Fuji Switching Power Supply Control IC

FA5550 / 51

Application Note

February 2008
Fuji Electric Device Technology Co.,Ltd.

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Contents

Caution)

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- The application examples or the components constants in this note are shown to help your design, and variation of components and service conditions are not taken into account. In using these components, a design with due consideration for these conditions shall be conducted.

1. Overview

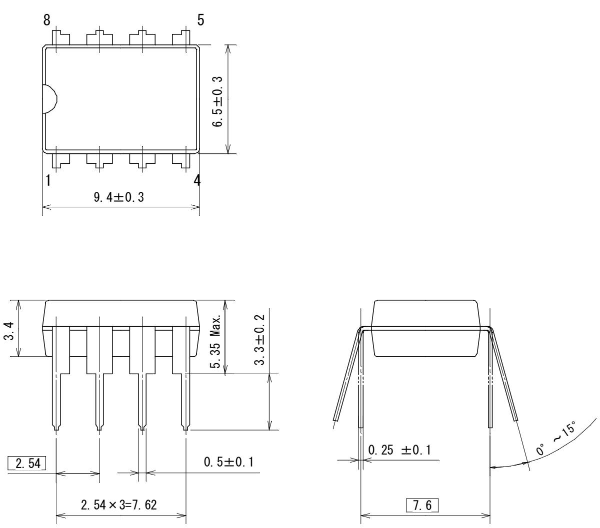
FA5550/51 are control ICs for power factor correction converter with continuouse conduction mode (CCM) of operation. Low power consumption is achieved by using high withstand voltage CMOS processes.

2. Features

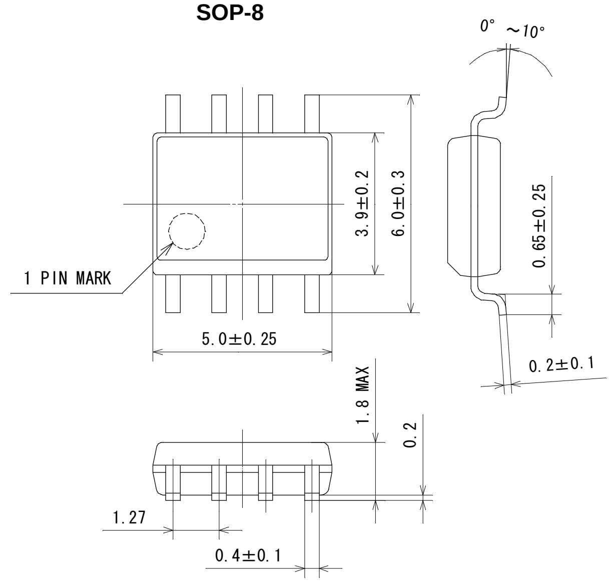
- CCM PFC controller with few external components
- low power consumption by using high withstand voltage CMOS processes
- Built-in drive circuit for the power MOSFET,
  Output current: 1A (source)/ 2A (sink)
- Over voltage protection function
- Brownout protection function
- Undervoltage Lockout function
  FA5550: 9.6V ON/ 9V OFF; FA5551: 13.0V ON/9V OFF
- Open/short protection at feedback(FB) pin
- Operational frequency: 65kHz (typ)
- Packages: DIP-8/SOP-8

