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TND6256/D

25 W 2 Channel Dimmable LED Buck Driver

Introduction

This document describes a constant current buck driver with hysteretic control. The input voltage range of the evaluation board is 8 V_{DC} ~ 60 V_{DC} and 600 mA is regulated for LED load.

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REFERENCE DESIGN

Table 1.

Description		Symbol	Value	Comments
Input Voltage		$V_{IN.MIN}$	8 V_{DC}	Minimum DC Input Voltage
		$V_{IN.MAX}$	60 V_{DC}	Maximum DC Input Voltage
		$V_{IN.NOMINAL}$	40 V_{DC}	Nominal DC Input Voltage
Output Current		$I_{OUT.NOMINAL}$	589.1 mA	V_{DIM} = 3.5 V
		$I_{OUT.MIN.ADIM}$	22.5 mA (3.8%)	Min. Analog dimming. V_{DIM} = 0.5 V
		$I_{OUT.MIN.PDIM}$	3.74 mA (0.64%)	Min. PWM dimming. $Duty_{PWM}$ = 0.4%. $Freq._{PWM}$ = 100 Hz / 2 kHz
CC Regulation		CC_{VIN}	< ±1.4%	V_{IN} : 15~50 V_{DC}, V_{OUT} : 9 V (3 LEDs)
		CC_{VOUT}	< ±2.1%	V_{IN} : 35 V_{DC}, V_{OUT} : 3~27 V (1~9 LEDs)
Efficiency		η	94.58%	V_{IN} : 35 V_{DC}, V_{OUT} : 27 V (9 LEDs)
Standby Power		P_{STB}	13.5 mW	V_{IN} : 40 V_{DC}
Temperature (T_A = 25°C)	FL7760	T_{FL7760}	44.2°C	FL7760 controller
	MOSFET	T_{MOSFET}	40.5°C	Buck switching MOSFET
	Diode	T_{DIODE}	40.5°C	Buck switching diode

Key Features

- Wide Input Range (8 VDC~60 VDC)
- Continuous Conduction Mode Operation
- Hysteresis Control with Accurate Reference
- Analog and PWM Dimming Control
- Wide Dimming Range (Analog Dimming Ratio is less than 5%, PWM Dimming Duty is less than 0.2% at 2 kHz)

- High Switching Frequency up to 1 MHz
- High Source / Sink Current of 1.5 A / 2.5 A
- Cycle−by−Cycle Peak Current Limit
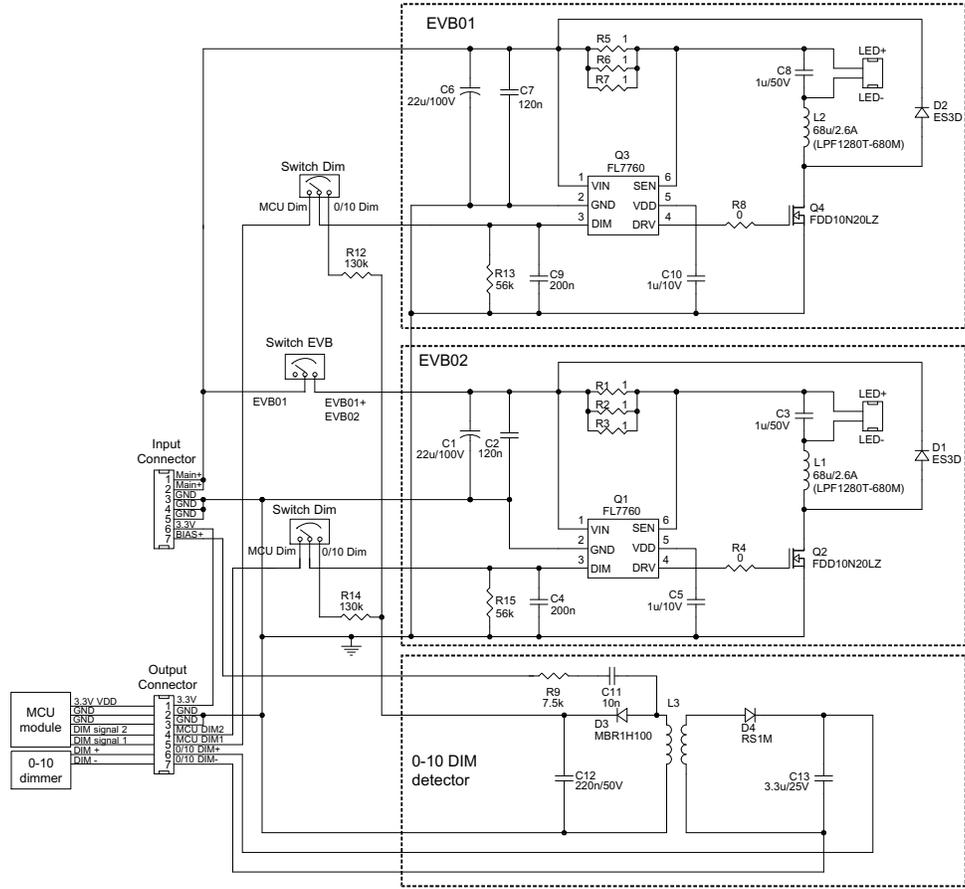- Low Operating Current (150 μA)

