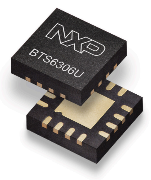
AN14043

BTS6306U Evaluation Board Application Note

Rev. 2.1 — 15 April 2024 | Application note



1 Introduction

This application note focuses on the BTS6306U evaluation board, the application diagram, board layout, bill of materials and control signals are described. Also some typical measurement graphs are shown, even under Digital Pre-Distortion (DPD) conditions.

Refer to the data sheet for the detailed RF performance of the BTS6306U.

The Customer Evaluation Kit contains the following items:

- BTS6306U EVB
- 5 samples

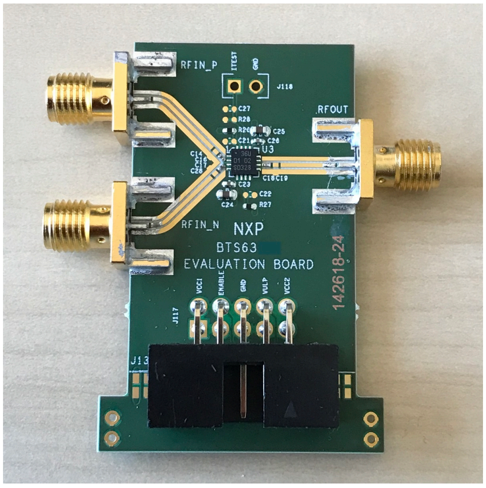


Figure 1. BTS6306U customer evaluation board (EVB)

CAUTION

This product has not undergone formal EMC assessment. It is the responsibility of the user to ensure that any finished assembly complies with applicable regulations on EMC interference. EMC testing, and other testing requirements for CE is the responsibility of the user.

2 Ordering information

Table 1. Ordering information

Description	Part name	Ordering 12NC
BTS6306U Customer Evaluation Kit	OM1718/BTS6306U	9354 599 15598

3 Product description

The BTS6306U is a wideband high linearity pre-driver amplifier with differential input for 5G massive MIMO infrastructure applications, with fast on-off switching to support TDD systems. The amplifier is designed to operate between 3.3 GHz and 4.2 GHz. The BTS6306U is housed in a 3 mm x 3 mm x 0.85 mm 16-terminal HVQFN package.

- High saturated output power $P_{o(sat)}$ = 28.5 dBm
- High power-gain G_p = 38 dB
- High linearity performance ACLR better than -45 dBc
- Unconditionally stable
- Fast switching to support TDD systems
- 5 V single supply, quiescent current 100 mA
- Small 16-terminal leadless package 3 mm x 3 mm x 0.85 mm
- ESD protection on all terminals
- Moisture sensitivity level 1

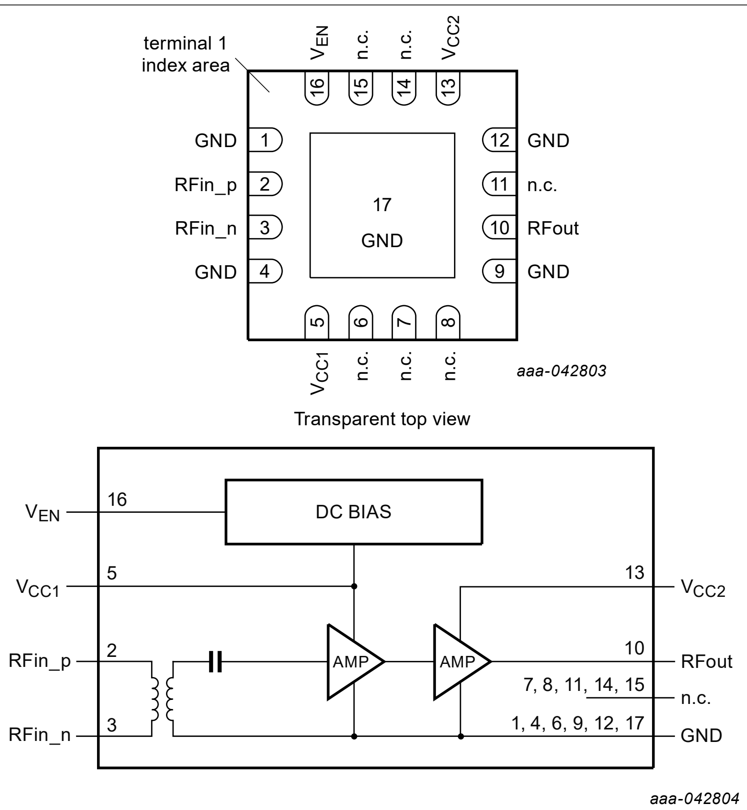


Figure 2. BTS6306U pin configuration and functional diagram

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4 Application board

The BTS6306U evaluation board simplifies the RF evaluation of this pre driver. The evaluation board enables testing the RF performance of the device, in an isolated environment. In case no differential drive source is available, an external 180^{o} Hybrid (Balun) is required. It is possible to test the part with one input connected (other input terminated) with compromises on RF performance. To de-embed applied RF output connector and transmission line up to the output DC blocking capacitor, de-embedding data is available on request.

The BTS6306U evaluation board is fabricated on a 26 mm x 48 mm x 1 mm thick 4 layer PCB. The 0.254 mm top layer uses R4350B for optimal RF performance. The other 2 layers are mainly for mechanical strenght. The board is fully assembled according to the schematic shown below. The board is supplied with three SMA connectors to connect input and output to the RF test equipment.

4.1 Application circuit

The application board circuit diagram that is implemented on the EVB is shown in Figure 3.

