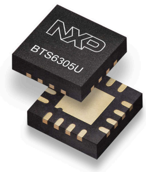
AN13899

BTS6305U Evaluation Board Application Note

Rev. 1.1 — 15 April 2024

Application note



1 Introduction

This application note focuses on the BTS6305U 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 BTS6305U.

The Customer Evaluation Kit contains the following items:

- BTS6305U EVB
- 5 samples

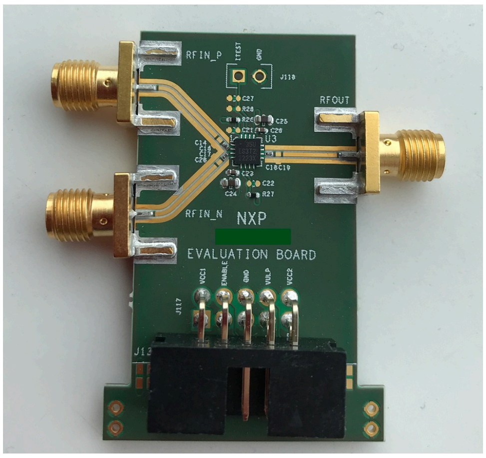


Figure 1. BTS6305U customer evaluation board (EVB)

2 Ordering information

Table 1. Ordering information

Description	Part name	Ordering 12NC
BTS6305U Customer Evaluation Kit	OM1715/BTS6305U	9354 533 61598

3 Product description

The BTS6305U is a wideband high linearity pre-driver amplifier with differential input 2.3 GHz - 4.2 GHz for infrastructure applications, with fast on-off switching to support TDD systems and differential input. The amplifier is designed to operate between 2.3 GHz and 4.2 GHz. The BTS6305U is housed in a 3 mm x 3 mm x 0.85 mm 16-terminal HVQFN package.

- High saturated output power $P_{o(sat)}$ = 29 dBm
- High power-gain G_p = 39.5 dB
- High linearity performance ACLR = -42 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

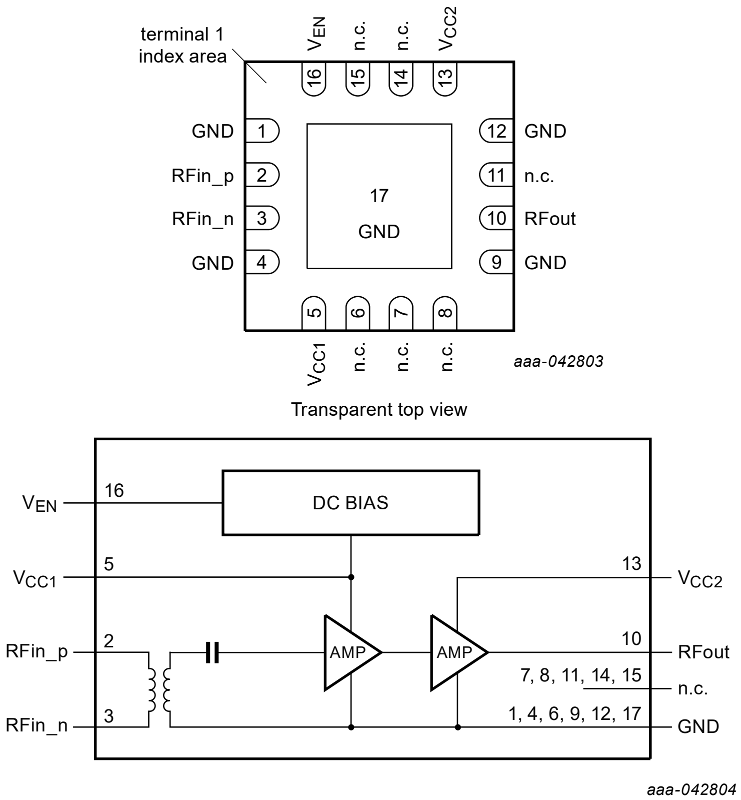


Figure 2. BTS6305U pin configuration and functional diagram

4 Application board

The BTS6305U 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 Balun is required or one input way be terminated compromising gain. 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 BTS6305U 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 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.

