PETI-678-EVAL-01

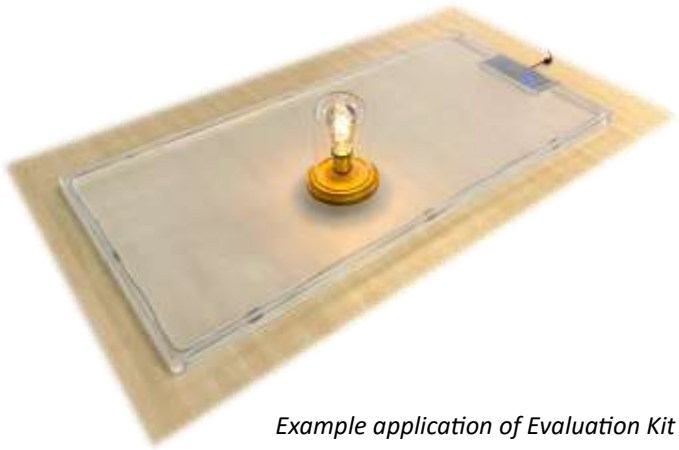
Powercast Magnetic Resonance Kit User Manual

DESCRIPTION

This Evaluation Kit is intended for quick prototyping using Powercast's Magnetic Resonance Technology, powered by Etherdyne. It contains one transmitter and eight receivers capable of providing between 0.1W and 7W of DC power. The transmitter consists of a constant-current RF generator and a magnetic loop antenna which defines the outer dimensions of the power zone. The receivers can freely move within the power zone while receiving power.

FEATURES

- Uses 6.78MHz ISM band
- 1 transmitter and 8 receivers included
- Constant RF current regulation in transmitter
- Autotuned transmitter allows flexible transmitter loop configurations
- Frequency locking for multiple-transmitter systems
- Built-in circuit protection in transmitter
- Constant-voltage regulation on output of receivers



Example application of Evaluation Kit
(Light bulb and acrylic base not included)

KIT CONTENTS

Powercast kit includes the loop antenna which comes on a mat out of the box; the starting loop size is 51" x 18". The contents of the kit are shown in the image and the table below:

+1 (412) 455-5800
www.powercastco.com / contact@powercastco.com

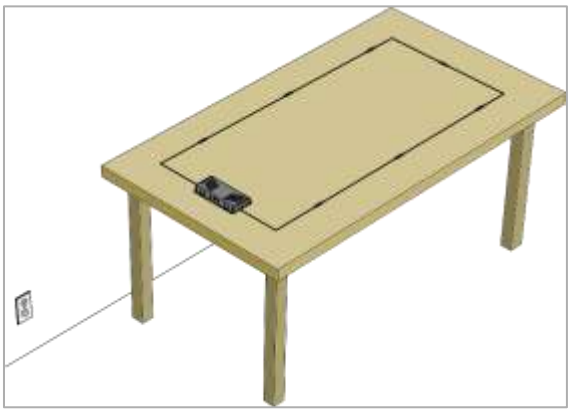
Qty	Item	Description
RF Generator	1	48VDC input. 6.78MHz, 4.3A constant current RF output.
Loop Antenna	1	Resonant Magnetic Loop Antenna. 333cm total length.
48V power adapter	1	120/240VAC, 50/60Hz input. 48VDC, 2.2A output. 2.5mm barrel.
AC power cord	1	North American three prong AC power cord.
LED Field Probes	2	Wireless LED for testing system and probing power zone.
Rx1-R	1	3.4cm (1.3”) ⌀ Receiver, 5V, 100mW.
Rx2-R	1	4.6cm (1.8”) ⌀ Receiver, 5V, 200mW.
Rx3-R	1	5.6cm (2.2”) ⌀ Receiver, 5V, 300mW.
Rx4-R	1	6.8cm (2.7”) ⌀ Receiver, 12V, 1W.
Rx5-R	1	6.8cm (2.7”) ⌀ Receiver, 24V, 1W.
Rx6-R	1	7.8cm (3.1”) ⌀ Receiver, 24V, 2W.
Rx7-R	1	10.8cm (4.3”) ⌀ Receiver, 24V, 4W.
Rx8-R	1	13.0cm (5.1”) ⌀ Receiver, 24V, 7W.

SET-UP AND OPERATION

STEP BY STEP INSTALLATION

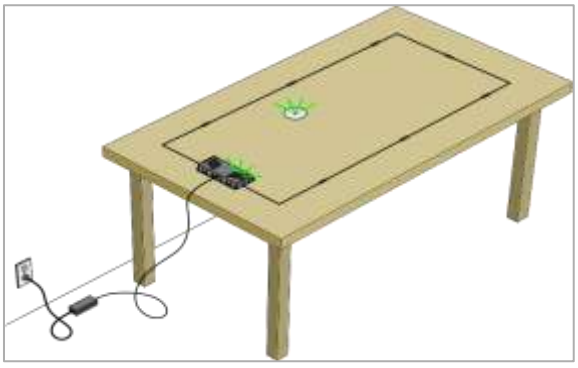
Step 1:

Place the transmitter on a non-metallic table. (Check under the table to ensure the table edge does not have a metal frame.) Arrange the wire loop neatly into a rectangular shape. Ensure the wire lies flat and is not tangled.



Step 2:

Plug the power supply into an AC outlet and connect the power cable to the transmitter. The Status Light inside the RF Generator should glow continuous green *(Refer Figure 26).* If not, or if the Status Light glows red *(Refer Section 'Troubleshooting').* Place a field probe on the table inside the Loop Antenna. The LED on the Field Probe should glow continuously. If the Field Probe LED doesn't light, or if it flashes *Refer Section 'Troubleshooting.'*

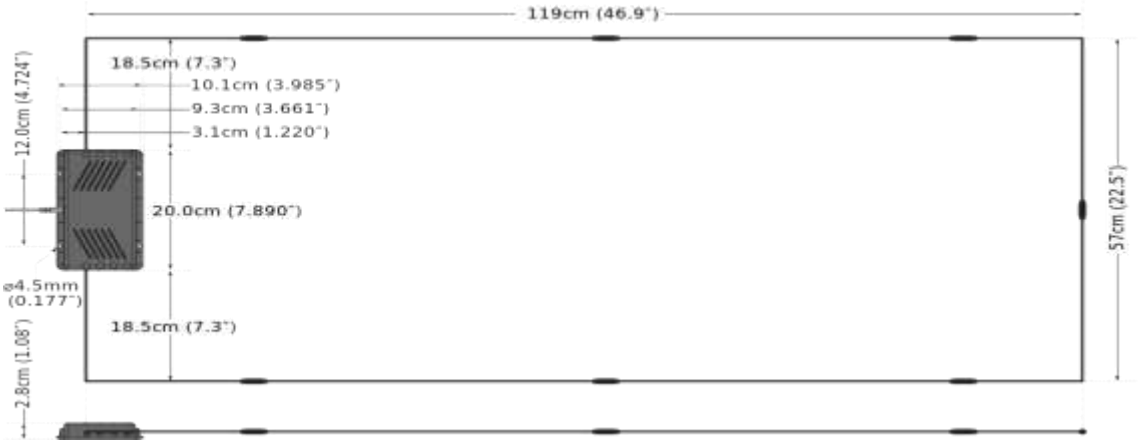


Step 3:

Place a receiver on the table inside the Loop Antenna and check the output terminals with a multimeter to confirm the output voltage and polarity are correct. Connect a device to the output terminals of the receiver. *Refer Section 'Receiver Specifications'* for output voltage, current and power levels.