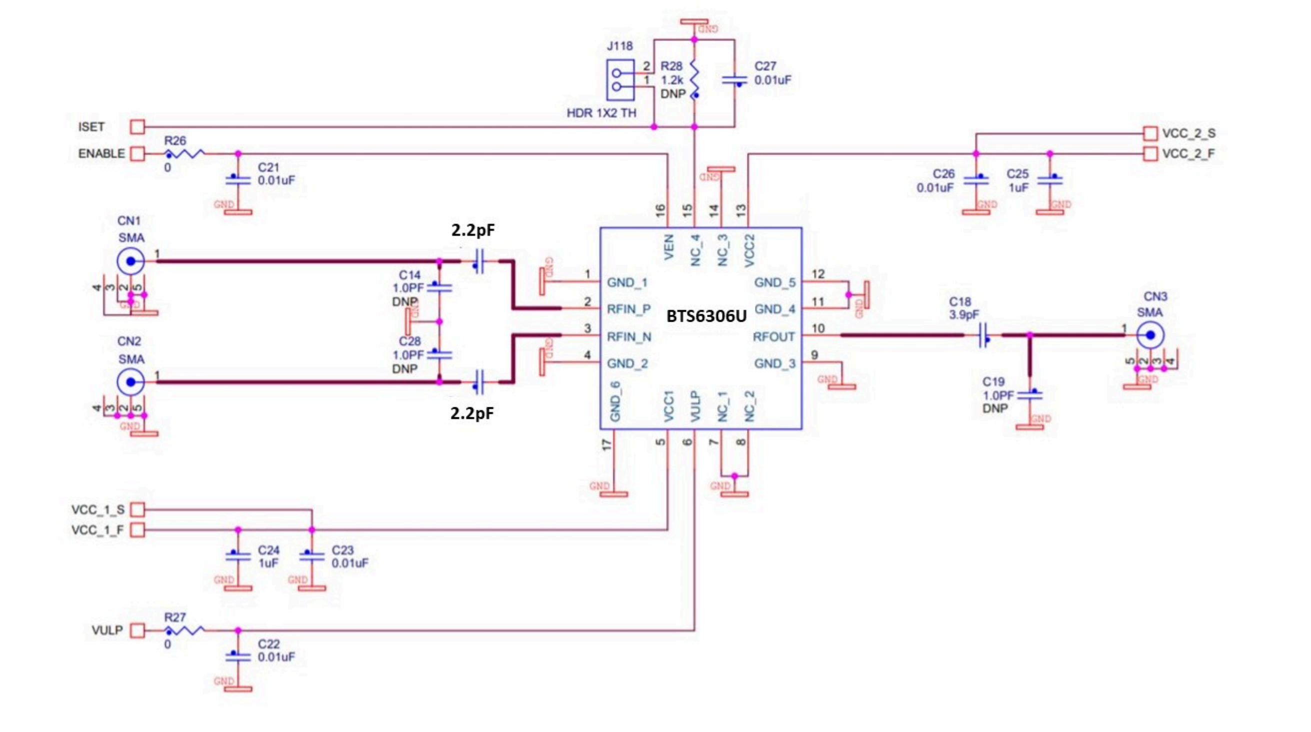

Figure 3. Application board circuit diagram

The differential RF input (RFin_P, RFin_N) is supplied via CN1 and CN2. Output signals can be applied via SMA connector CN3. Capacitors C16, C17, and C18 are DC-blocking capacitors. Although the RF input ports are DC free, blocking capacitors are recommended in order not to short both differential inputs for DC. These blocking capacitors also prevent DC voltages above the maximum specified value.

Note: *The components indicated with DNP are not necessary (Do Not Place), but provide means to experiment on matching and decoupling if necessary.*

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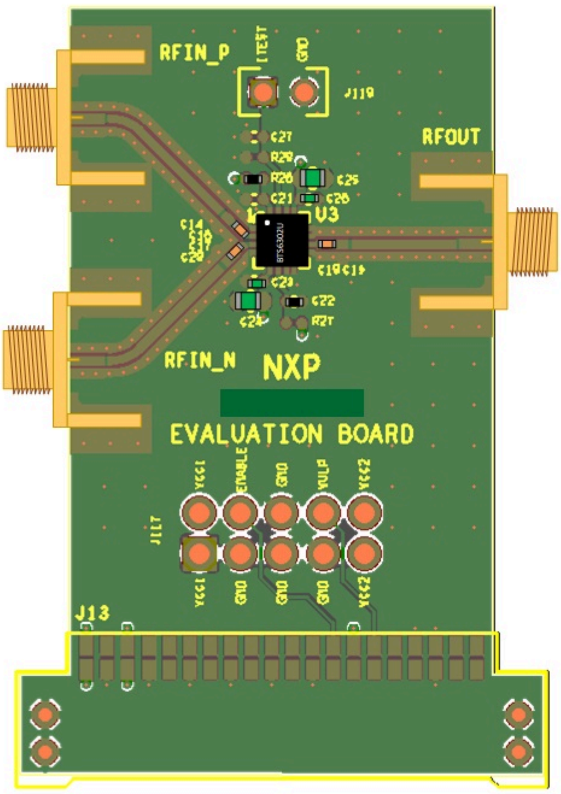
4.2 PCB Layout information and component selection

- A good PCB layout is an essential part of an RF circuit design. The evaluation board of the BTS6306U can serve as a guideline for laying out a board using the BTS6306U.
- The evaluation board uses micro strip coplanar ground structures for controlled impedance lines for the high frequency input and output.
- V_{CC1} and V_{CC2} are bypassed via C23, and 24, and C25, and C26 decoupling capacitors respectively. C23, and C26 should be located as close as possible < 1 mm to the device, to avoid AC leakage via the bias lines. For long bias lines, it may be necessary to add decoupling capacitors along the line further away from the device.
- The parameters related to the differential input (like CMRR) are assuming a symmetrical source. The DC blocking capacitors and corresponding routed tracks can be considered as part of the source. Therefore it is important to keep those as balanced as possible. Applying tight tolerance capacitors for C16/C17 (2.2pF recommended value) will help to maintain optimal symmetry.
- Proper grounding of the GND pins is also essential for good RF performance. Either connect the GND pins directly to the ground plane or through vias, or do both, which is recommended. The layout and component placement of the BTS6306U evaluation board is given in Figure 4
- Resistor R26 in the V_{EN} Line on EVB is chosen to be 0 Ω. For current limitations in the system application, it is recommended to use a resistor value 2 kΩ. With 2 kΩ the current in the V_{en} will be limited to values below 1 mA.

4.2.1 Evaluation board layout



V_{ULP} is not used in this application.

Figure 4. BTS6306U evaluation board layout and component

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4.2.2 PCB stack and recommended footprint

The PCB material used to implement the pre-driver circuit is a symmetrical stack. Applying 2 times 0.254 mm R4350B low loss material at a core of FR4 with 0.432 mm thickness. See Figure 5. The official drawing of the recommended footprint can be found via following link SOT758-1.pdf. When using micro strip coplanar PCB technology, it is recommended using at least 12 ground-via holes of 300 µm diameter in the ground plane under the device. This technique is also used on the EVBs as shown in Figure 6.