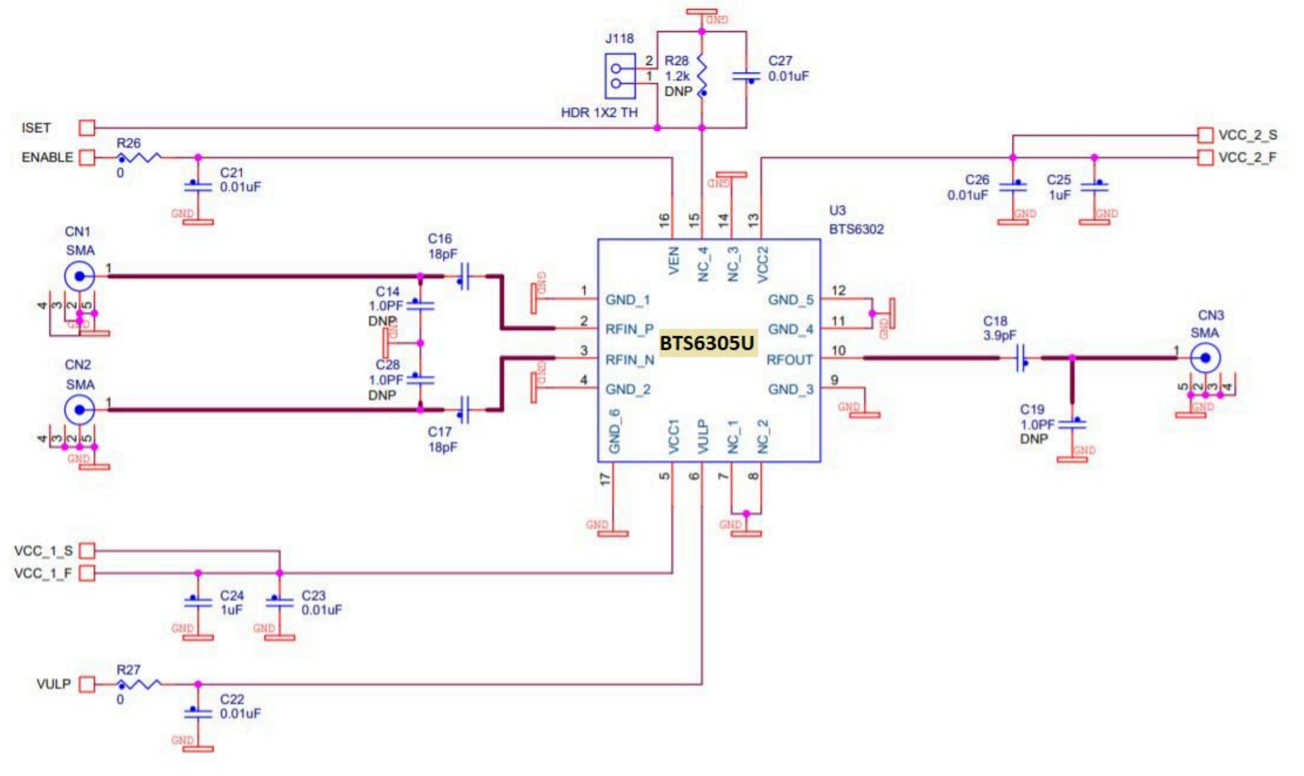


Figure 3. Application board circuit diagram

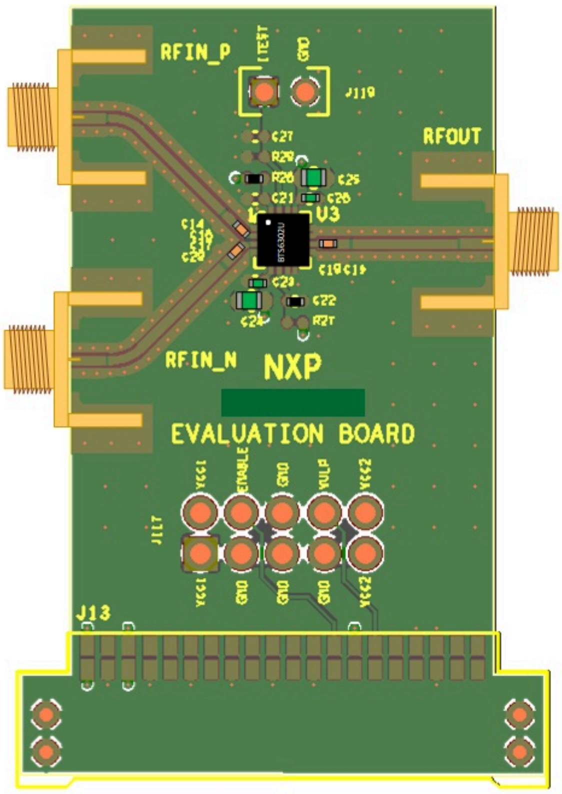
The differential RF input (RFin_P, RFin_N) is supplied via CN1 and CN2. Output signals can be applied via SMA connector CN3. Capacitors C16, C17, and C18 are DC-blocking capacitors. Although the RF input ports are DC free, blocking capacitors are recommended in order not to short both differential inputs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

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 BTS6305U can serve as a guideline for laying out a board using the BTS6305U.
- 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.
- In this report as well as in the data sheet the value of C16, and C17 are stated as 18 pF. The values of these capacitors are critical for power on/off settling time. In case the value for those capacitors is increased significantly the switching time is affected.
- 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 BTS6305U 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

4.2.1 Evaluation board layout



V_{ULP} is not used in this application.

Figure 4. BTS6305U evaluation board layout and component

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.

