AC/DC Advanced Digital Power Controller for Phase-Cut Compatible I^2C Digital Dimming LED Drivers

1 Description

The iW3690 is a single-stage, high performance AC/DC off-line power supply controller for intelligent LED luminaires. A master controller can communicate with the iW3690 through the I^2C bus interface to control the LED driver output current. With advanced digital control, the iW3690 regulates a constant current to an LED load over a 1% to 100% dimming range without flicker or shimmer. The driver can support either wired or wireless links via the master controller. Moreover, the master digital controller can set the iW3690 to sleep mode to achieve remote light off function at low standby power.

The iW3690 uses Dialog's proprietary Dual-Dim technology, which enables intelligent LED luminaires that are compatible with wall dimmers while offering superior performance. When a wall dimmer only is used, the LED driver output current is controlled based on the phase conduction angle of the dimmer. This same information is used to set the high limit of the LED current when a digital dimming command is received from the I^2C bus. While the I^2C bus has priority over the wall dimmer, the iW3690 can respond to both dimmer interfaces at the same time, allowing the driver to enter a stable sleep mode state at any wall phase conduction angle. Dialog's Dual-Dim technology allows the light output to be dimmed to 1% without flicker.

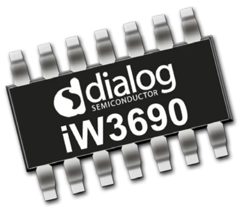
The iW3690 offers all the advanced features of Dialog's industry leading phase-cut dimming technology, including high efficiency and superior dimmer compatibility at low BOM cost. The iW3690 offers high performance, a wide dimming range and excellent dimmer compatibility while minimizing the external component count through high system-level integration. Dialog's EZ-EMI® technology works to simplify the input EMI filter, further reducing circuit size and cost while providing excellent noise rejection capability to AC line distortions.

2 Features

- Isolated/non-isolated off-line $120V_{AC}$/$230V_{AC}$ intelligent LED driver up to 25W output power
- I^2C digital link dimmable and phase-cut (TRIAC) dimmable (Dual-Dim)
  - Digital link dimming at any phase-cut conduction angle or no dimmer
  - Remote on/off at any phase-cut conduction angle or no dimmer
- Resonant control to achieve high efficiency (typical > 85% without dimmer)
- Excellent AC line distortion immunity ensures high quality of light under real-life circumstances
- Over-temperature LED current foldback and shutdown
- Tight LED current regulation (±5%)
- Low standby power < 0.5W when I^2C requests remotely off under no dimmer condition
- Wide 1% to 100% dimming range for both I^2C dimming and phase-cut dimming
- Total harmonic distortion (THD) < 20%, PF > 0.92
- Advanced IC power management and voltage sensing enables use of off-the-shelf inductor
- Fast start-up (< 0.5s without dimmer)
- Multiple protection features include:
  - LED open-circuit and short-circuit protection
  - AC line over-voltage protection
  - Over-current protection

3 Applications

- Dimmable LED intelligent lamps up to 25W
- Dimmable LED intelligent luminaires up to 25W



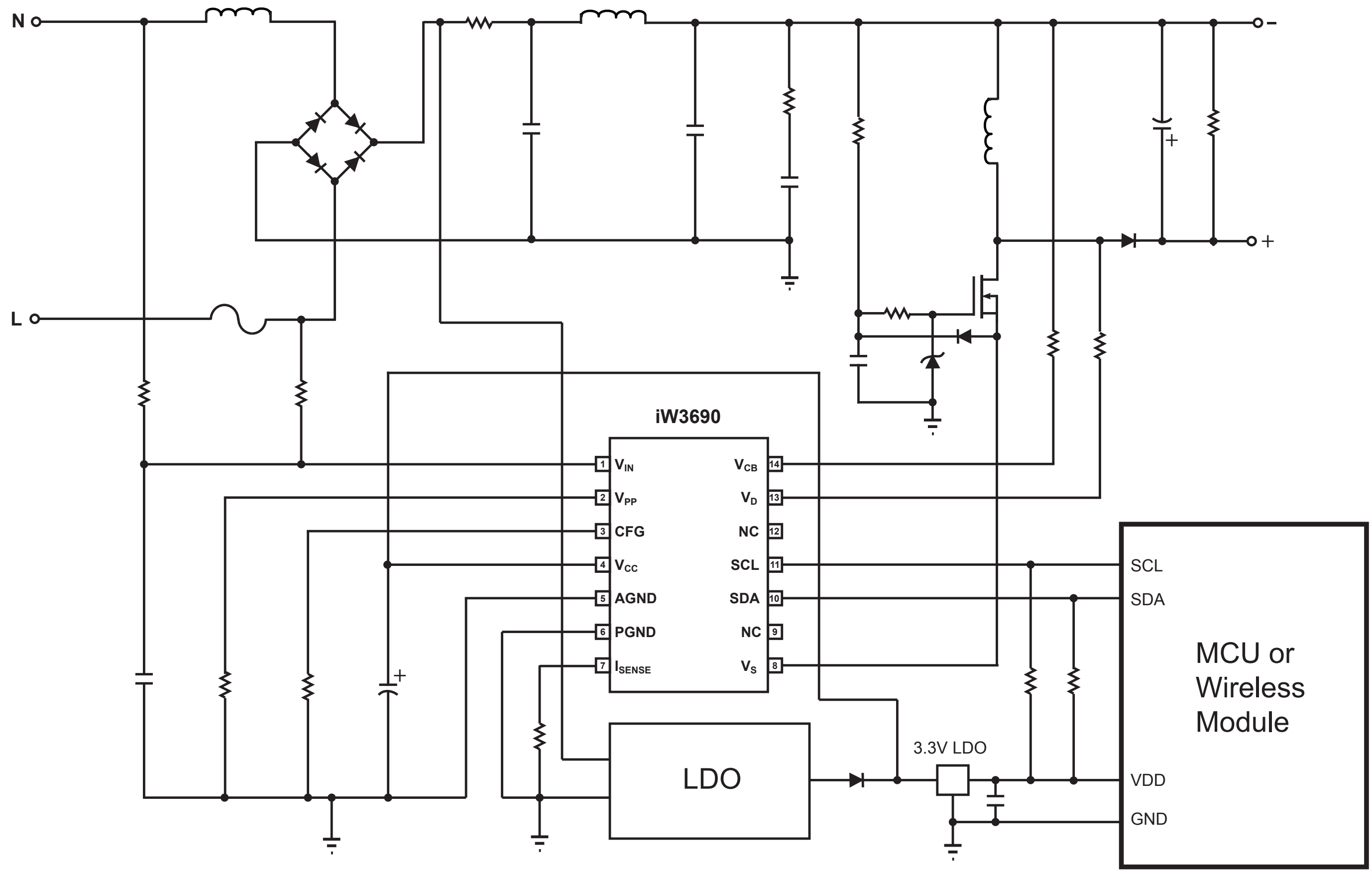


Figure 3.1 : Simplified Application Circuit:
iW3690 Supporting External MCU or Wireless Module Powered from LDO

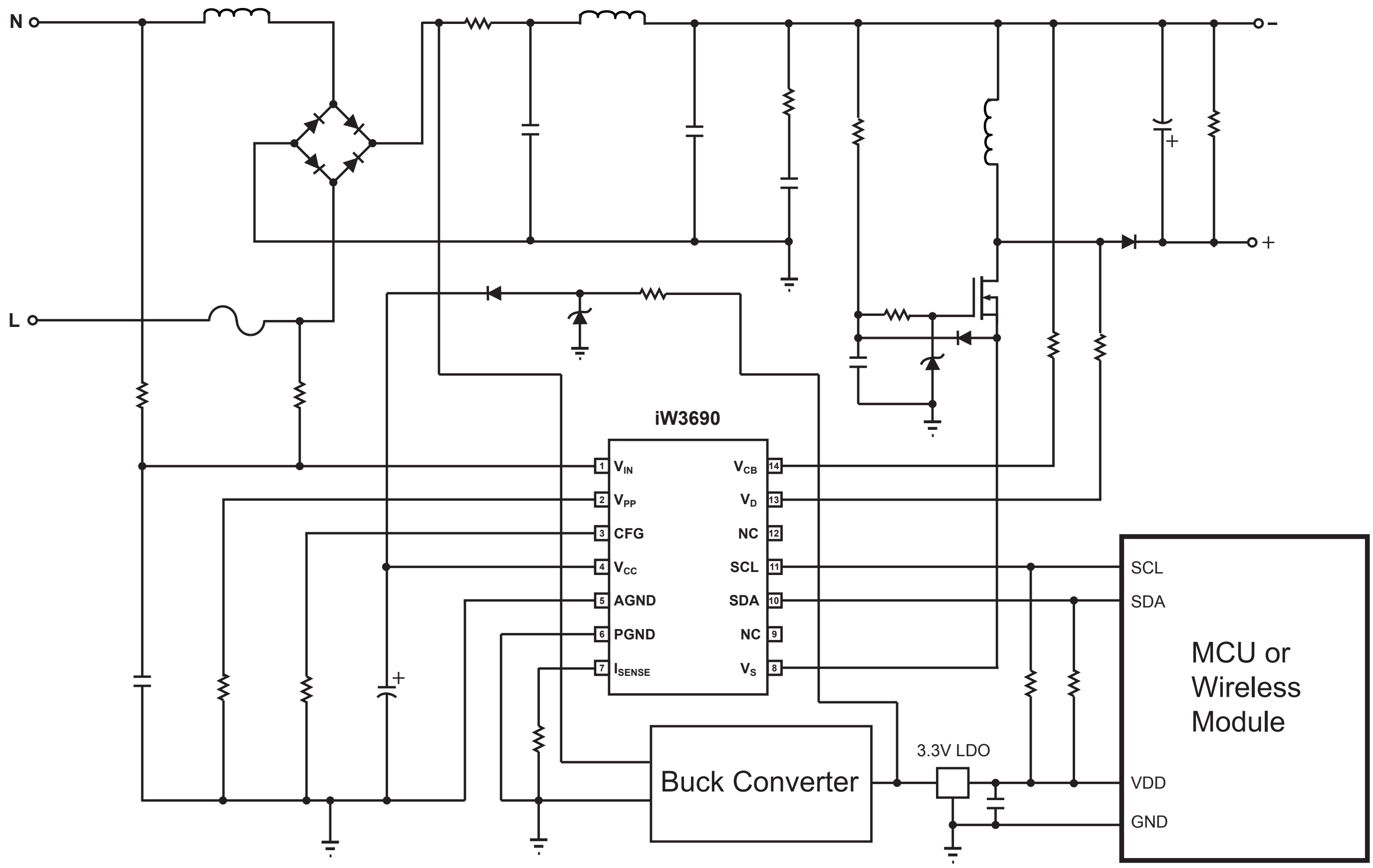


Figure 3.2 : Simplified Application Circuit:
iW3690 Supporting External MCU or Wireless Module Powered from Buck Converter

