

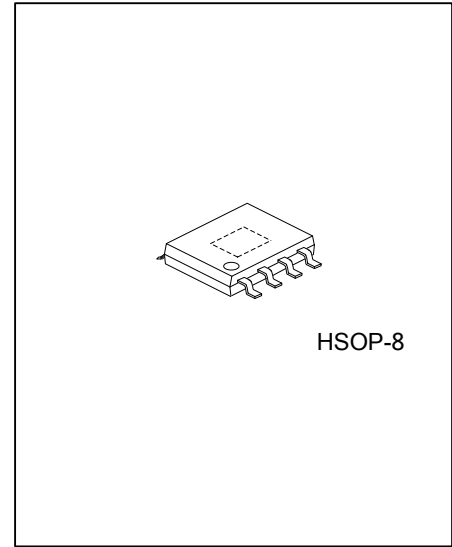


LED DRIVER CONTROLLER

DESCRIPTION

Featured Device, UTC **UL22**, is a PWM controller with innovative Free-Dimming™ technology. The controller drives one of the two strings of LEDs by an ON/OFF AC wall switch and provides a cost effective solution for light control. It supports power-factor-correction function in applications.

UTC **UL22** provides several protection features. It includes a cycle-by-cycle current limit to the power switch; over-current protection at the LED load; bias voltage V_{DD} over-voltage protection. In addition, the driver output (DRV) voltage is clamped for driving the external power MOSFET effectively and safely. The controller also features an internal over-temperature protection.



FEATURES

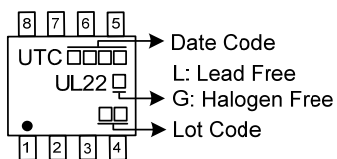
- * Free-Dimming™ technology
- * Proprietary technology using ON/OFF wall switch to select one of the two LED channels
- * Supports high-side Buck, Buck-Boost and Flyback topologies
- * High power factor with Discontinue-Current-Mode (DCM) control
- * Low start-up current and operating current to maximize conversion efficiency
- * Under-voltage lockout (UVLO) with hysteresis
- * Provides complete protection functions
 - Maximum gate driver output clamp
 - V_{DD} pin Over-Voltage Protection
 - Cycle-by-cycle current limit
 - LEDs Over-Current Protection
 - LEDs Open-Loop Protection
 - LEDs Short-Circuit Protection
 - Internal Over-Temperature Protection

ORDERING INFORMATION

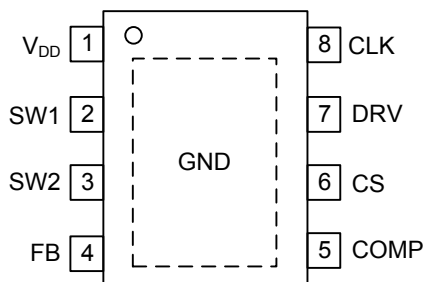
Ordering Number		Package	Packing
Lead Free	Halogen Free		
UL22L-SH2-R	UL22G-SH2-R	HSOP-8	Tape Reel

<p>UL22G-SH2-R</p> <ul style="list-style-type: none"> (1) Packing Type (2) Package Type (3) Green Package 	<ul style="list-style-type: none"> (1) R: Tape Reel (2) SH2: HSOP-8 (3) G: Halogen Free and Lead Free, L: Lead Free
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MARKING



