

## Description

The ZXLD1615Q is a PFM inductive-boost-converter designed to provide output voltages of up to 28V from a 2.5V to 5.5V input supply.

The ZXLD1615Q includes the output switch and peak current sense resistor, and can provide up to 10mA output current at maximum output voltage. Higher current is available at lower output voltages.

Quiescent current is typically 60 $\mu$ A and a shutdown function is provided to reduce this current to less.

Nominal output voltage can be set up to a maximum of 28V by two external resistors and can be adjusted to lower values by a PWM control signal applied to the 'Enable' pin. Depending upon the control frequency, the PWM signal will provide either continuous (low ripple) or gated control. The PWM filter components are contained within the chip. Minimum output voltage is determined by the input supply.

The device is assembled in a low profile TSOT25 package.

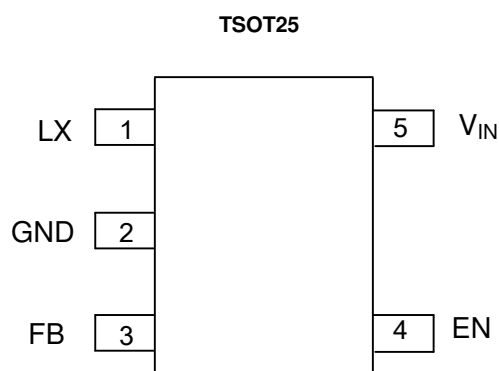
The ZXLD1615Q is qualified to AEC-Q100 Grade 3 and is Automotive-Compliant supporting PPAPs.

## Features

- Internal PWM Filter for Adjustable Output
- High Efficiency (85% typ.)
- Wide Input Voltage Range: 2.5V to 5.5V
- Up to 250mA Output Current at 5V
- Low 60 $\mu$ A Quiescent Current
- 100nA Maximum Shutdown Current
- Up to 1MHz Switching Frequency
- Low External Component Count
- Green Molding in Small Package TSOT25
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **Automotive-Compliant**
- **Qualified to AEC-Q100 Grade 3**
- **PPAP Capable (Note 4)**

- Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
  2. See [http://www.diodes.com/quality/lead\\_free.html](http://www.diodes.com/quality/lead_free.html) for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
  3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
  4. Automotive compliant products are AEC-Q100 qualified and are PPAP capable. Please refer to <https://www.diodes.com/quality/product-compliance-definitions/>.

