

Green Mode onsemi Buck Switch

FSL336LR

Description

The FSL336LR integrated Pulse Width Modulator (PWM) and SENSEFET[®] is specifically designed for high-performance offline buck, buck-boost, and non-isolation flyback Switched Mode Power Supplies (SMPS) with minimal external components. This device integrates a high-voltage power regulator that enables operation without auxiliary bias winding. An internal transconductance amplifier reduces external components for the feedback compensation circuit.

The integrated PWM controller includes: 10 V regulator for no external bias circuit, Under-Voltage Lockout (UVLO), Leading-Edge Blanking (LEB), an optimized gate turn-on / turn-off driver, EMI attenuator, Thermal Shutdown (TSD), temperature-compensated precision current sources for loop compensation, and fault-protection circuitry. Protections include: Overload Protection (OLP), Over-Voltage Protection (OVP), and Feedback Open Loop Protection (FB_OLP). FSL336LR offers good soft-start performance during startup.

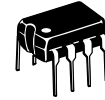
The internal high-voltage startup switch and the Burst-Mode operation with very low operating current reduce the power loss in Standby Mode. As the result, it is possible to reach power loss of 120 mW without external bias and 25 mW with external bias when input voltage is 230 V_{AC}.

Features

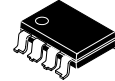
- Built-in Avalanche-Rugged SENSEFET: 650 V
- Fixed Operating Frequency: 50 kHz
- No-Load Power Consumption:
 - <25 mW at 230 V_{AC} with External Bias;
 - <120 mW at 230 V_{AC} without External Bias
- No Need for Auxiliary Bias Winding
- Frequency Modulation for Attenuating EMI
- Pulse-by-Pulse Current Limiting
- Ultra-Low Operating Current: 250 μA
- Built-in Soft-Start and Startup Circuit
- Adjustable Peak Current Limit
- Built-in Transconductance (Error) Amplifier
- Various Protections: Overload Protection (OLP), Over-Voltage Protection (OVP), Feedback Open-Loop Protection (FB_OLP), Thermal Shutdown (TSD)
- Fixed 650 ms Restart Time for Safe Auto-Restart of All Protections
- These Devices are Pb-Free, Halide Free and are RoHS Compliant

Applications

- SMPS for Home Appliances and Industrial Applications
- SMPS for Auxiliary Power

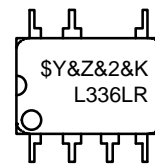


PDIP-7 (PDIP-8 LESS PIN 6)
CASE 626A



PDIP7 MINUS PIN 6 GW
CASE 707AA

MARKING DIAGRAM



- \$Y = Logo
- &Z = Assembly Plant Code
- &2 = 2-Digit Date Code
- &K = 2-Digits Lot Run Traceability Code
- LR336LR = Specific Device Code

ORDERING INFORMATION

See detailed ordering and shipping information on page 11 of this data sheet.

