

RFSA2013 and RFSA2023 Broadband High Performance Voltage-Controlled Attenuators

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PIN diode-based RF attenuators (Figures 1 and 2) have been the preferred method in the past to achieve voltage-variable RF gain, but they are often troublesome to design and require a large number of associated components. A commonly used PIN diode attenuator topology based on diode quads is shown in Figure 1. Common struggles with this topology include achieving wideband frequency response due to the parasitics of the diodes, selection of appropriate resistors to match the diode attenuation versus current

curve, sizable PCB land area necessary to accommodate the peripheral components, large control voltage swing, and maintaining linearity over the full attenuation range.

Another well-known PIN diode attenuator based on a hybrid coupler is shown in Figure 2. This topology has some advantages over the quad-based attenuator in that it is simpler to implement and makes it possible to maintain good linearity across its attenuation range. The main drawback to using this topology, however, is that it suffers

from very narrow bandwidth. This causes users of this PIN attenuator variant to design multiple custom attenuators based on the band of interest. Both PIN-based attenuators suffer from attenuation curves which deviate significantly from the desired linearity in dB response. This is usually solved by adding additional DC control signal conditioning components such as op-amps that significantly increase the cost

and board space requirements to implement. Previously, these PIN diode-based circuit topologies were a necessary evil when voltage variable gain was needed, however, the RFSA2013 and RFSA2023 parts from RFMD solve these issues in an easy-to-use, single 3mm x 3mm QFN package with much higher overall performance.

The RFSA2013 (5V supply) and the RFSA2023 (3.3V supply) devices shown in Figure 3

