Never stop thinking

Low Barrier Schottky Diode BAT62

RF Power Detection

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1 Introduction

Device: Low Barrier Schottky Diode BAT62

Application: RF Power Detection

Radio frequency devices must control the transmitted rf power efficiently in order to minimize both power consumption and rf interference with other electronic devices. This is leading to a demand on rf power detectors for the wireless market such as cell phones, cordless phones, WLAN, RFID tags, and wireless communication infrastructure.

This application note is focusing on a solution for rf power detection for hand cells working with a constant envelope modulation scheme such as the GMSK (Gaussian Minimum Shift Keying) for GSM. In this case a peak detector is a good choice. However, communication systems with high crest factors like UMTS will use rms power detectors.

The low barrier rf Schottky diode (BAT62) from Infineon Technologies can be used as an rf rectifier in peak power detectors. The conventional design concept includes one diode as rf rectifier and the second reference diode for temperature compensation together with reducing the impact on power detection by the variation of manufacturing process. A temperature compensated differential peak power detector with differential amplifier is shown in Figure 1 incorporating two Schottky diodes (detector and reference diode), input matching, and biasing network.

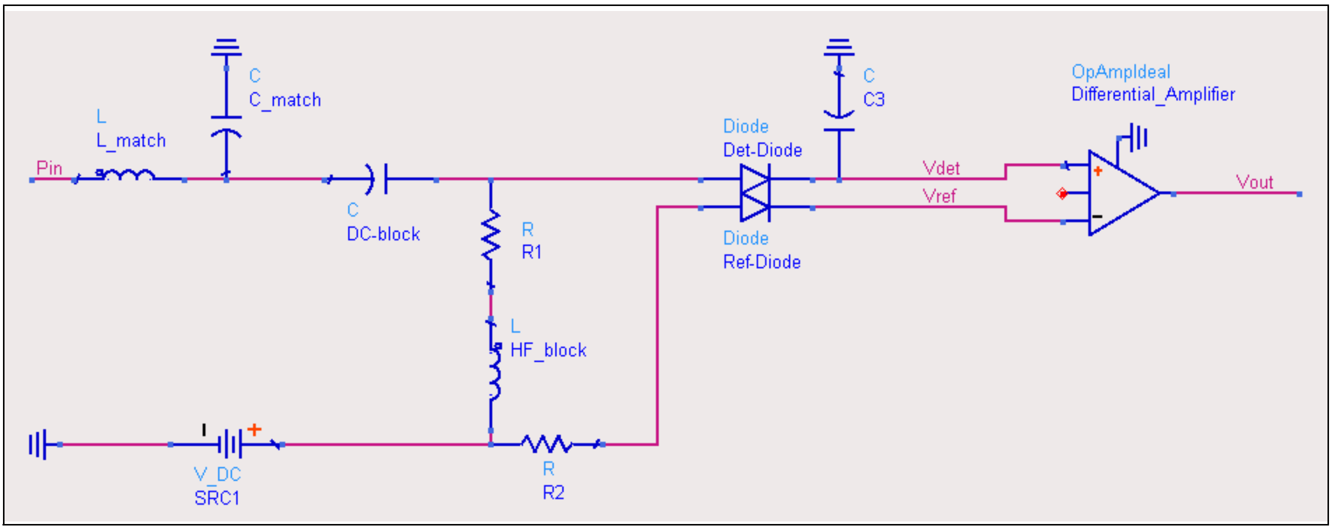

Figure 1 Differential peak power detection network

2 Low Barrier RF Schottky Diode

The device characteristic of the Schottky diode is similar to a typical one sided abrupt pn diode which follows the same current voltage characteristic as being shown in equation (1). However, there are some magnificiant differences between the pn junction diode and the Schottky diode. For example, the Schottky diode exhibits a lower forward voltage drop (0.15V to 0.45V) than the pn diode (0.7V to 1.7V). Furthermore, the voltage drop of Schottky diodes in forward direction can be adjusted by the applied contact material and also zero biased Schottky diodes can be processed based on p-doped materials.

