

### Constant current inverse buck LED driver using L6562A

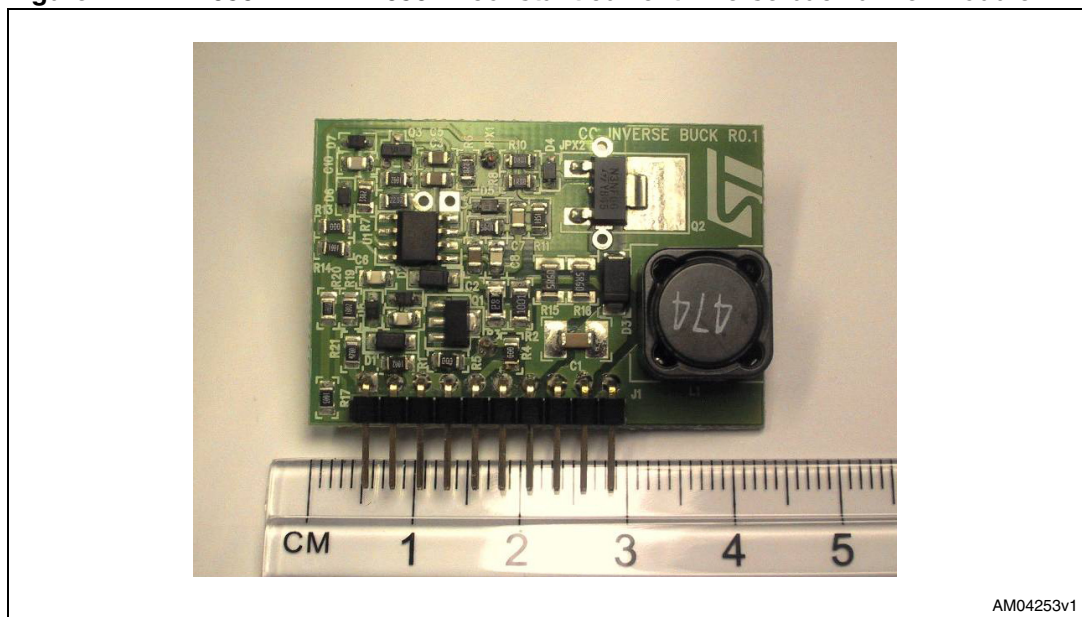
#### Introduction

Whenever a lighting application, such as street lighting for example, requires an elevated number of LEDs, there are basically two solutions: the first is to connect all the diodes in series in a single "string"; the second is to place several strings in parallel with fewer elements in each one.

The first solution, even if simpler, poses stringent safety requirements due to the high supply voltage. The latter needs a lower input voltage but the current through each string has to be independently controlled.

Since, from a system point of view, the second solution seems more viable, we have developed an application to investigate the possibility of employing an L6562A to implement such a constant current controller. This document describes the EVL6562A-LED demonstration board and summarizes the relevant results obtained.

**Figure 1. EVL6562A-LED: L6562A constant current inverse buck driver module**



# Contents

<b>1</b>	<b>Main characteristics</b> .....	<b>4</b>
1.1	System configuration .....	4
1.2	Requirements .....	4
1.3	Interface .....	5
<b>2</b>	<b>Circuit description</b> .....	<b>6</b>
2.1	Power section .....	6
2.2	L6562A controller .....	8
2.3	FOT (fixed off time) delay circuit .....	9
2.4	Current setting .....	11
2.5	LED number compensation .....	15
2.6	Shutdown/dimming .....	18
2.7	Auxiliary power .....	21
2.8	Open-/short-circuit protection .....	22
<b>3</b>	<b>Measurements</b> .....	<b>24</b>
3.1	LED voltage dependency .....	24
3.2	Input voltage dependency .....	26
<b>4</b>	<b>Electrical schematic and bill of materials</b> .....	<b>27</b>
<b>5</b>	<b>References</b> .....	<b>30</b>
<b>6</b>	<b>Revision history</b> .....	<b>31</b>

## List of figures

Figure 1.	EVL6562A-LED: L6562A constant current inverse buck driver module . . . . .	1
Figure 2.	System configuration . . . . .	4
Figure 3.	Module schematic . . . . .	6
Figure 4.	Standard buck converter. . . . .	7
Figure 5.	Inverse buck converter . . . . .	7
Figure 6.	Controller diagram . . . . .	8
Figure 7.	Simulated waveforms . . . . .	9
Figure 8.	FOT net. . . . .	9
Figure 9.	toff delay (actual) . . . . .	10
Figure 10.	toff delay (nominal) . . . . .	11
Figure 11.	Current setting . . . . .	11
Figure 12.	I <sub>Led</sub> /V <sub>trim</sub> . . . . .	15
Figure 13.	I <sub>Led</sub> /V <sub>Led</sub> . . . . .	18
Figure 14.	Enable/dimming detailed view (turn-on) . . . . .	19
Figure 15.	Enable/dimming detailed view (turn-off) . . . . .	19
Figure 16.	Dimming 1% . . . . .	20
Figure 17.	Dimming 10% . . . . .	20
Figure 18.	Dimming 50% . . . . .	20
Figure 19.	Dimming 90% . . . . .	21
Figure 20.	Dimming 99% . . . . .	21
Figure 21.	Auxiliary power . . . . .	21
Figure 22.	Short-circuit protection . . . . .	22
Figure 23.	Short-circuit application . . . . .	23
Figure 24.	Short-circuit removal. . . . .	23
Figure 25.	Short-circuit detection. . . . .	23
Figure 26.	Load current decay . . . . .	23
Figure 27.	LED current (average, maximum, minimum) . . . . .	24
Figure 28.	LED current (ripple) . . . . .	24
Figure 29.	Switching frequency . . . . .	25
Figure 30.	Efficiency [%] . . . . .	25
Figure 31.	LED current (average) . . . . .	26
Figure 32.	Switching frequency . . . . .	26
Figure 33.	Efficiency [%] . . . . .	26
Figure 34.	EVL6562A-LED electrical schematic . . . . .	27

# 1 Main characteristics

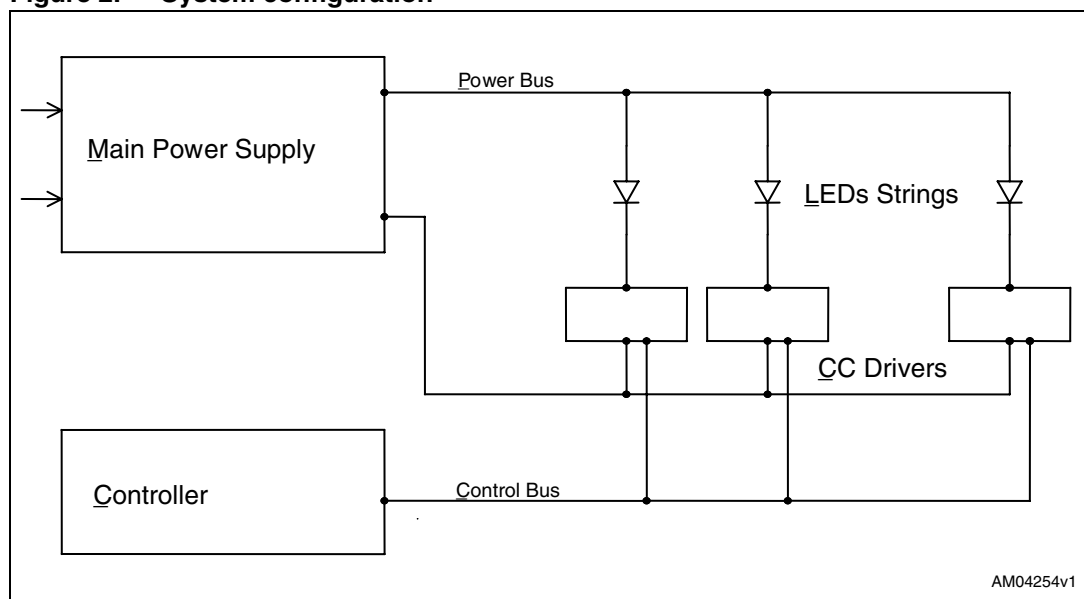
## 1.1 System configuration

Figure 2 shows a possible system configuration, in which the key modules are:

- the main power supply, which converts the AC input voltage to an internal power bus.
- the CC drivers, which are the modules that implement the constant current sources.
- the controller that configures the CC current drivers through a dedicated bus.
- the LEDs strings.

The CC drivers are the modules considered in this application note and implemented in the EVL6562A-LED demonstration board.

**Figure 2. System configuration**



## 1.2 Requirements

The board's design takes into account the following key points.

- Input voltage: 48 V (+/- 20%)
- Output current (average): 0.35 A
- Output ripple current < 140 mA (+/- 20%)
- Output current setting/calibration
- Digital dimming
- Open-/short-circuit protection
- Absence of electrolytic capacitors

The design can be easily changed to adapt to different needs.

## 1.3 Interface

Ideally the module should have only two pins and behave as a constant current sink, but for practical reasons, and in order to gain a higher degree of flexibility, its connector has the following pinout.

