

# FAN302HLMY\_F117

## PWM Controller for Low Standby Power Battery-Charger Applications — mWSaver™ Technology

### Features

- mWSaver™ Technology Provides Industry's Best-in-Class Standby Power
  - Ultra Low Power Consumption at No Load (<10 mW at 230 V<sub>AC</sub>)
  - Proprietary 500V High-Voltage JFET Startup Reduces Startup Resistor Loss
  - Low Operation Current in Burst Mode: 350 µA Maximum
- Constant-Current (CC) Control without Secondary-Feedback Circuitry
- Fixed PWM Frequency at 85kHz with Frequency Hopping to Reduce EMI
- High-Voltage Startup
- Low Operating Current: 3.5 mA
- Peak-Current-Mode Control with Slope Compensation
- Cycle-by-Cycle Current Limiting
- V<sub>DD</sub> Over-Voltage Protection (Auto-Restart)
- V<sub>S</sub> Over-Voltage Protection (Latch Mode)
- V<sub>DD</sub> Under-Voltage Lockout (UVLO)
- Gate Output Maximum Voltage Clamped at 15 V
- Fixed Over-Temperature Protection (Latch Mode)
- Available in an 8-Lead SOIC Package

### Applications

- Battery Chargers for Cellular Phones, Cordless Phones, PDAs, Digital Cameras, and Power Tools
- Replaces Linear Regulators and RCC SMPS

### Description

The FAN302HLMY\_F117 advanced PWM controller significantly simplifies isolated power supply design that requires CC regulation of the output. The output current is precisely estimated with information in the primary side of the transformer and controlled with an internal compensation circuit. This removes the output current sensing loss and eliminates all external Control Circuitry (CC). The Green-Mode function, with an extremely low operating current (200 µA) in Burst Mode, maximizes the light-load efficiency, enabling conformance to worldwide Standby Mode efficiency guidelines.

Integrated protections include two-level pulse-by-pulse current limit, Over-Voltage Protection (OVP), brownout protection, and Over-Temperature Protection (OTP).

Compared with a conventional approach using an external control circuit in the secondary side for CC regulation, the FAN302HLMY\_F117 can reduce total cost, component count, size, and weight; while simultaneously increasing efficiency, productivity, and system reliability.

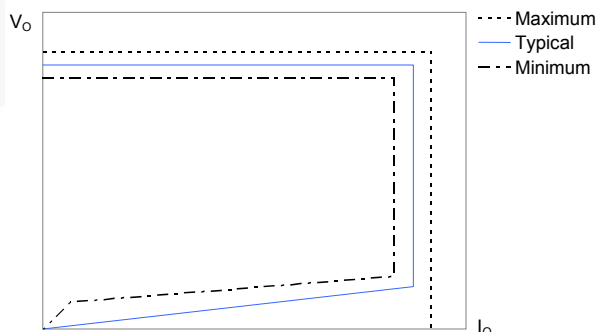


Figure 1. Typical Output V-I Characteristic

### Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FAN302HLMY_F117	-40°C to +105°C	8-Lead, Small Outline Package (SOIC), JEDEC MS-012, .150-Inch Narrow Body	Tape & Reel

## Application Diagram

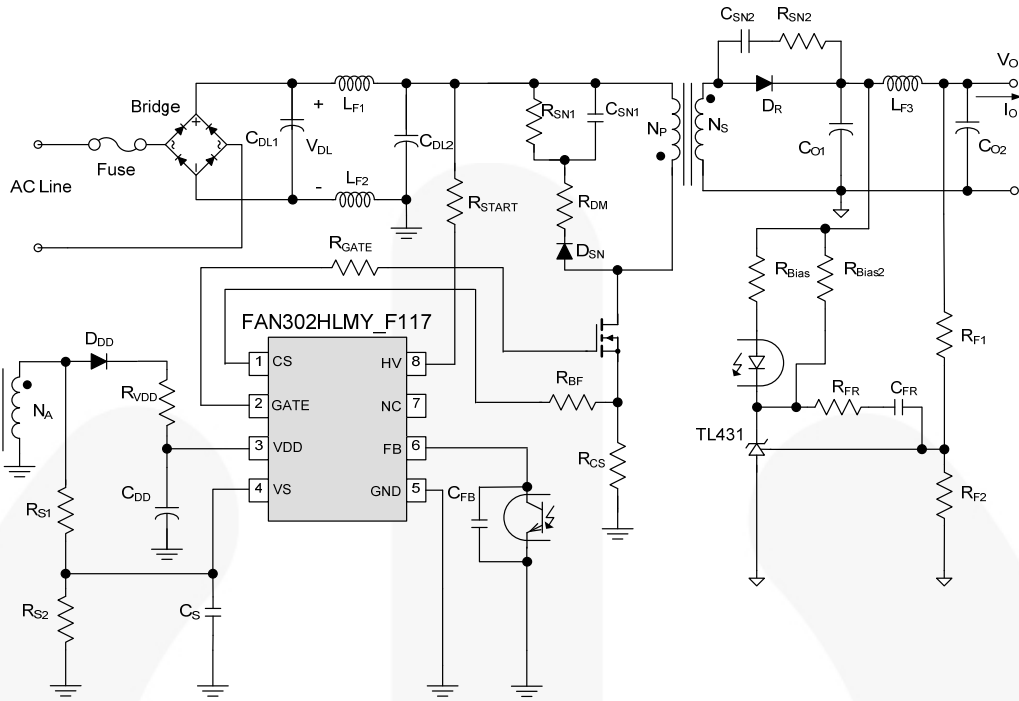


Figure 2. Typical Application

## Internal Block Diagram

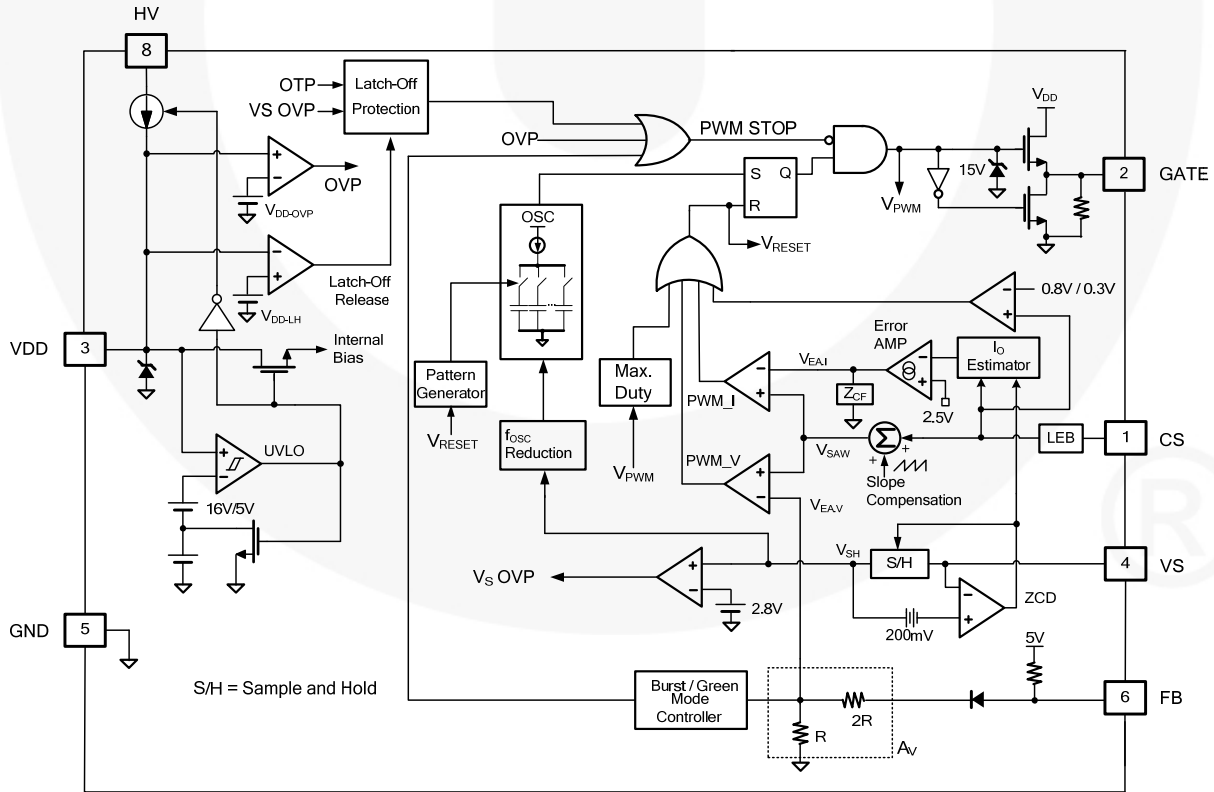
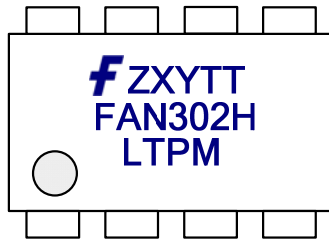


Figure 3. Functional Block Diagram

## Marking Information



F: Fairchild Logo  
 Z: Assembly Plant Code  
 X: Year Code  
 Y: Week Code  
 TT: Die Run Code  
 T: M=SOIC  
 P: Y= Green Package  
 M: Manufacture Flow Code

Figure 4. Top Mark

## Pin Configuration

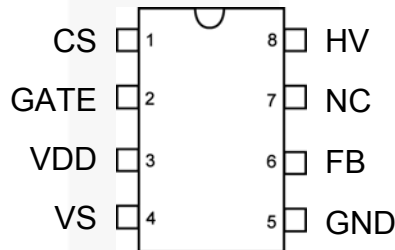


Figure 5. Pin Assignments

## Pin Definitions

Pin #	Name	Description
1	CS	<b>Current Sense.</b> This pin connects a current-sense resistor to sense the MOSFET current for Peak-Current-Mode control for output regulation. The current-sense information is also used to estimate the output current for CC regulation.
2	GATE	<b>PWM Signal Output.</b> This pin has an internal totem-pole output driver to drive the power MOSFET. It is internally clamped at 15 V.
3	VDD	<b>Power Supply.</b> IC operating current and MOSFET driving current are supplied through this pin. This pin is typically connected to an external $V_{DD}$ capacitor.
4	VS	<b>Voltage Sense.</b> This pin detects the output voltage information and diode current discharge time based on the voltage of the auxiliary winding.
5	GND	<b>Ground</b>
6	FB	<b>Feedback.</b> Typically, an opto-coupler is connected to this pin to provide feedback information to the internal PWM comparator. This feedback is used to control the duty cycle in CV regulation.
7	NC	No Connect
8	HV	<b>High Voltage.</b> This pin connects to the DC bus for high-voltage startup.

