CoolSET™

24 V / 350 mA LED PSU Using ICE3B0365JG

Power Management & Supply

Never stop thinking

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CoolSET™

Revision History:	**2007-10**	**V1.1**
Previous Version:	2007-05	V1.0

Page	Subjects (major changes since last revision)
Page 11	2007-10 Update Schematics (Figure 2 and Figure 3)

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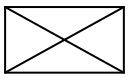

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1 Abstract

High brightness LEDs are becoming more popular in replacing conventional incandescent lamps in terms of efficiency, reliability and space requirement. Moreover, the field of emergency lighting and advertising has been made available to LED lighting. In using an integrated off line switching regulator like CoolSET™ in combination with the current regulator TLE4305, a low cost and high efficient LED driver for multiple LEDs has been developed to drive the LEDs from an extended wide line input voltage.

2 Introduction

This document introduces the isolated offline coφnstant current high line LED driver based on the CoolSET™ family. The paper contains a list of features, power supply specification, schematic, bill of material and the transformer construction documentation. Typical operating characteristics are presented at the rear of this report and consist of performance curves and scope waveforms.

3 Application

The Infineon Technologies AG proposes an isolated off line switch mode power supply (SMPS, see Figure 1) for a LED cluster used for wide line input voltage applications from V_{ACIN} = 90 V up to 270 V in flyback topology. The application is fully protected against an open loop gain (OLP), short circuit (OCP), over temperature (OTP), over voltage at the V_{CC} stage (OVP), under voltage (UVLO) and a highly accurate power limiting in case of over load via Propagation Delay Compensation™ (patented by Infineon Technologies AG) in the whole line input voltage range. All protection features are using the auto restart mode. Optional, the application is able to drive the LEDs in a continuous load (Figure 2), or for alternating load, in that case, the LEDs are protected against surge currents during alternating loads (see Figure 3). The driver application uses the Infineon jitter system IC CoolSET™ F3 as PWM current mode controller with integrated MOSFET (CoolMOS™) and the TLE4305G as a current regulator on the secondary side. The application is designed to drive one 350 mA high brightness LED or optional a series connection of up to 6 high brightness LEDs (350 mA) in a high efficiency.

Bottom View TOP View

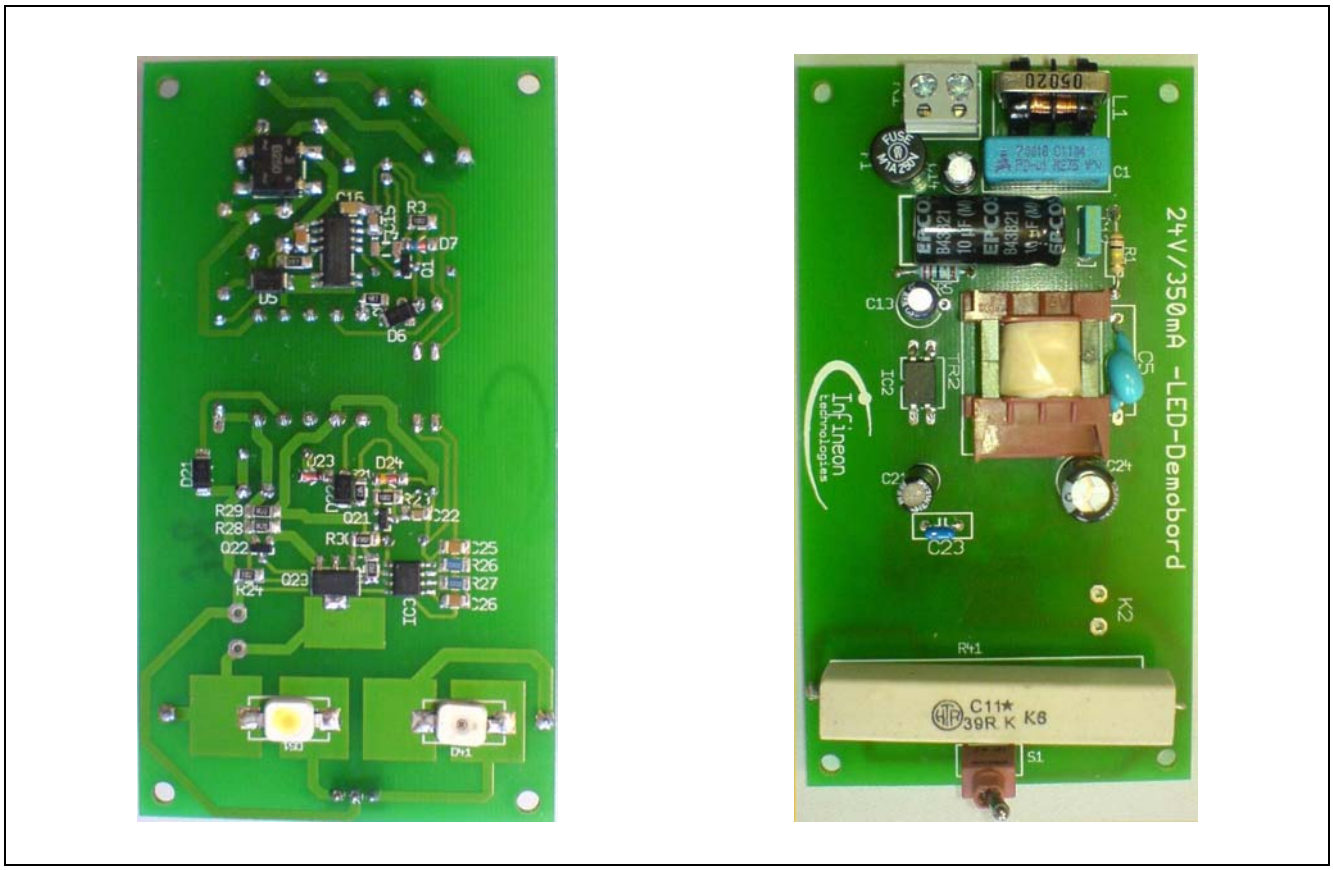


Figure 1 LED-ICE3B0365JG Demoboard

4 CoolSET™ Third Generation of System ICs

The CoolSET™ family is a smart hybrid power device combines the superior technology of the high voltage MOSFET CoolMOS™ and a PWM current mode control IC. It is designed for switched mode power supplies using a lower external component count - standard applications require only 7 external components to drive the CoolSET™. In order to increase the reliability, the integrated control circuit offers the benefit of enhanced protection features all with auto restart (hiccup mode), an active burst mode for extreme low standby power, a high voltage start up cell, a programmable soft start and blanking window function and a frequency jittering to reduces EMI. The lowest area specific $R_{DS(ON)}$, a high avalanche ruggedness and the low switching losses of the CoolMOS™ increase the efficiency and improves the standby power. The integrated Propagation Delay Compensation™ (patented by Infineon Technologies) results a highly accurate power limiting in the whole line input voltage range – optimized design for a global application.

