4.5A, 500kHz Step-Down Switching Regulator

RH1959

1.0 SCOPE

This specification documents the detail requirements for space qualified product manufactured on Analog Devices, Inc.'s QML certified line per MIL-PRF-38535 Level V except as modified herein.

The manufacturing flow described in the ADI STANDARD SPACE PRODUCTS PROGRAM brochure is to be considered a part of this specification. http://www.analog.com/space

This data specifically details the space grade version of this product. A more detailed operational description and a complete data sheet for commercial product grades can be found at https://www.analog.com/LT1959.

2.0 Part Number

The complete part number(s) of this specification follows:

Specific Part Number	Description
RH1959MW	4.5A, 500kHz Step-Down Switching Regulator

3.0 Case Outline

The case outline(s) are as designated in MIL-STD-1835 and as follows:

Outline Letter	Descriptive Designator	Terminals Lead	Finish	Package style
X	CDFP3-F16	16-lead	Hot Solder Dip	Bottom Brazed Flat Pack

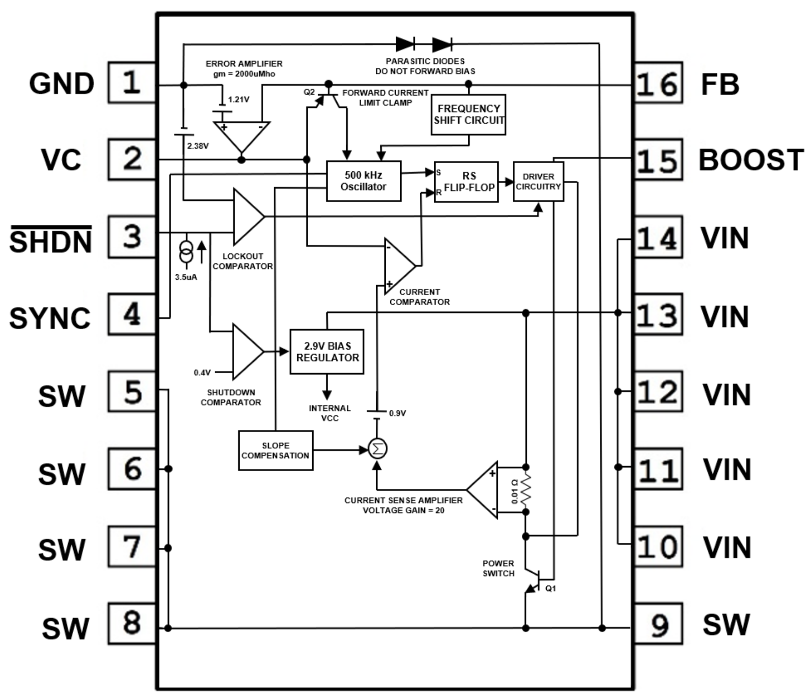

Figure 1 – Functional Block Diagram 1/

1/ Package top view

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Package: X			
Pin Number	Terminal Symbol	Pin Type	Pin Description
1, Package Base 1/	GND	Power	Ground
2	VC	Output	The VC pin is the output of the error amplifier and the input of the peak switch current comparator.
3	$\overline{SHDN}$	Input	The shutdown pin is used to turn off the regulator and to reduce input drain current to a few microamperes.
4	SYNC	Input	The sync pin is used to synchronize the internal oscillator to an external signal.
5, 6, 7, 8, 9	SW	Output	The switch pin is the emitter of the on-chip power NPN switch.
10, 11, 12, 13, 14	VIN	Input/Power	This is the collector of the on-chip power NPN switch. This pin powers the internal circuitry and internal regulator.
15	BOOST	Input/Power	The BOOST pin is used to provide a drive voltage, higher than the input voltage, to the internal bipolar NPN power switch.
16	FB	Input	The feedback pin is used to set output voltage using an external voltage divider that generates 1.21V at the pin with the desired output voltage.

Figure 2 - Terminal Connections

1/ The package bottom has an exposed metal pad that must be connected to the printed circuit board (PCB) output.

4.0 Specifications

4.1. Absolute Maximum Ratings 1/

Input Voltage.. +16 V
BOOST Voltage .... +30 V
BOOST Pin Above Input Voltage.. +15 V
SHDN Pin Voltage .... +7 V
FB Pin Voltage... +3.5 V
FB Pin Current...1mA
SYNC Pin Voltage........................ .... 7 V
Storage Temperature Range .... -65°C to +150°C
Maximum Junction Temperature (T_{JMAX}).. 150°C
Thermal Resistance: Junction to Ambient (θ_{JA}) .... 78.73°C/W
Thermal Resistance: Junction to Case (θ_{JC}) .... 3.86°C/W
Lead Temperature (Soldering, 10 Sec).. 300°C
ESD Sensitivity (FICDM)........................ .... Class C3
ESD Sensitivity (HBM)........................ .... Class 3A

4.2. Recommended Operating Conditions

Ambient operating temperature range (T_A) .... -55°C to +125°C

4.3. Nominal Operating Performance Characteristics (25°C)

V_C Pin High Clamp... 2.1 V
SYNC Pin Input Resistance... 40 kΩ
VC Pin to Switch Transconductance .... 5.3 A/V
Slope Compensation .... 0.8 A

4.4. Radiation Features

Maximum total dose available (50-300 rads(Si)/s) .... 100 krads (Si)

1/ Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions outside of those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum ratings for extended periods may affect device reliability.