## 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 <sub>HV</sub>	HV Pin Input Voltage		500	V	
V <sub>VDD</sub>	DC Supply Voltage <sup>(1,2)</sup>		30	V	
V <sub>VS</sub>	VS Pin Input Voltage	-0.3	7.0	V	
V <sub>CS</sub>	CS Pin Input Voltage	-0.3	7.0	V	
V <sub>FB</sub>	FB Pin Input Voltage	-0.3	7.0	V	
P <sub>D</sub>	Power Dissipation (T <sub>A</sub> =25°C)		660	mW	
θ <sub>JA</sub>	Thermal Resistance (Junction-to-Air)		150	°C/W	
θ <sub>JC</sub>	Thermal Resistance (Junction-to-Case)		39	°C/W	
T <sub>J</sub>	Operating Junction Temperature	-40	+150	°C	
T <sub>STG</sub>	Storage Temperature Range	-55	+150	°C	
T <sub>L</sub>	Lead Temperature, (Wave Soldering or IR, 10 Seconds)		+260	°C	
ESD	Electrostatic Discharge Capability	Human Body Model, JEDEC:JESD22_A114 (Except HV Pin) <sup>(3)</sup>		5000	V
		Charged Device Model, JEDEC:JESD22_C101 (Except HV Pin) <sup>(3)</sup>		1500	

### Notes:

- All voltage values, except differential voltages, are given with respect to GND pin.
- Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.
- ESD ratings including the HV pin: HBM=400 V, CDM=750 V.

## Electrical Characteristics

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

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit	
<b>HV Section</b>							
$V_{HV-MIN}$	Minimum Startup Voltage on HV Pin				50	V	
$I_{HV}$	Supply Current Drawn from HV Pin	$V_{HV}=100\text{ V}$ , $V_{DD}=0\text{ V}$ , Controller Off	0.8	1.5	5.0	mA	
$I_{HV-LC}$	Leakage Current Drawn from HV Pin	$V_{HV}=500\text{ V}$ , $V_{DD}=15\text{ V}$ (Controller On with Auxiliary Supply)		0.8	3.0	$\mu\text{A}$	
<b>V<sub>DD</sub> Section</b>							
$V_{OP}$	Continuous Operation Voltage	Limited by $V_{DD}$ Over-Voltage Protection (OVP)			25	V	
$V_{DD-ON}$	Turn-On Threshold Voltage	$V_{DD}$ Rising	15	16	17	V	
$V_{DD-OFF}$	Turn-Off Threshold Voltage	$V_{DD}$ Falling	4.7	5.0	5.3	V	
$V_{DD-LH}$	Threshold Voltage for Latch-Off Release	$V_{DD}$ Falling		2.5		V	
$I_{DD-ST}$	Startup Current	$V_{DD}=V_{DD-ON} - 0.16\text{ V}$		400	450	$\mu\text{A}$	
$I_{DD-OP}$	Operating Supply Current	$V_{DD}=18\text{ V}$ , $f=f_{OSC}$ , $C_{GATE}=1\text{ nF}$		3.5	4.0	mA	
$I_{DD-BURST}$	Burst-Mode Operating Supply Current	$V_{DD}=8\text{ V}$ , $C_{GATE}=1\text{ nF}$		200	350	$\mu\text{A}$	
$V_{DD-OVP}$	$V_{DD}$ Over-Voltage Protection Level		25.0	26.5	28.0	V	
$t_{D-VDDOVP}$	$V_{DD}$ Over-Voltage Protection Debounce Time	$f=85\text{ kHz}$		100	180	$\mu\text{s}$	
<b>Oscillator Section</b>							
$f_{OSC}$	Frequency	Center Frequency	$V_{CS}=5\text{ V}$ , $V_S=2.5\text{ V}$ , $V_{FB}=5\text{ V}$	82	85	88	kHz
		Hopping Range			$\pm 3$		
$f_{OSC-CM-MIN}$	Minimum Frequency for Continuous Conduction Mode (CCM) Prevention Circuit <sup>(4)</sup>		13	18	23	kHz	
$f_{OSC-CCM}$	Minimum Frequency in Constant Current (CC) Regulation	$V_{CS}=5\text{ V}$ , $V_S=0\text{ V}$	23	26	29	kHz	
<b>Feedback Input Section</b>							
$A_V$	Internal Voltage Scale-Down Ratio of FB Pin <sup>(5)</sup>		1/3.5	1/3.0	1/2.5	V/V	
$Z_{FB}$	FB Pin Input Impedance		38	42	44	k $\Omega$	
$V_{FB-OPEN}$	FB Pin Pull-Up Voltage	FB Pin Open		5.3		V	
$V_{FB-L}$	FB Threshold to Disable Gate Drive in Burst Mode	$V_{FB}$ Falling, $V_{CS}=5\text{ V}$ , $V_S=0\text{ V}$	1.2	1.4	1.6	V	
$V_{FB-H}$	FB Threshold to Enable Gate Drive in Burst Mode	$V_{FB}$ Rising, $V_{CS}=5\text{ V}$ , $V_S=0\text{ V}$	1.3	1.5	1.7	V	
<b>Over-Temperature Protection Section</b>							
$T_{OTP}$	Threshold for Over-Temperature Protection (OVP)		+130	+140	+150	$^\circ\text{C}$	

Continued on the following page...

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

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
<b>Voltage-Sense Section</b>						
I <sub>TC</sub>	Bias Current	V <sub>CS</sub> =5 V	8.75	10.00	11.25	μA
V <sub>VS-CM-MIN</sub>	V <sub>S</sub> Sampling Voltage to Switch to the Second Pulse-by-Pulse Current Limit in Power Limit Mode <sup>(6)</sup>			0.55		V
V <sub>VS-CM-MAX</sub>	V <sub>S</sub> Sampling Voltage to Switch Back to the Normal Pulse-by-Pulse Current Limit <sup>(6)</sup>			0.75		V
V <sub>SN-CC</sub>	V <sub>S</sub> Sampling Voltage to Start Frequency Decreasing in CC Mode	V <sub>CS</sub> =5 V, f <sub>S1</sub> =f <sub>OSC</sub> -2 kHz	2.05	2.15	2.25	V
V <sub>SG-CC</sub>	V <sub>S</sub> Sampling Voltage to End Frequency Decreasing in CC Mode	V <sub>CS</sub> =5 V, f <sub>S2</sub> =f <sub>OSC-CCM</sub> +2 kHz	0.45	0.70	0.95	V
S <sub>G-CC</sub>	Frequency Decreasing Slope of CC Regulation	S <sub>G-CC</sub> =(f <sub>S1</sub> -f <sub>S2</sub> ) / (V <sub>SN-CC</sub> -V <sub>SG-CC</sub> )	30	38	46	kHz/V
V <sub>VS-OFFSET</sub>	ZCD Comparator Internal Offset Voltage <sup>(6)</sup>			200		mV
V <sub>VS-OVP</sub>	Output Over-Voltage Protection with V <sub>S</sub> Sampling Voltage		2.70	2.80	2.85	V
t <sub>VS-OVP</sub>	Output Over-Voltage Protection Debounce Time	f <sub>OSC</sub> =85 kHz		8		cycles
<b>Current-Sense Section</b>						
V <sub>VR</sub>	Internal Reference Voltage for CC Regulation		2.475	2.500	2.525	V
V <sub>CCR</sub>	Variation Test Voltage on CS Pin for CC Output (Non-Inverting Input of Error Amplifier for CC Regulation)	V <sub>CS</sub> =0.47 V	2.405	2.430	2.455	V
V <sub>STH</sub>	Normal Current Limit Threshold Voltage			0.8		V
V <sub>STH-VA</sub>	Second Current Limit Threshold Voltage, Power Limit Mode (V <sub>S</sub> <V <sub>VS-CM-MAX</sub> )	V <sub>VS</sub> =0.3 V		0.30		V
t <sub>PD</sub>	GATE Output Turn-Off Delay			100	150	ns
t <sub>MIN</sub>	Minimum On Time	V <sub>CS</sub> =5 V, V <sub>VS</sub> =2.5 V, V <sub>FB</sub> =5 V (Test Mode)	430	530	630	ns
t <sub>LEB</sub>	Leading-Edge Blanking Time <sup>(6)</sup>		100	150	200	ns
V <sub>SLOPE</sub>	Slope Compensation <sup>(6)</sup>	Maximum Duty Cycle		0.3		V
<b>GATE Section</b>						
D <sub>MAX</sub>	Maximum Duty Cycle		64	67	70	%
V <sub>GATE-L</sub>	Output Voltage Low	V <sub>DD</sub> =25 V, I <sub>O</sub> =10 mA	0		1.5	V
V <sub>GATE-H</sub>	Output Voltage High	V <sub>DD</sub> =8 V, I <sub>O</sub> =1 mA	5		8	V
V <sub>GATE-H</sub>	Output Voltage High	V <sub>DD</sub> =5.5 V, I <sub>O</sub> =1 mA	4.0		5.5	V
t <sub>r</sub>	Rising Time	V <sub>DD</sub> =15 V, C <sub>GATE</sub> =1 nF	100	140	180	ns
t <sub>f</sub>	Falling Time	V <sub>DD</sub> =15 V, C <sub>GATE</sub> =1 nF	30	50	70	ns
V <sub>GATE-CLAMP</sub>	Gate Output Clamping Voltage	V <sub>DD</sub> =25 V	13	15	17	V

**Notes:**

- f<sub>OSC-CM-MIN</sub> occurs when the power unit enters CCM operation.
- A<sub>V</sub> is a scale-down ratio of the internal voltage divider of the FB pin.
- Guaranteed by design; not production tested.

