# Medium Power Wireless Energy Harvesting Assembly

45.1 x 32.8 mm RF to DC Converter with Capacitor Charge/Discharge Power Management

**RF Diagnostics, LLC**

## Overview

The RFD-ASSY-01 is a medium power RF-DC converter assembly that uses four RFD102A RF-DC converter modules and one RFD88A energy harvesting engine module for capacitor charge/discharge power management. When used with a high value capacitor (not included), the assembly helps produce higher pulsed currents than are possible with the RFD102A's alone. This design is ideal for use with motors and charging applications and can be used in CW mode or pulsed current mode.

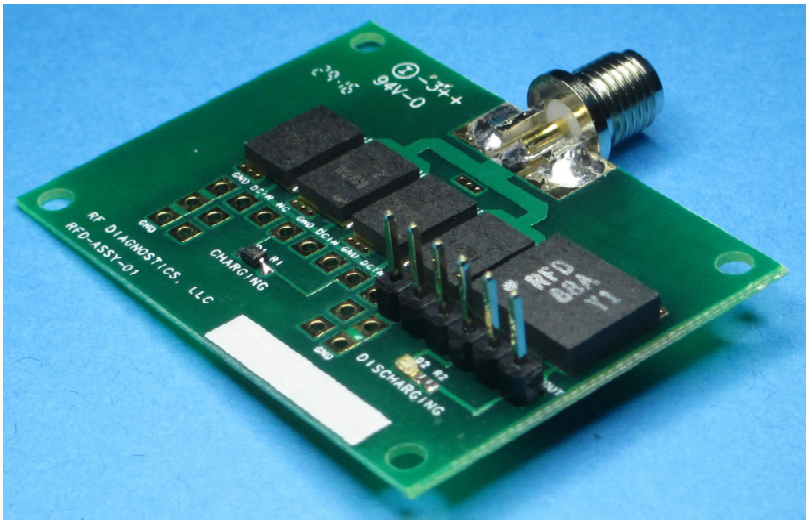
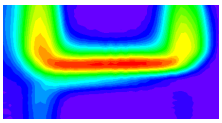



**Figure 1. RFD-ASSY-01 45.1 x 32.8 mm RF to DC converter with capacitor charge/discharge power management.**

## Theory of Operation

RF power enters the SMA connector and is power divided four ways into four RFD102A RF-DC converter modules. The DC outputs of the RFD102A's are then combined (DCIN: header pin #2) and go to the RFD88A input pin. The RFD88A acts like a voltage sensitive switch and will stay off until the DCIN voltage reaches 5.2V (default setting). At this condition the RFD88A will switch on and output the voltage to DCOUT (header pin #6). A red LED will light up when the RFD88A switches on and will turn off when the voltage goes below 1.0V.

The user is expected to add a large value capacitor between the DCIN node and GND





(GND: header pin #1) that will charge up when RF power is available. Header holes allow the user to solder this capacitor directly to the PCB. Please note that 1F super capacitors may take a long time to charge (>30mins) so some experimentation may be needed to determine the optimal capacitor value for the system. When the capacitor's voltage reaches 5.2V the RFD88A will switch on and discharge the capacitor until the capacitor's voltage goes below 1.0V. At this point the RFD88A will switch off and the charging cycle will repeat. The upper voltage is selectable to be 5.2V (default), 3.0V (header pin #5 shorted to header pin #4) or 2.5V (header pin #3 shorted to header pin #4). The lower voltage is fixed at 1.0V. Please contact us if different voltages are required.

The system is designed to drive systems like a motor or other higher current system that can handle the output voltage ranges from 1.0V to 2.5V, 1.0V to 3.0V or 1.0V to 5.2V and operate intermittently when the capacitor reaches its upper voltage limit. If a tighter range of voltage is required then a low dropout regulator may need to be added to the application circuit. A 5.6V Zener diode on the DCIN node helps limit the voltage out of the RFD102A's and serves to protect the RFD88A from an overvoltage condition which can damage the RFD88A. The 5.6V Zener diode also helps protect any super capacitors from overvoltage. Up to 60mA of CW output current is possible at the DCIN pin of the RFD102A's. Up to 140mA of burst current can be achieved with a voltage range between 5.2V down to 1.0V.

