

# KA7541

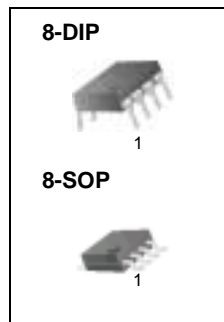
## Simple Ballast Controller

### Features

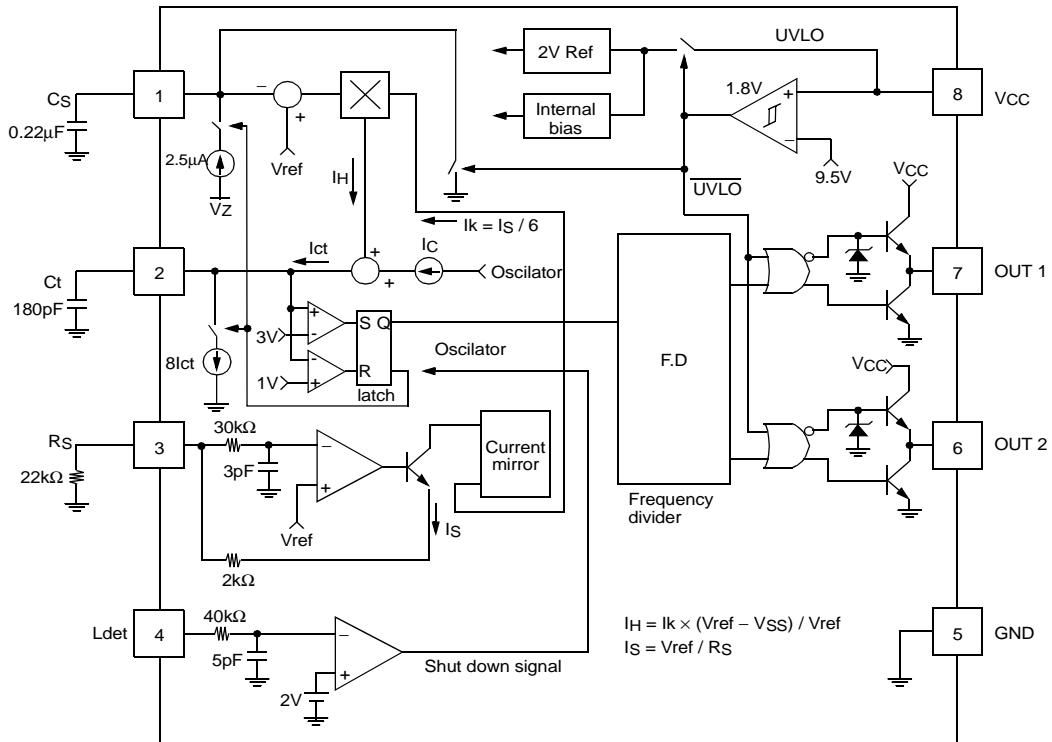
- Internal soft start
- Flexible soft start frequency
- No lamp protection
- Trimmed 1.5% internal bandgap reference
- Under voltage lock out with 1.8V of hysteresis
- Totem pole output with high state clamp
- Low start up and operating current

### Descriptions

The KA7541 provides simple and high performance electronic ballast control functions. KA7541 is optimized for electronic ballast requiring a minimum board area, reduced component count and low power dissipation. Internal soft start circuitry eliminates the need for an external soft start PTC resistor. The initial soft start switching frequency and soft start time can be adjusted depending on the types of lamps. Protection circuitry has also been added to prevent burning out of switches in no lamp condition. output gate drive circuit clamps power MOSFET gate voltage irrespective of supply voltage



