Zywyn

Preliminary Information
Application Note
AN022

ZD1680EVB Evaluation Board Manual

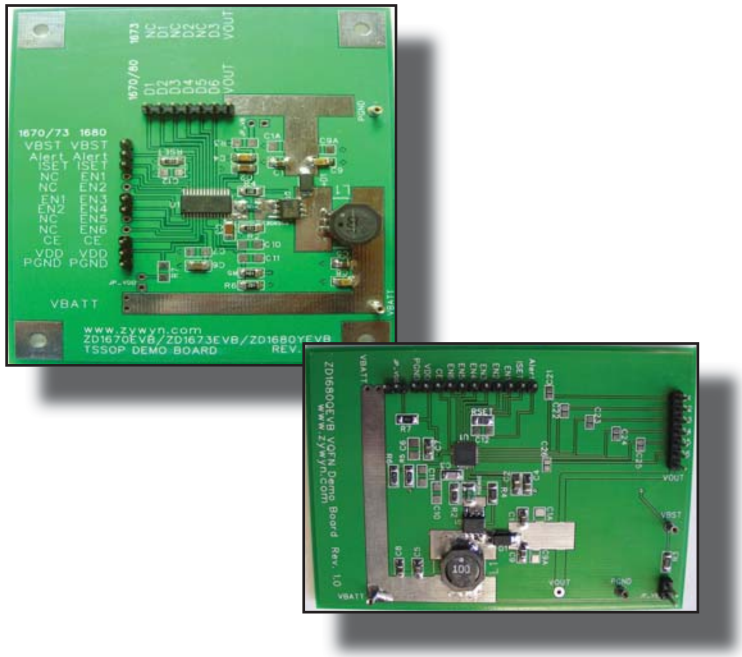
General Description

The ZD1680 is a high efficiency step-up controller especially designed for driving multiple strings of serially connected LEDs. 6 channels of low dropout current sinks are included to provide excellent matching of currents for each LED string. The boost converter control loop regulates the current source outputs to 0.3V for maximum efficiency. All 6 channel LED current outputs are set by a resistor RSET to ground at the ISET pin. A CHIP ENABLE (CE) input provides an enable or shutdown function to the IC and the ISET pin can be used to adjust the LED string current with a PWM signal or a DC voltage. ***All 6*** LED channels are controlled by individual EN pins (EN1~EN6). Also included is an Under Voltage Lockout (UVLO) circuit to discontinue operation when input VDD falls below 2.7V and automatic soft start to limit inrush currents during power start-up or following a re-CHIP ENABLE function. Output Over-Voltage Protection (OVP) is available by user-defined resistor network setting to protect the LEDs and the IC.

The ZD1680 is available in a 5x5mm 32-pin VQFN or 28-pin Exposed- TSSOP Green Package.

ZD1680EVB Evaluation Board Factory Default Settings

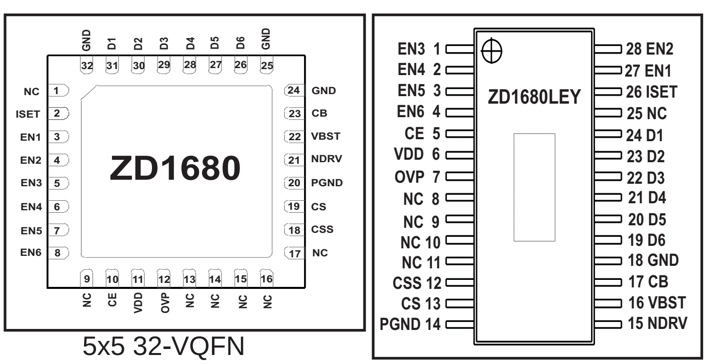
The ZD1680EVB is configured to operate with a single power supply with an input range of 7V to 12VDC at the VBATT, providing a voltage source to the VDD and VBST of the device, with RVDD and RVBST connected in series respectively. (Details are shown in Figure 4 under the Typical Applications Section).



Ordering Information

Part Number	Temperature Range	Package Type
ZD1680LEQ	–40°C to +85°C	32-Pin 5x5 VQFN
ZD1680LEY	–40°C to +85°C	28-EP-TSSOP
ZD1680YEVB	n/a	Evaluation Board for ZD1680LEY/
ZD1680QEVB	n/a	Evaluation Board for ZD1680LEQ

Pin Configuration



5x5 32-VQFN

28-Exposed-TSSOP

Typical Application

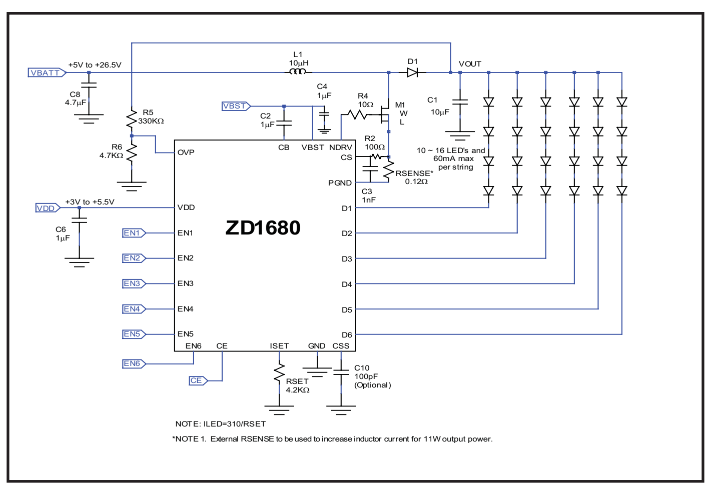


Figure 1. ZD1680 high efficiency step-up controller for LEDs with 6 channels of constant current sink and enables

Electrical Characteristics

T_A = +25°C, VDD = +3.6V, VBATT=5V, VOUT=30V, unless otherwise noted.

