THE BEAST

AUTOMOTIVE IN-CABIN WIRELESS CHARGING TRANSMITTER

SPK-4101-3C15A

FEATURES

- WPC Qi v1.2.4 15W EPP certified
- Supports all fast charge smartphones
- Supports future products and standards with a firmware upgrade
- Charger is backward compatible with low-power and legacy devices
- Fixed frequency architecture to meet strict automotive requirements
- CISPR 25 Class 4 certified, unique power drive architecture minimizes EMI
- Precise frequency control to prevent adverse effects on other automotive systems
- Full power charging with a 6 - 19V input supply, supporting vehicle stop/start
- Supports multi-coil configurations (standard and custom)
- Standard 3 coil (MP-A13 or MP-A9), 2 coil and single coil solutions
- Single MCU supports wireless charging, system application, CAN and external NFC interface functions

spark connected

Powering the world, wirelessly

CONTENTS

OVERVIEW

The Beast wireless power transmitter evaluation module is a high-performance, easy-to-use development system for the design of automotive in-cabin wireless charging solutions. The SPK-4101-3C15A system supports all the basic functions of a Qi-compliant, wireless charger for automotive applications. The three-coil transmitter provides the designer a certified platform that drastically reduces the development time of their end application. The system supports WPC v1.2.4 receivers up to 15W, as well as all legacy Qi certified receivers. Smartphones with proprietary fast charge capability are also supported. Additional features and future standards changes can be supported by the easy-to-upgrade software.

SPECIFICATIONS

Table 1 provides a summary of performance specifications at an ambient temperature of 25°C.

Table 1. SPK-4101-3C15A Specifications

Parameter		Conditions	Min	Typ	Max	Units
V_{in}	Input voltage	RX output up to 15W	6	12	19	V
I_{in}	Input current	V_{in} = 12V, RX output V_{out} = 12V, I_{out} = 1.25A		1.6		A
	Input standby current	V_{in} = 12V		125		mA
f_{sw}	Switching frequency			127.8		kHz
E_{pk}	Peak efficiency	V_{in} = 12V, RX output V_{out} = 12V, I_{out} = 1.25A			77	%
t_A	Operation temp	Ambient		25	85	°C

CERTIFICATIONS

Table 2 provides a summary of completed regulatory certifications. See the Appendix for certificates.

Table 2. SPK-4101-3C15A Certifications

Regulation	Level	Laboratory	Description
WPC Qi	v1.2.4 EPP	Intertek, Hong Kong	Wireless Power Consortium product certification
CISPR-25	Class 4	NTS, Dallas TX	Automotive EMI product certification

CONNECTOR DESCRIPTIONS

Table 3 provides a list of connectors and their functions.

Table 3. SPK-4101-3C15A Connections

Connector	Name	Description
J1	JTAG	JTAG serial communications interface for debug use
J2	DAP	MCU debug interface for use with Infineon KIT_DAP_MINIWIGGLER_USB
J3	UART	UART serial debug interface for use with Spark GUI application
J4	SPI	Serial Peripheral Interface (SPI) for connection to external devices
J5	DC IN	Input supply connection (6V - 19V DC)
J6	COIL_REF	Coil reference connection
J7	COIL_TEMP1	Coil #1 thermistor connection
J8	COIL_H1	Coil #1 connection
J9	COIL_L1	Coil #1 connection
J10	COIL_TEMP2	Coil #2 thermistor connection
J11	COIL_H2	Coil #2 connection
J12	COIL_L2	Coil #2 connection
J13	COIL_TEMP3	Coil #3 thermistor connection
J14	COIL_H3	Coil #3 connection
J15	COIL_L3	Coil #3 connection
J16	CAN	CAN interface
J17	FOD	Spark optional enhanced FOD function

LED BEHAVIOR

Table 4 provides a summary of the LED indicator behavior.

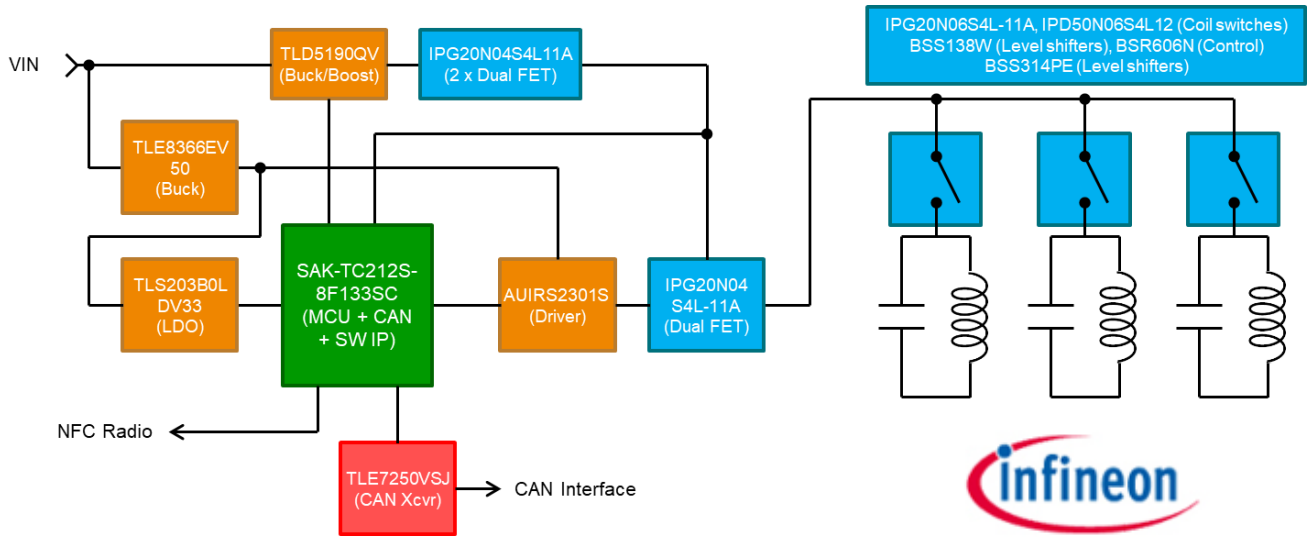
Table 4. SPK-4101-3C15A LED Behavior

LED Behavior	Description
Single Green Flash	One green flash at power-up; indicates system is working properly
Solid Green	Normal charging; indicates a receiver is on the charging surface
Solid Red	Error condition; FOD object detected Error condition; Communication error

BLOCK DIAGRAM

Figure 1 shows a block diagram of the major functions.

