iW3626

Off-Line Digital Power Controller for LED Driver with High Power-Factor and Low-Ripple Current

1.0 Features

- All-in-one non-dimmable low-cost off-line LED driver (isolated and non-isolated applications)
- Supports universal input voltage range (90V_{AC} to 277V_{AC}) and output power up to 10W
- High power factor (PF) with low current-ripple control technology
- User-configurable power factor setting (>0.7 to >0.9)
- User-configurable over-temperature protection (OTP) with temperature-current derating
- Very tight LED current regulation (±5%) across line and load, and within primary inductance tolerance (±20%)
- Isolated design without opto-coupler
- Supports wide range of LED numbers with tight current regulation
- Stabilized LED current-ripple control without visible shimmer or flicker
- Active start-up scheme enables fastest possible start-up
- 72kHz maximum PWM switching frequency with quasi-resonant operation
- Dynamic base current control to drive low-cost BJT
- ***EZ-EMI***® design enhances manufacturability
- Built-in single-point fault protection features: LED open-/short-circuit protection and over-current protection
- No audible noise over entire operating range

2.0 Description

The iW3626 is a high performance, single-stage AC/DC power controller for LED luminaires with power factor (PF) correction. The device uses digital control technology to build unique hybrid mode control in PWM flyback power supplies to achieve high power factor meanwhile minimizing LED current ripple. This distinctive control approach enables the capability for users to make trade-offs between PF and LED current ripple in a single-stage design. It can achieve excellent LED current regulation over line and load variation, without the need for secondary feedback circuit. The built-in temperature sensor along with control logic can automatically adjust output current in real-time without visible flicker during the process. The iW3626 operates in quasi-resonant mode to provide high efficiency along with a number of key built-in protection features while minimizing the external component count, simplifying EMI design and lowering the total bill of material cost. It also eliminates the need for loop compensation components while maintaining stability over all operating conditions. The built-in power limit function enables optimized transformer design in universal off-line applications with input voltage from 90V_{AC} to 277V_{AC}.

iWatt's innovative proprietary technology maximizes the iW3626 performance in a tiny SOT-23 package. The iW3626 offers two multi-function pins allowing users to configure PF and OTP as required with no cost or size impact, thereby providing design flexibility. The active start-up scheme enables the shortest possible start-up time without sacrificing active efficiency.

3.0 Applications

- Solid-state LED lighting
- LED lighting ballast

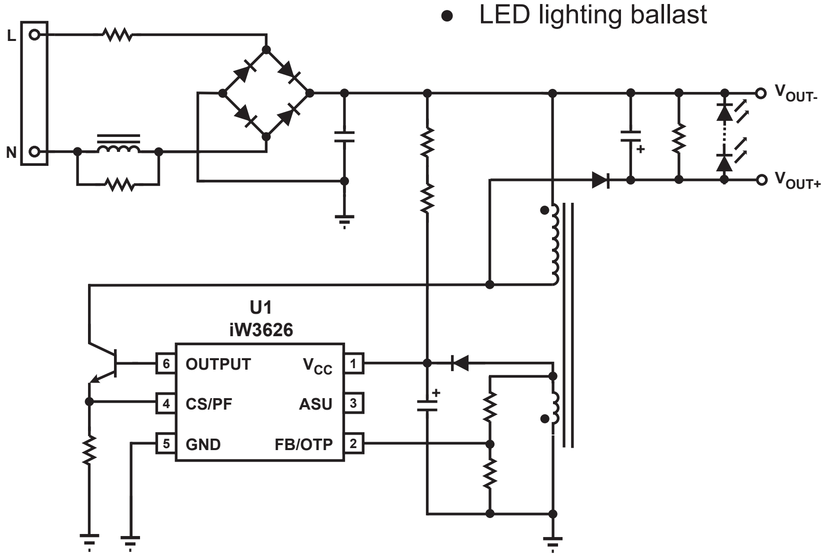


Figure 3.1: iW3626 Typical Application Circuit (Non-isolated Application)

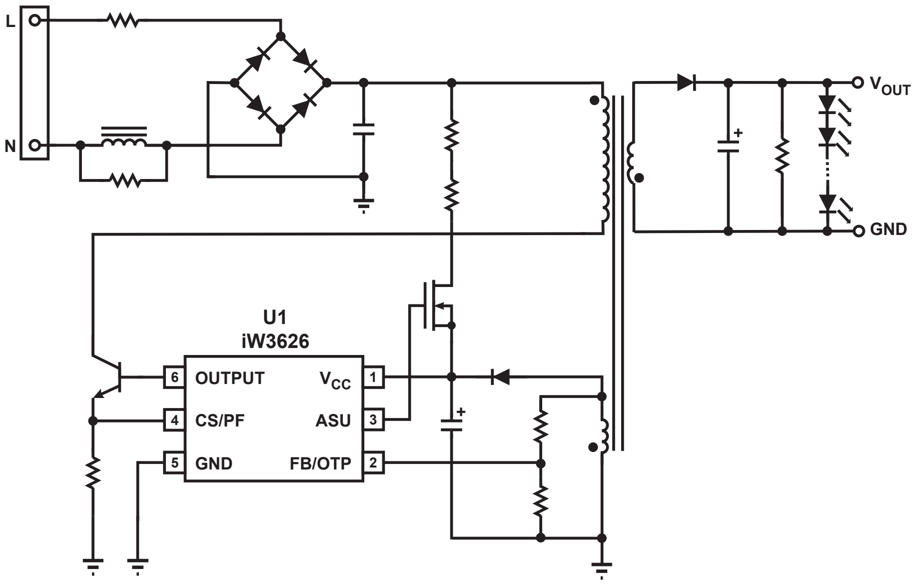


Figure 3.2: iW3626 Typical Application Circuit (Isolated Application)

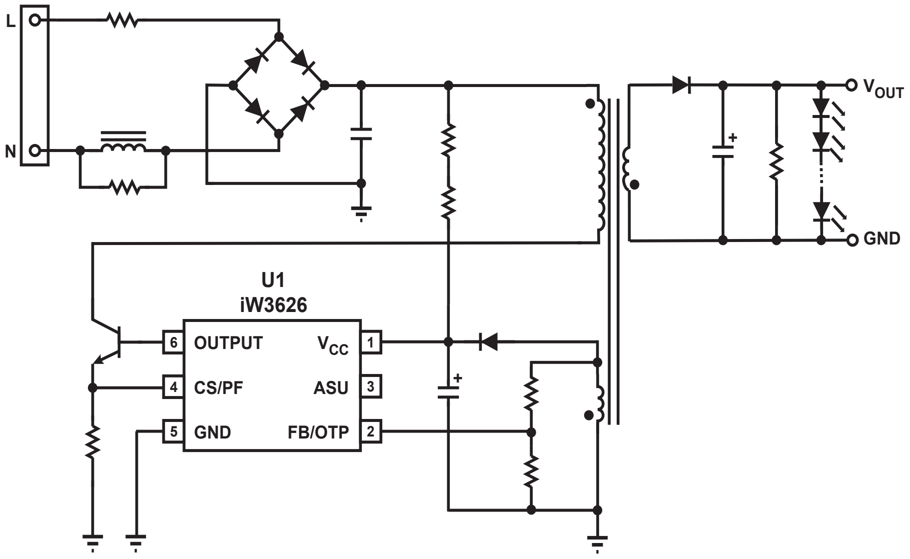


Figure 3.3: iW3626 Typical Application Circuit (Isolated Application without Using Active Start-up Device)

