PCF8811

80 x 128 pixels matrix LCD driver

Rev. 04 — 27 June 2008 Product data sheet

1. General description

The PCF8811 is a low-power CMOS LCD controller driver, designed to drive a graphic display of 80 rows and 128 columns or a graphic display of 79 rows and 128 columns and an icon row of 128 symbols. All necessary functions for the display are provided in a single chip, including on-chip generation of the LCD supply and bias voltages, resulting in a minimum of external components and low power consumption. The PCF8811 can interface microcontrollers via a parallel bus, serial bus or I^2C-bus interface.

2. Features

- Single-chip LCD controller/driver
- 80 row and 128 column outputs
- Display data RAM 80 × 128 bit
- 128 icons (row 80 can be used for icons in extended command set and when icon rows are enabled)
- Low power consumption; suitable for battery operated systems
- An 8-bit parallel interface, 3 or 4-line Serial Peripheral Interface (SPI) and high-speed I^2C-bus
- On-chip:
  - Configurable voltage multiplier generating LCD supply voltage V_{LCD}; an external V_{LCD} is also possible
  - Linear temperature compensation of V_{LCD}; 8 programmable temperature coefficients (extended command set); one fixed temperature coefficient which can be set as default by OTP programming (basic command set)
  - Generation of intermediate LCD bias voltage
  - Oscillator requires no external components
- OTP calibration for V_{LCD} and accurate frame frequency
- External reset input pad
- External clock input possible
- Multiplex rate: 1:16 to 1:80 in steps of 8 when no icon row is used, with the icon row steps of 16 can be used
- Logic supply voltage range V_{DD1} to V_{SS}:
  - 1.7 V to 3.3 V
- High-voltage multiplier supply voltage range V_{DD2}, V_{DD3} to V_{SS}:
  - 1.8 V to 3.3 V
- Display supply voltage range V_{LCD} to V_{SS}:
  - 3 V to 9 V

- Programmable bottom row pads mirroring; for compatibility with both Tape Carrier Packages (TCP) and Chip-On-Glass (COG) applications (extended command set)
- Status read, which allows for chip recognition and content checking of some registers
- Start address line which allows, for instance, the scrolling of the displayed image
- Programmable display RAM pointers for variable display sizes
- Slim chip layout, suited for COG applications
- Temperature range: T_{amb} = –40 °C to +85 °C
- CMOS compatible inputs

3. Applications

- Automotive displays
- Telecom equipment
- Portable instruments
- Point-of-sale terminals

4. Ordering information

Table 1. Ordering information

Type number	Package		
	Name	Description	Version
PCF8811U/2DA/1	-	chip with bumps in tray (not covered by Motif license agreement)	-
PCF8811MU/2DA/1	-	chip with bumps in tray (sold under license from Motif)	-

5. Block diagram

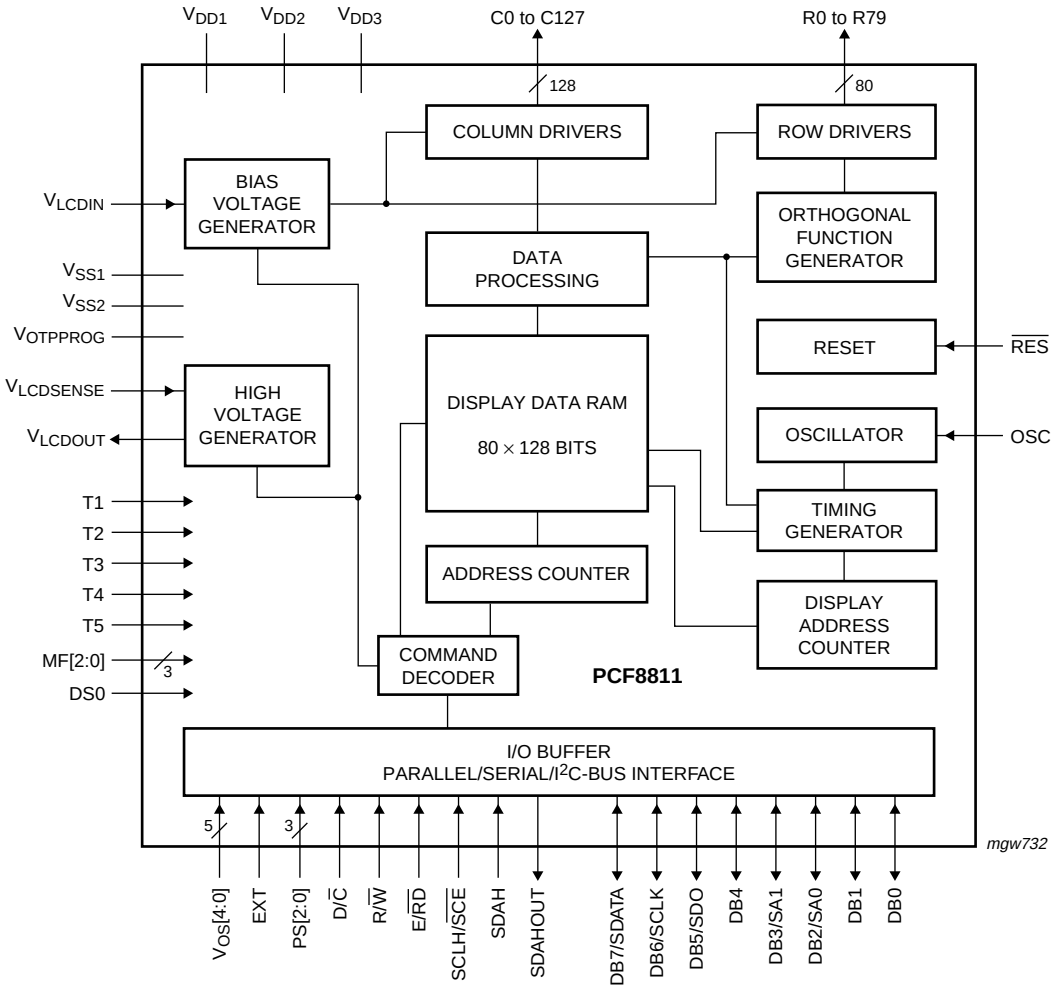
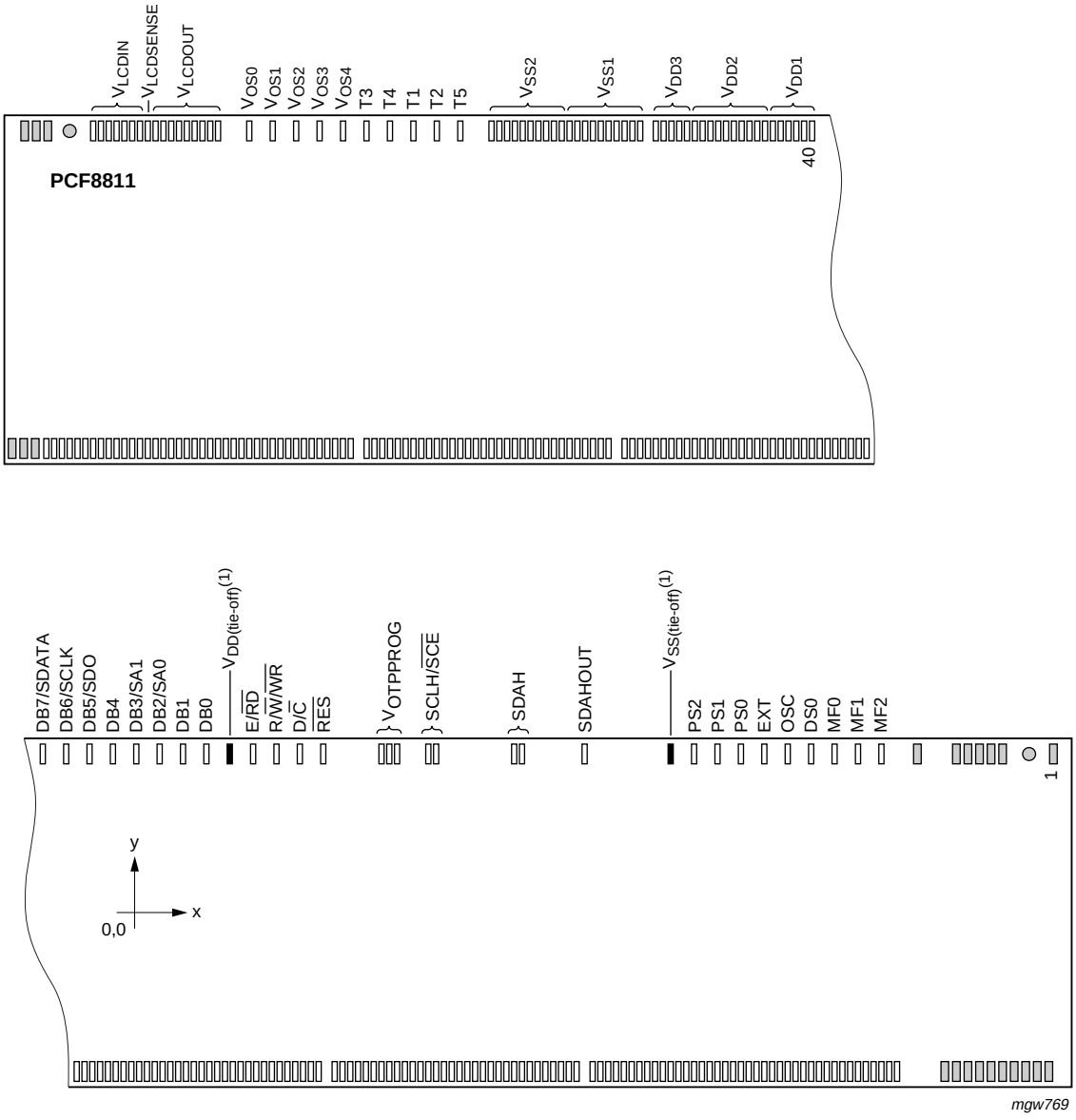


Fig 1. Block diagram of PCF8811

6. Pinning information

6.1 Pinning



(1) $V_{SS(tie\text{-}off)}$ and $V_{DD(tie\text{-}off)}$ are used for local tie-offs.

Fig 2. Bonding pad locations for PCF8811 (bottom view)

Table 2. Pad allocation table

Pad	Symbol	Pad	Symbol
1 to 8	-	38	DB6/SCLK
9	MF2	39	DB7/SDATA
10	MF1	40 to 45	V_{DD1}
11	MF0	46 to 55	V_{DD2}
12	DS0	56 to 60	V_{DD3}
13	OSC	61 to 70	V_{SS1}
14	EXT	71 to 80	V_{SS2}
15	PS0	81	T5
16	PS1	82	T2
17	PS2	83	T1
18	$V_{SS(tie-off)}$	84	T4
19	SDAHOUT	85	T3
20 and 21	SDAH	86	V_{OS4}
22 and 23	SCLH/$\overline{SCE}$	87	V_{OS3}
24 to 26	$V_{OTPPROG}$	88	V_{OS2}
27	$\overline{RES}$	89	V_{OS1}
28	D/$\overline{C}$	90	V_{OS0}
29	R/$\overline{W}$/$\overline{WR}$	91 to 99	V_{LCDOUT}
30	E/$\overline{RD}$	100	$V_{LCDSENSE}$
31	$V_{DD(tie-off)}$	101 to 107	V_{LCDIN}
32	DB0	108 to 114	-
33	DB1	115 to 154	R79 to R40
34	DB2/SA0	155	R79[1]
35	DB3/SA1	156 to 283	C0 to C127
36	DB4	284 to 323	R0 to R39
37	DB5/SDO	324 to 333	-

[1] Duplicate of R79.

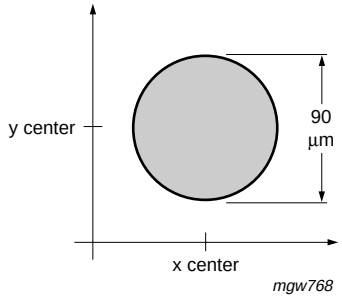


Fig 3. Alignment marker

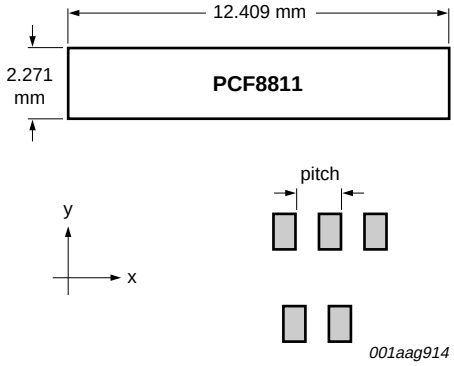


Fig 4. Chip dimensions

Table 3. Bonding pad and chip dimensions

Pad	Row/Column side (μm)	Interface side (μm)
Pad pitch	51.84 min	54.0 min
Pad size (aluminium)	42.84 × 105	50 × 100
Bump dimensions	29.9 × 98.5 (±3)	32.2 × 93.5 (±3)
Wafer thickness (excluding bumps)	381 (±25)	
	Fab 1 (mm)[1]	**Fab 2 (mm)[2]**
Die size X	12.45	12.41
Die size Y	2.31	2.27

[1] Fabrication 1 identification starts with nnnnnn, where n represents a number between 0 and 9.

[2] Fabrication 2 identification starts with AXnnnn, where X represents a letter and n represents a number between 0 and 9.

Table 4. Alignment marker position[1]

Pad	X (μm)	Y (μm)
2	5995	1017
108	–5904	1017

[1] For the position of each pad, see Table 5.

6.2 Pin description

Table 5. Bonding pad description

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
-	1	6092.00	1030.00	dummy_slanted
-	2	5995.00	1017.00	alignment mark
-	3	5876.00	1030.00	dummy
-	4	5822.00	1030.00	dummy
-	5	5768.00	1030.00	dummy
-	6	5714.00	1030.00	dummy
-	7	5660.00	1030.00	dummy
-	8	5390.00	1030.00	dummy
MF2	9	5012.00	1030.00	manufacturer device ID input
MF1	10	4850.00	1030.00	manufacturer device ID input
MF0	11	4688.00	1030.00	manufacturer device ID input
DS0	12	4526.00	1030.00	device recognition input
OSC	13	4364.00	1030.00	oscillator input
EXT	14	4094.00	1030.00	extended command set input
PS0	15	3932.00	1030.00	parallel/serial/I^2C-bus data selection input
PS1	16	3770.00	1030.00	parallel/serial/I^2C-bus data selection input
PS2	17	3608.00	1030.00	parallel/serial/I^2C-bus data selection input
$V_{SS(tie-off)}$	18	3446.00	1030.00	-

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
SDAHOUT	19	2960.00	1030.00	I^2C-bus data output
SDAH	20	2420.00	1030.00	I^2C-bus data input
SDAH	21	2366.00	1030.00	I^2C-bus data input
SCLH/$\overline{SCE}$	22	1826.00	1030.00	I^2C-bus clock input or chip enable active LOW (6800 interface)
SCLH/$\overline{SCE}$	23	1772.00	1030.00	I^2C-bus clock input or chip enable active LOW (6800 interface)
$V_{OTPPROG}$	24	1664.00	1030.00	supply voltage for OTP (can be combined with SCLH/$\overline{SCE}$)
$V_{OTPPROG}$	25	1610.00	1030.00	supply voltage for OTP (can be combined with SCLH/$\overline{SCE}$)
$V_{OTPPROG}$	26	1556.00	1030.00	supply voltage for OTP (can be combined with SCLH/$\overline{SCE}$)
$\overline{RES}$	27	1448.00	1030.00	external reset input
D/$\overline{C}$	28	1232.00	1030.00	data or command active LOW input
R/$\overline{W}$/$\overline{WR}$	29	962.00	1030.00	read or write active LOW input (6800 interface)
E/$\overline{RD}$	30	800.00	1030.00	clock enable or read active LOW input (6800 interface)
$V_{DD(tie-off)}$	31	638.00	1030.00	-
DB0	32	476.00	1030.00	parallel data input/output
DB1	33	314.00	1030.00	parallel data input/output
DB2/SA0	34	152.00	1030.00	parallel data input/output or I^2C-bus slave address input
DB3/SA1	35	–10.00	1030.00	parallel data input/output or I^2C-bus slave address input
DB4	36	–172.00	1030.00	parallel data input/output
DB5/SDO	37	–334.00	1030.00	parallel data input/output or serial data output
DB6/SCLK	38	–550.00	1030.00	parallel data input/output or serial clock input
DB7/SDATA	39	–712.00	1030.00	parallel data input/output or serial data input
V_{DD1}	40	–874.00	1030.00	supply voltage (logic)
V_{DD1}	41	–928.00	1030.00	supply voltage (logic)
V_{DD1}	42	–982.00	1030.00	supply voltage (logic)
V_{DD1}	43	–1036.00	1030.00	supply voltage (logic)
V_{DD1}	44	–1090.00	1030.00	supply voltage (logic)
V_{DD1}	45	–1144.00	1030.00	supply voltage (logic)
V_{DD2}	46	–1198.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	47	–1252.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	48	–1306.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	49	–1360.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	50	–1414.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	51	–1468.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	52	–1522.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	53	–1576.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	54	–1630.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD2}	55	–1684.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD3}	56	–1738.00	1030.00	supply voltage for the internal voltage multiplier

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
V_{DD3}	57	−1792.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD3}	58	−1846.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD3}	59	−1900.00	1030.00	supply voltage for the internal voltage multiplier
V_{DD3}	60	−1954.00	1030.00	supply voltage for the internal voltage multiplier
V_{SS1}	61	−2062.00	1030.00	ground
V_{SS1}	62	−2116.00	1030.00	ground
V_{SS1}	63	−2170.00	1030.00	ground
V_{SS1}	64	−2224.00	1030.00	ground
V_{SS1}	65	−2278.00	1030.00	ground
V_{SS1}	66	−2332.00	1030.00	ground
V_{SS1}	67	−2386.00	1030.00	ground
V_{SS1}	68	−2440.00	1030.00	ground
V_{SS1}	69	−2494.00	1030.00	ground
V_{SS1}	70	−2548.00	1030.00	ground
V_{SS2}	71	−2602.00	1030.00	ground for voltage multiplier
V_{SS2}	72	−2656.00	1030.00	ground for voltage multiplier
V_{SS2}	73	−2710.00	1030.00	ground for voltage multiplier
V_{SS2}	74	−2764.00	1030.00	ground for voltage multiplier
V_{SS2}	75	−2818.00	1030.00	ground for voltage multiplier
V_{SS2}	76	−2872.00	1030.00	ground for voltage multiplier
V_{SS2}	77	−2926.00	1030.00	ground for voltage multiplier
V_{SS2}	78	−2980.00	1030.00	ground for voltage multiplier
V_{SS2}	79	−3034.00	1030.00	ground for voltage multiplier
V_{SS2}	80	−3088.00	1030.00	ground for voltage multiplier
T5	81	−3250.00	1030.00	test input 5
T2	82	−3304.00	1030.00	test input 2
T1	83	−3466.00	1030.00	test input 1
T4	84	−3628.00	1030.00	test input 4
T3	85	−3790.00	1030.00	test input 3
V_{OS4}	86	−4060.00	1030.00	V_{LCD} offset input pad 4
V_{OS3}	87	−4222.00	1030.00	V_{LCD} offset input pad 3
V_{OS2}	88	−4384.00	1030.00	V_{LCD} offset input pad 2
V_{OS1}	89	−4654.00	1030.00	V_{LCD} offset input pad 1
V_{OS0}	90	−4816.00	1030.00	V_{LCD} offset input pad 0
V_{LCDOUT}	91	−4924.00	1030.00	voltage multiplier output
V_{LCDOUT}	92	−4978.00	1030.00	voltage multiplier output
V_{LCDOUT}	93	−5032.00	1030.00	voltage multiplier output
V_{LCDOUT}	94	−5086.00	1030.00	voltage multiplier output
V_{LCDOUT}	95	−5140.00	1030.00	voltage multiplier output

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
V_{LCDOUT}	96	–5194.00	1030.00	voltage multiplier output
V_{LCDOUT}	97	–5248.00	1030.00	voltage multiplier output
V_{LCDOUT}	98	–5302.00	1030.00	voltage multiplier output
V_{LCDOUT}	99	–5356.00	1030.00	voltage multiplier output
$V_{LCDSENSE}$	100	–5410.00	1030.00	voltage multiplier regulation input
V_{LCDIN}	101	–5464.00	1030.00	LCD supply voltage
V_{LCDIN}	102	–5518.00	1030.00	LCD supply voltage
V_{LCDIN}	103	–5572.00	1030.00	LCD supply voltage
V_{LCDIN}	104	–5626.00	1030.00	LCD supply voltage
V_{LCDIN}	105	–5680.00	1030.00	LCD supply voltage
V_{LCDIN}	106	–5734.00	1030.00	LCD supply voltage
V_{LCDIN}	107	–5788.00	1030.00	LCD supply voltage
-	108	–5904.00	1017.00	alignment mark
-	109	–6004.00	1030.00	dummy
-	110	–6058.00	1030.00	dummy
-	111	–6112.00	1030.00	dummy
-	112	–6129.24	–1032.50	dummy
-	113	–6077.40	–1032.50	dummy
-	114	–6025.56	–1032.50	dummy
R79	115	–5973.72	–1032.50	LCD row driver output (R79 is the icon row when the icon row is enabled)
R78	116	–5921.88	–1032.50	LCD row driver output
R77	117	–5870.04	–1032.50	LCD row driver output
R76	118	–5818.20	–1032.50	LCD row driver output
R75	119	–5766.36	–1032.50	LCD row driver output
R74	120	–5714.52	–1032.50	LCD row driver output
R73	121	–5662.68	–1032.50	LCD row driver output
R72	122	–5610.84	–1032.50	LCD row driver output
R71	123	–5559.00	–1032.50	LCD row driver output
R70	124	–5507.16	–1032.50	LCD row driver output
R69	125	–5455.32	–1032.50	LCD row driver output
R68	126	–5403.48	–1032.50	LCD row driver output
R67	127	–5351.64	–1032.50	LCD row driver output
R66	128	–5299.80	–1032.50	LCD row driver output
R65	129	–5247.96	–1032.50	LCD row driver output
R64	130	–5196.12	–1032.50	LCD row driver output
R63	131	–5144.28	–1032.50	LCD row driver output
R62	132	–5092.44	–1032.50	LCD row driver output
R61	133	–5040.60	–1032.50	LCD row driver output
R60	134	–4988.76	–1032.50	LCD row driver output

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
R59	135	–4936.92	–1032.50	LCD row driver output
R58	136	–4885.08	–1032.50	LCD row driver output
R57	137	–4833.24	–1032.50	LCD row driver output
R56	138	–4781.40	–1032.50	LCD row driver output
R55	139	–4729.56	–1032.50	LCD row driver output
R54	140	–4677.72	–1032.50	LCD row driver output
R53	141	–4625.88	–1032.50	LCD row driver output
R52	142	–4574.04	–1032.50	LCD row driver output
R51	143	–4522.20	–1032.50	LCD row driver output
R50	144	–4470.36	–1032.50	LCD row driver output
R49	145	–4418.52	–1032.50	LCD row driver output
R48	146	–4366.68	–1032.50	LCD row driver output
R47	147	–4314.84	–1032.50	LCD row driver output
R46	148	–4263.00	–1032.50	LCD row driver output
R45	149	–4211.16	–1032.50	LCD row driver output
R44	150	–4159.32	–1032.50	LCD row driver output
R43	151	–4107.48	–1032.50	LCD row driver output
R42	152	–4055.64	–1032.50	LCD row driver output
R41	153	–4003.80	–1032.50	LCD row driver output
R40	154	–3951.96	–1032.50	LCD row driver output
R80	155	–3900.12	–1032.50	duplicate of R79
C0	156	–3640.92	–1032.50	LCD column driver output
C1	157	–3589.08	–1032.50	LCD column driver output
C2	158	–3537.24	–1032.50	LCD column driver output
C3	159	–3485.40	–1032.50	LCD column driver output
C4	160	–3433.56	–1032.50	LCD column driver output
C5	161	–3381.72	–1032.50	LCD column driver output
C6	162	–3329.88	–1032.50	LCD column driver output
C7	163	–3278.04	–1032.50	LCD column driver output
C8	164	–3226.20	–1032.50	LCD column driver output
C9	165	–3174.36	–1032.50	LCD column driver output
C10	166	–3122.52	–1032.50	LCD column driver output
C11	167	–3070.68	–1032.50	LCD column driver output
C12	168	–3018.84	–1032.50	LCD column driver output
C13	169	–2967.00	–1032.50	LCD column driver output
C14	170	–2915.16	–1032.50	LCD column driver output
C15	171	–2863.32	–1032.50	LCD column driver output
C16	172	–2811.48	–1032.50	LCD column driver output
C17	173	–2759.64	–1032.50	LCD column driver output