**Table 1. EVL6562A-LED interface**

Pin number	Signal name	Connection	Notes
1	D_Dimm	Shutdown / digital dimming	Digital input
2	C_Set	Load current setting	0.. 12 V input
3	Gnd	Auxiliary power (Gnd)	
4	Gnd	Auxiliary power (Gnd)	
5	Vcc	Auxiliary power (Vcc)	(18 V) input/output
6	n.c.		
7	Vin_Gnd	Main power (Gnd)	
8	Vin	Main power (Vin)	(48 V nom.) input
9	LEDs_A	LEDs anode Interconnection	Output
10	LEDs_K	LEDs cathode interconnection	Output

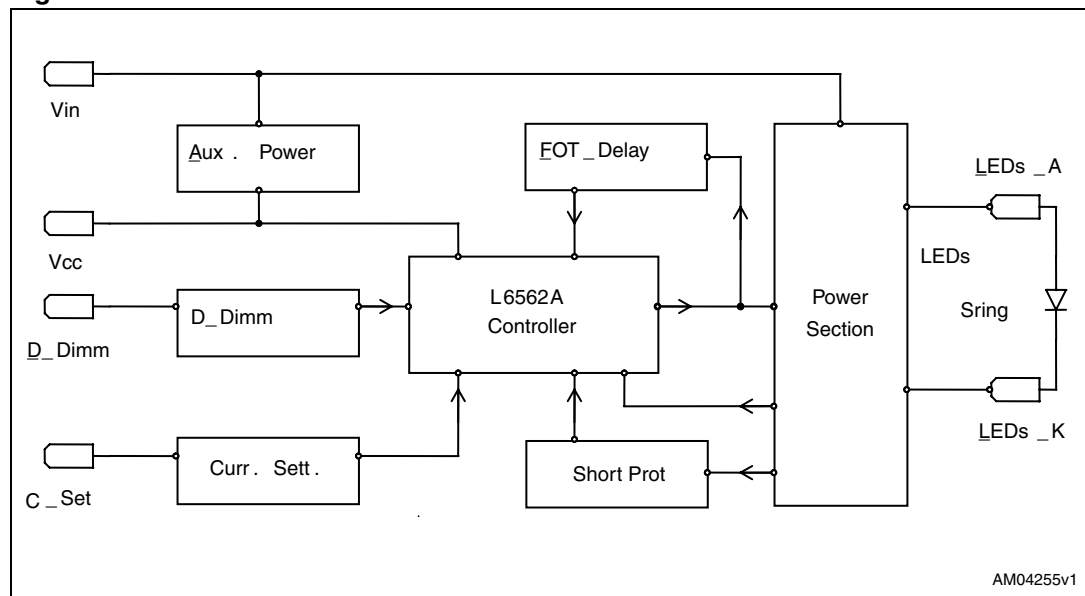
- D\_Dimm is a digital (TTL) input for the module. A high level shuts off the circuit. A low level enables the nominal load current and a square wave with variable duty cycle can be used as a dimming control
- C\_Set is an analog input (0...12 V). A voltage applied to this pin is used to set the load current to the required value
- Gnd pins 3 and 4 are the ground return for the controller's power supply (Vcc). D\_Dimm and C\_set are referred to this ground
- Vcc is the connection to the controller's power supply input
- Vin\_Gnd is the main power supply return, internally connected to the Gnd pins
- Vin is the main power supply input (48 V)
- LEDs\_A is the connection to the anode of the diode string
- LEDs\_K is the connection to the cathode of the diode string

## 2 Circuit description

The following is a list of the main components that form the module EVL6562A-LED.

- Power section
- L6562A controller
- Fixed off time (FOT) delay
- Current setting
- LED number compensation
- Shutdown/dimming
- Auxiliary power
- Open-/short-circuit protection

**Figure 3. Module schematic**



### 2.1 Power section

The topology of this stage is the so-called inverse buck (also referred to as modified or low-side buck). Simply stated, it is a standard buck converter with the power and ground connections interchanged, as shown in [Figure 4](#) and [Figure 5](#).

Figure 4. Standard buck converter

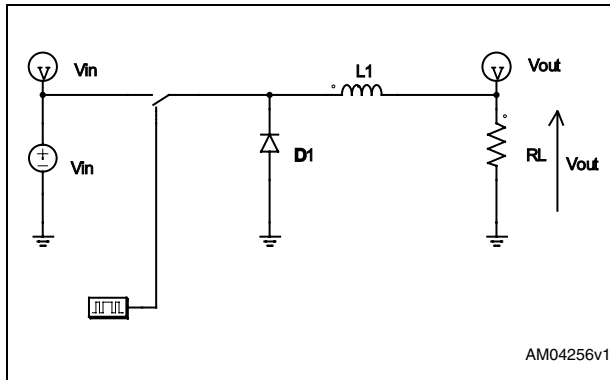
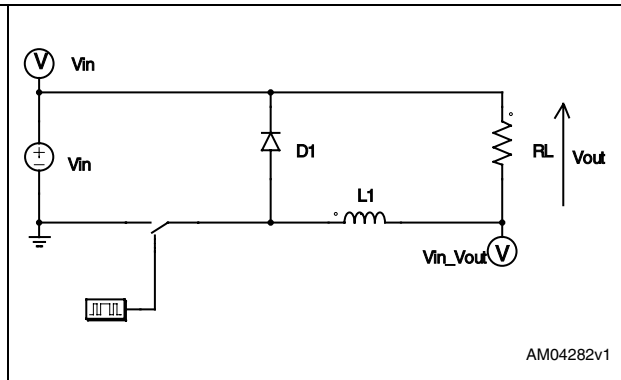


Figure 5. Inverse buck converter



Other than the power and ground connections being exchanged, there are no differences between the two configurations; the behavior and dimensioning of the inverse buck are the same as that of the standard buck. Refer to application note AN2928<sup>(a)</sup> for a detailed description and design rules. The following are a reminder of the fundamental applicable equations.

### Inductor current variation (charging period)

#### Equation 1

$$\Delta I_{\text{ton}} = \left[ \frac{V_{\text{in}} - V_{\text{Led}}}{L} \right] * \text{ton}$$

### Inductor current variation (discharging period)

#### Equation 2

$$\Delta I_{\text{toff}} = \left[ \frac{V_{\text{Led}}}{L} \right] * \text{toff}$$

The circuit works in continuous conduction mode, then in steady-state the current variations during *ton* and *toff* are the same (in module) and equivalent to the ripple current  $I_{\text{rip}}$ .

### Ripple current

#### Equation 3

$$I_{\text{rip}} = |\Delta I_{\text{ton}}| = |\Delta I_{\text{toff}}|$$

### Duty cycle

#### Equation 4

$$D = \left[ \frac{\text{ton}}{T} \right] = \left[ \frac{V_{\text{Led}}}{V_{\text{in}}} \right]$$

Additionally, the average current of the LED can be expressed as:

a. See [Chapter 5: References on page 30](#).

## Equation 5

$$I\_Led\_avg = I\_Led\_pk - \frac{1}{2}I\_rip$$

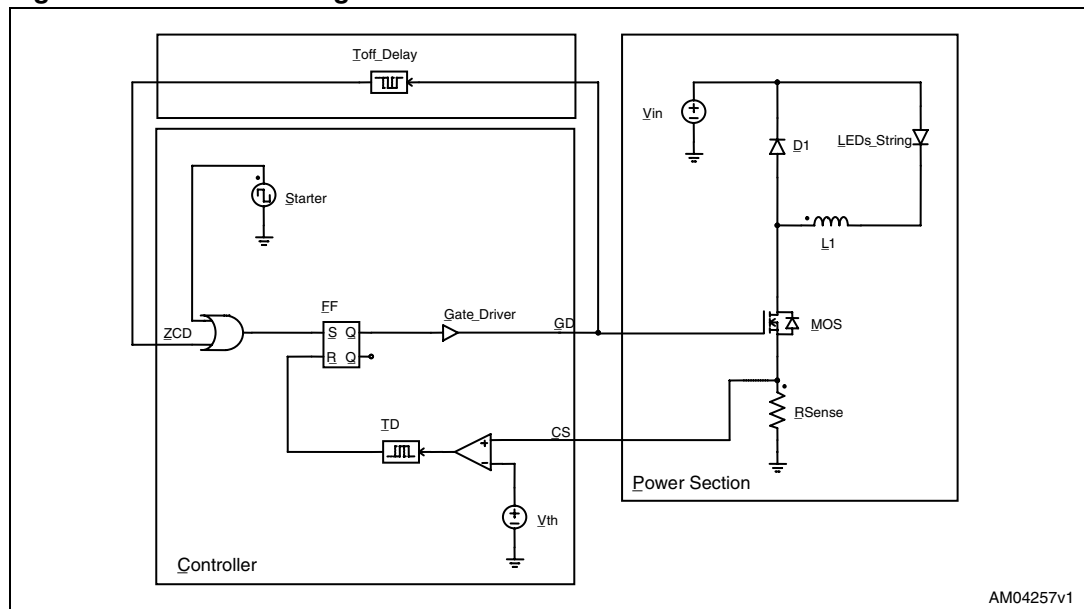
## Equation 6

$$I\_Led\_avg = I\_Led\_pk - \frac{1}{2} \left[ \frac{VLed}{L} \right] * toff$$

## 2.2 L6562A controller

The L6562A is used in a "fixed off time" and "peak current mode" topology. [Figure 6](#) represents the controller with its main functional blocks, the FOT\_Delay circuitry and the power section.

**Figure 6. Controller diagram**



At power-on, the "starter" sets the flip-flop, whose output (Q) goes high activating the gate driver (GD).

The power MOSFET transistor is turned on and the load current ( $I\_Led$ ) flows through the LED diodes, inductor, power MOSFET transistor and sense resistor.

The load current develops a voltage on the sense resistor:  $V_S = I\_Led * R_{Sense}$ .

This voltage is applied to the CS input of the controller where it is compared to the reference voltage  $V_{th} = 1.08 \text{ V}$  (nom.)

When  $V_S$  becomes higher than  $V_{th}$ , the comparator's output goes high, activating the reset input of the FF.

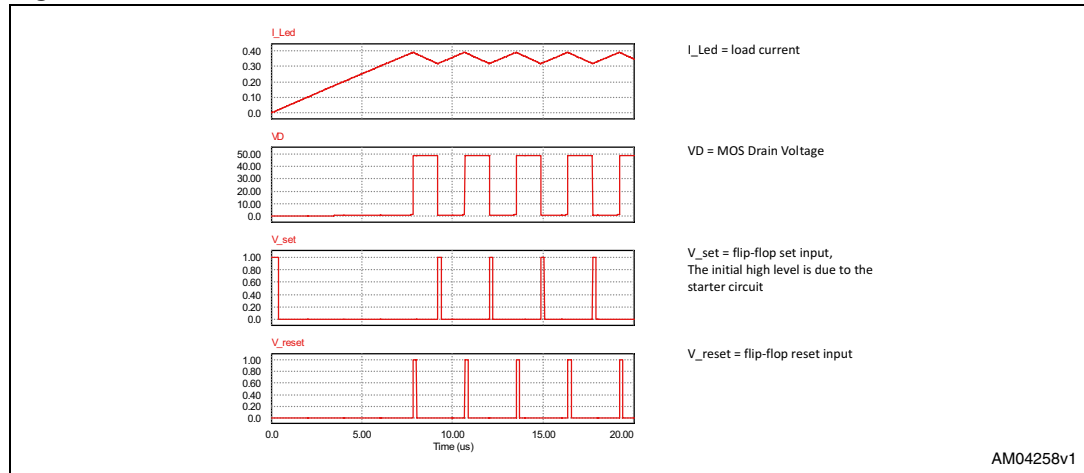
The FF Q output is set to low and the gate driver output voltage goes to gnd.

The power MOSFET is turned off,  $V_S$  goes to zero and the  $I\_Led$  current decreases, flowing through the LEDs, inductor and Flywheel diode.



