SY22748

Charge Pump PFC LLC Low side controller, High PF, Low THD

General Description

SY22748 is the low side LLC controller integrated with a 500V MOSFET, it is used in charge pump PFC application. High PF is achieved by inherent PFC function and low LED current ripple is achieved by LLC topology. Single stage structure and primary side regulation save BOM cost a lot. Meanwhile, LLC topology improves efficiency and EMI.

It should work with SY22749, which is the high side LLC controller integrated with a 500V MOSFET.

Ordering Information

SY22748□(□□)□
- Temperature Code
- Package Code
- Optional Spec Code

Ordering Number	Package type	Note
SY22748FAC	SO8	----

Features

- Integrated 500V MOSFET
- Charge Pump PFC LLC Topology with Low BOM Cost
- PF>0.95, THD<20%
- Primary Side I_{LED} Regulation and Less than 2% I_{LED} Ripple
- Short LED Protection (SLP), Open LED Protection (OLP), E-cap over Voltage Protection (HV OVP)
- Zero Voltage Overshoot on Resonant Capacitor at Startup
- Compact Package: SO8

Applications

- LED Lighting

Recommended operating output power @ Vout=42V	
Products	198~264Vac
SY22748	42W

Typical Applications

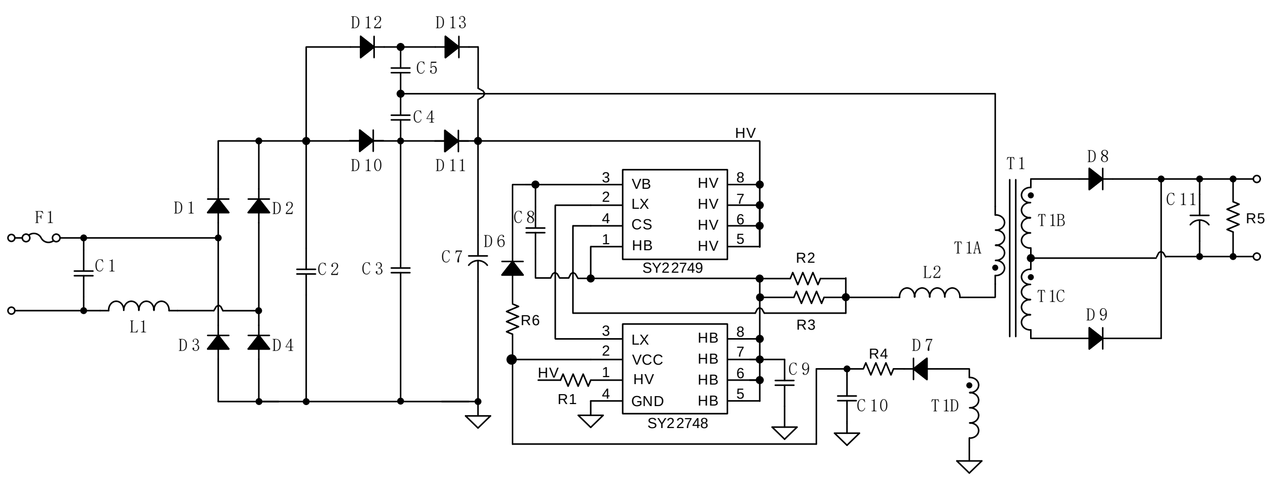


Figure.1a Typical Application

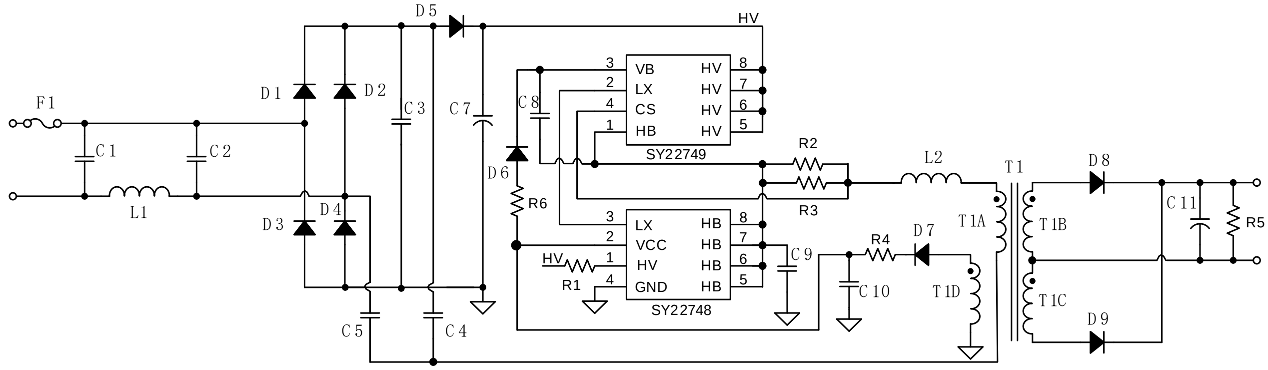


Figure.1b Typical Application

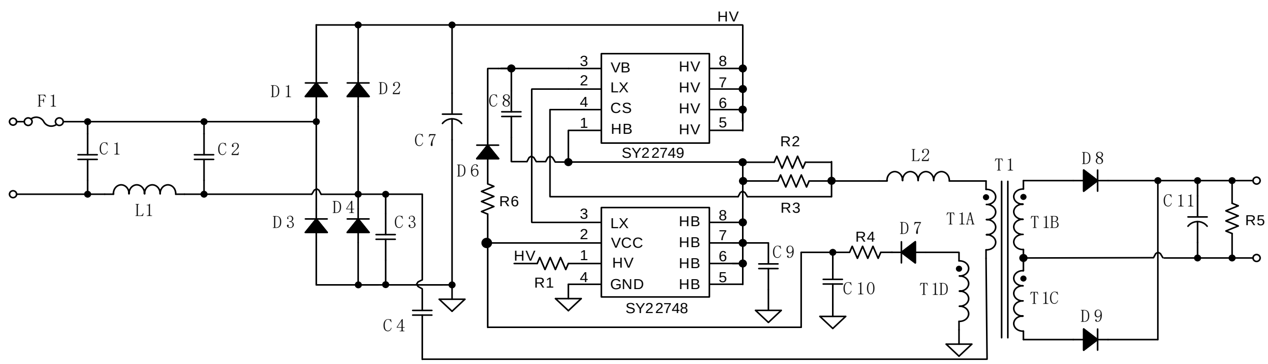


Figure.1c Typical Application

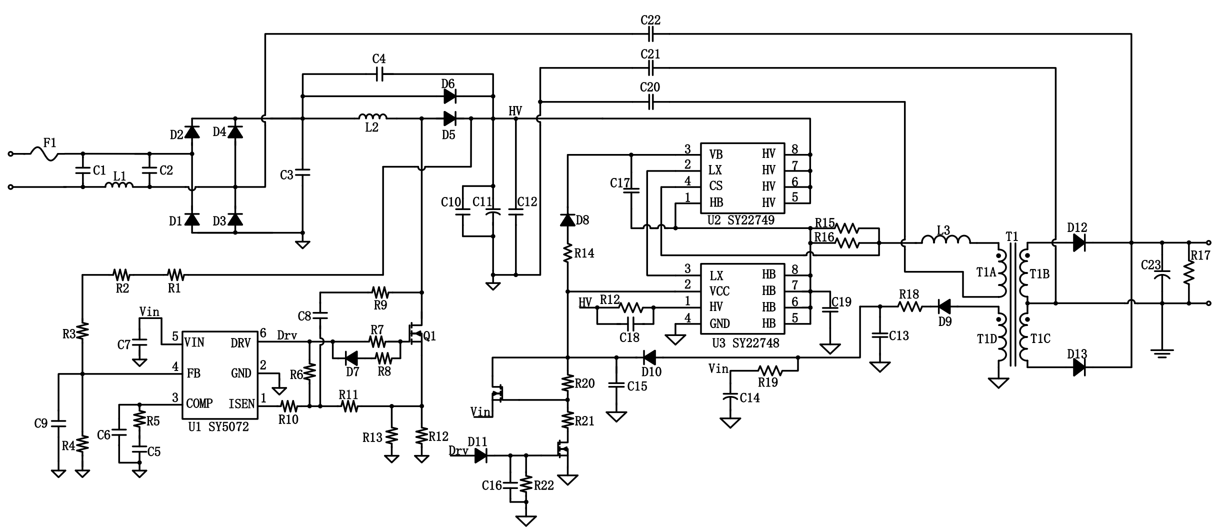
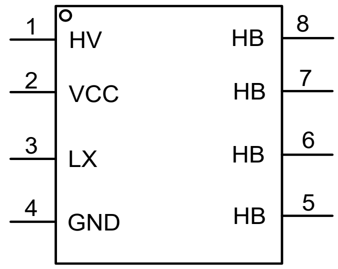