PIN CONFIGURATION

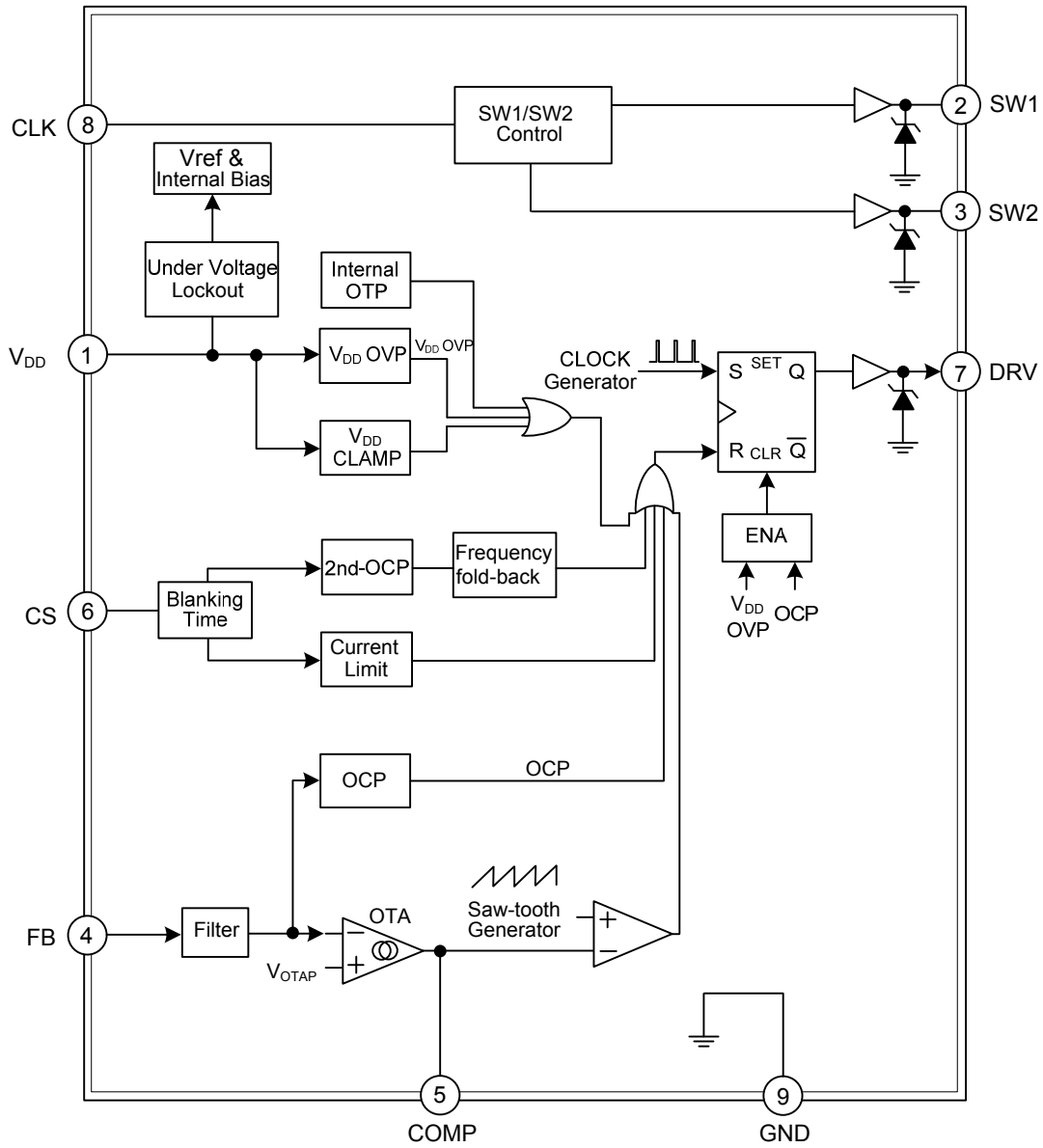


PIN DESCRIPTION

PIN NO.	I/O (Note 1)	PIN NAME	DESCRIPTION
1	Power	V _{DD}	Power supply.
2	O	SW1	Output of the 1st channel LED string control signal.
3	O	SW2	Output of the 2nd channel LED string control signal.
4	I	FB	LED string current sense pin.
5	O	COMP	Output of the error amplifier.
6	I	CS	Current sense in series with power switch.
7	O	DRV	Totem-pole output to drive the external power MOSFET.
8	I	CLK	Line-voltage detection pin for 2-channel control.
9	Power	GND	Power ground.

Note: I=Input, O=Output

■ BLOCK DIAGRAM



■ ABSOLUTE MAXIMUM RATING

PARAMETER	SYMBOL	RATINGS	UNIT
Supply Voltage to V _{DD} Pin	V _{DD}	-0.3 ~ 30	V
V _{DD} Maximum Supply Current Limit for OVP Condition	V _{OVP}	20.0	mA
Input Voltage to FB Pin	V _{FB}	-0.3 ~ 7	V
Input Voltage to CS Pin	V _{CS}	-0.3 ~ 7	V
Input Voltage to CLK Pin	V _{CLK}	-0.3 ~ 7	V
Output Voltage at the COMP pin	V _{COMP}	-0.3 ~ 7	V
Maximum Operating Junction Temperature	T _J	+150	°C
Storage Temperature	T _{STG}	-55 ~ +150	°C

Note: Absolute maximum ratings are those values beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.

■ RECOMMENDED OPERATING RANGE (Note)

PARAMETER	SYMBOL	RATINGS	UNIT
V _{DD} Supply Voltage	V _{DD}	18 ~ 24	V
Operation Ambient Temperature	T _A	-40 ~ +85	°C
Operating Junction Temperature	T _J	+125	°C

■ THERMAL DATA (Note)

PARAMETER	SYMBOL	RATINGS	UNIT
Junction to Ambient	θ _{JA}	50	°C/W
Junction to Case	θ _{JC}	8	°C/W

Note: Not to exceed the maximum junction temperature of the IC, which relates to the operating power of the IC and the thermal resistance of the IC/package as above. The operation power of the IC can be calculated by $P_d = V_{DD_IN} \times I_{IN}$, where V_{DD_IN} represents the input voltage at the V_{DD} pin of the IC and I_{IN} represents the current flow into the V_{DD} pin of the IC.

