Fuji Switching Power Supply Control IC

FA5540/5541/5542

Application Note

July 2007
Fuji Electric Device Technology Co., Ltd.

Caution

1. The contents of this note (Product Specification, Characteristics, Data, Materials, and Structure etc.) were prepared in July 2007.
   The contents will subject to change without notice due to product specification change or some other reasons. In case of using the products stated in this document, the latest product specification shall be provided and the data shall be checked.

2. The application examples in this note show the typical examples of using Fuji products and this note shall neither assure to enforce the industrial property including some other rights nor grant the license.

3. Fuji Electric Device Technology Co.,Ltd. is always enhancing the product quality and reliability. However, semiconductor products may get out of order in a certain probability.
   Measures for ensuring safety, such as redundant design, spreading fire protection design, malfunction protection design shall be taken, so that Fuji Electric semiconductor product may not cause physical injury, property damage by fire and social damage as a result.

4. Products described in this note are manufactured and intended to be used in the following electronic devices and electric devices in which ordinary reliability is required:
   - Computer - OA equipment - Communication equipment (Terminal) - Measuring equipment
   - Machine tool - Audio Visual equipment - Home appliance - Personal equipment
   - Industrial robot etc.

5. Customers who are going to use our products in the following high reliable equipments shall contact us surely and obtain our consent in advance. In case when our products are used in the following equipment, suitable measures for keeping safety such as a back-up-system for malfunction of the equipment shall be taken even if Fuji Electric semiconductor products break down:
   - Transportation equipment (in-vehicle, in-ship etc.) - Communication equipment for trunk line
   - Traffic signal equipment - Gas leak detector and gas shutoff equipment
   - Disaster prevention/Security equipment - Various equipment for the safety.

6. Products described in this note shall not be used in the following equipments that require extremely high reliability:
   - Space equipment - Aircraft equipment - Atomic energy control equipment
   - Undersea communication equipment - Medical equipment.

7. When reprinting or copying all or a part of this note, our company's acceptance in writing shall be obtained.

8. If obscure parts are found in the contents of this note, contact Fuji Electric Device Technology Co.,Ltd. or a sales agent before using our products. Fuji Electric Device Technology Co.,Ltd. and its sales agents shall not be liable for any damage that is caused by a customer who does not follow the instructions in this cautionary statement.

Contents

Caution)

・The contents of this note will subject to change without notice due to improvement.

・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. Description

FA5540/41/42 is a quasi-resonant type switching power supply control IC possible to drive a power MOSFET directly. Low power consumption is achieved by using high-voltage CMOS process. Though it is a small package with 8 pins, it has a lot of functions and enables to decrease external parts. Therefore it is possible to realize a small space and high cost-performance power supply.

2. Features

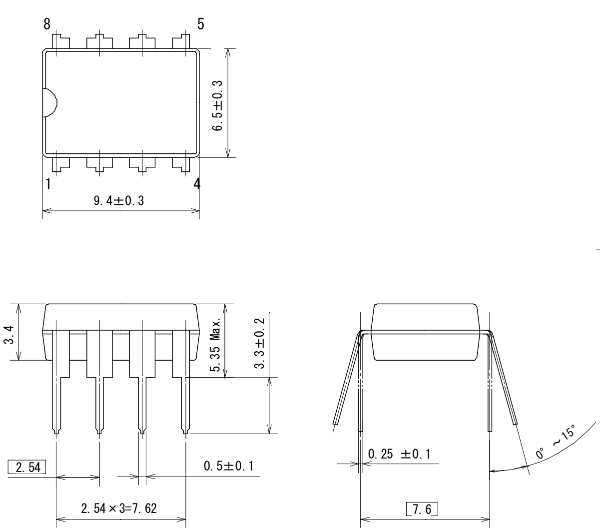
- Low power consumption by using high-voltage CMOS process.
- Low power consumption with built-in startup circuit.
- Low current consumption, in operation : 1mA(FA5540), 1.2mA(FA5541/42)
- Maximum frequency limitation function : 60kHz(FA5540), 120kHz(FA5541/42)
- Burst function at light load.
- Drive circuit possible to connect to a power MOSFET directly.
  Output current: 0.5A (sink) 0.25A (source)
- Over load protection function (FA5540/41 : auto restart , FA5542 : timer latch)
- Over voltage shutdown circuit in latch mode.
- Under voltage lockout circuit
- Package : DIP-8/SOP-8

Function list for each type

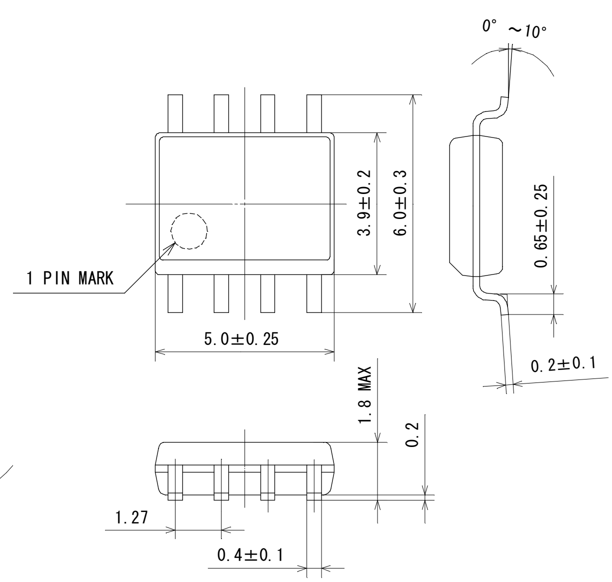
Type	Maximum frequency	Over load protection	Recommended operating voltage	Over voltage protection（VCC）
FA5540	60kHz(typ)	Auto restart	12 to 14.5V	16V(typ)
FA5541	120kHz(typ)	Auto restart	12 to 26V	28V(typ)
FA5542	120kHz(typ)	Timer latch	12 to 26V	28V(typ)

3. Outline

DIP-8

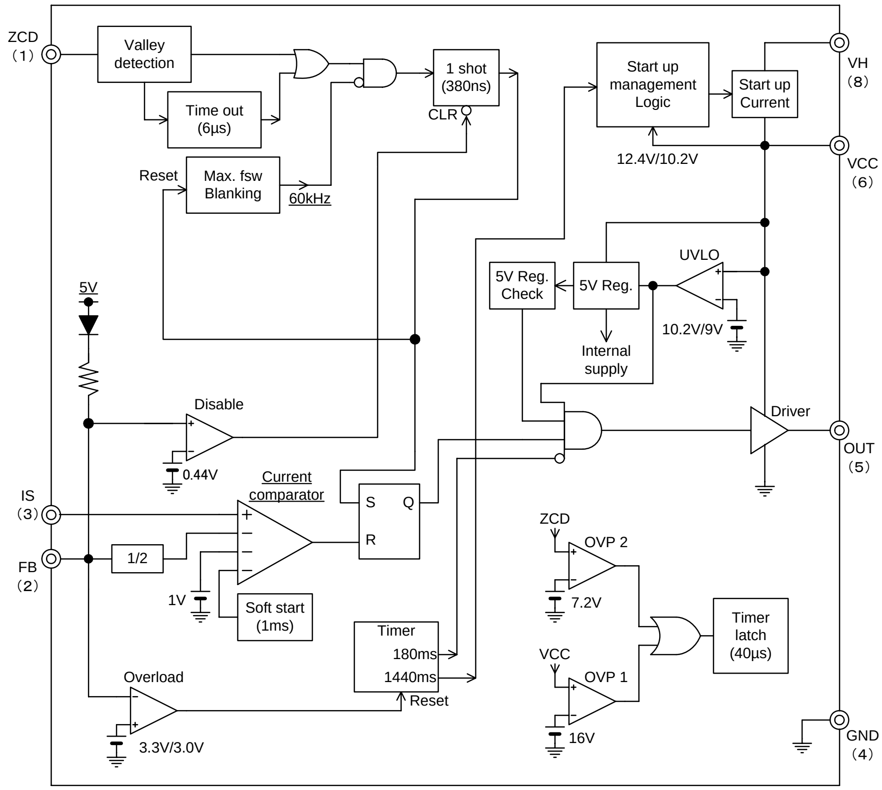


SOP-8

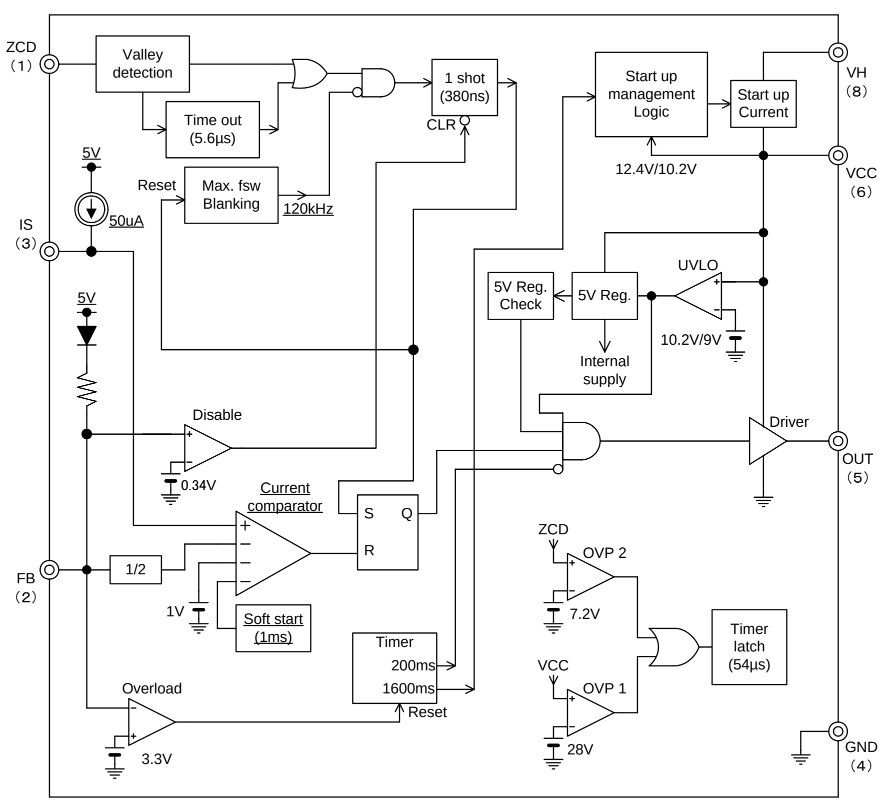


4. Block diagram

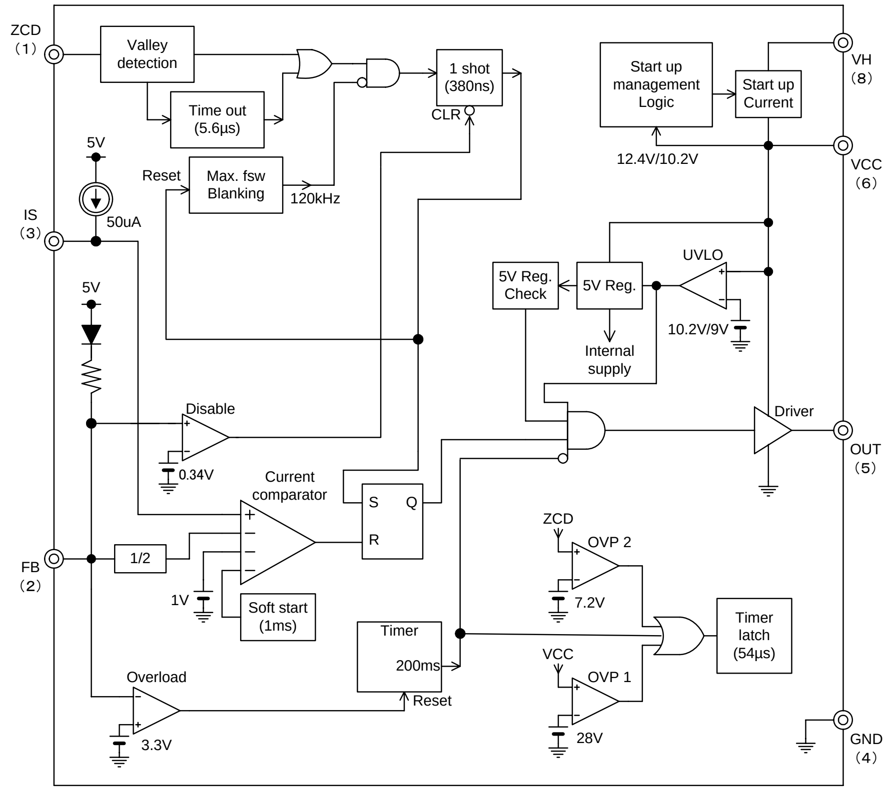
FA5540



FA5541



FA5542



5. Pin assignment

Pin number	Pin name	Function of pin
1	ZCD	Zero current detection input
2	FB	Feed-back input
3	IS	Current sense input
4	GND	Ground
5	OUT	Output
6	VCC	Power supply
7	NC	
8	VH	High voltage input

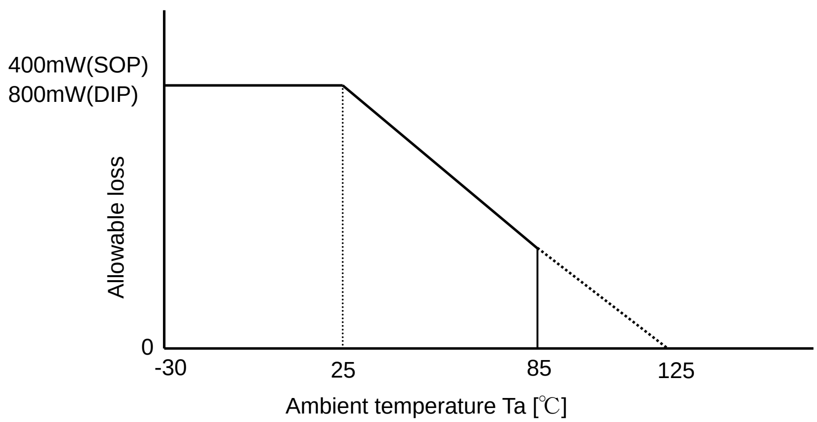
6. Rating and characteristics

* "+" shows sink and "–" shows source in current prescription.

