BGS15AN16

Performance of SP5T Antenna Switch

LTE, WCDMA, EDGE Mobile Receive Diversity Applications

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1 Introduction

The BGS15AN16 is a generic SP5T RF CMOS switch for applications in the frequency range from 0.1 to 3GHz with standard GPIO control. It typically is used in mobile cellular devices for LTE, WCDMA and GSM/ EDGE receive-diversity. This application note puts special focus on solutions including very high frequencies as 3GPP band VII up to 2690MHz.

Any of the 5 ports can be used as termination of the diversity antenna handling up to 30 dBm.

This SP5T offers low insertion loss and high robustness against interferer signals at the antenna port and low harmonic generation in termination mode.

An integrated LDO allows to connect Vdd directly to battery, hence no regulated supply voltage is required. A power down mode is implemented to avoid current drain when the device is not in use.

The on-chip GPIO controller integrates CMOS logic and level shifters, driven by control inputs from 1.5 V to Vdd. Unlike GaAs technology, external DC blocking capacitors at the RF Ports are only required if DC voltage is applied externally.

The BGS15AN16 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.

The device has a very small size of only 2.3 x 2.3 mm² and a maximum height of 0.77 mm.

2 BGS15AN16 Features

2.1 Main Features

- 5 high-linearity Rx ports with power handling capability of up to 30 dBm
- All ports fully symmetrical
- No external decoupling components required
- High ESD robustness up to 8kV accordind IEC-61000-4-2 with external inductor
- Low harmonic generation
- Low insertion loss
- High port-to-port-isolation
- 0.1 to 3.0 GHz coverage
- Direct connect to battery
- Power down mode
- On-chip control logic supporting logic levels from 1.5 V to Vdd
- Lead and halogen free package (RoHS and WEEE compliant)
- Small leadless package TSNP16 with the size of 2.3 x 2.3 mm² and a maximum height of 0.77 mm

