1A LED Driver with Internal Switch

Features

- 1A output current
- Wide input voltage range: 5V to 30V
- High efficiency (up to 95%)
- Internal NDMOS power switch
- Single pin on/off and brightness control using PWM
- Hysteretic PFM improves efficiency at light loads
- With Thermal/Soft start /LED open-short detect protection
- Only 4 External Components
- Up to 1Mhz switching frequency
- Typical 3% output current accuracy

Product Description

NU360 is a high efficiency, constant current, continuous mode inductive step-down converter, designed for driving constant current to high power (single or multiple) LED with only 4 external components. NU360 operates from input supply between 5V and 30V and provides an externally adjustable output current of up to 1A.

The NU360 is specifically designed with PFM control to enhance the efficiency up to 95%. The Output current can be modify by an external resister , and can adjusted, by applying an external control signal to the DIM pin, The DIM pin will accept a PWM waveform.

Additionally, to ensure the system reliability, NU360 is built-in with over temperature protection, and LED open-circuit short-circuit protection to protect system from being damaged.
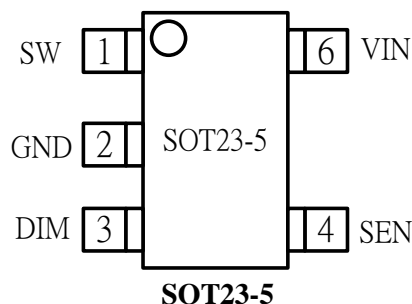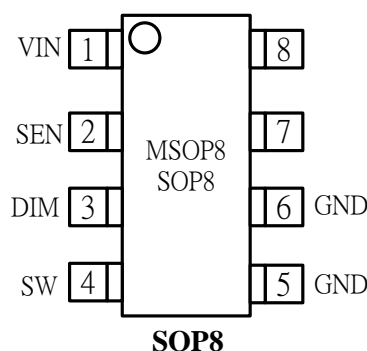
Package Type

SOP8
SOT23-5

Applications

- High power LED lighting
- Low voltage industrial lighting
- LED back-lighting
- Constant current source

Pin Assignment

SOP8

SOT23-5

Terminal Description

Pin Name	Pin Description
SW	Drain of NDMOS switch
GND	Ground pad
DIM	Dimming control pad
SEN	Connect resistor RS from this pin to VIN to define nominal average output current
VIN	Power pad

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● **Maximum Ratings (T = 25°C)**

| Item	Symbol	Rating		Unit
Supply Voltage	V_{IN}	0 ~ 30		V
Output Current	I_{OUT}	1.25		A
Sustaining voltage at SW pin	V_{SW}	-0.5 ~ 30		V
Power dissipation*	P_D	SOP8	1	W
		SOT23	0.4	
Thermal resistance	$R_{th(j-a)}$	SOP8	100	°C/W
		SOT23	400	
Operating Temperature	Top	-40°C - +85°C		°C
Storage Temperature	Tsto	-55°C - +150°C		°C

* 2 layer, PCB size is 22mm*20mm

Electrical Characteristics

(Condition: Ta= 25 ℃，V_{IN}=12V, V_{OUT}=3.6V, L1=68uH)

Item	Symbol	Condition	Min	Typical	Max	Unit
Operating voltage	V_{IN}		5	24	-	V
Operating current	I_{IN}	V_{IN} = 5V ~ 30V	-	1	2	mA
Output current	I_{OUT}		-	-	1	A
Output current Accuracy	$\Delta I_{OUT}/I_{OUT}$	150mA $\leqq$ I_{OUT} $\leqq$ 1A	-	±3	±5	%
Efficiency		V_{IN}=12V, $I_{OUT=}$350mA,V_{out}=10.8V	-	95	-	%
SW Dropout voltage	ΔVsw	I_{OUT}=1A	-	0.5	-	V
Switch on resistance	$R_{DS(ON)}$	V_{IN}=12V, $I_{OUT=}$350mA,V_{out}=10.8V	-	0.5	1	Ω
Input voltage	V_{IH}		3.5	-	5	V
	V_{IL}		-	-	0.5	V
Sense threshold hysteresis	$V_{SENSEHYS}$		-	±15		%
Mean current sense threshold voltage	VSENSE		95	100	105	mV
Minimum switch 'ON' time	T_{ONmin}		100	350	450	nS
Minimum switch 'OFF' time	T_{OFFmin}		100	350	450	nS
Recommended duty cycle range of switch	Dsw		0.2	-	0.8	
Operating frequency	Freq		40	-	1000	kHz
Thermal shutdown threshold	T_{SD}		-	160	-	°C
Thermal shutdown hystersis	T_{SD-HYS}		-	20	-	°C
Duty cycle range of PWM signal applied to DIM pin	$Duty_{DIM}$	PWM frequency = 1kHz	0.01	-	1	
Rise time of output current	T_r	I_{OUT} = 350mA , V_{OUT} = 3.6V F_{DIM}= 1kHz , Duty= 50%	-	20	-	nS
Fall time of output current	T_f	I_{OUT} = 350mA , V_{OUT} = 3.6V F_{DIM} = 1kHz , Duty = 50%	-	20	-	nS

Block diagram
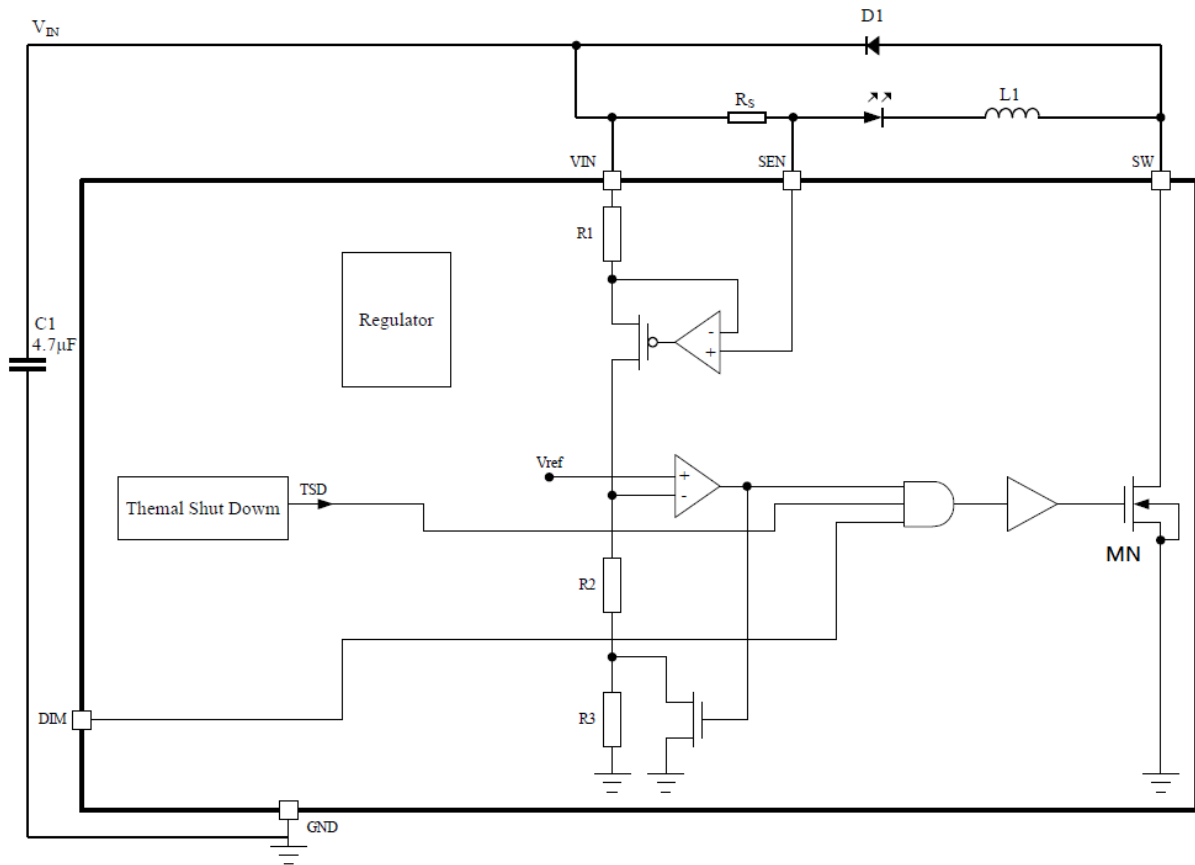
Application circuit
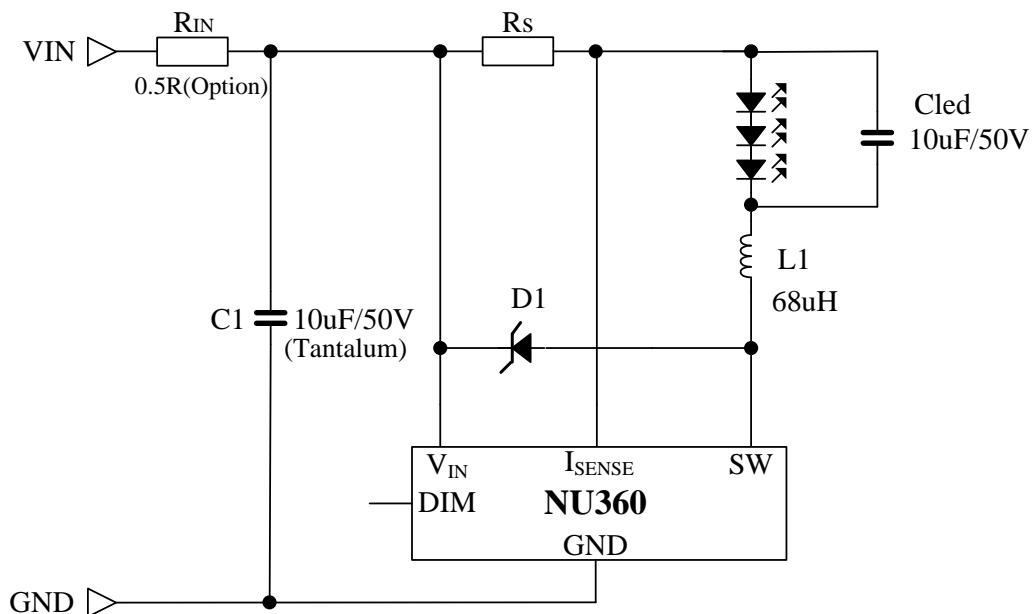
Note. For hot plug, please add a R_{IN} or C1 use tantalum capacitors.