4 Pinout Description

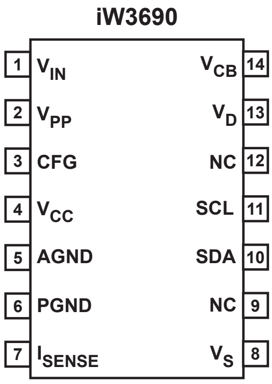


Figure 4.1 : 14-Lead SOIC-14 Package

Pin Number	Pin Name	Type	Pin Description
1	V_{IN}	Analog Input	Rectified AC line voltage input.
2	V_{PP}	Analog Input	Connects an 18kΩ resistor to GND.
3	CFG	Analog Input	Configures OTP threshold on start-up. See the applications section for configuration information.
4	V_{CC}	Power	Power supply for control logic.
5	AGND	Ground	Signal ground. It should be connected to the power ground on PCB.
6	PGND	Ground	Power ground.
7	I_{SENSE}	Analog Input	Current sense.
8	V_S	Analog Input	Source voltage of MOSFET.
9	NC	No Connection	Not internally connected.
10	SDA	Digital Input/ Output	I²C data signal, connected to external controller.
11	SCL	Digital Input/ Output	I²C clock signal, connected to external controller.
12	NC	No Connection	Not internally connected.
13	V_D	Analog Input	Drain voltage of MOSFET.
14	V_{CB}	Analog Input	Input capacitor voltage after EMI filter.

5 Absolute Maximum Ratings

Absolute maximum ratings are the parameter values or ranges which can cause permanent damage if exceeded. For maximum safe operating conditions, refer to Section 6 Electrical Characteristics.

Parameter	Symbol	Value	Units
DC supply voltage range (pin 4)	V_{CC}	-0.3 to 6	V
V_{IN} input (pin 1)		-0.3 to 6	V
CFG input (pin 3)		-0.3 to 6	V
V_{PP} input (pin 2)		-0.3 to 20	V
I_{SENSE} input (pin 7)		-0.3 to 6	V
V_S input (pin 8)		-0.3 to 20	V
SDA input (pin 10)		-0.3 to 6	V
SCL input (pin 11)		-0.3 to 20	V
V_D input voltage (pin 13)		-0.3 to 6	V
V_{CB} input voltage (pin 14)		-0.3 to 6	V
Maximum V_D input current (pin 13)	$I_{IN(VD)}$	750	µA
Maximum V_{CB} input current (pin 14)	$I_{IN(VCB)}$	750	µA
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-PCB [gnd lead]	Ψ_{JB}	45	°C/W
ESD rating per JEDEC JESD22-A114		±1,000	V
Latch-up test per JESD78A		±100	mA

6 Electrical Characteristics

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
V_{IN} SECTION						
Start-up voltage threshold (Note 2 & 3)	$V_{IN(ST)}$	T_A = 25°C, pulse width ≥ 500μs		0.4		V
Over-voltage shutdown threshold -00/-20 (Note 2 & 3)	$V_{IN(OVP)}$	T_A = 25°C	1.582	1.758	1.933	V
Over-voltage shutdown threshold -01/-21 (Note 2 & 3)	$V_{IN(OVP)}$	T_A = 25°C	1.512	1.68	1.848	V
V_{IN} scaling resistance (Note 4)	Z_{VIN}	After start-up, T_A = 25°C	2.425	2.5	2.575	kΩ
V_{IN} sampling range (Note 2 & 3)	V_{IN}	After start-up	0		1.8	V
V_D/V_{CB} SECTION						
Output over-voltage protection (OVP) threshold (Note 3)	$V_{SENSE(OVP)}$	T_A = 25°C, negative edge		1.95		V
Output nominal threshold (Note 3)	$V_{SENSE(NOM)}$	T_A = 25°C, negative edge		1.5		V
Output under-voltage protection (UVP) threshold	$V_{SENSE(UVP)}$	T_A = 25°C, negative edge		0.3		V
Source Switch SECTION						
Internal switching MOSFET ON-resistance	$R_{DS(ON)}$	T_A = 25°C		0.2	0.4	Ω
Maximum switching frequency (Note 5)	$f_{SW(MAX)}$			90		kHz
Sinking current at half range (Note 6)	$I_{PK(CS)\_HALF}$	V_S = 12V, T_A = 25°C		134		mA
V_{CC} SECTION						
Operating voltage	V_{CC}	T_A = 25°C		5	5.6	V
Start-up threshold	$V_{CC(ST)}$			5		V
Under-voltage lockout threshold	$V_{CC(UVL)}$			4		V
Operating current	I_{CC}			2.5		mA
I_{SENSE} SECTION						
I_{SENSE} short protection reference	V_{RSENSE}			0.16		V
Over-current limit threshold	V_{OCP}			0.4		V

6 Electrical Characteristics (continued)

V_{CC} = 5V, -40°C ≤ T_A ≤ 85°C, unless otherwise specified (Note 1)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Configuration SECTION						
CFG pin configuration current	$I_{CFG(CFG)}$		95	100	105	µA
Temperature Derating and Over-Temperature Protection SECTION						
Shutdown threshold (Note 3)	$T_{OTP(START)}$			150		°C

Notes:

Note 1. Adjust V_{CC} above the start-up threshold before setting at 5V.

Note 2. Refer to the voltage level at the V_{IN_A} point in Figure 8.1. The typical impedance between the V_{IN} pin and V_{IN_A} point is 500Ω.

Note 3. These parameters are not 100% tested. They are guaranteed by design.

Note 4. Refer to Z_{VIN} in Figure 8.1.

Note 5. Operating frequency varies based on the line and load conditions. See the Theory of Operation section (Section 9) for more details.

Note 6. The peak sinking current is twice the sinking current at half range.

7 Typical Performance Characteristics

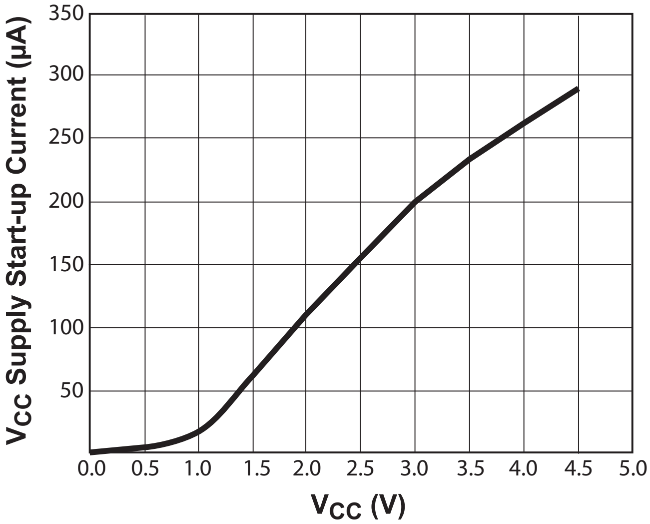


Figure 7.1 : V_{CC} vs. V_{CC} Supply Start-up Current

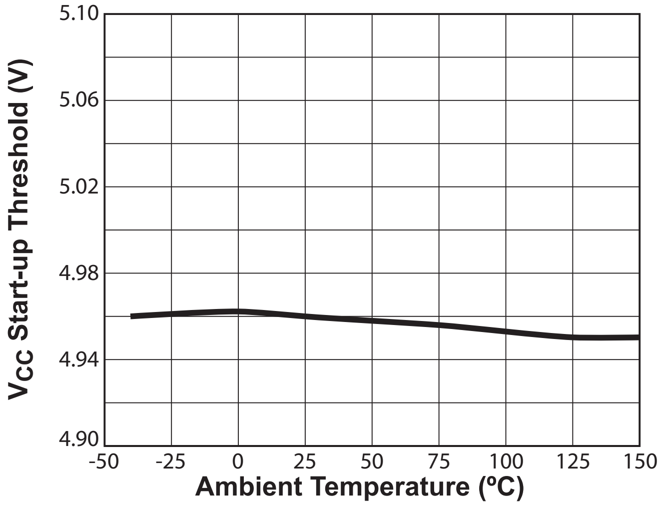


Figure 7.2 : V_{CC} Start-Up Threshold vs. Temperature

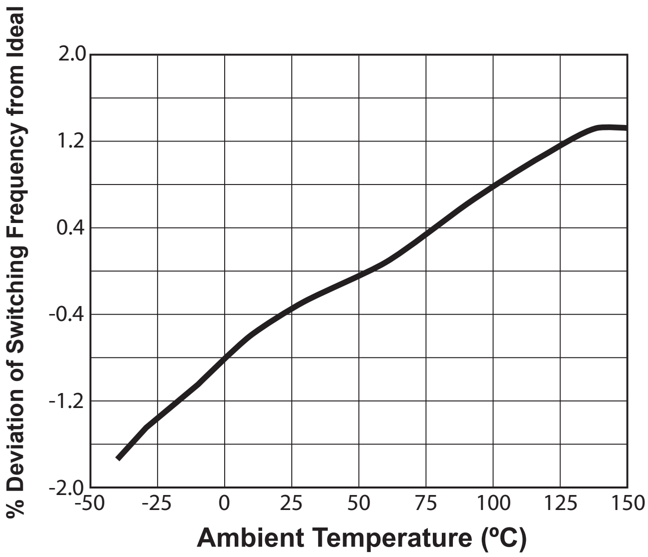


Figure 7.3 : % Deviation of Switching Frequency to Ideal Switching Frequency vs. Temperature