The RFD-ASSY-01 can harvest energy from 1MHz to 6GHz. When connected to an antenna, the assembly can extract power from wireless sources.

**Header Pin Descriptions** (from the inside of the PCB to the PCB edge)
1: Ground
2: DCIN - Output voltage from the RFD102A modules
3: P2 - Short this pin to pin 4 or ground to set upper voltage to 2.5V
4: Ground
5: P3 - Short this pin to pin 4 or ground to set upper voltage to 3.0V
6: DCOUT - Output from the RFD88A (located closest to the edge of the PCB)

RFD-ASSY-01

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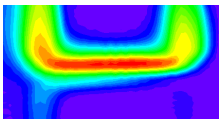

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The following data was taken on a typical unit at room temperature in a 50-Ohm system. Input power levels and voltages on header pin 2 were collected befor the RFD88A was triggered. This data can be used as a guide for system design.

## Typical Electrical Properties at 300MHz

| Input Power (dBm) | Internal Voltage DCIN | DCOUT From the RFD88A | VHIGH (V) | VLOW (V) |
|---|---|---|---|---|
| 3 | 2.43 | No output | 0 | 0 |
| 4 | 2.79 | Triggered w/ P2 Shorted to GND | 2.5 | 1 |
| 5 | 3.18 | Triggered w/ P2 Shorted to GND | 2.5 | 1 |
| 6 | 3.62 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 7 | 4.12 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 8 | 4.68 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 9 | 5.18 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 10 | >5.2 | Triggered w/ No Jumpers | 5.2 | 1 |

## Typical Electrical Properties at 433MHz

| Input Power (dBm) | Internal Voltage DCIN | DCOUT From the RFD88A | VHIGH (V) | VLOW (V) |
|---|---|---|---|---|
| 5 | 2.44 | No output | 0 | 0 |
| 6 | 2.80 | Triggered w/ P2 Shorted to GND | 2.5 | 1 |
| 7 | 3.26 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 8 | 3.74 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 9 | 4.27 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 10 | 4.88 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 11 | >5.2 | Triggered w/ No Jumpers | 5.2 | 1 |

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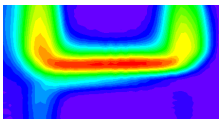

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## Typical Electrical Properties at 867MHz

| | | | | |
|---|---|---|---|---|
| 7 | 2.16 | No output | 0 | 0 |
| 8 | 2.50 | Triggered w/ P2 Shorted to GND | 2.5 | 1 |
| 9 | 2.86 | Triggered w/ P2 Shorted to GND | 2.5 | 1 |
| 10 | 3.28 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 11 | 3.72 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 12 | 4.22 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 13 | 4.88 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 14 | >5.2 | Triggered w/ No Jumpers | 5.2 | 1 |

## Typical Electrical Properties at 2450MHz

| Input Power (dBm) | Internal Voltage DCIN | DCOUT From the RFD88A | VHIGH (V) | VLOW (V) |
|---|---|---|---|---|
| 4 | 2.24 | No output. | 0 | 0 |
| 5 | 2.57 | Triggered w/ P2 Shorted to GND | 2.5 | 1 |
| 6 | 2.95 | Triggered w/ P2 Shorted to GND | 2.5 | 1 |
| 7 | 3.38 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 8 | 3.86 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 9 | 4.41 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 10 | 5.04 | Triggered w/ P3 Shorted to GND | 3 | 1 |
| 11 | >5.2 | Triggered w/ No Jumpers | 5.2 | 1 |

