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# FSL137MRIN

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

### Features

- Advanced Soft Burst Mode for Low Standby Power and Low Audible Noise
- Random Frequency Fluctuation (RFF) for Low EMI
- Under 50 mW Standby Power Consumption at 265 V<sub>AC</sub>, No-load Condition with Burst Mode
- Pulse-by-Pulse Current Limit
- Overload Protection (OLP), Over-Voltage Protection (OVP), Abnormal Over-Current Protection (AOCP), Internal Thermal Shutdown (TSD) with Hysteresis, Output-Short Protection (OSP), and Under-Voltage Lockout (UVLO) with Hysteresis, Line Over-Voltage Protection (LOVP)
- Low Operating Current (0.4 mA) in Burst Mode
- Internal Startup Circuit
- Internal High-Voltage SenseFET: 700 V
- Built-in Soft-Start: 15 ms
- Auto-Restart Mode

### Applications

- Power Supply for Home Appliances, LCD Monitors, STBs, and DVD Players

### Description

The FSL137MRIN is an integrated Pulse Width Modulation (PWM) controller and SenseFET specifically designed for offline Switched Mode Power Supplies (SMPS) with minimal external components. The PWM controller includes an integrated fixed-frequency oscillator, Line Over-Voltage Protection (LOVP), Under-Voltage Lockout (UVLO), Leading-Edge Blanking (LEB), optimized gate driver, internal soft-start, temperature-compensated precise current sources for loop compensation, and self-protection circuitry.

Compared with a discrete MOSFET and PWM controller solution, the FSL137MRIN reduces total cost, component count, size, and weight; while simultaneously increasing efficiency, productivity, and system reliability. This device provides a basic platform suited for cost-effective design of flyback converters.

### Ordering Information

Part Number	Package <sup>(1)</sup>	Operating Junction Temperature	Current Limit (Typ.)	R <sub>DS(ON)</sub> (Max.)	Output Power Table <sup>(2)</sup>			
					230 V <sub>AC</sub> ±15%		85-265 V <sub>AC</sub>	
					Adapter <sup>(3)</sup>	Open Frame <sup>(4)</sup>	Adapter <sup>(3)</sup>	Open Frame <sup>(4)</sup>
FSL137MRIN	8-DIP	-40°C ~ +125°C	1.3 A	4.75 Ω	25 W	30 W	15 W	20 W

#### Notes:

1. Lead-free package per JEDEC J-STD-020B.
2. The junction temperature can limit the maximum output power.
3. Typical continuous power in a non-ventilated enclosed adapter measured at 50°C ambient temperature.
4. Maximum practical continuous power in an open-frame design at 50°C ambient temperatures.

