WD3170

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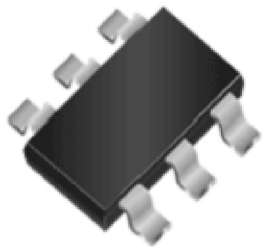
38V Step-Up Backlight White LED Driver with Flash Mode

Descriptions

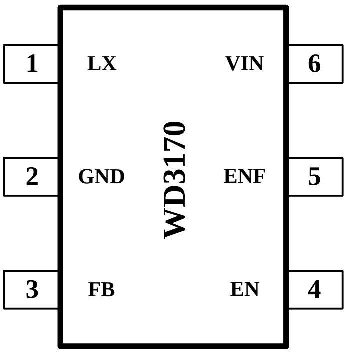
The WD3170 is a constant current, high efficiency LED driver. Internal MOSFET can drive up to 10 white LEDs in series with 1.8A current limit and 45V Power HV-NMOS. A Pulse-Width-Modulation (PWM) signal can be applied to the EN pin for LED dimming. The device operates at 900KHz fixed switching frequency to reduce output ripple, improve conversion efficiency, and allows using small external components.

When pull up the ENF pin, WD3170 enters into flash mode. In flash mode, WD3170 can burst LED current to 3 times of the full scale setting backlight current. Meanwhile, the WD3170 receives PWM signal at ENF pin for flash dimming. To protect white LED, the WD3170 automatically exits flash mode if it lasts for more than 1s, and the WD3170 will not operate in flash mode until ENF is re-cycled from low to high.

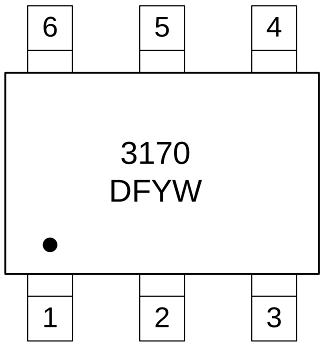
The WD3170 is available in TSOT-23-6LPackage. Standard product is Pb-free and Halogen-free.



TSOT-23-6L



Pin configuration (Top view)



3170 = Device code
Y = Year code
W = Week code

Marking

Features

- Input voltage range : 2.7~5.5V
- Open LED Protection : LX > 38V && FB < 50mV
- Reference Voltage : 200mV (Backlight Mode)
  : 600mV (Flash Mode)
- Switching freq : 900KHz (Typ.)
- Efficiency : Up to 92%
- Current limit : 1.8A (Typ.)
- PWM Dimming freq : 20KHz to 100KHz
- PWM Dimming Duty : 0.3% ~ 100%
- Flash Time-Out : 1.0 s

Applications

- Smart Phones
- Tablets
- Portable games

Order information

Device	Package	Shipping
WD3170F-6/TR	TSOT-23-6L	3000/Reel&Tape

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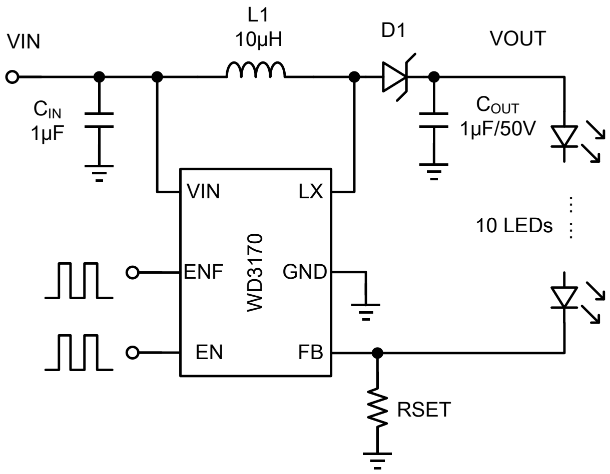
Typical applications



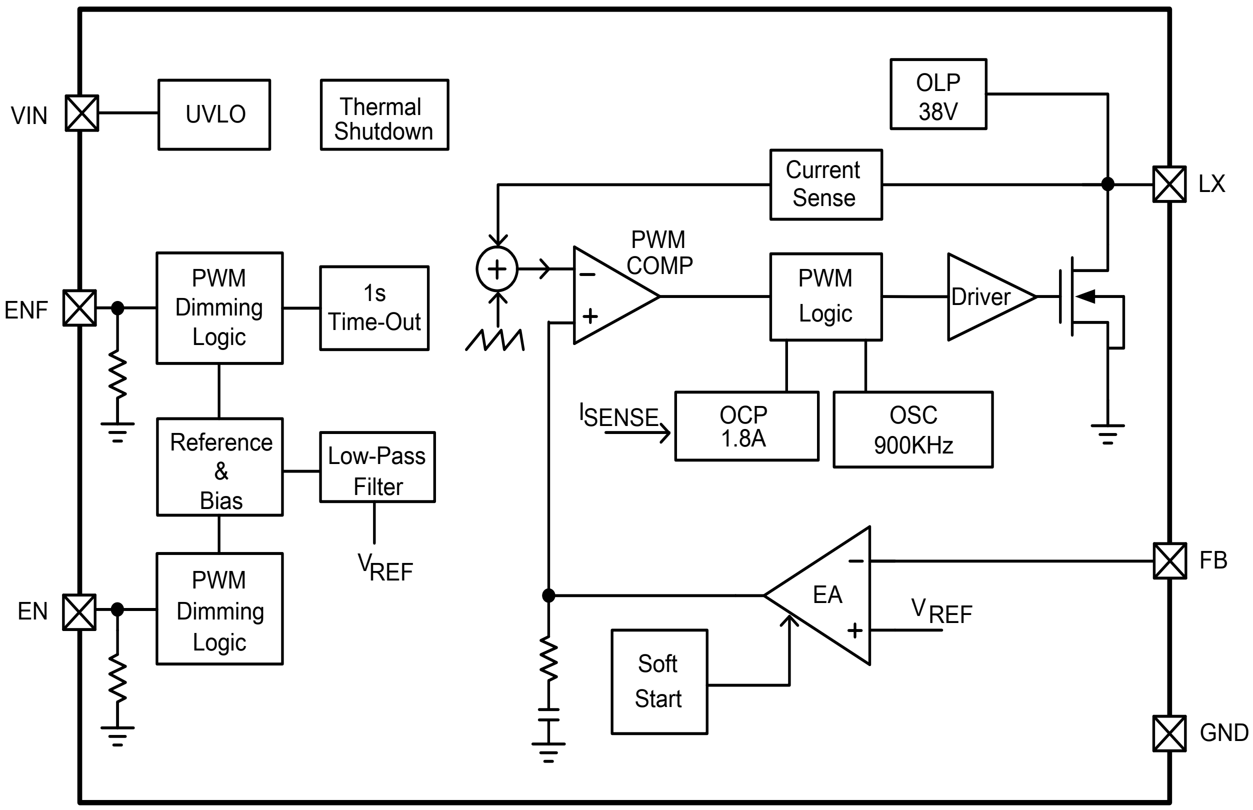
Pin descriptions

Symbol	Pin No.	Descriptions
LX	1	Switch node
GND	2	Ground
FB	3	Feedback
EN	4	Backlight Enable
ENF	5	Flash Mode Enable
VIN	6	Power Supply

Operation Mode

EN	ENF	Mode
0	0	Shutdown
1 / PWM Dimming	0	Backlight Mode
X	1 / PWM Dimming	Flash Mode

Block diagram



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Absolute maximum ratings

Parameter	Symbol	Value	Unit
VIN pin voltage range	V_{IN}	-0.3～6.5	V
EN, ENF pins voltage range	-	-0.3～V_{IN}	V
LX pin voltage range (DC)	-	-0.3～45	V
Power Dissipation – SOT-23-6L (Note 1)	P_D	0.5	W
Power Dissipation – SOT-23-6L (Note 2)		0.3	W
Junction to Ambient Thermal Resistance – SOT-23-6L (Note 1)	$R_{\theta JA}$	250	ºC/W
Junction to Ambient Thermal Resistance – SOT-23-6L (Note 2)		416	ºC/W
Junction temperature	T_J	150	ºC
Lead temperature(Soldering, 10s)	T_L	260	ºC
Operation temperature	Topr	-40 ~ 85	ºC
Storage temperature	Tstg	-55 ~ 150	ºC
ESD ratings	HBM	4000	V
	MM	200	V