SCHEMATIC

Figure 1. Schematic for 2ch Buck

The reference design has two connectors and three switches for selection of the number of channel and dimming method (MCU analog/PWM dimming or 0−10 dimming). When testing, each set method follows the table below.

Table 2. SWITCH AND CONNECTOR SET METHOD IN THE EVALUATION BOARD

| Item	Name	Description	FL7760 (25W, 1Ch)	FL7760 (50W, 2Ch)	FL7740+FL7760
Input Connector	Main+	Main input voltage for FL7760.	8 V_{DC}~60 V_{DC}	8 V_{DC}~60 V_{DC}	50 V main output in FL7740 board
	BIAS+	0−10 DIM BIAS signal from FL7740 board	N.C	N.C	FL7740 transformer winding signal
	3.3V	3.3V to MCU VDD supply from FL7740 board	N.C	N.C	MCU bias output in FL7740 board
Output Connector	MCU Dim1	MCU dimming signal input for EVB01	Dim Signal (Analog/PWM)	Dim Signal (Analog/PWM)	Dim Signal (Analog/PWM)
	MCU Dim2	MCU dimming signal input for EVB02	N.C	Dim Signal (Analog/PWM)	Dim Signal (Analog/PWM)
	3.3V	3.3V to MCU power supply	N.C	N.C	External MCU VDD
	0/10 Dim+	0/10 dimming signal positive input	N.C	N.C	0−10 dimmer + input
	0/10 Dim-	0/10 dimming signal negative input	N.C	N.C	0−10 dimmer − input
Switch EVB	EVB01	Single channel (EVB01) setting	Connect	N.C	Connect for 1Ch
	EVB01+02	Multi channel (EVB01 + EVB02) setting	N.C	Connect	Connect for 2Ch

Table 2. SWITCH AND CONNECTOR SET METHOD IN THE EVALUATION BOARD

Switch Dim	0/10 Dim	0/10 dimming setting	N.C	N.C	Connect for 0–10 dimming
	MCU Dim	MCU dimming (Analog/PWM) setting	Connect for MCU dimming	Connect for MCU dimming	Connect for MCU dimming

Table 3. BILL OF MATERIALS (BOM)

