1.0 Features

- Isolated AC/DC offline 100V<sub>AC</sub>/230V<sub>AC</sub> LED driver with different external components value
- Line frequency ranges from 45Hz to 66 Hz
- Intelligent wall dimmer detection
  - Leading-edge dimmer
  - No-dimmer detected
  - Unsupported dimmer
- Hybrid dimming scheme
- Wide dimming range from 1% up to 100%
- No visible flicker
- Resonant control to achieve high efficiency, 85% without dimmer
- Temperature compensated LED current
- Small size design
  - Small size input bulk capacitor
  - Small size output capacitor
  - Small transformer
- Primary-side sensing eliminates the need for opto-isolator feedback and simplifies design
- Tight LED current regulation ± 5%
- Fast start-up, typically 10μA start-up current
- Hot-plug LED module support
- Multiple protection features:
  - LED open circuit protection
  - Single-fault protection
  - Over-current protection
  - LED short circuit protection
  - Current sense resistor short circuit protection
  - Over-temperature protection
  - Input over-voltage protection
- Up to 10W output power

2.0 Description

The iW3602-30C is a high performance AC/DC offline power supply controller for dimmable LED luminaires, which uses advanced digital control technology to detect the dimmer type and phase. The dimmer conduction phase controls the LED brightness. The LED brightness is modulated by PWM-dimming. The iW3602-30C’s unique digital control technology eliminates visible flicker.

The iW3602-30C can operate with all dimmer schemes including leading-edge dimmer and other dimmer configurations such as R-type, or R-L type. When a dimmer is not present, the controller can automatically detect that there is no dimmer.

The iW3602-30C operates in a quasi-resonant mode to provide high efficiency. It offers a number of key built-in features and uses advanced primary-side sensing technology to achieve excellent line and load regulation without secondary feedback circuitry. Additionally, its pulse-by-pulse waveform analysis technology allows accurate LED current regulation. The iW3602-30C maintains stability over all operating conditions without the need for loop compensation components. Therefore, the device minimizes external component count, simplifies EMI design, and lowers the overall bill of materials cost.

3.0 Applications

- Dimmable LED luminaires
- Optimized for 3W to 10W output power
AC/DC Digital Power Controllers for Dimmable LED Drivers

4.0 Pinout Description

<table>
<thead>
<tr>
<th>Pin #</th>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OUTPUT(TR)</td>
<td>Output</td>
<td>Gate drive for bleeding MOSFET switch.</td>
</tr>
<tr>
<td>2</td>
<td>VSENSE</td>
<td>Analog Input</td>
<td>Auxiliary voltage sense (used for primary side regulation and ZVS).</td>
</tr>
<tr>
<td>3</td>
<td>VIN</td>
<td>Analog Input</td>
<td>Rectified AC line voltage sense.</td>
</tr>
<tr>
<td>4</td>
<td>VT</td>
<td>Analog Input</td>
<td>External power limit and shutdown control.</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>Ground</td>
<td>Ground.</td>
</tr>
<tr>
<td>6</td>
<td>ISENSE</td>
<td>Analog Input</td>
<td>Primary current sense (used for cycle-by-cycle peak current control and limit).</td>
</tr>
<tr>
<td>7</td>
<td>OUTPUT</td>
<td>Output</td>
<td>Gate drive for main MOSFET switch.</td>
</tr>
<tr>
<td>8</td>
<td>VCC</td>
<td>Power Input</td>
<td>Power supply for control logic and voltage sense for power-on reset circuitry.</td>
</tr>
</tbody>
</table>