These are stress ratings only. Stresses exceeding the range specified under “Absolute Maximum Ratings” may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

Note 1: Surface mounted on FR-4 Board using 1 square inch pad size, dual side, 1oz copper
Note 2: Surface mounted on FR-4 Board using minimum pad size, 1oz copper

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Electronics Characteristics (Ta=25°C, V_{IN}=3.6V, V_{EN}=V_{IN}, C_{IN}=C_{OUT}=1uF, unless otherwise noted)

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
Basic Operation						
Operation Voltage Range	V_{IN}		2.7	--	5.5	V
Under Voltage Lockout	V_{UVLO}	V_{IN} Rising	1.8	2.3	2.5	V
UVLO Hysteresis	$V_{UVLO-HYS}$			0.15		V
Quiescent Current	I_Q	No Switching		0.3	1	mA
Supply Current	I_S	Switching		0.65	2	mA
Shutdown Current	I_{SD}	V_{EN}< 0.4V			1	μA
Enable Control						
EN Threshold Voltage	V_{ENL}				0.4	V
	V_{ENH}		1.5			V
ENF Threshold Voltage	V_{ENFL}				0.4	V
	V_{ENFH}		1.5			V
EN Pull-down Resistance	R_{EN}			1		MΩ
ENF Pull-down Resistance	R_{ENF}			1		MΩ
EN Shutdown Delay	$t_{SHDN,\ EN}$			0.12		ms
ENF Disable Delay	$t_{SHDN,\ ENF}$			0.12		ms
Flash Time Out	t_{FTO}			1		s
Voltage and Current Control						
Operation Frequency	f_{OSC}		0.7	0.9	1.1	MHz
Maximum Duty Cycle	D_{MAX}		92	95		%
PWM Dimming Clock Rate	f_{EN}, f_{ENF}	Recommended	20		100	KHz
PWM Dimming Duty Cycle		Recommended	0.3		100	%
Feedback Reference	V_{REF}	100% Full Scale	190	200	210	mV
		1% Dimming Duty		2.2		
		0.3% Dimming Duty	0.3	0.8	1.2	
		100% Flash Mode	570	600	630	
Feedback Input Bias Current	I_{FB}				1	μA
Power Switch						
On Resistance	R_{ON}	I_{LX}=100mA		0.3		Ω
Main Switch Leakage Current	I_{LN_MS}	V_{LX}=40V, Disable			1	μA
Current Limit	I_{LIM}		1.35	1.8		A
Protection						
Open LED Protection Threshold	V_{OLP}		36	38	40	V
Thermal Shutdown Temperature	T_{SD}			160		°C
T_{SD} Hysteresis	T_{SD-HYS}			30		°C

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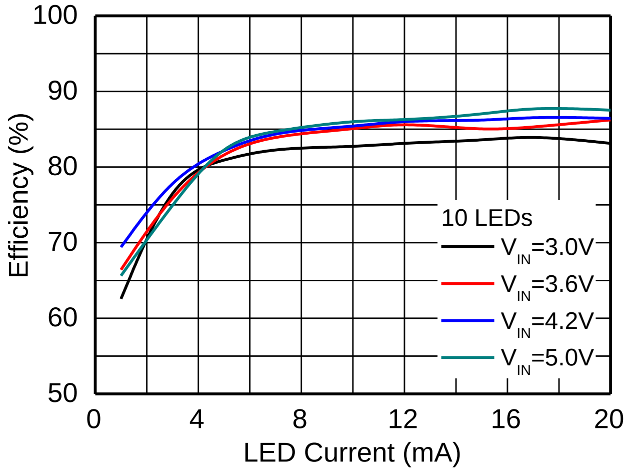
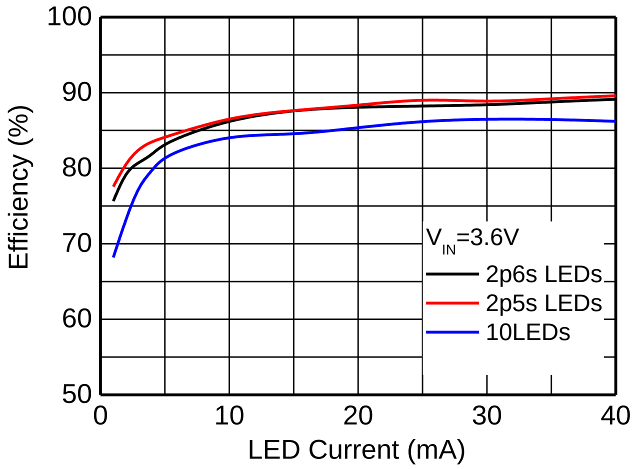
Typical Characteristics

(Ta=25ºC, V_{IN}=3.6V, V_{EN}=V_{IN}, C_{IN}=C_{OUT}=1µF, L=10µH, 10 LEDs, unless otherwise noted)



Efficiency vs. LED Current



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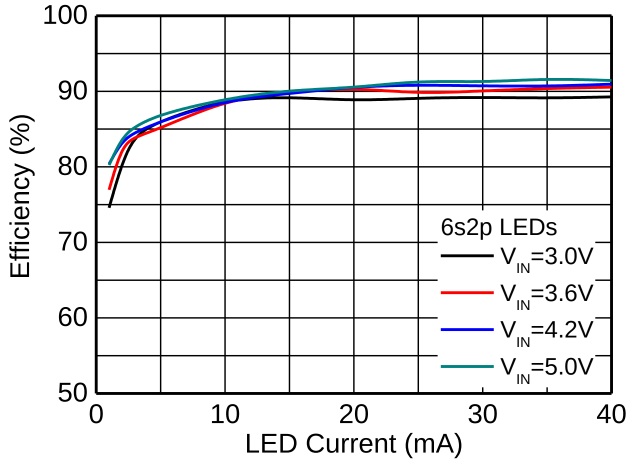

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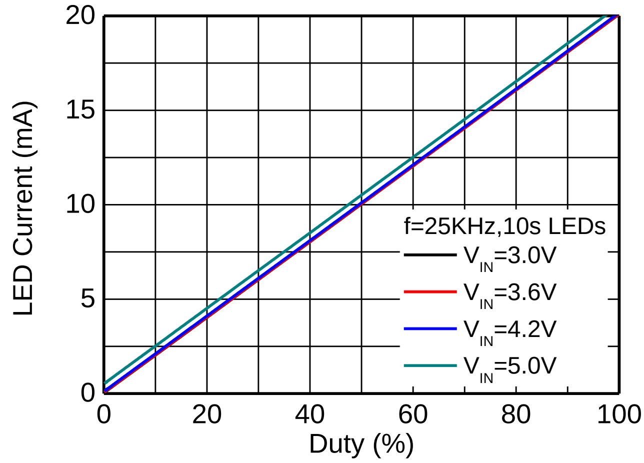
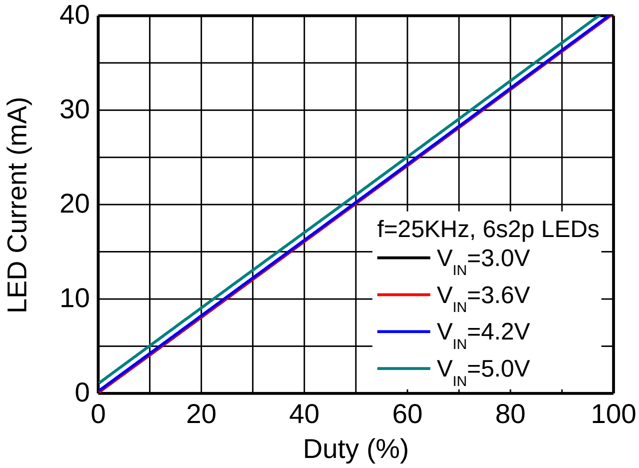


