Application Note AN-67
LYTSwitch-1 Family

Design Guide

Introduction

The LYTSwitch™-1 family is ideal for inexpensive single-stage high power factor constant current LED bulbs and tubes with outputs up to 22 W.

The family incorporates a high-voltage MOSFET with a variable on-time CrM controller. Extensive protection features with minimum external components provide industry leading power density and functionality. The devices can be used in high-side or low-side non-isolated buck topology.

The internal supply current is drawn from a high-voltage current source connected to the DRAIN pin, eliminating the need for bias windings and allows the use of low-cost off-the-shelf drum chokes.

Protection features with auto-restart include input and output overvoltage protection, output short-circuit protection, and open-loop protection.

Thermal foldback ensures that light continues to be delivered at elevated temperatures. Over-temperature shutdown provides protection during fault conditions.

Scope

This application note is intended for engineers designing a non-isolated AC-DC buck power supply using the LYTSwitch-1 family of devices. It provides a step-by-step design procedure for the selection of all circuit components.

The application note makes use of the PIXls Designer, a spreadsheet based application that gives the power supply engineer more control during the design process. The software is part of the PI Expert™ design software suite which can be downloaded from http://www.power.com/en/design-support/pi-expert-design-software.

In addition to this application note you may also find the LYTSwitch-1 Reference Design Kit (RDK), containing engineering prototype boards, reports, and device samples, useful as the starting point for a new design.

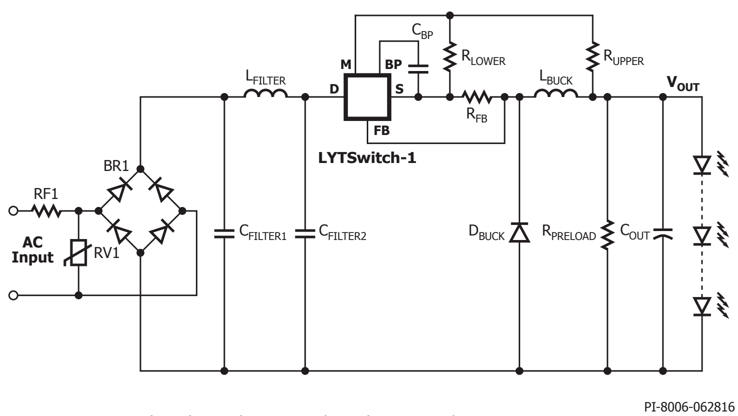
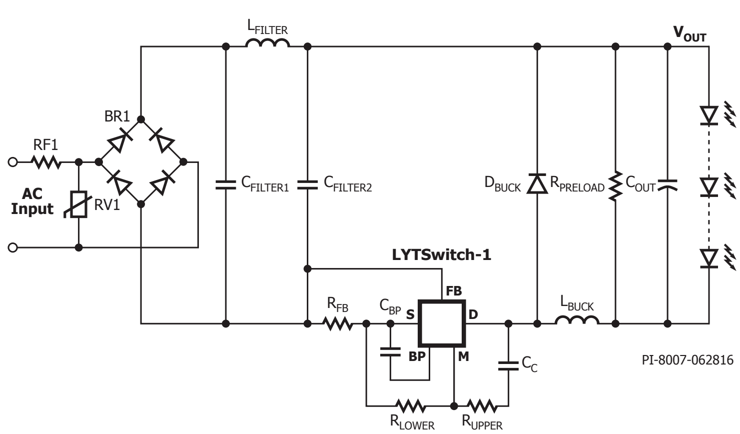
Topology	Basic Circuit Schematic	Key Advantages
High-Side Buck	 *Figure 1. High-Side Buck – Typical Application Schematic.*	• Low component count • Accurate Output OVP Sensing
Low-Side Buck	 *Figure 2. Low-Side Buck – Typical Application Schematic.*	• Lower EMI – allows the use of drum choke

Table 1. LYTSwitch-1 Circuit Configurations.

Pin Function Description

Pin Name	Functionality
BYPASS (BP) Pin	5.22 V supply rail
MULTIFUNCTION (M) Pin	Mode 1: FET OFF • Detection of inductor de-magnetization (ZCD) to ensure CrM • Output OVP sensing • Steady-state operation voltage range is [1 V – 2.4 V] Mode 2: FET ON • Line OVP sensing
FEEDBACK (FB) Pin	• FET current sensing using external current sense resistor • Normal operation voltage range is [$V_{FB(REF)}$ – 0 V]
DRAIN (D) Pin	High-voltage internal MOSFET
SOURCE (S) Pin	Power and signal ground

Table 2. Pin Function Descriptions.

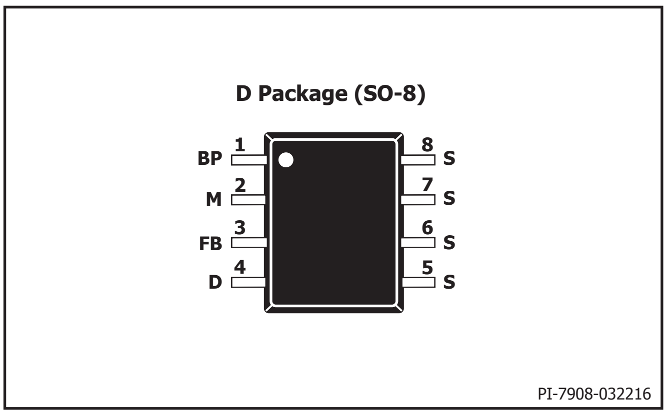


Figure 3. LYTSwitch-1 Pin Configuration.

LYTSwitch-1 Operation

The basis of control scheme is derived from states of operation in Critical Mode Conduction (CrM). In buck topology the average inductor current is the output current. The true triangular nature of inductor current waveform in CrM allows for accurate prediction of average current per switching period $<I_L>_{TSW}$.

$$< I_L >_{TSW} = \frac{I_{LPK}}{2} \quad \text{(Eq.1)}$$

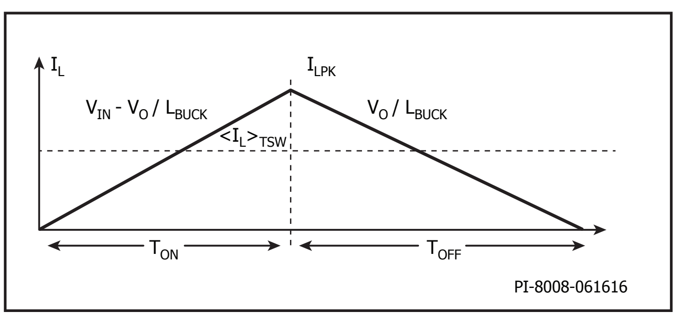


Figure 4. Critical Conduction Mode (CrM) Inductor Current Profile.

