BGS12SL6

Performance of SPDT RF Switch

Mid Power Applications

Application Note AN300

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1 Introduction

The BGS12SL6 RF MOS switch is designed for mid power and pre PA applications. Any of the 2 ports can be used as termination of the diversity antenna handling up to 27.5 dBm.

This single supply chip integrates on-chip CMOS logic driven by a simple, single-pin CMOS or TTL compatible control input signal. The 0.1 dB compression point exceeds the switch's maximum input power level of 29 dBm, resulting in linear performance at all signal levels. The RF switch has a very low insertion loss of 0.25 dB in the 1 GHz and 0.35 dB in the 2.5 GHz range.

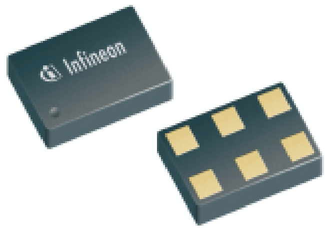
Unlike GaAs technology, external DC blocking capacitors at the RF ports are only required if DC voltage is applied externally.

The BGS12SL6 RF switch is manufactured in Infineon's patented MOS technology, offering the performance of GaAs with the economy and integration of conventional CMOS including the inherent higher ESD robustness.

2 BGS12SL6 Features

2.1 Main Features

- 2 high-linearity TRx paths with power handling capability of up to 27.5 dBm
- High switching speed
- All ports fully symmetrical
- No external decoupling components required
- Low insertion loss
- Low harmonic generation
- High port-to-port-isolation
- 0.1 to 6 GHz coverage
- High ESD robustness
- On-chip control logic
- Very small leadless and halogen free package TSLP-6-4 (0.7x1.1mm^2) with super low height of 0.31 mm
- RoHS compliant package



2.2 Functional Diagram

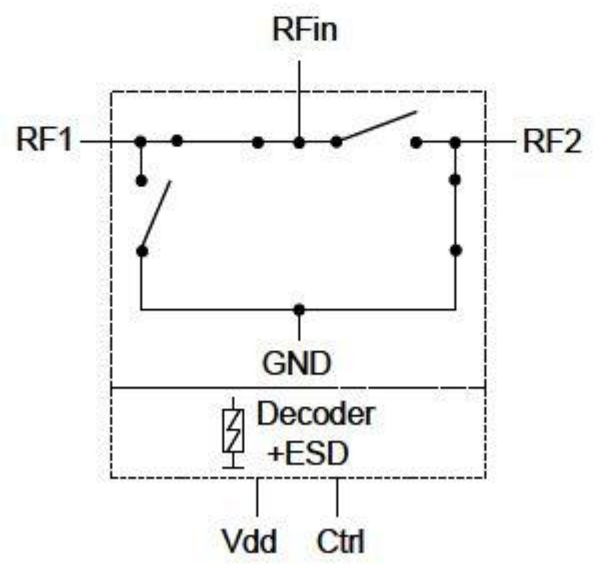


Figure 1 BGS12SL6 Functional Diagram

2.3 Pin Configuration

In Figure 2 the pin configuration in top view is given.

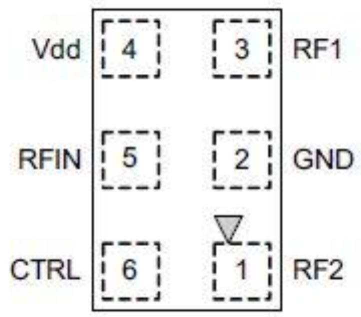


Figure 2 Pin configuration

2.4 Pin Description

Table 1 Pin Description (top view)

Pin NO	Name	Pin Type	Function
1	RF2	I/O	RF port 2
2	GND	GND	Ground
3	RF1	I/O	RF port 1
4	Vdd	PWR	Supply Voltage
5	RFIN	I/O	RF port In
6	CTRL	I	Control Pin

3 Application

3.1 Band Selection with RF CMOS Switch in Single-Ended Configuration

The number of LTE bands to support in a mobile phone is increasing rapidly worldwide. A simple way to support more bands in a mobile phone is to implement band selection function by adding a RF CMOS switch to existing transceiver/diversity ICs. Following two examples show band selection with the BGS12SL6 switch in single-ended configuration.

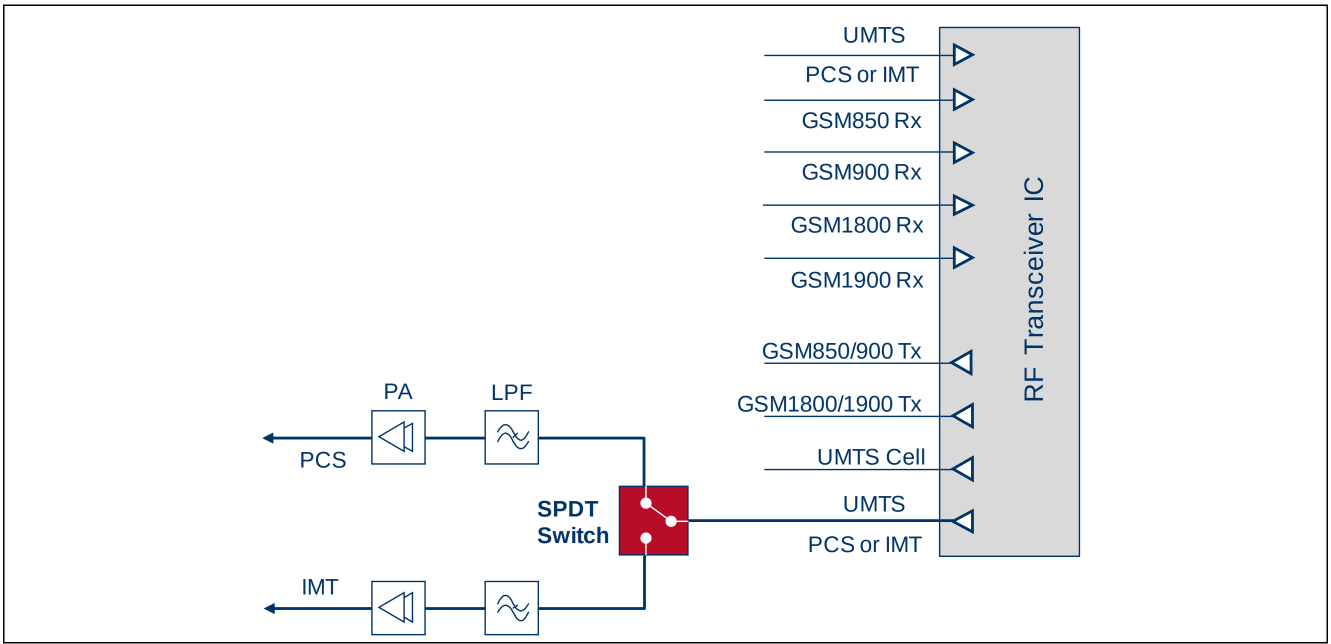


Figure 3 PCS/IMT band switching

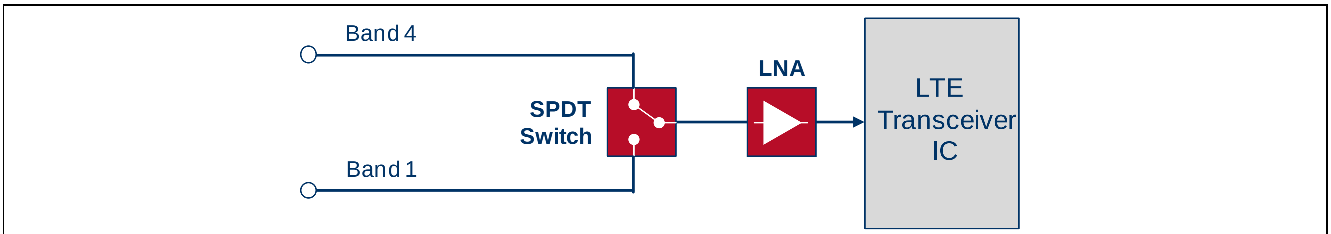


Figure 4 LTE Band -1/Band -4 switching

3.2 Application Board

Below is a picture of the evaluation board used for the measurements (Figure 5). The board is designed so that all connecting 50 Ohm lines have the same length.

