RF and microwave power detection with Schottky diodes

About this document

Scope and purpose

This application note shows radio frequency (RF) power detection circuits for automatic gain control or level control with Infineon low-barrier Schottky diodes. Single and dual Schottky diode-based detector structures are outlined. Various Infineon low-barrier Schottky diodes are used, namely BAT15-02EL, BAT62-02V, BAT63-02V for single diode detector structure and BAT15-04W for double diode detector structure.

Intended audience

This document is intended for engineers who need to design RF power detection circuits.

Table of contents

1 Introduction

1.1 RF power detectors

RF devices must control the transmitted RF power efficiently in order to minimize both power consumption and RF interference with other electronic devices. Power control is required in automatic gain control (AGC) and automatic level control (ALC) to maintain suitable output levels. This leads to a demand on RF power detectors for the transmitter.

A diode-based detector offers a simple solution. The principle of diode detection is rectifying the AC signal through a unidirectional transfer characteristic diode and then transferring the rectified signal through an integrator to obtain the DC component. The schematic of the single diode detector is shown in Figure 1. Bypass capacitor C is chosen to be sufficiently large that its capacitive reactance is small compared to the diode's impedance. It must provide a good RF short-circuit to the diode, to ensure that all of the RF voltage appears across the diode terminals. The load resistor R_L, together with capacitor C, determines the detection speed. The key element in this detector circuit can be a Schottky diode.

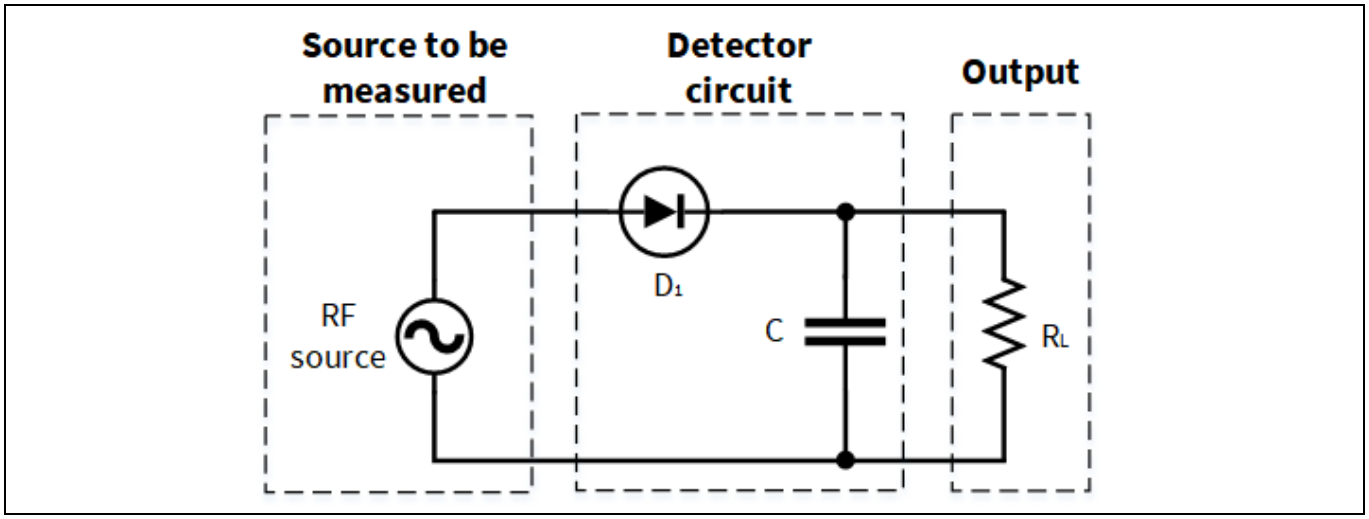

Figure 1 Schematic of single diode detector

The device characteristics of the Schottky diode are similar to a typical PN diode and follow similar current voltage characteristics. The key advantage of a Schottky diode compared to a PN diode is that it shows a lower forward voltage drop (0.15 V to 0.45 V) than the PN diode (0.7 V to 1.7 V). Furthermore, PN junction diodes are minority semiconductor devices suffering from the low recombination velocity of the minority carriers in the space charge region, whereas Schottky diodes are controlled by the charge transport over the barrier from the majority carriers. This leads to very fast switching action for the Schottky diodes and makes them very attractive for RF and microwave rectification.

1.2 Infineon RF Schottky diodes

Infineon RF Schottky diodes are silicon low barrier N-type devices and they are offered in industry-standard 0201 and 0402 form factors as well as conventional industry packages and in various junction diode configurations. Their low barrier height and very small forward voltage, along with low junction capacitance, make this series of devices an excellent choice for power detection and mixer functions at frequencies as high as 24 GHz.

The main parameters of Schottky diodes used in this application note are listed in the following table.

Table 1 Schottky diodes – main parameters

Product type		V_R (max) [V]	I_F (max) [mA]	C_T [pF]	V_F at 1 mA [mV]	Package
BAT15-02EL		4	110	0.20	250	TSLP-2
BAT15-04W	D	4	110	0.30	250	SOT323
BAT62-02V		40	20	0.35	440	SC79
BAT63-02V		3	100	0.65	190	SC79

D= double diode configuration

2 Single diode detector circuit

A single Schottky diode detection circuit is shown in Figure 2. Bypass capacitor C is chosen to be 1 nF so that it has low ohmic capacitive reactance up to 6 GHz. Usually the diode-based detectors can achieve broadband performance. The diode itself will define the frequency range of the detector circuit. The detection sensitivity of the circuit is dependent on the value of R_L, so the circuit was tested with different values of R_L to find the optimum value for maximum sensitivity.

