



TK5401
Application Note (Ver.1.2)

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1. General Description

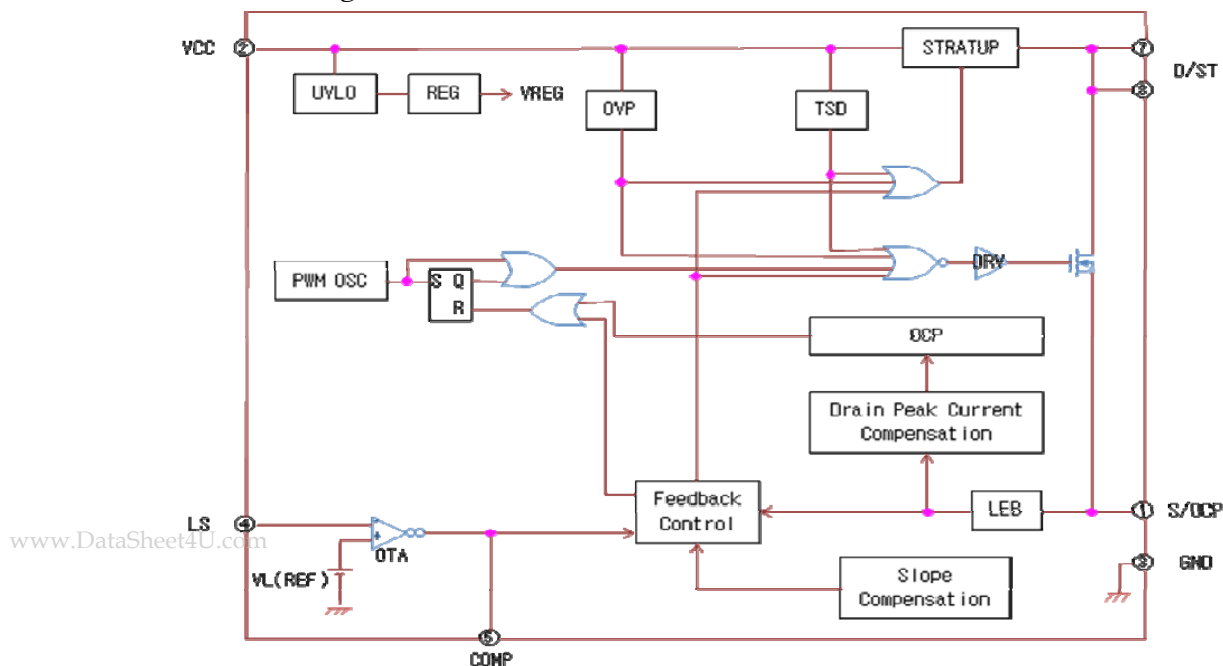
The TK5401 is a power supply IC for LED driver that had a characteristic to operate without electrolytic capacitors which is necessary for the DC power supply structure.

The IC has the high voltage power MOSFET and the control circuit built-in one package. And it is realized miniaturization, low cost by removing electrolytic capacitors. Moreover, it is realized long operating life and high energy efficiency of LED lamp.

2. Features

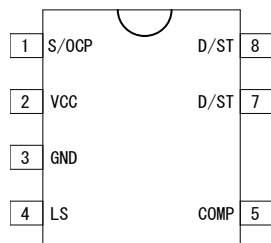
- Built-in the high voltage power MOSFET (650V / 1.9Ω)
- Supports the universal AC input voltage (AC85V~AC265V)
- Supplies low power with built-in the start-up circuit
- PWM controls the power MOSFET at average oscillator frequency (67kHzTyp), feedback controls that assumed reference voltage (0.3VTyp) a standard to keep a fixed LED output current. Stop operating when a VCC voltage became less than Operating Supply Voltage.
- Over Voltage Protection / Thermal Shut Down (Stop operating by latch mode)
- Adjustable Over Current Protection
- Doing the input voltage monitor level in the 0V neighborhood by intermittent operation and operating repeatedly (In the case of the use to have power factor or dimming function, it is possible by adjustment of the voltage monitor)

3. Block Diagram

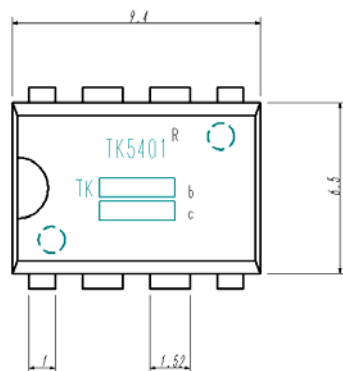


4. Pin Functional Description

Pin #	Symbol	Function
1	S/OCP	Power MOSFET source connection Current limit sense
2	Vcc	Power supply voltage
3	GND	Ground
4	LS	LED output current sense
5	COMP	Erramp output / Phase compensation
7	D/ST	Power MOSFET drain connection Input for start-up current
8		

