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75-W Continuous Conduction Mode (CCM) Buck LED Driver

Wide Analog Dimming and Precise LED Current Regulation

TND6339/D

ON Semiconductor®

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REFERENCE DESIGN

Introduction

This Reference Design includes specifications, testing, typical operating characteristics, and construction of reference design, based on the NCL35076 Continuous Conduction Mode (CCM) Buck controller. The Reference Design for 75−W performs accurate LED current regulation and wide analog dimming range.

Table 1. SPECIFICATION FOR REFERENCE DESIGN

Description		Symbol	Value	Comments
Input Voltage		V_{IN}	60 V_{DC}	60 V_{DC} or PFC Output voltage
Output	Current	$I_{OUT.MAX}$	1500 mA	
		$I_{OUT.MIN}$	< 4.2 mA	~0.2% dimming level
	Voltage	$V_{OUT.MIN}$	10 V	
		$V_{OUT.MAX}$	50 V	
Maximum Output Power		$P_{OUT.MAX}$	75 W	Condition: V_{OUT} 50 V, I_{OUT} 1500 mA
CC Tolerance in wide V_{OUT}: Calculated by 300 dimming curves (100 pcs boards × 10/30/50 V_{OUT})		$CC_{100\%}$	±1.5%	Dimming Range: 0.2%~100% Ambient Temperature: 25°C
		$CC_{10\%}$	±3%	
		$CC_{1\%}$	±9%	
CC Tolerance at single V_{OUT}: Calculated by 100 dimming curves (100 pcs boards × 10 V_{OUT}, worst case)		$CC_{100V-100\%}$	±1%	Dimming Range: 0.2%~100% Ambient Temperature: 25°C
		$CC_{100V-10\%}$	±1.5%	
		$CC_{100V-1\%}$	±7%	
System Efficiency		$Eff._{50V}$	97.50%	V_{OUT}: 50 V I_{LED}: 1500 mA, External VDD supply
		$Eff._{30V}$	96.10%	V_{OUT}: 30 V I_{LED}: 1500 mA, External VDD supply
		$Eff._{10V}$	91.00%	V_{OUT}: 10 V I_{LED}: 1500 mA, External VDD supply
PCB Size			36 × 30 mm	System Size Without IN/OUT Connector

Key Features

- Wide Analog Dimming Range: 0.2~100%
- Excellent CC Tolerance:
  - ±3% in 10~100% Load
  - ±9% at 1% Load
- Low System BOM
- LED Off Mode at Standby
- PWM Dimming Available
- Robust Protection Features
  - LED Short Protection
  - Over Current Protection
  - Thermal Shutdown
  - VDD Over Voltage Protection

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NCL35076LED1GEVB PHOTOGRAPHS

(System Dimensions: 36 mm (L) × 30 mm (W))

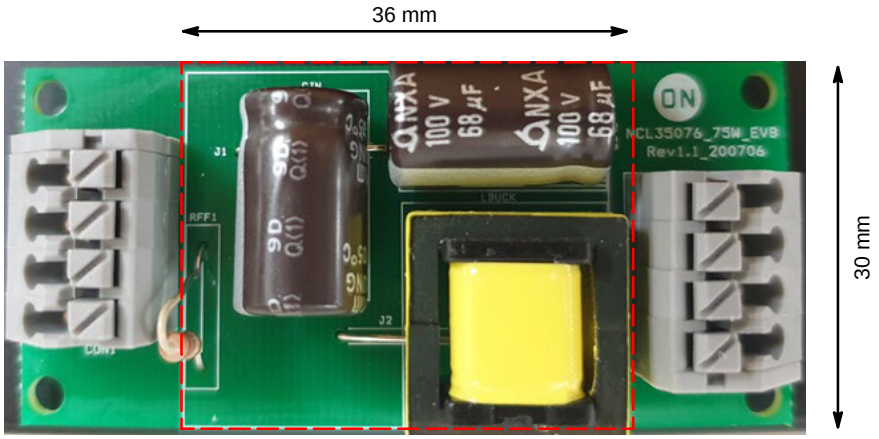


Figure 1. Top View

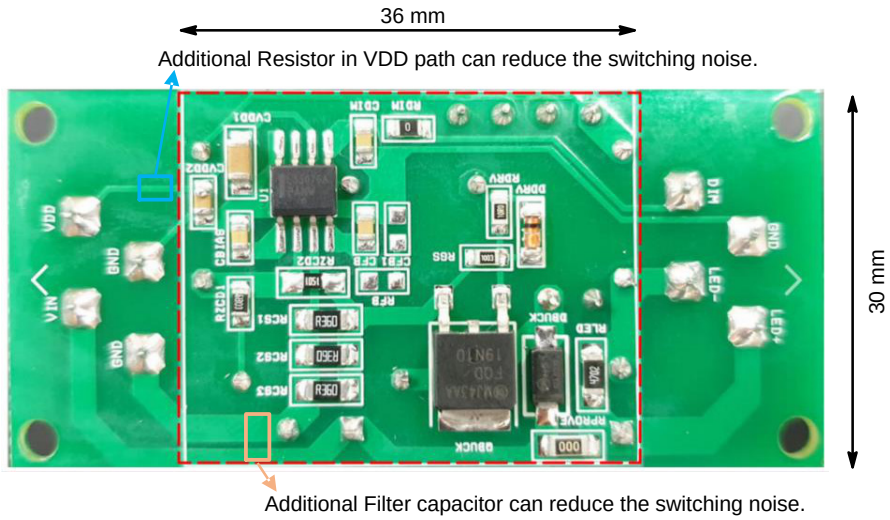


Figure 2. Bottom View

NCL35076LED1GEVB GERBER VIEW

(PCB Outline: 65 mm (L) × 30 mm (W), FR−4, Thickness 1.6T)