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
C18	174	–2707.80	–1032.50	LCD column driver output
C19	175	–2655.96	–1032.50	LCD column driver output
C20	176	–2604.12	–1032.50	LCD column driver output
C21	177	–2552.28	–1032.50	LCD column driver output
C22	178	–2500.44	–1032.50	LCD column driver output
C23	179	–2448.60	–1032.50	LCD column driver output
C24	180	–2396.76	–1032.50	LCD column driver output
C25	181	–2344.92	–1032.50	LCD column driver output
C26	182	–2293.08	–1032.50	LCD column driver output
C27	183	–2241.24	–1032.50	LCD column driver output
C28	184	–2189.40	–1032.50	LCD column driver output
C29	185	–2137.56	–1032.50	LCD column driver output
C30	186	–2085.72	–1032.50	LCD column driver output
C31	187	–2033.88	–1032.50	LCD column driver output
C32	188	–1878.36	–1032.50	LCD column driver output
C33	189	–1826.52	–1032.50	LCD column driver output
C34	190	–1774.68	–1032.50	LCD column driver output
C35	191	–1722.84	–1032.50	LCD column driver output
C36	192	–1671.00	–1032.50	LCD column driver output
C37	193	–1619.16	–1032.50	LCD column driver output
C38	194	–1567.32	–1032.50	LCD column driver output
C39	195	–1515.48	–1032.50	LCD column driver output
C40	196	–1463.64	–1032.50	LCD column driver output
C41	197	–1411.80	–1032.50	LCD column driver output
C42	198	–1359.16	–1032.50	LCD column driver output
C43	199	–1308.12	–1032.50	LCD column driver output
C44	200	–1256.28	–1032.50	LCD column driver output
C45	201	–1204.44	–1032.50	LCD column driver output
C46	202	–1152.60	–1032.50	LCD column driver output
C47	203	–1100.76	–1032.50	LCD column driver output
C48	204	–1048.92	–1032.50	LCD column driver output
C49	205	–997.08	–1032.50	LCD column driver output
C50	206	–945.24	–1032.50	LCD column driver output
C51	207	–893.40	–1032.50	LCD column driver output
C52	208	–841.56	–1032.50	LCD column driver output
C53	209	–789.72	–1032.50	LCD column driver output
C54	210	–737.88	–1032.50	LCD column driver output
C55	211	–686.04	–1032.50	LCD column driver output
C56	212	–634.20	–1032.50	LCD column driver output

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
C57	213	–582.36	–1032.50	LCD column driver output
C58	214	–530.52	–1032.50	LCD column driver output
C59	215	–478.68	–1032.50	LCD column driver output
C60	216	–426.84	–1032.50	LCD column driver output
C61	217	–375.00	–1032.50	LCD column driver output
C62	218	–323.16	–1032.50	LCD column driver output
C63	219	–271.32	–1032.50	LCD column driver output
C64	220	–115.80	–1032.50	LCD column driver output
C65	221	–63.96	–1032.50	LCD column driver output
C66	222	–12.12	–1032.50	LCD column driver output
C67	223	39.72	–1032.50	LCD column driver output
C68	224	91.56	–1032.50	LCD column driver output
C69	225	143.40	–1032.50	LCD column driver output
C70	226	195.24	–1032.50	LCD column driver output
C71	227	247.08	–1032.50	LCD column driver output
C72	228	298.92	–1032.50	LCD column driver output
C73	229	350.76	–1032.50	LCD column driver output
C74	230	402.60	–1032.50	LCD column driver output
C75	231	454.44	–1032.50	LCD column driver output
C76	232	506.28	–1032.50	LCD column driver output
C77	233	558.12	–1032.50	LCD column driver output
C78	234	609.96	–1032.50	LCD column driver output
C79	235	661.80	–1032.50	LCD column driver output
C80	236	713.64	–1032.50	LCD column driver output
C81	237	765.48	–1032.50	LCD column driver output
C82	238	817.32	–1032.50	LCD column driver output
C83	239	869.16	–1032.50	LCD column driver output
C84	240	921.00	–1032.50	LCD column driver output
C85	241	972.84	–1032.50	LCD column driver output
C86	242	1024.68	–1032.50	LCD column driver output
C87	243	1076.52	–1032.50	LCD column driver output
C88	244	1128.36	–1032.50	LCD column driver output
C89	245	1180.20	–1032.50	LCD column driver output
C90	246	1232.04	–1032.50	LCD column driver output
C91	247	1283.88	–1032.50	LCD column driver output
C92	248	1335.72	–1032.50	LCD column driver output
C93	249	1387.56	–1032.50	LCD column driver output
C94	250	1439.40	–1032.50	LCD column driver output
C95	251	1491.24	–1032.50	LCD column driver output

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
C96	252	1646.76	–1032.50	LCD column driver output
C97	253	1698.60	–1032.50	LCD column driver output
C98	254	1750.44	–1032.50	LCD column driver output
C99	255	1802.28	–1032.50	LCD column driver output
C100	256	1854.12	–1032.50	LCD column driver output
C101	257	1905.96	–1032.50	LCD column driver output
C102	258	1957.80	–1032.50	LCD column driver output
C103	259	2009.64	–1032.50	LCD column driver output
C104	260	2061.48	–1032.50	LCD column driver output
C105	261	2113.32	–1032.50	LCD column driver output
C106	262	2165.16	–1032.50	LCD column driver output
C107	263	2217.00	–1032.50	LCD column driver output
C108	264	2268.84	–1032.50	LCD column driver output
C109	265	2320.68	–1032.50	LCD column driver output
C110	266	2372.52	–1032.50	LCD column driver output
C111	267	2424.36	–1032.50	LCD column driver output
C112	268	2476.20	–1032.50	LCD column driver output
C113	269	2528.04	–1032.50	LCD column driver output
C114	270	2579.88	–1032.50	LCD column driver output
C115	271	2631.72	–1032.50	LCD column driver output
C116	272	2683.56	–1032.50	LCD column driver output
C117	273	2735.40	–1032.50	LCD column driver output
C118	274	2787.24	–1032.50	LCD column driver output
C119	275	2839.08	–1032.50	LCD column driver output
C120	276	2890.92	–1032.50	LCD column driver output
C121	277	2942.76	–1032.50	LCD column driver output
C122	278	2994.60	–1032.50	LCD column driver output
C123	279	3046.44	–1032.50	LCD column driver output
C124	280	3098.28	–1032.50	LCD column driver output
C125	281	3150.12	–1032.50	LCD column driver output
C126	282	3201.96	–1032.50	LCD column driver output
C127	283	3253.80	–1032.50	LCD column driver output
R0	284	3461.16	–1032.50	LCD row driver output
R1	285	3513.00	–1032.50	LCD row driver output
R2	286	3564.84	–1032.50	LCD row driver output
R3	287	3616.68	–1032.50	LCD row driver output
R4	288	3668.52	–1032.50	LCD row driver output
R5	289	3720.36	–1032.50	LCD row driver output
R6	290	3772.20	–1032.50	LCD row driver output

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
R7	291	3824.04	–1032.50	LCD row driver output
R8	292	3875.88	–1032.50	LCD row driver output
R9	293	3927.72	–1032.50	LCD row driver output
R10	294	3979.56	–1032.50	LCD row driver output
R11	295	4031.40	–1032.50	LCD row driver output
R12	296	4083.24	–1032.50	LCD row driver output
R13	297	4135.08	–1032.50	LCD row driver output
R14	298	4186.92	–1032.50	LCD row driver output
R15	299	4238.76	–1032.50	LCD row driver output
R16	300	4290.60	–1032.50	LCD row driver output
R17	301	4342.44	–1032.50	LCD row driver output
R18	302	4394.28	–1032.50	LCD row driver output
R19	303	4446.12	–1032.50	LCD row driver output
R20	304	4497.96	–1032.50	LCD row driver output
R21	305	4549.80	–1032.50	LCD row driver output
R22	306	4601.64	–1032.50	LCD row driver output
R23	307	4653.48	–1032.50	LCD row driver output
R24	308	4705.32	–1032.50	LCD row driver output
R25	309	4757.16	–1032.50	LCD row driver output
R26	310	4809.00	–1032.50	LCD row driver output
R27	311	4860.84	–1032.50	LCD row driver output
R28	312	4912.68	–1032.50	LCD row driver output
R29	313	4964.52	–1032.50	LCD row driver output
R30	314	5016.36	–1032.50	LCD row driver output
R31	315	5068.20	–1032.50	LCD row driver output
R32	316	5120.04	–1032.50	LCD row driver output
R33	317	5171.88	–1032.50	LCD row driver output
R34	318	5223.72	–1032.50	LCD row driver output
R35	319	5275.56	–1032.50	LCD row driver output
R36	320	5327.40	–1032.50	LCD row driver output
R37	321	5379.24	–1032.50	LCD row driver output
R38	322	5431.08	–1032.50	LCD row driver output
R39	323	5482.92	–1032.50	LCD row driver output
-	324	5638.44	–1032.50	dummy
-	325	5690.28	–1032.50	dummy
-	326	5742.12	–1032.50	dummy
-	327	5793.96	–1032.50	dummy
-	328	5845.80	–1032.50	dummy
-	329	5897.64	–1032.50	dummy

Table 5. Bonding pad description *…continued*

All x/y coordinates represent the position of the center of each pad with respect to the center (x/y = 0) of the chip; see Figure 2.

Symbol	Pad	X (μm)	Y (μm)	Description
-	330	5949.48	–1032.50	dummy
-	331	6001.32	–1032.50	dummy
-	332	6053.16	–1032.50	dummy
-	333	6105.00	–1032.50	dummy

7. Functional description

7.1 Pad functions

7.1.1 R0 to R79: row driver outputs

These pads output the display row signals.

7.1.2 C0 to C127: column driver signals

These pads output the display column signals.

7.1.3 V_{SS1} and V_{SS2}: negative power supply rails

- V_{SS2} for voltage multiplier
- These 2 supply rails must be connected together

7.1.4 V_{DD1} to V_{DD3}: positive power supply rails

- V_{DD2} and V_{DD3} are the supply voltages for the internal voltage multiplier
- V_{DD2} and V_{DD3} have the same voltage and may be connected together outside of the chip; see Section 17
- V_{DD1} is used as supply for the rest of the chip
- V_{DD1} can be connected together with V_{DD2} and V_{DD3}
- If the internal voltage multiplier is not used then pads V_{DD2} and V_{DD3} must be connected to V_{DD1}; see Section 17
- In the case that V_{DD1}, V_{DD2} and V_{DD3} are connected together, care must be taken with respect to the supply voltage range; see Section 14

7.1.5 $V_{OTPPROG}$: OTP power supply

Supply voltage for the OTP programming; see Section 18. $V_{OTPPROG}$ can be combined with the SCLH/$\overline{SCE}$ pad in order to reduce the external connections.

7.1.6 V_{LCDOUT}, V_{LCDIN}, and $V_{LCDSENSE}$: LCD power supply

Positive power supply for the liquid crystal display.

- If the internal V_{LCD} multiplier is used, then all three inputs must be connected together
- If V_{LCD} multiplier is disabled and an external voltage is supplied to V_{LCDIN}, then V_{LCDOUT} must be left open-circuit and $V_{LCDSENSE}$ must be connected to V_{LCDIN}
- V_{DD2} and V_{DD3} should be applied according to the specified voltage range

- If the PCF8811 is in Power-save mode, the external LCD supply voltage can be switched off

7.1.7 T1 to T5: test pads

T1, T2 and T5 must be connected to V_{SS}. T3 and T4 must be left open-circuit. These test pads are not accessible to the user.

7.1.8 MF2 to MF0

Manufacturer device ID pads. (Manufacturer ID 100 = NXP Semiconductors).

7.1.9 DS0

Device recognition pad; see Table 15.

7.1.10 V_{OS4} to V_{OS0}

These 5 input pads enable the calibration of the offset of the programmed V_{LCD}; see Equation 4 and Equation 5 in Section 12.10.

V_{OS4} to V_{OS0} must be connected to V_{DD1} or V_{SS1}.

7.1.11 EXT: extended command set

Input to select the basic command set or the extended command set. Must be connected on the module to have only one command set enabled; see Table 6.

Table 6. Command set selection

Pad	Level	Description
EXT	LOW (V_{SS1})	basic command set
	HIGH (V_{DD1})	extended command set

Remark: NXP Semiconductors recommends that the extended command set is used.

7.1.12 PS0, PS1 and PS2

Parallel/serial/I^2C-bus interface selection; see Table 7.

Table 7. Interface selection

PS[2:0]	Interface
000	3-line SPI
001	4-line SPI
010	no operation
011	6800 parallel interface
100 or 110	high speed I^2C-bus interface
101 or 111	3-line serial interface

7.1.13 D/$\overline{C}$

Input to select either data or command input. Not used in the 3-line serial interface, 3-line SPI and I^2C-bus interface and must be connected to V_{DD1} or V_{SS1}.

7.1.14 R/$\overline{W}$/$\overline{WR}$

Input to select read or write mode when the 6800 parallel interface is selected. Not used in the serial and I^{2}C-bus mode and must be connected to V_{DD1} or V_{SS1}.

7.1.15 E/$\overline{RD}$

E is the clock enable input for the 6800 parallel bus. Not used in the serial or I^{2}C-bus interface and must be connected to V_{DD1} or V_{SS1}.

7.1.16 SCLH/$\overline{SCE}$

Input to select the chip and so allowing data or commands to be clocked in or input for serial clock when the I^{2}C-bus interface is selected.

7.1.17 SDAH

I^{2}C-bus serial data input. When not used, it must be connected to V_{DD1} and V_{SS1}.

7.1.18 SDAHOUT

SDAHOUT is the serial data acknowledge output for the I^{2}C-bus interface.

- By connecting SDAHOUT to SDAH externally, the SDAH line becomes fully I^{2}C-bus compatible
- The acknowledge output is separated from the serial data line due to the following reasons:
  - In COG applications where the track resistance from the SDAHOUT pad to the system SDAH line can be significant, a potential divider is generated by the bus pull-up resistor and the ITO track resistance
  - It is possible that during the acknowledge cycle the PCF8811 will not be able to create a valid LOW level
  - By splitting the SDAH input from the SDAHOUT output the device could be used in a mode that ignores the acknowledge bit
  - In COG applications where the acknowledge cycle is required, it is necessary to minimize the track resistance from the SDAHOUT pad to the system SDAH line to guarantee a valid LOW level
- When not used it must be connected to V_{DD1} or V_{SS1}.

7.1.19 DB7 to DB0

These input/output lines are used by several interfaces as described below. When not used in the serial interface or the I^{2}C-bus interface they must be connected to V_{DD1} or V_{SS1}.

7.1.19.1 DB7 to DB0 (parallel interface)

8-bit bidirectional bus. DB7 is the MSB.

7.1.19.2 DB7, DB6 and DB5 (serial interface)

- DB7 is used for serial input data (SDATA) when the serial interface is selected
- DB6 (SCLK) is used for the serial input clock when the serial interface is selected
- DB5 is used as the serial output of the serial interface (SDO)

7.1.19.3 DB3 and DB2 (I^2C-bus interface)

DB3 and DB2 are respectively the SA1 and SA0 inputs when the I^2C-bus interface is selected and can be used so that up to four PCF8811s can be distinguished on one I^2C-bus interface.

7.1.20 OSC: oscillator

- When the on-chip oscillator is used this input must be connected to V_{DD1}
- If an external clock signal is used, it is connected to this input
- If the oscillator and an external clock are both inhibited by connecting the OSC pad to V_{SS1}, the display is not clocked and may be left in a Direct Current (DC) state. To avoid a DC on display, the chip should always be put into Power-down mode before stopping the clock

7.1.21 $\overline{RES}$: reset

This signal will reset the device and must be applied to properly initialize the chip. The signal is active LOW.

7.2 Block diagram functions

See Figure 1 for the block diagram layout.

7.2.1 Oscillator

The on-chip oscillator provides the clock signal for the display system. No external components are required, and the OSC input must be connected to V_{DD1}. An external clock signal, if used, is connected to this input.

7.2.2 Address counter

The address counter assigns addresses to the display data RAM for writing. The X address X[6:0] and the Y address Y[3:0] are set separately.

7.2.3 Display data RAM

The PCF8811 contains an 80×128 bit static RAM which stores the display data.

- The RAM is divided into 10 banks of 128 bytes ($10 \times 8 \times 128$ bit)
- The icon row (when enabled) is always row 79 and located in bank 9
- During RAM access, data is transferred to the RAM via the parallel interface, serial interface or I^2C-bus interface
- There is a direct correspondence between the X address and the column output number

7.2.4 Timing generator

The timing generator produces the various signals required to drive the internal circuitry. Internal chip operation is not affected by operations on the data bus.

7.2.5 Display address counter

The display is generated by reading out the RAM content for 2, 4 or 8 rows simultaneously, depending on the current selected display size. This content is processed with the corresponding set of 2, 4 or 8 orthogonal functions and so generates the signals for switching the pixels in the display on or off according to the RAM content. The value p defines the number of rows which are simultaneously selected. It is possible to set the p value for the display sizes 64 and 80 manually to p = 4; see Table 10.

The display status (all dots on/off and normal/inverse video) is set by the bits DON, DAL and E in the command display control; see Table 11.

7.2.6 LCD row and column drivers

The PCF8811 contains 80 row and 128 column drivers, which connect the appropriate LCD bias voltages in sequence to the display in accordance with the data to be displayed.

8. Addressing

Data is written in bytes to the RAM matrix of the PCF8811 as shown in Figure 5. The display RAM has a matrix of 80 × 128 bits. The columns are addressed by the address pointer. The address ranges are: X = 0 to 127 (111 1111), Y = 0 to 9 (1001). The Y address represents the bank number. The effective X and Y addresses are programmed in such an order to use the PCF8811 with different display sizes, without additional loading of the microprocessor. Addresses outside these ranges are not allowed. The icon row when enabled is always row 79 and therefore located in bank 9.

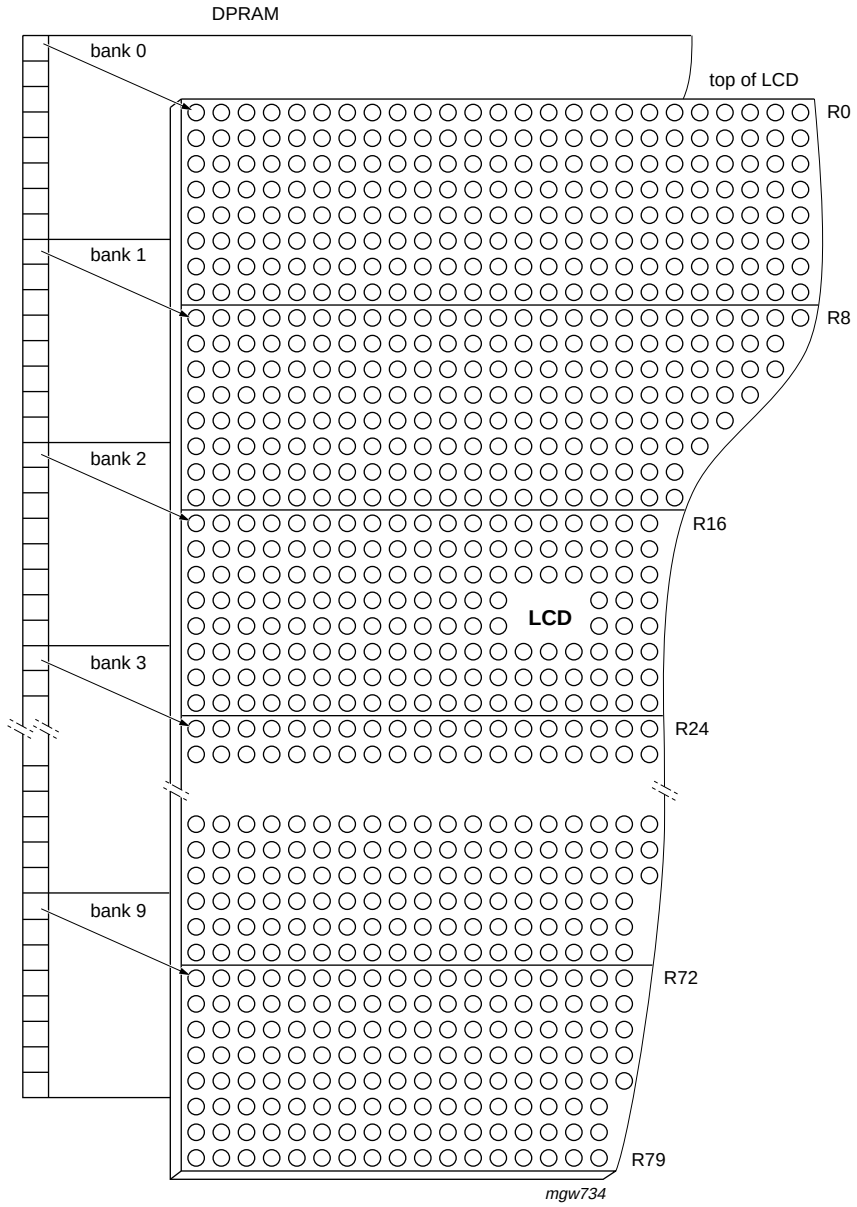


Fig 5. DDRAM to display mapping

8.1 Display data RAM structure

The mode for storing data into the data RAM depends on the selected command set.

8.1.1 Basic command set

After a write operation the column address counter (X address) auto-increments by one, and wraps to zero after the last column is written. The number of columns (X address) after which the wrap around must occur can be programmed.

The Y address counter does not auto-increment in the basic command set. The counter stops when a complete bank has been written to. In this case the Y address counter must be set; for Y address, see Table 10. To write the next bank, see Figure 6.

When only a part of the RAM is used, both X (X_{max}) and Y (Y_{max}) addresses can be set.

The data order in the basic command set is as defined in Figure 6.

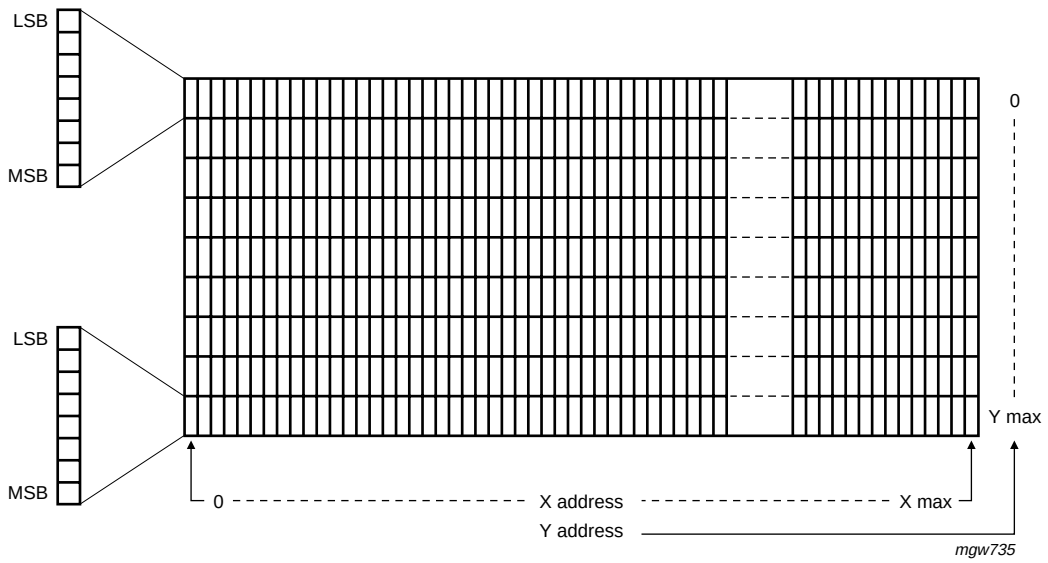


Fig 6. Sequence of writing data bytes into the RAM (basic command set)

8.1.2 Extended command set

8.1.2.1 Horizontal/vertical addressing

Two different address modes are possible with the extended command set: horizontal address mode and vertical address mode.

In the horizontal address mode (V = 0) the X address increments after each byte. After the last X address, X wraps around to 0 and Y increments to address the next row; see Figure 7. The number of columns (last X address) after which the wrap around must occur can be programmed. In Figure 7 it can be seen that the X address is programmed as 127, and the Y address is programmed as 9. With X_{max} and Y_{max} the X and Y addresses can be programmed while the whole RAM is not being used.

In the vertical addressing mode (V = 1) the Y address increments after each byte. After the last Y address (Y = 9), Y wraps around to 0 and X increments to address the next column; see Figure 8. The last Y address, after which Y wraps to 0, can be programmed. In Figure 8 it can be seen that the X address is programmed as 127, and the Y address is programmed as 9. With X_{max} and Y_{max} the X and Y addresses can be programmed while the whole RAM is not being used.

After the very last address, the address pointers wrap around to address X = 0 and Y = 0 in both horizontal and vertical addressing modes.

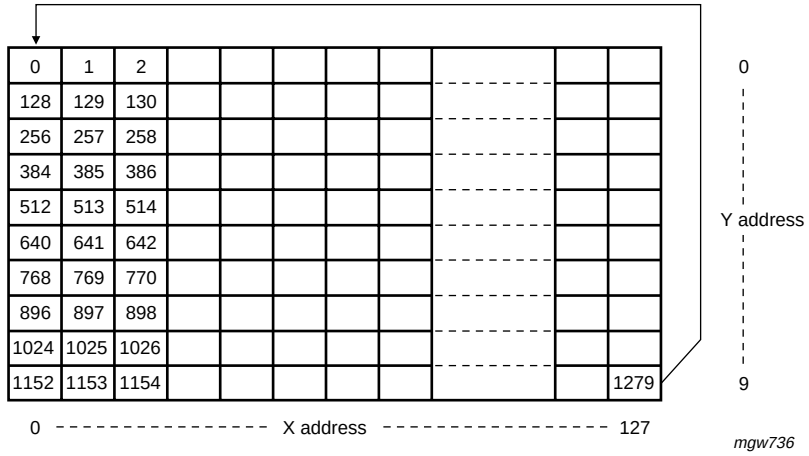


Fig 7. Sequence of writing data bytes into the RAM with horizontal addressing; V = 0 (extended command set)

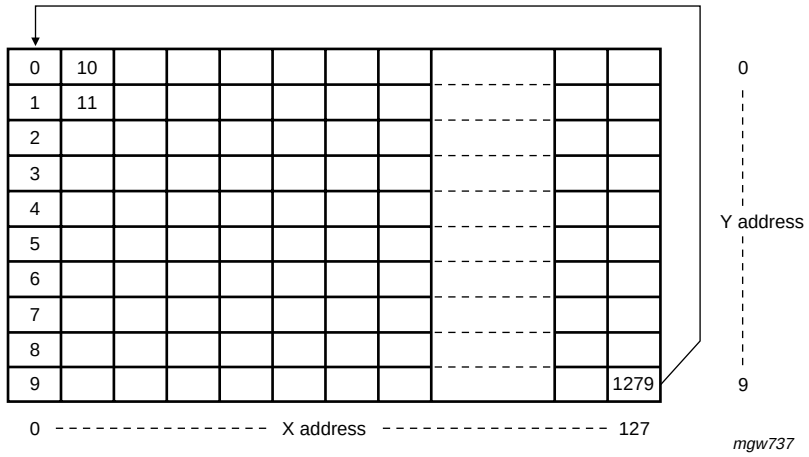


Fig 8. Sequence of writing data bytes into the RAM with vertical addressing; V = 1 (extended command set)

8.1.2.2 Data order

The data order bit (DOR) defines the bit order (LSB or MSB on top) for writing into the RAM; see Figure 9 and Figure 10. This feature is only available in the extended command set.

