WIRELESS CHARGING

User Guide

TSDMRX-5W-EVM
Dual-Mode (Qi and PMA) Receiver

Introduction

The Semtech TSDMRX-5W-EVM is an evaluation platform for test and experimentation of a wireless charging receiver based on a pair of high efficiency Semtech ICs: the TS81000 Receiver Controller for Wireless Power Systems and TS51111 Synchronous Rectifier and Charging IC. This evaluation module provides a complete system solution for both Qi and PMA standards of wireless power transfer, making this receiver an ideal platform compatible with the majority of wireless power systems in use today.

Objectives

The objective of this User Guide is to provide a fast, easy and thorough method to experiment with and evaluate the Semtech solutions for wireless charging systems. Sufficient information is provided to support the engineer in all aspects of adding wireless charging support to their products. Semtech offers a range of solutions to meet the needs of a wide range of system developers. Developers are provided with all the information on how this EVM was built as a starting point for their own designs using the TS81000 and other Semtech components.

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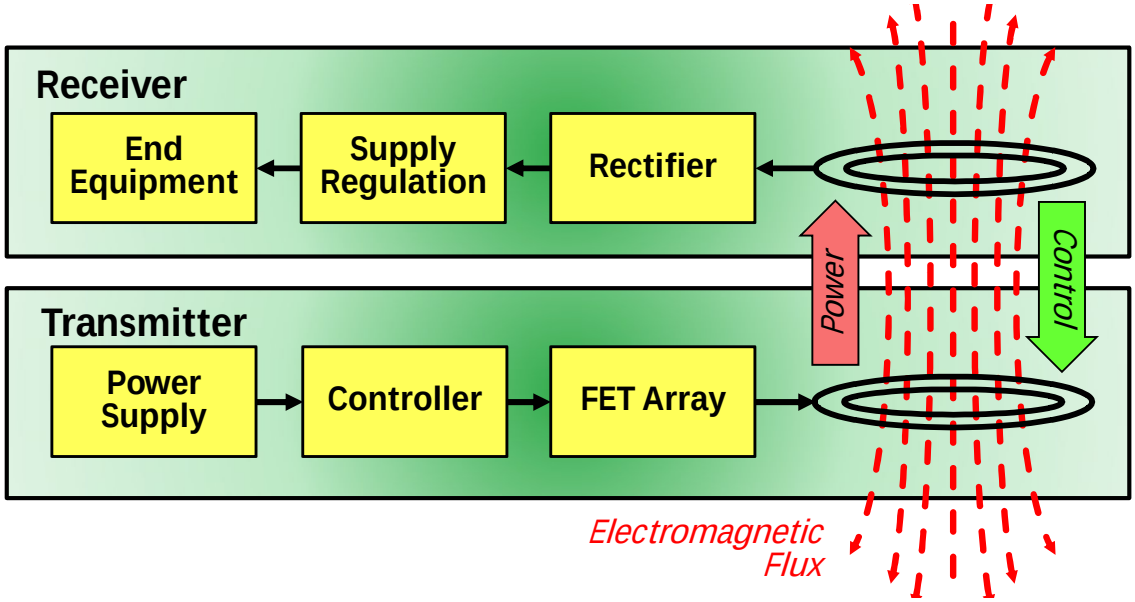
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Wireless Charging Concepts

Wireless power transfer is, essentially, a transformer. Power is provided to a primary coil which produces an electromagnetic (EM) field. In this field, a secondary coil is placed. The EM field induces a current into the secondary coil, providing power to whatever it is connected to.

However, unlike a conventional power transformer that operates at line frequencies and requires an iron core for efficiency, wireless power systems are designed to operate in the 100 kHz range, and thus can perform efficiently with an air core. As such, the primary and secondary windings, if closely spaced, can be in separate devices, the primary being part of a transmitter and the secondary within a receiver. This implementation can also be described as a radio broadcast process, and as such, these transformer coils can also be seen as antennas with equal validity, and the two terms will be used interchangeably in this text.



Wireless power systems differ in another major aspect from conventional transformers, in that they are intelligently managed. A transmitter will only provide power when a receiver is present, and only produce the amount of power requested by the receiver. In addition, the system is capable of recognizing when the electromagnetic field has been interrupted by an unintended element, a 'foreign object', and will shut down the transfer to prevent any significant amount of power being absorbed by anything but a proper receiver. The intelligent management of the wireless power transmission process is achieved though the programming of the TS81000. When introduced to a compliant transmitter, the TSDMRX-5W-EVM receiver informs the transmitter of its power requirements, and transmission begins. The receiver then verifies the right amount of power is being sent, and that none is being lost to foreign objects. The receiver continually provides ongoing requests for power to maintain the transaction. If these requests cease, the transaction terminates. Via this protocol, even complex charging patterns can be supported, as the transmitter can provide varying amounts of power at different times, as requested by the TSDMRX-5W-EVM. Should the TSDMRX-5W-EVM require no further power, such as when a battery charge is completed, it can request no further power be sent, and the transmitter will reduce its output accordingly.

Wireless power systems have been broken into three basic power categories. “Wearable” devices, such as headsets, wrist-band devices, medical sensors, and so forth - all operate in the low power range, up to 5 watts. Medium power devices, in the 5- to 15-watt range, include most handheld devices, such as cell phones, tablets, and medical electronics. High power wireless systems are intended to support devices such as power tools, radio controlled (“RC”) devices such as drones, and other equipment requiring 15 to 100 watts of power.

Product Description

The TSDMRX-5W-EVM Evaluation Module is a ready-to-use demonstration platform allowing testing of up to 5 watts of wireless power transmission compliant with the dominant industry standards – Qi and PMA.

The receiver may be coupled with any Qi or PMA transmitter module to form a complete wireless power transmission system. For the system designer, a likely choice might be the complementary TSDMTX-5V-EVM, which can allow a variety of experiments to easily be performed in order to learn more about the behavior of the system.

