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NCL30083

Dimmable Quasi-Resonant Primary Side Current-Mode Controller for LED Lighting with Thermal Fold-back

The NCL30083 is a PWM current mode controller targeting isolated flyback and non-isolated constant current topologies. The controller operates in a quasi-resonant mode to provide high efficiency. Thanks to a novel control method, the device is able to precisely regulate a constant LED current from the primary side. This removes the need for secondary side feedback circuitry, biasing and an optocoupler.

The device is highly integrated with a minimum number of external components. A robust suite of safety protection is built in to simplify the design. This device is specifically intended for very compact space efficient designs. It supports step dimming by monitoring the AC line and detecting when the line has been toggled on-off-on by the user to reduce the light intensity in 5 steps down to 5% dimming.

Features

- Quasi-resonant Peak Current-mode Control Operation
- Primary Side Sensing (no optocoupler needed)
- Wide V_{CC} Range
- Source 300 mA/Sink 500 mA Totem Pole Driver with 12 V Gate Clamp
- Precise LED Constant Current Regulation $\pm 1\%$ Typical
- Line Feed-forward for Enhanced Regulation Accuracy
- Low LED Current Ripple
- 250 mV $\pm 2\%$ Guaranteed Voltage Reference for Current Regulation
- ~ 0.9 Power Factor with Valley Fill Input Stage
- Low Start-up Current (13 μ A typ.)
- 5 State Quasi-log Dimmable
- Thermal Fold-back
- Programmable soft-start
- Wide Temperature Range of -40 to $+125^{\circ}\text{C}$
- Pb-free, Halide-free MSL1 Product
- Robust Protection Features
 - ◆ Over Voltage / LED Open Circuit Protection
 - ◆ Over Temperature Protection
 - ◆ Secondary Diode Short Protection
 - ◆ Output Short Circuit Protection
 - ◆ Shorted Current Sense Pin Fault Detection

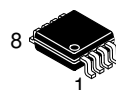
Typical Applications

- Integral LED Bulbs
- LED Power Driver Supplies
- LED Light Engines



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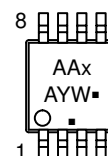


Micro8
DM SUFFIX
CASE 846A

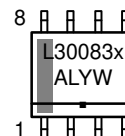


SOIC-8
D SUFFIX
CASE 751

MARKING DIAGRAM



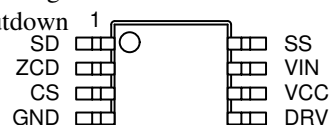
AAx = Specific Device Code
x = E or F
A = Assembly Location
Y = Year
W = Work Week
▪ = Pb-Free Package
(Note: Microdot may be in either location)



L30083x = Specific Device Code
x = B
A = Assembly Location
L = Wafer Lot
Y = Year
W = Work Week
▪ = Pb-Free Package

- ◆ Latched and Auto-recoverable Versions
- ◆ Brown-out
- ◆ V_{CC} Under Voltage Protection
- ◆ Thermal Shutdown

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 35 of this data sheet.

NCL30083

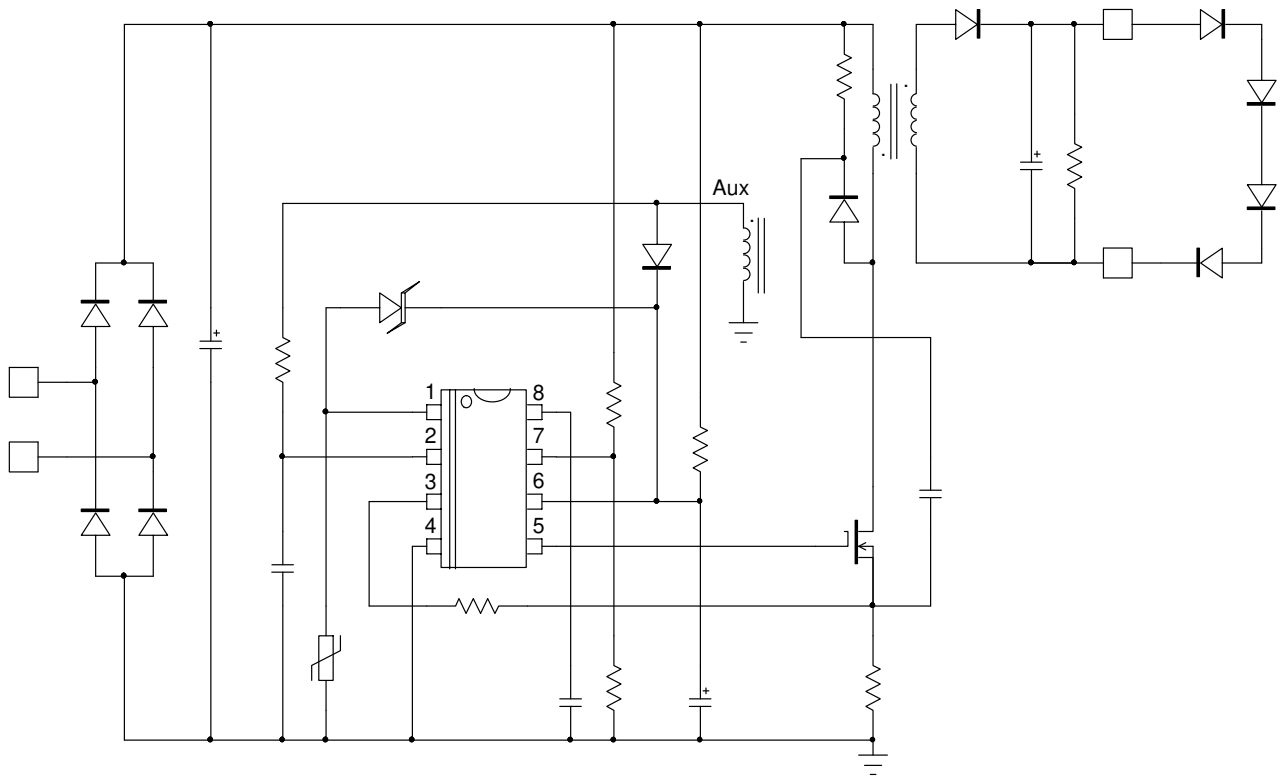


Figure 1. Typical Application Schematic for NCL30083

Table 1. PIN FUNCTION DESCRIPTION

Pin No	Pin Name	Function	Pin Description
1	SD	Thermal Fold-back and shutdown	Connecting an NTC to this pin allows reducing the output current down to 50% of its fixed value before stopping the controller. A Zener diode can also be used to pull-up the pin and stop the controller for adjustable OVP protection
2	ZCD	Zero Crossing Detection	Connected to the auxiliary winding, this pin detects the core reset event.
3	CS	Current sense	This pin monitors the primary peak current
4	GND	-	The controller ground
5	DRV	Driver output	The current capability of the totem pole gate drive (+0.3/-0.5 A) makes it suitable to effectively drive a broad range of power MOSFETs.
6	VCC	Supplies the controller	This pin is connected to an external auxiliary voltage.
7	VIN	Brown-Out Input voltage sensing	This pin observes the HV rail and is used in valley selection. This pin also monitors and protects for low mains conditions.
8	SS	Soft-Start	A capacitor connected to ground select the soft-start duration.

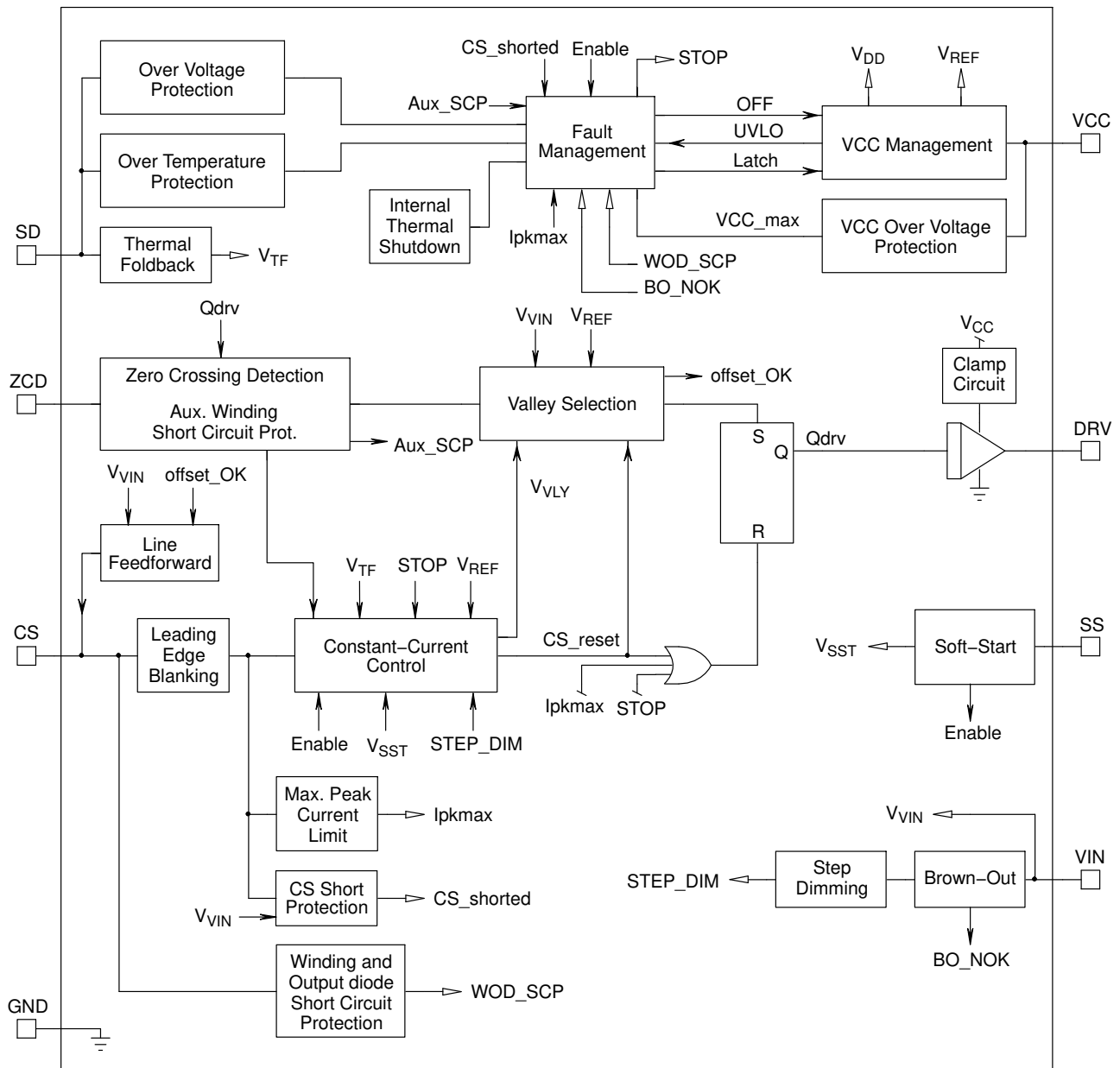


Figure 2. Internal Circuit Architecture

Table 2. MAXIMUM RATINGS TABLE

Symbol	Rating	Value	Unit
$V_{CC(MAX)}$ $I_{CC(MAX)}$	Maximum Power Supply voltage, VCC pin, continuous voltage Maximum current for VCC pin	-0.3, +35 Internally limited	V mA
$V_{DRV(MAX)}$ $I_{DRV(MAX)}$	Maximum driver pin voltage, DRV pin, continuous voltage Maximum current for DRV pin	-0.3, V_{DRV} (Note 1) -500, +800	V mA
V_{MAX} I_{MAX}	Maximum voltage on low power pins (except pins ZCD, SS, DRV and VCC) Current range for low power pins (except pins ZCD, DRV and VCC)	-0.3, +5.5 -2, +5	V mA
$V_{ZCD(MAX)}$ $I_{ZCD(MAX)}$	Maximum voltage for ZCD pin Maximum current for ZCD pin	-0.3, +10 -2, +5	V mA
$V_{SST(MAX)}$	Maximum voltage for SS pin	-0.3, +10	V
$R_{\theta J-A}$	Thermal Resistance, Junction-to-Air	289	°C/W
$T_{J(MAX)}$	Maximum Junction Temperature	150	°C
	Operating Temperature Range	-40 to +125	°C
	Storage Temperature Range	-60 to +150	°C
	ESD Capability, HBM model (Note 2)	4	kV
	ESD Capability, MM model (Note 2)	200	V

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

- V_{DRV} is the DRV clamp voltage $V_{DRV(high)}$ when V_{CC} is higher than $V_{DRV(high)}$. V_{DRV} is V_{CC} unless otherwise noted.
- This device series contains ESD protection and exceeds the following tests: Human Body Model 4000 V per JEDEC JESD22-A114-F and Machine Model Method 200 V per JEDEC JESD22-A115-A.
- This device contains latch-up protection and exceeds 100 mA per JEDEC Standard JESD78 except for VIN pin which passes 60 mA.