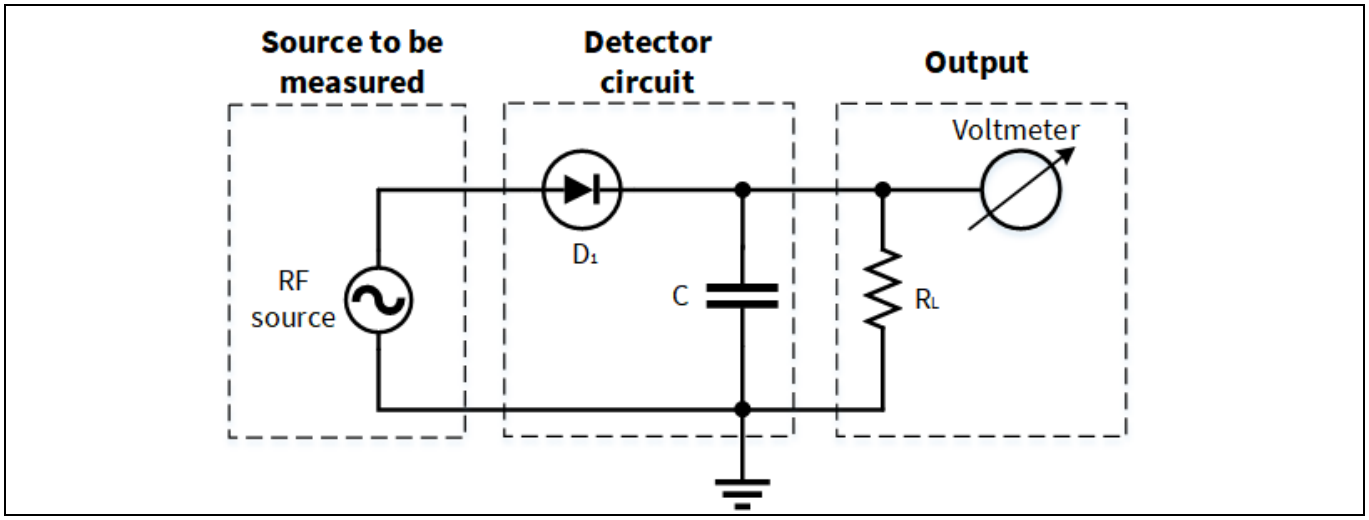

Figure 2 Single diode detector schematic in sensitivity and dynamic range measurement set-up

The measurement results for BAT15-02EL, BAT62-02V and BAT63-02V are shown in Figure 3 and Figure 4. The measurements are done at 2.4 GHz and 5.5 GHz using bypass capacitor C of 1 nF and load resistor R_L of 1 MΩ for all circuits.

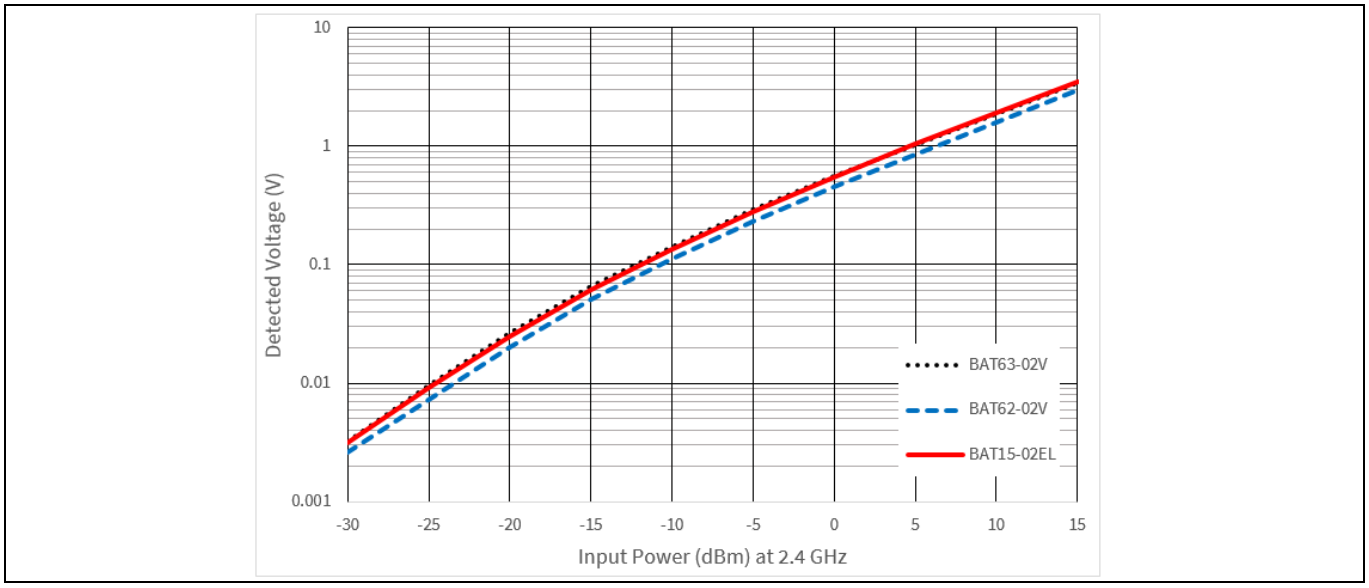

Figure 3 Measurement results at 2.4 GHz for BAT15-02EL, BAT62-02V and BAT63-02V with load resistor R_L of 1 MΩ