4.0 Pinout Description

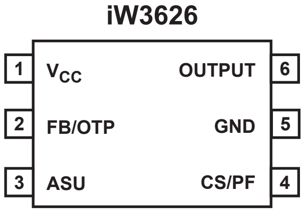


Figure 4.1: 6-Lead SOT23 Package

Pin #	Name	Type	Pin Description
1	V_{CC}	Power Input	Power supply for control logic and BJT drive.
2	FB/OTP	Analog Input	Multi-function pin. Used for OTP current derating configuration at the beginning of start-up and to provide auxiliary voltage sense for primary regulation during normal operation.
3	ASU	Output	Control signal for active start-up device (BJT or depletion mode NFET).
4	CS/PF	Analog Input	Multi-function pin. Used for PF configuration at the beginning of start-up and to provide primary current sense for cycle-by-cycle peak current control and limit during normal operation.
5	GND	Ground	Ground.
6	OUTPUT	Output	Base drive for BJT.

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.

Parameter	Symbol	Value	Units
DC supply voltage range (pin 1, I_{CC} = 20mA max)	V_{CC}	-0.3 to 18.0	V
Continuous DC supply current at V_{CC} pin (V_{CC} = 15V)	I_{CC}	20	mA
ASU output (pin 3)		-0.3 to 18.0	V
OUTPUT (pin 6)		-0.3 to 4.0	V
FB/OTP input (pin 2, $I_{FB/OTP} \leq$ 10mA)		-0.7 to 4.0	V
CS/PF input (pin 4)		-0.3 to 4.0	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
Lead temperature during IR reflow for ≤ 15 seconds	T_{LEAD}	260	°C
Thermal resistance junction-to-ambient	θ_{JA}	190	°C/W
ESD rating per JEDEC JESD22-A114		2,000	V
Latch-up test per JEDEC 78		±100	mA

6.0 Electrical Characteristics

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

Parameter		Test Conditions	Min	Typ	Max	Unit
FB/OTP SECTION (Pin 2)						
Input leakage current	I_{BVS}	FB/OTP = 2V			1	μA
Nominal voltage threshold	$FB_{(NOM)}$	T_A=25°C, negative edge	1.521	1.536	1.551	V
Output OVP threshold	$FB_{(OVP)}$	T_A=25°C, negative edge		1.838		V
CS/PF SECTION (Pin 4)						
Overcurrent threshold	V_{OCP}			1.15		V
CS/PF regulation upper limit (Note 1)	$V_{IPK(HIGH)}$			1.00		V
CS/PF regulation lower limit (Note 1)	$V_{IPK(LOW)}$			0.25		V
Input leakage current	I_{LK}	CS/PF = 1.0V			1	μA
OUTPUT SECTION (Pin 6)						
Output low level ON-resistance	$R_{DS(ON)LO}$	I_{SINK} = 5mA		1	3	Ω
Maximum switching frequency (Note 2)	f_{SW}			72		kHz
V_{CC} SECTION (Pin 1)						
Maximum operating voltage (Note 1)	$V_{CC(MAX)}$				16	V
Start-up threshold	$V_{CC(ST)}$	V_{CC} rising		11.0		V
Undervoltage lockout threshold (Note 3)	$V_{CC(UVL)}$	V_{CC} falling		4.0 5.0		V
Start-up current	$I_{IN(ST)}$	V_{CC} = 10V		7		μA
Quiescent current	I_{CCQ}	V_{CC} = 14V, without driver switching		3.1		mA
Zener breakdown voltage	V_{ZB}	Zener current = 5mA T_A=25°C		19.5		V
ASU SECTION (Pin 3)						
Maximum operating voltage (Note 1)	$V_{ASU(MAX)}$				16	V
Resistance between V_{CC} and ASU	R_{Vcc_ASU}			1000		kΩ

Notes:

Note 1: These parameters are not 100% tested, and they are guaranteed by design and characterization. Refer to Section 9.0 for operation details.

Note 2: Operating frequency varies based on the operating conditions, see Section 9.9 for more details.

Note 3: Refer to product options in Section 11.0, for maximum driver current of 40mA, $V_{CC(UVL)}$ = 4.0V; otherwise $V_{CC(UVL)}$ = 5.0V.

7.0 Typical Performance Characteristics

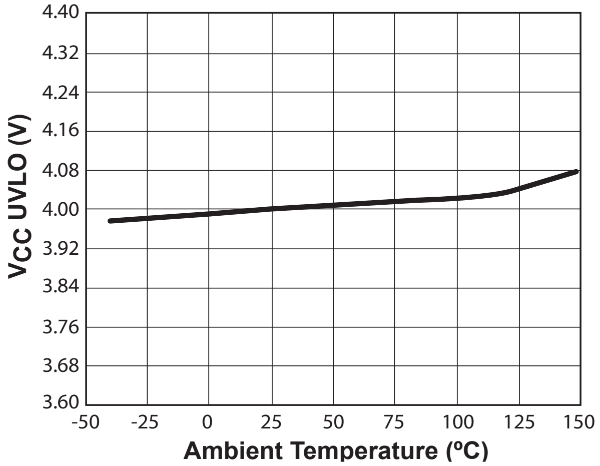


Figure 7.1 : V_{CC} UVLO vs. Temperature[1]

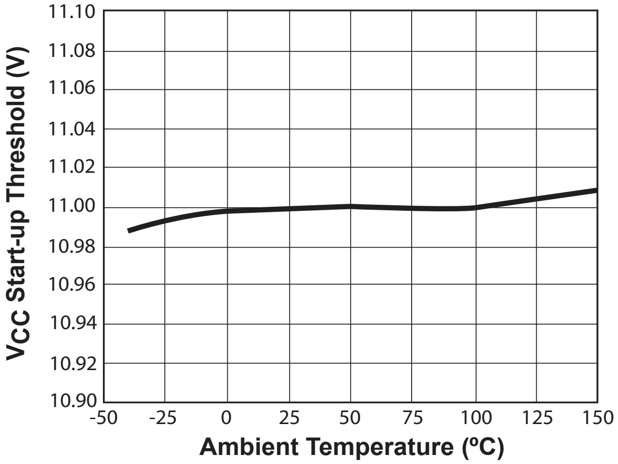


Figure 7.2 : Start-Up Threshold vs. Temperature

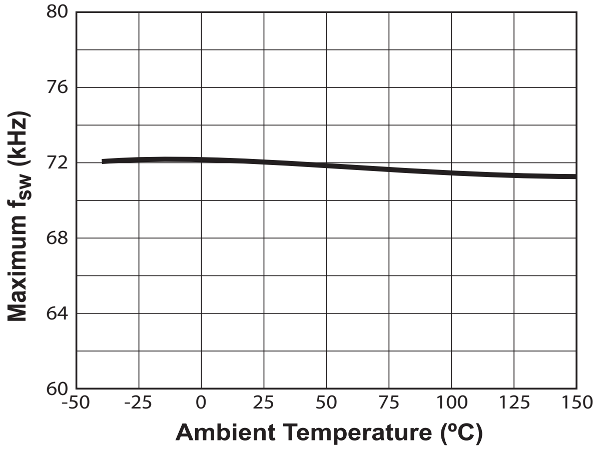


Figure 7.3 : Switching Frequency vs. Temperature[2]

