Data Sheet

RHM4900

Quad, 40V_{IN}, Silent Switcher µModule Regulator with Configurable 3A Output Array

FEATURES

- No single-event latchup (SEL) ≤40.8MeV linear energy transfer (LET), up to 15V_{IN}
- 75krads maximum total ionizing dose (TID) available
- Wafer diffusion lot traceability, radiation monitoring for SEL, TID, and outgassing characterization
- Commercial space low (CSL) production flow
- Four complete 3A (4A peak) step-down switching power supplies
- Low noise Silent Switcher® architecture
- Compliant with CISPR22 Class B/CISPR25 Class 5
- Wide input voltage range: 3V to 40V
- Wide output voltage range: 0.8V to 8V
- 4A continuous output current per channel at 12V_{IN}, 3.3V_{OUT}, f_{SW} = 2MHz, T_A = 60°C
- Multiphase or multi-µModule® parallelable for increased output current
- *165-Lead, 16mm × 11.9mm × 3.32mm, BGA* package

APPLICATIONS

- Low earth orbit (LEO) satellites
- Point-to-point communications systems
- Avionics

GENERAL DESCRIPTION

The RHM4900 is a quad, 40V_{IN}, 3A (4A peak) step-down, Silent Switcher® power µModule (micromodule) regulator designed for CSL applications. The *Silent Switcher* architecture minimizes electromagnetic interference (EMI), while delivering high efficiency at frequencies of up to 3MHz. The package includes the controllers, power switches, inductors, and support components. Operating over a wide input voltage range, the RHM4900 supports output voltages from 0.8V to 8V, and a switching frequency range of 200kHz to 3MHz, each set by a single resistor. Only bulk input and output filter capacitors are needed to finish the design.

The RHM4900 is packaged in a compact, over-molded, ball-grid array (BGA) package suitable for automated assembly by standard surface-mount equipment. The RHM4900 is available in SnPb or RoHS-compliant terminal finish. The outputs can be parallel in an array for up to 12A (16A peak) capability (see *Figure 1*).

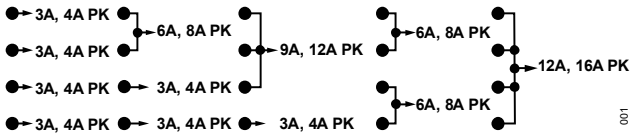

Figure 1. Configurable Output Array

TYPICAL APPLICATION

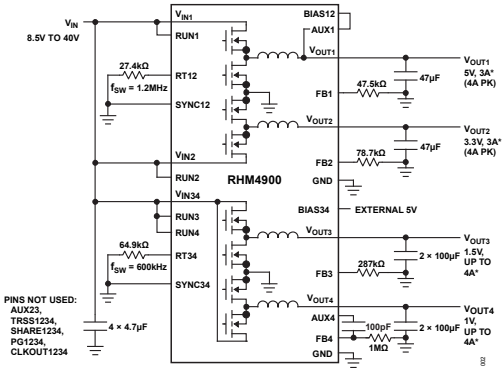

Figure 2. Quad 3A (4A Peak) Output from 8.5V to 40V Input

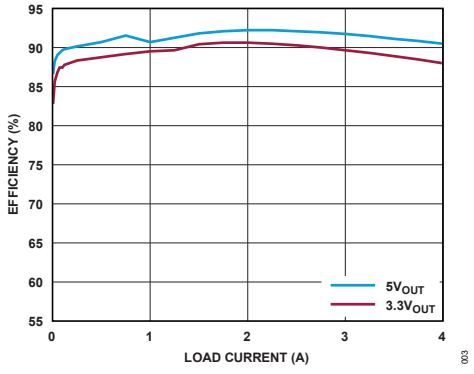

Figure 3. Efficiency, V_{IN} = 24V, BIAS = 5V

*Output current capability (transient peak or continuous) is subject to environmental factors such as ambient temperature, airflow, or other cooling techniques. For different V_{IN}, V_{OUT}, and T_A conditions, see the notes section (Note *3*) in the *Electrical Characteristics* table and the derating curves in the *Applications Information* section.

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REVISION HISTORY

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGE NUMBER
0	07/26	Initial release	—

SPECIFICATIONS

DC Specifications

Table 1. Electrical Characteristics

(Specifications are at T_A = 25°C. V_{INn} = 12V, RUNn = 2V, unless otherwise noted. [1,2])

PARAMETER	CONDITIONS	COMMENTS	MIN	TYP	MAX	UNITS
Minimum V_{IN1} input voltage	V_{IN1} = 3V	–40°C ≤ T_J ≤ 125°C			3	V
Minimum V_{IN34} input voltage	V_{IN1} = 3V	–40°C ≤ T_J ≤ 125°C			3	V
Minimum V_{IN2} input voltage	V_{IN1} = 3V	–40°C ≤ T_J ≤ 125°C			2	V
Output DC voltage	FBn open			0.8		V
	FBn = 21.5kΩ, V_{INn} = 30V			10		V
Maximum output DC current	[3]				6	A
Quiescent current into V_{INn}	RUNn = 0				8	µA
	BIASn = 5V, SYNCn = 3.3V, no load			7		mA
Current into BIASn	RUNn = 0, BIASn = 5V				0.5	µA
	BIASn = 5V, SYNCn = 3.3V, no load			18		mA
Line regulation	5V < V_{INn} < 40V, I_{OUTn} = 1A			0.05		%
Load regulation	12V_{INn}, 0.1A < I_{OUTn} < 4A			0.1		%
Output RMS ripple	3.3V_{OUTn}, I_{OUTn} = 4A			10		mV
FBn voltage			792	800	808	mV
		–40°C ≤ T_J ≤ 125°C	784	800	816	mV
Current out of FBn	V_{OUTn} = 1V, FBn = 0V			4		µA
Minimum BIASn for proper operation					3.2	V
Switching frequency	RTn = 200kΩ			200		kHz
	RTn = 35.7kΩ			1		MHz
	RTn = 8.06kΩ			3		MHz
RUNn threshold				0.74		V
RUNn input current	RUNn = 0V				100	nA
PGn threshold at FBn	Lower threshold			740		mV
	Upper threshold			860		mV
PGn output sink current	PGn = 0.1V		100			µA
CLKOUTn V_{OL}				0.2		V
CLKOUTn V_{OH}				3.2		V

(Specifications are at T_A = 25°C. V_{INn} = 12V, RUNn = 2V, unless otherwise noted. [1,2])

PARAMETER	CONDITIONS	COMMENTS	MIN	TYP	MAX	UNITS
SYNCn input high threshold			1.5			V
SYNCn input low threshold					0.8	V
SYNCn threshold to enable spread spectrum			2.8		4.0	V
SYNCn current	SYNCn = 6V			60		µA
TRSSn source current	TRSSn = 0V			2		µA
TRSSn pull-down resistance	Fault condition, TRSSn = 0.1V			200		Ω

1 The RHM4900 is tested under pulsed load conditions such that $T_J = T_A$. The RHM4900 is guaranteed to meet specifications over the full –40°C to 125°C internal operating temperature range. Note that the maximum internal temperature is determined by specific operating conditions in conjunction with the board layout, the rated package thermal resistance, and other environmental factors.

2 n represents each individual channel. Four outputs are tested separately, and the same testing condition is applied to each output.

3 The maximum current out of any channel may be limited by the internal temperature of the RHM4900. For different V_{IN}, V_{OUT} and T_A conditions, see the output current derating curves in the *Applications Information* section.

Radiation Test and Limit Specifications

Table 2. Radiation Test and Limit Specifications

(All minimum and maximum specifications are at T_J (Junction Temperature) = 25°C. Total ionizing dose (TID) testing characterized to 75krads.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Minimum V_{IN1} input voltage	V_{IN1} = 3V			3	V
Minimum V_{IN34} input voltage	V_{IN1} = 3V			3	V
Minimum V_{IN2} input voltage	V_{IN1} = 3V			2	V
Output DC voltage	FBn open		0.8		V
	FBn = 21.5kΩ, V_{INn} = 30V		10		V
Maximum output DC current				6	A
Quiescent current into V_{INn}	RUNn = 0			30	µA
	BIASn = 5V, SYNCn = 3.3V, no load		7		mA
Current into BIASn	RUNn = 0, BIASn = 5V			20	µA
	BIASn = 5V, SYNCn = 3.3V, no load		18		mA
Line regulation	5V < V_{INn} < 40V, I_{OUTn} = 1A		0.05		%
Load regulation	12V_{INn}, 0.1A < I_{OUTn} < 4A		0.1		%
Output RMS ripple	3.3V_{OUTn}, I_{OUTn} = 4A		10		mV
FBn voltage		792	800	808	mV
Current out of FBn	V_{OUTn} = 1V, FBn = 0V		4		µA
Minimum BIASn for proper operation				3.2	V
Switching frequency	RTn = 200kΩ		200		kHz
	RTn = 35.7kΩ		1		MHz
	RTn = 8.06kΩ		3		MHz
RUNn threshold			0.74		V
RUNn input current	RUNn = 0V			100	nA
PGn threshold at FBn	Lower threshold		740		mV
	Upper threshold		860		mV
PGn output sink current	PGn = 0.1V	100			µA
CLKOUTn V_{OL}			0.2		V
CLKOUTn V_{OH}			3.2		V
SYNCn input high threshold		1.5			V
SYNCn input low threshold				0.8	V

(All minimum and maximum specifications are at T_J (Junction Temperature) = 25°C. Total ionizing dose (TID) testing characterized to 75krads.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SYNCn threshold to enable spread spectrum		2.8		4.0	V
SYNCn current	SYNCn = 6V		60		µA
TRSSn source current	TRSSn = 0V		2		µA
TRSSn pull-down resistance	Fault condition, TRSSn = 0.1V		200		Ω

ABSOLUTE MAXIMUM RATINGS

T_A = 25°C unless otherwise specified.

Table 3. Absolute Maximum Ratings

PARAMETER	RATING
V_{INn}, RUNn, PGn	42V
V_{OUTn}, BIASn, AUXn	10V
FBn, TRSSn, SHAREn, RTn	4V
SYNCn	6V
Maximum internal temperature [1]	125°C
Storage temperature	–55°C to 125°C
Peak solder reflow package body temperature	245°C

1 The RHM4900 is tested under pulsed load conditions such that $T_J = T_A$. The RHM4900 is guaranteed to meet specifications over the full –40°C to 125°C internal operating temperature range. Note that the maximum internal temperature is determined by specific operating conditions in conjunction with board layout, the rated package thermal resistance, and other environmental factors.

Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

Thermal Resistance

Thermal performance is directly linked to the printed circuit board (PCB) design and operating environment. Close attention to PCB thermal design is required.

Outgas and Radiation Testing

The criteria used for the acceptance and rejection of materials must be determined by the user, and based upon specific component and system requirements. Historically, a total mass loss (TML) of 1.00% and collected volatile condensable material (CVCM) of 0.10% have been used as screening levels for rejection of spacecraft materials.

Table 4. Outgas Testing

SPECIFICATION (TESTED PER ASTM E595 - 15)	VALUE	UNIT
Total mass loss	0.10	%
Collected volatile condensable material	0.01	%
Water vapor recovered	0.05	%

Table 5. Radiation Testing

SPECIFICATION	VALUE	UNIT
Maximum total dose available (dose rate = 50rad (Si)/sec to 300rad (Si)/sec) [1]	75	krad (Si)
No single event latchup (SEL) occurs at the effective linear energy transfer (LET), $V_{IN} \leq 15V$ [2]	≤40.8	MeV-cm^2/mg

1 Guaranteed by device and process characterization. Contact Analog Devices for data available up to 75krads.

2 Limits are characterized by initial qualification and after any design or process changes specified by the customer. For more information on the single-event effect (SEE) test results, contact Analog Devices for further data beyond the published report on the Analog Devices website. Additional application and technical information can be found in the *Commercial Space Products Program* brochure.

Electrostatic Discharge (ESD)

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only Human body model (HBM) per ANSI/ESDA/JEDEC JS-001 field-induced charged device model (FICDM) and charged device model (CDM) per ANSI/ESDA/JEDEC JS-002. International electrotechnical commission (IEC) electromagnetic compatibility: Part 4-2 (IEC) per IEC 61000-4-2. Machine model (MM) per ANSI/ESD STM5.2. MM voltage values are for characterization only.

ESD Ratings

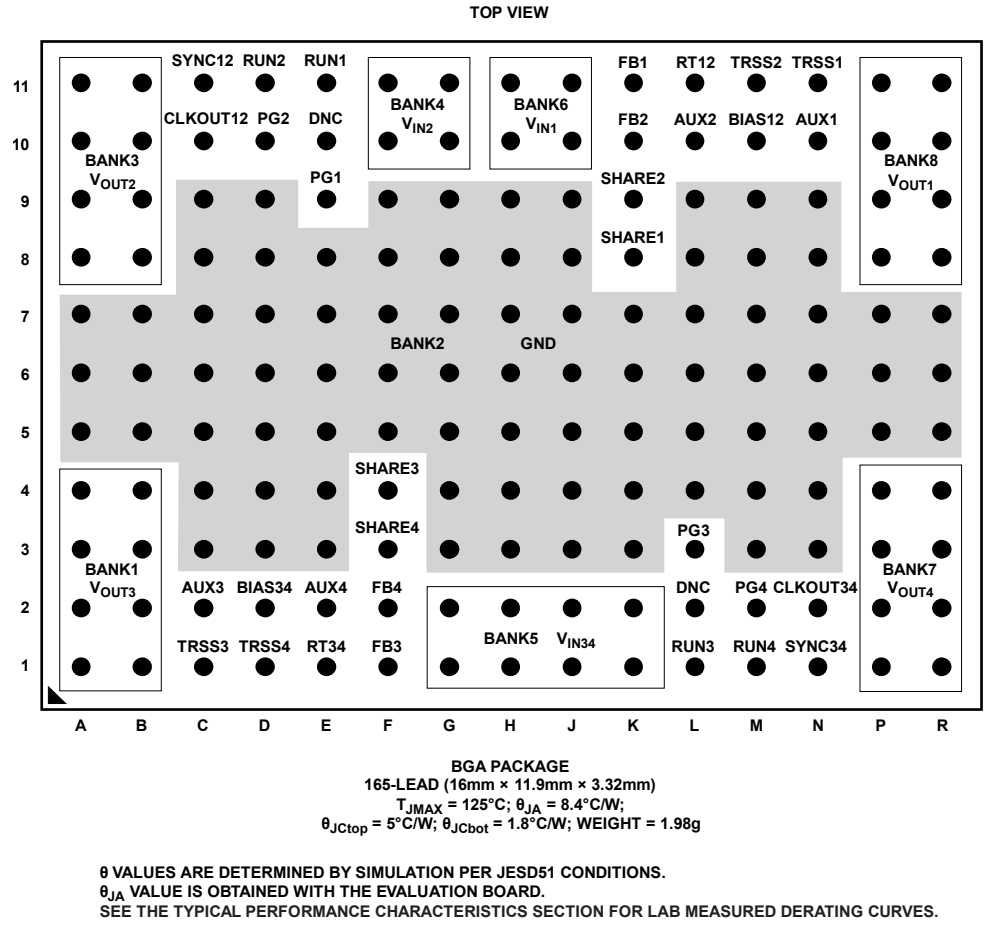
Table 6. RHM4900 ESD Ratings

ESD MODEL	WITHSTAND THRESHOLD (V)	CLASS
HBM	±4000	3A
CDM	±1250	C3

ESD Caution

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS



BGA PACKAGE
165-LEAD (16mm × 11.9mm × 3.32mm)
T_{JMAX} = 125°C; θ_{JA} = 8.4°C/W;
θ_{JCtop} = 5°C/W; θ_{JCbot} = 1.8°C/W; WEIGHT = 1.98g

θ VALUES ARE DETERMINED BY SIMULATION PER JESD51 CONDITIONS.
θ_{JA} VALUE IS OBTAINED WITH THE EVALUATION BOARD.
SEE THE TYPICAL PERFORMANCE CHARACTERISTICS SECTION FOR LAB MEASURED DERATING CURVES.

004

Figure 4. Pinout Configuration

PACKAGE ROW AND COLUMN LABELING MAY VARY AMONG µModule PRODUCTS. REVIEW EACH PACKAGE LAYOUT CAREFULLY.

Pin Descriptions

Table 7. Pin Descriptions

PIN	NAME	DESCRIPTION
CFG 1		
Bank 2	GND	Connect these GND pins to a local ground plane below the RHM4900 and the circuit components. In most applications, the bulk of the heat flow out of the RHM4900 is through these pads. So, the PCB design has a large impact on the thermal performance of the device. See the *PCB Layout* and *Thermal Considerations* sections for more details. Return the feedback divider (R_{FB}) to this net.

