Design Considerations for Wireless Energy Harvesting Systems Using the RFD102A RF-DC Converter Module

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The RFD102A (figure 1) is a 5mm x 7mm x 1.8mm RF-DC converter module developed by RF Diagnostics, LLC that has been optimized for 60Hz-6GHz broadband operation. The module accepts the wireless energy at the RF INPUT pin and converts the wireless energy to a useable DC voltage for low power electronics. Figure 2 displays a block diagram of a typical wireless energy harvesting system. The module has a maximum output current limit of ~18mA and is capable of driving low power electronics provided there is a strong enough stray wireless power source such as a microwave oven, wireless LAN router, power lines, high current lines near a dryer, RFID reader, transmitting cell phone, etc…

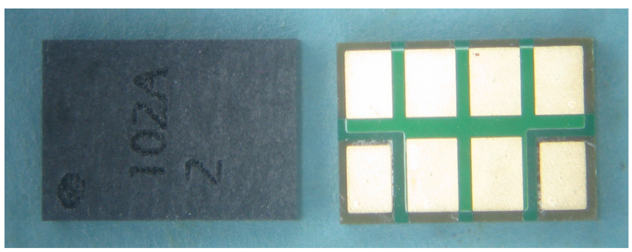

Figure 1. RFD102A module top and bottom views. Pin 1 is the DC output and pin 4 is the RF input. All other pins are grounds and are tied together. The module can be used with an antenna to capture wireless energy and convert it to a useable DC voltage for low power applications.

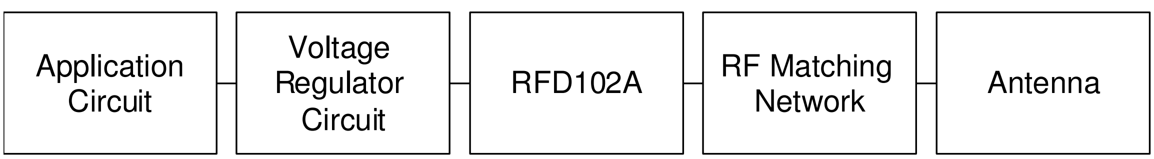

Figure 2. Typical block diagram for a wireless energy harvesting system.

RFD102A Performance

The RFD102A was designed to achieve high input sensitivity over a very broad frequency range. Typically the part can produce 0.35V at -14dBm into a 1MOHM load at 915MHz. The design also can produce very high output voltages as seen in figure 3. An output of 37V can be achieved into a 1-MOhm load with 26dBm input power at 915MHz. Since the output voltage is not regulated, a Zener diode on the output or some other voltage regulator is recommended to prevent damage to the application circuit during operation.

Due to the resistances and the current limitations of the internal circuitry, the maximum output voltage drops as the DC load is lowered. A peak current of 18mA DC can be achieved and should be the upper design limit for any system that needs to be operated continuously. If a higher output current is desired then several modules may be used to increase the output current or an energy storage circuit can be designed to store energy and periodically release the energy from a capacitor.