### Application Circuit

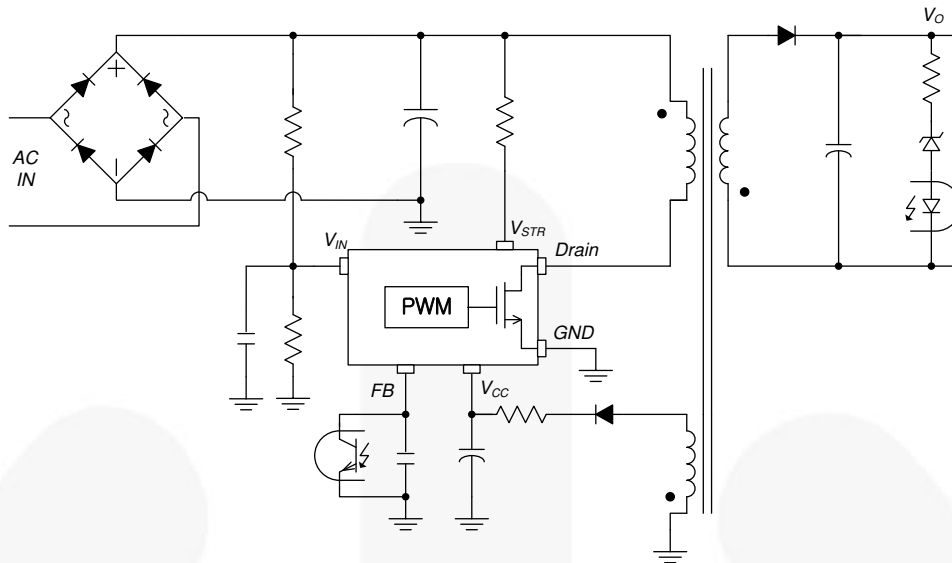


Figure 1. Typical Application Circuit

### Internal Block Diagram

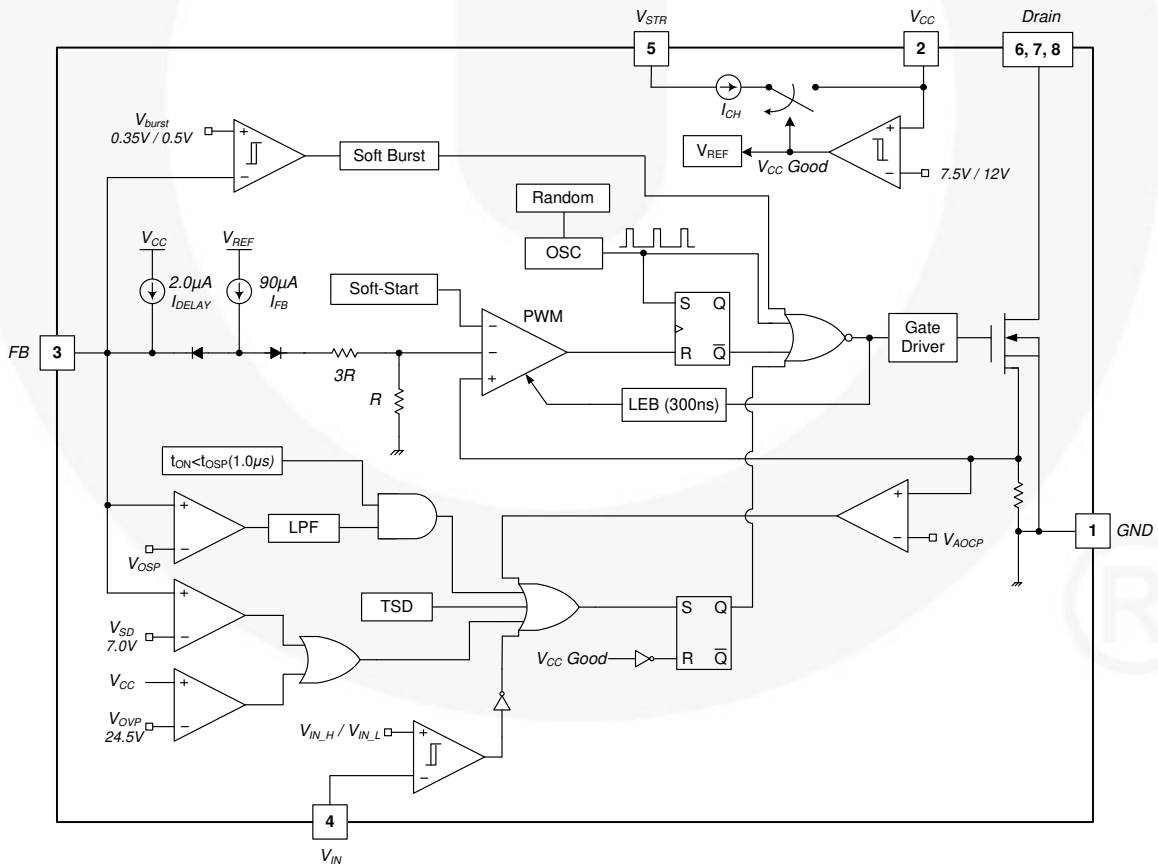


Figure 2. Internal Block Diagram

## Pin Configuration

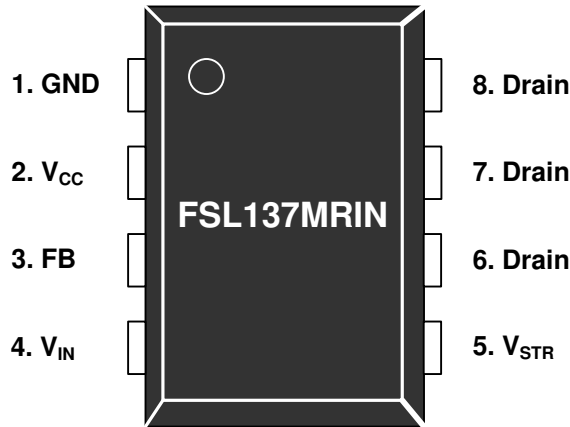


Figure 3. Pin Assignments (Top View)

## Pin Definitions

Pin #	Name	Description
1	GND	<b>Ground.</b> This pin is the control ground and the SenseFET source.
2	V <sub>CC</sub>	<b>Power Supply.</b> This pin is the positive supply input, which provides the internal operating current for both startup and steady-state operation.
3	FB	<b>Feedback.</b> This pin is internally connected to the inverting input of the PWM comparator. The collector of an opto-coupler is typically tied to this pin. For stable operation, a capacitor should be placed between this pin and GND. If the voltage of this pin reaches 7 V, the overload protection triggers, which shuts down the FPS.
4	V <sub>IN</sub>	<b>Line Over-Voltage Input.</b> This is the input pin of line voltage. The voltage, which is divided by resistors, is the input of this pin. If this pin voltage is higher than V <sub>INH</sub> voltage, the LOVP triggers, which shuts down the FPS. Do not leave this pin floating. If LOVP is not used, this pin should be directly connected to GND.
5	V <sub>STR</sub>	<b>Startup.</b> This pin is connected directly, or through a resistor, to the high-voltage DC link. At startup, the internal high-voltage current source supplies internal bias and charges the external capacitor connected to the V <sub>CC</sub> pin. Once V <sub>CC</sub> reaches 12 V, the internal current source (I <sub>CH</sub> ) is disabled.
6	Drain	<b>SenseFET Drain.</b> High-voltage power SenseFET drain connection.
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 <sub>STR</sub>	V <sub>STR</sub> Pin Voltage		700	V
V <sub>DS</sub>	Drain Pin Voltage		700	V
V <sub>CC</sub>	V <sub>CC</sub> Pin Voltage		26	V
V <sub>FB</sub>	Feedback Pin Voltage	-0.3	10.0	V
V <sub>IN</sub>	V <sub>IN</sub> Pin Voltage	-0.3	10.0	V
I <sub>DM</sub>	Drain Current Pulsed		12	A
I <sub>D</sub>	Continuous Switching Drain Current <sup>(5)</sup>		3	A
E <sub>AS</sub>	Single-Pulsed Avalanche Energy <sup>(6)</sup>		230	mJ
P <sub>D</sub>	Total Power Dissipation (T <sub>C</sub> =25°C) <sup>(7)</sup>		1.5	W
T <sub>J</sub>	Maximum Junction Temperature		150	°C
	Operating Junction Temperature <sup>(8)</sup>	-40	+125	°C
T <sub>STG</sub>	Storage Temperature	-55	+150	°C
ESD	Electrostatic Discharge Capability	Human Body Model, JESD22-A114	4.5	kV
		Charged Device Model, JESD22-C101	2.0	

### Notes:

- Repetitive peak switching current when the inductive load is assumed: limited by maximum duty (D<sub>MAX</sub>=0.73) and junction temperature (see Figure 4).
- L=45 mH, starting T<sub>J</sub>=25°C.
- Infinite cooling condition (refer to the SEMI G30-88).
- Although this parameter guarantees IC operation, it does not guarantee all electrical characteristics.

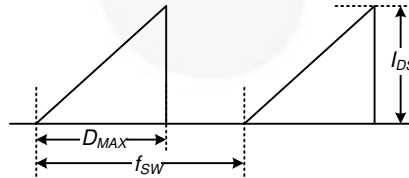


Figure 4. Repetitive Peak Switching Current

## Thermal Impedance

T<sub>A</sub>=25°C unless otherwise specified.