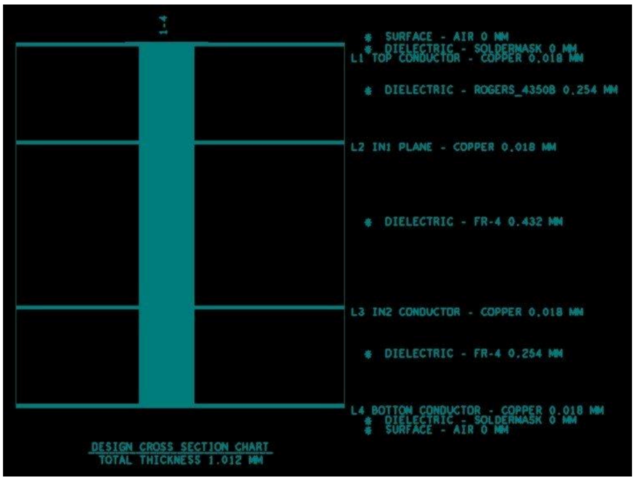


Figure 5. Cross section of the PCB Layer stack

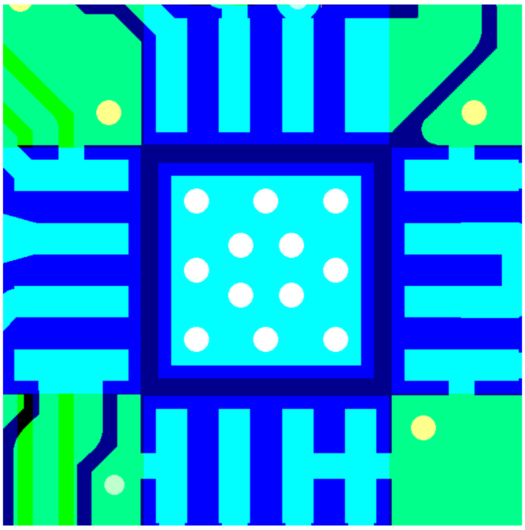


Figure 6. Recommended footprint

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	BTS6305U				
PCB	26 mm x 48 mm x 1 mm				RO4350
C14, C19, C28	capacitor	0402	n.a.		for experimenting only
C16, C17	capacitor	0201	18 pF	Murata	DC block
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

5 Evaluating the BTS6305U

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 BTS6305U 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}.

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	-	122	150	mA
		ON state, quiescent	-	100	125	mA
		OFF state	-	1.2	2.5	mA
G_p	power gain	ON state				
		f = 2.6 GHz,	36	38.5	41	dB
		f = 3.5 GHz,	37	39.5	42	dB
		f = 4.2 GHz,	34	36.5	39	dB
		OFF state	-	-49	-47	dB
G_{flat}	gain flatness	f = 2.4 GHz to 2.7 GHz	-	1.4	-	dB
		f = 3.3 GHz to 3.8 GHz	-	1.3	-	dB
		f = 3.8 GHz to 4.2 GHz	-	1.9	-	dB
$t_{d(grp)}$	group delay time	f = 2.4 GHz to 2.7 GHz	-	0.4	0.5	ns
		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 = 2.6 GHz	-	29	-	dBm
		f = 3.5 GHz	26	29	-	dBm
		f = 4.2 GHz	-	28.5	-	dBm
$P_{L(1dB)}$	output power at1 dB gain compression	f = 2.6 GHz	-	28	-	dBm
		f = 3.5 GHz	-	28.5	-	dBm
		f = 4.2 GHz	-	27.5	-	dBm
$IP3_o$	output third-order intercept point	2-tone; tone spacing = 100 MHz; P_o = 15 dBm	-	33	-	dBm
CMRR	common mode rejection ratio	f = 2.6 GHz	22	28	-	dB
		f = 3.5 GHz	22	31	-	dB
		f = 4.2 GHz	22	31.5	-	dB
RL_i	input return loss	f = 2.6 GHz	10	13	-	dB
		f = 3.5 GHz	10	13.5	-	dB
		f = 4.2 GHz	10	14	-	dB
RL_o	output return loss	f = 2.6 GHz	10	21	-	dB
		f = 3.5 GHz	10	14	-	dB
		f = 4.2 GHz	10	15	-	dB
ISL_r	reverse isolation		-	80	-	dB

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
NF	noise figure	f = 2.6 GHz [1]	-	4	-	dB
		f = 3.5 GHz [1]	-	4	-	dB
		f = 4.2 GHz [1]	-	3.5	-	dB
$t_{s(pon)}$	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	-	0.7	0.8	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 100 MHz channel BW, QPSK modulation, and 60 kHz SCS, fully allocated, P_o = 15 dBm	-	-42	-	dBc

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

5.2 S-parameters

The measured S-parameters and Rollett stability factor K, are given in the graphs below. For the measurements, a typical BTS6305U EVB is used. All the S-parameter measurements have been carried out using the setup Figure 20.

