TRF1305B1 Single-Channel, DC to > 6.5GHz, 3dB-Bandwidth, Fully Differential Amp

1 Features

- Three performance-optimized power gain variants:
  - 15dB (TRF1305A1)
  - 10dB (TRF1305B1)
  - 5dB (TRF1305C1)
- Fixed gain can be reduced with external resistors
- Wide large-signal RF bandwidth:
  - TRF1305B1: 7.2GHz (3dB), 6.4GHz (1dB)
- OP1dB (differential 100Ω load):
  - 15.7dBm (2GHz), 12.8dBm (4GHz)
- OIP3: 34dBm (2GHz), 25.5dBm (4GHz)
- Noise Figure: 10.4dB (2GHz), 13.4dB (4GHz)
- Slew rate: 25kV/µs
- Large input (±1V) and output (±0.5V) common-mode voltage ranges
- Flexible configurations and modes:
  - Single-ended input, differential output (S2D)
  - Differential input, differential output (D2D)
  - Single-ended output (limited performance)
  - AC- or DC-coupled input/output
  - Adjustable output common-mode voltage
  - Input common-mode range extension mode
- Supports 5V, flexible single or split supplies
- Active power dissipation: 500mW
- Power-down mode

2 Applications

- RF sampling or GSPS ADC driver
- Test and measurement
- Wireless communications test
- RF digitizers
- Oscilloscopes (DSOs)
- High speed digitizer
- Spectrum analyzer
- Vector signal transceiver (VST)
- Mass spectrometry systems
- Common-mode level shifting
- IQ mixer interface

3 Description

The TRF1305B1 is a very-high-performance, closed-loop, single-channel RF amplifier that has an operational bandwidth from true-dc to > 6.5GHz. The device has excellent performance to drive high-speed, high-performance ADCs, such as the ADC12DJ5200RF and ADC32RF5x with a dc- or ac-coupled interface. The amplifier is optimized for use in RF, zero and complex IF, and high-speed time-domain applications. The device is optimized for performance in the fixed gain configuration. If lower gain is desired, use external resistors.

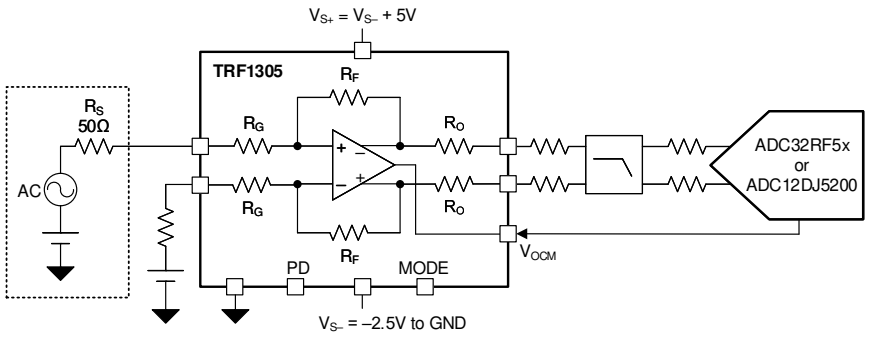
The TRF1305B1 features a VOCM pin that allows setting different output common-mode and input common-mode voltages; for example, level-shifting or for most IQ down-converter ADC-interface applications that have differing dc common-mode voltages. The TRF1305B1 also features a floating 2-rail split or single-supply option, and a MODE pin that allows extending the input common-mode range closer to the supplies.

The TRF1305B1 has a power-down feature. The device is fabricated with TI's proprietary advanced BiCMOS process and is available in a space-saving, 2mm × 2mm, 12-pin, WQFN-FCRLF package.

Device Information

PART NUMBER(1)	D2D POWER GAIN	PACKAGE(2)
TRF1305A1 (3)	15dB	RPV (WQFN-FCRLF, 12)
TRF1305B1	10dB	
TRF1305C1 (3)	5dB	

(1) See Section 4.
(2) For more information, see Section 11.
(3) Preview information (not Advanced Information).



TRF1305x1 in S2D Configuration Driving a High-Speed ADC

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4 Device Comparison Table

DEVICE	GAIN	CHANNEL COUNT
TRF1305A1 (preview)	15dB	1
TRF1305B1	10dB	
TRF1305C1 (preview)	5dB	
TRF1305A2 (preview)	15dB	2
TRF1305B2 (active)	10dB	
TRF1305C2 (preview)	5dB	

5 Pin Configuration and Functions

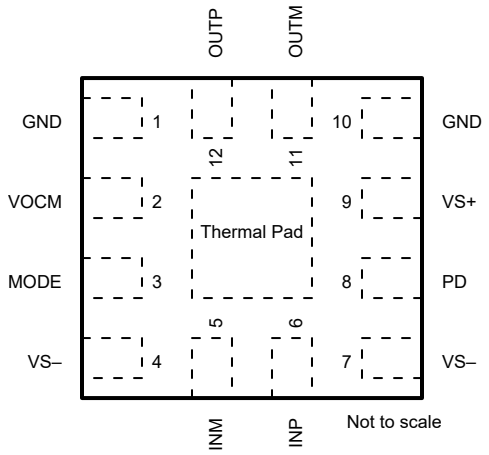

Figure 5-1. RPV Package, 12-Pin WQFN-FCRLF (Top View)

Table 5-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
GND	1, 10	Ground	Ground. Reference for RF signals and PD control signal. Connect to ground plane on the board. Internally shorted to the thermal pad.
INM	5	Input	Negative side of differential input signal
INP	6	Input	Positive side of differential input signal
MODE	3	Input	Mode selection pin. See also MODE Pin section.
OUTM	11	Output	Negative side of differential output signal
OUTP	12	Output	Positive side of differential output signal
PD	8	Input	Power-down signal, referenced to thermal pad. Supports both 1.8V and 3.3V logic. Logic 0 or open = device enabled. Logic 1 = device powered down.
VOCM	2	Input	Output common-mode voltage input pin. Floating the pin sets the output common-mode voltage to $V_{S–}$ + 2.5V.
VS–	4, 7	Power	Negative supply voltage
VS+	9	Power	Positive supply voltage
Thermal Pad	Pad	Ground	Reference for RF signals and PD control signal; also serves as a thermal pad. Connect to heat-dissipating ground or $V_{S–}$ plane on the board.

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6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
$V_{S–}$	Negative supply voltage, referenced to thermal pad	–3	3	V
V_{S+}	Positive supply voltage	–0.3	$V_{S–}$ + 5.5	V
V_S	Total supply voltage, $V_S = V_{S+} – V_{S–}$	–0.3	5.5	V
P_{IN}	Input RF power		20	dBm
V_{PD}	PD pin voltage, referenced to thermal pad, $V_{S+} \geq 3.3V$	–0.3	3.6	V
	PD pin voltage, referenced to thermal pad, $V_{S+} < 3.3V$	–0.3	V_{S+} + 0.3	
V_{OCM}	VOCM pin voltage	$V_{S–}$ + 1	$V_{S–}$ + 4	V
V_{MODE}	MODE pin voltage	$V_{S–}$ – 0.3	$V_{S–}$ + 3.3	V
T_J	Junction temperature	–40	150	°C
T_{stg}	Storage temperature	–40	150	°C

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. Absolute maximum ratings do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If briefly operating outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not sustain damage, but it may not be fully functional. Operating the device in this manner may affect device reliability, functionality, performance, and shorten the device lifetime.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1)	±1000	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002, all pins(2)	±500	

(1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_{S+}	Positive supply voltage	2.5		5	V
$V_{S–}$	Negative supply voltage	–2.5		0	V
V_S	Total supply voltage, $V_S = V_{S+} – V_{S–}$		5		V
T_J	Junction temperature	–40		125	°C

6.4 Thermal Information

THERMAL METRIC(1)		TRF1305x1 RPV (WQFN-FCRLF) 12 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	66.9	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	64.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	17.4	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	1.7	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	17.2	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	9.0	°C/W

(1) For information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Electrical Characteristics - TRF1305B1

at T_A = 25°C, V_{S+} = 5V, $V_{S–}$ = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output with differential source impedance (Z_S) = 100Ω, differential output load (Z_L) = 100Ω, external input resistor network (see Figure 8-3), and inputs de-embedded up to R_{IN_SER} and outputs up to the device pins (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
AC PERFORMANCE						
SSBW	Small-signal bandwidth (3dB)	P_{IN} = –20dBm at each input		7.3		GHz
	Small-signal bandwidth (1dB)	P_{IN} = –20dBm at each input		6.4		
LSBW	Large-signal bandwidth (3dB)	Differential P_{IN} = –3dBm		7.2		GHz
	Large-signal bandwidth (1dB)	Differential P_{IN} = –3dBm		6.4		
S21	Power gain	f = 4GHz		10		dB
	Gain variation over temperature	f = 4GHz, T_A = –40°C to +85°C		1		
S11	Input return loss	f = 10MHz to 7.5GHz		–11.3		dB
S12	Reverse isolation	f < 10GHz (device enabled)		–20		dB
G_{IMB}	Differential gain imbalance	f < 5GHz, S2D, P_{IN} = –20dBm with 50Ω Z_S		±0.2		dB
PH_{IMB}	Differential phase imbalance	f < 5GHz, S2D, P_{IN} = –20dBm with 50Ω Z_S		±2		°
OP1dB	Output 1dB compression point	f = 500MHz		15.5		dBm
		f = 1GHz		16		
		f = 2GHz		15.7		
		f = 3GHz		15		
		f = 4GHz		12.8		
		f = 5GHz		11		
HD2	Second-order harmonic distortion	f = 500MHz, $V_O = 2V_{PP}$		–84		dBc
		f = 1GHz, $V_O = 2V_{PP}$		–72		
		f = 2GHz, $V_O = 2V_{PP}$		–62		
		f = 3GHz, $V_O = 2V_{PP}$		–56		
		f = 4GHz, $V_O = 2V_{PP}$		–53		
HD3	Third-order harmonic distortion	f = 500MHz, $V_O = 2V_{PP}$		–68		dBc
		f = 1GHz, $V_O = 2V_{PP}$		–62		
		f = 2GHz, $V_O = 2V_{PP}$		–61		
		f = 3GHz, $V_O = 2V_{PP}$		–51		
		f = 4GHz, $V_O = 2V_{PP}$		–47		
OIP2	Output second-order intercept point	f = 500MHz, P_O = 1dBm per tone, 2MHz spacing		85		dBm
		f = 1GHz, P_O = 1dBm per tone, 2MHz spacing		71.5		
		f = 2GHz, P_O = 1dBm per tone, 2MHz spacing		64		
		f = 3GHz, P_O = 1dBm per tone, 2MHz spacing		58		
		f = 4GHz, P_O = 1dBm per tone, 2MHz spacing		54.5		
		f = 5GHz, P_O = 1dBm per tone, 2MHz spacing		56.5		