LED Current vs. Duty Cycle



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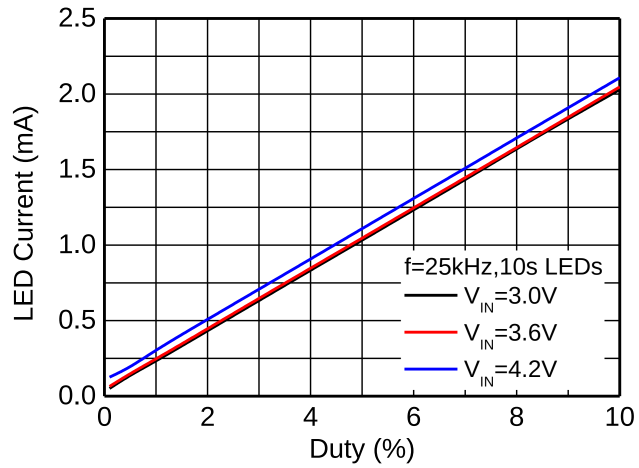

LED Current vs. Duty Cycle

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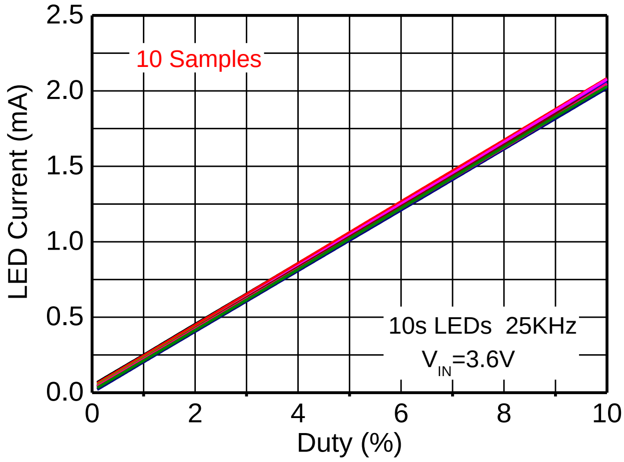
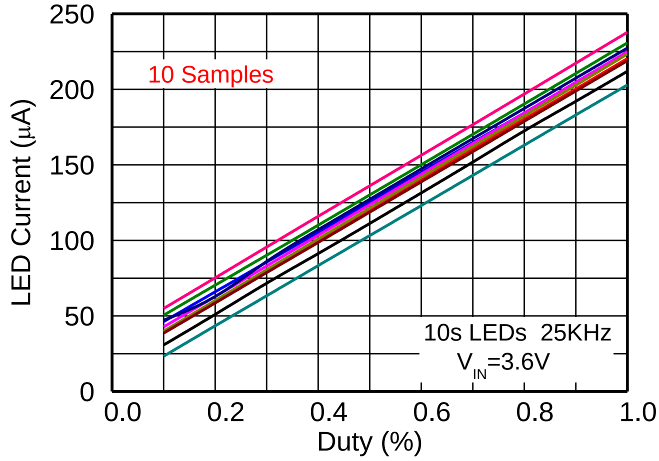
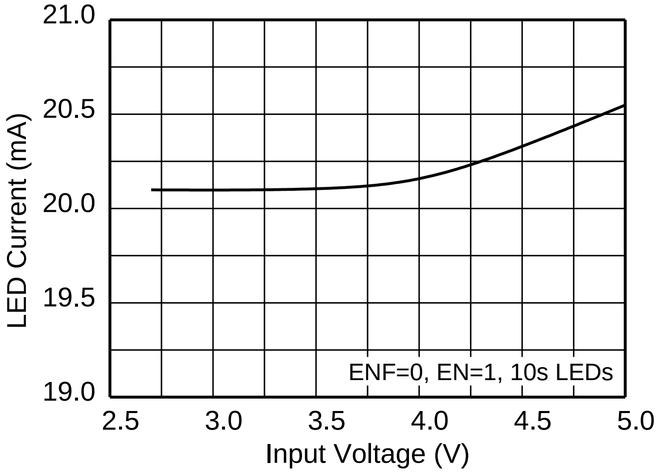


