SEMTECH

WIRELESS CHARGING

User Guide

LinkCharge™ 40
40 W Wireless Charging Solution

Introduction

The LKCH-TXRX40W-EVB wireless charging solution includes one transmitter and one receiver. The transmitter is named "Semtech TSDMTX-24V3-EVM" which is an evaluation platform for test and experimentation of a wireless charging solution based on the Semtech TS80003 Wireless Power Transmitter Controller, TS61002 FET Driver, TS30041 DC/DC Converter, and TS94033 Current Sense Amplifier. This evaluation module provides a complete system solution and is compatible with the Wireless Power Consortium (WPC) or Qi standards of power transmission, making this transmitter an ideal platform for powering the majority of wireless receivers in use today. The receiver is named "Semtech TSDMRX-19V/40W-EVM" which is an evaluation platform for test and experimentation of a high power wireless charging receiver based on a suite of high efficiency Semtech ICs: the TS80003 Receiver Controller for Wireless Power Systems, TS61002 Driver, TS30041 Buck Regulator and the SC508 Buck Regulator Controller. This evaluation module, in conjuction with the TSDMTX-24V3-EVM, provides a complete system solution for the transmission of high power and charging of batteries with high energy capacity.

Objectives

The objective of this User Guide is to provide a fast, easy and thorough method to fully test and evaluate the Semtech solutions for wireless charging systems. 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 TS80003 and other Semtech components.

Features

- 24V Input / 40W Output Power
- Variable output voltage (19V default, up to 24V capable)
- WPC1.2 compliant
- Foreign object detection function
- Supports various smartphones charging protocols (with the latest firmware)
- Supports up to 15W output power with WPC1.2 receivers
- Supports **up to 40W output power <u>with Semtech receivers</u>**

Please make sure to download the latest software visit www.semtech.com/wireless-charging to download the latest EVM software for your evaluation board

Table of Contents

Wireless Charging Concepts

Wireless power transfer is, essentially, a transformer. Current 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.
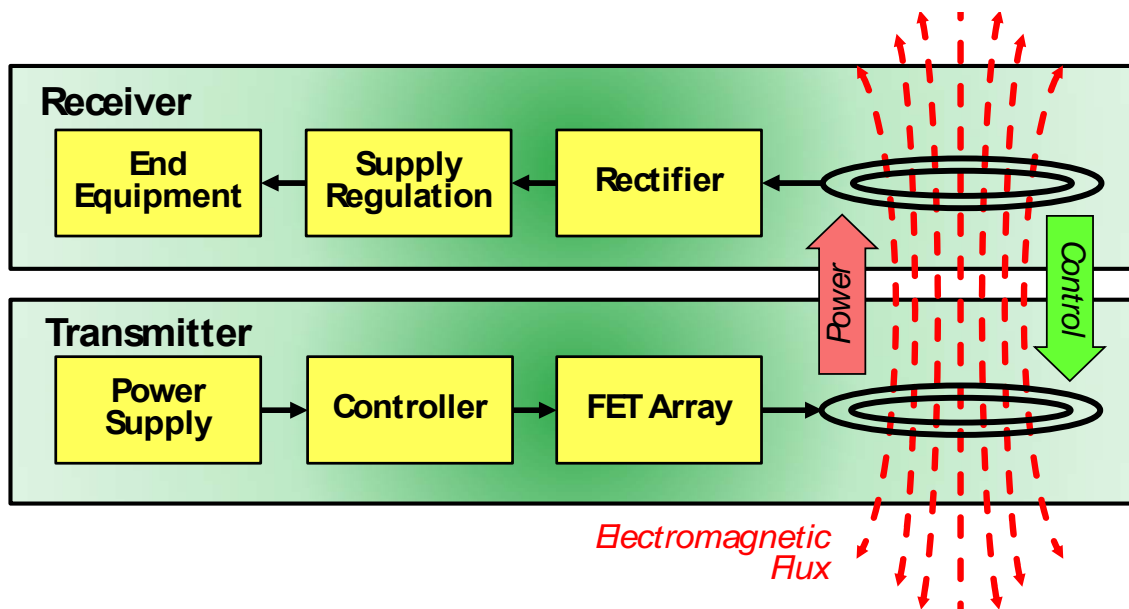
Wireless power systems differ in another major aspect from conventional transformers, in that they are intelligently managed. A transmitter will only provide power when a receiver is present, and only produce the amount of power requested by the receiver. In addition, the system is capable of recognizing 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 TS80003, which first searches for a receiver. Once found, the receiver informs the transmitter of its power requirements, and transmission begins. The system then verifies the right amount of power being sent, and that no power is being lost to foreign objects. The receiver will continually provide ongoing requests for power to maintain the transaction. If the 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 receiver. If the receiver requires no further power, such as when a battery is fully charged, it can request no further power being sent, and the transmitter will reduce its output accordingly.

Wireless power systems have been broken into three power categories. "Wearable" devices, such as headsets, wrist-band devices, medical sensors etc - operate in the low power range, up to 3 watts. Medium power devices, in the 5- to 15-watt range, include handheld devices, such as cell phones, tablets, and medical electronics. High power systems support devices such as power tools, radio controlled ("RC") devices such as drones, and other equipments requiring 15 to 100 watts of power.

Transmitter Description

The TSDMTX-24V3-EVM Evaluation Module is a ready-to-use demonstration platform allowing testing of up to 40 watts (when used in conjunction with TSDMRX-19V/40W-EVM) of wireless power transmission compliant with the dominant industry WPC/Qi standard.

The transmitter may be coupled with any Qi receiver module to form a complete wireless power transmission system. For the system designer, a likely choice might be the complementary Semtech TSDMRX-19V/40W-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 a number of other Semtech Receiver EVMs that support different power levels and output voltages, any of which can be used as they are compatible with Qi standard and therefore are compatible with the TSDMTX-24V3-EVM transmitter.

In addition, the evaluator can also use any existing Qi compliant product, though the limited access these devices offer may make the range of experiments that can be performed more limited.

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 in the EVM is the Semtech TS80003 integrated circuit, which controls the system and implements the Qi protocol. Developers can vary the supporting componentry to meet their goals as desired.

In this user guide, an introduction will be provided to the evaluator about how to use the EVM for wireless power transmission as well as how the TSDMRX-19V/40W-EVM can be used in conjunction with it.

Once the system is set up and working, a selection of tests and activities will be described that the evaluator can choose to perform.
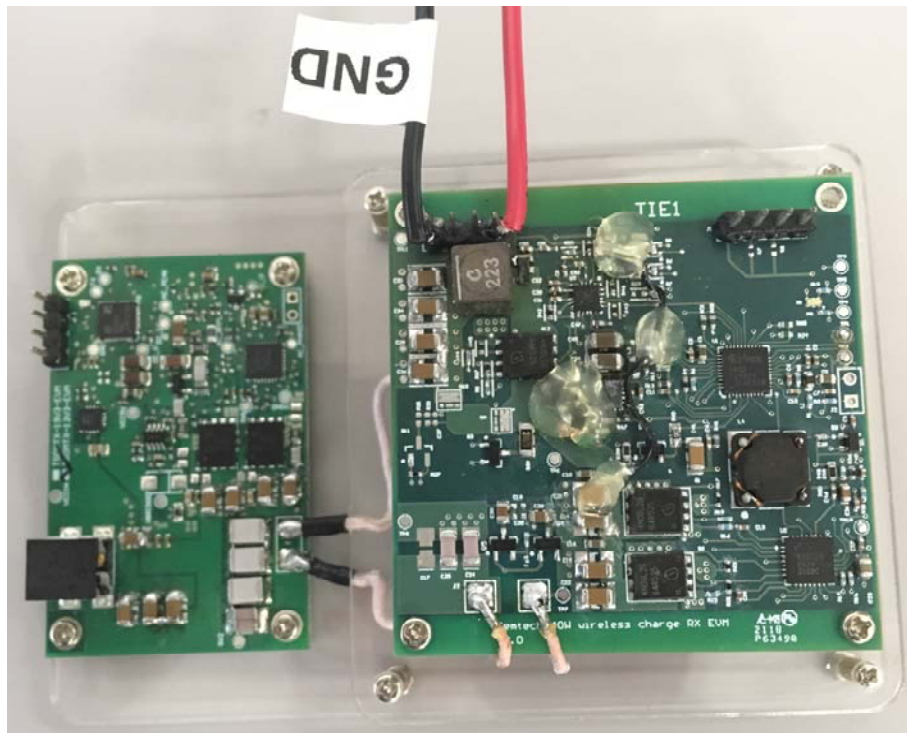
TX LED Behavior

The red and green LEDs on the EVM let the user know what the transmitter is doing as it operates. As seen in the diagram below, when power is applied, the transmitter initializes as indicated by the green LED lighting for about a half second. Next, as the transmitter searches for a nearby receiver, no LED is lit, keeping power to a minimum level in this standby state. When a receiver is located, the transmitter receives instructions on the upcoming transaction to perform. Power is then transmitted and the green LED flashes each second indicating an ongoing charging event. During charging, if a foreign object is detected, charging is aborted and the red LED will flash each second indicating the fault detected, and will continue to do so until the receiver is removed from the target zone. Similarly, any other detected error will also abort the charging process, indicated by a steady red LED that remains lit until the receiver is taken away. Error conditions include communication errors between receiver and transmitter, and detection of excess voltage, current, power, or temperature on the receiver or transmitter. Absent an error, charging continues until the receiver indicates no further power is required, usually when an attached battery is fully recharged. At this point, the transmitter enters the charge complete state, as indicated by the green LED being lit steadily, which it continues to do until the receiver is removed from the transmitter. Whenever the receiver is removed from the target area, the transmitter returns to the standby state, searching for another transaction to begin.
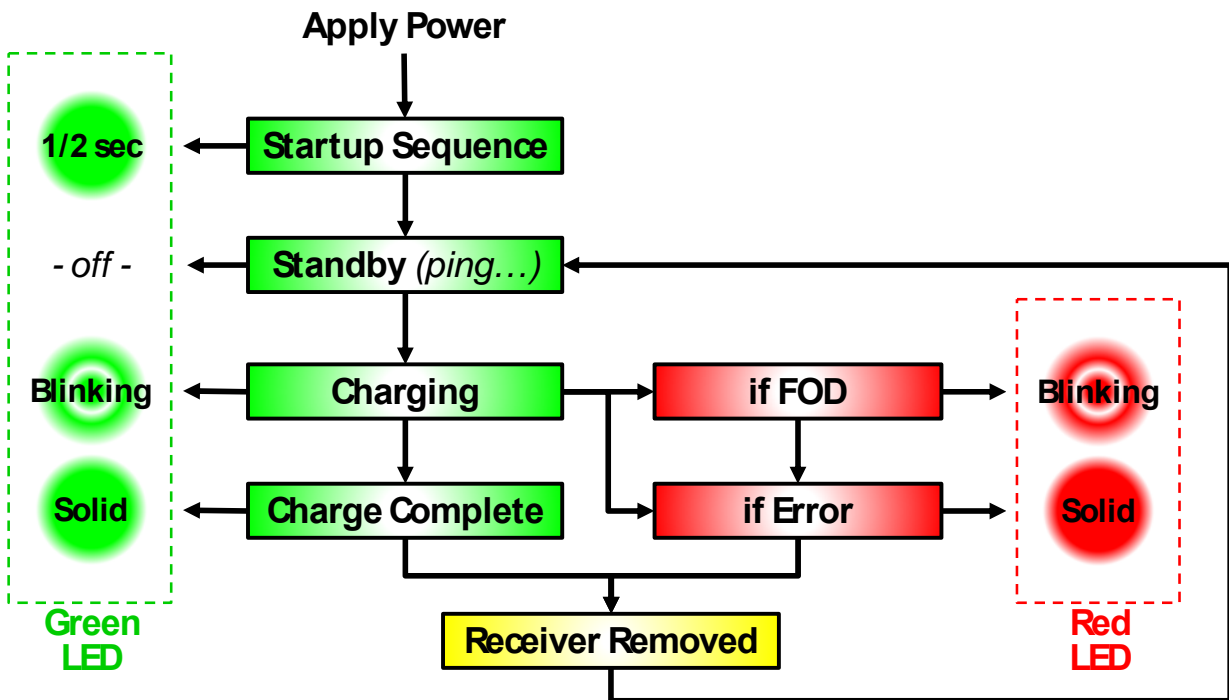
Receiver Description

The TSDMRX-19V/40W-EVM Evaluation Module and its compatible transmitter module, the TSDMTX-24V3-EVM, form a complete, high power, wireless power transmission system to supply a load or charge Li-ion batteries with over 2A of current.

