

1.5A LED Driver with internal switch

General Description

TTP933 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. TTP933 operates from input supply between 5V and 33V and provides an externally adjustable output current of up to 1.5A.

The TTP933 is specifically designed with PFM control to enhance the efficiency up to 97%. 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, TTP933 is built-in with over temperature protection, and LED open-circuit short-circuit protection to protect system from being damaged.

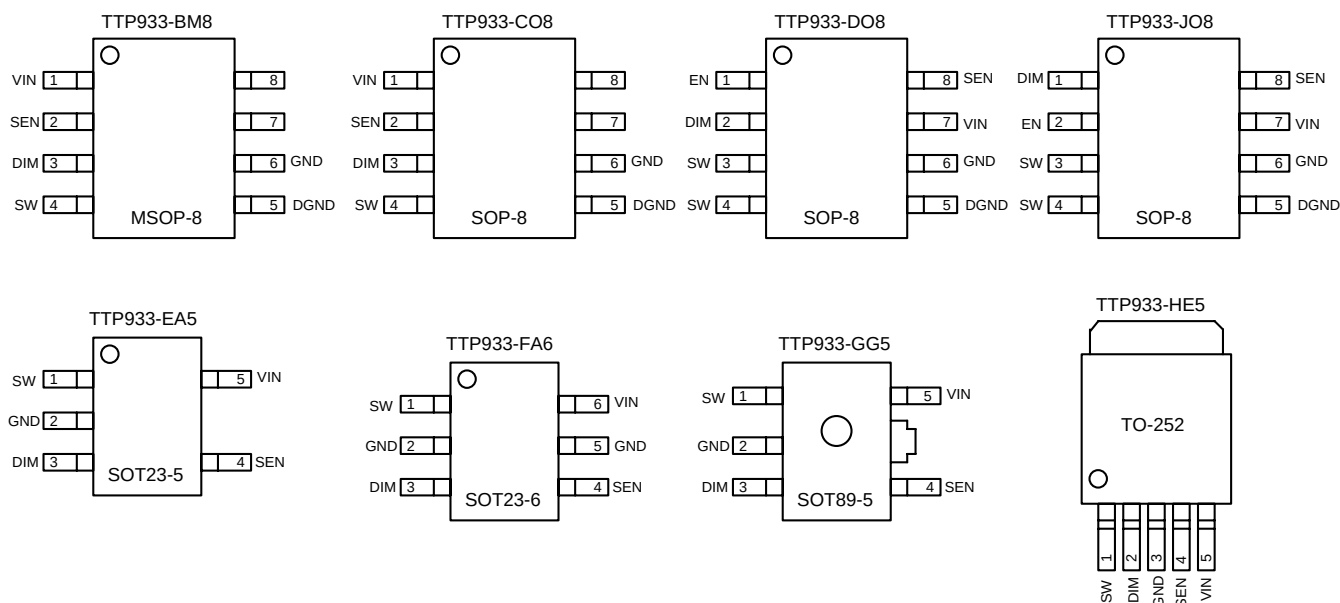
Features

- ✧ 1.5A output current
- ✧ Wide input voltage range: 5V to 33V
- ✧ High efficiency (up to 97%)
- ✧ 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

Applications

- High power LED lighting
- Automotive LED lighting
- Low voltage industrial lighting
- LED back-up lighting
- Constant Current Source

.Package type



TTP933-BM8: MSOP8 (with Thermal Pad)

TTP933-CO8: SOP8 (with Thermal Pad)

TTP933-DO8: SOP8 (with Thermal Pad)

TTP933-EA5: SOT23-5

TTP933-FA6: SOT23-6

TTP933-GG5: SOT89-5

TTP933-HE5: T0252-5

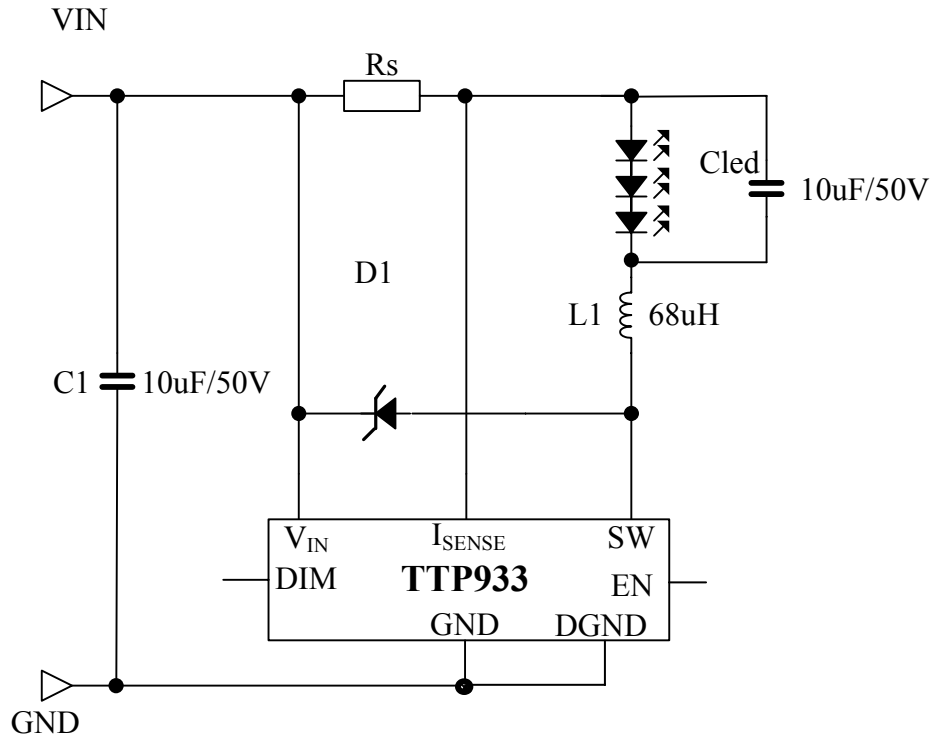
TTP933-JO8: SOP8 (with Thermal Pad)

.Pin Description

Pin Name	Pin Description
SW	Drain of NDMOS switch
GND	Ground pad
DGND	Source of NDMOS
DIM	Dimming control pad
SEN	ISENSE Connect resistor RS from this pin to VIN to define nominal average output current
VIN	Power pad
EN	Enable control signal, H:Active , L:Power down, Built-in pull high

.Application circuit

Typical application circuit



.Absolute maximum ratings

ITEM		SYMBOL	RATING	UNIT
Supply Voltage		V_{IN}	0-33 (40V for 0.5 sec)	V
Output Current		I_{OUT}	1.8	A
Sustaining Voltage at SW pin		V_{SW}	-0.5~33 (40V for 0.5 sec)	V
Power Dissipation *	SOP8	PD	1.4	W
	MSOP8(thermal Pad)		1.45	
	TO252		2.8	
	SOT23-6		1.2	
	SOT23-5		1.2	
	SOT89-5		1.45	
Thermal Resistance	SOP8	$R_{th(j-a)}$	89.3	$^{\circ}\text{C/W}$
	MSOP8(thermal Pad)		86.2	
	TO252		44.6	
	SOT23-6		104.2	
	SOT23-5		104.2	
	SOT89-5		86.2	
Operating Temperature		Top	-40 $^{\circ}\text{C}$ - +85 $^{\circ}\text{C}$	$^{\circ}\text{C}$
Storage Temperature		Tsto	-55 $^{\circ}\text{C}$ - +150 $^{\circ}\text{C}$	$^{\circ}\text{C}$
Junction Temperature		Tj-MAX	150	$^{\circ}\text{C}$

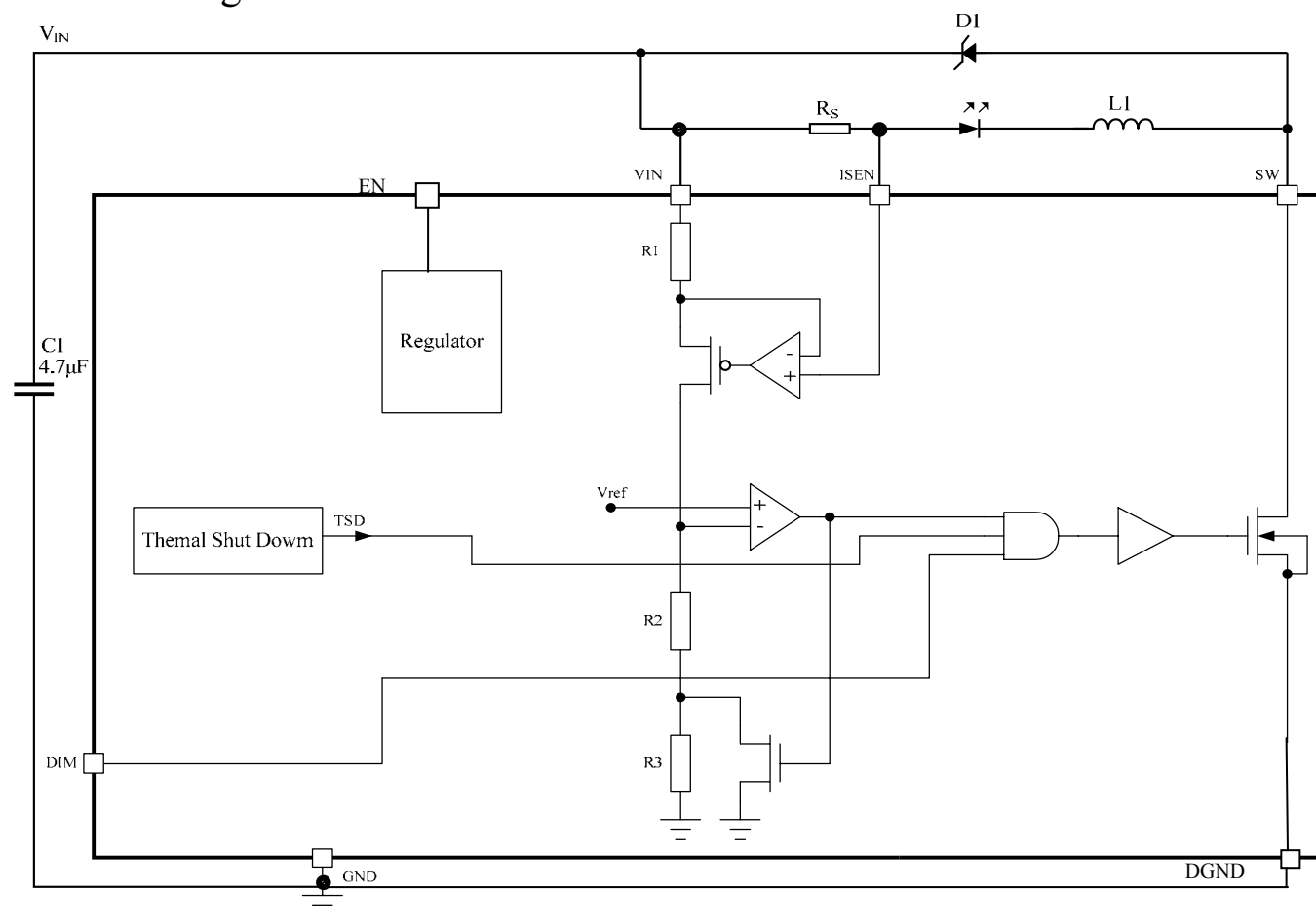
* 2 layer The PCB size is 22mm*20mm

** Power Dissipation depend on PCB layout.

. Electrical Characteristics

Test condition : $V_{IN}=12V$, $V_{OUT}=3.6V$, $L1=68\mu H$, $C_{IN}=C_{OUT}=10\mu F$, $T_a=25\text{ }^{\circ}C$; unless otherwise specified.

