

Low Standby-Power Offline AC/DC Power Switch

1 Description

AL612 is a highly performance AC/DC converter for wide voltage input, which integrates a PWM controller and 1200V MOSFET with high voltage startup to achieve ultra-low standby power consumption. By adopting hybrid PWM/PFM/Burst modulation technology, it ensures optimal system efficiency over the full load range, and also integrates frequency dithering technology to simplify system EMI design. The AL612 also provides excellent protection functions, including cycle-by-cycle overcurrent protection, CS resistor short-circuit protection, VDD overvoltage protection, overload protection, output short-circuit protection, open feedback protection, over-temperature protection and over-temperature protection.

2 Features

- Built-in 1200V MOSFET
- Built-in high-voltage starting circuit
- Built-in line voltage compensation and slope compensation
- Integrated frequency expansion technology
- Frequency doubling function to improve magnetic field interference (only available in AL612D7B)
- PWM/PFM/Burst hybrid control mode

- No-load power consumption <50mW @230 VAC
- Complete protection functions (OCP, OLP, UVLO, VDD OVP, OTP)

3 Applications

- Small power meter switching power supply
- Smart Meter

4 Ordering Information

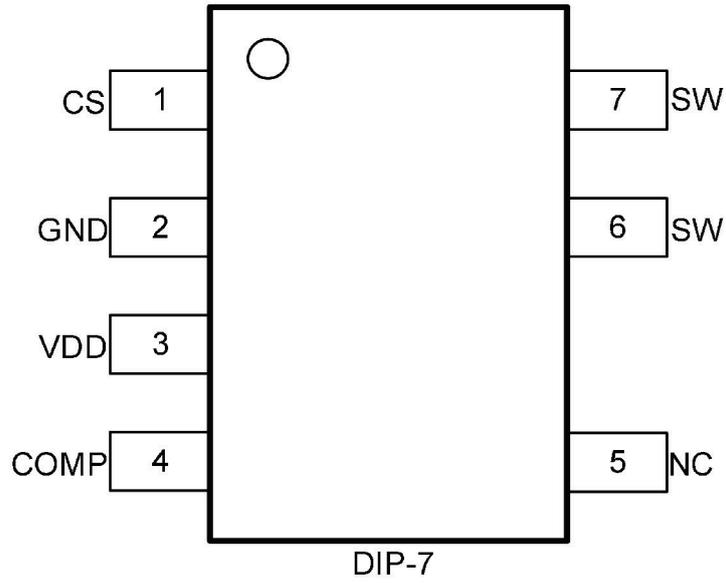
| Product Number | Package | Quantity/Tape |
|----------------|---------|---------------|
| AL612D7 | DIP-7 | 50PCS/Tape |
| AL612D7B | DIP-7 | 50PCS/Tape |

5 Marking

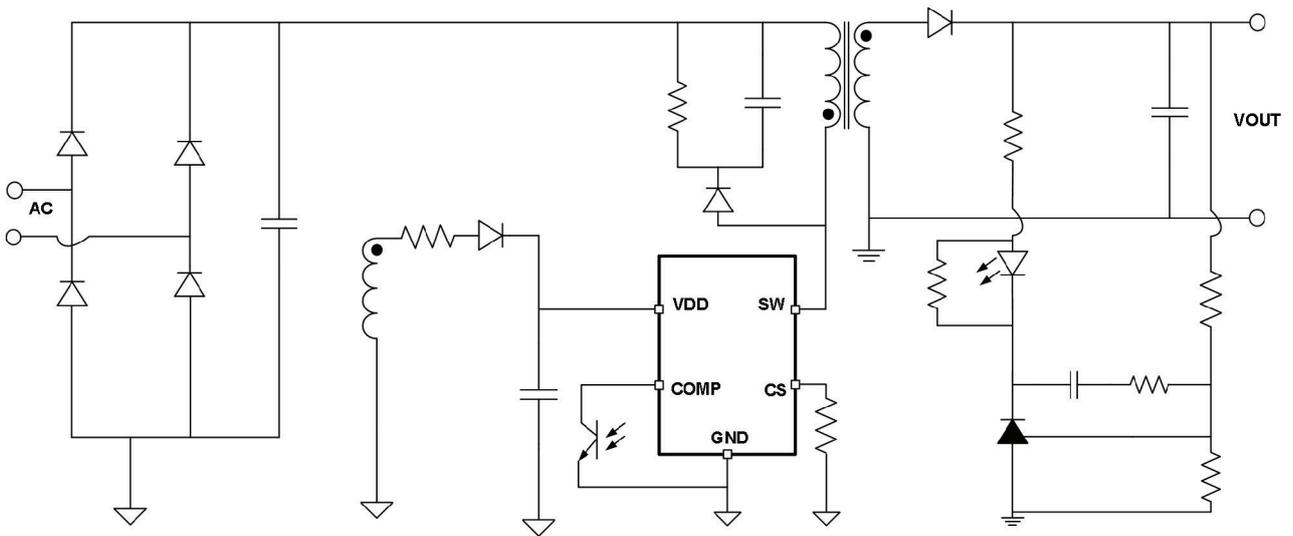
| Product Number | Marking* |
|----------------|---------------|
| AL612D7 | AL612D7/YYWW |
| AL612D7B | AL612D7B/YYWW |

Note*: YY=Year; WW=Week.

