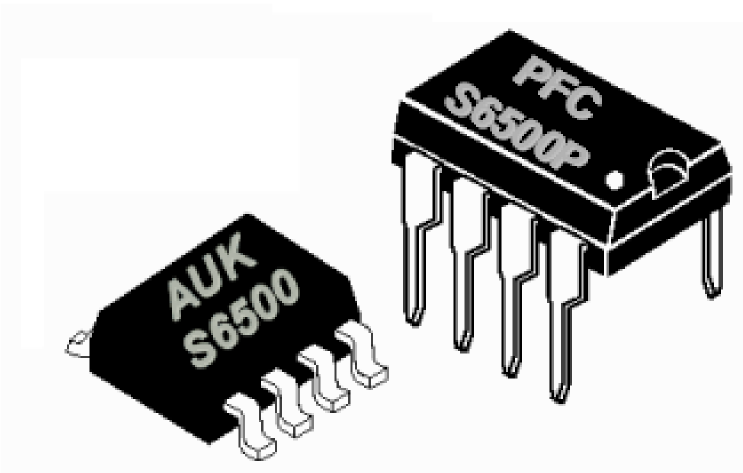
POWER FACTOR CORRECTOR

S6500



Marketing Team

AUK

Introduction

Conventional AC/DC Converter, most electronic ballast and SMPS, employ a full wave rectifier bridge with a simple capacitor filter to draw DC power from the mains AC, Fig.1

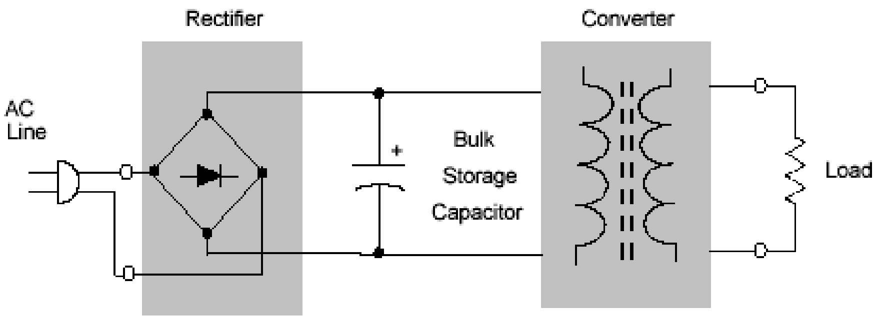


Fig. 1 Uncorrected power factor circuit

This filter capacitor must be large enough to supply the total power during most of each half-cycle while instantaneous line voltage is below the DC output voltage. With this Bulk capacitor filter, the line current waveform is a narrow pulse, this occurs near the line voltage peak and results in a high charge current spike, Fig 2.

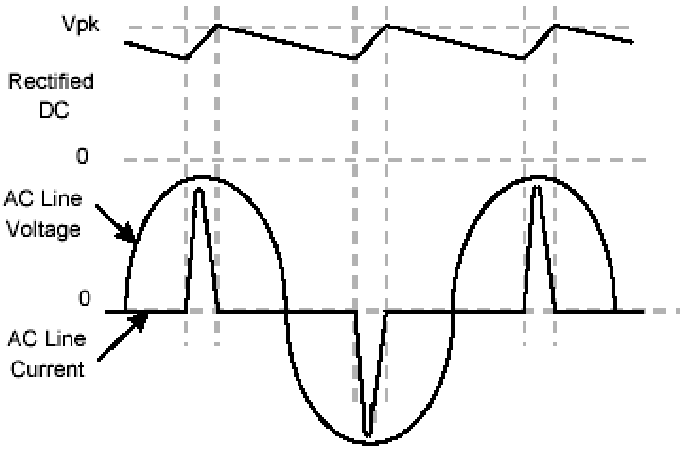


Fig. 2 Uncorrected power factor input waveform figure

Since power is only taken near the line voltage peaks, the resulting spikes of current are extremely non-sinusoidal with a high content of harmonics. This results in a poor power factor condition. Power Factor ratios of 0.5 to 0.7 are common.

Power factor correction can be achieved with the use of either a passive or an active input circuit. Passive circuits usually contain a combination of large capacitors, inductors, and rectifiers that operate at the ac line frequency.

Active circuits incorporate some form of a high frequency switching converter for the power processing, with the boost converter being the most popular topology, Figure 3

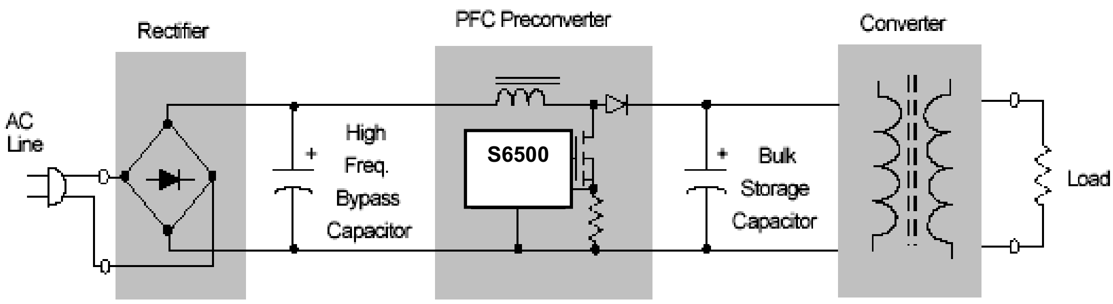


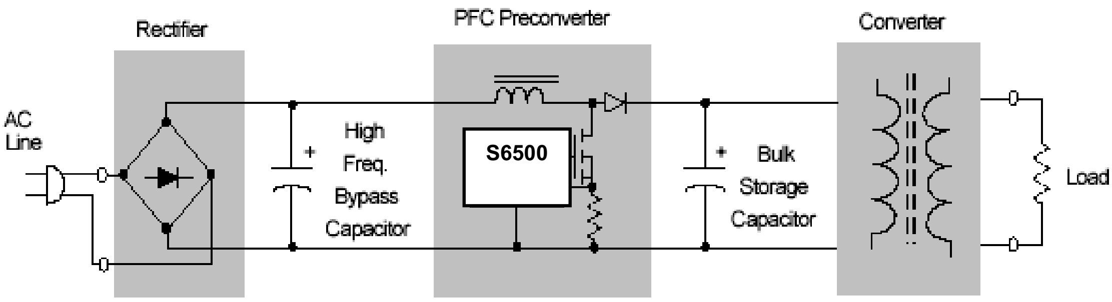
Fig. 3 Active power factor correction pre-converter