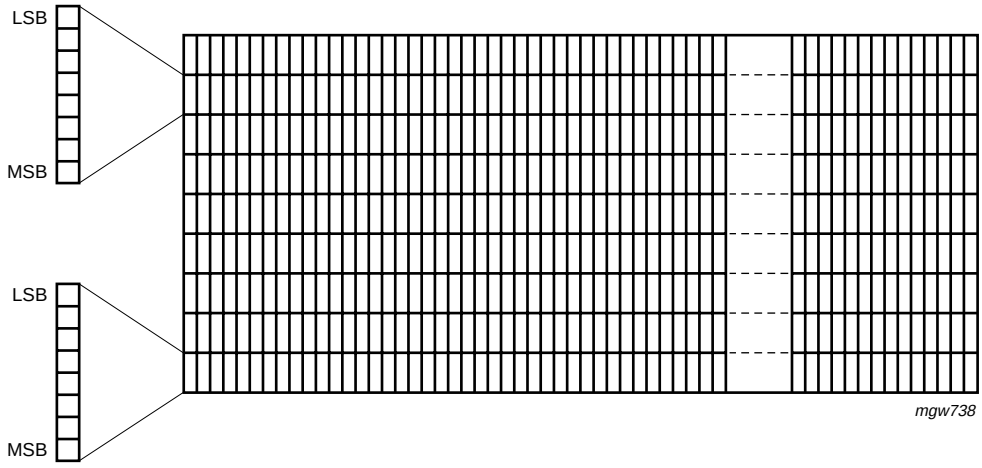


Fig 9. RAM byte organization, if DOR = 0 (extended command set)

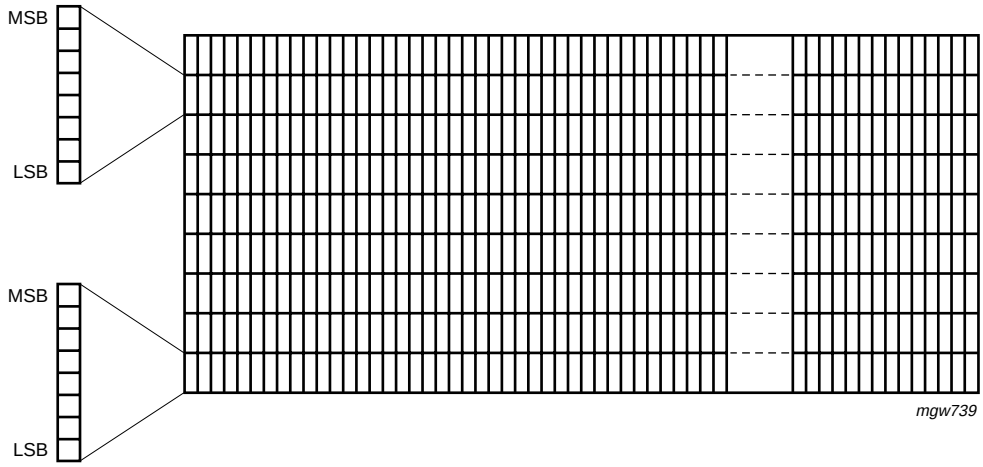


Fig 10. RAM byte organization, if DOR = 1 (extended command set)

8.1.2.3 Features available in both command sets

Mirror X (MX): The MX bit allows horizontal mirroring: when MX = 1, the X address space is mirrored; the address X = 0 is then located at the right side (X_{max}) of the display; see Figure 11. When MX = 0, the mirroring is disabled and the address X = 0 is located at the left side (column 0) of the display; see Figure 12.

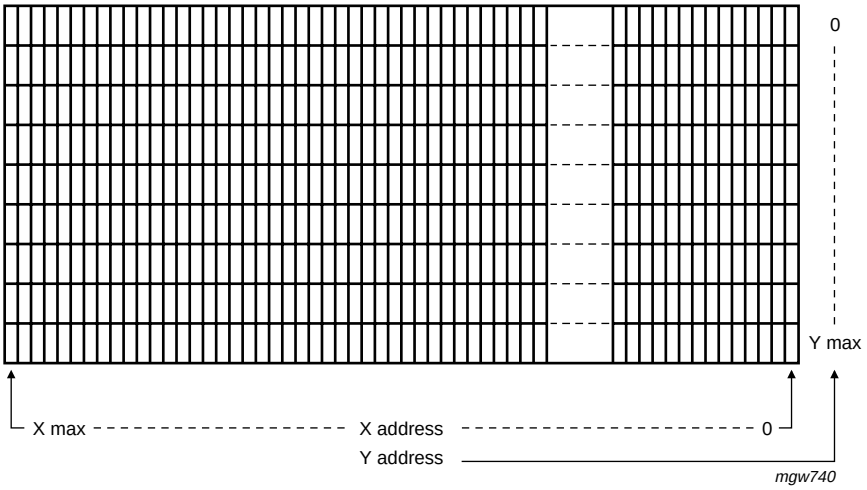


Fig 11. RAM format addressing; MX = 1 (both command sets)

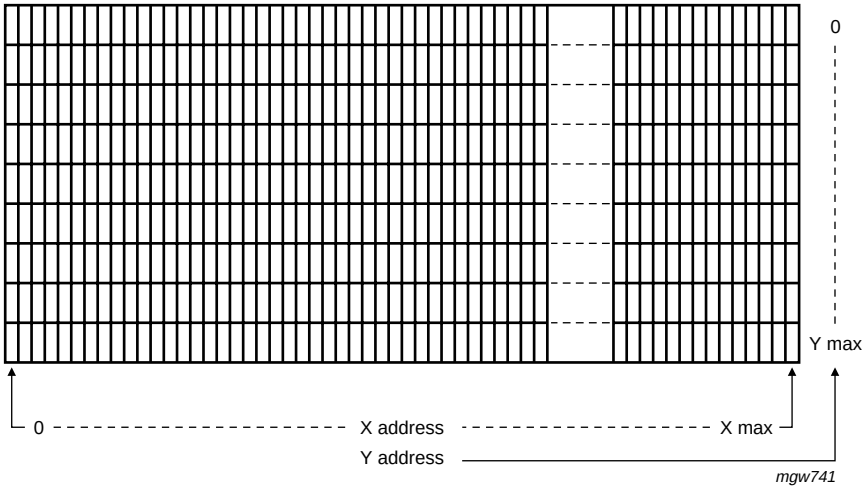


Fig 12. RAM format addressing; MX = 0 (both command sets)

Mirror Y (MY): The MY bit allows vertical mirroring: when MY = 1, the Y address space is mirrored; the address Y = 0 is then located at the bottom of the display; see Figure 13. When MY = 0, the mirroring is disabled and the address Y = 0 is located at top of the display; see Figure 14.

The icon row, when enabled, is always located in bank 9 and row 79.

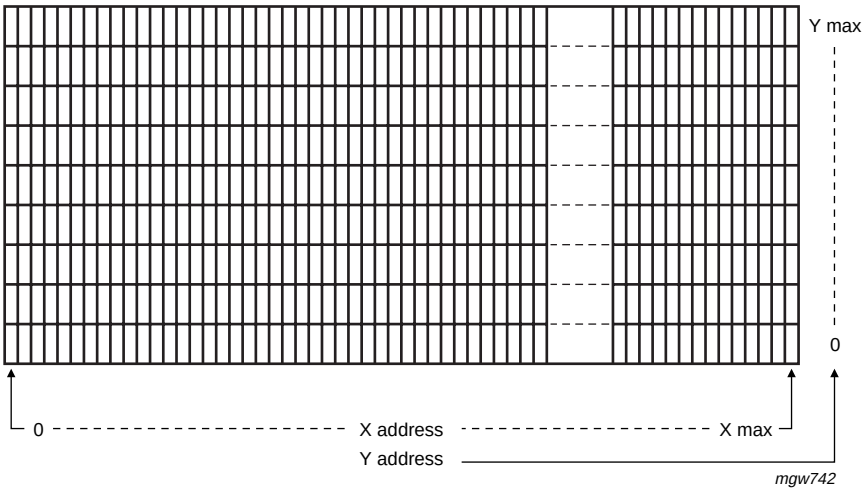


Fig 13. RAM format addressing; MY = 1 (both command sets)

Fig 14. RAM format addressing; MY = 0 (both command sets)

9. Parallel interface

The parallel interface, which can be selected, is the 6800 series 8-bit bidirectional interface for communication between the microcontroller and the LCD driver chip. The selection of this interface is achieved with pads PS[2:0]; see Section 7.1.12.

9.1 6800 series parallel interface

The interface functions of the 6800 series parallel interface are given in Table 8.

Table 8. 6800 series parallel interface functions

D/$\overline{C}$	R/$\overline{W}$/$\overline{WR}$	Operation
0	0	command data write
0	1	read status register
1	0	display data write
1	1	none

The parallel interface timing diagram for the 6800 series is given in Section 16.1, Figure 39 and Figure 40. The timing diagrams differ because in Figure 39 the clock is connected to the enable (E) input. In Figure 40 the clock is connected to the chip enable input ($\overline{SCE}$) and the enable input (E) is tied HIGH.

10. Serial interfacing (SPI and serial interface)

Communication with the microcontroller can also occur via a clock-synchronized Serial Peripheral Interface (SPI). It is possible to select between either a 3-line (SPI or serial interface) or a 4-line serial peripheral interface. Selection is achieved via PS[2:0]; see Section 7.1.12).

10.1 Serial peripheral interface lines

The serial peripheral interface is a 3-line or 4-line interface for communication between the microcontroller and the LCD driver chip. The 3 lines are:

- $\overline{SCE}$ (chip enable)
- SCLK (serial clock)
- SDATA (serial data)

For the 4-line serial peripheral interface a separate D/$\overline{C}$ line is added.

The PCF8811 is connected to the serial data I/O (SDA) of the microcontroller by connecting the two pads SDATA (data input) and SDO (data output) together.

10.1.1 Write mode

The display data/$\overline{command}$ indication may be controlled either via software or the D/$\overline{C}$ select pad. When the D/$\overline{C}$ pad is used, display data is transmitted when D/$\overline{C}$ is HIGH, and command data is transmitted when D/$\overline{C}$ is LOW; see Figure 15 and Figure 16. When pad D/$\overline{C}$ is not used, the display data length instruction is used to indicate that a specific number of display data bytes (1 to 255) are to be transmitted; see Figure 17. The next byte after the display data string is handled as an instruction command.

When the 3-line SPI interface is used, the display data/$\overline{command}$ is controlled by software.

If $\overline{SCE}$ is pulled HIGH during a serial display data stream, the interrupted byte is invalid data but all previously transmitted data is valid. The next byte received will be handled as an instruction command; see Figure 18.

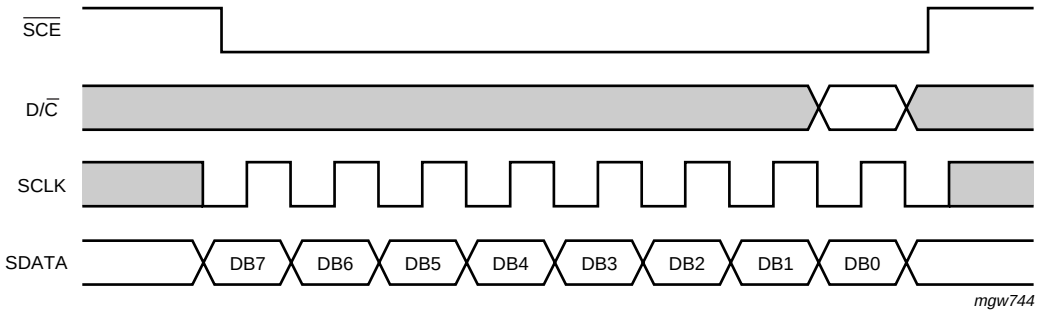


Fig 15. Serial bus protocol: transmission of one byte

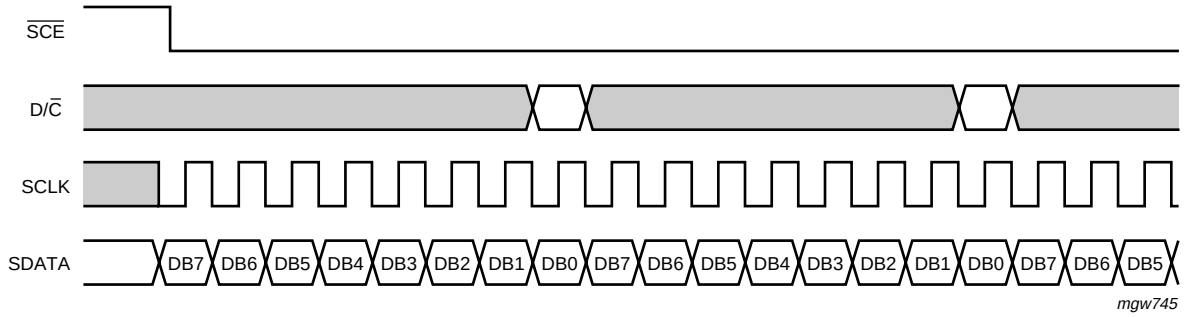


Fig 16. Serial bus protocol: transmission of several bytes

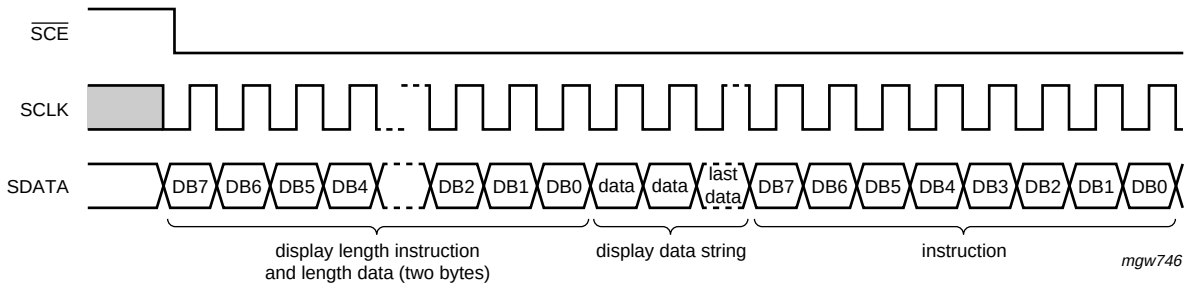


Fig 17. Transmission of several bytes

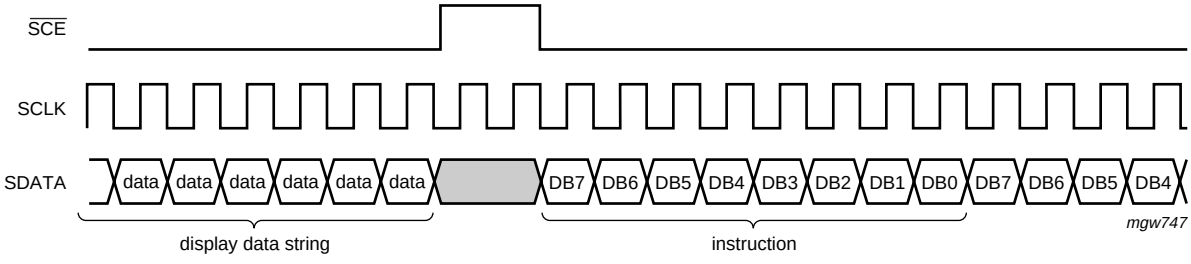


Fig 18. Transmission interrupted by $\overline{SCE}$

10.1.2 Read mode (only extended command set)

The read mode of the interface means that the microcontroller reads data from the PCF8811. To do so, the microcontroller first has to send a command (the read status command) and then the PCF8811 will respond by transmitting data on the SDO line. After that, $\overline{SCE}$ is required to go HIGH; see Figure 19.

The PCF8811 samples the SDATA data on rising SCLK edges, but shifts SDO data on falling SCLK edges. So, the microcontroller is supposed to read SDO data on rising SCLK edges.

After the read status command has been sent, the SDATA line must be set to 3-state not later then the falling SCLK edge of the last bit; see Figure 19.

Serial interface timing diagrams are shown in Section 16.2.

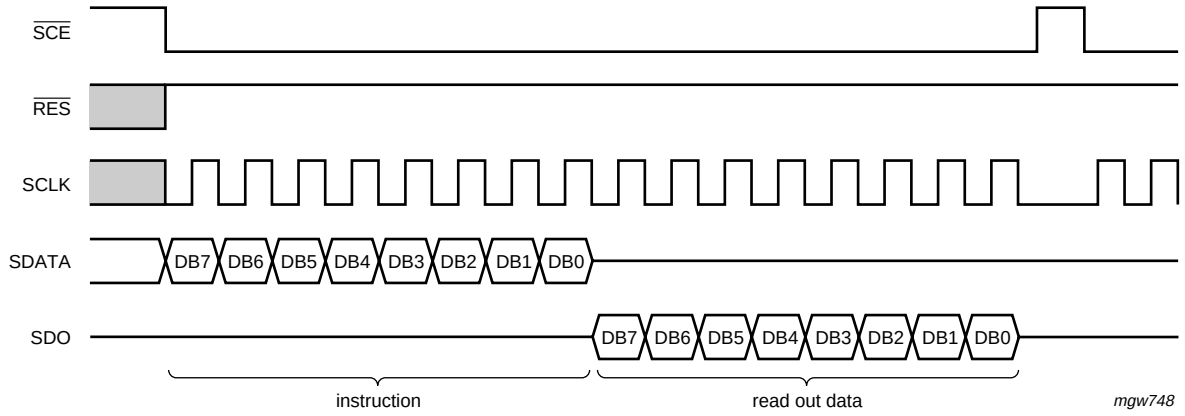


Fig 19. Read mode SPI 3-line and 4-line

10.2 Serial interface (3-line)

The serial interface is also a 3-line bidirectional interface for communication between the microcontroller and the LCD driver chip. The 3 lines are:

- $\overline{SCE}$ (chip enable)
- SCLK (serial clock)
- SDATA (serial data)

The PCF8811 is connected to the SDA of the microcontroller by two lines: SDATA (data input) and SDO (data output) which are connected together.

10.2.1 Write mode

The write mode of the interface means that the microcontroller writes commands and data to the PCF8811. Each data packet contains a control bit (D/$\overline{C}$) and a transmission byte. If D/$\overline{C}$ is LOW, the following byte is interpreted as a command byte. The instruction set is shown in Table 10. If D/$\overline{C}$ is HIGH, the following byte is stored in the display data RAM. After every data byte the address counter is incremented automatically. Figure 20 shows the general format of the write mode and the definition of the transmission byte.

Any instruction can be sent in any order to the PCF8811; the MSB is transmitted first. The serial interface is initialized when $\overline{SCE}$ is HIGH. In this state, SCLK clock pulses have no effect and no power is consumed by the serial interface. A falling edge on $\overline{SCE}$ enables the serial interface and indicates the start of data transmission.

Figure 21, Figure 22 and Figure 23 show the protocol of the write mode:

- when $\overline{SCE}$ is HIGH, SCLK clocks are ignored; during the HIGH time of $\overline{SCE}$ the serial interface is initialized
- SCLK must be LOW on the falling $\overline{SCE}$ edge; see Figure 41
- SDATA is sampled on the rising edge of SCLK
- D/$\overline{C}$ indicates, whether the byte is a command (D/$\overline{C}$ = 0) or RAM data (D/$\overline{C}$ = 1); it is sampled on the first rising SCLK edge
- If $\overline{SCE}$ stays LOW after the last bit of a data/$\overline{command}$ byte, the serial interface receives the D/$\overline{C}$ bit of the next byte on the next rising edge of SCLK; see Figure 22
- A reset pulse $\overline{RES}$ interrupts the transmission. The data being written into the RAM may be corrupted. The registers are cleared. If $\overline{SCE}$ is LOW after the rising edge of $\overline{RES}$, the serial interface is ready to receive the D/$\overline{C}$ bit of a data/$\overline{command}$ byte; see Figure 23.

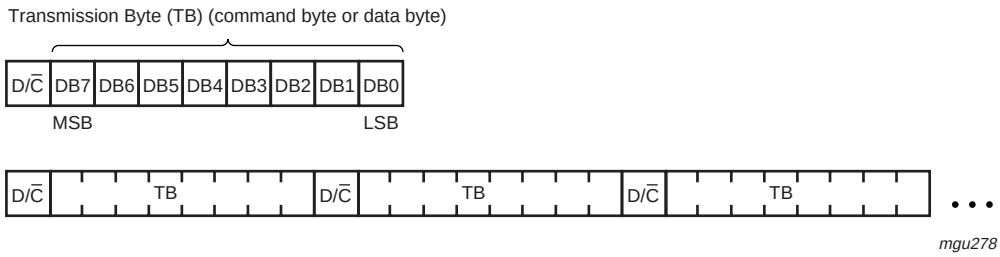


Fig 20. Serial data stream; write mode

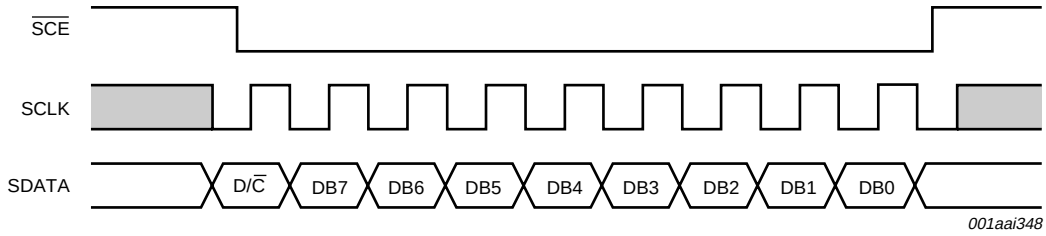


Fig 21. Write mode: a control bit followed by a transmission byte

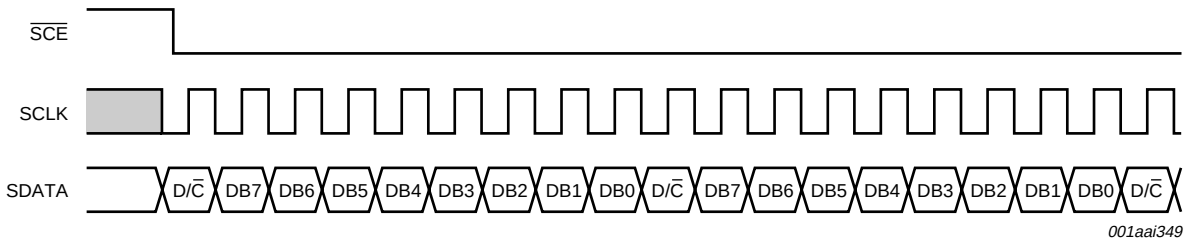


Fig 22. Write mode: transmission of several bytes

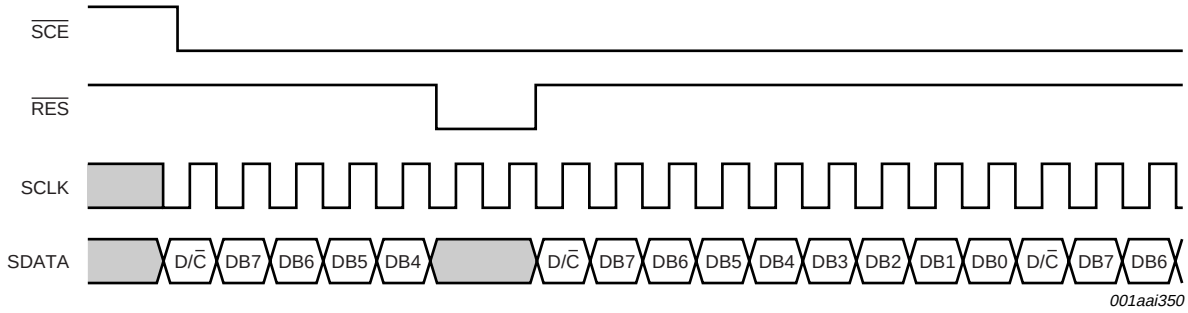


Fig 23. Write mode: interrupted by reset ($\overline{RES}$)

10.2.2 Read mode (only extended command set)

The read mode of the interface means that the microcontroller reads data from the PCF8811. To do so, the microcontroller first has to send a command (the read status command) and then the following byte is transmitted in the opposite direction using SDO; see Figure 24. After that, $\overline{SCE}$ is required to go HIGH before a new command is sent.

The PCF8811 samples the SDATA data on the rising SCLK edges, but shifts SDO data on the falling SCLK edges. Thus the microcontroller is supposed to read SDO data on rising SCLK edges.

After the read status command has been sent, the SDATA line must be set to 3-state not later then the falling SCLK edge of the last bit; see Figure 24.

The 8th read bit is shorter than the others because it is terminated by the rising SCLK edge; see Figure 44. The last rising SCLK edge sets SDO to 3-state after the delay time t_4.