PIN CFG 1	NAME	DESCRIPTION
Bank 4	V_{IN2}	Input Power for the Channel 2 Regulator. Decouple V_{IN2} to ground with an external low equivalent series resistance (ESR) capacitor. See *Table 9* for the recommended values.
Bank 5	V_{IN34}	Input Power for the Channel 3 and Channel 4 Regulator. The V_{IN34} bank powers the internal control circuitry for both Channel 3 and Channel 4, and is monitored by the undervoltage lockout (UVLO) circuitry. The V_{IN34} voltage must be greater than 3V for either Channel 3 or Channel 4 of the RHM4900 to operate. Decouple V_{IN34} to ground with an external, low-ESR capacitor. See *Table 9* for the recommended values.
Bank 6	V_{IN1}	Input Power for the Channel 1 Regulator. The V_{IN1} powers the internal control circuitry for Channel 1 and Channel 2, and is monitored by the UVLO circuitry. The V_{IN1} voltage must be greater than 3V for either Channel 1 or Channel 2 of the RHM4900 to operate. Decouple V_{IN1} to ground with an external, low-ESR capacitor. See *Table 9* for the recommended values.
Banks 8, 3, 1, 7	V_{OUT1}, V_{OUT2}, V_{OUT3}, V_{OUT4}	Power Output for Channel 1 through Channel 4, Respectively. Apply the output filter capacitor and output load between these pins and the GND plane.
C10, N2	CLKOUT12, CLKOUT34	Synchronization Output. When SYNC12/SYNC34 are greater than 2.8V, the CLKOUT12/CLKOUT34 pins provide a waveform of about 90° out-of-phase with Channel 1 and Channel 3, respectively. This allows synchronization with other regulators with up to four phases. When an external clock is applied to the SYNC12/SYNC34 pins, the CLKOUT12/CLKOUT34 pins output a waveform with about the same phase, duty cycle, and frequency as the SYNC12/SYNC34 waveform. In Burst Mode® operation, the CLKOUT12/CLKOUT34 pins are internally grounded. Float these pins if the CLKOUT12/CLKOUT34 function is not used. Do not drive these pins.
C11, N1	SYNC12, SYNC34	External Clock Synchronization Input. Ground these pins for low ripple Burst Mode operation at low output loads; this also disables the CLKOUT function. Apply a DC voltage between 2.8V and 4V for forced continuous mode (FCM) operation with spread-spectrum modulation. Float the SYNCn pin for FCM operation without spread-spectrum modulation. Apply a clock source to the SYNCn pin for synchronization to an external frequency. The RHM4900 is in FCM when an external frequency is applied.
E9, D10, L3, M2	PG1, PG2, PG3, PG4	The PGn pins are the open-drain output of an internal comparator. The PGn pin remains low until the FBn pin is within ±7.5% of the final regulation voltage, and until there are no fault conditions. The PGn pin is pulled low during V_{INn} UVLO, thermal shutdown, or when the RUNn pins are low.
E10, L2	DNC	Do not connect these pins.
E11, D11, L1, M1	RUN1, RUN2, RUN3, RUN4	The corresponding channel of the RHM4900 is shut down when these pins are low and active when these pins are high. Connect to V_{INn} if the shutdown feature is not used. An external resistor divider from V_{INn} can be used to program a V_{INn} threshold, below which the corresponding channel of the RHM4900 shuts down. Do not float these pins.

PIN CFG 1	NAME	DESCRIPTION
K8, K9, F4, F3	SHARE1, SHARE2, SHARE3, SHARE4,	Channel 1 through Channel 4 Current Sharing Control. Connect the SHAREn pins together when paralleling outputs. The RHM4900 can also share current between modules. See the *Typical Applications* section for the current sharing between channels and current sharing between modules.
K11, K10, F1, F2	FB1, FB2, FB3, FB4	The RHM4900 regulates the FBn pin to 800mV. Connect the feedback resistor to this pin to set the output voltage.
L11, E1	RT12, RT34	Connect a resistor between RTn and ground pins to set the switching frequency. Do not drive these pins.
M10, D2	BIAS12, BIAS34	The internal regulator draws current from BIASn instead of V_{IN1} or V_{IN34} when BIASn is connected to a voltage higher than 3.2V. For output voltages of 3.3V and above, these pins should be connected to V_{OUTn}. If these pins are connected to a supply other than V_{OUTn}, use a local bypass capacitor on these pins.
N10, L10, C2, E2	AUX1, AUX2, AUX3, AUX4	Low Current Voltage Source for BIAS. In many designs, the BIAS pin is connected to V_{OUT} through the AUX pins. The AUXn pins are internally connected to V_{OUTn} and placed adjacent to the BIASn pins to ease PCB routing. Although these pins are internally connected to V_{OUT}, they are not intended to deliver a higher current. So, do NOT connect these pins to the load. If these pins are not connected to BIAS, leave them floating.
N11, M11, C1, D1	TRSS1, TRSS2, TRSS3, TRSS4	Output Tracking and Soft Start Pins. These pins allow to control the output voltage ramp rate during start-up. A TRSSn voltage below 0.8V forces the RHM4900 to regulate the FBn pin to equal the TRSSn pin voltage. When TRSSn is above 0.8V, the tracking function is disabled, and the internal reference resumes control of the error amplifier. An internal 2µA pull-up current on these pins allows a capacitor to program the output voltage slew rate. These pins are pulled to ground during shutdown and during fault conditions; use a series resistor if driving from a low impedance output. These pins may be left floating if the soft-start feature is not being used.

Table 8. RHM4900 Pinout (Sorted by Pin Number)

PIN	PIN NAME	PIN	PIN NAME	PIN	PIN NAME	PIN	PIN NAME
A1 TO D11							
A1	V_{OUT3}	B1	V_{OUT3}	C1	TRSS3	D1	TRSS4
A2	V_{OUT3}	B2	V_{OUT3}	C2	AUX3	D2	BIAS34
A3	V_{OUT3}	B3	V_{OUT3}	C3	GND	D3	GND
A4	V_{OUT3}	B4	V_{OUT3}	C4	GND	D4	GND
A5	GND	B5	GND	C5	GND	D5	GND
A6	GND	B6	GND	C6	GND	D6	GND
A7	GND	B7	GND	C7	GND	D7	GND
A8	V_{OUT2}	B8	V_{OUT2}	C8	GND	D8	GND
A9	V_{OUT2}	B9	V_{OUT2}	C9	GND	D9	GND
A10	V_{OUT2}	B10	V_{OUT2}	C10	CLKOUT12	D10	PG2
A11	V_{OUT2}	B11	V_{OUT2}	C11	SYNC12	D11	RUN2
E1 TO H11							
E1	RT34	F1	FB3	G1	V_{IN34}	H1	V_{IN34}
E2	AUX4	F2	FB4	G2	V_{IN34}	H2	V_{IN34}
E3	GND	F3	SHARE4	G3	GND	H3	GND
E4	GND	F4	SHARE3	G4	GND	H4	GND
E5	GND	F5	GND	G5	GND	H5	GND
E6	GND	F6	GND	G6	GND	H6	GND
E7	GND	F7	GND	G7	GND	H7	GND
E8	GND	F8	GND	G8	GND	H8	GND
E9	PG1	F9	GND	G9	GND	H9	GND
E10	DNC	F10	V_{IN2}	G10	V_{IN2}	H10	V_{IN1}
E11	RUN1	F11	V_{IN2}	G11	V_{IN2}	H11	V_{IN1}
J1 TO M11							
J1	V_{IN34}	K1	V_{IN34}	L1	RUN3	M1	RUN4
J2	V_{IN34}	K2	V_{IN34}	L2	DNC	M2	PG4
J3	GND	K3	GND	L3	PG3	M3	GND
J4	GND	K4	GND	L4	GND	M4	GND
J5	GND	K5	GND	L5	GND	M5	GND

PIN	PIN NAME	PIN	PIN NAME	PIN	PIN NAME	PIN	PIN NAME
J6	GND	K6	GND	L6	GND	M6	GND
J7	GND	K7	GND	L7	GND	M7	GND
J8	GND	K8	SHARE1	L8	GND	M8	GND
J9	GND	K9	SHARE2	L9	GND	M9	GND
J10	V_{IN1}	K10	FB2	L10	AUX2	M10	BIAS12
J11	V_{IN1}	K11	FB1	L11	RT12	M11	TRSS2
N1 TO R11							
N1	SYNC34	P1	V_{OUT4}	R1	V_{OUT4}		
N2	CLKOUT34	P2	V_{OUT4}	R2	V_{OUT4}		
N3	GND	P3	V_{OUT4}	R3	V_{OUT4}		
N4	GND	P4	V_{OUT4}	R4	V_{OUT4}		
N5	GND	P5	GND	R5	GND		
N6	GND	P6	GND	R6	GND		
N7	GND	P7	GND	R7	GND		
N8	GND	P8	V_{OUT1}	R8	V_{OUT1}		
N9	GND	P9	V_{OUT1}	R9	V_{OUT1}		
N10	AUX1	P10	V_{OUT1}	R10	V_{OUT1}		
N11	TRSS1	P11	V_{OUT1}	R11	V_{OUT1}		

TYPICAL PERFORMANCE CHARACTERISTICS

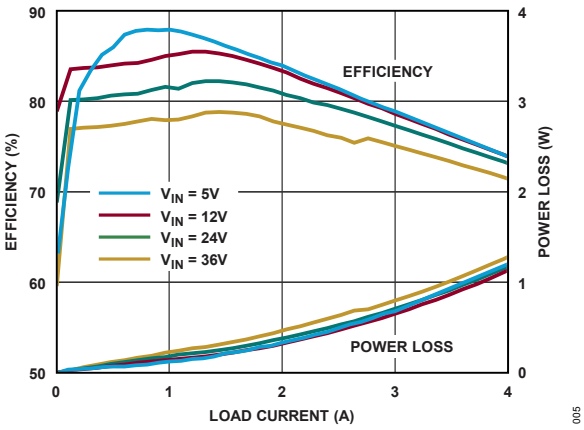


Figure 5. Efficiency vs. Power Loss, V_{OUT} = 0.8V, BIAS = 5V, Burst Mode Operation

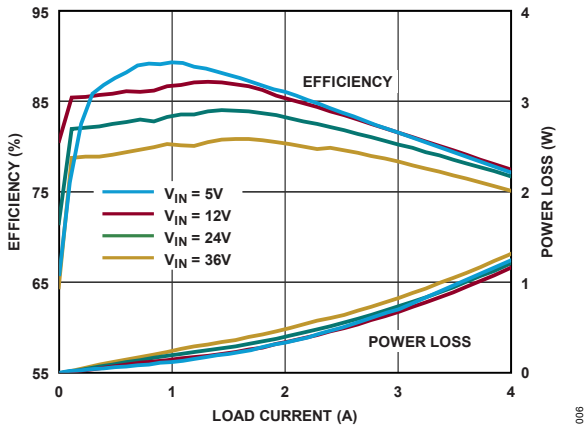


Figure 6. Efficiency vs. Power Loss, V_{OUT} = 1V, BIAS = 5V, Burst Mode Operation

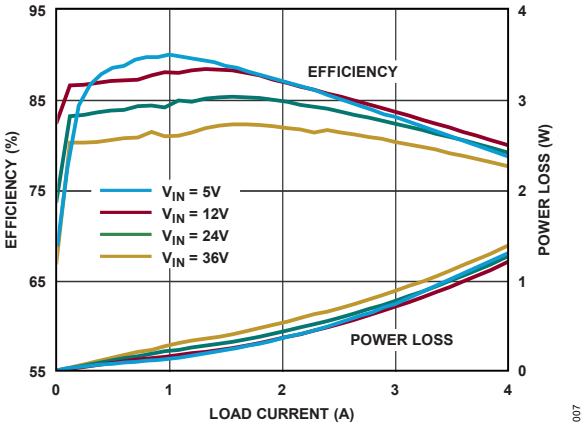


Figure 7. Efficiency vs. Power Loss, V_{OUT} = 1.2V, BIAS = 5V, Burst Mode Operation

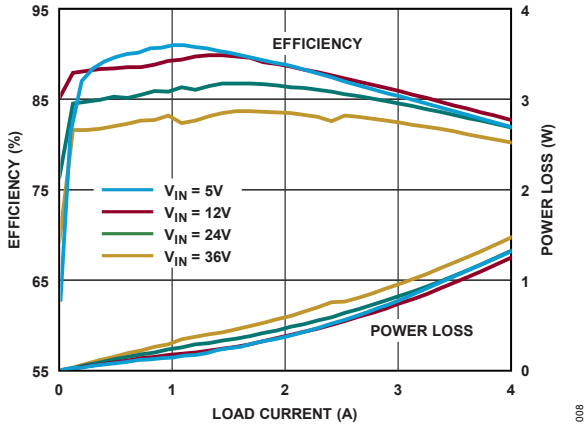


Figure 8. Efficiency vs. Power Loss, V_{OUT} = 1.5V, BIAS = 5V, Burst Mode Operation

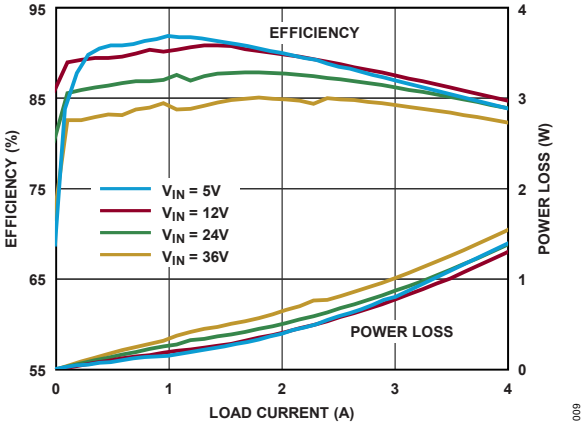


Figure 9. Efficiency vs. Power Loss, V_{OUT} = 1.8V, BIAS = 5V, Burst Mode Operation

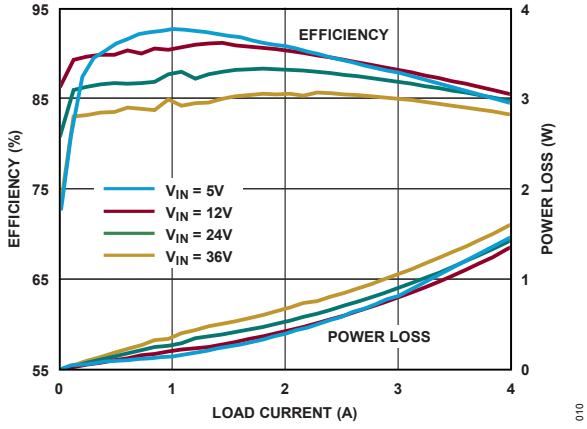


Figure 10. Efficiency vs. Power Loss, V_{OUT} = 2V, BIAS = 5V, Burst Mode Operation

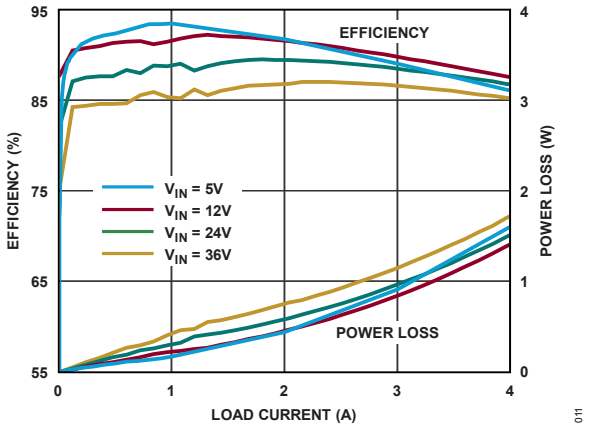


Figure 11. Efficiency vs. Power Loss, V_{OUT} = 2.5V, BIAS = 5V, Burst Mode Operation

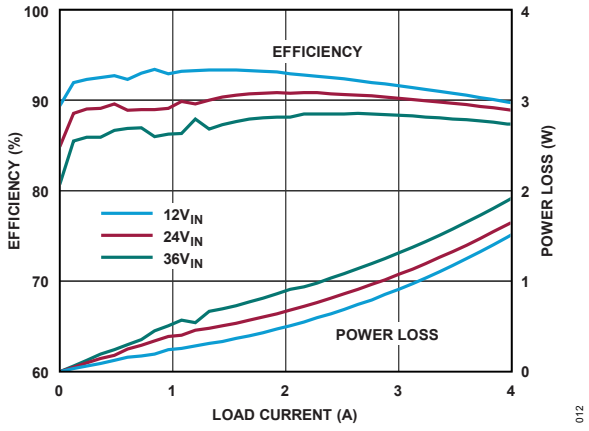


Figure 12. Efficiency vs. Power Loss, V_{OUT} = 3.3V, BIAS = 5V, Burst Mode Operation