TABLE I – ELECTRICAL PERFORMANCE CHARACTERISTICS

Parameter See notes at end of table	Conditions 1/ 2/ Unless otherwise specified		Sub-Group	Limit Min	Limit Max	Units
Feedback Voltage (Adjustable)	All Condition		1	1.19	1.23	V
			2,3	1.19	1.23	V
		M, D, P, L, R	1	1.19	1.23	V
Reference Voltage Line Regulation	4.3V ≤ VIN ≤ 15V		1	-0.03	0.03	%/V
			2,3	-0.03	0.03	%/V
		M, D, P, L, R	1	-0.03	0.03	%/V
Feedback Input Bias Current 9/			1	-0.5	0.5	uA
			2,3	-0.5	0.5	uA
Error Amplifier Voltage Gain 3/			1	200		
			2, 3	200		
		M, D, P, L, R	1	200		
Error Amplifier Transconductance	ΔI (V_C) = ±10µA		1	1500	2700	µMho
			2,3	1000	3100	µMho
		M, D, P, L, R	1	1500	2700	µMho
Error Amplifier Source Current	V_{FB}= 1.05V		1,3	140	320	µA
			2	120	320	µA
		M, D, P, L, R	1	140	320	µA
Error Amplifier Sink Current	V_{FB}= 1.35V		1,3	140	320	µA
			2	120	320	µA
		M, D, P, L, R	1	140	320	µA
VC Pin Switching Threshold	Duty Cycle = 0		1	0.72	1.04	V
			2	0.6	1.04	V
			3	0.72	1.1	V
		M, D, P, L, R	1	0.72	1.04	V
Switch Current Limit 9/	V_C Open, VFB= 1.05V, DC ≤50%		1	4.5	8.5	A
			2, 3	4.5	8.5	A
Switch On Resistance 4/ 9/	I_{SW}= 4.5A		1		0.1	Ω
			2, 3		0.13	Ω
Maximum Switch Duty Cycle	V_{FB}= 1.05V, Boost = V_{IN} + 3V		4	90		%
			5, 6	86		%
		M, D, P, L, R	4	90		%
Switch Frequency	V_C Set to Give 50% Duty Cycle, Boost = V_{IN} + 3V		4	460	540	kHz
			5, 6	440	560	kHz
		M, D, P, L, R	4	425	540	kHz

Parameter See notes at end of table	Conditions 1/ 2/ Unless otherwise specified		Sub-Group	Limit Min	Limit Max	Units
Switch Frequency Line Regulation	4.3V ≤ VIN ≤ 15V		1	-0.15	0.15	%/V
			2,3	-0.15	0.15	%/V
		M, D, P, L, R	1	-0.15	0.175	%/V
Frequency Shifting Threshold on FB Pin	Δf = 10kHz		1	0.5	1.0	V
			2,3	0.5	1.0	V
		M, D, P, L, R	1	0.5	1.0	V
Minimum Input Voltage 5/			1		4.3	V
			2, 3		4.3	V
		M, D, P, L, R	1		4.3	V
Minimum Boost Voltage 6/ 9/	I_{SW} ≤ 4.5A		1		2.75	V
			2,3		3.0	V
Boost Current 7/ 9/	I_{SW} = 1A		1		35	mA
			2,3		35	mA
	I_{SW} = 4.5A		1		130	mA
			2		140	mA
			3		145	mA
Input Supply Current 8/			1		5.4	mA
			2, 3		5.4	mA
		M, D, P, L, R	1		5.4	mA
Shutdown Supply Current	V_{SHDN} = 0V, V_{SW} = 0V, V_C Open		1		50	µA
			2, 3		75	µA
		M, D, P, L, R	1		50	uA
Lockout Threshold 9/	V_C Open		1	2.3	2.46	V
			2, 3	2.3	2.46	V
Shutdown Thresholds	V_C Open Device Shutting Down		1	0.13	0.6	V
			2, 3	0.13	0.6	V
		M, D, P, L, R	1	0.13	0.6	V
	Device Starting Up		1	0.25	0.7	V
			2, 3	0.25	0.7	V
		M, D, P, L, R	1	0.25	0.7	V
Synchronization Threshold 9/			1		2.2	V
			2, 3		2.2	V
Synchronizing Range 9/			4, 6	580	1000	kHz
			5	580	600	kHz

