NCL30002

Buck LED Driver Controller

http://onsemi.com

SOIC−8
D SUFFIX
CASE 751

The NCL30002 is a switch mode power supply controller intended for low to medium power single stage power factor (PF) corrected LED Drivers. The device operates as a critical conduction mode (CrM) buck controller to regulate LED current at a high power factor for a specific line voltage range. The current limit threshold is tightly trimmed allowing open loop control techniques to reduce parts count while maintaining accurate current regulation and high power factor. CrM operation is particularly suited for LED applications as very high efficiency can be achieved even at low power levels. These are important in LED lighting to comply with regulatory requirements and meet overall system luminous efficacy requirements. In CrM, the switching frequency will vary with line and load. Switching losses are low as recovery losses in the output rectifier are negligible since the current goes to zero prior to reactivating the main MOSFET switch.

The device features a programmable on time limiter, zero current detect sense block, gate driver, trans−conductance error amplifier as well as all PWM control circuitry and protection functions required to implement a CrM switch mode power supply. Moreover, for high efficiency, the device features low startup current enabling fast, low loss charging of the V_{CC} capacitor. The current sense protection threshold has been set at 485 mV to minimize power dissipation in the external sense resistor. To support the environmental operation range of Solid State Lighting, the device is specified across a wide junction temperature range of −40°C to 125°C.

Features

- Very Low 24 μA Typical Startup Current
- Cycle−by−Cycle Current Protection
- Tightly Trimmed Low Current Sense Threshold of 485 mV ±2%
- Low 2 mA Typical Operating Current
- Source 500 mA / Sink 800 mA Totem Pole Gate Driver
- Wide Operating Temperature Range
- Enable Function and Overvoltage Protection
- These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant

Typical Applications

- LED Driver Power Supplies
- LED Based Bulbs
- Commercial and Residential LED Fixtures