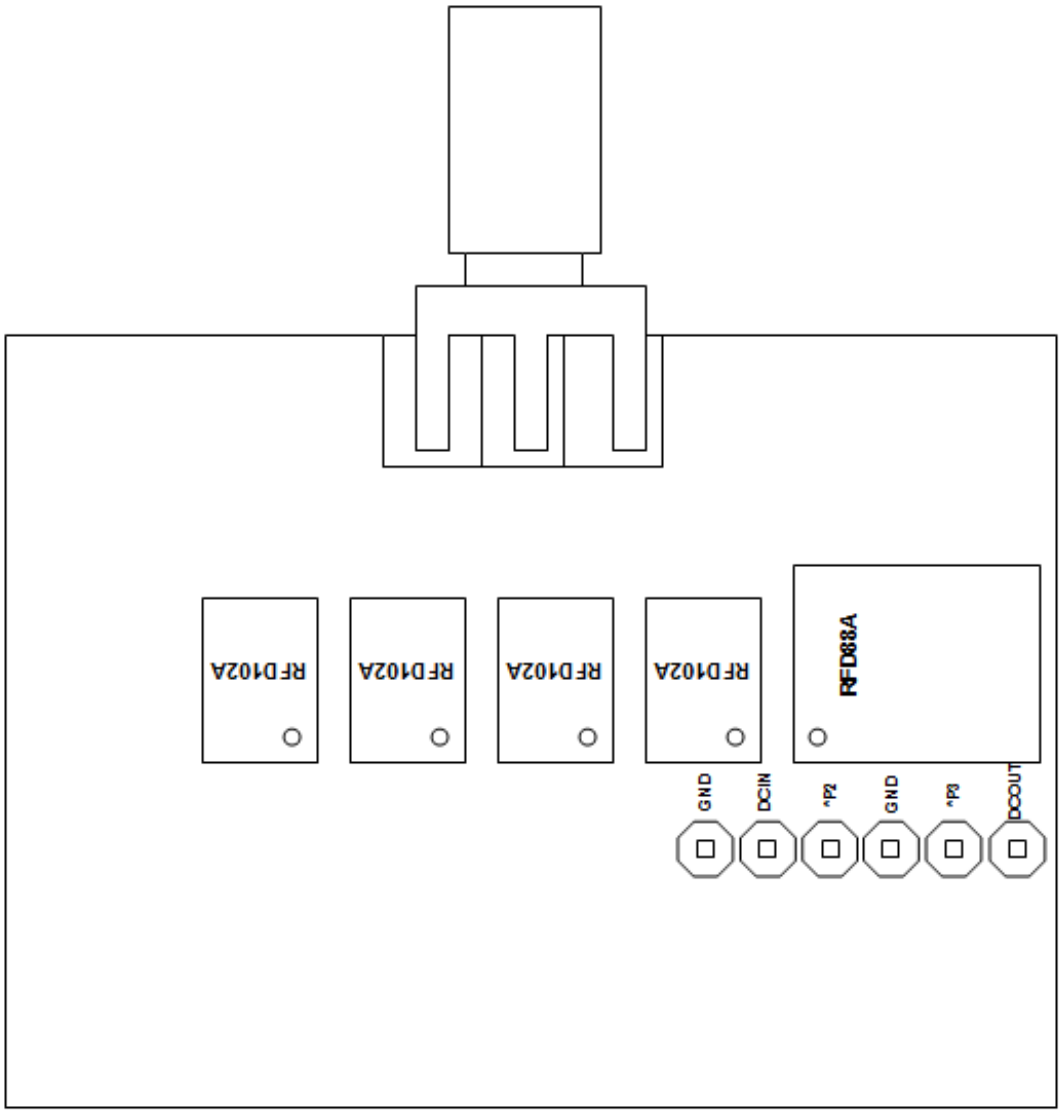



**Figure 2. RFD-ASSY-01 assembly diagram and pin-out. Connect the super capacitor to DCIN and GND and the application circuit to DCOUT and GND for 5.2VHIGH and 1.0VLOW. For lower DCOUTs, jumped P3 to GND for 3.0VHIGH or P2 to GND for 2.5VHIGH.**