■ ELECTRICAL CHARACTERISTICS ($V_{DD}=18V$, $T_A=25^\circ C$ unless otherwise specified)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Supply Voltage (V_{DD} Pin)						
Startup Current	I_{ST}	$V_{DD}=10V$			25	μA
Operating Current	I_{DD}	$V_{DD}=18V$; $DRV=F_{OSC}$, $C_{L-DRV}=1nF$			3	mA
Turn-on Threshold Voltage	V_{DD-ON}		14.5	15.0	16.5	V
Turn-off Threshold Voltage Note: DRV Mini Level must be Higher than 6V	V_{DD-OFF}		8	9.5	11	V
CLK Portion Turn-off and Reset Logic Threshold Voltage	$V_{DD-RESET}$				4.0	V
V_{DD} OVP Threshold	V_{DD-OVP}		24	25.5	27	V
V_{DD} Clamp Voltage	$V_{DD-CLAMP}$	20mA Sink Capability		28.5		V
Internal OTA (FB and COMP pin)						
Reference for Non-Inverting Input	V_{OTAP}	$T_A=25^\circ C$	239	252	265	mV
Over Current Protection Threshold Voltage	V_{FB-OCF}		0.75	0.8	0.85	V
Min. Duty Voltage on COMP pin	$V_{COMP-MIN}$		0.5	0.55	0.6	V
Internal CLK Comparator (CLK Pin)						
Threshold for Line Cycle Detection	V_{CLK-ON}			1.5		V
Threshold for Line Cycle Detection	$V_{CLK-OFF}$			1.3		V
Debounce Time for CLK Detection	t_{CLK}	$DRV=F_{OSC}$		19		ms
Color Control Output (SW1/SW2 Pin)						
Rise Time	t_{SWR}	$C_L=1nF$	70	135	200	μs
Fall Time	t_{SWF}	$C_L=1nF$	40	80	120	μs
Gate Clamp Voltage	$V_{SW-CLAMP}$	$V_{DD}=22V$		18	20	V
Oscillator						
Normal Frequency	F_{OSC}	$V_{DD}=18V$	62	66	70	kHz
Maximum Duty Cycle PWM	DC_{MAX}	Centre $F_{OSC}=67KHz$	75	79	83	%
Minimum On-Time	t_{ON-MIN}	$DRV=F_{OSC}$		250		ns
Current Sense (CS pin)						
Current Limit Threshold	V_{CL}	$V_{COMP}=5V$, $V_{FB}=0.1V$	0.75	0.8	0.85	V
2nd OCP Threshold	V_{SC}	CS Pin	1.05	1.15	1.25	V
GATE Drive Output (DRV Pin)						
Rise Time	t_R	$C_L=1nF$, $V_{DD}=15.0V$, 10~90%		100		ns
Fall Time	t_F	$C_L=1nF$, $V_{DD}=15.0V$, 90~10%		80		ns

FUNCTIONAL DESCRIPTION

Refer to both the Block Diagram in Figure 1 and a reference design circuit in Figure 4 for the following discussions. All parameters mentioned below are typical values.

Start-up Circuit

Applying AC power to the LED driver shown in Figure 4, initiates the operation. To minimize power losses, large start-up resistors are preferred to be connected between rectified line voltage and V_{DD} pin. During start-up, capacitor C5 is charged up to 15.0V (V_{DD-ON}) by resistors R1, R2 and R3. The turn-on and turn-off thresholds of the controller are 15.0V and 9.5V (V_{DD-OFF}) respectively. Once the V_{DD} exceeds 15.0V, all of the internal circuits are activated. Referring to Figure 2, the hysteresis voltage for V_{DD} pin is implemented to keep IC operating for a period of time with external hold-up capacitor C5. When V_{DD} drops below 9.5V, the controller shuts off the driver output yet keeping color control function active. The controller will be in shut-off mode with control logic being reset when V_{DD} drops below 4.0V.

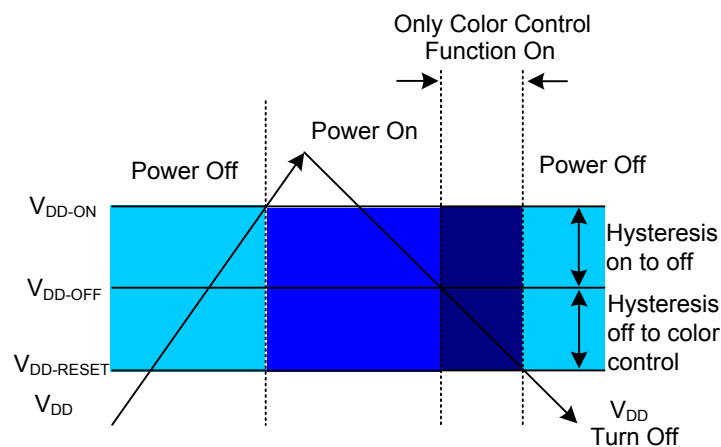


Figure 1. V_{DD} Power Supply Hysteresis

Control

UTC **UL22** operates with 66 KHz, fixed-frequency PWM voltage-mode control for converter operation. It can be used for providing regulated current for high-brightness LED applications. To keep the converter operating under discontinuous mode over various conditions, the primary-side inductance of the power inductor T1 must be designed and operated in Critical Conduction Mode (CRM) at minimum line voltage and maximum load.