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Table 3. ELECTRICAL CHARACTERISTICS (Unless otherwise noted: For typical values $T_J = 25^\circ\text{C}$, $V_{CC} = 12\text{ V}$; For min/max values $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$, Max $T_J = 150^\circ\text{C}$, $V_{CC} = 12\text{ V}$)

Description	Test Condition	Symbol	Min	Typ	Max	Unit
STARTUP AND SUPPLY CIRCUITS						
Supply Voltage						V
Startup Threshold	V_{CC} increasing	$V_{CC(on)}$	16	18	20	
Minimum Operating Voltage	V_{CC} decreasing	$V_{CC(off)}$	8.2	8.8	9.4	
Hysteresis $V_{CC(on)} - V_{CC(off)}$	V_{CC} decreasing	$V_{CC(HYS)}$	8	–	–	
Internal logic reset		$V_{CC(reset)}$	3.5	4.5	5.5	
Over Voltage Protection						V
VCC OVP threshold		$V_{CC(OVP)}$	26	28	30	
$V_{CC(off)}$ noise filter		$t_{VCC(off)}$	–	5	–	μs
$V_{CC(reset)}$ noise filter–		$t_{VCC(reset)}$	–	20	–	
Startup current		$I_{CC(start)}$	–	13	30	μA
Startup current in fault mode		$I_{CC(sFault)}$	–	46	60	μA
Supply Current						mA
Device Disabled/Fault	$V_{CC} > V_{CC(off)}$	I_{CC1}	0.8	1.2	1.4	
Device Enabled/No output load on pin 5	$F_{sw} = 65\text{ kHz}$	I_{CC2}	–	2.3	4.0	
Device Switching ($F_{sw} = 65\text{ kHz}$)	$C_{DRV} = 470\text{ pF}$, $F_{sw} = 65\text{ kHz}$	I_{CC3}	–	2.7	5.0	
CURRENT SENSE						
Maximum Internal current limit		V_{ILIM}	0.95	1	1.05	V
Leading Edge Blanking Duration for V_{ILIM} ($T_J = -25^\circ\text{C}$ to 125°C)		t_{LEB}	250	300	350	ns
Leading Edge Blanking Duration for V_{ILIM} ($T_J = -40^\circ\text{C}$ to 125°C)		t_{LEB}	240	300	350	ns
Input Bias Current	DRV high	I_{bias}	–	0.02	–	μA
Propagation delay from current detection to gate off–state		t_{ILIM}	–	50	150	ns
Threshold for immediate fault protection activation		$V_{CS(stop)}$	1.35	1.5	1.65	V
Leading Edge Blanking Duration for $V_{CS(stop)}$		t_{BCS}	–	120	–	ns
Blanking time for CS to GND short detection $V_{pinVIN} = 1\text{ V}$		$t_{CS(blank1)}$	6	–	12	μs
Blanking time for CS to GND short detection $V_{pinVIN} = 3.3\text{ V}$		$t_{CS(blank2)}$	2	–	4	μs
GATE DRIVE						
Drive Resistance						Ω
DRV Sink		R_{SNK}	–	13	–	
DRV Source		R_{SRC}	–	30	–	
Drive current capability						mA
DRV Sink (Note 4)		I_{SNK}	–	500	–	
DRV Source (Note 4)		I_{SRC}	–	300	–	
Rise Time (10% to 90%)	$C_{DRV} = 470\text{ pF}$	t_r	–	40	–	ns
Fall Time (90% to 10%)	$C_{DRV} = 470\text{ pF}$	t_f	–	30	–	ns
DRV Low Voltage	$V_{CC} = V_{CC(off)} + 0.2\text{ V}$ $C_{DRV} = 470\text{ pF}$, $R_{DRV} = 33\text{ k}\Omega$	$V_{DRV(low)}$	8	–	–	V
DRV High Voltage	$V_{CC} = 30\text{ V}$ $C_{DRV} = 470\text{ pF}$, $R_{DRV} = 33\text{ k}\Omega$	$V_{DRV(high)}$	10	12	14	V

4. Guaranteed by design
5. OTP triggers when $R_{NTC} = 4.7\text{ k}\Omega$

NCL30083

Table 3. ELECTRICAL CHARACTERISTICS (Unless otherwise noted: For typical values $T_J = 25^\circ\text{C}$, $V_{CC} = 12\text{ V}$; For min/max values $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$, Max $T_J = 150^\circ\text{C}$, $V_{CC} = 12\text{ V}$)

Description	Test Condition	Symbol	Min	Typ	Max	Unit
ZERO VOLTAGE DETECTION CIRCUIT						
ZCD threshold voltage	V_{ZCD} increasing	$V_{ZCD(THI)}$	25	45	65	mV
ZCD threshold voltage (Note 4)	V_{ZCD} decreasing	$V_{ZCD(THD)}$	5	25	45	mV
ZCD hysteresis (Note 4)	V_{ZCD} increasing	$V_{ZCD(HYS)}$	10	–	–	mV
Threshold voltage for output short circuit or aux. winding short circuit detection		$V_{ZCD(short)}$	0.8	1	1.2	V
Short circuit detection Timer	$V_{ZCD} < V_{ZCD(short)}$	$t_{OVL D}$	70	90	110	ms
Auto-recovery timer duration		$t_{recovery}$	3	4	5	s
Input clamp voltage High state Low state	$I_{pin1} = 3.0\text{ mA}$ $I_{pin1} = -2.0\text{ mA}$	V_{CH} V_{CL}	– –0.9	9.5 –0.6	– –0.3	V
Propagation Delay from valley detection to DRV high	V_{ZCD} decreasing	t_{DEM}	–	–	150	ns
Equivalent time constant for ZCD input (Note 4)		t_{PAR}	–	20	–	ns
Blanking delay after on-time		t_{BLANK}	2.25	3	3.75	μs
Timeout after last demag transition		t_{TIMO}	5	6.5	8	μs
CONSTANT CURRENT CONTROL						
Reference Voltage at $T_J = 25^\circ\text{C}$		V_{REF}	245	250	255	mV
Reference Voltage $T_J = -40^\circ\text{C}$ to 125°C		V_{REF}	242.5	250	257.5	mV
70% reference voltage		V_{REF70}	–	175	–	mV
40% reference Voltage		V_{REF40}	–	100	–	mV
25% reference Voltage		V_{REF25}	–	62.5	–	mV
10% reference Voltage		V_{REF10}	–	25	–	mV
5% reference Voltage		V_{REF05}	–	12.5	–	mV
Current sense lower threshold for detection of the leakage inductance reset time		$V_{CS(low)}$	30	55	80	mV
LINE FEED-FORWARD						
V_{VIN} to $I_{CS(offset)}$ conversion ratio		K_{LFF}	15	17	19	$\mu\text{A/V}$
Offset current maximum value	$V_{pinVIN} = 4.5\text{ V}$	$I_{offset(MAX)}$	67.5	76.5	85.5	μA
V_{REF} value below which the offset current source is turned off	V_{REF} decreases	$V_{REF(off)}$	–	37.5	–	mV
V_{REF} value above which the offset current source is turned on	V_{REF} increases	$V_{REF(on)}$	–	50	–	mV
VALLEY SELECTION						
Threshold for line range detection V_{in} increasing (1 st to 2 nd valley transition for $V_{REF} > 0.75\text{ V}$)	V_{VIN} increases	V_{HL}	2.28	2.4	2.52	V
Threshold for line range detection V_{in} decreasing (2 nd to 1 st valley transition for $V_{REF} > 0.75\text{ V}$)	V_{VIN} decreases	V_{LL}	2.18	2.3	2.42	V
Blanking time for line range detection		$t_{HL(blank)}$	15	25	35	ms

4. Guaranteed by design

5. OTP triggers when $R_{NTC} = 4.7\text{ k}\Omega$

NCL30083

Table 3. ELECTRICAL CHARACTERISTICS (Unless otherwise noted: For typical values $T_J = 25^\circ\text{C}$, $V_{CC} = 12\text{ V}$;
For min/max values $T_J = -40^\circ\text{C}$ to $+125^\circ\text{C}$, Max $T_J = 150^\circ\text{C}$, $V_{CC} = 12\text{ V}$)

Description	Test Condition	Symbol	Min	Typ	Max	Unit
VALLEY SELECTION						
Valley thresholds						mV
1 st to 2 nd valley transition at LL and 2 nd to 3 rd valley HL	V_{REF} decreases	$V_{VLY1-2/2-3}$	177.5	187.5	197.5	
2 nd to 1 st valley transition at LL and 3 rd to 2 nd valley HL	V_{REF} increases	$V_{VLY2-1/3-2}$	185.0	195.0	205.0	
2 nd to 4 th valley transition at LL and 3 rd to 5 th valley HL	V_{REF} decreases	$V_{VLY2-4/3-5}$	117.5	125.0	132.5	
4 th to 2 nd valley transition at LL and 5 th to 3 rd valley HL	V_{REF} increases	$V_{VLY4-2/5-3}$	125.0	132.5	140.0	
4 th to 7 th valley transition at LL and 5 th to 8 th valley HL	V_{REF} decreases	$V_{VLY4-7/5-8}$	–	75.0	–	
7 th to 4 th valley transition at LL and 8 th to 5 th valley HL	V_{REF} increases	$V_{VLY7-4/8-5}$	–	82.5	–	
7 th to 11 th valley transition at LL and 8 th to 12 th valley HL	V_{REF} decreases	$V_{VLY7-11/8-12}$	–	37.5	–	
11 th to 7 th valley transition at LL and 12 th to 8 th valley HL	V_{REF} increases	$V_{VLY11-7/12-8}$	–	50.0	–	
11 th to 13 th valley transition at LL and 12 th to 15 th valley HL	V_{REF} decreases	$V_{VLY11-13/12-15}$	–	15.0	–	
13 th to 11 th valley transition at LL and 15 th to 12 th valley HL	V_{REF} increases	$V_{VLY13-11/15-12}$	–	20.0	–	
SOFT-STAT PIN						
SS pin voltage for zero output current (enable)		$V_{SST(EN)}$	0.66	0.7	0.74	V
SS pin voltage for 100% of output current		V_{SST100}	2.25	2.45	2.65	V
Clamping voltage for SS pin		$V_{SST(CLP)}$	–	7.8	–	V
Soft-start current source		I_{SST}	8.5	10	11.5	μA
Pre-charge current source	$V_{SST} < V_{SST(EN)}$	$I_{SST(pre)}$	–	100	–	μA
THERMAL FOLD-BACK AND OVP						
SD pin voltage at which thermal fold-back starts		$V_{TF(start)}$	0.9	1	1.2	V
SD pin voltage at which thermal fold-back stops ($I_{out} = 50\% I_{out(nom)}$)		$V_{TF(stop)}$	0.64	0.68	0.72	V
Reference current for direct connection of an NTC (Note 5)		$I_{OTP(REF)}$	80	85	90	μA
Fault detection level for OTP (Note 5)	V_{SD} decreasing	$V_{OTP(off)}$	0.47	0.5	0.53	V
SD pin level at which controller re-start switching after OTP detection	V_{SD} increasing	$V_{OTP(on)}$	0.64	0.68	0.72	V
Timer duration after which the controller is allowed to start pulsing (Note 5)		$t_{OTP(start)}$	180	–	300	μs
Clamped voltage (SD pin left open)	SD pin open	$V_{SD(clamp)}$	1.13	1.35	1.57	V
Clamp series resistor		$R_{SD(clamp)}$	–	1.6	–	$\text{k}\Omega$
SD pin detection level for OVP	V_{SD} increasing	V_{OVP}	2.35	2.5	2.65	V
Delay before OVP or OTP confirmation (OVP and OTP)		$T_{SD(delay)}$	15	30	45	μs
THERMAL SHUTDOWN						
Thermal Shutdown (Note 4)	Device switching (F_{SW} around 65 kHz)	T_{SHDN}	130	155	170	$^\circ\text{C}$
Thermal Shutdown Hysteresis (Note 4)		$T_{SHDN(HYS)}$	–	55	–	$^\circ\text{C}$
BROWN-OUT						
Brown-Out ON level (IC start pulsing)	V_{SD} increasing	$V_{BO(on)}$	0.90	1	1.10	V
Brown-Out OFF level (IC shuts down)	V_{SD} decreasing	$V_{BO(off)}$	0.85	0.9	0.95	V
BO comparators delay		$t_{BO(delay)}$	–	30	–	μs
Brown-Out blanking time		$t_{BO(blank)}$	35	50	65	ms
Brown-out pin bias current		$I_{BO(bias)}$	–250	–	250	nA