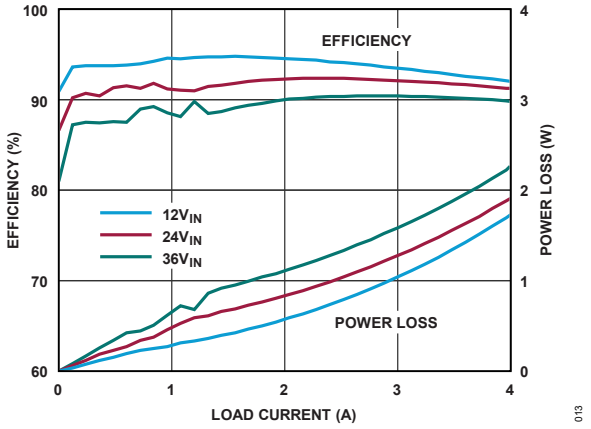


Figure 13. Efficiency vs. Power Loss, V_{OUT} = 5V, BIAS = 5V, Burst Mode Operation

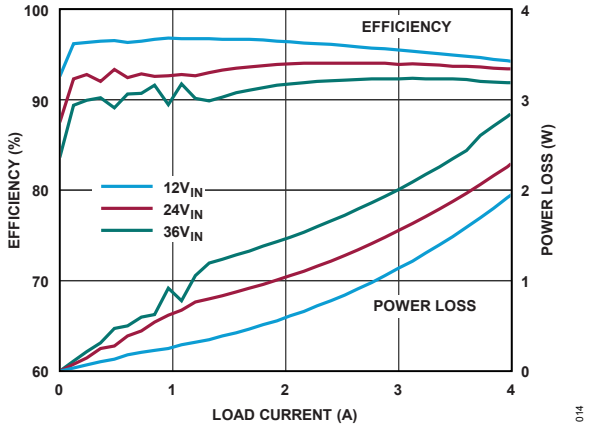


Figure 14. Efficiency vs. Power Loss, V_{OUT} = 8V, BIAS = 5V, Burst Mode Operation

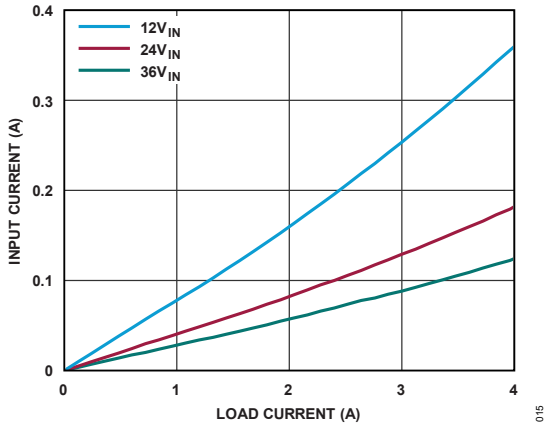


Figure 15. Input vs. Load Current, V_{OUT} = 0.8V, BIAS = 5V, Burst Mode Operation

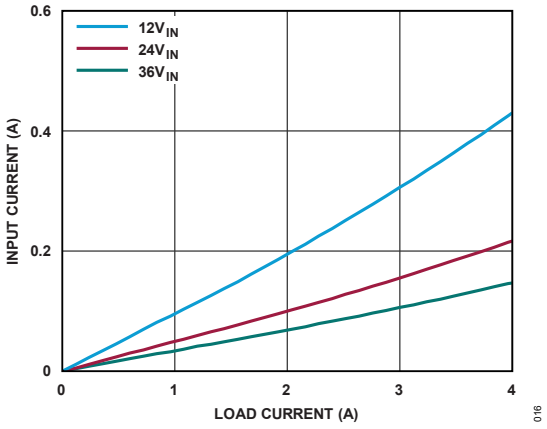


Figure 16. Input vs. Load Current, V_{OUT} = 1V, BIAS = 5V, Burst Mode Operation

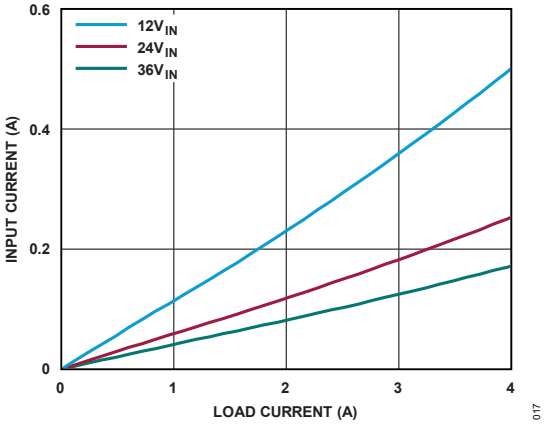


Figure 17. Input vs. Load Current, V_{OUT} = 1.2V, BIAS = 5V, Burst Mode Operation

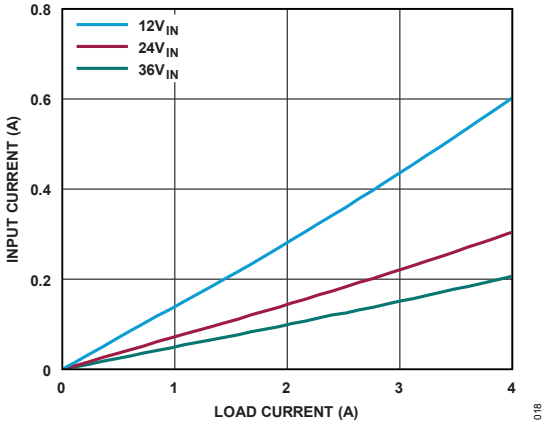


Figure 18. Input vs. Load Current, V_{OUT} = 1.5V, BIAS = 5V, Burst Mode Operation

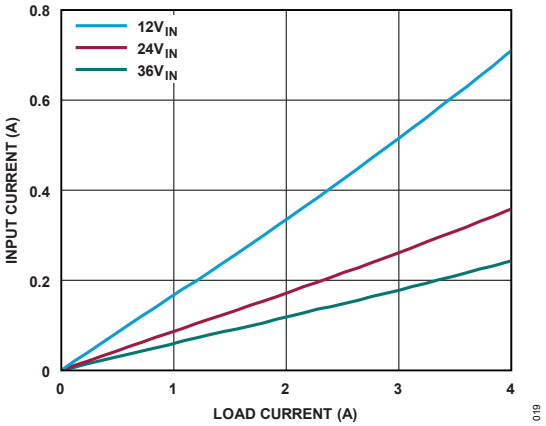


Figure 19. Input vs. Load Current, V_{OUT} = 1.8V, BIAS = 5V, Burst Mode Operation

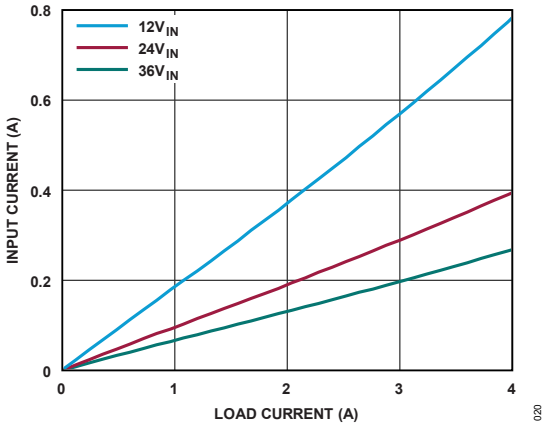


Figure 20. Input vs. Load Current, V_{OUT} = 2V, BIAS = 5V, Burst Mode Operation

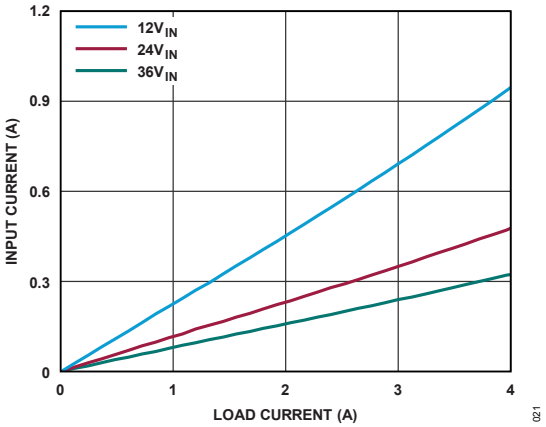


Figure 21. Input vs. Load Current, V_{OUT} = 2.5V, BIAS = 5V, Burst Mode Operation

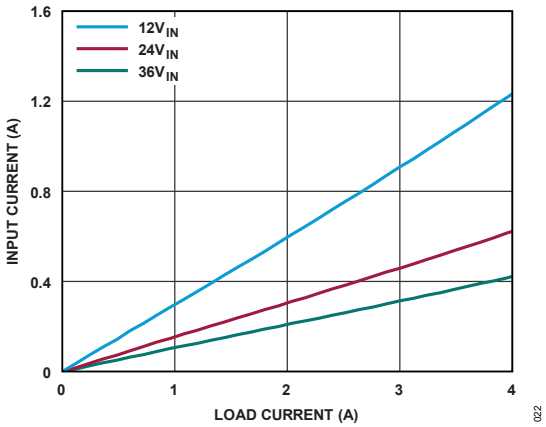


Figure 22. Input vs. Load Current, V_{OUT} = 3.3V, BIAS = 5V, Burst Mode Operation

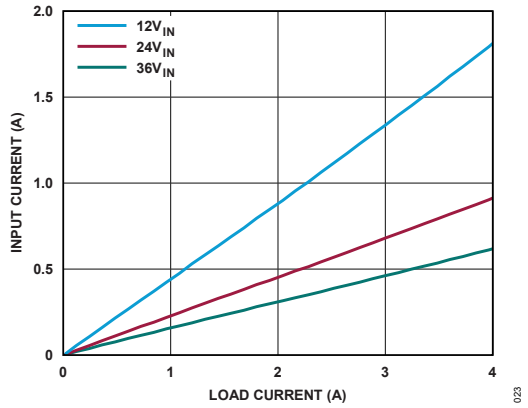


Figure 23. Input vs. Load Current, V_{OUT} = 5V, BIAS = 5V, Burst Mode Operation

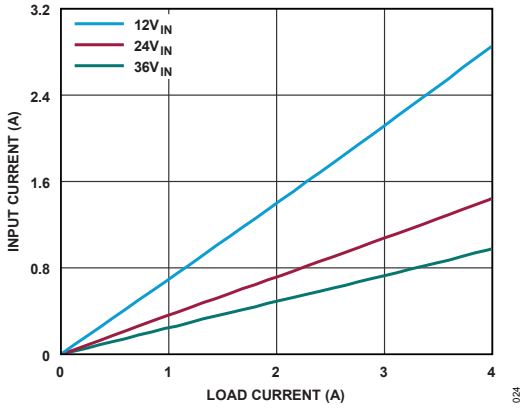


Figure 24. Input vs. Load Current, V_{OUT} = 8V, BIAS = 5V, Burst Mode Operation

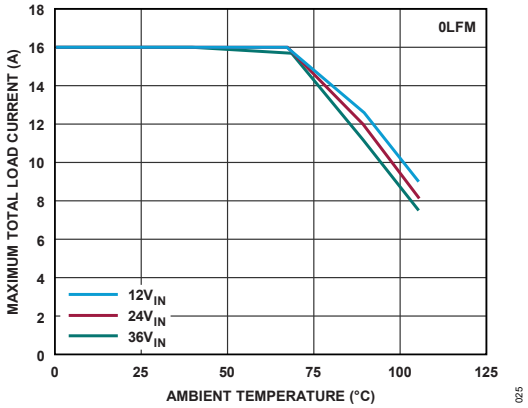


Figure 25. Derating, V_{OUT} = 0.8V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

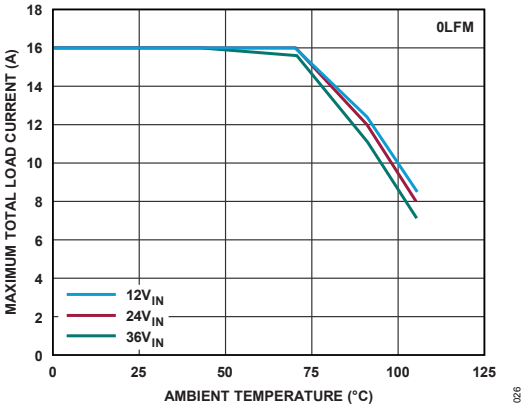


Figure 26. Derating, V_{OUT} = 1V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

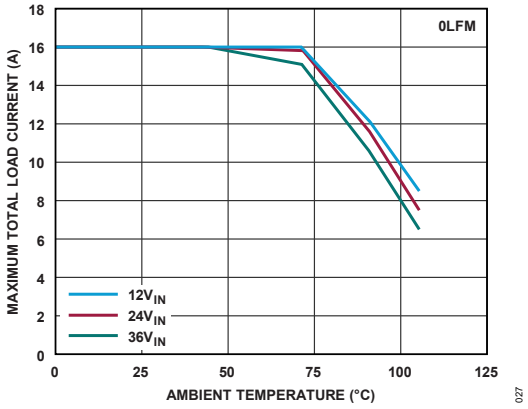


Figure 27. Derating, V_{OUT} = 1.2V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

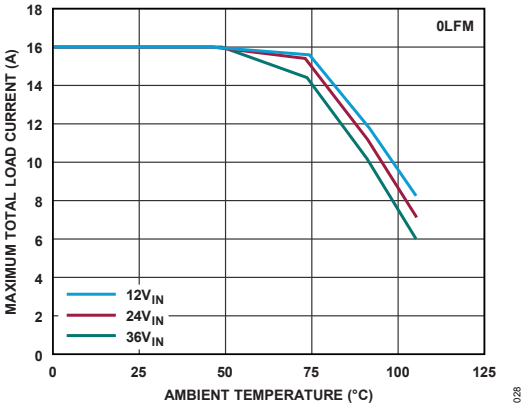


Figure 28. Derating, V_{OUT} = 1.5V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode, All Channels at the Same Load

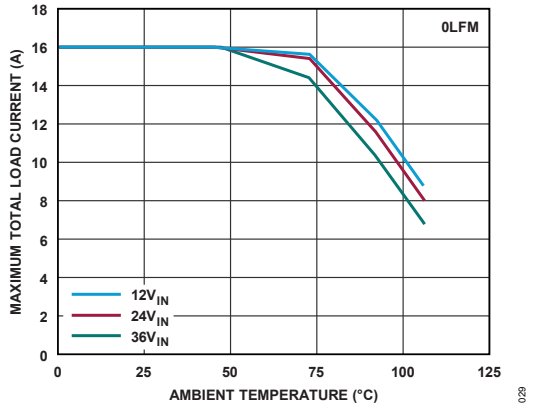


Figure 29. Derating, V_{OUT} = 1.8V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

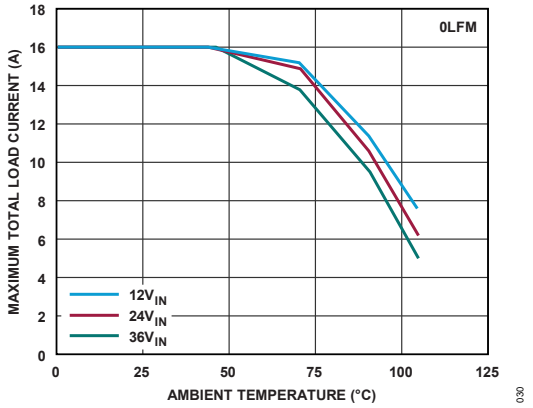


Figure 30. Derating, V_{OUT} = 2V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

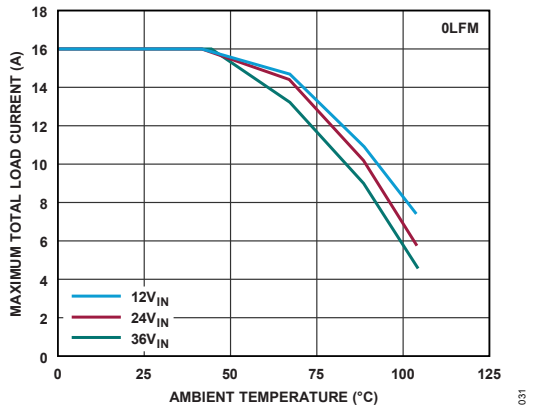


Figure 31. Derating, V_{OUT} = 2.5V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

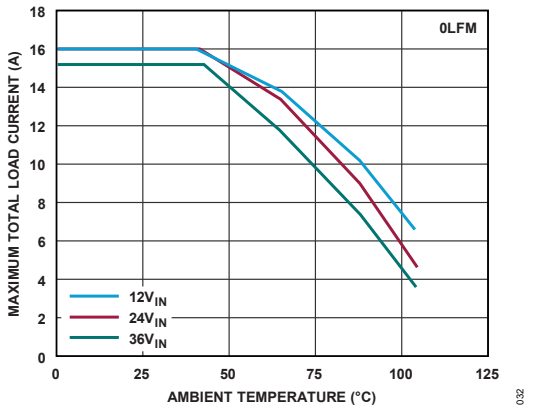


Figure 32. Derating, V_{OUT} = 3.3V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

