

Coaxial

# High Power Solid-State Amplifier ZHL-2425-250X+

50Ω 250W 2.4 to 2.5 GHz

## The Big Deal

- High output power, 300W
- 2.4 to 2.5GHz ISM band
- Suitable for CW and pulsed signals
- High gain, 40 dB typical
- High efficiency, 60%
- High ruggedness
- Built-in monitoring and protection for temperature, current forward and reflected power
- User friendly I2C control interface



## Product Overview

The ZHL-2425-250X+ is a new generation solid state connectorized high-power amplifier module which can be used in a wide range of industrial, scientific and medical applications in the 2400-2500 MHz ISM band. The ZHL-2425-250X+ provides many advantages over traditional magnetrons, such as longer lifespan, greater frequency tuning, better frequency stability, precise control of output power, and lower power supply voltage. This rugged amplifier is capable of amplifying signals (CW & pulsed) from 1W to 300W output power with built-in monitoring and protection for temperature, current, forward power, reverse power.

The amplifier has internal shutdown circuitry and integrated protection functions for added reliability under difficult operating conditions, making it virtually impossible to destroy both in single and multi-channel systems. The basic amplifier can be controlled externally with a few logic inputs or through a user friendly I2C control interface to monitor forward and reflected power to support dynamic load analysis, temperature, current, shutdown alarms, enabling the PA, and for resetting protection alarms. For advanced mode, users may consult the factory for more in depth amplifier control commands, access to FWD/REFL power coefficients, and protection overrides.

## Key Features

Feature	Advantages
High CW Power	Supports high power applications for a wide range of industrial, scientific and medical applications in the 2400 – 2500 MHz ISM frequency band. Power can be regulated accurately from 1W up to 300W (~P3dB, @+25C).
High Gain	A typical gain of 41 dB allows the ZHL-2425-250+ to be driven to full output power with commercially available integrated signal generators with a 14dBm output signal.
High Efficiency	The ZHL-2425-250+ uses high efficiency state of the art LDMOS technology. This combined with adaptive frequency control enables a high efficiency of typically 60% in most applications.
Built-in protection	The amplifier has built-in monitoring and protection for temperature, current, forward power, reverse power, and internal shutdown circuitry for added reliability under difficult operating conditions. When the prestored limits shown in the protection limits table are exceeded the amplifier will shut down.
Ruggedness	The amplifier has excellent reverse isolation and ruggedness with an onboard circulator. Reverse power is monitored, and the amplifier is shut down when the reverse power exceeds the prestored limits shown in the protection limits table.
Forward & Reverse Power detection	The amplifier features integrated couplers and detectors for Forward (FWD) and Reflected (REFL) power detection. FWD and REFL power detection supports accurate RF power measurements as well as dynamic load analysis and can be used to control or shut-off the amplifier by using the internal monitoring or an external controller.
Easy interfacing	Easy access to the amplifiers analog and digital (I2C) data, enabling dynamic ISM applications with either single or multiple modules to be controlled.
Small and lightweight	With a small footprint (55.9mm x 171.5mm x 15mm) the lightweight (0.29 kg) modular design is flexible for single or multiple amplifier system integration.
Cooling	The amplifier can either be air or water cooled. Mounting screw holes are available on the amplifier.
Low voltage	The ZHL-2425-250+ is powered by a low 32V supply.



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## Features

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- High efficiency, 60%
- High ruggedness
- Built-in protection for temperature, current, forward and reflected power
- User friendly I2C control interface
- Small light weight modular design
- Excellent reverse isolation and ruggedness with onboard circulator



