iW3662

Low Voltage ($12V_{AC}$) Dual-Mode Digital Control Dimmable LED Driver

1.0 Features

- 10 to $24V_{DC}$ input voltage or $12V_{AC}$ input voltage
- Output power up to 8W
- Supports magnetic or electronic transformers
- Two operational modes:
  - » Boost-Buck - low voltage LED arrays
  - » Boost-Linear - high voltage COB LEDs
- Integrated boost controller and buck/linear current regulator controller
- Flickerless™ technology for flicker-free LED dimming
- Wide dimmer compatibility (leading edge, trailing edge, and digital)
- Deep dimming to 5% (depends on dimmers)
- Power factor > 0.7
- Tight LED current regulation (+/- 5%) in both modes
- Optimized dimming curve for maximizing dimmer and electronic transformer compatibility
- Over-temperature protection derating
- OVP, OCP, and open load protection
- 16-lead QFN (4x4mm) or 16-lead TSSOP

2.0 Description

The iW3662 advanced digital LED driver, designed for low voltage AC and DC input voltages, combines support for both low voltage LEDs and high voltage Chip-On-Board (COB) LED modules at power levels up to 8W.

The iW3662 features two selectable operating modes to accommodate both low voltage LEDs and high voltage COB LEDs in one part. The Boost-Buck mode provides a boost converter to step-up the input voltage to an intermediate voltage, which a second buck regulator stage steps down to create a highly efficient, constant current LED controller. The Boost-Linear mode, designed to work with high voltage COB LEDs, steps up the input voltage to a higher voltage than in the Boost-Buck mode, then, with the buck converter now disabled and reconfigured into a linear current regulator, provides a highly accurate constant current sink to drive the LEDs.

The highly configurable digital control circuitry allows the end user to specify one part for multiple applications, covering the bulk of low voltage LED replacement bulb applications. Using Dialog's Flickerless™ technology allows the iW3662 to operate without visible flicker and operate with a broad range of input dimmer types (leading edge, trailing edge and digital) while effectively detecting and managing both electronic and magnetic transformers automatically. When the iW3662 detects a magnetic transformer, an additional output drives an external switch that can add extra input capacitance needed to ensure proper operation, easing the design of replacement bulbs compatible with both transformer types.

The iW3662 also integrates an internal bleeder FET to add a dynamic load to the input to optimize electronic transformer performance during low dimming ranges. Also, full protection features including over-temperature protection derating, which lowers the output current drive to the LEDs when an over-temperature event occurs to maintain light output even during a fault condition, provides robust and functional solutions for low voltage LED replacement lighting.

3.0 Applications

- V_{AC} or V_{DC} input dimmable LED lighting
- Optimized for use with all transformers, including electronic and magnetic
- MR16 bulbs, AR111 fixtures/bulbs

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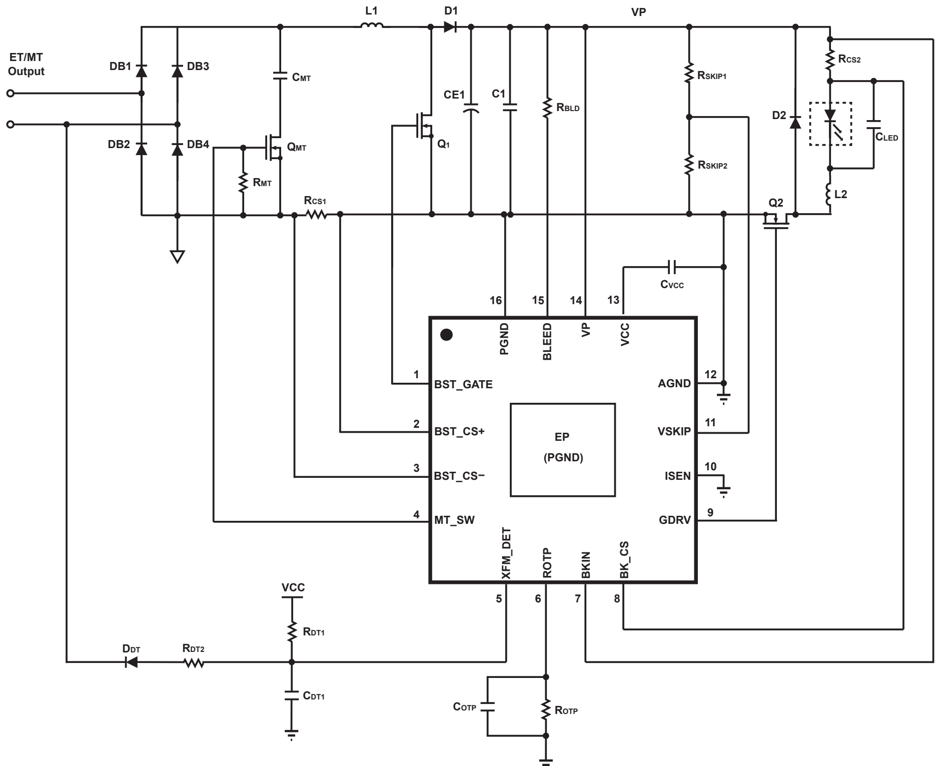