2.2 Functional Diagram

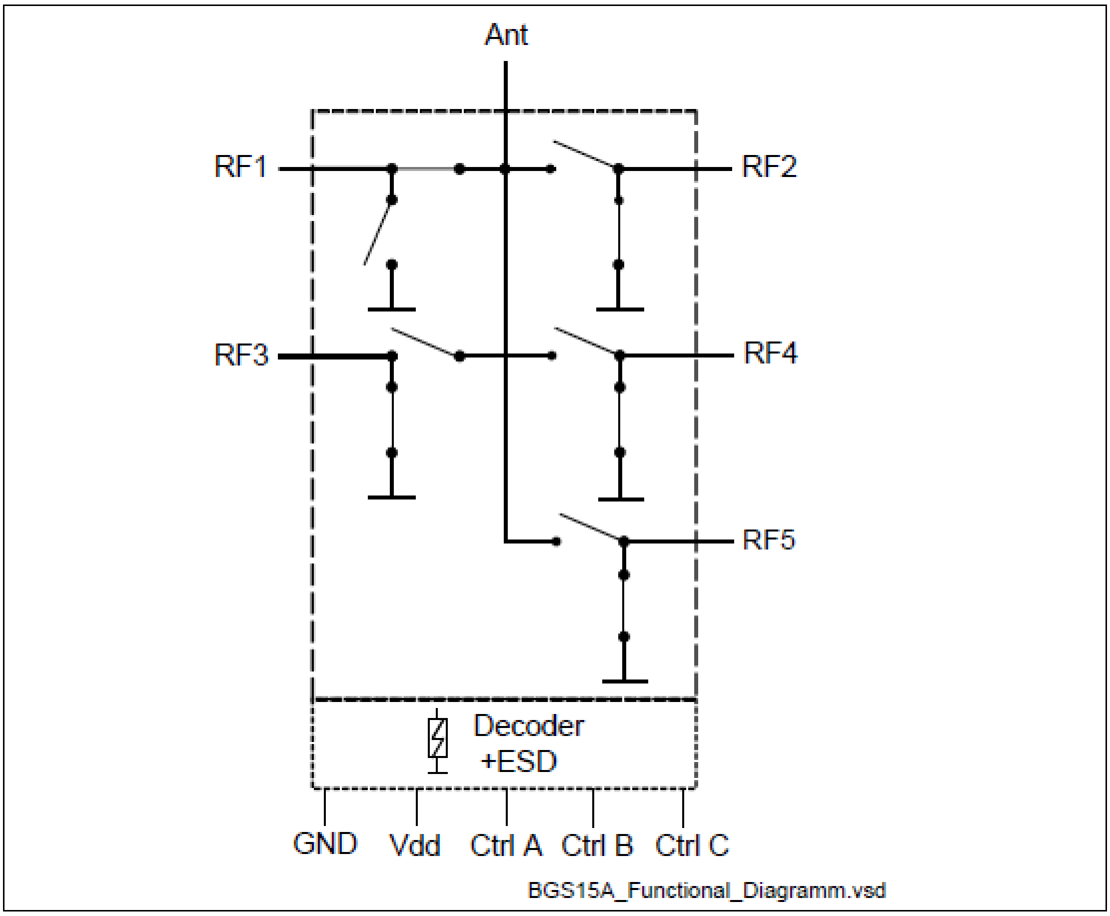


Figure 1 BGS15AN16 Functional Diagram

2.3 Pin Configuration

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

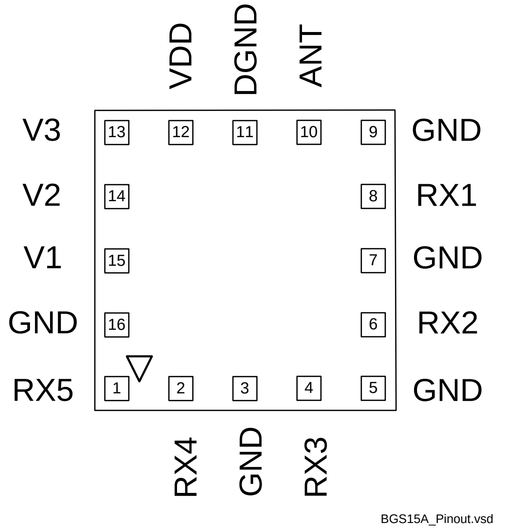


Figure 2 Pin configuration

2.4 Pin Description

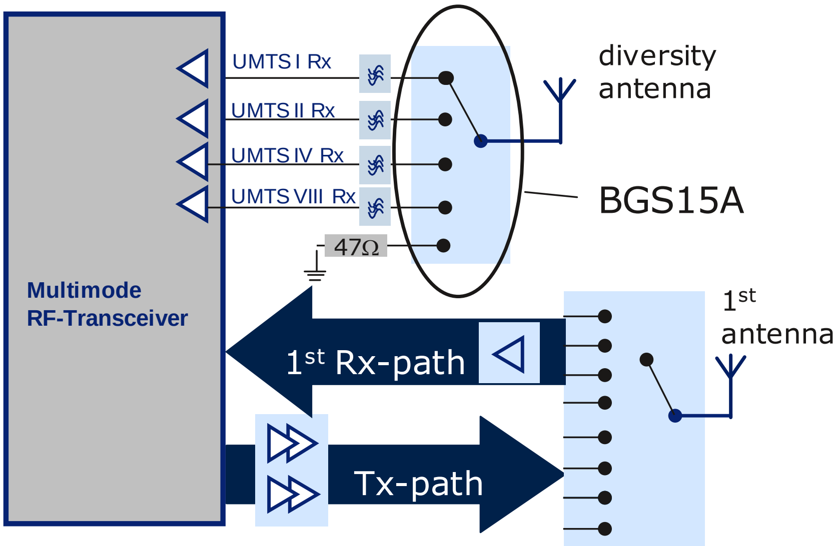
Table 1 Pin Description (top view)

Pin NO	Name	Pin Type	Function
1	RX5	RX5	Rx RF port 5
2	RX4	I/O	RX RF port 4
3	GND	GND	Ground
4	RX3	I/O	Rx RF port 3
5	GND	GND	Ground
6	RX2	I/O	Rx RF port 2
7	GND	GND	Ground
8	RX1	I/O	Rx RF port 1
9	GND	GND	Ground
10	ANT	I/O	Antenna port
11	DGND	GND	Ground
12	VDD	PWR	Vdd supply
13	V3	I	Control pin3
14	V2	I	Control pin2
15	V1	I	Control pin1
16	GND	GND	Ground

3 Application

3.1 Application Example

In Figure 3 one possible application for the BGS15AN16 is shown. The BGS15AN16 is used as a diversity switch in combination with a multiband UMTS transceiver.



4-band UMTS transceiver with antenna diversity switch

Figure 3 Application multiband transceiver with antenna diversity switch

3.2 Application Board

In figure 4 the circuit diagram of the BGS15AN16 is shown. Only one inductor at the antenna input is required to get a good RF performance up to 2.2 GHz.

For Applications where LTE band 41 (2496 - 2690MHz) is used the antanna matching consists of two inductors and one capaticity to achieve a good solution for this broadband frequency range.

For ESD protection, and matching as far as 2.2 GHz a 27nH SMD inductor is placed at the antenna port. To reach a capable broadband matching there are two more matching componenet necessary, one series inductance (1.5 nH) and one shunt capaticity (0.5 pF).

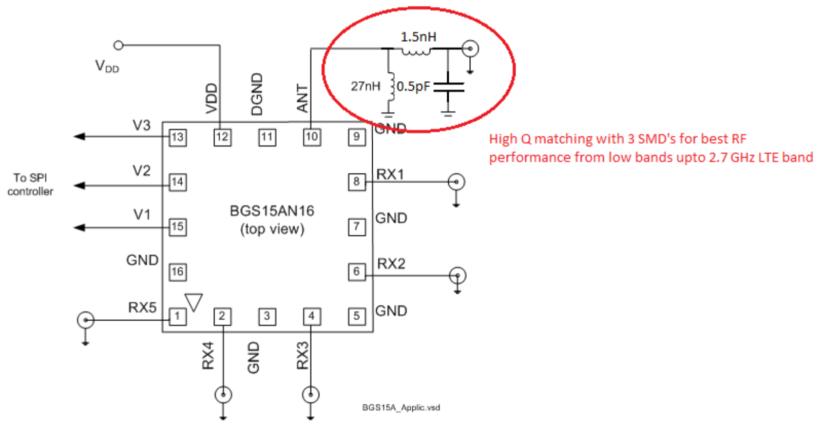


Figure 4 Circuit diagram of BGS15AN16 application board

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

To get correct values for the insertion loss of the BGS15AN16 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.

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

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

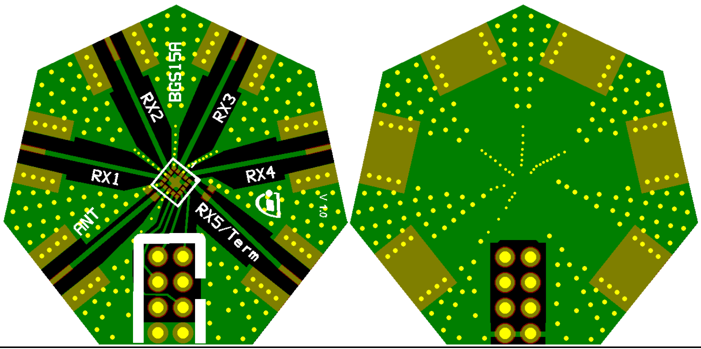


Figure 5 Layout of the application board

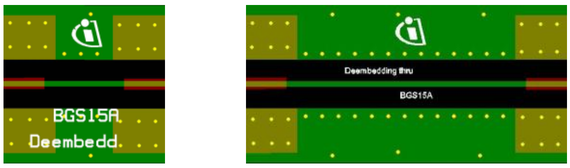


Figure 6 Layout of de-embedding boards

The construction of the PCB is shown in Figure 7.