In a rectified AC input, the peak inductor current varies during the excursion of the AC input; hence, to maintain a constant average inductor current, the average over rectified AC cycle must be controlled.

The LYTSwitch-1 IC accomplishes this by forcing a peak current limit and controlling T_{ON} to maintain a constant ratio between the time in the constant current region (T_{CC}) and the time in dead zone (T_{DZ}).

$$\frac{T_{CC}}{T_{DZ}} = \text{Constant} \quad \text{(Eq.2)}$$

By keeping the ratio constant, very accurate current regulation can be achieved for a reasonably wide input voltage, output voltage, and component variation. This is analogous to keeping the area of geometrical shapes the same by varying their contour (Figure 6).

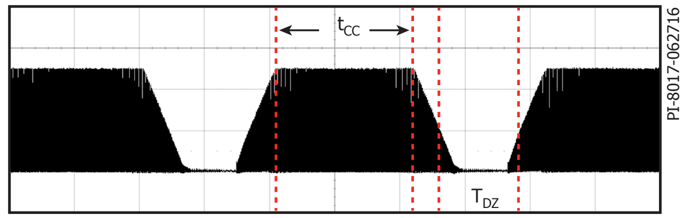


Figure 5. LYTSwitch-1 Constant Ratio Control Scheme.

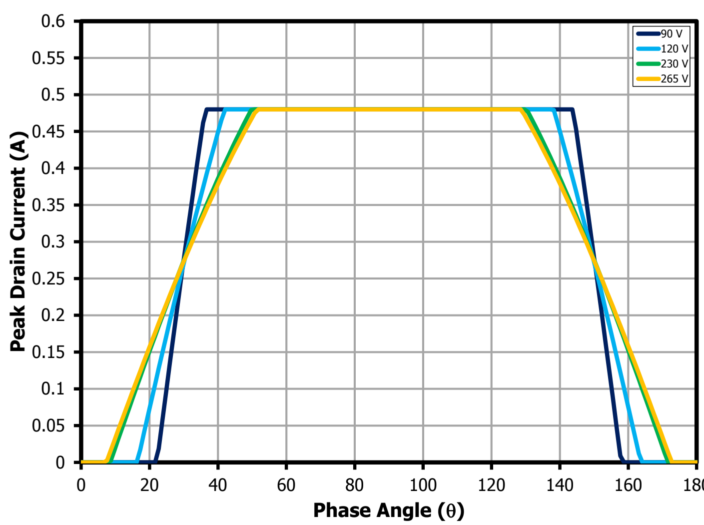


Figure 6. Constant Area Contours.

LYT140x maintains a ratio of 2, while LYT160x maintains a ratio of 0.75.

Step-by-Step Design Procedure

Step 1 – Enter Application Variables VAC_{MIN}, VAC_{TYP}, VAC_{MAX}, f_L, V_O, I_O, V_D, Optimization Parameter

ENTER APPLICATION VARIABLES				
LINE VOLTAGE RANGE		Universal		AC line voltage range
VACMIN		90	V	Minimum AC line voltage
VACTYP		115	V	Typical AC line voltage
VACMAX		265	V	Maximum AC line voltage
fL		50	Hz	AC mains frequency
VO		60	V	Output Voltage
IO		160	mA	Average output current specification
EFFICIENCY		0.90		Efficiency estimate
PO		9.60	W	Continuous output power
VD		0.70	V	Output diode forward voltage drop
OPTIMIZATION PARAMETER	THD	THD		BOM selects IC with lowest peak current. THD selects IC for lowest THD.

Figure 7. Application Variables Section of the Design Spreadsheet.

Line Voltage Range and Line Frequency

Determine the input voltage range and line frequency from Table 3.

Input Voltage	VAC_{MIN}	VAC_{TYP}	VAC_{MAX}	F_L (Hz)
Low-Line only	90	100/115	132	50/60
High-Line only	180	230	265	50
Wide Range	90	115/230	265	50/60

Table 3. Input Line Voltage Ranges and Line Frequency.

Nominal Output Voltage, V_O (V)

Enter the nominal LED output voltage based on Table 4. Choose from the recommended V_O column for best CC regulation. The extended V_O column provides the user flexibility to use the device beyond the recommended value. The CC regulation, however, is not guaranteed and has to be verified in actual prototype. If either device family can support the required V_O, narrow down the choice based on optimization parameter.

Input Voltage Range (V_{AC})	Device Family	Recommended V_O	Extended V_O
Low-Line or Wide Range	LYT140x	25-55	10-55
	LYT160x	45-60	10-90
High-Line only	LYT140x	25-80	10-120
	LYT160x	45-130	10-130

Table 4. Output Voltage Range.

Nominal Output Current, I_O (mA)

Enter the nominal output current.

Output Diode Forward-Voltage Drop, V_D (V)

Enter the average forward-voltage drop of the output diode. V_D has a default value of 0.7 V.

Optimization Parameter

Use Table 5 to select between BOM and THD. PIXls will flag a warning if the chosen parameter does not match the output voltage range.

	LYT140x	LYT160x
Optimization	BOM	THD
Peak Current	Lower	
Wide Range CC Regulation	Best	
THD		Best
Core Size	Smaller	
Device Size	Smaller	

Table 5. Comparison Between LYT140x and LYT160x.

Step 2 – Select LYTSwitch-1 Device

Select "Auto" to let PIXls choose the appropriate device size. For manual selection, select the device from Table 5, taking into account the V_O and optimization parameter restrictions in Table 3 and Table 4, respectively.

Product	Optimized for BOM	
	$V_O \leq 45$ V	$V_O \geq 45$ V
LYT1402D	$V_O \times 0.177$ A	8 W
LYT1403D	$V_O \times 0.318$ A	15 W
LYT1404D	$V_O \times 0.483$ A	22 W
Product	**Optimized for THD**	
	$V_O \leq 54$ V	$V_O \geq 55$ V
LYT1602D	$V_O \times 0.147$ A	8 W
LYT1603D	$V_O \times 0.265$ A	15 W
LYT1604D	$V_O \times 0.403$ A	22 W

Table 6. Output Power Table (Buck Topology).