In order to get accurate values for the insertion loss of the BGS12PL6 all influences and losses of the evaluation board, lines and connectors have to be eliminated. Therefore a separate de-embedding board, representing the line length is necessary (Figure 6).

The calibration of the network analyser (NWA) is done in severall steps:

- Perform full calibration on all NWA ports.
- Attach empty SMA connector at port 2 and perform "open" port extension. Turn port extensions on.
- Connect the "half" de-embedding board (Figure 5 left board) between port1 and port2, store this as a s-parameter (s2p) file.
- Turn all port extentions off.
- Load the stored s-parameter file as de-embedding file for all used NWA ports
- Switch all port extentions on
- Check insertion loss with the de-embedding through board (Figure 6 right board)

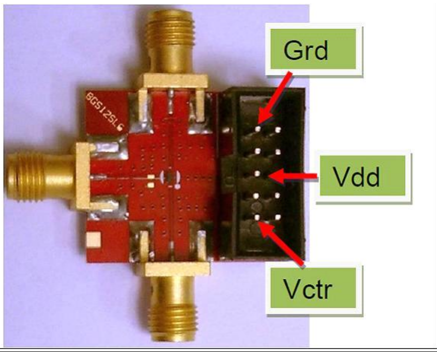


Figure 5 Layout of the application board

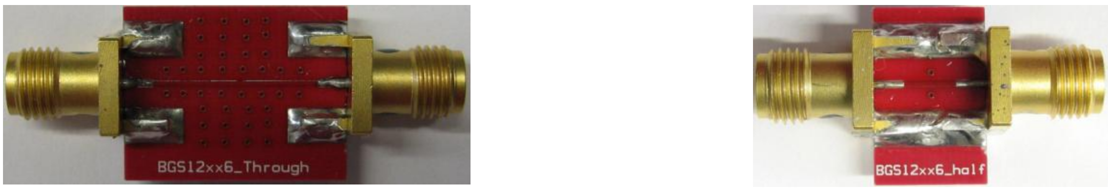


Figure 6 Layout of de-embedding boards

The construction of the PCB is shown in Figure 7.

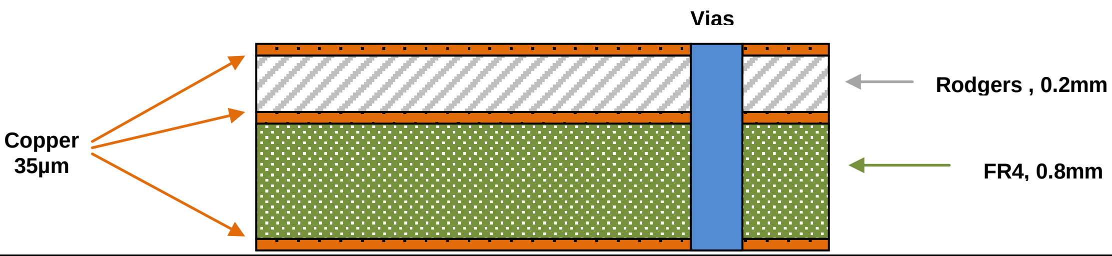


Figure 7 PCB layer information

4 Small Signal Characteristics

The small signal characteristics are measured at 25 °C with a Network analyzer connected to an automatic multiport switch box.

4.1 Measurement Results

In the following tables and graphs the most important RF parameter of the BGS12SL6 are shown. The markers are set to the most important frequencies of the WDCDMA system.

Table 2 Forward Transmission from RFIN Port to the Respective RF Port with All Other Ports Terminated with 50Ω

Frequency (MHz) / RF Path	824	915	1000	1710	1910	2170	2690
RF1	-0.38	-0.39	-0.39	-0.46	-0.47	-0.51	-0.58
RF2	-0.37	-0.38	-0.38	-0.44	-0.46	-0.49	-0.57

Table 3 Reflection RFin Port to the Respective RF Port with All Other Ports Terminated with 50Ω

Frequency (MHz) / RF Path	824	915	1000	1710	1910	2170	2690
RF1	-29.1	-27.8	-27.7	-25.3	-24	-22.2	-20
RF2	-29.2	-28.1	-27.9	-25.4	-23.9	-22	-19.6

Table 4 Reflection RF Port to the Respective RF Port with All Other Ports Terminated with 50Ω

Frequency (MHz) / RF Path	824	915	1000	1710	1910	2170	2690
RF1	-29.8	-29.4	-29.3	-26.2	-25.3	-23.7	-20.2
RF2	-30.8	-30.2	-30.3	-26.6	-25.4	-23.2	-19.3

