KA7541

Simple Ballast Controller

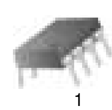
Features

- 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

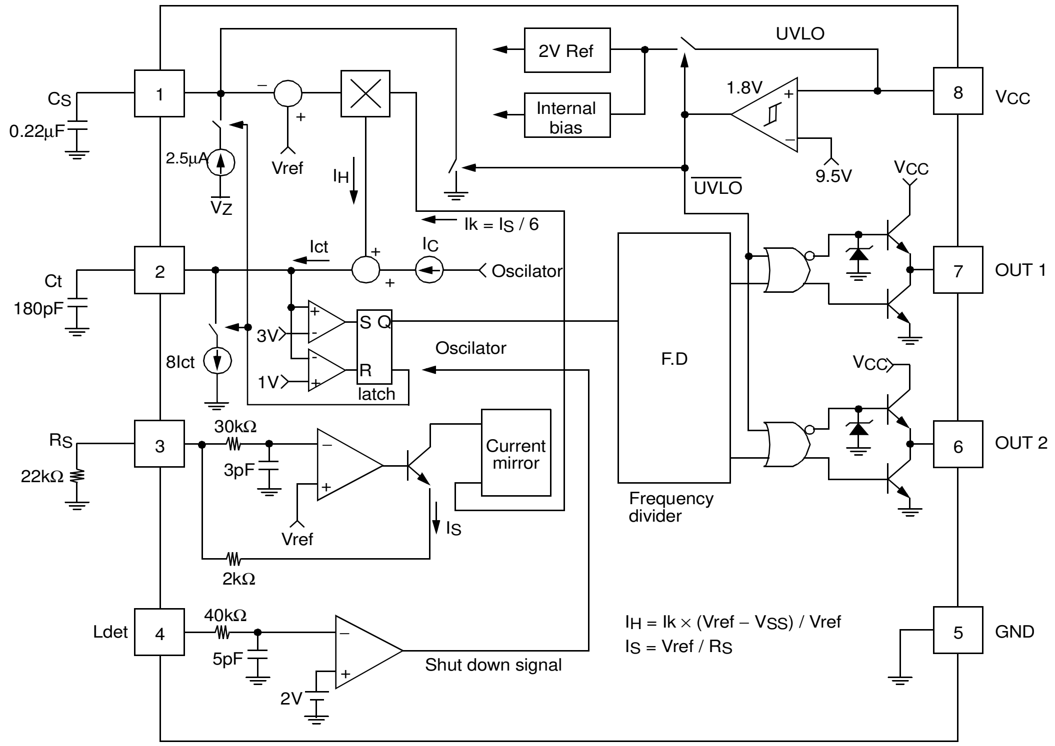
8-DIP



8-SOP

Rev. 1.0.3

Internal Block Diagram



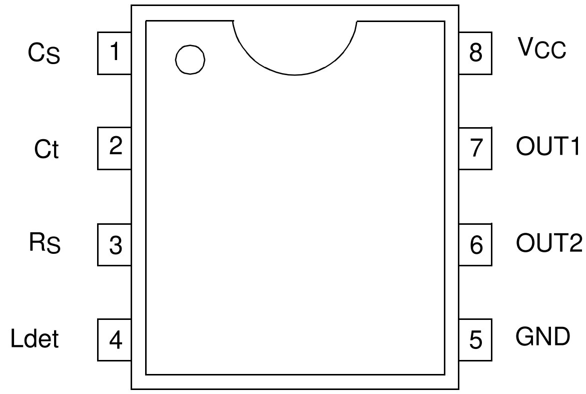
Absolute Maximum Ratings

Parameter		Symbol	Value	Unit
Supply voltage		V_{CC}	30	V
Peak drive output current		I_{OH}, I_{OL}	±300	mA
Drive output clamping diodes $V_O > V_{CC}$, or $V_O < -0.3$		Iclamp	±10	mA
Soft start, and no lamp detection input voltage		V_{IN}	–0.3 to 6	V
Operating temperature range		Topr	-25 to 125	°C
Storage temperature range		Tstg	–65 to 150	°C
Power dissipation	8-DIP	Pd	0.8	W
	8-SOP		0.5	
Thermal resistance (Junction-to-air)	8-DIP	θja	100	°C/W
	8-SOP		165	

Absolute Maximum Ratings (-25°C≤Ta≤125°C)

