

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Maximum Drain Voltage ⁽¹⁾	V _{D,MAX}	800	V
Drain-Gate Voltage (R _{GS} =1MΩ)	V _{DGR}	800	V
Gate-Source (GND) Voltage	V _{GS}	±30	V
Drain Current Pulsed ⁽²⁾	I _{DM}	24.0	ADC
Single Pulsed Avalanche Energy ⁽³⁾	E _{AS}	455	mJ
Avalanche Current ⁽⁴⁾	I _{AS}	20	A
Continuous Drain Current (T _C =25°C)	I _D	6.0	ADC
Continuous Drain Current (T _C =100°C)	I _D	3.8	ADC
Maximum Supply Voltage	V _{CC,MAX}	30	V
Input Voltage Range	V _{FB}	-0.3 to V _{SD}	V
Total Power Dissipation	P _D	150	W
	Derating	1.21	W/°C
Operating Ambient Temperature	T _A	-25 to +85	°C
Storage Temperature	T _{STG}	-55 to +150	°C

Note:

1. T_j = 25°C to 150°C
2. Repetitive rating: Pulse width limited by maximum junction temperature
3. L = 24mH, V_{DD} = 50V, R_G = 25Ω, starting T_j = 25°C
4. L = 13μH, starting T_j = 25°C

Electrical Characteristics (SenseFET part)

(Ta=25°C unless otherwise specified)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Drain-Source Breakdown Voltage	BVDSS	VGS=0V, ID=50μA	800	-	-	V
Zero Gate Voltage Drain Current	IDSS	VDS=Max., Rating, VGS=0V	-	-	50	μA
		VDS=0.8Max., Rating, VGS=0V, TC=125°C	-	-	200	μA
Static Drain-Source On Resistance ^(note1)	RDS(ON)	VGS=10V, ID=5.0A	-	1.6	2.0	Ω
Forward Transconductance ^(note1)	gfs	VDS=15V, ID=5.0A	1.5	2.5	-	S
Input Capacitance	Ciss	VGS=0V, VDS=25V, f=1MHz	-	1600	-	pF
Output Capacitance	Coss		-	140	-	
Reverse Transfer Capacitance	Crss		-	42	-	
Turn On Delay Time	td(on)	VDD=0.5BVDSS, ID=8.0A (MOSFET switching time are essentially independent of operating temperature)	-	60	-	nS
Rise Time	tr		-	150	-	
Turn Off Delay Time	td(off)		-	300	-	
Fall Time	tf		-	130	-	
Total Gate Charge (Gate-Source+Gate-Drain)	Qg	VGS=10V, ID=8.0A, VDS=0.5BVDSS (MOSFET switching time are essentially independent of operating temperature)	-	70	-	nC
Gate-Source Charge	Qgs		-	16	-	
Gate-Drain (Miller) Charge	Qgd		-	27	-	

Note:

1. Pulse test: Pulse width ≤ 300μS, duty cycle ≤ 2%

2. $S = \frac{1}{R}$

Electrical Characteristics (control part) (Continued)

(Ta=25°C unless otherwise specified)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
UVLO SECTION						
Start Threshold Voltage	VSTART	-	14	15	16	V
Stop Threshold Voltage	VSTOP	After turn on	8	9	10	V
OSCILLATOR SECTION						
Initial Frequency	FOSC	-	60	66	72	kHz
Frequency Change With Temperature ⁽²⁾	$\Delta F/\Delta T$	$-25^{\circ}\text{C} \leq T_a \leq +85^{\circ}\text{C}$	-	± 5	± 10	%
Maximum Duty Cycle	Dmax	-	45	50	55	%
Voltage Stability	Fstable	$12\text{V} \leq V_{CC} \leq 23\text{V}$	0	1	3	%
FEEDBACK SECTION						
Feedback Source Current	IFB	Ta=25°C, $0\text{V} \leq V_{fb} \leq 3\text{V}$	0.7	0.9	1.1	mA
Shutdown Delay Current	Idelay	Ta=25°C, $5\text{V} \leq V_{fb} \leq V_{SD}$	4.0	5.0	6.0	μA
Shutdown Feedback Voltage	Vsd		6.9	7.5	8.1	V
SOFT START SECTION						
Soft Start Voltage	VSS	VFB =2V	4.7	5.0	5.3	V
Soft Start Resistor	Rsoft	Bias=Vref, SS=0V	16.0	18.5	22.0	kΩ
REFERENCE SECTION						
Output Voltage ⁽¹⁾	Vref	Ta=25°C	4.80	5.00	5.20	V
Temperature Stability ⁽¹⁾⁽²⁾	Vref/ΔT	$-25^{\circ}\text{C} \leq T_a \leq +85^{\circ}\text{C}$	-	0.3	0.6	mV/°C
CURRENT LIMIT (SELT-PROTECTION)SECTION						
Peak Current Limit	I _{OVER}	Max. inductor current	3.52	4.00	4.48	A
PROTECTION SECTION						
Thermal Shutdown Temperature (Tj) ⁽¹⁾	TSD	-	140	-	-	°C
Over Voltage Protection Voltage	VOVP	-	25	28	31	V
Over Current Protection Voltage	VOCP	-	1.05	1.10	1.15	V
TOTAL DEVICE SECTION						
Start Up Current	ISTART	VCC=14V	-	40	80	μA
Operating Supply Current (Control Part Only)	IOP	Ta=25°C	-	8	12	mA
	Iop(lat)	After latch, Vcc=Vstop-0.1V	150	250	350	μA

Note:

1. These parameters, although guaranteed, are not 100% tested in production
2. These parameters, although guaranteed, are tested in EDS (wafer test) process

General Application

In general, the FPS consists of several functional sections: under voltage lockout circuit (UVLO), reference voltage, oscillator (OSC), pulse width modulation (PWM) block, protection circuits and gate drive circuit.