Item	Symbol	Condition	min.	typ.	Max.	unit
Operating voltage	V_{IN}		5	-	33	V
Operating current	I_{IN}	$V_{IN}=5V\sim 33V$	-	1	2	mA
Power down current	I_{OFF}	$V_{IN}=5V\sim 33V$, EN pin grounded		50		μA
Output current	I_{OUT}		-	-	1.5	A
Output current Accuracy	$\Delta I_{OUT}/I_{OUT}$	$150mA \leq I_{OUT} \leq 1A$		± 3	± 5	%
Efficiency		$V_{IN}=12V$, $I_{OUT}=350mA$, $V_{out}=10.8V$		97		%
SW Dropout voltage	ΔV_{SW}	$I_{OUT}=1A$		0.5		V
Internal propagation delay	TPD		100	200	300	nS
Input voltage	V_{IH}		3.5		5	V
	V_{IL}				0.5	V
Sense threshold hysteresis	$V_{SENSEHYS}$			± 15	-	%
Mean current sense threshold voltage	V_{SENSE}		95	100	105	mV
Switch on resistance	$R_{DS(ON)}$	$V_{IN}=12V$, $I_{OUT}=350mA$, $V_{out}=10.8V$		0.33		Ω
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	
maximum operating frequency	Freq _{MAX}		40		1000	KHz
Thermal Shutdown Threshold	T_{SD}		145	160	175	$^{\circ}C$
Thermal Shutdown Hysteresis	T_{SD-HYS}			20		$^{\circ}C$
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	$V_{OUT}=3.6V$, $I_{OUT}=350mA$, $f_{DIM}=1kHz$, Duty _{DIM} =50%		20		ns
Fall Time of Output current	T_f	$V_{OUT}=3.6V$, $I_{OUT}=350mA$, $f_{DIM}=1kHz$, Duty _{DIM} =50%		20		ns

.BLOCK diagram**Device description**

The device, in conjunction with the coil (L1) and current sense resistor (RS), forms a selfoscillating continuous-mode buck converter.

Device operation (Refer to block diagram and Figure 1 - Operating waveforms)

Operation can be best understood by assuming that the DIM pin of the device is unconnected and the voltage on this pin (VDIM) appears directly at the (+) input of the comparator.

When input voltage VIN 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 VIN to ground, via RS, L1 and the LED(s). The current rises at a rate determined by VIN and L1 to produce a voltage ramp (VSENSE) across RS. The supply referred voltage VSENSE 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 VIN. 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 $V_{ref} \pm 15\%$.

Switching thresholds

With $V_{ADJ} = V_{REF}$, the ratios of R1, R2 and R3 define an average V_{SENSE} switching threshold of 100mV (measured on the ISENSE 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 $\pm 15mV/R_S$

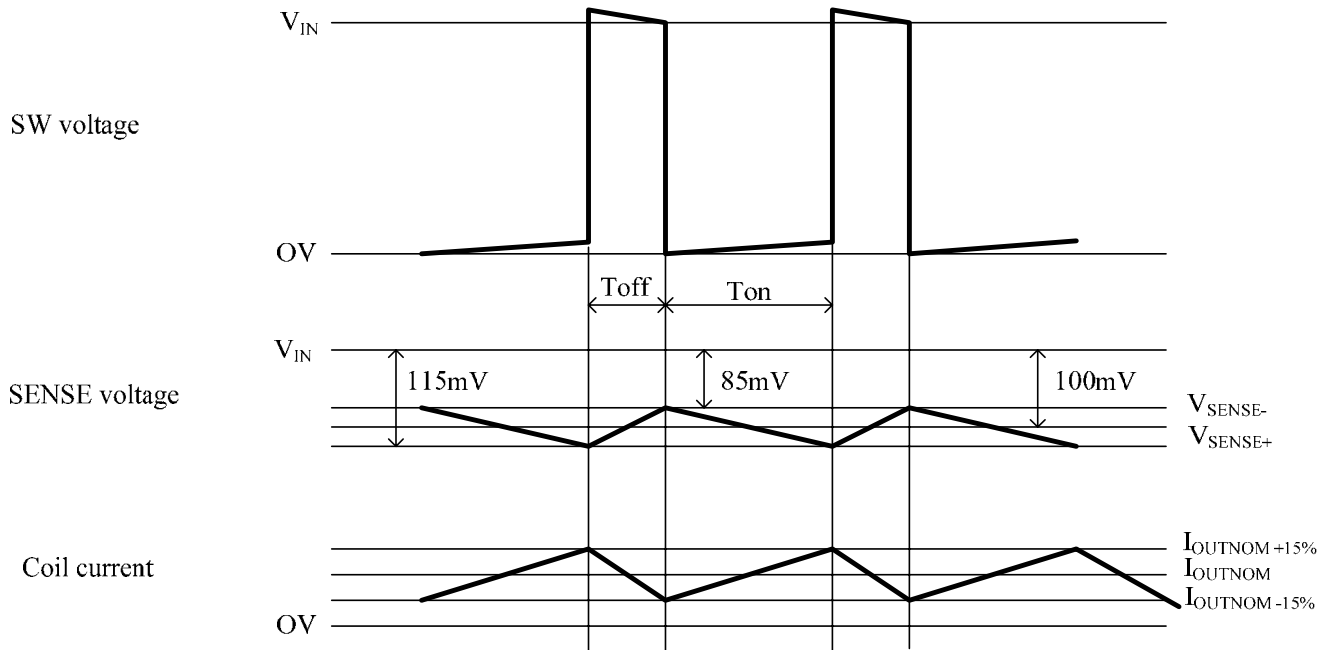
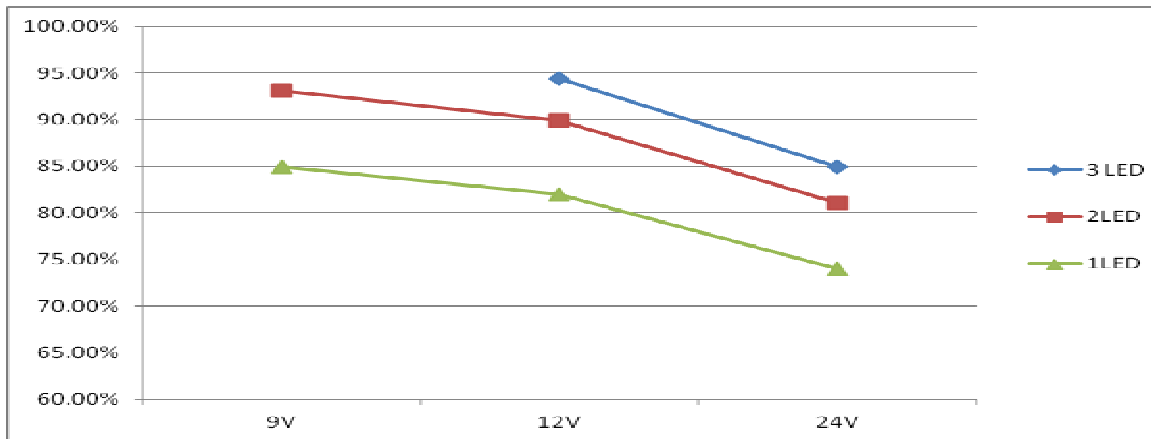


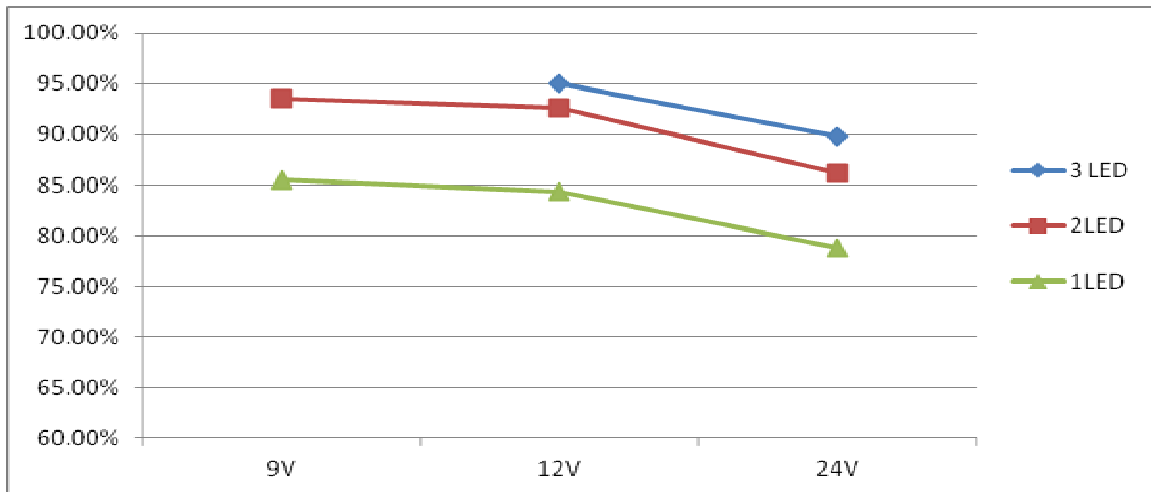
Figure 1-Operating waveforms

Typical Performance Characteristics

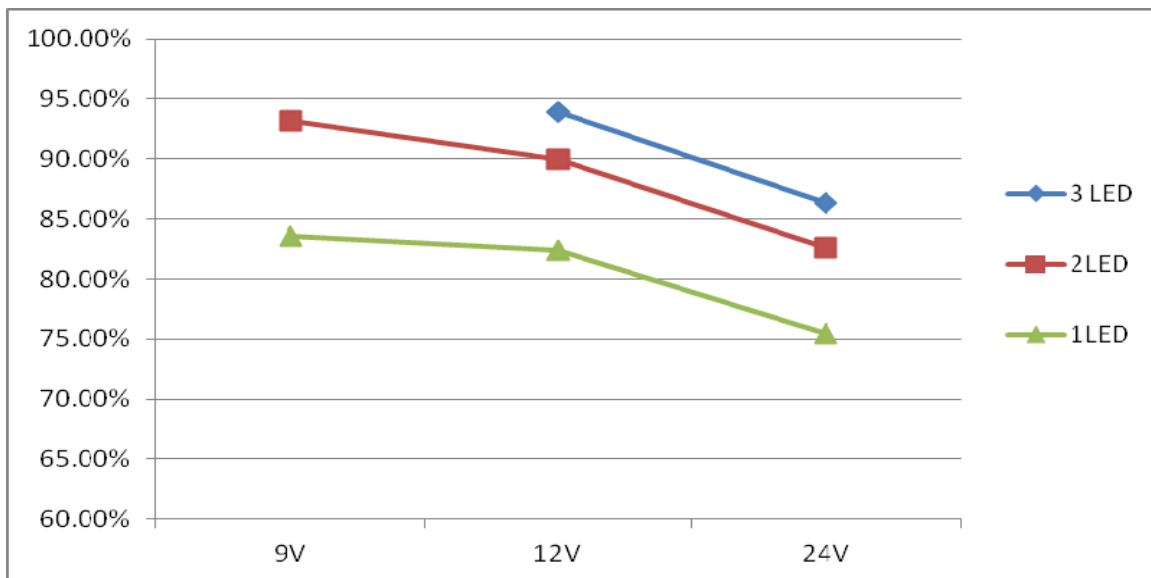
1. Efficiency vs. Input Voltage at Various LED Cascaded Number