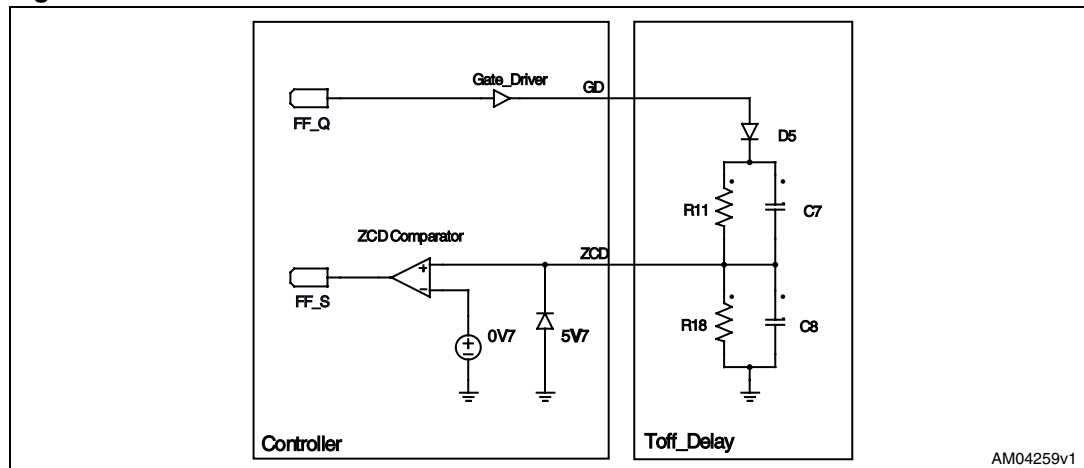
The falling edge of the gate driver starts the *toff* delay (see [Section 2.3 on page 9](#)). At the end of the *toff* delay the set input of the FF is activated and a new cycle begins.

**Figure 7. Simulated waveforms**



## 2.3 FOT (fixed off time) delay circuit

**Figure 8. FOT net**



The fixed off time delay circuit is implemented by connecting the gate drive (GD) output to the ZCD input by means of a diode D5 in series with R11 and C7 (in parallel), and ZCD to ground with R18 and C8 in parallel.

There is a clamp circuit behind the ZCD pin of the controller that limits the maximum voltage to 5.7 V, and a comparator whose output goes high if the input voltage falls below the threshold level of 0.7 V.

Hence when GD is high (10 V nominal), ZCD is forced to the clamp level of 5.7 V, but as soon as the gate driver goes low, the diode D5 turns off and the capacitor C8 discharges through R18 until the voltage reaches 0.7 V.

At this point the comparator switches on and triggers the set input of the flip-flop, whose output goes high.

This causes the gate driver to go high again and then the power MOSFET to conduct.

The time delay *toff* is simply governed by the equation of the discharge of the capacitor C8 through the resistor R18 with the boundary conditions  $V(t_0) = 5.7\text{ V}$ ,  $V(t_1) = 0.7\text{ V}$ .

#### Equation 7

$$V(t_1) = V(t_0) * e^{-\left[\frac{\text{toff}}{R_{18} * C_8}\right]}$$

#### Equation 8

$$\ln\left[\frac{V(t_1)}{V(t_0)}\right] = -\left[\frac{\text{toff}}{R_{18} * C_8}\right]$$

#### Equation 9

$$\text{toff} = (R_{18} * C_8) * \ln\left[\frac{V(t_0)}{V(t_1)}\right]$$

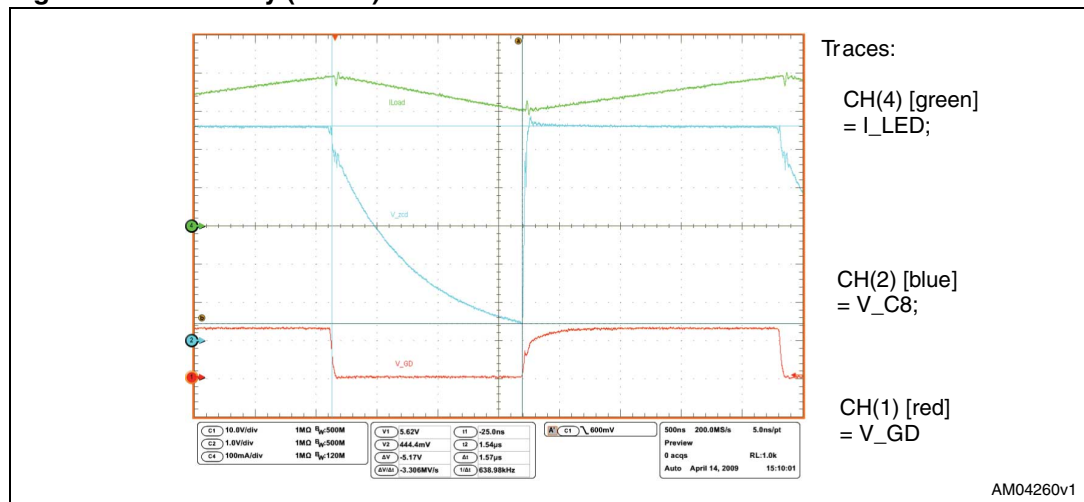
With our values this gives:

#### Equation 10

$$\text{toff} = (R_{18} * C_8) * \ln\left[\frac{5.7}{0.7}\right] = 2.1 * (R_{18} * C_8) = 1.17\mu\text{S}$$

Refer to AN2782<sup>(b)</sup> for a detailed description of the FOT controller. [Figure 9](#) shows the key waveforms with the LEDs' current (*I\_LED*), capacitor (C8) voltage (*V\_C8*) and gate drive output voltage (*V\_GD*).

**Figure 9. toff delay (actual)**

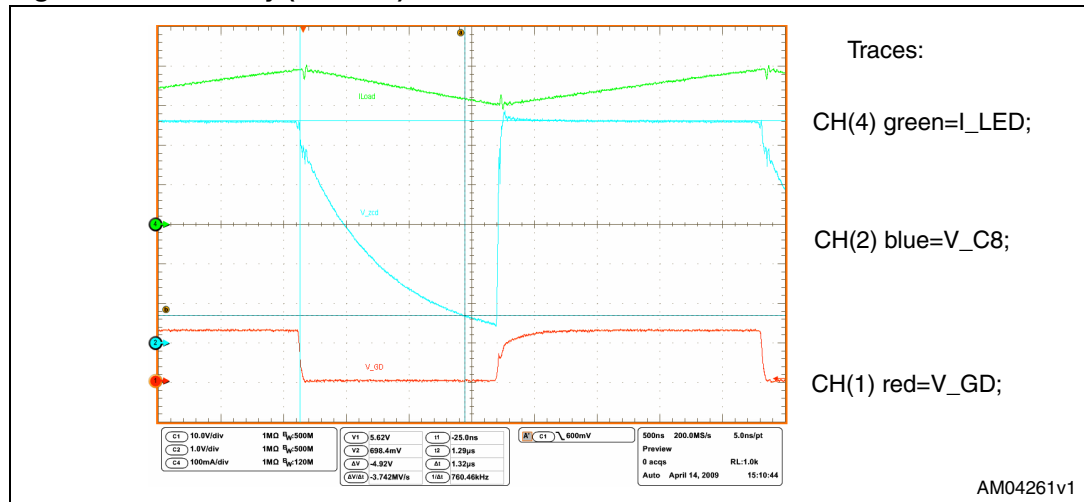


It is worth noting that the real *toff* time is  $1.57\mu\text{S}$  and that the low threshold is  $0.44\text{ V}$ . This is due to the components' tolerance and to the propagation delay from the comparator input to the gate driver output.

b. See [Chapter 5: References on page 30](#).

If we consider the time at which the capacitor voltage crosses the 0.7 V threshold, the equivalent *toff* time is 1.32  $\mu$ S (+150 nS compared to the nominal value, due to the tolerance of C8 and stray capacitance) while the remaining 250 nS are related to the propagation delay (during which the voltage falls from 0.7 V to 0.44 V).

Figure 10. *toff* delay (nominal)



## 2.4 Current setting

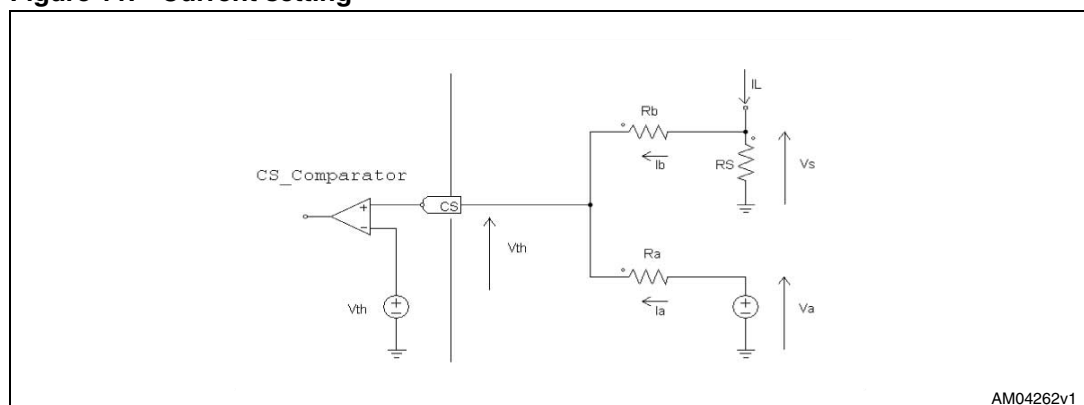
As already indicated, the CS pin of the L6562A controller is internally connected to the non-inverting input of the CS comparator, whose threshold ( $V_{th}$ ) is fixed to 1.08 V (nom.).

Tying it to the sense resistor forces the comparator's output high when  $I_{Led} = V_{th} / R_S$ .

This is a very simple way to detect – and limit – the peak load current to a fixed value.

In order to make this value adjustable, we can introduce an auxiliary voltage source ( $V_a$ ), connected to the CS pin through a resistor ( $R_a$ ) and another resistor ( $R_b$ ) between CS and the sense resistor, as indicated in Figure 11. In this way the auxiliary source can be used to modify the threshold at which the (peak) load current triggers the comparator.

