

# Green Mode Power Switch

## FSL136HR

### Description

The FSL136HR integrated Pulse Width Modulator (PWM) and SENSEFET® is specifically designed for high-performance offline Switch-Mode Power Supplies (SMPS) with minimal external components. FSL136HR includes integrated high-voltage power switching regulators that combine an avalanche-rugged SENSEFET with a current-mode PWM control block.

The integrated PWM controller includes: Under-Voltage Lockout (UVLO) protection, Leading-Edge Blanking (LEB), a frequency generator for EMI attenuation, an optimized gate turn-on/turn-off driver, Thermal Shutdown (TSD) protection, and temperature-compensated precision current sources for loop compensation and fault protection circuitry. The FSL136HR offers good soft-start performance. When compared to a discrete MOSFET and controller or RCC switching converter solution, the FSL136HR reduces total component count, design size, and weight; while increasing efficiency, productivity, and system reliability. This device provides a basic platform that is well suited for the design of cost-effective flyback converters.

### Features

- Internal Avalanche-Rugged SENSEFET (650 V)
- Under 50 mW Standby Power Consumption at 265 Vac, No-load Condition with Burst Mode
- Precision Fixed Operating Frequency with Frequency Modulation for Attenuating EMI
- Internal Startup Circuit
- Built-in Soft-Start: 20 ms
- Pulse-by-Pulse Current Limit
- Various Protection: Over Voltage Protection (OVP), Overload Protection (OLP), Output-Short Protection (OSP), Abnormal Over-Current Protection (AOCP), Internal Thermal Shutdown Function with Hysteresis (TSD)
- Auto-Restart Mode
- Under-Voltage Lockout (UVLO)
- Low Operating Current: 1.8 mA
- Adjustable Peak Current Limit

Table 1. MAXIMUM OUTPUT POWER (Note 1)

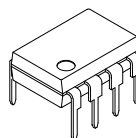
230 Vac ± 15% (Note 2)		85–265 Vac	
Adapter (Note 3)	Open Frame	Adapter (Note 3)	Open Frame
19 W	26 W	14 W	20 W

1. The junction temperature can limit the maximum output power.
2. 230 Vac or 100/115 Vac with doubler.
3. Typical continuous power in a non-ventilated enclosed adapter measured at 50°C ambient.

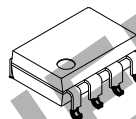


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PDIP8 9.42x6.38, 2.54P  
CASE 646CM



PDIP8 GW  
CASE 709AJ

### MARKING DIAGRAM



\$Y = ON Semiconductor Logo  
&E = Designated Space  
&Z = Assembly Plant Code  
&2 = 2-Digit Date code format  
&K = 2-Digits Lot Run Traceability Code  
FSL136HR = Specific Device Code Data

### ORDERING INFORMATION

See detailed ordering and shipping information on page 5 of this data sheet.

### Applications

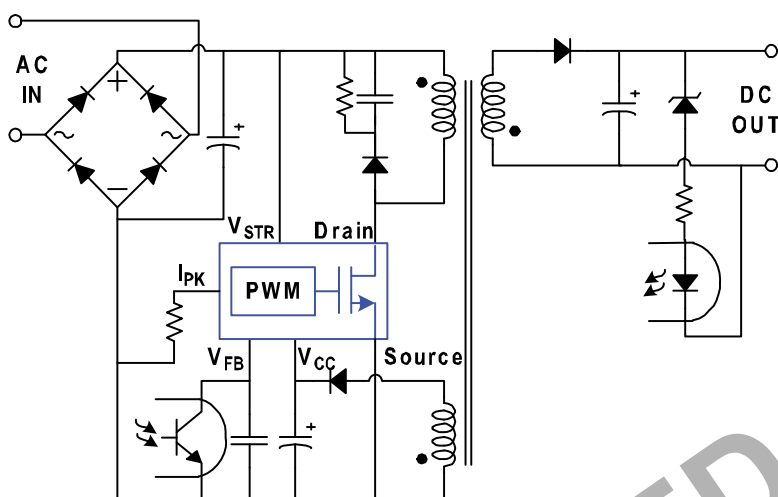
- SMPS for VCR, STB, DVD & DVCD Players
- SMPS for Home Appliance
- Adapter

### Related Resources

- <https://www.onsemi.com/pub/Collateral/AN-4137.pdf.pdf>
- <https://www.onsemi.com/pub/Collateral/AN-4141.pdf.pdf>
- <https://www.onsemi.com/PowerSolutions/home.do>

