SY22106

Secondary Side Flyback LED Controller

General Description

The SY22106 is a device which includes a LED controller and an operational amplifier. The single stage solution uses an external MOSFET to enable controlling a string of LEDs using Constant Current (CC) regulation, while also enabling creating a Constant Voltage (CV) output.

The controller is designed to simplify and reduce the solution cost for flyback converters used in LED backlight applications such as LCD panels for TV sets and computer monitors.

SY22106 has an 8~16V input voltage range. The operational amplifier integrates an internal voltage reference to facilitate creating a compensation network used to regulate the output voltage. The LED maximum current is programmed using an external resistor. The PWM input and Analog output dimming function allows accurate LED current control.

Features

- Single Stage Solution for CC and CV Output
- 8~16V Input Voltage Range
- Integrated Reference and Operational Amplifier
- Resistor programmable LED Current
- PWM Input Frequency: 10kHz~1MHz
- LED Open Protection
- LED Short protection
- LED Dimming MOSFET Drain and Source Short Protection
- Thermal Shutdown Protection
- SSOP10 Package

Applications

- TV and Monitor Panel Backlight

Typical Application

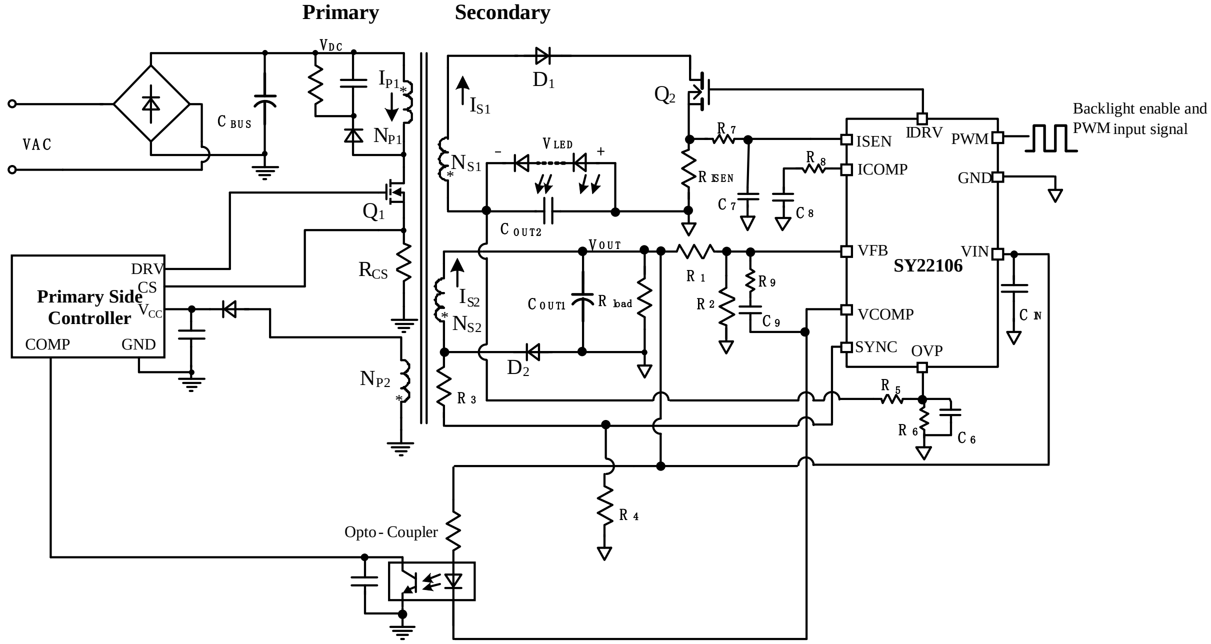


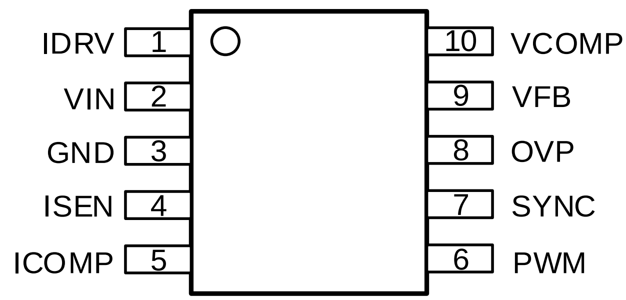
Figure1. Schematic Diagram

Ordering Information

Ordering Part Number	Package type	Top Mark
SY22106FHC	SSOP10 RoHS Compliant and Halogen Free	**BIW*xyz***

x=year code, y=week code, z= lot number code

Pinout (top view)



Pin Name	Pin Number	Pin Description
IDRV	1	Gate driver output for external MOSFET.
VIN	2	Power Supply pin. Decouple this pin to ground with a ceramic capacitor of at least 1µF.
GND	3	Ground pin.
ISEN	4	Current sense pin for LED current control.
ICOMP	5	Compensation pin for LED current control loop.
PWM	6	Backlight enable and PWM signal input pin.
SYNC	7	Secondary winding voltage transition detection pin.
OVP	8	LED string output voltage sense pin for LED open and short protection.
VFB	9	Feedback input for flyback CV output.
VCOMP	10	Compensation pin for flyback CV output.