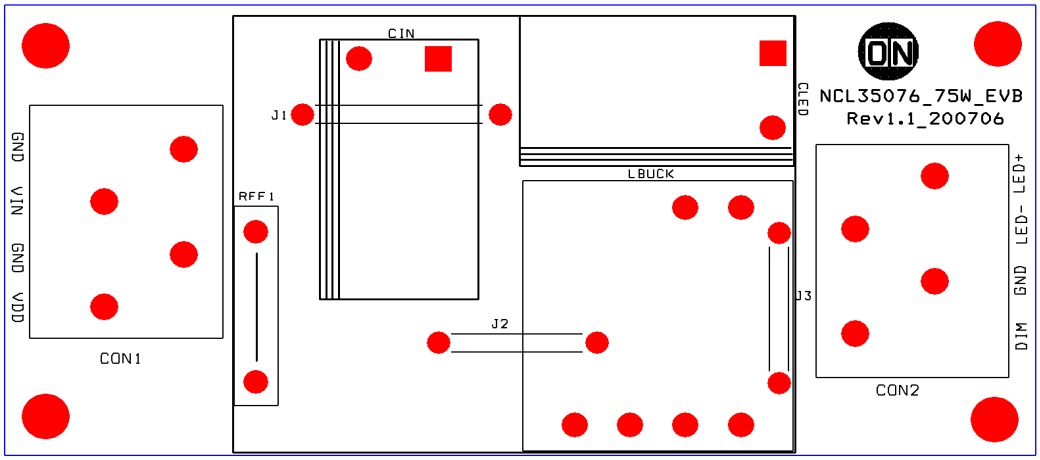


Figure 3. Top View

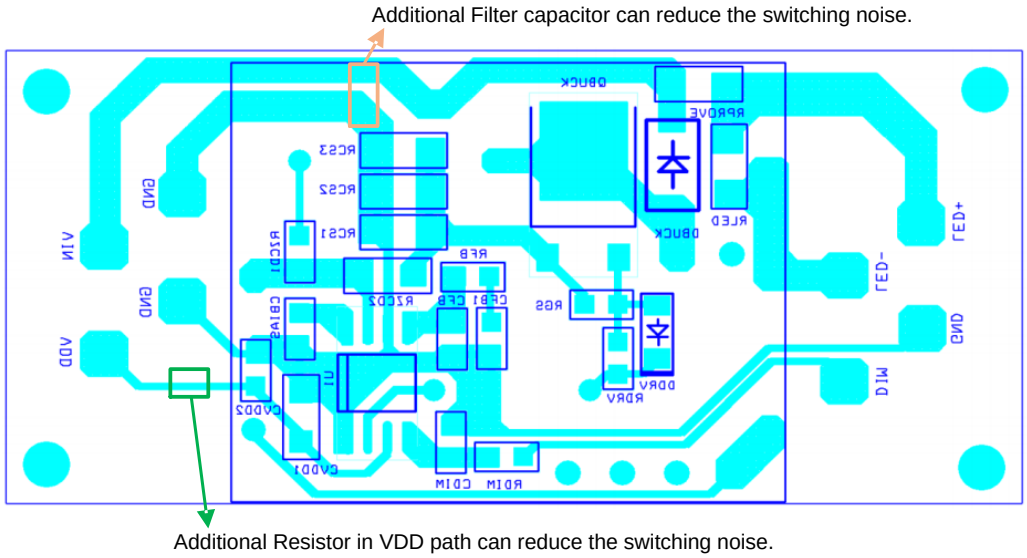
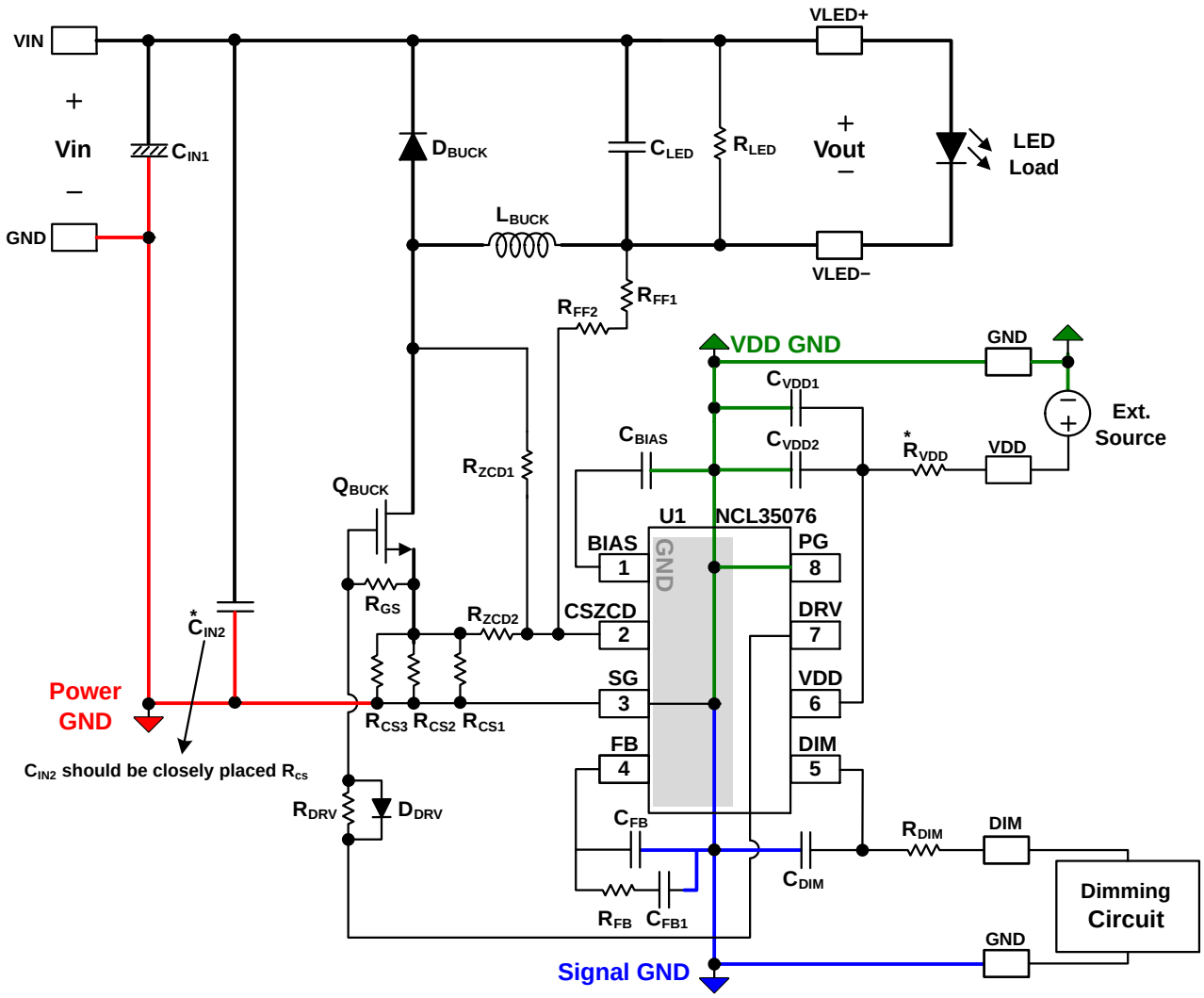