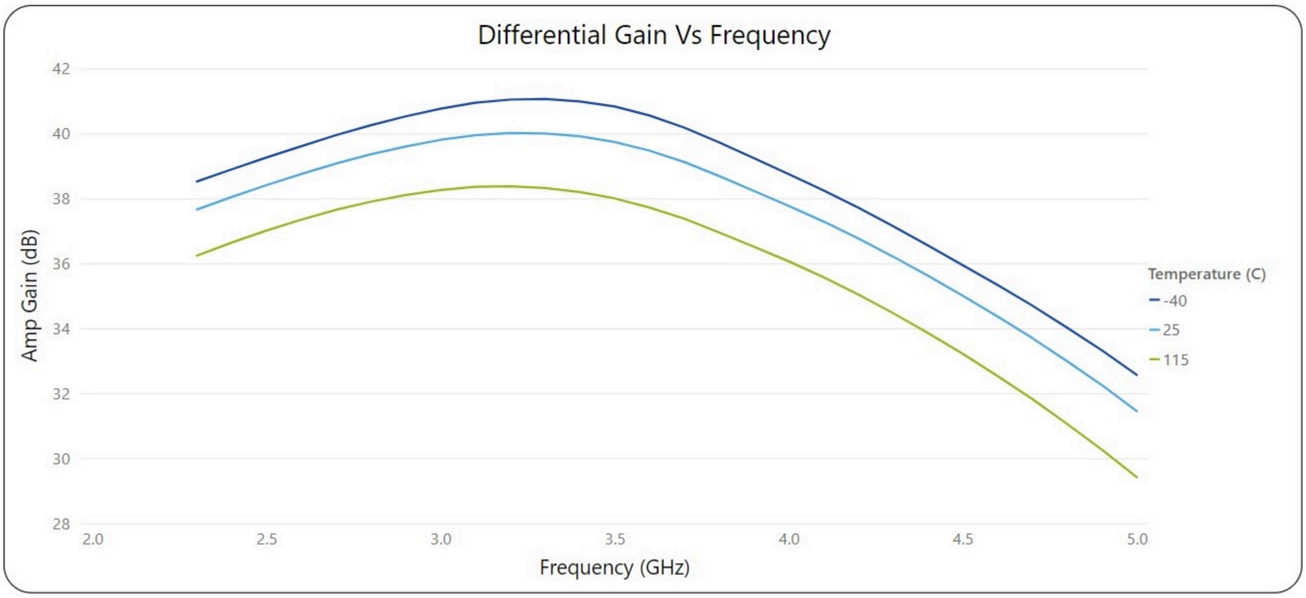


Figure 7. BTS6305U differential gain (typical values). VCC = 5 V, Pi = -25 dBm

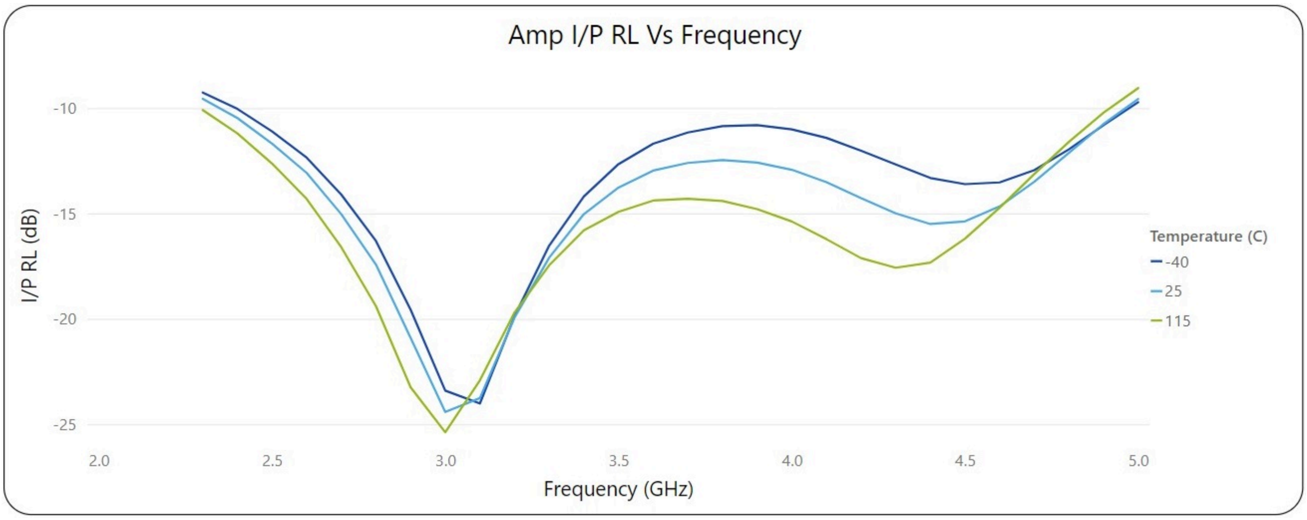


Figure 8. BTS6305U differential RLi (typical values). VCC = 5 V, Pi = -25 dBm

5.2 S-parameters...*continued*