Single diode detector circuit

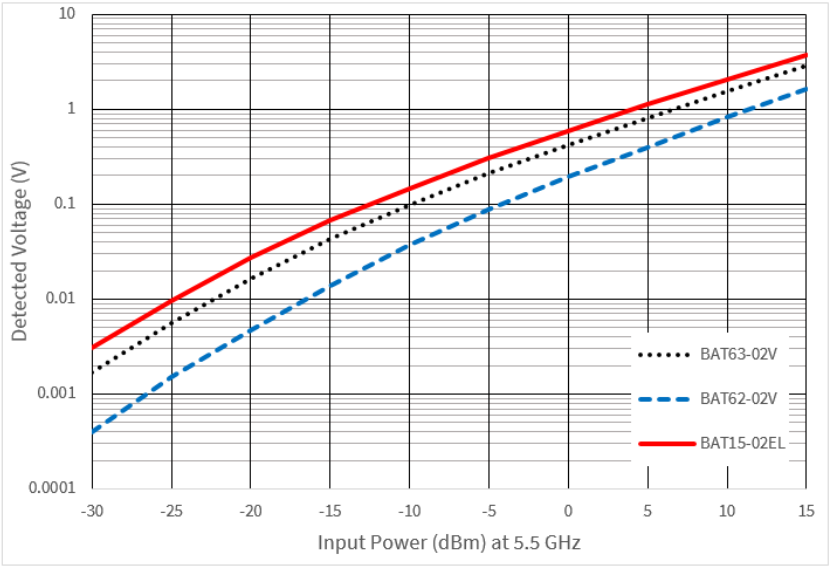

Figure 4 Measurement results at 5.5 GHz for BAT15-02EL, BAT62-02V and BAT63-02V with load resistor R_L of 1 MΩ

2.1 BAT62-02V and BAT63-02V

BAT62-02V and BAT63-02V are single diodes in a compact SC79 package, as shown in Figure 5. They can be used in applications where surface mount devices (SMDs) are required.

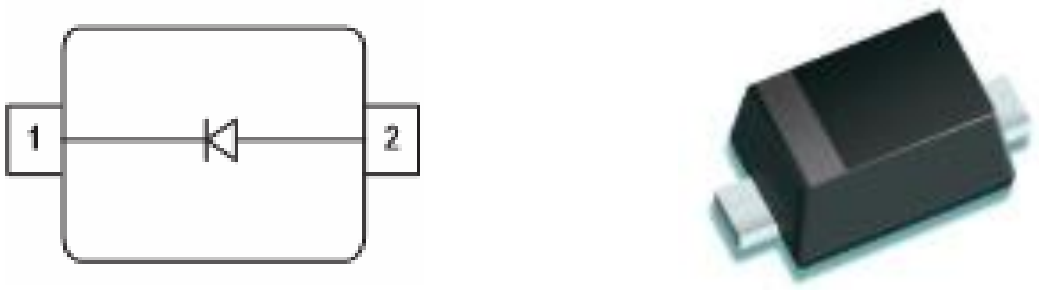

Figure 5 BAT62-02V, BAT63-02V single diode, SC79 package

Bill of Materials (BOM)

Item	Symbol	Value	Manufacturer	Size
Schottky diode	D_1	BAT62-02V BAT63-02V	Infineon	SC79
Capacitor	C	1 nF	Various	0402
Resistor	R_L	10 kΩ to 1 MΩ	Various	0402

Single diode detector circuit

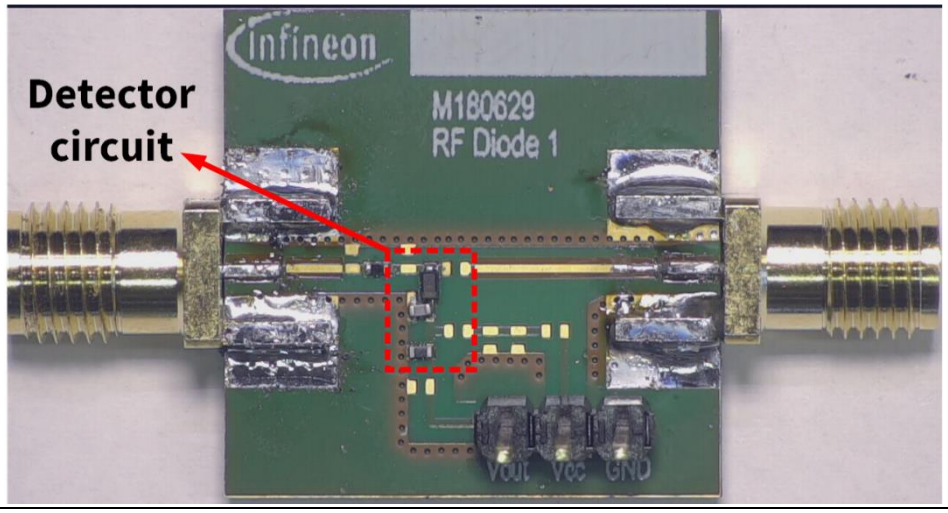

Figure 6 **Photo of the evaluation board for BAT62-02V, BAT63-02V single diode detector circuit**