Start-Up

The minimum current that FPS requires for the start-up is $80\mu\text{A}$. This current can be provided by the DC link bulk capacitor (DC start-up) or directly by the AC line (AC start-up).

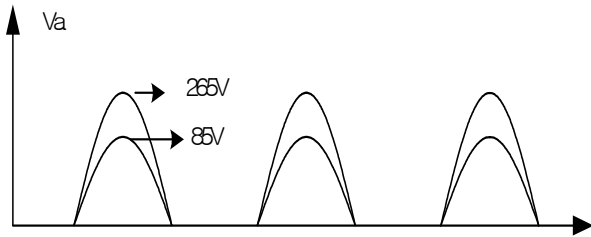
DC start-up

Assuming wide range input voltage (85-265V), the maximum value of Rstart is calculated with the minimum input voltage as follows:

$$R_{\text{start}} = \frac{85\sqrt{2} - 15}{80\mu\text{A}} = 1.3\text{M}\Omega$$

The maximum power dissipation in Rstart is calculated with the maximum input voltage as follows:

$$P_{\text{loss}} = \frac{(265\sqrt{2} - 15)^2}{1.3\text{M}\Omega} = 0.1(\text{W})$$



AC start-up

When the start-up current is provided directly by the AC line through a single rectifier diode, the maximum value of Rstart is calculated with the minimum input voltage as follows:

$$R_{\text{Start}} = \frac{2 \cdot 85\sqrt{2} - 15\pi}{2\pi} \div (80\mu\text{A})$$

$$= 380\text{k}\Omega$$

The maximum power dissipation in Rstart is calculated with the maximum input voltage as follows:

$$V_{a(\text{rms})} = \sqrt{\frac{1}{2\pi} \int_0^\pi (V_p \sin t - 15)^2 dt}$$

$$= 177\text{V} (V_p = 265\sqrt{2})$$

$$P_{\text{loss}} = \frac{V_{a(\text{rms})}^2}{R_{\text{start}}} = \frac{(177)^2}{380\text{k}}$$

$$= 82(\text{mW})$$

The current provided through the starting resistor charges the Vcc capacitor. When Vcc becomes higher than the threshold voltage, the FPS starts the switching operation of the built-in

power MOSFET. Then, the current required by the control IC is suddenly increased to 7mA, which makes it difficult for FPS to operate with the current provided through Rstart. Therefore, after FPS starts, the auxiliary winding of the transformer should supply most of the power required by the FPS. It is suitable to use an appropriately sized VCC capacitor, generally about $33\mu\text{F}$, because the starting time can be delayed if it is too large. This operation is described in figure 2. Although VCC needs to be set only above 9V during the normal operation, it should be set to such an extent that over voltage protection (OVP) is not activated during an overload condition. For full load, about 18~20V is appropriate for VCC and for no load, about 13~14V is suitable.

Protection

The FPS has not only pulse by pulse current limit circuit, but also several self-protection circuits. These protection circuits are fully integrated and do not require external components. After the protection circuits are activated, the FPS completely stops the SMPS (Latch Mode Protection) until the power on reset circuit is activated by removing and restoring input power, or restarts the SMPS automatically (Auto Restart Mode Protection).

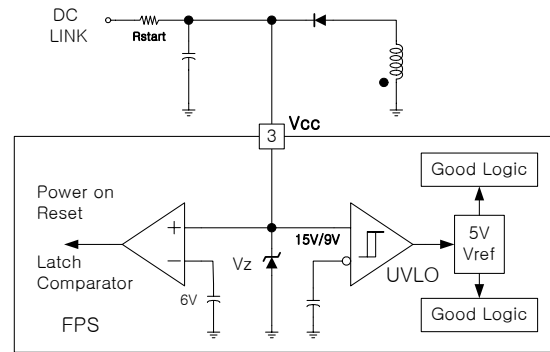


Figure 1. Undervoltage lockout (UVLO) circuit

These two operations are user-selected operations, so the user can select proper device according to the shutdown mode. The operations principle and applications for each protection are described as follows.