FSL336LR

APPLICATION DIAGRAMS

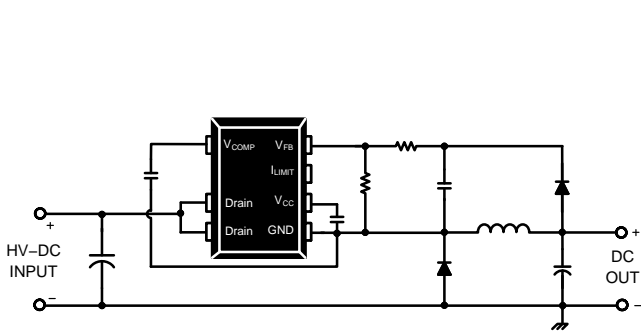


Figure 1. Buck Converter Application

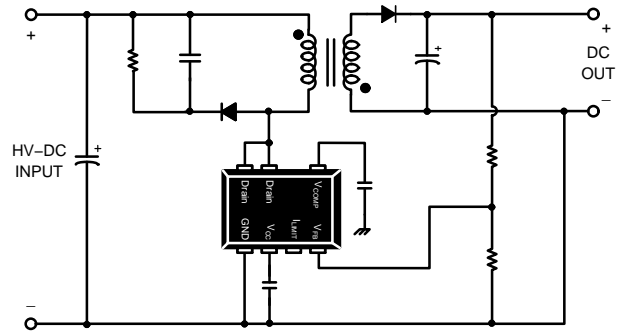


Figure 2. Non-Isolation Flyback Converter Application

BLOCK DIAGRAM

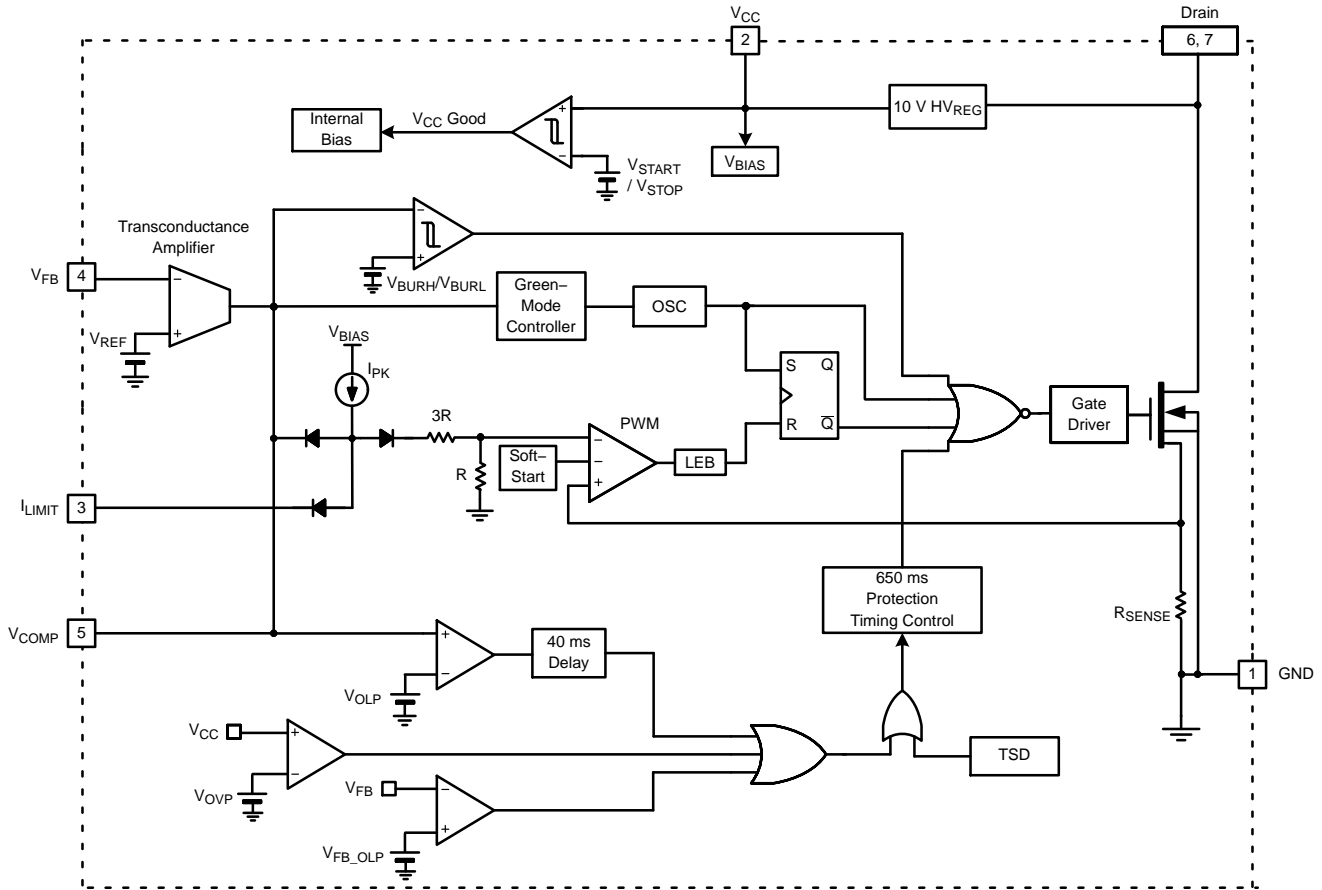


Figure 3. Internal Block Diagram

FSL336LR

PIN CONFIGURATION

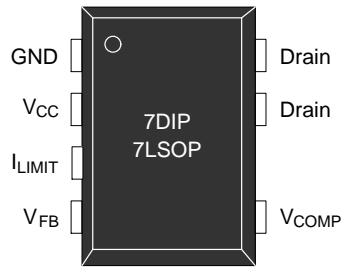


Figure 4. Pin Configuration

PIN DEFINITIONS

Pin #	Name	Description
1	GND	<i>Ground.</i> SENSEFET source terminal on the primary side and internal control ground.
2	V _{CC}	<i>Positive Supply Voltage Input.</i> This pin is the positive supply input that provides the internal operating current for startup and steady-state operation. This pin voltage is regulated to 10 V, without the external bias circuit, via an internal 10-V HVREG (see Figure 3). When the external bias voltage is >10 V, it disables the internal high-voltage regulator to reduce power consumption.
3	I _{LIMIT}	<i>Peak Current Limit.</i> Adjusts the peak current limit of the SENSEFET. The internal 50 μ A current source is diverted to the parallel combination of an internal 46 k Ω (3R + R) resistor and any external resistor to GND on this pin to determine the peak current limit.
4	V _{FB}	<i>Feedback Voltage.</i> Inverting input of the transconductance amplifier. This pin controls the converter output voltage by outputting a V _{COMP} -pin current proportional to the difference between the reference voltage and the output voltage divided by external resistor divider.
5	V _{COMP}	<i>Comp Voltage.</i> Output of the transconductance amplifier. The compensation networks are placed between the V _{COMP} and GND pins to achieve stability and good dynamic performance.
6, 7	Drain	<i>Drain.</i> High-voltage power SENSEFET drain connection. In addition, during startup and steady-state operation; the internal high-voltage current source supplies internal bias and charges the external capacitor connected to the V _{CC} pin. Once V _{CC} reaches 8 V, all internal blocks are activated. The internal high-voltage current source is enabled until V _{CC} reaches 10 V. After that, the internal high-voltage regulator turns on and off regularly to maintain V _{CC} at 10 V.

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

Symbol	Parameter	Min	Max	Unit
V _{DS}	Drain Pin Voltage	-0.3	650.0	V
V _{CC}	Supply Voltage	-0.3	26.0	V
V _{COMP}	V _{COMP} Pin Voltage	-0.3	Internally Clamped Voltage (Note 1)	V
V _{FB}	Feedback Voltage	-0.3	12.0	V
I _{LIMIT}	Current Limit Pin Voltage	-0.3	12.0	V
I _{DM}	Drain Current Pulsed (Note 2)	-	12	A
E _{AS}	Single Pulsed Avalanche Energy (Note 3)	-	230	mJ
P _D	Total Power Dissipation	-	1.25	W
T _J	Operating Junction Temperature (Note 4)	-40	125	°C
	Maximum Junction Temperature	-	150	°C
T _{STG}	Storage Temperature	-55	150	°C

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.

- V_{COMP} is clamped by internal clamping diode (11 V, I_{CLAMP_MAX} < 100 μA).
- Repetitive rating: pulse width is limited by maximum junction temperature.
- L = 51 mH, starting T_J = 25°C.
- Although this parameter guarantees IC operation, it does not guarantee all electrical characteristics.

