Application Note AN-68
LYTSwitch-7 Family

Design Guide

Background

As the LED market becomes a mainstream commodity, the pressure to reduce the manufacturing cost becomes a top priority. Based on the DOE cost breakdown projection for a typical A19 bulb, the LED driver represents about 15% to 20% of the system cost. Thus, all LED OEMs must find ways to reduce the BOM cost of the driver as a means to adapt in a very competitive market.

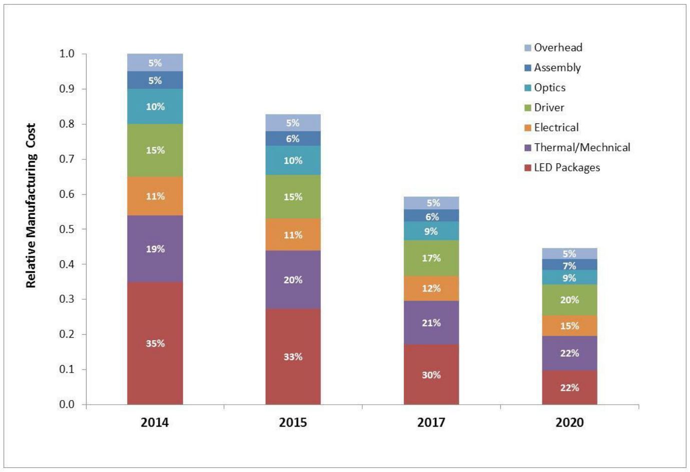


Figure 1. Cost Breakdown Projection for a Typical A19 Replacement Lamp. (Source: DOE SSL Roundtable and Workshop attendees)

Dimmable LED drivers circuitry usually are complex and require a lot of components to make them compatible with retrofit dimmers, which are mainly designed for high-power, resistive loads such as incandescent bulbs.

LYTSwitch-7 ICs addresses dimming compatibility while taking into consideration the need for a low-cost, but reliable solution.

Introduction

The LYTSwitch™-7 family is ideal for inexpensive single-stage, high power factor (PF) constant current, and damper-less dimmable LED bulbs.

The family incorporates a high-voltage MOSFET with a variable on-time Critical Conduction Mode (CrM) controller. Extensive protection features with minimum external components provide industry leading power density and functionality.

Low-side configurations allow the use of a single pull-up resistor from the DC bus to the BYPASS 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.

The control algorithm results in a fast turn-on, low pop-on, better than 10:1 dimming ratio, and monotonic dimming profile.

Scope

This application note is intended for engineers designing a non-isolated AC-DC buck power supply using the LYTSwitch-7 family of devices. It provides a step-by-step design procedure for the selection of all circuit components.

This 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-7 Reference Design Kit (RDK), containing engineering prototype boards, reports, and device samples, useful as the starting point for a new design.

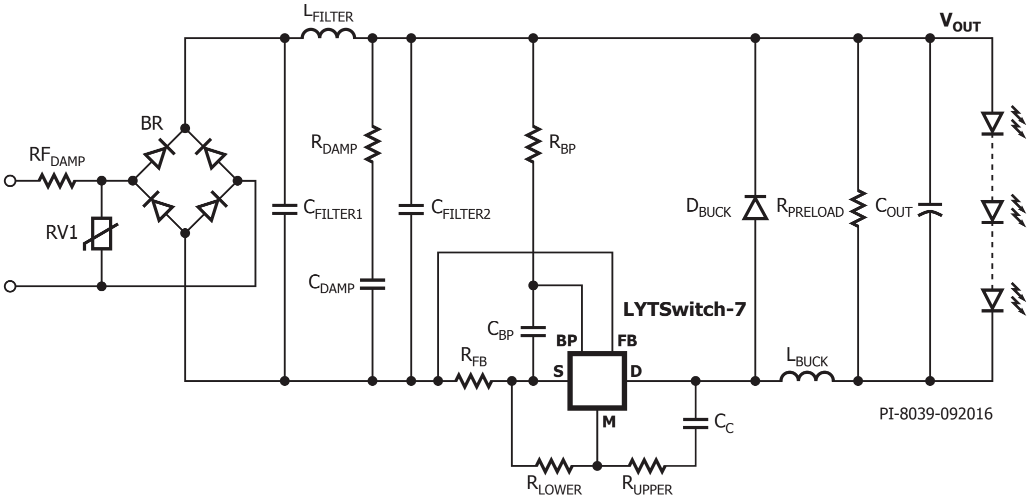


Figure 2. Typical LYTSwitch-7 Schematic in Low-Side Buck Configuration.

Pin Function Descriptions

Pin Name	Functionality
BYPASS (BP) Pin	5.22 V supply rail
MULTIFUNCTION (M) Pin	Mode 1: MOSFET 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: MOSFET ON • Line OVP sensing
FEEDBACK (FB) Pin	• MOSFET 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 1. Pin Function Descriptions.

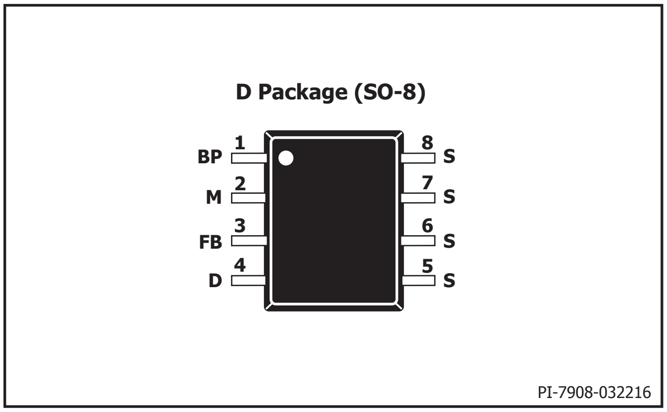


Figure 3. LYTSwitch-7 Pin Configuration.

LYTSwitch-7 Operation

LYTSwitch-7 ICs operate in Critical Conduction Mode (CrM) buck topology, where the output current equals the average inductor current.

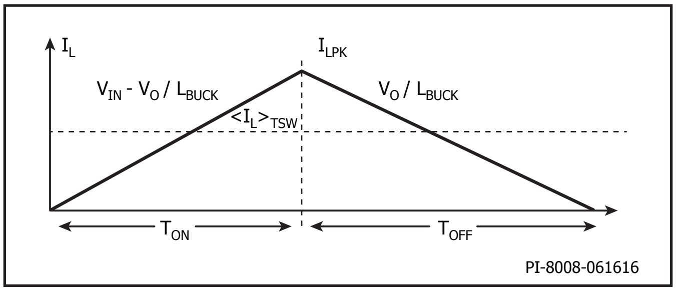


Figure 4. Critical Conduction Mode (CrM) Inductor Current Profile.

When there is no dimmer connected, LYTSwitch-7 ICs maintain constant current (CC) regulation by forcing a peak current limit and controlling T_{ON} to maintain a constant ratio between the time in the constant current limit region (t_{CC}) and the time in dead zone (T_{DZ}).

$$\frac{t_{CC}}{T_{DZ}} = 1$$

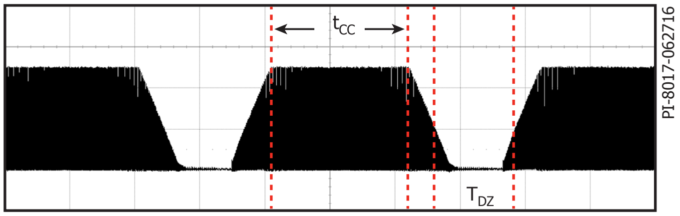


Figure 5. LYTSwitch-7 Constant Ratio Control Scheme.

Operating with phase-cut input, LYTSwitch-7 ICs will try to maintain the ratio of 1 by adjusting T_{ON}. However, once $T_{ON(MAX)}$ is reached, natural dimming will follow – i.e., a change in conduction angle will reduce the average inductor current, which results to a lower output current.

Figures 6 to 9 further demonstrate how dimming is achieved with LYTSwitch-7 ICs on DER-539.