(1) Absolute maximum rating

Item	Symbol	Rating	Unit
Power supply voltage	V_{CC}	30	V
OUT pin output peak current	I_{OH}	-0.25	A
	I_{OL}	+0.5	A
OUT pin voltage	V_{OUT}	-0.3 to VCC+0.3	V
FB, IS pin input voltage	V_{LT}	-0.3 to 5.0	V
ZCD pin current	I_{SOZCD}	-2.0	mA
	I_{SIZCD}	+3.0	
VH pin input voltage	VVH	-0.3 to 500	V
Total loss (Ta<25℃)	Pd	800 (DIP-8) 400 (SOP-8)	mW
Maximum junction temperature	Tj	125	℃
Storage temperature	Tstg	- 40 to +150	℃

* Allowable loss reducing characteristics



(2) Recommended operating conditions

Item		Symbol	MIN	TYP	MAX	Unit
Power supply voltage	FA5540	Vcc	12		14.5	V
	FA5541/42		12	15	26	
VH pin input voltage		V_{VH}	80		450	V
VCC pin capacity		C_{VCC}	10	33		µF
Operating ambient temperature		Ta	-30		85	℃

(3) Electrical characteristics (in case nothing specified: Vcc=13V(FA5540) / 15V(FA5541/42), Tj=25℃)

Current sensing part (IS pin)

Item	Symbol	Condition		MIN	TYP	MAX	Unit
Input bias current	I_{IS}	V_{IS}=0V	FA5540	-2.0	-0.2	2.0	μA
			FA5541/42	-60	-50	-40	
Maximum input threshold voltage	V_{thIS1}	V_{FB}=2.5V		0.9	1.0	1.1	V
Voltage gain	AV_{IS}	$\Delta V_{FB}/\Delta V_{IS}$			2.0		V/V
Minimum ON width	Tonmin	FB=3V, IS=1V			380		ns
Blanking time	T_{BLANK}				205		ns
Output delay time	T_{pdIS}				175		ns

Feedback part (FB pin)

Item	Symbol	Condition		MIN	TYP	MAX	Unit
Pulse shutdown FB pin voltage	V_{THFB0}	Duty cycle=0%	FA5540	340	440	540	mV
			FA5541/42	240	340	440	
FB pin input resistance	R_{FB}	V_{FB}=1V to 2V		12.8	16.0	19.2	kΩ
FB pin current	I_{FB1}	V_{FB}=1V			-190		μA

Zero current detection part (ZCD pin)

Item	Symbol	Condition		MIN	TYP	MAX	Unit
Input threshold voltage	V_{THZCD1}	V_{ZCD} decreasing		45	62	100	mV
	V_{THZCD2}	V_{ZCD} increasing		95	152	240	mV
Hysteresis width	V_{HYZCD}				90		mV
Input clamp voltage	V_{IH}	I_{ZCD}=+3mA (High state)			9.2		V
	V_{IL}	I_{ZCD}=-2mA			-0.83		V
ZCD delay time	T_{ZCD}				155		ns
Maximum blanking frequency	F_{max}	V_{FB}=2.5V	FA5540	48	60	72	kHz
			FA5541/42	96	120	144	
Timeout duration from the latest ZCD trigger	T_{OUT}		FA5540		6.0		μs
			FA5541/42		5.6		
ZCD pin internal resistance	Rzcd				30		kΩ

Over voltage protection part (VCC pin, ZCD pin)

Item	Symbol	Condition		MIN	TYP	MAX	Unit
VCC pin over voltage Threshold level	V_{OVP1}		FA5540	14.5	16.0	17.5	V
			FA5541/42	26	28	30	
ZCD pin over voltage Threshold level	V_{OVP2}			6.4	7.2	8.0	V
Timer latch delay time	T_{LAT}		FA5540		40		μs
			FA5541/42		54		

Over load protection part (FB pin)

Item	Symbol	Condition		MIN	TYP	MAX	Unit
FB pin over load detection Threshold level	V_{OLP}			3.0	3.3	3.6	V
OLP delay time	T_{OLP}	FA5540: Switching duration after detecting over load.			180		ms
		FA5541: Switching duration after detecting over load. FA5542: Timer latch delay time after detecting over load.			200		
OLP output shutdown time	T_{OFF}	Switching shutdown time after T_{OLP} period	FA5540		1260		ms
			FA5541		1400		

Soft start part

Item	Symbol	Condition	MIN	TYP	MAX	Unit
Soft start time	T_{SFT}			1.0		ms

Output part (OUT pin)

Item	Symbol	Condition		MIN	TYP	MAX	Unit
L output voltage	V_{OL}	I_{OL}=100mA			1.0	2.0	V
H output voltage	V_{OH}	I_{OH}=-100mA V_{CC}=15V	FA5540	10.4	11.4		V
		I_{OH}=-100mA V_{CC}=15V	FA5541/42	12.5	13.5		
Start up time	tr	CL=1nF, Tj=25°C			50		ns
Fall down time	tf	CL=1nF, Tj=25°C			40		ns

High voltage input part (VH pin)

Item	Symbol	Condition	MIN	TYP	MAX	Unit
VH pin input current	I_{Hrun}	V_{VH}=400V, V_{CC}>V_{STOFF}	10	20	30	µA
	I_{VHO}	V_{CC}=0V, V_{VH}=100V Tj=25°C		7.6		mA
VCC pin charging current	I_{pre0}	V_{CC}=0V, V_{VH}=100V Tj=25°C		-7.5		mA
	I_{pre1}	V_{CC}=VCCOFF, V_{VH}=100V Tj=25°C		-6.3		mA

Low voltage malfunction protection circuit (UVLO) part (VCC pin)

Item	Symbol	Condition	MIN	TYP	MAX	Unit
ON threshold voltage	V_{CCON}		8.7	10.2	11.7	V
OFF threshold voltage	V_{CCOFF}		7.5	9.0	10.5	V
Hysteresis width	V_{HYS1}		0.7	1.2	1.7	V
Startup circuit shutdown voltage	V_{STOFF}	Vcc increasing	10.9	12.4	13.9	V
Startup circuit reset voltage	V_{STRST1}	Vcc decreasing	8.7	10.2	11.7	V

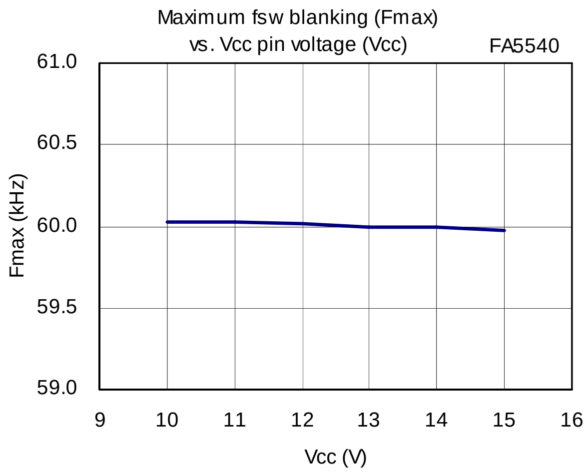
Current consumption (VCC pin)

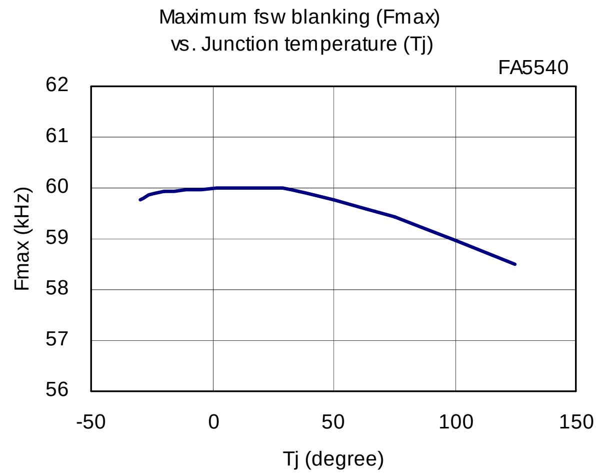
Item	Symbol	Condition		MIN	TYP	MAX	Unit
Power supply current in operation	I_{CCOP1}	fsw=60kHVFB=2.5V, no load	FA5540		1.1		mA
		fsw=120kHVFB=2.5V, no load	FA5541/42		1.2		mA
Power supply current at latch	I_{CCL}				200	400	µA
Power supply zener voltage	V_Z				30		V

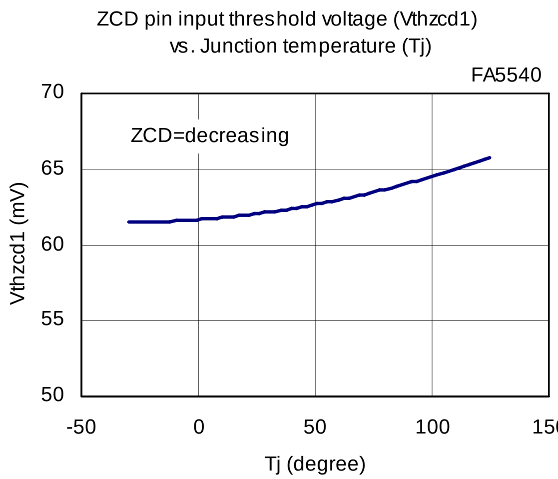
7. Characteristic curve

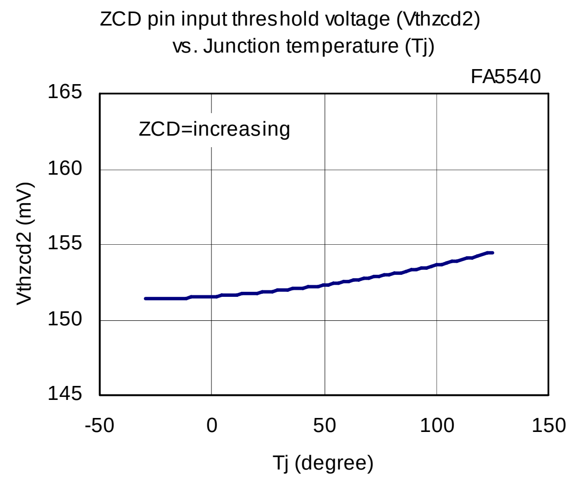
- In case nothing is specified : Ta=25℃, VCC＝13V(FA5540) / VCC=15V(FA5541/42)
- "+" shows sink and "–" shows source in current prescription.
- Data written here shows the typical characteristics of the IC and does not guarantee the characteristics.

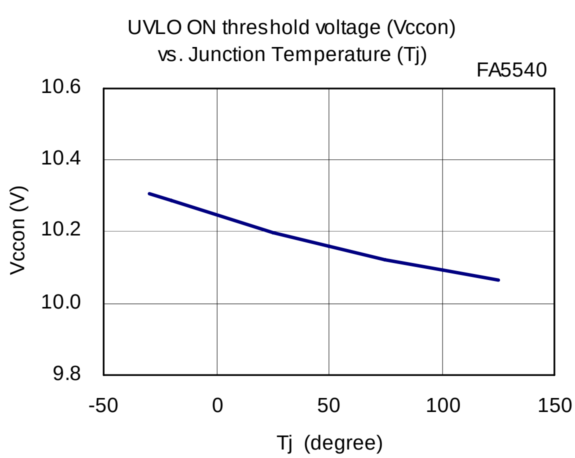
(FA5540)