6 Pin Configuration

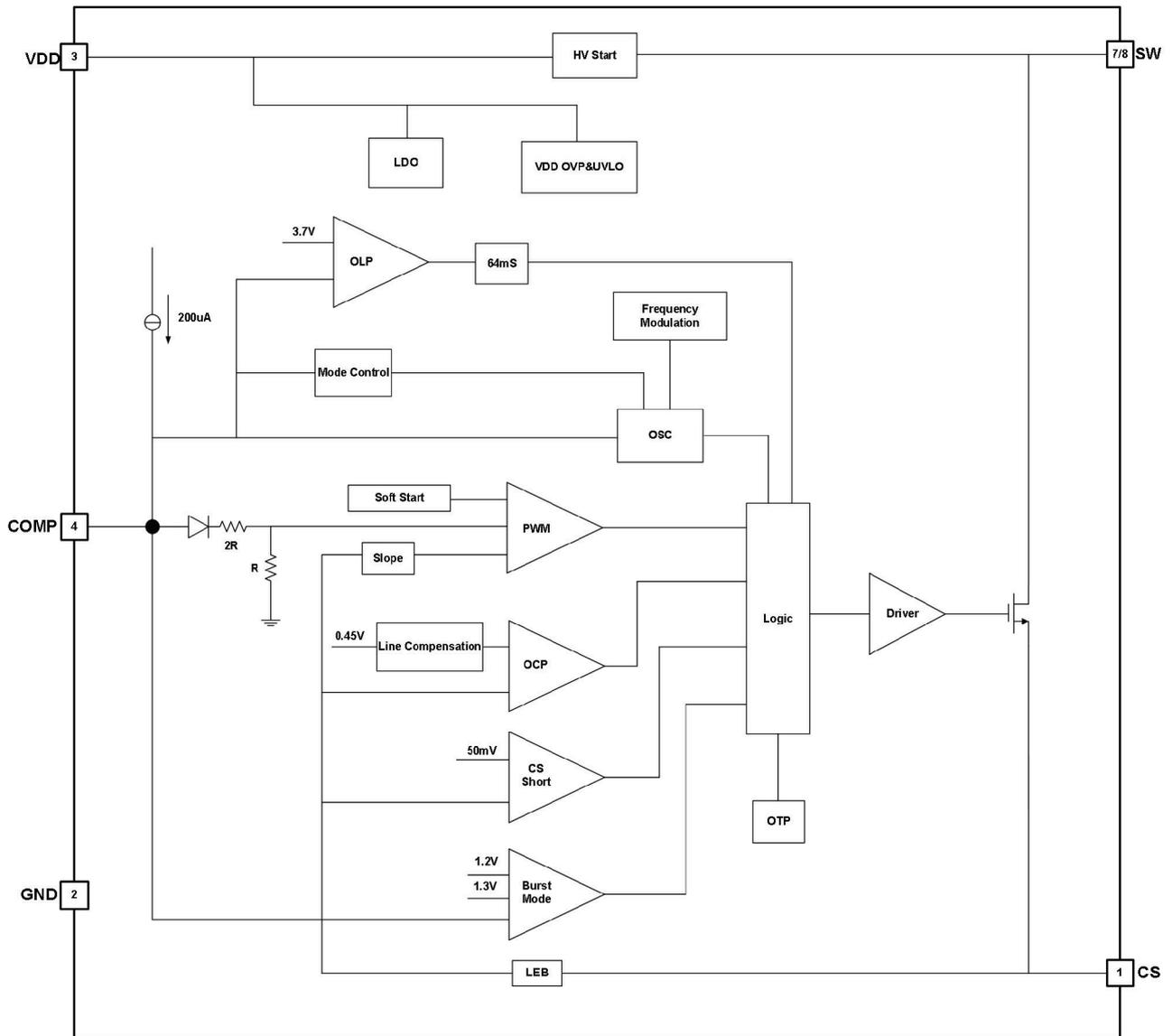


7 Typical Application



Typical Application Diagram of AL612

8 Block Diagram



Functional Block Diagram of AL612

9 Pin Descriptions

| Pin Name | Pin No. | Descriptions |
|----------|---------|--|
| CS | 1 | Built-in high voltage MOSFET source pin, current sense pin |
| GND | 2 | Ground |
| VDD | 3 | Operating Voltage Input Pin |
| COMP | 4 | Feedback Pin |
| NC | 5 | No connection |
| SW | 6,7 | Built-in high-voltage MOSFET drain pin, connected to transformer primary winding |

10 Specifications

10.1 Absolute Maximum Ratings

| Parameter | Value | Units |
|---|----------|-------|
| VDD pin withstand voltage | 50 | V |
| SW pin withstand voltage | 1200 | V |
| CS, COMP pin withstand voltage | -0.3~5.5 | V |
| Junction operating temperature range | -40~150 | °C |
| Storage Temperature Range | -55~150 | °C |
| Pin soldering temperature (10 seconds) | 260 | °C |
| Package thermal resistance R θ_{JC} (DIP-7) | 40 | °C/W |
| Drain pulse current (Tpulse=100us) | 2 | A |

Note: Stress exceeds these ratings listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Expose to absolute-maximum-rated conditions for extended periods may affect device reliability.

10.2 ESD Ratings

| Discharge mode | Standard | Value | Units |
|----------------|-----------------------------|-------|-------|
| HBM | ANSI/ESDA/JEDEC JS-001-2023 | 4K | V |
| CDM | ANSI/ESDA/JEDEC JS-002-2022 | 2K | V |

10.3 Typical Output Power

| Package | Input Voltage Range | Open Average Power | Open Peak Power |
|---------|---------------------|--------------------|-----------------|
| DIP-7 | 85-425Vac | 11W | 14W |
| | 230V ± 15% | 12W | 17W |

10.4 Thermal Information

| Parameter | Descriptions | Value | Unit |
|-----------------|---------------------|-------|------|
| R θ_{JA} | Junction to ambient | 80 | °C/W |
| R θ_{JC} | Junction to case | 40 | °C/W |

10.5 Electrical Characteristics

Test conditions: $T_A=25^{\circ}\text{C}$, $V_{DD}=15\text{V}$, unless otherwise specified.

