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.

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Introduction

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 Rs, 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](image)

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.
RF and microwave power detection with Schottky diodes

Introduction

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

<table>
<thead>
<tr>
<th>Product type</th>
<th>$V_R$ (max) [V]</th>
<th>$I_F$ (max) [mA]</th>
<th>$C_T$ [pF]</th>
<th>$V_F$ at 1 mA [mV]</th>
<th>Package</th>
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<td>110</td>
<td>0.20</td>
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<td>TSLP-2</td>
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<td>BAT15-04W</td>
<td>D</td>
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<td>0.30</td>
<td>250</td>
<td>SOT323</td>
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<td>BAT62-02V</td>
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<td>440</td>
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<td>SC79</td>
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D= double diode configuration
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Single diode detector circuit

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.

![Diagram of single diode detector circuit](image)

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.

![Graph showing measurement results](image)

Figure 3 Measurement results at 2.4 GHz for BAT15-02EL, BAT62-02V and BAT63-02V with load resistor $R_L$ of 1 MΩ
RF and microwave power detection with Schottky diodes

Single diode detector circuit

![Graph showing 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.

![Diagram showing BAT62-02V and BAT63-02V single diode, SC79 package.]

**Bill of Materials (BOM)**

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<td>Infineon</td>
<td>SC79</td>
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<td></td>
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<td></td>
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<tr>
<td>Resistor</td>
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<td>Various</td>
<td>0402</td>
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RF and microwave power detection with Schottky diodes

Single diode detector circuit

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

![Detector circuit](image)

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

![Measurement results](image)

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

![Measurement results](image)
RF and microwave power detection with Schottky diodes

Single diode detector circuit

![Graph of detected voltage vs. input power for different load resistors at 2.4 GHz and 5.5 GHz.](image)

**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.

![BAT15-02EL single diode, leadless package](image)

**Figure 11**  BAT15-02EL single diode, leadless package.
RF and microwave power detection with Schottky diodes

Single diode detector circuit

BOM

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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
RF and microwave power detection with Schottky diodes

Single diode detector circuit

Figure 14  Measurement results for BAT15-02EL at 5.5 GHz with different values of load resistor $R_L$. 
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Double diode detector circuit

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.

![Double diode detector schematic in sensitivity and dynamic range measurement set-up](image)

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.

![BAT15-04W double diode, SOT323 package](image)

BOM

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RF and microwave power detection with Schottky diodes

Double diode detector circuit

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
RF and microwave power detection with Schottky diodes

Authors

4 Authors

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### Revision history

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