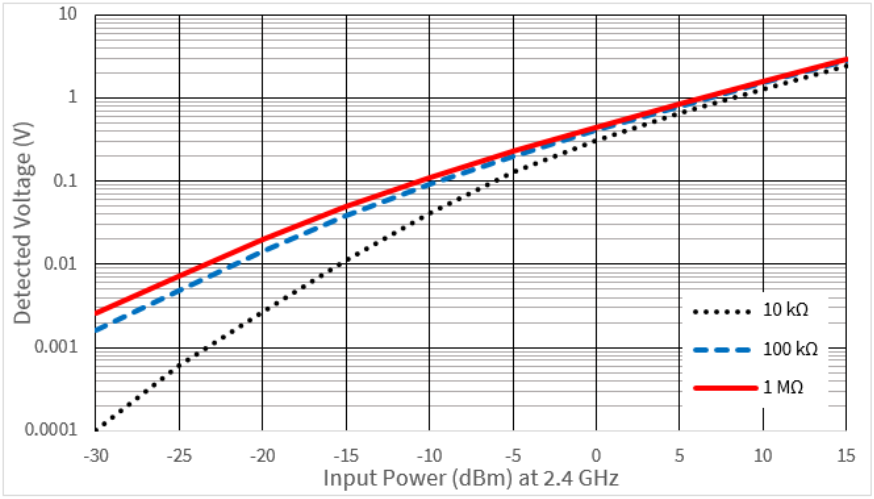

Figure 7 **Measurement results for BAT62-02V at 2.4 GHz with different values of load resistor R_L**

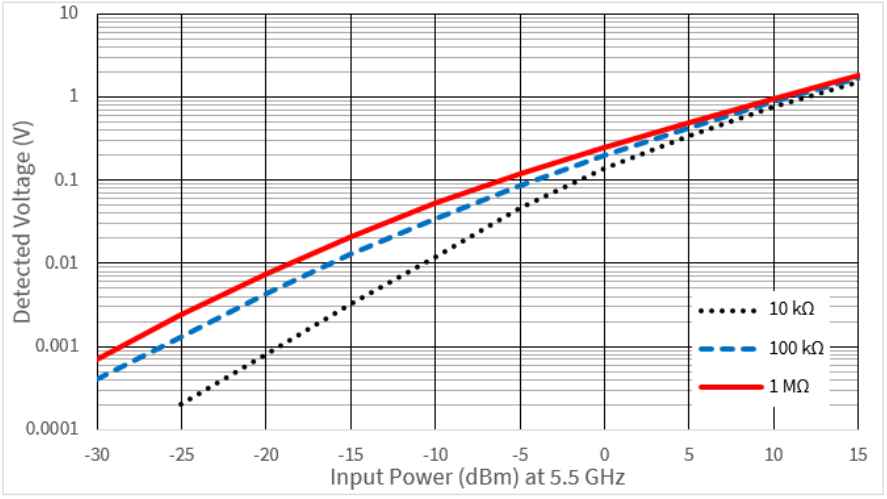

Figure 8 **Measurement results for BAT62-02V at 5.5 GHz with different values of load resistor R_L**

Single diode detector circuit

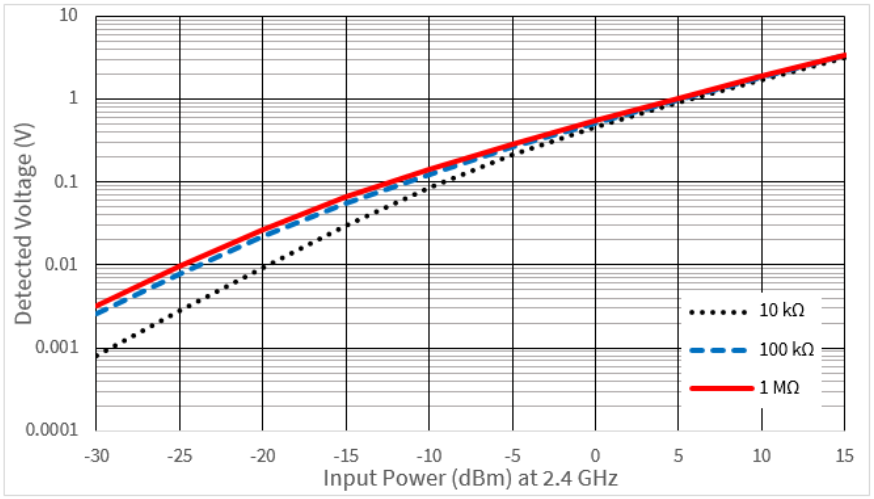

Figure 9 Measurement results for BAT63-02V at 2.4 GHz with different values of load resistor R_L

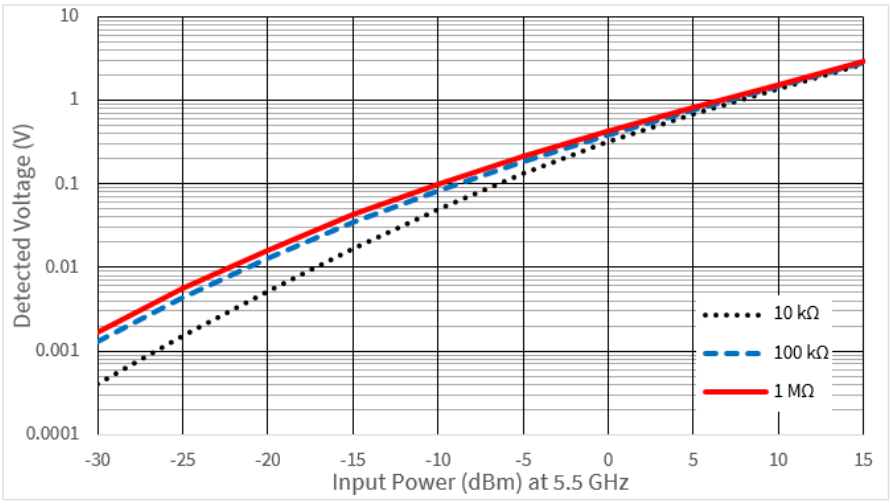

Figure 10 Measurement results for BAT63-02V at 5.5 GHz with different values of load resistor R_L

2.2 BAT15-02EL

BAT15-02EL is a single diode in a leadless package, as shown in Figure 11.