Symbol	Parameter	Value	Unit
θ <sub>JA</sub>	Junction-to-Ambient Thermal Impedance <sup>(9)</sup>	85	°C/W
ψ <sub>JL</sub>	Junction-to-Lead Thermal Impedance <sup>(10)</sup>	11	°C/W

### Notes:

- JEDEC recommended environment, JESD51-2, and test board, JESD51-10, with minimum land pattern.
- Measured on drain pin #7, close to the plastic interface under R<sub>thja</sub> test condition.

## Electrical Characteristics

$T_J = 25^\circ\text{C}$  unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit	
<b>SenseFET Section</b>							
$BV_{DSS}$	Drain-Source Breakdown Voltage	$V_{CC}=0\text{ V}, I_D=250\ \mu\text{A}$	700			V	
$I_{DSS}$	Zero-Gate-Voltage Drain Current	$V_{DS}=560\text{ V}, T_A=125^\circ\text{C}$			250	$\mu\text{A}$	
$R_{DS(ON)}$	Drain-Source On-State Resistance	$V_{GS}=10\text{ V}, I_D=1\text{ A}$		4.00	4.75	$\Omega$	
$C_{ISS}$	Input Capacitance <sup>(11)</sup>	$V_{DS}=25\text{ V}, V_{GS}=0\text{ V}, f=1\text{ MHz}$		315		pF	
$C_{OSS}$	Output Capacitance <sup>(11)</sup>	$V_{DS}=25\text{ V}, V_{GS}=0\text{ V}, f=1\text{ MHz}$		47		pF	
$t_r$	Rise Time	$V_{DS}=325\text{ V}, I_D=4\text{ A}, R_G=25\ \Omega$		34		ns	
$t_f$	Fall Time	$V_{DS}=325\text{ V}, I_D=4\text{ A}, R_G=25\ \Omega$		32		ns	
$t_{d(on)}$	Turn-On Delay	$V_{DS}=325\text{ V}, I_D=4\text{ A}, R_G=25\ \Omega$		11.2		ns	
$t_{d(off)}$	Turn-Off Delay	$V_{DS}=325\text{ V}, I_D=4\text{ A}, R_G=25\ \Omega$		28.2		ns	
<b>Control Section</b>							
$f_S$	Switching Frequency <sup>(11)</sup>	$V_{CC}=14\text{ V}, V_{FB}=4\text{ V}$	61	67	73	kHz	
$\Delta f_S$	Switching Frequency Variation <sup>(11)</sup>	$-25^\circ\text{C} < T_J < 125^\circ\text{C}$		$\pm 5$	$\pm 10$	%	
$D_{MAX}$	Maximum Duty Ratio	$V_{CC}=14\text{ V}, V_{FB}=4\text{ V}$	61	67	73	%	
$D_{MIN}$	Minimum Duty Ratio	$V_{CC}=14\text{ V}, V_{FB}=0\text{ V}$			0	%	
$I_{FB}$	Feedback Source Current	$V_{FB}=0\text{ V}$	65	90	115	$\mu\text{A}$	
$V_{START}$	UVLO Threshold Voltage	$V_{FB}=0\text{ V}, V_{CC}$ Sweep	11	12	13	V	
$V_{STOP}$		After Turn-on, $V_{FB}=0\text{ V}$	7.0	7.5	8.0		
$t_{SS}$	Internal Soft-Start Time	$V_{STR}=40\text{ V}, V_{CC}$ Sweep		15		ms	
$V_{RECOMM}$	Recommended $V_{CC}$ Range		13		23	V	
<b>Burst Mode Section</b>							
$V_{BURH}$	Burst-Mode Voltage	$V_{CC}=14\text{ V}, V_{FB}$ Sweep	0.45	0.50	0.55	V	
$V_{BURL}$			0.30	0.35	0.40		
Hys				150			mV
<b>Protection Section</b>							
$I_{LIM}$	Peak Drain Current Limit	$di/dt=300\text{ mA}/\mu\text{s}$	1.1	1.3	1.5	A	
$V_{SD}$	Shutdown Feedback Voltage	$V_{CC}=14\text{ V}, V_{FB}$ Sweep	6.45	7.00	7.55	V	
$I_{DELAY}$	Shutdown Delay Current	$V_{CC}=14\text{ V}, V_{FB}=4\text{ V}$	1.2	2.0	2.8	$\mu\text{A}$	
$t_{LEB}$	Leading-Edge Blanking Time <sup>(10,12)</sup>			300		ns	
$V_{OVP}$	Over-Voltage Protection	$V_{CC}$ Sweep	23.0	24.5	26.0	V	
$V_{INH}$	Line Over-Voltage Protection Threshold Voltage	$V_{CC}=14\text{ V}, V_{IN}$ Sweep	1.885	1.950	2.015	V	
$V_{INHYS}$	Line Over-Voltage Protection Hysteresis	$V_{CC}=14\text{ V}, V_{IN}$ Sweep		0.06		V	
$t_{OSP}$	Output-Short Protection <sup>(11)</sup>	Threshold Time	OSP Triggered when $t_{ON} < t_{OSP}$ & $V_{FB} > V_{OSP}$ (Lasts Longer than $t_{OSP\_FB}$ )	0.7	1.0	1.3	$\mu\text{s}$
$V_{OSP}$		Threshold $V_{FB}$		1.8	2.0	2.2	V
$t_{OSP\_FB}$		$V_{FB}$ Blanking Time		2.0	2.5	3.0	$\mu\text{s}$
TSD	Thermal Shutdown Temperature <sup>(11)</sup>	Shutdown Temperature	125	135	145	$^\circ\text{C}$	
$T_{HYS}$		Hysteresis		60		$^\circ\text{C}$	

Continued on the following page...