Figure 11. Current setting



**Equation 11**

$$V_{th} = V_s - I_b * R_b$$

**Equation 12**

$$V_{th} = V_a - I_a * R_a$$

Neglecting the current that flows through the CS pin (1  $\mu$ A max):

**Equation 13**

$$I_b = -I_a$$

And then:

**Equation 14**

$$V_{th} = V_s - I_b * R_b$$

**Equation 15**

$$V_{th} = V_a + I_b * R_a$$

Then:

**Equation 16**

$$V_s = V_{th} + I_b * R_b$$

and:

**Equation 17**

$$I_b = \left( \frac{1}{R_a} \right) * (V_{th} - V_a)$$

**Equation 18**

$$V_s = V_{th} + \left( \frac{1}{R_a} \right) * (V_{th} - V_a) * R_b$$

**Equation 19**

$$V_s = V_{th} + \left( \frac{R_b}{R_a} \right) * V_{th} - \left( \frac{R_b}{R_a} \right) * V_a$$

**Equation 20**

$$V_s = V_{th} * \left( \frac{R_a + R_b}{R_a} \right) - V_a * \left( \frac{R_b}{R_a} \right)$$

**Equation 21**

$$I_{Led\_pk} = \left( \frac{1}{R_s} \right) * \left[ V_{th} * \left( \frac{R_a + R_b}{R_a} \right) - V_a * \left( \frac{R_b}{R_a} \right) \right]$$

If we consider the limit condition  $V_a = 0$ , which is equivalent to connecting  $R_a$  directly to ground, the maximum peak LED current  $I_{Led\_pk}$  (max) can be obtained by:

**Equation 22**

$$I_{\text{Led\_pk(max)}} = I_{\text{Led\_pk(nom)}} * \left( \frac{R_a + R_b}{R_a} \right)$$

Where, as already seen, the (nominal) LED peak current is:

**Equation 23**

$$I_{\text{Led\_pk(nom)}} = \left( \frac{1}{R_s} \right) * V_{\text{th}}$$

On the other hand, if we fix  $I_{\text{Led\_pk}} = 0$  we can estimate the value of  $V_a$  for which the LED current is reduced to zero.

**Equation 24**

$$0 = \left( \frac{1}{R_s} \right) * \left[ V_{\text{th}} * \left( \frac{R_a + R_b}{R_a} \right) - V_a * \left( \frac{R_b}{R_a} \right) \right]$$

**Equation 25**

$$V_a * \left( \frac{R_b}{R_a} \right) = V_{\text{th}} * \left( \frac{R_a + R_b}{R_a} \right)$$

**Equation 26**

$$V_a = V_{\text{th}} * \left( \frac{R_a + R_b}{R_b} \right)$$

With our values of  $R_a = R_{19} = 10 \text{ k}\Omega$ , and  $R_b = R_{14} = 1 \text{ k}\Omega$ , [Equation 21](#) can be rewritten as:

**Equation 27**

$$I_{\text{Led\_pk}} = \left( \frac{1}{R_s} \right) * [(1.1) * V_{\text{th}} - (0.1) * V_a]$$

[Equation 22](#) becomes:

**Equation 28**

$$I_{\text{Led\_pk(max)}} = I_{\text{Led\_pk(nom)}} * (1.1)$$

And [Equation 25](#):

**Equation 29**

$$V_a = V_{\text{th}} * (11)$$

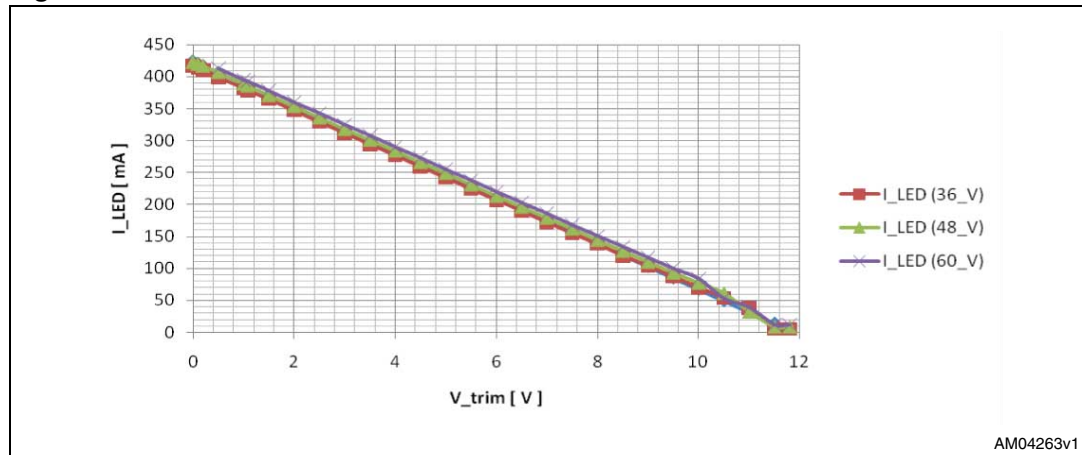
In the plot shown in [Figure 12](#) the LED current ( $I_{\text{Led}}$ ) is expressed as a function of the trim voltage  $V_{\text{trim}}$  (=  $V_a$ ) applied at the  $C_{\text{set}}$  module input, with the supply voltage ( $V_{\text{in}}$ ) as parameter (fixed at 36, 48 and 60 V).

As you can see, the linearity is quite good for currents in the range of 400 to 75 mA and voltages in the range 0... 10 V, while with  $V_{\text{trim}}$  from 10 to 12 V the current still decreases down to zero, but with some non-linearity.

This is due to the fact that the LED diodes are a non-linear load and their behavior at low current levels may change from one device to another.

Another point that has to be taken into account is that when the average current is reduced, the minimum LED current is reduced to zero, causing the converter to change from continuous conduction mode (CCM) to discontinuous conduction mode (DCM) operation.

Figure 12. I\_LED/V\_trim



## 2.5 LED number compensation

The average output current depends on the number of LEDs connected to the module, or to be more precise, on the voltage (V<sub>Led</sub>) developed across them. This is due to the fact that:

### Equation 30

$$I_{\_Led\_avg} = I_{\_Led\_pk} - \frac{1}{2}I_{\_rip}$$

and:

### Equation 31

$$I_{\_rip} = \left( \frac{toff}{L} \right) * VLed$$

and then:

### Equation 32

$$I_{\_Led\_avg} = I_{\_Led\_pk} - \frac{1}{2} \left( \frac{toff}{L} \right) * VLed$$

With a constant I<sub>Led\_pk</sub>, toff and L, it appears that if V<sub>Led</sub> increases, the average current decreases, and vice versa.

Usually the number of LEDs is determined in the early stages of the design phase, but if required, it is possible to make the load current almost independent of the number of LEDs employed by connecting two resistors (R17 and R20) from the LEDs' cathode to the CS pin of the controller.

With a technique similar to that of the current setting, the circuit senses the voltage [V<sub>in</sub> - V<sub>Led</sub>] that depends on the number of LEDs and corrects the voltage applied to the current sense pin.

In this way the circuit behaves as if the internal comparator triggers when the average current – instead of the peak current – exceeds the threshold value.

The drawback of this configuration is that since the circuit is now more sensitive to input voltage variations,  $V_{in}$  has to be more tightly regulated.

The following equations demonstrate what has been previously asserted.

**Equation 33**

$$I_{Led\_avg} = I_{Led\_pk} - \frac{1}{2} \left( \frac{toff}{L} \right) * VLed$$

**Equation 34**

$$I_{Led\_pk} = \left( \frac{1}{R_s} \right) * \left[ V_{th} * \left( \frac{R_a + R_b}{R_a} \right) - V_a * \left( \frac{R_b}{R_a} \right) \right]$$

Where:  $I_{Led\_avg}$  is the LEDs' average current,  $I_{Led\_pk}$  is the LEDs' peak current and  $V_a = (V_{in} - VLed)$  is the LEDs' cathode voltage.

**Equation 35**

$$I_{Led\_avg} = \left( \frac{1}{R_s} \right) * \left[ V_{th} * \left( \frac{R_a + R_b}{R_a} \right) - (V_{in} - VLed) * \left( \frac{R_b}{R_a} \right) \right] - \frac{1}{2} \left( \frac{toff}{L} \right) * VLed$$

**Equation 36**

$$I_{Led\_avg} = \left( \frac{1}{R_s} \right) * \left[ V_{th} * \left( \frac{R_a + R_b}{R_a} \right) - V_{in} * \left( \frac{R_b}{R_a} \right) \right] + VLed * \left[ \left( \frac{1}{R_s} \right) * \left( \frac{R_b}{R_a} \right) - \frac{1}{2} \left( \frac{toff}{L} \right) \right]$$

To make  $I_{Led\_avg}$  independent of  $VLed$ , the  $VLed$  coefficient has to be reduced to zero.

**Equation 37**

$$\frac{1}{R_s} * \left( \frac{R_b}{R_a} \right) - \frac{1}{2} \left( \frac{toff}{L} \right) = 0$$

That is to say, setting:

**Equation 38**

$$\left( \frac{R_b}{R_a} \right) = \frac{1}{2} \left( \frac{toff}{L/R_s} \right) = 0$$

reduces [Equation 36](#) to:

**Equation 39**

$$I_{Led\_avg} = \left( \frac{1}{R_s} \right) * \left[ V_{th} * \left( \frac{R_a + R_b}{R_a} \right) - (V_{in}) * \left( \frac{R_b}{R_a} \right) \right]$$

In other words, connecting  $R_a$  to the cathode of the LEDs' string, the average LED current depends only on  $V_{th}$  and  $V_{in}$ .



Going into further detail, we also have to consider the delay of the current sense comparator (tdel) and modify [Equation 33](#) as follows.