Furthermore, pn junction diodes belong to minority semiconductor devices suffering on the low recombination velocity of the minority carriers in the space charge region, whereas, the 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 it very attractive for rf rectification at frequencies above 1GHz.

$$I = I_S(T) \cdot \left(\exp\left(\frac{qU_j}{nkT}\right) - 1 \right) \quad (1)$$

(n: ideality factor, I_S :saturation current ,U_j : junction voltage, T : Temperature)

In normal forward operation at room temperature and moderate doping concentration ($N_d < 10^{17}$ cm^{-3}) four basic charge transports can be identified.

- Transport of electrons from semiconductor over the barrier to the metal
- Tunneling of electrons through the barrier
- Recombination in the space charge region
- Injection of holes from the metal to the semiconductor

2.1 Low Barrier RF Schottky Diode BAT62-L704

In order to guarantee temperature compensation of the detector diode due to temperature effects the reference device must be a mirror device from the detector diode. This can be guaranteed by the rf Schottky device BAT62-07L4 where 2 rf Schottky devices are housed in TSLP-4-4, a small leadless package with package size of only 0.8mm x 1.2mm x 0.4mm.

If the diode is used in a circuit simulator, the diode is typically implemented by a spice netlist. Below, an extract of the spice model is shown being used for the Si-die BAT62 which can be downloaded at the IFX product overview website http://www.infineon.com/cms/en/product/.

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
.SUBCKT D168  1  2
D1  1  2  D1
R1  1  2  40e6
.MODEL D1 D(IS=250.0n N=1.04 RS=190.0 XTI=1.5 EG=0.53
+ CJO=284.2f M=0.17 VJ=0.224 FC=0.5 TT=55.0p BV=42.0 IBV=10.0u)
.ENDS D168
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

The dc characteristics of the diode are determined by the saturation current IS and the ideality factor N. The bulk resistance of RS=190Ω is included which describes the IU-characteristic of the device beyond 400mV which is leading to current limitation. This can easily be seen by replacing the junction voltage U_j by $U_{ext} - I \cdot R_S$ in equation (1) whereas U_{ext} refers to the external applied voltage. Charge storage effects are modeled by the transit time, TT, and a nonlinear depletion layer capacitance which is determined by the parameters CJO, VJ, and M. The temperature dependence of the saturation current is defined by the parameters EG, the activation energy and XTI, the saturation current temperature exponent. The nominal temperature at which these parameters were measured is TNOM. Reverse breakdown is modeled by an exponential increase in the reverse diode current and is determined by the parameters BV and IBV. Additionally, a resistor of 40MOhm is connected in parallel to the diode in order to adjust the leakage current.

The two diodes are housed in the TSLP-4-4 package. The combination of package parasitic and device is shown in Figure 2. The package model takes into account the rf cross coupling between the neighboring diodes as well as the serial parasitic of the wire bonds.

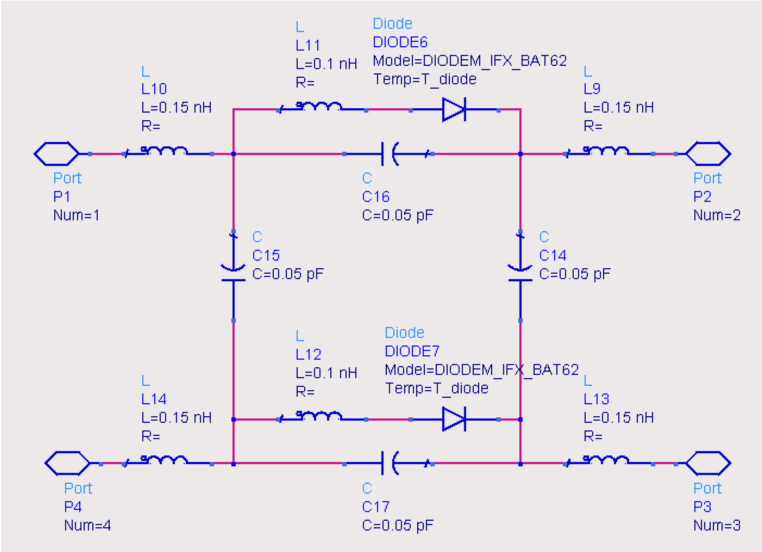

Figure 2 Equivalent circuit of BAT62-07L4 compromising the two Si-dies with the package parasitic

