KTD3112/KTD3113

## High Efficiency Boost 2P6S/3P6S LED Driver

Features

- Drive up to 6 LEDs per string
- KTD3112: 2 strings, 12 LEDs total
- KTD3113: 3 strings, 18 LEDs total
- High efficiency: up to 90%
- High frequency step-up converter (800kHz)
- Wide input range: 2.7V to 5.5V
- Integrated 30V Power MOSFET
- Internal compensation and soft start
- Integrated 2- or 3-channel current sink
- Preset max. 20mA/25mA current per channel
- 1.5% Typ. current matching
- PWM dimming with < 0.3µs rise/fall time
- Low quiescent current
- LED open/short protection
- 25V LED open-circuit (OVP) threshold
- Cycle-by-cycle inductor current limit
- < 1µA shutdown current
- Pb-free Packages: TQFN33-16, WLCSP-9 1.2mm x 1.2mm
- -40°C to +85°C Temperature Range

Applications

- Smartphone
- PDA
- GPS
- Portable media players
- Other 1-cell Li Ion LED applications
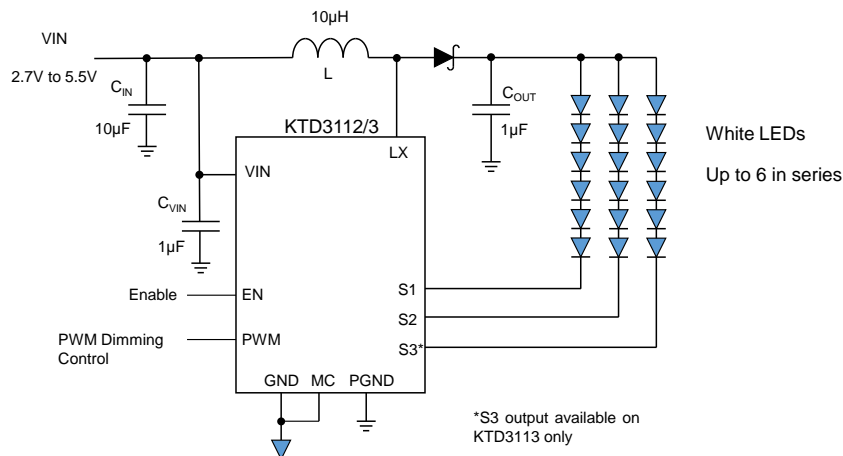
Brief Description

KTD3112/KTD3113 is the ideal power solution for white LED backlighting used with medium to small size LCD panels. It is a highly integrated step up DC-DC converter with input voltage range from 2.7V to 5.5V, accommodating 1-cell lithium ion battery or 5V regulated supply. KTD3112/3 integrates a 30V Power MOSFET as well as compensation and soft start circuitry, which results in a simpler and smaller solution with much fewer external components. High switching frequency (800kHz) allows the use of a smaller sized inductor and capacitor.

Two regulated current sinks in KTD3112 and three sinks in KTD3113 provide per channel 20mA/25mA (max.) factory programmed current. With a 25V OVP, each string can connect up to six LEDs in series, for a total of 12 or 18 LEDs in KTD3112 and KTD3113 respectively.

A PWM dimming control is included for wide output dimming range. The device has an EN pin which enables the IC.

Various protection features are built into KTD3112/3, including cycle-by-cycle input current limit protection, output over-voltage protection, LED fault (open or short) protection and thermal shutdown protection. The leakage current in shutdown mode is less than 1µA.

KTD3112/3 is available in a RoHS compliant and Green 16-lead 3mm x 3mm x 0.75mm ThinQFN or 9-lead 1.2mm x 1.2mm WLCSP package.

Typical Application

*S3 output available on KTD3113 only

Pin Descriptions

| Pin #				Name	Function
KTD3112		KTD3113			
TQFN33-16	WLCSP-9	TQFN33-16	WLCSP-9		
1, 2	B1	1, 2	B1	LX	Switching node of the step-up converter
3	A2	3	A2	PWM	Pulse width controlled dimming input. Connect this pin to VIN when not used. There is an internal 400kΩ pull-down resistor at this pin.
4, 5, 8, 11, 12, 13	C3	4, 5, 11, 12, 13	C3	NC	Not internally connected
6	A1	6	A1	EN	IC enable pin. There is an internal 400kΩ pull-down resistor at this pin.
7	B2, C1	7	C1	GND	Analog Ground pin. All GND pins must be connected in the PCB for proper operation.
N/A	N/A	8	B2	S3	Regulated output current sink #3
9	B3	9	B3	S2	Regulated output current sink #2
10	A3	10	A3	S1	Regulated output current sink #1
14	C2	14	C2	VIN	Input supply pin for the IC
15, 16	N/A	15, 16	N/A	PGND	Power Ground pin
MC		MC			Metal chassis. Connect to ground for electrical and thermal usage. MC is internally connected to Analog Ground pin.