Parameter	Symbol	Value	Unit
Temperature stability for reference voltage (Vref)	ΔVref(Typ)	15	mV
Temperature stability for operating frequency (fos)	Δfos(Typ)	5	kHz

Pin Assignments



(Top View)

Pin Definitions

Pin Number	Pin Name	Pin Function Descrition
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 Vcc=14V, Ta=25°C, For Min/Max values Ta is the operating ambient temperature range with $-25^oC \le Ta \le 125^oC$ and $11V \le V_{CC} \le 30V$

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
UNDER VOLTAGE LOCK OUT SECTION						
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
SUPPLY CURRENT SECTION						
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, Cl=1nF	-	7	14	mA
REFERENCE SECTION						
Reference voltage	V_{ref}	Iref=0mA, Vcc=14V	1.95	2	2.05	V
Line regulation	$\Delta V_{ref\ 1}$	$14V \le V_{CC} \le 25V$	-	0.1	10	mV
Temperature stability of Vref	$\Delta V_{ref\ 2}$	-25≤Ta≤125°C, Vcc=14V	-	15	-	mV
OSCILLATOR SECTION						
Operating frequency	fos	V_{SS}=3V, C_T=470pF	44	50	56	KHz
Operating dead time	tod	V_{SS}=3V, Vcc=14V	2.4	2.9	3.4	µs
Soft start frequency	fss	V_{SS}=0V, C_T=470pF	56	65	74	KHz
Soft start dead time	tsd	V_{SS}=0V, Vcc=14V	1.8	2.3	2.8	µs
OUTPUT SECTION						
Rising time (note1)	tr	Cl=1nF, Vcc=12V	-	120	200	ns
Falling time (note1)	tf	Cl=1nF, Vcc=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=100µA	-	-	1	V
NO LAMP PROTECTION SECTION						
No lamp detect voltage	Vnd	-	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

$$Rst < \frac{Vin(ac) \times \sqrt{2} - Vth(st),max}{Ist,max}$$

$$= \frac{85 \times \sqrt{2} - 10.5}{0.25 \times 10^{-3}} = 440k\Omega$$

$$P_{RSt} = \frac{(Vir\ (ac\_max) \cdot \sqrt{2} - Vcc)^2}{R_{St}} \leq 0.5W$$

$$R_{St} \geq 2 \times (Vin(ac\_max) \cdot \sqrt{2} - Vcc)^2$$

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

$$\therefore 260K \leq R_{St} \leq 440K$$

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 V_{CC} voltage of the Cst is also increased.

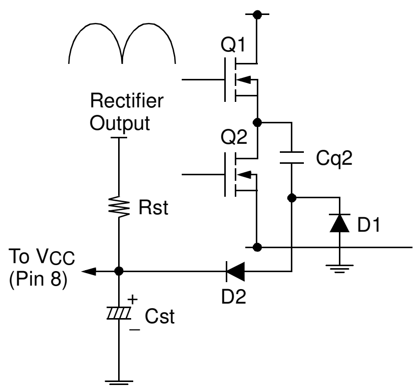


Figure 1. Start up circuit

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 50µA. The discharging current is seven times of the charging current (7× 50µA). 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.

Rising slope: dv / dt = i / C = 50µA / Ct

Falling slope: dv / dt = i / C = 7 × 50µA / Ct

For example, when the timing capacitor is 180pF,

ΔTch = 6.69µ

ΔTdis = 0.956µ

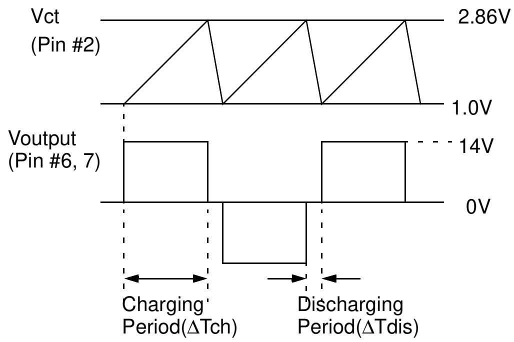


Figure 2. Oscillator sawtooth & Output gate drive waveform

As a result, the switching frequency is as following

$Ts = 2 \times (\Delta Tch + \Delta Tdis) = 15.29\mu$

$fsw = 1 / T_S = 65KHz$

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 (50µA). The rising and falling slope of the triangular waveform are increased due to this added current.
Soft start current (I_S) = 2V / R_S