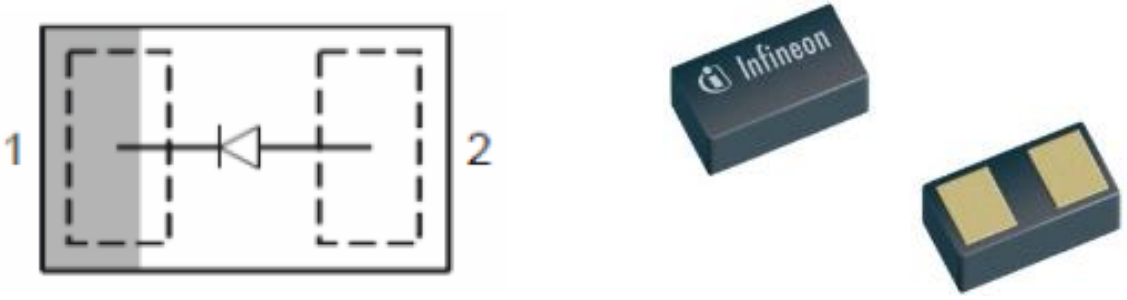

Figure 11 BAT15-02EL single diode, leadless package

Single diode detector circuit

BOM

Item	Symbol	Value	Manufacturer	Size
Schottky diode	D_1	BAT15-02EL	Infineon	TSLP-2-19
Capacitor	C	1 nF	Various	0402
Resistor	R_L	10 kΩ to 1 MΩ	Various	0402

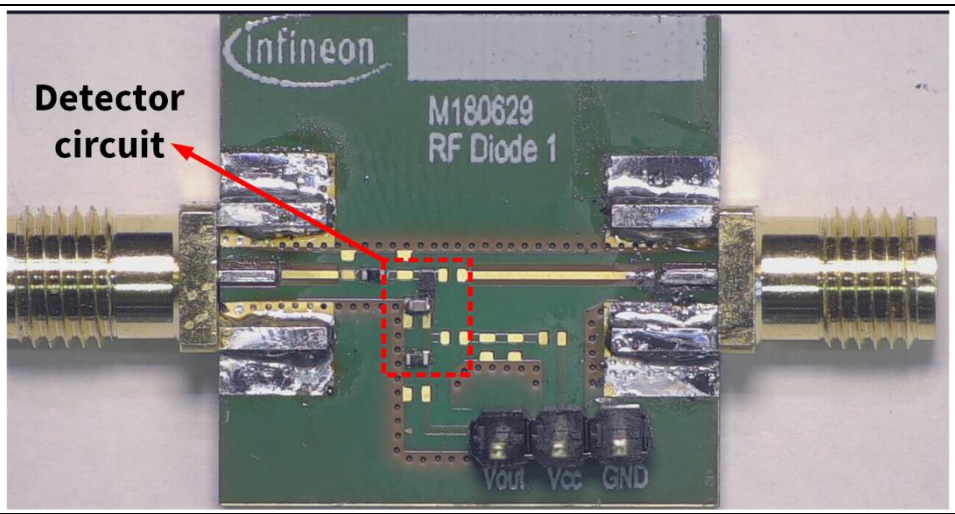

Figure 12 Photo of the evaluation board for BAT15-02EL single diode detector circuit

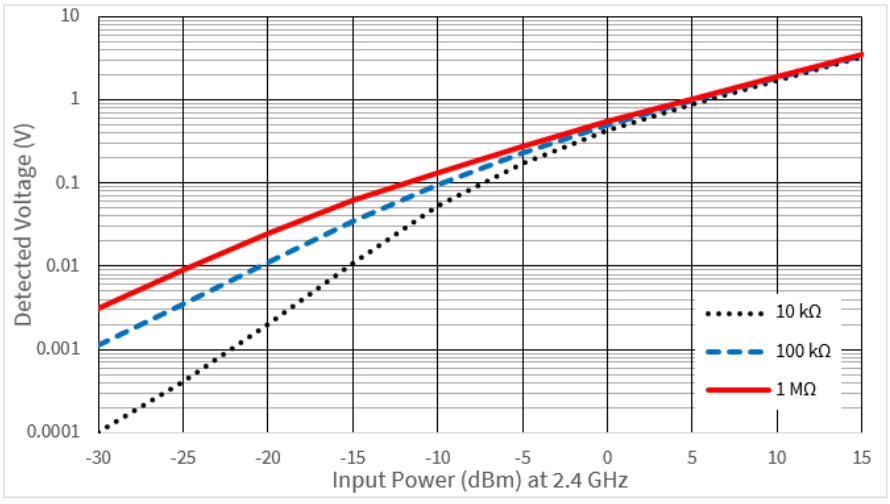

Figure 13 Measurement results for BAT15-02EL at 2.4 GHz with different values of load resistor R_L

Single diode detector circuit

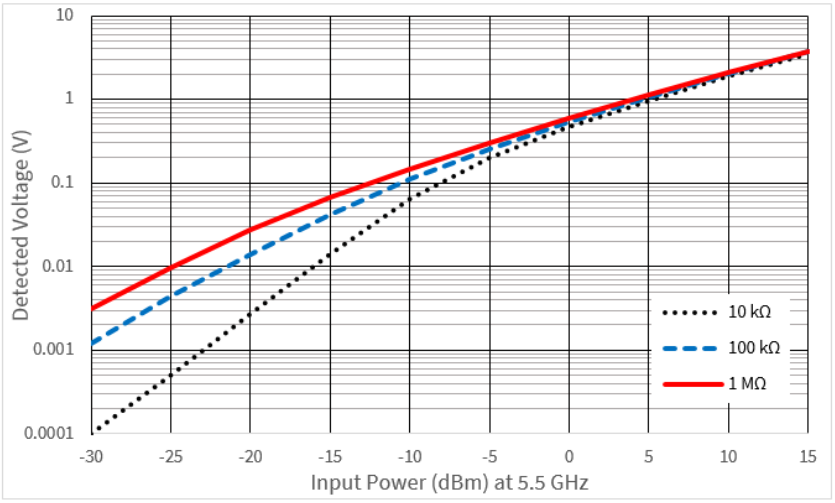

Figure 14 Measurement results for BAT15-02EL at 5.5 GHz with different values of load resistor R_L