This EVM demonstrates a working model and provides a starting point from which one can develop ones own wireless charging system or integrate its functions into existing systems. All documentation for this EVM is provided to in order to make this process as efficient as possible.

The key Semtech components in this EVM are the TS80003, TS61002, TS30041 and SC508. The TS 80003 provides Qi compliant communications and control of the receiver. The TS61002 controls the highly efficient synchronous rectification of AC current from the receiver's coil. The TS30041 provides 5V to all components requiring this operating voltage. Finally, the SC508 process the received power and provides a well regulated, current-limited, output voltage to a load or battery. The SC508 can be bypassed in order to allow the received power to be applied directly to the load or battery. This technique may be used in constant-power charging applications.

As seen in the photo below, the receiver is comprised of two parts, a receiver coil and receiver board. Two ports are provided, one for output power and the other for programming. They are located respectively in the upper and lower right corners of the board. A number of test points are provided to allow monitoring of internal signals and voltages and are documented in the schematic diagram herein.

A variety of tests and activities are described herein that the evaluator can choose to perform once the system is set up and working,
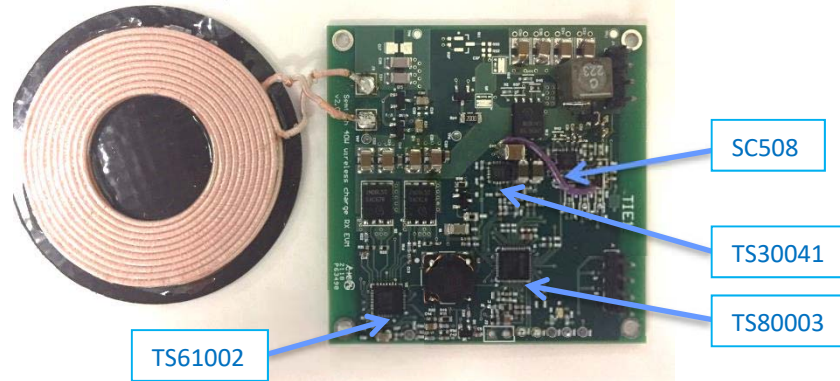
RX LED Behavior

The green LED on EVM let the user know the status of charge voltage. When power is applied, the receiver initializes as indicated by the green LED blinking. When a battery or a charge current occurs, the green LED will blink, once the charge ends, white LED will turn OFF.

FOD Test

In a production device, FOD (Foreign Object Detection) is an important feature, in that the transmission process is constantly inspected for the introduction of extraneous materials in the target area that could absorb the transmitted energy and become hot. When Foreign Objective is detected, the TS80003 shuts down power transmission as a safety precaution, and indicates the detected problem by blinking the red status LED.

This process is bypassed in the receiver EVM, however, in order to allow engineers to test different antennas and make other hardware modifications without triggering the FOD protocols and complicating the testing process. When such hardware changes are made, the parameters of the feedback measurements change, which the FOD protocol would perceive as a foreign object in the field, and cause the system to shut down.

In order to test the FOD protocol, the experimenter can use any Qi products certified to WPC 1.2 or higher as a receiver. A list of such products can be found at:

http://www.wirelesspowerconsortium.com/products/?brand_name=&product_name=&type_number=&product_type=2&compliant_automotive=&sort=&direction=asc

Experiments can be run on foreign objects on receivers with and without FOD management enabled to observe the differences. With FOD disabled, the metal object in the field will absorb some of the transmitted energy and become warm. Using a FOD-enabled production device, power transmission will be aborted when any significant interference in power transfer has been detected.

Once a FOD abort takes place, the transaction is terminated, as indicated by a blinking red LED. To restart power transmission, the receiver must be removed from the target area and a new transaction must be initiated. If the FOD is still present, the transaction will fail again, and continue to do so until the FOD is removed from the target area.

Standard Use

The TSDMTX-24V3-EVM is easy to set up and use. Use the power supply module and line cord that comes with the EVM kit to apply power to the EVM via "J2", the 24V power input jack. The acceptable input voltage range is from 22V to 26V. Once input power is provided, the green LED should light for about a half-second and then turn off.

At this point, the EVM is ready to transmit power. A few times each second, the transmitter emits a 'ping' of energy in search of a compliant receiver in range.

When receiver is in range (usually 4mm~8mm), the receiver is powered sufficiently during the ping-phase and is able to announce its presence to the transmitter, and a transaction begins. The transmitter provides a small amount of power to the newly discovered receiver, so receiver 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 blinking green LED. During power transfer, the receiver continuously communicates with the transmitter, actively directing the process. In this way, it is assured that power is only sent by how much it is required by an available and desirous receiver – and in the way that is compatible to the requirements of the receiver. If required, a receiver 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 and only the desired amount of power is provided.

Once charging is completed, the LED stops blinking and displays a steady green 'completed' state. If at any time an error is detected, the red LED is lit and transmission is halted. To restart, the receiver must be removed from the range of the transmitter and put back to the target zone to start a new transaction.

Productized Receiver Test

If you have a product that is Qi compliant, simply place it on the circular target of the black plastic antenna cover. The transmitter should demonstrate the above actions, and the device receiving power should indicate it is taking a charge in whatever manner its users guide states. You can also perform foreign object detection (FOD) by following the steps in the "FOD Testing" section below.

EVM Receiver Tests

Additional testing can be performed with the use of an EVM receiver module. There are a number of Semtech Receiver EVMs that support different power levels and output voltages, any of which can be used, as all support the Qi standard and therefore are compatible with the TSDMTX-24V3-EVM transmitter. In this User Guide, the TSDMRX-19V/40W-EVM has been selected as the receiver to experiment with. Other Semtech receiver EVMs may be used instead in a similar manner; refer to the user guide for the selected receiver for details specific to the selected device. Also, you can use phones which includes WPC wireless charging functions, like Samsung phone S6 or above and Iphone 8 or above, to test TSDMTX-24V3-EVM.

In order to use the TSDMRX-19V/40W-EVM as a target receiver, simply place the receiver over the target circle on the transmitter EVM module. You should see the LEDs on each EVM turn green, indicating a transaction has been established. The EVM's purpose is to receive power; next you can decide what to deliver that power to.

The user has a number of possible options to choose from. 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, please make 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 24 volt input up to 60 watts of power can be used as a desired test load.

Whatever load is selected, wires must be run from the VOUT+ and GND pins of the receiver EVM to the selected test load, as per the illustration below. Once the load is added, the receiver EVM can be used to perform a variety of tests. Alternately, power can be drawn from the VBUS and GND lines of the USB port if desired.

Connect a DC voltmeter across the VOUT+ and GND pins to monitor the voltage being output to the load, and a DC ammeter in series with the VOUT+ line. Set rating of those meters to allow for up to 24 volts and 3.0 amps to be observed.

No load being connected is also fine, place the receiver on the center of the transmitter target circle. Once transmission begins, you should observe approximately 24 volts and 0 amperes on the meters.

Apply a variety of loads to observe performance at 5, 10, and 15 watt levels. 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 placed back to start a new transaction.

Observe Coil Signals

The following information is provided for reviewing how the EVM works in detail, as what can be observed below is entirely managed by the Semtech TS80003 Wireless Controller. 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 one end of the antenna/coil, with the probe ground connected to the board ground (one of the fastener screws will suffice). Be sure the scope can handle signals up to 250 volts. While the EVM power supply is only 19 volts, the antenna is part of a resonant circuit where considerably higher voltage appears.

To observe the search ping, apply power to the transmitter and remove the receiver from the target zone. The scope should display a 'chirp' of 0.5 to 1mSec in duration with an initial peak of 15 to 20 volts. The frequency within the envelope of the chirp is in the 100-205 kHz range, which is the normal range of Qi systems.

Next, 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-volt peak-to-peak in the most demanding conditions.

Thermal images using TSDMRX-19V20W-EVM under 19V 20W condition

Operation ambient temperature: 26.5°C
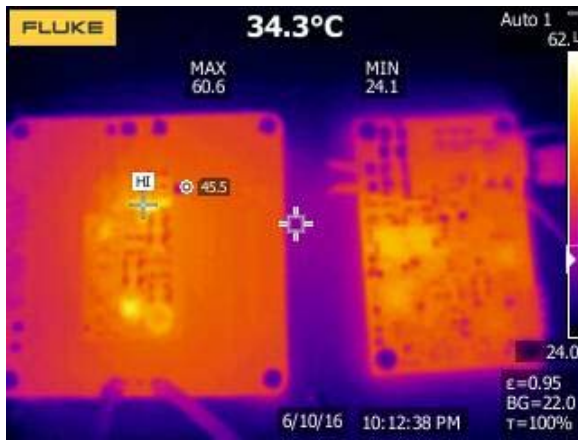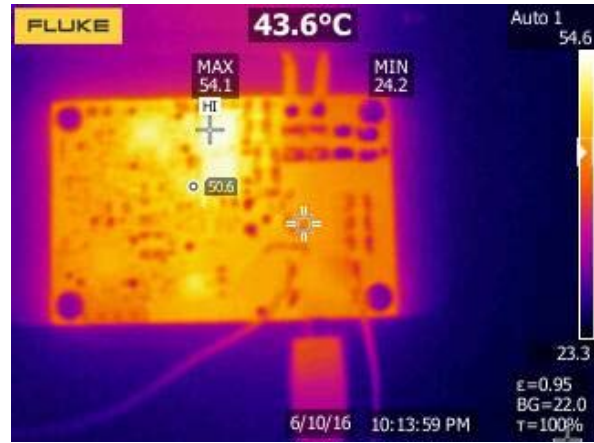
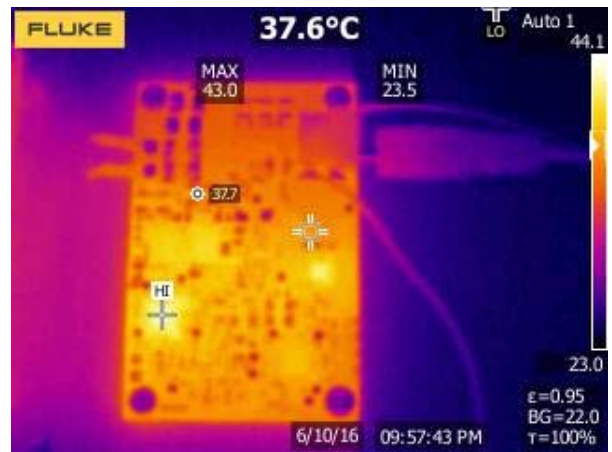Rx board: 60.6°C   Tx board: 54.1°C

Thermal images using TSDMRX-5V10W-EVM under 5V 10W condition

Rx board: 46°C   Tx board:43°C

The TSDMTX-24V3-EVM is easy to set up and use. Connect a 24V source capable of supplying greater than 50W to the transmitter's input jack using a 3.5mm OD coaxial power connector. Upon application of power, its green LED should light, indicating the board is now active.

At this point, the transmitter EVM is ready to transmit power. A few times each second, the transmitter emits a 'ping' of energy in search of a compliant receiver in range.

When in range, the receiver is powered by the ping sufficiently to be able to announce its presence to the transmitter, and a transaction begins. The transmitter then provides a small amount of power to the newly discovered receiver so that it can communicate and transmit its power requirements.

At the completion of this handshake, the transmitter begins providing the requested power. During power transfer, the receiver continuously communicates with the transmitter, actively directing the process. This assures that power is only sent when and how it is required by the receiver. If required, a receiver can actively increase or decrease its power request, and the transmitter will act accordingly. Thus, equipment with complex charging requirements can be precisely supported and only the desired amount of power provided.

EVM Receiver Tests

A variety of tests can be performed with the use of the TSDMTX-24V3-EVM transmitter module. Connect a 24V source capable of supplying greater than 50W to the transmitter's input jack using a 3.5mm OD coaxial power connector. Upon application of power, its green LED should light, indicating the board is now active.
In order to use the TSDMRX-19V/40W-EVM as a target receiver, simply place the receiver over the target circle (the 'primary coil' or 'transmitter antenna') on the transmitter EVM module, and then connect a battery to the J4 of the receiver. Connect a DC voltmeter across the VOUT and PGND pins to monitor the voltage, and a DC ammeter in series with the J4 line to monitor the charging current. Set levels to allow for up to 20 volts and 2.5 amps to be observed.