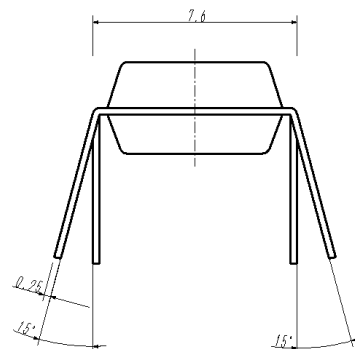
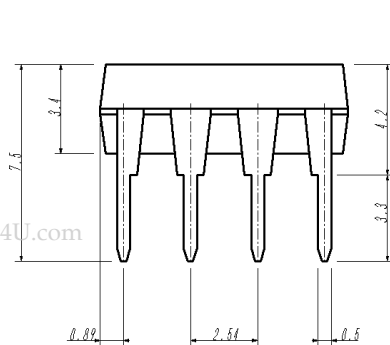


5. Package Outline



<Marking>

R	Product name
b	Lot number
1 st letter	the last digit of year
2 nd letter	month
3 rd letter	week
c	Registration number



Dimension [mm]

6. Electrical Characteristics

6.1. Absolute Maximum Ratings (Ta=25°C, unless otherwise noted)

Parameter	Symbol	Ratings	Unit	Conditions
Peak Drain Current	IDpeak	TBD	A	Single pulse ※1
Single Pulse Avalanche Energy	EAS	TBD	mJ	Single pulse ※1
	ILpeak	TBD	A	
S/OCP Pin Voltage	VOCP	-2~6	V	
Power Supply Voltage	Vcc	32	V	
LS Pin Voltage	VLS	-0.3~6	V	
COMP Pin Voltage	VCOMP	-0.3~6	V	
Power Dissipation (MOSFET)	PD1	1.35	W	※2
Power Dissipation (MIC)	PD2	1.2	W	※2
Storage Temperature	Tstg	-40~+125	°C	
Channel Temperature	Tch	-20~+150	°C	

Notes ※1 To Be Decided

※2 Mounted on board size 15mm×15mm, DIP8 package

6.2. Electrical Characteristics of Power MOSFET (Ta=25°C, unless otherwise noted)

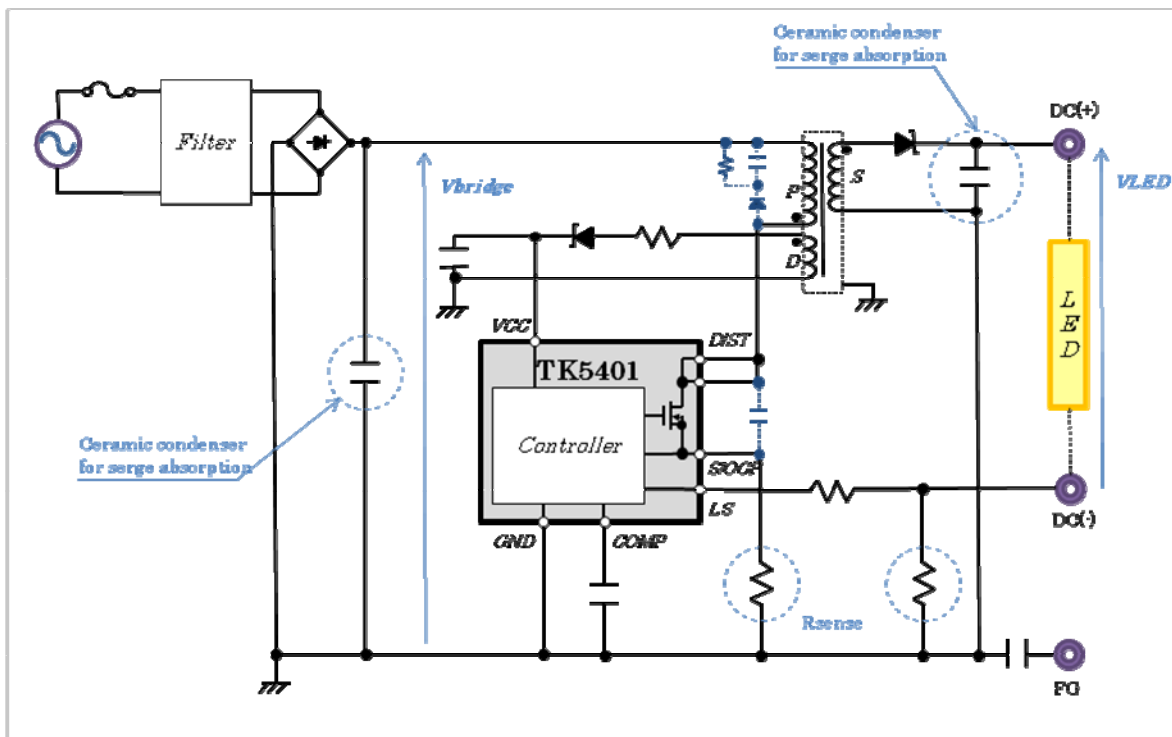
Parameter	Symbol	Values			Unit	Conditions
		MIN	TYP	MAX		
Drain to Source Breakdown Voltage	VDSS	650	—	—	V	
OFF-State Drain to Source Leakage Current	IDSS	—	—	300	μA	
Static Drain to Source On-Resistance	RDS(ON)	—	—	1.9	Ω	
Delay time	td	—	—	250	ns	
Thermal Resistance (Channel to Case)	θ ch-c	—	—	22	°C/W	※2