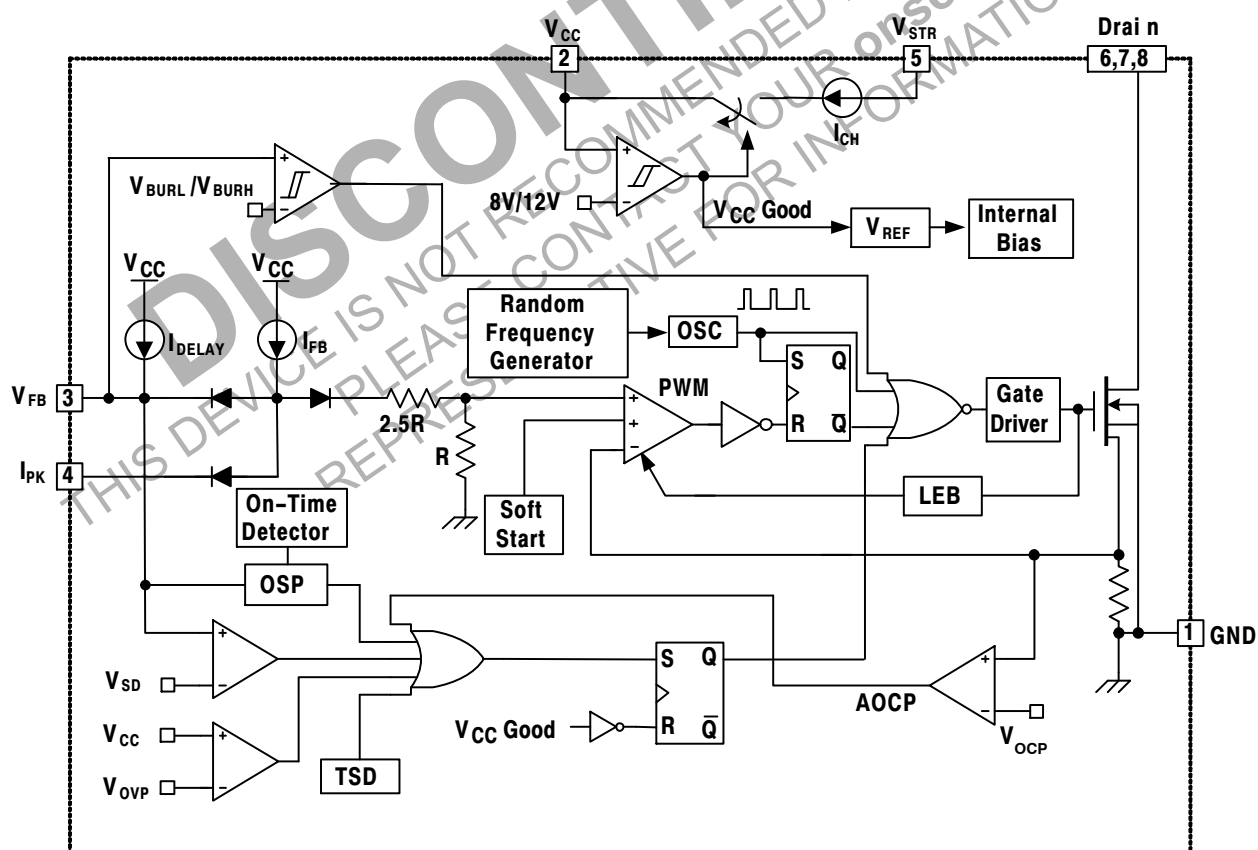
**FSL136HR**

## TYPICAL APPLICATION DIAGRAM



### Figure 1. Typical Application

## INTERNAL BLOCK DIAGRAM



### Figure 2. Internal Block Diagram

# FSL136HR

## PIN CONFIGURATION

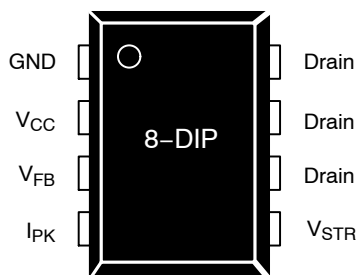


Figure 3. Pin Configuration

## PIN DEFINITIONS

Pin No.	Name	Description
1	GND	<b>Ground.</b> SENSEFET source terminal on the primary side and internal control ground.
2	VCC	<b>Positive Supply Voltage Input.</b> Although connected to an auxiliary transformer winding, current is supplied from pin 5 (VSTR) via an internal switch during startup (see Figure 2). Once VCC reaches the UVLO upper threshold (12 V), the internal startup switch opens and device power is supplied via the auxiliary transformer winding.
3	VFB	<b>Feedback Voltage.</b> The non-inverting input to the PWM comparator, it has a 0.4 mA current source connected internally, while a capacitor and opto-coupler are typically connected externally. There is a delay while charging external capacitor CFB from 2.4 V to 6 V using an internal 5 $\mu$ A current source. This delay prevents false triggering under transient conditions, but still allows the protection mechanism to operate under true overload conditions.
4	IPK	<b>Peak Current Limit.</b> Adjusts the peak current limit of the SENSEFET. The feedback 0.4 mA current source is diverted to the parallel combination of an internal 6 k $\Omega$ resistor and any external resistor to GND on this pin to determine the peak current limit.
5	VSTR	<b>Startup.</b> Connected to the rectified AC line voltage source. At startup, the internal switch supplies internal bias and charges an external storage capacitor placed between the VCC pin and ground. Once VCC reaches 12 V, the internal switch is opened.
6, 7, 8	Drain	<b>Drain.</b> Designed to connect directly to the primary lead of the transformer and capable of switching a maximum of 650 V. Minimizing the length of the trace connecting these pins to the transformer decreases leakage inductance.

## ABSOLUTE MAXIMUM RATINGS (TJ = 25°C unless otherwise specified)

Symbol	Parameter	Min	Max	Unit
VSTR	VSTR Pin Voltage	-0.3	650	V
VDS	Drain Pin Voltage	-0.3	650	V
VCC	Supply Voltage	-	26	V
VFB	Feedback Voltage Range	-0.3	12.0	V
ID	Continuous Drain Current	-	3	A
IDM	Drain Current Pulsed (Note 4)	-	12	A
EAS	Single Pulsed Avalanche Energy (Note 5)	-	230	mJ
PD	Total Power Dissipation	-	1.5	W
TJ	Operating Junction Temperature	Internally Limited		°C
TA	Operating Ambient Temperature	-40	+150	°C
TSTG	Storage Temperature	-55	+150	°C
ESD	Human Body Model, JESD22-A114 (Note 6)	5.0	-	kV
	Charged Device Model, JESD22-C101 (Note 6)	1.5	-	

# FSL136HR

## ABSOLUTE MAXIMUM RATINGS (continued) ( $T_J = 25^\circ\text{C}$ unless otherwise specified) (continued)

Symbol	Parameter	Min	Max	Unit
$\Theta_{JA}$	Junction-to-Ambient Thermal Resistance (Note 7, 8)	–	80	$^\circ\text{C/W}$
$\Theta_{JC}$	Junction-to-Case Thermal Resistance (Note 7, 9)	–	19	
$\Theta_{JT}$	Junction-to-Top Thermal Resistance (Note 7, 10)	–	33.7	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

4. Repetitive rating; pulse width limited by maximum junction temperature.

5.  $L = 51\text{ mH}$ , starting  $T_J = 25^\circ\text{C}$ .

