MMIC SURFACE MOUNT

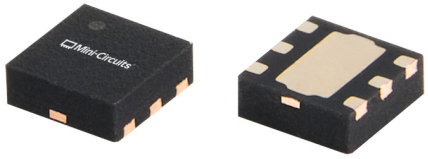
Low Noise Amplifier

TSS1-23ULN+

50Ω 10 to 2000 MHz Shutdown Feature

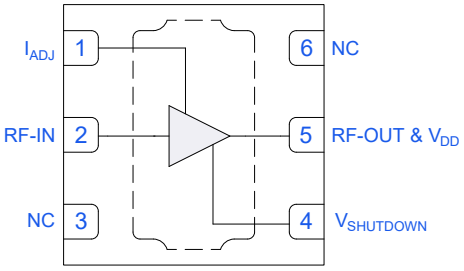
THE BIG DEAL

- Low Noise Figure, Typ. 0.4 dB
- High Gain, Typ. 20.1 dB
- High OIP3, Typ. +37.2 dBm
- Fast Shutdown Feature, 9.1 ns
- Single Supply Voltage, +5 V at 72.5 mA
- 1.5×1.5 mm 6-Lead QFN-style Package



Generic photo used for illustration purposes only

FUNCTIONAL DIAGRAM (TOP VIEW)



APPLICATIONS

- Cellular Infrastructure
- Satellite Communications
- Radar, EW, and ECM Defense Systems

PRODUCT OVERVIEW

The TSS1-23ULN+ is a pHEMT-based wideband, ultra-low noise MMIC amplifier with high P1dB, high IP3, and voltage-controlled shutdown capability. Operating from 10 to 2000 MHz, this amplifier features typical 0.4 dB noise figure, 20.1 dB gain, +20.6 dBm P1dB, and +37.2 dBm OIP3. This combination of characteristics makes it ideal for sensitive receiver applications. TSS1-23ULN+ operates on a single +5 V supply and comes in a small, low profile, 1.5×1.5 mm QFN-style package for ease of integration into dense circuit board layouts.

KEY FEATURES

Features	Advantages
Ultra-Low Noise Figure, Typ. 0.4 dB	Operating from a single supply, this ultra-low noise MMIC enables low system noise figure performance, without the need for complicated discrete-based solutions.
High Gain, Typ. 20.1 dB	The MMIC amplifier's high gain enables fewer system components in receiver signal chains.
Shutdown Feature	A voltage-controlled shutdown feature allows the part to be quickly disabled to conserve power when not in use.
High Dynamic Range • Gain, Typ. 20.1 dB • OIP3, Typ. +37.2 dBm • P1dB, Typ. +20.6 dBm	The MMIC amplifier's unique combination of low noise figure, high gain, high P1dB, and high OIP3 enables optimum performance in sensitive high dynamic range receivers.
1.5×1.5 mm 6-Lead QFN-Style Package	Small footprint saves space in dense layouts while providing low inductance, repeatable transitions, and excellent thermal contact to the PCB. Industry standard packaging allows for ease of assembly in high volume manufacturing processes.

Low Noise Amplifier

TSS1-23ULN+

50Ω 10 to 2000 MHz Shutdown Feature

ELECTRICAL SPECIFICATIONS[1] AT +25 °C AND Z_0 = 50Ω UNLESS NOTED OTHERWISE

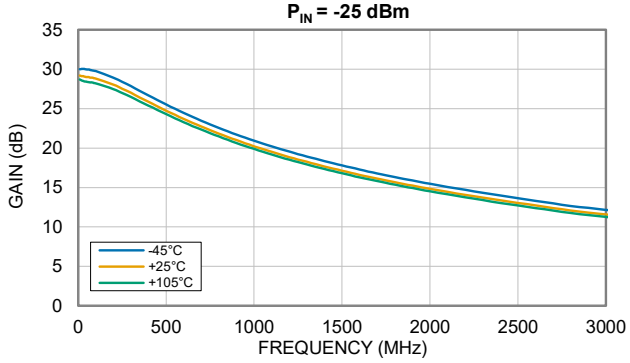
Parameter	Condition (MHz)	Amplifier - ON V_{DD} = +5 V ($V_{SHUTDOWN}$ = 0 V) Min.	Typ.	Max.	Amplifier - ON V_{DD} = +3 V ($V_{SHUTDOWN}$ = 0 V) Typ.	Amplifier - OFF[2] V_{DD} = +5 V ($V_{SHUTDOWN}$ = +5 V) Typ.	Units
Frequency Range		10		2000	10–2000	10–2000	MHz
Gain	10	27.8	29.1		27.4	-21.7	dB
	500	23.6	24.7		23.4	-31.0	
	1000	19.0	20.1		19.1	-34.0	
	1500	15.9	17.1		16.1	-31.9	
	2000	13.6	14.8		13.8	-26.1	
Input Return Loss	10		8		7		dB
	500		12		9		
	1000		14		12		
	1500		16		13		
	2000		16		14		
Output Return Loss	10		20		18		dB
	500		14		15		
	1000		13		14		
	1500		12		14		
	2000		12		14		
Isolation	10–2000		27.3		26.2	31.2	dB
Output Power at 1 dB Compression (P1dB)	10		+22.4		+16.6		dBm
	500		+20.9		+15.8		
	1000		+20.6		+16.0		
	1500		+20.9		+16.8		
	2000		+20.1		+16.0		
Output Third-Order Intercept Point (P_{OUT} = +4 dBm/Tone)	10		+33.4		+28.0		dBm
	500		+35.7		+27.0		
	1000		+37.2		+27.4		
	1500		+37.0		+27.9		
	2000		+38.5		+28.1		
Noise Figure[3]	10		1.0		0.9		dB
	500		0.4		0.4		
	1000		0.4		0.4		
	1500		0.4		0.4		
	2000		0.5		0.5		
ON Time (50% V_{CTRL} to 90% RF)			16.2				ns
RISE Time (10% RF to 90% RF)			6.7				ns
FALL Time (90% RF to 10% RF)			6.1				ns
OFF Time (50% V_{CTRL} to 10% RF)			9.1				ns
Device Operating Voltage (V_{DD})		+4.75	+5	+5.25	+3	+5	V
Device Operating Current (I_{DD})[4]			72.5		38	3	mA
Device Shutdown Voltage ($V_{SHUTDOWN}$)			0		0	+5	V
Device Shutdown Current ($I_{SHUTDOWN}$)			0.02		0.01	137	µA
Device Current Variation vs. Temperature[5]			0.0004		0.0004		mA/°C
Device Current Variation vs. Voltage[6]			0.0174		0.0174		mA/mV

1. Tested in Mini-Circuits Characterization Test/Evaluation Board TB-TSS1-23ULNC+. See Figure 2. Board loss de-embedded to the device.
2. Performance is comparable when V_{DD} = +5 V or +3 V when amplifier is OFF.
3. Typical value verified and set by averaging performance across multiple measurement setups.
4. Current at P_{IN} = -25 dBm. Increases to 90 mA at P1dB. I_{ADJ} is left floating to achieve device nominal current.
5. (Current at +105 °C - Current at -45 °C) / (+150 °C)
6. (Current at +5.25 V - Current at +4.75 V) / (+0.5 V)

