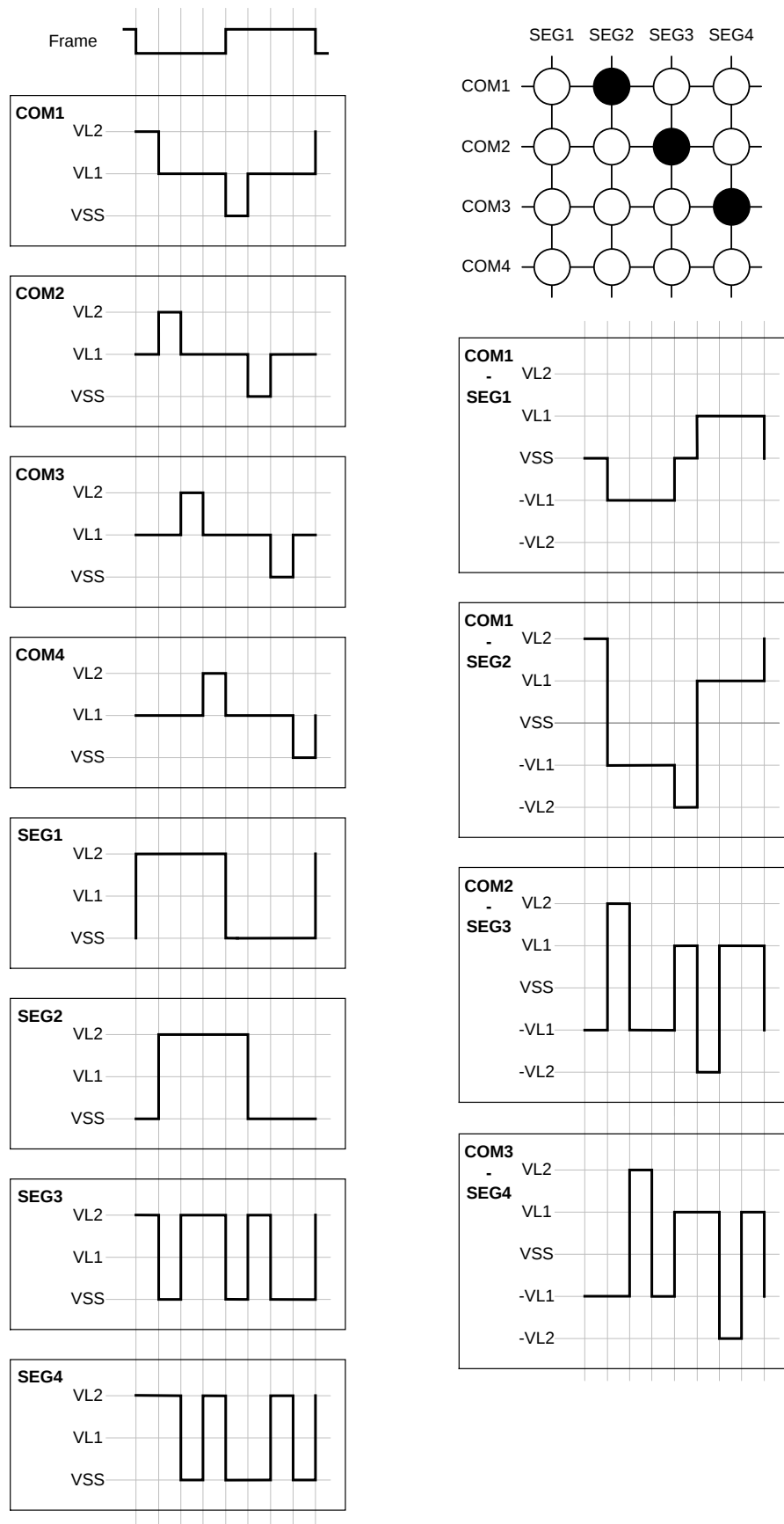


Figure 2-6 : LCD Driver Waveforms – Mux4 & Bias ½ mode

2.1.1.7. MUX4 & BIAS 1/3 MODE

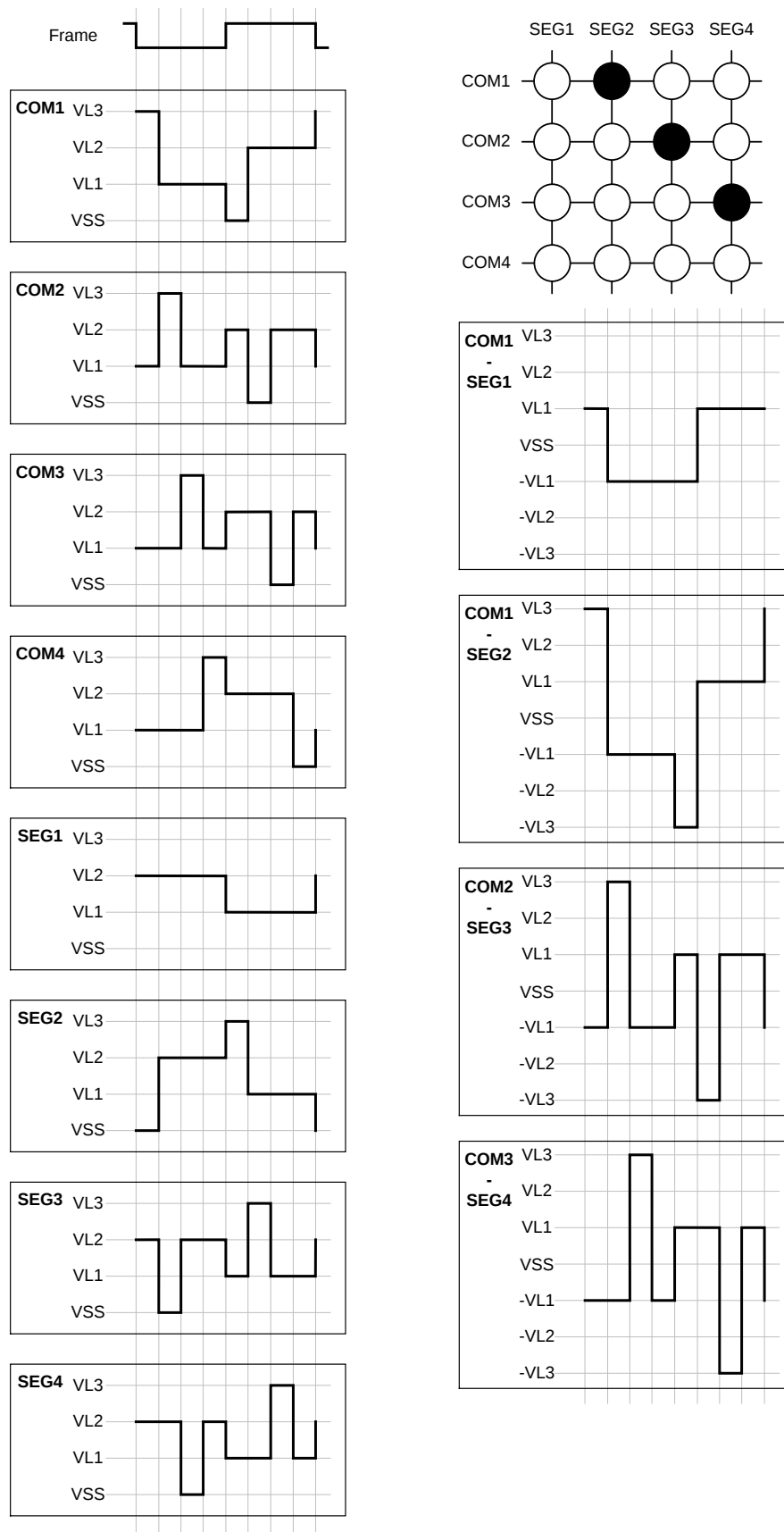


Figure 2-7 : LCD Driver Waveforms – Mux4 & Bias 1/3 mode

2.1.2. V_{REF} REFERENCE

The internal voltage V_{REF} is used as the reference for the generation of the LCD supply voltages. It is programmable by 25 mV steps. The "Vref_Level" bits set its value: $V_{REF} (V) = 0.8 + 0.025 \times Vref_Level = 0.8 V \dots 2.375 V$, with Vref_Level = [0, 63].

However, the supply voltage of the circuit can limit the maximum value of V_{REF} and therefore the possible Vref_Level values by the following condition: $VDD \geq 1.05 \times V_{REF}$. For example, if VDD = 1.5 V then the maximum value is V_{REF} = 1.425 V and thus the Vref_Level values are limited to the range [0, 25].

In Mux2, Mux3 and Mux4 there are two functional modes: Normal and Low Power mode. Depending on the selected mode, V_{REF} is either connected to VL1 or VL2. The selected mode also determines the value of the external capacitors C_{VL1} and C_{VL2}, where C_{VL1} is connected to the pin VL1 and C_{VL2} is connected to the pin VL2 (see section 2.9.5 for further information about the capacitors).

Mode	Connection	C _{VL1}	C _{VL2}
Normal	V _{REF} = VL1	1 µF	100 nF
Low Power	V _{REF} = VL2	100 nF	1 µF

Table 2-2 : V_{REF} connection and capacitors value in Mux2, Mux3 & Mux4

2.1.3. STATIC DRIVE

In static drive there are four different V_{ON} voltages that can be chosen: V_{REF} / 2, V_{REF}, 2 x V_{REF} or 3 x V_{REF}. Voltage V_{REF} / 2 is generated by dividing the voltage reference by 2, voltage V_{REF} is equal to the reference, and voltages 2 x V_{REF} and 3 x V_{REF} are generated by multiplying the reference by 2 and 3 respectively. The choice determines the value of the external capacitors C_{VL1} and C_{VL2} (see section 2.9.5 for further information about the capacitors). If V_{REF} is chosen, only a 1 µF capacitor is necessary.

Static drive options		C _{VL1}	C _{VL2}
V _{ON} =	V _{REF} / 2	100 nF	1 µF
	V _{REF}	1 µF	-
	2 x V _{REF}	1 µF	100 nF
	3 x V _{REF}	1 µF	100 nF

Table 2-3 : V_{ON} options and capacitors value in Static drive

In terms of system power consumption, the V_{ON} = V_{REF} / 2 option is the lowest one. The power consumption of the four options can be ordered in the following way: I_{VREF/2} < I_{VREF} < I_{2xVREF} < I_{3xVREF}. However, the supply voltage of the circuit can limit the V_{ON} choice (see section 2.1.2).

As can be seen in the Table 2-4, the range Vref_Level = [0, 63] is not fully valid for the four different V_{ON} choices (due to technology boundaries): VL1, VL2 and VL3 voltages may range from 0.8 V to 3.3 V. In both static and multiplex drives, if a non-valid Vref_Level value is set the internal logic automatically uses the closest valid value. For example in static drive and V_{ON} = V_{REF} / 2, Vref_Level = 10 is non-valid and the circuit would assign the value 32.

Static Drive - Condition: VDD ≥ 1.05 x V _{REF}				
Vref_Level	V _{ON} (V)			
	V _{REF} / 2	V _{REF}	2 x V _{REF}	3 x V _{REF}
0	0.800	0.800	1.600	2.400
1	0.800	0.825	1.650	2.475
2	0.800	0.850	1.700	2.550
3	0.800	0.875	1.750	2.625
4	0.800	0.900	1.800	2.700
5	0.800	0.925	1.850	2.775
6	0.800	0.950	1.900	2.850
7	0.800	0.975	1.950	2.925
8	0.800	1.000	2.000	3.000
9	0.800	1.025	2.050	3.075
10	0.800	1.050	2.100	3.150
11	0.800	1.075	2.150	3.225
12	0.800	1.100	2.200	3.300



Static Drive - Condition: $V_{DD} \geq 1.05 \times V_{REF}$				
Vref_Level	$V_{ON} (V)$			
	$V_{REF} / 2$	V_{REF}	$2 \times V_{REF}$	$3 \times V_{REF}$
13	0.800	1.125	2.250	3.300
14	0.800	1.150	2.300	3.300
15	0.800	1.175	2.350	3.300
16	0.800	1.200	2.400	3.300
17	0.800	1.225	2.450	3.300
18	0.800	1.250	2.500	3.300
19	0.800	1.275	2.550	3.300
20	0.800	1.300	2.600	3.300
21	0.800	1.325	2.650	3.300
22	0.800	1.350	2.700	3.300
23	0.800	1.375	2.750	3.300
24	0.800	1.400	2.800	3.300
25	0.800	1.425	2.850	3.300
26	0.800	1.450	2.900	3.300
27	0.800	1.475	2.950	3.300
28	0.800	1.500	3.000	3.300
29	0.800	1.525	3.050	3.300
30	0.800	1.550	3.100	3.300
31	0.800	1.575	3.150	3.300
32	0.800	1.600	3.200	3.300
33	0.812	1.625	3.250	3.300
34	0.825	1.650	3.300	3.300
35	0.837	1.675	3.300	3.300
36	0.850	1.700	3.300	3.300
37	0.862	1.725	3.300	3.300
38	0.875	1.750	3.300	3.300
39	0.887	1.775	3.300	3.300
40	0.900	1.800	3.300	3.300
41	0.912	1.825	3.300	3.300
42	0.925	1.850	3.300	3.300
43	0.937	1.875	3.300	3.300
44	0.950	1.900	3.300	3.300
45	0.962	1.925	3.300	3.300
46	0.975	1.950	3.300	3.300
47	0.987	1.975	3.300	3.300
48	1.000	2.000	3.300	3.300
49	1.013	2.025	3.300	3.300
50	1.025	2.050	3.300	3.300
51	1.038	2.075	3.300	3.300
52	1.050	2.100	3.300	3.300
53	1.063	2.125	3.300	3.300
54	1.075	2.150	3.300	3.300
55	1.088	2.175	3.300	3.300
56	1.100	2.200	3.300	3.300
57	1.113	2.225	3.300	3.300
58	1.125	2.250	3.300	3.300
59	1.138	2.275	3.300	3.300
60	1.150	2.300	3.300	3.300
61	1.163	2.325	3.300	3.300
62	1.175	2.350	3.300	3.300
63	1.188	2.375	3.300	3.300

Table 2-4 : V_{ON} in Static Drive

2.1.4. MULTIPLEX DRIVE: NORMAL MODE

In this mode $V_{REF} = V_{L1}$, $V_{ref_Level} = [0, 34]$ for bias $\frac{1}{2}$ and $V_{ref_Level} = [0, 12]$ for bias $\frac{1}{3}$. Table 2-5 and Table 2-6 show all the V_{ON} and V_{OFF} values: as can be seen, the supply voltage of the circuit can limit the possible V_{ON} and V_{OFF} values. In Normal mode: $C_{VL1} = 1 \mu F$ and $C_{VL2} = 100 nF$.