4. Guaranteed by design

5. OTP triggers when $R_{NTC} = 4.7\text{ k}\Omega$

TYPICAL CHARACTERISTICS

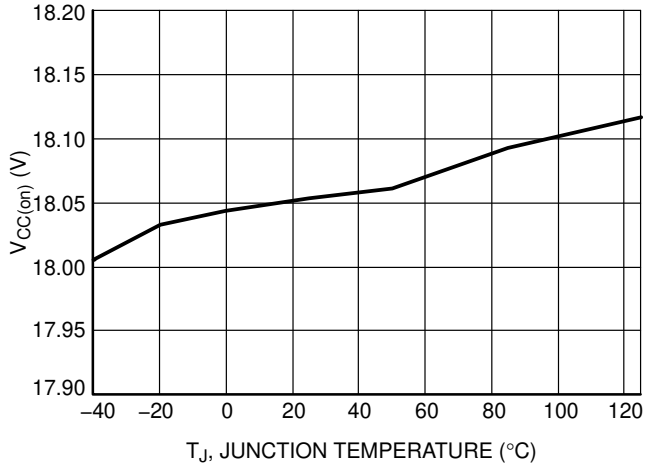


Figure 3. $V_{CC(on)}$ vs. Junction Temperature

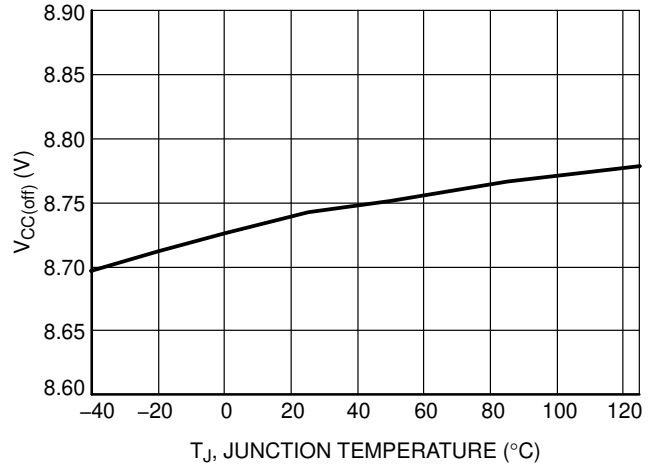


Figure 4. $V_{CC(off)}$ vs. Junction Temperature

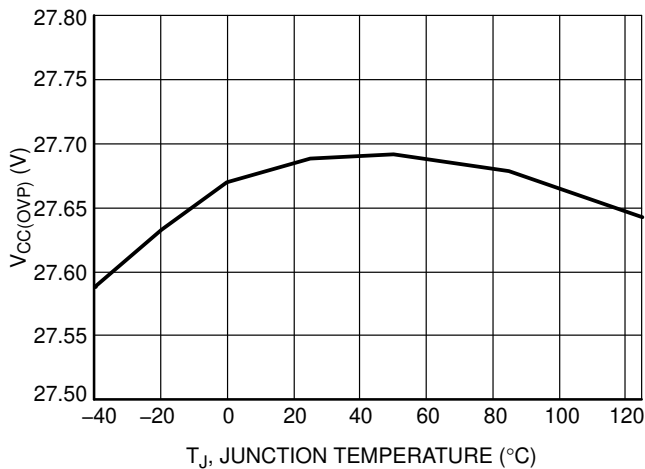


Figure 5. $V_{CC(OVP)}$ vs. Junction Temperature

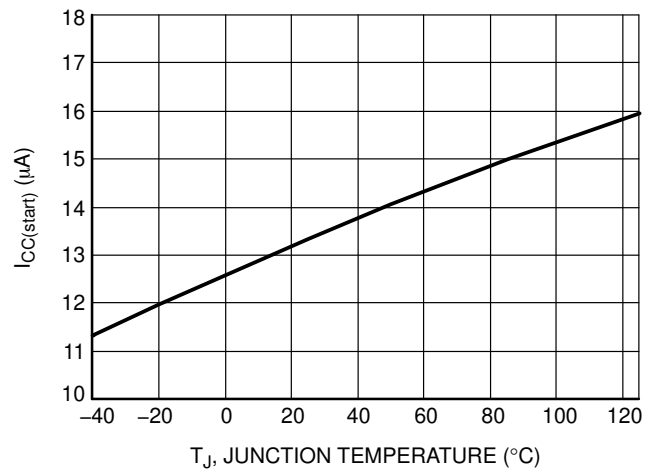


Figure 6. $I_{CC(start)}$ vs. Junction Temperature

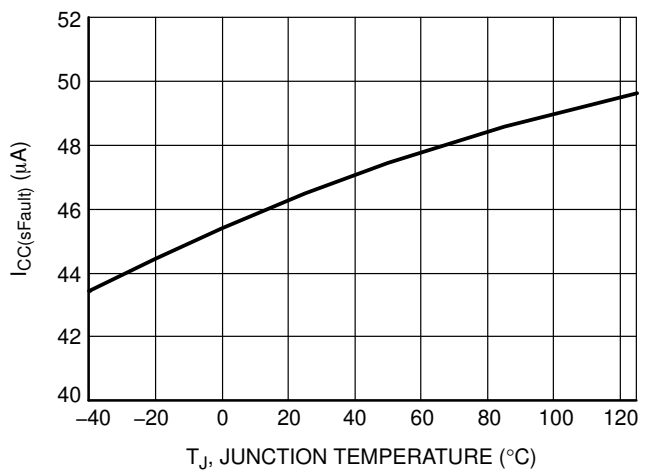


Figure 7. $I_{CC(sFault)}$ vs. Junction Temperature

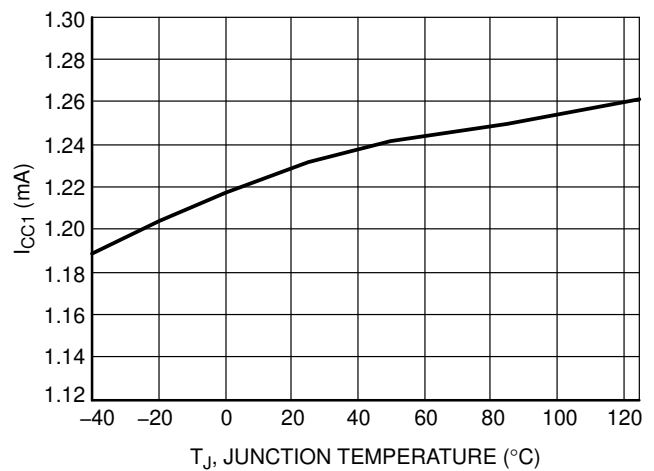


Figure 8. I_{CC1} vs. Junction Temperature

TYPICAL CHARACTERISTICS

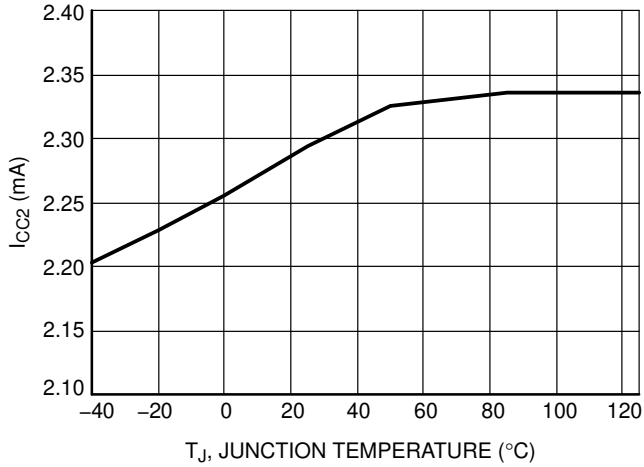


Figure 9. I_{CC2} vs. Junction Temperature

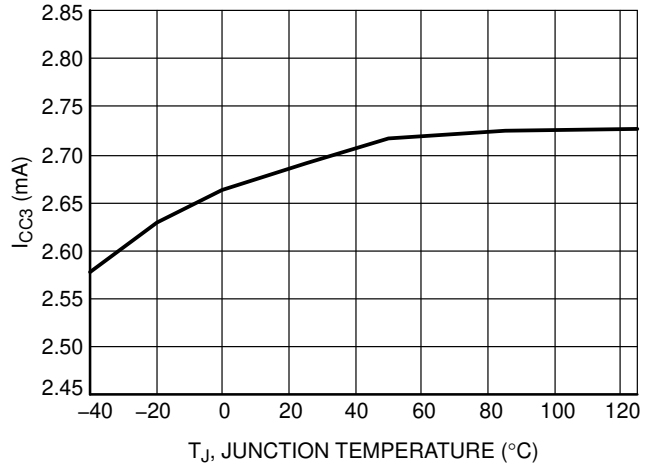


Figure 10. I_{CC3} vs. Junction Temperature

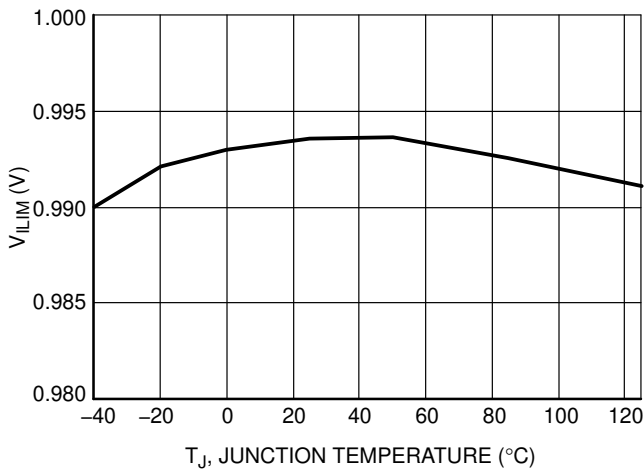


Figure 11. V_{ILIM} vs. Junction Temperature

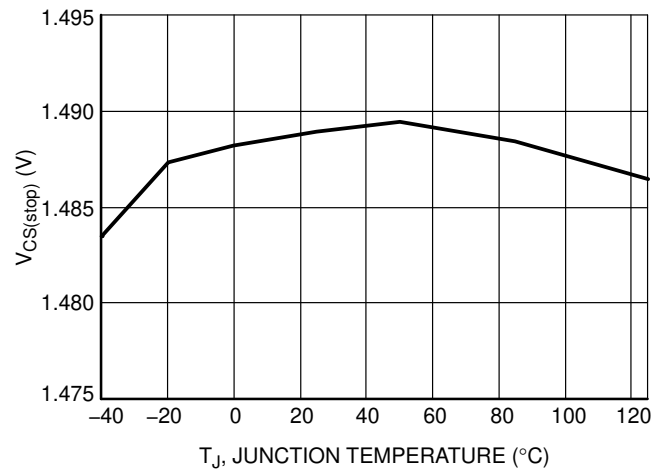


Figure 12. $V_{CS(stop)}$ vs. Junction Temperature

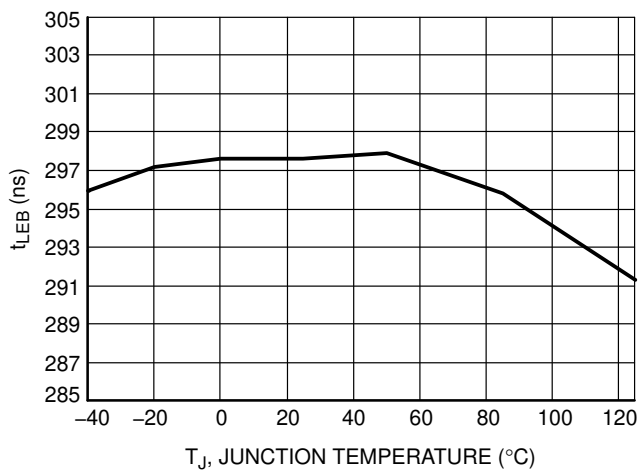


Figure 13. t_{LEB} vs. Junction Temperature

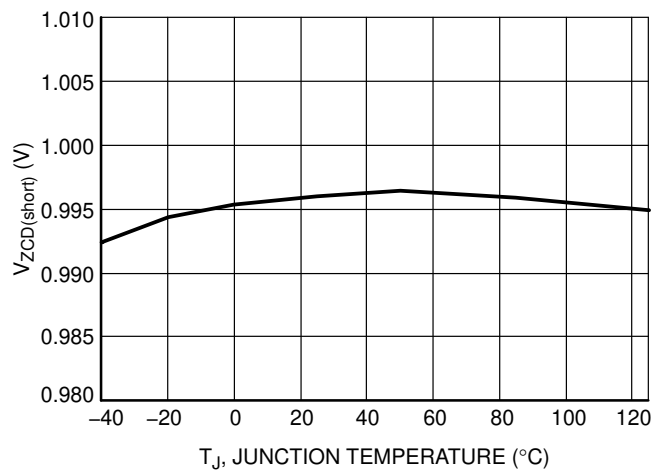


Figure 14. $V_{ZCD(short)}$ vs. Junction Temperature

TYPICAL CHARACTERISTICS

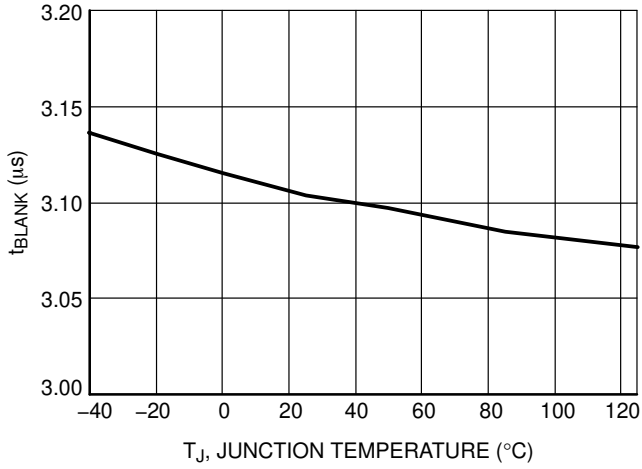


Figure 15. t_{BLANK} vs. Junction Temperature

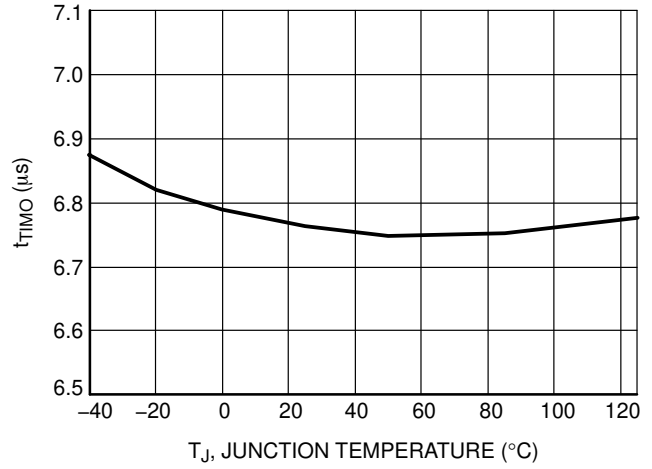


Figure 16. t_{TIMO} vs. Junction Temperature

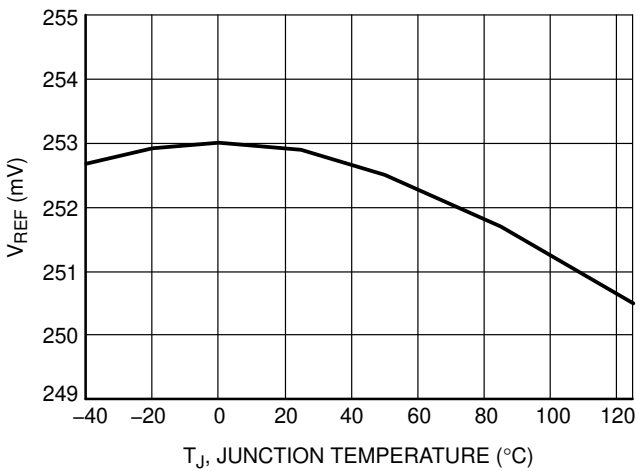


Figure 17. V_{REF} vs. Junction Temperature

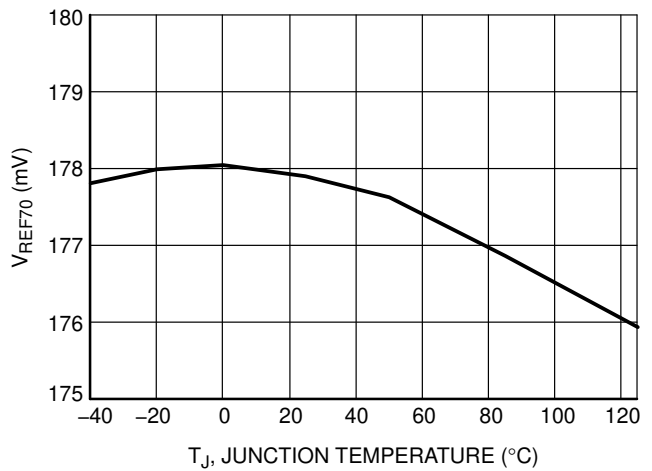


Figure 18. V_{REF70} vs. Junction Temperature

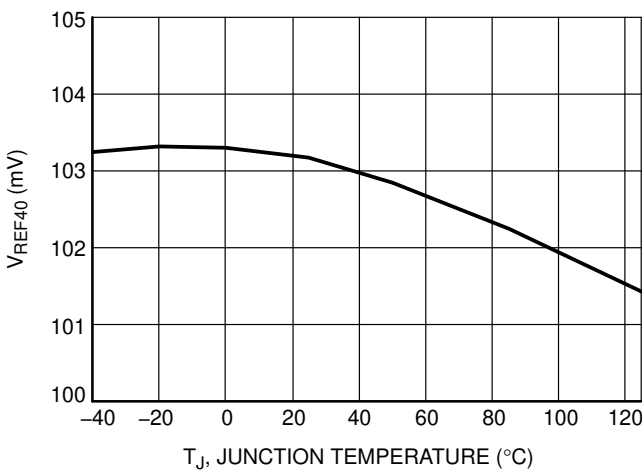


Figure 19. V_{REF40} vs. Junction Temperature

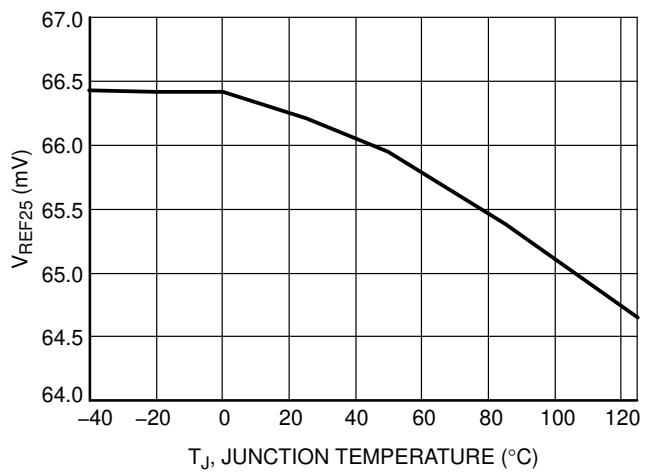


Figure 20. V_{REF25} vs. Junction Temperature

TYPICAL CHARACTERISTICS

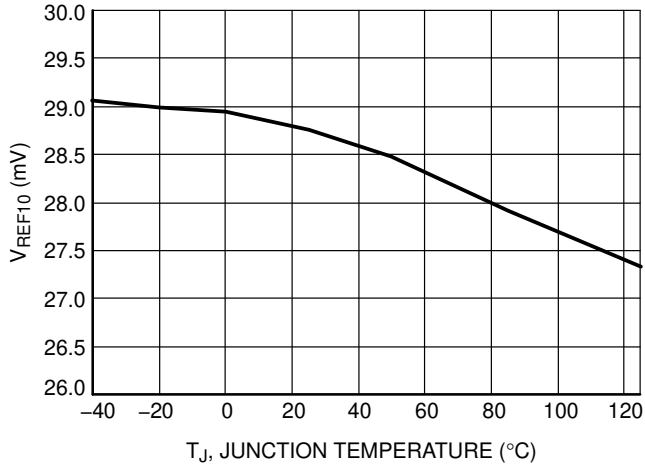


Figure 21. V_{REF10} vs. Junction Temperature

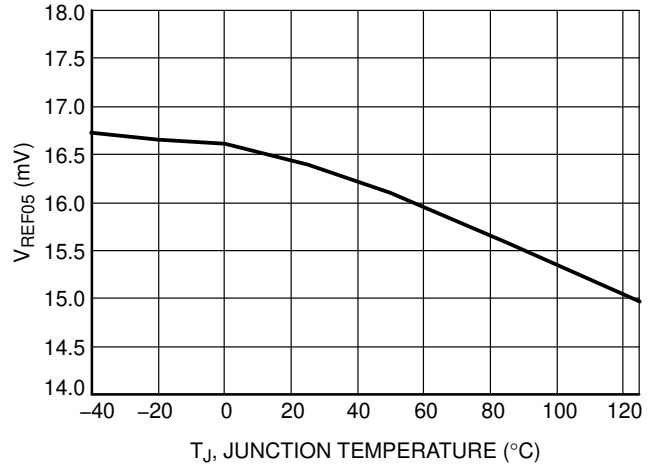


Figure 22. V_{REF05} vs. Junction Temperature

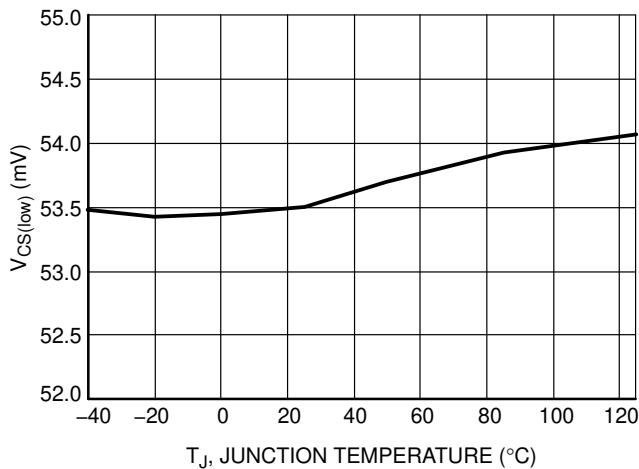


Figure 23. V_{CS(low)} vs. Junction Temperature

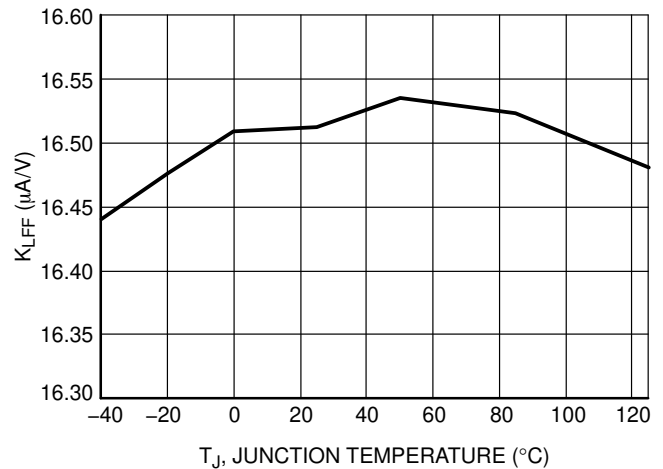


Figure 24. K_{LFF} vs. Junction Temperature

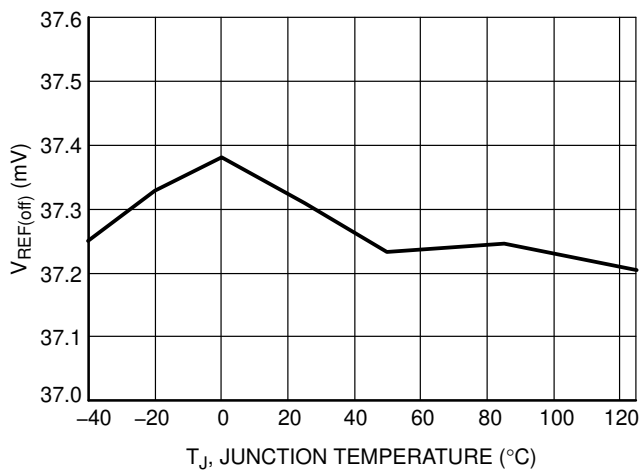


Figure 25. V_{REF(off)} vs. Junction Temperature

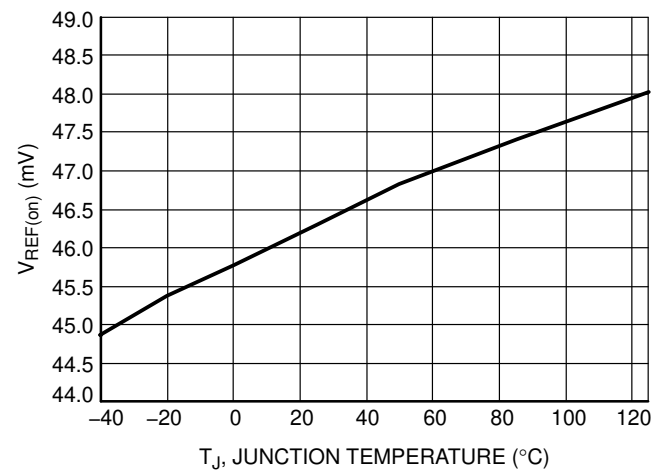


Figure 26. V_{REF(on)} vs. Junction Temperature

TYPICAL CHARACTERISTICS

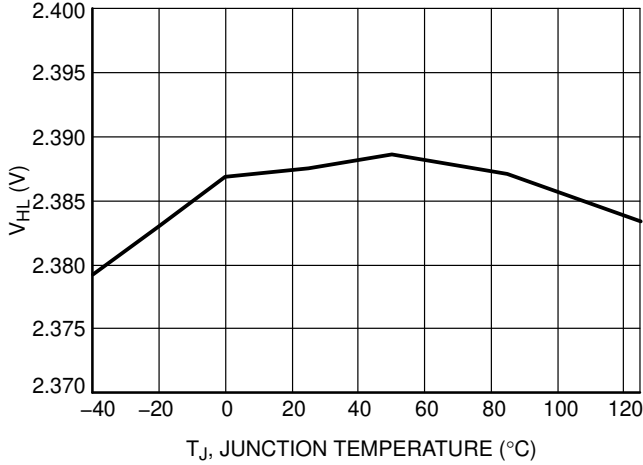


Figure 27. V_{HL} vs. Junction Temperature

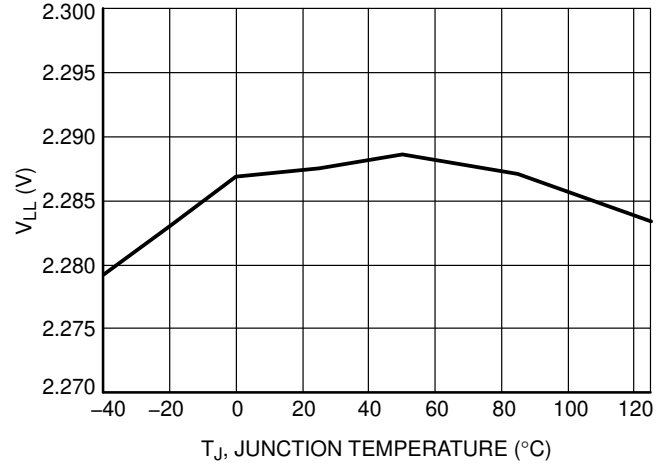


Figure 28. V_{LL} vs. Junction Temperature

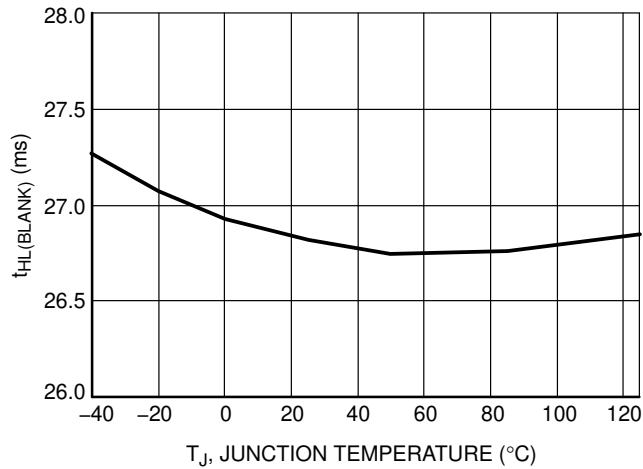


Figure 29. $t_{HL(BLANK)}$ vs. Junction Temperature

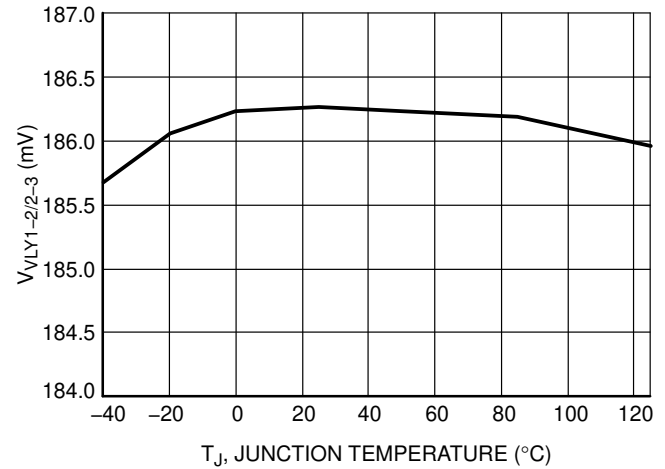


Figure 30. $V_{VLY1-2/2-3}$ vs. Junction Temperature

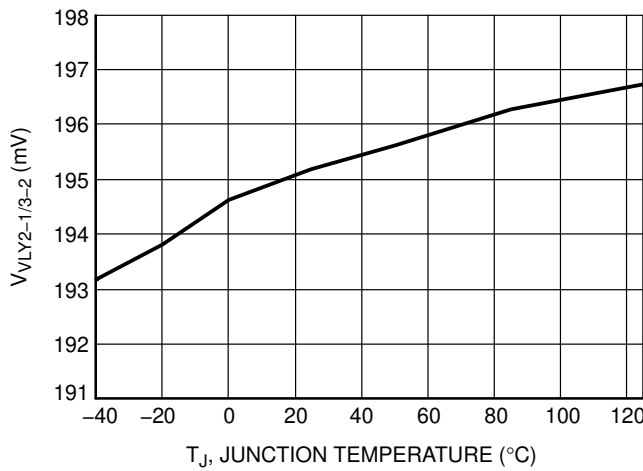


Figure 31. $V_{VLY2-1/3-2}$ vs. Junction Temperature