Figure 4. Bottom View

NCL35076LED1GEVB SCHEMATIC



* R_{VDD} and C_{IN2} must be added for improving switching noise immunity. (not applied in demo board)

Figure 5. Schematic for 75−W Design Reference

BILL OF MATERIAL FOR THE NCL35076LED1GEVB

Table 2. BILL OF MATERIAL FOR NCL35076LED1GEVB

Designator	Qty.	Description	Value	Footprint	Manufacturer	Part Number
U1	1	CCM Buck Controller	NCL35076	SOIC−8	ON Semiconductor	NCL50076
CIN, CLED	2	Electrolytic Capacitor	100 V/68 μF	10 × 16 mm	Samyoung	NXA series
LBUCK	1	Inductor	150 μH (0.45 pi, 54 turns)	EE16H 8pin Bobbin	SAMHO	
DBUCK	1	Schottky Rectifier	100 V/5 A	SMA−FL	ON Semiconductor	NTSAF5100T3G
QBUCK	1	N−Channel MOSFET	100 V 15.6 A, 63 mΩ	D−PAK	ON Semiconductor	FQD19N10
RFF1	2	Resistor Axial (±5%)	22 MΩ	Axial	Stackpole Electronics Inc	PCF14JT22M0
RCS1, RCS2, RCS3	3	Resistor SMD (±1%)	0.36 Ω	3216F	Yageo	RL1206FR−070R36L
RLED	1	Resistor SMD (±1%)	47 kΩ	3216	Yageo	
RZCD1	1	Resistor SMD (±1%)	680 kΩ	2012	Yageo	
RZCD2	1	Resistor SMD (±1%)	1.5 kΩ	2012	Yageo	
RFB	0	N.C				
RDIM	1	Resistor SMD (±1%)	0 Ω	2012	Yageo	
RDRV	1	Resistor SMD (±1%)	10 Ω	2012	Yageo	
RGS	1	Resistor SMD (±1%)	100 kΩ	2012	Yageo	
RPROVE	1	Resistor SMD (±1%) (For Inductor Current measurement)	0 Ω	3216	Yageo	
DDRV	1	Small Signal Diode	100 V/0.2 A	SOD80	ON Semiconductor	LL4148
CVDD1	1	MLCC X7R capacitor (±10%)	50 V/10 μF	3216	TDK	
CVDD2	1	MLCC X7R capacitor (±10%)	100 nF	2012	TDK	
CBIAS	1	MLCC X7R capacitor (±10%)	1 nF	2012	TDK	
CFB	1	MLCC X7R capacitor (±10%)	10 nF	2012	TDK	
CFB1	0	N.C				
CDIM	1	MLCC X7R capacitor (±10%)	1 nF	2012	TDK	
J1, J2, J3	3	Jumper Wire	Short	Axial	ANY	
CON1, CON2	2	IN/OUT Connector	4Pin	Pitch 3.5 mm	CUI Devices	TBL002A−350−04GY−2GY
PCB	1	FR−4, 1.6T, 65 mm (L) × 30 mm (W)	Single Layer PCB			

BUCK INDUCTOR DESIGN SPECIFICATION

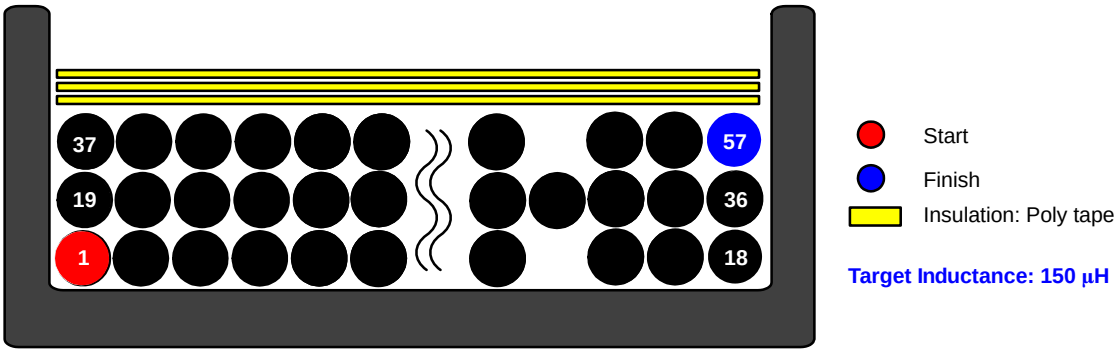


Figure 6. Buck Inductor (L_{BUCK}) Winding Structure

Table 3. BUCK INDUCTOR WINDING SPECIFICATIONS

No.	Winding	Pin (S → F)	Wire	Turns	Winding Layer
1	N_1	2→ 8	UEW 0.45φ	54 Ts	3−layer
2	Insulation: Polyester Tape t = 0.025 mm, 3−Layer				

SYSTEM TEST PROCEDURE

Table 4. NCL35076LED1GEVB TEST CONDITION AND EQUIPMENT LIST

Ambient Temperature	T_A = 25°C
Test Equipment	DC Power Source (V_{IN}): PCR500L by Kikusui Power Analyzer: PZ4000000 by Yokogawa Output Load: 100 V/200 V/300 V LED load Multi Meter: 8808A by FLUK, 34401A by Agilent Oscilloscope: 104Xi by LeCroy Thermometer: Thermal CAM T620 by FLIR SYSTEMS

The NCL35076 75−W Reference Board connection is shown the below figure.

Supply the Dimming signal and External V_{DD} source after applying V_{IN}.