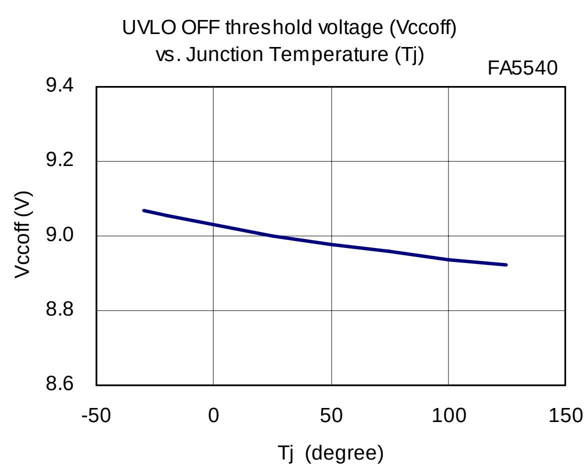


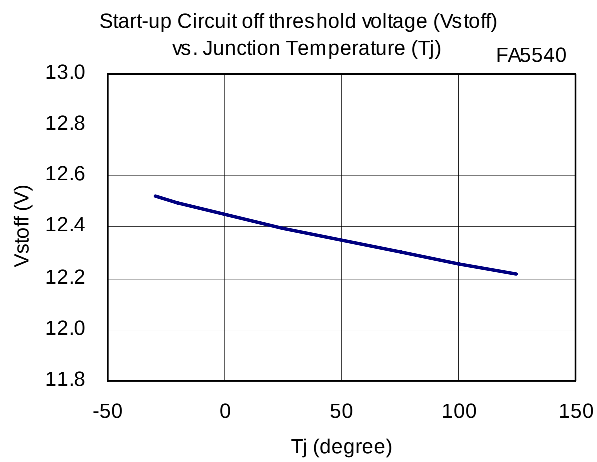


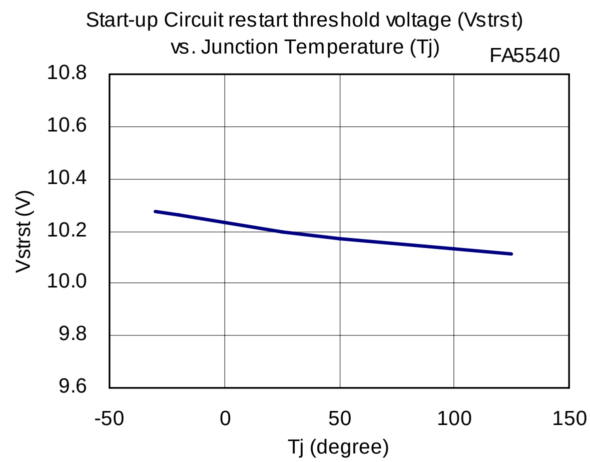


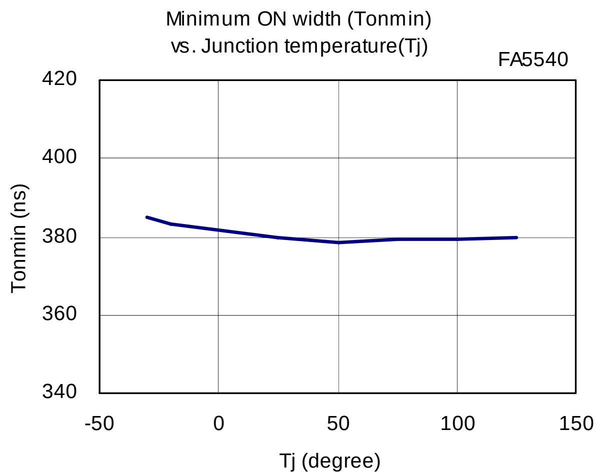


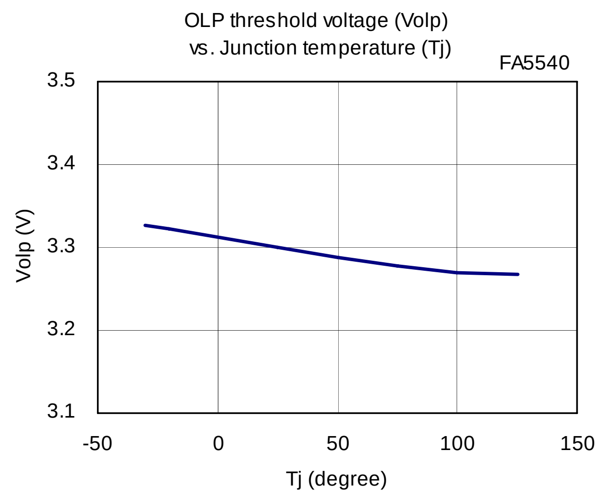


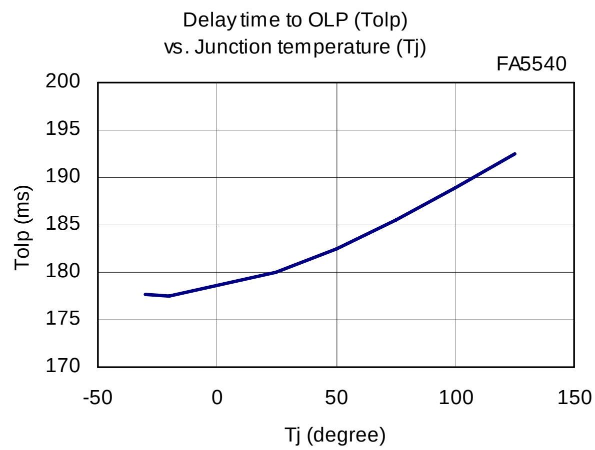


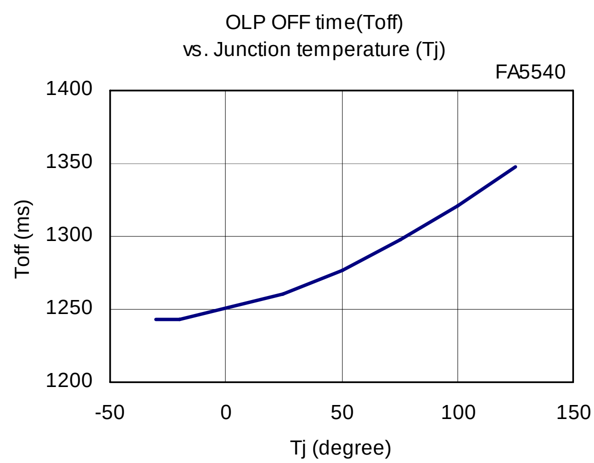

Start-up Circuit off threshold voltage (Vstoff)
vs. Junction Temperature (Tj)
FA5540
Vstoff (V)
13.0
12.8
12.6
12.4
12.2
12.0
11.8
-50
0
50
100
150
Tj (degree)

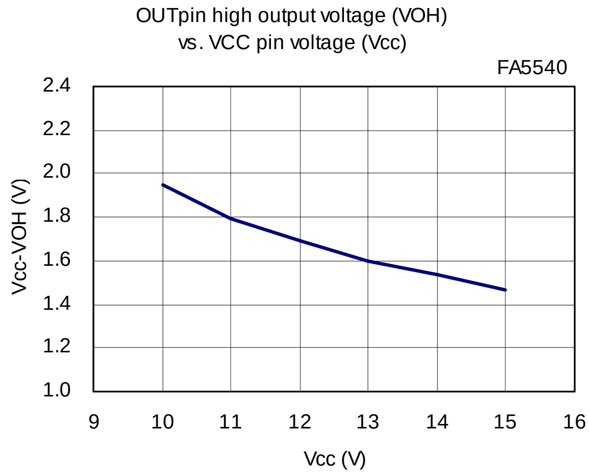

Start-up Circuit restart threshold voltage (Vstrst)
vs. Junction Temperature (Tj)
FA5540
Vstrst (V)
10.8
10.6
10.4
10.2
10.0
9.8
9.6
-50
0
50
100
150
Tj (degree)

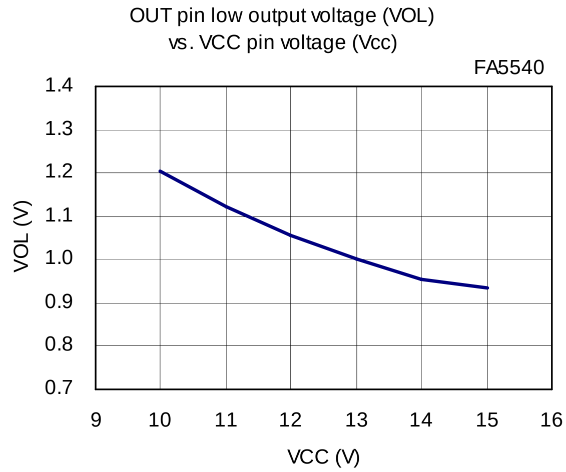

Minimum ON width (Tonmin)
vs. Junction temperature(Tj)
FA5540
Tonmin (ns)
420
400
380
360
340
-50
0
50
100
150
Tj (degree)

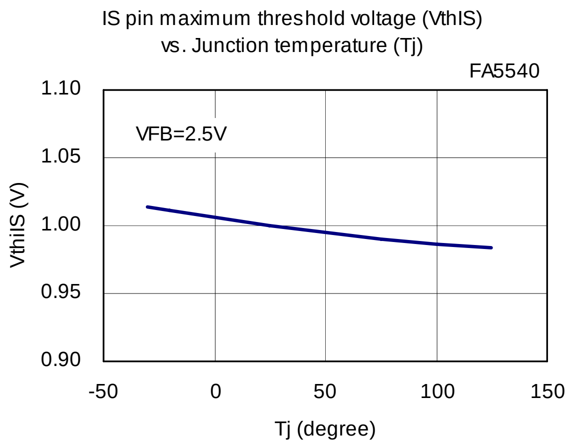

OLP threshold voltage (Volp)
vs. Junction temperature (Tj)
FA5540
Volp (V)
3.5
3.4
3.3
3.2
3.1
-50
0
50
100
150
Tj (degree)

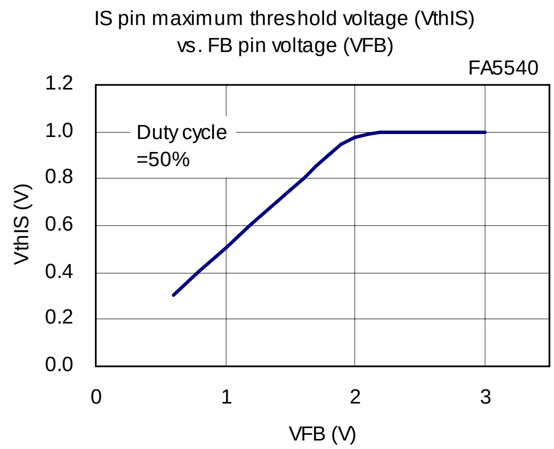

Delay time to OLP (Tolp)
vs. Junction temperature (Tj)
FA5540
Tolp (ms)
200
195
190
185
180
175
170
-50
0
50
100
150
Tj (degree)

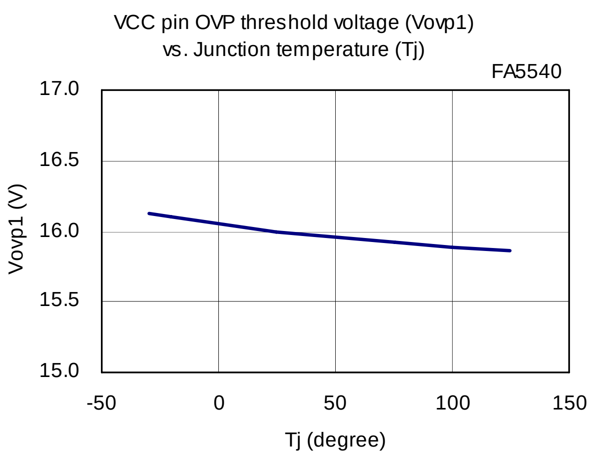

OLP OFF time(Toff)
vs. Junction temperature (Tj)
FA5540
Toff (ms)
1400
1350
1300
1250
1200
-50
0
50
100
150
Tj (degree)

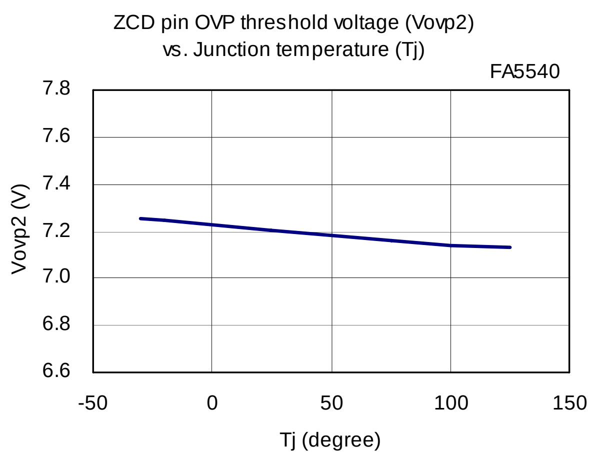

OUTpin high output voltage (VOH)
vs. VCC pin voltage (Vcc)
FA5540
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
Vcc-VOH (V)
9
10
11
12
13
14
15
16
Vcc (V)

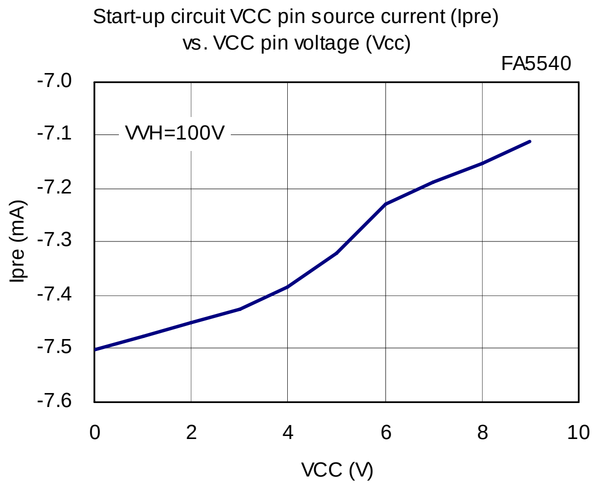

OUT pin low output voltage (VOL)
vs. VCC pin voltage (Vcc)
FA5540
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
VOL (V)
9
10
11
12
13
14
15
16
VCC (V)

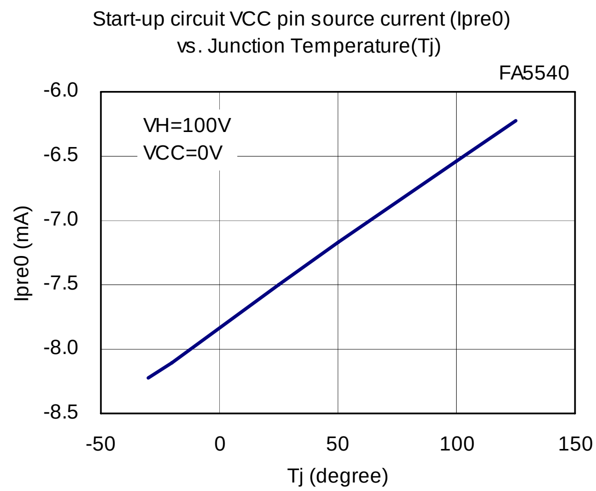

IS pin maximum threshold voltage (VthIS)
vs. Junction temperature (Tj)
FA5540
VFB=2.5V
1.10
1.05
1.00
0.95
0.90
VthIS (V)
-50
0
50
100
150
Tj (degree)

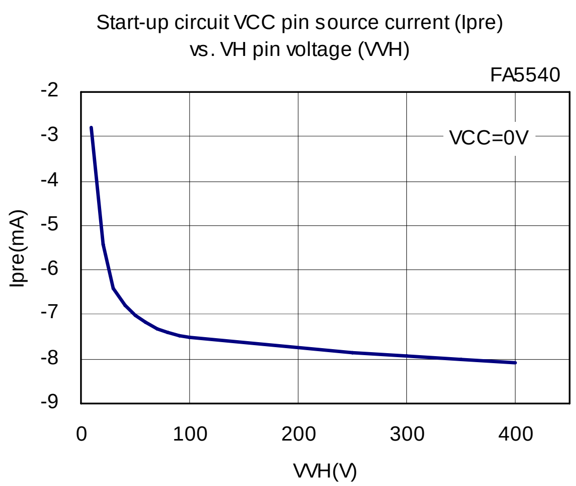

IS pin maximum threshold voltage (VthIS)
vs. FB pin voltage (VFB)
FA5540
Duty cycle
=50%
1.2
1.0
0.8
0.6
0.4
0.2
0.0
VthIS (V)
0
1
2
3
VFB (V)

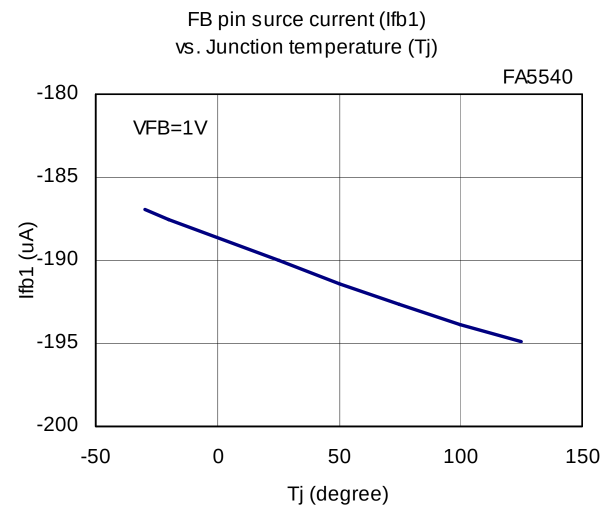

VCC pin OVP threshold voltage (Vovp1)
vs. Junction temperature (Tj)
FA5540
17.0
16.5
16.0
15.5
15.0
Vovp1 (V)
-50
0
50
100
150
Tj (degree)