Parameter	Condition	Min	Typ	Max	Units
Operating Voltage (VDD)		3.3		5.5	V
Operating Supply Current			0.6	1.2	mA
UVLO Threshold			2.7		V
UVLO Hysteresis			150		mV
FB (D1~6) Regulation Voltage			600		mV
CS Trip Voltage			230		mV
Minimum OFF Time			1.8		µs
Maximum ON Time			8		µS
NDRV Driver Sink/Source Current	VDD=5V, NDRV=2V		0.4		A
NDRV Driver RON	VDD=5V		4		Ω
CE, $EN_{1\sim6}$, V_{IH}		1.4			V
CE, $EN_{1\sim6}$, V_{IL}				0.4	V
ILED Scale Factor K	ILED=K/RSET	279	310	341	
ILED Output Current Sink (D1~6)	CE=VDD	10		60	mA
CE, $EN_{1\sim6}$, ISET PWM Frequency				10	kHz
Maximum Power Output	With External RSENSE (NOTE 1c)			15	W
VBST Range		VDD		13	V
Soft Start Time	From supply start-up or chip re-enable (CE); No external capacitor at CSS pin		250		µs
OVP Threshold Level			0.5		V
OVP Threshold Hysteresis	At OVP input pin		35		mV

Note 1. a) VOUT ranges from 6V to 60V, depending on the # of LEDs in series and the type of N-MOSFET power device used.

b) VBATT ranges: +5V ~ +12V; +12V ~ 18V; +18V ~ 26.5V.

c) Power Output depends on external RSENSE resistor to be used.
For RSENSE = 0.12Ω, POUT MAX = 11W
For RSENSE = 0.06Ω, POUT MAX = 15W

Note 2. See Table 1 for the suggested external components to be used for the VBATT ranges.

Table 1: Recommended external inductor values vs VBATT

VBATT Range	Recommended value for L1 inductor	Comments
5V to 12V	10µH	2 to 3 Li-Ion cells or car battery
12V to 18V	15µH	4 Li-Ion cells battery or car battery
18V to 26.5V	22µH	From CCFL power supply circuit or car battery

Pin Description

Pin Number		Pin Name	Pin Function
32-VQFN	28-TSSOP		
1	25	NC	No Connect Pin. Do not use this pin for making connections.
2	26	ISET	Sets LED Current. Connects external resistor here. (ILED=310/RSET)
3	27	EN1	LED Channel 1 Enable.
4	28	EN2	LED Channel 2 Enable.
5	1	EN3	LED Channel 3 Enable.
6	2	EN4	LED Channel 4 Enable.
7	3	EN5	LED Channel 5 Enable.
8	4	EN6	LED Channel 6 ENable.
9		NC	No Connect Pin. Do not use this pin for making connections.
10	5	CE	Chip Enable Pin. Set HIGH to enable the chip.
11	6	VDD	Input Supply Voltage. Decouple with a 1μF capacitor min. 5.5V max or externally clamped with a 6V zener diode.
12	7	OVP	Output Over-Voltage Protection Input. Set OVP level with external R3//R4 resistor divider. (VOVP = [(R5+R6)/R6] x 0.5)
13	8	NC	No Connect Pin. Do not use this pin for making connections.
14	9	NC	No Connect Pin. Do not use this pin for making connections.
15	10	NC	No Connect Pin. Do not use this pin for making connections.
16	11	NC	No Connect Pin. Do not use this pin for making connections.
17		NC	No Connect Pin. Do not use this pin for making connections.
18	12	CSS	Place a capacitor here to increase the Soft Start time delay. Optional. Typical cap value is 100 pF. Note: Additional Soft Start time also increases the load and line step recovery time.
19	13	CS	Power FET Current-Sense Input. Connects a 0.12Ω, 1W resistor here to PGND for 11W power output capability. (See Note 1c)
20	14	PGND	Power Ground.
21	15	NDRV	Gate Driver Output for external N-channel power MOSFET.
22	16	VBST	Auxiliary Gate Drive Voltage. Connects to VBATT or VDD, 13V max. Decouple with a 1μF capacitor to GND if supplied separately from VDD or VBATT. An externally clamped 15V zener diode is suggested. See application notes for further information.
23	17	CB	High side logic decoupling capacitor, place a 1μF ceramic capacitor to VBST.
24	18	GND	Ground.
25		GND	Ground.
26	19	D6	LED Current Sink #6.
27	20	D5	LED Current Sink #5.
28	21	D4	LED Current Sink #4.
29	22	D3	LED Current Sink #3.
30	23	D2	LED Current Sink #2.
31	24	D1	LED Current Sink #1.
32		GND	Ground.

Input Operation Description

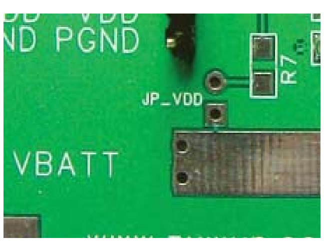
VBST, Auxilary Gate Drive Voltage With Input Power Supply VBATT

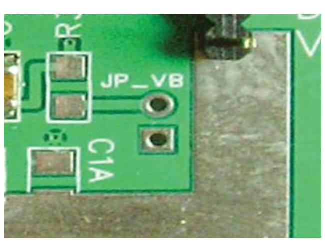
The 3 input supply voltage pins, VDD, VBST and VBATT can be powered in a variety of ways. The VBST input voltage is provided to create a higher gate drive voltage other then normally powered by internal VDD. In this way, the external power N-channel MOSFET can be driven from 5V to 13V, where the main input supply, VDD, would typically be 3.0V to 5.5V (for example, taken from a common system supply voltage or a TTL logic driver). This allows for a flexible VOUT and can maximize the drain current of the MOSFET. In some cases, only a single supply input voltage operation is desired. In other cases, it might be desirable to supply VBST from a third separate power supply different from VDD or VBATT, but this separate supply is not usually available. Therefore, in most application configurations, VBST is supplied either from VDD or VBATT (when higher gate drive is desired). The main output power is derived from VBATT which is usually connected directly to a battery source, such as a 2 or 3 cell Li-Ion battery pack or car battery. The exact battery voltage is not critical and the circuit automatically adjusts through out the battery voltage range.

