Features

- Integrated high voltage start and X-cap discharge function, simple peripheral circuit
- Integrated half-bridge drive, the maximum frequency support 600kHz
- High performance digital - analog hybrid control
- Flexible configuration of various control and protection parameters
- Current type control architecture
- Multimode control
- Enter Skip/burst mode in light load
- Enter Brown-in/Brown-out protection
- Fixed dead zone time, software configurable
- OverCurrent Protection(OCP)
- OverPower Protection(OPP)
- Capacitive Mode Regulation(CMR)
- Short circuit protection(SCP)
- Capacitive Mode Regulation(OVP)
- OverTemperature Protection(OTP)

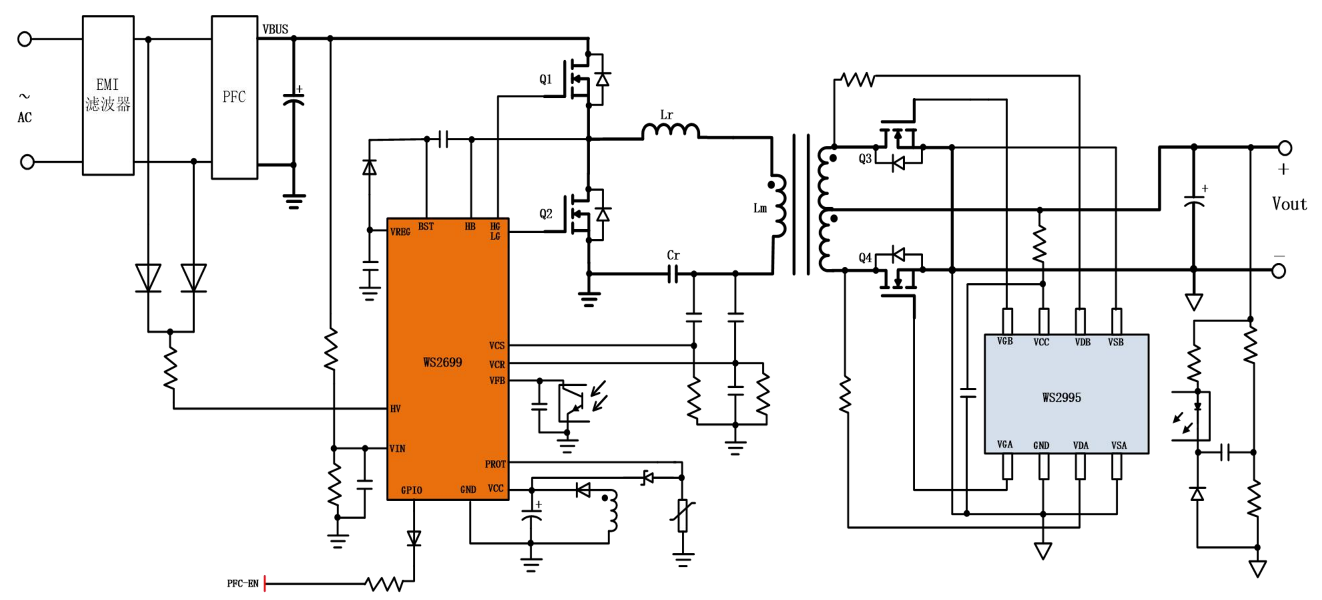
Application

- Desktop and notebook adapter
- power supply for TV and display
- LED driver
- AC-DC power supply

General Description

- WS2699 is a high integrated high performance LLC controller with mixed digital and analog, current mode and multi-mode operation.WS2699 can be used with dual channel synchronous rectifier controller WS2994/5 to achieve high efficiency and high reliability LLC design, suitable for medium and high power isolated power supply situations
- In order to simplify the overall design of the switching power supply and maximize the performance of LLC, WS2699 has carried out a comprehensive design optimization.IC adopts advanced multi-mode control, which can independently configure the working state of each mode, realizing the efficiency optimization of the full load range; Fixed dead zone control function can be set to reduce dead zone loss; Open register configuration, flexible configuration of various control and protection parameters, few peripheral devices and easy to design; Adopt current mode control structure, with good loop stability; For ultra-light load or no-load situation, carry out targeted energy-saving design, realize the maximum optimization of light load efficiency and standby power consumption; Integrated half-bridge drive module, can directly drive LLC bridge arm switch tube; In addition, the chip has built-in high-voltage startup function and X-Cap discharge function, which