Rising slope: $dv / dt = i / C = (50\mu A + I_S / 6) / Ct$

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

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

$$fsw(pre) = \frac{50 \times 10^{-6} + \frac{0.33}{Rs}}{Ct \times 4.25}$$

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 (tss). When VCC voltage exceeds the start-up voltage (Vth(st)), the soft start capacitor start to be charged by the current source (313nA). The switching frequency decreases linearly to fsw(nor) from fsw(pre) until the soft start capacitor voltage (V_{CS}) touches 2V. Therefore the soft start duration time (tss) can be acquired by the following formula.

$$tss = \frac{Cs \times V}{i}$$

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

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

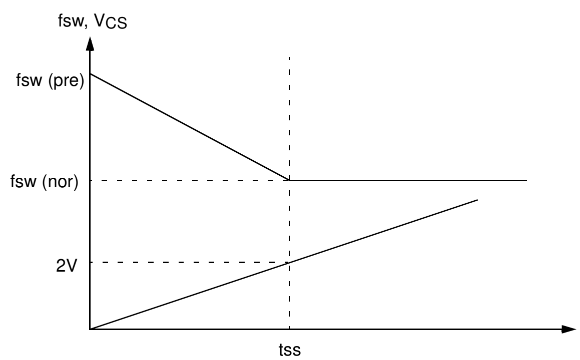


Figure 3. Frequency & Soft start capacitor voltage variation during soft start

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.

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

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

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

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.