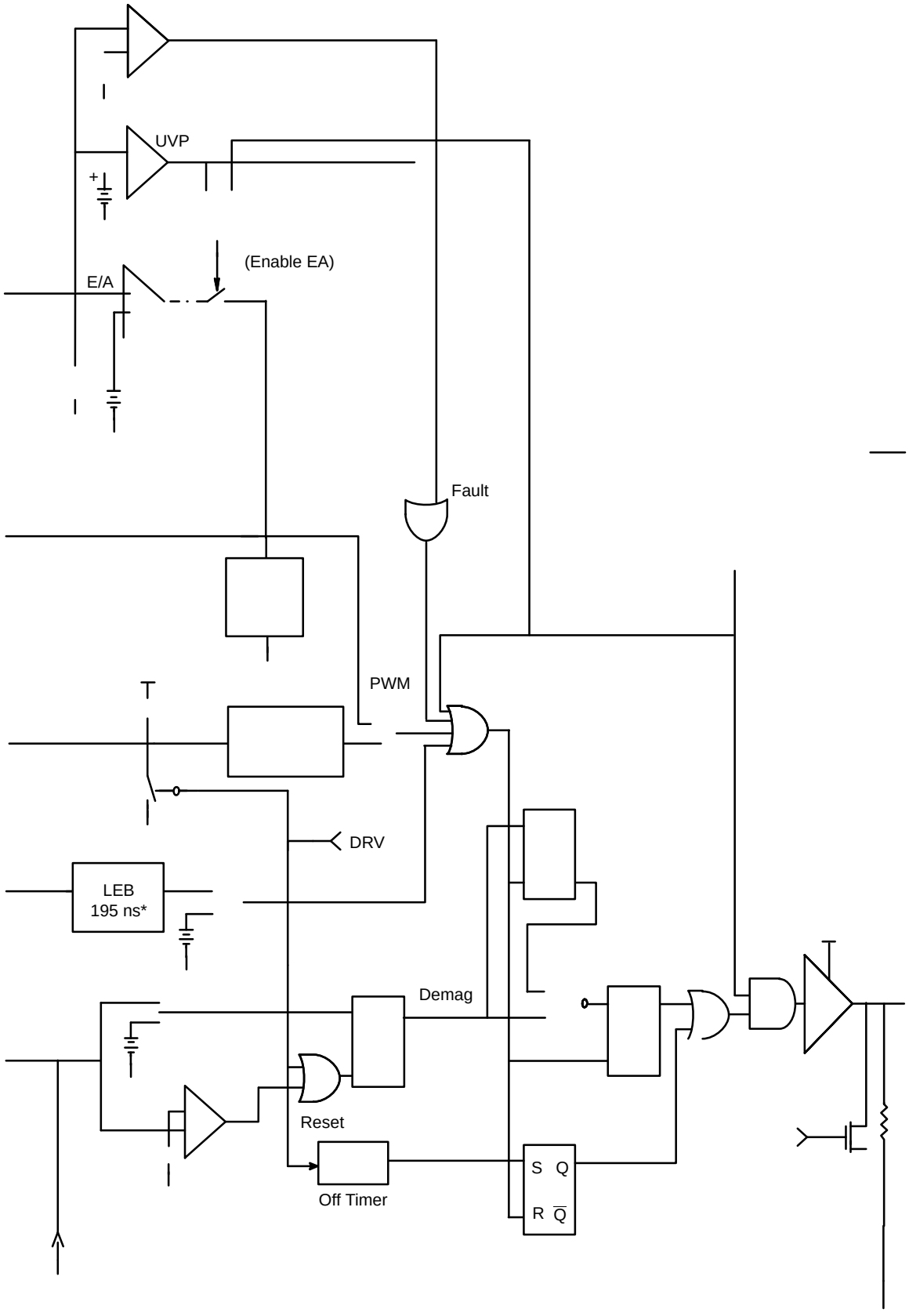


Figure 1. Block Diagram

Table 1. PIN FUNCTION DESCRIPTION

Pin	Name	Function
1	MFP	The multi−function pin is connected to the internal error amplifier. By pulling this pin below the V_{uvp} threshold, the controller is disabled. In addition, this pin also has an over voltage comparator which will disable the controller in the event of a fault.
2	COMP	The COMP pin is the output of the internal error amplifier. A compensation network connected between this pin and ground sets the loop bandwidth.
3	C_t	The C_t pin sources a regulated current to charge an external timing capacitor. The PWM circuit controls the power switch on time by comparing the C_t voltage to an internal voltage derived from $V_{Control}$. The C_T pin discharges the external timing capacitor at the end of the on time cycle.
4	CS	The CS input threshold is precisely trimmed to accurately sense the instantaneous switch current in the external MOSFET. This signal is conditioned by an internal leading edge blanking circuit. The current limit threshold is tightly trimmed for precise peak current control.
5	ZCD	The voltage of an auxiliary zero current detection winding is sensed at this pin. When the ZCD control block circuit detects that the winding current has gone to zero, a control signal is sent to the gate drive block to turn on the external MOSFET.
6	GND	This is the analog ground for the device. All bypassing components should be connected to the GND pin with a short trace length.
7	DRV	The high current capability of the totem pole gate drive (+0.5/−0.8 A) makes it suitable to effectively drive high gate charge power MOSFETs. The driver stage provides both passive and active pull down circuits that force the output to a voltage less than the turn−on threshold voltage of the power MOSFET when $V_{CC(on)}$ is not reached.
8	V_{CC}	This pin is the positive supply of the controller. The circuit starts to operate when V_{CC} exceeds $V_{CC(on)}$, nominally 12 V and turns off when V_{CC} goes below $V_{CC(off)}$, typically 9.5 V. After startup, the operating range is 10.2 V up to 20 V.

