

INTRODUCTION

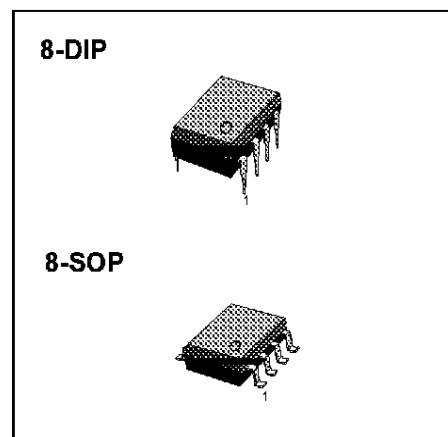
The KA7540/41 provides simple, yet high performance electronic ballast control functions. KA7540/41 is optimized for electronic ballast requiring a minimum board area, reduced component count and low power dissipation. Internal soft start circuitry eliminates the need for an external soft start PTC resistor. The initial soft start switching frequency and soft start time can be adjusted depending on the types of lamps. 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 burning out of switches in no lamp condition. Output gate drive circuit clamps power MOSFET gate voltage irrespective of supply voltage

FEATURES

- Internal soft start
- Flexible soft start frequency (KA7540)
- No lamp protection
- Voltage controlled dimming (KA7541)
- 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