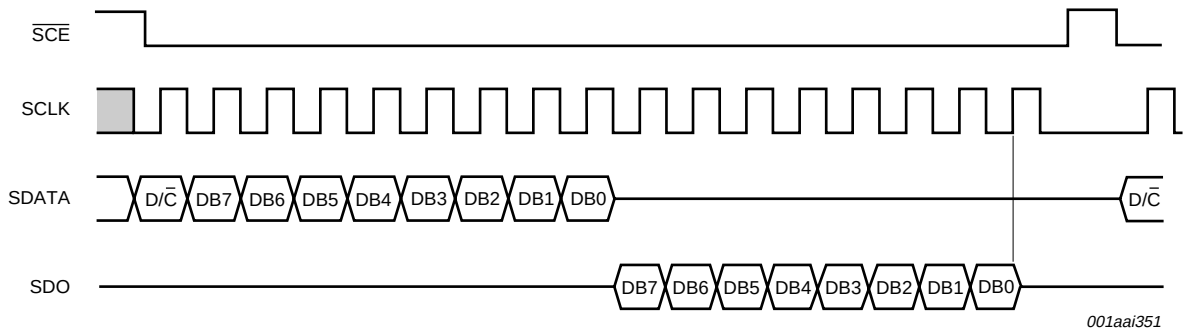


Fig 24. Read mode serial interface 3-line

11. I²C-bus interface

11.1 Characteristics of the I²C-bus (Hs-mode)

The I²C-bus Hs-mode is for bidirectional, two-line communication between different ICs or modules with speeds of up to 3.4 MHz. The only difference between Hs-mode slave devices and F/S-mode slave devices is the speed at which they operate. Because of this the buffers on the SCLH and SDAH have open-drain outputs. This is the same for I²C-bus master devices which have an open-drain SDAH output and a combination of an open-drain, pull-down and current source pull-up circuits on the SCLH output. Only the current source of one master is enabled at any one time, and only during Hs-mode. Both lines must be connected to a positive supply via a pull-up resistor.

Data transfer may be initiated only when the bus is not busy.

11.1.1 System configuration

The system configuration is shown in Figure 25.

Definitions of the I²C-bus terminology:

- **transmitter:** the device which sends the data to the bus
- **receiver:** the device which receives the data from the bus
- **master:** the device which initiates a transfer, generates clock signals and terminates a transfer
- **slave:** the device addressed by a master
- **multi-master:** more than one master can attempt to control the bus at the same time without corrupting the message
- **arbitration:** procedure to ensure that, if more than one master simultaneously tries to control the bus, only one is allowed to do so and the message is not corrupted
- **synchronization:** procedure to synchronize the clock signals of two or more devices

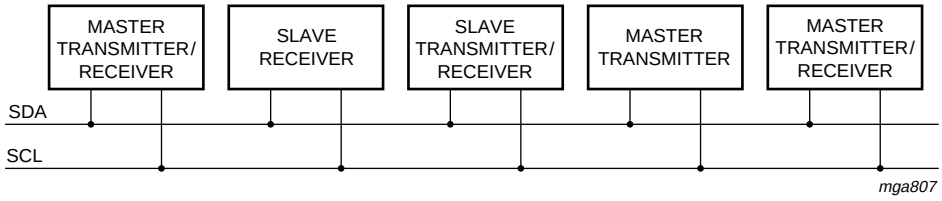


Fig 25. System configuration

11.1.2 Bit transfer

One data bit is transferred during each clock pulse; see Figure 26. The data on the SDA line must remain stable during the HIGH period of the clock pulse as changes in the data line at this time will be interpreted as a control signal.

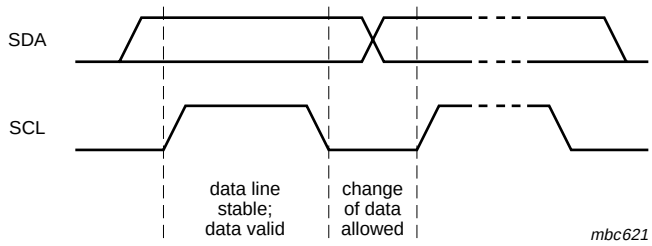


Fig 26. Bit transfer

11.1.3 Start and stop conditions

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 the START condition (S). A LOW-to-HIGH transition of the data line while the clock is HIGH is defined as the STOP condition (P). The START and STOP conditions are shown in Figure 27.

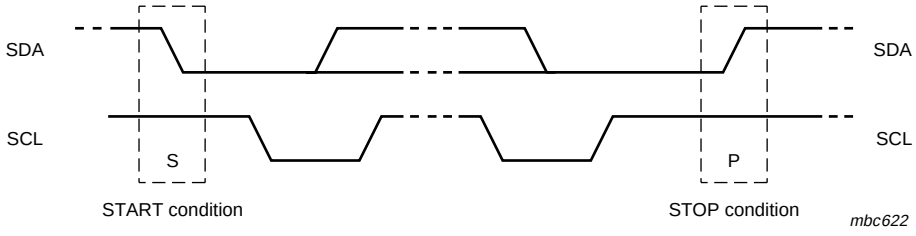


Fig 27. Definition of START and STOP conditions

11.1.4 Acknowledge

Each byte of eight bits is followed by an acknowledge bit; see Figure 28. The acknowledge bit is a HIGH signal put on the bus by the transmitter during which time the master generates an extra acknowledge-related clock pulse. A slave receiver which is addressed must generate an acknowledge after the reception of each byte. A master receiver must also generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter. The device that acknowledges must pull-down the SDA line during the acknowledge clock pulse, so that the SDA line is stable LOW during the HIGH period

of the acknowledge-related clock pulse (set-up and hold times must be taken into consideration). A master receiver must signal an end-of-data to the transmitter by not generating an acknowledge on the last byte that has been clocked out of the slave. In this event the transmitter must leave the data line HIGH to enable the master to generate a STOP condition.

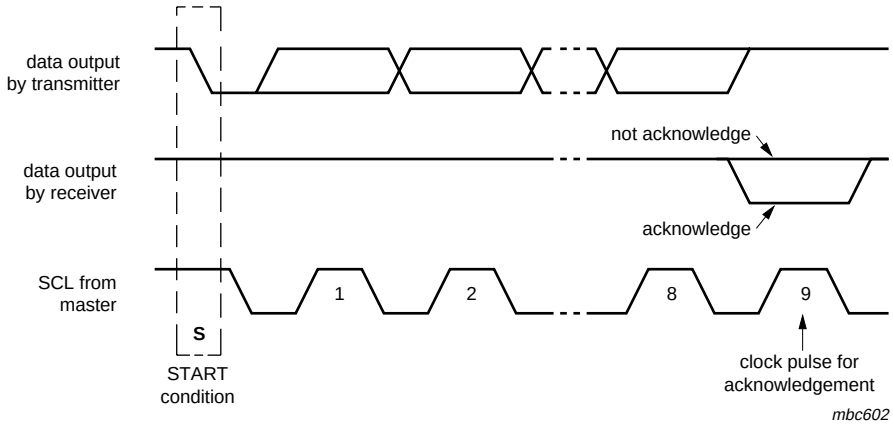


Fig 28. Acknowledge on the I²C-bus

11.2 I²C-bus Hs-mode protocol

The PCF8811 is a slave receiver/transmitter. If data is to be read from the device, the SDAH pad must be connected, otherwise the SDAH pad is unused.

Hs-mode can only commence after the following conditions:

- START condition (S)
- 8-bit master code (0000 1xxx)
- Not-acknowledge bit ($\overline{A}$)

The master code has two functions: it allows arbitration and synchronization between competing masters at F/S-mode speeds, resulting in one winner. The master code also indicates the beginning of an Hs-mode transfer. These conditions are shown in Figure 29 and Figure 30.

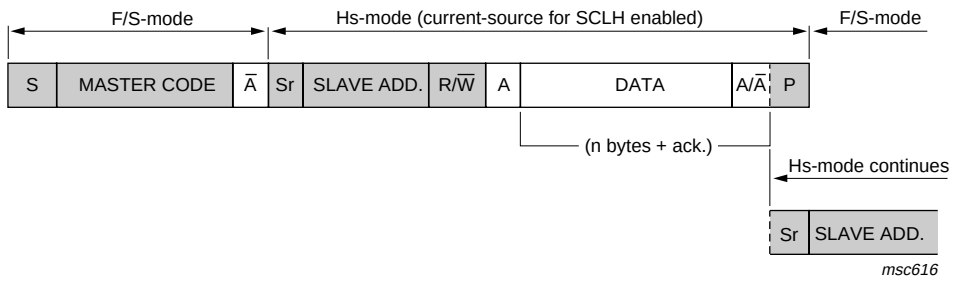


Fig 29. Data transfer format in Hs-mode

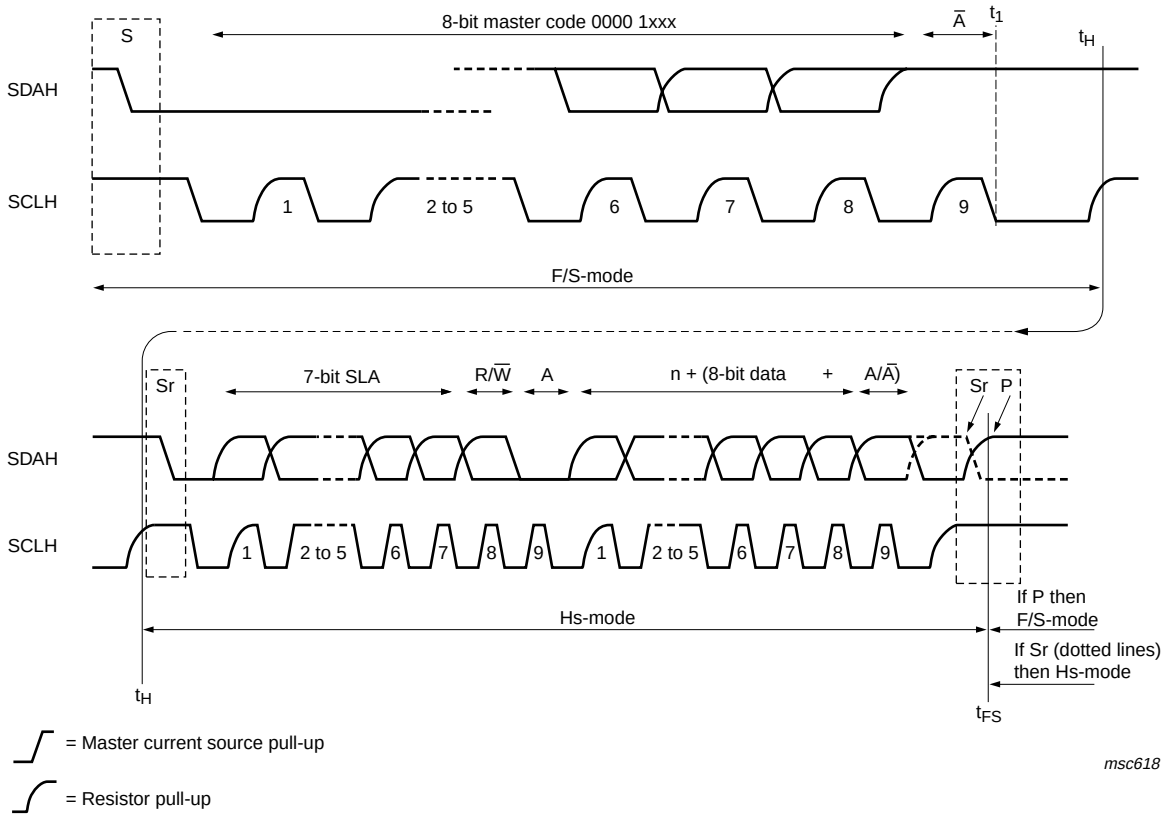


Fig 30. Data transfer timing format in F/S-mode and Hs-mode

As no device is allowed to acknowledge the master code, the master code is followed by a not-acknowledge ($\overline{A}$). After this $\overline{A}$ bit, and the SCLH line pulled up to a HIGH level, the active master switches to Hs-mode and enables at t_H the current-source pull-up circuit for the SCLH signal; see Figure 30.

The active master will then send a repeated START condition (Sr) followed by a 7-bit slave address (SLA) with a R/$\overline{W}$ bit, and receives an acknowledge bit (A) from the selected slave.

After each acknowledge bit (A) or not-acknowledge bit ($\overline{A}$) the active master disables its current source pull-up circuit. The active master re-enables its current source again when all devices have been released and the SCLH signal reaches a HIGH level. The rising of the SCLH signal is done by a pull-up resistor and therefore is slower, the last part of the SCLH rise time is speeded up because the current source is enabled. Data transfer only switches back to F/S-mode after a STOP condition (P).

A write sequence after the Hs-mode is selected is shown in Figure 31. The sequence is initiated with a START condition (S) from the I^2C-bus master which is followed by the slave address. All slaves with the corresponding address acknowledge in parallel, the remainder will ignore the I^2C-bus transfer.

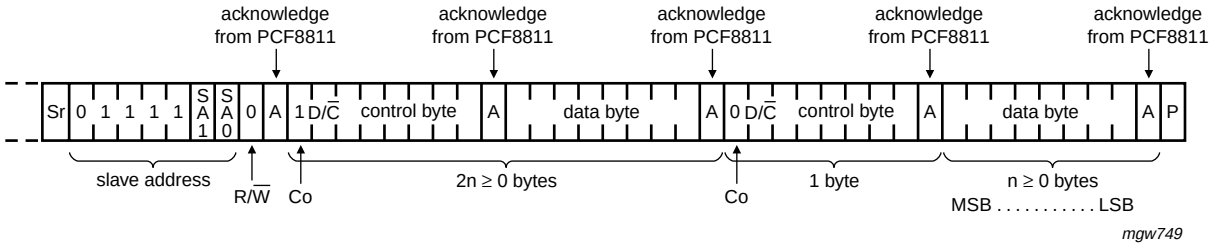


Fig 31. Master transmits in Hs-mode to slave receiver; write mode

After the acknowledgement cycle of a write ($\overline{W}$), one or more command words will follow which define the status of the addressed slaves. A command word consists of a control byte, which defines continuation bit Co and D/$\overline{C}$, plus a data byte; see Figure 31 and Table 9.

The last control byte is initiated by bit Co (a cleared MSB). The control and data bytes are also acknowledged by all addressed slaves on the bus.

Table 9. Co and D/$\overline{C}$ definitions

Bit	Logic state	R/$\overline{W}$	Action
Co	0	N/$\overline{A}$	last control byte to be sent; only a stream of data bytes are allowed to follow; this stream may only be terminated by a STOP or RESTART condition
	1	N/$\overline{A}$	another control byte will follow the data byte unless a STOP or RESTART condition is received
D/$\overline{C}$	0	0	data byte will be decoded and used to set-up the device
		1	data byte will return the status byte
	1	0	data byte will be stored in the display RAM
		1	RAM read back is not supported

A read sequence is shown in Figure 32 and again this sequence follows after the Hs-mode is selected. The PCF8811 will immediately start to output the requested data until a not-acknowledge is transmitted by the master. Before the read access, the user has to set the D/$\overline{C}$ bit to the appropriate value by a preceding write access. The write access must be terminated by a RESTART condition so that the Hs-mode is not disabled.

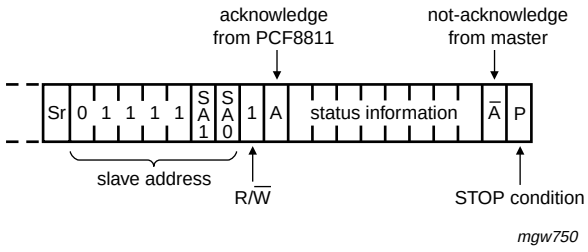


Fig 32. Master receives from slave transmitter (status register is read); read mode

After the last control byte, depending on the D/$\overline{C}$ bit setting, either a series of display data bytes or command data bytes may follow. If the D/$\overline{C}$ bit was set to logic 1, these display bytes are stored in the display RAM at the address specified by the data pointer.

The data pointer is automatically updated and the data is directed to the intended PCF8811 device. If the D/$\overline{C}$ bit of the last control byte was set to logic 0, these command bytes will be decoded and the setting of the device will be changed according to the received commands. The acknowledgement after each byte is made only by the addressed PCF8811. At the end of the transmission the I^2C-bus master issues a STOP condition (P) and switches back to the F/S-mode, however, to reduce the overhead of the master code, it is possible that a master can link a number of Hs-mode transfers, separated by repeated START conditions (Sr).

11.3 Command decoder

The command decoder identifies command words that are received on the I^2C-bus:

- pairs of bytes: information in second byte, first byte determines whether information is display or instruction data
- Stream of information bytes after Co = 0: display or instruction data depending on last D/$\overline{C}$

The most significant bit of a control byte is the continuation bit Co. If this bit is at logic 1, it indicates that only one data byte, either command or RAM data, will follow. If this bit is at logic 0, it indicates that a series of data bytes, either command or RAM data, may follow. The DB6 bit of a control byte is the RAM data/command bit D/$\overline{C}$. When this bit is at logic 1, it indicates that a RAM data byte will be transferred next. If the bit is at logic 0, it indicates that a command byte will be transferred next.

12. Instructions

The PCF8811 interfaces via an 8-bit parallel interface, two different 3-line serial interfaces, a 4-wire serial interface or an I^2C-bus interface. Processing of the instructions does not require the display clock.

Data accesses to the PCF8811 can be broken down into two areas: those that define the operating mode of the device, and those that fill the display RAM.

In the case of the parallel and 4-wire SPI interfaces, the distinction is the D/$\overline{C}$ pad. When the D/$\overline{C}$ pad is at logic 0, the chip will respond to instructions as defined in Table 10. When the D/$\overline{C}$ bit is at logic 1, the chip will send data to the RAM.

When the 3-wire SPI, the 3-wire serial interface or the I^2C-bus interface is used, the distinction between instructions which define the operating mode of the device and those that fill the display RAM, is made respectively by the display data length instruction (3-line SPI) or by the D/$\overline{C}$ bit in the data stream (3-line serial interface and I^2C-bus interface).

There are 4 types of instructions. Those which:

1. Define the PCF8811 functions, such as display configuration etc.
2. Set internal RAM addresses
3. Perform data transfer with internal RAM
4. Others.

In normal use, category 3 instructions are used most frequently.

A basic and an extended instruction set is available. If the EXT pad is set LOW the basic command set is used. If the EXT pad is set HIGH the extended command set is used.

Both command sets are detailed in Table 10.

Table 10. Instruction set[1]

Instruction	Pad			Command byte								Description
	EXT[2]	D/$\overline{C}$	R/$\overline{W}$/$\overline{WR}$	DB7[3]	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
NOP	X	0	0	0	1	0	0	1	1	X	X	no operation
	X	0	0	1	1	1	0	0	1	0	0	
Reset	X	0	0	1	1	1	0	0	0	1	0	soft reset
Write data	X	1	0	D7	D6	D5	D4	D3	D2	D1	D0	write data to display RAM
Display data length	X	0	0	1	1	1	0	1	0	0	0	only used in 3-line SPI
	X	0	0	D7	D6	D5	D4	D3	D2	D1	D0	
Status read	X	0	1	BUSY	DON	$\overline{RES}$	MF2	MF1	MF0	DS1	DS0	read status byte
	X	0	X	1	1	0	1	1	0	1	X	read status byte
Display control	X	0	0	1	0	1	0	1	1	1	DON	display on or off
	X	0	0	1	0	1	0	0	1	1	E	normal or reverse mode
	X	0	0	1	0	1	0	0	1	0	DAL	all pixels on or off
	X	0	0	1	0	1	0	0	0	0	MX	mirror X
	X	0	0	1	1	0	0	MY	X	X	X	mirror Y
	1	0	0	1	1	1	0	1	1	1	IC	icon enable or disable[4]
	1	0	0	1	0	1	0	0	0	1	V	vertical or horizontal addressing[4]
	1	0	0	1	1	1	0	1	0	1	DOR	data order[4]
	1	0	0	1	1	1	0	1	1	0	BRS	bottom row swap[4]
Address commands	X	0	0	1	0	1	1	Y_3	Y_2	Y_1	Y_0	set Y address; $0 \leq Y \leq 9$
	X	0	0	0	0	0	1	0	X_6	X_5	X_4	set X address; $0 \leq X \leq 127$
	X	0	0	0	0	0	0	X_3	X_2	X_1	X_0	
	X	0	0	0	0	0	1	1	0	0	1	set Y_{max}; $0 \leq Y \leq 9$
		0	0	X	X	X	X	Y_{max3}	Y_{max2}	Y_{max1}	Y_{max0}	
	X	0	0	0	0	0	1	1	0	0	0	set X_{max}; $0 \leq X \leq 127$
				X	Y_{max6}	Y_{max5}	Y_{max4}	Y_{max3}	Y_{max2}	Y_{max1}	Y_{max0}	
Set initial display line	X	0	0	0	1	0	0	0	0	X	X	set initial display line; $0 \leq L \leq 79$[5]
	X	0	0	X	L_6	L_5	L_4	L_3	L_2	L_1	L_0	
Set initial row	X	0	0	0	1	0	0	0	1	X	X	set start row; $0 \leq C \leq 79$[6]
	X	0	0	X	C_6	C_5	C_4	C_3	C_2	C_1	C_0	
Set partial display	X	0	0	0	1	0	0	1	0	X	X	set partial display 1:16 to 1:80
	X	0	0	X	P_6	P_5	P_4	P_3	P_2	P_1	P_0	

Table 10. Instruction set[1] *...continued*

Instruction	Pad			Command byte								Description
	EXT[2]	D/$\overline{C}$	R/$\overline{W}$/$\overline{WR}$	DB7[3]	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
V_{OP} setting	0	0	0	1	0	0	0	0	0	0	1	set V_{OP}[7][8]
	0	0	0	X	X	V_{PR5}	V_{PR4}	V_{PR3}	V_{PR2}	V_{PR1}	V_{PR0}	
	0	0	0	0	0	1	0	0	V_{OFF2}	V_{OFF1}	V_{OFF0}	offset for V_{OP}[7][8]
	1	0	0	1	0	0	0	0	0	0	1	set V_{OP}[4]
	1	0	0	V_{PR7}	V_{PR6}	V_{PR5}	V_{PR4}	V_{PR3}	V_{PR2}	V_{PR1}	V_{PR0}	
Power control	X	0	0	0	0	1	0	1	PC_1	PC_0	1	switch HVgen on/off
HVgen stages	0	0	0	0	1	1	0	0	1	S_1	S_0	set multiplication factor
	1	0	0	0	1	1	0	0	S_2	S_1	S_0	set multiplication factor[4]
FR	1	0	0	0	0	0	1	1	1	FR_1	FR_0	set frame rate frequency[4]
TC[9]	1	0	0	0	0	1	1	1	TC_2	TC_1	TC_0	set temperature coefficient[4]
Bias system	0	0	0	0	1	0	1	0	BS_2	BS_1	BS_0	set bias system[10]
Manual p value (p = 4)	1	0	0	0	0	0	1	1	0	1	MP	set manual p value[4][11]
Power-save on	X	0	0	1	0	1	0	1	0	0	1	Power-save mode
Power-save off	X	0	0	1	1	1	0	0	0	0	1	exit Power-save mode
Internal oscillator	X	0	0	1	0	1	0	1	0	1	OS	switch internal oscillator on/off
Internal oscillator	1	0	0	1	1	1	0	0	1	1	EC	enable or disable the internal or external oscillator[4]
Enter CALMM mode	X	0	0	1	0	0	0	0	0	1	0	enter CALMM mode
Reserved	X	0	0	0	0	1	0	1	X	X	0	reserved
Reserved	X	0	0	0	1	1	1	X	X	X	X	reserved
Test	X	0	0	1	1	1	1	X	X	X	X	do not use; reserved for testing

[1] X = value without meaning.

[2] NXP Semiconductors recommends that the extended command set be used.

[3] D7 = MSB.

[4] Commands only available with the extended command set, EXT = 1. If EXT = 0 these commands have no effect.

[5] When the icon mode is enabled the set initial display line $0 \leq L \leq 78$.

[6] When the icon mode is enabled the set initial row line $0 \leq C \leq 78$.

[7] Commands only used for the basic command set EXT = 0. If EXT = 1 these commands have no effect. It must be checked, when setting V_{OP} in the basic command set that it is followed by another command.

[8] The programming of V_{OP} in the basic command set must be done in the following order:

a) V_{PR}[5:0]

b) V_{OFF}[2:0]

c) must be followed by another command.

[9] One fixed TC is set automatically if the basic command set is used.

[10] Bias system settings which can be received when the chip is used as a replacement for the Alt-Pleshko driving method (NOP).

[11] Only for multiplex rates 1:64 and 1:80. The number of simultaneous rows can be set manually to p = 4; see Table 18.

12.1 Instruction set commands

12.1.1 Common instructions of the basic and extended command set

Table 11. Common commands

Bit	Logic 0	Logic 1	Reset state
DON	display off	display on	0
E	normal display	inverse video mode	0
DAL	normal display	all pixels on	0
MX	no X mirroring	X mirroring	0
MY	no Y mirroring	Y mirroring	0
OC	stop frame frequency calibration	start frame frequency calibration	0
OS	internal oscillator off	start internal oscillator	0
X[6:0]	set X address (column) for writing in the RAM		000 0000
Y[3:0]	set Y address (bank) for writing in the RAM		0000
$X_{max[6:0]}$	set wrap around X address (column)		111 1111
$Y_{max[3:0]}$	set wrap around Y address (bank)		1001
L[6:0]	sets line address of the display; this command cannot access the icon driver row, row 80, if the icon row is enabled		000 0000
C[6:0]	sets the initial row 0 of the display; this command cannot access the icon driver row, row 80, if the icon row is enabled		000 0000
P[6:0]	partial display mode 1:16 to 1:80 [1]		101 0000 (1:80)/100 0000 (1:64)
PC[1:0]	switch HV multiplier on/off		00
S[1:0]	charge pump multiplication factor		00

[1] Partial displays can be selected in steps of 8, when the icon mode is not selected. When the icon mode is selected, partial displays can be selected in steps of 16. For example, without icons the available partial display sizes are 8, 16, 24, 32, 40, 48, 56, 64 or 72 lines. With icons there are 16, 32, 48 or 64 lines possible.