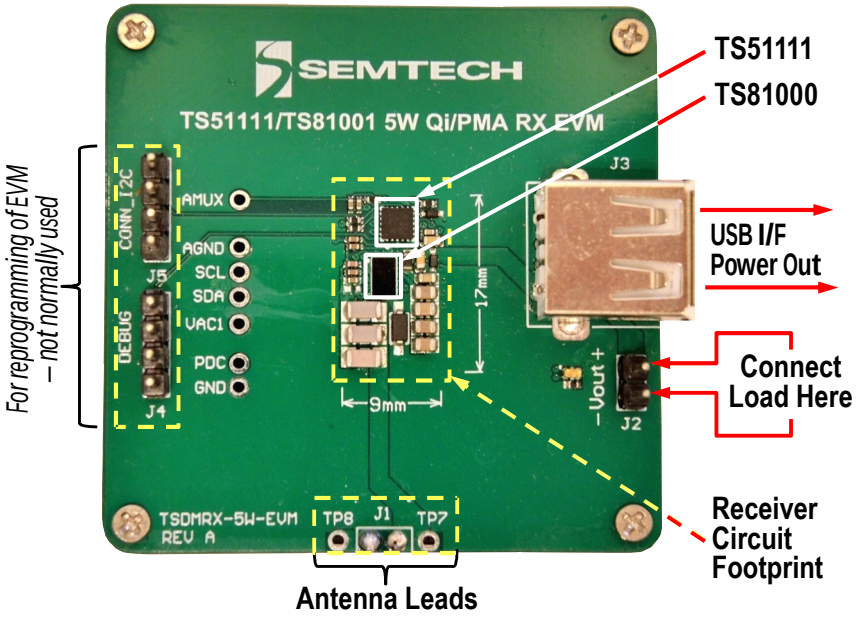
There are other Qi and/or PMA standard Semtech Transmitter EVMs that support different power levels which can be used as they are compatible with the TSDMRX-5W-EVM receiver.

Those who wish to develop their own board, or integrate this functionality into an existing system can use the EVM as a starting point for their design, as it demonstrates a working model from which to proceed. Toward this end, all documentation for the EVM is provided to make the process as efficient as possible.

The key technology components of the EVM are a pair of Semtech integrated circuits, the TS81000 and TS51111. The TS81000 provides the Qi/PMA compliant communications and control for wireless receivers of up to 40+ watts. All the intelligent management of the process is handled by the TS81000. The TS51111 is the synchronous rectifier and charging solution in the system. Up to 5 watts of power acquired from the receiver antenna is fed to the TS51111, converted to DC, and output at 5 VDC, with efficiencies up to 98+%. This EVM presents a working example of how these two components can be used together to form a complete wireless power receiver solution with high efficiency, low part count and minimized space requirements.

As seen in the photo below, the board contains a number of sections. In the center of the board is the receiver circuit, occupying a rectangle of 17x9 mm. Surrounding it are various test points brought out for conveniece during experimentation. The USB port can be used to provide output power to a device via a standard USB cable. Headers J4 and J5 are used for firmware update. Key test points will be employed in the following text; all are documented in the schematic diagram below.

In the following section, an introduction will be provided to the evaluator for how to use the EVM for wireless power reception as well as how the TSDMTX-5V-EVM can be used in conjunction with it.



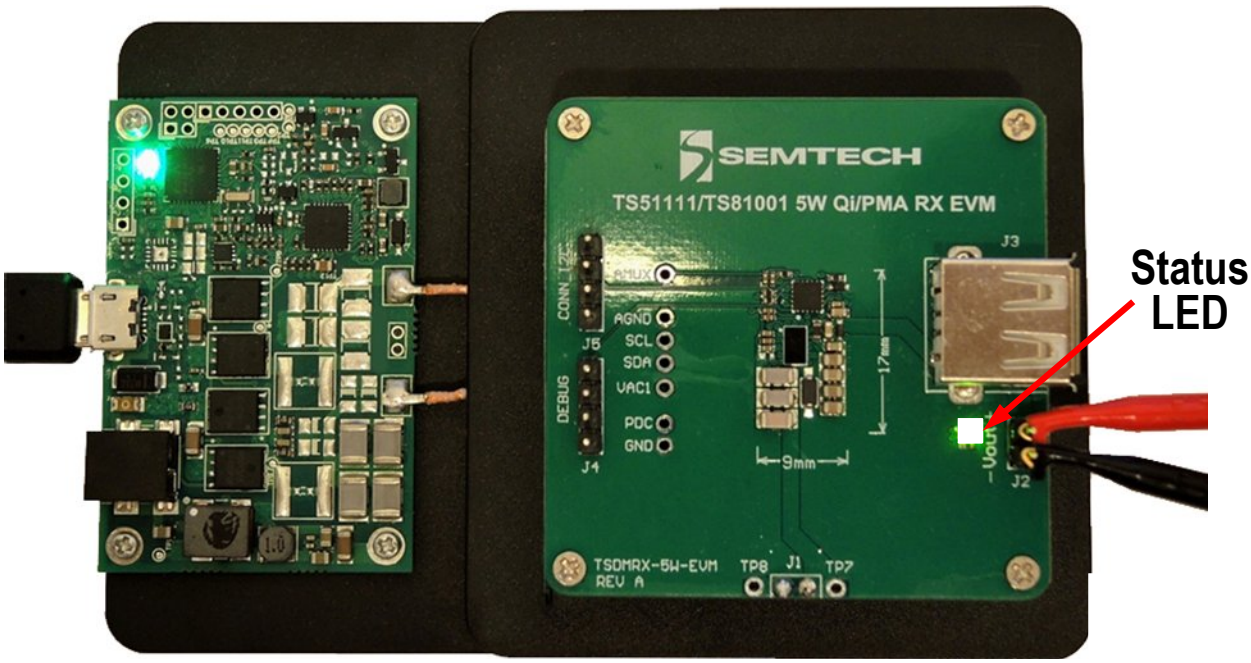
Standard Use

The TSDMRX-5W-EVM is very easy to use. Start by applying power to the TSDMTX-5V-EVM transmitter. A few times each second, the transmitter emits a 'ping' of energy in search of a compliant receiver in range - in this document, the TSDMRX-5W-EVM.