Figure 1. SPK-4101-3C15A Block Diagram



TEST SETUP

Spark recommends using a certified WPC Qi v1.2 15W EPP receiver for system evaluation. If a certified WPC v1.2 receiver is not available, a certified WPC v1.1 or newer will also suffice. Use of non-certified Qi receivers (sometimes called "Qi compatible") is not recommended as functionality and performance are not guaranteed. Spark does not support the use of non-certified receivers with the SPK-4101-3C15A.

The transmitter fully complies with WPC v1.2.4 EPP protocol, allowing it to charge all WPC Qi certified receivers, regardless of power level, up to 15W receiver output. The following test set-up and testing results reflect the use of a WPC v1.2 EPP receiver.

Equipment required to test the transmitter:

- Qi certified receiver (15W EPP recommended)
- Power supply (12V, 3A recommended)
- Electronic load (constant current)
- Multimeters to measure input / output voltage and current
- Oscilloscope (optional) to measure signal waveforms
- Computer with a USB port (optional)

Operation of the system:

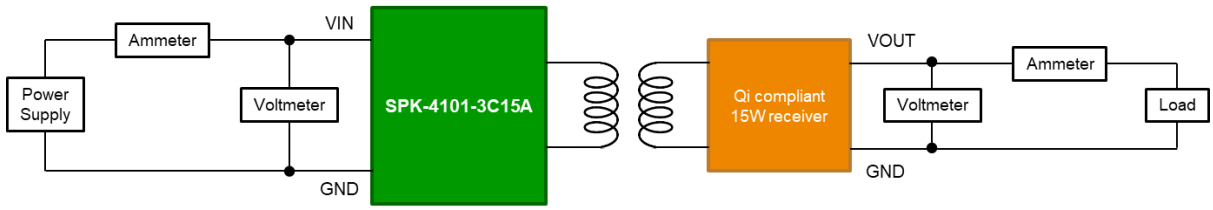
1. Connect the Multimeters per the diagram, to measure input / output voltage and current
2. Adjust the power supply to 12V and connect to J5
3. Turn on power supply; the status LED will flash green once to indicate the system is working
4. Place the receiver on the charging surface
5. Measure the system parameters

6. If a PC is connected to J3 using a USB-to-UART cable, the user can monitor the transmitter operation through either a serial terminal window or the Spark Connected GUI application
7. The system software can be updated using the Spark Connected GUI application via a USB-to-UART cable connected to J3

For more information on the SPK-4101-3C15A and to download the Spark Connected GUI application, please go to www.sparkconnected.com/automotive.

Figure 2 shows the test equipment setup.

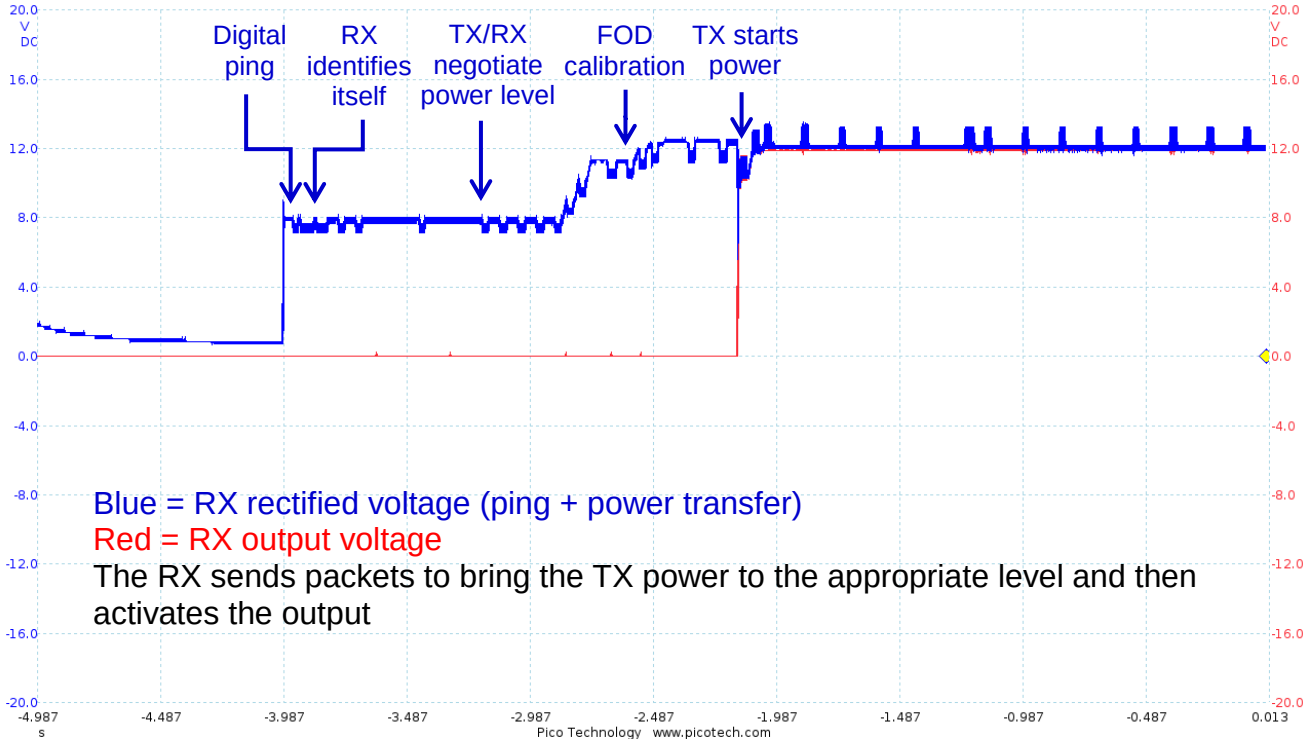
Figure 2. SPK-4101-3C15A Test Equipment Setup



RECEIVER STARTUP

Figure 3 shows an oscilloscope capture of the transmitter behavior when a certified Qi receiver is placed on the charging surface.

