

# ON Semiconductor

## Is Now

# onsemi™

To learn more about onsemi™, please visit our website at  
[www.onsemi.com](http://www.onsemi.com)

---

**onsemi** and **onsemi** and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi** product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). **onsemi** reserves the right to make changes at any time to any products or information herein, without notice. The information herein is provided "as-is" and **onsemi** makes no warranty, representation or guarantee regarding the accuracy of the information, product features, availability, functionality, or suitability of its products for any particular purpose, nor does **onsemi** assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using **onsemi** products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by **onsemi**. "Typical" parameters which may be provided in **onsemi** data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. **onsemi** does not convey any license under any of its intellectual property rights nor the rights of others. **onsemi** products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use **onsemi** products for any such unintended or unauthorized application, Buyer shall indemnify and hold **onsemi** and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of the part. **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner. Other names and brands may be claimed as the property of others.

# TND6256/D

## 25 W 2 Channel Dimmable LED Buck Driver



ON Semiconductor®

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

### REFERENCE DESIGN

#### Introduction

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

Table 1.

Description	Symbol	Value	Comments	
Input Voltage	$V_{IN.MIN}$	8 V <sub>DC</sub>	Minimum DC Input Voltage	
	$V_{IN.MAX}$	60 V <sub>DC</sub>	Maximum DC Input Voltage	
	$V_{IN.NOMINAL}$	40 V <sub>DC</sub>	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 <sub>PWM</sub> = 0.4%. Freq. <sub>PWM</sub> = 100 Hz / 2 kHz	
CC Regulation	CC <sub>VIN</sub>	< ±1.4%	$V_{IN} : 15 \sim 50 V_{DC}$ , $V_{OUT} : 9 V$ (3 LEDs)	
	CC <sub>VOU</sub>	< ±2.1%	$V_{IN} : 35 V_{DC}$ , $V_{OUT} : 3 \sim 27 V$ (1~9 LEDs)	
Efficiency	$\eta$	94.58%	$V_{IN} : 35 V_{DC}$ , $V_{OUT} : 27 V$ (9 LEDs)	
Standby Power	P <sub>STB</sub>	13.5 mW	$V_{IN} : 40 V_{DC}$	
Temperature ( $T_A = 25^\circ C$ )	FL7760	T <sub>FL7760</sub>	44.2°C	FL7760 controller
	MOSFET	T <sub>MOSFET</sub>	40.5°C	Buck switching MOSFET
	Diode	T <sub>DIODE</sub>	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  $\mu A$ )