| Parameter | Symbol | Conditions | Value | | | Unit |
|--|---------------------|--|-------|------|-----|------|
| | | | Min | Typ | Max | |
| Chip power supply section | | | | | | |
| Starting Voltage | V_{SW_START} | | | | 55 | V |
| Startup charging current | I_{DD_CH} | $V_{SW}=105\text{V}$, $V_{COMP}=\text{GND}$, $V_{DD}=10\text{V}$ | | 1 | | mA |
| Operating Voltage Range | V_{DD} | After turn-on | 9 | | 28 | V |
| VDD Over -Voltage Protection | V_{DDOVP} | $V_{CS}=0\text{V}$, $V_{COMP}=2\text{V}$, Ramp up VDD until gate is off | 28 | 30 | 32 | V |
| UVLO Threshold Voltage | V_{DDON} | $V_{COMP}=\text{GND}$ | 12 | 13 | 14 | V |
| | V_{DDOFF} | $V_{COMP}=\text{GND}$ | 7.5 | 8 | 8.5 | V |
| Operating Supply Current | I_{DD0} | $V_{DD}=15\text{V}$, $V_{COMP}=\text{GND}$ | | 0.8 | 1.2 | mA |
| Operating Switching Current | I_{DD1} | $V_{DD}=15\text{V}$, $V_{COMP}=2\text{V}$ | | 1.5 | 2 | mA |
| Protection Mode Current | I_{DD_FAULT} | | | 170 | 220 | uA |
| Undervoltage Working Current | I_{DD_OFF} | $V_{DD}=6\text{V}$ | | 100 | 130 | uA |
| COMP section | | | | | | |
| Open Loop Voltage | V_{COMP_OPEN} | | | 4.8 | | V |
| Overload Protection Threshold | V_{COMP_OLP} | | | 3.7 | | V |
| Boost Mode Threshold (only for AL612D7B) | V_{COMP_TRI} | | | 3.0 | | V |
| PFM Operating Mode Threshold | V_{COMP_PFM} | Voltage falling when frequency decrease | | 2.0 | | V |
| Burst Mode Threshold | V_{COMP_BM} | Voltage falling | | 1.2 | | V |
| Burst Mode Hysteresis Threshold | $V_{COMP_BM_HYS}$ | Voltage rising | | 1.3 | | V |
| COMP Short Circuit Current | I_{COMP} | $V_{COMP}=\text{GND}$ | | -200 | | uA |
| Overload Protection Delay Time | T_{D_OLP} | | | 64 | | ms |
| Detection Voltage Gain | AVCS | | | 3.3 | | V/V |
| Current detection section | | | | | | |
| Soft Start Time | T_{SS} | | | 10 | | ms |
| Minimum T_{ON} | T_{ON_MIN} | | | 500 | | ns |
| Turn Off Delay Time | T_D | | | 150 | | ns |
| Leading-Edge Blanking Time | T_{LEB} | | | 350 | | ns |

| | | | | | | |
|---|--|---|-------|------|-------|----------|
| Peak Drain Current Limit Threshold | V_{TH_OC} | | 0.425 | 0.45 | 0.475 | V |
| Peak Current Limit Clamp Voltage | $V_{OCP_CLAMPING}$ | | | 0.55 | | V |
| Built-in oscillator section | | | | | | |
| Maximum Switching Frequency (only for AL612D7B) | F_{OSC_MAX} | | 162 | 180 | 198 | kHz |
| Normal Switching Frequency | F_{OSC} | VDD in operating voltage range $V_{COMP}=2V$ | 54 | 60 | 66 | kHz |
| Frequency Jitter Range | F_D | | | ±5 | | kHz |
| Frequency Modulation | F_M | | | 250 | | Hz |
| Maximum Duty Cycle | D_{MAX} | | 70 | | 85 | % |
| Burst-Mode Frequency | F_{Burst} | | 21.5 | 25 | | kHz |
| Over-temperature protection section | | | | | | |
| Over-Temperature Protection | T_{SD} | | 135 | 150 | | °C |
| Over-Temperature Protection Hysteresis | T_{HYST} | | | 30 | | °C |
| Built-in power tube section | | | | | | |
| BV_{DS} | $I_{SW}=250\mu A,$ $T_J=25^\circ C$ | | 1200 | | | V |
| $R_{DS(ON)}$ | $I_{SW}=0.5A, T_J=25^\circ C$ | | | 9 | | Ω |

11 Detailed Description

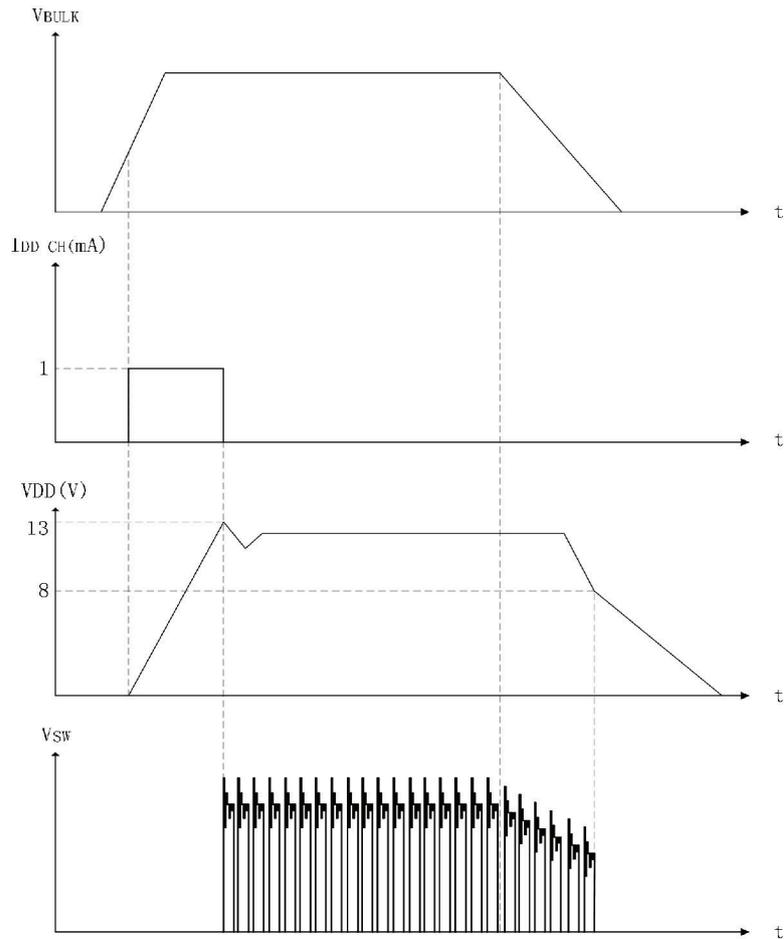
11.1 Overview

AL612 is an efficient switching power supply controller integrating power MOSFET and PWM controller, and the extremely compact peripheral components are more conducive to the design of switching power supplies. AL612 provides extremely complete and intelligent protection functions, including pulse-by-pulse overload protection, over-voltage protection, CS short-circuit protection, over-temperature protection and soft-start function, etc. In addition, the three mixed modulation techniques of PWM, PFM and Burst can realize the best performance of the system under different loads; the unique high-voltage start-up strategy can achieve lower standby power consumption. In addition, the three mixed modulation techniques of PWM, PFM and Burst can realize the best performance of the system under different loads; and the unique high-voltage start-up strategy can realize lower standby power consumption. The built-in frequency dithering function and frequency modulation technology enable better EMI performance, and the AL612 provides a reliable solution for ultra-low standby power application scenarios.