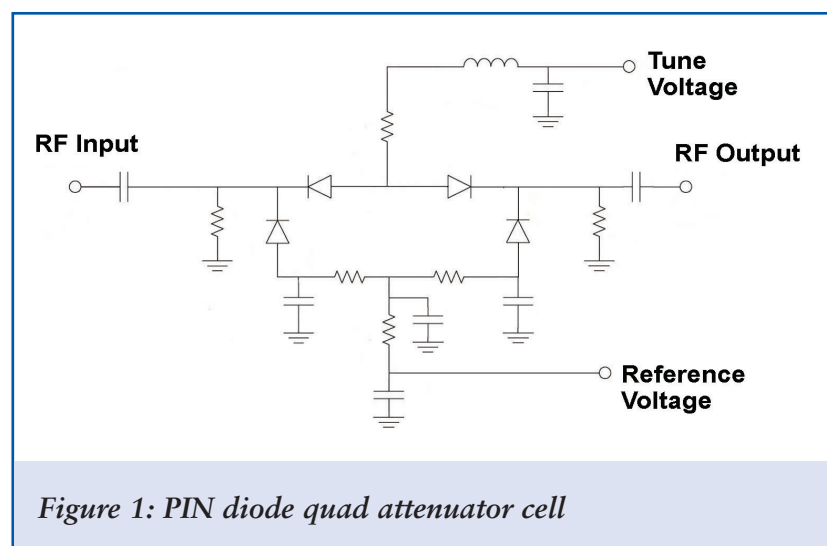


Figure 1: PIN diode quad attenuator cell

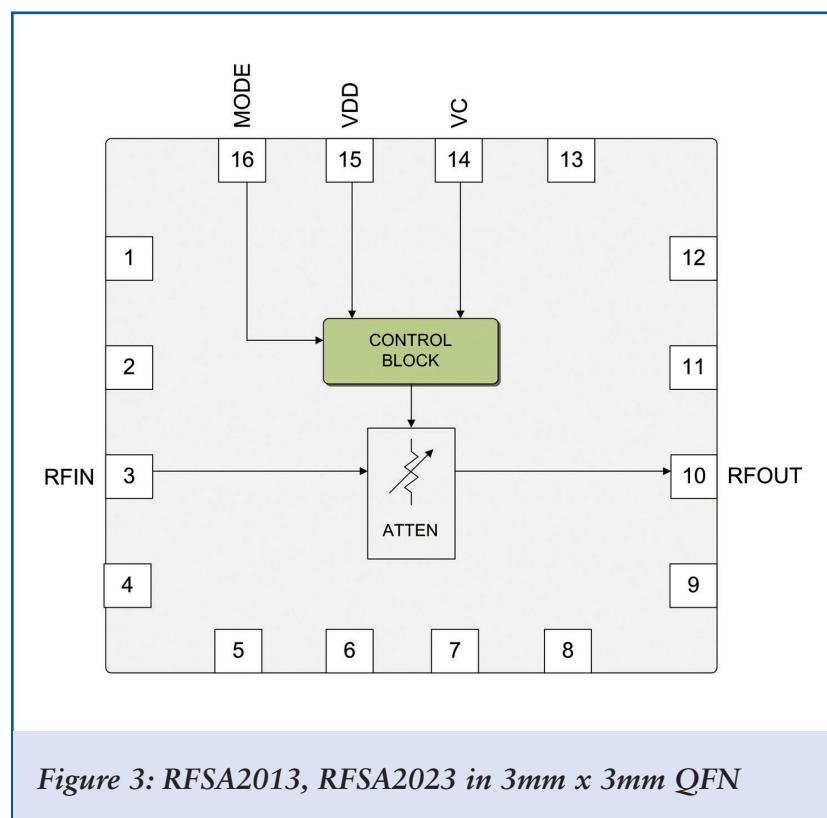


Figure 3: RFSA2013, RFSA2023 in 3mm x 3mm QFN