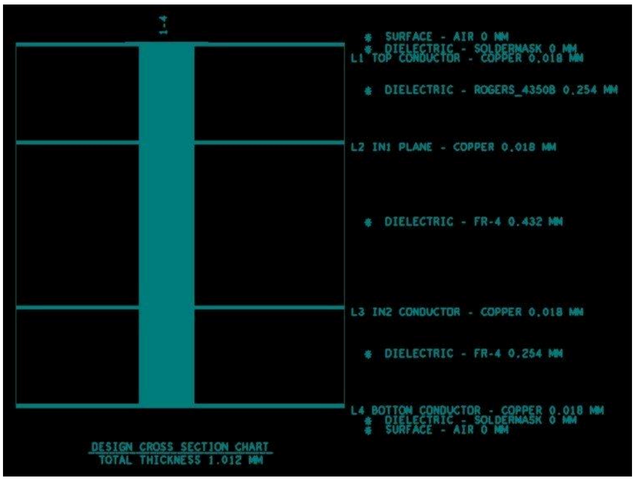

Figure 5. Cross section of the PCB Layer stack

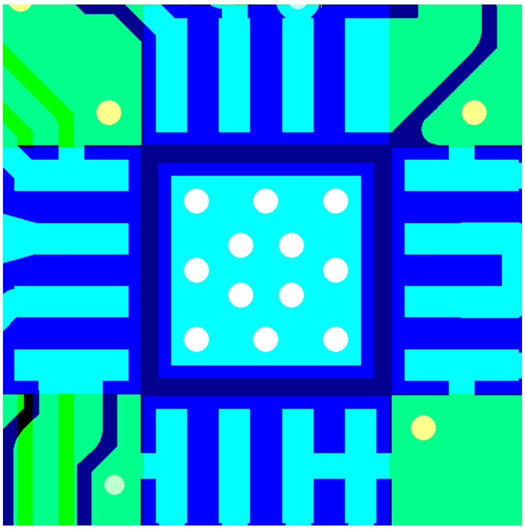

Figure 6. Recommended footprint

4.3 Bill of materials

Table 2. Evaluation board BOM

Gives the bill of materials as is used on the EVB

Designator	Description	Footprint	Value	Supplier Name/type	Comment/function
IC1	BTS6306U				
PCB	26 mm x 48 mm x 1 mm				RO4350
C14, C19, C28	capacitor	0402	n.a.		for experimenting only
C16, C17	capacitor	0201	2.2 pF	Murata	DC block / gain flatness opt.
C18	capacitor	0201	3.9 pF	Murata	DC block
C21, C22,	capacitor	0402	10 nF	Murata	optional
C23, C26	capacitor	0402	10 nF	Murata	supply decoupling
C24, C25	capacitor	0603	1 µF	Murata	
R26, R27	resistor	0402	0 Ω	Phycomp	bridge (Location for R27 is C22)
J1, J2, and J3	DC header			Johnson Emmerson	DC connections
J117	DC header			Amphenol	DC connections

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5 Evaluating the BTS6306U

All RF performance results given in the next chapters are referenced to the SMA connectors on the evaluation board. In the data sheet characteristics, board connectors and PCB tracks are de-embedded up-to the product input and output DC blocking capacitors.

The typical device performance given in the data sheet is characterized on the evaluation board equal to the board described in this application note. The BTS6306U mounted on the evaluation board in the customer evaluation kit is industrially tested on the most important RF parameters, like Gain, Noise Figure, $IP3_o$, and $P_{L(1dB)}$.

All connection names are clearly displayed on the board. See Section 4.2.1.

Note: *Because of the standard layout, the board is used for different amplifier products. Not all connections are used, like V_{ULP}.*

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5.1 Characteristics

Table 3. Characteristics

V_{CC} = 5 V; T_{amb} = 25 °C; input 100 Ω, and output 50 Ω; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{CC}	supply current	ON state, P_o = 15 dBm	-	115	140	mA
		ON state, quiescent	-	100	125	mA
		OFF state	-	1.1	2.5	mA
G_p	power gain	ON state				
		f = 3.3 GHz,	36.5	38.5	40.5	dB
		f = 3.8 GHz,	36	38	40	dB
		f = 4.2 GHz,	35	37	39	dB
		OFF state	-	-50	-48	dB
G_{flat}	gain flatness	f = 3.3 GHz to 3.8 GHz	-	0.05	-	dB
		f = 3.8 GHz to 4.2 GHz	-	0.3	-	dB
$t_{d(grp)}$	group delay time	f = 3.3 GHz to 3.8 GHz	-	0.4	0.5	ns
		f = 3.8 GHz to 4.2 GHz	-	0.4	0.5	ns
$P_{o(sat)}$	saturated output power	f = 3.3 GHz	-	29	-	dBm
		f = 3.8 GHz	-	28.5	-	dBm
		f = 4.2 GHz	-	28	-	dBm
$P_{L(1dB)}$	output power at1 dB gain compression	f = 3.3 GHz	-	28	-	dBm
		f = 3.8 GHz	-	27.5	-	dBm
		f = 4.2 GHz	-	27	-	dBm
$IP3_o$	output third-order intercept point	2-tone; tone spacing = 100 MHz; P_o = 15 dBm	-	34.5	-	dBm
CMRR	common mode rejection ratio	f = 3.3 GHz	-	26	-	dB
		f = 3.8 GHz	-	24.5	-	dB
		f = 4.2 GHz	-	22.5	-	dB
RL_i	input return loss	f = 3.3 GHz	12	24	-	dB
		f = 3.8 GHz	12	18	-	dB
		f = 4.2 GHz	12	18	-	dB
RL_o	output return loss	f = 3.3 GHz	12	24	-	dB
		f = 3.8 GHz	12	18	-	dB
		f = 4.2 GHz	12	18	-	dB
ISL_r	reverse isolation		-	75	-	dB
NF	noise figure	f = 3.3 GHz [1]	-	3.5	-	dB
		f = 3.8 GHz	-	4	-	dB
		f = 4.2 GHz	-	4	-	dB

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Table 3. Characteristics*...continued*

V_{CC} = 5 V; T_{amb} = 25 °C; input 100 Ω, and output 50 Ω; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{s(pon)}$	power-on settling time	V_{EN} from LOW to HIGH to gain settled within 0.1 dB of final value and phase settled to within 1 degree of final value	-	0.4	0.6	μs
$t_{s(poff)}$	power-off settling time	V_{EN} from HIGH to LOW to gain settled to be < 5 % of gain in ON state	-	0.05	0.1	μs
K	Rollett stability factor	1 MHz to 15 GHz	1.8	-	-	
ACLR	adjacent channel leakage ratio	CP-OFDM with 20 MHz channel BW, QPSK modulation, and 60 kHz SCS, fully allocated, P_o = 15 dBm	-	-	-45	dBc

[1] Connector and Printed-Circuit Board (PCB) losses have been de-embedded.