# TND6256/D

## SCHEMATIC

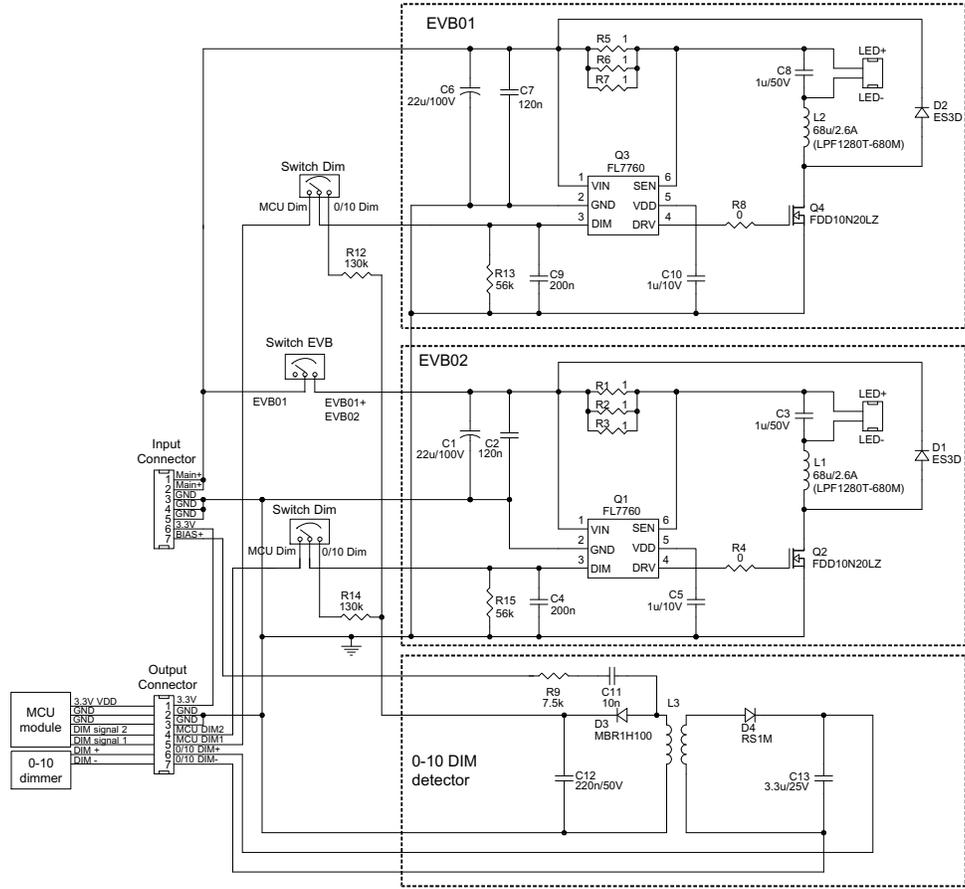


Figure 1. Schematic for 2ch Buck

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 <sub>DC</sub> ~60 V <sub>DC</sub>	8 V <sub>DC</sub> ~60 V <sub>DC</sub>	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

# TND6256/D

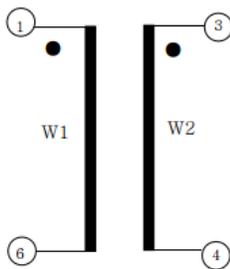
**Table 2. SWITCH AND CONNECTOR SET METHOD IN THE EVALUATION BOARD**

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**

## TND6256/D

**Table 4. WINDING SPECIFICATIONS**

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	W <sub>1</sub>	1 → 6	2UEW 0.35φ	30 Ts	
2	W <sub>2</sub>	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.

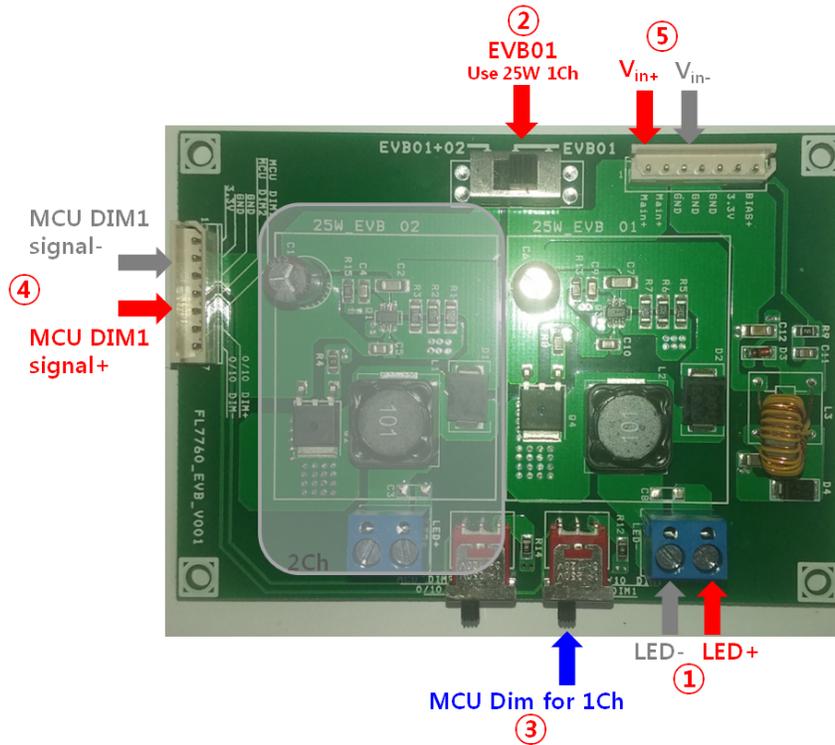


Figure 4. Evaluation Board Structure for 1 Channel (25 W) with MCU Dimming

# TND6256/D

## PERFORMANCE

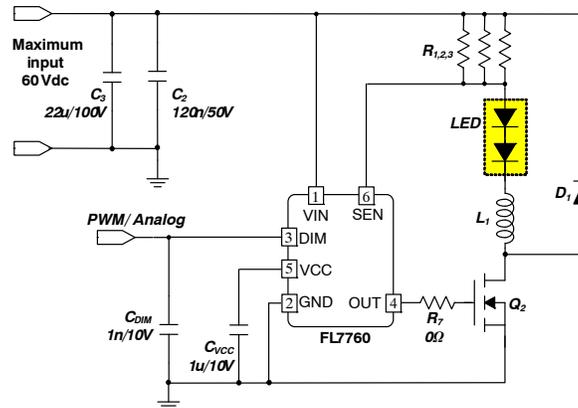
**Table 6. TEST CONDITION & EQUIPMENT LIST**

