Application Note

Mobile Backlight Selection Guide

For ams Lightning Management Units and Backlight Drivers

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1 General Description

This guide enables the determination which LED driver product, LED configuration, and external component selection will give the best output in terms of efficiency and solution size for mobile lightning applications.

2 Driving LEDs for Mobile Backlight Applications

Depending on the application or display size, the amount of LEDs is different. For smartphone and feature phones the LED requirements are quite similar. LEDs are used in the current range of 2~30mA. The bigger the display gets the more LEDs are needed, also the more pixels the display contains for higher resolution the more LEDs are required to brighten up the display. Typically all LEDs inside the display are driven with the same amount of current.

Figure 1: Market Research of several on the market available phones: display size vs. LED count

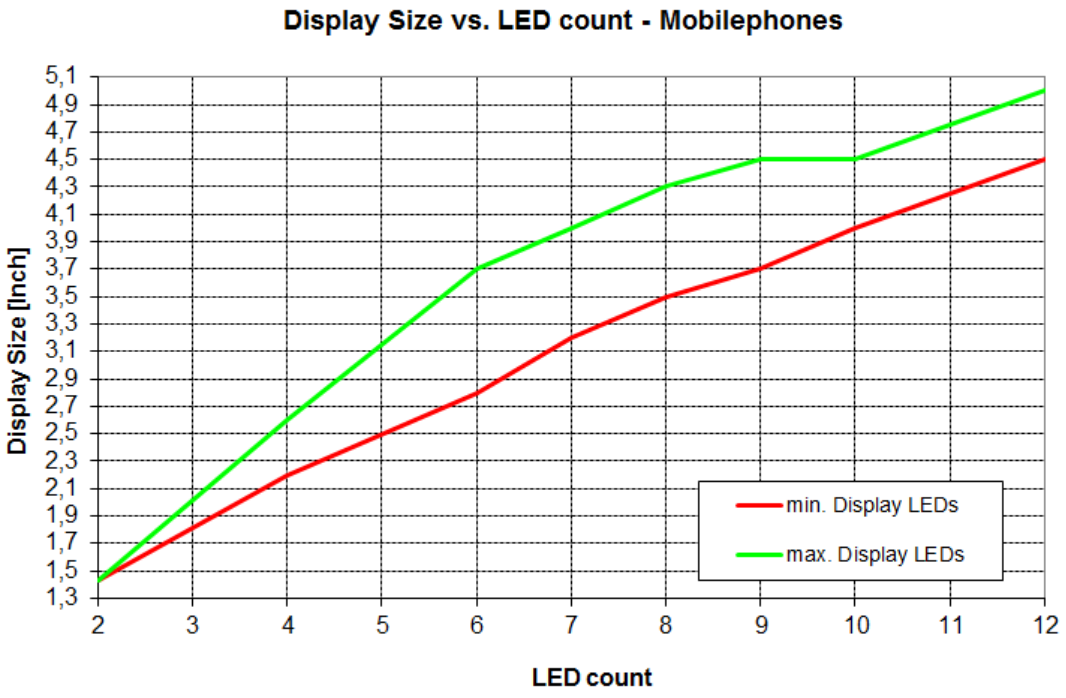
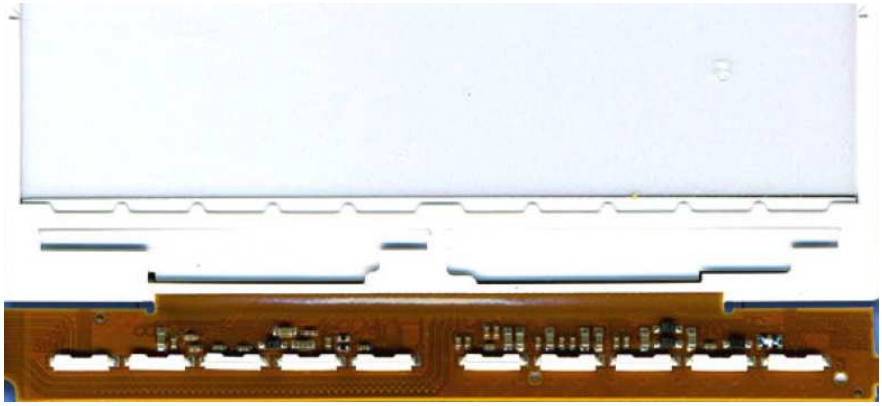


Figure 2: Example of a 4.3” smartphone display with 10 LEDs



3 LED Configuration Nomenclature

The ams display nomenclature can be used for any kind of display or non-display LED configurations. The nomenclature explains the relation of serial LEDs in a string to the amount of parallel strings.

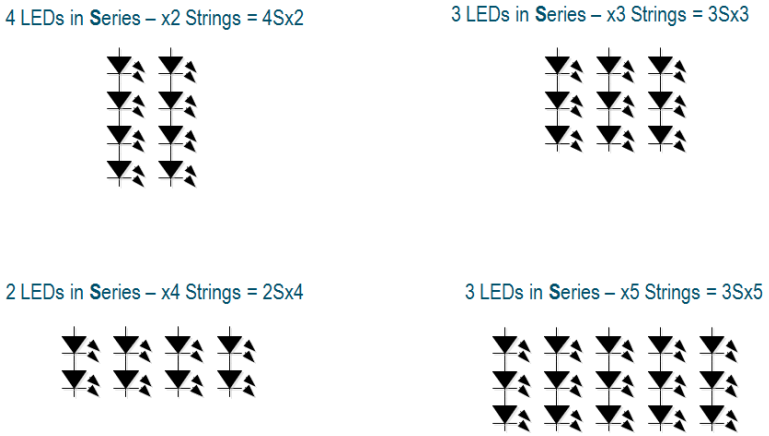
First number is the amount of LEDs in series.

Second number is the amount of LED strings in parallel

For example:

6Sx2 = 6 LEDs in one string with 2 parallel strings

Figure 3: ams Display Nomenclature Examples



4 Product Overview

Figure 4: Product Overview

Part Number		AS3490	AS3492	AS3675	AS3676	AS3677	AS3687 XM	AS3688	AS3689
Keypad	Lighting	✓	✓	✓	✓	✓	✓	✓	✓
	Inductive DCDC	✓	✓	✓	✓	✓	✓	✓	✓
	Chargepump			400mA	400mA	50mA	150mA	400mA	400mA
Display	# Current Sinks	3	5	13	13	6	6	12	15
	ALS				✓	✓			
	DLS	✓	✓		✓	✓ (2x)			
Camera	Flash			✓	✓			✓	✓
	Flash Current			150mA	150mA			900mA	150mA
	Flash Timeout			✓	✓			✓	✓
	Indicator LED			✓	✓			✓	✓
	Supply LDOs			1	1			2	1
Features	LED Test	✓	✓	✓	✓	✓	✓	✓	✓
	LED Dimming	✓	✓	✓	✓	✓	✓	✓	✓
	RGB Pattern			✓	✓	✓	✓	✓	✓
	Audio Sync			✓	✓		✓		

Package	Type	WLP12	WLP12	WLP30	WLP30	WLP25	WLP20	QFN32	WLP36
	Size in mm	1.8x1.4	1.8x1.4	3x2.5	3x2.5	2.2x2.2	2x2.5	5x5	3x3
	Pitch in mm	0.4	0.4	0.5	0.5	0.4	0.5		0.5

5 Choosing the LED Configuration

The LED configuration should be considered after the number of LEDs given by the application, i.e. by the display and notification lights. As an adder to this, it is necessary to take external factors into account. A few of these are highlighted below:

- LED forward voltage
- LED max. forward voltage
- DCDC maximum ratings and limitations
- External component limits
- Required display runtime / efficiency

NOTE: The LED configuration could also be already fixed by the display module suppliers, which then makes the LED configuration easy. It is recommended for display applications to use the inductive DCDC boost converter due to a broader efficiency range.

Although for small size applications or applications which have parallel LED configurations it is also possible to use the capacitive boost converter.

LED configurations which need individual control like RGB LEDs or indicator LEDs should be connected to the capacitive charge-pump converter. It is not recommended to combine a larger number of serial connected LEDs with an shorter LED string in terms of forward voltage, due to the energy waste.

6 LED Configurations for Chargepump

Figure 5: LED Configurations for Chargepump

Configuration	Product
1Sx4	AS3687XM, AS3676, AS3668
1Sx5	AS3676
1Sx6	AS3676
1Sx7 or higher	AS3676

Figure 6: Example for small solution size with the AS3687xm chargepump for display backlight and a RGB notification LED

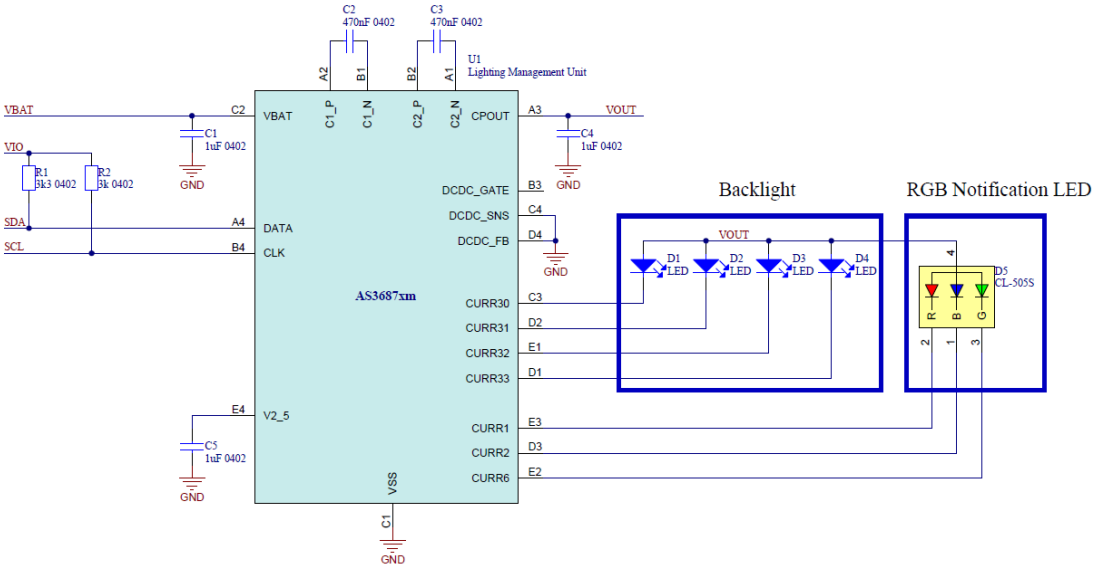


Figure 7: PCB placement example using the AS3687xm with its chargepump for 4 LED backlight in 1Sx4 configuration with a RGB notification LED