THERMAL IMPEDANCE (T_A = 25°C unless otherwise specified)

Symbol	Characteristic	Value	Unit
θ _{JA}	Junction-to-Ambient Thermal Impedance (Note 5)	100	°C/W

- JEDEC recommended environment, JESD51-2, and test board, JESD51-3, with minimum land pattern.

ESD CAPABILITY

Symbol	Characteristic	Value	Unit
ESD	Human Body Model, ANSI/ESDA/JEDEC JS-001-2012 (Note 6)	4	kV
	Charged Device Model, JESD22-C101 (Note 6)	2	

- Meets JEDEC standards ANSI/ESDA/JEDEC JS-001-2012 and JESD 22-C101.

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
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SENSEFET SECTION

BV _{DSS}	Drain-Source Breakdown Voltage	V _{CC} = 0 V, I _D = 250 μA	650	-	-	V
I _{DSS}	Zero Gate Voltage Drain Current	V _{DS} = 520 V, T _A = 125°C	-	-	250	μA
R _{DS(ON)}	Drain-Source On-State Resistance	V _{GS} = 10 V, I _D = 1 A	-	3.5	4.0	Ω
C _{ISS}	Input Capacitances	V _{GS} = 0 V, V _{DS} = 25 V, f = 1 MHz	-	290	-	pF
C _{OSS}	Output Capacitance	V _{GS} = 0 V, V _{DS} = 25 V, f = 1 MHz	-	45	-	pF
C _{RSS}	Reverse Transfer Capacitance	V _{GS} = 0 V, V _{DS} = 25 V, f = 1 MHz	-	5.5	-	pF
t _r	Rise Time	V _{DD} = 350 V, I _D = 3.5 A	-	22	-	ns
t _f	Fall Time	V _{DD} = 350 V, I _D = 3.5 A	-	19	-	ns

CONTROL SECTION

f _{OSC}	Switching Frequency	V _{COMP} = 2.5 V	45	50	55	kHz
f _M	Frequency Modulation (Note 7)	V _{COMP} = 2.5 V, Randomly	-	±3	-	kHz
t _{on,max}	Maximum Turn-On Time	V _{COMP} = 2.5 V	11.2	13.3	15.4	μs

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ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified) (continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
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CONTROL SECTION

V _{START}	UVLO Threshold Voltage	V _{COMP} = 0 V, V _{CC} Sweep	7.2	8.0	8.8	V
V _{STOP}		After Turn On	6.3	7.0	7.7	V
I _{PK}	Current Limit Source Current	V _{COMP} = 2.5 V	35	50	65	μA
t _{SS}	Soft-Start Time	V _{COMP} = 2.5 V	7	10	13	ms

BURST MODE SECTION

V _{BURH}	Burst-Mode HIGH Threshold Voltage	V _{CC} = 15 V, V _{COMP} Increase	0.58	0.65	0.72	V
V _{BURL}	Burst-Mode LOW Threshold Voltage	V _{CC} = 15 V, V _{COMP} Decrease	0.52	0.59	0.66	V
HYS _{BUR}	Burst-Mode Hysteresis		–	60	–	mV

PROTECTION SECTION

I _{LIM}	Peak Current Limit	V _{COMP} = 2.5 V, di/dt = 1.2 A/μs	1.6	1.8	2.0	A
t _{CLD}	Current Limit Delay (Note 7)		–	200	–	ns
V _{OLP}	Overload Protection	V _{COMP} Increase	2.7	3.0	3.3	V
t _{LEB}	Leading-Edge Blanking Time (Note 7)		–	200	–	ns
V _{FB_OLP}	FB Open-Loop Protection	V _{FB} Decrease	0.4	0.5	0.6	V
V _{OV}	Over-Voltage Protection	V _{CC} Increase	23.0	24.5	26.0	V
TSD	Thermal Shutdown Temperature (Note 7)		125	135	150	°C
HYS _{TSD}	TSD Hysteresis Temperature (Note 7)		–	60	–	°C
t _{DELAY}	Overload Protection Delay (Note 7)	V _{COMP} > 3 V	–	40	–	ms
t _{RESTART}	Restart Time After Protection (Note 7)		–	650	–	ms

TRANSCONDUCTANCE AMPLIFIER SECTION

G _m	Transconductance of Error Amplifier		380	480	580	μmho
V _{REF}	Voltage Feedback Reference		2.45	2.50	2.55	V
I _{EA,SR}	Output Sourcing Current	V _{FB} = V _{REF} – 0.025 V	–	–12	–	μA
I _{EA,SK}	Output Sink Current	V _{FB} = V _{REF} + 0.025 V	–	12	–	μA

HIGH-VOLTAGE REGULATOR SECTION

V _{HVREG}	HV Regulator Voltage	V _{COMP} = 0 V, V _{DRAIN} = 40 V	9	10	11	V
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TOTAL DEVICE SECTION

I _{OP1}	Operating Supply Current (Control Part Only, without Switching)	0 V < V _{COMP} < V _{BURL}	–	0.25	0.35	mA
I _{OP2}	Operating Supply Current (While Switching)	V _{BURL} < V _{COMP} < V _{OLP}	–	0.8	1.3	mA
I _{CH}	Startup Charging Current	V _{CC} = 0 V, V _{DRAIN} > 40 V	–	6	–	mA
I _{START}	Startup Current	V _{CC} = Before V _{START} , V _{COMP} = 0 V	–	120	155	μA
V _{DRAIN}	Minimum Drain Supply Voltage	V _{CC} = V _{COMP} = 0 V, V _{DRAIN} 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.