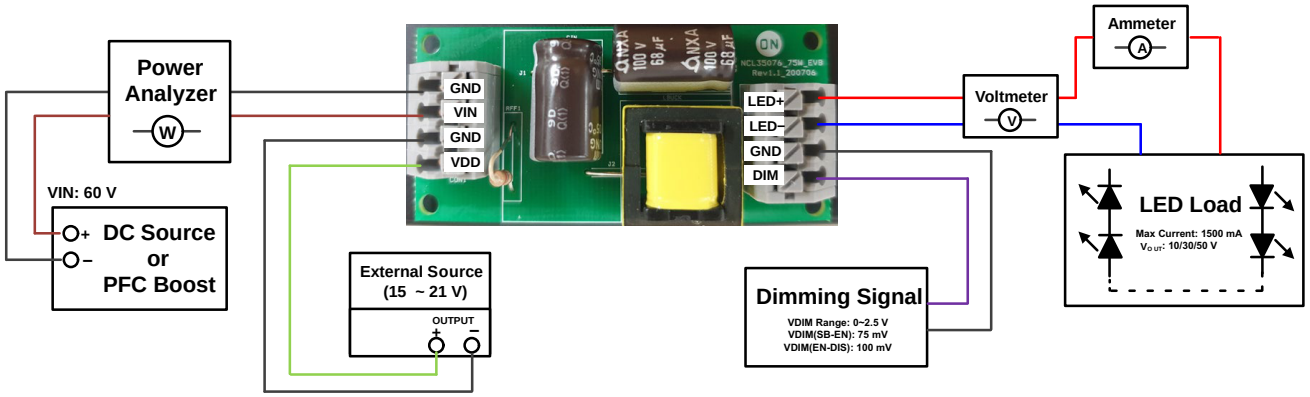


Figure 7. NCL35076LED1GEVB Test Set up Configuration

SYSTEM PERFORMANCE

Figure 8. shows dimming curve linearity and Constant Current (CC) tolerance of 100pcs system boards. The test condition is variable output voltage (10, 30, 50 V) in 60 V_{DC} input and dimming range is 100% to 0%. The dimming ratio is calculated by (VDIM−0.25)/2.25 *100 [%].

As a result, total CC tolerance in the wide output condition is ±1.5% at 100% load and ±9% at 1% load. In the single output condition, CC tolerance is ±1.5% at 100% load and ±7% at 1% load.

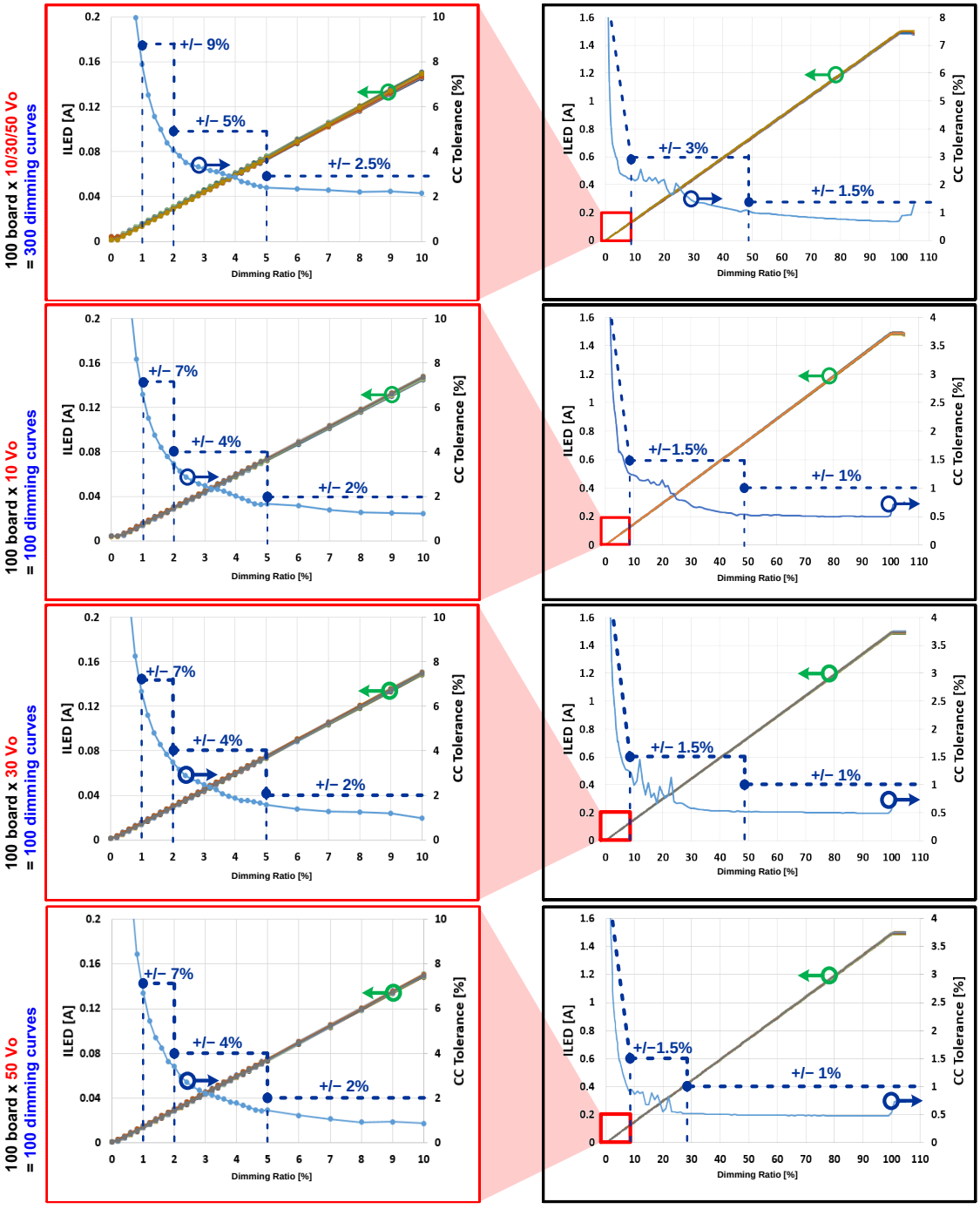


Figure 8. NCL35076LED1GEVB Dimming Curve and CC Tolerance

Start−up

NCL35076 starts up with soft start function to smoothly set the LED current at a steady state level without overshoot. At full load condition, startup time is 70 ms with no overshoot as shown in Figure 9.