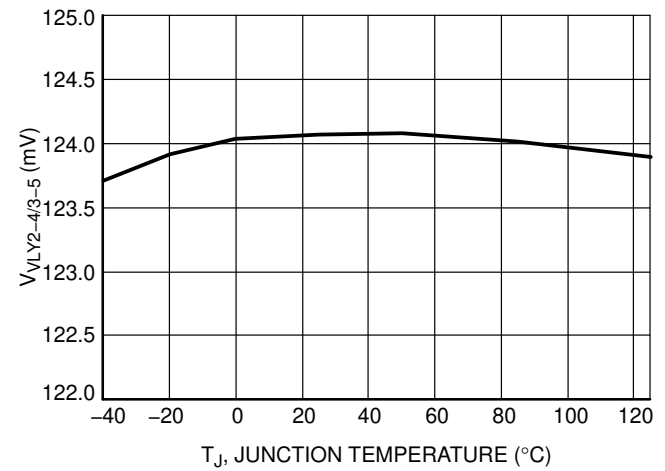


Figure 32. $V_{VLY2-4/3-5}$ vs. Junction Temperature

TYPICAL CHARACTERISTICS

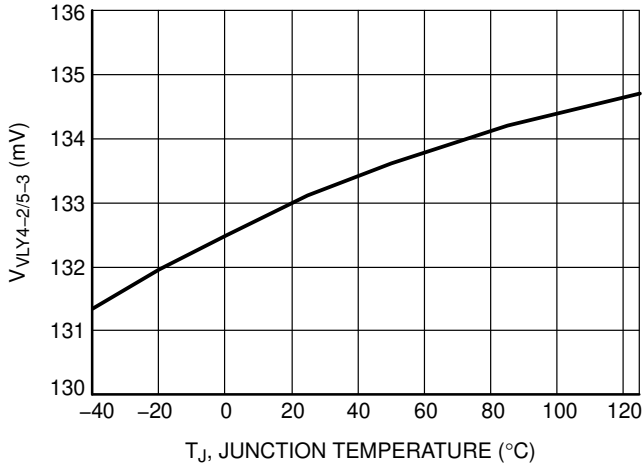


Figure 33. $V_{VLY4-2/5-3}$ vs. Junction Temperature

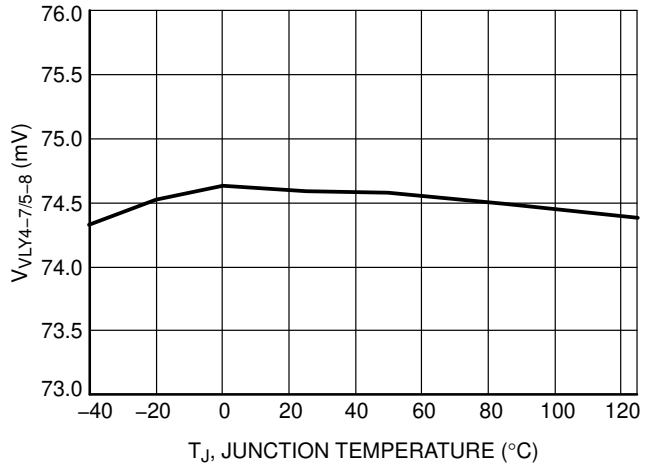


Figure 34. $V_{VLY4-7/5-8}$ vs. Junction Temperature

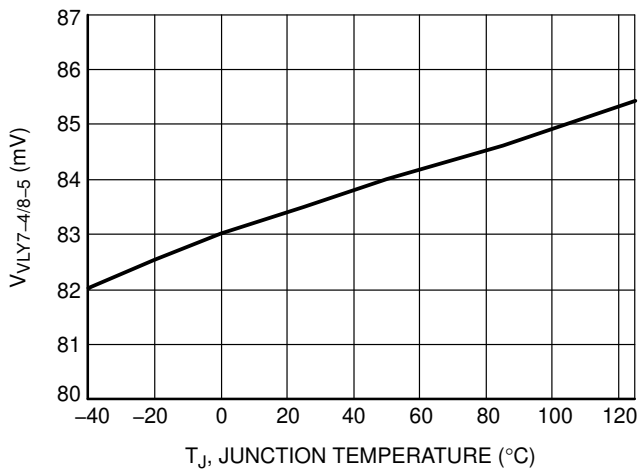


Figure 35. $V_{VLY7-4/8-5}$ vs. Junction Temperature

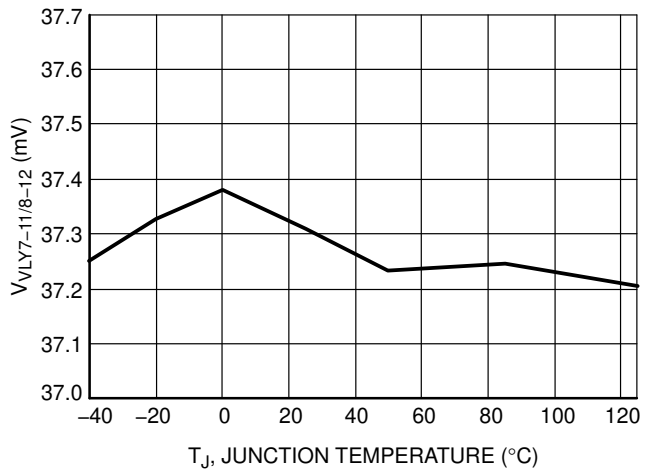


Figure 36. $V_{VLY7-11/8-12}$ vs. Junction Temperature

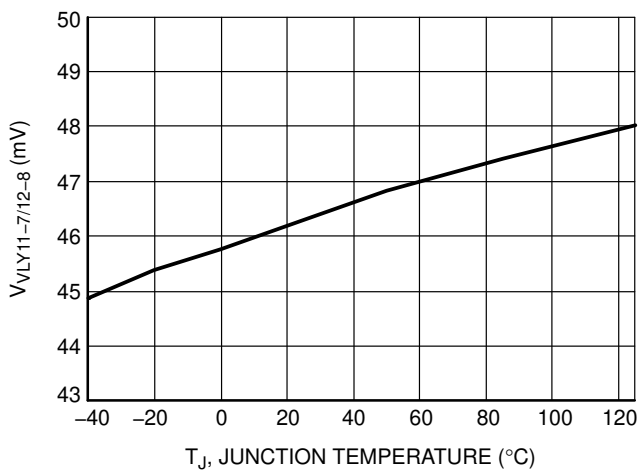


Figure 37. $V_{VLY11-7/12-8}$ vs. Junction Temperature

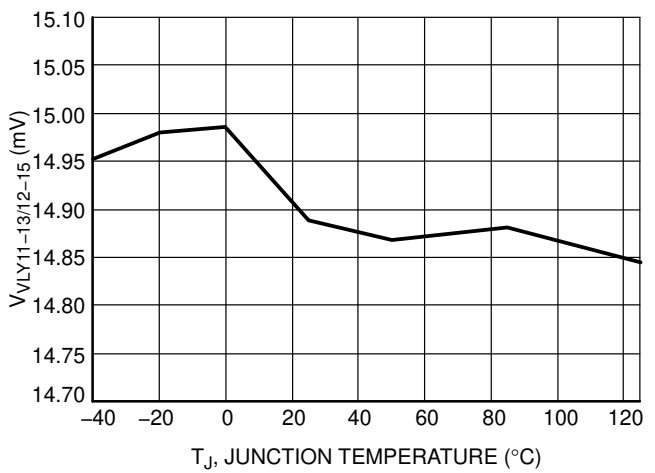


Figure 38. $V_{VLY11-13/12-15}$ vs. Junction Temperature

TYPICAL CHARACTERISTICS

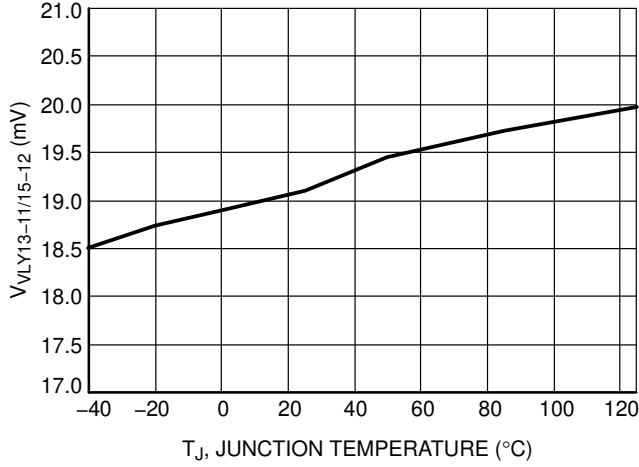


Figure 39. $V_{VLY13-11/15-12}$ vs. Junction Temperature

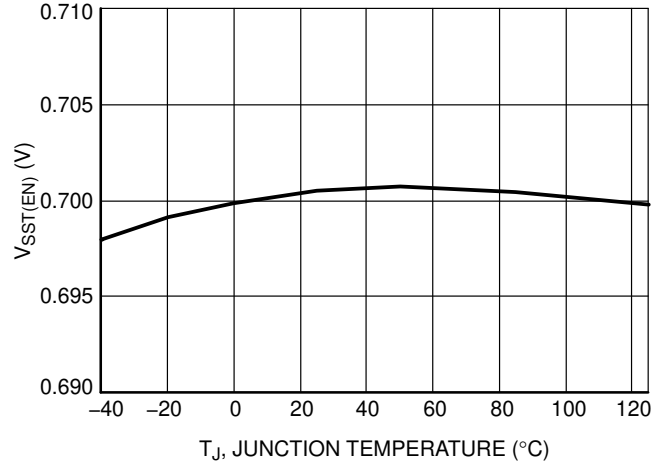


Figure 40. $V_{SST(EN)}$ vs. Junction Temperature

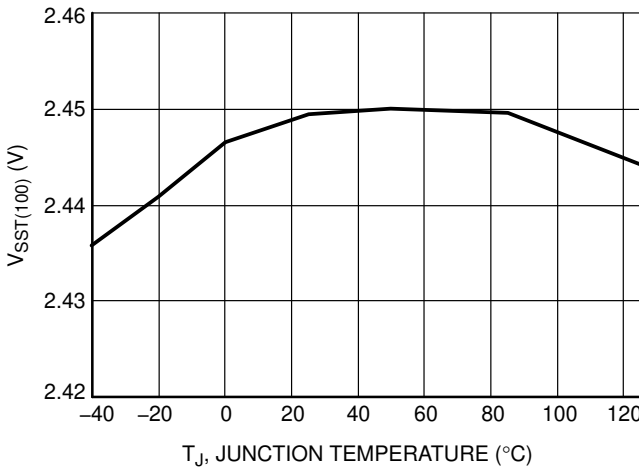


Figure 41. $V_{SST(100)}$ vs. Junction Temperature

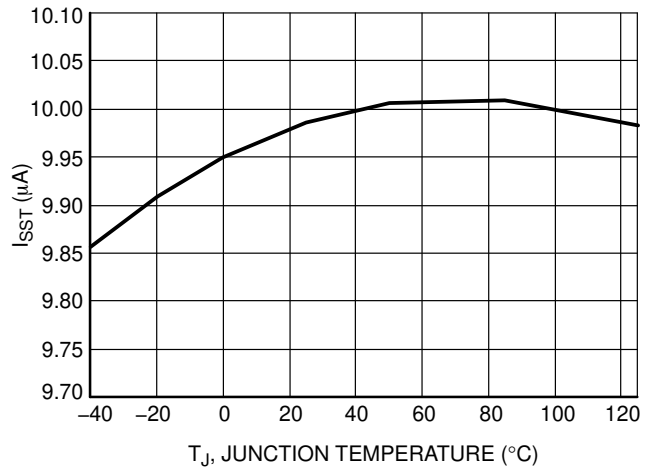


Figure 42. I_{SST} vs. Junction Temperature

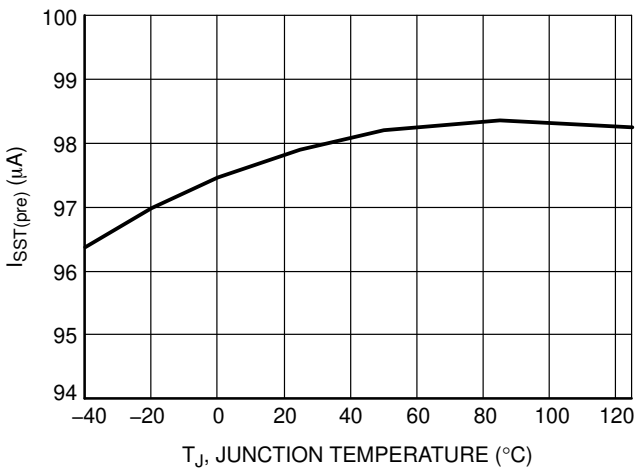


Figure 43. $I_{SST(pre)}$ vs. Junction Temperature

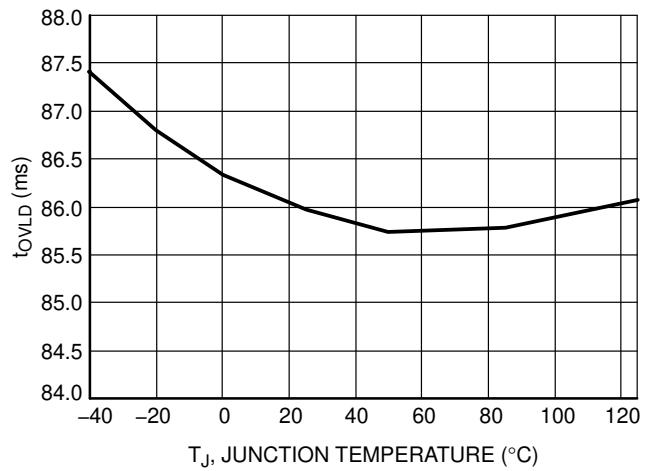


Figure 44. t_{OVLD} vs. Junction Temperature

TYPICAL CHARACTERISTICS

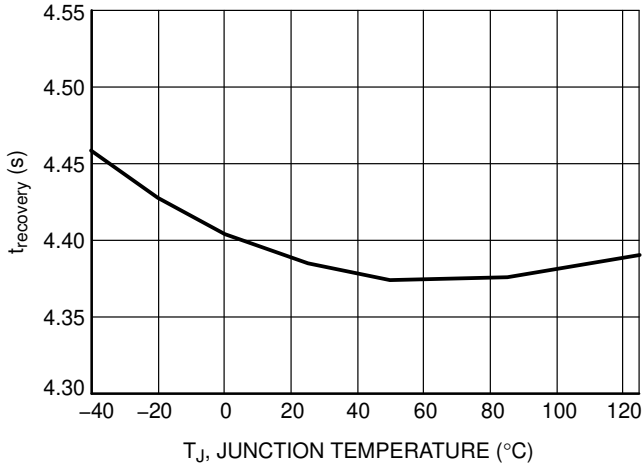


Figure 45. t_{recovery} vs. Junction Temperature

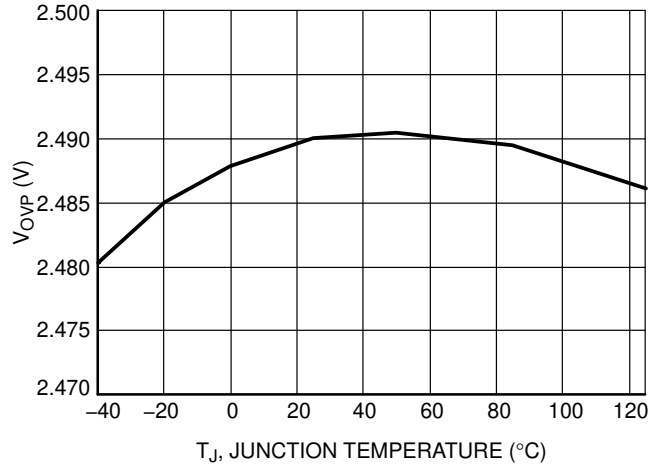


Figure 46. V_{OVP} vs. Junction Temperature

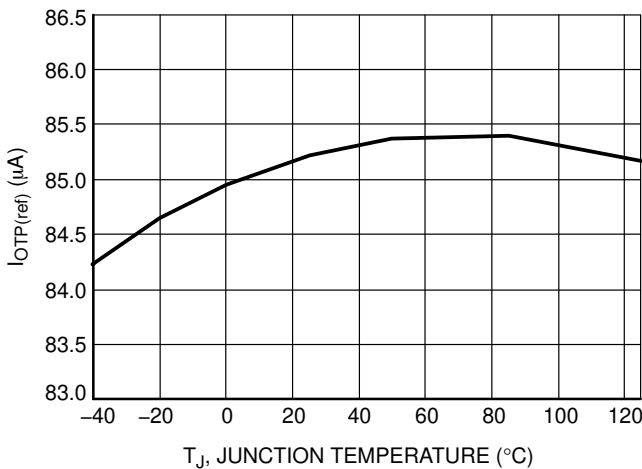


Figure 47. $I_{\text{OTP(ref)}}$ vs. Junction Temperature

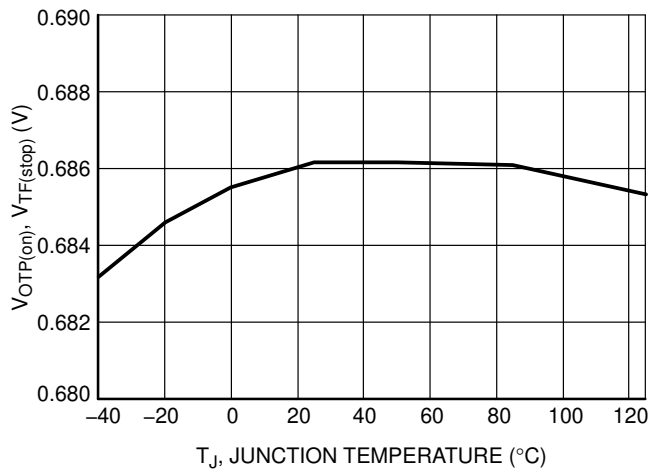


Figure 48. $V_{\text{OTP(on)}}$, $V_{\text{TF(stop)}}$ vs. Junction Temperature

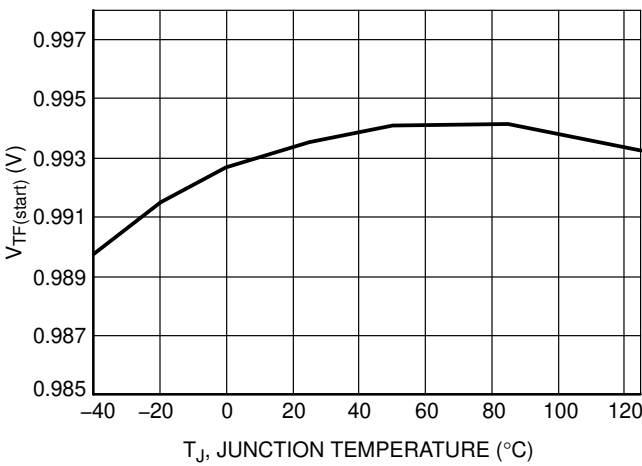


Figure 49. $V_{\text{TF(start)}}$ vs. Junction Temperature

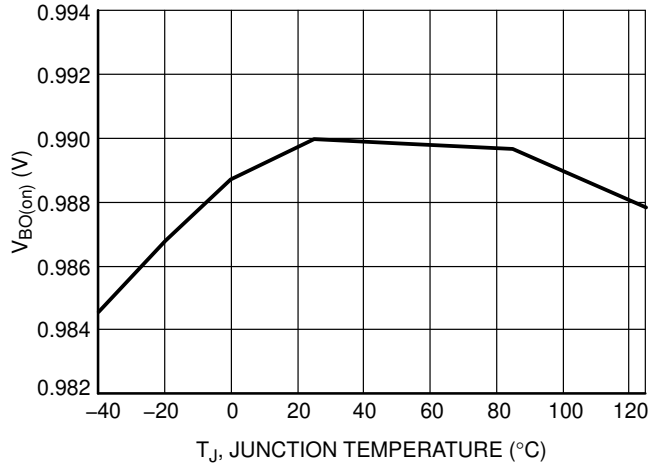
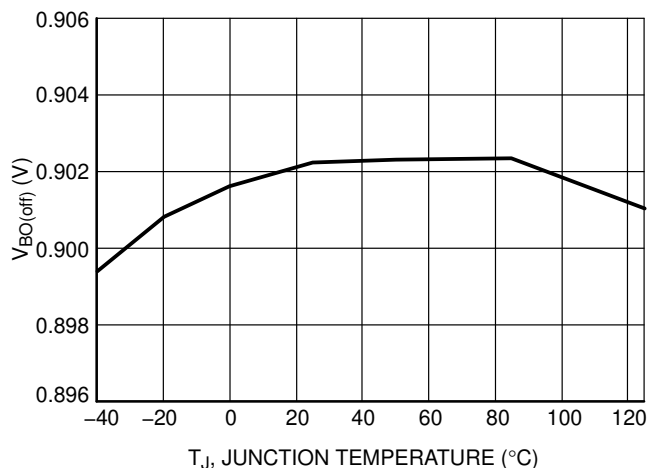
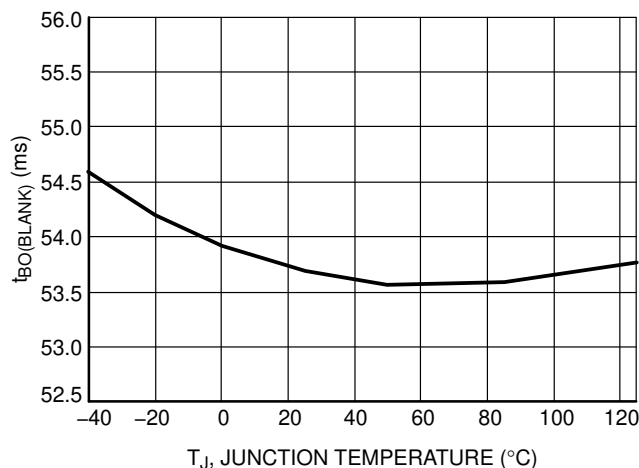


Figure 50. $V_{\text{BO(on)}}$ vs. Junction Temperature

TYPICAL CHARACTERISTICS

Figure 51. $V_{BO(off)}$ vs. Junction TemperatureFigure 52. $t_{BO(BLANK)}$ vs. Junction Temperature

APPLICATION INFORMATION

The NCL30083 implements a current-mode architecture operating in quasi-resonant mode. Thanks to proprietary circuitry, the controller is able to accurately regulate the secondary side current of the flyback converter without using any opto-coupler or measuring directly the secondary side current.

- Quasi-Resonance Current-Mode Operation:** implementing quasi-resonance operation in peak current-mode control, the NCL30083 optimizes the efficiency by switching in the valley of the MOSFET drain-source voltage. Thanks to a smart control algorithm, the controller locks-out in a selected valley and remains locked until the input voltage or the output current set point significantly changes.