4.2 Forward Transmission

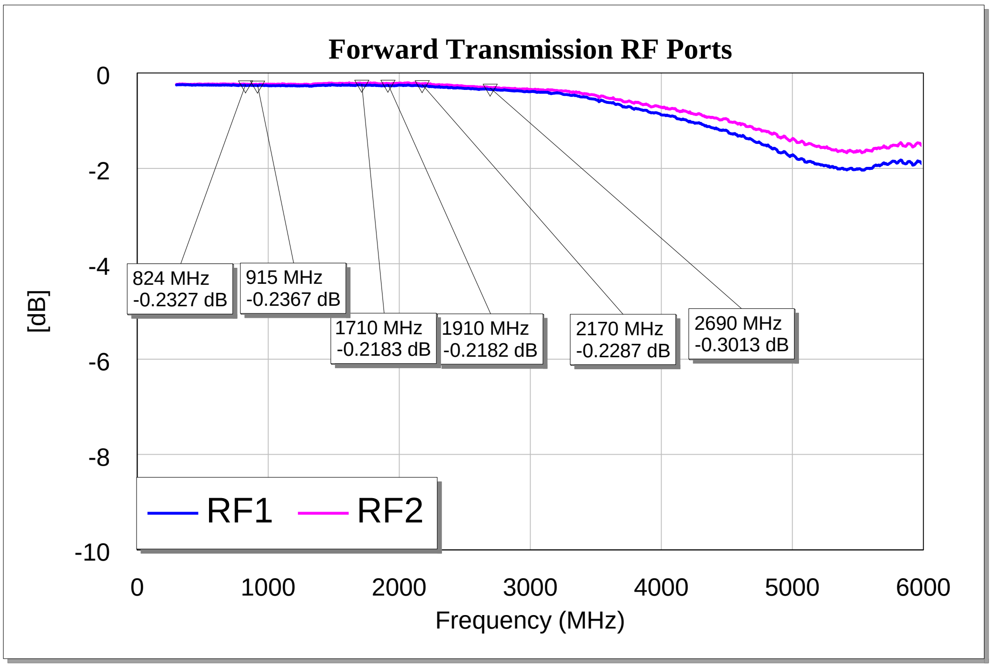


Figure 8 Forward Transmission Curves for RF Ports

4.3 Reflction RFin Port

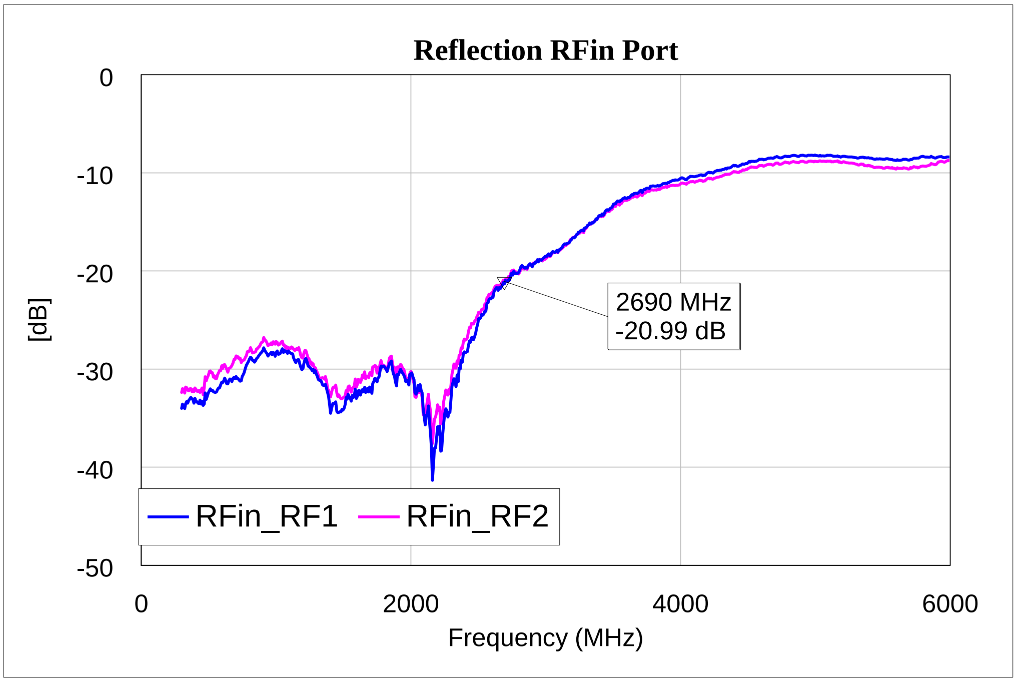


Figure 9 Reflction RFin Port

4.4 Isolation RF1

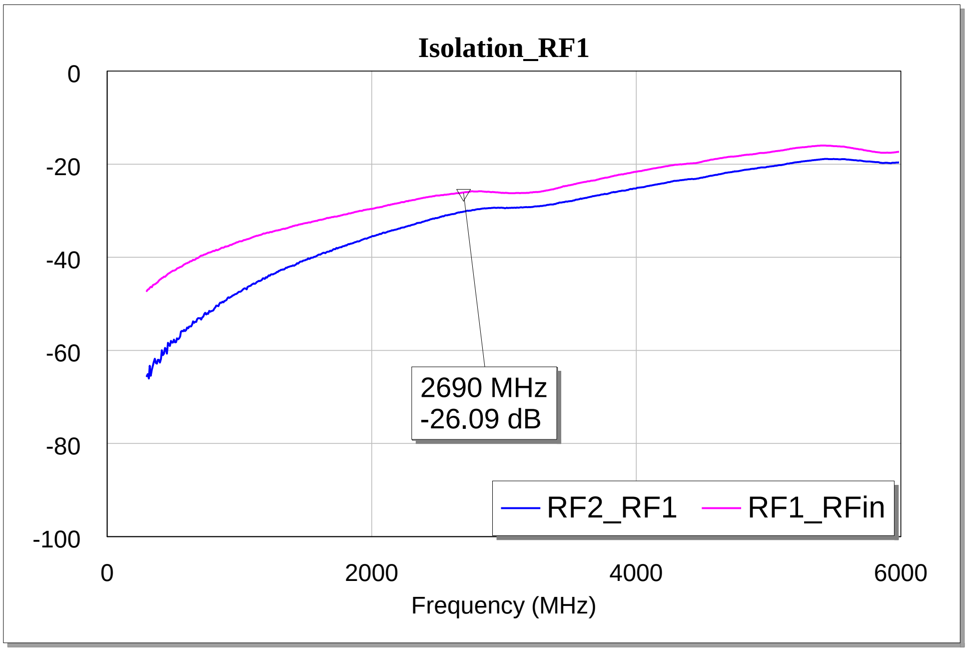


Figure 10 Isolation RF1

4.5 Isolation RF2

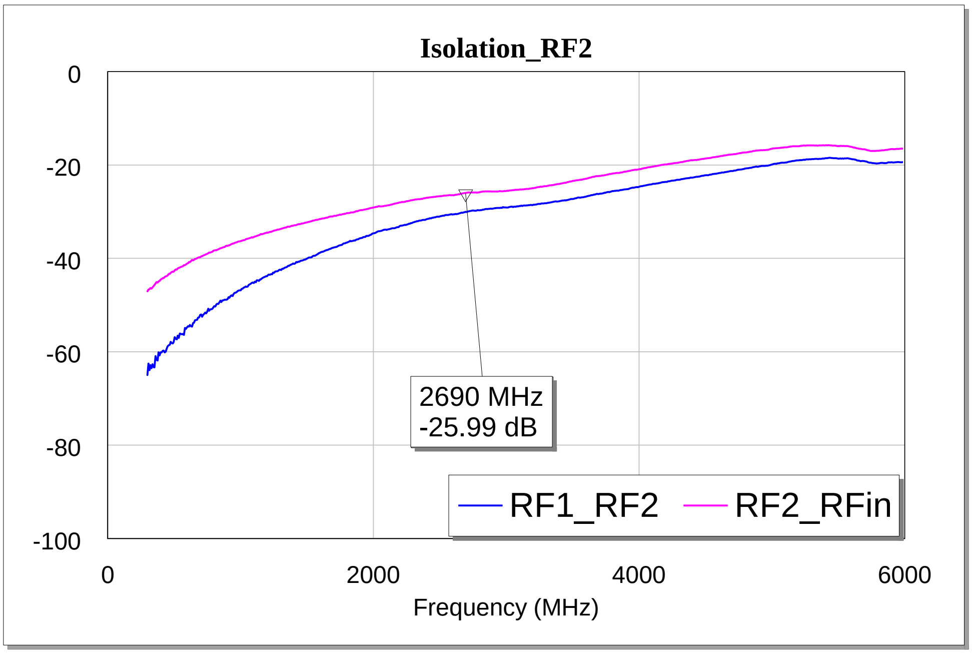


Figure 11 Isolation RF2

5 Intermodulation

Another very important parameter of a RF switch is the large signal capability. One of the possible intermodulation scenarios is shown in Figure 12. The transmission (Tx) signal from the main antenna is coupled into the diversity antenna with with high power.This signal (20 dBm) and a received Jammer signal (-15 dBm) are entering the switch.