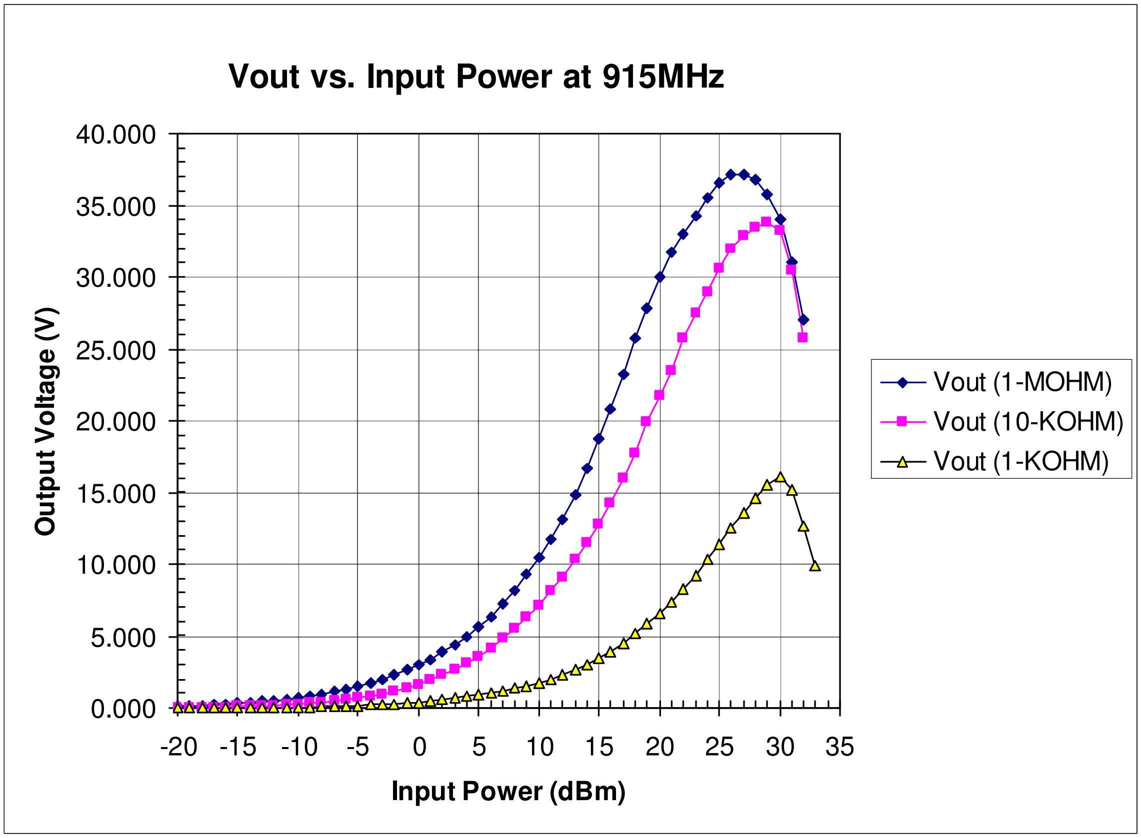

Figure 3. Output voltage versus input power at 915MHz using the RFD102A mounted on the test board into 1-MOhm, 10-kOhm and 1-kOhm loads.

Figure 4 displays the RF-DC conversion efficiency of a typical RFD102A. A peak efficiency of 53% is observed with 11-14dBm input power into a 10-kOhm load. Using a 1-kOhm load results in slightly lower efficiency when compared to the 10-kOhm load performance. As can be seen from the measurements, at input powers >30dBm (1W) the RFD102A's performance degrades due to device heating. It is recommended that the input power level not exceed +32dBm for reliable operation.