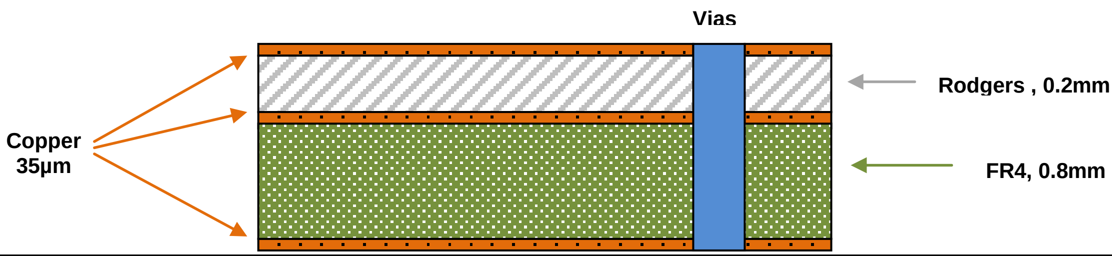


Figure 7 PCB layer information

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 Insertion Loss from Antenna to the respective RF port with all other ports terminated with 50Ω

Table 2 Insertion Loss (dB)

Frequency (MHz) RF Path	824	915	1000	1710	1910	2110	2170	2690
RF1	-0.31	-0.3	-0.32	-0.45	-0.48	-0.52	-0.52	-0.65
RF 2	-0.32	-0.31	-0.32	-0.44	-0.46	-0.5	-0.51	-0.56
RF 3	-0.32	-0.31	-0.32	-0.44	-0.46	-0.51	-0.51	-0.58
RF 4	-0.32	-0.31	-0.31	-0.45	-0.46	-0.52	-0.54	-0.59
RF 5	-0.33	-0.33	-0.33	-0.47	-0.51	-0.57	-0.59	-0.68

4.2 Return Loss measured at the Antenna port with all other ports terminated at 50Ω

Table 3 Return Loss (dB)

Frequency (MHz) RF Path	824	915	1000	1710	1910	2110	2170	2690
RF 1	32.9	31	26.3	16.8	17	17.7	18	17.8
RF 2	32.4	37.7	29.9	17.8	18.3	18.9	19.3	24
RF 3	29.7	39.2	31.3	18.2	18.5	19	19.5	22.8
RF 4	26.6	32.4	28.9	17.5	17.2	17.6	17.9	23.4
RF 5	26.1	30.6	30.4	17.8	17.4	17.2	17.3	20.3

4.3 Return Loss measured at the Antenna port with all other ports terminated at 50Ω

Table 4 Return Loss (dB)

Frequency (MHz) RF Path	824	915	1000	1710	1910	2110	2170	2690
RF 1	33.2	32.5	28.8	18.7	18.5	18.9	19	17.6
RF 2	28.7	31.4	30	20.1	21	22.5	23	30.8
RF 3	27.4	32.2	32.2	21.3	22.5	23.6	24.1	33.7
RF 4	26.4	34.8	40.5	20.6	21.1	21.8	22.4	31.8
RF 5	25.6	32	39.9	22.4	21.1	21.2	21.8	23.7

4.4 Measurement Results

In the following tables and graphs the most important RF parameter of the BGS15AN16 are shown. The markers are set to the most important frequencies of the WDCDMA system.