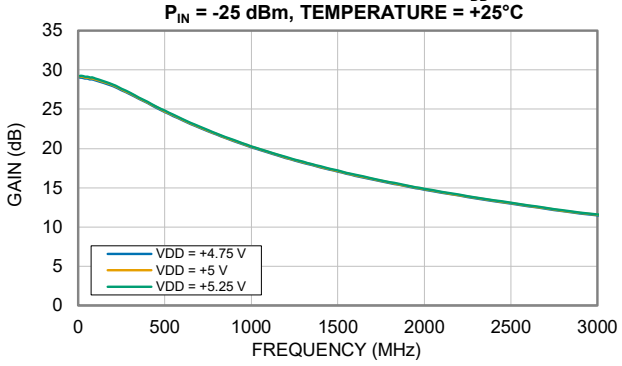
TYPICAL PERFORMANCE GRAPHS

Note: The following data was taken on the Mini-Circuits Characterization Test Board TB-TSS1-23ULNC+ (Figure 2). All data taken at nominal condition of V_{DD} = +5 V and at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.

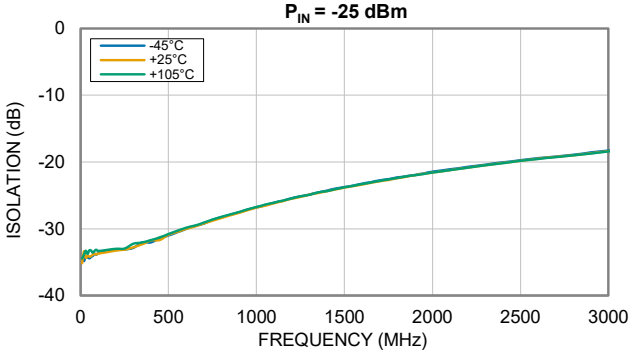
GAIN vs. TEMPERATURE
P_{IN} = -25 dBm



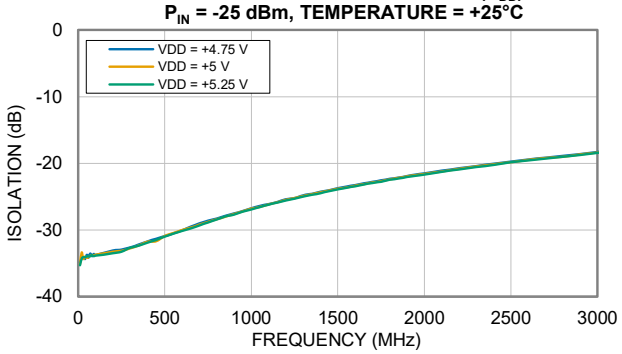
GAIN vs. DEVICE VOLTAGE (V_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



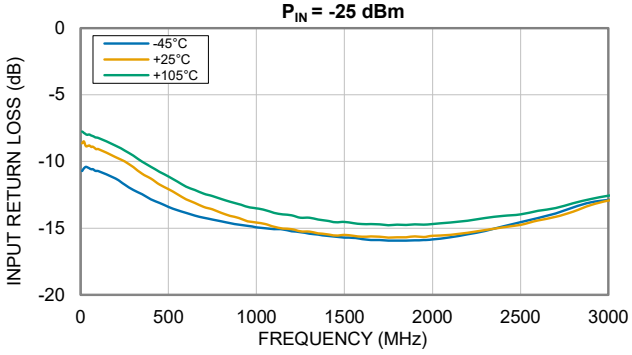
ISOLATION vs. TEMPERATURE
P_{IN} = -25 dBm



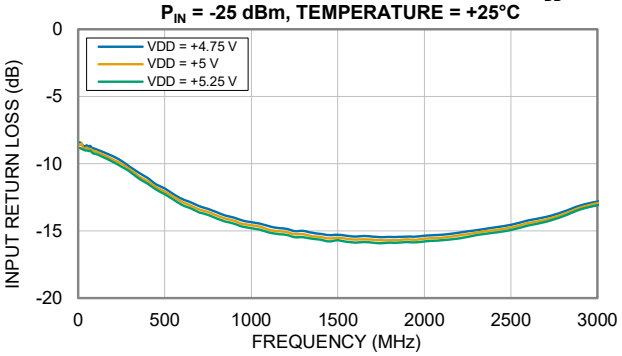
ISOLATION vs. DEVICE VOLTAGE (V_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



INPUT RETURN LOSS vs. TEMPERATURE
P_{IN} = -25 dBm



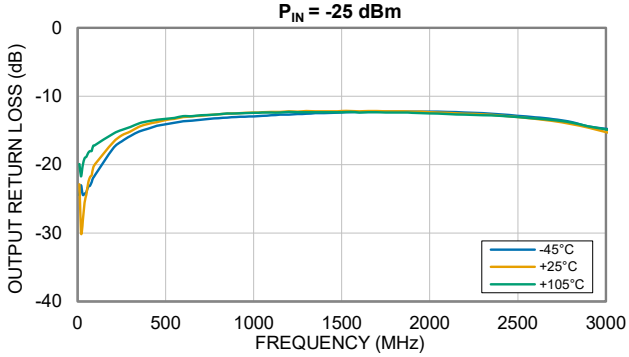
INPUT RETURN LOSS vs. DEVICE VOLTAGE (V_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



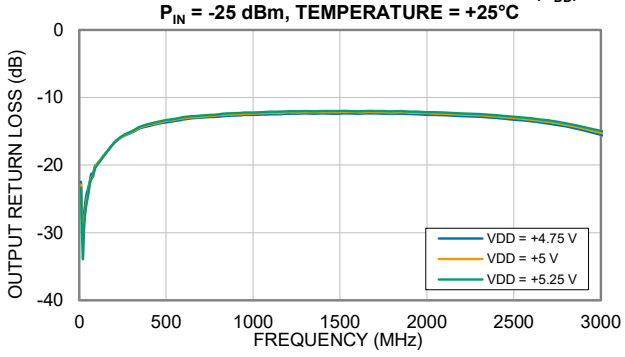
TYPICAL PERFORMANCE GRAPHS

Note: The following data was taken on the Mini-Circuits Characterization Test Board TB-TSS1-23ULNC+ (Figure 2). All data taken at nominal condition of V_{DD} = +5 V and at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.