3. Outline

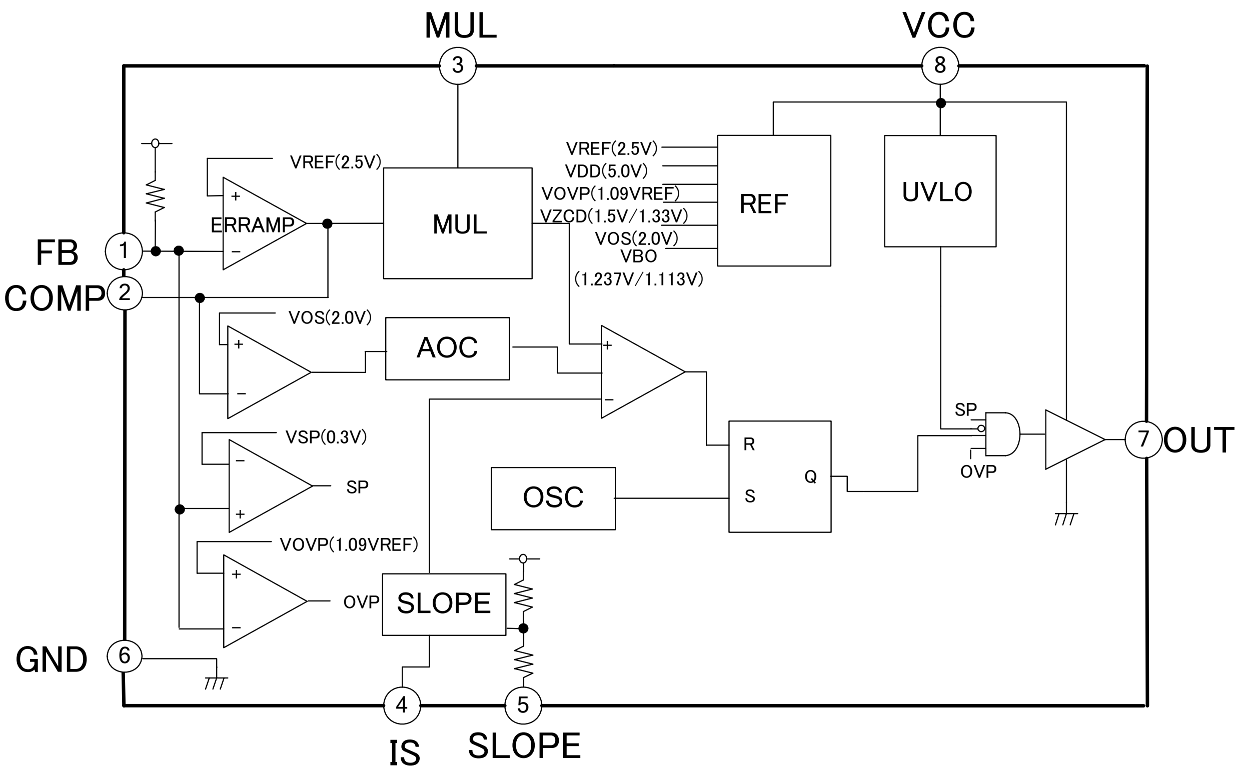
DIP-8



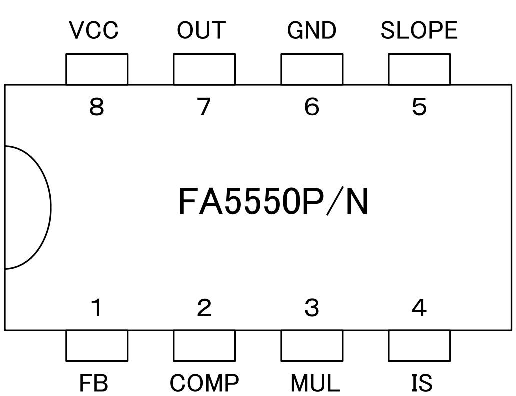
SOP-8



4. Block diagram



5. Pin assignment



Pin No.	Symbol	Function of pin	Functional description
1	FB	Voltage feed-back input	Input pin from converter output voltage
2	COMP	Error amplifier compensation pin	Output pin for error amplifier
3	MUL	Multiplier input	Input pin for sine-wave AC power supply waveform
4	IS	Current sense input	Input pin for current detection of MOSFET
5	SLOPE	SLOPE compensation pin	Pin for regulation of SLOPE compensation
6	GND	Ground	Pin for power supply grounding
7	OUT	Output	Output pin for direct drive of MOSFET
8	VCC	Power supply	Pin for power supply input to operate IC

6. Absolute maximum rating

Item (Parameter)		Symbol	Rated value	Unit
Total power supply current and Zener current		Icc+Iz	30	mA
Power supply voltage	Built-in zener clamp (Icc+Iz<30mA)	Vcc	Self limiting	V
Output current		Io	-1000 +2000	mA
Input voltage (IS, MUL, FB)		Vin	-0.3 to 5	V
Total loss (Ta=25℃)	DIP-8	Pd1	800	mW
	SOP-8	Pd2	400	mW
Operational ambient temperature		Ta	-30 to +105	℃
Junction temperature		Tj	+150	℃
Storage temperature		Tstg	-40 to +150	℃

7. Recommendable operating conditions

Item	Symbol	Condition	Min	Typ	Max	Unit
Power supply voltage	Vcc		10	15	28	V
Resistance to regulate slope compensation	Rslope		0		200k	Ω

8. Electric characteristics

(When not specified, Tj=25℃, VCC=15V)

1) Error amplifier (FB and COMP pins)

Item	Symbol	Condition	Min	Typ	Max	Unit
Input threshold voltage	Vfb	Ta=25℃		2.5		V
Line regulation	Regline	Vcc=10V to Ta=25℃		-20		mV
Stability of temperature	VdT	Ta=-30 to 105		-0.5 to +0.5		mV/℃
Transconductance	Gm	Ta=25℃		90		μmho
Output current	Io	Source (Vfb=2.3V)		10		μA
		Sink		10		