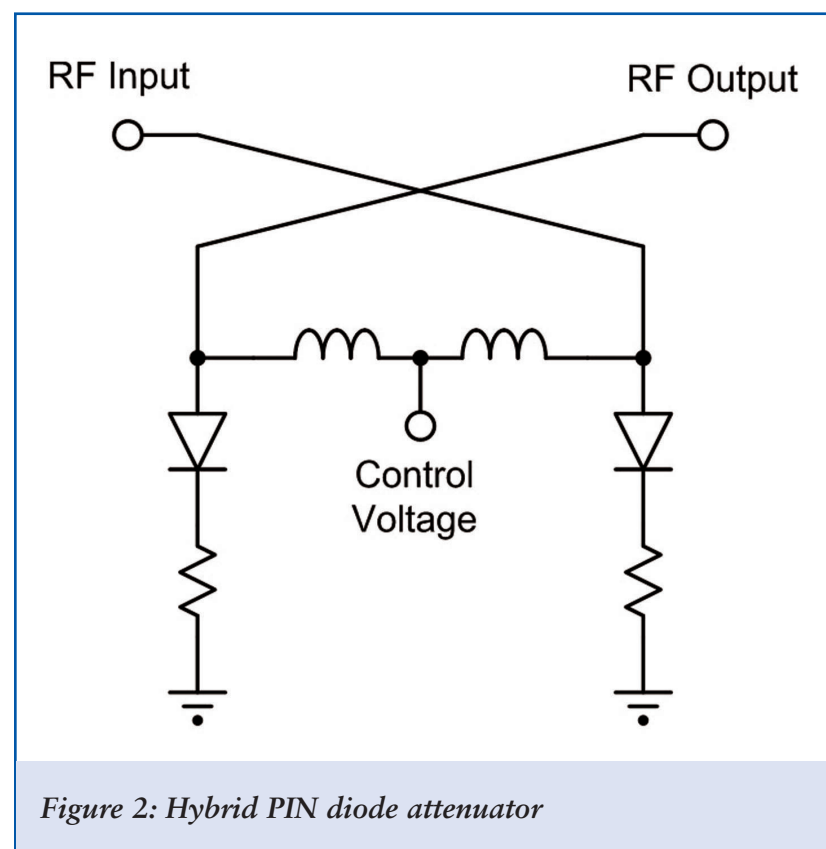


Figure 2: Hybrid PIN diode attenuator

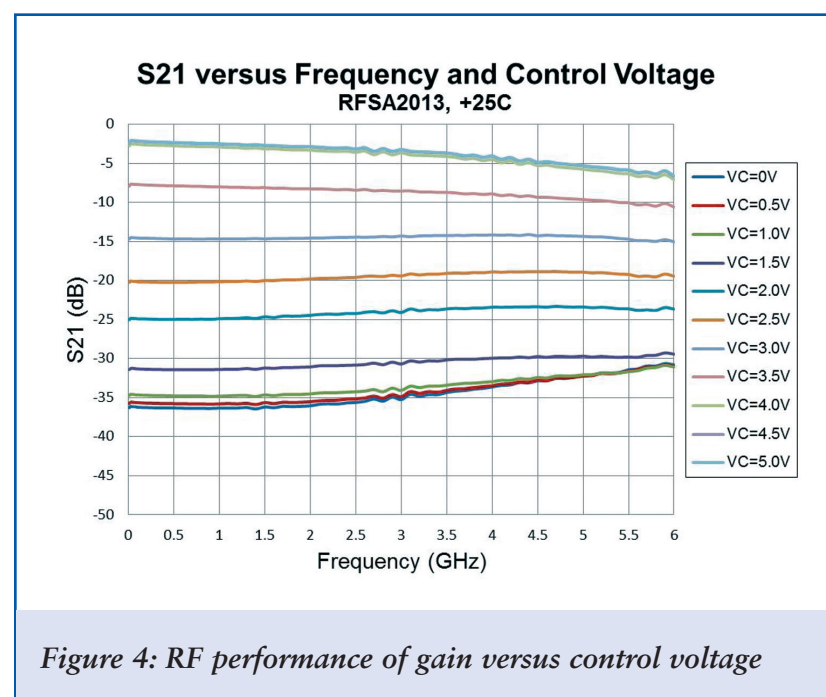


Figure 4: RF performance of gain versus control voltage

