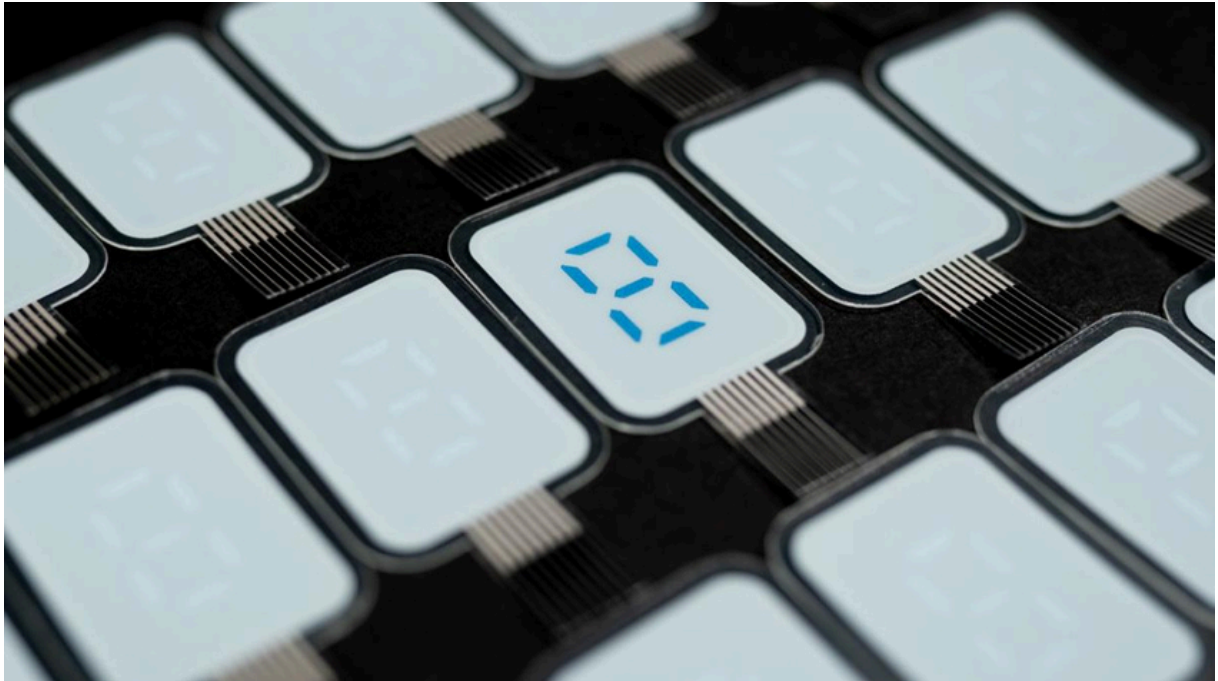




Printed E-Paper Display

Gen. 2
Datasheet



CONTACT US

+44 (0)1634 791600

info@crystal-display.com

Table of Contents

Version History	3
Notes	3
1. Introduction	4
2. Optical Characteristics	4
3. Mechanical Characteristics	4
4. Timing Characteristics	5
5. Electrical Characteristics	5
6. Power Consumption	5
7. Environmental	6
7.1 UV Exposure	6
8. Lifetime	6
9. Integration	6
9.1 Suitable Connectors.....	6
9.2 Anisotropic Conductive Film	6
9.3 Anisotropic Conductive Glue	6
10. Circuit Suggestions	7
10.1 – Circuit 1 (voltage regulator circuit)	7
10.2 – Circuit 2 (DAC output on common electrode)	7
10.3 – Circuit 3 (2-level variable counter electrode).....	8
10.4 – Circuit 4 (digital outputs)	8
11. Recommended Driving Scheme.....	9
11.1 Driving Scheme A (Compatible with circuits 1, 2 & 3)	9
11.2 Driving Scheme B (Compatible with circuits 1, 2, 3 & 4).....	10
11.3 Driving Scheme C (Compatible with circuits 1, 2 & 3 if $ V_{ON} + V_{OFF} = V_{supply}$)	10
11.4 Driving Scheme D (Compatible with circuit 4)	11
11.5 Driving Scheme E (Compatible with circuit 4)	11

Version History

Version	Date	Description	Changed by
1.0			
1.1	2022-02-28	First issue	Philip Holgersson
	2022-03-07	Added circuits	Philip Holgersson

Notes

Ynvisible's displays shall not be used for equipment that requires extremely high reliability, such as nuclear power control equipment, medical equipment for life support, military and space applications, or aerospace equipment.