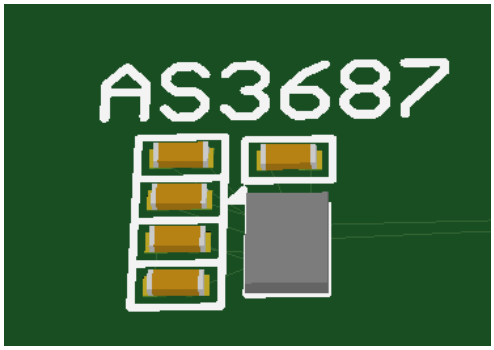
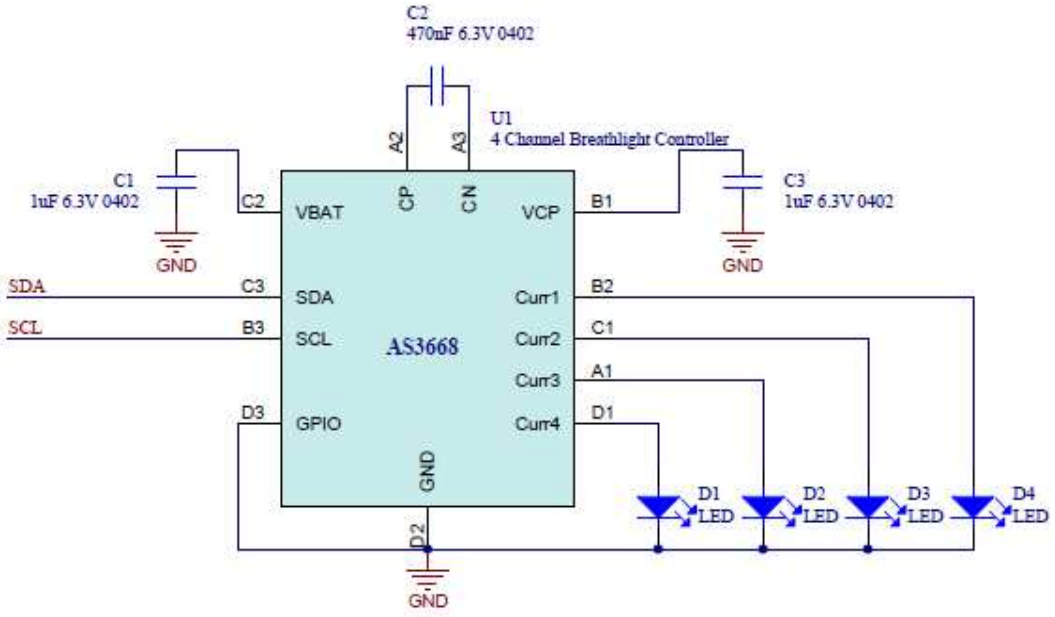


Figure 8: Example for the AS3668 as backlight driver for 4 LEDs backlight in a 1Sx4 configuration



7 LED Configurations for DCDC

Figure 9: LED Configurations for DCDC

LED	Configuration	Product	Recommended (*2)
4 LEDs			
	4Sx1	AS3687xm/AS3677/AS3676	AS3677
	2Sx2	AS3490/ AS3687xm	AS3490
5 LEDs			
	5Sx1	AS3677/AS3676	AS3677
6 LEDs			
	3Sx2	AS3687xm, AS3676, AS3677	AS3677
	6Sx1	AS3687xm(*1), AS3676, AS3677	AS3677
	2Sx3	AS3490, AS3687xm, AS3676,AS3677	AS3490
7 LEDs			
	7Sx1	AS3676	AS3676
8 LEDs			

	8Sx1	AS3676(*1)	AS3676
	4Sx2	AS3676, AS3677, AS3687	AS3677
	2Sx4	AS3492	AS3492
9 LEDs			
	9Sx1	AS3676(*1)	AS3676
	3Sx3	AS3676, AS3677	AS3677
10 LEDs			
	10Sx1	AS3676(*1)	AS3676
	5Sx2	AS3676, AS3677	AS3677
	2Sx5	AS3492	AS3492
12 LEDs			
	12Sx1	AS3676(*1)	AS3676
	6Sx2	AS3676, AS3677	AS3676
	4Sx3	AS3676, AS3677	AS3677
15 LEDs			
	5Sx3	AS3676, AS3677(*5)	AS3676
	3Sx5	AS3676(*3), AS3677(*6)	AS3676
18 LEDs			
	6Sx3	AS3676, AS3677(*5)	AS3676
	3Sx6	AS3676(*3)	AS3676
20 LEDs			
	4Sx5	AS3676(*3)	AS3676
More LEDs	Up to 7Sx6	AS3676(*4)	AS3676

Notes:

*1 = external cascode transistor may be needed / depending on Vf of the LED string

*2 = recommendation criteria: optimized for size and efficiency.

*3 = possible if the display module has connected top anodes and bottom cathodes together

*4 = maximum current = 114mA

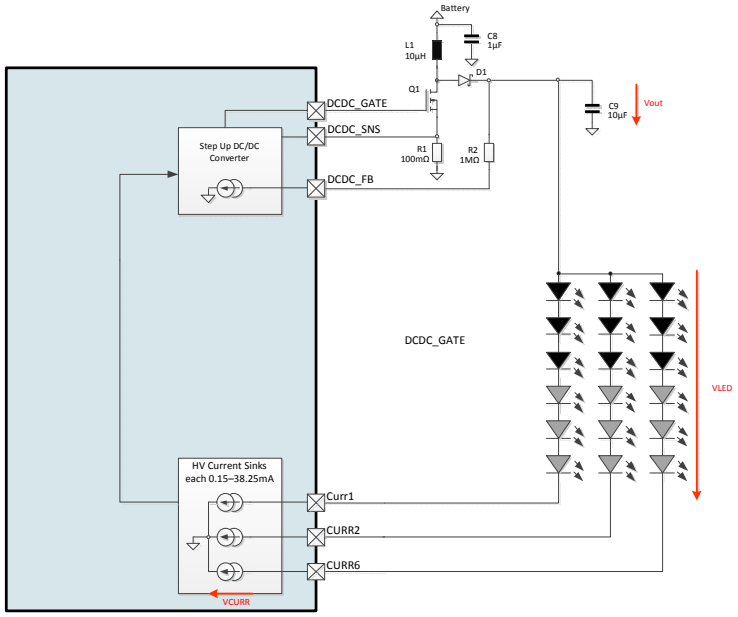
*5 = depending on Vf and VBatmin

Green Box = best efficiency

7.1 DCDC Regulation

7.1.1 AS3687xm/75/76 DCDC

Figure 10: AS3687xm/75/76 DCDC

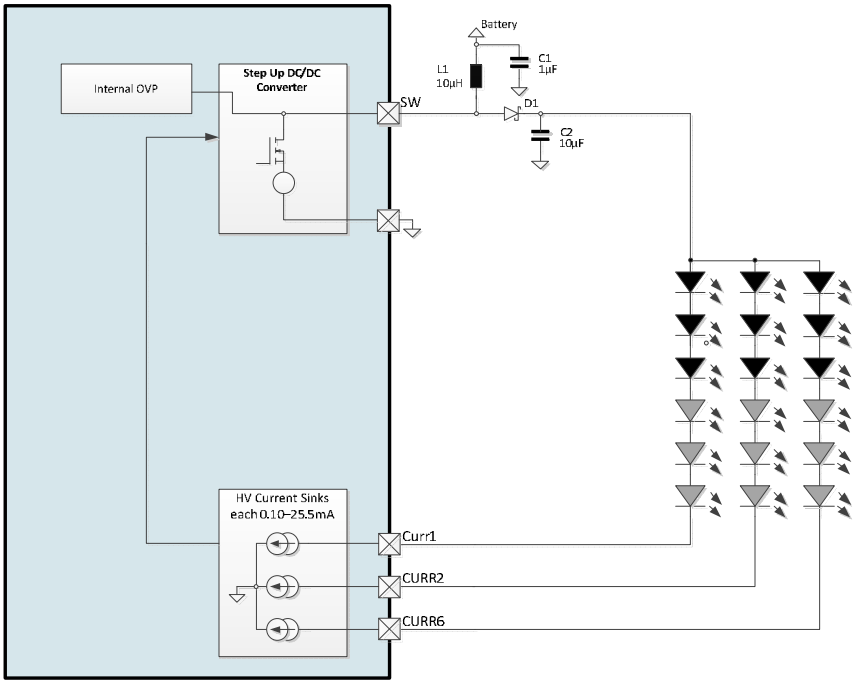


This DCDC boost has basically no limitation in output voltage. The maximum output voltage is defined by the limits of the external NMOS, the maximum output voltage of the output capacitor and the diode. The high voltage current-sinks of the AS3687xm/75 are capable of allowing up to 15V. The high voltage current sinks of the AS3676 are able to allow up to 25V. If the voltage limits of the high voltage current-sinks are exceeded, an external cascode transistor has to be used. Otherwise an irreversible damage could happen to the IC. Please refer to selection for “Single string solution’s with higher forward voltages” for detailed explanation.

The driving current of this DCDC is limited by the saturation current of the inductor, resistance of inductor / transistors, current limit of the sense resistor and the current driving ability of the high voltage current-sinks. High-voltage DCDC regulated strings need to be connected to the HV current sinks CURR1,CURR2, and CURR6.

7.1.2 AS3677 DCDC

Figure 11: AS3677 DCDC



The AS3677 has an integrated NMOS, with internal programmable overvoltage protection and additionally internal overcurrent limitation. The voltage limit can be set to max. 25V. The maximum NMOS current is 1200mA (typ), for worst case calculation the minimum value has to be chosen. The maximum output current for 25V close applications is 50mA. High-voltage DCDC regulated strings need to be connected to the HV current sinks CURR1, CURR 2, and CURR 6.

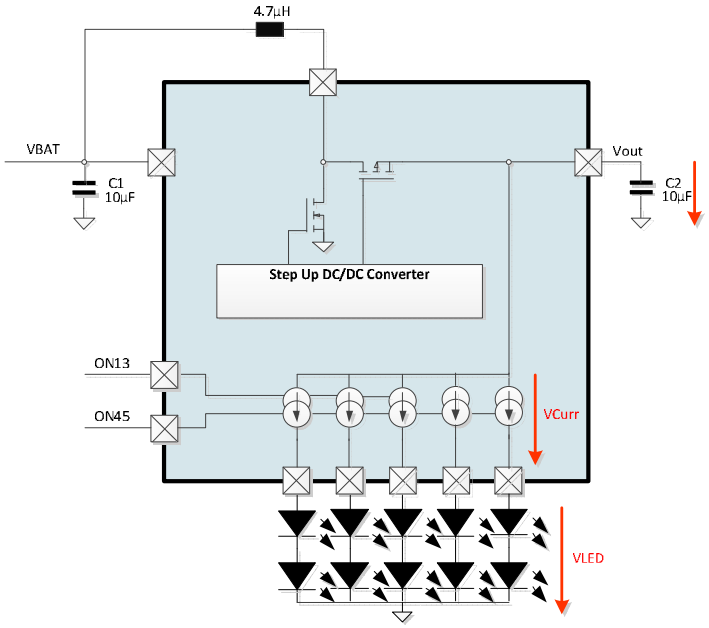
The AS3687xm/75/76/77 DCDC Regulates with the principle of :

Vout = VLED + Vcurr

for AS3687xm/75/76/77 Vcurr is regulated to 500mV

7.1.3 AS3490/AS3492 DCDC

Figure 12: AS3490/AS3492 DCDC



The AS3490/AS3492 has an Integrated NMOS and PMOS, also unlike the other backlight drivers this device has high side current sources. High sided current sources offer the advantage that the return line of LED current can be used as GND line. This offers additional PCB routing benefits. The voltage limit of the DCDC is 9.3V (typ). This allows the use of 2 LEDs in series configurations, from 2Sx2 to 2Sx5.