Figure 3.1 : iW3602-30C Typical Application Circuit

Figure 4.1 : 8-Lead SOIC-8 Package
5.0 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 Electrical Characteristics in Section 6.0.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC supply voltage range (pin 8, $I_{CC} = 20mA$ max)</td>
<td>$V_{CC}$</td>
<td>-0.3 to 18</td>
<td>V</td>
</tr>
<tr>
<td>DC supply current at $V_{CC}$ pin</td>
<td>$I_{CC}$</td>
<td>20</td>
<td>mA</td>
</tr>
<tr>
<td>OUTPUT (pin 7)</td>
<td></td>
<td>-0.3 to 18</td>
<td>V</td>
</tr>
<tr>
<td>OUTPUT(TR) (pin 1)</td>
<td></td>
<td>-0.3 to 18</td>
<td>V</td>
</tr>
<tr>
<td>$V_{SENSE}$ input (pin 2, $I_{Sense} \leq 10mA$)</td>
<td></td>
<td>-0.7 to 4.0</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IN}$ input (pin 3)</td>
<td></td>
<td>-0.3 to 18</td>
<td>V</td>
</tr>
<tr>
<td>$I_{SENSE}$ input (pin 6)</td>
<td></td>
<td>-0.3 to 4.0</td>
<td>V</td>
</tr>
<tr>
<td>$V_{T}$ input (pin 4)</td>
<td></td>
<td>-0.3 to 4.0</td>
<td>V</td>
</tr>
<tr>
<td>Power dissipation at $T_A \leq 25^\circ$C</td>
<td>$P_D$</td>
<td>526</td>
<td>mW</td>
</tr>
<tr>
<td>Maximum junction temperature</td>
<td>$T_{JMAX}$</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>Operating junction temperature</td>
<td>$T_{JOPT}$</td>
<td>-40 to 150</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>$T_{STG}$</td>
<td>-65 to 150</td>
<td>°C</td>
</tr>
<tr>
<td>Thermal Resistance Junction-to-Ambient [Still Air]</td>
<td>$\theta_{JA}$</td>
<td>160</td>
<td>°C/W</td>
</tr>
<tr>
<td>ESD rating per JEDEC JESD22-A114</td>
<td></td>
<td>±2,000</td>
<td>V</td>
</tr>
<tr>
<td>Latch-up test per JESD78A</td>
<td></td>
<td>±100</td>
<td>mA</td>
</tr>
</tbody>
</table>
### 6.0 Electrical Characteristics

$V_{CC} = 12V$, $-40^\circ C \leq T_A \leq 85^\circ C$, unless otherwise specified (Note 1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>V_IN SECTION (Pin 3)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start-up current</td>
<td>$I_{INST}$</td>
<td>$V_{IN} = 10V$, $C_{VCC} = 10\mu F$</td>
<td>10</td>
<td>15</td>
<td></td>
<td>$\mu A$</td>
</tr>
<tr>
<td>Input impedance</td>
<td>$Z_{IN}$</td>
<td>$T_A = 25^\circ C$</td>
<td></td>
<td>2.5</td>
<td></td>
<td>$k\Omega$</td>
</tr>
<tr>
<td>$V_{IN}$ Range</td>
<td>$V_{IN}$</td>
<td></td>
<td>0</td>
<td></td>
<td>1.8</td>
<td>$V$</td>
</tr>
<tr>
<td><strong>V_SENSE SECTION (Pin 2)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input leakage current</td>
<td>$I_{IN(Vsense)}$</td>
<td>$V_{SENSE} = 2V$</td>
<td></td>
<td>1</td>
<td></td>
<td>$\mu A$</td>
</tr>
<tr>
<td>Nominal voltage threshold</td>
<td>$V_{SENSE(NOM)}$</td>
<td>$T_A = 25^\circ C$, negative edge</td>
<td>1.523</td>
<td>1.538</td>
<td>1.553</td>
<td>$V$</td>
</tr>
<tr>
<td>Output OVP threshold</td>
<td>$V_{SENSE(MAX)}$</td>
<td>$T_A = 25^\circ C$, negative edge</td>
<td>1.65</td>
<td>1.7</td>
<td>1.75</td>
<td>$V$</td>
</tr>
<tr>
<td><strong>OUTPUT SECTION (Pin 7)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output low level ON-resistance</td>
<td>$R_{DS(ON)LO}$</td>
<td>$I_{SINK} = 5mA$</td>
<td></td>
<td>30</td>
<td></td>
<td>$\Omega$</td>
</tr>
<tr>
<td>Output high level ON-resistance</td>
<td>$R_{DS(ON)HI}$</td>
<td>$I_{SOURCE} = 5mA$</td>
<td></td>
<td>150</td>
<td></td>
<td>$\Omega$</td>
</tr>
<tr>
<td>Rise time (Note 2)</td>
<td>$t_R$</td>
<td>$T_A = 25^\circ C$, $C_L = 330pF$ 10% to 90%</td>
<td></td>
<td>150</td>
<td></td>
<td>$ns$</td>
</tr>
<tr>
<td>Fall time (Note 2)</td>
<td>$t_F$</td>
<td>$T_A = 25^\circ C$, $C_L = 330 pF$ 90% to 10%</td>
<td></td>
<td>30</td>
<td></td>
<td>$ns$</td>
</tr>
<tr>
<td>Maximum switching frequency (Note 3)</td>
<td>$f_{SW(MAX)}$</td>
<td></td>
<td></td>
<td>200</td>
<td></td>
<td>$kHz$</td>
</tr>
<tr>
<td><strong>V_CC SECTION (Pin 8)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum operating voltage</td>
<td>$V_{CC(MAX)}$</td>
<td></td>
<td></td>
<td>16</td>
<td></td>
<td>$V$</td>
</tr>
<tr>
<td>Start-up threshold</td>
<td>$V_{CC(ST)}$</td>
<td>$V_{CC}$ rising</td>
<td></td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Undervoltage lockout threshold</td>
<td>$V_{CC(UVL)}$</td>
<td>$V_{CC}$ falling</td>
<td></td>
<td>7</td>
<td>7.5</td>
<td>8</td>
</tr>
<tr>
<td>Operating current</td>
<td>$I_{CCQ}$</td>
<td>$C_L = 330pF$, $V_{SENSE} = 1.5V$</td>
<td></td>
<td>4.1</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>Zener diode clamp voltage</td>
<td>$V_{Z(CLAMP)}$</td>
<td>$T_A = 25^\circ C$, $I_Z = 5mA$</td>
<td></td>
<td>18.5</td>
<td>19</td>
<td>20.5</td>
</tr>
<tr>
<td><strong>I_SENSE SECTION (Pin 6)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over-current limit threshold</td>
<td>$V_{OCP}$</td>
<td></td>
<td></td>
<td>1.83</td>
<td>1.89</td>
<td>1.95</td>
</tr>
<tr>
<td>$I_{SENSE}$ short protection reference</td>
<td>$V_{RSNS}$</td>
<td></td>
<td></td>
<td>0.16</td>
<td></td>
<td>$V$</td>
</tr>
<tr>
<td>CC regulation threshold limit (Note 4)</td>
<td>$V_{REG-TH}$</td>
<td></td>
<td></td>
<td>1.8</td>
<td></td>
<td>$V$</td>
</tr>
</tbody>
</table>
6.0 Electrical Characteristics (cont.)