Item No.	Part Reference	Part Number	Description	Manufacturer
1	C1, C6	KMG100VB22M	22 uF / 100 V	Sam Young
2	C2, C7	CS3216X7R124J500NR	120 nF / 50 V SMD Capacitor 3216	Samwha
3	C3, C8		Open	
4	C4, C9	CS2012X7R224J160NR	220 nF / 16 V SMD Capacitor 2012	Samwha
5	C5, C10	CS2012X7R105J160NR	1 uF / 16 V SMD Capacitor 2012	Samwha
6	C11	CS2012X7R103J160NR	10 nF / 16 V SMD Capacitor 2012	Samwha
7	C12	CS3216X7R224J500NR	220 nF / 50 V SMD Capacitor 3216	Samwha
8	C13	CS3216X7R225J250NR	2.2 uF / 25 V SMD Capacitor 3216	Samwha
9	R1, R2, R3, R5, R6, R7	RT1206FRC101R	1 Ω SMD Resistor 3216 F 1/4W	Yageo
10	R4, R8	RT0805FRC0R	0 Ω SMD Resistor 2012 F 1/4W	Yageo
11	R9	RT0805FRC7K5	7.5 kΩ SMD Resistor 2012 F 1/4W	Yageo
12	R12, R14	RT0805FRC130K	130 kΩ SMD Resistor 2012 F 1/4W	Yageo
13	R13, R15	RT0805FRC56K	56 kΩ SMD Resistor 2012 F 1/4W	Yageo
14	D1, D2	ES3D	200 V / 3 A Schottky Rectifier	ON Semiconductor
15	D3	L4148	100 V / 1.0 A SMA package fast recovery diode	ON Semiconductor
16	D4	RS1M	1000 V / 1.0 A SMA package fast recovery diode	ON Semiconductor
17	L1, L2	LPF1280T–101M	100 uH	ABCO
18	L3		3 mH	
19	Q1, Q3	FL7760AM6X	With delay time version	ON Semiconductor
20	Q2, Q4	FDD10N20LZ	200 V 10 A	ON Semiconductor
21		002203508	Connector (In/Output) 2EA	Molex
22		TB03V–2P–LS	Connector (LED String) 2EA	Molex
23		MSS–102–A2	SW1 (EVB selection) 1EA	TELELONGEN-TERPRISE
24		5FS1S102M6QE	SW2 (Dimming selection) 2EA	Dongyang

INDUCTOR DESIGN (L3, USE 0–10 DIMMING ONLY)
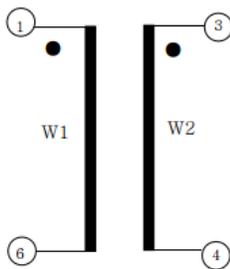
Figure 2. Pin Configuration

Figure 3. Inductor Winding Structure

Table 4. WINDING SPECIFICATIONS

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	W_1	1 → 6	2UEW 0.35φ	30 Ts	
2	W_2	3 → 4	TEX 0.35φ	30 Ts	

Table 5. ELECTRICAL CHARACTERISTICS

No	Item	Terminal	Specifications	Remarks
1	Inductance	1–6,3–4	3.0 mH min	1 kHz, 1 V
2	Withstanding Voltage	Coil to core	1.0 kV 1 mA 1sec	KIKUSU TOS 8850
3	Insulation Resistance	Coil to core	MΩ min.	
4	DC Resistance	1–6,3–4	Ω max.	

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

REFERENCE DESIGN PERFORMANCE

This reference design provides Analog, PWM and Hybrid dimming by MCU and 0−10 dimming function. In 0−10 dimming application, LED load is isolated from 0−10 dimmer by L3.

The reference design comprises two channels of LED drivers and each channel can drive 25 W to LED load and the user can select either multi channel or single channel by using an EVB section switch. When moving the EVB section switch to EVB01, user can test for one channel (25 W) LED driver, and when moving the EVB section switch to EVB01+02, user can test for two channels (25 W + 25 W) in parallel with two independent LED loads.

To set the board for testing of 25 W (1Ch), follow the procedure below to test single channel.
1. Connect the LED load.
2. Set the EVB section switch to EVB01.
   Based on the location of the Fig 9, the left side of switch is EVB01+02 and the right side is EVB01.
3. Connect the jumper between left and middle pin to set analog/PWM dimming.
   Based on the location of the Fig 9, the left side of switch is MCU Dim and the right side is 0/10 Dim.
4. Apply analog/PWM dimming signal to MCU DIM1 and GND.
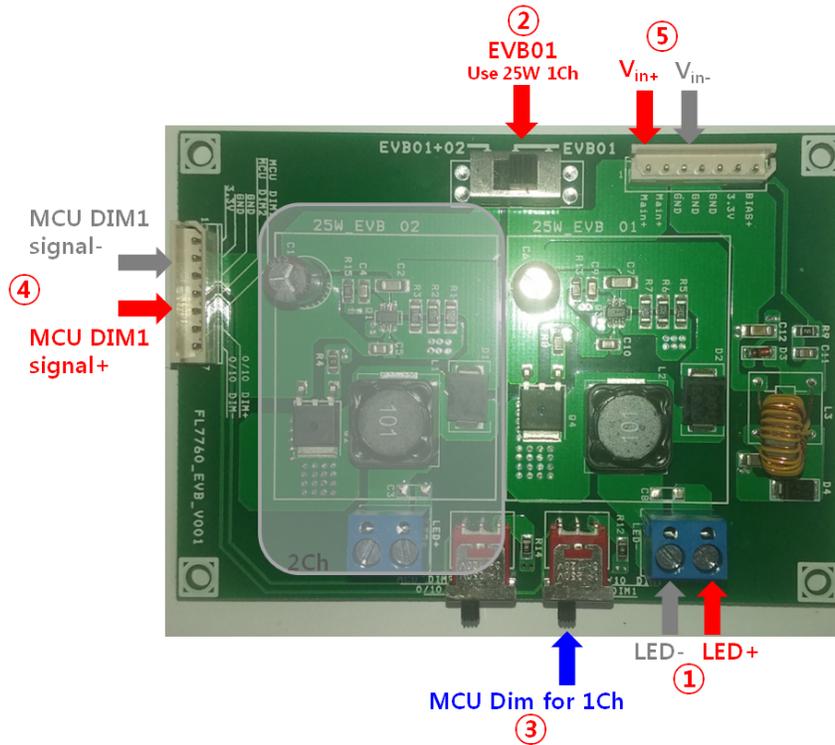5. Apply input voltage to Main + pin and GND pin.