The voltage current characteristics are shown in Figure 3 whereas in Figure 4 the load dependent rectified voltage over rf input power is shown. Especially, the temperature dependent rectified voltage is dominated by the rf voltages smaller than 300mV

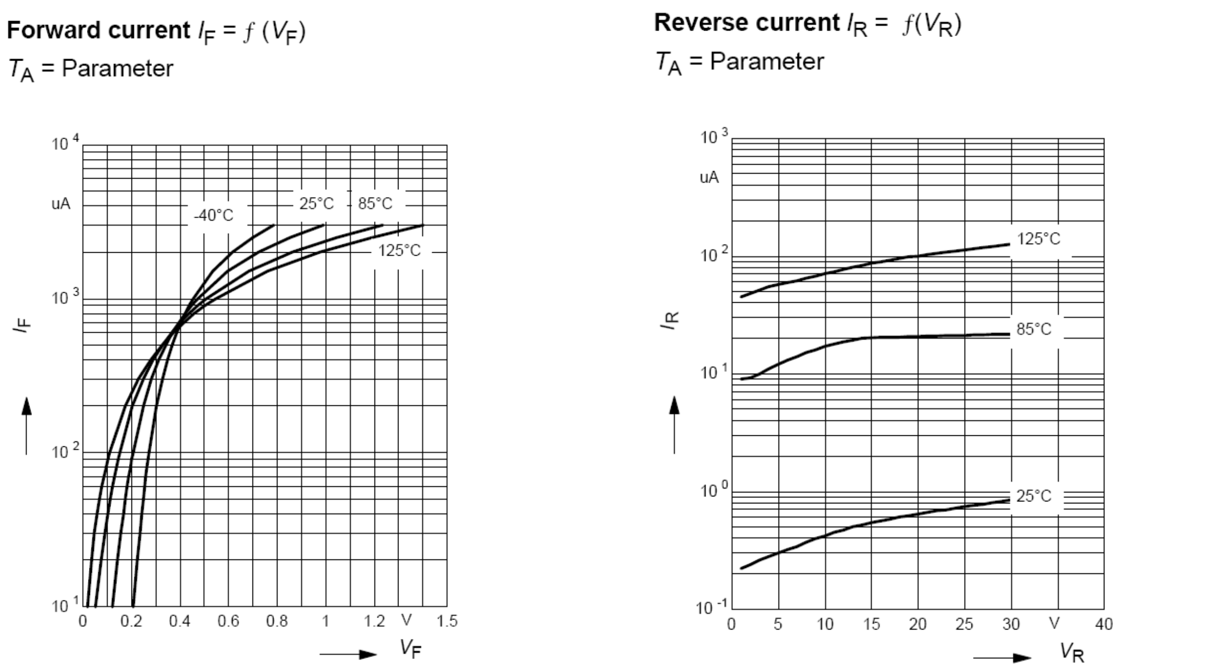

Figure 3 Voltage Current Characteristics for different temperature values

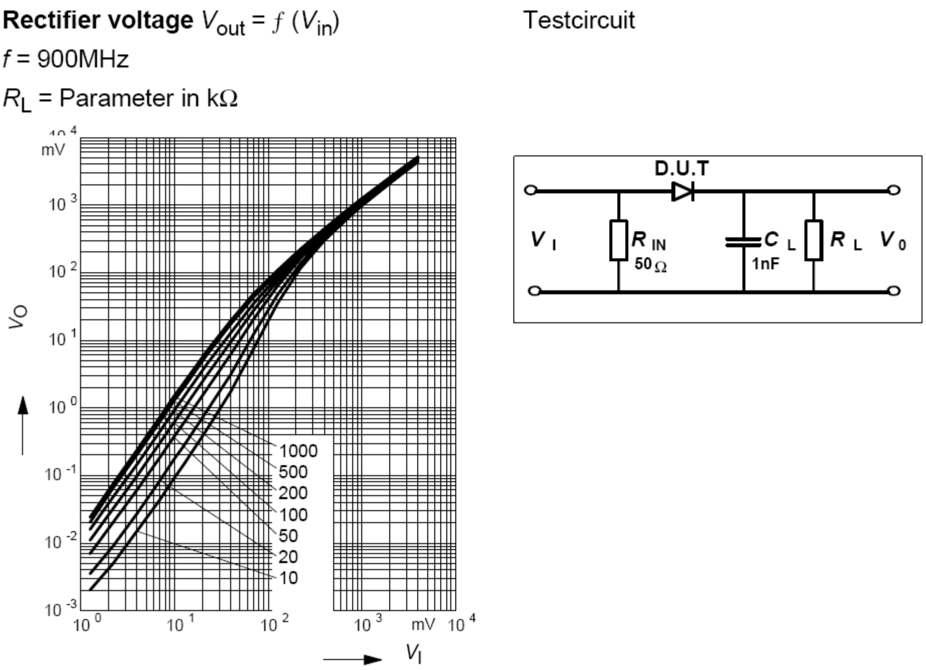

Figure 4 The rf rectification of a sinusoidal voltage at 900 MHz in dependence of the load resistance

In this section two low barrier Schottky diodes housed in TSLP-4-4 with

- Low capacitance (0.3pF)
- Internal ESD protection (Guard Ring) (HBM -1A)
- Operation up to 5 GHz

were presented.