Table 12. Power control register

PC[1:0]	Description
00	HVgen off
x1	HVgen on
1x	HVgen on

Table 13. Power-save mode (PSM), OS, DON, DAL and E combinations[1]

PSM	OS	DON	DAL	E	Description
0	0	X	X	X	oscillator off; HVgen disabled
0	1	X	0	X	oscillator on; HVgen disabled
0	1	0	1	X	display off; pads Rn/Cn at V_{SS}; oscillator off; HVgen disabled[2]
0	1	1	0	0	normal display mode
0	1	1	0	1	inverse display mode
0	1	1	1	X	all pixels on[3]
1	X	X	X	X	Power-save mode: display off; pads Rn/Cn at V_{SS}; oscillator off; HVgen disabled

[1] X = value without meaning.

[2] Bit DON can only be addressed after bit DAL is activated.

[3] Bit DAL has priority over bit E.

Table 14. Read status byte

Bit	Description
BUSY	if BUSY = 0 the chip is able to accept new commands
DON	same bit as in Table 13
$\overline{RES}$	if $\overline{RES}$ = 1 a reset is in progress
MF[2:0]	device manufacturer ID
DS0	device recognition; see Table 15

Table 15. Device recognition[1]

DS0	Description
0	64 row driver
1	80 row driver

[1] This is the only default setting after reset; another setting can be selected with the ‘set partial display mode’ command.

Table 16. Multiplication settings

S[1:0]	Description
00	4 × voltage multiplier
01	5 × voltage multiplier
10	6 × voltage multiplier
11	7 × voltage multiplier

12.1.2 Specific commands of the basic command set

Table 17. Specific basic commands

Bit	Description	Reset state
V_{PR}[5:0]	programming value of V_{LCD}	00 0000
V_{OFF}[2:0]	offset for the programming value of V_{LCD}	000

12.1.3 Specific commands of the extended command set

Table 18. Specific extended commands

Bit	Logic 0	Logic 1	Reset state
$V_{PR}[7:6] + V_{PR}[5:0]$	programming value of V_{LCD}		000 0000
FR[1:0]	frame rate frequency		11
TC[2:0]	temperature coefficient		010
S[2:0]	charge pump multiplication factor		100
V	horizontal addressing	vertical addressing	0
DOR	LSB at top	MSB at top	0
IC	no icon row (multiplex rate 1:16 to 1:80)	icon row (multiplex rate 1:16 to 1:80)	0
BRS	bottom rows are not mirrored	bottom rows are mirrored	0
MP[1]	multiplex rate driven p value (automatic)	p = 4 selected for multiplex rate 1:64 and 1:80	0
EC	use internal oscillator	use external oscillator	0

[1] NXP Semiconductors recommends to use the p = 4 setting.

Table 19. Frame rate frequency

FR[1:0]	Frame rate frequency
00	30 Hz
01	40 Hz
10	50 Hz
11	60 Hz

Table 20. Temperature coefficient[1]

TC[2:0]	Temperature coefficient
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

[1] For further information about temperature coefficient, see Table 30.

Table 21. Multiplication settings

S[2:0]	Description
000	2 × voltage multiplier
001	3 × voltage multiplier
010	4 × voltage multiplier

Table 21. Multiplication settings *...continued*

S[2:0]	Description
011	5 × voltage multiplier
100	4 × voltage multiplier
101	5 × voltage multiplier
110	6 × voltage multiplier
111	7 × voltage multiplier

12.2 Initialization

Reset is accomplished by applying an external reset pulse (active LOW) at pad $\overline{RES}$. When reset occurs within the specified time, all internal registers are reset, however the RAM is still undefined. The state after reset is described in Section 12.3. Pad $\overline{RES}$ must be ≤ 0.3 V_{DD1} when V_{DD1} reaches $V_{DD(min)}$ (or higher) within a maximum time t_{VHRL} after V_{DD1} goes HIGH; see Figure 47.

A reset can also be achieved by sending a reset command. This command can be used during normal operation but not to initialize the chip after power-on.

12.3 Reset function

12.3.1 Basic command set

After reset the LCD driver has the following state:

- Display setting E = 0 and DAL = 0
- Address commands X[6:0] = 0 and Y[3:0] = 0
- V_{LCD} is equal to 0, the HV multiplier is switched off (PC[1:0] = 00)
- No offset of the programming range (V_{OFF}[2:0] = 0)
- HV multiplier programming (V_{PR}[5:0] = 0)
- 4 × voltage multiplier (S[1:0] = 00)
- After power-on, RAM data is undefined, the reset signal does not change the content of the RAM
- All LCD outputs at V_{SS} (display off)
- Initial display line set to line 0 (L[6:0] = 0)
- Initial row set to row 0 (C[6:0] = 0)
- Full display selected (P[6:0] = multiplex rate 1:80 or 1:64)
- Display is not mirrored (MX = 0; MY = 0)
- Internal oscillator is off
- Power-save mode is on
- No frame calibration is running

12.3.2 Extended command set

After reset the LCD driver has the following state:

- Display settings E = 0 and DAL = 0

- Icons disabled (IC = 0)
- Address counter X[6:0] = 0 and Y[3:0] = 0
- Temperature control mode TC2 (TC[2:0] = 010)
- V_{LCD} is equal to 0 V; the HV multiplier is switched off (PC[1:0] = 0)
- HV multiplier programming (V_{PR}[7:0] = 0)
- 4 × voltage multiplier (S[2:0] = 100)
- Frame-rate frequency (FR[1:0] = 11)
- After power-on, RAM data is undefined, the reset signal does not change the content of the RAM
- All LCD outputs at V_{SS} (display off)
- Full display selected (P[6:0] = multiplex rate 1:80 or 1:64)
- Initial display line set to line 0 (L[6:0] = 0)
- Initial row set to row 0 (C[6:0] = 0)
- Display is not mirrored (MX = 0; MY = 0)
- Internal oscillator is off
- Power-save mode is on
- Horizontal addressing enabled (V = 0)
- No data order swap (DOR = 0)
- No bottom row swap (BRS = 0)
- Internal oscillator enabled (EC = 0)
- No frame calibration running (OC = 0)

12.4 Power-save mode

In the Power-save mode the LCD driver has the following state:

- All LCD outputs at V_{SS} (display off)
- Bias generator and V_{LCD} generator switched off; external V_{LCD} can be disconnected
- Oscillator off (external clock possible)
- RAM contents not cleared; RAM data can be written
- V_{LCD} discharged to V_{SS} in Power-down mode

There are two ways to put the chip into Power-save mode:

- The display must be off (DON = 0) and all the pixels on (DAL = 1)
- The Power-save mode command is activated

12.5 Display control

The bits DON, E and DAL select the display mode; see Table 13.

12.5.1 Bit MX

When MX = 0 the display RAM is written from left to right (X = 0 is on the left side and X = X_{max} is on the right side of the display).

When MX = 1 the display RAM is written from right to left (X = 0 is on the right side and X = X_{max} is on the left side of the display).

The MX bit has an impact on the way the RAM is written to. So if a horizontal mirroring of the display is desired, the RAM must first be rewritten, after changing the MX bit.

12.5.2 Bit MY

When MY = 1, the display is mirrored vertically. A change to this bit has an immediate effect on the display.

12.6 Set Y address of RAM

Y[3:0] defines the Y address of the display RAM.

Table 22. RAM X/Y address range

Y3	Y2	Y1	Y0	Content	Allowed X range
0	0	0	0	bank 0 (display RAM)	0 to 127
0	0	0	1	bank 1 (display RAM)	0 to 127
0	0	1	0	bank 2 (display RAM)	0 to 127
0	0	1	1	bank 3 (display RAM)	0 to 127
0	1	0	0	bank 4 (display RAM)	0 to 127
0	1	0	1	bank 5 (display RAM)	0 to 127
0	1	1	0	bank 6 (display RAM)	0 to 127
0	1	1	1	bank 7 (display RAM)	0 to 127
1	0	0	0	bank 8 (display RAM)	0 to 127
1	0	0	1	bank 9 (display RAM)	0 to 127

When the icon row (row 79) is enabled it will always be in bank 9 independent of the multiplex rate which is programmed.

12.7 Set X address of RAM

The X address points to the columns. The range of X is 0 to 127 (7Fh).

12.8 Set display start line

L[6:0] (see Table 11) is used to select the display line address of the display RAM to be displayed on the initial row, row 0. The selection of L[6:0] is limited to steps of 8. When the icon row is selected, the selection of L[6:0] is limited to steps of 16. When a partial mode is selected, the selection of L[6:0] is also limited in steps. In addition, the selection of L[6:0] = 72 is not allowed when the icon row is enabled or disabled.

The initial row can, in turn, be set by C[6:0]; see Table 11. Row 0 cannot be set to icon row 79 when enabled.

An example of the mapping from the RAM content to the display is shown in Figure 33. The content of the RAM is not modified. This feature allows, for instance, screen scrolling without rewriting the RAM.

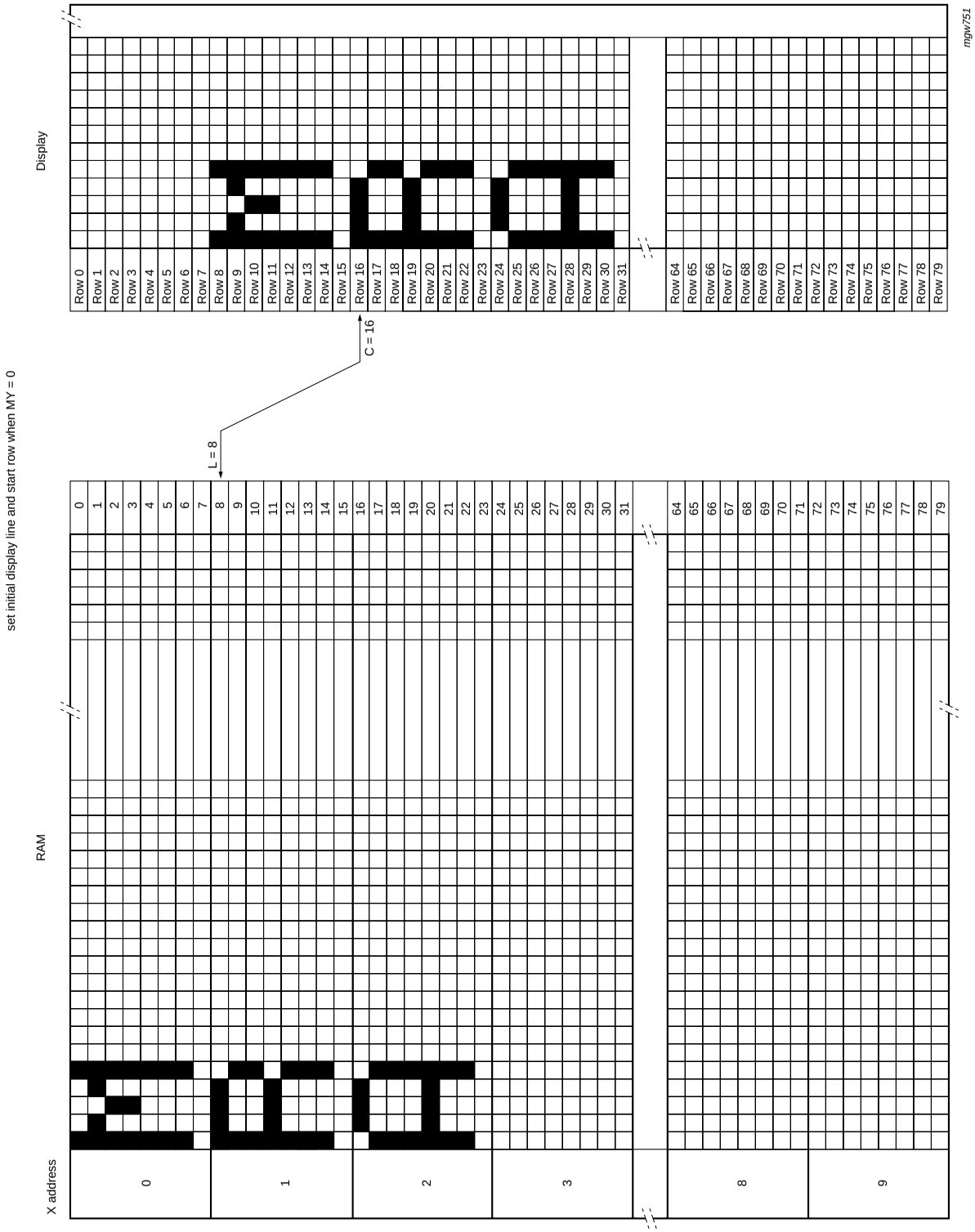


Fig 33. Programming the L[6:0] address and C[6:0] address when MY = 0

12.9 Bias levels

The bias levels for a MRA (Multiple Row Addressing) driving method with p = 8 are given in Figure 34 when G_{max} and F have the same value. The value p defines the number of rows which are simultaneously selected.

Fig 34. Bias levels for an MRA system with p = 8 and G_{max} = F

The row voltage F depends on the multiplex rate selected (number of rows N), the threshold voltage of the liquid (V_{TH}), the number of simultaneously selected rows (p) and the multiplexibility (m):

$$F = \frac{1}{\sqrt{p}} \times V_{TH} \times \sqrt{\frac{N}{2} \times \frac{\sqrt{m} \pm \sqrt{m-N}}{\sqrt{m}-1}} \quad (1)$$

The column voltages are situated around the common level V_C. The column voltage levels are equidistant from each other. In Table 23 the column voltage levels are given as a function of F.

Table 23. Bias levels for MRA driving method

Symbol	Bias voltages	DC shifted bias voltages
F = G_{max}		
V_{LCD}	F	V_{LCD}
V3_H	$(p-2) \times \frac{F}{\sqrt{m}-\sqrt{m-N}}$	$\frac{V_{LCD}}{2} \times \left(1 + \frac{(p-2)}{\sqrt{m}-\sqrt{m-N}}\right)$
V2_H	$(p-4) \times \frac{F}{\sqrt{m}-\sqrt{m-N}}$	$\frac{V_{LCD}}{2} \times \left(1 + \frac{(p-4)}{\sqrt{m}-\sqrt{m-N}}\right)$
V1_H	$(p-6) \times \frac{F}{\sqrt{m}-\sqrt{m-N}}$	$\frac{V_{LCD}}{2} \times \left(1 + \frac{(p-6)}{\sqrt{m}-\sqrt{m-N}}\right)$
V_C	0	$\frac{1}{2}V_{LCD}$
V1_L	$-(p-6) \times \frac{F}{\sqrt{m}-\sqrt{m-N}}$	$\frac{V_{LCD}}{2} \times \left(1 - \frac{(p-6)}{\sqrt{m}-\sqrt{m-N}}\right)$
V2_L	$-(p-4) \times \frac{F}{\sqrt{m}-\sqrt{m-N}}$	$\frac{V_{LCD}}{2} \times \left(1 - \frac{(p-4)}{\sqrt{m}-\sqrt{m-N}}\right)$

Table 23. Bias levels for MRA driving method *...continued*

Symbol	Bias voltages	DC shifted bias voltages
V3_L	$-(p-2)\times\frac{F}{\sqrt{m}-\sqrt{m-N}}$	$\frac{V_{LCD}}{2}\times\left(1-\frac{(p-2)}{\sqrt{m}-\sqrt{m-N}}\right)$
V_{SS}	–F	V_{SS}

The row voltages (F) are not necessarily larger then the column voltages. This depends on the number of rows which are selected, the multiplexibility and the value of p. However, the PCF8811 is designed in such a way that the maximum column voltages are always equal to the row voltages. In Table 24 the V_{LCD} and the different bias levels are given for the PCF8811. The V_{LCD} voltage is defined as:

$$V_{LCD} = 2F \tag{2}$$

Where F is defined in Equation 1.

The bias system settings for different display modes are given in Table 24. All bias levels can be calculated by using the third column of Table 23 and the variables given in Table 24. Programming of the bias levels is not necessary in the PCF8811. The selection of the appropriate bias level voltages for each display mode is done automatically. Only the appropriate V_{LCD} voltage must be programmed according to Equation 1 and Equation 2 for the display modes listed in Table 24.

Table 24. Relationship between multiplex rates and bias setting variables without icon row

Multiplex rate	Variable		
	N	m	p
1:16	16	25	2
1:24	24	49	2
1:32	32	81	2
1:40	40	49	4
1:48	48	64	4
1:56	56	81	4
1:64	64	64	8
1:72	72	81	8
1:80	80	81	8

The variables for calculating V_{LCD}, when the icon row is enabled, are given in Table 25. The icon row can only be addressed in the extended command set.

The PCF8811 allows the value of p for certain multiplex rates to be chosen manually. This is only possible for the multiplex rates 1:64 and 1:80. If other multiplex rates are chosen the PCF8811 determines the optimum value of p. By setting the value of p manually a compromise can be made between contrast and power consumption with certain liquids for the high multiplex rates 1:64 and 1:80. However, care must be taken that the liquid which is chosen ensures that the row voltages (F) and the maximum column voltages are equal.

Table 25. Relationship between multiplex rates and bias setting variables with the icon row (only extended command set)

Multiplex rate	Variable		
	N	m	p
1:16	24	49	2
1:32	40	49	4
1:48	56	81	8
1:64	80	81	8
1:80	80	81	8

12.10 Set V_{OP} value

For multiplex rate 1:80 the optimum operation voltage of a liquid can be calculated with the variables given in Table 25, Equation 1 and Equation 2.

$$V_{LCD} = \frac{2}{\sqrt{8}} \times V_{TH} \times \sqrt{\frac{80}{2} \times \frac{\sqrt{81} - \sqrt{81-80}}{\sqrt{81-1}}} = 4.472 \times V_{TH} \quad (3)$$

Where V_{TH} is the threshold voltage of the liquid crystal material used.

The programming method for the V_{OP} value is implemented differently in the basic command set from that in the extended command set. In the basic command set two commands are sent to the PCF8811: namely V_{PR}[5:0] and V_{OFF}[2:0]. In the extended command set only one command V_{PR}[7:0] is sent to the PCF8811. The programming of V_{OP} in the basic command set can be used when the PCF8811 is used as a replacement for an IAPT (Improved Alt-Pleshko Technique) LCD driver. The ROM look-up table Table 28 shows the possible values for V_{OFF}[2:0], V_{PR}[5:0], V_{OP}[7:0] and V_{LCD}.

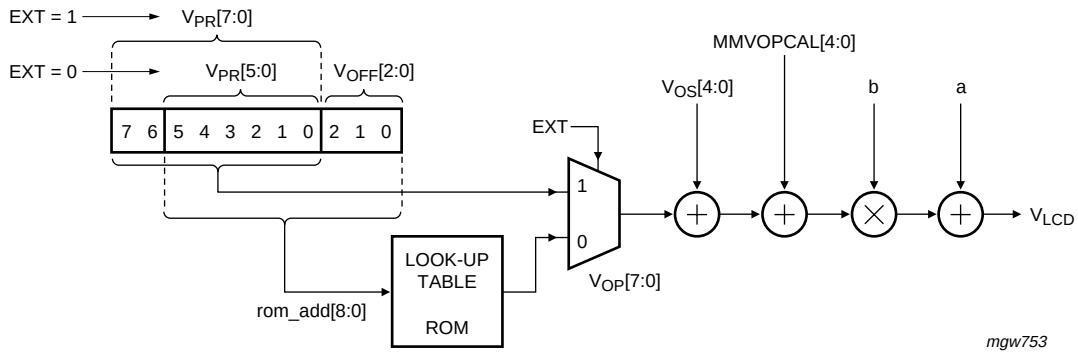


Fig 35. Setting of V_{OP} in the basic and extended command set

12.10.1 Basic command set

The V_{LCD} at T = T_{CUT} in the basic command set is determined by the conversion in the ROM look-up table with the programmed values of V_{PR}[5:0] and V_{OFF}[2:0]. It can, additionally, be adjusted with the V_{LCD} offset pads V_{OS}[4:0] to obtain the optimum optical performance.

Example: To get the value of 6 V for V_{LCD} the following values have to be taken; see Table 26.

Table 26. Example values of V_{PR}, V_{OP} and V_{OFF} for V_{LCD} = 6 V

Register	Value in Table 28	Binary value
V_{PR}[5:0]	15	0 1111
V_{OP}[7:0]	100	110 0100
V_{OFF}[2:0]	010	010

Instead of using the V_{LCD} offset pads (V_{OS}[4:0]) the V_{LCD} can be adjusted with the module maker calibration setting MMVOPCAL[4:0]; see Section 18.

$$V_{LCD(T = T_{CUT})} = a + (V_{OS}[4{:}0] + V_{OP}[7{:}0]) \times b \quad (4)$$

Where:

- T_{CUT} is a reference temperature; see Section 12.11
- a is a fixed constant value; see Table 27
- b is a fixed constant value; see Table 27
- V_{OP}[7:0] is the result of the conversion table
- V_{OS}[4:0]/MMVOPCAL[4:0] is the value of the offset V_{LCD} pads or the value stored in the OTP cells

Table 27. Parameters of V_{LCD} for the basic and extended command set

Symbol	Value	Unit
T_{CUT}	40	°C
b	0.03	V
a	3	V

Table 28. ROM look-up table with values of V_{OFF}, V_{PR}, V_{OP} and V_{LCD}

V_{OFF}[000]			V_{OFF}[001]			V_{OFF}[010]			V_{OFF}[011]			V_{OFF}[100]			V_{OFF}[101]			V_{OFF}[110]			V_{OFF}[111]		
V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)
0	13	3.39	0	48	4.44	0	82	5.46	0	116	6.48	0	150	7.5	0	185	8.55	0	219	9.57	0	253	10.59
1	14	3.42	1	49	4.47	1	83	5.49	1	118	6.54	1	152	7.56	1	187	8.61	1	221	9.63	1	256	10.68
2	15	3.45	2	50	4.5	2	84	5.52	2	119	6.57	2	154	7.62	2	189	8.67	2	223	9.69	2	256	10.68
3	15	3.45	3	51	4.53	3	86	5.58	3	121	6.63	3	156	7.68	3	191	8.73	3	226	9.78	3	256	10.68
4	16	3.48	4	52	4.56	4	87	5.61	4	122	6.66	4	157	7.71	4	192	8.76	4	228	9.84	4	256	10.68
5	17	3.51	5	53	4.59	5	88	5.64	5	123	6.69	5	159	7.77	5	194	8.82	5	230	9.9	5	256	10.68
6	18	3.54	6	54	4.62	6	89	5.67	6	125	6.75	6	161	7.83	6	196	8.88	6	232	9.96	6	256	10.68
7	19	3.57	7	55	4.65	7	90	5.7	7	126	6.78	7	162	7.86	7	198	8.94	7	234	10.02	7	256	10.68
8	19	3.57	8	56	4.68	8	92	5.76	8	128	6.84	8	164	7.92	8	200	9	8	236	10.08	8	256	10.68
9	20	3.6	9	57	4.71	9	93	5.79	9	129	6.87	9	166	7.98	9	202	9.06	9	239	10.17	9	256	10.68
10	21	3.63	10	58	4.74	10	94	5.82	10	131	6.93	10	167	8.01	10	204	9.12	10	241	10.23	10	256	10.68
11	22	3.66	11	59	4.77	11	95	5.85	11	132	6.96	11	169	8.07	11	206	9.18	11	243	10.29	11	256	10.68
12	22	3.66	12	60	4.8	12	97	5.91	12	134	7.02	12	171	8.13	12	208	9.24	12	245	10.35	12	256	10.68
13	23	3.69	13	61	4.83	13	98	5.94	13	135	7.05	13	173	8.19	13	210	9.3	13	247	10.41	13	256	10.68
14	24	3.72	14	62	4.86	14	99	5.97	14	137	7.11	14	174	8.22	14	212	9.36	14	249	10.47	14	256	10.68
15	25	3.75	15	63	4.89	15	100	6	15	138	7.14	15	176	8.28	15	214	9.42	15	252	10.56	15	256	10.68
16	25	3.75	16	64	4.92	16	102	6.06	16	140	7.2	16	178	8.34	16	216	9.48	16	254	10.62	16	256	10.68
17	26	3.78	17	65	4.95	17	103	6.09	17	141	7.23	17	179	8.37	17	218	9.54	17	256	10.68	17	256	10.68
18	27	3.81	18	66	4.98	18	104	6.12	18	143	7.29	18	181	8.43	18	220	9.6	18	256	10.68	18	256	10.68
19	28	3.84	19	66	4.98	19	105	6.15	19	144	7.32	19	183	8.49	19	221	9.63	19	256	10.68	19	256	10.68
20	29	3.87	20	68	5.04	20	106	6.18	20	145	7.35	20	184	8.52	20	223	9.69	20	256	10.68	20	256	10.68
21	29	3.87	21	69	5.07	21	108	6.24	21	147	7.41	21	186	8.58	21	225	9.75	21	256	10.68	21	256	10.68
22	30	3.9	22	70	5.1	22	109	6.27	22	148	7.44	22	188	8.64	22	227	9.81	22	256	10.68	22	256	10.68
23	31	3.93	23	71	5.13	23	110	6.3	23	150	7.5	23	190	8.7	23	229	9.87	23	256	10.68	23	256	10.68
24	32	3.96	24	72	5.16	24	111	6.33	24	151	7.53	24	191	8.73	24	231	9.93	24	256	10.68	24	256	10.68
25	32	3.96	25	73	5.19	25	113	6.39	25	153	7.59	25	193	8.79	25	233	9.99	25	256	10.68	25	256	10.68
26	33	3.99	26	74	5.22	26	114	6.42	26	154	7.62	26	195	8.85	26	235	10.05	26	256	10.68	26	256	10.68
27	34	4.02	27	75	5.25	27	115	6.45	27	156	7.68	27	196	8.88	27	237	10.11	27	256	10.68	27	256	10.68
28	35	4.05	28	76	5.28	28	116	6.48	28	157	7.71	28	198	8.94	28	239	10.17	28	256	10.68	28	256	10.68