$V_{CC} = 12\text{V}, -40°C \leq T_A \leq 85°C$, unless otherwise specified (Note 1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Test Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>V$_T$ SECTION (Pin 4)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power limit high threshold (Note 4)</td>
<td>$V_{P-LIM(HI)}$</td>
<td></td>
<td>0.56</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Power limit low threshold (Note 4)</td>
<td>$V_{P-LIM(LO)}$</td>
<td></td>
<td>0.44</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Shutdown threshold (Note 4)</td>
<td>$V_{SH-TH}$</td>
<td></td>
<td>0.22</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Input leakage current</td>
<td>$I_{IN(VT)}$</td>
<td>$V_T = 1.0\text{V}$</td>
<td></td>
<td>1</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>Pull-up current source</td>
<td>$I_{VT}$</td>
<td></td>
<td>90</td>
<td>100</td>
<td>110</td>
<td>µA</td>
</tr>
<tr>
<td><strong>OUTPUT (TR SECTION) (Pin 1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output low level ON-resistance</td>
<td>$R_{DS-TR(ON)LO}$</td>
<td>$I_{SINK} = 5\text{mA}$</td>
<td></td>
<td>100</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>Output high level ON-resistance</td>
<td>$R_{DS-TR(ON)HI}$</td>
<td>$I_{SOURCE} = 5\text{mA}$</td>
<td></td>
<td>200</td>
<td></td>
<td>Ω</td>
</tr>
</tbody>
</table>

**Notes:**

Note 1. Adjust $V_{CC}$ above the start-up threshold before setting at 12V.

Note 2. These parameters are not 100% tested. They are guaranteed by design and characterization.

Note 3. Operating frequency varies based on the line and load conditions, see Theory of Operation for more details.