Block Diagram

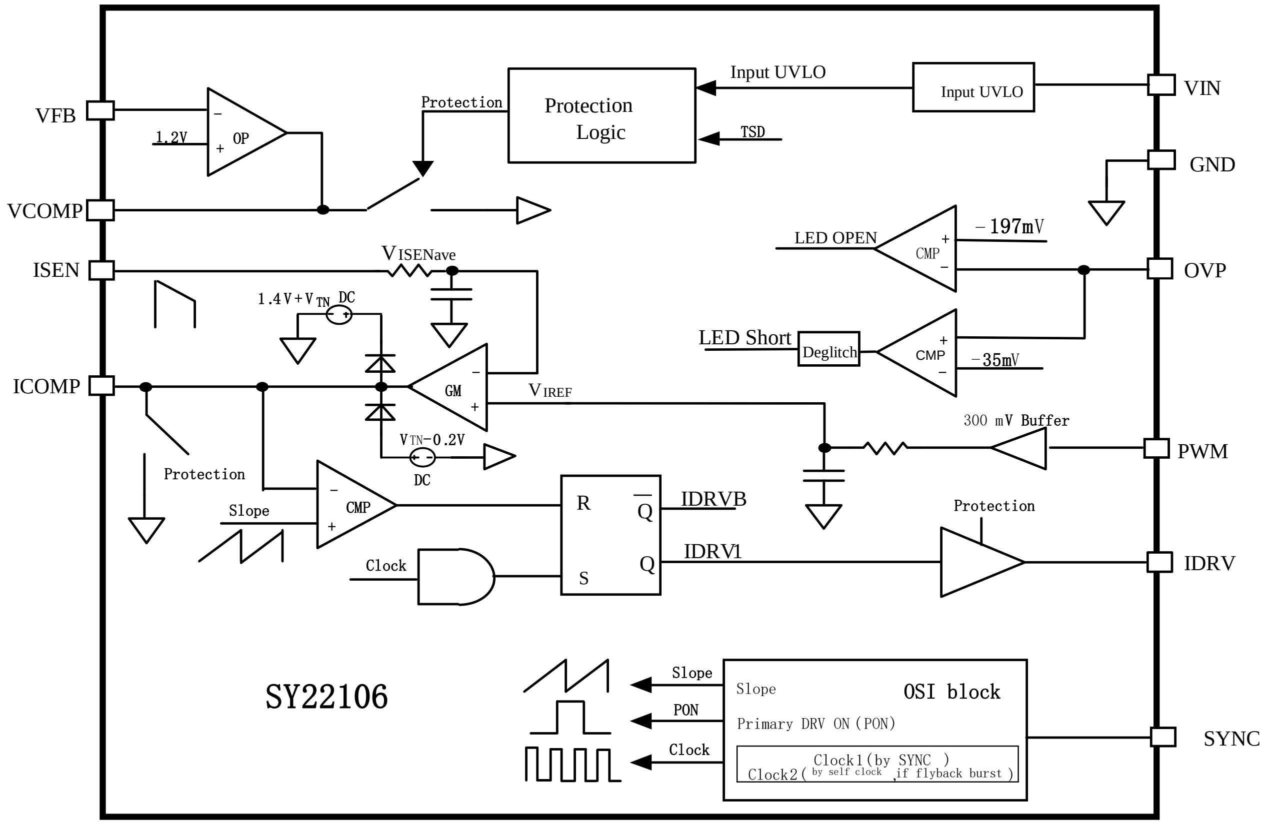


Figure2. Block Diagram

Absolute Maximum Ratings (1)	Min	Max	Unit
IDRV, IN, ISEN, ICOMP, PWM, SYNC, OVP, VFB, VCOMP	-0.3	18	V
Dynamic VFB Voltage in 200ns duration	IN+0.6	GND-0.7	V
Junction Temperature, Operating		150	°C
Lead Temperature (Soldering,10sec.)		260	
Storage Temperature	-55	150	

Thermal Information (2)	SSOP10	Unit
θ_{JA} Junction-to-ambient Thermal Resistance	126	°C/W
θ_{JC} Junction-to-case Thermal Resistance	31.5	
P_D Power Dissipation T_A=25°C	1	W

Recommended Operating Conditions (3)	Min	Max	Unit
IN	8	16	V
Ambient Temperature	-40	85	°C

Electrical Characteristics

Electrical Characteristics T_A = 25°C, V_{IN}=12V, C_{IN}=10µF, unless otherwise specified						
Parameter	**Symbol**	**Test Conditions**	**Min**	**Typ**	**Max**	**Unit**
Power Supply Range	V_{IN}		8		16	V
Quiescent Current	I_Q	PWM=0V VFB =1.3V	240	305	365	µA
VIN UVLO Rising Threshold	V_{IN_UVLO}		7		7.9	V
VIN UVLO Hysteresis	$V_{IN\_UVLOHYS}$	Falling edge		0.5		V
VFB Reference Voltage	V_{FB_REF}		1.188	1.2	1.212	V
ISEN Current Regulate Reference	$V_{ISENREF}$	R_{ISEN}=1Ω, I_{LED}=300mA	294	300	306	mV
Analog Output Current Accuracy	I_{LEDacc}	R_{ISEN}=1Ω, I_{LEDSET}=300mA, f_{PWM}=20kHz, PWM Duty=10%, I_{LEDacc}= (I_{LED}- I_{LEDSET} ×Duty)/I_{LEDSET}×Duty	-10		+10	%
IDRV Source Current	I_{DRV_SOURCE}	Peak current		0.2		A
IDRV Sink Current	I_{DRV_SINK}	Peak current		0.4		A
LED Open OVP Threshold	V_{OVP}		-211	-197	-184	mV
ICOMP Up Clamp	$I_{COMP\_Up\ Clamp}$		1.4	1.47	1.54	V
PWM High Level	V_{HPWM}		1.5			V
PWM Low Level	V_{LPWM}				0.4	V
Gain Bandwidth of Operational Amplifier	GBP			2		MHz
Operational Amplifier (OP) Sink Current	I_{SINK_MAX}			75		mA
Operational Amplifier (OP) Source Current	I_{SOURCE_MAX}			20		mA
Thermal Shutdown Temperature	T_{SD}			150		°C
Thermal Shutdown Hysteresis	T_{HYS}			20		°C

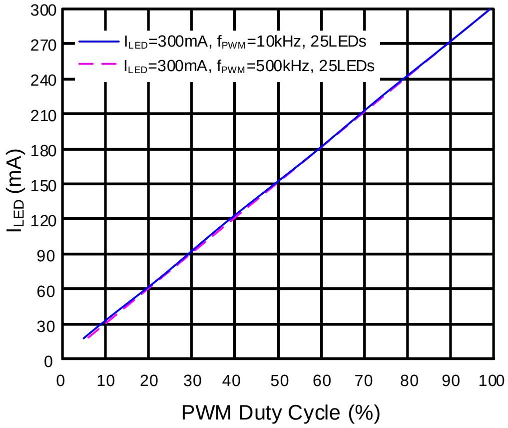
Note 1: Stresses beyond the "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on high effective four-layer thermal conductivity test board of JEDEC 51-2 thermal measurement standard. Test board is built according to JESD51-5 and 51-7.