**Electrical Characteristics** (Continued)T<sub>J</sub> = 25°C unless otherwise specified.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>Total Device Section</b>						
I <sub>OP</sub>	Operating Supply Current, (Control Part in Burst Mode)	V <sub>CC</sub> =14 V, V <sub>FB</sub> =0 V	0.3	0.4	0.5	mA
I <sub>OPS</sub>	Operating Switching Current, (Control Part and SenseFET Part)	V <sub>CC</sub> =14 V, V <sub>FB</sub> =2 V		1.2	1.5	mA
I <sub>START</sub>	Start Current	V <sub>CC</sub> =11 V (Before V <sub>CC</sub> Reaches V <sub>START</sub> )	85	120	155	μA
I <sub>CH</sub>	Startup Charging Current	V <sub>CC</sub> =V <sub>FB</sub> =0 V, V <sub>STR</sub> =40 V	0.7	1.0	1.3	mA
V <sub>STR</sub>	Minimum V <sub>STR</sub> Supply Voltage	V <sub>CC</sub> =V <sub>FB</sub> =0 V, V <sub>STR</sub> Sweep		26		V

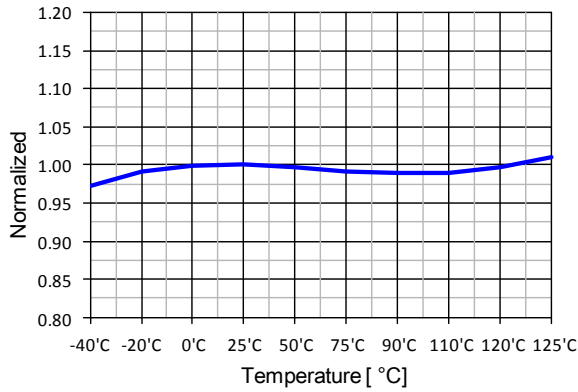
**Notes:**

11. These parameters are guaranteed; not 100% tested in production.
12. t<sub>LEB</sub> includes gate turn-on time.

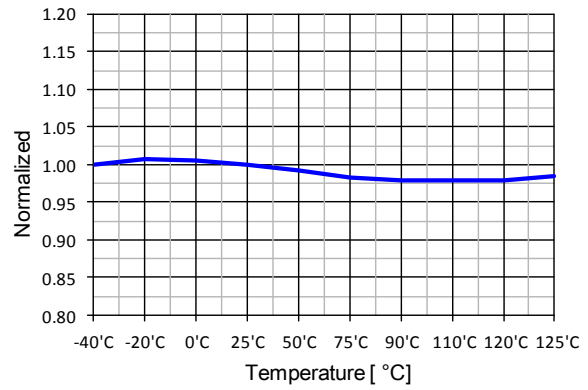


## Typical Performance Characteristics

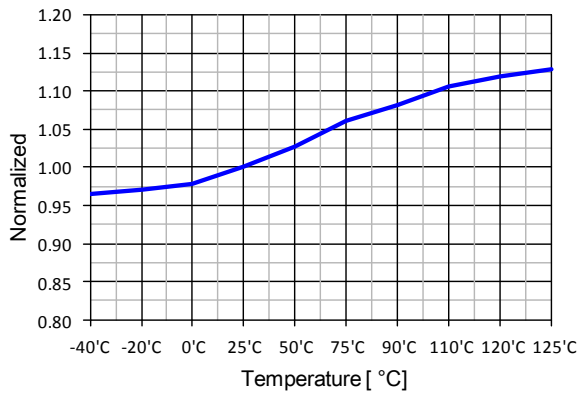
Characteristic graphs are normalized at  $T_A=25^\circ\text{C}$ .



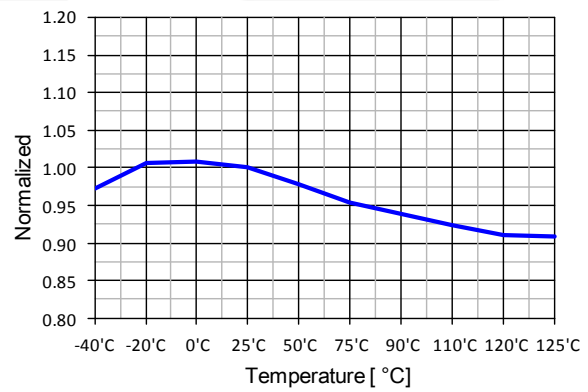
**Figure 5. Operating Supply Current ( $I_{OP}$ ) vs.  $T_A$**



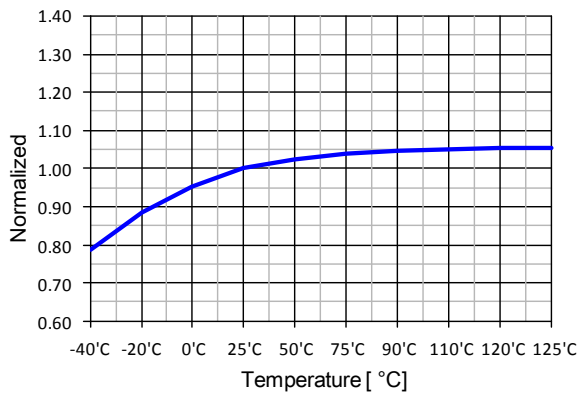
**Figure 6. Operating Switching Current ( $I_{OPS}$ ) vs.  $T_A$**



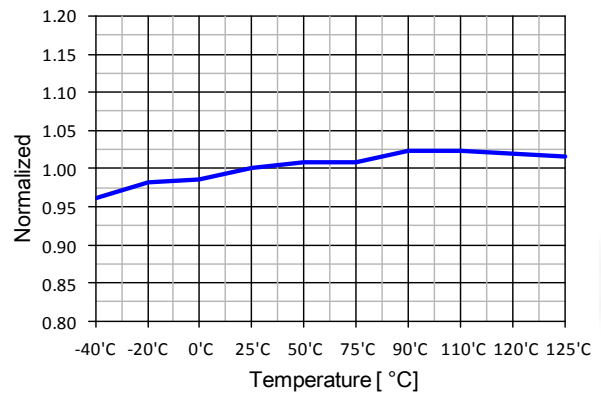
**Figure 7. Startup Charging Current ( $I_{CH}$ ) vs.  $T_A$**



**Figure 8. Peak Drain Current Limit ( $I_{LIM}$ ) vs.  $T_A$**



**Figure 9. Feedback Source Current ( $I_{FB}$ ) vs.  $T_A$**



**Figure 10. Shutdown Delay Current ( $I_{DELAY}$ ) vs.  $T_A$**

## Typical Performance Characteristics

Characteristic graphs are normalized at  $T_A=25^\circ\text{C}$ .