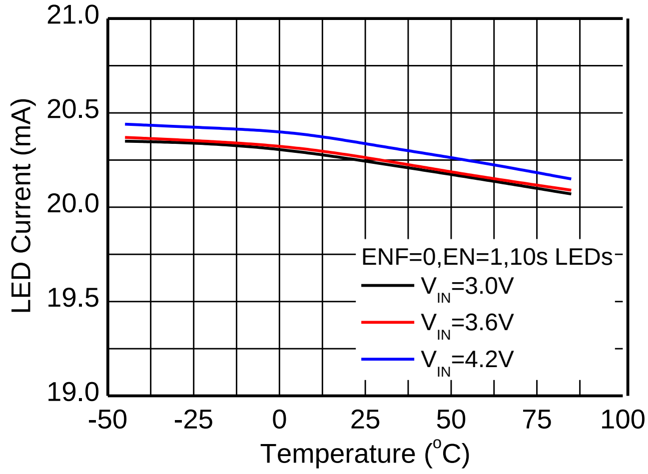
LED Current vs. Duty Cycle



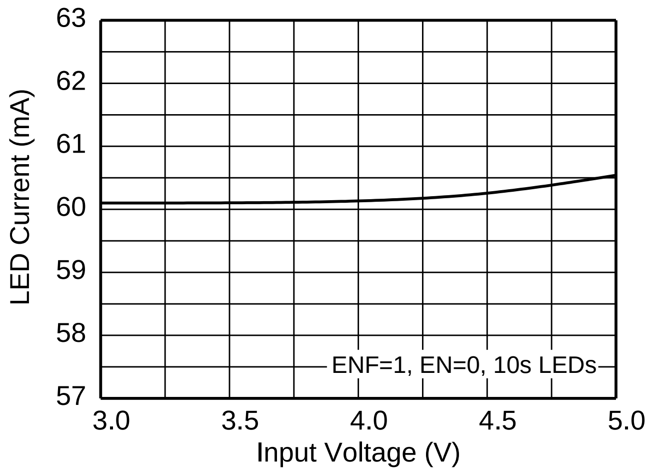
LED Current vs. Duty Cycle



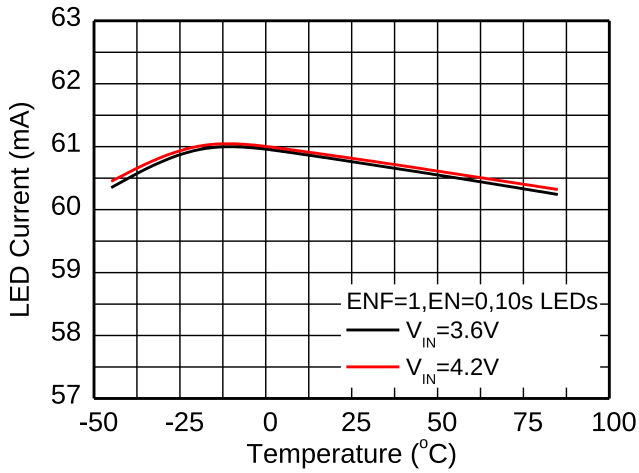
LED Current vs. Input Voltage



LED Current vs. Temperature



LED Current vs. Input Voltage



LED Current vs. Temperature

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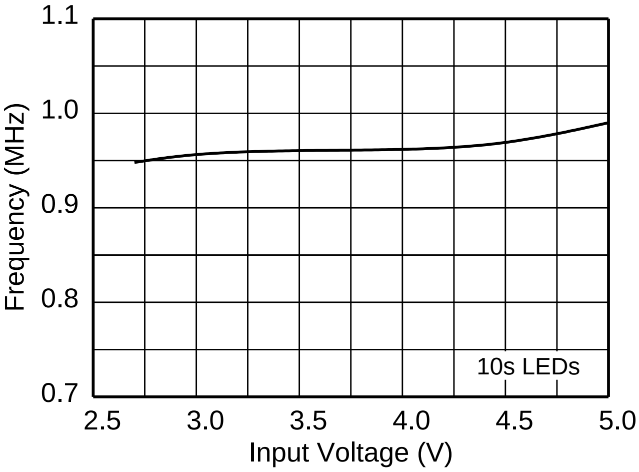
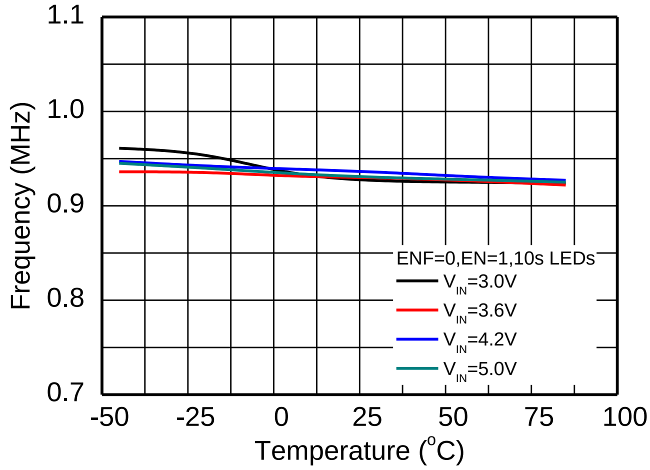
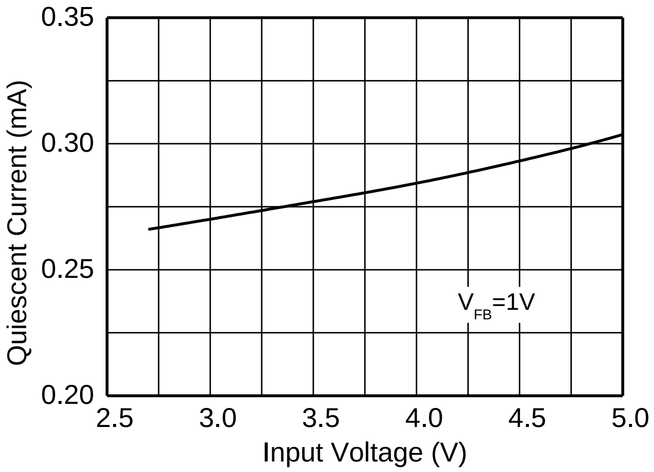


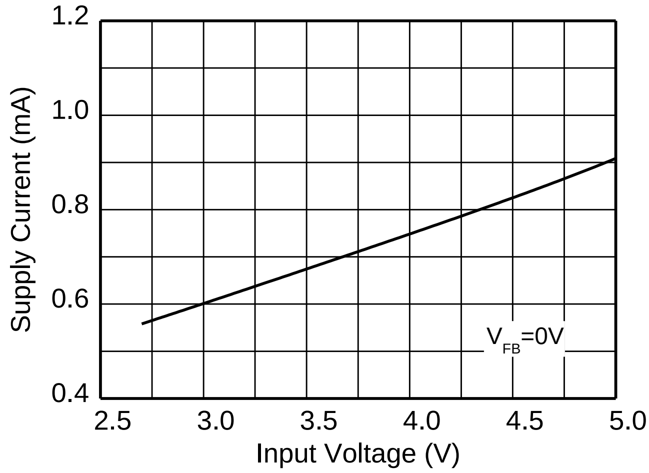
Frequency vs. Input Voltage



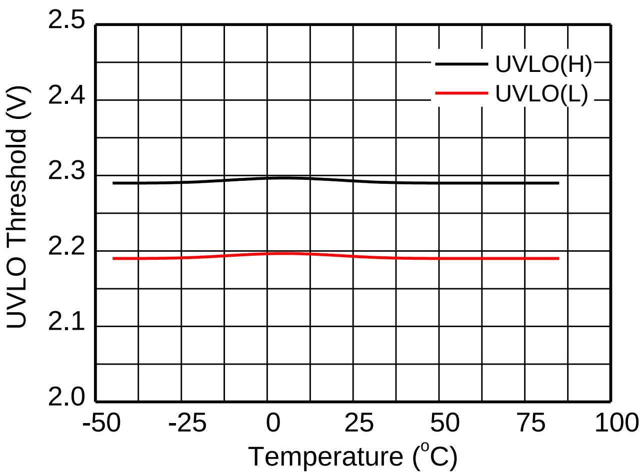
Frequency vs. Temperature



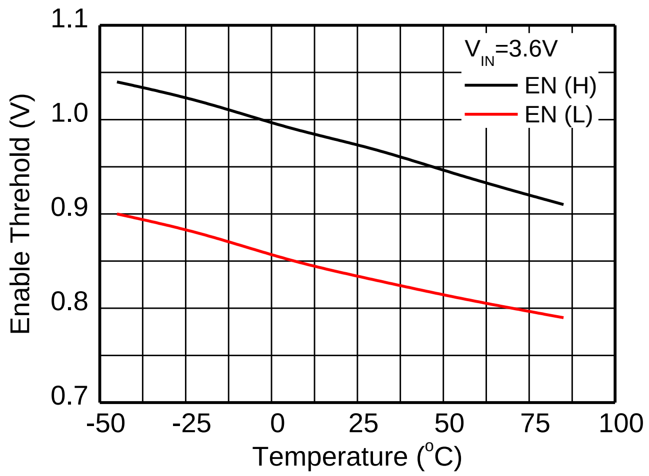
Quiescent Current vs. Input Voltage



Supply Current vs. Input Voltage



UVLO Threshold vs. Temperature



Enable Threshold vs. Temperature

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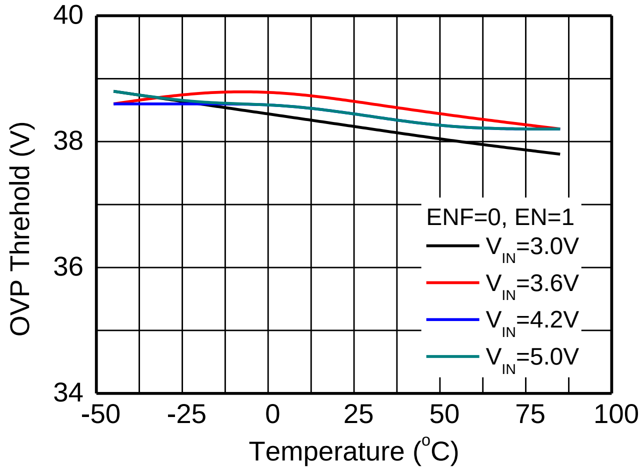
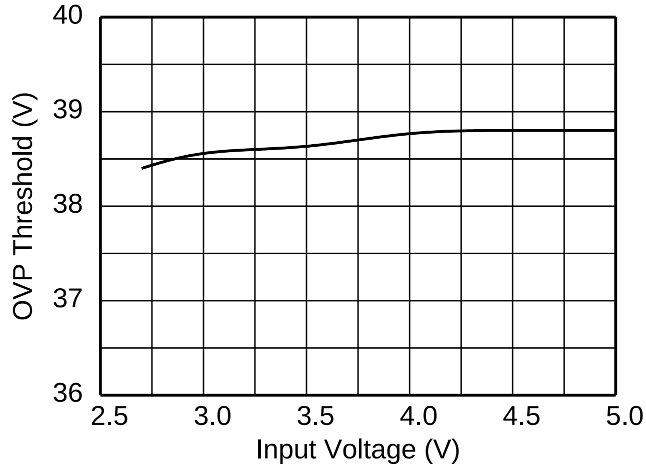
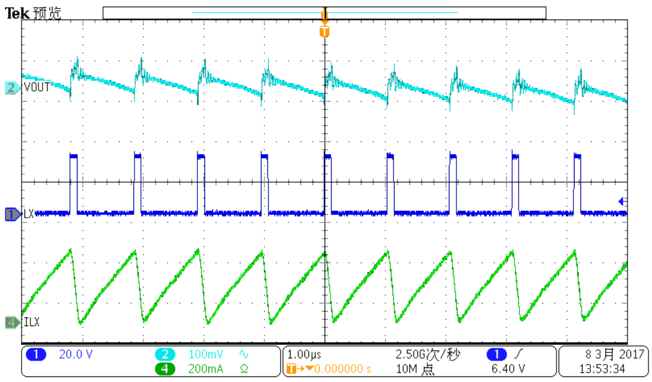