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5.2 S-parameters

The measured S-parameters and Rollett stability factor K, are given in the graphs below. For the measurements, a typical BTS6306U EVB is used. All the S-parameter measurements have been carried out using the setup Figure 20.

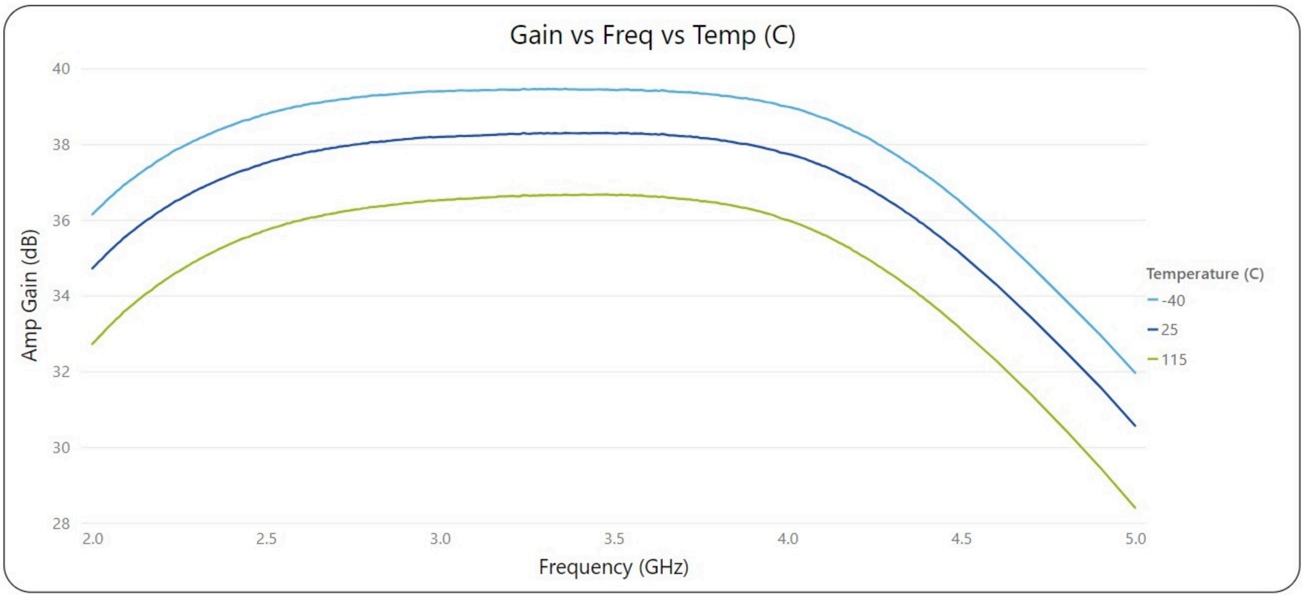

Figure 7. BTS6306U differential gain (typical values). VCC = 5 V, Pi = -25 dBm

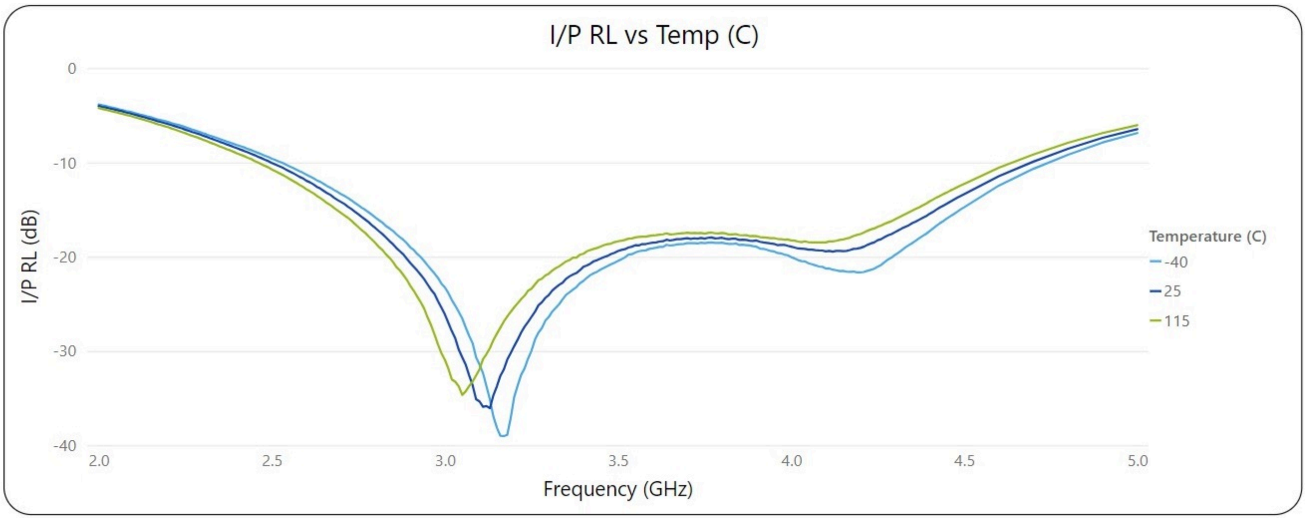

Figure 8. BTS6306U differential RLi (typical values). VCC = 5 V, Pi = -25 dBm

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5.2 S-parameters...*continued*