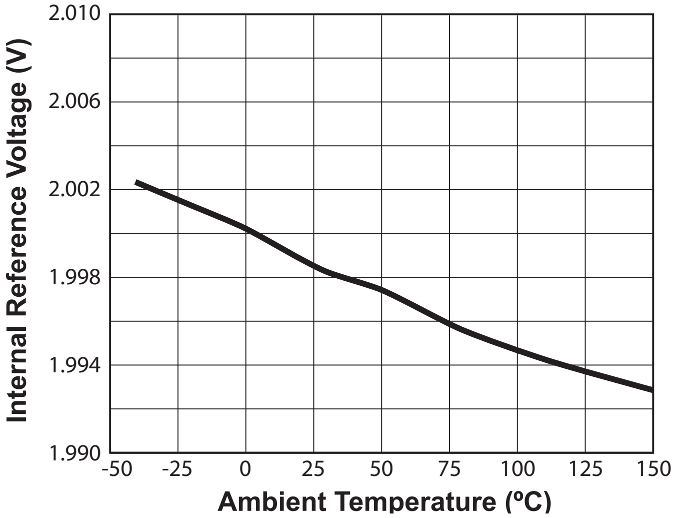


Figure 7.4 : Internal Reference vs. Temperature

8 Functional Block Diagram

This section discusses the iW3690 functional block.

8.1 Digital Core

The digital core has two major operational modes:

1. Stand-alone mode

2. I²C-slave mode

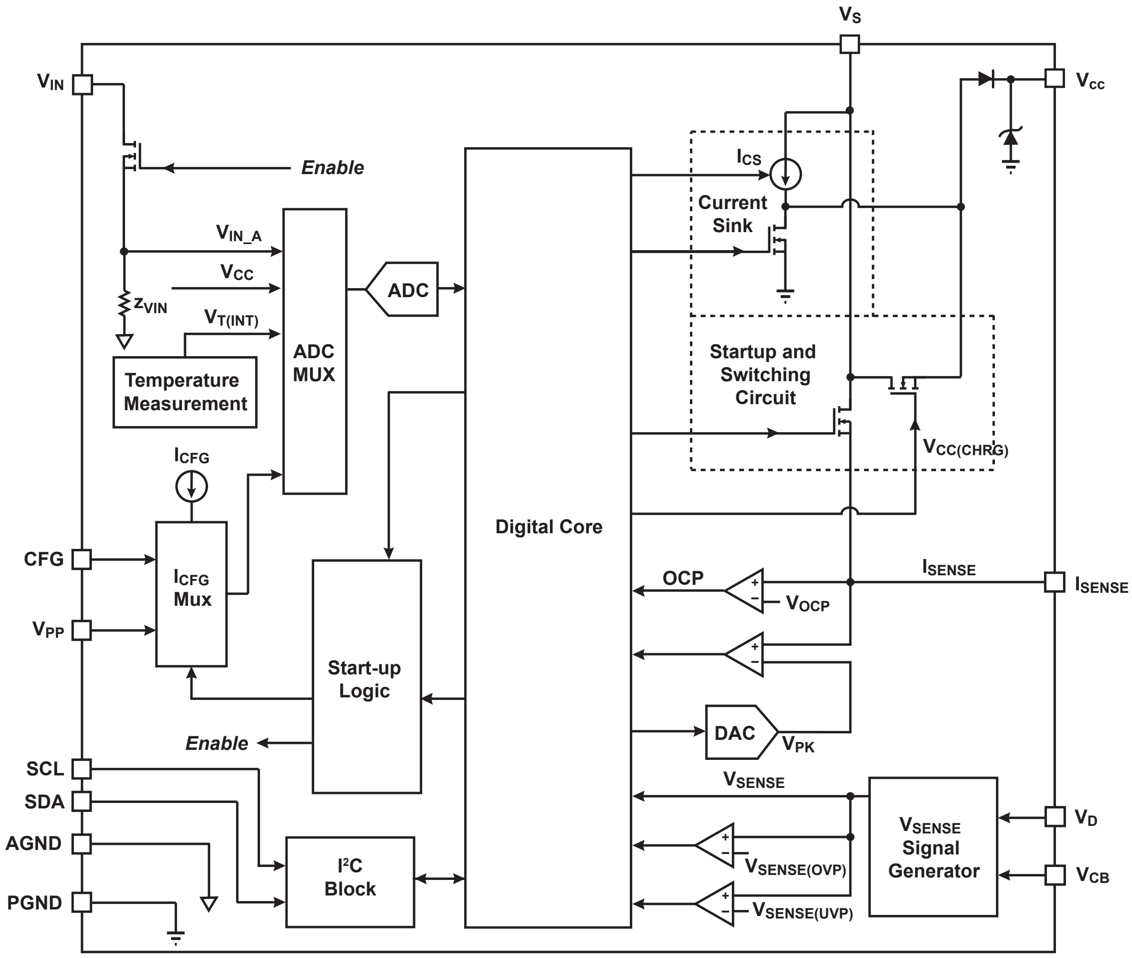


Figure 8.1 : iW3690 Functional Block Diagram

8.1.1 Stand-Alone Mode

When there is no I²C command from the external controller (for example, an MCU in RF module), the digital core operates in stand-alone mode. In this mode, it analyzes the rectified AC waveform and determines whether a dimmer is connected on the line. There are two modes in the iW3690: no-dimmer and phase-cut mode. When there is no dimmer on the line, the iW3690 operates in “no dimmer mode”. Only switching is used for best power efficiency. When there is a wall dimmer on the line, the iW3690 operates in “phase-cut mode”. Switching is used for powering the LED and current-sink is for interfacing with the wall dimmer and V_{CC} maintenance. More information can be found in section 9.1

8.1.2 I²C-Slave Mode

When receiving valid commands from the I²C bus, the digital core works in the I²C-slave mode. In this mode, the external controller (MCU) can read information through the I²C bus regarding whether there is a wall dimmer on the line and information about the phase angle. Based on that information, the MCU firmware can be designed to set the LED light output level and mode of operation (no dimmer mode, phase-cut mode) based on both the wall dimmer phase and light brightness level request from an end-user, such as an app of a smart phone or a remote controller. More information about this can be found in section 9.2.

8.2 V_{SENSE} Direct Sensing

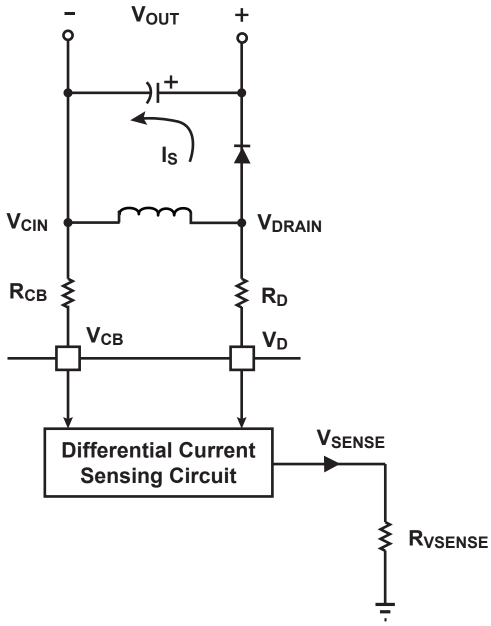


Figure 8.2 : V_{SENSE} Circuit Inside the iW3690

In conventional LED driver solutions, there is an auxiliary winding in the main inductor/transformer. Three main functions of this auxiliary winding are: 1. To supply V_{CC} for the controller IC; 2. To provide output voltage information; 3. To provide magnetic flux information of the inductor. The iW3690 does not rely on the auxiliary winding to charge the V_{CC}. In addition, Dialog's proprietary V_{SENSE} Direct Sensing technology allows the iW3690 to obtain LED output voltage and magnetic flux information without an auxiliary winding.

Inside the iW3690, there is a high performance differential current sensing circuit between the V_D and V_{CB} pin (shown in Figure 8.2). This circuit generates a differential current that is equal to the current flow into the V_D pin subtracted by the current flow into the V_{CB} pin. This differential current is directed to an internal precise resistor, R_{VSENSE}, to generate a voltage called V_{SENSE}. The V_{SENSE} is essentially a scaled-down version of V_{DRAIN} minus V_{CIN}, which is the same as the auxiliary winding generated signal.

The resistances of R_{CB} and R_D are determined by the nominal output voltage, V_{OUT}. In Figure 13.1 R_{CB} refers to R13, and R_D refers to R15.

$$V_{SENSE} = \left(\frac{V_{DRAIN}}{R_D} - \frac{V_{CIN}}{R_{CB}}\right) \times R_{VSENSE} \qquad (8.1)$$

During the period of inductor discharge, the V_{DRAIN} minus V_{CIN} is approximately equal to V_{OUT}. By making R_{CB} and R_D the same, their values can be determined by

$$R_{CB} = R_D = \frac{V_{OUT}}{V_{SENSE}} \times R_{VSENSE} \qquad (8.2)$$

8.3 Controller Power Management

Unlike most off-line LED controllers, the iW3690 does not rely on the auxiliary winding of the main power inductor/ transformer to supply the operating current. Instead, it uses Dialog's proprietary multi-path charging technology to sustain the V_{CC} voltage. Also, a lower nominal V_{CC} level is made possible with a source switching structure, which reduces the IC power consumption and enables the use of a smaller size V_{CC} capacitor.

