

AN12826

BTS6201U evaluation board application note

Rev. 1.2 — 23 February 2021

Application note

Document information

Information	Content
Keywords	BGU6201U, 5G NR TX pre driver, Massive MIMO.
Abstract	This application note describes the design considerations/choices for the product evaluation board (EVB) and gives an overview of the typical performance as measured on the EVB. The BTS6201U is a wideband, high linearity, pre-driver amplifier for 5G massive MIMO infrastructure applications. To enable easy evaluation of the product, the EVB is supplied with all necessary connectors.



1 Front matter

Revision history		
Rev	Date	Description
1.0	20200710	Initial document
1.1	20200721	Small updates after review.
1.2	20210223	Updates at CQS gate.

2 Introduction

NXP semiconductors BTS6201U is a wideband high linear pre-driver amplifier for 5G, sub 6 GHz, massive MIMO infrastructure applications, with fast on-off switching to support TDD systems. The BTS6201U is designed to operate between 2.3 GHz and 4.2 GHz.

Being manufactured in NXP's high performance QUBiC RF Gen 8 SiGeC technology, the BTS6201U combines high gain, high linearity with process stability and ruggedness, which are the characteristics of the SiGeC technology.

This application note focuses on the BTS6201U evaluation board, the application diagram, board layout, bill of materials and control signals are described.

Refer to the data sheet for the detailed RF performance of the BTS6201U. The Customer Evaluation Kit (CEK) contains the following items:

- BTS6201U EVB
- DC supply cables

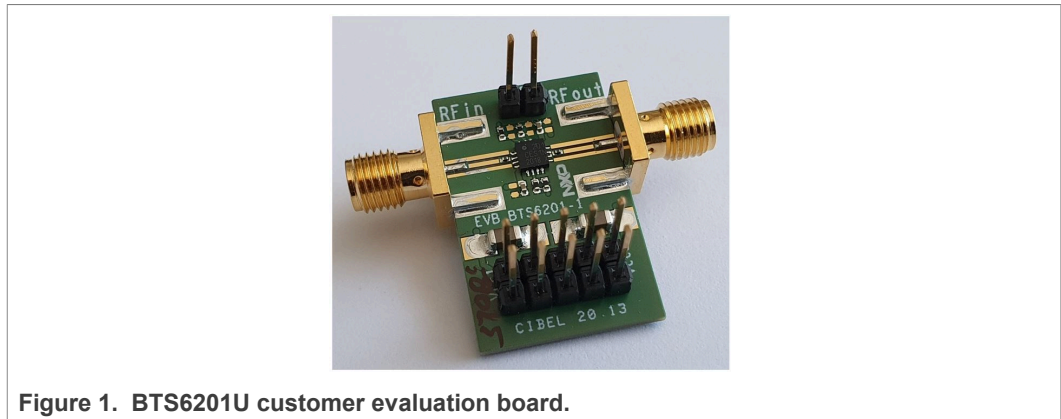


Figure 1. BTS6201U customer evaluation board.

2.1 Ordering information

Table 1. Ordering information

Description	Type	ordering 12NC
BTS6201UCustomer Evaluation Kit (CEK)	OM17076	9354 046 28598

3 Product description

The BTS6201U is a wideband, high linearity, pre-driver amplifier for 5G massive MIMO infrastructure applications, with fast on-off switching to support TDD systems. The amplifier is designed to operate between 2.3 GHz and 4.2 GHz. BTS6201U comes in the industry standard 3 mm × 3 mm × 0.85 mm 16 terminal plastic thin small outline package HVQFN16 (SOT758-1). The amplifier is ESD protected on all terminals.

The BTS6201U key features and benefits are listed below.

- High saturated output power $P_{o(sat)} = 27$ dBm
- High power-gain $G_p = 29$ dB
- High linearity performance ACLR = -46 dBc
- Unconditionally stable
- Programmable bias current (via external resistor)
- Fast switching to support TDD systems
- 5 V single supply, quiescent current 78 mA
- Small 16-terminal leadless package 3 mm × 3 mm × 0.85 mm
- ESD protection on all terminals
- Moisture sensitivity level 1

BTS6201U Pinout and Functional diagram

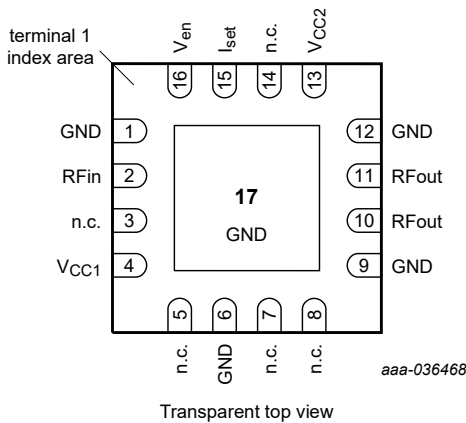


Figure 2. Pinout

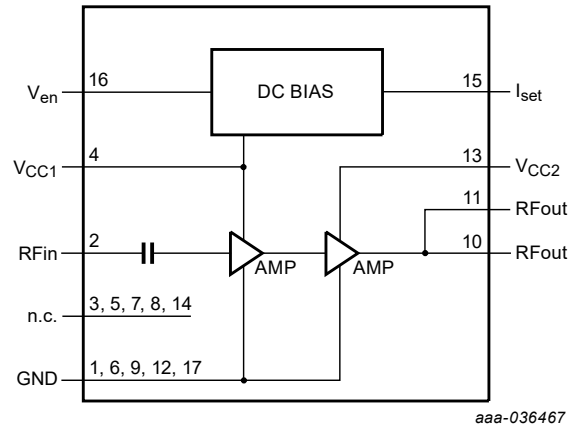


Figure 3. Functional diagram

4 Application board

The BTS6201U evaluation board simplifies the RF evaluation of the BTS6201U. The evaluation board enables testing the device RF performance, in an isolated environment, and requires no additional support circuitry. To de-embed applied RF connectors, and transmission lines up to the input and output DC blocking capacitors de-embedding data is available on request. Input and output track are symmetrical.

The BTS6201U evaluation board is fabricated on a 28 mm x 17 mm x 1 mm thick 3 layer PCB. The 0.3 mm top layer uses TU-862 for optimal RF performance. The board is fully assembled according to the schematic shown below. The board is supplied with two 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 5](#).