Bias $\frac{1}{2}$ - Condition: $V_{DD} \geq 1.05 \times V_{REF}$							
		Mux2		Mux3		Mux4	
Vref_Level	$V_{REF} = V_{L1}$ (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)
0	0.800	1.265	0.566	1.131	0.653	1.058	0.693
1	0.825	1.304	0.583	1.167	0.674	1.091	0.714
2	0.850	1.344	0.601	1.202	0.694	1.124	0.736
3	0.875	1.383	0.619	1.237	0.714	1.158	0.758
4	0.900	1.423	0.636	1.273	0.735	1.191	0.779
5	0.925	1.463	0.654	1.308	0.755	1.224	0.801
6	0.950	1.502	0.672	1.344	0.776	1.257	0.823
7	0.975	1.542	0.689	1.379	0.796	1.290	0.844
8	1.000	1.581	0.707	1.414	0.816	1.323	0.866
9	1.025	1.621	0.725	1.450	0.837	1.356	0.888
10	1.050	1.660	0.742	1.485	0.857	1.389	0.909
11	1.075	1.700	0.760	1.520	0.878	1.422	0.931
12	1.100	1.739	0.778	1.556	0.898	1.455	0.953
13	1.125	1.779	0.795	1.591	0.919	1.488	0.974
14	1.150	1.818	0.813	1.626	0.939	1.521	0.996
15	1.175	1.858	0.831	1.662	0.959	1.554	1.018
16	1.200	1.897	0.849	1.697	0.980	1.587	1.039
17	1.225	1.937	0.866	1.732	1.000	1.621	1.061
18	1.250	1.976	0.884	1.769	1.021	1.654	1.083
19	1.275	2.016	0.902	1.803	1.041	1.687	1.104
20	1.300	2.055	0.919	1.838	1.061	1.720	1.126
21	1.325	2.095	0.937	1.874	1.082	1.753	1.147
22	1.350	2.135	0.955	1.909	1.102	1.786	1.169
23	1.375	2.174	0.972	1.945	1.123	1.819	1.191
24	1.400	2.214	0.990	1.980	1.143	1.852	1.212
25	1.425	2.253	1.008	2.015	1.164	1.885	1.234
26	1.450	2.293	1.025	2.051	1.184	1.918	1.256
27	1.475	2.332	1.043	2.086	1.204	1.951	1.277
28	1.500	2.372	1.061	2.121	1.225	1.984	1.299
29	1.525	2.411	1.078	2.157	1.245	2.017	1.321
30	1.550	2.451	1.096	2.192	1.266	2.050	1.342
31	1.575	2.490	1.114	2.227	1.286	2.084	1.364
32	1.600	2.530	1.131	2.263	1.306	2.117	1.386
33	1.625	2.569	1.149	2.298	1.327	2.150	1.407
34	1.650	2.609	1.167	2.333	1.347	2.183	1.429
35 ... 63	1.650	2.609	1.167	2.333	1.347	2.183	1.429

Table 2-5 : V_{ON} and V_{OFF} in Bias $\frac{1}{2}$ for Mux 2, 3 & 4 (Normal mode)

Bias $\frac{1}{3}$ - Condition: $V_{DD} \geq 1.05 \times V_{REF}$							
		Mux2		Mux3		Mux4	
Vref_Level	$V_{REF} = VL1$ (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)
0	0.800	1.789	0.800	1.532	0.800	1.386	0.800
1	0.825	1.845	0.825	1.580	0.825	1.429	0.825
2	0.850	1.901	0.850	1.628	0.850	1.472	0.850
3	0.875	1.957	0.875	1.675	0.875	1.516	0.875
4	0.900	2.012	0.900	1.723	0.900	1.559	0.900
5	0.925	2.068	0.925	1.771	0.925	1.602	0.925
6	0.950	2.124	0.950	1.819	0.950	1.645	0.950
7	0.975	2.180	0.975	1.867	0.975	1.689	0.975
8	1.000	2.236	1.000	1.915	1.000	1.732	1.000
9	1.025	2.292	1.025	1.963	1.025	1.775	1.025
10	1.050	2.348	1.050	2.011	1.050	1.819	1.050
11	1.075	2.404	1.075	2.058	1.075	1.862	1.075
12	1.100	2.460	1.100	2.106	1.100	1.905	1.100
13 ... 63	1.100	2.460	1.100	2.106	1.100	1.905	1.100

Table 2-6 : V_{ON} and V_{OFF} in Bias $\frac{1}{3}$ for Mux 2, 3 & 4 (Normal mode)

2.1.5. MULTIPLEX DRIVE: LOW POWER MODE

The Low Power mode uses a novel technique that enables to further reduce the power consumption of the driver and the display. When both Normal mode and Low Power mode are available, the latter is recommended. However, the Low Power mode is only available when $V_{REF} \geq 1.6$ V and therefore when $V_{DD} \geq 1.68$ V.

In this mode, $V_{REF} = VL2$, Vref_Level = [32, 63] for bias $\frac{1}{2}$ and Vref_Level = [32, 56] for bias $\frac{1}{3}$. Table 2-7 and Table 2-8 show all the V_{ON} and V_{OFF} values, and as in Normal mode, the supply voltage of the circuit can limit the possible V_{ON} and V_{OFF} values. In Low Power mode: $C_{VL1} = 100$ nF and $C_{VL2} = 1$ μ F.

Bias $\frac{1}{2}$ - Condition: $V_{DD} \geq 1.05 \times V_{REF}$							
		Mux2		Mux3		Mux4	
Vref_Level	$V_{REF} = VL2$ (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)
0 ... 31	1.600	1.265	0.566	1.131	0.653	1.058	0.693
32	1.600	1.265	0.566	1.131	0.653	1.058	0.693
33	1.625	1.285	0.575	1.149	0.663	1.075	0.704
34	1.650	1.304	0.583	1.167	0.674	1.091	0.714
35	1.675	1.324	0.592	1.184	0.684	1.108	0.725
36	1.700	1.344	0.601	1.202	0.694	1.124	0.736
37	1.725	1.364	0.610	1.220	0.704	1.141	0.747
38	1.750	1.383	0.619	1.237	0.714	1.158	0.758
39	1.775	1.403	0.628	1.255	0.725	1.174	0.769
40	1.800	1.423	0.636	1.273	0.735	1.191	0.779
41	1.825	1.443	0.645	1.290	0.745	1.207	0.790
42	1.850	1.463	0.654	1.308	0.755	1.224	0.801
43	1.875	1.482	0.663	1.326	0.765	1.240	0.812
44	1.900	1.502	0.672	1.344	0.776	1.257	0.823
45	1.925	1.522	0.681	1.361	0.786	1.273	0.834
46	1.950	1.542	0.689	1.379	0.796	1.290	0.844
47	1.975	1.561	0.698	1.397	0.806	1.306	0.855
48	2.000	1.581	0.707	1.414	0.816	1.323	0.866
49	2.025	1.601	0.716	1.432	0.827	1.339	0.877
50	2.050	1.621	0.725	1.450	0.837	1.356	0.888
51	2.075	1.640	0.734	1.467	0.847	1.372	0.899
52	2.100	1.660	0.742	1.485	0.857	1.389	0.909
53	2.125	1.680	0.751	1.503	0.868	1.406	0.920
54	2.150	1.700	0.760	1.520	0.878	1.422	0.931
55	2.175	1.719	0.769	1.538	0.888	1.439	0.942
56	2.200	1.739	0.778	1.556	0.898	1.455	0.953

Bias $\frac{1}{2}$ - Condition: $VDD \geq 1.05 \times V_{REF}$							
		Mux2		Mux3		Mux4	
Vref_Level	$V_{REF} = VL2$ (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)
57	2.225	1.759	0.787	1.573	0.908	1.472	0.963
58	2.250	1.779	0.795	1.591	0.919	1.488	0.974
59	2.275	1.799	0.804	1.609	0.929	1.505	0.985
60	2.300	1.818	0.813	1.626	0.939	1.521	0.996
61	2.325	1.838	0.822	1.644	0.949	1.538	1.007
62	2.350	1.858	0.831	1.662	0.959	1.554	1.018
63	2.375	1.878	0.840	1.679	0.970	1.571	1.028

Table 2-7 : V_{ON} and V_{OFF} in Bias $\frac{1}{2}$ for Mux 2, 3 & 4 (Low Power mode)

Bias $\frac{1}{3}$ - Condition: $VDD \geq 1.05 \times V_{REF}$							
		Mux2		Mux3		Mux4	
Vref_Level	$V_{REF} = VL2$ (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)	V_{ON} (V)	V_{OFF} (V)
0 ... 31	1.600	1.789	0.800	1.532	0.800	1.386	0.800
32	1.600	1.789	0.800	1.532	0.800	1.386	0.800
33	1.625	1.817	0.813	1.556	0.813	1.407	0.813
34	1.650	1.845	0.825	1.580	0.825	1.429	0.825
35	1.675	1.873	0.838	1.604	0.838	1.451	0.838
36	1.700	1.901	0.850	1.628	0.850	1.472	0.850
37	1.725	1.929	0.863	1.652	0.863	1.494	0.863
38	1.750	1.957	0.875	1.675	0.875	1.516	0.875
39	1.775	1.985	0.888	1.699	0.888	1.537	0.888
40	1.800	2.012	0.900	1.723	0.900	1.559	0.900
41	1.825	2.040	0.913	1.747	0.913	1.580	0.913
42	1.850	2.068	0.925	1.771	0.925	1.602	0.925
43	1.875	2.096	0.938	1.795	0.938	1.624	0.938
44	1.900	2.124	0.950	1.819	0.950	1.645	0.950
45	1.925	2.152	0.962	1.843	0.962	1.667	0.962
46	1.950	2.180	0.975	1.867	0.975	1.689	0.975
47	1.975	2.208	0.987	1.891	0.987	1.710	0.987
48	2.000	2.236	1.000	1.915	1.000	1.732	1.000
49	2.025	2.264	1.013	1.939	1.013	1.754	1.013
50	2.050	2.292	1.025	1.963	1.025	1.775	1.025
51	2.075	2.320	1.038	1.987	1.038	1.797	1.038
52	2.100	2.348	1.050	2.011	1.050	1.819	1.050
53	2.125	2.376	1.063	2.035	1.063	1.840	1.063
54	2.150	2.404	1.075	2.058	1.075	1.862	1.075
55	2.175	2.432	1.088	2.082	1.088	1.884	1.088
56	2.200	2.460	1.100	2.106	1.100	1.905	1.100
57 ... 63	2.200	2.460	1.100	2.106	1.100	1.905	1.100

Table 2-8 : V_{ON} and V_{OFF} in Bias $\frac{1}{3}$ for Mux 2, 3 & 4 (Low Power mode)

2.2. PROGRAMMABLE GROUPS OF LCD SEGMENTS

The LCD segments are defined in a logical view, independently of their physical arrangement. This view consists of a given number of groups, of up to eight segments each; in the case of the EM6115, you are given 32 groups of 8 segments and you can address each segment independently of the others, without taking care of its physical or multiplex connection. The aim of this idea is to reduce the overall number of data transfers in the system by an efficient grouping of the segments.

The translation from the logical to the physical segments is done through a so-named mapping dictionary, where you must define for each physical segment, to which logical group and to which individual bit of this group it belongs. By this way, you can group all the segments of a digit in the same logical group and define a common group for the symbols spread around the LCD. The programming of the mapping dictionary can be done either by a user command or directly from the embedded EEPROM at startup.

2.2.1. LOGICAL SEGMENTS AND GROUPS

The LCD segments are activated by writing values in the group registers (named GroupX in chapter 2.7.3) or in the group individual blink registers (named Blk_GrX in chapter 2.7.3). Each group register is identified by a suffix number from 0 to 31, and each bit in a group is identified by a prefix letter: bit0 (LSBit) = A, bit 1 = B, bit 2 = C, bit 3 = D ... bit 7 (MSBit) = H.

For example, the bit 0 of the group 0 is named A0, the bit 7 of the group 3 H3, the bit 6 of the group 14 G14. These bit names are used for the segment activation and for the mapping dictionary definition.

The internal decoding mechanism is designed towards ultra-low power consumption: you can only write to the group or individual blink registers, but you cannot readback these registers, nor the current active physical segments.

2.2.2. DICTIONARY

In the mapping dictionary each physical LCD segment is defined by its group number and its group bit. Five (5) bits are necessary to code the group number (Ngrp[4:0]) and three (3) bits for the group bit (Nbit[2:0]).

Group bit position	Group bit prefix	Nbit[2:0]
0 (LSBit)	A	000
1	B	001
2	C	010
3	D	011
4	E	100
5	F	101
6	G	110
7 (MSBit)	H	111

Table 2-9 : Correspondence of Nbit[2:0]

The mapping dictionary can be written by the MCU with the command "WRITE_DIC" (see chapter 2.4). This command is incremental, i.e. it starts defining the group number and the group bit for the combination SEG[1] & COM[1] and continues with the following combinations. The communication transfer can be seen in the Table 2-10.