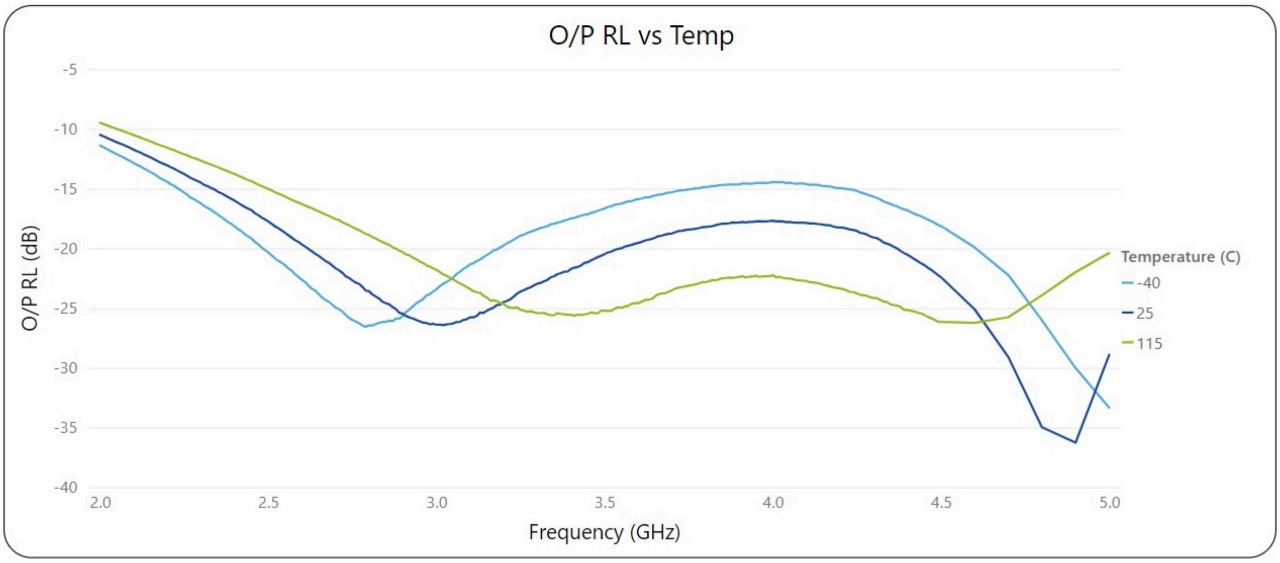

Figure 9. BTS6306U RL_o (typical values). V_{CC} = 5 V, P_i = -25 dBm

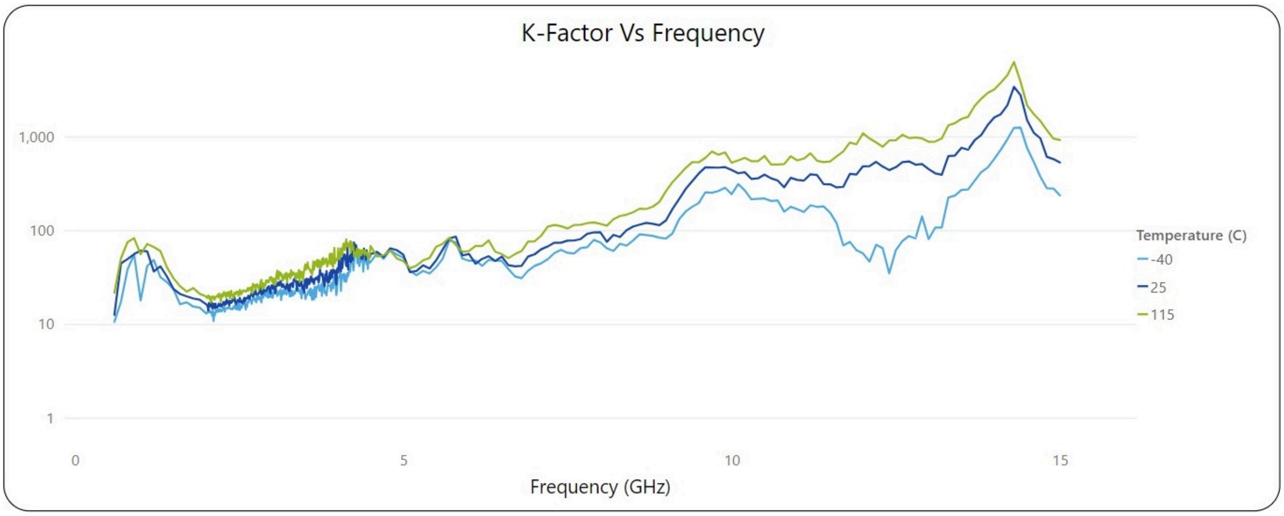

Figure 10. BTS6306U K-factor (typical values). V_{CC} = 5 V, P_i = -25 dBm

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5.3 P-out, and Gain versus P-in

The P_o and Gain are measured versus P_i using the setup shown in Figure 20.

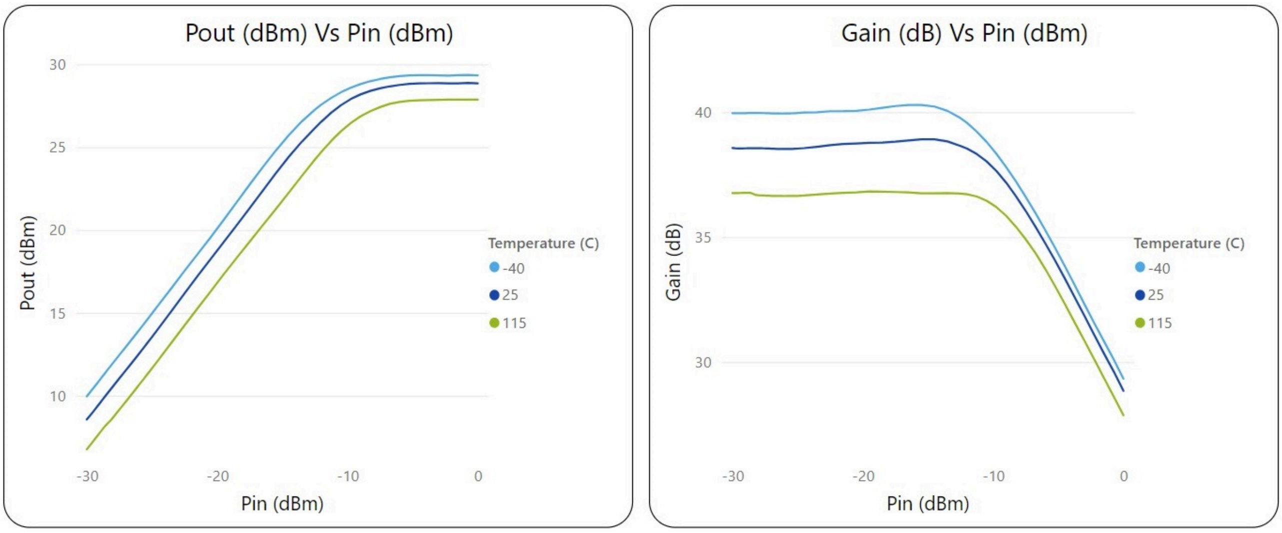

Figure 11. Pout, and Gain versus input power (typical values). V_{CC} = 5 V, f = 3.5 GHz