- Primary Side Constant Current Control:** thanks to a proprietary circuit, the controller is able to take into account the effect of the leakage inductance of the transformer and allow accurate control of the secondary side current.
- Line Feed-forward:** compensation for possible variation of the output current caused by system slew rate variation.
- Open LED protection:** if the voltage on the VCC pin exceeds an internal limit, the controller shuts down and waits 4 seconds before restarting pulsing.
- Thermal Fold-back / Over Temperature / Over Voltage Protection:** by combining a dual threshold on the SD pin, the controller allows the direct connection of an NTC to ground plus a Zener diode to a monitored voltage. The temperature is monitored and the output current is linearly reduced in the event that the temperature exceeds a prescribed level. If the

temperature continues to increase, the current will be further reduced until the controller is stopped. The control will automatically restart if the temperature is reduced. This pin can implement a programmable OVP shutdown that can also auto-restart the device.

- Brown-Out:** the controller includes a brown-out circuit which safely stops the controller in case the input voltage is too low. The device will automatically restart if the line recovers.
- Cycle-by-cycle peak current limit:** when the current sense voltage exceeds the internal threshold V_{ILIM} , the MOSFET is turned off for the rest of the switching cycle.
- Winding Short-Circuit Protection:** an additional comparator with a short LEB filter (t_{BCS}) senses the CS signal and stops the controller if V_{CS} reaches $1.5 \times V_{ILIM}$. For noise immunity reasons, this comparator is enabled only during the main LEB duration t_{LEB} .
- Output Short-circuit protection:** If a very low voltage is applied on ZCD pin for 90 ms (nominal), the controllers assume that the output or the ZCD pin is shorted to ground and enters shutdown. The auto-restart version (B suffix) waits 4 seconds, then the controller restarts switching. In the latched version (A suffix), the controller is latched as long as V_{CC} stays above the $V_{CC(reset)}$ threshold.
- Soft-start:** The soft-start pin can be used to slowly increase the output current at startup and provide a smooth turn-on of the LED light.
- Step dimming:** Each time the IC detects a brown-out condition, the output current is decreased by discrete steps.

Constant Current Control

Figure 54 portrays the primary and secondary current of a flyback converter in discontinuous conduction mode (DCM). Figure 53 shows the basic circuit of a flyback converter.

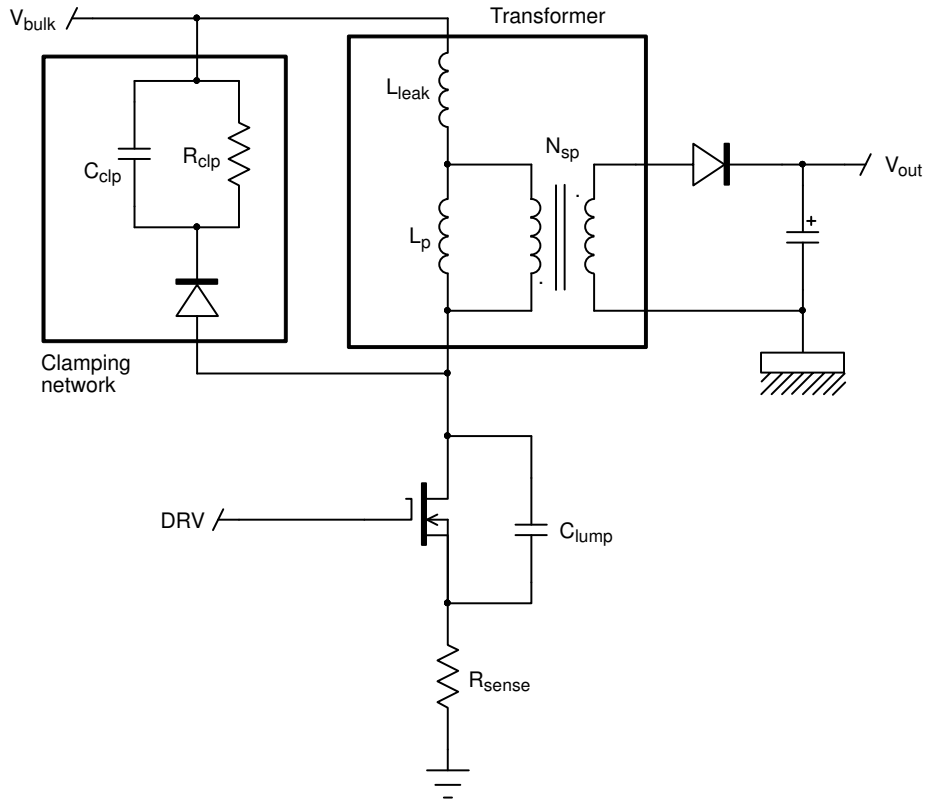


Figure 53. Basic Flyback Converter Schematic