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6.5 Electrical Characteristics - TRF1305B1 (continued)

at T_A = 25°C, V_{S+} = 5V, $V_{S–}$ = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output with differential source impedance (Z_S) = 100Ω, differential output load (Z_L) = 100Ω, external input resistor network (see Figure 8-3), and inputs de-embedded up to R_{IN_SER} and outputs up to the device pins (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OIP3	Output third-order intercept point	f = 500MHz, P_O = 1dBm per tone, 2MHz spacing		43.5		dBm
		f = 1GHz, P_O = 1dBm per tone, 2MHz spacing		40		
		f = 2GHz, P_O = 1dBm per tone, 2MHz spacing		34		
		f = 3GHz, P_O = 1dBm per tone, 2MHz spacing		32		
		f = 4GHz, P_O = 1dBm per tone, 2MHz spacing		25.5		
		f = 5GHz, P_O = 1dBm per tone, 2MHz spacing		19		
NF	Noise figure	f = 500MHz		8		dB
		f = 1GHz		8.8		
		f = 2GHz		10.4		
		f = 4GHz		13.4		
		f = 5GHz		13.3		
NSD	Output noise spectral density	f = 500MHz		–155.3		dBm/Hz
		f = 1GHz		–154.8		
		f = 2GHz		–153.8		
		f = 4GHz		–150.7		
		f = 5GHz		–150.7		
DC PERFORMANCE						
V_{OD-MAX}	Max differential output voltage	f = 1GHz		4		V_{PP}
	Slew rate	2V V_O step, S2D configuration, V_{S+} = 2.5V, $V_{S–}$ = –2.5V		25		kV/µs
	Output differential offset voltage			±3		mV
	Overdrive recovery time	From 2 × overdrive of each SE output to each output voltage settling to < ±50mV		6		ns
COMMON-MODE						
V_{ICM}	Input common-mode voltage	Default range[1]	$V_{S–}$ + 1.5		$V_{S–}$ + 3.5	V
V_{OCM}	Output common-mode voltage		$V_{S–}$ + 2		$V_{S–}$ + 3	V
	Output common-mode offset voltage from V_{OCM} voltage			±10		mV
IMPEDANCE						
Z_{in-SE}	Single-ended input impedance	At INP pin with appropriate termination on INM pin		47		Ω
Z_{O-DIFF}	Differential output impedance	f = near dc		8		Ω

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6.5 Electrical Characteristics - TRF1305B1 (continued)

at T_A = 25°C, V_{S+} = 5V, V_{S-} = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output with differential source impedance (Z_S) = 100Ω, differential output load (Z_L) = 100Ω, external input resistor network (see Figure 8-3), and inputs de-embedded up to R_{IN_SER} and outputs up to the device pins (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLY						
I_{QA}	Active quiescent current			102		mA
I_{QPD}	Power-down quiescent current			25		mA
POWER DOWN						
V_{PD_Hi}	PD pin logic high	Referenced to PAD, see Section 6.1	1.35			V
V_{PD_Lo}	PD pin logic low	Referenced to PAD, see Section 6.1			0.3	V
I_{PD_Bias}	PD bias current (current on PD pin)	PD = high (1.8V logic)		15		µA
		PD = high (3.3V logic)		30		
t_{ON}	Turn-on time	From 50% V_{PD} transition to 90% RF out		25		ns
t_{OFF}	Turn-off time	From 50% V_{PD} transition to 10% RF out		20		ns

(1) V_{ICM} range can be extended closer to V_{S+} or V_{S-} in D2D configuration. See also Section 7.4.1.

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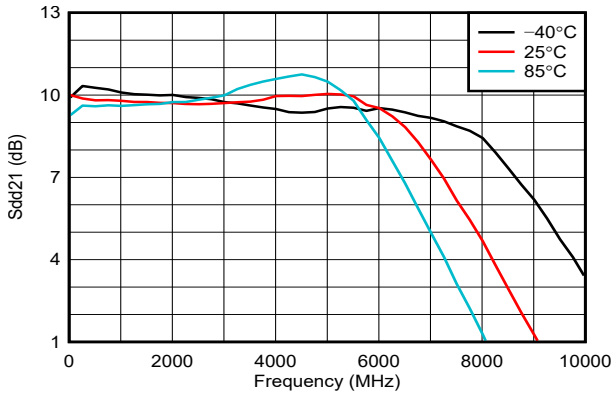
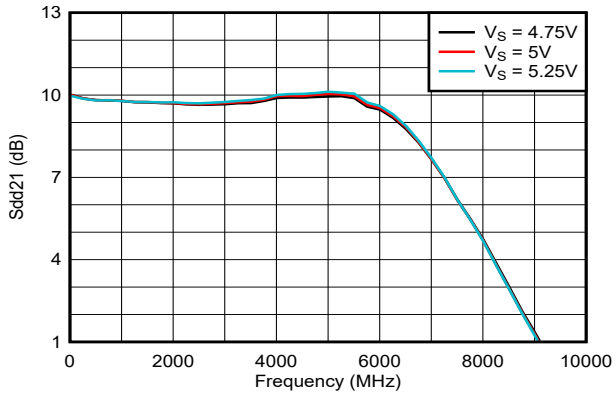
6.6 Typical Characteristics - TRF1305B1

at T_A = 25°C, V_{S+} = 5V, V_{S-} = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output configuration with Z_S = 100Ω, Z_L = 100Ω, external input resistor network (see Figure 8-3), inputs de-embedded up to R_{IN_SER} and outputs up to the device pins, ambient temperatures shown, and resistor network included as part of DUT characteristic plots (unless otherwise noted)



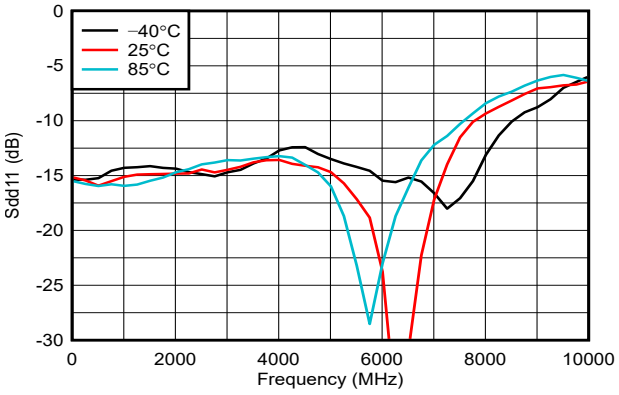
P_{IN} = –20dBm at each input pin with 50Ω source

Figure 6-1. Power Gain (S21) Across Temperature



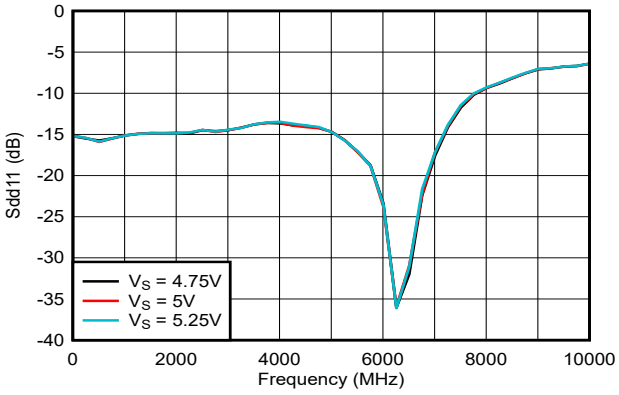
P_{IN} = –20dBm at each input pin with 50Ω source

Figure 6-2. Power Gain (S21) Across Supply Voltage



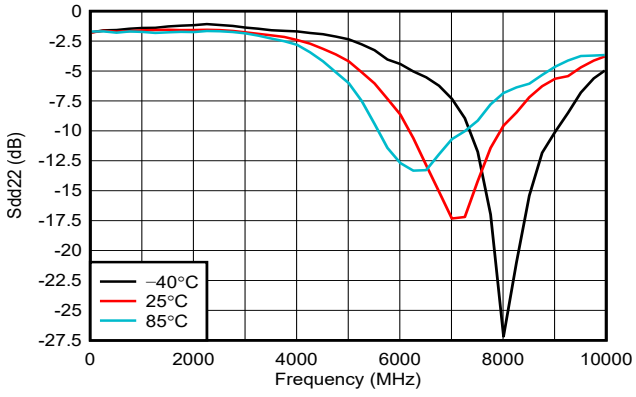
P_{IN} = –20dBm at each input pin with 50Ω source

Figure 6-3. Input Return Loss (S11) Across Temperature



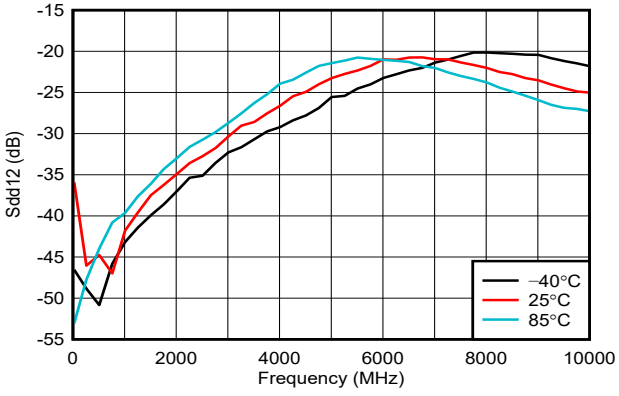
P_{IN} = –20dBm at each input pin with 50Ω source

Figure 6-4. Input Return Loss (S11) Across Supply Voltage



P_{IN} = –20dBm at each input pin with 50Ω source

Figure 6-5. Output Return Loss (S22) Across Temperature

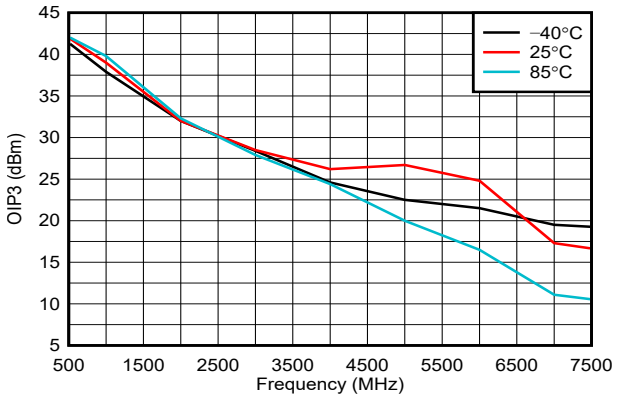


P_{IN} = –20dBm at each input pin with 50Ω source

Figure 6-6. Reverse Isolation (S12) Across Temperature

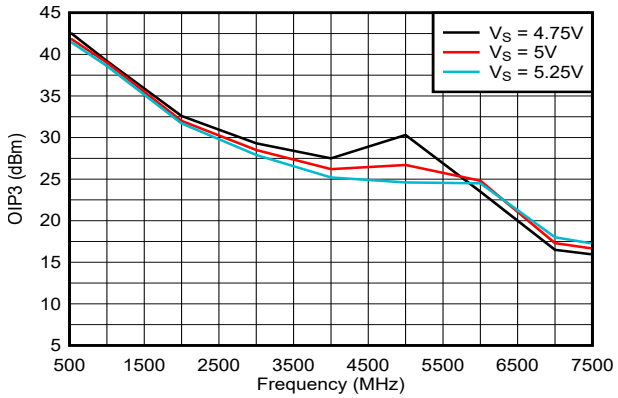
6.6 Typical Characteristics - TRF1305B1 (continued)

at T_A = 25°C, V_{S+} = 5V, $V_{S–}$ = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output configuration with Z_S = 100Ω, Z_L = 100Ω, external input resistor network (see Figure 8-3), inputs de-embedded up to R_{IN_SER} and outputs up to the device pins, ambient temperatures shown, and resistor network included as part of DUT characteristic plots (unless otherwise noted)