During normal operation conditions, current flowing through the LEDs is detected at the sense resistors R10 and R17 connected to FB pin. The signal at FB pin is processed to compare with a reference voltage by internal OTA (Operational Transconductance Amplifier) which produces a compensated signal (V_{COMP}) at COMP pin. The compensated signal is then compared with an internal saw-tooth signal to generate a pulse-width-modulation signal for the driver output. When the internal saw-tooth signal intersects with the compensated signal, the switch Q1 will be turned off. Therefore, the COMP pin voltage level determines the turn-on time of power switch and regulates the energy stored in power inductor. The higher level voltage at COMP results in larger duty cycle to the driver which provides higher brightness on LEDs.

Capacitor C6 connected at COMP pin provides a stable close-loop response. The slower the response, the higher power factor converter provides.

The driver output (DRV pin) provides a maximum duty cycle of 79%. For operating conditions with high V_{IN} -to- V_{OUT} ratios, the minimum on-time of 250ns should be considered in design of the circuit.

Color Control Function - Free-Dimming™

The controller implements a proprietary control technique to turn on a desired LED string (of the two) by using an AC ON/OFF wall switch. It provides an example of color-temperature control for applications where each string provide a unique color temperature.

CLK pin monitors a divided voltage signal from AC input through resistor divider (R1, R2, R4 and R5 in Figure 4).

The detected thresholds are set at 1.5V for CLK ON and 1.0V for CLK OFF, which can be designed appropriately according to the AC input voltage range.

■ FUNCTIONAL DESCRIPTION (Cont.)

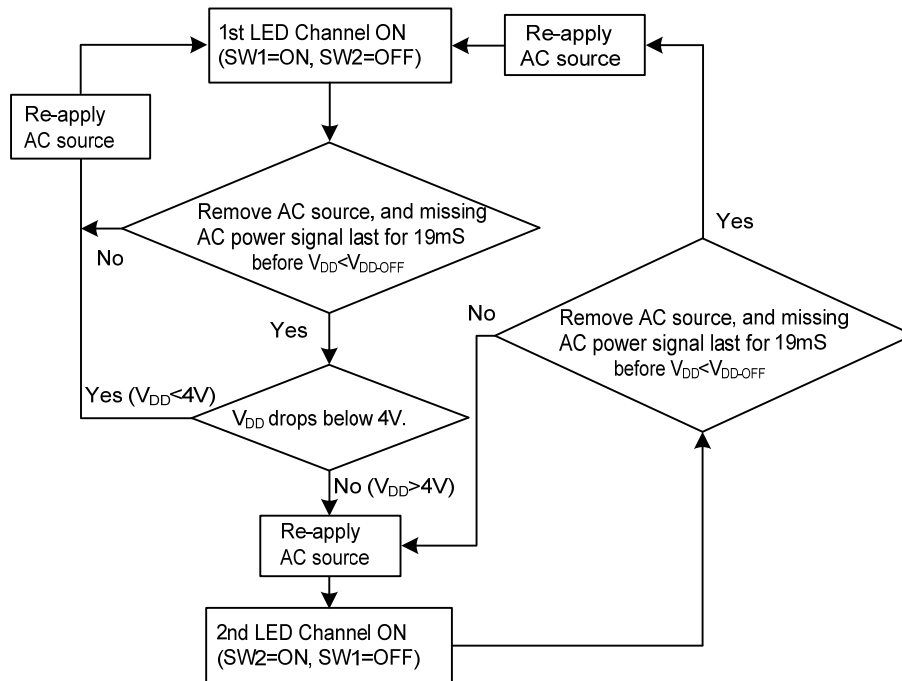


Figure 3: Dimming Flowchart

Refer to the dimming flowchart in Figure 3 and a reference design circuit in Figure 4. When AC input voltage is applied to the LED Driver, the controller will be activated and started switching operation when the V_{DD} voltage exceeds 15.0V. The first-string of LEDs for example, Cool-White is activated by Q2 (SW1 signal). Its current is detected by resistors R10 and R17. The detected voltage is compared with an internal reference then controller outputs DRV duty signal with appropriate turn-on time. This regulates the LEDs current to the current setting level.

While Q2 (SW1) is initially turned on, the switch Q3 (SW2) is turned OFF. As the AC input voltage is removed (wall switch turned off), both the V_{DD} and CLK pin voltage decrease. Once CLK signal falls below its OFF threshold of approximately 1.0V, the internal timer activates. If the 19ms (milli-second) period is completed before V_{DD} drops below 9.5V, Q2 will be turned off and Q3 will be turned on when AC input is re-applied with V_{DD} exceeds 15.0V. The current flowing through the second-string of LEDs follows the same current setting.

Note that the DRV output will be turned off once the 19ms period is completed. During 19ms period, V_{DD} pin level must be held and kept above OFF threshold for proper control.