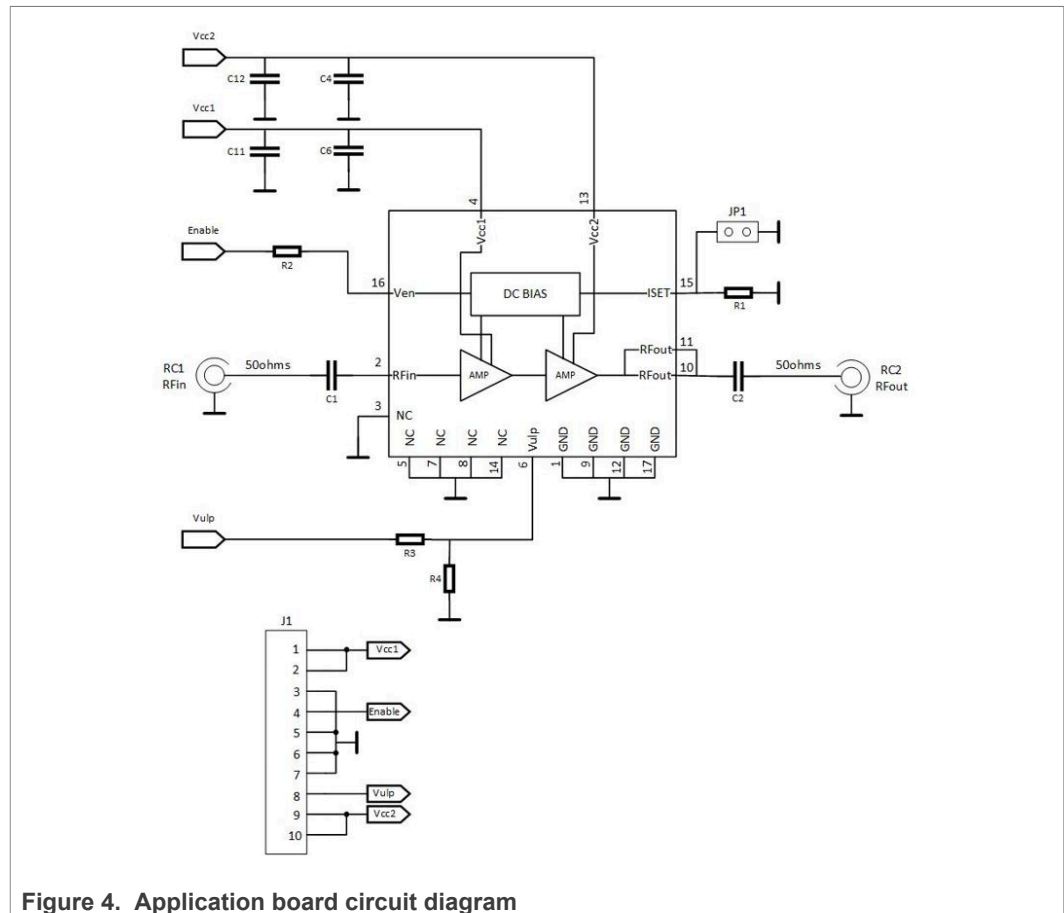


Figure 4. Application board circuit diagram

The RF input and output signals can be applied via SMA connector RC1 and RC2, capacitors C1 and C2 are DC-blocking capacitors.

The evaluation board is supplied with a 1.2 kΩ I_{set} resistor R1. Adding R1 results in a quiescent current of ~78 mA.

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 BTS6201U can serve as a guideline for laying out a board using the BTS6201U.
- 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 by C5 and C11 and C4 and C12 decoupling capacitors respectively. C5, C11 and C4, C12 decoupling capacitors respectively bypass V_{CC1} and V_{CC2} . C4 and C5 preferably 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 C1 and C2 are stated as 18 pF. The values of C1 and C2 are critical for power on/off settling time. In case the value for those capacitors is increased significantly the switching speed 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 BTS6201U evaluation board is given in [Figure 5](#)
- Resistor R2 in the Enable Line on EVB is chosen to be 0 Ω . For current limitations in the system application, it is recommended to use a R2 value of 2 k Ω .

4.2.1 Evaluation board layout

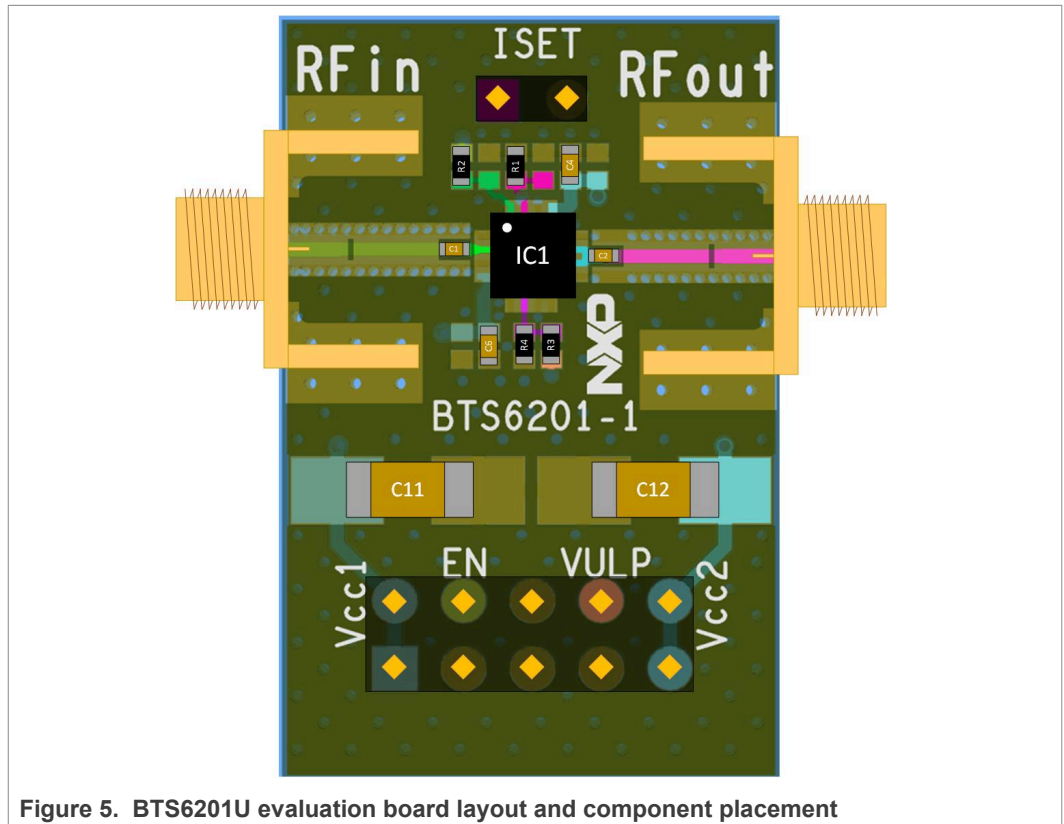


Figure 5. BTS6201U evaluation board layout and component placement

4.2.2 PCB stack and recommended footprint

The material stack-up used for the pre-driver circuit is a 0.3 mm TU-862 low RF loss layer, merged with a 0.7 mm FR4 layer. See Figure 6. The official drawing of the recommended footprint can be found via following link [SOT758-1.pdf](#). When micro strip coplanar PCB technology is used, it is recommended to use at least 12 ground-vias of 300 µm. These ground-vias are positioned in the ground plane under the device. This technique is also used on the EVBs as shown in Figure 7.