Typical Application Circuit



Note: 1，GPIO is used for system control, such as PFC standby control, to bring the whole system into deep standby;

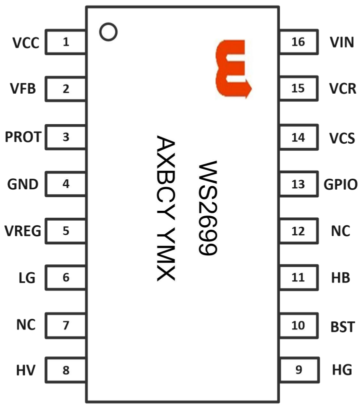
2，HV if connected to PFC output（VBUS）,disable the X-Cap discharge function；

3；The VIN is connected to the PFC output（VBUS）；

Ordering Information

PACKAGE	MARK	ORDER NUMBER
16-Pin SOIC-16,Pb-free	WS2699	WS2699

Pin Configuration



SOC16

WS2699xx：Product Code
A：Product code
X：Internal code
BCY：Internal quality control code
YMX：D/C

Pin Description

SOC16		
Pin Name	**Pin NO.**	**Pin Description**
VCC	1	IC power supply pin, the output of the internal HV to start the power supply, also acts as the input of the auxiliary power supply
VFB	2	Closed-loop feedback input
PROT	3	Output overvoltage protection, and through NTC detection to achieve external overtemperature protection
GND	4	Ground Terminal.
VREG	5	Internal voltage regulator output, as the LG power supply
LG	6	LLC lower tube drive output
NC	7,12	vacant
HV	8	High voltage start pin, charging the VCC when starting; Discharge the X-Cap when the AC power is off

HG	9	Tube driver output LLC
BST	10	HG power supply, external bootstrap capacitor and diode, diode anode link to VREG pin
HB	11	The midpoint of the half-bridge and HG form the upper tube driving loop
GPIO	13	Can be used for system control, such as PFC standby control
VCS	14	LLC resonator current detection
VCR	15	LLC resonant capacitor voltage detection for closed-loop control
VIN	16	Bus voltage detection, BI/BO control

Absolute Maximum Ratings

Parameter	Test Condition	Value	Unit
voltage on pin HV	I_{HV}<50uA	-0.3 ~ +700	V
current on pin HV		20	mA
voltage on pin BST		V_{HB} ~ V_{HB} + 14	V
voltage on pin HB	DC	-3 ~ +700	V
	t < 1 uS	-14	V
voltage on pin VCC		-0.3 ~ +36	V
oltage on pin VREG		-0.3 ~ +14	V
HG	Built-in upper tube drive	V_{HB} - 0.3 ~ V_{BS} + 0.3	V
LG	Built-in lower tube drive	-0.3 ~ +20	V
voltage on pin（VFB, PROT, VIN, GPIO）		-0.3 ~ +6.5	V
voltage on pin（VCS, VCR）		-6.5 ~ +6.5	V
total power dissipation	T_{amb} <75℃	0.7	W
storage temperature		-55 ~ +150	℃
junction temperature		-40 ~ +150	℃

Recommended work scope

Symbol	Parameter	Value	Unit
VCC	DC supply voltage	0~33	V
T_j	Working junction temperature	-40~125	℃

ESD

Symbol	Parameter	Value	Unit
V_{ESD_HBM}	human body model，pin HV、BST、HG and HB	±1500	V
	human body model，other pins	±2000	V
V_{ESD_MM}	Machine model	±500	V