Byte	Word	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
0	WRITE_DIC	\$20							
1	SEG[1] & COM[1]	Ngrp_011[4:0]				Nbit_011[2:0]			
2	SEG[1] & COM[2]	Ngrp_012[4:0]				Nbit_012[2:0]			
3	SEG[1] & COM[3]	Ngrp_013[4:0]				Nbit_013[2:0]			
4	SEG[1] & COM[4]	Ngrp_014[4:0]				Nbit_014[2:0]			
5	SEG[2] & COM[1]	Ngrp_021[4:0]				Nbit_021[2:0]			
6	SEG[2] & COM[2]	Ngrp_022[4:0]				Nbit_022[2:0]			
...	...	...				...			
199	SEG[50] & COM[3]	Ngrp_503[4:0]				Nbit_503[2:0]			
200	SEG[50] & COM[4]	Ngrp_504[4:0]				Nbit_504[2:0]			

Table 2-10 : Communication transfer for "WRITE_DIC" command

Multiple physical LCD segments can be defined with the same group number and group bit. In that case, the LCD segments are controlled by the same bit in the functional registers and, therefore, they are linked together.

It is not necessary to write the mapping dictionary for all the possible combinations if they are not used. It is sufficient to send the group number and the group bit from the SEG[1] & COM[1] combination to the last used SEG & COM combination. By default, the unused combinations are defined as logical segment A0. In that case, the bit A of the Group0 should not be used to define any used and valid combination. However, all the combinations from SEG[1] & COM[1] to the last used SEG & COM must be defined even if they are not used. For example, if MUX2 is used, the combinations using COM[3] and COM[4] must be defined as well. One option would be to define all of them as logical segment A0.

2.2.3. EXAMPLE DICTIONARY

The Figure 2-8 shows a typical physical segment design (gray zone) and its connection to the LCD controller in MUX2 mode. The segment-LCD is represented by the combination of SEG and COM lines that drives it. In this example, the segments of the first 7-segment digit are ordered in the same group independently of the connection to the driver. However and as can be seen in the two other digits of this example, this grouping is not the only possibility.

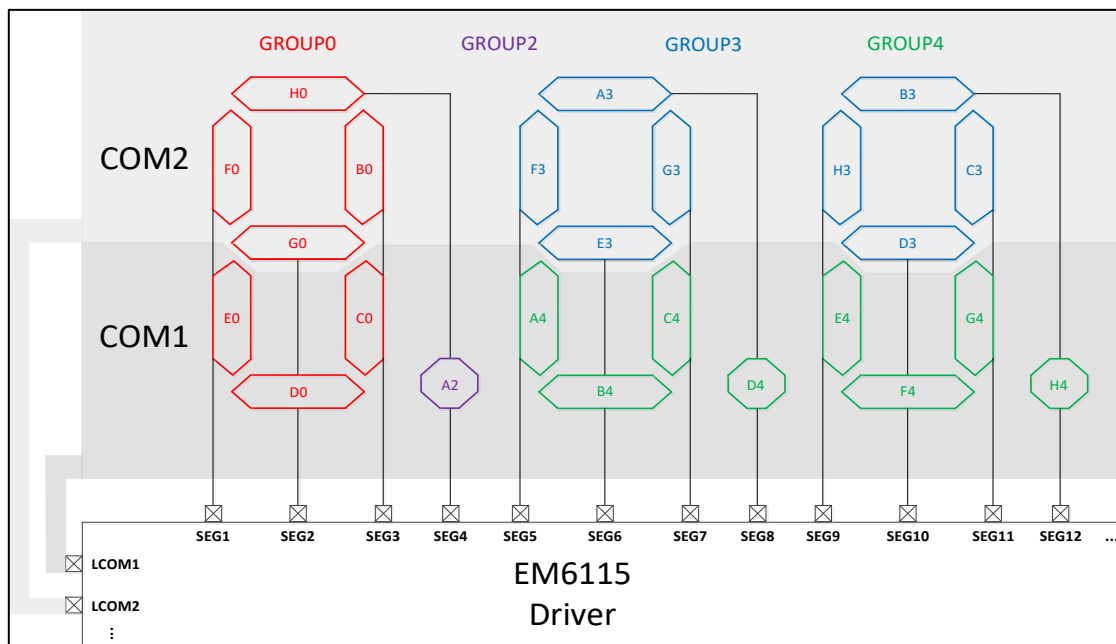


Figure 2-8 : Groups definition example

The mapping dictionary is shown in Table 2-11 and defines how the LCD segments are ordered into groups. The Table 2-12 shows the beginning of the communication transfer to setup the dictionary of the example; the unused physical segments are included in this transfer (segments addressed with COM[3] and COM[4]), but the length of the transfer is strictly limited to the connected segments (SEG[12])

SEG	COM	Group	Bit	Bit name
SEG1	COM1	0	4	E0
SEG1	COM2	0	5	F0
SEG2	COM1	0	3	D0
SEG2	COM2	0	6	G0
SEG3	COM1	0	2	C0
SEG3	COM2	0	1	B0
SEG4	COM1	2	0	A2
SEG4	COM2	0	7	H0
SEG5	COM1	4	0	A4
SEG5	COM2	3	5	F3
SEG6	COM1	4	1	B4
SEG6	COM2	3	4	E3
SEG7	COM1	4	2	C4
SEG7	COM2	3	6	G3
SEG8	COM1	4	3	D4
SEG8	COM2	3	0	A3
SEG9	COM1	4	4	E4
SEG9	COM2	3	7	H3
SEG10	COM1	4	5	F4
SEG10	COM2	3	3	D3
SEG11	COM1	4	6	G4
SEG11	COM2	3	2	C3
SEG12	COM1	4	7	H4
SEG12	COM2	3	1	B3

Table 2-11 : Dictionary example

Byte	Word	Content
0	WRITE_DIC	\$20
1	SEG[1] & COM[1]	\$04
2	SEG[1] & COM[2]	\$05
3	SEG[1] & COM[3]	\$00 (non-used)
4	SEG[1] & COM[4]	\$00 (non-used)
5	SEG[2] & COM[1]	\$03
6	SEG[2] & COM[2]	\$06
7	SEG[2] & COM[3]	\$00 (non-used)
8	SEG[2] & COM[4]	\$00 (non-used)
9	SEG[3] & COM[1]	\$02
10	SEG[3] & COM[2]	\$01
11	SEG[3] & COM[3]	\$00 (non-used)
12	SEG[3] & COM[4]	\$00 (non-used)
13	SEG[4] & COM[1]	\$10
14	SEG[4] & COM[2]	\$07
15	SEG[4] & COM[3]	\$00 (non-used)
16	SEG[4] & COM[4]	\$00 (non-used)
17	SEG[5] & COM[1]	\$20
...	...	...
45	SEG[12] & COM[1]	\$27
46	SEG[12] & COM[2]	\$19

Table 2-12 : Dictionary setup of the example (section 2.2)

Referring to the example described above, the Figure 2-9 and the Table 2-13 show an active display and the corresponding communication data transfers. In the first transfer the address is \$40 (Group0). The group value is equal to \$CE that in this example means lighting the number 3 in the first 7-segment digit. Afterwards a new transfer is done starting at Group2 with a group value of \$01. Notice that if the transfer continues, the next byte is the group value of address group incremented by one, in this case Group3, as specified in the section 2.7.

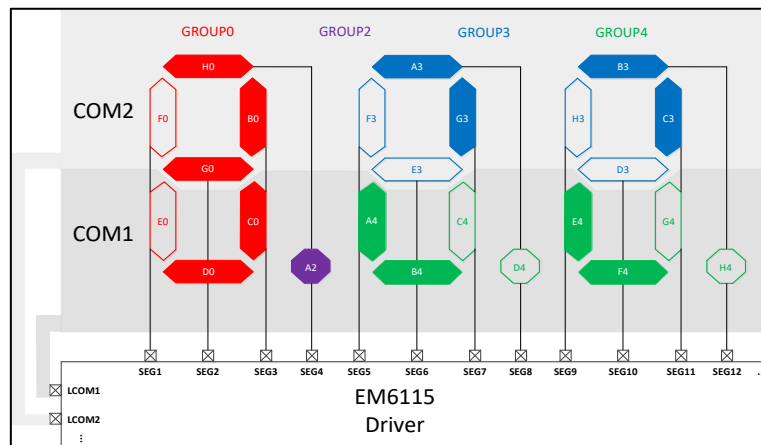


Figure 2-9 : Example of active segments

Com Transfer	Content	Byte	Group
1	WRITE_REG address 0	\$40	-
1	Value	\$CE	0
2	WRITE_REG address 2	\$42	-
2	Value	\$01	2
2	Value	\$47	3
2	Value	\$33	4

Table 2-13 : Example of group write transfer

2.3. COMMUNICATION INTERFACE

The communication interface is slave only and allows a synchronous and serial communication between the host and the device. The interface is selected through the CIS pin. If CIS is low, the SPI interface is selected. If CIS is high, the I²C interface is used. A transfer begins with a command followed by data until the transfer is stopped (STOP condition with I²C interface or nSS driven high for SPI). The internal register address pointer is automatically incremented in case of multiple-byte access. The communication interface configuration must not be modified while the circuit is active: pin EN = VDD.

Pins	CIS = VDD			CIS = VSS		
	Name	Type	Description	Name	Type	Description
CIO0	SCL	I/O	I ² C clock	SCK	I	SPI Clock
CIO1	SDA	I/O	I ² C data	MOSI	I	SPI Data In
CIO2	EN_IWPU	I	Enable I ² C internal Weak pull-up resistors on CIO0 and CIO1	MISO	O	SPI Data Out (if enabled), or Low Level Output
CI3	EN_ISPU	I	Enable I ² C internal Strong pull-up resistors on CIO0 and CIO1	nSS	I	SPI Slave Select (Active low)
CI4	A0	I	I ² C address bit 0	-	-	Not-used
CI5	A1	I	I ² C address bit 1	CK_POL	I	SPI SCK Polarity
CI6	A2	I	I ² C address bit 2	CK_PHA	I	SPI SCK Phase
CI7	A3	I	I ² C address bit 3	MSB_FIRST	I	SPI MSB First selection
CI8	ICRDY_POL	I	ICRDY polarity	ICRDY_POL	I	ICRDY polarity

Table 2-14 : Interface pins configuration

2.3.1. I²C INTERFACE

The I²C is a 2-wire interface (serial clock and serial data). The serial clock (SCL) provides the timing for the interface. The serial data (SDA) is bidirectional and is used to transfer data, according to NXP UM10204 Specification (I²C-bus specification and user manual, Version 6.0, 4th of April 2014).

The I²C interface has the following restrictions:

- Only Standard-mode and Fast-mode are supported. Thus, the maximum clock frequency is 400 kHz.
- Only standard 7-bit addressing is supported. The default values of the 3 MSB are "001" while the 4 LSB are defined by A3...A0 input pins; the available address range is \$10 to \$1F.
- General Calls are ignored.
- Each I²C bidirectional pin can use a weak (40 kΩ) and/or a strong (20 kΩ) internal pull-up resistor. These resistors can be enabled by connecting respectively the EN_IWPU and/or EN_ISPU input pins to VDD, and this setting is independent of the global chip enable (pin EN). However, as these internal pull-up resistors have been designed to minimize power consumption, the capacitive bus loads are limited, even when both pull-up resistors are simultaneously enabled. For higher capacitive bus loads, external I²C pullup resistors must be added.
- Clock stretching is not supported.

Both data and clock lines remain high when the bus is not busy. A high to low transition of the data line, while the clock is high is defined as a START condition. A low to high transition of the data line while the clock is high is defined as a STOP condition. One data bit is transferred during each SCL pulse. The data on SDA line is sampled at the falling edge of the SCL line and must remain stable during the high period of SCL pulses, as any change at this time would be interpreted as a START or a STOP condition. Data is always transferred MSB first.