OVP Threshold vs. Temperature

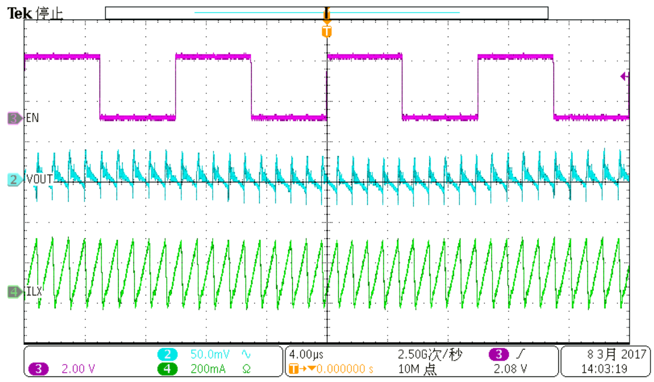


OVP Threshold vs. Input Voltage

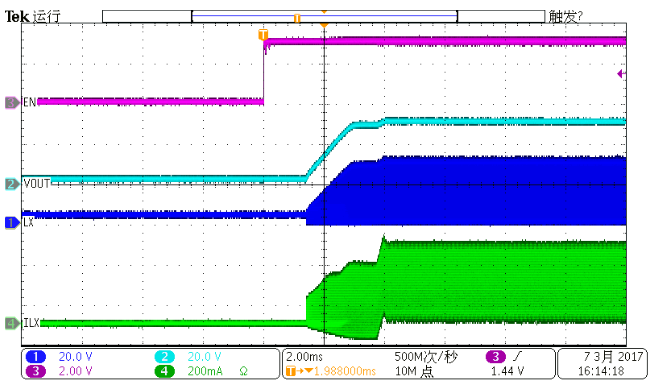
Operation Waveforms



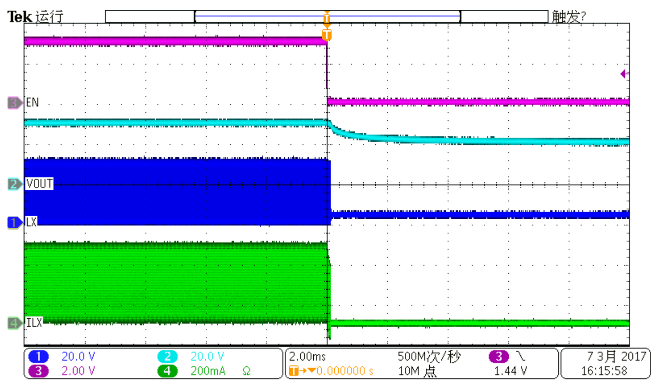
PWM Dimming Waveforms



Start-Up from EN



Shut-Down from EN



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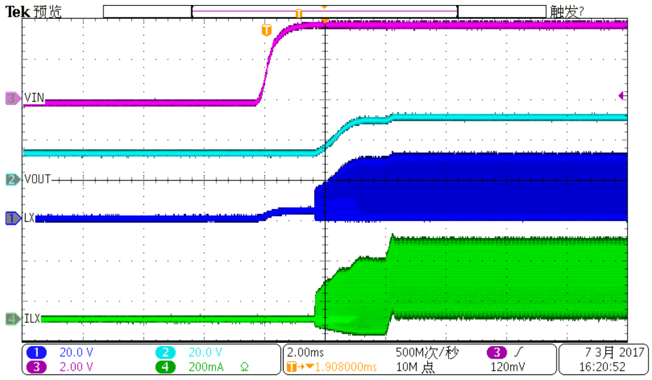
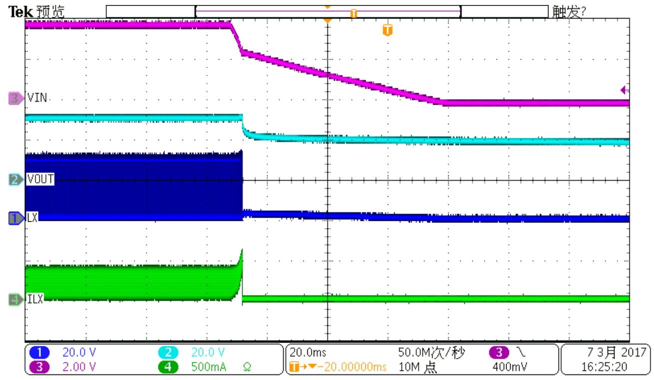
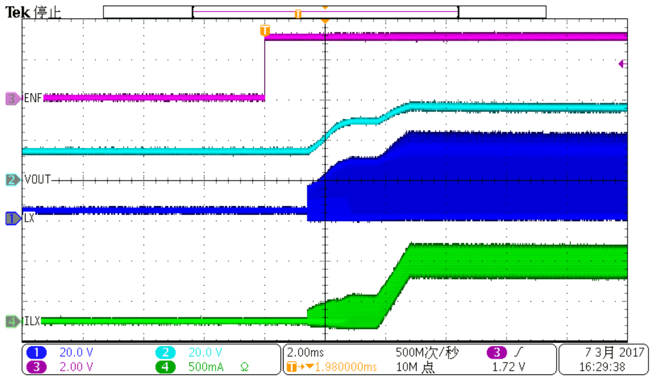
Start-Up from VIN



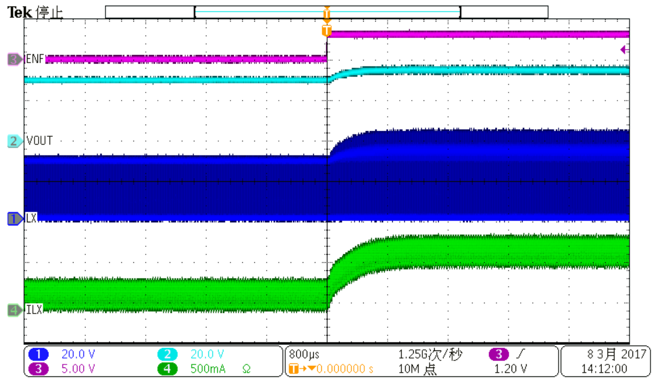
Shut-Down from VIN



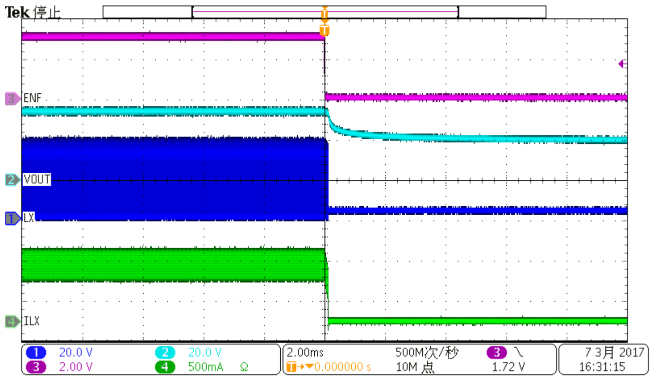
Start-Up from ENF with EN = ‘0’



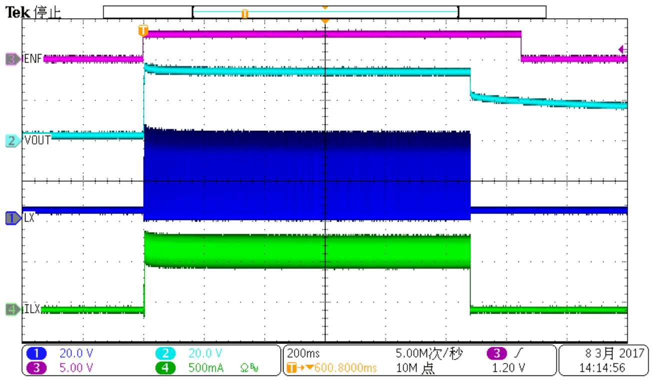
Start-Up from ENF with EN = ‘1’