Figure 3.1: Typical Schematic for 12V/350mA (4W) Boost-Buck Configuration

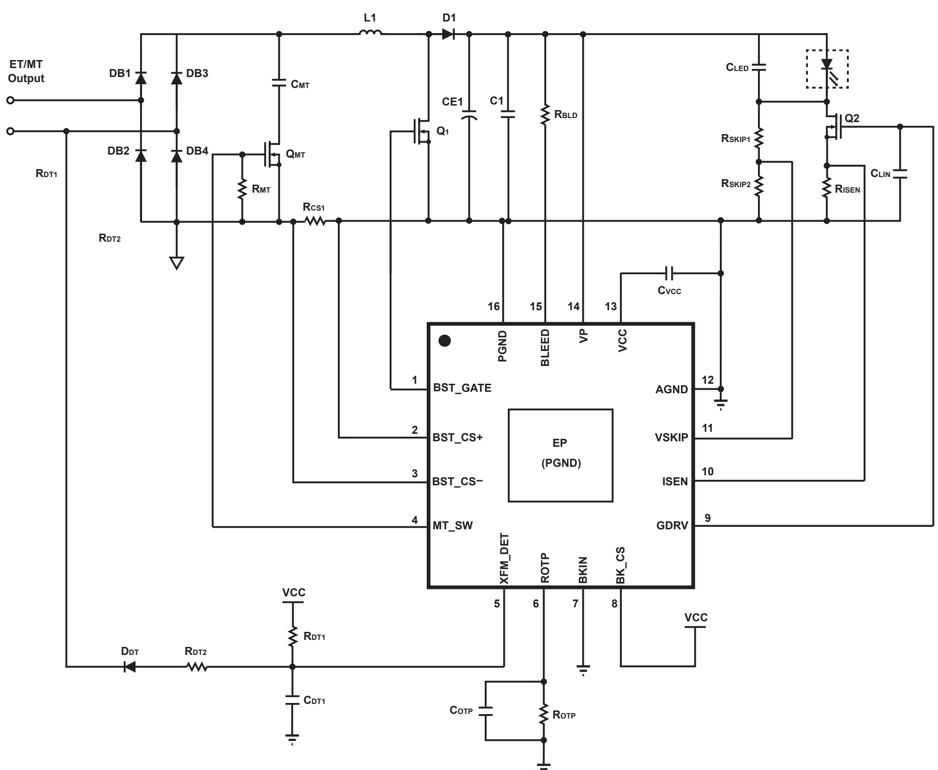

Figure 3.2: Typical Schematic for 38V/105mA (4W) Boost-Linear Configuration

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4.0 Pinout Description

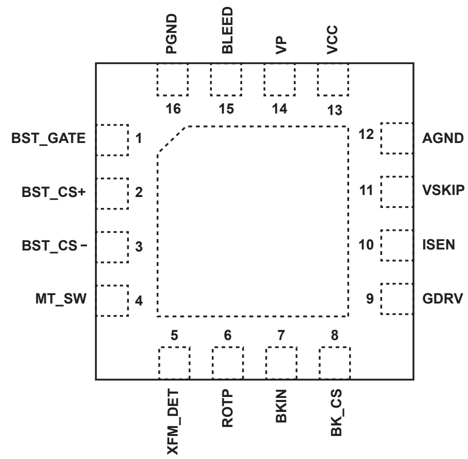

Figure 4.1: 16-Lead QFN Package

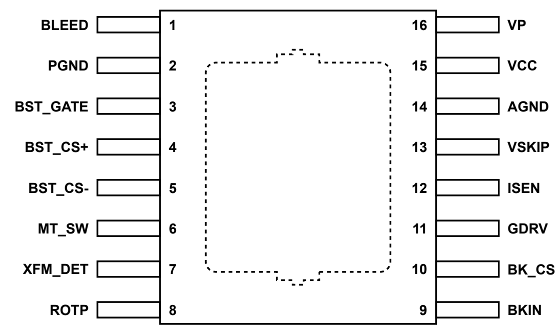

Figure 4.2: 16-Lead TSSOP Package

Pin #		Name	Type	Pin Description
QFN	TSSOP			
1	3	BST_GATE	Output	Gate driver for boost converter.
2	4	BST_CS+	Input	Boost current sense postive input.
3	5	BST_CS-	Input	Boost current sense negative input.
4	6	MT_SW	Output	Indicator of MT/ET detection with PMOS open drain output. MT: MT_SW = V_{CC}; ET: MT_SW = open drain, connect pull-down resistor to Ground.
5	7	XFM_DET	Input	MT/ET detection input. Internal 1MΩ pull-down to AGND
6	8	ROTP	Input	OTP threshold program pin. Used to set the power derating temparature that is determined by an external resistor tied to AGND.
7	9	BKIN	Input	Buck power supply input. It is also used to configure the operation mode. $V_{BKIN} > 2V$: Boost-Buck mode; $V_{BKIN} < 2V$: Boost-Linear mode
8	10	BK_CS	Input	Buck current sense input. Connect resistor RCS2 from this pin to BKIN to define nominal average output current. It is also used to configure the skip function when in boost-linear mode. $V_{BK\_CS} < 2V$: Disable skip function in boost-linear mode. $V_{BK\_CS} > 2V$: Enable skip function in boost-linear mode.
9	11	GDRV	Output	Dual function: Boost-Buck mode: Gate driver for Buck FET. Boost-Linear mode: Gate driver for linear current regulator.

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Pin #		Name	Type	Pin Description
QFN	TSSOP			
10	12	ISEN	Input	Current sense input for the linear current regulator in Boost-Linear mode. In Boost-Buck mode, used to enable/disable DCM operation. VISEN > 2V: Disable DCM function in Boost-Buck mode. VISEN < 2V: Enable DCM function in Boost-Buck mode.
11	13	VSKIP	Input	Skip voltage threshold set pin.
12	14	AGND	Ground	Chip ground.
13	15	VCC	Output	LDO 5V output. Connect a 4.7μF capacitor typically to AGND.
14	16	VP	Power	Chip power supply input.
15	1	BLEED	Output	Input for the internal bleeder FET. Internal 1MΩ resistor to VP. See Section 9.5 for more details.
16	2	PGND	Ground	Power ground for bleeder FET.
		EP	Ground	Exposed PAD. It is internally tied to PGND.

5.0 Absolute Maximum Ratings

Absolute maximum ratings are the parameter values or ranges which can cause permanent damage if exceeded.

Parameter	Symbol	Value		Unit
VP to AGND		-0.3 to 60		V
BLEED, VSKIP to AGND		-0.3 to V_P		V
BKIN, BK_CS to AGND		-0.3 to V_P		V
BST_CS- to AGND		-5 to 0.3		V
XFM_DET, MT_SW to AGND		-0.3 to 6.5		V
Other pins to AGND		-0.3 to 6.5		V
Voltage difference between BKIN and BK_CS		-6.5 to 6.5		V
Maximum junction temperature	T_{JMAX}	150		°C
Operating junction temperature	T_{JOPT}	-40 to 150		°C
Storage temperature	T_{STG}	-65 to 150		°C
Thermal Resistance Junction-to-Ambient [Still Air]	θ_{JA}	QFN4x4	TBD	°C/W
		TSSOP16	TBD	
ESD rating per JEDEC JESD22-A114		±2,000		V

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6.0 Electrical Characteristics

V_{CC} = 12V, -40°C ≤ T_A ≤ 85°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	
Power Supply						
V_P input voltage	V_P		7		60	V
V_P pin UVLO threshold	V_{P_UVLO}	V_P increasing	5	5.5	6	V
V_P pin UVLO hysteresis	$V_{P\_UVLO\_HYS}$	V_P decreasing	0.7	0.8	0.9	V
V_P pin OVP threshold	V_{P-OVP}	BB mode, V_P increasing		32		V
		BL mode, V_P increasing		45		V
V_P pin OVP hysteresis	$V_{P\_OVP\_HYS}$	V_P decreasing		1		%
V_P pin OVP_SD threshold	V_{P-OVP_SD}	BB mode, V_P increasing		33.5		V
		BL mode, V_P increasing		48		V
V_P input operating current	I_{IN}	V_P = 30V, no switching		TBD		mA
V_P input shut-down current	I_{IN-SD}	V_P = 4V			TBD	μA
V_{CC} Regulator						
V_{CC} pin output voltage	V_{CC}	C_{VCC} = 4.7μF, no load		5		V
V_{CC} pin UVLO threshold (Note 3)	V_{CC_UVLO}	V_{CC} increasing		4		V
V_{CC} pin UVLO hysteresis (Note 3)	$V_{CC\_UVLO\_HYS}$	V_{CC} decreasing		300		mV
V_{CC} pin current capacity	$I_{VCC\_CAPACITY}$	V_{CC} decrease by 10%	15	20		mA
V_{CC} pin current limit (Note 3)	I_{VCC_LIM}	V_{CC} = 0V	30	60		mA
Transformer Type Detection						
XFM_DET input frequency	f_{DET}				Note 2	kHz
XFM_DET threshold voltage	V_{DET_TH}			2		V
MT_SW $R_{DS(ON)}$		Open drain			3	kΩ
MT_SW output voltage high	V_{OH_SW}	R_{MT} = 100 KΩ; V_{CC} = 5V	4.5			V
Boost Controller						
Voltage reference for peak current setting	V_{REF_PEAK}			0.22		V
Voltage reference for valley current setting	V_{REF_VALLEY}			0.1		V
BST_GATE output voltage low	$V_{BST\_GATE\_OL}$	I_{SINK} = 10mA		0.1	0.2	V
BST_GATE output voltage high	$V_{BST\_GATE\_OH}$	I_{SOURCE} = 10mA	V_{CC} -0.2	V_{CC} -0.1		V
BST_GATE pin rise time	$t_{BST\_GATE\_RISE}$	BST_GATE pin load = 1nF		TBD		ns
BST_GATE pin fall time	$t_{BST\_GATE\_FALL}$	BST_GATE pin load = 1nF		TBD		ns

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6.0 Electrical Characteristics (cont.)