11.2 Functional Descriptions

11.2.1 Startup

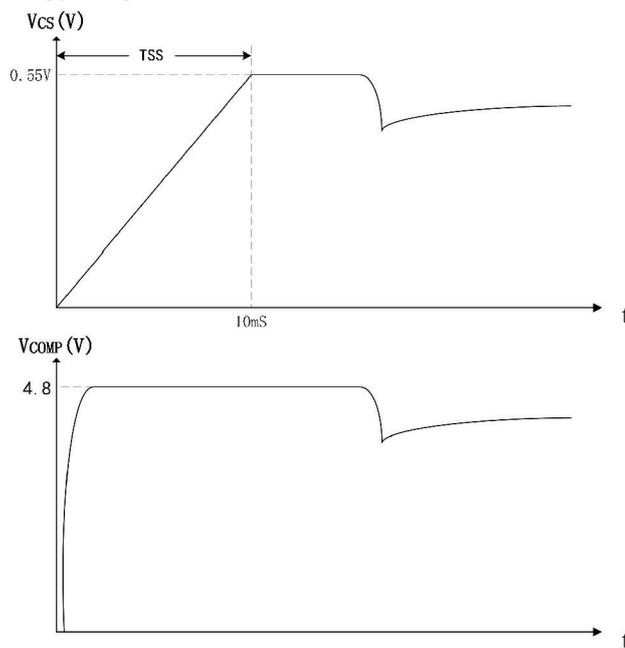
The built-in high voltage starter tube provides 1mA current to charge the external VDD capacitor. Once the VDD voltage reaches 13V, AL612 starts to work immediately, at this time the high voltage starter tube will stop charging the VDD capacitor, the VDD capacitor discharges to maintain the chip working, the VDD voltage drops slightly, then the transformer auxiliary winding provides energy to the VDD capacitor to keep the VDD capacitor voltage stable.



11.2.2 Soft Start

During the start-up phase, the limit value of the maximum peak current at the drain of the built-in power tube is slowly raised; this minimizes the stress on the device and prevents transformer saturation.

The soft-start time of AL612 is typically 10ms.



11.2.3 Output Driver

AL612 adopts unique driving technology and optimizes the totem pole structure to reasonably configure the driving current and dead time, resulting in better EMI performance and lower loss.

11.2.4 Oscillator

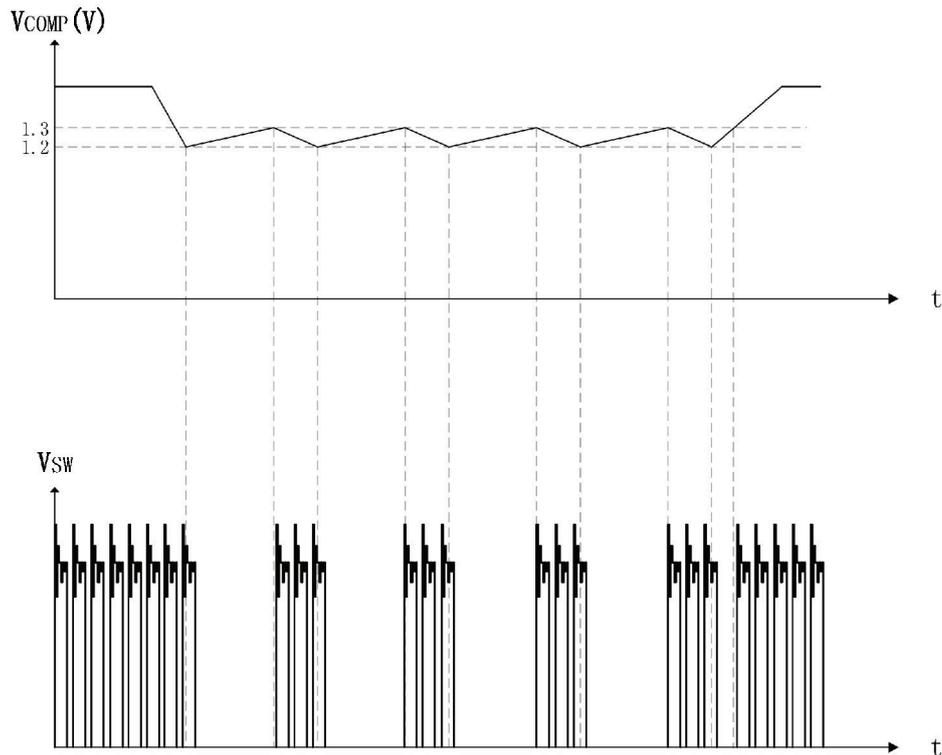
AL612 does not require peripheral circuitry for frequency setting, the built-in oscillator frequency is fixed at 60kHz, equipped with a unique frequency dithering technology, which can further optimize the EMI characteristics.

11.2.5 Feedback Control

The chip adopts the current mode control strategy, the voltage of COMP pin can control the current of the power tube, so as to achieve the purpose of voltage regulation.

11.2.6 Intermittent Operation Mode

Under light load, AL612 will operate in intermittent mode to reduce system power consumption. When the load is lightened, the COMP pin voltage decreases and the chip enters the intermittent operation mode when V_{COMP} is less than the Burst mode threshold (typically 1.2V). Once V_{COMP} exceeds the Burst mode hysteresis threshold, AL612 can exit Burst mode.