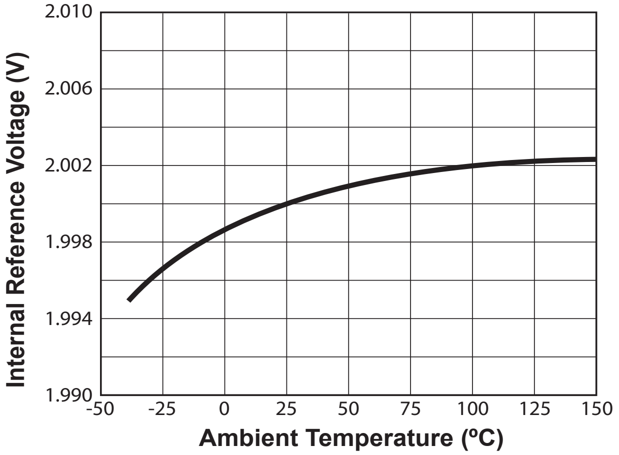


Figure 7.4 : Internal Reference vs. Temperature

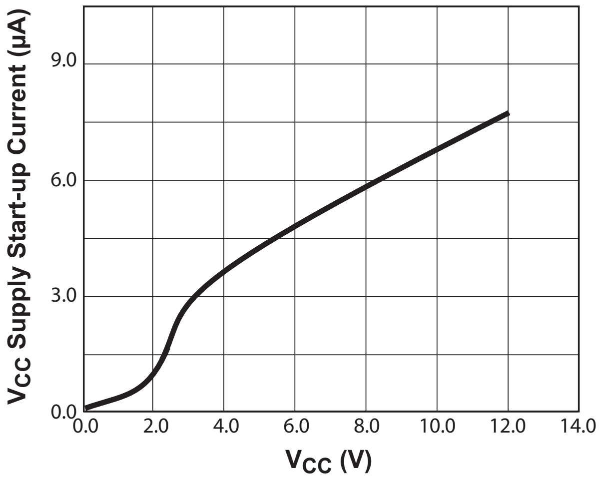


Figure 7.5 : V_{CC} vs. V_{CC} Supply Start-up Current

Notes:

Note 1. For products with maximum driver current of 40mA; for other products, shift the curve up by 1.0V.

Note 2. Operating frequency varies based on the operating conditions; see Section 9.9 for more details.

8.0 Functional Block Diagram

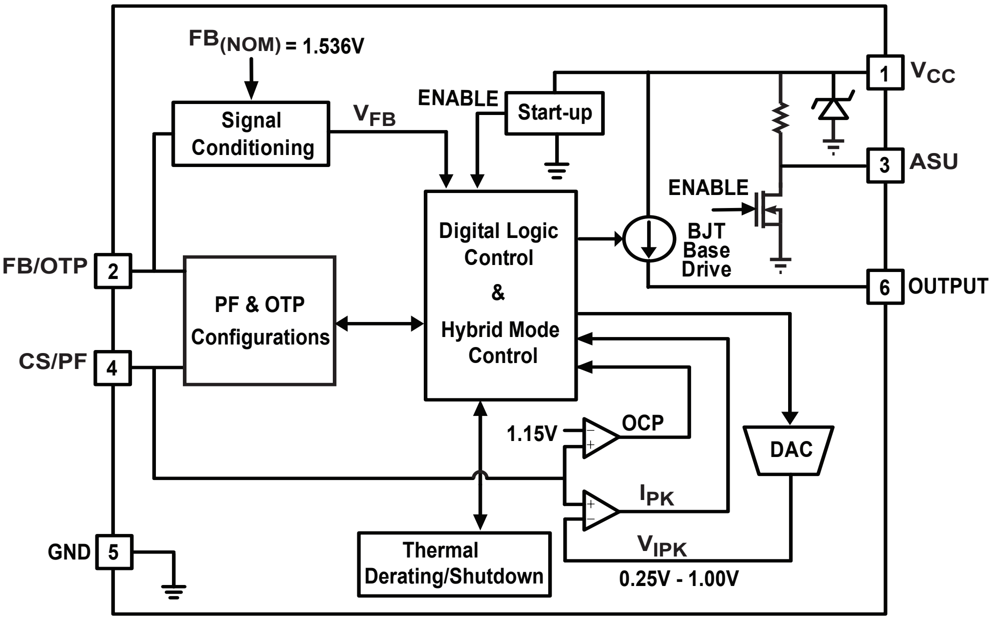


Figure 8.1: iW3626 Functional Block Diagram

9.0 Theory of Operation

The iW3626 is a digital power controller dedicated for single-stage off-line LED driver with power factor correction. The device uses a new, proprietary primary-side control technology to eliminate the opto-isolated feedback and secondary regulation circuits required in traditional designs. This results in a low-cost small-size solution for LED lighting applications. The iW3626 uses a unique hybrid mode control in PWM flyback power supplies to achieve high power factor meanwhile minimizing LED current ripple. Furthermore, iWatt's digital control technology enables tight output current regulation, user-programmability to allow for making trade-offs between PF and LED current ripple, as well as full-featured circuit protection with primary-side control.

Referring to the block diagram in Figure 8.1, the iW3626 has CS/PF and FB/OTP pins for two-fold functions. At the beginning of start-up, a fixed current source flows out of the two pins alternatively, generating voltage levels proportional to resistance values from the pins to GND, which are then identified by the controller to set the requirement for PF and OTP respectively. During normal operation, the iW3626 operates in proprietary hybrid mode control to achieve high power factor. Without directly sensing input AC line voltage, the iW3626 breaks down line period into two portions - one is for peak current mode control (or constant current control) and the other is for constant T_{ON} (fixed ON-time) control (See Section 9.5 for details). During peak current mode control, the digital logic control block generates the switching on-time and off-time information based on the output voltage and current feedback signal and provides commands to dynamically control the external BJT base current. The CS/PF is an analog input configured to sense the primary current in a voltage form. In order to achieve the peak current mode control and cycle-by-cycle current limit, the V_{IPK} sets the threshold for the CS/PF to compare with, and it varies in the range of 0.25V (typical) to 1.00V (typical) under different line and load conditions. During constant T_{ON} operation, the iW3626 operates at fixed ON-time, which is automatically determined by the controller, based on the PF requirement configured via CS/PF pin. During any AC line cycle, the iW3626 alternates its operation between peak current mode control and constant T_{ON} control to realize high power factor correction with minimal output current ripple.