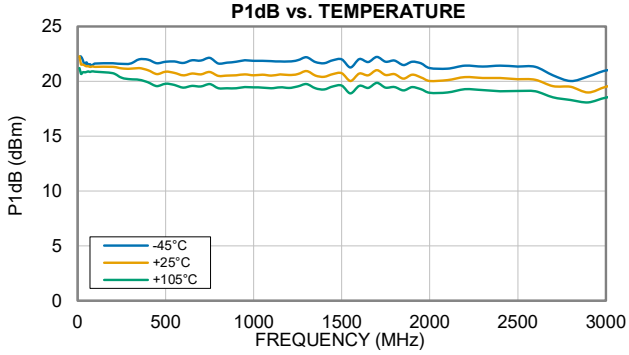
OUTPUT RETURN LOSS vs. TEMPERATURE
P_{IN} = -25 dBm



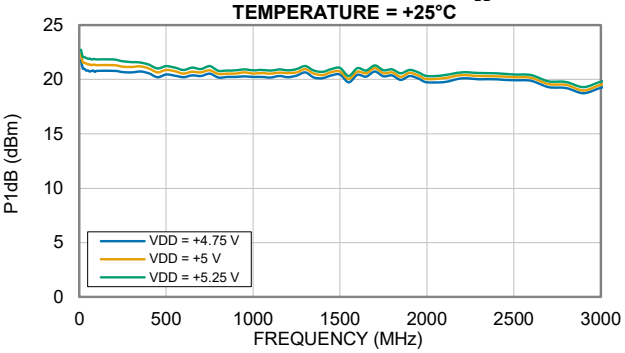
OUTPUT RETURN LOSS vs. DEVICE VOLTAGE (V_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



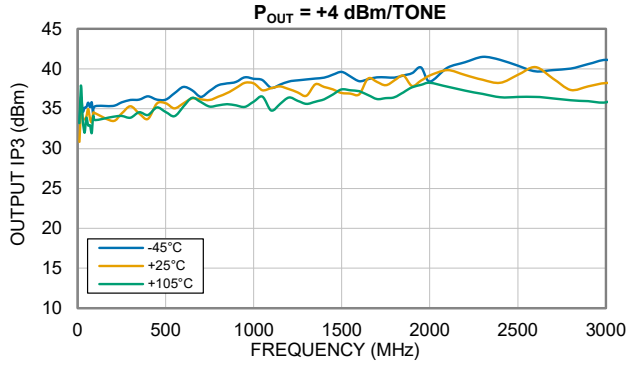
P1dB vs. TEMPERATURE



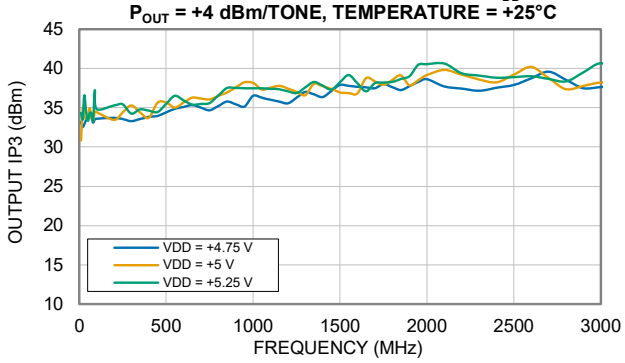
P1dB vs. DEVICE VOLTAGE (V_{DD})
TEMPERATURE = +25°C



OUTPUT IP3 vs. TEMPERATURE
P_{OUT} = +4 dBm/TONE



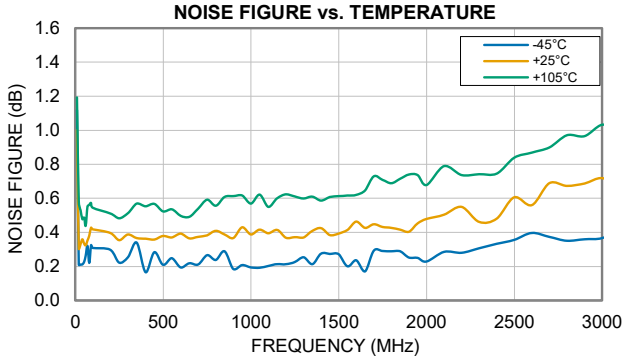
OUTPUT IP3 vs. DEVICE VOLTAGE (V_{DD})
P_{OUT} = +4 dBm/TONE, TEMPERATURE = +25°C



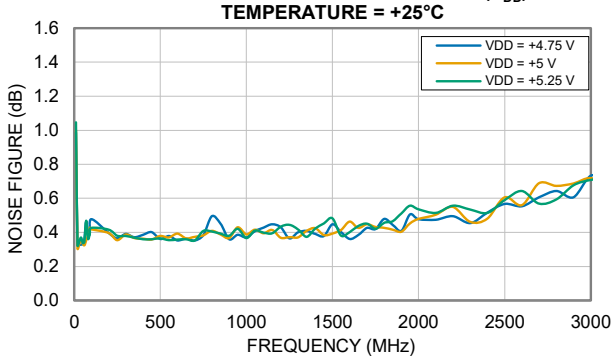
TYPICAL PERFORMANCE GRAPHS

Note: The following data was taken on the Mini-Circuits Characterization Test Board TB-TSS1-23ULNC+ (Figure 2). All data taken at nominal condition of V_{DD} = +5 V and at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.

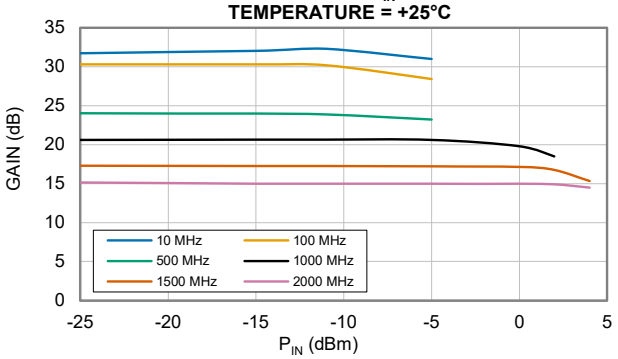
NOISE FIGURE vs. TEMPERATURE



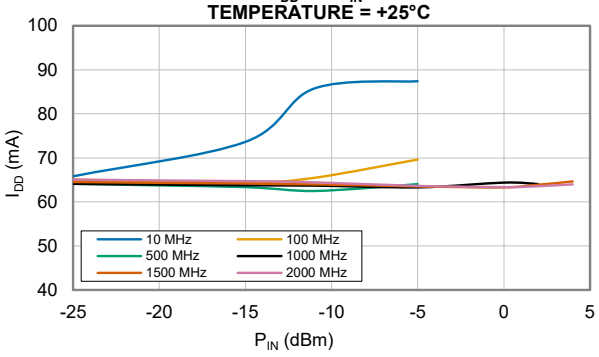
NOISE FIGURE vs. DEVICE VOLTAGE (V_{DD})
TEMPERATURE = +25°C