ENTER LYTSWITCH-1 VARIABLES				
DEVICE BREAKDOWN VOLTAGE		725	V	This Spreadsheet supports 725V device only
DEVICE	Auto	LYT1603D		Actual LYTSwitch-1 device
ILIMITMIN		1.06	A	Minimum Current Limit
ILIMITTYP		1.15	A	Typical Current Limit
ILIMITMAX		1.24	A	Maximum Current Limit
TON		6	us	On-time during the fixed on-time region at VACTYP
FSW		55	kHz	Maximum switching frequency in the fixed current limit region at VACTYP
DMAX		0.90		Maximum duty cycle possible in the fixed on-time region

Figure 8. LYTSwitch-1 Variables Section of the Design Spreadsheet.

The sample design scenario below demonstrates the difference between LYT140x and LYT160x.

Input Voltage: Wide range
Output Voltage: 48 V
Output Current: 160 mA
Output Power: 7.68 W

From Table 4, either LYT140x or LYT160x can be chosen. From the power table (Table 6), the choice is either LYT1402 or LYT1603. The increase in MOSFET size is because for the same output current, the operating peak current of LYT160x is 20% higher than LYT140x.

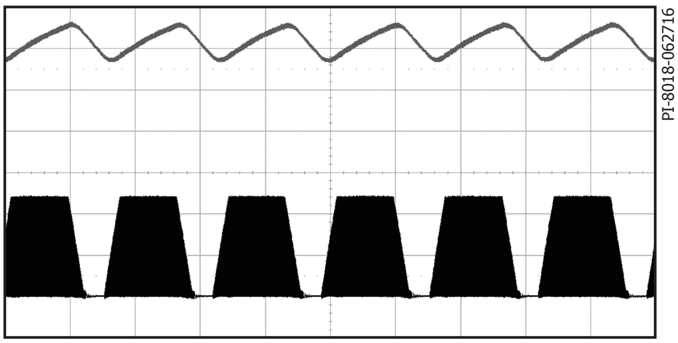


Figure 9. LYT1402 Drain Current Profile.

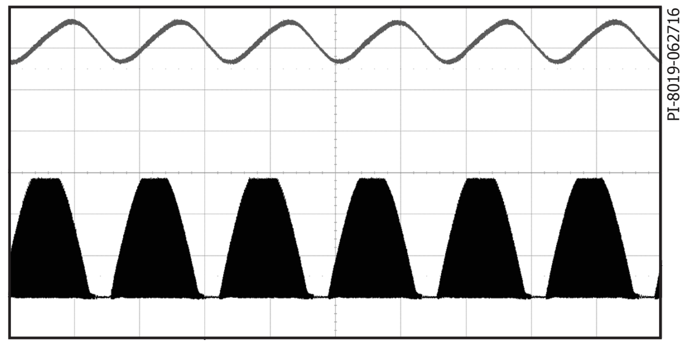


Figure 10. LYT1603 Drain Current Profile.

Step 3 – Determine the Output Inductance

INDUCTOR DESIGN PARAMETERS				
LP_MIN		535	uH	Absolute minimum design inductance
LP_TYP		1200	uH	Typical design inductance
LP_TOLERANCE		10	%	Tolerance of the design inductance
LP_MAX		3616	uH	Absolue maximum design inductance

Figure 11. Inductor Section of the Design Spreadsheet.

The design spreadsheet already calculates the recommended inductance, LP_{TYP}. However, any value between L_{P_MIN} and L_{P_MAX} may be used, in order to optimize the performance based on priority:

- Switching Frequency – The higher the inductance, the lower the peak switching frequency. This allows the user to tune the switching frequency for better EMI performance.
- Inductor / Bobbin Size – Higher inductance means more turns and possibly larger core size.
- Line Regulation – The higher the inductance, the more negative the line regulation becomes. This may be important when optimizing for best regulation (See Figure 12).
- Input Ringing – Higher inductance is more prone to input ringing particularly at low input voltage.

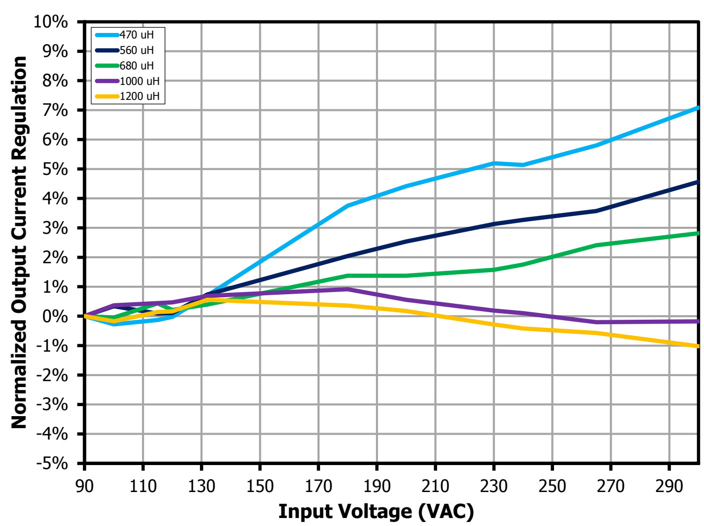


Figure 12. Effect of Output Inductance on CC Regulation.

Step 4 – Select the Type of Output Inductor

The user has an option to use either a bobbin-type or an off-the-shelf drum-core inductor. Drum-core is generally cheaper than bobbin-type inductor. However, please use extra precaution when using unshielded drum-core.

Guidelines in using Unshielded Drum-Core for Output Inductor

- Use low-side configuration for lower EMI.
- Provide enough clearance between the input filter inductor and output inductor if both are unshielded.
- Provide some clearance between the output inductor and output electrolytic capacitor since the capacitor has metallic enclosure.
- Avoid metallic enclosure if possible.
- If metallic enclosure is required, verify the output regulation and EMI are not affected.
- It may be necessary to control the start-end winding of the drum-core to make the regulation and EMI performance consistent.

On PIXls, choose from a list of common transformer cores or choose "Custom" and fill-out the parameters if using a different core. Choose "Off the shelf" for drum-core. See Table 7 for standard values.

Standard Off-The-Shelf Inductor Values	
470 μH	1800 μH
560 μH	2200 μH
680 μH	2700 μH
820 μH	3300 μH
1000 μH	3900 μH
1200 μH	4700 μH
1500 μH	5600 μH

Table 7. Standard Drum Core Inductor Values.

Step 5 – Select the Freewheeling Diode

Select the freewheeling diode based on the following:

- Reverse Recovery Time, t_{RR} – CrM operation allows the use of output diode with slower reverse recovery (up to 250 ns).
- Peak Inverse Voltage, PIV_D – Select the peak inverse voltage (PIV) rating with at least 25% margin above the peak input voltage.
- Forward Current, I_F – Use output current I_O as the minimum forward current rating. A 1 A diode is recommended for designs with I_O < 300 mA. For higher I_O, check the forward current derating curve to determine if 2 A diode is necessary at a given operating temperature.