3 RF Power Detection for mobile phones (GSM, DCS, PCN)

The transmitted output power of the PA is controlled by the automatic power control (APC). The monitoring of the transmitted power will be done by a directional coupler with a coupling of about 20dB. This rf power will then be represented by the corresponding rectified signal of the power detector (see Figure 5).

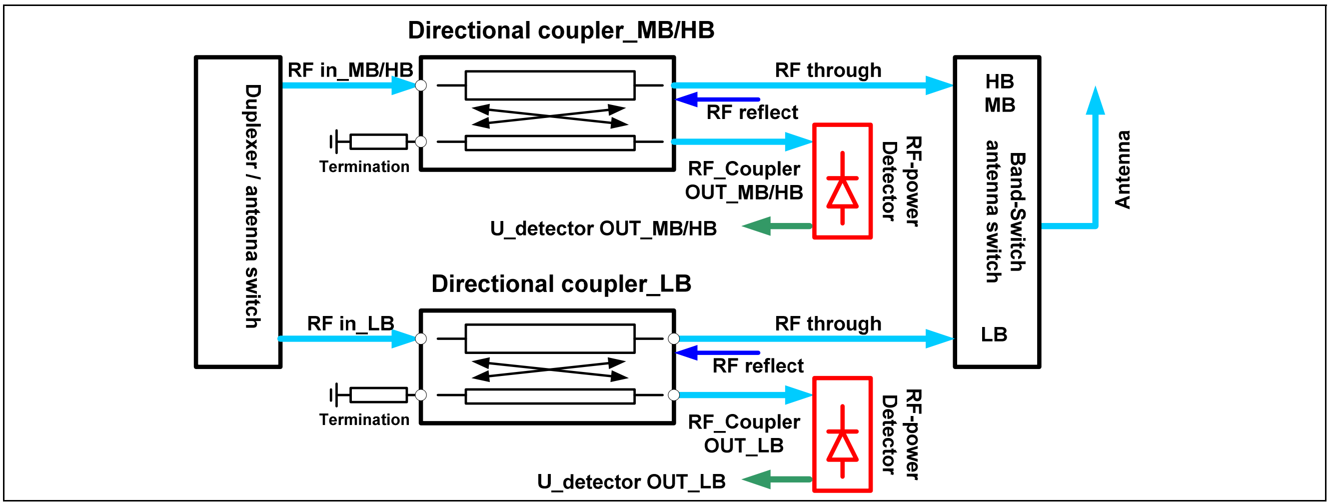

Figure 5 Block diagram of a typical power detection network used for mobile phones

3.1 Design Concept for Power Detection at Lowband (~900MHz)

The widely used differential peak power detection method with temperature compensation was designed and optimized with ADS2008 by applying a large signal simulation.