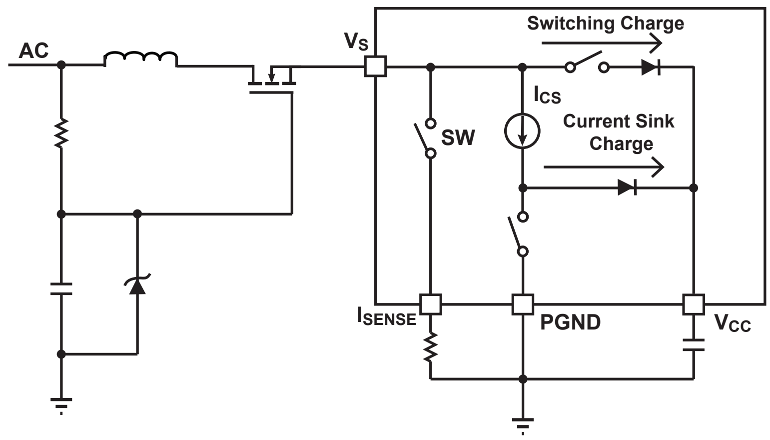


Figure 8.3 : V_{CC} Charging Circuit

The iW3690's operating current is supplied by two paths (shown in Figure 8.3). The first path, called switching charge, re-directs the switching current into the V_{CC} capacitor when the MOSFET is turned on. The second path, called sinking charge, re-directs the sinking current into the V_{CC} capacitor. When there is no dimmer on the line and iW3690 is in stand-alone mode, only the switching charge is used to achieve high efficiency. When there is a dimmer on the line or when dimming is in the I²C-slave mode, both the switching and sinking charge are used to ensure the V_{CC} is sustained across the entire dimming range.

The iW3690 regulates the V_{CC} voltage by adjusting the duration of the charging time. The V_{CC} voltage is smoothly regulated to the nominal level when the iW3690 operates in no-dimmer mode. When the iW3690 operates in dimmer mode, the window for V_{CC} charging is limited. Therefore, the iW3690 charges the V_{CC} voltage to $V_{CC(HIGH)}$ in the charging window. Although the V_{CC} voltage droops before the next charging window, the iW3690 guarantees the V_{CC} level is always above the $V_{CC(UVL)}$ when a proper sized V_{CC} capacitor is used.

8.4 Miscellanous Functional Blocks

The iW3690 uses a source-switching structure where power loop current goes into the IC from the V_S pin. Internally, the V_S current is routed to different paths for switching, current-sinking, and V_{CC} maintenance. For switching, the peak current mode control is used by comparing the target peak current level (DAC) with the actual peak current multiplied by the current sense resistor. Once the target peak current is reached, the power FET is turned off.

The ADC in the iW3690 is used to sense the input voltage level and shape, the V_{CC} level, as well as the internal temperature sensor through a mux. The V_{IN} information reflecting the AC voltage shape is used to determine the wall dimmer presence and phase angle. The V_{CC} is sampled so that it is maintained within the target range. The V_T is used for temperature derating and OTP shutdown protection. See Section 11.3 for details.

9 Theory of Operation

9.1 Stand-alone Operation

When the iW3690 I²C bus is not connected to an external controller (MCU), it works as a stand-alone LED controller that can be dimmed by wall dimmers.

9.1.1 System Start-up

When the AC voltage is applied, the gate voltage of MOSFET V_G is charged up through the RC circuit (R6, and C5 in Figure 13.1). When $V_{GS} > V_{GS(TH)}$, the MOSFET starts to turn on and charge the V_{CC} capacitors (C7 and C8 in Figure 13.1). When the V_{CC} voltage reaches the V_{CC} start-up threshold $V_{CC(ST)}$, the iW3690's control logic is activated and the IC starts up.

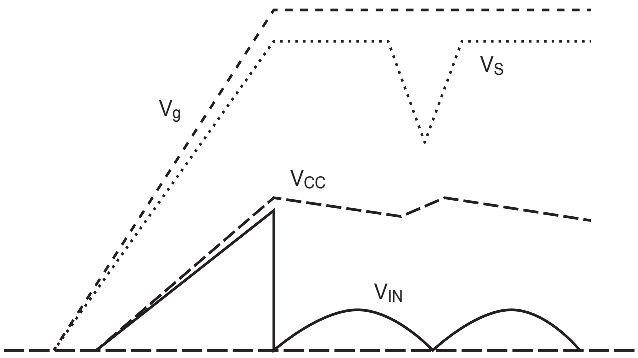


Figure 9.1 : Start-up Sequence Diagram

9.1.2 Wall Dimmer Detection

The wall dimmer cuts a portion of the AC voltage in time domain (shown in Figure 9.2) to lower the RMS input voltage of the lamp to achieve dimming with incandescent lamps. Therefore, it is also called a phase-cut dimmer. Normally, a wall dimmer is either an R-type or RL-type.

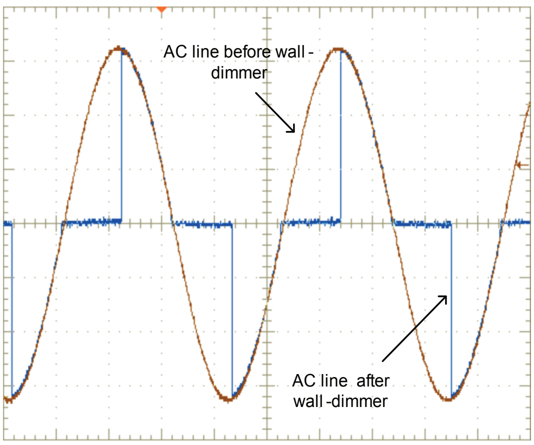


Figure 9.2 : Wall Dimmer Waveform

The dimmer detection stage occurs in the iW3690 immediately after the IC starts up. During this stage, the iW3690 stays in the current sink mode to place a low impedance load on the AC line, where the current through MOSFET is regulated by the digital core. As a result, the iW3690 can accurately detect whether there is a wall dimmer on the AC line.

When the V_{IN_A} signal is above $V_{IN(ST)}$ for 500μs and the AC line frequency is within the range, the AC input signal is qualified for a start-up. If the V_{CC} drops below $V_{CC(UVL)}$, the iW3690 resets and the start-up sequence is initiated.

9.1.3 No-Dimmer Operation

If there is no dimmer on the line, the iW3690 operates in no-dimmer mode to optimize power factor and to minimize harmonic distortion. The current sink circuit is disabled in this mode and only the switching circuit is used.

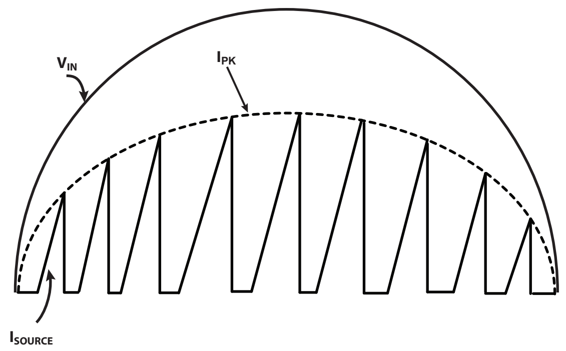


Figure 9.3 : Peak Current Regulation in No-Dimmer Mode

The iW3690 works in critical conduction mode. The power inductor current in one switching cycle is the combination of I_P and I_S in Figure 9.4 below. The average output current in one switching cycle can be expressed by the I_{SEC} below,

$$I_{SEC} = 0.5 \times I_{PK} \times \frac{T_R}{T_P} \qquad (9.1)$$

where I_{PK} is the peak value of the L1 (shown in Figure 13.1) current, T_R is the L1 current ramp-down time, and T_P is the entire switching period.

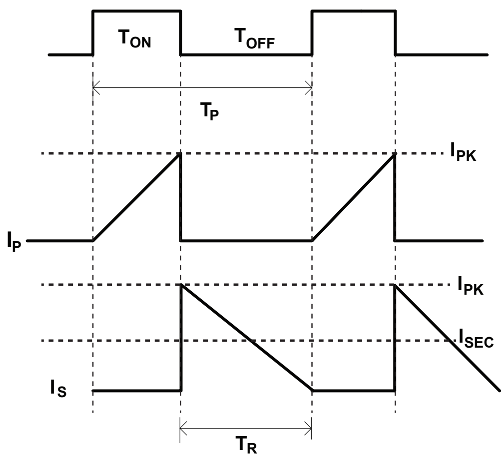


Figure 9.4 : Cycle-to-Cycle Peak Current Regulation

The I_{PK} is determined by the voltage generated on the current sense resistor R19 (shown in Figure 13.1): $I_{PK} = V_{PK}/R19$. Therefore, the equation can be written as

$$I_{SEC} = 0.5 \times \frac{V_{PK}}{R19} \times \frac{T_R}{T_P} \qquad (9.2)$$

In steady state, the average output current is equal to the average I_{SEC} over one half-AC-cycle. Therefore, the average output current can be obtained by averaging equation 9.2 over one half-AC-cycle.

The iW3690 regulates the averaged V_{PK} * (T_R/T_P) to be a constant over one AC half-cycle. Therefore, the nominal output current $I_{OUT(NOM)}$ can be determined by equation 9.3.

$$I_{OUT(NOM)} = \frac{0.5}{R19} \times 0.35V \times \eta \qquad (9.3)$$

η is the converter efficiency.

9.14 Phase-Cut Mode Operation

If there is a wall dimmer on the line, the iW3690 operates in phase-cut mode to match the impedance required for the wall dimmer.