Step 6 – Select the Output Capacitor

LYTSwitch-1 can operate even without an output capacitor at the expense of high ripple current. Nevertheless, limiting the ripple current is often necessary for better LED reliability.

The ripple current is a function of both the output capacitance and the LED bulk resistance. It is therefore necessary to size the output capacitance on actual LED load to determine the minimum value required for a given ripple current specification.

An electrolytic capacitor with a voltage rating above the output OVP level is recommended.

Step 7 – Select the Pre-load Resistor

A pre-load resistor is necessary to prevent the output capacitor voltage from creeping up during open-load condition. The minimum recommended value is given by this formula:

$$R_{PRELOAD} = \frac{V_O}{1\,mA} \quad \text{(Eq.3)}$$

Step 8 – Select the Bypass Capacitor

The value of the BYPASS pin capacitor should be large enough to keep the BYPASS pin voltage from falling below V_{BP} reset, especially when the instantaneous input voltage is below V_O. A 4.7 μF with a voltage rating of greater than 7 V is recommended for most designs.

Step 9 – Determine the Feedback Resistor

Use this formula to calculate the feedback sense resistor R_{FB}:

$$R_{FB} = \frac{V_{FB(REF)}}{k \times I_{OUT}} \quad \text{(Eq.4)}$$

Where:

R_{FB}: Feedback sense resistor
$V_{FB(REF)}$: FEEDBACK pin reference voltage (-280 mV)
I_O: Output current
k: Ratio between I_{PK} and I_O (k = 3 for LYT140x, and k = 3.6 for LYT160x)

Trimming R_{FB} may be necessary to center I_O at the nominal input voltage.

ENTER INDUCTOR CORE/CONSTRUCTION VARIABLES				
CORE	EE13	EE13		Enter Transformer Core
CUSTOM CORE NAME				If custom core is used - Enter part number here
AE		17.10	mm^2	Core effective cross cectional area
LE		30.20	mm	Core effective path length
AL		1130.00	nH/turn^2	Core ungapped effective inductance
AW		21.28	mm^2	Window Area of the bobbin
BW		7.40	mm	Bobbin physical winding width
LAYERS		6.0		Number of Layers

Figure 13. Standard Drum Core Inductor Values.

Step 10 – Determine the MULTIFUNCTION Pin Components

Buck Configuration
High-side buck has one less component count than low-side buck. It also has a more accurate line and output OVP detection. Low-side buck, on the other hand, provides better EMI performance and potentially allows the use of smaller filter components.

R_{UPPER} Selection
Use the table below to select the default R_{UPPER} value:

Input Voltage Range	Recommended R_{UPPER}
Low-Line only	402 kΩ, 1%, 0805
High-Line only / Wide Range	402 kΩ, 1%, 1206

Table 8. Recommended R_{UPPER} Values.

R_{LOWER} Selection
R_{UPPER} and R_{LOWER} form a voltage divider network that sets the output OVP threshold VO_{OVP}. On high-side configuration, the recommended OVP point is 120% of V_O.

$$R_{LOWER}(High-Side)=\frac{2.4\,V\times R_{UPPER}}{120\%\times V_{OUT}-2.4\,V}\quad\text{(Eq.5)}$$

On low-side configuration, the output voltage is sensed with the use of a coupling capacitor. This approach eliminates the need for transformer-based buck inductor with auxiliary winding. The selection of R_{LOWER} in low-side configuration requires extra attention to prevent false-triggering of output OVP during normal operation.

The peak MULTIFUNCTION pin voltage is affected by the inductance, V_O and input voltage. Use the equation below to calculate the proper R_{LOWER} in low-side configuration:

$$R_{LOWER}(Low-Side)=\frac{V_{MREF}\times R_{UPPER}}{V_{OUT}-V_{MREF}}\quad\text{(Eq.6)}$$

Where:

V_{MREF}: MULTIFUNCTION pin reference voltage shown in Table 9.

	V_{MREF} (Low-Side Configuration), V		
	High-Line		Low-Line / Wide Range
F_{SW} (kHz)	V_O < 70 V	V_O ≥ 70 V	
>70	1.9	1.9	1.9
60-70	1.85	1.85	1.85
50-60	1.8	1.8	1.8
40-50	1.7	1.8	1.8
30-40	1.6	1.7	1.7
20-30	1.5	1.6	1.6

Table 9. Reference MULTIFUNCTION Pin Voltage in Low-Side Configuration (V_{MREF}).

Coupling Capacitor Selection
The coupling capacitor is only applicable in low-side configuration. Use a 100 pF, COG or NPO dielectric, 1 kV, ceramic capacitor.

LYTSWITCH EXTERNAL COMPONENTS				
FB Pin Resistor				
RFB_T		0.486	Ohms	Theoretical calculation of the feedback pin sense resistor
RFB		0.487	Ohms	Standard 1% value of the feedback pin sense resistor
M Pin Components				
BUCK_CONFIG	Low Side Buck			Buck Topology Switch Configuration
RUPPER		402.00	kOhms	Upper resistor on the M-pin divider network (E96 / 1%)
RLOWER		12.40	kOhms	Lower resistor on the M-pin divider network (E96 /1%)
VO_OVP		79.5	V	!!Info1. The VO_OVP is 1.33 of VO.
Line_OVP		462	V	Line overvoltage threshold
CC		100	pF	Coupling Capacitor for Low Side Buck Configuration
RPRELOAD		60	kOhms	Minimum Output Preload Resistor

Figure 14. External Components Section of the Design Spreadsheet.

Step 11 – Design Input Stage

The standard input stage configuration is shown on Figure 15.

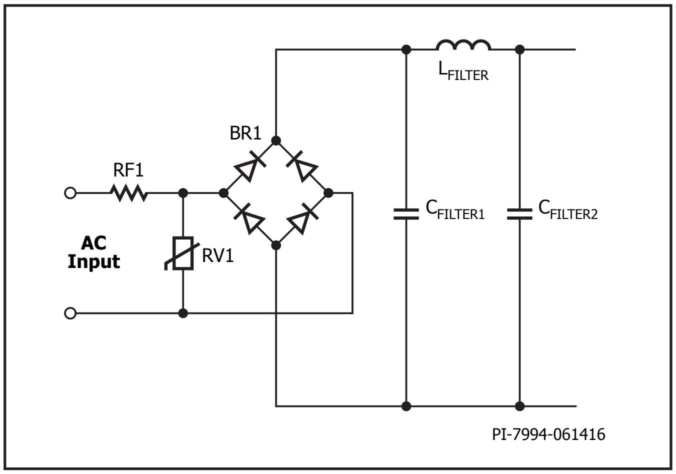


Figure 15. Standard Input Stage Configuration.