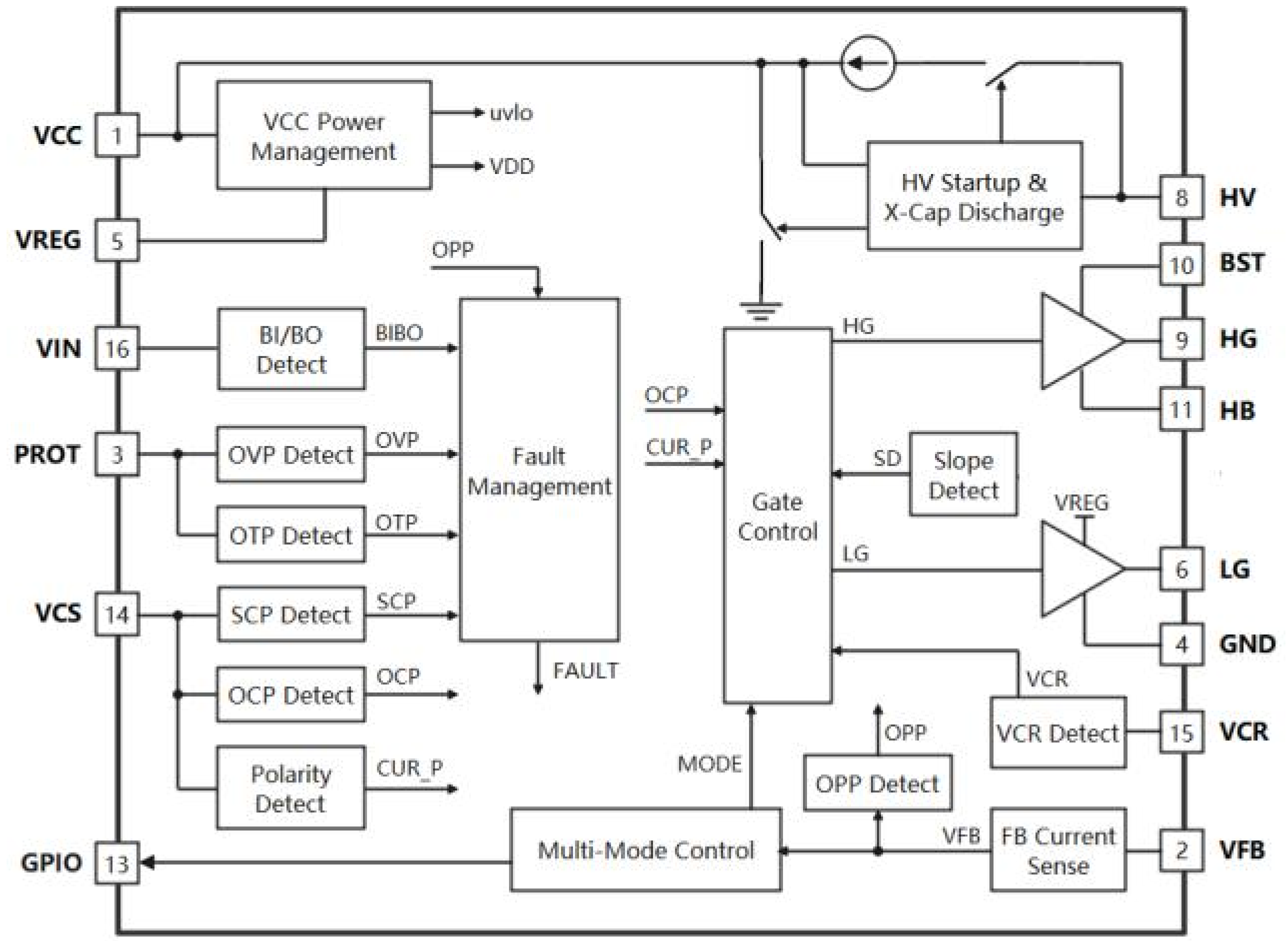
Note1：The maximum limit indicates that the chip may be damaged if it exceeds the working range. The recommended operating range indicates that the device functions normally within the recommended operating range, but it is not guaranteed to meet individual performance specifications. Electrical parameters define the DC and AC parameters of the device within its operating range and under test conditions that guarantee specific performance indicators. For parameters without upper and lower limits, the specification does not guarantee their accuracy, but their typical values reasonably reflect the device performance.