During zero-crossing, the current-sink circuit provides a low impedance loading to enable the RC timer inside the wall dimmer to function properly and fires the TRIAC when a phase angle is reached. Once the TRIAC fires, the switching circuit is operating to provide holding current for the wall dimmer as well as delivering energy to the LED. After the desired output current is delivered to LED, both current-sink and switching circuit are turned off. At the AC zero-crossing point, the current sink circuit is activated again to discharge the capacitor in the driver and start the next AC half-cycle.

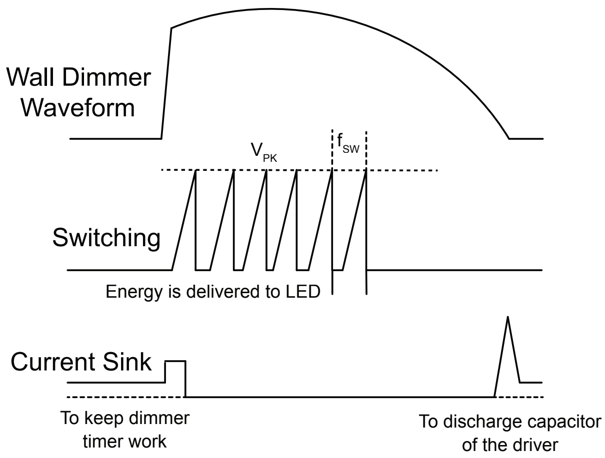


Figure 9.5 : Phase Cut Mode Operation

The peak current in the inductor (V_{PK}) is a fixed value set by the internal register. The switching frequency (f_{SW}) is also a fixed value set by the internal register. If the buck-boost or flyback is operating in DCM, a fixed V_{PK} and f_{SW} control can achieve stable I_{SEC} regulation because the energy delivered to the LED is fixed regardless of input voltage variation.

The instantaneous inductor current delivered to the LED is accumulated every switching cycle. The iW3690 uses the same method to calculate the output current level as no-dimmer operation. When the accumulated current delivery in one half-AC-cycle reaches $I_{OUT(DIM)}$, the iW3690 disables the switching circuit. The reference output current, $I_{OUT(DIM)}$, is calculated by equation 9.4.

$I_{OUT(DIM)} = I_{OUT(NOM)} \times$ dimming percentage *(9.4)*

An internal mapping between the phase conduction angle percentage and dimming percentage is pre-programmed in the iW3690 as shown in Figure 9.6

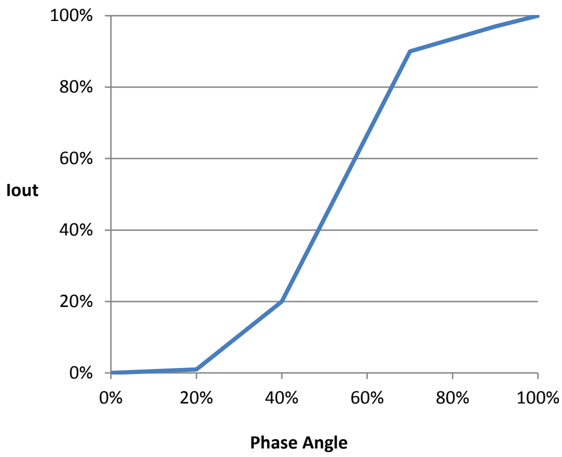


Figure 9.6 : iW3690 Internal Mapping

In stand-alone mode, the iW3690 sets the LED current percentage based on wall dimmer phase angle. The mapping is illustrated in Figure 9.6. In I²C-slave mode, an external MCU can override the iW3690 and independently set output current percentage to achieve further dimming under a given dimmer phase conduction angle. (See section 9.2.3 for details).

9.2 I²C-Slave-Mode Operation

This section discusses the I²C-slave-mode operation.

9.2.1 Connection and Setting

When working in the I²C-slave mode, the iW3690 can be connected to an external controller (MCU) via an I²C bus. Both the SCL and SDA pins need to be externally pulled up to 3.3V with 4.7kΩ resistor respectively. The I²C interface operates at 100kHz (standard mode) and the iW3690 is configured as a slave device. See section 12.0 for details of the iW3690's I²C protocol definition. The SCL and SDA pins should be configured as an open-drain in the MCU.

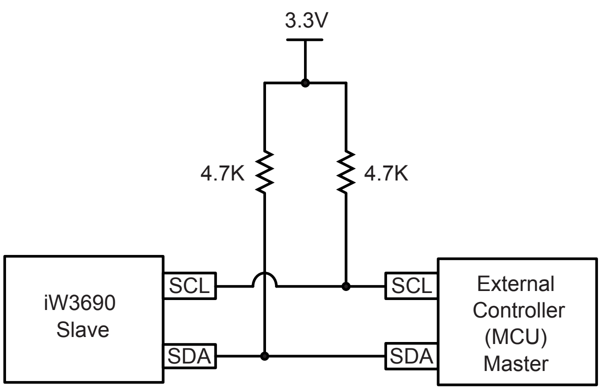


Figure 9.7 : I²C Connection Between iW3690 and External Controller

9.2.2 Control Registers

The control registers of iW3690 are listed in Table 9.1 as below.

Name	R/W	Range	Description
Dimmer phase R0x76 [6:0]	R only	0 - 100	For MCU to determine if there is a wall dimmer and dimmer conduction phase. If > 88, it is considered as no-dimmer; if < 85 it is considered as there is a dimmer.
Control type R0x10 [7]	R/W	0/1	When set to 0, the iW3690 is in a stand-alone mode. When set to 1, the iW3690 is in an I²C-slave mode.
Output level R0x10 [6:0]	R/W	0 - 100	Sets the output current percentage when the iW3690 is in I²C-slave mode.
On / off R0x52 [0]	R/W	0/1	When set to 0, the iW3690 runs normally; When set to 1, the iW3690 stays in power-on SHUTDOWN mode. Internal registers keeps their values as long as V_{CC} is above $V_{CC(UVL)}$.
Dimmer parameter R0x3B	R/W	0-255	To set current-sink value for wall dimmers. Use 0x40 when there is no wall dimmer. Use 0xF0 when there is a wall dimmer.
Dimmer parameter R0x3D	R/W	0-255	To set current-sink value for wall dimmer configuration stage. Use 0x0C when there is no wall dimmer. Use 0x30 when there is a wall dimmer.
Fault registers R0x77, R0x75 [4:3]	R only	0-255	When = 0, no fault. Any bit = 1 means there is a certain kind of fault.
Passkey register R0x42	W only	0-255	Password to access the iW3690. Need to write this register after AC power on. Once written and passed, no need to write again unless the AC power cycles.

Table 9.1: iW3690 Control Register Table

9.2.3 MCU Firmware Control Flow

Dimmer/No dimmer Detection

The MCU needs to periodically monitor for a wall dimmer and the phase angle of the wall dimmer. It is recommended to read the dimmer phase register around every 100ms and to compare it with decimal number 88. If the phase register is > 88, it can be considered as no dimmer on the line; If the phase register is < 85, it can be considered as there is a wall dimmer on the line. There is a hysteresis of 3 to avoid back-and-forth transition.

LED Current Mapping vs. Dimmer Phase

Once the dimmer phase angle is acquired, it is necessary to know what the LED current percentage is if the iW3690 is working in a stand-alone mode. This is because the internal mapping of the iW3690 is also the maximum LED current level that a given dimmer phase angle can possibly support. Therefore, the upper boundary of the dimming level that the MCU can set is limited by this mapping. Figure 9.8 illustrates this concept. The internal dimming mapping of the iW3690 has four critical points. They are:

- 20% phase maps to 1% I_{OUT}
- 40% phase maps to 20% I_{OUT}
- 70% phase maps to 90% I_{OUT}
- 90% phase maps to 97% I_{OUT}

Any point in-between can be derived by a linear regression.

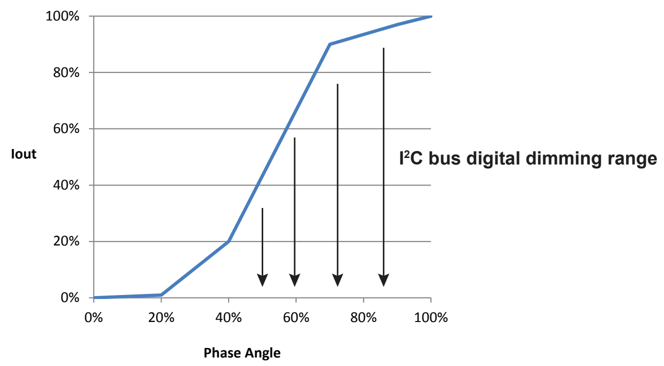


Figure 9.8 : MCU Dimming Range vs. Phase Angle

Dimming with Wall Dimmers

As the iW3690 is working in an I²C-slave mode, the iW3690 does not have the ability to change the LED current level by itself when the dimmer phase changes. Therefore, it is necessary for the MCU to read the dimmer phase periodically and update the iW3690 LED current according to the dimmer phase change. The recommended time interval for reading a dimmer phase is 100ms to ensure the smoothness of the wall dimming.

Once the dimmer phase is read, the firmware should be able to determine: whether the dimmer phase has any change compared to the previous read. If not, do nothing. If yes, update the iW3690 LED current percentage through I²C bus based on the latest phase information and mapping.

There are two common control strategies to set LED current:

1. Digital dimming takes the control with LED current upper limit set by dimmer phase

Set the LED current based on the smaller number between dimmer phase mapping and digital dimming requested level. In this case, the digital dimming has superiority over a dimmer. The LED current does not follow a dimmer phase change unless the dimmer phase is too small to support digital dimming requested output level. For example, the digital dimming requests to output 70% LED current. The dimmer sets a phase to 30% which mapped to 15% current according to the mapping curve in Figure 9.8. The MCU firmware needs to set the LED current to 15%, as 30% dimmer phase cannot support 70% LED current.