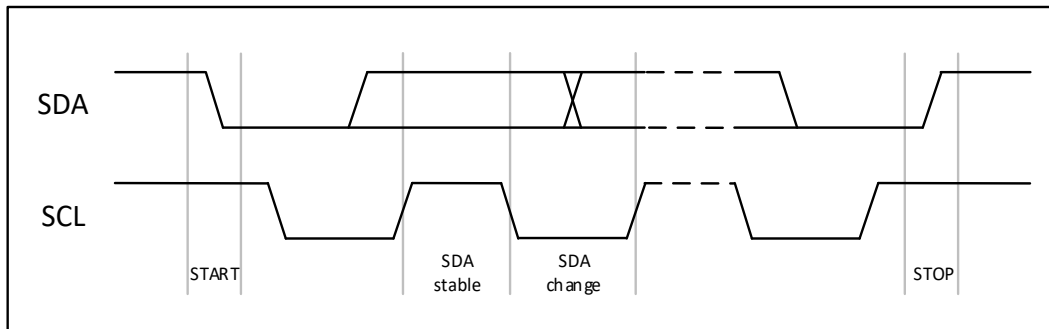


Figure 2-10 : I²C START, STOP and data validity conditions

The number of data bytes between the START and the STOP conditions is unlimited. Each byte of eight bits is followed by an acknowledge bit. After a START condition, the slave address combined with the R/W bit must be sent first. If the slave address corresponds to the device address, it will send an acknowledge bit by pulling down the SDA line and the data transfer is enabled. The I²C bus configurations for the read and write operations are shown in the following figures:

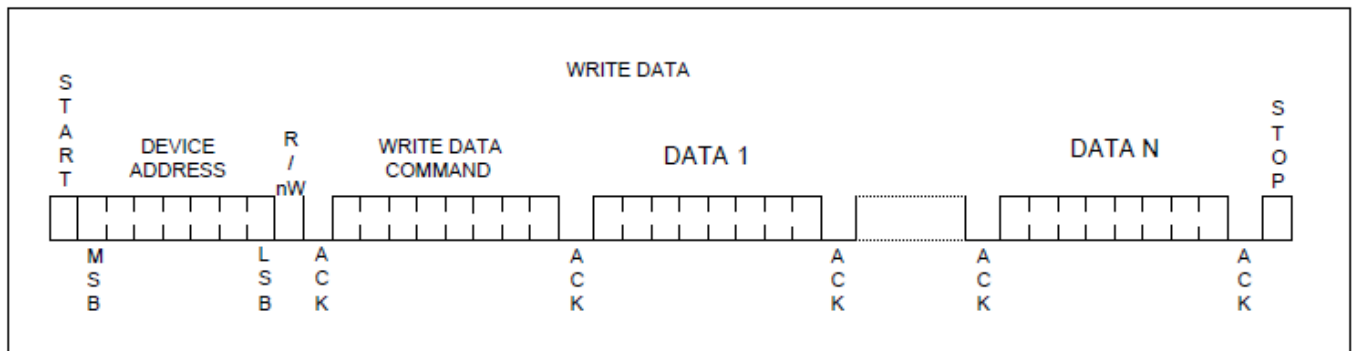


Figure 2-11 : Write data transfer

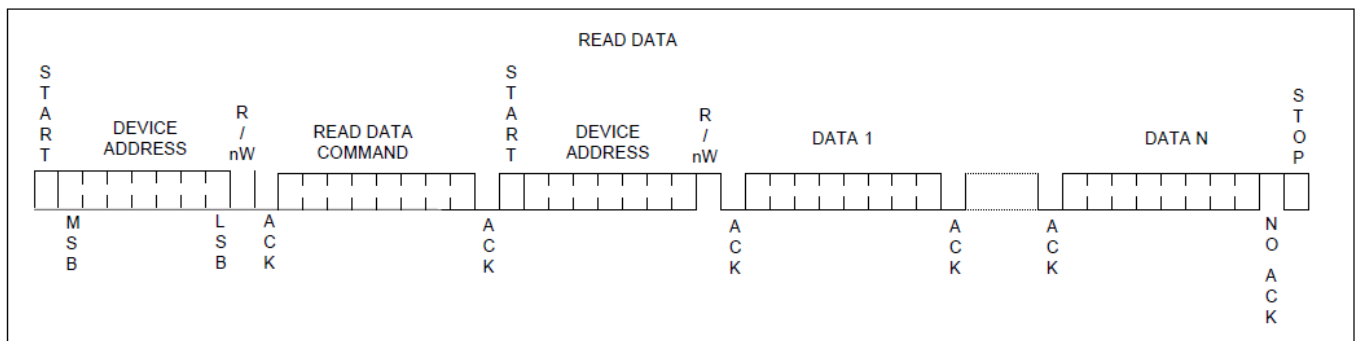


Figure 2-12 : Read data transfer

2.3.2. SPI INTERFACE

The SPI is a 4-wire interface. The nSS input is the control signal used to enable the device SPI interface. The clock signal SCK generated by the host synchronizes data transmission. The MOSI signal is the data input. The MISO signal is the data output and it is disabled by default; however, it can be enabled by software through the “en_MISO” bit in the configuration registers.

EN	nSS	en_MISO bit	MISO
VSS	'x'	'x'	hi-Z
VDD	VDD	'x'	hi-Z
VDD	VSS	'0'	VSS
VDD	VSS	'1'	Data

Table 2-15 : MISO pin status as a function of nSS and en_MISO

When the device is disabled (EN = VSS) and the SPI interface is selected (CIS = VSS), the pin CIO2 (MISO signal) is in hi-Z state.

When nSS = VSS and en_MISO = '1', the pin MISO outputs '0' during write operations.

Three input pins allow to configure the SPI.

The CK_POL input selects the polarity of the SPI Clock:

- When set to VSS, the SCK clock signal is set to VSS between transmissions.
- When set to VDD, the SCK clock signal is set to VDD between transmissions.

The CK_PHA input pin selects the clock edge that samples data:

- When set to VSS, the data on MOSI input is sampled at the first edge of the SPI Clock.
- When set to VDD, the data on MOSI input is sampled at the second edge of the SPI Clock.

The MSB_FIRST input pin selects the ordering of the bits :

- When set to VSS, the bytes are sent LSB first.
- When set to VDD, the bytes are sent MSB first.

The SPI timing is shown in Figure 2-13, Figure 2-14, Figure 2-15 and Figure 2-16.

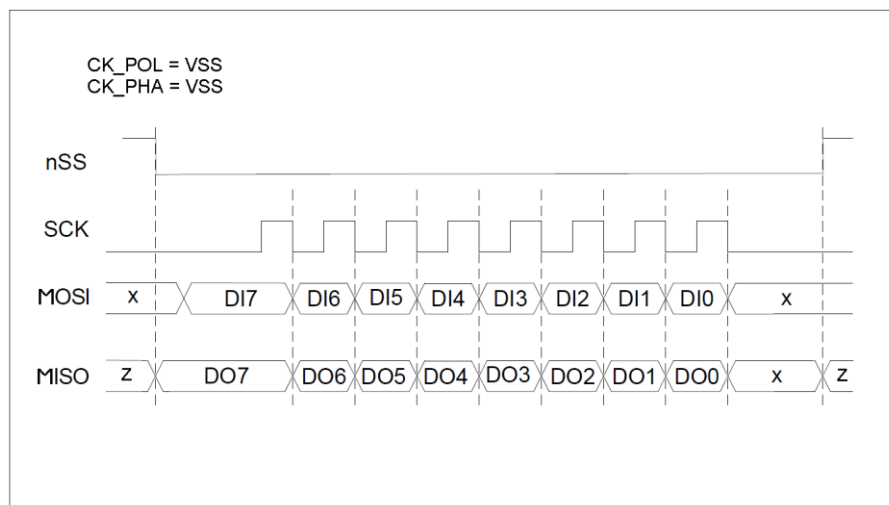


Figure 2-13 : SPI timing with MSB_FIRST = VDD, CK_POL = VSS & CK_PHA = VSS

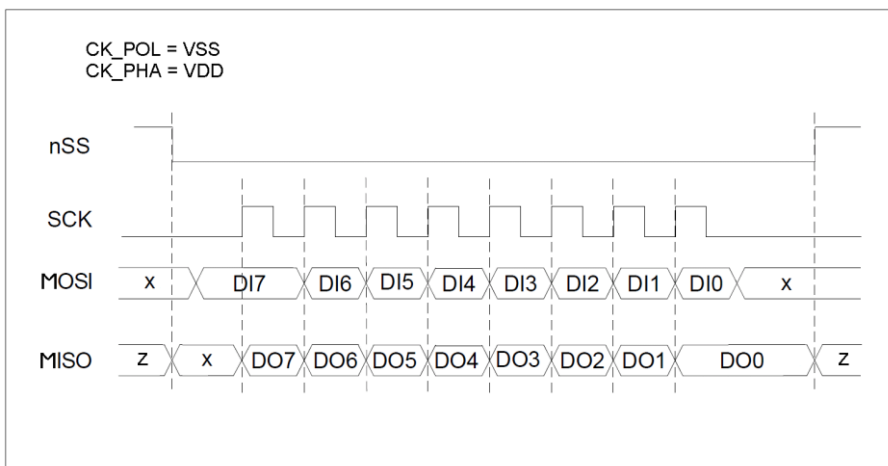


Figure 2-14 : SPI timing with MSB_FIRST = VDD, CK_POL = VSS & CK_PHA = VDD

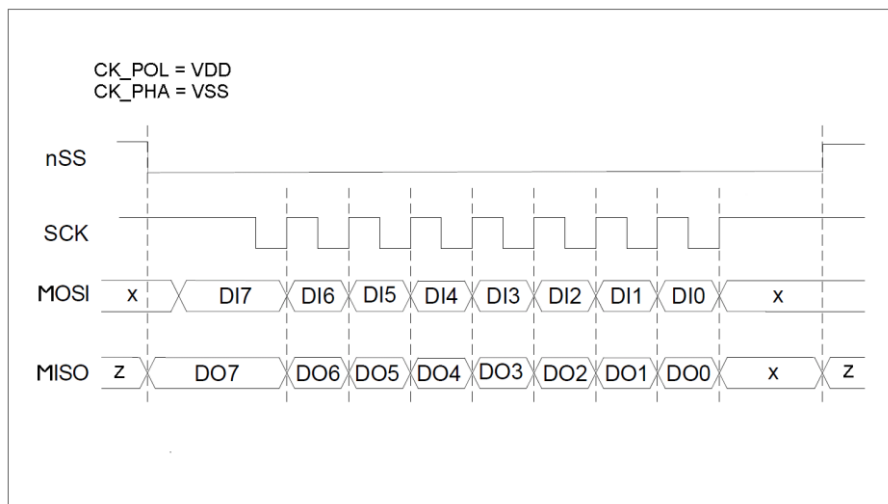


Figure 2-15 : SPI timing with MSB_FIRST = VDD, CK_POL = VDD & CK_PHA = VSS

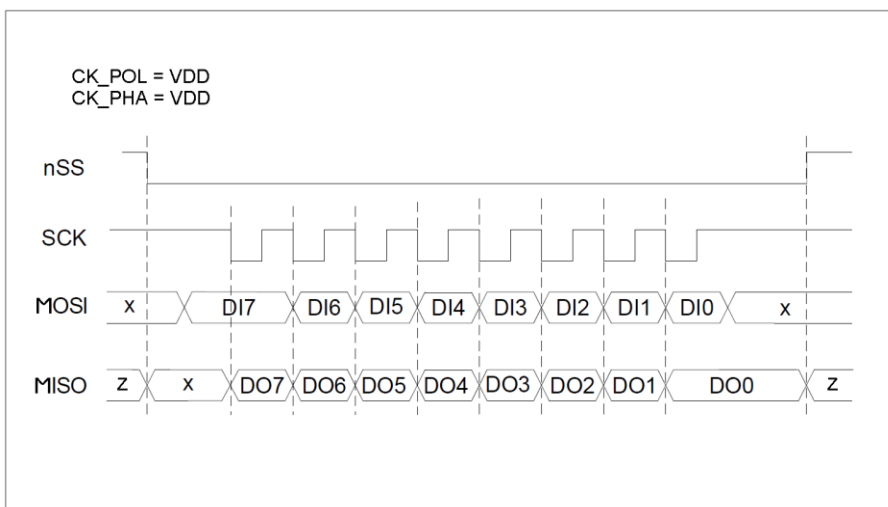


Figure 2-16 : SPI timing with MSB_FIRST = VDD, CK_POL = VDD & CK_PHA = VDD

2.4. COMMAND SET

The communication interface supports commands which enable to access the mapping dictionary and the registers. The first byte of a communication transfer is interpreted as a command. The commands are listed in the Table 2-16.

Command	Opcode	Description
WRITE_REG	"0XXXXXX"	Write internal registers at address XXXXXXX = \$00 to \$1F, \$40 to \$5F and \$60 to \$7F; the range \$20 to \$3F is not allowed.
READ_REG	"1XXXXXX"	Read internal registers at address XXXXXXX = \$00 to \$1F; the range \$20 to \$7F is not allowed. See note ⁵ .
WRITE_DIC	"00100000"	Write dictionary with groups definition. Value = \$20.
READ_DIC	"10100000"	Read dictionary with groups definition. Value = \$A0. See note 5.

Table 2-16 : Command Set

When the I²C interface is selected, the user shall take care of the consistency between the interface and the command directions (read or write):

- A "WRITE_" command must follow the I²C write data protocol (see Figure 2-11)
- A "READ_" command must follow the I²C read data protocol (see Figure 2-12)
- Any inconsistent access results in unpredictable behavior, for example an I²C read access with a "WRITE_REG" command.

2.5. RESET AND INITIALIZATION OF THE LCD SEGMENT DRIVER

The circuit is reset when it is powered on, when a brownout occurs during the active state or when the pin EN is set to VSS. If the reset is due to the power-on or a brownout, the MCU can detect it by two ways:

1. Through an interruption in the pin ICRDY. When a reset occurs, the ICRDY pin becomes inactive until the device is ready again to receive commands from the host. The polarity of the pin ICRDY is defined by the pin C18/ICRDY_POL.

C18/ICRDY_POL	ICRDY	Device:
VSS	'0'	Ready
	'1'	Not ready
VDD	'0'	Not ready
	'1'	Ready

Table 2-17 : Meaning of ICRDY as a function of ICRDY_POL

2. Reading the bit "Reset" in the command register. When a reset occurs, the bit "Reset" is set to '1'.

In harsh environments, it is strongly recommended to actively check for the reset occurrence.

After a reset, it is necessary to initialize the device. The following procedure is recommended:

1. If ICRDY is used, wait until the pin ICRDY is active. If ICRDY is not used, wait for the Communication interface start-up time (see subsection 3.7) and then check the bit "Reset" of the command register to '1', before writing it to '0'.
2. If necessary (see note 6), write the mapping dictionary with the definition of the LCD segments groups and the configuration registers with the following parameters: mux rate, frame frequency, V_{REF} level, ...
3. Enable the LCD using the "LCD_On" bit in the command register.

When LCD_On = '1', writing the mapping dictionary or many configuration registers is forbidden; the command and functional registers values can be modified.

⁵ The commands READ_REG and READ_DIC have no effect in SPI mode if the MISO pin is disabled

⁶ If the internal E²PROM is not used for the dictionary nor for the configuration registers initialization.