KTD3112 TQFN33-16 - Top View
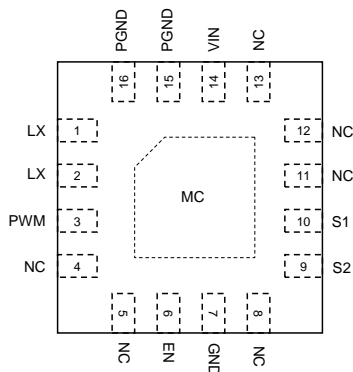
KTD3113 TQFN33-16 - Top View
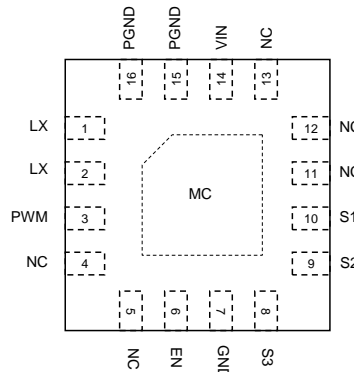
KTD3112 WLCSP-9, 1.2mm x 1.2mm - Top View
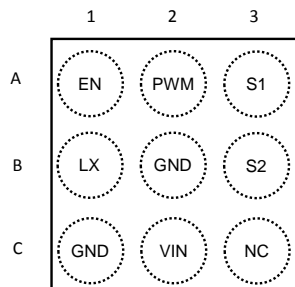
KTD3113 WLCSP-9, 1.2mm x 1.2mm - Top View
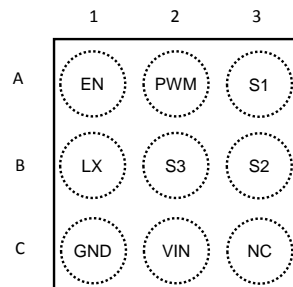
Absolute Maximum Ratings[1]

(T_A = 25°C unless otherwise noted)

Symbol	Description	Value	Units
VIN	Input voltage	-0.3 to 6	V
LX	High voltage node	-0.3 to 30	V
S_x	High voltage node	-0.3 to 22	V
EN, PWM	Control pins	-0.3 to VIN+0.3	V
T_J	Operating Temperature Range	-40 to 150	°C
T_s	Storage Temperature Range	-65 to 150	°C
T_{LEAD}	Maximum Soldering Temperature (at leads, 10 sec)	300	°C

Thermal Capabilities

Symbol	Description	Value	Units
TQFN33-16			
θ_{JA}	Thermal Resistance – Junction to Ambient[2]	50	°C/W
P_D	Maximum Power Dissipation at $T_A \leq$ 25°C	2.0	W
$\Delta P_D/\Delta T$	Derating Factor Above T_A = 25°C	-20	mW/°C
WLCSP-9			
θ_{JA}	Thermal Resistance – Junction to Ambient[2]	100	°C/W
PD	Maximum Power Dissipation at T_A = 25°C	1.1	W
$\Delta P_D/\Delta T$	Derating Factor Above T_A = 25°C	-10.0	mW/°C

Ordering Information

Part Number	Max. Sink Current (nominal)	Marking[3]	Operating Temperature	Package
KTD3112EFJ-20-TR	20mA	FZYYZ	-40°C to +85°C	TQFN33-16
KTD3112EFJ-25-TR	25mA	FHYYZ	-40°C to +85°C	TQFN33-16
KTD3112EAA-20-TR	20mA	FZYYZ	-40°C to +85°C	WLCSP-9 1.2x1.2mm
KTD3112EAA-25-TR	25mA	FHYYZ	-40°C to +85°C	WLCSP-9 1.2x1.2mm
KTD3113EFJ-20-TR	20mA	GDYYZ	-40°C to +85°C	TQFN33-16
KTD3113EAA-20-TR	20mA	GDYYZ	-40°C to +85°C	WLCSP-9 1.2x1.2mm

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum rating should be applied at any one time.

2. Junction to Ambient thermal resistance is highly dependent on PCB layout. Values are based on thermal properties of the device when soldered to an EV board.

3. "YYZ" is the date code and assembly code.

Electrical Characteristics[4]

Unless otherwise noted, the *Min* and *Max* specs are applied over the full operation temperature range of –40°C to +85°C, while *Typ* values are specified at room temperature (25°C). VIN = 3.6V,