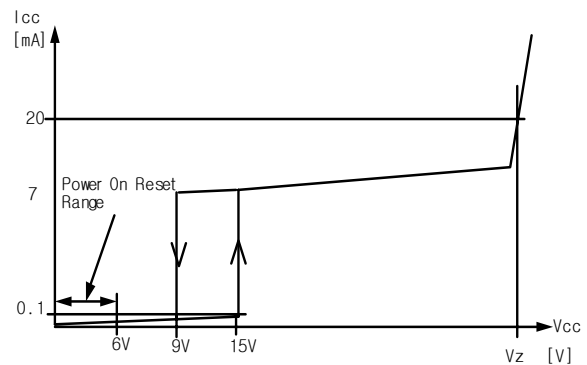


Figure 2. Variation of Icc according to Vcc

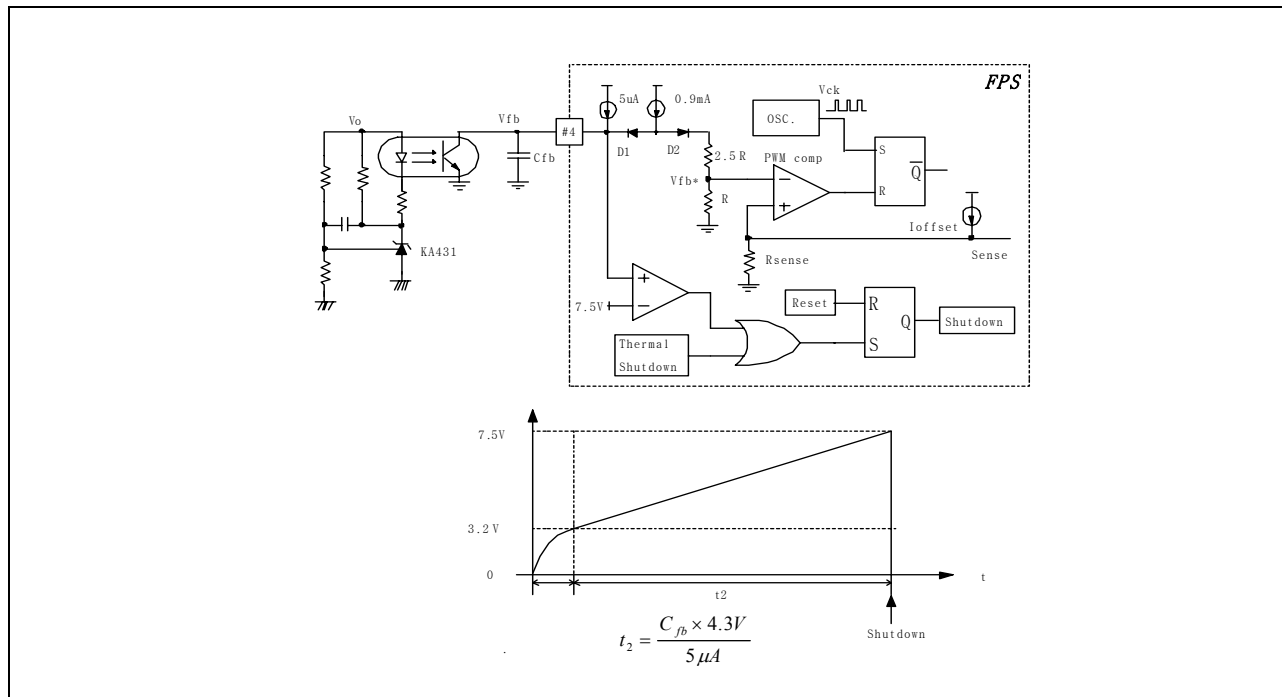


Figure 3. Pulse-width-modulation (PWM) block

Pulse by pulse current limit

Figure 3 shows the pulse-width-modulation (PWM) block of the FPS. Since the FPS employs the peak current mode control, the current through the power MOSFET is limited by the inverting input voltage of PWM comparator (V_{fb}^*).

Assuming that the 0.9mA current source flows only through the internal resistor ($2.5R + R = 2.8k$) and the diode forward voltage drop is 0.7V, the anode voltage of diode D2 is about 3.2V. Since D1 is blocked when the feedback voltage (V_{fb}) exceeds 3.2V, the maximum voltage of the anode of D2 is 3.2V. Therefore, the maximum value of V_{fb}^* is about 0.7V, which determines the maximum current through the power MOSFET.

Over Load Protection

Overload means that the load current exceeds a pre-set level due to the abnormal situation. In this situation, protection circuit should be activated in order to protect the SMPS. However, even when the SMPS is in the normal operation, the over load protection circuit can be activated during the load transition. In order to avoid this undesired operation, the over load situation should be distinguished from the normal load transition situation. As a measure against this problem, over load protection circuit in the FPS is designed to be activated after a specified period to determine whether it is a transient situation or an overload situation. The protection circuit is allowed to shut down the SMPS only when the over load condition continues longer than preset period. The detailed operation principle is explained in figure 3. Because of the pulse by pulse current limit circuit, the maximum current through the FPS is limited, and therefore the maximum

input power is restricted with a given input voltage. If the output consumes beyond this maximum power, the output voltage (V_o) decreases below the set voltage. This reduces the current through the opto-coupler diode, which also reduces opto-coupler transistor current increasing V_{fb} . If V_{fb} exceeds 3.2V, D1 is blocked and the 5μA current source starts to charge C_{fb} slowly compared to when the 0.9mA current source charges C_{fb} . V_{fb} continues increasing until it reaches 7.5V, and the FPS shuts down at that time. The delay time for shutdown is the time required to charge C_{fb} from 3.2V to 7.5V with 5μA. When C_{fb} is 10nF (103), t_2 is approximately 8.6ms and when C_{fb} is 0.1μF (104), t_2 is approximately 86ms. These values are enough to prevent SMPS from being shut down for most transient situations. Just increasing C_{fb} to obtain a longer delay time may cause problems, because C_{fb} is an important parameter for determining the response speed of the SMPS. To solve this problem, auxiliary capacitor in series with zener diode can be used in parallel with C_{fb} . The breakdown voltage of the zener diode should be about 3.9 ~ 4.7V. When V_{fb} is below the zener voltage, the system dynamics is determined by C_{fb} . When V_{fb} exceeds the zener voltage, the delay time is determined by the auxiliary capacitor. By using large auxiliary capacitor, the delay time can be extended without sacrifice of the dynamic response.

Over voltage Protection (OVP) Circuit

The FPS has a self-protection feature against malfunctions, such as feedback circuit open or short-circuit. When the feedback terminal is open due to a malfunction in the secondary side feedback circuit or a defect of solder, the current through the opto-coupler transistor becomes almost zero.