1. T_{OFF} is reduced from 1300 μs ($T_{OFF.MAX}$) in Fast SS by Internal Soft start counter.
2. Slow SS starts when there is no ZCD in CCM.
3. When internally calculated LED current is close to a reference level, V_{FB} start to find a steady state level.
4. V_{FB} is settled to a steady state level. T_{OFF} is set by FB signal in CCM.

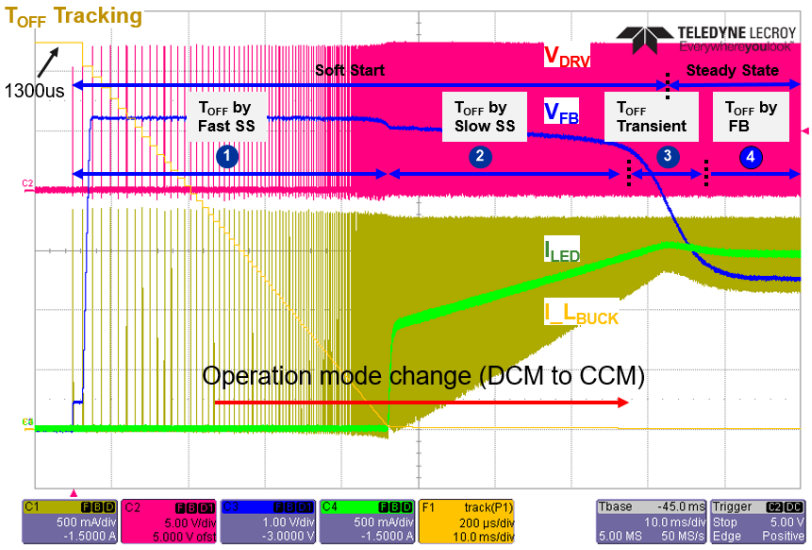


Figure 9. Startup Operation (Condition: 50 V_{OUT}, 1500 mA, V_{DIM} 2.5 V)

Steady State

The NCL35076 operates in multi−mode between CCM and DCM according to the dimming condition.

The multi−mode operation provides low LED current ripple with small output capacitor by CCM at heavy load and deep analog dimming by DCM at light load.

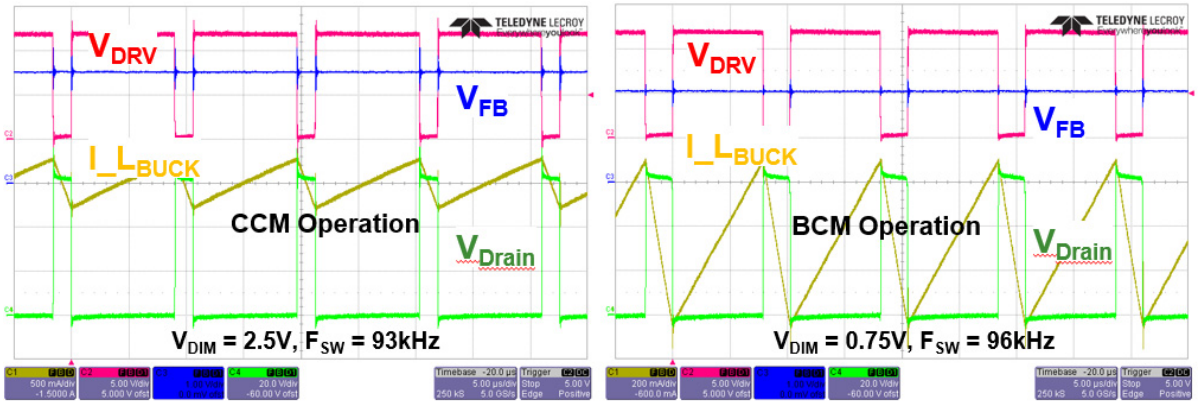


Figure 10. Steady−state CCM/BCM Operation (V_{OUT}: 50 V)

NCL35076 entered DCM operation mode at light load condition. When V_{DIM} is lower than 0.2 V, internal reference is set to 0 V and V_{FB} is pulled down 0.5 V clamping voltage. In this period, the LED current is under open loop control and T_{OFF} is set by $T_{OFF.MAX}$ (1300 μs).

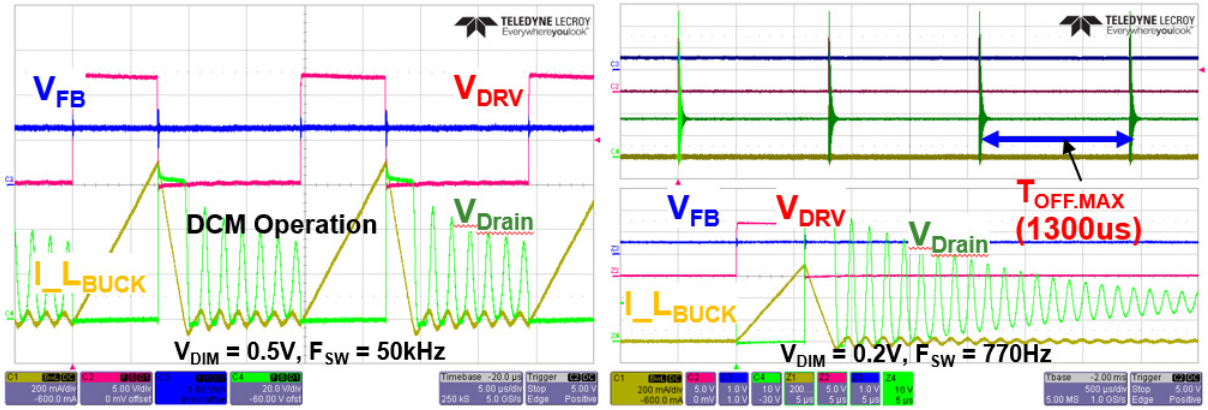


Figure 11. Steady−state DCM Operation (V_{OUT}: 50 V)

Standby Mode

When V_{DIM} is lower than a standby threshold voltage ($V_{DIM(SB-EN)}$) for 10 ms, Standby mode is triggered with LED turn−off and IC operating current is minimized. When V_{DIM} is higher than a standby disable threshold voltage ($V_{DIM(SB-DIS)}$), Standby mode is immediately terminated.