V_{CC} = 12V, -40°C ≤ T_A ≤ 85°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Linear Current Regulator						
Voltage reference for maximum linear current	V_{LIN_FS}			0.2		V
Voltage reference accuracy	$V_{LIN\_ACCURACY}$	V_{LIN_FS} = 0.2V	-5		+5	%
Input common-mode voltage range	V_{LIN}		10		200	mV
DCM function selection threshold	V_{DCM_SEL}	Boost-Buck mode		2		V
Buck Controller						
Buck input voltage	V_{BKIN}		7		60	V
Mode selection threshold	V_{MODE_SEL}	V_{BKIN} increasing		2		V
Skip function selection threshold	V_{SKIP_SEL2}	Boost-Linear mode		2		V
BKIN input current	I_{BKIN}			25		µA
BK_CS input current	I_{BK_CS}			25		µA
Mean current sense threshold voltage (defines LED current)	V_{SENSE}		5		100	mV
Mean current sense threshold voltage accuracy	$V_{SENSE\_ACCURACY}$	V_{SENSE} = 100mV	-5		5	%
Mean current sense threshold voltage hysteresis	V_{SENSE_HYS}		±5	±15	±20	mV
G_{DRV} output voltage low	V_{DRV_OL}	I_{SINK} = 10mA		0.1	0.2	V
G_{DRV} output voltage high	V_{DRV_OH}	I_{SOURCE} = 10mA	V_{CC} -0.2	V_{CC} -0.1		V
G_{DRV} pin rise time	t_{DRV_RISE}	G_{DRV} pin load = 1nF		TBD		ns
G_{DRV} pin fall time	t_{DRV_FALL}	G_{DRV} pin load = 1nF		TBD		ns
Recommend maximum operating frequency	f_{BK-MAX}				1	MHz
Recommended duty cycle range			0.3		0.7	
Internal comparator propagation delay (Note 3)	T_{BK-PD}			20		ns
Bleeder						
Maximum input average current	I_{BLD_MAX}	$V_{BLEED-IN}$ < 0.5V			0.15	A
Integrated MOSFET $R_{DS(ON)}$	R_{DSON_BLD}	I_{BLD} = 0.1A		20	40	Ω

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6.0 Electrical Characteristics (cont.)

V_{CC} = 12V, -40°C ≤ T_A ≤ 85°C, unless otherwise specified.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Skip Function						
Voltage reference	V_{REF}	Boost-Buck mode		1.4		V
		Boost-Linear mode		1.0		V
Thermal Protection						
Current source for OTP	$I_{OTP\text{-}BIAS}$	Only effects during IC start up.	9	10	11	μA
Thermal shutdown temperature (Note 3)	T_{OTP}	T_J rising		150		°C
Power derating start point (Note 3)	T_{DER_ST}	R_{OTP} < 10KΩ	Forbidden			
		10KΩ< R_{OTP} < 35KΩ	Disable OTP and Power Derating			
		50KΩ< R_{OTP} < 75KΩ		90		°C
		95KΩ< R_{OTP} < 115KΩ		100		°C
		145KΩ< R_{OTP} < 155KΩ		110		°C
		190KΩ< $_{ROTP}$ < 200KΩ		120		°C
		235KΩ< R_{OTP} < 245KΩ		130		°C
		R_{OTP} > 290KΩ		140		°C
Power derating start point hysteresis (Note 3)	$T_{DER\_ST\text{-}HYS}$			5		°C

Notes:

Note 1. See Section 9.1 Input Voltage for details.

Note 2. See Section 9.2 Transformer Type Detection for details.

Note 3. These specifications are guaranteed by design.

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7.0 Typical Performance Characteristics

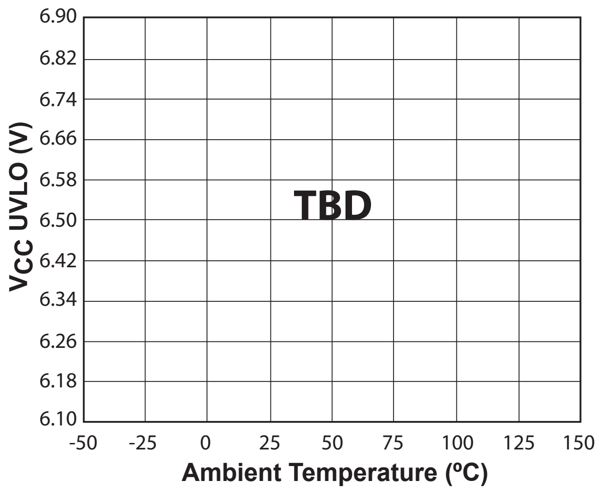

Figure 7.1 : V_{CC} UVLO vs. Temperature

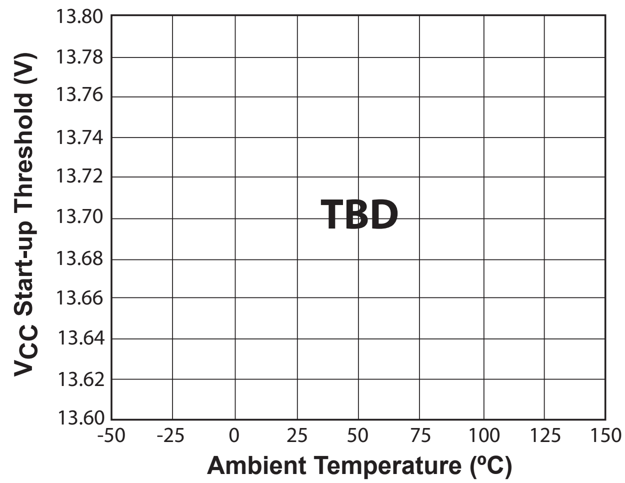

Figure 7.2 : Start-Up Threshold vs. Temperature

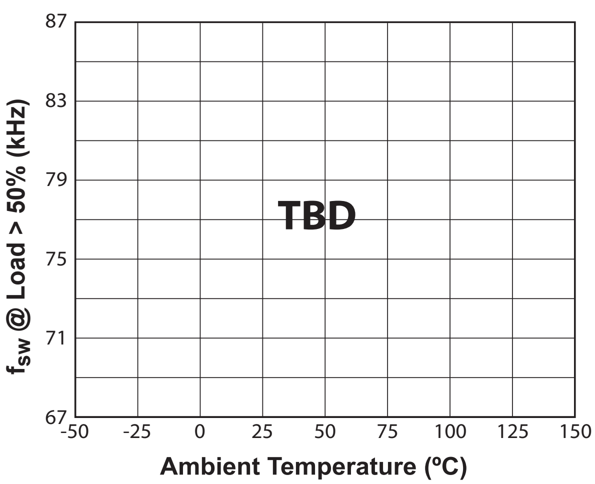

Figure 7.3 : Switching Frequency vs. Temperature[1]