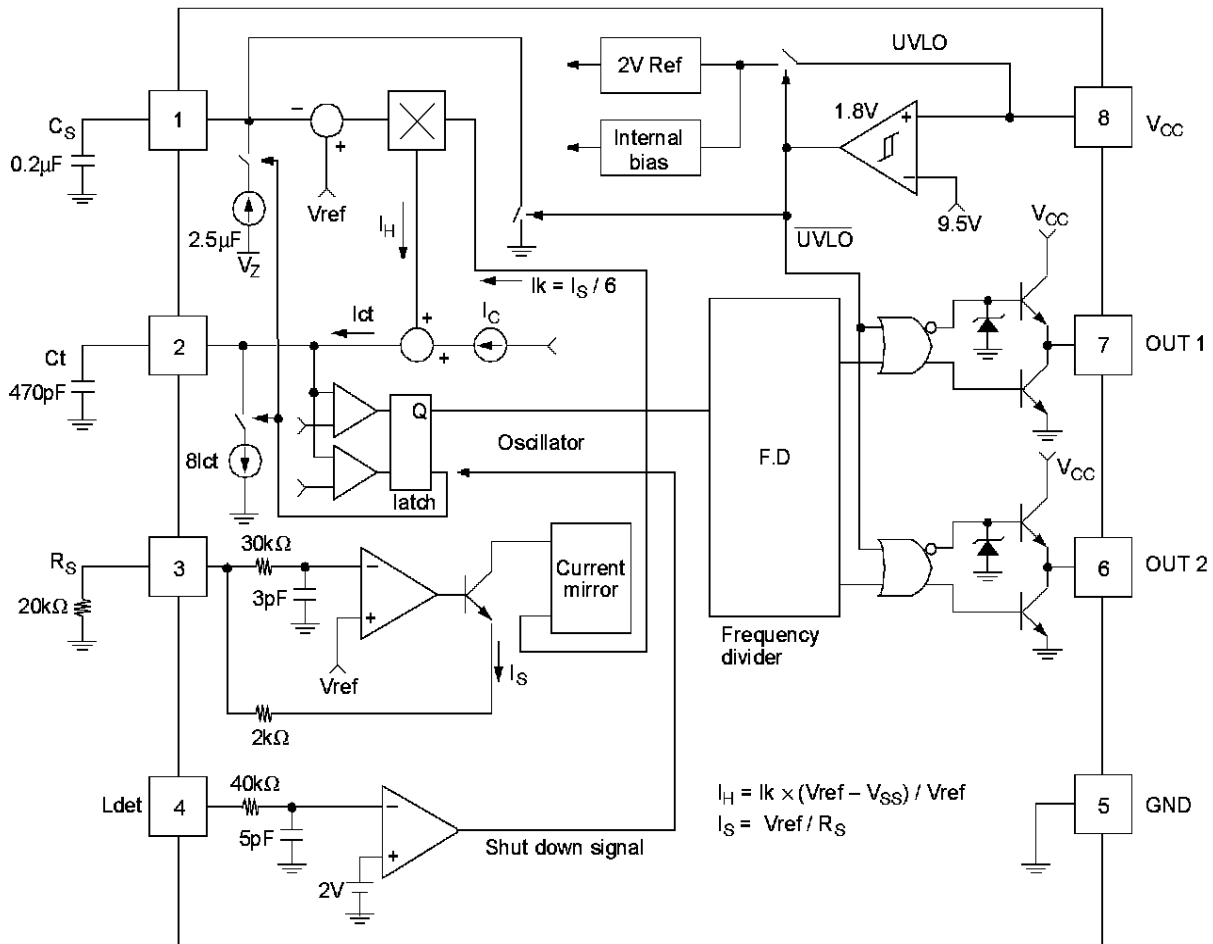
- Electronic Ballast



ORDERING INFORMATION

Device	Package	Operating Temperature
KA7540/41	8-DIP	0 ~ +105°C
KA7540D/41D	8-SOP	

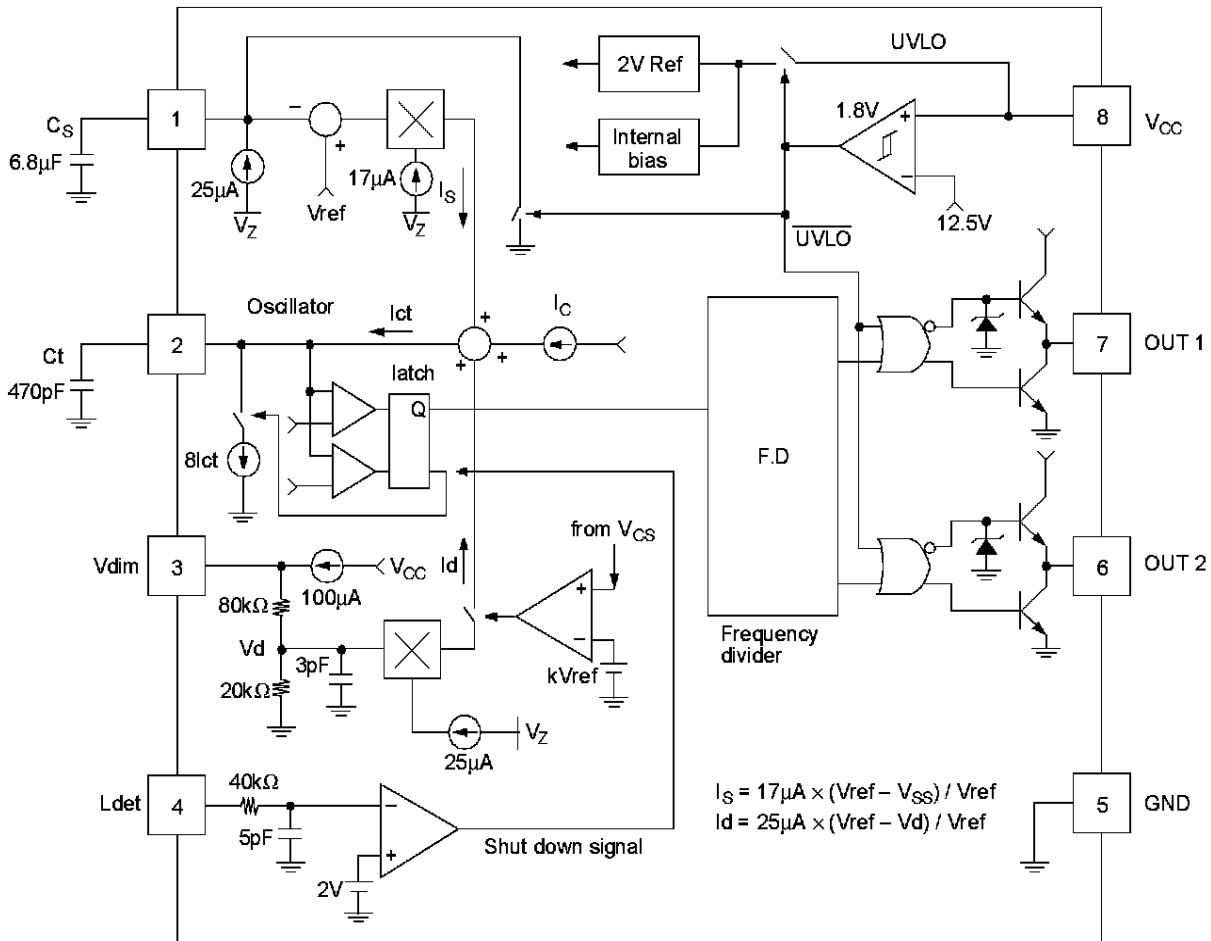
BLOCK DIAGRAM (KA7540)