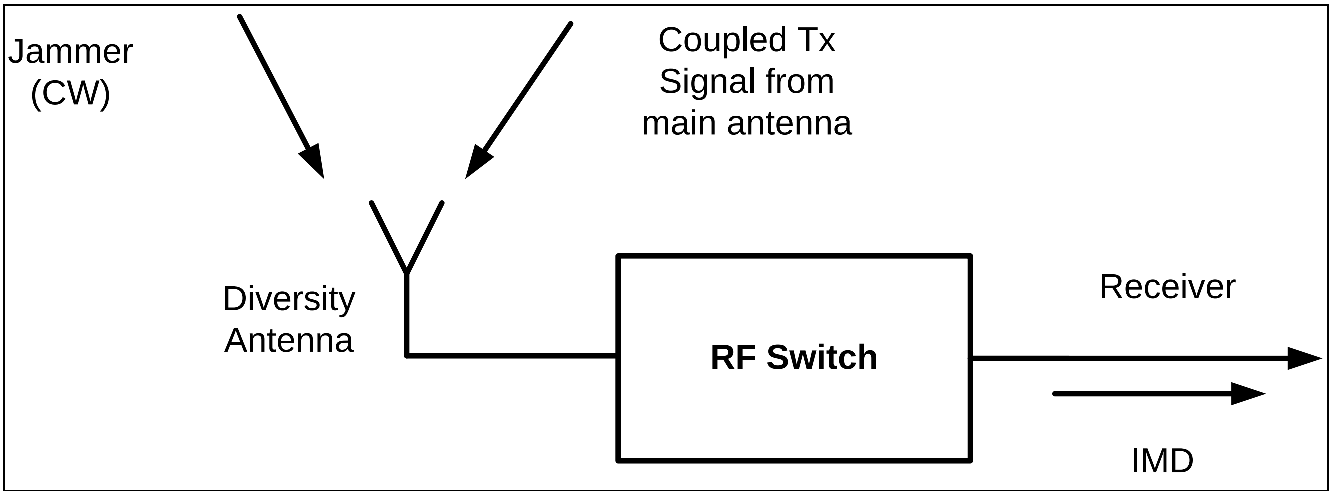


Figure 12 Block diagram of RF Switch intermodulation

Special combinations of TX and Jammer signal are producing intermodulation products 2nd and 3rd order, which fall in the RX band and disturb the wanted RX signal.

In Table 5 frequencies for 3 bands and the linearity specifications for an undisturbed communication are given.

Table 5 Test conditions and specifications of IMD measurements

Test Conditions (Tx = +20dBm, Bl = -15dBm,freq.in MHz,@25°C)						Linearity Specification			
Band	**Tx Freq.**	**Rx Freq.**	**IMD2 Low Jammer 1**	**IMD3 Jammer 2**	**IMD2 High Jammer 3**	**IM2 (dBm)**	**IIP2 (dBm)**	**IM3 (dBm)**	**IIP3 (dBm)**
850	836.5	881.5	45	791.5	1718	**-105**	110	**-105**	65
1900	1880	1960	80	1800	3840	**-105**	110	**-105**	65
2100	1950	2140	190	1760	4090	**-105**	110	**-105**	65

The test setup for the IMD measurements has to provide a very high isolation between RX and TX signals. As an example the test set-up and the results for the high band are shown (Figure 13 and Figure 14).

For the RX / TX separation a professional duplexer with 80 dB isolation is used.

In Figure 14 the results for High band are given. For each distortion scenario there is a min and a max value given. This variation is caused by a phase shifter connected between switch and duplexer. In the test set-up the phase shifter represents a no ideal matching of the switch to 50 Ohm.

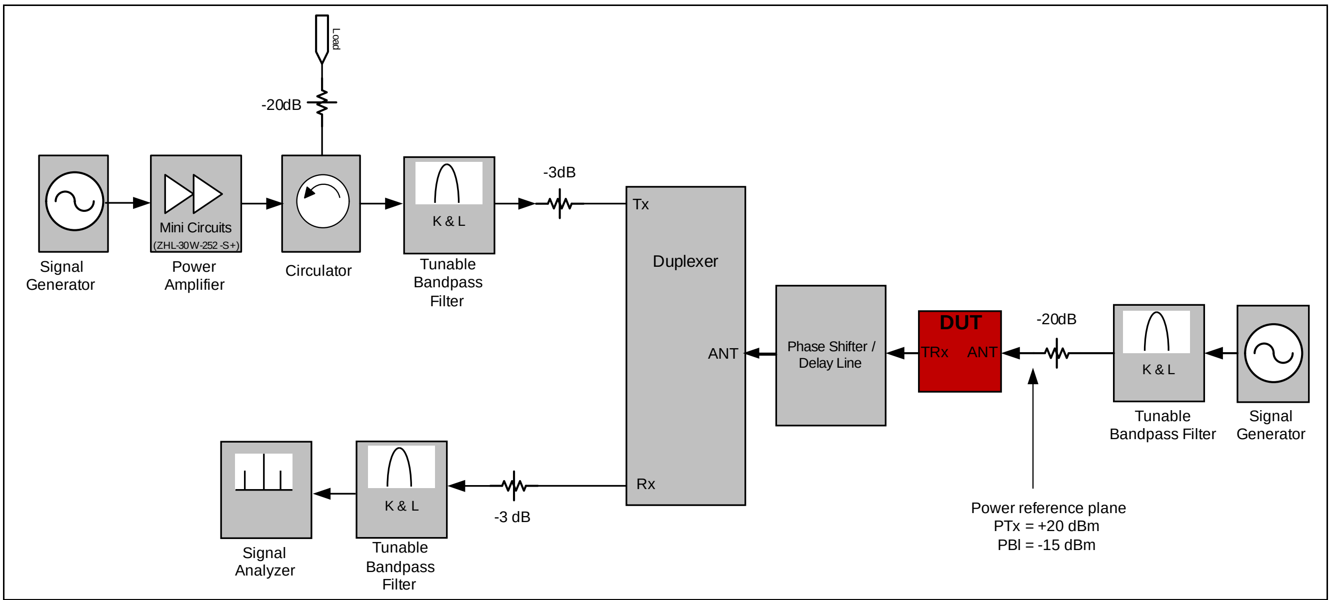


Figure 13 Test set-up for IMD Measurements

		IMD Band - I					
	T= 25°C Vdd = 3.5V	IMD2 low		IMD2 High		IMD3	
		f_b = 190 MHz		f_b = 4090 MHz		f_b = 1760 MHz	
Power	RF-port	Min	Max	Min	Max	Min	Max
P_{Tx} = +10dBm	RF1	-122,34	-113,08	-120,21	-118,33	-127,55	-119,25
P_{int} = -15dBm	RF2	-124,81	-115,11	-116,65	-115,19	-127,71	-120,40
P_{Tx} = +20dBm	RF1	-115,64	-108,17	-113,89	-112,03	-106,90	-102,72
P_{int} = -15dBm	RF2	-119,33	-109,86	-109,13	-107,58	-106,88	-103,30

Figure 14 IMD2 and IMD3 results for Band I

		IMD Band - V					
	T= 25°C Vdd = 3.5V	IMD2 low		IMD2 High		IMD3	
		f_b = 45 MHz		f_b = 1718 MHz		f_b = 791.5 MHz	
Power	RF-port	Min	Max	Min	Max	Min	Max
P_{Tx} = +10dBm	RF1	-118,56	-106,83	-122,16	-116,43	-124,66	-119,97
P_{int} = -15dBm	RF2	-120,40	-107,44	-120,72	-115,55	-124,46	-120,70
P_{Tx} = +20dBm	RF1	-110,13	-98,15	-111,39	-107,70	-105,84	-104,74
P_{int} = -15dBm	RF2	-109,42	-98,20	-110,41	-106,68	-105,74	-104,77

Figure 15 IMD Results for Band V

6 Harmonic Generation

Harmonic generation is another important parameter for the characterization of a RF switch. RF switches have to deal with high RF levels, up to 33 dBm. With this high RF power at the input of the switch harmonics are generated. These harmonics (2^{nd} and 3^{rd}) can disturb the other reception bands or cause distortion in other RF applications (GPS, WLan) within the mobile phone.