7. Though guaranteed by design; not 100% tested in production.

TYPICAL PERFORMANCE CHARACTERISTICS

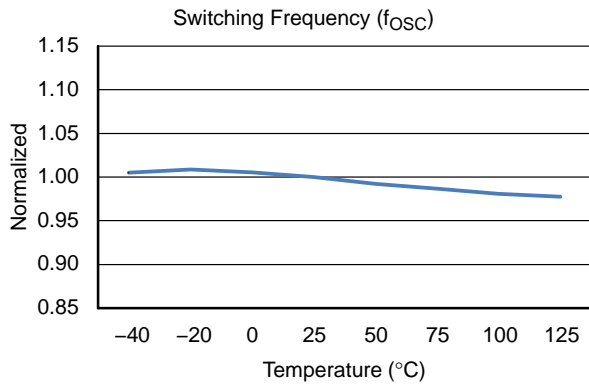


Figure 5. Operating Frequency vs. Temperature

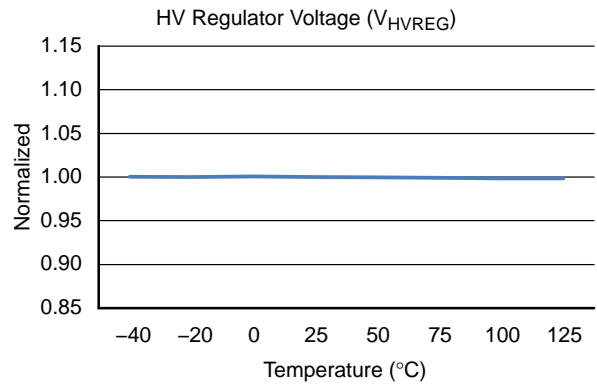


Figure 6. HV Regulator Voltage vs. Temperature

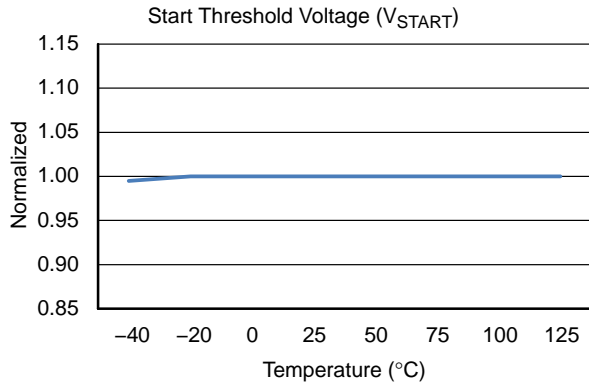


Figure 7. Start Threshold Voltage vs. Temperature

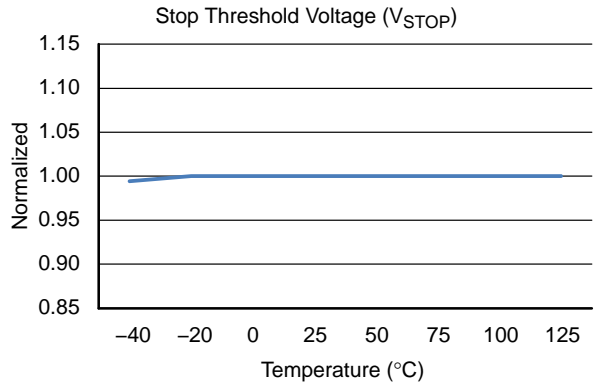


Figure 8. Stop Threshold Voltage vs. Temperature

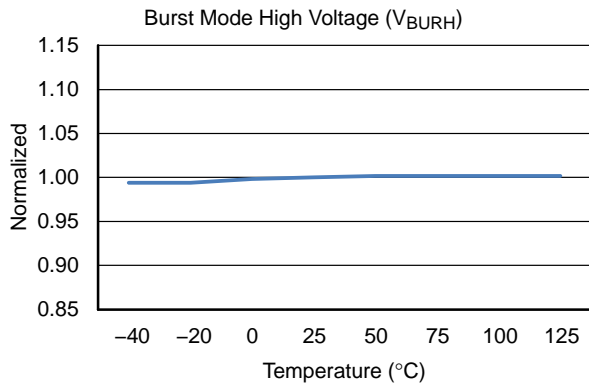


Figure 9. Burst Mode High Voltage vs. Temperature

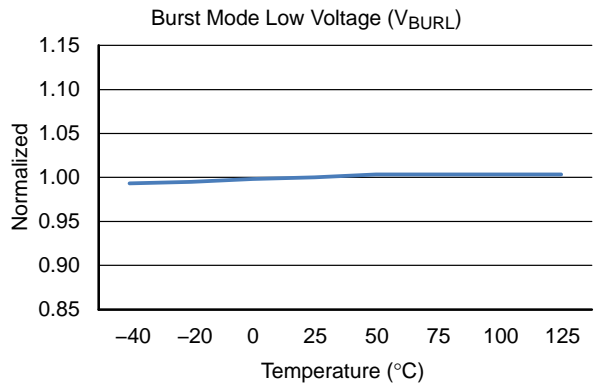


Figure 10. Burst Mode Low Voltage vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