IC SELECTION GUIDE

Function	Option	KA7540
Initial soft start frequency		Flexable
Voltage controlled dimming		None

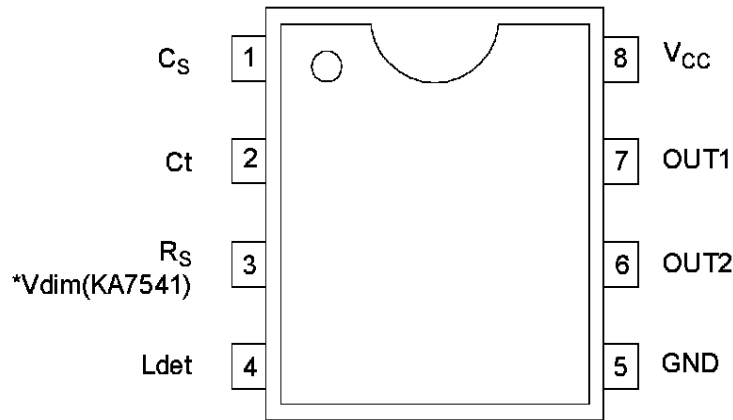
BLOCK DIAGRAM (KA7541)



IC SELECTION GUIDE

Function	Option	KA7541
Initial soft start frequency		1.33 × normal operating frequency
Voltage controlled dimming		0 ~ 10V

PIN CONNECTION



(Top View)

PIN FUNCTIONS

Pin No.	Name	Function
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	R_S *Vdim(KA7541)	Soft start resistor connection pin. The soft start resistor value determines the initial preheating switching frequency during soft start mode. *Input to the dimming stage. The pin voltage sets the switching frequency in dimming mode. (KA7541)
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 high-current power driver capable of driving the gate of a power MOSFET.
8	V_{CC}	The logic and control power supply connection.

MAXIMUM RATINGS

Characteristics	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 $V_O < -0.3$	I_{clamp}	± 10	mA
Dimming, soft start, and no lamp detection input voltage	V_{IN}	-0.3 to 6	V
Operating junction temperature range	T_{opr}	-25 to 150	$^{\circ}C$
Storage temperature range	T_{stg}	-65 to 150	$^{\circ}C$
Power dissipation	P_d	0.8	W
Thermal resistance (Junction-to-air)	θ_{ja}	100	W / $^{\circ}C$

MAXIMUM RATINGS ($0^{\circ}C \leq T_a \leq 105^{\circ}C$)

Characteristics	Symbol	Value	Unit
Temperature stability for reference voltage (V_{ref})	ΔV_{ref} (Typ)	15	mV
Temperature stability for operating frequency (fs)	ΔV_{ref} (Typ)	5	kHz

ELECTRICAL CHARACTERISTICS

Unless otherwise specified, these specifications apply over operating ambient temperatures for the KA7540/41 with $0^{\circ}\text{C} \leq T_a \leq 105^{\circ}\text{C}$ and $V_{CC} = 14\text{V}$