2. Latest action takes the control

Set the LED current based on dimmer phase mapped result as soon as the dimmer phase changes. In this case, the LED output always responds to a dimmer action. It avoids “freeze” of the LED current output even the dimmer phase changes in the previous case, if the digital dimming requested level is always < dimmer phase mapped result.

However, the side impact in this case is that the LED current may have an abrupt change in the following situation: the last digital dimming requested level is low and the dimmer phase is large in a steady state. Then the dimmer phase change and digital dimming has no new request, light output jumps from a low level (previously set by digital dimming) to a high level (currently set by wall dimmer).

Dimming with Digital Dimming

When MCU receives an external commend from the end user through a wireless signal to adjust the LED output level, it can write to the "output level" register through the I²C bus. The output level is a decimal from 1 to 99 representing 1% to 99% LED output current level.

For 100%, a firmware needs to separate the two cases. When there is no dimmer (by reading the phase register as described in the previous section), the firmware needs to set the control type register to 0 for best efficiency and power factor. If there is a wall dimmer, the firmware needs to set the control type register to 1 and write 100 to the output level register to output the full brightness while keeping the dimmer impedance matched.

Remote Standby

When the MCU receives an external command from the end user through a wireless signal to turn off the LED, the firmware also needs to separate the two cases to have the iW3690 turning off LEDs.

When there is no dimmer (by reading the phase register as described in the previous section), the firmware needs to set on/off the register to 1 for the lowest standby power. If there is a wall dimmer, the firmware needs to write 0 to the output level register to turn off the LED while keeping the dimmer impedance matched.

To turn the LED on, if there is no dimmer, set the on/off register to 0. If there is a dimmer, set the output level register to any value except 0 as requested by end user.

Fault Protection Handling

It is necessary for the firmware to read the fault register once a while to check if there is any fault condition of the smart lighting system. If any bit of the fault registers is 1, it means one or more fault conditions happened.

When a fault happens, the iW3690 cannot reset itself because an auxiliary power supply is holding up the V_{CC}. The firmware needs to toggle on/off the register to reset the iW3690 by writing 1 and 0 through the I²C bus. It is recommended to have 10ms interval between writing 1 and 0. It is also recommended to reset the iW3690 once per second or longer if a fault condition continuously exists. This is to avoid resetting the iW3690 too frequently, which causes over-stress of the LED driver board.

9.3 Auxiliary Power Supply

This section discusses auxiliary power supply for the iW3690-based smart lighting LED driver.

9.3.1 Overview and Requirement

In order to provide V_{CC} to the MCU module and the iW3690 at remote standby state, an auxiliary power supply system is necessary. The power supply should have the capability to take AC line voltage input and convert it to about $5V_{DC}$ output without excessive voltage ripple.

- For RF/MCU module that consumes < 4mA, LDO can be used with reasonable power loss and meet 500mW standby.
- For RF/MCU module that consumes > 4mA, a high voltage buck converter is recommended to fulfill this function.

A low voltage LDO is necessary to convert $5V_{DC}$ output of auxiliary power supply to the RF/MCU module V_{CC}. The main reason is to remove the high frequency noise and keep sensitive analog circuit of the MCU/RF module quiet.

9.3.2 Example Designs

The Dialog CR1510 or Dialog iW1840 off-line PWM controller is a good fit for the iW3690's auxiliary power supply when necessary. An example design based on the Dialog CR1510 is shown in Figure 9.9 below.

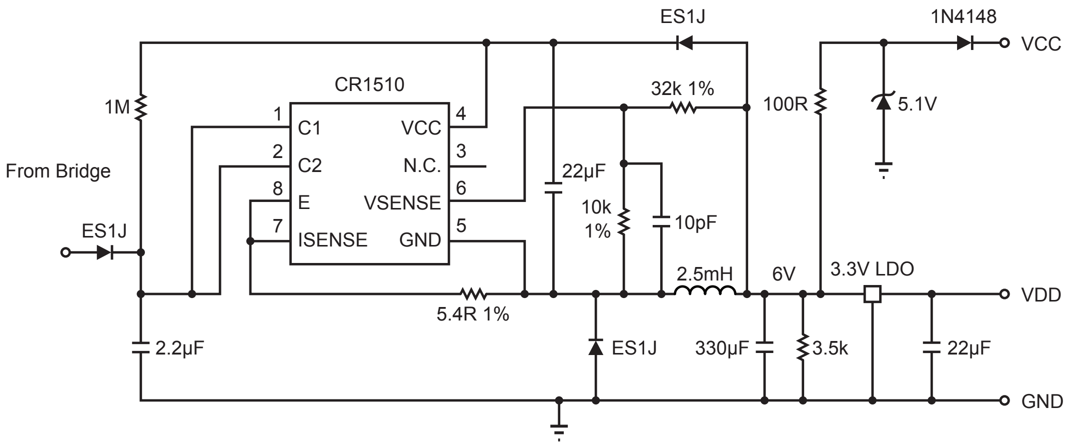


Figure 9.9 : CR1510-Based Auxiliary Power Supply System Reference Design

10 Configuration

At start-up, a current source in the iW3690 drives the configuration current I_{CFG} (100µA) into the CFG pin. The iW3690 reads the CFG pin voltage to determine the configuration option. The CFG pin configuration selects the temperature derating start point. A resistor of 18kΩ should be connected between the V_{PP} pin to GND for all application designs.

By choosing different resistor values for R18 (shown in Figure 13.1), different configuration values are selected (illustrated in Table 10.1).

CFG Option	CFG Pin Resistor (R18 in Fig. 11.1)			Temperature Derating Starting Point (°C) (Internal Sensor) (Fig. 9-11)
	Typical Value (kΩ)	Min Value (kΩ)	Max Value (kΩ)	
0	0.40		0.69	disable temperature derating
1	1.65	1.39	1.91	100
2	3.00	2.78	3.22	105
3	4.45	4.28	4.62	110
4	6.05	5.88	6.22	115
5	7.85	7.70	8.00	120
6	9.88	9.74	10.01	125
7	12.18	12.04	12.31	130
8	14.85	14.67	15.03	135

Table 10.1 CFG Pin Configuration Resistor Values

11 Protection

This section discusses the iW3690 protection features.

11.1 Output Over-Voltage/LED Open Protection

The iW3690 includes a function that protects against an output over-voltage.

The output voltage is monitored by the V_{SENSE} voltage. If the V_{SENSE} voltage exceeds $V_{SENSE(OVP)}$, the iW3690 shuts down the switching circuit and current sink circuit immediately. As a result, the MOSFET is turned off. After the shutdown of the current sink and switching circuits, the iW3690 remains powered, while the V_{CC} continues to discharge. In order to avoid over-charging of the output voltage, the iW3690 employs an extended discharge time as described below if the V_{CC} does not drop below $V_{CC(UVL)}$. Otherwise, when the V_{CC} drops below $V_{CC(UVL)}$, the iW3690 resets itself and then initiates a new soft-start cycle.

Under the fault condition, the iW3690 tries to start up for three consecutive times. If all three start-up attempts fail, the iW3690 enters an inactive mode, during which the iW3690 does not respond to the V_{CC} power-on requests. The iW3690 is activated again after it sees 29 start-up attempts. Typically, this extended discharge time is around three to five seconds.

11.2 Output Short Protection

The iW3690 includes a function that protects against an output short-circuit fault.

When output is shorted, the V_{SENSE} is below $V_{SENSE(UVP)}$. As a result, an output short fault is detected. The iW3690 shuts down the switching circuit and current sink circuit immediately. As a result, the MOSFET is turned off. After the turn-off of the MOSFET, the iW3690 remains powered while the V_{CC} continues to discharge. In order to avoid excessive power stress due to auto-restart, the iW3690 employs an extended discharge time as described in section 11.1 if the V_{CC} does not drop below $V_{CC(UVL)}$. Otherwise, when the V_{CC} drops below $V_{CC(UVL)}$, the iW3690 resets itself and then initiates a new soft-start cycle.

To support applications with high output capacitance, output short protection is not activated during the initial LED current soft start period. This allows the voltage to build up in the output capacitor without triggering the protection.

11.3 Temperature Derating and Over-Temperature Protection

The iW3690 can detect and protect against an over-temperature event. The iW3690 utilizes an internal sensor for temperature measurement.

When the monitored temperature reaches $T_{DERATE(ST)}$, the maximum output current limit begins to reduce linearly from 100% to 70% of the nominal value until the temperature reaches $T_{DERATE(FINISH)}$ threshold as shown in Figure 11.1, where $T_{DERATE(FINISH)} = T_{DERATE(ST)} + 20°C$. At $T_{DERATE(FINISH)}$, the maximum output current limit is clamped to 70%. If the temperature further increases to $T_{OTP(START)}$, the iW3690 shuts down.

The iW3690 remains in a shutdown mode as long as the monitored temperature is above $T_{OTP(START)}$. If the detected temperature falls below $T_{OTP(START)}$ at anytime, the iW3690 starts up. From $T_{DERATE(FINISH)}$ to $T_{DERATE(ST)}$, the maximum output current limit increases linearly from 70% to 100% as shown in Figure 11.1. The device goes back to normal operation if the sensed temperature falls below $T_{DERATE(ST)}$. This bi-directional operation enables the LED current thermal fold-back instead of an abrupt shut-down of the LED current.

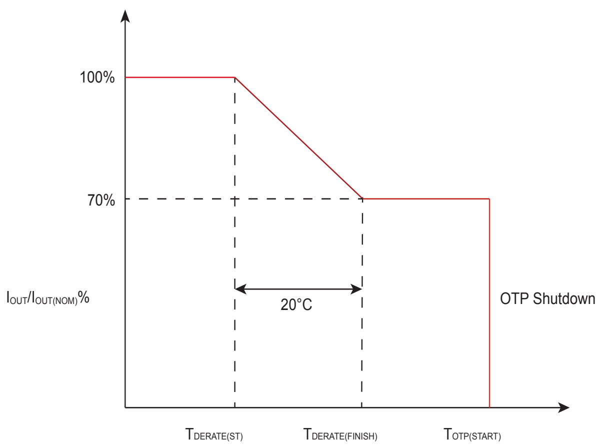


Figure 11.1 : Temperature Derating and OTP

The values of $T_{DERATE(ST)}$ and $T_{DERATE(FINISH)}$ can be adjusted through the CFG pin resistor.

