AN11566

Driving an LED backlight, a buzzer, implementing a charge pump and a low-power system by the PCF8551 and PCF8553

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Document information

Info	Content
Keywords	PCF8551, PCF8553, buzzer, charge pump, power-on reset, driving LED backlight
Abstract	The PCF8551 and PCF8553 devices are capable of driving a backlight LED and/or an electroacoustic converter like a buzzer or speaker circuit. Additionally a simple charge pump for low supply voltage operation is sketched out. The application note lists some variants of implementing these features.

Revision history

Rev	Date	Description
v1	20140627	initial version

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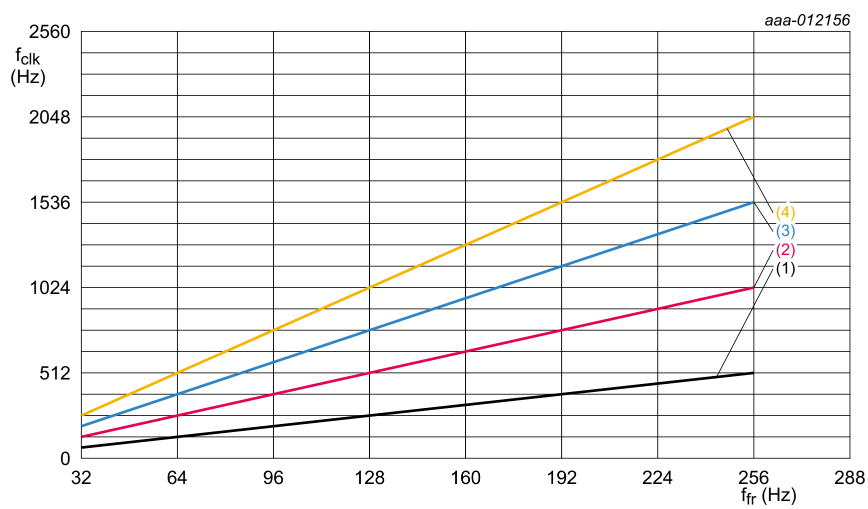
1. Introduction

The PCF8551 and PCF8553 devices are capable of driving a backlight LED (see Section 3) and/or an electroacoustic converter like a buzzer or speaker circuit as described in Section 2. The application note lists some variants of implementing these features. Additionally a simple charge pump for low supply voltage operation is sketched out in Section 4. A hint on a reset circuitry is provided in Section 5 .

2. Buzzer

The internally generated clock signal can be fed to pin CLK, which is then used as a digital output driver. As the clock frequencies are all within the audible range of 64 Hz to 2048 Hz and the output driver is able to deliver a reasonable amount of power, the clock signal can be directly fed to an electroacoustic transducer. Attenuation of the signal, if necessary, is easily achieved by adding a series resistor or capacitor. Output frequencies are controlled according to the combination of frame frequency and multiplex rate as shown in Figure 1. They are not independent of the requirements posed by the display, which should be given preference. For details, see the individual data sheets of PCF8551 and PCF8553 respectively.



(1) n_{MUX} = 1.

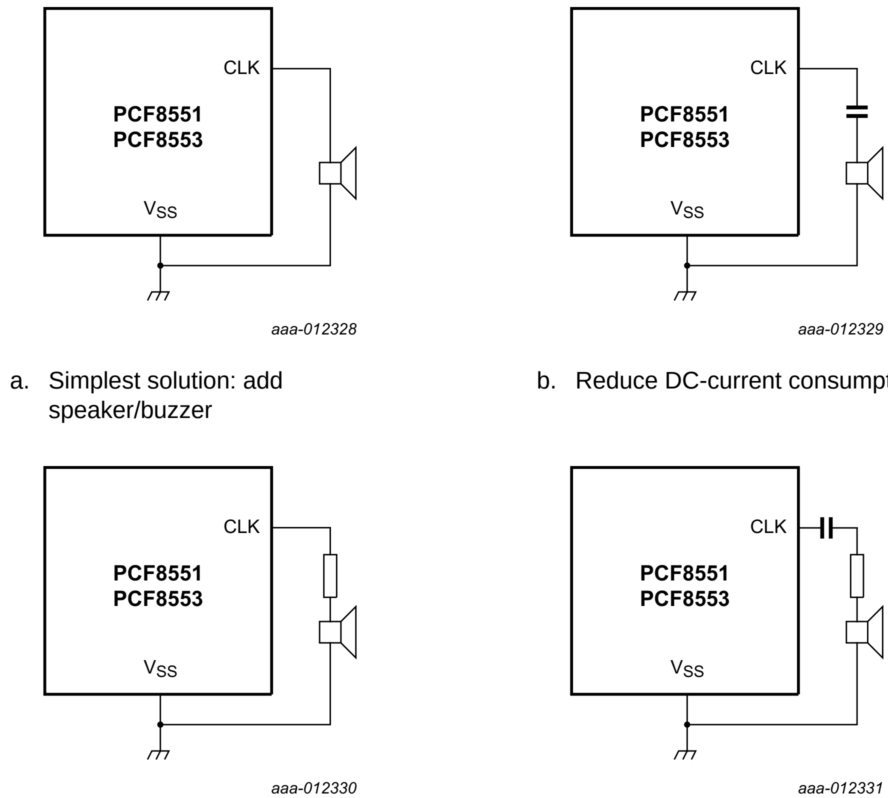
(2) n_{MUX} = 2.