Application description (Refer to block diagram and application circuit above)

Operation can be best understood by assuming that the DIM pin of the device is unconnected and the voltage on this pin (V_{DIM}) appears directly at the logic high. When input voltage V_{IN} is first applied, the initial current in L1 and RS is zero and there is no output from the current sense circuit. Under this condition, the (-) input to the comparator is at ground and its output is high. This turns MN on and switches the SW pin low, causing current to flow from V_{IN} to ground, via RS, L1 and the LED(s). The current rises at a rate determined by V_{IN} and L1 to produce a voltage ramp (V_{SENSE}) across R_S. The supply referred voltage V_{SENSE} is forced across internal resistor R1 by the current sense circuit and produces a proportional current in internal resistors R2 and R3. This produces a ground referred rising voltage at the (-) input of the comparator. When this reaches the threshold voltage (Vref), the comparator output switches low and MN turns off. The comparator output also drives another NMOS switch, which bypasses internal resistor R3 to provide a controlled amount of hysteresis. The hysteresis is set by R3 to be nominally 15% of Vadj.

When MN is off, the current in L1 continues to flow via D1 and the LED(s) back to V_{IN}. The current decays at a rate determined by the LED(s) and diode forward voltages to produce a falling voltage at the input of the comparator. When this voltage returns to Vadj, the comparator output switches high again. This cycle of events repeats with the comparator input ramping between limits of Vref ±15%.

- **Switching thresholds**

With $V_{ADJ} = V_{REF}$, the ratios of R1, R2 and R3 define an average VSENSE switching threshold of 100mV (measured on the I_{SENSE} pin with respect to V_{IN}). The average output current I_{OUTNOM} is then defined by this voltage and R_S according to:

$I_{OUTNOM} = 100mV/R_S$
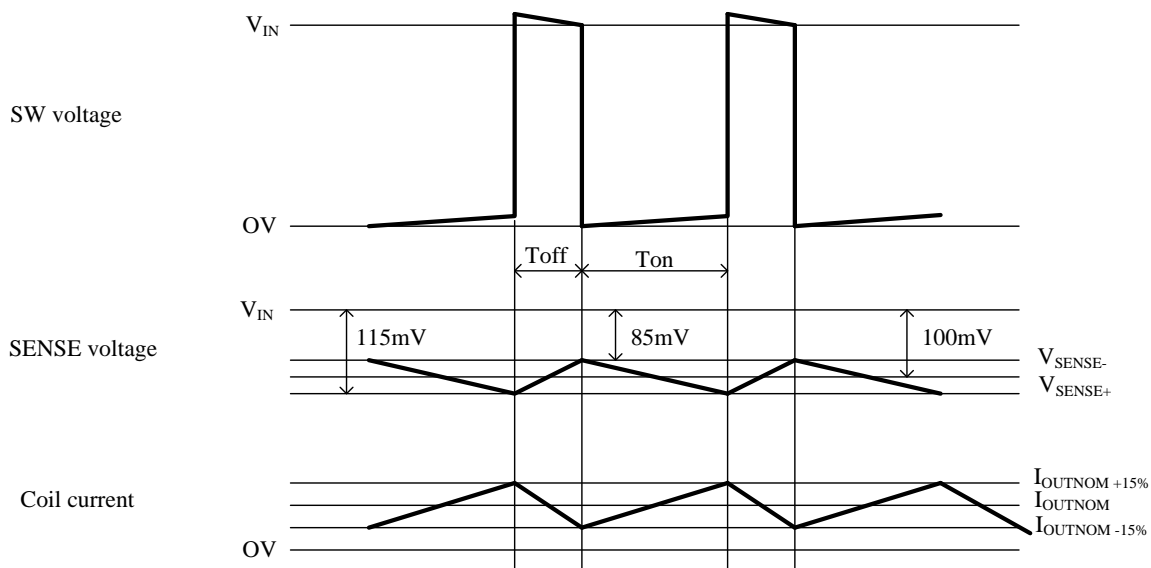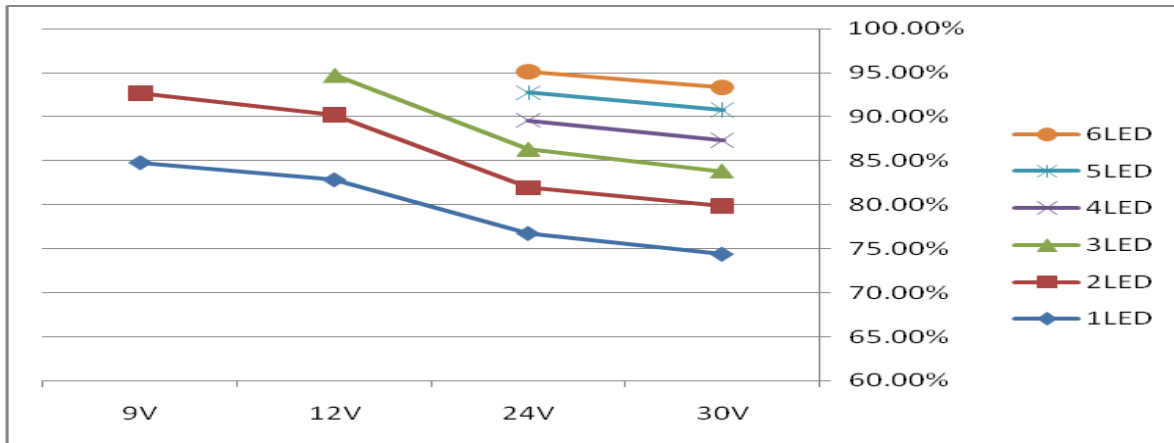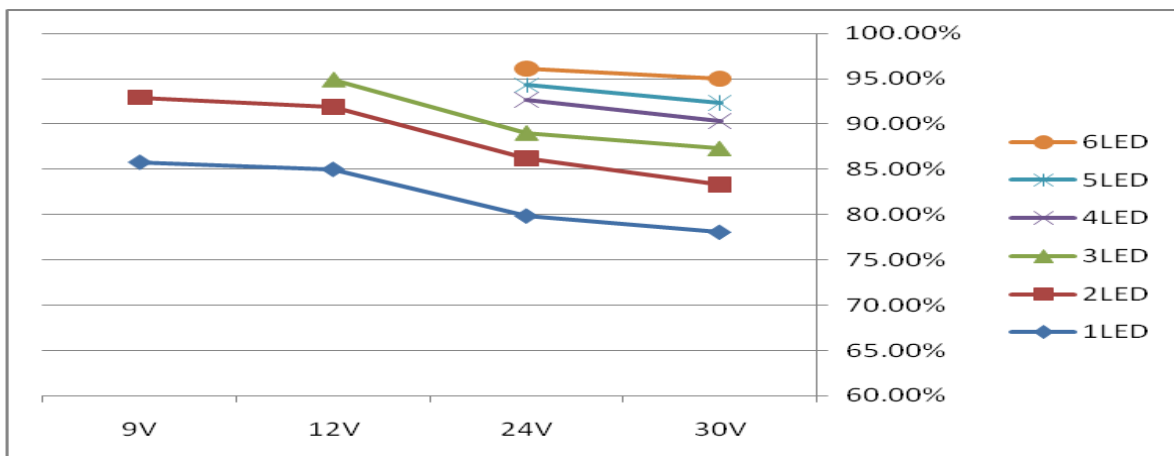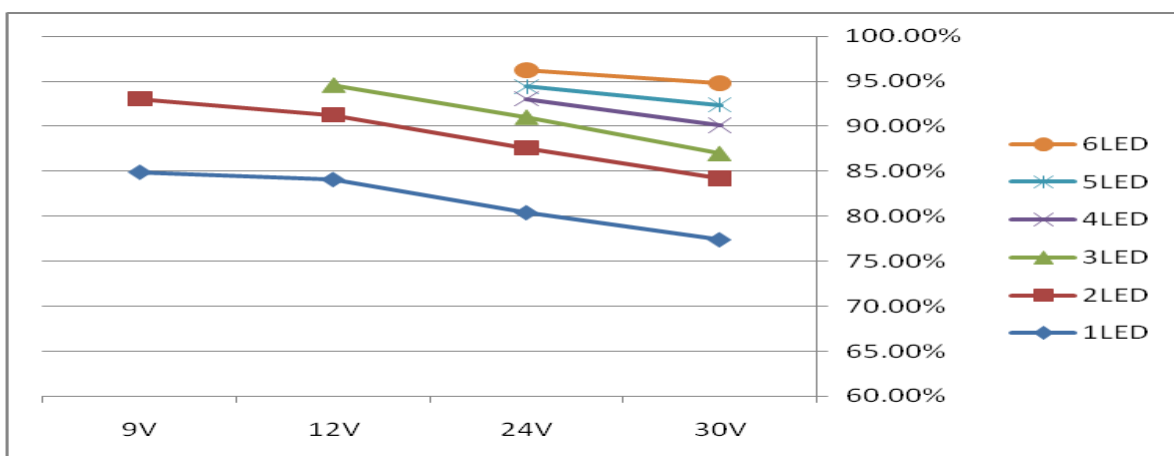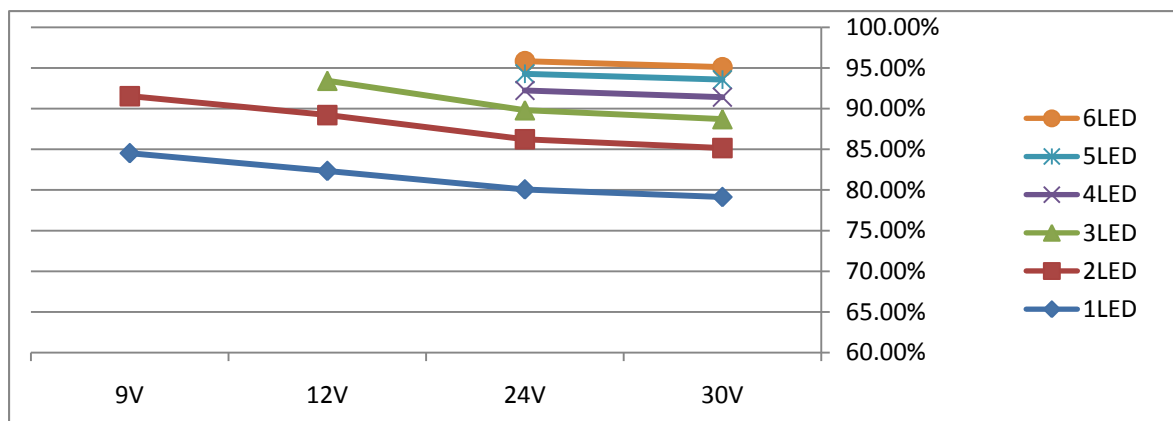
Nominal ripple current is $\pm15mV/R_S$