**Equation 40**

$$I_{\text{Led\_avg}} = I_{\text{Led\_pk}} - \frac{1}{2}I_{\text{rip}} + I_{\text{del}}$$

With:

**Equation 41**

$$I_{\text{del}} = \left(\frac{\text{tdel}}{L}\right) * (V_{\text{in}} - V_{\text{Led}})$$

**Equation 42**

$$I_{\text{Led\_avg}} = \left(\frac{1}{R_s}\right) * \left[ V_{\text{th}} * \left(\frac{R_a + R_b}{R_a}\right) - V_{\text{in}} * \left(\frac{R_b}{R_a}\right) \right] + V_{\text{in}} * \left(\frac{\text{tdel}}{L}\right) + V_{\text{Led}} * \left[ \left(\frac{1}{R_s}\right) * \left(\frac{R_b}{R_a}\right) - \frac{1}{2} \left(\frac{\text{toff}}{L}\right) \right] - V_{\text{Led}} * \left(\frac{\text{tdel}}{L}\right)$$

**Equation 43**

$$I_{\text{Led\_avg}} = \left(\frac{1}{R_s}\right) * \left[ V_{\text{th}} * \left(\frac{R_a + R_b}{R_a}\right) - V_{\text{in}} * \left[ \left(\frac{R_b}{R_a}\right) - \left(\frac{\text{tdel}}{L/R_s}\right) \right] \right] + V_{\text{Led}} * \left[ \left(\frac{1}{R_s}\right) * \left(\frac{R_b}{R_a}\right) - \frac{1}{2} \left(\frac{\text{toff}}{L}\right) - \left(\frac{\text{tdel}}{L}\right) \right]$$

And with [Equation 38](#) that now becomes:

**Equation 44**

$$\left(\frac{R_b}{R_a}\right) = \frac{1}{2} \left(\frac{\text{toff}}{L/R_s}\right) + \left(\frac{\text{tdel}}{L/R_s}\right)$$

And [Equation 40](#):

**Equation 45**

$$I_{\text{Led\_avg}} = \left(\frac{1}{R_s}\right) * \left[ V_{\text{th}} * \left(\frac{R_a + R_b}{R_a}\right) - V_{\text{in}} * \left[ \left(\frac{R_b}{R_a}\right) - \left(\frac{\text{tdel}}{L/R_s}\right) \right] \right]$$

With the values of our application:

**Equation 46**

$$\text{toff} = 1.57 \mu\text{S}, \text{tdel} = 0.2 \mu\text{S}, L = 470 \mu\text{H}, R_s = 2.8 \Omega$$

**Equation 47**

$$\left(\frac{L}{R_s}\right) = \left(\frac{470 * 10^{-6}}{2.8}\right) = (1.68 * 10^{-4}) \text{S}$$

**Equation 48**

$$\frac{1}{2}(\text{toff}) + (\text{tdel}) = (0.985 * 10^{-6}) \text{S}$$

And then:

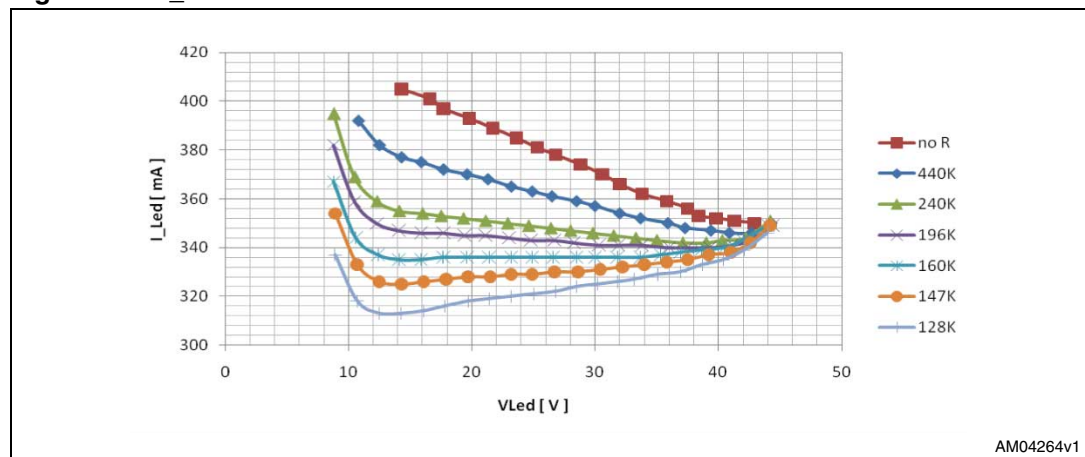
#### Equation 49

$$\left(\frac{R_a}{R_b}\right) = \frac{(1.68 * 10^{-4})}{(0.985 * 10^{-6})} = 170$$

On the demonstration board several measures have been taken with  $V_{in} = 48 \text{ V}$ , and  $R_b = 1 \text{ k}\Omega$ .

*Figure 13* is the plot of the LED current as a function of the voltage on the LED string ( $V_{Led}$ ) with  $R_a$  (actually  $R_{17} + R_{20}$ ) as a parameter.

**Figure 13.  $I_{Led}/V_{Led}$**



## 2.6 Shutdown/dimming

The  $D\_Dim$  input (pin 1 of the J1 connector) has a dual function.

- Module enable
- Digital (PWM) dimming

Forcing it low, or leaving it floating, enables the controller's normal activity (current sink), while pulling it high ( $> 2.7 \text{ V}$ ) causes the module to shut down. Therefore, this input can be used to switch the load on and off.

*Figure 14* and *Figure 15* highlight the turn-on and turn-off with an input voltage ( $V_{in}$ ) of  $48 \text{ V}$  and an equivalent output voltage ( $V_{Led}$ ) of  $20 \text{ V}$ . In these conditions, the rise and fall times of the load current are lower than  $10 \mu\text{s}$ .

Applying a square wave to this pin forces the module to 'work and stop' at the input signal frequency; in this way the average load current can be modified by simply changing the duty cycle of the PWM control.

Supposing a dimming frequency of  $200 \text{ Hz}$  is used, and taking into account the  $10 \mu\text{s}$  of rise/fall time of the LED current, we can estimate the minimum dimming as  $(20 \mu\text{s}) * (200 \text{ Hz}) = 0.4\%$ .

*Figure 16*, *17*, *18*, *19*, and *20* show the LED current for different dimming factors between 1% and 99%.

Note: *R1 = 10 kΩ, C9 = 100 pF, and D1= 5.6 V Zener diode. All these devices have been introduced to protect the controller from excessive input voltages or noise; in a complete system, with a driver directly connected, they can be avoided.*

Figure 14. Enable/dimming detailed view (turn-on)

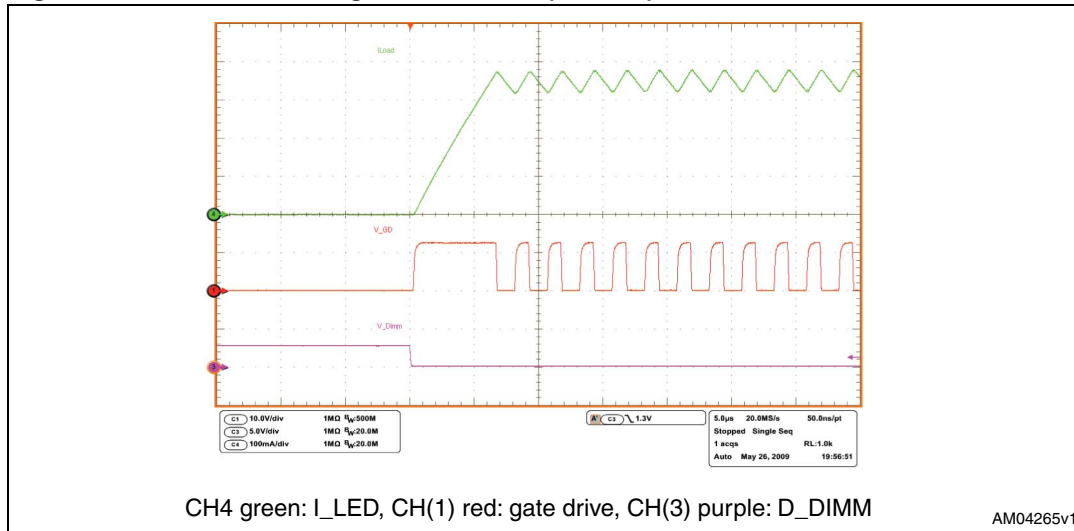


Figure 15. Enable/dimming detailed view (turn-off)