| Symbol	Description	Conditions	Min	Typ	Max	Units
IC Supply						
V_{IN}	Input operating range		2.7		5.5	V
UVLO	Input under voltage lockout	Rising edge		2.5	2.65	V
$UVLO_{HYST}$	UVLO hysteresis			0.15		V
I_Q	IC standby current	Not switching		0.65		mA
	IC operating current	Switching		1.5		mA
I_{SHDN}	VIN pin shutdown current	EN = GND			1.0	µA
Step-Up Converter						
$R_{DS(ON)}$	NMOS on-resistance			0.35		Ω
I_{LIM}	Peak NMOS current limit			1.5		A
$I_{INRUSH-SU}$	Peak Inductor Current During Startup	KTD3112, V_{IN} = 3.6V, 2p6s LEDs, I_{LED} = 25mA, L = 10µH, C_{OUT} = 1µF		700		mA
F_{SW}	Oscillator frequency			800		kHz
D_{max}	Maximum duty cycle		92	95		%
OVP	Over voltage threshold	Measured at LX pin		25		V
Current Sink						
I_D	Output current accuracy	Current setting = 20mA/25mA, (Duty Cycle 100%)		±2		%
	Output current matching[5]	Current setting = 20mA/25mA, (Duty Cycle 100%)		1.5		%
V_sov	Current sink over voltage threshold			6.7		V
T_{FAULT}	Current sink Fault Delay			80		ms
Control						
V_{TH-L}	EN, PWM pin logic low threshold				0.4	V
V_{TH-H}	EN, PWM pin logic high threshold		1.4			V
R_{EN}	EN pin pull-down resistor			400		kΩ
R_{PWM}	PWM pin pull-down resistor			400		kΩ
F_{PWM}	PWM dimming frequency		100		30000	Hz
$t_{PWM(ON)}$	PWM dimming on-time		0.5			µs
T_{J-TH}	IC junction thermal shutdown threshold			150		°C
	IC junction thermal shutdown hysteresis			15		°C

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4. KTD3112/3 is guaranteed to meet performance specifications over the –40°C to +85°C operating temperature range by design, characterization and correlation with statistical process controls.

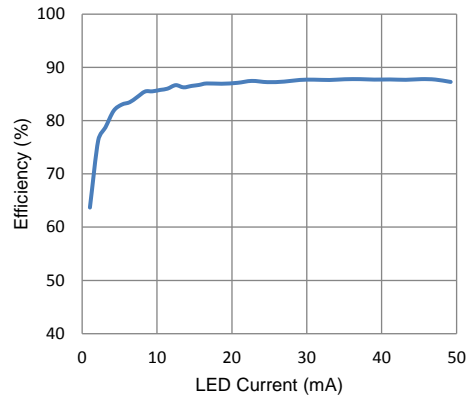5. The current matching between channels is defined as |Id-Iavg|max/Iavg.

Typical Characteristics

V_{IN} = 3.6V, L = 10µH, C_{IN} = 10µF, C_{VIN} = 1µF, C_{OUT} = 1µF with 2P6S LEDs in series at 25mA, T_{AMB} = 25°C unless otherwise specified.
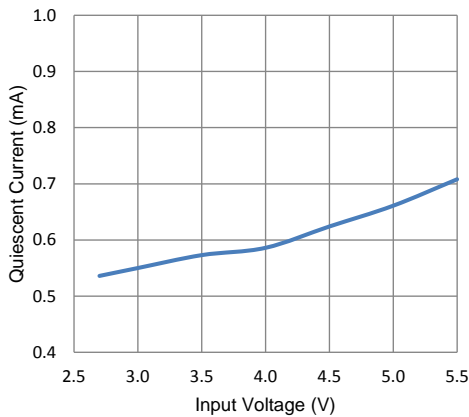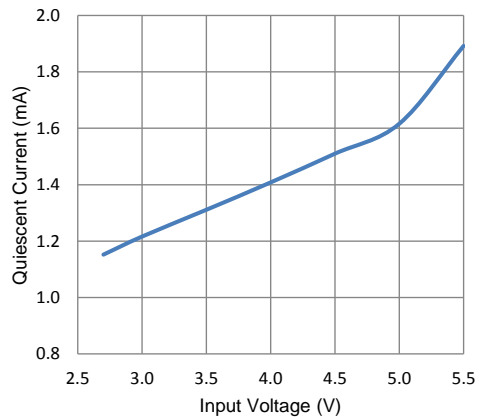
Efficiency vs. Input Voltage
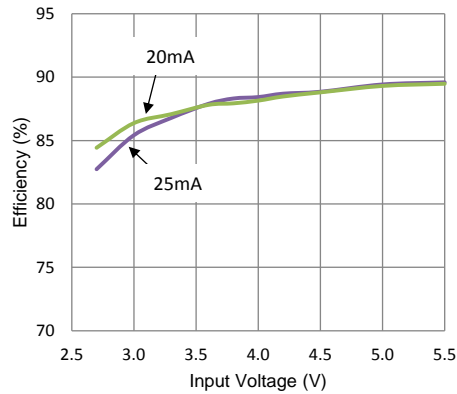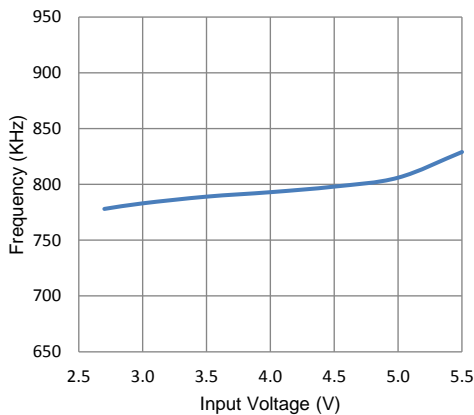
Efficiency vs. LED Current