Place the TSDMRX-5W-EVM over the target area of the transmitter EVM. The TSDMRX-5W-EVM is initially powered by the ping sufficiently to be able to announce its presence to the transmitter, and a transaction begins. The transmitter next provides a small amount of power to the newly discovered receiver, so the TSDMRX-5W-EVM can tell the transmitter what its power requirements are.

At the completion of the handshake, the transmitter begins providing the requested power, indicated by a green LED on the receiver EVM. During power transfer, the TSDMRX-5W-EVM continuously communicates with the transmitter, actively directing the process. In this way, it is assured that power is only sent when and how it is required by the receiver. If required by the load, the TSDMRX-5W-EVM can actively increase or decrease its power request, and the transmitter will act accordingly. As such, equipment with complex charging requirements can be precisely supported by the TSDMRX-5W-EVM and only the desired amount of power is provided. If at any time an error is detected, transmission is halted. To restart, the TSDMRX-5W-EVM must be removed from the range of the transmitter and returned to the target zone to start a new transaction.

The receiver EVM can deliver up to 5 watts of power at 5 volts to any load the user would like to experiment with. For general experimentation, the optimal load to select would be a Programmable DC Electronic Load. A 'load box' can easily be set to draw a selected current or power at the turn of a knob, making them very flexible and easy to use in observing power supply operation in general. If a load box is not available, a power resistor decade box is nearly as convenient, as it can easily be set to any desired resistance to simulate a range of load conditions. In either case, be sure the test load is rated for at least the amount of power being tested. If need be, a selection of power resistors could be used as test loads, though without the ease of modification of the prior options. Finally, any device that uses a 5 volt input up to 5 watts of power can be used as a test load should that be desired.



If using the USB port, power is provided via pin 1 (VBUS) and pin 4 (GND). Otherwise, run wires from the VOUT+ and VOUT- pins of the receiver EVM to the selected test load, as per the illustration above. Once the load is added, the receiver EVM can be used to perform a variety of tests.

Connect a DC voltmeter across the VOUT+ and VOUT- pins to monitor the voltage being output to the load, and a DC ammeter in series with the VOUT+ line. Set levels to allow for up to 10 volts and 2 amps to be observed.

With no load selected, place the receiver on the center of the transmitter target circle. Once transmission begins, you should observe approximately 5 volts and 0 amperes on the meters.

Apply a variety of loads to observe performance between 0 and 5 watts. Voltage should remain nearly constant, and current should follow the P=V*I relationship. Experiment with the maximum power that can be drawn before the receiver detects an overload and cuts off power. You should be able to observe on a minor overload, the receiver will attempt to restore power by retesting the load intermittently. In the case of a major overload, the transmitter may register an error, as indicated by a red LED on the transmitter, which will halt further activity until the receiver is removed from the target area for several seconds before being returned to start a new transaction.

Observe Coil Signals

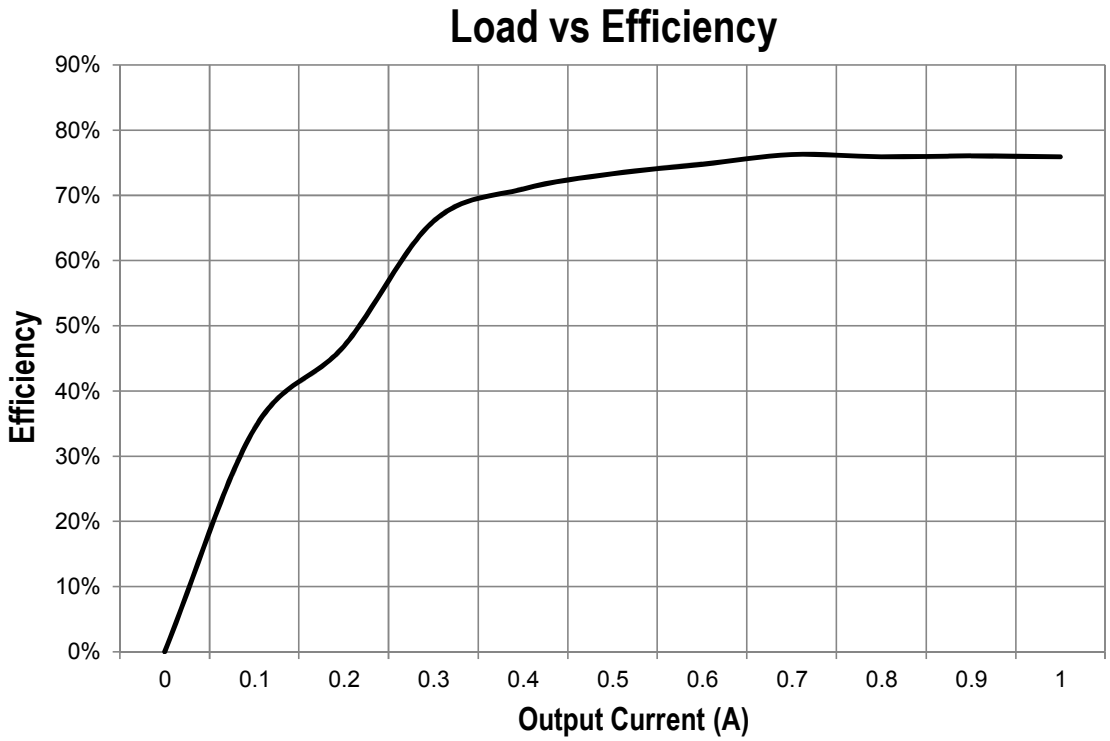
The following information is not required in order to use the EVM, as what can be observed below is entirely managed by the Semtech TS81000 Wireless Controller. However, it allows the observer an opportunity to see how the receiver and transmitter actively manage the wireless power process.