Generic photo used for illustration purposes only

Connectors	Model
N-Type	ZHL-2425-250X+

**+RoHS Compliant**  
 The +Suffix identifies RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications

## Electrical Specifications at +25°C, 32V, 50Ω System, 3.3V logic levels

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units	
Frequency Range	f		2400	—	2500	MHz	
Input Power	P <sub>in</sub>	f=2400 MHz to 2500 MHz			16	dBm	
Output Power	P <sub>OUT</sub>	f=2400 MHz to 2500 MHz				Watts	
				250	300		dBm
Power Gain	G <sub>P</sub>	@ P <sub>OUT</sub> , f=2400 MHz to 2500 MHz	39	41		dB	
Gain Flatness	G <sub>FLAT</sub>	@ P <sub>OUT</sub> , f=2400 MHz to 2500 MHz	—	0.5	1.0	dB	
Efficiency	η	@ P <sub>OUT</sub> , f=2400 MHz to 2500 MHz	50	60	—		
Input VSWR	I_VSWR	@ P <sub>OUT</sub> , f=2400 MHz to 2500 MHz	—	1.9:1	2.3:1		
Insertion Phase (unit-unit)	F	@ P <sub>OUT</sub> , f=2400 MHz to 2500 MHz	—	10	15	deg.	
Operating Voltage	V <sub>DC</sub>	@ P <sub>OUT</sub> , f=2400 MHz to 2500 MHz	31.5	32	32.5	V	
Supply Current	I <sub>DC</sub>	@ P <sub>OUT</sub> , f=2400 MHz to 2500 MHz	—	16	18	A	
Temperature @ pallet base (based on analog output)	T <sub>PB</sub>	T <sub>PB</sub> =(−72.183 x TEMP_AOUT)+187.04 (TEMP_AOUT is the analog voltage on pin 8 of the conn. J2)					°C
Supply Current (based on analog output)	I <sub>current</sub> <sup>3</sup>	I <sub>current</sub> =(5.2968 x ISENSE_AOUT)−0.0464 (ISENSE_AOUT is the analog voltage on pin 8 of the conn. J2)					A
PA On / Off	—	Enable (TTL low) / Disable (TTL high) on Pin 5 of Connector J2 or via I2C command					

## Protection Limits<sup>1</sup>

Parameter	Symbol	Min.	Max.	Units
Temperature at pallet base	T <sub>PB</sub>	—	65	°C
Forward Power	FWD_POWER_A	—	320	Watts
			55	dBm
Reverse Power	REFL_POWER_A	—	250	Watts
			54	dBm
Voltage Supply	VDS_SENSE_A	24	40	V
Current Supply	ISENSE_A	—	18	A

## Maximum Ratings<sup>2</sup>

Parameter	Ratings
Operating Pallet Base Temperature	0°C to +65°C
Storage Temperature	−20°C to +85°C
DC Voltage	40V
Input RF Power (no damage)	+17 dBm

1. When the prestored limits are exceeded the amplifier will shut-down and remain disabled until a reset command is sent thru the I2C interface or by applying a logic high level to pin 3 of connector J2.