The output voltage of the AS3490/ AS3492 is regulated under the condition:

VOUT = VLED + VCURR

for the AS3490/ AS3492 VCURR can be assumed with 100mV

7.1.4 High Voltage Current Sink Overview

Figure 13: High Voltage Current Sink Overview

	High Voltage current sinks	Max. voltage for HV-current sinks	Current of HV current sinks	Compliance voltage
AS3687xm	3x	15V	38.25mA	500mV
AS3675	3x	15V	38.25mA	500mV
AS3676	3x	25V	38.25mA	500mV
AS3677	3x	25V	25.5mA	500mV
AS3490	3x	10V	25.5mA	100mV
AS3492	5x	10V	25.5mA	100mV

7.2 General DCDC Application Component Selection

The performance of the application depends on:

- **Inductor**
  - too small inductors or wrong selected inductors do not improve the efficiency
  - for most applications Wire-wound inductors show better performance than multi layer inductors
    - multilayer type inductors have the disadvantage that with higher output voltage the parasitic capacitance and core losses are more dominant compared to wire-wound inductors
  - higher Inductances help to increase for light load conditions (12~15~18uH)
  - much too big inductors in terms of size do not improve the efficiency
- **LED Configuration**
  - multiple strings reduce the parasitic capacitance at the switching node and core losses
- **Switching Transistor**
  - low gate charge helps to increase the efficiency in light load conditions
  - integrated diode in the transistor module is beneficial for size & efficiency
- **Driver IC**
  - low quicence current at DCDC & currentsink increase the application efficiency
- **Schottky Diode**
  - too small discrete diodes are decreasing efficiency

- too big diode capacity also decreases the DCDC efficiency

7.3 Single String Solutions

Single string configurations are the most used solution for displays. Single String solutions are possible with the AS3687xm/75/76/77.

Figure 14: Design Example with the AS3677 for a 6Sx1 LED configuration

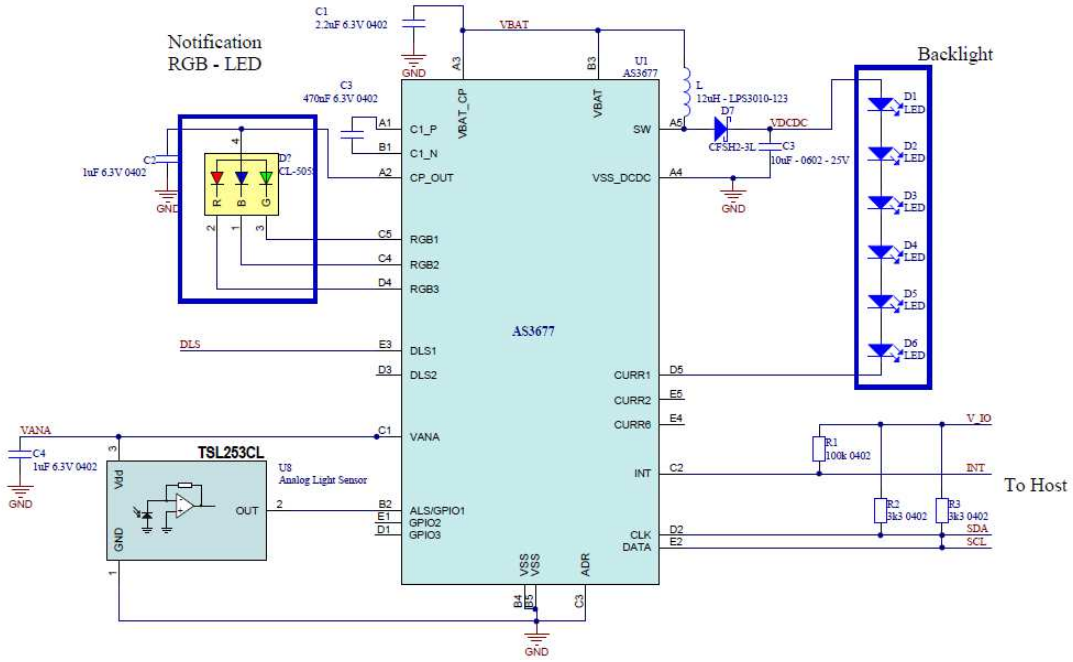
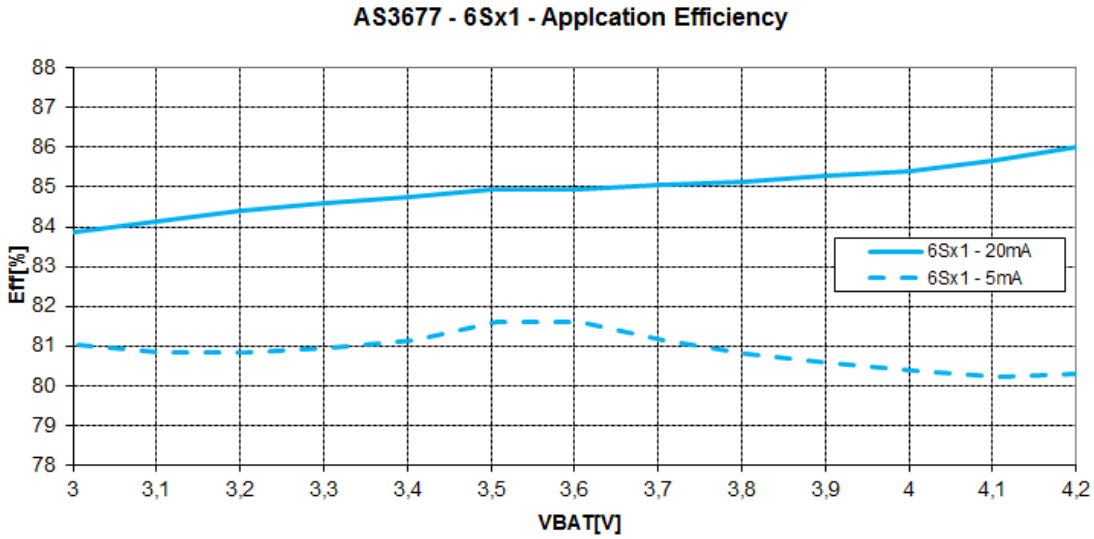


Figure 15: AS3677 6Sx1 Application Efficiency



If the DCDC voltage is higher than the maximum voltage of the current-sinks it is mandatory to use a cascode transistor. Please refer to the chapter “Single string solutions with higher forward voltages” for detailed explanation.

Figure 16: AS3676 DCDC Efficiency vs VOUT

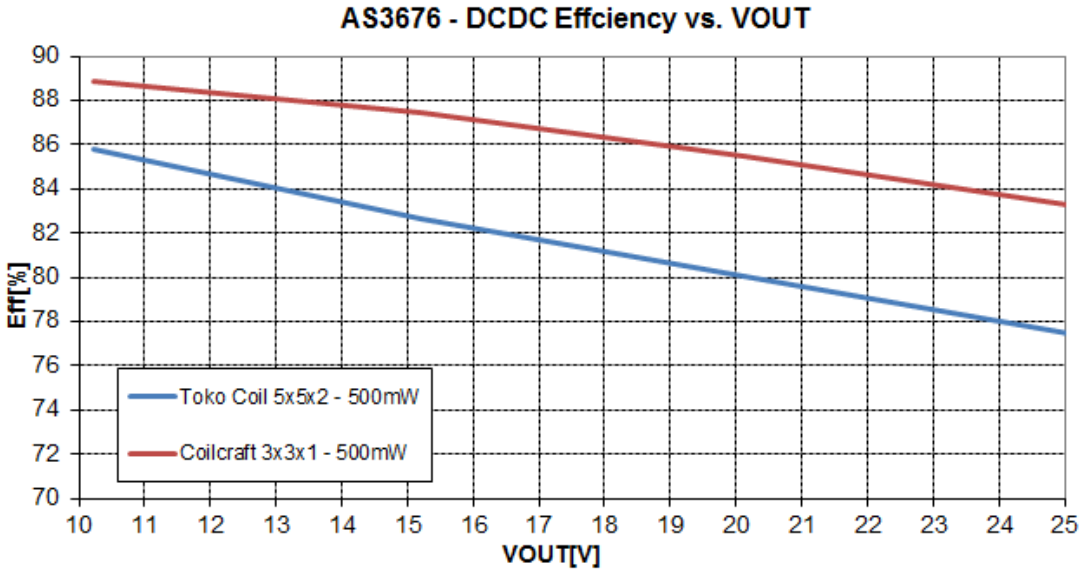
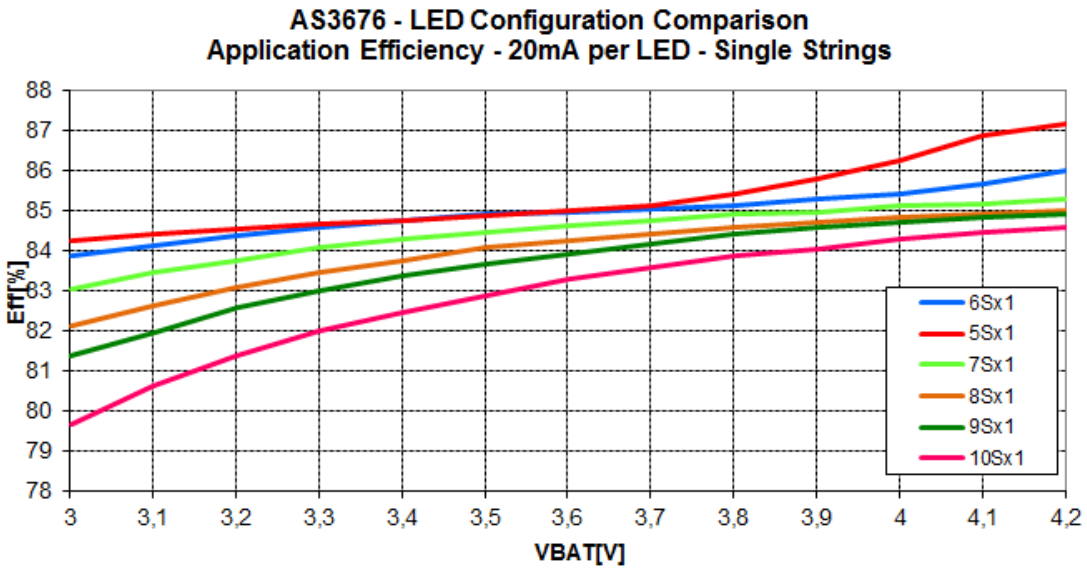


Figure 17: AS3676 DCDC Efficiency vs VOUT Measurement Setup

IC	AS3676
Load	0.5W constant power load / VOUT Sweep
Transistor	FDFMA3N109
Diode	FDFMA3N109
Inductor	different
Shunt	0R1
Frequency	1MHz
Used LED	Resistors used

Due to the parasitic capacitance at the switching node and core losses the efficiency of the DCDC converter reduces the higher the output voltage becomes. This graph has been measured with the AS3676 and a constant power of 0.5W to the LEDs, which comes close to the power requirements of a 4” Display.

Figure 18: AS3676 LED Configuration Comparison



This graph shows the AS3676 with different single string LED configurations: 5Sx1, 6Sx1, 7Sx1,8Sx1, 9Sx1, 10Sx1.