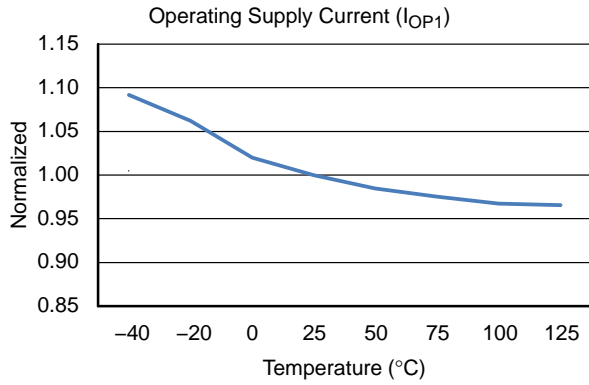


Figure 11. Operating Supply Current 1 vs. Temperature

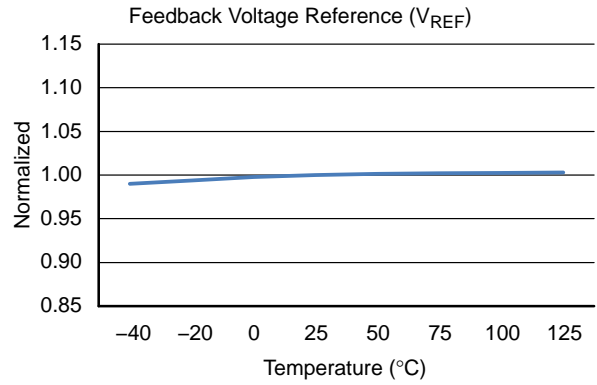


Figure 12. Feedback Voltage Reference vs. Temperature

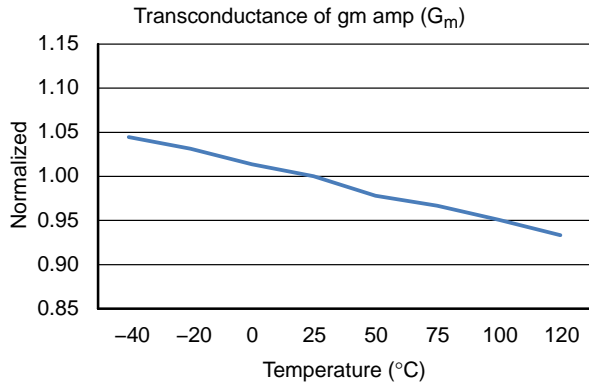


Figure 13. Transconductance of gm Amplifier vs. Temperature

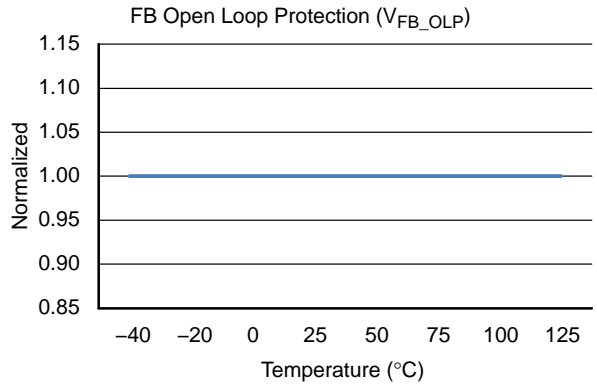


Figure 14. FB Open-Loop Protection Voltage vs. Temperature

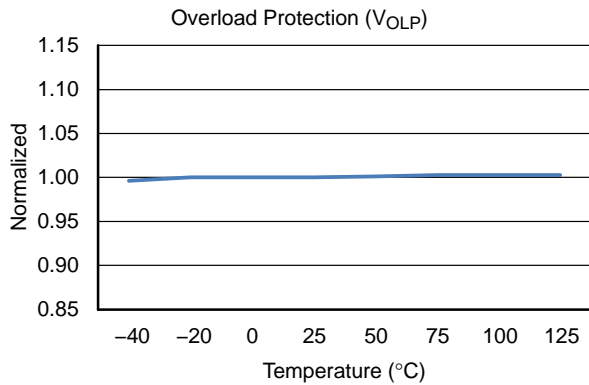


Figure 15. Overload Protection vs. Temperature

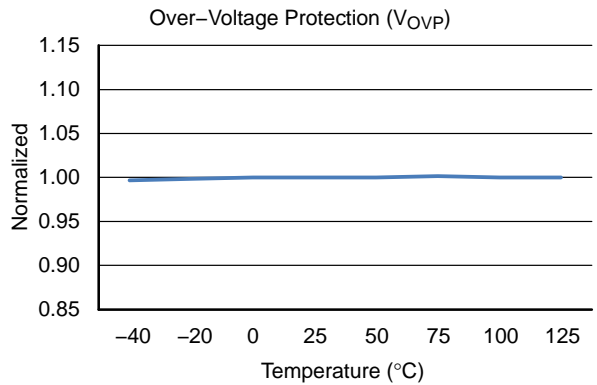


Figure 16. Over-Voltage Protection vs. Temperature

Pulse-by-Pulse Current Limit

Because current-mode control is employed, the peak current flowing through the SENSEFET is limited by the inverting input of PWM comparator, as shown in Figure 19. Assuming that 50 μ A current source flows only through the internal resistors ($3R + R = 46 \text{ k}\Omega$), the cathode voltage of diode D2 is about 2.4 V. Since D1 is blocked when V_{COMP} exceeds 2.4 V, the maximum voltage of the cathode of D2 is clamped at this voltage. Therefore, the peak value of the current of the SENSEFET is limited.

Leading Edge Blanking (LEB)

At the instant the internal SENSEFET is turned on, a high-current spike through the SENSEFET is typically caused by: primary-side capacitance and secondary-side rectifier diode reverse recovery of flyback application, the freewheeling diode reverse recovery, and other parasitic capacitance of buck application. Excessive voltage across the sensing resistor (R_{SENSE}) leads to incorrect feedback operation in the current-mode control. To counter this effect, the FSL336LR has a Leading-Edge Blanking (LEB) circuit (see Figure 19). This circuit inhibits the PWM comparator for a short time (t_{LEB}) after the SENSEFET is turned on.