During the on-time of the MOSFET, the bulk voltage V_{bulk} is applied to the magnetizing and leakage inductors L_p and L_{leak} and the current ramps up.

When the MOSFET is turned-off, the inductor current first charges C_{lump} . The output diode is off until the voltage across L_p reverses and reaches:

$$N_{sp}(V_{out} + V_f) \tag{eq. 1}$$

The output diode current increase is limited by the leakage inductor. As a consequence, the secondary peak current is reduced:

$$I_{D,pk} < \frac{I_{L,pk}}{N_{sp}} \tag{eq. 2}$$

The diode current reaches its peak when the leakage inductor is reset. Thus, in order to accurately regulate the output current, we need to take into account the leakage inductor current. This is accomplished by sensing the clamping network current. Practically, a node of the clamp capacitor is connected to R_{sense} instead of the bulk voltage V_{bulk} . Then, by reading the voltage on the CS pin, we have an image of the primary current (red curve in Figure 54).

When the diode conducts, the secondary current decreases linearly from $I_{D,pk}$ to zero. When the diode current has turned off, the drain voltage begins to oscillate because of the resonating network formed by the inductors ($L_p + L_{leak}$) and the lump capacitor. This voltage is reflected on the auxiliary winding wired in flyback mode. Thus, by looking at the auxiliary winding voltage, we can detect the end of the conduction time of secondary diode. The constant current control block picks up the leakage inductor current, the end of conduction of the output rectifier and controls the drain current to maintain the output current constant.

We have:

$$I_{out} = \frac{V_{REF}}{2N_{sp}R_{sense}} \tag{eq. 3}$$

The output current value is set by choosing the sense resistor:

$$R_{sense} = \frac{V_{ref}}{2N_{sp}I_{out}} \tag{eq. 4}$$

From Equation 3, the first key point is that the output current is independent of the inductor value. Moreover, the leakage inductance does not influence the output current value as the reset time is taken into account by the controller.

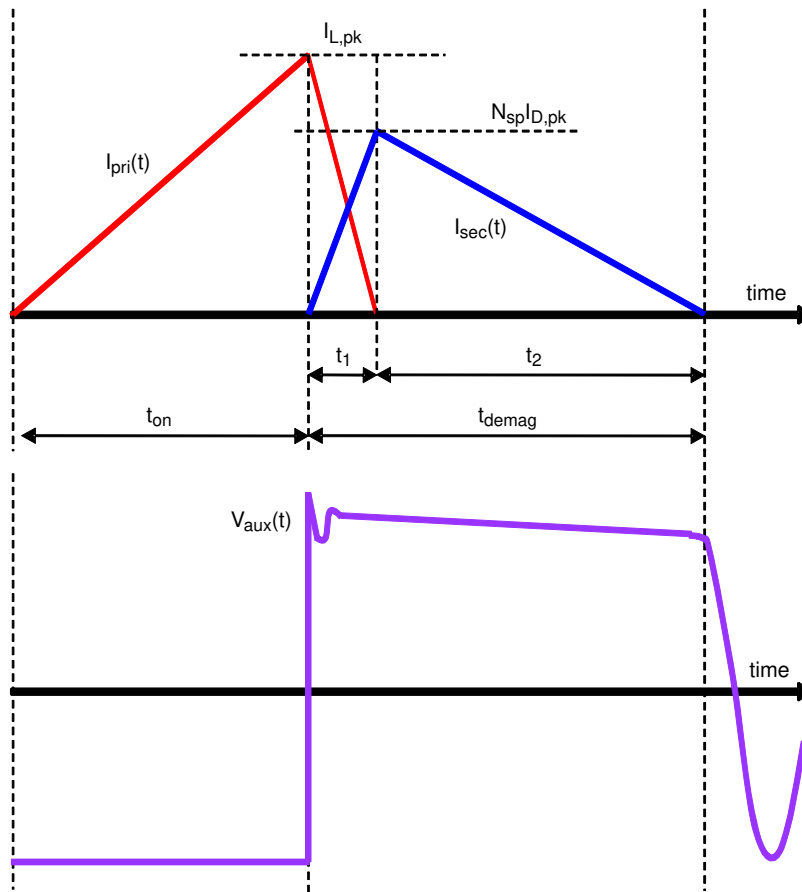


Figure 54. Flyback Currents and Auxiliary Winding Voltage in DCM

Internal Soft-Start

At startup or after recovering from a fault, there is a small internal soft-start of 40 μ s.

In addition, during startup, as the output voltage is zero volts, the demagnetization time is long and the constant

current control block will slowly increase the peak current towards its nominal value as the output voltage grows. Figure 55 shows a soft-start simulation example for a 9 W LED power supply.

NCL30083

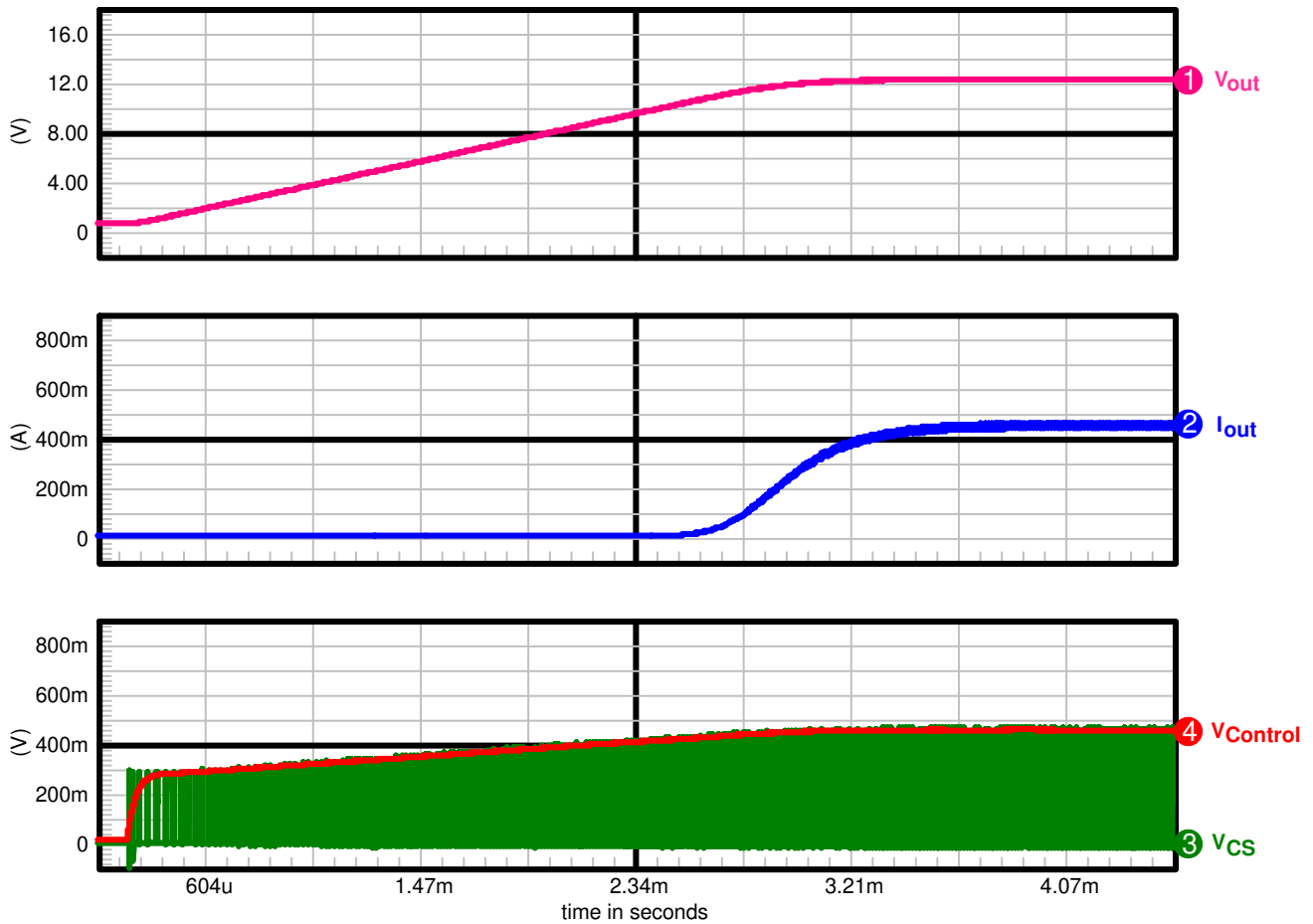


Figure 55. Startup Simulation Showing the Natural Soft-start

Cycle-by-Cycle Current Limit

When the current sense voltage exceeds the internal threshold V_{ILIM} , the MOSFET is turned off for the rest of the switching cycle (Figure 56).