Resistors can be used to supply the two voltages, VDD and VBST, from VBATT. The supply current from either VDD or VBST inputs are fairly constant during normal operation. The default setting on the ZD1680EVB is configured for single power supply (Figure 3) from 7V to 12VDC at VBATT with the jumpers JP_VDD and JP_VB connecting VDD and VBST to the VBATT through the limiting resistors R7 and R3 respectively. Table 1 shows other setups of the power supplies that can be used.

# of PS	VBATT	VDD	VBST	Figure
1	7V to 12V	JP_VDD	JP_VB	Figure 3
2	7V to 12V	JP_VDD	5V to 13V	Figure 4
2	7V to 12V	3V to 5.5V	JP_VB	Figure 5
3	7V to 26.5V	3V to 5.5V	5V to 13V	Figure 1

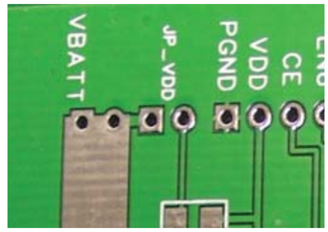
Table 2a. Power Supply Configurations for ZD1680YEVB

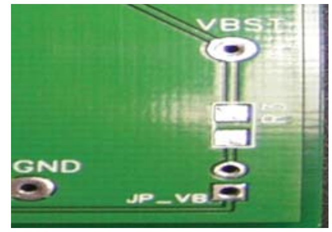




# of PS	VBATT	VDD	VBST	Figure
1	7V to 12V	JP_VDD	JP_VB	Figure 3
2	7V to 12V	JP_VDD	5V to 13V	Figure 4
2	7V to 12V	3V to 5.5V	JP_VB	Figure 5
3	7V to 26.5V	3V to 5.5V	5V to 13V	Figure 1

Table 2b. Power Supply Configurations for ZD1680QEVB





Chip Enable/Enable

A CHIP ENABLE (CE, enabled "H") logic input provides an enable or shutdown function of the IC and the ISET pin can be used to adjust the LED string current with a PWM signal or a DC voltage. Each LED channel (D1~D6) is controlled by its designated enable pin (EN1~EN6 active high) for individual channel activation. Also included is an Under Voltage Lockout (UVLO) circuit to discontinue operation when input VDD falls below 2.7V and automatic soft start to limit inrush currents during power start-up or following a re-enable (CE only) function.

Input Operation Description cont.

PWM Dimming

The output current of the ZD1680, ILED, can be dimmed by applying an input pulse-width modulated (PWM) signal (50Hz to 10kHz) to the $EN_{1\sim6}$ pins as shown in the circuit of Figure 2. This allows for a wide range of dimming gradient. The dimming ratio is proportional to the PWM duty cycle, which can range from 10% to 90%.

Analog Voltage Dimming

LED dimming can also be accomplished by connecting an analog voltage to the ISET pin as shown in Figure 2. When the DC voltage is set at 0V for example, the ILED current is positioned at its maximum desired value. Increasing the DC voltage from 0V to 5V will dim the LEDs with decreased ILED current. Setting the DC voltage at midpoint upon device power-up can control the dimming up and down function.

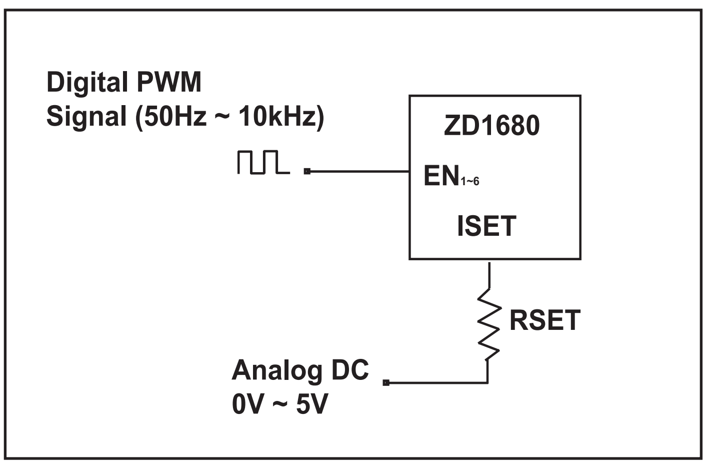


Figure 2. Digital PWM or Analog DC voltage controls for dimming function

Typical Applications

Default Configuration: Single power supply

The ZD1680EVB is designed for evalution using a single 7V to 12V power supply applied to the VBATT. A 10µH inductor with a current rating of 3.6A is chosen for voltage range of the evaluation board The jumpers JP_VDD and JP_VB connect the VBATT to the limiting resistors R7 and R3 respectively. **The evaluation board is configured for driving a maximum of 6 strings of 10 LEDs at 50mA per string (See Figure 3 and 3a).** The equations for the V_{OVP} (see datasheet for details),

$$V_{OVP} = (0.5V)(R5+R6)/R6$$

and

$$V_{OVP} = N*V_{Dmax} + 0.5V;\text{ where } N = \text{\# of LED'S per string,}$$

When N = 10 and V_{Dmax} = 3.5V which then calculates R5 = 330kΩ and R6 = 4.7kΩ as the closest common resistors available for a V_{OVP} = 35.5V.