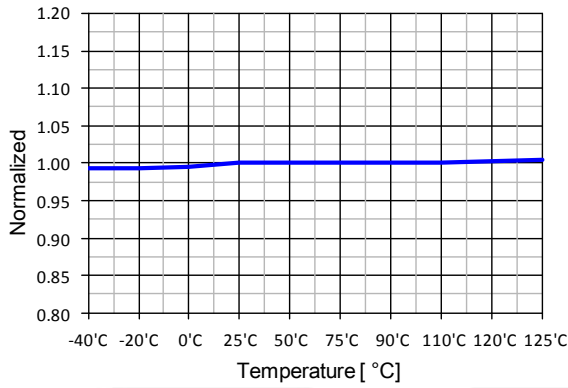


Figure 11. UVLO Threshold Voltage ( $V_{\text{START}}$ ) vs.  $T_A$

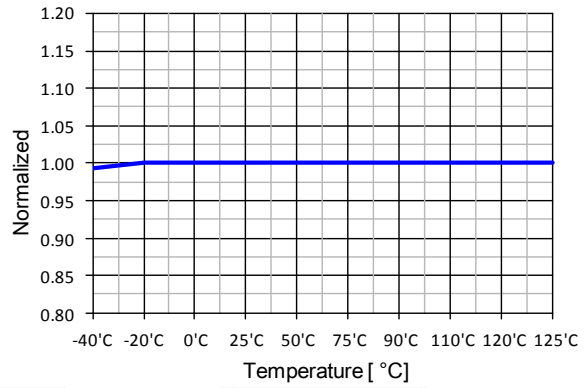


Figure 12. UVLO Threshold Voltage ( $V_{\text{STOP}}$ ) vs.  $T_A$

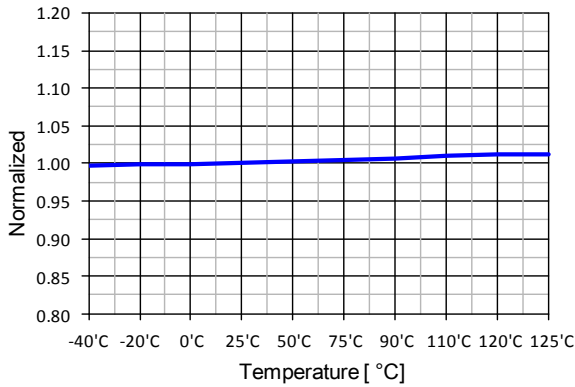


Figure 13. Shutdown Feedback Voltage ( $V_{\text{SD}}$ ) vs.  $T_A$

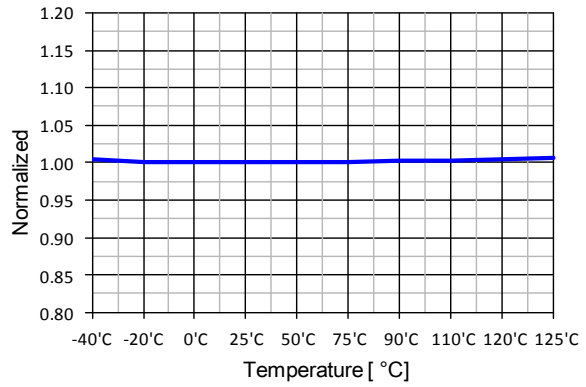


Figure 14. Over-Voltage Protection ( $V_{\text{OVP}}$ ) vs.  $T_A$

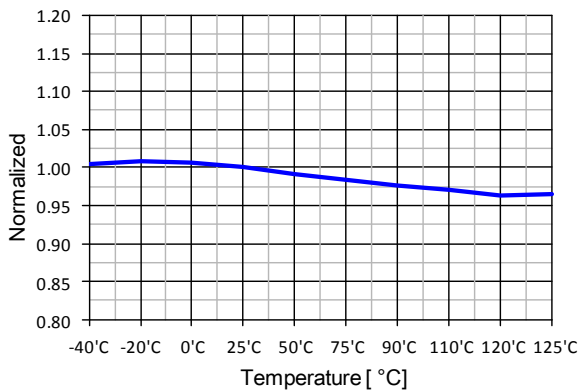


Figure 15. Switching Frequency ( $f_s$ ) vs.  $T_A$

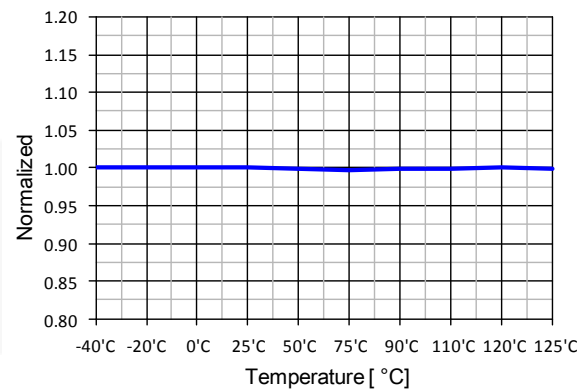


Figure 16. Maximum Duty Ratio ( $D_{\text{MAX}}$ ) vs.  $T_A$

## Typical Performance Characteristics

Characteristic graphs are normalized at  $T_A=25^\circ\text{C}$ .