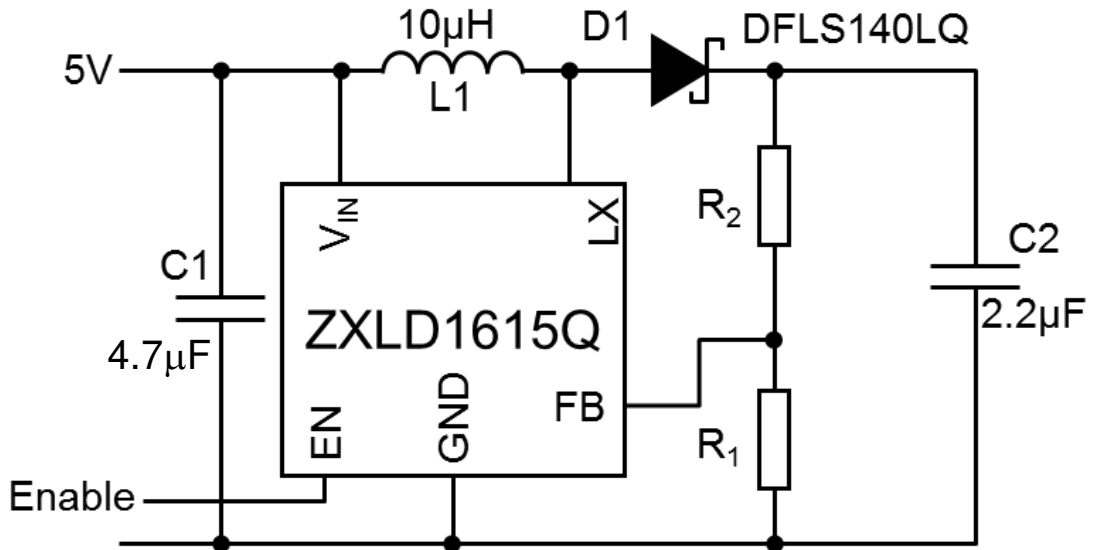
## Pin Assignments



## Applications

- Automotive LCD Panels

**Typical Application Circuit**



**Pin Description**

Pin Number	Pin Name	Function
1	LX	Drain of NDMOS Switch
2	GND	Ground (0V)
3	FB	Feedback Pin for Voltage Control Loop Nominal Voltage 1.025V
4	EN	Enable Input (Active High to Turn on Device) Also Used to Adjust Output Current by PWM Signal - Connect to VIN for Permanent Operation
5	V <sub>IN</sub>	Input Voltage (2.5V to 5.5V) Decouple with Capacitor Close to Device



## Recommended Operating Conditions

Symbol	Parameter	Min	Max	Unit
V <sub>IN</sub>	Input Voltage	2.5	5.5	V
V <sub>LX</sub>	LX Pin (MOSFET Switch's Drain) Output Voltage	0	28	V
V <sub>ENH</sub>	EN Pin High Level Input Voltage	1.5	V <sub>IN</sub>	V
V <sub>ENL</sub>	EN Pin Low Level Input Voltage	0	0.4	V
f <sub>LX MAX</sub>	Recommended Maximum Operating Frequency	—	1,000	kHz
T <sub>A</sub>	Operating Ambient Temperature Range	-40	+85	°C

## Electrical Characteristics (Test conditions: @ V<sub>IN</sub> = V<sub>EN</sub> = 3V, T<sub>A</sub> = +25°C, unless otherwise specified.)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
I <sub>INQ_OFF</sub>	Quiescent Supply Current - Output Off	V <sub>EN</sub> = 0V	—	<10	100	nA
I <sub>INQ_ON</sub>	Quiescent Supply Current - Output Not Switching	V <sub>EN</sub> = V <sub>IN</sub> , I <sub>LX</sub> = 0A	—	60	100	μA
V <sub>FB</sub>	FB Pin Control Voltage	—	0.98	—	1.07	V
f <sub>LX</sub>	Operating Frequency	L=10μH, V <sub>OUT</sub> =28V, 5mA Load	—	600	—	kHz
t <sub>OFF</sub>	LX Output "OFF" Time	—	350	500	—	ns
t <sub>ON</sub>	LX Output "ON" Time (Note 7)	—	—	—	5	μs
R <sub>LX</sub>	Switch 'ON' Resistance	—	—	1.75	—	Ω
I <sub>LX_PK</sub>	Switch Peak Current Limit	V <sub>LX</sub> = 20V	—	320	—	mA
I <sub>LX(LEAK)</sub>	Switch Leakage Current	V <sub>LX</sub> = 20V	—	—	1	μA
I <sub>ENH</sub>	EN Pin High Level Input Current	V <sub>EN</sub> = V <sub>IN</sub>	—	—	-100	nA
I <sub>ENL</sub>	EN Pin Low Level Input Current	V <sub>EN</sub> = 0V	—	—	1	μA
t <sub>EN(HOLD)</sub>	EN Pin Turn off Delay (Note 8)	V <sub>EN</sub> Switched from High to Low	—	120	—	μs
PWMDC	PWM Duty Cycle Range at 'EN' Input for DC Output Voltage Control	10kHz < f < 100kHz, V <sub>ENH</sub> = V <sub>IN</sub>	20	—	100	%
f <sub>LPF</sub>	Internal PWM Low Pass Filter Cut-Off Frequency	—	—	4	—	kHz
A <sub>LPF</sub>	Filter Attenuation	f = 30kHz	—	52.5	—	dB

Notes: 7. Nominal 'on' time (t<sub>ON\_NOM</sub>) is defined by the input voltage (V<sub>IN</sub>), coil inductance (L) and peak current (I<sub>LX\_PKDC</sub>) according to the expression:

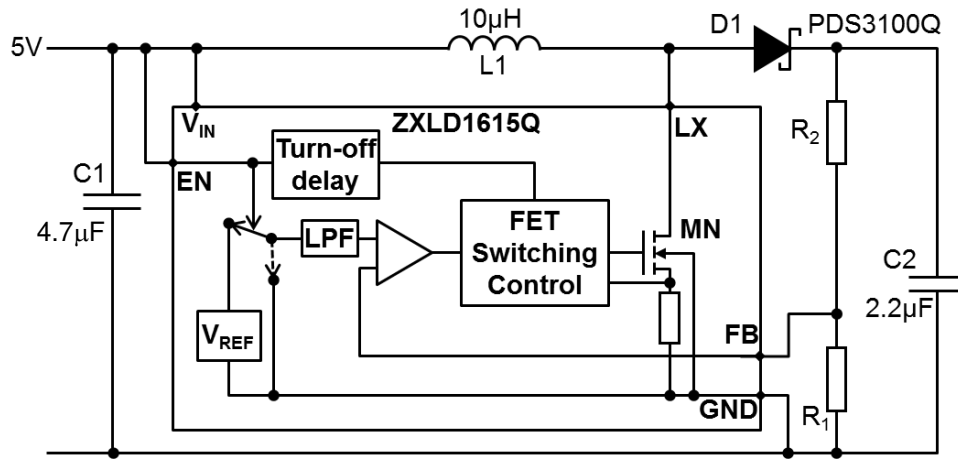
$$t_{ON\_NOM} = \{I_{LX\_PKDC} \times L / V_{IN}\} + 200ns.$$

8. This is the time for which the device remains active after the EN pin has been asserted low. This delay is necessary to allow the output to be maintained during dc PWM mode operation.

## Device Description

The device is a PFM flyback DC-DC boost converter, working in discontinuous mode.

With reference to the chip block diagram and typical application circuit, the operation of the device is as follows:



ZXLD1615Q Block-Circuit Diagram

### Control Loop

When 'EN' is high, the control circuits become active and the low side of the coil (L1) is switched to ground via NDMOS transistor (MN). The current in L1 is allowed to build up to an internally defined level (nominally 320mA) before MN is turned off. The energy stored in L1 is then transferred to the output capacitor (C2) via Schottky diode (D1).

The output voltage is sensed at pin 'FB' by external resistors R1 and R2 and compared to a reference voltage  $V_{REF}$  (1.025V nominal). A comparator senses when the output voltage is above that set by the reference and its output is used to control the 'off' time of the output switch. The control loop is self-oscillating, producing pulses of up to 5µs maximum duration (switch 'on'), at a frequency that varies in proportion to the output current.

The feedback loop maintains a voltage of  $V_{REF}$  at the FB pin and therefore defines a maximum output voltage equal to  $V_{REF} \times (R1+R2)/R1$ .

The minimum 'off' time of the output switch is fixed at 0.5µs nominal, to allow time for the coil's energy to be dissipated before the switch is turned on again. This maintains stable and efficient operation in discontinuous mode.

### Filtered PWM Operation

The input of an internal low-pass filter is switched to  $V_{REF}$  when the EN pin is high and switched to ground when the EN pin is low. The output of this filter drives the comparator within the control loop. A continuous high state on EN therefore provides a filtered voltage of value  $V_{REF}$  to the comparator.

However, by varying the duty cycle of the EN signal at a suitably high frequency ( $f > 10\text{kHz}$ ), the control loop will see a voltage, that has an average value equal to the duty cycle multiplied by  $V_{REF}$ . This provides a means of adjusting the output voltage to a lower value. It also allows the device to be both turned on and adjusted with a single signal at the 'EN' pin.

The output during this mode of operation will be a DC voltage equal to:

$$V_{REF} \times (R1+R2)/R1 \times D$$

Where D is the Duty Cycle

### Gated PWM Operation

The internal circuitry of the ZXLD1615Q is turned off when no signal is present on the 'EN' pin for more than 120µs (Nominal).