11.4 Over-Current Protection

Over-current protection (OCP) is a feature that is built into the iW3690. With the I_{SENSE} pin, the iW3690 is able to monitor the primary peak current of the buck-boost or flyback converter during switching mode. This allows for cycle-by-cycle peak current control and limit. When the primary peak current multiplied by the I_{SENSE} pin sensing resistor (R19 in Figure 13.1) is greater than V_{OCP}, over-current is detected and the iW3690 immediately shuts down the switching circuit until the next switching cycle. The switching circuit sends out a switching pulse in the next switching cycle, and the switching pulse continues if the V_{OCP} is not reached; or, if the V_{OCP} is reached, the switching pulse turns off again.

11.5 Current Sensing Resistor Short Protection

The iW3690 uses a MOSFET as its main switch for the buck-boost or flyback converter. If the I_{SENSE} pin sensing resistor (R19 in Figure 13.1) is shorted, there is a potential danger of the over-current condition not being detected. Thus the iW3690 is designed to detect this sensing-resistor short fault. When the sensing resistor short fault is detected, the iW3690 shuts down the switching circuit and current sink circuit immediately. As a result, the MOSFET is turned off. After the turn-off of the MOSFET, the iW3690 remains powered while V_{CC} continues to discharge. In order to prevent over-stress of the power circuit components, the iW3690 employs an extended discharge time if the V_{CC} does not drop below $V_{CC(UVL)}$). Otherwise, when the V_{CC} drops below $V_{CC(UVL)}$, the iW3690 resets itself and then initiates a new soft-start cycle.

11.6 Current Sense Resistor Open Protection

If the I_{SENSE} pin sensing resistor (R19 in Figure 13.1) is open and not being detected, it may cause potential damage to the internal circuit during the switching mode. Thus, the iW3690 is designed to detect the I_{SENSE} pin open fault. When the I_{SENSE} pin open fault is detected, the iW3690 shuts down the switching circuit and current sink circuit immediately. As a result, the MOSFET is turned off. After the turn-off of the MOSFET, the iW3690 remains powered while the V_{CC} continues to discharge. In order to prevent over-stress of power circuit components, the iW3690 employs an extended discharge time if the V_{CC} does not drop below $V_{CC(UVL)}$. Otherwise, when V_{CC} drops below $V_{CC(UVL)}$, the iW3690 resets itself and then initiates a new soft-start cycle.

11.7 AC Input Over-Voltage Protection

The iW3690 supports over-voltage protection of the AC input.

If V_{IN_A} is higher than $V_{IN(OVP)}$ continuously for 2ms within every 16ms period, and this condition lasts for eight consecutive half AC cycles, the iW3690 shuts down the switching circuit and current sink circuit immediately. As a result, the MOSFET is turned off. After the turn-off of the MOSFET, the iW3690 remains powered while V_{CC} continues to discharge. The iW3690 employs an extended discharge time before restart if the V_{CC} does not drop below $V_{CC(UVL)}$. Otherwise, when the V_{CC} drops below $V_{CC(UVL)}$, the iW3690 resets itself and then initiates a new soft-start cycle.

12 I²C Interface Description

The I²C interface provides access to the register array via I²C communication; SDA/SCL are used as communication pins respectively. For communication protocols an external pull-up resistor is required – a value of 4.7kΩ is recommended. The I²C interface operates at 100kHz standard-mode and the iW3690 is configured as a slave device.

12.1 I²C-Bus Timing

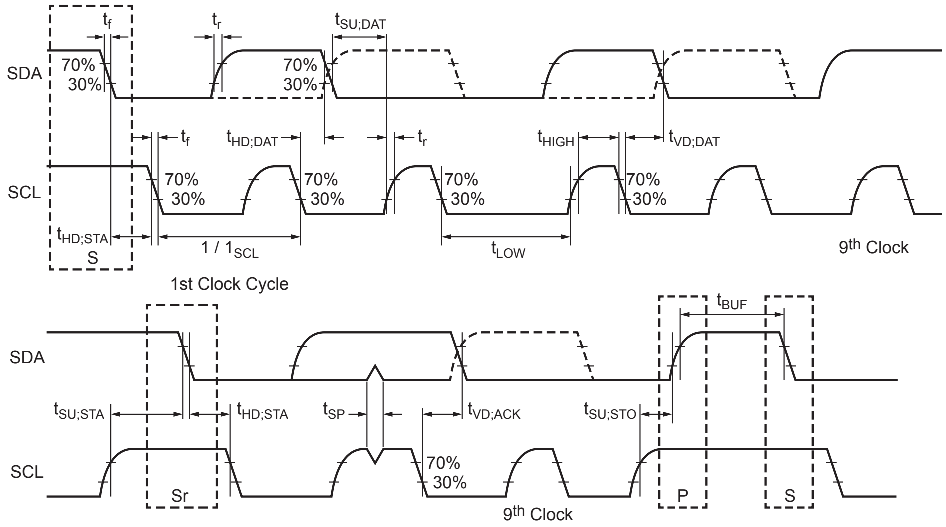


Figure 12.1 : I²C Bus Timing Diagram

12.2 I²C-Bus Protocol

The iW3690 operates as an I²C-bus slave device with default 7-bit slave address of 0x38.

I²C-bus slave address

B7	B6	B5	B4	B3	B2	B1	B0
0	1	1	1	0	0	0	R/W_N

12.3 I²C-Bus Data Layer

Control of the chip via I²C is based on a register access protocol. All data transfers start with an 8-bit address.

I²C bus register writes:

Master writes to slave

S	SLAVE ADDRESS	R/Wn	A	ADDR	A	DATA0	//	An	P

0 = write

N bytes + acknowledge

I²C bus register reads:

Setting the read address

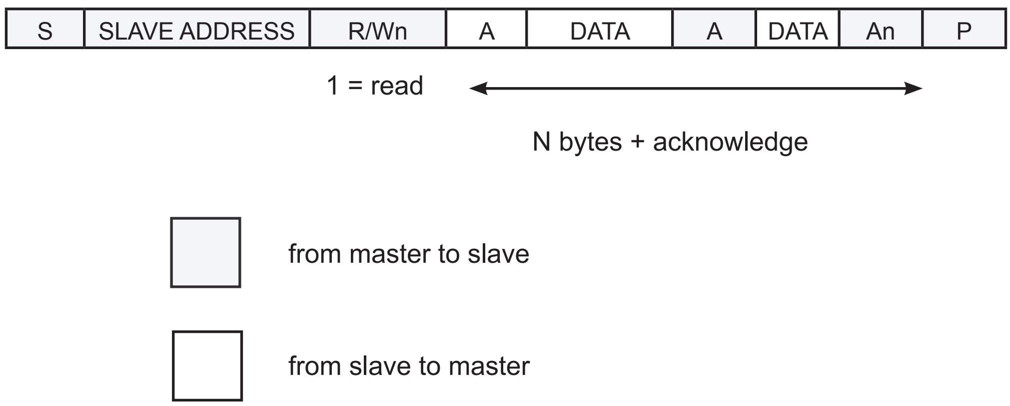
Master writes to slave

S	SLAVE ADDRESS	R/Wn	A	ADDR	P

0 = write

Reading the data

Master writes to slave



A = acknowledge (SDA L)

An = not acknowledge (SDA H)

S = START condition (SDA HL, SCL H)

P = STOP condition (SDA LH, SCL H)