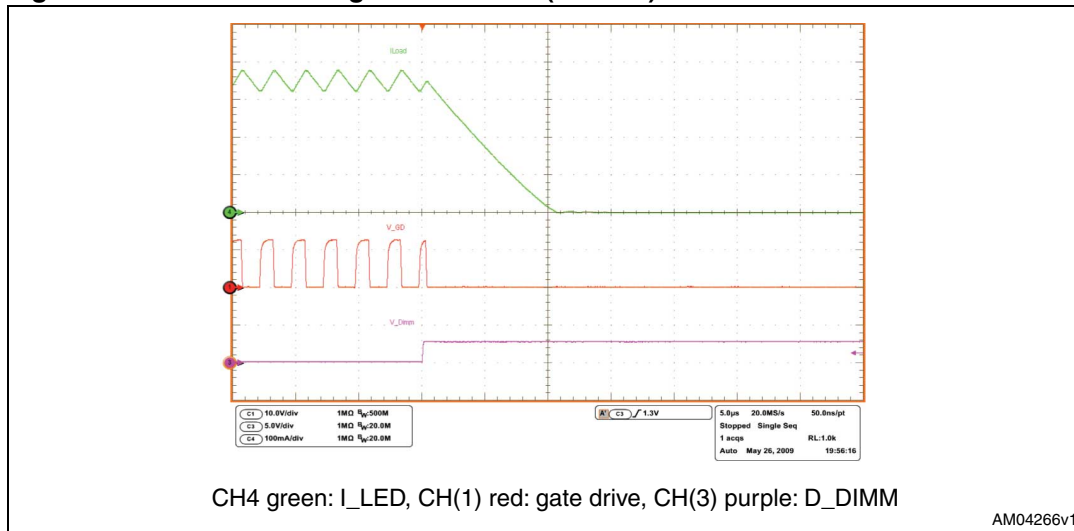


Figure 16. Dimming 1%

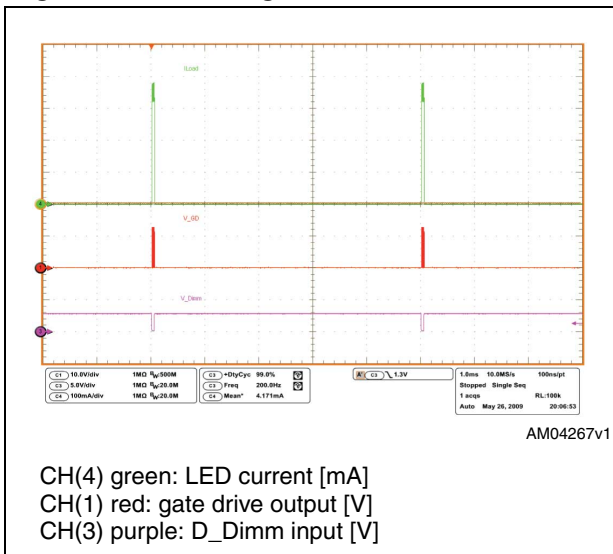


Figure 17. Dimming 10%

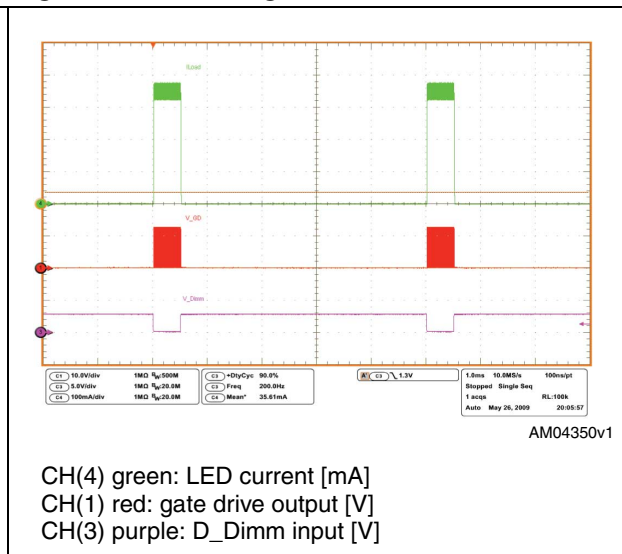


Figure 18. Dimming 50%

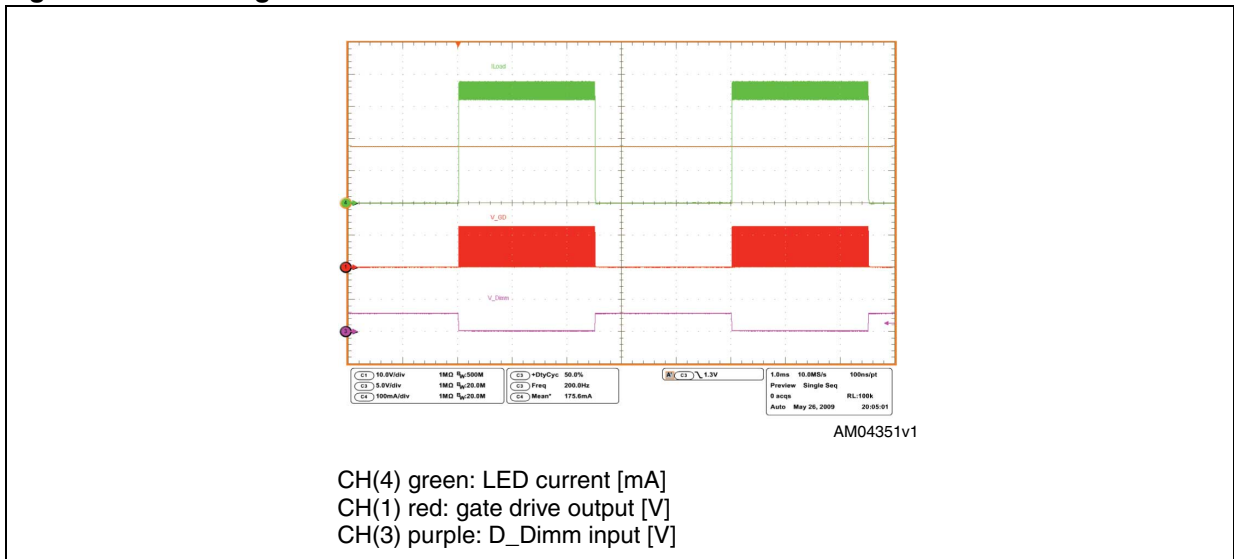


Figure 19. Dimming 90%

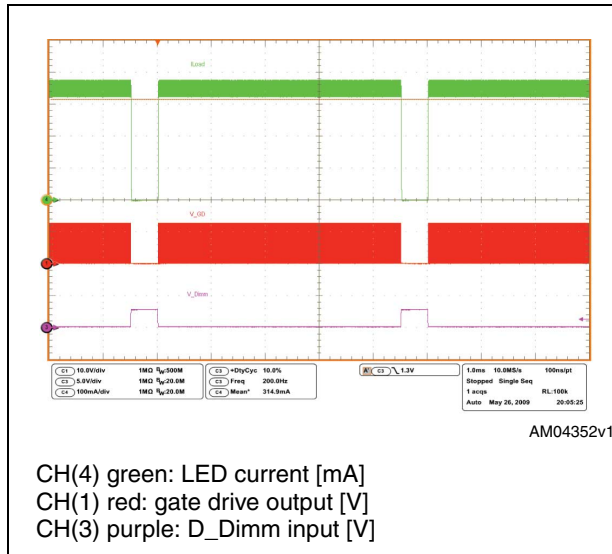
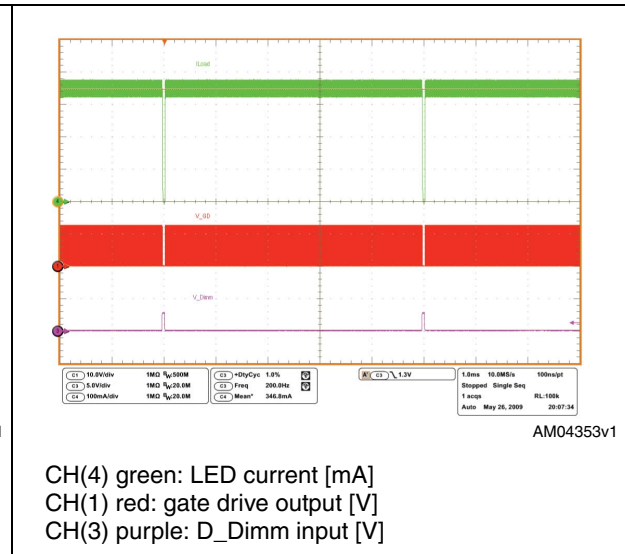


Figure 20. Dimming 99%



## 2.7 Auxiliary power

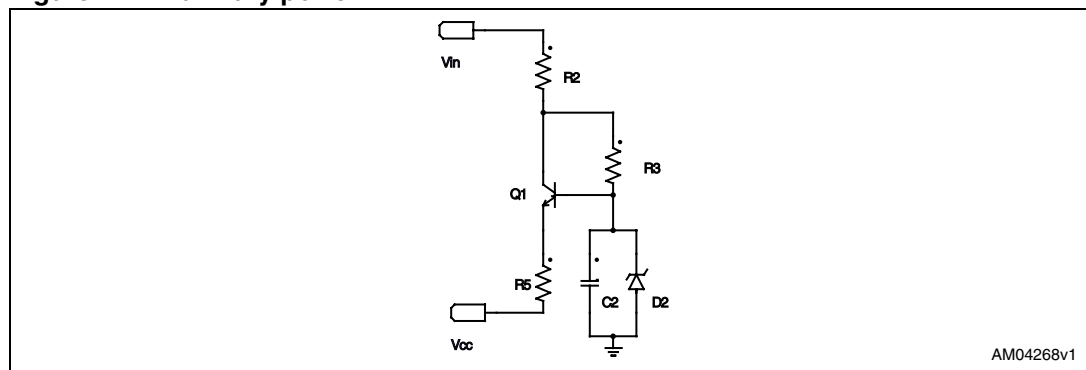
The components for the auxiliary power supply are Q1, D2, C2, R2, R3, and R5.

This section is included as a commodity to reduce the main voltage (48 V nominal) to the 18 V required from the Vcc input of the L6562A controller, thus avoiding the use of another power supply. It has been designed to work with input voltages in the range of 33 to 65 V, but can be easily resized for different ranges.

Note that it is a linear regulator and that its efficiency is not very good. For this reason, in real applications where multiple modules are employed, it is better to consider a solution with an external supply common to all the modules.

Simply removing R2 and R5 disconnects the entire block and allows the power supply (Vcc) to be provided from pin 5 of the header connector.

Figure 21. Auxiliary power





resistor, Q3 turns off allowing C5 to charge through R6, and the voltage of the INV pin rises again. When it reaches 0.45 V the disable condition is removed and the controller restarts.

If the short-circuit condition is removed, the circuit restores its normal functionality. If the short-circuit condition persists, the hiccup cycle is repeated.

Figure 23. Short-circuit application

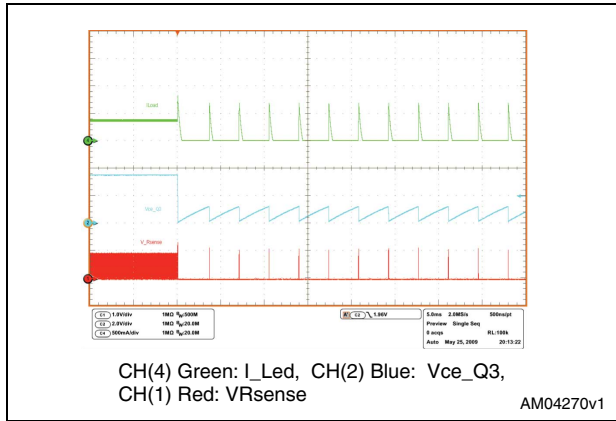


Figure 24. Short-circuit removal

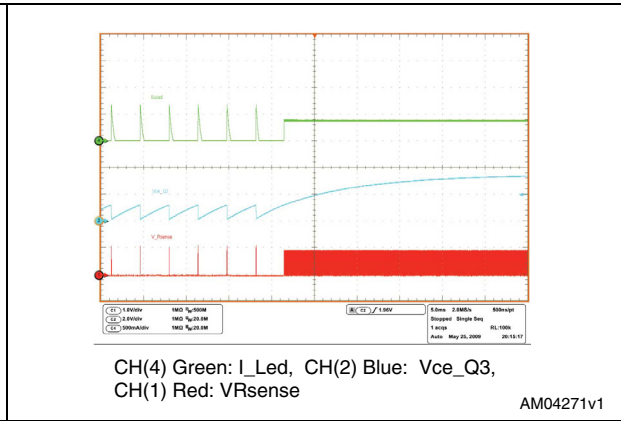


Figure 25. Short-circuit detection

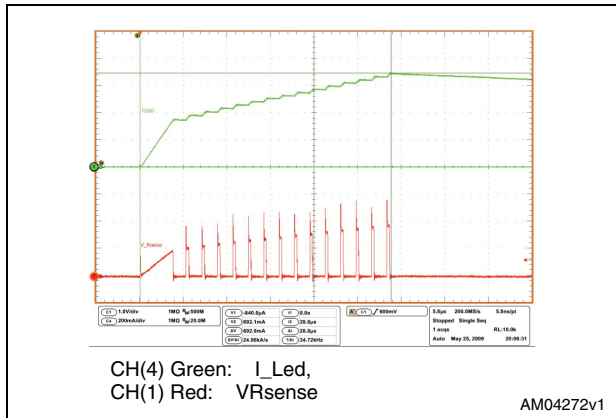
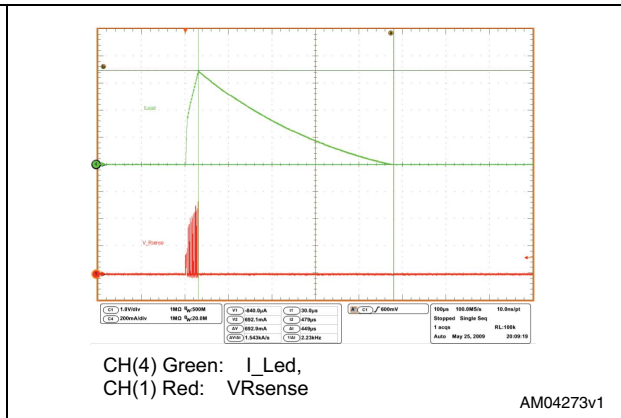