TRANSMITTER SPECIFICATIONS

DIMENSIONS[1]*



**Disclaimer: This figure is for reference purposes only. Please Note: the loop antenna comes on a mat out of the box where the starting loop size is 51" x 18"*

[1] The Loop Antenna dimensions shown here are the standard dimensions used for characterizing the power zone and receiver power levels. Other loop aspect ratios are possible, but the receiver powers will vary from the specifications quoted in *(Refer Section 'Receiver Specifications').*

ELECTRICAL PARAMETERS

Parameter	Values			Unit
	Min.	Typ.	Max.	
Input DC Voltage[2]	10	48	53	V
Input DC Current[3]	0.27	--	2.2	A
Input DC Power[3]	13.2	--	105	W
Output RF Current	3.9	4.3	4.5	A
Output Frequency	6.765	6.780	6.795	MHz

DESCRIPTION OF OPERATION

The transmitter consists of an RF Generator and a Loop Antenna. The RF Generator drives a current at a frequency of 6.78MHz through the Loop Antenna, creating an oscillating magnetic field like that shown in *Figure 1*. Receivers can capture RF power from this oscillating field and convert it to DC power.

Figure 1: Magnetic field of the transmitter represented by dashed lines

[2] The RF current and magnetic field strength are proportional to the input DC voltage *(Refer Figure 12)* The provided power supply outputs 48V. The receiver power specifications *(Refer Section 'Receiver Specifications')* are given for operation at 48V.

[3] The maximum and minimum DC current and power are defined at 48V DC input. *(Refer Figure 11)* for upper and lower DC power limits at other supply voltages. The input power and current will vary depending on the loading condition. *(Refer Figure 6)* The RF Generator draws the minimum power when unloaded.

The magnetic field can be blocked by metallic surfaces. For optimal operation, minimize the presence and size of metallic surfaces near the Loop Antenna or between the Loop Antenna and the receivers. Do not operate the transmitter on a metallic surface. It will shut down until the metallic surface is removed *(Refer Section 'Troubleshooting').*

The RF Generator has multiple functions which maintain stable operation under varying operating conditions:

- Highly efficient 6.78 MHz Class-E amplifier
- Specialized Magnetic Loop Antenna with distributed capacitance allowing lower RF voltage operation
- Electrically controlled variable reactance for auto-tuning the Loop Antenna for different shapes and objects in the field
- Support for Loop Antenna aspect ratios ranging from approximately 1:1 to 3:1 as *shown in Figure 2*

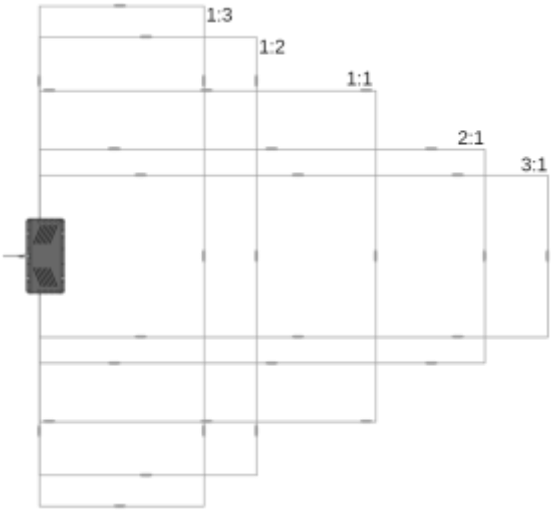


Figure 2: Reactance Range vs loop aspect ratios

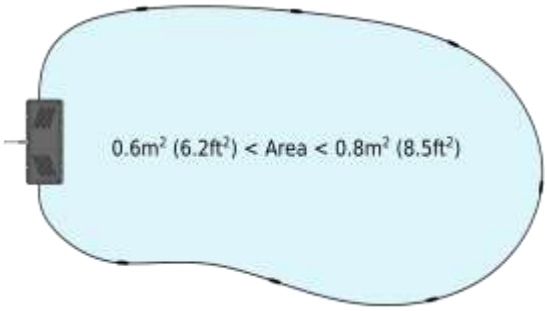


Figure 3: Loop Antenna

- Operation with Loop Antenna arranged in an arbitrary shape as long as its enclosed area is between approximately 0.6m^2 (6.2ft^2) and 0.8m^2 (8.5ft^2) – *as shown in Figure 3*. (If the Magnetic Loop Antenna dimensions exceed the upper or lower limits of this range, or if the Magnetic Loop Antenna is perturbed by conducting or magnetic materials in its

environment, the transmitter may shut down. If this occurs, adjust the loop area and/or remove the perturbing materials.)

- Blue and yellow indicator LEDs to show the level of the tuning control signal (Yellow indicates a high reactance of the loop, and blue indicates a low reactance – *as shown in Figure 28)*.
- Frequency locking to allow transmitters placed in proximity to each other to operate without interference – *as shown in Figure 4.*

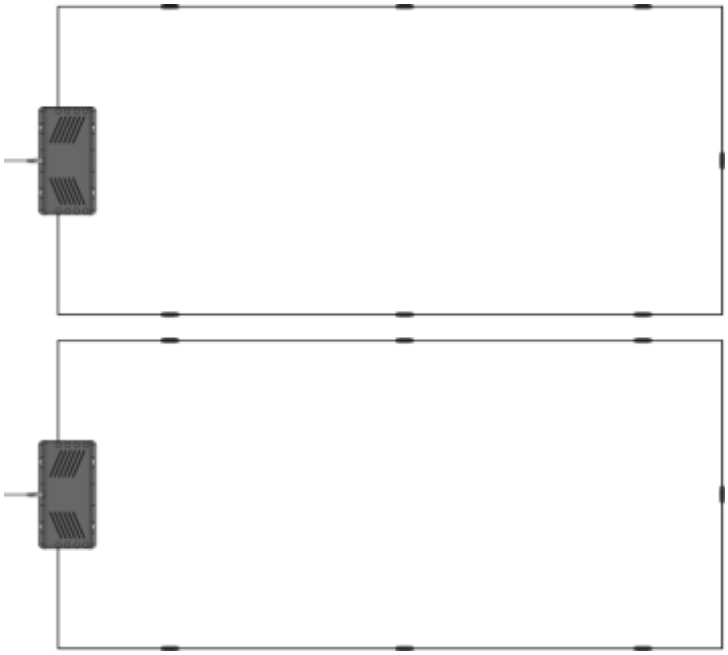


Figure 4: Two frequency-locked transmitters

- Over-temperature sensor (max internal temperature of 75C), RF over-current sensor (2.2A max), input over-voltage sensor (53V max), and a tuning-limit sensor
- Vents for convective air cooling – *as shown in Figure 5* (Install the RF Generator in a location which permits free air flow and do not block the vents)