Table 5. NCL35076 STANDBY MODE SPECIFICATION

Parameter	Symbol	Min	Typ	Max	Unit
Standby Enabling DIM Voltage	$V_{DIM(SB-ENA)}$	50	75	100	mV
Standby Disabling DIM Voltage	$V_{DIM(SB-DIS)}$	50	100	150	mV
Standby Delay Time	$t_{SB(DELAY)}$	9	10	11	ms

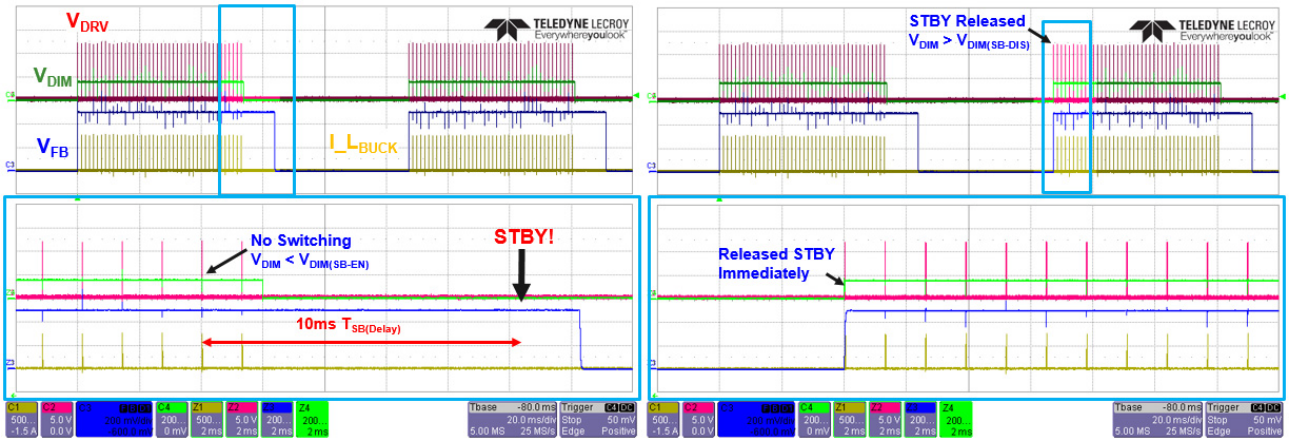


Figure 12. Standby Mode Operation (V_{OUT}: 50 V, V_{DIM}: Rectangular Pulse 0/150 mV)

Protection – Over Current Protection (OCP)

When CSZCD voltage exceeds the over current threshold voltage ($V_{CS(OCP)}$) in the short circuit condition of the freewheeling diode (D_{BUCK}), the controller is immediately shut down after leading edge blanking time. After auto recovery time 1 second, startup sequence reinitiates. This behavior lasts until the fault condition is removed.

Table 6. NCL35076 OCP SPECIFICATION

Parameter	Symbol	Min	Typ	Max	Unit
CS Over Current Protection Threshold	$V_{CS(OCP)}$	0.4	0.5	0.6	V
Auto Restart Time at Protection	$t_{AR(PROT)}$	0.9	1	1.1	s

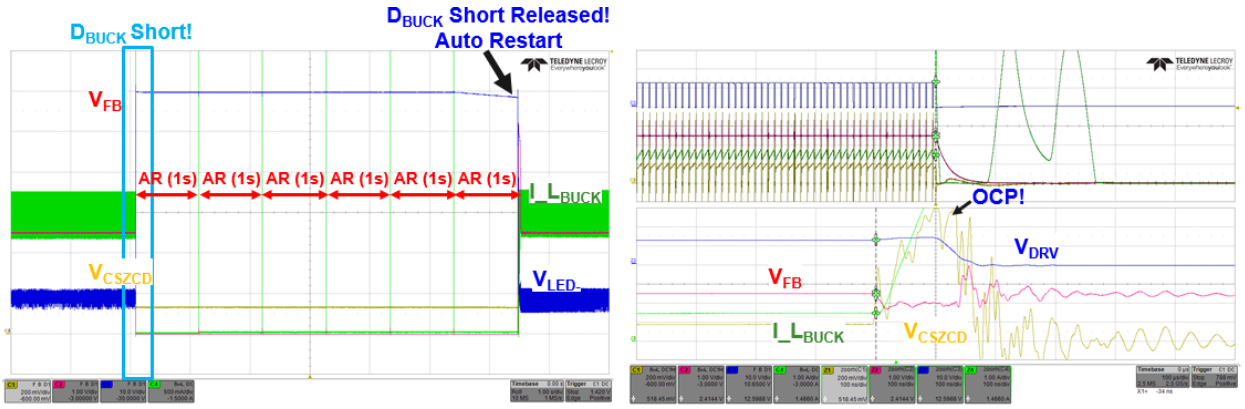


Figure 13. Over Current Protection (OCP)
(DBUCK Short and Released at Max Load: 50 V_{OUT}, 1500 mA, V_{DIM} 2.5 V)

Protection – LED Short Protection (SLP)

When LED is short−circuited, the NCL35076 operates in CCM with maximum turn−off time. If CCM and $t_{OFF(MAX)}$ are detected for SLP monitoring time (20 ms), SLP is triggered. Figure 14 shows Short LED Protection performance at 20% load condition (V_{OUT}: 10 V, I_{LED}: 1500 mA). In order to prevent unexpected SLP triggered at startup, SLP monitoring is disabled for 12 ms after 1st switching begins.