Characteristic	Symbol	Test conditions	Min.	Typ.	Max.	Unit	
UNDER VOLTAGE LOCK OUT SECTION							
Start threshold voltage	KA7540	$V_{TH(st)}$	V_{CC} increasing	8.5	9.5	10.5	V
	KA7541			11.5	12.5	13.5	V
UVLO hysteresis	$HY(st)$	–	1.4	1.8	2.2	V	
SUPPLY CURRENT SECTION							
Start up supply current	KA7540	I_{ST}	$V_{CC} < V_{TH(st)}$	–	0.15	0.25	mA
	KA7541			–	0.2	0.3	mA
Operating supply current	I_{CC}	Output not switching	–	6	10	mA	
Dynamic operating supply current	I_{DCC}	50kHz, $C_I = 1\text{nF}$	–	7	14	mA	
REFERENCE SECTION							
Reference voltage	V_{ref}	$I_{ref} = 0\text{mA}$	1.95	2	2.05	V	
Line regulation	$\Delta V_{ref 1}$	$14\text{V} \leq V_{CC} \leq 25\text{V}$	–	0.1	10	mV	
Temperature stability of V_{ref}	$\Delta V_{ref 2}$	$0 \leq T_a \leq 75^{\circ}\text{C}$	–	15	–	mV	
OSCILLATOR SECTION							
Operating frequency	f_{os}	$V_{SS} = 3\text{V}$, $C_T = 470\text{pF}$	40	50	60	kHz	
Operating dead time	t_{od}	$V_{SS} = 3\text{V}$	2.4	2.9	3.4	μs	
Soft start frequency	f_{ss}	$V_{SS} = 3\text{V}$, $C_T = 470\text{pF}$	54	67	80	kHz	
Soft start time current	KA7541	I_{SS}	$V_{SS} = 0\text{V}$	17	25	33	μA
Soft start dead time		t_{sd}	$V_{SS} = 0\text{V}$	1.8	2.3	2.8	μs
Dimming frequency	KA7541	f_d	–	58	72	86	kHz
Dimming voltage range	KA7541	ΔV_{dim}	–	1	–	10	V
OUTPUT SECTION							
Rising time ^(note)	t_r	$C_I = 1\text{nF}$	–	120	200	ns	
Falling time ^(note)	t_f	$C_I = 1\text{nF}$	–	50	100	ns	
Maximum output voltage	$V_{omax(o)}$	$V_{CC} = 20\text{V}$	12	14.5	17	V	
Output voltage with UVLO activated	$V_{omin(o)}$	$V_{CC} = 5\text{V}$, $I_O = 100\mu\text{A}$	–	–	1	V	
NO LAMP PROTECTION SECTION							
No lamp detect voltage	V_{nd}	–	1.9	2	2.1	V	

NOTE: This parameter, although guaranteed, is not 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.

$$R_{st} = \frac{V_{CC} \times \sqrt{2} - V_{CC}}{I_{CC}} = \dots \Omega$$

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.

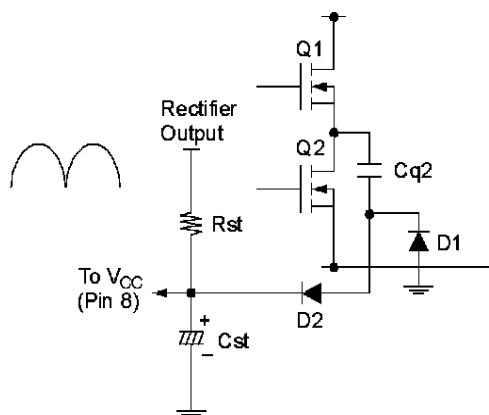


Figure 1. Start-up circuit

OSCILLATOR

The gate drive output frequency is as half as that of the triangular waveform in timing capacitor (Ct) at pin #12. In normal operating mode, the timing capacitor charging current is 50mA. 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 the off-duty of the gate drive.