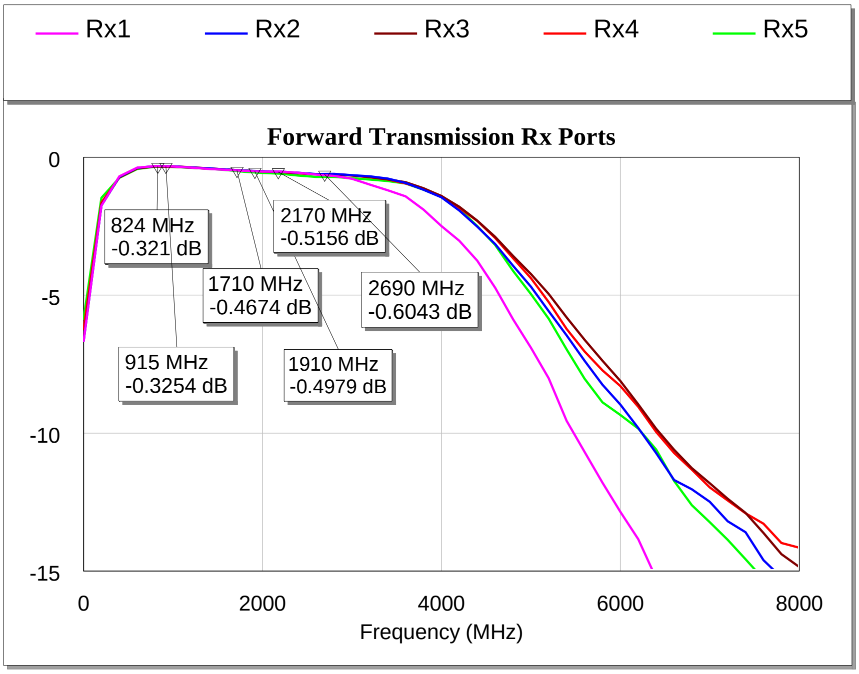


Figure 8 Forward transmission curves for all RF parts

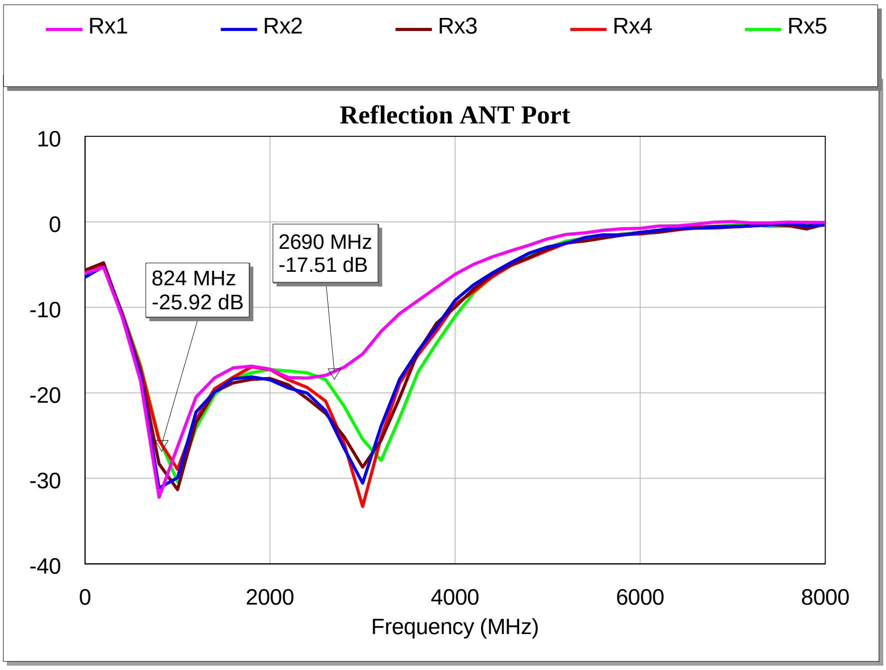


Figure 9 Return loss for antenna for each active RF path

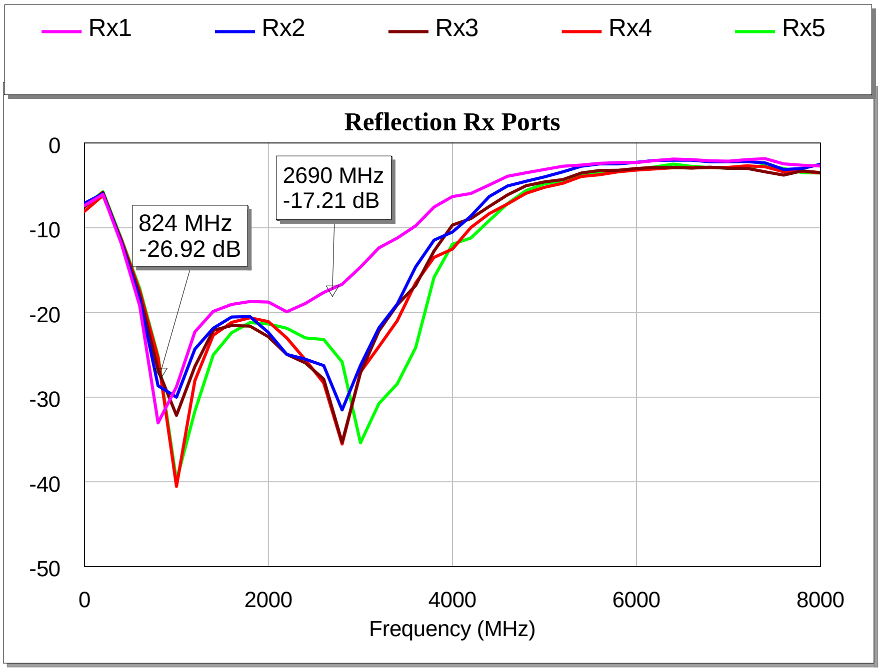


Figure 10 Return loss of several ports for each active RF path

In Table 5 the isolation values antenna to the different RF ports are given.

Table 5 BGS15 antenna to port isolation (in dB)

	Freq (MHz)	Ant > Rx1	Ant > Rx2	Ant > Rx3	Ant > Rx4	Ant > Rx5
Rx1	**824**		40.2	42.4	41.2	39.7
	915		39.1	41.1	40	38.5
	1710		33.1	33.1	32.8	31.3
	1910		32	31.3	31.4	29.8
	2170		30.7	29.5	29.6	28
	2690		28.7	26.1	26.1	24.5
Rx2	**824**	38.8		35.2	39.8	39.4
	915	37.8		34.2	38.7	38.1
	1710	31.5		28.2	32.4	31.4
	1910	30.5		27.3	31.3	29.8
	2170	28.7		24.8	29.8	27.9
	2690	26.7		23.4	28	27.4
Rx3	**824**	40.3	47.4		38.2	40.9
	915	39	45.6		36.9	39.5
	1710	32.5	37		30.6	32
	1910	31.2	35.3		29.5	30.5
	2170	29.9	33.3		28	28.7
	2690	27.8	30.3		25.6	25.6
Rx4	**824**	41.1	48.8	45.7		38.9
	915	39.9	46.5	43.5		37.9
	1710	33	39.3	33.2		29.6
	1910	31.8	37.7	31.2		27.8
	2170	30.4	35.6	29.3		26.3
	2690	28.1	33	26.1		23.4
TM5	**824**	41.9	47.7	45.6	37.9	
	915	40.7	46.5	43.6	36.6	
	1710	34	38.6	34	29.5	
	1910	32.8	37.2	32.5	28.1	
	2170	31.5	35.4	30.4	26.4	
	2690	29	32.4	26.9	23.6	

The values for the port to port isolation are given in Table 6

Table 6 BGS15 port to port isolation (in dB)

	Freq (MHz)	Rx1	Rx2	Rx3	Rx4	Rx5
Rx1	**824**		49.6	44.1	45.7	45.3
	915		48.7	42.8	44.4	43.9
	1710		48.1	41.7	43.7	42.7
	1910		42.4	34.8	37.3	35.8
	2170		40.9	33.1	35.6	34.1
	2690		39.2	31.4	34.1	32.3
Rx2	**824**	32.9		43.7	57.1	55
	915	31.9		42.7	55.3	53.6
	1710	30.9		42	54.4	52.3
	1910	25.6		34.8	46.8	44.8
	2170	24.9		33.3	45.5	43.6
	2690	23.9		31.1	44.3	42.3
Rx3	**824**	33.7	36.5		47.9	43.8
	915	32.6	35.4		47.1	42.7
	1710	31.7	34.5		45.8	41.5
	1910	26.4	29.2		38.2	34.6
	2170	25.3	28.1		36.2	33.1
	2690	24.4	27.1		34.1	31.4
Rx4	**824**	34	42	39.1		32.5
	915	32.8	40.7	37.8		31.4
	1710	32	39.8	36.8		30.5
	1910	26.3	35.1	30.4		25.5
	2170	25.2	34.2	29.1		24.6
	2690	24.3	33	27.8		23.5
TM5	**824**	34.5	41.7	40.6	31.9	
	915	33.4	40.7	39.4	30.7	
	1710	32.5	39.8	38.4	29.8	
	1910	27.1	34.6	32.4	24.2	
	2170	26.1	33.4	31.3	23.4	
	2690	25.1	32.3	30.2	22.6	

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 11. 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.