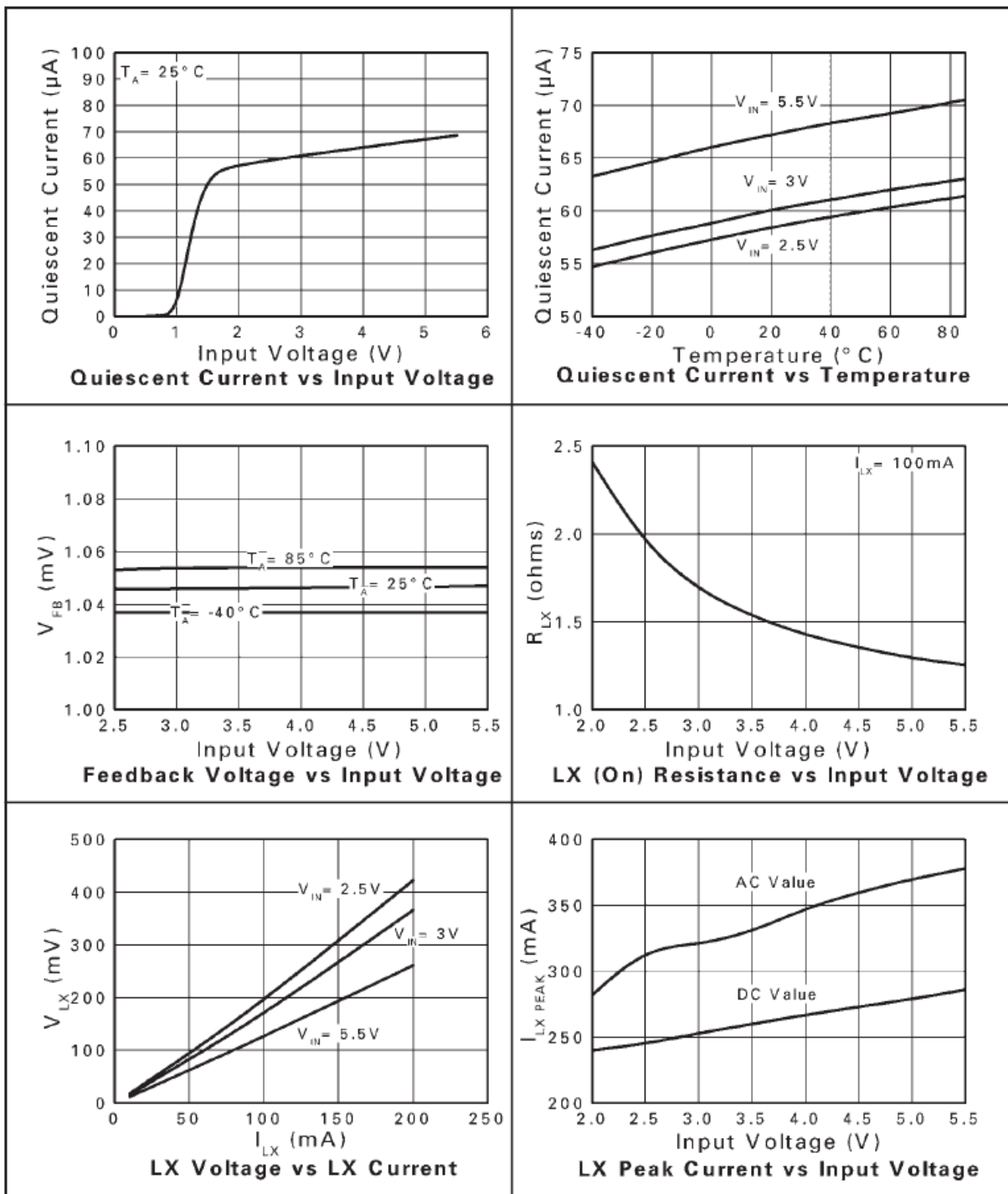
A low-frequency signal applied to the EN pin will therefore gate the device 'on' and 'off' at the gating frequency and the duty cycle of this signal can be varied to provide an average output equal to:

$$V_{REF} \times (R1+R2)/R1 \times D$$

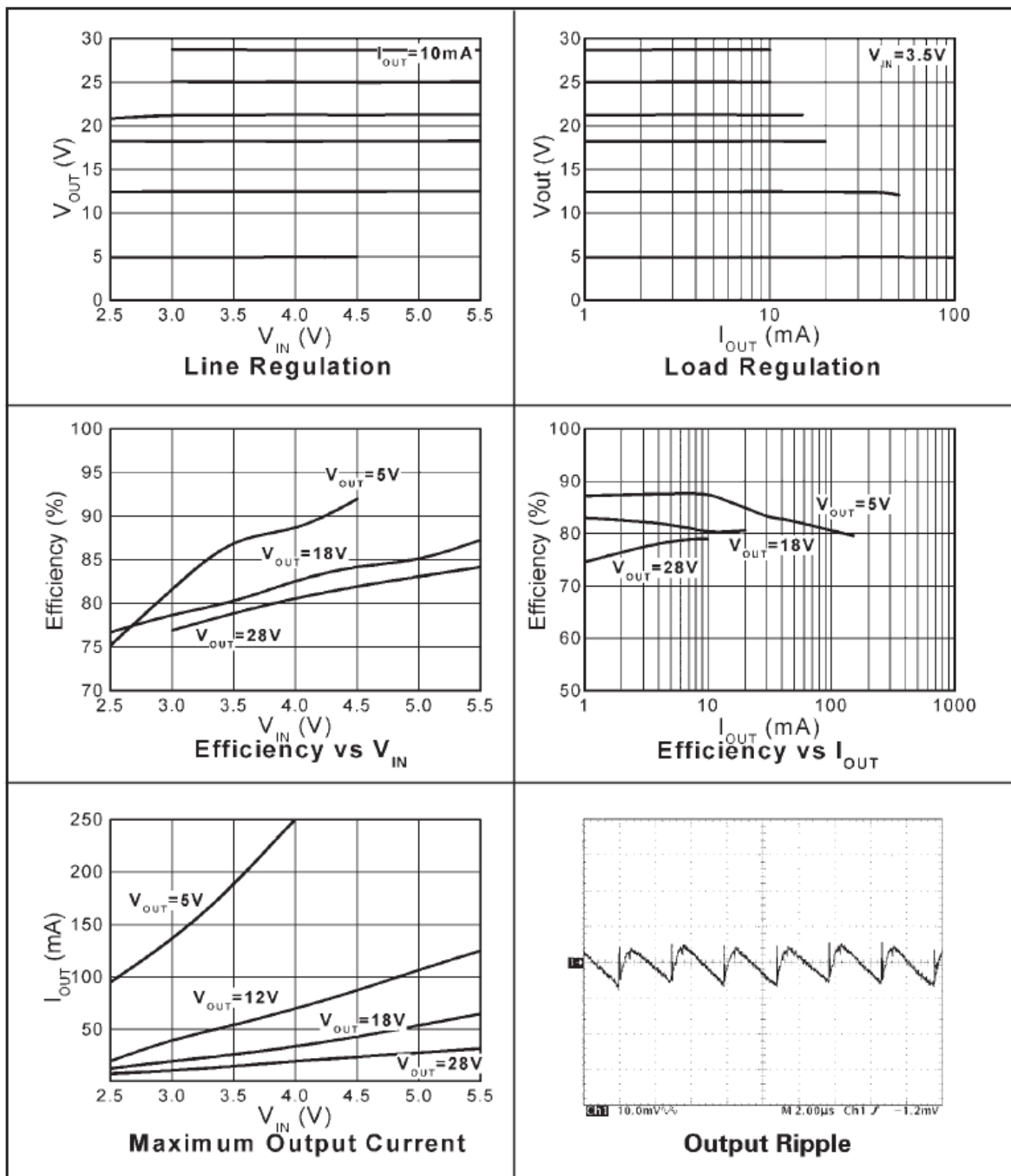
For best accuracy, the gating frequency should be made as low as possible (e.g. below 1kHz), such that the turn-off delay of the chip is only a small proportion of the gating period.

Further details of setting output current are given in the application notes.