Note 3: The device is not guaranteed to function outside its operating conditions.

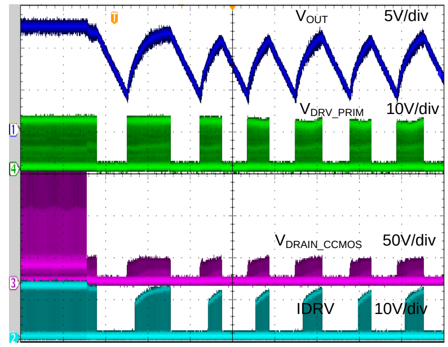
Typical Performance Characteristics

Analog Output Dimming Curve



LED Dimming MOSFET DS Short Protection

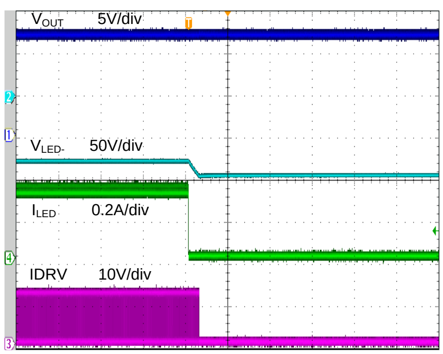
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



Time (10ms/div)

LED Open Protection

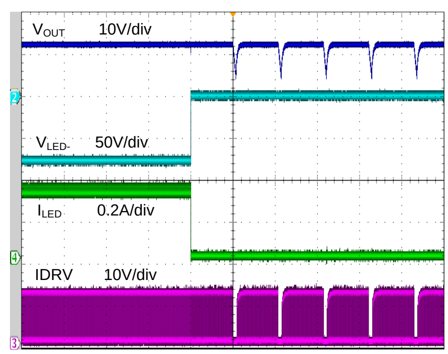
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



Time (10ms/div)

LED Short Protection

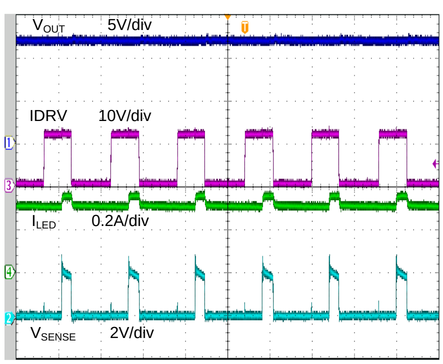
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



Time (100ms/div)

Steady Waveform ($V_{IN(AC)}$=110V)

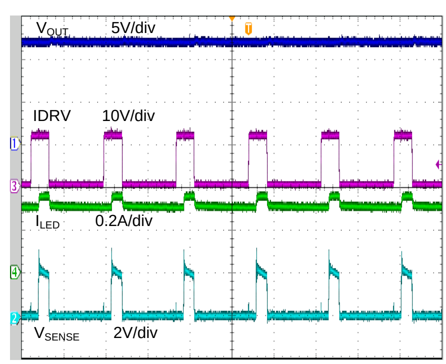
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



Time (10μs/div)

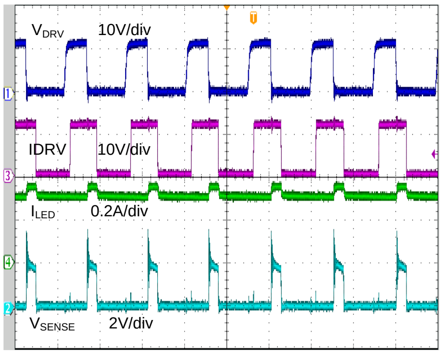
Steady Waveform ($V_{IN(AC)}$=220V)

(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



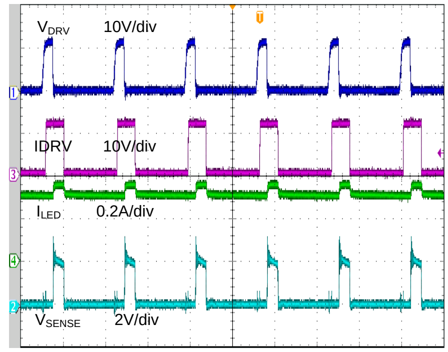
Time (10μs/div)

Steady Waveform ($V_{IN(AC)}$=110V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



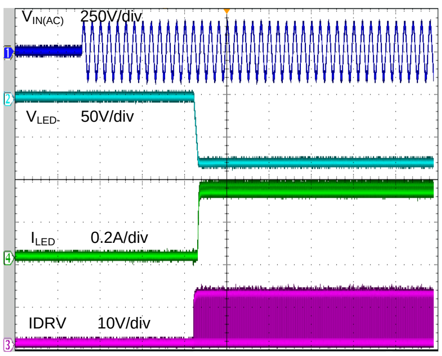
Time (10μs/div)

Steady Waveform ($V_{IN(AC)}$=220V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



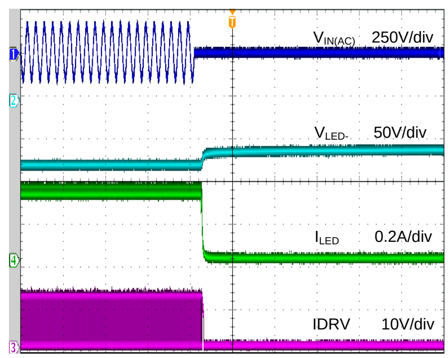
Time (10μs/div)

Power ON ($V_{IN(AC)}$=110V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



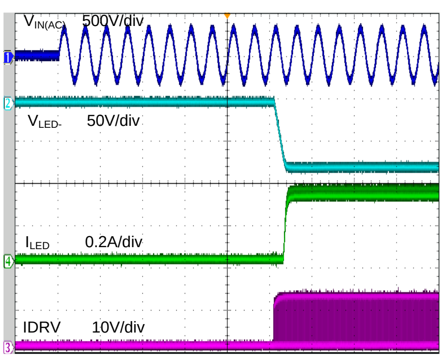
Time (100ms/div)

