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## GF001H

### Green-Mode Fairchild Power Switch (FPS™)

#### Features

- Advanced Burst Mode Operation at No-Load Condition
- 700 V High-Voltage JFET Startup Circuit
- Internal Avalanche-Rugged 700 V SenseFET
- Built-in 5 ms Soft-Start
- Peak-Current-Mode Control
- Cycle-by-Cycle Current Limiting
- Leading-Edge Blanking (LEB)
- Synchronized Slope Compensation
- Frequency Modulation to Attenuating EMI
- Internal Overload / Open-Loop Protection (OLP)
- $V_{DD}$  Under-Voltage Lockout (UVLO)
- $V_{DD}$  Over-Voltage Protection (OVP)
- Internal Auto-Restart Circuit (OLP,  $V_{DD}$  OVP)
- Adjustable Peak Current Limit

#### Description

The GF001H is a next-generation, Green-Mode Fairchild Power Switch (FPS™). It integrates an advanced current-mode Pulse Width Modulator (PWM) and an avalanche-rugged 700 V SenseFET in a single package, allowing auxiliary power designs with higher standby energy efficiency, reduced size, improved reliability, and lower system cost than previous solutions.

A new frequency modulation reduces EMI emission and built-in synchronized slope compensation allows stable peak-current-mode control over a wide range of input voltage.

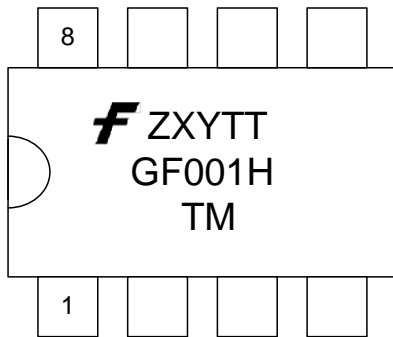
Requiring a minimum number of external components, the GF001H provides a solid platform for cost-effective flyback converter design with low standby power consumption.

#### Ordering Information

Part Number	SenseFET	Operating Temperature Range	Package	Packing Method
GF001HN	2 A 700 V	-40°C to +105°C	8-Pin, Dual Inline Package (DIP)	Tube



## Marking Information



**F** – Fairchild Logo  
**Z** – Plant Code  
**X** – 1-Digit Year Code  
**Y** – 1-Digit Week Code  
**TT** – 2-Digit Die Run Code  
**T** – Package Type (N: DIP)  
**M** – Manufacture Flow Code

Figure 3. Top Mark

## Pin Configuration

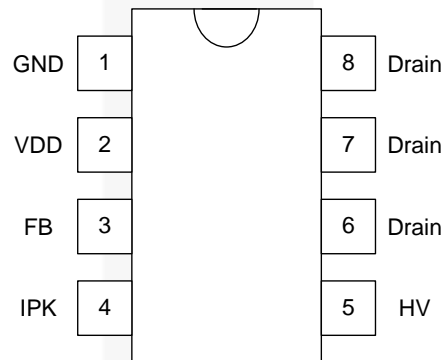


Figure 4. Pin Assignment

## Pin Definitions

Pin #	Name	Description
1	GND	<b>Ground.</b> This pin internally connects to the SenseFET source and signal ground of the PWM controller.
2	VDD	<b>Supply Voltage of the IC.</b> Typically the hold-up capacitor connects from this pin to ground. A rectifier diode in series with the transformer auxiliary winding connects to this pin to supply bias during normal operation.
3	FB	<b>Feedback.</b> The signal from the external compensation circuit connects to this pin. The PWM duty cycle is determined by comparing the signal on this pin and the internal current-sense signal.
4	IPK	<b>Adjust Peak Current.</b> Typically a resistor connects from this pin to the GND pin to program the current-limit level. The internal current source (50 $\mu$ A) introduces voltage drop across the resistor, which determines the current-limit level of pulse-by-pulse current limit.
5	HV	<b>Startup.</b> Typically, resistors in series from DC line connect to this pin to supply internal bias and to charge the external capacitor connected between the VDD pin and the GND pin during startup. This pin is also used to sense the line voltage for brownout protection.
6	Drain	<b>SenseFET Drain.</b> This pin is designed to directly drive the transformer.
7		
8		

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Symbol	Parameter	Min.	Max.	Unit
$V_{\text{DRAIN}}$	Drain Pin Voltage <sup>(5,6)</sup>		700	V
$I_{\text{DM}}$	Drain Current Pulsed <sup>(7)</sup>		8.0	A
$E_{\text{AS}}$	Single Pulsed Avalanche Energy <sup>(8)</sup>		140	mJ
$V_{\text{DD}}$	DC Supply Voltage		25	V
$V_{\text{FB}}$	FB Pin Input Voltage	-0.3	6.0	V
$V_{\text{IPK}}$	IPK Pin Input Voltage	-0.3	6.0	V
$V_{\text{HV}}$	HV Pin Input Voltage		700	V
$P_{\text{D}}$	Power Dissipation ( $T_{\text{A}} < 50^{\circ}\text{C}$ )		1.5	W
$T_{\text{J}}$	Operating Junction Temperature	-40	Internally Limited <sup>(9)</sup>	$^{\circ}\text{C}$
$T_{\text{STG}}$	Storage Temperature Range	-55	+150	$^{\circ}\text{C}$
$T_{\text{L}}$	Lead Soldering Temperature (Wave Soldering or IR, 10 Seconds)		+260	$^{\circ}\text{C}$

### Notes:

- All voltage values, except differential voltages, are given with respect to the network ground terminal.
- Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.
- Non-repetitive rating: pulse width is limited by the maximum junction temperature.
- $L = 51 \text{ mH}$ , starting  $T_{\text{J}} = 25^{\circ}\text{C}$ .
- Internally limited by Over-Temperature Protection(OTP). Refer to  $T_{\text{OTP}}$ .