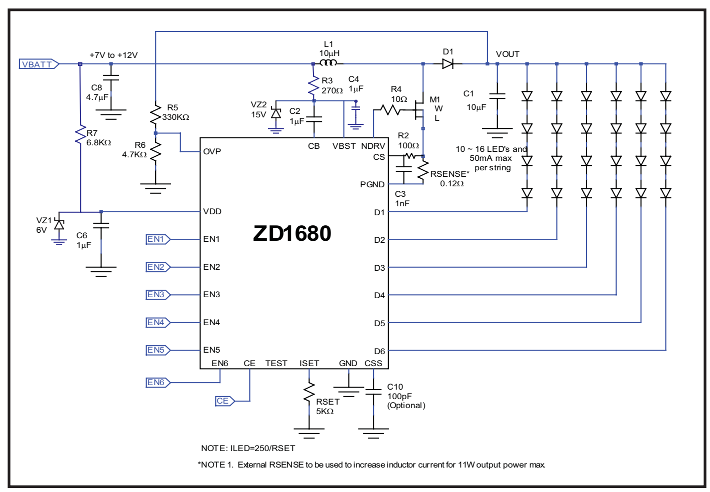


Figure 3. Default Configuration of ZD1680EVB. Recommended external clamping diodes (15V on VBST) and (6V on VDD) are not on the Default Configuartion when shipped.

Bill of Materials Listing for the default configuration of the ZD1680YEVB.

Item	Quantity	Location	Part
1	1	C1	10μF/50VDC
2	1	C8	4.7μF/16VDC
3	3	C2, C4, C6	1μF/16VDC
4	1	C3	1nF
5	1	C10 (optional)	100pF
6	1	RSENSE	0.12Ω
7	1	RSET	5kΩ
8	1	R2	100Ω
9	1	R3	270Ω
10	1	R4	10Ω
11	1	R5	330kΩ
12	1	R6	4.7kΩ
13	1	R7	6.8kΩ
14	1	U1	ZD1680LEY
15	1	M1	IRF7488PBF
16	60	VOUT	LEDs
17	1	D1	CD214A-B360 or equivalent
18	1	L1	10μH/3.6A
19	1	VZ1	6V Zener
20	1	VZ2	15V Zener

Bill of Materials Listing for the default configuration of the ZD1680QEVB.

Item	Quantity	Location	Part
1	1	C1	10μF/50VDC
2	1	C8	4.7μF/16VDC
3	3	C2, C4, C6	1μF/16VDC
4	1	C3	1nF
5	1	C10 (optional)	100pF
6	1	RSENSE	0.12Ω
7	1~6	C21~26(optional on ZD1680QEVB only)	1nF
8	1	RSET	5kΩ
9	1	R2	100Ω
10	1	R3	270Ω
11	1	R4	10Ω
12	1	R5	330kΩ
13	1	R6	4.7kΩ
14	1	R7	6.8kΩ
15	1	U1	ZD1680LEQ
16	1	M1	IRF7488PBF
17	60	VOUT	LEDs
18	1	D1	CD214A-B360 or equivalent
19	1	L1	10μH/3.6A
20	1	VZ1	6V Zener
21	1	VZ2	15V Zener

Single power supply driving 90 LEDs

The ZD1680EVB is designed to drive 6 strings of 15 LEDs from a single 7V to 12V power supply applied to the VBATT. The values for the V_{OVP} resistors (see datasheet for details), will have N = 15 and V_{Dmax} = 3.5V which will give R5 = 120kΩ and R6 = 1kΩ as the closest common resistors available for a V_{OVP} = 60.5V.

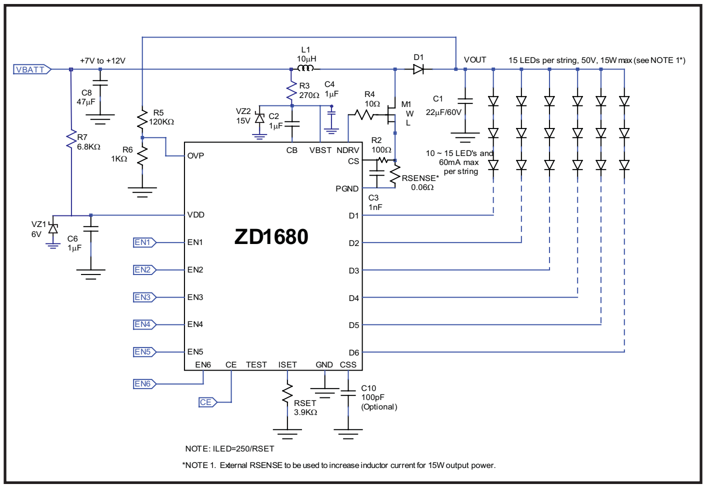


Figure 4. Single power supply driving 90 LEDs

Bill of Materials Listing for driving 90 LEDs or 15W application using ZD1680YEVB

Item	Quantity	Location	Part
1	1	C1	22µF/60VDC
2	1	C8**	47µF/16VDC
3	3	C2, C4, C6	1µF/16VDC
4	1	C3	1nF
5	1	C10 (optional)	100pF
6	1	RSENSE	0.06Ω
7	1	RSET	3.9kΩ
8	1	R2	100Ω
9	1	R3	270Ω
10	1	R4	10Ω
11	1	R5	120kΩ
12	1	R6	1kΩ
13	1	R7	6.8kΩ
14	1	U1	ZD1680LEY
15	1	M1	IRF7488PBF
16 (Fig. 4)	90	VOUT	LEDs
16 (Fig. 5)	15	VOUT	*Cree XLamp® 7090 XR-E*
17	1	D1	CD214A-B360 or equivalent
18	1	L1	10µH/3.6A
19	1	VZ1	6V Zener
20	1	VZ2	15V Zener