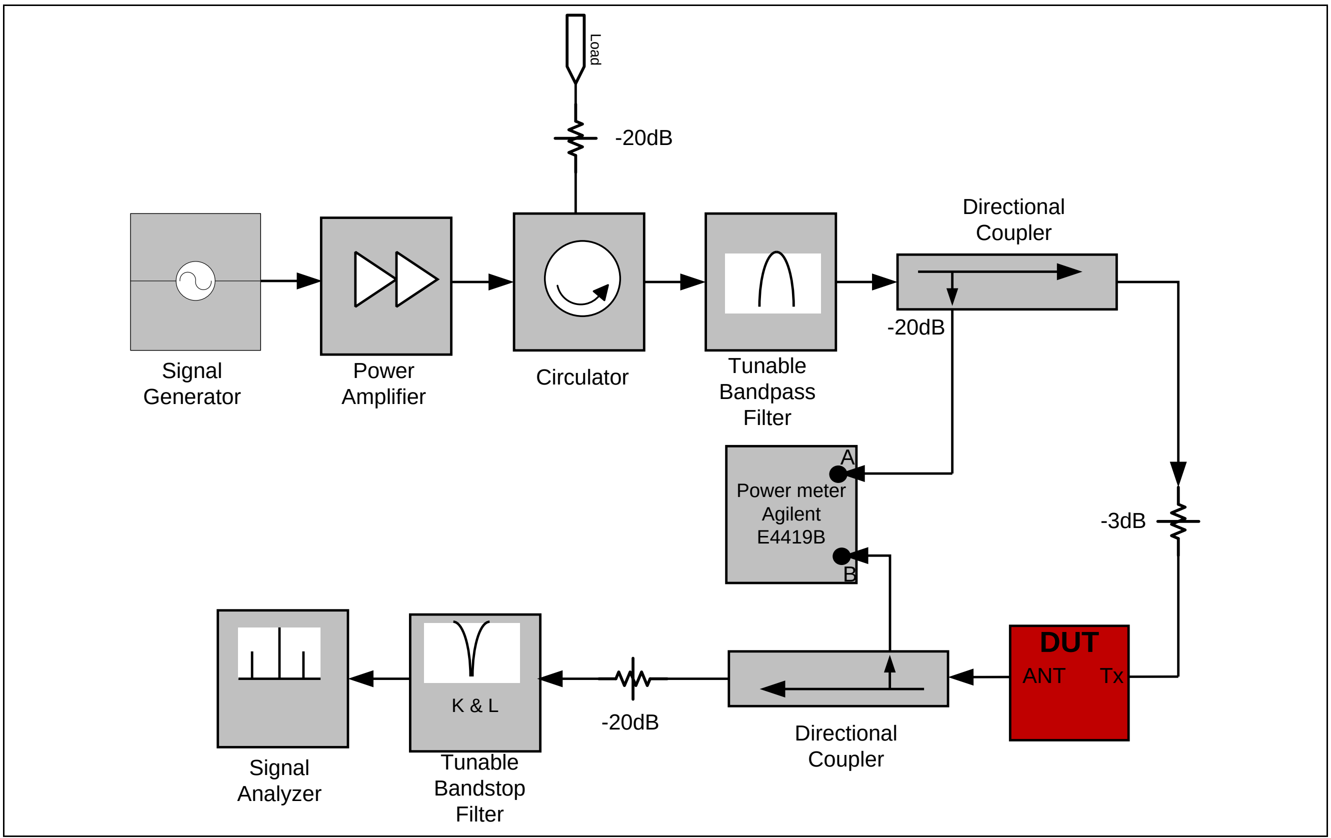


Figure 16 Set-up for harmonics measurement

The results for the harmonic generation at 830 MHZ are shown in Figure 17 (2^{nd} harmonic) and Figure 18 (3^{rd} harmonic) for all RF ports.

At the x-axis the input power is plotted and at the y- axis the generated harmonics in dBm.