## Internal Block Diagram



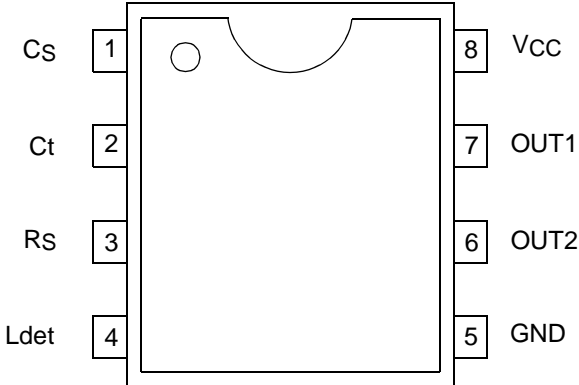
## Absolute Maximum Ratings

| Parameter   | Symbol                            | Value      | Unit |
|---|-----------------------------------|------------|------|
| Supply voltage  | V <sub>CC</sub>                   | 30         | V    |
| Peak drive output current   | I <sub>OH</sub> , I <sub>OL</sub> | ±300       | mA   |
| Drive output clamping diodes<br>V <sub>O</sub> >V <sub>CC</sub> , or V <sub>O</sub> <-0.3 | I <sub>clamp</sub>                | ±10        | mA   |
| Soft start, and no lamp detection input voltage   | V <sub>IN</sub>                   | -0.3 to 6  | V    |
| Operating temperature range   | T <sub>opr</sub>                  | -25 to 125 | °C   |
| Storage temperature range   | T <sub>stg</sub>                  | -65 to 150 | °C   |
| Power dissipation   | 8-DIP                             | 0.8        | W    |
|   | 8-SOP                             | 0.5        |      |
| Thermal resistance (Junction-to-air)  | 8-DIP                             | 100        | °C/W |
|   | 8-SOP                             | 165        |      |

## Absolute Maximum Ratings (-25°C ≤ T<sub>a</sub> ≤ 125°C)

| Parameter  | Symbol                  | Value | Unit |
|--|-------------------------|-------|------|
| Temperature stability for reference voltage (V <sub>ref</sub> )  | ΔV <sub>ref</sub> (Typ) | 15    | mV   |
| Temperature stability for operating frequency (f <sub>os</sub> ) | Δf <sub>os</sub> (Typ)  | 5     | kHz  |

## Pin Assignments



(Top View)

## Pin Definitions

| Pin Number | Pin Name | Pin Function Description  |
|------------|----------|---|
| 1          | CS       | Soft start capacitor connection pin. The pin voltage determines the phase of soft start, normal mode.   |
| 2          | CT       | Timing capacitor connection pin. The timing capacitor is charged and discharged to generate the sawtooth waveform that determines the oscillation frequency in the internal oscillator block. |
| 3          | RS       | Soft start resistor connection pin. The soft start resistor value determines the initial preheating switching frequency during soft start mode.   |
| 4          | Ldet     | Input to the protection circuit. If the pin voltage is lower than 2V, the output of the gate driver is inhibited.   |
| 5          | GND      | The ground potential of all the pins.   |
| 6          | OUT 2    | The output of a high-current power driver capable of driving the gate of a power MOSFET   |
| 7          | OUT 1    | The output of a high-current power driver capable of driving the gate of a power MOSFET.  |
| 8          | VCC      | The logic and control power supply connection.  |

## Electrical Characteristics

Unless otherwise specified, for typical values  $V_{CC}=14V$ ,  $T_a=25^{\circ}C$ , For Min/Max values  $T_a$  is the operating ambient temperature range with  $-25^{\circ}C \leq T_a \leq 125^{\circ}C$  and  $11V \leq V_{CC} \leq 30V$