Power OFF ($V_{IN(AC)}$=110V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



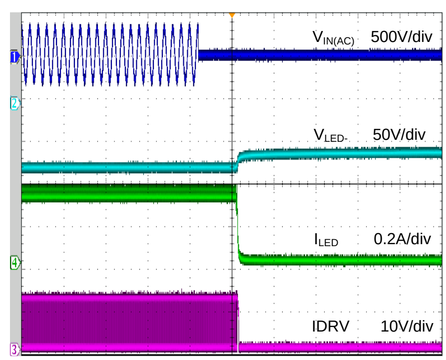
Time (100ms/div)

Power ON ($V_{IN(AC)}$=220V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



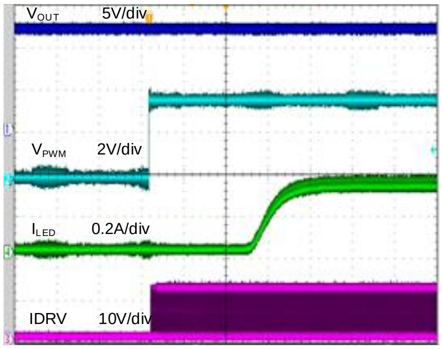
Time (40ms/div)

Power OFF ($V_{IN(AC)}$=220V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



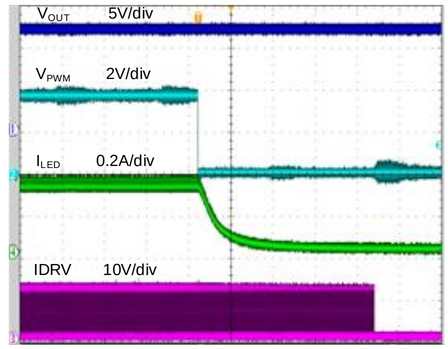
Time (100ms/div)

ADIM ON ($V_{IN(AC)}$=110V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



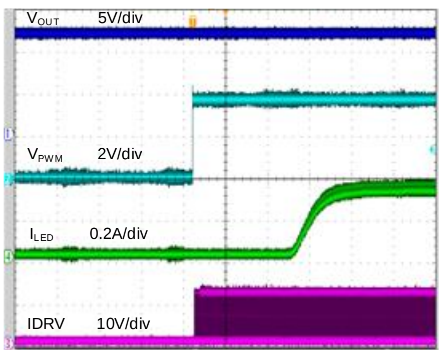
Time (4ms/div)

ADIM OFF ($V_{IN(AC)}$=110V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



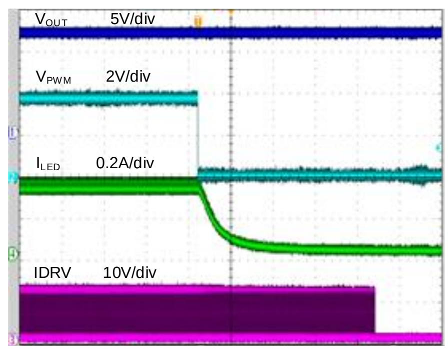
Time (4ms/div)

ADIM ON ($V_{IN(AC)}$=220V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



Time (4ms/div)

ADIM OFF ($V_{IN(AC)}$=220V)
(V_{OUT}=12V, I_{OUT}=3A, V_{LED}=80V, I_{LED}=300mA)



Time (4ms/div)

Functional Description and Applications Information

1. Control Strategy for Energy Transfer between the LED (CC Output) and the DC Output (CV) Windings

The detailed operation is shown below in figures 3 and 4. When the primary side MOSFET Q1 is turned on by the primary side controller, the LED winding MOSFET Q2 will be turned off by SY22106. During this phase, energy from the power input V_{DC} flowing through the primary winding N_{P1} is stored in the airgap of the transformer ferrite core. When Q1 turns off, the stored energy will be transferred to the LED winding N_{S1}, thus providing energy for the LED string. When Q2 is turned off by SY22106, the rest of the energy from the N_{S1} winding will be transferred to the DC output winding for regulating the CV output. This completes a full switching cycle, and a new cycle can be initiated by the primary side controller.

When the LED winding N_{S1} outputs energy to LED string, the DC output winding doesn't output energy to its load. When Q2 is turned off, the remaining LED winding's energy will be transferred from N_{S1} to the DC output winding N_{S2} which will supply its load immediately. For the above mechanism to operate correctly, the flyback transformer winding turn ratio (N_{S2}/N_{S1}) must meet the equation described below:

$$(V_{LED}+V_{D1}+V_{Q2}+V_{SEN}) \times N_{S2}/N_{S1}<V_{OUT}+V_{D2}$$

Simplifying:

$$V_{LED}\times N_{S2}/N_{S1}<V_{OUT}$$

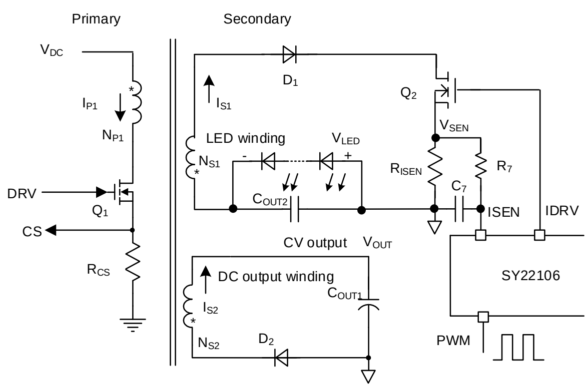
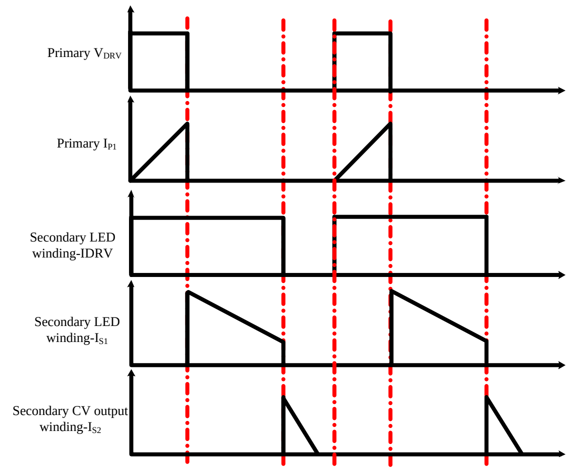
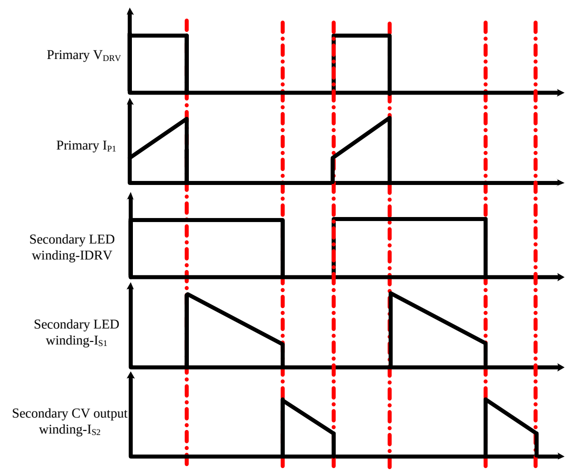