PCB stack and footprint information

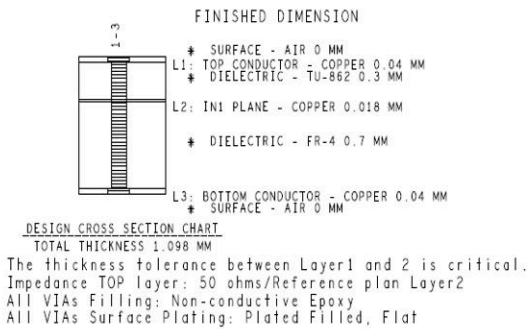


Figure 6. Cross section off the PCB layer stack

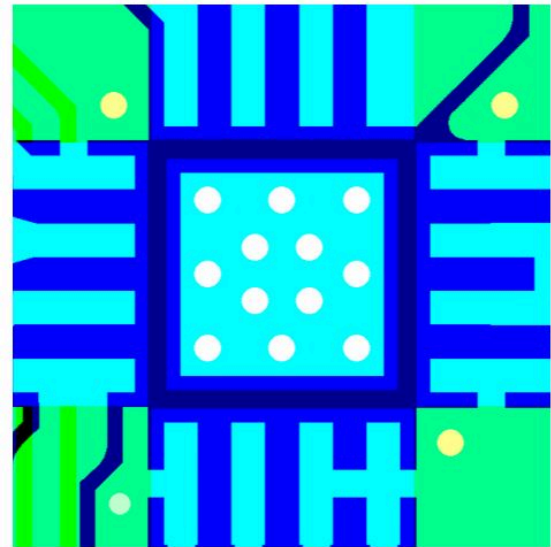


Figure 7. Recommended footprint

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	BTS6201U				
PCB	28x17x1mm				TU-862
C1, and C2	Capacitor	0201	18 pF	Various	DC block
C4, and C6	Capacitor	0402	10 nF	Various	RF decoupling
C11, and C12	Capacitor	1206	10 µF	Various	Optional
R1	Resistor	0402	1.2 kΩ	Various	Quiescent current setting
R2, R3, and R4	Resistor	0402	0 Ω	Various	Bridge
RC1, and RC2	SMA RF connector			Johnson, End launch SMA 142-0701-841	RF connections
JP1	Jumper			Molex, PCB header,	
J1	DC header			Molex, PCB header, straight, 2 row 5 way	DC connections

5 Evaluating the BTS6201U

All RF performance results given in the next chapters are referenced to the SMA connectors RC1 and RC2 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.

5.1 Typical results

For detailed performance of the BTS6201U, we refer to the device product data sheet.

Typical EVB performance

$V_{CC} = 5.0\text{ V}$; $V_{en}=1.8\text{ V}$; $T_{amb} = 25\text{ }^{\circ}\text{C}$; *input and output 50 Ω ; unless otherwise specified. All RF parameters have been characterized on the evaluation board described in this application note.*

Table 3.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
I_{CC}	supply current	$V_{en} 1.8\text{ V Pin-15 dBm}$		78.0		mA
G_P	power gain	2300 MHz 3500 MHz 4300 MHz		30.0 30.4 28.3		dB dB dB
$IP3_i$	Input third-order intercept point, tone spacing 100 MHz, $P_i = -15\text{ dBm}$	2300 MHz 3500 MHz 4300 MHz		36.5 35.5 34.0		dBm dBm dBm
$P_{L(1dB)}$	Output power at 1 dB gain compression	2300 MHz 3500 MHz 4300 MHz		26.1 27.1 26.1		dBm dBm dBm

5.2 S-parameters

The measured wideband S-parameters and Rollett stability factor K, are shown in the graphics in [Figure 8](#) to [Figure 11](#). The measured narrowband S-parameters and Rollett stability factor K, are shown in the graphics in [Figure 12](#) to [Figure 15](#). For the measurements, a typical BTS6201U EVB is used. All the S-parameter measurements have been carried out using the setup in [Figure 22](#).

BTS6201U wideband S-Parameters, and Rollett stability factor (typical values)