2. Specifications apply to CW signals only. Permanent damage may occur if any of these limits are exceeded.

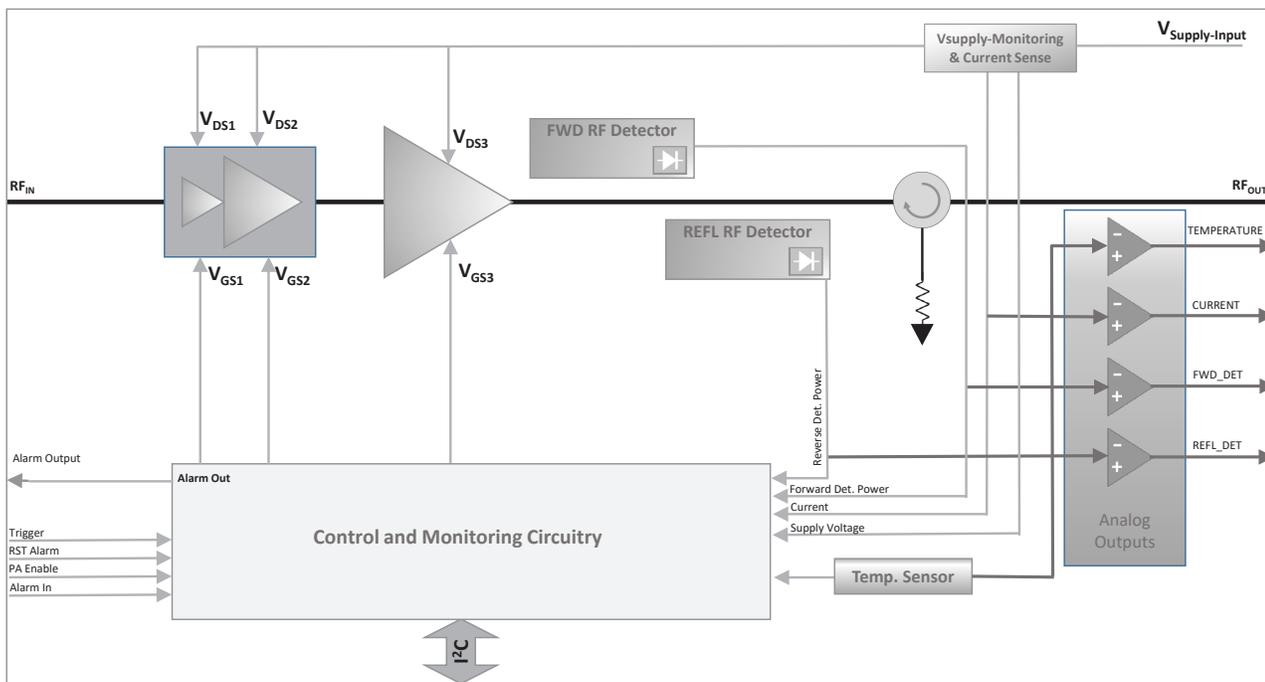
3. Typically <1% error for greater than 5W output power.

## Application

The ZHL-2425-250X+ amplifier module can be used as a building block in any single or multi-channel system for high power RF Energy applications such as:

- Industrial heating
- Materials processing
- Food processing (heating, tempering, and pasteurization)
- Microwave-assisted chemistry
- Plasma generation
- Plasma surface treatment
- Disinfection
- Chemistry
- RF-excited lasers
- Medical (heating, hyperthermia, and ablation)
- Semiconductor RF generators

## Block Diagram



## Application Overview

The ZHL-2425-250X+ can easily be driven by most standard signal generators, when connected to a DC power supply and mounted to a heat sink. The module is ready to deliver RF power to any applicator, i.e., a “device” to contain and/or apply the RF energy. The use of the latest generation solid state devices guarantee high efficiency, long lifetime, fully controllable and stable output power in a compact module outline. The amplifier has built-in monitoring and protection for temperature, current, forward power, reverse power, and internal shutdown circuitry for added reliability under difficult operating conditions, making it virtually impossible to destroy in single and multi-channel systems due to the integrated circulator and protection functions. When the prestored limits shown in the protection limits table are exceeded the amplifier will shut down and remain disabled until an alarm reset is sent either by an I2C command or a TTL high applied to pin 3 of the multi-pin connector J2. For advanced mode, users may consult the factory for more in-depth amplifier control commands, access to FWD/REFL power coefficients, and protection overrides.

There are two operation modes supported by the ZHL-2425-250X+

## 1. Standard operation mode (StdOM)

- PA Enable/Disable
- Built-in protection features enabled
- Ability to reset protection shutdown via I2C command or logic high on pin3
- Access to analog outputs for temperature, forward power, reverse power, and current that can be correlated to output power
- Access through the I2C to read Temperature (°C), forward power (dBm or W), reverse power (dBm or W), supply voltage (V), and current (A)

## 2. Advanced operation mode (AdvOM)

- All of the “standard operation mode” features are available
- Access to the prestored protection limits for shutdown
- Access to enable/disable internal protection shutdown or change prestored internal shutdown limits (amplifier warranty is no longer valid in this situation)
- Access to all coefficients and digital data for forward detected power, reverse detected power, temperature, supply voltage, and current