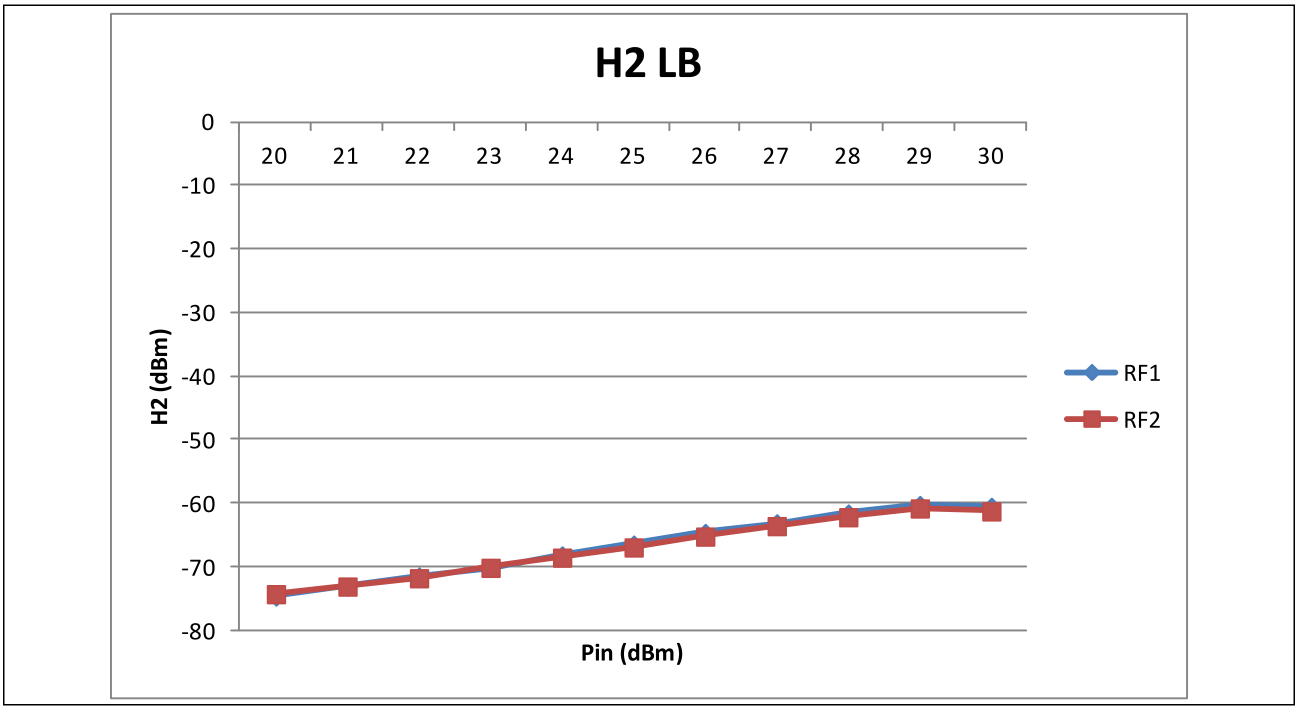


Figure 17 2nd harmonic at f_c=830 MHz

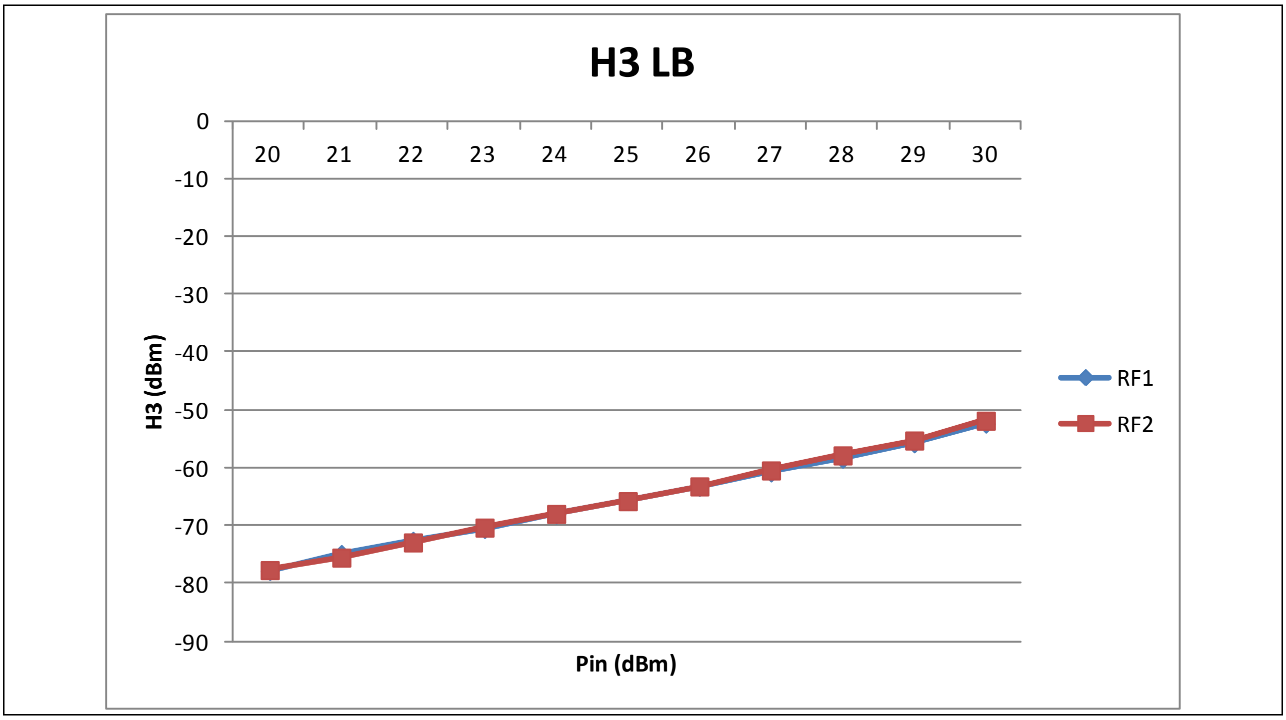


Figure 18 3rd harmonic at f_c=830 MHz

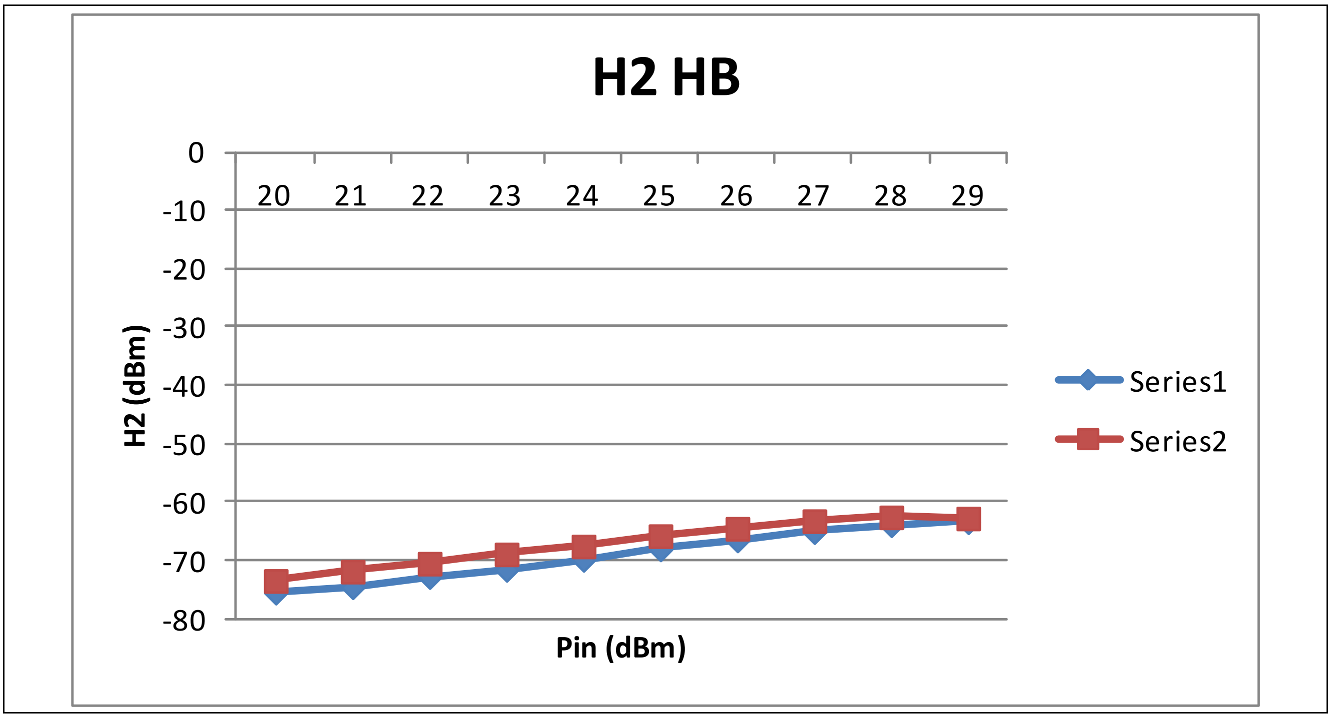


Figure 19 2nd Harmonic at f_c=1800 MHz

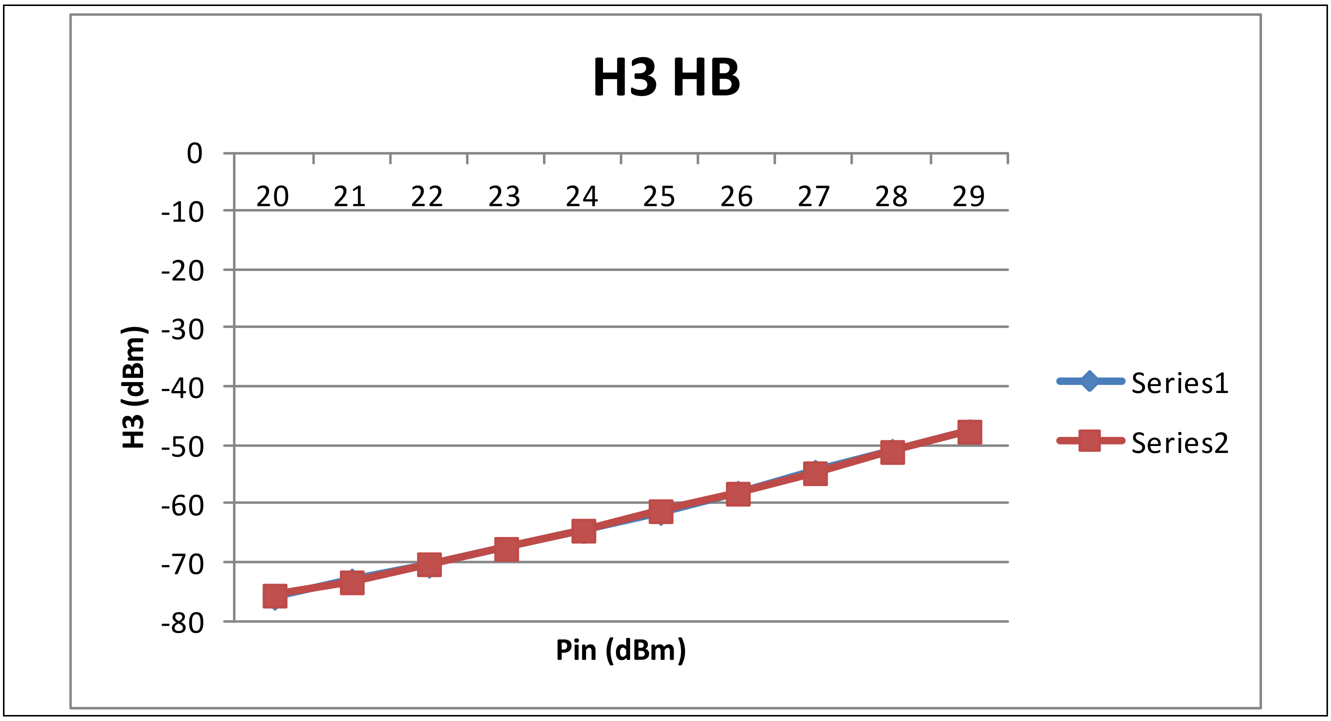


Figure 20 3rd Harmonic at f_c=1800 MHz

7 Power Compression Measurements on all RF Paths

To judge the large signal capability the power compression is a usual measurement tool. The output the power is measured while increasing the input power. At a certain point the output power does not follow the input and the switch compresses the RF signal. In the diagram below (Figure 21) the IL is plotted versus the injected input power. The input power can be increased to 30 dBm and there is no compression visible on none of the RF ports.