$V_{CC} = 5 V, P_i = -15 dBm$

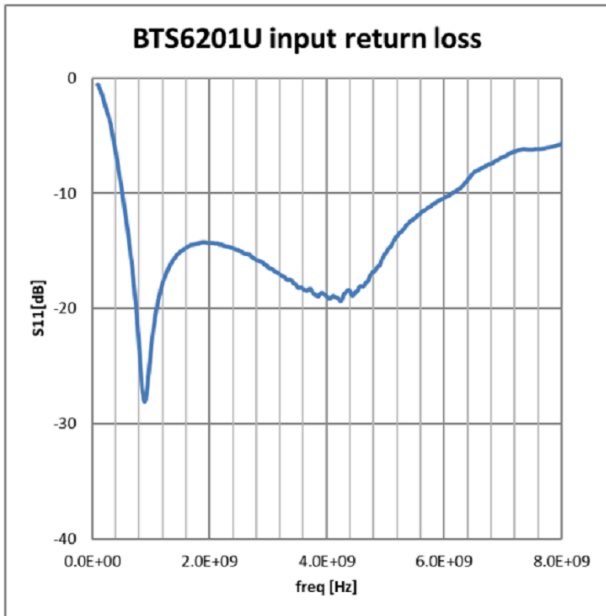


Figure 8. Input return loss

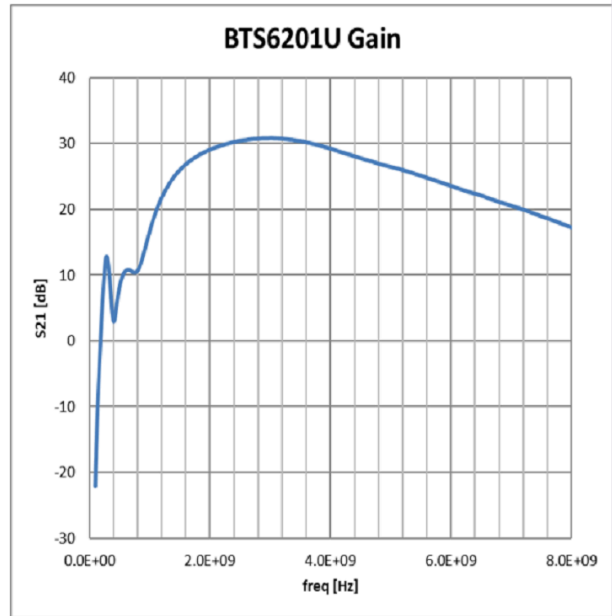


Figure 9. Gain wideband

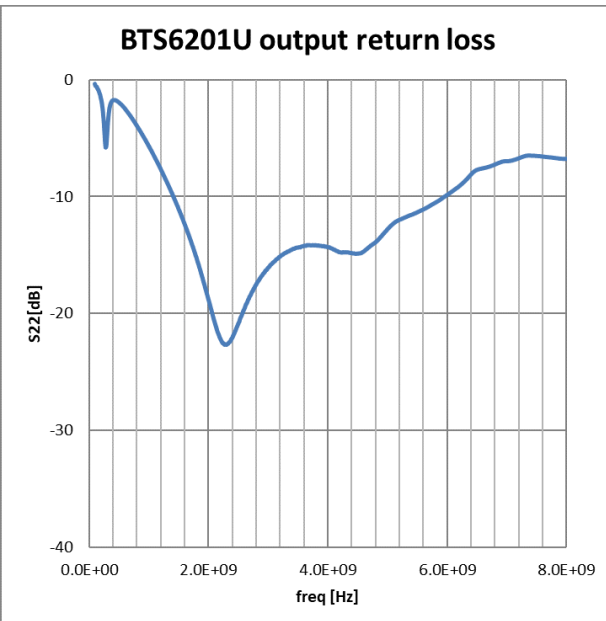


Figure 10. Output return loss

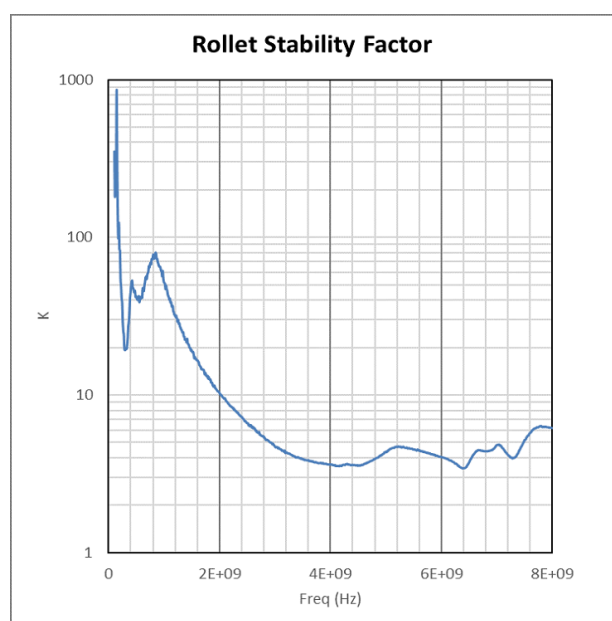


Figure 11. Rollett stability factor

BTS6201U narrowband S-Parameters, and Rollett stability factor (typical values)