Note 4. These parameters refer to digital preset values, and they are not 100% tested.
7.0 Typical Performance Characteristics

![Graph 1: Vcc vs. Vcc Supply Start-up Current](image1)

*Figure 7.1: Vcc vs. Vcc Supply Start-up Current*

![Graph 2: Start-Up Threshold vs. Temperature](image2)

*Figure 7.2: Start-Up Threshold vs. Temperature*

![Graph 3: % Deviation of Switching Frequency from Ideal vs. Temperature](image3)

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

![Graph 4: Internal Reference Voltage vs. Temperature](image4)

*Figure 7.4: Internal Reference vs. Temperature*
The iW3602-30C is optimized for low-cost designs supporting leading-edge, R type and R-L type dimmers. The iW3602-30C combines two functions: 1) wall dimmer type detection and dimmer phase measurement; and 2) output LED light dimming. It uses digital control technology, which consists of: 1) bleeding circuit, which serves as a dynamic impedance to load the dimmer; 2) primary side controlled isolated flyback converter. The iW3602-30C provides a low cost dimming solution which enables the LED bulb to be used with most of the common wall dimmers. This allows LED bulbs to directly replace conventional incandescent bulbs with ease. The iW3602-30C can detect and operate with leading-edge dimmer and no-dimmer. The controller operates in critical discontinuous conduction mode (CDCM) to achieve high power efficiency and minimum EMI. The iW3602-30C incorporates proprietary primary-feedback constant current control technology to achieve tight LED current regulation.

Figure 3.1 shows a typical iW3602-30C application schematic. Figure 8.1 shows the functional block diagram. The advanced digital control mechanism reduces system design time and improves reliability. The start-up algorithm makes sure the $V_{CC}$ supply voltage is ready before powering up the IC.

The iW3602-30C provides multiple protection features for current limiting, over-voltage protection, and over-temperature protection. The $V_T$ function can provide over-temperature compensation for the LED bulb. With an external NTC thermistor attached to the $V_T$ pin, an internal current source develops a voltage across the NTC which is inversely proportional to the LED bulb temperature. If the $V_T$ pin voltage is below $V_{P,LIM(HI)}$, the controller reduces the LED current in order to reduce the LED bulb temperature. If the $V_T$ pin voltage is below $V_{SH-TH}$ then the controller turns off.

Figure 8.1 : iW3602-30C Functional Block Diagram
AC/DC Digital Power Controllers for Dimmable LED Drivers

9.0 Theory of Operation

The iW3602-30C is a high performance AC/DC off-line power supply controller for dimmable LED luminaires, which uses advanced digital control technology to detect the dimmer type and dimmer phase to control the LED brightness. A PWM-dimming scheme is used to modulate the LED current with a dimming frequency of 900Hz at low dimming levels. iW3602-30C can work with all types of leading-edge dimmers, as well as other dimmer configurations such as R-type or R-L type without visible flicker. The controller can also work when no dimmer is connected.

The iW3602-30C operates in a quasi-resonant mode to provide high efficiency and to simplify EMI design. In addition, the iW3602-30C includes a number of key built-in protection features. Using the state-of-the-art primary-feedback technology, the iW3602-30C removes the need for secondary feedback circuitry while achieving excellent line and load regulation. The iW3602-30C also eliminates the need for loop compensation components while maintaining stability over all operating conditions. Pulse-by-pulse waveform analysis allows for accurate LED current regulation. Hence, the iW3602-30C can provide high performance dimming solutions, with minimal external component count and low bill of materials cost.

9.1 Pin Detail

**Pin 1 – OUTPUT(TR)**
Gate drive for the chopping circuit MOSFET switch.

**Pin 2 – VSENSE**
Sense signal input from auxiliary winding. This pin provides secondary voltage feedback used for output regulation.

**Pin 3 – VIN**
Sense signal input from the rectified line voltage. VIN is used for dimmer phase detection. The input line voltage is scaled down using a resistor network. It is used for input under-voltage and over-voltage protection. This pin also provides the supply current to the IC during start-up.

**Pin 4 – VT**
External power limit and shutdown control. If the shutdown control is not used, this pin should be connected to GND via a resistor.

**Pin 5 – GND**
Ground.

**Pin 6 – ISENSE**
Primary current sense. Used for cycle-by-cycle peak current control.

**Pin 7 – OUTPUT**
Gate drive for the external MOSFET switch.

**Pin 8 – VCC**
Power supply for the controller during normal operation. The controller starts up when VCC reaches 12V (typical) and shuts down when the VCC voltage is below 7.5V (typical).

High-frequency transients and ripples can be easily generated on the VCC pin due to power supply switching transitions and line and load disturbances. Excess ripples and noises on VCC may cause the iW3602-30C to function undesirably, hence a decoupling capacitor must be connected between the VCC pin and GND. It is suggested that a ceramic capacitor of minimum 0.1uF be connected as close as possible to the VCC pin.