Electrical Characteristics(VCC = 24V; Tamb = 25℃ unless otherwise specified.)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
High voltage starting pin (HV)						
Current source voltage	V_{HV_ON}			40		V
Working current on pin HV	I_{HV2}	V_{CC} > V_{CC_SCP2}	10	12	14	mA
current limit on pin HV	I_{HV1}	V_{CC} < V_{CC_SCP1}	0.4	0.85	1.3	mA
off-state current on HV pin	I_{HV_OFF}	V_{HV} = 400V V_{CC} = 24V	6	8	10	uA
X-Cap Discharge function(HV)						
Disconnect the AC input test	$T_{line\_Removal}$			96		ms
Discharge time	$T_{line\_Discharge}$			32		ms
Detection time	T_{line_Detect}			32		ms
Discharge frequency	$N_{line\_Discharge}$	End the discharge after 8 times		8		n
IC power supply pin (VCC)						
start voltage on pin VCC	V_{CC_ON}	V_{HV} > V_{HV_ON}	16.1	18.2	19.6	V
System starting voltage on VCC	V_{CC_SYSON}		21	22.5	24	V
Low voltage on VCC	V_{CC-low}	With V_{CC_OFF}(HV starts charging again)		12.5		V
VCC pin undervoltage threshold	V_{CC_OFF}	Auxiliary winding power supply	11.3	12.4	12.7	V
VCC pin reset voltage	V_{CC_RST}		5.0	5.5	6.0	V
VCC pin short circuit voltage	V_{CC_SCP}		1.8	1.9	2.0	V
Working current on pin VCC	I_{CC_Normal}	Fsw=100kHz, HG=LG=nc		5.5		mA
Burst Off working current on pin VCC	I_{CC_Burst}			1.5		mA
Internal voltage regulator output pin (VREG)						
Adjust the voltage VREG pin	V_{REG}	VCC = 24V, I_{CC} = 50 mA	10.8	11.3	11.8	V
VREG pin undervoltage threshold	V_{REG_UVP}		9.0	9.2	9.5	V
Upper tube auxiliary source pin (BST)						
VBST pin undervoltage threshold	V_{BST_OFF}	V_{BST}-V_{HB}	6.2	6.8	7.4	V
VBST static current	I_{BST_IQ}				28	uA
Working current on pin VBST	I_{BST}				520	uA
Resonant capacitor voltage detection pin (VCR)						
VCR slope compensation	V_{Slop_Ramp}	Programmable, in 8 gears, 30mV/uS	30	60	240	mV/uS
VCR slope compensation accuracy		60mV	58.2	60	61.8	mV/uS
Resonator current detection pin (VCS)						
Overcurrent protection voltage	V_{OCP}	Normal polarity	1.44	1.50	1.56	V
		Negative polarity	-1.62	-1.50	-1.38	V
Current polarity determines voltage	$V_{Polarity}$	Normal，8 gear (+20mV/step)	20		160	mV
		Negative，8gear (-20mV/step)	-160		-20	mV
Accuracy of current polarity judgment	$V_{Polarity+}$		35	40	85	mV
	$V_{Polarity-}$		-60	-40	-20	mV
Current crossing comparison	V_{CS_zero}		-30	0	30	mV
Closed-loop feedback input pin (VFB)						
voltage on pin FB	V_{FB}		3.239	3.3	3.361	V
FB pin bias voltage	V_{FB_OFFSET}		0.505	0.506	0.507	V
Current on pin FB	I_{FB}		80	82	84	uA
Resistance on pin FB	R_{FB}		38	40	43	kΩ
Drive pin（LG & HG）						
Pull current on pin HG	I_{source_HG}			-1		A
Pull current on pin LG	I_{source_LG}			-1		A
Irrigation current on the HG pin	L_{sink_HG}			1.5		A
Irrigation current on the LG pin	L_{sink_LG}			1.5		A

Guard pin (PROT)						
overvoltage protection voltage	V_{OVP}	If the voltage is higher than the reference value, it is considered as overvoltage	2.40	2.50	2.60	V
External overtemperature protection	V_{OTP}	If the temperature is lower than the reference value, the temperature is considered too high	0.76	0.8	0.84	V
Over temperature protection of external perfusion current	I_{OTP}	Pin outflow current	78.4	80	81.6	uA
Universal IO pin (GPIO)						
Output high level	V_{OH}		4.5		5.8	V
Output low level	V_{OL}		0		0.2	V
Input protection pin (VIN)						
Brown-in threshold	V_{BI}	Step=0.05V	2.1		2.45	V
Brown-out threshold	V_{BO}		1.7		2.05	V
IC internal overtemperature protection						
Overtemperature protection	T_{otp}					℃

Functional Block Diagram



Functional Description

High voltage start (HV, VCC)

The HV pin of WS2699 chip integrates the high-voltage starting function and X-cap discharge function. The functions of each part are described below.