Then, V_{fb} continues increasing and the preset maximum current flows through the primary side until the over load protection circuit is activated. Since maximum current is transferred to the secondary side, the secondary side voltage becomes much higher than the rated voltage. If there is no protection circuit against over voltage, the devices in the secondary side will be damaged. In order to prevent this situation, the FPS has an over voltage protection circuit (protection against feedback circuit abnormalities). In general, V_{cc} is proportional to the output voltage and FPS uses V_{cc} instead of directly monitoring the output voltage to detect over voltage situation. If V_{cc} exceeds 24 V, the FPS activates the OVP circuit. Therefore, V_{cc} should be properly designed to be below 24V during normal operation to avoid the undesired activation of OVP.

OCP (Over Current Protection)

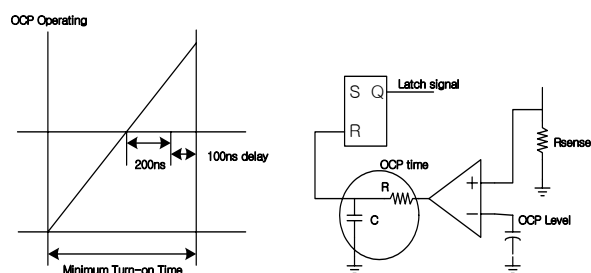


Figure 4. OCP Function & Block

Even though the FPS has OLP (Over Load Protection) and pulse by pulse current limiting feature, these are not enough to protect FPS when a secondary side diode short or load short occurs. Therefore, FPS has internal OCP (Over Current Protection) circuit as shown in figure 4. When the gate turn-on signal is applied to the power MOSFET, the OCP block is enabled and monitors the current through the sensing resistor for 1 μ s. The voltage across the resistor is compared with the preset OCP level. If the sensing resistor voltage is greater than the OCP level for longer than 200ns within the allowed comparison time of 1 μ s, the reset signal is applied to the latch, resulting in the shutdown of SMPS. Here, the additional delay of 100ns after the 200ns delay is the time required for the operation of the protection circuit.

Soft start operation

At startup, the voltage of the PWM comparator inverting input is saturated to its maximum value. In that case, the power MOSFET current is at its maximum value and maximum allowable power is delivered to the secondary side until the output voltage is established. It should be noted that when the SMPS delivers maximum power to the secondary side during the startup, the entire circuit is seriously stressed. By using a soft start function, such stresses can be alleviated. Figure 5 shows how the soft-start circuit is implemented. When it starts up, the soft start capacitor C_s on pin 5 begins to be charged through the internal resistor (R_{ss}), which forces the comparator inverting input voltage

to increase slowly, also increasing the duty ratio slowly. When the voltage of C_s reaches about 3.2V, PNP transistor is turned off and C_s continues being charged up to 5V through R_{ss} . Then, the voltage of the comparator inverting input follows the feedback voltage of pin 4 instead of following the voltage of C_s . When the SMPS is shut down by the protection circuits, C_s is discharged through the internal resistor allowing C_s to be charged from 0V when the SMPS starts up again.

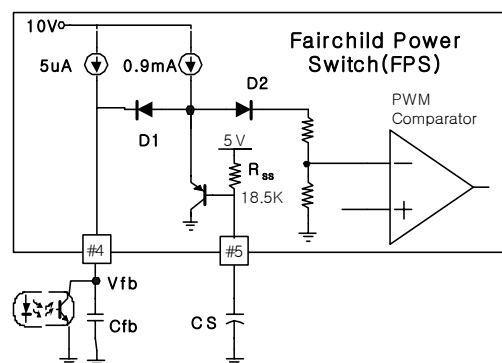
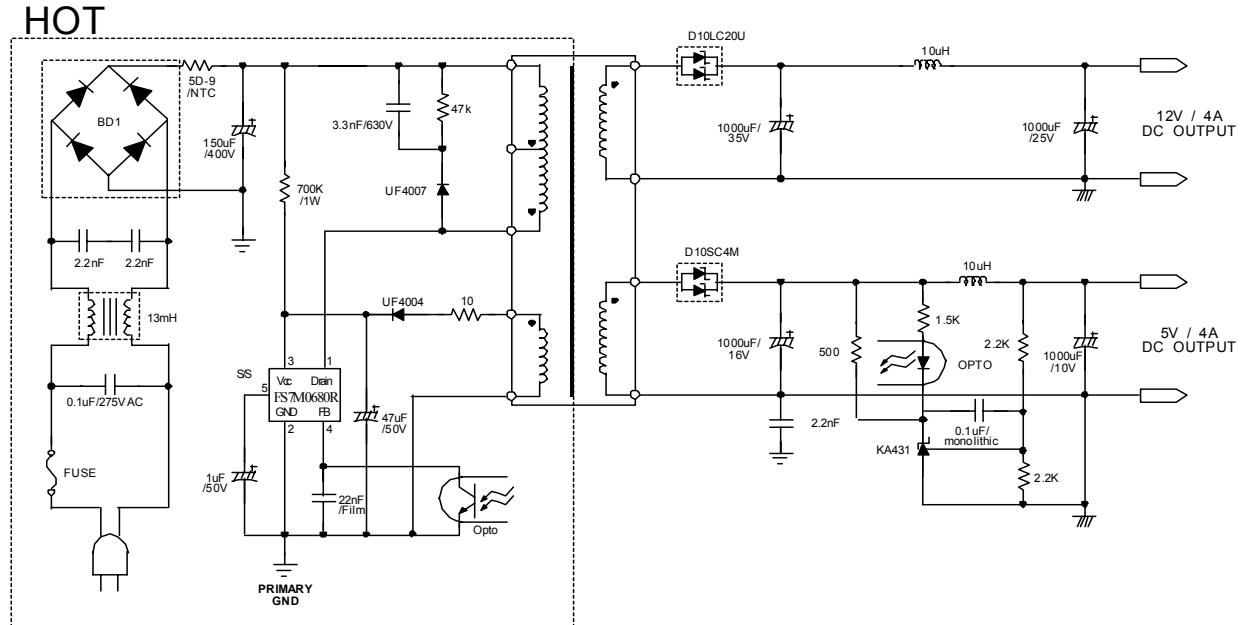