No Dimmer Connected
The output current is at a maximum. $t_{CC}/T_{DZ} = 1$. $T_{ON} < T_{ON(MAX)}$.

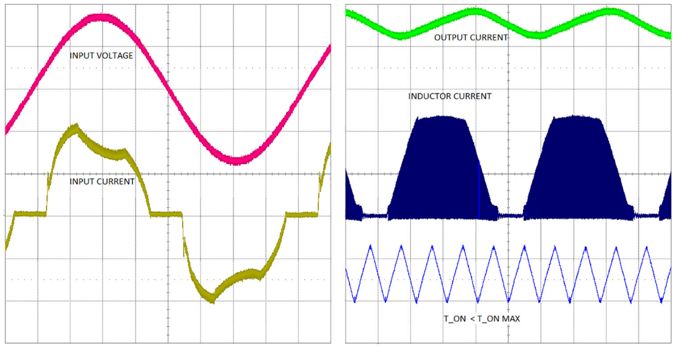


Figure 6. Input and Output Waveforms at Full AC Conduction.

Phase-Cut Dimming, 150° Conduction Angle
The output current naturally decreases. $t_{CC}/T_{DZ} = 1$ ratio is maintained. $T_{ON} < T_{ON(MAX)}$.

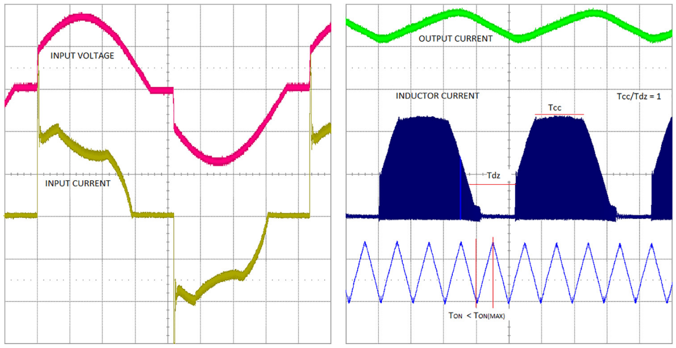


Figure 7. Input and Output Waveforms at 150° Conduction Angle.

Phase-Cut Dimming, 90° Conduction Angle

Further reduction of output current due to phase-cut. The t_{CC}/T_{DZ} ratio is < 1. $T_{ON} = T_{ON(MAX)}$. Switching is based on peak-current which increases the input current as the input voltage goes down.

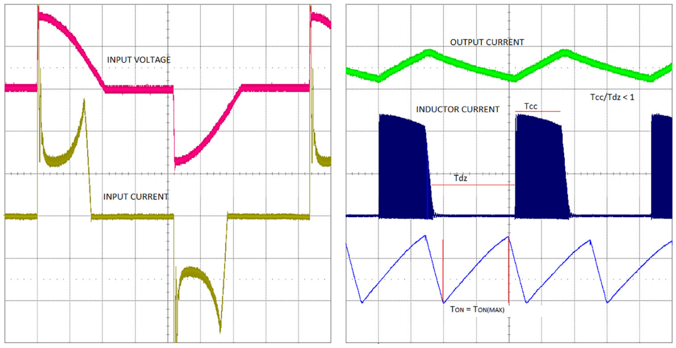


Figure 8. Input and Output Waveforms at 90° Conduction Angle.

Phase-Cut Dimming, 60° Conduction Angle

The T_{ON} is kept at $T_{ON(MAX)}$. Output current is reduced naturally. The input current naturally goes up as the input goes down, keeping the TRIAC dimmer operate normally.

Figure 10 shows the typical dimming curve of LYTSwitch-7 ICs which easily meets the NEMA SSL7A-2015 standards.

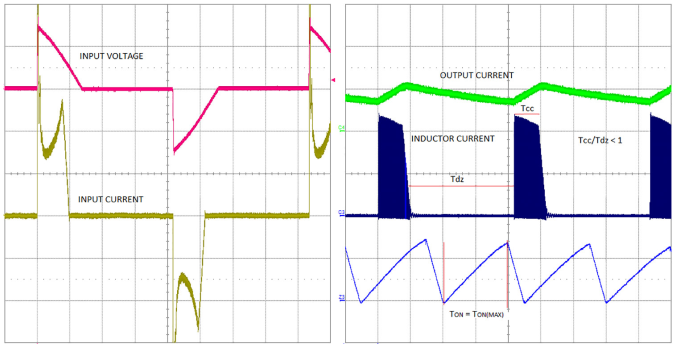


Figure 9. Input and Output Waveforms at 60° Conduction Angle.

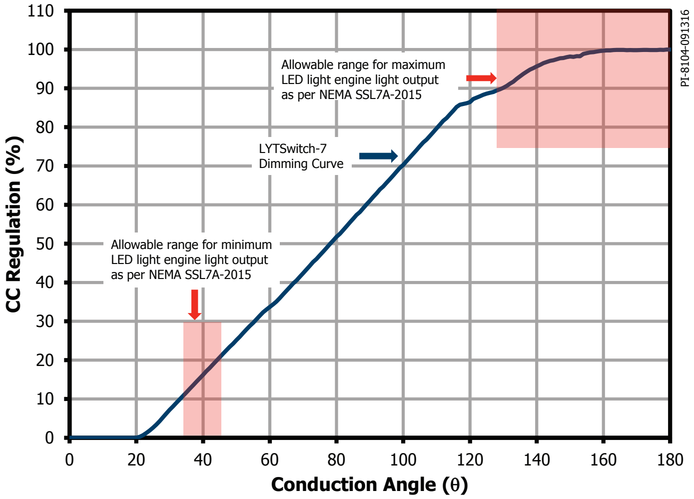
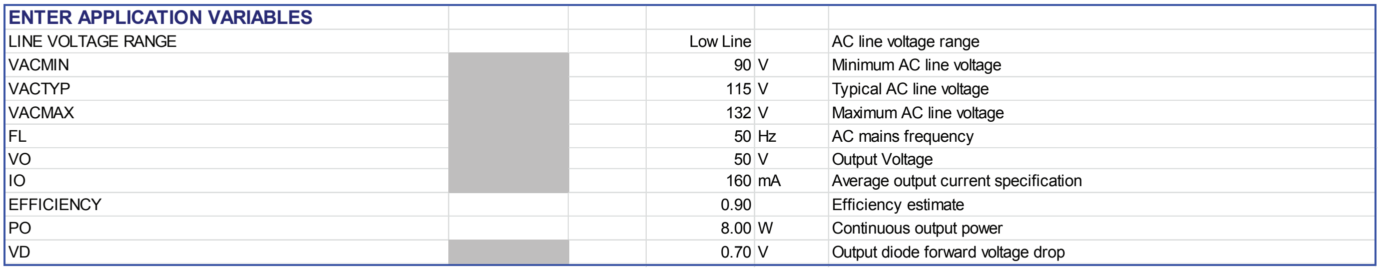


Figure 10. LYTSwitch-7 Dimming Curve vs. SSL7A-2015 Limits.

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			Low Line		AC line voltage range
VACMIN			90	V	Minimum AC line voltage
VACTYP			115	V	Typical AC line voltage
VACMAX			132	V	Maximum AC line voltage
FL			50	Hz	AC mains frequency
VO			50	V	Output Voltage
IO			160	mA	Average output current specification
EFFICIENCY			0.90		Efficiency estimate
PO			8.00	W	Continuous output power
VD			0.70	V	Output diode forward voltage drop

Figure 11. Application Variable Section of the Design Spreadsheet.

Line Voltage Range and Line Frequency

Determine the input voltage range and line frequency from Table 2.

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 2. Input Line Voltage Ranges and Line Frequency.

Nominal Output Voltage, V_O (V)

Enter the nominal LED output voltage based on Table 3. Choose from the recommended V_O column for best dimming performance. The extended V_O column provides the user flexibility to use the device beyond the recommended value. The dimming response, however, is not guaranteed and has to be verified in actual prototype.