2.6. BLINK FUNCTION WITH MULTIPLE DRIVERS

When using the blink function with multiple EM6115 drivers, the blink clocks of each driver are not synchronized and it results in an irregular blinking. To avoid this problem, the I/O pin called BLK_CK enables to output the internal blink clock or to input an external clock.

Two bits in the configuration registers control the blink clock sharing: "Blk_Share" and "Blk_Master". The bit "Blk_Share" enables the sharing function: if '0', the BLK_CK pin is configured as an input with internal pulldown and has no effect; if '1', the circuit can work as a master or as a slave depending on the value of the bit "Blk_Master". When the bit "Blk_Master" is set to '1', the circuit is master and BLK_CK is an output; when the bit "Blk_Master" is set to '0', the circuit is slave and BLK_CK is an input.

Additionally, the master needs the bit "LCD_On" = '1' to generate the blink clock.

It is recommended to configure the slave(s) first in order to avoid any signal conflict:

1. Slave(s): write '0' to bit "Blk_Master" and '1' to bit "Blk_Share"
2. Master: write '1' to bit "Blk_Master" and '1' to bit "Blk_Share"

In Figure 2-17, a typical application using two EM6115 drivers is shown. In this case, U1 is used as the master and U2 as the slave. The driver U1 outputs its internal blink clock and the driver U2 uses it instead of its own blink clock. This assures that the blinking is synchronous on both LCD drivers. Another possibility is to use both drivers as slaves and that a third circuit (not necessarily a driver) generates the blink clock. In this last case, the constraints on the BLK_CK input signal are as follows:

- BLK_CK signal level = '0': the LCD segments are ON.
- BLK_CK signal level = '1': the LCD segments are OFF.
- Minimum duration of each signal level, '0' or '1': one frame period (see chapter 2.7.2).
- Maximum frequency of BLK_CK signal: 10 Hz.

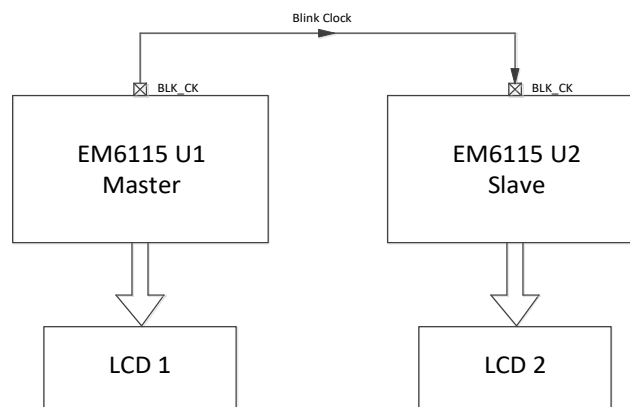


Figure 2-17 : Connection of two drivers with synchronous blink function

2.7. INTERNAL REGISTERS

Function	Addr	Rst	R/W	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	
Cmd	\$00	\$01	R/W	WRITE_EE	DUMP_EE	-	Inverse	Blank	Blink	LCD_On	Reset	
Password	\$01	\$00	R/W	Password [7:0]								
Reserved0	\$02	-	-	-	-	-	-	-	-	-	-	
...	...	...	...	...	...	...	...	...	...	...	...	
Reserved16	\$12	-	-	-	-	-	-	-	-	-	-	
End_address	\$13	\$0F	R/W	-	End_Addr [6:0]							
Cfg0	\$14	\$00	R/W	-	-	-	en_MISO	en_LowP	en_Bias3	Mux [1:0]		
Cfg1	\$15	\$2C	R/W	-	-	Frame_Freq [2:0]			Vgen_Freq [2:0]			
Cfg2	\$16	\$00	R/W	Ident [5:0]							Blk_Share	Blk_Master
Cfg3	\$17	\$08	R/W	Blk_Freq [1:0]		Vref_Level [5:0]						
en_Com	\$18	\$FF	R/W	en_LCom4	en_LCom3	en_LCom2	en_LCom1	en_RCom4	en_RCom3	en_RCom2	en_RCom1	
en_Seg [8:1]	\$19	\$FF	R/W	en_Seg8	en_Seg7	en_Seg6	en_Seg5	en_Seg4	en_Seg3	en_Seg2	en_Seg1	
en_Seg [16:9]	\$1A	\$FF	R/W	en_Seg16	en_Seg15	en_Seg14	en_Seg13	en_Seg12	en_Seg11	en_Seg10	en_Seg9	
en_Seg [24:17]	\$1B	\$FF	R/W	en_Seg24	en_Seg23	en_Seg22	en_Seg21	en_Seg20	en_Seg19	en_Seg18	en_Seg17	
en_Seg [32:25]	\$1C	\$FF	R/W	en_Seg32	en_Seg31	en_Seg30	en_Seg29	en_Seg28	en_Seg27	en_Seg26	en_Seg25	
en_Seg [40:33]	\$1D	\$FF	R/W	en_Seg40	en_Seg39	en_Seg38	en_Seg37	en_Seg36	en_Seg35	en_Seg34	en_Seg33	
en_Seg [48:41]	\$1E	\$FF	R/W	en_Seg48	en_Seg47	en_Seg46	en_Seg45	en_Seg44	en_Seg43	en_Seg42	en_Seg41	
en_Seg [50:49]	\$1F	\$23	R/W	-	-	-	-	-	-	en_Seg50	en_Seg49	
Group0	\$40	\$00	W	H0	G0	F0	E0	D0	C0	B0	A0	
Group1	\$41	\$00	W	H1	G1	F1	E1	D1	C1	B1	A1	
...	...	...	...	...	...	...	...	...	...	...	...	
Group31	\$5F	\$00	W	H31	G31	F31	E31	D31	C31	B31	A31	
Blk_Gr0	\$60	\$00	W	Blk_H0	Blk_G0	Blk_F0	Blk_E0	Blk_D0	Blk_C0	Blk_B0	Blk_A0	
Blk_Gr1	\$61	\$00	W	Blk_H1	Blk_G1	Blk_F1	Blk_E1	Blk_D1	Blk_C1	Blk_B1	Blk_A1	
...	...	...	...	...	...	...	...	...	...	...	...	
Blk_Gr31	\$7F	\$00	W	Blk_H31	Blk_G31	Blk_F31	Blk_E31	Blk_D31	Blk_C31	Blk_B31	Blk_A31	

Table 2-18 : Internal registers

The circuit is controlled by internal registers accessible via I²C or SPI. The registers are written with the command "WRITE_REG" which contains the register address. The first byte of the transfer is interpreted as the command and all the following byte(s) as register(s) value; notice that if the transfer contains more than one register value, the internal register address is automatically incremented after each register value. Within the specific address ranges \$40 to \$5F and \$60 to \$7F, the register address is automatically wrapped at the lowest address of this range; for example, the address \$5F is followed by the address \$40.

The greyed out registers can only be written when LCD_On = '0'.

Internal registers can be divided in four types:

- 1) Command register
- 2) Reserved, "Password" and "End_address" registers
- 3) Configuration registers
- 4) Functional registers

The "Password" and "End_address" registers are described in the chapter 2.8.

2.7.1. COMMAND REGISTER

Function	Addr	Rst	R/W	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Cmd	\$00	\$01	R/W	WRITE_EE	DUMP_EE	-	Inverse	Blank	Blink	LCD_On	Reset

Table 2-19 : Command register

Inverse: in inverse mode the OFF LCD segments become ON and the ON segments become OFF.

Blank: sets OFF all the LCD segments.

Blink: global blink of all LCD segments. It has priority over the individual blink selected by bits "Blk_GrX" in the functional registers.

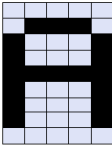
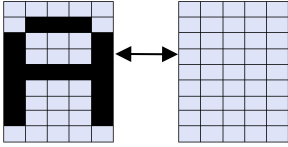
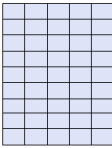
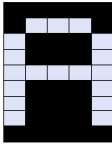
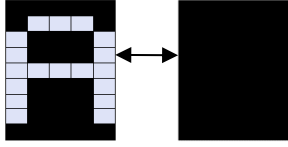
Inverse	Blank	Blink	Display
0	0	0	
0	0	1	 Alternating display
0	1	X	
1	0	0	
1	0	1	 Alternating display
1	1	X	

Table 2-20 : Combinations of Inverse, Blank & Blink modes

LCD_On: when '1' the circuit drives the LCD. When '0' the circuit enters in a low power state, but the content of the internal registers is maintained.

Reset: this bit indicates that a reset event occurred (bit value is '1'). If the user wants to detect further reset events, the bit should be cleared by writing it to '0'.

WRITE_EE & DUMP_EE: both bits can be accessed in engineering mode only.

2.7.2. CONFIGURATION REGISTERS

Function	Addr	Rst	R/W	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Cfg0	\$14	\$00	R/W	-	-	-	en_MISO	en_LowP	en_Bias3	Mux [1:0]	
Cfg1	\$15	\$2C	R/W	-	-	Frame_Freq [2:0]			Vgen_Freq [2:0]		
Cfg2	\$16	\$00	R/W	Ident [5:0]						Blk_Share	Blk_Master
Cfg3	\$17	\$08	R/W	Blk_Freq[0:1]		Vref_Level [5:0]					
en_Com	\$18	\$FF	R/W	en_LCom4	en_LCom3	en_LCom2	en_LCom1	en_RCom4	en_RCom3	en_RCom2	en_RCom1
en_Seg [8:1]	\$19	\$FF	R/W	en_Seg8	en_Seg7	en_Seg6	en_Seg5	en_Seg4	en_Seg3	en_Seg2	en_Seg1
en_Seg [16:9]	\$1A	\$FF	R/W	en_Seg16	en_Seg15	en_Seg14	en_Seg13	en_Seg12	en_Seg11	en_Seg10	en_Seg9
en_Seg [24:17]	\$1B	\$FF	R/W	en_Seg24	en_Seg23	en_Seg22	en_Seg21	en_Seg20	en_Seg19	en_Seg18	en_Seg17
en_Seg [32:25]	\$1C	\$FF	R/W	en_Seg32	en_Seg31	en_Seg30	en_Seg29	en_Seg28	en_Seg27	en_Seg26	en_Seg25
en_Seg [40:33]	\$1D	\$FF	R/W	en_Seg40	en_Seg39	en_Seg38	en_Seg37	en_Seg36	en_Seg35	en_Seg34	en_Seg33
en_Seg [48:41]	\$1E	\$FF	R/W	en_Seg48	en_Seg47	en_Seg46	en_Seg45	en_Seg44	en_Seg43	en_Seg42	en_Seg41
en_Seg [50:49]	\$1F	\$23	R/W	-	-	-	-	-	-	en_Seg50	en_Seg49

Table 2-21 : Configuration registers

The configuration registers from the address \$14 to \$15 can only be written when the bit "LCD_On" = '0'.

en_MISO: when '1' the MISO pin is enabled. When '0' it is disabled and outputs VSS (see Table 2-15).

en_LowP: selects either the Normal or Low Power mode when Mux2, Mux3 or Mux4 are used.

en_LowP	Mode
0	Normal
1	Low power

en_Bias3: selects the biasing scheme when Mux2, Mux3 or Mux4 addressing are used.

en_Bias3	Bias
0	$\frac{1}{2}$
1	$\frac{1}{3}$

en_LowP & en_Bias3: define the V_{ON} voltage used in static addressing.

en_LowP	en_Bias3	Static V _{ON}
0	0	2 x V _{REF}
0	1	V _{REF}
1	0	V _{REF} / 2
1	1	3 x V _{REF}

Mux [1:0]: sets the addressing mode (mux) of the driver.

Mux [1:0]	Addressing
00	Static
01	Mux2
10	Mux3
11	Mux4

Frame_Freq [2:0]: sets the frame rate frequency.

Frame_Freq [2:0]	Freq (Hz)			
	Static	Mux2	Mux3	Mux4
000	5.33	5.33	5.33	5.33
001	8	8	8.53	8
010	10.67	10.67	10.67	10.67
011	16	16	17.07	16
100	21.33	21.33	21.33	21.33
101	32	32	34.13	32
110	42.67	42.67	42.67	42.67
111	64	64	68.27	64

Vgen_Freq [2:0]: sets the clock frequency for the charge pumps in the voltage generator. It should be adapted to the effective load current: the higher the frequency, the higher the load current, as shown in the following table. See also the section 2.9.5 for further details.

Vgen_Freq [2:0]	Charge Pumps Freq (Hz)	Recommended IDD with LCD connected (µA)
000	64	0.20
001	128	0.30
010	256	0.45
011	512	0.75
100	1024	1.3
101	2048	2.5
110	4096	5.0
111	8192	10.0

Ident [5:0]: reserved for the device identification. The default value is \$00.

Blk_Share: enable of the blink clock sharing. When '1' the circuit can work as a master or as a slave depending on the value of the bit "Blk_Master". When '0' the BLK_CK pin is configured as input with internal pulldown. When the pin EN = VSS, the BLK_CK pin is also configured as input with internal pulldown.

Blk_Master: used when the blink clock sharing is enabled. When '0' the circuit is in slave mode. When '1' the circuit is in master mode. Warning: take care to avoid any signal conflict when configured in master mode.

Blink_Freq [1:0]: sets the blinking frequency. The blinking frequency must be at most half of the frame frequency; both individual and global blink functions use the same frequency. The blink duty cycle is 50%. The change of blink frequency while blink is enabled can cause an artefact in the next blink period.

Blink_Freq [1:0]	Freq (Hz)
00	0.5
01	1
10	2
11	4

Vref_Level [5:0]: sets the voltage reference level, $V_{REF} (V) = 0.8 + 0.025 \times Vref_Level$. Depending on the selected circuit settings, the range $Vref_Level = [0, 63]$ can be not fully valid (see sections 2.1.3, 2.1.4 and 2.1.5).

en_LCom [4:1], en_RCom [4:1]: there are different possibilities to output COM lines: at the left, at the right or at both sides of the SEG lines. A disabled COM line outputs VSS and shall not be connected to any physical LCD plane.