6.3. Electrical Characteristics of Control (Vcc=18V,Ta=25°C, unless otherwise noted)

Parameter	Symbol	Values			Unit	Conditions
		MIN	TYP	MAX		
●Power Source / Start-up Functions						
Operating Supply Voltage	VCC(ON)	13.8	15.3	16.8	V	
Stop Supply Voltage (Undervoltage Lockout)	VCC(OFF)	7.3	8.1	8.9	V	
Operating Circuit Current	ICC(ON)	—	—	TBD	mA	
Start-up Supply Voltage	VST(ON)	—	TBD	—	V	
Start-up Supply Current	Istartup	-3.7	-2.5	-1.5	mA	
Supply Threshold Voltage	VCC(BIAS)	8.5	9.5	10.5	V	
Latch Keep Current	ICC(LATCH)	—	TBD	—	μ A	
●Oscillator Functions						
Average Oscillator Frequency	fosc(ave)	60	67	74	kHz	
Oscillator Frequency modulation	Δ f	—	5	—	kHz	
Maximum On Duty	Dmax	77	83	89	%	
Minimum On Time	TON(MIN)	—	540	—	ns	
●Over Current Protection Functions						
Leading Edge Blanking Time	TLEB	—	340	—	ns	
Drain Peak Current Adjustment Value	DPC	—	20	—	mV/μ s	
Drain Peak Current Adjustment Limit Duty	DDPC	—	36	—	%	
OCP Threshold Voltage (at Zero On Duty)	VOCP(L)	0.70	0.78	0.86	V	
OCP Threshold Voltage (at 36% Duty)	VOCP(H)	0.81	0.9	0.99	V	

Parameter	Symbol	Values			Unit	Conditions
		MIN	TYP	MAX		
●Reference Source / Erramp Functions						
Reference Voltage	VL(REF)	270	300	330	mV	
Input Bias Current	IBIAS	—	—	100	nA	
Erramp Gain	gm	—	TBD	—	μ S	
Erramp Source Current	ICOMP(SO)	TBD	-20	TBD	μ A	
Erramp Sink Current	ICOMP(SINK)	TBD	20	TBD	μ A	
●Over Voltage Protection / Thermal Shut Down Functions						
OVP Threshold Voltage	VCC(OVP)	26	29	32	V	
TSD Junction Temperature	Tj(TSD)	135	—	—	°C	

7. Power Supply IC Circuit Connection Example



8. Functional Description

8.1. Operating Oscillation

The general power supply IC has large capacitors which is essential to DC power supply structure. There is the input voltage monitor intermittent operation as the LED driver type which does not need large capacitors. The source of supply operating of the IC itself becomes a bridge output. The IC is possible to watches intermittent of this supply voltage and controls transformer and LED output. For the present conditions of the IC, this monitor level is set in the 0V neighborhood and operate repeatedly, and it is considered to lose a visual blink by LED driving pulse.

PWM controls the power MOSFET at average oscillator frequency, and feedback controls that assumed reference voltage a standard to keep a fixed LED output current. The inside reference voltage to use for this current control regards it as low voltage 0.3VTyp to reduce a loss of current sense resistance.

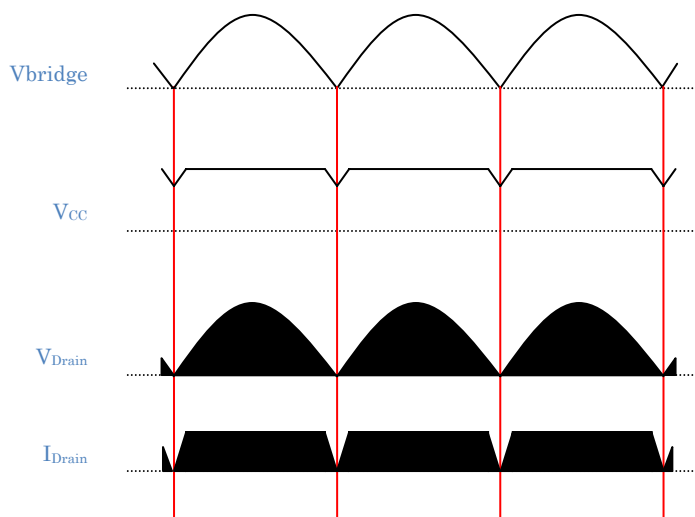


Figure1 Standard Sequence

In addition, the typical oscillator frequency $f_{osc(ave)}$ is set to an average of 67kHz, and it is equipped with a random switching function for noise reduction of the same frequency.