(3) n_{MUX} = 3.

(4) n_{MUX} = 4.

Fig 1. Relation of frame frequency (f_{fr}), clock frequency (f_{clk}) and multiplex-rate (n_{MUX})

The clock frequency is set by writing to registers 01h and 02h. To feed the clock-frequency to the output, the COE bit must be set to logic 1.



a. Simplest solution: add speaker/buzzer

b. Reduce DC-current consumption

c. Add attenuation, if necessary

d. DC-free attenuated signal

Fig 2. Speaker/buzzer set-up

Experiments with an 8 Ω speaker showed reasonable performance. It is also possible to drive a capacitive buzzer.

3. Backlight control

3.1 Basic solution

Figure 3 shows a simple backlight control limited to only turning the light on or off. The CLK output is able to drive one white LED without issues.

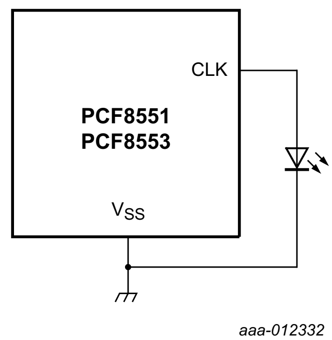


Fig 3. Basic backlight set-up

3.2 Solution with brightness control

In Figure 4 an N-channel MOS transistor T1 is used to drive a white LED. Its gate is controlled by a segment output to adjust brightness. Figure 9 shows the associated waveforms for SEGn.

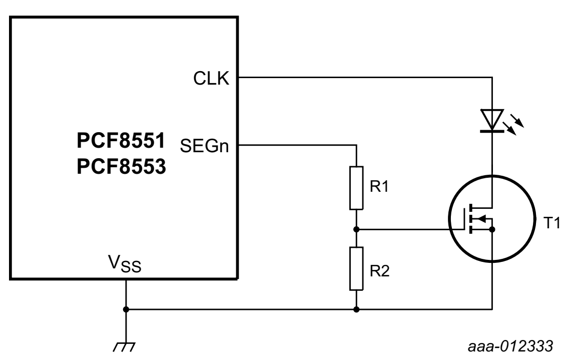


Fig 4. Set-up with brightness control

In this example, the backlight is turned on by enabling the CLK output. By adapting the switching level V_{SW} to the threshold V_{th} of T1, appropriate brightness control can be achieved. Resistor values must be in the several MΩ ranges to limit current loading. V_{OD} is the overdrive voltage at the gate for the transistor to deliver the appropriate amount of drain current.

$$V_{SW} = \frac{R1 + R2}{R2} \times (V_{th} + V_{OD}) \quad (1)$$

In the example of Section 3.4 a multiplexing of 1:4 is used with the switching level V_{SW} placed close to V_{LCD}. If more than one LED is supposed to be driven, they must be connected to V_{LCD}. T1 must be able to cope with the associated load current.