Table 1 List of Integrated CoolSET™ Features

Feature List
CoolSET™ Device **ICE3B0365JG** with 67 kHz Working Frequency
650V [1] CoolMOS™ with implemented Start Up Cell
Integrated active Burst Mode Function with immediate Response of Load Jumps
Programmable Over Current Blanking Window for short Term Over Current
Programmable Soft Start
Integrated Frequency Jitter to improve the EMI Behavior
Integrated Over Load Protection (OLP) with auto restart
Integrated Over Current Protection (OCP) with auto restart
Integrated Over Temperature (OTP) Shut Down with auto restart
Integrated Open Loop Protection (OLP) with auto restart
Integrated Under Voltage Lock Out (UVLO) with auto restart
Integrated Propagation Delay Compensation™ and Leading Edge Blanking
External Current Sense for highly accurate Power Limiting
PDSO16/12 SMD Package with extended Creepage Distance

[1] V_{DSBR} at T_j = 110°C

5 TLE4305 Constant Current Regulator

The TLE4305G is specifically designed to control the output voltage and the output current of a SMPS. Independent compensation networks for the voltage and the current loop can be realized by external circuitry. The device contains a high accuracy bandgap reference voltage, two operational transconductance amplifiers (OTA), an optocoupler driver output stage and a high-voltage bias circuit. The device is based on Infineons double isolated power line technology DOPL which allows producing high precision bipolar voltage regulators with breakdown voltages up to 45 V. The efficiency increases furthermore due to the very low voltage drop (only 200 mV) at the shunt resistors R_{28} and R_{29} of the TLE4305G.

6 Power Supply Specification

Table 2 Power Supply Specification

Description	Symbol	Min.	Typ.	Max.	Units
Input Section					
AC Input Voltage (f =16 – 400 Hz)	V_{ACIN}	90	115/230	270	V_{AC}
DC Input Voltage	V_{DCIN}	120		380	V_{DC}
Output Section					
Output Voltage @ no Load	V_{OUT}			23.6	V_{DC}
Output Voltage Conditions	V_{OUT}	4.0	16.7	22.5	V_{DC}
Output Current	I_{OUT}	340	340	340	mA_{DC}
Output Power Nominal	P_{OUT}	1.4	5.7	7.8	W
Efficiency (90 V_{AC})	η	77	86	87	%
Efficiency (270 V_{AC})	η	63	84	85	%
Environmental					
Ambient Temperature	T_A		25		°C
Thermal Consideration (Temperature Increase @ nom Load and V_{ACIN} = 90V)					
Transformer			20		°C
CoolSET™			20		°C
TLE4305			20		°C
Output Diode			50		°C
LED LA W57B			70		°C
Output Capacitors			20		°C

7 Schematics

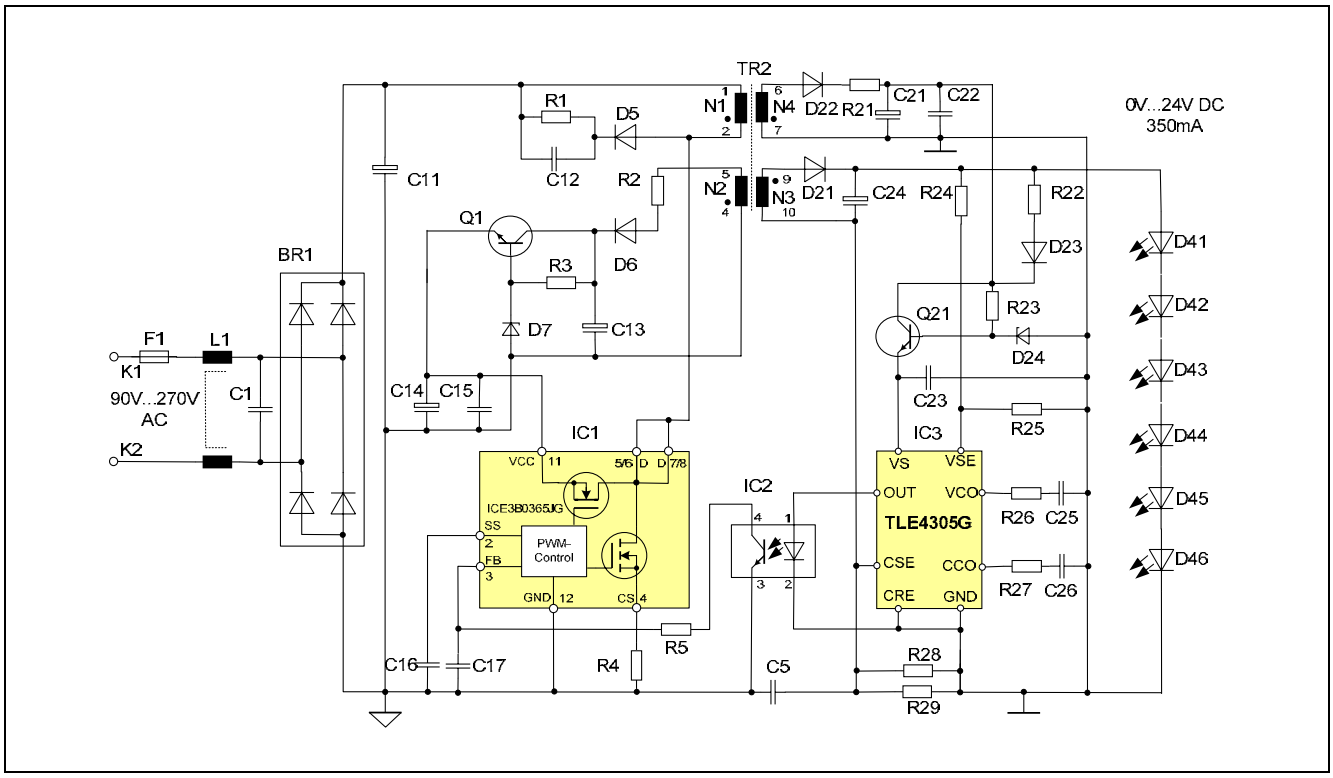


Figure 2 Power Supply Schematic for Continuous Load (Standard)