< Random Switching Function >

The IC is equipped with a random switching function in PWM control. According to the statement above, it can simplify to noise filters of input so that noise reduction of the same frequency. During switching operation, it lets slightly change in typically 5kHz peak-to-peak for average frequency at random.

Generally, the inside comparator replies to a sudden surge to occur when the power MOSFET turned on with current control mode. Therefore, there is the case that the power MOSFET turn off. The IC is equipped with a leading edge blanking function to prevent this phenomenon.

<Leading Edge Blanking Function>

This function arranges the blanking time of 340nSTyp from the moment when the power MOSFET turned on, and evades an above phenomenon.

8.2. Power supply and Start-up Circuit

VCC(2pin) is a terminal for the energy supply that is necessary for the control circuit. The start-up circuit is connected to D/ST(7,8pin) in the IC inside. The start-up current charges condenser connected to VCC pin. When VCC pin rises to operating supply voltage VCC(ON)=15.3VTyp, the IC operates. The start-up time is decided to capacity connected Vcc pin, can demand it by next type.

$$T_{START} = C \times (V_{CC(ON)} - V_{CC(int)}) / I_{STARTUP}$$

※TSTART : Start-up time [S], VCC(int) : VCC initial voltage [V], C : Capacity connected Vcc pin[F]

The start-up circuit after starting-up disappear loss by itself to intercept automatically.

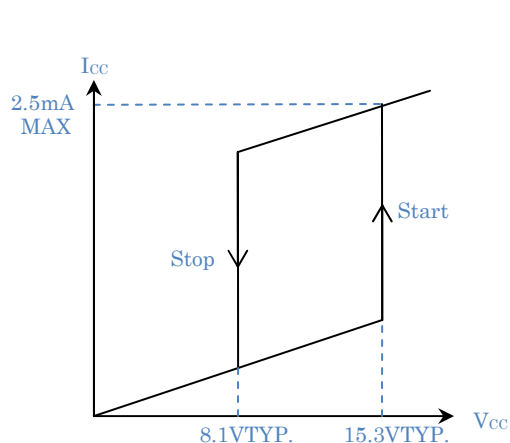


Figure2 Relation of Vcc and Icc

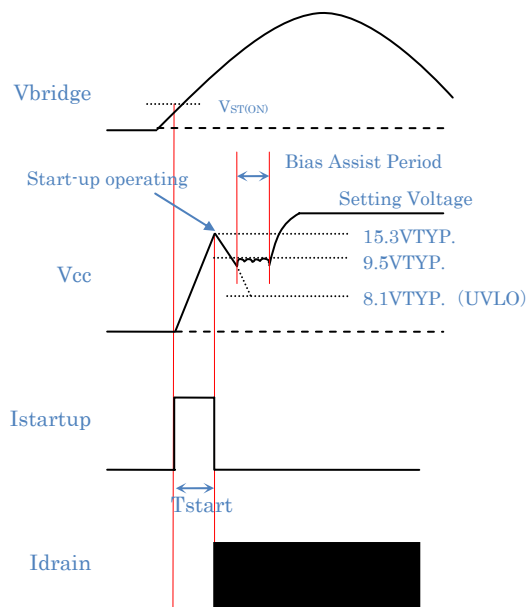


Figure3 Start-up Sequence

Shown in figure 2 is relation of Vcc voltage and circuit current. When the Vcc voltage reaches to 15.3V typical and the control circuit starts operating, the circuit current

increases. When the V_{CC} voltage reaches to 8.1V typical, the control circuit stops by under voltage lockout and comes back to the state before start-up again.

After the control circuit operating, the V_{CC} voltage gets a power supply by doing rectification flatness of winding voltage of a winding D. Please adjust of a winding D at around 20V from 15V so that the V_{CC} voltage becomes $V_{CC(OFF)}=8.9V_{MAX} < V_{CC} < V_{CC(OVP)}=26.0V_{MIN}$. Shown in figure 3 is start-up sequence. The voltage of a winding D does not rise to the setting voltage after the control circuit start operating immediately. Because the V_{CC} voltage begins to descend, and a bias assist function works when the V_{CC} voltage becomes less than 9.5V typical. During a bias assist function operation, it controls to drop of the V_{CC} terminal voltage, because the start-up current is supplied from the start-up circuit again.