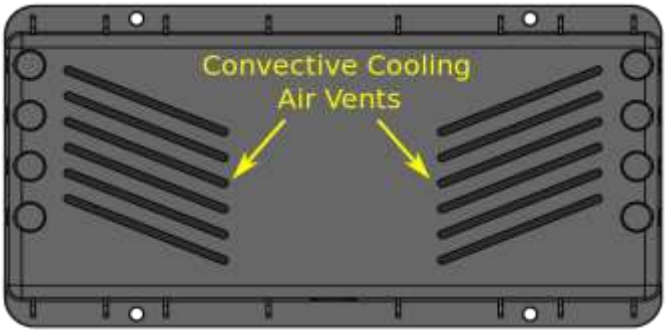


Figure 5: Top view of RF Generator case

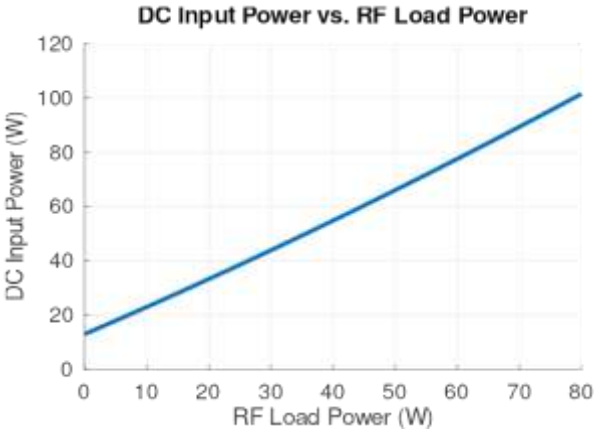


Figure 6: Test conditions: 48V, standard loop

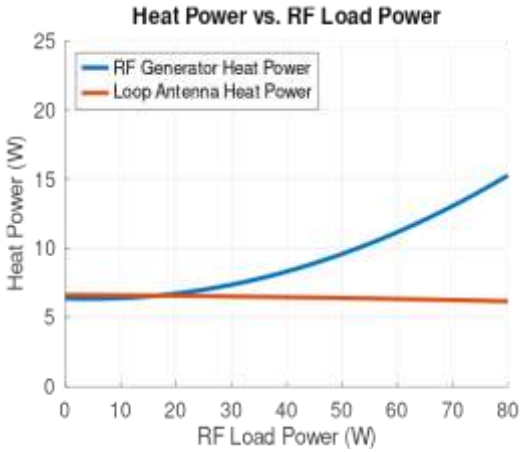


Figure 7: Heat Power based on loading conditions

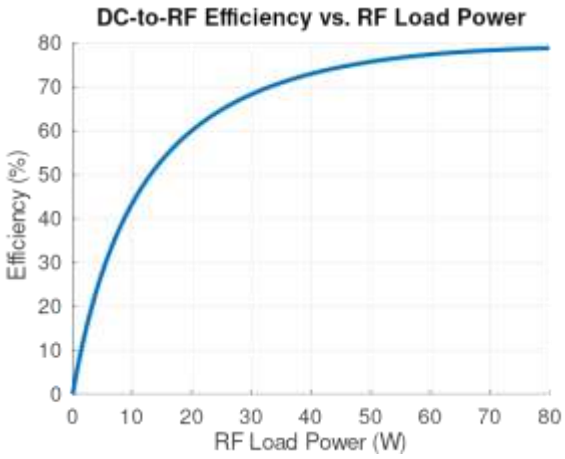


Figure 8: DC to RF efficiency

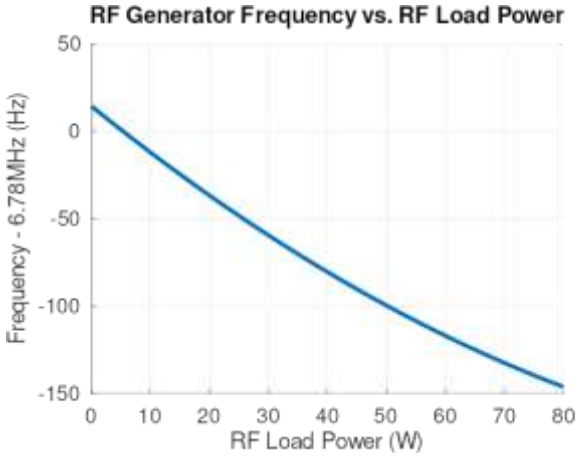


Figure 9: Generator Frequency and Load power

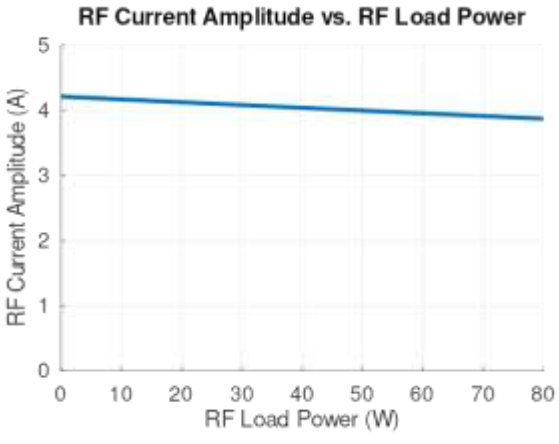


Figure 10: Test conditions: 48V, standard loop

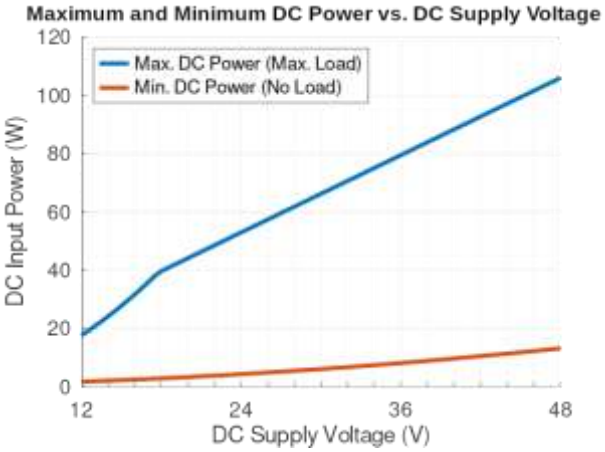


Figure 11: Upper & Lower DC power limits at other voltages

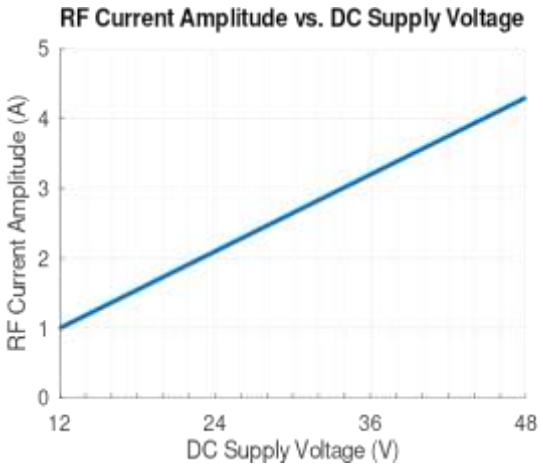


Figure 12: Test conditions: standard loop

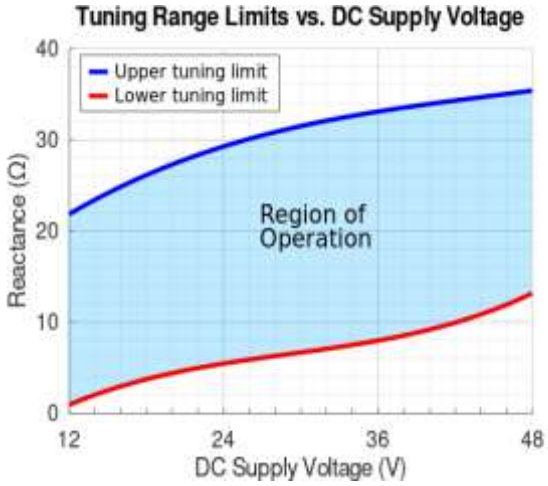


Figure 13: Range limits vs the supply voltage

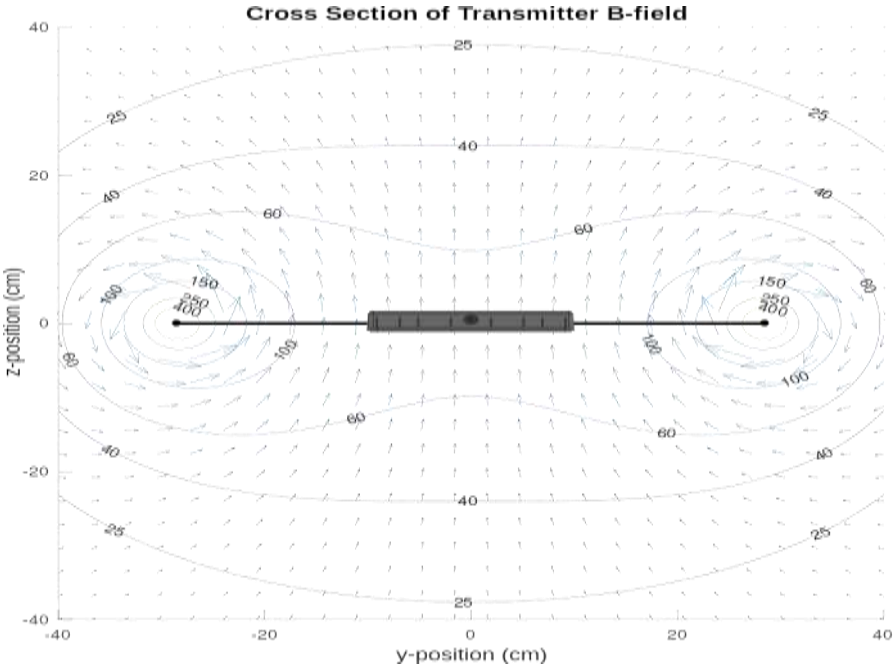


Figure 14: A vertical cross-section of the magnetic field of the transmitter in a plane passing through the center. The vector lengths indicate the magnitude of the B-field and their orientation indicates its direction at each point. The contours show the magnetic field strength in mGauss. The magnetic field is strongest in the near vicinity of the wire loop.

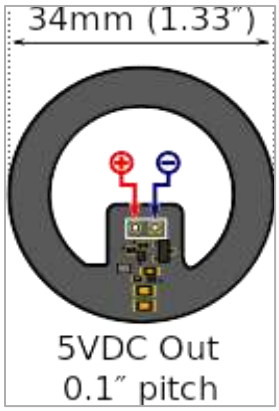
RECEIVER SPECIFICATIONS

SUMMARY

Receiver	Outer Diameter		Nominal Output Voltage	Nominal Output Power
	mm	inch		
Rx1-R	34	1.33	5V	0.1W
Rx2-R	46	1.81	5V	0.2W
Rx3-R	56	2.20	5V	0.3W
Rx4-R	68	2.67	12V	1.0W
Rx5-R	68	2.67	24V	1.0W
Rx6-R	78	3.07	24V	2.0W
Rx7-R	108	4.25	24V	4.0W
Rx8-R	130	5.11	24V	7.0W

+1 (412) 455-5800
www.powercastco.com / contact@powercastco.com

Rx1-R



Parameter	Values			Unit
	Min.	Typ.	Max.	
Output Voltage	4.7	4.9	5.15	V
Voltage Ripple	--	±230	--	mV