2) Oscillator

Item	Symbol	Condition	Min	Typ	Max	Unit
Oscillating frequency	Fosc	Ta=25℃		65		KHz
Stability of Power supply voltage	Fdv	Vcc=10V to Ta=25℃			2	%
Stability of temperature	FdT	Ta=-30 to 105℃		-0.04 to +0.04		%/℃
Maximum duty cycle	Dmax			96		%

3) Over-voltage protection comparator (FB pin)

Item	Symbol	Condition	Min	Typ	Max	Unit
OVP threshold voltage (high)	Vthovph			1.09Vfb		V
OVP threshold voltage (low)	Vthovpl			1.045Vfb		V

4) FB short circuit detection comparator (FB pin)

Item	Symbol	Condition	Min	Typ	Max	Unit
Input threshold voltage	Vthsht			0.3		V
Pull-up current	Ipullup	Vfb=2.5V		5		μA

5) Multiplier (COMP and MUL pins)

Item	Symbol	Condition	Min	Typ	Max	Unit
Input threshold voltage	Vthcomp			0.55		V
Linear operation range Pin3 (MUL) Pin2 (COMP)	 Vpin3 Vpin2			 0 to 3.5 Vthcomp to (Vthcomp+1.5)		V
On-Off threshold voltage	Vthonoff			0.3		V
Gain	K	Vpin3=0.5V Vpin2=Vthcomp +1.0		0.75		1/V

K=(Multiplier output)/{Vpin3(Vpin2-Vthcomp)}

6) Current detection comparator (IS pin)

Item	Symbol	Condition	Min	Typ	Max	Unit
IS threshold 1	Vthis1	Vpin3=1.763		1		V
Output delay	Tphl			170		nS

7) Brownout (MUL pin)

Item	Symbol	Condition	Min	Typ	Max	Unit
Brownout threshold voltage, high	Vthbro_h	R1=10KΩ R2=790KΩ		1.237 (-70)		V
Brownout threshold voltage, low	Vthbro_l	R1=10KΩ R2=790KΩ		1.113 (-63)		V
Delayed brownout threshold detection	Tbro			220		mS

R1 is resistance between MUL and GND; R2 is resistance between AC voltage line after rectified and MUL pin.

8) Output (OUT pin)

Item	Symbol	Condition	Min	Typ	Max	Unit
Output voltage (L)	Vol	Vcc=15V Isink=200mA		1.2		V
Output voltage (H)	Voh	Vcc=15V Isouce=200mA		11.8		V
Output rise time	Tr	Cl=1.0nF		50		nS
Output fall time	Tf	Cl=1.0nF		25		nS

9) Slope compensation (SLOPE pin)

Item	Symbol	Condition	Min	Typ	Max	Unit
Slope compensation	Slope			24.5		mV/µS
Slope increasing rate	Slope_inc	0 Ω to 200kΩ		0.12		(mV/µS)/KΩ

10) Low voltage protection (VCC pin)

Item	Symbol	Condition	Min	Typ	Max	Unit
ON threshold voltage	Von1	FA5550		9.6		V
	Von2	FA5551		13		V
OFF threshold voltage	Voff			9		V
Hysteresis width	Vhys1	FA5550		0.6		V
	Vhys2	FA5551		4		V

11) All devices (VCC pin)

Item	Symbol	Condition	Min	Typ	Max	Unit
Zener voltage	Vz	Icc=25mA		33		V
Start-up current	Istart	Vcc=8.0V			20	μA
Operating current	Icc	Vcc=15V		2		mA
Dynamic operating current	Iop	Cl=1.0nF		2.5		mA

9. Basic operational description

These ICs are used to control the power factor correction converter using boosting chopper, adopting peak value control in operations. The outline of those operations is described here using a rough schematic diagram of the circuit shown in Fig. 1.

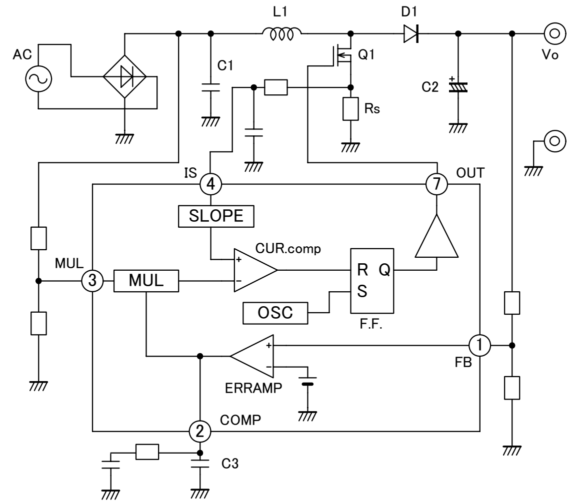


Fig.1 Overview of operating circuit block

(1) Switching operation

Figure 2 shows the outline of waveforms of the switching operation in each part under the steady-state condition.