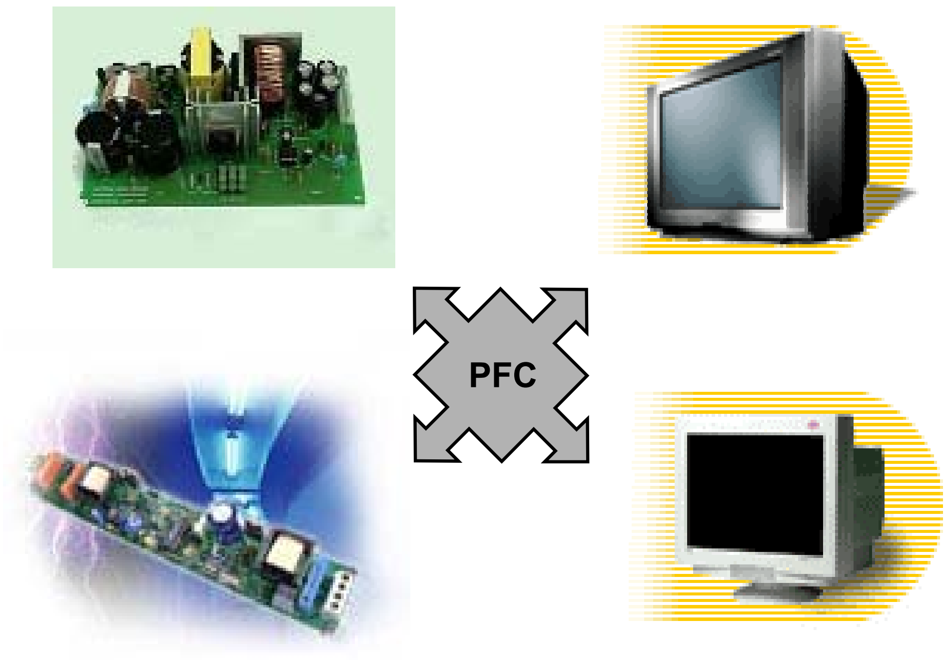
With proper control of the pre-converter, interposed between the input rectifier bridge and the bulk filter capacitor, the power factor will be improved(up to 0.99). Almost any complex load can be made to appear resistive to the ac line, thus significantly reducing the harmonic current content.

S6500 is an integrated circuit especially designed to be used in lighting application and switching mode power supply to perform the control of active PFC circuit.

Typical Application of PFC

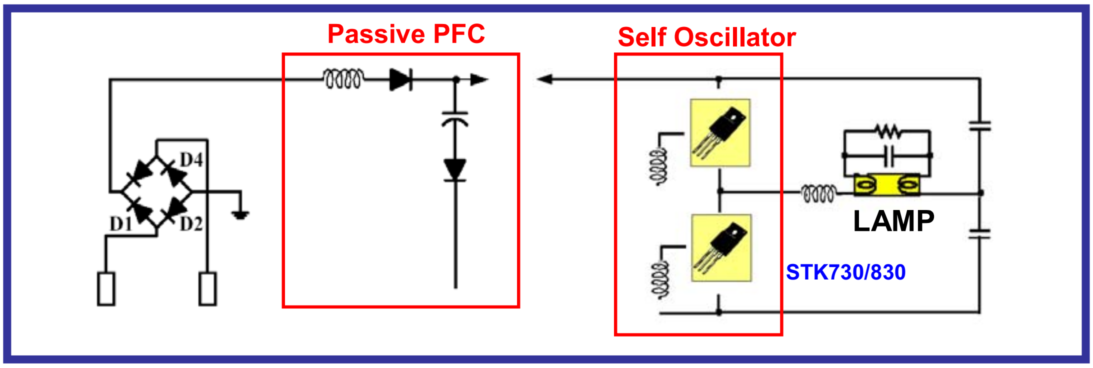
- Electric Ballast
- SMPS
- TV & Monitor SMPS





Feature of Electronic Ballast depend on composition

Passive PFC + Self Oscillator



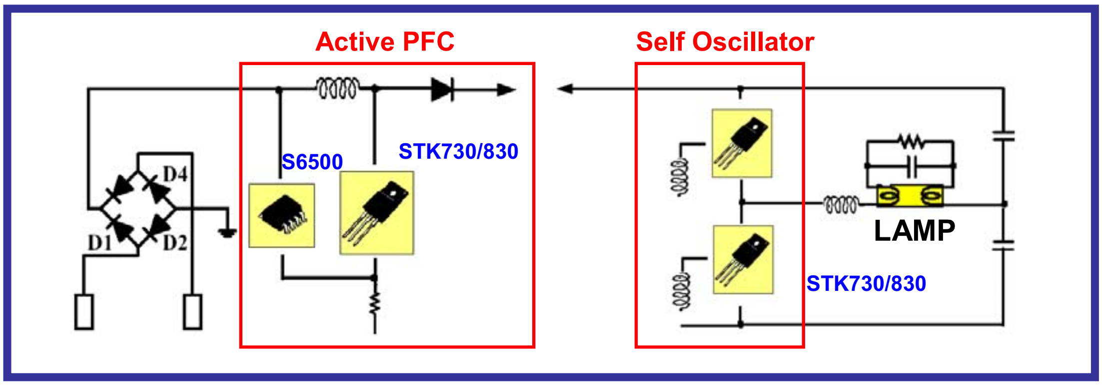
✓ Disadvantage

- Hard Inverter Design
- Unstable with Load Variation
- Unstable with Input Variation
- Lack of Protection Circuit