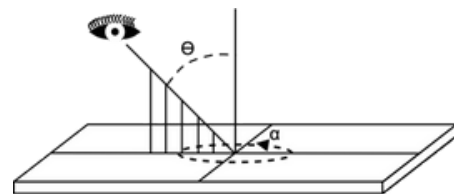
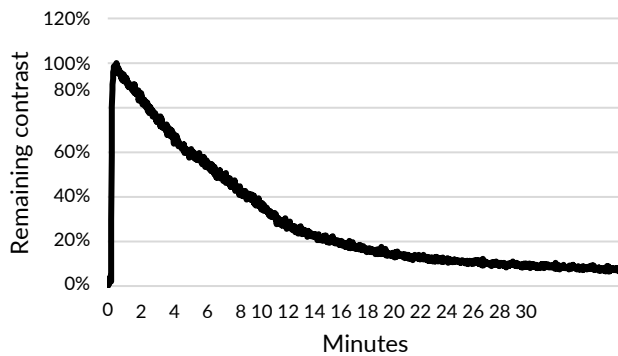
1. Introduction

This datasheet covers generalized information about e-paper display technology and is not specific to any display design or part number. Printed e-paper is an electrochromic reflective technology and has a very low angle dependency. It is ultra-low power and features semi- bistability, which means that the display mainly consumes power during display switches but requires a short refresh pulse approximately once every 2 minutes. The display can be connected to and driven by almost all MCUs. The features are summarized in the list below:

- A. Ultra-low-power
- B. Low operating voltage
- C. Reflective
- D. No viewing angle dependency
- E. Long refresh time
- F. Flexible
- G. Environmentally friendly

2. Optical Characteristics

Parameter	Test condition	Min	Typical	Max	Unit	Note
Reflectance	Bright state, 25°C	38%	40%	45%	Y-value	
Reflectance	Dark state, 25°C	8%	12%	14%	Y-value	
Viewing angle (θv)			89		°	
Refresh interval	25°C, (1) Time to 80% remaining contrast	n.a	2,5		Minutes	



3. Mechanical Characteristics

Parameter	Typical	Unit
Thickness	0,35	mm
Weight	0,04	g/cm ²
Bend radius	10	mm

4. Timing Characteristics

Parameter	Test Condition	Min	Typical	Max	Unit	Notes
ON	10 mm2 segment, 25°C, 30-50% RH		0,25		s	1,5V driving voltage
OFF	10 mm2 segment, 25°C, 30-50% RH		0,25		s	-1,5V driving voltage

5. Electrical Characteristics

Parameter	Test Condition	Min	Typical	Max	Unit	Notes
Energy consumption (switch)	10 mm2 segment, 25°C, 30-50% RH		1		mJ/cm2	1,5V driving voltage, From OFF to ON
Supply current (average)	10 mm2 segment, 25°C, 30-50% RH		1,1		μA/cm2	Steady state (ON)
Segment peak current	10 mm2 segment, 25°C, 30-50% RH		0,4		mA	1,5V driving voltage, From OFF to ON
Recommended ON voltage	10 mm2 segment, 25°C, 30-50% RH	1	1,5	1,65	V	
Recommended OFF voltage	10 mm2 segment, 25°C, 30-50% RH	0	-1,5	-1,65	V	

6. Power Consumption

Parameter	Test Condition	Typical	Unit	Notes
Average power consumption	25°C, 30-50% RH	1,67	μW/cm2	Steady state, all segments ON
Average power consumption	25°C, 30-50% RH	0	μW/cm2	Steady state, all segments OFF
Average power (10 switches)	25°C, 30-50% RH	1,78	μW/cm2	All segments changing state 10 times per day
Average power (100 switches)	25°C, 30-50% RH	2,82	μW/cm2	All segments changing state 100 times per day
Average power (1000 switches)	25°C, 30-50% RH	13,24	μW/cm2	All segments changing state 1000 times per day

7. Environmental

Parameter	Test Condition	Min	Max	Unit	Notes
Operating temperature	25°C, 30-50% RH	-20	60	°C	Internal test
Storage temperature	30-50% RH	-30	60	°C	Internal test

7.1 UV Exposure

The display intended for indoor applications; extended UV exposure may cause degradation. For outdoor applications a UV protection film testing is required.