The operations are performed as follows.

A trigger signal of switching frequency output from the oscillator is inputted to R-S F.F. as a set signal. Then, the OUT pin voltage changes to high state, and Q1 turns on (t1).

When Q1 is turned on, the current through L1 is increased. The current value from Q1 is converted to voltage with Rs, and the voltage is input to IS pin (VIS). When VIS reaches the reference value of the current comparator (CUR.comp) specified by output of a multiplier (MUL), a reset signal is input into R-S F.F. to turn off Q1 (t2). The shift to a next switching cycle (t1) is made by a setting signal output from the internal oscillator (f=65kHz(typ))

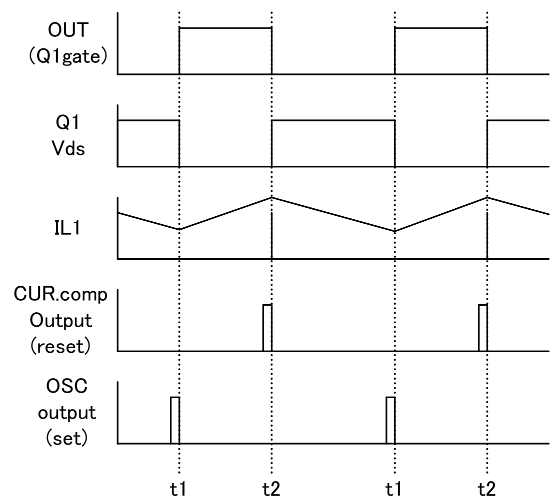


Fig.2 Switching operation; waveforms of each part (Overview)

(2) Power factor improvement operation

COMP pin voltage that is output of the error amplifier (ERRAMP) is smoothed approximately to a DC voltage with C3 under steady-state condition. This voltage is inputted into the multiplier. A waveform, which is made by rectification of the AC input voltage, is input to the other input of the multiplier.

As the result, the multiplier outputs a near-sinusoidal waveform that is product of these two waves proportioning to the AC input voltage.

This output near-sinusoidal voltage waveform is input into the current comparator (CUR.comp) as the reference of an inductance current.

As the result, homogenized current value through the inductance forms a sinusoidal wave. By eliminating and equaling switching ripples in the current through this inductor L1 using C1, the current output from an AC input voltage forms a near sinusoidal wave. Thus, the power factor can be improved.

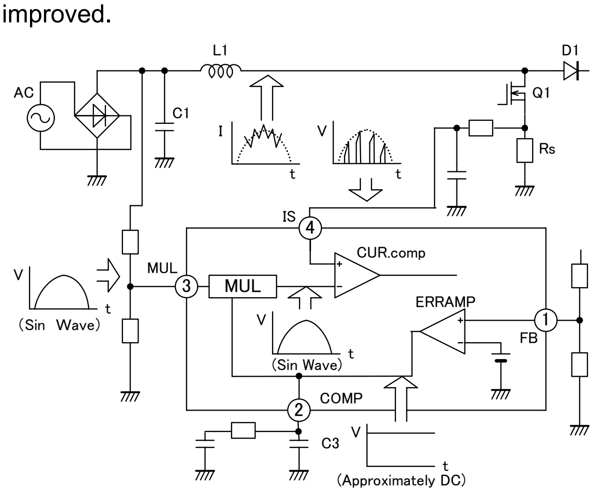


Fig.3 Images of operating waveforms in each part

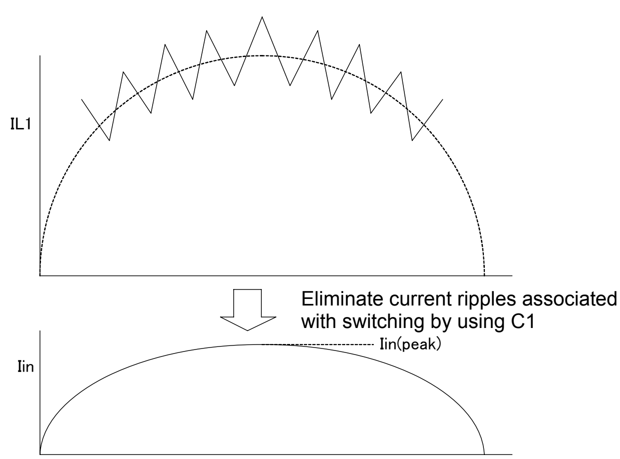


Fig.4 Operational waveform after improving Power Factor

10. Descriptions for use of each pin

(1) No.1 pin (FB pin)

