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KA7540

Simple Dimming Ballast Control IC

Features

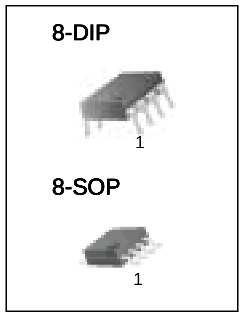
- Internal soft start
- No lamp protection
- Voltage controlled dimming
- Trimmed 1.5% internal bandgap reference
- Under voltage lock out with 1.8V of hysteresis
- Totem pole output with high state clamp
- Low start-up and operating current
- 8-pin DIP & 8-pin SOP

Applications

- Electronic Ballast
- Lighting Control System
- Half-bridge Drive Control System

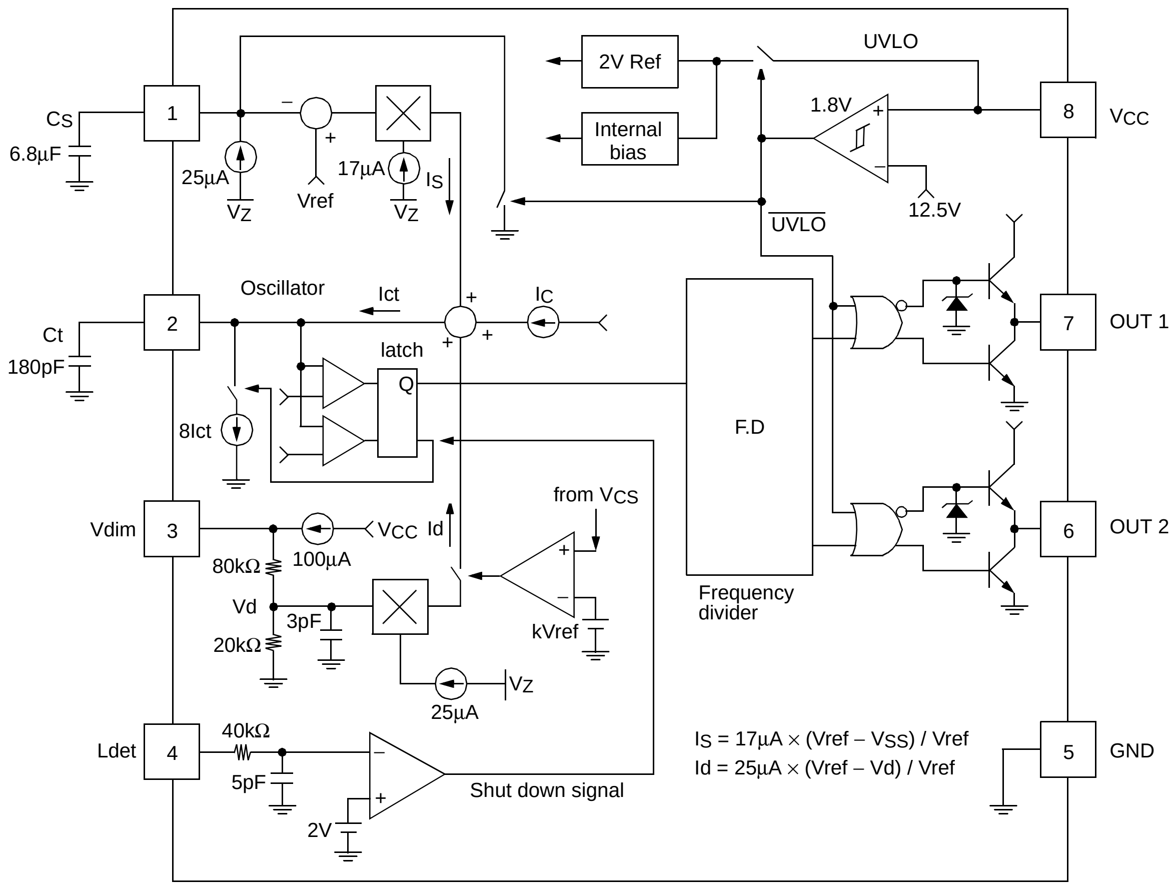
Descriptions

The KA7540 provides simple and high performance electronic ballast control functions. KA7540 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. Voltage controlled dimming circuit is built into the IC to control the lighting output in a wide range.
Protection circuitry has also been added to prevent switches from burning out in no lamp condition. Output gate drive circuit clamps power MOSFET gate voltage irrespective of supply voltage.