Shut-Down from ENF in 1s



Shut-Down from ENF 1s expired



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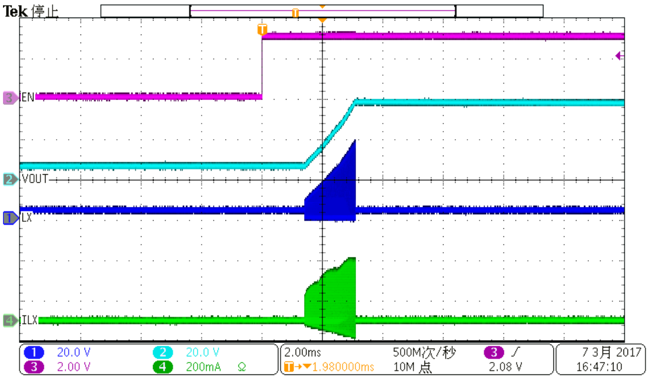
Start-Up with LED Open



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Operation Information

Normal Operation

The WD3170 is a high efficiency, high output voltage boost converter. The device is ideal for driving white LED. The LED connection provides even illumination by sourcing the same output current through all LEDs. The device integrates 38V/1.8A switch FET and operates in pulse width modulation (PWM) with 900kHz fixed switching frequency. The beginning of each cycle turns on the Power MOSFET. A slope compensation ramp is added to the current sense amplifier and the result is fed into the positive input of the comparator (COMP). When this voltage goes above the output voltage of the error amplifier (EA), the Power MOSFET is turned off. The FB voltage can be regulated to the reference voltage of bandgap with EA block. The feedback loop regulates the FB pin to a low reference voltage (200mV typical), reducing the power dissipation in the current sense resistor.

Flash Mode

When pull up the ENF pin, WD3170 enters into flash mode. In flash mode, when the ENF pin is constantly high, the FB voltage is regulated to 600mV rather than 200mV in normal backlight mode. So, WD3170 could burst LED current to 3 times of the full scale setting backlight current. However, the ENF pin allows a PWM signal to reduce this regulation voltage and achieves flash dimming. To protect white LED from damage, the WD3170 automatically exits flash mode if it lasts for more than 1s. The WD3170 will not operate in flash mode until ENF is re-cycled from low to high.

Soft-Start

The WD3170 Build-in Soft-Start function limits the inrush current while the device turn-on.

Cycle-by-Cycle Current Limit

The WD3170 uses a cycle-by-cycle current limit circuitry to limit the inductor peak current in the event of an overload condition. The current flow through inductor in charging phase is detected by a current sensing circuit. As the value comes across the current limiting threshold the N- MOSFET turns off, so that the inductor will be forced to leave charging stage and enter in discharging stage. Therefore, the inductor current will not increase over the current limiting threshold.

Open LED Protection

Open LED protection circuitry prevents IC damage as the result of white LED disconnection. The WD3170 monitors the voltage at the LX pin and FB pin during each switching cycle. The circuitry turns off the switch FET and shuts down the IC when both of the following conditions persist for 4 switching clock cycles: (1) the LX voltage exceeds the V_{OLP} threshold and (2) the FB voltage is less than 50mV.Then, the WD3170turns off the power switch FET and shuts down IC until EN or power supply is recycled to enable IC.

UVLO Protection

To avoid malfunction of the WD3170 at low input voltages, an under voltage lockout is included that disables the device, until the input voltage exceeds 2.3V (Typ.).

Shutdown Mode

Drive both EN and ENF to GND to place the WD3170 in shutdown mode. In shutdown mode, the reference, control circuit, and the main switch turn off. Input current falls to smaller than 1μA during shutdown mode.

Over-Temperature-Protection (OTP)

As soon as the junction temperature (T_J) exceeds 160ºC (Typ.), the WD3170 goes into thermal shutdown. In this mode, the main N-MOSFET is turned off until temperature falls below typically 130ºC. Then the device starts switching again.

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Application Information

External component selection for the application circuit depends on the load current requirements. Certain trade-offs between different performance parameters can also be made.

LED Current Setting

The loop of Boost structure will keep the FB pin voltage equal to the reference voltage V_{REF}. Therefore, when R_{SET} connects FB pin and GND, the current flows from V_{OUT} through LED and R_{SET} to GND will be decided by the current on R_{SET}, which is equal to following equation:

$$I_{LED} = \frac{V_{FB}}{R_{SET}} = \frac{200mV}{R_{SET}}$$

Where

I_{LED} = output current of LEDs

V_{FB} = regulated voltage of FB

R_{SET} = current sense resistor

So in flash mode, the LED current turns to be following:

$$I_{LED,Flash} = \frac{V_{FB}}{R_{SET}} = \frac{600mV}{R_{SET}}$$

The output current tolerance depends on the FB accuracy and the current sensor resistor accuracy.

Backlight Dimming Control

For the brightness dimming control of the WD3170, the IC provides typically 200mV feedback voltage when the EN pin is pulled constantly high. However, EN pin allows a PWM signal to reduce this regulation voltage by changing the PWM duty cycle to achieve LED brightness dimming control.

$$V_{FB} = Duty \times 200mV$$

Where

Duty = Duty Cycle of the EN applied PWM signal

As shown in Figure 1, the duty cycle of the PWM signal is used to chop the internal 200mV reference voltage. An internal low pass filter is used to filter the pulse signal. And then the reference voltage can be made by connecting the output of the filter to the error amplifier for the FB pin voltage regulation.

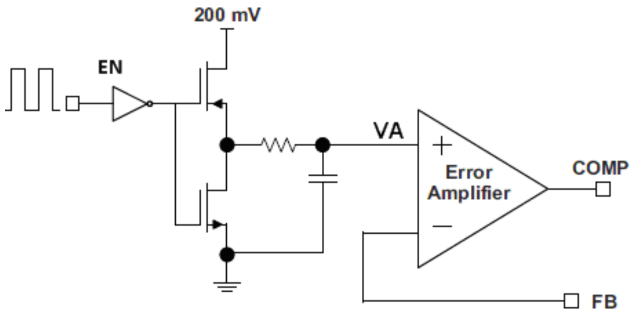

Figure 1

Therefore, although a PWM signal is applied for dimming, but only the WLED DC current is modulated. This help to eliminate the audible noise which often occurs when the LED current is pulsed in replica of the frequency and the duty cycle of PWM control. The minimum dimming frequency is limited by EN shutdown delay time. For optimum performance, recommend to select PWM dimming frequency in the range of 20kHz~100kHz. And the recommended minimum PWM Duty Cycle is 0.3% for stable LED driving and no blind dimming.

The EN shutdown delay time is set to 0.12ms. This means the IC needs to be shutdown by pulling the EN low for 0.12ms.

Flash Dimming Control

The WD3170 receives PWM dimming signal at ENF pin to control the total output current. When the ENF pin is constantly high, the FB voltage is regulated to 600mV typically. When the duty cycle of the input PWM signal is low, the regulation voltage at FB pin is reduced, and the total output current is reduced; therefore, it achieves flash dimming. The relationship between the duty cycle and FB regulation voltage is given by:

$$V_{FB} = 200mV + Duty \times 400mV$$

Where

Duty = Duty cycle of the ENF applied PWM signal

Thus, the user can easily control the LED brightness

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in flash mode by controlling the duty cycle of the PWM signal.

The circuit implementation of the FB pin voltage regulation is similar to the front part. The recommended PWM frequency is in the range of 20k Hz~100k Hz. And the ENF shutdown delay time is set to 0.12ms.

Boost Inductor Selection

The selection of the inductor affects steady state operation as well as transient behavior and loop stability. Inductor values can have ±20% tolerance with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the 0A value depending on how the inductor vendor defines saturation current. Using an inductor with a smaller inductance value forces discontinuous PWM when the inductor current ramps down to zero before the end of each switching cycle. This reduces the boost converter's maximum output current, causes large input voltage ripple and reduces efficiency. Large inductance value provides much more output current and higher conversion efficiency. The inductor should have low core loss at 1MHz and low DCR for better efficiency. For these reasons, the recommended value of inductor for 10 series WLEDs applications is 10μH. A 10μH inductor with Low DCR optimized the efficiency for most application while maintaining low inductor peak to peak ripple.