Ambient Temperature	$T_A = 25^\circ\text{C}$
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

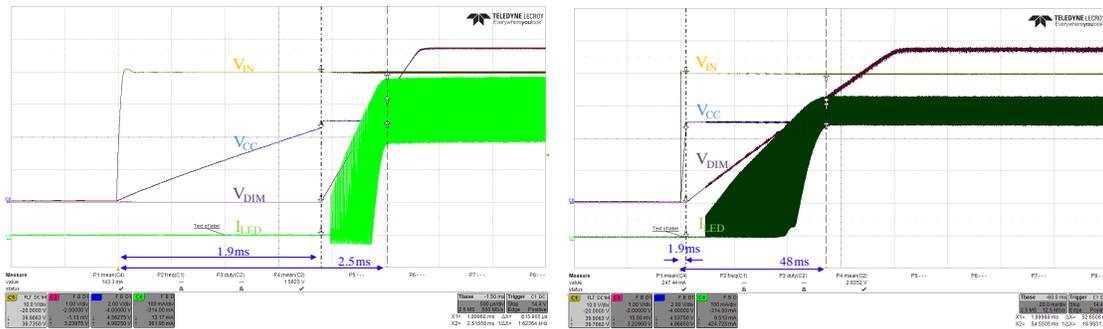
### Startup

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  $V_{IN}$  pin

voltage is increased up to 8 V, IC starts charging  $V_{CC}$  capacitor ( $C_{VCC}$ ) and when  $V_{CC}$  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)  $C_{DIM} = 1 \text{ nF}$

b)  $C_{DIM} = 68 \text{ nF}$

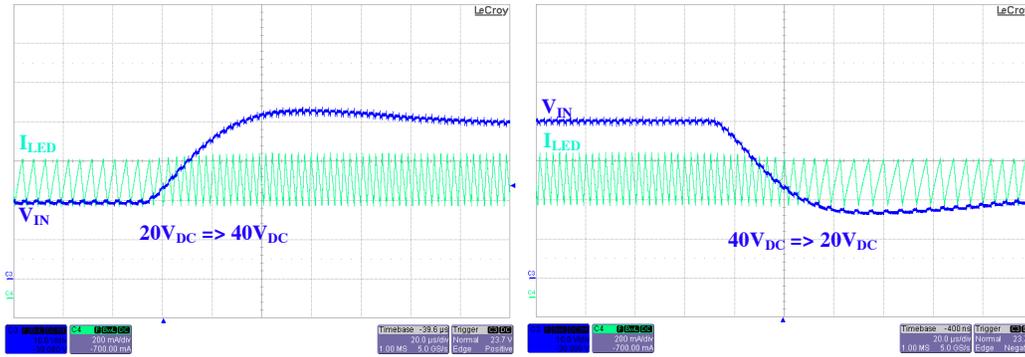
CH1:  $V_{IN}$  (10 V / div), CH2:  $V_{DIM}$  (1 V / div), CH3:  $V_{CC}$  (2 V / div), CH4:  $I_{LED}$  (100 mA / div)

**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.

# TND6256/D

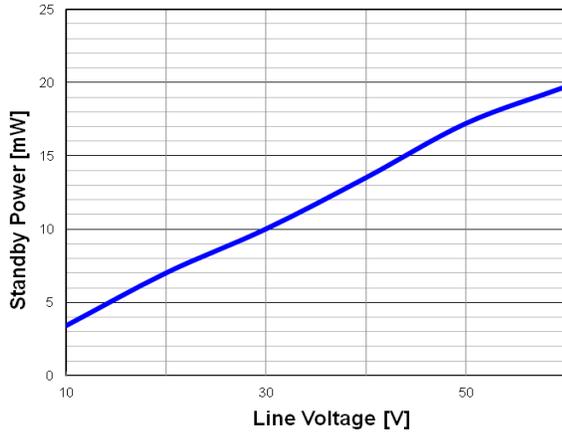


CH3: VIN (10 V / div), CH4: ILED (200 mA / div), Time Scale: (20 us / div)

**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 <sub>DC</sub>	19.7	mW
50 V <sub>DC</sub>	17.2	mW
40 V <sub>DC</sub>	13.5	mW
30 V <sub>DC</sub>	10	mW
20 V <sub>DC</sub>	7	mW
10 V <sub>DC</sub>	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.