** Note 2. For AC application, C8 = 470µF.

Single power supply driving Cree XLamp® 7090 XR-E Series 1W x 15 LEDs

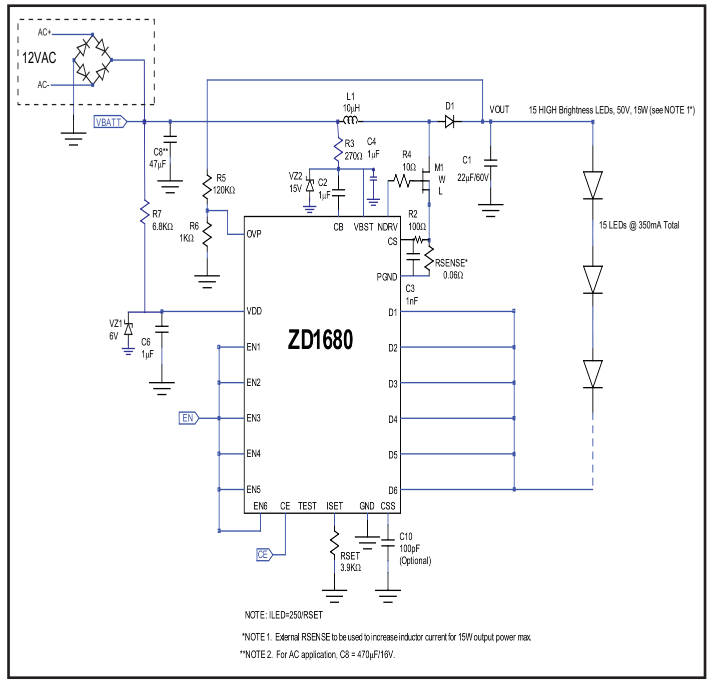


Figure 5. Single power supply 12VAC/12VDC for 15W application

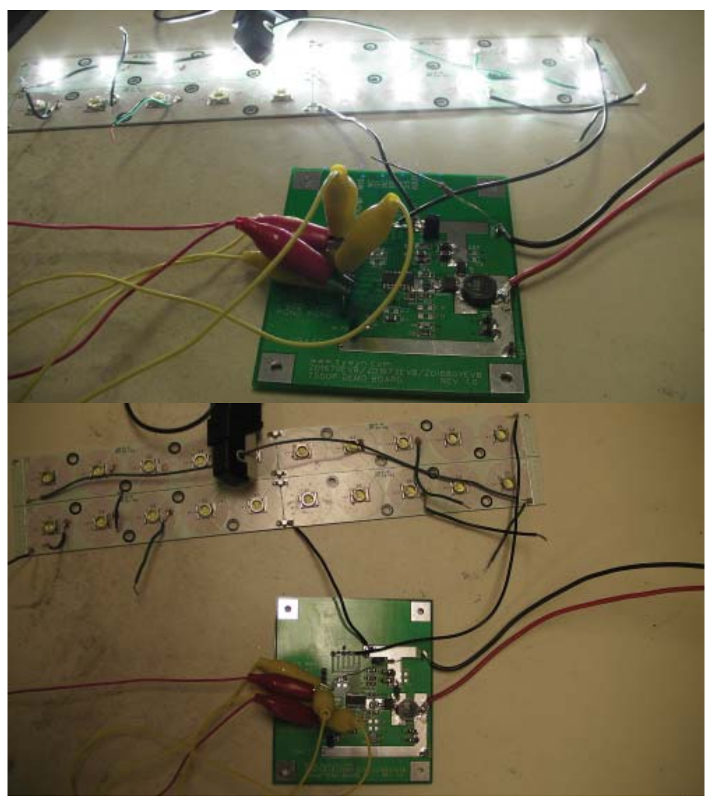


Figure 6. ZD1680 driving 1W x 15 *Cree XLamp® 7090 XR-E* LEDs.

Typical Applications

Single Ended Primary Inductor Converter

The Single Ended Primary Inductor Converter (SEPIC) is a DC-DC converter which allows the output voltage, controlled by a switch, to be above, below, or equal to the input voltage.

The SEPIC circuit can be designed by adding two components (L2 and C_{SEP})to the ZD1680 applications, the SEPIC circuit can be designed to incorporate applications where the total forward-bias voltage of the LEDs in a string can be higher or lower than the VBATT voltage.