Figure 1-Operating waveforms

- **Typical performance characteristics**
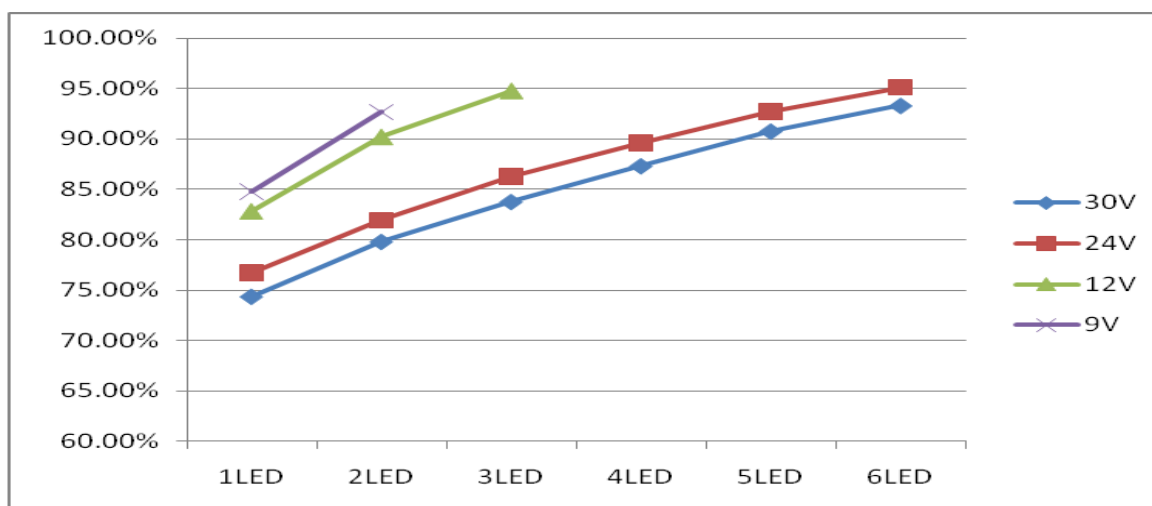
1.   *Efficiency vs. Input Voltage at Various LED Cascaded Number*

Efficiency vs. input voltage @ L=22uH, I$_{OUT}$=370mA

Efficiency vs. input voltage @ L=68uH, I$_{OUT}$=370mA

Efficiency vs. input voltage @ L=100uH, I$_{OUT}$=370mA

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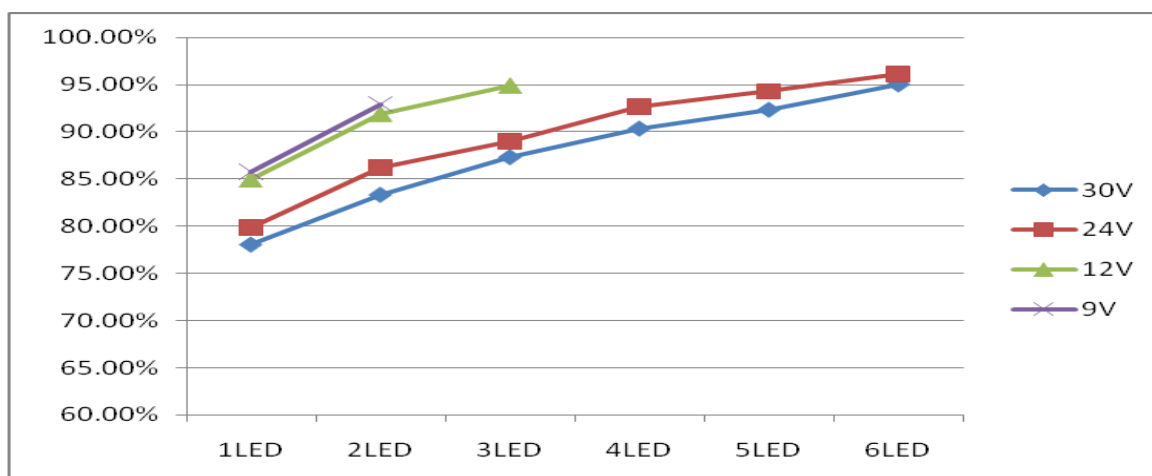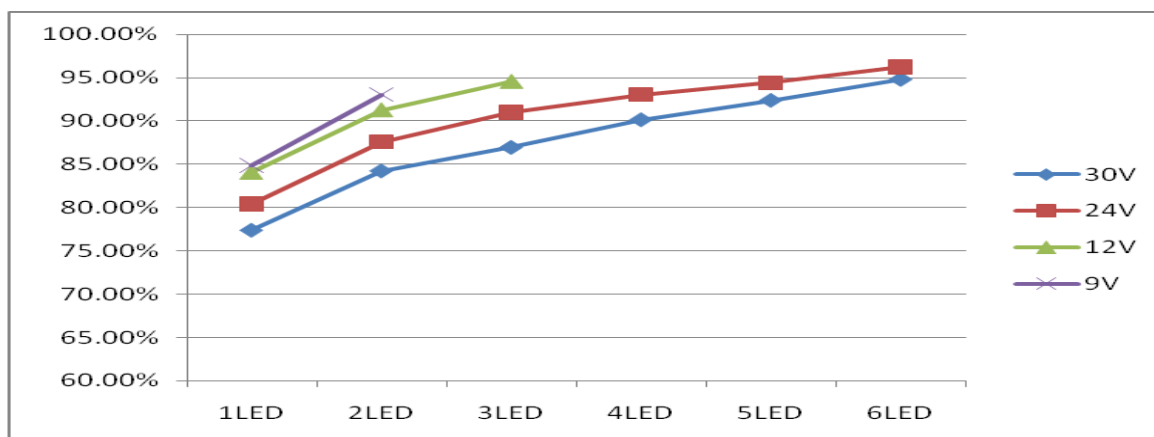
Efficiency vs. input voltage @ L=68uH, I_{OUT}=770mA

2. *Efficiency vs. LED Cascaded Number at Various Input Voltage*

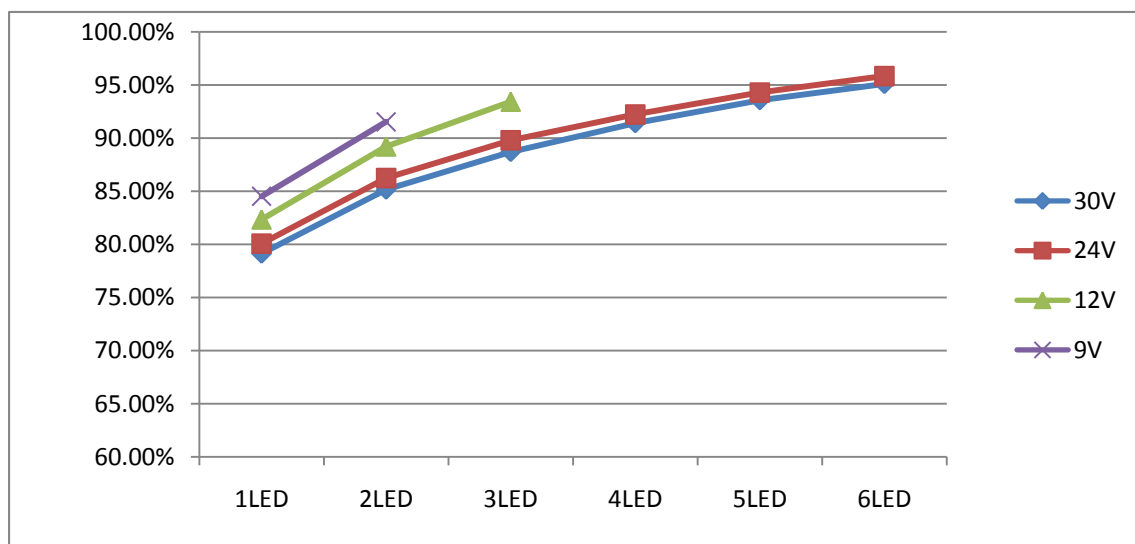Efficiency vs. LED cascaded number @ L=22uH, I_{OUT}=370mA