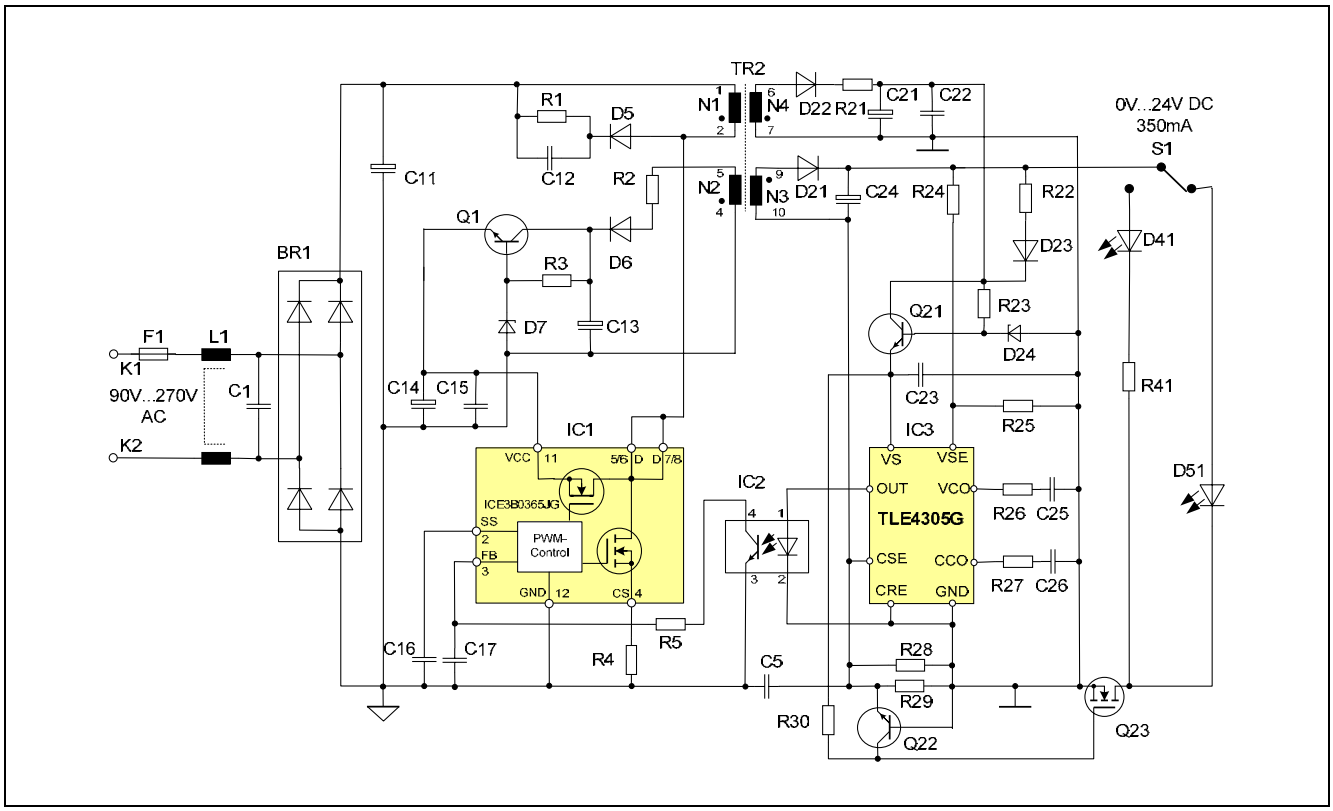


Figure 3 Power Supply Schematic for Alternating Load

8 PCB Layout

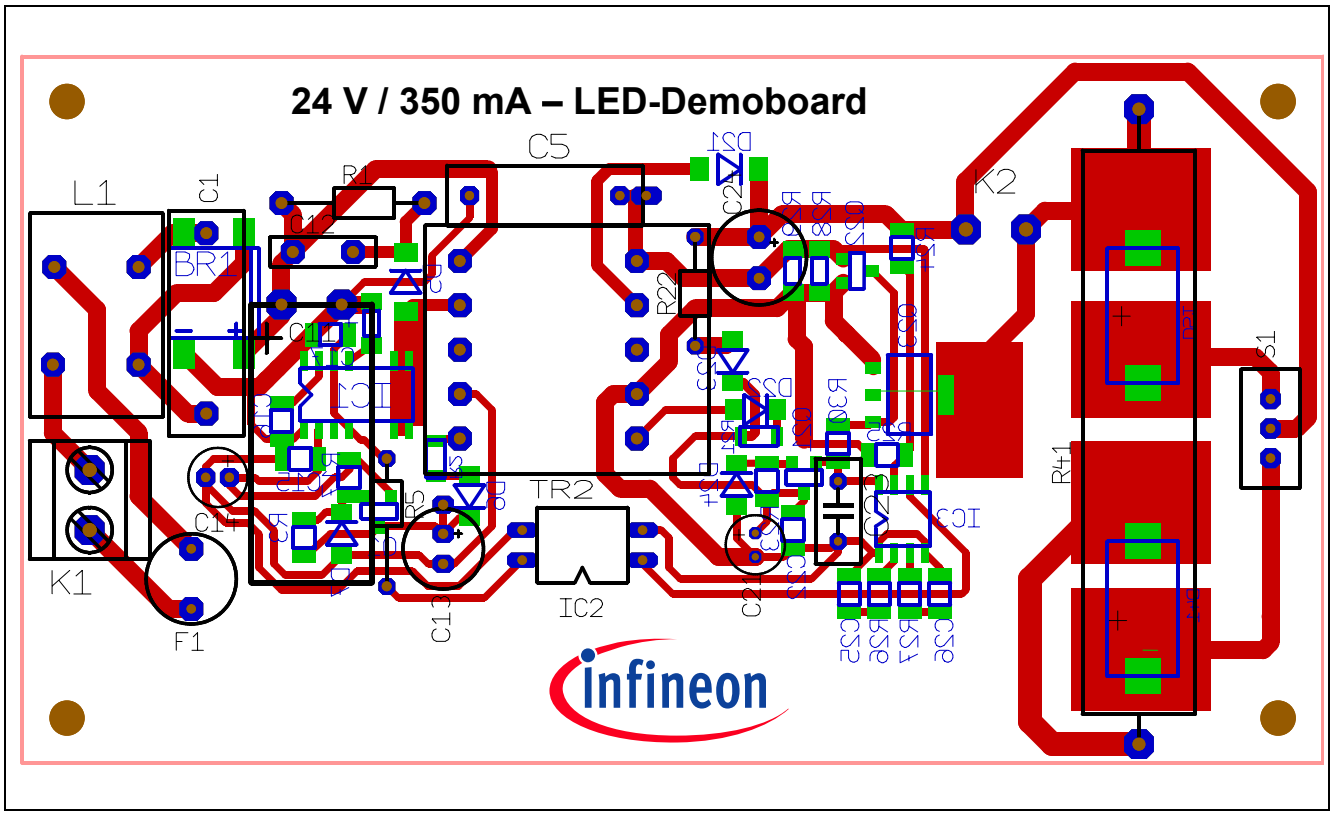


Figure 4 Power Supply PCB Layout

9 Board Description

The SMPS for a LED cluster is an isolated off line discontinuous current mode (DCM) application in flyback mode using ICE3B0365JG – the smallest system IC from the CoolSET™ - F3 family. The circuit diagram in Figure 2 (standard continuous load) and Figure 3 (for alternating load) details a 24 V / 350 mA power supply which operates from an extended AC line input voltage range from 90 V_{AC} to 270 V_{AC}, suitable for applications requiring either an open frame supply or an enclosed application. By replacing R_{41} with high brightness LEDs, the application is able to drive 1 white and in additional 6 red LEDs. The efficiency of the application is above 85% - the TLE4305G regulates the current and a constant no load voltage.

9.1 Start Up

After switch on the AC line input voltage, the integrated start up cell (depletion MOSFET on the CoolMOS™ inside CoolSET™) charges the chip supply stage up to V_{CC} = 18 V, the controller starts working. In that moment, the start up cell shuts off and is inactive during operation mode in order to increase the efficiency.

9.2 Operation Mode

The IC will be supplied from the auxiliary winding N2 in forward mode, R_2 and the rectifier diode D6. C_{13} and C_{14} are taking care of a sufficient V_{CC} voltage during different operation modes from no load to nominal load operation. The chip supply voltage (V_{CC}) of the CoolSET™ follows the AC line input voltage from 0 V up to 22.5 V_{DC}. In case of a higher V_{CC} than 19 V, the network Q1, R_3 and D7 clamps the chip supply voltage at V_{DC} = 19 V in order to protect the chip supply stage of CoolSET™ against over voltage.

9.3 Snubber Network

A RCD snubber (R_1, C_{12} and D5) clamps the drain source voltage below 600 V in order to prevent an avalanche breakdown of the MOSFET.

9.4 Soft Start

For a soft start during a start up or an auto restart after failure case, the soft start capacitor C_{16} avoids stress on the MOSFET and the diode and prevents audible noise during start up.

9.5 Feedback Network (optional)

Optional, a low pass filter (C_{17} and R_5) can be set to eliminate disturbances of the signal of the optocoupler (IC2) at the feedback PIN 3 of the CoolSET™.

9.6 Peak Power Limitation (Limitation of the Primary Current)

R_4 adjusts the primary current and furthermore, the shunt resistor limits the maximum power in case of over load during the whole AC input voltage range (integrated Propagation Delay Compensation, patented by Infineon Technologies AG). The accuracy of the power limitation depends only on the tolerance of the shunt (R_4).