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

7. All items are tested with the standards JESD 51-2 and JESD 51-10.

8.  $\Theta_{JA}$  free-standing, with no heat-sink, under natural convection.

9.  $\Theta_{JC}$  junction-to-lead thermal characteristics under  $\Theta_{JA}$  test condition.  $T_C$  is measured on the source #7 pin closed to plastic interface for  $\Theta_{JA}$  thermo-couple mounted on soldering.

10.  $\Theta_{JT}$  junction-to-top of thermal characteristic under  $\Theta_{JA}$  test condition.  $T_t$  is measured on top of package. Thermo-couple is mounted in epoxy glue.

## ELECTRICAL CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ unless otherwise specified)

Symbol	Parameter	Test Condition	Min	Typ	Max	Unit
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### SENSEFET SECTION

$BV_{DSS}$	Drain-Source Breakdown Voltage	$V_{CC} = 0\text{ V}$ , $I_D = 250\text{ }\mu\text{A}$	650	–	–	V
$I_{DSS}$	Zero Gate Voltage Drain Current	$V_{DS} = 650\text{ V}$ , $V_{GS} = 0\text{ V}$	–	–	250	$\mu\text{A}$
$R_{DS(ON)}$	Drain-Source On-State Resistance	$V_{GS} = 10\text{ V}$ , $V_{DS} = 0\text{ V}$ , $T_C = 25^\circ\text{C}$	–	3.5	4.0	$\Omega$
$C_{ISS}$	Input Capacitance	$V_{GS} = 0\text{ V}$ , $V_{DS} = 25\text{ V}$ , $f = 1\text{ MHz}$	–	290	–	pF
$C_{OSS}$	Output Capacitance	$V_{GS} = 0\text{ V}$ , $V_{DS} = 25\text{ V}$ , $f = 1\text{ MHz}$	–	45	–	pF
$C_{RSS}$	Reverse Transfer Capacitance	$V_{GS} = 0\text{ V}$ , $V_{DS} = 25\text{ V}$ , $f = 1\text{ MHz}$	–	5.5	–	pF
$t_{d(on)}$	Turn-on Delay	$V_{DD} = 350\text{ V}$ , $I_D = 3.5\text{ A}$	–	12	–	ns
$t_r$	Rise Time	$V_{DD} = 350\text{ V}$ , $I_D = 3.5\text{ A}$	–	22	–	ns
$t_{d(off)}$	Turn-off Delay	$V_{DD} = 350\text{ V}$ , $I_D = 3.5\text{ A}$	–	20	–	ns
$t_f$	Fall Time	$V_{DD} = 350\text{ V}$ , $I_D = 3.5\text{ A}$	–	19	–	ns

### CONTROL SECTION

$f_{OSC}$	Switching Frequency	$V_{DS} = 650\text{ V}$ , $V_{GS} = 0\text{ V}$	90	100	110	kHz
$\Delta f_{OSC}$	Switching Frequency Variation	$V_{GS} = 10\text{ V}$ , $V_{GS} = 0\text{ V}$ , $T_C = 125^\circ\text{C}$	–	$\pm 5$	$\pm 10$	%
$f_{FM}$	Frequency Modulation		–	$\pm 3$	–	kHz
$D_{MAX}$	Maximum Duty Cycle	$V_{FB} = 4\text{ V}$	71	77	83	%
$D_{MIN}$	Minimum Duty Ratio	$V_{FB} = 0\text{ V}$	0	0	0	%
$V_{START}$	UVLO Threshold Voltage		11	12	13	V
$V_{STOP}$		After Turn-on	7.0	8.0	9.0	V
$I_{FB}$	Feedback Source Current	$V_{FB} = 0$	320	400	480	$\mu\text{A}$
$t_{S/S}$	Internal Soft-Start Time	$V_{FB} = 4\text{ V}$	15	20	25	ms

### BURST-MODE SECTION

$V_{BURH}$	Burst-Mode Voltage	$T_J = 25^\circ\text{C}$	0.4	0.5	0.6	V
$V_{BURL}$			0.25	0.35	0.45	V
$V_{BURH(HYS)}$			–	150	–	mV

### PROTECTION SECTION

$I_{LIM}$	Peak Current Limit	$T_J = 25^\circ\text{C}$ , $di/dt = 300\text{ mA}/\mu\text{s}$	1.89	2.15	2.41	A
$t_{CLD}$	Current Limit Delay Time (Note 11)		200	–	–	ns
$V_{SD}$	Shutdown Feedback Voltage	$V_{CC} = 15\text{ V}$	5.5	6.0	6.5	V

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## ELECTRICAL CHARACTERISTICS (T<sub>A</sub> = 25°C unless otherwise specified) (continued)

Symbol	Parameter		Test Condition	Min	Typ	Max	Unit
PROTECTION SECTION							
I <sub>DELAY</sub>	Shutdown Delay Current		V <sub>FB</sub> = 5 V	3.5	5.0	6.5	μA
V <sub>OVP</sub>	Over-Voltage Protection Threshold		V <sub>FB</sub> = 2 V	22.5	24.0	25.5	V
t <sub>OSP</sub>	Output Short Protection (Note 11)	Threshold Time	T <sub>J</sub> = 25°C OSP Triggered when t <sub>ON</sub> < t <sub>OSP</sub> & V <sub>FB</sub> > V <sub>OSP</sub> , which lasts longer than t <sub>OSP_FB</sub>	–	1.00	1.35	μs
V <sub>OSP</sub>		Threshold Feedback Voltage		1.44	1.60	–	V
t <sub>OSP_FB</sub>		Feedback Blanking Time		2.0	2.5	–	μs
V <sub>AOCP</sub>	AOCP Voltage (Note 11)		T <sub>J</sub> = 25°C	0.85	1.00	1.15	V
TSD	Thermal Shutdown (Note 11)	Shutdown Temperature		125	137	150	°C
HYS <sub>TSD</sub>		Hysteresis		–	60	–	°C
t <sub>LEB</sub>	Leading-Edge Blanking Time (Note 11)			300	–	–	ns