| Parameter                             | Symbol             | Conditions                                      | Min. | Typ. | Max. | Unit    |
|---------------------------------------|--------------------|---|------|------|------|---------|
| <b>UNDER VOLTAGE LOCK OUT SECTION</b> |                    |   |      |      |      |         |
| Start threshold voltage               | $V_{TH(st)}$       | $V_{CC}$ increasing                             | 8.5  | 9.5  | 10.5 | V       |
| UVLO hysteresis                       | $HY(st)$           | -   | 1.3  | 1.8  | 2.3  | V       |
| <b>SUPPLY CURRENT SECTION</b>         |                    |   |      |      |      |         |
| Start up supply current               | $I_{ST}$           | $V_{CC} < V_{TH(st)}$                           | -    | 0.15 | 0.25 | mA      |
| Operating supply current              | $I_{CC}$           | Output not switching                            | -    | 6    | 10   | mA      |
| Dynamic operating supply current      | $I_{DCC}$          | 50kHz, $C_I=1nF$                                | -    | 7    | 14   | mA      |
| <b>REFERENCE SECTION</b>              |                    |   |      |      |      |         |
| Reference voltage                     | $V_{ref}$          | $I_{ref}=0mA$ , $V_{CC}=14V$                    | 1.95 | 2    | 2.05 | V       |
| Line regulation                       | $\Delta V_{ref 1}$ | $14V \leq V_{CC} \leq 25V$                      | -    | 0.1  | 10   | mV      |
| Temperature stability of $V_{ref}$    | $\Delta V_{ref 2}$ | $-25 \leq T_a \leq 125^{\circ}C$ , $V_{CC}=14V$ | -    | 15   | -    | mV      |
| <b>OSCILLATOR SECTION</b>             |                    |   |      |      |      |         |
| Operating frequency                   | $f_{os}$           | $V_{SS}=3V$ , $C_T=470pF$                       | 44   | 50   | 56   | KHz     |
| Operating dead time                   | $t_{od}$           | $V_{SS}=3V$ , $V_{CC}=14V$                      | 2.4  | 2.9  | 3.4  | $\mu s$ |
| Soft start frequency                  | $f_{ss}$           | $V_{SS}=0V$ , $C_T=470pF$                       | 56   | 65   | 74   | KHz     |
| Soft start dead time                  | $t_{sd}$           | $V_{SS}=0V$ , $V_{CC}=14V$                      | 1.8  | 2.3  | 2.8  | $\mu s$ |
| <b>OUTPUT SECTION</b>                 |                    |   |      |      |      |         |
| Rising time <sup>(note1)</sup>        | $t_r$              | $C_I=1nF$ , $V_{CC}=12V$                        | -    | 120  | 200  | ns      |
| Falling time <sup>(note1)</sup>       | $t_f$              | $C_I=1nF$ , $V_{CC}=12V$                        | -    | 50   | 100  | ns      |
| Maximum output voltage                | $V_{omax(o)}$      | $V_{CC}=20V$                                    | 12   | 15   | 18   | V       |
| Output voltage with UVLO activated    | $V_{omin(o)}$      | $V_{CC}=5V$ , $I_O=100\mu A$                    | -    | -    | 1    | V       |
| <b>NO LAMP PROTECTION SECTION</b>     |                    |   |      |      |      |         |
| No lamp detect voltage                | $V_{nd}$           | -   | 1.9  | 2    | 2.1  | V       |

**Note:**

1. These parameters, although guaranteed, are not 100% tested in production.

## Start-up Circuit

Start up current is supplied to the IC through the start up resistor (Rst). In order to reduce the power dissipation in Rst, the Rst is connected to the full wave rectified output voltage.

The following equation can be used to calculate the size of Rst

$$R_{St} < \frac{V_{in(ac)} \times \sqrt{2} - V_{th(st),max}}{I_{st,max}} \quad P_{R_{St}} = \frac{(V_{in(ac\_max)} \cdot \sqrt{2} - V_{cc})^2}{R_{St}} \leq 0.5W$$

$$= \frac{85 \times \sqrt{2} - 10.5}{0.25 \times 10^{-3}} = 440k\Omega \quad R_{St} \geq 2 \times (V_{in(ac\_max)} \cdot \sqrt{2} - V_{cc})^2 \quad \therefore 260K \leq R_{St} \leq 440K$$

$$R_{St} \geq 260K$$

The size of start up capacitor (Cst) is normally decided in terms of the start up time and operating current build up time with auxiliary operating current source.

The turn off snubber capacitor (Cq2) and two diodes (D1, D2) constitute the auxiliary operating current source for the IC. The charging current through the Cq2 flows into the IC and also charges the start-up capacitor. If the size of Cq2 is increased, the VCC voltage of the Cst is also increased.

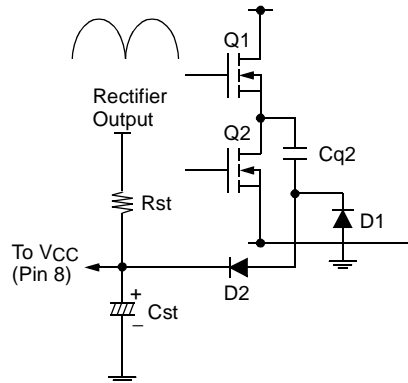


Figure 1. Start up circuit

## Oscillator

The gate drive output frequency is as half as that of the triangular waveform in timing capacitor (Ct) at pin #2. In normal operating mode, the timing capacitor charging current is  $50\mu A$ . The discharging current is seven times of the charging current ( $7 \times 50\mu A$ ). The charging period of the timing capacitor is the on duty of the gate drive. The discharging period is the off duty of the gate drive.