Similarly, if the controller is subjected to another OFF-ON action of the AC power as described above, Q2 will be turned on while Q3 is OFF. The SW1 and SW2 can therefore select the LED channel to provide a light control.

If the AC input is re-applied after the V_{DD} voltage drops below 4.0V, the controller and COLOR control temporal circuit is reset. In this case, the circuit will result in Q2 being turned ON while Q3 is OFF; same as mentioned in the initial AC power ON condition.

Gate Driver

The totem-pole DRV output delivers the gate-drive signal to the external power MOSFET. A proprietary soft-clamp technique limits the output driver at 19.5V maximum. It is used to protect the external power MOSFET from being over stressed.

Both SW1 and SW2 outputs deliver the gate-drive signals to the external MOSFETs for 2-channel LED color control. The gate clamping voltage is 19.5V maximum.

Leading-Edge Blanking Time

In applications, when MOSFET Q1 is switched on, a current spike may occur at CS pin due to parasitic components in the circuit. The controller employs a built-in filter to ignore the initial 750ns period of each switching cycle at CS signal to avoid the MOSFET being turned off inadvertently.

■ FUNCTIONAL DESCRIPTION (Cont.)

LED Current Setting

LEDs current sensing resistors R10 and R17 connected to FB pin are selected for the LEDs current setting. The LEDs current can be calculated by

$$I_{LED}(\text{mA}) = \frac{252(\text{mV})}{R10 // R17(\text{ohm})}$$

Open LED Protection (OVP)

When either one of the LED strings is opened, the control loop intends to regulate the rated current flowing through LEDs. The output voltage rises, reflected voltage on the auxiliary winding and the voltage at V_{DD} will therefore increase. UTC **UL22** provides V_{DD} pin Over Voltage Protection which stops all switching operation when V_{DD} voltage exceeds 25.5V and enters auto-recovery (hiccup) mode. This temporary shutdown of operation does not allow circuit to resume until V_{DD} drops to 9.5V followed by the rise to above 15.0V.

Under abnormal condition V_{DD} level continues to rise, the. Internal to the chip, V_{DD} is clamped at 28.5V with 20mA current sinking capability.

The OVP protection threshold can therefore be designed by the following equations:

$$V_{OUT-OVP} = \frac{N_{SEC}(N_{56})}{N_{AUX}(N_{34})} \times 25.5V(\text{Flyback}), \text{Fig.4}$$

$$V_{OUT-OVP} = \frac{N_L(N_{12})}{N_{AUX}(N_{13})} \times 25.5V(\text{Buck - Boost}), \text{Fig.5}$$

$$V_{OUT-OVP} = \frac{N_L(N_{13})}{N_{AUX}(N_{12})} \times 25.5V(\text{H-S Buck}), \text{Fig.6}$$

where N_{SEC} is the number of turns of the secondary winding, and N_{AUX} is the number of turns of the auxiliary winding.

Short LED Protection

When a number of LEDs in a string are shorted, current flowing through the sense resistors R10 and R17 will be increased. To prevent any damage, UTC **UL22** provides Over Current Protection. When the voltage at FB pin reaches 0.8V, the controller will turn off the driver signal DRV to the power MOSFET Q1. This operation does not allow circuit to resume until V_{DD} drops below 9.5V followed by the rise to above 15.0V.

If the output terminal for the LED load is shorted to ground, there is no sense signal at FB pin, and current flowing through the power transformer rises sharply. Once the CS pin voltage exceeds 0.8V threshold, the controller turns off the output driver. It will not be turned on again until the next switching cycle starts provided V_{DD} voltage is still above 9.5V. This cycle-by-cycle current-limit function prevents external components from being damaged under the fault condition.

As the short-circuit condition continues, the auxiliary winding, coupled to the secondary winding, cannot support and sustain the V_{DD} bias voltage. The V_{DD} voltage will drop below 9.5V and the controller will shut off the DRV signal.

Note that when controller is shut off, the rectified input AC voltage will supply the charging current for V_{DD} via R1, R2 and R3 start-up resistors. The current, however cannot sustain the operating current of controller. Therefore, the V_{DD} voltage will fall gradually, and DRV signal will be shut off. V_{DD} will then be charged to 15.0V, the circuit operates as a hiccup mode under the short-circuit condition.