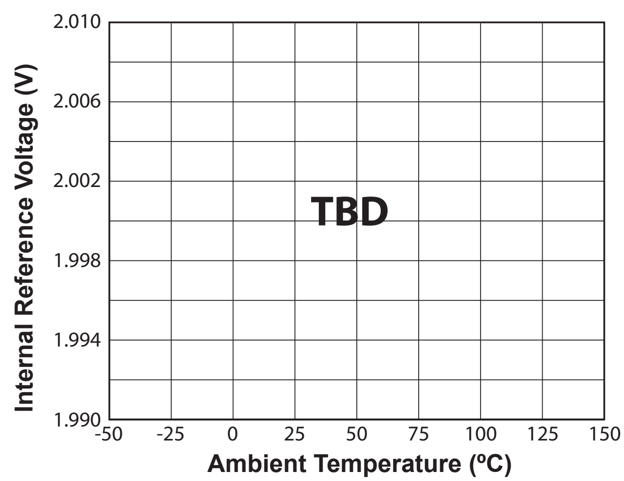

Figure 7.4 : Internal Reference vs. Temperature

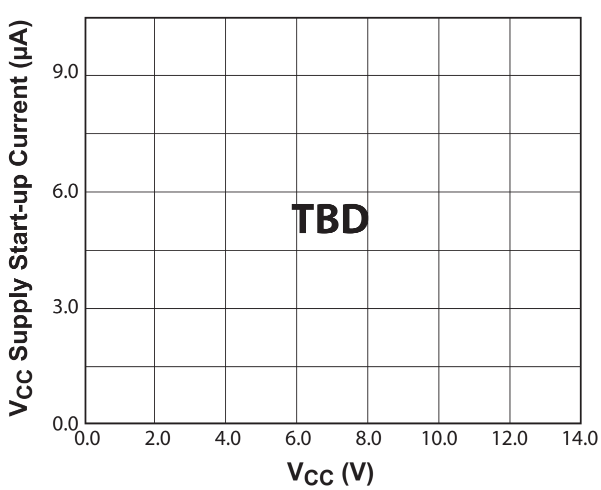

Figure 7.5 : V_{CC} vs. V_{CC} Supply Start-up Current

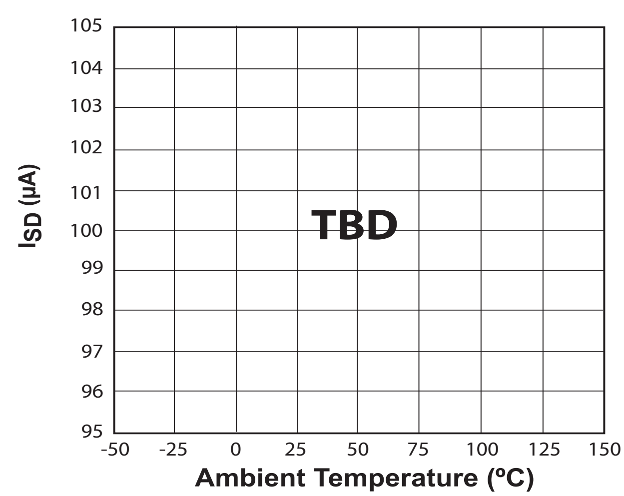

Figure 7.6 : I_{SD} vs. Temperature

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8.0 Functional Block Diagram

The iW3662 integrates two controllers, a boost controller and a buck/linear regulator controller in a dual-mode device designed to drive LEDs from a low voltage AC or DC input voltage. In Boost-Buck mode, the initial boost stage steps up the input voltage to a configurable intermediate voltage and provides the input voltage for the second, buck (step-down) stage. The second stage is a constant-current step-down current regulator that provides the regulated output current to the low voltage LED array. A second operational mode, the Boost-Linear mode, works by disabling the buck stage, the boost stage steps up the voltage and the LED current is regulated by a linear current regulator.

The first stage of the iW3662 is a boost stage to step up the input voltage to a higher intermediate voltage. The second stage is a control circuit that drives an external MOSFET for either a buck converter (Boost-Buck mode) or a linear current regulator (Boost-Linear mode), making a highly configurable IC for driving discrete LEDs or high-voltage Chip-On-Board (COB) LED modules.

Integrated in the iW3662 is a detection circuit allowing the device to work with either Electronic Transformers (ET) or Magnetic Transformers (MT). When a magnetic transformer is detected, the device enables an external switch that allows for additional input capacitance to be added to the input line. As a device with Dialog's Flickerless™ technology integrated, the iW3662 works with a wide range of dimmers and provides flicker-free operation over the full dimming range. The dimming algorithm is optimized for operation with electronic transformers to ensure compatibility.

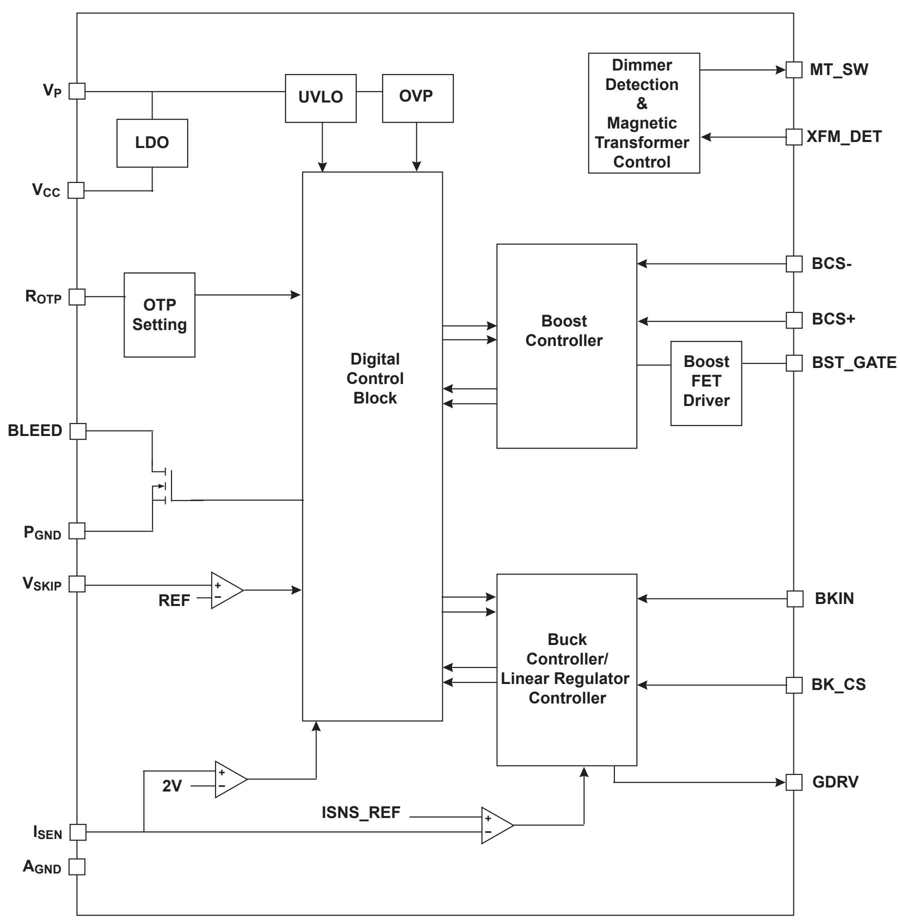

Figure 8.1 : iW3662 Functional Block Diagram

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9.0 Theory of Operation

9.1 Input Voltage (V_P)

The V_P pin on the iW3662 is the main input power supply and has an operating range of 7V to 60V. An under voltage lock out (UVLO) circuit protects the circuit from an undervoltage condition by holding the main gate driver output low (MOSFET off) until the input voltage reaches a minimum of 5.5V typical. The UVLO circuit also incorporates 800mV of hysteresis to prevent chattering.