9.7 Output Section and Current Regulation via TLE4305G

The voltage on the secondary side is rectified via a fast rectifier diode D21 with a low forward voltage. A low ESR Capacitor C_{24} buffers energy for the output stage. The output voltage is set by the voltage divider R_{24} and R_{25} to V_{OUT} = 24 V_{DCmax}. The chip supply voltage of the TLE4305G is rectified via diode D22. R_{21} (optional) and capacitor C_{21} perform energy buffering for the chip supply stage at PIN V_S of the TLE4305G. C_{22} and C_{23} eliminate glitches on the chip supply stage. R_{22} and D23 ensure stable operation during no load condition (P_{OUT} = 0 W). Due to the wide output voltage range from 0 V up to 22.5 V_{DC}, the chip supply voltage (V_S) of the TLE4305G follows the line input voltage. In case of a higher V_{CC} than 12 V, the network Q21, R_{23} and D24 clamps the chip supply voltage at V_{DC} = 12 V in order to protect the chip supply stage of TLE4305G against over voltage. R_{26}, C_{25} and R_{27}, C_{26} are compensation networks for the output voltage and current. The current is sensed via shunt resistors R_{28} and R_{29}.

9.8 Alternating Load during Operation

Note: This network is only needed in case of alternating load operation e.g. changing LEDs during operation mode and not for continuous load operations. In case of alternating load, a discharge current from the output capacitor C_{24} is present. This current causes a surge current peak through the LEDs. This might results a damage or a destruction of the LEDs. To prevent a destruction of the LEDs, an optional surge current compensation network (R_{30}, Q22 and Q23 in Figure 3) can be implemented to limit the discharging current from the capacitor C_{24}.

10 Conclusion

The Infineon Technologies off line LED SMPS solution - using the Infineon current mode control system IC CoolSET™ with integrated frequency jitter and TLE4305G - was designed to give maximum protection against electrical shock from the high line input voltage, application reliability, improved EMI behavior and protects the LED against surge current during load jumps. The compact design is able to be used worldwide without any adjustments, has a high efficiency at a different numbers of LEDs, a highly accurate output current control and a very low standby power rating during no load condition (P_{OUT} = 0 W). The high integration of both Infineon devices enables a minimum of external components with a maximum of protection features for a cost saving SMPS design.