Bits	Description
en_LCom [4:1]	Left side LCOM [4:1] pin individual enable
en_RCom [4:1]	Right side RCOM [4:1] pin individual enable

en_Seg [50:1]: enable for each of the 50 SEG lines. All disabled SEG lines are set at VSS for power saving and shall not be connected to any physical LCD segment.

2.7.3. FUNCTIONAL REGISTERS

Function	Addr	Rst	R/W	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Group0	\$40	\$00	W	H0	G0	F0	E0	D0	C0	B0	A0
Group1	\$41	\$00	W	H1	G1	F1	E1	D1	C1	B1	A1
...	...	...	...	...	...	...	...	...	...	...	...
Group31	\$5F	\$00	W	H31	G31	F31	E31	D31	C31	B31	A31
Blk_Gr0	\$60	\$00	W	Blk_H0	Blk_G0	Blk_F0	Blk_E0	Blk_D0	Blk_C0	Blk_B0	Blk_A0
Blk_Gr1	\$61	\$00	W	Blk_H1	Blk_G1	Blk_F1	Blk_E1	Blk_D1	Blk_C1	Blk_B1	Blk_A1
...	...	...	...	...	...	...	...	...	...	...	...
Blk_Gr31	\$7F	\$00	W	Blk_H31	Blk_G31	Blk_F31	Blk_E31	Blk_D31	Blk_C31	Blk_B31	Blk_A31

Table 2-22 : Functional registers

These registers are “write-only” and any read operation at their addresses returns meaningless values.

GroupX: when ‘1’, switches ON the corresponding LCD segments within a group, according to their definition in the mapping dictionary.

Blk_GrX: when ‘1’, enables the blink of the corresponding LCD segments within a group. The definition of groups is the same as that used in the registers GroupX (defined in the mapping dictionary). Only the LCD segments that are switched ON can blink.

2.8. ENGINEERING MODE

The engineering mode unlocks the EEPROM access under specific conditions. This 128x16 EEPROM memory can be useful at the reset of the circuit, as it is automatically dumped to the internal registers and the mapping dictionary. By this way, the host does not need to write the configuration registers nor the mapping dictionary and the circuit is completely functional after startup.

2.8.1. ACCESS AND FUNCTIONS OF THE ENGINEERING MODE

Function	Addr	Rst	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Cmd	\$00	\$01	WRITE_EE	DUMP_EE	-	Inverse	Blank	Blink	LCD_On	Reset
Password	\$01	\$00	Password [7:0]							
End_address	\$13	\$0F	-	End_Addr [6:0]						

Table 2-23 : Relevant registers for the Engineering mode

This mode is accessed by the password (value = \$AC) written to the internal register "Password". The engineering mode does not allow access to individual addresses of the EEPROM for writing or reading, but considers a block of data ending at the EEPROM address End_Addr[6:0]. This value can only be written to the register "End_address" when the bit "LCD_On" = '0'; the valid values are \$09 to \$7F. It is strongly recommended to reset the password value after the completion of an EEPROM operation to avoid unwanted effects.

As can be seen in Table 2-24 : EEPROM operations, the register "Cmd" gets two functional bits, "WRITE_EE" and "DUMP_EE" that can be accessed only in engineering mode. These bits can be set to start an EEPROM operation, and they are automatically reset after completion; however, the operation's completion cannot be checked with these bits, as the communication interface is disabled during the EEPROM operation. The end of the EEPROM operation is only signaled by the state of the ICRDY pin (see Chapter 2.5 for the pin polarity setting), or by waiting for a given delay (t_{WRITE_EE} and t_{DUMP_EE} in Table 3-1). Both bits "WRITE_EE" and "DUMP_EE" can only be written when the bit "LCD_On" = '0'.

WRITE_EE	DUMP_EE	Description	Last EEPROM address accessed
0	1	Dump content of EEPROM to internal registers and mapping dictionary	End_Addr [6:0] written in EEPROM
1	X	Copy content of internal registers and mapping dictionary to EEPROM	End_Addr [6:0] written in register "End_address"

Table 2-24 : EEPROM operations

2.8.2. EEPROM READ OPERATION

In order to read the internal EEPROM, the steps are as follows:

1. Disable the LCD driver: reset bit "LCD_On" in the register "Cmd".
2. Unlock the Engineering Mode: write the password value (\$AC) to the register "Password".
3. Set the bit "DUMP_EE" in the register "Cmd".
4. Check the ICRDY pin or wait for the delay t_{DUMP_EE} .
5. Lock the Engineering Mode: write the value \$00 to the register "Password".

2.8.3. EEPROM WRITE OPERATION

In order to write the internal EEPROM, the steps are as follows:

1. Disable the LCD driver: reset bit "LCD_On" in the register "Cmd".
2. Set the VDD pin to VDD_{WR} value.
3. Write the desired data to the configuration registers and the dictionary, and then update the register "End_address" with the desired last EEPROM address to be written.
4. Unlock the Engineering Mode: write the password value (\$AC) to the register "Password".
5. Set the bit "WRITE_EE" in the register "Cmd".
6. Check the ICRDY pin or wait for the delay t_{WRITE_EE} .
7. Lock the Engineering Mode: write the value \$00 to the register "Password".

Warning: any interruption of external supply during write operation can induce an error. In that case, the user should repeat the operation again.



2.8.4. EEPROM CORRESPONDENCE TO INTERNAL REGISTERS AND DICTIONARY

The content of the internal registers (from \$14 to \$1F) are stored at the addresses \$0A to \$0F of the 128X16 EEPROM, and the mapping dictionary is stored at the addresses \$10 to \$73. The format is as follows (yellow = configuration registers; green = mapping dictionary):

Function	Addr	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
-	\$00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reserved1 & Reserved0	\$01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
End_address& Reserved16	\$09	-	End_Addr [6:0]							-	-	-	-	-	-	-	-
Cfg1 & Cfg0	\$0A	-	-	Frame_Freq [2:0]				Vgen_Freq [2:0]			-	-	-	en_MISO	en_LowP	en_Bias3	Mux [1:0]
Cfg3 & Cfg2	\$0B	Blk_Freq [1:0]		Vref_Level [5:0]						Ident [5:0]						Blk_Share	Blk_Master
en_Seg[8:1] & en_Com[4:1]	\$0C	en_Seg8	en_Seg7	en_Seg6	en_Seg5	en_Seg4	en_Seg3	en_Seg2	en_Seg1	en_LCom4	en_LCom3	en_LCom2	en_LCom1	en_RCom4	en_RCom3	en_RCom2	en_RCom1
en_Seg [24:9]	\$0D	en_Seg24	en_Seg23	en_Seg22	en_Seg21	en_Seg20	en_Seg19	en_Seg18	en_Seg17	en_Seg16	en_Seg15	en_Seg14	en_Seg13	en_Seg12	en_Seg11	en_Seg10	en_Seg9
en_Seg [40:25]	\$0E	en_Seg40	en_Seg39	en_Seg38	en_Seg37	en_Seg36	en_Seg35	en_Seg34	en_Seg33	en_Seg32	en_Seg31	en_Seg30	en_Seg29	en_Seg28	en_Seg27	en_Seg26	en_Seg25
en_Seg [50:41]	\$0F	-	-	-	-	-	-	en_seg50	en_Seg49	en_Seg48	en_Seg47	en_Seg46	en_Seg45	en_Seg44	en_Seg43	en_Seg42	en_Seg41
SEG1 : COM2 & COM1	\$10	Ngrp_012[4:0]					Nbit_012[2:0]			Ngrp_011[4:0]				Nbit_011[2:0]			
SEG1 : COM4 & COM3	\$11	Ngrp_014[4:0]					Nbit_014[2:0]			Ngrp_013[4:0]				Nbit_013[2:0]			
SEG2 : COM2 & COM1	\$12	Ngrp_022[4:0]					Nbit_022[2:0]			Ngrp_021[4:0]				Nbit_021[2:0]			
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
SEG50 : COM4 & COM3	\$73	Ngrp_504[4:0]					Nbit_504[2:0]			Ngrp_503[4:0]				Nbit_503[2:0]			
-	\$74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
-	\$7F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2-25 : EEPROM correspondence to internal registers and dictionary

2.9. ANALOG SYSTEM FUNCTIONS

2.9.1. VOLTAGE REGULATOR

The regulated voltage V_{REG} is connected to the following blocks: logic, internal registers, oscillator, EEPROM and POR. The voltage V_{REG} is available at the pin VREG, where the capacitor C_{VREG} must be connected to implement the filter function. The nominal value of V_{REG} is 1.05 V; as the VDD supply voltage approaches 1.0 V, the internal voltage regulator becomes a voltage follower with a minimum voltage drop.

The C_{VREG} capacitor nominal value is 1 μ F. The capacitor should be of type MLCC (Multi-Layer Ceramic Typ II).

2.9.2. POWER ON RESET

The POR senses the regulated voltage V_{REG} . The cell has two functions:

1. It triggers a system reset after the voltage regulator is switched on. The POR produces a reset until the end of the POR delay, after V_{REG} becomes higher than the threshold voltage V_{POR} . The delay is long enough to assure the correct reset of all the registers in the circuit.
2. It monitors the regulated voltage and initiate a system reset if V_{REG} drops below the threshold voltage V_{POR} . This threshold is defined to a value which is below the specified regulated voltage range, but high enough to ensure that all the registers can maintain their states.

2.9.3. OSCILLATOR

The circuit has an internal 8.2 kHz RC oscillator. The necessary clock signals for the voltage generator and for the LCD waveforms generator are obtained through programmable prescalers.

2.9.4. VOLTAGE REFERENCE

The device has an on-chip voltage reference which determines the voltage level of the LCD waveforms. The voltage reference is programmable with the register "Vref_Level" and can therefore be adapted to different LCD module characteristics.

2.9.5. VOLTAGE GENERATOR

To generate the necessary voltage levels VL1, VL2 and VL3, the driver is equipped with a voltage generator based on two charge pumps. The charge pumps frequency is programmable ("Vgen_Freq") and should be adapted to the current consumption of the display. If the frequency is too low for a given load current, the generated voltages will be lower than expected, and this can result in a DC offset voltage on the LCD segments. It is strongly recommended to control the generated voltages with the display connected to the circuit.

External capacitors (100 nF and 1 μ F nominal value) are needed and should be of type MLCC (Multi-Layer Ceramic Typ II).

Depending on the selected circuit settings, C_{VL1} or C_{VL2} need a capacitor with a nominal value of 1 μ F (see sections 2.1.2 and 2.1.3). The effective capacitance of the 1 μ F capacitor can affect the stability of the circuit because the capacitor is used by the voltage reference. Stability is ensured with an effective capacitance of 300 nF or higher. The effective capacitance refers to the capacitance after taking into account the tolerance, the bias voltage derating and the temperature derating of the capacitor. Using a capacitor with a nominal value of 300 nF does not ensure stability because the effective capacitance under the operating conditions must not be less than 300 nF.

All other capacitors in the voltage generator have a nominal value of 100 nF. These 100 nF capacitors do not affect the stability of the circuit because they are used by the charge pumps. Therefore, there are no special requirements for their effective capacitance.

3. ELECTRICAL SPECIFICATIONS

3.1. ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Conditions	Min.	Max.	Unit
Storage temperature	T _{STORE}		-40	125	°C
Supply voltage	VDD	VSS = 0 V	-0.2	3.6	V
Voltage on any pin	V _{MAX}		VSS-0.2	VDD+0.2	V
V _{ESD}	ESD Voltage	HBM Note ⁷		±2000	V
I _{LU}	Latch-up Current	Jedec Note ⁸		±100	mA

Stresses above these listed maximum ratings may cause permanent damage to the device. Exposure beyond specified electrical characteristics may affect device reliability or cause malfunction.

3.2. HANDLING PROCEDURES

This device has built-in protection against high static voltages or electric fields; however, anti-static precautions must be taken as for any other CMOS component. Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the voltage range. Unused inputs must always be tied to a defined logic voltage level.

3.3. OPERATING CONDITIONS

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Operating temperature	T _{OP}		-40		85	°C
Supply voltage range	VDD		1.0		3.6	V
Reference terminal	VSS			0		V
Regulator capacitor	C _{VREG}			1		μF

3.4. ELECTRICAL CHARACTERISTICS AT VDD=3V

Operating conditions unless otherwise specified: VDD = 3 V, T = 25°C

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply current: disable	IDDIS	EN = VSS			10	nA
Supply current: LCD OFF	IDDOFF	EN = VDD, LCD_On = '0'		50		nA
Supply current: normal mode	IDDNM	Note ⁹	Vref_Level = \$08	150		nA
Supply current: low power mode	IDDLP		Vref_Level = \$30	130		nA

⁷ HBM: Human Body Model according to JS-001.