The input is also protected from overvoltage events by two different levels of protection. If the input exceeds the overvoltage protection (OVP) threshold, the iW3662 stops switching the boost MOSFET until the input voltage drops below the OVP threshold plus 1% of hysteresis. In the event that the overvoltage event continues for more than 50ms, or if a secondary higher threshold (OVP_SD) is tripped, the device shuts down and does not re-start until the system power is cycled. When in Boost-Buck Mode, the OVP threshold is set at 32V with the OVP_SD threshold at 33.5V. In the Boost-Linear mode, OVP is 45V and OVP_SD is 48V.

9.2 V_{CC} Regulator

An internal LDO regulator provides a stable 5V power supply to the MOSFET driver and bias circuits inside the iW3662. A low-ESR, 4.7µF ceramic capacitor should be placed between V_{CC} and the AGND pin for stability. A UVLO circuit prevents the internal circuitry from enabling until the output of the LDO is at least 4V. Once the voltage on the V_{CC} pin goes above the 4V level, the iW3662 is enabled.

9.3 Transformer Type Detection

Both the Magnetic Transformers and Electronic Transformers have a distinct waveform which contains frequency information that can be used by the iW3662 to detect which type of transformer is being used. Figure 9.1 shows the waveforms for both the Magnetic and Electronic Transformers.

The iW3662 detects the transformer type by extracting the information from the waveform and, using a digital detection circuit, determines which type is connected. The iW3662 starts in a default state that assumes an Electronic Transformer is used. This default state assures that users of ET devices do not have to populate any external components and those who use MT devices are also ensured proper start-up, detection and operation. As seen in Figure 9.1, electronic transformers with an AC output have a high frequency component. The iW3662 detects this frequency to determine that an ET type transformer is being used. The iW3662 can detect an output frequency of up to 300kHz.

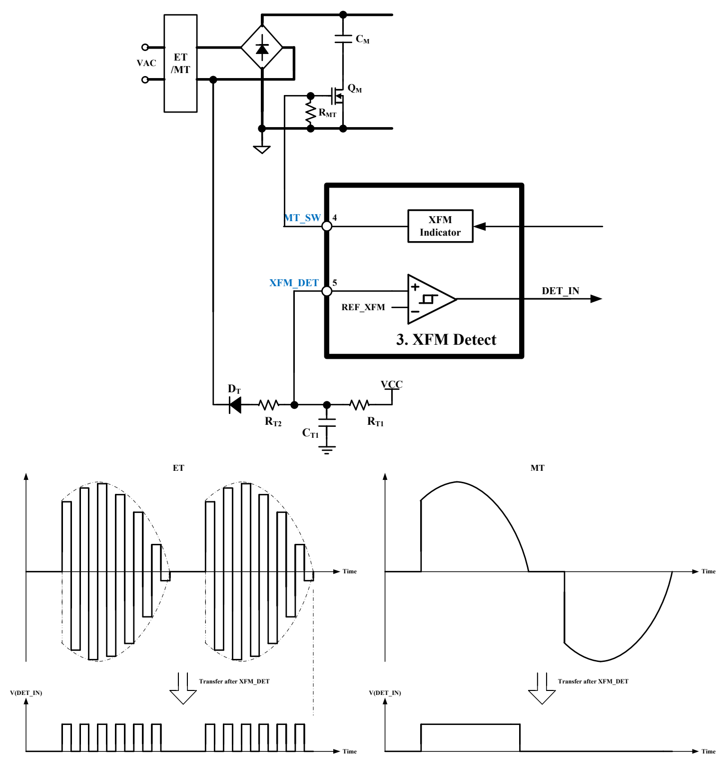

Figure 9.1 : Electronic and Magentic Transformer Waveforms

The The MT_SW output defaults in a low state (V_{OL}) and if a magnetic transformer is detected, the output of MT_SW then goes high (V_{OH}). The MT_SW pin drives an external MOSFET that allows additional input capacitance to be added to the circuit when a magnetic transformer is detected. The output of the MT_SW pin is an open-drain PMOS device and requires a pull-down resistor to make sure that the output is in a known (Low) state until the internal circuitry powers up correctly.

For Figure 9.1, the MT/ET recommended detection circuit, the recommended circuit values for optimal balance between speed and power consumption is R_{T1} = 50kΩ, R_{T2} = 1kΩ, C_{DT1} = 10pF.

9.4 Operation Mode Selection

In order to program the iW3662 for operation either in the Boost-Buck mode or Boost-Linear mode, the BKIN pin serves the dual purpose to facilitate the programming

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process without adding additional pins. When the BKIN pin detects a voltage higher than 2V, the device automatically switches into Boost-Buck mode. If the BKIN pin is grounded , the iW3662 switches into Boost-Linear mode, disabling the buck controller mode and enabling the linear current regulator mode.

9.5 Output Voltage Selection

The output voltage of the iW3662 is primarily set by the LED current requirements. In Boost-Linear mode, the output voltage is set automatically by the internal control algorithm, which regulates the current through the linear regulator. The boost voltage will be set at the minimum voltage necessary to maintain the LED current regulation constant.

In Boost-Buck mode, the boost converter output voltage is programmed using a resistor divider from the boost output to the Vskip pin and ground. See section 9.7 for setting the output voltage of the boost converter (VP).

9.6 Bleeder, Skip Mode and Dimming

The iW3662 uses multiple factors to ensure dimmer compatibility and to determine the dimmer percentage when a dimmer is detected. This functionality is best understood in parts.

The device initially detects and determines the type of transformer and subsequently the dimmer interface. When an electronic transformer is used, the amount of current required to keep the ET device is higher than that of the magnetic transformer. Since MR16 LED replacement bulbs consume a significantly lower amount of power compared to the bulbs they replace, there is a risk that the output of an AC ET device could stop oscillating at low dimming percentages, and therefore low LED currents. The simplest way to obtain maximum compatibility is to use the integrated bleeder function to set a minimum current. But, at low dimming conditions, that bleeder current will become a high percentage of the input power consumption and cause the efficiency to be very low. The skip mode, along with the bleeder, via a proprietary digital algorithm, are used to reduce power loss while maintaining a wide dimming range and high efficiency.

Similarly, when interfacing with a magnetic transformer, the device works to minimize power loss while maximizing dimmer compatibility and dimming range.

The iW3662 uses digital algorithms to determine the LED current based requested dimming from the dimmer. The input voltage applied to the iW3662 that comes from the ET/MT device determines the rest of the system characteristics. The iW3662 uses multiple detection points to control the current through the LED. The bleeder circuit and the skip mode function also work to control the output dimming characteristic to maximize dimming range. In boost-buck mode, the device monitors the output of the boost converter and other detection points to determine the LED current. In boost-buck mode at very low dimming percentages, the device automatically enters a DCM control mode to aid in regulating the LED current. The ISEN pin in boost-buck mode should be grounded to ensure that DCM operation is enabled to maximize the dimming range. If that pin is pulled above 2V, DCM operation will be disabled.