Rev. 1.0.1

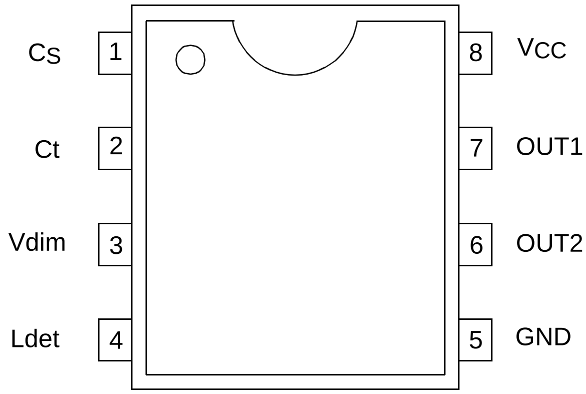
Internal Block Diagram



IC Characteristics

Parameter	KA7540
Initial soft start frequency	1.33 × normal operating frequency
Voltage controlled dimming	1 ~ 10V

Pin Assignments



(Top View)

Pin Definitions

Pin Number	Pin Name	Pin Function Description
1	C_S	Soft start capacitor connection pin. The pin voltage determines the phase of soft start, normal and dimming mode.
2	C_T	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	Vdim	Input to the dimming stage. The pin voltage sets the switching frequency in dimming 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	V_{CC}	The logic and control power supply connection.

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
Dimming, 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)	∆Vref (Typ)	15	mV
Temperature stability for operating frequency (fos)	∆fos (Typ)	5	kHz

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°C ≤ Ta ≤ 125°C and 14V≤ Vcc≤ 30V

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
UNDER VOLTAGE LOCK OUT SECTION						
Start threshold voltage	V_{TH}(st)	V_{CC} increasing	11.5	12.5	13.5	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), Vcc=14V	-	0.2	0.3	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(Note1)	Vref	Iref=0mA, Vcc=14V	1.95	2	2.05	V
Line regulation(Note1)	ΔVref 1	14V≤V_{CC}≤25V	-	0.1	10	mV
Temperature stability of Vref(Note1)	ΔVref 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 time current	I_{SS}	V_{SS}=0V	17	25	33	µA
Soft start dead time	tsd	V_{SS}=0V, Vcc=14V	1.8	2.3	2.8	µs
Dimming frequency	fd	Vss=5V, Vdim=1V	58	72	86	kHz
OUTPUT SECTION						
Rising time (Note2)	tr	Cl=1nF	-	120	200	ns
Falling time (Note2)	tf	Cl=1nF	-	50	100	ns
Maximum output voltage	Vomax(o)	V_{CC}=20V	12	15	18	V
Output voltage with UVLO activated	Vomin(o)	V_{CC}=5V, I_O=100µA	-	-	1	V
NO LAMP PROTECTION SECTION						
No lamp detect voltage	Vnd	-	1.9	2	2.1	V

Notes :
1. This parameter is not tested in production but tested in wafer.
2. This parameter, although guaranteed, is 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 AC line voltage.

The following equation can be used to calculate the value of Rst.

$$R_{st} \le \frac{Vin(ac) \times \sqrt{2} - Vth(st), max}{Ist, max} = \frac{85 \times \sqrt{2} - 13.5}{0.3 \times 10^{-3}} = 356K\Omega$$

$$P_{Rst} = \frac{(Vin(ac\_max) \cdot \sqrt{2} - V_{CC})^2}{Rst} \le 1W$$

$$Rst \ge (Vin(ac\_max) \cdot \sqrt{2} - V_{CC})^2$$

$$Rst \ge 130K\Omega$$

$$\therefore 130K\Omega \le Rst \le 356K\Omega$$

The value of start-up capacitor (Cst) is normally determined in terms of the start-up time and operating current build up time with the 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 value of Cq2 is increased, the V_{CC} voltage of the Cst is also increased.