5.4 Noise Figure

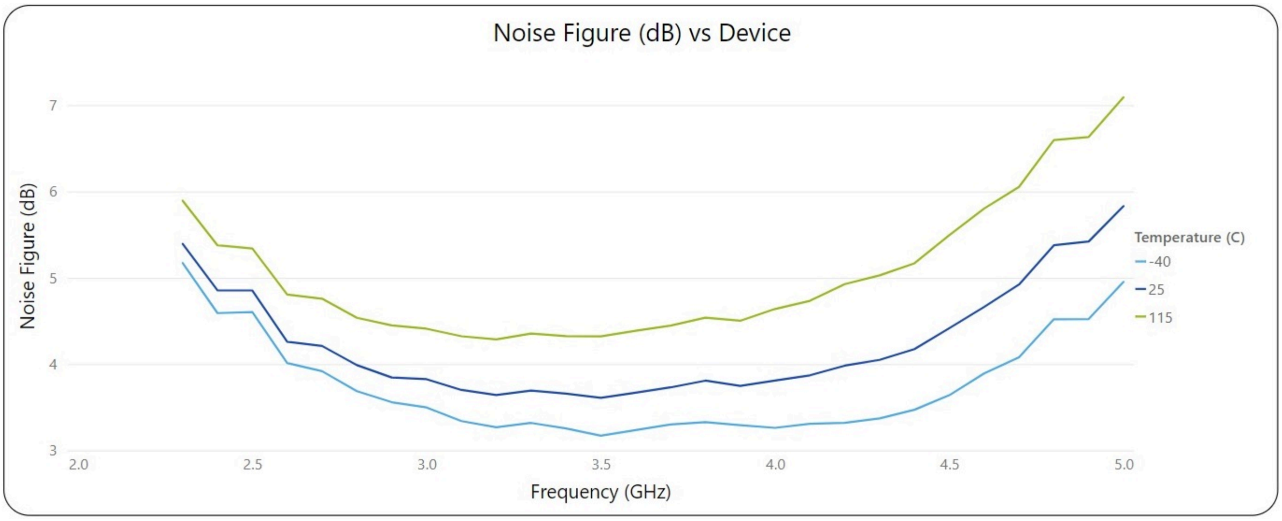

Figure 12. BTS6306U Noise Figure vs Frequency (typical values). V_{CC} = 5 V

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5.5 1dB compression power (output)

The OP1dB is measured using the setup shown in Figure 20.

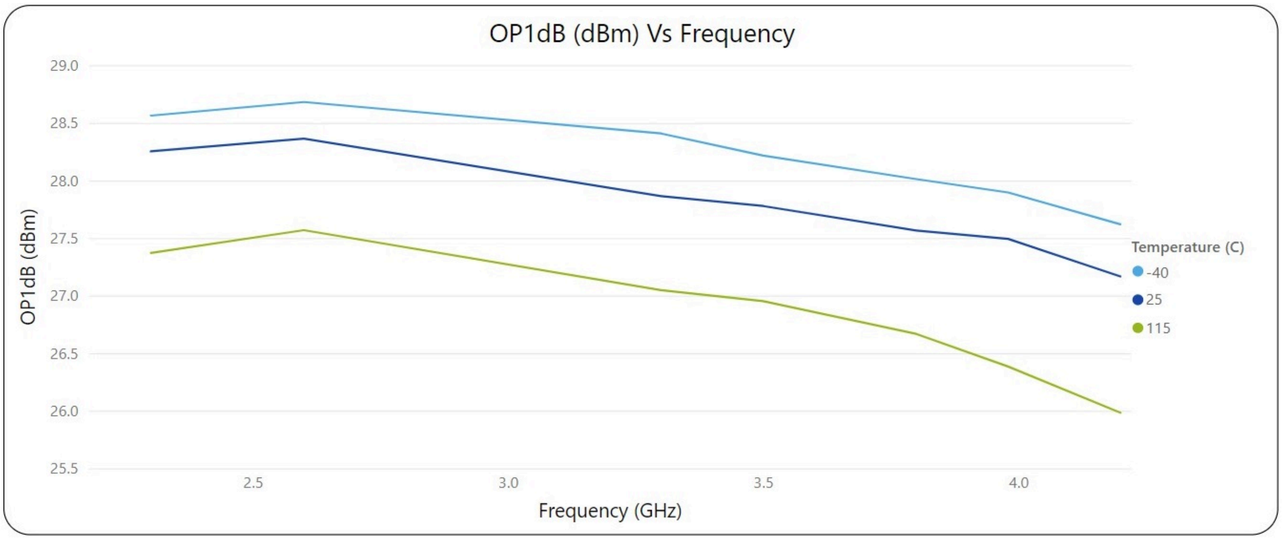

Figure 13. BTS6306U $P_{o(1dB)}$ versus Frequency (typical values). V_{CC} = 5 V

5.6 Third order intercept point

$IP3_o$ is measured using the setup shown in Figure 21.