The iW3626 operates in quasi-resonant mode to provide high efficiency and simplify EMI design. In addition, the iW3626 incorporates a number of key built-in protection features, including LED short-circuit and open protections, over-current protection, and moreover, a distinctive temperature-current derating function in an attempt to maximize LED current under safe operating condition before initiating thermal shutdown. Using iWatt's state-of-the-art primary-feedback technology, the iW3626 removes the need for secondary feedback circuit while achieving excellent line and load regulation. Furthermore, the iW3626 eliminates the need for loop compensation components while maintaining stability over all operating conditions.

9.1 Pin Detail

Pin 1 – V_{CC}

Power supply for the controller during normal operation. The controller starts up when V_{CC} reaches 11.0V (typical) and shuts down when the V_{CC} voltage drops below 4.0V (typical) or 5.0V (typical) respectively depending on product options (See Section 6.0). A decoupling capacitor of 0.1µF or so should be connected between the V_{CC} pin and GND.

Pin 2 – FB/OTP

Used to configure OTP setting at the beginning of start-up, and sense output via auxiliary winding during normal operation for output regulation.

Pin 3 – ASU

Control signal for active start-up device. This signal is pulled low after start-up is finished to cut off the active device.

Pin 4 – CS/PF

Used to configure PF setting at the beginning of start-up, and sense primary current during normal operation for cycle-by-cycle peak current control and limit.

Pin 5 – GND

Ground.

Pin 6 – OUTPUT

Base drive for the external power BJT switch.

9.2 Active Start-up and Adaptively Controlled Soft-Start

The iW3626 features a proprietary soft-start scheme to achieve fast build-up of output voltage and smooth ramp-up of LED current for a variety of output conditions including output voltage up to 100V above and output capacitor ranging from 330µF to 5000µF. In addition, the active start-up scheme enables shortest possible turn-on delay without sacrificing operating efficiency.

Refer to Figure 8.1 for the block diagram and Figure 3.2 for the active start-up circuit using external depletion NFET. Prior to start-up, the ENABLE signal is low, and the ASU pin voltage closely follows the V_{CC} pin voltage, as shown in Figure 9.1. Consequently, the depletion NFET is turned on, allowing the start-up current to charge the V_{CC} bypass capacitor. When the V_{CC} bypass capacitor is charged to a voltage higher than the start-up threshold $V_{CC(ST)}$, the ENABLE signal becomes active and the iW3626 begins to perform PF and OTP configurations (See Section 9.3) followed by initial OTP check (See Section 9.14). Afterwards, the iW3626 commences soft-start function. From the beginning of soft-start process, the controller starts to operate in hybrid mode control by alternating peak current mode control and constant T_{ON} control. The length of time during which the controller is in constant T_{ON} operation within an AC line cycle is gradually adjusted towards the steady-state value specified during PF configuration. In addition, the whole soft-start process can break down into several stages based on the output voltage levels, which is indirectly sensed by FB/OTP signal at the primary side. At different stages, the iW3626 adaptively controls the switching frequency and primary-side peak current such that the output voltage can always build up very fast at the early stages before LEDs light up, and smoothly transition to the desired regulation current level, meanwhile meeting the power factor requirement at steady-state operation. In the iW3626, the transition can be selected to happen early or late by product options (Section 11.0). For designs supporting wide range of output voltage, the transition needs to happen early in order to avoid LED current overshoot for applications with low output voltage. Otherwise, the transition can be set to happen late in order to speed up start-up.

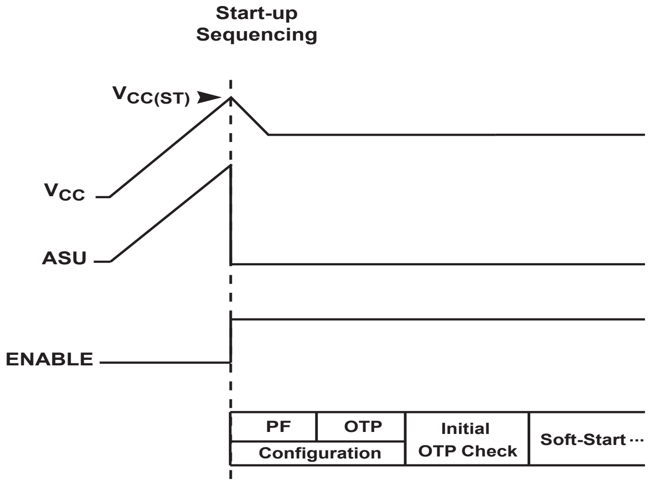


Figure 9.1: Start-up Sequencing Diagram

While the ENABLE signal initiates the soft-start process, it also pulls down the ASU pin voltage at the same time, which turns off the depletion NFET, thus minimizing the no-load standby power consumption and improving active operating efficiency.

If at any time the V_{CC} voltage drops below under voltage lockout (UVLO) threshold $V_{CC(UVL)}$ then the iW3626 goes to shutdown. At this time ENABLE signal becomes low, the depletion NFET, and the V_{CC} capacitor begins to charge up again towards the start-up threshold to initiate a new soft-start process.

In applications where the active start-up is not needed, the start-up resistor can be directly connected to the V_{CC} pin without using the active start-up device, and the ASU pin can be left unconnected. Refer to Figure 3.3 for the application circuit.

9.3 PF and OTP Configurations

The iW3626 incorporates an innovative approach to allow users to configure PF and OTP current derating selections externally. In the iW3626, power factor can be adjusted by setting different percentage of time within each AC line cycle during which the device operates in constant T_{ON} mode, and in peak current control mode for the rest time of line cycle (See Section 9.5 for details). This percentage can be set externally during configuration stage. In addition, for the over-temperature protection, the temperature at which the device starts to derate LED current can also be selected at configuration stage.

The configurations of PF and OTP derating are only performed once after the ENABLE signal becomes active, and completed before the soft-start commences. The configurations involve CS/PF and FB/OTP pins and some resistors connected to the pins. Figure 9.2 shows the schematic highlighting the resistors used for configurations. During PF configuration, the iW3626 does not send out any drive signal at OUTPUT pin, and the switch Q1 remains

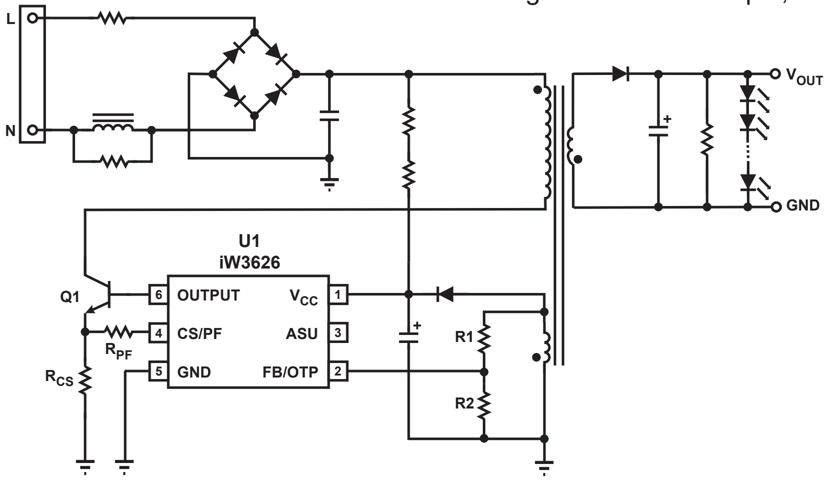


Figure 9.2: Typical Application Circuit Highlighting Configuration Resistors

Table 9.1: Recommended resistance range to set power factor (PF) level

PF Level	1 (L)	2 (M)	3 (H)	4 (No)
R_{PF} Range* (kΩ)	0 - 0.88	1.36 – 3.00	3.87 – 5.60	6.95 – 20
Percentage in constant T_{ON} mode	25%	50%	62.5%	0%**