Output Current[4] [5]	16	20	22	mA
Output Power[4] [5]	0.08	0.10	0.11	W
RF-to-DC Efficiency	--	50	--	%

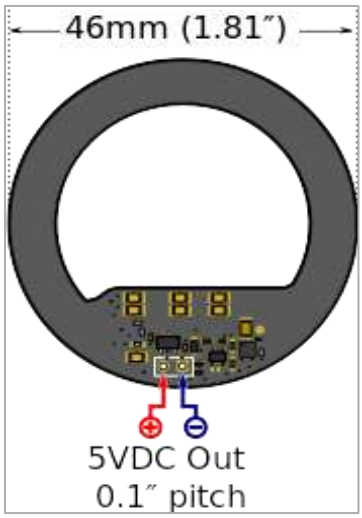
Absolute Maximum Ratings

Parameter	Value	Unit
Output Current	300	mA

[4] The output power is defined for the receiver located at the center of a standard size transmitter loop at zero height, oriented parallel to the surface. The available power is lowest at the center, and higher at all other locations inside the loop *(Refer Figure 19). (Refer Section 'Power vs. Height' and 'Power vs Angle')* for other receiver locations and orientations

[5] The power output may be reduced if two receivers are in close proximity to each other or in proximity to metallic surfaces or magnetic materials. Non-conductive and non-magnetic materials in proximity to the receivers are acceptable, as are small metallic objects like small, non-magnetic screws. Wires in proximity to the receivers are acceptable as long as they are twisted pairs and do not form a closed conductive loop near the receiver loop. For best performance, avoid large, flat metal surfaces or large, closed loops of conductor parallel to the surface of the receiver.

Rx2-R

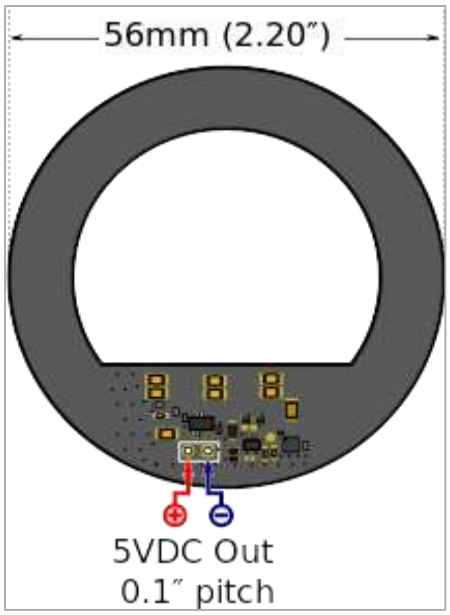


Parameter	Values			Unit
	Min.	Typ.	Max.	
Output Voltage	4.7	4.9	5.15	V
Voltage Ripple	--	±230	--	mV
Output Current[4 5]	40	47	50	mA
Output Power[4 5]	0.20	0.23	0.25	W
RF-to-DC Efficiency	--	53	--	%

Absolute Maximum Ratings

Parameter	Value	Unit
Output Current	370	mA

Rx3-R

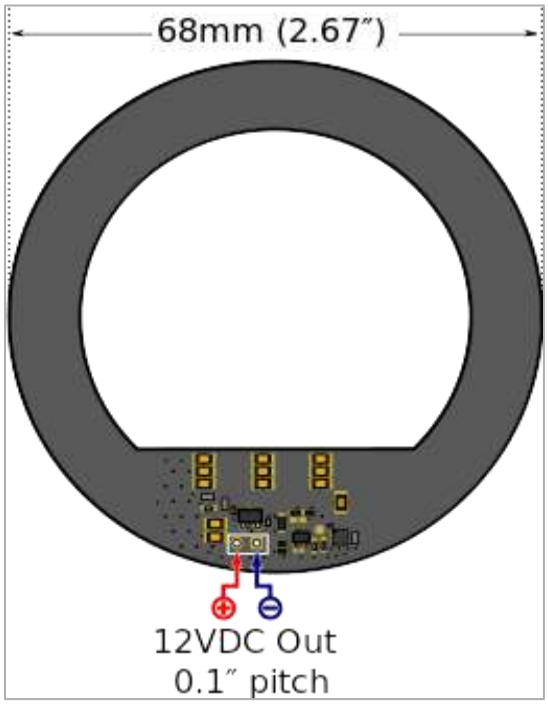


Parameter	Values			Unit
	Min.	Typ.	Max.	
Output Voltage	4.7	4.9	5.15	V
Voltage Ripple	--	±230	--	mV
Output Current[4 5]	49	63	71	mA
Output Power[4 5]	0.24	0.31	0.35	W
RF-to-DC Efficiency	--	32	--	%