Figure 1 shows the startup process of WS2699 (see Figure 1) : HV is connected to the DC input or the AC input through the resistance; When a voltage greater than 40V is applied to the HV pin, the internal high voltage current source charges the capacitor connected to the VCC pin. In order to prevent the IC from overheating and damaging due to power loss caused by short circuit in the startup process of VCC, the charging current of the high voltage current source is limited to IHV1(1mA) when the VCC voltage is lower than VCC_SCP1 (2.0V). When VCC is greater than VCC_SCP1, the charging current of the high-voltage current source is IHV2(55mA), and the VCC voltage will rise rapidly. When the VCC voltage exceeds VCC_ON(18.5V), the high voltage start current source shuts down. At the same time, UVLO set high effective, IC internal circuit starts to work, the system begins to detect whether the input exceeds the Brown-in threshold VBI, if not, the VCC voltage in VCC_ON (18.5V) and VCC_OFF (12.5V) back and forth charge and discharge; If the input exceeds VBI is detected, the high voltage start current source is turned on until the VCC voltage reaches VCC_SYSON (21V) and the IC begins to output the drive.

After startup, when LLC works normally, VCC is powered by the auxiliary winding, and HV power supply is turned off in this state. When the system is working in burst mode, the HV will start again to charge the VCC when the VCC voltage is lower than the VCC-low (13V) voltage to avoid the VCC triggering the undervoltage protection. If shutdown reset is required, the VCC should fall below the reset voltage vCC-rst (5.5V).

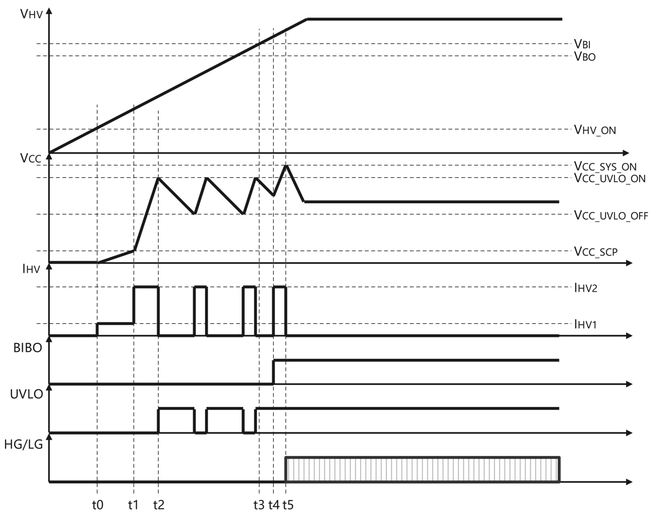


Figure 1

X-cap capacitor discharge (HV connected to AC input L,N terminal)

X capacitors are key components placed on the power input terminals to filter out differential mode EMI noise and provide a bypass loop for lightning strike or surge voltage. When the input AC voltage is removed, the residual voltage on the X-cap may cause harm to the user. The safety standard requires that the input voltage should be discharged to the safe voltage within a certain period of time. In general, resistors are connected in parallel to the X-cap to provide a discharge path. The disadvantage is that discharge resistor produces constant power loss when AC is connected, making standby power consumption difficult to meet the requirements of strict specifications. Therefore, intelligent X-cap discharge is needed to improve standby power consumption. The intelligent X-cap discharge circuit is integrated in the WS2699. When the AC power failure is detected, it will automatically discharge the X-cap. In normal operation, the circuit will be turned off (if it is connected to the PFC output, the X-cap discharge function will be turned off).

Regulated power supply (VREG)

The VCC generates an 11V voltage output to the VREG pin via an internal voltage regulator. This output can be used to:

- IC pipe under internal LLC drive power supply
- tube on the bootstrap circuit to LLC drive power supply
- as an external reference voltage

The IC can output the driver only when the VREG voltage exceeds VREG_uvp (9.2V). When the VREG voltage is lower than VREG_uvp, the IC stops output the driver.

Upper tube floating power supply (BST)

The bootstrap power supply circuit of the upper tube is shown in Figure 2. VREG charges the CBST through the bootstrap diode DBST. When the voltage of BST is lower than VBST_OFF, the upper tube drive cannot be enabled.