Figure 3. SPK-4101-3C15A 15W Qi Startup Sequence



EFFICIENCY

Figure 4 shows the DC-to-DC efficiency of the system when tested with a certified Qi 15W EPP receiver with a 50mm diameter 10µH coil. The receiver was tested at 15W (12V output) and 5W (5V output).

Figure 4. SPK-4101-3C15A System Efficiency

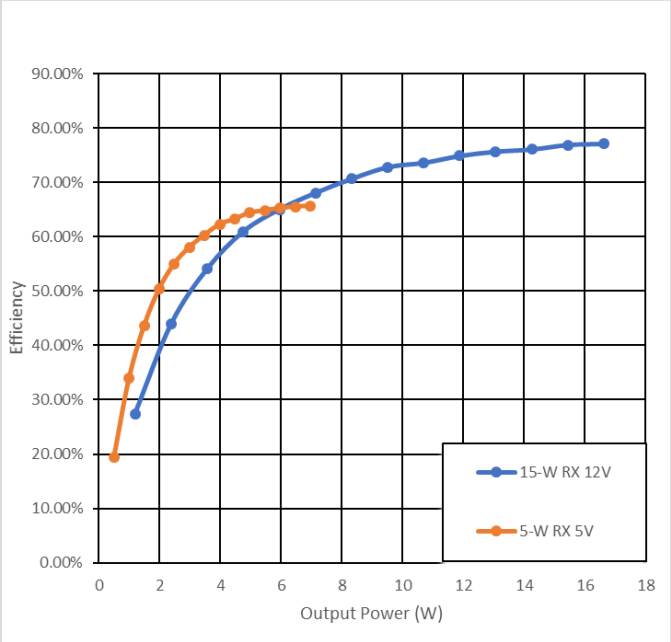


Figure 5 and Table 5 show the DC-to-DC efficiency of the system with the receiver placed at different locations on the charging surface.

Figure 5. SPK-4101-3C15A Efficiency Map

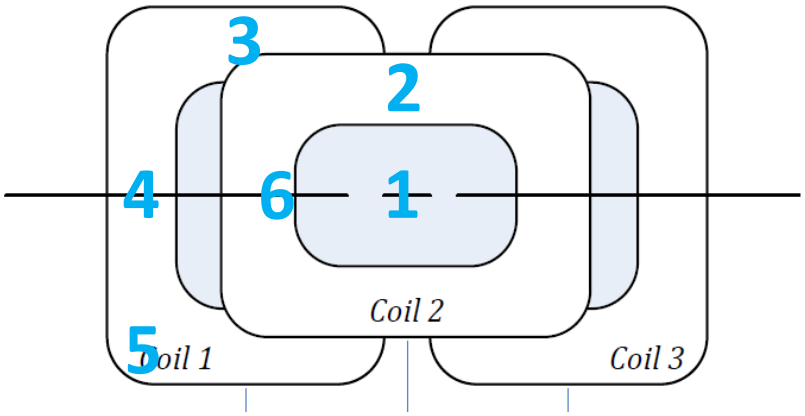


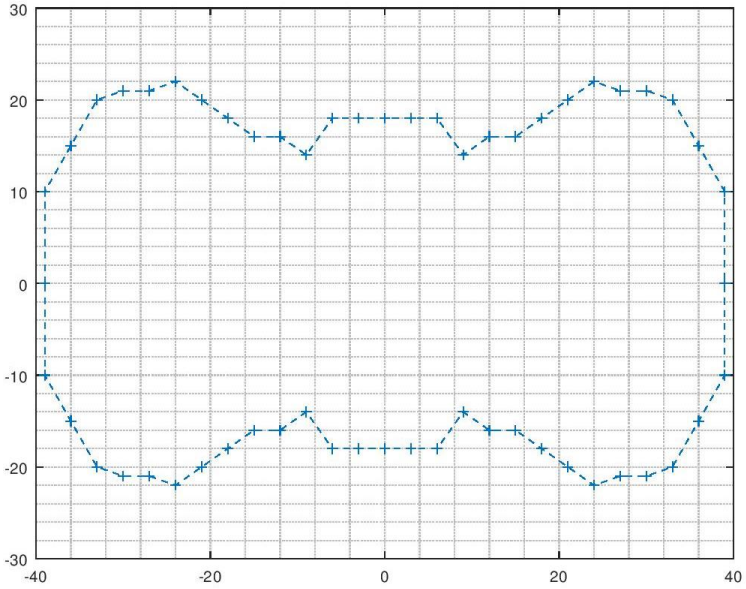
Table 5. SPK-4101-3C15A Efficiency Map

Position	V_{in} (V)	I_{in} (A)	V_{out} (V)	I_{out} (A)	P_{out} (W)	Efficiency
1	11.82	1.639	11.88	1.25	14.85	76.65%
2	11.81	1.824	11.66	1.25	14.58	67.66%
3	11.82	1.672	11.24	1.25	14.05	71.09%
4	11.81	1.803	11.55	1.25	14.44	67.80%
5	11.81	1.836	11.44	1.25	14.3	65.95%
6	11.82	1.777	11.89	1.25	14.86	70.76%

CHARGING AREA

Figure 6 shows the charging area of the system when tested with an Apple iPhone 8. The outline represents the outside limit for placement of the receiver coil center point where phone charging begins.