13 Typical Application Circuit

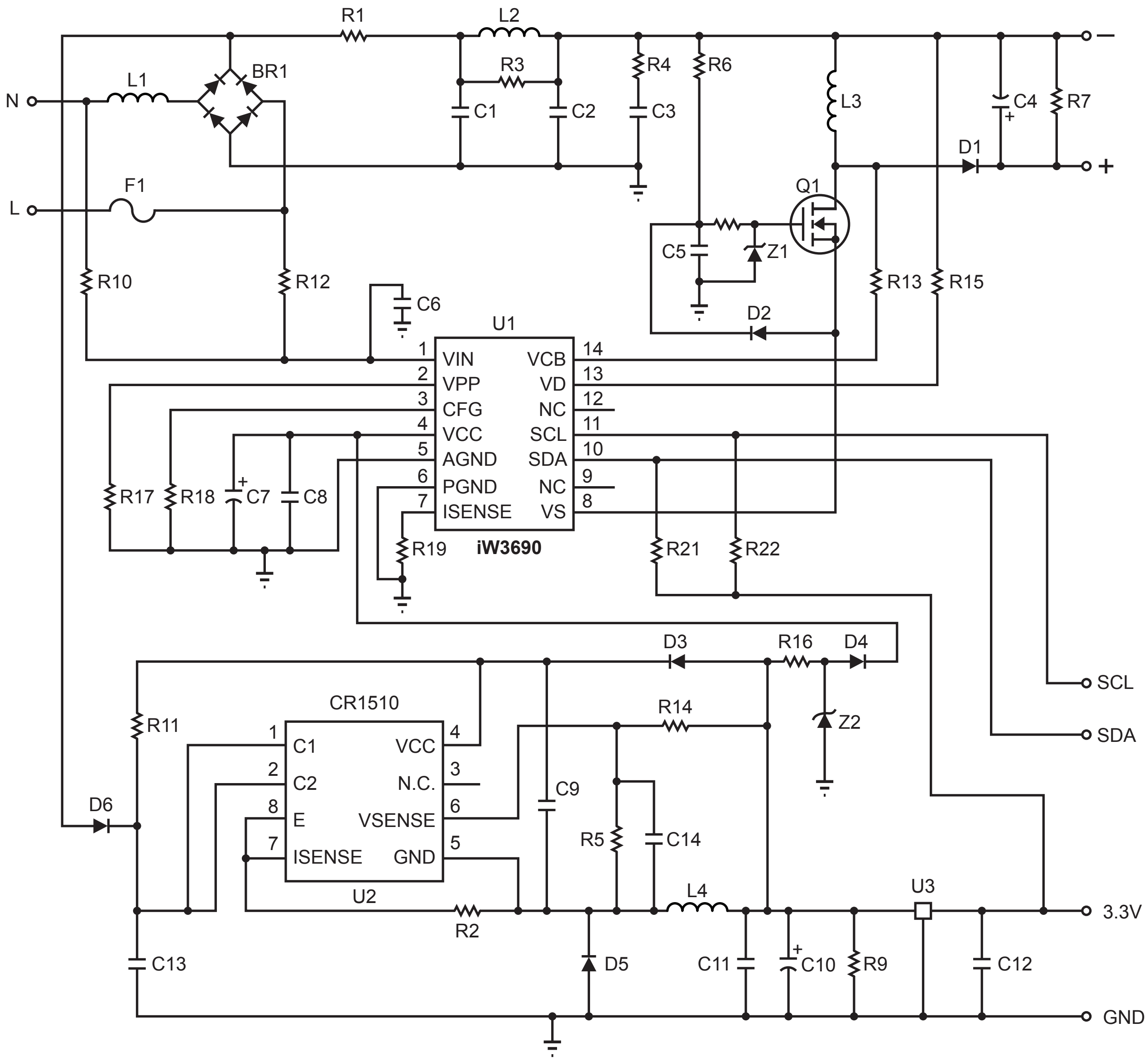


Figure 13.1 : iW3690 Typical Application Circuit with Buck Converter

Typical Application Circuit (continued)

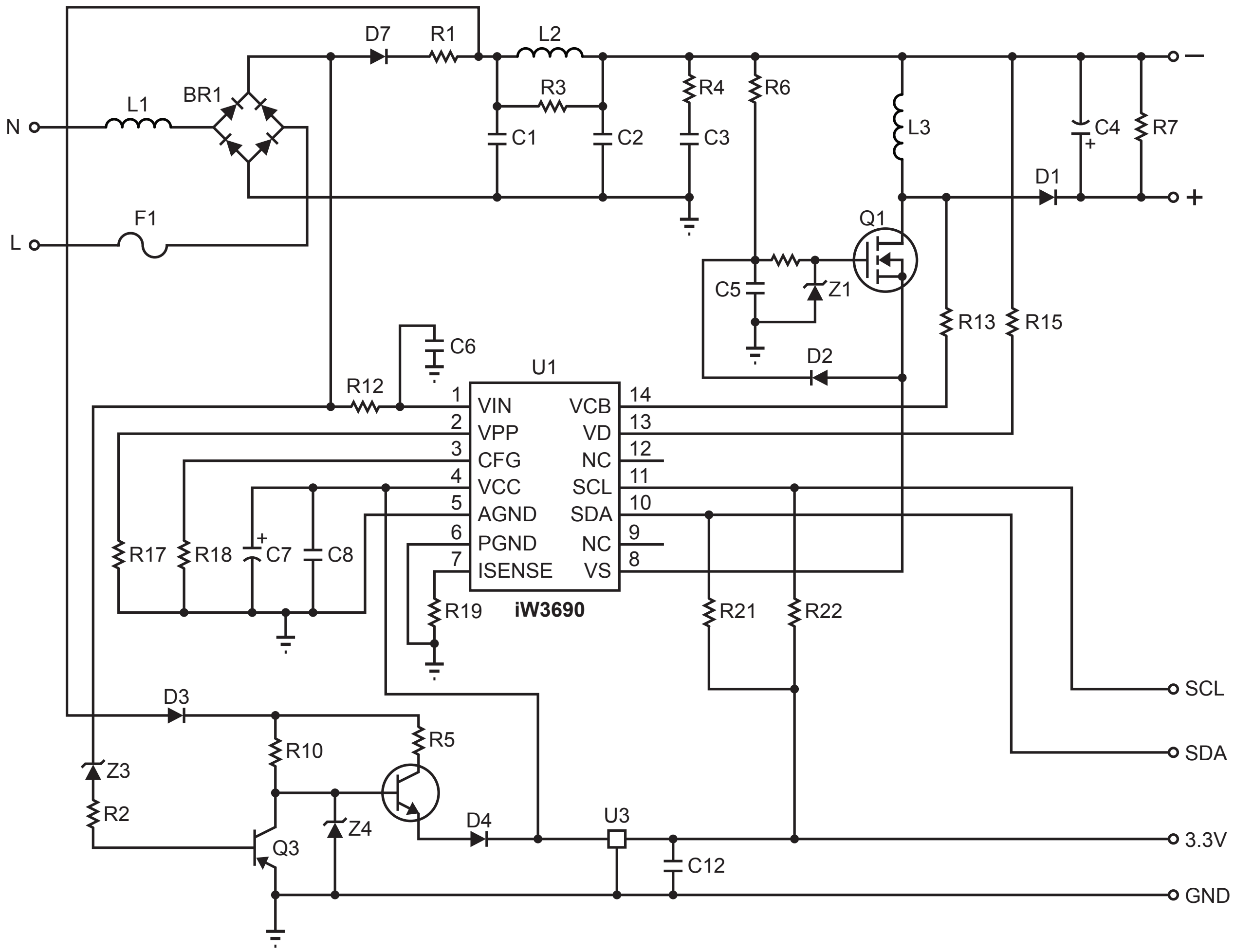
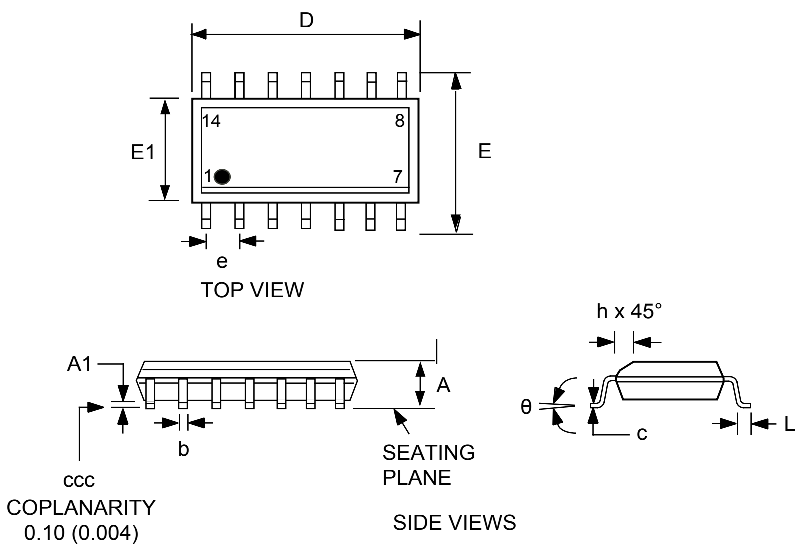


Figure 13.2 : iW3690 Typical Application Circuit with LDO

14 Physical Dimensions

14-Lead SOIC Package



Symbol	Inches		Millimeters	
	MIN	MAX	MIN	MAX
A	0.053	0.069	1.35	1.75
A1	0.004	0.010	0.10	0.25
b	0.013	0.020	0.33	0.51
c	0.007	0.010	0.19	0.25
D	0.337	0.344	8.55	8.75
E1	0.150	0.157	3.80	4.00
E	0.228	0.244	5.80	6.20
e	0.050 BSC		1.27 BSC	
L	0.016	0.050	0.40	1.27
h	0.010	0.020	0.25	0.50
θ	0°	8°	0°	8°
ccc	0.004		0.10	

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 10 s immersion < 260˚C

Dimension D does not include mold flash, protrusions or gate burrs. Mold flash, protrusions or gate burrs shall not exceed 0.15 mm per end. Dimension E does not include interlead flash or protrusion. Interlead flash or protrusion shall not exceed 0.25 mm per side.

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.

Figure 14.1 : 14-Lead SOIC Package

15 Ordering Information

Part No.	Options	Package	Description
iW3690-00	120V_{AC} Input for up to 25W	SOIC-14	Tape & Reel[1]

Note 1: Tape & Reel packing quantity is 2,500/reel. Minimum ordering quantity is 2,500.

Disclaimer

RoHS Compliance

Dialog Semiconductor's suppliers certify that its products are in compliance with the requirements of Directive 2011/65/EU of the European Parliament on the restriction of the use of certain hazardous substances in electrical and electronic equipment. RoHS certificates from our suppliers are available on request.

Contacting Dialog Semiconductor

United Kingdom
Dialog Semiconductor (UK) Ltd
Phone: +44 1793 757700

Germany
Dialog Semiconductor GmbH
Phone: +49 7021 805-0

The Netherlands
Dialog Semiconductor B.V.
Phone: +31 73 640 88 22

Email
info_pcbg@diasemi.com

North America
Dialog Semiconductor Inc.
Phone: +1 408 845 8500

Japan
Dialog Semiconductor K. K.
Phone: +81 3 5425 4567

Taiwan
Dialog Semiconductor Taiwan
Phone: +886 281 786 222

Web site:
www.dialog-semiconductor.com

Singapore
Dialog Semiconductor Singapore
Phone: +65 648 499 29

Hong Kong
Dialog Semiconductor Hong Kong
Phone: +852 2607 4271

Korea
Dialog Semiconductor Korea
Phone: +82 2 3469 8200

China
Dialog Semiconductor (Shenzhen)
Phone: +86 755 2981 3669

Dialog Semiconductor (Shanghai)
Phone: +86 21 5424 9058