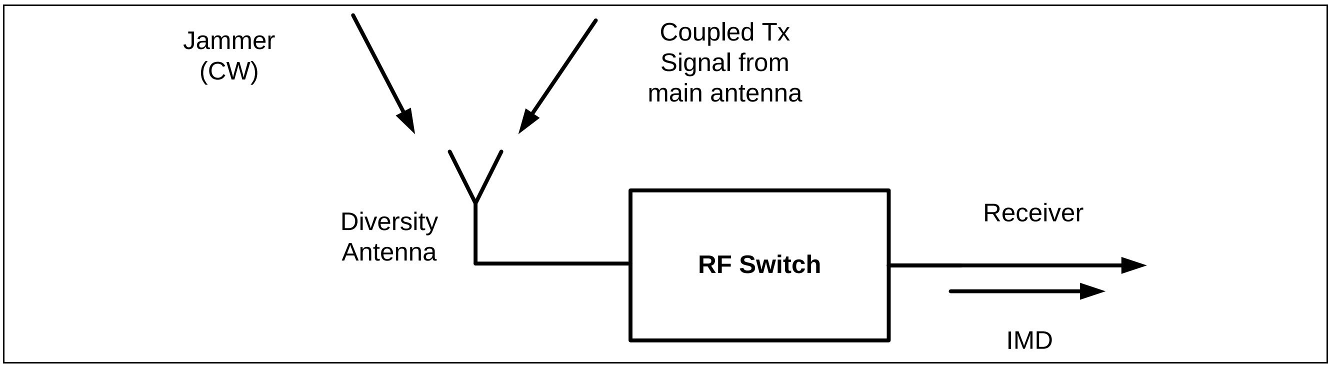


Figure 11 Block diagram of RF Switch intermodulation

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 7 frequencies for 3 bands and the linearity specifications for an undisturbed comunication are given.

Table 7 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 12 and Figure 13).

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

In Figure 13 the results for High band are given. For each distortion scenario there i 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.