The rising slope and falling slope of the triangular waveform are as following.

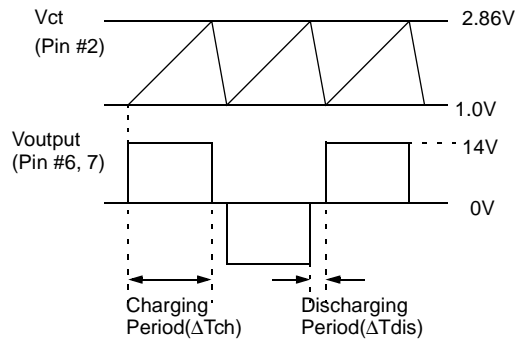
$$\text{Rising slope: } dv / dt = i / C = 50\mu A / Ct$$

$$\text{Falling slope: } dv / dt = i / C = 7 \times 50\mu A / Ct$$

For example, when the timing capacitor is 180pF,

$$\Delta T_{ch} = 6.69\mu$$

$$\Delta T_{dis} = 0.956\mu$$



**Figure 2. Oscillator sawtooth & Output gate drive waveform**

As a result, the switching frequency is as following

$$T_s = 2 \times (\Delta T_{ch} + \Delta T_{dis}) = 15.29\mu$$

$$f_{sw} = 1 / T_s = 65\text{KHz}$$

The explicit equation calculating the size of the timing capacitor for a certain switching frequency is written below.

$$C_t = \frac{11.76 \times 10^{-6}}{f_{sw}}$$

### Soft Start

The switching frequency is linearly decreasing from the pre-heating frequency to the normal switching frequency. In KA7541, the initial pre-heating frequency can be adjusted depending on the types of the lamps used. During the pre-heating mode, a sixth of the soft start current ( $I_S$ ) which flows through the soft start resistor ( $R_S$ ) at pin #3 is added to the normal timing capacitor charging current ( $50\mu\text{A}$ ). The rising and falling slope of the triangular waveform are increased due to this added current.

$$\text{Soft start current } (I_S) = 2V / R_S$$

$$\text{Rising slope: } dv / dt = i / C = (50\mu\text{A} + I_S / 6) / C_t$$

$$\text{Falling slope: } dv / dt = i / C = 7 \times (50\mu\text{A} + I_S / 6) / C_t$$

So, once the value of  $R_S$  and  $C_t$  are known, the pre-heating frequency can be calculated straightforward by using the following equation.

$$f_{sw}(\text{pre}) = \frac{50 \times 10^{-6} + \frac{0.33}{R_S}}{C_t \times 4.25}$$

The dead time ratio during pre-heating mode is maintained to be constant as well as in normal mode. (on duty: dead time = 7:1)

The voltage of the soft start capacitor ( $C_S$ ) determines the soft start time ( $t_{ss}$ ). When  $V_{CC}$  voltage exceeds the start-up voltage ( $V_{th}(\text{st})$ ), the soft start capacitor start to be charged by the current source ( $313\text{nA}$ ). The switching frequency decreases linearly to  $f_{sw}(\text{nor})$  from  $f_{sw}(\text{pre})$  until the soft start capacitor voltage ( $V_{CS}$ ) touches  $2V$ . Therefore the soft start duration time ( $t_{ss}$ ) can be acquired by the following formula.

$$t_{ss} = \frac{C_s \times V}{i}$$

$$= \frac{0.2 \times 10^{-6} \times 2}{313 \times 10^{-9}} = 1.28s$$

For example, the soft start capacitor of 0.2μF makes the soft start time (tss) to be 1.28sec.