**Figure 4. Evaluation Board Structure for 1 Channel (25 W) with MCU Dimming**

PERFORMANCE

Table 6. TEST CONDITION & EQUIPMENT LIST

| Ambient Temperature	$T_A = 25°C$
Test Equipment	AC Power Source: PCR500L by Kikusui Power Analyzer: PZ4000000 by Yokogawa LED Load: EHP−AX08EL/GT01H−P03/4556/Y/K53 Oscilloscope: 104Xi by LeCroy Thermometer: Thermal CAM SC640 by FLIR SYSTEMS

Startup

The FL7760 can perform a soft start by adding a capacitor (C_{DIM}) to the DIM pin. Figure 9 shows the application circuit example for startup and Figure 10 shows the overall startup performance at full load condition. When VIN pin voltage is increased up to 8 V, IC starts charging Vcc capacitor (C_{VCC}) and when Vcc voltage reaches to 4.5 V, IC operation begin and start charging C_{DIM}. Soft start time can be adjusted by changing C_{DIM}.
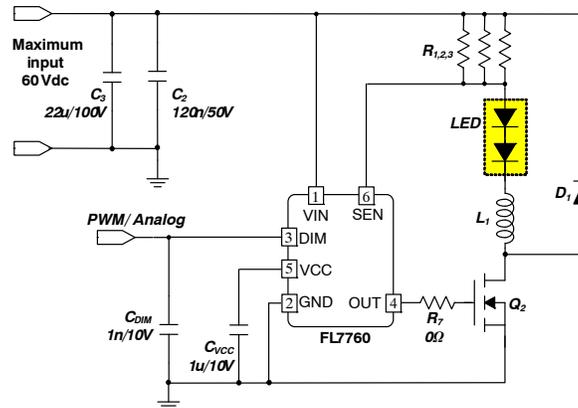
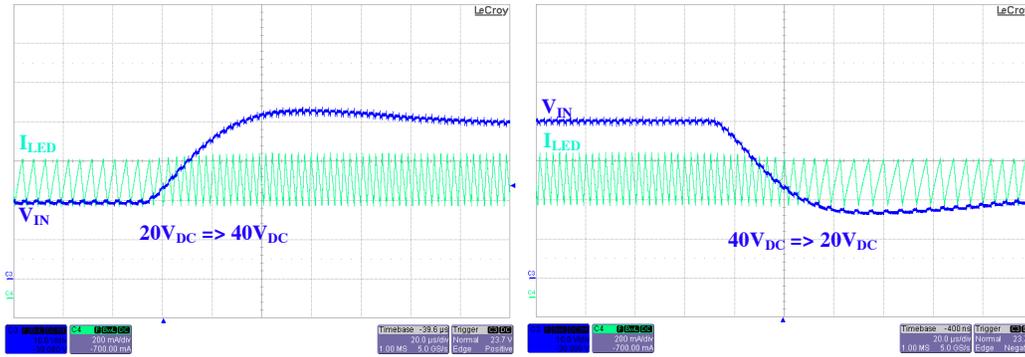**Figure 5. Application Circuit for Start Up**
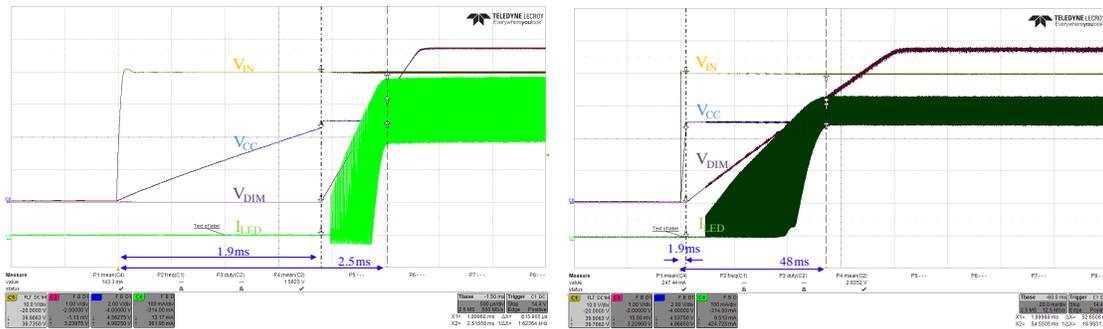
a) $C_{DIM} = 1$ nF   b) $C_{DIM} = 68$ nF