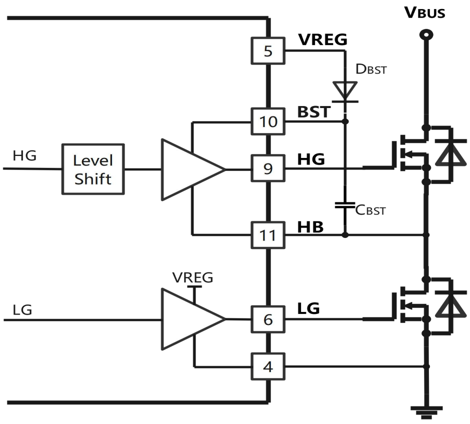


Figure 2

Input Brown-in/Brown-out protection (VIN)

The VIN pin is connected to the bus (previous PFC output) voltage through the outer part of the voltage resistance to detect the Brown-in/Brown-out state. If the VIN pin voltage is greater than the Brown-in threshold VBI voltage and lasts for a certain time (filter time tfilter(BI)), IC starts to output drive. If the VIN pin voltage is less than the Brown-out threshold VBO voltage for a certain amount of time (filter time tfilter(BO)), the IC stops the output drive until Brown-in is detected again.

Multi-mode control (VFB, VCR

WS2699 adjusts the output power by adjusting the voltage at both ends of the primary side resonant capacitor (Cr).

The input power of the resonant converter can be expressed as follows:

$$P_{in} = V_{BUS} \cdot I_{BUS} = V_{BUS} \cdot Cr \cdot \Delta V_{Cr} \cdot f_{SW} \quad (1)$$

It can be seen that the input power (which is related to the output power) is linearly correlated with the voltage variation ΔVCr on the resonant capacitor, so the output power can be adjusted by adjusting the voltage variation on the primary side resonant capacitor.

When the high-side switch is on, the primary side current flows through the transformer and the resonant capacitor Cr. Half of the energy provided by the input is transferred to the output. The other half charges the resonant capacitor Cr. The voltage at both ends of the resonant capacitor increases.

When the high side switch is off and the low side switch is on, the energy stored in the resonant capacitor Cr is transferred to the output, and its voltage is reduced. In this way, a linear relationship can be seen between the growth of the resonant capacitor voltage and the output power.

The feedback network composed of TL431 and optical coupler will give back the output load state in real time. The larger the optocoupling current, the lighter the output load, and the smaller the optocoupling current, the heavier the output load. For example, as the output load increases, the current pulled from the VFB pin will decrease. WS2699 increases the high level value of the resonant capacitor (Cr) voltage and decreases the low level value. According to formula (1), the output power increases.

WS2699 adjusts ΔVCr by sampling the optocoupler current, as shown in Figure 3. VCr(ref) is set according to the optocoupler current. When the capacitor voltage of Cr exceeds VCr(ref), the upper tube drives HG off, and the lower tube opens after delay. When Cr capacitor voltage is lower than VCr(ref), the lower tube drive LG is off, and the upper tube is opened after delay; The upper and lower tubes are symmetrically connected within one switching cycle.

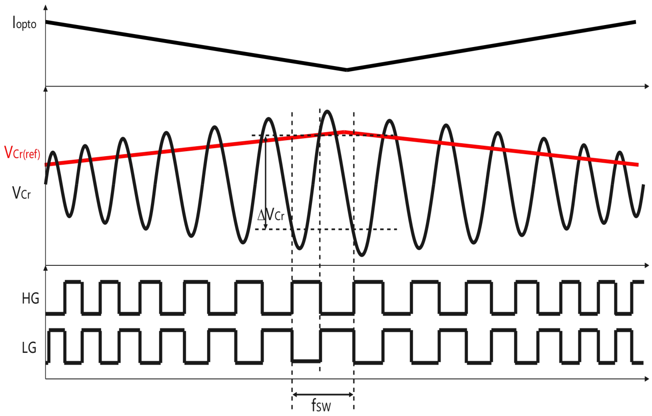


Figure 3

As the load becomes lighter, LLC switching frequency gradually increases and switching loss becomes larger and larger. WS2699 proposes a multi-mode control mode, which adopts different control modes under different load conditions to achieve full-range efficiency optimization.

The control modes under different load conditions are shown in FIG. 4. Under heavy load, IC works in Normal Mode, VCr(ref) decreases with the decrease of load, and the switching frequency increases slowly. When the power is reduced to P1, in order to reduce switching loss, IC works in Skip Mode. In this Mode, several switches are opened within a skip cycle, and then the switch is turned off for a period of time, which effectively reduces the switching frequency to achieve efficiency improvement. In order to prevent audio noise, the frequency of Skip Mode is generally greater than 25kHz. When the load is further reduced, the IC works in Burst Mode in order to optimize the no-load efficiency.