Absolute Maximum Ratings

Parameter	Value	Unit
Output Current	370	mA

Rx4-R

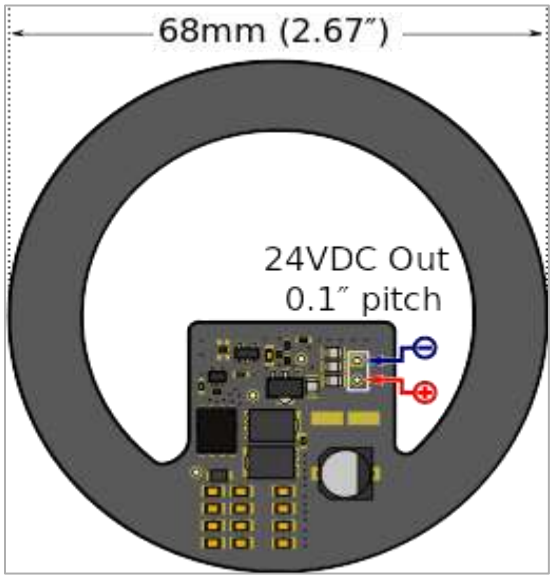


Parameter	Values			Unit
	Min.	Typ.	Max.	
Output Voltage	11.5	12.2	12.8	V
Voltage Ripple	--	±650	--	mV
Output Current[4 5]	74	82	90	mA
Output Power[4 5]	0.9	1.0	1.1	W
RF-to-DC Efficiency	--	72	--	%

Absolute Maximum Ratings

Parameter	Value	Unit
Output Current	460	mA

Rx5-R

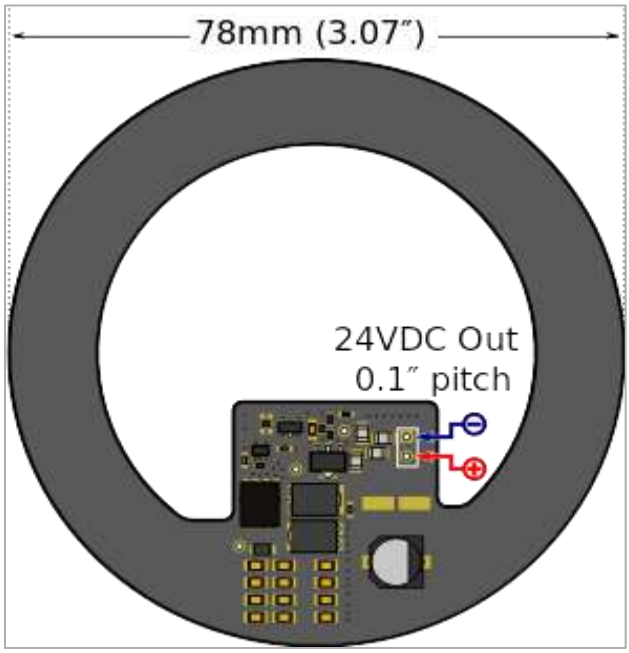


Parameter	Values			Unit
	Min.	Typ.	Max.	
Output Voltage	23.5	24.2	24.8	V
Voltage Ripple	--	±500	--	mV
Output Current[4 5]	50	55	56	mA
Output Power[4 5]	1.2	1.34	1.35	W
RF-to-DC Efficiency	--	48	--	%

Absolute Maximum Ratings

Parameter	Value	Unit
Output Current	420	mA

Rx6-R

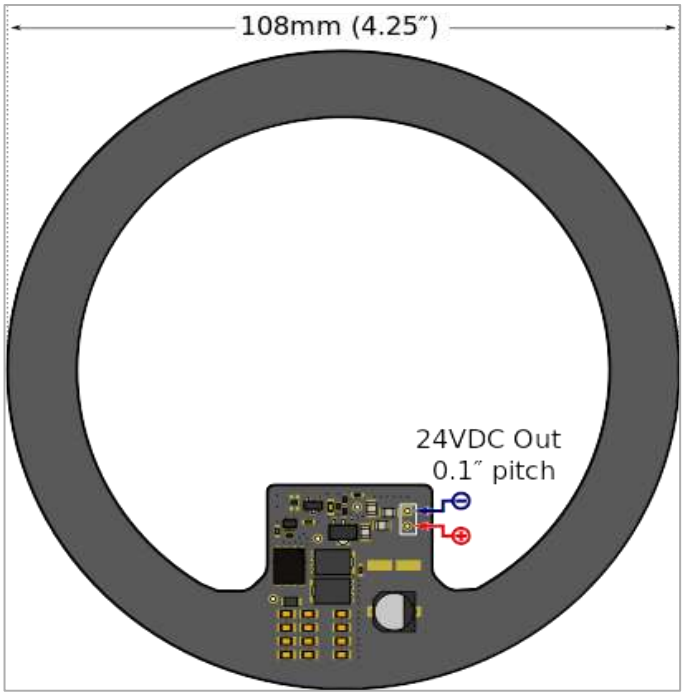


Parameter	Values			Unit
	Min.	Typ.	Max.	
Output Voltage	23.5	24.2	24.8	V
Voltage Ripple	--	±500	--	mV
Output Current[4 5]	79	83	89	mA
Output Power[4 5]	1.9	2.0	2.15	W
RF-to-DC Efficiency	--	59	--	%

Absolute Maximum Ratings

Parameter	Value	Unit
Output Current	420	mA

Rx7-R

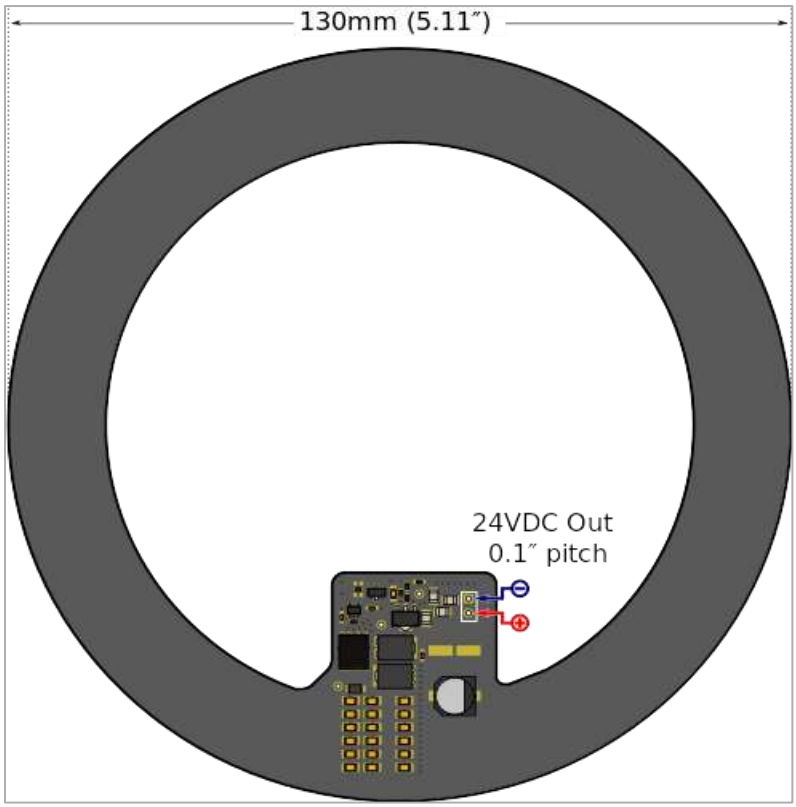


Parameter	Values			Unit
	Min.	Typ.	Max.	
Output Voltage	23.5	24.2	24.8	V
Voltage Ripple	--	±500	--	mV
Output Current[4 5]	210	220	223	mA
Output Power[4 5]	5.1	5.3	5.4	W
RF-to-DC Efficiency	--	76	--	%