In boost-linear mode, the iW3662 monitors the drain voltage of the linear current regulation MOSFET, and other variables, to determine the LED current for dimming.

Skip mode can be disabled in boost-linear mode for higher power applications when the conditions are such that the bulk output capacitance on the boost cannot sustain the boost output voltage with a reasonable amount of ripple. At high load and low bulk capacitance on the output of the boost, the skip mode could cause some flicker on the output of the LED and in that circumstance, disabling skip mode by pulling the BK_CS pin to ground would remove that flicker.

9.6.1 Bleeder

An integrated protection circuit on the internal bleeder switch works to ensure safe operation. If the protection circuit detects an abnormal situation during start-up, the boost converter is shutdown.

The Bleeder function only operates for a limited period of time so as to reduce power loss and maintain high efficiency. The on-time for the bleeder switch occurs during half of the line cycle and is internally limited as a function of the line frequency. In Boost-Buck mode, the on-time of the switch is limited to a maximum of 1.12ms. In Boost-Linear mode, the on-time is limited to a maximum of 0.45ms.

The maximum power loss of the bleed resistor can be calculated based on the input voltage, V_P, the on-time and the resistance value. The higher the power consumption in the bleeder resistor, the better the input power jitter can be filtered. In order to minimize size and optimize system effiency, the max power loss in the bleeder resistor should be no more than 0.3W.

The maximum bleeder loss is calculated based on the maximum time limit, the voltage at V_P and the period of the line voltage. In the examples shown in Figures 3.1 and 3.2, used for these calculations, the line frequency is assumed to be 50Hz.

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$$P_{BLD} = \frac{V_P^2}{R_{BLD}} \times \frac{t_{lim}}{\frac{1}{2}T_{ac}} \quad (9.0)$$

For the Boost-Buck mode operation, the output voltage of the boost converter in Figure 3.1 is 24V and for the Boost-Linear mode operation of Figure 3.2, the boost voltage is 42V. Using equation 9.1, the R_{BLD} values calculate out to 215Ω for the Boost-Buck mode and 264Ω for the Boost-Linear mode.

9.7 Skip Mode Function

The iW3662 integrates a skip function to aid in maintaining flicker-free operation and optimize efficiency as discussed in section 9.6. The skip function disables the boost circuit when the input power goes higher than necessary for the output power consumption at that time. This helps to reduce flicker and improve efficiency. In Boost-Linear mode, the skip function can be disabled by pulling the BK_CS pin below 2V.

To calculate the Skip resistor values for Boost-Buck mode, assume 28V for the voltage at V_P where skip mode should begin (4V above the nominal 24V in Boost-Buck mode). The V_{REF} of 1.4V is the set point for the $V_{P\text{-}SKIP}$ output voltage. Using $V_{P\text{-}SKIP}$ and V_{REF}, we can solve for R_{SKP1} and R_{SKP2}.

$$V_{P\text{-}SKIP} \times \frac{R_{SKP2}}{R_{SKP1} + R_{SKP2}} = V_{REF} = 1.4\text{V} \quad (9.1)$$

The ratio of R_{SKP1} to R_{SKP2} comes out to 19:1, which when using standard 1% resistor values, comes out to 190kΩ for R_{SKP1} and 10kΩ for R_{SKP2} for Boost-Buck mode.

For Boost-Linear mode, the skip mode resistors monitor the drain voltage of the linear MOSFET. Skip mode should start when the voltage at the drain equals 3.0V. Using equation 9.1 again, but substituting VP for the drain voltage of 3V and the reference voltage in boost-linear mode of 1.0V, the resistors calculate out to a ratio of 2:1, or an R_{SKP1} of 200kΩ and R_{SKP2} of 100kΩ.

9.8 Boost Controller

The boost controller is a hysteretic peak and valley mode control topology. The current is monitored via a current sense resistor connected between the BST_CS+ and BST_CS- pins. Internal circuitry removes any false readings due to current spikes, removing sensitivity to poor layout.

9.8.1 Boost Output Capacitor

On the output of the boost converter stage, two output capacitors are recommended for optimal operation. The main, bulk capacitance (CE1) and a second, high quality, low-ESR ceramic capacitor (C1) to help smooth out the ripple current. The main bulk capacitance provides energy to the output stage of the circuit during transients and when an electronic transformer has no output. For design purposes, a maximum dead-time of 4ms can be used for calculating the capacitance value.

Figure 3.1 shows the schematic for a typical Boost-Buck application circuit and capacitor CE1 can be calculated by using the following assumptions. The iW3662 can tolerate a droop on the output of the boost converter up to 5V during the dead-time in Boost-Buck mode. Using this voltage droop and the known 4ms dead-time, the required output capacitance value can easily be calculated.

$$C_{E1} = \frac{I_{LED1} \times T_{DEAD}}{\Delta V} \quad (9.2)$$

$$C_{E1} = \frac{350mA \times 4ms}{5\text{V}} = 280\mu F \quad (9.3)$$

For Boost-Linear mode, C_{E1} can be calculated using equation 9.1, but using a maximum droop voltage of 3V and 105mA of LED current, the current rating of Figure 3.2.

$$C_{E1} = \frac{105mA \times 4ms}{3\text{V}} = 140\mu F \quad (9.4)$$

To obtain the best performance possible in Boost-Linear mode, it is recommended to use the following capacitance values:

Output Power	Output Capacitanc (C_{E1})
4W	150µF or Larger
6W	220µF or Larger
8W	330µF or Larger

9.8.2 Boost Current Sense Resistor

A current sense resistor, R_{CS1}, is used by the boost converter for its peak and valley mode control scheme. Equation 9.5 is used to calculate the current sense resistor value.

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$$R_{CS1} = \frac{V_{REF\_IPEAK} + V_{REF\_IVALLEY}}{2 \times I_{L\_AVG}} \quad (9.5)$$

Where V_{REF_IPEAK} is 0.22V and $V_{REF\_IVALLEY}$ is 0.1V, and for better ET compatibility, the average inductor current is 1.1A. Using equation 9.5, the R_{CS1} value can be calculated for the example used in Figures 3.1 and 3.2 to be 0.145Ω or 0.15Ω, a more standard value. Using these values, then the Peak and Valley currents can be calcuated.

$$I_{PEAK} = \frac{V_{REF\_IPEAK}}{R_{CS1}} \quad (9.6)$$

$$I_{VALLEY} = \frac{V_{REF\_IVALLEY}}{R_{CS1}} \quad (9.7)$$

Using the variables above, I_{PEAK} calculates out to 1.467A and I_{VALLEY} calculates out to 0.667A. The difference between the peak current and valley current gives the full change in current in the boost inductor.

$$\Delta I_{L1} = I_{PEAK} - I_{VALLEY} = 0.8\text{A} \quad (9.8)$$

9.8.3 Boost Inductor

To calculate the boost inductor value required for the first stage, first the on-time and off-time must be determined. Then, using the currents determined in section 9.8.2 and the on and off times, the inductor value required can easily be determined. First, the equations for on time and off time.

$$t_{on} = \frac{L \times \Delta I}{V_{ET}} \quad (9.9)$$

$$t_{off} = \frac{L \times \Delta I}{V_P - V_{ET}} \quad (9.10)$$

The operating period of the boost converter, and therefore the frequency, can be determined using the on and off times.

$$f = \frac{1}{t_{on} + t_{off}} = \frac{1}{L \times \Delta I \times \left(\frac{1}{V_{ET}} + \frac{1}{V_P - V_{ET}}\right)} = \frac{V_{ET} \times (V_P - V_{ET})}{} \quad (9.11)$$

Solving for the inductance value using equation 9.11 gives the following.

$$L = \frac{1}{f \times \Delta I} \times \frac{V_{ET} \times (V_P - V_{ET})}{V_P} \quad (9.12)$$

In order to properly select the inductance value, the minimum boost frequency should be determined based on the minimum voltage out of the ET. In this case, the minimum voltage is 6V and the recommended switching frequency for optimal size and efficiency is recommended to be 400kHz. Using these new variables and previous assumptions about the output voltage of the boost converter (24V for Boost-Buck mode and 42V for Boost-Linear mode), the inductance value for each operating mode can easily be calculated.