## Thermal Resistance Table

Symbol	Parameter	Value	Unit
$\theta_{\text{JA}}$	Junction-to-Air Thermal Resistance	86	$^{\circ}\text{C/W}$
$\psi_{\text{JT}}$	Junction-to-Package Thermal Resistance <sup>(10)</sup>	20	$^{\circ}\text{C/W}$

### Note:

- Measured on the package top surface.

## ESD Capability

Symbol	Parameter	Value	Unit
ESD	Human Body Model, JESD22-A114 <sup>(11)</sup>	All pins excluding HV pin	7
		All pins including HV pin	3
	Charged Device Model, JESD22-C101 <sup>(11)</sup>	All pins excluding HV pin	2
		All pins including HV pin	2

### Note:

- Meets JEDEC standards JESD 22-A114 and JESD 22-C101.

## Electrical Characteristics

$V_{DD}=15\text{ V}$ , and  $T_A=25^\circ\text{C}$  unless otherwise specified.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
<b>SenseFET Section<sup>(12)</sup></b>						
$BV_{DSS}$	Drain-Source Breakdown Voltage	$V_{DS} = 700\text{ V}$ , $V_{GS} = 0\text{ V}$	700			V
$I_{DSS}$	Zero-Gate-Voltage Drain Current	$V_{DS} = 700\text{ V}$ , $V_{GS} = 0\text{ V}$			50	$\mu\text{A}$
		$V_{DS} = 560\text{ V}$ , $V_{GS} = 0\text{ V}$ , $T_C = 125^\circ\text{C}$			200	
$R_{DS(ON)}$	Drain-Source On-State Resistance <sup>(12)</sup>	$V_{GS} = 10\text{ V}$ , $I_D = 0.5\text{ A}$		6.0	7.2	$\Omega$
$C_{ISS}$	Input Capacitance	$V_{GS} = 0\text{ V}$ , $V_{DS} = 25\text{ V}$ , $f = 1\text{ MHz}$		550	715	pF
$C_{OSS}$	Output Capacitance	$V_{GS} = 0\text{ V}$ , $V_{DS} = 25\text{ V}$ , $f = 1\text{ MHz}$		38	50	pF
$C_{RSS}$	Reverse Transfer Capacitance	$V_{GS} = 0\text{ V}$ , $V_{DS} = 25\text{ V}$ , $f = 1\text{ MHz}$		17	26	pF
$t_{d(on)}$	Turn-On Delay	$V_{DS} = 350\text{ V}$ , $I_D = 1.0\text{ A}$		20	50	ns
$t_r$	Rise Time	$V_{DS} = 350\text{ V}$ , $I_D = 1.0\text{ A}$		15	40	ns
$t_{d(off)}$	Turn-Off Delay	$V_{DS} = 350\text{ V}$ , $I_D = 1.0\text{ A}$		55	120	ns
$t_f$	Fall Time	$V_{DS} = 350\text{ V}$ , $I_D = 1.0\text{ A}$		25	60	ns
<b>Control Section</b>						
<b>VDD Section</b>						
$V_{DD-ON}$	UVLO Start Threshold Voltage		11	12	13	V
$V_{DD-OFF1}$	UVLO Stop Threshold Voltage		5	6	7	V
$V_{DD-OFF2}$	$I_{DD-OLP}$ Enable Threshold Voltage		8	9	10	V
$V_{DD-OLP}$	$V_{DD}$ Voltage Threshold for HV Startup Turn-On at Protection Mode		5	6	7	V
$I_{DD-ST}$	Startup Supply Current	$V_{DD-ON} - 0.16\text{ V}$			30	$\mu\text{A}$
$I_{DD-OP1}$	Operating Supply Current with Normal Switching Operation	$V_{DD}=15\text{ V}$ , $V_{FB}=3\text{ V}$			3.8	mA
$I_{DD-OP2}$	Operating Supply Current without Switching Operation	$V_{DD}=15\text{ V}$ , $V_{FB}=1\text{ V}$			1.8	mA
$I_{DD-OLP}$	Internal Sinking Current	$V_{DD-OLP} + 0.1\text{ V}$	30	60	90	$\mu\text{A}$
$V_{DD-OVP}$	$V_{DD}$ Over-Voltage Protection		23	24	25	V
$t_{D-VDDOVP}$	$V_{DD}$ Over-Voltage Protection Debounce Time		40	105	170	$\mu\text{s}$
<b>HV Section</b>						
$I_{HV}$	Supply Current Drawn from HV Pin	$HV=120\text{ V}_{DC}$ , $V_{DD}=0\text{ V}$ with $10\text{ }\mu\text{F}$	1.5		5.0	mA
$V_{HV}$	Minimum HV Voltage for $V_{DD}$ being charged to $V_{DD-ON}$	$R_{HV}=0\text{ }\Omega$ , $T_A=-40^\circ\text{C}$ to $105^\circ\text{C}$	30			V
$I_{HV-LC}$	Leakage Current after Startup	$HV=700\text{ V}$ , $V_{DD}=V_{DD-OFF1}+1\text{ V}$			10	$\mu\text{A}$
$V_{DC-ON}$	Brown-in Threshold Level ( $V_{DC}$ )	DC Voltage Applied to HV Pin Through $200\text{ k}\Omega$ Resistor	104	114	124	V
$V_{DC-OFF}$	Brownout Threshold Level ( $V_{DC}$ )		89	99	109	V
$t_{UVP}$	Brownout Protection Time		0.8	1.2	1.6	s