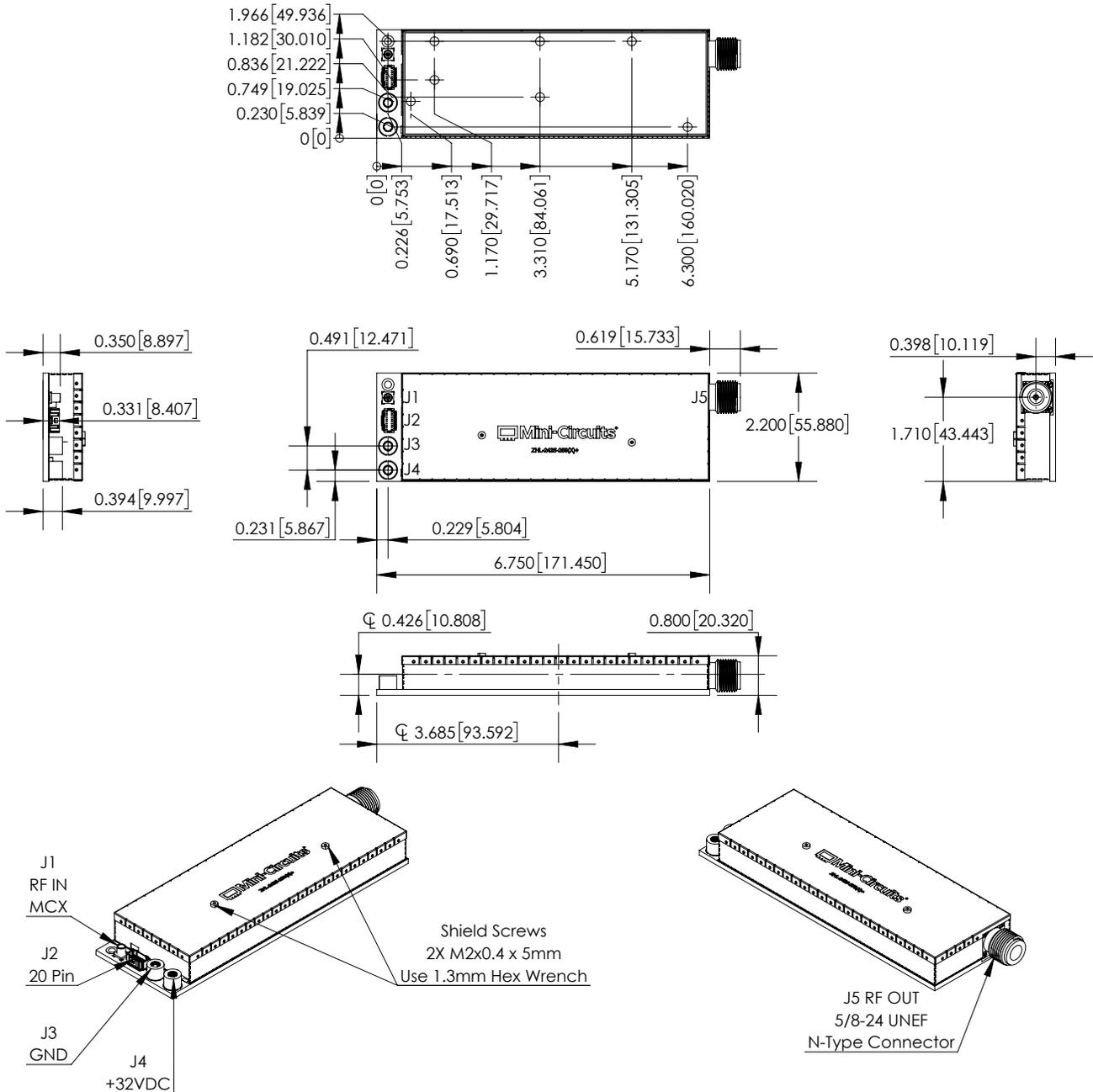
With either mode the external analog, digital signals, and control logic can optimize the RF vector (frequency, power, and time) depending on the application’s needs in real time.