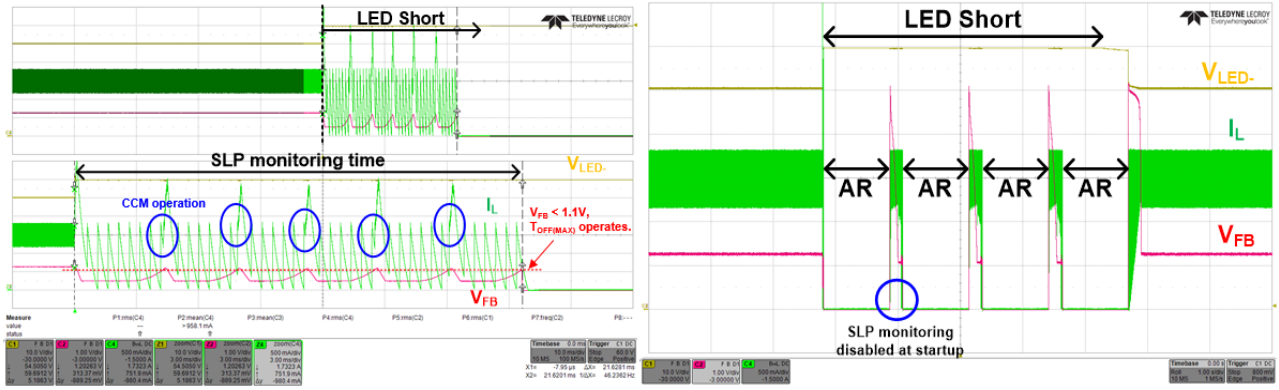


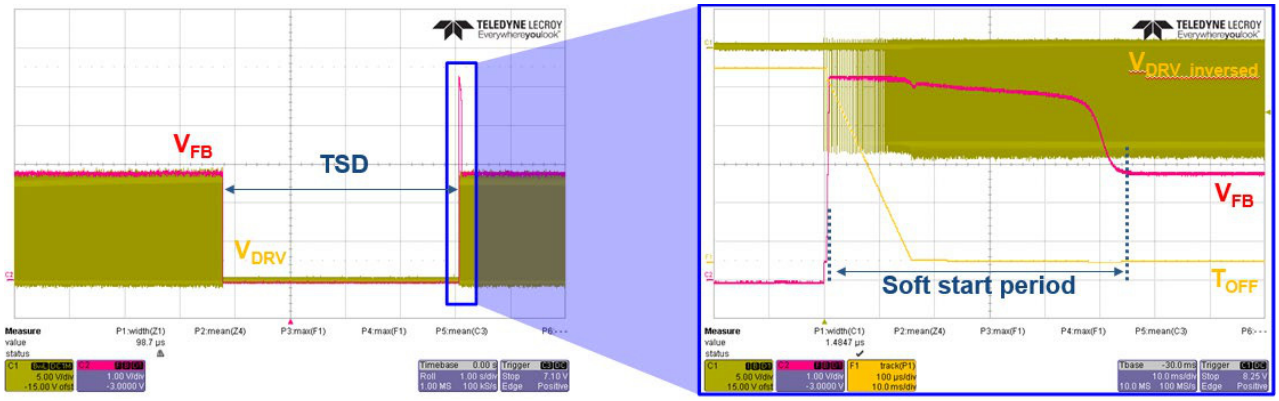
Figure 14. LED Short Protection (SLP)
(LED Load Short and Released at 20% Load: 10 V_{OUT}, 1500 mA, V_{DIM} 2.5 V)

Protection – Thermal Shut Down (TSD)

When IC junction temperature is higher than 150°C Thermal Shut Down (TSD) is triggered and released when the temperature is lower than 120°C.

Table 7. NCL35076 TSD SPECIFICATION

Parameter	Symbol	Min	Typ	Max	Unit
Thermal Shut Down Temperature	T_{SD}	130	150	170	°C
Thermal Shut Down Hysteresis	$T_{SD(HYS)}$	25	30	35	°C



<TSD (Thermal Shut Down) Operation> <Auto Restart when TSD is Terminated>

Figure 15. Thermal Shut Down Protection (TSD)
(Thermal Stress at Max Load: 50 V_{OUT}, 1500 mA, V_{DIM} 2.5 V)

Operating Temperature

The temperature result were measured at Max load (75 W) condition after 30 minutes burn−in. (T_A: 25°C)

<Max Load Top Side> <Max Load Bottom Side>

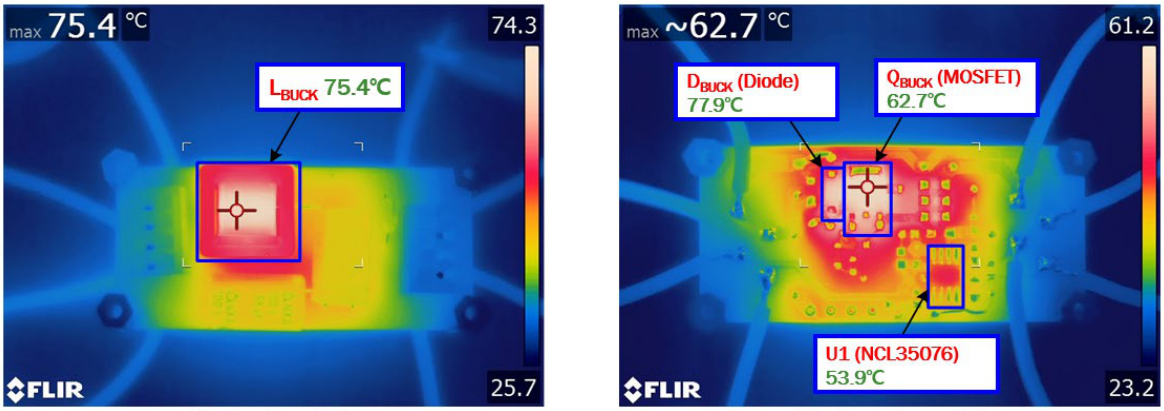


Figure 16. Operating System Temperature (Max Load: 50 V_{OUT}, 1500 mA)

Efficiency

Figure 17 shows system efficiency data at the output voltage range from 10 V to 50 V from 10% to 100% load condition. The system efficiency is over 96% from 30~50 V_{OUT} with 100% load condition.