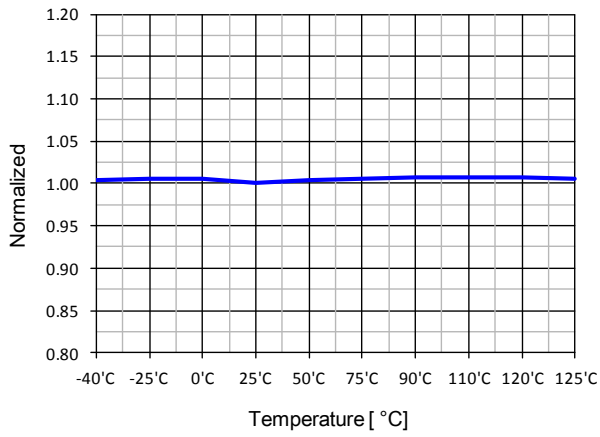


Figure 17. Line OVP ( $V_{INH}$ ) vs.  $T_A$

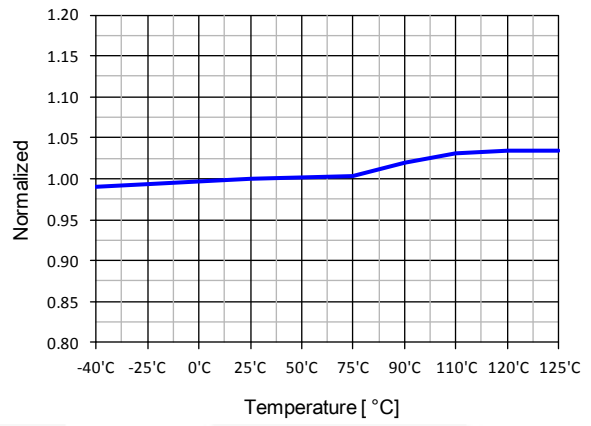
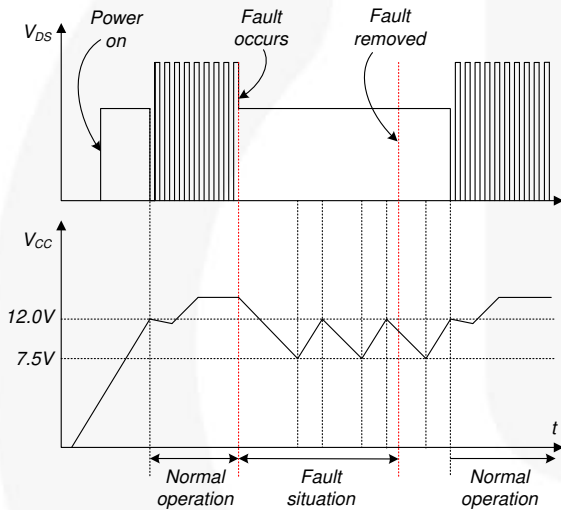


Figure 18. Hysteresis of LOVP ( $V_{INHYS}$ ) vs.  $T_A$



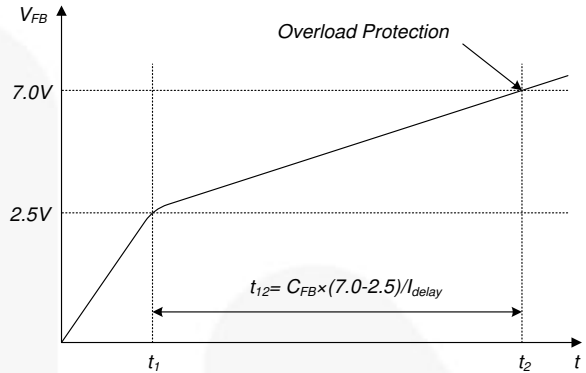
**4. Protection Circuits:** The FSL137MRIN has several self-protective functions; such as Overload Protection (OLP), Abnormal Over-Current Protection (AOCP), Output-Short Protection (OSP), Over-Voltage Protection (OVP), and Thermal Shutdown (TSD). All the protections are implemented as auto-restart. Once a fault condition is detected, switching is terminated and the SenseFET remains off. This causes  $V_{CC}$  to fall. When  $V_{CC}$  falls to the Under-Voltage Lockout (UVLO) stop voltage of 7.5 V, the protection is reset and the startup circuit charges the  $V_{CC}$  capacitor. When  $V_{CC}$  reaches the start voltage of 12.0 V, normal operation resumes. If the fault condition is not removed, the SenseFET remains off and  $V_{CC}$  drops to stop voltage again. In this manner, the auto-restart can alternately enable and disable the switching of the power SenseFET until the fault condition is eliminated. Because these protection circuits are fully integrated into the IC without external components, reliability is improved without increasing cost.



**Figure 21. Auto-Restart Protection Waveforms**

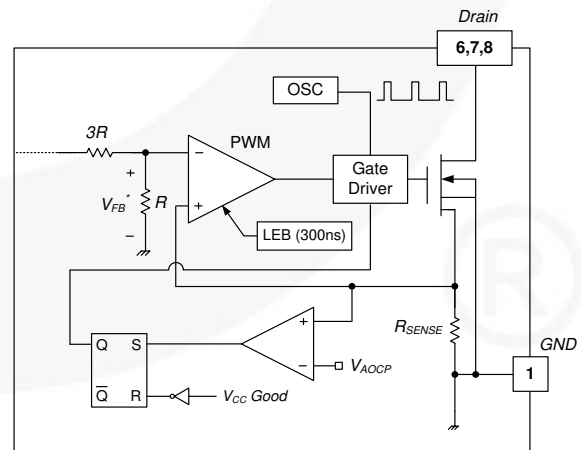
**4.1 Overload Protection (OLP):** Overload is defined as the load current exceeding its normal level due to an unexpected abnormal event. In this situation, the protection circuit should trigger to protect the SMPS. However, even when the SMPS is in normal operation, the overload protection circuit can be triggered during the load transition. To avoid this undesired operation, the overload protection circuit is designed to trigger only after a specified time to determine whether it is a transient situation or a true overload situation. Because of the pulse-by-pulse current-limit capability, the maximum peak current through the SenseFET is limited and, therefore, the maximum input power is restricted with a given input voltage. If the output consumes more than this maximum power, the output voltage ( $V_{OUT}$ ) decreases below the set voltage. This reduces the current through the opto-coupler LED, which also reduces the opto-coupler transistor current, increasing the feedback voltage ( $V_{FB}$ ). If  $V_{FB}$  exceeds 2.5 V, D1 is blocked and the 2.0  $\mu$ A current source starts to charge  $C_{FB}$  slowly up. In this condition,  $V_{FB}$  continues

increasing until it reaches 7.0 V, when the switching operation is terminated, as shown in Figure 22. The delay for shutdown is the time required to charge  $C_{FB}$  from 2.5 V to 7.0 V with 2.0  $\mu$ A. A 25 ~ 50 ms delay is typical for most applications. This protection is implemented as auto-restart.