11 Bill of Material

350 mA / 24 V LED-SMPS with peak current limitation

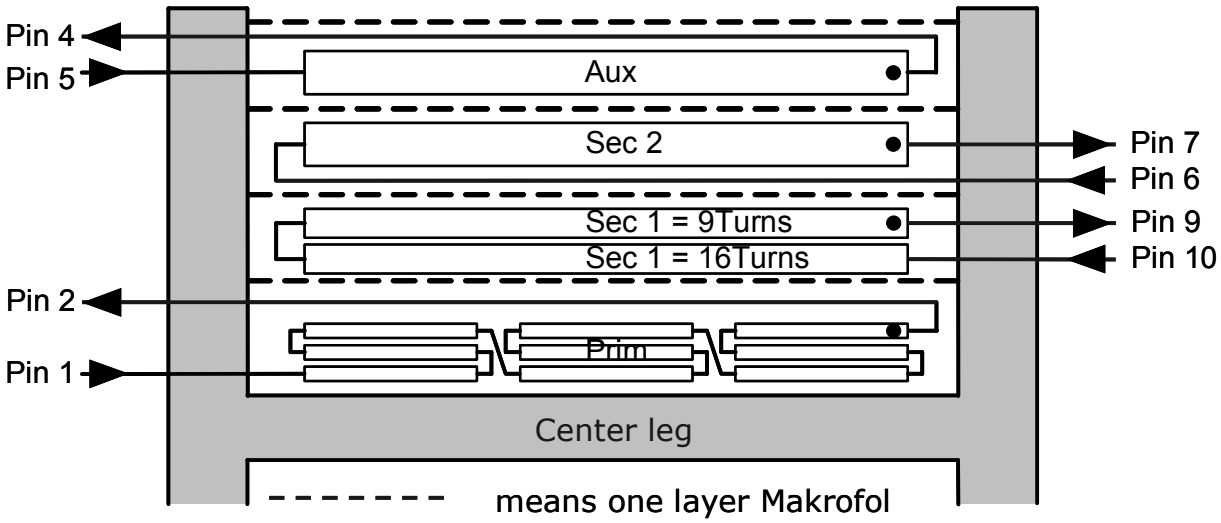
AC Input 90 V_{AC} … 270 V_{AC}

Component	Value	Package		Component	Value	Package
K1				C_{21}	10 µF / 40 V	RM2.5
K2				C_{22}	100 nF / 50 V	1206
F1	Fuse 1A fast	Microfuse		C_{23}	100 nF / 50 V	RM5
IC1	ICE3B0365JG	P-DSO-16/12		C_{24}	100 µF / 35 V	RM5 low ESR
IC2	SFH617A-3			C_{25}	33 nF / 50 V	1206
IC3	TLE4305G	P-DSO-8		C_{26}	33 nF / 50 V	1206
BR1	B250S	SMD		L_1	2.2 mH / 0.5 A	SU9V
D5	MURS 160	MELF-B		TR2	Air Gap 0.2 mm	EF16
D6	ES1D	Mini-MELF			N1 = 116 turns	
D7	ZMM 20	Mini-MELF			N2 = 13 turns	
D21	ES1D	MELF-B			N3 = 25 turns	
D22	ES1D	Mini-MELF			N4 = 12 turns	
D23	LL4148	Mini-MELF		R_1	100 kΩ	axial
D24	ZMM 12	1206		R_2	4.7 Ω	1206
D41	LA W57B			R_3	10 kΩ	1206
D51	LW5SG			R_4	2.7 Ω	1206
Q1	BC846B	SOT23		R_5	22 Ω	axial
Q21	BC846B	SOT23		R_{21}	4.7 Ω	1206
Q22	BC817	SOT23		R_{22}	4.7 kΩ	axial
Q23	BSP 320S	SOT223		R_{23}	10 kΩ	1206
C_1	100 nF / 250 V_{AC}-X2	RM15		R_{24}	33 kΩ	1206
C_5	1 nF / 250 V_{AC}-Y1	RM15		R_{25}	3.9 kΩ	1206
C_{11}	10 µF / 400 V	RM5		R_{26}	22 kΩ	1206
C_{12}	1 nF / 400 V	RM5		R_{27}	22 kΩ	1206
C_{13}	4.7 µF / 25 V	RM2.5		R_{28}	1.2 Ω	1206
C_{14}	10 µF / 40 V	RM2.5		R_{29}	1.2 Ω	1206
C_{15}	100 nF / 50 V	1206		R_{30}	15 kΩ	1206
C_{16}	470 nF / 50 V	1206		R_{41}	39 Ω / 10 W	axial
C_{17}	2.2 nF / 50 V	1206		S1	N2F4PCA	Switch

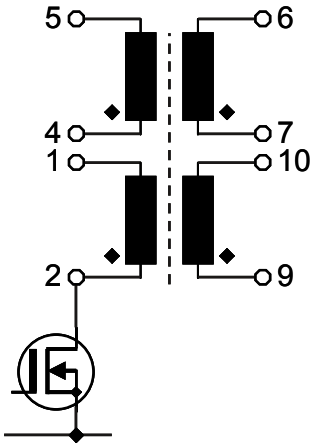
12 Transformer Construction Documentation

9W LED Flyback Transformator 24V/350mA-Demoboard

Core: EF16/8/5	Material: N67	Total Air Gap: 0,2mm
Coil Former: horizontal	Inductivity: 1,75mH	Peak Current: 0,4A



Primary winding	116 turns 0,18 mm ⌀
Secondary winding 1	25 turns 0,35 mm ⌀ TEX-E wire
Secondary winding 2	12 turns 0,35 mm ⌀ TEX-E wire
Auxiliary winding	13 turns 0,18 mm ⌀ spread



Bottom View:

13 Performance Data

13.1 Efficiency

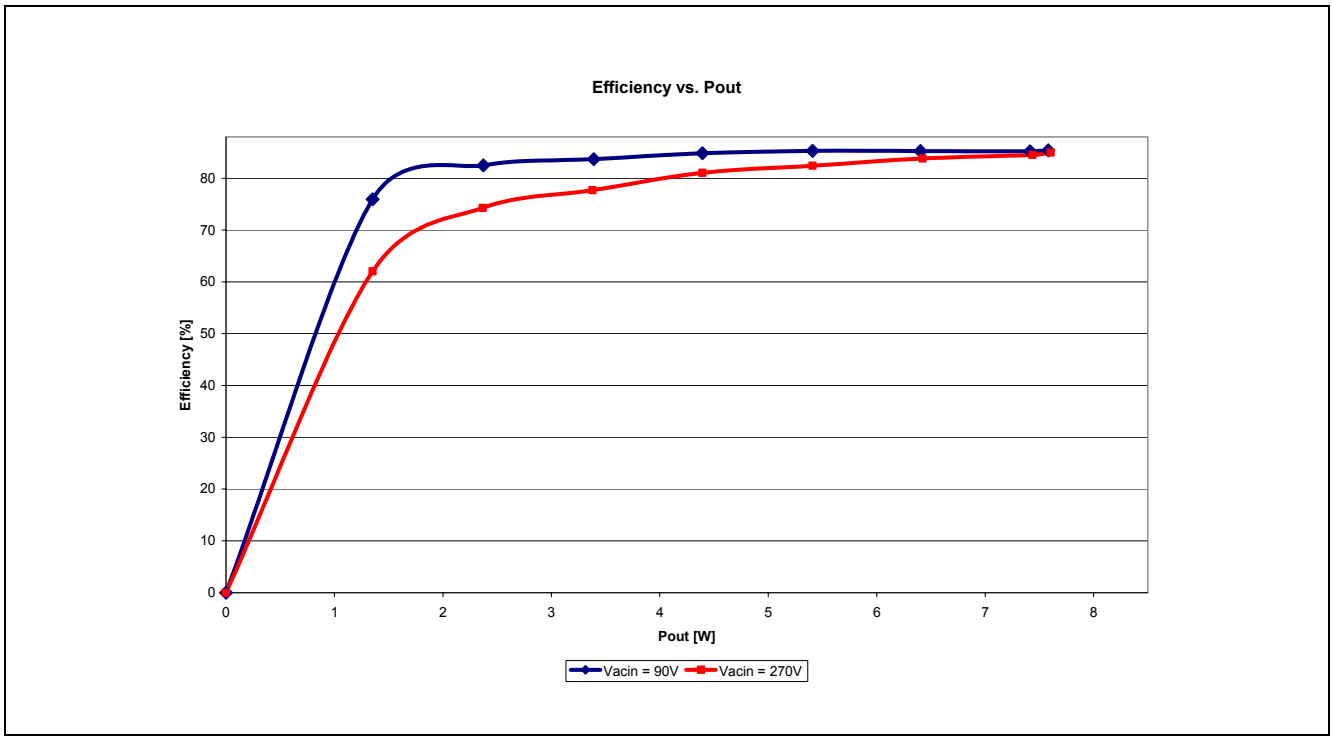


Figure 5 Efficiency versus Output Power

Figure 5 shows the efficiency (y-axis) versus output power (x-axis) of the LED SMPS at low line input voltage V_{ACIN} = 90 V and high line input voltage V_{ACIN} = 270 V for different numbers of LEDs.

13.2 Output Current Regulation

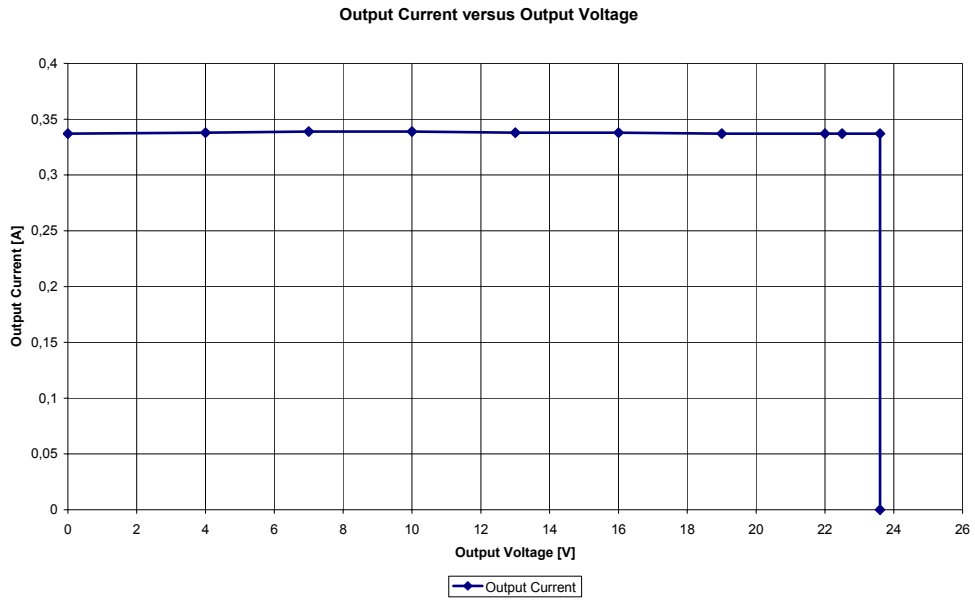


Figure 6 Controlled Output Current versus Output Voltage

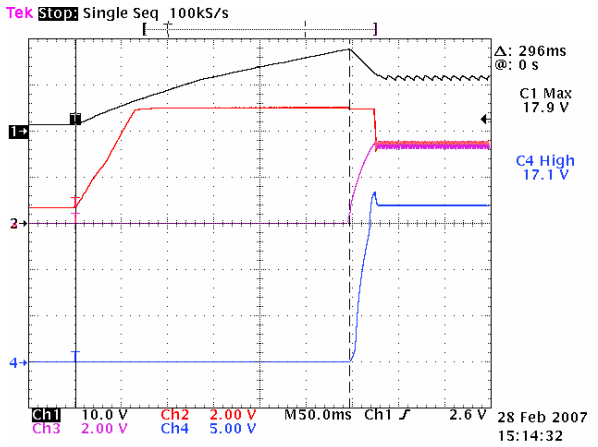
Figure 6 shows the current regulation characteristic of the output stage. The output voltage (x-axis) rises with increasing load from P_{OUTmin} until maximum load (1 white and add. 6 red high brightness LEDs). While exceeding maximum load (respective maximum output voltage) the TLE4305G decreases the current (y-axis) down to zero and holds the output voltage stable at the maximum level of V_{OUT} = 23.6 V.

14 Waveforms and Scope Plots

14.1 Start Up @ Low and High Line

Figure 7 and Figure 8 are showing a typical start up from plug in the AC line input voltage till working mode. The chip supply voltage V_{CC} (Ch1) will be charged up via the implemented start up cell to the V_{CCON} threshold @ typ. 18 V. If the chip supply voltage exceeds this threshold, the start up cell is inactive. Now, the control IC starts working and switches the gate drive on. In the soft start phase - the soft start voltage (Ch3) rises from 1 V up to 3 V to limit the primary current via duty cycle limitation. If the soft start voltage reach the operation threshold at typ. 3.2 – 3.6 V (sawtooth wave form) and the output voltage (Ch4) reaches the working level, the feedback voltage (Ch2) decreases from its reference voltage down to the operation level dependent from the load at the output.