Function:
(a) Input of feedback signal for setting output voltage
(b) Detection of FB pin short circuit
(c) Detection of output over-voltage condition

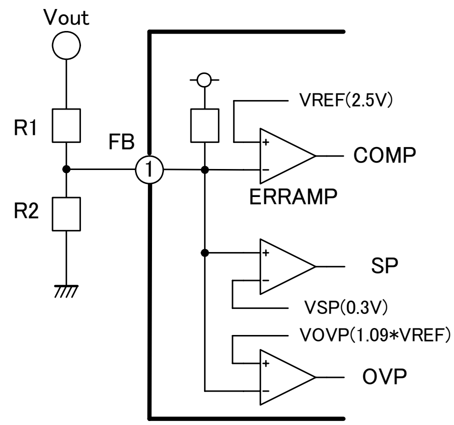


Fig.5 FB pin circuit

How to use:
(a) Input of feedback signal
・How to connect:
Connection of voltage-divided part into voltage-dividing resistance circuit for setting output voltage
・Operation
Vout, an output voltage of PFC, is controlled so that the voltage input to the FB pin divided by using resistance corresponds to the internal reference voltage (2.5V).

(b) Detection of FB pin short circuit:
・How to connect:
The same method as the input of the feedback signal
・Operation
When the input voltage of the FB pin comes down under 0.3V because of such as a short circuit fault in R2, etc. in the voltage-dividing resistance circuit, the comparator (SP) turns over its output to make stop the output of the IC.

(c) Detection of an output over-voltage:
・How to connect:
The same method as the input of the feedback signal
・Operation
The usual voltage of FB pin operates with 2.5V almost the same to the reference voltage of the error amplifier. When the voltage of FB pin rises due to some sort of causes and outreached the reference voltage (1.09*VREF) of the comparator, the comparator (OVP) turns over its output in the meantime to stop OUT pulse. When the output voltage comes back to the normal value, OUT pulse is outputted again.

(2) No.2 pin (COMP pin)

Function:
(a) Phase compensation of the built-in ERRAMP output
(b) ON/OFF operation with external signals

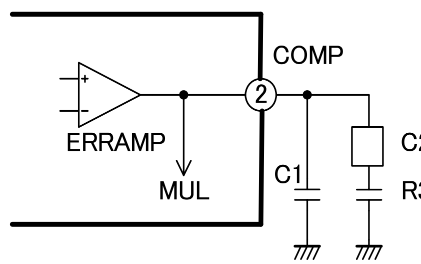


Fig.6 COMP pin circuit

How to use:
(a) Phase compensation of the built-in ERRAMP output
・How to connect:
Connect C and R between COMP and GND as shown in Fig. 6.
・Operation
Connect C and R to COMP pin so that FB output does not have the ripple element which is the second harmonic of AC line.

(b) ON/OFF with external signals
・How to connect:
Pull down COMP pin with an external signal.
・Operation
By pulling down COMP pin lower than VthCOMP, the output pulse from the IC is interrupted.

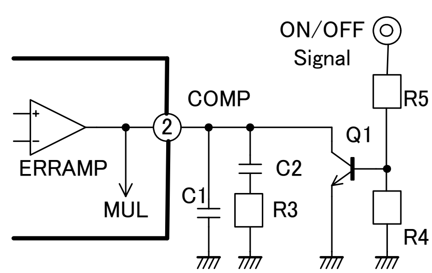


Fig.7 COMP pin ON/OFF circuit

(3) No. 3 pin (MUL pin)

Function:

(a) Input of input voltage waveform (sine-wave)

(b) Detection of brownout

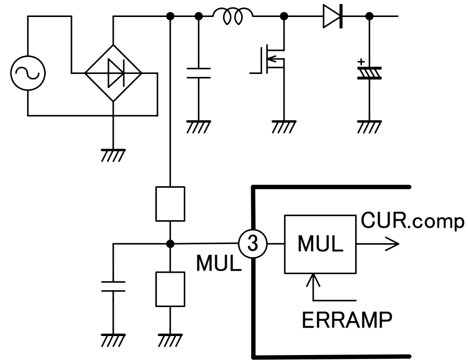


Fig.8 MUL pin circuit

How to use:

(a) Input of input voltage waveform (sine-wave).