** R_{CS} is usually very small (a few Ohms), and can be neglected compared to R_{PF} in consideration.*

*** Not intended to operate in constant T_{ON} mode, however, the part has maximum T_{ON} of 20µs in this setting.*

Table 9.2: Recommended resistance range to over-temperature protection (OTP) selection

OTP Level	1	2	3
Paralleled R1 and R2 Range (kΩ)	1.80 - 2.25	2.97 - 3.78	4.78 - 20
The temperature at which the iW3626 starts to derate output current	120°C	130°C	140°C

in off-state. A fixed current flows out of CS/PF pin, which generates a voltage proportional to the resistance value of R_{PF} and R_{CS} (in series). The internal digital control block identifies the resistance value between CS/PF pin to ground, and then sets the percentage of time in constant T_{ON} mode to a predetermined value accordingly. Table 9.1 lists the resistance range of R_{PF} for configuring four-level of PF (low, medium, high and no-PF) and the related percentage of time in constant T_{ON} operation for each AC line cycle.

In applications, the selection of R_{PF} and R_{CS} is straightforward. R_{CS} is usually small and its resistance is negligible compared to R_{PF} in determining PF level during configuration. However, it directly sets output current, whereas R_{PF} does not play a role (See Section 9.6). Therefore, the values of R_{PF} and R_{CS} can be determined separately.

Following the completion of configuring PF, the iW3626 enters the stage of configuring OTP derating selection. During this stage, switch Q1 still remains in off-state, and the fixed current flows out of FB/OTP pin and generates a voltage proportional to the paralleled resistance of R1 and R2, since the bias winding is virtually shorted. Consequently, the paralleled resistance of R1 and R2 is identified and used to set the OTP derating levels. Meanwhile, during normal operation, the FB/OTP pin reflects output voltage in real-time. The ratio of R1 to R2 sets nominal output voltage, which represents the voltage level the iW3626 attempts to regulate to during constant voltage operation. Based on the two equations, R1 and R2 can be readily derived.

The iW3626 provides 3-level OTP derating selections. Table 9.2 lists the resistance range of paralleled R1 and R2 for each configuration level.

In practice, for both PF and OTP configurations, it is recommended that the resistance be selected in the middle of the range where possible.

After completing PF and OTP configurations, the iW3626 will perform an initial OTP check, and will initiate a soft-start process if the junction temperature is below 110°C (typical).

9.4 Understanding Primary Feedback

Figure 9.3 illustrates a simplified flyback converter. When the switch Q1 conducts during $t_{ON}(t)$, the current $i_g(t)$ is directly drawn from rectified sinusoid $v_g(t)$. The energy $E_g(t)$ is stored in the magnetizing inductance L_M. The rectifying diode D1 is reverse biased and the load current I_O is supplied by the secondary capacitor C_O. When Q1 turns off, D1 conducts and the stored energy $E_g(t)$ is delivered to the output.

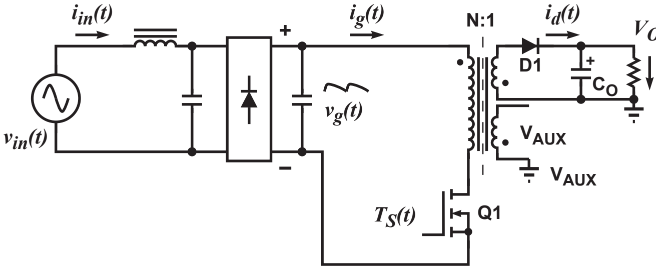


Figure 9.3: Simplified Flyback Converter

In order to tightly regulate the output voltage, the information about the output voltage and load current need to 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 Q1 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 Q1 is zero. The current in Q1 ramps up linearly at a rate of:

$$\frac{di_g(t)}{dt} = \frac{v_g(t)}{L_M} \tag{9.1}$$

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

$$i_{g\_peak}(t) = \frac{v_g(t) \times t_{ON}}{L_M} \tag{9.2}$$

This current represents a stored energy of:

$$E_g = \frac{L_M}{2} \times i_{g\_peak}(t)^2 \tag{9.3}$$

When Q1 turns off at t_O, $i_g(t)$ 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 t_O, the primary current transfers to the secondary at a peak amplitude of:

$$i_d(t) = \frac{N_P}{N_S} \times i_{g\_peak}(t) \tag{9.4}$$

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

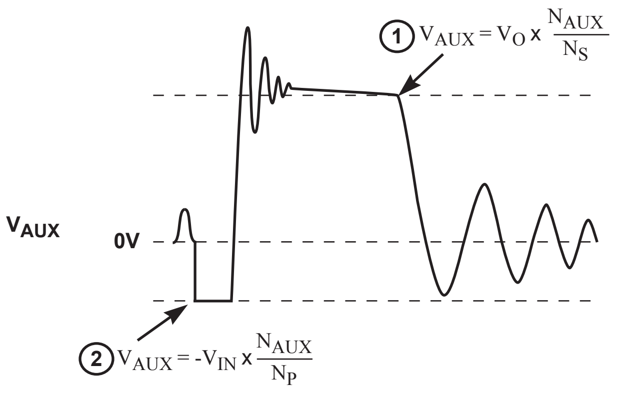


Figure 9.4: Auxiliary Voltage Waveforms

The auxiliary voltage is given by:

$$V_{AUX} = \frac{N_{AUX}}{N_S}\left(V_O + \Delta V\right) \tag{9.5}$$

and reflects the output voltage as shown in Figure 9.4.

The voltage at the load differs from the secondary voltage by a diode drop and IR losses. Thus, if the secondary voltage is always read at a constant secondary current, the difference between the output voltage and the secondary voltage is a fixed ΔV. Furthermore, if the voltage can be read when the secondary current is small, ΔV is also small. With the iW3626, ΔV can be ignored.

The real-time waveform analyzer in the iW3626 reads this information cycle by cycle. The part then generates a feedback voltage V_{FB}. The V_{FB} signal precisely represents the output voltage under most conditions and is used to regulate the output voltage.