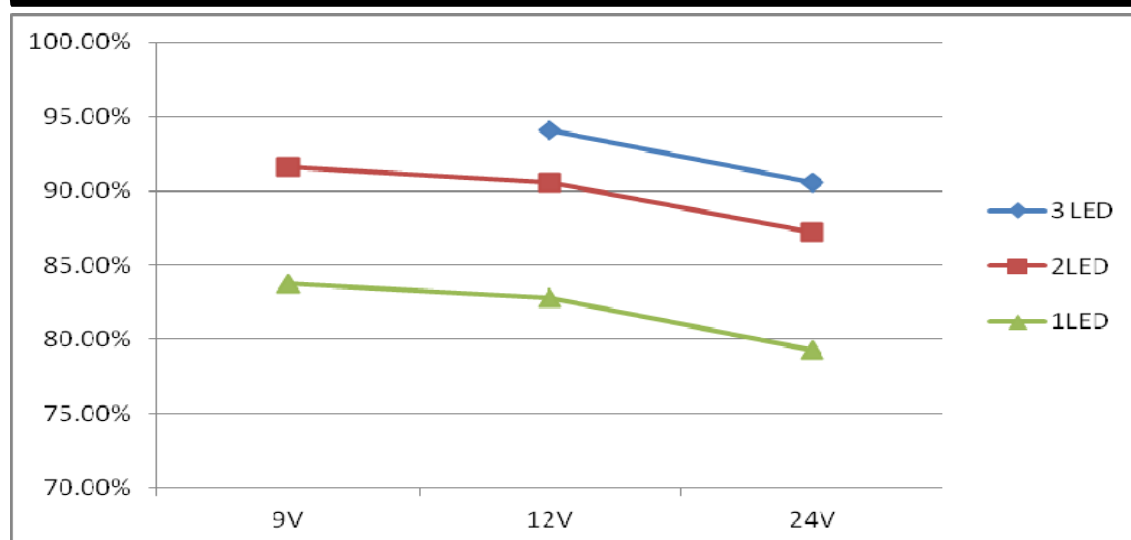
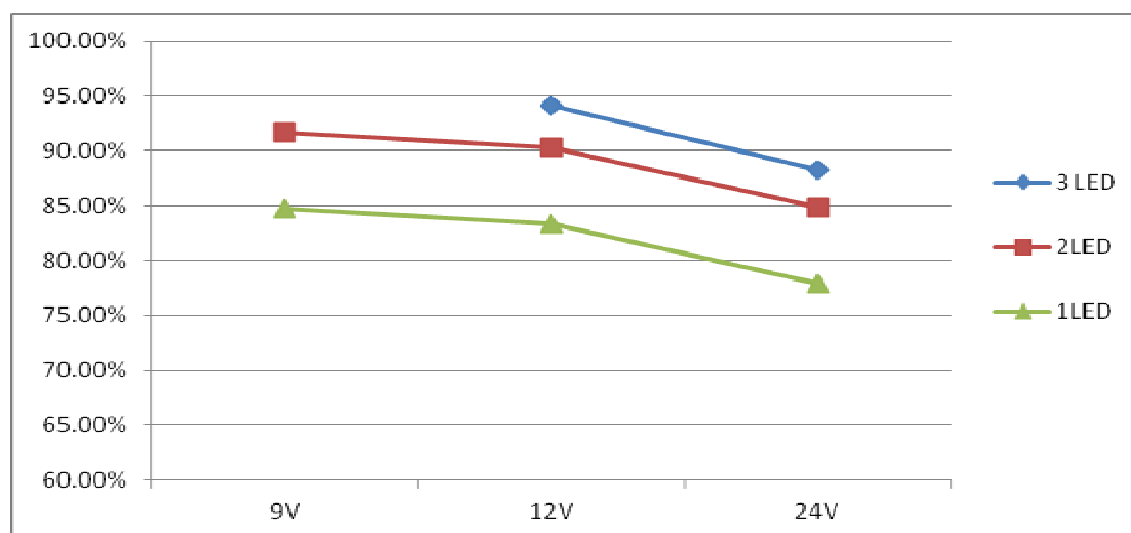
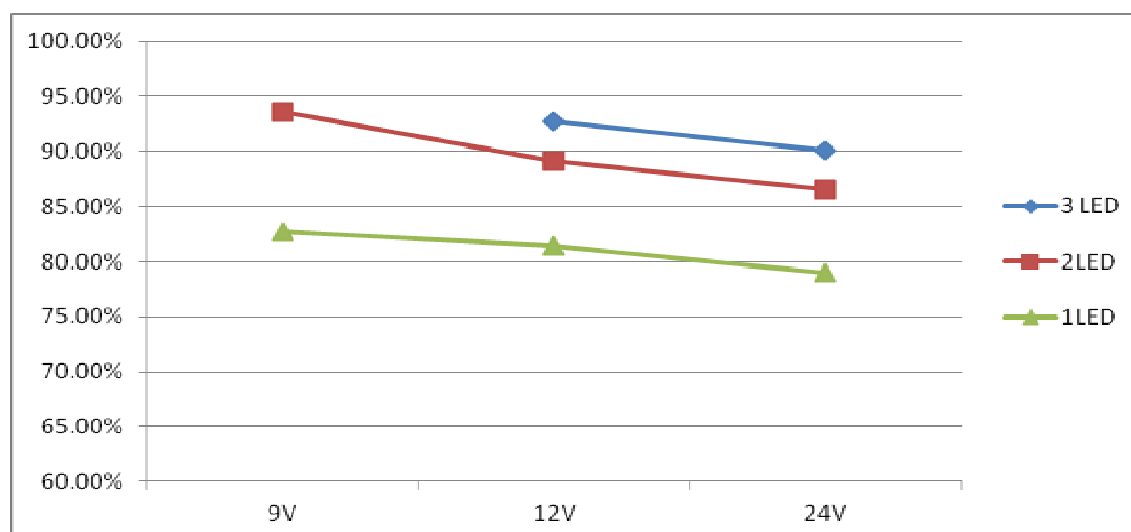
Efficiency vs. input voltage @L=22uH, I_{OUT} =384mA



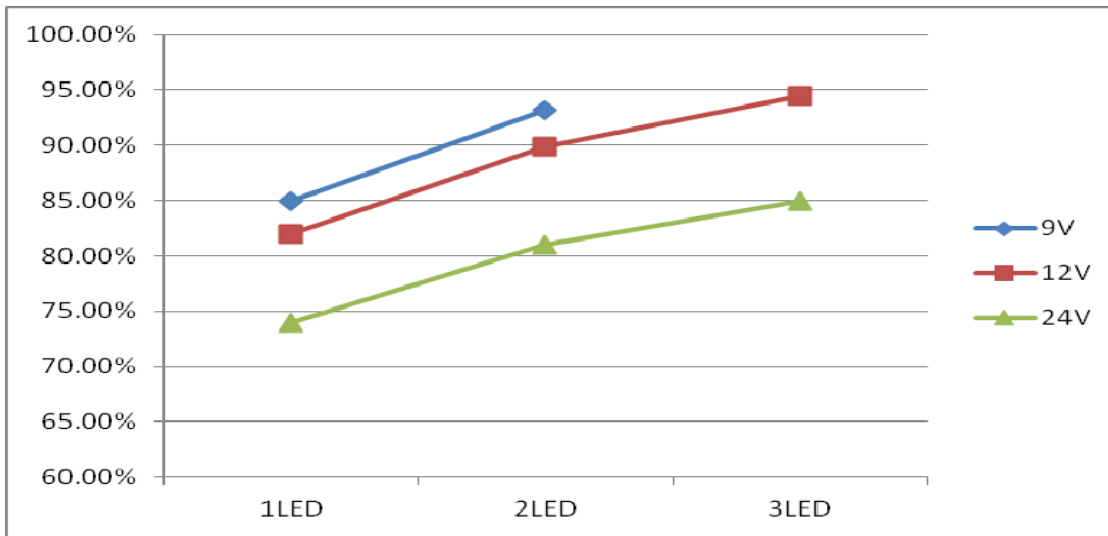
Efficiency vs. input voltage @L=68uH, I_{OUT} =384mA



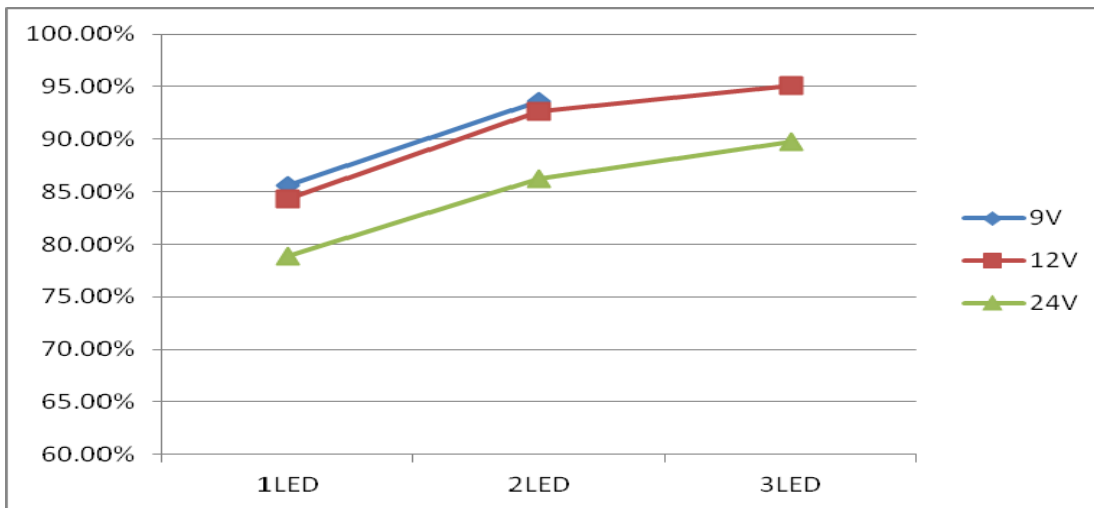
Efficiency vs. input voltage @L=22uH, I_{OUT} =769mA

Efficiency vs. input voltage @L=68uH, $I_{OUT}=769\text{mA}$ Efficiency vs. input voltage @L=22uH, $I_{OUT}=1000\text{mA}$ Efficiency vs. input voltage @L=68uH, $I_{OUT}=1000\text{mA}$

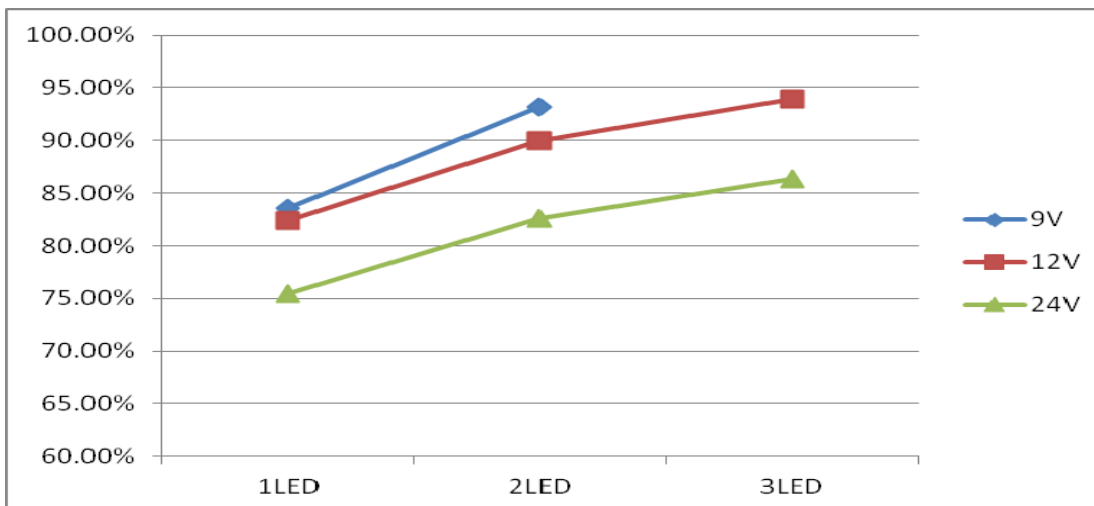
2. Efficiency vs. LED Cascaded Number at Various Input Voltage