If you wish to observe the intrinsic wireless process, place an oscilloscope probe on the right-most J1 pin (an antenna lead), with the probe ground run to the board ground on VOUT-. Be sure the scope can handle signals up to 200 volts. While the EVM power output is only 5 volts, the antenna is part of a resonant circuit where considerably higher voltages are developed.

Place the receiver on the transmitter target. With the scope set to 0.5 to 1 uSec and 10 to 20 volts per division, you should observe a signal that is a composite of the sinusoidal power signal with a digital 'notch' in the sinewave which is produced by the communication between the receiver and transmitter. Note as you vary the load and the location of the receiver on the target that the amplitude and frequency of the coil signal changes. The greater the load, the more signal is sent to transfer the power required by the load. Similarly, the less well coupled the receiver antenna is to the transmitter coil, the more power must be sent to compensate for the inefficient misalignment. You may note voltages near 140 volts peak-to-peak in the most demanding conditions.

Measure Efficiency

By measuring the power from the receiver's VOUT+ and VOUT- pins in comparison to the power entering the transmitter EVM, you can determine the efficiency of the power transfer through the system. For the EVMs used here, the diagram below demonstrates that efficiency is a function of output current, and runs about 75% at higher power levels, assuring good efficiency and minimal heat dissipation concerns.

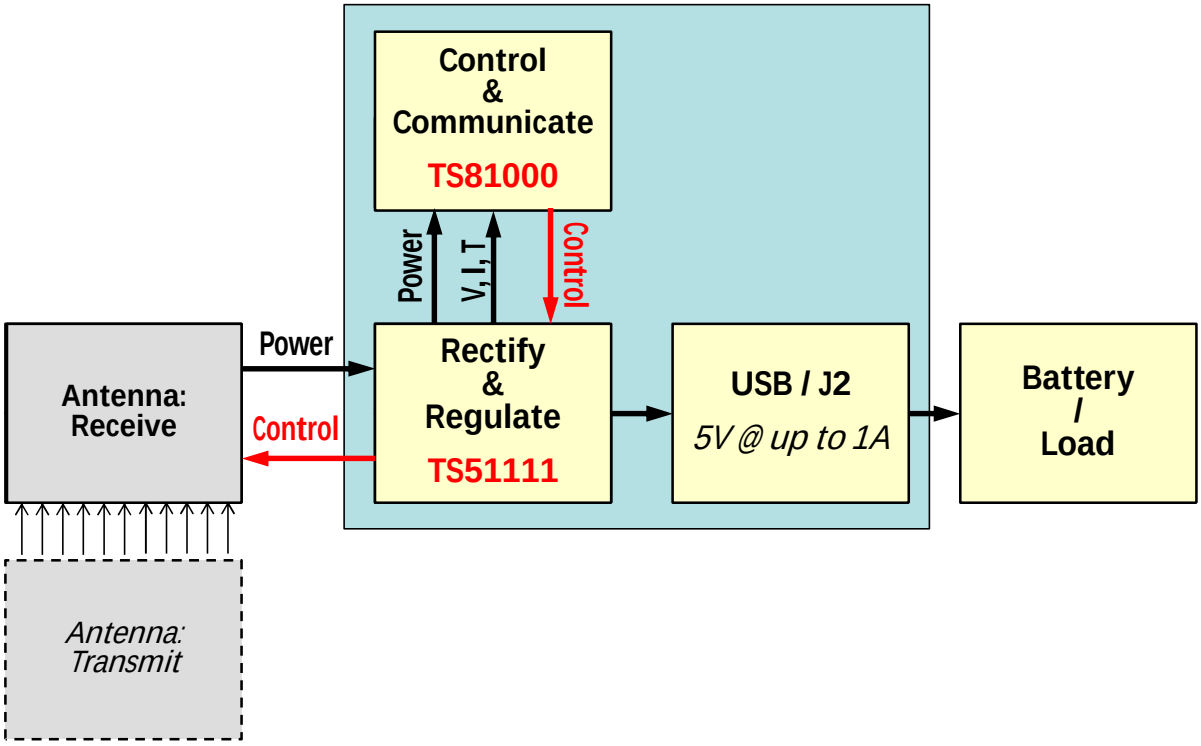


Documentation

The following sections document the hardware design of the TSDMRX-5W-EVM. This information can be used to better understand the functionality of the design, as well as assist in creating your own hardware solution based on this design.

A. Block Diagram

The TSDMRX-5W-EVM may be divided into a number of sub-blocks as show in the diagram below:



Antenna: Transmit – power source driving the receiver EVM (in this document: part of the TSDMTX-5V-EVM).

Antenna: Receive – coil of wire placed in proximity to the transmit antenna to power the EVM receiver system.