Input Voltage Range (V_{AC})	Recommended V_O	Extended V_O
Low-Line or Wide Range	25 - 55	15 - 72
High-Line Only	25 - 80	15 - 120

Table 3. Output Voltage Range.

Nominal Output Current, I_O (mA)

Enter the nominal output current. The maximum allowable output current is 400 mA for LYT7504D and 265 mA for LYT7503D to ensure that the device does not hit the internal current limit. The relationship between I_O and I_{PK} is given by:

$$I_{PK} \cong 3.6 \times I_O$$

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.

Step 2 – Select LYTSwitch-7 Device

Select "Auto" to let PIXls choose the appropriate device size. For manual selection, select the device from the power table.

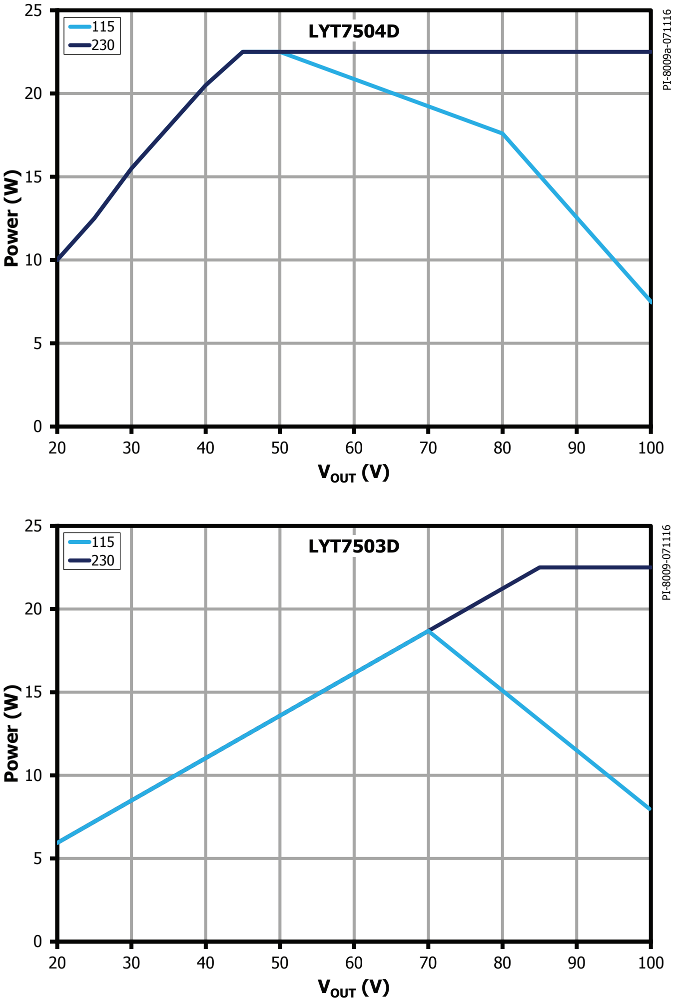


Figure 12. Output Power Table Graphs.

Step 3 – Determine the Output Inductance

The design spreadsheet calculates a recommended inductance to use, $L_{P(TYP)}$. It also calculates the range of inductance such that any value between $L_{P(MIN)}$ and $L_{P(MAX)}$ can be used. The calculation considers the following design parameters for best performance with respect to operating inductance.

- Switching Frequency – Higher 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 – Higher inductance, the flatter the line regulation becomes.

Step 4 – Select the Type of Output Inductor

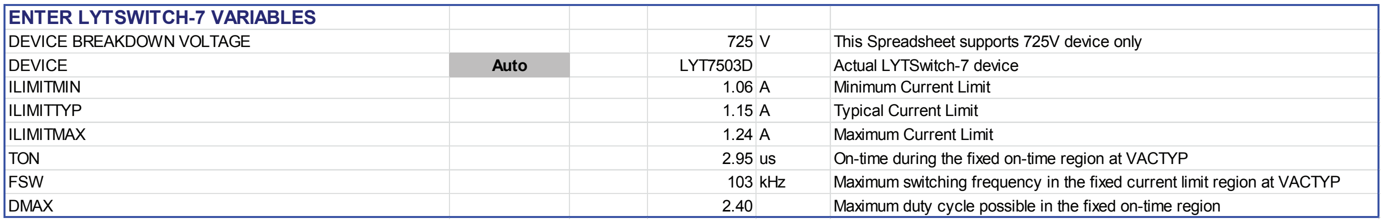
The user has an option to use either a bobbin-type or an off-the-shelf drum-core inductor. Drum-choke is significantly cheaper than bobbin-type inductor.

Tips Using Unshielded Drum-Core Output Inductor

LYTSwitch-7 ICs low-side switching buck topology makes it possible to use unshielded drum-chokes with low EMI. The following tips are recommended to ensure consistent performance. The main idea of managing the position and location of the inductors (i.e. main and EMI inductors) in the system is to prevent magnetic flux coupling between these inductors and shorting the magnetics flux to a conductive surface.

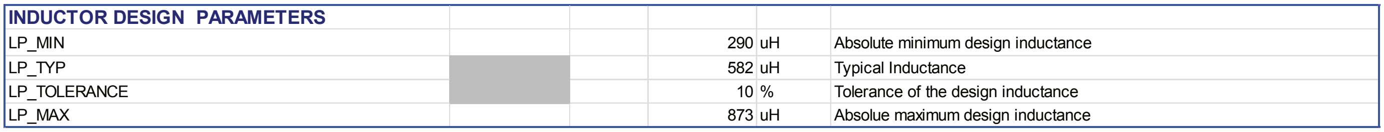
- Provide ample clearance between the input filter inductor and output inductors if both are unshielded.
- Provide ample clearance between the output inductor and output electrolytic capacitor since the capacitor has aluminum metal enclosure.
- Position the inductors in the middle of the PCB if possible away for metal enclosure. Verify the output regulation and EMI are not affected with driver inside the metal enclosure.
- Orient the inductors such that the magnetics flux will be opposing each other. It may be necessary to control start-end winding to maintain the orientation of the drum-choke when inserted into the PCB.

In 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 4 for standard values.



ENTER LYTSWITCH-7 VARIABLES					
DEVICE BREAKDOWN VOLTAGE			725	V	This Spreadsheet supports 725V device only
DEVICE	Auto		LYT7503D		Actual LYTSwitch-7 device
ILIMITMIN			1.06	A	Minimum Current Limit
ILIMITTYP			1.15	A	Typical Current Limit
ILIMITMAX			1.24	A	Maximum Current Limit
TON			2.95	us	On-time during the fixed on-time region at VACTYP
FSW			103	kHz	Maximum switching frequency in the fixed current limit region at VACTYP
DMAX			2.40		Maximum duty cycle possible in the fixed on-time region

Figure 13. LYTSwitch-7 Variables Section of the Design Spreadsheet.



INDUCTOR DESIGN PARAMETERS					
LP_MIN			290	uH	Absolute minimum design inductance
LP_TYP			582	uH	Typical Inductance
LP_TOLERANCE			10	%	Tolerance of the design inductance
LP_MAX			873	uH	Absolue maximum design inductance

Figure 14. Inductor Design Section of the Design Spreadsheet.

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. One ampere diode is recommended for designs with I_O < 300 mA. For higher output current (I_O), check the forward current derating curve to determine if a 2 A diode is necessary in a given operating temperature.

Step 6 – Select the Output Capacitor

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 4. Standard Drum Core Inductor Values.

LYTSwitch-7 ICs 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 and prevents shimmer during dimming.

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.