## Control Interface Pin out and Functionality (J2 multi-pin connector, 3.3V logic levels)

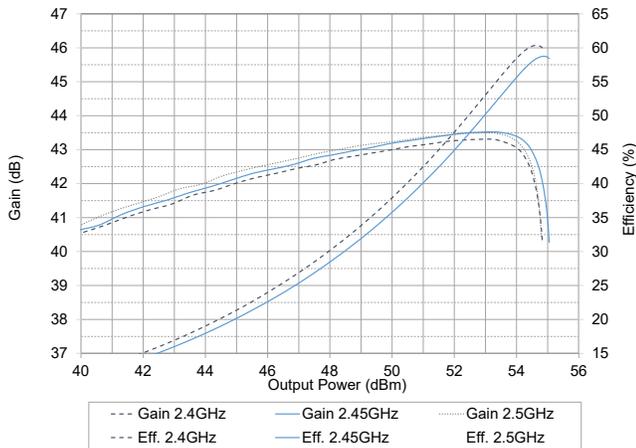
Pin Number	Label	Type	Functionality and Control
1	TRIG_IN		
2	REFL_AOUT		Analog voltage (0 to 3.3V) that can be correlated to the level of the reflected power or power incident at the J5 connector.
3	RST_ALARM		Reset Alarm – Internal protection shutdown can be reset thru the I2C communication or applying a TTL high to this pin.
4	FWD_AOUT		Analog voltage (0 to 3.3V) that can be correlated to the level of the forward output power.
5	PA_ENABLE		Enable (TTL low) / Disable (TTL high). Normally low, enabled, and can be disabled when a TTL high is applied.
6	ISENSE_AOUT		Analog voltage (0 to 3.3V) that correlates to the amplifier current level
7	ALARM_IN		This can be used by a system controller or another ZHL-2425-250X+ amplifier to send an alarm input to shut down the amplifier. This pin is normally low and can be set to a TTL high to shut-down the amplifier.
8	TEMP_AOUT		Analog voltage (0 to 3.3V) that can be correlated to the temperature. See equation in electrical specification table
9	Do Not Connect		Reserved pin for manufacturer
10	Do Not Connect		Reserved pin for manufacturer
11	ALARM_OUT		When the protection limits are exceeded and the amplifier is shutdown, this pin will go from normally TTL low to TTL high. This output can be used by an external controller to shut down the system or can be connected to other ZHL-2425-250X+ amplifiers ALARM_IN pins to shut them down.
12	Do Not Connect		Reserved pin for manufacturer
13	SCL		I2C control
14	Do Not Connect		Reserved pin for manufacturer
15	SDA		I2C control
16	GND		Ground
17	Do Not Connect		Reserved pin for manufacturer
18	Do Not Connect		Reserved pin for manufacturer
19	Do Not Connect		Reserved pin for manufacturer
20	Do Not Connect		Reserved pin for manufacturer

## Outline Drawing

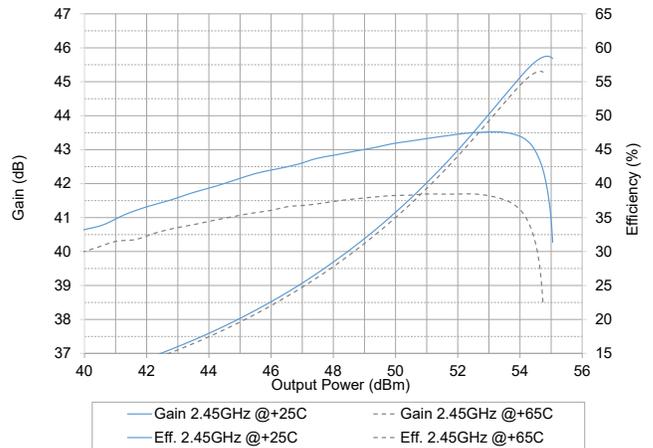
Mounting Hole Locations  
(Lid Requires Temporary Removal to Install Mounting Screws)



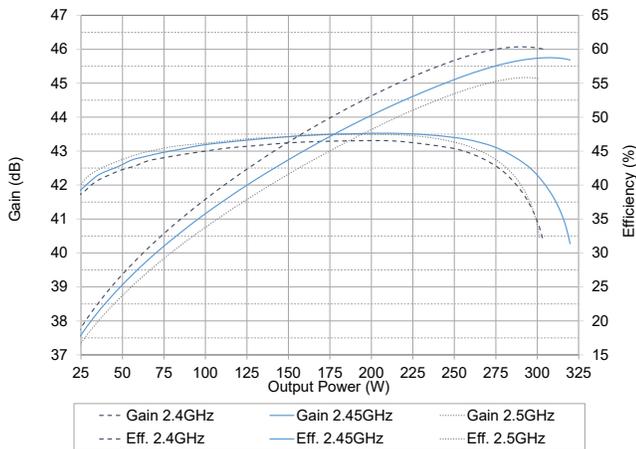
## Typical Performance Data (32V, 50Ω System)