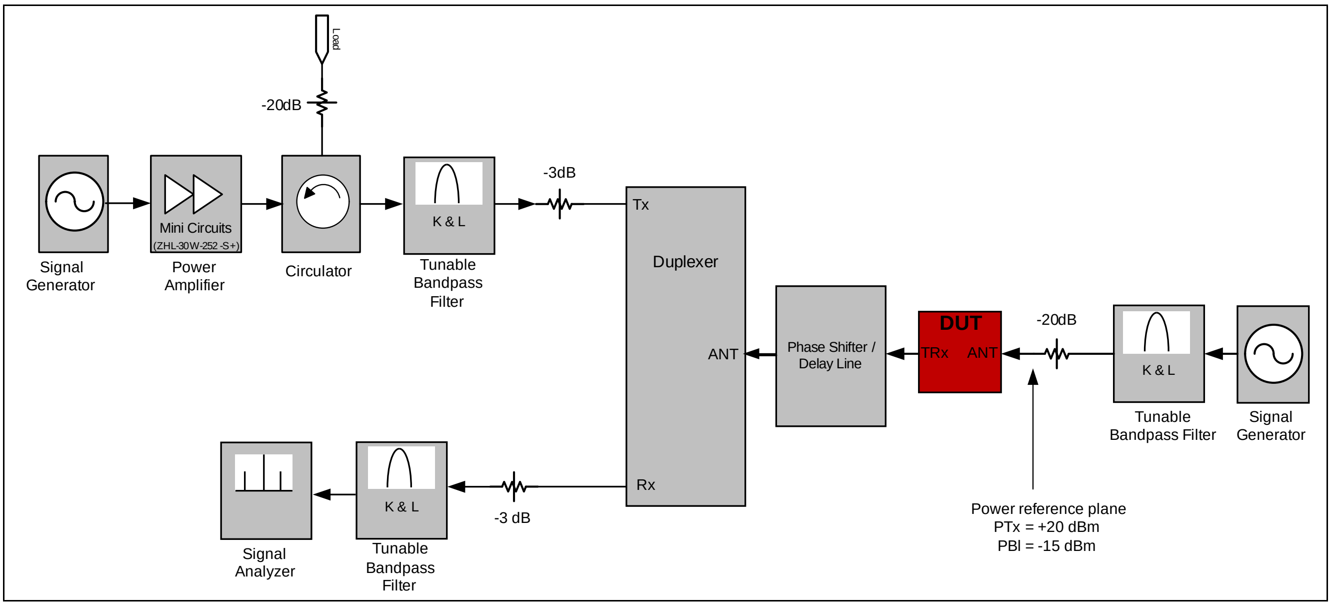


Figure 12 Test set-up for IMD Measurements

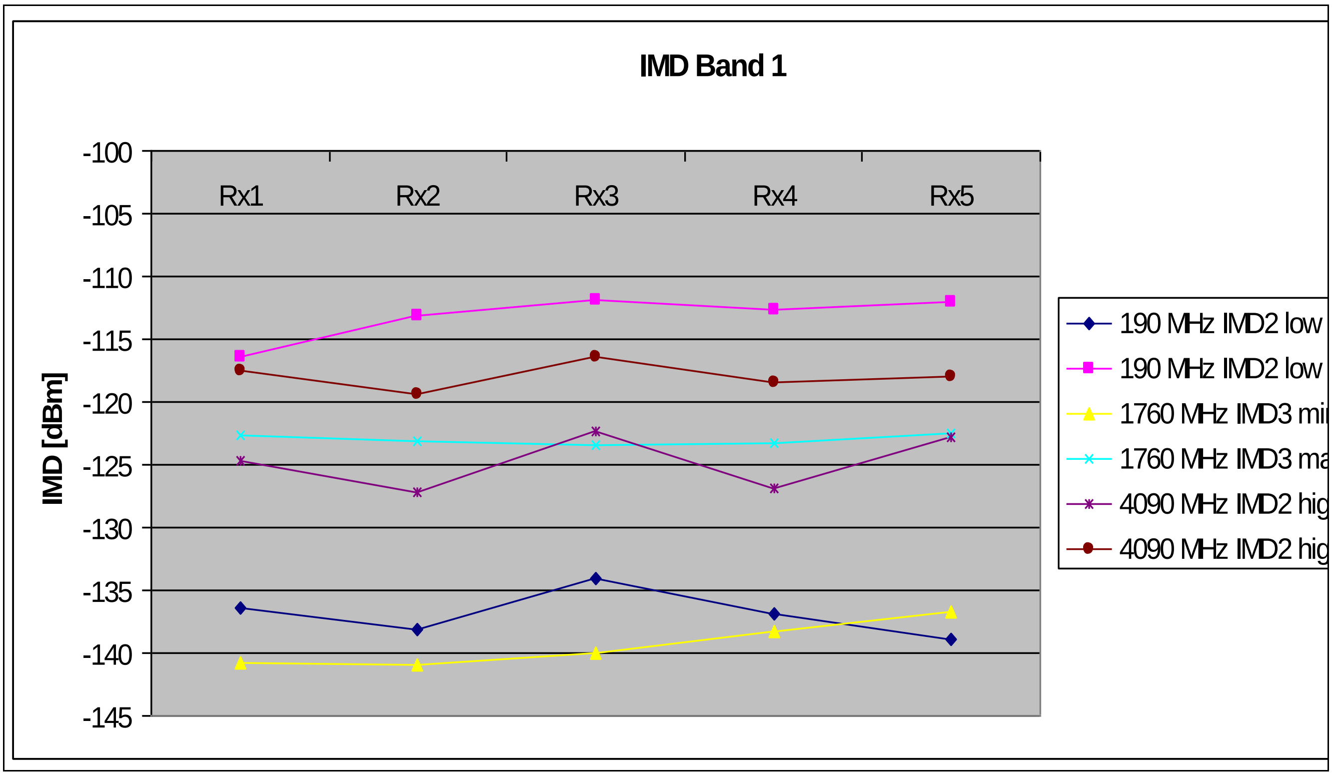


Figure 13 IMD2 and IMD3 results for Band I

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. This harmonics (2nd and 3rd) can disturb the other reception bands or cause distortion in other RF applications (GPS, WLan) within the mobile phone.

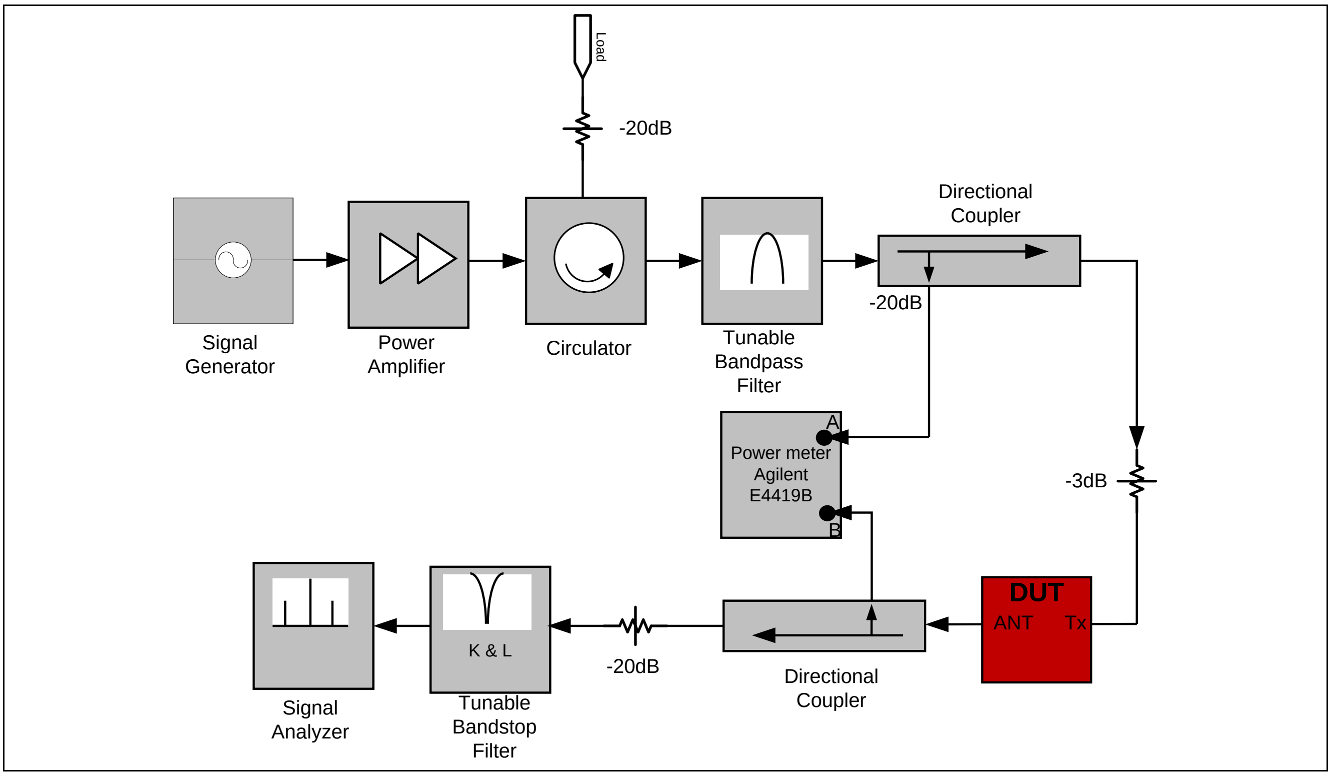


Figure 14 Set-up for harmonics measurement

The results for the harmonic generation at 830 MHZ are shown in Figure 15 (2nd harmonic) and Figure 16 (3rd harmonic) for all RF ports.