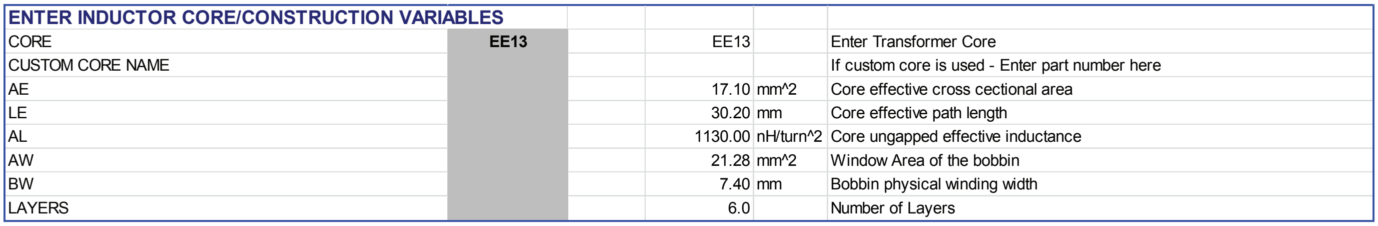
Step 7 – Select the Pre-load Resistor

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:

$$R_{PRELOAD} = \frac{V_O}{1\,mA}$$

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 10 μF with a voltage rating of greater than 7 V is recommended for most designs.



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 15. Inductor Core/Construction Variables Section of the Design Spreadsheet.

Step 9 – Determine the Feedback Resistor

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

$$R_{FB} = \frac{V_{FB(REF)}}{3.6 \times I_O}$$

Where:

R_{FB}: Feedback sense resistor
$V_{FB(REF)}$: FEEDBACK pin reference voltage (-279 mV)
I_O: Output current

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

Step 10 – Determine the MULTI-FUNCTION Pin 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 5. 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 low-side configurations, 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 configurations 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:

$$R_{LOWER}(Low - Side) = \frac{V_{MREF} \times R_{UPPER}}{V_{OUT} - V_{MREF}}$$

Where:

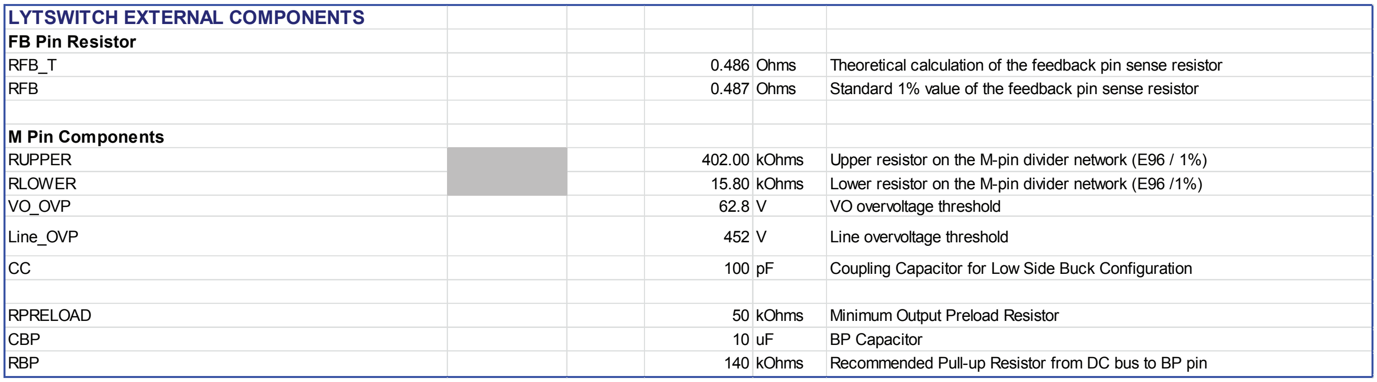
V_{MREF}: MULTIFUNCTION pin reference voltage given in Table 6.

	V_{MREF} (Low-Side Configuration), V		
	High-Line		Low-Line / Wide Range
F_{SW} (kHz)	$V_O < 70$ V	$V_O \geq 70$ 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 6. 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			
RUPPER	402.00	kOhms	Upper resistor on the M-pin divider network (E96 / 1%)
RLOWER	15.80	kOhms	Lower resistor on the M-pin divider network (E96 /1%)
VO_OVP	62.8	V	VO overvoltage threshold
Line_OVP	452	V	Line overvoltage threshold
CC	100	pF	Coupling Capacitor for Low Side Buck Configuration
RPRELOAD	50	kOhms	Minimum Output Preload Resistor
CBP	10	uF	BP Capacitor
RBP	140	kOhms	Recommended Pull-up Resistor from DC bus to BP pin

Figure 16. External Components Section of the Design Spreadsheet.

Step 11 – Select Dimming Components

The main dimming components to be optimized are highlighted in Figure 17.

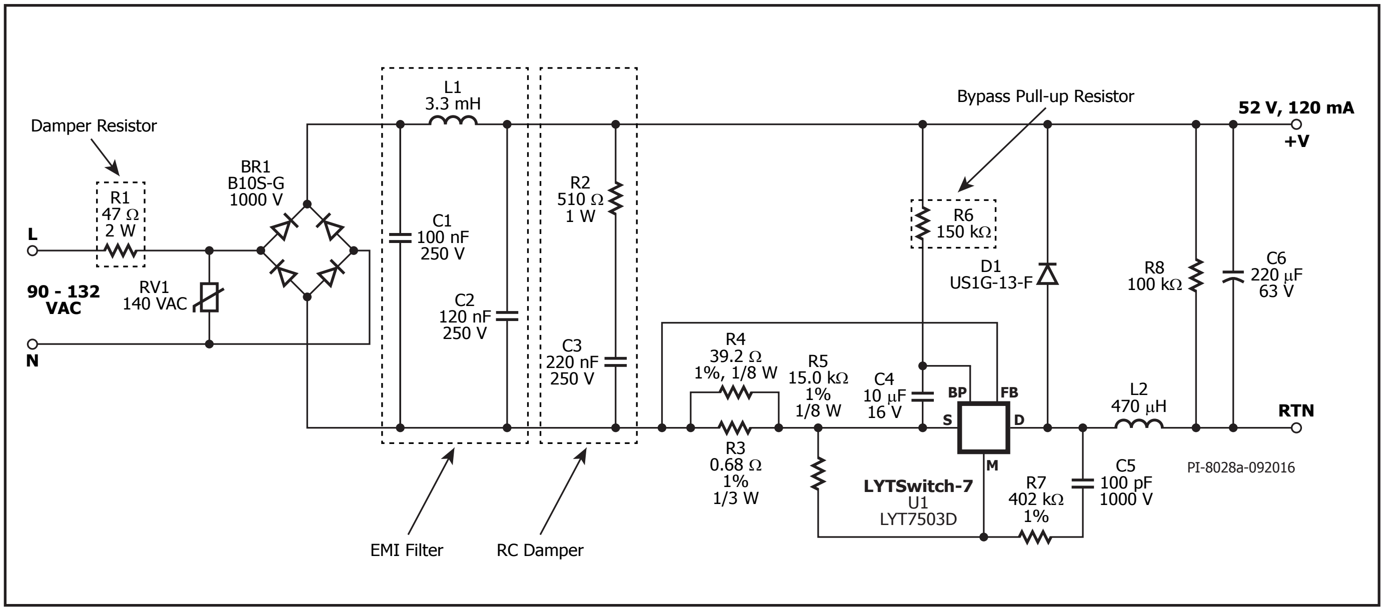


Figure 17. DER-539 Low-Line Input 6.24 W, 52 V, 120 mA Dimmable Non-Isolated A19 LED Driver using LYT7503D in Low-Side Buck Configuration.

Damper Resistor

The damper resistor acts as a damper for dimming and as a fuse for safety protection (must use safety rated fusible type resistor). Its value depends on the type of dimmer, input voltage, output power, and efficiency requirement.

Different dimmers behave differently from one another due to the difference on the components used. Those with TRIAC that have high latching and holding current requirements are generally more challenging because those are designed for high-power load. Designing for high-line operation is also more challenging because the input current is lower than at low-line for a given output power. Figures 19 to 22 show how different resistor values affect the input current. Ideally, the waveform should look like in Figure 22. However, in some instances, the value is limited by efficiency requirements. The recommended value of the damper resistor for a given output power and input voltage, is given on Figure 18. Furthermore, Table 7 provides the actual dimming components used on various LYTSwitch-7 DERs.