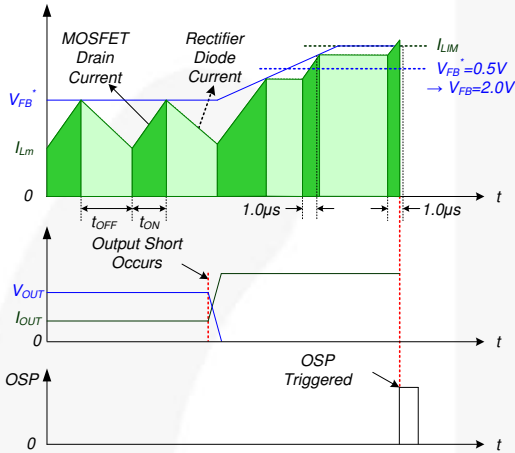
**Figure 22. Overload Protection**

**4.2 Abnormal Over-Current Protection (AOCP):** When the secondary rectifier diodes or the transformer pins are shorted, a steep current with extremely high  $di/dt$  can flow through the SenseFET during the minimum turn-on time. Even though the FSL137MRIN has overload protection, it is not enough to protect the FSL137MRIN in that abnormal case; due to the severe current stress imposed on the SenseFET until OLP is triggered. The internal AOCP circuit is shown in Figure 23. When the gate turn-on signal is applied to the power SenseFET, the AOCP block is enabled and monitors the current through the sensing resistor. The voltage across the resistor is compared with a preset AOCP level. If the sensing-resistor voltage is greater than the AOCP level, the set signal is applied to the S-R latch, resulting in the shutdown of the SMPS.



**Figure 23. Abnormal Over-Current Protection**

**4.3. Output-Short Protection (OSP):** If the output is shorted, steep current with extremely high di/dt can flow through the SenseFET during the minimum turn-on time. Such a steep current creates high-voltage stress on the drain of the SenseFET when turned off. To protect the device from this abnormal condition, OSP is included. It is comprised of detecting  $V_{FB}$  and SenseFET turn-on time. When the  $V_{FB}$  is higher than 2.0 V and the SenseFET turn-on time is lower than 1.0  $\mu$ s, this condition is recognized as an abnormal error and PWM switching shuts down until  $V_{CC}$  reaches  $V_{START}$  again. An abnormal condition output short is shown in Figure 24.

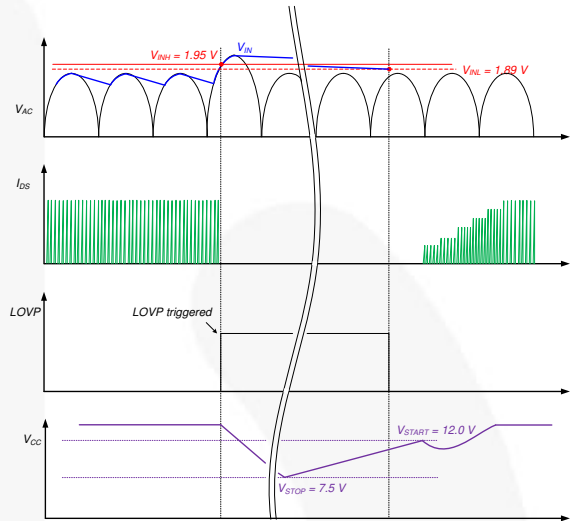


**Figure 24. Output-Short Protection**

**4.4 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 almost zero. Then  $V_{FB}$  climbs up in a similar manner to overload situation, forcing the preset maximum current to be supplied to the SMPS until the overload protection is triggered. Because more energy than required is provided to the output, the output voltage may exceed the rated voltage before the overload protection is triggered, resulting in the breakdown of the devices in the secondary side. To prevent this situation, an OVP circuit is employed. In general, the  $V_{CC}$  is proportional to the output voltage and the FSL137MRIN uses  $V_{CC}$  instead of directly monitoring the output voltage. If  $V_{CC}$  exceeds 24.5 V, an OVP circuit is triggered, resulting in the termination of the switching operation. To avoid undesired activation of OVP during normal operation,  $V_{CC}$  should be designed below 24.5 V.

**4.5 Thermal Shutdown (TSD):** The SenseFET and the control IC on a die in one package makes it easier for the control IC to detect the temperature of the SenseFET. If the temperature exceeds  $\sim 135^{\circ}\text{C}$ , the thermal shutdown is triggered and stops operation. The FSL137MRIN operates in Auto-Restart Mode until the temperature decreases to around  $75^{\circ}\text{C}$ , when normal operation resumes.

**4.6 Line Over-Voltage Protection (LOVP):** If the line input voltage is increased to an undesirable level, high line input voltage creates high-voltage stress on the entire system. To protect from this abnormal condition, LOVP is included. It is comprised of detecting  $V_{IN}$  using divided resistors. When  $V_{IN}$  is higher than 1.95 V, this condition is recognized as an abnormal error and PWM switching shuts down until  $V_{IN}$  decreases to around 1.89 V (60 mV hysteresis).



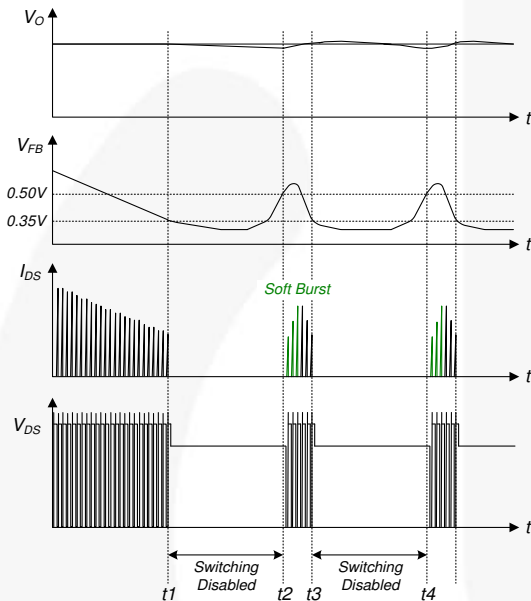
**Figure 25. Line Over-Voltage Protection**