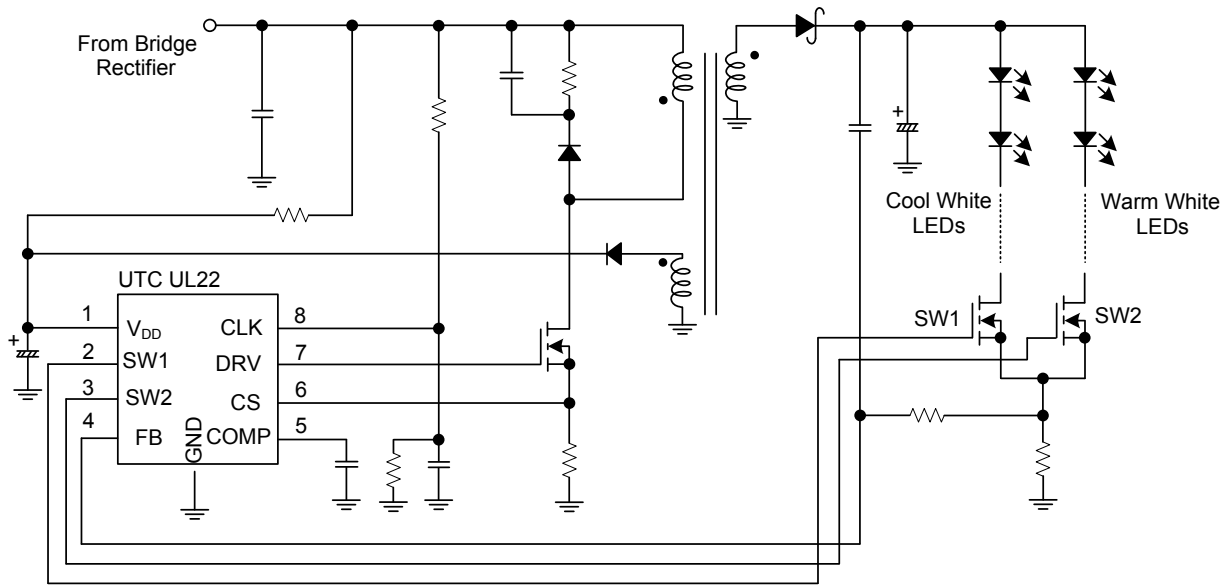
Frequency Fold-back

A large current may flow in the primary-side of the transformer when output short circuit to ground. Even though the V_{DD} voltage will fall due to the collapse of the auxiliary winding voltage, but the 750ns leading-edge blanking time blocks off the control function which may cause transformer to be saturated before V_{DD} drops below 9.5V. In order to protect the power MOSFET Q1 and other components from being damaged, UTC **UL22** provides a frequency fold-back function. When the voltage at CS pin exceeds 1.15V, the DRV signal will be interrupted and rested for 3 cycles followed by the next pulse output.

Thermal Protection

Thermal protection occurs when the IC experiences a high junction temperature. The MOSFET drive DRV is turned off once the junction temperature exceeds approximately 140°C. It resumes normal operation when the junction temperature drops to or below approximately 110°C.

■ TYPICAL APPLICATION CIRCUIT



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■ REFERENCE DESIGN

1. 4.5W, 2-channel COLOR control by ON/OFF AC-Switch (Free-Dimming™)

Featured Device	Application	Input Voltage	Output Voltage (Rated Current)	Rated Output Power	Topology
UTC UL22	LED Driver with Free-Dimming™	90~264V _{AC}	30V/150mA	4.5W	Flyback with DCM fixed F _{osc}