⁸ Latch-up testing according to JESD78 Class I (room temperature) level A (100 mA)

⁹ Mux2; Bias ½; without LCD display; 50% LCD segments ON; Frame_Freq = \$05; Vgen_Freq = \$02



Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Input Pins							
Low level input voltage	V _{IL}					0.3xVDD	V
High level input voltage	V _{IH}			0.7xVDD			V
Input leakage	I _{IN}	V _{IN} = VSS or VDD		-100		100	nA
LCD Pins							
COM Low level output current	I _{OL_COM}	VL3=3V	V _{OUT} = 50 mV			-400	μA
COM High level output current	I _{OH_COM}		V _{OUT} = VL3 - 50 mV	200			μA
SEG Low level output current	I _{OL_SEG}		V _{OUT} = 50 mV			-60	μA
SEG High level output current	I _{OH_SEG}		V _{OUT} = VL3 - 50 mV	30			μA
Regulator							
Regulator Voltage	V _{REG}	10 μA load		1.00	1.05	1.10	V
Power-On-Reset at V _{REG}							
Threshold Voltage	V _{POR}			0.70	0.80	0.90	V
RC Oscillator							
Frequency	F _{RC}			8.0	8.2	8.4	kHz
LCD Driver							
Voltage Level 1	VL1	Note ¹⁰	Vref_Level = \$00		0.800		V
			Vref_Level = \$01		0.825		
			Vref_Level = \$02		0.850		
			Vref_Level = \$04		0.900		
			Vref_Level = \$08	-1.5%	1.000	+1.5%	
			Vref_Level = \$10		1.200		
			Vref_Level = \$20		1.600		
			Vref_Level = \$3F		2.375		
VL1 temperature dependency	ΔVL1/ΔT		Vref_Level = \$08		-200		ppm/°C
VL1 voltage dependency	ΔVL1/ΔVDD		Vref_Level = \$08; VDD = 1.1 to 3.6 V		1.4		mV/V

¹⁰ 1 μA load; Static Drive, $V_{ON} = V_{REF}$; SEGs and COMs disabled

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Voltage Level 2	VL2	Note ¹¹	1 μ A load in VL2	$2 \times VL1_{MIN} - 30 \text{ mV}$	$2 \times VL1$	$2 \times VL1_{MAX} + 30 \text{ mV}$	V
Voltage Level 3	VL3		1 μ A load in VL3	$3 \times VL1_{MIN} - 45 \text{ mV}$	$3 \times VL1$	$3 \times VL1_{MAX} + 45 \text{ mV}$	V
DC Voltage	V _{DC}	Note ¹²				50	mV

3.5. ELECTRICAL CHARACTERISTICS AT VDD=1.55V

Operating conditions unless otherwise specified: VDD = 1.55 V, T = 25°C

Parameter	Symbol	Conditions		Min.	Typ.	Max.	Unit
Supply current: disable	IDD _{DIS}	EN = VSS				10	nA
Supply current: LCD OFF	IDD _{OFF}	EN = VDD, LCD_On = '0'			50		nA
Supply current: normal mode	IDD _{NM}	Note ¹³	Vref_Level = \$08		150		nA
Input Pins							
Low level input voltage	V _{IL}					0.3xVDD	V
High level input voltage	V _{IH}			0.7xVDD			V
Input leakage	I _{IN}	V _{IN} = VSS or VDD		-100		100	nA
LCD Pins							
COM Low level output current	I _{OL_COM}	VL3=3V	V _{OUT} = 50 mV			-400	μA
COM High level output current	I _{OH_COM}		V _{OUT} = VL3 - 50 mV	200			μA
SEG Low level output current	I _{OL_SEG}		V _{OUT} = 50 mV			-60	μA
SEG High level output current	I _{OH_SEG}		V _{OUT} = VL3 - 50 mV	30			μA
Regulator							
Regulator Voltage	V _{REG}	10 μA load		1.00	1.05	1.10	V
Power-On-Reset at V _{REG}							
Threshold Voltage	V _{POR}			0.70	0.80	0.90	V
RC Oscillator							
Frequency	F _{RC}			8.0	8.2	8.4	kHz

¹¹ Vref_Level = \$08; Vgen_Freq = \$07; SEGs and COMs disabled; Normal mode, Bias 1/5

¹² Average voltage measured between any SEG and COM outputs, over a whole frame period

¹³ Mux2; Bias 1/2; without LCD display; 50% LCD segments ON; Frame_Freq = \$05; Vgen_Freq = \$02

Operating conditions unless otherwise specified: VDD = 1.55 V, T = 25°C

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	
LCD Driver							
Voltage Level 1	VL1	Note ¹⁴	Vref_Level = \$00		0.800	V	
			Vref_Level = \$01		0.825		
			Vref_Level = \$02		0.850		
			Vref_Level = \$04		0.900		
			Vref_Level = \$08	-1.5%	1.000		+1.5%
			Vref_Level = \$10		1.200		
VL1 temperature dependency	$\Delta VL1/\Delta T$		Vref_Level = \$08		-200		ppm/°C
VL1 voltage dependency	$\Delta VL1/\Delta VDD$		Vref_Level = \$08; VDD = 1.1 to 3.6 V		1.4		mV/V
Voltage Level 2	VL2	Note ¹⁵	1 uA load in VL2	2 x VL1 _{MIN} - 30 mV	2 x VL1	2 x VL1 _{MAX} + 30 mV	V
Voltage Level 3	VL3		1 uA load in VL3	3 x VL1 _{MIN} - 45 mV	3 x VL1	3 x VL1 _{MAX} + 45 mV	V
DC Voltage	V _{DC}	Note ¹⁶				50	mV

3.6. EEPROM ACCESS – SPECIFICATIONS

Operating conditions unless otherwise specified: VDD = 3 V, T = 25°C

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Operating temperature in EEPROM write	T _{WR}		-10	25	60	°C
VDD range for valid EEPROM write	VDD _{WR}		1.4		3.6	V
V _{REG} during EEPROM write	V _{REG_WR}	10 µA load	1.04	1.14	1.24	V
Delay for complete EEPROM write (WRITE_EE)	t _{WRITE_EE}			700	1000	ms
Delay for complete EEPROM read (DUMP_EE)	t _{DUMP_EE}			10	12	ms
Writing endurance	n _{CYC}		100 0			cycles

Table 3-1 : EEPROM access specifications

3.7. TIMING CHARACTERISTICS

Operating conditions unless otherwise specified: VDD = 1.55 & 3 V, T = 25°C

¹⁴ 1 µA load; Static Drive, V_{ON} = V_{REF}; SEGs and COMs disabled

¹⁵ Vref_Level = \$08; Vgen_Freq = \$07; SEGs and COMs disabled; Normal mode, Bias 1/3

¹⁶ Average voltage measured between any SEG and COM outputs, over a whole frame period



Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Communication interface Start-up time	t _{ST}	Note ¹⁷			25	ms
Device disable time	t _{DIS}	Note ¹⁸	50			ms
I²C						
SCL frequency	f _{SCL}			100	400	kHz
SCL low period	t _{LOW}		1.3			μs
SCL high period	t _{HIGH}		600			ns
SDA setup time	t _{SU;DAT}		100			ns
SDA hold time	t _{HD;DAT}		0		900	ns
SCL and SDA rise time	t _R		20		300	ns
SCL and SDA fall time	t _F				300	ns
Setup time for a repeated start condition	t _{SU;STA}		600			ns
Hold time for a start condition	t _{HD;STA}		600			ns
Setup time for a stop condition	t _{SU;STO}		600			ns
Spike width on SCL and SDA	t _{SP}				50	ns
Time before a new transmission can start	t _{BUF}		1.3			μs
SPI						
SCK frequency	f _{SPI}				500	kHz
SCK low period	t _{SCL}		900			ns
SCK high period	t _{SCH}		900			ns
SCK rise time	t _{SCR}				100	ns
SCK fall time	t _{SCF}				100	ns
MOSI setup time	t _{MOSU}		250			ns
MOSI hold time	t _{MOH}		50			ns
MISO hold time	t _{MIH}				0	ns
MISO delay out	t _{MIDO}				250	ns
MISO delay Z	t _{MIDZ}				250	ns

¹⁷ The communication interface is ready when the pin ICRDY is active. If ICRDY is not used, the given time must be respected.

¹⁸ After disabling the device (pin EN = VSS), a delay must be respected before re-enabling it (pin EN = VDD).

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
nSS setup time	t_{nSSSU}		1.0			μs
nSS hold time	t_{nSSH}		250			ns
nSS high time (Bus free time between communication frames)	t_{SPBUF}		1.5			μs

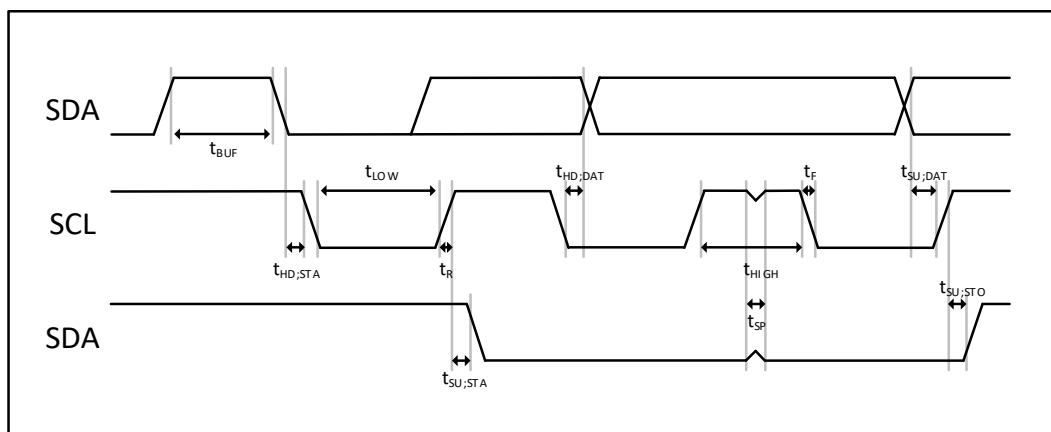


Figure 3-1 : I2C timing characteristics

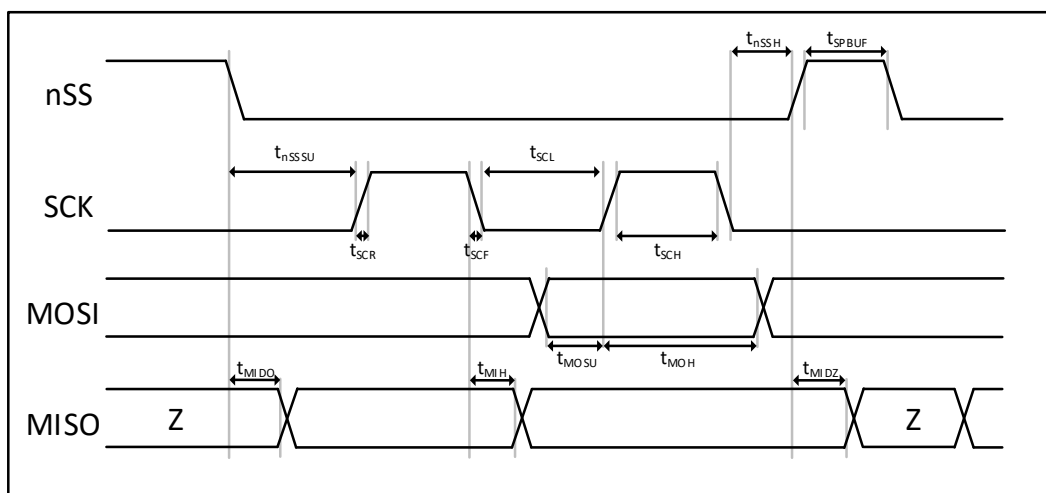


Figure 3-2 : SPI timing characteristics with CK_POL = VSS & CK_PHA = VSS

4. TYPICAL APPLICATIONS

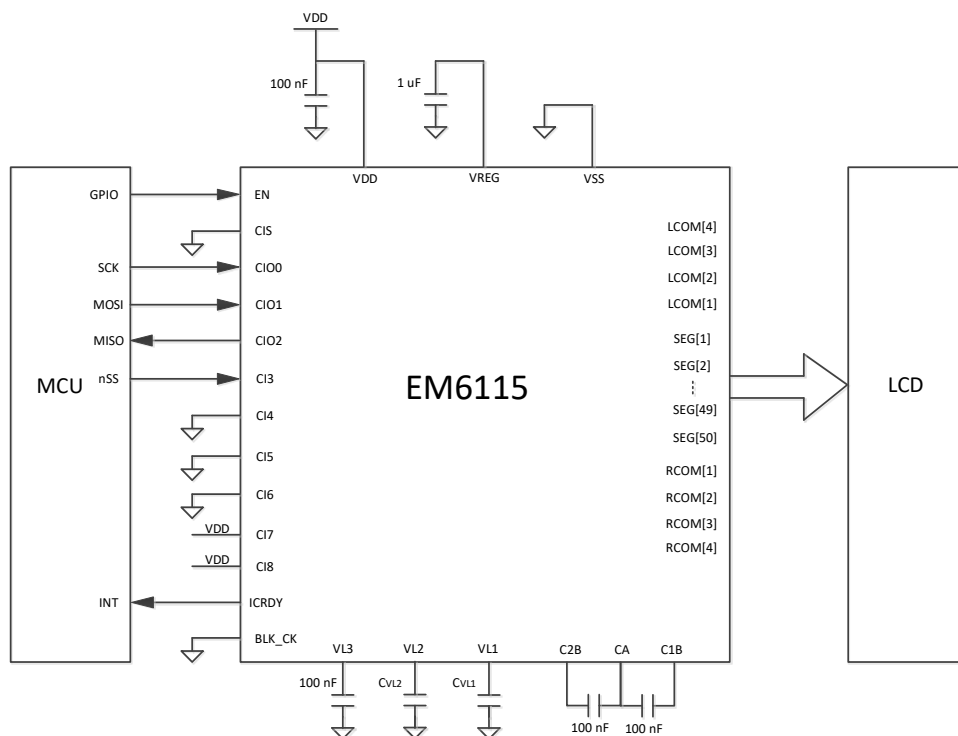


Figure 4-1 : Bias $\frac{1}{3}$ & Static $3 \times V_{REF}$ (see Note ¹⁹)