11.2.7 Down Conversion Operation Mode

AL612 provides a down conversion operation mode, which detects the COMP pin voltage and reduces the switching frequency under light load and no-load conditions to improve the light load efficiency. When the COMP pin voltage is less than the PFM operation mode threshold (typical 2V), the

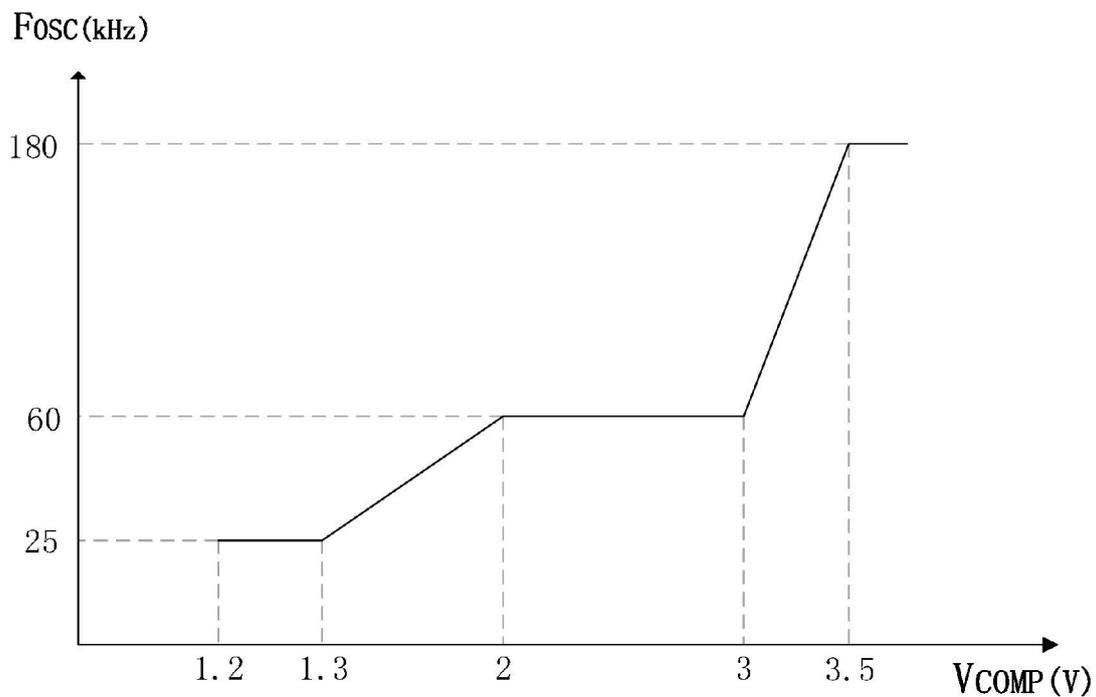
chip enters the down conversion operation mode, where the switching frequency decreases with the load, and the minimum frequency of this chip is 25kHz to eliminate audio noise under light load conditions.

11.2.8 PWM Operation Mode

When AL612 operates in the heavy load V_{COMP} greater than 2V condition, it enters the PWM operation mode and the operating frequency is kept constant at 60kHz.

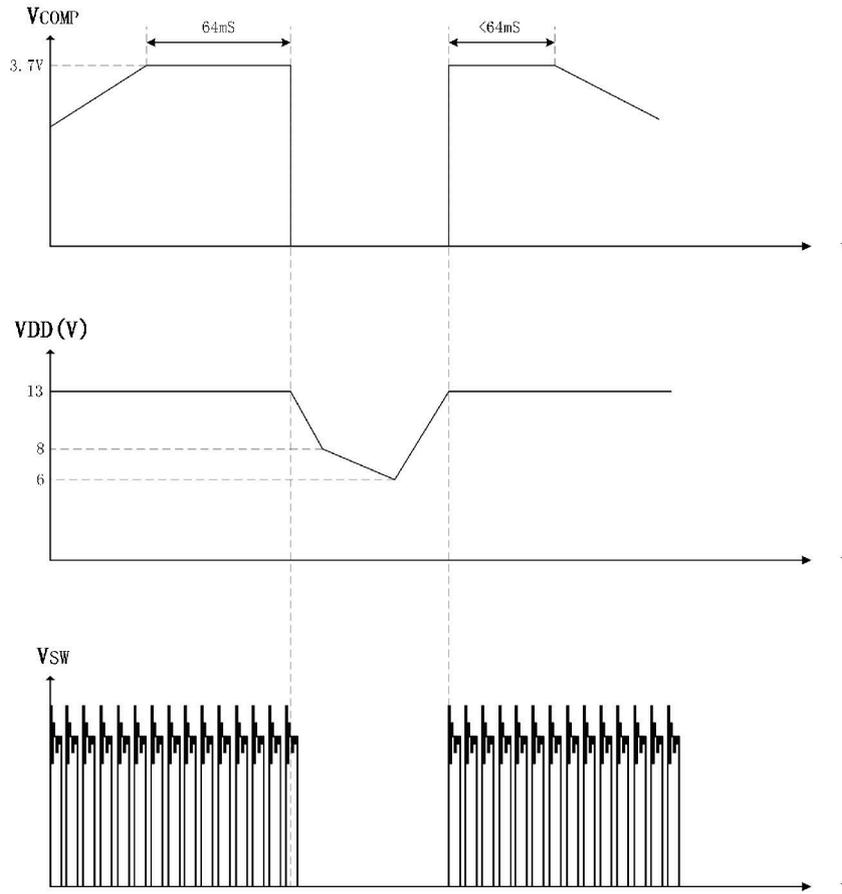
11.2.9 Up Sampling Operating Mode (Only Available in AL612D7B)

When AL612D7B operates under strong magnetic or overload V_{COMP} greater than 3V, it will enter the step-up mode of operation, and the operating frequency will be linearly increased to 3 times of the original with V_{COMP} to compensate for the effect of the transformer inductance decreasing to 1/3 of the original under the strong magnetic field.



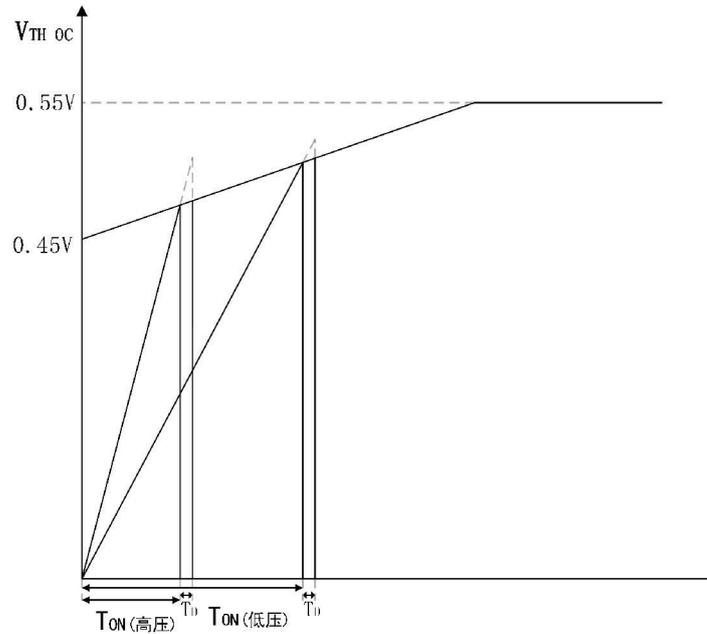
11.2.10 Overload Protection

When the load current exceeds the preset value, the system will enter the overload protection ("hiccup" type protection): it can protect the system under abnormal conditions. When the V_{COMP} pin voltage exceeds 3.7V and after a fixed delay of 64ms, the chip will stop working, and after the fault is removed, the chip can resume operation.