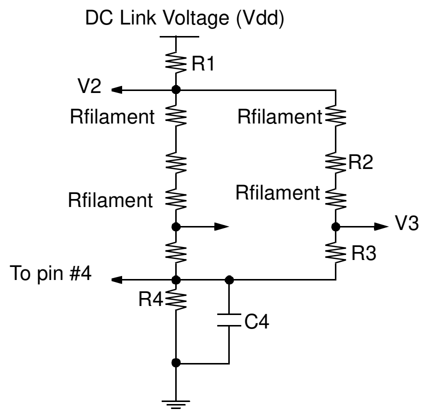
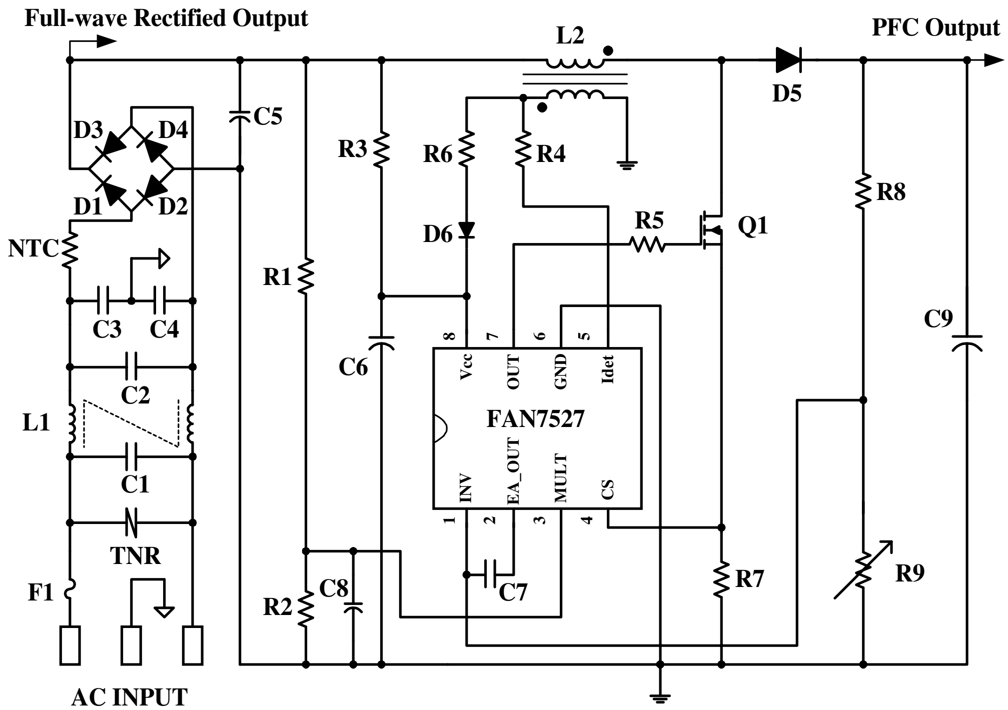
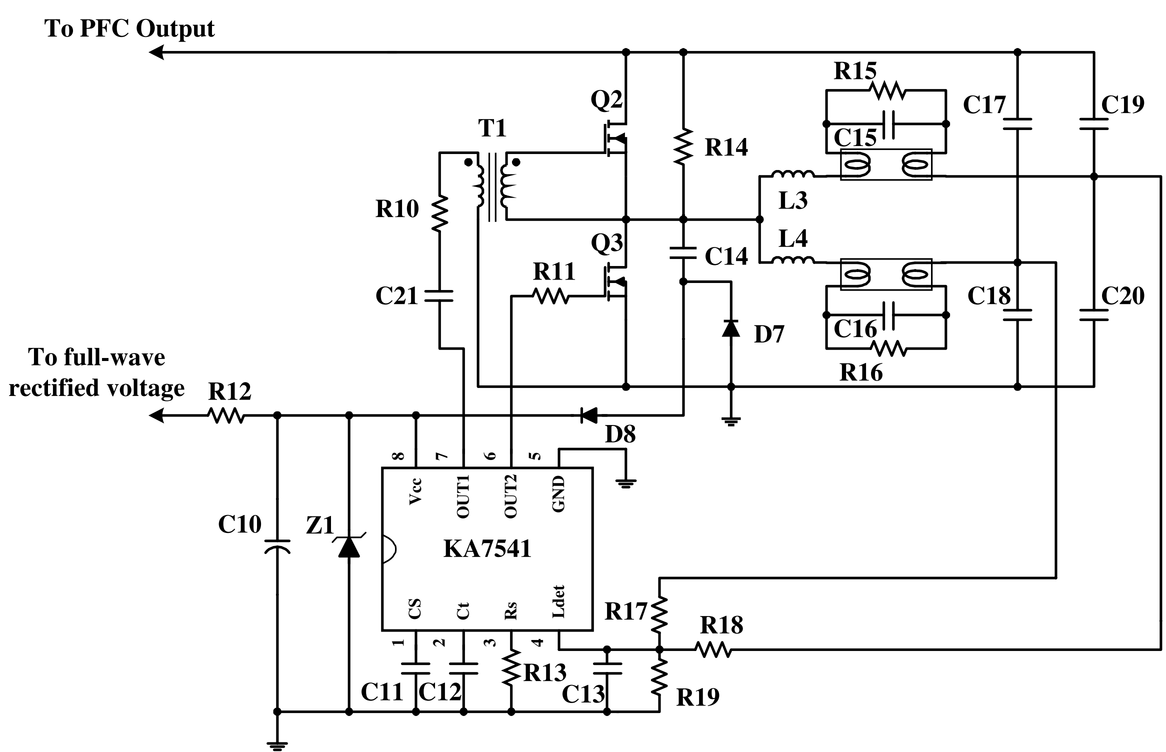