Absolute Maximum Ratings

Parameter	Value	Unit
Output Current	420	mA

Rx8-R



Parameter	Values			Unit
	Min.	Typ.	Max.	
Output Voltage	23.5	24.2	24.8	V
Voltage Ripple	--	±500	--	mV
Output Current[4 5]	330	339	343	mA
Output Power[4 5]	8.0	8.2	8.3	W
RF-to-DC Efficiency	--	80	--	%

Absolute Maximum Ratings

Parameter	Value	Unit
Output Current	420	mA

DESCRIPTION OF OPERATION

A receiver consists of four main components: (1) an inductive loop which captures magnetic flux from the transmitter, (2) a set of capacitors chosen to make the inductive loop resonant, (3) a rectifier, to convert RF to DC, and (4) a power regulation circuit *(Refer Figure 15).*

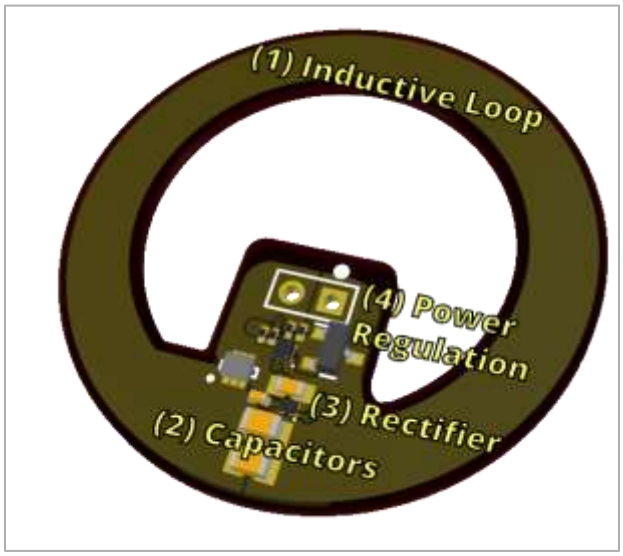


Figure 15: Components of the Receivers

The peak power transferred to the receiver depends on the local magnetic field strength, which varies with the position of the receiver within the power zone. The receivers regulate the load voltage by switching the receiver on and off rapidly using pulse-width modulation (PWM). This ensures that, on average, the receiver only receives the power that is needed to maintain the load voltage.

The PWM frequency ranges from a few Hertz at low power to several kHz at high power. As a result of the PWM, the output voltage has a constant-amplitude triangle-wave ripple at the PWM frequency *(as shown in Figure 16-18)*. For applications that are sensitive to voltage ripples, an extra power conditioning stage (such as a Low-Dropout Regulator) may be used to smooth the DC output voltage of the receiver. However, this will cause a drop in the output voltage and a reduction in the receiver efficiency.

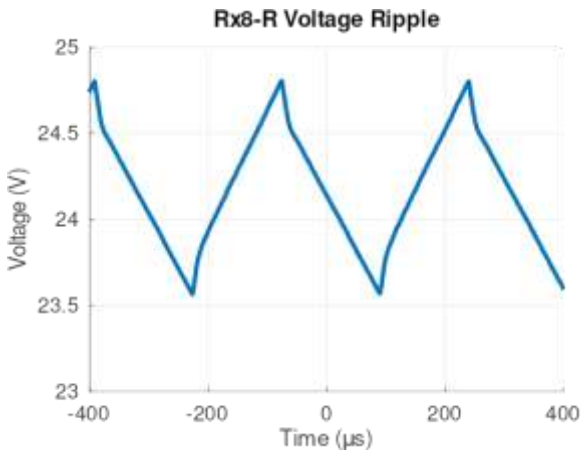


Figure 16: Typical voltage ripple of 24V receiver

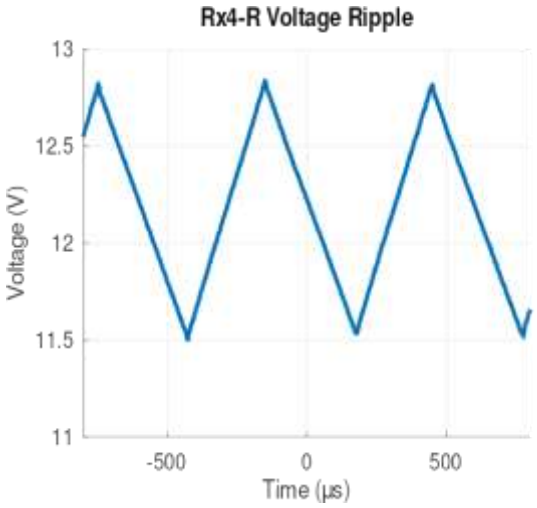


Figure 17: Output Voltage Waveform for Rx4

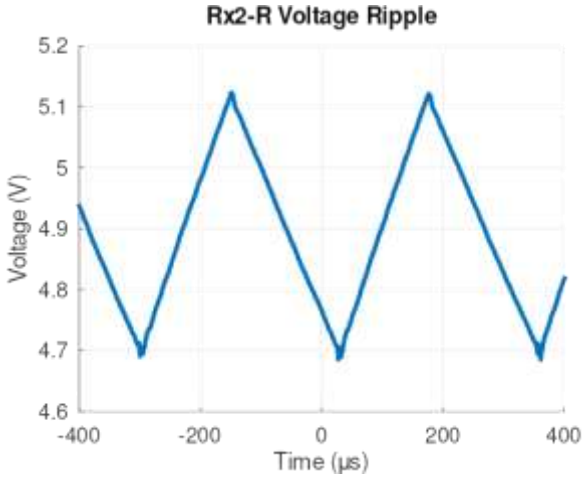


Figure 18: Output Voltage Waveform for Rx4

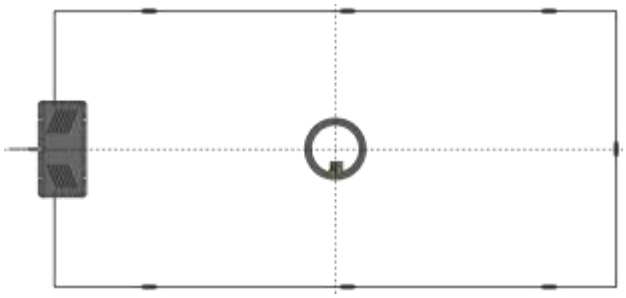


Figure 19: Power distribution in a loop

POWER VS. HEIGHT

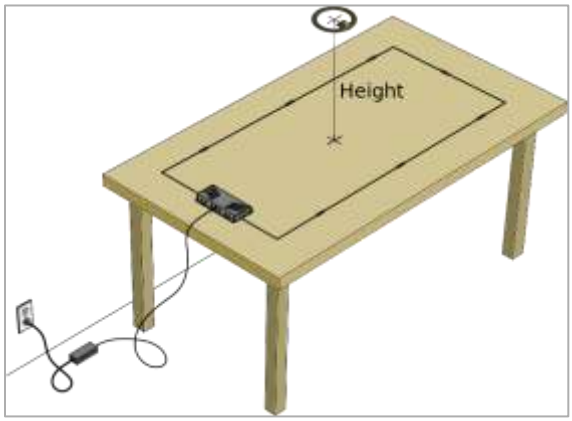


Figure 20: Measurement setup for power vs. height. The field also extends below the surface of the transmitter, so the receiver power levels are the same at an equal distance below the plane of the transmitter