Figure3.Operation Schematic Diagram



Discontinuous Conduction Mode operation (DCM)



Continuous Conduction Mode operation (CCM)

Figure4.Operation Waveform

2. SYNC Application Information

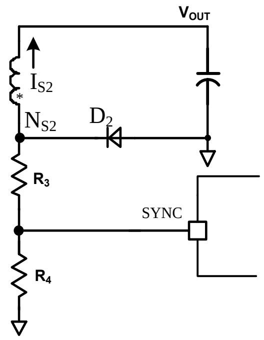


Figure5. SYNC Application Circuit

Across the entire input voltage range for the primary side (V_{DC}), the maximum voltage at the SYNC input must be higher than 1.2V in order to provide the internal clock signal for IDRV.

Calculation Example: If the AC input voltage range $V_{IN(AC)}$ is 90Vac to 264Vac, considering an input capacitor voltage ripple of about 30%, when VAC=90Vac, the minimum VDC voltage is 90 ×1.414 ×(1-30%)=89V; when VAC=264Vac, the minimum VDC voltage is 264 × 1.414 ×0.7=261V.

When the flyback primary MSOFET is ON, the SYNC voltage can be calculated as:
$V_{SYNC} = (V_{OUT}+VDC \times N_{S2}/ N_{P1}) \times R_4/ (R_3+R_4)$
Using N_{S2}/N_{P1}=1/8, V_{OUT}=12V for VAC=90Vac, V_{SYNC}= $(12+89\times1/8) \times R_4/(R_3+R_4)>1.2\times120\%$,
A design margin of 120% was used in this example.
The calculated resistor values are:
$R_3<15\times R4$. R3=1200kΩ, R4=82kΩ

Design Verification:
When VAC=90Vac,
V_{SYNC} =(12V+89V×1/8) × 82k/(1200k+82k) = 1.479V.

When VAC=264Vac,
V_{SYNC} =(12V+261V×1/8) × 82k/(1200k+82k) = 2.85V.

3. LED Current Setting and Analog Output Dimming

If the PWM high level on PWM pin is longer than 100ns (Typical Value), the backlight function is enabled. If the low PWM level is longer than 20ms (Typical Value), the backlight will be turned off.

In figure 2, when the backlight function is enabled, the LED current will be regulated according to the PWM signal driving the PWMM pin using the following formula: I_{LED}=300mV×(PWM Duty Cycle)/R_{ISEN}.
It is recommended that the PWM frequency is higher than 10kHz and the minimum high level is than 100ns.

To get good LED current accuracy, the peak voltage of ISEN signal needs to be less than 2V.

4. DC Output Feedback and Operational Amplifier (OP)

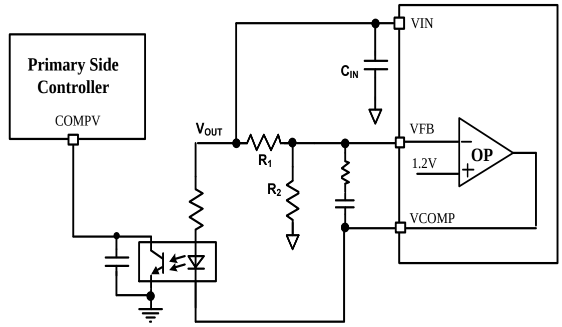


Figure6. DC Output Feedback Application Circuit

In figure5, SY22106 regulates the DC output voltage using the integrated reference and the operational amplifier (OP). The inverting input of the operational amplifier is connected to the VFB pin, the non-inverting input is connected to the internal reference voltage with a nominal value of 1.2V, and the operational amplifier output is connected to the VCOMP pin.

Calculation example: In figure 6 resistors R_1 and R_2 are configured to program the Output voltage V_{out} For a design with the requirement:
V_{out} = 12V .
Select R_2=2.49kΩ and calculate R_1 using the following equation:
$V_{out} = (1+ R_1/ R_2) \times 1.2V$
R_1 = (12V/ 1.2V-1)×2.49kΩ=22.41 kΩ.

5. LED Open/Short Protection

The SY22106 monitors the LED string Cathode node voltage for LED Open/Short protection. Because the LED string Anode node is connected to GND, the LED string voltage at the Cathode node is negative.

For the LED Open fault, the internal reference voltage is -197mV (typical value). If the voltage at the OVP pin goes below the threshold, the ICOMP and IDRV outputs will be pulled down, and the backlight LED string is turned off. During this condition the VFB and VCOMP will continue to operate and provide power to the DC output (CV) rail. The LED Open protection fault condition features a latch off function.
Clearing the fault condition and restarting normal operation can be done following one of the following steps:

1. PWM pin is pulled down for more than 20ms then pulled high for more than 100ns.
2. Power Recycle – Decrease VIN below the device UVLO threshold to turn off SY22106, and then turn power back on.

Note: The thermal protection also clears the LED Open fault.