Winding and Output Diode Short-Circuit Protection

In parallel with the cycle-by-cycle sensing of the CS pin, another comparator with a reduced LEB (t_{BCS}) and a higher threshold (1.5 V typical) is able to sense winding short-circuit and immediately stops the DRV pulses. The controller goes into auto-recovery mode in version B.

In version A, the controller is latched. In latch mode, the DRV pulses stop and VCC ramps up and down. The circuit un-latches when VCC pin voltage drops below $V_{CC(reset)}$ threshold.

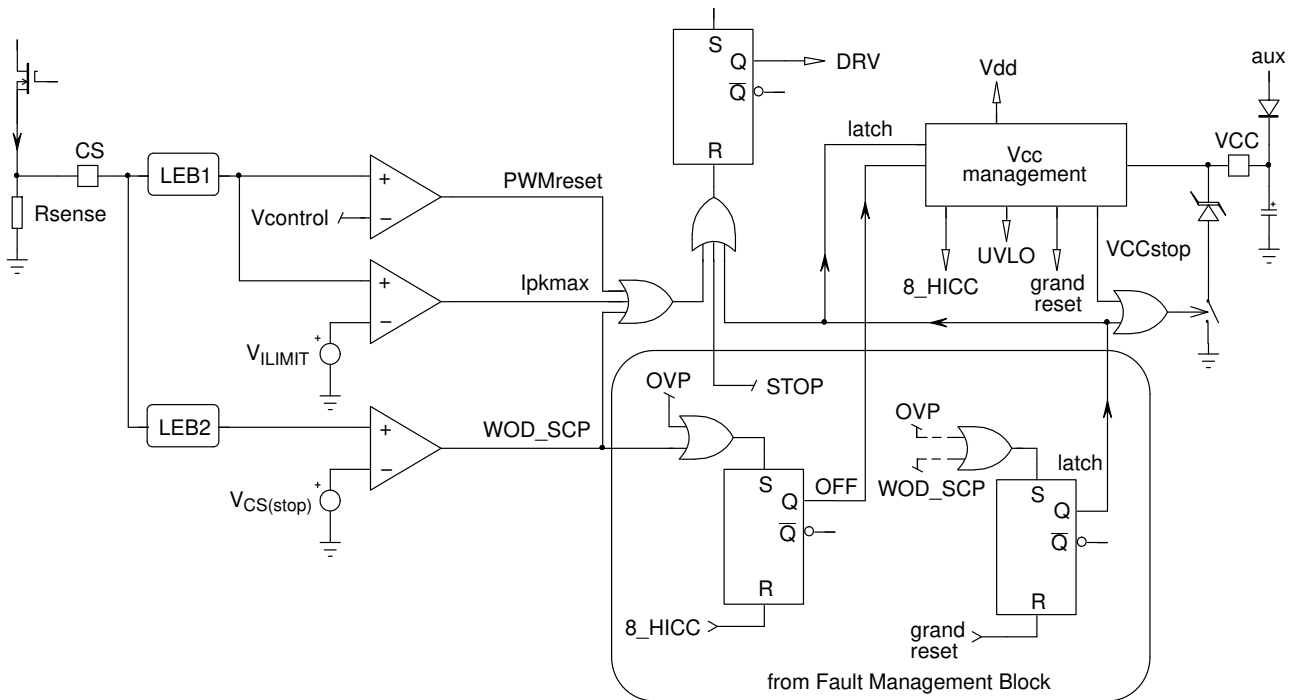


Figure 56. Winding Short Circuit Protection, Max. Peak Current Limit Circuits

Thermal Fold-back and Over Voltage / Over Temperature Protection

The thermal fold-back circuit reduces the current in the LED string when the ambient temperature exceeds a set point. The current is gradually reduced to 50% of its nominal value if the temperature continues to rise. (Figure 58). The thermal foldback starting temperature depends on the Negative Coefficient Temperature (NTC) resistor chosen by the power supply designer.

Indeed, the SD pin allows the direct connection of an NTC to sense the ambient temperature. When the SD pin voltage V_{SD} drops below $V_{TF(start)}$, the internal reference for the constant current control V_{REF} is decreased proportionally to V_{SD} . When V_{SD} reaches $V_{TF(stop)}$, V_{REF} is clamped to V_{REF50} , corresponding to 50% of the nominal output current.

If V_{SD} drops below V_{OTP} , the controller enters into the auto-recovery fault mode for version B, meaning that the 4-s timer is activated. The controller will re-start switching after the 4-s timer has elapsed and when $V_{SD} > V_{OTP(on)}$ to provide some temperature hysteresis (around 10°C).

For version A, this protection is latched: reset occurs when $V_{CC} < V_{CC(reset)}$.

The thermal fold-back and OTP thresholds correspond roughly to the following resistances:

- Thermal fold-back starts when $R_{NTC} \leq 11.76 \text{ k}\Omega$.
- Thermal fold-back stops when $R_{NTC} \leq 8.24 \text{ k}\Omega$.
- OTP triggers when $R_{NTC} \leq 5.88 \text{ k}\Omega$.
- OTP is removed when $R_{NTC} \geq 8.24 \text{ k}\Omega$.

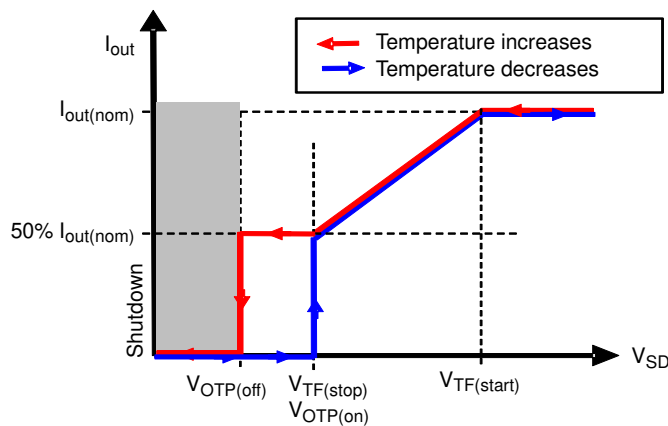


Figure 57. Output Current Reduction versus SD Pin Voltage

At startup, when V_{CC} reaches $V_{CC(on)}$, the controller is not allowed to start pulsing for at least 180 μs in order to allow the SD pin voltage to reach its nominal value if a

filtering capacitor is connected to the SD pin. This is to avoid flickering of the LED light in case of over temperature.

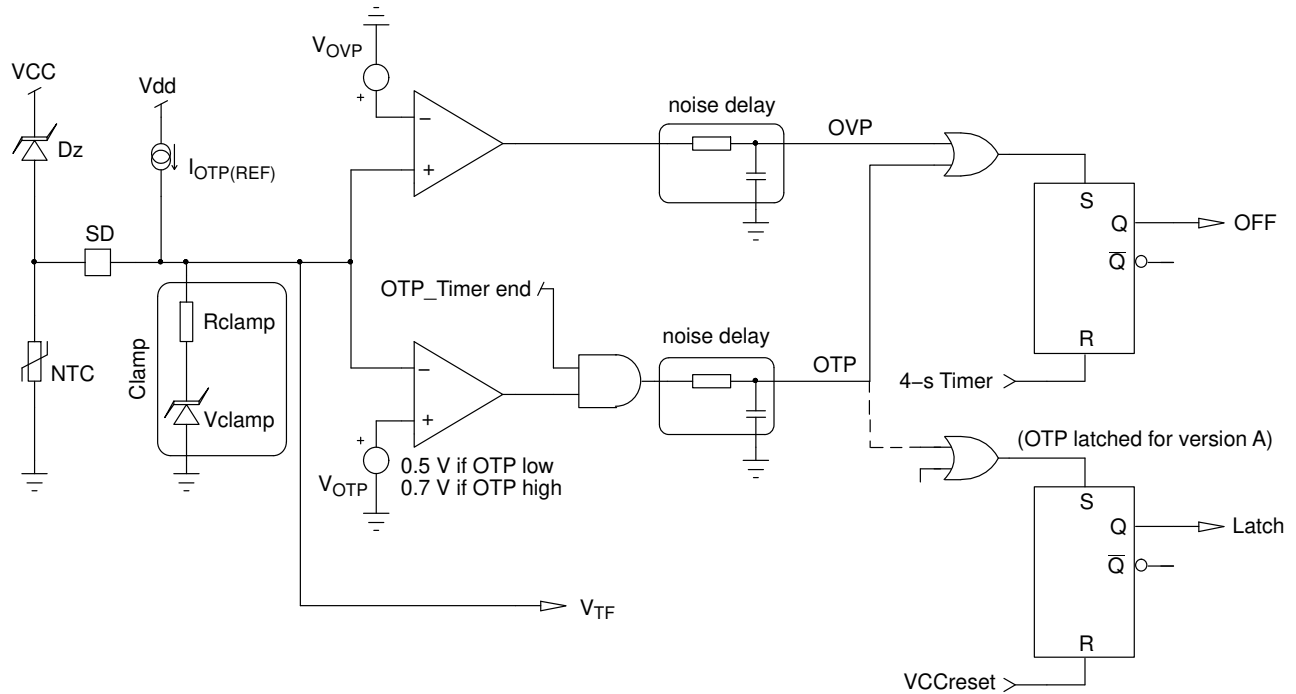


Figure 58. Thermal Fold-back and OVP/OTP Circuitry

In case of over voltage, the Zener diode starts to conduct and inject current inside the internal clamp resistor R_{clamp} thus causing the pin SD voltage to increase. When this

voltage reaches the OVP threshold (2.5 V typ.), the controller shuts-down and waits for at least 4 seconds before restarting switching.