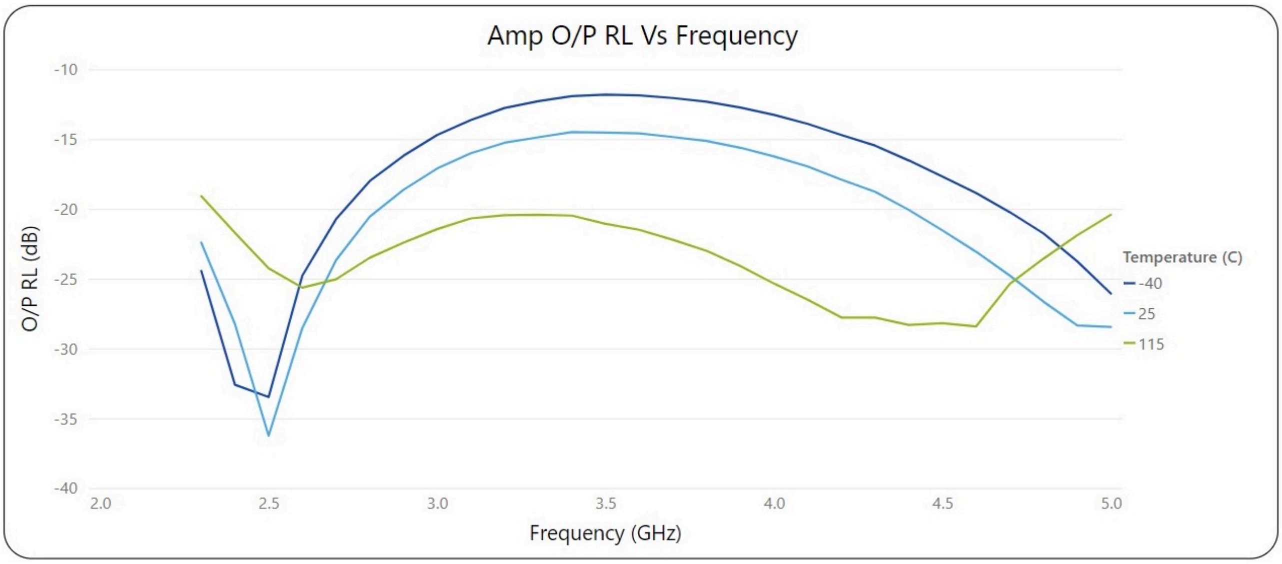


Figure 9. BTS6305U RL_o (typical values). V_{CC} = 5 V, P_i = -25 dBm

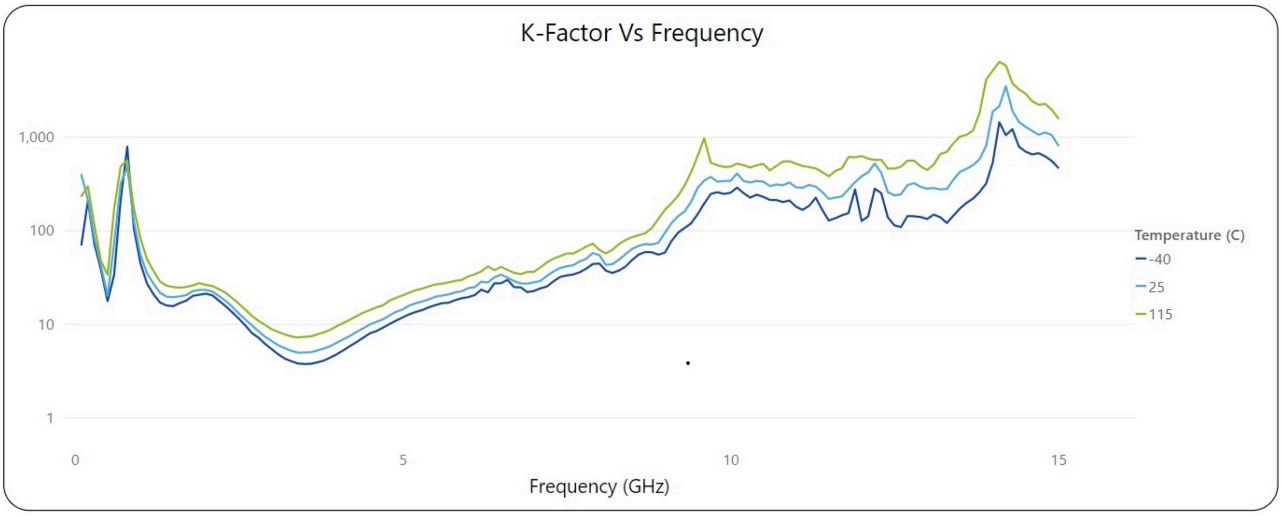


Figure 10. BTS6305U K-factor (typical values). V_{CC} = 5 V, P_i = -25 dBm

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.