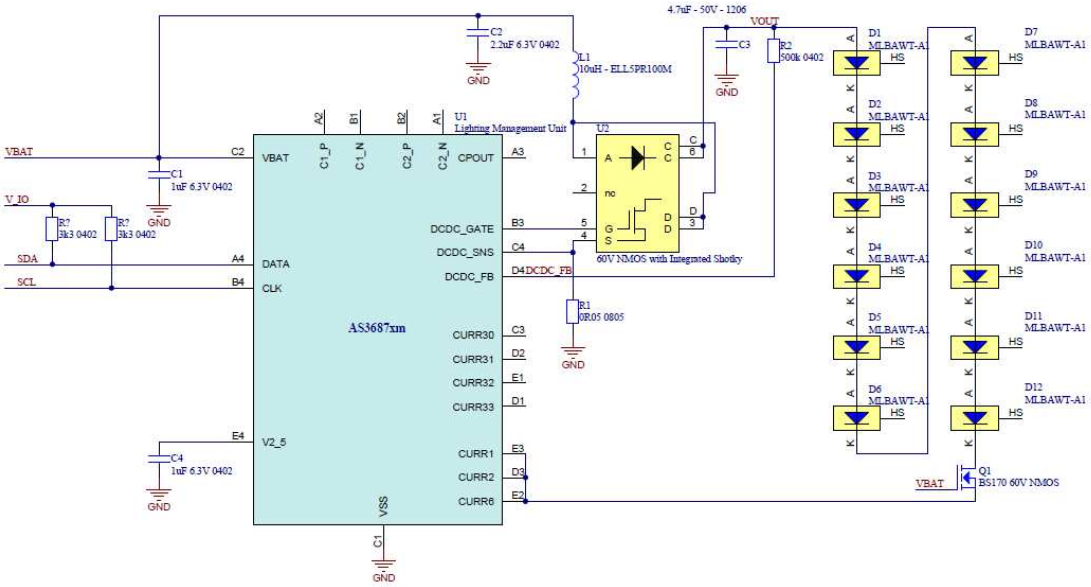
Figure 19: AS3676 LED Configuration Comparison Measurement Setup

IC	AS3676		
Voltage	Sweep		
Load	20mA	per LED	
Transistor	FDFME3N311ZT		Fairchild
Diode	FDFME3N311ZT		Fairchild
Inductor	LPS3010-123		Coilcraft
Frequency	1MHz		
Shunt	0R1		
Config	different		
Used LED	CL-120A		Citizen

7.3.1 Single String Solutions with higher Forward Voltages

For driving a Display with single string solutions with higher forward voltage, it needs to be considered that the current-sinks can only drive a certain amount of voltage. For the AS3687 the maximum voltage for the high voltage current-sinks is limited to 15V. The AS3676 maximum voltage limit for the high voltage current-sinks is 25V. If voltages are required which go above the maximum voltage limits of the high voltage current-sinks a cascode transistor can be used to protect the current-sink.

Figure 20: AS3687 with external cascode transistor, 12 LEDs in series, DCDC output Voltage = 39,6V, LED Current = 100mA



The external cascode transistor has to have a maximum drain source voltage which is higher than the application voltage.

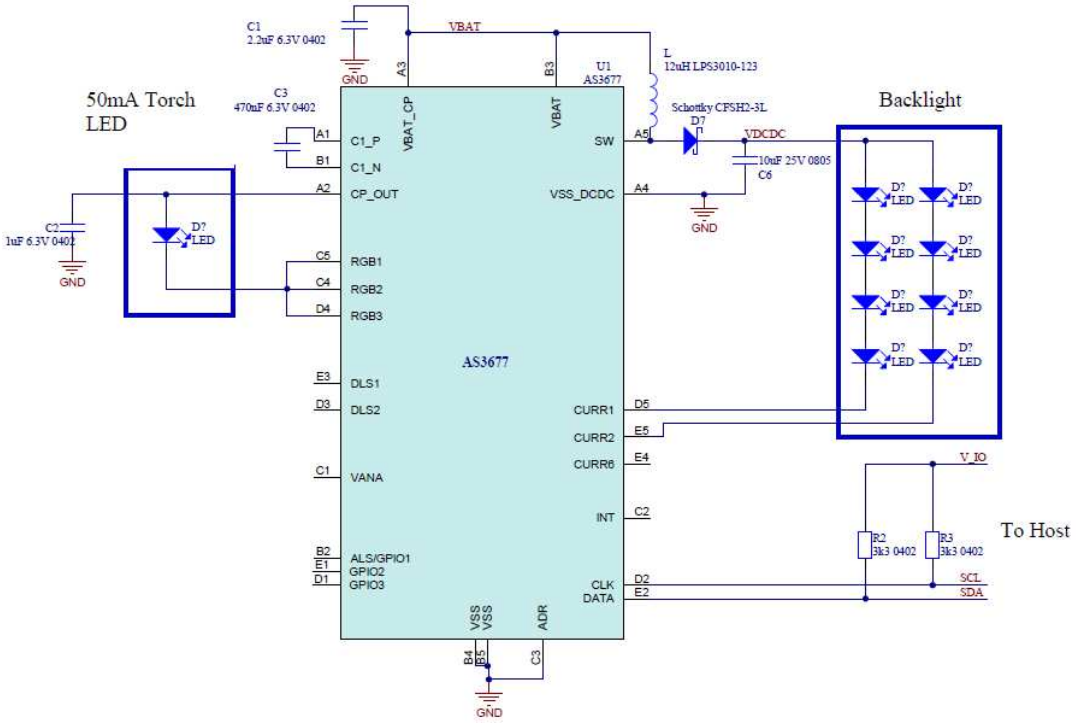
Efficiency improvement possiblities for higher String voltages:

- increasing the inductance
- reduction of switching frequency
- inductors with lower parasitic capacitance
- transistors with lower capacity between drain-source and drain-gate
- schottky diodes with less forward voltage
- schottky diodes with less capacity

7.4 Multiple String Solutions

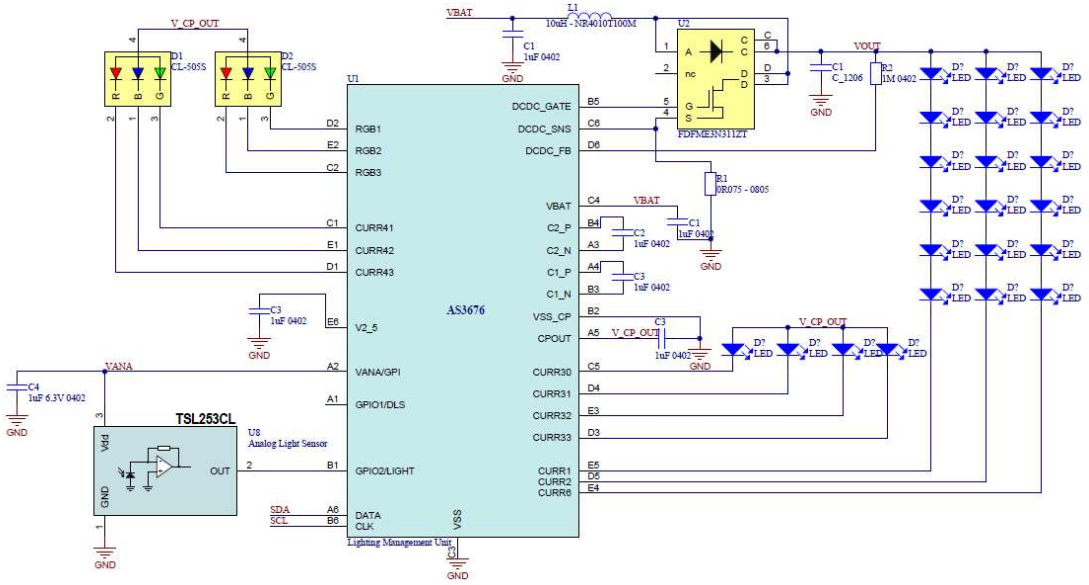
Multiple string solutions can be used to reduce the maximum output voltage of the DCDC. This helps to reduce the component sizes of capacitors and inductors. For example the output capacitors get bigger the more voltage they need to sustain.

Figure 21: AS3677 design example for a 4Sx2 configuration - 4" Smartphone



This example shows the AS3677 with it's integrated NMOS and an external schottky diode for a 4Sx2 configuration. Additionally the chargepump is driving a 50mA torch LED.

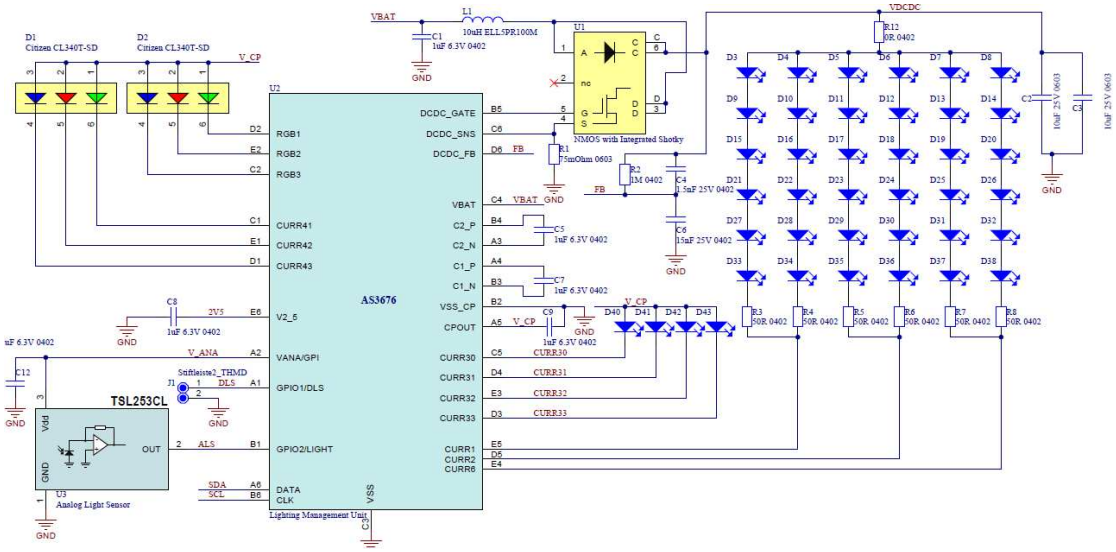
Figure 22: AS3676 design example for a 6Sx3 configuration – 7" tablet



This example shows the AS3676 with an external NMOS with integrated schottky diode for a 6Sx3 configuration which can drive up to 2 Watts of LED power. Additionally there are 2 RGB LEDs and 4 indicator LEDs for the status indication of capacitive buttons.