CH1: VIN (10 V / div), CH2: VDIM (1 V / div), CH3: VCC (2 V / div), CH4: ILED (100 mA / div)

Figure 6. Soft Startup by C_{DIM}

Fast Transient Response

Figure 11 shows fast line voltage transient performance. When input voltage is changed from 20 V to 40 V, LED current is constantly managed by hysteresis control.

CH3: VIN (10 V / div), CH4: ILED (200 mA / div), Time Scale: (20 us / div)

Figure 7. Line Transient Response

Standby Power

When the voltage of the DIM pin falls below 0.5 V for 34 ms blanking time, the FL7760 operates in standby mode and reduces the operating current of the IC. Figure 12 shows standby power performance with no load condition. Standby power is lower than 20 mW in the allowed input voltage range to 60 V.
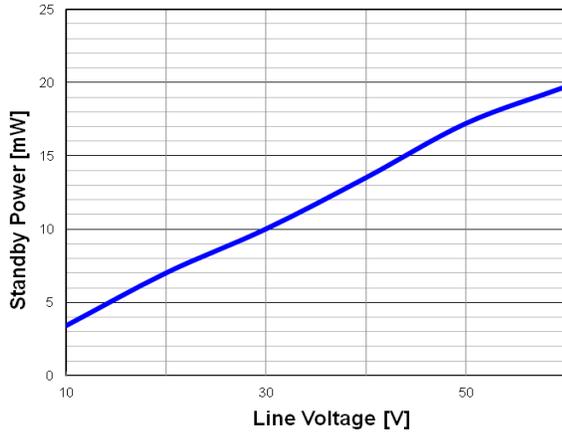
Figure 8. Standby Power vs Input Voltage

Table 7. STANDBY POWER WITH DIFFERENT INPUT VOLTAGE

Input Voltage	Standby Power	Units
60 V_{DC}	19.7	mW
50 V_{DC}	17.2	mW
40 V_{DC}	13.5	mW
30 V_{DC}	10	mW
20 V_{DC}	7	mW
10 V_{DC}	3.4	mW

Analog and PWM Dimming Performance

FL7760 has an internal current source in DIM pin and it can be used for pull up when no external components are connected at DIM pin. In this EVB, DIM voltage is set close to 0 V by external 56 kΩ pull down resistor when no external DIM signal is applied.