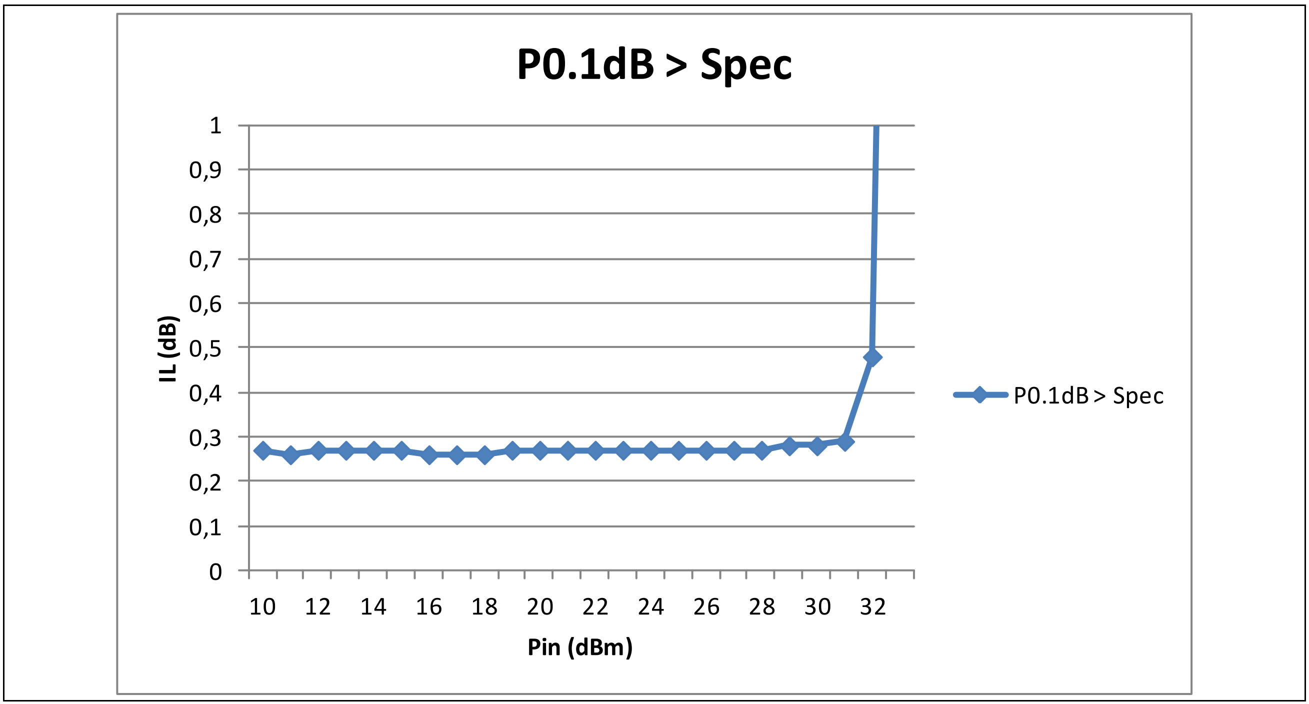


Figure 21 Power Compression Measurement Results at f_c=830 MHz

The measurements are done on Large Signal measurement setup which is not calibrated for Insertion Loss with high precision. So the values here may differ with the actual IL values earlier in this report.