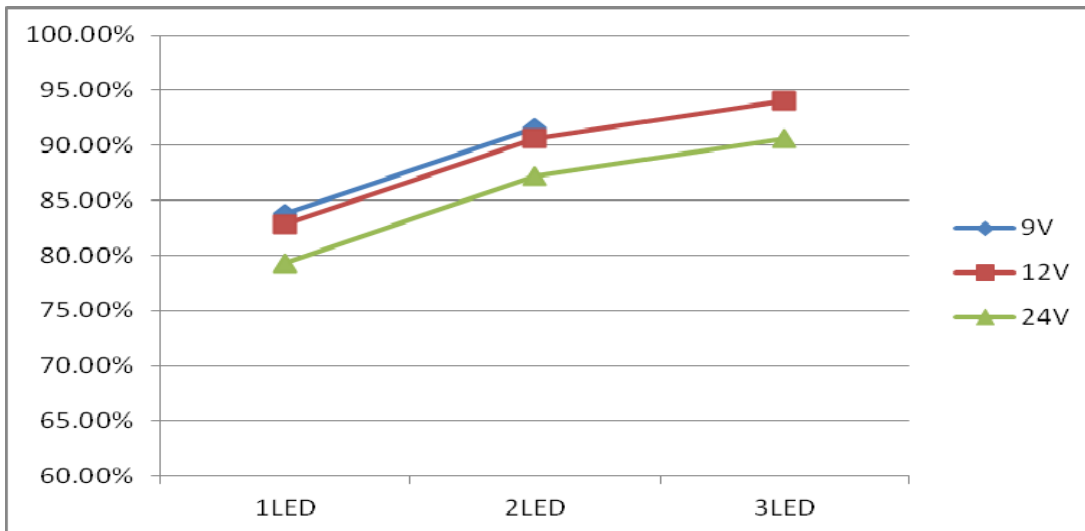
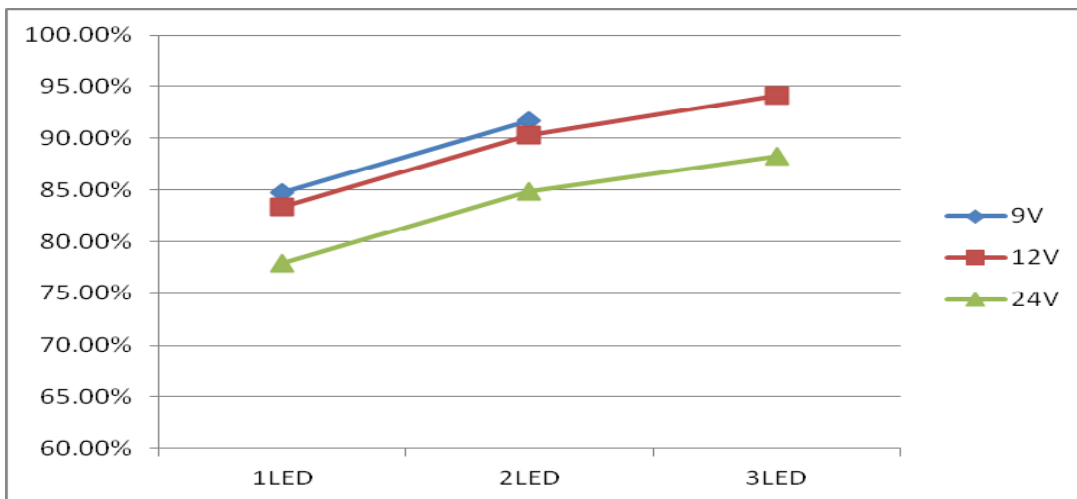
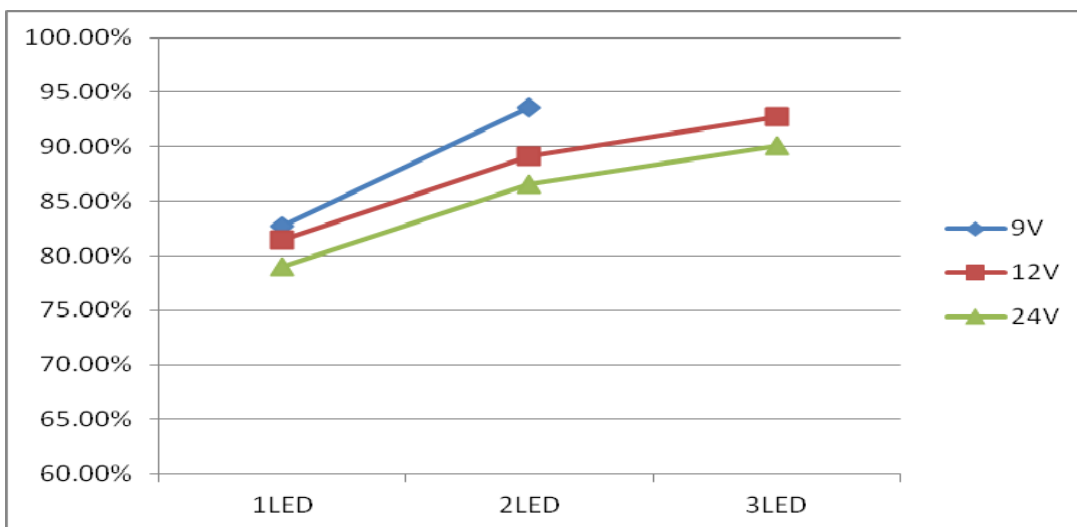
Efficiency vs. LED cascaded number @L=22uH, $I_{OUT}=384mA$



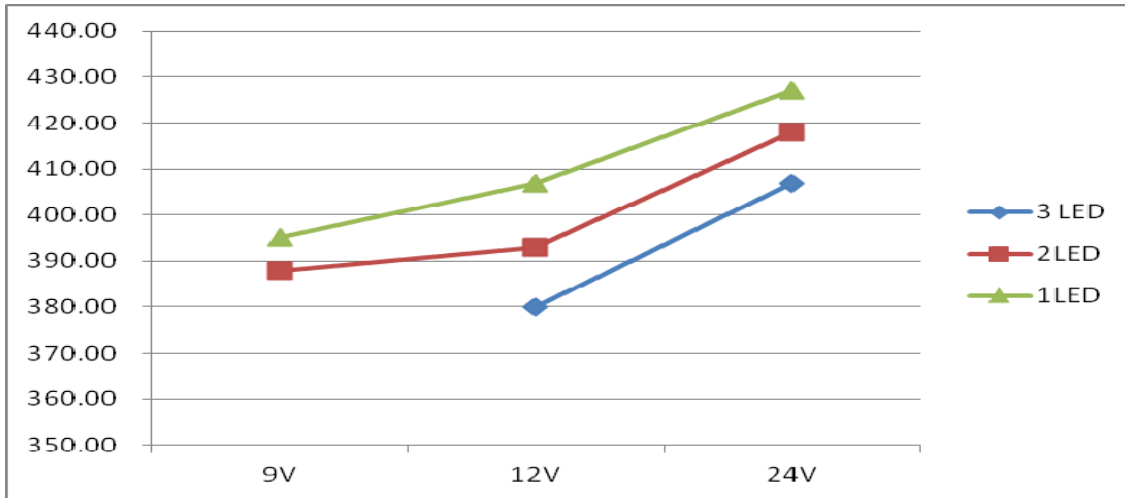
Efficiency vs. LED cascaded number @L=68uH, $I_{OUT}=384mA$



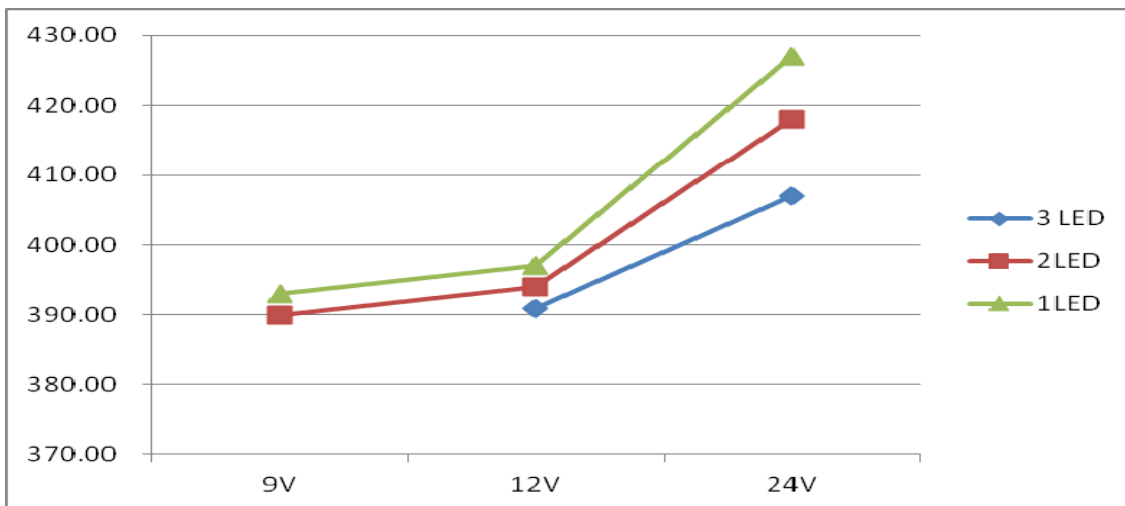
Efficiency vs. LED cascaded number @L=22uH, $I_{OUT}=769mA$

Efficiency vs. LED cascaded number @L=68uH, $I_{OUT}=769\text{mA}$ Efficiency vs. LED cascaded number @L=22uH, $I_{OUT}=1000\text{mA}$ Efficiency vs. LED cascaded number @L=68uH, $I_{OUT}=1000\text{mA}$

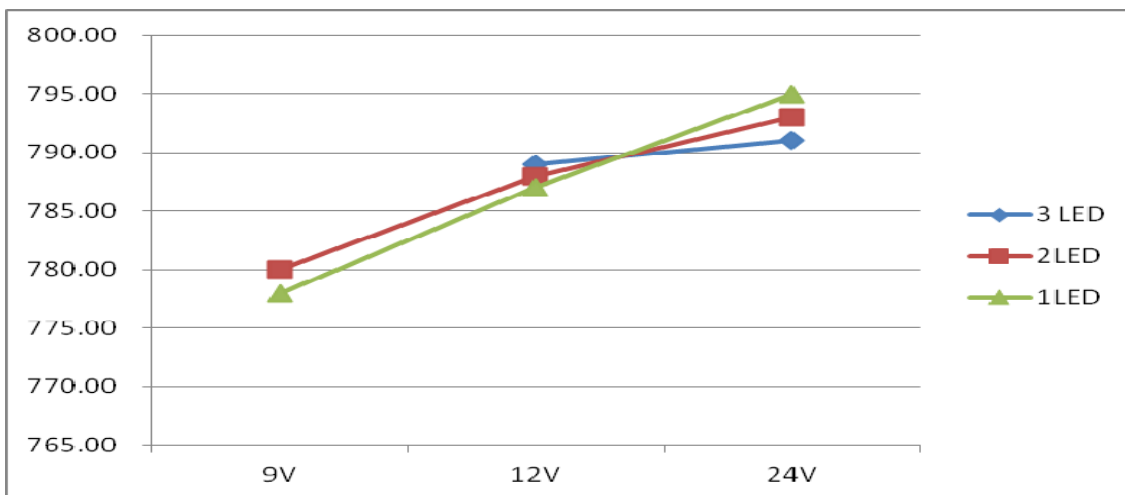
3. Output Current vs. Input Voltage at Various LED Cascaded Number



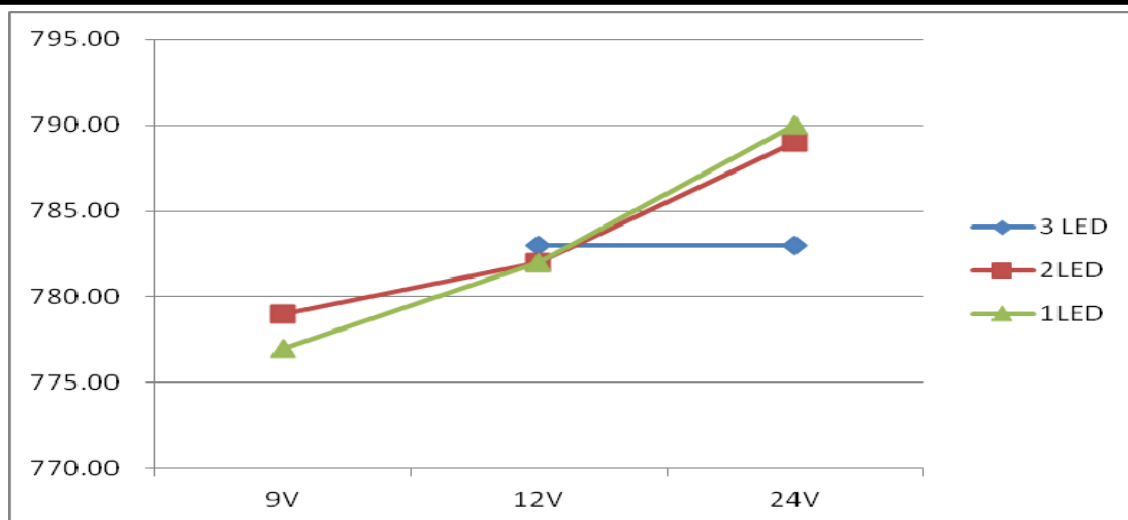
Output current vs. input voltage @ $L=22\mu\text{H}$, $I_{\text{OUT}}=384\text{mA}$