DER #	V_O (V)	I_O (mA)	P_O (W)	Line	R_{DAMPER} (Ω)	R_{BLEED} (Ω)	C_{BLEED} (Ω)	Efficiency (%)
539	52	0.12	6.24	LL	47	510	220	86
540	52	0.09	4.68	LL	68	820	220	85
558	50	0.15	7.5	HL	100	510	220	85
561	60	0.125	7.5	WR	47	510	220	88
563	52	0.355	18.46	HL	100	560	220	86
568	84	0.12	10.08	HL	130	510	220	88

Table 7. Dimming Component Values on LYTSwitch-7 DERs.

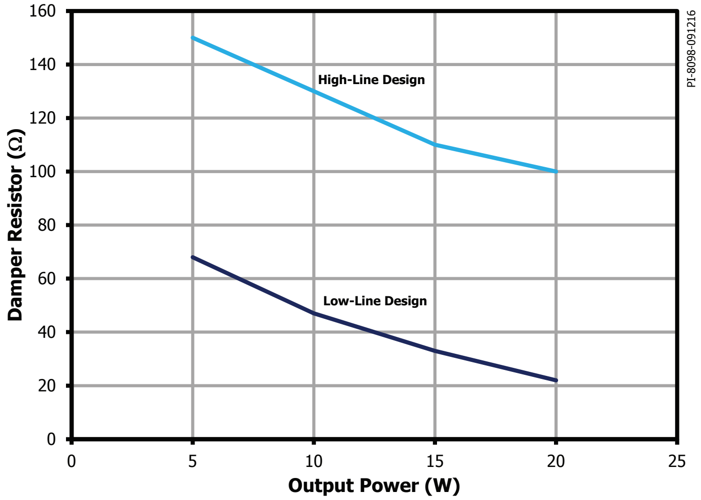


Figure 18. Recommended Damper Resistor Value.

Figures 19 to 22 show effects of different values of damper resistor (R1) on the input current of DER-539 at 90° conduction angle. As the value increases the damping effect increases, hence ringing is subdued.

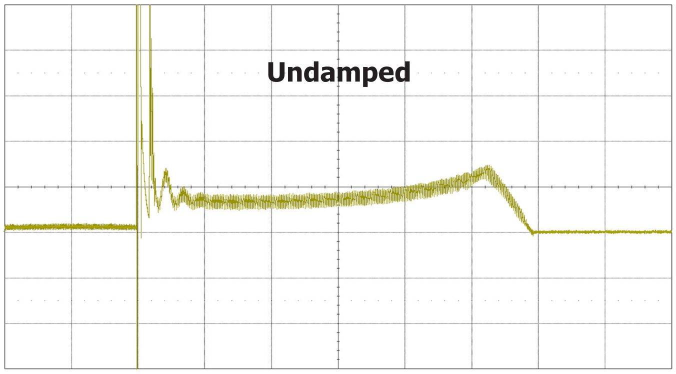


Figure 19. Input Current Without Damper Resistor.

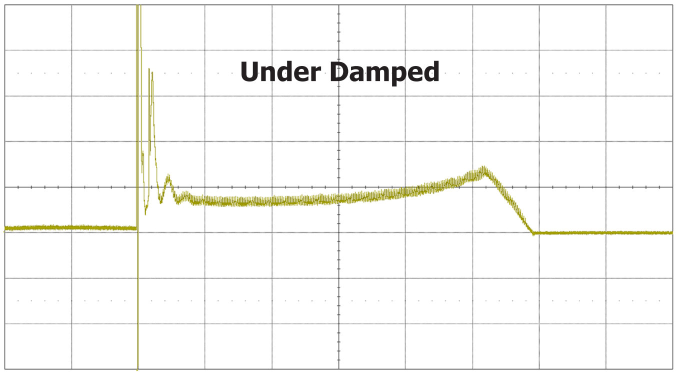


Figure 20. Input Current With 10 Ω Damper Resistor.

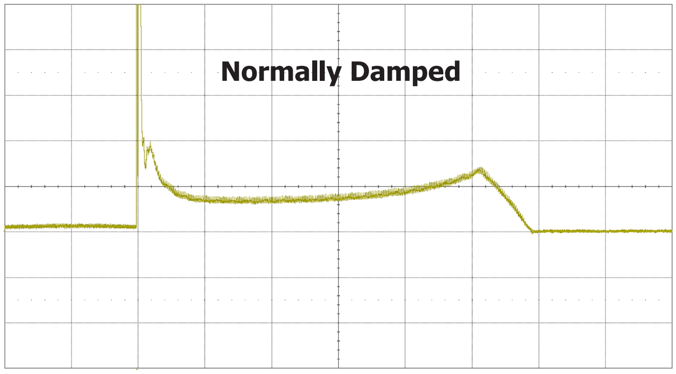


Figure 21. Input Current With 22 Ω Damper Resistor.

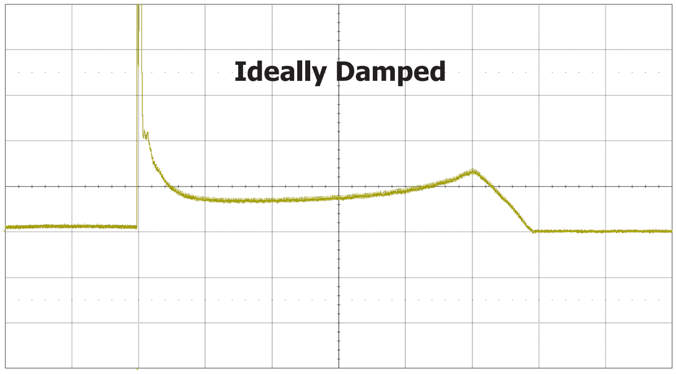


Figure 22. Input Current With 47 Ω Damper Resistor.

Surge Protection

The MOV acts as a voltage clamp that limits the voltage stress due to line surge or swells across the bridge rectifier (BR1) and the internal MOSFET of the controller (U1).

EMI Filter

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

The effect of the 1st capacitor (C1) on the input current is shown in Figure 23. The capacitor creates a high input current spike, but while this is good for the TRIAC latching current, the ringing it creates might go below the holding current and may cause flicker, especially if the capacitance is low.

For input power below 5 W, it may be possible to pass EMI with an LC filter only. In most cases, however, the 1st capacitor is required and a value between 47 nF and 100 nF is recommended.

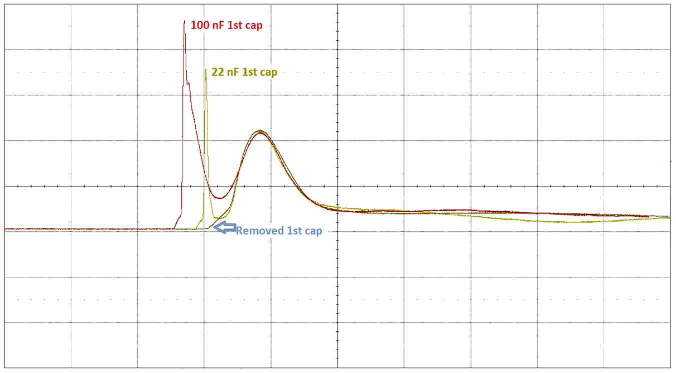


Figure 23. Effect of 1st Filter Capacitor on the Input Current.

A value between 100 nF and 220 nF is recommended for 2nd input filter capacitor C2. A high value helps damp the TRIAC input current ringing and may increase compatibility. However, if PF of >0.9 is required at 230 V, then use 25 nF/W to quickly select the total input capacitance. For low-line design, high PF can be achieved even with relatively high input capacitance.

The filter inductor ranges from 1 mH to 4.7 mH. Use the smallest possible inductance by maximizing the input capacitance values. Choose the right current rating for this inductor, it can potentially create audible noise will dimming especially when it saturates due to the in-rush current when the TRIAC turns on.