11.2.11 Line Voltage Compensation

AL612 provides overcurrent line voltage compensation to achieve constant output power limitation over the full voltage range. T_D is the conduction delay time, the conduction time is shorter for high-voltage input than for low-voltage input, and the V_{TH_OC} is lower for high-voltage input after line voltage compensation, but the current sampling value of the CS pin is higher during the T_D time, and after the combination of the two, the peak currents at the high-voltage and low-voltage inputs are basically the same.



11.2.12 Ramp Compensation

The AL612 provides ramp compensation, which superimposes a voltage sawtooth signal on the sampled current signal and is used to improve the stability of the system loop.

11.2.13 Overcurrent Protection

This chip is cycle-by-cycle overcurrent protection. The overcurrent protection point can be adjusted by setting the R_{CS} resistor between the CS pin and GND to detect and control the current flowing through the switching tube.

11.2.14 CS Short Circuit Protection

The AL612 provides CS short circuit protection. If the CS resistor is short-circuited before the system starts up, the chip enters the CS short-circuit protection state. It can protect the system under abnormal conditions.

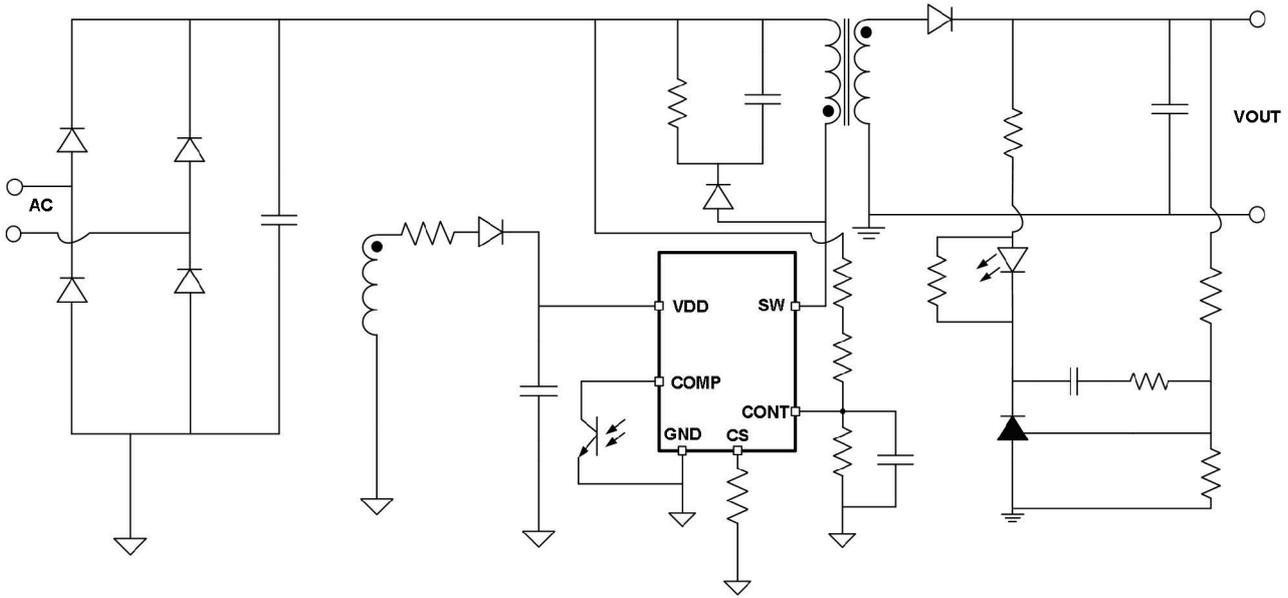
11.2.15 Over Temperature Protection

The power MOSFET and the control chip are integrated together, making it easier for the control circuit to detect the temperature of the MOSFET. When the temperature exceeds 150°C, the chip enters the over-temperature protection state; when the temperature recovers to 120°C, the chip can resume operation.

12 Application Information

12.1 Typical Application

The following figure shows the schematic of a typical application circuit that can be used as a means of evaluating the performance of AL612. This section describes the design process specific to the application schematic.



12.2 Selection of Input High Voltage Electrolytic Capacitor Capacity C_{BUS}

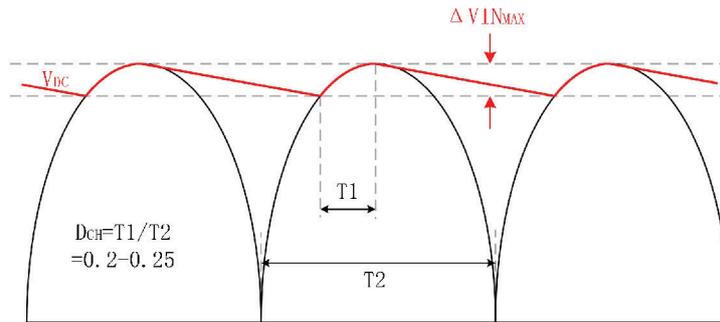
$$C_{BUS} = \frac{P_{IN} \times (1 - D_{CH})}{\sqrt{2} \times VAC_{MIN} \times 2 \times f_L \times \Delta VIN_{MAX}}$$

- Input Power $P_{IN} = P_o / \eta$ (η is the efficiency)
- VAC_{MIN} is the minimum AC input voltage
- f_L is the line AC frequency, generally 50~60Hz
- D_{CH} is the charging duty cycle of the input rectifier filter capacitor, its typical value is 0.2~0.3

Generally set ΔVIN_{MAX} as 10%~30% of $\sqrt{2}VAC_{MIN}$.