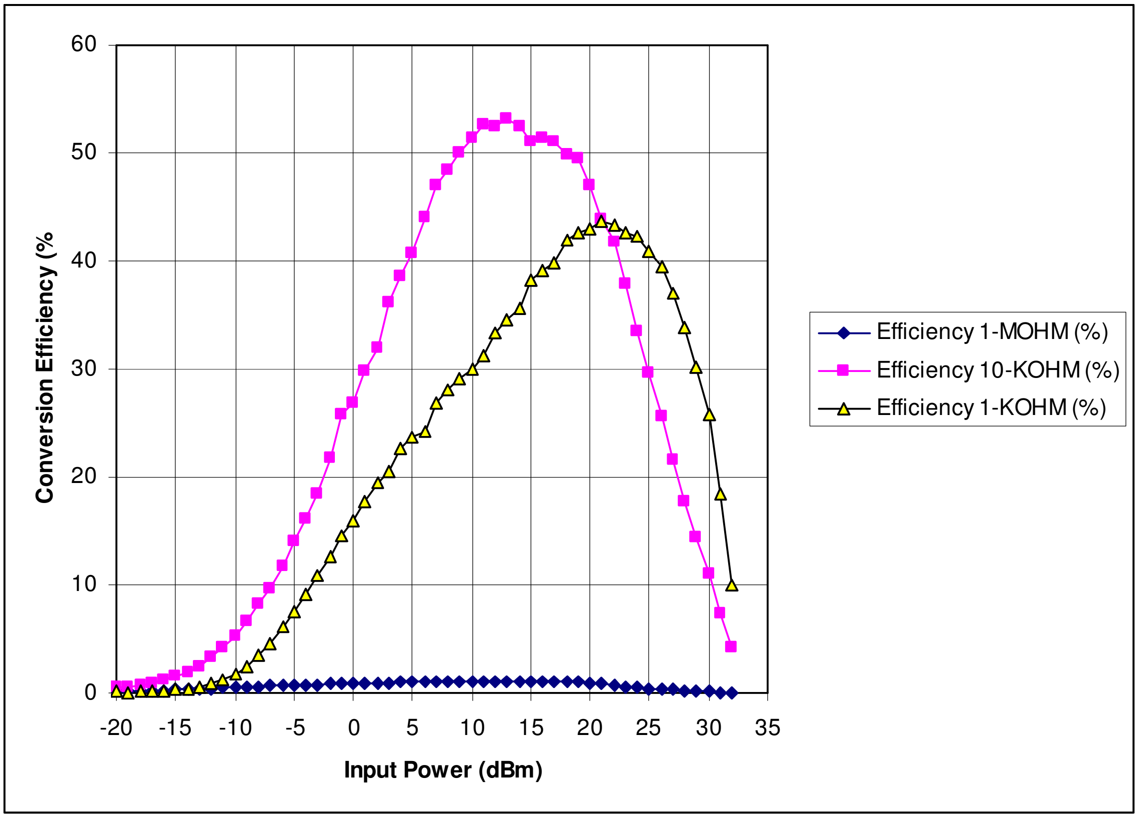

Figure 4. RF-DC conversion efficiency versus input power at 915MHz using the RFD102A mounted on the test board into 1-MOhm, 10-kOhm and 1-kOhm loads.

Antenna Selection

The RFD102A can be used with any antenna. A simple wire dipole can be soldered directly to the module pins (pin #4 RF-IN and pin #5-GND) and the DC output can be soldered directly to the application circuit. For 2.5GHz operation the wire lengths should be approximately 2.9cm long (1.125 inches). For other frequencies the wire lengths should be scaled appropriately. Figure 5 shows the RFD102A that has been modified to be a 2.5GHz detector with a wire dipole and an LED soldered directly to the DC/GND pins.

Chip antennas may also be used as well as monopole antennas. Some experimentation may be required to optimize the matching between the RFD102A and the antenna. RF tuning a non-linear device is a complex task and time should be allowed to explore different tuning options during project development.

Figure 5. Microwave energy detector created using the RFD102A, a two-wire dipole and a surface mount LED.

Leakage Resistance

An ideal energy harvesting system would charge a capacitor and the charge would remain on the capacitor indefinitely. Unfortunately nothing is ideal and leakage resistances will drain any capacitor of its charge. In the RFD102A a series of diodes are used to generate the DC voltage and there is a finite reverse leakage resistance of 45-60kOhms that needs to be taken into account. Systems that need to store charge for long periods of time will need to use a switch between the RFD102A and the storage capacitor.

Maximum Input/Output Ratings

The RFD102A RF input pin is protected by a transient voltage suppressor. This type of protection is common for mobile phone antennas to protect the internal circuitry from electrostatic discharge. However full testing in the application is required to understand the true strength of the protection. Designers are advised to include a spare 0201 component site to GND on the antenna line as a backup in case the protection within the RFD102A is not enough to protect the entire circuit from electrostatic discharge.

The RFD102A also has DC blocking capacitors inside the module that are rated to 10VDC.

The DC output voltage line has a 100nF/50V capacitor inside the module. Test data has shown that the RFD102A can reliably output 37V into a 1MOhm load. However if higher value loads are used, care should be taken not to exceed 40V for safety margin.

Also the DC output line is not protected from a negative voltage. Care should be taken never to exceed -0.5V on the DC output line.