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

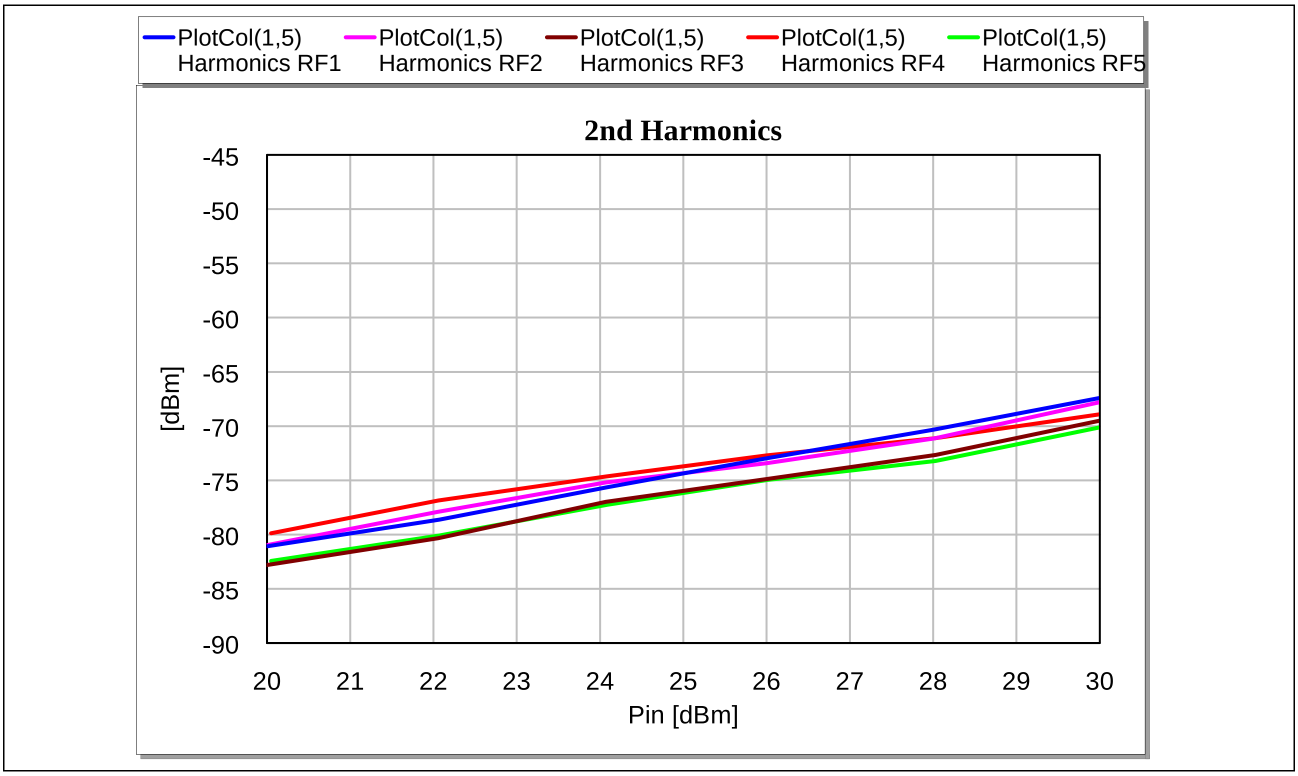


Figure 15 2nd harmonic at f_c=830 MHz

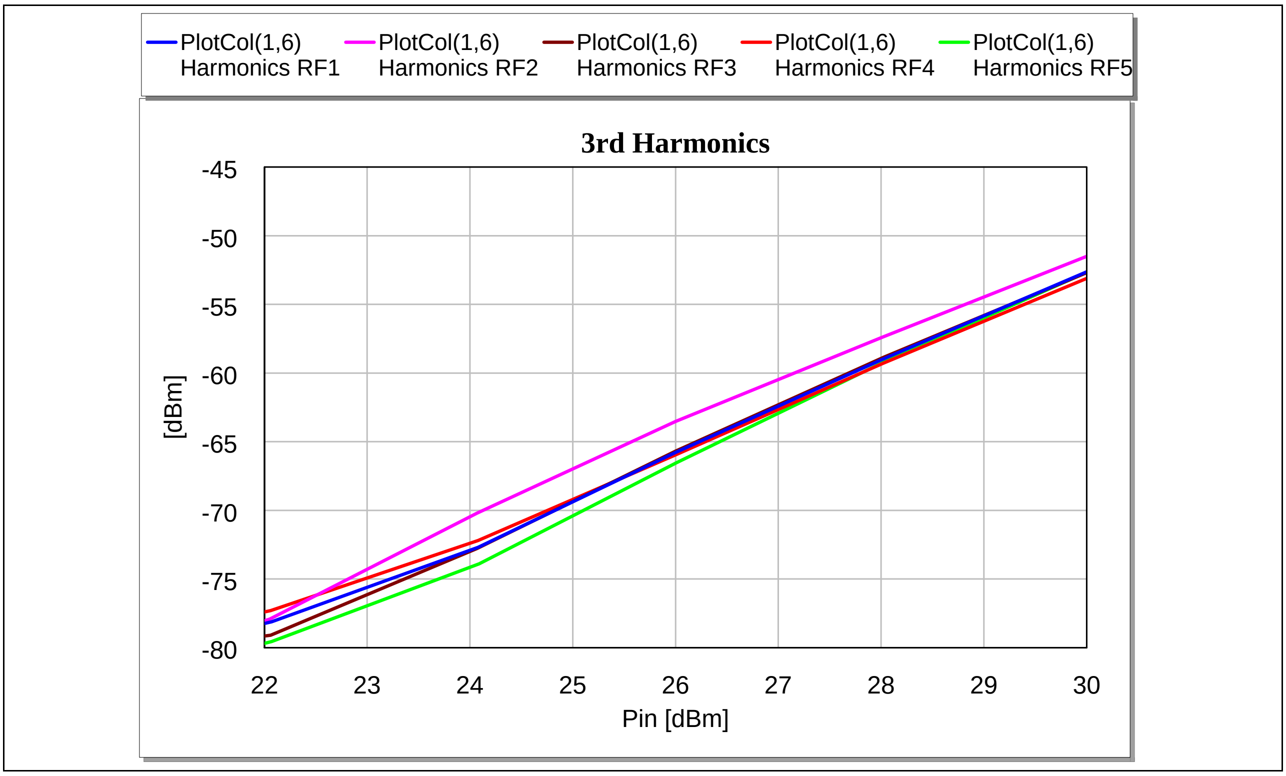


Figure 16 3rd harmonic at f_c=830 MHz

7 Power Compression Measurements on All RF Paths

To judge the large signal capability the power compression is a usual measurement tool. The input power is increase and at the output the power is measured. At a certain point the output power could not follow the input and the switch compresses the RF signal. In the diagram below (Figure 17) the output power 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.