Shown it in figure 4, there is the case that the V_{CC} voltage changes by a value of output current in the real power supply circuit. Because it is charged peak capacity connected V_{CC} pin by a surge voltage to occur when the MOSFET turned off. It is effective to add a resistance in series with a zener diode to prevent this phenomenon. It is really necessary for the most suitable value of this resistance to adjust a transformer to use in different by transformer structure to use.

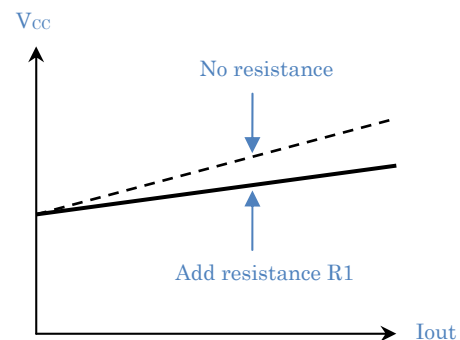


Figure4 Relation of I_{out} and V_{CC}

In addition, the rate of change of the V_{CC} voltage for output voltage turns worse so that transformer combination is bad. Therefore, this peak charge is relaxed by reducing under the influence of the surge voltage from primary winding P to a winding D.

From the point of view, it is necessary to attention the scroll position of winding D in the transformer design.

Shown in figure5, figure6 is the reference example of the scroll position of a winding D.

- Separate distance with winding D and primary winding P (figure5)
- Structure to sandwich winding D in second side control winding S (figure6)

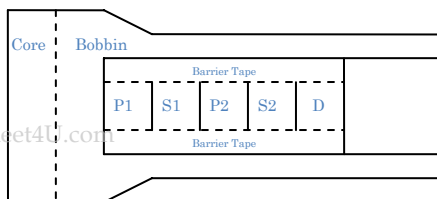


Figure5 Winding structure example1

P1,P2 : primry
D : for V_{CC}

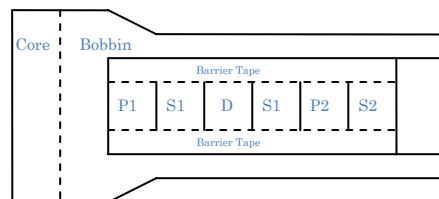


Figure6 Winding structure example2

S1 : second control
S2 : second output

8.3. Constant Current Control Circuit

The IC converts this current into a voltage for current sense resistance to control output current of the LED and input it into LS(4pin) terminal. The IC controls so that makes constant voltage to this voltage.

Shown in figure 7 is constant feedback waveform. This control voltage is input into the Feedback Control circuit and generates the target voltage of the comparator by adding slope adjustment more. In addition, the Feedback Control circuit operates so that the drain peak current approach to above-mentioned target voltage. As a result, the IC compares this peak value and controls it.

Shown it in figure 8, as for the power supply of the peak current control method, drain current waveform change by a period of integer double of the switching frequency. Such a phenomenon call a subharmonic oscillation. It is theoretically problem to occur. Therefore a suitable adjustment that is stable operating is necessary.

In the case of continuous mode, even if the drain peak current is constant, the ON period change for the initial value of drain current. As a result, the suitable operation is not maintained in a period of switching. The IC has the slope compensation circuit built-in to control this phenomenon.

The slope compensation circuit operates so that fall drain peak current as ON duty become wide, and controls a subharmonic oscillation.

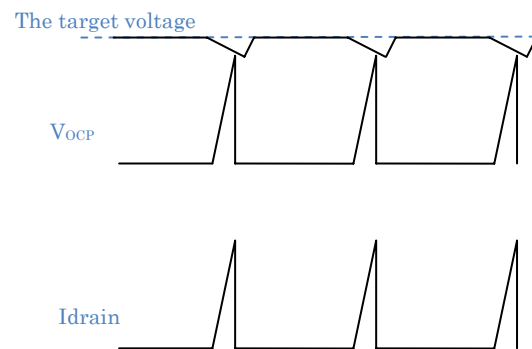


Figure7 Constant Feedback Waveform

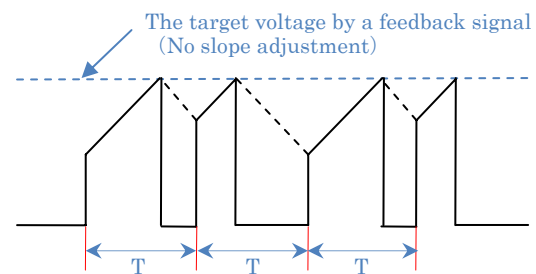


Figure8 Drain Current Waveform by a Subharmonic Oscillation

8.4. Adjustable Over Current Protection Circuit

This circuit detects the peak value of drain current by every pulse and it is switched off the power MOSFET when D/ST(7pin,8pin) terminal voltage became over the OCP voltage. As this circuit has a input adjustable circuit built-in, it is realized overcurrent protection with a little AC input dependent.