- How to connect:

  Input rectified voltage of AC input with its voltage in resistance-divided. In addition, connect C between MUL and GND.

- Operation

  The rectified voltage input to MUL pin and ERRAMP output are inputted into the multiplier (MUL), and a near-sinusoidal wave is outputted from the multiplier. The output of the multiplier is set as a reference of the comparator, and the comparator controls the input voltage in the form of sine waves. In addition, because the rectified voltage of AC input contains much noise components due to the switching of Q1, a capacitor is normally connected as a filter.

(b) Brownout

- How to connect:

  The same method as the control of the input current in the form of the sine-wave

- Operation

  Brownout function stops the output pulses when AC input voltage drops below programmed voltage. (See page 14)

(4) No.4 pin (IS pin)

Function:

(a) Detection of MOSFET current value

How to use:

(a) Detection of MOSFET current value

- How to connect:

  Connect a current detecting resistor Rs between the source pin of MOSFET and GND, and input the current signal of MOSFET generated with this resistor.

- Operation

  When output voltage of the multiplier and voltage of IS pin are inputted into the comparator and IS pin voltage becomes larger than the output of the multiplier, the comparator turns over its output signal to turn OFF the OUT output.

  The overcurrent limiting function limits the maximum threshold voltage of IS pin within 1V.

- Supplementary explanations

  When MOSFET turns on, gate driving current of MOSFET and surge current due to discharge from parasitic capacitics in thecircuit may run through the current detection resistor Rs. The large surge current may result in malfunction and distortion of the input current waveform. CR filters are usually connected as the measure.

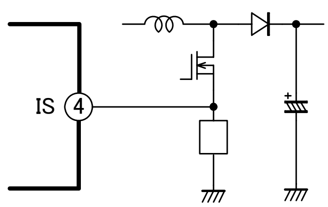


Fig.9 IS pin circuit

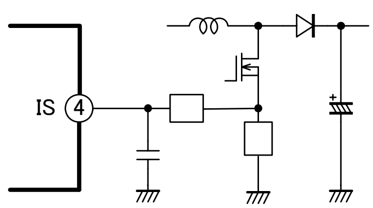


Fig.10 Filters of IS pin

(5) No.5 pin (SLOPE pin)

Function:

(a) SLOPE compensation of IS pin

How to use:

(a) SLOPE compensation

・How to connect:

Connect a resistor between SLOPE pin and GND, or short circuit to GND. A SLOPE compensation value with the resistor connection shall be 0.12(mV/us)/kΩ.

・Operation

sub-harmonic oscillation is prevented by adding specific gradient voltage (Slope) to IS pin voltage.

・Supplementary explanation

In case of current mode for peak value controls, oscillations which are integral multiples of the switching frequency may occur if the circuit is operated in continuouse conduction mode and duty cycle of 50 percent or more. This is called as sub-harmonic oscillation.

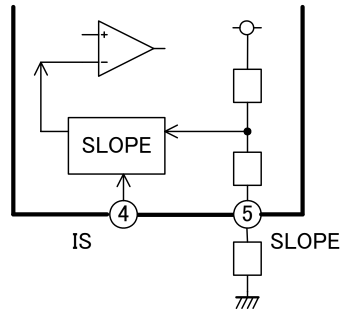


Fig.11 SLOPE pin circuit

(6) No.6 pin (GND pin)

Function:

This is used as the reference voltage for each part of the IC.

(7) No.7 pin (OUT pin)

Function:

Driving of MOSFET

How to use:

・How to connect:

Connect to the gate pin of MOSFET through a resistor.

・Operation

During MOSFET is being on, this is in the state of "High", and the voltage almost equal to the VCC is outputted.

During MOSFET is being off, this is in the state of "Low", and the voltage almost equal to 0V is outputted.

・Supplementary explanation

Connect a gate resistor aiming at current limit of OUT pin and prevention of oscillations of the gate pin voltage.

The rated output currents of the IC are 1A at the source and 2A at the sink.

In connections shown in Figures 13 and 14, gate driving currents of MOSFET for ON and OFF can be set independently.