The receiver LED should be green when the receiver is placed on the active transmiter. This indicates that its output voltage is normal.

The programmed CC charge current can be set with R_{43} - the resistor that ties the Ilim pin to the switch node of the converter. Its value programs the output current indirectly by causing switching cycle termination when the the valley of the inductor current reaches a predetermined level.   The valley current can be calculated by:

$$Ivalley * (Rdson + Rpwb) = Ilim * Rlim$$

Where: *Rdson is the bottom mosfet's on resistance.*
        Rpwb is the circuit board trace resistance between the sense point(s) and the mosfet.
        Ilim is 10μA.
        Rlim is the resistance of R43.

The charge current is the average inductor current. The difference between the average current and the valley current is ½ of the peak to peak inductor ripple. The peak to peak inductor ripple current can be calculated by:

$$Ipkpk = \frac{(1 - D) * Vout}{Fsw * L}$$

Where: *D is the converter's duty cycle defined as D=Vout / Vpdc. Vpdc is programmed to be 30V.*
        Vout is the open circuit output voltage of the receiver.
        Fsw is the converter's switching frequency. It is programmed to be 500KHz.
        L is the converter's output inductor. It has a value of 22uH.

Thus, the receiver's charge current is:

$$Ichg = \frac{Ilim * Rlim}{Rdson + Rpwb} + \frac{(1 - D) * Vout}{2 * Fsw * L}$$

Thermal images of TSDMRX-19V/40W-EVM under 19V 40W condition

The thermal image of TSDMRX-19V/40W-EVM under full-load test is shown below. The hottest component on the board is the mosfet in the buck regulator (75⁰C).
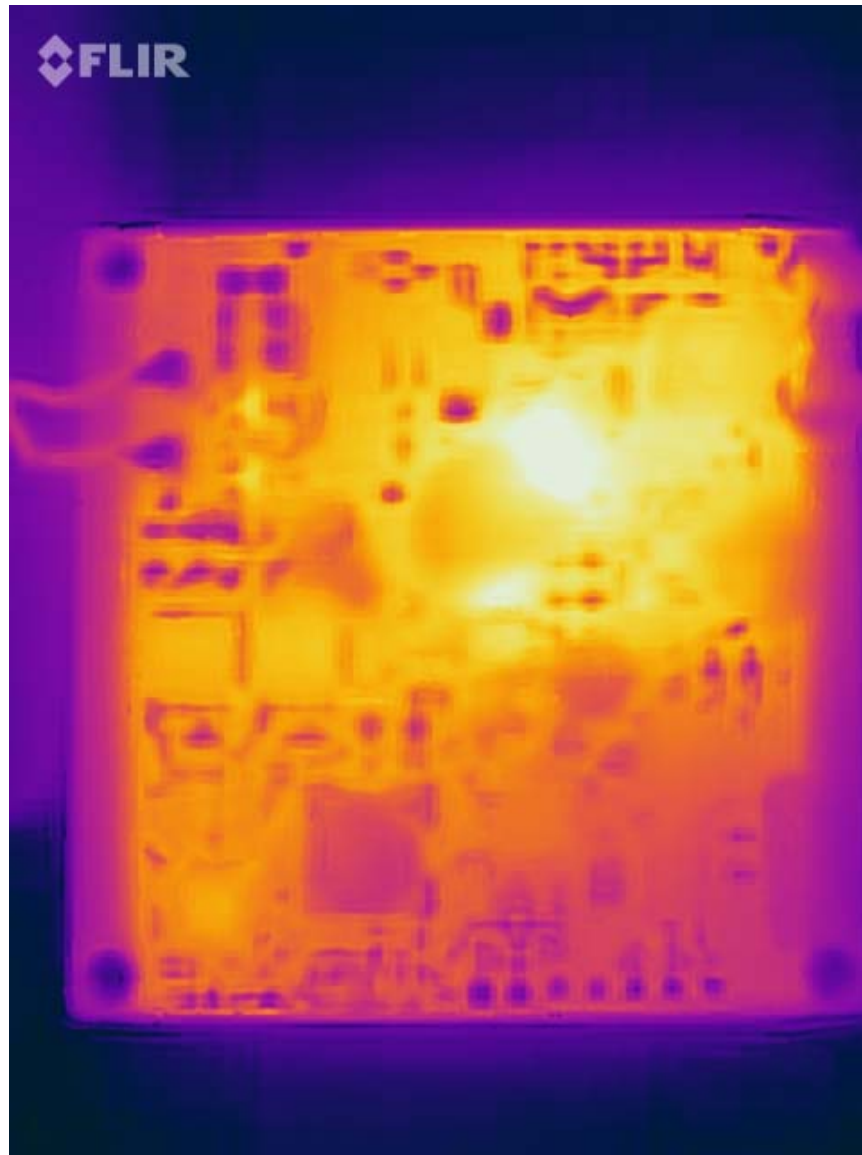
Transmitter Documentation
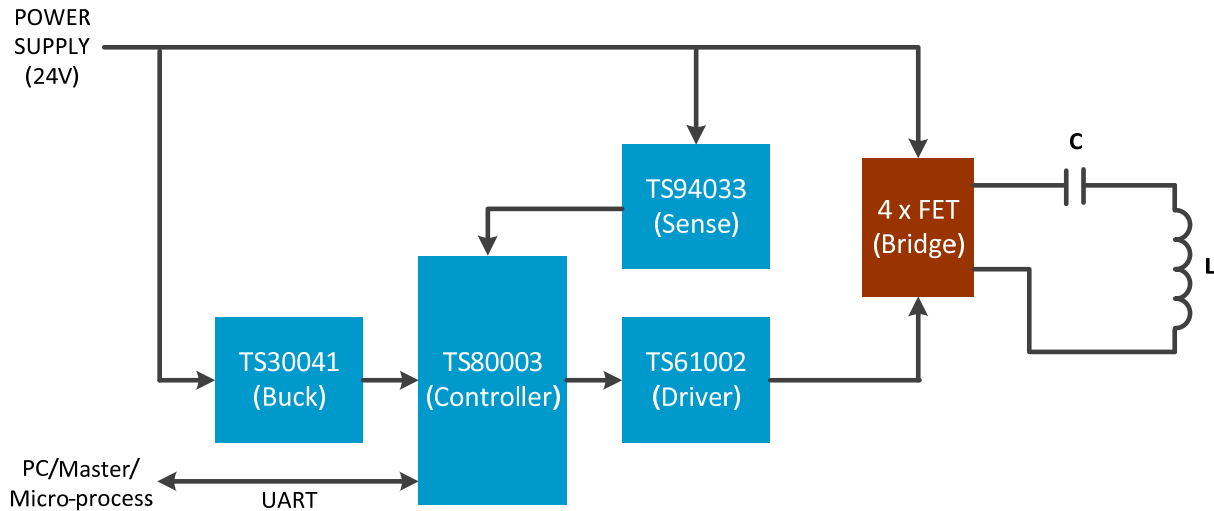
The following sections document the hardware design of the TSDMTX-24V3-EVM. This information can be used to better understand the functionality of the design, as well as assist in creating your own hardware solution based on this design.

A. Block Diagram

The TSDMTX-24V3-EVM may be divided into a number of sub-blocks as shown in the diagram below:

24 Volt Supply - the external 'brick' that converts AC power to 24 volts

5 Volt Buck – based on the TS30041, converts 24 vdc to 5 vdc

Controller – based on the TS80003 Wireless Power Controller. Includes I/O: USB, I2C, Temp Sensor, LED display

FET Driver – based on the TS61002 Full-bridge FET Driver, powers the FETs based on inputs from controller, supply 3Vcc for Controller

Bridge FETs – gates drive power from the 19v supply to drive the resonant tank circuit (antenna)

B. Schematic

Below are the schematics for the TSDMTX-24V3-EVM. Annotation has been added to indicate which part of the block diagram each component is a member of.

FET Driver supply

VCC5V

C14 22uF 6.3V
C13 22uF 6.3V
PGND

L2 4.7uH
R9 47K
R10 10K
PGND PGND
PGND PGND

C11 47nF

U2 TS30041-M000QFNR
BST
VSW
VSW
VSW
VSW
FB
GND
PGND
PGND
PAD
VCC
VCC
VCC
EN
PG

VCCIN
C12 1uF 35V
PGND

VCCIN
C10 100nF 50V
C9 22uF 35V
PGND
J2

TP7
TP8
TP9
TP10
VCCIN
VCC5V
PGND
GND

TIE1
GND PGND
TIE2
GND AGND

VSENSE

U0 74LVC1G66GW NP
VCC
E
Y
Z
GND

AVCC
DIV_EN
R26_0 0
AGND

R25 7.5K
R27 7.5K
AVCC
AGND

VCC3V
D3 BAT54SW-7-F
C47 33pF
AGND
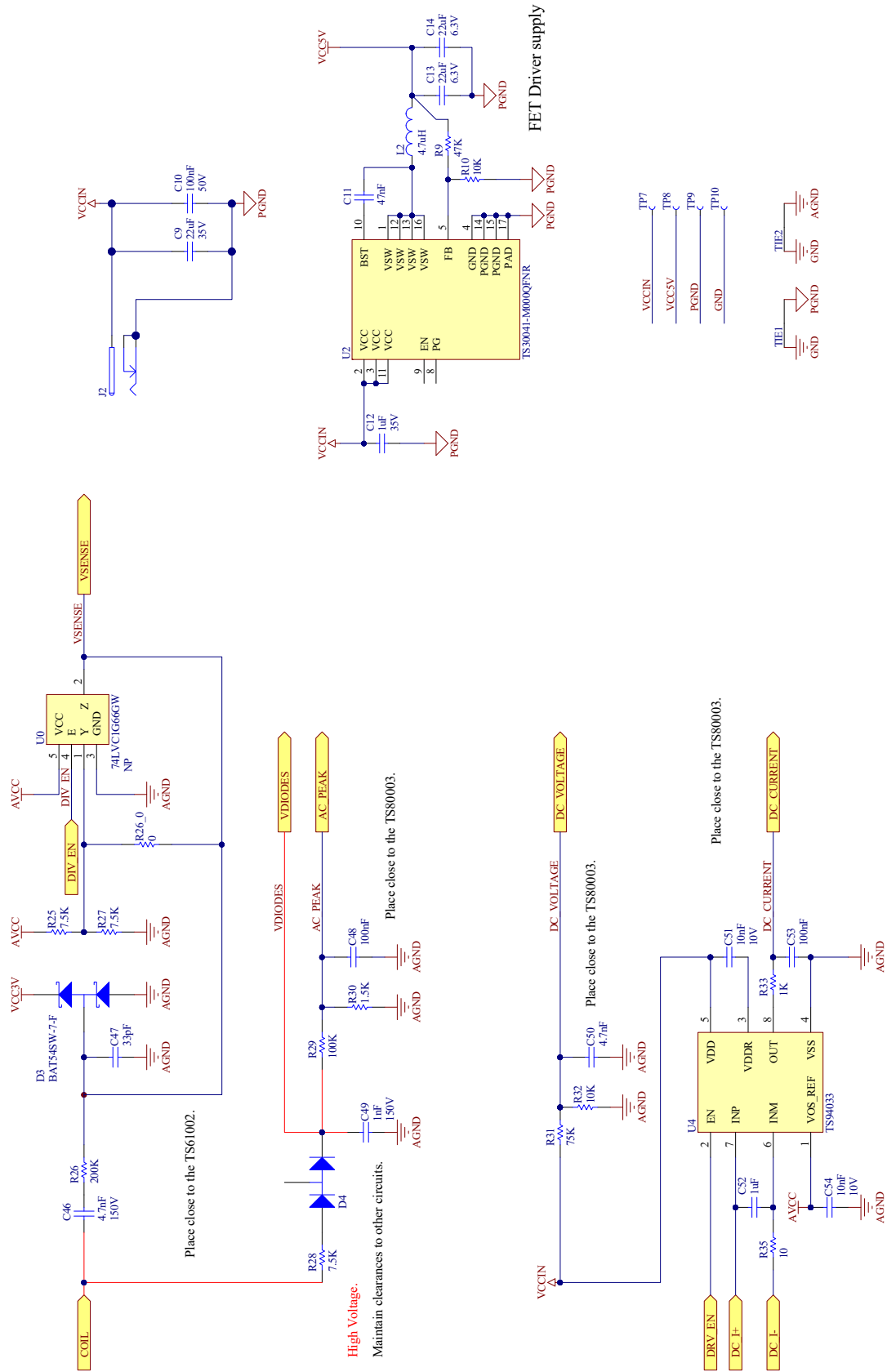
R26 200K
C46 4.7nF 150V

Place close to the TS61002.