✓ Advantage

- Very Low Cost

Active PFC + Self Oscillator



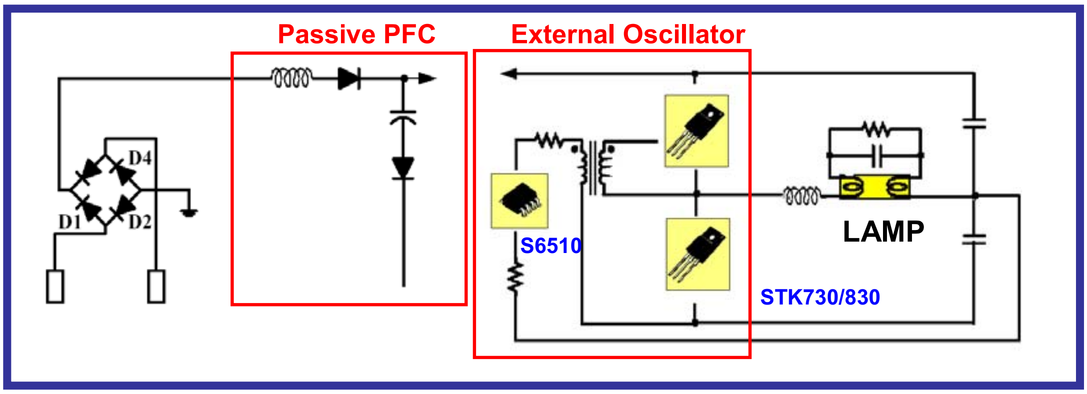
✓ Disadvantage

- Hard Inverter Design
- Lack of Protection Circuit

✓ Advantage

- Stable with Load Variation
- Universal Input Voltage

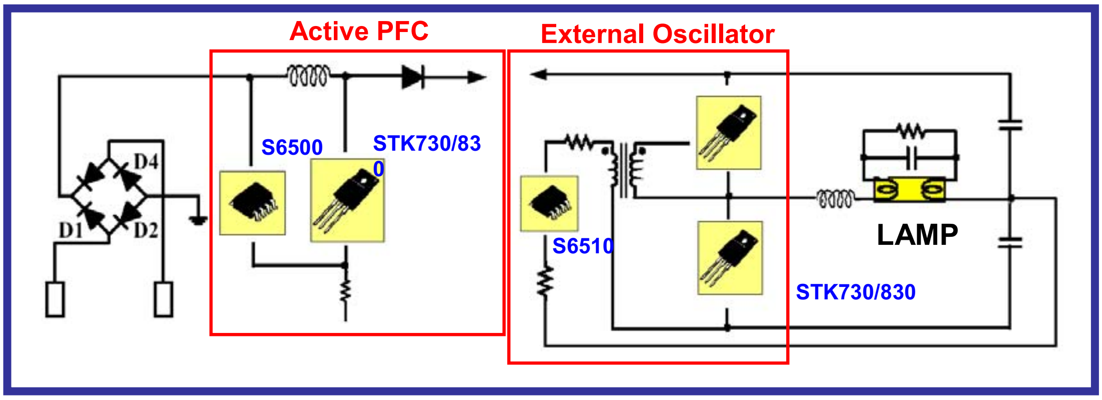
Passive PFC + External Oscillator



✓ Disadvantage
- Unstable with Load Variation
- Unstable with Input Variation

✓ Advantage
- Low Cost
- Easy to Design of Inverter
- Easy Protection Design

Active PFC + External Oscillator



✓ Disadvantage
- High Cost

✓ Advantage
- Easy Inverter Design
- Stable with Load Variation
- Universal Input Voltage
- Easy Protection Design
- High Efficiency & Reliability

Product

- ✓ Description
- ✓ Block Diagram
- ✓ Feature
- ✓ Pin Configuration
- ✓ Device Block Description
  - Error Amplifier and Over Voltage Protection Block
  - Multiplier Block
  - Current Sense Comparator Block
  - Zero Current Detector Block
- ✓ Application Circuit

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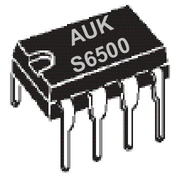
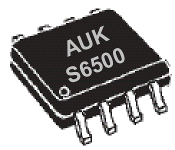
Description

The S6500 is an active power factor correction (PFC) Controller for boost PFC application which operates In the critical conduction mode. This device provides the necessary features which are required to significantly enhance poor power factor loads by keeping the ac line current sinusoidal and in phase with the line voltage. S6500 contains many of the building Blocks and protection features that are employed in modern high performance current mode power supply controllers.

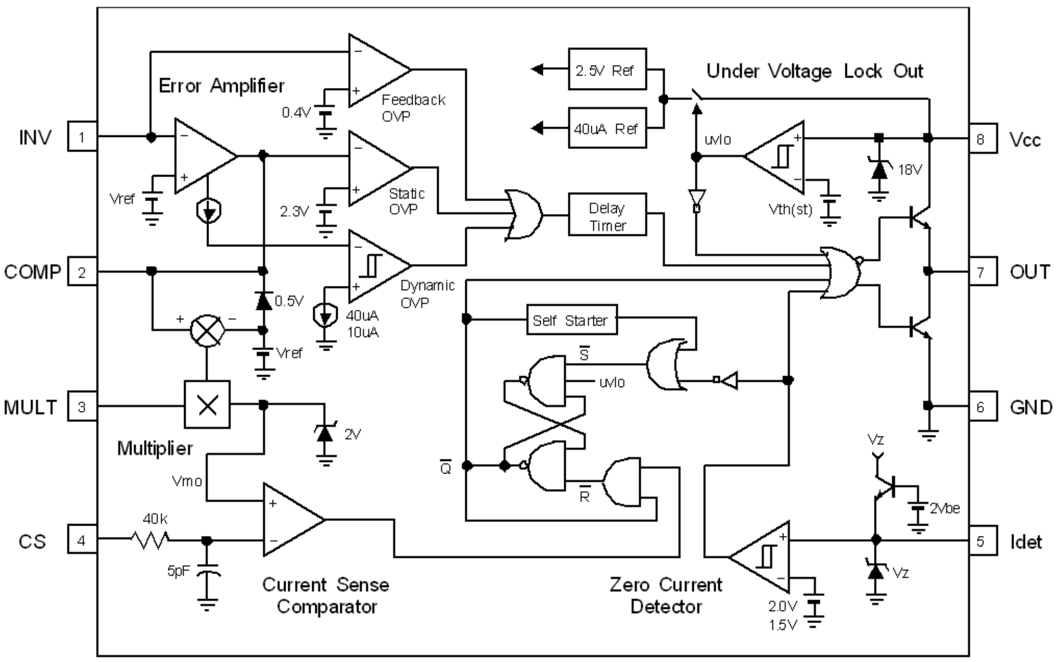


8 DIP



8 SOP

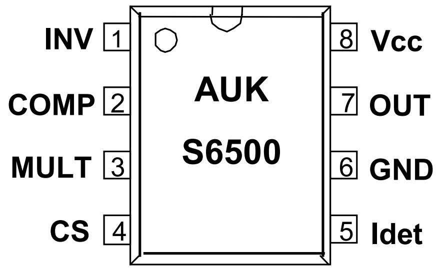
Block Diagram



Feature of S6500

- Dynamic, Static OVP and Add feedback OVP
- Extremely Low Start up Current (30uA Typ.)
- Very Low Operating Current (4mA Typ.)
- Internal Self Start Timer
- Current Sense with Internal RC Filter
- Trimmed ±1.5% Internal Reference
- Under Voltage Lock Out with Hysteresis
- Pin Compatible to World Standard
- High Current Totem Pole Gate Drive
- 8DIP/8SOP Package
- Low Cost, Good efficiency