7.4.1 Multiple Strings for Tablets

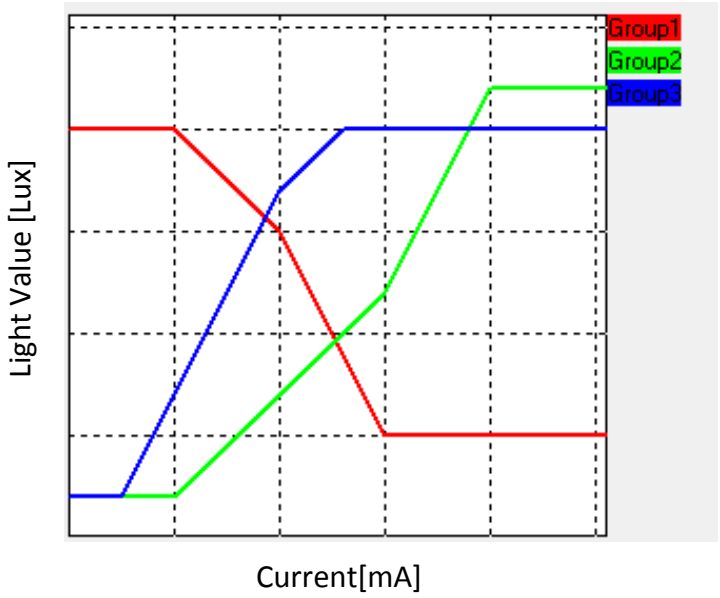
Figure 23: Design example for the AS3676 as 10.1" tablet backlight driver for a 6Sx6 LED configuration



Balance Resistors R3,R4,R5,R6,R7 and R8 are Optional

Design example for the AS3676 as 10.1” tablet backlight driver for a 6Sx6 LED configuration. Additionally there are 2x RGB indication LEDs and 4 indication LEDs. The AS3676 is connected with the TSL253CL for ambient light control. The RGB LEDs, indication LEDs and display backlight can be controled with independent ambient light calculation tables.

Figure 24: Light Value vs Current



Red = indication LED control curve

Blue = rgb LEDs control curve

Green = display backlight control curve

7.4.2 What is the best Configuration?

The best configuration for LEDs depends on the amount of LEDs needed for the application, and the typical use-case of current, DCDC efficiency and the compliance voltage of the current sinks.

Figure 26: AS3676 LED Configuration Comparison Measurement Setup

IC	AS3676		
Voltage	3.7V		
Load	20mA	per LED	
Transistor	FDFME3N311ZT		Fairchild
Diode	FDFME3N311ZT		Fairchild
Inductor	LPS3010-123	-	
Shunt	0R1		-
Frequency	1MHz		

Config	different		
Used LED	CL-120A		Citizen

Figure 27: AS3674/AS3492 LED Configuration Comparison Measurement Setup

IC	AS3674(AS3492)		
Voltage	3.7V		
Load	20mA	per LED	
Transistor	Internal NMOS		
Diode	Internal PMOS		
Inductor	CIG21K4R7SCD	-	
Frequency	2MHz		
Config	2Sx3/4/5		
Used LED	Firefly		Osram

7.4.3 Increasing efficiency in light load conditions

As light sensors are common in mobile handheld devices the dynamic range of the backlight can vary depending on the light condition. To increase the application efficiency in light load conditions it can be useful to increase the inductance. This can have, depending on the resistance of the inductor wire and the core losses, negative effects on the efficiency under high load conditions.

Figure 28: AS3677 4Sx3 Applicatin Efficiency

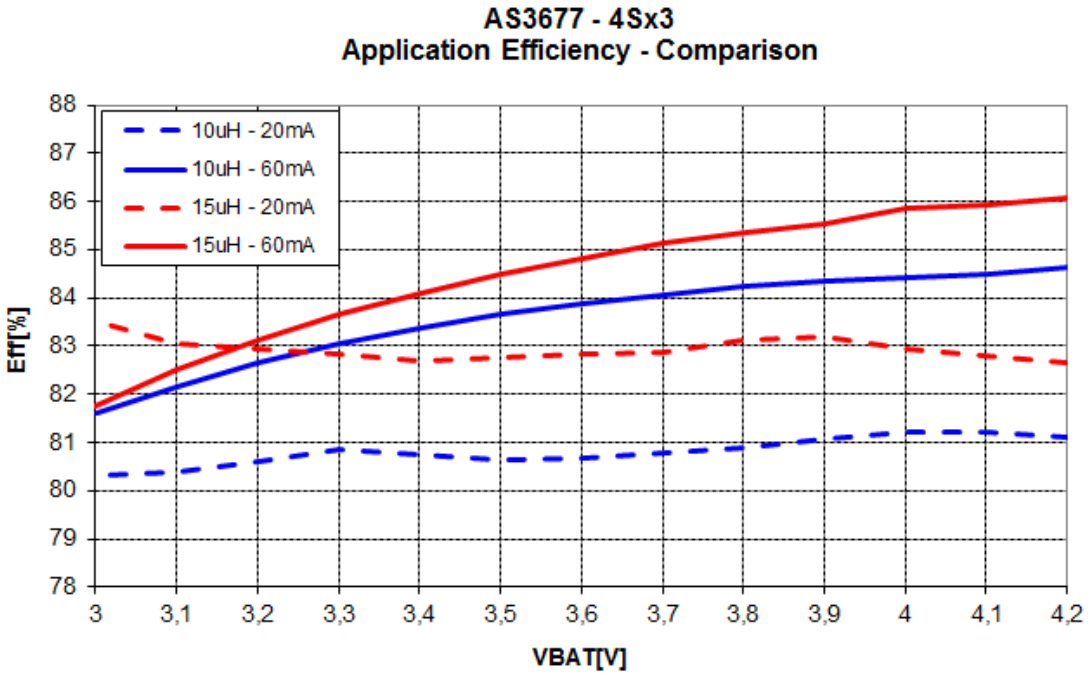
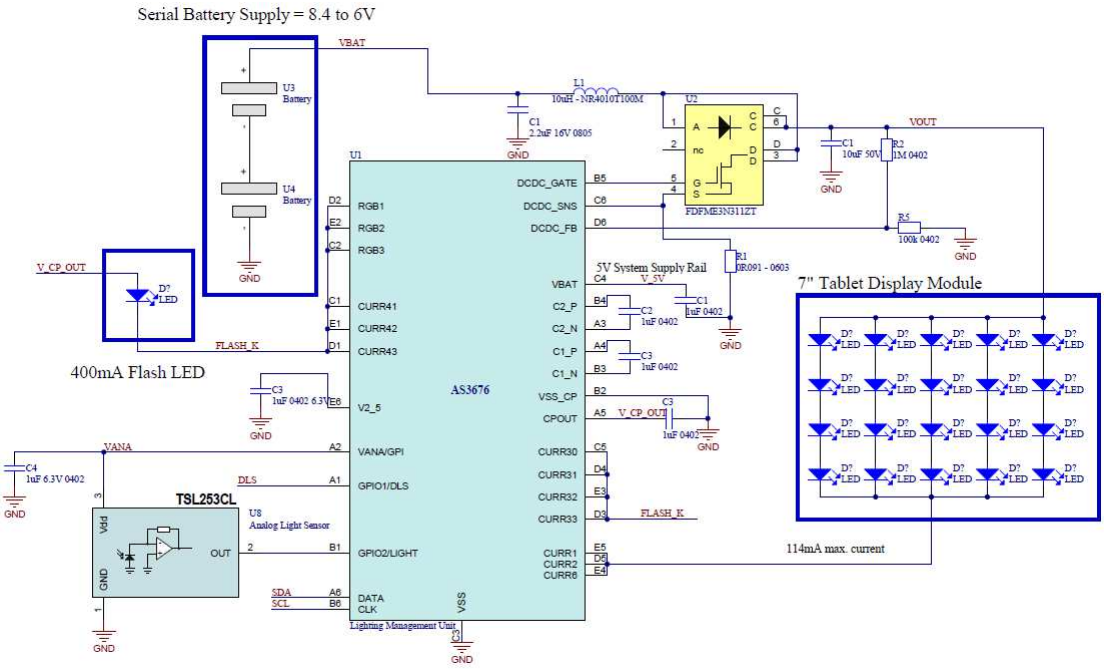


Figure 29: AS3677 4Sx3 Applicatin Efficiency Measurement Setup

Pout @ 60mA	0.75W
Pout @ 20mA	0.25W
Used LED Config	4Sx3
10uH Inductor	LQH3NPN100MJ0
15uH Inductor	LQH3NPN150NJ0
Used Diode	CMDSH05-4
Inductor Size	3x3x1mm

7.5 Driving the DCDC with Serial Batteries

Figure 30: Driving the DCDC with Serial Batteries



It is possible to connect the AS3687xm/75/76/77 to supply systems which have 2 batteries in series. The way how to do this is supplying IC VBAT pin with a general purpose system supply and connecting the Battery directly to the DCDC for the backlight application. This connection will have a beneficial effect to the system application efficiency. This example shows how the AS3676 is connected in a system with two serial batteries. The 7" tablet display module is configured in a 4Sx5 configuration where the LEDs are connected together at the bottom cathodes and the top anodes. The high voltage currentsinks of the AS3676 can drive, connected together, up to 114mA of current. Additionally this example is using the ams-TAOS TSL253CL as ambient light sensor for backlight control, and the 400mA chargepump as flash LED driver.

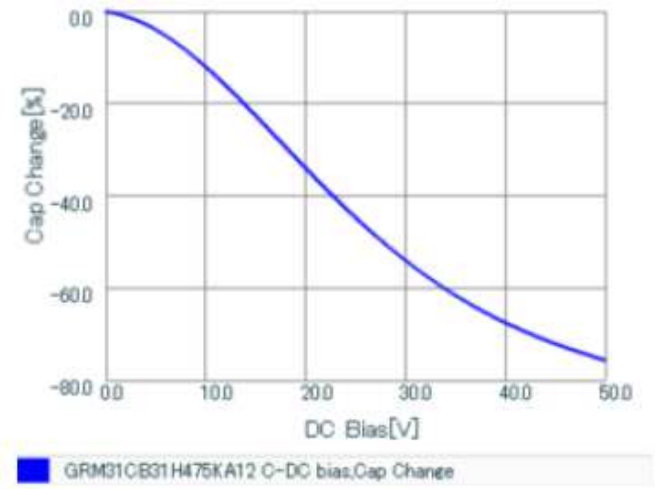
7.6 Dimension of external Components

Output Capacitor:

It is mandatory that the capacity of the output capacitor for AS3687xm/75/76/77 has under all conditions more than 0.7uF. For this please check the DC bias characteristics of the capacitor with the maximum voltage which would happen in the application with max. LED forward voltage and include the tolerances of the capacitor.

For AS3492 or AS3490 the minimum capacity is 4.8uF.