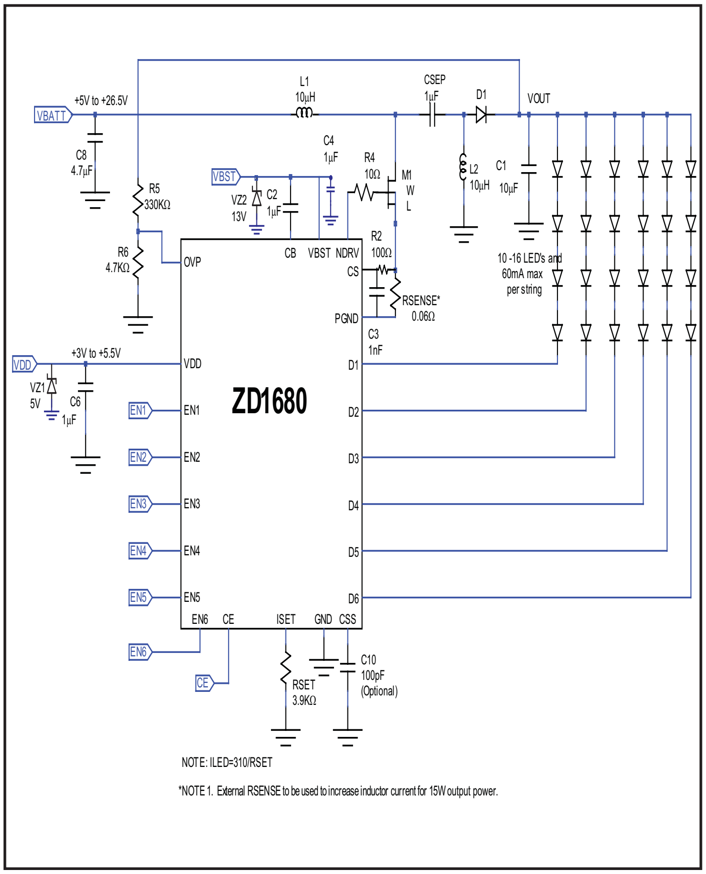


Figure 7. SEPIC Application using the ZD1680EVB

Bill of Materials Listing for SEPIC applications

Item	Quantity	Location	Part
1	1	C1	10µF/50VDC
2	1	C8	4.7µF/16VDC
3	3	C2, C4, C6	1µF/16VDC
4	1	C3	1nF
5	1	C10 (optional)	100pF
6	1	RSENSE	0.06Ω
7	1	RSET	3.9kΩ
8	1	R2	100Ω
9	1	R3	270Ω
10	1	R4	10Ω
11	1	R5	330kΩ
12	1	R6	4.7kΩ
13	1	R7	6.8kΩ
14	1	U1	ZD1680LEY
15	1	M1	IRF7488PBF
16	60	VOUT	LEDs
17	1	D1	CD214A-B360 or equivalent
18	2	L1, L2	10µH/3.6A
19	1	C_{SEP}	1µF/16VDC
20	1	VZ1	5V Zener/0.5W
21	1	VZ2	13V Zener/0.5W

Typical Applications

SEPIC Configuration driving CREE XLamp® MC-E LED

Using the SEPIC topology, the ZD1680 can be used to drive the *Cree XLamp® MC-E* LED in a 4 series x 1 parallel (5W) configuration. A fixed single power supply of 12V DC or a fixed 24V DC can be applied to the VBATT without changing any components in this circuit.

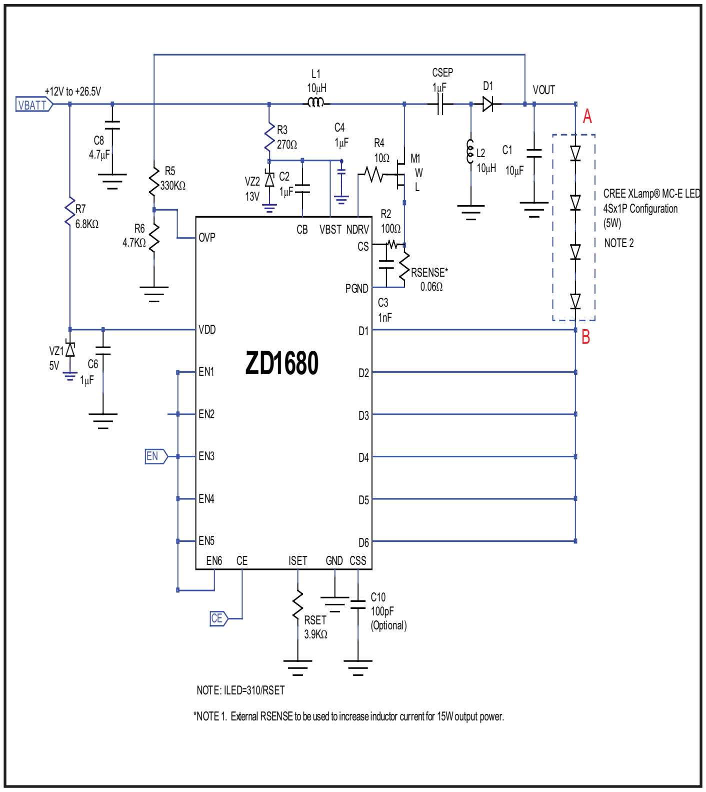
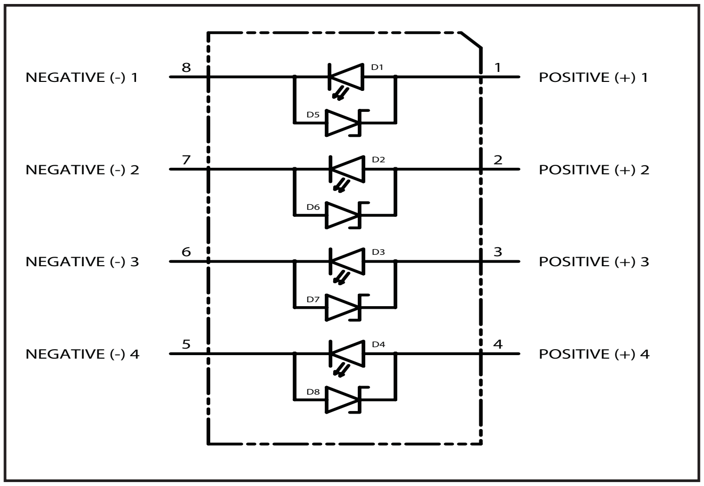


Figure 8. SEPIC Application using the ZD1680EVB with ***CREE XLamp® MC-E*** LED in 4Sx1P configuration

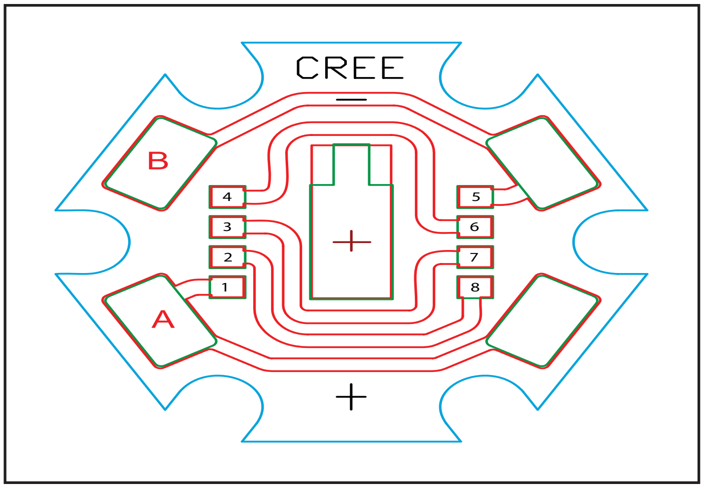
Note 2: ***CREE XLamp® MC-E*** LED connection for 5W application



Bill of Materials Listing for SEPIC configuration to drive the CREE XLamp® MC-E LED