## Mechanical Drawing

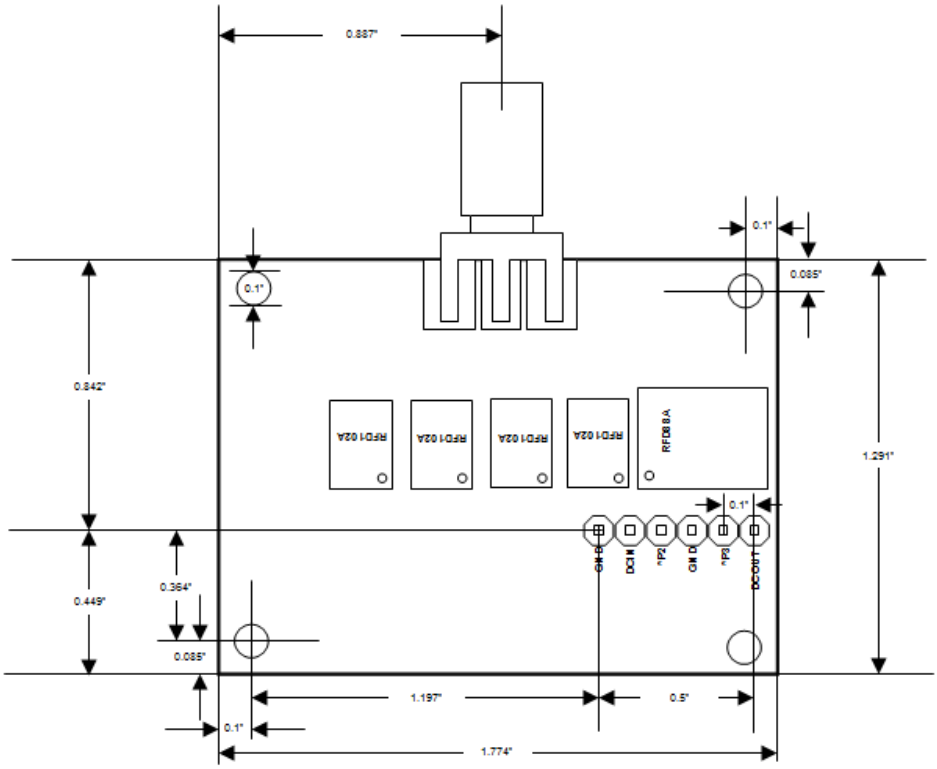



**Figure 3. RFD-ASSY-01 mechanical drawing. Dimensions are in inches. The PCB is 0.031" thick and has been designed to fit in a Hammond Manufacturing 1551KFLBK plastic enclosure.**