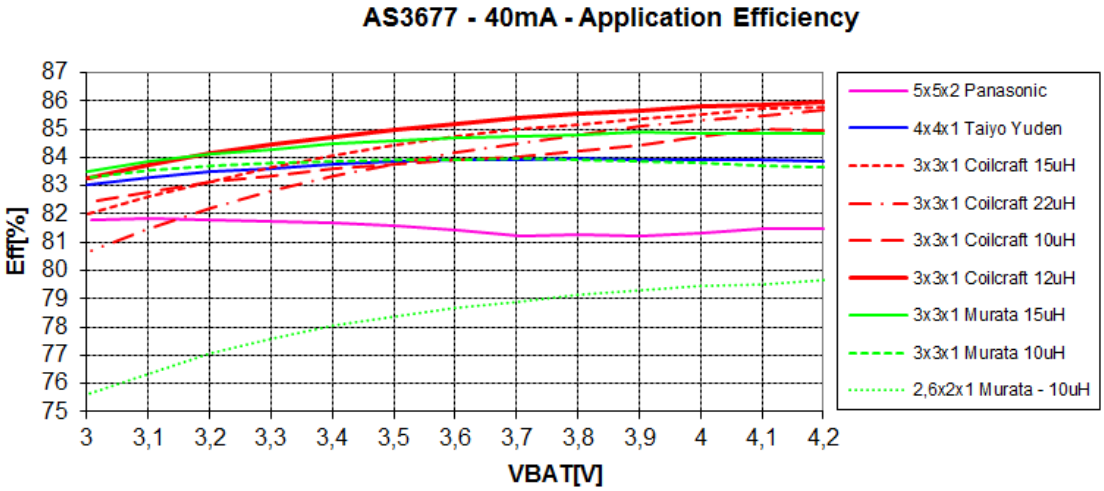
Figure 1: Example for the DC Bias characteristics of a 10uF capacitor



Inductor:

The inductor is an important component to select for the DCDC. Too small inductors will result in bad efficiency. Also too big inductors will also result in bad efficiency values. Also it can be that 10uH is not always the best suitable inductor as shown below. It is necessary to check if the inductor for AS3687xm/75/76/77 has all conditions more than 7uH. For AS3490 and AS3492 the minimum inductance under all conditions is 2,45uH.

Figure 32: AS3677 40mA Application Efficiency



This measurement graph shows that the 12uH - 3x3x1 Inductor was best in class. Also that the 2,6x2x1mm Inductor has a low application efficiency of 79%.

Figure 33: AS3677 40mA Application Efficiency Measurement Setup

Output Current	20mA	per LED
Frequency	1MHz	
Inductor	Sweep	
Load	4Sx2	
IC	AS3677	

8 Conclusion

Figure 34: Recommended Configurations

LED Amount	Recommended Configuration	IC	Display
4	2Sx2	AS3490	Up to 3.2”
5	5Sx1	AS3677	Up to 3.5”
6	2Sx3	AS3490	Up to 3.7”
7	7Sx1	AS3676	Up to 4.0”
8	2Sx4	AS3492	Up to 4.3”
9	3Sx3	AS3677	4.0~4.5”
10	2Sx5	AS3492	4.0~4.7”
12	4Sx3	AS3677	4.5”~5.0”
15	5Sx3	AS3676	5.0”~
18	6Sx3	AS3676	7.0”~
20	4Sx5	AS3676	7.0”~
36	6Sx6	AS3676	10.1”~
42	7Sx6	AS3676	10.1”

Conclusion of single string solutions:

Pro:

- less connections to the display

Con:

- efficiency suffering due to parasitic capacitance on the switching node and core losses (higher ripple current)
- bigger inductor and lower frequency needed to improve efficiency
- output capacitors get bigger due to high voltage

Conclusion of multiple string solutions

Pro:

- higher efficiency due to lower parasitic capacitance and core losses at the DCDC
- smaller external components like inductor and capacitors possible

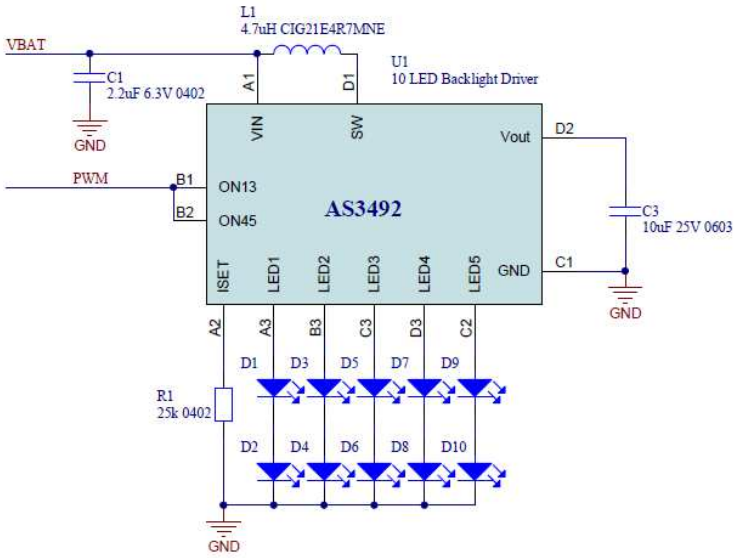
Con:

- more connections needed

9 Design Examples

9.1 Smartphone with 4.3” Display

Figure 2: AS3492 backlight driver for smartphones

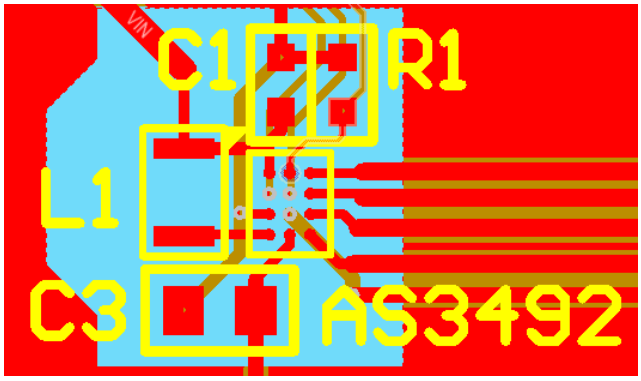


This example shows the AS3492 as backlight driver for smartphones with display sizes up to 4.3” or depending on specifications even bigger. The components are tiny, as the DCDC has a switching with a frequency of 2MHz. The CIG21E4R7MNE Inductor from SEMCO, or the LQM2HPN4R7_G Inductor from Murata have a size of 2x1,2x1mm, the input capacitor is a 2.2uF

0402 capacitor, while the output capacitor is a 10uF, 25V 0603 capacitor. The solution enables the AS3492 to reduce it's solution size down to 15mm² (with ams design rules).

Figure 3: PCB 3D Drawing of the AS3492

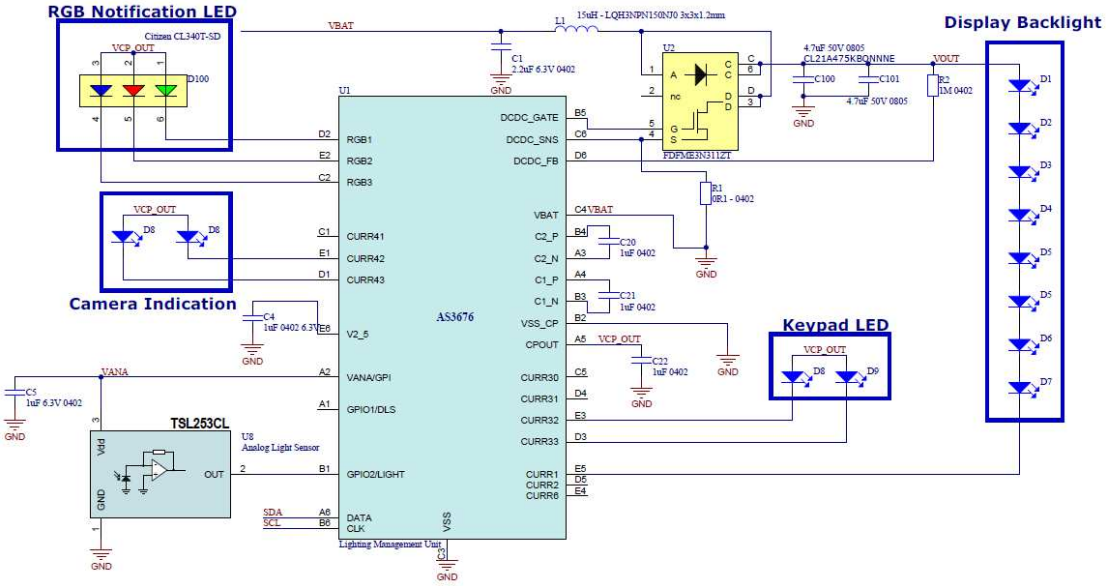
Figure 4: PCB Drawing of the AS3492



Additionally keeping the GND away from the Inductor helps to reduce eddy current losses. This efficiency improving PCB design technique is ams internally known as "hovering Inductor layout", it is an additional efficiency improvement technique. The GND plane can be placed already on MID Layer #1 or Layer#2.

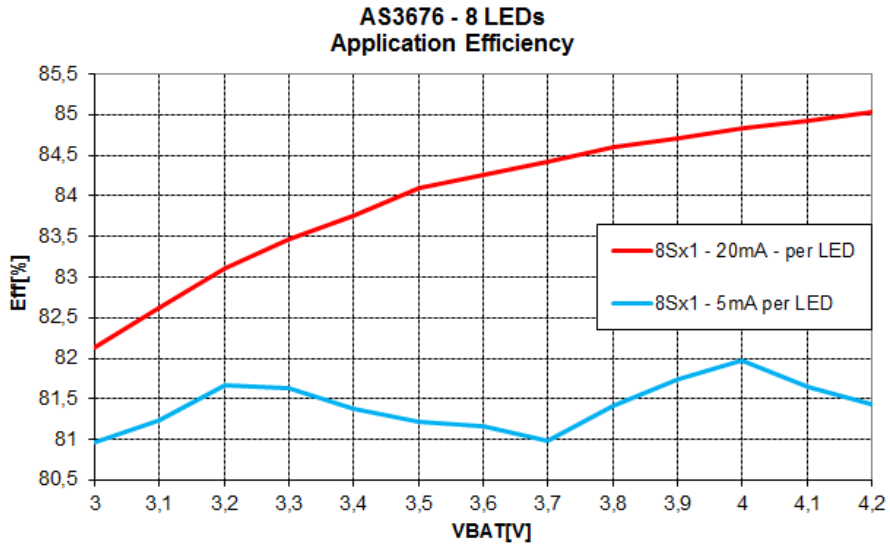
9.2 Smartphone with 4.5” Display

Figure 38: AS3676 smartphone LED driver



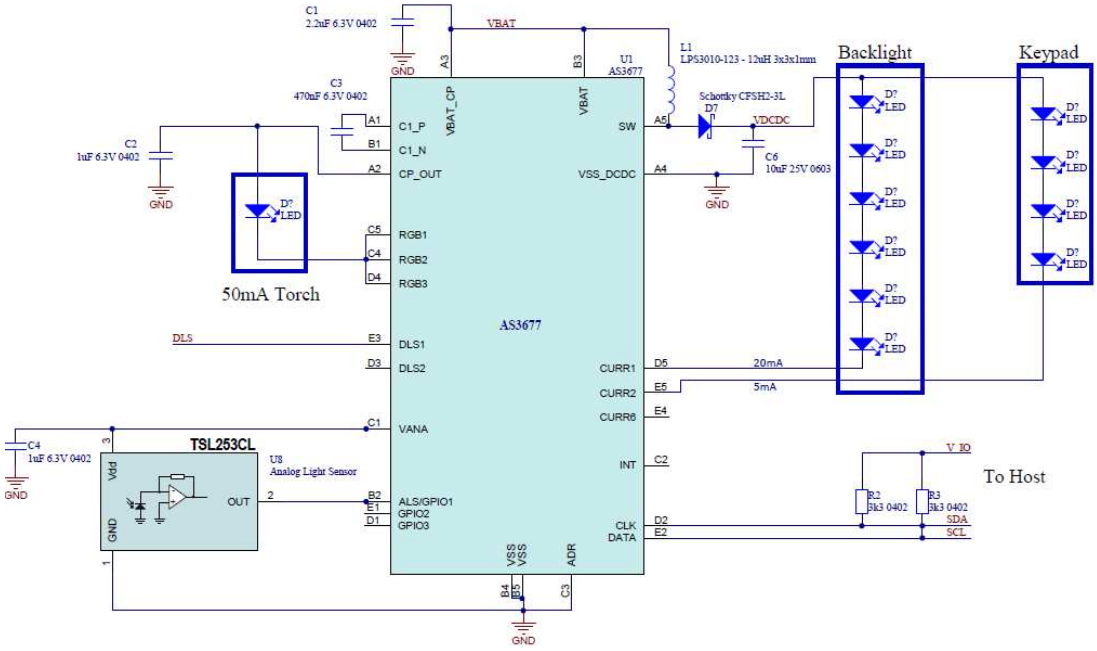
The example shows the AS3676 as smartphone LED driver. It has an 8Sx1 LED configuration for the display backlight which is powered by the inductive DCDC. The display can have a size from 4” to 4.5”. Also there are LEDs which are powered by the capacitive charge pump for the keypad backlight, camera indication and the RGB notification LED.