Protection Circuits

The protective functions include Overload Protection (OLP), Over-Voltage Protection (OVP), Under-Voltage Lockout (UVLO), Feedback Open-Loop Protection (FB_OLP), and Thermal Shutdown (TSD). All of the protection circuits are fully integrated within the IC without external components, reliability is improved without increasing cost or PCB space. If a fault condition occurs, switching is terminated and the SENSEFET remains off. At the same time, internal protection timing control is activated to decrease power consumption and stress on passive and active components during Auto-Restart Mode. When internal protection timing control is activated, V_{CC} is regulated with 10 V through the internal high-voltage regulator until switching is terminated. This internal protection timing control continues until the restart time (650 ms) expires. After 650 ms, the internal high-voltage regulator is disabled and V_{CC} is decreased. When V_{CC} reaches the UVLO stop voltage V_{STOP} (7 V), the protection is reset and the internal high-voltage current source charges the V_{CC} capacitor via the drain pin again. When V_{CC} reaches the UVLO start voltage, V_{START} (8 V), normal operation resumes. In this manner, Auto-Restart Mode can alternately enable and disable the switching of the power SENSEFET until the fault condition is eliminated.

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, when the SMPS operates normally, the OLP circuit can be enabled during load transition or startup. To avoid this undesired operation, an internal fixed delay (40 ms) circuit

determines whether it is a transient situation or a true overload situation (see Figure 21). The current-mode feedback path limits the maximum power current and, when the output consumes more than this maximum power, the output voltage (V_{O}) decreases below its rated voltage. This reduces feedback pin voltage, which increases the output current of the internal transconductance amplifier. Eventually V_{COMP} is increased. When V_{COMP} reaches 3 V, the internal fixed OLP delay (40 ms) is activated. After this delay, the switching operation is terminated, as shown in Figure 22.

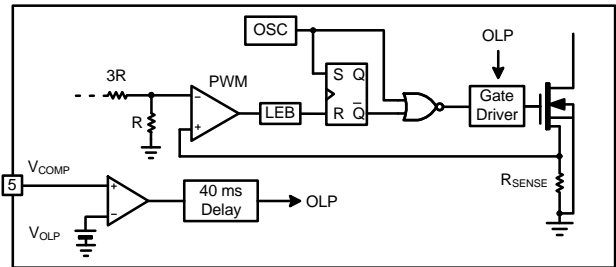


Figure 21. Overload Protection Internal Circuit

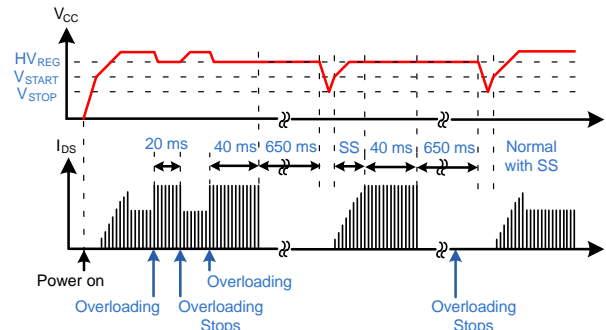


Figure 22. Overload Protection (OLP) Waveform

Thermal Shutdown (TSD)

The SENSEFET and control IC integrated on the same package makes it easier to detect the temperature of the SENSEFET. When the junction temperature exceeds 135°C, thermal shutdown is activated. The FSL336LR is restarted after the temperature decreases to 60°C.

Over-Voltage Protection (OVP)

If any feedback loop components fail due to a soldering defect, V_{COMP} climbs up in manner similar to the overload situation, forcing the preset maximum current to be supplied to the SMPS until the OLP is triggered. In this case, excessive energy is provided to the output and the output voltage may exceed the rated voltage before the OLP is activated. To prevent this situation, an Over-Voltage Protection (OVP) circuit is employed. In general, output voltage can be monitored through V_{CC} and, when V_{CC} exceeds 24.5 V, OVP is triggered, resulting in termination of switching operation. To avoid undesired activation of OVP during normal operation, V_{CC} should be designed below 24.5 V (see Figure 23).

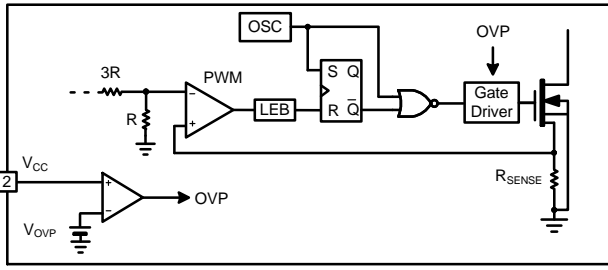


Figure 23. Over-Voltage Protection Circuit

Feedback Open Loop Protection (FB_OLP)

In the event of a feedback loop failure, especially a shorted lower-side resistor of the feedback pin; not only does V_{COMP} rise in a similar manner to the overload situation, but V_{FB} starts to drop to IC ground level. Although OLP and OVP also can protect the SMPS in this situation, FB_OLP can reduce stress on SENSEFET. If there is no FB_OLP, output voltage is much higher than the rated voltage before OLP or OVP triggers. When V_{FB} drops below 0.5 V, FB_OLP is activated, switching off. To avoid undesired activation during startup, this function is disabled during soft-start time.

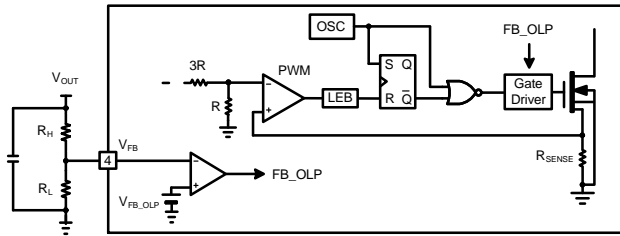


Figure 24. Feedback Open-Loop Protection Circuit

Soft-Start

The internal soft-start circuit slowly increases the SENSEFET current after it starts. The typical soft-start time is 10 ms, as shown in Figure 25, where progressive increments of the SENSEFET current are allowed during startup. 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 gradually increased to smoothly establish the required output voltage. Soft-start also helps to prevent transformer saturation and reduces stress on the secondary diode.