Operating Current (non-switching)
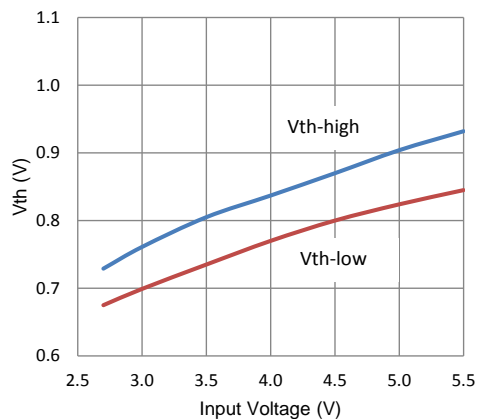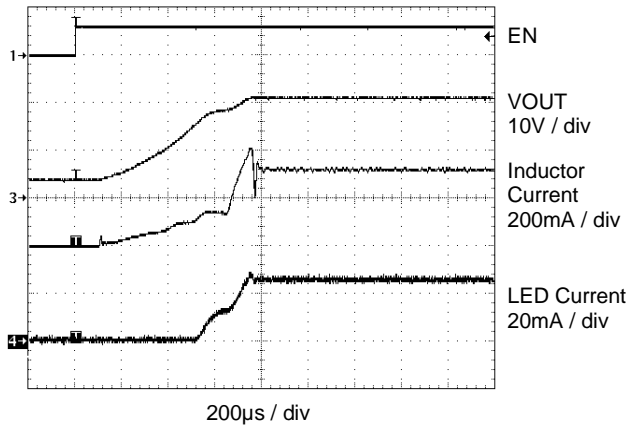
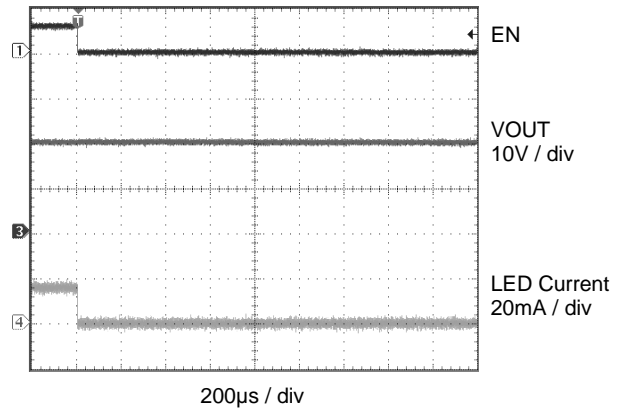Operating Current (switching)

Switching Frequency

EN Logic Threshold Voltage

Typical Characteristics (continued)

V_{IN} = 3.6V, L = 10µH, C_{IN} = 10µF, C_{VIN} = 1µF, C_{OUT} = 1µF with 2P6S LEDs in series at 25mA, T_{AMB} = 25°C unless otherwise noted.
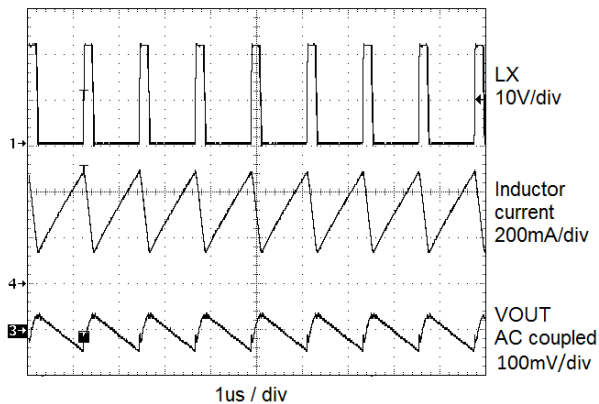
Soft-Start Turn On

200µs / div

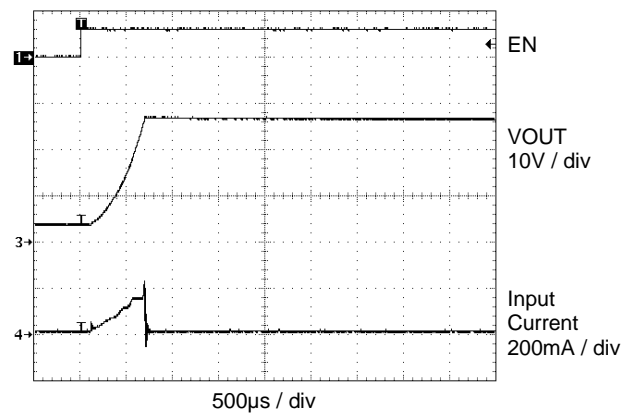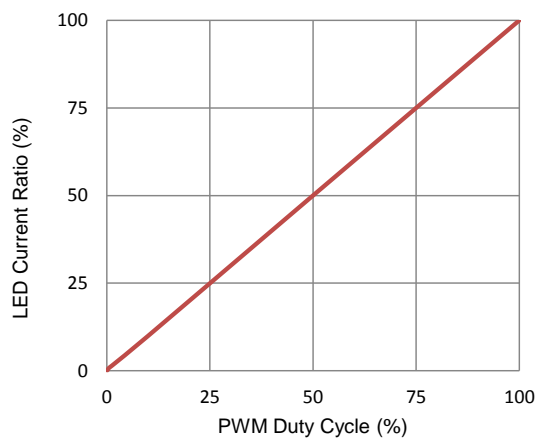Turn Off

200µs / div

Steady State Switching

1us / div

Turn On with LED Open (OVP)

500µs / div

PWM Dimming at 20kHz

Typical Characteristics (continued)

V_{IN} = 3.6V, L = 10μH, C_{IN} = 10μF, C_{OUT} = 1μF with 2P6S LEDs in series at 25mA, T_{AMB} = 25°C unless otherwise specified.