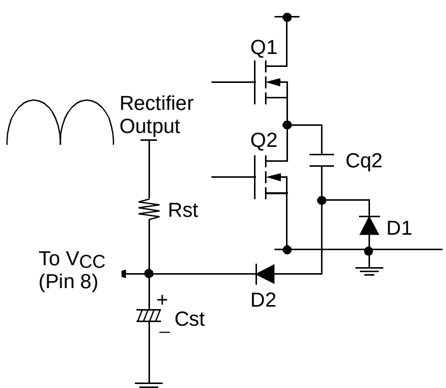


Figure 1. Start-up circuit

Oscillator

The frequency of the gate drive output 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). During the charging period, one of the two MOSFETs remains ON state. On the contrary both of MOSFETs are OFF during the discharging period.
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 470pF, ΔV(Vhigh - Vlow) = (2.86V - 1.0V) = 1.86V,

ΔTch = 17.5µs, ΔTdis = 2.5µs

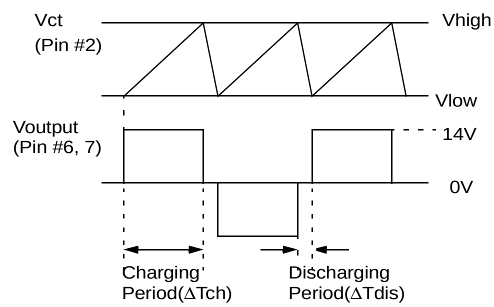


Figure 2. Oscillator sawtooth & Output gate drive waveform

As a result, the switching frequency is as following

$Ts = 2 \times (\Delta Tch + \Delta Tdis) = 40\mu s$

$fsw = 1 / T_S = 25kHz$

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

$$Ct = \frac{11.76 \times 10^{-6}}{fsw}$$

Soft Start

The switching frequency is decreasing linearly from the pre-heating frequency to the normal switching frequency. In KA7540, the normal timing capacitor charging current is increased by 25µA during the pre-heating mode. This addition of the charging current sets the pre-heating frequency to be 1.33 times the switching frequency at the normal mode.

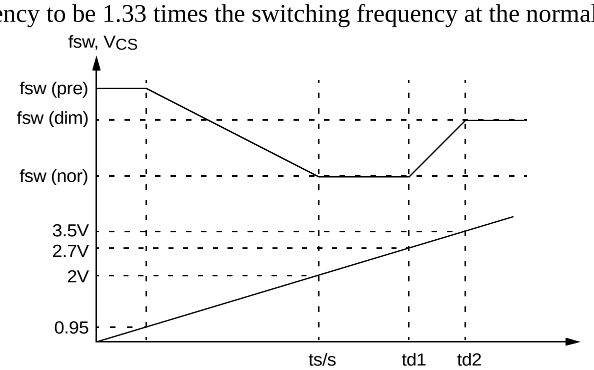


Figure 3. Frequency & Soft start capacitor voltage variation during soft start and dimming mode

No Lamp Protection

When the voltage at pin #4 is lower than 2V, the gate drive output is off-state, so the external power MOSFETs stop 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.

When 2 Lamp

$$V_{R4} = Vdd \times \frac{R19}{R14 + \frac{R15 + R18 + 2 \times Rf}{2} + R19}$$

$$\equiv 400 \times \frac{15k\Omega}{180k\Omega + \frac{330k\Omega + 680k\Omega}{2} + 15k\Omega}$$

$$V3 = V2 \times \frac{R18}{R15 + R18} \equiv 200V$$

$$V_{R4} > 2V$$

When 1 Lamp

$$V_{R4} = Vdd \times \frac{R19}{R14 + R15 + R18 + 2Rf + R19}$$

$$\equiv 400 \times \frac{15k\Omega}{180k\Omega + 330k\Omega + 680k\Omega + 15k\Omega}$$

$$V_{R4} > 2V$$

When No Lamp

$$V_{R4} = 0V(<2V) \quad \Rightarrow \text{Stop switching}$$

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

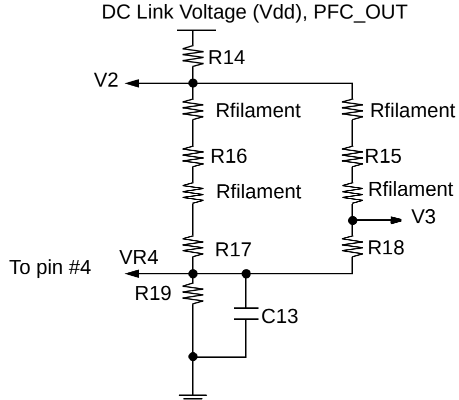


Figure 4. Lamp detection resistor network

Dimming Control

The lighting output of the lamp can be controlled by varying the switching frequency of the ballast circuit. In voltage source series resonant type converter, the output power is inversely proportional to the switching frequency. As a result, in order to make the lamp lighting output less bright (so called "dimming"), the switching frequency should be increased compared to that of the normal full lighting output frequency.