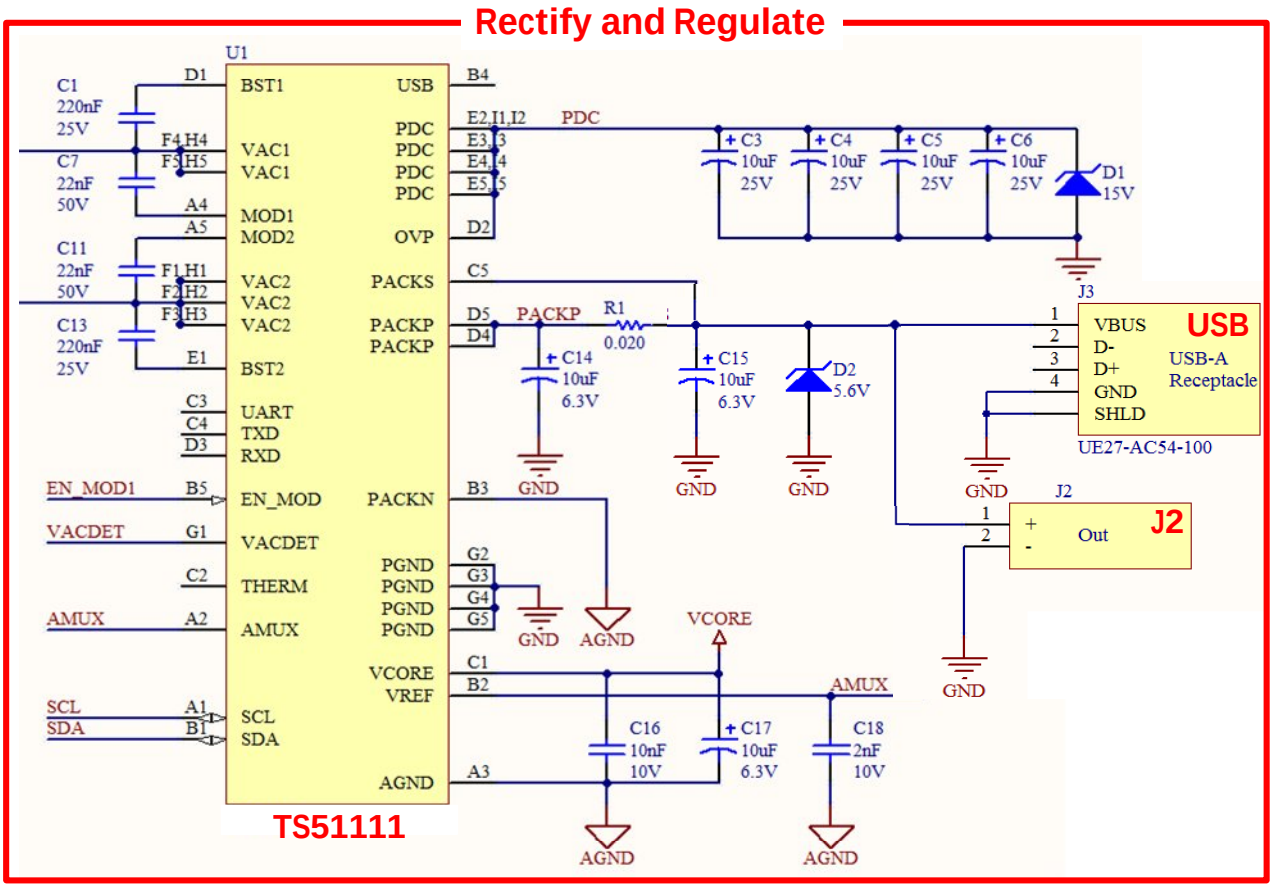
Rectify and Regulate – based on the TS51111 High Efficiency Synchronous Rectifier and Charging IC which performs all power supply operations – rectification of input power from antenna through conversion of resultant DC into regulated 5 volt output at up to 1 ampere.

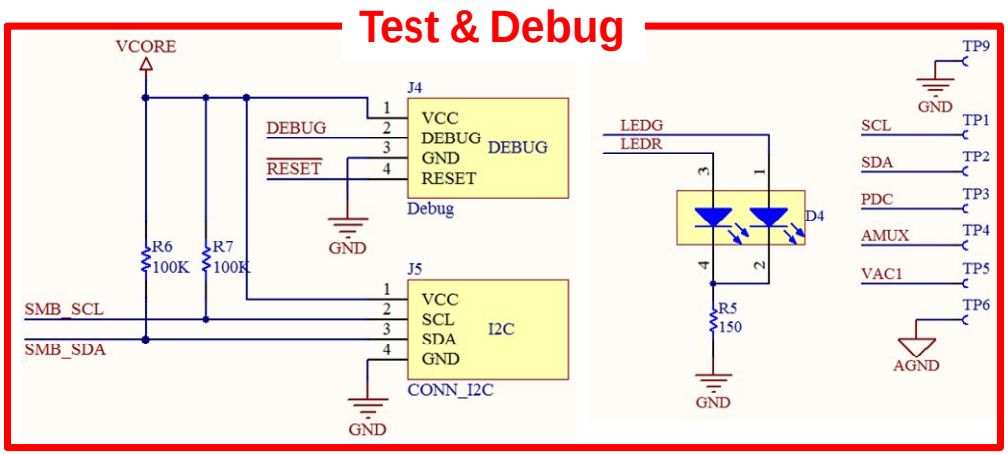
Controller – based on the TS81000 High Efficiency Receiver Controller for Wireless Power Systems. Powered by the TS51111, the TS81000 collects voltage, current, and temperature feedback signals from the receiver system, controls the actions of the TS51111, and provides control signals to direct the power provided by the transmitter system which is passed through the antennas via the TS51111.