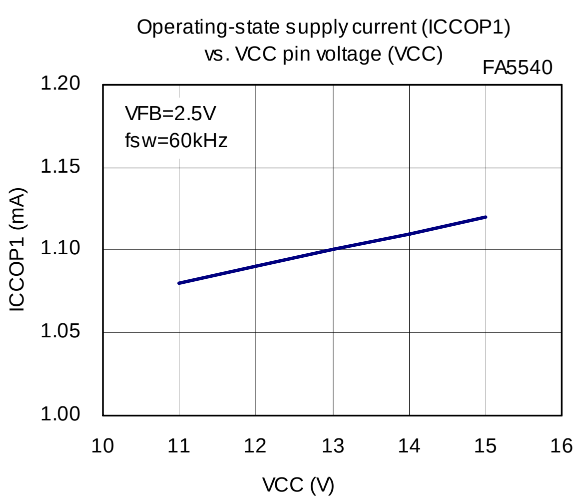

ZCD pin OVP threshold voltage (Vovp2)
vs. Junction temperature (Tj)
FA5540
7.8
7.6
7.4
7.2
7.0
6.8
6.6
Vovp2 (V)
-50
0
50
100
150
Tj (degree)

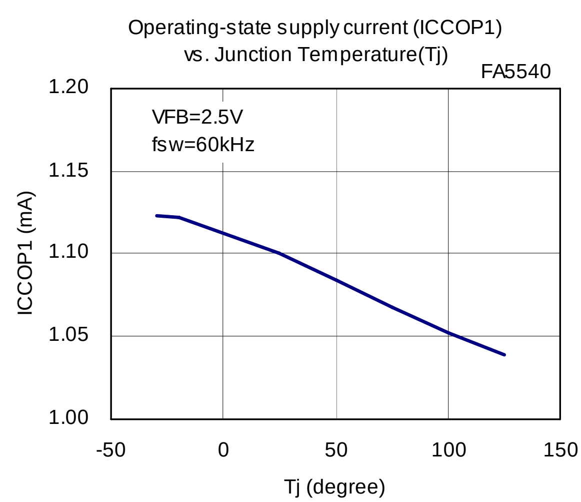

Start-up circuit VCC pin source current (Ipre)
vs. VCC pin voltage (Vcc)
FA5540
VVH=100V
Ipre (mA)
-7.0
-7.1
-7.2
-7.3
-7.4
-7.5
-7.6
0
2
4
6
8
10
VCC (V)


Start-up circuit VCC pin source current (Ipre0)
vs. Junction Temperature(Tj)
FA5540
VH=100V
VCC=0V
Ipre0 (mA)
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
-50
0
50
100
150
Tj (degree)

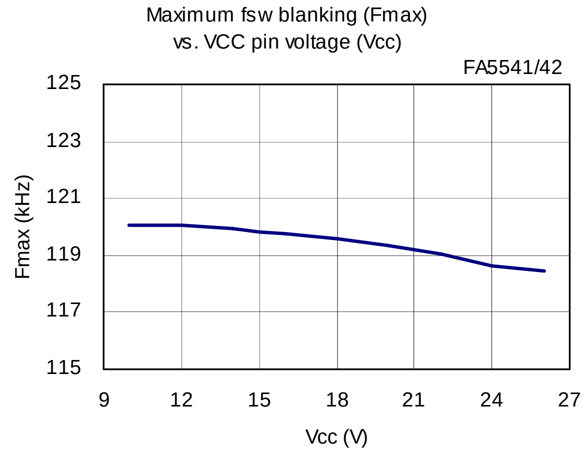

Start-up circuit VCC pin source current (Ipre)
vs. VH pin voltage (VVH)
FA5540
VCC=0V
Ipre(mA)
-2
-3
-4
-5
-6
-7
-8
-9
0
100
200
300
400
VVH(V)

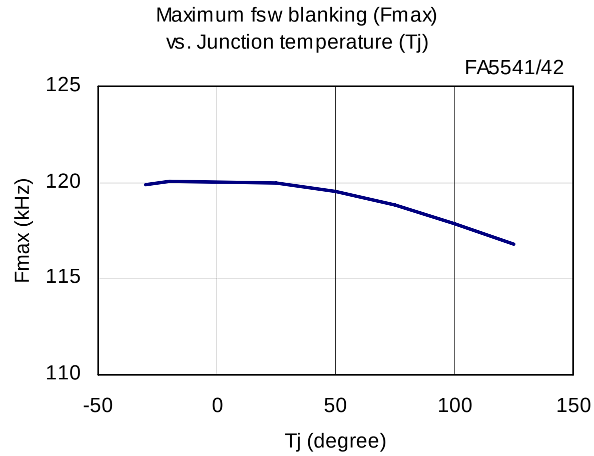

FB pin surce current (Ifb1)
vs. Junction temperature (Tj)
FA5540
VFB=1V
Ifb1 (uA)
-180
-185
-190
-195
-200
-50
0
50
100
150
Tj (degree)

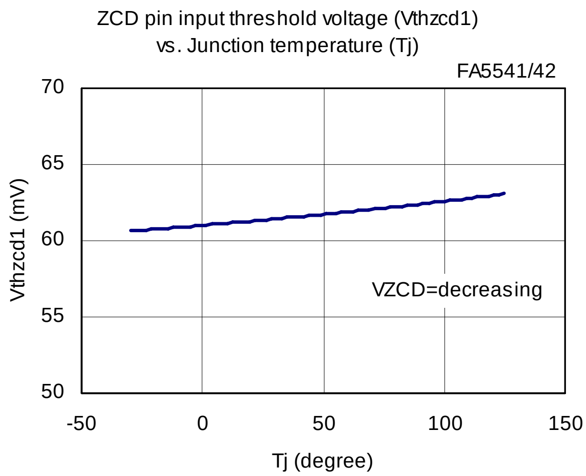

Operating-state supply current (ICCOP1)
vs. VCC pin voltage (VCC)
FA5540
VFB=2.5V
fsw=60kHz
ICCOP1 (mA)
1.20
1.15
1.10
1.05
1.00
10
11
12
13
14
15
16
VCC (V)

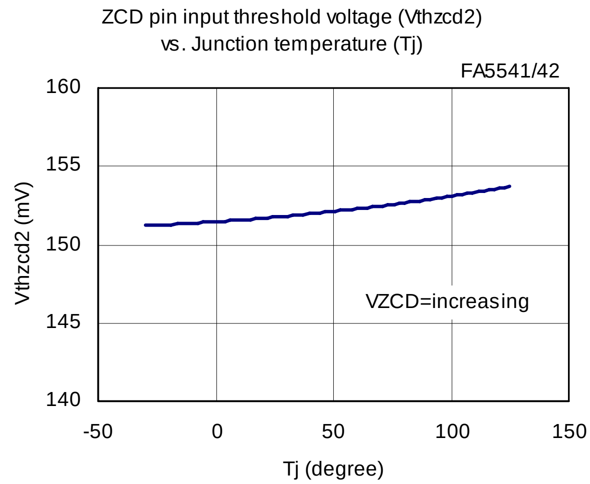

Operating-state supply current (ICCOP1)
vs. Junction Temperature(Tj)
FA5540
VFB=2.5V
fsw=60kHz
ICCOP1 (mA)
1.20
1.15
1.10
1.05
1.00
-50
0
50
100
150
Tj (degree)

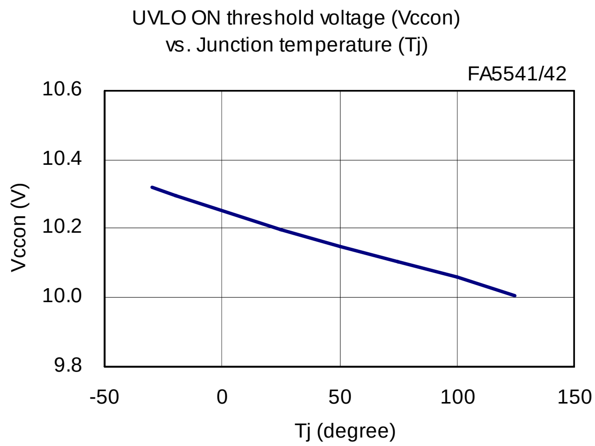
(FA5541/42)

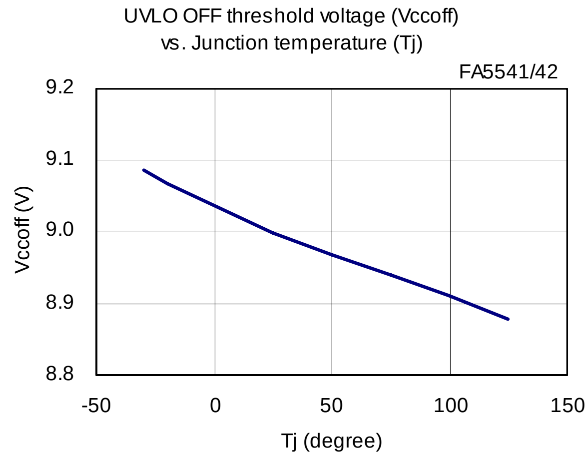

Maximum fsw blanking (Fmax)
vs. VCC pin voltage (Vcc)
FA5541/42
Fmax (kHz)
125
123
121
119
117
115
9
12
15
18
21
24
27
Vcc (V)


Maximum fsw blanking (Fmax)
vs. Junction temperature (Tj)
FA5541/42
Fmax (kHz)
125
120
115
110
-50
0
50
100
150
Tj (degree)

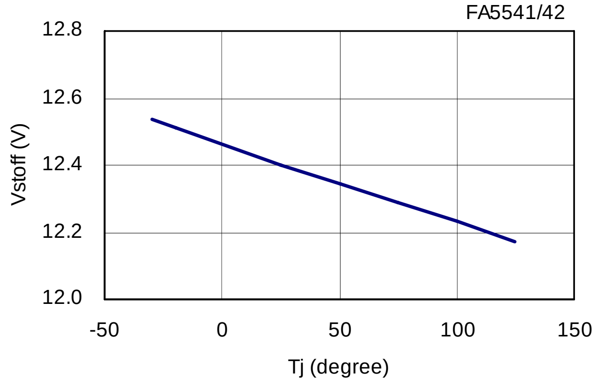

ZCD pin input threshold voltage (Vthzcd1)
vs. Junction temperature (Tj)
FA5541/42
Vthzcd1 (mV)
70
65
60
55
50
VZCD=decreasing
-50
0
50
100
150
Tj (degree)


ZCD pin input threshold voltage (Vthzcd2)
vs. Junction temperature (Tj)
FA5541/42
Vthzcd2 (mV)
160
155
150
145
140
VZCD=increasing
-50
0
50
100
150
Tj (degree)

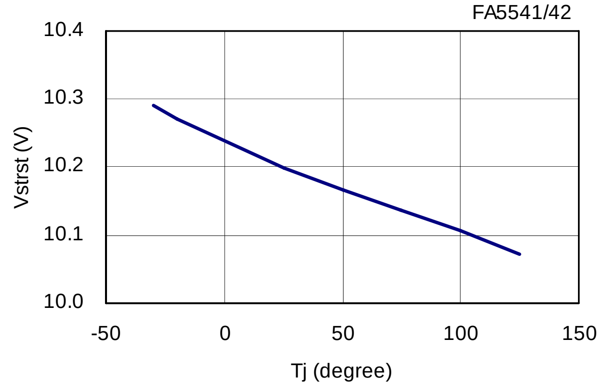

UVLO ON threshold voltage (Vccon)
vs. Junction temperature (Tj)
FA5541/42
Vccon (V)
10.6
10.4
10.2
10.0
9.8
-50
0
50
100
150
Tj (degree)


UVLO OFF threshold voltage (Vccoff)
vs. Junction temperature (Tj)
FA5541/42
Vccoff (V)
9.2
9.1
9.0
8.9
8.8
-50
0
50
100
150
Tj (degree)

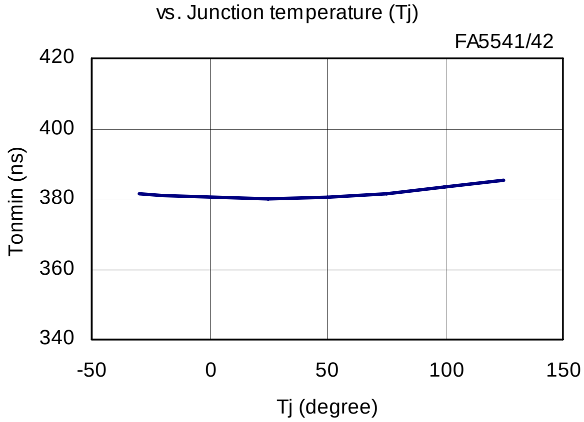
Start-up circuit off threshold voltage (Vstoff)
vs. Junction temperature (Tj)



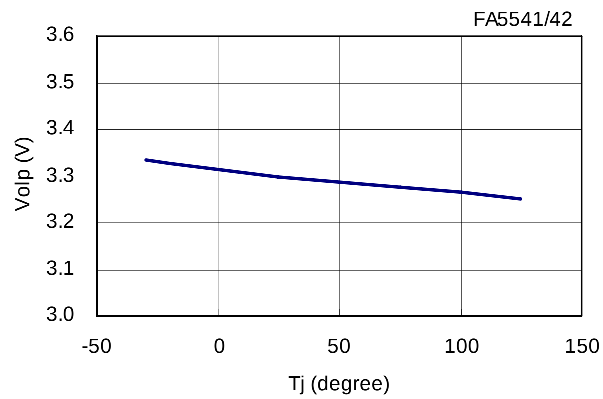
Start-up circuit restart threshold voltage (Vstrst)
vs. Junction temperature (Tj)



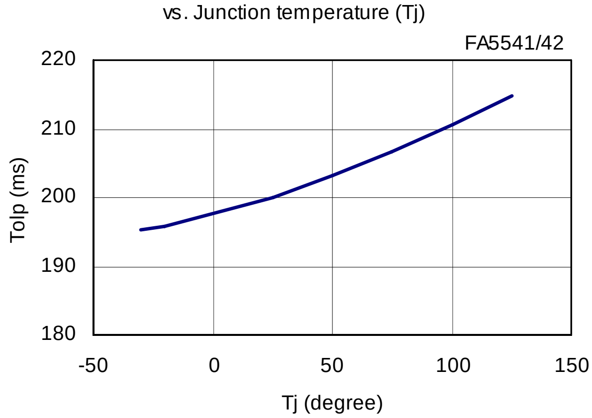
Minimum ON width (Tonmin)
vs. Junction temperature (Tj)