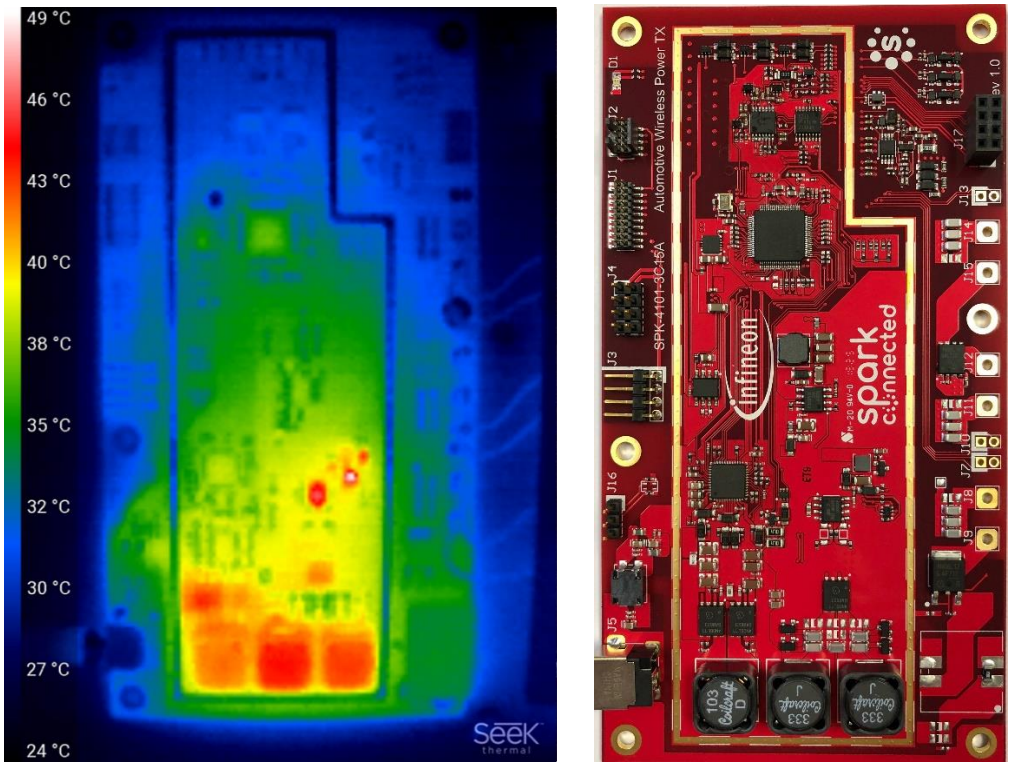
Figure 6. SPK-4101-3C15A Charging Area Map in mm (iPhone 8)



THERMAL PERFORMANCE

Figure 7 shows the FLIR thermal image for a system when tested with a certified Qi 15W EPP receiver with a 50mm diameter 10µH coil. The image was taken at steady state operation with a receiver output of 15W. The maximum temperature on the PCB is 49°C, measured at an ambient of 24°C.

Figure 7. SPK-4101-3C15A Thermal Image



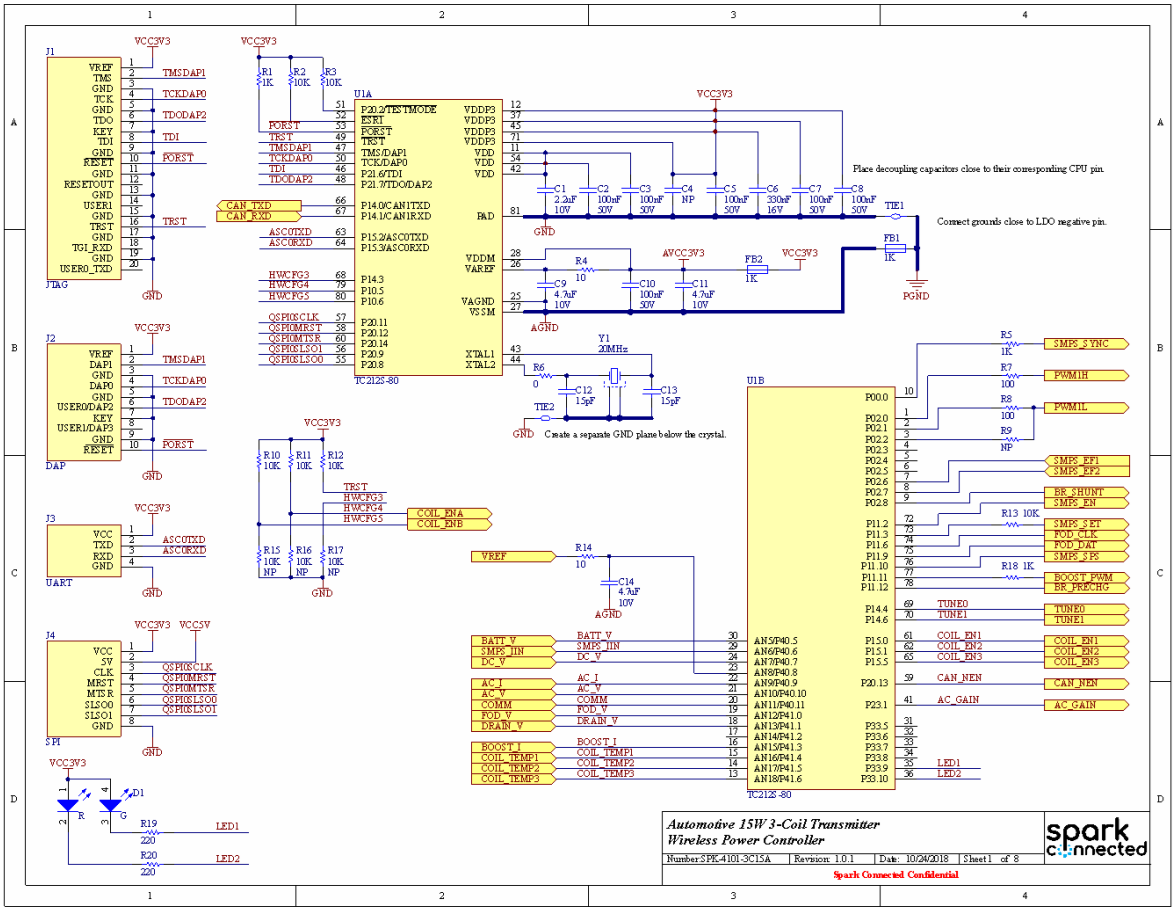
FOREIGN OBJECT DETECTION (FOD)