In order to independently optimize the light-load efficiency, Skip Mode is divided into two working modes. Skip Mode1 realizes frequency adjustment by locking the bottom of the half-bridge midpoint. Skip Mode2 realizes frequency adjustment through independent frequency curve. Through these two modes, the whole efficiency curve of light load can be optimized independently.

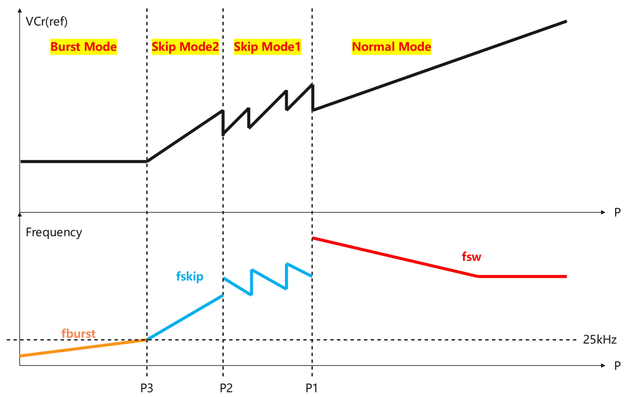


Figure 4

Resonant current detection (VCS)

The resonant current of WS2699 is realized by detecting the variation of the resonant capacitor voltage. Resonant current detection has the following purposes:

1. Capacitive mode detection: The zero crossing state of positive current and negative current is detected by two comparators respectively. The threshold voltage VCMR ranges from 20mV to 160mV, and is divided into 8 levels for selection on average.

2. Overcurrent protection. The threshold of overcurrent protection is 1.5V.

3. Zero crossing detection, the last upper tube in skip mode is shut off when the resonant capacitor current crosses zero.

Dead zone regulation (HB)

PROT pins are used for output overvoltage protection (OVP) and external overtemperature protection (OTP). Figure 5 shows the connection relationship under different applications. You can enable only one protection or both protection. The internal 80uA current is poured into the external NTC resistance to detect the overtemperature state, and the overtemperature threshold voltage is 0.8V. The overvoltage protection threshold voltage is 2.5V. When protection occurs, the IC stops the output drive.

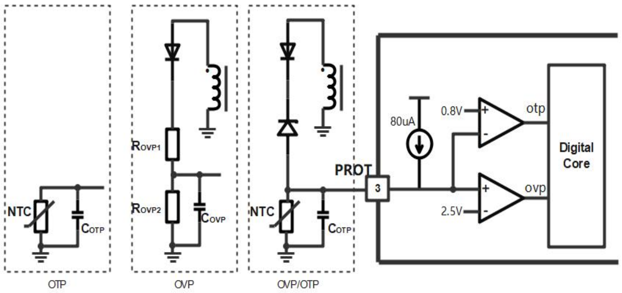


Figure 5

System Standby Optimization (GPIO)

GPIO can be used to optimize system standby power control, such as PFC standby control. When the system is running normally, GPIO pin output is low. When the system runs in no-load mode (Burst mode), the GPIO pin outputs high level and connects to the PFC circuit of the previous stage, so that the PFC of the previous stage also enters Burst mode and reduces the standby power consumption of the whole machine.

Protection control

WS2699 provides comprehensive protection features to ensure the reliability of system work. As shown in Table 1, the system includes input Brown-in/Brown-out protection, overpower protection (OPP), overcurrent protection (OCP), output short-circuit protection (SCP), output overvoltage protection (OVP), external overtemperature protection (OTP), and capacitable-mode regulation (CMR).

Overpower protection (OPP), overcurrent protection (OCP), output short-circuit protection (SCP), output overvoltage protection (OVP), and external overtemperature protection (OTP) can be independently configured. Overpower protection (OPP), output short-circuit protection (SCP), output overvoltage protection (OVP), and external overtemperature protection (OTP) can be configured independently.

Protection	Notes	Mode
BIBO	Input Brown-in/Brown--out	Real-time protection
OPP	Overpower protection	retry,hiccup,latch
CMR	Capacitive mode regulation	cycle-by-cycle
OCP	Overcurrent protection	cycle-by-cycle
SCP	Output short-circuit protection	retry,hiccup,latch
OVP	Output overvoltage protection	retry,hiccup,latch
OTP	External overtemperature protection	retry,hiccup,latch

If the protection is configured as latch, the VCC recovers only after a power failure. If the protection is set to retry or hiccup, the system stops working for a period of time (protection restart time tretry) and then restarts.