R28 7.5K

High Voltage.
Maintain clearances to other circuits.

COIL

VDIODES
AC_PEAK
Place close to the TS80003.
C48 100nF AGND
R30 1.5K AGND
R29 100K
C49 1nF 150V AGND
D4

DC_VOLTAGE
Place close to the TS80003.
C50 4.7nF AGND
R32 10K AGND
R31 75K
VCCIN

DC_CURRENT
Place close to the TS80003.
C51 10nF 10V
R33 1K
C53 100nF AGND

U4 TS94033
VDD
VDDR
OUT
VSS
EN
INP
INM
VOS_REF

C52 1uF
R35 10
AVCC
C54 10nF 10V AGND

DRV_EN
DC_I+
DC_I-

Use a current sense resistor with a low temperature coefficient.

Connect the current-sense amplifier using Kelvin connections directly to the resistor pads.

Do not allow high current to flow through the Kelvin connections.

Place pin 19 close to the TS80003.

High Voltage.

C. Bill of Materials "BOM"

Below is a list of the parts used in the TSDMTX-24V3-EVM. An excel spreadsheet file with this information is available on the Semtech website as an additional convenience.

Item	Designator	Qt.	Value	Value2	Footprint	Description
1	C1, C5, C42	3	4.7uF	6.3V	CAPC0603L	Capacitor
2	C10, C18, C19	3	100nF	50V	CAPC0402L	Capacitor
3	C11, C24, C37	3	47nF	25V	CAPC0402L	Capacitor
4	C12	1	1uF	35V	CAPC0805L	Capacitor
5	C13, C14	2	22uF	6.3V	CAPC1206N	Capacitor
6	C2, C3, C4, C6, C8, C41, C48, C53	8	100nF	10V	CAPC0402L	Capacitor
7	C20, C28	2	100nF	50V	CAPC0603L	Capacitor
8	C26, C39	2	2.7nF	50V	CAPC0805L	Capacitor
9	C27	1	47pF	10V	CAPC0402L	Capacitor
10	C32, C33	2	47nF	200V	CAPC1812-1210N	Capacitor
11	C34	1	22nF	200V	CAPC1812-1210N	Capacitor
12	C40	1	10uF	16V	CAPC0805L	Capacitor
13	C46	1	4.7nF	150V	CAPC1206N	Capacitor
14	C47	1	33pF	10V	CAPC0402L	Capacitor
15	C49	1	1nF	150V	CAPC1206N	Capacitor
16	C51, C54	2	10nF	10V	CAPC0402L	Capacitor
17	C52	1	1uF	10V	CAPC0402L	Capacitor
18	C7, C50	2	4.7nF	10V	CAPC0402L	Capacitor
19	C9, C15, C16, C17, C21, C22, C29, C30	8	22uF	35V	CAPC1210N	Capacitor
20	D1	1			LED_APHB1608	LED Dual Color
21	D3	1			SOT323-3N	Schottky Diode
22	D4	1			SOT23-3N	Diode
23	J2	1			CON_HEADER	Power Supply Connector
24	J4	1			CON_COIL_PIN_2P_TDK_A21	Coil connector, 2 contacts, solder pads
25	L1	1	600		RESC0603L	Ferrite Bead
26	L2	1	4.7uH		RESC0805L	Inductor
27	Q1, Q2	2			QFN8-INF	DUAL MOSFET
28	R0, R12, R15, R19, R23, R26_0	6	0		RESC0402L	Resistor
29	R1	1	1.0		RESC0402L	Resistor
30	R11	1	0.020	1%	RESC0805L	Current Sense Resistor
31	R13, R21	2	1		RESC0402L	Resistor
32	R14, R22	2	2.0		RESC0805L	Resistor
33	R16, R25, R27	3	7.5K		RESC0402L	Resistor
34	R2, R9	2	47K		RESC0402L	Resistor
35	R26	1	200K		RESC0603L	Resistor
36	R28	1	7.5K		RESC0603L	Resistor
37	R29	1	100K		RESC0805L	Resistor
38	R3, R17, R20	3	100K		RESC0402L	Resistor
39	R30	1	1.5K		RESC0402L	Resistor
40	R31	1	75K		RESC0402L	Resistor
41	R33	1	1K		RESC0402L	Resistor
42	R35	1	10		RESC0402L	Resistor
43	R6, R10, R32	3	10K		RESC0402L	Resistor
44	R7, R8	2	150		RESC0402L	Resistor
45	U1	1	TS80003		PG-VQFN-40-17	wireless charge controller

46	U2	1	TS30041		QFN50P300X300-16V6-165N	Current-Mode Synchronous Buck DC/DC Converter
47	U3	1	TS61002		QFN50P500X500-28W1L	Full-Bridge FET driver
48	U4	1	TS94033		SC70-8N	Current Sense Amplifier

Tx Coil Specifications:

Vendor	Part Number	Induct-ance	DCR(typ.)	Dimension
Wurth Electronics	760308102144	20uH	0.07Ω	54mm X 54mm

Attention:

1. Resonance capacitors (C32, C33, C34) should be COG capacitor, it should any Qi products certified to WPC 1.2 or higher as a receiver;
2. Current sense resistor (R11) should be 1% 75PPM/C or better.

Coil size 54mm X 54mm

D. Board Layout

The diagram below shows the locations of the components used in the TSDMTX-24V3-EVM PCB.
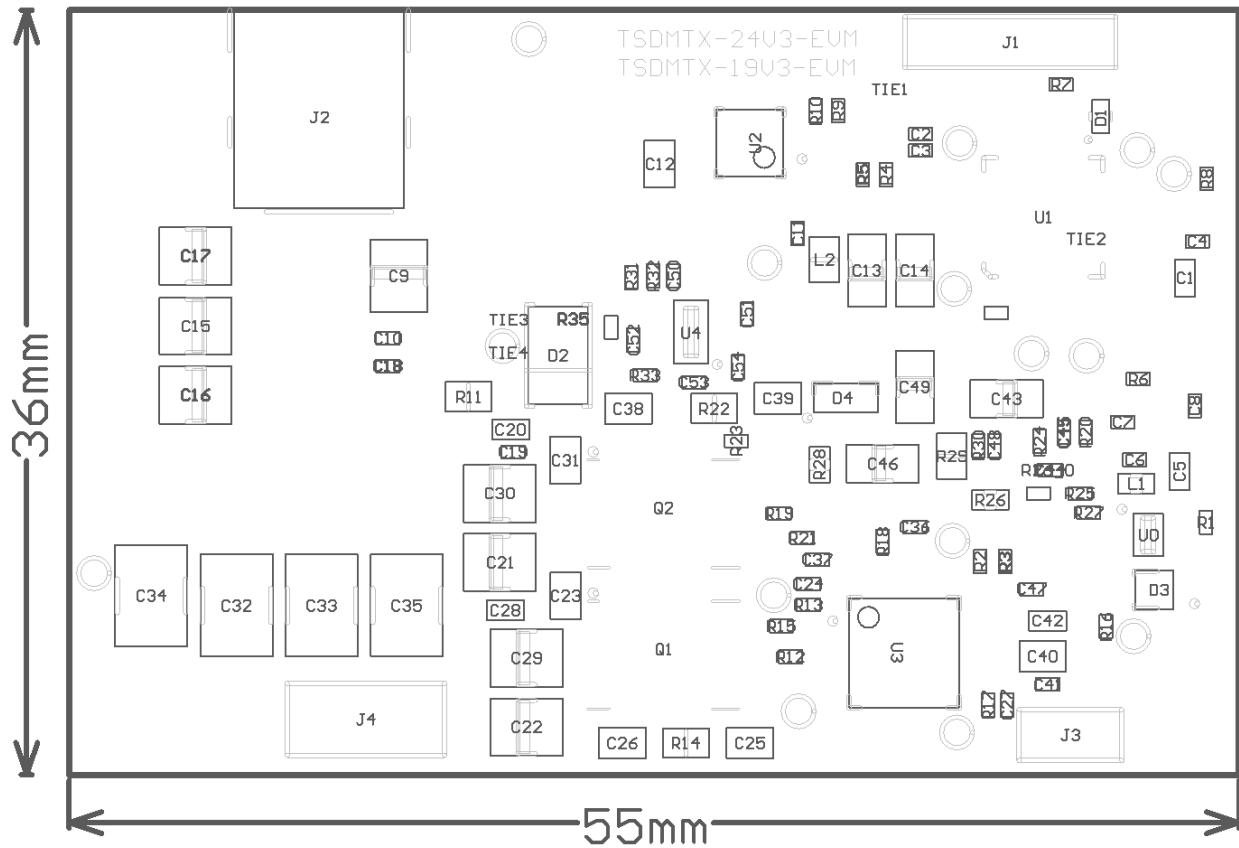