## Typical Performance Characteristics

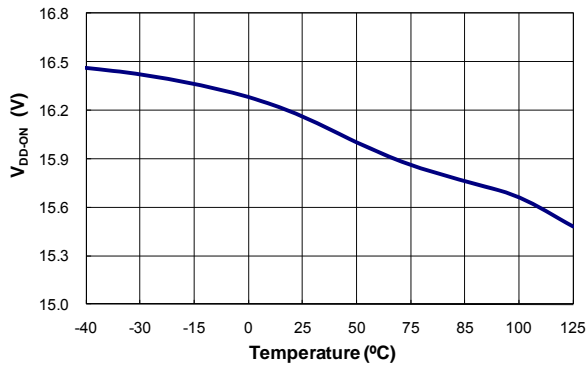


Figure 6. V<sub>DD</sub> Turn-On Threshold Voltage (V<sub>DD-ON</sub>) vs. Temperature

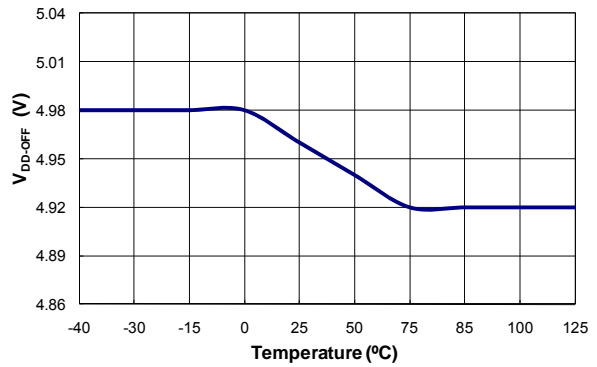


Figure 7. V<sub>DD</sub> Turn-Off Threshold Voltage (V<sub>DD-OFF</sub>) vs. Temperature

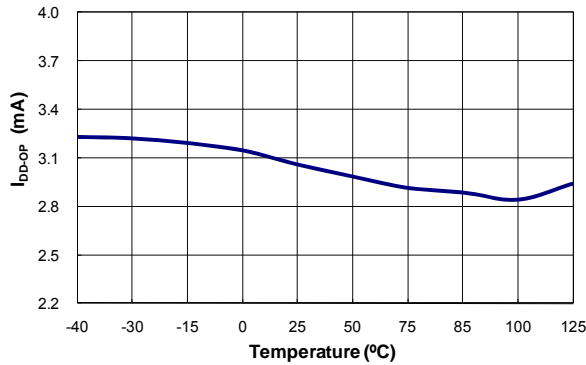


Figure 8. Operating Current (I<sub>DD-OP</sub>) vs. Temperature

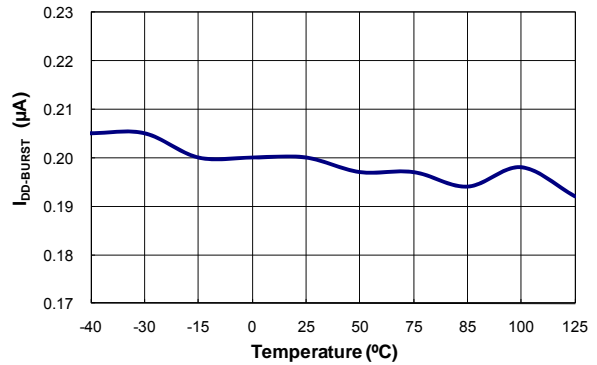


Figure 9. Burst Mode Operating Current (I<sub>DD-BURST</sub>) vs. Temperature

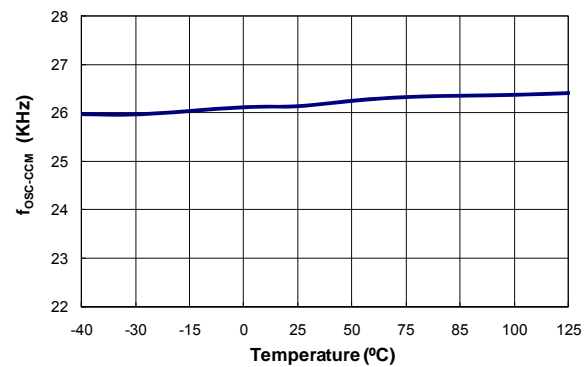


Figure 10. CC Regulation Minimum Frequency (f<sub>OSC-CCM</sub>) vs. Temperature

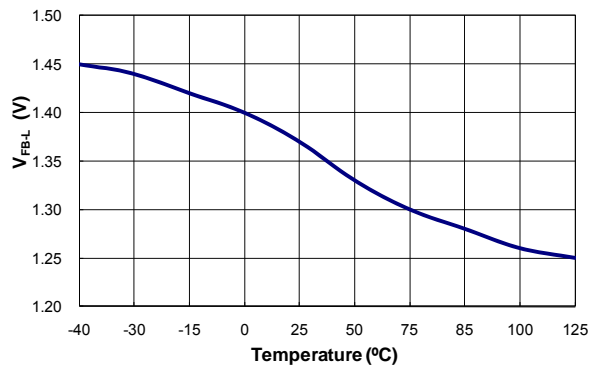
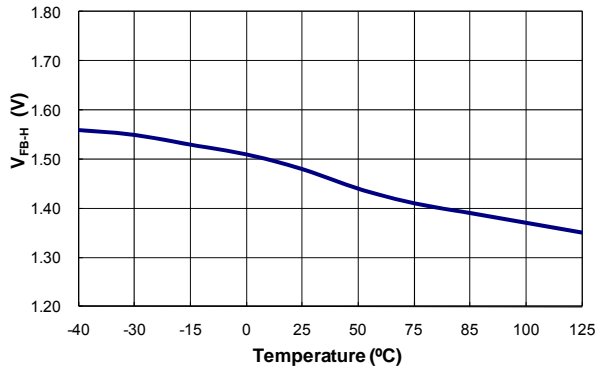
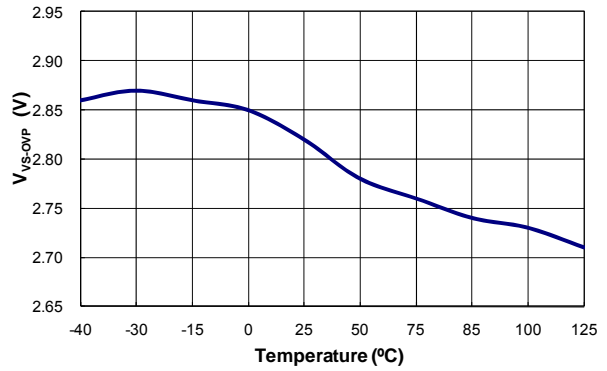


Figure 11. Enter Zero-Duty Cycle of FB Voltage (V<sub>FB-L</sub>) vs. Temperature

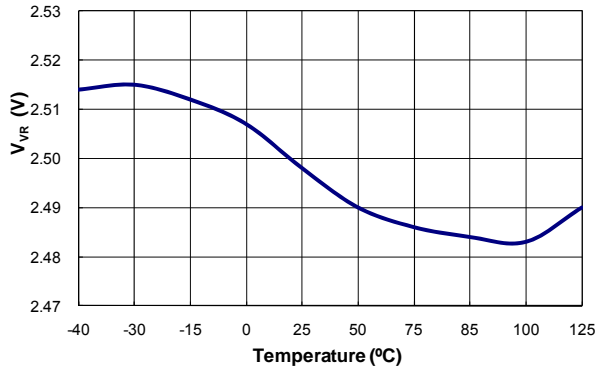
## Typical Performance Characteristics



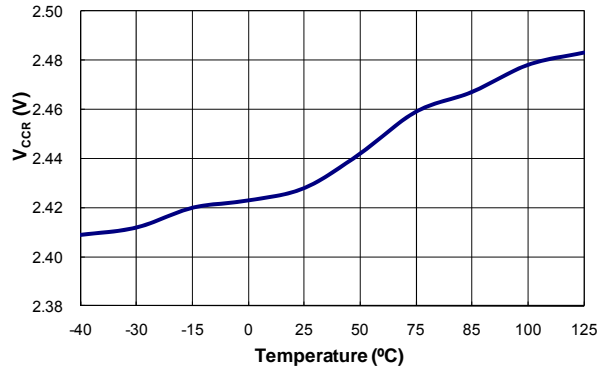
**Figure 12. Leave Zero Duty Cycle of FB Voltage ( $V_{FB-H}$ ) vs. Temperature**



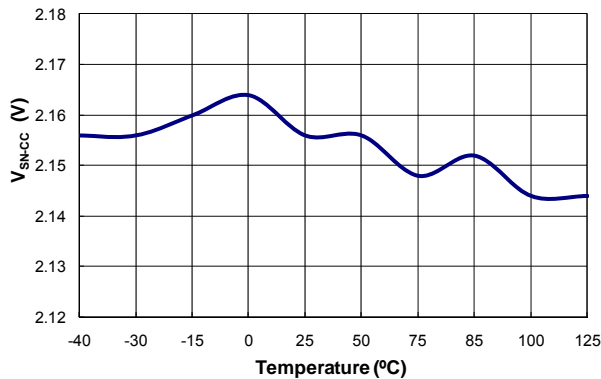
**Figure 13.  $V_S$  Over-Voltage Protection ( $V_{VS-OVP}$ ) vs. Temperature**



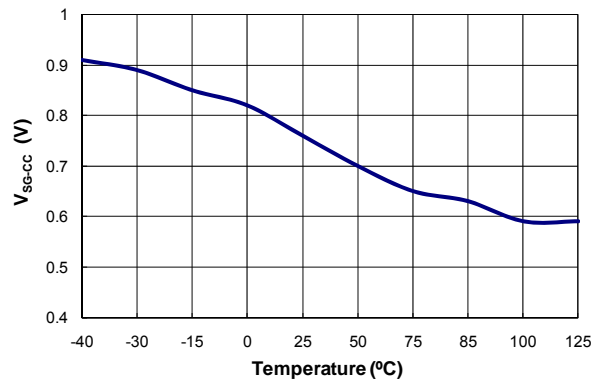
**Figure 14. Reference Voltage of CS ( $V_{VR}$ ) vs. Temperature**