Figure 5. Soft Start Circuit

3. Application Note using the FPS

-Flyback Application (70W)



Transformer Specification

2. Winding Specification

No.	PIN(S → F)	WIRE	TURNS	WINDING METHOD
NP/2	2 → 4	0.35 $\phi \times 1$	23	SOLENOID WINDING
INSULATION : POLYESTER TAPE t = 0.050mm, 1Layer				
NB	1 → 3	0.3 $\phi \times 1$	10	COPPER WINDING
INSULATION : POLYESTER TAPE t = 0.050mm, 3Layer				
N5V	8 → 9	0.45 $\phi \times 4$	3	SOLENOID WINDING
INSULATION : POLYESTER TAPE t = 0.050mm, 1Layer				
N12V	12 → 10	0.3 $\phi \times 4$	7	
INSULATION : POLYESTER TAPE t = 0.050mm, 1Layer				
NP/2	4 → 5	0.4 $\phi \times 1$	23	SOLENOID WINDING
OUTER INSULATION : POLYESTER TAPE t = 0.050mm, 3Layer				

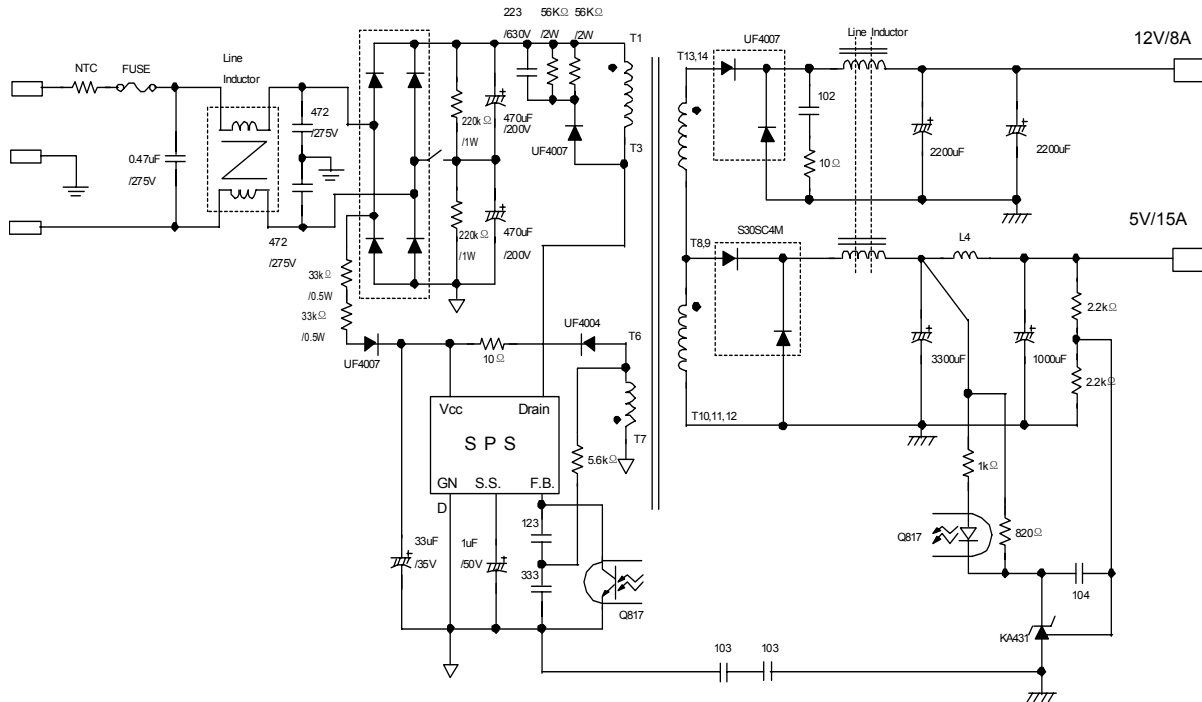
3. Electical Characteristic

CLOSURE	PIN	SPEC.	REMARKS
INDUCTANCE	2 - 5	700uH $\pm 10\%$	1kHz, 1V
LEAKAGE L	2 - 5	15uH MAX.	2nd ALL SHORT

4. Core & Bobbin

CORE : EER 2834
BOBBIN : EER2834

-Forward Application (180W)



Transformer Specification

2. Winding Specification

No.	PIN(S → F)	WIRE	TURNS	WINDING METHOD
NP/2	1 → 3	0.65 ϕ × 1	50T	SOLENOID WINDING
N+5V	8, 9 → 10, 11, 12	14mm × 1	4T	COPPER WINDING
N+12V	13, 14 → 9	0.65 ϕ × 4	5T	SOLENOID WINDING
NP/2	1 → 3	0.65 ϕ × 1	50T	SOLENOID WINDING
NVCC	7 → 6	0.65 ϕ × 1	6T	SOLENOID WINDING

3. Electrical Characteristic

CLOSURE	PIN
INDUCTANCE	1 - 3
LEAKAGE L	1 - 3

4. Secondary Inductor(L2) Specification

Core : Power Core 27 ϕ 16 Grade

5V : 12T (1 ϕ × 2)