Fig.1d LLC LED Driver with Front End PFC

Pinout (top view)



（SO8）

Top Mark: CUG *xyz* (device code: CUG, ***x=year code, y=week code, z= lot number code*)**

Pin Name	Pin number	Pin Description
HV	1	HV start pin, HV OVP and HV UVP sense pin.
VCC	2	Bias supply for low side circuit, LED OVP detection.
LX	3	Low side driver control pin. This pin receives the control signal from SY22749, internal voltage comparator and slope detection circuit can provide reliable switching strategy of internal MOSFET.
GND	4	Ground pin for low side circuit. Source of low side internal 500V MOSFET.
HB	5-8	Drain of internal 500V MOSFET.

Block Diagram

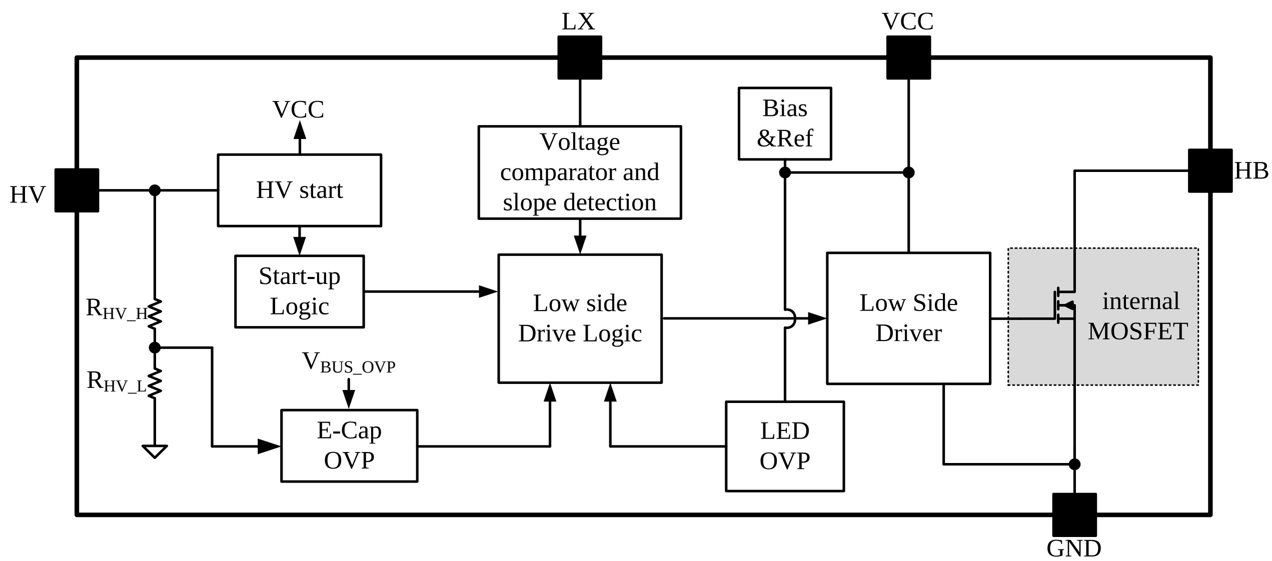


Figure.3 Block Diagram

Absolute Maximum Ratings (Note 1)

HV -- -0.3V ~ 600V
VCC -- -0.3V ~ 36V
LX -- -0.6V ~ 600V
HB -- -0.6V ~ 500V
Power Dissipation, @ TA = 25°C SO8 -- 1.1W
Package Thermal Resistance (Note 2)
SO8, θ_{JA}-- 88°C/W
SO8, θ_{JC}-- 45°C/W
Maximum Junction Temperature -- 150°C
Lead Temperature (Soldering, 10 sec.) -- 260°C
Storage Temperature Range -- -65°C to 150°C

Recommended Operating Conditions

Junction Temperature Range -- -40°C to 150°C
Ambient Temperature Range --- -40°C to 120°C

Electrical Characteristics

(V_{IN} = 15V, T_A = 25°C unless otherwise specified)