For the LED Short fault, the internal reference voltage is -35mV (typical value). If the voltage at the OVP pin falls below the reference voltage for a duration longer than the deglitch time (2ms), the SY22106 will drive low the ICOMP output to shutdown IDRV and pull down V_{COMP}. The primary controller's COMP pin voltage will also decrease to shutdown primary side MOSFET. In this case the flyback converter will stop transferring energy to secondary side.

The below condition can clear the LED Short fault protection:

1. The flyback converter stops transferring energy to secondary side which makes VIN decrease below 4V to clear the fault, then increase VIN above the UVLO threshold to turn on the device.

Note: The thermal protection also clears the LED Short fault.

Design example:
In figure 7 resistors R_5 and R_6 are configured to program the LED open/short thresholds.
For a design with the following requirements:
Normal operating voltage of the LED string = 80V
LED open protection threshold = 100V,
Select R_6=1.5kΩ
Calculate R5 using the following equation:

$$R_5=(\frac{V_{LED-}}{V_{OVP}}-1)\times R_6$$

$R_5 = [(-100V)/ (-0.197V)-1] \times 1.5k\Omega$.
A value of 760kΩ is selected for R5.

Note: R_5 and C_6 form a RC filter used to suppress noise, to avoid triggering OVP in noisy environments.

Using the above resistors and given the internally set threshold, the corresponding LED short protection will trigger for voltages above -17.8V.

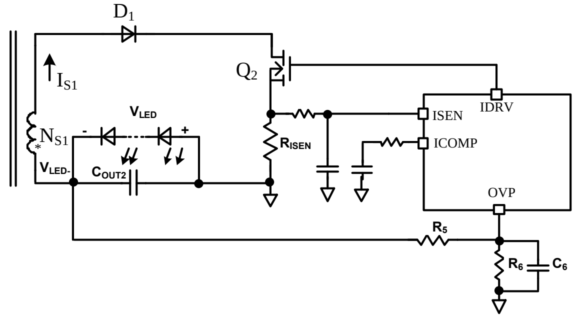


Figure7. LED Open/Short Protection Application Circuit

6. LED Dimming MOSFET Drain Source Short Protection

For the secondary LED dimming MOSFET Drain and Source short detection, an internal threshold voltage is set 100 mV above the dimming reference. If the voltage at the ISEN input is higher than this internal threshold voltage for a duration of longer than 2 ms, the SY22106 will trigger the fault condition. As a result the ICOMP output will be driven low to shutdown IDRV and pull down V_{COMP}, then the primary COMPV voltage will also decrease to shutdown primary MOSFET. In this case the flyback converter will stop transferring energy to the secondary side.

The below condition can clear LED dimming MOSFET short fault:

1. The flyback converter stops transferring energy to secondary side which makes VIN decrease below 4V to clear the fault, then increase VIN above the UVLO threshold to turn on IC again

Note: The thermal protection clears the LED dimming MOSFET Drain-Source short fault.

7. Thermal Shutdown Protection

When the die temperature increases above T_{SD}, the device will enter thermal protection, and the nodes IDRV, ICOMP, VCOMP will be pulled down to turn off the LED string and the DC output. The primary controller COMP pin voltage will decrease to shutdown the primary MOSFET which will stop transfer energy from the input. The device resumes normal operation when the die temperature falls below T_{SD} -T_{HYS}.

8. Layout Design:

Proper PCB layout and component placement are critical to the performance of the device and for preventing noise and electromagnetic interference problems.
Follow the guidelines below for proper PCB layout:

1) The loop formed by the LED winding, rectifier diode, MOSFET and output capacitor must be as short as possible.

2) The loop formed by the 12V winding, output capacitor and rectifier diode must be as short as possible.

3) The input capacitor C_{IN} must be close to the Device VIN and GND pins. The loop area formed by C_{IN} and GND must be minimized.

4) The IDRV, ISEN, SYNC pin connections must be as short as possible.

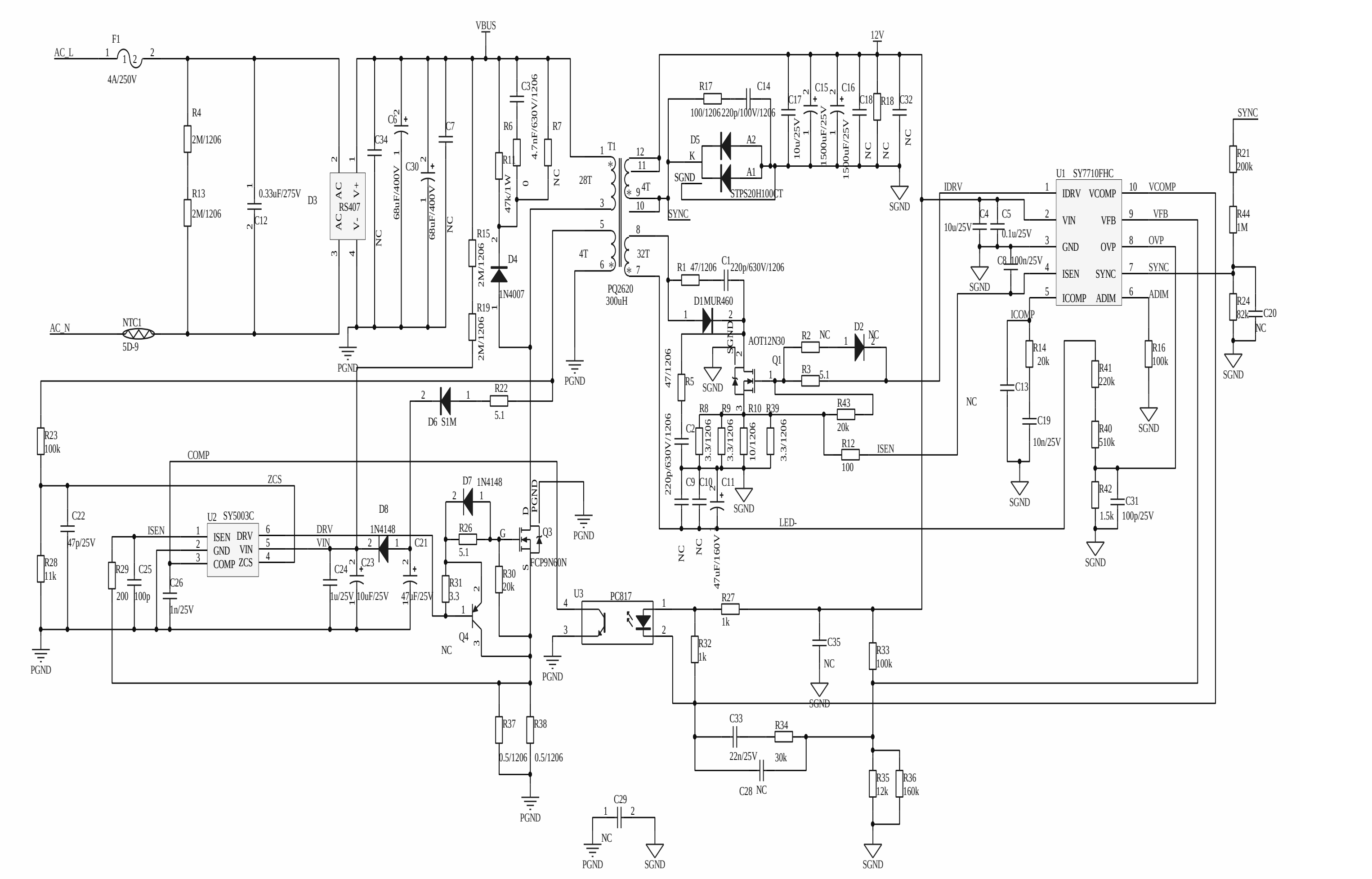
5) Place the ICOMP RC filter components close to ICOMP pin.