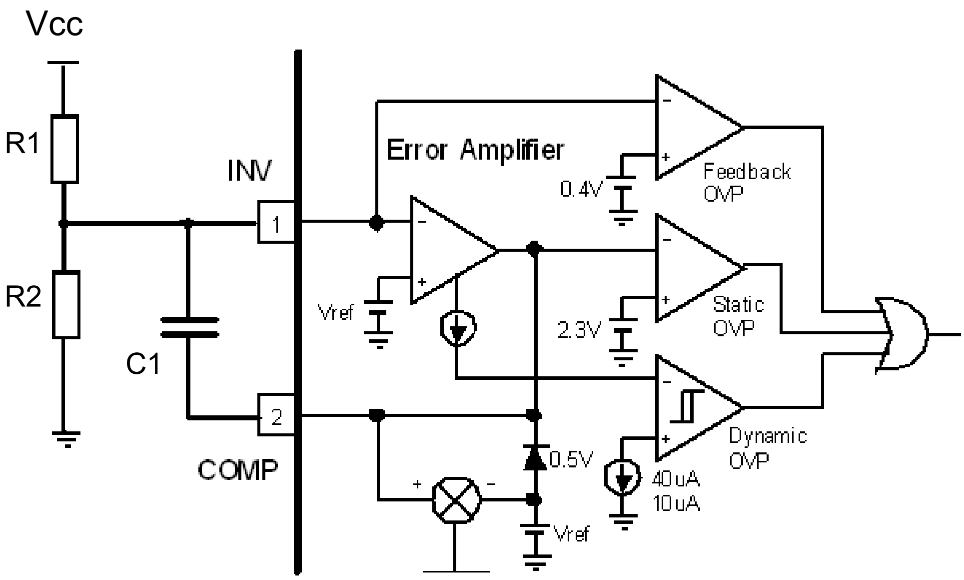
Pin Configuration



NUM	Name	Function
1	INV	Inverting input of the error amplifier. The output of the boost converter should be resistively divided to 2.5V and connected to this pin.
2	COMP	Output of the error amplifier. A feedback compensation network is placed between this pin and INV pin.
3	MULT	Input to the multiplier stage. The full wave rectified AC Voltage is divided to less than 4V and is connected to this pin.
4	CS	Input to the comparator of the control loop. The MOSFET current is sensed by a resister and the resulting voltage is applied to this pin. An internal R/C filter is included to reject any high frequency noise.
5	IDET	Zero Current detection input.
6	GND	Ground of the control section.
7	OUT	Gate drive output. A push pull output stage is able to drive the Power MOSFET with peak current of 500mA.
8	Vcc	Supply Voltage of output driver and control circuits.

Device Block Description

Error Amplifier and Over Voltage Protection Block



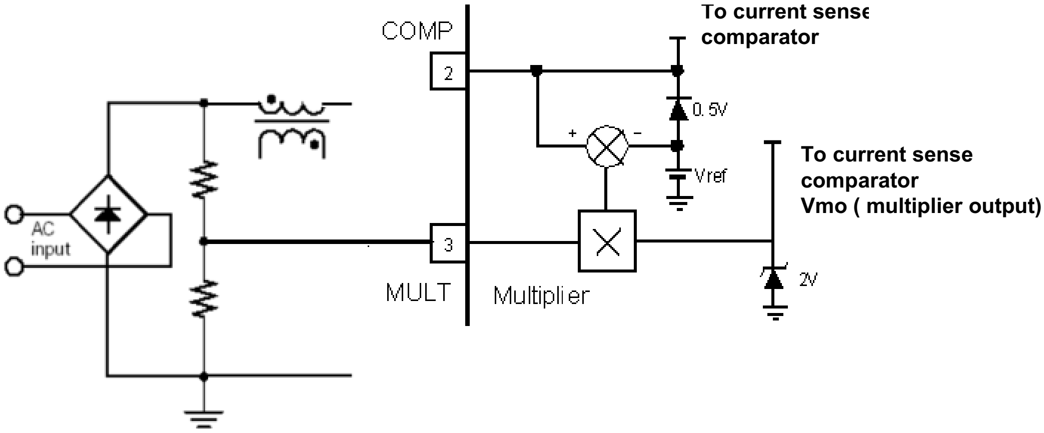
An Error Amplifier (E/A) with access to the inverting input and output is generated. The sensed and divided output voltage(with R1, R2) is feedback to the error amplifier inverting input (INV) to regulate the output voltage. The non-inverting input is internally biased at Vref (2.5V)

The Error Amplifier output is internally connected to the multiplier and is pinned out for the loop compensation (with external C1). The control loop bandwidth of PFC converter is set below 20Hz to get a good power factor. In case of over voltage condition, the E/A must be saturated low as soon as possible, but the narrow E/A bandwidth slows down the response. To make the over voltage protection fast, the soft OVP and dynamic OVP is used. The S6500 monitored the current flowing into the COMP pin.

If the monitored current reaches about 30uA, the output of multiplier is forced to be decreased, thus reducing the input current drawn from the mains (soft OVP). If the monitored current exceeds 40uA, the OVP protection is triggered (dynamic OVP), then the external power transistor is switched off until the current falls below about 10uA. However, if the over voltage lasts so long that the output of E/A goes below 2.3V, then the protection is activated (static OVP) keeping the output stage and the external power switch turned off. The operation of the device is re-enabled as the E/A output goes back into its linear region. And S6500 add **Feedback OVP** function for feedback loop fault.