Figure 26. Load current decay

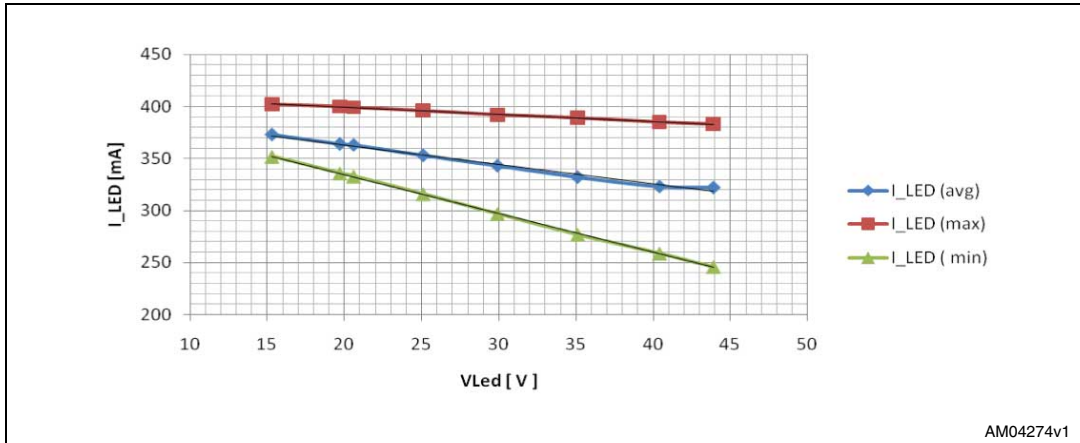


### 3 Measurements

#### 3.1 LED voltage dependency

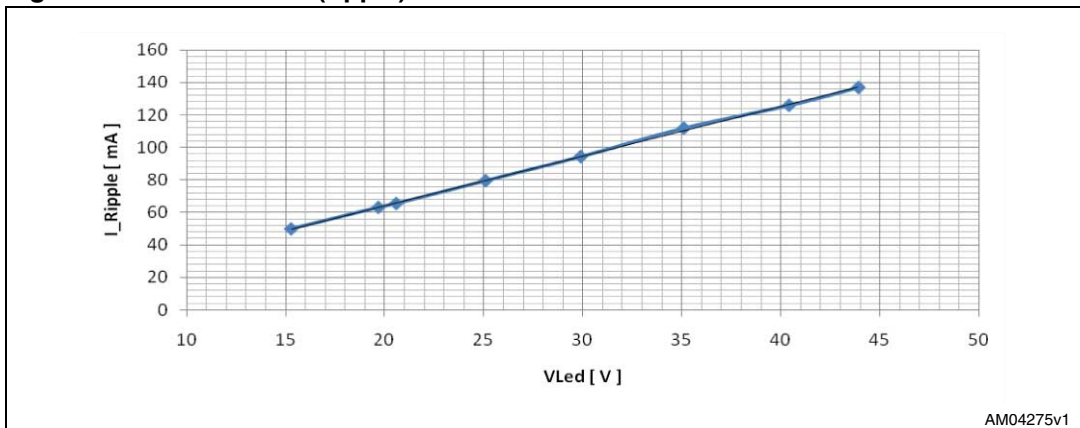
The first set of measures was taken at a nominal input voltage with  $V_{in} = 48\text{ V}$  and with the output voltage ( $V_{led}$ ) as a parameter.

**Figure 27. LED current (average, maximum, minimum)**



AM04274v1

**Figure 28. LED current (ripple)**



AM04275v1



Figure 29. Switching frequency

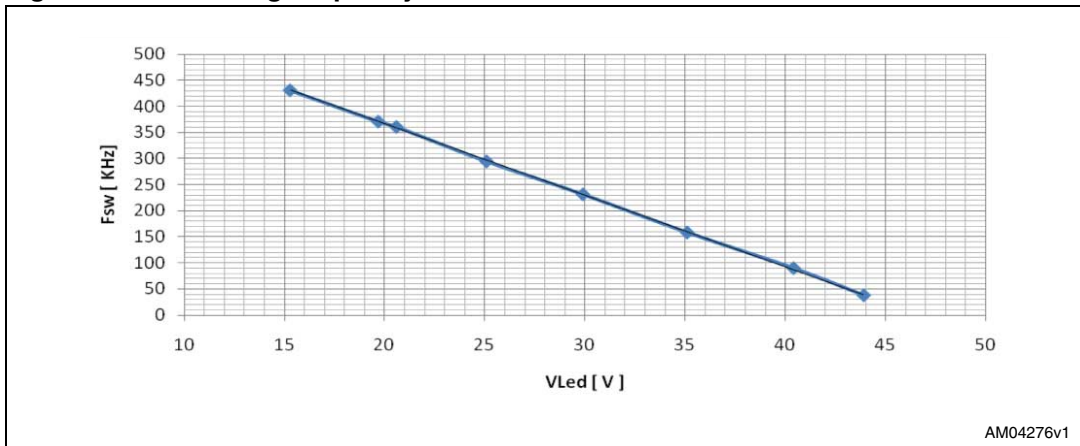
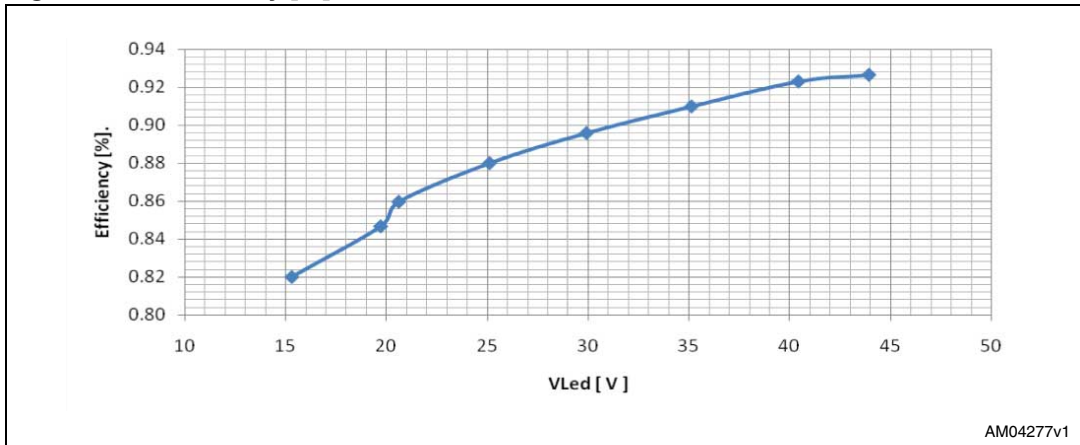


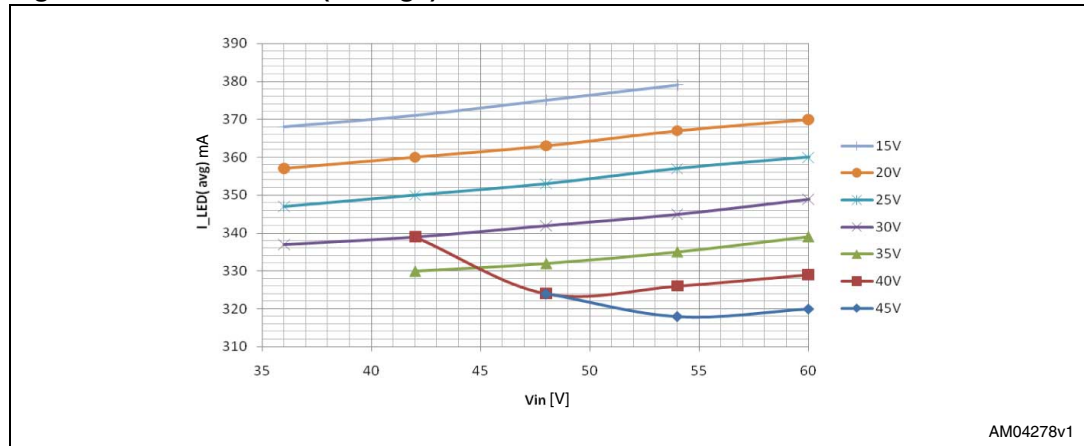
Figure 30. Efficiency [%]



### 3.2 Input voltage dependency

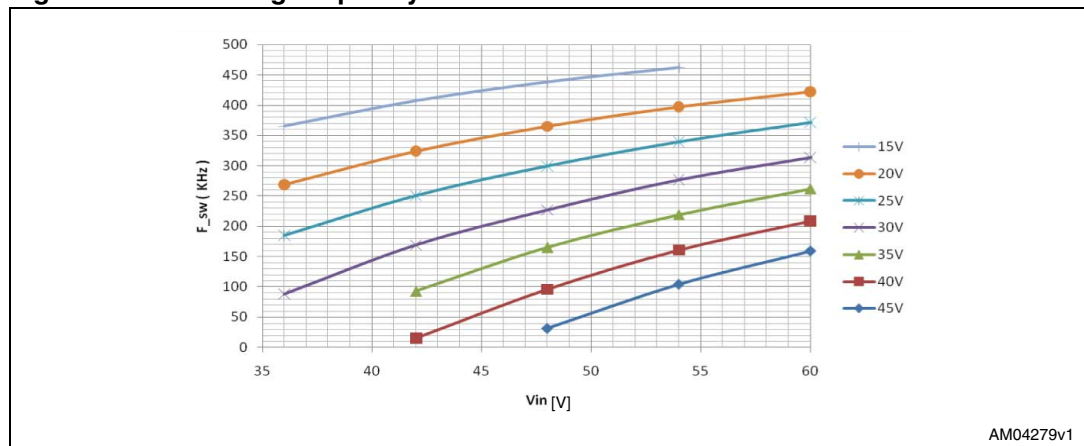
A second set of measures was taken varying the input voltage from 36 to 60 V with several load conditions as parameters (VLed from 15 to 45 V).