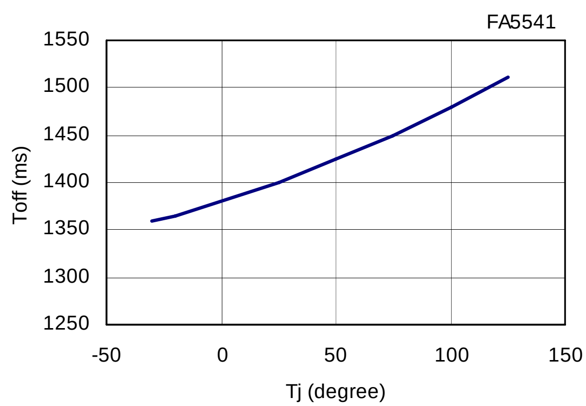
OLP threshold voltage (Volp)
vs. Junction temperature (Tj)

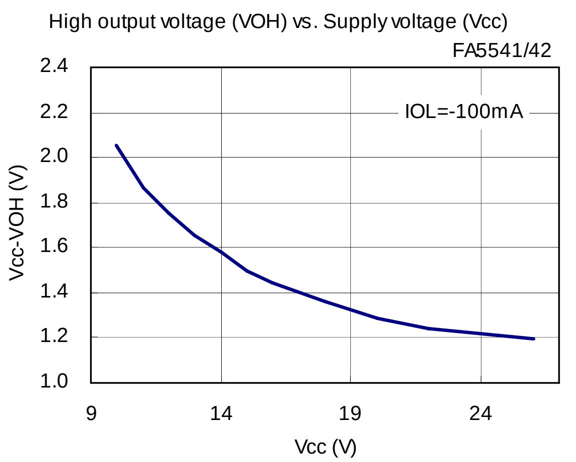


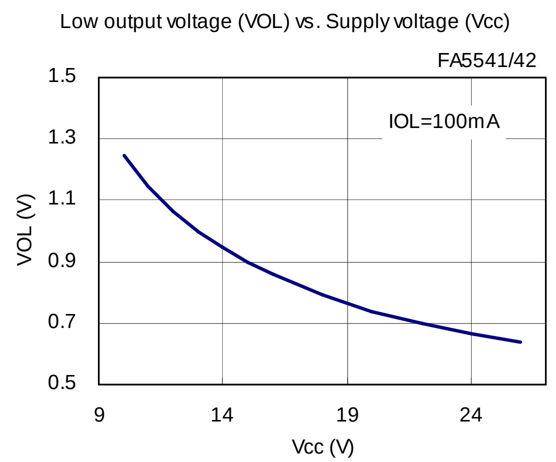
Delay time to OLP (Tolp)
vs. Junction temperature (Tj)

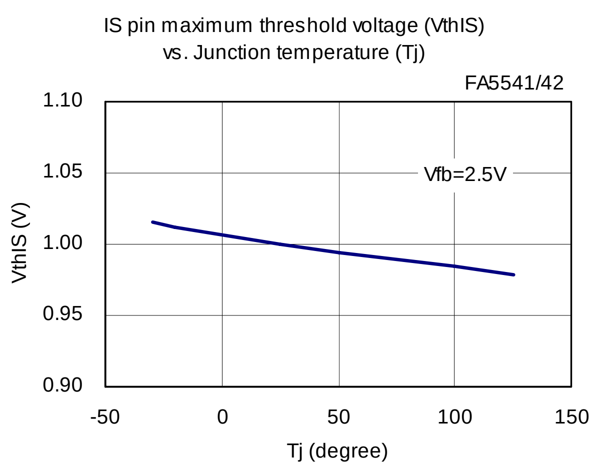


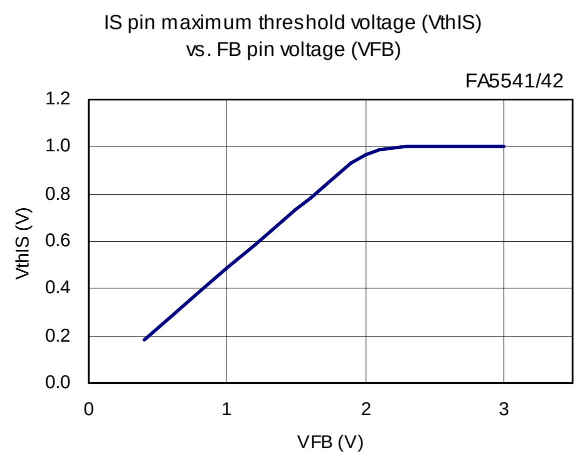
OLP off time (Toff) vs. Junction temperature (Tj)

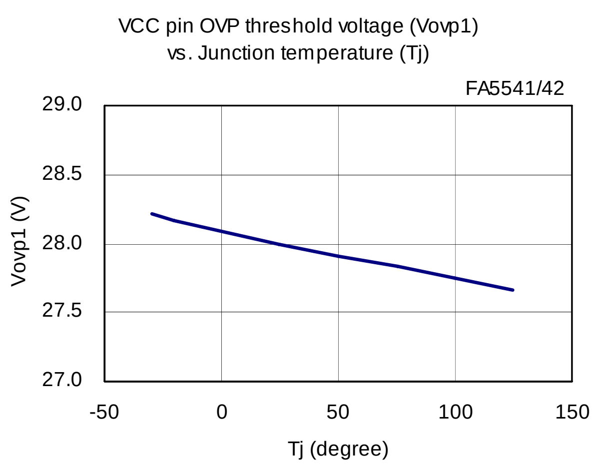


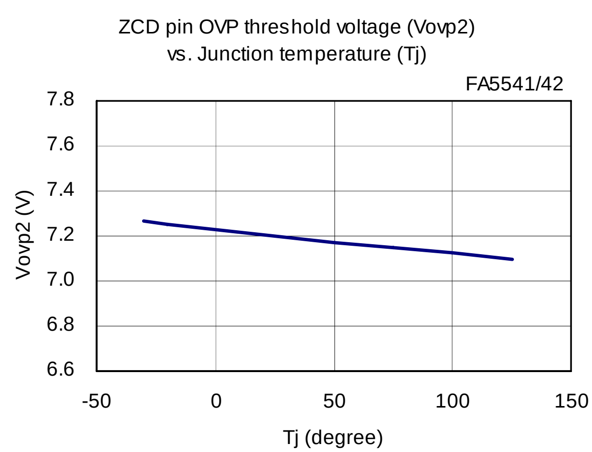

High output voltage (VOH) vs. Supply voltage (Vcc)
FA5541/42
IOL=-100mA
Vcc-VOH (V)
Vcc (V)

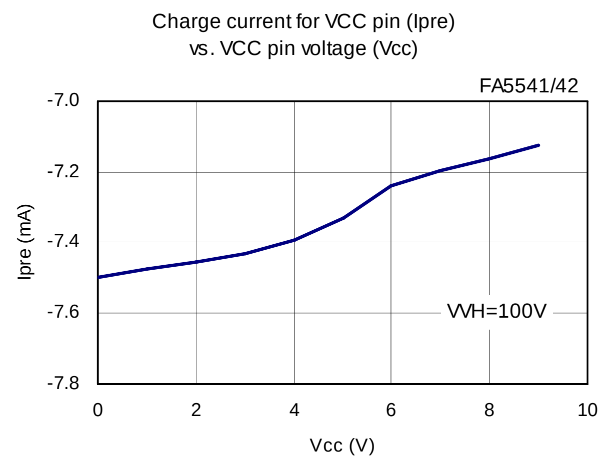

Low output voltage (VOL) vs. Supply voltage (Vcc)
FA5541/42
IOL=100mA
VOL (V)
Vcc (V)

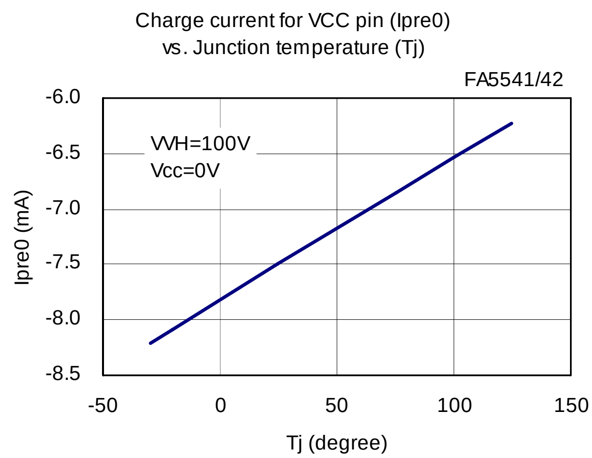

IS pin maximum threshold voltage (VthIS)
vs. Junction temperature (Tj)
FA5541/42
Vfb=2.5V
VthIS (V)
Tj (degree)

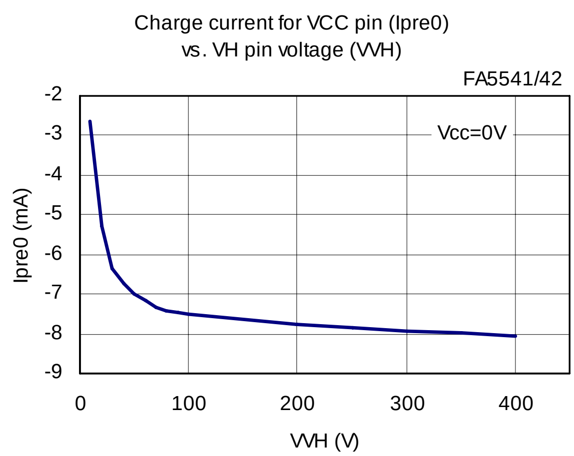

IS pin maximum threshold voltage (VthIS)
vs. FB pin voltage (VFB)
FA5541/42
VthIS (V)
VFB (V)

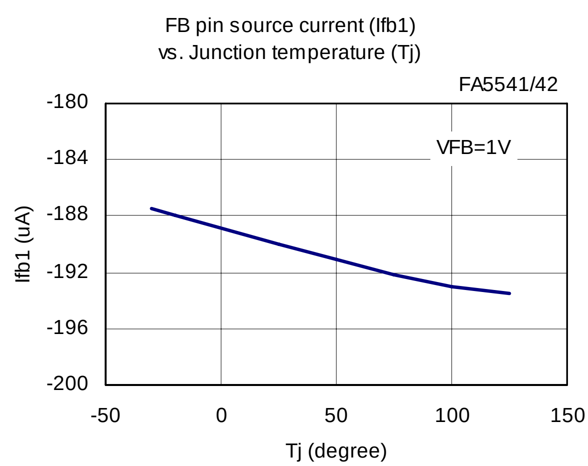

VCC pin OVP threshold voltage (Vovp1)
vs. Junction temperature (Tj)
FA5541/42
Vovp1 (V)
Tj (degree)

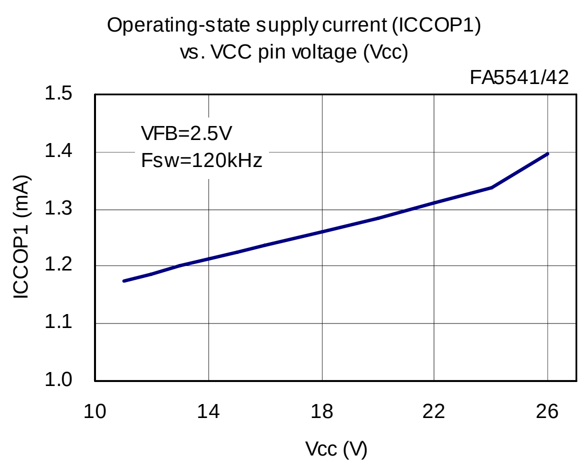

ZCD pin OVP threshold voltage (Vovp2)
vs. Junction temperature (Tj)
FA5541/42
Vovp2 (V)
Tj (degree)

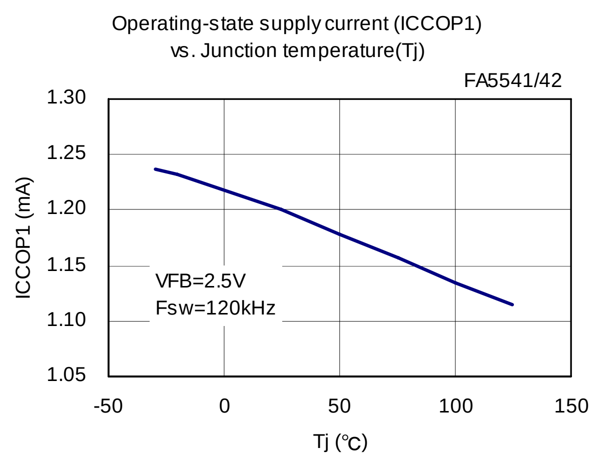

Charge current for VCC pin (Ipre)
vs. VCC pin voltage (Vcc)
FA5541/42
Ipre (mA)
Vcc (V)
VVH=100V


Charge current for VCC pin (Ipre0)
vs. Junction temperature (Tj)
FA5541/42
Ipre0 (mA)
Tj (degree)
VVH=100V
Vcc=0V


Charge current for VCC pin (Ipre0)
vs. VH pin voltage (VVH)
FA5541/42
Ipre0 (mA)
VVH (V)
Vcc=0V


FB pin source current (Ifb1)
vs. Junction temperature (Tj)
FA5541/42
Ifb1 (uA)
Tj (degree)
VFB=1V


Operating-state supply current (ICCOP1)
vs. VCC pin voltage (Vcc)
FA5541/42
ICCOP1 (mA)
Vcc (V)
VFB=2.5V
Fsw=120kHz


Operating-state supply current (ICCOP1)
vs. Junction temperature(Tj)
FA5541/42
ICCOP1 (mA)
Tj (℃)
VFB=2.5V
Fsw=120kHz

8. Basic operation

The basic operation of the power supply using this IC is not switching operation using fixed frequency with an oscillator but switching using self-excited oscillation. This is shown in Fig.1 Basic circuit diagram and Fig.2 Waveform in operation.

t1 to t2

Q1 turns ON, and Q1 drain current Id (primary current of T1) begins to rise from zero. Q1 current is converted into voltage at Rs and input into IS pin.

t2

When the current of Q1 gets up to the reference voltage of the current comparator that is fixed by the voltage of FB pin, a reset signal is input into RS flip-flop and Q1 turns OFF.

t2 to t3

When Q1 turns OFF, and the winding voltage of the transformer turns over and current IF is provided from the transformer into secondary side through D1.

t3 to t4

When the current from the transformer into secondary side goes out and the current at D1 gets to zero, the voltage of Q1 drops rapidly due to the resonance of transformer inductance and capacitor Cd. At the same time the transformer auxiliary winding voltage Vsub also drops rapidly.