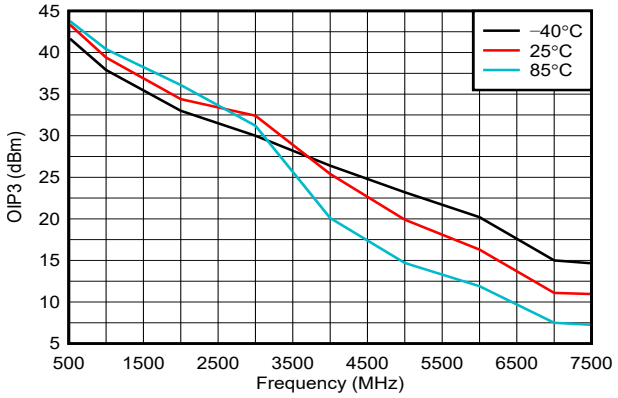
P_O = –5dBm/tone, 2MHz tone spacing

Figure 6-7. OIP3 Across Temperature



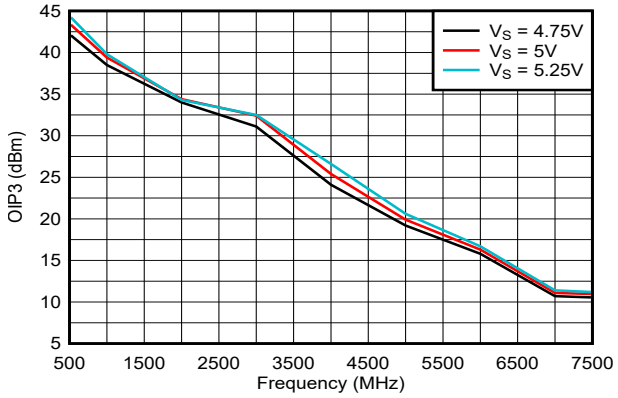
P_O = –5dBm/tone, 2MHz tone spacing

Figure 6-8. OIP3 Across Supply Voltage



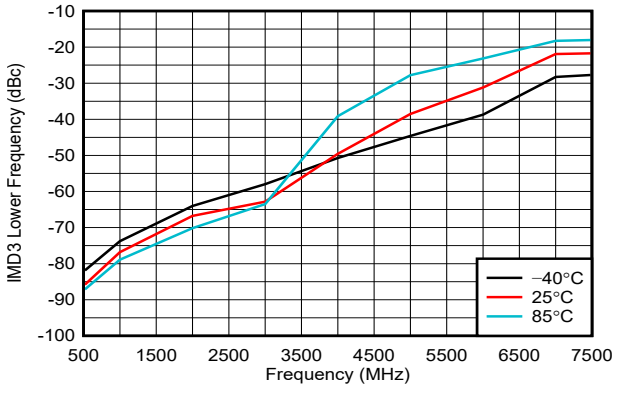
P_O = 1dBm/tone, 2MHz tone spacing

Figure 6-9. OIP3 Across Temperature



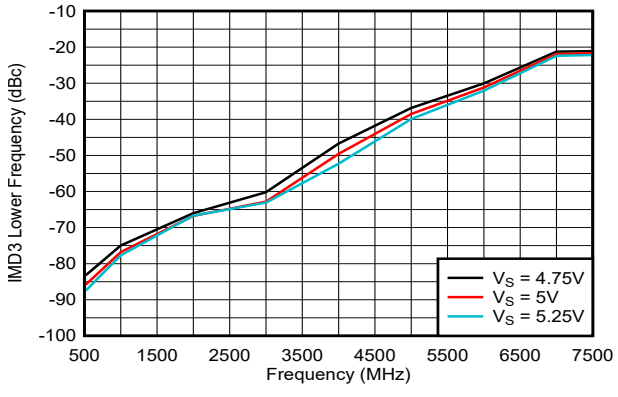
P_O = 1dBm/tone, 2MHz tone spacing

Figure 6-10. OIP3 Across Supply Voltage



At ($2f_1 – f_2$) frequency where $f_1 < f_2$,
P_O = 1dBm/tone, 2MHz tone spacing

Figure 6-11. IMD3 Lower Across Temperature



At ($2f_1 – f_2$) frequency where $f_1 < f_2$,
P_O = 1dBm/tone, 2MHz tone spacing

Figure 6-12. IMD3 Lower Across Supply Voltage

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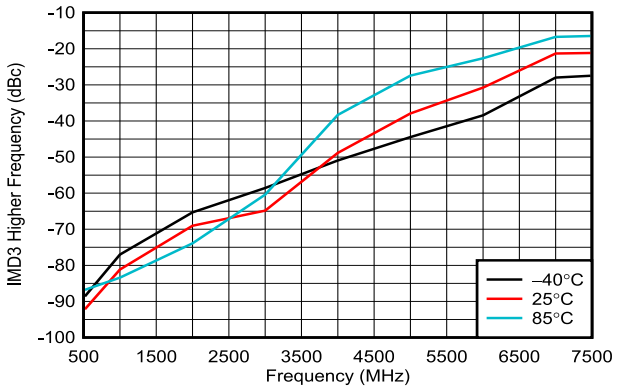
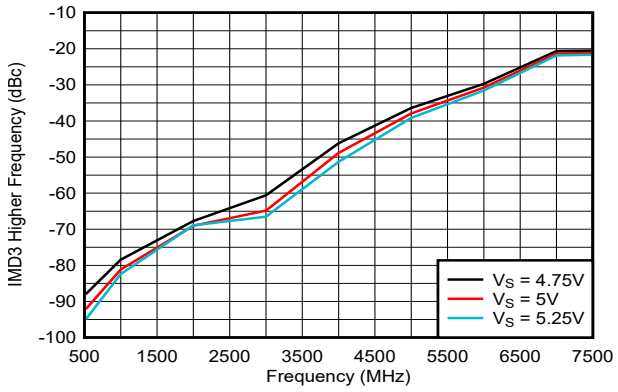
6.6 Typical Characteristics - TRF1305B1 (continued)

at T_A = 25°C, V_{S+} = 5V, $V_{S–}$ = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output configuration with Z_S = 100Ω, Z_L = 100Ω, external input resistor network (see Figure 8-3), inputs de-embedded up to R_{IN_SER} and outputs up to the device pins, ambient temperatures shown, and resistor network included as part of DUT characteristic plots (unless otherwise noted)



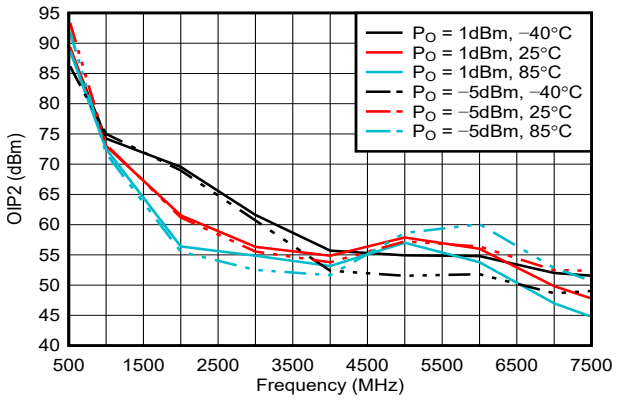
At ($2f_2 – f_1$) frequency where $f_1 < f_2$, P_O = 1dBm/tone, 2MHz tone spacing

Figure 6-13. IMD3 Higher Across Temperature



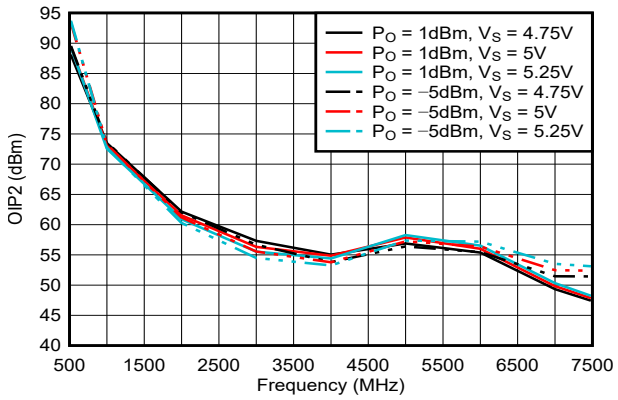
At ($2f_2 – f_1$) frequency where $f_1 < f_2$, P_O = 1dBm/tone, 2MHz tone spacing

Figure 6-14. IMD3 Higher Across Supply Voltage



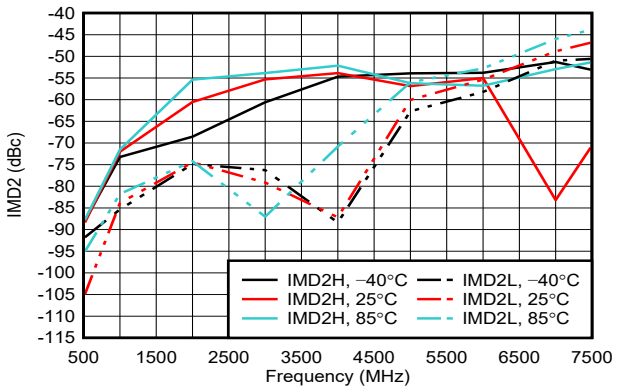
Per tone P_O as shown, 2MHz tone spacing

Figure 6-15. OIP2 Across Temperature



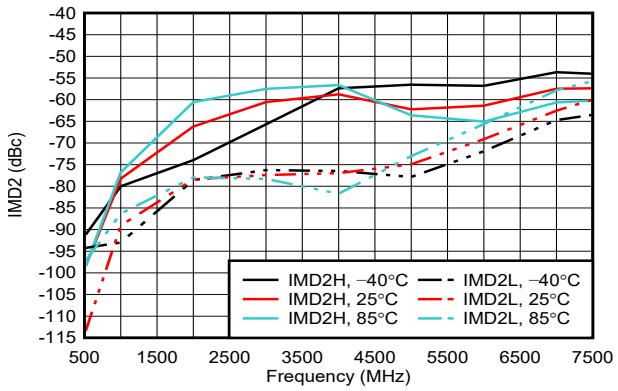
Per tone P_O as shown, 2MHz tone spacing

Figure 6-16. OIP2 Across Supply Voltage



P_O = 1dBm/tone, 2MHz tone spacing

Figure 6-17. IMD2 Across Temperature



P_O = –5dBm/tone, 2MHz tone spacing

Figure 6-18. IMD2 Across Temperature

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6.6 Typical Characteristics - TRF1305B1 (continued)

at T_A = 25°C, V_{S+} = 5V, V_{S-} = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output configuration with Z_S = 100Ω, Z_L = 100Ω, external input resistor network (see Figure 8-3), inputs de-embedded up to R_{IN_SER} and outputs up to the device pins, ambient temperatures shown, and resistor network included as part of DUT characteristic plots (unless otherwise noted)