**Typical Characteristics**



**Typical Characteristics** (Cont.)



## Applications Information

### Setting Output Voltage

The ZXLD1615Q has an adjustable output voltage allowing the end user maximum flexibility. To set the output voltage, a potential divider network is needed (see R1 and R2 in typical applications circuit). The output voltage is determined by the equation:

$$V_{OUT} = V_{FB} \left( 1 + \frac{R1}{R2} \right)$$

Where  $V_{FB} = 1.025V$

The following table gives suggested values for various output voltages.

Required Output Voltage	R1	R2
5V	270kΩ	1MΩ
12V	91kΩ	1MΩ
18V	60kΩ	1MΩ
21V	51kΩ	1MΩ
25V	43kΩ	1MΩ
28V	39kΩ	1MΩ

Output voltage can be adjusted from  $V_{IN} + V_F$  to the maximum output voltage rating of the internal switch, 30V.

Once the nominal output voltage has been set, it can be adjusted to a lower value by applying a pulse width modulated (PWM) control signal to the EN pin.

PWM adjustment permits the device to be turned on and the output voltage set by a single logic signal applied to the EN pin. No external resistors are required and the amplitude of the control signal is not critical, providing it conforms to the limits defined in the electrical characteristics.

### 1) PWM Output Voltage Adjustment (Analog Mode)

During this mode of operation the device operation is continuous, providing a low ripple output voltage ( $V_{OUT}$ ) directly proportional to the Duty Cycle (D) of the logic signal applied to the EN pin according to the relationship:

$$V_{OUT} = D \times V_{OUT(NOM)}$$

Square wave signals applied to the EN pin, for example, will turn the device on and produce a nominal regulated output of 13.5V.

The ZXLD1615Q contains a timing circuit that switches the device on a few microseconds after the application of a rising edge to EN and turns it back off again nominally 120μs after the falling edge of EN. For continuous PWM mode operation, the frequency of the control signal must therefore be maintained above 10kHz at all times, to prevent the internal delay circuit from timing out and switching the device into standby mode. The maximum frequency applied to EN should be limited to 100kHz to minimize errors due to internal switching delays.

### 2) PWM Output Voltage Adjustment (Gated Mode)

This method of adjustment can be used in applications where the output ripple is less important than the supply current. The method of adjustment is the same as in 1) above, however, during this mode of operation, the device is gated on and off, providing an average output voltage ( $V_{OUT}$ ) directly proportional to the Duty Cycle (D) of the logic signal applied to the EN pin according to the relationship:

$$V_{OUT(AVG)} = D \times V_{OUT(NOM)}$$

The ripple on this voltage will be determined by the size of the output capacitor.

The output voltage can be adjusted all the way down to the input voltage by either method of PWM control, but for best results, the duty cycle range should be kept within the specified range. Lower duty cycles will result in increased output ripple and non-linearity in the relationship between duty cycle and output voltage. If a greater control range is required, the nominal output can be reduced by the use of external resistors before the PWM signal is applied.

### Minimizing Output Voltage Ripple

For applications requiring lower output ripple it may be necessary to add a small ceramic capacitor in parallel with R2. A value of 4.7pF is suitable for most output ranges.



## Applications Information (Cont.)

### Capacitor Selection

A ceramic capacitor grounded close to the GND pin of the package is recommended at the output of the device. Surface mount types offer the best performance due to their lower inductance. A minimum value of 0.22 $\mu$ F is advised, although higher values will lower switching frequency and improve efficiency especially at lower load currents. A higher value will also minimize ripple when using the device to provide an adjustable DC output current.

A good quality, low ESR capacitor should also be used for input decoupling, as the ESR of this capacitor is effectively in series with the 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 4.7 $\mu$ F is acceptable if the input source is close to the device, but higher values will improve performance at lower input voltages, when the source impedance is high. The input capacitor should be mounted as close as possible to the IC.

### Inductor Selection

The choice of inductor will depend on available board space as well as required performance.

Small value inductors have the advantage of smaller physical size and may offer lower series resistance and higher saturation current compared to larger values.

A disadvantage of lower inductor values is that they result in higher frequency switching, which in turn causes reduced efficiency due to switching losses. Higher inductor values can provide better performance at lower supply voltages. However, if the inductance is too high, the output power will be limited by the internal oscillator, which will prevent the coil current from reaching its peak value. This condition will arise whenever the ramp time ( $L_{X(PEAK)} \times L/V_{IN}$ ) exceeds the nominal 5 $\mu$ s maximum 'on' time limit for the LX output.