ZCD pin receives this auxiliary winding voltage but it has a little amount of delay time due to CR circuit composed of R_{ZCD} and CZCD on the way.

t4

When ZCD pin voltage drops lower than the threshold voltage (62mV(typ.)) of Valley detection, a set signal is input into R-S flip-flop and Q1 turns ON again. If the delay time of CR circuit placed between the auxiliary winding and ZCD pin is adjusted suitably, Q1 can be turned on at the bottom of the voltage. Switching loss of TURN ON can be controlled to the minimum by this operation. (Return to t1)

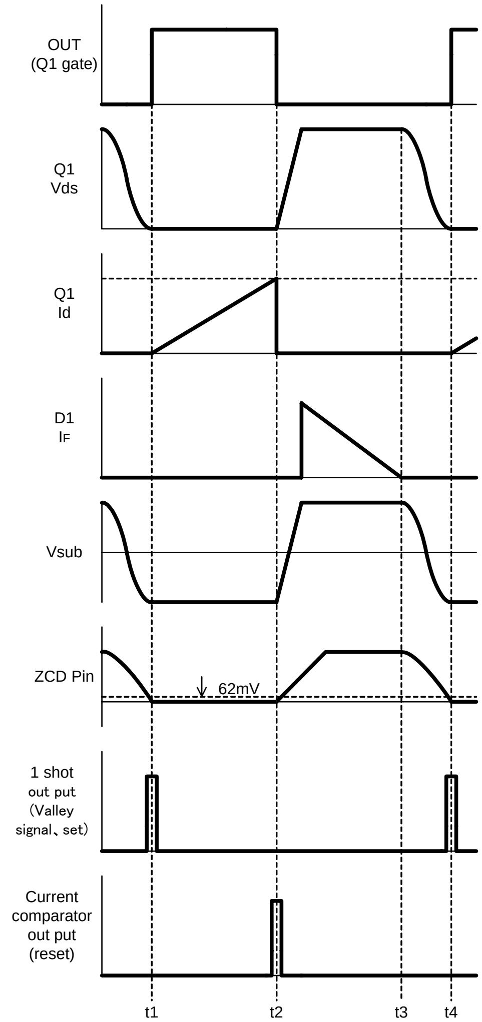


Fig.2 Waveform in basic operation

After this, repeat from t1 to t4 and continue switching.

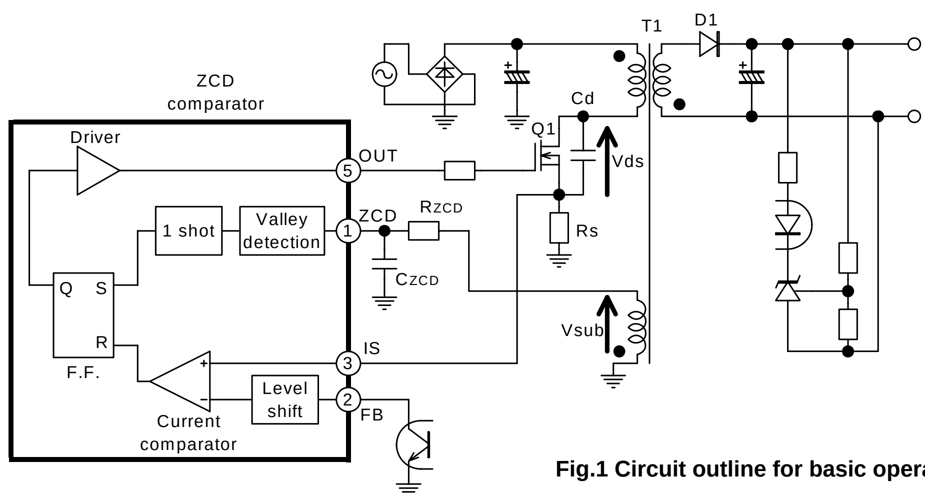


Fig.1 Circuit outline for basic operation

9. Description of the function

(1) Steady- state operation

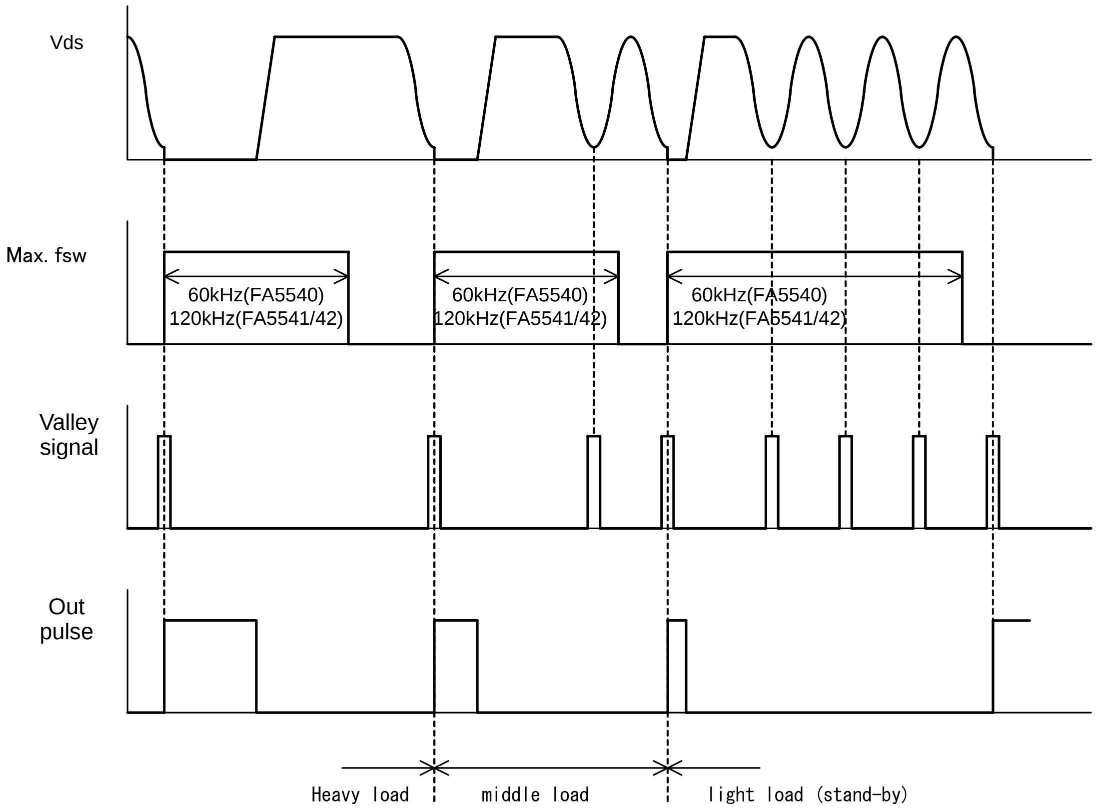


Fig.3 Steady-state operation timing chart

At each switching cycle, TURN ON is carried out at the first Valley signal that exceeds the time corresponding to the maximum frequency limit of 60kHz(FA5540)/120kHz(FA5541/42), counting from the previous TURN ON.

(2) Burst operation at light load

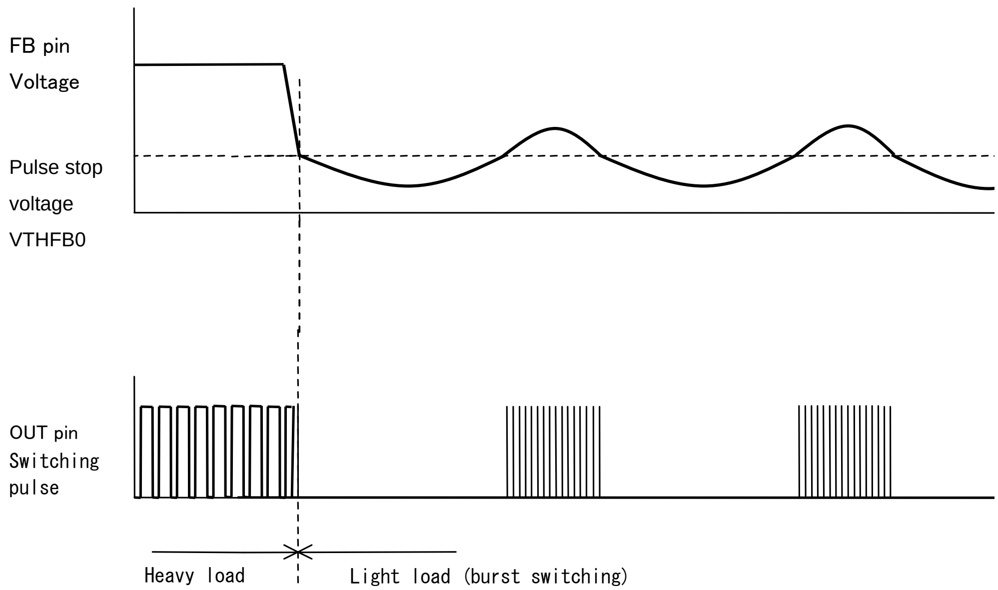


Fig.4 Burst operation at light load

When FB pin voltage drops lower than the pulse shutdown threshold voltage, switching is shut down. On the contrary when FB pin voltage rises higher than the pulse shutdown threshold voltage, switching is started again. FB pin voltage overshoots and undershoots centering around the pulse shutdown threshold voltage for mode change. Continuous pulse is output during the overshoot period and long period burst frequency is obtained during the undershoot period.

(3) Startup circuit and auxiliary winding voltage

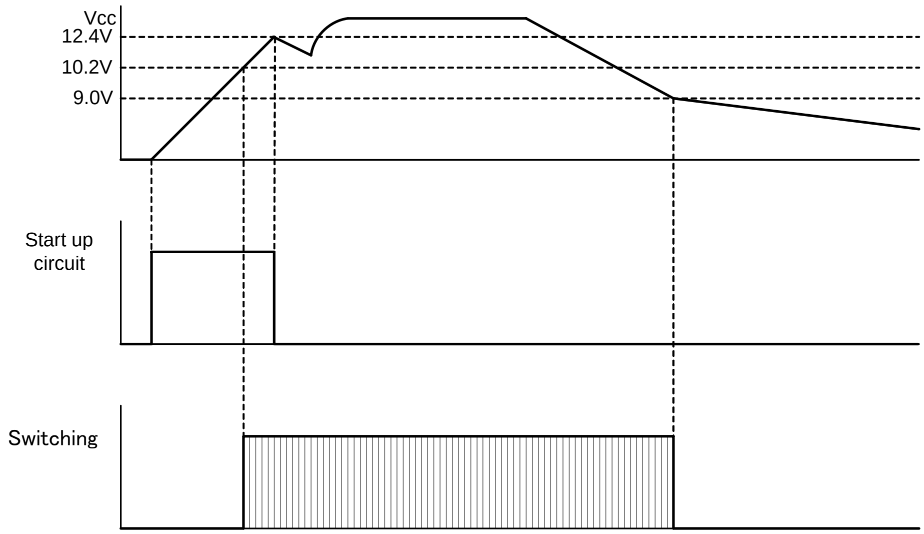


Fig.5 Startup and shutdown (the auxiliary winding voltage is higher than 10.2 V)

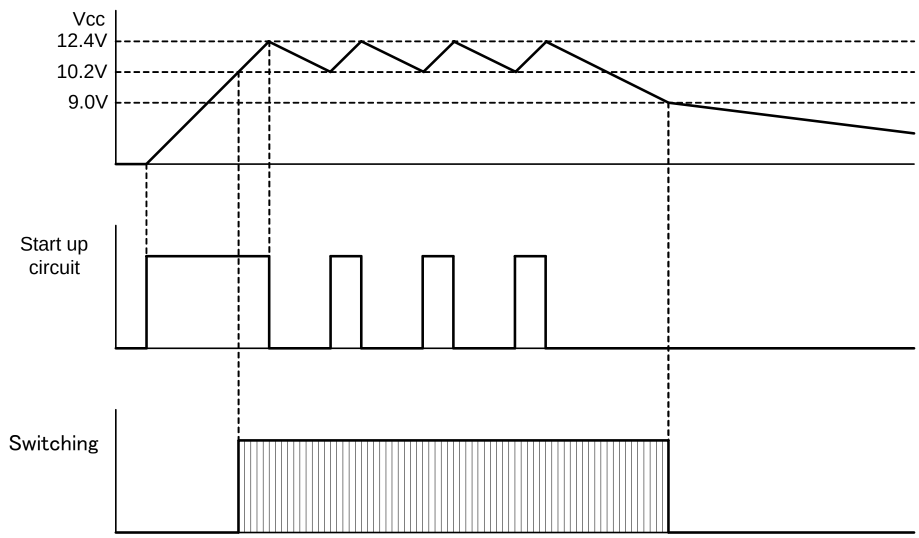


Fig.6 Startup and shutdown (The auxiliary winding voltage is lower than 10.2V)

In case that the auxiliary winding voltage is higher than 10.2V, the startup circuit operates only at the startup and operates afterwards as a power supply using the auxiliary winding voltage.
On the other hand, in case that the auxiliary winding voltage is lower than 10.2V, the startup circuit continues to keep Vcc between 10.2V and 12.4V by switching ON-OFF of the startup circuit.