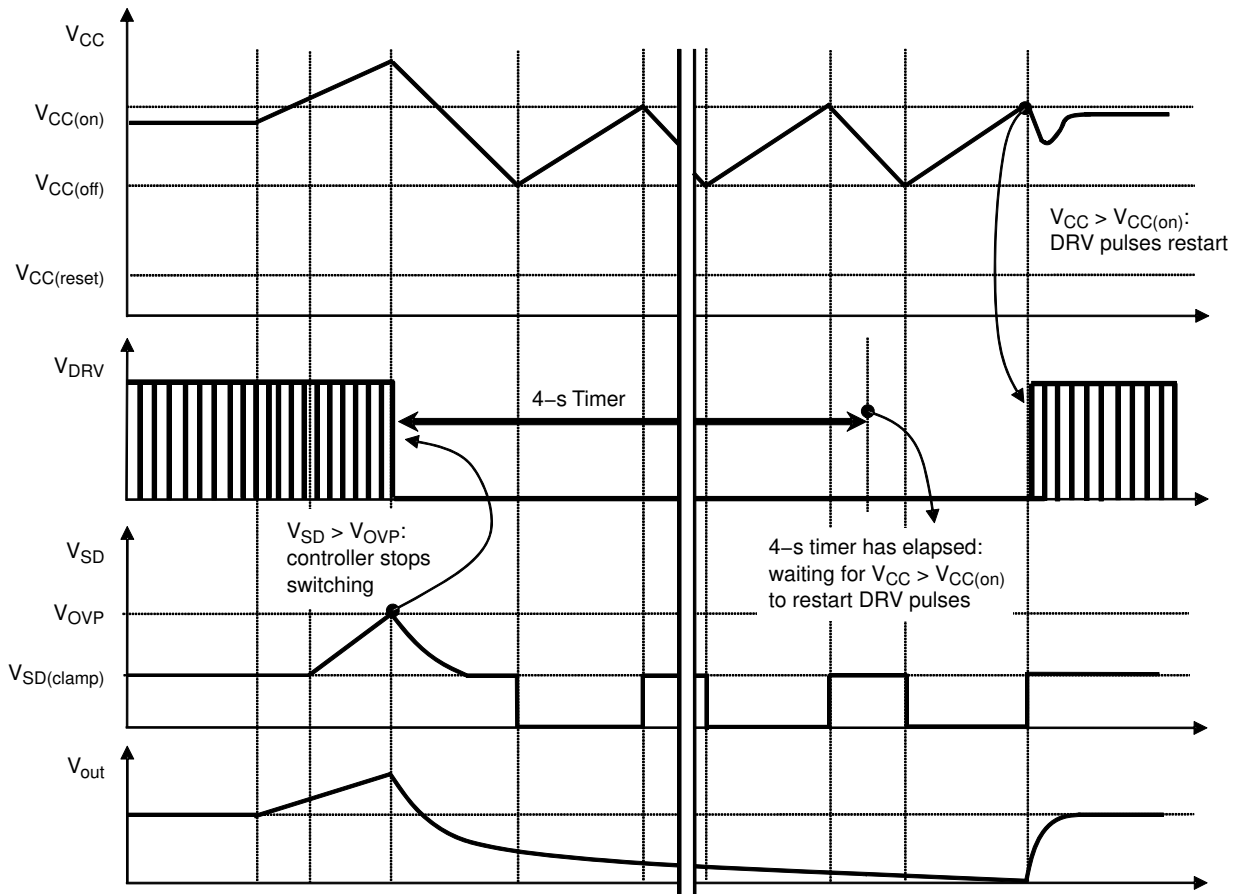


Figure 59. OVP with SD Pin Chronograms

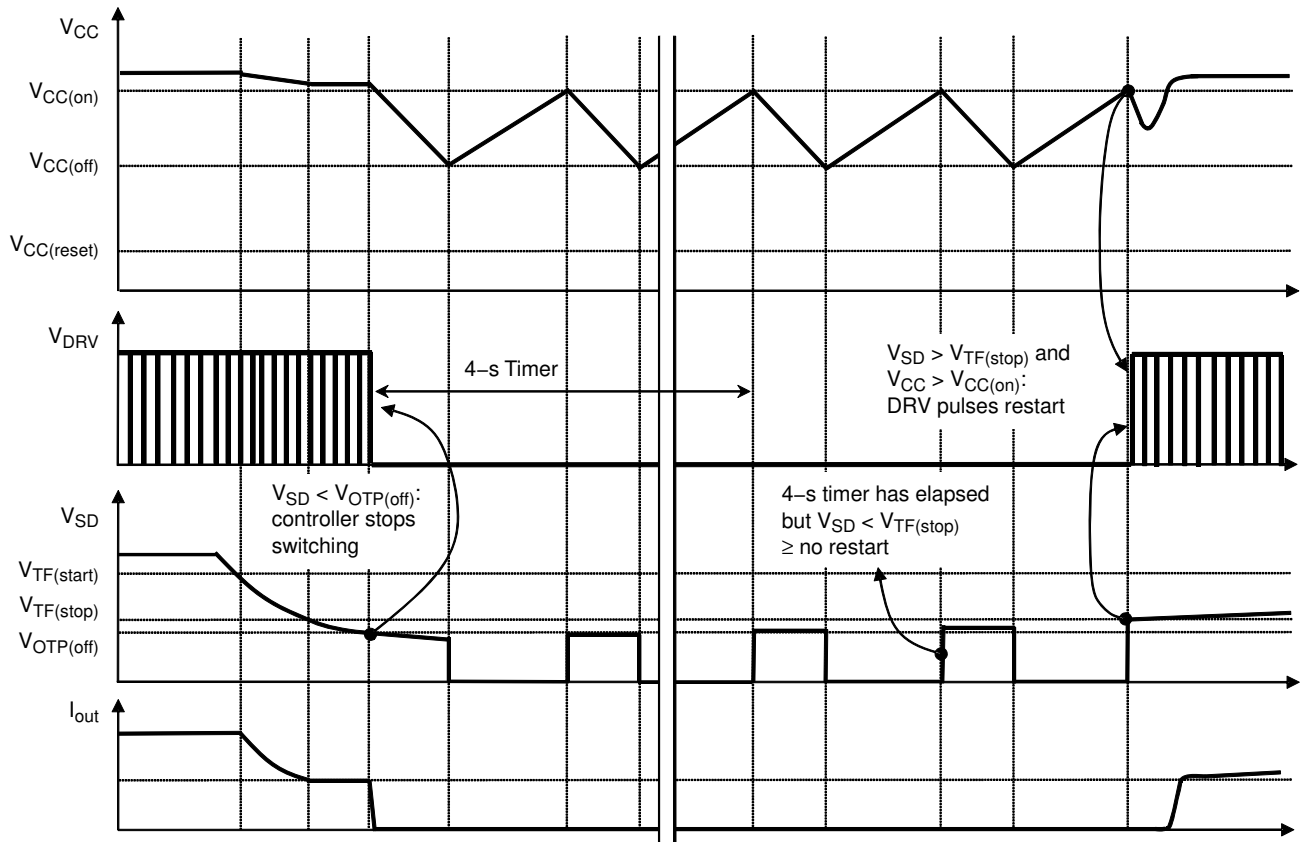


Figure 60. Thermal Fold-back / OTP Chronograms

Soft-Start

The NCL30083 provides a soft-start pin allowing increasing slowly the LEDs light at startup. An internal current source I_{SSST} charges the soft-start capacitor. The generated voltage ramp directly controls the amount of current flowing in the LEDs.

At startup, if there are no faults (except “Enable_b” high), an internal pre-charging current source $I_{SSST(pre)}$ connected

in parallel with I_{SSST} charges the soft-start capacitor until it reaches the $V_{SSST(EN)}$ threshold. After that, $I_{SSST(pre)}$ is turned off and the soft-start capacitor keep on charging with the soft-start current source I_{SSST} .

When a fault is detected, the soft-start pin is discharged down to $V_{SSST(EN)}$ to provide a clean soft-start when the fault is removed.

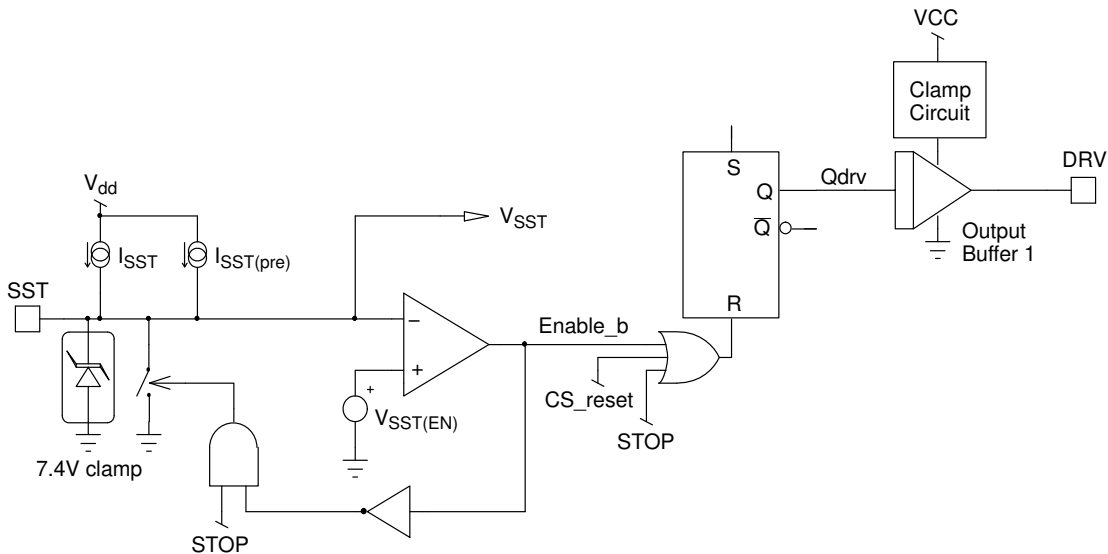


Figure 61. Soft-start Pin Bloc Diagram

Step Dimming

The step dimming function decreases the output current from 100% to 5% of its nominal value in discrete steps. There are 5 steps in total. Table 4 shows the different steps value and the corresponding output current set-point. Each time a brown-out is detected, the output current is decreased by decreasing the reference voltage V_{REF} setting the output current value.

When the 5% dimming step is reached, if a brown-out event occurs, the controller restarts at 100% of the output current.

Table 4. DIMMING STEPS

Dimming Step	I_{out}	Perceived Light
ON	100%	100%
1	70%	84%
2	40%	63%
3	25%	50%
4	10%	32%
5	5%	17%

Note:

The power supply designer must ensure that V_{CC} stays high enough when the light is turned-off to let the controller memorize the dimming step state.

The power supply designer should use a split V_{CC} circuit for step dimming with a capacitor allowing providing enough V_{CC} for 1 s (47 μ F to 100 μ F capacitor).

The step dimming state is memorized by the controller until V_{CC} crosses $V_{CC(reset)}$.

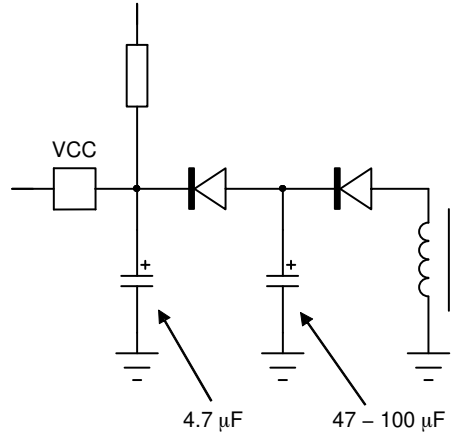


Figure 62. Split VCC Supply

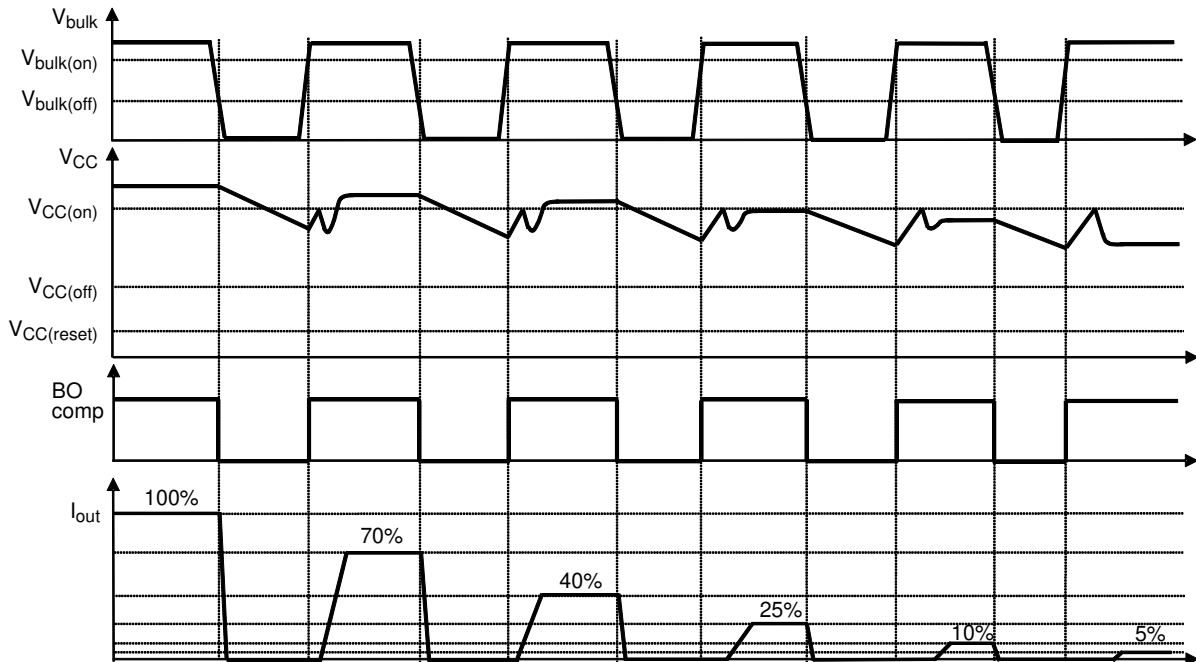


Figure 63. Step Dimming Chronograms

V_{CC} Over Voltage Protection (Open LED Protection)

If no output load is connected to the LED power supply, the controller must be able to safely limit the output voltage excursion.

In the NCL30083, when the V_{CC} voltage reaches the V_{CC(OVP)} threshold, the controller stops the DRV pulses and the 4-s timer starts counting. The IC re-start pulsing after the 4-s timer has elapsed and when V_{CC} ≥ V_{CC(on)}.

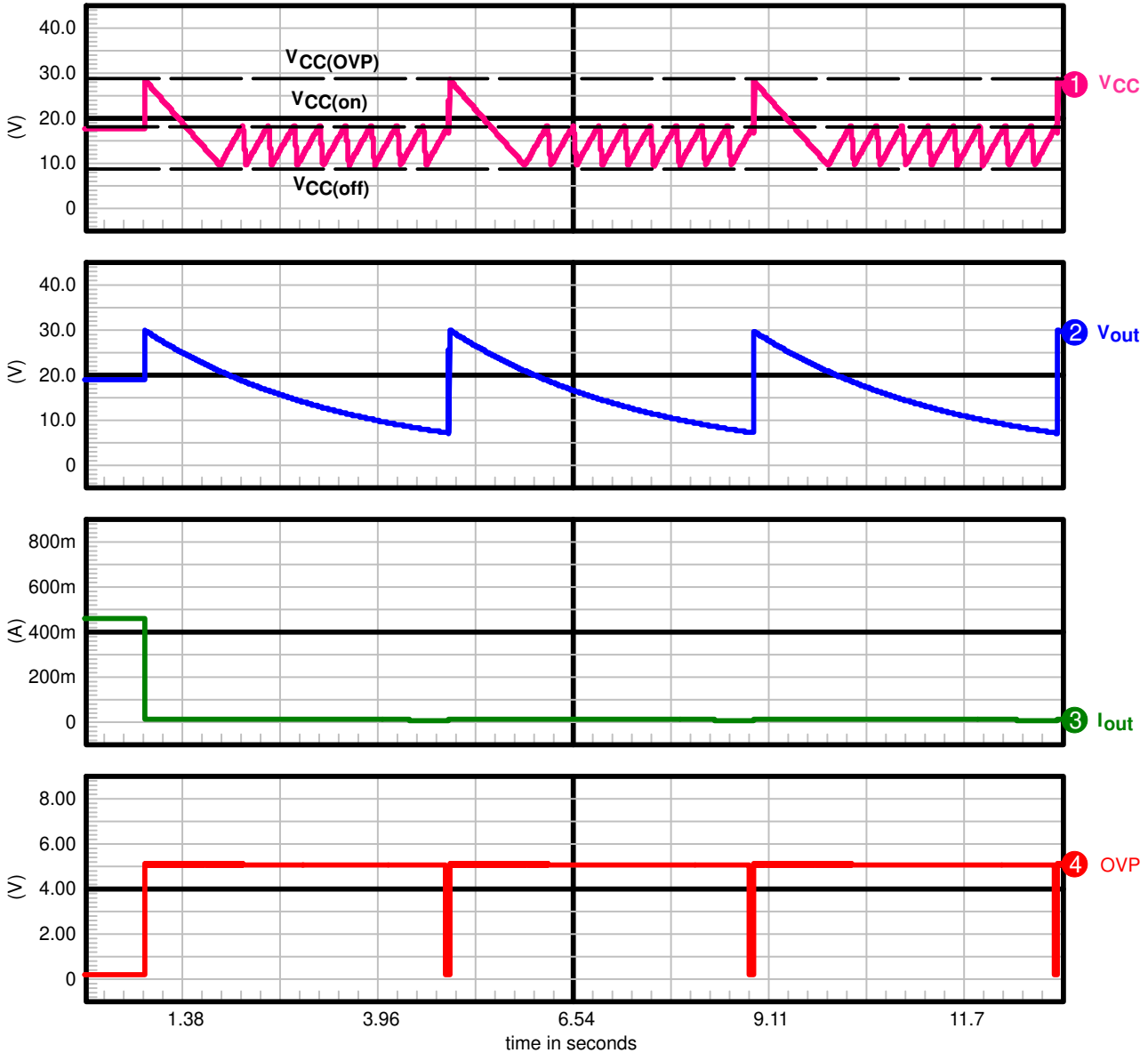


Figure 64. Open LED Protection Chronograms

Valley Lockout

Quasi-Square wave resonant systems have a wide switching frequency excursion. The switching frequency increases when the output load decreases or when the input voltage increases. The switching frequency of such systems must be limited.

The NCL30083 changes valley as the input voltage increases and as the output current set-point is varied (thermal fold-back and step dimming). This limits the switching frequency excursion. Once a valley is selected, the controller stays locked in the valley until the input

voltage or the output current set-point varies significantly. This avoids valley jumping and the inherent noise caused by this phenomenon.

The input voltage is sensed by the VIN pin. The internal logic selects the operating valley according to VIN pin voltage (line range detector in Figure 65), SD pin voltage and dimming state imposed by the Step Dimming circuit.

By default, when the output current is not dimmed, the controller operates in the first valley at low line and in the second valley at high line.