Low Side Controller						
Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Supply Section						
VCC Turn-on Threshold	V_{VCC_ON}		10.6	11.4	12.2	V
VCC Turn-off Threshold	V_{VCC_OFF}		7.2	7.9	8.6	V
VCC OVP Voltage	V_{VCC_OVP}		26.0	27.8	29.6	V
Quiescent Current	I_Q	before V_{VCC_ON}	190	245	300	µA
HV Start up Current	I_{ST_HV}		1.4	2.0	2.6	mA
MOSFET Section						
MOSFET Rdson	R_{dson}		0.75	1	1.25	Ω
Breakdown Voltage	V_{BV}	V_{GS}=0, I_{DS}=250µA	500	540		V
HV Section						
HV OVP	V_{HV_OVP}		455	483	511	V
HV UVP	V_{HV_UVP}		160	178	196	V
Logic Section						
MIN_ON	T_{MIN_ON}		400	525	650	ns

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 a low effective single layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard. Test condition: Device mounted on 2” x 2” FR-4 substrate PCB, 2oz copper, with minimum recommended pad on top layer and thermal vias to bottom layer ground plane.

Operation

SY22748 is the low side LLC controller integrated with a 500V MOSFET, it is used in charge pump PFC application, which is targeting at LED lighting applications. High PF is achieved by inherent PFC function and low LED current ripple is achieved by LLC topology. Single stage structure and primary side regulation save BOM cost a lot.

SY22748 contains reliable turn on and turn off logic, which can avoid LLC half bridge shoot through and support high switching frequency more than 200kHz. SY22748 also adopts special design to achieve zero voltage overshoot on resonant capacitor at startup. It also uses slope detection function to make sure the valley turn on of MOSFET to achieve higher efficiency.

LLC topology improves efficiency and EMI, furthermore, one external NP0 capacitor can be put between midpoint between LLC half bridge and GND point (or BUS point) to further improve system performance.

SY22748 provides reliable protections including short circuit protection (SCP), open LED protection (OLP), and E-cap over voltage protection (HV OVP).
SY22748 is available with SO8 package, and should work with SY22749, which is the high side LLC controller integrated with a 500V MOSFET.

Applications Information

Start up
After AC supply or DC BUS is powered on, capacitor C_{VCC} across VCC and GND pin is charged by internal current source. This current source comes from HV pin, which is connected to V_{BUS} through one external resistor R_{HV_EXT}.

The whole start up process can be divided into 4 sections shown in Fig.3, HO and LO are internal gate of SY22749 and SY22748, respectively. t_{STC1} is the C_{VCC} charging up section. t_{STD} is midpoint HB voltage and HV voltage detecting section, during this time, C_{VCC} will charge back and forth between V_{VCC_ON} and V_{VCC_OFF}, until HB voltage is below 6V and HV voltage is lower than HV OVP. SY22748 provides a constant internal current to pull down HB voltage through LX pin, so when MOSFET of SY22748 is turned on, there won't be large resonant current flowing through resonant capacitor. After the above two conditions are met, SY22748 will exit t_{STD} stage and enter into t_{STC2} stage. t_{STC2} is the C_{VCC} together with C_{VB} charging up section, once V_{VB} reaches V_{VB_ON}, internal MOSFET of SY22748 is turned off, switching control starts to work and HV pin stops to provide charge current. t_{STO} is the output voltage building up section, V_{VCC} and V_{VB} will be pulled down by internal consumption current until the auxiliary winding of LLC transformer can supply enough energy to maintain V_{VCC} above V_{VCC_OFF}.

Design of HV pin resistor R_{HV_EXT}, C_{VCC} and C_{VB} is not strict, below are some suggestions:
a) Use R_{HV_EXT} smaller than 200kohms, resistance of R_{HV_EXT} will influence E-cap over voltage protection (HV OVP).
b) Use C_{VCC} larger than 470nF, use C_{VB} larger than 100nF, there no need to use very large C_{VCC} or C_{VB} capacitor, suggest using 2uF C_{VCC} and 1uF C_{VB}.
c) If C_{VCC} and C_{VB} are not big enough to build up output voltage at one time, increase C_{VCC} and C_{VB}, or check whether the output E-cap is too large.

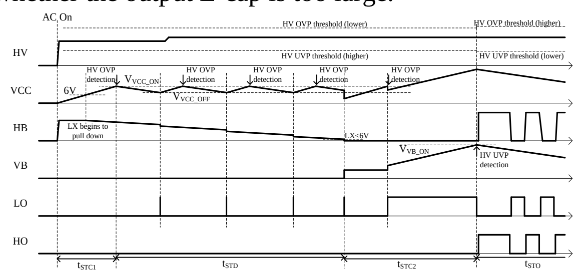


Fig.3 Start up Process of SY22748 and SY22749

After V_{VB_ON} and high side MOSFET is turned on, soft start up function works, it prevents resonant current from being too high at start up. Switching frequency is fixed at maximum switching frequency f_{SW_MAX} during the first few resonant periods.