(4) Operation at overload

■FA5540 (Auto restart type)

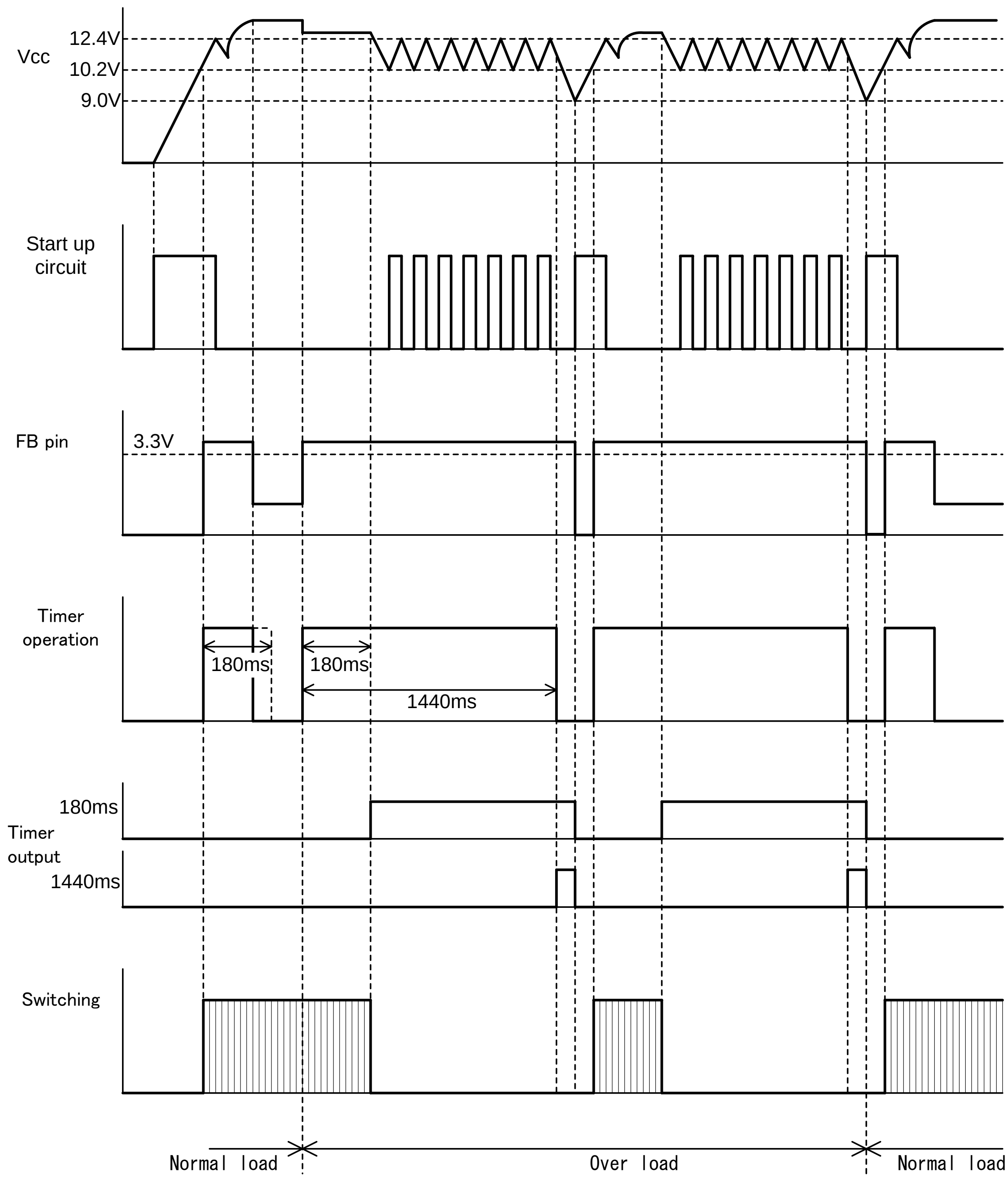


Fig.7 Operation at overload (FA5540)

If an overload condition continues more than 180ms, switching is forced to shutdown using an internal timer. In addition the startup circuit is possible to operate within 1440ms from beginning of an overload condition. If an overload condition continues, switching is done for 180ms and after that Vcc is provided by a startup circuit for 1260ms and the operation halt condition is maintained.
When 1440ms passes after beginning of an overload condition, a startup circuit stops its operation and Vcc begins to drop. When Vcc decreases to 9.0V, IC is once reset and restarted. Since then startup and shutdown are repeated if an overload condition continues. If load returns to normal, IC returns to an ordinary operation. However, the output voltage must rise up to the setting value within 180ms settled by the timer at the startup.

■**FA5541 (auto restart type)**

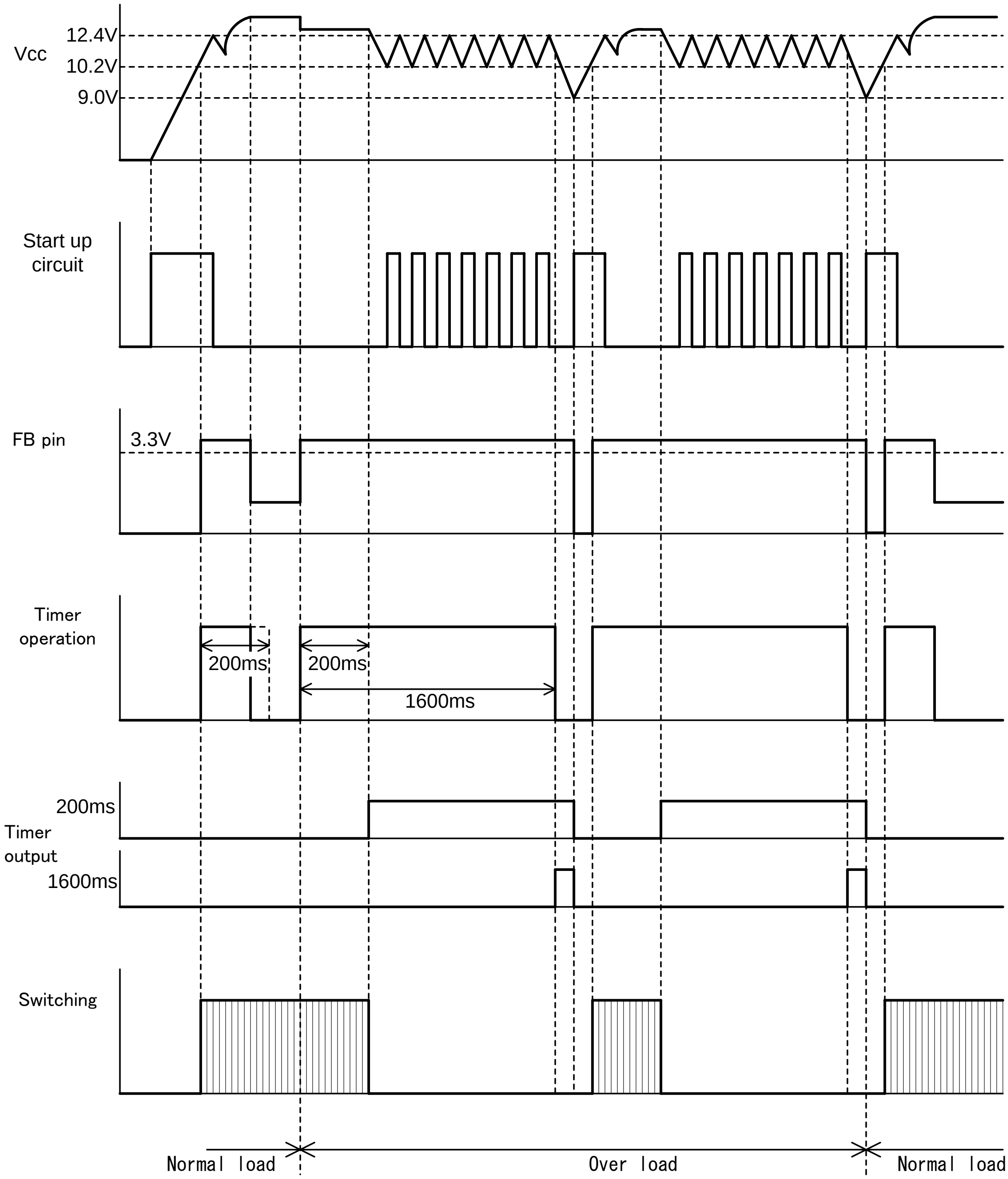


Fig.8 Operation at overload (FA5541)

If an overload condition continues more than 200ms, switching is forced to shutdown using an internal timer. In addition the startup circuit is possible to operate within 1600ms from beginning of an overload condition.
If an overload condition continues, switching is done for 200ms and after that Vcc is provided by a startup circuit for 1400ms and the operation halt condition is maintained.
When 1600ms passes after beginning of an overload condition, a startup circuit stops its operation and Vcc begins to drop. When Vcc decreases to 9.0V, IC is once reset and restarted. Since then startup and shutdown are repeated if an overload condition continues. If load returns to normal, IC returns to an ordinary operation. However, the output voltage must rise up to the setting value within 200ms settled by the timer at the startup.

■**FA5542 (latch type)**

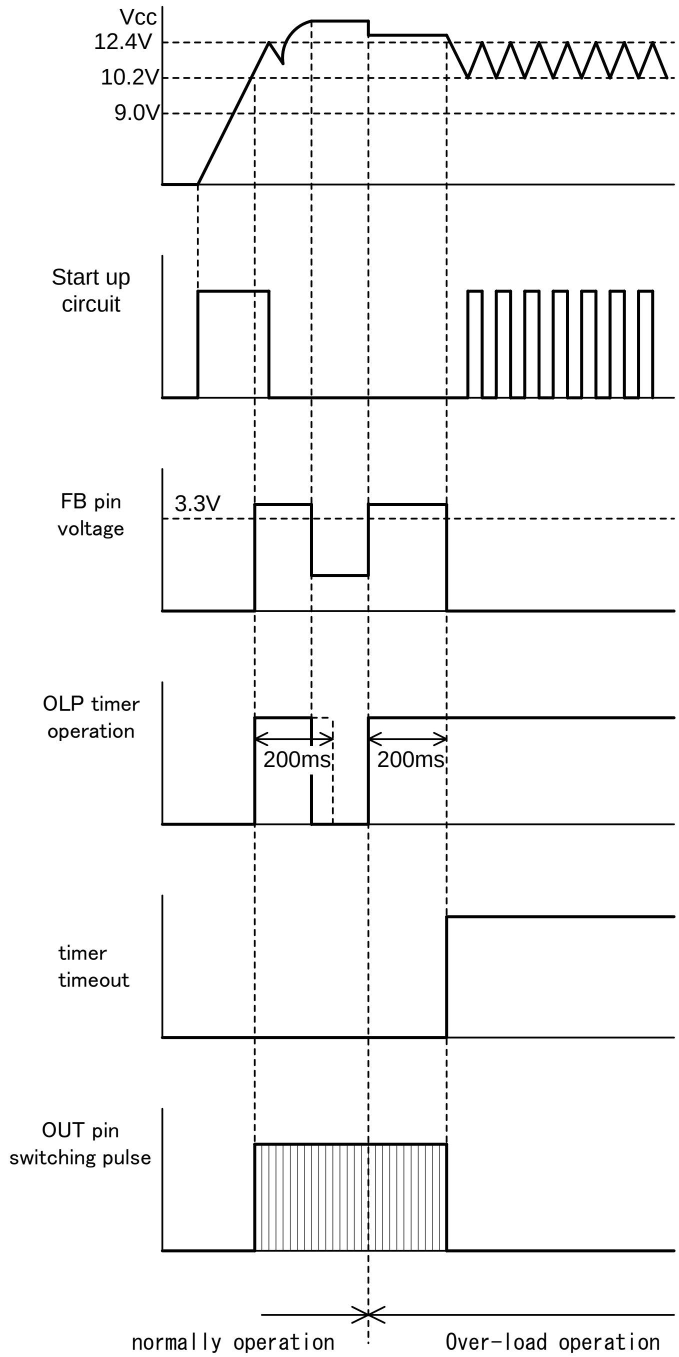


Fig.9 Operation at overload (FA5542)

If the overload condition continues more than 200ms, switching is forced to shutdown using an internal timer and changes to latch mode to maintain this condition. During the condition when switching is shutdown due to an overload latch, Vcc is provided by the startup circuit and the operation halt condition is maintained.
To reset an overload latch, it is required to shutdown the provision of Vcc from the startup circuit by stopping the input voltage and reduce Vcc lower than OFF-threshold voltage 9.0V.
However, the output voltage must rise up to the setting value within 200ms settled by the timer at the startup.

(5) Miscellaneous

- Vcc is always observed and if it exceeds 16V (FA5540) / 28V (FA5541/42), it is shutdown. This condition is maintained until Vcc drops to UVLO off-threshold voltage by interrupting its input voltage.

- By pull-upping ZCD pin voltage higher than 7.2V from outside, shutdown is carried out like the case of the overload voltage and this condition is maintained.

- Auto restart by overload protection
  If Vcc is provided by other power supply, it latches and stops.

10. Method for using each pin

(1) No.1 pin (ZCD)

Function

(i) Detection of timing to make MOSFET ON.
(ii) Latch protection by an external signal.

Usage

(i) Detection of turn-on timing

・Connection

This pin is connected to a transformer auxiliary winding through CR circuit with RZCD and CZCD. (Fig.10)

Be careful about polarity of an auxiliary winding.

・Operation

When ZCD pin voltage drops lower than 62mV, MOSFET is turned on.

The auxiliary winding voltage swings + and – direction widely along with switching. A clamp circuit is equipped to protect IC from this voltage. If the auxiliary winding voltage is plus, it passes a current shown in Fig. 11 and if minus, shown in Fig.12. And then it clamps ZCD pin voltage.

・Complement

Since the threshold voltage of latch protection by an external signal is 6.4V (min.) as described in function (ii), the resistor RZCD must be adjusted for ZCD pin voltage not to exceed 6.4V in ordinary operation. At the same time the resistor RZCD must be adjusted for ZCD pin current not to exceed the absolute maximum rating.

The MOSFET voltage oscillates just before TURN ON due to the resonance effect between transformer inductance and resonant capacitor Cd. CZCD is adjusted for MOSFET to turn on at the bottom of this resonance (Fig.13). Generally RZCD is several 10kΩ and CZCD is several 10pF. However CZCD is unnecessary if good timing is obtained.

(ii) Latch protection

・Connection

Pull up ZCD pin by an external signal.

Fig. 14 shows the connection example in case of primary over-voltage.

・Operation

When ZCD pin voltage exceeds 7.2V (typ.) and continues for more than 40µs (FA5540) / 54µs (FA5541/42) (typ.), latch protection operates.

Once latch protection operates, IC output pulse is shutdown and maintained as it is.

It can be reset by decreasing Vcc lower than UVLO off-threshold voltage.