Efficiency vs. LED cascaded number @ L=68uH, I_{OUT}=370mA

Efficiency vs. LED cascaded number @ L=100uH, I_{OUT}=370mA

Efficiency vs. LED cascaded number @ L=68uH, I_{OUT}=770mA

3. *Output Current vs. Input Voltage at Various LED Cascaded Number*
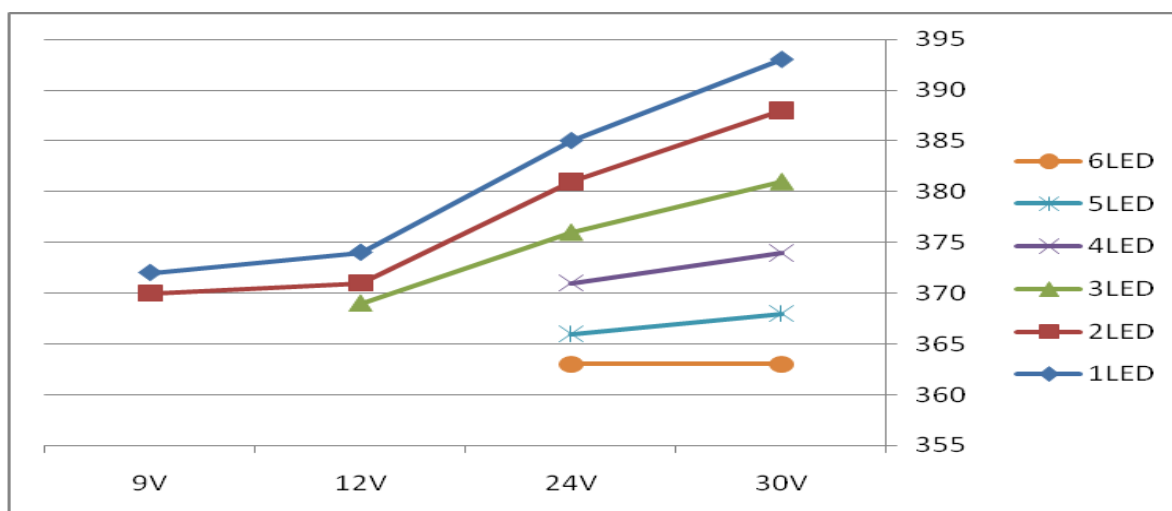
Output current vs. input voltage @ L=22uH, I_{OUT}=370mA
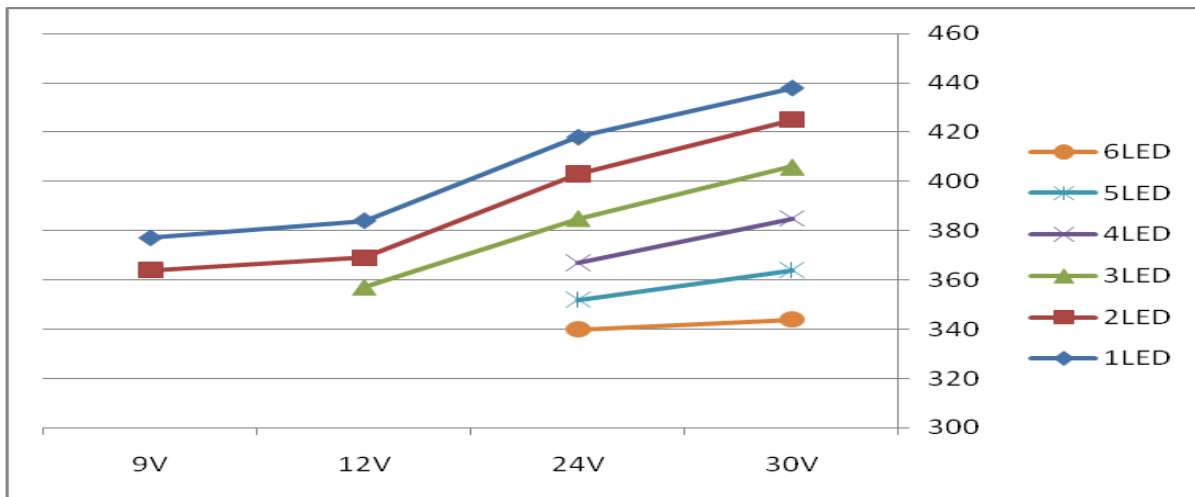
Output current vs. input voltage @ L=68uH, I_{OUT}=370mA

Output current vs. input voltage @ L=100uH, I_{OUT}=370mA

Output current vs. input voltage @ L=68uH, I_{OUT}=770mA

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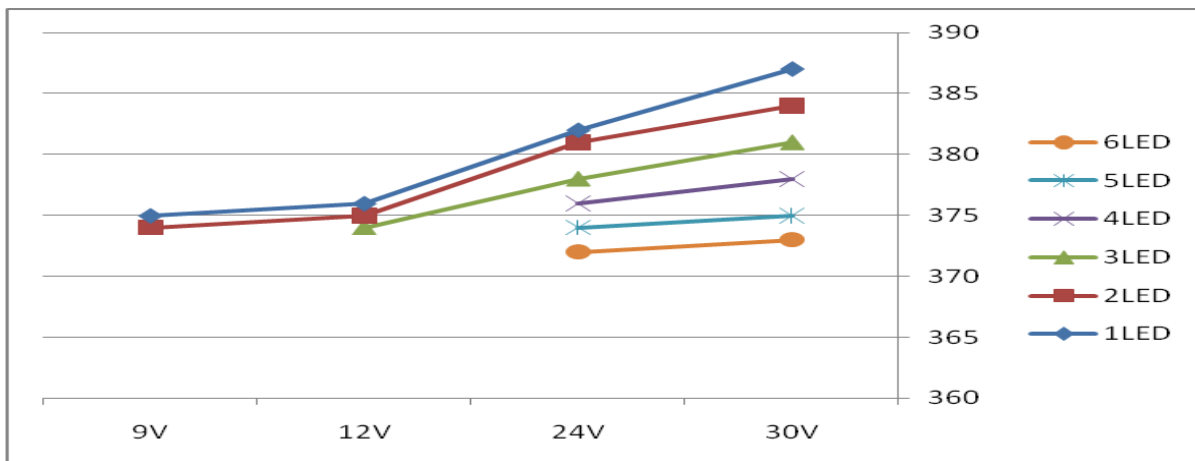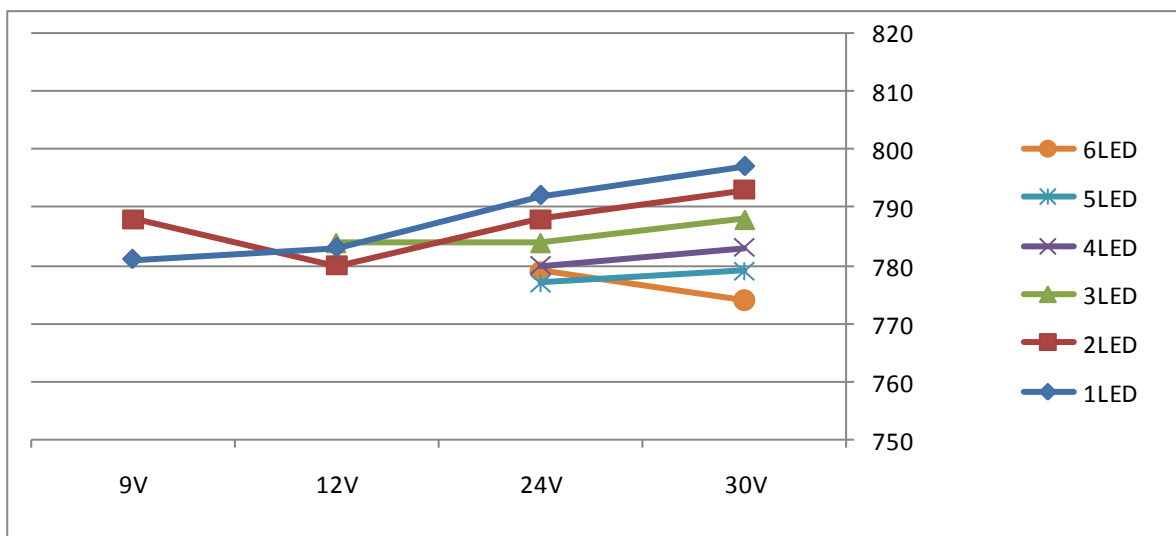
4. *Output Currnet vs. Input Voltage at Various Inductor*
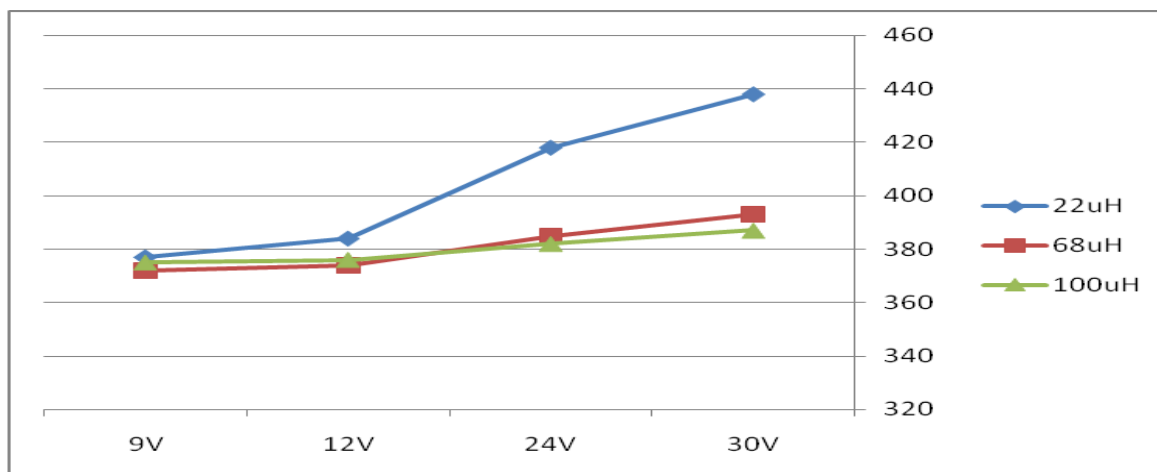
Output current vs. input voltage @1-LED in cascaded, I_{OUT}=370mA
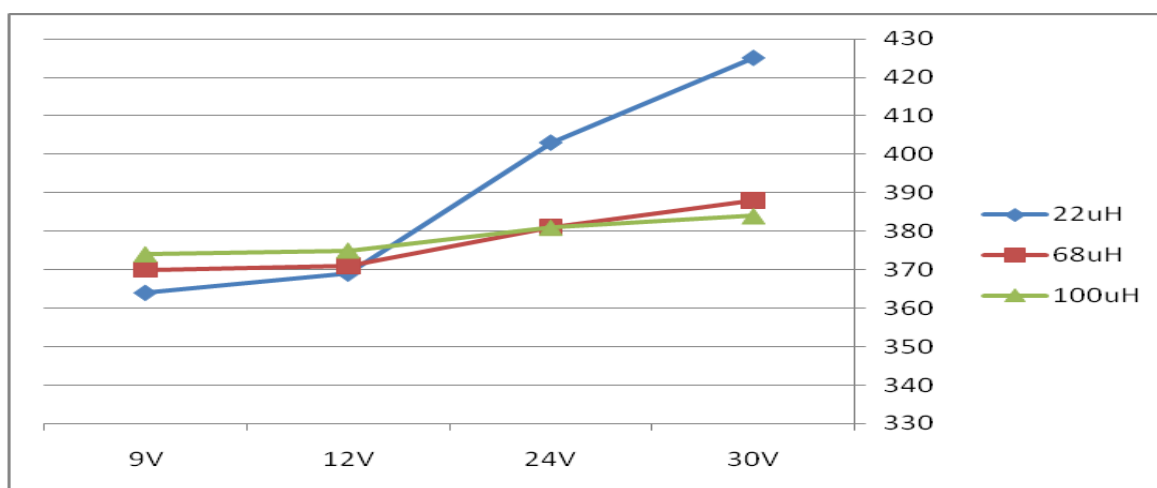
Output current vs. input voltage @2-LED in cascaded, I_{OUT}=370mA
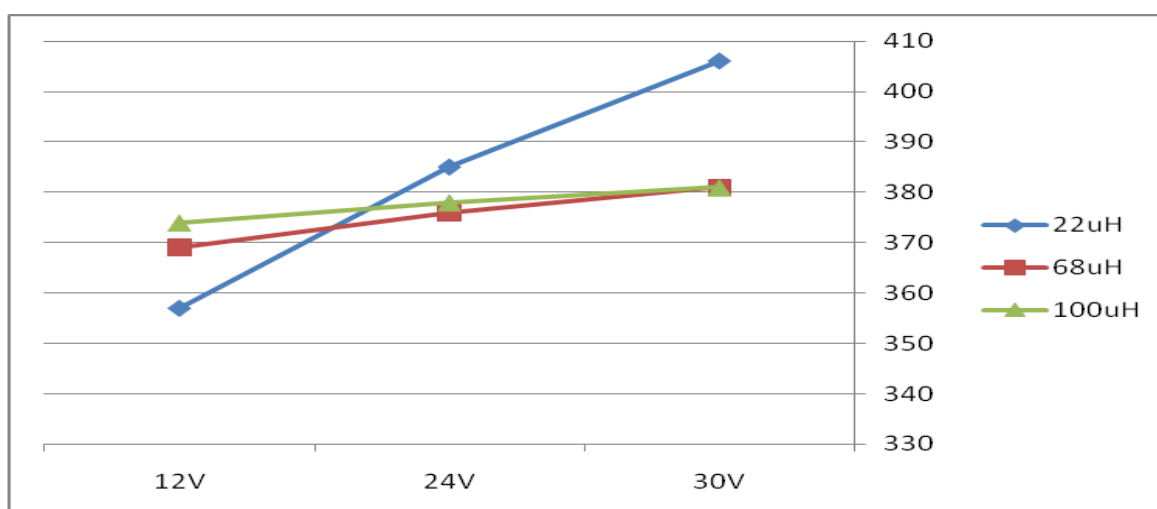