The FL7760 can implement PWM and analog dimming with single DIM pin. In analog dimming, LED current is clamped to maximum when DIM voltage is higher than 3 V. When DIM voltage is reduced from 3 V to 0.5 V, FL7760A (A version) reduces LED current down to 3.8% by delay time control for wide analog dimming as shown in Figure 13. If linear analog dimming curve is preferred, FL7760B (B version) can be selected and additional PWM dimming recommended in the deep dimming range for wide dimming because analog dimming range of FL7760B is narrow.
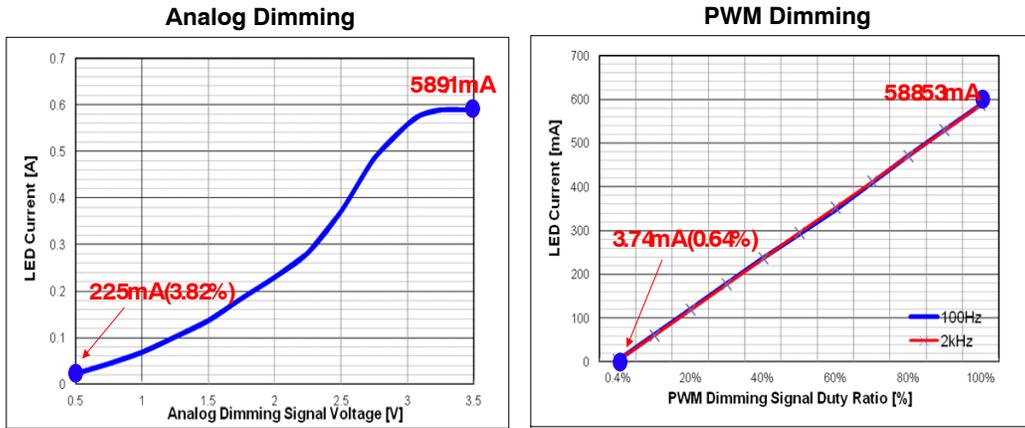
Analog Dimming **PWM Dimming**

Figure 9. Analog and PWM Dimming Performance

Table 8. TEST DATA FOR ANALOG AND PWM DIMMING

Analog Dimming				PWM Dimming		
V_{DIM}	I_{LED} [mA]	F_{SW} [kHz]	V_{LED} [V]	Duty	100 Hz	2 kHz
3.5	589.1	334.6	29.75	100%	588.53	587.55
3	552.8	294.25	29.58	80%	470.29	469.34
2.5	367.6	178.43	28.63	60%	347.55	352.3
2	227.2	155.62	27.19	40%	236.78	235.95
1.5	141.5	147.62	25.91	20%	120.17	118.68
1	71.7	144.51	24.61	10%	61.75	60.39
0.5	22.5	143.57	23.41	1%	9.2	5.76
0	0	0	0	0.4%	3.74	3.75

Efficiency and Regulation

Figure 14 shows the efficiency at 3 ~ 27 V_{DC} output voltage range (1~9 LEDs) and 15 ~ 50$V_{DC.IN}$ input voltage range. System efficiency is over 94.58 % at 35 $V_{DC.IN}$ and 27 V_{OUT} (9 LEDs) condition. Figure 15 shows the CC regulation in the wide load and line voltage range and CC regulation is ±2.1% at 1 ~ 9 LEDs condition and ±1.4% at 15 ~ 50 $V_{DC.IN}$ condition.
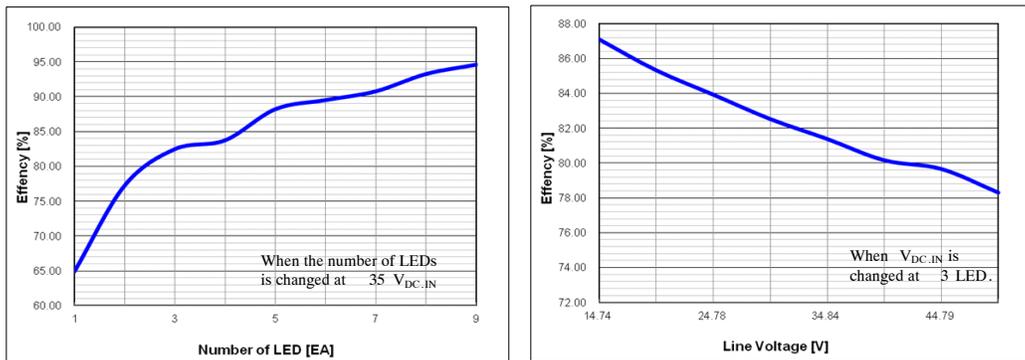
Figure 10. Efficiency in the Wide Load and Line Voltage Range
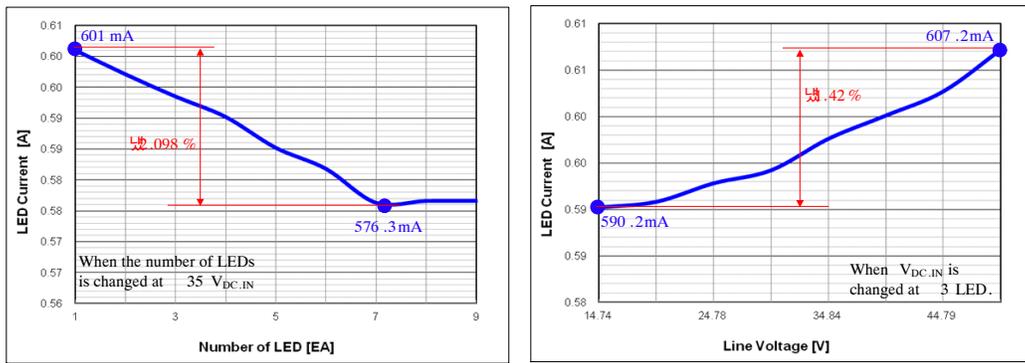
Figure 11. CC Regulation in the Wide Load and Line Voltage Range