Shut down
After AC supply or DC BUS is powered off, LLC still works for a while to consume the energy stored in input E-cap. During this time, auxiliary winding can still provide stable VCC voltage so SY22748 and SY22749 can continue with the internal working logic. Once HV pin voltage reaches E-cap under voltage protection (HV UVP), SY22748 will keep internal MOSFET off and SY22749 will turn off its internal MOSFET soon.. Once high side and low side MOSFET are turned off, C_{VCC} and C_{VB} will discharge, discharge current of C_{VCC} is quiescent current of SY22748 and discharge current of C_{VB} is constant 6mA. Usually, V_{VB} reaches V_{VB_OFF} earlier than V_{VCC} reaches V_{VCC_OFF}. When V_{VB} reaches V_{VB_OFF}, 6mA discharge current will be removed. When V_{VCC} reaches V_{VCC_OFF}, SY22748 will restart and HV pin starts to provide charge current.

To avoid flashback after shut down, SY22748 adopts a hysteresis loop at HV UVP threshold, the lower threshold is used at normal shut down process, and the higher threshold is used at start up process. After V_{VB} reaches V_{VB_ON}, SY22748 detects HV voltage to determine whether it's enough. So after system shut down, HV voltage needs to be higher to restart up successfully and flashback is avoided.

Short LED protection (SLP), open LED protection (OLP), E-cap over voltage protection (HV OVP)

SLP: When output is in short circuit condition, auxiliary winding cannot provide charge current to C_{VCC}, so C_{VCC} and C_{VB} will discharge synchronously by operating current consumption. Once V_{VB} reaches V_{VB_OFF}, SY22749 will turn off MOSFET and pull down LX pin from VB to HB. Later when V_{VCC} reaches V_{VCC_OFF}, SY22748 begins to restart.

OLP: Output voltage is reflected by auxiliary winding of LLC transformer, V_{VCC} is proportional to output voltage. When the load is null, secondary side current of LLC transformer will charge output E-cap continuously and V_{VCC} will increase. Once V_{VCC} reaches V_{VCC_OVP}, SY22748 will enter fault state and system will restart later. So the turns of auxiliary winding N_{AUX} and secondary winding N_S will influence the output voltage V_{O_OLP} in OLP situation, V_D is the voltage drop of rectifier diode, as shown in Fig.4.

$$V_{O\_OLP} = \frac{N_S}{N_{AUX}} \times (V_{VCC\_OVP} + V_D) - V_D$$

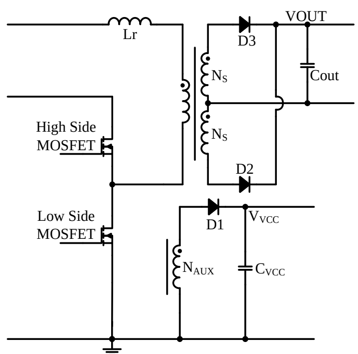


Fig.4 OLP Principle of SY22748

HV OVP: When AC supply or DC BUS is too high, or surge comes, or in output short circuit condition, V_{BUS} may be over voltage, which will lead to the failure of input E-cap or internal MOSFET in SY22748 and SY22749. There is a resistor divider composed of one external HV pin resistor R_{HV_EXT} and two internal HV pin resistors. Two internal HV resistors are R_{HV_H} and R_{HV_L}, their resistance are 4MΩ and 10kΩ. As shown in Fig.5, voltage across R_{HV_L} is used to compare with V_{BUS_OVP}, the actual V_{BUS} in HV OVP can be calculated as below:

$$V_{HV\_OVP} = \frac{R_{HV\_EXT} + R_{HV\_H} + R_{HV\_L}}{R_{HV\_L}} \times V_{BUS\_OVP}$$

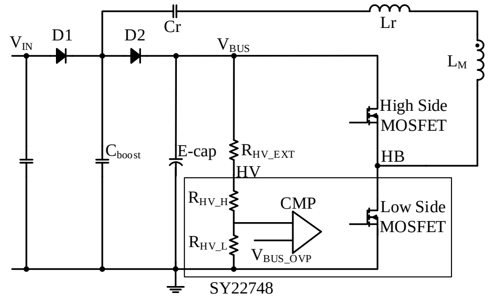


Fig.5 HV OVP Principle of SY22748

R_{HV_H}, R_{HV_L} and V_{BUS_OVP} all influence V_{HV_OVP}, and V_{HV_OVP} is the key parameter that affect the system, so V_{HV_OVP} with 0Ω R_{HV_EXT} is provided in electrical characteristics table. Besides, R_{HV_EXT} can adjust V_{HV_OVP} within a certain range.