Output current vs. input voltage @3-LED in cascaded, I_{OUT}=370mA

5.   Output Current vs. LED Cascaded Number at Various Input Voltage
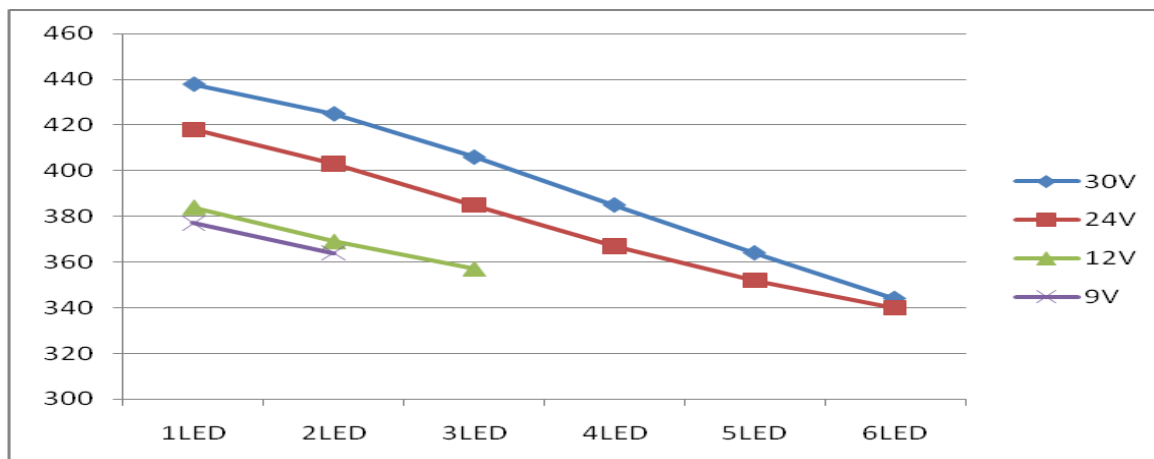
Output current vs. LED cascaded number @ L=22uH, I_{OUT}=370mA
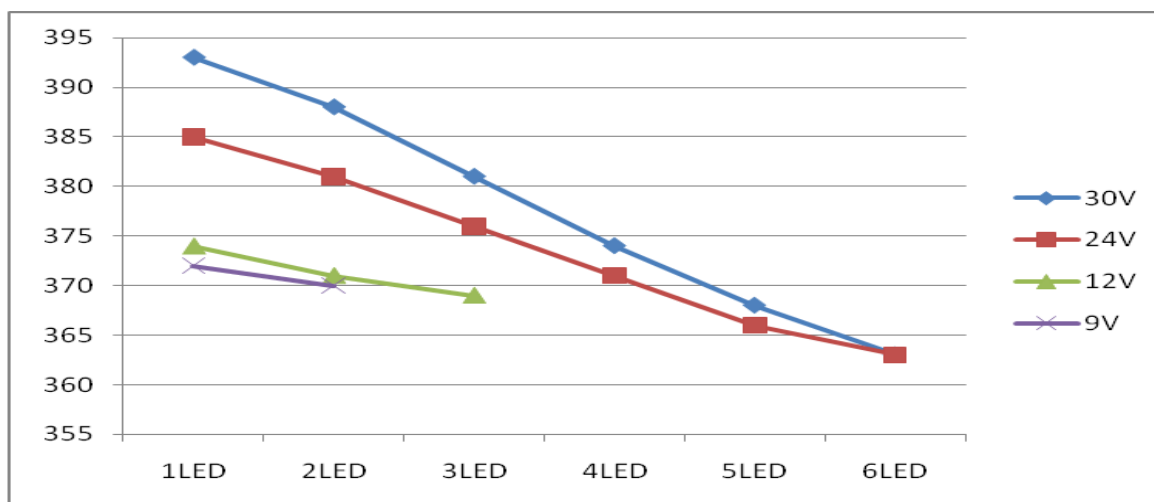
Output current vs. LED cascaded number @ L=68uH, I_{OUT}=370mA
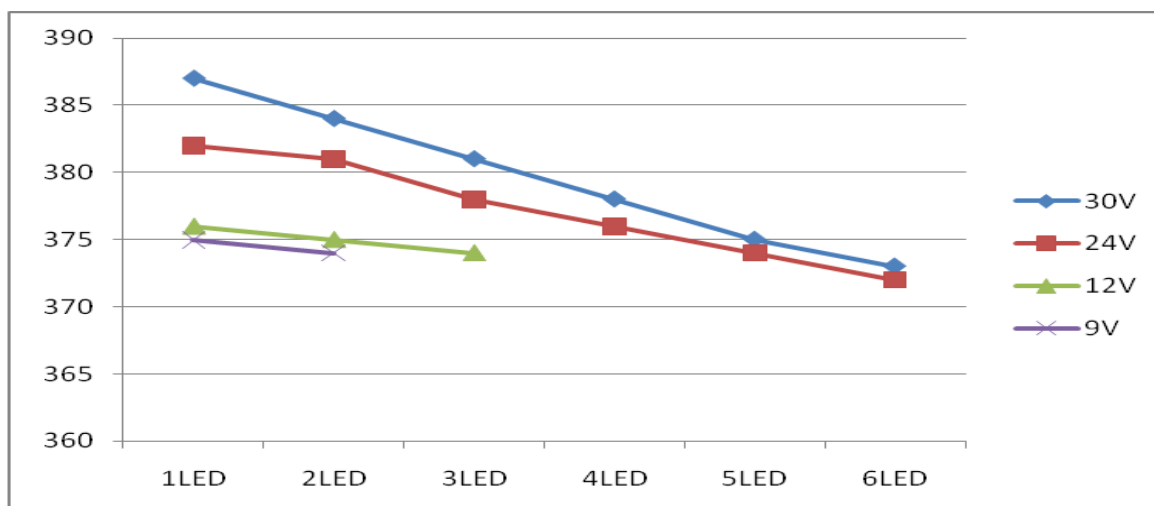
Output current vs. LED cascaded number @ L=100uH, I_{OUT}=370mA
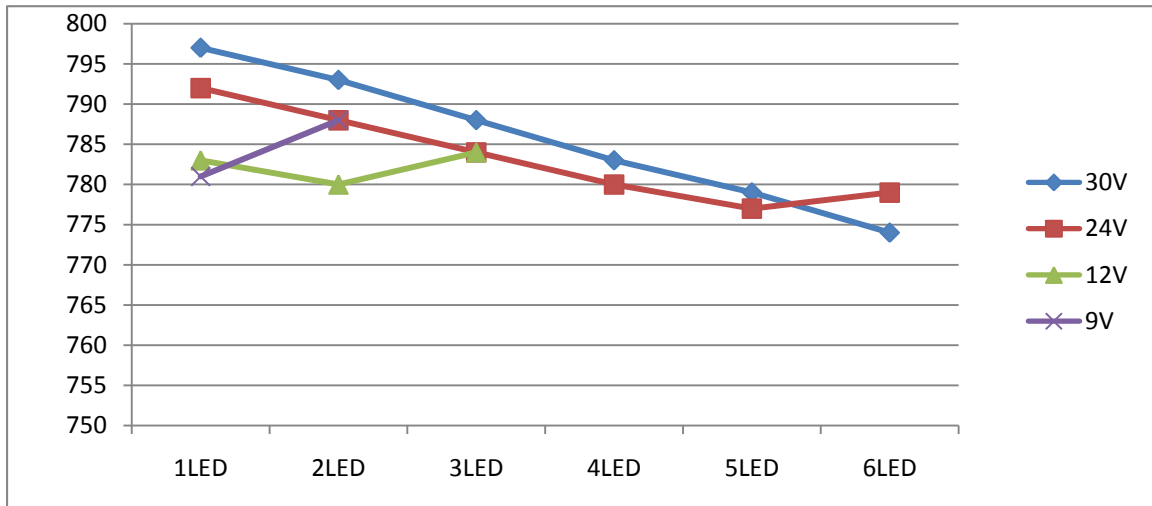
Output current vs. LED cascaded number @ L=68uH, I_{OUT}=770mA