6) Place the VCOMP RC filter components must close to the VCOMP pin.

7) Split power ground and signal ground and connect them together in an optimal place to avoid the power ground currents crossing and creating interference on the signal ground.

Typical Application Schematic

Input Voltage (V)	CV Output configuration	LED configuration
90~264V_{AC}	12,3A	25LEDs, 300mA

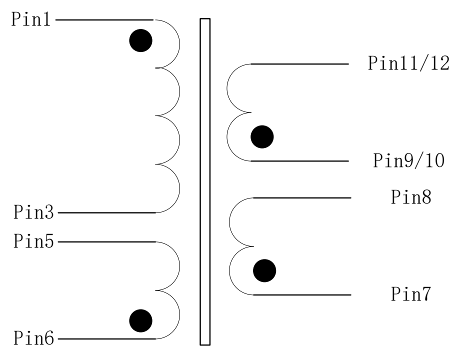


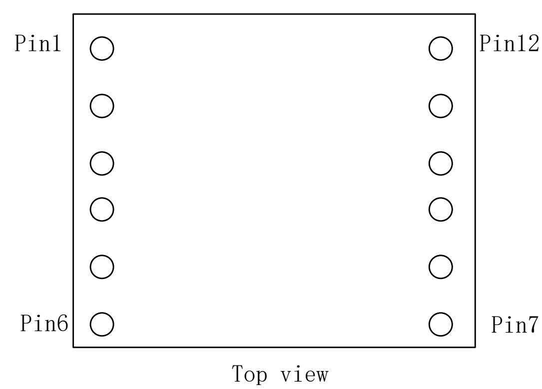
BOM List

Designator	Comment	Footprint
C_1, C_2	220pF/630V	1206
C_3	4.7nF/630V	1206
C_4	10µF/25V	0805
C_5	0.1µF /25V	0603
C_6, C_{30}	68µF /400V	Ecap
C_7, C_9, C_{10}, C_{18}, C_{32}, C_{34}	NC	
C_8	100nF/25V	0603
C_{11}	47µF /160V	Ecap
C_{12}	0.33µF /275V	X-cap
C_{13}, C_{20}, C_{28}, C_{29}, C_{35}	NC	
C_{14}	220p/100V	1206
C_{15}, C_{16}	1500µF /25V	Ecap
C_{17}	10µF /25V	1206
C_{19}	10nF/25V	0603
C_{21}	47µF /25V	Ecap
C_{22}	47pF/25V	0603
C_{23}	10µF /25V	Ecap
C_{24}	1µF /25V	0603
C_{25}	100pF	0603
C_{26}	1nF/25V	0603
C_{31}	100pF/25V	0603
C_{33}	22nF/25V	0603
D_1	MUR460	MUR460
D_2	NC	
D_3	RS407	RS407
D_4	1N4007	DO41
D_5	STPS20H100CT	TO220
D_6	S1M	SMA
D_7, D_8	1N4148	SOD-323
F_1	T4A/250V	FUSE
NTC1	5D-9	NTC
Q_1	AOT12N30	TO220
Q_3	FCP9N60N	TO220
Q_4	NC	
R_1, R_5	47/1206	1206
R_2, R_7, R_{18}	NC	
R_3, R_{22}, R_{26}	5.1Ω	0805
R_4, R_{13}, R_{15}, R_{19}	2MΩ	1206
R_6	0Ω	1206
R_8, R_9, R_{39}	3.3Ω/1206	1206
R_{10}	10Ω/1206	1206
R_{11}	47kΩ/1W	
R_{12}	100Ω	0603
R_{14}, R_{30}, R_{43}	20kΩ	0603
R16, R23, R_{33}	100kΩ	0603

R_{17}	100Ω	1206
R_{21}	200kΩ	0603
R_{24}	82kΩ	0603
R_{27}, R_{32}	1kΩ	0603
R_{28}	11kΩ	0603
R_{29}	200Ω	0603
R_{31}	3.3Ω	0805
R_{34}	30kΩ	0603
R_{35}	12kΩ	0603
R_{36}	160kΩ	0603
R_{37}, R_{38}	0.5Ω	1206
R_{40}	510kΩ	0603
R_{41}	220kΩ	0603
R_{42}	1.5kΩ	0603
R_{44}	1MΩ	0603
T_1	PQ2620	
U_1	SY22106FHC	SSOP10
U_2	SY22813C	SOT23-6
U_3	PC817	PC817