Continued on the following page...

**Electrical Characteristics** (Continued)V<sub>DD</sub>=15 V, T<sub>A</sub>=25°C unless otherwise specified.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
<b>Oscillator Section</b>						
f <sub>OSC</sub>	Frequency in Nominal Mode	Center Frequency	94	100	106	kHz
f <sub>M</sub>	Frequency Modulation			±6		kHz
f <sub>OSC-G</sub>	Green-Mode Frequency		20	23	26	kHz
f <sub>DV</sub>	Frequency Variation vs. V <sub>DD</sub> Deviation	V <sub>DD</sub> =11 V to 22 V			5	%
f <sub>DT</sub>	Frequency Variation vs. Temperature Deviation <sup>(12)</sup>	T <sub>A</sub> =-40 °C to 105 °C			5	%
<b>Feedback Input Section</b>						
A <sub>V</sub>	Internal Voltage Dividing Factor of FB Pin <sup>(12)</sup>		1/4.5	1/4.0	1/3.5	V/V
Z <sub>FB</sub>	Pull-Up Impedance of FB Pin		15	21	27	kΩ
V <sub>FB-OPEN</sub>	FB Pin Pull-Up Voltage	FB Pin Open	5.2	5.4	5.6	V
V <sub>FB-OLP</sub>	FB Voltage Threshold to Trigger Open-Loop Protection		4.3	4.6	4.9	V
t <sub>D-OLP</sub>	Delay of FB Pin Open-Loop Protection		46	56	66	ms
V <sub>FB-N</sub>	FB Voltage Threshold to Exit Green Mode	V <sub>FB</sub> is Rising	2.4	2.6	2.8	V
V <sub>FB-G</sub>	FB Voltage Threshold to Enter Green Mode	V <sub>FB</sub> is Falling		V <sub>FB-N</sub> -0.2		V
V <sub>FB-ZDC</sub>	FB Voltage Threshold to Enter Zero-Duty State	V <sub>FB</sub> is Falling	1.1	1.2	1.3	V
V <sub>FB-ZDCR</sub>	FB Voltage Threshold to Exit Zero-Duty State	V <sub>FB</sub> is Rising		V <sub>FB-ZDC</sub> +0.1		V
<b>IPK Pin Section</b>						
V <sub>IPK-OPEN</sub>	IPK Pin Open Voltage		3.0	3.5	4.0	V
V <sub>IPK-H</sub>	Internal Upper Clamping Voltage of IPK Pin <sup>(12)</sup>				3	V
V <sub>IPK-L</sub>	Internal Lower Clamping Voltage of IPK Pin <sup>(12)</sup>		1.5			V
I <sub>PK</sub>	Internal Current Source of IPK Pin	T <sub>A</sub> =-40 °C to 105 °C, V <sub>IPK</sub> =2.25 V	45	50	55	μA
I <sub>LMT-H</sub>	Flat Threshold Level of Current Limit for the Highest IPK Level	V <sub>IPK</sub> =3 V	0.90	1.00	1.10	A
I <sub>LMT-L</sub>	Flat Threshold Level of Current Limit for the Lowest IPK Level	V <sub>IPK</sub> =1.5 V	0.45	0.50	0.55	A
<b>Current-Sense Section<sup>(13)</sup></b>						
t <sub>PD</sub>	Current Limit Turn-Off Delay <sup>(14)</sup>			100	200	ns
t <sub>LEB</sub>	Leading-Edge Blanking Time <sup>(14)</sup>		160	210	260	ns
t <sub>SS</sub>	Soft-Start Time <sup>(12)</sup>			5		ms
<b>GATE Section<sup>(13)</sup></b>						
DCY <sub>MAX</sub>	Maximum Duty Cycle		70			%
<b>Over Temperature Protection Section (OTP)</b>						
T <sub>OTP</sub>	Junction Temperature to Trigger OTP <sup>(12)</sup>		140			°C

**Notes:**

12. Guaranteed by design; not 100% tested in production.
13. Pulse test: pulse width ≤ 300 μs, duty ≤ 2%.
14. These parameters, although guaranteed, are tested in wafer-sort process.