## TOTAL DEVICE SECTION

I <sub>OP1</sub>	Operating Supply Current (Note 11) (While Switching)	V <sub>CC</sub> = 14 V, V <sub>FB</sub> > V <sub>BURH</sub>	–	2.5	3.5	mA
I <sub>OP2</sub>	Operating Switching Current, (Control Part Only)	V <sub>CC</sub> = 14 V, V <sub>FB</sub> < V <sub>BURL</sub>	–	1.8	2.5	mA
I <sub>CH</sub>	Startup Charging Current	V <sub>CC</sub> = 0 V	0.9	1.1	1.5	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> Increase	35	–	–	V

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

11. Though guaranteed by design, it is not 100% tested in production.

## ORDERING INFORMATION

Part Number	Operating Temperature Range	Top Mark	Package	Packing Method†
FSL136HR	–40 to 105 °C	FSL136HR	8-Lead, Dual Inline Package (DIP)	Rail
FSL136HRL			8-Lead, Surface Mount Package (LSOP)	Rail
FSL136HRLX				Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

# TYPICAL PERFORMANCE CHARACTERISTICS

(These characteristics graphs are normalized  $T_A = 25^\circ\text{C}$ .)

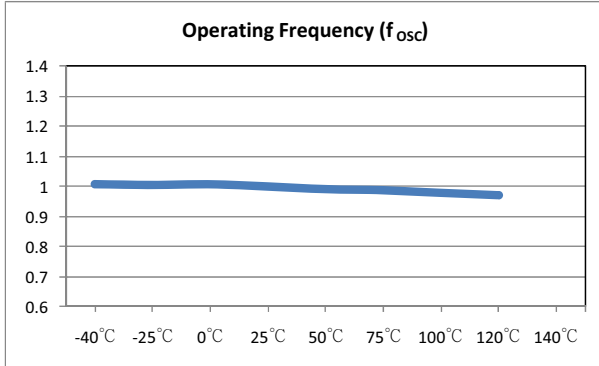


Figure 4. Operating Frequency vs. Temperature

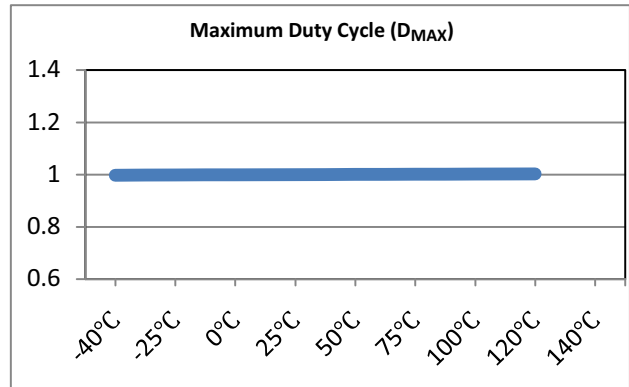


Figure 5. Maximum Duty Cycle vs. Temperature

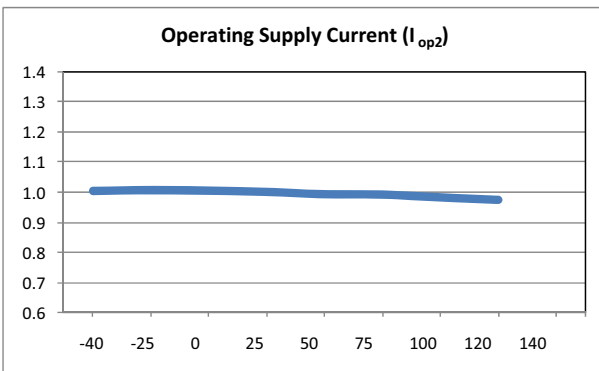


Figure 6. Operating Supply Current vs. Temperature

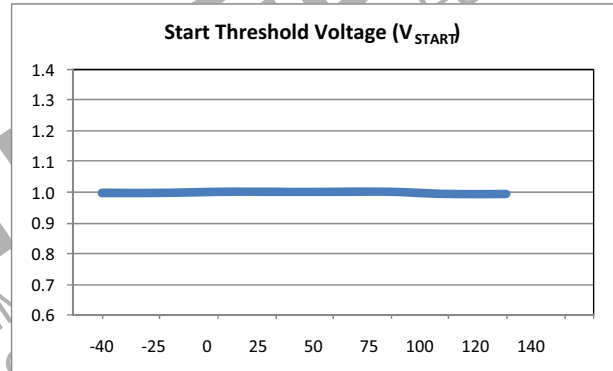


Figure 7. Start Threshold Voltage vs. Temperature