9.5 Hybrid Mode Control for Power Factor Correction

The iW3626 uses a unique hybrid mode control to achieve high power factor meanwhile maintaining low LED current ripple. As shown in Figure 9.5, the iW3626 breaks down its operation into peak current mode operation and constant T_{ON} operation within each rectified line cycle. In particular, for the peak current mode control, the averaged secondary diode current over one switching cycle remains constant, or equivalently, if this secondary diode current were to be filtered by output capacitor, the DC component would be constant (See Section 9.6) - therefore, this operation mode is also named constant current operation. For constant T_{ON} operation, the switch ON-time is fixed, whereas the switching frequency is determined by critical conduction mode.

Although input line voltage is not directly sensed, the iW3626 can intelligently search for a voltage level based on the rectified AC line waveform, such that for the time period when the instantaneous line voltage is above this voltage level (dashed line in Figure 9.5), the iW3626 operates in constant current operation; otherwise it operates in constant T_{ON} mode, with the ON-time derived from the turn-on time of the particular switching cycle in constant current operation just before the controller gets into the constant T_{ON} mode. In general for a fixed AC line period, as the portion of constant T_{ON} operation increases, then the portion of constant current operation will decrease. This results in an increased power factor and better harmonics performance.

For a single-stage off-line LED driver, one fundamental conflict is to achieve high power factor and meanwhile to maintain low LED current ripple. Conventional approaches can achieve >0.9 PF, however it is difficult for them to achieve lower PF with significantly less output current ripple.

The iW3626 combines the two operation modes, and it is capable of adjusting the percentage of constant T_{ON} operation during one line cycle by moving the dashed line up and down. Regardless of line voltages and power supply designs, once the percentage is determined during configuration stage by users (Section 9.3), the part can operate in this hybrid mode with the percentage regulated to the desired value.

By combining the two operation modes, the device gives users flexibility to trade power factor requirement for LED current-ripple performance which fundamentally conflict for a single-stage off-line power converter.

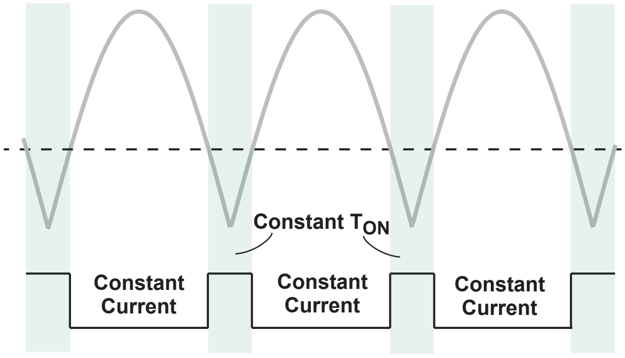


Figure 9.5: Hybrid Control to Achieve High PF

The iW3626 also provides one PF setting to disable high power factor operation (i.e. Level 4), which indicates during whole AC line cycle, the operation is in constant current mode operation. However, for this configuration, the iW3626 sets a maximum ON-time to be 20µs. As input voltage varies within an AC line cycle, the ON-time will also vary and increase at low input in order to maintain constant current operation. If the bulk capacitor cannot hold voltage high enough, there will be a chance that ON-time will increase to a point beyond which the ON-time is clamped to 20µs. Then, the iW3626 will run into a combination of constant current and constant T_{ON} operations again, and yield some PF.

9.6 Constant Current Mode Operation

In hybrid mode control in the iW3626, the constant current mode operation is critical. The iW3626 employs a patented primary-side-only technology to regulate cycle-by-cycle averaged secondary diode current to be constant, regardless of large input voltage variation within an AC line cycle. This feature helps the iW3626 to achieve tight control over PF, harmonics and LED ripple current. In addition, it also helps achieve tight LED current regulation over line voltages and over different numbers of LEDs.

To achieve this regulation the iW3626 senses the load current indirectly through the primary current. The primary current is detected by the CS/PF pin through a resistor from the BJT emitter to ground.

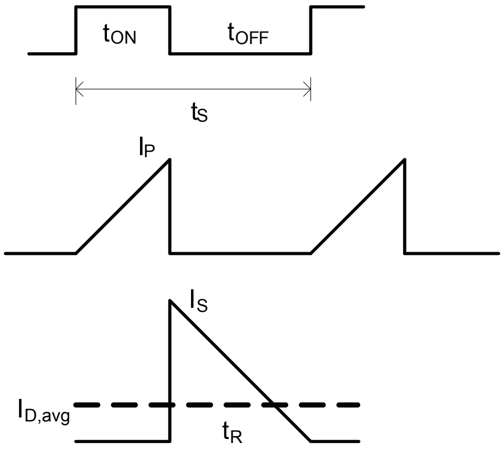


Figure 9.6: Constant Current Operation

The cycle-by-cycle averaged current of the secondary diode current is determined by:

$$I_{D,avg} = \frac{1}{2} \times N_{PS} \times \frac{V_{IPK}}{R_{CS}} \times \frac{t_R}{t_S} \qquad (9.6)$$

In the iW3626, the current $I_{D,\ avg}$ is well regulated to be constant during constant current mode operation, while avoiding continuous conduction mode operation.

During constant current mode operation, the output voltage regulation is not guaranteed. The point 1 in Figure 9.4, which reflects output voltage is not regulated to $FB_{(NOM)}$ (i.e. 1.536V). For LED applications, where current regulation is critical, design needs to ensure the point 1 is well below $FB_{(NOM)}$ with some margin.

9.7 Constant LED Current Regulation

The iW3626 achieves superior LED current regulation over line and load range. Figure 9.7 shows the output current waveform under the hybrid mode control. Note the switching ripple is neglected for simplicity since it is insignificant. During constant current operation, the cycle-by-cycle averaged secondary diode current, $I_{D,avg}$, is constant. Therefore it is flat in the waveform for this portion in Figure 9.7. During constant T_{ON} operation, the $I_{D,avg}$ can be approximated by following input voltage trend, ramping between the constant current to a small quantity, which is related to how low input voltage can dip. Averaging this current shape results in the LED DC current, I_{LED_dc}, highlighted as a solid line. The real LED current, I_{LED}, will have a double-line-frequency ripple and negligible switching ripple.

Due to the particular wave-shape of $I_{D,avg}$, the LED ripple current in the iW3626 is less than that in other traditional approaches.

In the iW3626, to maintain tight LED current regulation, it is required to ensure that CS/PF pin is regulated within 0.25V to 1.0V range. In particular, for low line and low power factor setting, care needs to be taken to ensure the CS/PF pin voltage is not clamped to 1.0V before system gets into constant T_{ON} operation.

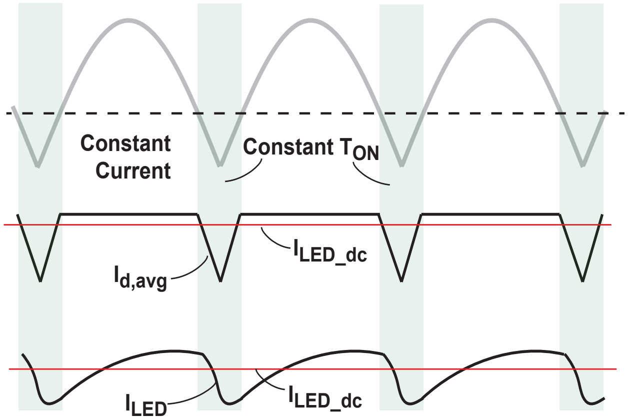


Figure 9.7: Output LED Current

The iW3626 also provides a way to tune up LED current regulation across line voltages. In Figure 9.8, the resistor R_{PF} used to configure power factor setting can also be used to compensate for LED current difference over line voltages.