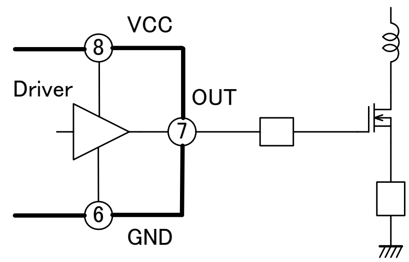


Fig.12 OUT pin circuit (1)

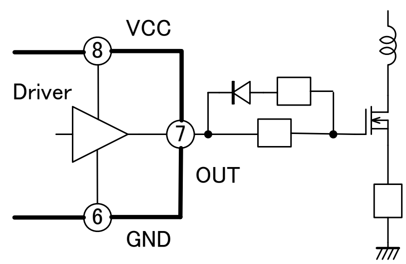


Fig.13 OUT pin circuit (2)

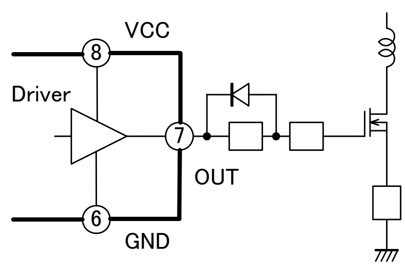


Fig.14 OUT pin circuit (3)

(8) No.8 pin (VCC pin)

Function:

(a) Power Supply to the IC

How to use:

(a) Power Supply to the IC

・How to connect:

Connect a starting resistor between the voltage line after rectified and Vcc pin.
In general, connect voltage of the subsidiary coil attached to transformer after rectifying and smoothing it.
Or, connect an external DC power source.

・Operation

When the VCC voltage is supplied from the subsidiary coil, the current running through the starting resistor is charged into the smoothing capacitor at start-up, and the IC will start if the voltage increases up to the UVLO on-threshold voltage.
The current of 20uA or more at least, which is the start-up current of the IC, needs to be supplied just before of start-up.
During the usual operation, VCC is supplied with the subsidiary coil of the inductor.

When the power supply voltage is increasing from 0V, FA5550 starts to operate at the voltage of 9.6V (typ) and FA5551 at the voltage of 13V (typ).
Both ICs stop to operate at the voltage of 9V (typ) when the power supply voltage is decreasing after start-up of the operation.
During the period when the low voltage malfunction prevention circuit is activated and the IC is stopped, OUT pin is made to "Low" and the output is interrupted.

(Supplementary explanations)
The low voltage malfunction prevention function is a function to prevent malfunctions of the circuit at the power supply voltage lowering.

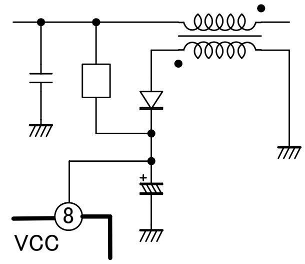


Fig.15 VCC pin circuit (1)

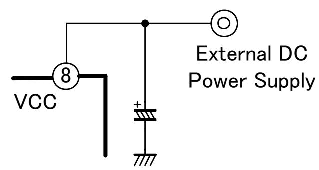


Fig.16 VCC pin circuit (2)

11. Directions for design

(1-1) Output voltage setting

In order to detect FB pin open, pull-up current (Ipullup) is fed through FB pin. This current flows into GND via R2. When setting output voltage (Vout), therefore, set resistors R1 and R2 in consideration of this current.

$$Vout = (VREF / R2 - Ipullup) \times R1 + VREF$$

VREF : Reference voltage = 2.5V (typ)
Ipullup : Pull-up current in FB pin = 5uA (typ)

(For reference)
The current IR2 flowing through R2 is given as:

$$IR2 = (Vout - VREF) / R1 + Ipullup$$

Voltage at the FB pin, VREF is given as:

$$VREF = R2 \times IR2$$
$$= R2 \times \{(Vout - VREF) / R1 + Ipullup\}$$

The integrated result of Vout is given by the above formula.

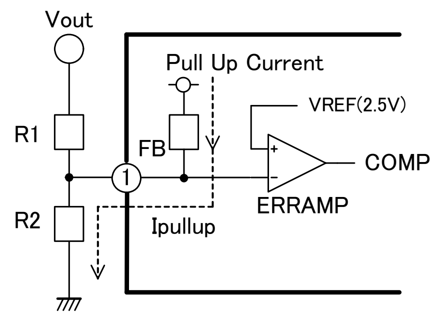


Fig.17 Output voltage setting circuit

(1-2) Slope compensation

Sub-harmonic oscillation may be generated in the current mode control in case of current continuous mode operation with the duty cycle of 50 percent or more. To avoid this phenomenon, FA5550/51 have slope compensation circuits built-in. In addition, it is possible to enhance the slope compensation by connecting a resistor (Rslope) between No.5 pin (SLOPE pin) and GND. The following formula shows the amount of slope compensation in case of connecting the resistor. See P.14 for regulation of the slope compensation.

$$SLOPE = 24.5 + (0.12 \times Rslope) \quad (mV / us)$$

Rslope : Resistance (kΩ) between SLOPE pin and GND
For direct connection of SLOPE pin to GND, the slope compensation value of 24.5mV/us is obtained.