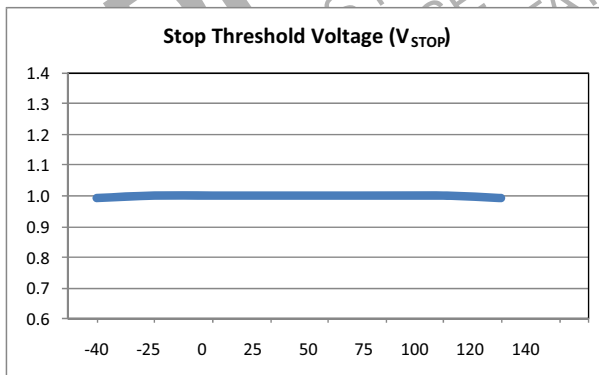


Figure 8. Stop Threshold Voltage vs. Temperature

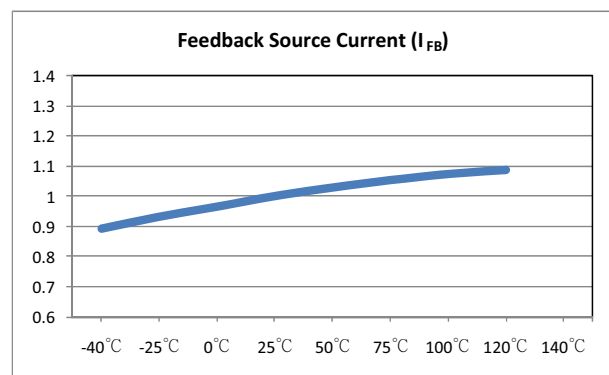


Figure 9. Feedback Source Current vs. Temperature

## TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

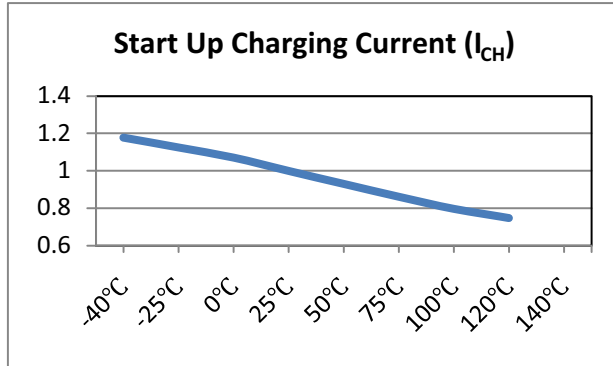
(These Characteristic graphs are normalized at  $T_A = 25^\circ\text{C}$ .)

Figure 10. Startup Charging Current vs. Temperature

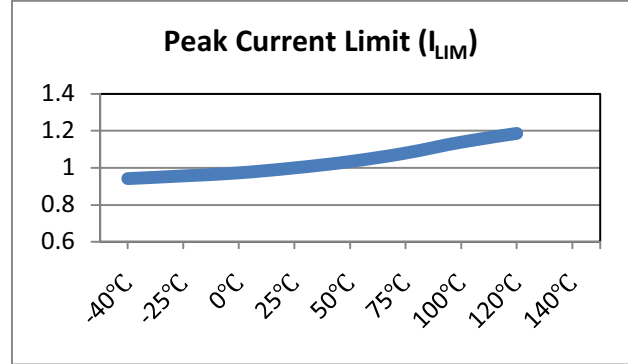


Figure 11. Peak Current Limit vs. Temperature

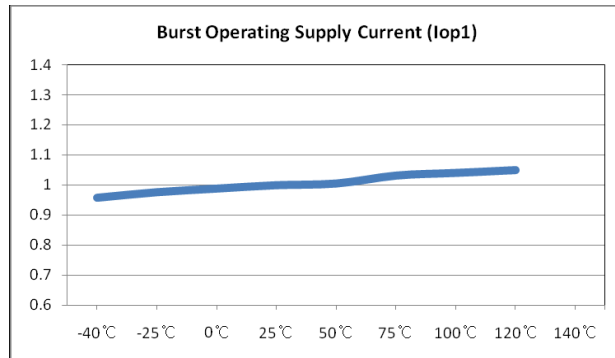


Figure 12. Burst Operating Supply Current vs. Temperature

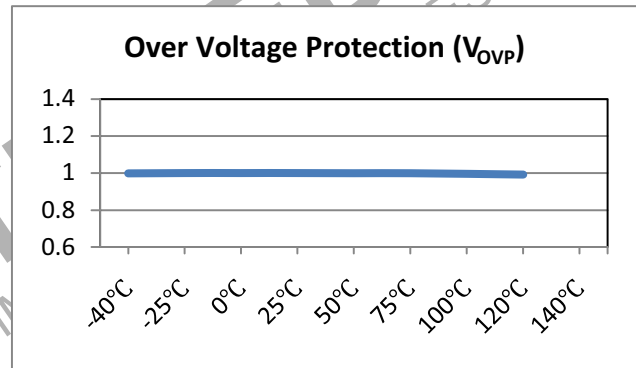


Figure 13. Over-Voltage Protection vs. Temperature

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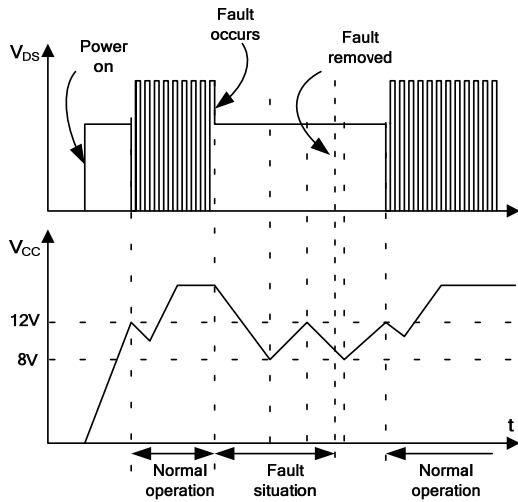


Figure 17. Pulse-Width-Modulation Circuit

### Overload Protection (OLP)

Overload is defined as the load current exceeding a preset level due to an unexpected event. In this situation, the protection circuit should be activated to protect the SMPS. However, even when the SMPS is operating normally, the overload protection (OLP) circuit can be activated during the load transition or startup. To avoid this undesired operation, the OLP circuit is designed to be activated after a specified time to determine whether it is a transient situation or a true overload situation.