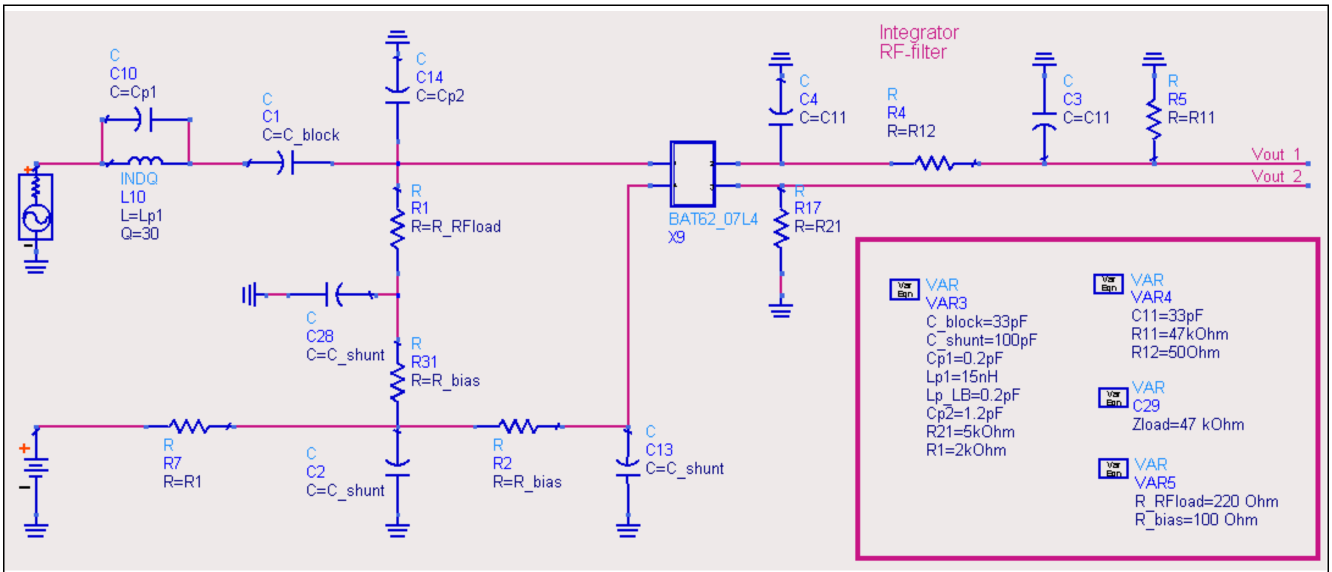

Figure 6 Differential peak power detection design consisting of two Schottky diodes (Detector Diode + Reference Diode in one package – BAT62-07L4) being used for temperature compensation

A matching circuit at the input has to transform the input impedance (50 Ohm in this example) to a (higher) impedance level, which is provided by R_RF_load and the diode´s capacitance. In order to improve bandwidth or harmonic suppression the matching circuit can be adopted additionally and the component values should be used as a reference. In the product implementation, component values may differ slightly depending on the output impedance of the directional coupler at the TX-link, component place, and board parasitics (e.g. Cp1). Over and above, additional filter circuits can be used to increase the sensitivity of the receiver.

The power detection depends on operation temperature as well as on the rf input power. The saturation current of a Schottky diode strongly depends on device temperature. Additionally, the rf power cause a change in the device operation point due to the rf rectification of the ac current (self biasing) and herewith to a change in the matching as being shown in Figure 7.