8. Lifetime

Parameter	Test Condition	Min	Typical	Max	Unit	Method	Notes
Switch cycles	25°C, 30-50% RH	300 000	1 000 000	-	Switch cycles	Internal	ON/OFF cycles 1

9. Integration

9.1 Suitable Connectors

Name	Pitch	Type
FH12-XX-1SH	1000 µm	ZIF Connector
HFVXXR-1STE1H1LF	1000 µm	Non-ZIF Connector

XX should be replaced with a suitable pin number for the specific display.

9.2 Anisotropic Conductive Film

Product name	Comments
Dexerials CP883TX-25AJ	Epoxy based
Dexerials CP990 CM-25AC 3M 7303	Acrylate based
3M Electrically Conductive Adhesive Transfer Tape 9703	Can be applied by hand in room temperature conditions, mainly recommended for prototyping.

9.3 Anisotropic Conductive Glue

Product Name	Comments
Delo IC343	Isotropic conductive

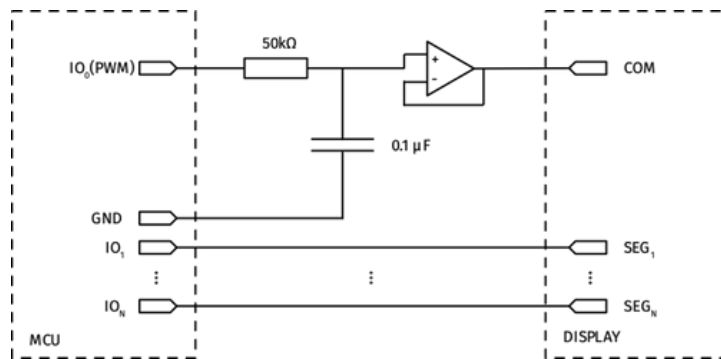
¹ The total number of times the display can be turned on and off without losing more than 20% of the initial contrast.

10. Circuit Suggestions

There are many ways to add the Ynvisible E-paper Display to a circuit. It typically requires zero or very few additional components. All suggestion are based around an MCU with IOs that can be set to High-Z mode (almost all MCUs have this feature).

10.1 – Circuit 1 (voltage regulator circuit)

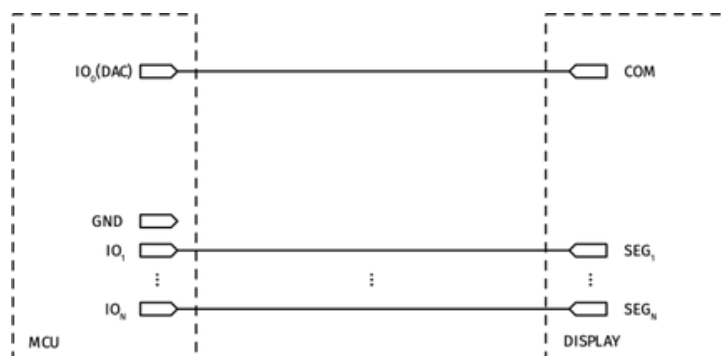
A low pass filter and an operational amplifier is used to create a variable virtual ground on the common electrode. By adjusting the frequency of the PWM signal the voltage can be adjusted to the desired driving voltage. In this way, the correct voltage can be applied to the segments, independent of the MCU operating voltage. The IOs require High-Z state to be able to maintain the image between the updates.



Component	Example	Value	Unit	Comment
Resistor		50	kΩ	Different resistor values may be used depending on PWM frequency and required response time.
Capacitor		0,1	μF	Different capacitors may be used depending on PWM frequency and required response time.
Operational amplifier	Texas Instruments TLV9001SIDBVR			Used to maintain a stable com potential at different loads.

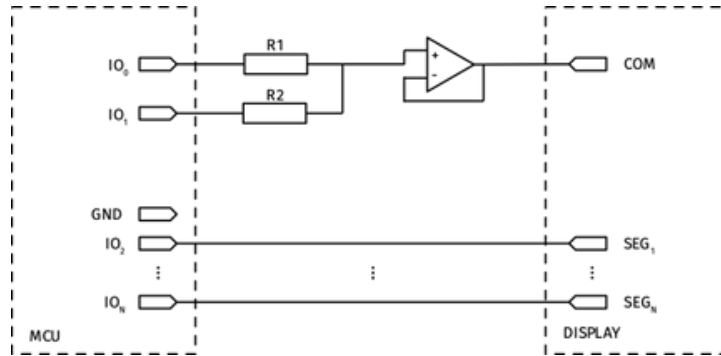
10.2 – Circuit 2 (DAC output on common electrode)

If the MCU has a built-in DAC, it can be used as a virtual ground for the common electrode. The DAC replaces the external components in circuit 1. The IOs require High-Z state to be able to maintain the image between the updates.