Fuse Element

The input fuse provides safety protection from component failures. A flameproof, fusible resistor can also be used since it is generally cheaper than a standard fuse and it also helps reduce the voltage stress during line surge. In addition, it can also minimize the input ringing at low input voltage in some designs. The main drawbacks are lower efficiency and slower response time during fault conditions.

Surge Protection

The MOV acts as a voltage clamp that limits the voltage spike seen by the led driver during line voltage surge events.

EMI Filter

The recommended EMI filter uses a low-cost pi configuration. The filter design is also critical to the overall circuit performance because it directly affects the power factor, THD, and stability.

1. Determine the maximum total input capacitance ($C_{FILTER1}$ + $C_{FILTER2}$). If PF >90% at 230 V is required, use 25 nF/W to quickly select the required capacitance. For low-line design, higher capacitance is permitted.
2. Select the proper $C_{FILTER1}$ and $C_{FILTER2}$ values. For low-line and wide range design, use the largest possible value of $C_{FILTER2}$. Limit $C_{FILTER1}$ to a minimum of 22 nF. For high-line design, the distribution is not critical and only depends on EMI response.
3. The filter inductor ranges from 1 mH to 4.7 mH. Use the smallest possible inductance.
4. Use a fusible resistor if a slight drop in efficiency is acceptable. The resistor provides damping which may increase PF, and prevents input oscillation.

Protection Features

SOA Protection

During power-up, overload and short-circuit conditions, lower or no output voltage can cause deep CCM (Continuous Conduction Mode) mode of operation because of no inductor discharge during flywheel conduction, FET current can staircase to SOA limits and cause irreversible damage. In buck topology this is manifested more severely than other topologies. SOA mode is detected when peak currents are reached within minimum ON-time (~ 500 ns or soon after the expiration of leading-edge blanking time).

Eight switching pulses (F_{MIN} cycles) are skipped once SOA pulse is detected to reset the inductor current to zero before next switching cycle is enabled.

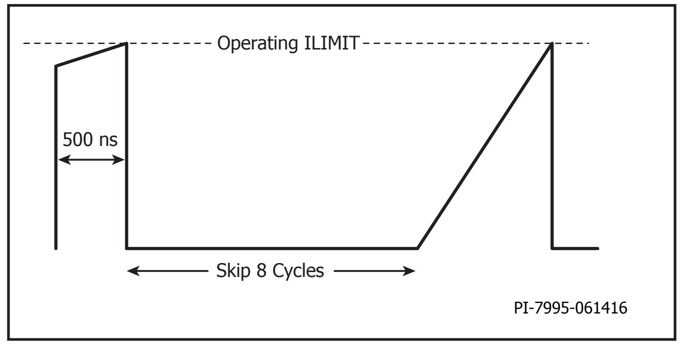


Figure 16. SOA Skip-Cycle Timing.

Output Short-Circuit Protection

In case of output short-circuit, pulse skipping mode is enabled when SOA event is triggered. If output short-circuit persists for more than 2 SOA events then 100 ms auto-restart delay is enabled before the next switching attempt. If SOA fault persists following two 100 ms auto-restart attempts then the delay is increased to 1 s.

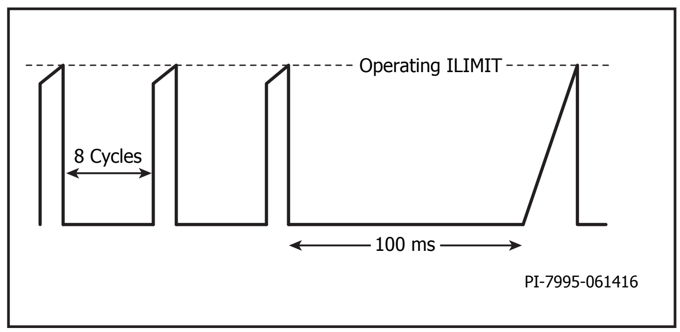


Figure 17. Three Consecutive SOA Event Timing.

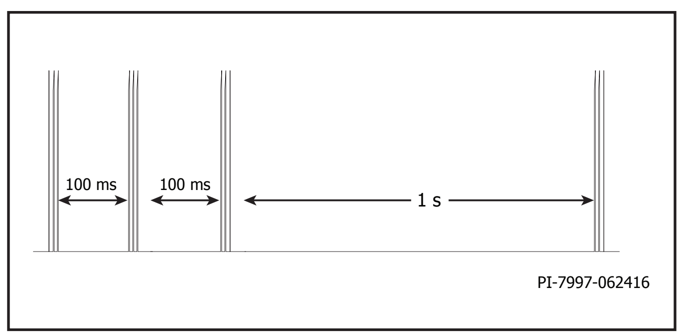


Figure 18. 1s Auto-Restart.

In some cases, the unit does not detect 3 consecutive SOA events. A secondary protection is achieved with MULTIFUNCTION pin undervoltage.

MULTIFUNCTION Pin Undervoltage Protection

If the MULTIFUNCTION pin voltage is kept below 1 V for 500 ms, the device will trigger 1s auto-restart. This may occur when the output is shorted.

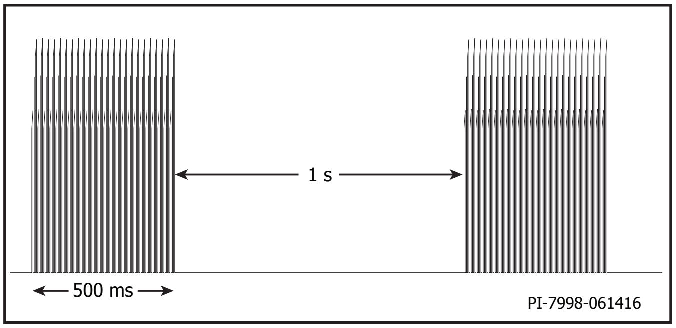
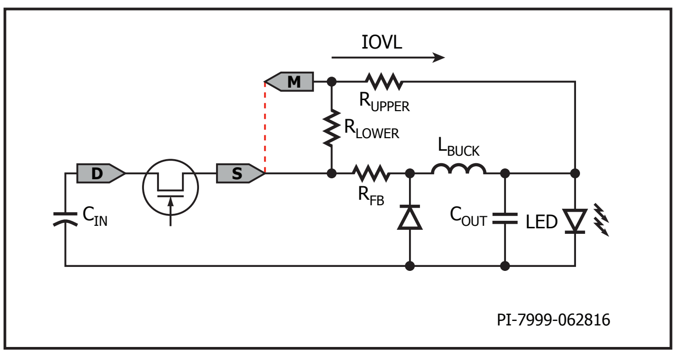


Figure 19. MULTIFUNCTION Pin Undervoltage Auto-Restart Timing.