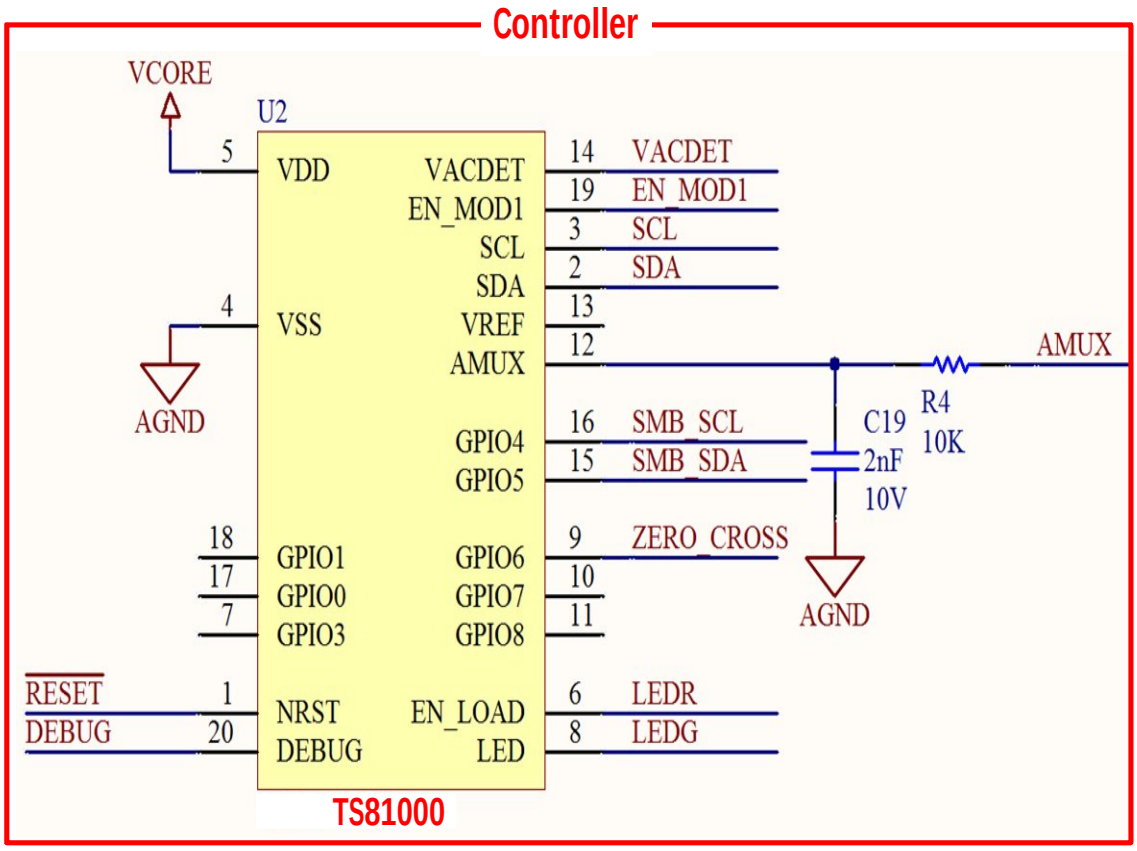
USB/J2 – Either port provides 5 VDC output to the user-selected recipient of the received power at up to one ampere. The USB port provides convenient interface to USB powered devices, and J2 allows test probes to be easily attached for experimentation in the lab.

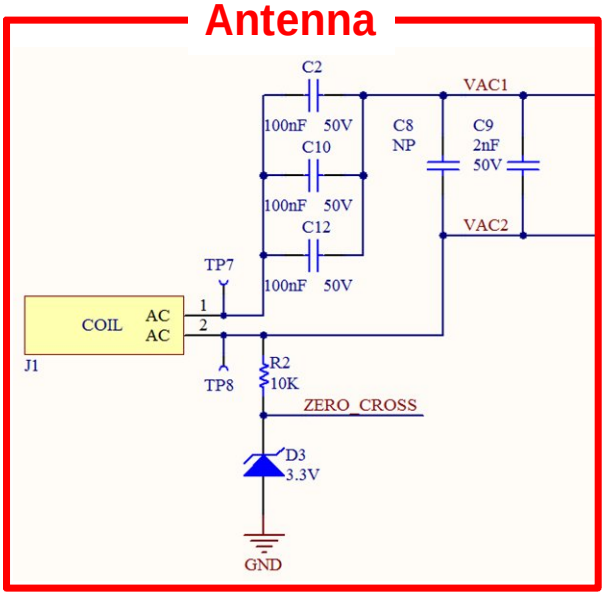
B. Schematic

Below are the schematics for the TSDMRX-5W-EVM. Annotation has been added to indicate which part of the block diagram each component is a member of:






Controller
VCORE
U2
5
VDD
4
VSS
AGND
VACDET
EN_MOD1
SCL
SDA
VREF
AMUX
GPIO4
GPIO5
GPIO1
GPIO0
GPIO3
GPIO6
GPIO7
GPIO8
NRST
DEBUG
EN_LOAD
LED
14 VACDET
19 EN_MOD1
3 SCL
2 SDA
13
12
AMUX
R4
10K
C19
2nF
10V
AGND
16 SMB_SCL
15 SMB_SDA
18
17
7
9 ZERO_CROSS
10
11
RESET
1
DEBUG
20
6 LEDR
8 LEDG
TS81000


Antenna
C2
100nF 50V
C10
100nF 50V
C12
100nF 50V
C8
NP
C9
2nF
50V
VAC1
VAC2
TP7
TP8
COIL
AC
AC
1
2
J1
R2
10K
ZERO_CROSS
D3
3.3V
GND