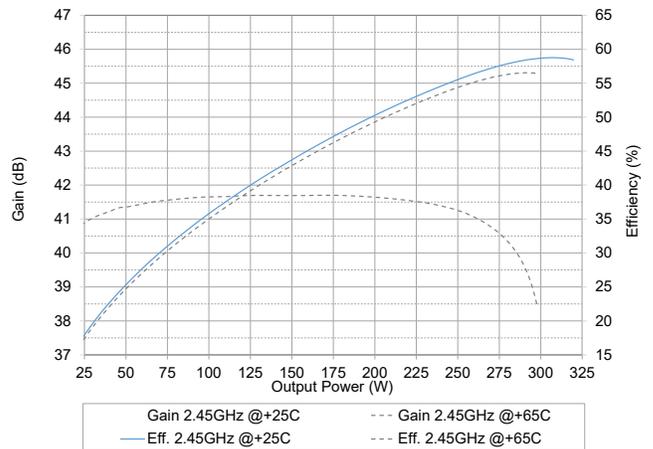
Gain & Efficiency as a function of Output Power (dBm) @ +25°C base temperature



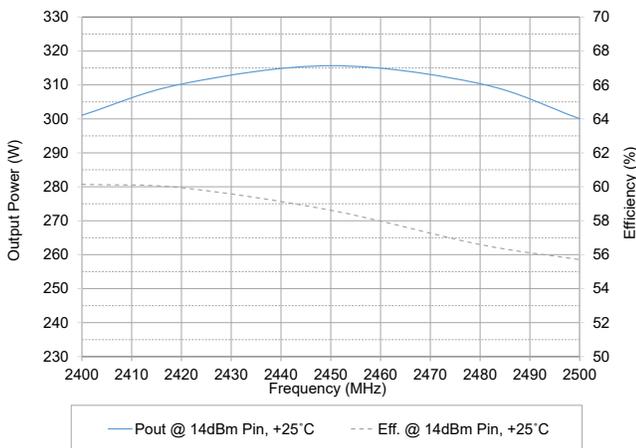
Gain & Efficiency as a function of Output Power (dBm) @ 2.45 GHz for +25°C & +65°C base temperature



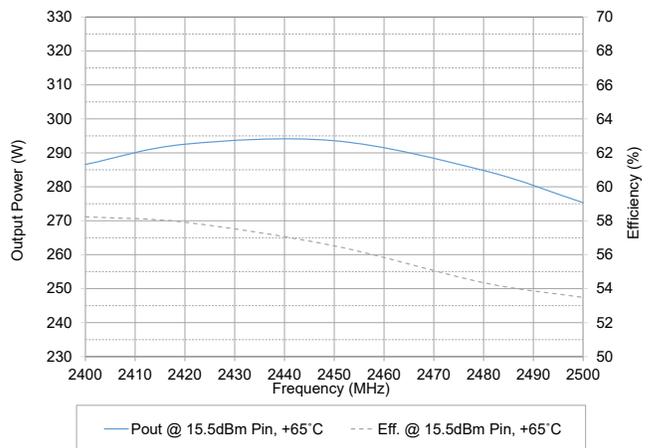
Gain & Efficiency as a function of Output Power (W) @ +25°C base temperature



Gain & Efficiency as a function of Output Power (W) @ 2.45 GHz for +25°C & +65°C base temperature