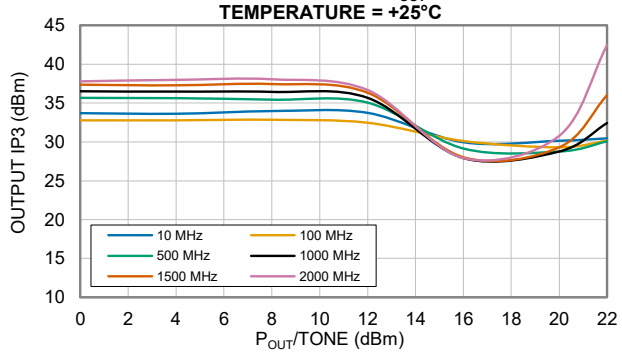
GAIN vs. P_{IN}
TEMPERATURE = +25°C



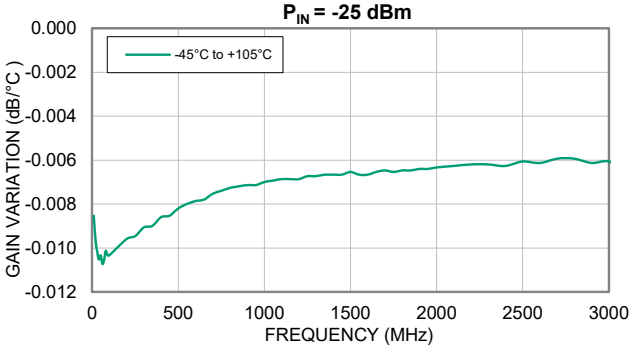
I_{DD} vs. P_{IN}
TEMPERATURE = +25°C



OUTPUT IP3 vs. P_{OUT}
TEMPERATURE = +25°C



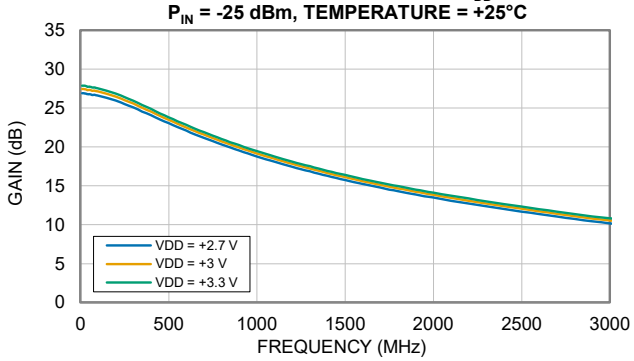
GAIN VARIATION vs. TEMPERATURE
P_{IN} = -25 dBm



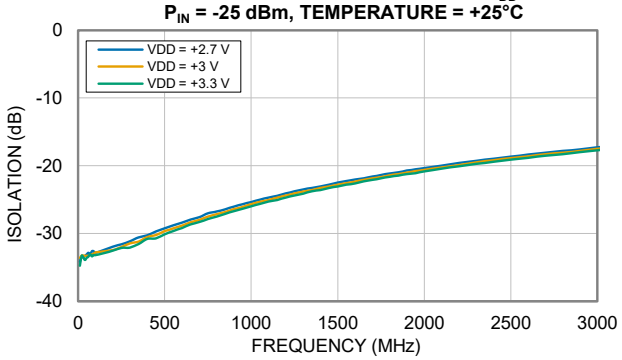
TYPICAL LOW VOLTAGE PERFORMANCE GRAPHS

Note: The following data was taken on the Mini-Circuits Characterization Test Board TB-TSS1-23ULNC+ (Figure 2). All data taken at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.

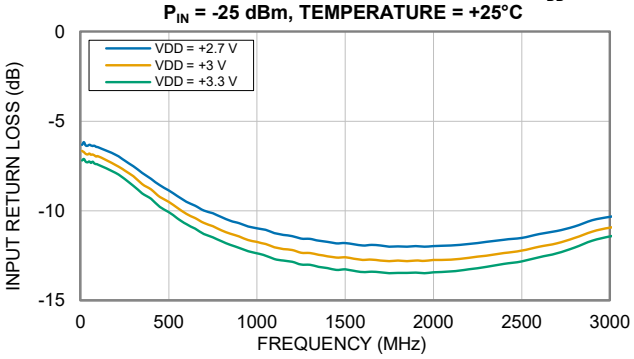
GAIN vs. DEVICE VOLTAGE (V_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



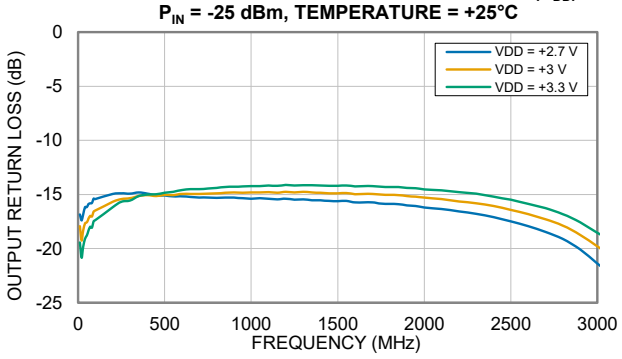
ISOLATION vs. DEVICE VOLTAGE (V_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



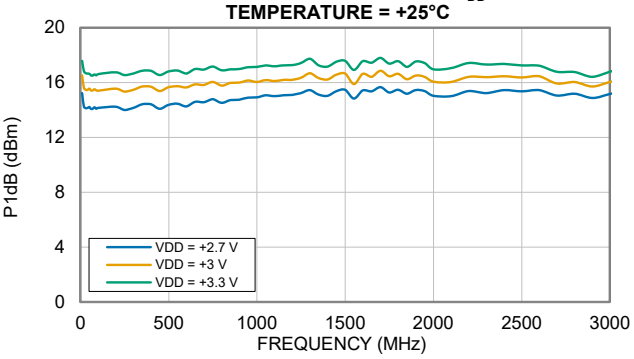
INPUT RETURN LOSS vs. DEVICE VOLTAGE (V_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



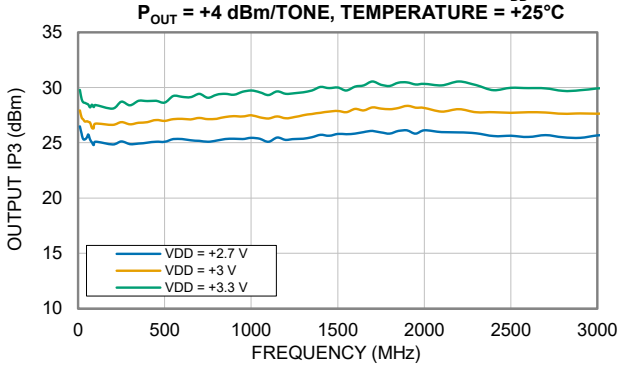
OUTPUT RETURN LOSS vs. DEVICE VOLTAGE (V_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



P1dB vs. DEVICE VOLTAGE (V_{DD})
TEMPERATURE = +25°C

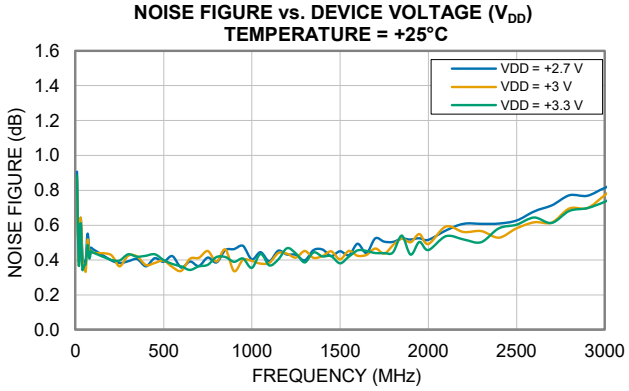


OUTPUT IP3 vs. DEVICE VOLTAGE (V_{DD})
P_{OUT} = +4 dBm/TONE, TEMPERATURE = +25°C



TYPICAL LOW VOLTAGE PERFORMANCE GRAPHS

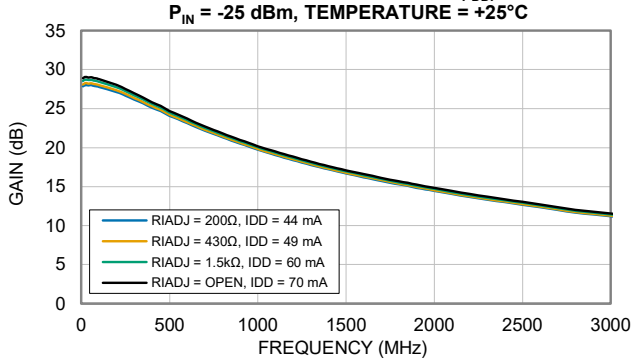
Note: The following data was taken on the Mini-Circuits Characterization Test Board TB-TSS1-23ULNC+ (Figure 2). All data taken at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.