Table 9. EFFICIENCY AND CC REGULATION IN THE LOAD AND INPUT VOLTAGE CHANGE

Load Change	35 Vin, 600 mA, 9~1 LED						
	LED	Vin [V.avr]	Iin [A.avr]	Pin [W]	VLED [V.avr]	ILED [A.avr]	Pout [W]	Eff [%]
Number of LED Change	9	34.85	0.4728	16.47	27.02	0.5766	15.58	94.58
	8	34.83	0.4294	14.95	24.18	0.5766	13.94	93.24
	7	34.85	0.3842	13.39	21.08	0.5763	12.15	90.75
	6	34.82	0.3379	11.77	18.10	0.5818	10.53	89.50
	5	34.83	0.2877	10.02	15.10	0.5852	8.84	88.19
	4	35.48	0.2381	8.45	11.99	0.5902	7.07	83.73
	3	34.85	0.1881	6.55	9.11	0.5935	5.41	82.47
	2	34.83	0.1348	4.69	6.07	0.5971	3.63	77.25
	1	34.82	0.0786	2.74	2.96	0.6010	1.78	64.92

Line Change	50~15 Vin, 600 mA, 3 LED						
	LED	Vin [V.avr]	Iin [A.avr]	Pin [W]	VLED [V.avr]	ILED [A.avr]	Pout [W]	Eff [%]
Input Voltage Change	3	49.79	0.1396	6.95	8.96	0.6072	5.44	78.29
	3	44.79	0.1517	6.79	8.98	0.6027	5.41	79.65
	3	39.83	0.1686	6.72	8.97	0.6001	5.38	80.15
	3	34.84	0.1888	6.58	8.96	0.5976	5.35	81.38
	3	29.84	0.2159	6.44	8.95	0.5942	5.32	82.53
	3	24.78	0.2548	6.31	8.94	0.5928	5.30	83.94
	3	19.77	0.3124	6.18	8.92	0.5908	5.27	85.34
	3	14.74	0.4101	6.04	8.92	0.5902	5.27	87.12

Operating Temperature

   Temperatures of all components on this board are less than 45°C. The temperature was measured at 40 $V_{DC.IN}$ and 27 V_{OUT} (9 LEDs) condition after 30 minutes burn−in.
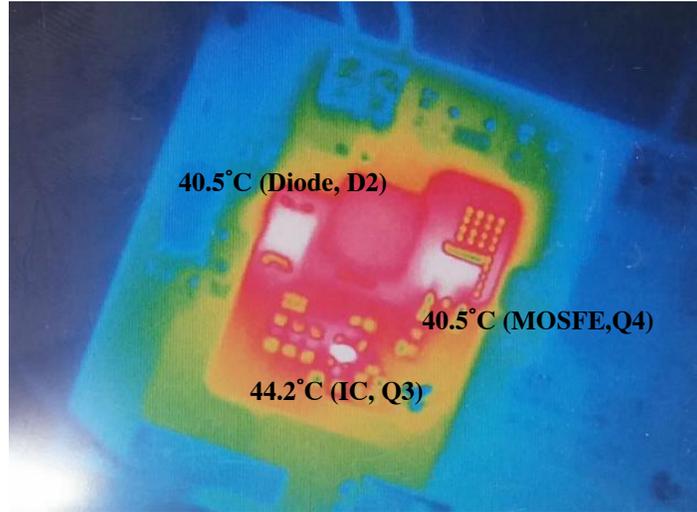
Figure 12. Operating Temperature at 40 $V_{DC.IN}$ / 600 mA