Input Capacitor Selection

Connect the input capacitance from V_{IN} to the reference ground plane. Input capacitance reduces the ac voltage ripple on the input rail by providing a low-impedance path for the switching current of the boost converter. The capacitor in the range of 1μF to 10μF/X7R or X5R is recommended for input side.

Output Capacitor Selection

The output capacitor is mainly selected to meet the requirements for the output ripple and loop stability. This ripple voltage is related to the capacitor's capacitance and its equivalent series resistance (ESR). The recommended minimum capacitor on Output is a 1uF/50V, X5R or X7R ceramic capacitor.

Diode Selection

The rectifier diode supplies current path to the inductor when the internal MOSFET is off. Use a schottky with low forward voltage to reduce losses. The diode should be rated for a reverse blocking voltage greater than the output voltage used. The average current rating must be greater than the maximum load current expected, and the peak current rating must be greater than the peak inductor current.

Diode the following requirements:

- Low forward voltage
- High switching speed : 50ns max.
- Reverse voltage : V_{OUT} + V_F or more
- Rated current : I_{PK} or more

PCB Layout Considerations

A good circuit board layout aids in extracting the most performance from the WD3170. Poor circuit layout degrades the output ripple and the electromagnetic interference (EMI) or electro-magnetic compatibility (EMC) performance. The evaluation board layout is optimized for the WD3170. Use this layout for best performance.

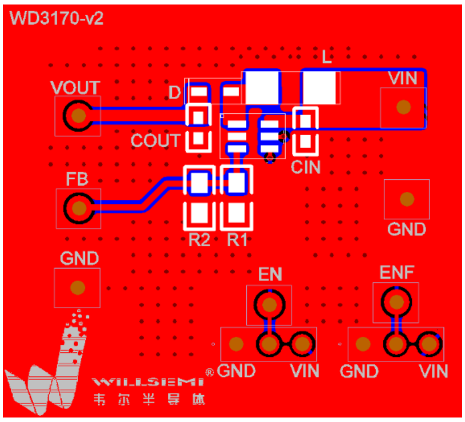

Figure 2, WD3170 PCB Layout Demo

If the layout needs changing, use the following guidelines:

1. Use separated power supply trace and power ground planes from other sensitive blocks.
2. Locate C_{IN} as close to the V_{IN} pin as possible.

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And connect the lower plate of C_{IN} Close to IC's GND.

3. Route the high current path from C_{IN}, through L to the LX and GND pins as short as possible. And keep high current traces as short and as wide as possible.

4. Route the high current path from L to Diode and C_{OUT} as short as possible. And keep high current traces as short and as wide as possible. Connect the lower plate of C_{OUT} as Close to IC's GND as possible.

5. Avoid routing sensitive trace near this block, especially LX Node. Place a ground plane shield between the traces.

6. Place the R_{SET} resistor as close to FB pin as possible, for the FB is a high impedance input pin which is susceptible to noise and high voltage spike.

7. Avoid routing a long V_{OUT} or FB trace parallel to other sensitive signal. Place a ground plane shield between the traces.

These guidelines should be considered seriously. Additionally, an RC-snubber network could be placed between LX and ground to reduce EMI, which is referred to Figure 5. And the PCB Layout is shown as followed.

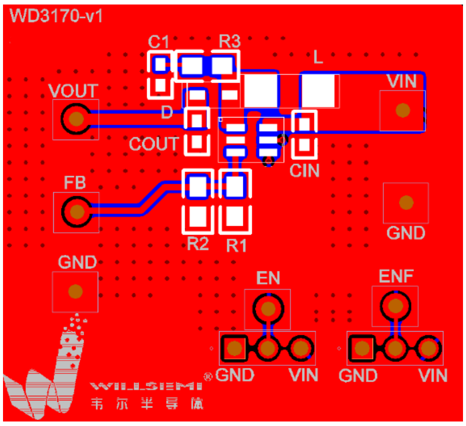

Figure 3, WD3170 PCB Layout with Snubber

Typical Applications

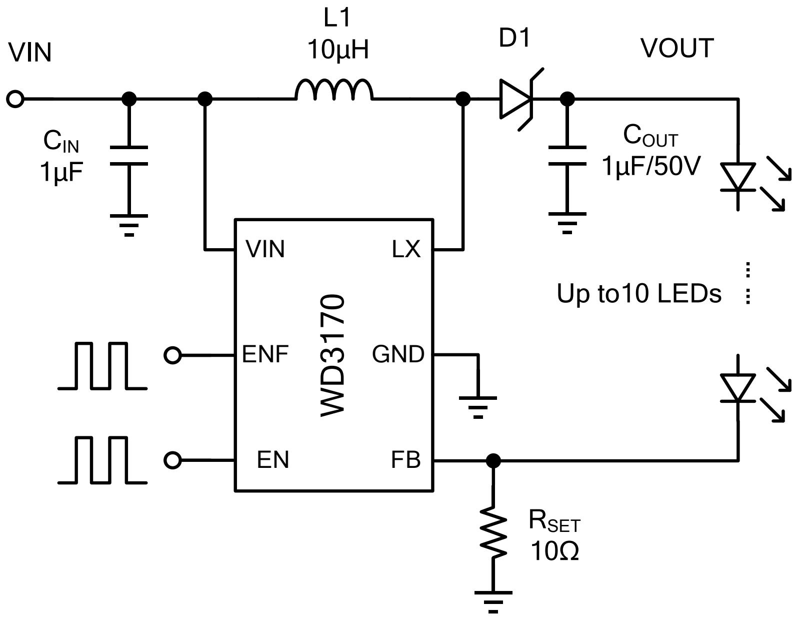

Figure 4, Li-Ion Driver for 10-S White LEDs

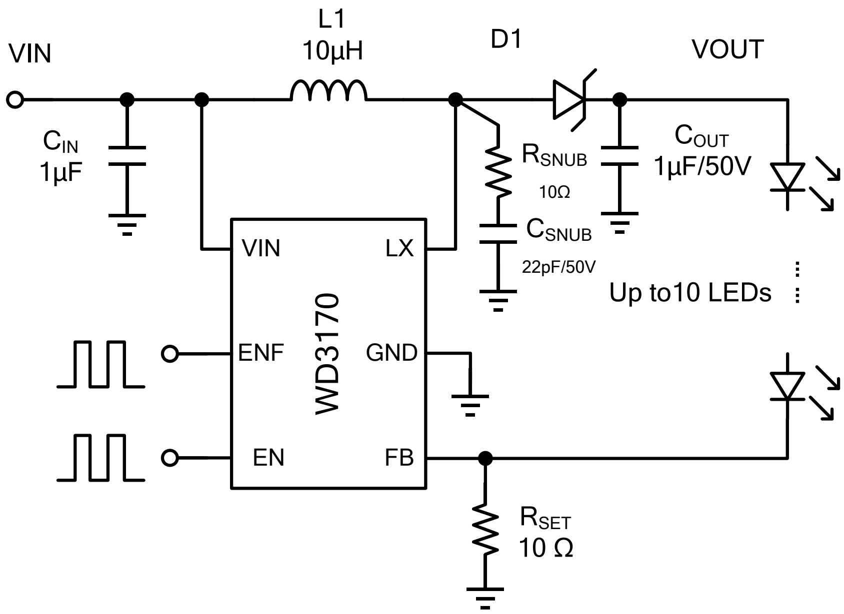

Figure 5, Li-Ion Driver for 10-S White LEDs with Snubber Network to Reduce EMI

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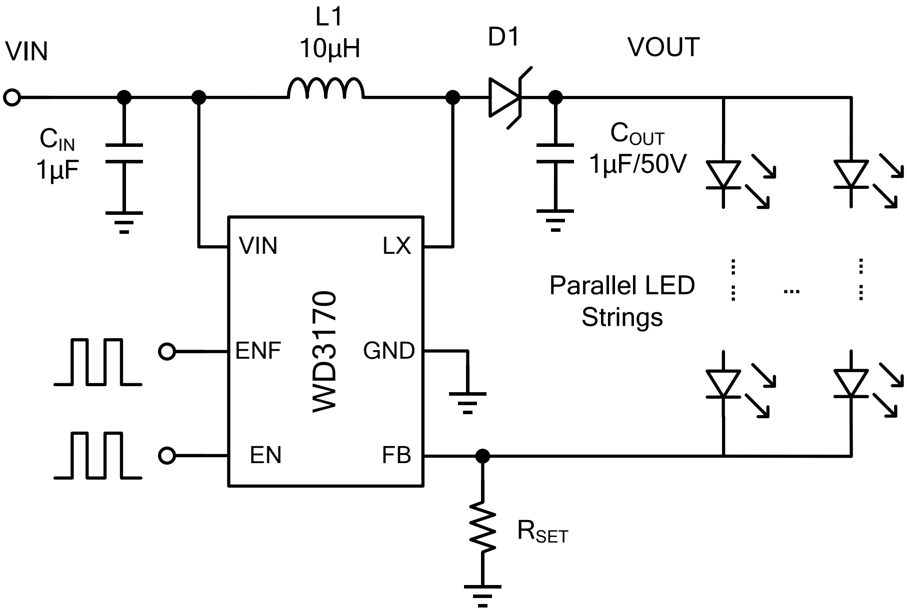