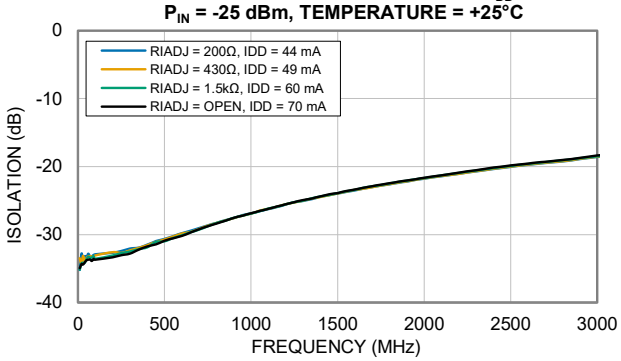
TYPICAL CURRENT ADJUST (I_{ADJ}) PERFORMANCE GRAPHS

Note: The following data was taken on the Mini-Circuits Characterization Test Board TB-TSS1-23ULNC+ by varying R_{IADJ} (Figure 3). All data taken at nominal condition of V_{DD} = +5 V and at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.

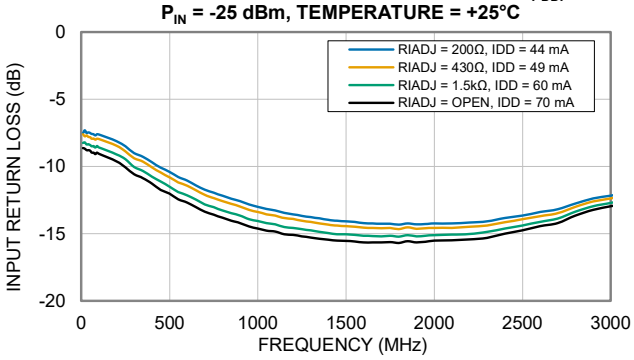
GAIN vs. DEVICE CURRENT (I_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



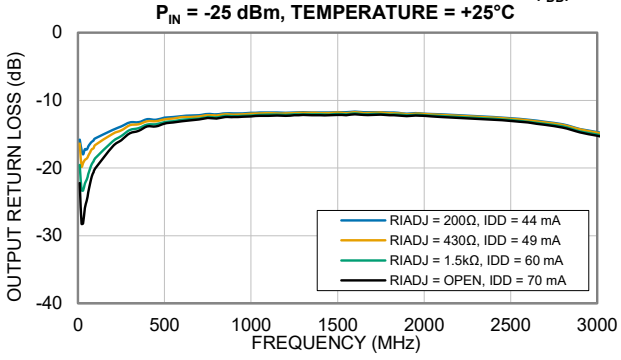
ISOLATION vs. DEVICE CURRENT (I_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



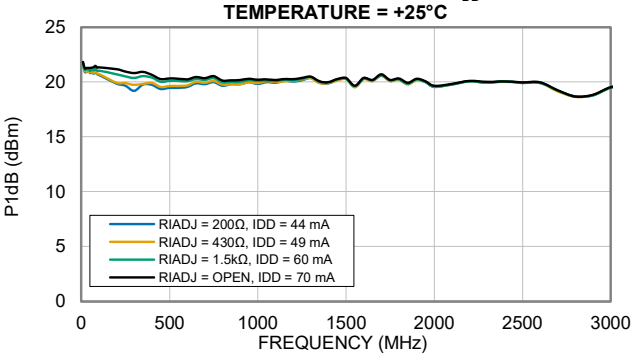
INPUT RETURN LOSS vs. DEVICE CURRENT (I_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



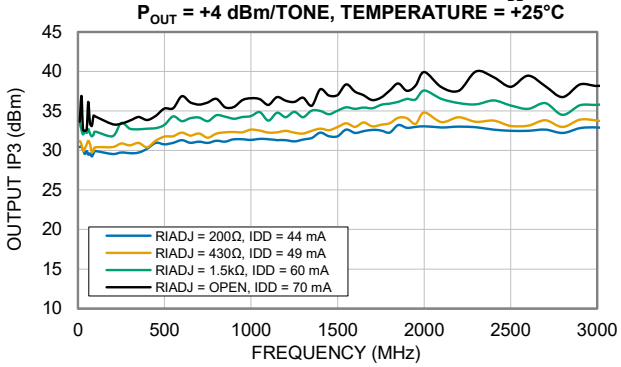
OUTPUT RETURN LOSS vs. DEVICE CURRENT (I_{DD})
P_{IN} = -25 dBm, TEMPERATURE = +25°C



P1dB vs. DEVICE CURRENT (I_{DD})
TEMPERATURE = +25°C

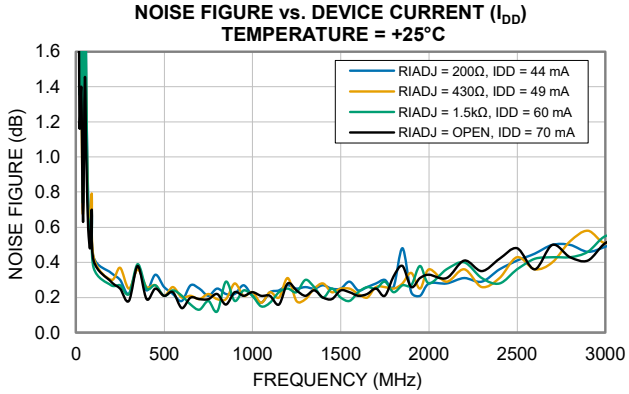


OUTPUT IP3 vs. DEVICE CURRENT (I_{DD})
P_{OUT} = +4 dBm/TONE, TEMPERATURE = +25°C



TYPICAL CURRENT ADJUST (I_{ADJ}) PERFORMANCE GRAPHS

Note: The following data was taken on the Mini-Circuits Characterization Test Board TB-TSS1-23ULNC+ by varying R_{IADJ} (Figure 3). All data taken at nominal condition of V_{DD} = +5 V and at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.