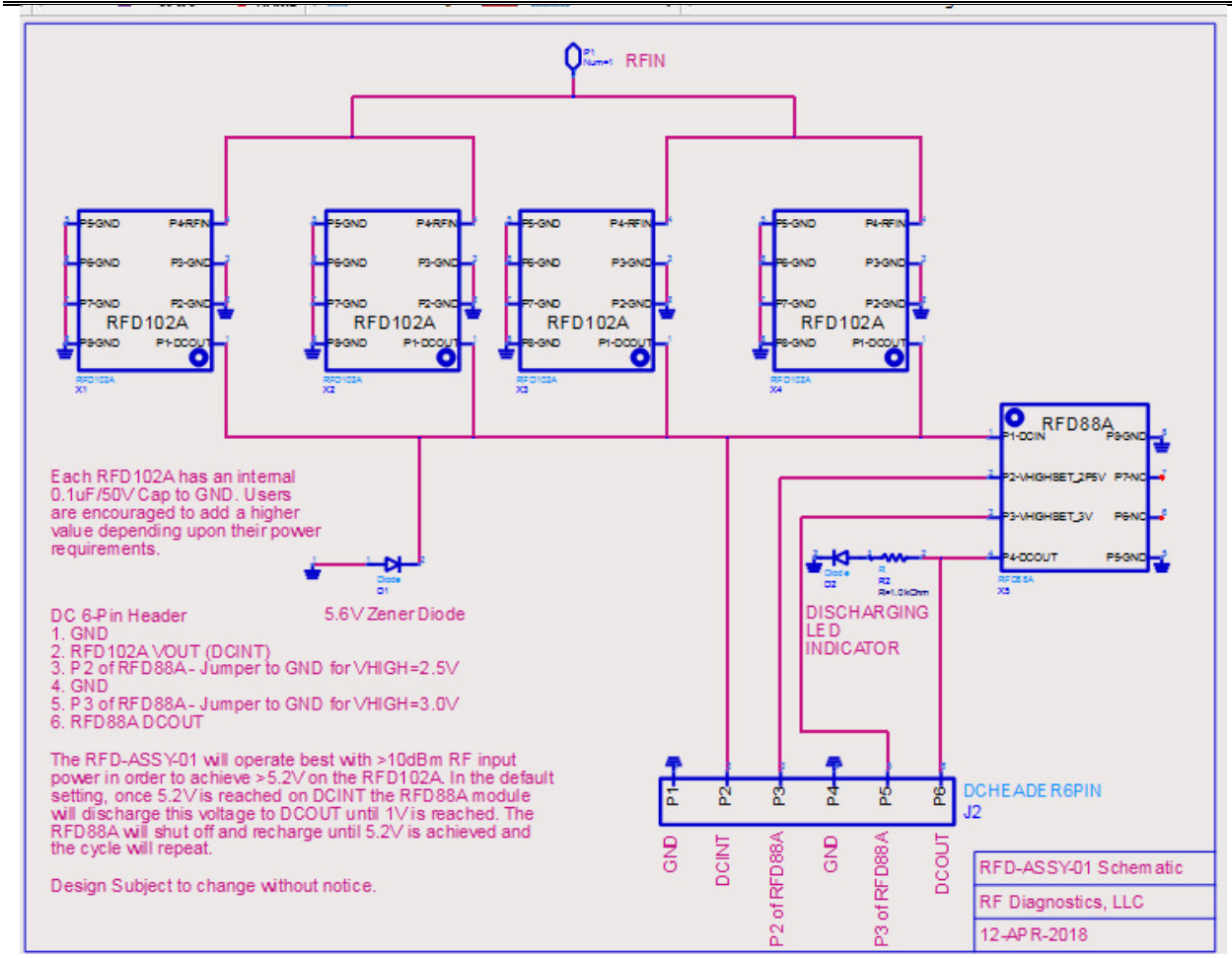



**Figure 4. RFD-ASSY-01 DC Schematic.**

The DC schematic along with basic operating instructions are shown in figure 4. We recommend some initial tests at low input powers for users to get experience with how this design works.

**Test Procedure to Verify Proper Operation**

- Connect two voltmeters to DCINT (header pin 2) and DCOUT (header pin 6) and GND (header pin 1).
- Connect a signal generator at 100MHz to the RF input. Be careful to hold the SMA connector on the PCB while tightening the SMA to avoid flexing the PCB which can damage the unit.
- Set RF power to 0dBm and turn the RF power on.
- DCINT should read a positive voltage <3V and DCOUT should read 0V.
- Raise the input +1dBm at a time and watch DCINT increase while DCOUT is still reading 0V.
- At +5dBm input power the RFD88A should switch on and the red LED should light up.

All voltages will drop because the 1kOhm+LED are consuming power.
- Increasing the input power will eventually get the DCINT voltage to 5.6V where the Zener diode will turn on and dissipate the excess power. Do not keep increasing input power once this has occurred to prevent damage to the RFD88A and the Zener diode. A lower value load on DCOUT is needed to further dissipate the excess RF power.

## Leakage Resistance of the RFD102A & RFD-ASSY-01

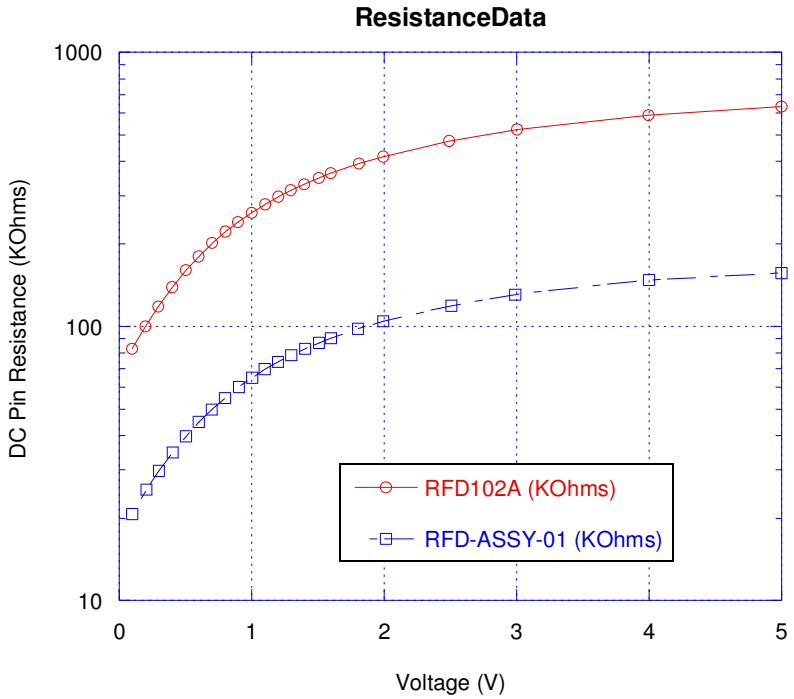
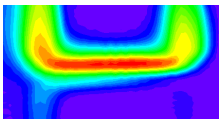