Device Block Description

Multiplier Block

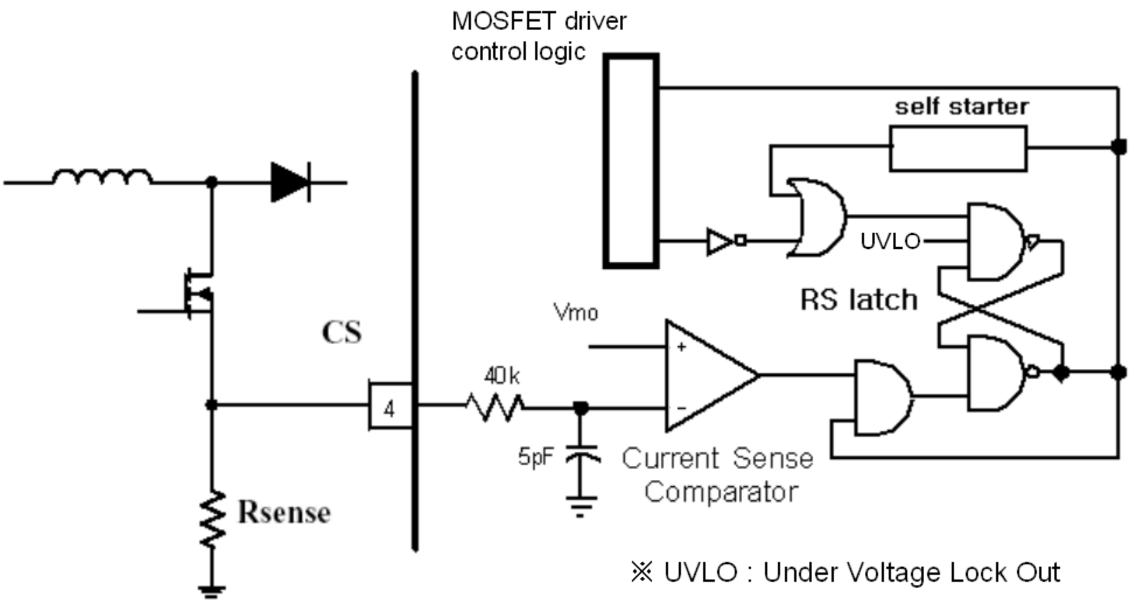


A single quadrant, two input multiplier is the critical element that enables this device to get power factor correction. One input of multiplier (pin 3) is connected to an external resistor divider which monitors the rectified ac line voltage.The other input is internally driven by a DC voltage which is the difference between error amplifier output (pin 2) and reference voltage, Vref.

The multiplier output controls the current sense comparator threshold voltage as the ac voltage traverses sinusoid from zero to peak line. This allows the inductor peak current to follow the ac line thus forcing the average input current to be sinusoidal. In other words, this has the effect of forcing the MOSFET on-time to track the input line voltage, resulting in a fixed drive output on-time, thus making the pre-converter load appear to be resistive to the ac line.

Device Block Description

Current Sense Comparator Block

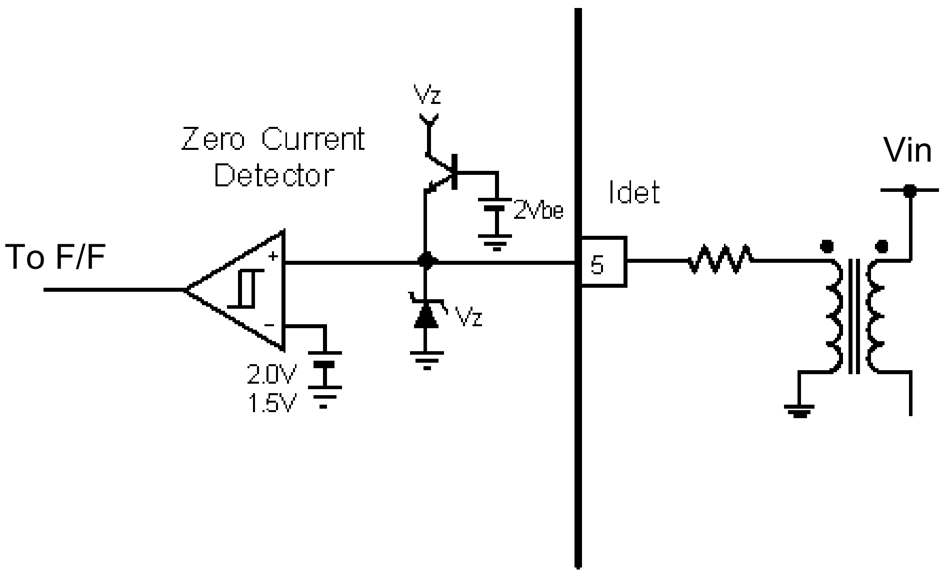


The current sense comparator adopts the RS latch configuration to ensure that only a single pulse appears at the drive output during a given cycle. MOSFET drain current is sensed using an external sense resistor in series with the external MOSFET. When the sensed voltage exceeds the threshold set by the multiplier output, the current sense comparator turns off the MOSFET and resets the PWM latch. The latch insures that the output remains in a low state after the MOSFET drain current falls back to zero. The peak inductor current under the normal operating condition is controlled by the multiplie output, **Vmo**. The abnormal operating condition occurs during pre-converter start-up at extremely high line or as output voltage sensing is lost.

Under these conditions, the multiplier output and current sense threshold will be internally clamped to 1.8V. Therefore, the maximum peak switch current is limited to 1.8V / Rsense S6500 has **internal R/C filter (40KΩ, 5pF)** to attenuate any high frequency noise that may be present on the current waveform. This block eliminates the need for an external R/C filter.

Device Block Description

Zero Current Detector Block

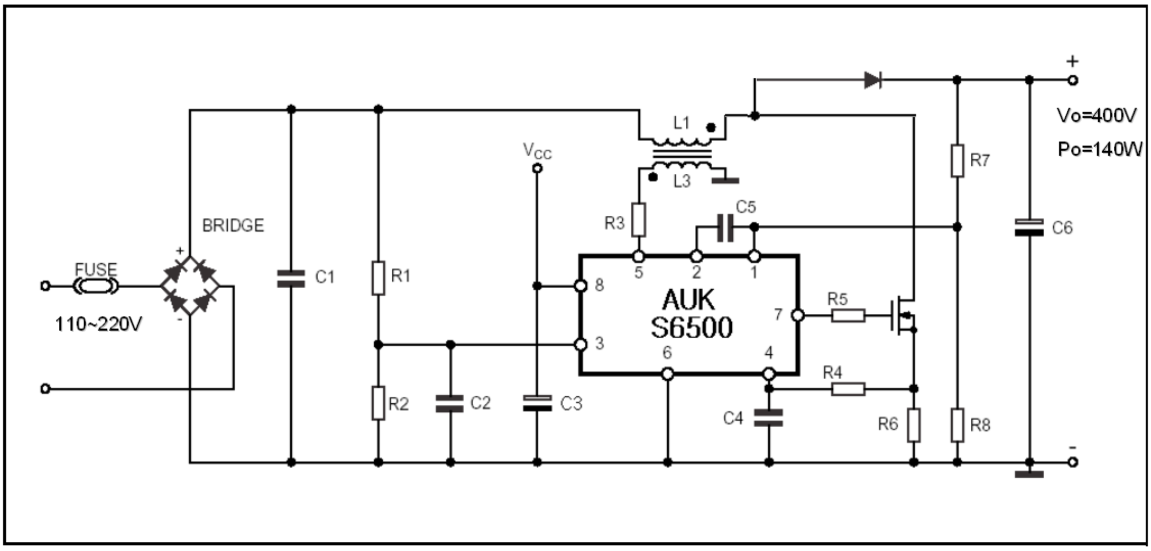


S6500 operates as a critical conduction current mode controller. The zero current detector switches on the external MOSFET as the voltage across the boost inductor reverses, just after the current through the boost inductor gas gone to zero. The slope of the inductor current is indirectly detected by monitoring the voltage across an auxiliary winding and connection it to the zero current detector pin 5.