## Typical Characteristics

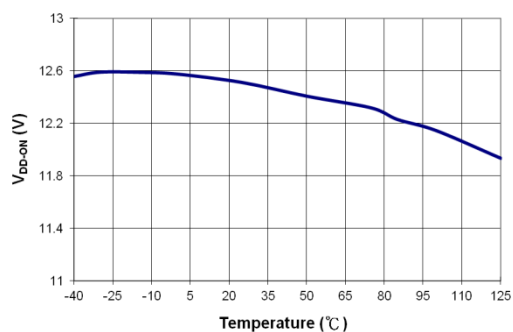


Figure 5. V<sub>DD-ON</sub> vs. Temperature

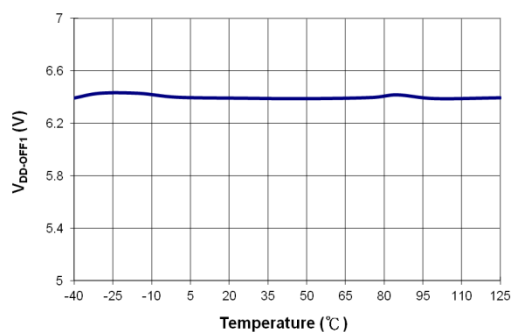


Figure 6. V<sub>DD-OFF1</sub> vs. Temperature

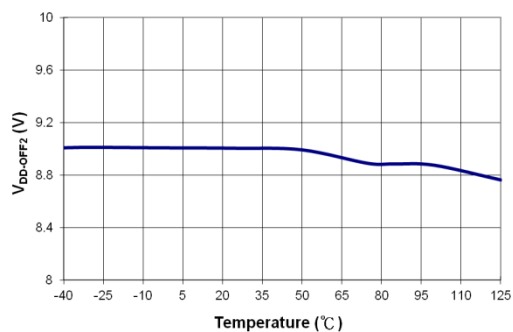


Figure 7. V<sub>DD-OFF2</sub> vs. Temperature

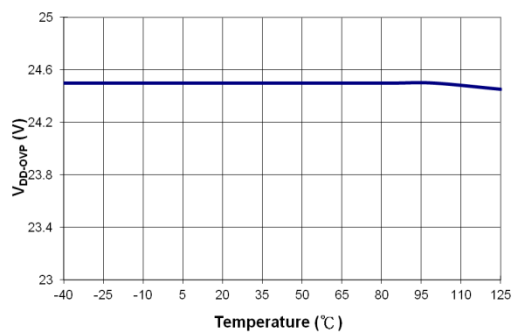


Figure 8. V<sub>DD-OVP</sub> vs. Temperature

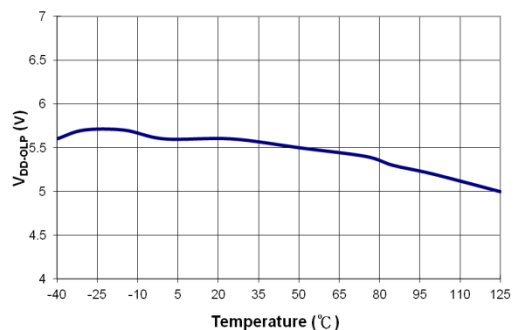


Figure 9. V<sub>DD-OLP</sub> vs. Temperature

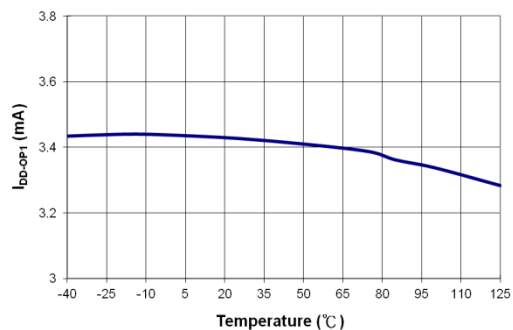


Figure 10. I<sub>DD-OP1</sub> vs. Temperature

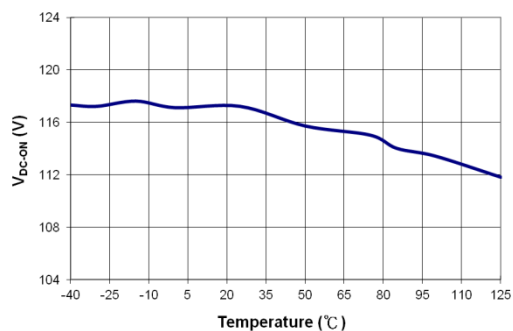


Figure 11. V<sub>DC-ON</sub> vs. Temperature

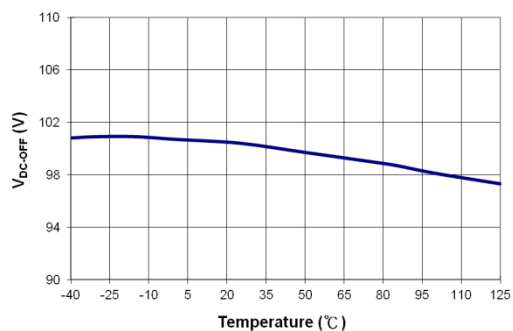


Figure 12. V<sub>DC-OFF</sub> vs. Temperature



## Typical Characteristics (Continued)

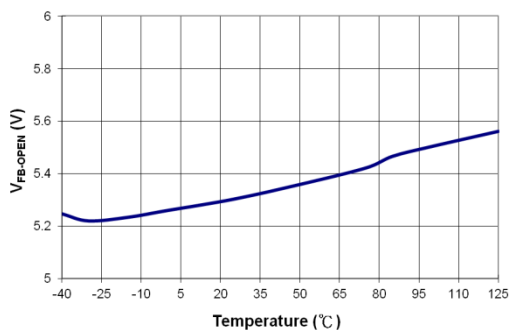


Figure 13. V<sub>FB-OPEN</sub> vs. Temperature

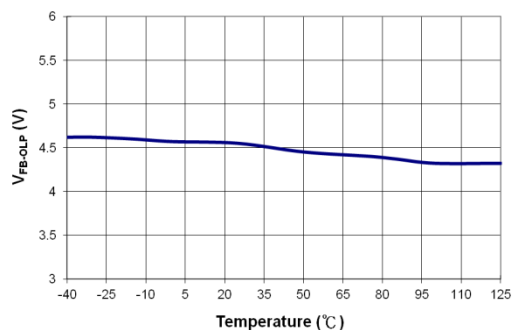


Figure 14. V<sub>FB-OLP</sub> vs. Temperature

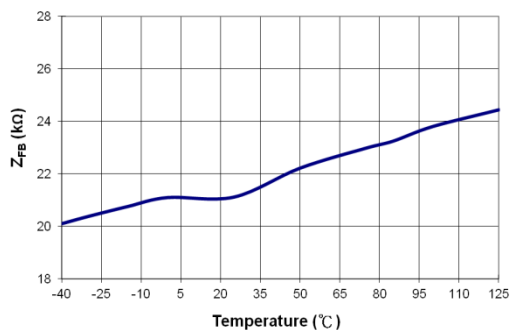


Figure 15. Z<sub>FB</sub> vs. Temperature

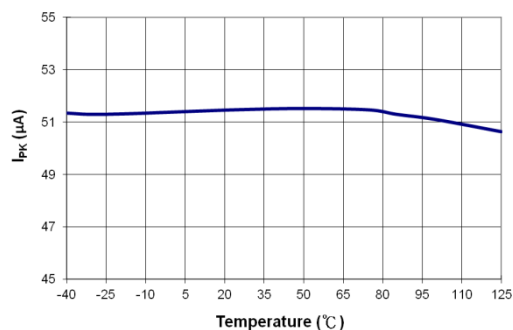


Figure 16. I<sub>PK</sub> vs. Temperature

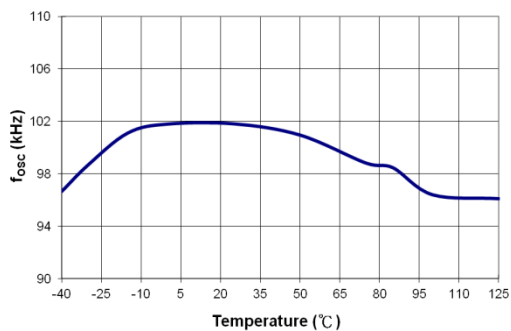


Figure 17. f<sub>osc</sub> vs. Temperature

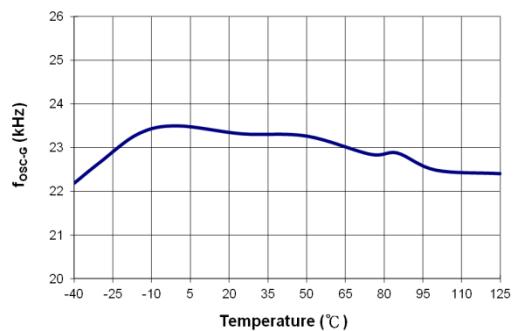


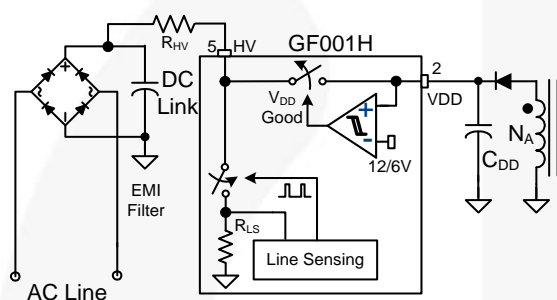
Figure 18. f<sub>osc-G</sub> vs. Temperature