Input Overvoltage Protection

When the MOSFET is ON, the MULTIFUNCTION pin is virtually shorted to Source and line OVP is triggered if the current through R_{UPPER} exceeds 1 mA. Switching stops immediately once the fault is triggered and the device goes into auto-restart.

$$V_{IN(OVP)} = 1\,mA \times R_{UPPER} + V_{OUT} \qquad \text{(Eq.7)}$$



Output Overvoltage Protection

During flywheel diode conduction time, if the voltage across the MULTIFUNCTION pin exceeds V_{OOV} (2.4 V) for 500 µs, output OVP will be triggered and the unit will go into auto-restart.

For high-side, $$V_{OUT(OVP)} = 2.4\,V \times \frac{R_{UPPER} + R_{LOWER}}{R_{LOWER}} \qquad \text{(Eq.8)}$$

For low-side, $$V_{OUT(OVP)} = V_{OUT} \times \frac{2.4\,V}{V_{MREF}} \qquad \text{(Eq.9)}$$

Over-Current Protection

When the internal current limit is reached, such as when the R_{FB} is shorted, the unit goes into auto-restart.

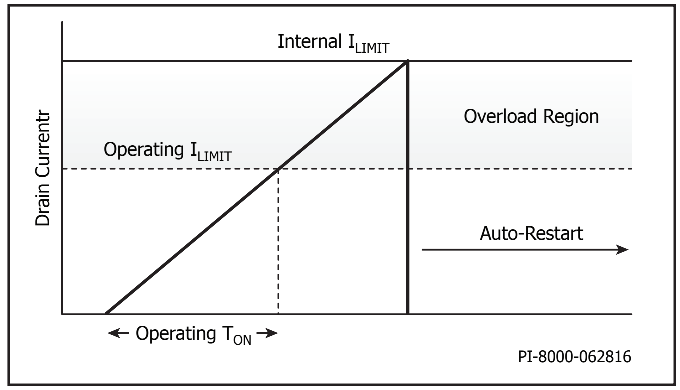


Figure 20. Over-Current Protection.

Thermal Fold-back and Over-temperature Protection

Thermal fold-back kicks-in when the junction temperature exceeds 145 °C. Output current drops linearly by approximately -2.5% / °C until the over-temperature shutdown is triggered at 160 °C. The device auto-recovers when the temperature drops to 85 °C.

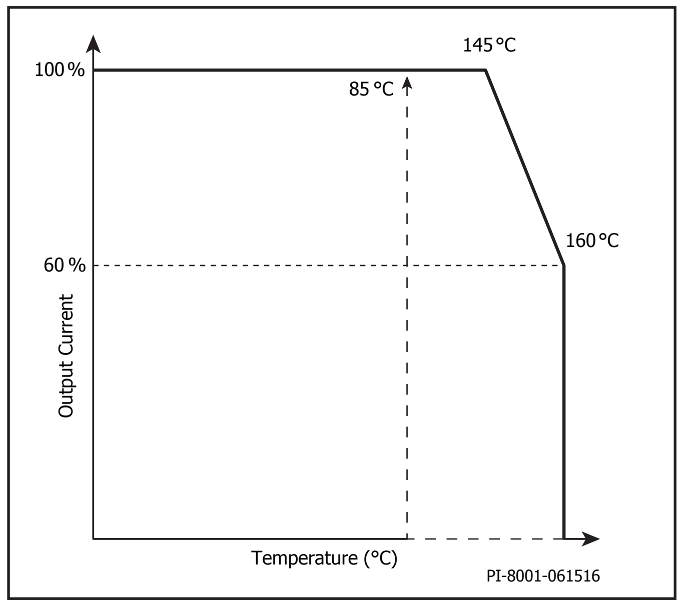


Figure 21. Thermal Fold-Back and OTP.

Other Information

Factors affecting iTHD

- Device Selection – Use LYT160x for best THD.
- Input Capacitance – Lower capacitance means lower THD.
- Output Voltage – Figure 22 shows how the THD changes with output voltage. The absolute minimum may vary depending on power, but in general, the lowest THD at 230 VAC can be achieved if the output voltage is between 50 V and 80 V.

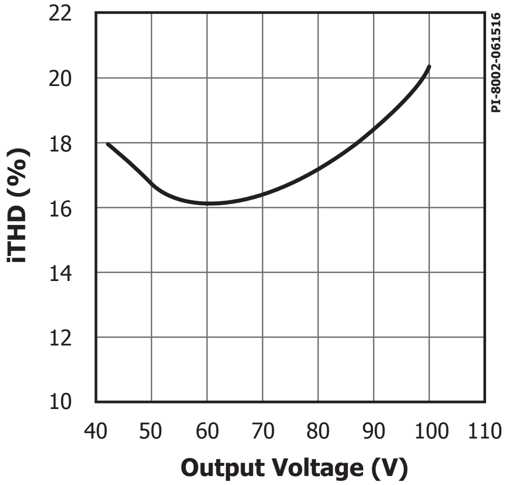


Figure 22. iTHD at 230 VAC vs. Output Voltage.

PCB Layout Considerations

In Figure 23, the EMI filter components should be located close together to improve filter effectiveness. Place the EMI filter components C1 and L1 as far away as possible from any switching nodes on the circuit board especially U1 drain node, output diode (D1) and the transformer (T3).

Care should be taken in placing the components on the layout that are used for processing input signals for the feedback loop that any high frequency noise coupled to the signal pins of U1 may affect proper system operation. The critical components in RDK-464 are R4, R5, R6, R7 and C5. It is highly recommended that these components be placed very close to the pins of U1 (to minimize long traces which could serve as antenna) and far away as much as possible from any high-voltage and high current nodes in the circuit board to avoid noise coupling.

The bypass supply capacitor C5 should be placed directly across BYPASS pin and SOURCE pin of U1 for effective noise decoupling.

As shown in Figure 23, minimize the loop areas of the following switching circuit elements to lessen the creation of EMI.

- Loop area formed by the transformer winding (T3), free-wheeling rectifier diode (D1) and output capacitor (C6).
- Loop area formed by input capacitor (C4), U1 internal MOSFET, free-wheeling rectifier diode (D1) and sense resistor (R5).