Once the inductor current reaches ground level, the polarity of the voltage across the winding is reversed. When the Idet input falls below 1.5V, the comparator output is triggered to the low state.

To prevent false tripping, 0.5V hysteresis is provided. The zero current detector input is protected internally by two clamps. The upper Vz clamp prevents input over voltage break-down while the lower 0.75 V clamp prevents substrate injection. An internal current limit resistor protects the lower clamp transistor in case the Idet pin is shorted to the IC to eliminate the need for an external oscillator when used in stand-alone applications. The timer provides a means to start or restart the pre-converter automatically if the drive output has been off for more than 500us after the inductor current reached zero.

Application Circuit



Description of Part list

Device	Function Block	Description
R1	**Multiplier**	External divider resistor which monitors the rectified ac line voltage.
R2		
R3	**Zero Current Detector**	Zero current detector resistor
R6	**Current sense**	Sensing resistor which MOSFET drain current
R7	**E/A and OVP**	Divider resistor which monitors the output voltage.
R8		
C1	**Ac line**	Rectifier current capacitor
C3	**Start up**	Charged by current through Vcc. Once the capacitor voltage reaches the start up threshold, the S6500 turns on.
C5	**E/A**	E/A Loop compensation capacitor

Comparison

- ✓ Advantage of S6500
- ✓ Competitor comparison table
- ✓ Cross reference

Advantages of S6500

- **Unnecessary External Vcc Protection Circuit**

  External zener diode and blocking Cap.
  Save the cost

- **Internal R/C filter for Current Sensing and Noise Blocking**

- **Low Start up Current**

  Typ. 30uA

- **Low Dynamic Operating Current**

  TyP. 4mA

- **Strengthening OVP Function**

  Soft OVP, Static OVP, Dynamic OVP, Feedback OVP
  Protection for Open Load Start up, Load Runaway Regulation and Feedback Loop fault.

- **Wide multiplier input range for universal input**

  For Free Voltage Operation

Competitors Comparison Table

Company	Company S	Company I	Company F	AUK S6500
Threshold Voltage	14.5V / 12V	11 V	11.5V	10.5 V
UVLO Hysteresis	4.7V / 2.8V	2.5 V	3V	2.5 V
Start up Supply Current	300 uA	200 uA	60 uA	30 uA
Dynamic Operating Current	3.2 mA	4.2 mA	4 mA	4 mA
Max Vm1 Voltage Range	0~4.2 V	0~4 V	0~3.8 V	0~4 V
Max Vcs Voltage	1.9 V	1.3 V	1.8 V	1.9 V
Restart Time	60 us	190 us	150 us	150 us
Dynamic and Static OVP	YES	YES	YES	YES
Feedback Loop Fault Protection	NO	NO	NO	YES
RC Filter or Delay Time (DT)	DT (0.2us)	RC Filter	DT (0.9us)	RC Filter
Max Supply Voltage	20 V	17 V	30V	20 V
Package	8DIP/SO8	8DIP/SOP	8DIP/SOP	8DIP/SOP

Cross Reference Table

AUK	Product	Company	Remark
S6500	L6560A	ST	Pin Compatible
	L6561	ST	Pin Compatible
	FAN7527B	FKS	Pin Compatible
	IP3001	INTERPION	Pin Compatible
	LX1562	Infinity	Pin Compatible
	TDA4862	INTERPION	Pin Compatible
	MC33262	On semi	Function Compatible

Appendix

- ✓ **Reliability Assurance Process**
  - ▪ Reliability Assurance Test
  - ▪ ESD Test
- ✓ **Package Specification**
- ✓ **Packing Specification**
- ✓ **Contact point**

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Quality Assurance Process

- **Life and Environmental**
  . HTOL, THB, HTS, TS, PCT, SHT
- **Mechanical**
  . Solderability, Lead integrity
- **Other**
  . ESD

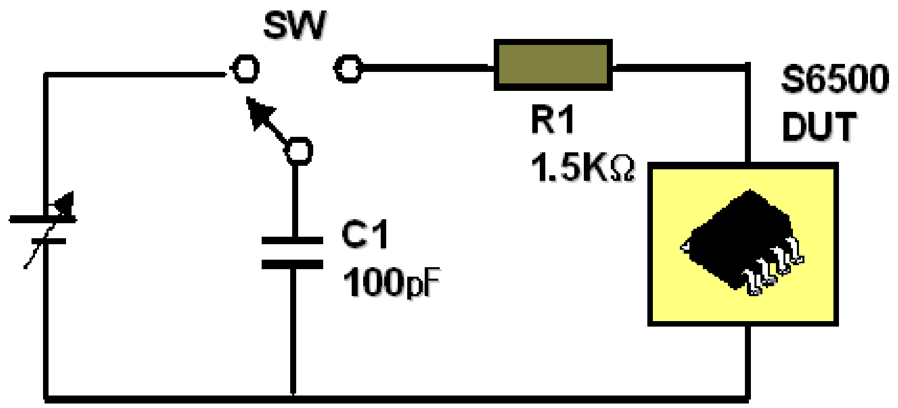
Reliability Assurance Test

NUM	TEST Item	Description	Test Condition	Sample Size
1	HTOL	High Temperature Operating Life Test	Ta=80℃ PD=1.6W T=1000HR'S	45
2	THB	Temp-Humidity Bias Test	Ta=85℃ RH=85% Vcc=18V T=1000HR'S	45
3	HTS	High Temperature Storage Test	Ta=150℃ T=1000HR'S	45
4	TS	Thermal Shock Test	Ta=-65℃/150℃ (Each 10 Minute) TC=200 Cycle	45
5	PCT	Pressure Cooker Test	Ta=121℃ P=2atm T=168HR'S	45
6	SHT	Solder Heat Test	Ta=260℃ T=10 second	45