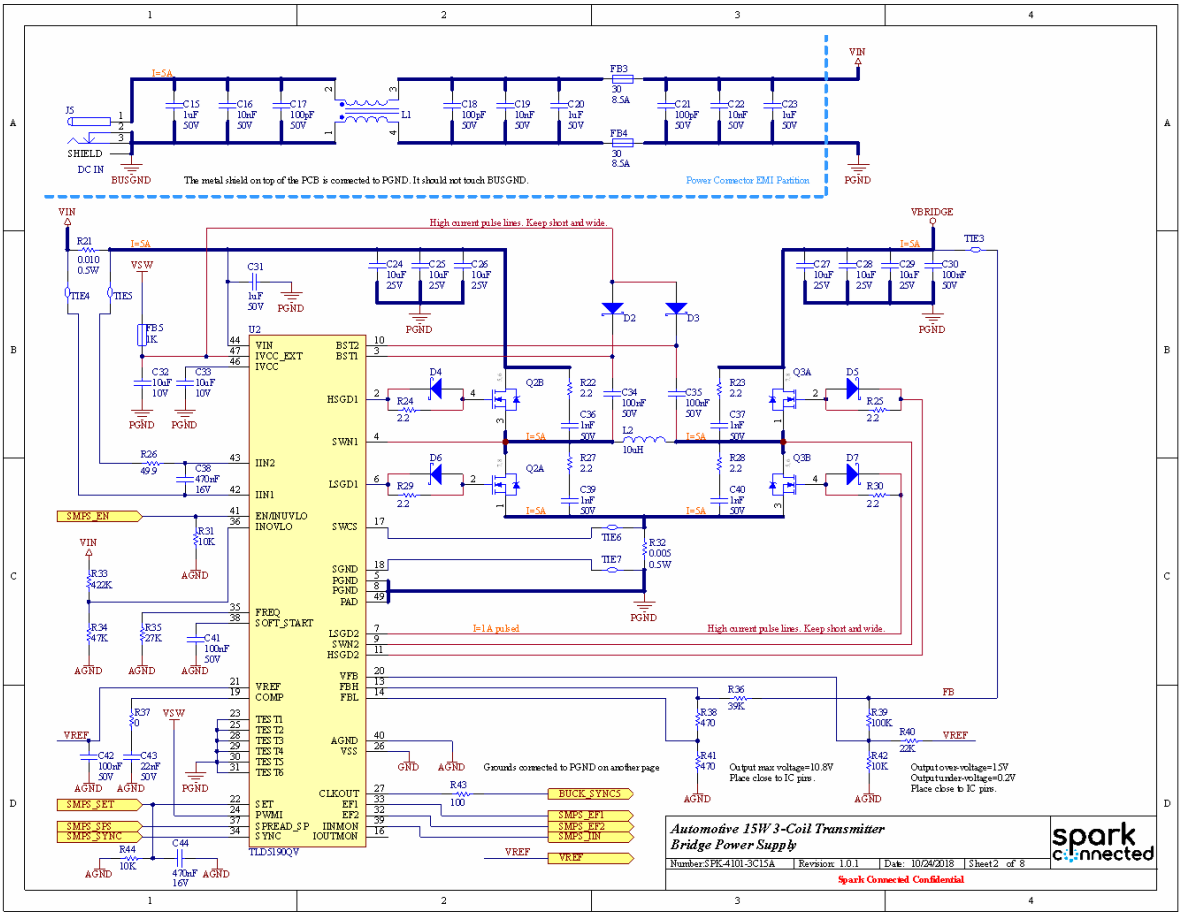
Lower transmitter operating frequencies utilized by the WPC Qi standard (110kHz - 205kHz) require a safety mechanism to prevent heating of metallic objects within the charging field. These are referred to as “foreign objects” and can be located both inside the device (referred to as “friendly”) and outside the device. Sensing these objects and preventing safety issues is referred to as Foreign Object Detection (FOD). Qi employs two main techniques for FOD.