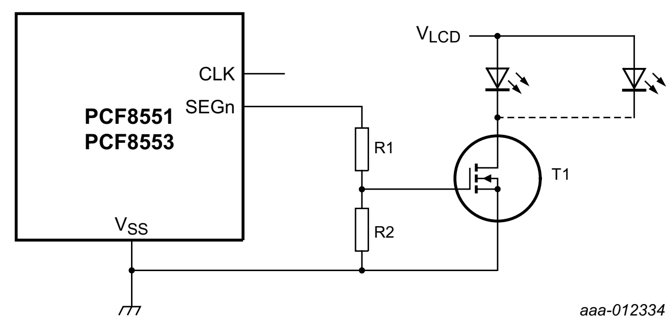


Fig 5. Driving more than one LED

Potentially a temperature compensation needs to be implemented, because V_{th} decreases with temperature, a fact, which might be canceled by adding a diode within the voltage divider. On the other hand, the current drive capability of T1 decreases with temperature. The voltage divider must be adapted appropriately.

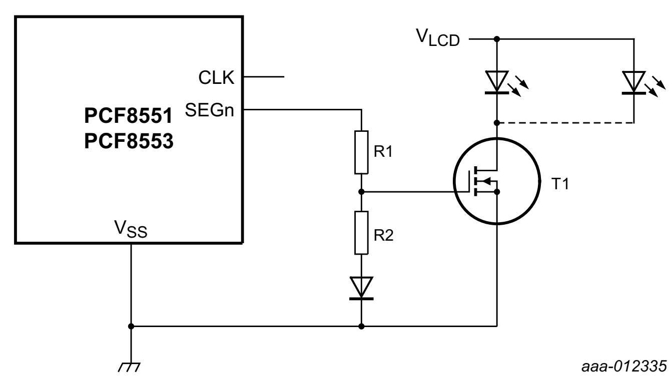


Fig 6. Potential temperature compensation

3.3 Multi-color with brightness control

For backlights, providing individual control of separate LEDs for red, green, and blue, the amount of individual color can be controlled by separate segment outputs, in case they are not required for the normal display function.

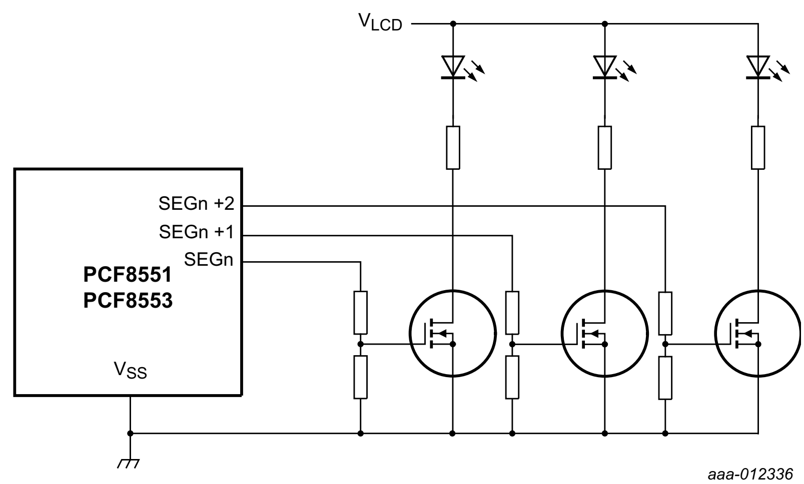


Fig 7. Set-up with multi-color brightness control

3.4 Case of application

In a case of application, it was possible to drive a DE LP-301-RGB backlight by DISPLAY Elektronik GmbH. This comprises of 3 LEDs, a red, a green, and a blue one, which combined, result in white backlight, but they can also be driven individually to change colors.

3.4.1 Schematic and elements

A BS170 N-channel MOSFET was used to drive the backlight. The gate was controlled by segment 0, which was also fed to the display for verification. In practice, an unused segment should be used for this purpose. V_{LCD} was set to 5 V to match the display as well as the backlight requirements. Due to its lower threshold voltage, the red LED needs a series resistor to match the brightness levels and adjust color temperature.