Capacitor withstand voltage should be more than $VIN_{MAX} = \sqrt{2} \times VAC_{MAX}$, VAC_{MAX} is the maximum AC input voltage.

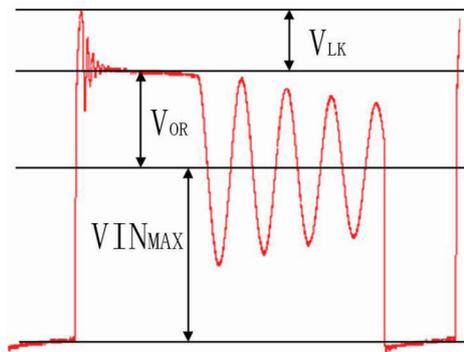
It is also possible to follow the empirical values of 2~3uF/W for C_{BUS} for general purpose input range (85VAC~265VAC) and 1uF/W for C_{BUS} for high voltage input (195VAC~265VAC).



12.3 Transformer Design

12.3.1 Determination of Turns Ratio

When the MOSFET is turned off, the drain inductance voltage V_{LK} , the input voltage V_{IN} , and the output voltage V_{OR} reflected to the primary will be applied to terminals of the MOSFET.



The reflected voltage V_{OR} is:

$$V_{OR} = V_{DS_MAX} - V_{LK} - V_{IN_MAX} - V_{MARGIN}$$

- V_{LK} is the leakage inductance spike voltage
- V_{DS_MAX} is the maximum MOSFET voltage
- V_{MARGIN} is the margin (100V for consumer, 300V for power)

From this one can calculate the turns ratio n

$$n = \frac{V_{OR}}{V_O + V_F}$$

- V_F is the output diode forward voltage drop

12.3.2 Maximum Duty Cycle

$$D = \frac{V_{OR}}{V_{OR} + V_{IN_MIN}}$$

- V_{IN_MIN} is the DC voltage corresponding to the lowest AC input voltage,

$$V_{IN_MIN} = (0.7 \sim 0.9) \times \sqrt{2} \times V_{AC_MIN}$$

Note: The maximum duty cycle D should not exceed the maximum duty cycle of the chip, and to leave a certain margin, it is recommended to be around 0.5.

$$N_A = N_S \times \frac{V_{DD} + V_F}{V_O + V_F}$$

Where V_F is the rectifier diode forward conduction drop voltage

12.3.6 Calculation of Primary and Secondary Wire Diameters

The primary coil current RMS value I_{P_RMS} is:

$$I_{P_RMS} = I_L \times \sqrt{\frac{D}{3} \times (3 + \frac{r^2}{4})}$$

The secondary coil current RMS value I_{S_RMS} is:

$$I_{S_RMS} = n \times I_L \times \sqrt{\frac{1-D}{3} \times (3 + \frac{r^2}{4})}$$

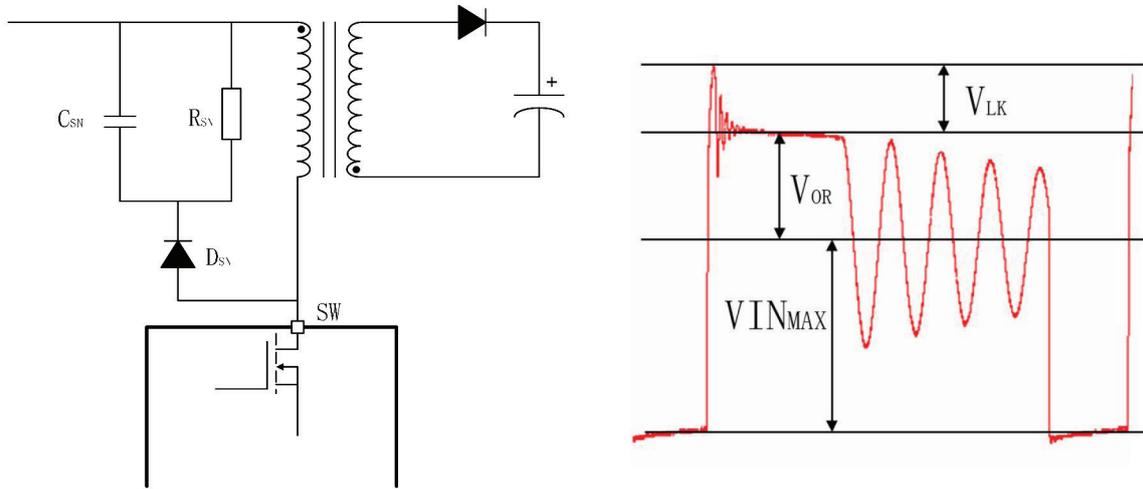
The cross-sectional area of the winding wire $S = I_{RMS}/J$, where J is the current density, generally taken as 6~8A/mm².

The winding wire diameter d is

$$d = \sqrt{\frac{4 \times S}{\pi}}$$

12.4 Calculation of RCD Snubber

The following figure shows the reference diagram of the RCD absorption circuit with the SW voltage waveform on the right.



In the figure, V_{LK} is the leakage inductance spike voltage, V_{OR} is the transformer reflection voltage, the diode in the RCD circuit is recommended to choose a high voltage diode with a current capacity of 1A or more, and the capacitance is selected with reference to the following formula:

$$P_{SN} = 0.5 \times L_{LK} \times I_{PK}^2 \times F_{SW} \times \frac{V_{LK} + V_{OR}}{V_{LK}}$$

$$R_{SN} = \frac{(V_{LK} + V_{OR}) \times V_{LK}}{0.5 \times L_{LK} \times I_{PK}^2 \times F_{SW}}$$

$$C_{SN} = \frac{V_{LK} + V_{OR}}{R_{SN} \times F_{SW} \times \Delta V_{SN}}$$

Among them:

- P_{SN} is the leakage inductance loss
- L_{LK} is the transformer leakage inductance
- I_{PK} is the transformer peak current
- F_{SW} is the switching frequency, typical value is 60KHz
- ΔV_{SN} is the capacitor ripple, according to experience, the value is generally taken as 10%~30% of the voltage ($V_{LK}+V_{OR}$) on both sides of the capacitor.