To tune up the current, one capacitor C_{CMP} may be needed in order to generate a proper delay formed by R_{PF} and C_{CMP}, which leads to a gradual increment in LED current as line voltage increases.

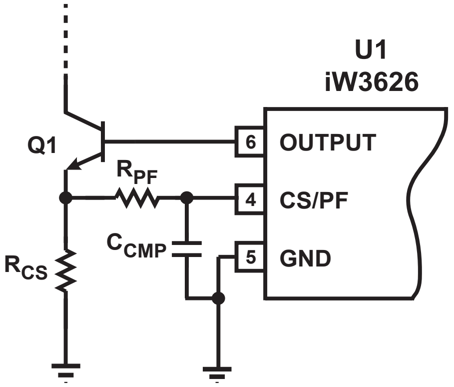


Figure 9.8: Compensation for LED Current

9.8 Constant Voltage Operation

The iW3626 also incorporates constant voltage (CV) operation, where output voltage maintains constant by regulating the point 1 indicated in Figure 9.4 to FB_{NOM} (1.536V typically). During constant voltage operation, the iW3626 may operate in pulse-width-modulation (PWM) mode or pulse-frequency-modulation (PFM) mode, depending on load conditions. In particular, the iW3626 allows the switching frequency to drop as low as 275Hz at PFM mode, which helps system stay regulated at very light load condition, thus improving active operating efficiency by using large pre-load resistor (50kΩ or above).

Figure 9.9 shows power envelope for the iW3626. After soft-start is completed, the digital control block measures the output conditions. It determines output power levels and adjusts the control system to operate either in CV mode or hybrid mode.

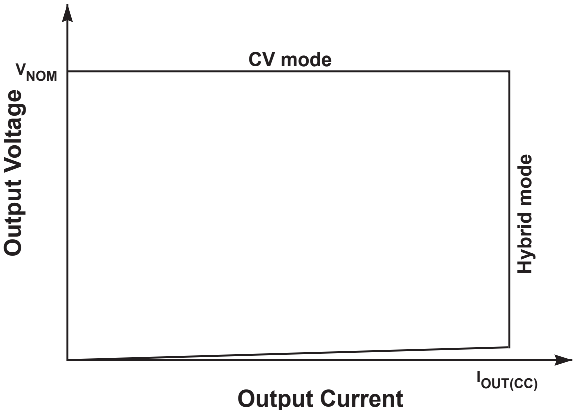


Figure 9.9: Power Envelope

For LED applications, care is needed to select R1 and R2 (in Figure 9.2), such that the output voltage is below CV mode and the iW3626 can thus run in hybrid mode for good current regulation.

9.9 Variable Frequency Operation Mode

At each of the switching cycles, the falling edge of FB/OTP is checked. If the falling edge of FB/OTP is not detected, the off-time is extended until the falling edge of FB/OTP is detected. This results in the variable switching frequency operation. In particular in hybrid mode control, for low line input voltage, the ON-time could be pushed relatively high, and in order to maintain DCM operation, the switching frequency can drop much less than the nominal 72kHz. Additionally, in constant voltage operation, the switching frequency in PFM mode can be pushed as low as 275Hz at very light load to improve operating efficiency.

In the iW3626, the maximum allowed transformer reset time is 110μs. When the transformer reset time reaches 110μs, the iW3626 shuts off.

9.10 Quasi-Resonant Switching

The iW3626 also incorporates a unique proprietary quasi-resonant switching scheme that achieves valley-mode turn on for every switching cycle. In valley mode switching, the BJT switch is turned on at the point where the resonant voltage across the collector and emitter of the BJT is at its lowest point (see Figure 9.10). By switching at the lowest V_{CE}, the switching loss will be minimized.

Turning on at the lowest V_{CE} generates lowest dV/dt, thus valley mode switching can also reduce EMI. Due to the nature of quasi-resonant switching, the actual switching frequency can vary slightly cycle by cycle, providing the additional benefit of reducing EMI.

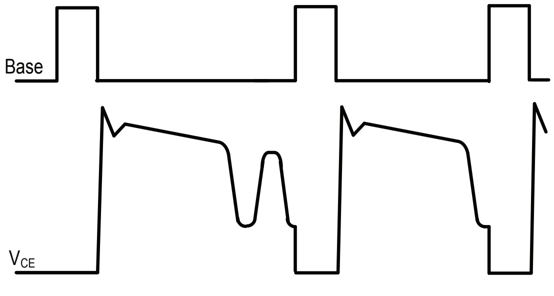


Figure 9.10: Valley Mode Switching

9.11 Internal Loop Compensation

The iW3626 incorporates an internal Digital Error Amplifier with no requirement for external loop compensation. For a typical power supply design, the loop stability is guaranteed to provide at least 45 degrees of phase margin and -20dB of gain margin.

9.12 LED Open and Short Protections

The constant voltage operation in the iW3626 provides protection against LED open fault. During normal operation, the iW3626 operates in hybrid mode with the output voltage below the nominal voltage set by $FB_{(NOM)}$. After LED is open, the output voltage will be pushed higher momentarily. Depending on the output capacitor and LED operating current, system may gradually settle down and stay regulated at constant voltage operation at no-load condition. Or, if the output voltage overshoot exceeds the output OVP threshold set by $FB_{(OVP)}$ in Section 6.0, the iW3626 shuts down.

LED short fault is detected via FB/OTP pin. When the point 1 in Figure 4 is below 115mV for several consecutive cycles, the iW3626 shuts down.

When any of these faults are met the IC remains biased to discharge the V_{CC} supply. Once V_{CC} drops below UVLO threshold, the controller resets itself and then initiates a new soft-start cycle. The controller continues attempting start-up until the fault condition is removed.

9.13 PCL, OCP and SRS Protection

Peak-current limit (PCL), over-current protection (OCP) and sense-resistor-short protection (SRSP) are features built into the iW3626. With the CS/PF pin the iW3626 is able to monitor the peak primary current. This allows for cycle-by-cycle peak current control and limit. When the peak primary current multiplied by the CS/PF resistor is greater than 1.15V, over-current is detected and the IC immediately turns off the output driver until the next cycle. The output driver sends out a switching pulse in the next cycle, and the switching pulse continues if the OCP threshold is not reached; or, the switching pulse turns off again if the OCP threshold is reached. If the OCP occurs for several consecutive switching cycles, the iW3626 shuts down.

If the CS/PF resistor is shorted there is a potential danger that over-current condition may not be detected. Thus, the IC is designed to detect this sense-resistor-short fault during start-up and shut down immediately. The V_{CC} is discharged since the IC remains biased. Once V_{CC} drops below the UVLO threshold, the controller resets itself and then initiates a new soft-start cycle. The controller continues attempting to start-up, but does not fully start-up until the fault condition is removed.