**Figure 15. Variation Voltage on CS Pin for Constant-Current Regulation ( $V_{CCR}$ ) vs. Temperature**



**Figure 16. Starting Voltage of Frequency Decreasing of CC Regulation ( $V_{SN-CC}$ ) vs. Temperature**



**Figure 17. Ending Voltage of Frequency Decreasing of CC Regulation ( $V_{SG-CC}$ ) vs. Temperature**



## Typical Performance Characteristics

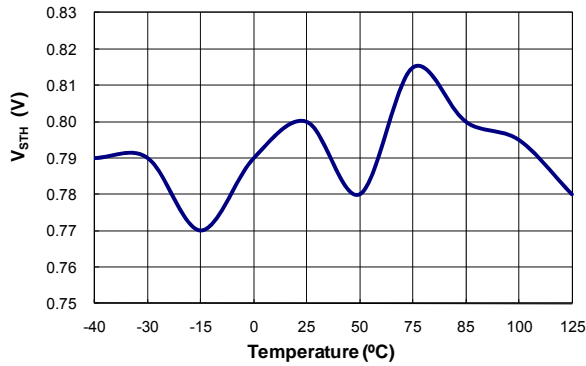


Figure 18. Threshold Voltage for Current Limit ( $V_{STH}$ ) vs. Temperature

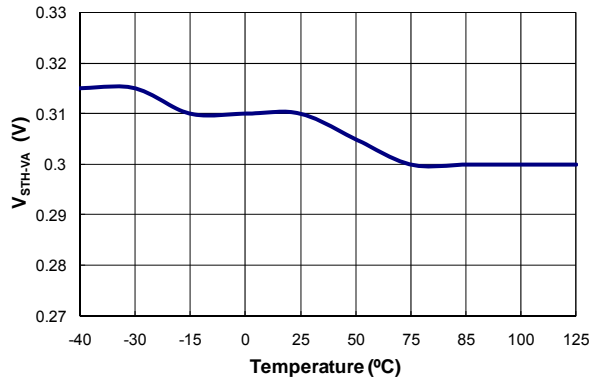


Figure 19. Threshold Voltage for Current Limit at Power Mode ( $V_{STH-VA}$ ) vs. Temperature

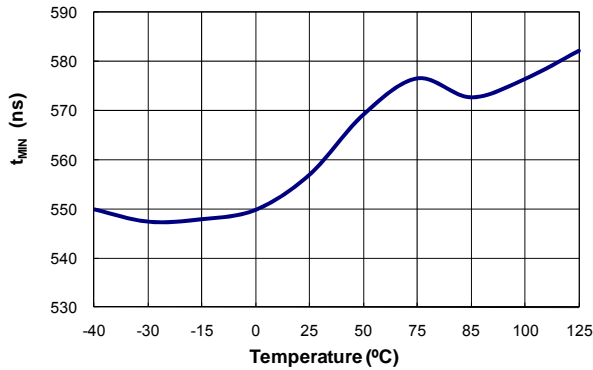


Figure 20. Minimum On Time ( $t_{MIN}$ ) vs. Temperature

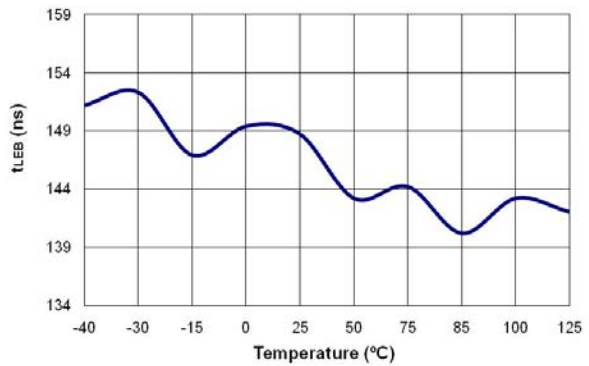


Figure 21. Leading-Edge Blanking Time ( $t_{LEB}$ ) vs. Temperature

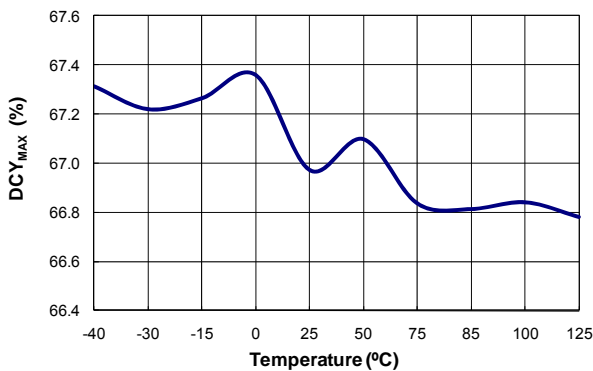


Figure 22. Maximum Duty Cycle ( $DCY_{MAX}$ ) vs. Temperature

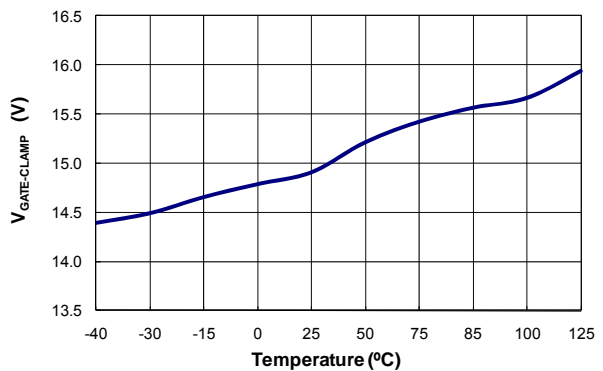


Figure 23. Gate Output Clamp Voltage ( $V_{GATE-CLAMP}$ ) vs. Temperature

## Operational Description

### Basic Control Principle

Figure 24 shows the internal PWM control circuit. The constant voltage (CV) regulation is implemented in the same way as the conventional isolated power supply, where the output voltage is sensed using a voltage divider and compared with the internal 2.5 V reference of a shunt regulator (KA431) to generate a compensation signal. The compensation signal is transferred to the primary side using an opto-coupler and scaled down through attenuator  $A_v$ , generating the  $V_{EA,V}$  signal. Then the error signal  $V_{EA,V}$  is applied to the PWM comparator (PWM.V) to determine the duty cycle.

Meanwhile, the CC regulation is implemented internally without directly sensing the output current. The output current estimator reconstructs output current information ( $V_{CCR}$ ) using the transformer primary-side current and diode current discharge time. Then  $V_{CCR}$  is compared with a reference voltage (2.5 V) by an internal error amplifier, generating the  $V_{EA,I}$  signal to determine the duty cycle.

The two error signals,  $V_{EA,I}$  and  $V_{EA,V}$ , are compared with an internal sawtooth waveform ( $V_{SAW}$ ) by PWM comparators PWM.I and PWM.V to determine the duty cycle. As shown in Figure 25, the outputs of two comparators (PWM.I and PWM.V) are combined with an OR gate and used as a reset signal of flip-flop to determine the MOSFET turn-off instant. The lower signal,  $V_{EA,V}$  or  $V_{EA,I}$ , determines the duty cycle, as shown in Figure 25. During CV regulation,  $V_{EA,V}$  determines the duty cycle while  $V_{EA,I}$  is saturated to HIGH. During CC regulation,  $V_{EA,I}$  determines the duty cycle while  $V_{EA,V}$  is saturated to HIGH.

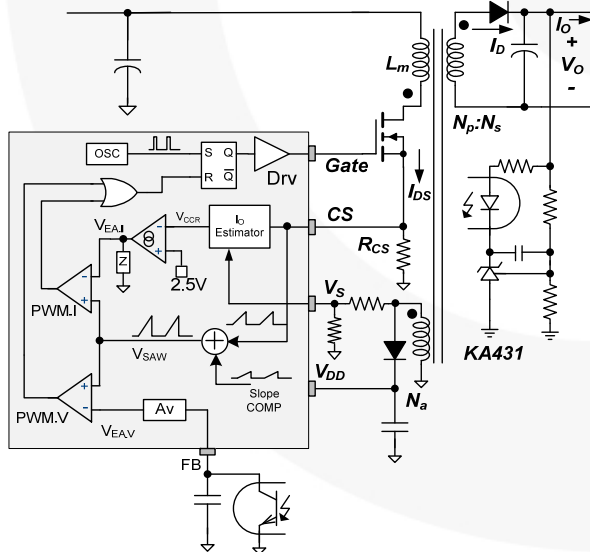


Figure 24. Internal PWM Control Circuit

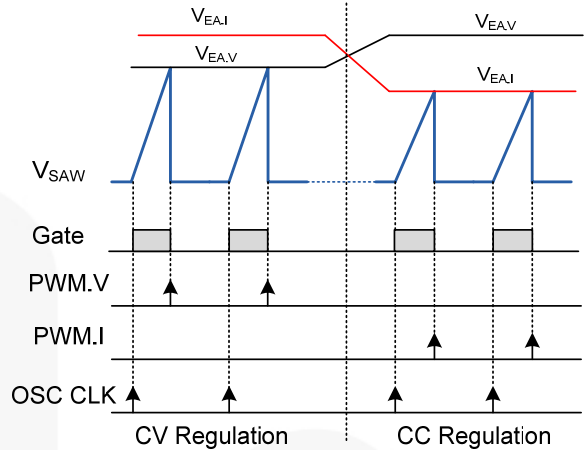


Figure 25. PWM Operation for CC and CV

### Output Current Estimation

Figure 26 shows the key waveform of a flyback converter operating in Discontinuous Conduction Mode (DCM), where the secondary-side diode current reaches zero before the next switching cycle begins. Since the output current estimator is designed for DCM operation, the power stage should be designed such that DCM is guaranteed for the entire operating range. The output current is obtained by averaging the triangular output diode current area over a switching cycle:

$$I_o = \langle I_D \rangle_{AVG} = I_{PK} \frac{N_p}{N_s} \cdot \frac{t_{DIS}}{2t_s} \quad (1)$$

where  $I_{PK}$  is the peak value of the primary-side current;  $N_p$  and  $N_s$  are the number of turns of transformer primary-side and secondary-side, respectively;  $t_{DIS}$  is the diode current discharge time; and  $t_s$  is the switching period.

With a given current sensing resistor, the output current can be programmed as:

$$I_o = \frac{1.25}{K \cdot R_{SENSE}} \frac{N_p}{N_s} \quad (2)$$

where  $K$  is the design parameter of IC, which is 10.5.