Item	Quantity	Location	Part
1	1	C1	10µF/50VDC
2	1	C8	4.7µF/16VDC
3	3	C2, C4, C6	1µF/16VDC
4	1	C3	1nF
5	1	C10 (optional)	100pF
6	1	RSENSE	0.06Ω
7	1	RSET	3.9kΩ
8	1	R2	100Ω
9	1	R3	270Ω
10	1	R4	10Ω
11	1	R5	330kΩ
12	1	R6	4.7kΩ
13	1	R7	6.8kΩ
14	1	U1	ZD1680LEY
15	1	M1	IRF7488PBF
16	1	VOUT	*Cree XLamp® MC-E*
17	1	D1	CD214A-B360 or equivalent
18	2	L1, L2	10µH/3.6A
19	1	C_{SEP}	1µF/16VDC
20	1	VZ1	5V Zener/0.5W
21	1	VZ2	13V Zener/0.5W

CREE XLamp® MC-E Star PCB - Series Configuration



Dual Power Supply Configurations

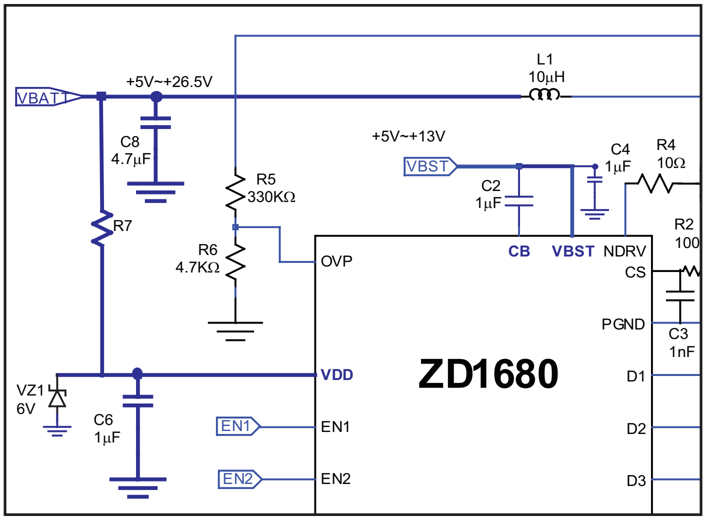


Figure 9. VBATT connected to VDD with VBST connected to a seperate power supply.

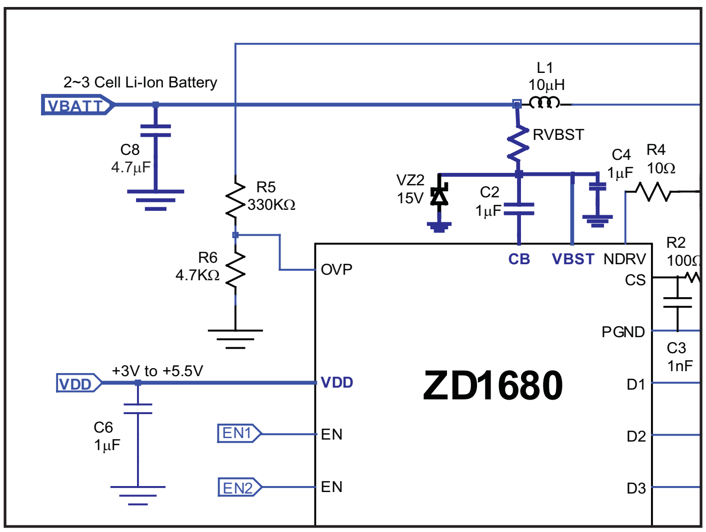


Figure 10. VBATT connected to VBST with VDD connected to a seperate power supply.

Components Selection

Capacitor Selection

The small size of ceramic capacitors makes them ideal for ZD1680 applications. X5R and X7R types retain their capacitance over wider voltage and temperature ranges and are recommended over Y5V or Z5U types.

AVX	www.avxcorp.com
Kemet	www.kemet.com
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com

Table 4. Recommended Capacitor Manufacturers

Inductor Selection

Use the following equations to calculate the inductor for the ZD1680 applications.

$$P_{OUT} = V_{FORWARD-LED} \times N \times S \times ILED_{(\max)}$$

where
N = # of LEDs per string
S = # of strings

$$I_{VBATT(\max)} = I_{PEAK} = \frac{P_{OUT}}{V_{BATT(\min)}}$$

$$L1 = \frac{(R_{L1} \times I_{PEAK}) + V_{DIODE} + V_{OUT} - V_{BATT(\min)}}{I_{PEAK}} \times t_{OFF}$$

where
R_{L1} and V_{DIODE} can be set to zero for simplicity and t_{OFF} is typically 1µs. Choose closest standard values for L1.

Part Number	DCR (mΩ)	Current Rating (A)	Inductance (µH)	Manufacturer
SRU1048 Series	18.5 ~ 63	2.1 ~ 4.5	10 ~ 33	Bourns www.bourns.com

Table 5. Recommended Inductor Manufacturers

Diode Selection

Schottky diodes are recommended for most applications and should be chosen with breakdown voltages higher than the output voltage VOUT and peak current rating higher than the peak inductor current.

Part Number	Forward Current (A)	Voltage Drop(V)	Reverse Breakdown Voltage (V)	Manufacturer
CD214A-B360	3.0	0.5 at 3.0A	60	Bourns www.bourns.com/

Table 6. Recommended Diode Manufacturers

MOSFET Selection

Choose a MOSFET with breakdown voltage greater than the VOUT, a low RDS(ON) for greater efficiency, a drain current rating greater than the I_{PEAK}, and a gate charge Qg < 25nC.