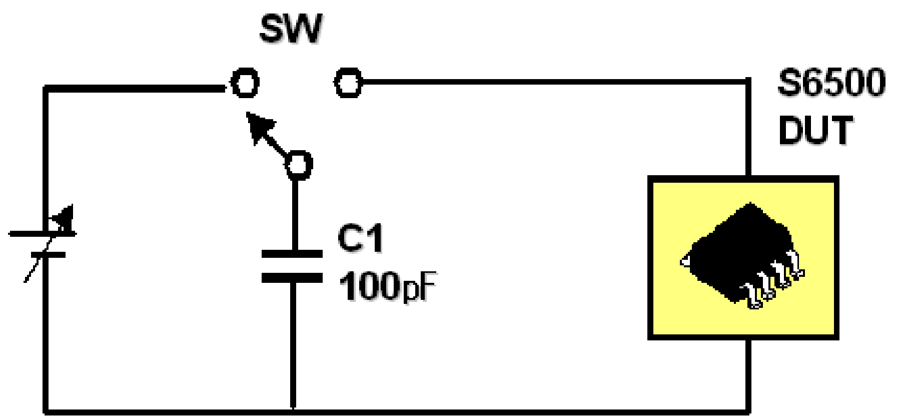
ESD(Electrostatic Discharge) TEST

ESD MODEL	Condition			SPEC.
	C1(pF)	R1(kΩ)	Pulse time	
HBM (Human Body Model)	100	1.5	3 time	2KV ↑
MM (Machine Model)	200	0	5 time	200V ↑