The peak value of primary-side current is obtained by an internal peak detection circuit, while diode current discharge time is obtained by detecting the diode current zero-crossing instant. Since the diode current cannot be sensed directly with primary-side control, Zero Crossing Detection (ZCD) is accomplished indirectly by monitoring the auxiliary winding voltage. When the diode current reaches zero, the transformer winding voltage begins to drop by the resonance between the MOSFET output capacitance and the transformer magnetizing inductance. To detect the starting instant of the resonance, the  $V_s$  is sampled at 85% of diode current discharge time of the previous switching cycle, then compared with the instantaneous  $V_s$  voltage. When instantaneous  $V_s$  drops below the sampled voltage by more than 200 mV, ZCD of diode current is obtained, as shown in Figure 27.

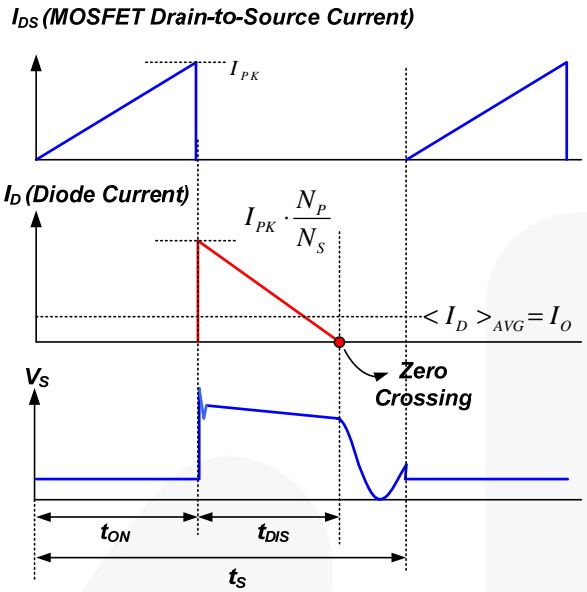


Figure 26. Key Waveforms of DCM Flyback Converter

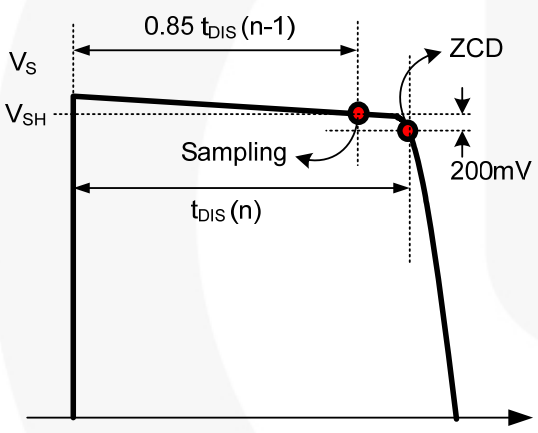


Figure 27. Detailed Waveform for ZCD

**Frequency Reduction in CC Mode**

An important design consideration is that the transformer guarantee DCM operation across the whole range since the output current is properly estimated only in DCM operation. As can be seen in Figure 28, the discharge time ( $t_{DIS}$ ) of the diode current increases as the output voltage decreases in CC Mode. The converter tends to go into CCM as output voltage drops in CC Mode when operating at the fixed switching frequency. To prevent this CCM operation while maintaining good output current estimation in DCM, FAN302HLMY\_F117 decreases switching frequency as output voltage drops, as shown in Figure 28 and Figure 29. FAN302HLMY\_F117 indirectly monitors the output voltage by the sample-and-hold voltage ( $V_{SH}$ ) of  $V_S$ , which is taken at 85% of diode current discharge time of the previous switching cycle, as shown in Figure 27. Figure 30 shows how the frequency reduces as the sample-and-hold voltage of  $V_S$  decreases.

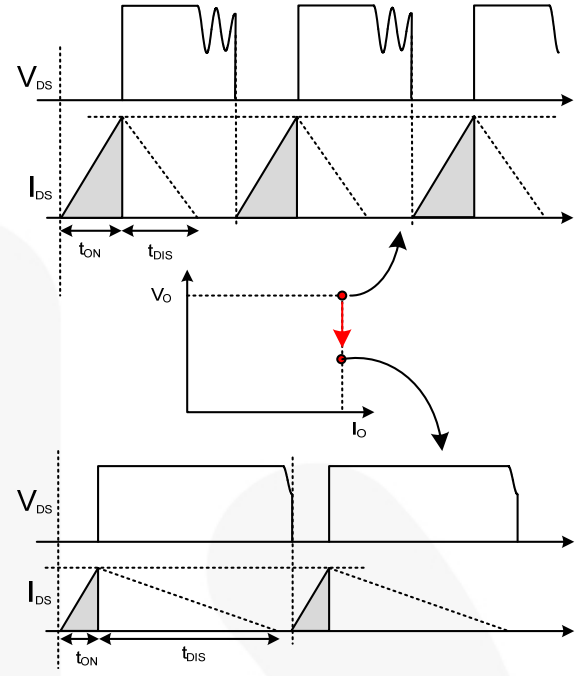


Figure 28.  $t_{DIS}$  Variation in CC Mode

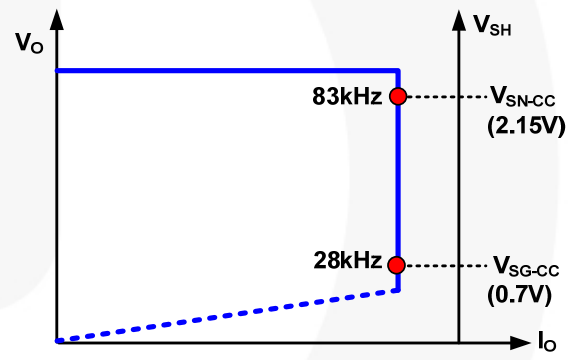


Figure 29. Frequency Reduction with  $V_{SH}$

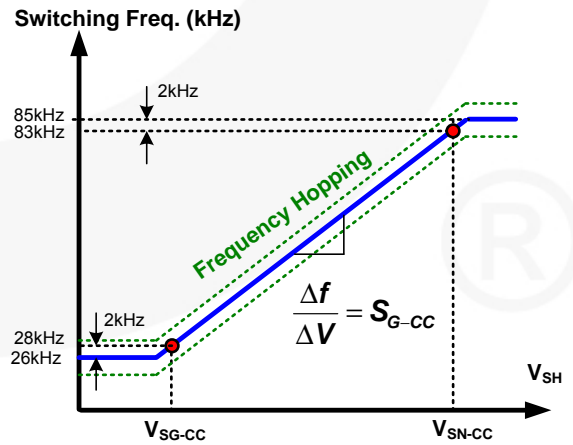
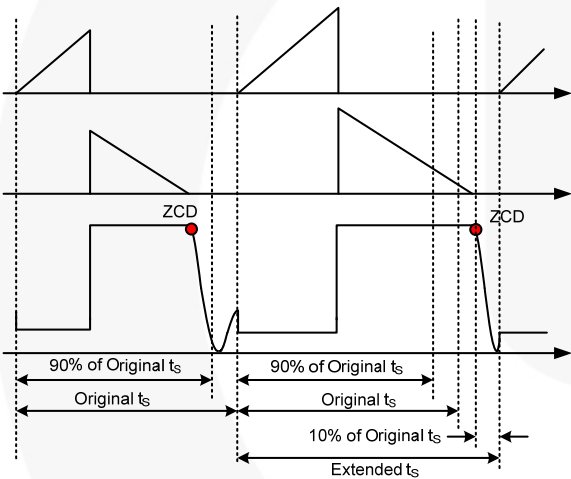


Figure 30. Frequency Reduction Curve in CC Regulation

### CCM Prevention Function

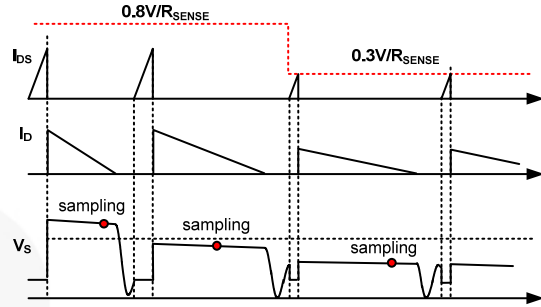
Even if the power supply is designed to operate in DCM, it can go into CCM when there is not enough design margin to cover all the circuit parameter variations and operating conditions. FAN302HLMY\_F117 has a CCM-prevention function that delays the next cycle turn-on of MOSFET until ZCD on the VS pin is obtained, as shown in Figure 31. To guarantee stable DCM operation, FAN302HLMY\_F117 prohibits the turn-on of the next switching cycle for 10% of its switching period after ZCD is obtained. In Figure 31, the first switching cycle has ZCD before 90% of its original switching period and, therefore, the turn-on instant of the next cycle is determined without being affected by the ZCD instant. The second switching cycle does not have ZCD by the end of the original switching period; thus, the turn-on of the third switching cycle occurs after ZCD is obtained, with a delay of 10% of its original switching period. The minimum switching frequency that CCM prevention function allows is 18 kHz ( $f_{OSC-CM-MIN}$ ). If the ZCD is not given until the end of maximum switching period of  $55.6 \mu s$  ( $1/18 \text{ kHz}$ ), the converter can go into CCM operation, losing output regulation.



**Figure 31. CCM Prevention Function**

### Power Limit Mode

When the sampled voltage of VS ( $V_{SH}$ ) drops below  $V_{S-CM-MIN}$  (0.55 V), FAN302HLMY\_F117 enters constant Power Limit Mode, where the primary-side current-limit voltage ( $V_{CS}$ ) changes from  $V_{STH}$  (0.8 V) to  $V_{STH-VA}$  (0.3 V) to avoid  $V_S$  sampling and ZCD, as shown in Figure 32. Once  $V_S$  sampling voltage is higher than  $V_{S-CM-MAX}$  (0.75 V), the  $V_{CS}$  returns to  $V_{STH}$ . This mode prevents the power supply from going into CCM and losing output regulation when the output voltage is too low. This effectively protects the power supply when there is a fault condition in the load, such as output short or overload. This mode also implements soft-start by limiting the transformer current until  $V_S$  sampling voltage reaches  $V_{S-CM-MAX}$  (0.75 V).