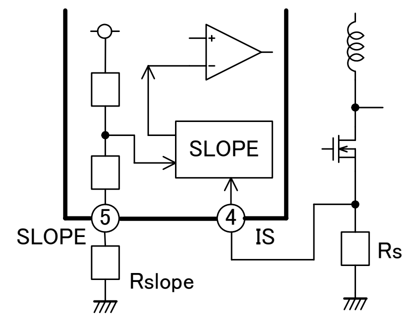


Fig.18 Slope compensation circuit

(1-3) Brownout protection

FA5550/51 detect the AC input voltage using MUL pin voltage. When the AC input voltage decreases, protection circuit is activated to stop the output of the IC. For resistors connected to MUL pin, 10kΩ and 790kΩ are recommendable for R_{MUL1} and R_{MUL2} respectively. In this case, the brownout protection operating voltages become 70Vac and 63Vac respectively.
With MUL pin, AC input voltage compensation is made on over-current detection level. Changing the resistance values of R_{MUL1} and R_{MUL2} connected to MUL pin may result in difference of the compensation values. Therefore, the above resistance values are recommendable.

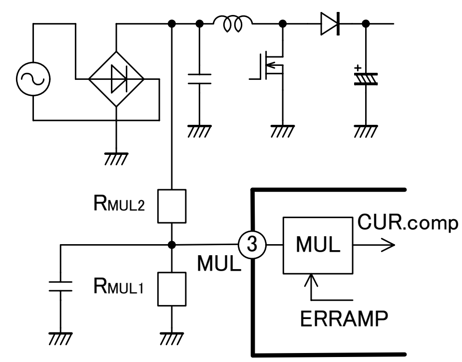


Fig.19 Brownout setting circuit

(For reference)

Sub-harmonic oscillation and slope compensation

In case of current mode in peak value control, there is a possibility to oscillate in a time cycle having integer multiple of the switching frequency, if the circuit is operated in inductor current continuous mode and in duty cycles of 50 percent or more. This is called as sub-harmonic oscillation.

An example of inductor current waveform is shown in Fig.20 when sub-harmonic oscillation is generated.

It is shown that ON-period and OFF-period are changing even though there are no variation in peak values of the inductor current, the switching time cycle and the current slope inclinations of ON- and OFF-periods.
This sub-harmonic oscillation may cause increases of ripple voltages contained in output voltages and abnormal noises.

In response, through addition of a certain amount of slope inclination to threshold value shown in Fig.21, the circuit can be prevented from the sub-harmonic oscillation. This is called as slope compensation.

In general, amount of the slope compensation value required to avoid the sub-harmonic oscillation is shown as following relational expression:

$$Kc > \frac{Ld - Lu}{2}$$

Where;
Lu: Slope inclination of inductor current during ON-period
Ld: Slope inclination of inductor current during OFF- period
Kc: Inclination of slope compensation

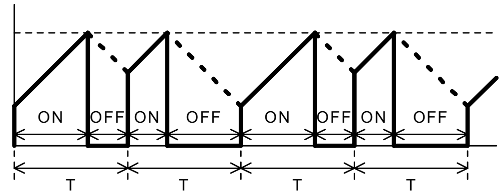


Fig.20 A case without slope compensation

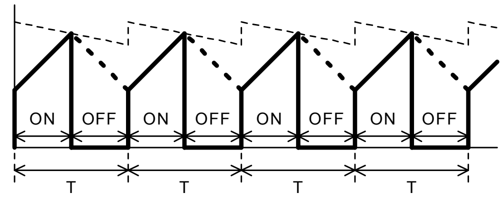


Fig.21 A case with slope compensation

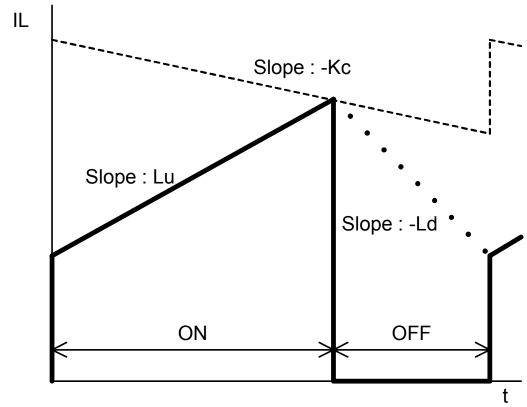


Fig.22 Slope compensation

12. Application circuit example