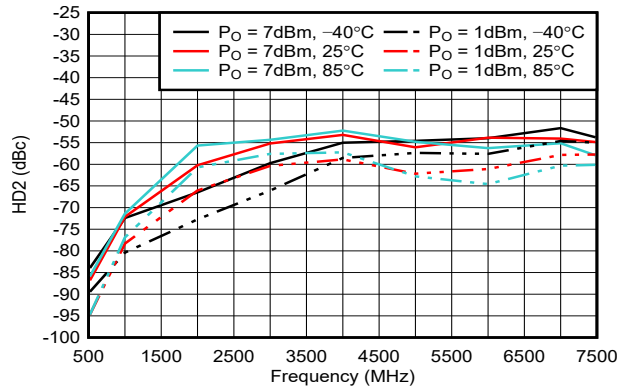

Figure 6-19. HD2 Across Output Power and Temperature

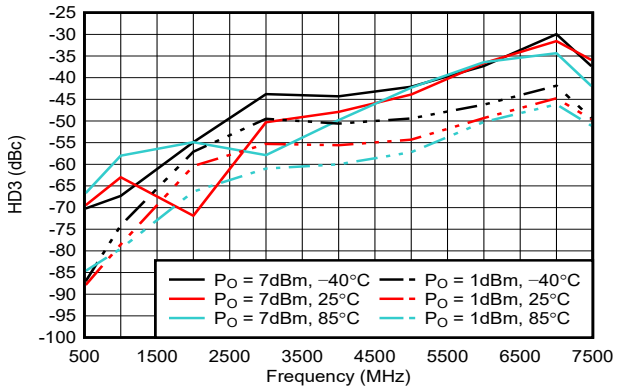

Figure 6-20. HD3 Across Output Power and Temperature

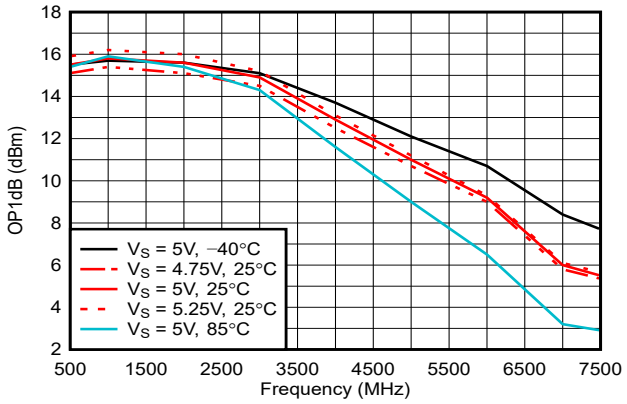

Figure 6-21. OP1dB Across Supply Voltage and Temperature

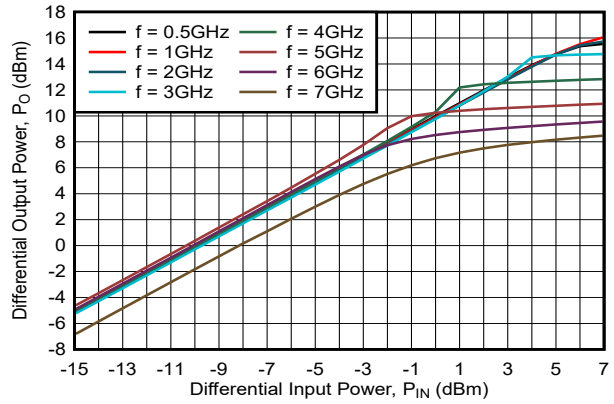

Figure 6-22. Differential Input vs Differential Output Power

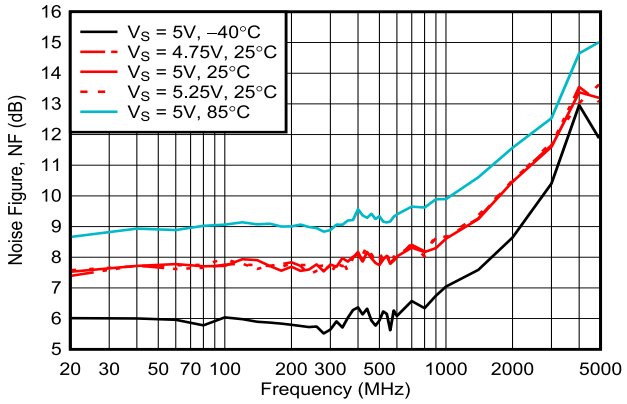

Figure 6-23. Noise Figure Across Temperature

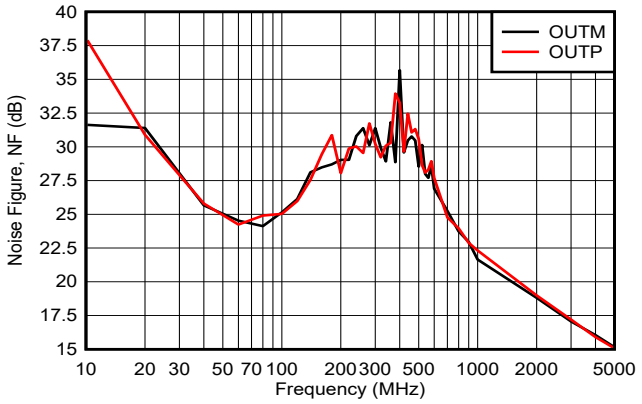

Figure 6-24. Noise Figure at Each Single-Ended Output

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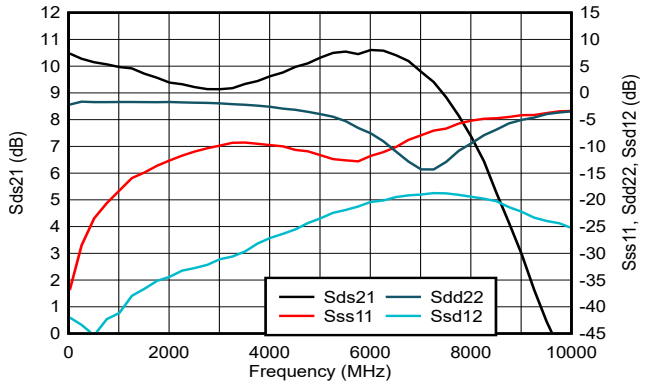
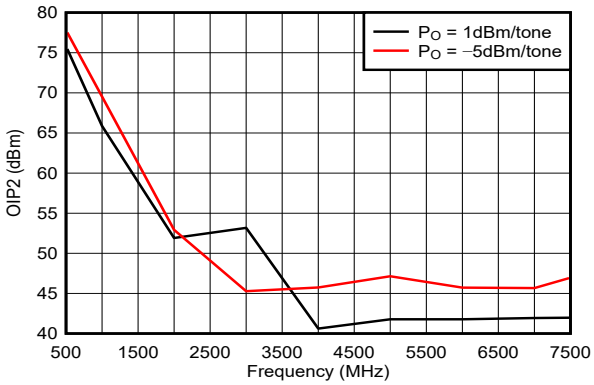
6.6 Typical Characteristics - TRF1305B1 (continued)

at T_A = 25°C, V_{S+} = 5V, V_{S-} = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output configuration with Z_S = 100Ω, Z_L = 100Ω, external input resistor network (see Figure 8-3), inputs de-embedded up to R_{IN_SER} and outputs up to the device pins, ambient temperatures shown, and resistor network included as part of DUT characteristic plots (unless otherwise noted)



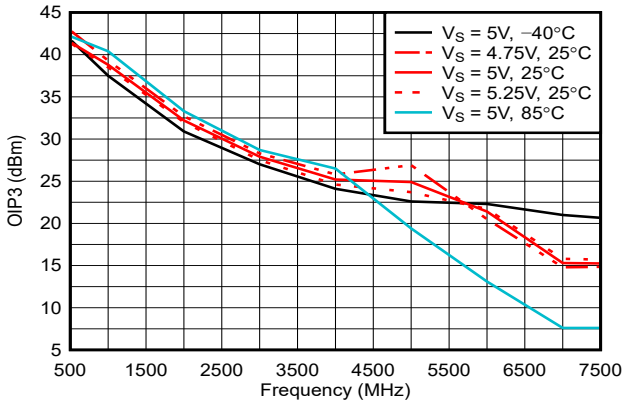
S2D, P_{IN} = –20dBm at each input pin with 50Ω source, de-embedded up to INP and OUTP/OUTM pins

Figure 6-25. S-Parameters in S2D Configuration



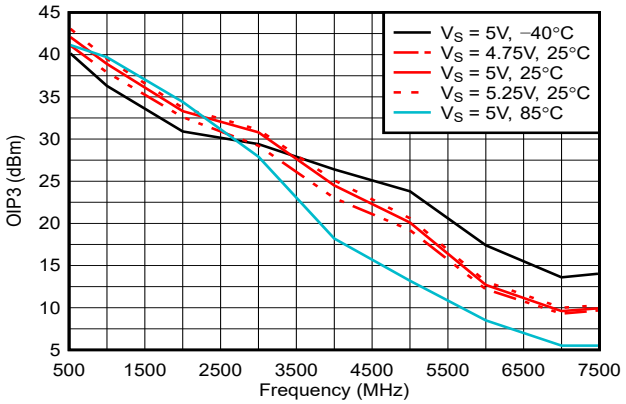
S2D, de-embedded up to INP and OUTP/OUTM pins

Figure 6-26. OIP2 Across Output Power



S2D, P_O = –5dBm/tone, 2MHz tone spacing, de-embedded up to INP and OUTP/OUTM pins

Figure 6-27. OIP3 Across Supply Voltage and Temperature



S2D, P_O = 1dBm/tone, 2MHz tone spacing, de-embedded up to INP and OUTP/OUTM pins