3 Double diode detector circuit

The schematic for a double diode detector circuit is shown in Figure 15. The double diode detector circuit utilizes both positive and negative cycles of the AC signal for rectification, increasing the sensitivity and dynamic range of detection. Bypass capacitor C_2 is chosen to be 1 nF so that it has low ohmic capacitive reactance up to 6 GHz. The diode itself will define the frequency range of the detector circuit. The detection sensitivity of the circuit is dependent on the value of R_L, so the circuit was tested with different values of R_L to find the optimum value for maximum sensitivity.

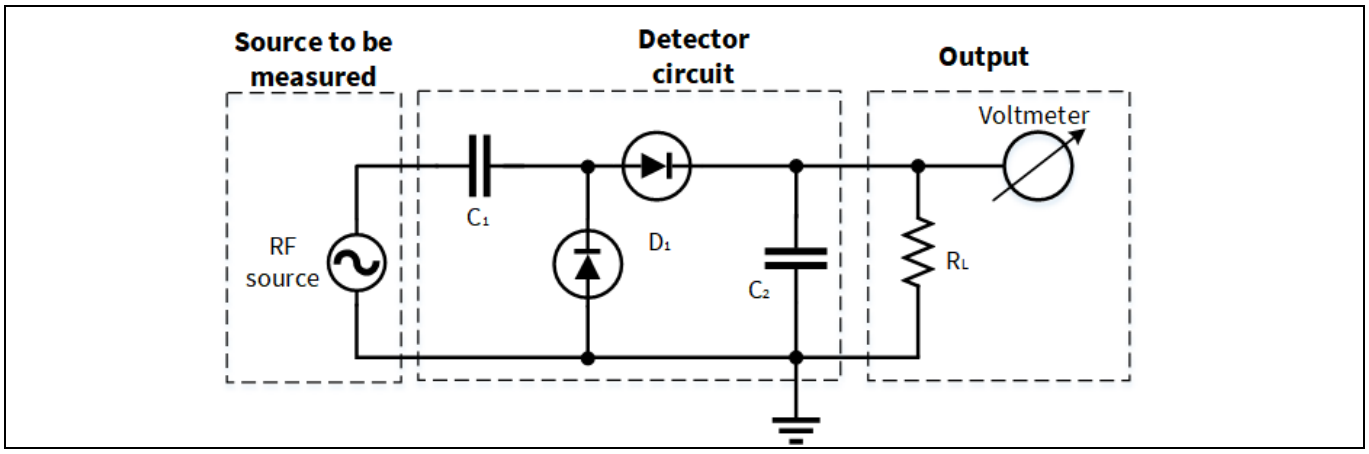

Figure 15 Double diode detector schematic in sensitivity and dynamic range measurement set-up

3.1 BAT15-04W

BAT15-04W is a double diode version in a compact SOT323 package, as shown in Figure 16. This compact version facilitates the assembly of a double diode detection circuit. A detector circuit using BAT15-04W offers broadband operation (up to 6 GHz). Measurements are done at 2.4 GHz and 5.5 GHz.

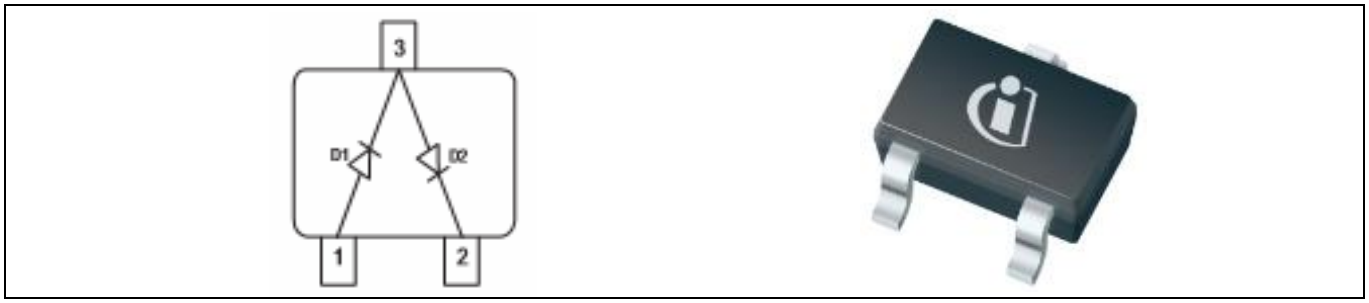

Figure 16 BAT15-04W double diode, SOT323 package

BOM

Item	Symbol	Value	Manufacturer	Size
Schottky diode	D_1	BAT15-04W	Infineon	SOT323
Capacitor	C_1	1 nF	Various	0402
Capacitor	C_2	1 nF	Various	0402
Resistor	R_L	10 kΩ to 1 MΩ	Various	0402