$V_{CC} = 5\text{ V}$, $P_i = -15\text{ dBm}$

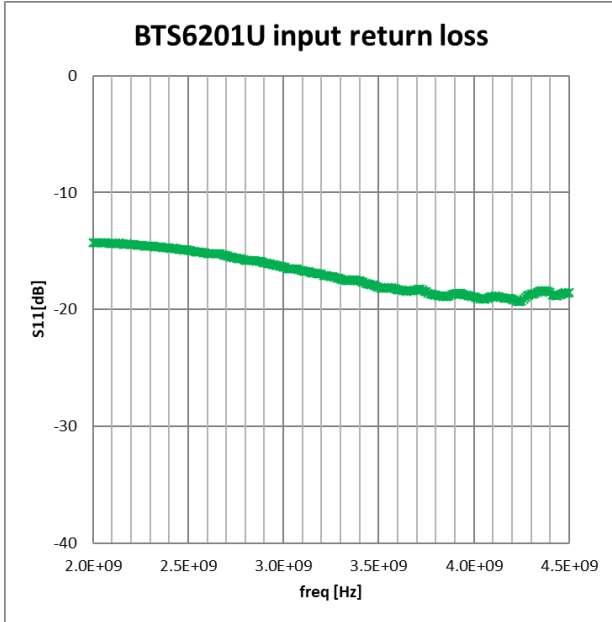


Figure 12. Narrowband Input return loss

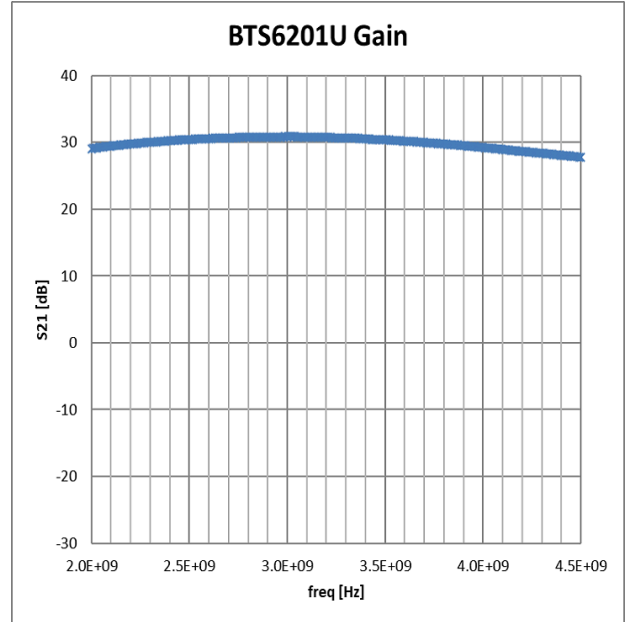


Figure 13. Narrowband gain

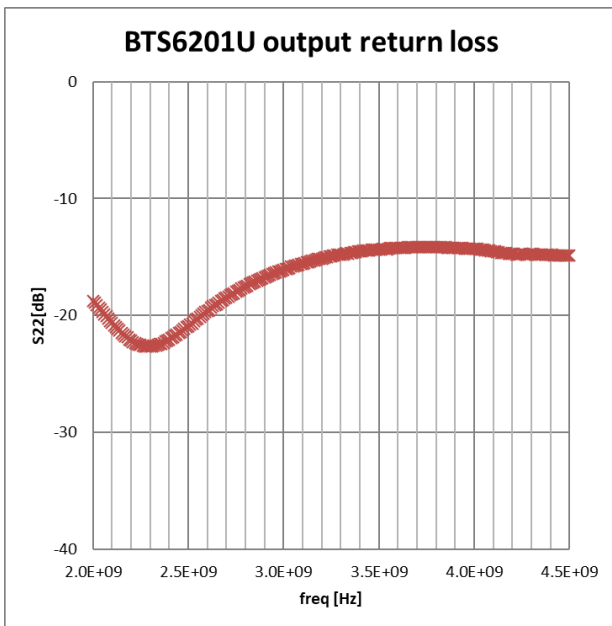


Figure 14. Narrowband output return loss

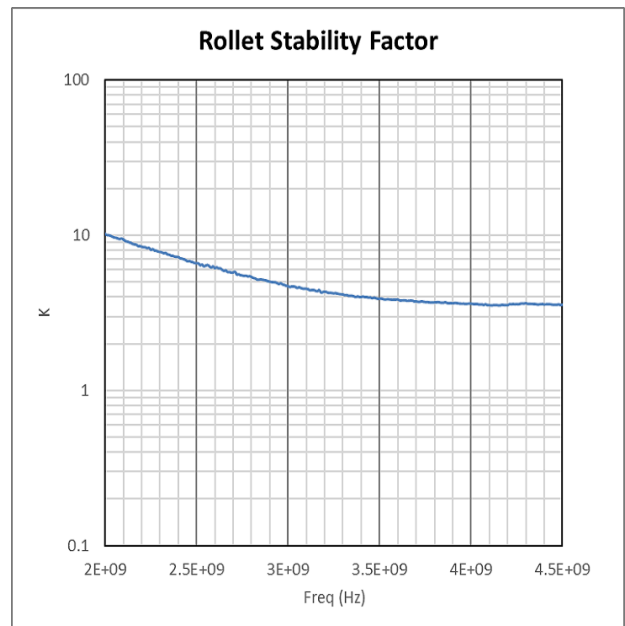


Figure 15. Rollett stability factor

5.3 1 dB Gain compression point

The 1 dB gain compression point has been measured using the set-up shown in [Figure 22](#).

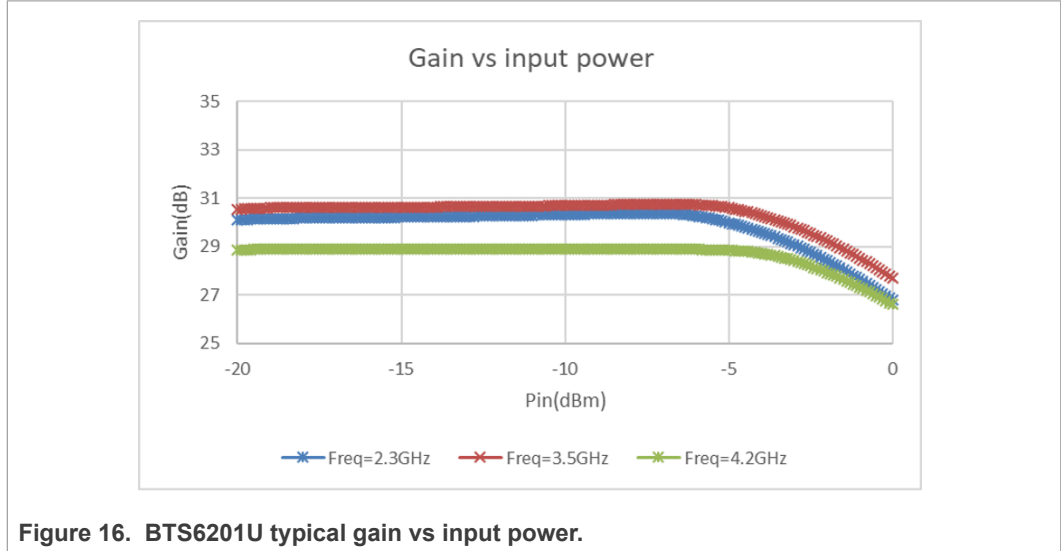


Figure 16. BTS6201U typical gain vs input power.