Schematic

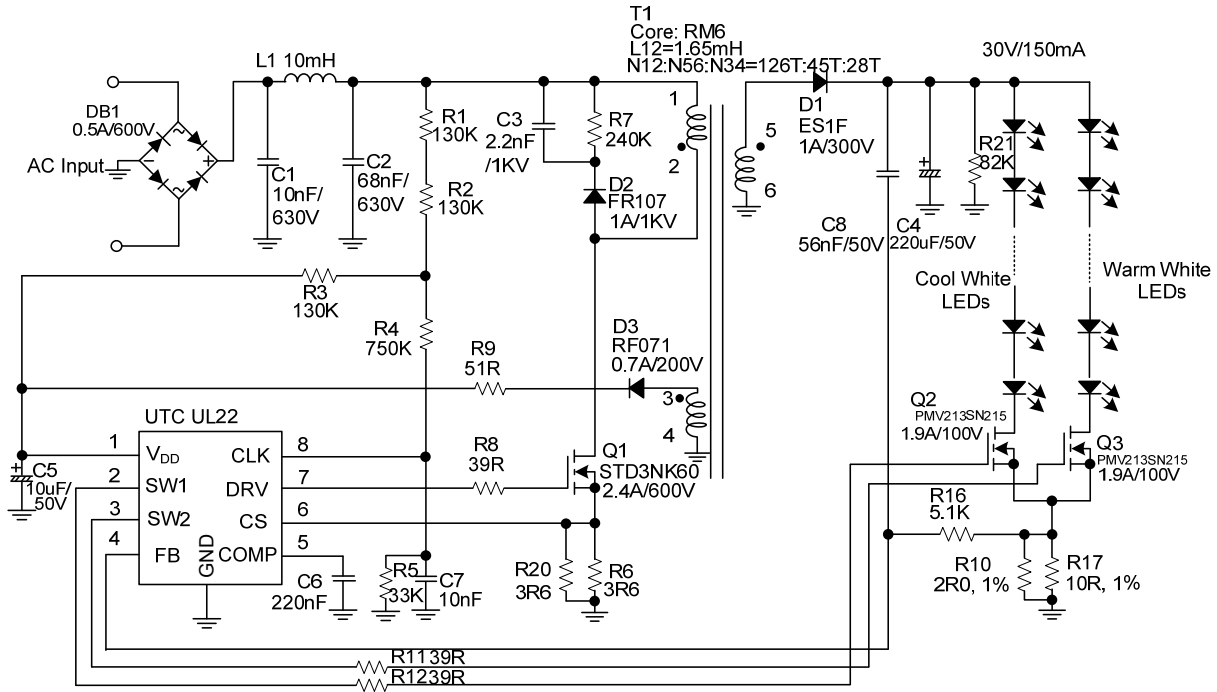


Figure 4: Schematic

Typical Performance

Table 1: Measured Results

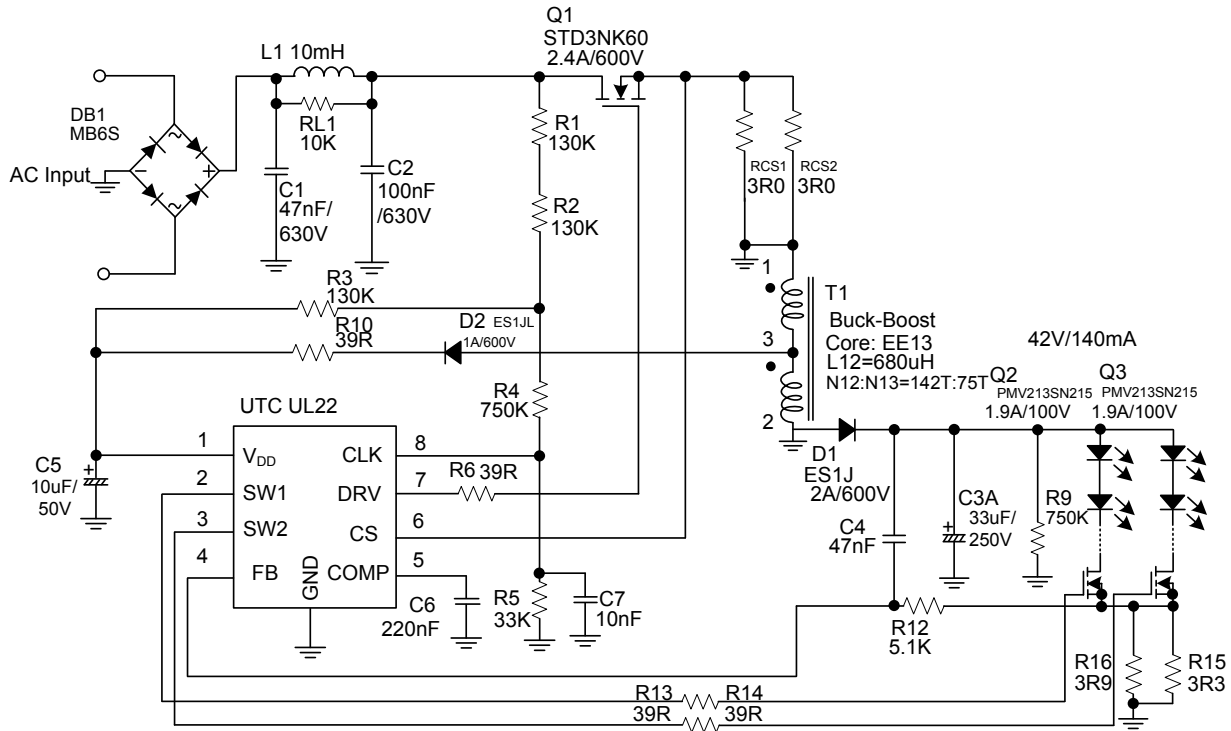
V _{in}	90Vac	110Vac	135Vac	175Vac	220Vac	264Vac
P _{in} , [W]	5.644	5.585	5.584	5.629	5.691	5.797
V _{LED} , [V]	32.20	31.93	31.93	31.91	31.90	31.90
I _{LED} , [mA]	149.3	149.2	149.2	149.2	149.3	149.4
EFF _{LED} , [%]	85.18	85.3	85.31	84.58	83.69	82.21
A _{CC} , [%]	0.00	-0.07	-0.07	-0.07	0.00	0.07
THD, [%]	8.389	7.122	9.859	10.328	15.356	19.949
PF	0.993	0.99	0.983	0.967	0.939	0.907

■ REFERENCE DESIGN (Cont.)

2. 5.8W, 2-channel COLOR control by ON/OFF AC Switch (Free-Dimming™)

Featured Device	Application	Input Voltage	Output Voltage (Rated Current)	Rated Output Power	Topology
UTC UL22	LED Driver with Free-Dimming™	180~264V _{AC}	42V/140mA	5.88W	Buck-Boost with DCM fixed F _{osc}

Schematic



Good Layout consideration with proper filter should be considered.