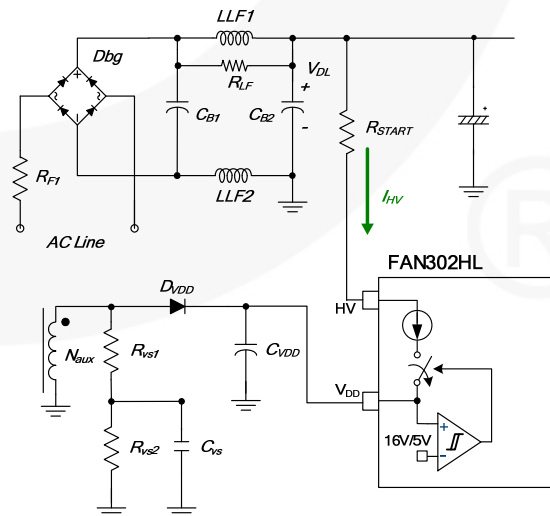


**Figure 32. Power Limit Mode Operation**

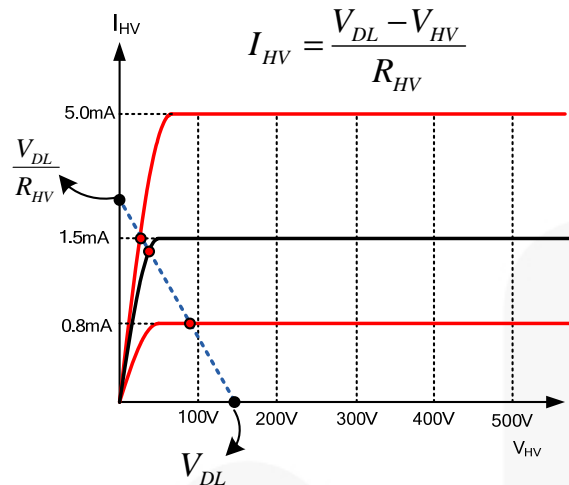
### High-Voltage Startup

Figure 33 shows the high-voltage (HV) startup circuit. Internally, JFET is used to implement the high-voltage current source, whose characteristics are shown in Figure 34. Technically, the HV pin can be directly connected to the DC link ( $V_{DL}$ ). To improve reliability and surge immunity, it is typical to use about a 100 k $\Omega$  resistor between the HV pin and the DC link. The actual HV current with given DC link voltage and startup resistor is determined by the intersection of V-I characteristics line and load line, as shown in Figure 34.

During startup, the internal startup circuit is enabled and the DC link supplies the current,  $I_{HV}$ , to charge the hold-up capacitor,  $C_{VDD}$ , through  $R_{START}$ . When the  $V_{DD}$  voltage reaches  $V_{DD-ON}$ , the internal HV startup circuit is disabled and the IC starts PWM switching. Once the HV startup circuit is disabled, the energy stored in  $C_{VDD}$  should supply the IC operating current until the transformer auxiliary winding voltage reaches the nominal value. Therefore,  $C_{VDD}$  should be designed to prevent  $V_{DD}$  from dropping to  $V_{DD-OFF}$  before the auxiliary winding builds up enough voltage to supply  $V_{DD}$ . Capacitance tolerance is an important factor to consider for  $C_{DD}$  selection. Connecting a 22  $\mu F$  capacitor between the  $V_{DD}$  and GND pins is recommended to ensure system stability across the wide operation temperature range.



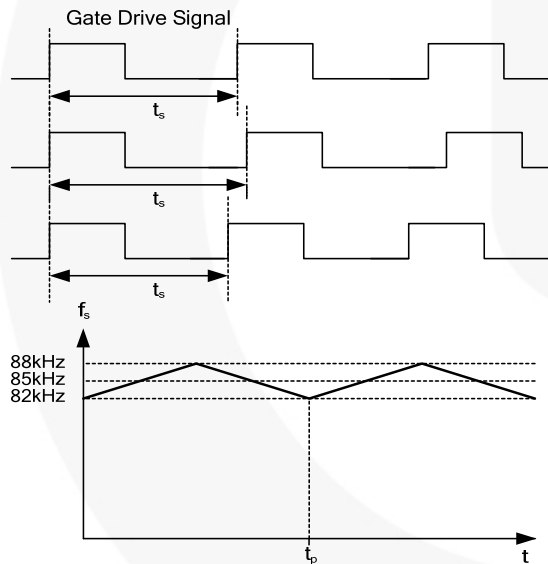
**Figure 33. HV Startup Circuit**



**Figure 34. V-I Characteristics of HV Pin**

### Frequency Hopping

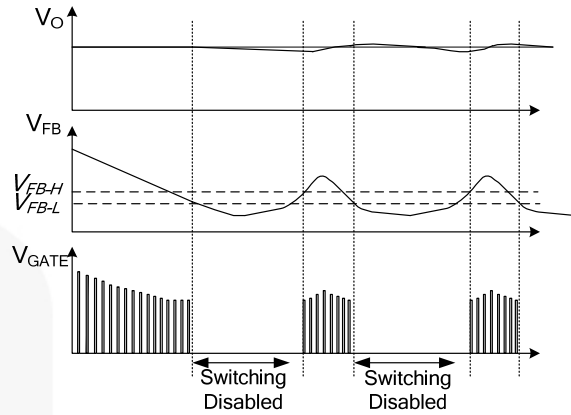
EMI reduction is accomplished by frequency hopping, which spreads the energy over a wider frequency range than the bandwidth of the EMI test equipment. The frequency-hopping circuit changes the switching frequency progressively between 82 kHz and 88 kHz with a period of  $t_p$ , as shown in Figure 35.



**Figure 35. Frequency Hopping**

### Burst-Mode Operation

The power supply enters Burst Mode at no-load or extremely light-load conditions. As shown in Figure 36, when  $V_{FB}$  drops below  $V_{FB-L}$ ; the PWM output shuts off and the output voltage drops at a rate dependent on load current. This causes the feedback voltage to rise. Once  $V_{FB}$  exceeds  $V_{FB-H}$ , the internal circuit starts to provide switching pulse. The feedback voltage then falls and the process repeats. Burst Mode operation alternately enables and disables switching of the MOSFET, reducing the switching losses in Standby Mode. Once FAN302HLMY\_F117 enters Burst Mode, the operating current is reduced from 3.5 mA to 200  $\mu$ A to minimize power consumption.



**Figure 36. Burst-Mode Operation**

### Slope Compensation

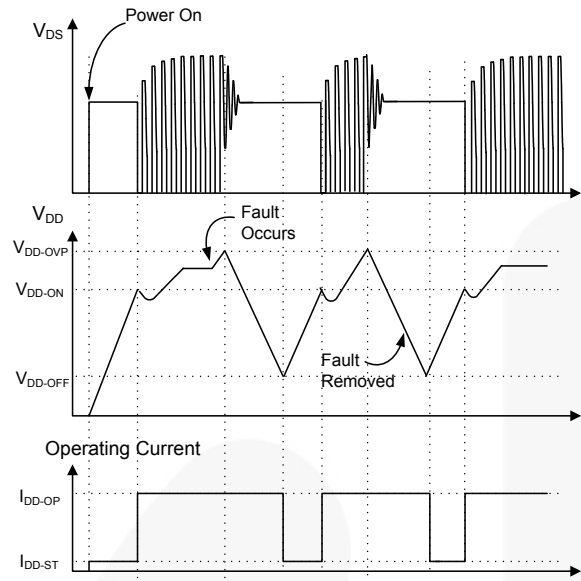
The sensed voltage across the current-sense resistor is used for Current-Mode control and pulse-by-pulse current limiting. A synchronized ramp signal with positive slope is added to the current sense information at each switching cycle, improving noise immunity of Current-Mode control.

### Protections

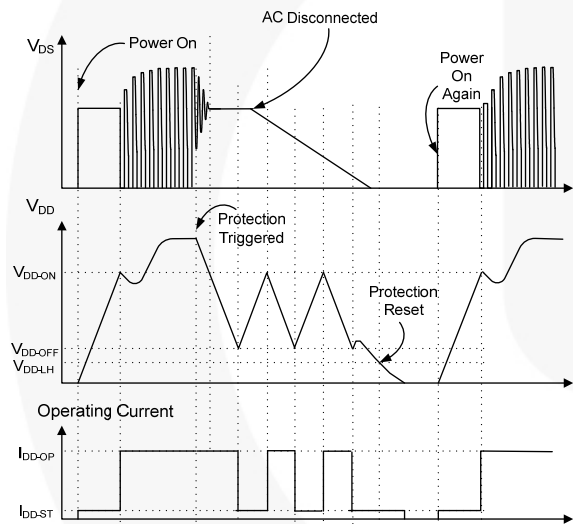
The self-protection functions include  $V_{DD}$  Over-Voltage Protection (OVP), internal Over-Temperature Protection (OTP),  $V_S$  Over-Voltage Protection (OVP), and brownout protection.  $V_{DD}$  OVP and brownout protection are implemented as Auto-Restart Mode, while the  $V_S$  OVP and internal OTP are implemented as Latch Mode.

When an Auto-Restart Mode protection is triggered, switching is terminated and the MOSFET remains off, causing  $V_{DD}$  to drop. When  $V_{DD}$  drops to the  $V_{DD}$  turn-off voltage of 5 V; the protection is reset, the internal startup circuit is enabled, and the supply current drawn from the HV pin charges the hold-up capacitor. When  $V_{DD}$  reaches the turn-on voltage of 16 V, normal operation resumes. In this manner, auto-restart alternately enables and disables MOSFET switching until the abnormal condition is eliminated, as shown in Figure 37.

When a Latch Mode protection is triggered, PWM switching is terminated and the MOSFET remains off, causing  $V_{DD}$  to drop. When  $V_{DD}$  drops to the  $V_{DD}$  turn-off voltage of 5 V, the internal startup circuit is enabled without resetting the protection and the supply current drawn from HV pin charges the hold-up capacitor. Since the protection is not reset, the IC does not resume PWM switching even when  $V_{DD}$  reaches the turn-on voltage of 16 V, disabling HV startup circuit. Then  $V_{DD}$  drops down to 5 V. In this manner, the Latch Mode protection alternately charges and discharges  $V_{DD}$  until there is no more energy in the DC link capacitor. The protection is reset when  $V_{DD}$  drops to 2.5 V, which is allowed only after the power supply is unplugged from the AC line, as shown in Figure 38.