For Boost-Buck mode:

$$L = \frac{1}{400 \times 10^3 \times 0.8} \times \frac{6 \times (24 - 6)}{24} = 14.06\mu\text{H} \qquad L = 15\mu\text{H} \quad (9.13)$$

For Boost-Linear mode:

$$L = \frac{1}{400 \times 10^3 \times 0.8} \times \frac{6 \times (42 - 6)}{42} = 16.07\mu\text{H} \qquad L = 15\mu\text{H} \quad (9.14)$$

In both operating modes, the inductance value selected comes out at 15µH in order to use standard inductor values. The switching frequency range for each mode is substantially different in that the Boost-Buck mode, with the lower output voltage, gives a tighter range of switching frequency. The Boost-Linear mode, with the much higher output voltage on the output voltage of the boost, gives a switching frequency variation of almost 2:1.

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9.8.4 Boost Output Rectifing Diode

A schottky diode in the output of the boost converter is needed to rectify the output voltage. The diode must have a reverse voltage rating minimum of the output voltage of the boost converter, while the forward conduction current rating must support the full output current of the boost converter at a low forward voltage drop.

9.9 Buck Controller

The buck controller integrated in the iW3662 provides the constant current control portion of the Boost-Buck mode. The controller operates in hysteretic mode with dynamic hysteresis to control the inductor current and maximize the dimming range that operates flicker-free. The switching frequency of the buck converter is determined by the hysteresis, load current and output filter. At the lower end of the dimming range, the switching frequency increases in order to prevent dimming or jittering that can be caused by minimum pulse widths at low duty cycle operation.

The pins that govern the buck controller functionality start with the BKIN and BK_CS pins. The BKIN pin has two functions. It functions as a current sense input for the buck controller along with BK_CS, and it also is an input pin to define the operating mode of the iW3662 as discussed in section 9.4. For designs using only the Boost-Linear mode, the BKIN pin should be grounded, disabling the buck controller circuitry.

9.9.1 Buck Current Sense Resistor

The current supplied to the LED in Boost-Buck mode is determined by the current sense resistor connected between BKIN and BK_CS and it is determined by the following equation.

$$I_{LED1} = \frac{0.1\text{V}}{R_{CS2}} \tag{9.15}$$

$$R_{CS2} = \frac{0.1\text{V}}{I_{LED1}} = \frac{0.1\text{V}}{350\text{mA}} = 0.285\Omega \tag{9.16}$$

9.9.2 Buck Inductor

The inductor for the buck converter can be determined very similarly to how the boost inductor was determined in section 9.7.3. First, the on and off times are calculated, then the switching frequency and finally the required inductance value.

$$t_{on} = \frac{L \times \Delta I}{V_P - V_{LED}} \tag{9.17}$$

$$t_{off} = \frac{L \times \Delta I}{V_{LED}} \tag{9.18}$$

$$f = \frac{1}{t_{on} + t_{off}} = \frac{1}{L \times \Delta I \times \left(\frac{1}{V_{LED}} + \frac{1}{V_P - V_{LED}}\right)} = \frac{V_{LED} \times (V_P - V_{LED})}{L \times \Delta I \times V_P} \tag{9.19}$$

$$L = \frac{1}{f \times \Delta I} \times \frac{V_{LED} \times (V_P - V_{LED})}{V_P} \tag{9.20}$$

The recommended buck converter switching frequency for optimal efficiency is 250kHz. Using this number and plugging in the rest of the variables, the inductance value can easily be calculated. For the example shown in Figure 3.2, V_P is 24V, V_{LED} is 12V and I_{LED} is 350mA.

$$L = \frac{1}{250 \times 10^3 \times 0.35 \times 30\%} \times \frac{12 \times (24 - 12)}{24} = 229\mu\text{H} \qquad L = 220\mu\text{H} \tag{9.21}$$

Care must be taken in specifying the inductor so that the saturation current rating is higher than the peak current and that the continuous current rating is above the mean output current.

9.9.3 Buck Rectifier Diode

A rectifier diode from V_P to the Drain of the power N-channel MOSFET must be used to ensure high efficiency. A schottky diode with current capability rated to be above the peak current rating in forward conduction mode and low leakage in reverse conduction mode at max input voltage is recommended to maximize efficiency.

9.10 Linear Current Regulator

When in Boost-Linear mode, the control circuits used in Boost-Buck mode to control the buck converter function

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become the control circuits for a linear current regulator. This provides stable current control for high voltage Chip-On-Board (COB) LEDs. When in Boost-Linear mode, the GDRV output controls an N-Channel MOSFET and current sense resistor via the ISEN pin (Figure 3.2). The LED current is programmed by the voltage at ISEN and the current sense resistor. The voltage at ISEN is 0.2V and it is adjusted by and internal circuit in order to dim the LED current. The current regulation accuracy is better than +/-5%. A 1.5nF capacitor from GDRV to AGND is recommended to aid in stabilizing the output of the driver.

R_{ISEN} is calculated by a very simple ohm's law calculation.

$$I_{LED2} = \frac{0.2V}{R_{ISEN}} \quad (9.22)$$

$$R_{ISEN} = \frac{0.2V}{I_{LED2}} = \frac{0.2V}{105mA} = 1.9\Omega \quad (9.23)$$

9.11 LED Shunt Capacitor

A capacitor can be placed across the LED load, whether in Boost-Buck mode of Boost-Linear mode to aid in reducing the ripple current. The capacitor does not affect stability nor efficiency, but it reduces start-up time as the output has to charge the C_{LED} capacitor before the LEDs begin to emit light. A value of 1µF is recommended.

9.12 Protection Features - Over-Temperature Protection (OTP)

The iW3662 integrates Dialog's unique over-temperature protection derating circuit that reduces the output current to the LEDs in small steps when a maximum temperature threshold is crossed. The LED current reduces to reduce the power dissipation and protect both the IC and the rest of the LED driver circuit. When the temperature decreases, the output current returns back to its maximum level in equal steps, with hysteresis built in to ensure smooth operation.

An external resistor to ground programs the threshold temperature at which the OTP derating starts. See the OTP section of the EC table for the resistor value ranges and the corresponding temperature thresholds.

Figure 9.2 shows the OTP characteristic of the iW3662. The device reduces drive from 100% of programmed output current to 80% output current and at that point, if the temperature keeps rising, it trips a secondary thermal shutdown threshold which shuts down the output completely.