SY22748 adopts a hysteresis loop at HV OVP threshold, the lower threshold is only used during t_{STD} at start up process. After V_{VB} reaches V_{VB_ON}, HV OVP threshold turns to the higher one. This hysteresis loop is used to avoid the system locked in the HV OVP state at some very special situations.

Magnetic Element Design

According to the design table, calculate the resonant inductor, resonant capacitor and boost capacitor. Left part of design table is one standard design with good performance, this topology has good normalized property, which means the resonant parameters is related to output current I_O, resonant frequency f_r and maximum output voltage V_{O_MAX}.

Inductor

System works in LC resonant condition, the peak value and RMS value of resonant current can be calculated:

$$I_{r\_peak} = 2 \times I_O / N_{ps}$$

$$I_{RMS} = \frac{I_{r\_peak}}{\sqrt{3}}$$

Usually select B_{max_ind} between 0.2 and 0.3, so turn number of inductor can be calculated:

$$n_{ind} = \frac{I_{r\_peak} \times L_r}{A_{e\_ind} \times B_{max\_ind}}$$

It's recommended to use litz wire for lower temperature rise. Current density j_{ind} is selected at 8A/mm^2, so the number of 0.1mm enameled wire n_{litz} can be calculated:

$$n_{litz} = \frac{4 \times I_{RMS}}{\pi \times j_{ind} \times 0.1^2}$$

Transformer

RMS value of primary winding current is the same as inductor, so the wire diameters of primary and secondary winding are easy to get. Usually select B_{max_trans} as 0.3, and the turn number of primary winding can be calculated:

$$n_{p\_trans} = \frac{V_{O\_MAX} \times n_{ps}}{4 \times f_r \times B_{max\_trans} \times A_{e\_trans}}$$

$$n_{s\_trans} = \frac{n_{s\_trans}}{n_{ps}}$$

The auxiliary winding should satisfy the following conditions:

$$V_{O\_OLP} + V_D = \frac{N_S}{N_{AUX}} \times (V_{VCC\_OVP} + V_D)$$

$$(V_{O\_MIN} + V_D) \times \frac{N_{AUX}}{N_S} - V_D > 13V$$

No air gap is required for transformer cores, large inductance of primary winding is needed, it's suggested that the ratio of inductance of primary winding and resonant inductor be larger than 3. If the ratio is small, it needs to change the bobbin and core size of inductor or transformer.

Magnetic Integrated Design

It's recommended to use magnetic integrated design for better efficiency and power density. In this design, leakage inductance of transformer primary winding is used as resonant inductor, so the key of magnetic integrated design is the control of leakage inductance. Fig.6 shows the structure of magnetic integrated transformer, primary and secondary windings are placed at left side and right side, respectively, between them is a big gap for larger leakage inductance. Leakage inductance mainly depends on the turn number of primary winding, bobbin size and the big gap in the middle. Red line represents the leakage inductance of primary winding, which is equivalent to the role of resonant inductor, and the green line represents the transformer excitation loop.

In magnetic integrated design, usually it's no need to consider the inductance ratio between primary winding and resonant inductor, because the bobbin size of transformer becomes larger than discrete design, the excitation inductance is much larger.

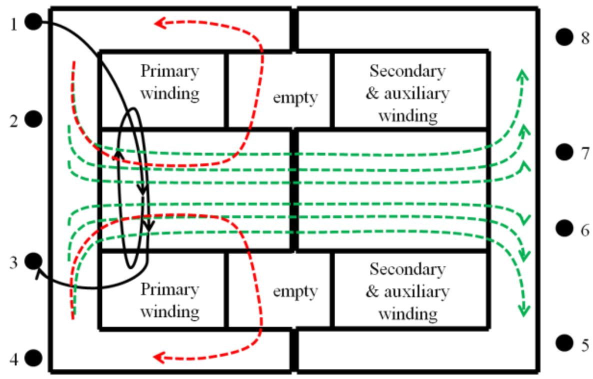


Fig.6 Structure of Magnetic Integrated Transformer

Layout

(a) Because of the charge pump structure, it's not necessary to put the input E-cap close to bridge rectifier. Make sure the loop composed of input E-cap, HV of SY22749, HB of SY22749, HB of SY22748 and GND of SY22748 to be as small as possible.