Low Noise Amplifier TSS1-23ULN+

50Ω 10 to 2000 MHz Shutdown Feature

ABSOLUTE MAXIMUM RATINGS[7]

Parameter	Ratings
Operating Temperature	-45 °C to +105 °C
Storage Temperature	-65 °C to +150 °C
Total Power Dissipation	1.34 W
Junction Temperature[8]	+150°C
Input Power (CW)	
V_{DD} = +5 V & $V_{SHUTDOWN}$ = 0 V	+21 dBm
V_{DD} = +3 V & $V_{SHUTDOWN}$ = 0 V	+21 dBm
DC Voltage on RF-OUT & V_{DD}	
$V_{SHUTDOWN}$ = 0 V	+10 V
$V_{SHUTDOWN}$ = +5 V	+10 V
DC Voltage on RF-IN	
$V_{SHUTDOWN}$ = 0 V	+1 V
$V_{SHUTDOWN}$ = +5 V	+1 V
DC Voltage on $V_{SHUTDOWN}$	
V_{DD} = +5 V	+10 V
V_{DD} = +3 V	+10 V
DC Current on RF-OUT & V_{DD}	
$V_{SHUTDOWN}$ = 0 V	100 mA
$V_{SHUTDOWN}$ = +5 V	10 mA
DC Current $V_{SHUTDOWN}$	
V_{DD} = +5 V	10 mA
V_{DD} = +3 V	10 mA

7. Permanent damage may occur if any of these limits are exceeded. Maximum ratings are not intended for continuous normal operation.
8. Peak temperature on top of Die.

POWER ON / POWER OFF LOGIC

Amplifier State	V_{DD}			$V_{SHUTDOWN}$		
	Min	Typ.	Max	Min	Typ.	Max
Amplifier - ON (V_{DD} = +5 V)	+2.7 V	+5 V	+5.25 V	0 V	0 V	+1.3 V
Amplifier - OFF (V_{DD} = +5 V)				+1.4 V	+5 V	+5.25 V
Amplifier - ON (V_{DD} = +3 V)	+2.7 V	+3 V	+5.25 V	0 V	0 V	+1.3 V
Amplifier - OFF (V_{DD} = +3 V)				+1.4 V	+3 V	+5.25 V

THERMAL RESISTANCE

Parameter	Ratings
Thermal Resistance (Θ_{JC})[9]	33.6 °C/W

9. Θ_{JC} = (Hot Spot Temperature on Die - Temperature at Ground Lead)/Dissipated Power

ESD RATING

	Class	Voltage Range	Reference Standard
HBM	1A	250 V to < 500 V	ANSI/ESDA/JEDEC JS-001-2023
CDM	C3	> 1000 V	ANSI/ESDA/JEDEC JS-002-2022

ESD HANDLING PRECAUTION: This device is designed to be Class 1A for HBM. Static charges may easily produce potentials higher than this with improper handling and can discharge into DUT and damage it. As a preventive measure Industry standard ESD handling precautions should be used at all times to protect the device from ESD damage.

MSL RATING

Moisture Sensitivity: MSL1 in accordance with IPC/JEDEC J-STD-020E /JEDEC J-STD-033C

Low Noise Amplifier

TSS1-23ULN+

50Ω 10 to 2000 MHz Shutdown Feature

FUNCTIONAL DIAGRAM

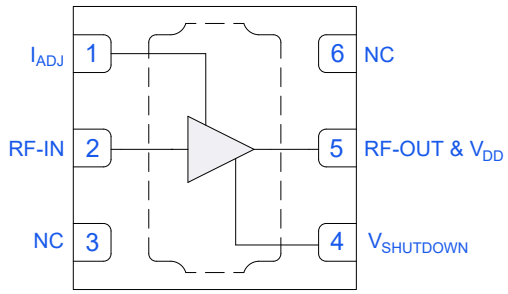


Figure 1. TSS1-23ULN+ Functional Diagram

PAD DESCRIPTION

Function	Pad Number	Description (Refer to Figure 2)
RF-OUT & V_{DD}	5	RF-OUT & V_{DD} Pad connects to RF-Output port and voltage input port, $V_{DD.}$
$V_{SHUTDOWN}$	4	DC Input Pad connects to voltage input port, $V_{SHUTDOWN}$.
RF-IN	2	RF-IN Pad connects to RF-Input port.
I_{ADJ}	1	DC Pad used to adjust current by adjusting R_{IADJ}. For normal operation I_{ADJ} should be left unconnected.
NC	3 & 6	Not used internally. Connected to ground on test board.
GND	Paddle	Connects to ground.

EVALUATION BOARD

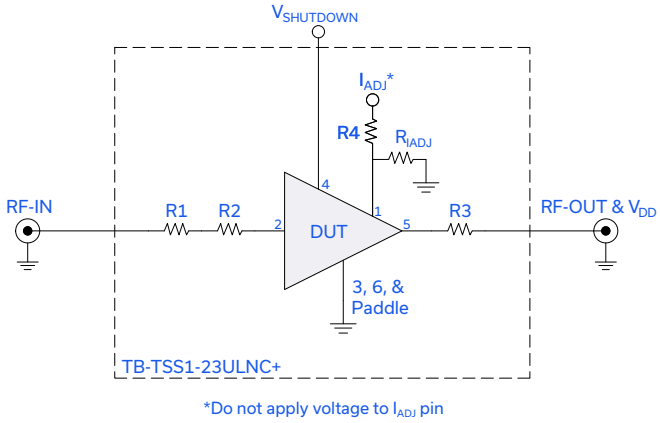


Figure 2. TSS1-23ULN+ Evaluation and Application Circuit

Component	Size	Value	Part Number	Manufacturer
R1-R4	0402	0Ω	RK73Z1ETTP	KOA Speer
R_{IADJ}	0402	DNI	N/A	N/A

Electrical Parameters and Conditions
Gain, Return Loss, Output Power at 1 dB Compression (P1dB), Output IP3 (OIP3), and Noise Figure measured using N5242A PNA-X microwave network analyzer.

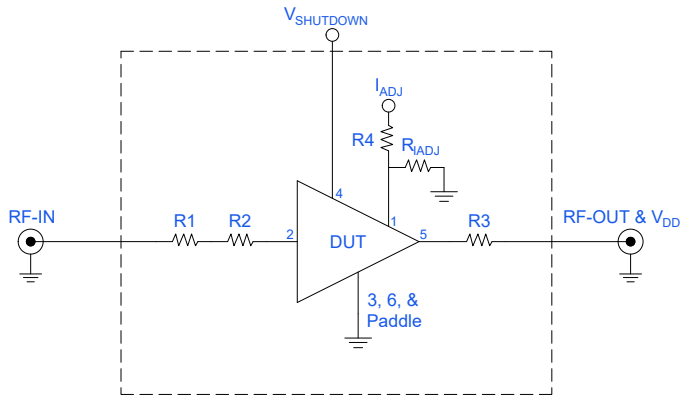
Conditions:
1. Gain and Return Loss: P_{IN} = -25 dBm
2. Output IP3 (OIP3): Two tones, spaced 1 MHz apart, +4 dBm/tone at output.

Power ON/Power OFF Sequence:
Caution: Permanent damage to the device will occur if the Power ON and Power OFF sequences are not followed.

POWER ON:
1. Set $V_{SHUTDOWN}$ = 0 V for ON mode or $V_{SHUTDOWN}$ = +5 V for OFF mode.
2. Set V_{DD} = +5 V.
3. Turn on $V_{SHUTDOWN}$.
4. Turn on V_{DD}.
5. Apply RF Signal.