With KA7540, the switching frequency can be controlled by the voltage level at the pin #3 (Vdim). Since the IC starts to operate, the voltage level at the dimming pin doesn't affect the oscillator frequency until the time of td1 in figure 3. At the time td1, the switching frequency starts to ramp up to the dimming switching frequency level that is determined by the voltage level at the pin #3 (Vdim). In dimming mode, the timing capacitor charging current is increased by the following amount of the dimming current (Id).
Id = 25uA × (Vref - Vd) / Vref

Vd = Vdim / 5

So, the equations for the dimming frequency are as following.

$$\frac{dV}{dt} = \frac{50uA + Id}{Ct}$$

$$dTch(dim) = \frac{dV \times Ct}{50uA + \left(\frac{25uA(Vref - Vd)}{Vref}\right)}$$

$$dTdis(dim) = \frac{dV \times Ct}{7 \times 50uA + \left(\frac{25uA(Vref - Vd)}{Vref}\right)}$$

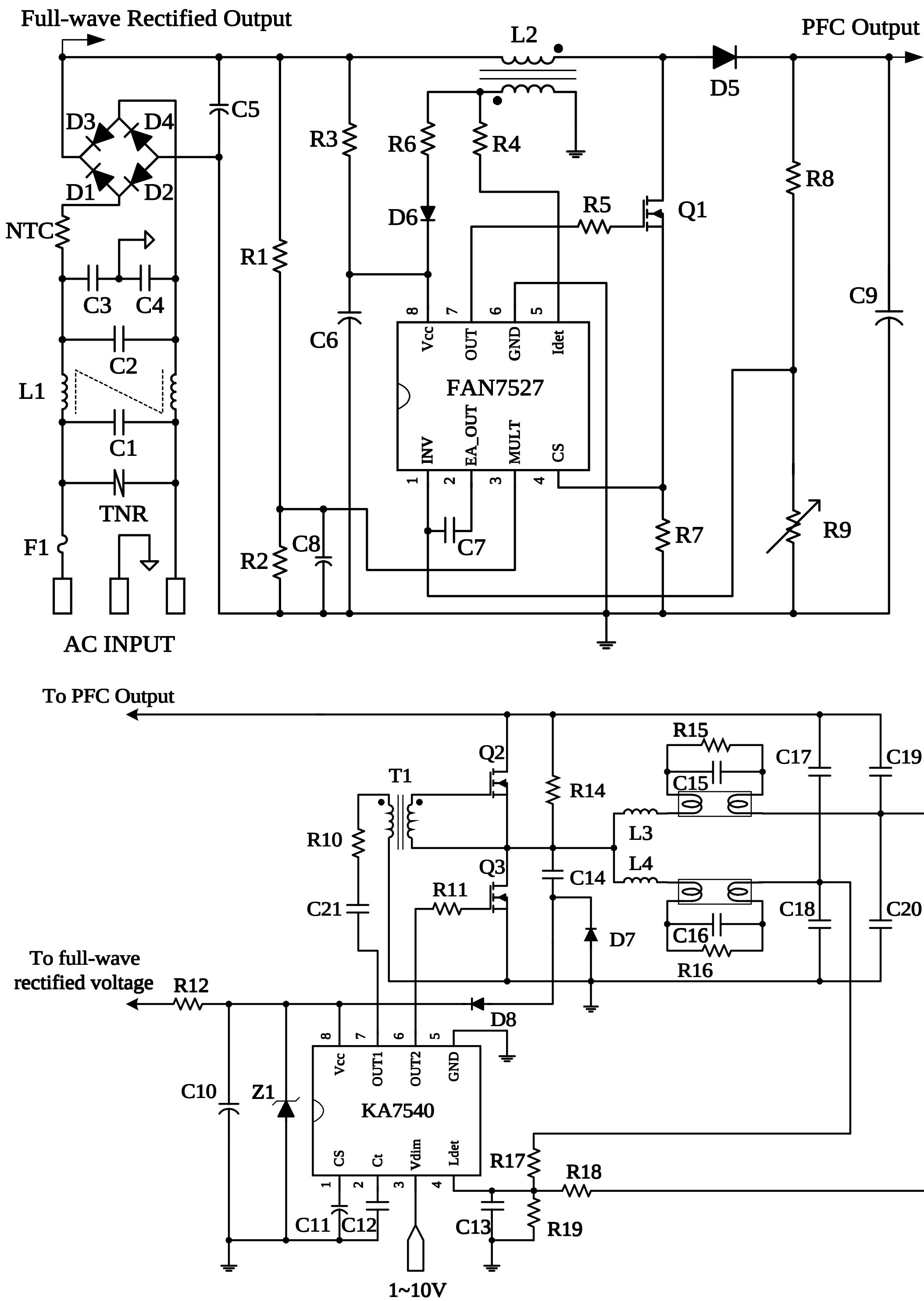
$$Ts(dim) = 2 \times (Tch(dim) + Tdis(dim))$$

$$f_{SW(dim)} = \frac{1}{Ts(dim)}$$

If the dimming pin is open, the dimming pin voltage becomes 10V due to the internal 100µA current source, which is equivalent to the normal full lighting output case.
Dimming Control can be reallized by simple voltage source and current source of variable resistor at pin #3.