Table IA NOTES:

1/ Device supplied to this drawing have been characterized through all levels M, D, P, L, R of irradiation. However, device is only tested at the "R" level. Pre and Post irradiation values are identical unless otherwise specified in Table I. When performing post irradiation electrical measurements for any RHA level, T_A = +25°C.
2/ T_A = 25°C, V_{IN} = 5V, V_C = 1.5V, Boost = V_{IN}. switch open, otherwise noted.
3/ Gain is measured with a V_C swing equal to 200mV above the switching threshold level to 200mV below the upper clamp level.
4/ Switch on resistance is calculated by dividing V_{IN} to V_{SW} voltage by the forced current (4.5A).
5/ Minimum input voltage is not measured directly but is guaranteed by other tests. It is defined as the voltage where internal bias lines are still regulated so that the reference voltage and oscillator frequency remain constant. Actual minimum input voltage to maintain a regulated output will depend on output voltage and load current.
6/ This is the minimum voltage across the boost capacitor needed to guarantee full saturation of the internal power switch.
7/ Boost current is the current flowing into the boost pin with the pin held 5V above input voltage. It flows only during switch on time.
8/ Input supply current is the bias current drawn by the input pin with switching disabled.
9/ Not tested Post-Rad.

TABLE IIA – ELECTRICAL TEST REQUIREMENTS:

Test Requirements	Subgroups (in accordance with MIL-PRF-38535, Table III)
Interim Electrical Parameters	1
Final Electrical Parameters	1, 2, 3, 4, 5, 6 1/ 2/
Group A Test Requirements	1, 2, 3, 4
Group C end-point electrical parameters	1, 2, 3, 4 2/
Group D end-point electrical parameters	1, 2, 3, 4
Group E end-point electrical parameters	1

Table IIA Notes:
1/ PDA applies to Table I subgroup 1 and 4 and Table IIB delta parameters.
2/ See Table IIB for delta parameters.

TABLE IIB – LIFE TEST/BURN-IN DELTA LIMITS (1/,2/,3/)

Parameter	Delta	Units
Feedback Voltage, $V_{IN} = 5V$, $V_C = 1.5V$	± 5	mV
Feedback Voltage, $V_{IN} = 5V$, $V_C = V_{OL} + 0.2V$	± 5	mV
Feedback Voltage, $V_{IN} = 4.3V$, $V_C = V_{OH} - 0.2V$	± 5	mV

Table IIB Notes:
1/ 240-hour burn-in and 1000-hour life test end point electrical parameters.
2/ Deltas are performed at T_A = +25°C only.
3/ Product is tested in accordance with conditions in Table I.

5.0 Burn-In Life Test, and Radiation

5.1. Burn-In Test Circuit, Life Test Circuit

5.1.1. The test conditions and circuit shall be maintained by the manufacturer under document revision level control and shall be made available to the preparing or acquiring activity upon request. The test circuit shall specify the inputs, outputs, biases, and power dissipation, as applicable, in accordance with the intent specified in method 1015 test condition B of MIL-STD-883.

5.1.2. HTRB is not applicable for this drawing.

6.0 MIL-PRF-38535 QMLV Exceptions

6.1 Wafer Fabrication

WLA per MIL-STD-883 TM 5007 and SEM inspection per MIL-STD-883 TM2018 are not available for this product.

6.2 Device contains bi-metallic wire bonds (Gold bond wires on Aluminum die pads).

7.0 Application Notes

7.1 Feedback Pin Function

The feedback (FB) pin on the RH1959 is used to set output voltage and provide several overload protection features. The first part of this section deals with selecting resistors to set output voltage and the remaining part talks about foldback frequency and current limiting created by the FB pin.

The suggested value for the output divider resistor (see Figure 3) from FB to ground (R2) is 2.5k or less, and a formula for R1 is shown below. The output voltage error caused by ignoring the input bias current on the FB pin is less than 0.1% with R2 = 2.5k. Please read the following if divider resistors are increased above the suggested values.