The TSDMTX-24V3-EVM PCB is based on four-layer design as shown below. The ground plane in layer two is recommended to reduce noise and signal crosstalk. All components are placed on the top of the board for easier evaluation of the system. End product versions of this design can be made significantly smaller by distributing components on both sides of the board. The Gerber files for this artwork can be downloaded from the Semtech web page.
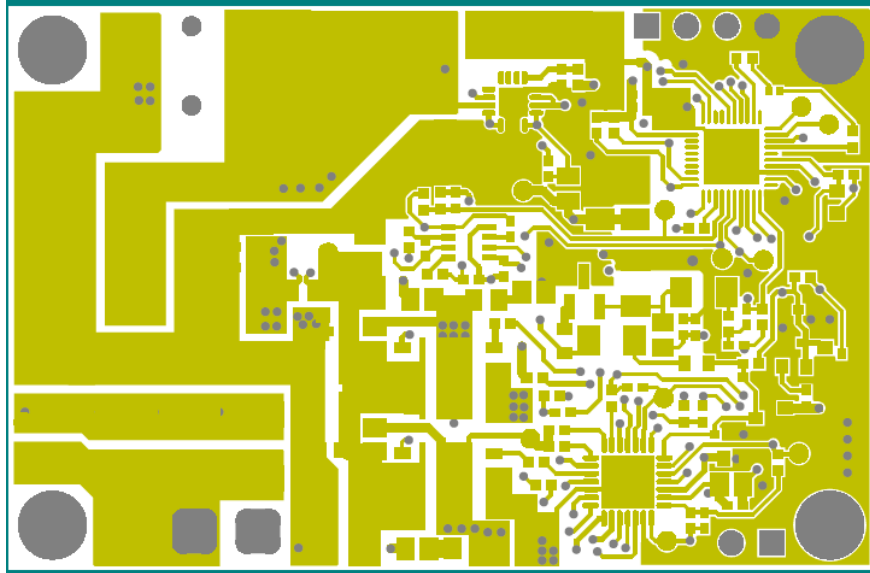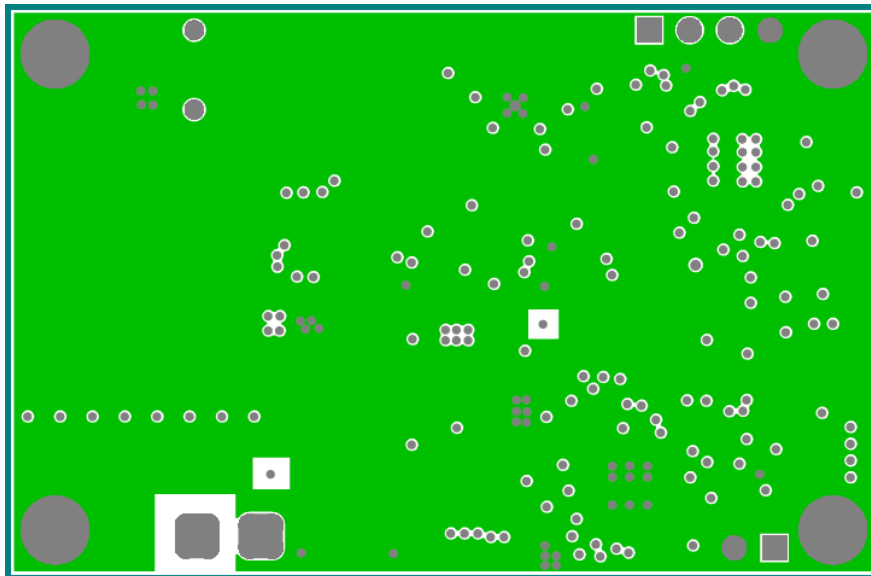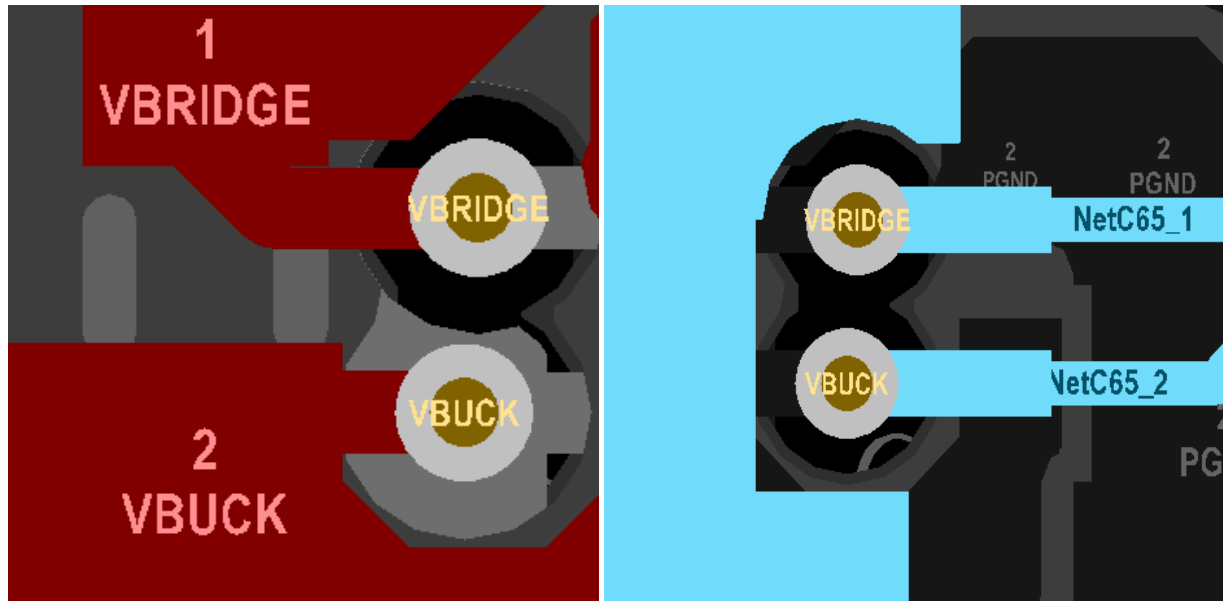
Top Layer
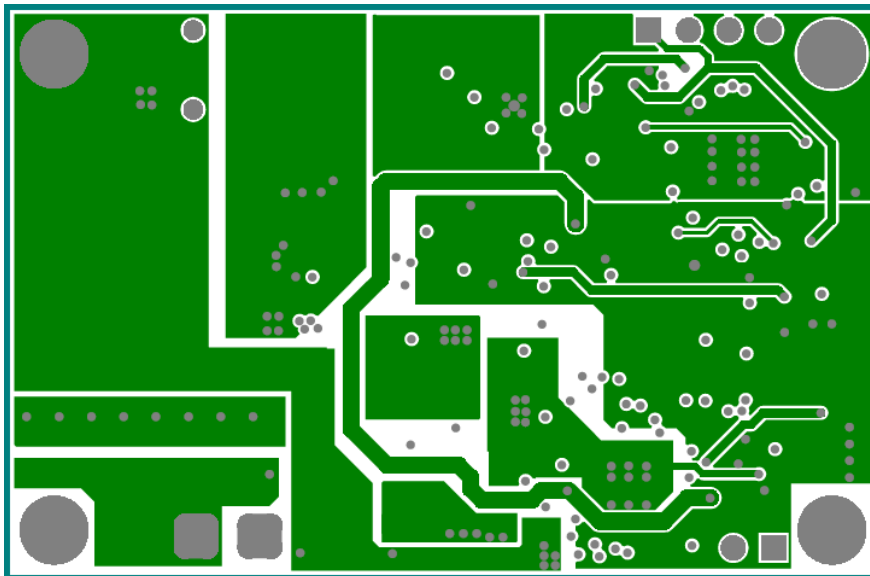
Ground Plane
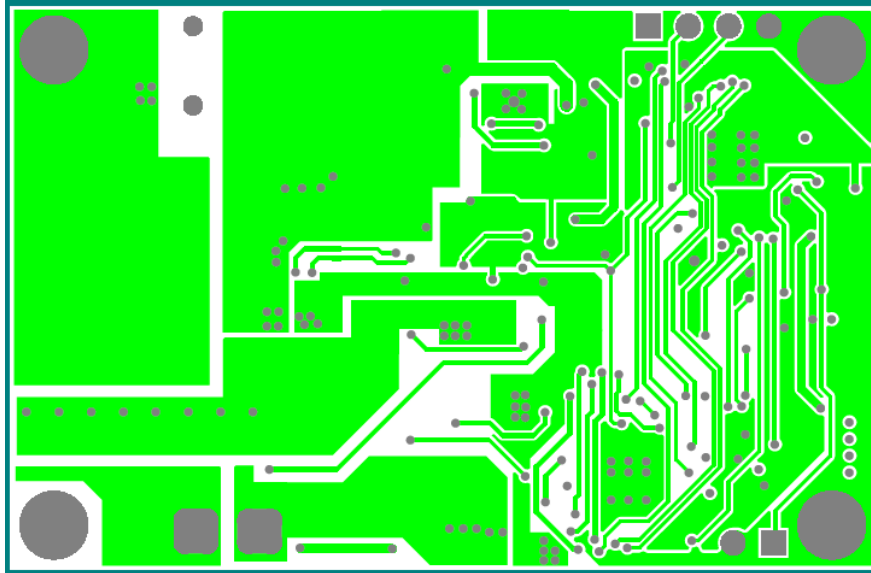
Signal Layer

Bottom Layer

Attention

Connect the current-sense amplifer using Kelvin connections directly to the Current sense resistor pads, and do NOT allow high current to flow through the Kelvin connections. It is an example for the layout.