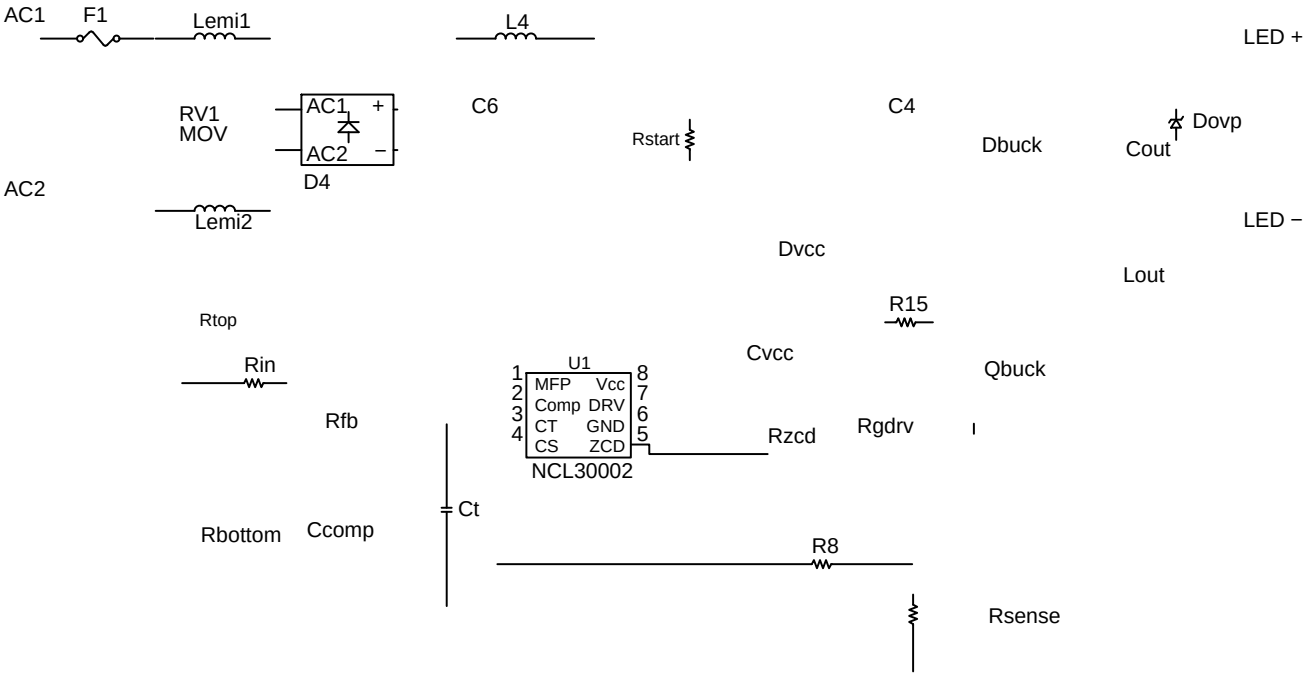


Figure 2. Simplified PFC Buck Application

Table 3. ELECTRICAL CHARACTERISTICS
V_{MFP} = 2.4 V, $V_{Control}$ = 4 V, Ct = 1 nF, V_{CS} = 0 V, V_{ZCD} = 0 V, C_{DRV} = 1 nF, V_{CC} = 12 V, unless otherwise specified
(For typical values, T_J = 25°C. For min/max values, T_J = −40°C to 125°C, unless otherwise specified)

Characteristic	Test Conditions	Symbol	Min	Typ	Max	Unit
STARTUP AND SUPPLY CIRCUITS						
Startup Voltage Threshold	V_{CC} Increasing	$V_{CC(on)}$	11	12	12.5	V
Minimum Operating Voltage	V_{CC} Decreasing	$V_{CC(off)}$	8.8	9.5	10.2	V
Supply Voltage Hysteresis		H_{UVLO}	2.2	2.5		

Table 3. ELECTRICAL CHARACTERISTICS (Continued)
V_{MFP} = 2.4 V, $V_{Control}$ = 4 V, Ct = 1 nF, V_{CS} = 0 V, V_{ZCD} = 0 V, C_{DRV} = 1 nF, V_{CC} = 12 V, unless otherwise specified
(For typical values, T_J = 25°C. For min/max values, T_J = −40°C to 125°C, unless otherwise specified)