The detection of drain current connects a current sense resistor between S/OCP(1pin) terminal to GND(3pin) terminal and carries it out. When

the drop voltage by sense resistor reached the OCP threshold voltage, it is turned off the power MOSFET. The general PWM control IC tends to occur unevenness of drain peak current movement point for AC input voltage change.

Shown in figure 9 is output overload characteristics when the overcurrent protection circuit operated.

The IC has a input adjustable circuit built-in to adjust the unevenness. This circuit adjusts a difference of drain peak current movement point for AC input voltage change.

This quantity of adjustment depend the value of drain peak current adjustment and on time. OCP threshold voltage after adjustment can demand it by next type.

$$V_{OCP} [V] = V_{OCP(L)} [V] + (DPC [V/\mu S] \times ON Time [\mu S])$$

But, OCP threshold voltage over ON duty 36% become $V_{OCP(H)}=0.9V_{Typ}$.

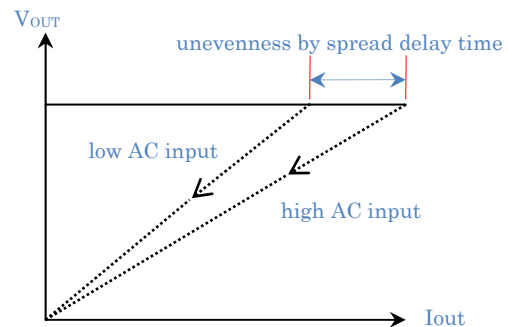


Figure9 output overload characteristics

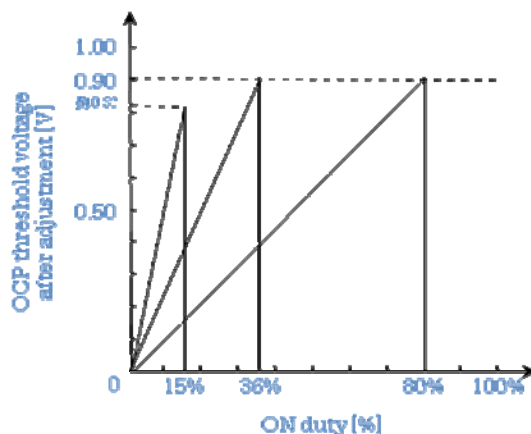


Figure10 Relation of ON duty and OCP threshold voltage after adjustment @ fosc(ave)=67kHzTyp

Shown in figure 10 is relation ON duty and OCP threshold voltage after adjustment. When you designed the transformer to become ON duty 36% in peak load and AC85V, the OCP movement point become to $V_{OCP(H)}=0.9V_{Typ}$.

8.5. COMP Pin Function

The COMP pin is a terminal for phase compensation of the feedback control circuit. The condenser capacity to add, big one is stable, but it is necessary to adjust a fixed number after having confirmed a lead and delay of phase.

- (1) Stable operation, Abnormal oscillations or not
- (2) Start-up failure and Re-start failure or not

8.6. Latch Function

The latch circuit is stopped switching when OVP circuit and TSD circuit operated each and it protects the IC by keeping the stop state.

This circuit makes the delay time to prevent an irregular operation by noises and operates in the case of following to protect more than a constant time.

When the IC stops switching by this circuit, Vcc terminal voltage begins falling down. when Vcc terminal voltage falled down to 9.5V typical, it supplies start-up current in Vcc terminal. and it keeps the latch state to prevent falling down to 8.1V typical.

The latch cancellation turns off AC input once basically and it is canceled by falling Vcc terminal voltage to less than 8.1V typical.

8.7. Thermal Shut Down Circuit

When the junction temperature of IC reaches to 135°C by rising of the ambient temperature, the latch circuit operates.

The real temperature detection goes in a control element.

8.8. Over Voltage Protection Circuit

When the power supply IC became the no load state in constant current control, it become uncontrollable and occur to overvoltage in output. With it, the Vcc terminal voltage rises too. Shown in figure 11 is OVP circuit sequence.

The IC have the over voltage protection function built-in to protect output and load from overvoltage. The IC does not directly monitor, but it protects load by monitoring Vcc terminal voltage. In other words, the latch circuit operates and stops switching when Vcc terminal voltage exceed 29V typical.