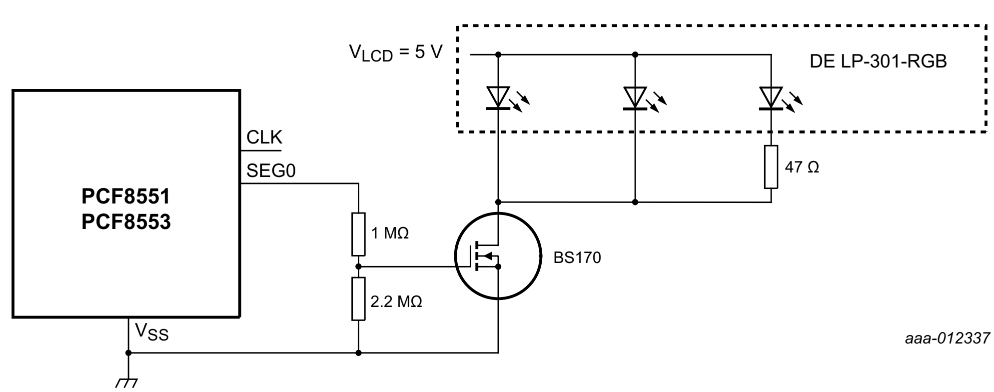
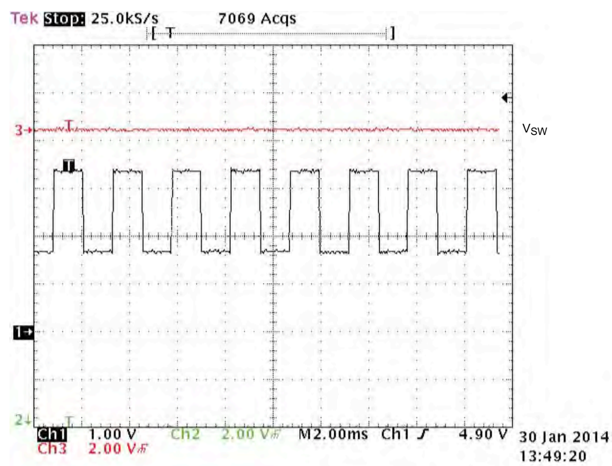


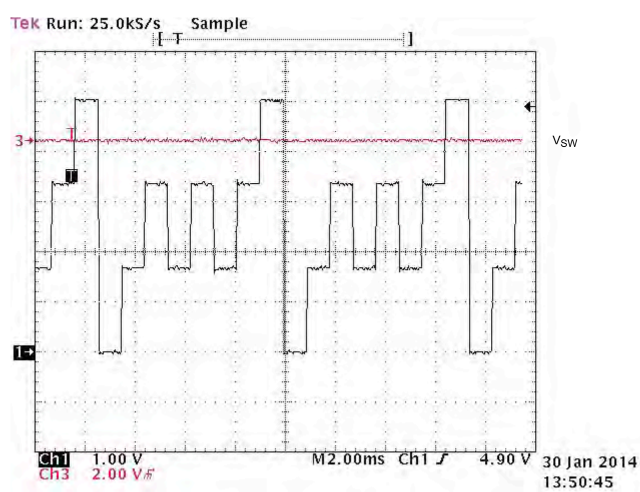
Fig 8. Schematic of the use case

The threshold voltages for green and blue are specified to be 3.1 V, while it is 1.9 V for the red light. Typical current consumptions are 15 mA, 15 mA, and 10 mA respectively; so a total amount of 40 mA must be provided. Due to the duty cycle of the segment signal, this requires a peak current of ~80 mA for the BS170.

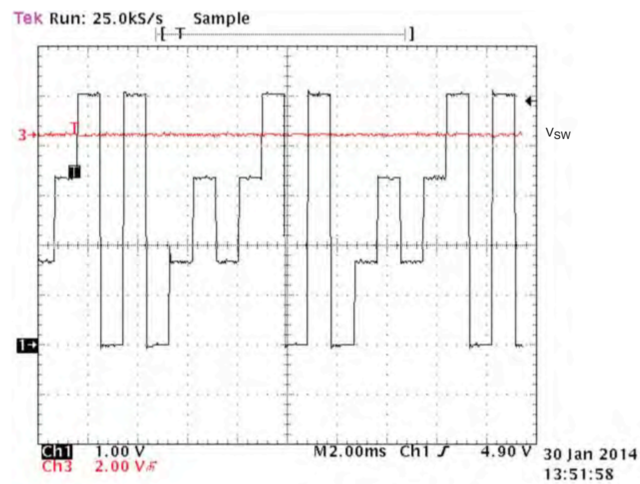
Figure 9 depicts the waveforms at the segment output, while Figure 10 shows the performance when running through the individual brightness control steps.