Characteristic	Test Conditions	Symbol	Min	Typ	Max	Unit
RAMP CONTROL						
Ct Peak Voltage	V_{COMP} = open	$V_{Ct(MAX)}$	4.535	4.93	5.25	V
On Time Capacitor Charge Current	V_{COMP} = open V_{Ct} = 0 V to $V_{Ct(MAX)}$	I_{charge}	240	270	292	μA
Ct Capacitor Discharge Duration	V_{COMP} = open V_{Ct} = $V_{Ct(MAX)}$ −100 mV to 500 mV	$t_{Ct(discharge)}$	−	50	150	ns
PWM Propagation Delay	dV/dt = 30 V/μs V_{Ct} = $V_{Control}$ − $Ct_{(offset)}$ to V_{DRV} = 10%	t_{PWM}	−	130	220	ns
ZERO CURRENT DETECTION						
ZCD Arming Threshold	V_{ZCD} = Increasing	$V_{ZCD(ARM)}$	1.25	1.4	1.55	V
ZCD Triggering Threshold	V_{ZCD} = Decreasing	$V_{ZCD(TRIG)}$	0.6	0.7	0.83	V
ZCD Hysteresis		$V_{ZCD(HYS)}$	500	700	900	mV
ZCD Bias Current	V					

TYPICAL CHARACTERISTICS