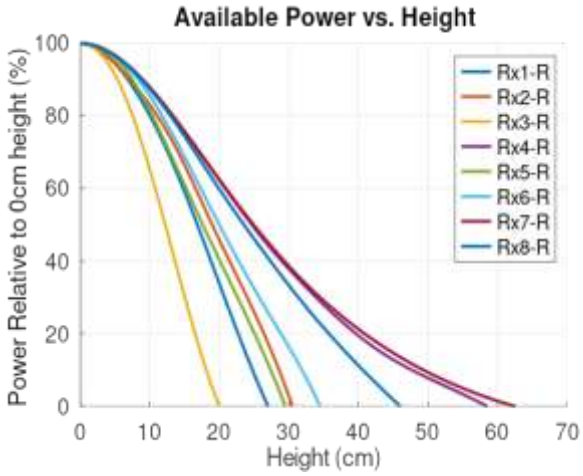


Figure 21: Power vs Height Graph

POWER VS. ANGLE

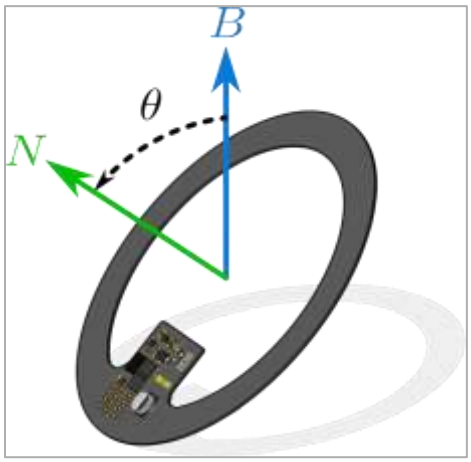


Figure 22: Power vs Angle

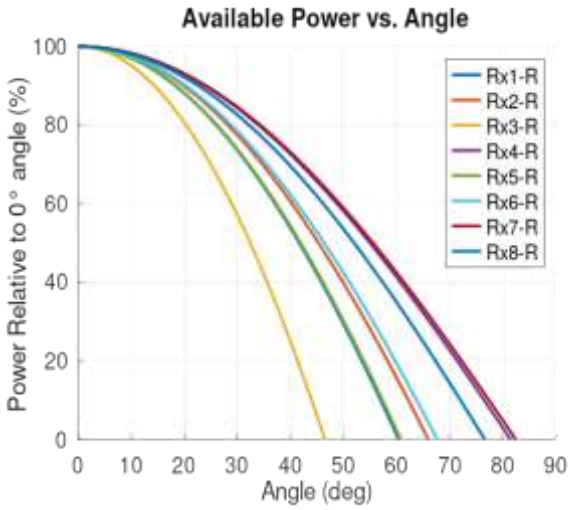


Figure 23: Power vs Angle Graph

RECEIVER HEAT DISSIPATION AND ABSOLUTE MAXIMUM DC CURRENT

The receivers have voltage regulations, but no current limit, so care should be taken to ensure that the load does not draw more current than the absolute maximum DC current rating for each receiver. The power dissipation in the rectifier diodes is proportional to the output DC current, and they will experience a temperature rise above ambient which is proportional to their power dissipation. The Absolute Maximum DC current limits are the point where the rectifier diode temperatures exceed about 100°C (212°F) with an ambient temperature of 25°C (77°F).

When operating the receivers at or near their Absolute Maximum power point, take care not to touch the rectifier diodes or other nearby components on the PCB, as they will be hot *(Refer Figure 24 and 25)*. For standard use-cases, the receiver PCBs are intended to be installed inside non-conductive enclosures which prevent the user or metallic objects from touching the PCB or the components when the receiver is in operation.

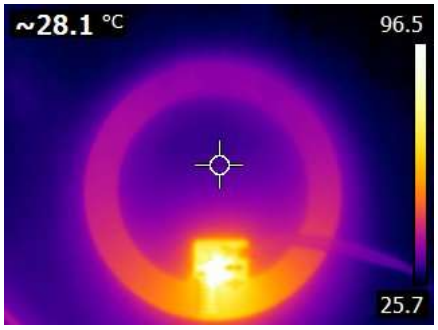


Figure 24: Thermal image of Rx8 while outputting 10W of DC power

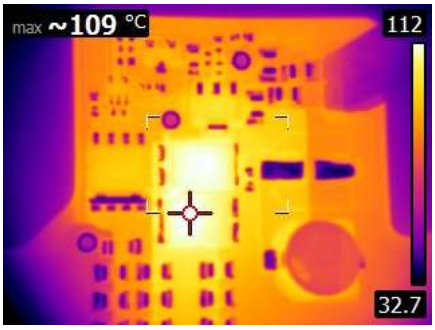


Figure 25

TROUBLESHOOTING

When the RF Generator is shut down, a red indicator LED will illuminate, and the RF Generator will remain in the shut-down state for at least half a second, or as long as the problem condition persists. Once a half-second has elapsed or the problem condition has been removed, the RF Generator will attempt to re-start. If a problem is sensed, another shutdown will be triggered. Otherwise, the RF Generator will resume normal operation. In normal operation, a green indicator LED will illuminate. (See Locations and Colors of LED Indicators on RF Generator, *Refer Figure 26, 27, 28* for photos of indicator LEDs.)

LOCATIONS AND COLORS OF LED INDICATORS ON RF GENERATOR

Figure 26: Green status indicator. An illuminated green LED indicates the RF Generator is operating properly and is outputting RF current

Figure 27: Red Status Indicator

Figure 28: Blue Status Indicator

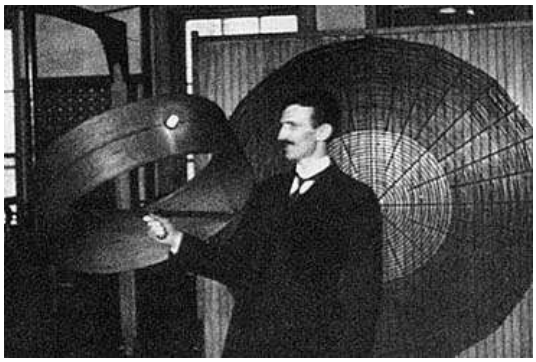
+1 (412) 455-5800
www.powercastco.com / contact@powercastco.com