Figure 39: Application efficiency of the 8Sx1 configuration for display backlight



9.3 Mid – range Smartphone, Backlight, Keypad, Torch and ALS

Figure 40: AS3677 display backlight driver

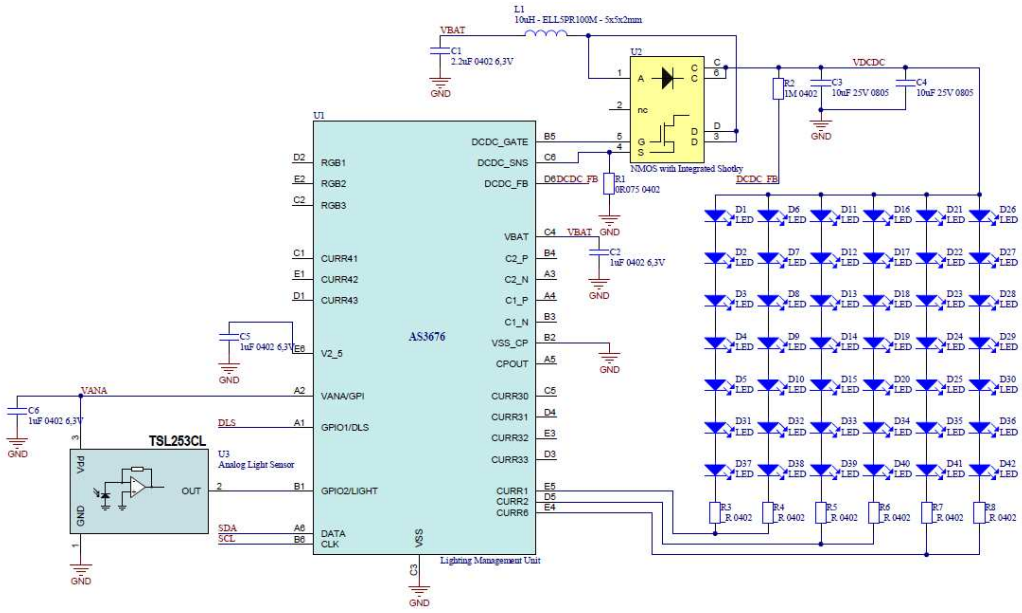


AS3677 as display backlight driver with a 6Sx1 configuration. Additionally the DCDC also drives a keypad backlight with low current. The chargepump is used for a 50mA torch LED. Generally it is recommended to have balanced LED strings – if this is not possible the efficiency will be reduced, but as the energy in the keypad LED string is usually much smaller compared to the backlight LED string it will only slightly affect efficiency.

Additionally it should be checked if the power dissipation inside the driver due to unbalanced LED strings does not exceed the datasheet specifications (see absolute max. ratings)

9.4 10.1” Tablet with 7Sx6 configuration (42 LEDs) + ALS

Figure 5: AS3676 as display backlight driver for 42 LEDs in a 7Sx6 configuration



9.5 Smartphone backlight: 4.3 ~ 5” with higher currents

Figure 6: AS3687xm as 5” tablet backlight driver; max. current = 38mA per LED

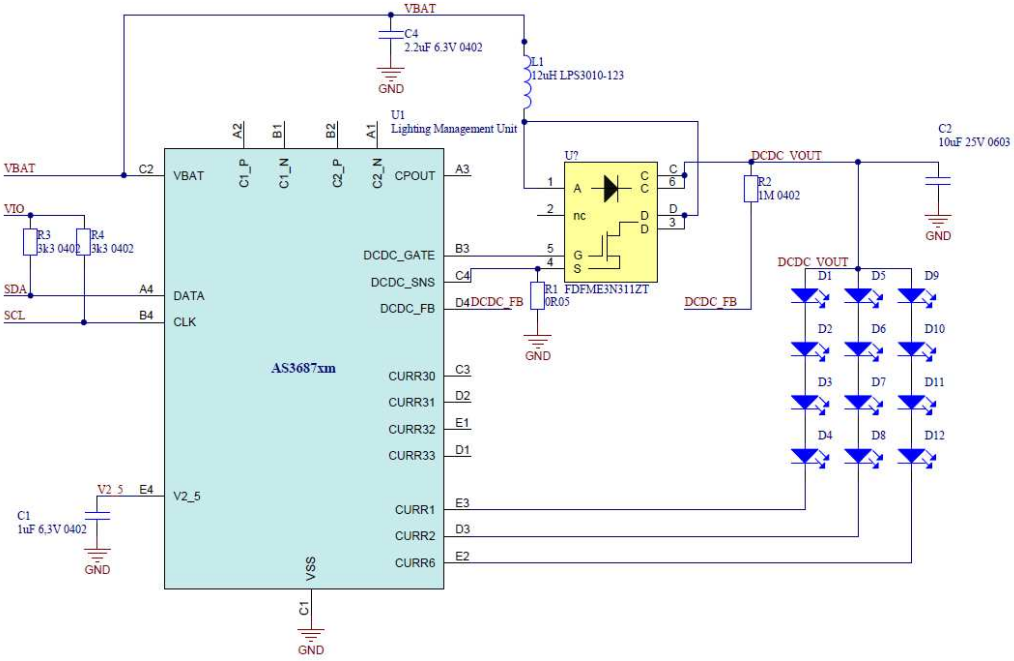
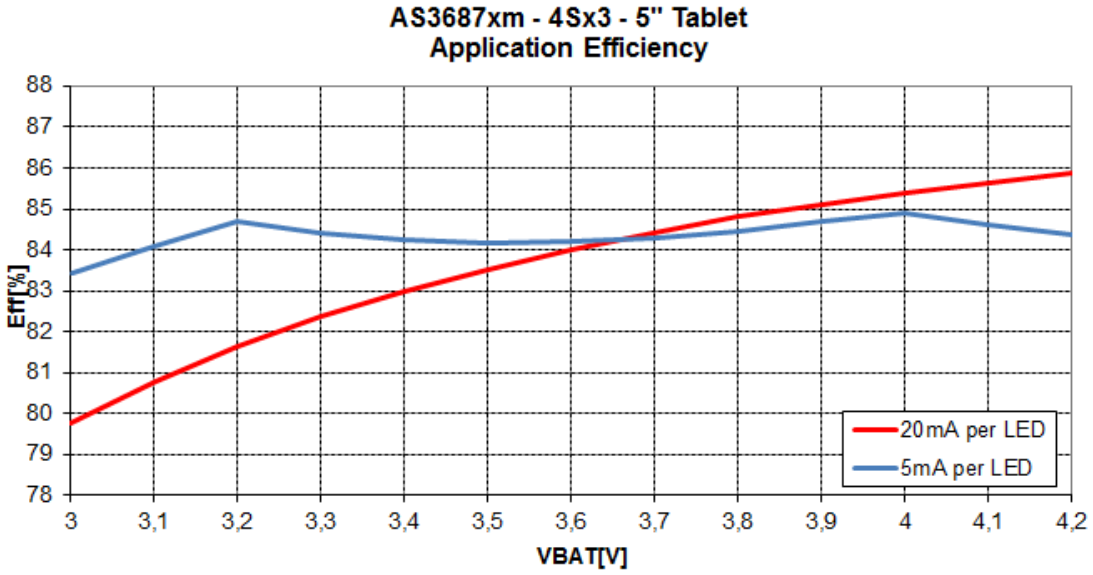


Figure 7: Application efficiency of the AS3687xm as 5” tablet backlight driver



9.6 Smartphone backlight: 4.3 ~ 5” + Button Backlight & ALS

Figure 8: AS3677 as 5” tablet backlight driver with ambient light sensing and keypad LED control. This solution is optimized for best efficiency and lowest size, max. current per LED = 25mA.