Figure 6-28. OIP3 Across Supply Voltage and Temperature

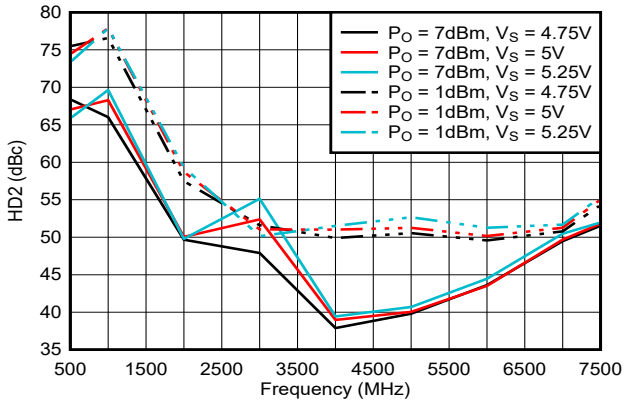


Figure 6-29. HD2 Across Supply Voltage and Output Power

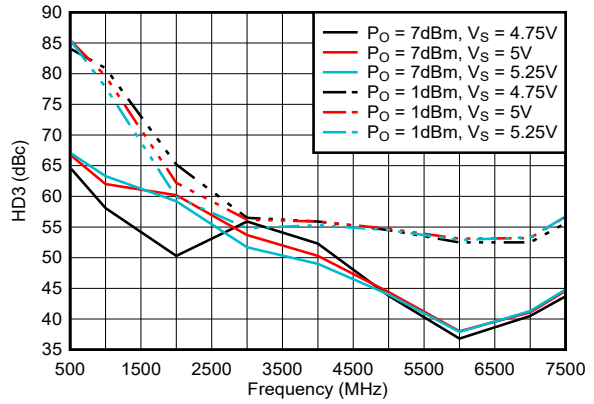
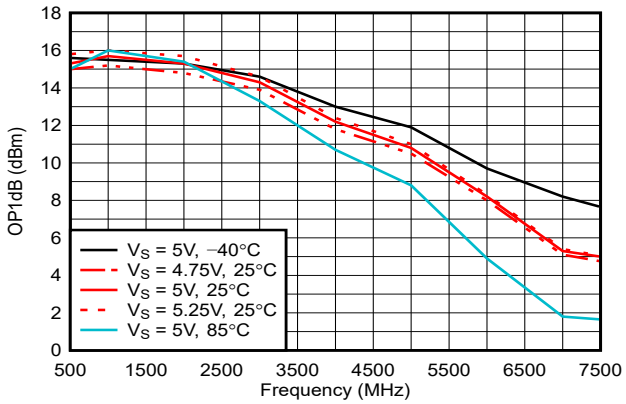


Figure 6-30. HD3 Across Supply Voltage and Output Power

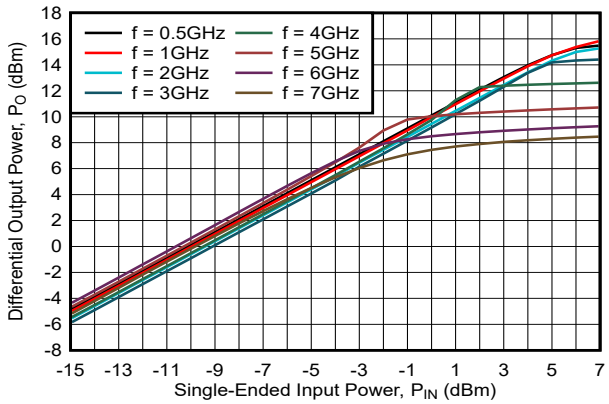
6.6 Typical Characteristics - TRF1305B1 (continued)

at T_A = 25°C, V_{S+} = 5V, $V_{S–}$ = 0V, floating VOCM, PD, and MODE pins, V_{ICM} = midsupply, D2D ac-coupled input/output configuration with Z_S = 100Ω, Z_L = 100Ω, external input resistor network (see Figure 8-3), inputs de-embedded up to R_{IN_SER} and outputs up to the device pins, ambient temperatures shown, and resistor network included as part of DUT characteristic plots (unless otherwise noted)



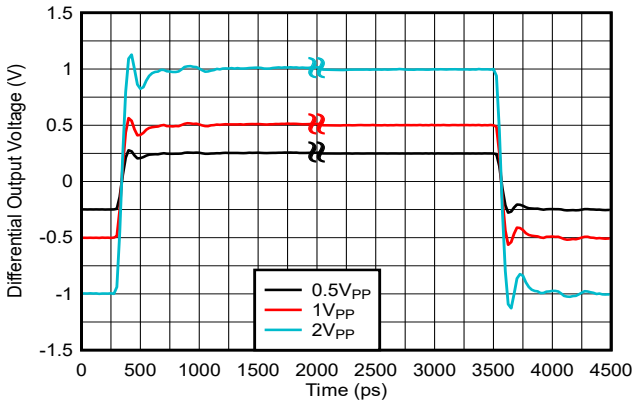
S2D, de-embedded up to INP and OUTP/OUTM pins

Figure 6-31. OP1dB Across Supply Voltage and Temperature



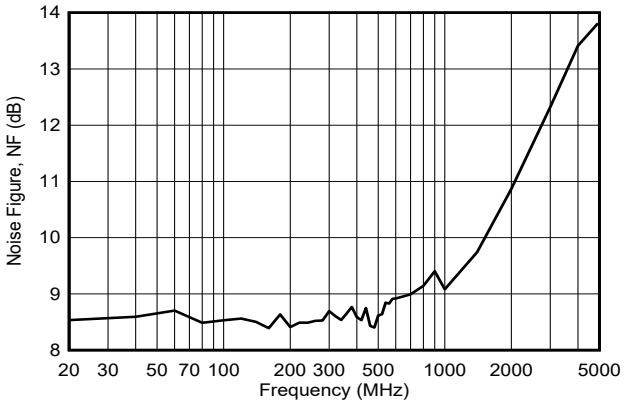
S2D, de-embedded up to INP and OUTP/OUTM pins

Figure 6-32. Single-Ended Input vs Differential Output Power



V_{S+} = 2.5V, $V_{S–}$ = –2.5V

Figure 6-33. Step Response



S2D, de-embedded up to INP and OUTP/OUTM pins

Figure 6-34. Noise Figure in S2D Configuration

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7 Detailed Description

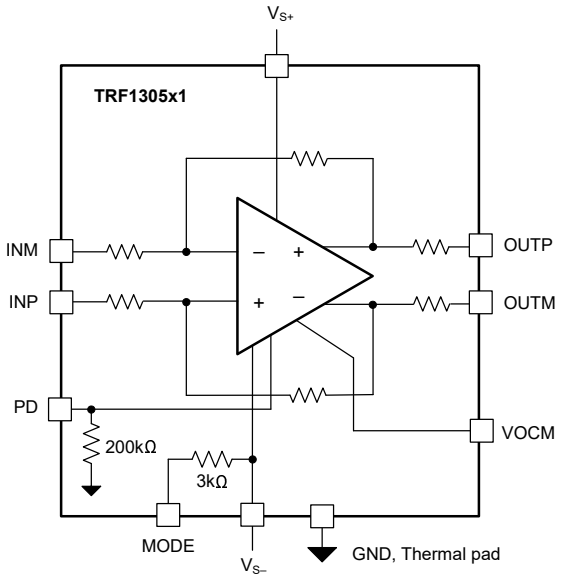
7.1 Overview

The TRF1305A1, TRF1305B1, and TRF1305C1 (TRF1305x1) devices are single-channel, high-performance fully differential RF amplifiers optimized for very wideband signals from dc to > 6.5GHz. This device family is primarily designed to interface with high-speed and RF data converters that often require differential input (ADCs) and output (DACs) signaling. The TRF1305x1 can be dc or ac coupled, and configured as single-ended input and differential output (S2D) or differential input and differential output (D2D). The devices feature an output common-mode pin (VOCM) that allows the flexibility to set a desired common-mode output voltage. The amplifier allows the data converters to interface with a dc-coupled IQ demodulator or modulator if used in a direct conversion system. The TRF1305x1 family comes in three fixed power gain variants (15dB, 10dB, and 5dB), and has a closed-loop feedback-amplifier architecture.

The devices are powered using two-rail supplies with a typical differential voltage of 5V between the positive and negative supplies, and usable in split- or single-supply configurations. A power-down feature is also available that allows the amplifier to be powered down.

The output of the amplifiers is low impedance. Use appropriate external series termination to match to an arbitrary impedance.

7.2 Functional Block Diagram



7.3 Feature Description

The TRF1305x1 includes the following key features:

- Two-rail floating supply with supply-independent thermal pad
  - Connect the thermal pad to GND or V_{S-}
  - RF signals and PD pin are referenced to thermal pad
- Single-supply or split-supply operation
- Supports single-ended and differential input configurations
- Performance-optimized preset fixed-gain variants
- Output common-mode control
- Input common-mode range selection by pullup resistor
- MODE pin: V_{ICM} range extension closer to V_{S+} or V_{S-} modes
- Digital-logic-controllable power-down option

7.3.1 Fully Differential RF Amplifier

The TRF1305x1 is a voltage-feedback fully differential amplifier (FDA) with wide bandwidth. The amplifier is designed for a differential power gain of 15dB, 10dB, or 5dB depending on the device variant. This amplifier has excellent time-domain specifications with high slew rate, high input and output common-mode ranges, and fast transient settling time.

The output average voltage (common-mode) of the FDA device is controlled by a separate common-mode loop. The target output common-mode voltage is set by the VOCM input pin.

7.3.2 Output Common-Mode Control

Figure 7-1 shows a functional diagram of the output common-mode control. Internally, the VOCM pin potential is set by the LDO output voltage that is equal to $V_{S–}$ + 2.5V connected through a 2.5kΩ resistor.

Floating the VOCM pin is allowed. The output common-mode voltage at the output pins, OUTP and OUTM, defaults to the LDO output voltage of $V_{S–}$ + 2.5V when VOCM pin is floated. Floating the VOCM pin results in a V_{OCM} voltage equal to midsupply when V_S = 5V. If the VOCM pin is driven, then drive the pin from a low-impedance source. Limit the value of R_{OCM} to less than 25Ω for accurate reflection of the forced V_{OCM} voltage at the device outputs.

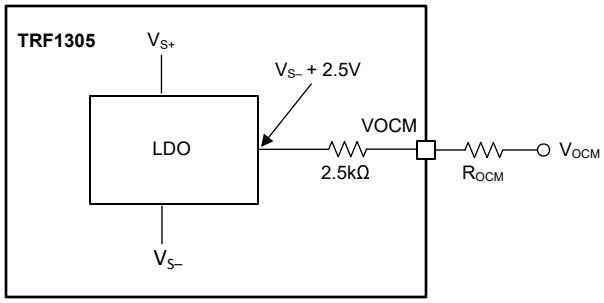


Figure 7-1. Output Common-Mode Control

7.3.3 Internal Resistor Configuration

Figure 7-2 shows the internal resistor configurations of TRF1305x1. Table 7-1 provides the values of these resistors for different gain variants.

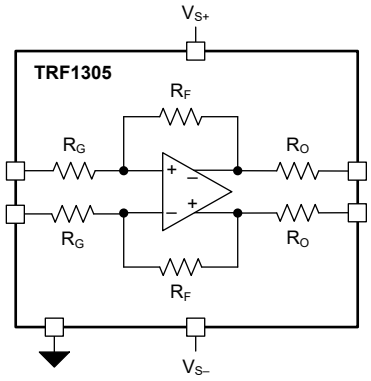


Figure 7-2. TRF1305x1 Internal Resistor Configuration

Table 7-1. Resistor Values

DEVICE NAME	GAIN (dB)	R_G (Ω)	R_F (Ω)	R_O (Ω)
TRF1305A1	15	6.25	258	4
TRF1305B1	10	12.5	161	4
TRF1305C1	5	17	97	4

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7.4 Device Functional Modes

7.4.1 MODE Pin

The TRF1305x1 have additional useful features that can be configured using the MODE pin. To select the device mode, either connect a ±2% maximum tolerance pullup resistor between the MODE pin and VS+, or force a voltage on the MODE pin. Internally, the MODE pin is referenced to $V_{S–}$ through a 3kΩ resistor (see Section 7.2).