PWM Dimming at 200Hz
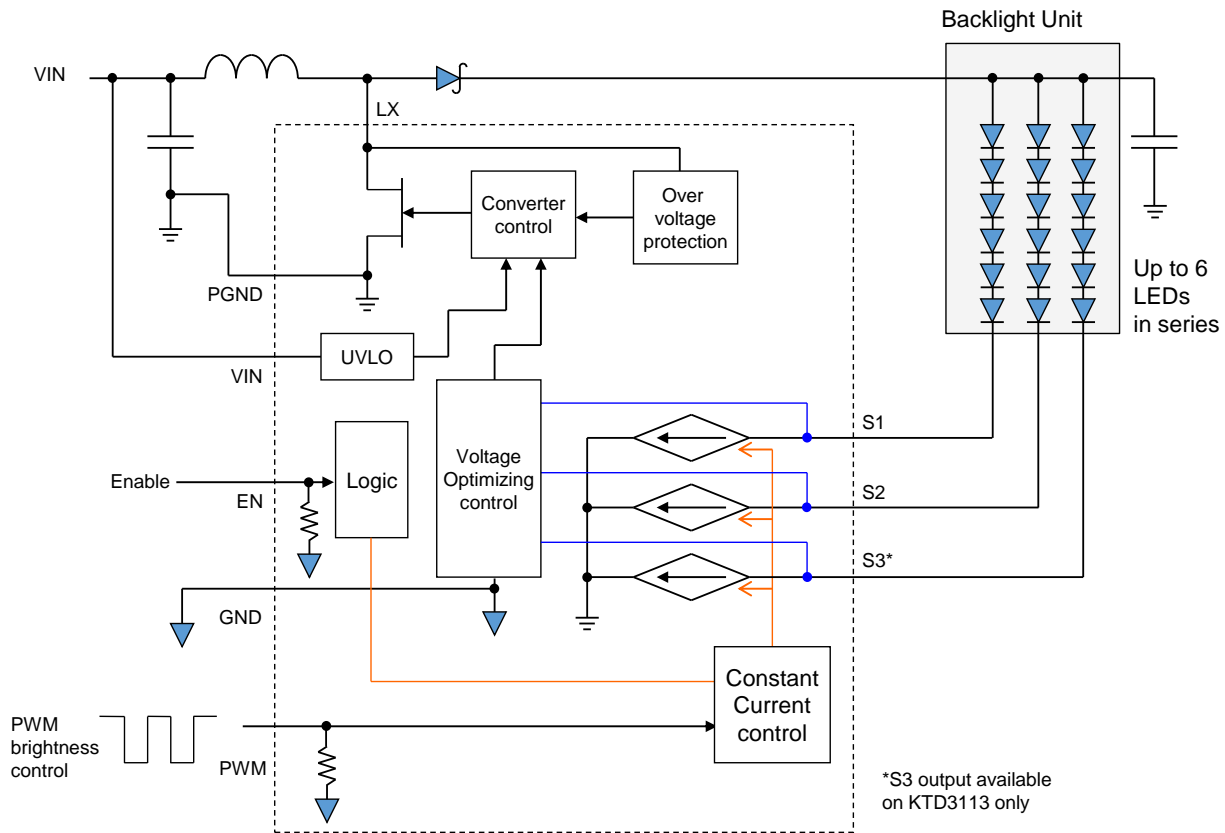

1→   PWM

3→   VOUT
      AC coupled
      100mV/div

4→   LED current
      20mA/div

1ms / div

PWM Dimming at 20kHz

1→   PWM

3→   VOUT
      AC coupled
      500mV/div

4→   LED current
      20mA/div

20us / div
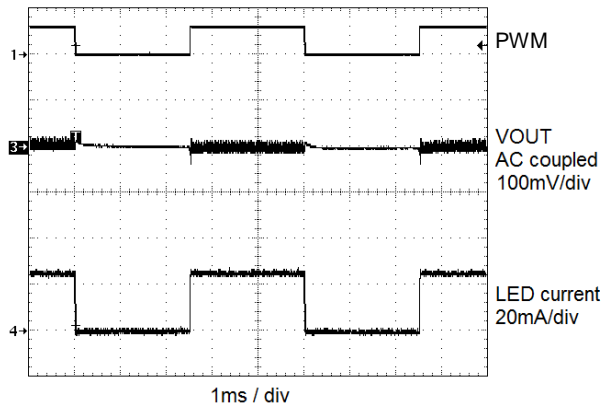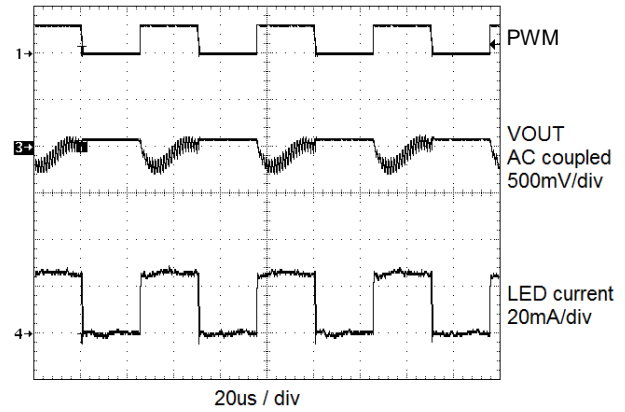
Functional Block Diagram

Functional Description

The KTD3112/KTD3113 are current regulated step-up (boost) converters which respectively can drive two or three strings of LEDs. Unused channels, if any, need to be connected to ground (GND).

The voltage step-up is accomplished by a boost topology, using an inductor-based DC-DC switching converter, in which the inductor serves as an energy storage device in the system. By integrating a high voltage optimized MOSFET, KTD3112/3 internal switching frequency is 800kHz while still maintaining high power efficiency. Unlike a traditional DC-DC boost converter with a fixed output voltage, KTD3112/3 dynamically changes its output voltage regulation parameters depending on the load. The use of unique control schemes maintains accurate current regulation in each of the current sinks while leaving the output voltage at a minimum, increasing the overall conversion efficiency. The internal step-up converter dynamically controls the voltage at the output high enough to drive the LED string with the highest total forward voltage.

PWM pulses provided at PWM pin program the sink's on and off, so that the average LED current is proportional to the PWM duty cycle. Asserting a logic high on EN pin turns each output sink on to maximum LED current. LED dimming is based on the popular PWM dimming scheme which is supported via the PWM pin.

Application Information

Current Dimming using PWM Pin

KTD3112/3 allows maximum flexibility with a PWM signal control input which can be used for dimming. The IC must remain Enabled at EN pin during PWM dimming. Each LED channel can typically recover from no current within 0.3μs. This allows very short PWM on-time or a duty-cycle with fine resolution. Assume a 50μs minimum on-time for a 100Hz PWM signal, a 200:1 ratio can be achieved by PWM.

In order to guarantee a soft-start during start-up, the EN input should always transition from low to high during power-up. If the EN input is kept high while PWM operates in burst mode, the soft-start is no longer supported resulting in some inrush current during subsequent power-ups.

Fault Protection