9.2 Wall Dimmer Detection

A dimmer detection, or discovery, takes place during the third cycle after start-up. The controller determines whether no dimmer exists, or there is a leading-edge dimmer.

![Figure 9.1: Leading-Edge Wall Dimmer Waveforms](image-url)

Vcross is internally generated by comparing the digitized VIN signal to the threshold of 0.14V. The VIN period (tPERIOD) is measured between two consecutive rising edge zero-crossings. tCROSS is generated by the internal digital block (refer to Figure 9.2); when VIN is higher than 0.14V tCROSS is set to high and when VIN falls below 0.14V tCROSS is reset to zero. If tCROSS is much shorter than the VIN period then a dimmer is detected. Using filtered derivatives the
controller decides which type of dimmer is present. A large positive derivative value indicates a leading-edge dimmer, then the controller enters the leading-edge dimmer mode; otherwise it enters no dimmer mode.

During the dimmer detection stage, the OUTPUT(TR) is kept high to turn on the switching FET in the bleeding circuit, creating a resistive load for the wall dimmer.

\[ D_{RATIO} = \text{Dimmer Phase} \times K_1 - K_2 \quad (9.2) \]

where, \( K_1 \) is set to 1.768 and \( K_2 \) is set to 0.238.

Using \( V_{\text{sense(NOM)}} \) to represent the nominal 100% LED current, the \( V_{\text{sense}} \), which modulates the output LED current, is controlled by:

\[ V_{\text{sense}} = V_{\text{sense(NOM)}} \times D_{RATIO} \quad (9.3) \]

When \( D_{RATIO} \) is 1, the converter outputs 100% of nominal power to the LED. If \( D_{RATIO} \) is 0.01, the converter outputs 1% of nominal power to the LED.

### 9.4 Bleeding Operation

A bleeding circuit provides the dynamic impedance for the dimmer and builds the energy to the LED power converter. It consists of \( Q_C \), \( R_C \), \( R_S \), and \( D_2 \).

\[ Q_C \] is always on when \( t_{\text{CROSS}} \) is low and \( Q_C \) is always off when \( t_{\text{CROSS}} \) is high.

### 9.5 Start-up

Prior to start-up the \( V_{\text{IN}} \) pin charges up the \( V_{\text{CC}} \) capacitor through a diode between \( V_{\text{IN}} \) and \( V_{\text{CC}} \). When \( V_{\text{CC}} \) is fully charged to a voltage higher than the start-up threshold \( V_{\text{CC(ST)}} \), the ENABLE signal becomes active and enables the control logic, shown by Figure 9.6. When the control logic is enabled, the controller enters the configuration mode, where dimmer type and AC line period are measured. During the

### 9.3 Dimmer Tracking and Phase Measurements

The dimmer detection algorithm and the dimmer tracking algorithm both depend on an accurate input voltage period measurement. The \( V_{\text{IN}} \) period is measured during the second cycle of the dimmer detection process and is latched for use thereafter. Using the measured \( V_{\text{IN}} \) period in subsequent calculations rather than a constant allows for automatic 50/60Hz operation and allows for a 10% frequency variation.

The phase measurement starts when \( V_{\text{IN}} \) exceeds the rising threshold until \( V_{\text{IN}} \) falls below the falling threshold.

\[ \text{Dimmer Phase} = \frac{t_{\text{CROSS}}}{t_{\text{PERIOD}}} \quad (9.1) \]

The calculated dimmer phase is used to generate the signal \( D_{RATIO} \), which determines LED current. If the dimmer phase is less than 0.14 then the \( D_{RATIO} \) is clamped at 0.14; if the dimmer phase is greater than 0.7 then \( D_{RATIO} \) is clamped at 1.0; otherwise \( D_{RATIO} \) is calculated by equation 9.2.
configuration mode, which is implemented during the first 3 half AC cycles, OUTPUT(TR) is kept high to determine the dimmer type and measure the AC line period. After the configuration mode the constant current stage is enabled and the output voltage starts to ramp up. When the output voltage is above the forward voltage of the LED, the controller begins to operate in constant output current mode.

An adaptive soft-start control algorithm is applied during start-up state, where the initial output pulses are short and gradually get wider until the full pulse width is achieved. The peak current is limited cycle by cycle by the $I_{PEAK}$ comparator.