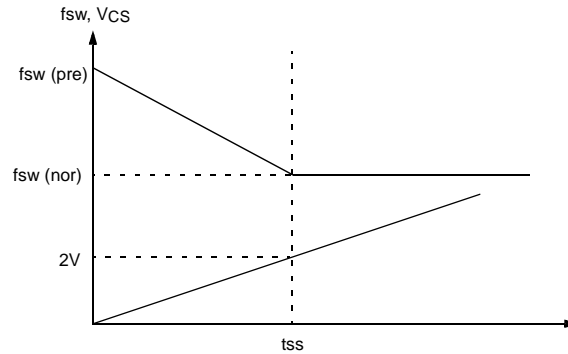


Figure 3. Frequency & Soft start capacitor voltage variation during soft start

### No Lamp Protection

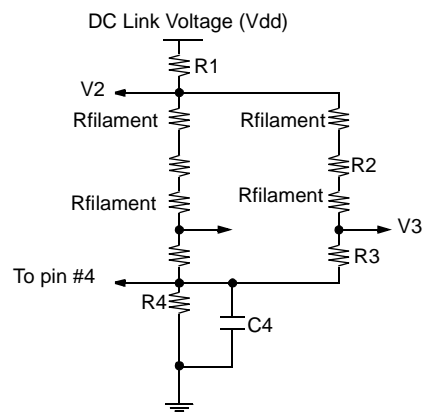
When the voltage at pin #4 is lower than 2V, the gate drive output is off state, so the external power MOSFET stops switching. In no lamp protection circuit the dc link voltage is divided by a couple of resistors including both lamp filaments, and The divided voltage is applied to the pin #4 before the MOSFETs start switching.

$$V_{R4} = V_{dd} \times \frac{R_4}{R_1 + \frac{R_2 + R_3 + 2 \times R_f}{2} + R_4}$$

$$\cong 400 \times \frac{15K\Omega}{180K\Omega + \frac{330K\Omega + 680K\Omega}{2} + 15K\Omega}$$

$$V_3 = V_2 \times \frac{R_3}{R_2 + R_3} \cong 200V$$

When in normal mode the average voltage of the V3 is the half of the dc link voltage (Vdd). So, in order to make stable start condition, the resistors are designed to make the voltage of V3 to be the half of the dc link voltage.