Figure 5: Schematic

Typical Performance

Table 2: Measured Results

V _{in}	180Vac	200Vac	220Vac	240Vac	264Vac
P _{in} , [W]	6.723	6.766	6.815	6.863	6.934
V _{LED} , [V]	40.98	40.92	40.88	40.84	40.8
I _{LED} , [mA]	140.8	140.7	140.7	140.7	140.6
EFF _{LED} , [%]	85.82	85.09	84.4	83.73	82.73
A _{CC} , [%]	0.07	0.00	0.00	0.00	-0.07
THD, [%]	12	14.12	16.16	17.87	20.78
PF	0.956	0.943	0.929	0.927	0.91

■ REFERENCE DESIGN (Cont.)

3. 20W, 1-channel, 2-dimming level control by ON/OFF AC Switch (Free-Dimming™)

Featured Device	Application	Input Voltage	Output Voltage (Rated Current)	Rated Output Power	Topology
UTC UL22	LED Driver with Free-Dimming™	175~264V _{AC}	170V/120mA/12 mA	20W/2W	H-Side Buck with DCM fixed Fosc

Schematic

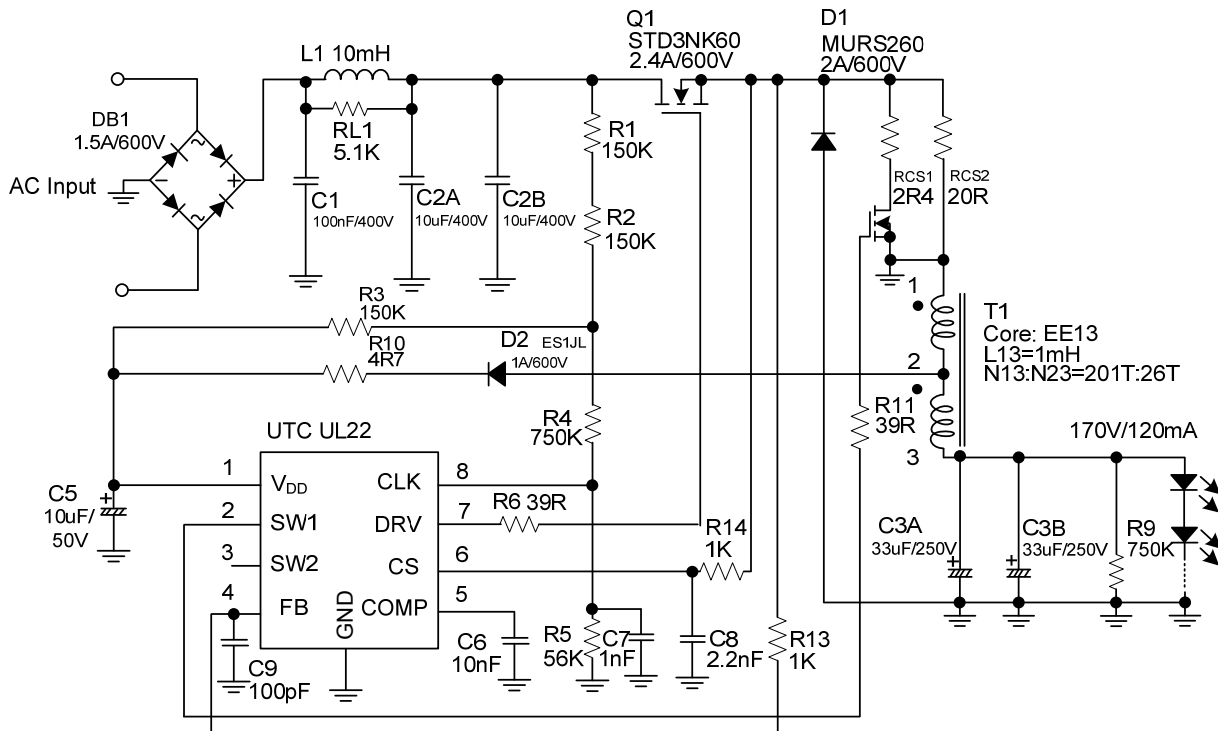


Figure 6: Schematic

Typical Performance

Table 3: Measured Results

TYPE	SYMBOL	UNIT	175Vac	200Vac	220Vac	240Vac	264Vac
Level 1	Pin	W	21.119	21.184	21.253	21.185	21.332
	V _{LED}	V	168.8	168.5	168.1	167.6	167.4
	I _{LED}	mA	119.7	119.8	119.9	120.0	120.1
	EFF _{LED}	%	95.67	95.29	94.83	94.94	94.25
	Acc	%	-0.17	-0.08	0.00	0.08	0.17
Level 2	Pin	mW	2.037	2.137	2.178	2.217	2.286
	V _{LED}	V	144.6	144.8	145.0	145.1	145.3
	I _{LED}	mA	12.3	12.38	12.45	12.52	12.6
	EFF _{LED, [%]}	%	87.31	83.89	82.89	81.94	80.09
	Acc	%	-1.20	-0.56	0.00	0.56	1.20

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