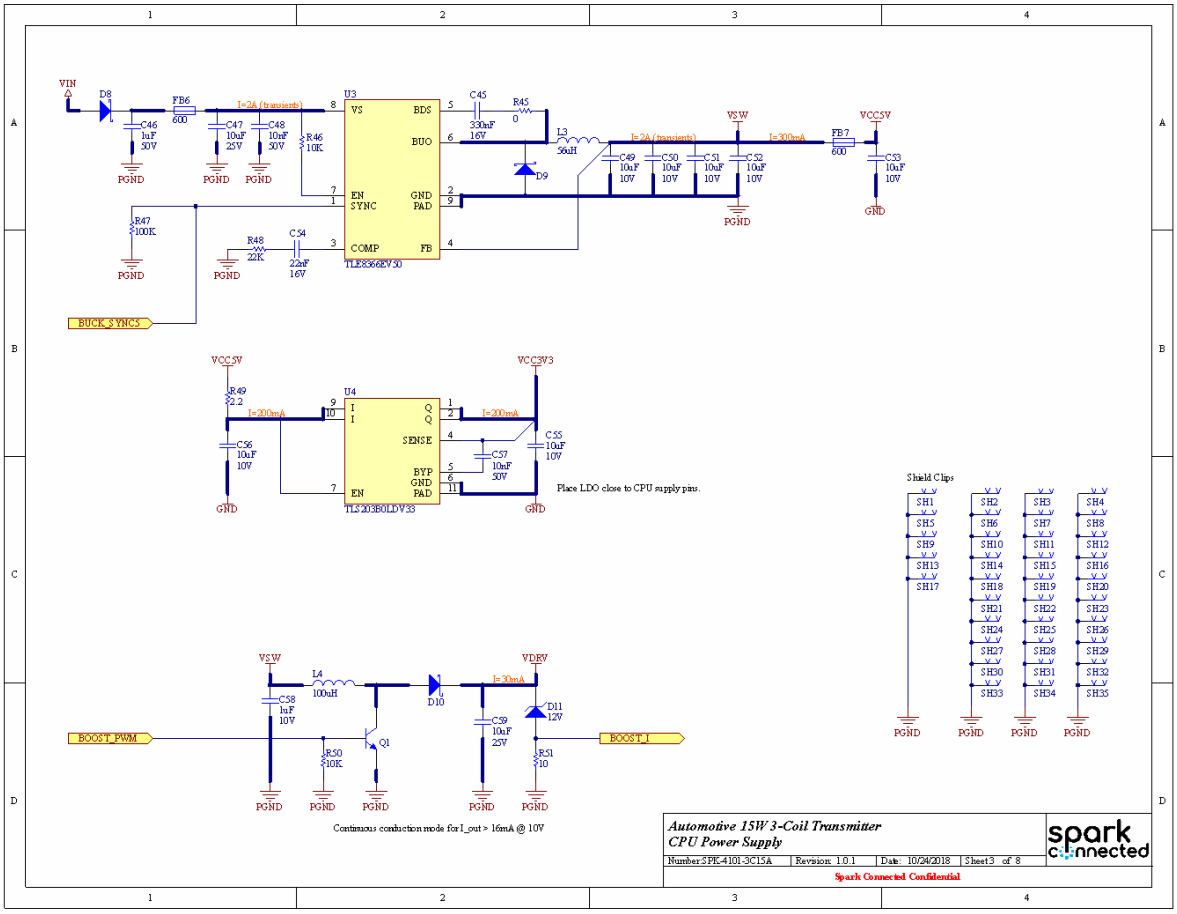
1. The transmitter performs a Quality Factor (QF) measurement of the coil system when a receiver is placed on the charging surface. If there is a metallic object within the charging field, it will reduce the QF measurement. This method is only enabled by a Qi receiver that supports the v1.2 EPP functionality. At startup, the receiver sends the transmitter a packet containing the real Quality Factor (QF) measurement for the receive coil system. This QF measurement is compared to the value measured by the transmitter. If the QF measurement by the transmitter is below that communicated by the receiver, then an FOD event is triggered and power transfer is stopped. The SPK-4101-3C15A signals the error by turning the LED indicator solid red. The transmitter will maintain the error status until both the receiver and the foreign object is removed from the transmitter surface. At that time the transmitter returns to standby mode.
2. The transmitter performs a Power Delta calculation during power transfer to determine if excess power is being absorbed by objects other than the receiver. This method is only enabled by a Qi receiver that supports the v1.1 or greater BPP functionality. During power transfer, the receiver sends regular packets reporting the power received, including losses in the receiver system (coil, rectifier, voltage regulator). The transmitter measures power output, including losses in the transmitter system (coil, bridge, voltage regulator, other fixed losses). The transmitter then subtracts received power from transmitted power, and if transmitted power is greater than received power by more than a certain margin, then an FOD event is triggered and power transfer is stopped. The SPK-4101-3C15A signals the error by turning the LED indicator solid red. The transmitter will maintain the error status until both the receiver and the foreign object is removed from the transmitter surface. At that time the transmitter returns to standby mode.

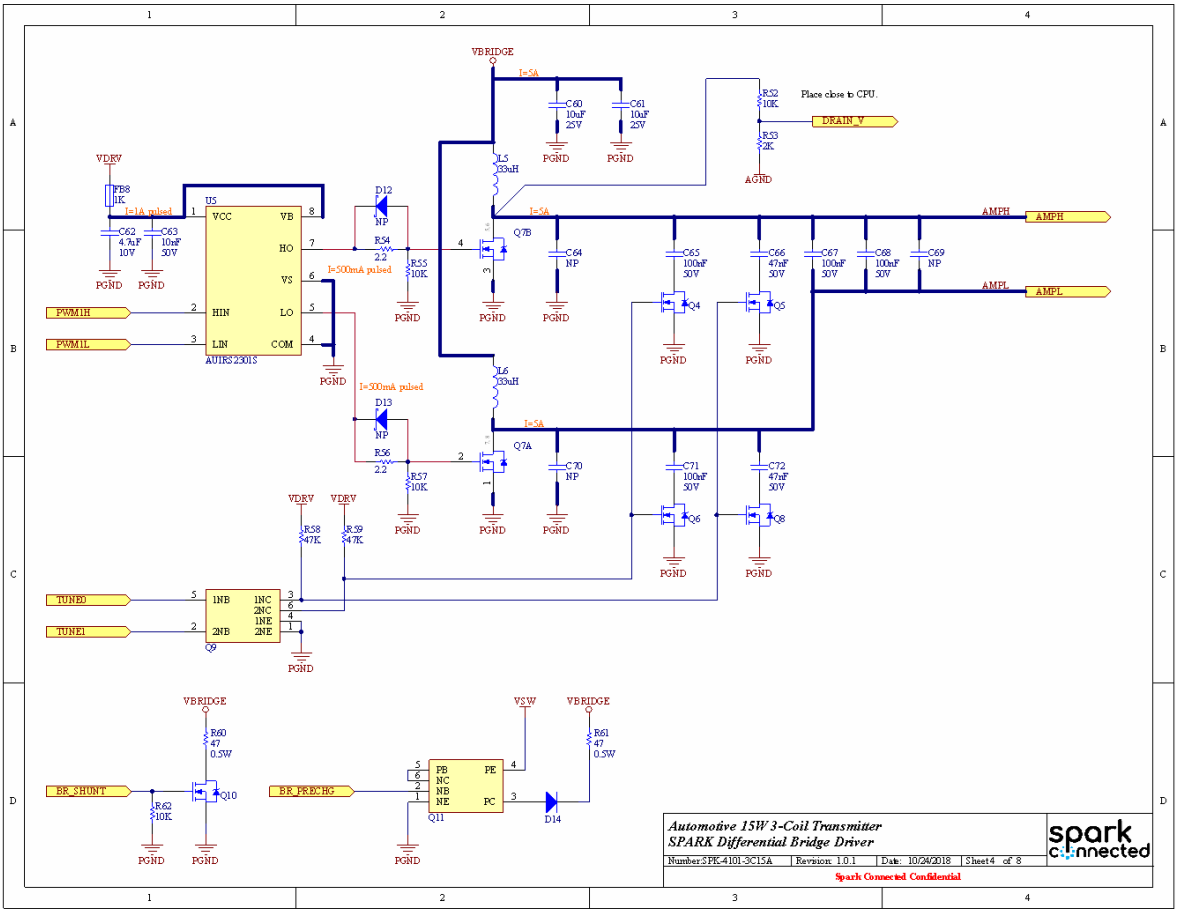
Since both FOD methods rely on information from the Qi receiver, the accuracy of the data provided by the receiver is critical to effective metallic object detection.