Figure 4. Lamp detection resistor network

Application Circuit

<85 ~ 265V$_{AC}$ Input, 400V$_{DC}$, 32W×2 Lamps Ballast>





Component Listing

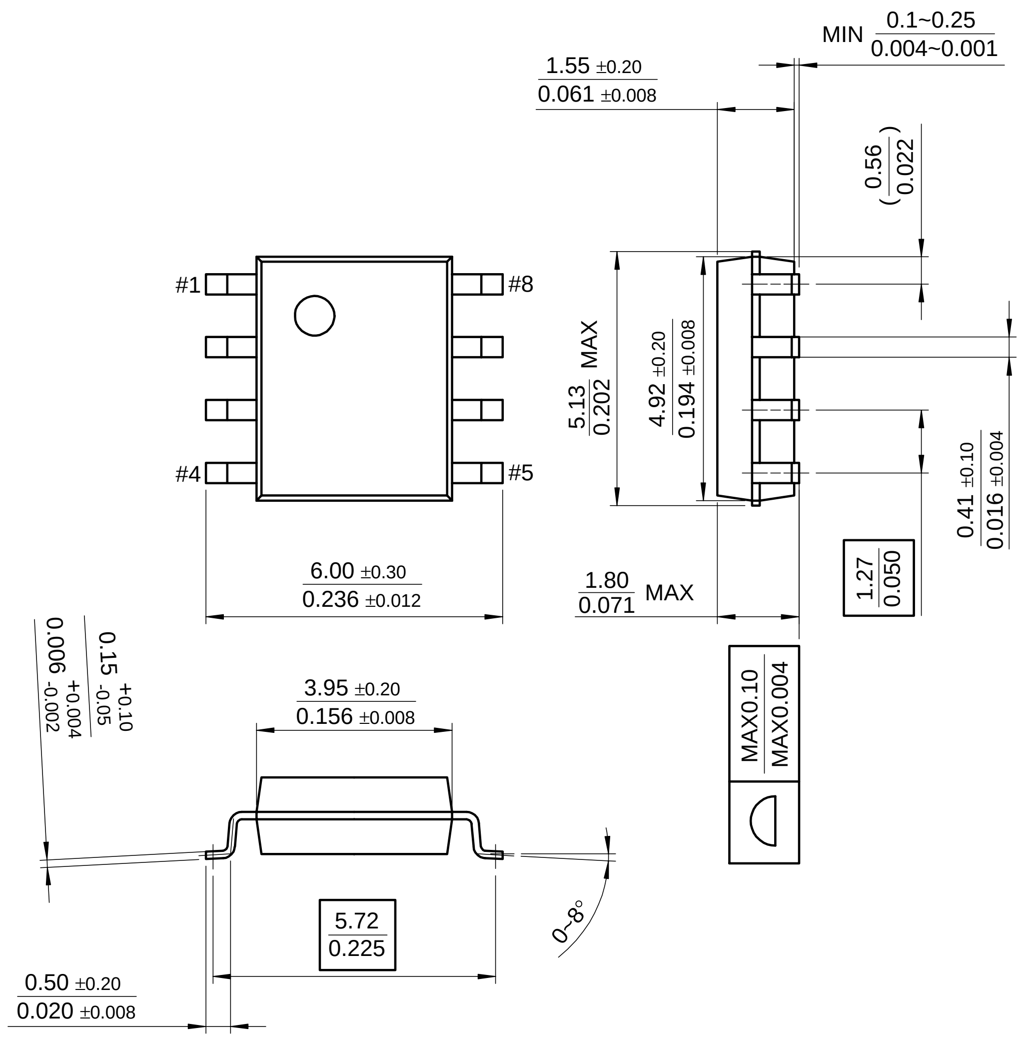
Part number	Value	Note	Manufacturer
R1	2.7MΩ	1/4W	-
R2	18kΩ	1/4W	-
R3, 12	150kΩ	1W	-
R4, 13	22kΩ	1/4W	-
R5, 10, 11	47Ω	1/4W	-
R6	3.3Ω	1/4W	-
R7	0.2Ω	1W	-
R8	1.2MΩ	1/4W	-
R9	103	Variable resistor	-
R14	180kΩ	1/4W	-
R15, 16	330kΩ	1/4W	-
R17, 18	680kΩ	1/4W	-
R19	15kΩ	1/4W	-
C1, 2	150nF, 275vac	Box-Cap	-
C3, 4	2200pF, 3000V	Y-Cap	-
C5	0.22µF, 630V	Miller-Cap	-
C6, 10	47µF, 35V	Electrolytic	-
C7	0.33µF	MLCC	-
C8	1nF, 25V	Ceramic	-
C9	47µF, 450V	Electrolytic	-
C11, 21	0.22µF, 25V	Ceramic	-
C12	180pF, 25V	Ceramic	-
C13	0.1µF, 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	590µH (62T:5T)	EI3026	
L3, 4	3.1mH (120T)	EI2820	-
T1	1.2mH(30T:60T)	EE1614	
F1	250V, 3A	Fuse	-
TNR	470V	471	-
NTC	10Ω	10D09	-