Start UP: V_{ACIN} = 90 V **(High Resolution Mode)**
Ch1: V_{CC} (Chip Supply Voltage PIN 11 to GND PIN 12)
Ch2: V_{FB} (Feedback Voltage PIN 31 to GND PIN 12)
Ch3: V_{SS} (Softstart Voltage PIN 2 to GND PIN 12)
Ch4: V_{OUT} (Output Voltage C_{24} to TLE GND)



Start UP: V_{ACIN} = 270 V **(High Resolution Mode)**
Ch1: V_{CC} (Chip Supply Voltage PIN 11 to GND PIN 12)
Ch2: V_{FB} (Feedback Voltage PIN 31 to GND PIN 12)
Ch3: V_{SS} (Softstart Voltage PIN 2 to GND PIN 12)
Ch4: V_{OUT} (Output Voltage C_{24} to TLE GND)

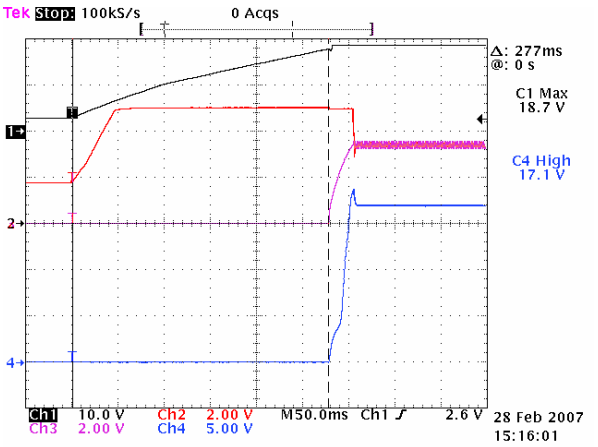
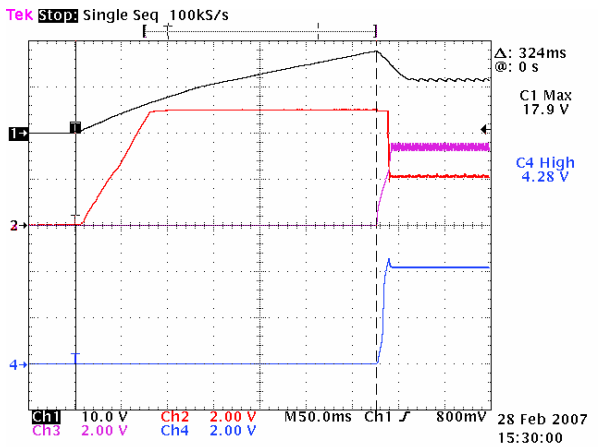


Figure 7 Startup @ Low and High AC Line Input Voltage and Nominal Load

Start UP: V_{ACIN} = 90 V **(High Resolution Mode)**
Ch1: V_{CC} (Chip Supply Voltage PIN 11 to GND PIN 12)
Ch2: V_{FB} (Feedback Voltage PIN 31 to GND PIN 12)
Ch3: V_{SS} (Softstart Voltage PIN 2 to GND PIN 12)
Ch4: V_{OUT} (Output Voltage C_{24} to TLE GND)



Start UP: V_{ACIN} = 270 V **(High Resolution Mode)**
Ch1: V_{CC} (Chip Supply Voltage PIN 11 to GND PIN 12)
Ch2: V_{FB} (Feedback Voltage PIN 31 to GND PIN 12)
Ch3: V_{SS} (Softstart Voltage PIN 2 to GND PIN 12)
Ch4: V_{OUT} (Output Voltage C_{24} to TLE GND)

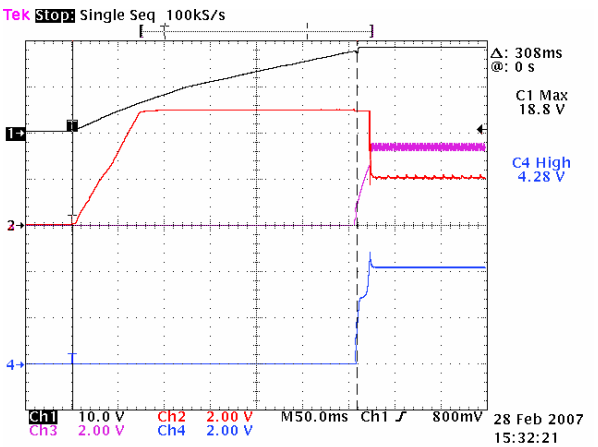
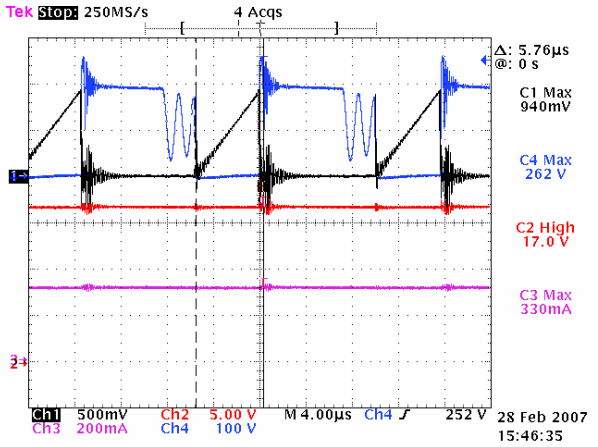


Figure 8 Startup @ Low and High AC Line Input Voltage and light Load

14.2 Drain Source Voltage and Current

RUN Mode: V_{ACIN} = 90 V **(High Res. Mode) @ nom. Load**
Ch1: V_{Sense} (Sense Voltage @ CoolSET PIN 4 to GND PIN 12)
Ch2: V_{OUT} (Output Voltage @ C_{24} to TLE GND PIN 5)
Ch3: I_{OUT} (Output Current @ through Golden Dragon Diode)
Ch4: V_{DS} (Drain Source Voltage @ Transformer PIN 2)



RUN Mode: V_{ACIN} = 270 V **(High Res. Mode) @ nom. Load**
Ch1: V_{Sense} (Sense Voltage @ CoolSET PIN 4 to GND PIN 12)
Ch2: V_{OUT} (Output Voltage @ C_{24} to TLE GND PIN 5)
Ch3: I_{OUT} (Output Current @ through Golden Dragon Diode)
Ch4: V_{DS} (Drain Source Voltage @ Transformer PIN 2)