Each current sink is protected against LED short or open conditions. If an LED short circuit condition arises, the current sink continues to regulate until $V_{SINK} > V_{SOV}$. When any sink node voltage goes above V_{SOV} (6.7V) for more than 80ms (while PWM dimming signal remains high), that channel's current sink will be turned off, and other channels will still work if they don't trigger this fault condition. For example, if one or more LEDs on a channel are shorted, that channel's sink voltage will increase. If the voltage goes above 6.7V for more than 80ms, the Current Sink Fault Protection will be triggered and only this faulty string will be disabled by shutting off this current sink. All other channels will continue normal operation if they don't have a fault condition. When PWM dimming control is used, the 80ms fault delay is accumulated only when PWM signal is high; the PWM low time is not counted into the fault delay, so the delay time will be 80ms/D_{PWM} (D_{PWM} is the duty cycle of the PWM signal).

In case of an LED failing open, the current sink voltage of the failed string will go close to ground and dominate the boost converter control loop. As a result the output voltage will move up to the over-voltage threshold. KTD3112/3 uses LX pin to sense the output over voltage. Once the over-voltage incident is flagged internally, the faulty channel(s) will be disabled. Then the output voltage of the boost converter will go back to normal level. During the entire process, the rest of the LED strings (healthy LED strings) would continue normal operation.

The fault conditions are reset by toggling EN pin or power on reset.

Thermal Shutdown

Thermal shutdown feature is included in the KTD3112/3. When the IC's junction temperature (T_J) reaches 150°C, the IC will immediately enter shutdown mode. Once T_J drops 15°C to approximately 135°C, the IC will resume normal operation.

Inductor Selection

A 10μH inductor is recommended for all applications. If high efficiency is a critical requirement, a low DCR inductor should be selected. The inductor's saturation current rating should also exceed the peak input current.

Table 1. Recommended Inductors

Application	Inductor Part Number	Value (μH)	DCR (Ω)	Saturation Current (A)	Dimensions (mm)	Manufacturer
2P6S LEDs	VLCF5020T-100MR	10	0.182 max	1.13	5×5×2.0	TDK
2P6S LEDs	LPS4018-103ML	10	0.200 max	1.3	4×4×1.8	Coilcraft

Capacitor Selection

Small size X5R or X7R ceramic capacitors with low ESR are recommended for all applications. A 10μF input capacitor next to the inductor and an additional small 1μF close to the driver VIN pin is required. On the output, a 1μF capacitor is ideal. The voltage rating of these capacitors should exceed the maximum possible voltage at the corresponding pins.