In order to tightly regulate the output voltage, the information about the output voltage and load current must be accurately sensed. In the DCM flyback converter, this information can be read via the auxiliary winding or the primary magnetizing inductance ($L_M$). During the $Q_1$ on-time, the load current is supplied from the output filter capacitor $C_O$. The voltage across $L_M$ is $v_g(t)$, assuming the voltage dropped across $Q_1$ is zero. The current in $Q_1$ ramps up linearly at a rate of:

$$\frac{di_g(t)}{dt} = \frac{v_g(t)}{L_M} \quad (9.6)$$

At the end of on-time, the current ramps up to:

$$i_{g\_peak}(t) = \frac{v_g(t) \times t_{ON}}{L_M} \quad (9.7)$$

This current represents a stored energy of:

$$E_g = \frac{L_M}{2} \times i_{g\_peak}(t)^2 \quad (9.8)$$

When $Q_1$ turns off, $i_g(t)$ in $L_M$ forces a reversal of polarities on all windings. Ignoring the communication-time caused by the leakage inductance $L_K$ at the instant of turn-off, the primary current transfers to the secondary at a peak amplitude of:

$$i_d(t) = \frac{N_p}{N_S} \times i_{g\_peak}(t) \quad (9.9)$$

Assuming the secondary winding is master and the auxiliary winding is slave.

The auxiliary voltage is given by:

$$V_{AUX} = V_O \times \frac{N_{AUX}}{N_S} \quad (9.10)$$

and reflects the output voltage as shown in Figure 9.9.

The voltage at the load differs from the secondary voltage by a diode drop and IR losses. The diode drop is a function of current, as are IR losses. Thus, if the secondary voltage is always read at a constant secondary current, the difference

**Figure 9.6 : Start-up Sequencing Diagram**

**Figure 9.7 : Simplified Flyback Converter**

**Figure 9.8 : Auxiliary Voltage Waveforms**
between the output voltage and the secondary voltage is a fixed $\Delta V$. If the voltage can be read when the secondary current is small, for example, at the knee of the auxiliary waveform (see Figure 9.9), then $\Delta V$ is also small. With the iW3602-30C, $\Delta V$ can be ignored.

The real-time waveform analyzer in the iW3602-30C reads the auxiliary waveform information cycle by cycle. The part then generates a feedback voltage $V_{FB}$. The $V_{FB}$ signal precisely represents the output voltage and is used to regulate the output voltage.

**9.7 Valley Mode Switching**

In order to reduce switching losses in the MOSFET and EMI, the iW3602-30C employs valley mode switching during constant output current operation. In valley mode switching, the MOSFET switch is turned on at the point where the resonant voltage across the drain and source of the MOSFET is at its lowest point (see Figure 9.9). By switching at the lowest $V_{DS}$, the switching loss is minimized.

Turning on at the lowest $V_{DS}$ generates lowest $dV/dt$, thus valley mode switching can also reduce EMI. To limit the switching frequency range, the iW3602-30C can skip valleys (seen in the first cycle in Figure 9.9) when the switching frequency becomes greater than $f_{SW(MAX)}$.

At each of the switching cycles, the falling edge of $V_{SENSE}$ is checked. If the falling edge of $V_{SENSE}$ is not detected, the off-time is extended until the falling edge of $V_{SENSE}$ is detected.

**9.8 LED Current Regulation**

The iW3602-30C incorporates a patented primary-side only constant current regulation technology. The iW3602-30C regulates the output current at a constant level regardless of the output voltage, while avoiding a continuous conduction mode. To achieve this regulation the iW3602-30C senses the load current indirectly through the primary current. The primary current is detected by the $I_{SENSE}$ pin through a resistor from the MOSFET source to ground.

The $I_{SENSE}$ resistor determines the maximum current output of the power supply. The output current of the power supply is determined by:

$$I_{OUT} = \frac{1}{2} N_{PS} \times \frac{V_{REG-IN}}{R_{SENSE}} \times \frac{t_R}{t_S}$$

(9.11)

where $N_{PS}$ is the turns ratio of the primary and secondary windings and $R_{SENSE}$ is the $I_{SENSE}$ resistor.

**9.9 $V_{IN}$ Resistors**

$V_{IN}$ resistors are chosen primarily to scale down the input voltage for the IC. The scale factor for the input voltage in the IC is 0.0086. Since the internal impedance of this pin is 2.5 kΩ, then, the $V_{IN}$ resistors should equate to:

$$R_{Vin} = \frac{2.5\,k\Omega}{0.0086} - 2.5\,k\Omega = 288\,k\Omega$$

(9.12)

**9.10 Voltage Protection Functions**

The iW3602-30C includes a function that protects against an input over-voltage ($V_{IN}$ OVP) and output over-voltage (OVP).