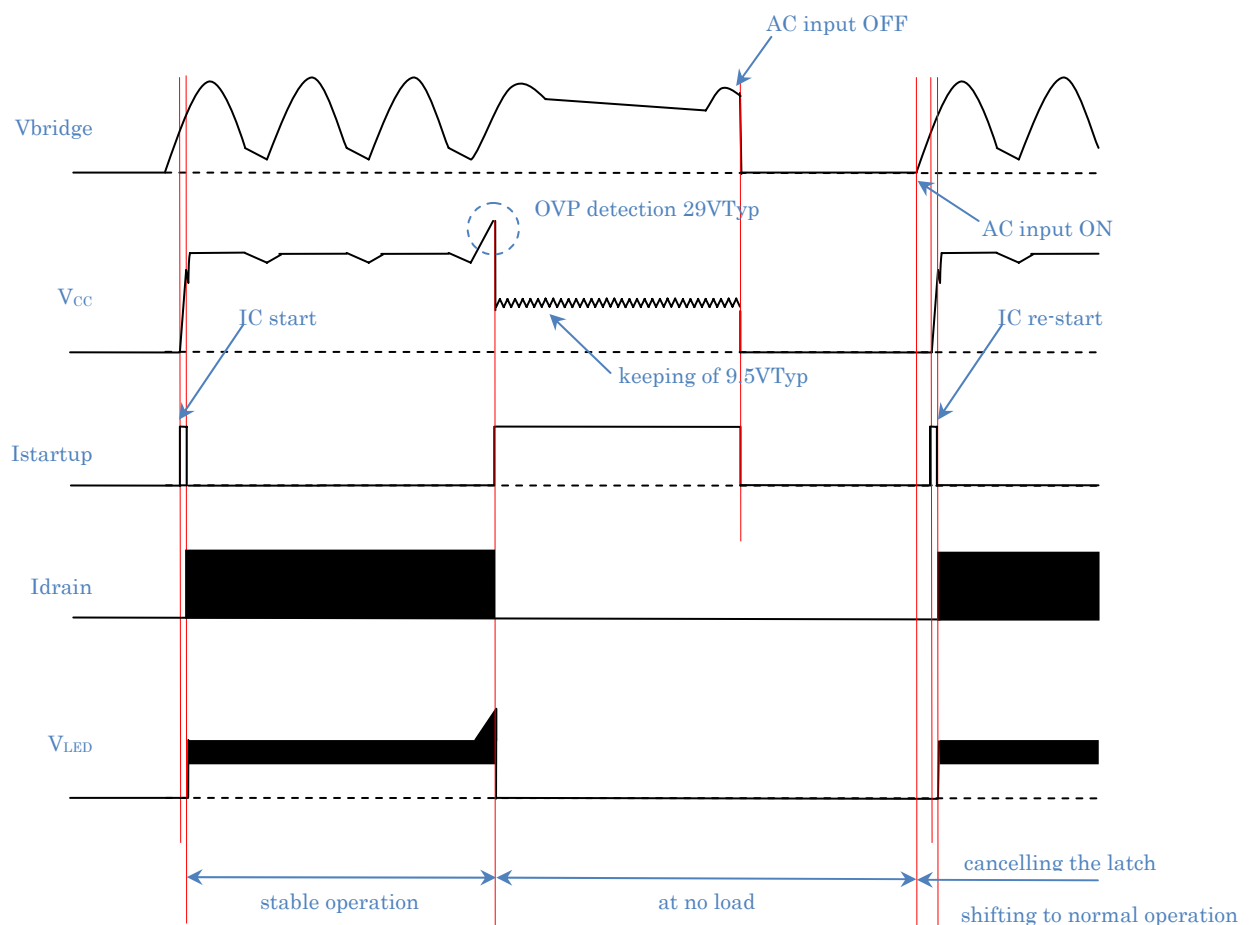


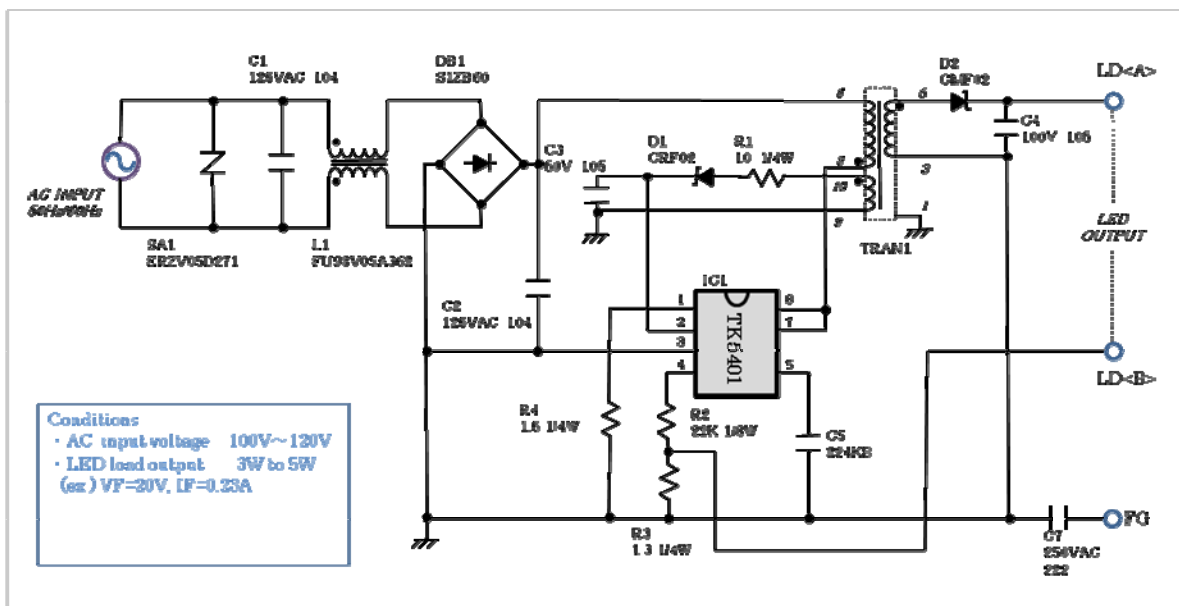
Figure11 OVP Circuit Sequence

9. Application Circuit Example for LED Driver

Shown below it is the application example for LED driver. The mention of parts name, parts placement, part fixed number are reference to the last.

For after considering attentions, the circuit fixed number and optimization of the transformer design, a heat design, EMC-prevention and so on are necessary for each load condition.

9.1. Application Circuit Example 1



10. Attentions

10.1. External Components

Each components of capacitance and inductance and power dissipation, please use it adapted in terms use. Transformer please suitably margin in each part for temperature rise by copper loss and iron loss. Please use a current sense resistor having small inside inductance and big surge tolerance because high frequency switching current flow.

Because a high frequency component is included for switching current, please find the transformer winding from a actual value of the operating current and select the current density of around 4 to 3A/mm2. In the case of temperature prevention,

For after considering the heating, it is necessary for transformer to adjust diameter and number of the winding that to lower the winding temperature by the increase of winding surface area by using Ritz lines.

10.2. Parts Placement and Pattern Design of Print Board

- (1) Shown it in figure 12, please wire it as possible thick and short for the loop patterns from S/OCF terminal to D/ST terminal of the IC so that switching current flow.