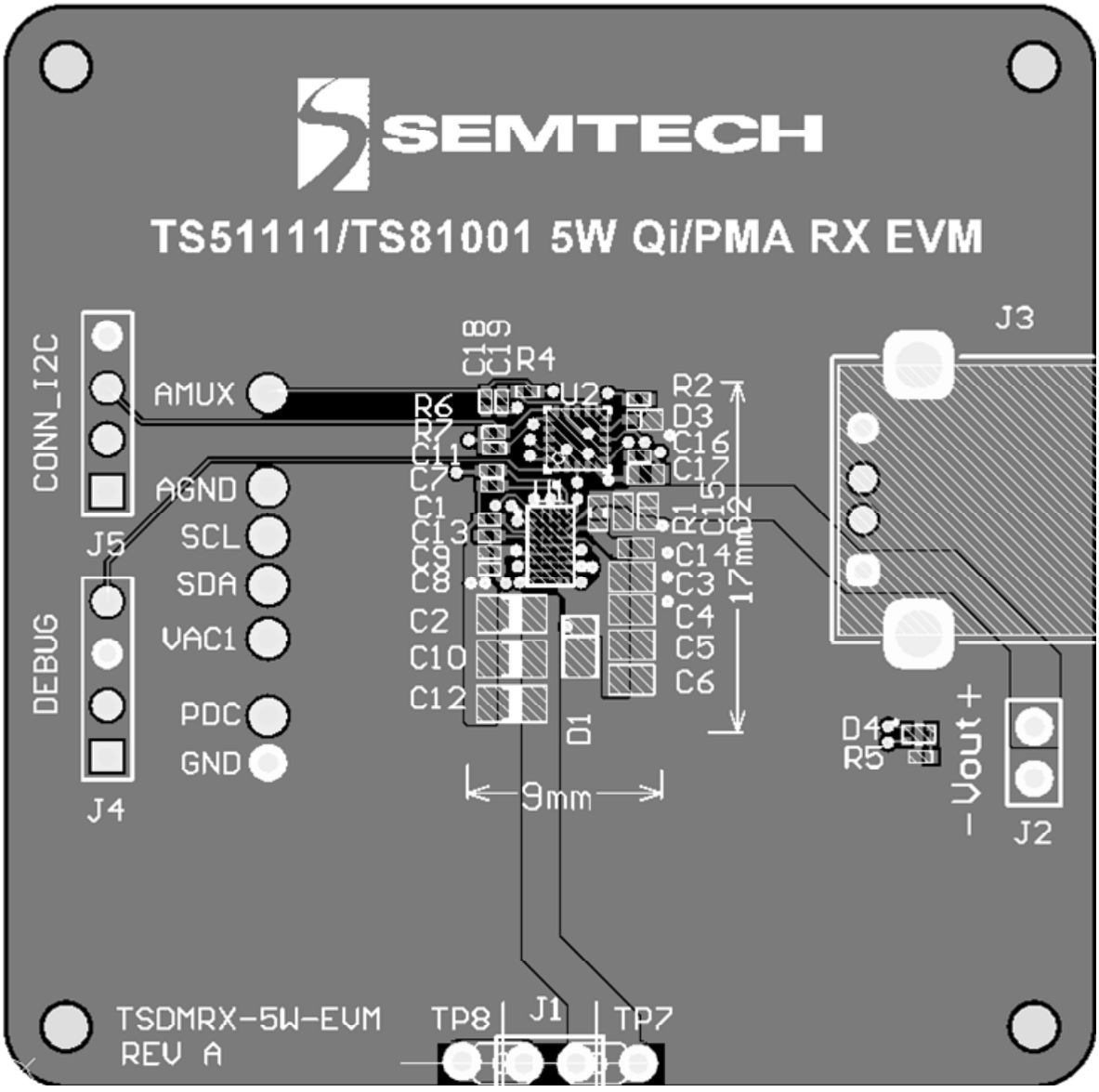
C. Bill Of Materials "BOM"

Below is a listing of the parts used in the TSDMRX-5W-EVM. An excel spreadsheet file with this information is available on the Semtech website as an added convenience.

	Designator	#	Val-ue	Val 2	Description	Manufacturer	Manufacturer Code
1	C1, C13	2	220nF	25V	Capacitor	TDK	
2	C3, C4, C5, C6	4	10uF	25V	Capacitor	TDK	
3	C7, C11	2	47nF	50V	Capacitor	TDK	
4	C8	1	NP		Capacitor	TDK	
5	C9	1	2nF	50V	Capacitor	TDK	
6	C10, C12, C2	3	100nF	50V	Capacitor C0G	TDK	CGA5L2C0G1H104J
7	C14, C15, C17	3	10uF	6.3V	Capacitor		
8	C16	1	10nF	10V	Capacitor		
9	C18, C19	2	2nF	10V	Capacitor		
10	Coil		7.3uH		Inductor	Wurth	7.60308E+11
11	D1	1	15V		Zener Diode	Diodes	BZT52C15-7-F
12	D2	1	5.6V		Zener Diode	ON Semiconductor	MM5Z5V6T1G
13	D3	1	3.3V		Zener Diode	ON Semiconductor	MM5Z3V3T1G
14	D4	1			LED Dual Color	Kingbright	APHB1608SGEC
15	R1	1	0.020	0.05W	Current Sense Resistor		
16	R2, R4	2	10K		Resistor		
17	R5	1	150		Resistor		RC0402FR-07150RL
18	R6, R7	2	100K		Resistor		
19	U1	1			Synchronous Rectifier / Direct Charging IC	Semtech	TS51111
20	U2	1			Wireless Charging Receiver Controller	Semtech	TS81001-QFN

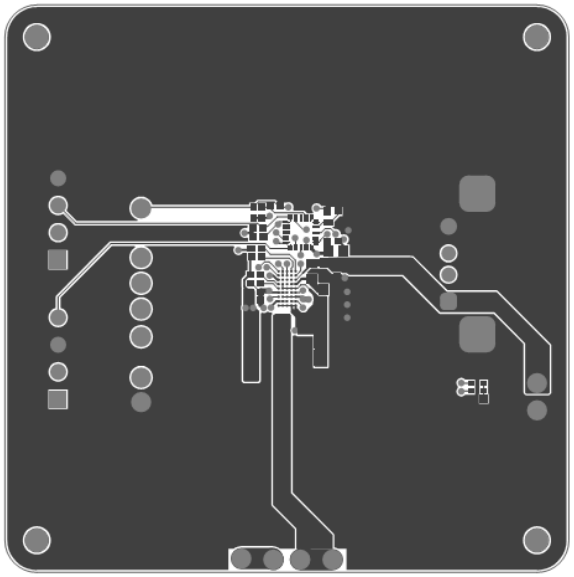
D. Board Layout

The diagram below shows the locations of the components used in the TSDMRX-5W-EVM PCB. Note especially that the majority of the board area is devoted to pinouts for testability, and that the actual circuit implementation footprint is 17mm x 9mm, or about the size of a micro-SD card. Also worth noting is that this solution is comprised of essentially just two ICs with a few dozen surrounding resistors and capacitors – a very efficient solution.