For maximum stability over temperature, capacitors with X7R dielectric are recommended, as these have a much smaller temperature coefficient than other types. A table of recommended manufacturers is provided below:

Manufacturer	Website
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com
Kemet	www.kement.com
AVX	www.avxcorp.com

Recommended inductor values for the ZXLD1615Q are in the range 6.8 $\mu$ H to 22 $\mu$ H. The inductor should be mounted as close to the device as possible with low resistance connections to the LX and  $V_{IN}$  pins. Suitable coils for use with the ZXLD1615Q are shown in the table below:

Part No.	L( $\mu$ H)	DCR ( $\Omega$ )	ISAT(A)	Manufacturer
CMD4D11-100MC	10	0.457	0.5	Sumida www.sumida.com
DO1608-103	10	0.16	1.1	Coilcraft www.coilcraft.com
LQH31CN100	10	1.3	0.23	Murata www.murata.com
LB2012Y100MR	10	0.5	0.1	Taiyo Yuden www.tyuden.com

### Diode Selection

The rectifier diode (D1) should be a fast low capacitance Schottky diode with low reverse leakage at the working voltage. It should also have a peak current rating above the peak coil current and a continuous current rating higher than the maximum output load current. The table below gives some typical characteristics for diodes that can be used with the ZXLD1615Q:

Diode	VF @ 100mA (mV)	IF (mA)	IR at 40V ( $\mu$ A)	Package
DFLS140LQ	360	1,000	100	PowerDI <sup>®</sup> 123 (Note 9)
DFLS160LQ	360	1,000	100	PowerDI <sup>®</sup> 123 (Note 9)

Note 9: PowerDI is a registered trademark of Diodes Incorporated.

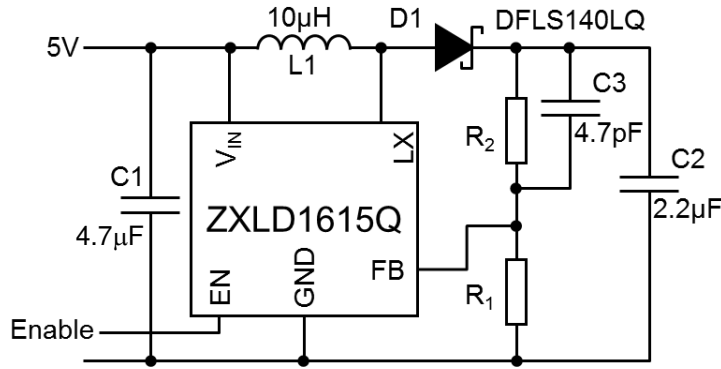
### Layout Considerations

PCB tracks should be kept as short as possible to minimize ground bounce, and the ground pin of the device should be soldered directly to the ground plane. It is particularly important to mount the coil and the input/output capacitors close to the device to minimize parasitic resistance and inductance, which will degrade efficiency. The FB pin is a high-impedance input, so PCB track lengths to this should also be kept as short as possible to reduce noise pickup. Excess capacitance from the FB pin to ground should be avoided.

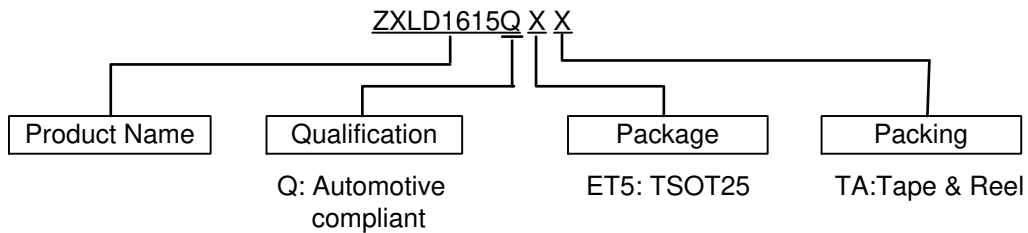
**Applications Information** (Cont.)