Receiver Documentation

The following sections document the hardware design of the TSDMRX-19V/40W-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-19V/40W-EVM may be divided into a number of sub-blocks as show in the diagram below:
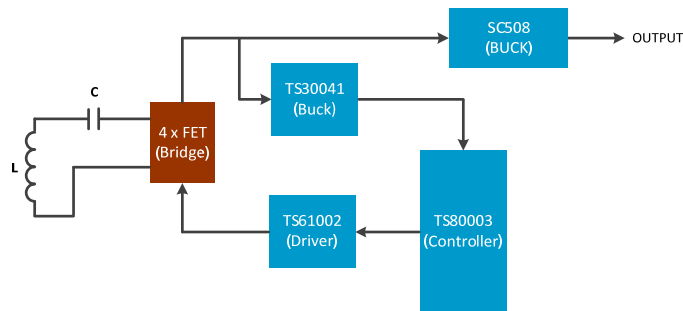
Antenna: Transmitter - primary coil providing power to the receiver; part of TSDMTX-24V3-EVM
Antenna: Receiver - secondary coil in the flux field of the transmit antenna; part of the 100 KHz resonant tank
Rectifier - converts AC voltage from the antenna to positive values; FET based for high efficiency conversion
Internal Regulator - based on the TS30041; converts rectified input to regulated 5V output used for power to receiver circuitry; includes protection circuitry
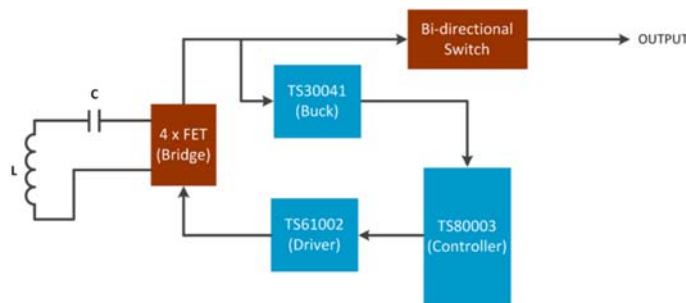**Internal Regulator** - based on the SC508; converts rectified input to regulated 19V, 40W capable output; includes protection circuitry
Comm. Generator - produces the 'handshake' signal telling the transmitter power required
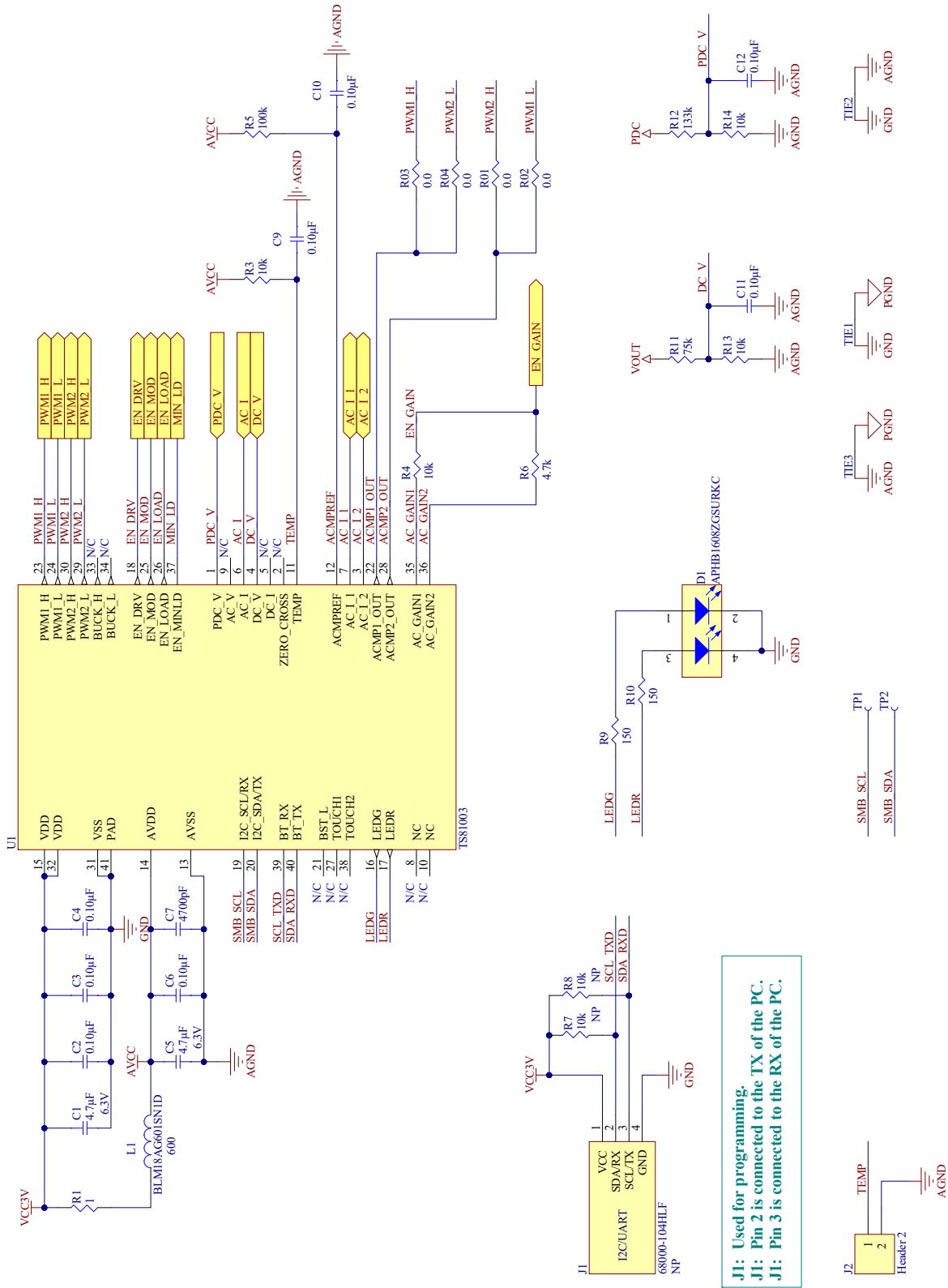**Comm. Modulator** - sends the handshake signal to the transmitter
Battery/Load – end equipment to be powered by the wireless receiver
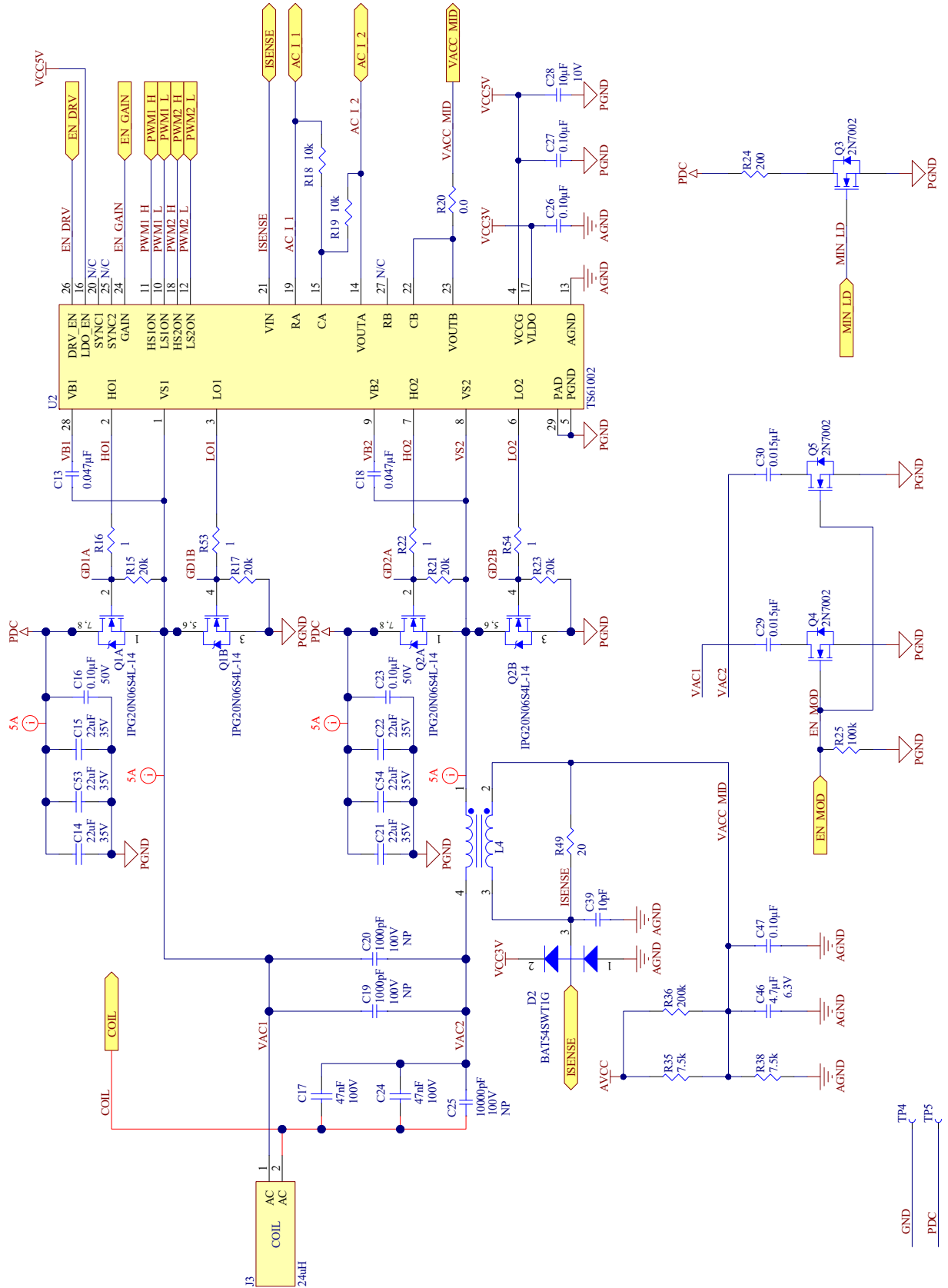
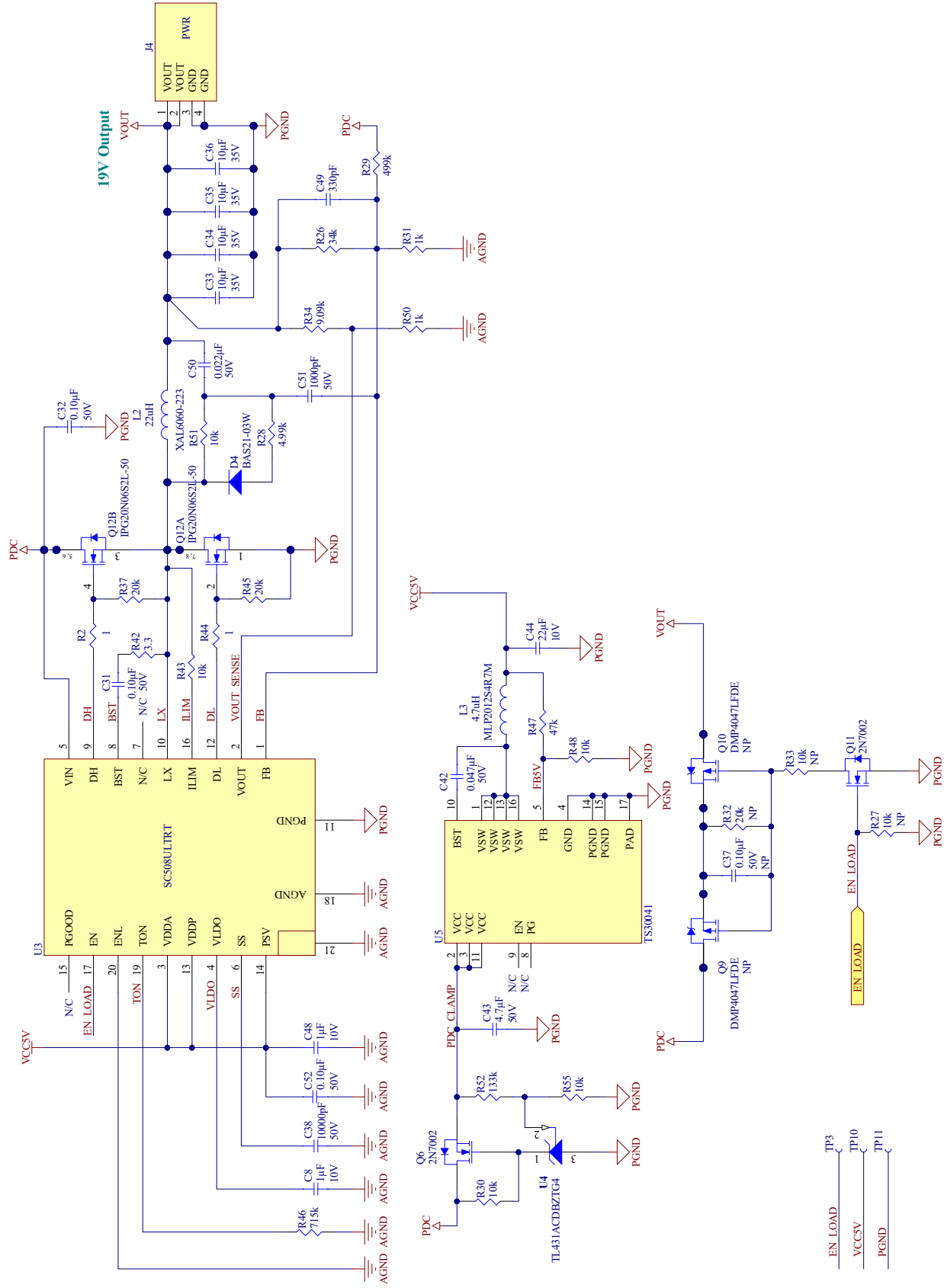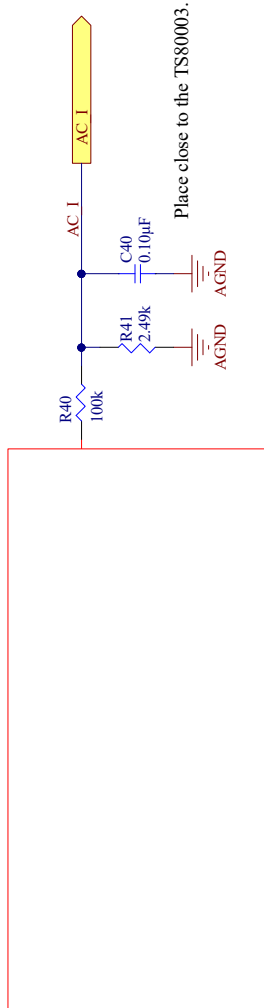The receiver can also be configured to directly charge batteries by bypassing the SC508 based buck converter:

B. Schematic

Below is the schematic for the TSDMRX-19V/40W-EVM.

U1 TS8I003

PWM1_H 23
PWM1_L 24
PWM2_H 30
PWM2_L 29
BUCK_H 33 N/C
BUCK_L 34 N/C

EN_DRV 18
EN_MOD 25
EN_LOAD 26
EN_MINLD 37

PDC_V   1
AC_V   9 N/C
AC_I   6
DC_V   4
DC_I   5 N/C
ZERO_CROSS 2 N/C
TEMP   11

ACMPREF 12
AC_I_1 7
AC_I_2 3
ACMP1_OUT 22
ACMP2_OUT 28
AC_GAIN1 35
AC_GAIN2 36

VDD 15
VDD 32
VSS 31
PAD 41
AVDD 14
AVSS 13
I2C_SCL/RX 19
I2C_SDA/TX 20
BT_RX 39
BT_TX 40
BST_L 21 N/C
TOUCH1 27 N/C
TOUCH2 38 N/C
LEDG 16
LEDR 17
NC 8 N/C
NC 10 N/C

PWM1_H, PWM1_L, PWM2_H, PWM2_L
EN_DRV, EN_MOD, EN_LOAD, MIN_LD
PDC_V
AC_I, DC_V
AC_I_1, AC_I_2
EN_GAIN

C1 4.7µF 6.3V
C2 0.10µF
C3 0.10µF
C4 0.10µF
C5 4.7µF 6.3V
C6 0.10µF
C7 4700pF
C9 0.10µF
C10 0.10µF
C11 0.10µF
C12 0.10µF

R1
R3 10k
R4 10k
R5 100k
R6 4.7k
R7 10k
R8 10k
R9 150
R10 150
R11 75k
R12 133k
R13 10k
R14 10k
R01 0.0
R02 0.0
R03 0.0
R04 0.0

L1 BLM18AG601SN1D 600

VCC3V
AVCC
AGND
GND
PGND

SMB SCL, SMB SDA
SCL TXD, SDA RXD
LEDG, LEDR

D1 APHB1608ZGSURKC

TP1, TP2

PDC V, PDC, VOUT, DC V, VOUT
TIE1, TIE2, TIE3

EN GAIN

J1 I2CUART
VCC 1
SDA/RX 2
SCL/TX 3
GND 4
68000-104HLF NP

SCL TXD, SDA RXD
NP

J1: Used for programming.
J1: Pin 2 is connected to the TX of the PC.
J1: Pin 3 is connected to the RX of the PC.

J2 TEMP
Header 2
1
2
AGND

AC_1

AC_1

Place close to the TS80003.

C40
0.10µF

AGND

R41
2.49k

AGND

R40
100k

C. Bill of Materials "BOM"

Below is a listing of the parts used in the TSDMRX-19V/40W-EVM. An excel spreadsheet file with this information is available on the Semtech website as an added convenience.