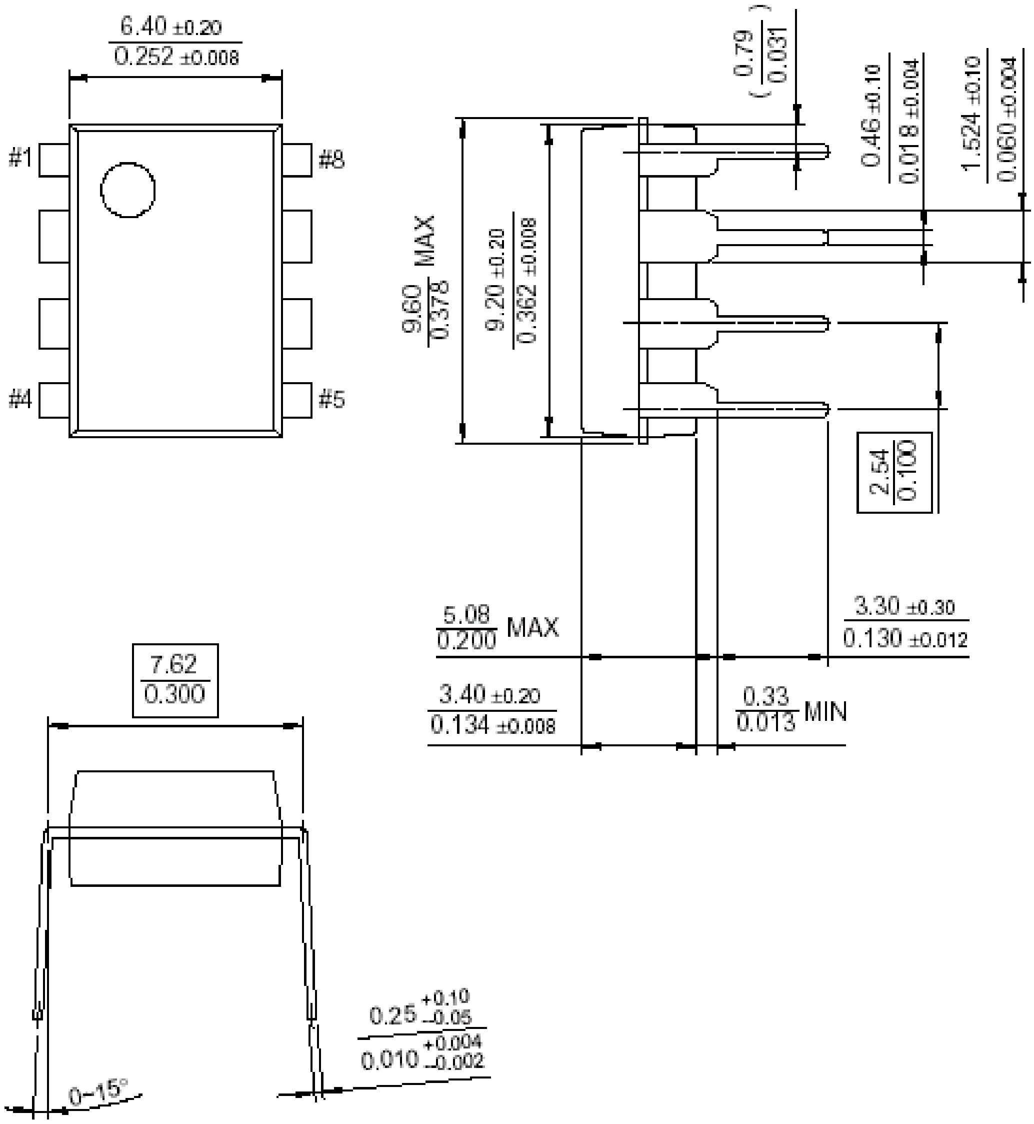
HBM Test Circuit



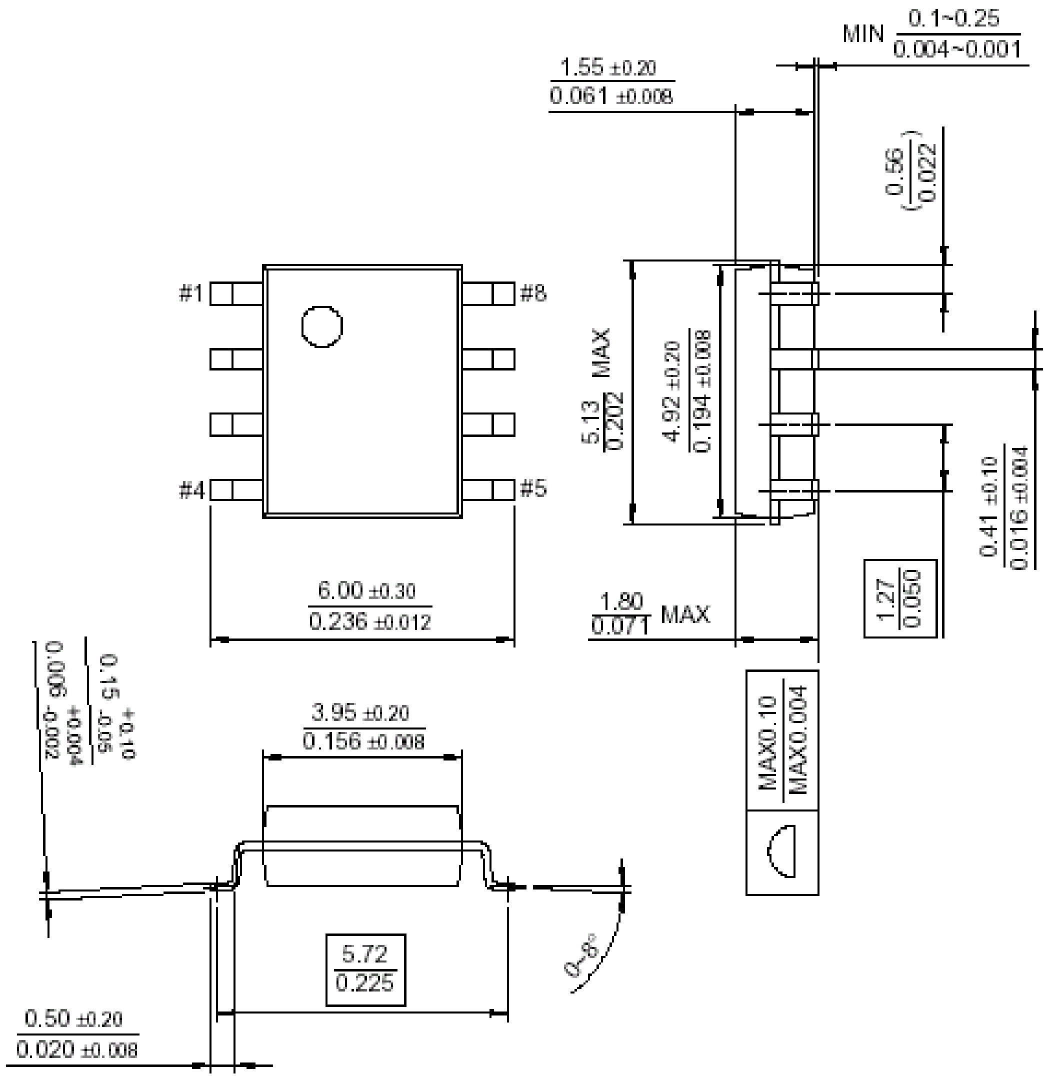
MM Test Circuit



Package Specification DIP-8



Package Specification SOP-8



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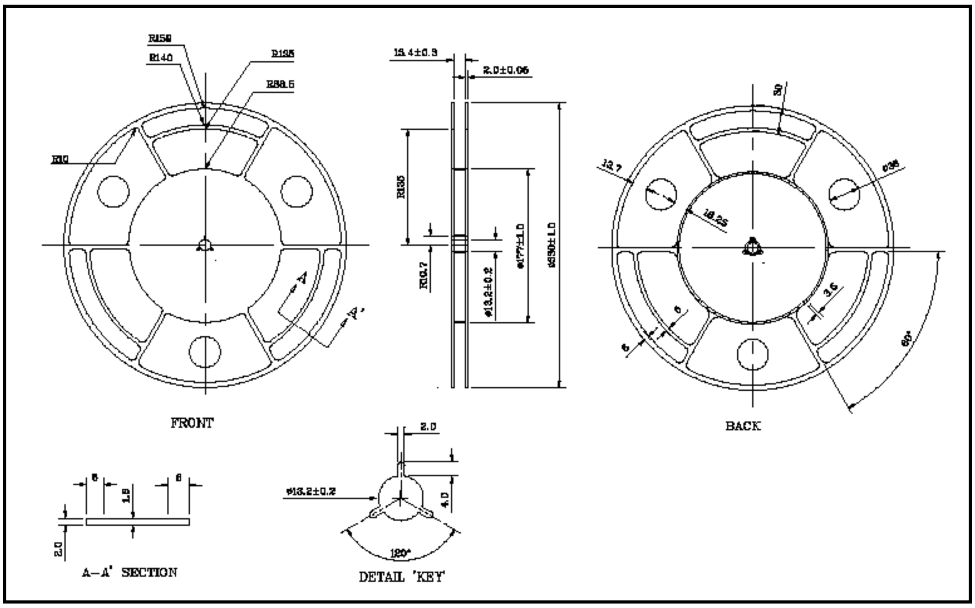
Packing Specification SOP-8

Package	Packing Form	Quantity		
		Unit [pcs]	Inner Box [Kpcs]	Out Box [Kpcs]
SOP-8	Tube Tape	98	9.8	156.8
SOP-8	Embossed Tape	2.5	5	20

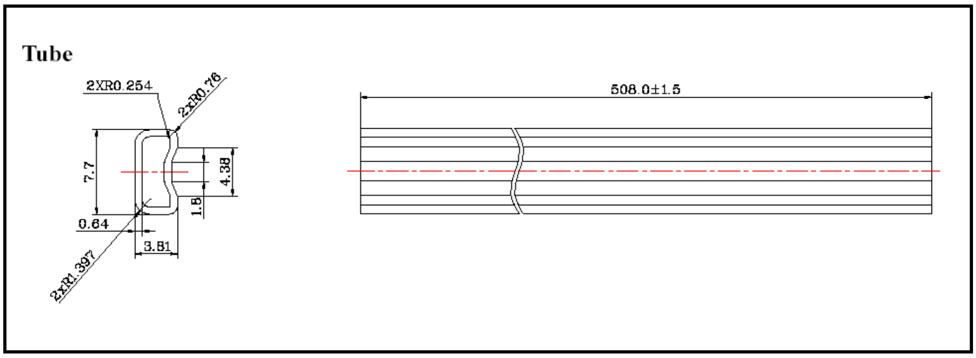
Dimensions of Reel

Unit : mm



Dimension of Tube

Unit : mm



Packing Specification DIP-8

Package	Packing Form	Quantity		
		Unit [pcs]	Inner Box [Kpcs]	Out Box [Kpcs]
SOP-8	Tube Tape	50	3	18

Dimension of Tube

Unit : mm