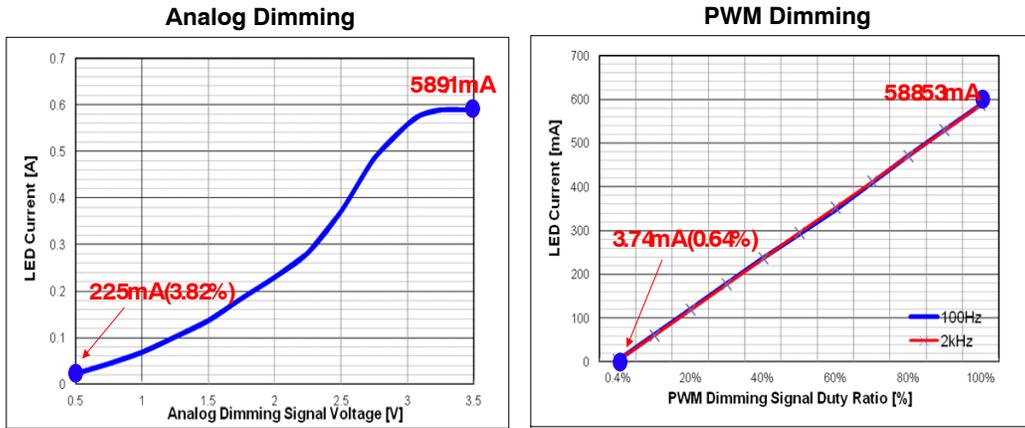


Figure 9. Analog and PWM Dimming Performance

Table 8. TEST DATA FOR ANALOG AND PWM DIMMING

Analog Dimming				PWM Dimming		
V <sub>DIM</sub>	I <sub>LED</sub> [mA]	F <sub>sw</sub> [kHz]	V <sub>LED</sub> [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<sub>DC</sub> output voltage range (1~9 LEDs) and 15 ~ 50V<sub>DC,IN</sub> input voltage range. System efficiency is over 94.58 % at 35 V<sub>DC,IN</sub> and