8 Switching time

8.1 Measurement Specifications

Switching On Time: 50% Trigger signal to 90 % RF Signal

Switching Off Time: 50% Trigger signal to 10% RF Signal

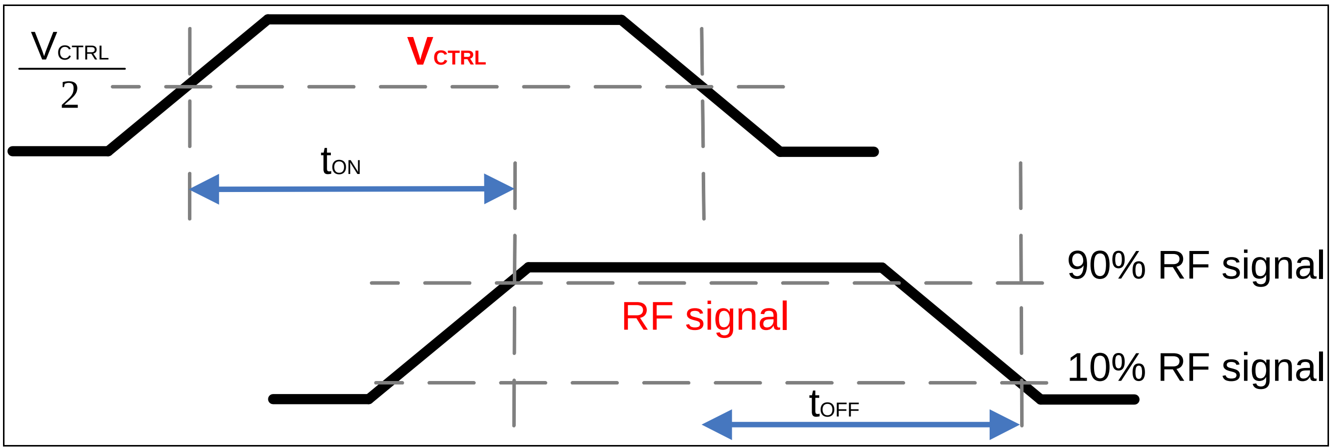


Figure 22 Switching Time

Rise time: 10% to 90% RF Signal

Fall time: 90% to 10% RF Signal

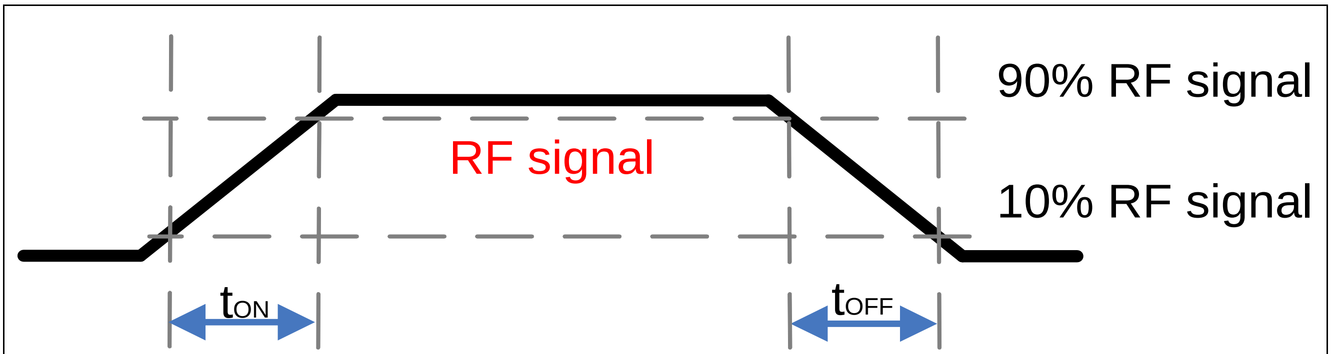


Figure 23 Rise/Fall Time

8.2 Measurement Setup

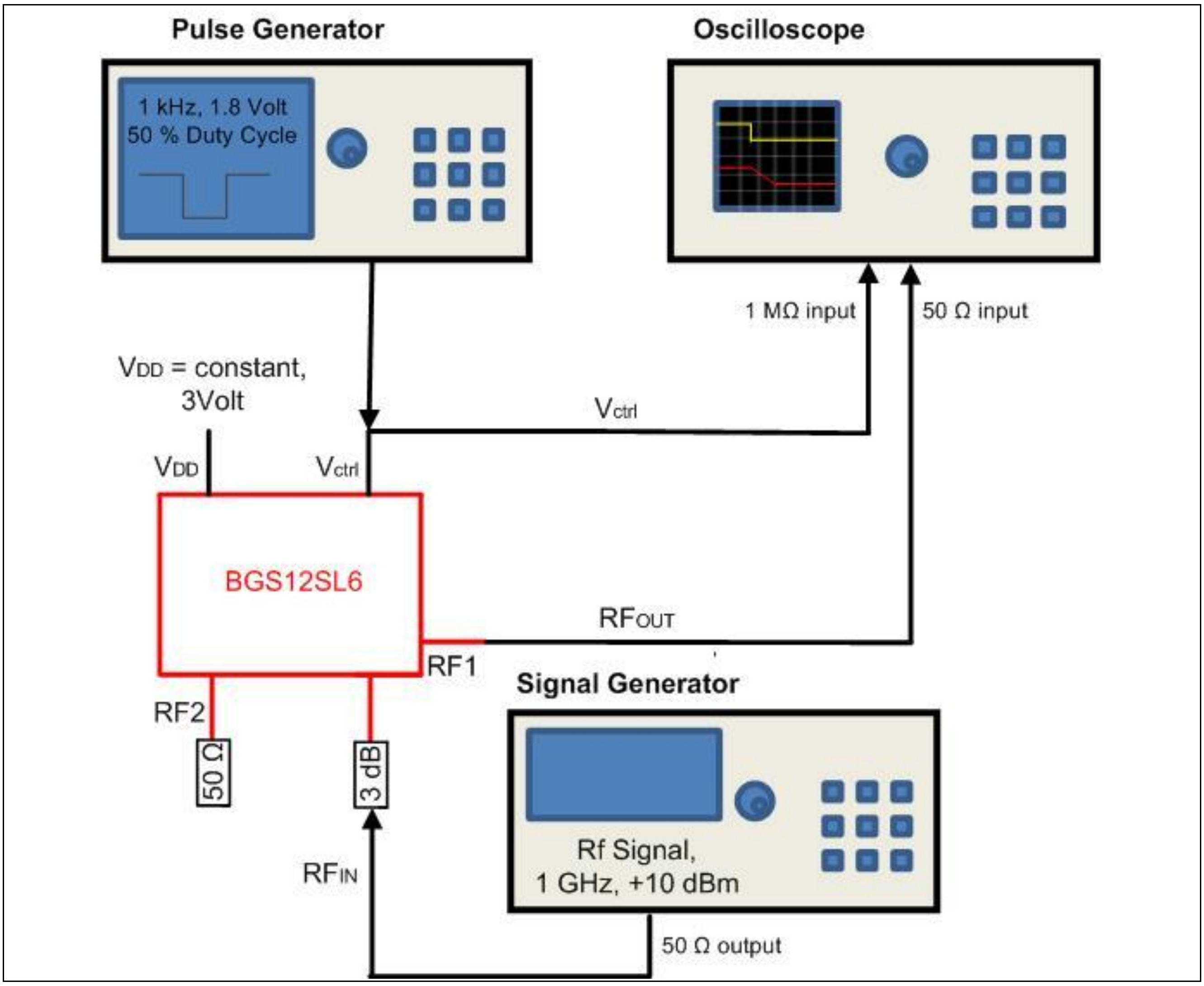


Figure 24 Switching Time Measurement Setup

8.3 Measurement results

The switching Time measurement setup consist of one pulse generator which generates a sqare wave with 50% duty cycle and an amplitude of 1.8 Volts, an oscilloscope which can detect the 1 GHz signal and the 1 kHz signal and one Signal generator which is set to an output signal of 1GHz with a power level 10 dBm.

If the oscilloscope cannot detect the 1 GHz signal of the RF path, due to small bandwith, it is possible to use a crystal oscillator in front of the oscilloscope (such a device detects any RF signal present at input and commutates that) so that the RF signal can be detected.

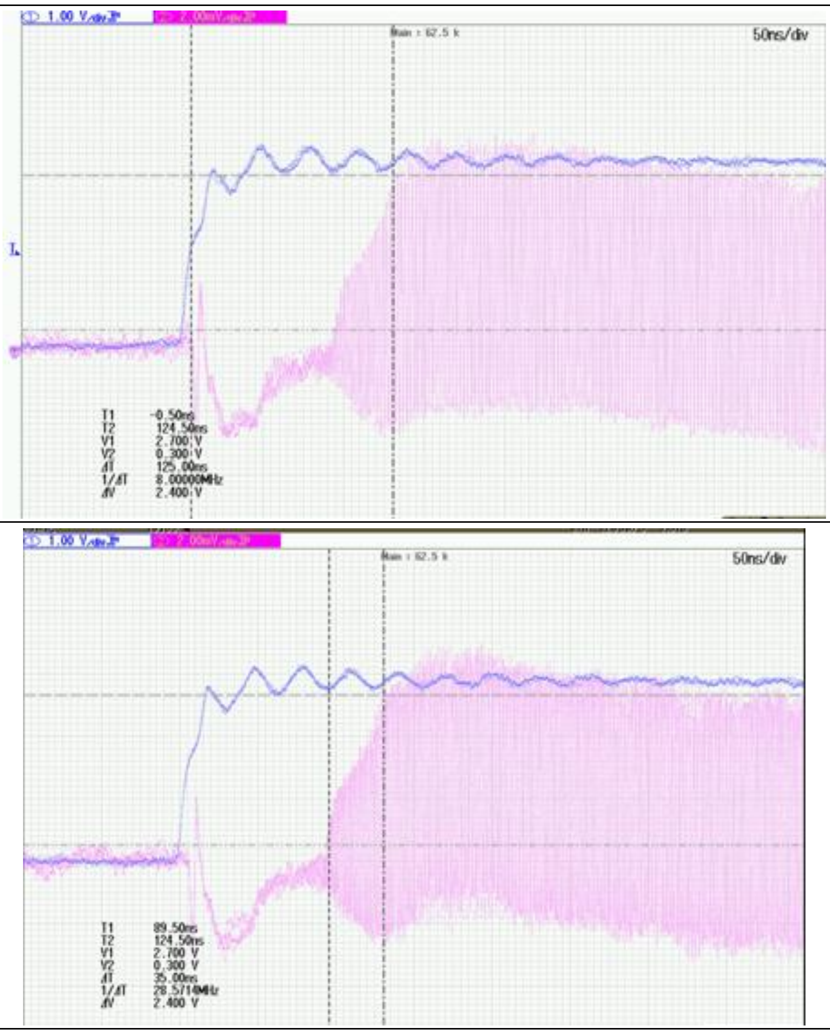


Figure 25 Screenshots of Switching Time Measurement BGS12SL6

Table 6 Switching time measurement results

	RF rise time (ns)	Switching time (ns)
BGS12SL6	35	125

9 Authors

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