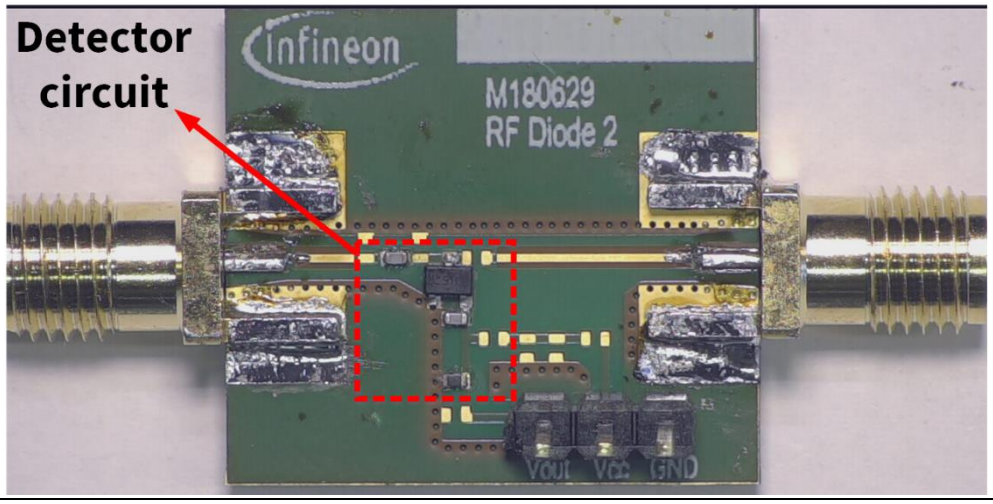

Figure 17 Photo of the evaluation board for BAT15-04W double diode detector circuit

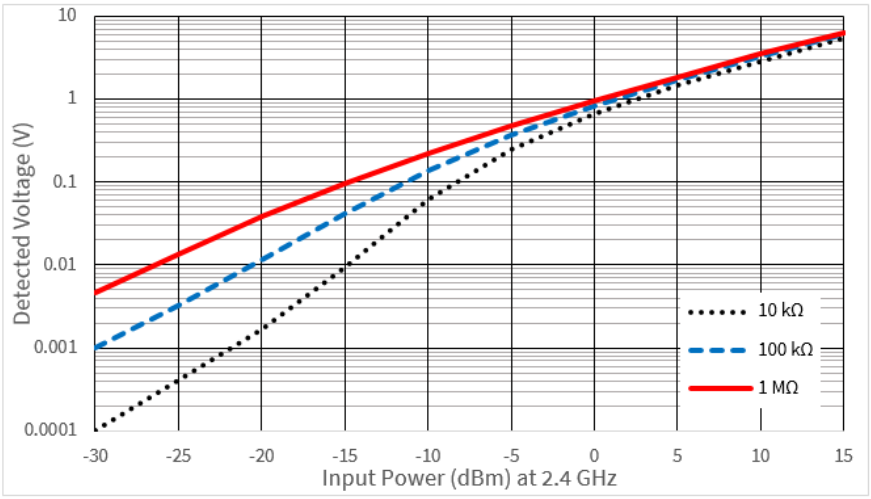

Figure 18 Measurement results for BAT15-04W at 2.4 GHz with different values of load resistor R_L

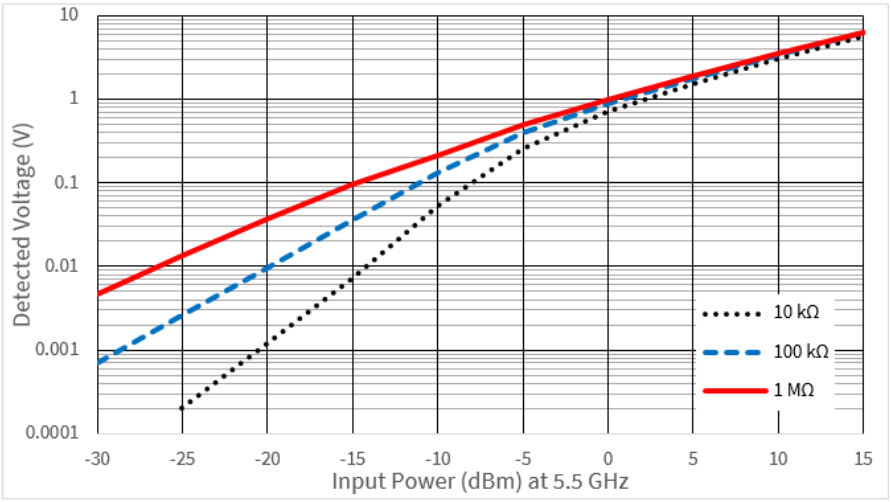

Figure 19 Measurement results for BAT15-04W at 5.5 GHz with different values of load resistor R_L

Double diode detector circuit

The measurement results for the single diode detector circuit (BAT15-02EL) and the double diode detector circuit (BAT15-04W) are shown in Figure 20 and Figure 21. The measurements are done at 2.4 GHz and 5.5 GHz using bypass capacitor C of 1 nF and load resistor R_L of 1 MΩ for both circuits.