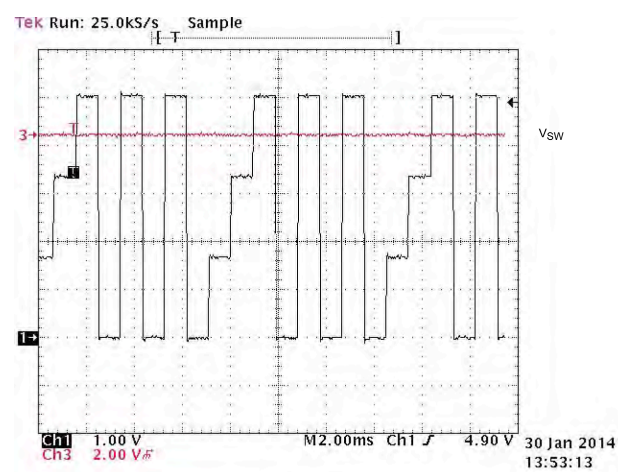
a. SEGn output: all pulses below switching level V_{SW} (maximum dimming)



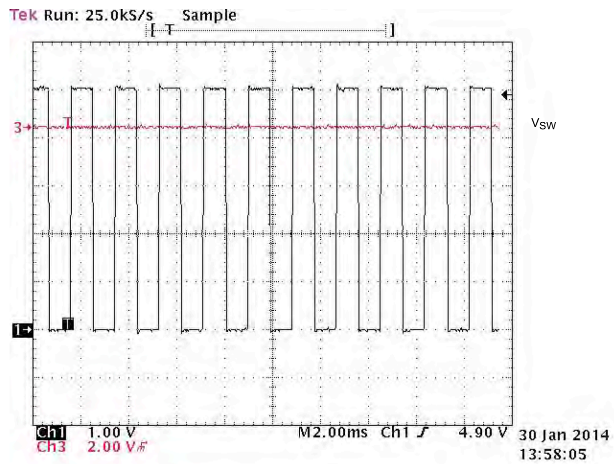
b. SEGn output: one pulse above switching level V_{SW}



c. SEGn output: two pulses above switching level V_{SW}



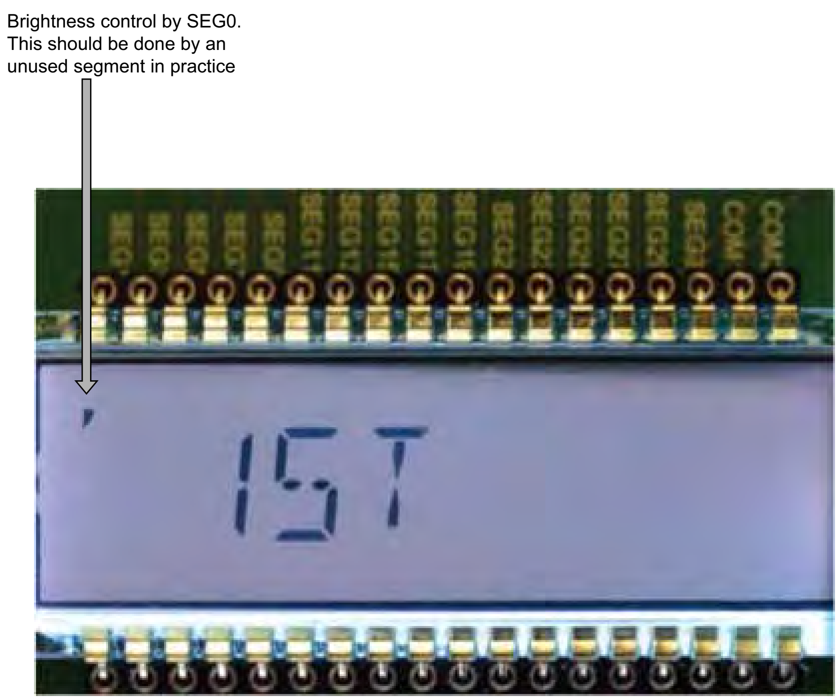
d. SEGn output: three pulses above switching level V_{SW}