Printed Circuit Board Footprint

Figure 6 displays the module PCB footprint. Pads are 1.25mm x 1.90mm on a 1.75mm pitch. Good grounding is recommended for this design with each ground pin tied together on the ground plane connected to at least 2 ground vias on each side of the module.

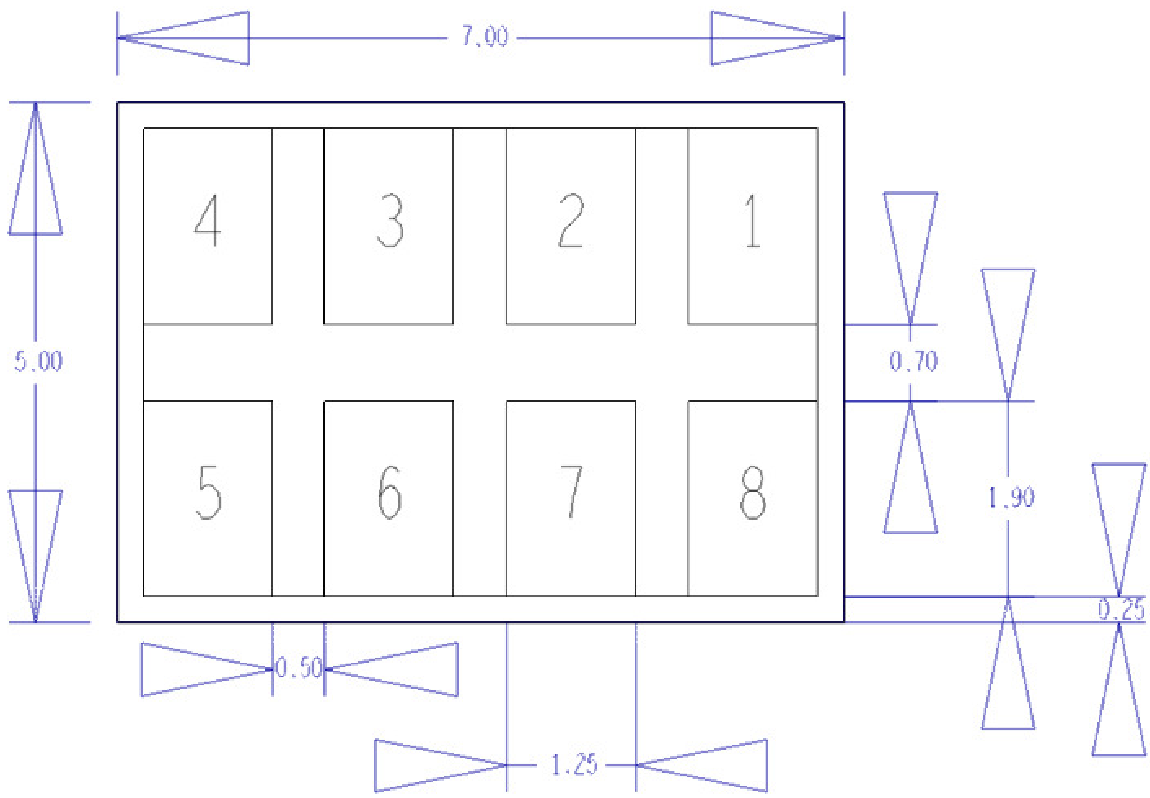

Figure 6. Module footprint. Dimensions are in millimeters. Pin 1=DC Output, Pin 4=RF Input, Pins 2,3,5,6,7,8=GND.

Soldering/Reflow/Handling

The RFD102A module is a laminate based Quad Flat No-Lean (QFN) design that is similar to modules used in mobile phones. It is recommended that the modules be prebaked at 95C for one hour prior to soldering/reflow to drive out any moisture that may be accumulated by the module. Prebaking the modules helps reduce the risk of delamination failures that could occur during reflow as the moisture inside the module expands and tries to escape. Modules that arrive in tape & reel will have dessicant inside however once the package is opened the parts will need to be kept in a dry box or used within 24 hrs of opening the sealed bag containing the parts. The module is assembled using Pb-free components and solderpaste and can follow a Pb-free reflow profile.