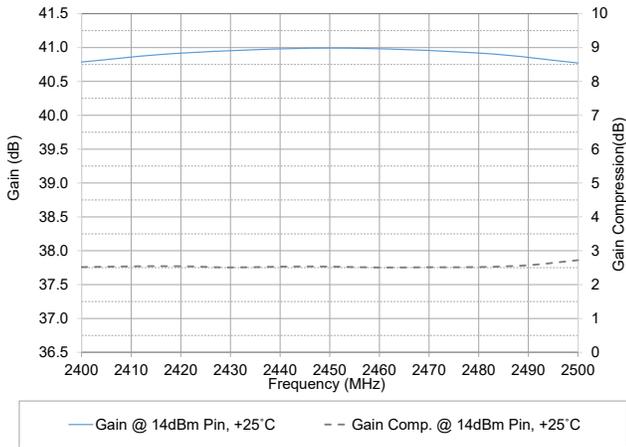


Output Power & Efficiency as a function of Frequency with +14dBm Fixed Input Power @ +25°C base temperature

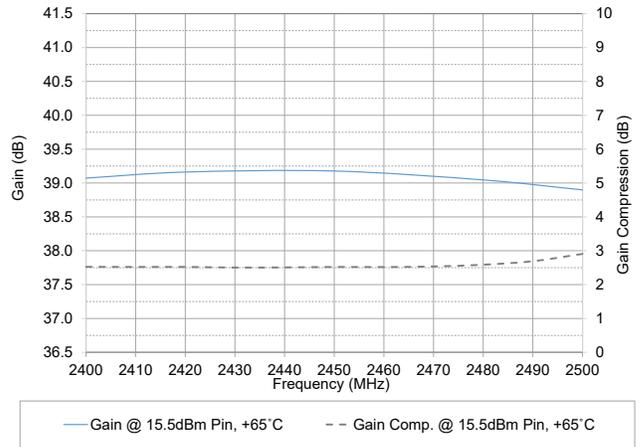


Output Power & Efficiency as a function of Frequency with +15dBm Fixed Input Power @ +65°C base temperature

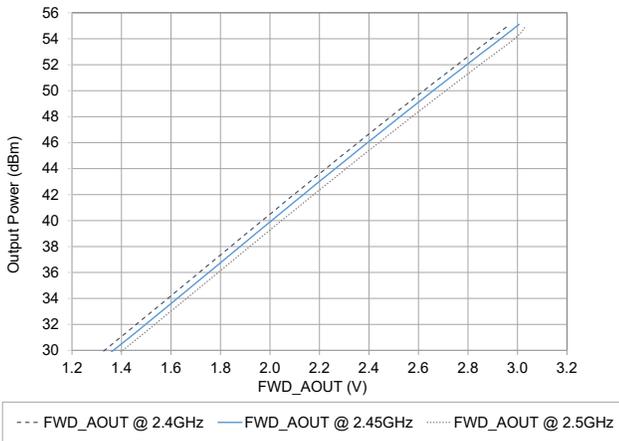
## Typical Performance Data (32V, 50Ω System)



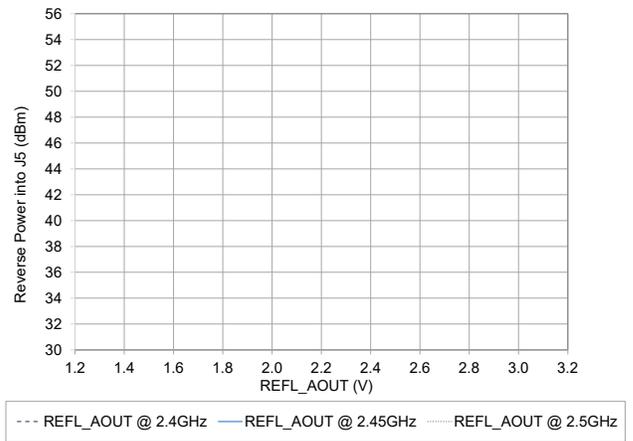
Gain & Gain Compression as a function of Frequency with +14dBm Fixed Input Power @ +25°C base temperature