Unlike previous FPS families, FSL137MRIN's  $V_{IN}$  pin can detect the AC line over-voltage protection function. When line input voltage exceeds pre-determined level at the  $V_{IN}$  pin, the controller initiates a fault signal and shuts down PWM output. To prevent erroneous activation of LOVP, the LOVP function is triggered when line over-voltage lasts more than specific time. Another important feature of LOVP function is auto-recovery. The controller continuously monitors line input voltage even under fault condition and turns PWM output on when over-voltage condition disappears. Equation (1) calculates the level of input over voltage to RMS value:

$$V_{IN\_ovp} = 1.95 \times \left( \frac{(R1 + R2)}{R1} \right) \quad (1)$$

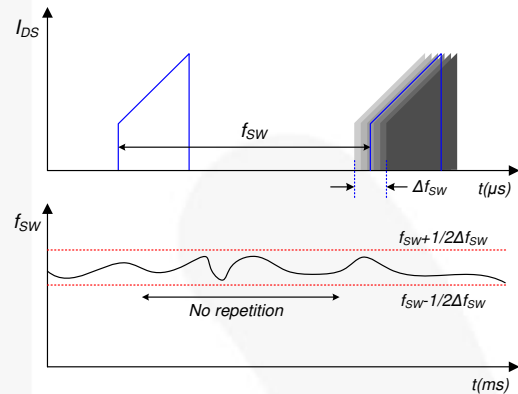
The resistance of divided resistor can be adjusted as necessary. Small resistance can bring relatively large stand-by power consumption at light-load condition. To avoid this situation, a several  $\text{M}\Omega$  resistor is recommended. For stable operation, a several  $\text{M}\Omega$  resistor should accompany a capacitor with hundreds of pF capacitance between the  $V_{IN}$  pin and GND.

**5. Soft Burst Mode:** To minimize power dissipation in Standby Mode, the FSL137MRIN enters Burst-Mode operation. As the load decreases, the feedback voltage decreases. As shown in Figure 26, the device automatically enters Burst Mode when the feedback voltage drops below  $V_{BURL}$  (350 mV). At this point, switching stops and the output voltages start to drop at a rate dependent on standby current load. This causes the feedback voltage to rise. Once it passes  $V_{BURH}$  (500 mV), switching resumes. The feedback voltage then falls and the process repeats. Burst Mode alternately enables and disables SenseFET switching, reducing switching loss in Standby Mode.



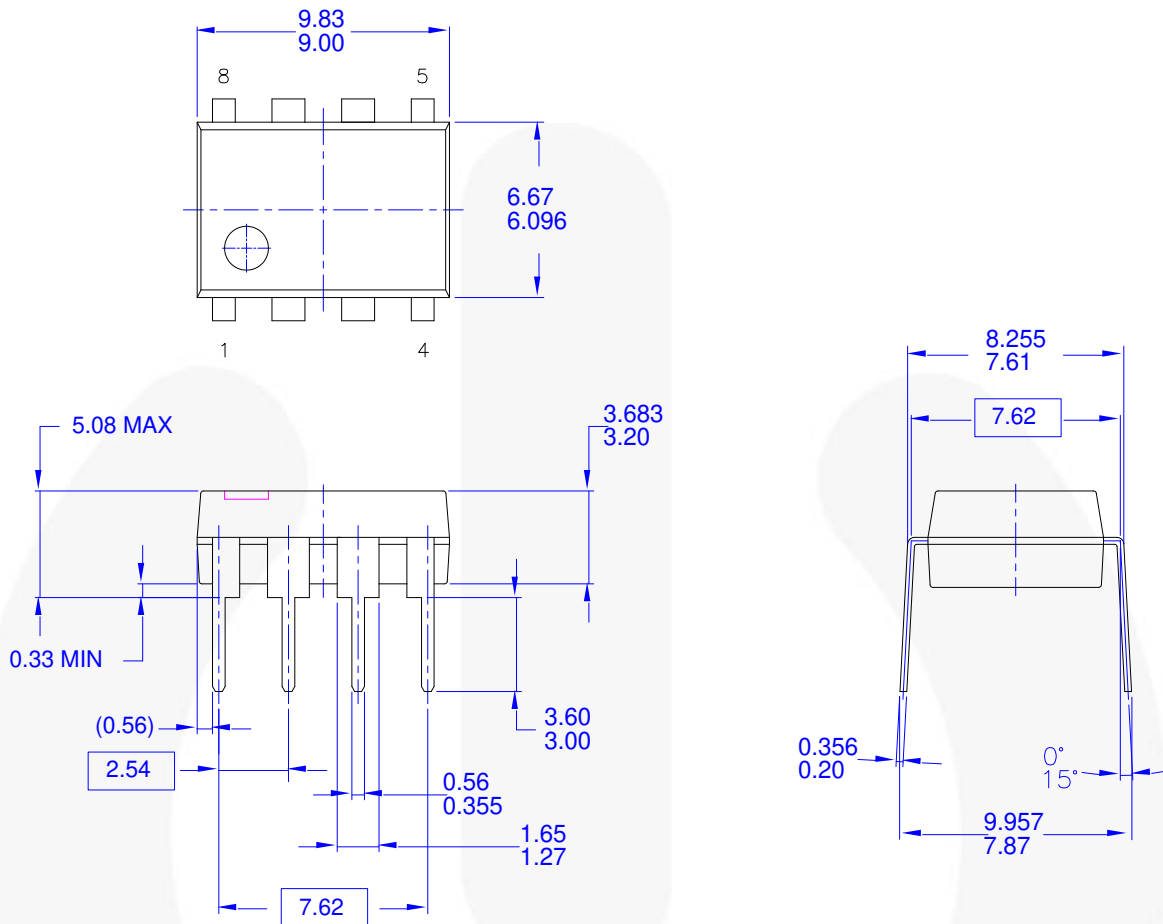
**Figure 26. Burst-Mode Operation**

**6. Random Frequency Fluctuation (RFF):** Fluctuating switching frequency of an SMPS can reduce EMI by spreading the energy over a wide frequency range. The amount of EMI reduction is directly related to the switching frequency variation, which is limited internally. The switching frequency is determined randomly by external feedback voltage and an internal free-running oscillator at every switching instant. RFF effectively scatters EMI noise around typical switching frequency (67 kHz) and can reduce the cost of the input filter included to meet the EMI requirements (e.g. EN55022).



**Figure 27. Random Frequency Fluctuation**

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**Figure 28. 8-Lead, MDIP, JEDEC MS-001, .300" Wide**

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