10.3 – Circuit 3 (2-level variable counter electrode)

A voltage divider is created with R1 and R2. By setting IO0 to HIGH and IO1 to LOW a first voltage level is achieved on the common electrode. By setting IO0 to LOW and IO1 to HIGH a second voltage level is achieved. The IOs require High-Z state to be able to maintain the image between the updates.

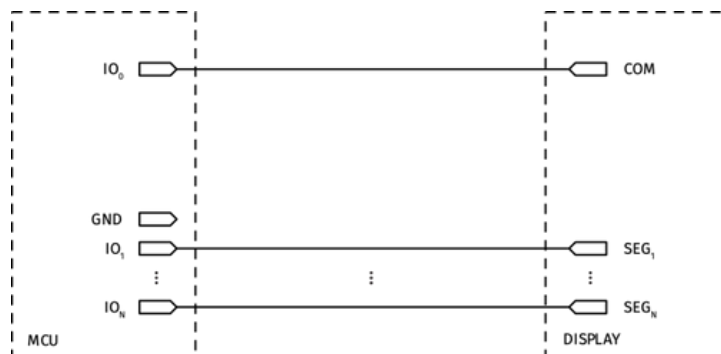


Resistor suggestions for different supply voltage to achieve $\pm 1,5V$ driving on different voltage levels:

Supply voltage	R1	R2	Comment
1.8 V	30 k Ω	6 k Ω	The resistors should be selected to create a voltage divider with an offset voltage of 1,5. Other resistor pairs are possible. However, smaller resistance value leads to more leakage.
3 V	30 k Ω	30 k Ω	
3.3 V	30 k Ω	36 k Ω	
5 V	30 k Ω	70 k Ω	

10.4 – Circuit 4 (digital outputs)

This approach does not require any external components. The voltage will be limited to the supply voltage of the MCU in use. The ideal driving voltage for the display is $\pm 1,5V$, however operating voltages of 1,8 V and higher can be considered if the lifetime requirements are limited. Adding a resistor in between IO0 and COM can also be considered to increase lifetime.

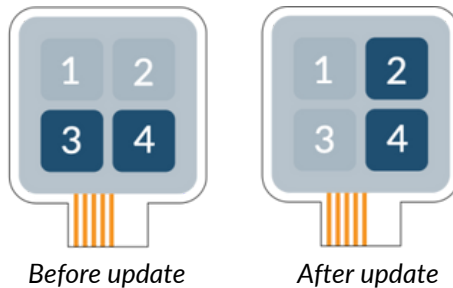


11. Recommended Driving Scheme

Fundamentally the displays are very straightforward to drive. A positive voltage (in reference to the counter electrode) turns ON the display segment, while a negative voltage (or shortening the work and counter electrode) turns OFF the segment. A higher voltage level enables a faster switching speed, while a lower voltage enables a longer lifetime. Typically, a good tradeoff between lifetime and switch speed is to use $\pm 1,5V$ across the segment. However, the displays achieve full contrast down to 1V. If switching speed is not an issue, it is recommended to keep the voltage to a minimum. Higher voltage is optional for devices with shorter lifetime requirements. Turn OFF voltage should typically be kept the same as turn ON voltage (but with the opposite polarity) but if a longer switching time is acceptable, it is possible to shorten ($\approx 0V$) the counter electrode and the work electrode to turn the segment OFF (Driving scheme E). Below follows a few different driving schemes suggestions.