Table 4. BTS6201U Typical input and output 1 dB gain compression performance

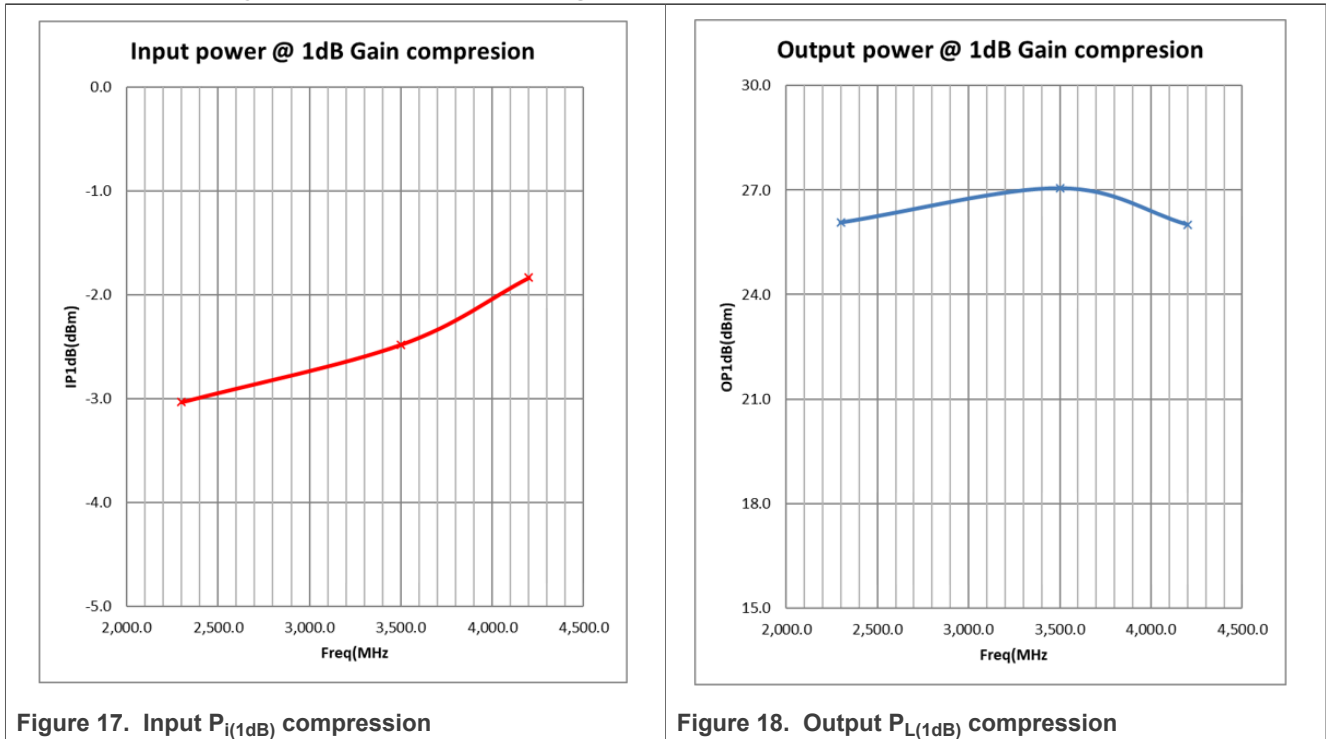


Figure 17. Input $P_{i(1dB)}$ compression

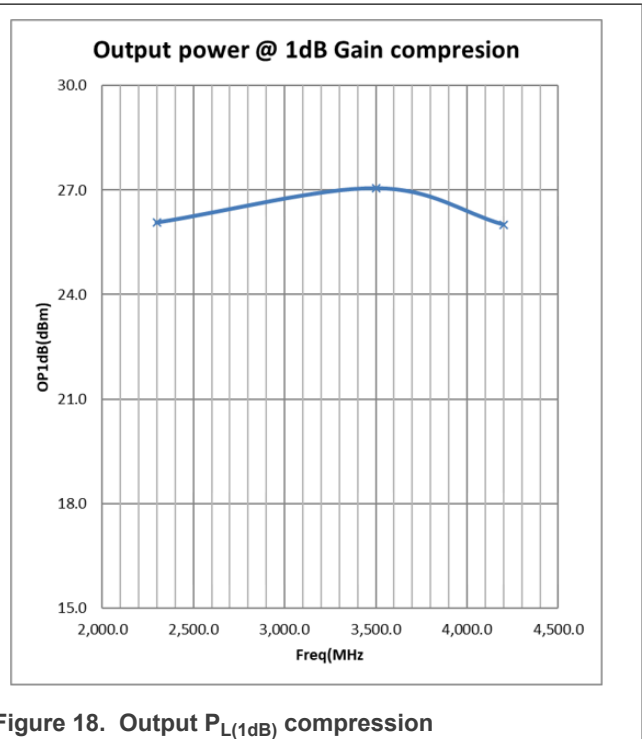
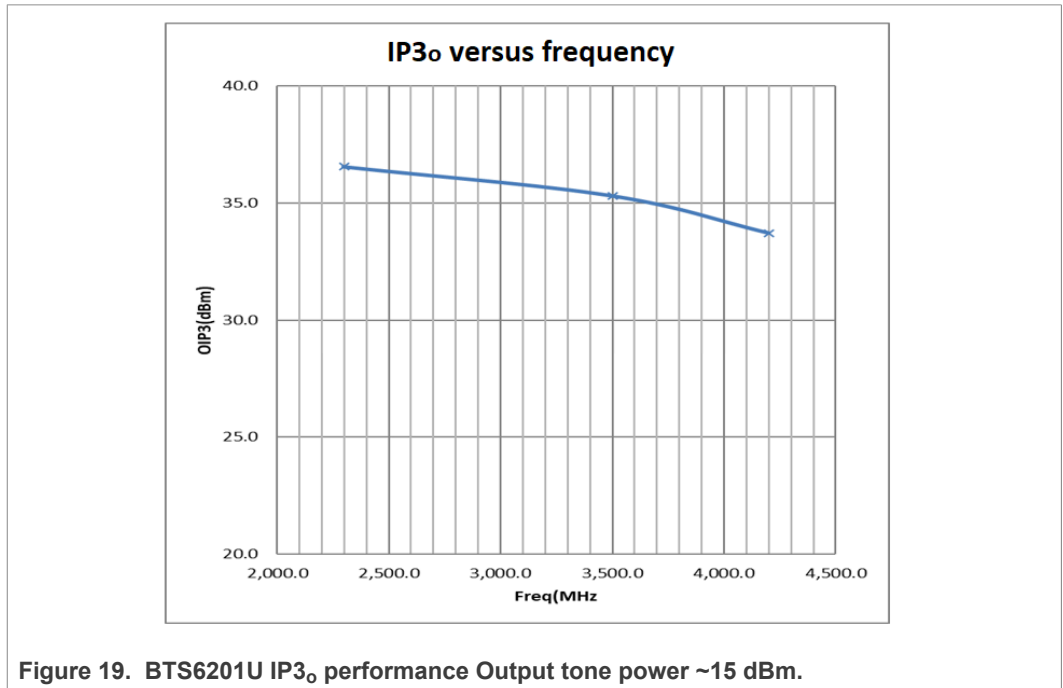


Figure 18. Output $P_{L(1dB)}$ compression

5.4 Third order intercept point

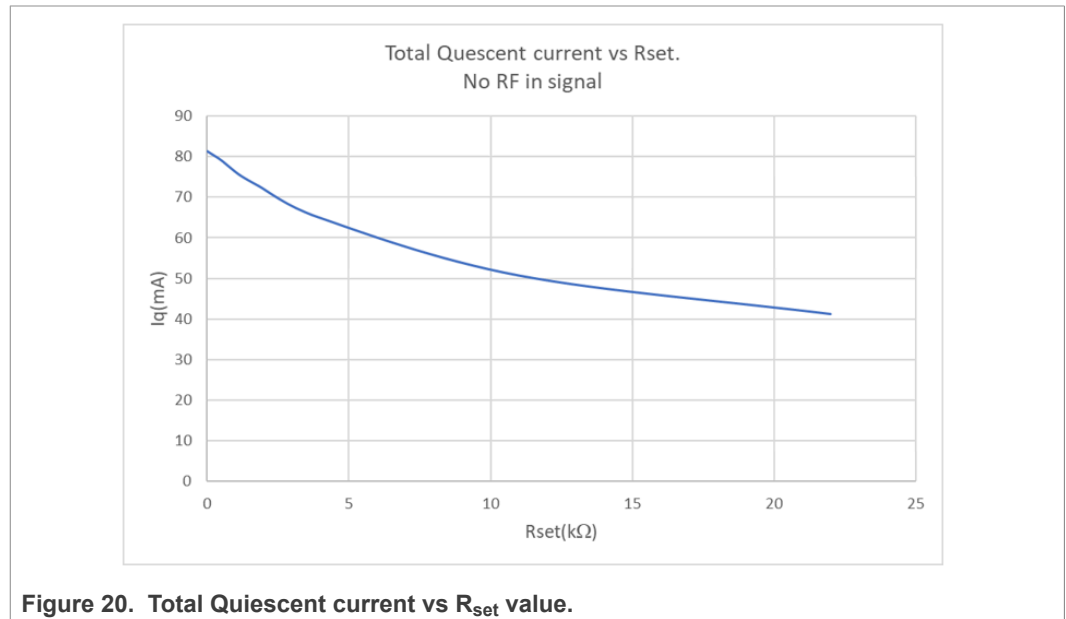
IP_{3o} is being measured using a setup like given in [Figure 23](#).



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 BTS6201U mounted on the evaluation board in the customer evaluation kit is industrially tested on the most important RF parameters. Like Gain, Noise Figure, IP_{3o}, and P_{L(1dB)}. The V_{ulp} pin is for internal use only. In the system, it can be grounded or left floating. On the EVB, it is connected to GND.