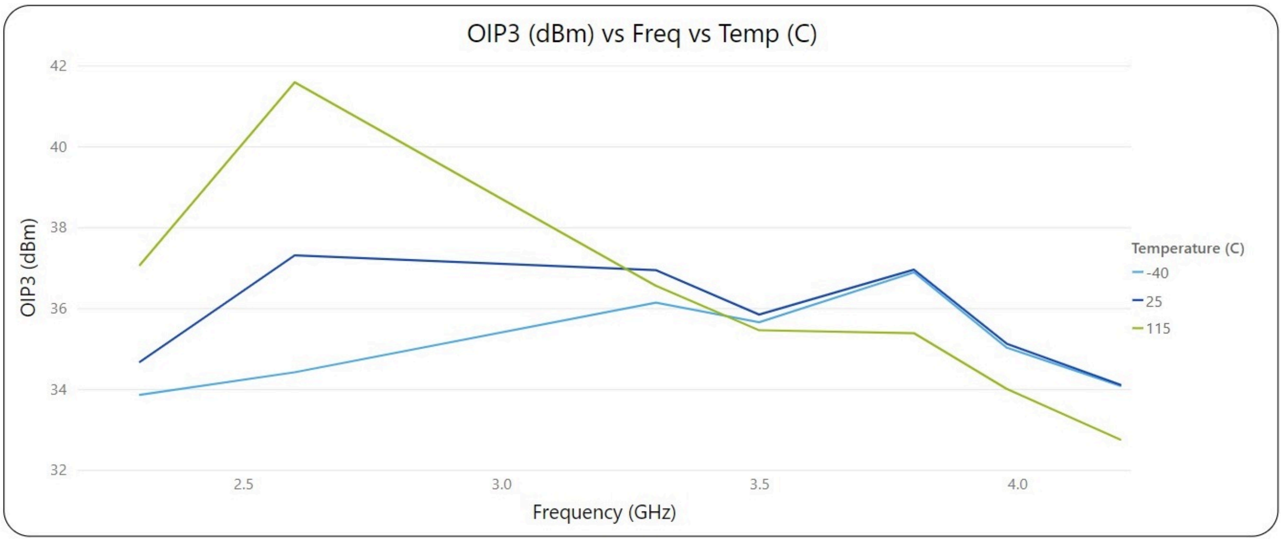

Figure 14. BTS6306U $IP3_o$ at 100 MHz spacing output tone power 12 dBm

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5.7 ACLR under DPD

In the TX line ups for mMIMO, Digital Pre-Distortion (DPD) is applied to linearize the final stages. So efficiency, and linearity-related parameters such as EVM are improved, after DPD is executed.

To what extent the BTS6306U must be predistorted depends on factors like, applied output power, and crest factor at the BTS6306U. As an example, the BTS6306U ACLR is measured at given Pout with and without applying DPD to note the differences.

The DPD engine applied is similar to DPD models found in n-MiMO g-nodeB (downlink signal path) to linearize Doherty PA's.

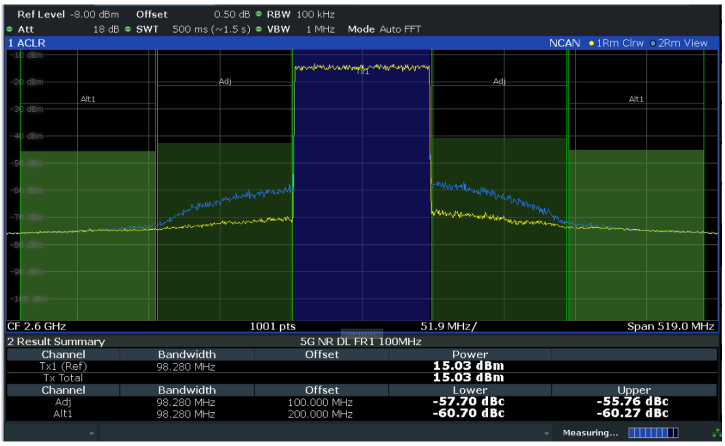

Figure 15. BTS6306U ACLR DPD versus none-DPD at 2.6 GHz center frequency and P_O = 15 dBm, CF 10 dB

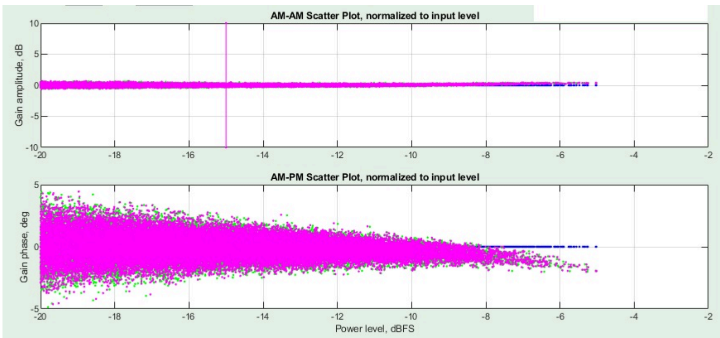

Figure 16. BTS6306U AMAM and AMPM at 2.6 GHz, 100 MHz IBW, 10 dB PAR.

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5.7 ACLR under DPD...*continued*

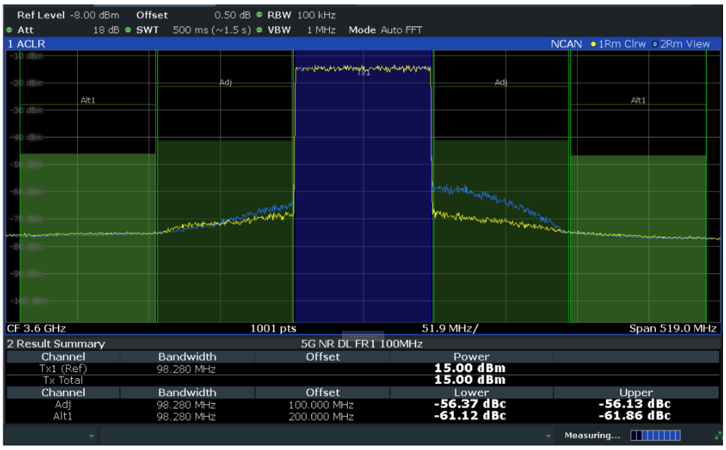

Figure 17. BTS6306U ACLR DPD versus none-DPD at 3.6 GHz center frequency and P_O = 15 dBm, CF 10 dB