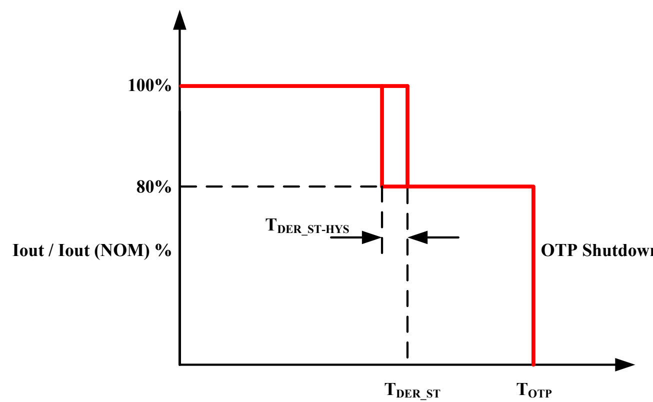

Figure 9.2 : Over-Temperature Protection Characteristic

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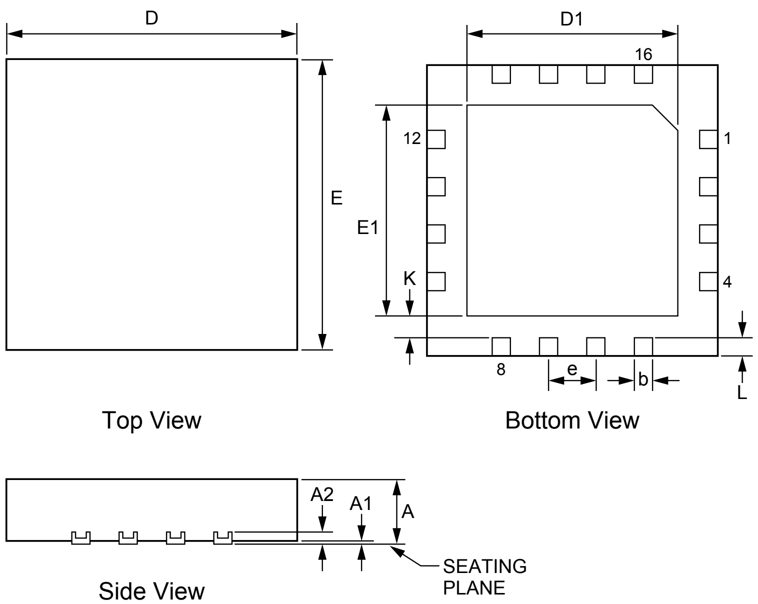
10.0 Physical Dimensions

Figure 10.1 : 16-Lead QFN4x4 Package



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.031	0.035	0.80	0.90
A1	0.0	0.002	0.00	0.05
A2	0.008 REF		0.20 REF	
b	0.010	0.014	0.25	0.35
D	0.157 BSC		4.00 BSC	
D1	0.110	0.118	2.80	3.00
E	0.157 BSC		4.00 BSC	
E1	0.110	0.118	2.80	3.00
e	0.026 BSC		0.65 BSC	
K	0.0098 REF		0.25 REF	
L	0.008	0.016	0.20	0.40

Compliant to JEDEC Standard MS12F

Controlling dimensions are in millimeters; inch dimensions are for reference only

This product is RoHS compliant and Halide free.

Soldering Temperature Resistance:
- [a] Package is IPC/JEDEC Std 020D Moisture Sensitivity Level 1
- [b] Package exceeds JEDEC Std No. 22-A111 for Solder Immersion Resistance; package can withstand 10 s immersion < 260˚C

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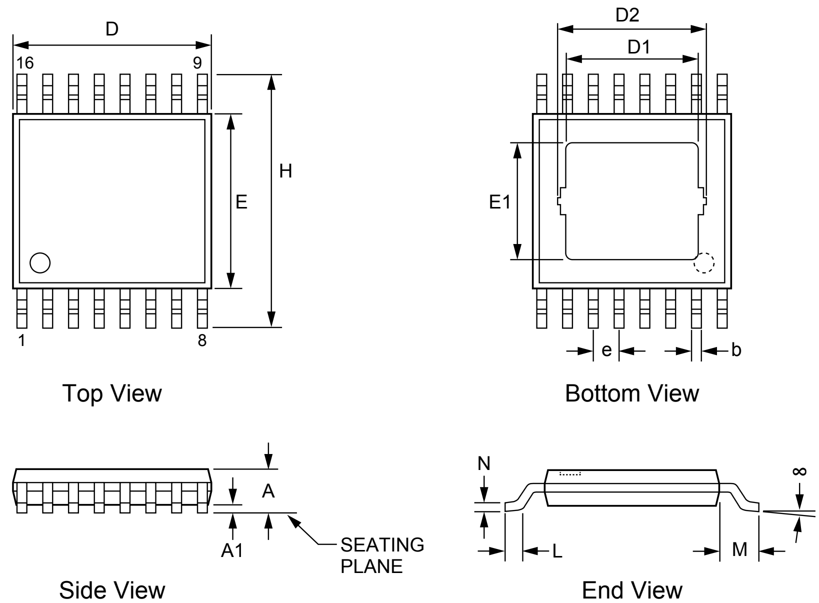
Figure 10.2 : 16-Lead TSSOP Package



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	—	0.043	—	1.10
A1	0.002	0.006	0.05	0.15
b	0.008	0.012	0.20	0.30
D	0.19	0.20	4.90	5.10
D1	0.13 REF		3.35 REF	
D2	0.15 REF		3.75 REF	
E	0.169	0.177	4.30	4.50
E1	0.116 REF		2.95 REF	
e	0.26 BSC		0.65 BSC	
H	0.25	0.26	6.30	6.50
L	0.02	0.03	0.45	0.75
M	0.035	0.043	0.90	1.10
N	0.05	0.08	0.13	0.20
∞	0°	8°	—	—

Compliant to JEDEC Standard MS12F

Controlling dimensions are in inches; millimeter dimensions are for reference only

This product is RoHS compliant and Halide free.

Soldering Temperature Resistance:
[a] Package is IPC/JEDEC Std 020D Moisture Sensitivity Level 1
[b] Package exceeds JEDEC Std No. 22-A111 for Solder Immersion Resistance; package can withstand immersion < 260˚C

The package top may be smaller than the package bottom. Dimensions D and E are determined at the outermost extremes of the plastic body exclusive of mold flash, tie bar burrs, gate burrs and interlead flash, but including any mismatch between the top and bottom of the plastic body.

11.0 Ordering Information

Part Number	Options	Package	Description
iW3662-00-QFN5	Low voltage SSL controller (12V$_{AC}$ or 10-24V$_{DC}$) in QFN 16-lead, 4x4mm package optimized for boost buck	QFN16, 4x4	Tape & Reel[1]
iW3662-01-QFN5	Low voltage SSL controller (12V$_{AC}$ or 10-24V$_{DC}$) in QFN 16-lead, 4x4mm package optimized for boost linear	QFN16, 4x4	Tape & Reel[1]
iW3662-00-TSE16[2]	Low voltage SSL controller (12V$_{AC}$ or 10-24V$_{DC}$) in TSSOP 16-lead package	TSSOP16	Tape & Reel[1]

Note 1: 7-inch Tape & Reel packing quantity is 1,500/reel. Minimum ordering quantity is 1,500.

Note 2: Please call Dialog for availability.

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Low Voltage ($12V_{AC}$) Dual-Mode Digital Control Dimmable LED Driver

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