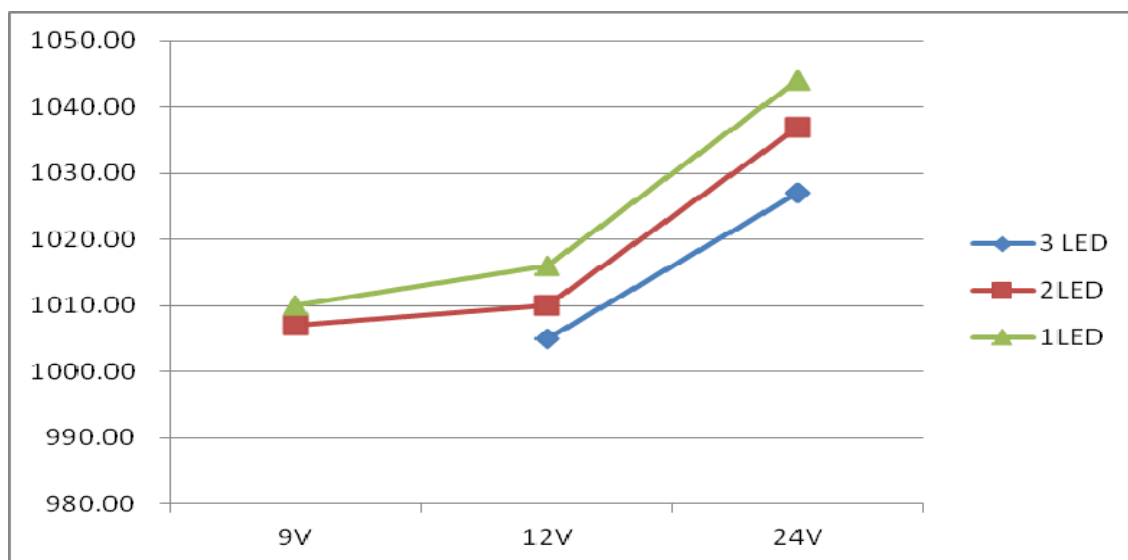
Output current vs. input voltage @ $L=68\mu\text{H}$, $I_{\text{OUT}}=384\text{mA}$



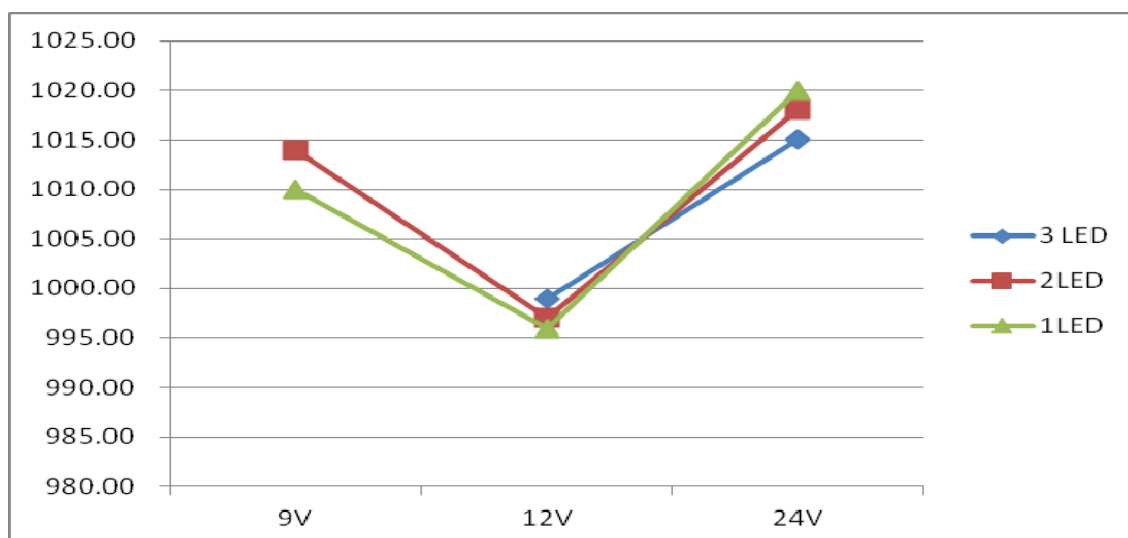
Output current vs. input voltage @ $L=22\mu\text{H}$, $I_{\text{OUT}}=769\text{mA}$



Output current vs. input voltage @L=68uH, $I_{OUT}=769\text{mA}$

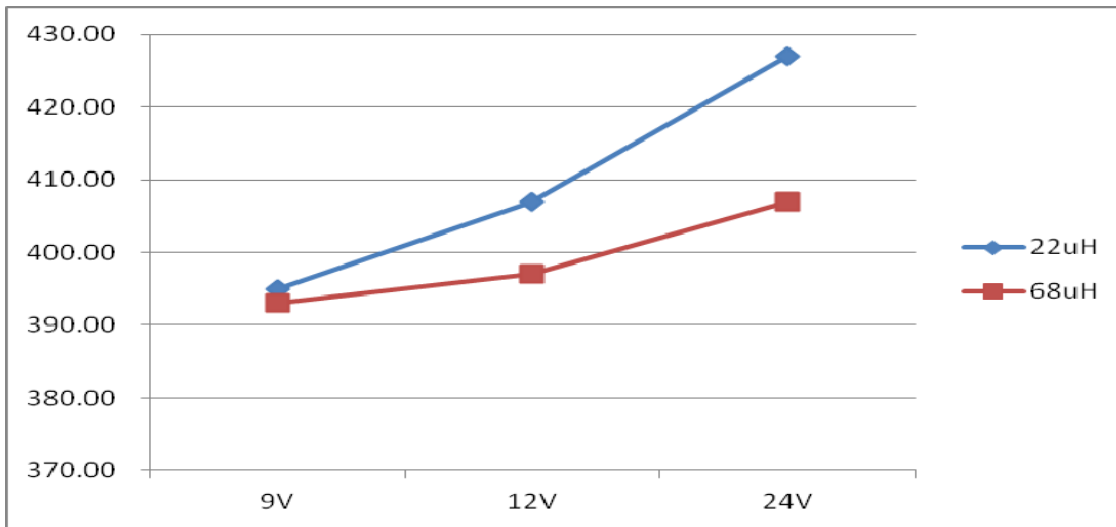


Output current vs. input voltage @L=22uH, $I_{OUT}=1000\text{mA}$

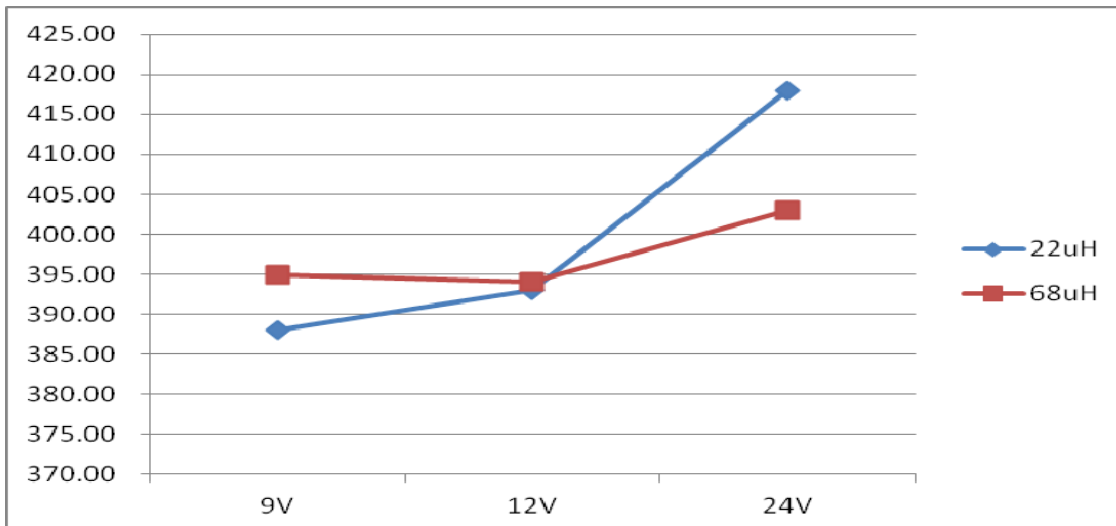


Output current vs. input voltage @L=68uH, $I_{OUT}=1000\text{mA}$

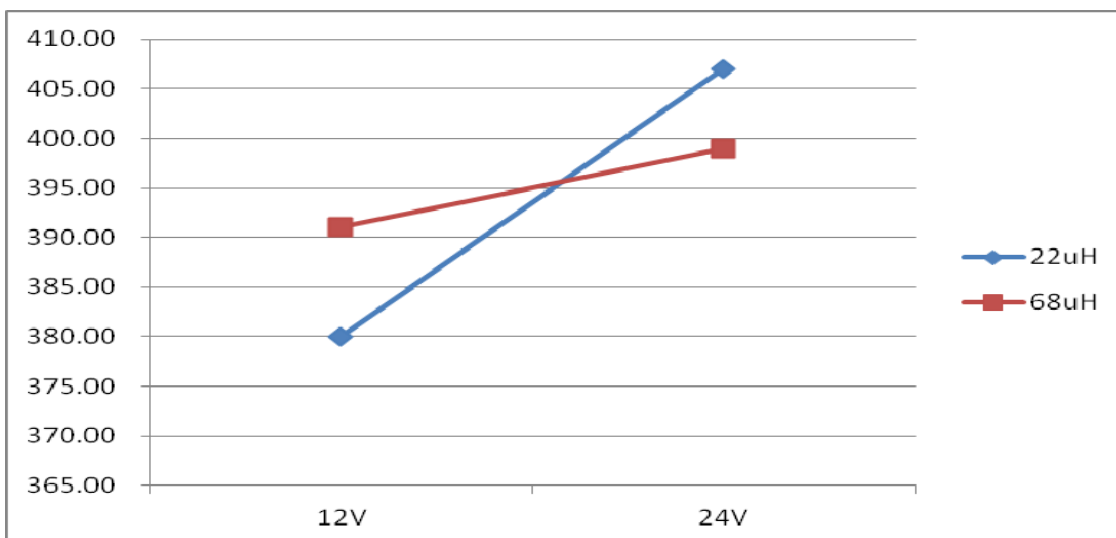
4. Output Current vs. Input Voltage at Various Inductor