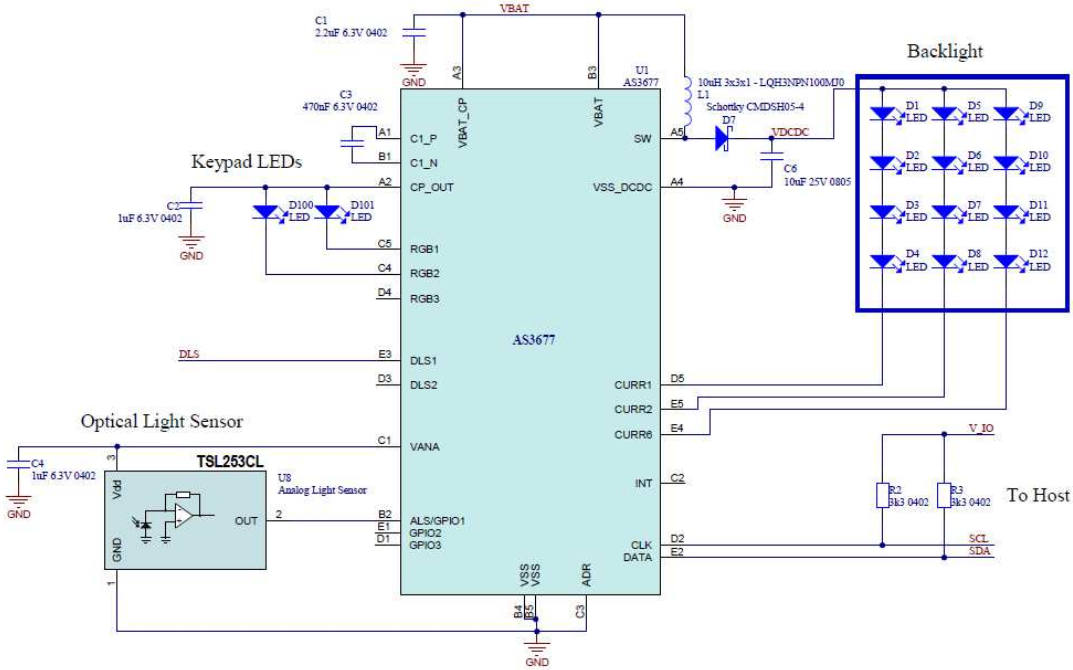
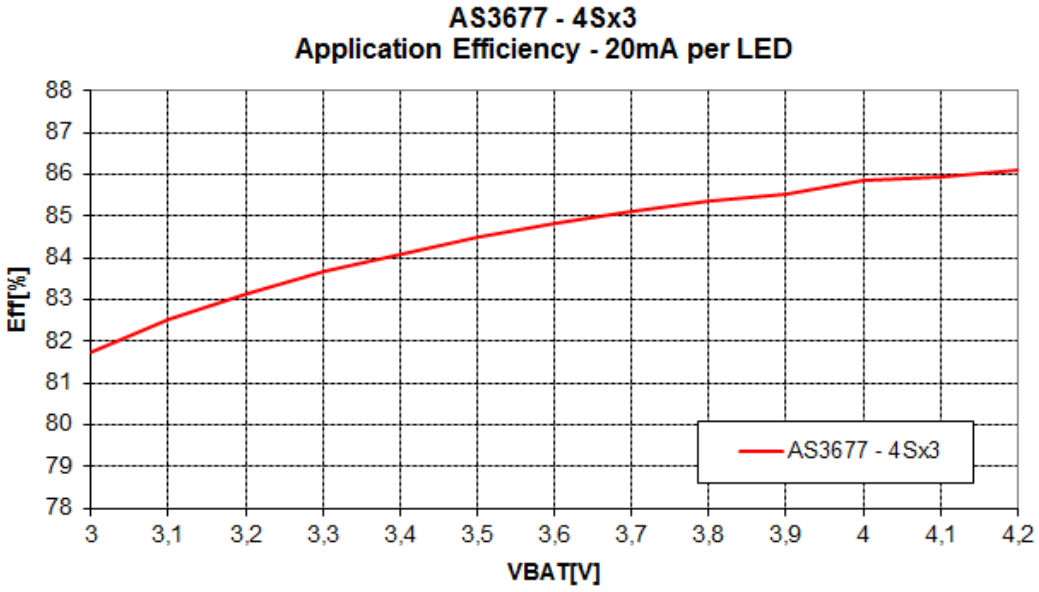
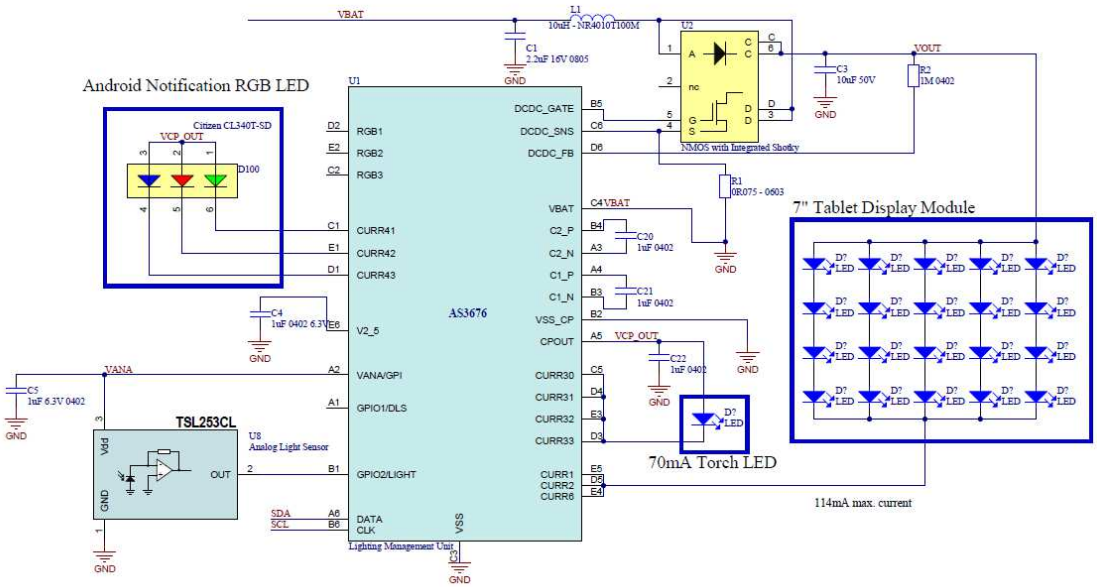


Figure 9: Application efficiency of the AS3677 setup above. Inductor: Murata LQH3NPN100MJ0, Diode CMDSH05-4



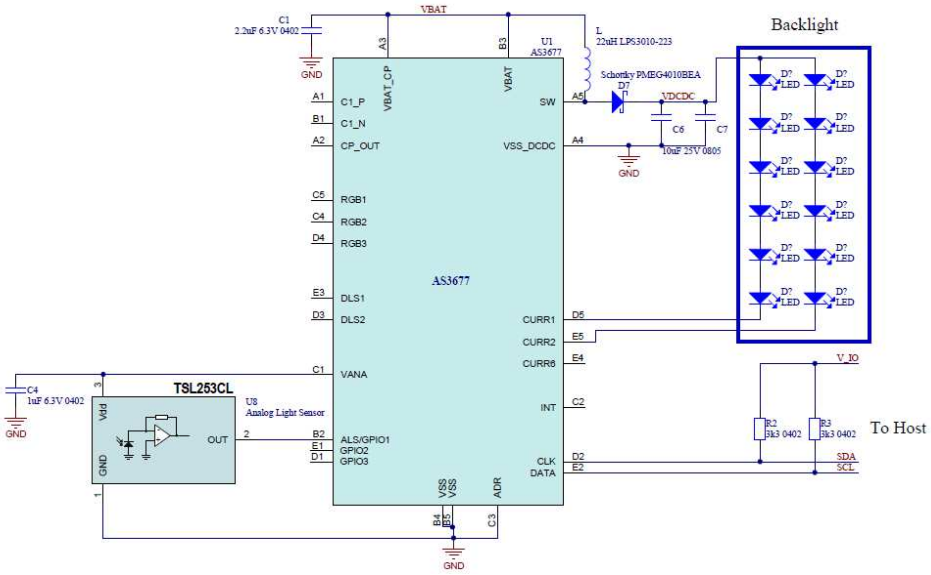
9.7 7” Tablet Backlight

Figure 10: This design example shows the AS3676 as 7” Tablet backlight driver with a 4Sx5 configuration, a 70mA torch LED, ambient light control, and an RGB notification LED.



9.8 Headlamp for ebooks or e-ink devices

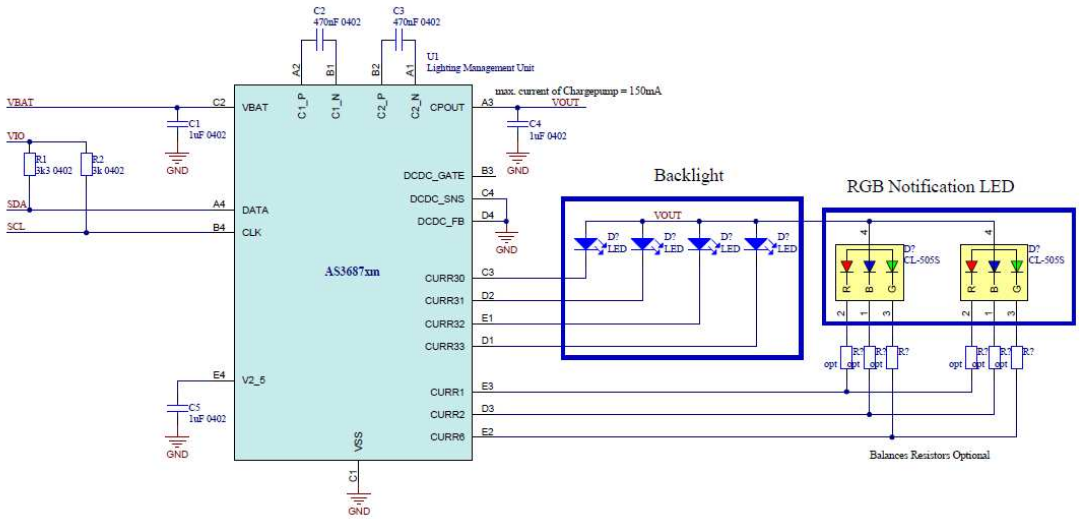
Figure 11: AS3677 headlamp for ebooks and E-Ink devices



This design example shows how the AS3677 is implemented as headlamp for ebooks or E-Ink devices. As these devices do not have any backlight it is not possible to read in the dark. It is possible to read by turning on side LEDs as headlamp. To optimize power consumption a light sensor can be used. As ebook or e-ink devices tend to turn off their main processor during the reading activity of the user, the automatic ambient light control will determine if actual light amount requires the need of the headlamp or not. This solution is optimized for higher efficiency for lower load currents as the application requires typically low light output.

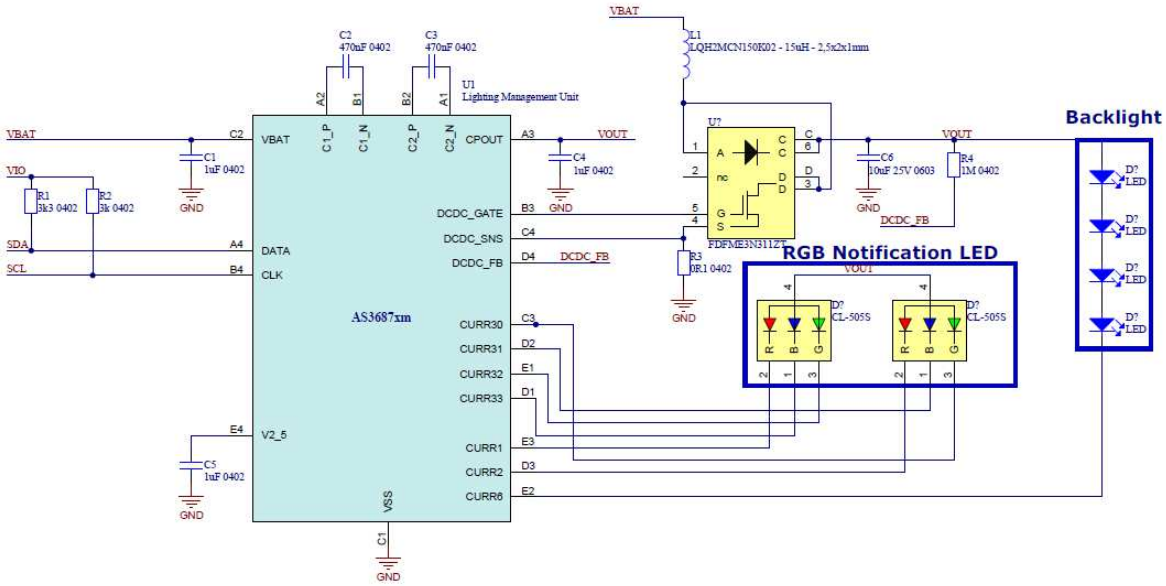
9.9 Feature phone – low size Backlight + 2x RGB LEDs

Figure 12: AS3687xm with 4 LEDs as display backlight and 2 RGB LEDs as low size solution for feature phones. Balance resistors are required depending on the current accuarcy for the RGB LEDs.



9.10 Feature phone – high efficiency Backlight + 2x RGB LEDs

Figure 13: AS3687xm with 4 LEDs as display backlight with high efficiency and 2 RGB LEDs which can be controlled independently. Typical application: feature phones.



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12 Revision Information

Changes from 1-01 (2012-Aug-25) to current revision 1-02 (2014-Jul-18)	Page
Update to corporate format	1-45

Note: Page numbers for the previous version may differ from page numbers in the current revision.