6.   *Output Current vs. LED Cascaded number at Various Inductor*
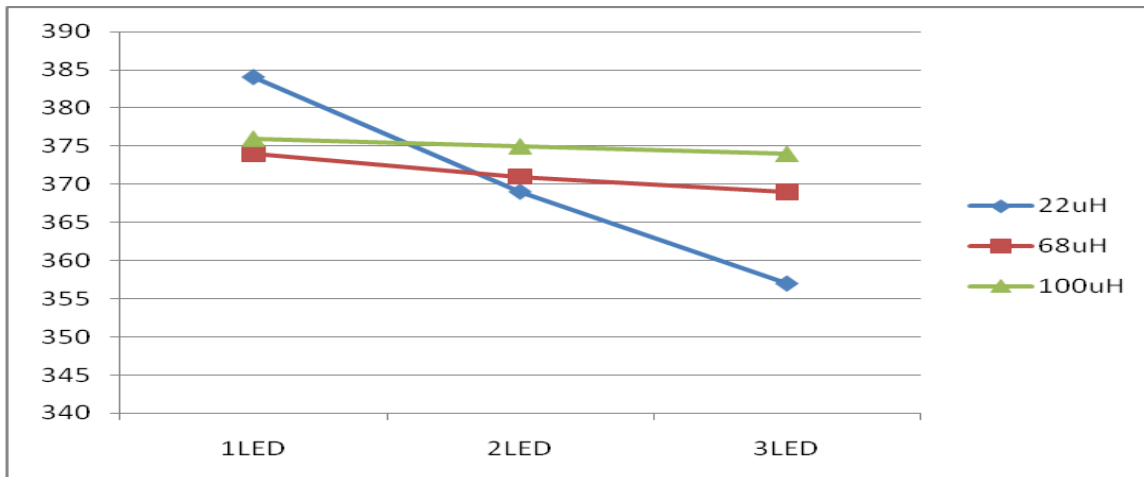
Output Current vs. LED Cascaded number @V_{IN}=12V, I_{OUT}=370mA

Output Current vs. LED Cascaded number @V_{IN}=24V, I_{OUT}=370mA

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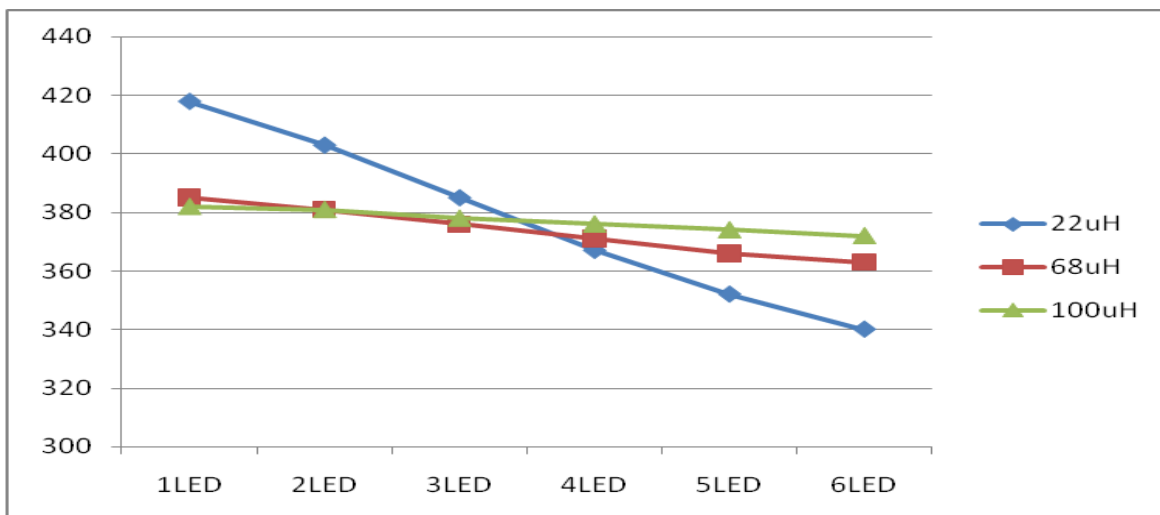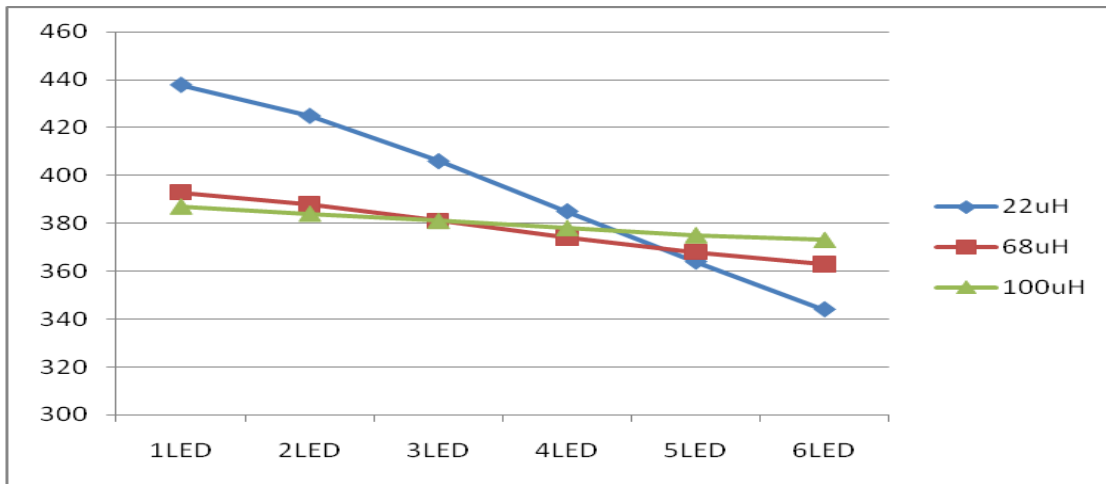
Output Current vs. LED Cascaded number @V_{IN}=30V, I_{OUT}=370mA

7. *Switching Frequency vs. LED Cascaded Number at Various Inductor*
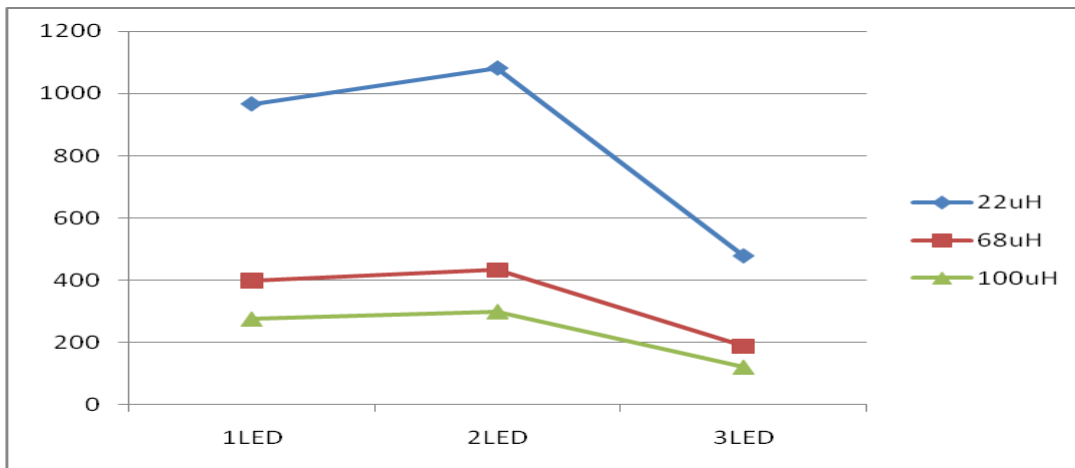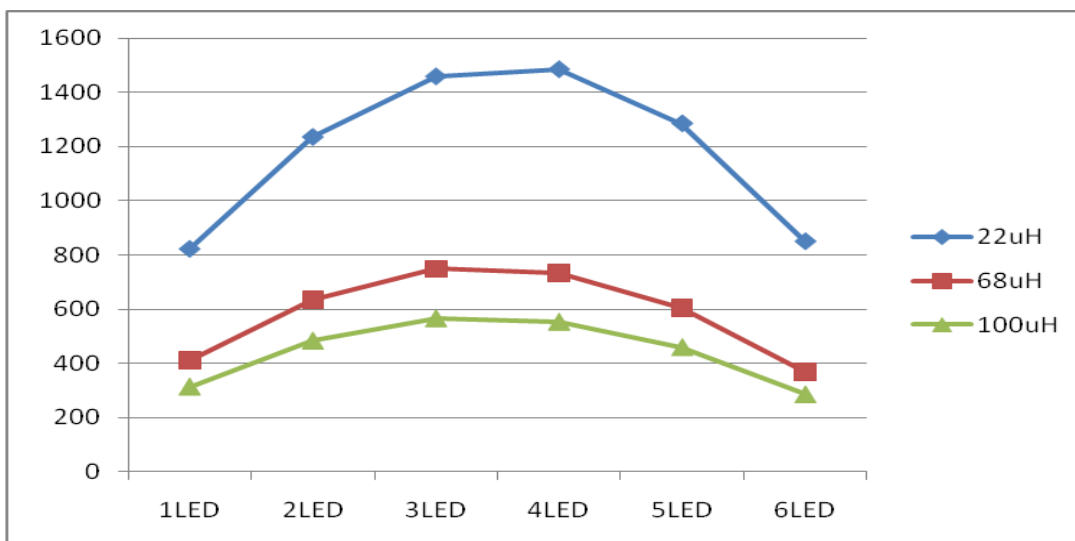
Switching Frequency vs. LED Cascaded Number @V_{IN}=12V, I_{OUT}=370mA