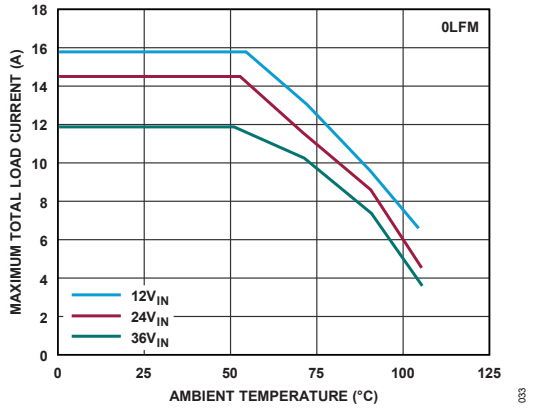


Figure 33. Derating, V_{OUT} = 3.3V, f_{SW} = 2MHz, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

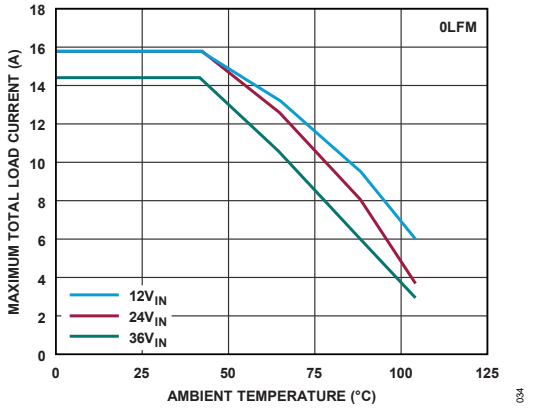


Figure 34. Derating, V_{OUT} = 5V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

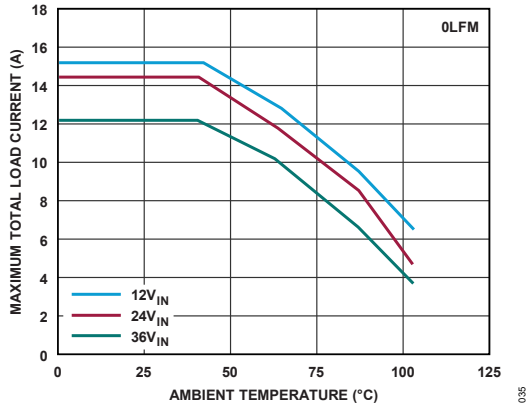


Figure 35. Derating, V_{OUT} = 5V, f_{SW} = 2MHz, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

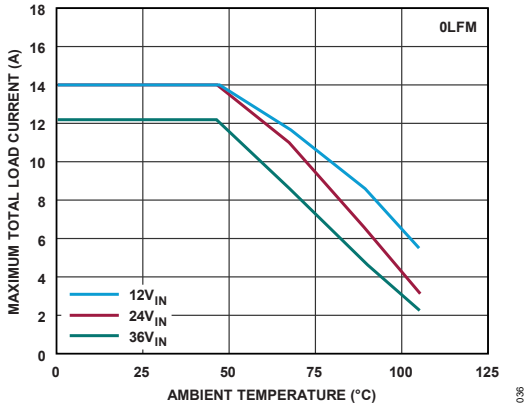


Figure 36. Derating, V_{OUT} = 8V, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation, All Channels at the Same Load

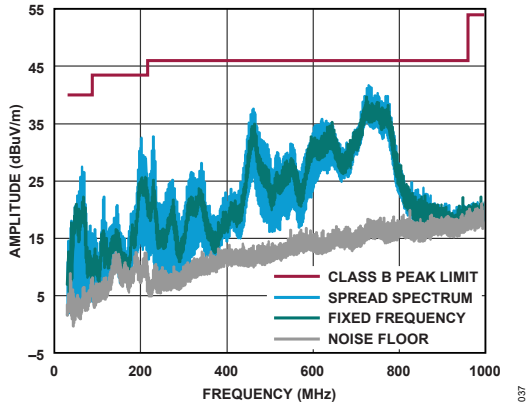


Figure 37. CISPR22 Class B Emissions, EVAL-RHM4900-AZ, V_{IN} = 24V, V_{OUT} = 5V, f_{SW} = 1.2MHz, All Channels Paralleled, I_{OUT} = 10A

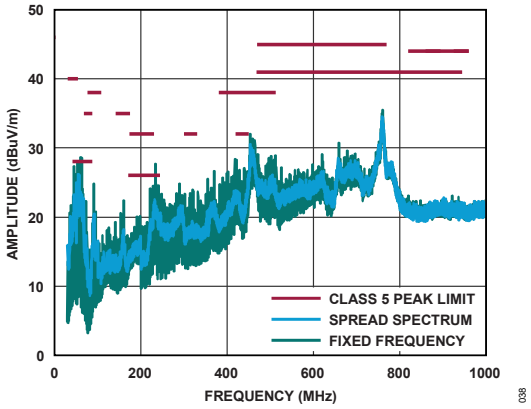


Figure 38. CISPR25 Radiated Emission with Class 5 Peak Limit, EVAL-RHM4900-AZ, V_{IN} = 14V, V_{OUT} = 5V, f_{SW} = 1.2MHz, All Channels Paralleled, I_{OUT} = 12A

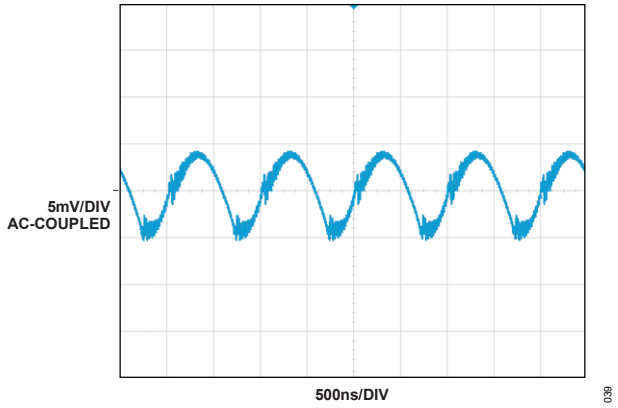


Figure 39. Output Voltage Ripple, EVAL-RHM4900-AZ, V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 3A, f_{SW} = 1MHz

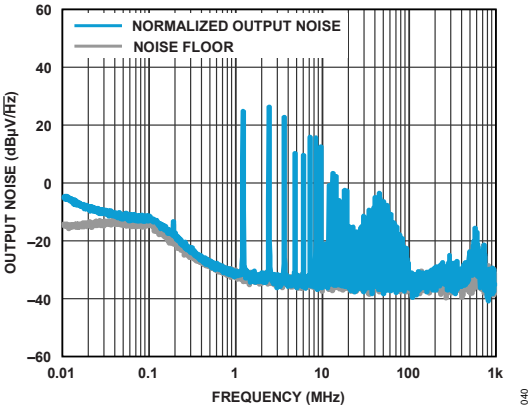


Figure 40. Output Noise Spectrum, EVAL-RHM4900-AZ, V_{IN} = 24V, V_{OUT} = 5V, I_{OUT} = 3A, f_{SW} = 1.2MHz

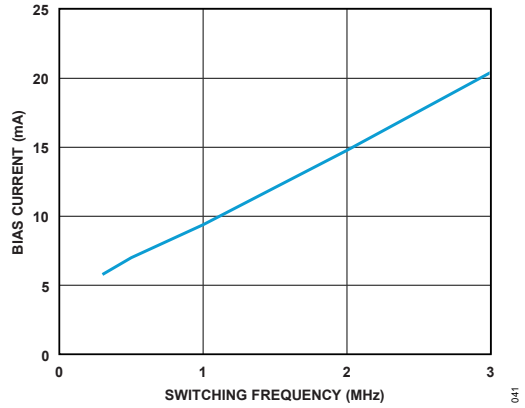


Figure 41. BIAS Current vs. Frequency, 12V_{IN} to 3.3V_{OUT}, FCM

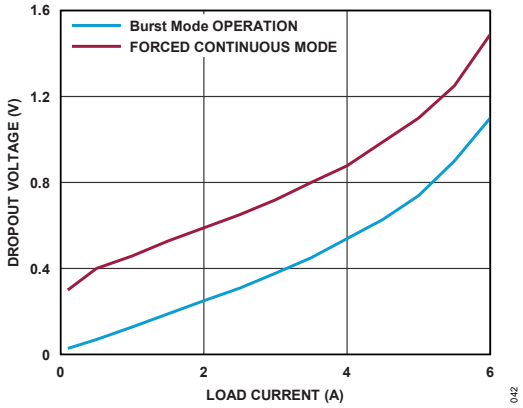


Figure 42. Dropout Voltage vs. Load Current

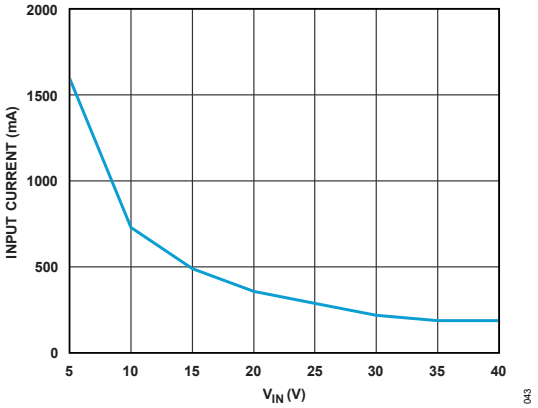


Figure 43. Input Current vs. V_{IN}, V_{OUT} Short-Circuited

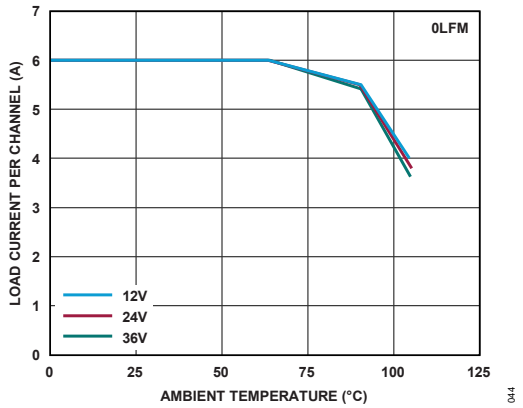


Figure 44. Single Channel Derating, V_{OUT} = 1.5V CH1 ON, CH2 to CH4 OFF, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation

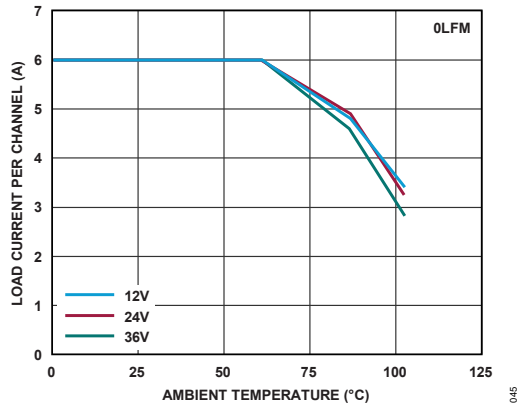


Figure 45. Single Channel Derating, V_{OUT} = 3.3V CH1 ON, CH2 to CH4 OFF, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation

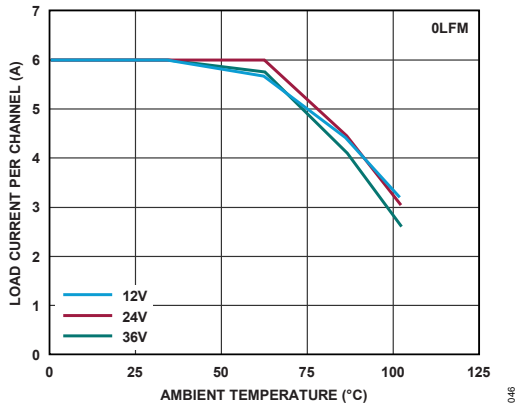


Figure 46. Single Channel Derating, V_{OUT} = 5V CH1 ON, CH2 to CH4 OFF, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation

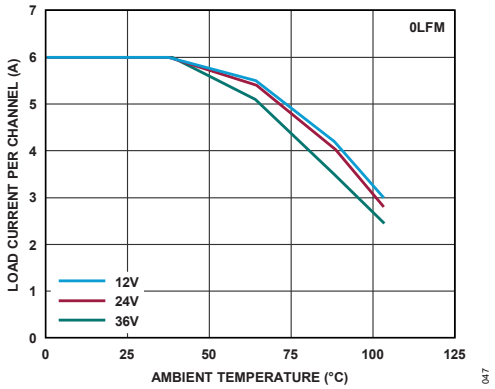


Figure 47. Dual Channel Derating, V_{OUT} = 1.5V CH1/CH3 ON, CH2/CH4 OFF, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation

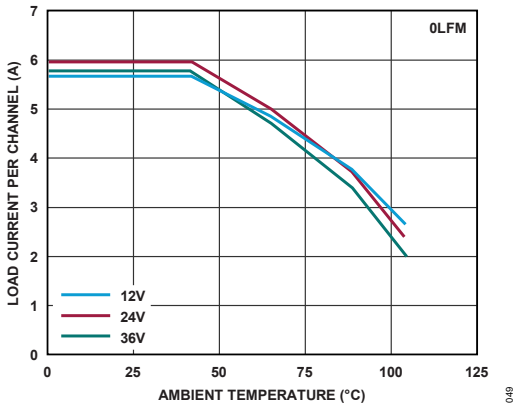


Figure 48. Dual Channel Derating, V_{OUT} = 3.3V CH1/CH3 ON, CH2/CH4 OFF, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation

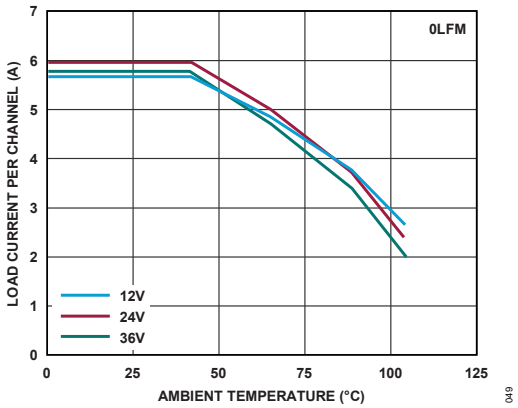


Figure 49. Dual Channel Derating, V_{OUT} = 5V CH1/CH3 ON, CH2/CH4 OFF, BIAS = 5V, EVAL-RHM4900-AZ, T_J = 120°C, Burst Mode Operation

THEORY OF OPERATION

RHM4900 Overview

The RHM4900 is a quad, standalone, non-isolated, step-down switching DC-to-DC power supply that can deliver a peak current of up to 4A per channel. The continuous current is determined by the internal operating temperature. It provides a precisely regulated output voltage programmable through one external resistor from 0.8V to 8V. The input voltage range for V_{IN1} and V_{IN34} is 3V to 40V, while the input voltage range for V_{IN2} is 2V to 40V.

Given that the RHM4900 is a step-down converter, ensure the input voltage is high enough to support the desired output voltage and load current. The RHM4900 has a fixed f_{SW} peak current mode architecture, which supports reliable clock interleaving. See *Figure 50* for the simplified block diagram.

The RHM4900 contains current mode controllers, power switching elements, power inductors, and a modest amount of input and output capacitance. The RHM4900 is a fixed-frequency, pulse-width modulation (PWM) regulator. The switching frequency is set by simply connecting the appropriate resistor value from the RTn pin to GND.

Internal regulators provide power to the control circuitries. Bias regulators normally draw power from the V_{INn} pin, but if the BIASn pin is connected to an external voltage higher than 3.2V, bias power is drawn from the external source (typically, the regulated output voltage). This improves efficiency. Connect BIASn to GND if it is not used.

To enhance efficiency, the RHM4900 automatically switches to Burst Mode operation in light or no-load situations. Between bursts, all circuitry associated with the controlling of the output switch is shut down, reducing the input supply current to just a few µA.

The TRSSn node acts as an auxiliary input to the error amplifier. The voltage at FBn servos to the TRSSn voltage until TRSSn goes above 0.8V. Soft-start is implemented by generating a voltage ramp at the TRSSn pin using an external capacitor, which is charged by an internal 2µA constant current. Alternatively, driving the TRSSn pin with a signal source or resistive network provides a tracking function. Do not drive the TRSSn pin with a low-impedance voltage source. See the *Applications Information* section for more details.

The RHM4900 contains power-good comparators that trip when the FBn pin is at about ±8% of its regulated value. The PGn output is an open-drain transistor that is off when the output is in regulation, allowing an external resistor to pull the PGn pin high.

The RHM4900 is equipped with a thermal shutdown that inhibits power switching at high junction temperatures. The activation threshold of this function is above the maximum temperature rating to avoid interfering with normal operation. So, prolonged or repetitive operation under a condition in which the thermal shutdown activates may damage or impair the reliability of the device.