5.5 RF performance at different quiescent current

The BTS6201U is supplied with a feature to set the quiescent current with an external resistor R1 connected between the I_{set} pin (15) and ground. The board in the evaluation kit is supplied with a value of R1 = 1.2 kΩ. This paragraph gives typical RF performance at different R1 further more named R_{set} values and consequent different quiescent currents. The relation between quiescent current and the value of R_{set} is given in [Figure 20](#).



Typical performance at different R_{set}, RF freq = 2300 MHz

V_{CC} = 5.0 V; V_{en} = 1.8 V; T_{amb} = 25 °C; input and output 50 Ω; unless otherwise specified. All RF parameters have been characterized on the evaluation board described in this application note.

Table 5.

R _{set}	I _q	G _p	RL _i	RL _o	ISL _r	P _{o(sat)}	P _{L(1dB)}	IP3 _o Δf 10 MHz	IP3 _o Δf 100 MHz	ACLR 100 MHz	ACLR 200 MHz
kΩ	mA	dB	dB	dB	dB	dBm	dBm	dBm	dBm	dBc	dBc
0	81.4	29.6	14.4	27.5	53.6	26.6	26.0	37.4	36.4	-47.35	-39.77
0.47	79.3	29.5	14.4	25.2	53.5	26.7	26.2	36.7	35.9	-46.84	-39.49
0.82	77.3	29.5	14.4	25.2	53.5	26.6	26.1	36.2	35.6	-46.58	-39.32
1.2	75.3	29.4	14.3	22.8	53.8	26.5	26.2	35.7	35.3	-46.07	-39.10
1.8	72.9	29.2	14.3	21.2	53.7	26.5	26.2	35.0	34.7	-45.22	-38.52
3.9	65.2	28.8	14.3	17.6	54.0	26.4	26.4	32.8	32.9	-41.87	-36.70
11	50.8	27.7	14.2	12.4	54.8	26.8	26.6	28.8	29.1	-34.59	-32.01
22	41.3	26.5	14.1	9.4	55.7	26.8	26.7	25.7	26.2	-29.99	-28.52

Typical performance at different R_{set} , RF freq = 3500 MHz

$V_{CC} = 5.0\text{ V}$; $V_{en} = 1.8\text{ V}$; $T_{amb} = 25\text{ }^{\circ}\text{C}$; input and output $50\ \Omega$; unless otherwise specified. All RF parameters have been characterized on the evaluation board described in this application note.

Table 6.

R_{set}	I_q	G_p	RL_i	RL_o	ISL_r	$P_{o(sat)}$	$P_{L(1dB)}$	$IP3_o \Delta f$ 10 MHz	$IP3_o \Delta f$ 100 MHz	ACLR 100 MHz	ACLR 200 MHz
k Ω	mA	dB	dB	dB	dB	dBm	dBm	dBm	dBm	dBc	dBc
0	81.4	30.2	19.2	13.9	48.0	27.1	26.7	42.2	35.2	-45.33	-40.00
0.47	79.3	30.2	19.1	13.9	48.1	27.2	26.8	41.7	35.3	-45.60	-39.98
0.82	77.3	30.2	19.1	13.9	48.1	27.1	26.8	40.0	35.3	-45.96	-40.03
1.2	75.3	30.0	19.1	13.8	48.2	27.1	26.8	38.7	35.4	-46.10	-39.98
1.8	72.9	29.9	19.0	13.8	48.1	27.0	26.9	37.3	35.4	-46.10	-39.93
3.9	65.2	29.5	18.9	13.3	48.3	26.9	27.2	34.1	34.7	-45.21	-39.12
11	50.8	28.3	18.6	11.3	48.5	27.7	27.5	29.3	30.5	-36.96	-34.57
22	41.3	27.1	18.3	9.1	48.9	27.7	27.8	26.1	27.1	-31.22	-29.92

Typical performance at different R_{set} , RF freq = 4200 MHz

$f = 4200\text{ MHz}$; $V_{CC} = 5.0\text{ V}$; $T_{amb} = 25\text{ }^{\circ}\text{C}$; input and output $50\ \Omega$; unless otherwise specified. All RF parameters have been characterized on the evaluation board described in this application note.

Table 7.

R_{set}	I_q	G_p	RL_i	RL_o	ISL_r	$P_{o(sat)}$	$P_{L(1dB)}$	$IP3_o \Delta f$ 10 MHz	$IP3_o \Delta f$ 100 MHz	ACLR 100 MHz	ACLR 200 MHz
k Ω	mA	dB	dB	dB	dB	dBm	dBm	dBm	dBm	dBc	dBc
0	81.4	28.4	18.1	14.3	45.5	26.4	25.9	33.9	33.8	-42.07	-37.90
0.47	79.3	28.3	18.0	14.2	45.6	26.5	26.0	33.8	34.0	-42.42	-38.01
0.82	77.3	28.3	18.0	14.2	45.6	26.4	26.0	33.9	34.2	-42.63	-38.02
1.2	75.3	28.2	18.0	14.0	45.5	26.4	26.0	33.9	34.4	-42.47	-38.13
1.8	72.9	28.0	17.9	13.8	45.6	26.4	26.1	34.0	34.7	-42.64	-38.20
3.9	65.2	27.6	17.7	13.2	45.6	26.4	26.3	35.4	36.6	-42.79	-38.31
11	50.8	26.5	17.4	11.2	45.6	26.8	26.6	28.8	30.8	-38.42	-36.00
22	41.3	25.4	17.0	9.1	45.7	26.8	26.7	22.5	26.8	-33.26	-31.77

5.6 Required Equipment

For the BTS6201U evaluation, the following equipment is needed.

- 1 DC power supply 5 V, 500 mA.
- 1 DC power supply 1.8 V, 5 mA for the enable voltage V_{en}
- A network analyzer for S-parameter measurements, and $P_{L(1dB)}$ measurements.
- 2 RF generators up to 12 GHz, and 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.

After switching on the power supply the BTS6201U comes up in the quiescent current, 1.8 V enable voltage must be applied. Preferable the supply start-up sequence is as follows.

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

The typical current at 5 V supply is 78 mA, in power down-mode V_{en} (0 V) - 0.5 mA.