Switching Frequency vs. LED Cascaded Number @V_{IN}=24V, I_{OUT}=370mA

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Switching Frequency vs. LED Cascaded Number @V_{IN}=30V, I_{OUT}=370mA

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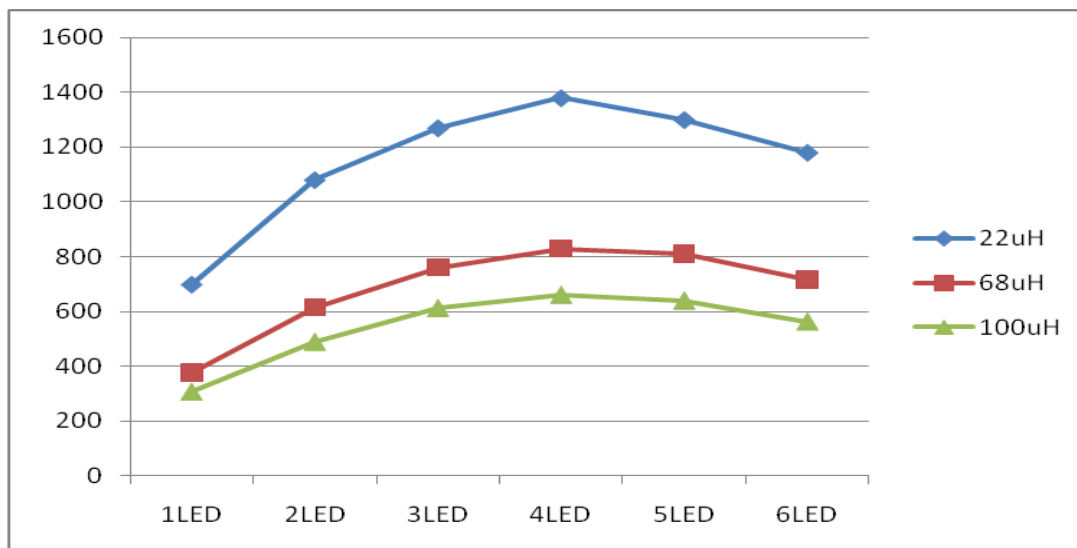
8.   Dimming and switching waveforms
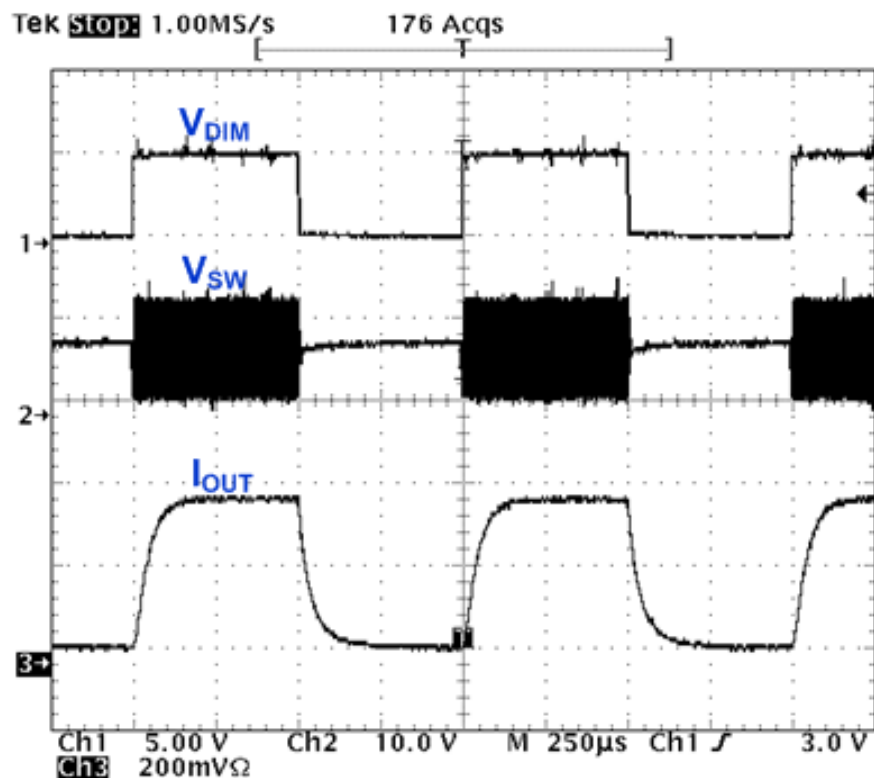
Dimming waveform(V_{IN}=12V, R_{SEN}=0.27Ω, 3-LED)

Switching waveform(V_{IN}=12V, R_{SEN}=0.27Ω, 3-LED)

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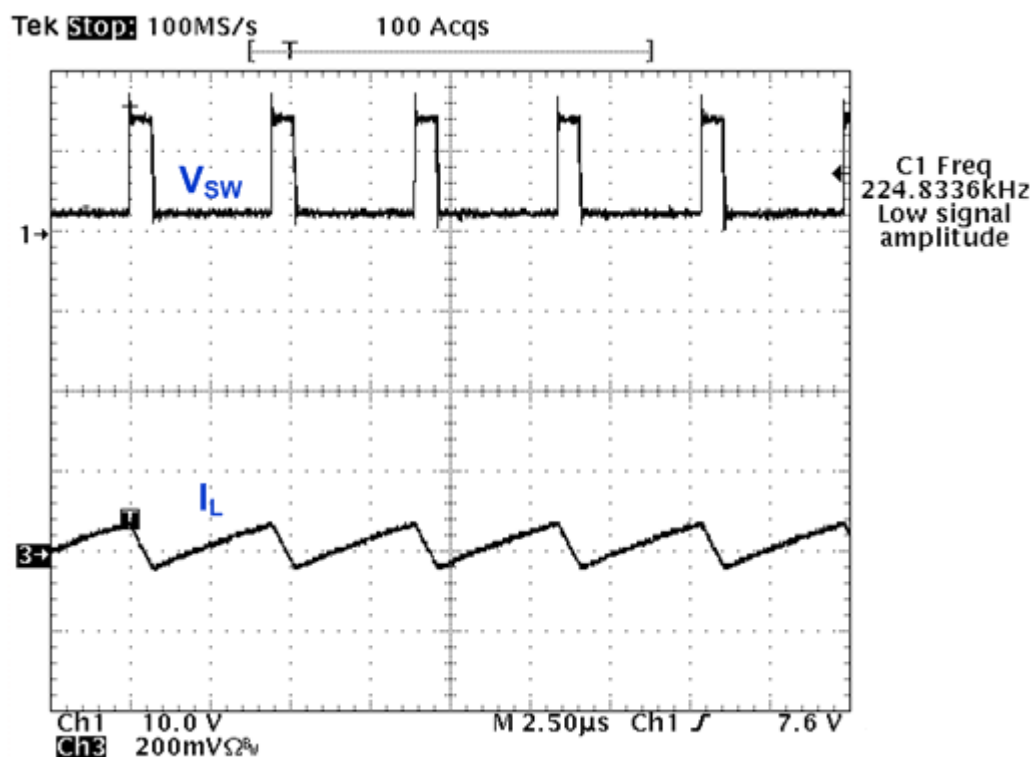
Application notes

- **Setting nominal average output current with external resistor R_S**

The nominal average output current in the LED(s) is determined by the value of the external current sense resistor (RS) connected between V_{IN} and Iout and is given by:

$I_{OUTNOM} = 0.1/R_S$ [for $R_S \geq 0.1\Omega$]

Nominal ripple current is $\pm 15mV/R_S$

The table below gives values of nominal average output current for several preferred values of current setting resistor (RS) in the typical application circuit shown on page 1:

RS(Ω)	Nominal average output current (mA)
0.1	1000
0.13	760
0.15	667

- **Dimming**

A Pulse Width Modulated (PWM) signal with duty cycle DPWM can be applied to the DIM pin. A logic low (below 0.5V) at DIM will disable the internal MOSFET and turn off the current flow to the LED array. An internal pull-high circuit ensures that the NU360 is ON when DIM pin is unconnected.

- **Open/short circuit LED protection**

When any LED is open-circuit, the output current will be turned off.
When any LED is short-circuit, the output current will keep normal.