9.14 OTP and Current-Derating

The iW3626 incorporates a distinctive over-temperature protection (OTP) with current-derating function. Before the soft-start process is initiated, the part will first check the junction temperature. If the junction temperature is above 110°C, then the system will not start up. Once the part starts up, the thermal shutdown temperature becomes 160°C. However, during normal operation, before the junction temperature reaches 160°C, the part will firstly derate output current in the predetermined steps in an attempt to reach thermal equilibrium before thermal shutdown kicks in. In this way, the part will stay in a safe operation meanwhile maximizing output current.

Figure 9.11 shows output current derating function. In this example, the LED current starts to derate output current when the junction temperature hits 120°C and will continue to derate the current if it hits next derating temperature thresholds such as 130°C, 140°C, 150°C. For each derating, the output current drop is roughly 10% of the nominal operating current. In addition, each derating step consists of a couple of small steps taking place in several seconds. In this way, the output current drops gradually, so that there is no visual observation of any flicker during current derating process.

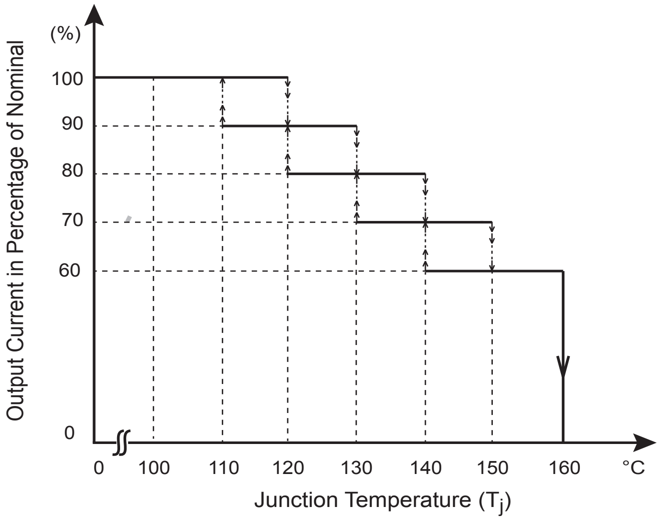


Figure 9.11: Thermal Derating

In the iW3626's derating function, a 10°C hysteresis is built in for each derating step. For example, after the junction temperature hits 120°C, the output current drops output current by roughly 10%. Afterwards, if the junction temperature is stabilized in the range from 110°C to 130°C (with both temperatures excluded), no action will take place; however if the junction temperature drops below 110°C, then output current will start to ramp up in an opposite way as derating to reach previous level of output current.

For different applications, there may be a need to derate output current starting at different temperature. This can be done in the iW3626 by configuring it to three levels via FB/OTP pin. Refer to Section 9.3 for details.

9.15 Dynamic Base Current Control

One important feature of the iW3626 is that it directly drives a BJT switching device with dynamic base current control to optimize performance. During the constant current control, the BJT base current is dynamically controlled according to the BJT collector current, which can be sensed via CS/PF pin voltage. The higher the output power, the higher the base current. Specifically, the base current is related to V_{IPK}, as shown in Figure 9.12.

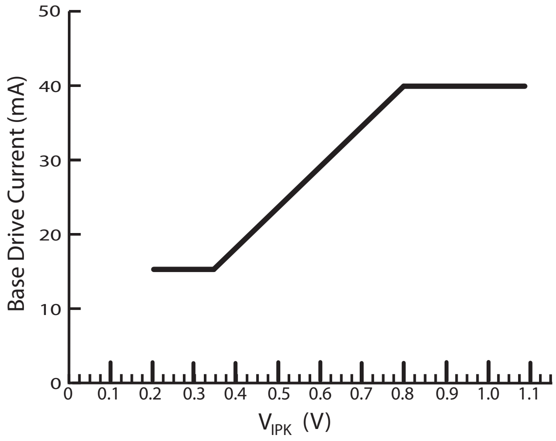
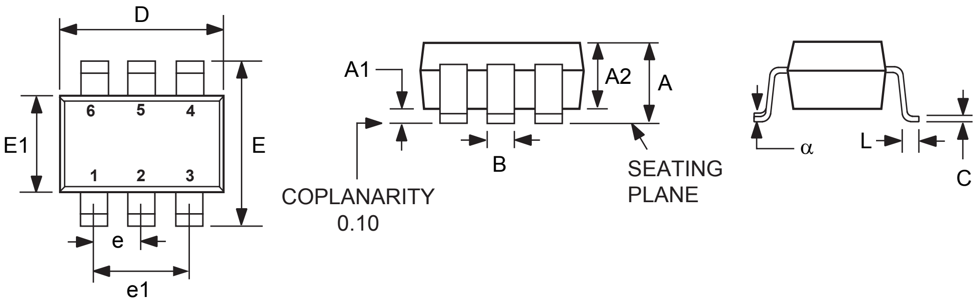


Figure 9.12: Base Drive Current vs. V_{IPK}

During constant T_{ON} operaion in hybrid mode, the input voltage is low, and the resulting collect current is less than that during constant current mode. In the iW3626, the driver current drops in this mode to improve operating efficiency.

10.0 Physical Dimensions

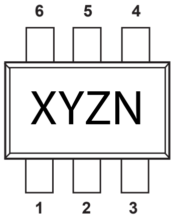
6-Lead SOT Package



Symbol	Millimeters MIN	Millimeters MAX
A	-	1.45
A1	0.00	0.15
A2	0.90	1.30
B	0.30	0.50
C	0.08	0.22
D	2.90 BSC	
E	2.80 BSC	
E1	1.60 BSC	
e	0.95 BSC	
e1	1.90 BSC	
L	0.30	0.60
α	0°	8°

Figure 10.1: Physical dimensions, 6-lead SOT23 package

SOT23-6 devices are marked with a 4-digit code. Orientation of Pin 1 is shown below:



Compliant to JEDEC Standard MO-178AB

Controlling dimensions are in millimeters

This package 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; packages can withstand 10 s immersion < 270ºC

Dimension D does not include mold flash, protrusions or gate burrs. Mold flash, protrusions or gate burrs shall not exceed 0.25 mm per side.

The package top may be smaller than the package bottom. Dimensions D and E1 are are determined at the outermost extremes of the plastic body exclusive of mold flash, tie bar burrs and interlead flash, but including any mismatch between top and bottom of the plastic body.

11.0 Ordering Information

Part Number	Options	Package	Description
iW3626-00	Maximum driver current = 40mA, wide V_{OUT} range	SOT-23	Tape & Reel[1]
iW3626-01	Maximum driver current = 40mA, narrow V_{OUT} range	SOT-23	Tape & Reel[1]
iW3626-02	Maximum driver current = 50mA, wide V_{OUT} range	SOT-23	Tape & Reel[1]

Notes:

1. Tape & Reel packing quantity is 3,000 per reel. Minimum ordering quantity is 3,000.

Trademark Information

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