- (2) Please wire it as possible thick and short for the pattern of Vcc line. please insert a film condenser C (a level of 50V/0.1 μ F) between Vcc terminal and GND terminal when the IC and distance with C2 are long by all means.
- (3) Drain terminal recommend so that make it as possible big pattern to be effective against the dissipation of heat.
- (4) Please wire it as possible short between S/OCF terminal and current sense resistor R1. In addition, please separate power GND and control GND by the other pattern well.

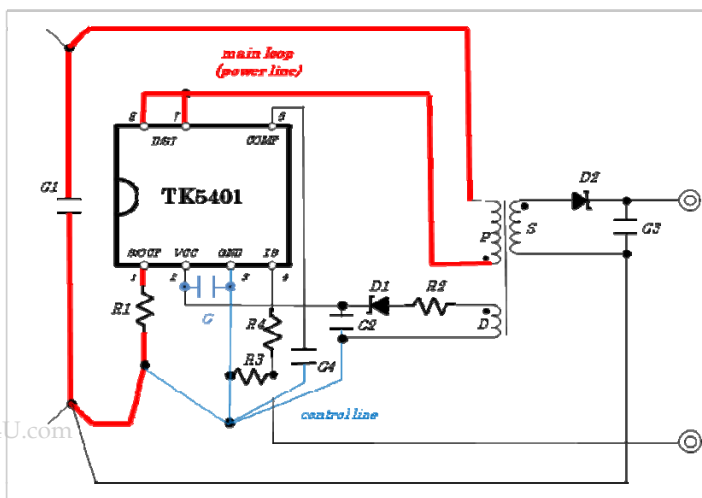


Figure12 Connect Pattern Example

10.3. Mounted Design of The Switching Power Supply

Please be careful wiring layout and parts placement enough because the irregular operation and noises and power loss show the great effect by patterning and mounting of conditions. Please consider it to lower the line impedance by making thick the pattern of high frequency current line and shortening the pattern of connection line between the parts.

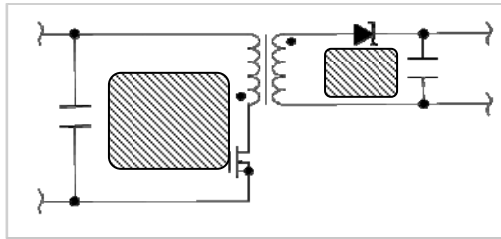


Figure13 Loop of High Frequency Current

Shown it in figure 13, please design pattern so that the loop area (section of diagonal) seem to become small as possible. Please shorten and thickly as possible ground line because it show the great effect for radiation noise.

The parts placement and the pattern distance that considered a safe standard are necessary because there are the route of high frequency and high voltage in general switching power supply.

Please be careful of designing the heat because the on-state resistance of Power MOSFET having a positive of temperature coefficient.

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