27 V<sub>OUT</sub> (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<sub>DC,IN</sub> condition.

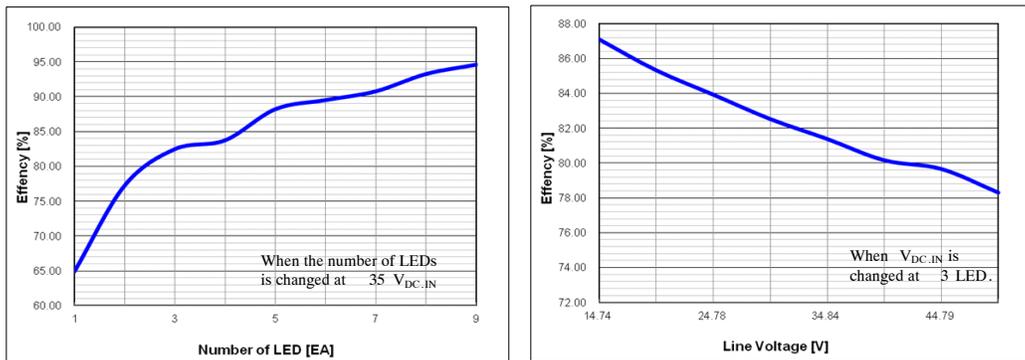


Figure 10. Efficiency in the Wide Load and Line Voltage Range

# TND6256/D

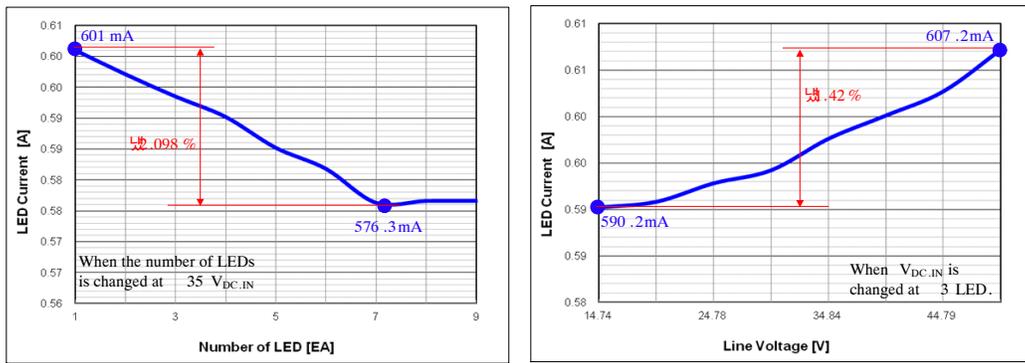


Figure 11. CC Regulation in the Wide Load and Line Voltage Range

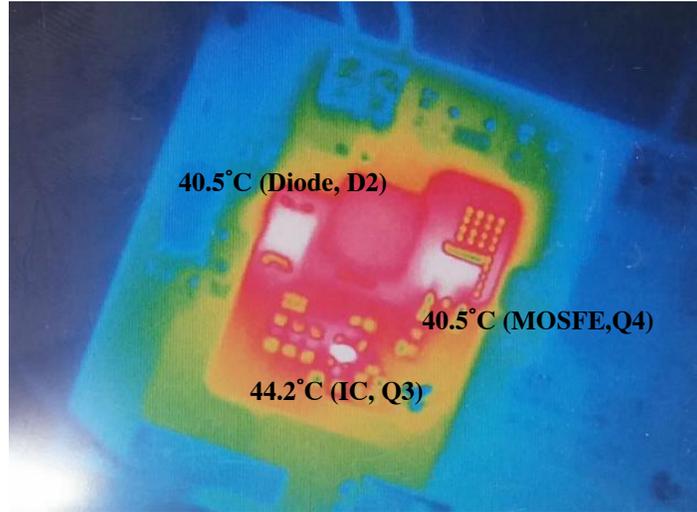
Table 9. EFFICIENCY AND CC REGULATION IN THE LOAD AND INPUT VOLTAGE CHANGE

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<sub>DC,IN</sub> and 27 V<sub>OUT</sub> (9 LEDs) condition after 30 minutes burn-in.



**Figure 12. Operating Temperature at 40 V<sub>DC,IN</sub> / 600 mA**

ON Semiconductor and  are trademarks of Semiconductor Components Industries, LLC dba ON Semiconductor or its subsidiaries in the United States and/or other countries. ON Semiconductor owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of ON Semiconductor's product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). ON Semiconductor reserves the right to make changes without further notice to any products herein. ON Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does ON Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation special, consequential or incidental damages. Buyer is responsible for its products and applications using ON Semiconductor products, including compliance with all laws, regulations and safety requirements or standards, regardless of any support or applications information provided by ON Semiconductor. "Typical" parameters which may be provided in ON Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including "Typicals" must be validated for each customer application by customer's technical experts. ON Semiconductor does not convey any license under its patent rights nor the rights of others. ON Semiconductor products are not designed, intended, or authorized for use as a critical component in life support systems or any FDA Class 3 medical devices or medical devices with a same or similar classification in a foreign jurisdiction or any devices intended for implantation in the human body. Should Buyer purchase or use ON Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold ON Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that ON Semiconductor was negligent regarding the design or manufacture of the part. ON Semiconductor is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

**PUBLICATION ORDERING INFORMATION**

**LITERATURE FULFILLMENT:**  
 Literature Distribution Center for ON Semiconductor  
 19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA  
**Phone:** 303-675-2175 or 800-344-3860 Toll Free USA/Canada  
**Fax:** 303-675-2176 or 800-344-3867 Toll Free USA/Canada  
**Email:** [orderlit@onsemi.com](mailto:orderlit@onsemi.com)

**N. American Technical Support:** 800-282-9855 Toll Free  
 USA/Canada  
**Europe, Middle East and Africa Technical Support:**  
 Phone: 421 33 790 2910

**ON Semiconductor Website:** [www.onsemi.com](http://www.onsemi.com)  
**Order Literature:** <http://www.onsemi.com/orderlit>

For additional information, please contact your local Sales Representative