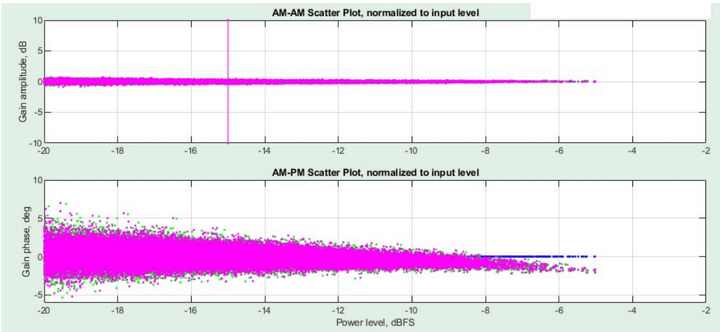

Figure 18. BTS6306U AMAM and AMPM at 3.6 GHz, 100 MHz IBW, 10 dB PAR

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5.8 Required Equipment

For the BTS6306U evaluation, the following equipment is needed as a base-line:

- 1 DC power supply 5 V, 200 mA (V_{CC1}, and V_{CC2})
- 1 DC power supply 1.8 V, 5 mA (V_{EN}), or a pulse generator in case pulsed measurements are required
- A suitable Balun like: Krytar model 4020080. See Figure 19
- A network analyzer for S-parameter, and P_{1dB} measurements. In case the NA is a 4-port version, 2 ports can be defined as differential outputs, in this case a Balun is not required. When the 2 ports are defined as differential outputs S-parameters, and the differential mode-related parameters can be evaluated
- 2 RF generators up to 12 GHz plus a combiner for IP3 measurements
- A spectrum analyzer with NF option for IP3, Noise figure measurements and ACLR
- High Quality RF cables with SMA/3.5 mm RF connectors
- DC currents meters.

Figure 19. Example of the Balun used for the different measurements

V_{CC1} and V_{CC2} can be combined and fed to the 5 V PSU. After switching on the power supply, the BTS6306U comes up in the quiescent current. 1.8 V_{EN} must be applied.

If necessary, to switch on the power supplies separately the preferable start-up sequence is as follows.

First switch on V_{CC1} second V_{CC2} and third V_{EN}.

Note: *If you want to switch on V_{CC1}, and V_{CC2} separately an extra 5 V, 200 mA power supply is required.*

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5.9 Connection and setup

1. Connect the EVB to a calibrated network analyzer see Figure 20, we advise the following settings for S-parameter measurements:
   a. Port power -25 dBm
   b. IF Bandwidth 100 Hz
2. The network analyzer can also be used for the 1 dB gain compression evaluation, for this evaluation we advise the following NWA setting
   a. Port 1 power sweep -30 dBm up to -10 dBm
   b. Port 2 20 dB attenuation on the receiver port b2.
   c. IF Bandwidth 100 Hz.
3. Gain and P_{1dB} gain compression data can also be determined using an RF generator and spectrum analyzer.
4. Turn on the DC power supplies and it should read typical I_{cc} = 100 mA.
5. Nonlinear distortion measurements IP3 can be performed with a set-up like is depicted in Figure 21. The following settings are recommended to perform the IP3 evaluation.
   a. -20 dBm for each fundamental tone.
   b. RBW and VBW of the spectrum analyzer 100 Hz
   c. Tone spacing 100 MHz

Table 4. Evaluation measurement setups

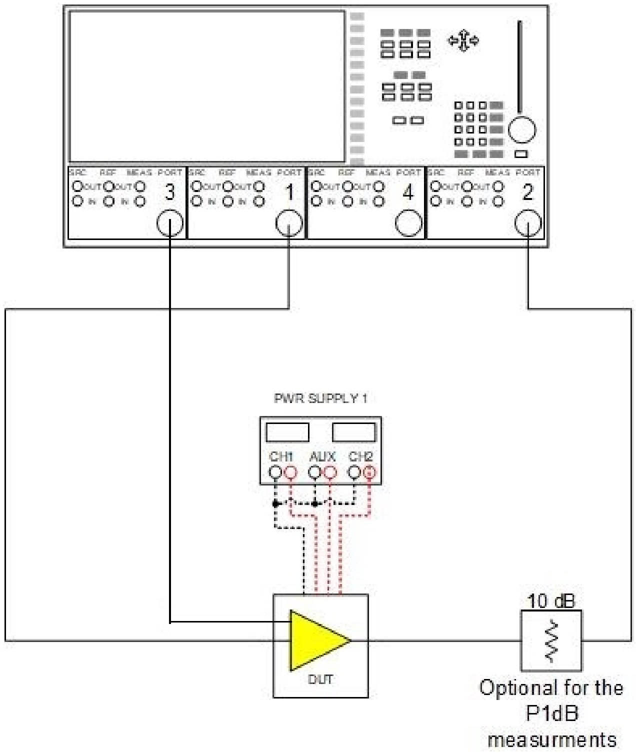

Figure 20. S-parameter and P_{1dB} gain compression setup

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Table 4. Evaluation measurement setups*...continued*

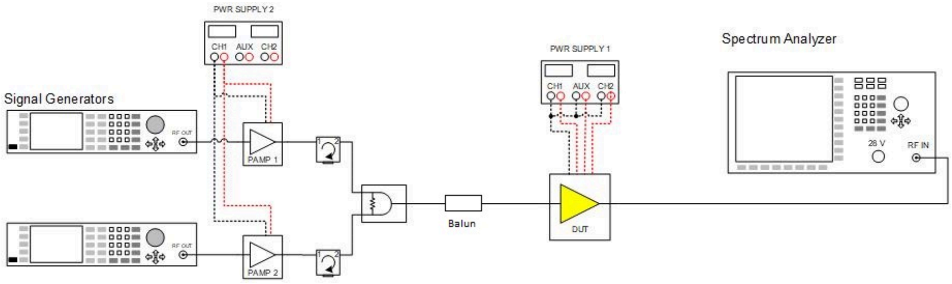

Figure 21. Third order intercept point measurement setup

6 Revision history

Table 5. Revision history

Document ID	Release date	Description
AN14043 Rev. 2.1	15 April 2024	• Updated Legal information and brought to current standard
AN14043 Rev. 2.0	2 October 2023	• Updated text in Section 4 • Updated Figure 3 • Updated text in Section 4.2 • Updated text in Section 5.2 • Added f = 3.5 GHz to Figure 11 title • Updated text in Section 5.7 • Updated text in Section 5.8 • Updated text in Section 5.9
AN14043 Rev. 1.0	8 September 2023	• Initial release of application note

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