$T_{Temperature}$

Figure 3. Overvoltage Detect Threshold vs. Junction Temperature

Figure 4. Overvoltage Hysteresis vs. Junction Temperature

TYPICAL CHARACTERISTICS

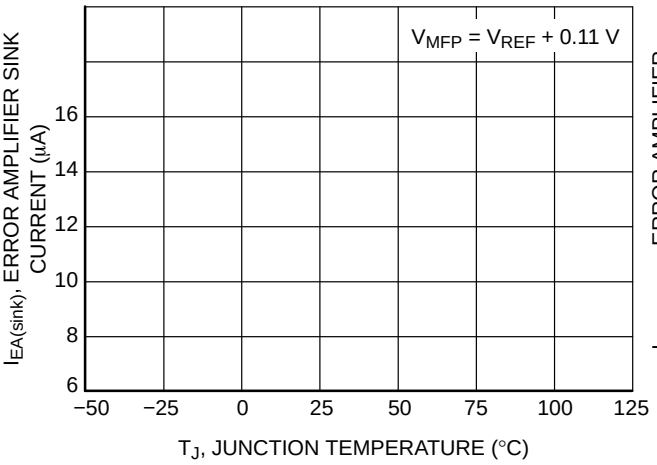


Figure 8. Error Amplifier Sink Current vs. Junction Temperature

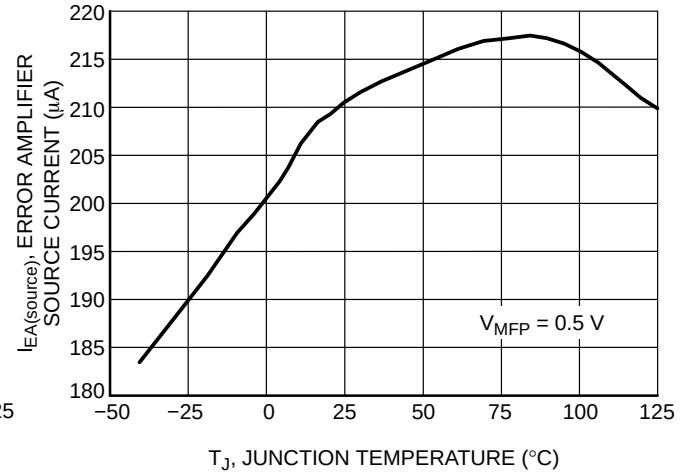


Figure 9. Error Amplifier Source Current vs. Junction Temperature

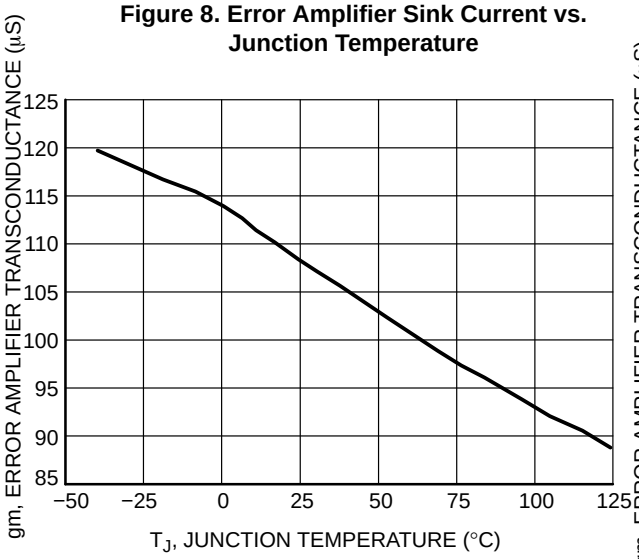


Figure 10. Error Amplifier Transconductance vs. Junction Temperature

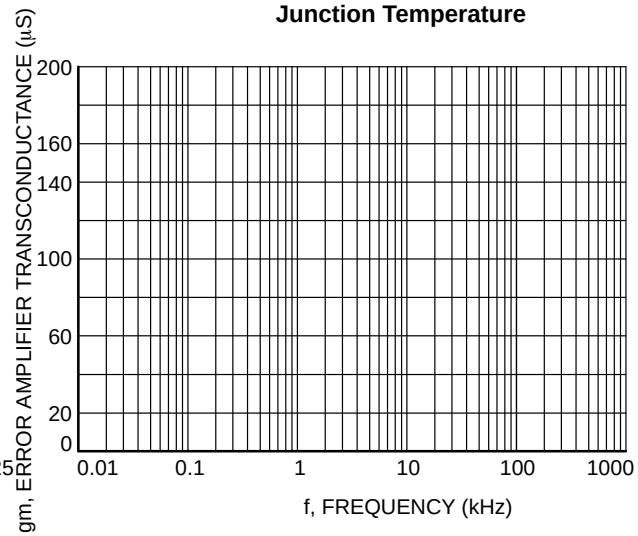


Figure 11. Error Amplifier Transconductance and Phase vs. Frequency

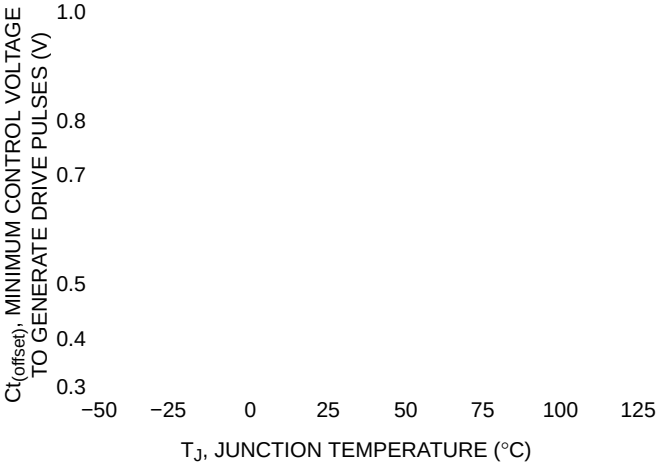


Figure 12. Minimum Control Voltage to Generate Drive Pulses vs. Junction Temperature