(b) The circuit loop of CS sampling should be kept small.

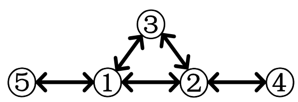
(c) The C_{VB} charge loop should be kept small, C_{VB} should be put near SY22749.

(d) The C_{VCC} and N_{AUX} charging loop should be kept small, C_{VCC} should be put near SY22748.

(e) Not recommend to put high voltage track under low voltage components, such as HV and LX.

(f) Recommend to use a high voltage MLCC in parallel with input E-cap, recommend to connect the core of inductor to low frequency input line after filter.

(g) The connection of ground is recommended as:



Ground ①: ground of input E-cap
Ground ②: ground of SY22748 and C_{VCC}
Ground ③: ground of external high voltage NP0 MLCC
Ground ④: ground of auxiliary winding
Ground ⑤: ground of bridge rectifier and C_{boost}

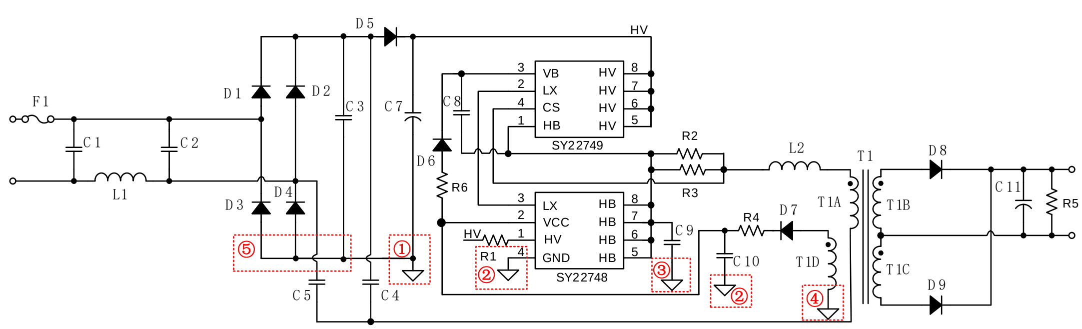


Fig.7 Ground Connection Recommended

Design Example

Table 1 and table 2 show the key parameters of standard design in design table and parameters defined by the customer, respectively. The relationship between them is also provided.

Table 1 Key Parameters of Standard Design

System Conditions		
Maximum Output Voltage	$V_{O\_MAX\_S}$	42V
Output Current	I_{O_S}	1A
Output Diode Drop	V_{DF_S}	1.3V
Main Resonant Frequency	f_{r_S}	52.5kHz
Key Parameters		
Turns Ratio	N_{PS_S}	1.75
Sampling Resistor	R_{CS_S}	0.26Ω
Resonant Inductor	L_{r_S}	700uH
Main Resonant Capacitor	C_{r_S}	27nF
Minor Resonant Capacitor	C_{r2_S}	3.3nF
Boost Capacitor	C_{boost_S}	15nF
Input E-cap	C_{in_S}	15uF

Table 2 Parameters Defined by Customer

System Conditions		
Maximum Output Voltage	$V_{O\_MAX\_C}$	40V
Output Current	I_{O_C}	0.8A
Output Diode Drop	V_{DF_C}	1.3V
Main Resonant Frequency	f_{r_C}	70kHz
Key Parameters		
Turns Ratio	N_{PS_C}	1.83
Sampling Resistor	R_{CS_C}	0.34Ω
Resonant Inductor	L_{r_C}	689uH
Main Resonant Capacitor	C_{r_C}	15.4nF
Minor Resonant Capacitor	C_{r2_C}	1.9nF
Boost Capacitor	C_{boost_C}	8.6nF
Input E-cap	C_{in_C}	11uF

$$N_{PS\_C} = N_{PS\_S} \times \frac{V_{O\_MAX\_S} + V_{DF\_S}}{V_{O\_MAX\_C} + V_{DF\_C}}$$

$$R_{CS\_C} = 0.15 \times \frac{N_{PS\_C}}{I_{O\_C}}$$

$$L_{r\_C} = L_{r\_S} \times \frac{V_{O\_MAX\_S} \times I_{O\_S} \times f_{r\_S}}{V_{O\_MAX\_C} \times I_{O\_C} \times f_{r\_C}}$$

$$C_{r\_C} = C_{r\_S} \times \frac{V_{O\_MAX\_C} \times I_{O\_C} \times f_{r\_S}}{V_{O\_MAX\_S} \times I_{O\_S} \times f_{r\_C}}$$