POWER OFF:
1. Turn off RF signal.
2. Turn off V_{DD}.
3. Turn off $V_{SHUTDOWN}$.

APPLICATION CIRCUIT - CURRENT ADJUST



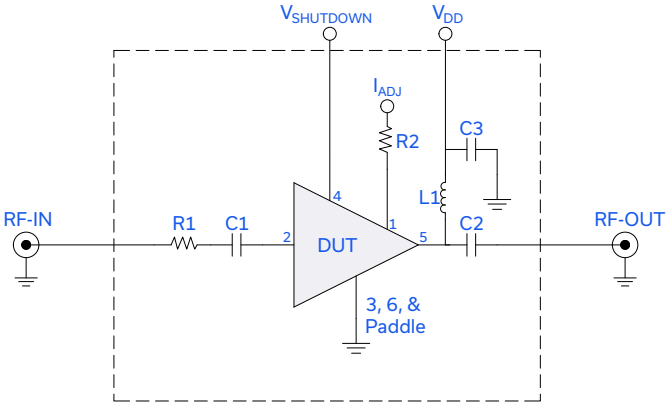
Electrical Parameters and Conditions
Gain, Return Loss, Output Power at 1 dB Compression (P1dB), Output IP3 (OIP3), and Noise Figure measured using N5242A PNA-X microwave network analyzer.

Conditions:
1. Gain and Return Loss: P_{IN} = -25 dBm
2. Output IP3 (OIP3): Two tones, spaced 1 MHz apart, +4 dBm/tone at output.

Figure 3. TSS1-23ULN+ Current Adjust Application Circuit

Component	Size	Value	Part Number	Manufacturer
R1-R4	0402	0Ω	RK73Z1ETTP	KOA Speer
RIADJ	0402	200Ω	RK73H1ETTP2000F	KOA Speer
		430Ω	RK73H1ETTP4300F	
		1.5kΩ	RK73H1ETTP1501F	

APPLICATION CIRCUIT - NARROWBAND MATCH



Electrical Parameters and Conditions
Gain, Return Loss, Output Power at 1 dB Compression (P1dB), Output IP3 (OIP3), and Noise Figure measured using N5242A PNA-X microwave network analyzer.

Conditions:
1. Gain and Return Loss: P_{IN} = -25 dBm
2. Output IP3 (OIP3): Two tones, spaced 1 MHz apart, +4 dBm/tone at output.

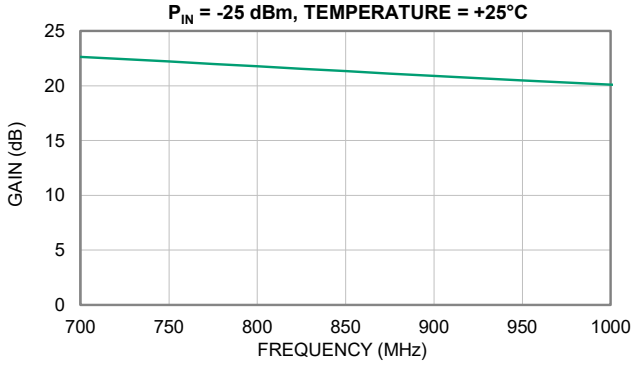
Figure 4. TSS1-23ULN+ 700–1000 MHz Application Circuit

Component	Size	Value	Part Number	Manufacturer
R1-R2	0402	0Ω	RK73Z1ETTP	KOA Speer
C1	0402	47 pF	GRM1555C1H470JA01D	Murata
C2	0402	4.7 pF	GRM1555C1H4R7CA01D	Murata
C3	0402	0.1 µF	GRM155R71H104KE14J	Murata
L1	0402	22 nH	LQW15AN22NG00D	Murata

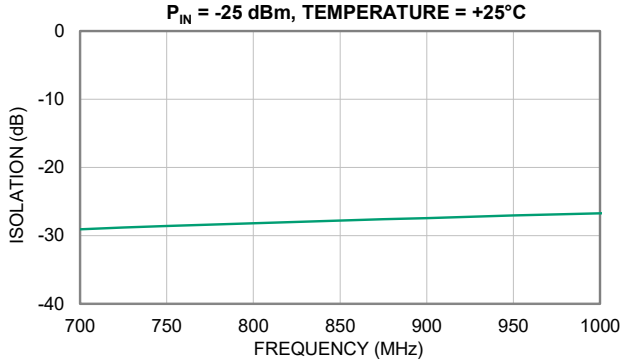
TYPICAL MATCHING TEST BOARD PERFORMANCE GRAPHS

Note: The following data was taken on the Mini-Circuits 700-1000 MHz Matched Characterization Test Board (Figure 4). All data taken at nominal condition of V_{DD} = +5 V and at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.

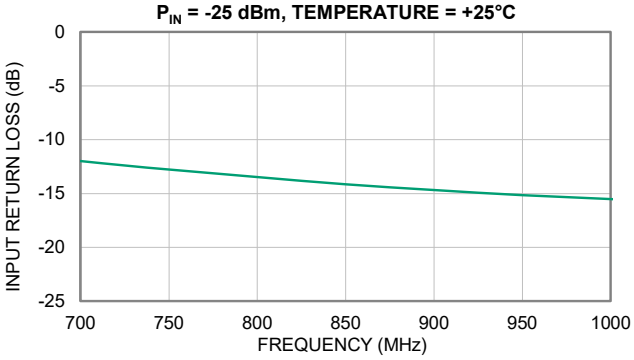
GAIN vs. FREQUENCY
P_{IN} = -25 dBm, TEMPERATURE = +25°C



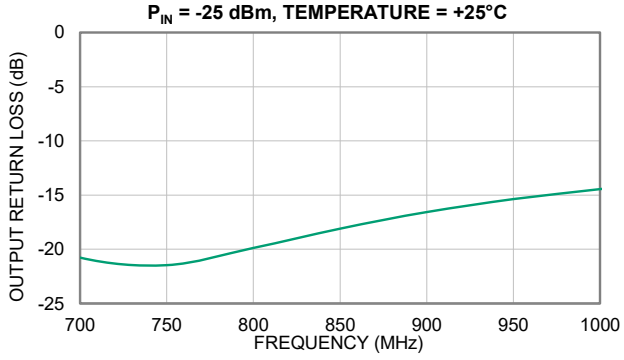
ISOLATION vs. FREQUENCY
P_{IN} = -25 dBm, TEMPERATURE = +25°C



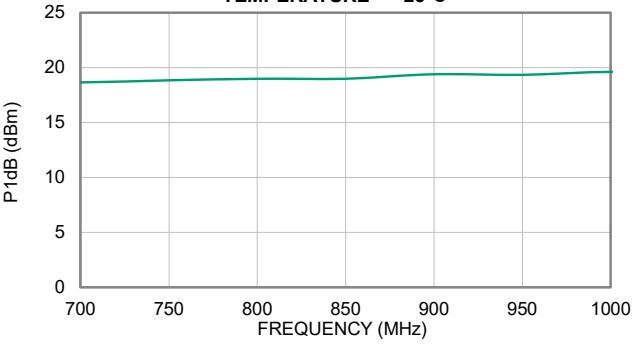
INPUT RETURN LOSS vs. FREQUENCY
P_{IN} = -25 dBm, TEMPERATURE = +25°C