**Figure 37. Auto-Restart Mode Operation**



**Figure 38. Latch-Mode Operation**

**Over-Temperature Protection (OTP)**

The temperature-sensing circuit shuts down PWM output if the junction temperature exceeds 140°C ( $t_{OTP}$ ).

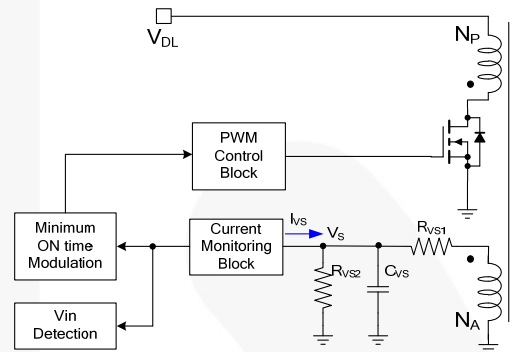
**V<sub>DD</sub> Over-Voltage Protection**

V<sub>DD</sub> over-voltage protection prevents IC damage from over-voltage exceeding the IC voltage rating. When the V<sub>DD</sub> voltage exceeds 26.5 V due to an abnormal condition, the protection is triggered. This protection is typically caused by open circuit in the secondary-side feedback network.

**Input Voltage Sensing**

The FAN302HL indirectly senses input voltage using the VS pin current while the MOSFET is turned on. Since the VS pin voltage is clamped at 0.7 V when the MOSFET is turned on, the current flowing out of the VS pin is approximately proportional to the input voltage as:

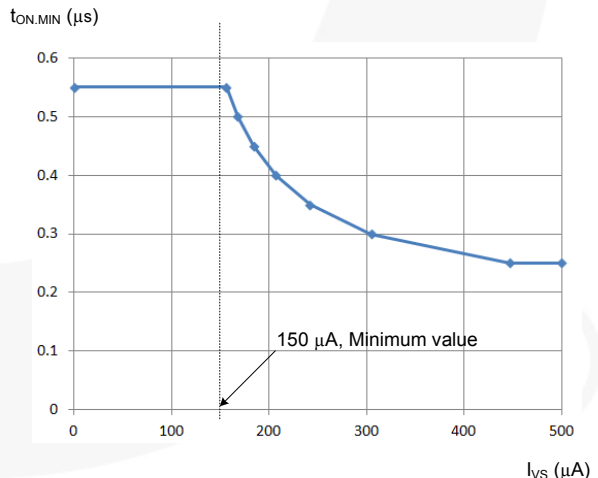
$$I_{VS.ON} = \frac{\left(\frac{N_A}{N_P} V_{DL} + 0.7\right)}{R_{VS1}} + \frac{0.7}{R_{VS2}} \approx \frac{N_A}{N_P} \frac{V_{DL}}{R_{VS1}} \quad (3)$$



**Figure 39. VS Pin Current Sensing**

FAN302HL modulates the minimum on time of the MOSFET such that it reduces as input voltage increases, as shown Figure 40. This allows smaller minimum on time for high line condition, ensuring Burst Mode operation occurs at almost same power level regardless of line voltage variation. The minimum on time is related to the bundle frequency of Burst Mode.

When selecting R<sub>VS1</sub> and R<sub>VS2</sub>, 150 μA is the VS current level to consider seriously. If the VS current is lower than 150 μA,  $t_{on\_min}$  won't be larger.



**Figure 40. Minimum On Time vs. VS Pin Current**

**V<sub>S</sub> Over-Voltage Protection (OVP)**

V<sub>S</sub> over-voltage protection prevents damage due to output over-voltage conditions. Figure 41 shows the VS OVP protection method. The OVP is triggered when the V<sub>S</sub> sampling voltage is above 2.8 V (V<sub>VS\_OVP</sub>) for longer than eight switching cycles. Then PWM pulses are disabled and FAN302HL enters Latch Mode. The protection is reset and normal operation resumes when V<sub>DD</sub> drops below V<sub>DD-LH</sub>. V<sub>S</sub> over-voltage conditions are usually caused by an open circuit in the secondary-side feedback network or abnormal behavior by the VS pin divider resistor.

When the secondary-side feedback circuit is opened, no current flows through the opto-coupler diode, which pulls up the feedback voltage, commanding maximum power be delivered to the load. Since more power than the load demand is delivered, the output voltage rises until the OVP is triggered.

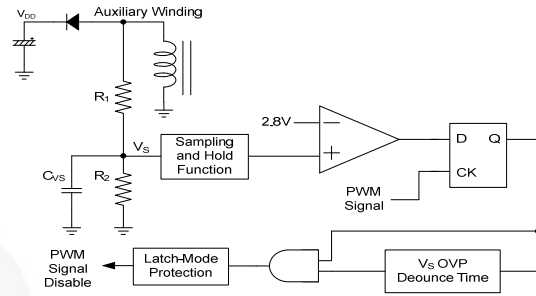
The worst-case OVP trip point at no load is calculated as:

$$V_{O}^{OVP} = \sqrt{\left[ V_{VS\_OVP} \frac{N_S R_{VS1} + R_{VS2}}{N_A R_{VS2}} \right]^2 + \frac{2E_{SURPLUS}}{C_O}} \quad (4)$$

where E<sub>SURPLUS</sub> is the surplus energy delivered to the load during the debounce time.

The E<sub>SURPLUS</sub> can be defined as:

$$E_{SURPLUS} = \frac{L_m}{2} \left( \frac{V_{STH}}{R_{CS}} + \frac{V_{DL}}{L_m} (t_{DLY.OFF}) \right)^2 \times 8 \quad (5)$$



**Figure 41. V<sub>S</sub> OVP Protection**

**Leading-Edge Blanking (LEB)**

Each time the power MOSFET is switched on, a turn-on spike occurs at the sense resistor. To avoid premature termination of the switching pulse, a 150 ns leading-edge blanking time is built in. Conventional RC filtering can therefore be omitted. During this blanking period, the current-limit comparator is disabled and it cannot switch off the gate driver.

**Noise Immunity**

Noise from the current sense or the control signal can cause significant pulse-width jitter. While slope compensation helps alleviate these problems, further precautions should still be taken. Good placement and layout practices should be followed. Avoid long PCB traces and component leads. Locate bypass filter components near the PWM IC.

## Typical Application Circuit (Flyback Charger)

Application	Fairchild Device	Input Voltage Range	Output
Cell Phone Charger	FAN302HLMY_F117	90~265 V <sub>AC</sub>	5 V/1.2 A (6 W)

### Features

- High Efficiency (>71% Avg.), Meets Energy Star V2.0 Standard (Avg. 68.17%)
- Ultra-Low Standby Power Consumption, <10 mW at 230 V<sub>AC</sub> (Pin=6.3 mW for 115 V<sub>AC</sub> and Pin=7.3 mW for 230 V<sub>AC</sub>)
- Output Regulation: CV= ±5%, CC= ±15%