5.7 Connection and setup

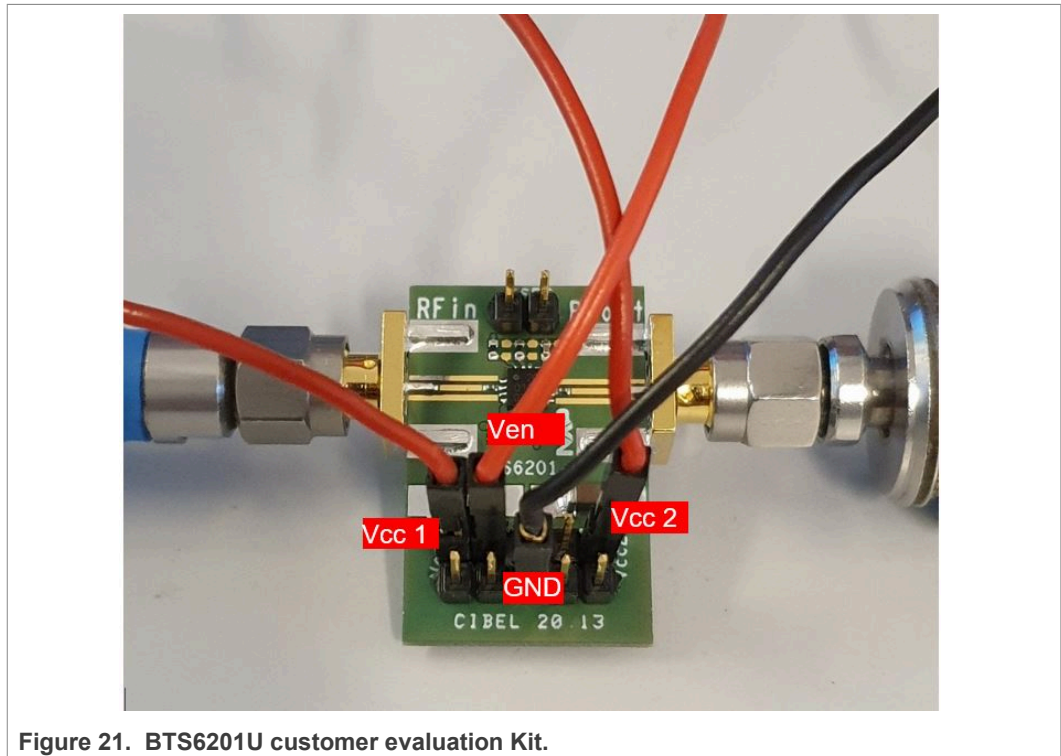


Figure 21. BTS6201U customer evaluation Kit.

1. Connect the EVB to a calibrated network analyzer see [Figure 21](#), we advise the following settings for S-parameter measurements:
 - a. Port power -15 dBm
 - b. IF Bandwidth 100 Hz
2. For the 1 dB gain compression evaluation, we advise the following NWA setting
 - a. Port 1 power sweep -20 dBm up to 0 dBm
 - b. Port 2, 20 dB attenuation on the receiver port b2.
 - c. IF Bandwidth 100 Hz.
3. Gain and 1 dB 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 $I_{cc} = 78$ mA.
5. Nonlinear distortion measurements IP3 can be performed with a set-up like is depicted in [Figure 23](#). The following settings are recommended to perform the IP3 evaluation.
 - a. -15 dBm for each fundamental tone.
 - b. RBW and VBW of the spectrum analyzer 100 Hz
 - c. Tone spacing 100 MHz

Evaluation measurement setups

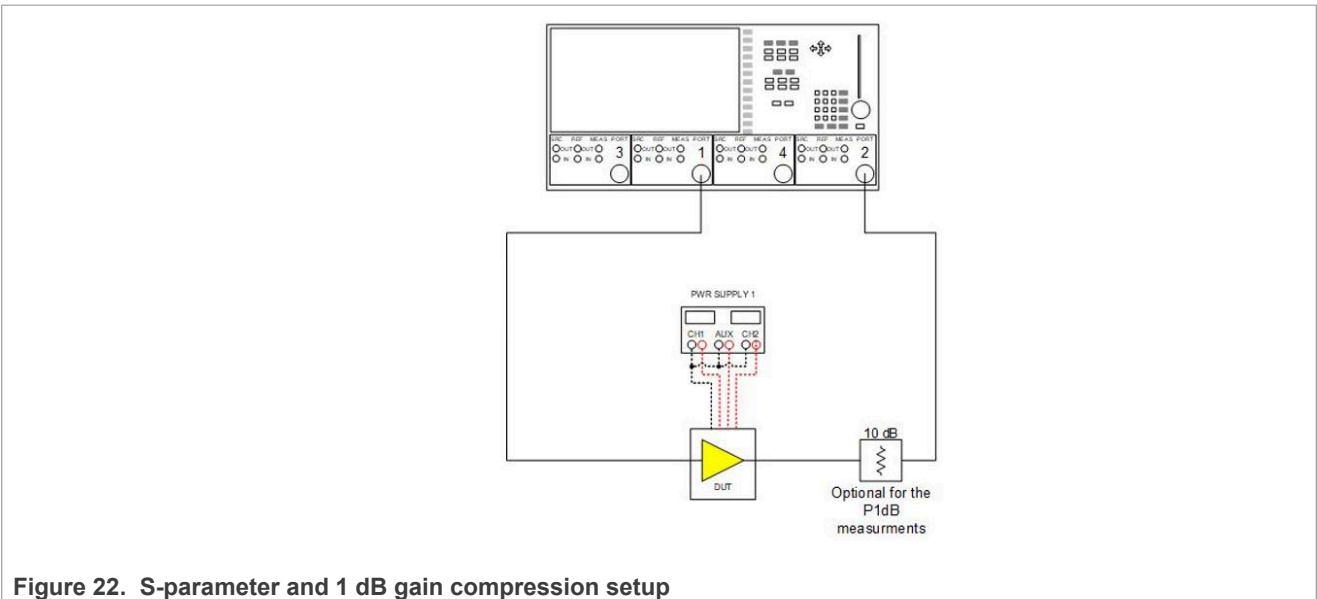


Figure 22. S-parameter and 1 dB gain compression setup

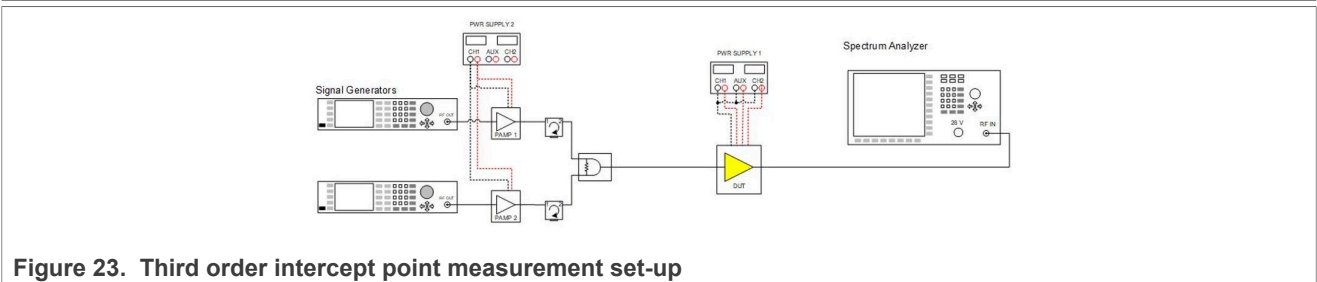


Figure 23. Third order intercept point measurement set-up

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