The input voltage is monitored by $V_{IN_A}$, as shown in Figure 8.1. If this voltage exceeds 1.73V for 15 continuous half AC cycles, the iW3602-30C considers $V_{IN}$ to be over-voltage. Output voltage is monitored by the $V_{SENSE}$ pin. If the voltage at this pin exceeds $V_{SENSE(MAX)}$ for 2 continuous switching cycles the iW3602-30C considers the output voltage to be over-voltage.

In both input over-voltage and output over-voltage cases, the IC remains biased, which discharges the $V_{CC}$ supply. In order to prevent overcharging the output voltage or overcharging the bulk voltage, the iW3602-30C employs an extended discharge time before restart. Initially if $V_{CC}$ drops below the UVLO threshold, the controller resets itself and then initiates a new soft-start cycle.
AC/DC Digital Power Controllers for Dimmable LED Drivers

Under the fault condition, the controller tries to start up for three consecutive times. If all three start-up attempts fail, the controller enters the inactive mode, during which the controller does not respond to $V_{CC}$ power-on requests. The controller is activated again after it sees 29 start-up attempts. The controller can also be reset to the initial condition if $V_{CC}$ is discharged. Typically, this extended discharge time is around 3 to 5 seconds.

This extended discharge time allows the iW3602-30C to support hot-plug LED modules without causing dangerously high output voltages while maintaining a quick recovery.

9.11 PCL, OC and SRS Protection

Peak-current limit (PCL), over-current protection (OCP) and sense-resistor short protection (SRSP) are features built into the iW3602-30C. The $I_{SENSE}$ pin enables the iW3602-30C to monitor the primary peak current; this allows for cycle by cycle peak current control and limit. When the primary peak current multiplied by the $I_{SENSE}$ sense resistor is greater than $V_{OCP}$, OCP engages and the IC immediately turns off the gate drive until the next switching cycle. The output driver continues to send out switching pulses; the IC immediately turns off the gate drive if the OCP threshold is reached again.

To ensure that a shorted $I_{SENSE}$ sense resistor does not cause any unsafe conditions to occur, the SRSP feature is enabled after start-up and shuts down the IC within one power supply cycle of the fault occurrence. The $V_{CC}$ is discharged since the IC remains biased. In order to prevent overcharging the output voltage, the iW3602-30C employs an extended discharge time before restart, similar to the discharge time described in section 9.10.

9.12 Over-Temperature Protection

If an NTC thermistor is connected from the $V_T$ pin to GND then, the iW3602-30C is able to detect and protect against an over--temperature event (OTP).

The iW3602-30C provides a current ($I_{VT}$) to the $V_T$ pin and detects the voltage on the pin. Based on this voltage the iW3602-30C can monitor the temperature of the NTC thermistor. As the $V_T$ pin voltage reduces, the iW3602-30C reduces the output current according to Figure 9.11 and Figure 9.12. There is a hysteresis of 84mV on $V_T$ pin voltage for each power limiting step.

When the $V_T$ pin voltage reaches $V_{P-LIM(HI)}$, the output current begins to reduce as shown in Figure 9.11. At $V_{P-LIM(LO)}$, the output current reduces to 1%. The device can be placed in shutdown mode by pulling the $V_T$ pin to ground or under $V_{SH-TH}$.
10.0 Performance Characteristics

**Figure 10.1 : Leading Edge Dimmer**

**Figure 10.2 : Leading Edge Dimmer 2**

**Figure 10.3 : No Dimmer**
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11.0 Typical Application Schematic

Figure 11.1 : iW3602-30C Typical Application Schematic
AC/DC Digital Power Controllers for Dimmable LED Drivers

12.0 Physical Dimensions

8-Lead Small Outline (SOIC) Package

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.

13.0 Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Options</th>
<th>Package</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>iW3602-30C</td>
<td>PF &lt; 0.7, Improved Bleeder</td>
<td>SOIC-8</td>
<td>Tape &amp; Reel¹</td>
</tr>
</tbody>
</table>

Note 1: Tape & Reel packing quantity is 2,500/reel. Minimum ordering quantity is 2,500.
AC/DC Digital Power Controllers for Dimmable LED Drivers

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