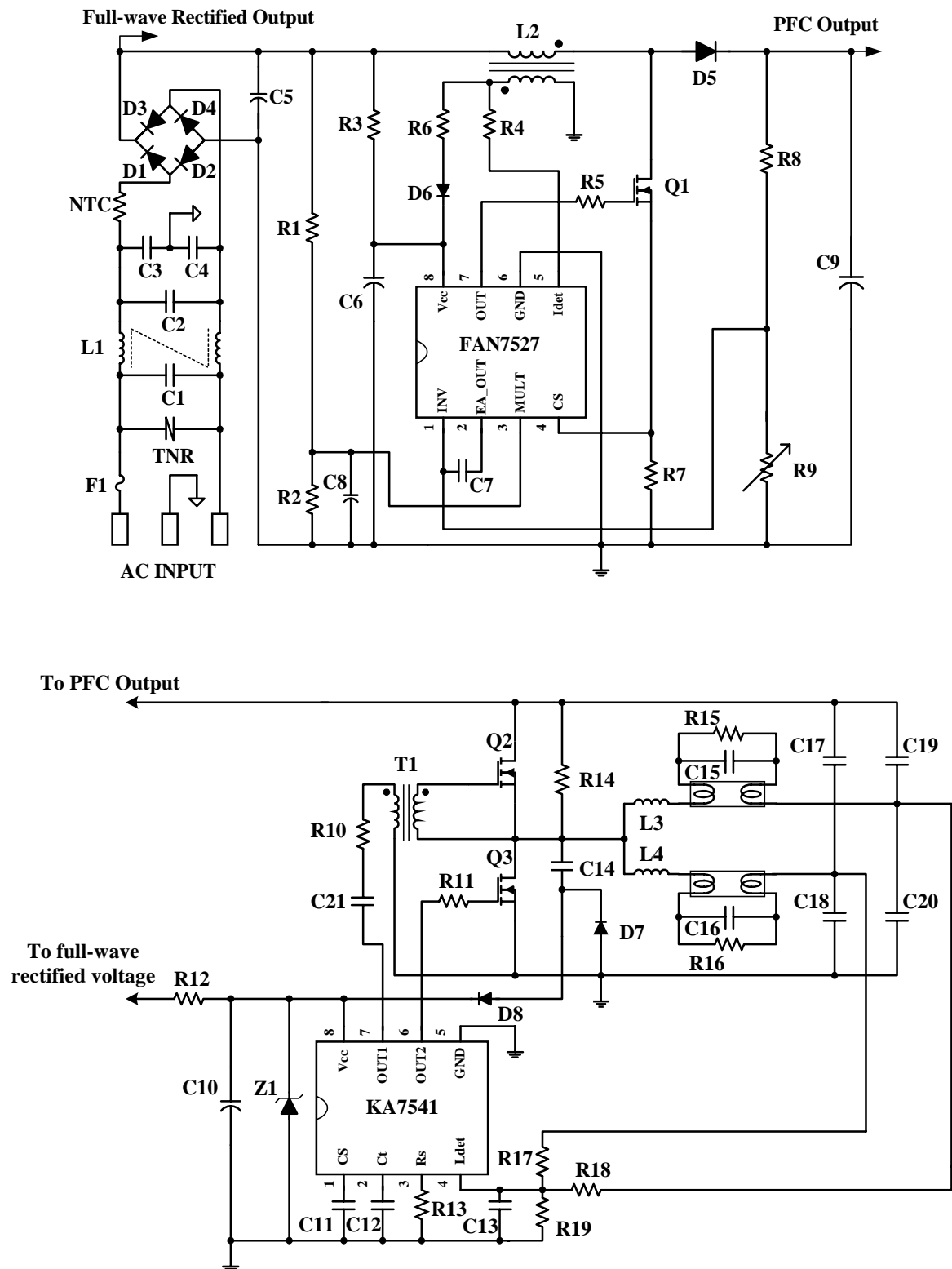


**Figure 4. Lamp detection resistor network**



## Application Circuit

<85 ~ 265VAC Input, 400VDC, 32W×2 Lamps Ballast>



## Component Listing

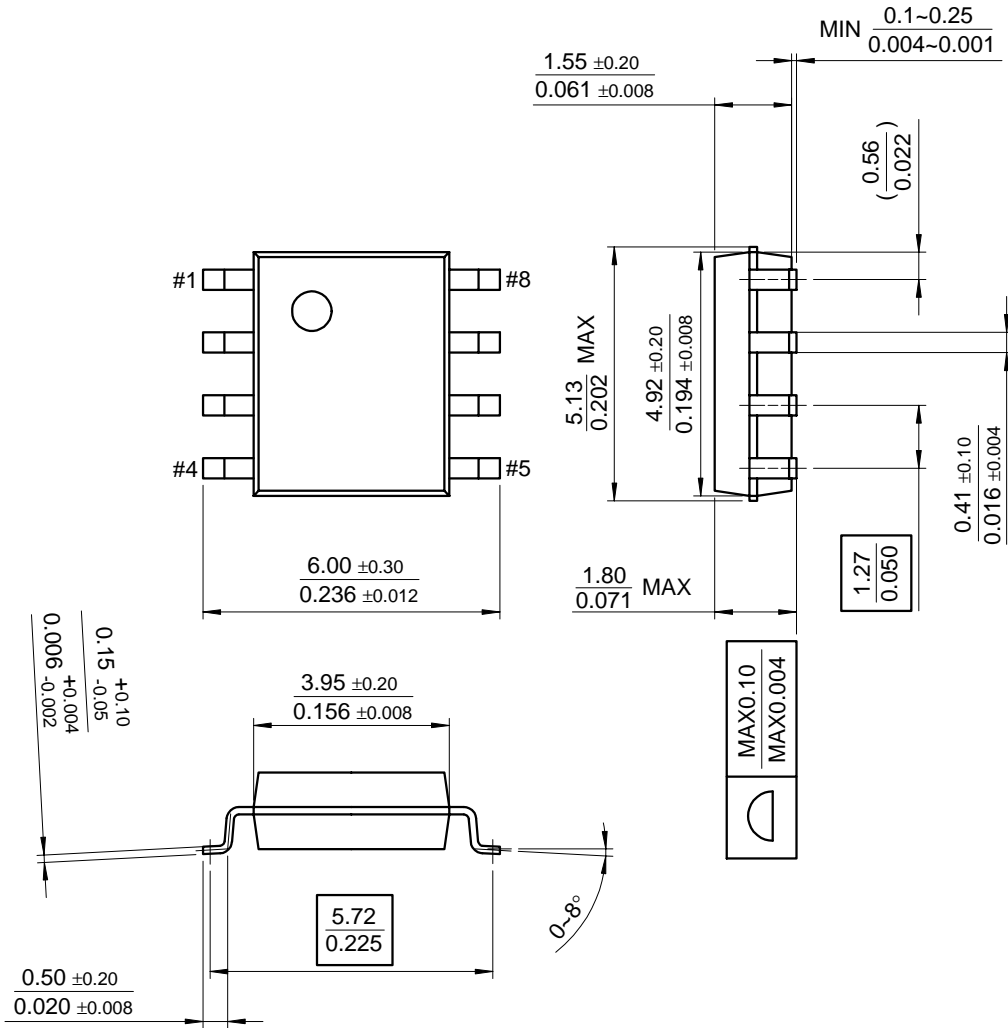
| Part number     | Value                | Note              | Manufacturer |
|-----------------|----------------------|-------------------|--------------|
| R1              | 2.7M $\Omega$        | 1/4W              | -            |
| R2              | 18k $\Omega$         | 1/4W              | -            |
| R3, 12          | 150k $\Omega$        | 1W                | -            |
| R4, 13          | 22k $\Omega$         | 1/4W              | -            |
| R5, 10, 11      | 47 $\Omega$          | 1/4W              | -            |
| R6              | 3.3 $\Omega$         | 1/4W              | -            |
| R7              | 0.2 $\Omega$         | 1W                | -            |
| R8              | 1.2M $\Omega$        | 1/4W              | -            |
| R9              | 103                  | Variable resistor | -            |
| R14             | 180k $\Omega$        | 1/4W              | -            |
| R15, 16         | 330k $\Omega$        | 1/4W              | -            |
| R17, 18         | 680k $\Omega$        | 1/4W              | -            |
| R19             | 15k $\Omega$         | 1/4W              | -            |
| C1, 2           | 150nF, 275vac        | Box-Cap           | -            |
| C3, 4           | 2200pF, 3000V        | Y-Cap             | -            |
| C5              | 0.22 $\mu$ F, 630V   | Miller-Cap        | -            |
| C6, 10          | 47 $\mu$ F, 35V      | Electrolytic      | -            |