In conjunction with the  $I_{PK}$  current limit pin (if used), the current-mode feedback path limits the current in the SENSEFET when the maximum PWM duty cycle is attained. If the output consumes more than this maximum power, the output voltage ( $V_O$ ) decreases below its rating voltage. This reduces the current through the opto-coupler LED, which also reduces the opto-coupler transistor current, thus increasing the feedback voltage ( $V_{FB}$ ). If  $V_{FB}$  exceeds 2.4 V, the feedback input diode is blocked and the 5  $\mu$ A current source ( $I_{DELAY}$ ) starts to charge  $C_{FB}$  slowly up to  $V_{CC}$ . In this condition,  $V_{FB}$  increases until it reaches 6 V, when the switching operation is terminated, as shown in Figure 18. The shutdown delay is the time required to charge  $C_{FB}$  from 2.4 V to 6 V with 5  $\mu$ A current source.

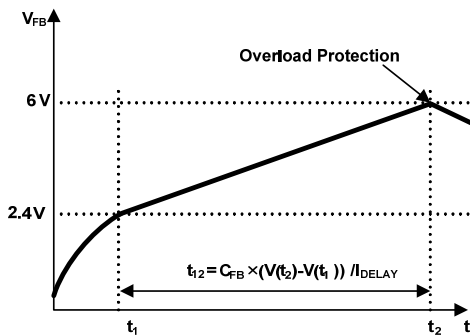


Figure 18. Overload Protection (OLP)

### Abnormal Over-Current Protection (AOCP)

When the secondary rectifier diodes or the transformer pin are shorted, a steep current with extremely high  $di/dt$  can flow through the SENSEFET during the LEB time. Even though the power switch has OLP (Overload Protection), it is not enough to protect the FPS in that abnormal case, since severe current stress is imposed on the SENSEFET until OLP triggers. The power switch includes the internal AOCP (Abnormal Over-Current Protection) circuit shown in Figure 19. 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 latch, resulting in the shutdown of the SMPS.

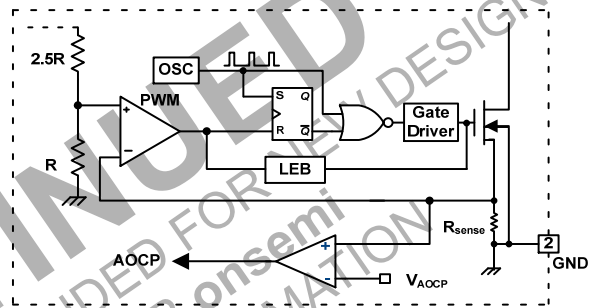


Figure 19. Abnormal Over-Current Protection

### Thermal Shutdown (TSD)

The SENSEFET and the control IC are integrated, making it easier to detect the temperature of the SENSEFET. When the temperature exceeds approximately 137°C, thermal shutdown is activated.

### Over-Voltage Protection (OVP)

In the event of a malfunction in the secondary-side feedback circuit or an open feedback loop caused by a soldering defect, the current through the opto-coupler transistor becomes almost zero. Then,  $V_{FB}$  climbs up in a similar manner to the overload situation, forcing the preset maximum current to be supplied to the SMPS until the overload protection is activated. Because excess energy is provided to the output, the output voltage may exceed the rated voltage before the overload protection is activated, resulting in the breakdown of the devices in the secondary side. To prevent this situation, an over-voltage protection (OVP) circuit is employed. In general,  $V_{CC}$  is proportional to the output voltage and the power switch uses  $V_{CC}$  instead of directly monitoring the output voltage. If  $V_{CC}$  exceeds 24 V, OVP circuit is activated, resulting in termination of the switching operation. To avoid undesired activation of OVP during normal operation,  $V_{CC}$  should be designed to be below 24 V.

### Output-Short Protection (OSP)

If the output is shorted, steep current with extremely high  $di/dt$  can flow through the SENSEFET during the LEB time. Such a steep current brings high-voltage stress on the drain of SENSEFET when turned off. To protect the device from such an abnormal condition, OSP detects  $V_{FB}$  and SENSEFET turn-on time. When the  $V_{FB}$  is higher than 1.6 V and the SENSEFET turn-on time is lower than 1.0  $\mu s$ , the FPS recognizes this condition as an abnormal error and shuts down PWM switching until  $V_{CC}$  reaches  $V_{START}$  again. An abnormal condition output is shown in Figure 20.

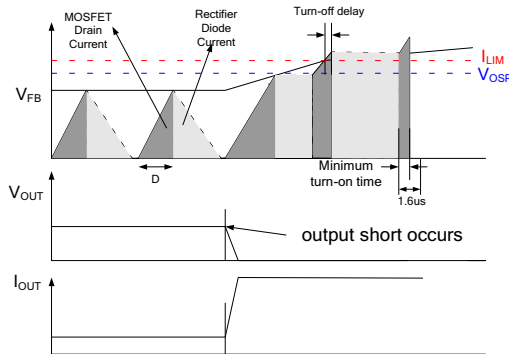


Figure 20. Output Short Waveforms (OSP)

### Soft-Start

The power switch has an internal soft-start circuit that slowly increases the feedback voltage, together with the SENSEFET current, after it starts. The typical soft-start time is 20 ms, as shown in Figure 21, where progressive increments of the SENSEFET current are allowed during the startup phase. The pulse width to the power switching device is progressively increased to establish the correct working conditions for transformers, inductors, and capacitors. The voltage on the output capacitors is progressively increased with the intention of smoothly establishing the required output voltage. Soft-start helps to prevent transformer saturation and reduce the stress on the secondary diode.