## Functional Description

## Startup Operation

The HV pin is typically connected to the DC link input through one resistor ( $R_{HV}$ ), as shown in Figure 19. When the DC input voltage is applied, the  $V_{DD}$  hold-up capacitor is charged by the line voltage through the resistor. After  $V_{DD}$  voltage reaches the turn-on threshold voltage ( $V_{DD-ON}$ ), the startup circuit charging the  $V_{DD}$  capacitor is switched off and  $V_{DD}$  is supplied by the auxiliary winding of the transformer. Once the GF001H starts, it continues operation until  $V_{DD}$  drops below 6 V ( $V_{DD-OFF1}$ ). The IC startup time with a given DC input voltage is:

$$t_{STARTUP} = R_{HV} \cdot C_{DD} \cdot \ln \frac{V_{DC}}{V_{DC} - V_{DD-ON}} \quad (1)$$



**Figure 19. Startup Circuit**

## Brown-in/out Function

The HV pin can detect the DC link voltage using a switched voltage divider that consists of external resistor ( $R_{HV}$ ) and internal resistor ( $R_{LS}$ ), as shown in Figure 19. The internal DC input voltage sensing circuit detects the input voltage using a sampling circuit and peak-detection circuit. Since the voltage divider causes power consumption when it is switched on, the switching is driven by a signal with a very narrow pulse width to minimize power loss. The sampling frequency is adaptively changed according to the load condition to minimize power consumption in light-load condition.