LYTSwitch-1 Low-Side Configuration

In Figure 25, LYTSwitch-1 employs low-side Buck configuration and the ground potential SOURCE pins are used for heat sinking. This allows the designer to maximize the copper area for good thermal management but, without having the risk of increased EMI.

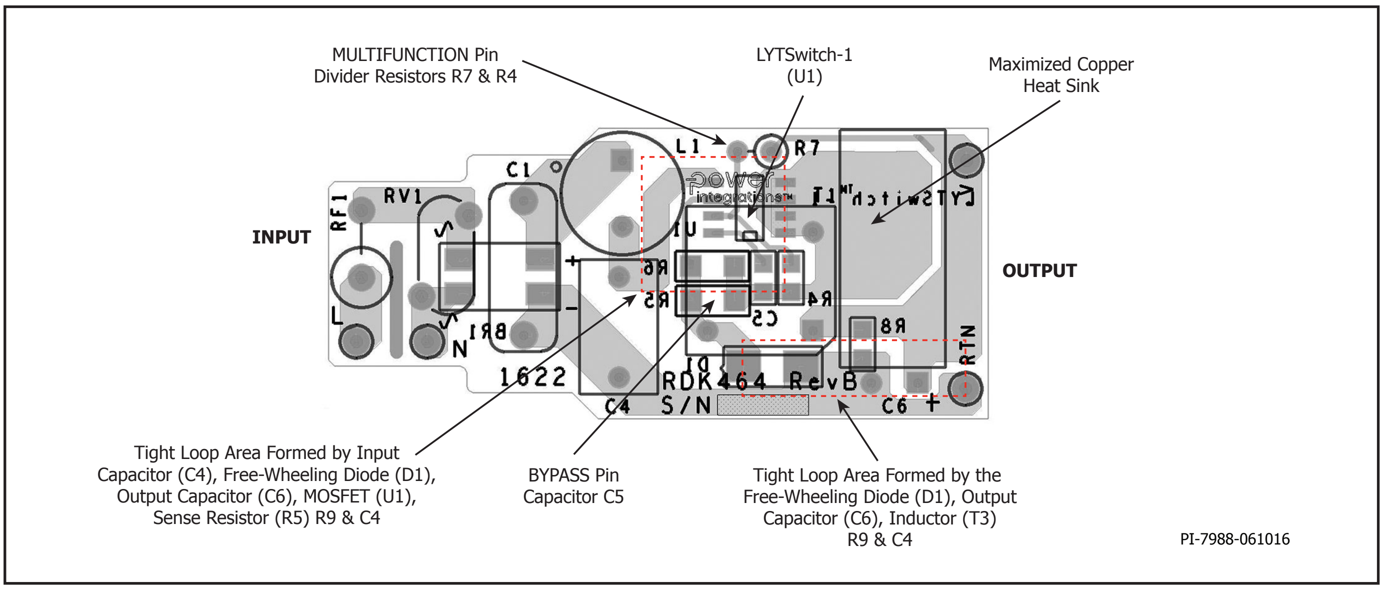


Figure 23. Design Example RDK-464 PCB Layout Showing the Critical Loop Areas with LYTSwitch-1 in High-Side Buck Configuration.

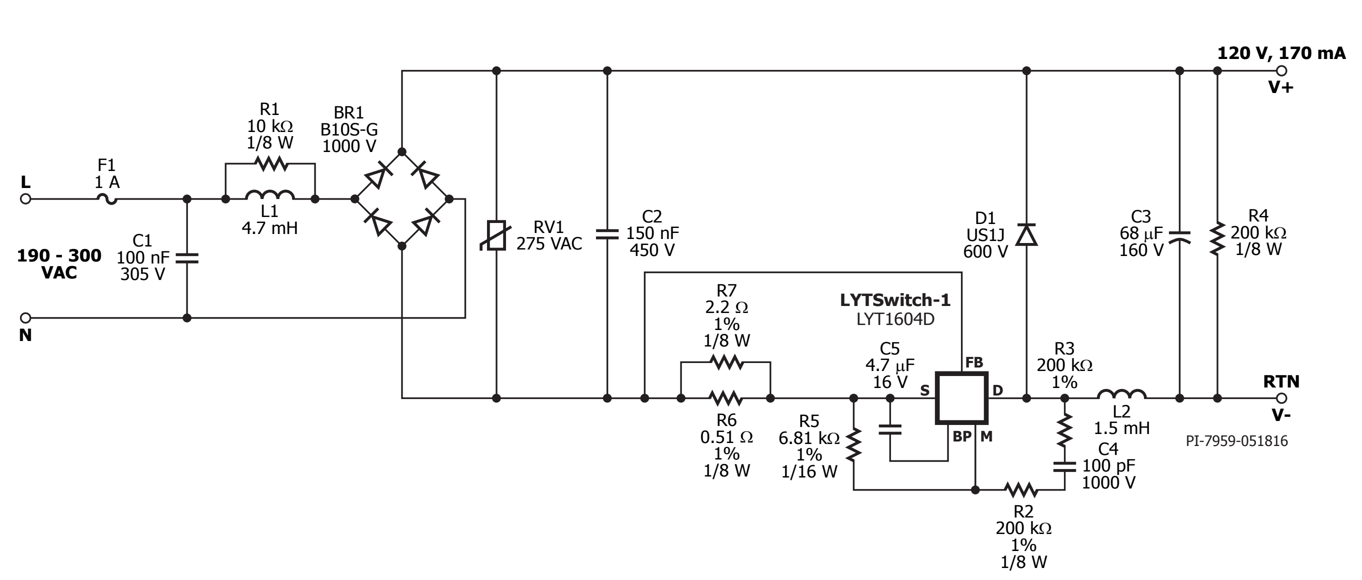


Figure 24. Schematic from DER-548 a 20 W, 120 V-170 mA Non-isolated LED Driver for Tube with High-line Input Range of 190 – 300 VAC using LYT1604D.