10V : 27T (1.2 ϕ × 1)

Typical Performance Characteristics

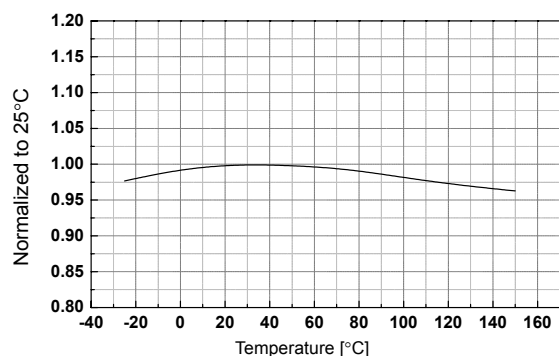


Figure 1. Operating Supply Current vs. Temp.

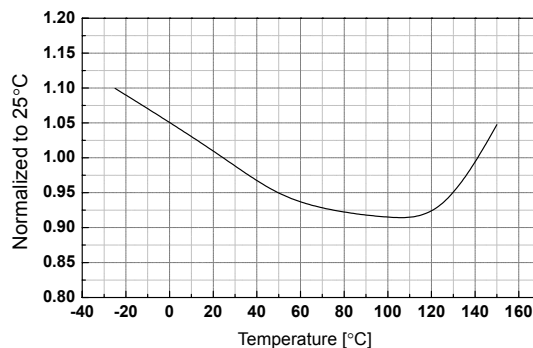


Figure 2. Start up Current vs. Temp.

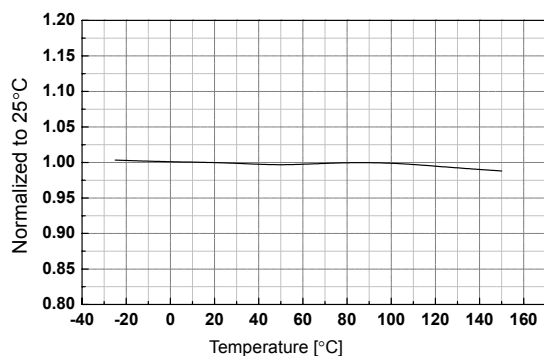


Figure 3. Start Threshold Voltage vs. Temp.

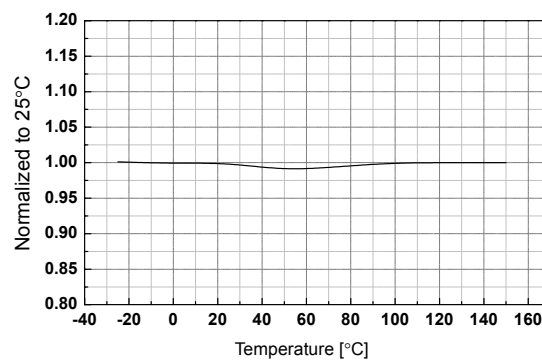


Figure 4. Stop Threshold Voltage vs. Temp.

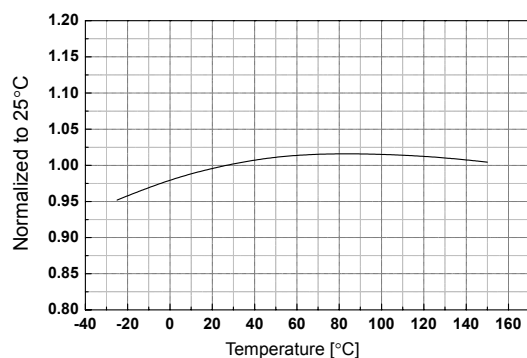


Figure 5. Operating Frequency vs. Temp.

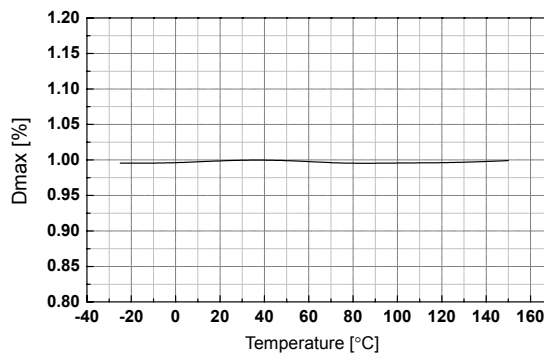


Figure 6. Maximum Duty Cycle vs. Temp.

Typical Performance Characteristics (Continued)

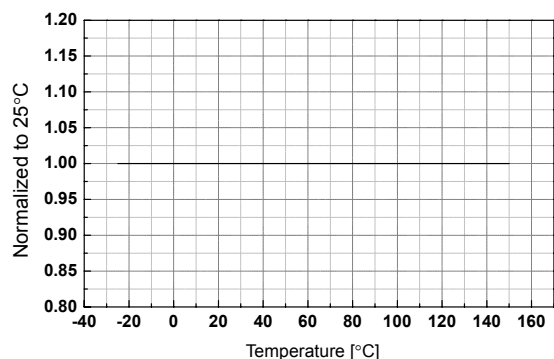


Figure 7. Minimum Duty Cycle vs. Temp.

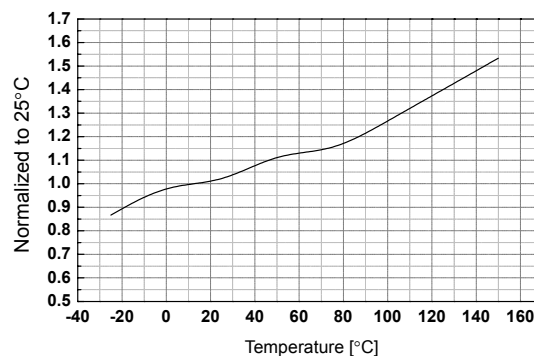


Figure 8. Feedback Offset Voltage vs. Temp.