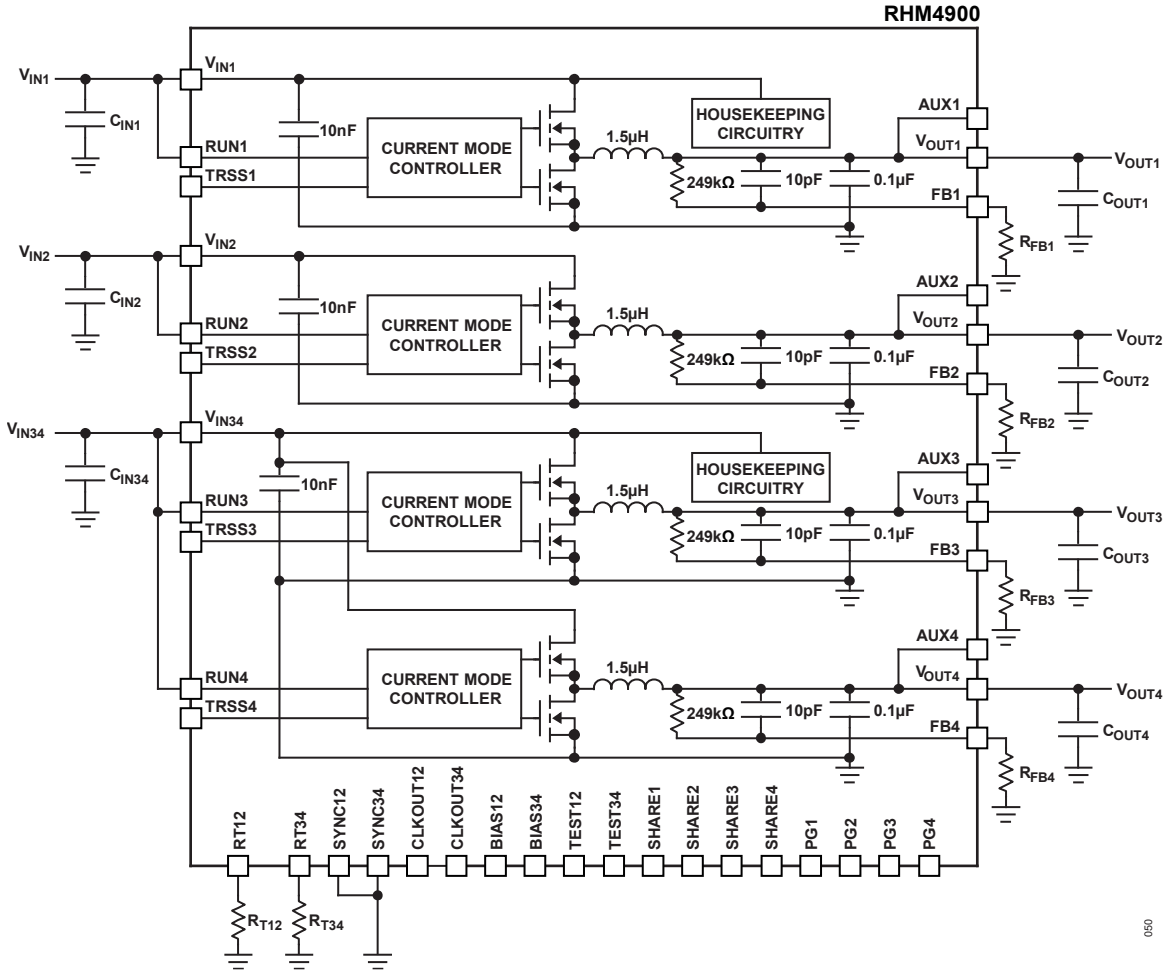


Figure 50. RHM4900 Simplified Block Diagram

APPLICATIONS INFORMATION

For most applications, the design process is straightforward, and summarized as follows.

1. See *Table 9* and find the row with the desired input range and output voltage.
2. Apply the recommended C_{IN}, C_{OUT}, R_{FB}, and R_T values.
3. Connect BIAS, as indicated.

When using the RHM4900 with different output voltages, the higher frequency recommended in *Table 9* usually results in the best operation. While these component combinations have been tested for proper operation, verify the proper operation over the intended system's line, load, and environmental conditions. Remember the maximum output current is limited by the junction temperature, the relationship between the input and output voltage magnitudes as well as other factors. See the graphs in the *Typical Performance Characteristics* section for guidance.

The maximum frequency (and attendant R_T value) at which the RHM4900 should be allowed to switch is given in *Table 9* in the maximum f_{SW} column, while the recommended frequency (and R_T value) for optimal efficiency over the given input condition is given in the f_{SW} column. There are additional conditions that must be satisfied if the synchronization function is used. See the *Synchronization* section for more details.

Set Output Voltage

The output voltage is programmed with an FB resistor, as shown in *Figure 51*. Choose the resistor value according to equation *1*.

$$R_{FB} = \frac{249k\Omega}{\frac{V_{OUT}}{0.8V} - 1} \qquad (1)$$

A 1% resistor is recommended to maintain the output voltage accuracy.

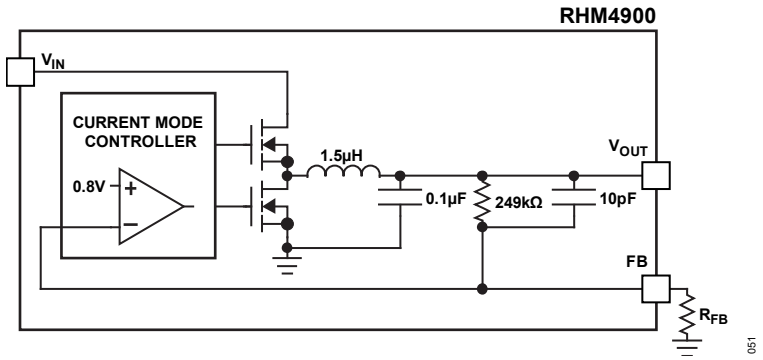


Figure 51. Set Output Voltage with an FB Resistor

Capacitor Selection Considerations

The C_{IN} and C_{OUT} capacitor values in *Table 9* are the minimum recommended values for the associated operating conditions. Applying a capacitor value below those indicated in *Table 9* is not recommended and may result in undesirable operation. Using a larger capacitor value is generally acceptable, and can yield improved dynamic response, if it is necessary. Again, verify the proper operation over the intended system's line, load, and environmental conditions.

The ceramic capacitors are small, robust, and have very low ESR. However, not all ceramic capacitors are suitable. The X5R and X7R types are stable over temperature and applied voltage, and give dependable service. Other types, including Y5V and Z5U, have very large temperature and voltage coefficients of capacitance. In an application circuit, they may have only a small fraction of their nominal capacitance, resulting in a much higher output voltage ripple than expected. The ceramic capacitors are also piezoelectric. In Burst Mode operation, the RHM4900's switching frequency depends on the load current, and can excite a ceramic capacitor at audio frequencies, generating audible noise. Since the RHM4900 operates at a lower current limit during Burst Mode operation, the noise is typically very quiet to a casual ear. If this audible noise is unacceptable, use a high-performance electrolytic capacitor at the output. It may also be a paralleled combination of a ceramic capacitor and a low-cost electrolytic capacitor.

A final precaution regarding ceramic capacitors concerns the maximum input voltage rating of the RHM4900. A ceramic input capacitor combined with trace or cable inductance forms a high-Q (underdamped) tank circuit. If the RHM4900 circuit is plugged into a live supply, the input voltage can ring to twice its nominal value, possibly exceeding the device's rating. This situation can be avoided easily (see the *Hot-Plugging Safely* section for more details).

Table 9. Recommended Component Values and Configuration (T_A = 25°C)

V_{IN} [1] (V)	V_{OUT} (V)	R_{FB} (Ω)	C_{IN} [2] (µF)	C_{OUT} (µF)	BIAS	C_{FF} (pF)	f_{SW} (Hz)	R_T (kΩ)	MAX f_{SW} (Hz)	MIN R_T (kΩ)
3 to 40	0.8	Open	4.7 50V X5R 1206	2 × 100 4V X5R 0805	3.2 to 10	100	400k	100	550k	69.8
3 to 40	1	1M	4.7 50V X5R 1206	2 × 100 4V X5R 0805	3.2 to 10	100	400k	100	700k	54.9
3 to 40	1.2	499k	4.7 50V X5R 1206	2 × 100 4V X5R 0805	3.2 to 10	68	500k	76.8	800k	46.4
3.2 to 40	1.5	287k	4.7 50V X5R 1206	2 × 100 4V X5R 0805	3.2 to 10	–	600k	64.9	1M	35.7
3.5 to 40	1.8	200k	4.7 50V X5R 1206	1 × 100 4V X5R 0805	3.2 to 10	–	650k	59	1.1M	32.4
3.5 to 40	2	165k	4.7 50V X5R 1206	1 × 100 4V X5R 0805	3.2 to 10	–	700k	54.9	1.25M	27.4
4.2 to 40	2.5	118k	4.7 50V X5R 1206	1 × 47 4V X5R 0805	3.2 to 10	–	800k	46.4	1.5M	22.1
5.5 to 40	3.3	78.7k	4.7 50V X5R 1206	1 × 47 6.3V X5R 0805	3.2 to 10	–	1M	35.7	2M	14.7
8.5 to 40	5	47.5k	4.7 50V X5R 1206	1 × 47 6.3V X5R 1206	3.2 to 10	–	1.2M	27.4	2.8M	9.09
11 to 40	8	27.4k	4.7 50V X5R 1206	1 × 47 10V X5R 1206	3.2 to 10	–	1.6M	19.6	3M	8.06

[1] The RHM4900 may be capable of the operating at lower input voltages but may skip switching cycles.

[2] A bulk input capacitor is required.

Frequency Selection

The RHM4900 uses a constant-frequency PWM architecture that can be programmed to switch from 200kHz to 3MHz using a resistor connected from the RT pin to ground. *Table 10* provides a list of the R_T resistor values and their resultant frequencies. The resistors in *Table 10* are standard 1% E96 values.

Operating Frequency Trade-Offs

It is recommended to apply the optimal R_T value given in *Table 10* for the input and output operating conditions. When using the RHM4900 with different output voltages, the higher frequency recommended in *Table 10* usually results in the best operation. System level or other considerations, however, may necessitate another operating frequency. While the RHM4900 is flexible enough to accommodate a wide range of operating frequencies, a haphazardly chosen one may result in undesirable operation under certain operating or fault conditions. A too high frequency can reduce efficiency, generate excessive heat, or even damage the RHM4900 if the output is overloaded or short-circuited. A too low frequency can result in a final design with too much output ripple or a too large output capacitor.

Table 10. Switching Frequency vs. R_T Value

f_{SW} (MHz)	R_T (kΩ)
0.2	200
0.3	137
0.4	100
0.5	76.8
0.6	64.9
0.7	54.9
0.8	46.4
0.9	41.2
1.0	35.7
1.2	27.4
1.4	23.2
1.6	19.6
1.8	16.9
2.0	14.7
2.2	12.7
2.4	11.3
2.6	10.2
2.8	9.09
3.0	8.06

BIASn Pin Considerations

The BIASn pin provides drive power for the internal power switching stage and operates other internal circuitry. For proper operation, it must be powered by at least 3.2V. If the output voltage is programmed to 3.2V or higher, BIASn may be simply connected to V_{OUTn}. If V_{OUTn} is less than 3.2V, BIASn can be connected to V_{INn} or some other voltage source. If the BIASn pin voltage is too high, the efficiency of the RHM4900 may suffer. The optimum BIASn voltage is dependent upon many factors, such as load current, input voltage, output voltage, and switching frequency. In all cases, ensure the maximum voltage at the BIASn pin is less than 10V. If BIASn power is applied from a remote or noisy voltage source, it may be necessary to apply a decoupling capacitor locally to the pin. A 1µF ceramic capacitor works well. The BIASn pin may also be connected to GND at the cost of a small degradation in efficiency.

Maximum Load

The maximum practical continuous load the RHM4900 can drive per channel, while rated at 3A (4A peak), depends upon both the internal current limit and internal temperature. The internal current limit is designed to prevent damage to the RHM4900 in case of an overload or a short-circuit. The internal temperature of the RHM4900 depends upon operating conditions such as the ambient temperature, power delivered, and heat-sinking capability of the system. For example, if the V_{OUT1} of the RHM4900 is configured to regulate at 1.5V, and the other three channels are turned off, the V_{OUT1} may continuously deliver 4A from $24V_{IN}$, if the ambient temperature is controlled to less than 60°C. This is much higher than the 3A (4A peak) rating. See the *Typical Performance Characteristics* section. Similarly, if all four channels of the RHM4900 are delivering $3.3V_{OUT}$ and the ambient temperature is 100°C, each channel delivers at most 1.5A from $24V_{IN}$, which is less than the 3A (4A peak) rating.

Power Derating

Figure 52 through *Figure 54* (power loss curves) can be used in coordination with the load current derating curves (*Figure 55* through *Figure 63*) to calculate an approximate θ_{JA} thermal resistance for the RHM4900 with airflow conditions. The power loss curves are taken at room temperature, and are increased with a 1.35 to 1.4 multiplicative factor at 125°C. These factors come from the fact that the power loss of the regulator increases by about 45% from 25°C to 150°C, thus, a 45% spread over 125°C delta equates to ~0.35%/°C loss increase. A 125°C maximum junction minus 25°C room temperature equates to a 100°C increase. This 100°C increase multiplied by 0.35%/°C equals a 35% power loss increase at the 125°C junction, thus, the 1.35 multiplier.

The derating curves are plotted with four V_{OUTn} at the same operating condition starting at 16A of total load current and low ambient temperature. The derating curves with the airflow are measured at output voltages of 1.5V, 3.3V, and 5V. These are chosen to include the lower and higher output voltage ranges to correlate the thermal resistance. Thermal models are derived from several temperature measurements in a controlled temperature chamber, along with thermal finite element analysis (FEA) modeling.

The junction temperatures are monitored while the ambient temperature is increased with and without airflow. The power loss increases with ambient temperature change and is factored into the derating curves. The junction temperatures are maintained at ~120°C maximum, while lowering output current or power, while increasing the ambient temperature. The decreased output current decreases the internal module loss as ambient temperature is increased.

The derived thermal resistances in *Table 11* through *Table 13* for the various conditions can be multiplied by the calculated power loss as a function of ambient temperature to derive temperature rise above ambient, thus, maximum junction temperature. The room temperature power loss can be derived from the power loss curves and adjusted with the above ambient temperature multiplicative factors. The printed circuit board (PCB) is a 1.6mm, thick, 6-layer board with two-ounce copper (50µm) for all the layers.