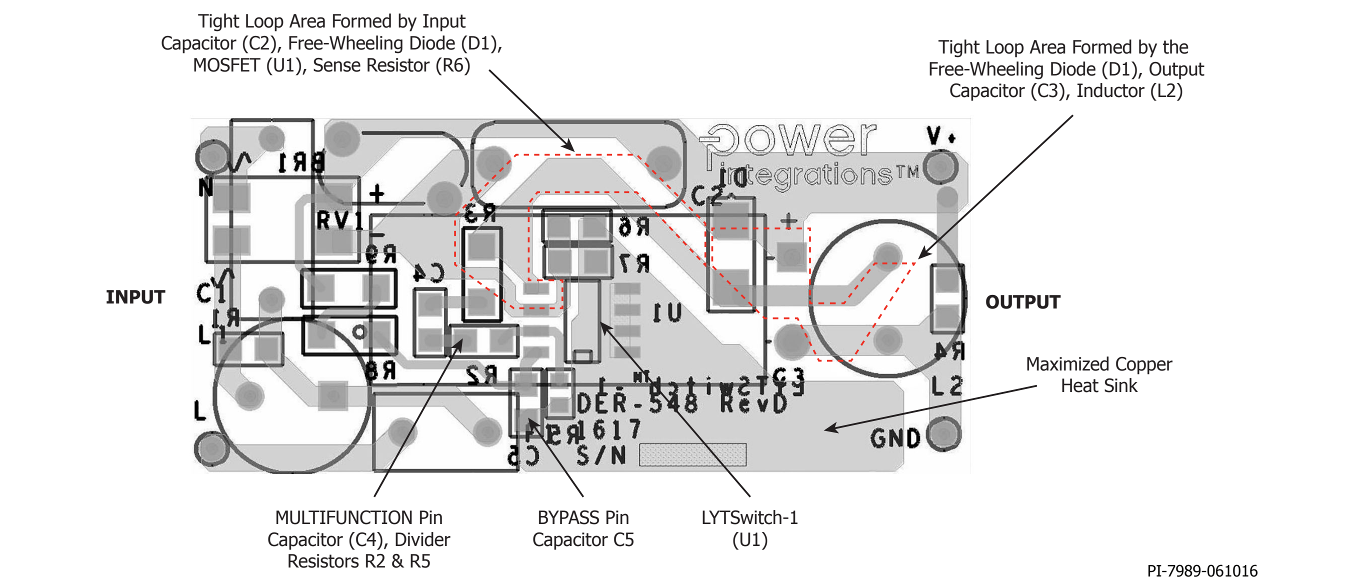


Figure 25. Design Example DER-548 PCB Layout Showing the Critical Components and Loop Areas with LYTSwitch-1 in Low-Side Buck Configuration.

Since the switch MOSFET is referenced to ground, the low-side buck configuration would also give an advantage of using a low-cost off-the-shelf dog bone type inductor as demonstrated in the design example DER-548. The addition of a small capacitor C4 (Figure 24) is needed to couple the high-voltage referenced signal of the output voltage into the MULTIFUNCTION pin of the IC through the resistor divider network R2, R3 and R5. Based on the simulation and bench results capacitance of 100 pF is a good compromise between AC line rejection and flatness of the output voltage during the off-time of the switch. Based on capacitance tolerance, 68 pF to 150 pF range can be used.

Fast AC Cycling

If the difference between the input and output voltage is small, e.g., V_{IN} = 90 VAC, V_{OUT} = 72 V, the internal tap supply may not be able to hold the BYPASS pin capacitor voltage after fast ac cycling.

If the voltage falls below 4.5 V, the unit will reset and might not be able to deliver the full power (Figure 26).

To avoid this condition, do any of the following:

- Design within the recommended V_{OUT}.
- Increase the BP capacitor to prevent the voltage from falling below 4.5 V.
- Increase the pre-load to allow the output voltage to drop sufficiently.
- For low-side configuration, add a pull-up resistor from the rectified DC bus to the BYPASS pin. Optimize the resistor value such that it is sufficient to prevent this condition while minimizing the impact on efficiency. A value between 100 k and 1 M may be used depending on the input/output parameters.

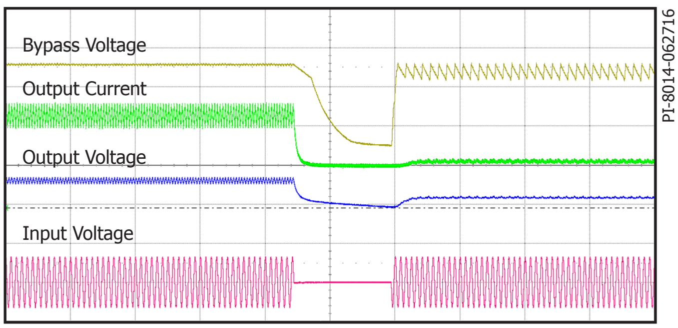


Figure 26. Insufficient Power Delivery after Fast AC Cycling.

Input Current Ringing

The clipping of the Drain current introduces a negative impedance characteristic which may cause input current ringing. This condition is more pronounced at lower input voltage and at higher power. Follow the EMI filter design and output inductor selection guidelines in order to address this condition.

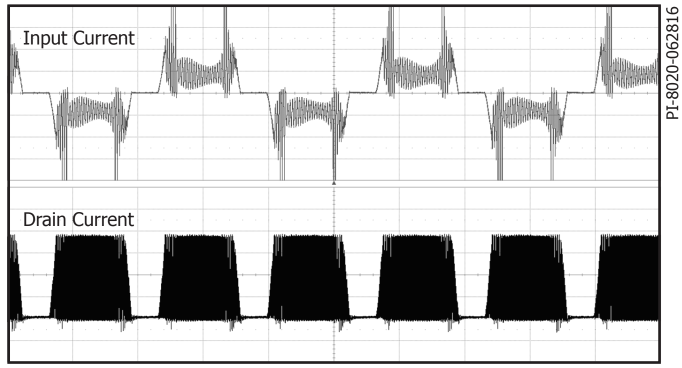


Figure 27. Input Current Ringing.

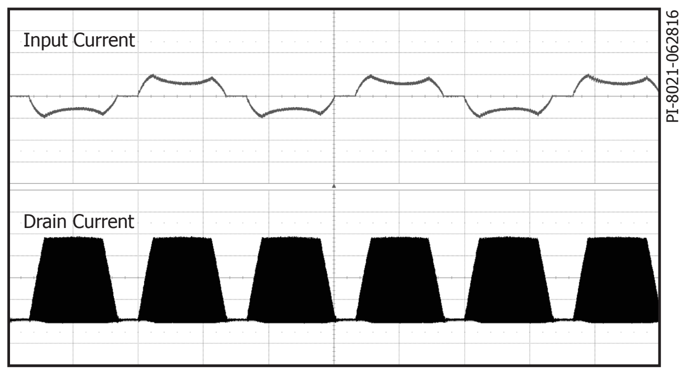


Figure 28. Input Current Without Oscillation.

Revision	Notes	Date
A	Initial Release.	06/16

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