| C7              | 0.33 $\mu$ F         | MLCC              | -            |
| C8              | 1nF, 25V             | Ceramic           | -            |
| C9              | 47 $\mu$ F, 450V     | Electrolytic      | -            |
| C11, 21         | 0.22 $\mu$ F, 25V    | Ceramic           | -            |
| C12             | 180pF, 25V           | Ceramic           | -            |
| C13             | 0.1 $\mu$ F, 25V     | Ceramic           | -            |
| C14             | 1nF, 630V            | Miller-Cap        | -            |
| C15, 16         | 4700pF, 1000V        | Miller-Cap        | -            |
| C17, 18, 19, 20 | 6800pF, 630V         | Miller-Cap        | -            |
| Q1, 2, 3        | 500V, 3.6A           | FQPF6N50          | FairChild    |
| D1, 2, 3, 4     | 1000V, 1A            | 1N4007            | -            |
| D5              | 1000V, 1A            | UF4007            | -            |
| D6              | 75V, 150mA           | 1N4148            | -            |
| D7, 8           | 600V, 1A             | 1N4937            | -            |
| ZD1             | 15V, 1W              | 1N4744            | -            |
| L1              | 45mH                 | Line Filter       | -            |
| L2              | 590 $\mu$ H (62T:5T) | EI3026            | -            |
| L3, 4           | 3.1mH (120T)         | EI2820            | -            |
| T1              | 1.2mH(30T:60T)       | EE1614            | -            |
| F1              | 250V, 3A             | Fuse              | -            |
| TNR             | 470V                 | 471               | -            |
| NTC             | 10 $\Omega$          | 10D09             | -            |