Select the RC Damper

The RC damper circuit plays an important role in damping the ringing caused by the resonance of the EMI filter when the TRIAC in the dimmer switches turn on. It prevents the input current from ringing below the TRIAC holding current (I_{HOLD}). Figure 24 shows the effect of the RC damper circuit to the input current waveform during dimming.

For most designs, the effective typical value for R and C are 510 Ω and 220 nF respectively. See Table 7 for reference on the actual RC damper values used on various LYTSwitch-7 DERs. Use those values as a starting point when optimizing dimer compatibility.

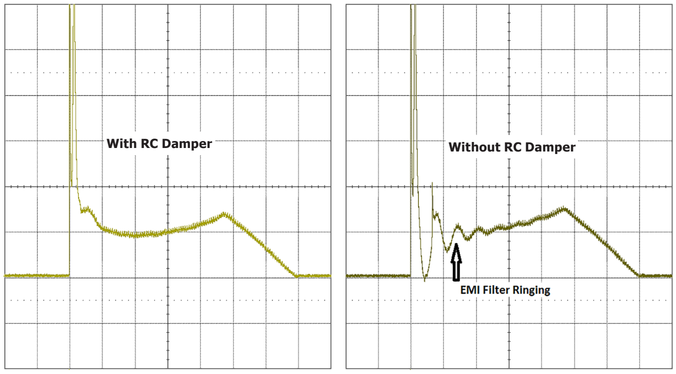


Figure 24. Shows the Effect of RC Damper on the Input Current Ringing.

RC Damper Placement

The typical placement of the RC damper (R2 and C3) is after the pi (π) filter (Figure 17). This configuration provides good dimming ratio (>10:1) with most leading-edge dimmers. However, depending on the maximum conduction angle of a particular TRIAC dimmer model or brand, if it is low (i.e. < 150° conduction angle) the maximum output current with such dimmer can be lower relative to when there is no dimmer connected. In order to increase the current, placing the RC damper before the bridge may increase the conduction angle, but with reduced dimming range. Figure 25 shows the difference in the output current with respect to the RC placement to the dimming performance of DER-539 using a typical TRIAC dimmer.

Determine the Bypass Pull-up Resistor

During dimming as the conduction angle becomes smaller, the voltage on the drain becomes lower and the non-switching time (dead-zone) becomes longer to a point where internal supply from the Drain can no longer sustain the bypass supply for the controller. It is necessary to keep the bypass voltage above 4.5 V during said condition or the IC will reset and stop switching.

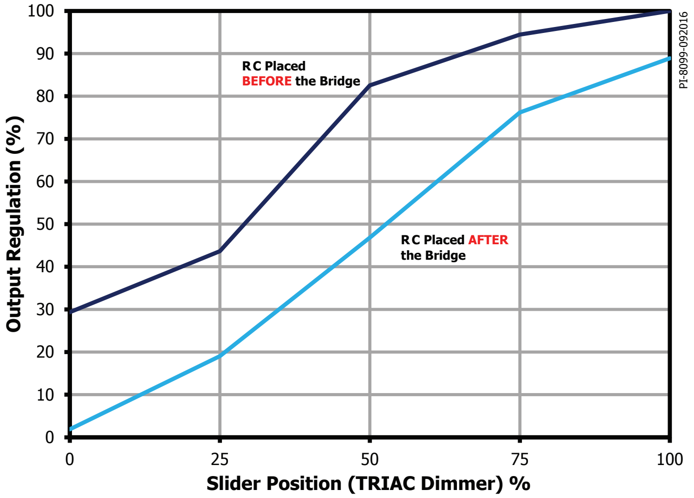


Figure 25. Effect of RC Damper Placement on the Dimming Curve.

Adding a pull-up resistor (R_{BP}) or R6 as shown in Figure 17 from the rectified DC bus to the BYPASS pin is recommended for proper operation of the IC down to small conduction angle. The recommended resistor is calculated using equation 6 (Eq.6). This ensures that the bypass voltage will always be above 4.5 V even at deep dimming.

$$R_{BP} = \frac{V_O \times 0.8 - 5\,V}{250\ \mu A} \qquad \text{(Eq.6)}$$

The resistor power rating must be properly sized for high-line operation because the power dissipation can be high depending on the maximum input voltage. Use equation 6 as the baseline value and adjust the resistor if necessary to decrease the power loss while keeping the bypass voltage above 4.5 V in deep dimming.

Design Methodology Summary

1. Use PIXls to design the magnetics and select the required components.
2. Optimize EMI – Higher input capacitance is better for compatibility so by knowing the minimum capacitance required for EMI, it is certain that EMI will pass after optimizing for dimmer compatibility.
3. Optimize Compatibility
    - Select the damper resistor
    - Select the RC damper
    - Determine R_{BP}

Protection Features

SOA Protection

During power-up, output overload or short-circuit condition, low or no output voltage can cause very continuous conduction mode (CCM) of operation due to the energy stored in the inductor has not given enough time to discharge during the flywheel conduction, MOSFET current can staircase to exceed its safe operating area (SOA) limits which can cause damage. In buck topology, this is manifested more severely than any other topologies. LYTSwitch-7 ICs have a protection feature which can avert such condition, SOA condition is detected when peak currents reached the operating current limit within 500 ns. Once detected, 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.

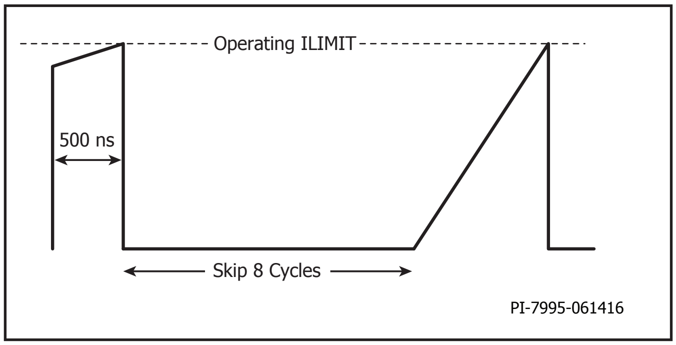


Figure 26. SOA Skip-Cycle Timing.

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.

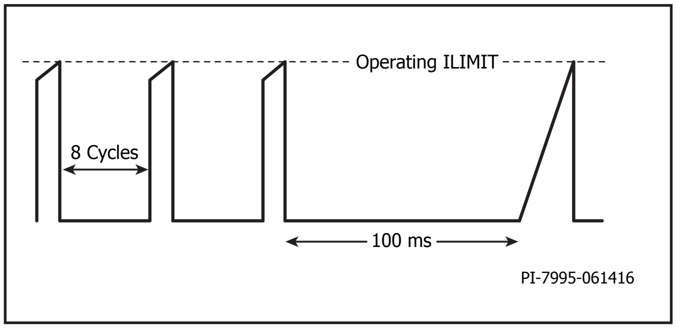


Figure 27. Three Consecutive SOA Event Timing.

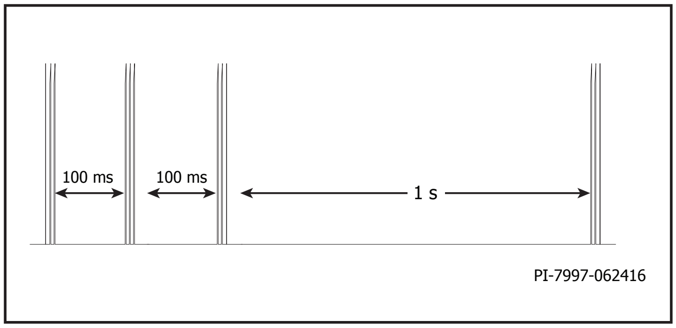


Figure 28. 1 s Auto-Restart.

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 29 – MULTIFUNCTION pin undervoltage auto-restart timing.