Designator	DNP	Value	Voltage	Tolerance	Part Number	Manufacturer
C1		4.7µF	6.3V	±20%	GRM155R60J475ME47D	Murata Electronics North America
C2		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C3		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C4		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C5		4.7µF	6.3V	±20%	GRM155R60J475ME47D	Murata Electronics North America
C6		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C7		4700pF	50V	±10%	GRM155R71H472KA01J	Murata Electronics North America
C8		1µF	10V	±10%	GRM155R61A105KE01D	Murata Electronics North America
C9		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C10		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C11		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C12		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C13		0.047µF	50V	±10%	GRM155R71H473KE14D	Murata Electronics North America
C14		22uF	35V	20%	C3216X5R1V226M160AC	TDK
C15		22uF		20%	C3216X5R1V226M160AC	TDK
C16		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C17		47nF		5%	CGA5H2C0G1H473J	TDK
C18		0.047µF	50V	±10%	GRM155R71H473KE14D	Murata Electronics North America
C19	NP	1000pF	100V	±10%	GRM155R72A102KA01D	Murata Electronics North America
C20	NP	1000pF	100V	±10%	GRM155R72A102KA01D	Murata Electronics North America
C21		22uF	35V	20%	C3216X5R1V226M160AC	TDK
C22		22uF	35V	20%	C3216X5R1V226M160AC	TDK
C23		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C24		47nF	100V	5%	CGA5H2C0G1H473J	TDK
C25	NP	10000pF	100V	±5%	GRM3195C2A103JA01D	Murata Electronics North America
C26		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C27		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C28		10µF	10V	±10%	GRM21BR71A106KE51L	Murata Electronics North America
C29		0.015µF	50V	±2%	GRM2195C1H153GA01D	Murata Electronics North America
C30		0.015µF	50V	±2%	GRM2195C1H153GA01D	Murata Electronics North America
C31		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C32		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C33		10µF	35V	±10%	GRM319R6YA106KA12D	Murata Electronics North America
C34		10µF	35V	±10%	GRM319R6YA106KA12D	Murata Electronics North America
C35		10µF	35V	±10%	GRM319R6YA106KA12D	Murata Electronics North America

C36		10µF	35V	±10%	GRM319R6YA106KA12D	Murata Electronics North America
C37	NP	0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C38		10000pF	50V	±10%	GRM155R71H103KA88D	Murata Electronics North America
C39		10pF	50V	±5%	GRM1555C1H100JA01D	Murata Electronics North America
C40		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C41	NP	1nF	200V	10%	C1206C102K2REC7210	KEMET
C42		0.047µF	50V	±10%	GRM155R71H473KE14D	Murata Electronics North America
C43		4.7µF	50V	±10%	GRM21BR61H475KE51L	Murata Electronics North America
C44		22µF	10V	±20%	GRM188R61A226ME15D	Murata Electronics North America
C46		4.7µF	6.3V	±10%	GRM188R60J475KE19D	Murata Electronics North America
C47		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C48		1µF	10V	±10%	GRM155R61A105KE01D	Murata Electronics North America
C49		330pF	50V	±10%	GRM155R71H331KA01J	Murata Electronics North America
C50		0.022µF	50V	±10%	GRM155R71H223KA12J	Murata Electronics North America
C51		1000pF	50V	±10%	GCM155R71H102KA37D	Murata Electronics North America
C52		0.10µF	50V	±20%	GRM155R71H104ME14D	Murata Electronics North America
C53		22uF	35V	20%	C3216X5R1V226M160AC	TDK
C54		22uF	35V	20%	C3216X5R1V226M160AC	TDK
D1					APHB1608ZGSURKC	Kingbright
D2			30V		BAT54SWT1G	On Semiconductor
D3			250V		BAS101S,215	NXP
D4			250V		BAS21-03W	
J2						
J3						
J4						
L1		600			BLM18AG601SN1D	Murata
L2		22uH			XAL6060-223	Coilcraft
L3		4.7uH			MLP2012S4R7M	TDK
L4		1:100			PA0368.100NLT	Pulse
Q1			40V		IPG20N04S4L-11A	Infineon
Q2			40V		IPG20N04S4L-11A	Infineon
Q3			60V		2N7002	Nexperia
Q4			60V		2N7002	Nexperia
Q5			60V		2N7002	Nexperia
Q6			60V		2N7002	Nexperia
Q9	NP		-40V		DMP4047LFDE	Diodes Inc.
Q10	NP		-40V		DMP4047LFDE	Diodes Inc.
Q11	NP		60V		2N7002	Nexperia
Q12			55V		IPG20N06S2L-50	Infineon
R01		0.0		Jumper	ERJ-2GE0R00X	Panasonic Electronic Components
R1		1		±1%	ERJ-2BQF1R0X	Panasonic Electronic Components

R02		0.0		Jumper	ERJ-2GE0R00X	Panasonic Electronic Components
R2		1		±1%	ERJ-2BQF1R0X	Panasonic Electronic Components
R03		0.0		Jumper	ERJ-2GE0R00X	Panasonic Electronic Components
R3		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R04		0.0		Jumper	ERJ-2GE0R00X	Panasonic Electronic Components
R4		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R5		100k		±1%	ERJ-2RKF1003X	Panasonic Electronic Components
R6		4.7k		±1%	ERJ-2RKF4701X	Panasonic Electronic Components
R7	NP	10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R8	NP	10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R9		150		±1%	ERJ-2RKF1500X	Panasonic Electronic Components
R10		150		±1%	ERJ-2RKF1500X	Panasonic Electronic Components
R11		75k		±1%	ERJ-2RKF7502X	Panasonic Electronic Components
R12		133k		±1%	ERJ-2RKF1333X	Panasonic Electronic Components
R13		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R14		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R15		20k		±1%	ERJ-2RKF2002X	Panasonic Electronic Components
R16		1		±1%	ERJ-2BQF1R0X	Panasonic Electronic Components
R17		20k		±1%	ERJ-2RKF2002X	Panasonic Electronic Components
R18		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R19		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R20		0.0		Jumper	ERJ-2GE0R00X	Panasonic Electronic Components
R21		20k		±1%	ERJ-2RKF2002X	Panasonic Electronic Components
R22		1		±1%	ERJ-2BQF1R0X	Panasonic Electronic Components
R23		20k		±1%	ERJ-2RKF2002X	Panasonic Electronic Components
R24		200		±1%	ERJ-8ENF2000V	Panasonic Electronic Components
R25		100k		±1%	ERJ-2RKF1003X	Panasonic Electronic Components
R26		34k		±1%	ERJ-2RKF3402X	Panasonic Electronic Components
R27	NP	10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R28		4.99k		±1%	ERJ-2RKF4991X	Panasonic Electronic Components
R29		499k		±1%	ERJ-2RKF4993X	Panasonic Electronic Components
R30		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R31		1k		±1%	ERJ-2RKF1001X	Panasonic Electronic Components
R32	NP	20k		±1%	ERJ-2RKF2002X	Panasonic Electronic Components
R33	NP	10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R34		9.09k		±1%	ERJ-2RKF9091X	Panasonic Electronic Components
R35		7.5k		±1%	ERJ-2RKF7501X	Panasonic Electronic Components
R36		200k		±1%	ERJ-2RKF2003X	Panasonic Electronic Components
R37		20k		±1%	ERJ-2RKF2002X	Panasonic Electronic Components
R38		7.5k		±1%	ERJ-2RKF7501X	Panasonic Electronic Components
R39		7.5k		±1%	ERJ-3EKF7501V	Panasonic Electronic Components

R40		100k		±1%	ERJ-2RKF1003X	Panasonic Electronic Components
R41		2.49k		±1%	ERJ-2RKF2491X	Panasonic Electronic Components
R42		3.3		±5%	ERJ-2GEJ3R3X	Panasonic Electronic Components
R43		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R44		1		±1%	ERJ-2BQF1R0X	Panasonic Electronic Components
R45		20k		±1%	ERJ-2RKF2002X	Panasonic Electronic Components
R46		715k		±1%	ERJ-2RKF7153X	Panasonic Electronic Components
R47		47k		±1%	ERJ-2RKF4702X	Panasonic Electronic Components
R48		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R49		20		±1%	ERJ-3EKF20R0V	Panasonic Electronic Components
R50		1k		±1%	ERJ-2RKF1001X	Panasonic Electronic Components
R51		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
R52		133k		±1%	ERJ-2RKF1333X	Panasonic Electronic Components
R53		1		±1%	ERJ-2BQF1R0X	Panasonic Electronic Components
R54		1		±1%	ERJ-2BQF1R0X	Panasonic Electronic Components
R55		10k		±1%	ERJ-2RKF1002X	Panasonic Electronic Components
U1					TS80003	Semtech
U2					TS61002	Semtech
U3					SC508ULTRT	Semtech
U4					TL431ACDBZTG4	Texas Instruments
U5					TS30041	Semtech

Rx Coil Specifications:

Vendor	Part Number	Inductance	DCR (Max.)	Dimension (Max.)
TDK	WT505090-20K2-A10-G	12.3±15%uH	100mΩ	Ø50mm
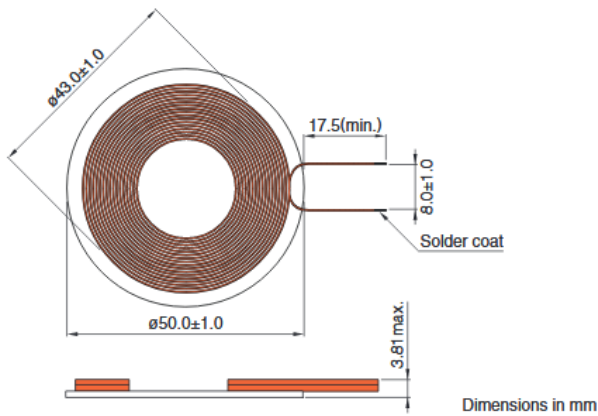
D. Board Layout

The diagram below shows the locations of the components used in the TSDMRX-19V/40W-EVM PCB.