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

Rising slop: $dv/dt = i/C = 50\mu A / Ct$

Falling slop: $dv/dt = i/C = 7 \times 50\mu A / Ct$

For example, when the timing capacitor is 47pF,

$$\Delta T_{ch} = 17.5\mu s$$

$$\Delta T_{dis} = 2.5\mu s$$

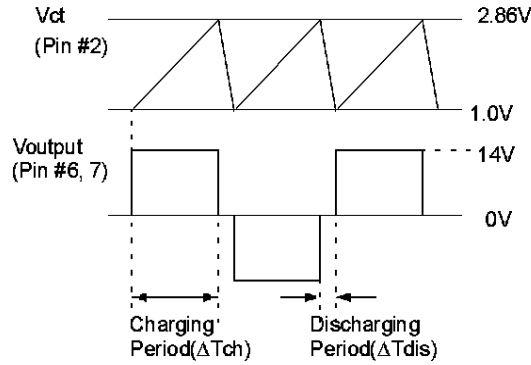


Figure 2. Oscillator sawtooth & Output gate drive waveform

As a result, the switching frequency is as following

$$T_s = 2 \times (\Delta T_{ch} + \Delta T_{dis}) = 40\mu s$$

$$f_{sw} = 1 / T_s = 25kHz$$

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

$$C = \frac{I_{ch} \times T_s}{V_{ct} - V_{out}}$$

SOFT START

The switching frequency is linearly decreasing from the pre-heating frequency to the normal switching frequency. In KA7541, the normal timing capacitor charging current is increased by 25μA during pre-heating mode. This addition of the charging current sets the pre-heating frequency to be 1.33 times the normal mode switching frequency.

$$f_{pre} = f_{sw} \times 1.33$$

With KA7540, in comparison to the KA7541, the initial pre-heating frequency can be adjusted depending on the types of the lamps used. During the pre-heating mode, the sixth of the soft start current (I_S) which flows through the soft start resistor (R_{SS}) at pin #3 is added to the normal timing capacitor charging current (50μA). The rising and falling slop of the triangular waveform are increased due to this added current.

Soft start current (I_S) = $2V / R_{SS}$

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

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

So, once the value of R_{SS} and C_t are known, the pre-heating frequency can be calculated straightforward by using the following equation.

$$f_{sw} = \frac{1}{C_t \times (50\mu A + I_S / 6) \times 6}$$

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

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

$$t_{s/s} = \frac{C_S \times (V_{th(st)} - 2V)}{313nA}$$

For example, the soft start capacitor of 0.2μF makes the soft start time ($t_{s/s}$) to be 1.28sec

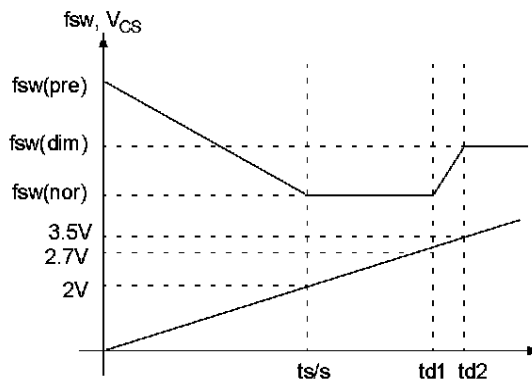


Figure 3. Frequency & Soft start capacitor voltage variation during soft start and dimming mode

NO LAMP PROTECTION

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

$$\begin{aligned}
 V_{pin4} &= V_{DD} \times \frac{R_{filament}}{R_{filament} + R_{filament} + R_1 + R_4} \\
 &\cong V_{DD} \times \frac{R_{filament}}{2R_{filament} + R_1 + R_4} \\
 &\cong V_{DD} \times \frac{R_{filament}}{R_{filament} + R_1 + R_4}
 \end{aligned}$$

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.

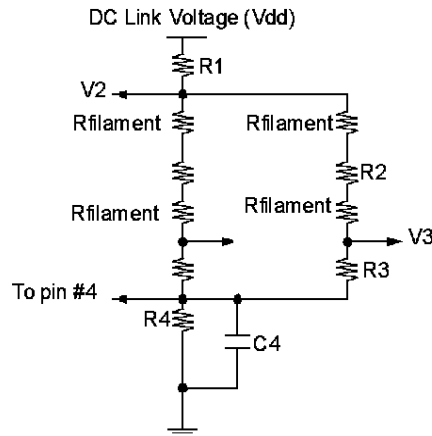


Figure 4. Lamp detection resistor network

DIMMING (KA7541)

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 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.