Part Number	RDS (ON) (mΩ)	Drain Current Rating (A)	Gate Charge (nC)	Break-down Voltage (V)	Manufac-turer
IRF-7488PBF	29@ V_{GS} = 10V	6.3	12	80	International Rectifier www.irf.com

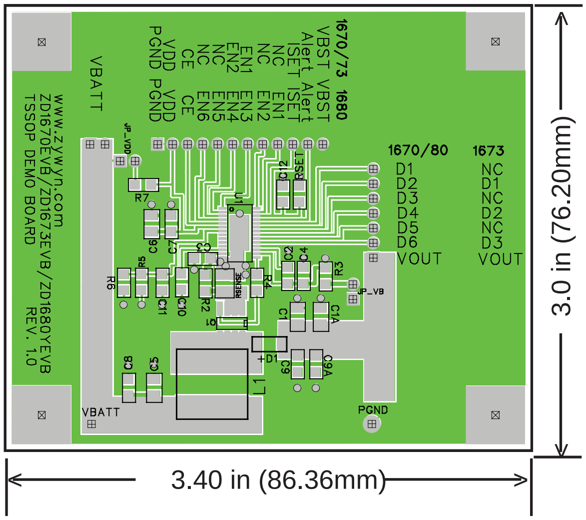
Table 7. Recommended MOSFET Manufacturers

LED Selection

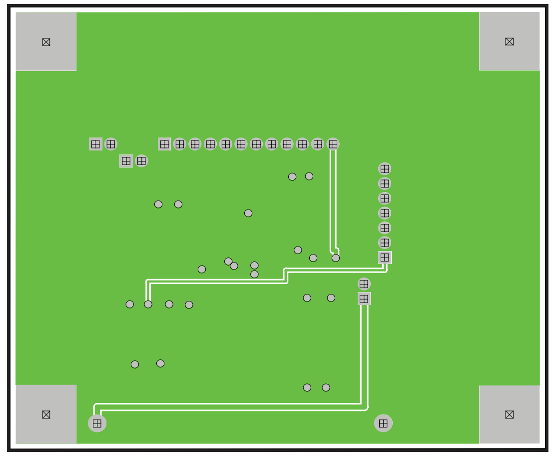
Choose LEDs with lower VForward at 50mA to maximize the number of LEDs.

For high power LEDs, *Cree XLamp® 7090 XR-E* LEDs are recommended.

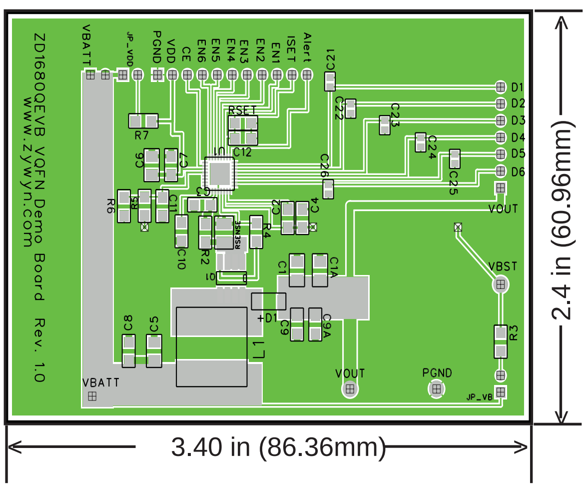
Evaluation Board Information



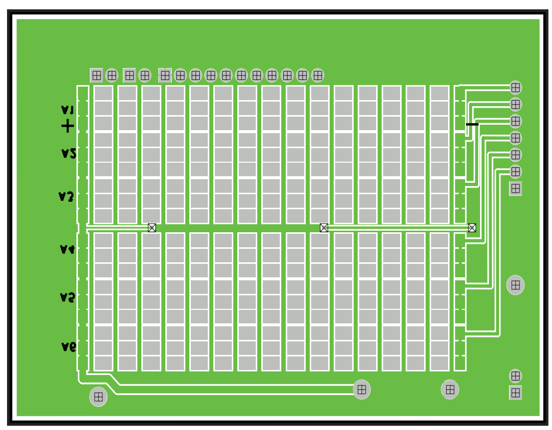
ZD1680YEVB Double-Layer Evaluation Board Component Side Layout Topview (for 28-EP-TSSOP)



ZD1680YEVB Evaluation Board Backside Layout Topview (for 28-EP-TSSOP)



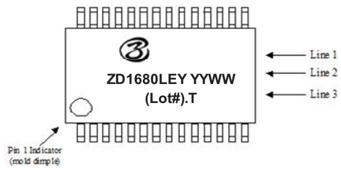
ZD1680QEVB Double-Layer Evaluation Board Component Side Layout Topview (for 5x5 32-VQFN)



ZD1680QEVB Evaluation Board Backside Layout Topview (for 5x5 32-VQFN)

Part Marking Information

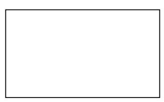
TOPSIDE MARK INSTRUCTIONS:



Line 1: Zywyn (logo)
Line 2: Zywyn Part Number "ZD1680LEY", Space " ", Date Code (Prod Year & Week)
Line 3: Lot#, dot and Country ".T"

Note: Pin # 1 "◯" Indicator Required if no mold dimple

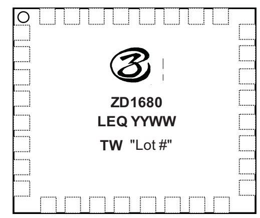
BOTTOMSIDE MARK INSTRUCTIONS:



No Backside Marking.

28-Pin Exposed TSSOP

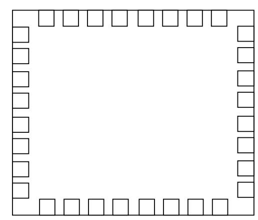
TOPSIDE MARK INSTRUCTIONS:



Line 1: Zywyn (logo)
Line 2: Zywyn Part Number "ZD1680"
Line 3: Zywyn Part Number cont. "LEQ", Space " ", Date Code: (Year & Work Week)
Line 4: Country of Origin "TW", Last 5-digit of Lot Number

Note: Pin # 1 "◯" Indicator Required if no Mold Dimple

BOTTOMSIDE MARK INSTRUCTIONS:



5 x 5 32-VQFN

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