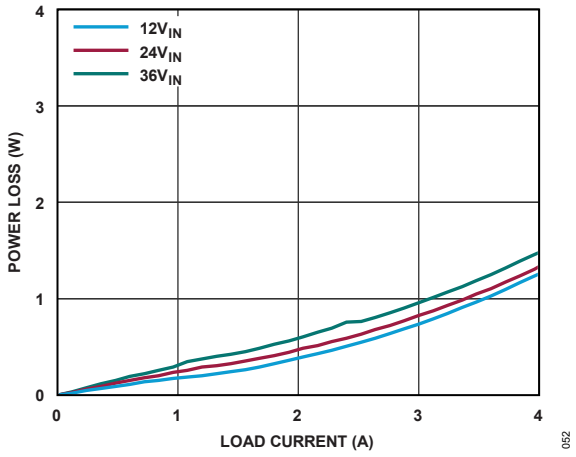


Figure 52. 1.5V_{OUT} Power Loss Curves

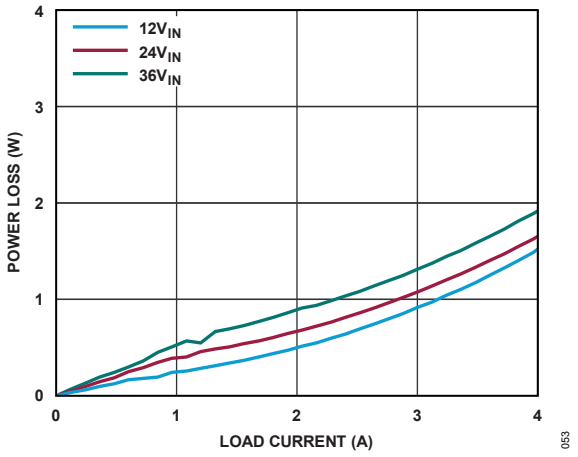


Figure 53. 3.3V_{OUT} Power Loss Curves

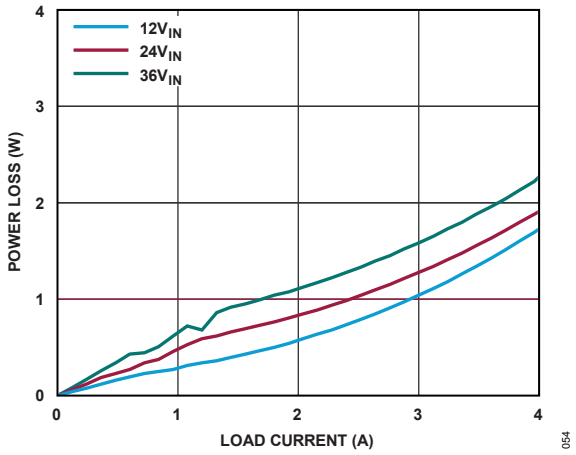


Figure 54. 5V_{OUT} Power Loss Curves

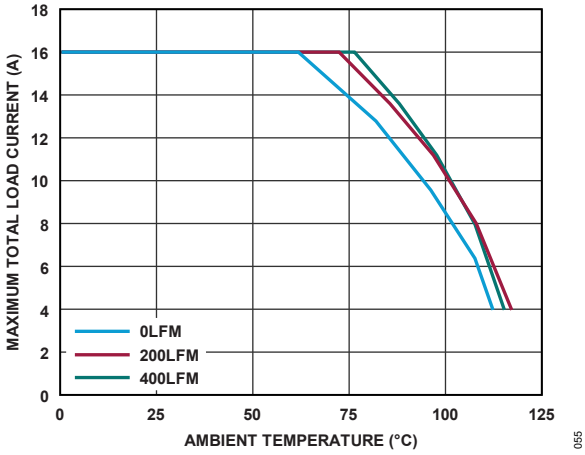


Figure 55. 12V_{IN} to 1.5V_{OUT} Derating with Airflow

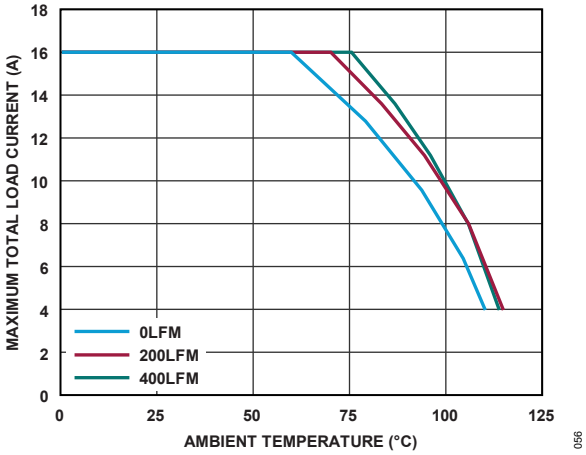


Figure 56. 24V_{IN} to 1.5V_{OUT} Derating with Airflow

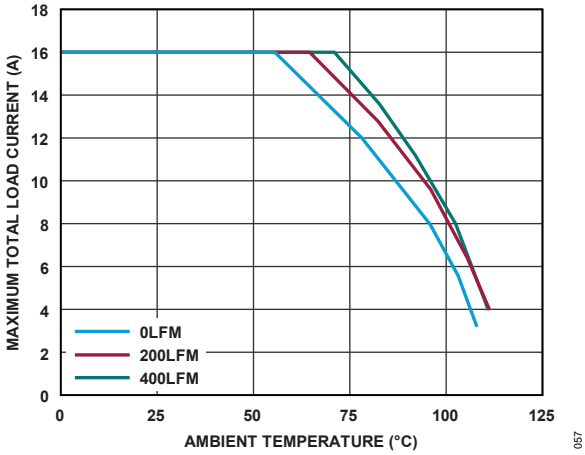


Figure 57. 36V_{IN} to 1.5V_{OUT} Derating with Airflow

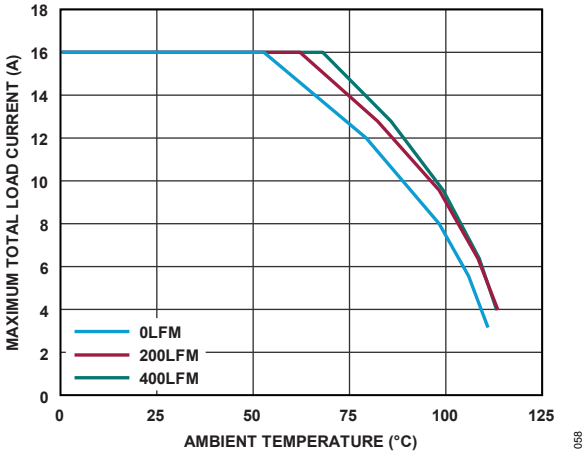


Figure 58. 12V_{IN} to 3.3V_{OUT} Derating with Airflow

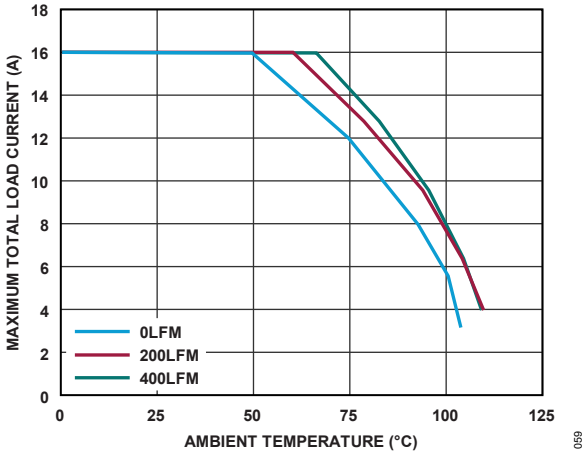


Figure 59. 24V_{IN} to 3.3V_{OUT} Derating with Airflow

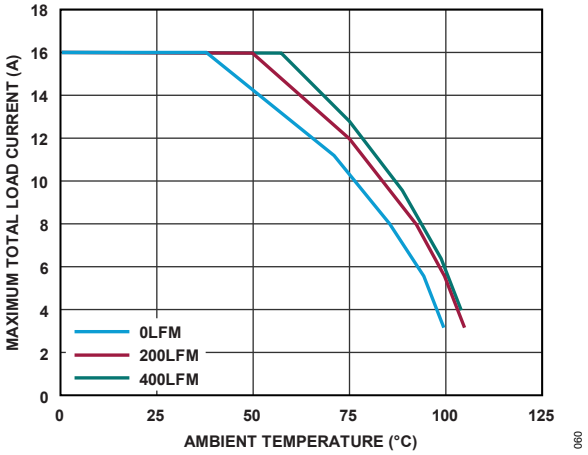


Figure 60. 36V_{IN} to 3.3V_{OUT} Derating with Airflow

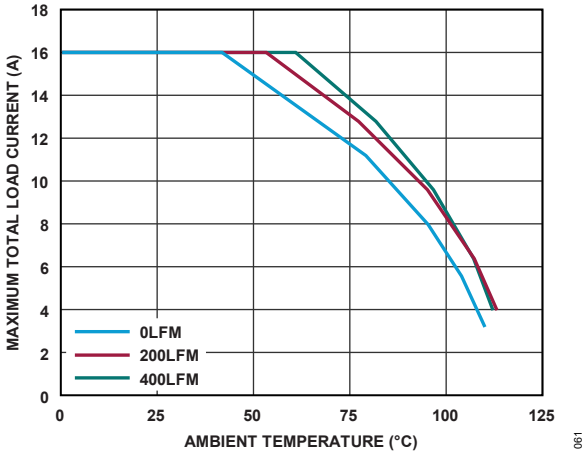


Figure 61. 12V_{IN} to 5V_{OUT} Derating with Airflow

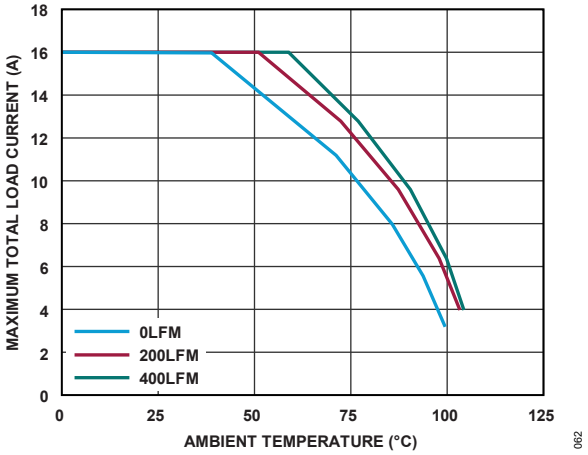


Figure 62. 24V_{IN} to 5V_{OUT} Derating with Airflow

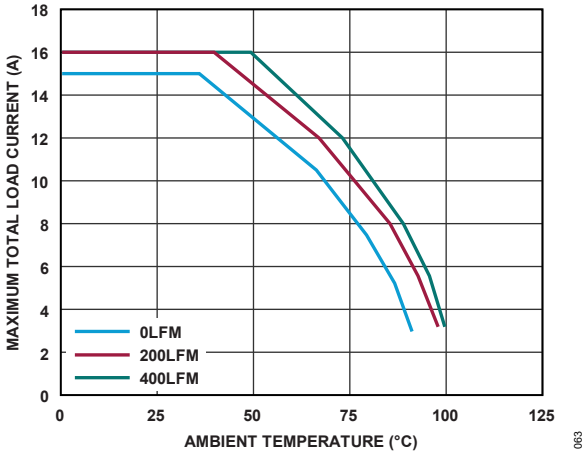


Figure 63. 36V_{IN} to 5V_{OUT} Derating with Airflow

Table 11. 1.5V Output

DERATING CURVE	V_{IN} (V)	POWER LOSS CURVES	AIRFLOW (LFM)	HEAT SINK	θ_{JA} (°C/W)
Figure 55, *Figure 56*, *Figure 57*	12, 24, 36	*Figure 52*	0	None	9
Figure 55, *Figure 56*, *Figure 57*	12, 24, 36	*Figure 52*	200	None	7.5
Figure 55, *Figure 56*, *Figure 57*	12, 24, 36	*Figure 52*	400	None	6.5

Table 12. 3.3V Output

DERATING CURVE	V_{IN} (V)	POWER LOSS CURVES	AIRFLOW (LFM)	HEAT SINK	θ_{JA} (°C/W)
Figure 58, *Figure 59*, *Figure 60*	12, 24, 36	*Figure 53*	0	None	9
Figure 58, Figure 59, Figure 60	12, 24, 36	*Figure 53*	200	None	7.5
Figure 58, Figure 59, Figure 60	12, 24, 36	*Figure 53*	400	None	6.5

Table 13. 5V Output

DERATING CURVE	V_{IN} (V)	POWER LOSS CURVES	AIRFLOW (LFM)	HEAT SINK	θ_{JA} (°C/W)
Figure 61, *Figure 62*, *Figure 63*	12, 24, 36	*Figure 54*	0	None	9
Figure 61, *Figure 62*, *Figure 63*	12, 24, 36	*Figure 54*	200	None	7.5
Figure 61, *Figure 62*, *Figure 63*	12, 24, 36	*Figure 54*	400	None	6.5

Load Sharing

The four RHM4900 channels may be paralleled to produce higher currents. To do this on two or more RHM4900 modules, connect the V_{INn}, V_{OUTn}, FBn, and SHAREn pins of all the paralleled channels/modules together. To ensure that paralleled channels start-up together, the TRSSn pins may be all connected together, as well. If it is inconvenient to connect the TRSSn pins together, ensure the same value soft-start capacitors are used for each µModule regulator. When load sharing among n units and using a single R_{FB} resistor, the value of the resistor is given by equation *2*.

$$R_{FB} = \frac{199.2}{n(V_{OUT} - 0.8)}, where\ R_{FB}\ is\ in\ k\Omega \quad (2)$$

Examples of load-sharing applications are given in *Figure 68* through *Figure 71* in the *Typical Applications* section.

Burst Mode Operation

To enhance efficiency at light loads, the RHM4900 automatically switches to Burst Mode operation, which keeps the output capacitor charged to the proper voltage, while minimizing the input quiescent current. During Burst Mode operation, the RHM4900 delivers single-cycle bursts of current to the output capacitor, followed by sleep periods, where most of the internal circuitry is powered off, and energy is delivered to the load by the output capacitor. During the sleep time, V_{INn} and BIASn quiescent currents are greatly reduced. So, as the load current decreases towards a no-load condition, the percentage of time the RHM4900 operates in sleep mode increases and the average input current is greatly reduced, resulting in higher light load efficiency.

The Burst Mode operation is enabled by tying SYNC to GND.

Minimum Input Voltage

The RHM4900 is a step-down converter. Therefore, a minimum amount of headroom is required to keep the output in regulation. Keep the input above 3V to ensure proper operation. Voltage transients or ripple valleys that cause the input to fall below 3V may turn off the RHM4900.

The V_{IN1} must be above 3V for Channel 1 and Channel 2 to operate. If V_{IN1} is above 3V, Channel 2 operates if V_{IN2} is above 2V.

The V_{IN34} must be above 3V for Channel 3 and Channel 4 to operate.

Output Voltage Tracking and Soft-Start

The RHM4900 allows to adjust its output voltage ramp rate using the TRSSn pin. An internal 2µA pulls up the TRSSn pin to about 2.4V. Putting an external capacitor on TRSSn enables soft-starting the output to reduce current surges on the input supply. During the soft-start ramp, the output voltage proportionally tracks the TRSSn pin voltage. For output tracking applications, TRSSn can be externally driven by another voltage source. From 0V to 0.8V, the TRSSn voltage overrides the internal 0.8V reference input to the error amplifier, thus regulating the FBn pin voltage to that of the TRSSn pin. When TRSSn is above 0.8V, tracking is disabled, and the feedback voltage is regulated to the internal reference voltage. The TRSSn pin may be left floating if the function is not needed.

An active pull-down circuit is connected to the TRSSn pin, which discharges the external soft-start capacitor in the case of fault conditions and restart the ramp when the faults are cleared. Fault conditions that clear the soft-start capacitor are the RUNn pin transitioning low, V_{INn} voltage falling too low, or thermal shutdown.

Prebiased Output

As discussed in the *Output Voltage Tracking and Soft-Start* section, the RHM4900 regulates the output to the FBn voltage determined by the TRSSn pin whenever TRSSn is less than 0.8V. If the RHM4900's output is higher than the target output voltage, and SYNCn is not held below 0.8V, the RHM4900 attempts to regulate the output to the target voltage by returning a small amount of energy to the input supply. If nothing is loading the input supply, its voltage may rise. Take care it does not rise so high that the input voltage exceeds the absolute maximum rating of the RHM4900. If SYNC pin is grounded, the RHM4900 does not return current to the input.

Frequency Foldback

The RHM4900 is equipped with frequency foldback, which acts to reduce the thermal and energy stress on the internal power elements during a short-circuit or output overload condition. If the RHM4900 detects the output has fallen out of regulation, the switching frequency is reduced as a function of how far the output is below the target voltage. This in turn limits the amount of energy that can be delivered to the load under fault. During the start-up time, frequency foldback is also active to limit the energy delivered to the potentially large output capacitance of the load. When a clock is applied to the SYNCn pin, the SYNCn pin is floated or held high, the frequency foldback is disabled, and the switching frequency slows down only during overcurrent conditions.

Synchronization

To select low ripple Burst Mode operation, connect the SYNCn pin below about 0.8V (this can be ground or a logic low output). To synchronize the RHM4900 oscillator to an external frequency, connect a square wave (with about 20% to 80% duty cycle) to the SYNCn pin. The square wave amplitude should have valleys below 0.8V and peaks above 1.5V.

The RHM4900 may be synchronized over a 200kHz to 3MHz range. The RHM4900 does not enter Burst Mode operation at light output loads while synchronized to an external clock. The R_T resistor should be chosen to set the switching frequency equal to or below the lowest synchronization input. For example, if the synchronization signal is 500kHz and higher, the R_T resistor should be selected for 500kHz or lower.

The RHM4900 features spread-spectrum operation to further reduce electromagnetic interference/electromagnetic interference compatibility (EMI/EMC) emissions. To enable spread-spectrum operation, apply between 2.8V and 4V to the SYNCn pin. In this mode, triangular frequency modulation is used to vary the switching frequency between the value programmed by R_T to about 20% higher than that value. The modulation frequency is about 7kHz. For example, when the RHM4900 is programmed to 2MHz, the frequency varies from 2MHz to 2.4MHz at a 7kHz rate. When spread-spectrum operation is selected, the Burst Mode operation is disabled, and the RHM4900 may run in discontinuous-conduction mode.

Shorted Input Protection

Care must be taken in systems where the output is held high when the input to the RHM4900 is absent. This may occur in battery charging applications or battery backup systems, where a battery or some other supply is diode OR'ed with the RHM4900's output. If the V_{INn} pin is allowed to float and the RUNn pin is held high (either by a logic signal or because it is connected to V_{INn}), the RHM4900's internal circuitry pulls its quiescent current through its internal power switch. This is fine if the system can tolerate a few milliamps in this state. If the RUNn pin is grounded, the internal current drops to zero. However, if the V_{INn} pin is grounded while the output is held high, parasitic diodes inside the RHM4900 can pull large currents from the output through the V_{INn} pin. *Figure 64* shows a circuit that runs only when the input voltage is present, and that protects against a shorted or reversed input.

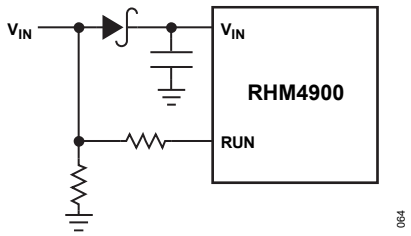


Figure 64. The Input Diode Prevents a Shorted Input from Discharging a Backup Battery Connected to the Output. It Also Protects the Circuit from a Reversed Input. The RHM4900 Runs Only when the Input is Present.