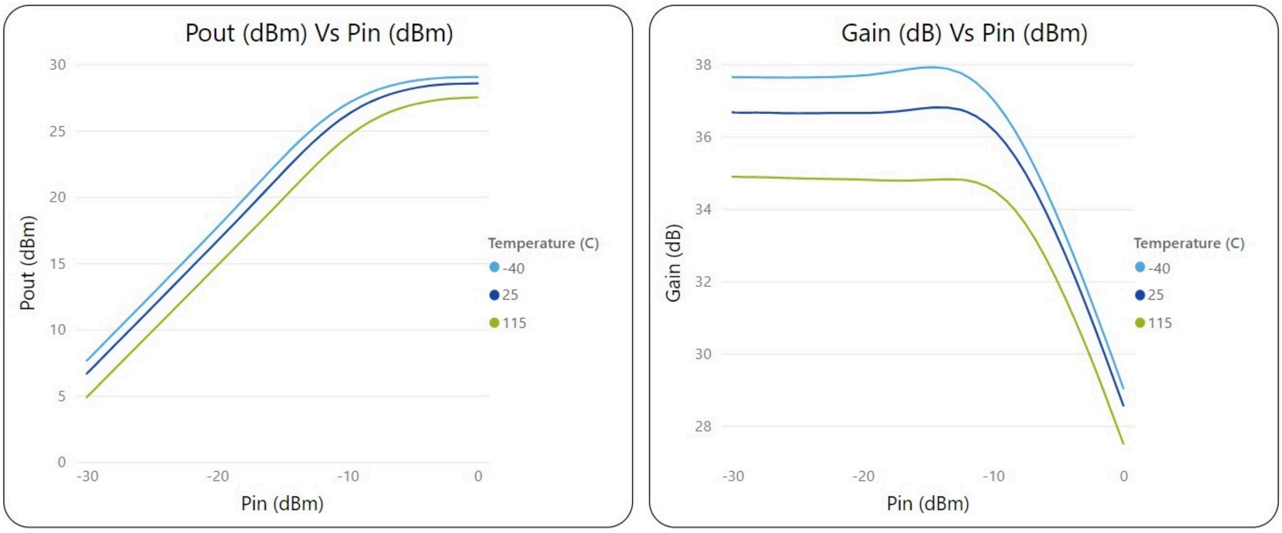


Figure 11. Pout, and Gain versus input power (typical values). V_{CC} = 5 V

5.4 Noise Figure

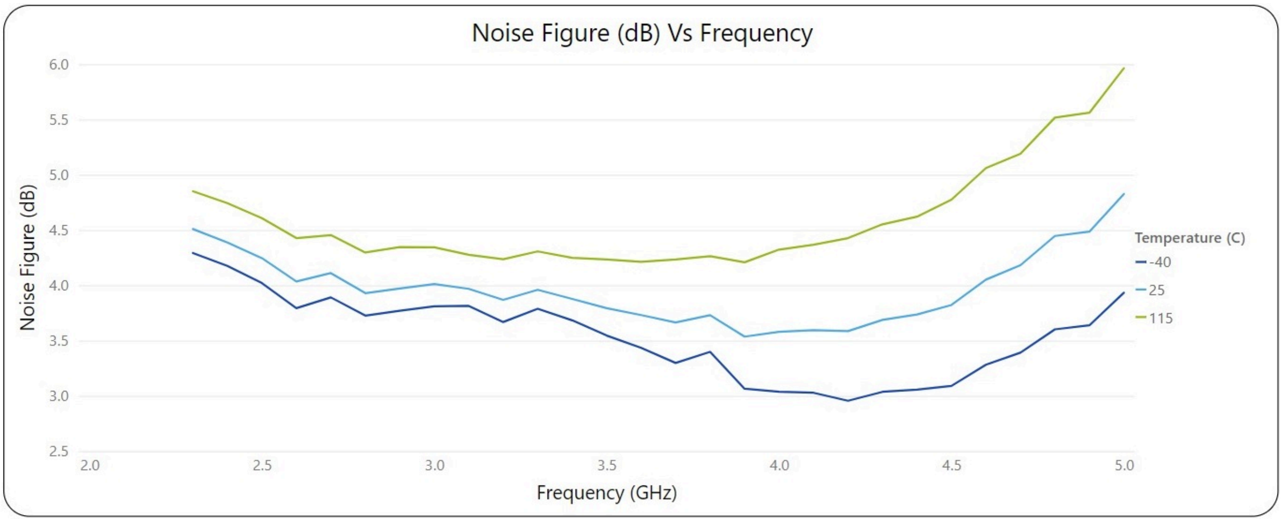


Figure 12. BTS6305U Noise Figure vs Frequency (typical values). V_{CC} = 5 V

5.5 1dB compression power (output)