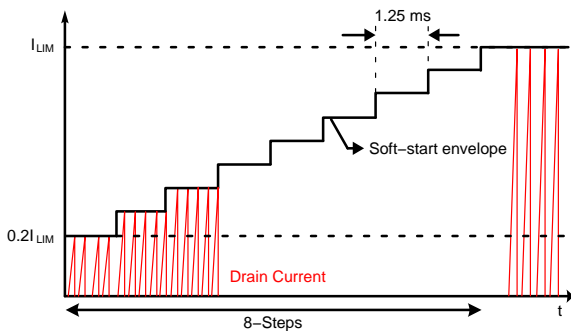


Figure 25. Internal Soft-Start

Burst Mode Operation

To minimize power dissipation in Standby Mode, the FSL336LR enters Burst Mode. As the load decreases, the V_{COMP} pin voltage (V_{COMP}) decreases. As shown in Figure 26, the device automatically enters Burst Mode when 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 V_{COMP} to rise. Once it passes V_{BURH} , switching resumes. V_{COMP} then falls and the process repeats. Burst Mode alternately enables and disables switching of the SENSEFET and reduces switching loss in Standby Mode.

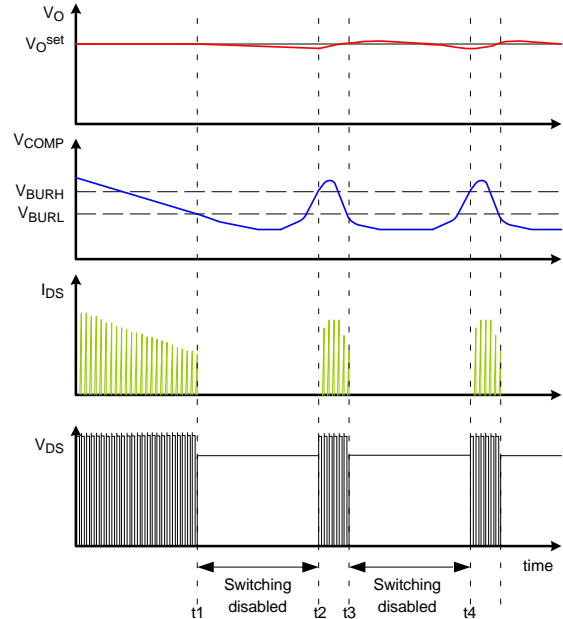


Figure 26. Burst Mode Operation

Green Mode Operation

As output load condition is reduced, the switching loss becomes the largest power loss factor. FSL306LR uses the V_{COMP} pin voltage to monitor output load condition. As output load decreases, V_{COMP} decreases and switching frequency declines, as shown in Figure 27. Once V_{COMP} falls to 0.8 V, the switching frequency varies between 21 kHz and 23 kHz before Burst Mode operation. At Burst Mode operation, random frequency fluctuation still functions.

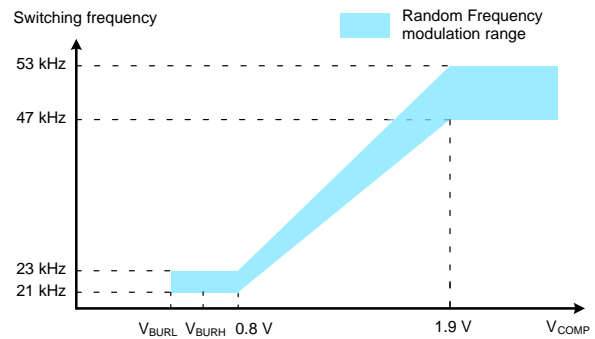


Figure 27. Green Mode Operation

MECHANICAL CASE OUTLINE

PACKAGE DIMENSIONS

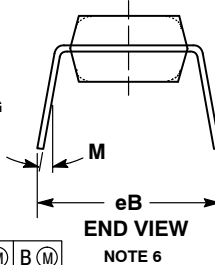
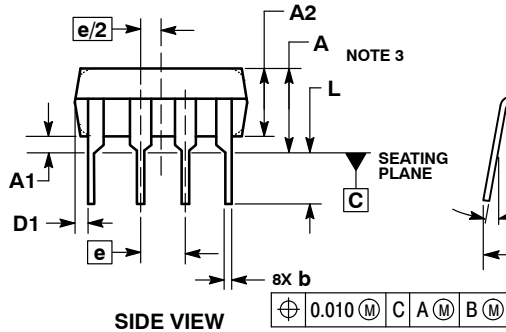
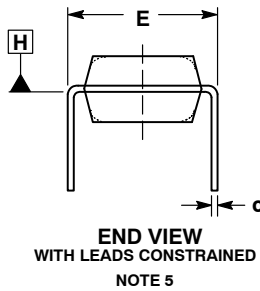
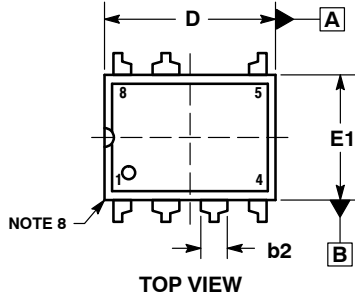
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PDIP-7 (PDIP-8 LESS PIN 6) CASE 626A ISSUE C

DATE 22 APR 2015

SCALE 1:1

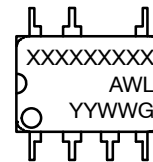


NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSIONS A, A1 AND L ARE MEASURED WITH THE PACKAGE SEATED IN JEDEC SEATING PLANE GAUGE GS-3.
4. DIMENSIONS D, D1 AND E1 DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS ARE NOT TO EXCEED 0.10 INCH.
5. DIMENSION E IS MEASURED AT A POINT 0.015 BELOW DATUM PLANE H WITH THE LEADS CONSTRAINED PERPENDICULAR TO DATUM C.
6. DIMENSION eB IS MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF THE LEADS, WHERE THE LEADS EXIT THE BODY.
8. PACKAGE CONTOUR IS OPTIONAL (ROUNDED OR SQUARE CORNERS).