Output current vs. input voltage @1-LED in cascaded, $I_{OUT}=384mA$

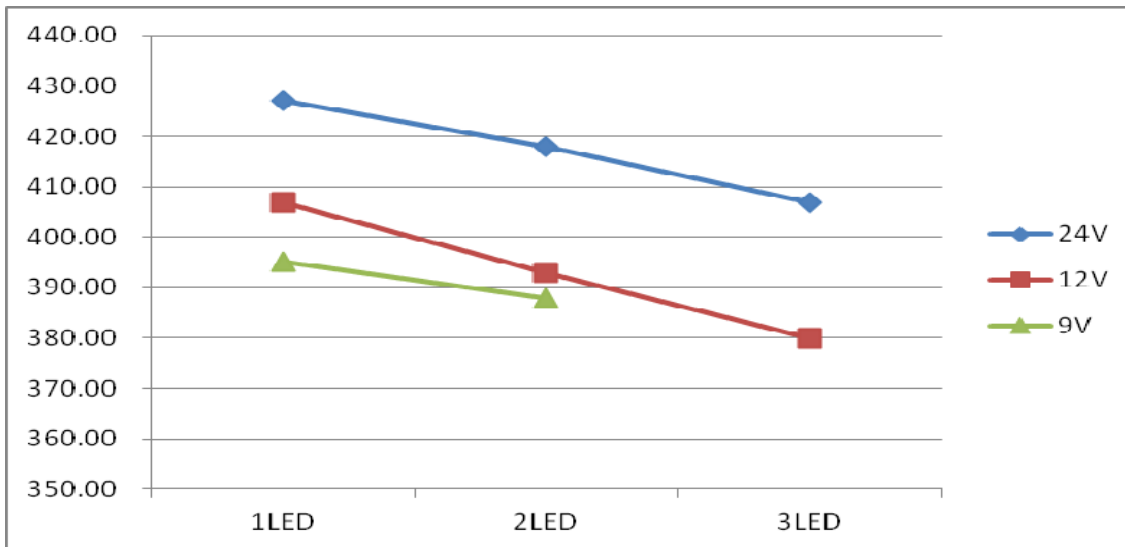
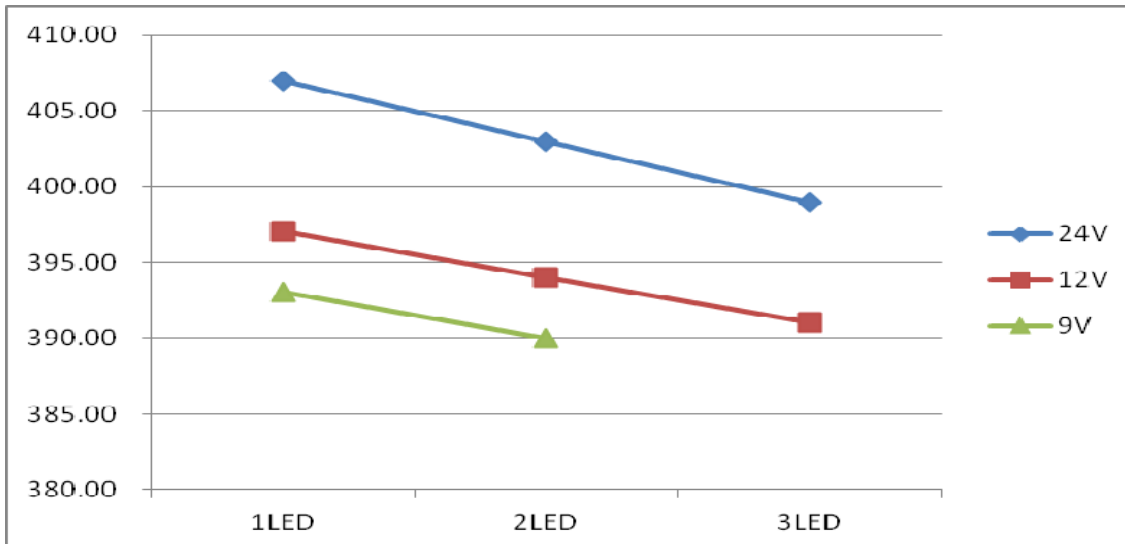
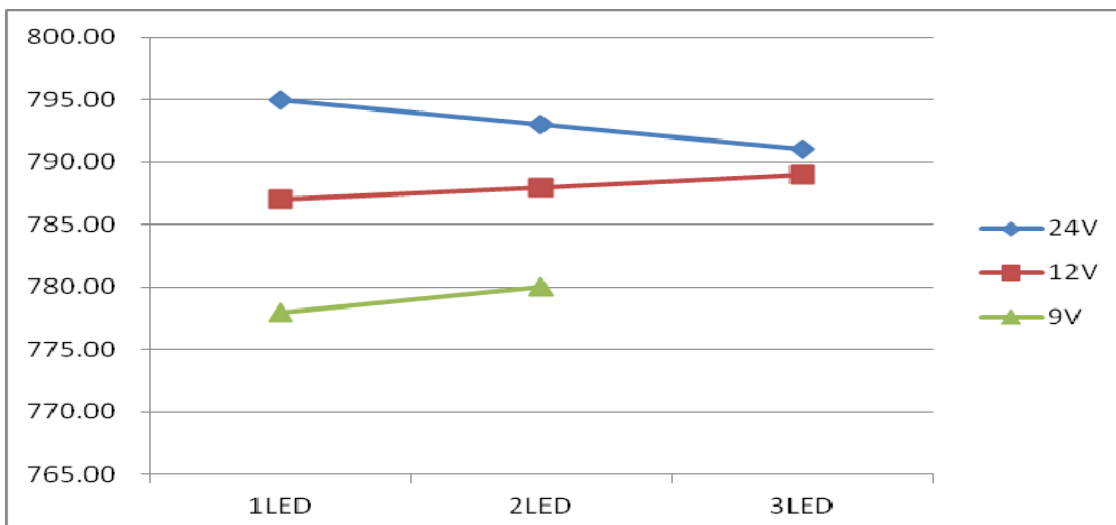


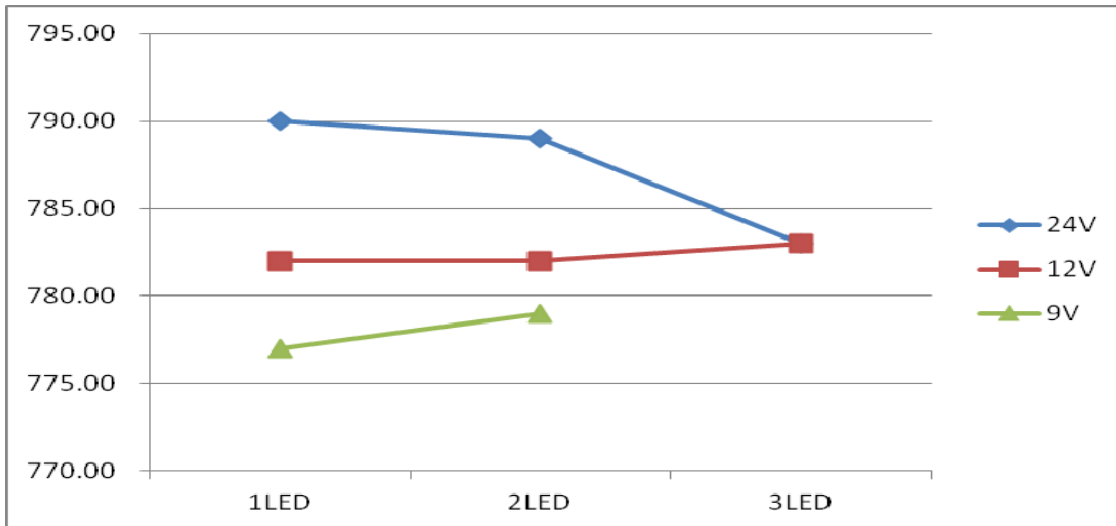
Output current vs. input voltage @2-LED in cascaded, $I_{OUT}=384mA$



Output current vs. input voltage @3-LED in cascaded, $I_{OUT}=384mA$

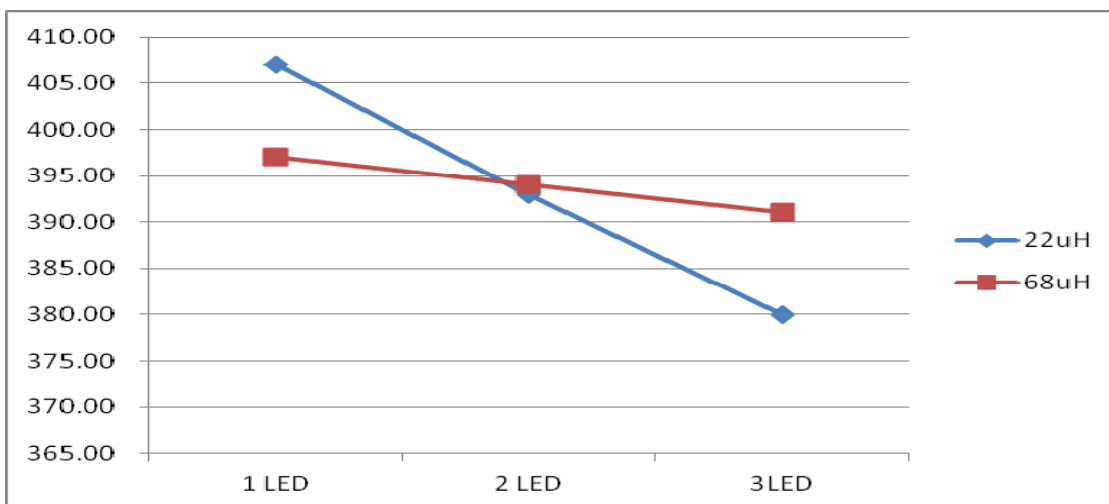
5. Output Current vs. LED Cascaded Number at Various Input Voltage

Output current vs. LED cascaded number @ $L=22\mu\text{H}$, $I_{\text{OUT}}=384\text{mA}$ Output current vs. LED cascaded number @ $L=68\mu\text{H}$, $I_{\text{OUT}}=384\text{mA}$ Output current vs. LED cascaded number @ $L=22\mu\text{H}$, $I_{\text{OUT}}=769\text{mA}$

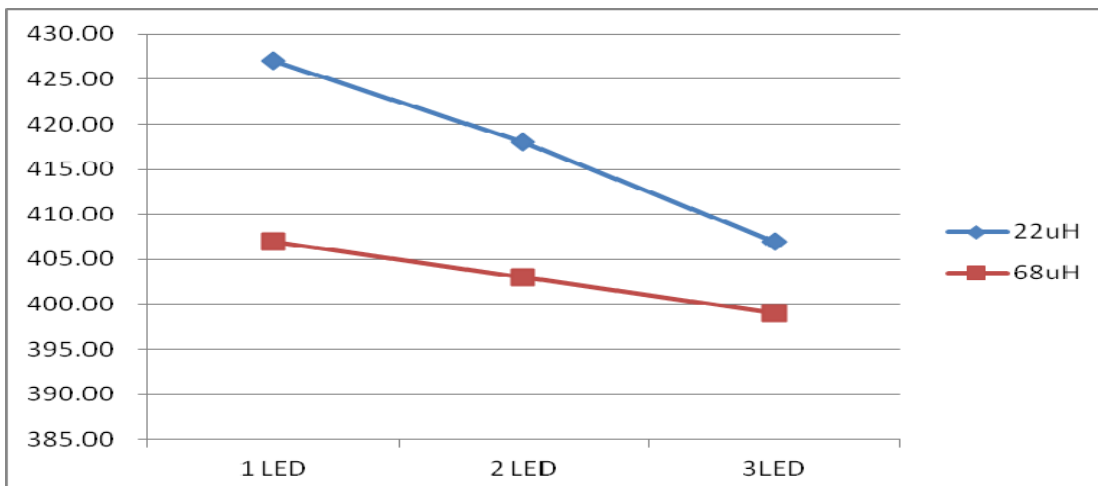


Output current vs. LED cascaded number @ $L=68\mu\text{H}$, $I_{\text{OUT}}=769\text{mA}$

6. Output Current vs. LED Cascaded number at Various Inductor

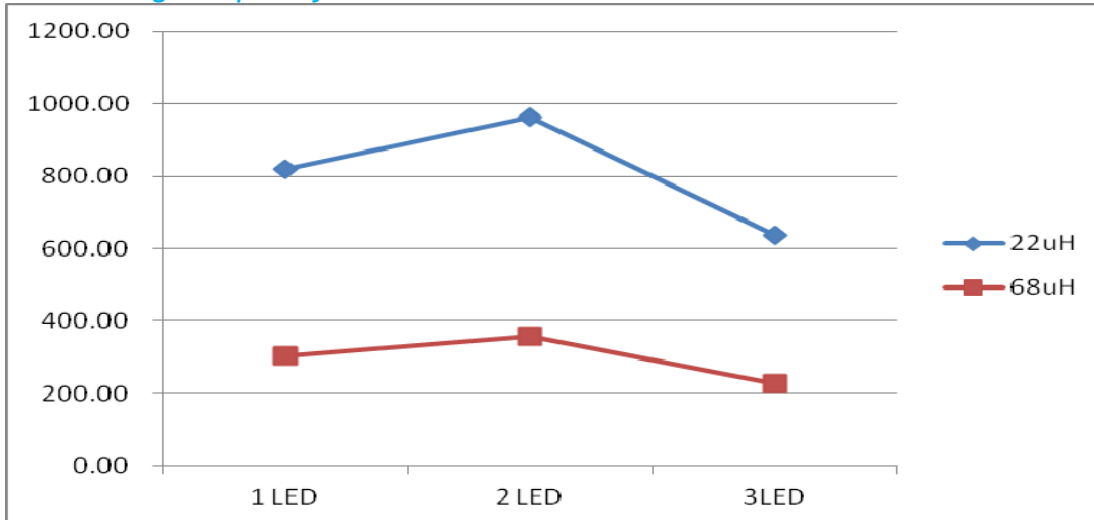


Output Current vs. LED Cascaded number @ $V_{\text{IN}}=12\text{V}$, $I_{\text{OUT}}=384\text{mA}$