12.5 Calculation of CS Sampling Resistance

The CS pin is the source of the internal integrated MOSFET. The AL612 has cycle-by-cycle overcurrent protection with $V_{CS}=0.45V$, and the peak current can be detected and controlled by the CS-to-ground resistor R_{CS} . Calculate the R_{CS} according to the following equation.

$$R_{CS} = \frac{V_{CS}}{I_{PK}}$$

12.6 Selection of VDD Capacitor

VDD capacitor in the chip startup phase first through the high-voltage starter tube charging, and then discharge to maintain chip operation, so the choice of VDD capacitor directly affects the startup time, it is recommended to set the value of 10uF ~ 47uF, the calculation formula is as follows:

$$T_{START} = \frac{C_{VDD} \times VDD}{I_{DD_CH}}$$

For example, if the VDD capacitance is selected to be 22uF, $I_{DD_CH} = 1\text{mA}$, and the startup voltage threshold of AL612 is 13V, the corresponding startup time is $T_{START} = 286\text{mS}$.

12.7 Selection of Output Rectifier Diode

The maximum reverse voltage V_{DR} of the output rectifier diode and the current RMS value I_{D_RMS} are:

$$V_{DR} = V_o + \frac{VIN_{MAX}}{n}$$

$$I_{D_RMS} = I_{S_RMS} \times \sqrt{\frac{VIN_{MIN}}{V_{OR}}}$$

In practice, the maximum reverse voltage V_{RRM} and the average forward current I_F of the rectifier diode are margined as follows:

$$V_{RRM} > 1.3 \times V_{DR}$$

$$I_F > 1.5 \times I_{D_RMS}$$

12.8 Selection of Output Capacitor

The selection of the output capacitor mainly considers the RMS value of the ripple current, ESR and withstand voltage.

The ripple current I_{C_RMS} of the output capacitor is:

$$I_{C_RMS} = \sqrt{(I_{D_RMS})^2 - (I_o)^2}$$

The voltage ripple of the output capacitor is mainly caused by the charging and discharging of the capacitor and ESR.

The ripple caused by the charging and discharging of the capacitor is:

$$\Delta V_{CO} = \frac{I_o \times D}{C_o \times F_{SW}}$$

- C_o is the capacitance value

The ripple due to ESR is:

$$\Delta V_{ESR} = I_{PK} \times n \times R_{ESR}$$

- R_{ESR} is the ESR of the output capacitor

Since the electrolytic capacitor capacity is relatively large, the ripple due to ESR is mainly

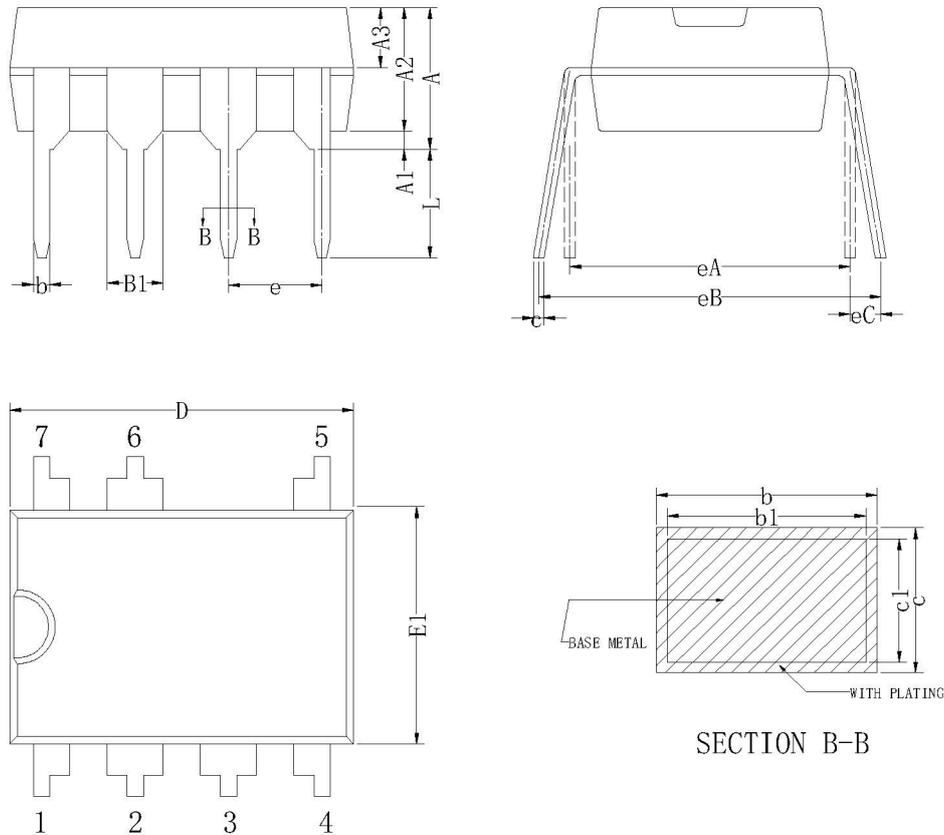
considered and R_{ESR} is calculated:

$$R_{ESR} = \frac{I_{PK} \times n}{\Delta V_{ESR}}$$

The withstand voltage of the output capacitor leaves a margin of at least 20% over the output voltage.

13 Package Information

DIP-7



| Dimension Symbol | Min (mm) | Nom (mm) | Max (mm) |
|---------------------|-------------|-------------|-------------|
| A | 3.60 | 3.80 | 4.00 |
| A1 | 0.51 | - | - |
| A2 | 3.20 | 3.30 | 3.40 |
| A3 | 1.55 | 1.60 | 1.65 |
| b | 0.44 | - | 0.52 |
| b1 | 0.43 | 0.46 | 0.49 |
| B1 | 1.52REF | | |
| c | 0.25 | - | 0.29 |
| c1 | 0.24 | 0.25 | 0.26 |
| D | 9.15 | 9.25 | 9.35 |
| E1 | 6.25 | 6.35 | 6.45 |
| e | 2.54BSC | | |
| eA | 7.62REF | | |
| eB | 7.62 | - | 9.30 |
| eC | 0 | - | 0.84 |
| L | 3.00 | - | - |