Application Circuit

[85 ~ 265Vac Input, 400V Vdd, 32W × 2 Lamps Ballast,Group Dimming Control]



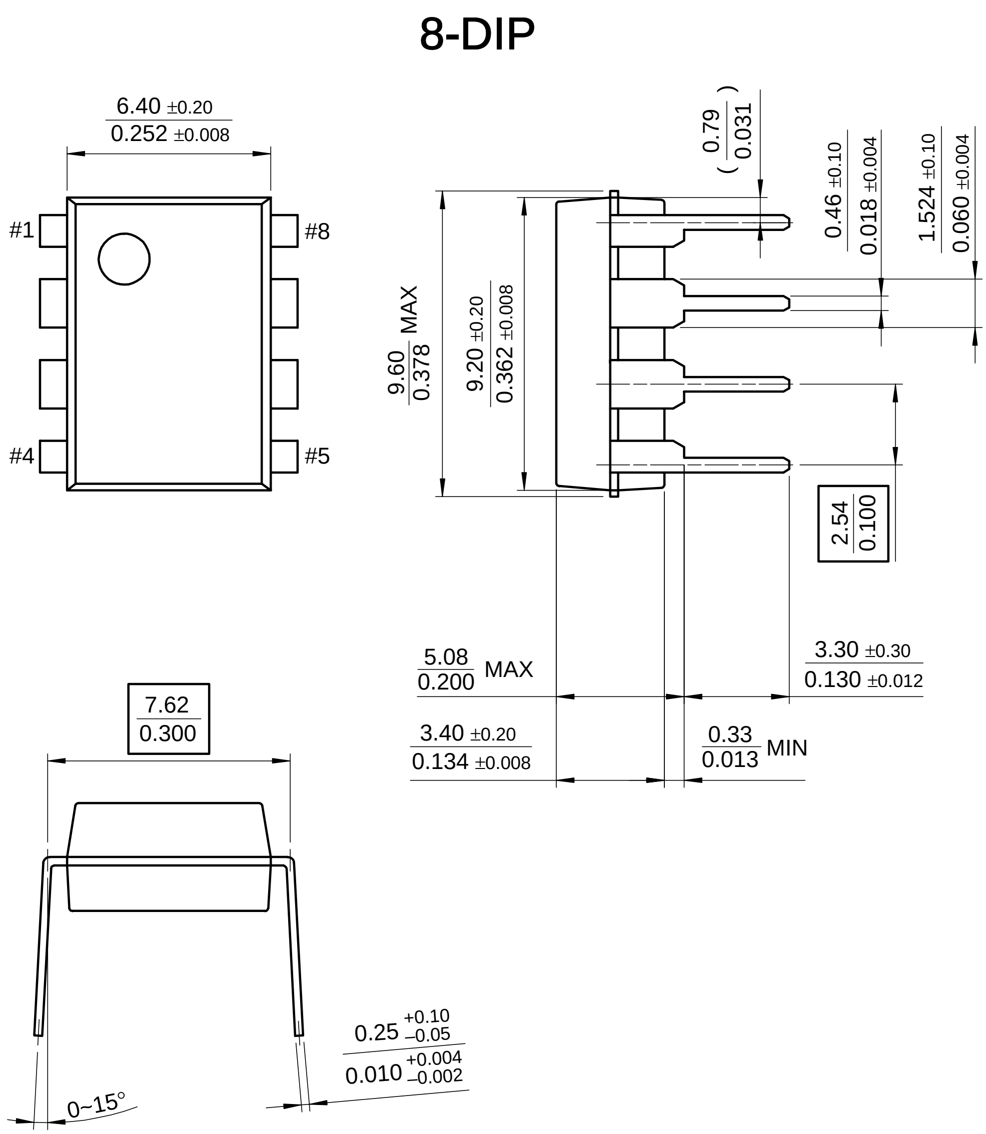
Component List

Part number	Value	Note	Manufacturer
R1	2.7MΩ	1/4W	-
R2	18kΩ	1/4W	-
R3, 12	150kΩ	1W	-
R4	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	6.8µF, 35V	Electrolytic	-
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	-
C21	0.22µF, 25V	Ceramic	-
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