Table 7-2 provides the value of the pullup resistor for each mode, the expected voltage, V_{MODE}, at the MODE pin when the pullup resistor is used or the necessary V_{MODE} voltage to set the device mode, and the mode configurations. The V_{MODE} voltage thresholds are approximately midway between the adjacent modes typical V_{MODE} voltage. If the mode functionality is used, use a decoupling capacitor on the MODE pin.

Table 7-2. MODE Pin Configuration

MODE NUMBER	PULLUP RESISTOR TO VS+ (±2% MAXIMUM TOLERANCE)	MODE PIN VOLTAGE, V_{MODE} (V)	V_{ICM} RANGE EXTENSION(1)
0	OPEN	$V_{S–}$	Default V_{ICM} range
1	25.6kΩ	$V_{S–}$ + 0.5V	Low side, extends V_{ICM} range closer to $V_{S–}$
2	12.8kΩ	$V_{S–}$ + 0.95V	High side, extends V_{ICM} range closer to V_{S+}
N/A	Do not use pullup resistor < 10kΩ or set V_{MODE} > $V_{S–}$ + 1.15V		

(1) Only available in D2D configuration.

To switch the mode without turning the supplies off, use a switch or MUX connected between the pullup resistor options and VS+, or force a mode-appropriate V_{MODE} voltage. However, powering down the device using the power-down feature between mode changes is preferred. The low-side and high-side V_{ICM} range extension modes source and sink currents, respectively (see also Section 7.4.1.1). Ensure that the external circuitry is ready to sink or source these currents before the device is put in the active mode from the powered-down state.

7.4.1.1 Input Common-Mode Extension

The TRF1305x1 supports a V_{ICM} voltage closer to either V_{S+} or $V_{S–}$ voltage than the default specified input common-mode range in the *Electrical Characteristics*, when configured in one of the V_{ICM} extension modes. The V_{ICM} extension mode can only be used in D2D configuration.

When configured in the low-side V_{ICM} extension mode, TRF1305B1 supports a 450mV lower input common-mode voltage than the default option. For example, the lower limit of V_{ICM} voltage range extends from a default value of $V_{S–}$ + 1.5V to $V_{S–}$ + 1.05V for the TRF1305B1 variant, and the higher limit also shifts lower from a default value of $V_{S–}$ + 3.5V to $V_{S–}$ + 3.05V. At the lowest V_{ICM} voltage, approximately 15mA current must be sunk by the external circuitry connected to the INP and INM pins.

When configured in the high-side V_{ICM} extension mode, TRF1305B1 supports a 450mV higher input common-mode voltage than the default option. For example, the higher limit of V_{ICM} voltage range extends from a default value of $V_{S–}$ + 3.5V to $V_{S–}$ + 3.95V for the TRF1305B1 variant, and the lower limit also shifts up from a default of $V_{S–}$ + 1.5V to $V_{S–}$ + 1.95V. At the highest V_{ICM} voltage, approximately 15mA current must be sourced by the external circuitry connected to the INP and INM pins.

Either resistors connected to supplies or external current sources can be used to sink or source the currents flowing out or into to the INP and INM pins during the low-side or high-side V_{ICM} extension modes, respectively.

7.4.2 Power-Down Mode

The TRF1305x1 have two bias modes, active and power-down, that are controlled by the voltage on the PD pin. The PD pin is referenced to the thermal pad through a 200kΩ resistor; see also Section 7.2. If the V_{S+} ≥ 3.3V configuration is used, ensure that the PD voltage does not exceed the *Absolute Maximum Ratings* in case the high PD voltage is derived from V_{S+}.

Both 1.8V and 3.3V digital logic is supported for power down control.

8 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

8.1 Application Information

8.1.1 Input and Output Interface Considerations

8.1.1.1 Single-Ended Input

In the single-ended input configuration, one of the amplifier input pins is driven from a source while the other input is terminated with an external resistor. Figure 8-1 shows an ac-coupled, single-ended input configuration driven from and matched to a 50Ω source. Figure 8-1 shows how the non-driven INM pin is terminated with a 50Ω external resistor to match to a source with the same 50Ω impedance at the INP pin. The configuration shown in Figure 8-1 works for all gain versions of TRF1305x1.

To configure the design in Figure 8-1 for single-ended, dc-coupled input, replace the ac-coupling capacitors with shorts, and externally bias both INP and INM pins to a voltage close to the mid-supply or within the common-mode limits of the amplifier.

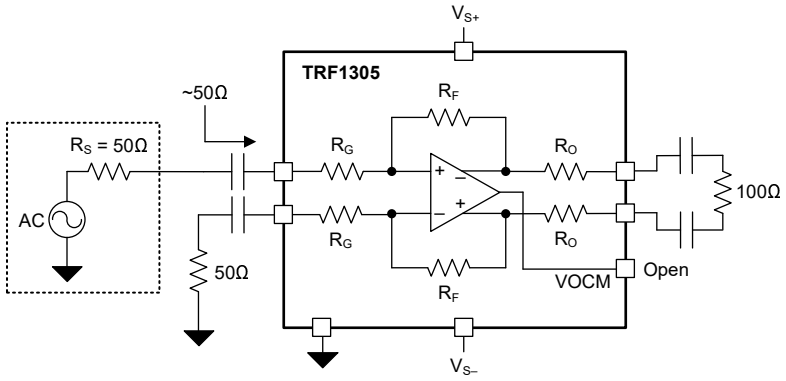

Figure 8-1. AC-Coupled, Single-Ended Input Matched to a 50Ω Source

8.1.1.2 Differential Input

Figure 8-2 shows how a simple network consisting of three resistors is used to match the differential input to a 100Ω differential source. Though the 1kΩ shunt resistor, R_{IN_SH}, does not have any impact at dc to low frequencies, the resistor is necessary to get the full wideband performance from TRF1305x1. Figure 8-3 shows the configuration for ac-coupled differential input designs. The resistors values shown in Figure 8-2 and Figure 8-3 work for all gain versions of the TRF1305x1 for an 100Ω input match to a 100Ω differential source.

Use small foot-print resistors (0201 preferred), and RF quality for high frequency matching.

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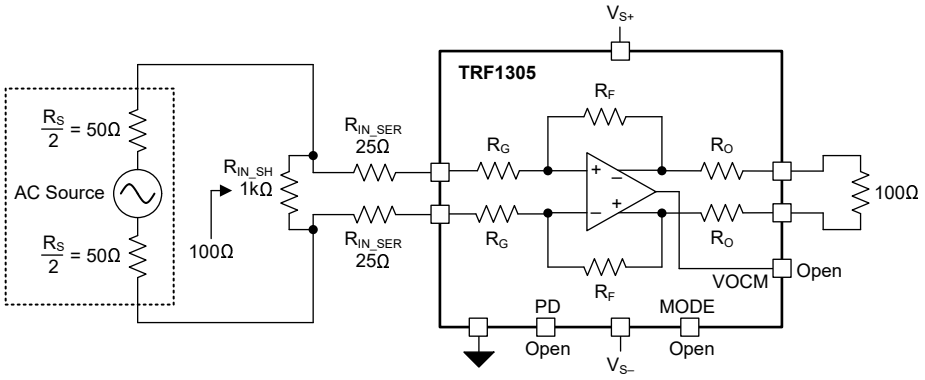

Figure 8-2. DC-Coupled Differential Input Matched to a 100Ω Differential Source

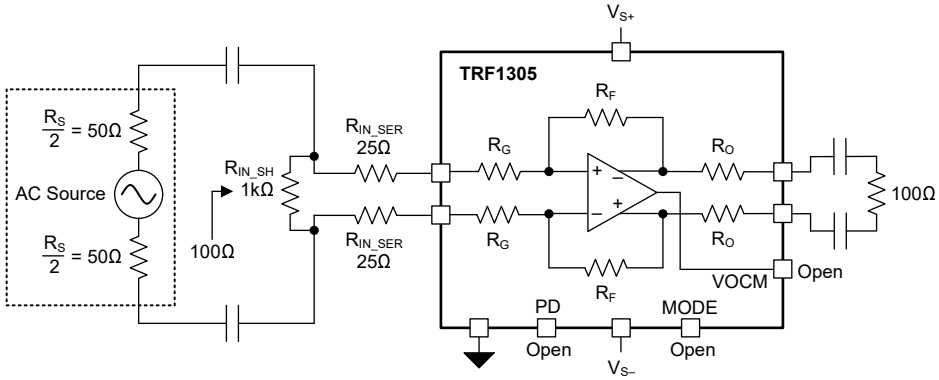

Figure 8-3. AC-Coupled Differential Input Matched to a 100Ω Differential Source

8.1.1.3 DC Coupling Considerations

The TRF1305x1 accepts a wide range of input dc common-mode (CM) voltages. Take into consideration the dc current loading of the source when the TRF1305x1 is dc-coupled at the input. Figure 8-4 shows that when the input CM voltage, V_{ICM}, is different than the output CM voltage, V_{OCM}, a net dc current flow from or to the source occurs. Equation 1 shows the relationship that the source or sink current, I_{CM}, has with the input and output CM voltages:

$$I_{CM} = \frac{(V_{OCM} - V_{ICM})}{(R_F + R_G)} \quad (1)$$

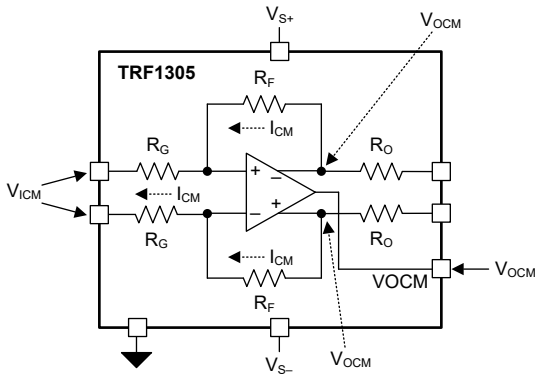

Figure 8-4. Net DC Current Flow When Input and Output Common-Mode Voltages are not Equal

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8.1.2 Gain Adjustment With External Resistors in a Differential Input Configuration

The TRF1305x1 allow minor gain adjustments by configuring the input external resistive network that is part of the differential input configuration. Figure 8-5 shows the external input network that comprises of a shunt resistor, R_{IN_SH}, and two series input resistors, R_{IN_SER}, connected to the input pins of the amplifier.