Mechanical Dimensions

Package

Dimensions in millimeters

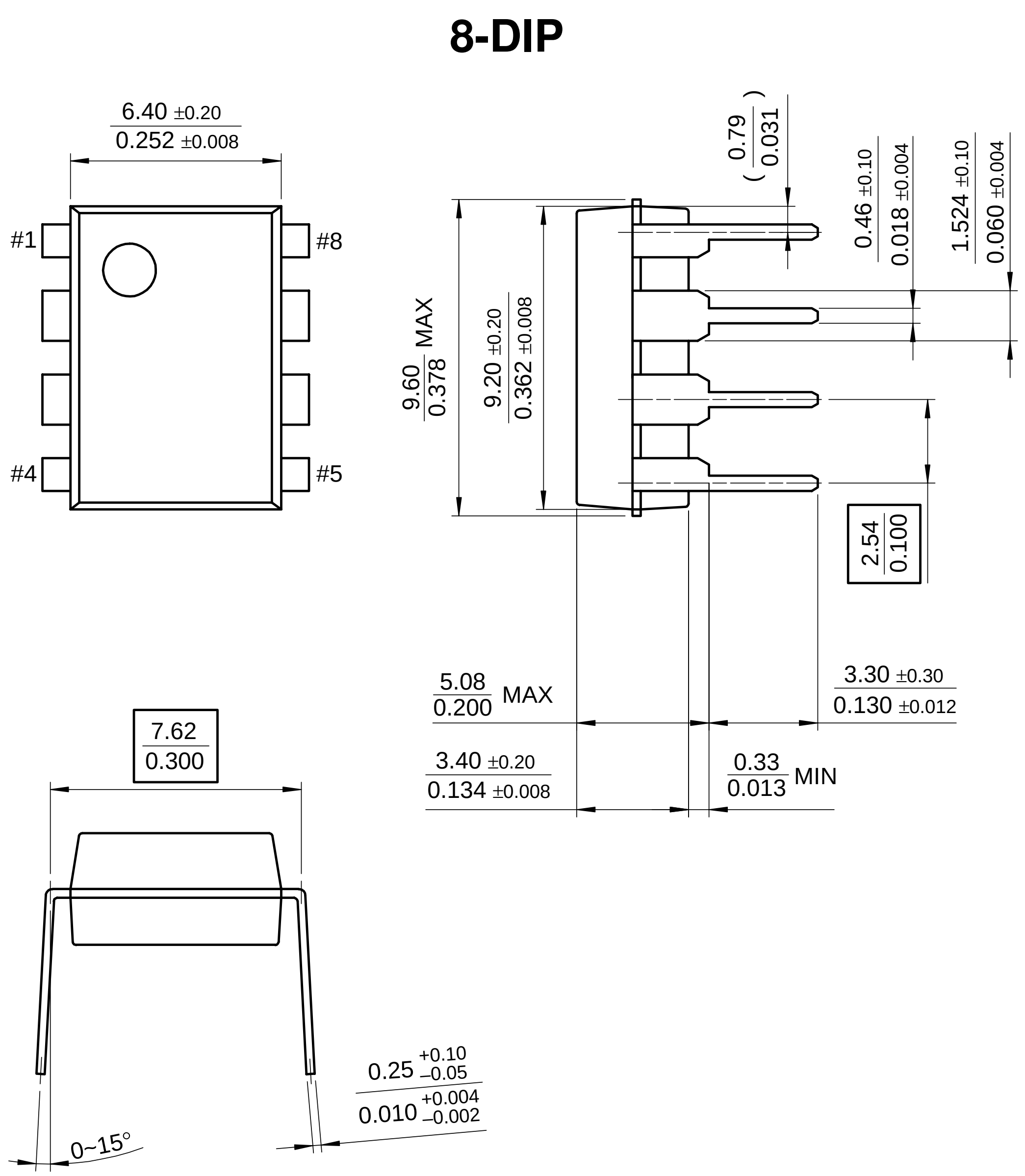
8-SOP



Mechanical Dimensions (Continued)

Package

Dimensions in millimeters



Ordering Information

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

9/27/01 0.0m 001
Stock#DSxxxxxxxx

KA7541
Electronic Ballast Controller

Contents
General description | Features | Product status/pricing/packaging | Application notes

Datasheet
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This page Print version

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General description

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back to top

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- Totem pole output with high state clamp
- Low start-up and operating current

back to top

Product status/pricing/packaging

Product	Product status	Package type	Leads	Packing method
KA7541D	Full Production	SOIC	8	RAIL
KA7541	Full Production	DIP	8	RAIL
KA7541DTF	Full Production	SOIC	8	TAPE REEL

back to top

Application notes

AN-4004: AN-4004 High Efficiency Power Factor Controller Design for Ballast (913 K) Jul 19, 2002

back to top