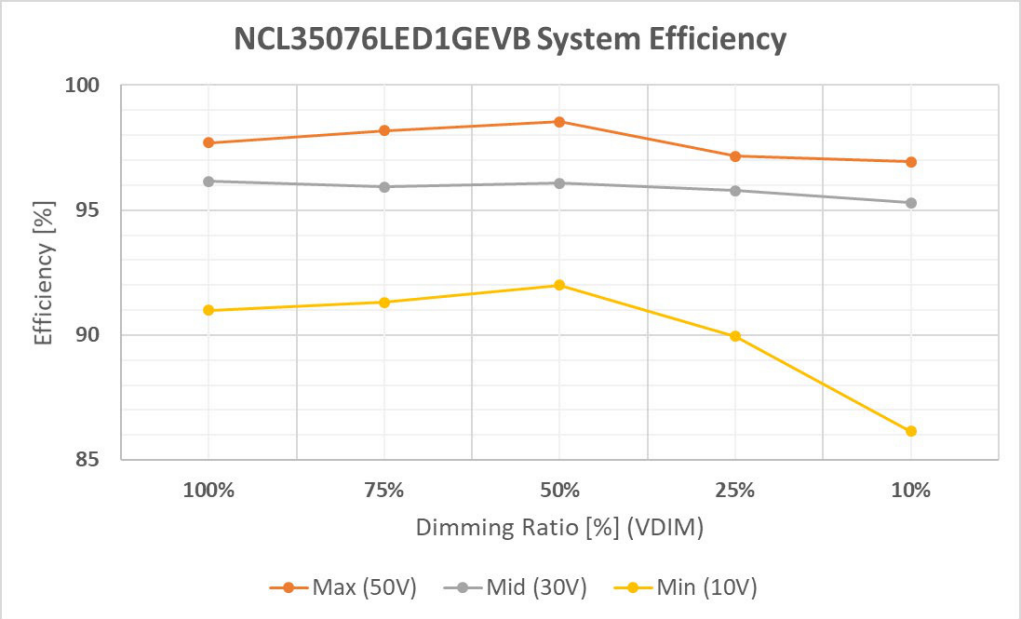


Figure 17. NCL35076LED1GEVB System Efficiency

Table 8. NCL35076LED1GEVB SYSTEM EFFICIENCY DATA

Load	Dim Ratio [%]	Pin [W]	V_{OUT} [V]	I_{OUT} [mA]	P_{OUT} [W]	Eff [%]
Max ($50 V_{OUT}$)	100%	76.2	49.96	1.49	74.4	**97.7**
	75%	55.7	48.79	1.12	54.6	**98.2**
	50%	36.2	47.51	0.75	35.6	**98.5**
	25%	17.5	46.03	0.37	17.0	**97.2**
	10%	6.9	44.85	0.15	6.7	**96.9**
Mid ($30 V_{OUT}$)	100%	46.3	29.85	1.49	44.5	**96.1**
	75%	33.6	29.02	1.11	32.2	**95.9**
	50%	21.7	28.16	0.74	20.8	**96.1**
	25%	10.5	27.18	0.37	10.1	**95.8**
	10%	4.2	26.43	0.15	4.0	**95.3**
Min ($10 V_{OUT}$)	100%	15.9	9.68	1.49	14.4	**91.0**
	75%	11.2	9.23	1.11	10.2	**91.3**
	50%	7.1	8.79	0.74	6.5	**92.0**
	25%	3.3	8.32	0.36	3.0	**89.9**
	10%	1.3	8.00	0.14	1.1	**86.2**

PCB LAYOUT GUIDANCE

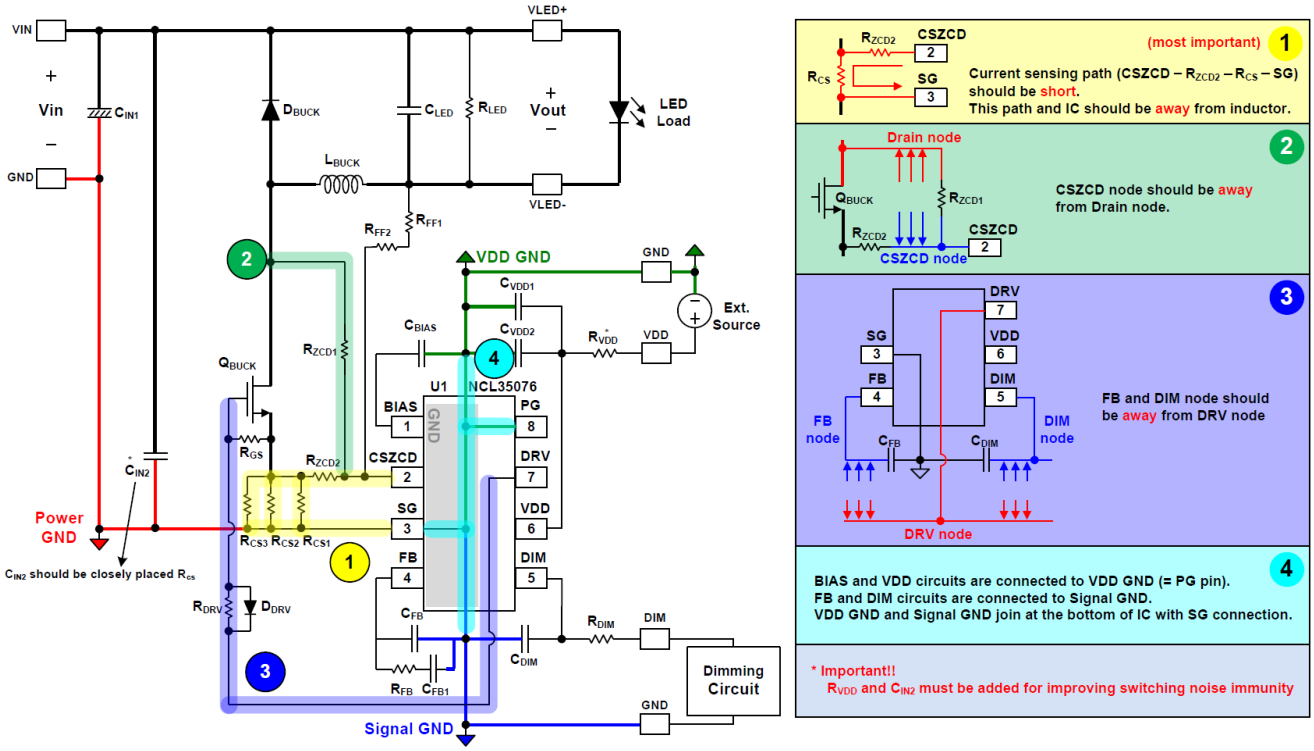


Figure 18. PCB Layout Guidance

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