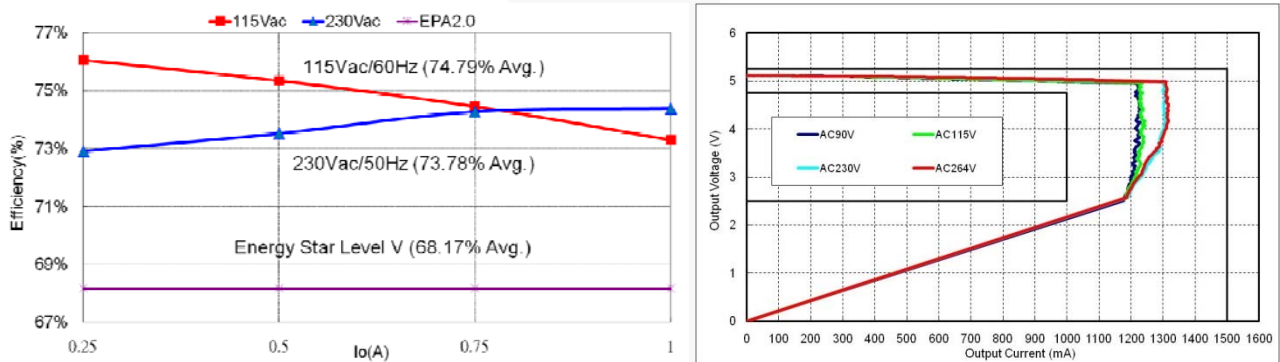


Figure 42. Measured Efficiency and Output Regulation

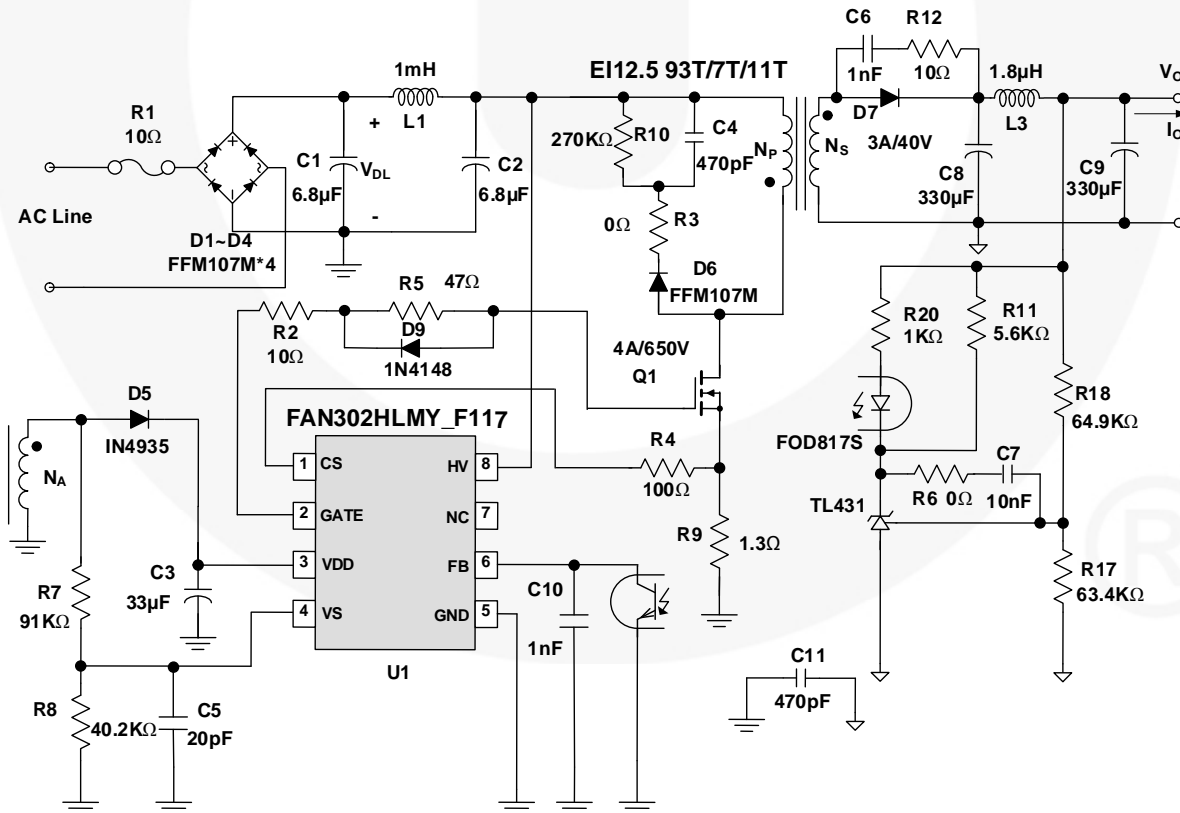


Figure 43. Schematic of Typical Application Circuit



## Typical Application Circuit (Continued)

### Transformer Specification

- Core: EI12.5
- Bobbin: EI12.5

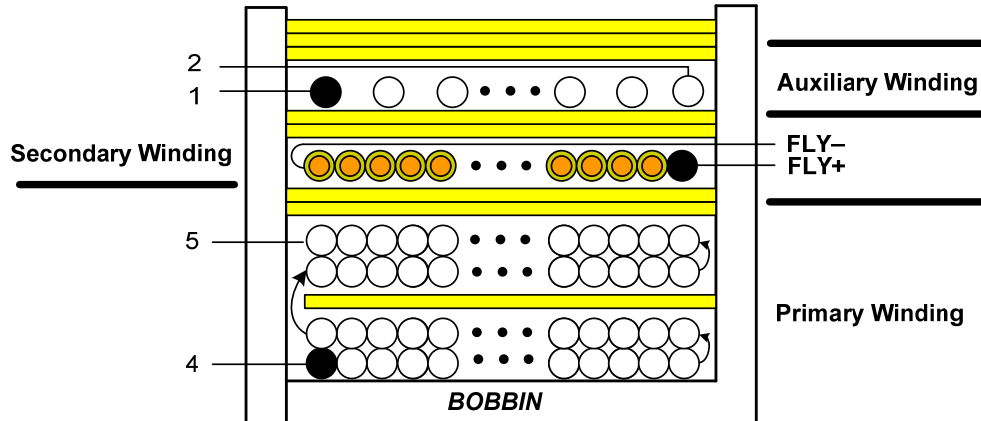


Figure 44. Transformer

#### Notes:

7. W1 consists of four layers with different number of turns. The number of turns of each layer is specified in Table 1. Add one insulation tape between the second and third layers.
8. W2 consists of two layers with triple-insulated wire. The leads of positive and negative fly lines are 3.5 cm and 2.5 cm, respectively.
9. W3 is space winding in one layer.

Table 1. Transformer Winding Specifications

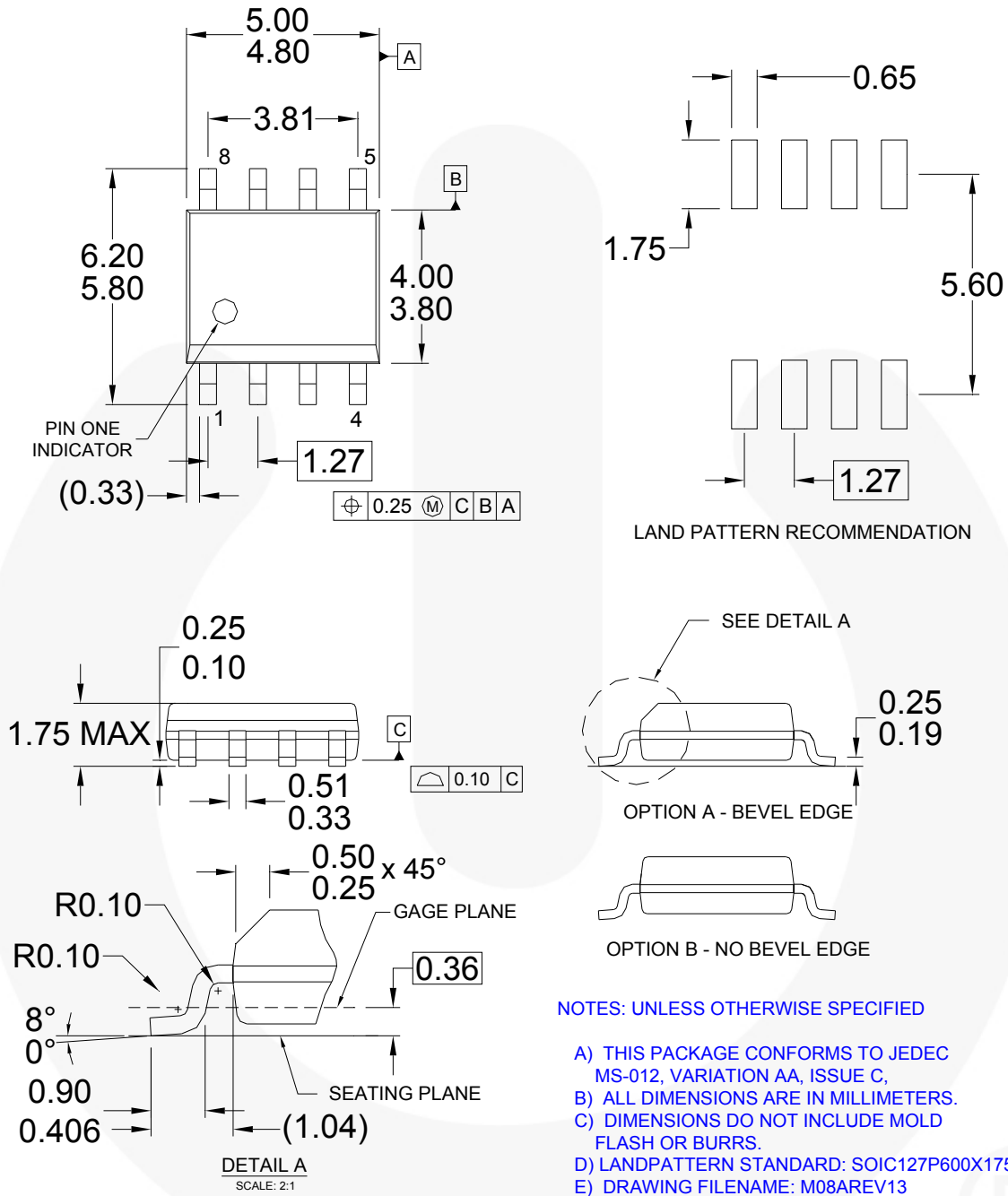
NO.	Terminal		Wire	Turns	Insulation
	Start Pin	End Pin			Turns
W1	4	5	2UEW 0.1*1	26	0
				25	1
				24	0
				18	2
W2	Fly+	Fly-	TEX-E 0.45*1	7	2
W3	1	2	2UEW 0.18*1	11	2
			Core Rounding Tape		3
			Core		0
W4	2		2UEW 0.18*1	5	2

#### Note:

10. W4 is the outermost and space winding.

	Pin	Specifications	Remark
Primary-Side Inductance	4-5	700 $\mu$ H $\pm$ 7%	100 kHz, 1 V
Primary-Side Leakage Inductance	4-5	130 $\mu$ H $\pm$ 7%	Short One of the Secondary-Side Windings

### Physical Dimensions



**Figure 45. 8-Lead, Small Outline Package (SOIC), JEDEC MS-012, .150-Inch, Narrow Body**

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| AX-CAP®*                 | FRFET®   | PowerXS™                              | TinyBoost™       |
| BitSiC™                  | Global Power Resource™                         | Programmable Active Droop™            | TinyBuck™        |
| Build it Now™            | GreenBridge™                                   | QFET®                                 | TinyCalc™        |
| CorePLUS™                | Green FPS™                                     | QS™                                   | TinyLogic®       |
| CorePOWER™               | Green FPS™ e-Series™                           | Quiet Series™                         | TINYOPTO™        |
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| CTL™                     | GTO™   |                                       | TinyPVM™         |
| Current Transfer Logic™  | IntelliMAX™                                    | Saving our world, 1mW/W/kW at a time™ | TinyWire™        |
| DEUXPEED®                | ISOPLANAR™                                     | SignalWise™                           | TranSiC™         |
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| EcoSPARK®                | MegaBuck™                                      | SMART START™                          | TRUECURRENT®*    |
| EfficientMax™            | MICROCOUPLER™                                  | Solutions for Your Success™           | µSerDes™         |
| ESBC™                    | MicroFET™                                      | SPM®                                  |                  |
|                          | MicroPak™                                      | STEALTH™                              | UHC®             |
| Fairchild®               | MicroPak2™                                     | SuperFET®                             | Ultra FRFET™     |
| Fairchild Semiconductor® | MillerDrive™                                   | SuperSOT™-3                           | UniFET™          |
| FACT Quiet Series™       | MotionMax™                                     | SuperSOT™-6                           | VCM™             |
| FACT®                    | mWSaver™                                       | SupreMOS®                             | VisualMax™       |
| FAST®                    | OptoHiT™                                       | SyncFET™                              | VoltagePlus™     |
| FastvCore™               | OPTOLOGIC®                                     |                                       | XS™              |
| FETBench™                | OPTOPLANAR®                                    |                                       |                  |

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No Identification Needed	Full Production	Datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design.
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