- **Over temperature protection**

When the junction temperature is over range NU360 will turn off the output current.

- **Minimum input voltage**

The Minimum Input Voltage is the sum of the voltage drops on R_{SEN}, L1, internal MOS switch and the total forward voltage of LEDs (V_{LED}).

$V_{IN(min)} = V_{RS}+V_{LED}+V_{L1}+V_{SW}$

- **Switching frequency**

For better output current accuracy, the switching frequency should be determined by minimum on/off time SW waveform.

$F_{SW} = (1-D)/T_{OFF,MIN}$ when the duty cycle is large than 0.5 (D = V_{OUT}/V_{IN}).

$F_{SW} = D/T_{ON,MIN}$ when the duty cycle is smaller than 0.5.

The switching frequency is related to efficiency (better at low frequency), the size/cost of components and the amplitude of output ripple voltage and current (smaller at high frequency). The slower switching frequency comes from the large value of inductor. In many applications, the sensitivity of EMI limits the switching frequency. The switching frequency can be ranged from 40 KHz to 1.0 MHz.

- **LED ripple current**

A LED constant current driver is designed to control the current through the cascaded LED, instead of the voltage across it. Higher LED ripple current allows the use of smaller inductance, smaller output capacitance and even without an output capacitor. The advantages of higher LED ripple current are to minimize PCB size and reduce cost because of no output capacitor. Lower LED ripple current requires large inductance and output capacitor. The advantages of lower LED ripple current are to extend LED life time and to reduce heating of LED. The recommended ripple current is from 5 % to 20% of normal LED output current.

- **Capacitor selection**

A low ESR capacitor should be used for input decoupling, as the ESR of this capacitor appears in series with the supply source impedance and lowers overall efficiency. This capacitor has to supply the relatively high peak current to the coil and smooth the current ripple on the input supply. A minimum value of 4.7uF is acceptable if the input source is close to the device, but higher values will improve performance at lower input voltages, especially when the source impedance is high. The input capacitor should be placed as close as possible to the NU360.

For maximum stability over temperature and voltage, capacitors with X7R, X5R, or better dielectric are recommended. Capacitors with Y5V dielectric are not suitable for decoupling in this application and should NOT be used. A suitable Murata capacitor would be GRM42-2X7R475K-50.

- **Inductor selection**

The inductance is determined by two factors: the switching frequency and the inductor ripple current. The calculation of the inductance, L1, can be described as

$$L1 > (V_{IN} - V_{OUT} - V_{SEN} - (Rds_{(ON)} \times I_{OUT})) \times D/(F_{SW} \times \Delta I_L)$$

Higher values of inductance are recommended at higher supply voltages in order to minimize errors due to switching delays, which result in increased ripple and lower efficiency. Higher values of inductance also result in a smaller change in output current over the supply voltage range. (See graphs). The inductor should be mounted as close to the device as possible with low resistance connections to the SW and V_{IN} pins.

The chosen coil should have a saturation current higher than the peak output current and a continuous current rating above the required mean output current.

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The inductor value should be chosen to maintain operating duty cycle and switch 'on'/'off' times within the specified limits over the supply voltage and load current range.

Switch on time

$T_{ON} = L\Delta I / (V_{IN} - V_{LED} - Iavg\,(R_S + rL + Rsw))$

$T_{OFF} = L\Delta I / (V_{LED} + V_D + Iavg\,(R_S + rL))$

Where

L is the coil inductance

rL is the coil resistance

R_S is the current sense resistance

Iavg is the required LED current

ΔI is the coil peak-peak ripple current {Internally set to 0.3 x Iavg}

V_{IN} is the supply voltage

V_{LED} is the total LED forward voltage

R_{SW} is the switch resistance

V_D is the diode forward voltage at the required load current
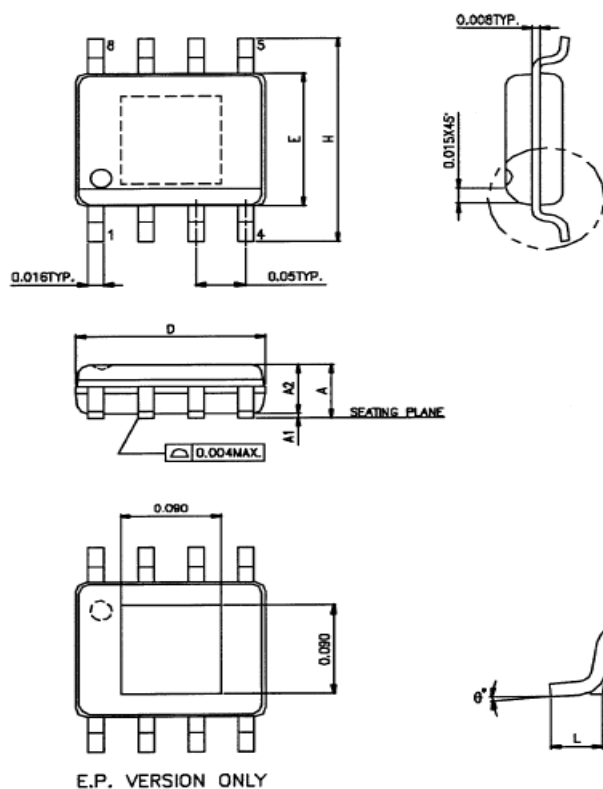
● **Diode selection :**

For maximum efficiency and performance, the rectifier (D1) should be a fast low capacitance Schottky diode with low reverse leakage at the maximum operating voltage and temperature. They also provide better efficiency than silicon diodes, due to a combination of lower forward voltage and reduced recovery time. It is important to select parts with a peak current rating above the peak coil current and a continuous current rating higher than the maximum output load current.

It is very important to consider the reverse leakage of the diode when operating above 85℃. Excess leakage will increase the power dissipation in the device and if close to the load may create a thermal runaway condition. The higher forward voltage and overshoot due to reverse recovery time in silicon diodes will increase the peak voltage on the SW output. If a silicon diode is used, care should be taken to ensure that the total voltage appearing on the SW pin including supply ripple, does not exceed the specified maximum value.

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Package dimensions

- **SOP8 (2500 ea/Reel)**

SYMBOLS	MIN.	MAX.
A	0.053	0.069
A1	0.004	0.010
A2	–	0.059
D	0.189	0.196
E	0.150	0.157
H	0.228	0.244
L	0.016	0.050
θ°	0	8

UNIT : INCH

NOTES:
1. JEDEC OUTLINE : MS–012 AA / E.P. VERSION : N/A
2. DIMENSIONS "D" DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.MOLD FLASH, PROTRUSIONS AND GATE BURRS SHALL NOT EXCEED .15mm (.006in) PER SIDE.
3. DIMENSIONS "E" DOES NOT INCLUDE INTER–LEAD FLASH, OR PROTRUSIONS. INTER–LEAD FLASH AND PROTRUSIONS SHALL NOT EXCEED .25mm (.010in) PER SIDE.

E.P. VERSION ONLY

- **SOT23-5 (3000 ea/Reel)**
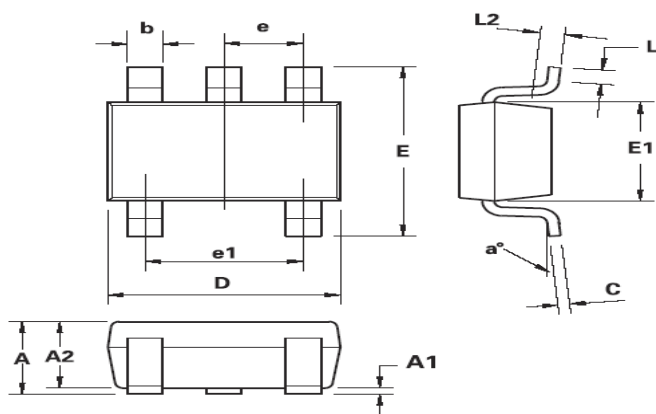
DIM	Millimeters		Inches	
	Min.	Max.	Min.	Max.
A	-	1.00	-	0.0393
A1	0.01	0.10	0.0003	0.0039
A2	0.84	0.90	0.0330	0.0354
b	0.30	0.45	0.0118	0.0177
c	0.12	0.20	0.0047	0.0078
D	2.90 BSC		0.114 BSC	
E	2.80 BSC		0.110 BSC	
E1	1.60 BSC		0.062 BSC	
e	0.95 BSC		0.0374 BSC	
e1	1.90 BSC		0.0748 BSC	
L	0.30	0.50	0.0118	0.0196
L2	0.25 BSC		0.010 BSC	
a°	4°	12°	4°	12°

Restrictions on product use

- This document is a preliminary specification data sheet. NUMEN Tech. reserves the right to update these specifications in the future.

- The information contained herein is subject to change without notice.

- NUMEN Technology will continually working to improve the quality and reliability of its products. Nevertheless, semiconductor device in general can malfunction or fail due to their inherent electrical sensitivity and vulnerability to physical stress. It is the responsibility of the buyer, when utilizing NUMEN products, to comply with the standards of safety in making a safe design for the entire system, and to avoid situations in which a malfunction or failure of such NUMEN products could cause loss of human life, bodily injury or damage to property. In developing your designs, please ensure that NUMEN products are used within specified operating ranges as set forth in the most recent NUMEN products specifications.

- The NUMEN products listed in this document are intended for usage in general electronics applications (lighting system, personal equipment, office equipment, measuring equipment, industrial robotics, domestic appliances, etc.). These NUMEN products are neither intended nor warranted for usage in equipment that requires extraordinarily high quality and/or reliability or a malfunction or failure of which may cause loss of human life or bodily injury ("Unintended Usage"). Unintended Usage include atomic energy control instruments, airplane or spaceship instruments, transportation instruments, traffic signal instruments, combustion control instruments, medical instruments, all types of safety devices, etc.. Unintended Usage of NUMEN products listed in this document shall be made at the customer's own risk.