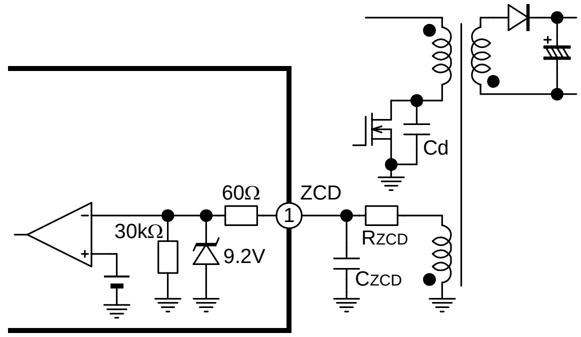


Fig. 10 ZCD pin circuit

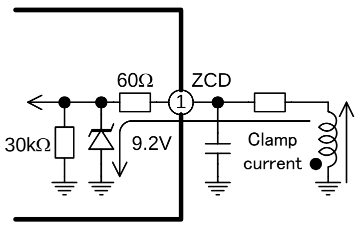


Fig.11 Clamp circuit (positive auxiliary winding voltage)

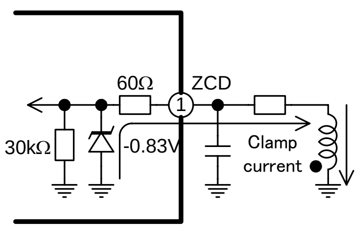


Fig.12 Clamp circuit (negative auxiliary winding voltage)

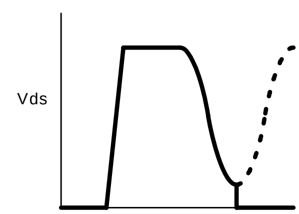


Fig.13 Vds waveform

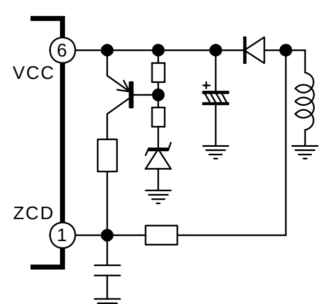


Fig.14 Primary side over voltage protection circuit

(2) No.2 pin (FB pin)

Function

(i) Input of a feed-back signal from secondary error-amplifier.
(ii) Detection of an overload condition.

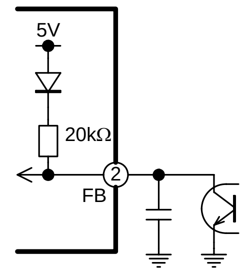


Fig. 15 FB pin circuit

Usage

(i) Input of a feedback signal

・Connection

This pin is connected with the receiver unit of a photo coupler. Concurrently it is connected a capacitor in parallel with the photo coupler to protect noise. (Fig. 15)

・Operation

This pin is biased by an IC internal power supply through a diode and a resistor.
The FB pin voltage is level-shifted and is input into a current comparator and finally gives the threshold voltage for MOSFET current signal that is detected on IS pin.

(ii) Detection of overload

・Connection

Same as (i) Input of the feed back signal.

・Operation

If the output voltage of a power supply drops lower than the set value in an overload condition, FB pin voltage rises and scales out. This state is detected and judged as an overload condition. The threshold voltage to detect an overload is 3.3V (typ).

・Complement

FA5540/41 operates intermittently in an overload condition and automatically restarts if the overload condition is removed. Refer to pages 23-24 for detail operation.
FA5542 stops switching in an overload condition and goes into latch mode to maintain this condition. Refer to page 25 for detail operation.

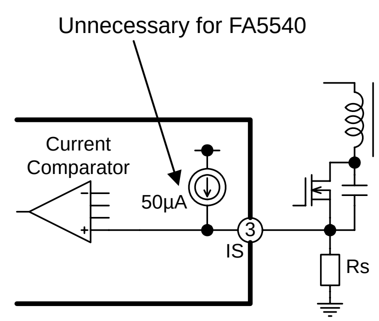


Fig. 16 IS pin circuit

(3) No.3 pin (IS pin)

Function

(i) Detection of MOSFET current
(ii) Suppression of a burst operation at light load

Usage

(i) Current detection

・Connection

Connect a current detecting resistor Rs between a source pin of MOSFET and GNC. Input The current signal that arises in the MOSFET is input to this resistor (Fig.16).

・Operation

A MOSFET current signal that is input into IS pin is input into a current comparator. When it gets to the threshold voltage that is designated by FB pin, it turns off MOSFET. The maximum threshold voltage is 1V (typ.). MOSFET current is restricted by the current that corresponds to this voltage (1V) even in a transient condition at the startup or in an abnormal condition at overload

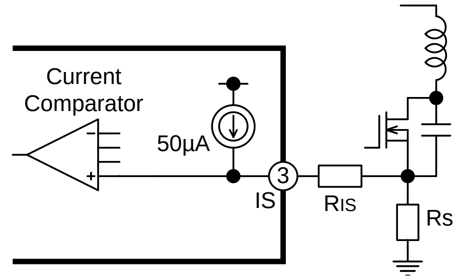


Fig. 17 Filter of IS pin

・Compliment

A blanking function of 205ns (L.E.B) is built-in, and CR filter is unnecessary in general.

(ii) Burst operation adjustment (for FA5541/42)

・Connection

A resistor RIS is inserted additionally between the current detecting resistor Rs and IS pin (Fig. 17).

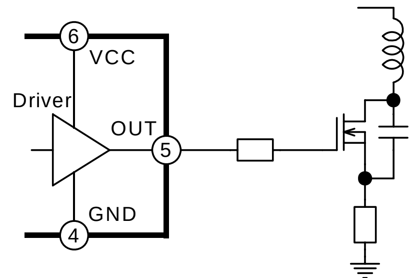


Fig. 18 OUT pin circuit (1)

・Operation

A 50 μ A current supply is included in IS pin of FA5541/42, and electric current is sent out from IS pin. The voltage that is equal to the multiplication of the current value and the resistor value is effective to restrain burst operation.

・Compliment

For example, when getting into burst operation in case of a heavy load, the output ripple becomes bigger. If this is a problem, this pin should be used. However the more difficult it becomes to get into burst operation, the more electric power consumption in waiting increases.

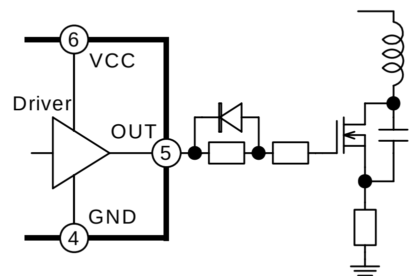


Fig. 19 OUT pin circuit (2)

(4) No.4 pin (GND pin)

Function

This is the standard voltage for each IC.

(5) No.5 pin (OUT pin)

Function

Driving of MOSFET.

Usage

・Connection

This pin is connected to MOSFET gate pin through a resistor (Fig.18, Fig.19, & Fig.20).

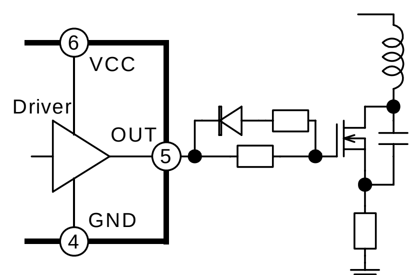


Fig. 20 OUT pin circuit (3)

・Operation

During the period MOSFET is ON, this pin is kept in high position and almost the same voltage as Vcc is output.

During the period MOSFET is OFF, this pin is kept in low position and nearly zero voltage is output.

・Compliment

A gate resistor is connected to restrict current of OUT pin and to protect oscillation of gate pin voltage.
Output current rating of IC is 0.25A for source and 0.5A for sink.

(6) No.6 pin (VCC pin)

Function

(i) Provision of power supply for IC
(ii) Detect over-voltage in primary side and activate latch protection.

Usage

(i) Provision of power supply for IC

・Connection

Generally the auxiliary winding voltage of a transformer is rectified and smoothed and is connected to this pin (Fig. 21).
In addition this auxiliary winding can also be connected with ZCD pin.

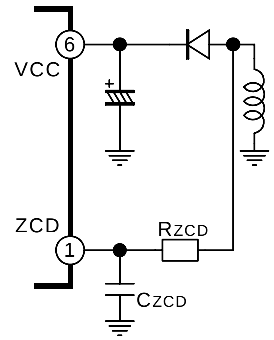


Fig.21 VCC circuit

・Operation

The voltage provided by the auxiliary winding should be set 12V to 14.5V (FA5540) / 12V to 26V (FA5541/42) in ordinary operation.
It is possible to drive IC with the current provided by a startup circuit without using an auxiliary winding but standby power requirement becomes larger and heat dissipation increases. Therefore it is better to provide Vcc by an auxiliary winding for low standby power requirement.
In addition, much attention is required in selecting MOSFET to drive, because there is a limit to the current to be provided when IC is driven only by a startup circuit.

(ii) Protection of over voltage

・Connection

Same as the connection described in (i) Provision of power supply for IC.

・Operation

If Vcc exceeds 16V (FA5540) / 28V (FA5541/42) (typ.) and maintains more than 40µs (FA5540) / 54µs (FA5541/42) (typ.), protection of over voltage is activated and IC is latched.

・Compliment

For example, if the output voltage rises abnormally due to the error of a feedback circuit, also Vcc rises abnormally. When Vcc exceeds 16V (FA5540) / 28V (FA5541/42), latch protection is activated. Therefore that operates as over voltage protection of primary side detection.

(7) No.7 pin (N.C.)

As this pin is next to a high voltage pin, this pin is not yet connected to IC inside.

(8) No.8 pin (VH pin)

Function

Provides startup current.

Usage

・Connection

This pin is connected to a high voltage line. If this is connected after the current is rectified, this should be connected through a resistor of several kΩ (Fig.22). On the other hand, if connected before the current is rectified, this should be connected to a high voltage line through a resistor of several kΩ and a diode (Fig.23, Fig.24).

・Operation

If VH pin is connected to high voltage, current flows out from Vcc pin through the startup circuit in the IC. This current charges the capacitor between Vcc and GND, and Vcc voltage rises. When Vcc exceeds 10.2V (typ), IC is activated and begins to operate.

If Vcc is provided by an auxiliary winding, a startup circuit goes into shutdown state. On the other hand, if no power is supplied from the auxiliary winding, IC operates normally with a current provided by the startup circuit.

・Compliment

If Vcc is provided not by an auxiliary winding but only by a startup circuit, standby power requirement becomes larger and heat dissipation increases. Therefore it is better to provide Vcc by an auxiliary winding for low standby power dissipation requirement.

In addition, much attention is required in selecting MOSFET to drive, because there is a limit to the current to be provided when IC is driven only by a startup circuit.

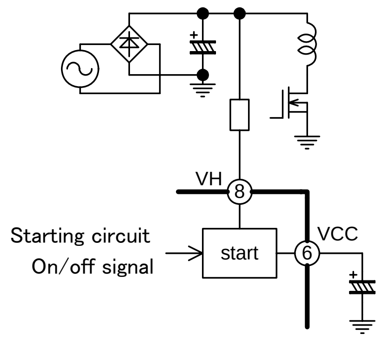


Fig.22 VH pin circuit (1)

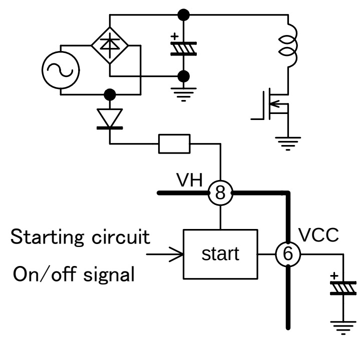


Fig.23 VH pin circuit (2)

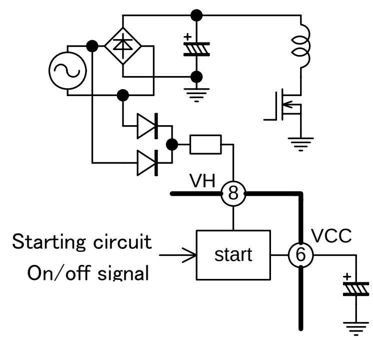
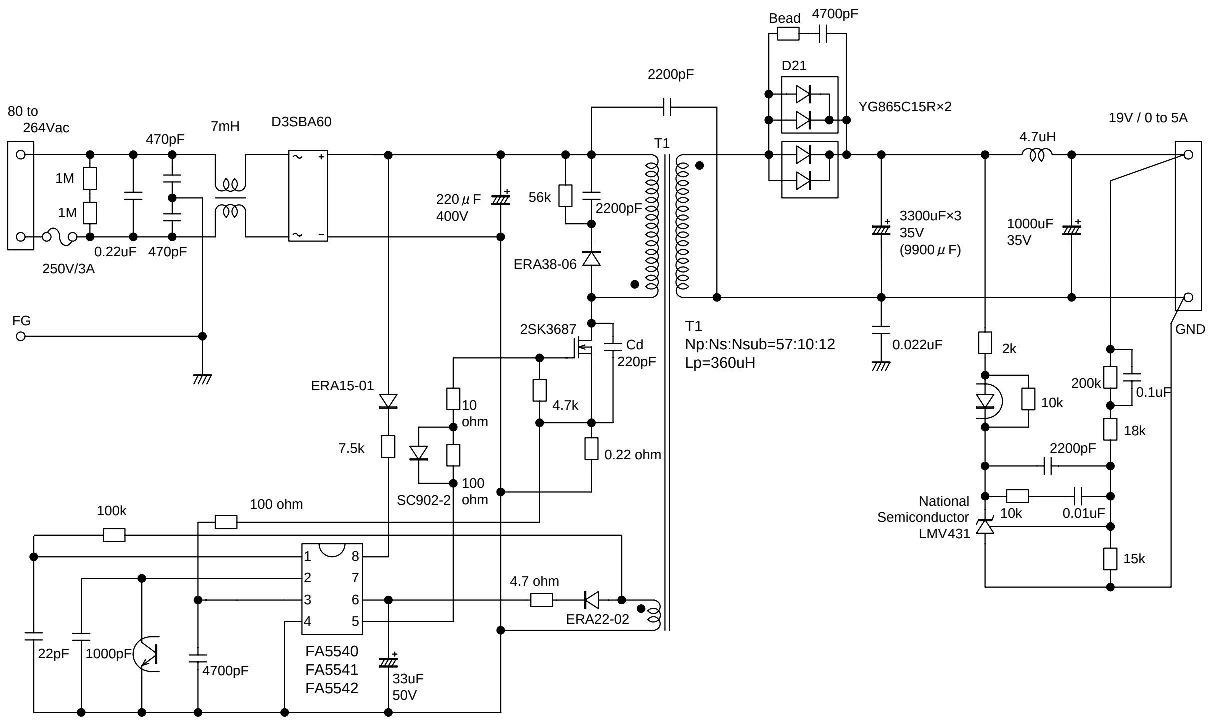


Fig.24 VH pin circuit (3)

11. Example of application circuit

These application examples show common specification for FA5540/41/42. The same circuitry can be adapted for FA5540/41/42 except the setting of Vcc pin voltage and the transformer designing that depends on a switching frequency. (L value and winding ratio of the transformer for FA5541/42 are shown in the figure below).

(1) Application circuit example 1



(2) Application circuit example 2

(VH pin (No.8) for startup is connected to AC side in order to speed up latch-reset after AC shutdown)