PCB Layout

Most of the headaches associated with PCB layout design have been alleviated or even eliminated by the high level of integration of the RHM4900. The RHM4900 is nevertheless a switching power supply, and care must be taken to minimize EMI and ensure proper operation. Even with a high level of integration, users may fail to achieve specified operations with a haphazard or poor layout. See *Figure 65* for a suggested layout. Ensure the grounding and heat sinking are acceptable.

Keep in mind the following rules.

1. Place the R_{FB} and R_T resistors as close as possible to their respective pins.
2. Place the C_{IN} capacitor as close as possible to the V_{IN} and GND connection.
3. Place the C_{OUT} capacitor as close as possible to the V_{OUT} and GND connection.
4. Place the C_{IN} and C_{OUT} capacitors such that their ground current flows directly adjacent to or underneath the RHM4900.
5. Connect all the GND connections to as large a copper pour or plane area as possible on the top layer. Avoid breaking the ground connection between the external components and the RHM4900.
6. Use vias to connect the GND copper area to the board's internal ground planes. Liberally distribute these GND vias to provide both a good ground connection and thermal path to the internal planes of the PCB. Pay attention to the location and density of the thermal vias in *Figure 65*. The RHM4900 can benefit from the heat sinking afforded by vias that connect to internal GND planes at these locations, due to their proximity to internal power handling components. The optimum number of thermal vias depends upon the PCB design. For example, a board might use very small via holes. It should employ more thermal vias than a board that uses larger holes.

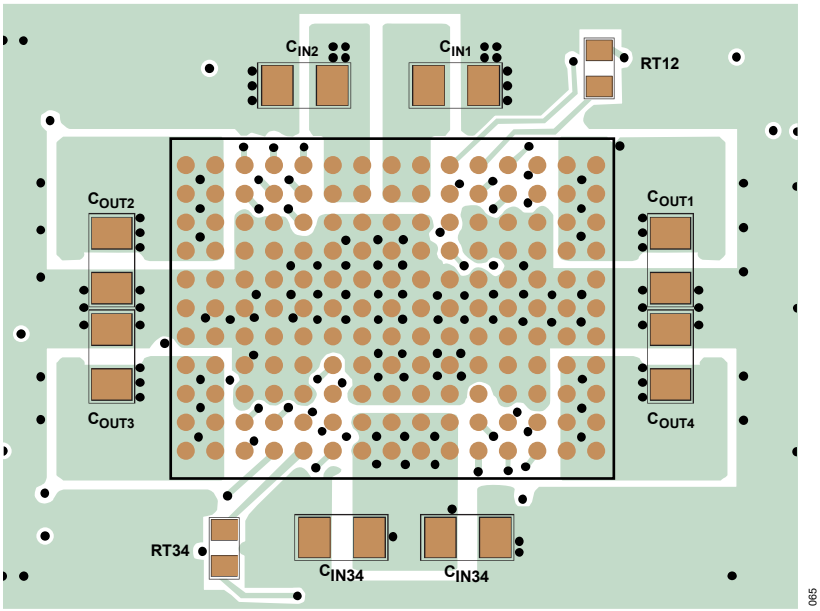


Figure 65. Layout Showing Suggested External Components, GND Plane, and Thermal Vias

Hot-Plugging Safely

The small size, robustness, and low impedance of ceramic capacitors make them an attractive option for the input bypass capacitor of the RHM4900. However, these capacitors can cause problems if the RHM4900 is plugged into a live supply (refer to the Analog Devices *Application Note 88* for a complete discussion). The low-loss ceramic capacitor combined with stray inductance in series with the power source forms an underdamped tank circuit, and the voltage at the VINn pin of the RHM4900 can ring to more than twice the nominal input voltage, possibly exceeding the RHM4900's rating and damaging the parts. If the input supply is poorly controlled or the RHM4900 is hot-plugged into an energized supply, the input network should be designed to prevent this overshoot. This can be accomplished by installing a small resistor in series to VINn, but the most popular method of controlling the input voltage overshoot is adding an electrolytic bulk cap to the VINn net. This capacitor's relatively high equivalent series resistance damps the circuit and eliminates the voltage overshoot. The extra capacitor improves low-frequency ripple filtering and can slightly improve the efficiency of the circuit, though it is likely to be the largest component in the circuit.

Thermal Considerations

The RHM4900 output current may need to be derated if it is required to operate in a high ambient temperature. The amount of current derating is dependent upon the input voltage, output power, and ambient temperature. The derating curves shown in *Figure 55* through *Figure 63* can be used as a guide. These curves were generated by the RHM4900 mounted to a 104cm^2, 6-layer, FR4 PCB. Boards of other sizes and layer counts can exhibit different thermal behavior. So, it is incumbent to verify the proper operation over the intended system's line, load, and environmental operating conditions.

For increased accuracy and fidelity to the actual application, many designers use FEA or computational fluid dynamics (CFD) to predict thermal performance. To that end, the pin configuration typically gives three dominant thermal coefficients:

7. θ_{JA} – Thermal resistance from junction to ambient.
8. θ_{JCbot} – Thermal resistance from the junction to the bottom of the product case.
9. θ_{JCtop} – Thermal resistance from the junction to the top of the product case.

While the meaning of each of these coefficients may seem to be intuitive, JEDEC has defined each to avoid confusion and inconsistency. These definitions are given in JESD51-12 and are quoted or paraphrased as follows.

10. θ_{JA} is the natural convection junction-to-ambient air thermal resistance measured in one cubic foot sealed enclosure. This environment is sometimes referred to as "still air", although natural convection causes the air to move. This value is determined with the RHM4900 mounted to a JESD51-9 defined test board, which does not reflect an actual application or viable operating condition.
11. θ_{JCbot} is the junction-to-board thermal resistance with all the component power dissipation flowing through the bottom of the package. In the typical µModule regulator, the bulk of the heat flows out the bottom of the package, but there is always heat flow out into the ambient environment. As a result, this thermal resistance value may be useful for comparing packages, but the test conditions do not generally match the user's application.
12. θ_{JCtop} is determined with nearly all the component power dissipation flowing through the top of the package. As the electrical connections of the typical µModule regulator are on the bottom of the package, it is rare for an application to operate such that most of the heat flows from the junction to the top of the parts. As in the case of θ_{JCbot}, this value may be useful for comparing packages, but the test conditions do not generally match the user's application.

Given these definitions, it should now be apparent that none of these thermal coefficients reflect an actual physical operating condition of a µModule regulator. Thus, none of them can be individually used to accurately predict the thermal performance of the product. Likewise, it is inappropriate to attempt to use any one coefficient to correlate to the junction temperature vs. load graphs given in this data sheet. The only appropriate way to use the coefficients is when running a detailed thermal analysis, such as FEA, which considers all the thermal resistances simultaneously.

Figure 66 is a graphical approximation of these dominant thermal resistances. Some thermal resistance elements, such as the heat flowing out the side of the package, are not defined by the JEDEC standard, and are not shown. The blue resistances are contained within the µModule regulator, and the green is outside.

The die temperature of the RHM4900 must be lower than the maximum rating. So, care must be taken in the layout of the circuit to ensure good heat sinking of the RHM4900. The bulk of the heat flow out of the RHM4900 is through the bottom of the package and the pads into the PCB. Consequently, a poor PCB design can cause excessive heating, resulting in impaired performance or reliability. See the *PCB Layout* section for a design suggestion.

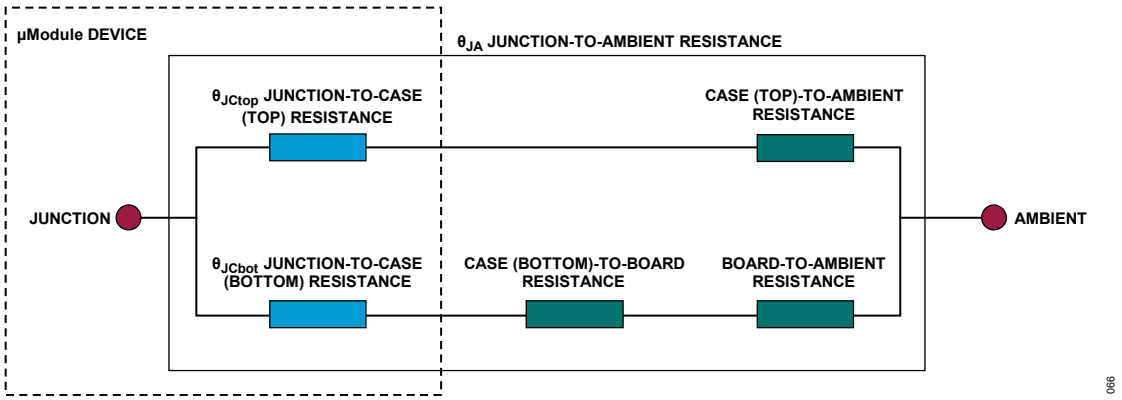


Figure 66. Graphical Representation of Thermal Coefficients, Including the JESD51-12 Terms

Typical Applications

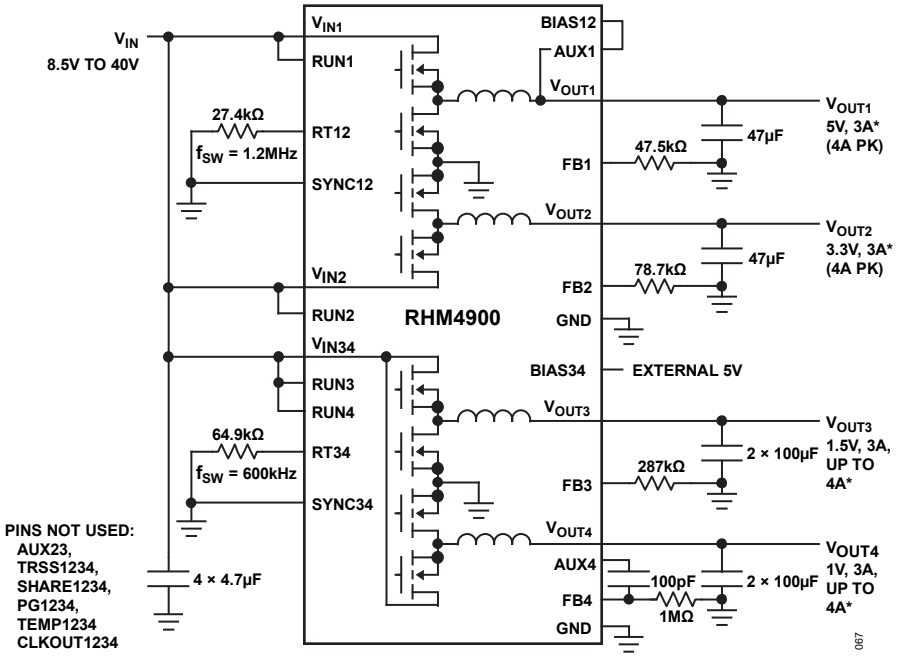


Figure 67. 8.5V to 40V Input to 5V at 3A (4A Peak), 3.3V at 3A (4A Peak), 5V at 3A (4A Peak), and 3.3V at 3A (4A Peak)

*Output current capability (transient peak or continuous) is subject to environmental factors such as ambient temperature, airflow, or other cooling techniques. For different V_{IN}, V_{OUT}, and T_A conditions, see the notes section (Note *3*) of the *Electrical Characteristics* table and the derating curves in the *Applications Information* section.

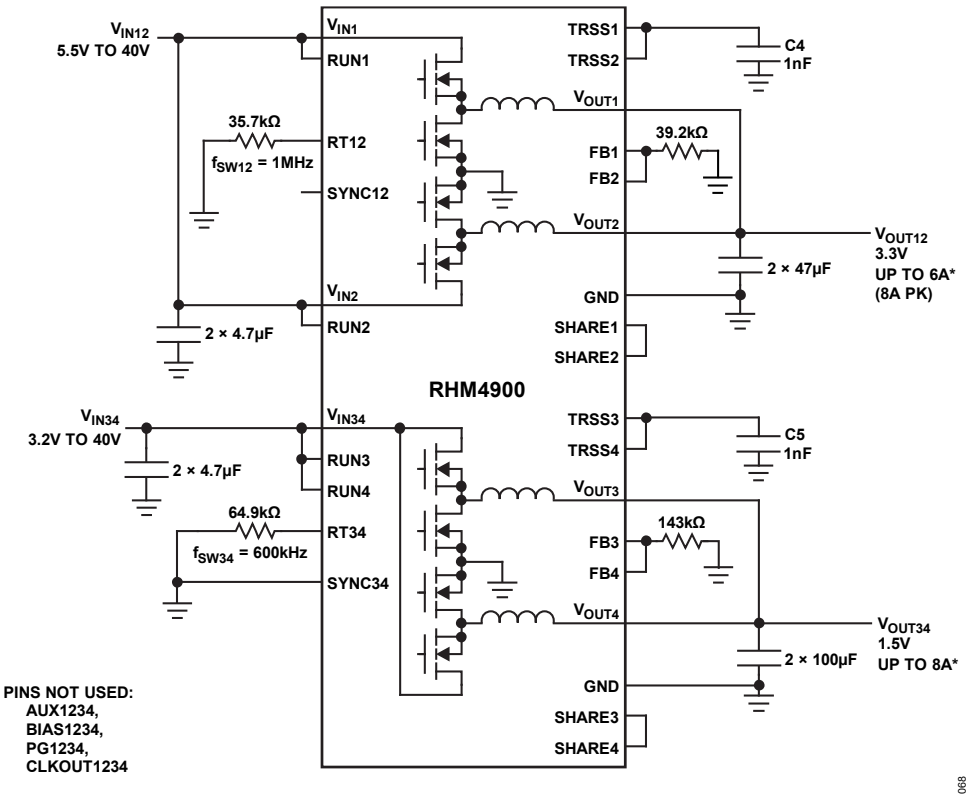


Figure 68. 5.5V to 40V Input to Paralleled 3.3V at 6A (8A Peak), 3.2V to 40V Input to Paralleled 1.5V at 8A

*Output current capability (transient peak or continuous) is subject to environmental factors such as ambient temperature, airflow, or other cooling techniques. For different V_{IN}, V_{OUT}, and T_A conditions, see the notes section (Note *3*) of the *Electrical Characteristics* table and the derating curves in the *Applications Information* section.

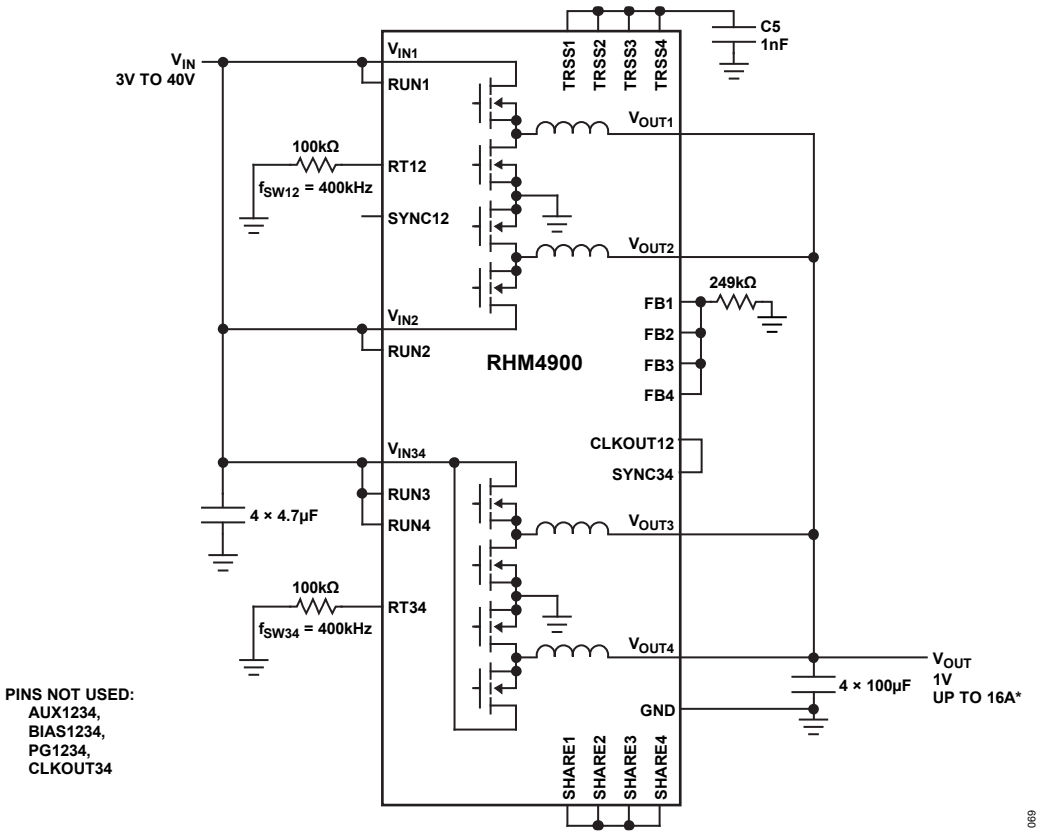


Figure 69. 3V to 40V Input to Paralleled 1V at 16A

*Output current capability (transient peak or continuous) is subject to environmental factors such as ambient temperature, airflow, or other cooling techniques. For different V_{IN}, V_{OUT}, and T_A conditions, see the notes section (Note *3*) of the *Electrical Characteristics* table and the derating curves in the *Applications Information* section.