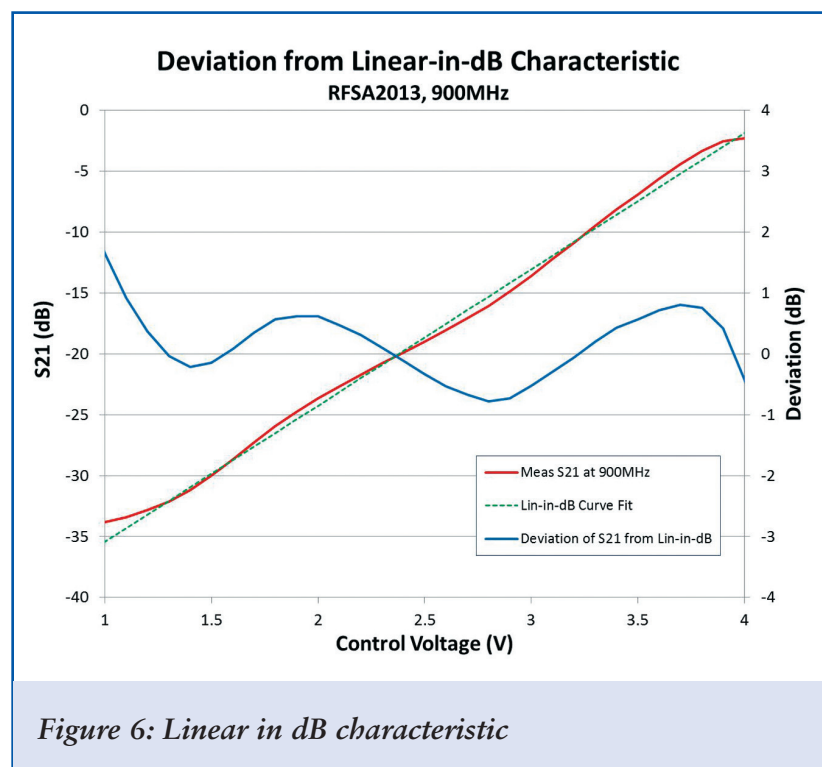
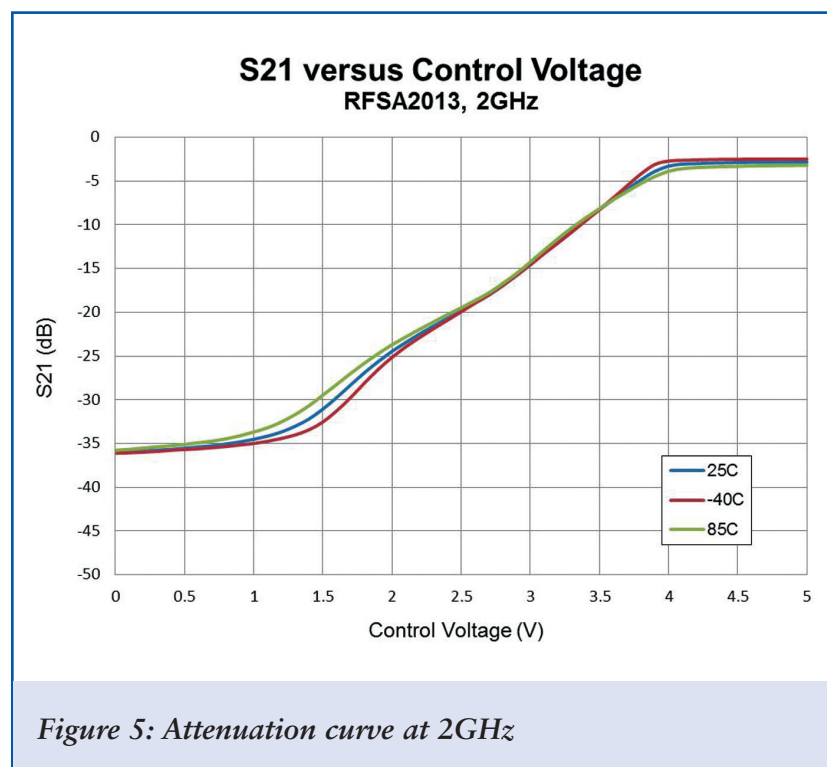


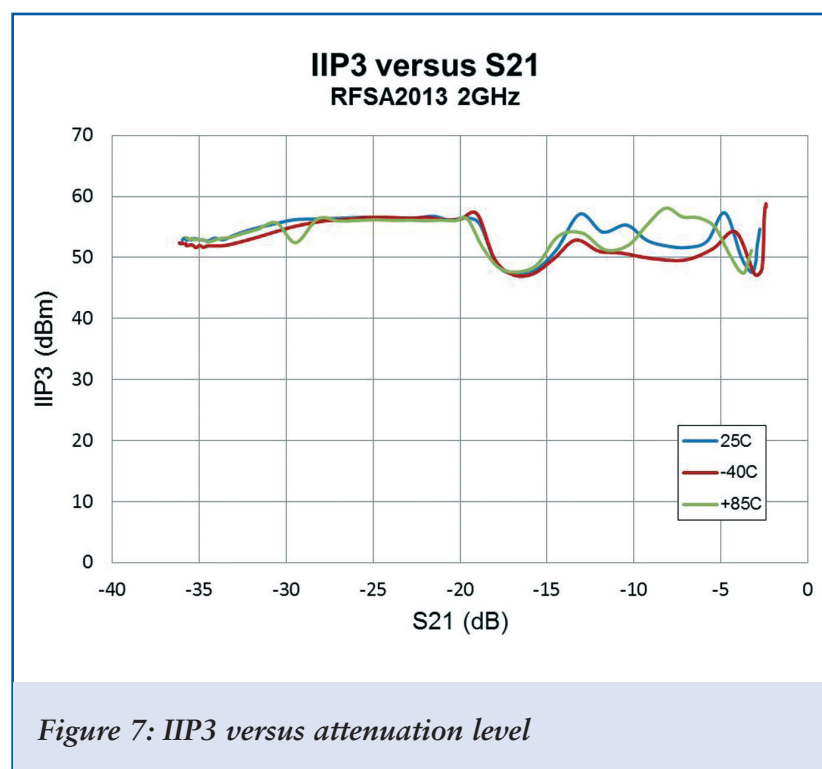
Table 1: Typical RFSA2013/RFSA2023 Performance