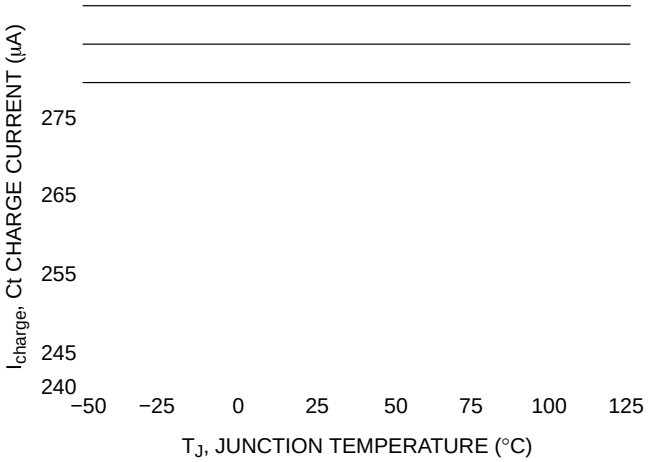


Figure 13. On Time Capacitor Charge Current vs. Junction Temperature

TYPICAL CHARACTERISTICS

T_J, JUNCTION TEMPERATURE (°

Figure 14. Ct Peak Voltage vs. Junction Temperature

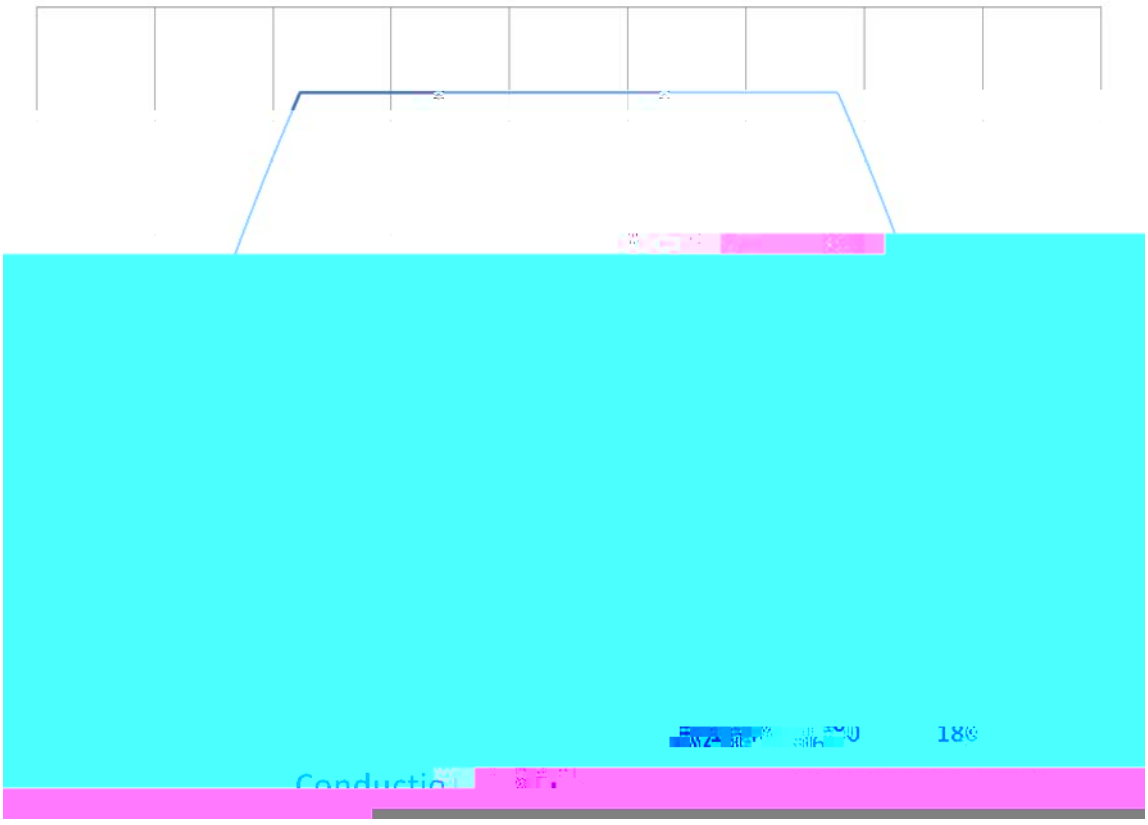
Figure 15. PWM Propagation Delay vs. Junction Temperature

THEORY OF OPERATION

High power factor, high efficiency, and small size are key parameters for LED drivers in the incandescent replacement market. The NCL30002 has all the features required to accomplish that is in a compact SOIC-8 package. Power factor is broadly defined as:

$$PF = \frac{P_{in}(avg)}{V_{in}(rms) \times I_{in}(rms)}$$

This differs from the classical definition where there is a phase angle difference between the input voltage and current. However, the underlying concept of optimizing