**Figure 5. Leakage resistance of the VOUT of the RFD102A and DCINT of the RFD-ASSY-01 versus voltage. The leakage resistance increases nonlinearly with voltage on the VOUT pins of the RFD102A.**

One design consideration when using the RFD102A's or the RFD-ASSY-01 with a capacitor for charge storage is the finite leakage resistance of the RFD102A modules. Figure 5 displays the leakage resistance of the RFD102A compared to the RFD-ASSY-01 at the DCINT node (VOUT of the RFD102A) when the RFD88A is off. As expected the leakage resistance of the RFD-ASSY-01 is 4x lower than the leakage of a single RFD102A because four RFD102A's are connected together in the RFD-ASSY-01. The parasitic leakage resistance increases as the DC voltage on the RFD102A's VOUT pin increases. This curve is useful for calculating the time charge will be available on a capacitor that has been partially charged before the RFD88A switches on.





## Additional Technical Information

RFD102A Datasheet

RFD88A Datasheet

## Maximum Ratings and Recommendations

- Be careful to hold the SMA connector on the PCB while tightening the SMA with a wrench to avoid flexing the PCB which can damage the unit.
- ESD protection for 8 keV pulse protection on the RF input line
- DCOUT is not ESD protected. Avoid hot connecting to this pin.
- +/-10VDC maximum on the RF input line.
- +36dBm maximum RF input power on the RF input pin.
- Always resistively load the DCOUT pin during operation. An open circuit on the DCOUT pin can lead to RFD88A damage if there is >6V on the DCIN node.
- Maximum DCIN node current is 60mA under CW drive.
- Maximum pulsed current is 140mA and is limited by the internal resistance of the RFD88A module switch.
- Exceeding the above limits can cause partial or permanent module damage.

## Tuning

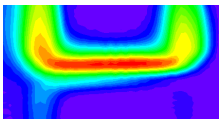
This design is not matched to 50-Ohms. Impedance matching can greatly improve the sensitivity of this design and improve the RF-DC conversion efficiency. This is a very complex nonlinear circuit and we are interested in working with you to achieve improved performance. Please contact us with a specific frequency, typical input power level and load as a starting point and we will work with you for the best matching solution.

## Efficiency

At a 1-KOHM DC Output load the RF-DC efficiency is 40-45% from 18dBm to 29dBm at 2.45GHz with a peak output current of 18mA/29dBm. With lower load resistances the current increases to 50-60mA but the efficiency may be reduced.

## Customization

The RFD-ASSY-01 can be customized upon request with an added assembly cost.





Some possible modifications are:

- Solder a specific leaded capacitor DCINT pin to GND
- Remove the RFD88A module or SMA connector
- Custom RFD88A module with 4.3V for VLOW and 5.2V for VHIGH
- Optimize input match for a specific frequency and power range
- Provide measured data at a specific frequency and power range of interest

If there is a specific test frequency or load resistance that is required for your application, please contact us at info@rfdiagnostics.com for additional test data.

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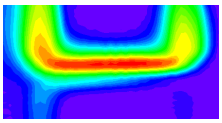

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## Disclaimer

This module is guaranteed to be defect free upon shipment. However the module is not intended for use in critical applications such as medical devices, automotive safety, or anywhere else where poor performance can result in injury, loss of life or property. The user agrees to assume all risks arising from use of the module and releases RF Diagnostics from all liability for its malfunction or misuse.

Specifications listed on datasheets are subject to change without notice.

Datasheet Revision: 4-11-2018