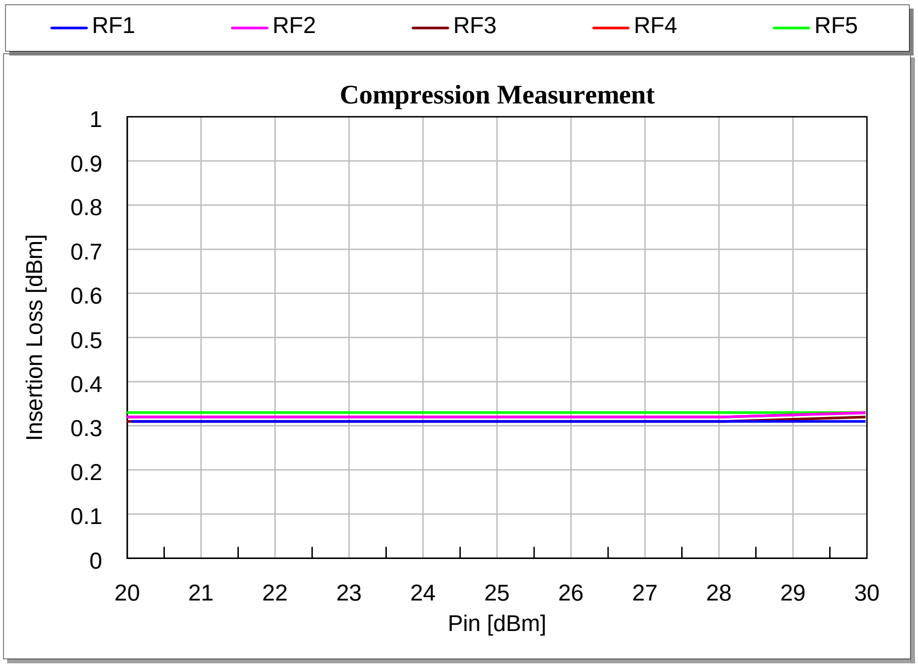


Figure 17 Power Compression Measurement Results at f_c=830 MHz

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.

Appendix: Switch Controller Unit

The BGS15AN16 is controlled via GPIO interface and Infineon offers a GPIO controller unit to ease the evaluation of its BGS15AN16 on application board. The unit is very simple to use with a few buttons to select the right device and different states.

This section helps as a short user guide for the controller unit shown in Figure 18. The controller unit requires a DC supply of 5.5V with a current capability of 50mA.

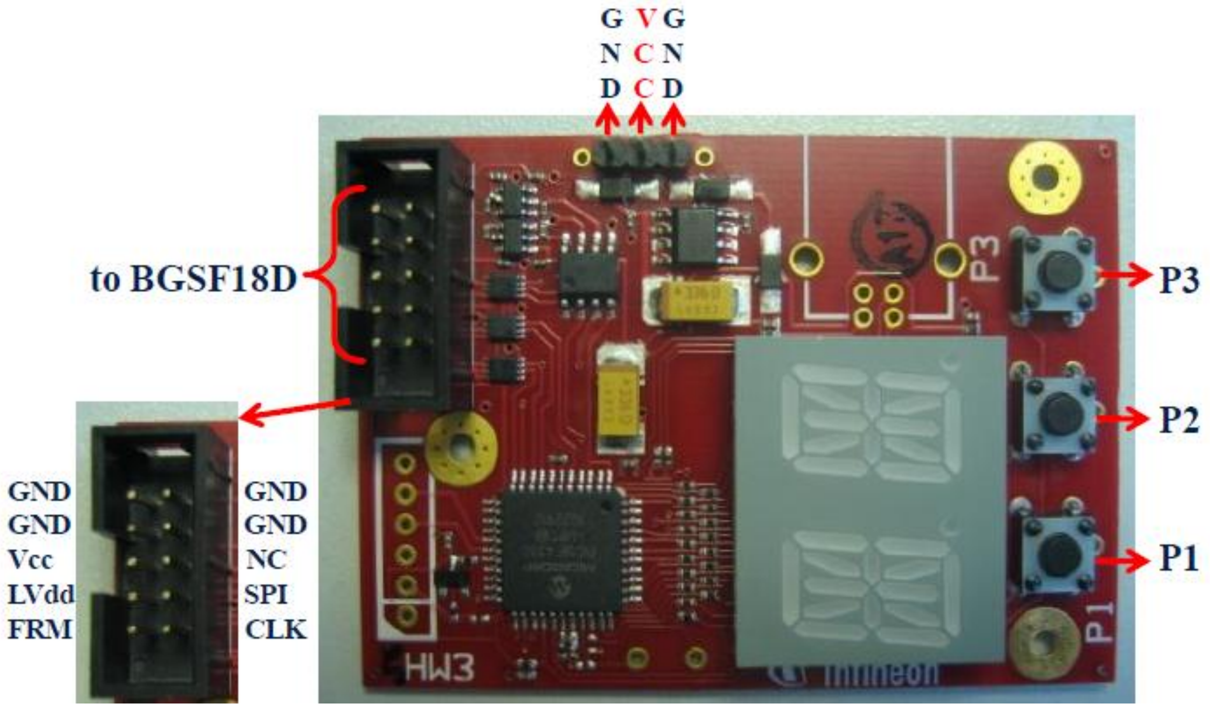


Figure 18 Switch Controller Unit Board

Please observe the following steps to use the controller unit:

1. **Step1:** Attach the power supply and "OK" appears on the display.
2. **Step2:** Set the control mode:
   a. Press and hold "P1" and "P3" simultaneously until "15" appears on the display
   b. "P2" can be used to set the Vdd to the switch between 1.8V, 3.5V (default) and 4.0V
   c. To use 4V, please connect to 6V power supply instead of 5.5V
   d. "15" addresses BGS15AN16 device
3. **Step3:** Connect the control unit to the switch with an appropriate cable according to the connector pin out shown in Figure 18.
4. **Step4:** Set the switch state to measure using "P1" and "P3". The active paths corresponding to the state displayed are tabulated in Table 8.

Table 8 Seeting Display of Active RF Path

Display	Active RF Path
R1	ANT – Rx1
R2	ANT – Rx2
R3	ANT – Rx3
R4	ANT – Rx4
TM	ANT – Rx5
DS	Switch Stand-by (Power Down)

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