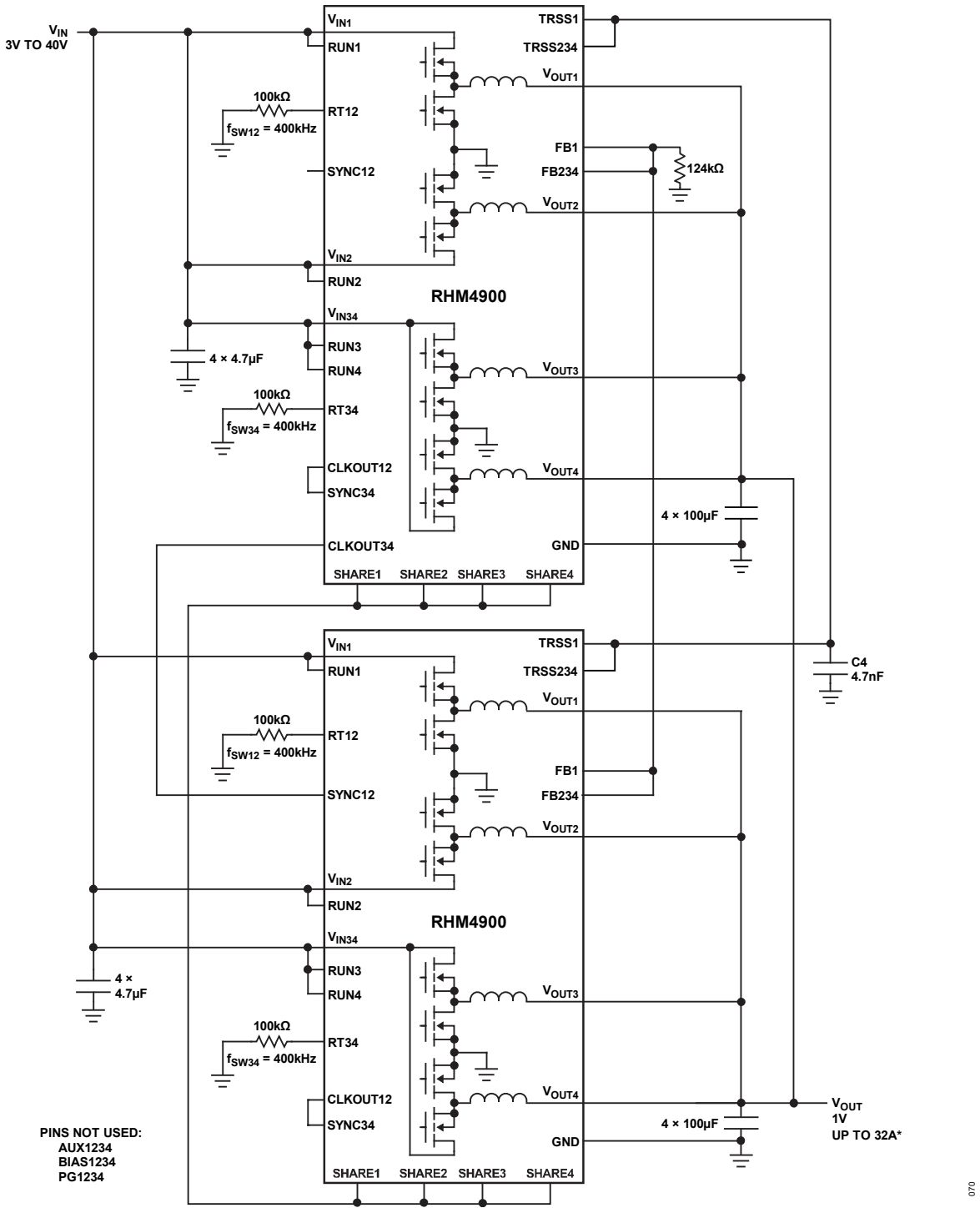


Figure 70. Two RHM4900 are Paralleled to Supply 1V at 32A Output in FCM

*Output current capability (transient peak or continuous) is subject to environmental factors such as ambient temperature, airflow, or other cooling techniques. For different V_{IN}, V_{OUT}, and T_A conditions, see the notes section (Note 3) of the *Electrical Characteristics* table and the derating curves in the *Applications Information* section.

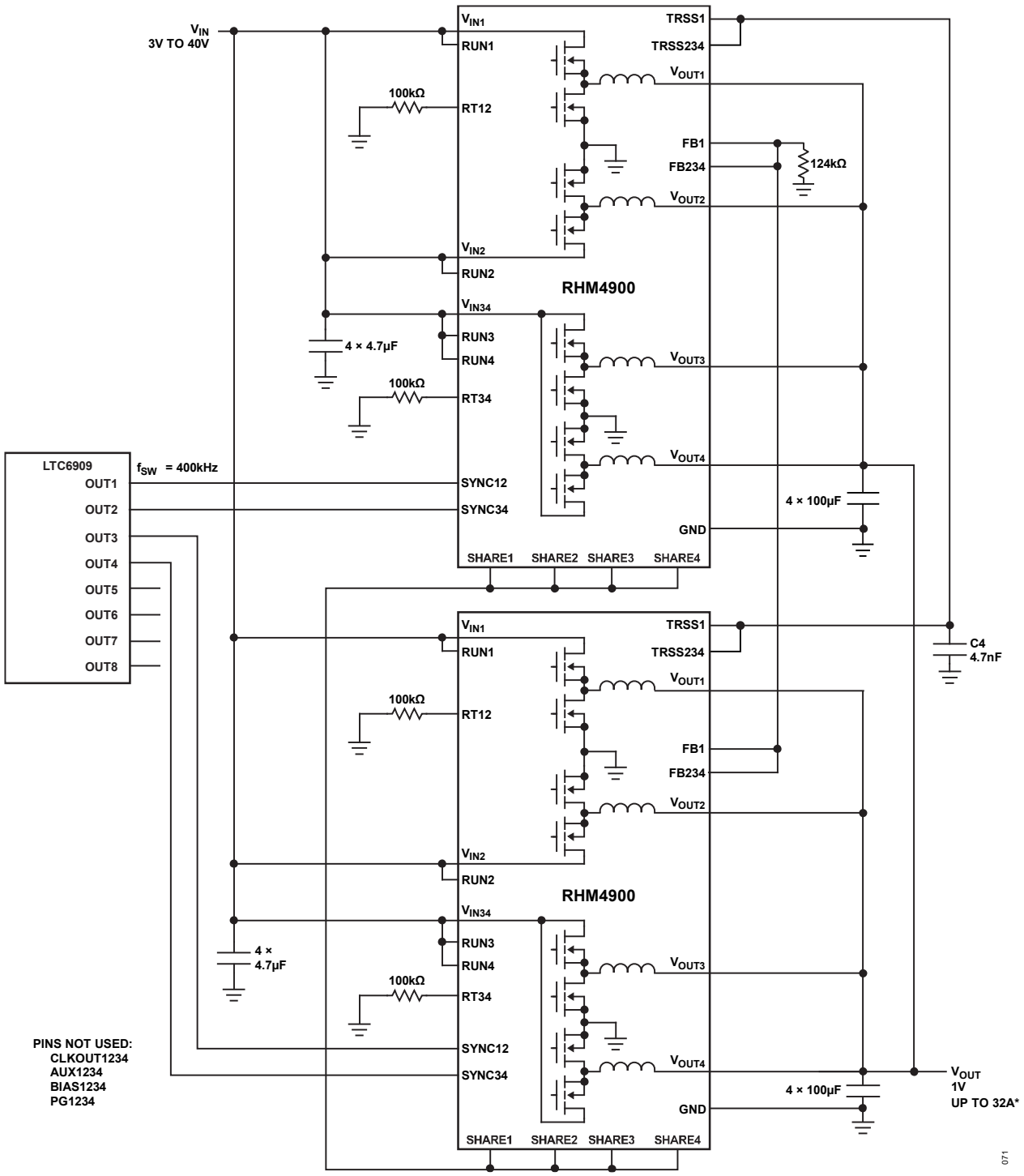


Figure 71. Two RHM4900 are Paralleled to Supply 1V at 32A Output with 45° Phase-Shift Interleaving Through All Eight Channels

*Output current capability (transient peak or continuous) is subject to environmental factors such as ambient temperature, airflow, or other cooling techniques. For different V_{IN}, V_{OUT}, and T_A conditions, see the notes section (Note 3) of the *Electrical Characteristics* table and the derating curves in the *Applications Information* section.

Related Parts

Table 14. RHM4900 Related Parts

PART NUMBER	DESCRIPTION	COMMENTS
RHM4900-1	40V, quad, 3A, step-down Silent Switcher µModule regulator with external (adjustable) compensation network and local or remote sensing capable for CSL applications.	3V ≤ V_{IN} ≤ 40V, 0.8V ≤ V_{OUT} ≤ 8V, 16mm × 11.9mm × 3.32mm, BGA package

OUTLINE DIMENSIONS

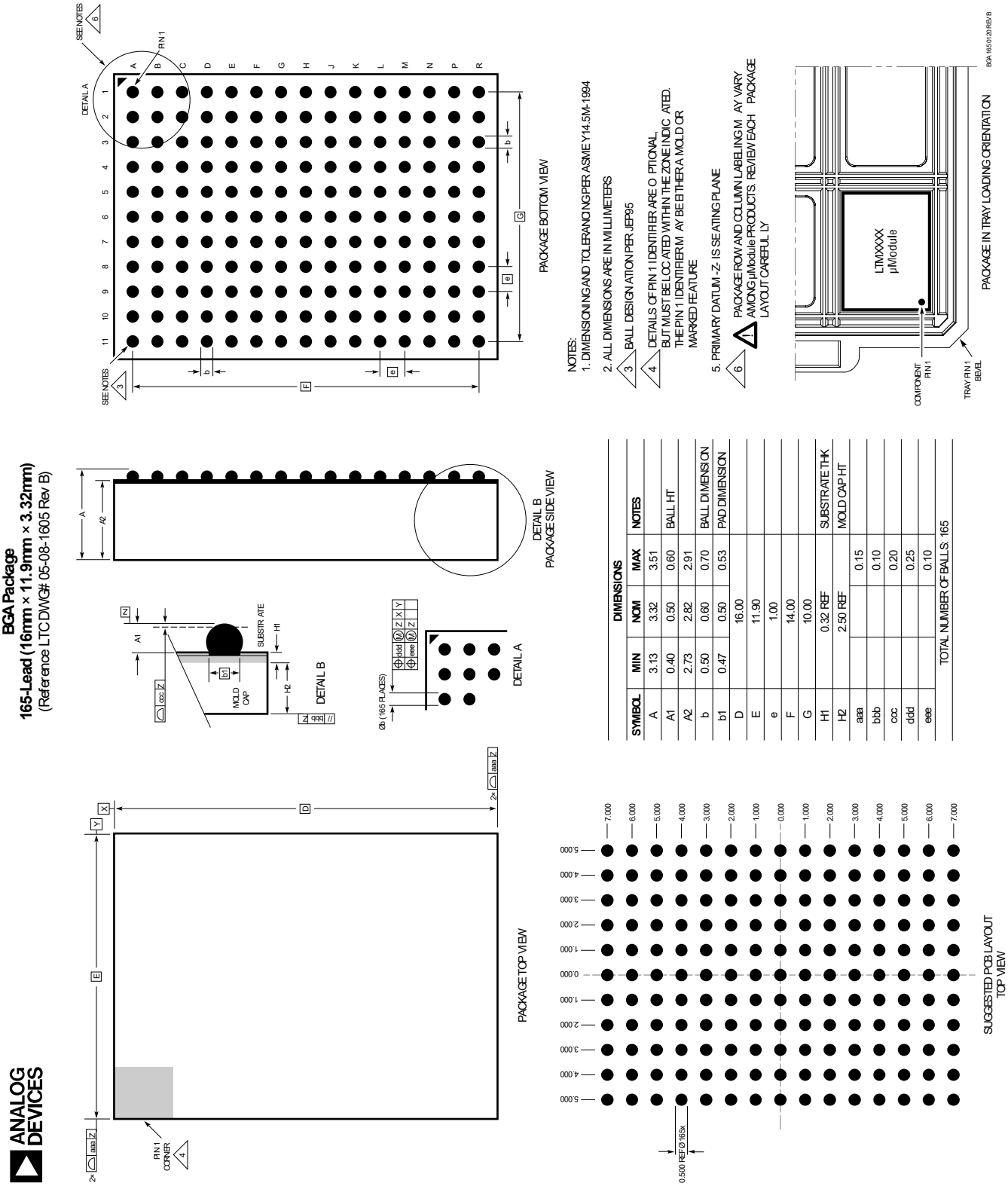


Figure 72. 165-Lead, 16mm × 11.9mm × 3.32mm, BGA

ORDERING GUIDE

Table 15. RHM4900 Ordering Information

MODEL	TEMPERATURE RANGE[1,2]	PACKAGE DESCRIPTION	PACKAGE OPTION [5]
RHM4900IY-CSL#PBF	–40°C to 125°C	RHM4900YL part marking SAC305 (RoHS) pad finish [3] e1 finish code Moisture sensitivity level 4 (MSL 4) rated device [4]	*165-Lead, 16mm × 11.9mm × 3.32mm, BGA*
RHM4900IY-CSL	–40°C to 125°C	RHM4900YL part marking SnPb (63/37)pad finish [3] e0 finish code Moisture sensitivity level 4 (MSL 4) rated device [4]	*165-Lead, 16mm × 11.9mm × 3.32mm, BGA*

1 The RHM4900 is guaranteed to meet specifications over the full –40°C to 125°C internal operating temperature range. Note that the maximum internal temperature is determined by the specific operating conditions in conjunction with the board layout, rated package thermal resistance, and other environmental factors.

2 Contact the factory for parts specified with wider operating temperature ranges.

3 Pad finish code is per IPC/JEDEC J-STD-609.

4 This product is not recommended for second side reflow and it is moisture sensitive. For more information, refer to the Analog Devices *µModule LGA and BGA Packaging Care and Assembly Instructions* document.

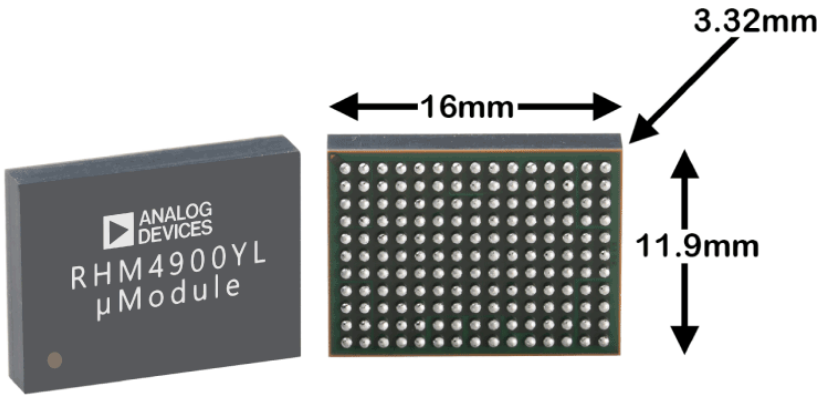
5 The BGA package should follow assembly and manufacturing procedures. For more information, refer to the Analog Devices *Assembly Considerations for the µModule BGA and LGA Packages* guidelines.

Table 16. Evaluation Board Ordering Information

PART NUMBER	DESCRIPTION
EVAL-RHM4900-AZ	Evaluation board featuring the RHM4900, a 40V_{IN}, quad, 3A, Silent Switcher µModule regulator for CSL applications.

SELECTOR GUIDE

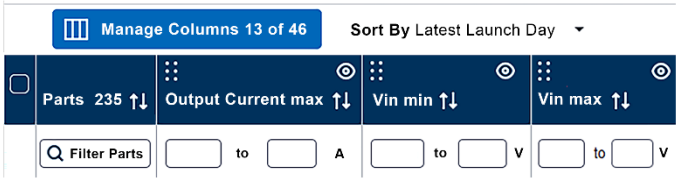
Package Photos



(Part Marking Is Laser Mark)

Design Resources

Table 17. µModule Power Technology

RESOURCES	DESCRIPTION	
µModule Design, Manufacturing, and Assembly	**Design** ▶ Evaluation guide boards and Gerber files ▶ Free design tools, including LTspice® and LTpowerCAD® ▶ Circuit simulations	**Manufacturing** ▶ Quick start guides ▶ PCB design, assembly, and manufacturing guidelines ▶ Package and board level reliability
µModule Regulator Products Search	▶ Manage columns and sort table of products by parameters, and download the result as a spread sheet. 	
Digital Power System Management	The Analog Devices family of digital power supply management ICs are highly integrated solutions that offer essential functions, including power supply monitoring, supervision, margining, and sequencing, and feature EEPROM for storing user configurations and fault logging.	

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