$$R1 = \frac{R2\left(V_{OUT} - 1.21\right)}{1.21}$$

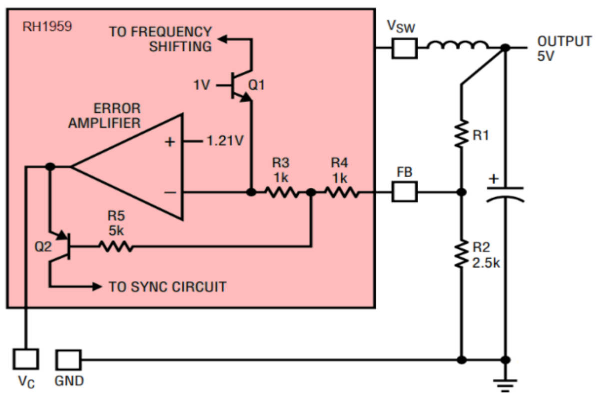

Figure 3. Frequency and Current Limit Foldback

7.2 Boost Pin Consideration

For most applications, the boost components are a 0.27µF capacitor and a 1N914 or 1N4148 diode. The anode is connected to the regulated output voltage, and this generates a voltage across the boost capacitor nearly identical to the regulated output. In certain applications, the anode may instead be connected to the unregulated input voltage. This could be necessary if the regulated output voltage is very low (<3V) or if the input voltage is less than 5V. Efficiency is not affected by the capacitor value, but the capacitor should have an ESR of less than 1Ω to ensure that it can be recharged fully under the worst-case condition of minimum input voltage. Almost any type of film or ceramic capacitor will work fine.

For nearly all applications, a 0.27µF boost capacitor works just fine, but for the curious, more details are provided here. The size of the boost capacitor is determined by switch drive current requirements. During switch on time, drain current on the capacitor is approximately $I_{OUT}/50$. At peak load current of 4.25A, this gives a total drain of 85mA. Capacitor ripple voltage is equal to the product of on time and drain current divided by capacitor value; $\Delta V = (t_{ON})(85mA/C)$. To keep capacitor ripple voltage to less than 0.6V (a slightly arbitrary number) at the worst-case condition of $t_{ON} = 1.8\mu s$, the capacitor needs to be 0.27µF. Boost capacitor ripple voltage is not a critical parameter, but if the minimum voltage across the capacitor drops to less than 3V, the power switch may not saturate fully and efficiency will drop. An approximate formula for absolute minimum capacitor value is:

$$C_{MIN} = \frac{\left(I_{OUT}/50\right)\left(V_{OUT}/V_{IN}\right)}{\left(f\right)\left(V_{OUT} - 2.8V\right)}$$

f = Switching frequency
V_{OUT} = Regulated output voltage
V_{IN} = Minimum input voltage

This formula can yield capacitor values substantially less than 0.27µF, but it should be used with caution since it does not take into account secondary factors such as capacitor series resistance, capacitance shift with temperature and output overload.

7.3 Shutdown Function and Undervoltage Lockout

Figure 4 shows how to add undervoltage lockout (UVLO) to the RH1959. Typically, ULVO is used in situations where the input supply is current limited or has a relatively high source resistance. A switching regulator draws constant power from the source, so source current increases as source voltage drops. This looks like a negative resistance load to the source and can cause the source to current limit or latch low under low source voltage conditions. ULVO prevents the regulator from operating at source voltages where these problems might occur.

Threshold voltage for lockout is about 2.38V. A 3.5µA bias current flows out of the pin at threshold. This internally generated current is used to force a default high state on the shutdown pin if the pin is left open. When low shutdown current is not an issue, the error due to this current can be minimized by making RLO 10k or less. If shutdown current is an issue, RLO can be raised to 100k, but the error due to initial bias current and changes with temperature should be considered.

$$R_{LO} = 10k \text{ to } 100k \left(25k \text{ suggested}\right)$$

$$R_{HI} = \frac{R_{LO}\left(V_{IN} - 2.38V\right)}{2.38V - R_{LO}\left(3.5\mu A\right)}$$

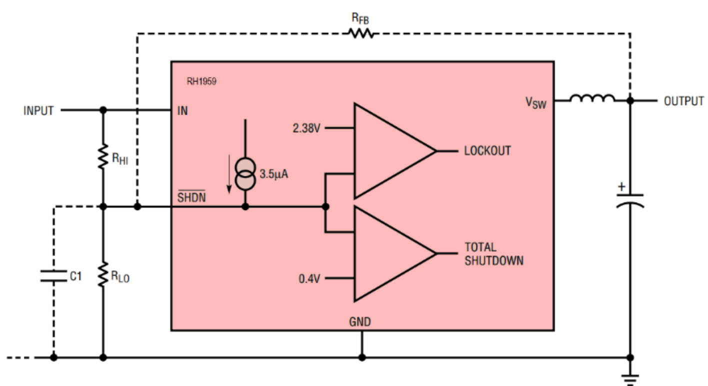

Figure 4. Undervoltage Lockout

8.0 Package Outline Dimensions

The W package and outline dimensions can also be found at https://www.analog.com or upon request.

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option
RH1959MW	−55°C to +125°C	16- Flat Pack Thermally Enhanced BBFP	CDFP3-F16

Revision History		
Rev	**Description of Change**	**Date**
A	Initial Production Release	9/25/2024

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