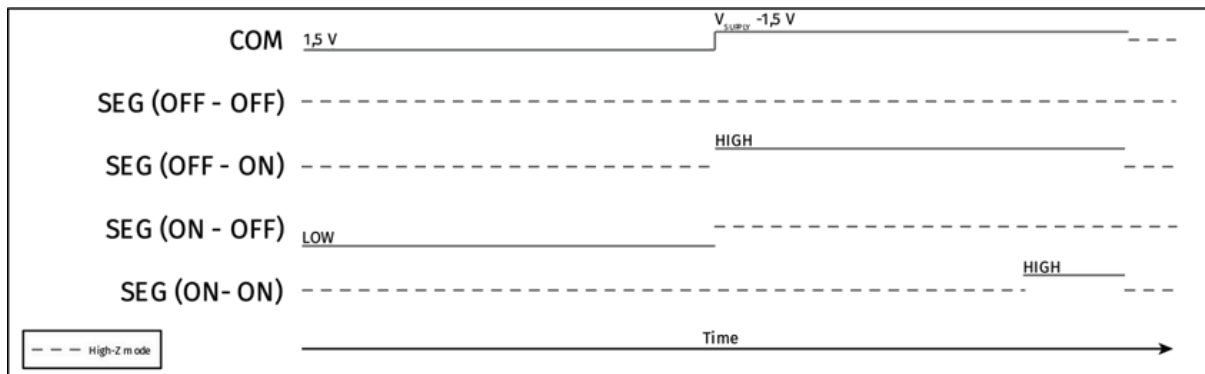
Definition of the conventions used in the following driving schemes:

Convention	Segment nr. in figure	Definition
COM	-	Common electrode
SEG (OFF - OFF)	1	Segments that should be kept in OFF state
SEG (OFF - ON)	2	Segments that should turn ON
SEG (ON - OFF)	3	Segments that should turn OFF
SEG (ON - ON)	4	Segment that should be kept in ON state



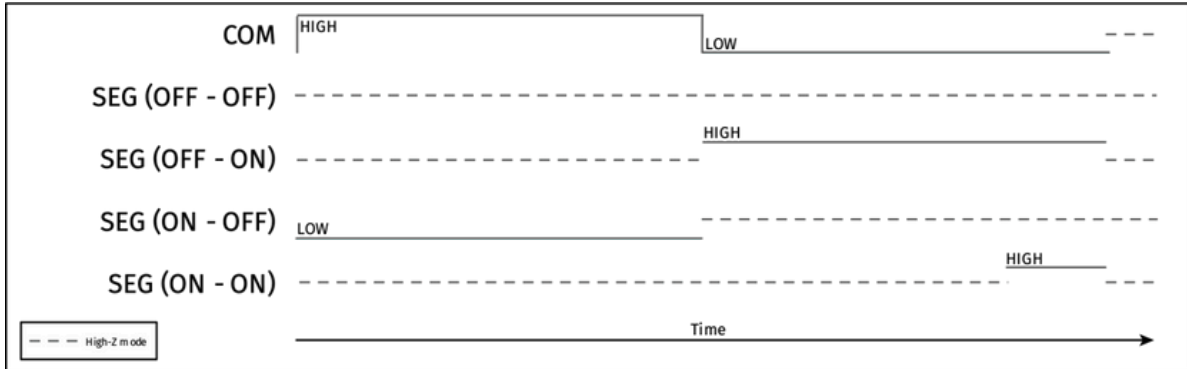
11.1 Driving Scheme A (Compatible with circuits 1, 2 & 3)

This driving scheme updates the display in two steps. First, some segments are turned off by setting the counter electrode to 1,5V and the relevant segment electrodes to LOW/0V (resulting in -1,5V across the segments). Secondly, some segments are turned off by setting the common voltage to $V_{SUPPLY}-1,5$ and the relevant segment electrodes to LOW/ V_{SUPPLY} (resulting in +1,5V across the segments). A shorter refresh pulse is required on the segments that should be kept in ON state. The sequence ends with setting all signals to High-Z to maintain the state.



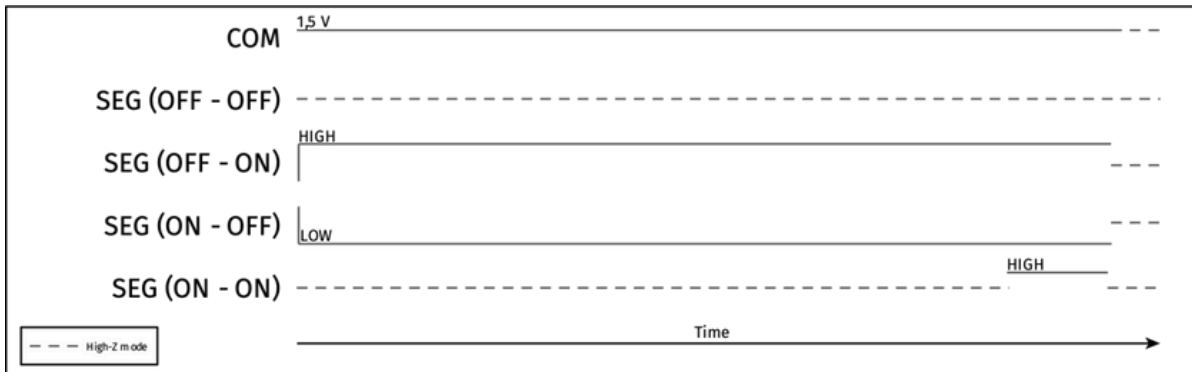
11.2 Driving Scheme B (Compatible with circuits 1, 2, 3 & 4)