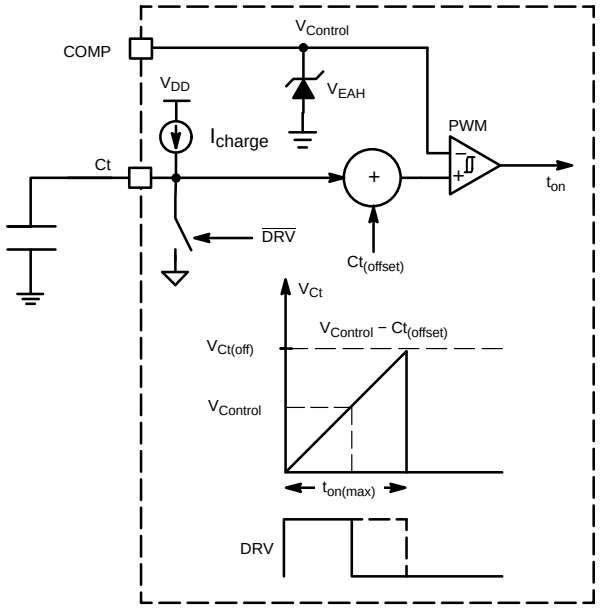


Figure 25. On Time Control

Off Time Sequence

The off time is determined by the peak inductor current, the inductance and the output voltage. In mode 2, the off time is variable because the peak inductor current is not fixed. However in mode 3, the off time is constant since the peak current and the output voltage are both fixed. The auxiliary winding used to provide bias to the NCL30002 is also used to detect when the current has dropped to zero. This is illustrated in Figure 26.

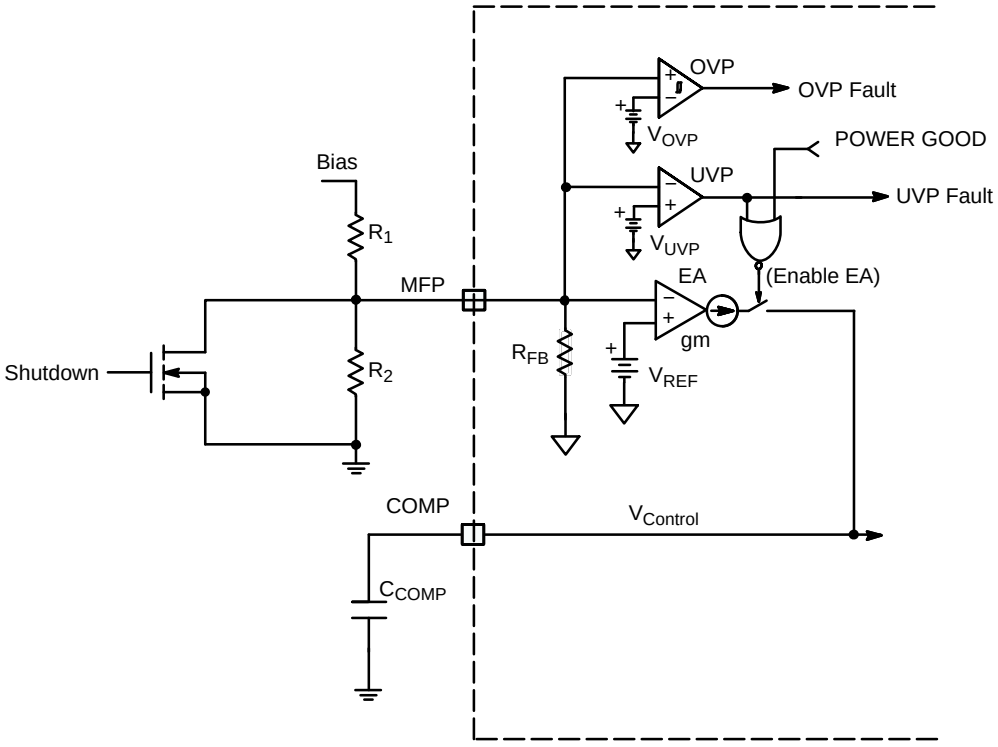


Figure 29. Multi−Function Pin Operation

The positive input of the transconductance amplifier is connected to a 2.51 V (nominal) reference. A filtered line feed-forward signal (see Figure 2) is connected to the negative input of the error amplifier and used to control the on-time of controller.

V_{CC} Management

The NCL30002 incorporates a supervisory circuitry to manage the startup and shutdown of the circuit. By managing the startup and keeping the initial startup current at less than 35 μ

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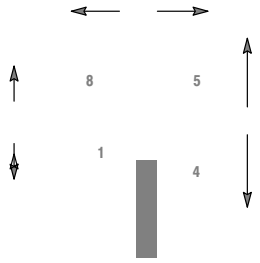

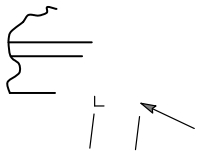

SEATING
PLANE