Table 28. ROM look-up table with values of V_{OFF}, V_{PR}, V_{OP} and V_{LCD} *…continued*

V_{OFF}[000]			V_{OFF}[001]			V_{OFF}[010]			V_{OFF}[011]			V_{OFF}[100]			V_{OFF}[101]			V_{OFF}[110]			V_{OFF}[111]		
V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)
29	35	4.05	29	77	5.31	29	118	6.54	29	159	7.77	29	200	9	29	241	10.23	29	256	10.68	29	256	10.68
30	36	4.08	30	78	5.34	30	119	6.57	30	160	7.8	30	201	9.03	30	243	10.29	30	256	10.68	30	256	10.68
31	37	4.11	31	79	5.37	31	120	6.66	31	162	7.86	31	203	9.09	31	245	10.35	31	256	10.68	31	256	10.68
32	38	4.14	32	80	5.4	32	121	6.63	32	163	7.89	32	205	9.15	32	247	10.41	32	256	10.68	32	256	10.68
33	39	4.17	33	81	5.43	33	123	6.69	33	165	7.95	33	207	9.21	33	249	10.47	33	256	10.68	33	256	10.68
34	39	4.17	34	82	5.46	34	124	6.72	34	166	7.98	34	208	9.24	34	250	10.5	34	256	10.68	34	256	10.68
35	40	4.2	35	83	5.49	35	125	6.75	35	167	8.01	35	210	9.3	35	252	10.56	35	256	10.68	35	256	10.68
36	41	4.23	36	84	5.52	36	126	6.78	36	169	8.07	36	212	9.36	36	254	10.62	36	256	10.68	36	256	10.68
37	42	4.26	37	85	5.55	37	127	6.81	37	170	8.1	37	213	9.39	37	256	10.68	37	256	10.68	37	256	10.68
38	42	4.26	38	86	5.58	38	129	6.87	38	172	8.16	38	215	9.45	38	256	10.68	38	256	10.68	38	256	10.68
39	43	4.29	39	87	5.61	39	130	6.9	39	173	8.19	39	217	9.51	39	256	10.68	39	256	10.68	39	256	10.68
40	44	4.32	40	88	5.64	40	131	6.93	40	175	8.25	40	218	9.54	40	256	10.68	40	256	10.68	40	256	10.68
41	45	4.35	41	89	5.67	41	132	6.96	41	176	8.28	41	220	9.6	41	256	10.68	41	256	10.68	41	256	10.68
42	45	4.35	42	90	5.7	42	134	7.02	42	178	8.34	42	222	9.66	42	256	10.68	42	256	10.68	42	256	10.68
43	46	4.38	43	91	5.73	43	135	7.05	43	179	8.37	43	224	9.72	43	256	10.68	43	256	10.68	43	256	10.68
44	47	4.41	44	92	5.76	44	136	7.08	44	181	8.43	44	225	9.75	44	256	10.68	44	256	10.68	44	256	10.68
45	48	4.44	45	93	5.79	45	137	7.11	45	182	8.46	45	227	9.81	45	256	10.68	45	256	10.68	45	256	10.68
46	48	4.44	46	94	5.82	46	139	7.17	46	184	8.52	46	229	9.87	46	256	10.68	46	256	10.68	46	256	10.68
47	49	4.47	47	95	5.85	47	140	7.2	47	185	8.55	47	230	9.9	47	256	10.68	47	256	10.68	47	256	10.68
48	50	4.5	48	96	5.88	48	141	7.23	48	187	8.61	48	232	9.96	48	256	10.68	48	256	10.68	48	256	10.68
49	51	4.53	49	97	5.91	49	142	7.26	49	188	8.64	49	234	10.02	49	256	10.68	49	256	10.68	49	256	10.68
50	52	4.56	50	98	5.94	50	143	7.29	50	189	8.67	50	235	10.05	50	256	10.68	50	256	10.68	50	256	10.68
51	52	4.56	51	99	5.97	51	145	7.35	51	191	8.73	51	237	10.11	51	256	10.68	51	256	10.68	51	256	10.68
52	53	4.59	52	100	6	52	146	7.38	52	192	8.76	52	239	10.17	52	256	10.68	52	256	10.68	52	256	10.68
53	54	4.62	53	101	6.03	53	147	7.41	53	194	8.82	53	241	10.23	53	256	10.68	53	256	10.68	53	256	10.68
54	55	4.65	54	102	6.06	54	148	7.44	54	195	8.85	54	242	10.26	54	256	10.68	54	256	10.68	54	256	10.68
55	55	4.65	55	103	6.09	55	150	7.5	55	197	8.91	55	244	10.32	55	256	10.68	55	256	10.68	55	256	10.68
56	56	4.68	56	104	6.12	56	151	7.53	56	198	8.94	56	246	10.38	56	256	10.68	56	256	10.68	56	256	10.68
57	57	4.71	57	105	6.15	57	152	7.56	57	200	9	57	247	10.41	57	256	10.68	57	256	10.68	57	256	10.68

Table 28. ROM look-up table with values of V_{OFF}, V_{PR}, V_{OP} and V_{LCD} *…continued*

V_{OFF}[000]			V_{OFF}[001]			V_{OFF}[010]			V_{OFF}[011]			V_{OFF}[100]			V_{OFF}[101]			V_{OFF}[110]			V_{OFF}[111]		
V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)	V_{PR} [5:0]	V_{OP} [7:0]	V_{LCD} (V)
58	58	4.74	58	105	6.15	58	153	7.59	58	201	9.03	58	249	10.47	58	256	10.68	58	256	10.68	58	256	10.68
59	58	4.74	59	107	6.21	59	155	7.65	59	203	9.09	59	251	10.53	59	256	10.68	59	256	10.68	59	256	10.68
60	59	4.77	60	108	6.24	60	156	7.68	60	204	9.12	60	252	10.56	60	256	10.68	60	256	10.68	60	256	10.68
61	60	4.8	61	109	6.27	61	157	7.71	61	206	9.18	61	254	10.62	61	256	10.68	61	256	10.68	61	256	10.68
62	61	4.83	62	110	6.3	62	158	7.74	62	207	9.21	62	256	10.68	62	256	10.68	62	256	10.68	62	256	10.68
63	62	4.86	63	111	6.33	63	160	7.8	63	209	9.27	63	256	10.68	63	256	10.68	63	256	10.68	63	256	10.68

12.10.2 Extended command set

The V_{LCD} at T = T_{CUT} is calculated using Equation 5. In the extended command set V_{PR}[7:0] is the same value as V_{OP}[7:0]. It can additionally be adjusted with the V_{LCD} offset pads V_{OS}[4:0] to obtain the optimum optical performance.

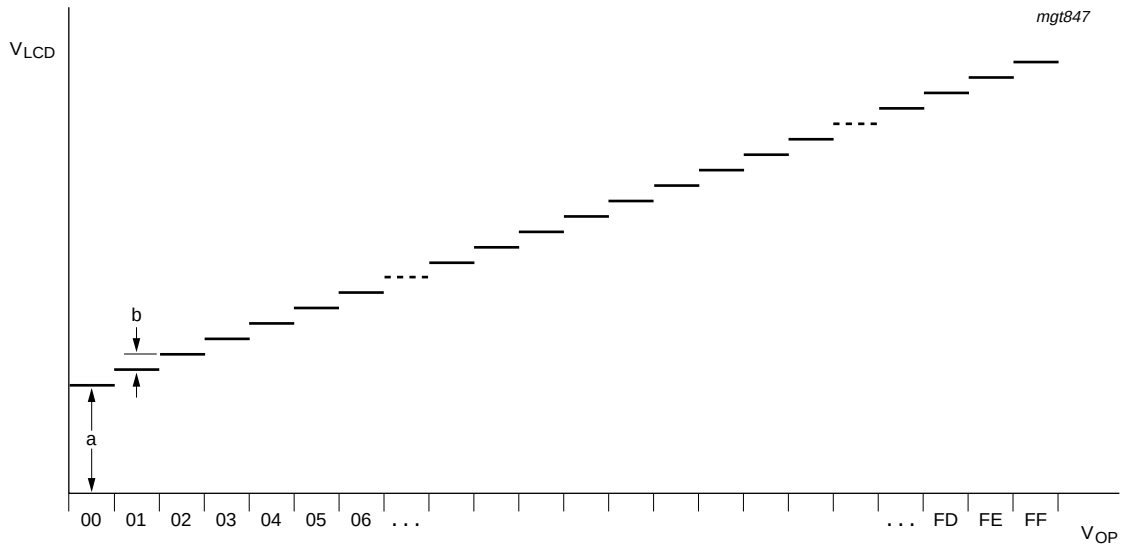
Instead of using the V_{LCD} offset pads (V_{OS}[4:0]) the V_{LCD} can be adjusted with the module maker calibration setting MMVOPCAL[4:0]; see Section 18.

$$V_{LCD(T = T_{CUT})} = a + (V_{OS}[4:0] + V_{OP}[7:0]) \times b \quad (5)$$

Where:

- T_{CUT} is a reference temperature; see Section 12.11
- a is a fixed constant value; see Table 27
- b is a fixed constant value; see Table 27
- V_{PR}[7:0] is the programmed V_{OP} value
- V_{OS}[4:0]/MMVOPCAL[4:0] is the value of the offset V_{LCD} pads or the value stored in the OTP cells

As the programming range for the internally generated V_{LCD} allows values above the maximum allowed V_{LCD} (9 V) the user has to ensure while setting the V_{PR} register and selecting the Temperature Compensation (TC), that under all conditions and including all tolerances the V_{LCD} remains below 9.0 V. This is valid for the two different command sets.



V_{OP}[7:0] programming, (00h to FFh).

Fig 36. V_{LCD} programming of the PCF8811

12.11 Temperature control

Due to the temperature dependency of the liquid crystals' viscosity, the LCD controlling voltage V_{LCD} might have to be increased at lower temperatures to maintain optimum contrast.

You can calculate the V_{LCD} at a specific temperature for both command sets. V_{LCD} (at T = T_{CUT}) is given by Equation 4 or Equation 5 depending on the command set which is used.

$$V_{LCD(T)} = V_{LCD(T = T_{CUT})} \times [1 + (T - T_{CUT}) \times TC] \quad (6)$$

In the extended command set and basic command set 8 different temperature coefficients are available; see Figure 37.

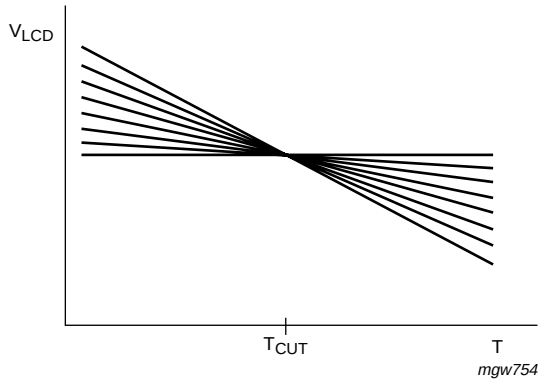
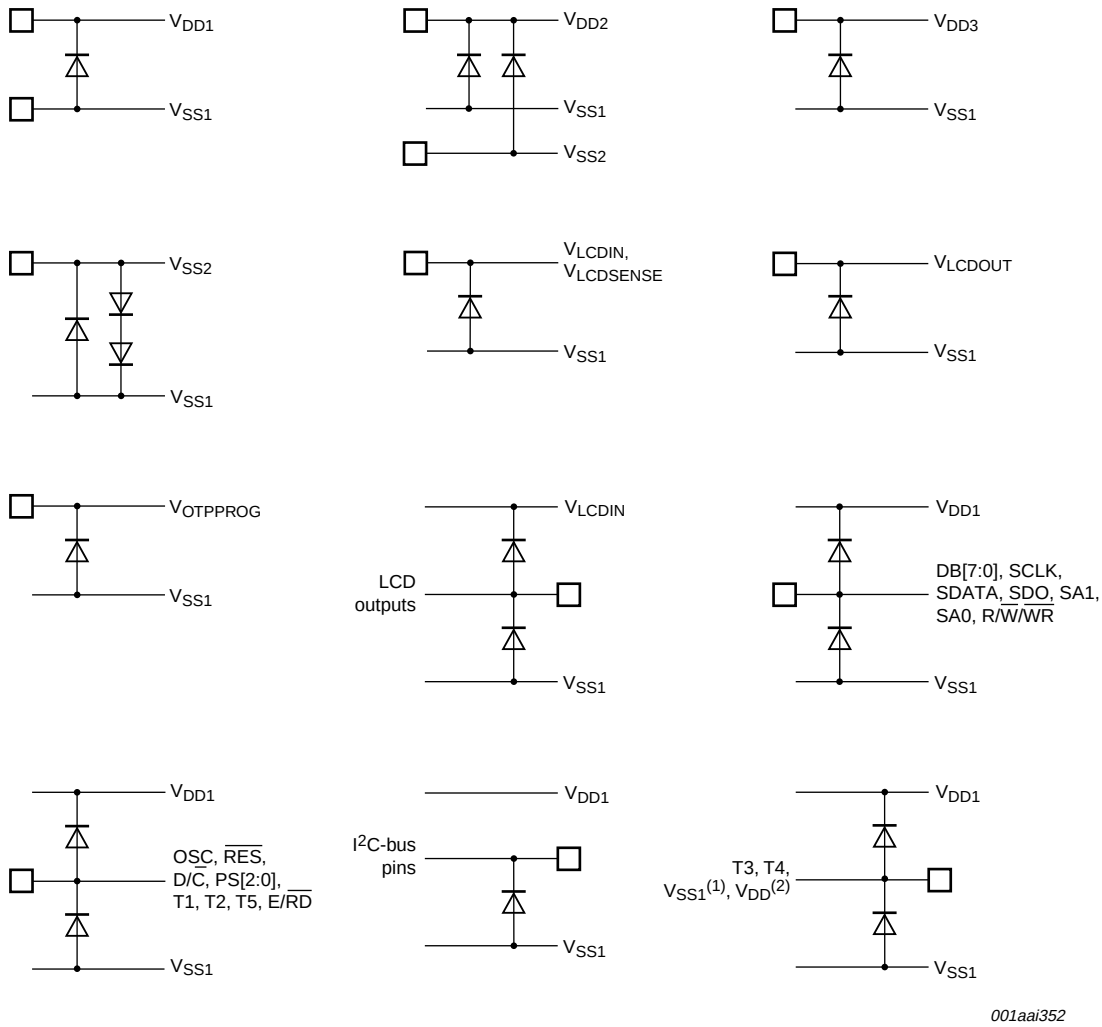


Fig 37. Temperature coefficients

The typical values of the different temperature coefficients are given in Section 15. The coefficients are proportional to the programmed V_{LCD}.

The basic and extended command set differ in the way that the temperature coefficients can be accessed. In the basic command set only one temperature coefficient is available. However, the possibility exists to program the default temperature coefficient by means of OTP programming; see Section 18. In the extended command set the different temperature coefficients are selected by the interface with three bits TC[2:0].

13. Internal circuitry



For test purposes only:

(1) The maximum forward current is 5 mA

(2) The maximum reverse voltage is 5 V

Fig 38. Device protection diagrams

14. Limiting values

Table 29. Limiting values[1]

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions		Min	Max	Unit
V_{DD1}	supply voltage 1	general		–0.5	+6.5	V
V_{DD2}	supply voltage 2	for internal voltage generator	[2]	–0.5	+4.5	V
V_{DD3}	supply voltage 3	for internal voltage generator	[2]	–0.5	+4.5	V

Table 29. Limiting values[1] …continued

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
V_{LCD}	LCD supply voltage		–0.5	+10	V
V_i	input voltage		–0.5	+6.5	V
$V_{OTPPROG}$	voltage applied to pad $V_{OTPPROG}$		–0.5	+12	V
I_I	input current	DC level	–10	+10	mA
I_O	output current	DC level	–10	+10	mA
I_{SS}	ground supply current		–50	+50	mA
P_{tot}	total power dissipation		-	300	mW
P/out	power dissipation per output		-	30	mW
T_{stg}	storage temperature		–65	+150	°C

[1] Parameters are valid over the whole operating temperature range unless otherwise specified. All voltages are referenced to V_{SS} unless otherwise specified.

[2] For the internal voltage multiplier.

15. Static characteristics

Table 30. Static characteristics

V_{DD1} = 1.7 V to 3.3 V; V_{SS} = 0 V; V_{LCD} = 3 V to 9 V; T_{amb} = –40 °C to +85 °C; unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DD1}	supply voltage 1	general		1.7	-	3.3	V
		basic command set; when using ROM look-up table; see Section 12.10		2	-	3.3	V
V_{DD2}	supply voltage 2	for internal voltage multiplier		1.8	-	3.3	V
V_{DD3}	supply voltage 3	for internal voltage multiplier		1.8	-	3.3	V
V_{LCDIN}	LCD supply voltage	LCD voltage externally supplied (voltage multiplier disabled)		3	-	9	V
V_{LCDOUT}	voltage multiplier output voltage	LCD voltage internally generated (voltage multiplier enabled)	[1]	-	-	9	V
$V_{LCD(tol)}$	tolerance of generated V_{LCD}	without calibration		–300	-	+300	mV
		with calibration	[2]	–70	-	+70	mV
I_{DD1}	supply current 1	general	[3][4]	0.5	1.5	5	µA
			[4][5]	15	25	50	µA
I_{DD2}	supply current 2	for internal voltage multiplier	[3][4]	0	0.5	1	µA
			[4][5]	130	150	200	µA
I_{DD3}	supply current 3	for internal voltage multiplier	[3][4]	0	0.5	1	µA
			[4][5]	130	150	200	µA
$I_{DD(tot)}$	total supply current	$V_{DD1} + V_{DD2} + V_{DD3}$	[4][5]	145	175	250	µA
Logic inputs; MF[2:0], V_{OS}[4:0], DS0, EXT, PS[2:0], $\overline{RES}$ and OSC							
V_i	input voltage			V_{SS} – 0.5		V_{DD1} + 0.5	V
V_{IL}	LOW-level input voltage			V_{SS}	-	$0.2V_{DD1}$	V

Table 30. Static characteristics *...continued*

V_{DD1} = 1.7 V to 3.3 V; V_{SS} = 0 V; V_{LCD} = 3 V to 9 V; T_{amb} = −40 °C to +85 °C; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IH}	HIGH-level input voltage		$0.8V_{DD1}$	-	V_{DD1}	V
I_L	leakage current	$V_I = V_{DD}$ or V_{SS}	−1	-	+1	µA
Column and row outputs						
R_{col}	column output resistance	C0 to C127; V_{LCD} = 5 V	-	-	5	kΩ
R_{row}	row output resistance	R0 to R79; V_{LCD} = 5 V	-	-	5	kΩ
$V_{bias(col)}$	bias tolerance voltage	C0 to C127	−100	0	+100	mV
$V_{bias(row)}$	bias tolerance voltage	R0 to R80	−100	0	+100	mV
LCD supply voltage multiplier						
TC0	LCD voltage temperature coefficient 0		-	0	-	1/°C
TC1	LCD voltage temperature coefficient 1		-	-0.16×10^{-3}	-	1/°C
TC2	LCD voltage temperature coefficient 2		-	-0.33×10^{-3}	-	1/°C
TC3	LCD voltage temperature coefficient 3		-	-0.50×10^{-3}	-	1/°C
TC4	LCD voltage temperature coefficient 4		-	-0.66×10^{-3}	-	1/°C
TC5	LCD voltage temperature coefficient 5		-	-0.833×10^{-3}	-	1/°C
TC6	LCD voltage temperature coefficient 6		-	-1.25×10^{-3}	-	1/°C
TC7	LCD voltage temperature coefficient 7	[6]	-	-1.66×10^{-3}	-	1/°C
Parallel interface; V_{DD1} = 1.8 V to 3.3 V						
V_i	input voltage		−0.5	-	V_{DD1} + 0.5	V
V_{IL}	LOW-level input voltage		V_{SS}	-	$0.2V_{DD1}$	V
V_{IH}	HIGH-level input voltage		$0.8V_{DD1}$	-	V_{DD1}	V
Serial interface; V_{DD1} = 1.7 V to 3.3 V						
V_i	input voltage		−0.5	-	V_{DD1} + 0.5	V
V_{IL}	LOW-level input voltage		V_{SS}	-	$0.2V_{DD1}$	V
V_{IH}	HIGH-level input voltage		$0.8V_{DD1}$	-	V_{DD1}	V
I^2C-bus interface; V_{DD1} = 1.8 V to 3.3 V						
V_i	input voltage		−0.5	-	+3.3	V
$I_{OL(SDA)}$	LOW-level output current on pin SDAH	V_{OL} = 0.4 V; V_{DD1} > 2 V	-	-	3	mA
		V_{OL} = 0.2 V_{DD1}; V_{DD1} < 2 V	-	-	2	mA
V_{IL}	LOW-level input voltage		V_{SS}	-	$0.3V_{DD1}$	V
V_{IH}	HIGH-level input voltage		$0.7V_{DD1}$	-	V_{DD1}	V
Output levels for all interfaces						
V_{OL}	LOW-level output voltage	I_{OL} = 0.5 mA	V_{SS}	-	$0.2V_{DD1}$	V
V_{OH}	HIGH-level output voltage	I_{OH} = −0.5 mA	$0.8V_{DD1}$	-	V_{DD1}	V

[1] The maximum possible V_{LCD} voltage that can be generated is dependent on voltage, temperature and (display) load.

[2] Valid for values of temperature, V_{PR} and TC used at calibration.

[3] During power-down all static currents are switched off.

[4] Conditions are: V_{DD1} = 1.8 V, V_{DD2} = 2.7 V, V_{LCD} = 8.05 V, voltage multiplier 4 × V_{DD2}, inputs at V_{DD1} or V_{SS}, interface inactive, internal V_{LCD} generation, V_{LCD} output is loaded by 10 µA and T_{amb} = 25 °C.

[5] Normal mode.

[6] TC7 can only be used when V_{DD2} = V_{DD3} = 2.4 V or higher.

16. Dynamic characteristics

Table 31. Dynamic characteristics[1]

V_{DD1} = 1.7 V to 3.3 V; V_{SS} = 0 V; $V_{LCD} \leq$ 9 V; T_{amb} = −40 °C to +85 °C; unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
f_{ext}	external frequency	external clock		-	200	-	kHz
f_{frame}	frame frequency	T_{amb} = 25 °C; V_{DD1} = 2.4 V		54	60	66	Hz
				43	58	73	Hz
t_{VHRL}	V_{DD} to $\overline{RES}$ LOW	see Figure 47	[2]	0	-	1	µs
t_{RW}	$\overline{RES}$ LOW pulse width	see Figure 47		500	-	-	ns

[1] All specified timings are based on 20 % and 80 % of V_{DD}.

[2] $\overline{RES}$ can be LOW before V_{DD} goes HIGH.

16.1 Parallel interface timing characteristics

Table 32. Parallel interface (6800 series) timing characteristics

V_{DD1} = 1.8 V to 3.3 V; V_{SS} = 0 V; $V_{LCD} \leq$ 9 V; T_{amb} = −40 °C to +85 °C; unless otherwise specified; see Figure 39 and Figure 40.