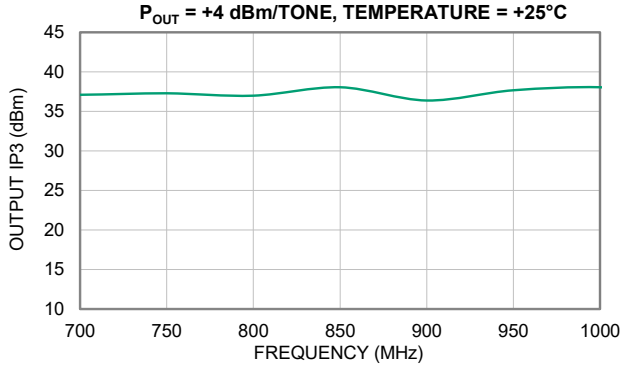
OUTPUT RETURN LOSS vs. FREQUENCY
P_{IN} = -25 dBm, TEMPERATURE = +25°C



P1dB vs. FREQUENCY
TEMPERATURE = +25°C

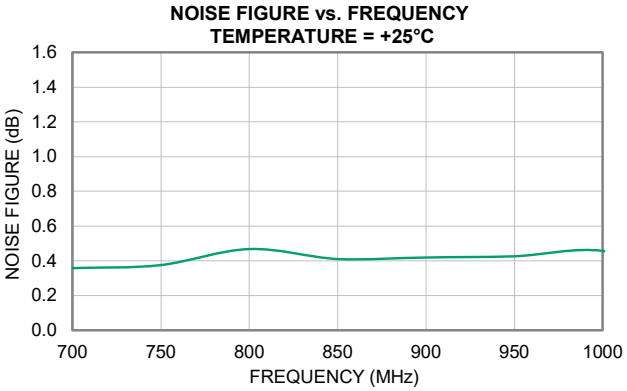


OUTPUT IP3 vs. FREQUENCY
P_{OUT} = +4 dBm/TONE, TEMPERATURE = +25°C



TYPICAL MATCHING TEST BOARD PERFORMANCE GRAPHS

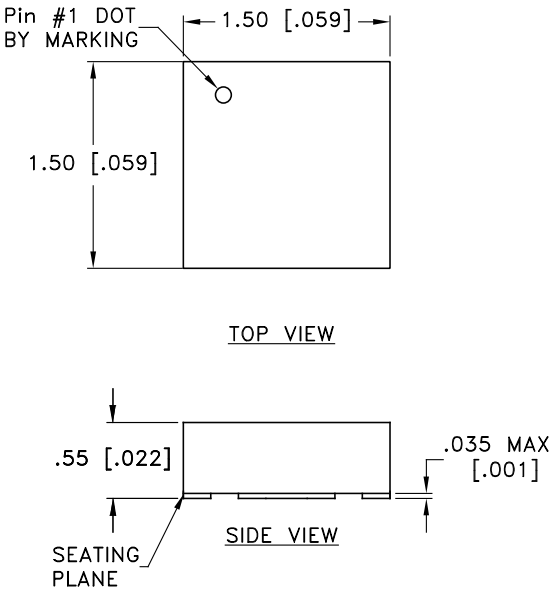
Note: The following data was taken on the Mini-Circuits 700-1000 MHz Matched Characterization Test Board (Figure 4). All data taken at nominal condition of V_{DD} = +5 V and at $V_{SHUTDOWN}$ = 0 V unless noted otherwise.

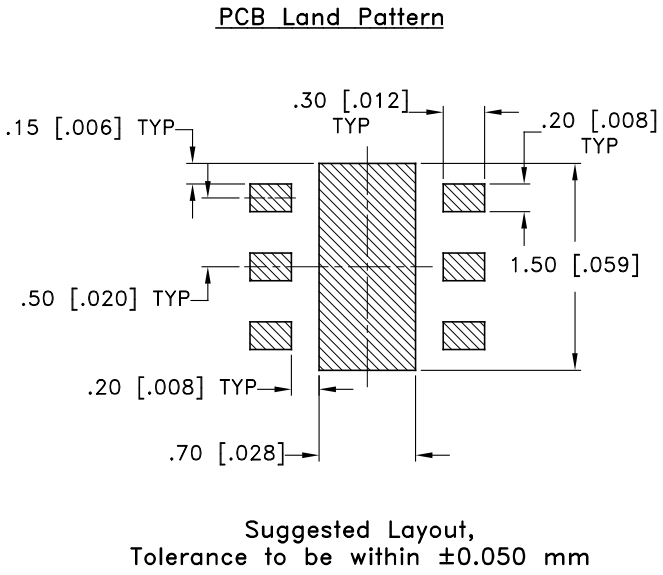


Low Noise Amplifier TSS1-23ULN+

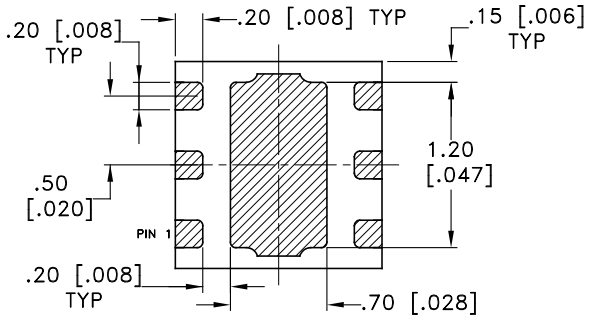
50Ω 10 to 2000 MHz Shutdown Feature

CASE STYLE DRAWING





Suggested Layout,
Tolerance to be within ±0.050 mm

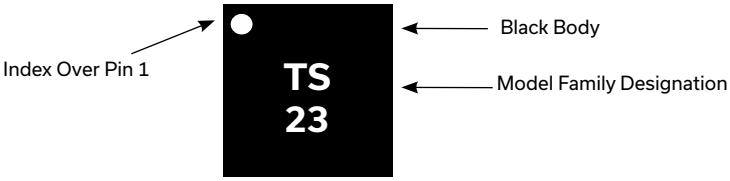


NOTES:

1. DENOTES METALLIZATION

Weight: 0.0036 grams
Dimensions are in mm [inches]. Tolerances: 2Pl. ±0.05 mm [0.002 inches].

PRODUCT MARKING



Marking may contain other features or characters for internal lot control.

Low Noise Amplifier TSS1-23ULN+

50Ω 10 to 2000 MHz Shutdown Feature

ADDITIONAL DETAILED INFORMATION IS AVAILABLE ON OUR DASHBOARD CLICK HERE

Performance Data & Graphs	Data Graphs S-Parameter (S2P Files) Data Set (.zip file)
Case Style	KC3011. Plastic package, exposed paddle, Lead Finish: Nickel Palladium Gold
RoHS Status	Compliant
Tape & Reel **Standard Quantities Available on Reel**	F66 7" Reels with 20, 50, 100, 200, 500, 1000, 2000, or 3000 devices
Suggested Layout for PCB Design	PL-862
Evaluation Board	TB-TSS1-23ULNC+ Gerber File
Environmental Ratings	ENV08T1

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-Circuits' 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/terms/viewterm.html