With KA7541 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 dimming pin. In dimming mode, the timing capacitor charging current is increased by the following amount of the dimming current (Id).

$$I_d = I_k \times (V_{ref} - V_d) / V_{ref}$$

$$I_k = 2 / (6 \times R_S)$$

$$V_d = V_{dim} / 5$$

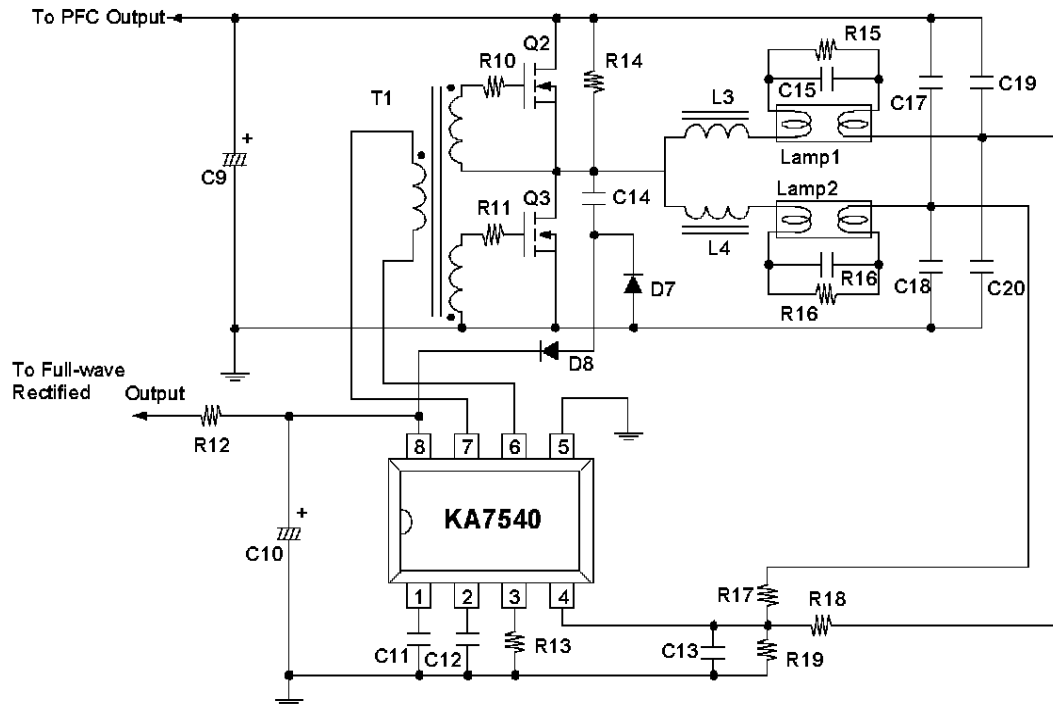
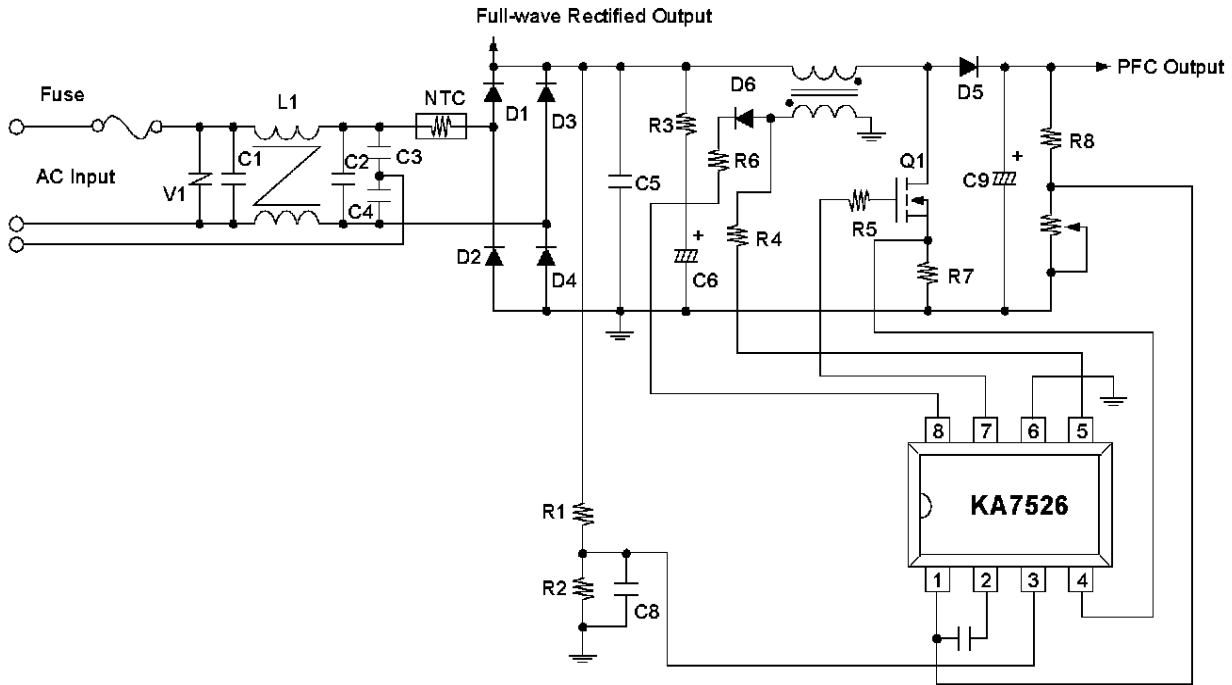
So, the explicit equation for the dimming frequency is as following.