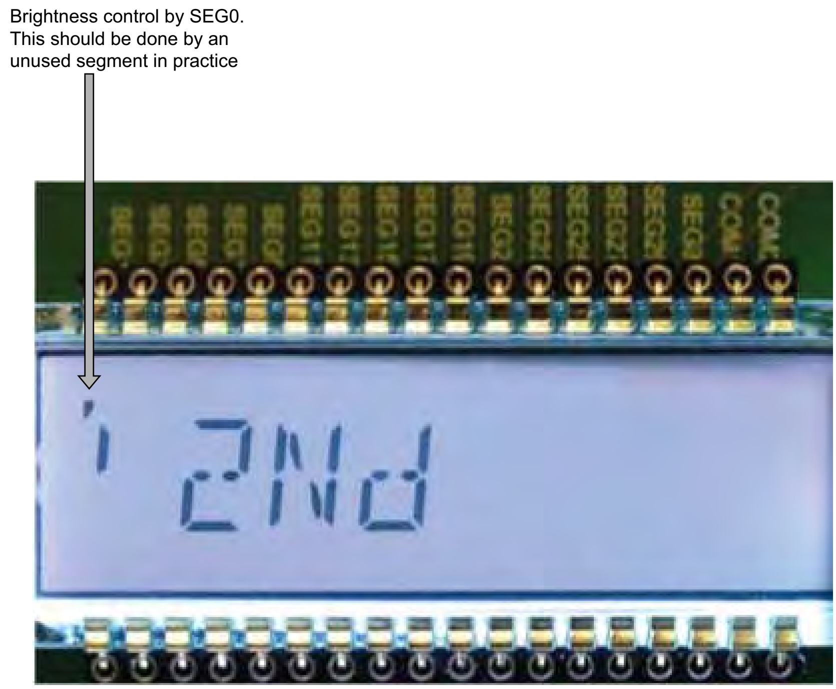
e. SEGn output: four pulses above switching level V_{SW} (maximum brightness)

Fig 9. Waveforms of SEGn output controlling N-channel gate

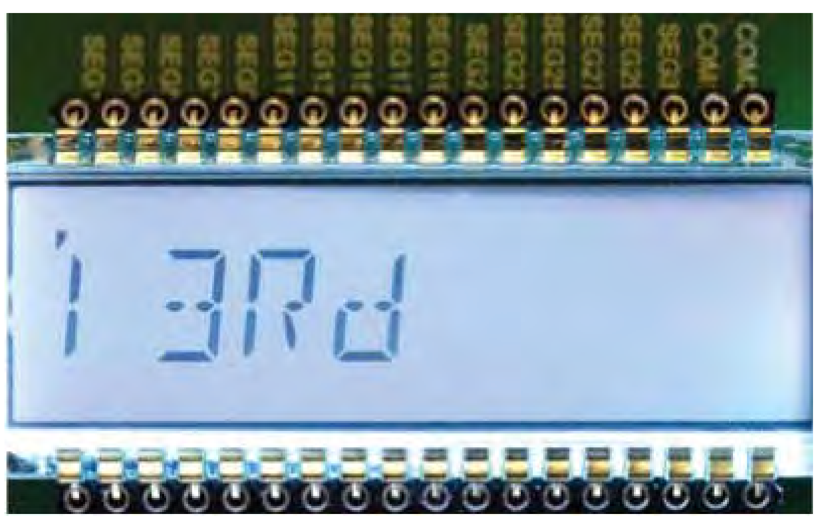
a. Maximum dimming



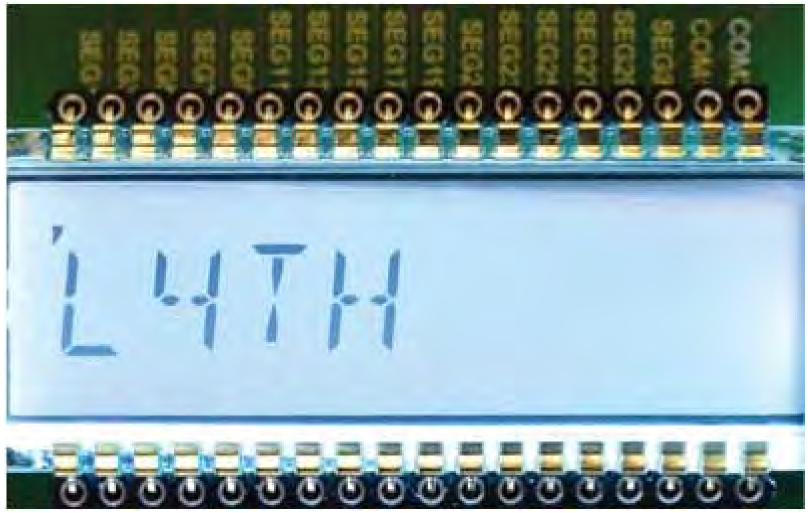
b. First step of brightness control



c. Second step of brightness control



d. Third step of brightness control



e. Fourth step of brightness control

Fig 10. Brightness control steps

4. Charge pump

If only a low supply voltage is available but the display needs a higher value, a simple charge pump can be implemented by using the CLK output.