**General Boost Converter**

V<sub>IN</sub> = 2.5V to 5.5V, V<sub>OUT</sub> up to 28V



**Ordering Information**



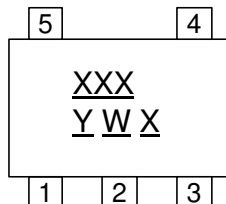
Part Number	Packaging (Note 10)	Pack Code	7" Tape & Reel			Qualification Grade (Note 11)
			Reel Width (mm)	Quantity Per Reel	Part Number Suffix	
ZXLD1615QET5TA	TSOT25	ET5	8	3,000	TA	Automotive-Compliant

- Notes: 10. For packaging details, go to our website at <https://www.diodes.com/design/support/packaging/diodes-packaging/>.  
 11. ZXLD1615Q has been qualified to AEC-Q100 grade 3 and is classified as "Automotive-Compliant" which supports PPAP documentation. See ZXLD1615 datasheet for commercial qualified versions.

**Marking Information**

Package Type: TSOT25

(Top View)

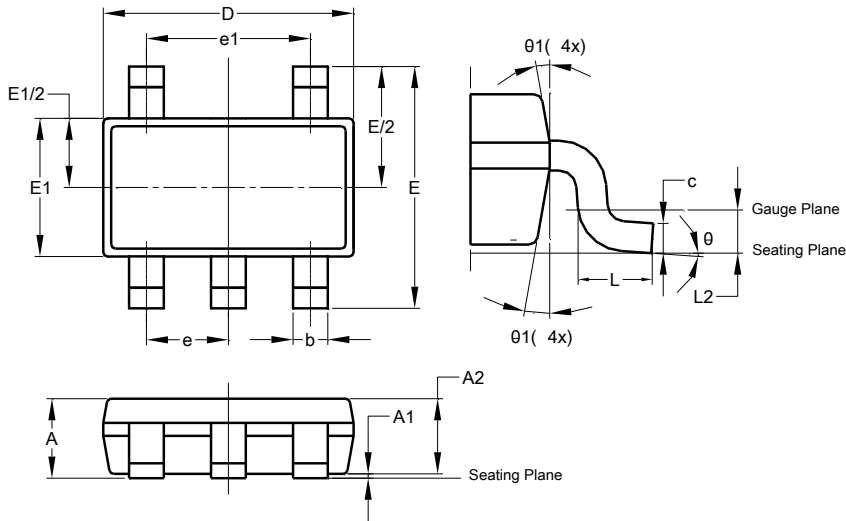


- XXX : Identification Code (615)
- Y : Year 0 to 9
- W : Week : A to Z : 1 to 26 week;  
a to z : 27 to 52 week; z represents 52 and 53 week
- X : Internal Code

## Package Outline Dimensions

Please see <http://www.diodes.com/package-outlines.html> for the latest version.

### TSOT25

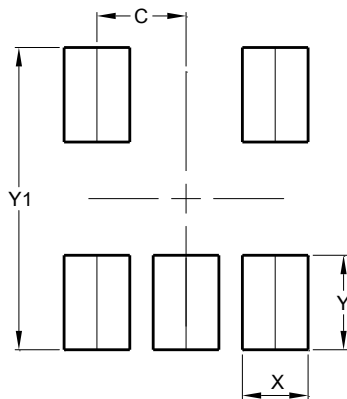


TSOT25			
Dim	Min	Max	Typ
A	-	1.00	-
A1	0.01	0.10	-
A2	0.84	0.90	-
b	0.30	0.45	-
c	0.12	0.20	-
D	-	-	2.90
E	-	-	2.80
E1	-	-	1.60
e	0.95 BSC		
e1	1.90 BSC		
L	0.30	0.50	-
L2	0.25 BSC		
θ	0°	8°	4°
θ1	4°	12°	-
All Dimensions in mm			

## Suggested Pad Layout

Please see <http://www.diodes.com/package-outlines.html> for the latest version.

### TSOT25



Dimensions	Value (in mm)
C	0.950
X	0.700
Y	1.000
Y1	3.199

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