Figure 31. LED current (average)



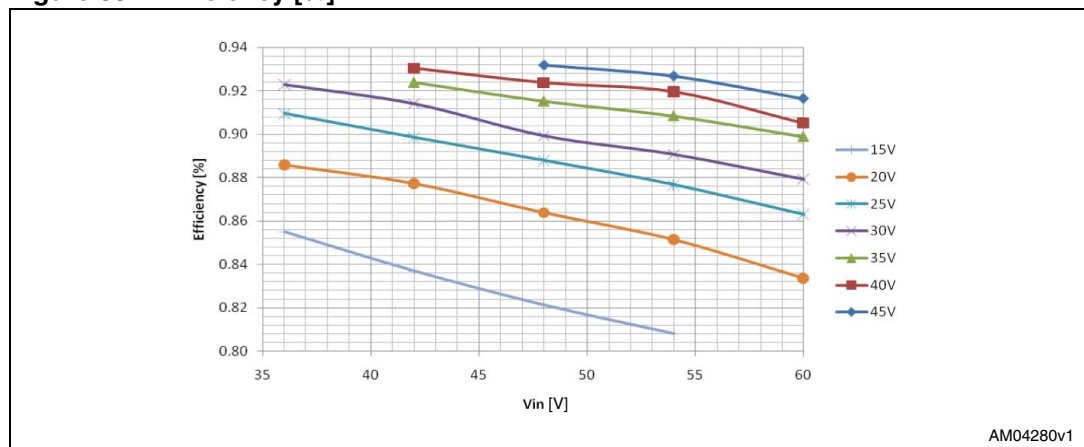
AM04278v1

Figure 32. Switching frequency



AM04279v1

Figure 33. Efficiency [%]



AM04280v1

# 4 Electrical schematic and bill of materials

Figure 34. EVL6562A-LED electrical schematic

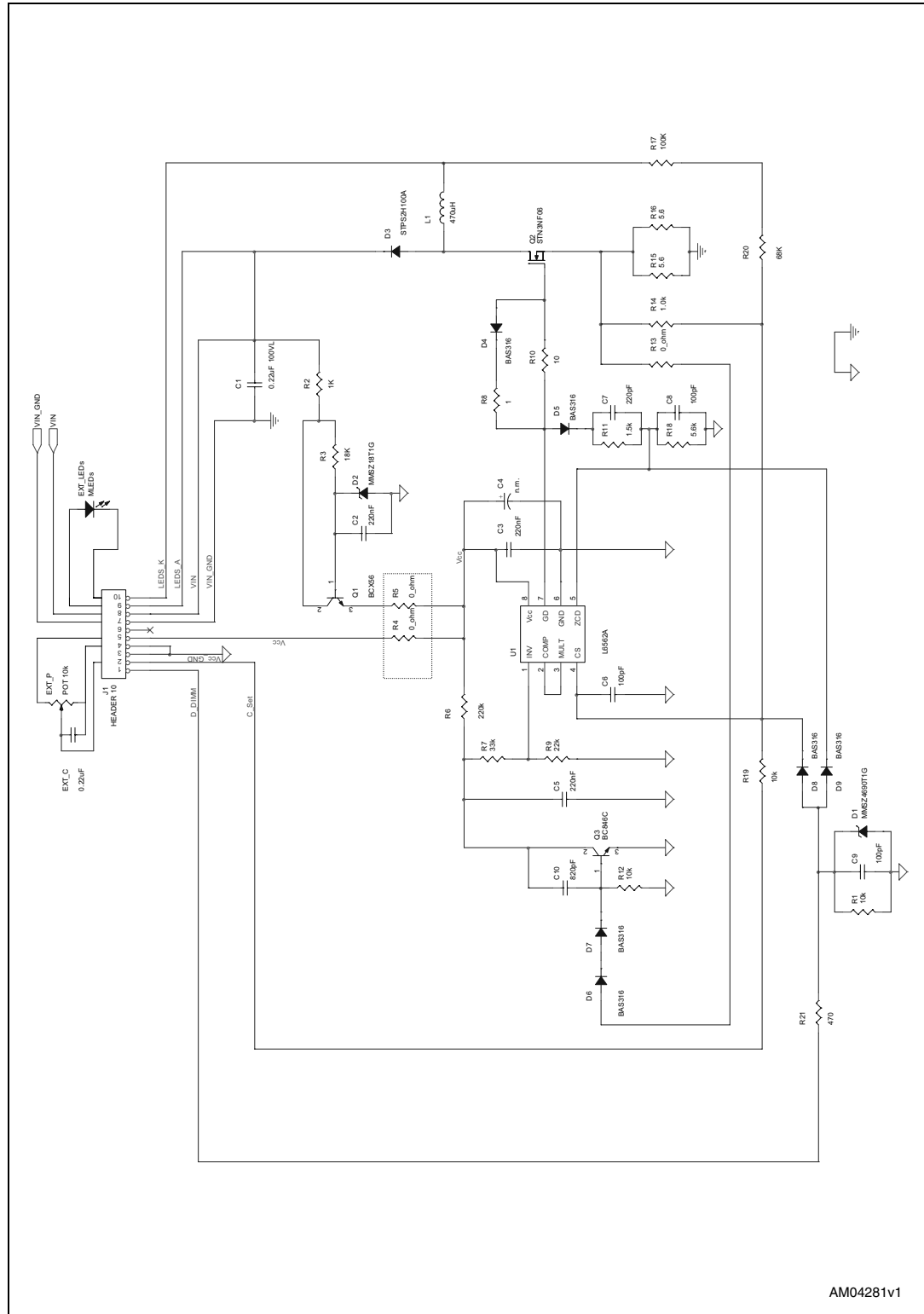


Table 2. EVL6562A-LED BOM

Item	Qty	Reference	Part	PCB footprint	Notes
1	1	C1	0.22 $\mu$ F 100VL	1812	
2	3	C2,C3,C5	220 nF	805	
3	1	C4	<i>Not mounted</i>		
4	3	C6,C8,C9	100 pF	805	
5	1	C7	220 pF	805	
6	1	C10	820 pF		
7	1	D1	MMSZ4690T1G	SOD-123	
8	1	D2	MMSZ18T1G	SOD-123	
9	1	D3	STPS2H100A	SMA	STMicroelectronics
10	6	D4,D5,D6,D7, D8,D9	BAS316	SOD-323	
11	1	EXT C	0.22 $\mu$ F		External jig
12	1	EXT LEDs	MLEDs		LEDs string
13	1	EXT P	POT 10 k $\Omega$ multitrans		External jig
14	1	J1	Strip header, 10-pin, 90°, 2.54 mm pitch		
15	1	L1	470 $\mu$ H		Coilcraft MMS1260-474KLB
16	1	Q1	BCX56	SOT-89	
17	1	Q2	STN3NF06	SOT-223	STMicroelectronics
18	1	Q3	BC846C	SOT-23	
19	3	R1,R12,R19	10 k $\Omega$	805	
20	1	R2	1 k $\Omega$	1206	
21	1	R3	18 k $\Omega$	1206	
22	3	R4,R5,R13	0 $\Omega$	805	
23	1	R6	220 k $\Omega$	805	
24	1	R7	33 k $\Omega$	805	
25	1	R8	1 $\Omega$	805	
26	1	R9	22 k $\Omega$	805	
27	1	R10	10 $\Omega$	805	
28	1	R11	1.5 k $\Omega$	805	
29	1	R14	1.0 k $\Omega$	805	
30	2	R15,R16	5.6 $\Omega$	1210	
31	1	R17	100 k $\Omega$	805	
32	1	R18	5.6 k $\Omega$	805	
33	1	R20	68 k $\Omega$	805	

**Table 2. EVL6562A-LED BOM (continued)**

Item	Qty	Reference	Part	PCB footprint	Notes
34	1	R21	470	805	
35	1	U1	L6562A	SO-8	STMicroelectronics

## 5 References

1. AN2928
2. AN2782
3. L6562A datasheet

*Note:* These references are available on the STMicroelectronics web site at [www.st.com](http://www.st.com).

## 6 Revision history

**Table 3. Document revision history**

Date	Revision	Changes
16-Dec-2009	1	Initial release.

**Please Read Carefully:**

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

**UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.**

**UNLESS EXPRESSLY APPROVED IN WRITING BY AN AUTHORIZED ST REPRESENTATIVE, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.**

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2009 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Philippines - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

[www.st.com](http://www.st.com)



## X-ON Electronics

Largest Supplier of Electrical and Electronic Components

*Click to view similar products for [Power Management IC Development Tools](#) category:*

*Click to view products by [STMicroelectronics](#) manufacturer:*

Other Similar products are found below :

[EVAL-ADM1168LQEBZ](#) [EVB-EP5348UI](#) [MIC23451-AAAYFL EV](#) [MIC5281YMME EV](#) [DA9063-EVAL](#) [ADP122-3.3-EVALZ](#) [ADP130-0.8-EVALZ](#) [ADP130-1.2-EVALZ](#) [ADP130-1.5-EVALZ](#) [ADP130-1.8-EVALZ](#) [ADP1712-3.3-EVALZ](#) [ADP1714-3.3-EVALZ](#) [ADP1715-3.3-EVALZ](#) [ADP1716-2.5-EVALZ](#) [ADP1740-1.5-EVALZ](#) [ADP1752-1.5-EVALZ](#) [ADP1828LC-EVALZ](#) [ADP1870-0.3-EVALZ](#) [ADP1871-0.6-EVALZ](#) [ADP1873-0.6-EVALZ](#) [ADP1874-0.3-EVALZ](#) [ADP1882-1.0-EVALZ](#) [ADP199CB-EVALZ](#) [ADP2102-1.25-EVALZ](#) [ADP2102-1.875EVALZ](#) [ADP2102-1.8-EVALZ](#) [ADP2102-2-EVALZ](#) [ADP2102-3-EVALZ](#) [ADP2102-4-EVALZ](#) [ADP2106-1.8-EVALZ](#) [ADP2147CB-110EVALZ](#) [AS3606-DB](#) [BQ24010EVM](#) [BQ24075TEVM](#) [BQ24155EVM](#) [BQ24157EVM-697](#) [BQ24160EVM-742](#) [BQ24296MEVM-655](#) [BQ25010EVM](#) [BQ3055EVM](#) [NCV891330PD50GEVB](#) [ISLUSBI2CKIT1Z](#) [LM2744EVAL](#) [LM2854EVAL](#) [LM3658SD-AEV/NOPB](#) [LM3658SDEV/NOPB](#) [LM3691TL-1.8EV/NOPB](#) [LM4510SDEV/NOPB](#) [LM5033SD-EVAL](#) [LP38512TS-1.8EV](#)