PROBLEMS AND SOLUTIONS

Problem	Solution
Status lights **not illuminated**	Check that the power supply is plugged in to a working AC outlet and the 2.5mm barrel connector is plugged in to the RF Generator.
Status light **red** or **red** with **flashing green** **No receivers** in transmitter loop	Verify that the transmitter is not placed on or near a metallic or conducting surface. Some tables may have an internal metal frame. Try moving the transmitter to a different surface. Make sure that the Loop Antenna lies flat and is fully extended.
Status light **red** or **red** with **flashing green** **Receivers present** in transmitter loop	The transmitter may be overloaded. Try removing receivers from the power zone. If the red LED is still illuminated after removing the receivers, verify that the transmitter is not placed on or near a metallic or conducting surface. Some tables may have an internal metal frame. Try moving the transmitter to a different surface. Make sure that the Loop Antenna lies flat and is fully extended.
Status light **illuminated green**. Receiver: **no power output**.	Try bringing the receiver closer to the transmitter or changing its angle relative to the Loop Antenna. Check that no metallic objects or other receivers are in proximity of the receiver. If there is still no power output from the receiver, check if the receiver is overloaded or shorted. Try removing the load and checking the receiver's output voltage.
Status light **illuminated green**. Receiver: **low output voltage**.	Try bringing the receiver closer to the transmitter or changing its angle relative to the Loop Antenna. If voltage is still low, check if the receiver is overloaded. Try removing the load and checking voltage again.
Status light **illuminated green**. Receiver: **full output voltage**. Device: **abnormal operation**	If the device is receiving full voltage, but not operating properly, check the peak power draw of the device and ensure that the receiver can supply both the average power and the peak power requirements of the device. (Some devices draw short pulses of current) If the device peak power draw is below the receiver output power limit and the device is still not operating properly, check that the device power supply requirements are compatible with the receiver output voltage ripple.

HOW MAGNETIC RESONANCE WORKS

The history of wireless power dates back to the work of Nikola Tesla in the late 1800's. Tesla discovered that resonance (i.e. the tendency of a system to ring at a certain frequency when disturbed) allows power to be transferred efficiently between two coupled electrical systems, even if the coupling is weak. This is because resonance allows the energy in both systems to accumulate over many cycles, as long as both systems are tuned to and driven at, the same frequency. As a result, the electrical amplitudes are much stronger than if the systems were non-resonant.



Powercast's Magnetic Resonance Technology[6] follows Tesla's approach by using resonant transmitters and receivers which are coupled through magnetic induction. Both electric and magnetic fields can be used to transfer power, but the technology primarily uses magnetic fields due to their weak interaction with organic and non-metallic materials.

Powercast's Magnetic Resonance Technology[6] wireless power systems generate magnetic fields which oscillate at 6.78MHz. This frequency is low enough that most of the magnetic energy does not radiate away into space as waves but rather stays localized in the vicinity of the transmitter in a region called the "power zone" *(green cloud in the diagram below – Figure 29)*. As the magnetic field expands and collapses, resonant receiver loops capture some of the magnetic energy contained within a volume of space surrounding each receiver. These capture volumes (gray spheres in diagram below) are proportional to the cube of each receiver resonator's diameter multiplied by its quality factor.

[6] Powercast's Magnetic Resonance Technology is powered by Etherdyne

Any magnetic energy that is not captured by receivers is returned to the transmitter when the magnetic field collapses. Some of this returned energy is lost as heat in the transmitter. The rest returns to the power zone as the field expands again. An RF generator continually replenishes the energy lost during each cycle. Its power draws depend on the sum of the energy lost to heat and the energy captured by the receivers. The system becomes more efficient as more receivers are added because more energy is captured and delivered to the loads relative to the constant energy lost per cycle in the transmitter.

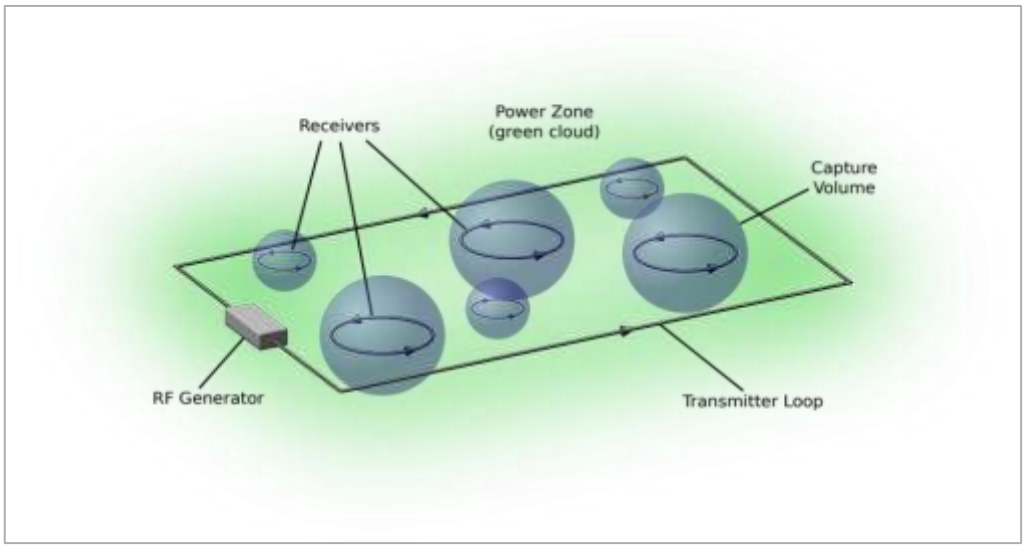


Figure 29: Green Cloud Diagram

COMPLIANCE

This equipment should be installed and operated such that a minimum separation distance of 1.5cm is maintained between the radiator (antenna) & user's/nearby person's body at all times.

IMPORTANT NOTICES

Information furnished by Powercast Corporation (Powercast) is believed to be accurate and reliable. However, no responsibility is assumed by Powercast for its use, nor for any infringements of patents or other rights of third parties that may result from its use.
Specifications are subject to change without notice.

No license is granted by implication or otherwise under any patent or patent rights of Powercast. Trademarks and registered trademarks are the property of their respective owners.

CRITICAL APPLICATIONS DISCLAIMER

POWERCAST PRODUCTS (INCLUDING HARDWARE AND/OR SOFTWARE) ARE NOT DESIGNED OR INTENDED TO BE FAIL-SAFE, FAULT TOLERANT OR FOR USE IN ANY APPLICATION THAT COULD LEAD TO DEATH, PERSONAL INJURY OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE (INDIVIDUALLY AND COLLECTIVELY, "CRITICAL APPLICATIONS"), SUCH AS LIFE-SUPPORT OR SAFETY DEVICES OR SYSTEMS, CLASS III MEDICAL DEVICES, NUCLEAR FACILITIES, APPLICATIONS THAT AFFECT CONTROL OF A VEHICLE OR AIRCRAFT, APPLICATIONS RELATED TO THE DEPLOYMENT OF AIRBAGS, OR ANY OTHER CRITICAL APPLICATIONS. CUSTOMER AGREES, PRIOR TO USING OR DISTRIBUTING ANY SYSTEMS THAT INCORPORATE POWERCAST PRODUCTS, TO THOROUGHLY TEST THE SAME FOR SAFETY PURPOSES. CUSTOMER ASSUMES THE SOLE RISK AND LIABILITY OF ANY USE OF POWERCAST PRODUCTS IN CRITICAL APPLICATIONS, SUBJECT ONLY TO APPLICABLE LAWS AND REGULATIONS GOVERNING LIMITATIONS ON PRODUCT LIABILITY.

Powercast warrants its products in accordance with Powercast's standard warranty available at
www.powercastco.com/terms-conditions

POWERCAST®
Wireless Power for a Wireless World®

Powercast Corporation
620 Alpha Drive, Suite 1
Pittsburgh, PA, USA 15238
www.powercastco.com
contact@powercastco.com
+1 (412)-455-5800