Symbol	Parameter	Min	Max	Unit
$t_{SU;DC}$	data/$\overline{command}$ set-up time	40	-	ns
$t_{HD;DC}$	data/$\overline{command}$ hold time	20	-	ns
$T_{cyc(DS)}$	data strobe cycle time	1000	-	ns
$t_{DS(L)}$	data strobe LOW time	320	-	ns
$t_{DS(H)}$	data strobe HIGH time	300	-	ns
$t_{SU;RW}$	read/$\overline{write}$ set-up time	280	-	ns
$t_{HD;RW}$	read/$\overline{write}$ hold time	20	-	ns
$t_{SU;CE}$	chip enable set-up time	280	-	ns
$t_{HD;CE}$	chip enable hold time	0	-	ns
$t_{SU;DAT}$	data set-up time	20	-	ns
$t_{HD;DAT}$	data hold time	40	-	ns
$t_{DAT;ACC}$	data output access time	-	280	ns
$t_{DAT;OH}$	data output disable time	-	20	ns

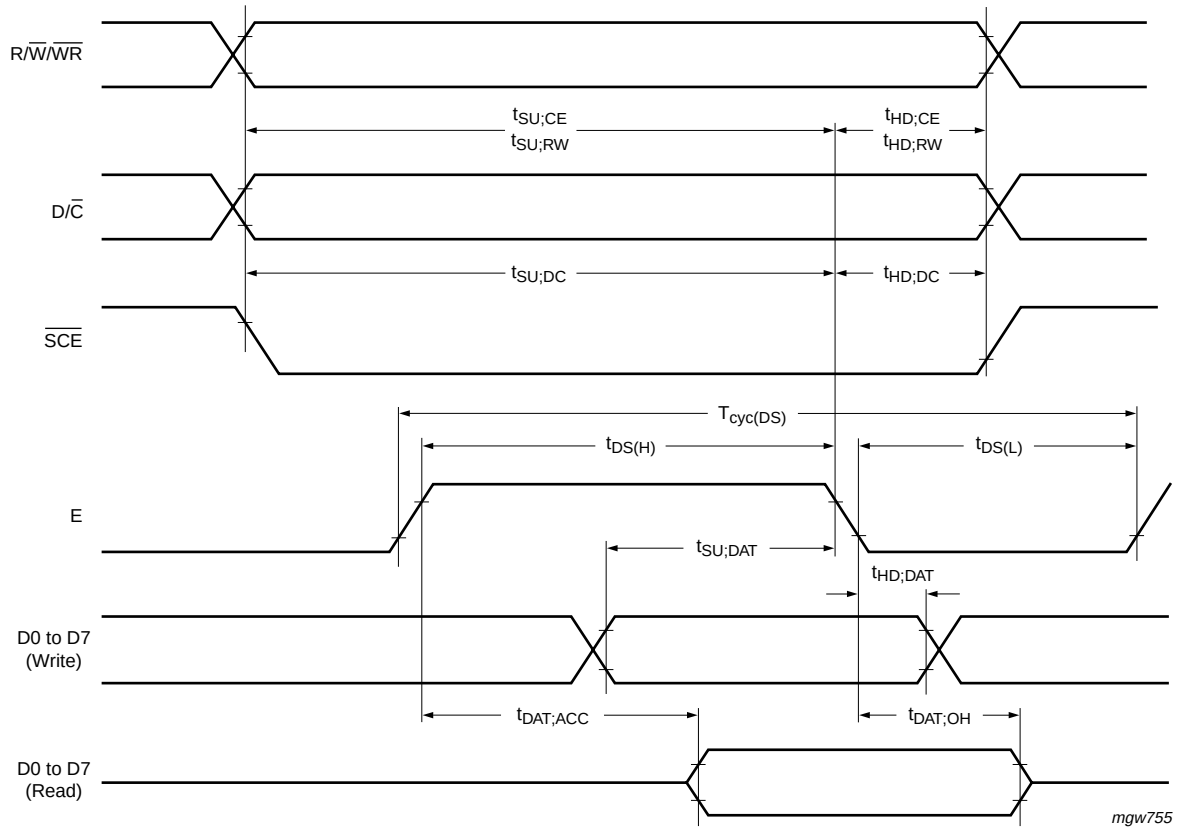


Fig 39. Parallel interface timing; 6800 series (read mode)

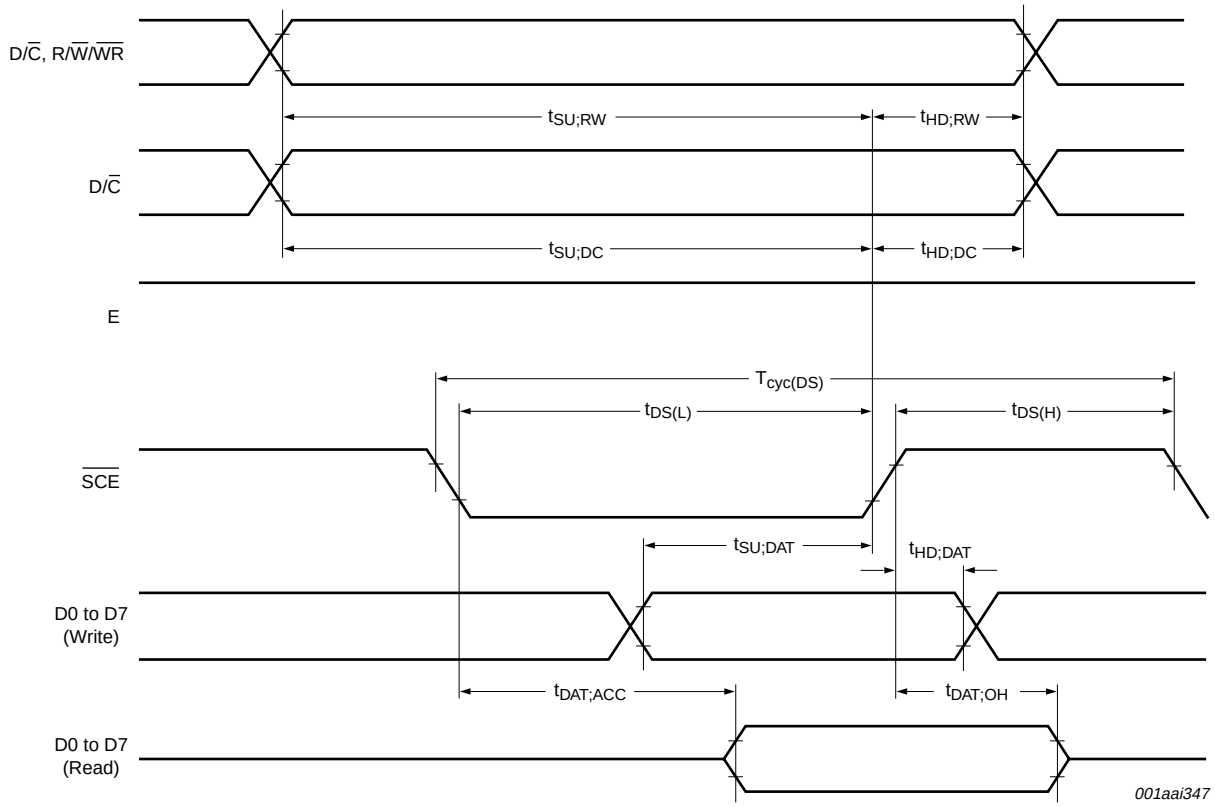


Fig 40. Parallel interface timing; 6800 series (write mode)

16.2 Serial interface timing characteristics

Table 33. Serial interface timing characteristics[1]

V_{DD1} = 1.8 V to 3.3 V; V_{SS} = 0 V; $V_{LCD} \leq 9$ V; T_{amb} = −40 °C to +85 °C; unless otherwise specified; see Figure 41, Figure 42, Figure 43 and Figure 44.

Symbol	Parameter		Min	Max	Unit
f_{SCLK}	clock frequency		9.00	-	MHz
T_{cyc}	clock cycle SCLK		111	-	ns
t_{PWH1}	SCLK pulse width HIGH		45	-	ns
t_{PWL1}	SCLK pulse width LOW		45	-	ns
t_{S2}	$\overline{SCE}$ set-up time		50	-	ns
t_{H2}	$\overline{SCE}$ hold time		45	-	ns
t_{PWH2}	$\overline{SCE}$ minimum HIGH time		50	-	ns
t_{H5}	$\overline{SCE}$ start hold time	[2]	50	-	ns
t_{S3}	data/$\overline{command}$ set-up time		50	-	ns
t_{H3}	data/$\overline{command}$ hold time		50	-	ns
t_{S1}	SDATA set-up time		50	-	ns
t_{H1}	SDATA hold time		50	-	ns
t_1	SDO access time		-	50	ns
t_2	SDO disable time	[3]	-	50	ns

Table 33. Serial interface timing characteristics[1] *...continued*

V_{DD1} = 1.8 V to 3.3 V; V_{SS} = 0 V; $V_{LCD} \leq 9$ V; T_{amb} = −40 °C to +85 °C; unless otherwise specified; see Figure 41, Figure 42, Figure 43 and Figure 44.

Symbol	Parameter		Min	Max	Unit
t_3	$\overline{SCE}$ hold time		50	-	ns
t_4	SDO disable time	[4]	25	100	ns
C_b	capacitive load for SDO	[5]	-	30	pF
R_b	series resistance for SDO	[5]	-	500	Ω

[1] All specified timings are based on 20 % and 80 % of V_{DD}.

[2] t_{H5} is the time from the previous SCLK rising edge (irrespective of the state of $\overline{SCE}$) to the falling edge of $\overline{SCE}$.

[3] SDO disable time for SPI 3-line or 4-line.

[4] SDO disable time for 3-line serial interface.

[5] Maximum values are for f_{SCLK} = 9 MHz. Series resistance includes ITO track + connector resistance + printed-circuit board.

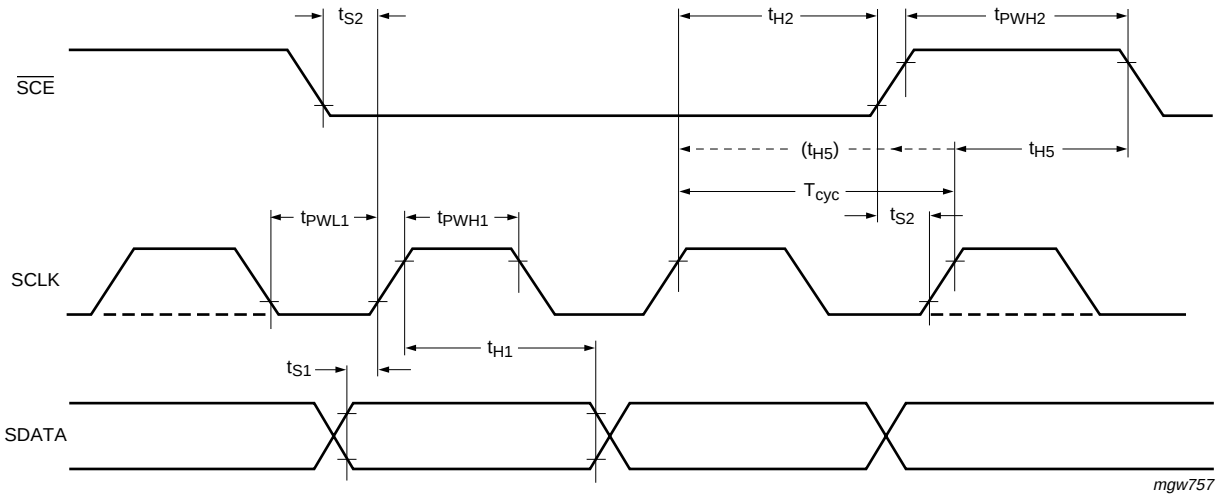


Fig 41. 3-line serial interface timing

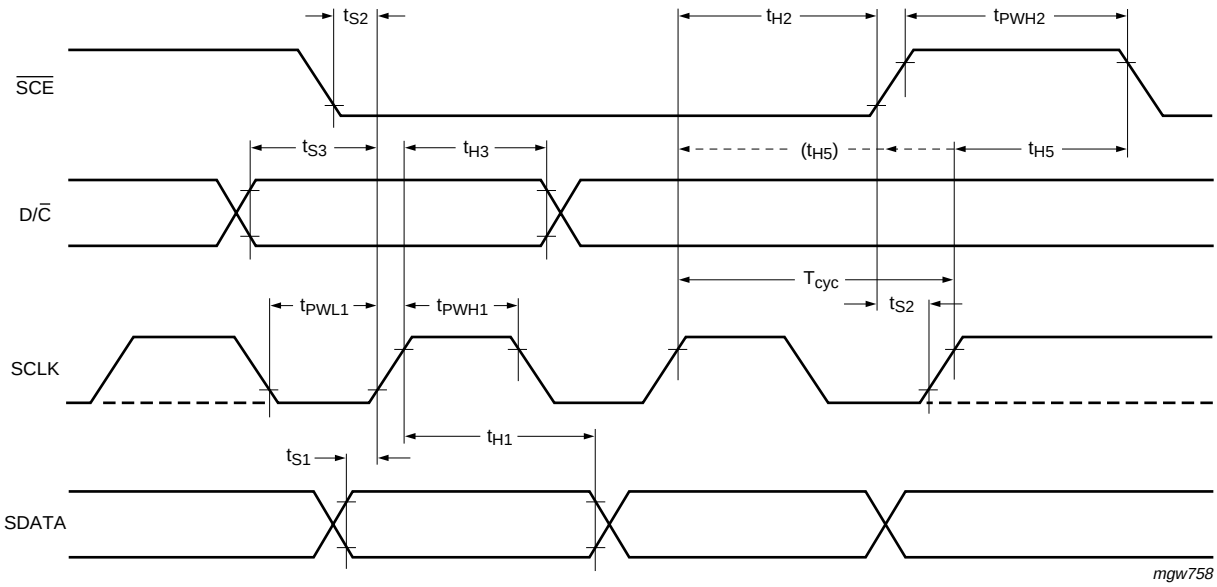


Fig 42. 4-line serial interface timing

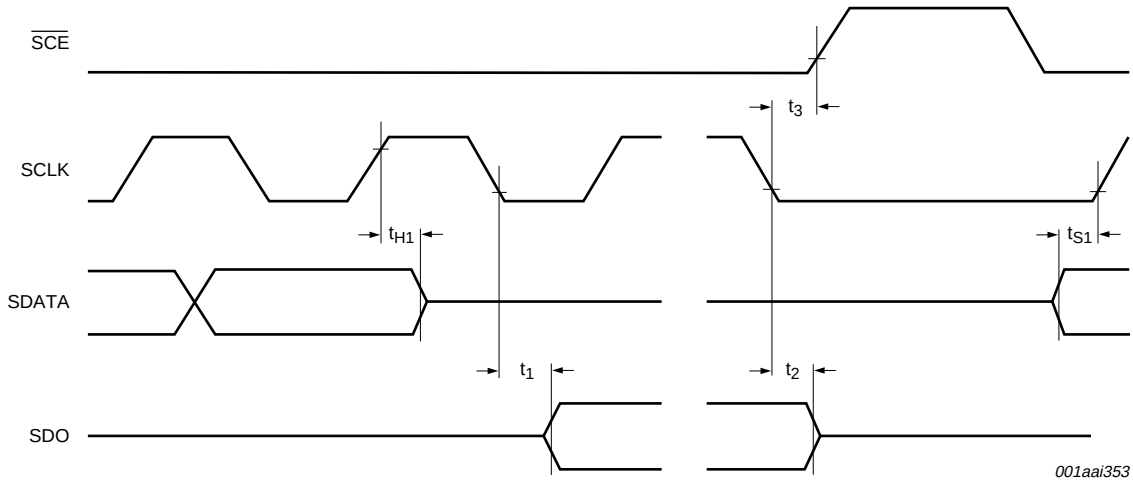


Fig 43. Serial interface timing; SPI 3-line or 4-line (read mode)

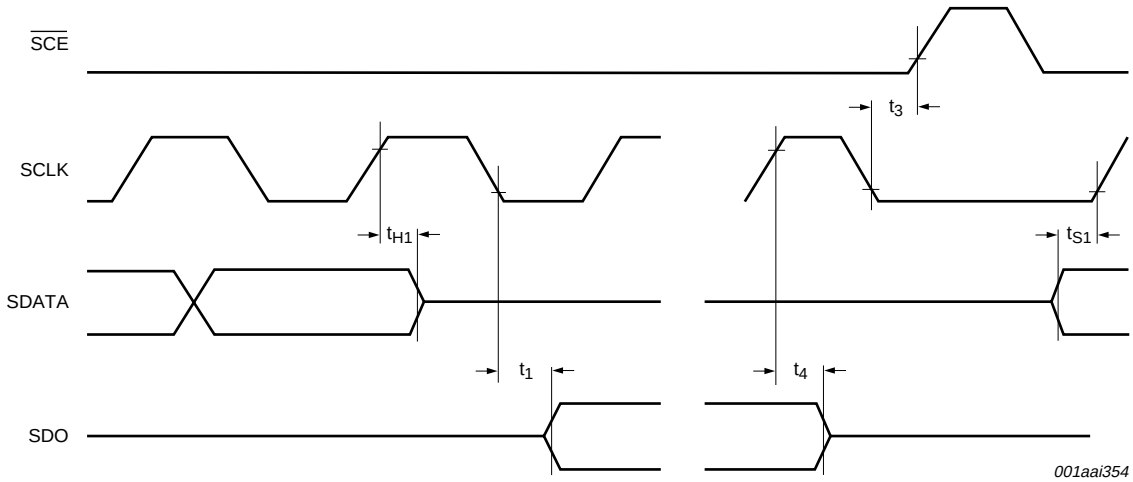


Fig 44. Serial interface timing; 3-line serial interface (read mode)

16.3 I²C-bus interface timing characteristics

Table 34. I²C-bus characteristics; F/S-mode

V_{DD1} = 1.8 V to 3.3 V; V_{SS} = 0 V; V_{LCD} ≤ 9 V; T_{amb} = −40 °C to +85 °C; unless otherwise specified[1]; see Figure 45.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{SCL}	SCL clock frequency		0	-	400	kHz
$t_{SU;STA}$	set-up time for a repeated START condition		600	-	-	ns
$t_{HD;STA}$	hold time (repeated) START condition		600	-	-	ns
t_{LOW}	LOW period of the SCL clock		1300	-	-	ns
t_{HIGH}	HIGH period of the SCL clock		600	-	-	ns
$t_{SU;DAT}$	data set-up time		100	-	-	ns
$t_{HD;DAT}$	data hold time		0	-	900	ns
t_r	rise time of both SDA and SCL signals		20 + 0.1C_b	-	300	ns
t_f	fall time of both SDA and SCL signals		20 + 0.1C_b	-	300	ns
C_b	capacitive load for each bus line		-	-	400	pF
$t_{SU;STO}$	set-up time for STOP condition		600	-	-	ns
t_{SP}	pulse width of spikes that must be suppressed by the input filter		-	-	50	ns
t_{BUF}	bus free time between a STOP and START condition		1300	-	-	ns
V_{nL}	noise margin at the LOW level	for each connected device (including hysteresis)	0.1V_{DD1}	-	-	V
V_{nH}	noise margin at the HIGH level	for each connected device (including hysteresis)	0.2V_{DD1}	-	-	V

[1] All specified timings are based on 20 % and 80 % of V_{DD}.

Table 35. I²C-bus characteristics; Hs-mode

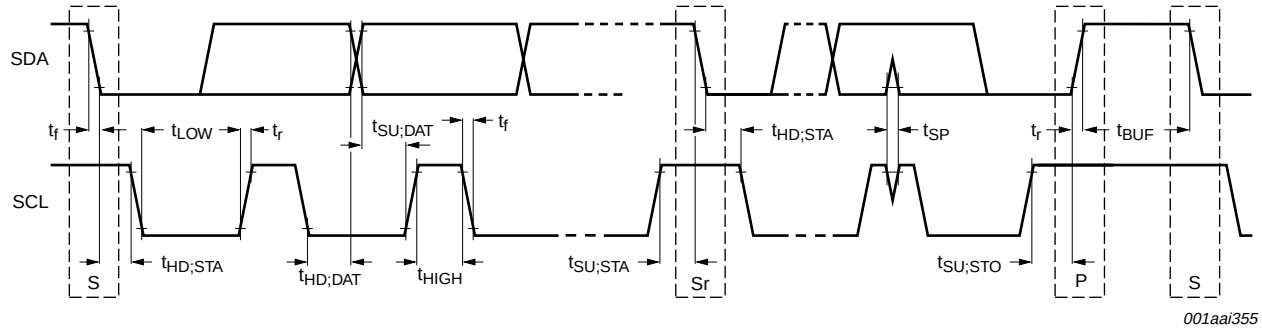
V_{DD1} = 1.8 V to 3.3 V; V_{SS} = 0 V; $V_{LCD} \leq 9$ V; T_{amb} = −40 °C to +85 °C; unless otherwise specified[1]; see Figure 46.

Symbol	Parameter	Conditions	C_b = 100 pF (max)		C_b = 400 pF[2]		Unit
			Min	Max	Min	Max	
f_{SCLH}	SCLH clock frequency		0	3.4	0	1.7	MHz
$t_{SU;STA}$	set-up time for a repeated START condition		160	-	160	-	ns
$t_{HD;STA}$	hold time (repeated) START condition		160	-	160	-	ns
t_{LOW}	LOW period of the SCLH clock		160	-	320	-	ns
t_{HIGH}	HIGH period of the SCLH clock		60	-	120	-	ns
$t_{SU;DAT}$	data set-up time		10	-	10	-	ns
$t_{HD;DAT}$	data hold time		20[3]	70	20[3]	150	ns
t_{rCL}	rise time of SCLH signal		10	40	20	80	ns
t_{rCL1}	rise time of SCLH signal after a repeated START condition and after an acknowledge bit		10	80	20	160	ns
t_{fCL}	fall time of SCLH signal		10	40	20	80	ns
t_{rDA}	rise time of SDAH signal		10	80	20	160	ns
t_{fDA}	fall time of SDAH signal		10	80	20	160	ns
$t_{SU;STO}$	set-up time for STOP condition		160	-	160	-	ns
t_{SP}	pulse width of spikes that must be suppressed by the input filter	SDAH and SCLH	0	5	0	5	ns
C_b	capacitive load for each bus line	SDAH and SCLH lines [2]	0	100	-	400	pF
		SDAH + SDA line and SCLH + SCL line	0	400	-	400	pF
V_{nL}	noise margin at the LOW level	for each connected device (including hysteresis)	$0.1V_{DD1}$	-	$0.1V_{DD1}$	-	V
V_{nH}	noise margin at the HIGH level	for each connected device (including hysteresis)	$0.2V_{DD2}$	-	$0.2V_{DD2}$	-	V

[1] All specified timings are based on 20 % and 80 % of V_{DD}.

[2] For bus line loads C_b between 100 pF and 400 pF the timing parameters must be linearly interpolated.

[3] A device must internally provide a data hold time to bridge the undefined part between V_{IH} and V_{IL} of the falling edge of the SCLH signal. An input circuit with a threshold as low as possible for the falling edge of the SCLH signal minimizes this hold time.

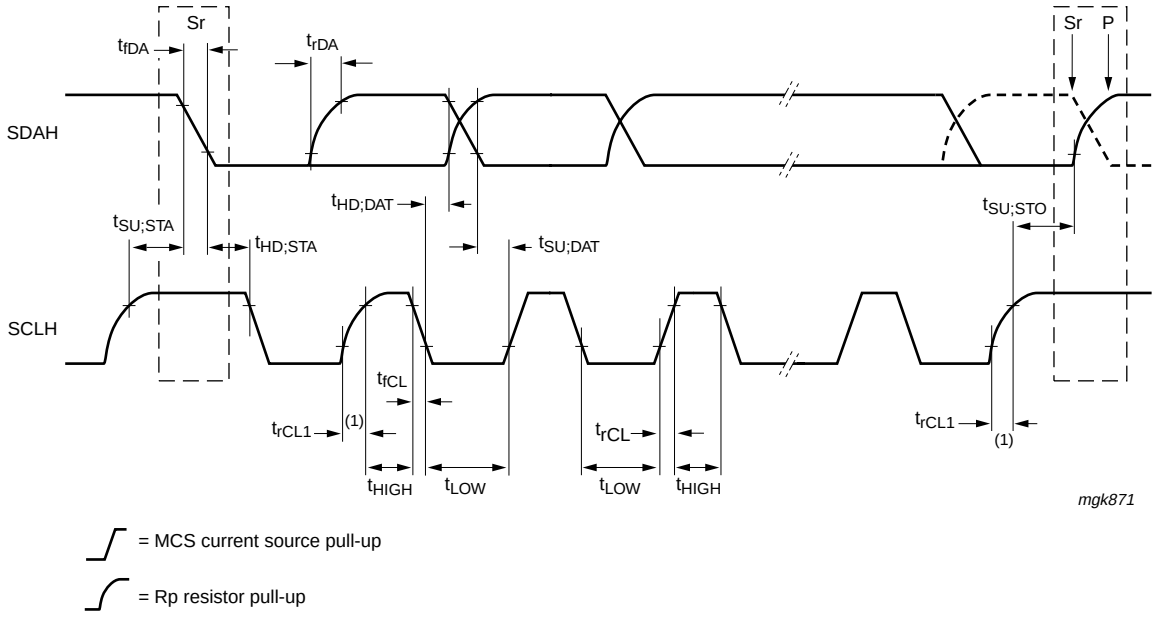


S = start

Sr = start repeated

P = stop

Fig 45. I²C-bus timing diagram (F/S-mode)



(1) Rising edge of the first SCLH clock pulse after an acknowledge bit.

Fig 46. I²C-bus timing diagram (Hs-mode)

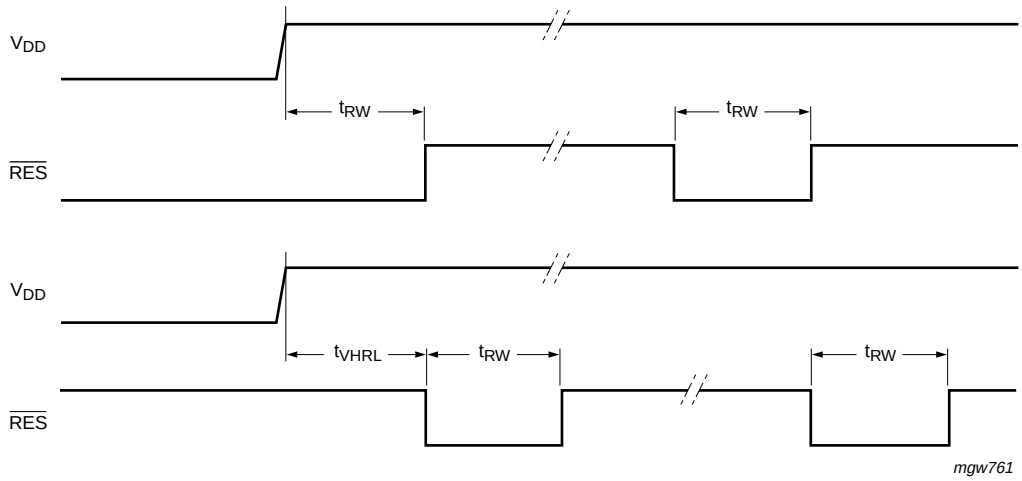


Fig 47. Reset timing

17. Application information

Semiconductors are light sensitive. Exposure to light sources can cause the IC to malfunction. In this application you must protect the IC from light. The protection has to be done on all sides of the IC, i.e. front, rear and all edges.

The pinning of the PCF8811 has an optimum design for single plane wiring e.g. for chip-on-glass display modules. Display size: 80 × 128 pixels.

For further application information refer to NXP Semiconductors Application Note *AN10170 Design guidelines for COG modules with Philips monochrome LCD drivers*.