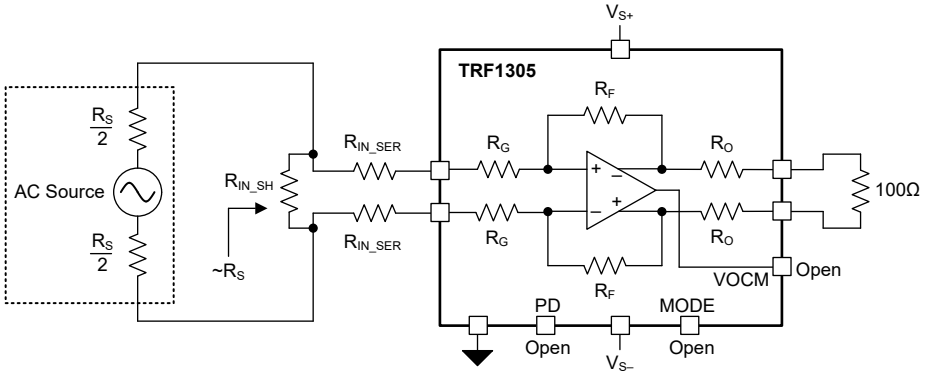

Figure 8-5. Gain Adjustment With External Resistor Network

Table 8-1 provides resistor configurations for a 100Ω differential source impedance.

Table 8-1. Resistor Table for R_S = 100Ω

TRF1305B1		
POWER GAIN (dB)	R_{IN_SH} (Ω)	R_{IN_SER} (Ω)
10	1000	25
9	408	30
8	267	35
7	204	41
6	169	47
5	146	54

Use external resistive attenuation network only for small gain adjustments because there is a dB-to-dB noise figure degradation with the resistive attenuators. Use an amplifier version that requires minimal attenuation for achieving the overall gain.

For example, to realize 10dB overall gain with R_S = 100Ω differential, the two options are:

1. TRF1305B1 with R_{IN_SH} = 1000Ω and R_{IN_SER} = 25Ω resistors
2. TRF1305A1 with R_{IN_SH} = 125Ω and R_{IN_SER} = 49Ω resistors

Option 1 is recommended because the NF is better by approximately 3dB compared to option 2.

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8.2 Typical Application

8.2.1 TRF1305x1 as ADC Driver in a Zero-IF Receiver

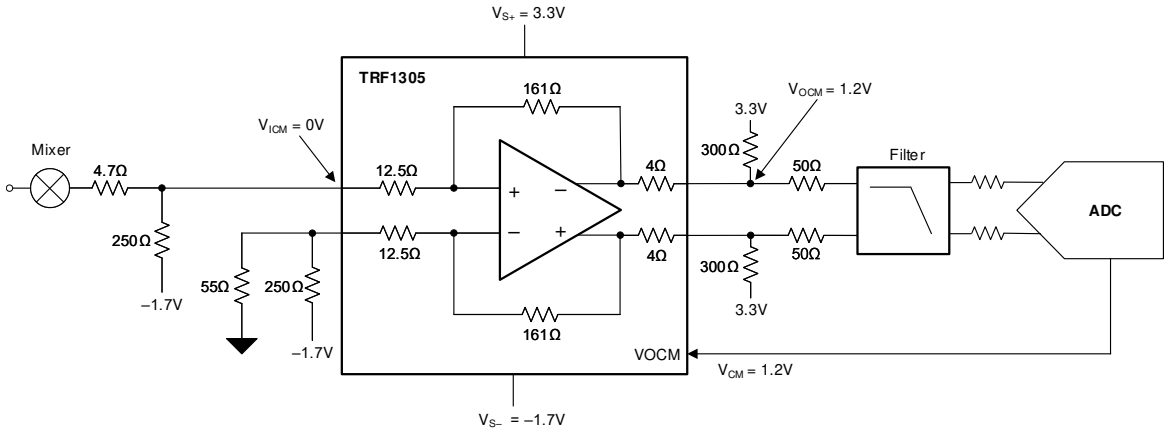

Figure 8-6. TRF1305x1 as ADC Driver in a Zero-IF Receiver

Consider a zero-IF (direct down conversion) application with an IQ demodulator interfaced to a pair of ADCs. In this case, the TRF1305x1 is used as an interface amplifier between the demodulator and the ADCs. The dc common-mode of the demodulator output and ADC input are different. The TRF1305x1 dc couples the demodulator to ADC without degrading the signal integrity of the signal chain.

8.2.1.1 Design Requirements

The primary design requirement for an IQ demodulator application is to interface a pair of passive mixers with an RF ADC. The mixers have a 0-V common-mode voltage. The ADC requires an input common-mode voltage of 1.2V with full-scale swing of 1.35V_{PP}. Choose the power supplies, and design the input/output network for the TRF1305x1 as the ADC driver amplifier, to perform the dc level shifting and amplification function.

8.2.1.2 Detailed Design Procedure

The first step is to choose the TRF1305x1 supplies. Ensure that the midsupply voltage, $V_{MIDSUPPLY}$, is between the ADC common-mode (CM) voltage and the mixer CM voltage. $V_{MIDSUPPLY}$ is typically positioned closer to the ADC CM because the output CM range of the amplifier is less than the input CM range. Ensure that the dc of the signal at the input and output of the amplifier are within the valid operating common-mode voltage range. Use the MODE pin for cases where an extended range of the input CM is required.

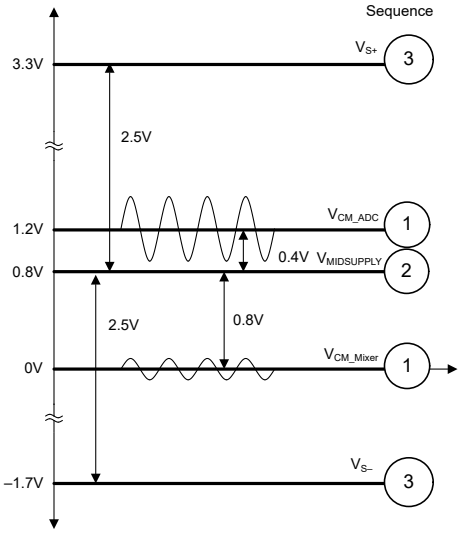

Figure 8-7. Choosing Supply Voltages With Given Common-Mode Voltages

Figure 8-7 shows how $V_{MIDSUPPLY}$ is chosen to be 0.8V, so that the amplifier input has a CM offset from $V_{MIDSUPPLY}$ of 0.8V and output has a CM offset from $V_{MIDSUPPLY}$ of 0.4V (1.2V – 0.8V). The CM offsets are within the valid common-mode range of the amplifier, so the supplies of the TRF1305B1 are chosen to be V_{S+} = 3.3V (0.8V + 2.5V) and $V_{S–}$ = −1.7V (0.8V – 2.5V).

The output CM is greater than the input CM; therefore, a net 6.9-mA ((1.2V – 0V) / (161Ω + 12.5Ω)) dc current flows from the output to input through the internal feedback resistors. Depending on the choice of the passive mixer, this current can required to be sunk outside the mixer so that the bias conditions of the mixer are not disturbed. A 250Ω pulldown resistor connected to the INP pin to −1.7V supply is adequate. If the 6.9mA dc current is sourced entirely from the amplifier, then the output headroom can be affected. Therefore, source the current externally from the supply using a pair of pullup resistors connected to the amplifier outputs. 300Ω pullup resistors from OUTP and OUTM to 3.3V are adequate.

The I-channel mixer output has a 50Ω port and is connected to the amplifier INP pin through a small (4.7Ω) series resistor. The INM pin is terminated to ground through a 55Ω resistor and to −1.7V through a 250Ω resistor. This configuration allows the amplifier to have the same input impedance at each of the INP and INM input pins. The impedance of the mixer is close to 43Ω and provides better than a −20-dB return loss (theoretically). Be aware that there is some drop in the gain due to these resistor networks. The values of the resistors chosen in Figure 8-6 are a good starting point; in practice, some adjustment is often needed to simultaneously meet the dc conditions and the RF performance.

At the amplifier output, 50Ω series resistors are used to match to the antialiasing filter with 100Ω differential input impedance. The filter output is connected to ADC with appropriate matching. Figure 8-6 only shows the I-channel; the Q-channel has an identical configuration.

ADVANCE INFORMATION

8.3 Power Supply Recommendations

8.3.1 Supply Voltages

For the TRF1305x1, the typical differential supply between VS+ and VS– is 5V. The VS+ and VS– supply pins can be floated with respect to ground within the specified range listed in the *Absolute Maximum Ratings* and *Recommended Operating Conditions*.

8.3.2 Single-Supply Operation

The VS– pin is connected to ground in the single-supply configuration. Single-supply operation is most convenient in ac-coupled configurations because the dc common-mode voltages of the source at the inputs and the driven circuit at the outputs are inherently decoupled.

8.3.3 Split-Supply Operation

In split-supply configuration, choose the V_{S+} and $V_{S–}$ voltages to be within the ranges specified in the *Absolute Maximum Ratings* and *Recommended Operating Conditions*. The TRF1305x1 allows choosing negative voltages for the $V_{S–}$ supply, thereby allowing the flexibility to choose input and output common-mode voltages according to the input network and output network requirements.

8.3.4 Supply Decoupling

The VS+ and VS– supply pins are decoupled individually to ground using external capacitors. Place the decoupling capacitors close to the device supply pins.

8.4 Layout

8.4.1 Layout Guidelines

The TRF1305x1 devices are wideband closed-loop feedback amplifiers. When designing with wideband RF amplifiers that have high gain, take certain board layout precautions to maintain stability and optimized performance. Use a multilayer board to maintain signal integrity, power integrity, and thermal performance.

Route the RF input and output lines as grounded coplanar waveguide (GCPW) lines. Ground pins are the reference for the RF signals. Ensure that the second layer of the PCB has a continuous ground layer without any ground cutouts in the vicinity of the amplifier. To minimize phase imbalance, match the length of the output differential lines of both channels. Length matching the input traces is also important, especially if the input configuration is differential. Use small-footprint, passive components wherever possible.

For good heat dissipation,connect the device thermal pad to the board ground planes using thermal vias under the device. For improved heat dissipation, connect the device thermal pad to the top layer ground plane of the board.

8.4.1.1 Thermal Considerations

The TRF1305x1 are packaged in a WQFN-FCRLF package that has excellent thermal properties. Connect the thermal pads underneath the devices to the thermally dissipative ground plane on the board. For good thermal design, use thermal vias to connect the thermal pad plane on the top layer of the PCB to the ground planes in the inner layers.

8.4.2 Layout Example

Figure 8-8 shows an example layout for TRF1305x1 with a differential input configuration. Key areas are highlighted in the figure.

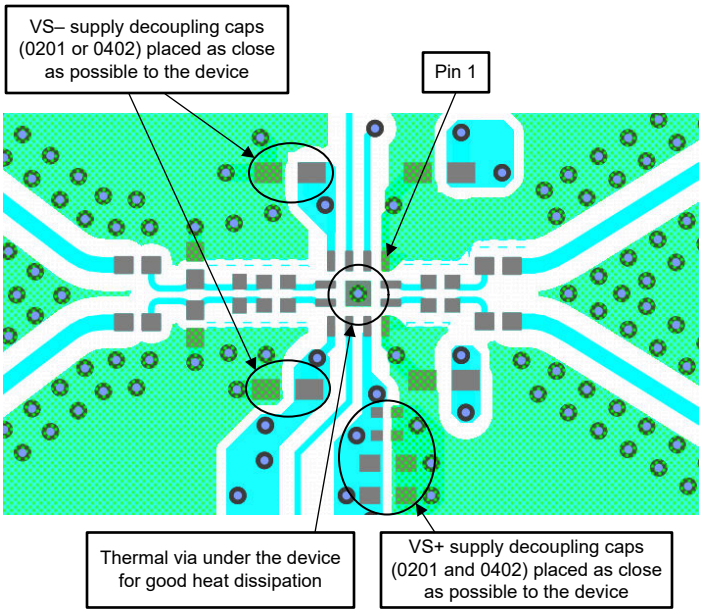

Figure 8-8. Layout Example: TRF1305x1 With Differential Input

The TRF1305x1 can be evaluated using EVM boards that can be ordered from the TRF1305B1 product folder. For more information about the evaluation board construction and test setup, see the *TRF1305x1 EVM User's Guide*.