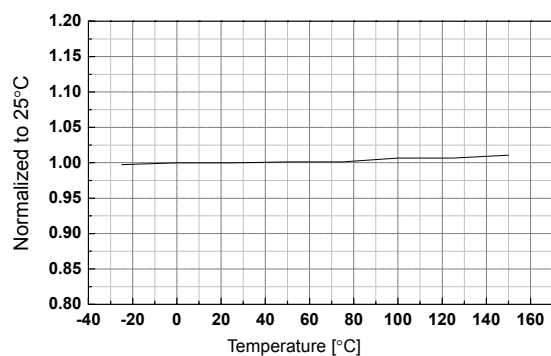


Figure 9. Shutdown Feedback Voltage vs. Temp.

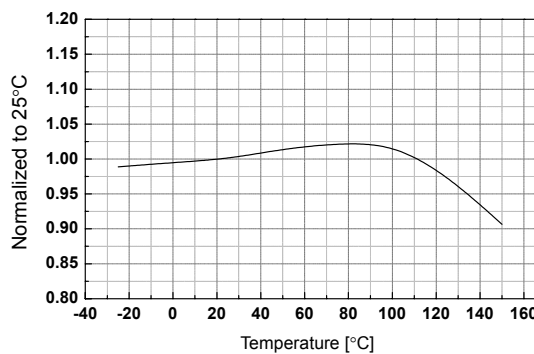


Figure 10. Shutdown Delay Current vs. Temp.

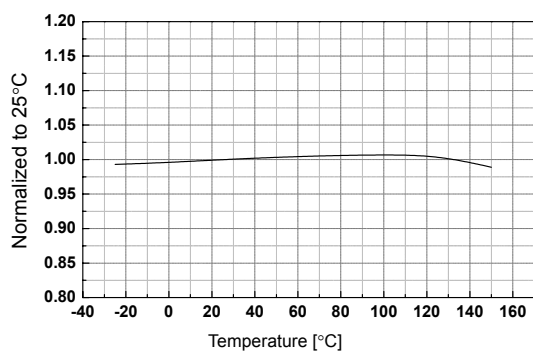


Figure 11. SoftStart Voltage vs. Temp.

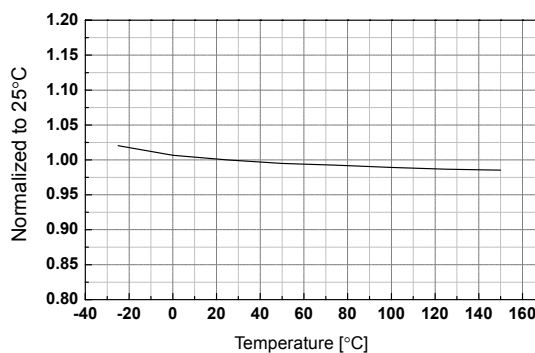


Figure 12. Over Voltage Protection vs. Temp.

Typical Performance Characteristics (Continued)

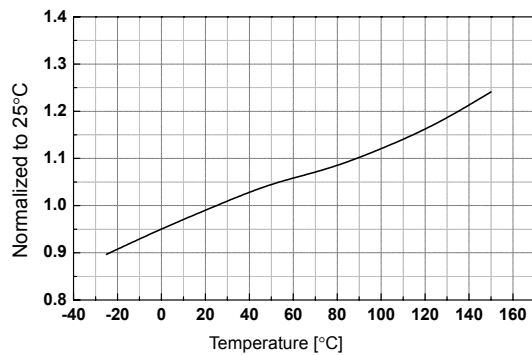


Figure 13. Feedback Sink Current vs. Temp.

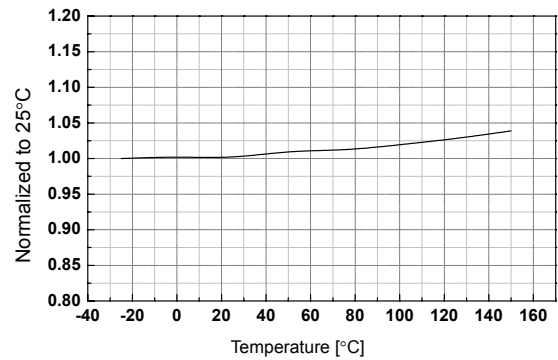


Figure 14. Peak Current vs. Temp.