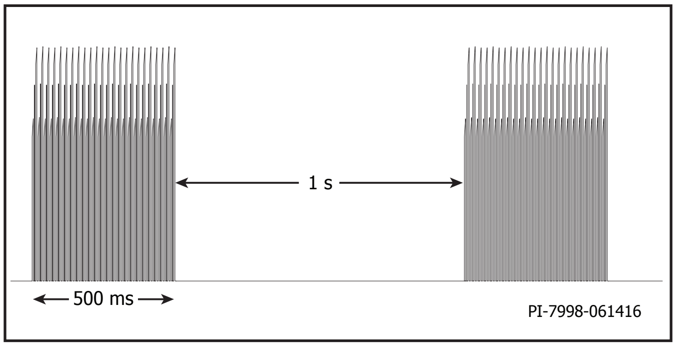


Figure 29. MULTIFUNCTION Pin Undervoltage Auto-Restart Timing.

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.

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

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.

$$V_{OUT\_OVP} = V_{OUT} \times \frac{2.4\,V}{V_{MREF}} \qquad \text{(Eq.8)}$$

Over-Current Protection

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

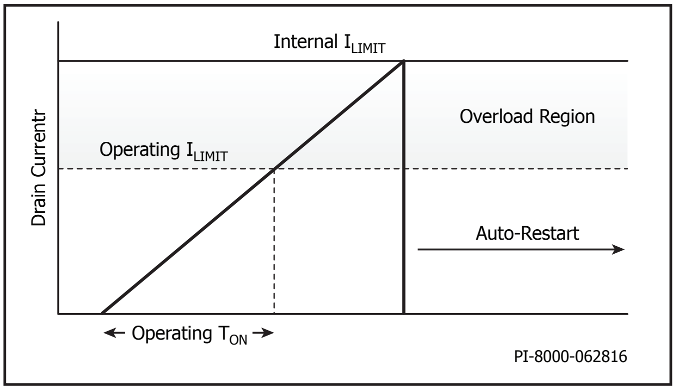


Figure 30. Over-Current Protection.

Thermal Fold-Back and Over-Temperature Shutdown

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.

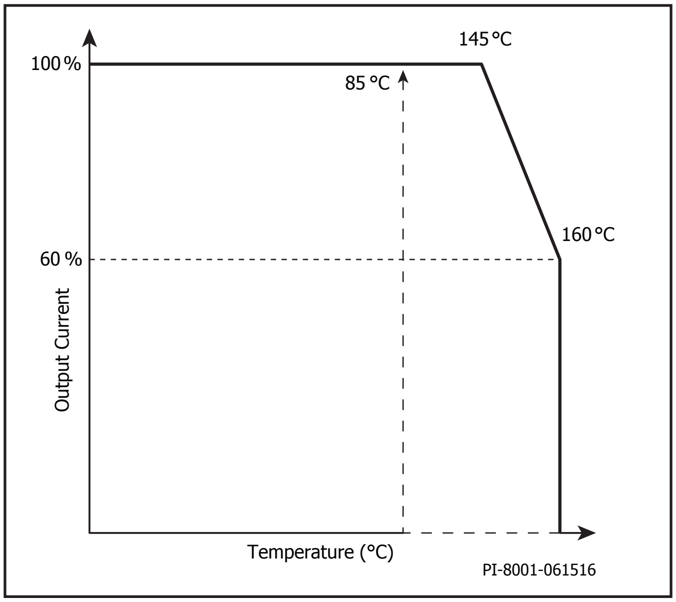


Figure 31. Thermal Fold-Back and OTP.

Notes on LED Compatible Dimmers

As incandescent lamps become obsoleted and a lot of new dimmers sold in the stores are now LED friendly, and it makes sense for any new products that they only claim to work with these most recent dimmers.

Some phase-cut dimmers are designed for use with dimmable LED bulbs. The information can be normally found by looking for the "LED" marking on the dimmer nameplate. For these dimmers, it may be possible to remove the RC damper and still be compatible.

The select dimmers on Table 8 have been verified to be working properly using DER-539 with no RC damper.

Brand	Model No.
Lutron	LGCL-153PLH-WH
Lutron	DVWCL-153PH-WH
Lutron	TGCL-153PH-WH
Lutron	CTCL-153PDH-WH
Leviton	IPL06
Leviton	6674

Table 8. Examples of Low-Line Dimmers Compatible with LED Drivers using LYTSwitch-7 .

Given that some dimmers are LED driver "friendly", the user has the option to experiment on different input configurations that are best suited for the dimmers to be used.

Table 9 summarizes the general observations of the four circuit configurations shown on Figures 32 to 35.

Performance Criteria	Config 1	Config 2	Config 3	Config 4
Compatibility	High	Med	Low	Med
Efficiency	Med	Med	High	Low
BOM Cost	High	High	Low	Med
Dimming Ratio	High	Med	High	High
Output Current Drop with Dimmer at Max Conduction	Med	Low	Low	Low

Table 9. Relative Performance Comparison of the Different Input Circuit Configurations for LYTSwitch-7.

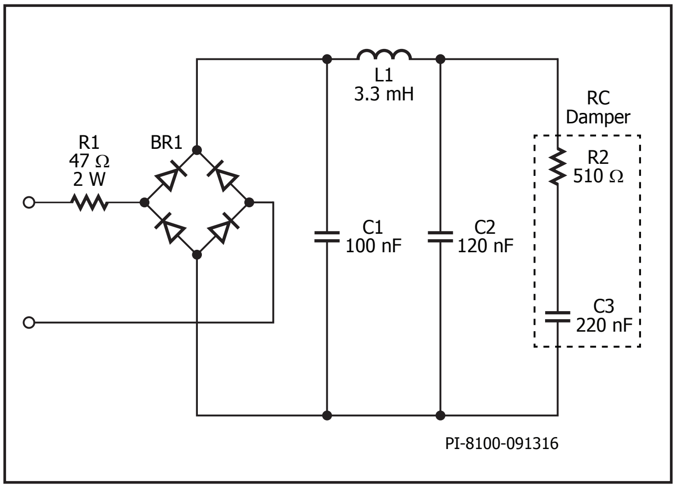


Figure 32. Configuration 1 – Reference as per DER-539.

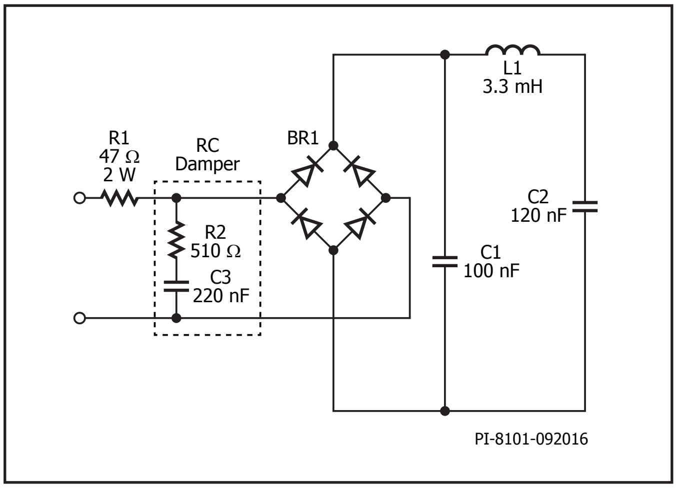


Figure 33. Configuration 2 – RC Damper Placed Before the Bridge.

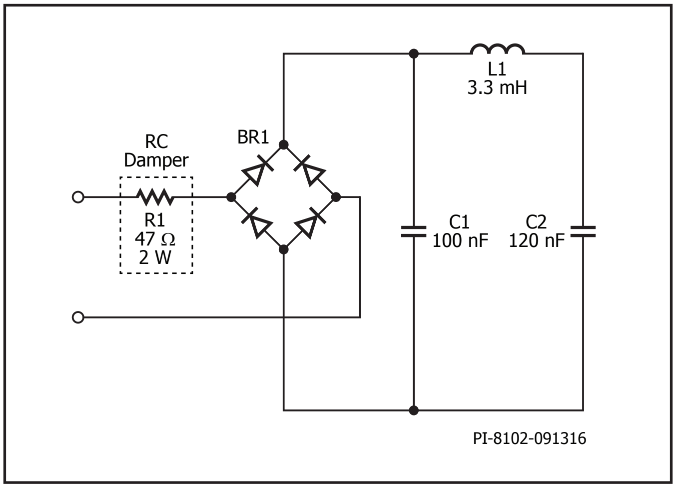


Figure 34. Configuration 3 – No RC Damper.