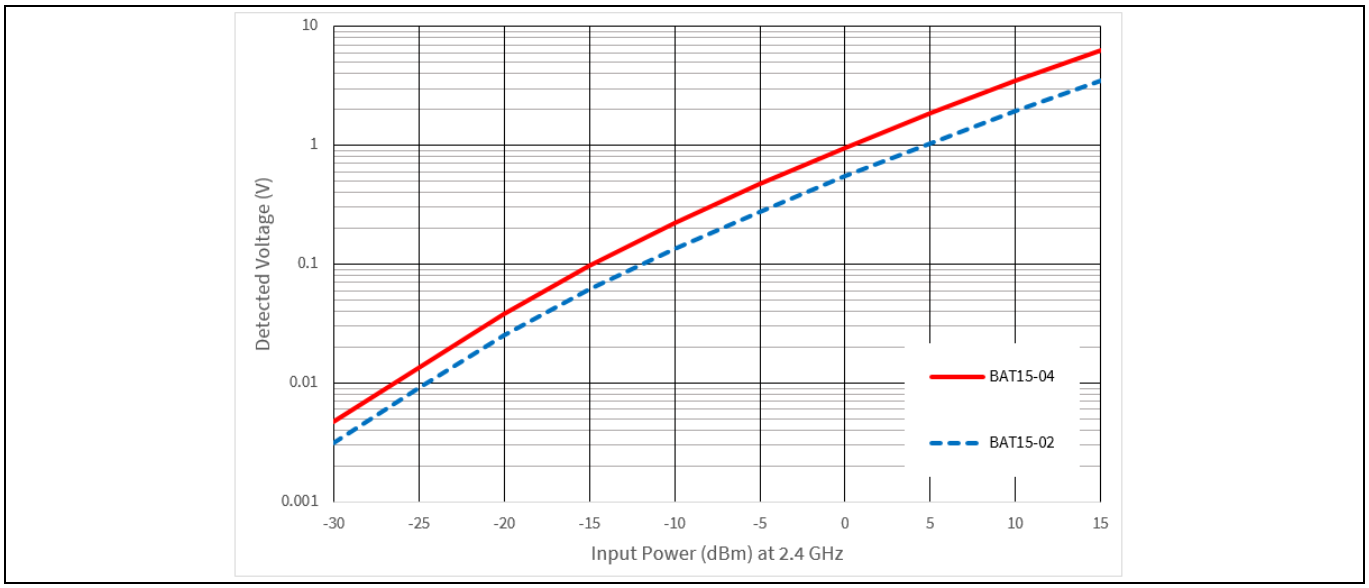

Figure 20 Measurement results at 2.4 GHz for BAT15-02EL and BAT15-04W with load resistor R_L of 1 MΩ

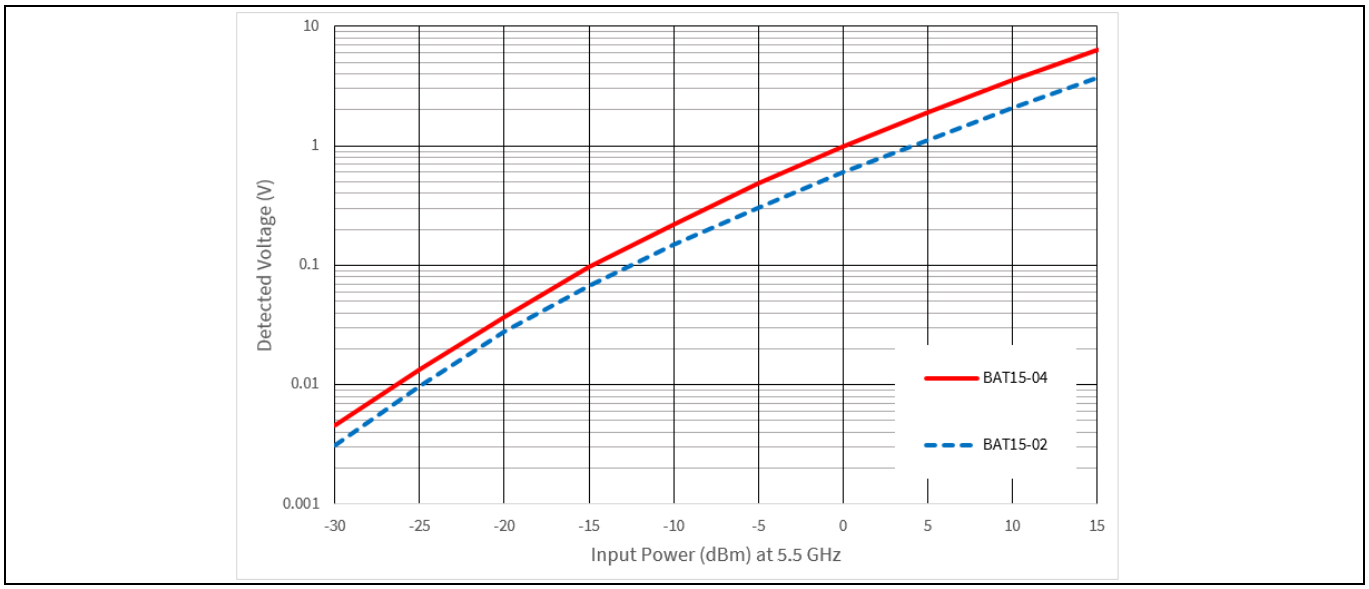

Figure 21 Measurement results at 5.5 GHz for BAT15-02EL and BAT15-04W with load resistor R_L of 1 MΩ

4 Authors

Atif Mehmood, RF application engineer of business unit RF and sensors.

Dr. Jie Fang, RF staff application engineer of business unit RF and sensors.

Revision history

Document version	Date of release	Description of changes

Trademarks
All referenced product or service names and trademarks are the property of their respective owners.

Edition 2018-07-31

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN_1807_PL32_1808_132434

IMPORTANT NOTICE

The information contained in this application note is given as a hint for the implementation of the product only and shall in no event be regarded as a description or warranty of a certain functionality, condition or quality of the product. Before implementation of the product, the recipient of this application note must verify any function and other technical information given herein in the real application. Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind (including without limitation warranties of non-infringement of intellectual property rights of any third party) with respect to any and all information given in this application note.

The data contained in this document is exclusively intended for technically trained staff. It is the responsibility of customer's technical departments to evaluate the suitability of the product for the intended application and the completeness of the product information given in this document with respect to such application.

For further information on the product, technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies office (**www.infineon.com**).

WARNINGS

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.