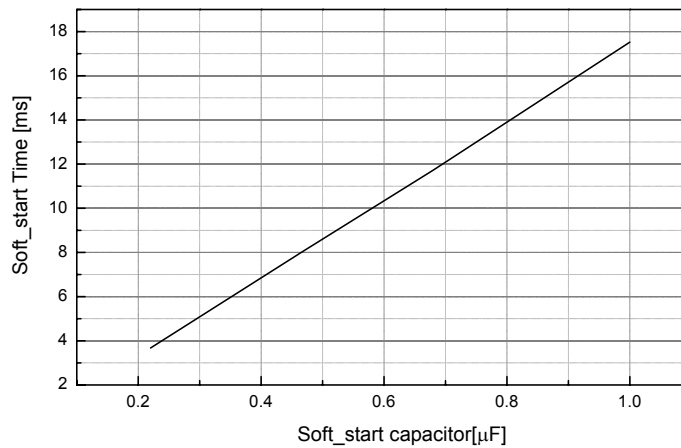
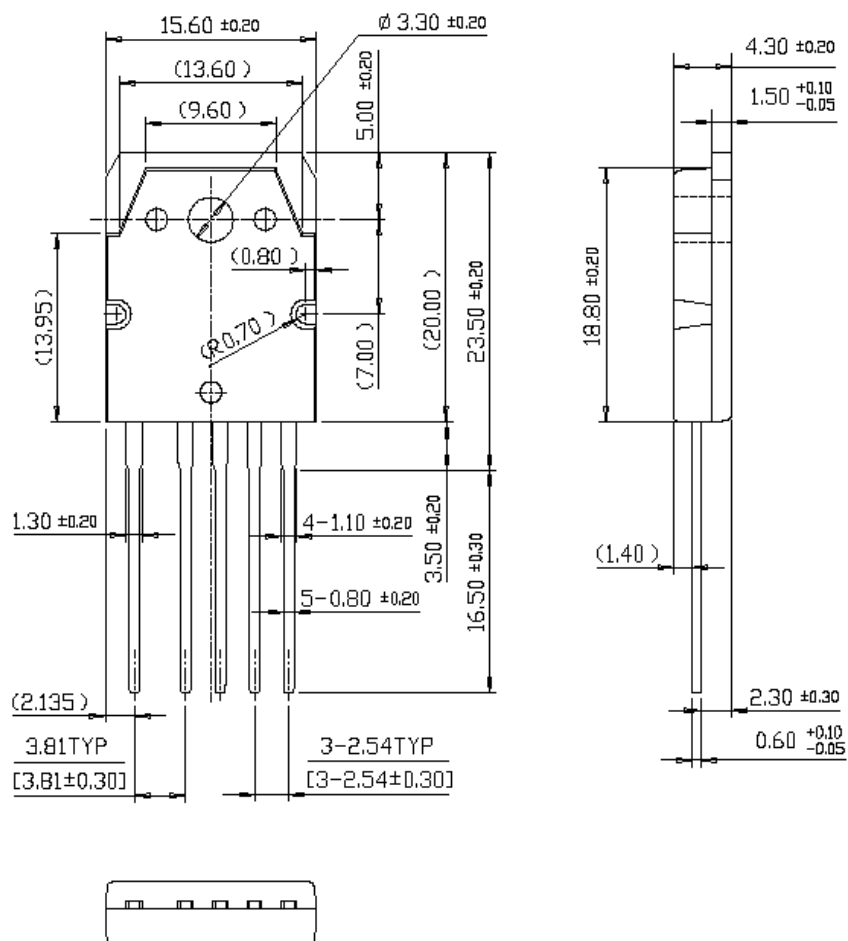


Figure 15. Soft_start Capacitor vs. Soft_start Temp.

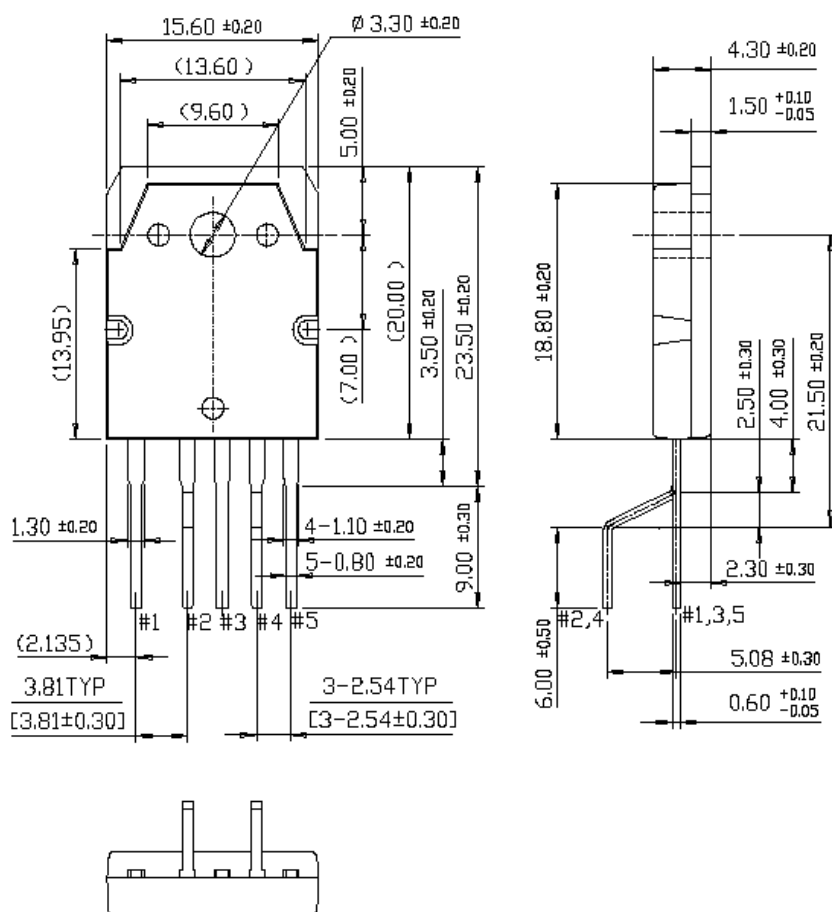
Package Dimensions

TO-3P-5L



Package Dimensions (Continued)

TO-3P-5L (Forming)



Ordering Information

Product Number	Package	Rating	Fosc
FS7M0680TU	TO-3P-5L	800V, 6A	67kHz
FS7M0680YDTU	TO-3P-5L(Forming)		

TU : Non Forming Type

YDTU : Forming type

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2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.