# Mechanical Dimensions

Package

Dimensions in millimeters

## 8-SOP

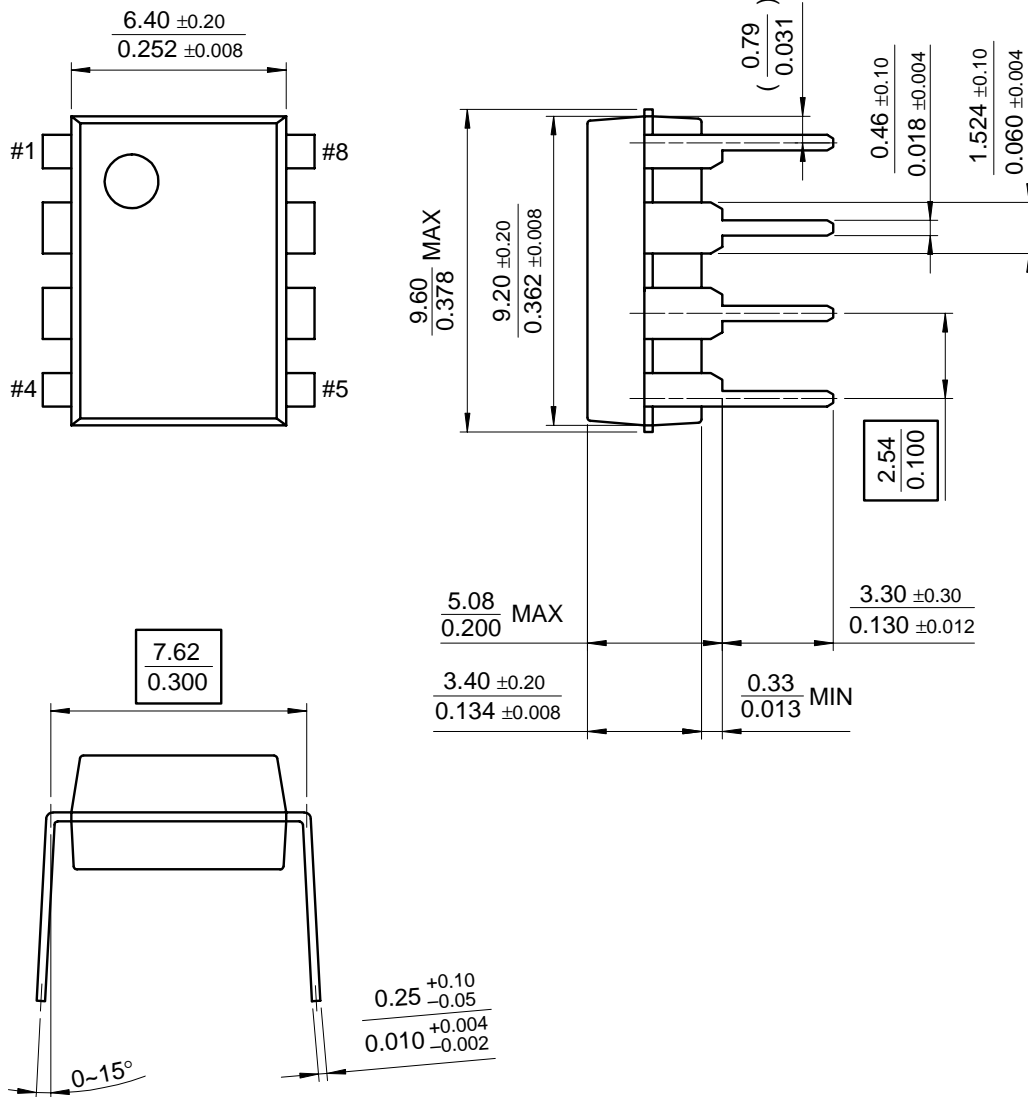


**Mechanical Dimensions** (Continued)

**Package**

Dimensions in millimeters

**8-DIP**



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## Ordering Information

| Product Number | Package | Operating Temperature |
|----------------|---------|-----------------------|
| KA7541         | 8-DIP   | -25°C ~ +125°C        |
| KA7541D        | 8-SOP   |                       |

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