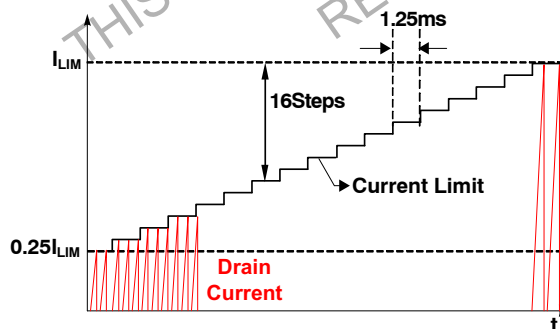


Figure 21. Internal Soft-Start

### Burst Operation

To minimize power dissipation in standby mode, the FPS enters burst mode. As the load decreases, the feedback voltage decreases. As shown in Figure 22, the device automatically enters burst mode when the feedback voltage drops below  $V_{BURH}$ . Switching continues, but the current limit is fixed internally to minimize flux density in the transformer. The fixed current limit is larger than that defined by  $V_{FB} = V_{BURH}$  and, therefore,  $V_{FB}$  is driven down further. Switching continues until the feedback voltage drops below  $V_{BURL}$ . At this point, switching stops and the output voltages start to drop at a rate dependent on the standby current load. This causes the feedback voltage to rise. Once it passes  $V_{BURH}$ , switching resumes. The feedback voltage then falls and the process repeats. Burst mode alternately enables and disables switching of the SENSEFET and reduces switching loss in standby mode.

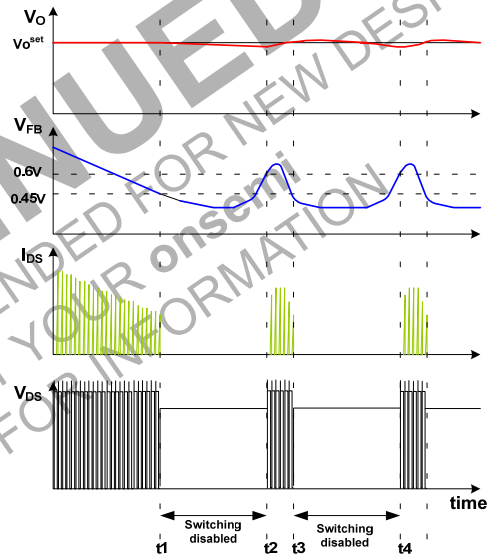


Figure 22. Burst-Mode Operation

### Adjusting Peak Current Limit

As shown in Figure 23, a combined 6 k $\Omega$  internal resistance is connected to the non-inverting lead on the PWM comparator. An external resistance of  $R_x$  on the current limit pin forms a parallel resistance with the 6 k $\Omega$  when the internal diodes are biased by the main current source of 400  $\mu A$ . For example, FSL136HR has a typical SENSEFET peak current limit ( $I_{LIM}$ ) of 2.15 A.  $I_{LIM}$  can be adjusted to 1.5 A by inserting  $R_x$  between the  $I_{PK}$  pin and the ground. The value of the  $R_x$  can be estimated by the following equations:

$$2.15 \text{ A} : 1.5 \text{ A} = 6 \text{ k}\Omega : X \text{ k}\Omega \quad (\text{eq. 1})$$

$$X = R_x \parallel 6 \text{ k}\Omega \quad (\text{eq. 2})$$

Where X is the resistance of the parallel network.

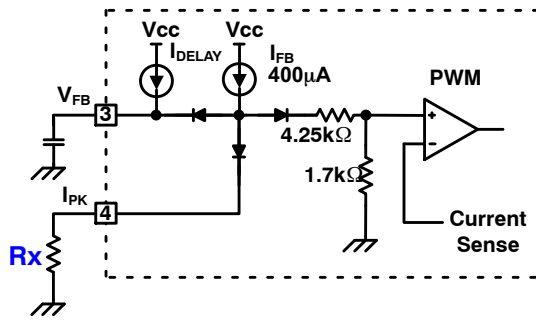
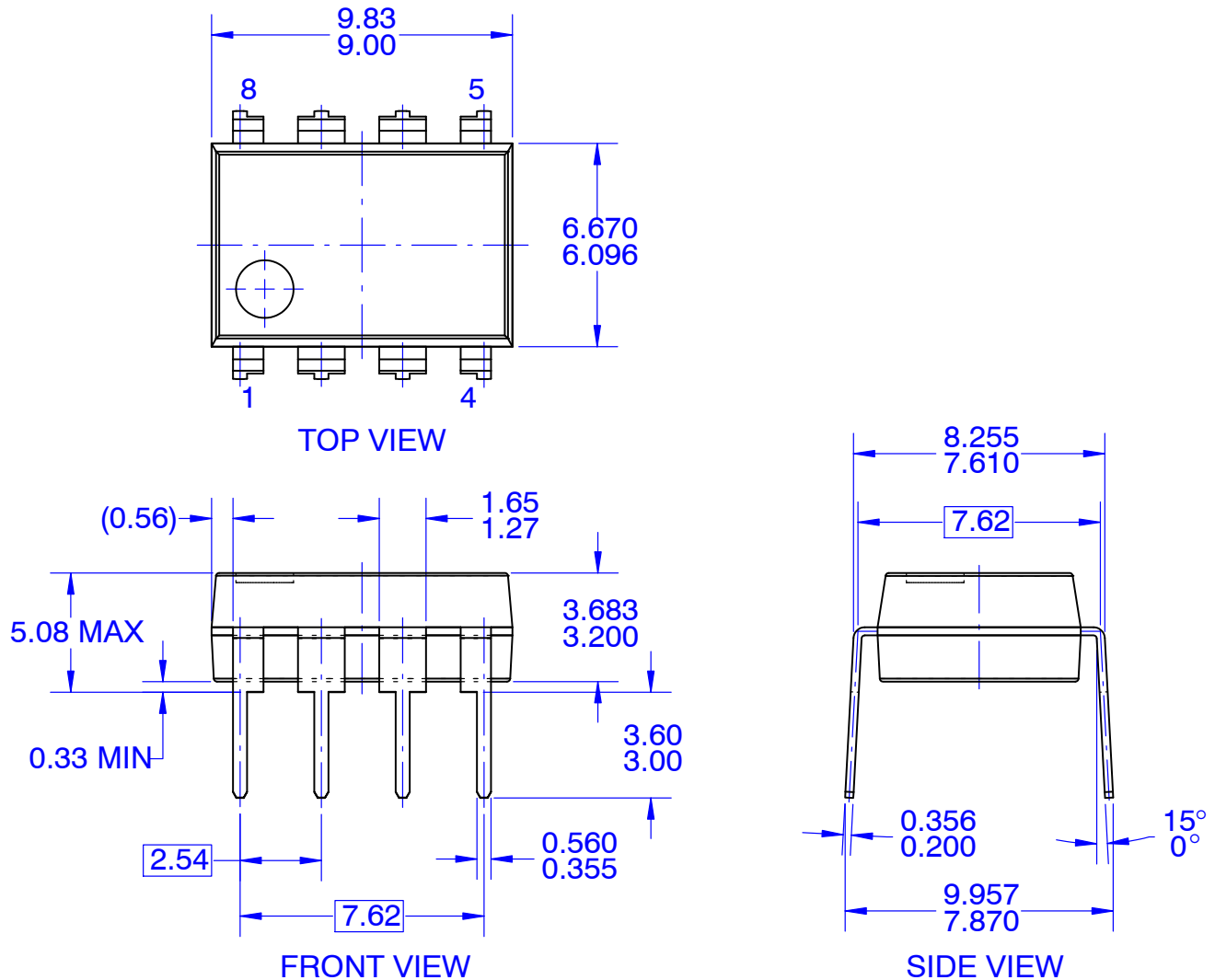