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

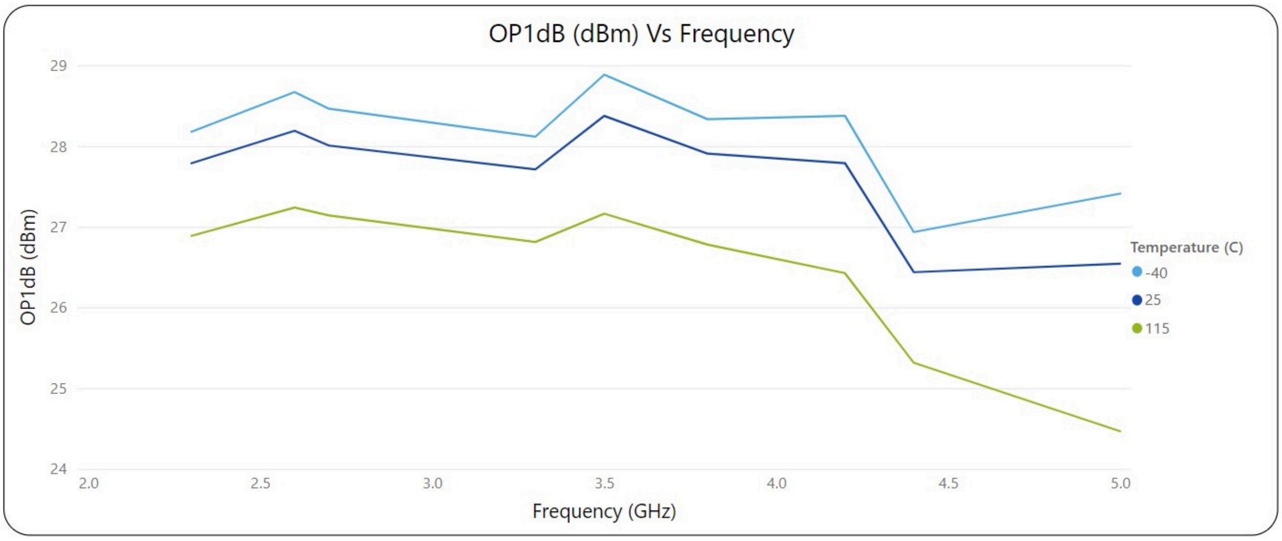


Figure 13. BTS6305U $P_{o(1dB)}$ versus Frequency (typical values). V_{CC} = 5 V

5.6 Third order intercept point

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

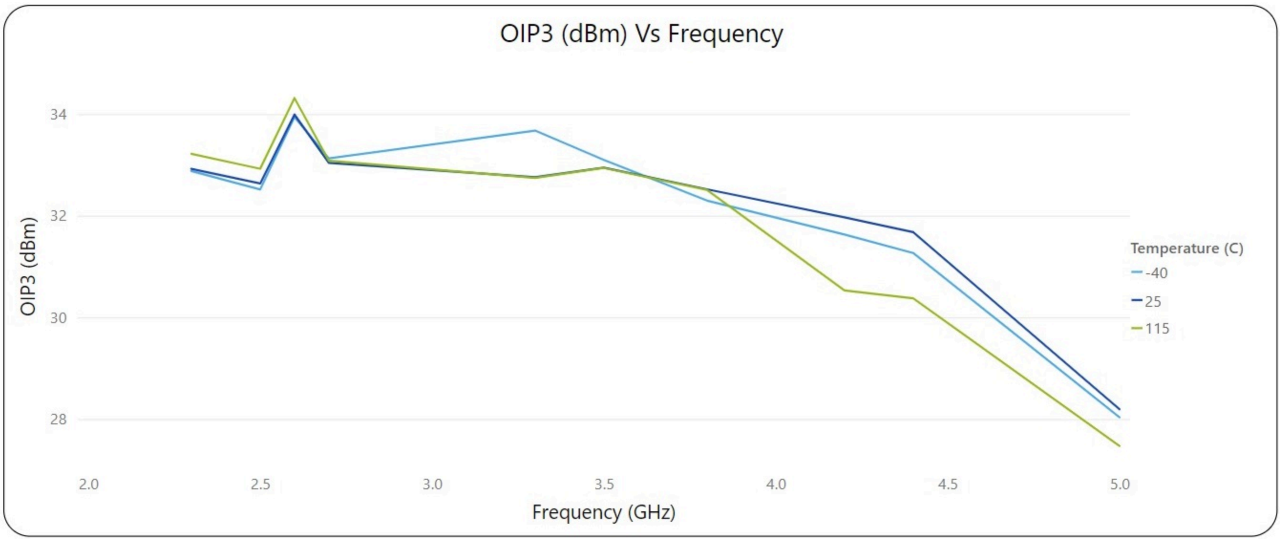


Figure 14. BTS6305U $IP3_o$ at 100 MHz spacing output tone power 12 dBm

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 extend the BTS6305U must be predistorted depends on factors like, applied output power, and crest factor at the BTS6305U. As an example, the BTS6305U is measured on ALCR 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.

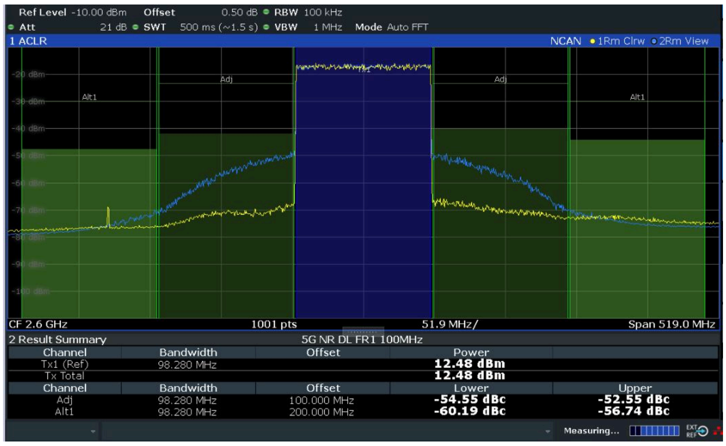


Figure 15. BTS6305U ACLR DPD versus none-DPD at 2.6 GHz center frequency and P_o = 15 dB, CF 11.7 dB

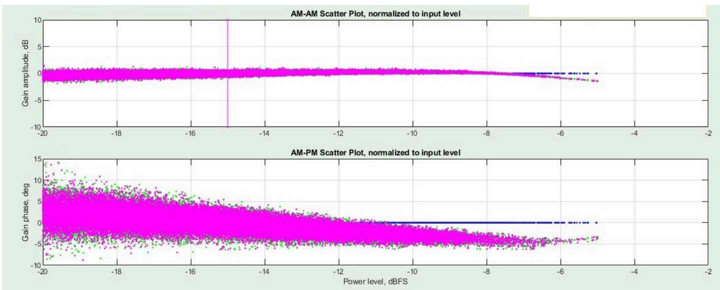


Figure 16. BTS6305U AMAM and AMPM at 2.6 GHz, 100 MHz IBW, 10 dB PAR.