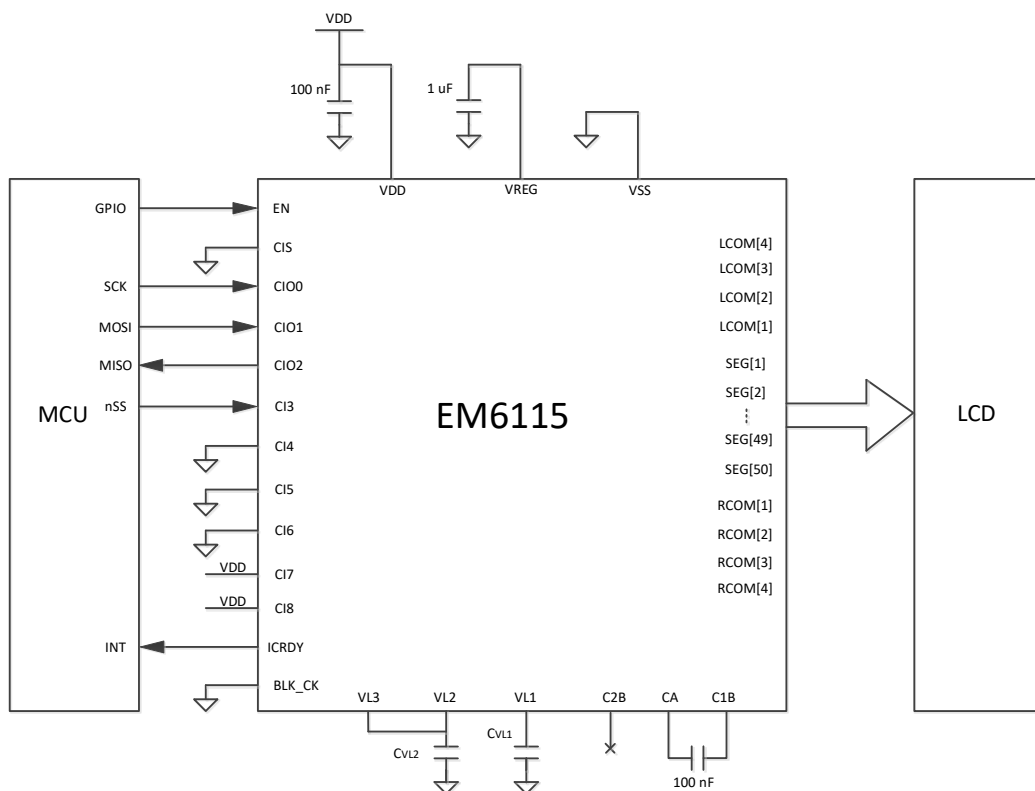


Figure 4-2 : Bias $\frac{1}{2}$, Static $V_{REF} / 2$ & Static $2 \times V_{REF}$ (see Note ²⁰)

¹⁹ For values of C_{VL1} and C_{VL2} see chapters 2.1.2 and 2.1.3

²⁰ For values of C_{VL1} and C_{VL2} see chapters 2.1.2 and 2.1.3

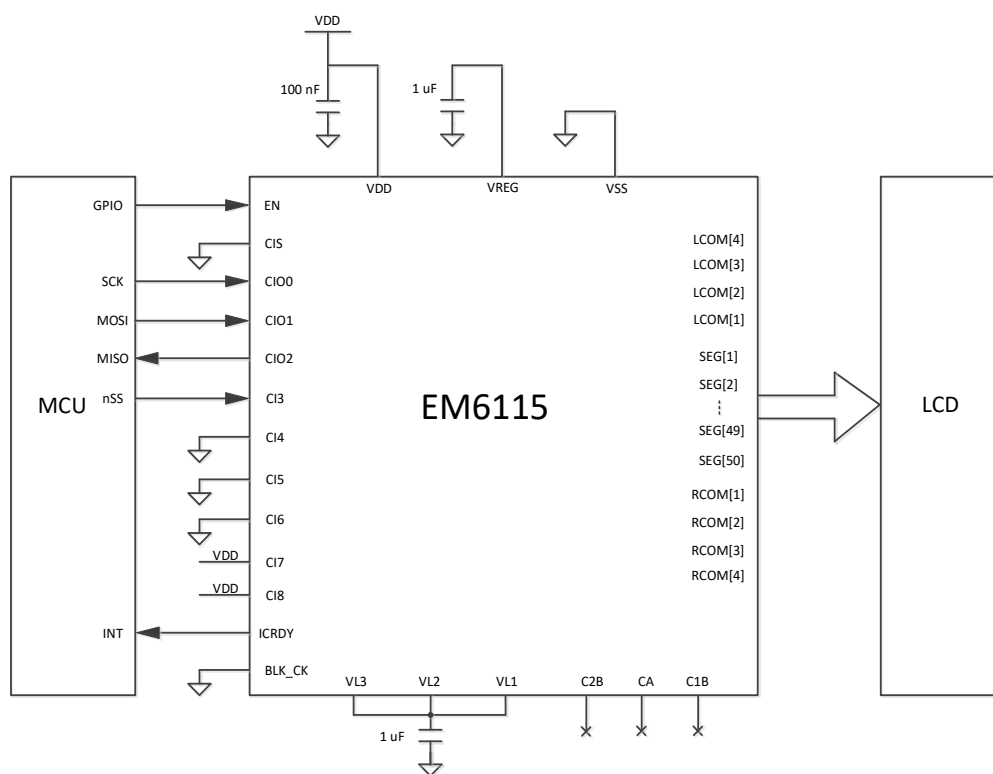
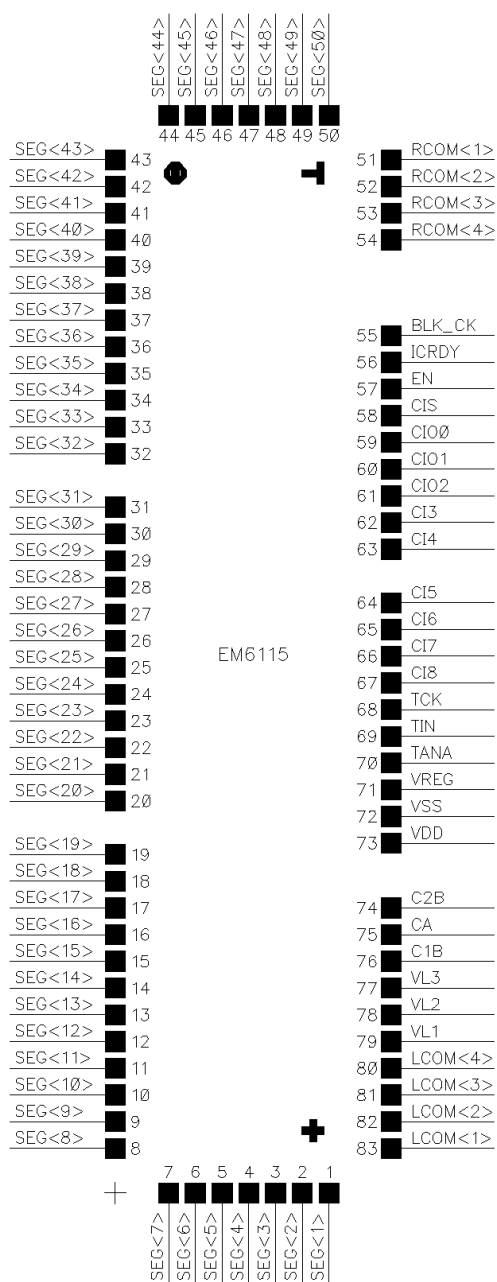


Figure 4-3 : Static V_{REF}

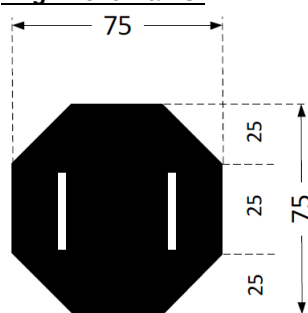
5. PAD LOCATION DIAGRAM

Pad location with a pitch of 90 μm
Pad opening: 68 x 68 μm^2
Chip Size: 3852 μm x 1152 μm = 4.438 mm²
Either wire bonded or flip chip bonded
Substrate connected to VSS

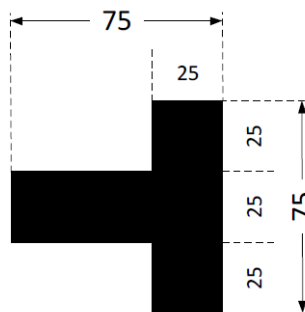
Chip assembly must protect the backside and the front side of the die from light. Effects of light may affect device reliability or cause malfunction.



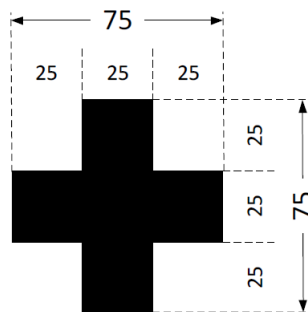
Alignment marks:



Octagon center: X = 273.71 μm ; Y = 3505.53 μm



Letter T center: X = 737.35 μm ; Y = 3505.53 μm



Cross center: X = 737.35 μm ; Y = 280.385 μm

Notes: The origin (0,0) microns is the lower left coordinate of center pads.

Pad to scribe right: 76.78 μm
 Pad to scribe left: 77.22 μm
 Pad to scribe top: 77.09 μm
 Pad to scribe bottom: 76.91 μm

#	Pin name	X in μm	Y in μm	#	Pin name	X in μm	Y in μm
1	SEG<1>	720	0	43	SEG<43>	0	3480
2	SEG<2>	630	0	44	SEG<44>	180	3630
3	SEG<3>	540	0	45	SEG<45>	270	3630
4	SEG<4>	450	0	46	SEG<46>	360	3630
5	SEG<5>	360	0	47	SEG<47>	450	3630
6	SEG<6>	270	0	48	SEG<48>	540	3630
7	SEG<7>	180	0	49	SEG<49>	630	3630
8	SEG<8>	0	150	50	SEG<50>	720	3630
9	SEG<9>	0	240	51	RCOM<1>	930	3480
10	SEG<10>	0	330	52	RCOM<2>	930	3390
11	SEG<11>	0	420	53	RCOM<3>	930	3300
12	SEG<12>	0	510	54	RCOM<4>	930	3210
13	SEG<13>	0	600	55	BLK_CK	930	2888
14	SEG<14>	0	690	56	ICRDY	930	2798
15	SEG<15>	0	780	57	EN	930	2708
16	SEG<16>	0	870	58	CIS	930	2618
17	SEG<17>	0	960	59	CIO0	930	2528
18	SEG<18>	0	1050	60	CIO1	930	2438
19	SEG<19>	0	1140	61	CIO2	930	2348
20	SEG<20>	0	1320	62	CI3	930	2258
21	SEG<21>	0	1410	63	CI4	930	2168
22	SEG<22>	0	1500	64	CI5	930	1988
23	SEG<23>	0	1590	65	CI6	930	1898
24	SEG<24>	0	1680	66	CI7	930	1808
25	SEG<25>	0	1770	67	CI8	930	1718
26	SEG<26>	0	1860	68	TCK	930	1628
27	SEG<27>	0	1950	69	TIN	930	1538
28	SEG<28>	0	2040	70	TANA	930	1448
29	SEG<29>	0	2130	71	VREG	930	1358
30	SEG<30>	0	2220	72	VSS	930	1268
31	SEG<31>	0	2310	73	VDD	930	1178
32	SEG<32>	0	2490	74	C2B	930	960
33	SEG<33>	0	2580	75	CA	930	870
34	SEG<34>	0	2670	76	C1B	930	780
35	SEG<35>	0	2760	77	VL3	930	690
36	SEG<36>	0	2850	78	VL2	930	600
37	SEG<37>	0	2940	79	VL1	930	510
38	SEG<38>	0	3030	80	LCOM<4>	930	420
39	SEG<39>	0	3120	81	LCOM<3>	930	330
40	SEG<40>	0	3210	82	LCOM<2>	930	240
41	SEG<41>	0	3300	83	LCOM<1>	930	150
42	SEG<42>	0	3390				

Table 27 : Pad coordinates

6. PACKAGE INFORMATION

Please contact EM Microelectronic-Marin for available package options

7. CUSTOMER DELIVERY: DEFAULT CONFIGURATION

Function	Addr	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
-	\$00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
End_address	\$09	-	End_Addr [6:0] = \$09							-	-	-	-	-	-	-	-
N/A	\$0A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
N/A	\$7F	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 28: EEPROM content delivered to customer

The configuration registers and dictionary are not defined in the EEPROM delivered to customers, as the value of End_Addr is limited to the reserved area. Therefore, the default configuration of the circuit is given by the reset values of both configuration registers and dictionary:

- The reset values of configuration registers can be found in the section 2.7.2.
- The reset values of dictionary are all '0' and, therefore, all physical segments are mapped to the bit 0 of the group 0 (named A0) in the internal registers.

8. ORDERING INFORMATION

Part Number	Delivery Form
EM6115V3WS8	Sawn wafer, 8 mils thickness
EM6115V3xxx	For other options, please contact the EM Microelectronic-Marin SA sales representative.

EM Microelectronic-Marin SA ("EM") makes no warranties for the use of EM products, other than those expressly contained in EM's applicable General Terms of Sale, located at <http://www.emmicroelectronic.com>. EM assumes no responsibility for any errors which may have crept into this document, reserves the right to change devices or specifications detailed herein at any time without notice, and does not make any commitment to update the information contained herein.

No licenses to patents or other intellectual property rights of EM are granted in connection with the sale of EM products, neither expressly nor implicitly.

In respect of the intended use of EM products by customer, customer is solely responsible for observing existing patents and other intellectual property rights of third parties and for obtaining, as the case may be, the necessary licenses.

Important note: The use of EM products as components in medical devices and/or medical applications, including but not limited to, safety and life supporting systems, where malfunction of such EM products might result in damage to and/or injury or death of persons is expressly prohibited, as EM products are neither destined nor qualified for use as components in such medical devices and/or medical applications. The prohibited use of EM products in such medical devices and/or medical applications is exclusively at the risk of the customer.