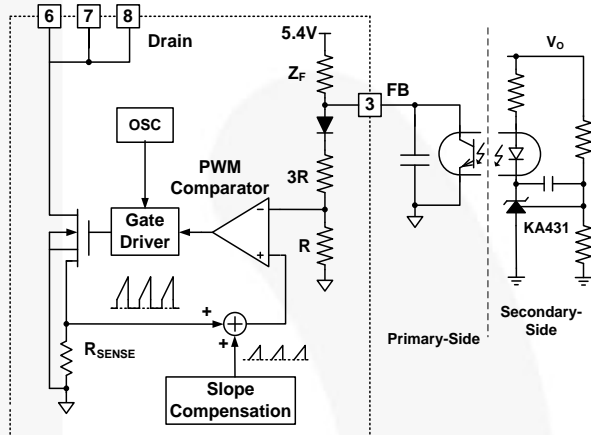
Based on the detected DC input voltage, brown-in and brownout thresholds are determined. Since the internal resistor ( $R_{LS}$ ) of the voltage divider is much smaller than  $R_{HV}$ , the thresholds are given:

$$V_{BROWN-IN} = \frac{R_{HV}}{200k} \cdot V_{DC\_ON} \quad (2)$$

$$V_{BROWNOUT} = \frac{R_{HV}}{200k} \cdot V_{DC\_OFF} \quad (3)$$

## PWM Control

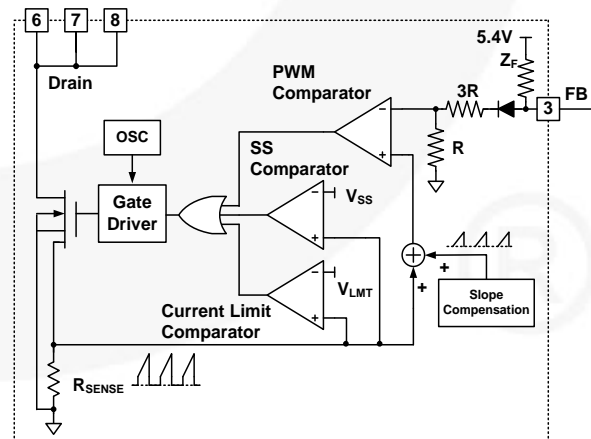
The GF001H employs current-mode control, as shown in Figure 20. An opto-coupler (such as the H11A817A) and shunt regulator (such as the KA431) are typically used to implement the feedback network. Comparing the feedback voltage with the voltage across the  $R_{sense}$  resistor makes it possible to control the switching duty cycle. A synchronized positive slope is added to the SenseFET current information to guarantee stable current-mode control over a wide range of input voltage. The built-in slope compensation stabilizes the current loop and prevents sub-harmonic oscillation.



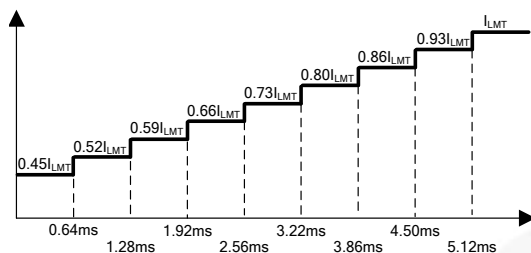
### Figure 20. Current Mode Control

## Soft-Start

The GF001H has an internal soft-start circuit that progressively increases the pulse-by-pulse current limit level of MOSFET during startup to establish the correct working conditions for transformers and capacitors, as shown in Figure 21. The current limit levels have nine steps, as shown in Figure 22. This prevents transformer saturation and reduces stress on the secondary diode during startup.



### Figure 21. Soft-Start and Current-Limit Circuit



**Figure 22. Current Limit Variation During Soft-Start**

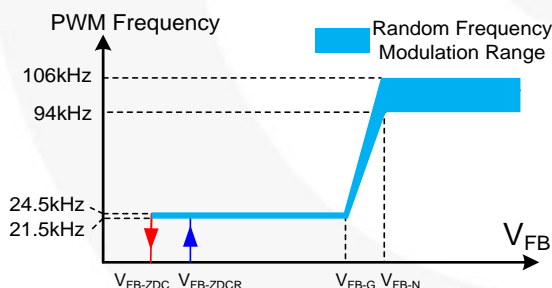
### Adjustable Peak Current Limit

The peak current limit is programmable using a resistor on the IPK pin. The internal current 50  $\mu$ A source for the IPK pin generates voltage drop across the resistor. The voltage of the IPK pin determines the current-limit level. Since the upper and lower clamping voltage of the IPK pin are 3 V and 1.5 V, respectively; the suggested resistor value is from 30 k $\Omega$  to 60 k $\Omega$ .