KTD3112/KTD3113

Table 2. Recommended Ceramic Capacitor Vendors

Manufacturer	Website
Murata	www.murata.com
AVX	www.avx.com
Taiyo Yuden	www.t-yuden.com

Diode Selection

Using a Schottky diode is recommended because of its low forward voltage drop and fast reverse recovery time. The current rating of the Schottky diode should exceed the peak current of the boost converter. The voltage rating should also exceed the OVP value. Schottky diodes with 30V voltage rating (or higher) are recommended.

Table 3. Recommended Schottky Diodes

Application	Schottky Diode Part Number	Forward Voltage (V)	Forward Current (mA)	Reverse Voltage (V)	Manufacturer
2P6S LEDs	B130	0.52	1000	30	Vishay
2P6S LEDs	PMEG4005EJ	0.42	500	40	NXP
2P6S LEDs	PMEG4010EJ	0.54	1000	40	NXP

Layout Considerations

PCB layout is very important for high frequency switching regulators in order to keep the loop stable and minimize noise. A small 1µF ceramic capacitor C_{VIN} is recommended to be placed close to the IC VIN pin to get the best decoupling. The path of the inductor L1, Schottky diode D1 and output capacitor COUT should be kept as short as possible to minimize noise and ringing.
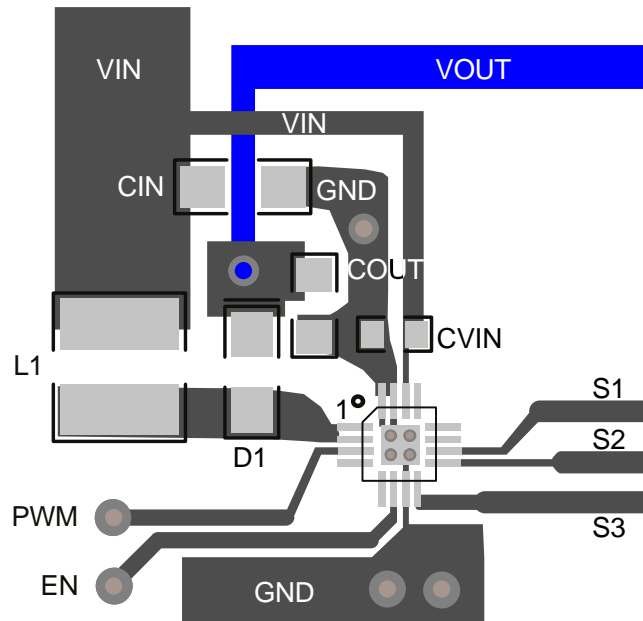
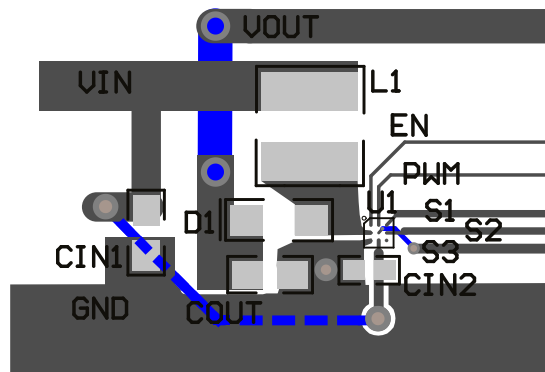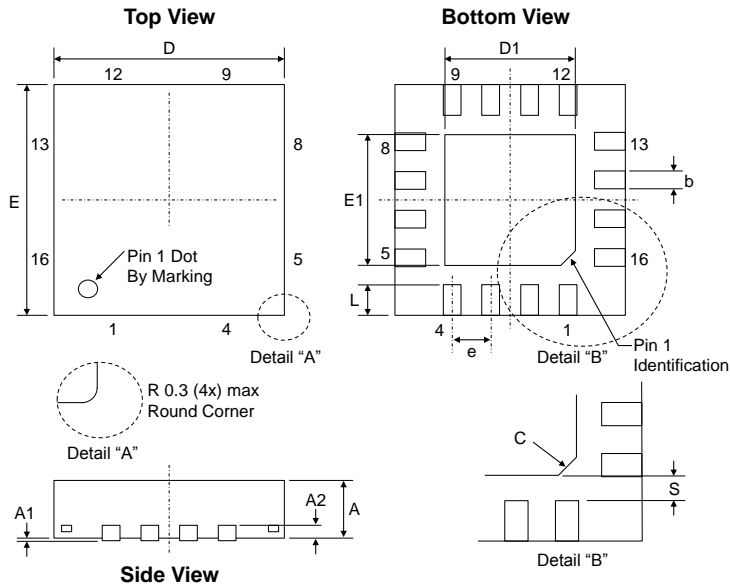**Figure 1. Recommended Layout for TQFN Package**