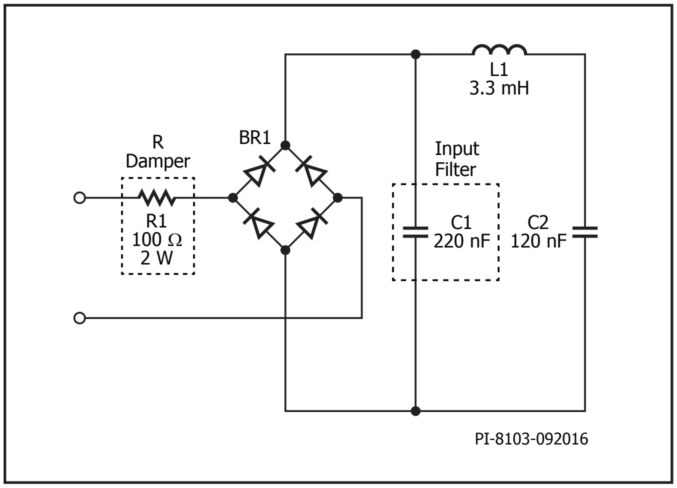


Figure 35. No RC Damper, Higher R Damper and 1st Capacitor Values.

PCB Layout Considerations

Shown in Figure 36, the EMI filter components should be located close together to improve filter effectiveness. Place the EMI filter components C1 and L1 as far as possible from any switching nodes on the circuit board especially the U1 drain node, output diode (D1) and the inductor (T1).

Care should be taken in placing the critical IC components, namely R3, R4, R5, R9, R10, C5 and C4. It is strongly recommended that these components be placed very close to the pins of controller U1 to minimize long traces (which act as antennae), and as far away as possible from any high-voltage and/or high current switching nodes in the circuit to avoid potential noise coupling that may affect system operation.

For effective noise decoupling, the bypass supply capacitor C4 should be placed directly across BYPASS pin and SOURCE pin of U1.

Minimizing the loop areas of the following switching circuit elements (as shown in Figure 8) lessen the creation of EMI.

- Loop area formed by the inductor winding (T1), free-wheeling rectifier diode (D1) and output capacitor (C6).
- Loop area formed by input capacitor (C2), controller internal MOSFET (U1), free-wheeling rectifier diode (D1) and sense resistors (R4, R5).

With LYTSwitch-7 ICs in a low-side configuration potential SOURCE pins are used for heat sinking are at ground potential. This allows the designer to maximize the copper area for good thermal management without increasing EMI.

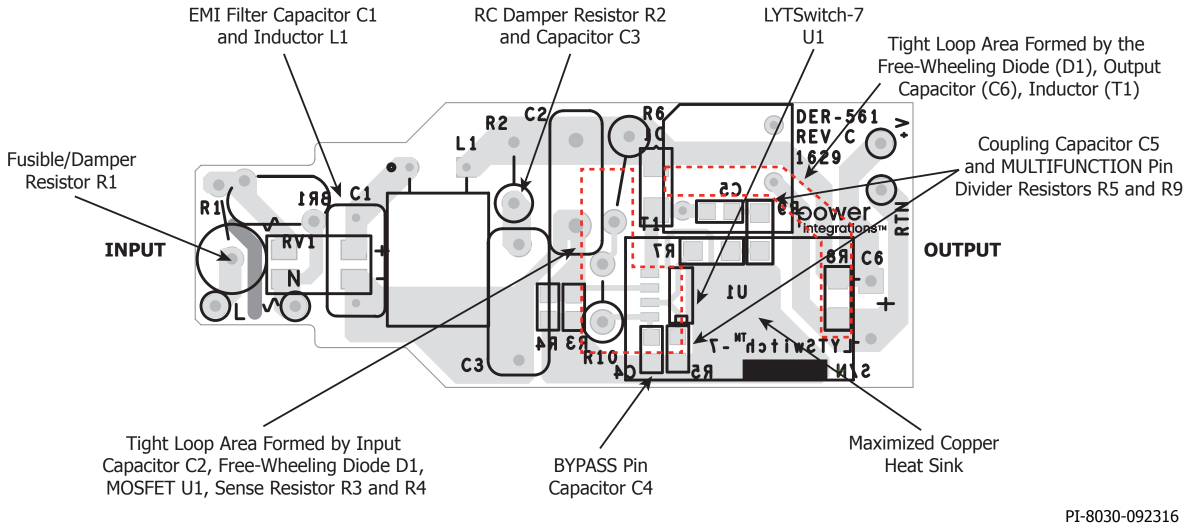


Figure 36. Design Example DER-561 PCB Layout Showing the Critical Loop Areas with LYTSwitch-7 in Buck Configuration.

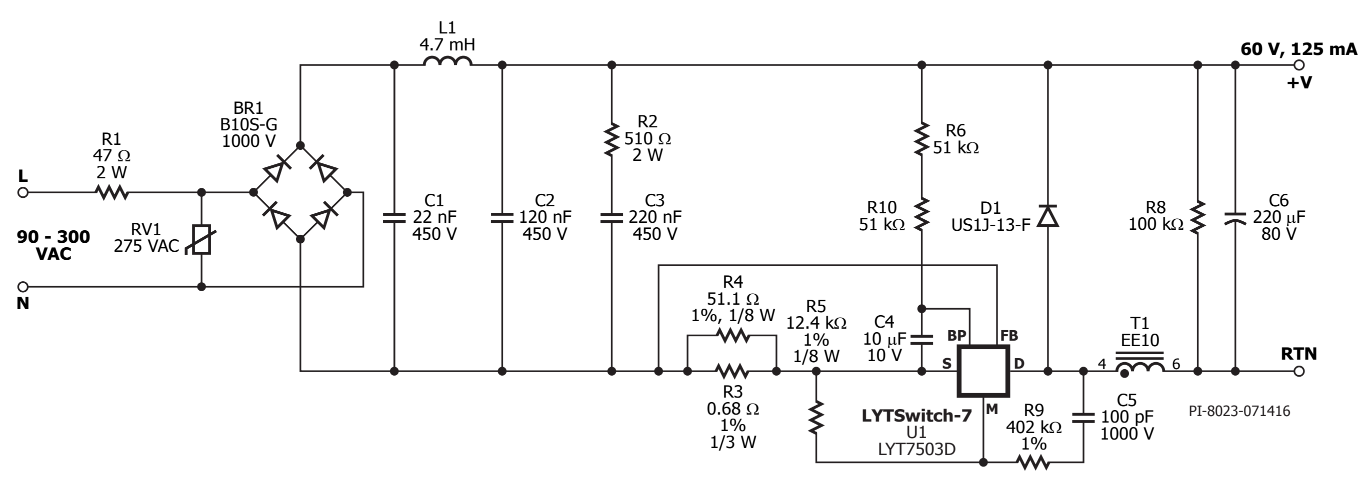


Figure 37. Design Example DER-561 Schematic.

Quick Design Checklist

Maximum Drain Voltage
Verify that the peak Drain voltage stress (VDS) does not exceed 725 V under any operating condition, including start-up and fault conditions.

Maximum Drain Current
Measure the peak Drain current under all operation conditions (including start-up and fault conditions). Look for inductor saturation (usually occurs at highest operating ambient temperatures). Verify that the peak current is less than the stated Absolute Maximum Rating in the data sheet.

Thermal Check
At maximum output power, for both minimum and maximum line voltage and maximum ambient temperature verify that component temperature limits are not exceeded.

Design Tools

Up-to-date information on design tools can be found at the Power Integrations web site: www.power.com

LYTSwitch-7 PIXls design spreadsheet can be accessed via PI Expert online: https://piexpertonline.power.com/site/login.

Revision	Notes	Date
A	Initial Release.	09/16

For the latest updates, visit our website: www.power.com

Patent Information

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