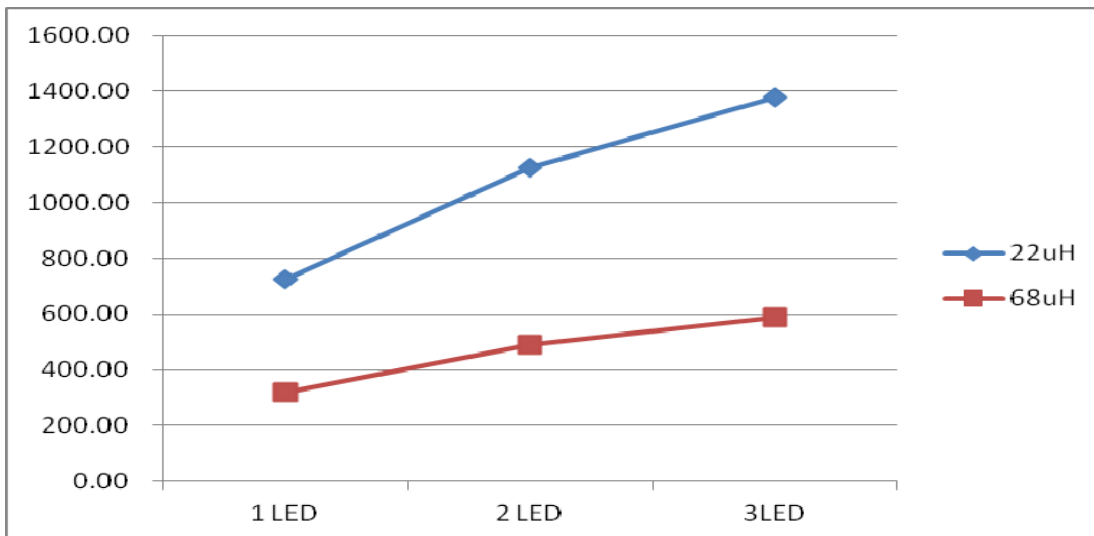


Output Current vs. LED Cascaded number @ $V_{\text{IN}}=24\text{V}$, $I_{\text{OUT}}=384\text{mA}$

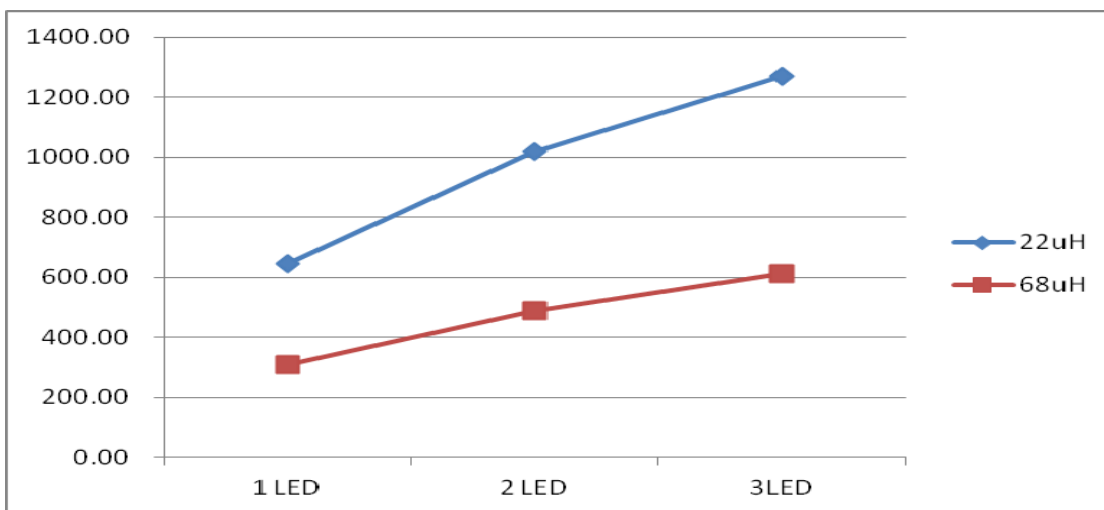
7. Switching Frequency vs. LED Cascaded Number at Various Inductor



Switching Frequency vs. LED Cascaded Number @VIN=12V, I_{OUT}=384mA

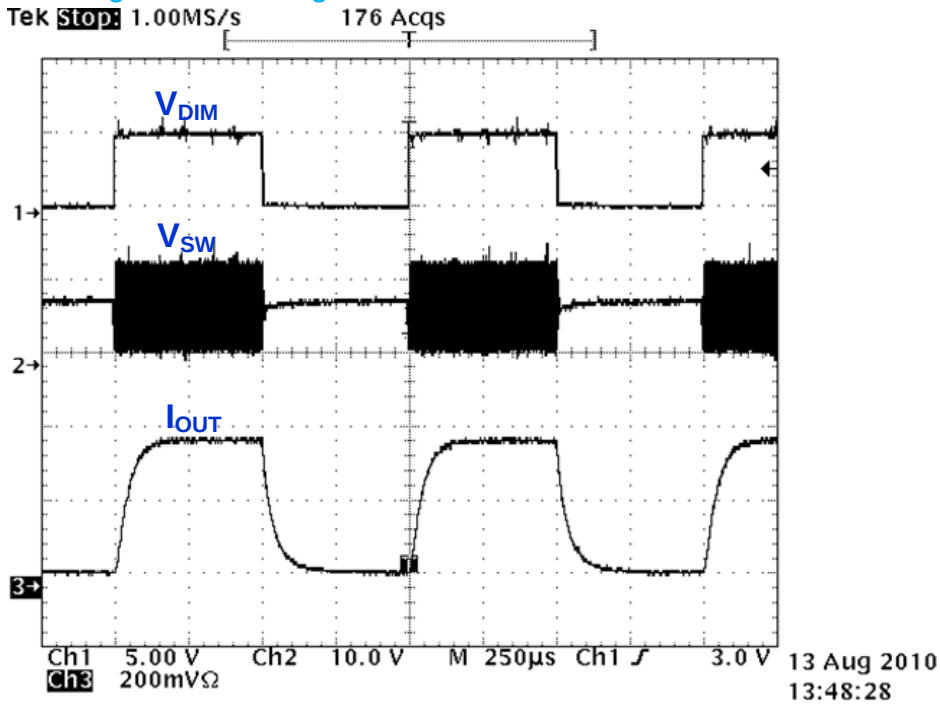


Switching Frequency vs. LED Cascaded Number @VIN=24V, I_{OUT}=384mA

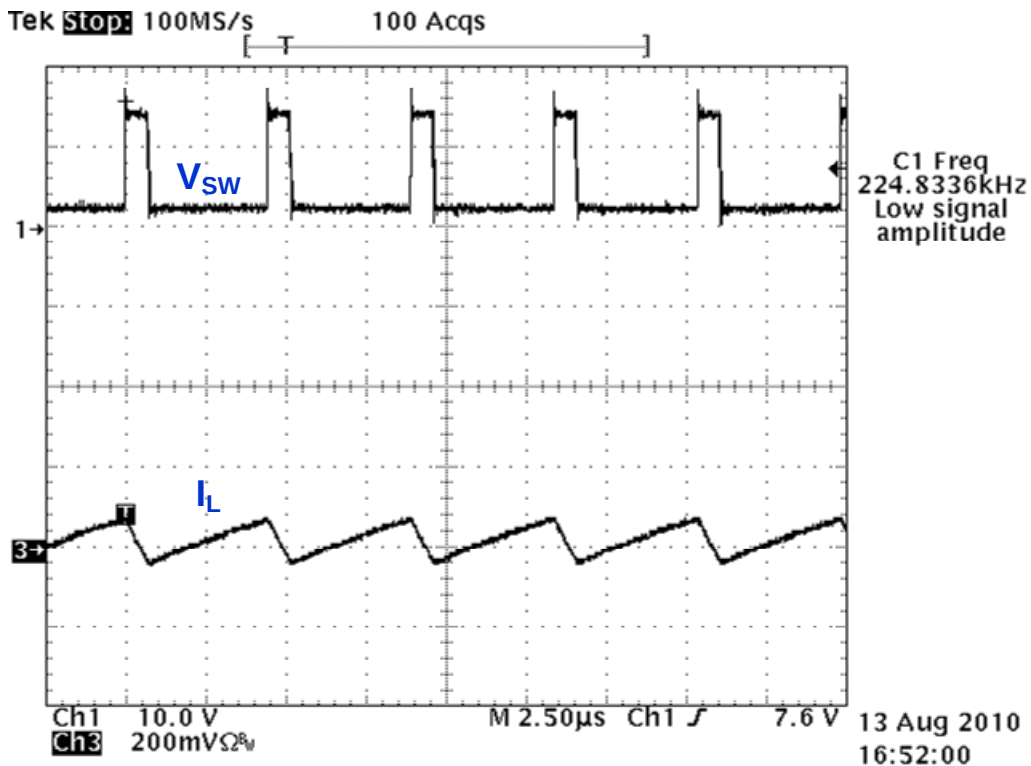


Switching Frequency vs. LED Cascaded Number @VIN=30V, I_{OUT}=384mA

8. Dimming and switching waveforms



Dimming waveform($V_{IN}=12V$, $R_{SEN}=0.27\Omega$, 3-LED)



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

. Application notes

.Setting nominal average output current with external resistor RS

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

$$I_{OUTnom} = 0.1/R_s \text{ [for } R_s \geq 0.1\Omega \text{]}$$

Nominal ripple current is $\pm 15\text{mV}/R_s$

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 TTP933 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 be limited to its preset value .

. Over Temperature protection

When the junction temperature over range . TTP933 will turn off output Current .

.Minimum Input Voltage

The Minimum Input Voltage is the sum of the voltage drops on R_{SEN} , DCR of L1 , $R_{ds(ON)}$ of Internal MOS switch and the total forward voltage of LEDS V_{LED} .

$$V_{in} = V_{RS} + V_{LED} + V_{L1} + V_{SW} .$$

.Design Consideration :

.Switching Frequency

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

$$\begin{aligned} &F_{SW} = (1-D)/T_{OFF,MIN} , \text{ when the duty cycle is large than } 0.5 \quad (D = V_{out} / V_{in}) \\ \text{or} \quad &F_{SW} = D/T_{ON,MIN} , \text{ when the duty cycle is smaller than } 0.5 \end{aligned}$$

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 40Khz To 1.0Mhz .

. 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 inductor 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 IC. 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

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

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 VIN 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.