Parameter	Typical Performance
Supply Voltage	3.3V/5V
Supply Current	1.2 mA
Operating Temperature	-40°C to +85°C
Frequency Range	50 MHz to 4 GHz
Attenuation Range	>30 dB
Minimum S21	2.6 dB
Return Loss	15 dB
Input P1dB	30 dBm
IIP3	50 dBm

are elegant solutions to a voltage variable attenuation function in one very simple-to-use package. Common applications such as receiver AGC loops, transmit power leveling loops, IF amplitude control, CATV line leveling, and any situation where a very high linearity, temperature-stable gain adjustment is needed can be satisfied easily. These parts exhibit a broad simultaneous RF bandwidth, meaning that they can be used over most common RF communication bands up to 4GHz and beyond without any external matching. Both parts also exhibit very high linearity over their entire attenuation range. The end user does not need to worry about linear-

ity performance degradation which is manifested in many other competing products.

As mentioned before, the RFSA2013 and RFSA2023 contain an internal control signal conditioning block which results in a linear-in-dB response to the external level control signal. No additional external components are needed to achieve this performance. Both attenuators maintain a nominal 50Ω match over the entire level control signal range and frequency band. Also, the variation in attenuation over temperature is minimized by the internal control signal conditioning block. The overall advantages of using these attenuators can be seen by



the simplicity of implementation, reduction in board space required, and reduction in cost.

An additional useful feature found with both parts and not with a standard PIN attenuator is a reversible gain versus voltage slope that can be changed on the fly by asserting the MODE input. Additionally, the low typical current draw of 1.2mA regardless of attenuation state is a benefit over a PIN diode solution that requires a much larger current draw that changes over insertion loss. The RFSA2013 and RFSA2023 have a robust ESD (HBM) rating of 1000V. Both parts share the same pin out,

performance specs, and are different only in control and bias voltages.

The RFSA2013 and RFSA2023 are FET-based analog attenuators using CMOS process technology. These attenuators utilize patent pending stacked-FET techniques to boost both signal handling capability and linearity. Both the control and RF circuits are implemented on a single monolithic substrate. The result is a compact, reliable and easy-to-use device.

The RF performance of these parts is outstanding over a very large bandwidth with a useful frequency range out to

6GHz. Control voltage versus frequency versus attenuation performance of the RFSA2013 is shown in [Figure 4](#).

[Figure 5](#) shows attenuation versus external control voltage for three temperatures. A closer inspection of the attenuation slope is shown in [Figure 6](#), showing the attenuation is linear in dB over the control range without any additional op-amp driver and conditioning needed. This is an impor-

tant advantage over PIN attenuator circuits which have a more exponential attenuation versus control voltage slope. Temperature performance is very well controlled with approximately 1.7dB peak-to-peak dispersion over temperature at the extremes. Asserting the MODE pin will reverse this shape of this slope.

[Figure 7](#) represents the IIP3 versus attenuation level at 2GHz. These attenuators show

extremely well-behaved, high IIP3 over the entire attenuation range and outperform the standard PIN cell by a large margin. Generally, PIN-based attenuators show a large variability in IP3 versus attenuation level since the diodes have a tendency to distort.

While the parts are specified to 4GHz, they are usable to 6GHz with degraded performance. Price is under \$2.00 in quantity.

References

1. *RFSA2013 Datasheet, RFMD Website*
2. *RFSA2023 Datasheet, RFMD Website*