ADVANCE INFORMATION

9 Device and Documentation Support

9.1 Documentation Support

9.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *TRF1305x1-D2D EVM User's Guide*

9.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

9.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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9.4 Trademarks

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9.5 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

9.6 Glossary

TI Glossary	This glossary lists and explains terms, acronyms, and definitions.

10 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
September 2024	*	Initial Release

11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

ADVANCE INFORMATION

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PTRF1305B1RPVR	ACTIVE	WQFN-HR	RPV	12	3000	TBD	Call TI	Call TI	-40 to 125		Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

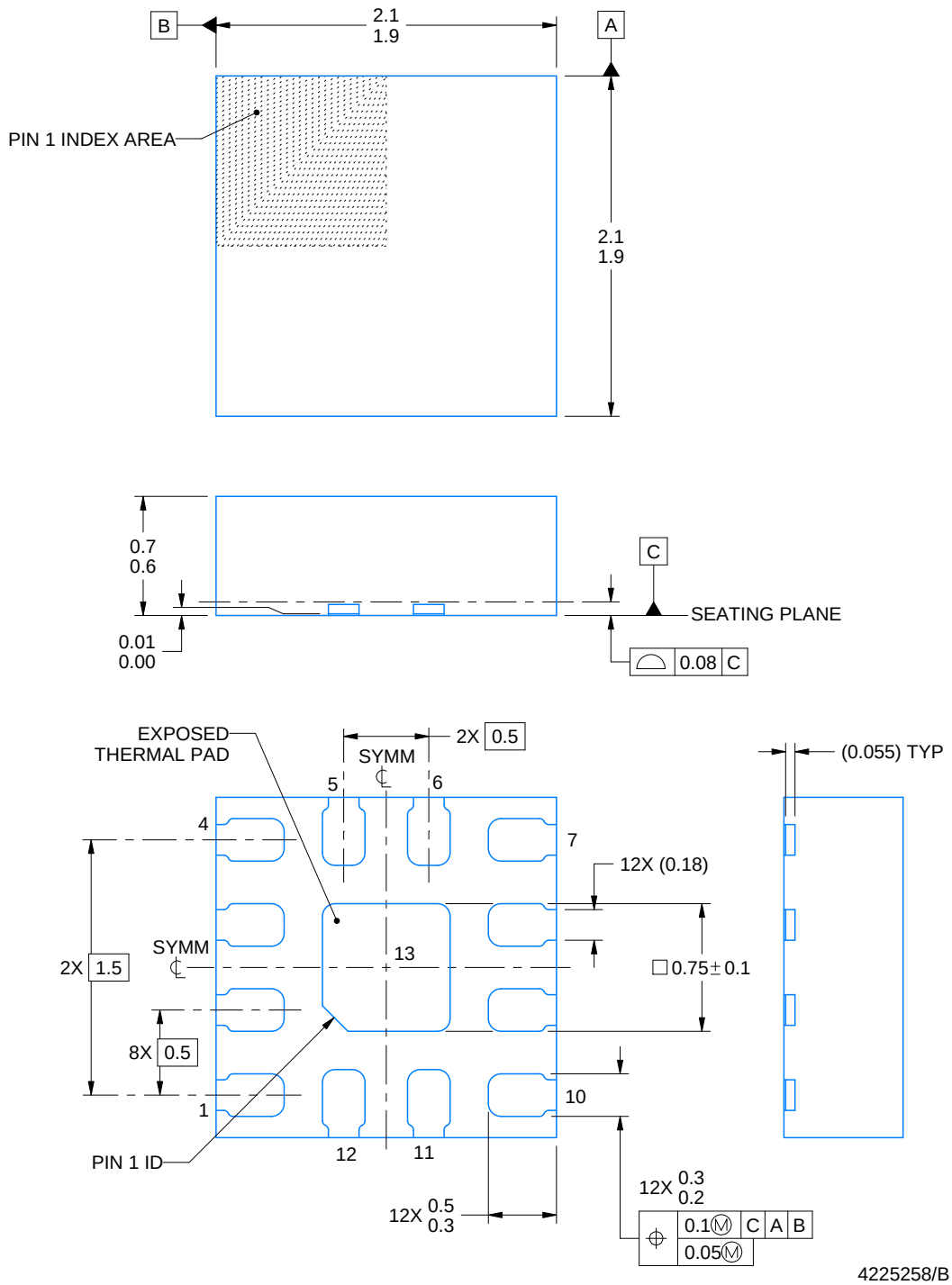
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

PACKAGE OUTLINE

RPV0012A

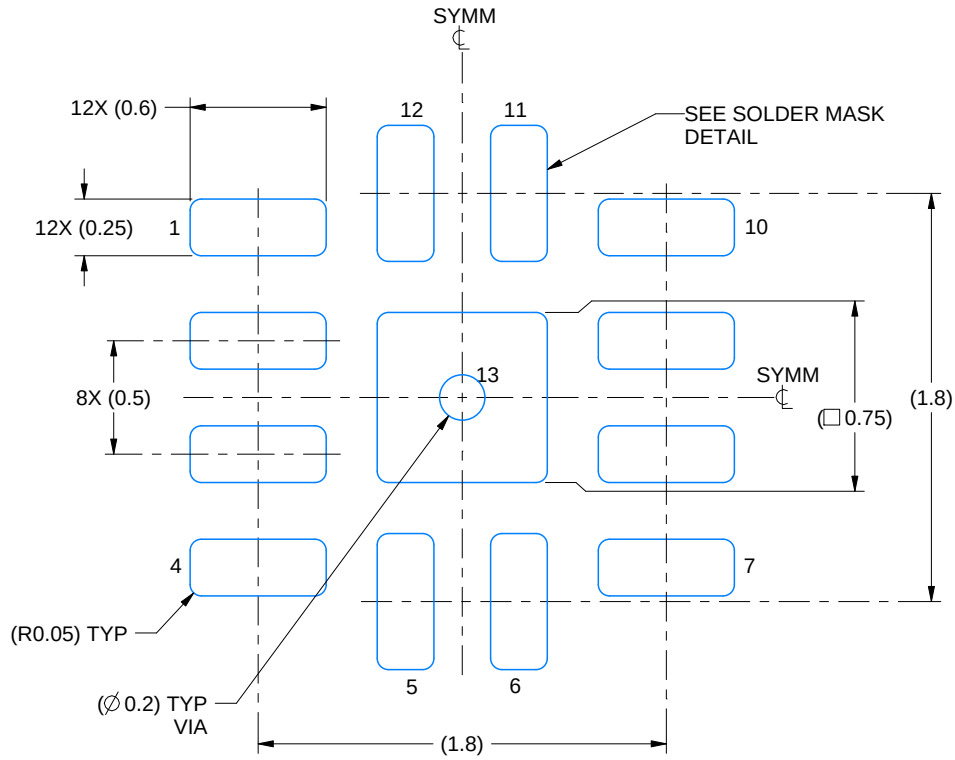
WQFN-FCRLF - 0.7 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

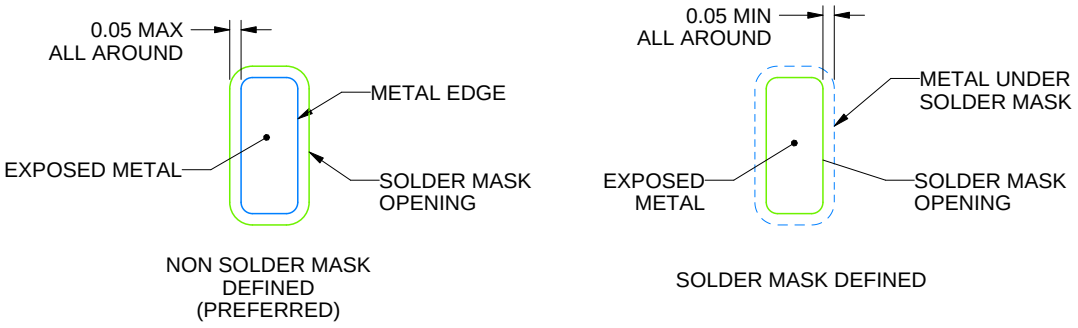


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 30X

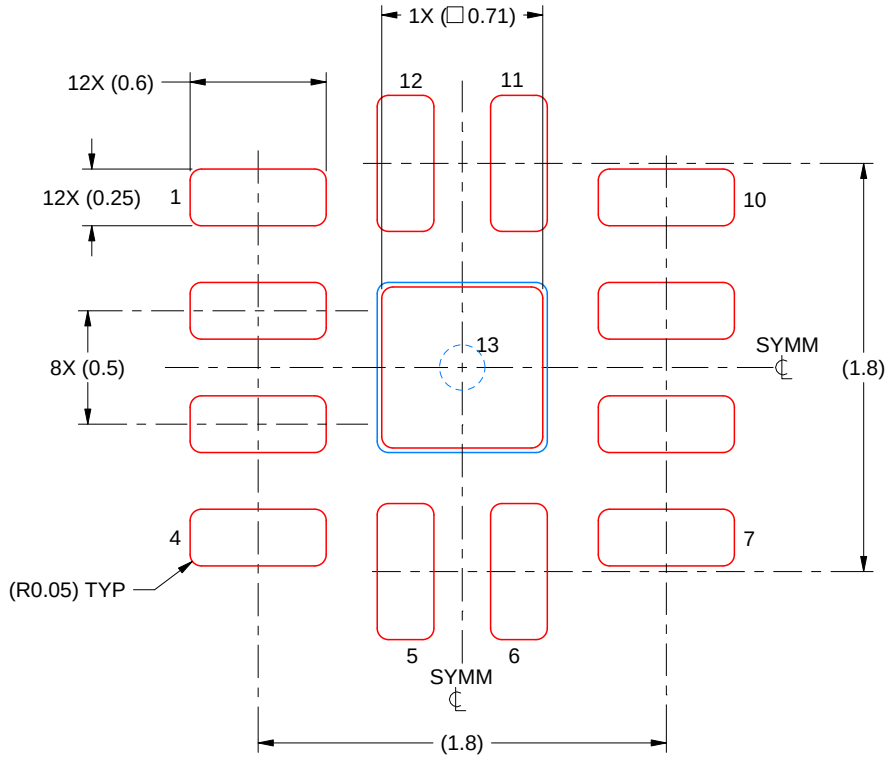


SOLDER MASK DETAILS

4225258/B 04/2020

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 30X

EXPOSED PAD 13
90% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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