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

$$T_{ON} = L \Delta I / (V_{IN} - V_{LED} - I_{avg} (R_S + r_L + R_{SW}))$$

$$T_{OFF} = L \Delta I / (V_{LED} + V_D + I_{avg} (R_S + r_L))$$

Where

L is the coil inductance

r_L is the coil resistance

R_s is the current sense resistance

I_{avg} is the required LED current

ΔI is the coil peak-peak ripple current {Internally set to $0.3 \times I_{avg}$ }

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

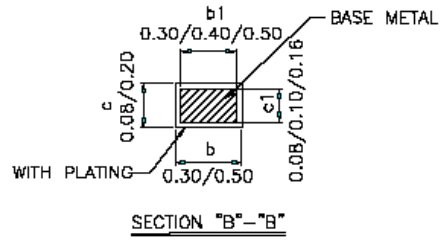
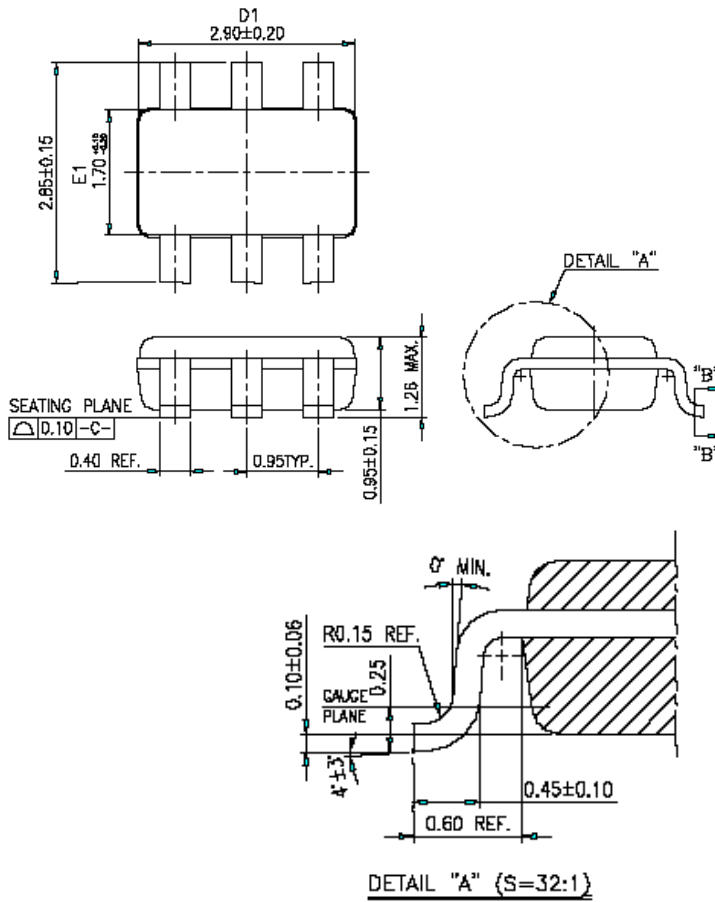
Diode selection :

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°C. 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.

Package Information

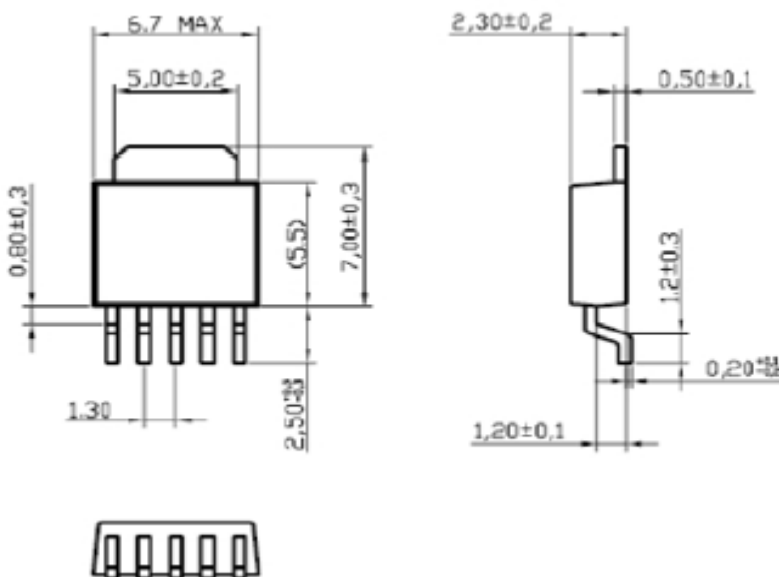
SOT23-6 (TTP933-FA6)



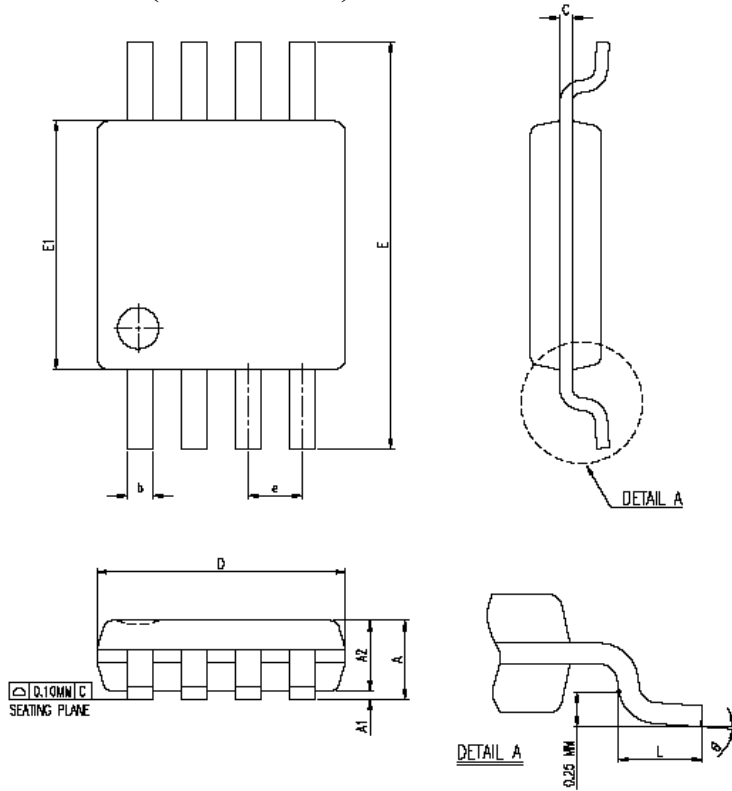
NOTES:

- 1.DIMENSION D1 & E1 DOES NOT INCLUDE MOLD PROTRUSION.
- 2.COPLANARITY OF ALL LEADS SHALL BE (BEFORE TEST) 0.1 MAX. FROM THE SEATING PLANE. UNLESS OTHERWISE SPECIFIED.
- 3.GENERAL PHYSICAL OUTLINE SPEC IS REFER TO TMC'S FINAL VISUAL INSPECTION SPEC UNLESS OTHERWISE SPECIFIED.

TO252-5(TTP933-HE5)



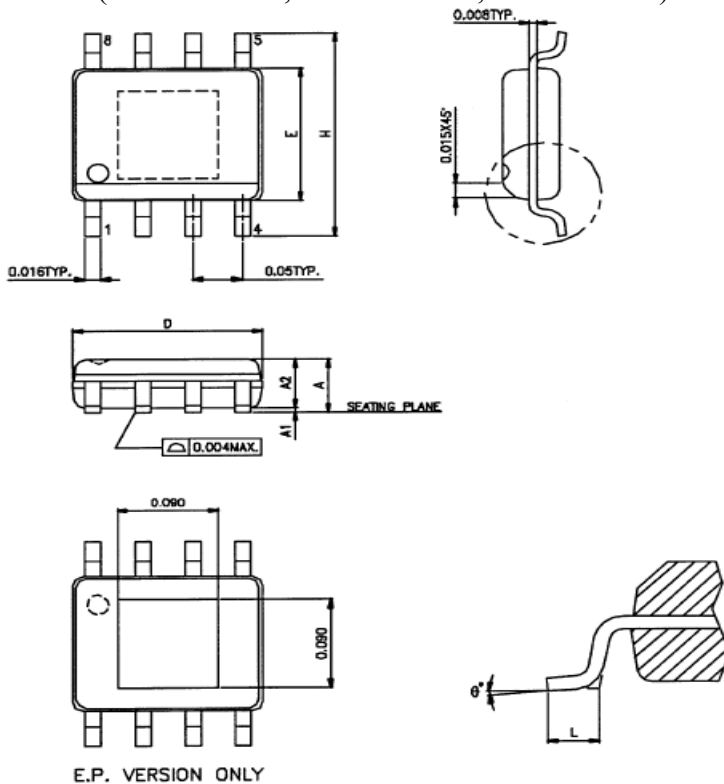
MSOP8(TTP933-BM8)



SYMBOL	DIMENSION IN MM			DIMENSION IN INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.81	1.02	1.10	0.032	0.040	0.043
A1	0.05		0.15	0.002		0.006
A2	0.76	0.86	0.95	0.030	0.034	0.037
b	0.28	0.30	0.38	0.011	0.012	0.015
C	0.13	0.15	0.23	0.005	0.006	0.009
D	2.90	3.00	3.10	0.114	0.118	0.122
E	4.75	4.90	5.05	0.187	0.193	0.199
E1	2.90	3.00	3.10	0.114	0.118	0.122
e	0.65 BASIC			0.026 BASIC		
L	0.40	0.55	0.70	0.016	0.022	0.028
Ø	0"	3"	6"	0"	3"	6"
JEDEC						

*NOTES : DIMENSION "D" DOES NOT INCLUDE MOLD PROTRUSIONS OR GATE BURRS.
MOLD PROTRUSIONS AND GATE BURRS SHALL NOT EXCEED 0.006 INCH (0.15 MM) PER SIDE .
DIMENSION "E1" DOES NOT INCLUDE MOLD PROTRUSIONS MOLD PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.25 MM) PER SIDE .

SOP8 (TTP933-CO8, TTP933-DO8, TTP933-JO8)

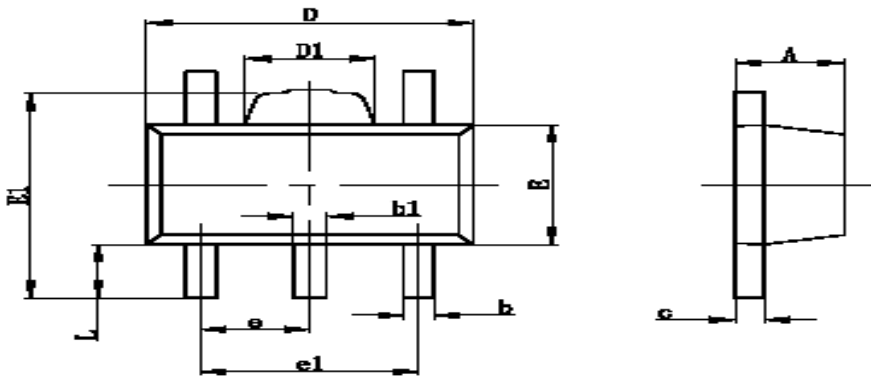


SYMBOLS	MIN.	MAX.
A	0.053	0.069
A1	0.004	0.010
A2	—	0.059
D	0.189	0.196
E	0.150	0.157
H	0.228	0.244
L	0.016	0.050
Ø"	0	8

UNIT : INCH

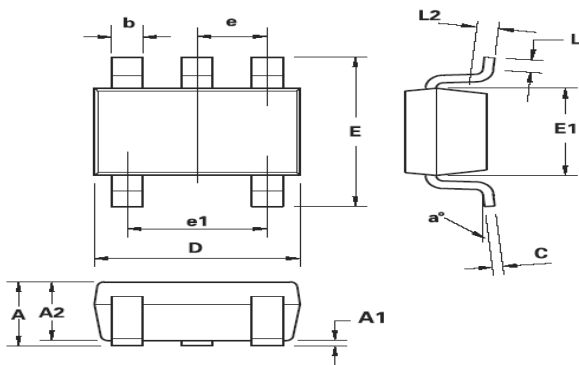
NOTES:
1.JEDEC OUTLINE : MS-012 AA / E.P. VERSION : N/A
2.DIMENSIONS "D" DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.MOLD FLASH, PROTRUSIONS AND GATE BURRS SHALL NOT EXCEED .15mm (.006in) PER SIDE.
3.DIMENSIONS "E" DOES NOT INCLUDE INTER-LEAD FLASH, OR PROTRUSIONS. INTER-LEAD FLASH AND PROTRUSIONS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

SOT89-5(TTP933-GG5)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.400	1.600	0.055	0.063
b	0.320	0.520	0.013	0.020
b1	0.360	0.560	0.014	0.022
c	0.350	0.440	0.014	0.017
D	4.400	4.600	0.173	0.181
D1	1.400	1.800	0.055	0.071
E	2.300	2.600	0.091	0.102
E1	3.940	4.260	0.155	0.167
e	1.500TYP		0.060TYP	
e1	2.900	3.100	0.114	0.122
L	0.900	1.100	0.035	0.043

SOT23-5 (TTP933-EA5)



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°

.ORDER INFORMATION

1. Package form: TTP933-BM8, TTP933-CO8, TTP933-DO8, TTP1933-EA5, TTP933-FA6,
TTP933-GG5, TTP933-HE5, TTP933-JO8
2. Chip form: TCP933

. Revise History

2013/03/05: Original version V1.0.

2013/05/02: Modify Package Information V1.1.

2013/08/23: Modify Package Information V1.2.