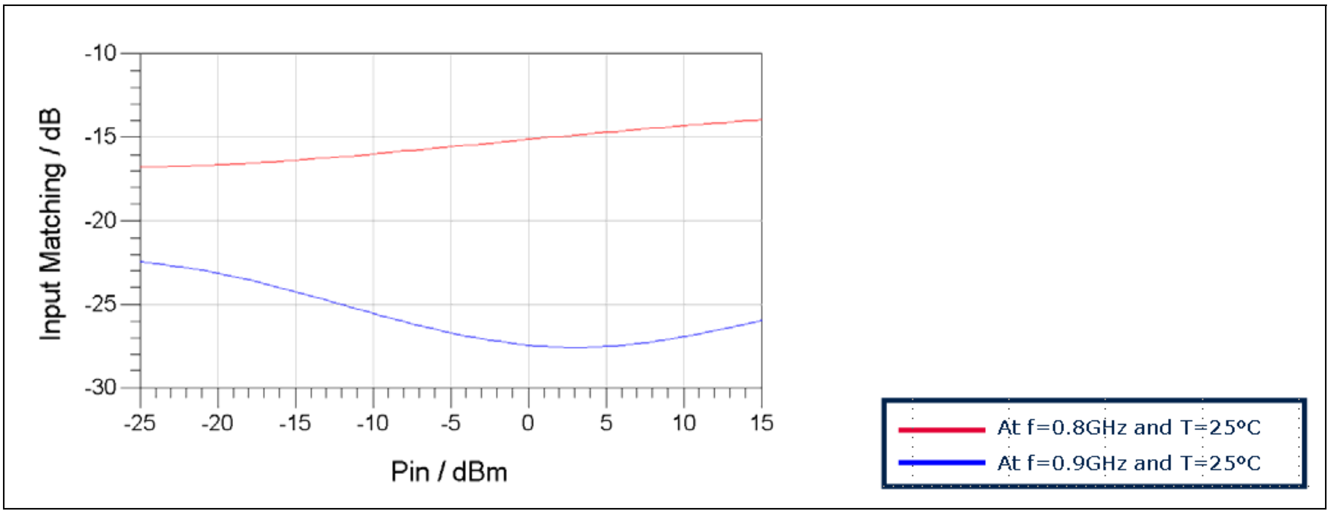

Figure 7 Input Matching versus input power at room temperature

In Figure 8 are the detector output voltages over rf power shown at different temperature values -30°C, 25°C, and 85°C).

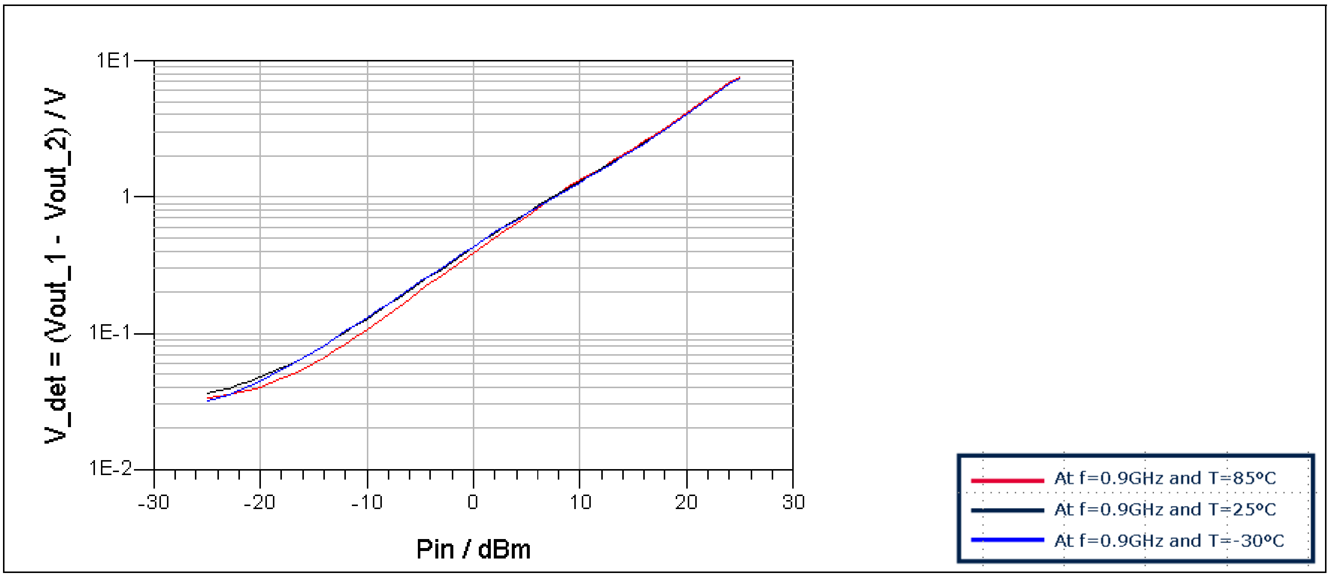

Figure 8 Detector Voltage over Pin for the corner ambient temperature values at -30°C, 25°C, and 85°C

4 Links and References

1. Antognetti and G. Massobrio. Semiconductor device modeling with SPICE , New York: McGraw-Hill, Second Edition 1993.
2. Datasheet - BAT62: http://www.infineon.com/cms/en/product/

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