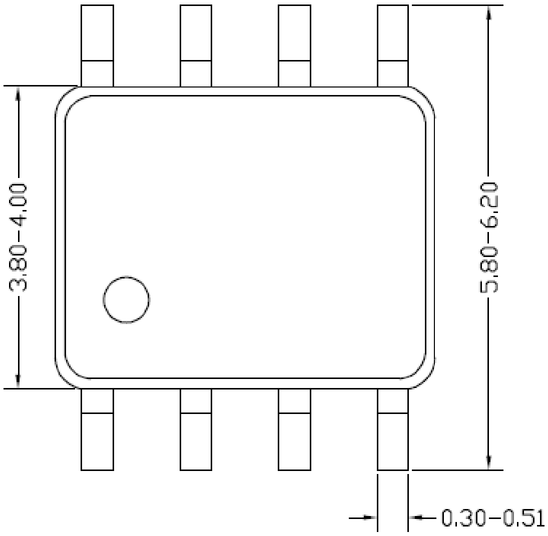
$$C_{r2\_C} = C_{r2\_S} \times \frac{V_{O\_MAX\_C} \times I_{O\_C} \times f_{r\_S}}{V_{O\_MAX\_S} \times I_{O\_S} \times f_{r\_C}}$$

$$C_{boost\_C} = C_{boost\_S} \times \frac{V_{O\_MAX\_C} \times I_{O\_C} \times f_{r\_S}}{V_{O\_MAX\_S} \times I_{O\_S} \times f_{r\_C}}$$

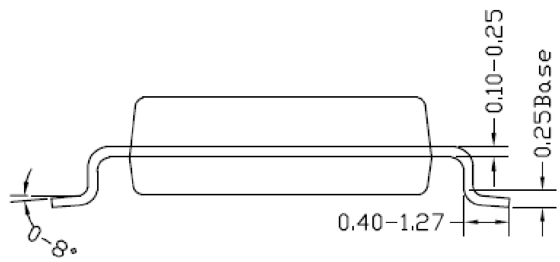
$$C_{in\_C} = C_{in\_S} \times \frac{V_{O\_MAX\_C} \times I_{O\_C}}{V_{O\_MAX\_S} \times I_{O\_S}}$$

$V_{O\_MAX\_C}$, I_{O_C}, V_{DF_C} and f_{r_C} are defined by customer, and other key parameters will be calculated according to the above normalization formula.

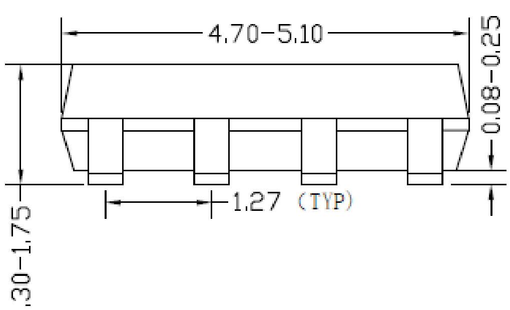
SO8 Package outline & PCB layout design



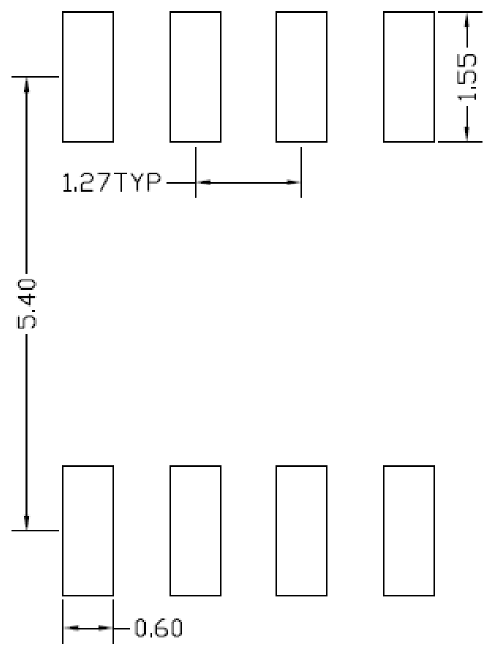
Top view



Side view



Front view



Recommended Pad Layout (Reference only)

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

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 28,2021	Revision 0.9	Initial Release

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