Overpower protection (OPP)

When the system detects that the optocoupler current is lower than the set value for a certain period of time (filter time tfilter(OPP)), the system generates OPP protection and stops the output driver.

Overcurrent protection (OCP)

The system adopts the cycle-by-cycle overcurrent protection control mode. During the upper tube turn-on, if the voltage of current sampling pin VCS exceeds +1.5V, the upper tube will be shut off immediately. If the voltage of current sampling pin VCS is lower than -1.5V during the down pipe turn-on, the down pipe will be shut off immediately.

Output short-circuit protection (SCP)

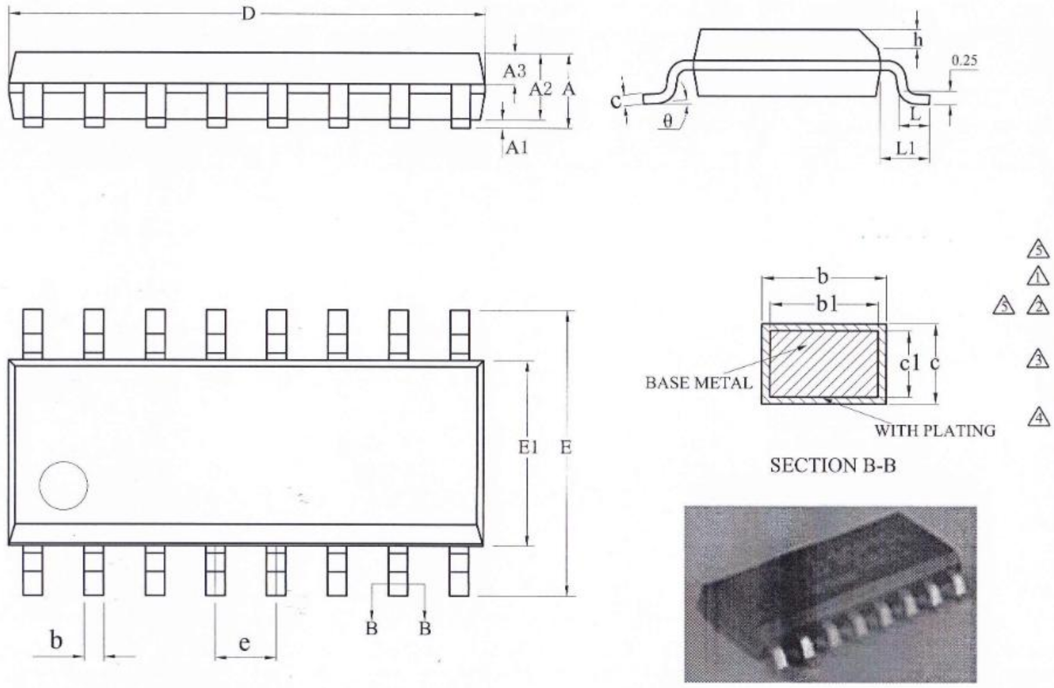
In case of an overcurrent, the internal counter will be increased by 1. In case of no overcurrent in consecutive NSCP_RST switching cycles, the counter will be cleared to zero. If the counter count value reaches NSCP, short circuit protection will occur and IC will stop output drive.

Capacitive mode regulation (CMR)

The system works in perceptual mode through capacitive mode adjustment mechanism. During the upper tube turn-on, if the resonant current is detected that is about to go down through the zero crossing (VCS<40mV), close the upper tube immediately; During the running of the lower tube, if it is detected that the resonant current is about to go down and up through the zero crossing (VCS>-40mV), close the lower tube immediately to avoid this operation mode

Package Outline

SOP16 Package Outline Dimensions



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.75
A1	0.10	—	0.225
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b (5)	0.39	—	0.47
b1 (1)	0.38	0.41	0.44
c (5) (2)	0.20	—	0.24
c1	0.19	0.20	0.21
D (3)	9.80	9.90	10.00
E	5.80	6.00	6.20
E1 (4)	3.80	3.90	4.00
e	1.27BSC		
h	0.25	—	0.50
L	0.50	—	0.80
L1	1.05REF		
θ	0	—	8°

NOTE:

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