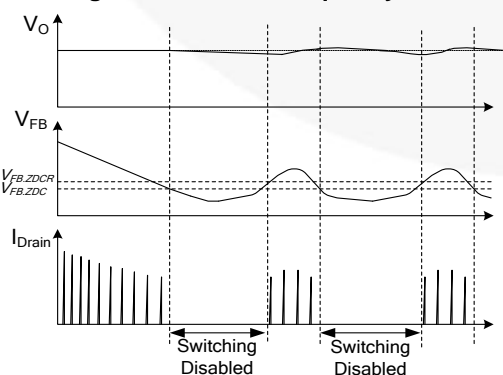
### Green Mode

As output load condition is reduced, the switching loss becomes the largest power loss factor. GF001H uses the FB pin voltage to monitor output load condition. As output load decreases,  $V_{FB}$  decreases and switching frequency declines, shown in Figure 23. Once  $V_{FB}$  falls to 2.4 V, the switching frequency varies between 21.5 kHz and 24.5 kHz before Burst Mode operation. At Burst Mode operation, random frequency fluctuation still functions.

As  $V_{FB}$  falls below  $V_{FB-ZDC}$ , the GF001H enters Burst Mode, where PWM switching is disabled. The output voltage starts to drop, causing the feedback voltage to rise. Once  $V_{FB}$  rises above  $V_{FB-ZDCR}$ , switching resumes. Burst Mode alternately enables and disables switching, thereby reducing switching loss to reduce power consumption, shown in Figure 24.



**Figure 23. PWM Frequency**



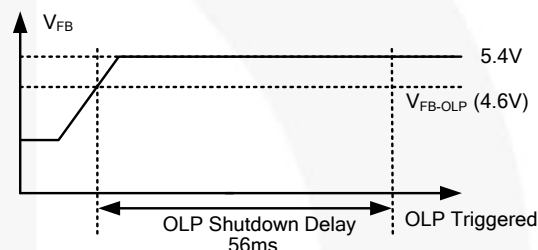
**Figure 24. Burst-Mode Operation**

### Protections

The GF001H provides protection functions that include Overload / Open-Loop Protection (OLP) and Over-Voltage Protection (OVP). All the protections are implemented as Auto-Restart Mode. Once the fault condition is detected, switching is terminated and the SenseFET remains off, this causes  $V_{DD}$  to fall. When  $V_{DD}$  falls to 6 V, the protection is reset and HV startup circuit charges  $V_{DD}$  up to 12 V voltage, allowing restart.

#### Open-Loop / Overload Protection (OLP)

Because of the pulse-by-pulse current-limit capability, the maximum peak current through the SenseFET is limited and maximum input power is limited. If the output consumes more than the limited maximum power, the output voltage ( $V_O$ ) drops below the set voltage. The current through the opto-coupler LED and the transistor become virtually zero and FB voltage is pulled HIGH, shown in Figure 25. If feedback voltage is above 4.6 V for longer than 56 ms, OLP is triggered. This protection is also triggered when the feedback loop is open due to a soldering defect.



**Figure 25. OLP Operation**

#### $V_{DD}$ Over-Voltage Protection (OVP)

If the secondary-side feedback circuit malfunctions or a solder defect causes an opening in the feedback path, the current through the opto-coupler transistor becomes virtually zero. Feedback voltage climbs in a similar manner to the overload situation, forcing the preset maximum current to be supplied to the SMPS until the overload protection triggers. Since more energy than required is provided to the output, the output voltage may exceed the rated voltage before the overload protection triggers, resulting in the breakdown of the devices in the secondary side. To prevent this situation, an OVP circuit is employed. Since  $V_{DD}$  voltage is proportional to the output voltage by the transformer coupling, the over-voltage of output is indirectly detected using  $V_{DD}$  voltage. The OVP is triggered when  $V_{DD}$  voltage reaches 24 V. Debounce time (typically 105  $\mu$ s) is applied to prevent false triggering by switching noise.

#### Two-Level UVLO

Since all the protections of the GF001H are auto-restart, the power supply repeats shutdown and restart until the fault condition is removed. GF001H has two-level UVLO, which is enabled when protection is triggered, to delay the re-startup by slowing down the discharge of  $V_{DD}$ . This effectively reduces the input power of the power supply during the fault condition, minimizing the voltage/current stress of the switching devices. Figure 26 shows the normal UVLO operation and two-step UVLO operation. When  $V_{DD}$  drops to 6 V without triggering the protection, PWM stops switching and  $V_{DD}$

is charged up by the HV startup circuit. Meanwhile, when the protection is triggered, GF001H has a different  $V_{DD}$  discharge profile. Once the protection is triggered, the IC stops switching and  $V_{DD}$  drops. When  $V_{DD}$  drops to 9 V, the operating current becomes very small and  $V_{DD}$  is slowly discharged. When  $V_{DD}$  is naturally discharged down to 6 V, the protection is reset and  $V_{DD}$  is charged up by the HV startup circuit. Once  $V_{DD}$  reaches 12 V, the IC resumes switching operation.