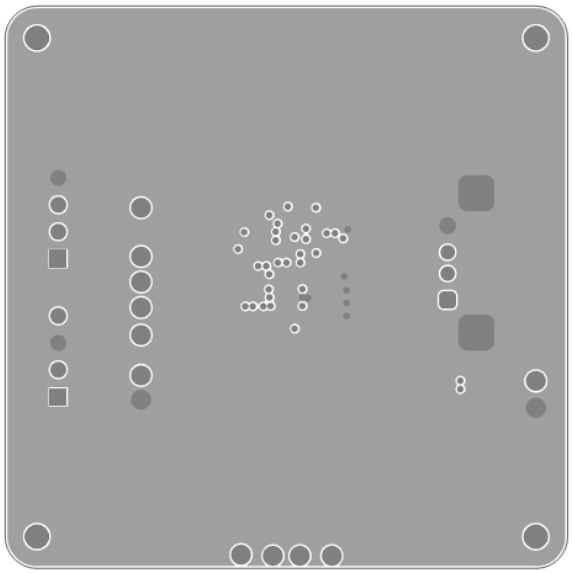


E. Board Layers

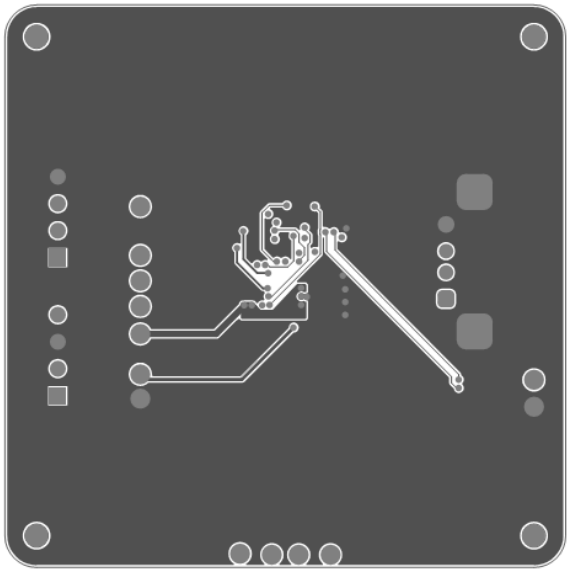
The TSDMRX-5W-EVM PCB is based on a four layer design as shown below. The ground plane in layer two is recommended to reduce noise and signal crosstalk. The EVM placed all components on the top of the board for easier evaluation of the system. End product versions of this design can be made significantly smaller by distributing components on both sides of the board. The Gerber files for this artwork can be downloaded from the Semtech web page.



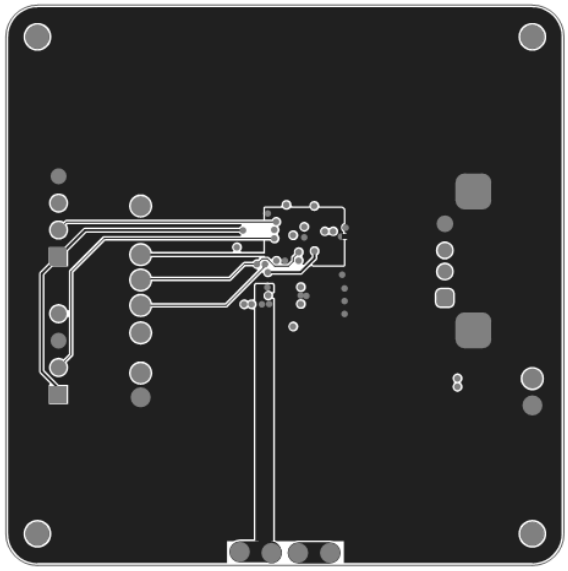
Top Layer



Ground Plane



Signal Layer



Bottom Layer

FAQs

Q: What output voltage is provided by the TSDMRX-5W-EVM system?

A: 5 volts, at up to 5 watts total power. The TSDMRX-9V/15W-EVM would provide up to 15W at 9V.

Q: What mode does the TSDMRX-5W-EVM operate in?

A: Qi is the default. With PMA-3 and PMA-8 transmitter types, PMA mode is selected.

Q: Where can I find more information on the Qi and PMA standards?

A: There are a number of websites that address this subject. A good starting point for Qi would be: http://www.wirelesspowerconsortium.com/technology/how-it-works.html.
PMA, which is now joined with A4WP, is now called AirFuel. Information on them can be found at the following website: http://www.airfuel.org/technologies/inductive.

Q: Does the EVM part number represent something in particular?

A: Yes. The part number is broken into a prefix, main body, and suffix, separated by dashes. The prefix is comprised of three two letter groupings that each help define the product represented. As such, the part number can be read as follows:

Prefix characters:

1+2 = Company :	TS = Triune/Semtech	
3+4 = Environment :	DM = Dual Mode	WI = Wearable Infrastructure
5+6 = Type :	TX = Transmit	RX = Receiver

Mid-section = Device Voltage and/or Wattage.

Suffix = Equipment type:

EVM = Evaluation Module

MOD = Production Module

Therefore, the TSDMRX–5W–EVM is a Dual Mode, 5 Watt Receiver Evaluation Module provided by Semtech.

Q: What if my questions weren't answered here?

A: Go to the Semtech website as described on the next page. An updated FAQ for the TSDMRX-5W-EVM is maintained there and may contain the answers you're looking for. Your local Semtech FAE can also assist in answering your questions.

Next Steps

For more information on Wireless Power, go to the Semtech webpage at:

https://www.semtech.com/power-management/wireless-charging-ics/

You may also scan the bar code to the right to go to the above web page:

There you can find the downloadable copies of the schematic, BOM, and board artwork, as well as additional information on how to obtain Semtech wireless power products, from the chip level all the way to complete board modules, as your needs require.

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