This driving scheme updates the display in two steps like driving scheme A, but without a variable counter electrode voltage. First, some segments are turned off by setting the counter electrode to HIGH and the relevant segment electrodes to LOW/0V (resulting in -VSUPPLY across the segments). Secondly, some segments are turned off by setting the common voltage to LOW and the relevant segment electrodes to HIGH (resulting in +VSUPPLY across the segments). A shorter refresh pulse is required on the segments that should be kept in ON state. The sequence ends with setting all signals to High-Z to maintain the state. If the system operates at a low voltage or if the lifetime requirements are limited this could be a good option.



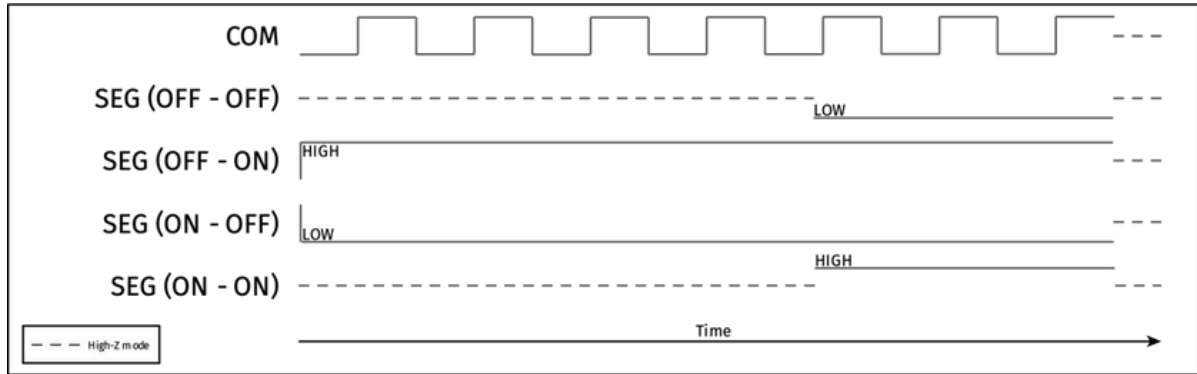
11.3 Driving Scheme C (Compatible with circuits 1, 2 & 3 if $|V_{ON}| + |V_{OFF}| = V_{supply}$)

This driving scheme updates the display in one single step. The segments are turned ON and OFF at the same time. This is enabled by setting the counter electrode to a voltage in between LOW and HIGH, typically $\pm 1.5V$ for a 3V system, but could also be for example $\pm 1V$ for a 2V system. In this way a positive and a negative voltage can be applied on the respective segment simultaneously. A shorter refresh pulse is required on the segments that should be kept in ON state. The sequence ends with setting all signals to High-Z to maintain the state.



11.4 Driving Scheme D (Compatible with circuit 4)

This driving scheme updates the display in one single step like driving scheme C. This is enabled by applying a PWM signal to the counter electrode to simulate a virtual ground in between the LOW and HIGH. On many MCUs this driving approach causes significant leakage leading to significantly higher energy consumption compared to driving scheme C. The sequence end with setting all signals to High-Z to maintain the state.



11.5 Driving Scheme E (Compatible with circuit 4)

This driving scheme updates the display in one single step like driving scheme C, but with the difference that the turn off voltage is 0V. Turning off the segments with 0V is significantly slower compared with applying a negative voltage (for example -1,5V). For this reason, it takes longer time for the segment that should be turned OFF to switch compared with the segments that should be turned ON. A shorter refresh pulse is required on the segments that should be kept in ON state. The sequence end with setting all signals to High-Z to maintain the state. With this driving method it is an option to connect the common electrode direction to ground.