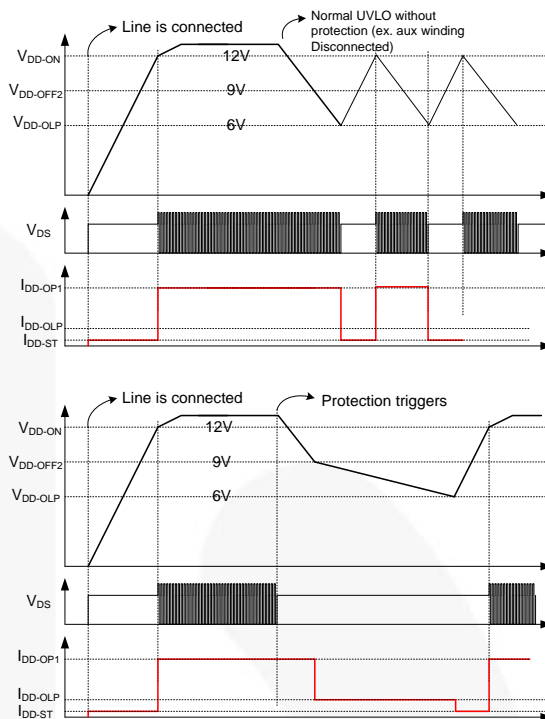
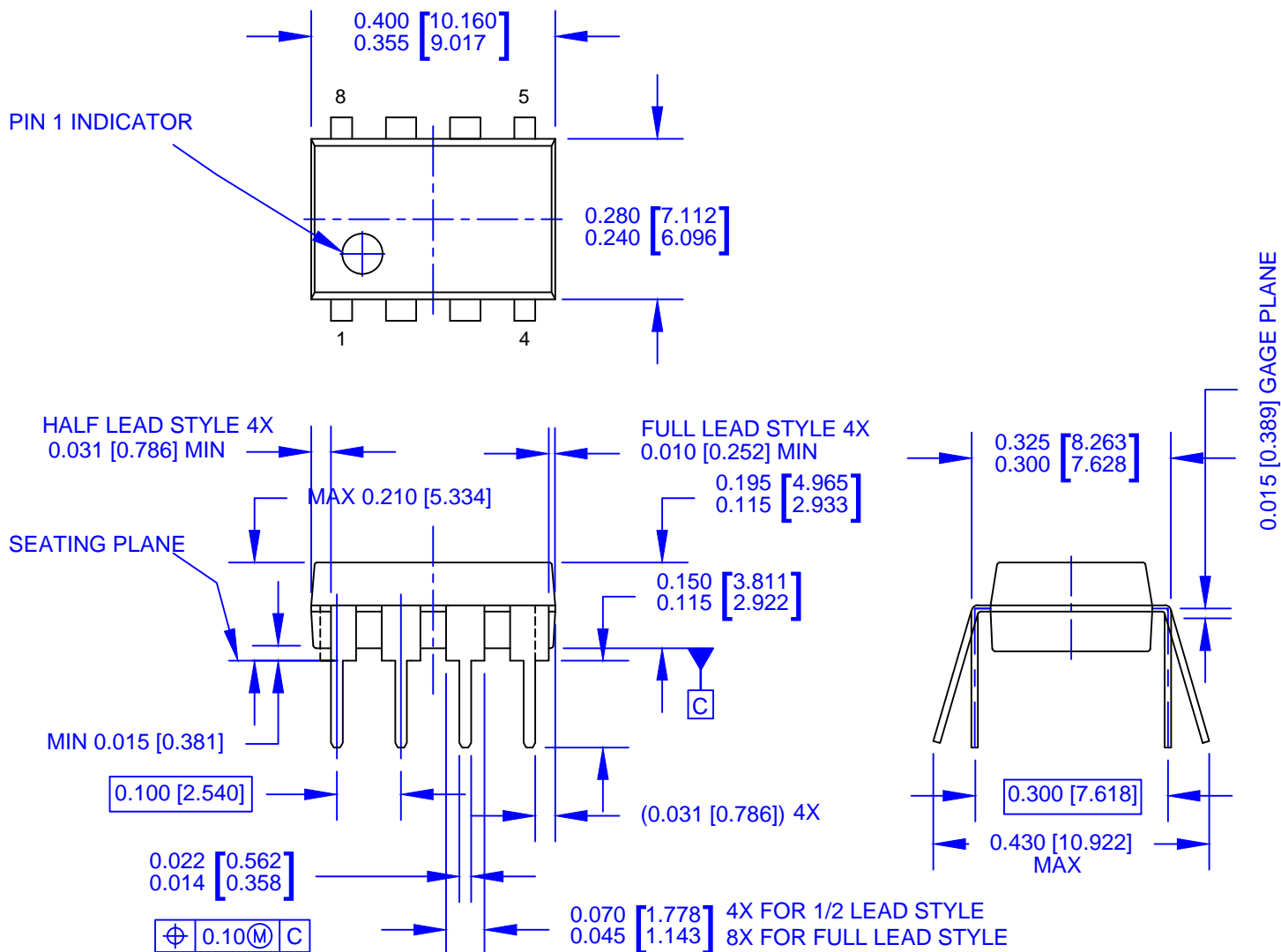


Figure 26. Two-Level UVLO



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