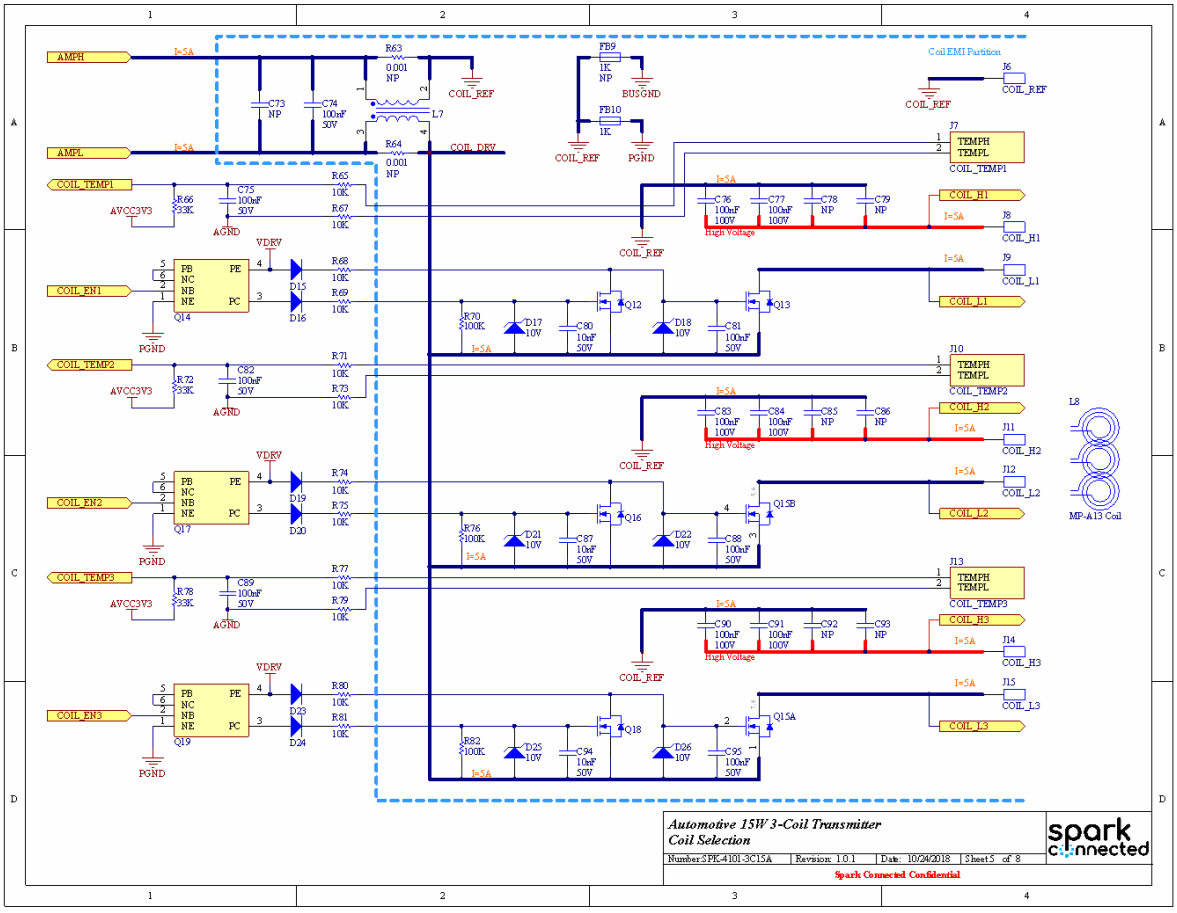
The SPK-4101-3C15A also performs other real-time measurements of AC coil voltage, AC coil current, system efficiency, and thermal input from any attached thermistors. Using these inputs, the system ensures safe and stable power delivery as environmental changes occur. If an error condition is detected, the SPI-4101-3C15A signals the error by turning the LED indicator solid red. To return the system to standby, the user is required to address the cause of the error.