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	----	0.210	----	5.33
A1	0.015	----	0.38	----
A2	0.115	0.195	2.92	4.95
b	0.014	0.022	0.35	0.56
b2	0.060 TYP		1.52 TYP	
C	0.008	0.014	0.20	0.36
D	0.355	0.400	9.02	10.16
D1	0.005	----	0.13	----
E	0.300	0.325	7.62	8.26
E1	0.240	0.280	6.10	7.11
e	0.100 BSC		2.54 BSC	
eB	----	0.430	----	10.92
L	0.115	0.150	2.92	3.81
M	----	10°	----	10°

GENERIC MARKING DIAGRAM*



- XXXX = Specific Device Code
- A = Assembly Location
- WL = Wafer Lot
- YY = Year
- WW = Work Week
- G = Pb-Free Package

*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present.

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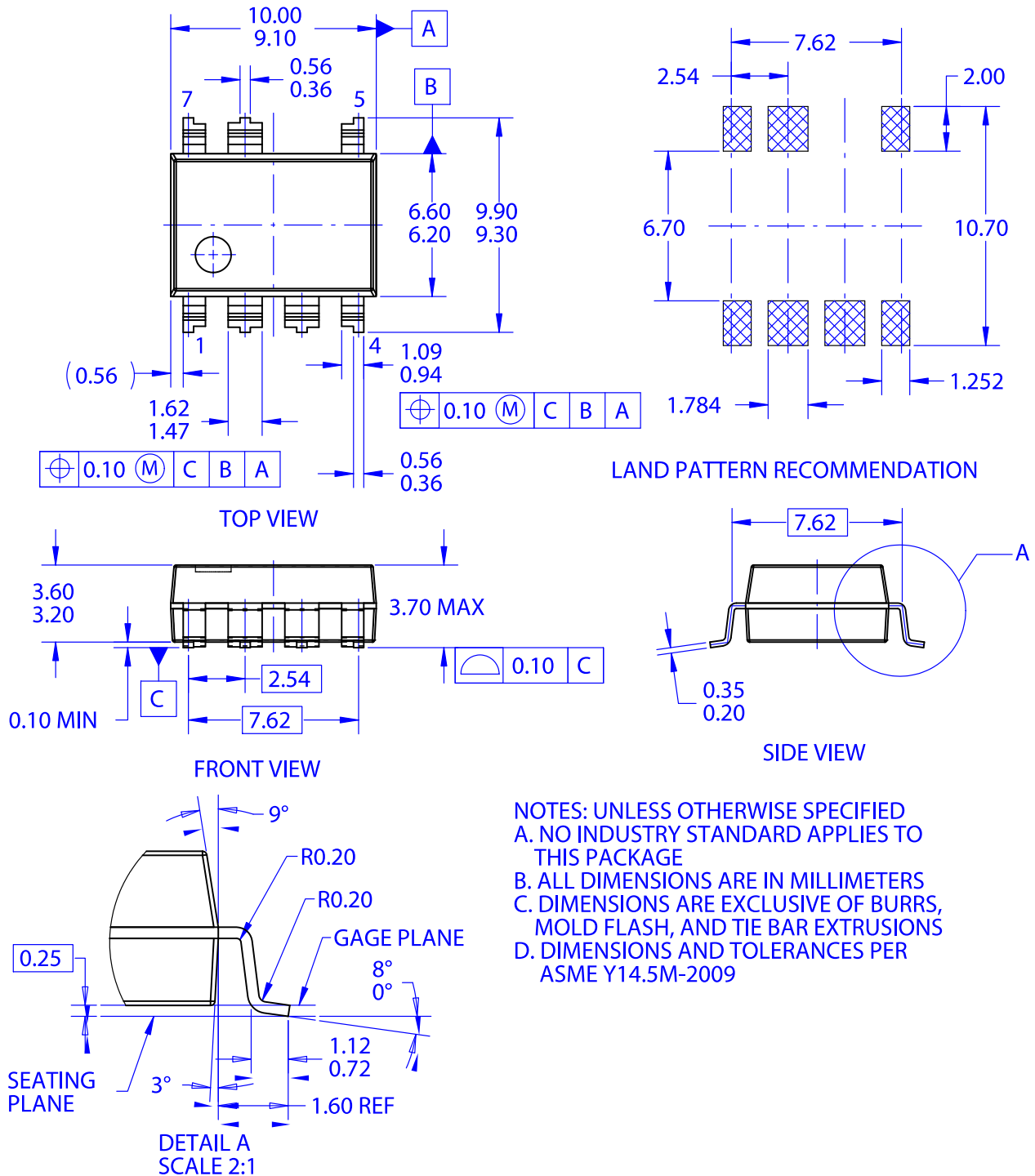
MECHANICAL CASE OUTLINE
PACKAGE DIMENSIONS

ON Semiconductor®



PDIP7 MINUS PIN 6 GW
CASE 707AA
ISSUE O

DATE 31 JAN 2017



- NOTES: UNLESS OTHERWISE SPECIFIED
 A. NO INDUSTRY STANDARD APPLIES TO THIS PACKAGE
 B. ALL DIMENSIONS ARE IN MILLIMETERS
 C. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS
 D. DIMENSIONS AND TOLERANCES PER ASME Y14.5M-2009

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