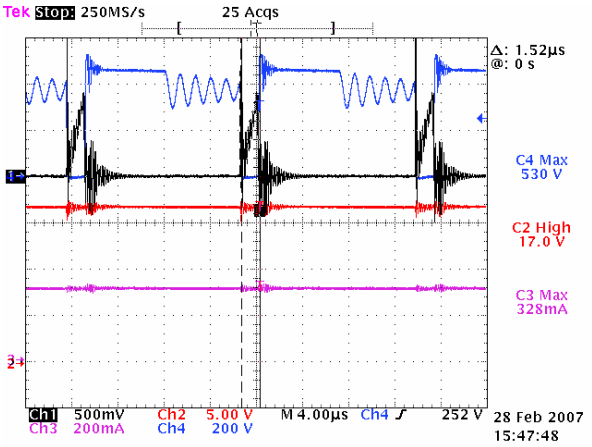
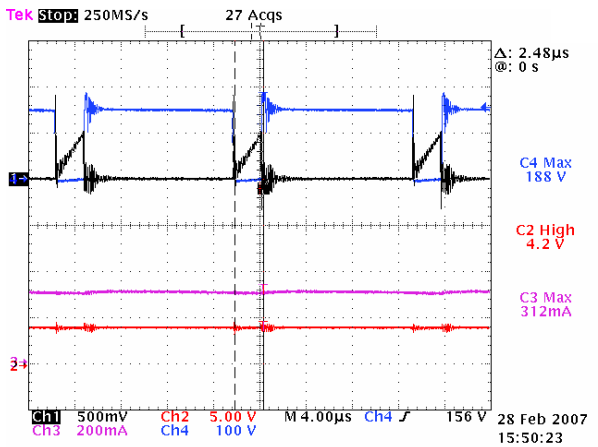


Figure 9 Drain Source Voltage and Current during Normal Operation @ nom. Load

RUN Mode: V_{ACIN} = 90 V **(High Res. Mode) @ light Load**
Ch1: V_{Sense} (Sense Voltage @ CoolSET PIN 4 to GND PIN 12)
Ch2: V_{OUT} (Output Voltage @ C_{24} to TLE GND PIN 5)
Ch3: I_{OUT} (Output Current @ through Golden Dragon Diode)
Ch4: V_{DS} (Drain Source Voltage @ Transformer PIN 2)



RUN Mode: V_{ACIN} = 270 V **(High Res. Mode) @ light Load**
Ch1: V_{Sense} (Sense Voltage @ CoolSET PIN 4 to GND PIN 12)
Ch2: V_{OUT} (Output Voltage @ C_{24} to TLE GND PIN 5)
Ch3: I_{OUT} (Output Current @ through Golden Dragon Diode)
Ch4: V_{DS} (Drain Source Voltage @ Transformer PIN 2)

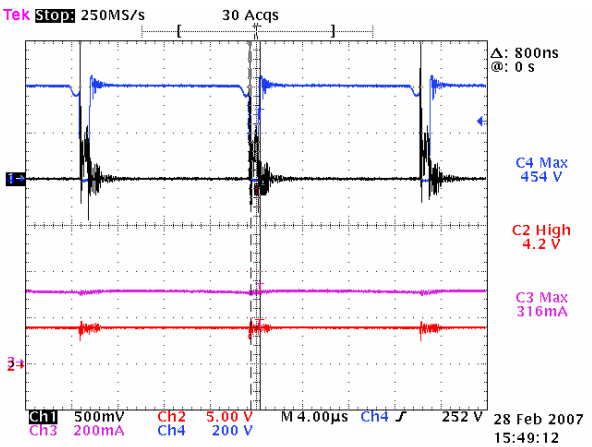
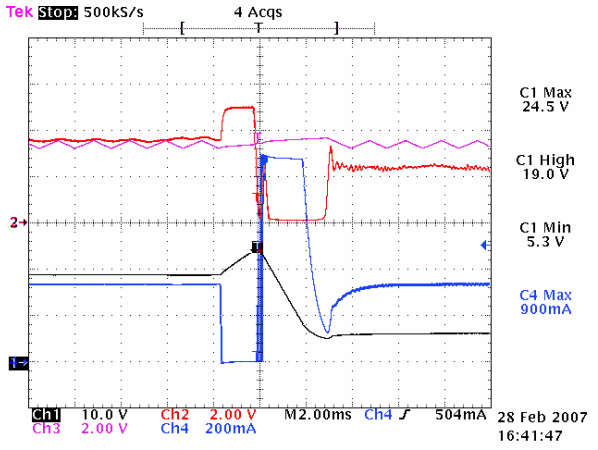


Figure 10 Drain Source Voltage and Current during Normal Operation @ light Load

14.3 Regulation Characteristic

Note: (optional, not needed for continuous load operation):
In case of alternating load, a discharge current from the output capacitor C_{24} is present. This current causes a surge current peak (Ch4) through the LEDs. This surge current will be compensated with the network (R_{30}, Q22 and Q23) in order to protect the LEDs. Figure 1111 shows regulation characteristic of this network regarding the surge current through the LEDs in two states: alternating load from nominal and no load into light load condition with out shut off of the application (feedback Ch2 and soft start voltage Ch3 are in its working levels).

Load Jump from nominal Load to light Load
Ch1: V_{OUT} (Output Voltage @ C24 to TEL GND PIN 5)
Ch2: V_{FB} (Feedback Voltage @ CoolSET PIN 3 to GND PIN 12)
Ch3: $V_{Soft\ Start}$ (Soft Start Voltage @ CoolSET PIN 2 to GND PIN 12)
Ch4: I_{OUT} (Output Current @ through Diodes Golden Dragon)



Load Jump from nominal Load to light Load
Ch1: V_{OUT} (Output Voltage @ C24 to TEL GND PIN 5)
Ch2: V_{FB} (Feedback Voltage @ CoolSET PIN 3 to GND PIN 12)
Ch3: $V_{Soft\ Start}$ (Soft Start Voltage @ CoolSET PIN 2 to GND PIN 12)
Ch4: I_{OUT} (Output Current @ through Diodes Golden Dragon)

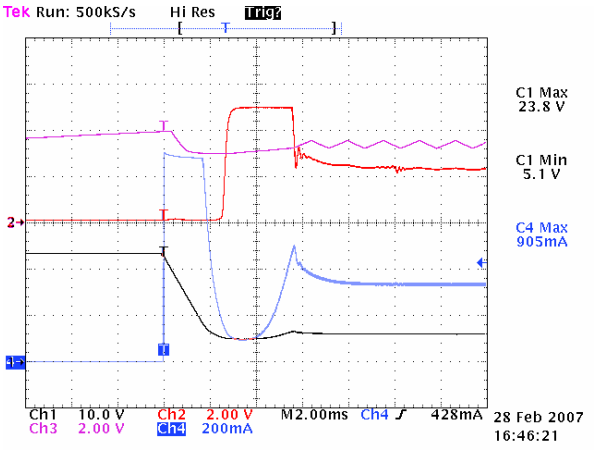


Figure 11 Load Jump Behavior

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[2] CoolSET™ – III
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[3]

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