Figure 6, Li-Ion Driver for Parallel White LED Strings

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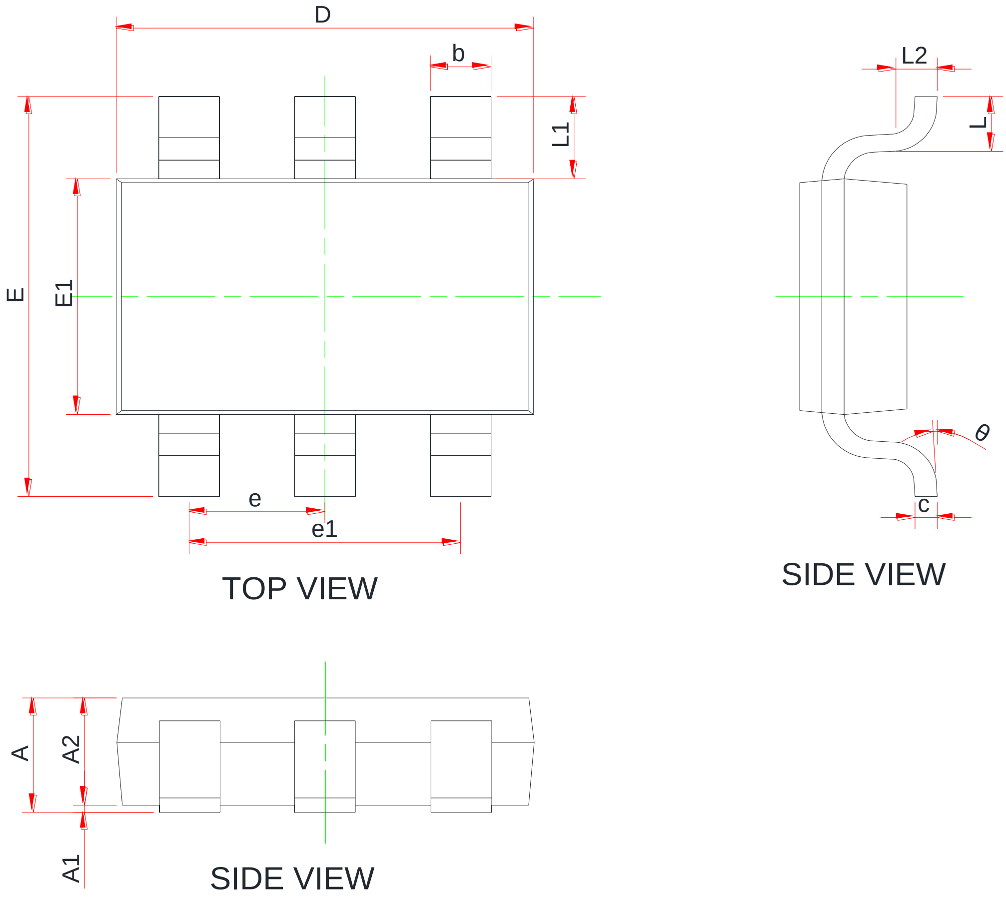
PACKAGE OUTLINE DIMENSIONS

TSOT-23-6L



Symbol	Dimensions in Millimeters		
	Min.	Typ.	Max.
A	-	-	0.900
A1	0.000	-	0.150
A2	0.650	0.750	0.850
b	0.350	-	0.500
c	0.080	-	0.200
D	2.820	-	3.050
E	2.650	2.800	2.950
E1	1.600	1.650	1.700
e	0.950 BSC		
e1	1.900 BSC		
L	0.300	0.450	0.600
L1	0.575 Ref.		
L2	0.250 BSC		
θ	0 °	-	8 °

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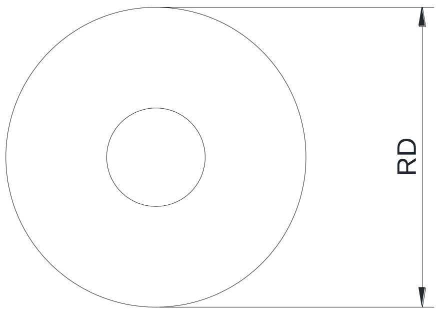
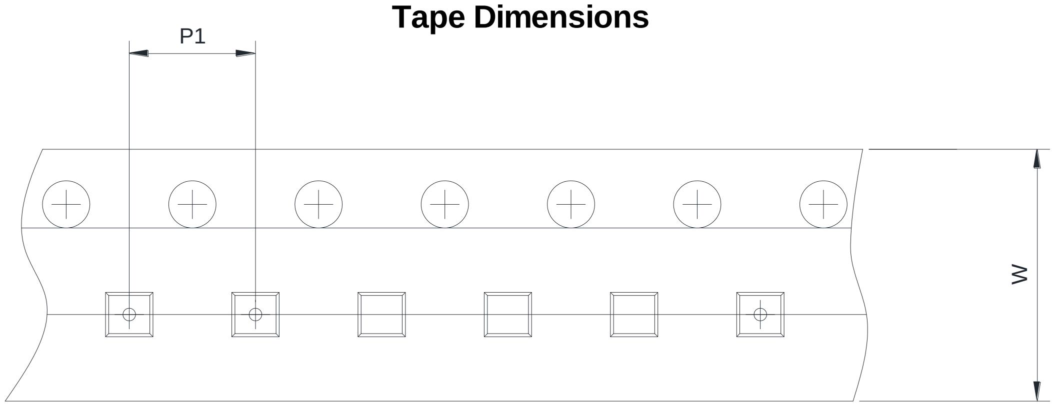
TAPE AND REEL INFORMATION

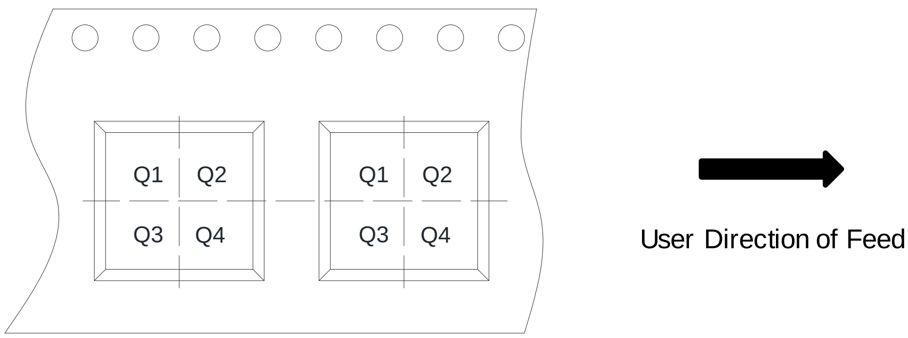
Reel Dimensions



Tape Dimensions



Quadrant Assignments For PIN1 Orientation In Tape



RD	Reel Dimension	☑ 7inch	☐ 13inch		
W	Overall width of the carrier tape	☑ 8mm	☐ 12mm	☐ 16mm	
P1	Pitch between successive cavity centers	☐ 2mm	☑ 4mm	☐ 8mm	
Pin1	Pin1 Quadrant	☐ Q1	☐ Q2	☑ Q3	☐ Q4

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