Figure 23. Peak Current Limit Adjustment

**DISCONTINUED**  
 THIS DEVICE IS NOT RECOMMENDED FOR NEW DESIGN  
 PLEASE CONTACT YOUR onsemi  
 REPRESENTATIVE FOR INFORMATION

PDIP8 9.42x6.38, 2.54P  
CASE 646CM  
ISSUE O

DATE 31 JUL 2016



**NOTES:**

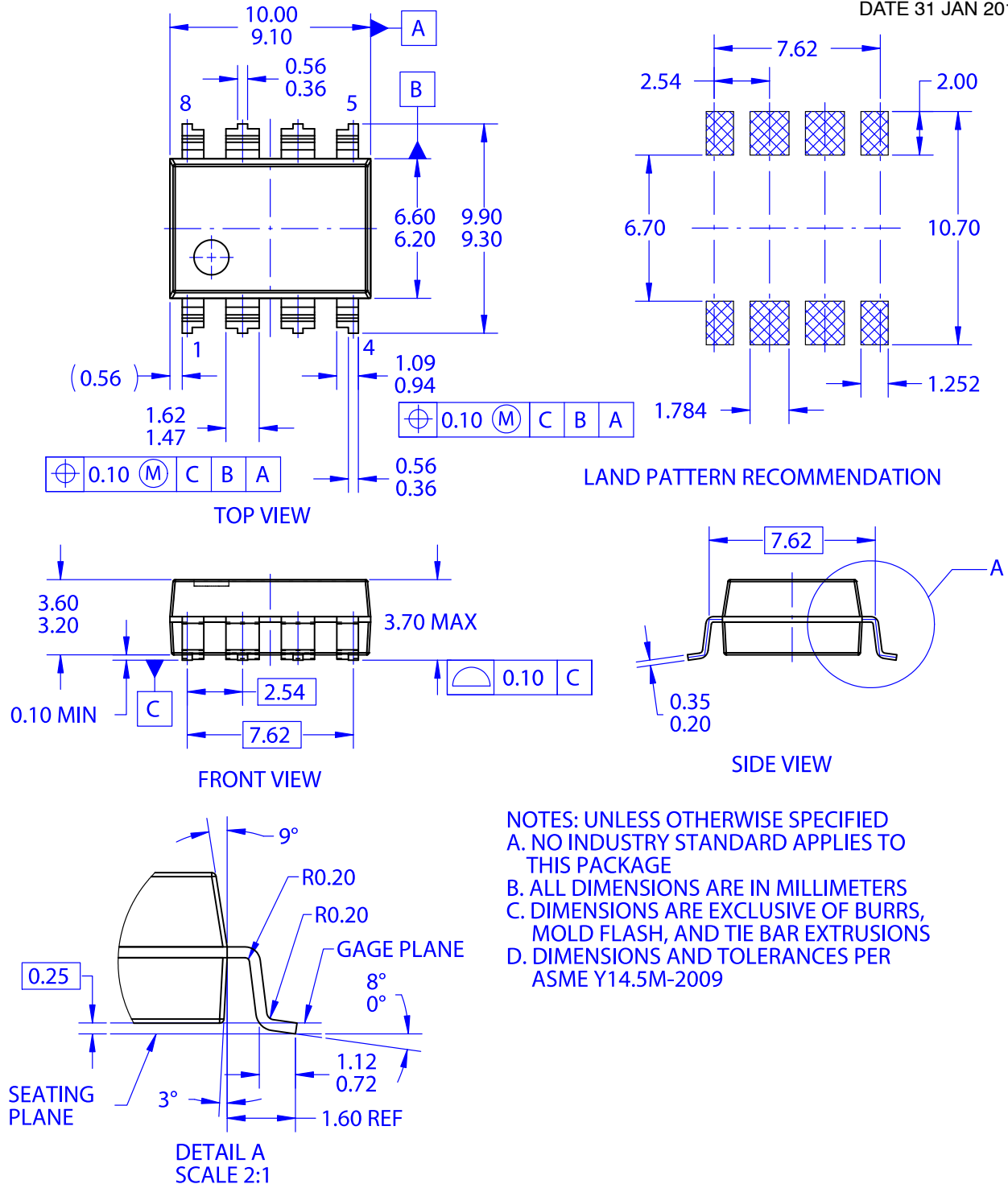
- A. CONFORMS TO JEDEC MS-001, VARIATION BA
- B. ALL DIMENSIONS ARE IN MILLIMETERS
- C. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS
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