Semtech 40W Wireless Charger RX EVM
v2.0
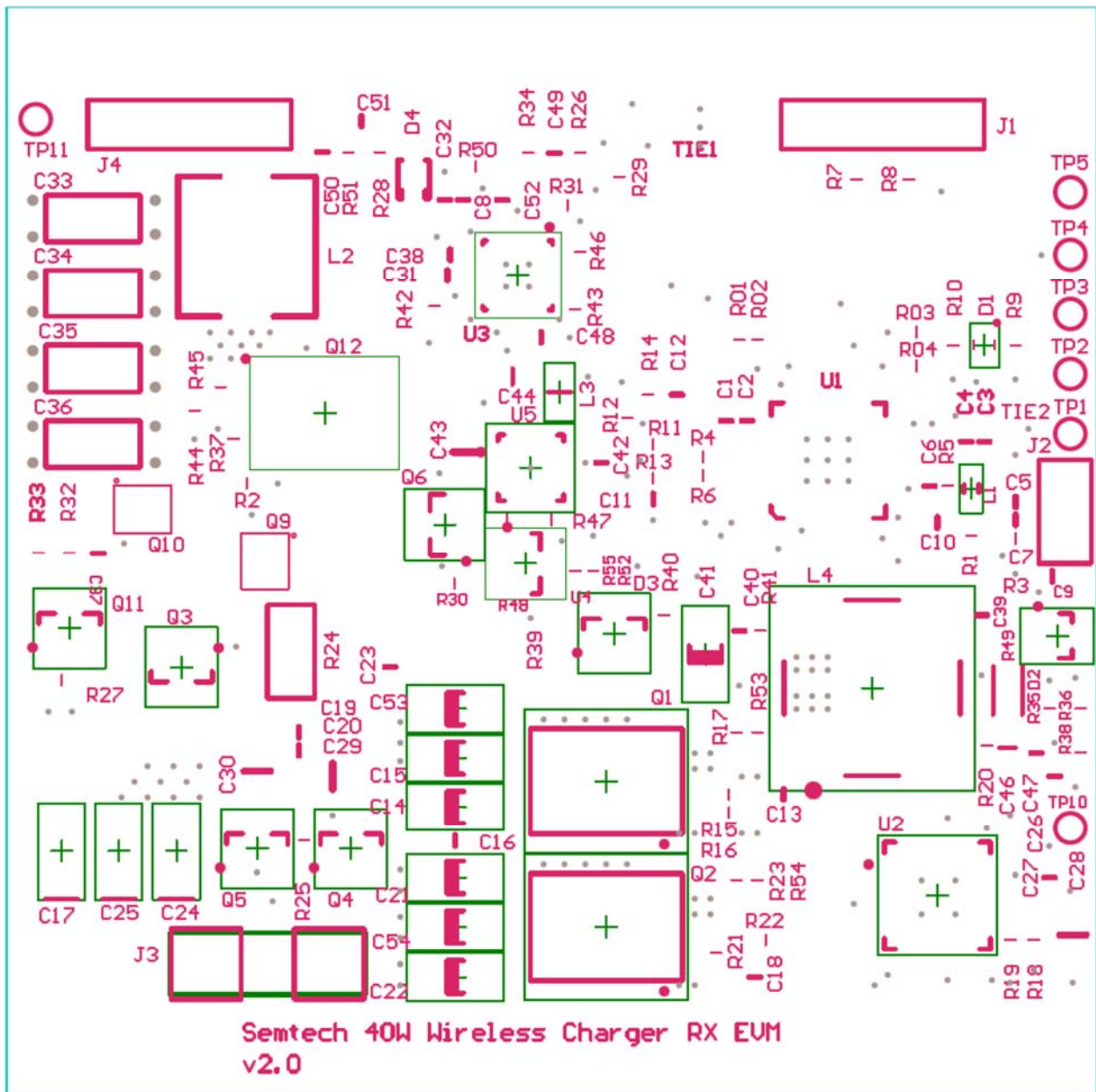
The TSDMRX-19V/40W-EVM PCB is based on a four-layer design as shown below. The ground plane on layer two is recommended to reduce noise and signal crosstalk. The EVM placed all components on the top of the board for easier evaluation of the system. End-product versions of this design can be made significantly smaller by distributing components on both sides of the board. The Gerber files for this artwork can be downloaded from the Semtech web page.
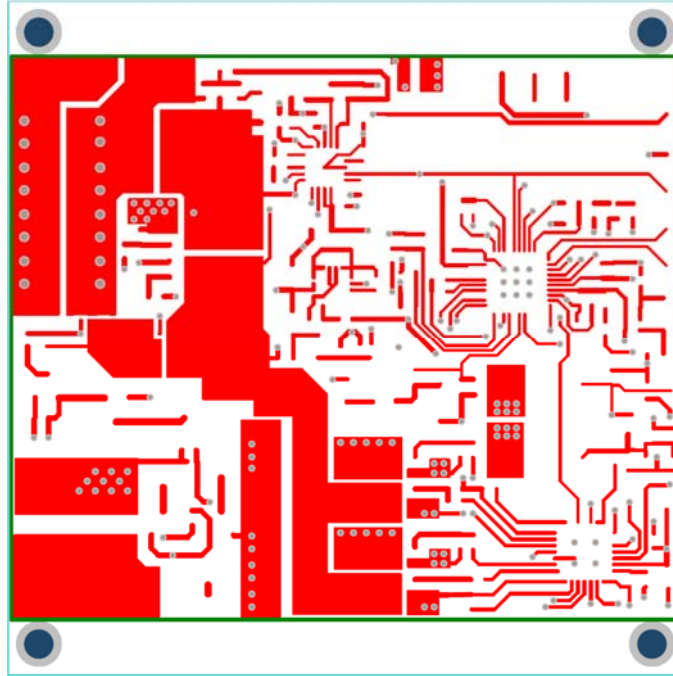
Top Layer
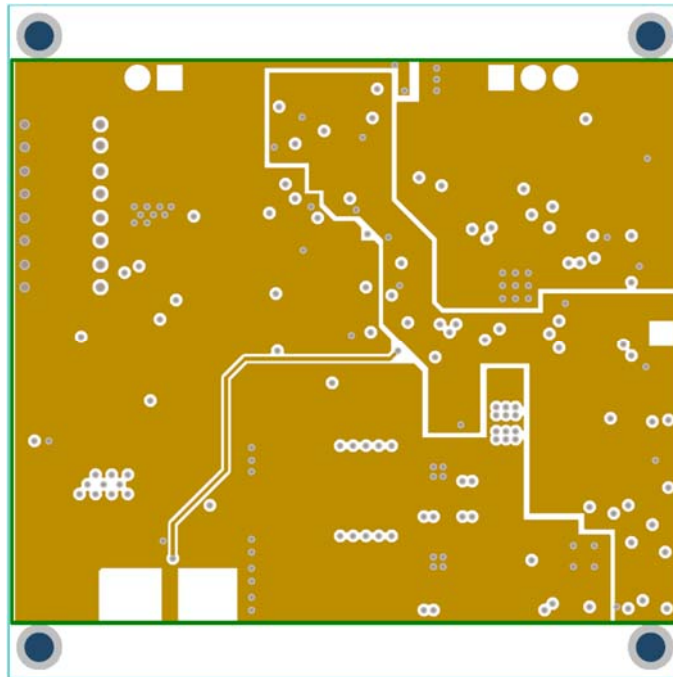
Layer 2
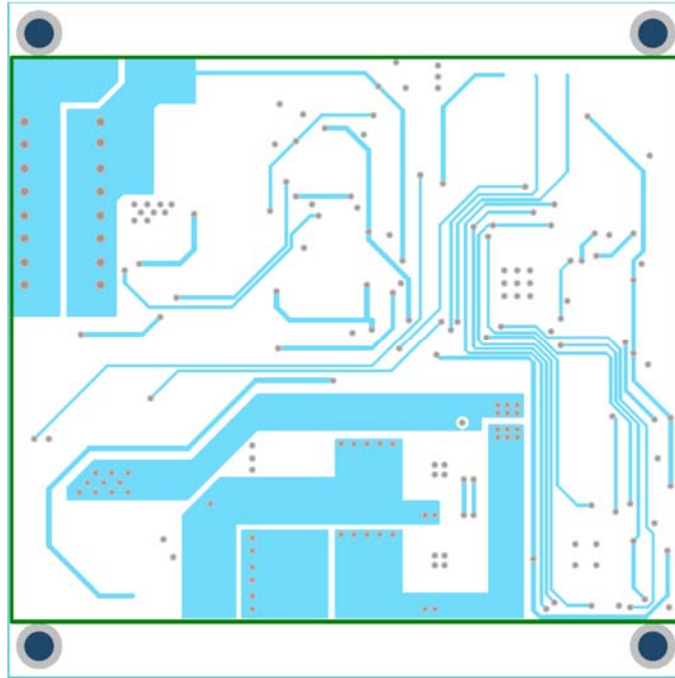
Layer 3
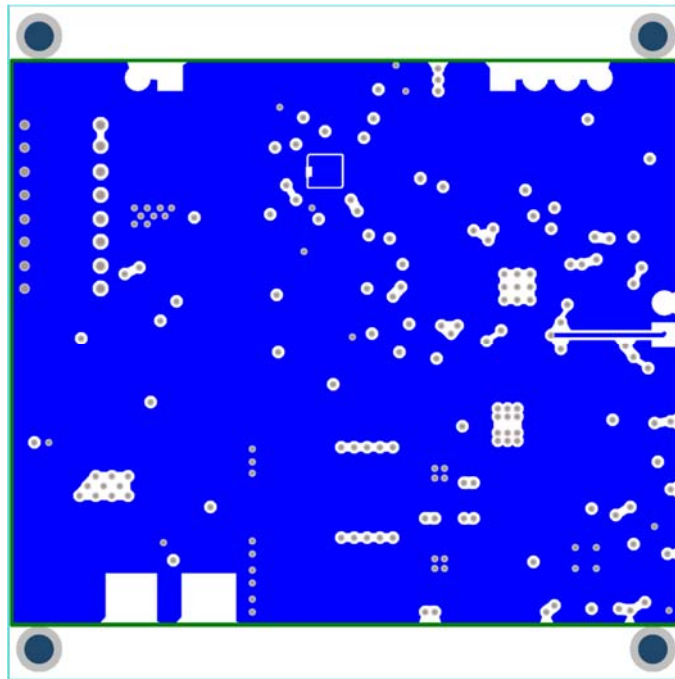
Bottom Layer

Efficiency Measurement

By measuring the power from the receiver's VOUT and GND pins in comparison to the power entering the transmitter EVM, one 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 50% at higher power levels, assuring good efficiency and minimal heat dissipation concerns.

Transmitter is Semtech TSDMTX-24V3-EVM.
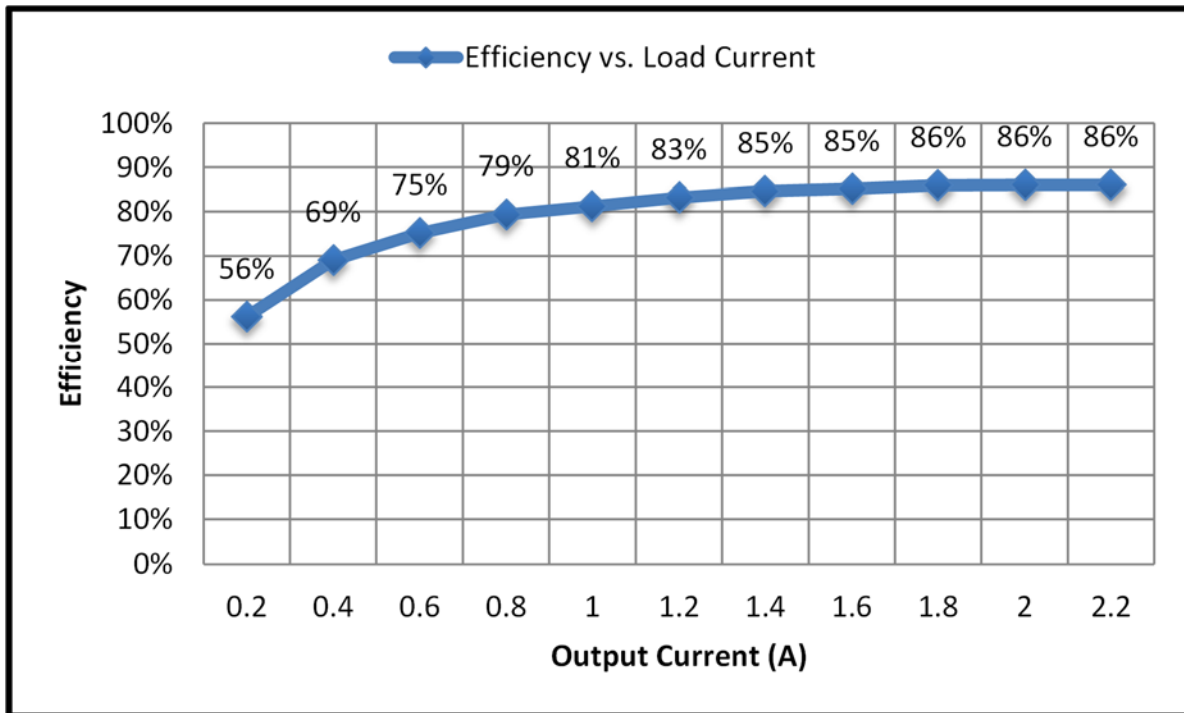
Firmware Management

The EVM is shipped with the latest released version of the firmware at the time it was manufactured. However, as the standard evolves, or enhancements are made to the board performance, the firmware updates will be available at https://www.semtech.com/power-management/wireless-charging-ics/wiireless-charging-evm-firmware/index.html.

Equipments for FW update:

Device	Qty.
TSDMTX-24V3-EVM	1
Universal USB TO UART adapter	1
Semtech TS80003 programming app	1

TS80003 programming app allows you install the latest firmware to your board, and also to interrogate the board as to which version of the firmware is currently installed. Here is the link in the Semtech website to download TS8000X GUI file, Docs& Resources item:

https://www.semtech.com/products/wireless-charging/linkcharge-ics/TS80003

Step 1:

Connect TS80003 board to PC via USB-UART adapter

TS80003 - VCC   -->   PC - 3.3V (if TS80003 is powered by other supply, then don't connect VCC pin)

TS80003 - Pin 39   -->   PC – TXD

TS80003 - Pin 40   -->   PC - RXD

TS80003 - Ground   -->   PC - Ground

Step 2:

Open the TS80003 programming app, click "Port" botton

Step 3:

Choose the correct port from the right drop-down box, then click "Select Port" botton

Step 4:

Click "Read Mode" botton

If the right box shows "Bootloader mode", then jump to Step 6 directly

If the right box shows "Firmware mode", then click "Reset" botton, and wait until the box shows "Resetted to Bootloader mode"

Step 5:

Click "Slect Firmware" botton and then choose the firmware to be downloaded

Step 6:

Wait for 2s, then click "Program" botton and wait unitl programming is finished

FAQs

Q: What output voltage is provided by the TSDMTX-24V3-EVM system?

A: It depends on which receiver is being used. For the TSDMRX-19V/40W-EVM, the output would be 19 volts, at up to 40-W output power. If the TSDMRX-5W-EVM was used, the output would be 5 volts, at up to 5 watts.

Q: Where can I find more information on the Qi 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.

Q: Does the TX 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 = Receive

Mid-section = Device Voltage and/or Wattage

Suffix = Equipment type:
EVM = Evaluation Module
MOD = Production Module

Therefore, the TSDMTX-24V3-EVM is a Dual Mode, 24-volt Transmitter Evaluation Module provided by Semtech.

Q: Does the RX 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 = Receive

Mid-section = Device Voltage and/or Wattage

Suffix = Equipment type:

    EVM = Evaluation Module

    MOD = Production Module

Therefore, the TSDMRX-19V/40W-EVM is a Dual Mode, 40W Receiver Evaluation Module provided by Semtech.

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

A: Please visit the Semtech website as described on the next page. An updated FAQ for the TSDMTX-24V3-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.

SEMTECH

Contact Information

Semtech Corporation
200 Flynn Road, Camarillo, CA 93012
Phone: (805) 498-2111, Fax: (805) 498-3804
www.semtech.com