5.7 ACLR under DPD...*continued*

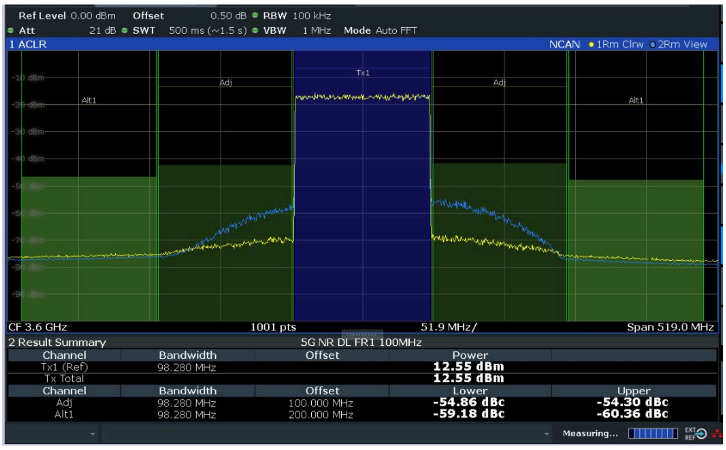


Figure 17. BTS6305U ACLR DPD versus none-DPD at 3.6 GHz center frequency and P_o = 15 dBm, CF 11.7 dB

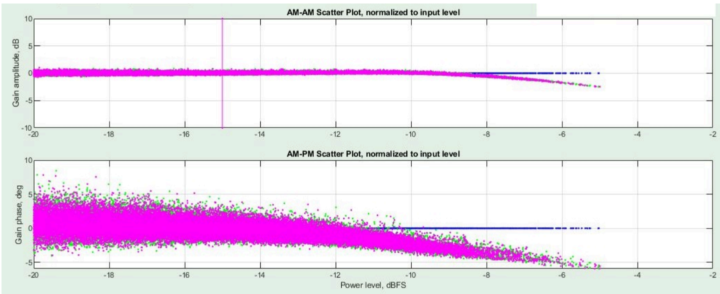


Figure 18. BTS6305U AMAM and AMPM at 3.6 GHz, 100 MHz IBW, 10 dB PAR

5.8 Required Equipment

For the BTS6305U 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 and Noise figure measurements
- 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 BTS6305U 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 you need an extra 5 V, 200 mA power supply.*

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} = ? 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

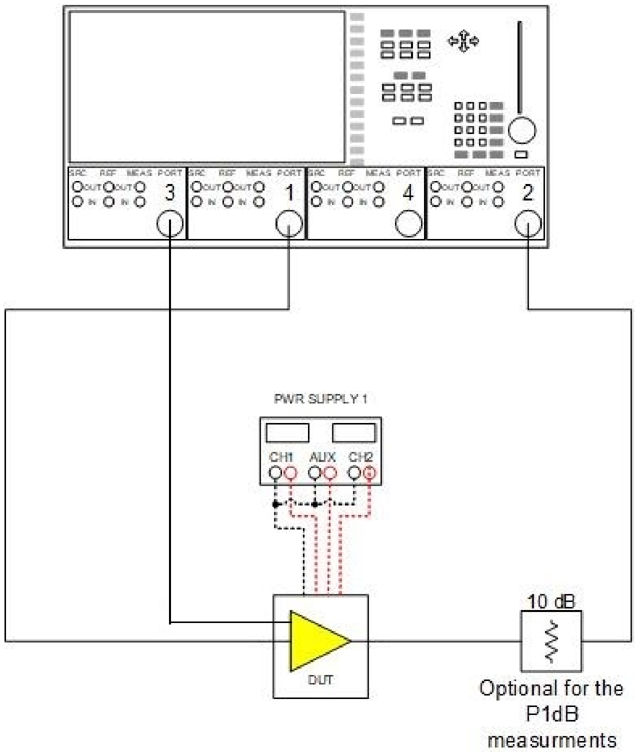


Figure 20. S-parameter and P_{1dB} gain compression setup

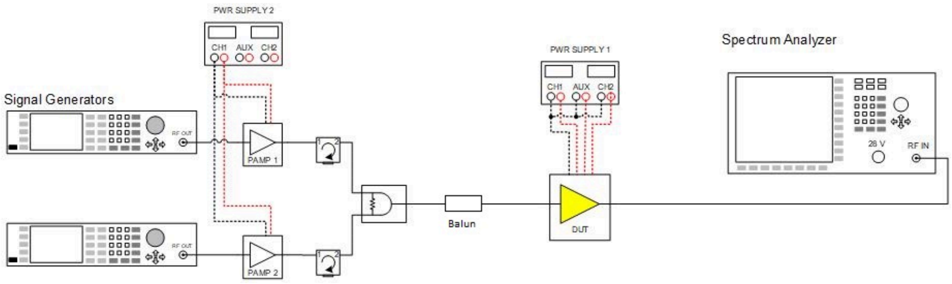


Figure 21. Third order intercept point measurement setup

6 EMC information

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.

7 Revision history

Table 5. Revision history

Document ID	Release date	Description
AN13899 Rev. 1.1	15 April 2024	• Updated Legal information and brought to current standard
AN13899 Rev. 1.0	1 May 2023	• Initial release of application note

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