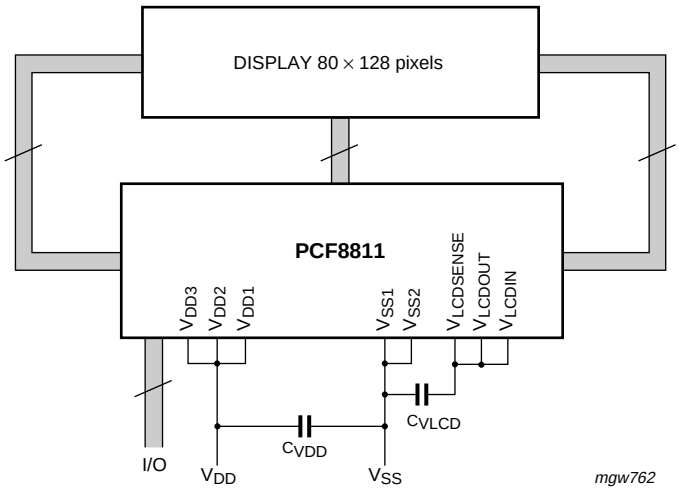


Fig 48. Application diagram: internal charge pump and a single supply

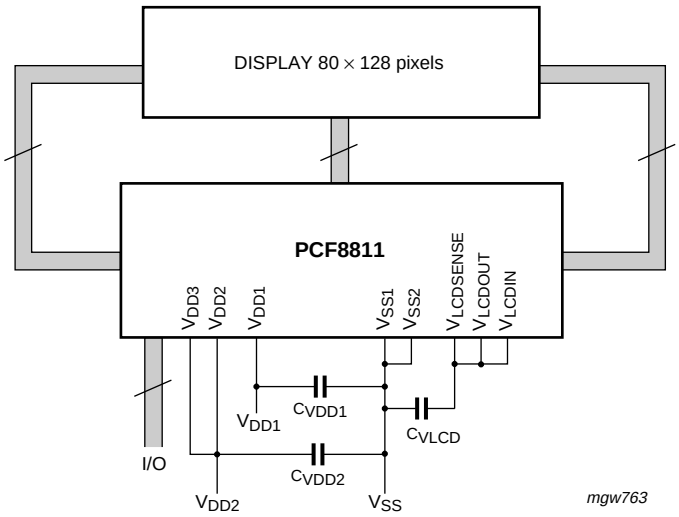


Fig 49. Application diagram: internal charge pump and two separate supplies (V_{DD1} and V_{DD2})

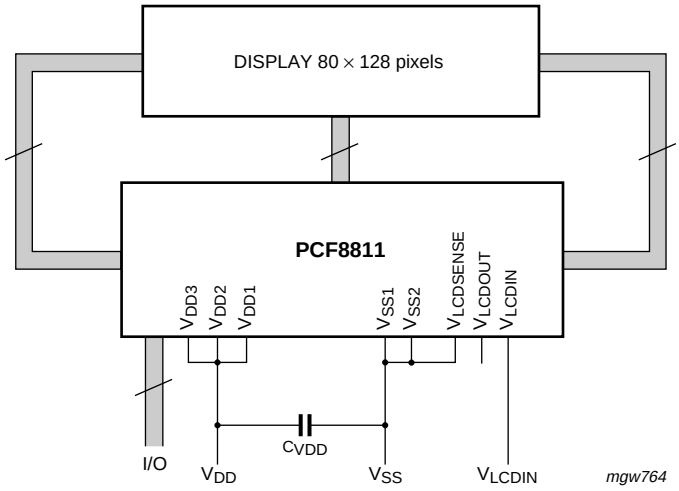


Fig 50. Application diagram: external high voltage

The required minimum value for the external capacitors in an application with the PCF8811 are:

C_{VLCD} = 1.0 µF to 4.7 µF depending on the application.

C_{VDD}, C_{VDD1}, C_{VDD2} = 1.0 µF. For these capacitors, higher values can be used.

18. Support information

18.1 Module maker programming

One Time Programmable (OTP) technology is implemented on the PCF8811. It enables the module maker to program some extended features of the PCF8811 after it has been assembled on an LCD module. Programming is made under the control of the interfaces and the use of one special pad. This pad must be made available on the module glass but need not be accessed by the set maker.

The PCF8811 features 3 parameters programmable by the module maker:

- V_{LCD} calibration
- Temperature coefficient selection
- Seal bit

18.1.1 V_{LCD} calibration

The first feature included is the ability to adjust the V_{LCD} voltage with a 5-bit code (MMVOPCAL). This code is implemented in two's complement notation giving rise to a positive or negative offset to the V_{PR} register. This is in the same manner as the on-glass calibration pads V_{OS}.

In theory, both may be used together but it is recommended that the V_{OS} pads are tied to V_{SS} when OTP calibration is being used. This sets them to a default offset of zero. If both are used then the addition of the two 5-bit numbers must not exceed a 5-bit result, otherwise the resultant value is undefined. The final adder in the circuit has underflow and overflow protection. In the event of an overflow, the output will be clamped to 255; during an underflow the output will be clamped to 0.

The final control to the high voltage multiplier, V_{OP}, is the sum of all the calibration registers and pads. The V_{LCD} Equation 4 or Equation 5 given in Section 12.10.1 or Section 12.10.2 must be extended to include the OTP calibration, as follows:

$$V_{LCD(T = T_{CUT})} = a + (V_{OS}[4{:}0] + \mathrm{MMVOPCAL}[4{:}0] + V_{OP}[7{:}0]) \times b \quad (7)$$

The possible values for MMVOPCAL[4:0] and V_{OS}[4:0] values are given in Table 36.

Table 36. V_{OS}/MMVOPCAL values in two's complement notation

Binary	Decimal	Binary	Decimal
0 0000	0	1 1111	–1
0 0001	+1	1 1110	–2
0 0010	+2	1 1101	–3
0 0011	+3	1 1100	–4
0 0100	+4	1 1011	–5
0 0101	+5	1 1010	–6
0 0110	+6	1 1001	–7
0 0111	+7	1 1000	–8
0 1000	+8	1 0111	–9
0 1001	+9	1 0110	–10

Table 36. V_{OS}/MMVOPCAL values in two's complement notation *...continued*

Binary	Decimal	Binary	Decimal
0 1010	+10	1 0101	–11
0 1011	+11	1 0100	–12
0 1100	+12	1 0011	–13
0 1101	+13	1 0010	–14
0 1110	+14	1 0001	–15
0 1111	+15	1 0000	–16

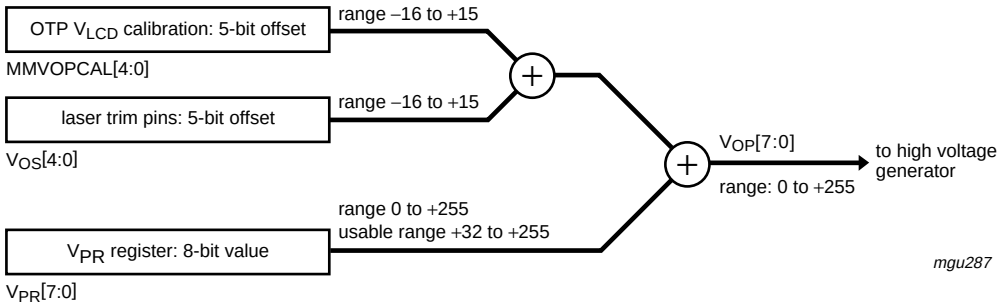


Fig 51. V_{LCD} calibration

18.1.2 Temperature coefficient selection

The second feature is an OTP factory default setting for the temperature coefficient selection (MMTC) in the basic command set. This 3-bit value will be loaded from OTP after leaving the Power-save mode or by the Refresh command. The idea of this feature is to provide, in the basic command set, the complete set of temperature coefficients without an additional command. In the extended command set the temperature coefficient can be programmed as given in Table 20 and Table 30.

18.1.3 Seal bit

The module maker programming is performed in a special mode: the calibration mode (CALMM). This mode is entered via a special interface command, CALMM. To prevent unwanted programming, a seal bit has been implemented which prevents the device from entering the calibration mode. This seal bit, once programmed, cannot be reversed so further changes in programmed values are not possible.

Applying the programming voltages when not in CALMM mode has no effect on the programmed values.

Table 37. Seal bit definition

Seal bit	Action
0	possible to enter calibration mode
1	calibration mode disabled

18.1.4 OTP architecture

The OTP circuitry in the PCF8811 contains 9 bits of data: 5 for V_{LCD} calibration (MMVOPCAL), 3 for the temperature coefficient default setting in the basic command set MMTC and 1 seal bit. The circuitry for 1-bit is called an OTP slice. Each OTP slice consists of 2 main parts: the OTP cell (a non-volatile memory cell) and the shift register cell (a flip-flop). The OTP cells are only accessible through their shift register cells: on the one hand both reading from and writing to the OTP cells is performed with the shift register cells, on the other hand only the shift register cells are visible to the rest of the circuit. The basic OTP architecture is shown in Figure 52.

This OTP architecture allows the following operations:

Reading data from the OTP cells — The content of the non-volatile OTP cells is transferred to the shift register where upon it may affect the PCF8811 operation.

Writing data to the OTP cells — All 9 data bits are shifted into the shift register via the interface. The content of the shift register is then transferred to the OTP cells. There are some limitations related to storing data in these cells; see Section 18.1.7.

Checking calibration without writing to the OTP cells — Shifting data into the shift register allows the effects on the V_{LCD} voltage to be observed.

The reading of data from the OTP cells is initiated by either:

- Exit from Power-save mode
- The ‘Refresh’ command (power control)

Remark: Note that in both cases the reading operation needs up to 5 ms to complete.

The shifting of data into the shift register is performed in the special mode CALMM. In the PCF8811 the CALMM mode is entered by the CALMM command. Once in the CALMM mode the data is shifted into the shift register via the interface at the rate of 1-bit per command. After transmitting the last (9^{th}) bit and exiting the CALMM mode, the serial interface will return to the normal mode and all other commands can be sent. Care should be taken that 9 bits of data (or a multiple of 9) are always transferred before exiting the CALMM mode, otherwise the bits will be in the wrong positions.

In the shift register the value of the seal bit is, like the others, always zero at reset. To ensure that the security feature (seal bit) works correctly, the CALMM command is disabled until a refresh has been performed. Once the refresh is completed, the seal bit value in the shift register will be valid and permission to enter the CALMM mode can thus be determined.

The 9 bits are shifted into the shift register in a predefined order: first 5 bits of MMVOPCAL[4:0], 3 bits for MMTC[2:0] and lastly the seal bit. The MSB is always first, thus the first bit shifted is MMVOPCAL[4] and the two last bits are MMTC[0] and the seal bit.

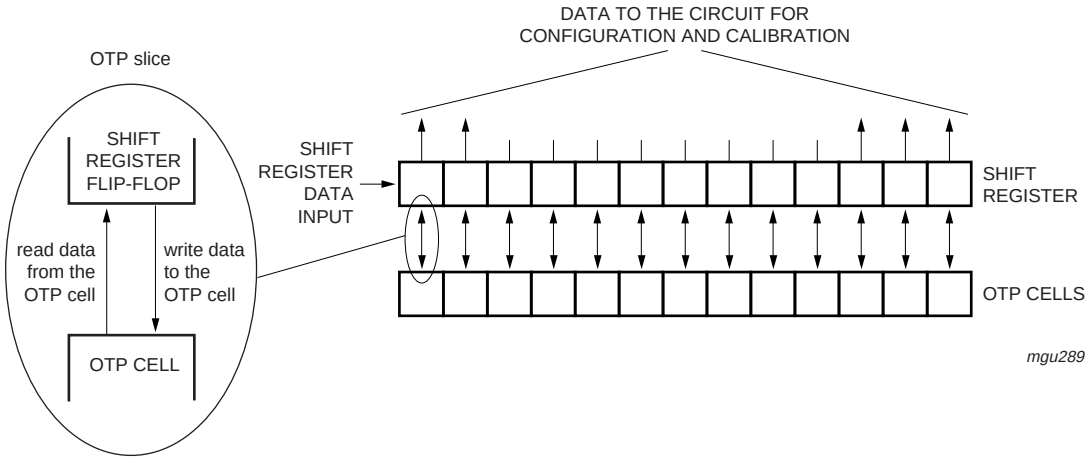


Fig 52. Basic OTP architecture

18.1.5 Interface commands

These instructions are in addition to those indicated in Table 10.

Table 38. Additional interface commands

Instruction	Pad			Command byte								Description
	EXT	D/$\overline{C}$	R/$\overline{W}$/$\overline{WR}$	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
CALMM	X[1]	0	0	1	0	0	0	0	0	1	0	enter CALMM mode
Power control (‘refresh’)	X[1]	0	0	0	0	1	0	1	PC1	PC0	1	switch HVgen on/off to force a refresh of the shift register

[1] X = value without meaning.

18.1.5.1 CALMM

This instruction puts the device in calibration mode. This mode enables the shift register for loading and allows programming of the non-volatile OTP cells to take place. If the seal bit is set then this mode cannot be accessed and the instruction will be ignored. Once in calibration mode all commands are interpreted as shift register data. The mode can only be exited by sending data with DB7 set to logic 0. Reset will also clear this mode. Each shift register data byte is preceded by D/$\overline{C}$ = 0 and has only 2 significant bits, thus the remaining 6 bits are ignored. DB7 is the continuation bit (DB7 = 1 remain in CALMM mode, DB7 = 0 exit CALMM mode). DB0 is the data bit and its value is shifted into the OTP shift register (on the falling edge of SCLK).

18.1.5.2 Refresh

The action of the ‘Refresh’ instruction is to force the OTP shift register to re-load from the non-volatile OTP cells. This instruction takes up to 5 ms to complete. During this time all other instructions may be sent.

In the PCF8811 the ‘Refresh’ instruction is associated with the ‘Power control’ instruction so that the shift register is automatically refreshed every time the high voltage multiplier is enabled or disabled. Note that if this instruction is sent while in Power-save mode, the PC[1:0] bits are updated but the refreshing is ignored.

18.1.6 Example sequence for filling the shift register

An example of the sequence of commands and data is shown in Table 39. In this example the shift register is filled with the following data: MMVOPCAL = –4 (1 1100b), MMTC = 2 (010b) and the seal bit is logic 0.

It is assumed that the PCF8811 has just been reset. After transmitting the last bit the PCF8811 can either exit or remain in the CALMM mode; see Table 39, Step 1. It should be noted that while in CALMM mode the interface does not recognize commands in the normal sense.

After this sequence has been applied it is possible to observe the impact of the data shifted in. The described sequence is, however, not useful for OTP programming because the number of bits with the value logic 1 is greater than that allowed for programming; see Section 18.1.7. The shift register after this action is shown in Figure 53.

Table 39. Sequence for filling the shift register; example 1[1]

Step	Pad			Command byte								Action
	EXT	D/$\overline{C}$	R/$\overline{W}$/$\overline{WR}$	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
1	X	0	0	1	1	1	0	0	0	0	1	exit power-down
2	-	-	-	-	-	-	-	-	-	-	-	wait 5 ms for refresh to take effect
3	X	0	0	1	0	0	0	0	0	1	0	enter CALMM mode
4	X	0	0	1	X	X	X	X	X	X	1	shift in data; MMVOPCAL[4] is first bit [2]
5	X	0	0	1	X	X	X	X	X	X	1	MMVOPCAL[3]
6	X	0	0	1	X	X	X	X	X	X	1	MMVOPCAL[2]
7	X	0	0	1	X	X	X	X	X	X	0	MMVOPCAL[1]
8	X	0	0	1	X	X	X	X	X	X	0	MMVOPCAL[0]
9	X	0	0	1	X	X	X	X	X	X	0	MMTC[2]
10	X	0	0	1	X	X	X	X	X	X	1	MMTC[1]
11	X	0	0	1	X	X	X	X	X	X	0	MMTC[0]
12	X	0	0	0	X	X	X	X	X	X	0	seal bit; exit CALMM mode
An alternative ending could be to stay in CALMM mode												
13	X	0	0	1	1	1	1	1	1	1	0	seal bit; remain in CALMM mode

[1] X = value without meaning.

[2] The data for the bits is not in the correct shift register position until all bits have been sent.

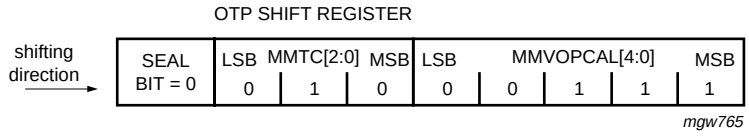


Fig 53. Shift register contents after example sequence; see Table 39

18.1.7 Programming flow

Programming is achieved whilst in CALMM mode and with the application of the programming voltages. As mentioned previously, the data for programming the OTP cell is contained in the corresponding shift register cell. The shift register cell must be loaded

with a logic 1 in order to program the corresponding OTP cell. If the shift register cell contains a logic 0, then no action will take place when the programming voltages are applied.

Once programmed, an OTP cell cannot be de-programmed. An already programmed cell, i.e. an OTP cell containing a logic 1, must not be re-programmed.

During programming, a substantial current flows in the V_{LCDIN} pad. For this reason it is recommended to program only one OTP cell at a time. This is achieved by filling all but one shift register cells with logic 0.

It should be noted that the programming specification refers to the voltages at the chip pads, contact resistance must therefore be considered by the user.

An example sequence of commands and data for OTP programming is given in Table 40. It is assumed that the PCF8811 has just been reset.

The order for programming cells is not significant. However, NXP Semiconductors recommends that the seal bit is programmed last. Once this bit has been programmed and the CALMM mode is exited, it is not possible to re-enter the CALMM mode.

Table 40. Sequence for filling the shift register; example 2[1]

Step	Pad			Command byte								Action
	EXT	D/$\overline{C}$	R/$\overline{W}$/$\overline{WR}$	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0	
1	X	0	0	1	1	1	0	0	0	0	1	exit power-save
2	-	-	-	-	-	-	-	-	-	-	-	wait 5 ms for refresh to take effect
3	X	0	0	1	0	1	0	1	0	0	1	re-enter power-down (DON = 0)
4	X	0	0	1	0	0	0	0	0	1	0	enter CALMM mode
5	X	0	0	1	0	X	X	X	X	X	1	shift in data; MMVOPCAL[4] is first bit
6	X	0	0	1	0	X	X	X	X	X	1	MMVOPCAL[3]
7	X	0	0	1	0	X	X	X	X	X	1	MMVOPCAL[2]
9	X	0	0	1	0	X	X	X	X	X	0	MMVOPCAL[1]
10	X	0	0	1	0	X	X	X	X	X	0	MMVOPCAL[0]
11	X	0	0	1	0	X	X	X	X	X	0	MMTC[2]
12	X	0	0	1	0	X	X	X	X	X	1	MMTC[1]
13	X	0	0	1	0	X	X	X	X	X	0	MMTC[0]
14	X	0	0	1	1	X	X	X	X	X	0	seal bit
15	-	-	-	-	-	-	-	-	-	-	-	apply programming voltage at pads $V_{OTPPROG}$ and V_{LCDIN}; see Section 18.1.8
Repeat steps 5 to 14 for each bit which must be programmed to 1; exit CALMM mode												
16	-	-	-	-	-	-	-	-	-	-	-	apply external reset

[1] X = value without meaning.

18.1.8 Programming specification

Table 41. Programming specification

See Figure 54.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$V_{OTPPROG}$	voltage applied to pad $V_{OTPPROG}$ relative to V_{SS1}	programming active	[1]	11	11.5	12	V
		programming inactive	[1]	V_{SS} – 0.2	0	V_{SS} + 0.2	V
V_{LCDIN}	voltage applied to pad V_{LCDIN} relative to V_{SS1}	programming active	[1][2]	9	9.5	10	V
		programming inactive	[1][2]	V_{DD2} – 0.2	V_{DD2}	4.5	V
I_{LCDIN}	current drawn by V_{LCDIN} during programming	when programming a single bit to logic 1		-	850	1000	mA
$I_{VOTPPROG}$	current drawn by $V_{OTPPROG}$ during programming			-	100	200	mA
$T_{amb(PROG)}$	ambient temperature during programming			0	25	40	°C
$t_{SU;SCLK}$	set-up time of internal data after last clock			1	-	-	µs
$t_{HD;SCLK}$	hold time of internal data before next clock			1	-	-	µs
$t_{SU;VOTPPROG}$	set-up time of $V_{OTPPROG}$ prior to programming			1	-	10	µs
$t_{HD;VOTPPROG}$	hold time of $V_{OTPPROG}$ after programming			1	-	10	ms
t_{PW}	pulse width of programming voltage			100	120	200	ms

[1] The voltage drop across the ITO track and zebra connector must be taken into account to guarantee a sufficiently high voltage at the chip pads.

[2] The Power-down mode (DON = 0 and DAL = 1) and CALMM mode must be active while the V_{LCDIN} pad is being driven.

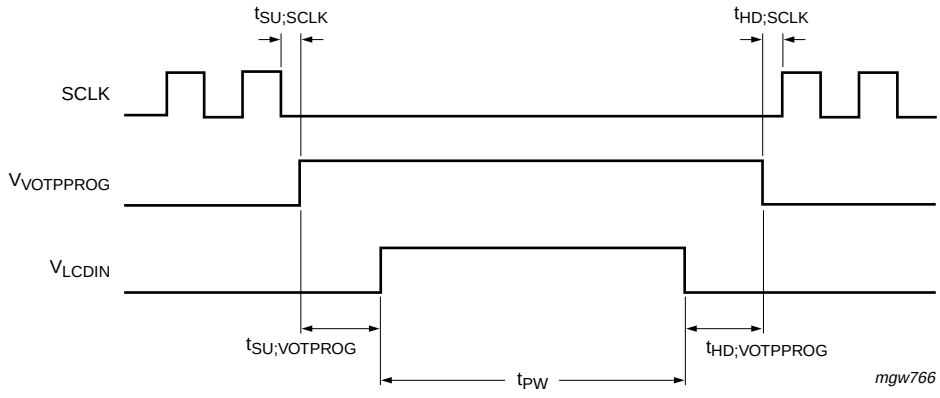


Fig 54. Programming waveforms

19. Package outline

Not applicable.

20. Handling information

Inputs and outputs are protected against electrostatic discharge in normal handling. However, to be completely safe you must take normal precautions appropriate to handling MOS devices; see *JESD625-A and/or IEC61340-5*.

21. Packing information

Table 42. Tray dimensions

See Figure 55.

Symbol	Description	Value
A	pocket pitch in x direction	13.77 mm
B	pocket pitch in y direction	4.45 mm
C	pocket width in x direction	12.55 mm
D	pocket width in y direction	2.41 mm
E	tray width in x direction	50.8 mm
F	tray width in y direction	50.8 mm
x	number of pockets, x direction	3
y	number of pockets, y direction	10

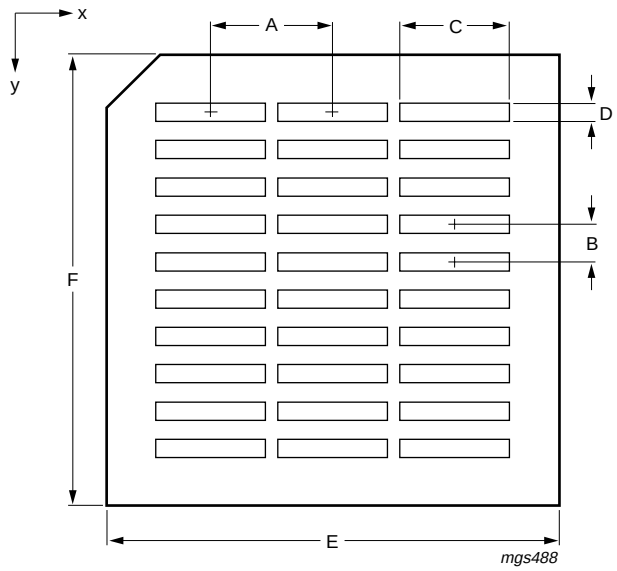


Fig 55. Tray details

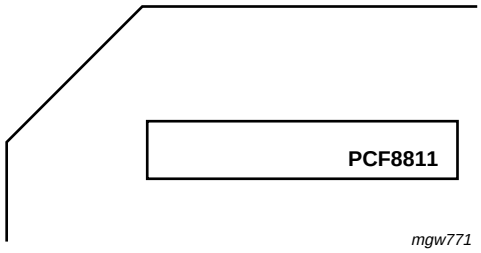


Fig 56. Tray alignment

The orientation of the IC in a pocket is indicated by the position of the IC type name on the die surface with respect to the chamfer on the upper left corner of the tray. Refer to the bonding pad location diagram (Figure 2) for the orientation and position of the type name on the die surface.

22. Abbreviations

Table 43. Abbreviations

Acronym	Description
CDM	Charged Device Model
CMOS	Complementary Metal Oxide Semiconductor
COG	Chip-On-Glass
DDRAM	Double Data Random Access Memory
ESD	ElectroStatic Discharge
HBM	Human Body Model
HV	High Voltage
IC	Integrated Circuit
ITO	Indium Tin Oxide
LCD	Liquid Crystal Display
LSB	Least Significant Bit
MM	Machine Model
MRA	Multiple Row Addressing
MSB	Most Significant Bit
MPU	MicroProcessing Unit
OTP	One Time Programmable
RAM	Read Access Memory
SPI	Serial Peripheral Interface
TC	Temperature Coefficient
TCP	Tape Carrier Packages

23. Revision history

Table 44. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
PCF8811_4	20080627	Product data sheet	-	PCF8811_3
Modifications:	• The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors. • Legal texts have been adapted to the new company name where appropriate. • Amendments to the text • Added ROM look-up Table 28 • Changed values in Table 30 and Table 31 • Changed Figure 2, Figure 4, Figure 48, Figure 49, and Figure 50 • Moved Figure 2 to Section 6 “Pinning information” • Moved Table 3 and Table 4 to Section 6 “Pinning information” • Added Fab 1 and Fab 2 details and adjusted die dimensions in Table 3			
PCF8811_3 (9397 750 13144)	20040517	Product specification	-	PCF8811_2
PCF8811_2 (9397 750 10285)	20021204	Product specification	-	PCF8811_1
PCF8811_1 (9397 750 09148)	20020814	Product specification	-	-

24. Legal information

24.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

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26. Contents

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