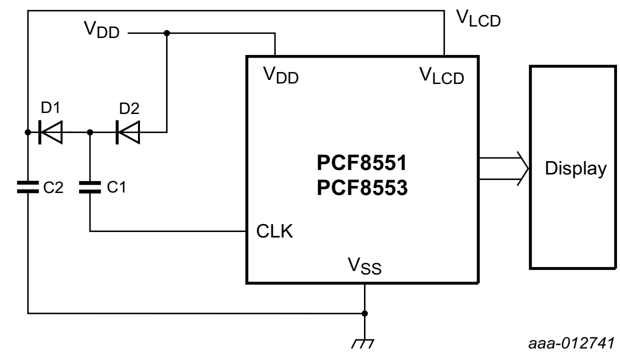
4.1 Basic set-up

Figure 11 depicts the basic set-up. If diodes D1 and D2 have a threshold voltage of V_{th}, the generated V_{LCD} calculates to

$$V_{LCD} = 2 \times (V_{DD} - V_{th}) - V_{DO} \quad (2)$$

with V_{DO} as the drop-out voltage across the equivalent resistor formed by the charge pump. This seems to be sufficient to drive a 5 V display from a Lithium battery.

While silicon diodes exhibit a threshold of ~0.6 V, the drop across D1/D2 can be reduced by using Schottky diodes with a threshold of ~0.3 V.

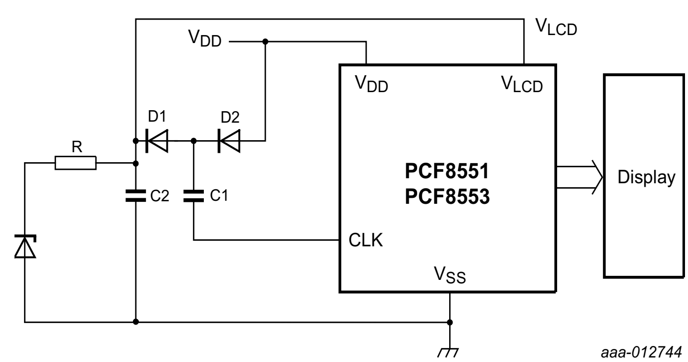


C1 > 20 nF; C2 > 200 nF; select highest clock frequency.

Fig 11. Basic charge pump to generate V_{LCD} from V_{DD}

4.2 Simple voltage regulation

In principle, the charge pump is unregulated, but to prevent overvoltage a certain amount of control may be required. One possibility could be using an LDO for this task. But the requirements on the LDO are probably difficult to fulfill with a standard catalog element. So the simpler variant with a Zener diode will probably be a more reasonable solution (see Figure 12).



R is used to reduce power consumption.

Fig 12. Voltage regulation with Zener diode

4.3 Voltage ripple

Voltage ripple is determined by f_{CLK}, I_{load} and can be controlled with the size of C2.

$$V_{ripple} = \frac{I_{load}}{f_{CLK} \times C2} \qquad (3)$$

5. Power-on reset

Chip variants, which comprise an $\overline{RST}$ pin can be reset at power-on by adding a capacitor on this pin. The value of this capacitor depends on the rising slope of V_{DD}.

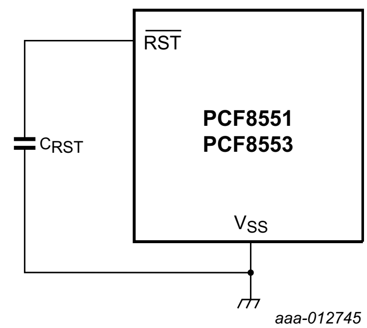


Fig 13. Power-on reset using a capacitor on pin $\overline{RST}$

5.1 Power-on with a slowly starting power supply

The built-in POR block acts on the rising edge of the V_{DD} supply voltage. It is designed to react to fast slopes. If the system supply starts slowly, it is recommended to initiate a software reset immediately after power-on.

6. References

[1] **PCF8551 —** Data sheet

[2] **PCF8553 —** Data sheet

[3] **DE-301-RGB/A —** Display Elektronik GmbH, 24-January-2011

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8. Figures

9. Contents

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