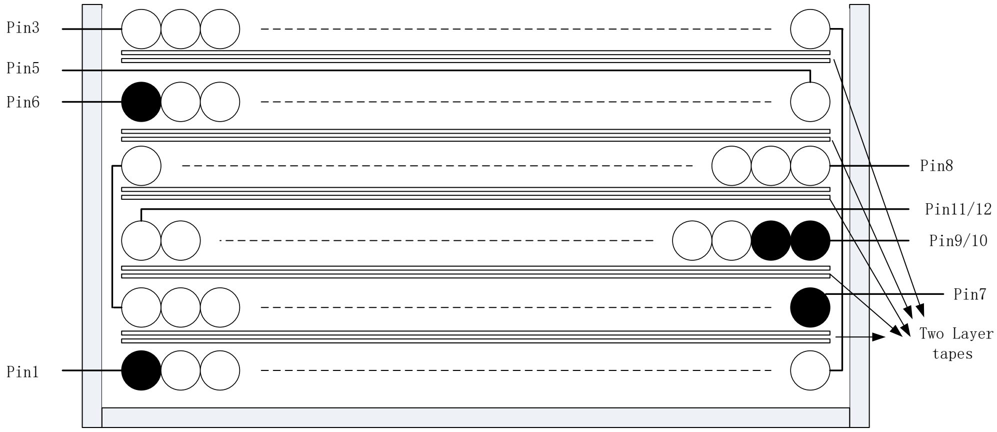
Transformer Design Specifications





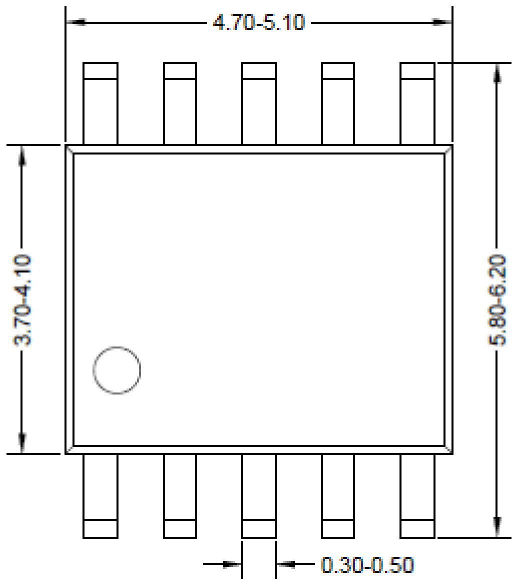
Temperature:25±5℃ Humidity:65±25%
Test Condition: 50kHz, 1V
L:PIN(1-3)=300μH±5%

Winding	Wire diameter*Number	Pin		TS	Insulating Tape (TS)
		IN	OUT		
N1	Φ0.3*2(2UEW)	1	3	28	2
N2	Φ0.3(2UEW)	6	5	4	2
N3	Φ0.6(TEX-E)	7	8	32	2
N4	Φ0.8*2(TEX-E)	9，10	11，12	4	2

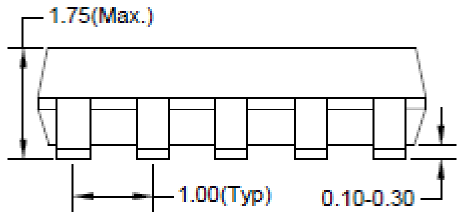


Transformer Structure

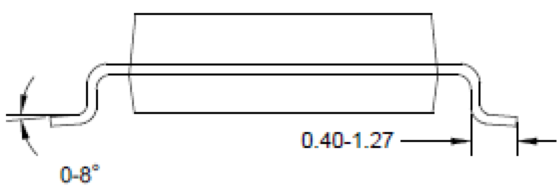
SSOP10 Package Outline



Top View



Side View A

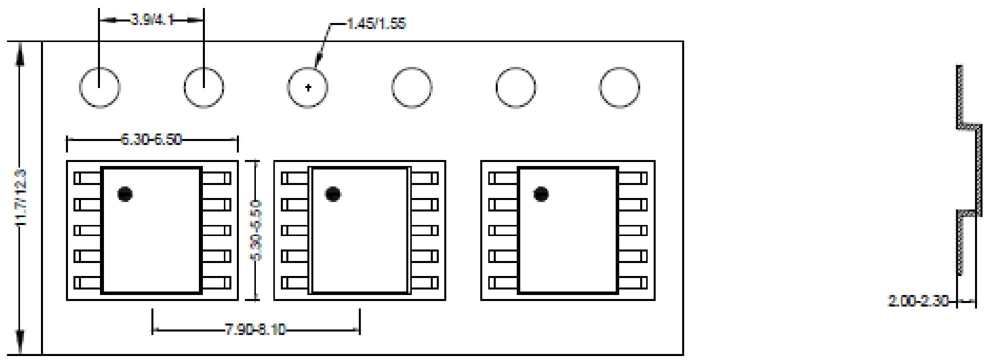


Side View B

Notes: All dimension in millimeter and exclude mold flash & metal burr.

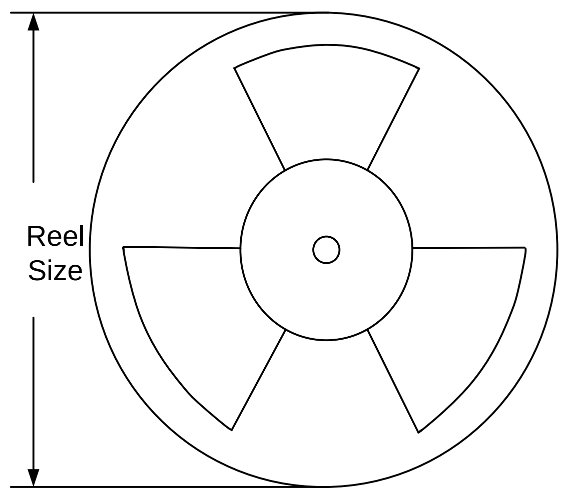
Taping & Reel Specification

1. SSOP10 taping orientation



Feeding direction →

2. Carrier Tape & Reel specification for packages



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer length(mm)	Leader length (mm)	Qty per reel
SSOP10	12	8	13"	400	400	2500

3. Others: NA

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	Revision	Change
December 17, 2019	Revision 1.0	Production Release
December 17, 2018	Revision 0.9	Initial Release

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