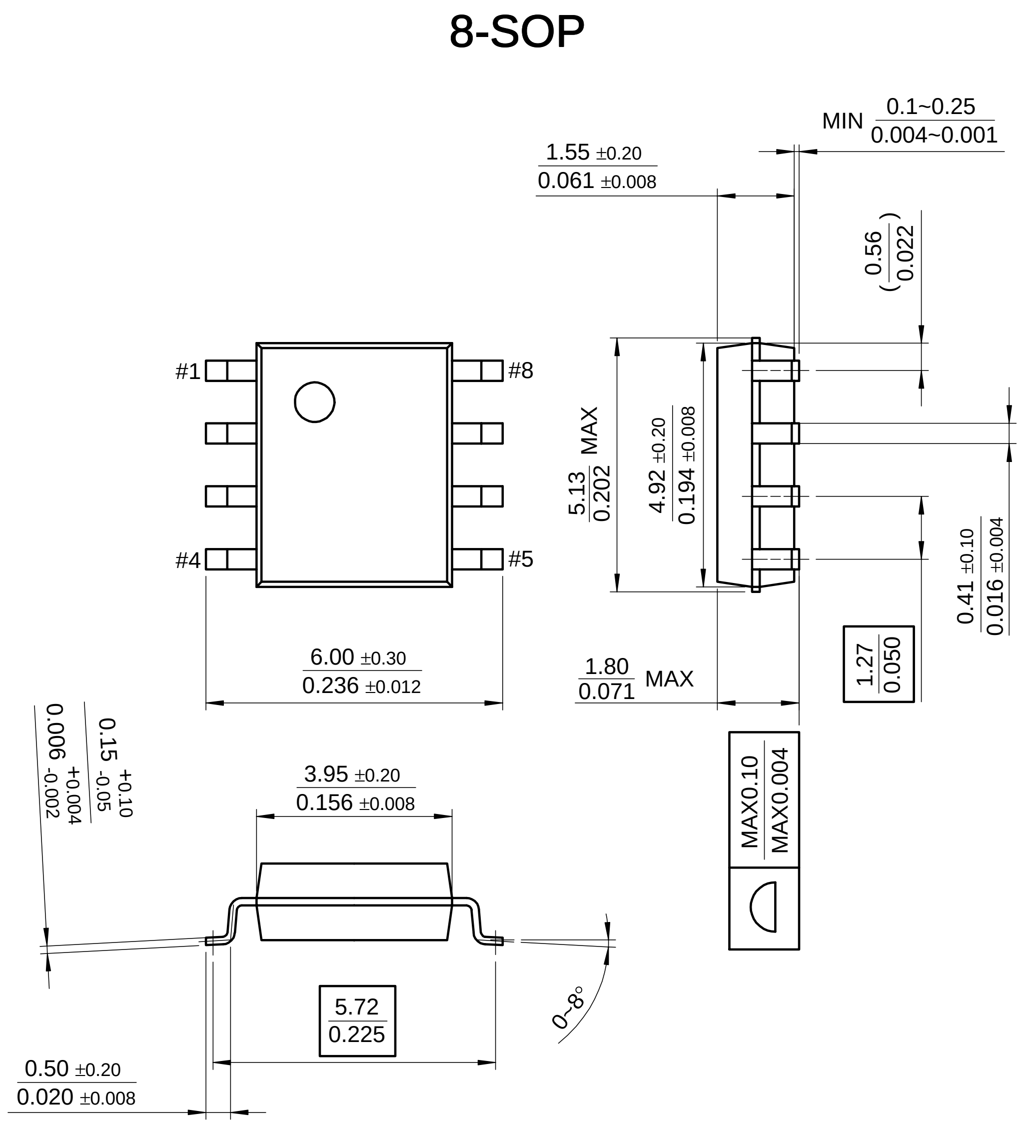
Dimensions in millimeters



Mechanical Dimensions (Continued)

Package

Dimensions in millimeters



Ordering Information

Product Number	Package	Operating Temperature
KA7540	8-DIP	-25°C ~ +125°C
KA7540D	8-SOP	

10/29/01 0.0m 001
Stock#DSxxxxxxxx