Figure 2. Recommended Layout for WLCSP Package

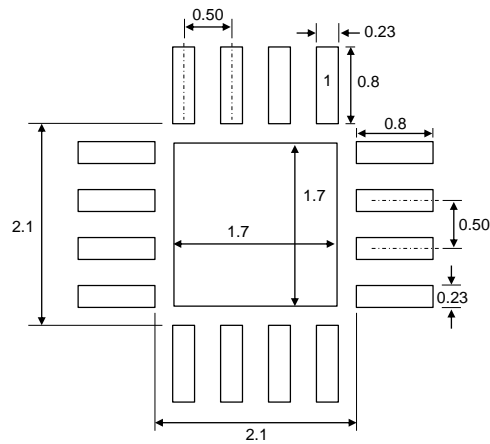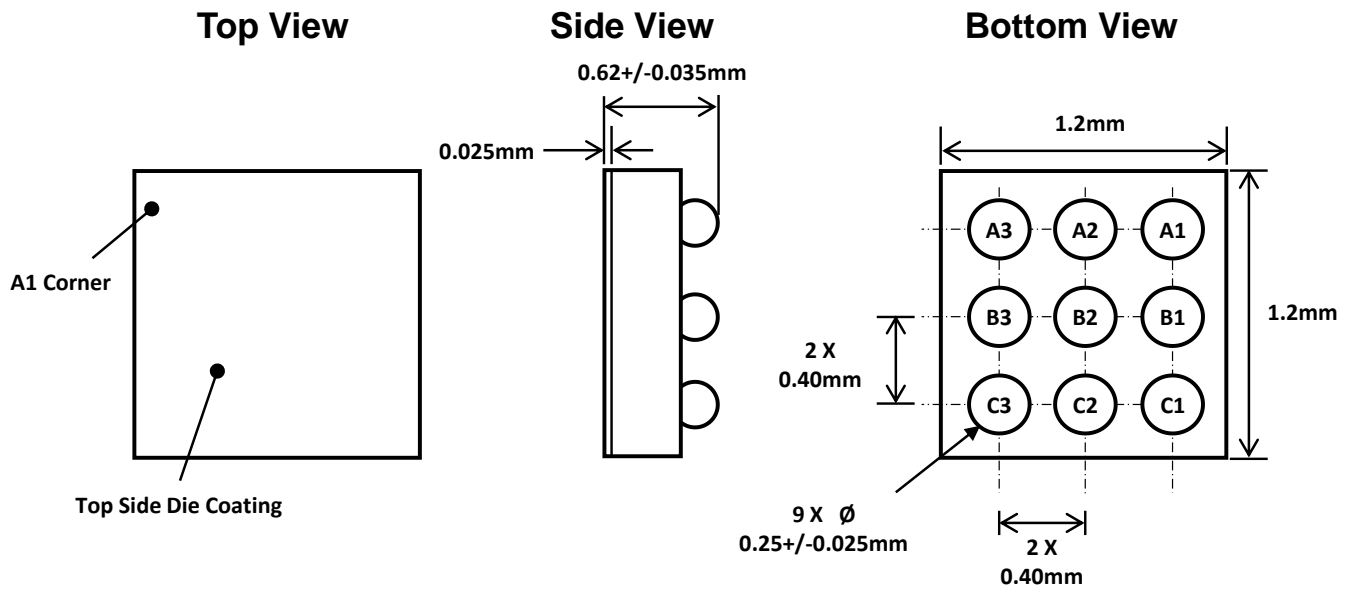## Packaging Information

TQFN33-16

Top View

D

12   9

13   8

E

16   5

1   4

Pin 1 Dot
By Marking

Detail "A"

R 0.3 (4x) max
Round Corner

Detail "A"

Side View

A1

A2 A

Bottom View

D1

9   12

8   13

E1   b

5   16

L

4   1

e

Detail "B"   Pin 1
Identification

C

S

Detail "B"

Dimension	mm		
	Min.	Typ.	Max.
A	0.65	0.75	0.85
A1	0.000	0.025	0.050
A2	0.154	0.203	0.280
b	0.18	0.23	0.30
C		0.3REF	
D	2.95	3.00	3.05
D1		1.7REF	
E	2.95	3.00	3.05
E1		1.7REF	
e	0.45	0.50	0.55
L	0.30	0.40	0.50
S		0.25REF	

Recommended Footprint

0.50

0.23

1   0.8

0.8

1.7

2.1

1.7

0.50

0.23

2.1

* Dimensions are in millimeters.

WLCSP-9 1.2mm x 1.2mm

Top View

A1 Corner

Top Side Die Coating

Side View

0.62+/-0.035mm

0.025mm

Bottom View

1.2mm

A3	A2	A1
B3	B2	B1
C3	C2	C1

1.2mm

2 X 0.40mm

9 X Ø 0.25+/-0.025mm

2 X 0.40mm

Recommended Footprint

(NSMD Pad Type)

0.40mm

0.40mm

0.80mm

0.80mm

0.21mm Copper Pad Diameter

0.31mm Solder Mask Opening

* Dimensions are in millimeters.