$$f_{dim} = \frac{1}{2 \times R_S \times C_T \times \left(1 + \frac{V_{ref}}{V_{dim}} \right)}$$

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.

APPLICATION CIRCUIT

<90 ~ 265V_{AC} Input, 400V_{DC}, 32W×2 Lamps Ballast>



COMPONENT LISTING

Reference	Value	Part number	Manufacturer
R1	2.2M Ω -F, 1/4W	26mm Type	ABCO
R2	11k Ω -F, 1/4W	26mm Type	ABCO
R3, R12	13k Ω -J, 1/4W	26mm Type	ABCO
R4	22k Ω -J, 1/4W	26mm Type	ABCO
R5, 10, 11	47 Ω -J, 1/4W	26mm Type	ABCO
R6	3.3 Ω , 1/4W	26mm Type	ABCO
R7	1 Ω -J, 1W	-	ABCO
R8	1M Ω -F, 1/4W	26mm Type	ABCO
R9	10k Ω Variable Resistor	26mm Type	ABCO
R13	22k Ω -F, 1/4W	26mm Type	ABCO
R14	180k Ω -J, 1/4W	26mm Type	ABCO
R15, R16	330k Ω -J, 1/4W	26mm Type	ABCO
R17, R18	680k Ω -J, 1/4W	26mm Type	ABCO
R19	8k Ω -J, 1/4W	26mm Type	ABCO
C1, 2	0.15 μ F, 630V	MEP-CAP	WOORYANG
C3, 4	2200pF, 3000V	Y-CAP	SAMSUNG
C5	0.22 μ F, 630V	MPE-CAP	WOORYANG
C6	22 μ F, 35V	Electrolytic	SAMSUNG
C7, 11	0.22 μ F, 25V	Ceramic	DONGLE
C8	0.01 μ F, 25V	Ceramic	DONGLE
C9	47 μ F, 450V	Electrolytic	SAMSUNG
C10	33 μ F, 35V	Electrolytic	SAMSUNG
C12	240pF, 25V	Ceramic	DONGLE
C13	0.1 μ F, 25V	Ceramic	DONGLE
C14	1500pF, 630V	PPF-CAP	WOORYANG
C15, 16	6800pF, 1000V	PPF-CAP	WOORYANG
C17, 18, 19, 20	6800pF, 630V	PPF-CAP	WOORYANG
D1, 2, 3, 4	1000V, 1A	IN4007GP	GI
D5	1000V, 1.5A	RGP15J	GI
D6, 7, 8	75V, 150mA	IN4148	ROHM

COMPONENT LISTING (Continued)

Reference	Value	Part number	Manufacturer
L1	–	BSF2125	NAMYANG
L2	0.45mH	EI2820	NAMYANG
L3, 4	3.1mH	EI2820	NAMYANG
T1	–	EI2820	NAMYANG
Fuse	–	52NM250V, 3A	SAMSUNG
V1	430V	INR140, 431	ILJIN
Q1, 2, 3	500V, 4.5A	IRF830	SAMSUNG

PACKAGE DIMENSION