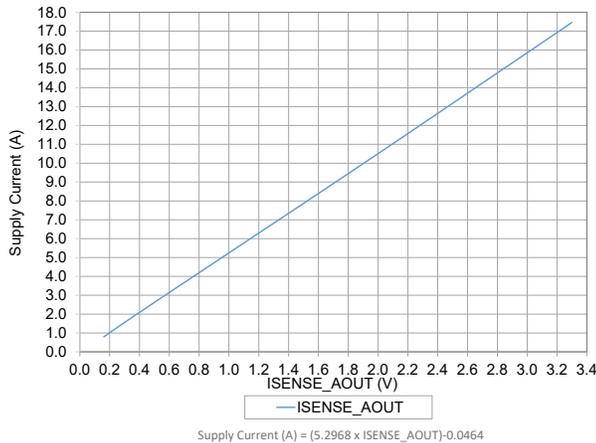
Gain & Gain Compression as a function of Frequency with +15.5dBm Fixed Input Power @ +65°C base temperature



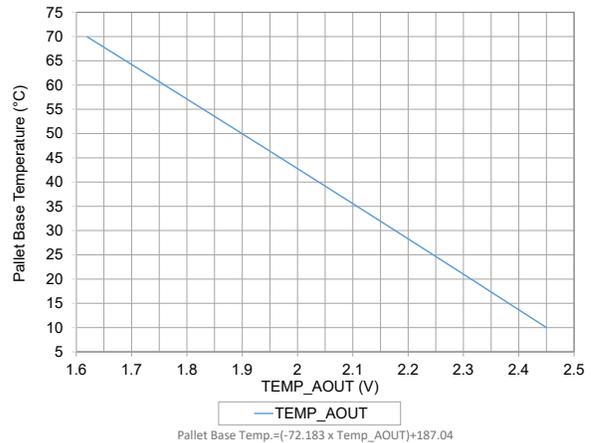
FWD\_AOUT (forward power analog output voltage) as a function of Output Power @ +25°C base temperature



REFL\_AOUT (reflected power analog output voltage) as a function of Power into J5 @ +25°C base temperature

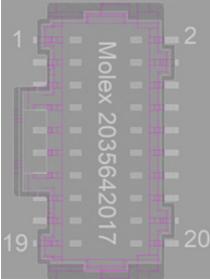
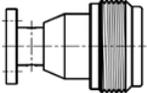


ISENSE\_AOUT (current sense analog output voltage) as a function of Supply Current @ +25°C base temperature



TEMP\_AOUT (temperature sense analog output voltage) as a function of Pallet base temperature

## Amplifier Interfaces and suggested mating hardware\*

	<p>J1 - MCX Connector Jack, Female Socket 50 Ohm (TTI/Amphenol P/N 919-384J-51PT)</p> <p>Mating CBL ASSY SMA female-MCX male RG316 6", Amphenol RF P/N 245130-01-06.00 (other lengths avail.)</p>
	<p>J2 - Control Connector, 20 Pin (Molex 203564-2017)</p> <p>Mating connector shell, Molex 501189-2010, and cables with pre-crimped leads, Molex 79758-1018 or 79758-1019.</p>
	<p>J3 – Ground Conn., M5 J4 – +32V Supply Conn., M5</p> <p>Tightening Torque 2.2 N-m (19.5 in-lbs)</p> <p>Mating M5 screw (Mcmaster P/N 92095A308) Belville washer (Mcmaster P/N 90895A027) Ring Terminal (Mcmaster P/N7113K29)</p>
	<p>Output connector N-type female</p> <p>Recommended Torque for N-type connector mate is 1.36 N-m (12 in-lbs)</p>

\*Mating hardware not included with amplifier. Similar mating hardware available from other manufactures.

### Additional Notes

- A. Performance and quality attributes and conditions not expressly stated in this specification document are intended to be excluded and do not form a part of this specification document.
- B. Electrical specifications and performance data contained in this specification document are based on Mini-Circuit's applicable established test performance criteria and measurement instructions.
- C. The parts covered by this specification document are subject to Mini-Circuits standard limited warranty and terms and conditions (collectively, "Standard Terms"); Purchasers of this part are entitled to the rights and benefits contained therein. For a full statement of the Standard Terms and the exclusive rights and remedies thereunder, please visit Mini-Circuits' website at [www.minicircuits.com/MCLStore/terms.jsp](http://www.minicircuits.com/MCLStore/terms.jsp)