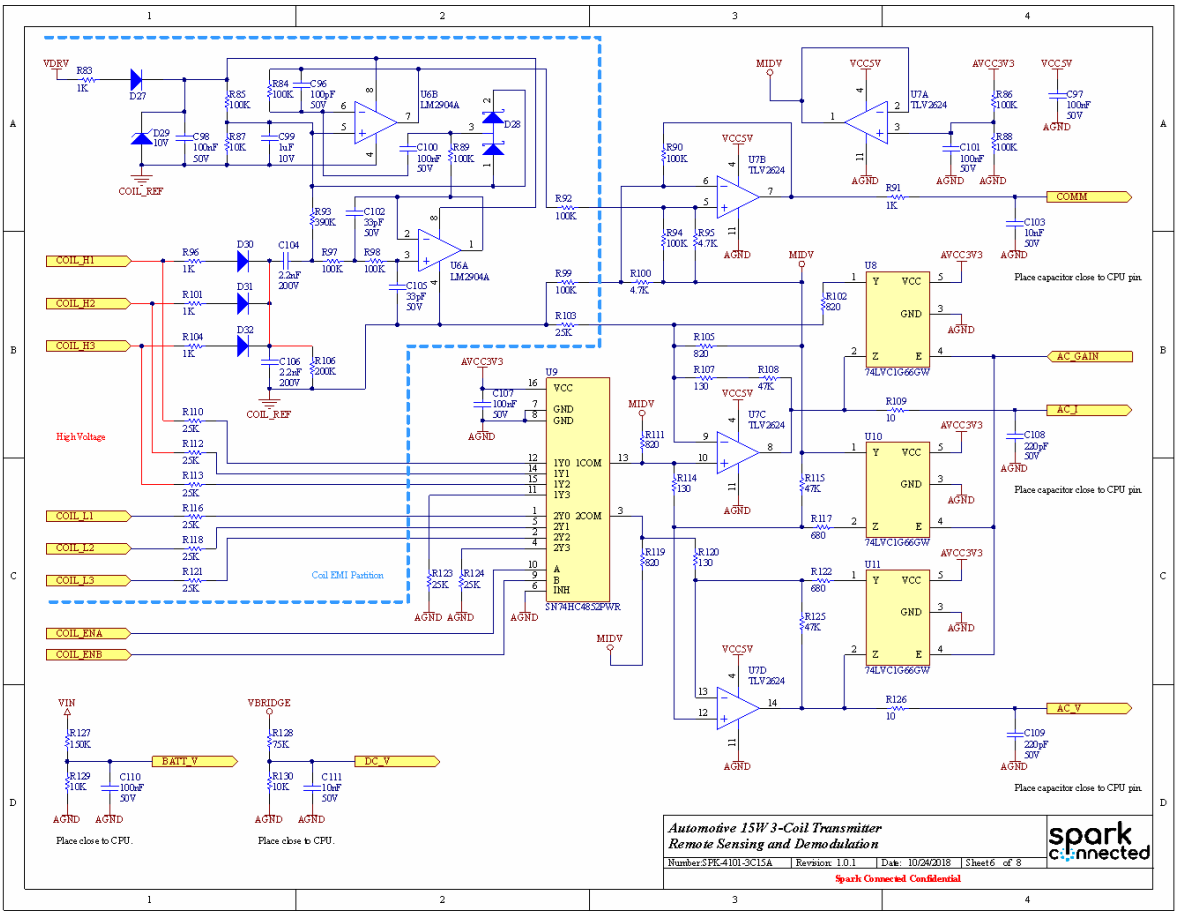


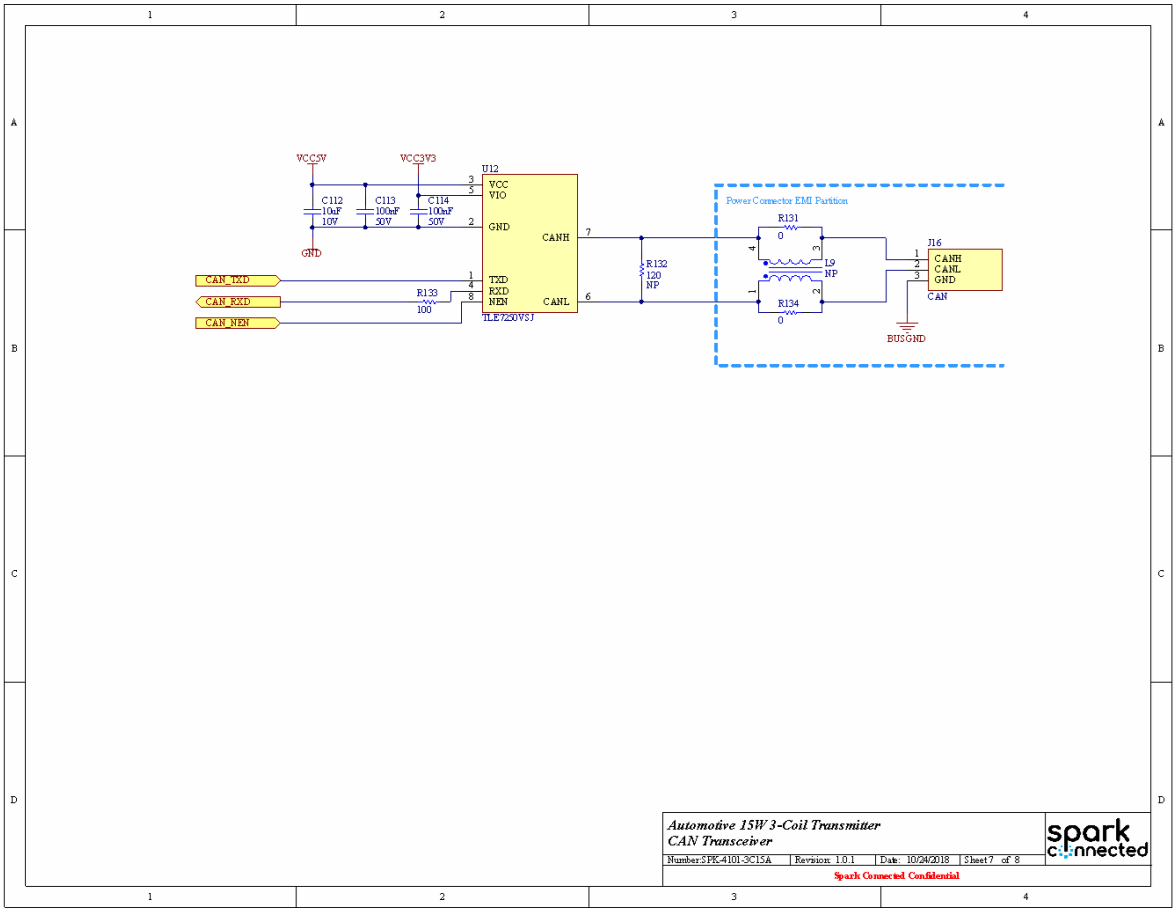












BILL OF MATERIALS (BOM)

Table 6 provides a list of components and their functions.

Table 6. SPK-4101-3C15A BOM

Designator	Value	Rating	Part Number	Manufacturer	Qty	Description
C1	2.2uF	10V	LMK107BJ225KAHT	Taiyo Yuden	1	Ceramic Capacitor
C2, C3, C5, C7, C8, C10, C41, C42, C43, C75, C82, C89, C97, C100, C101, C107, C110, C113, C114, C116	100nF	50V			20	Ceramic Capacitor
C6, C45	330nF	16V	AC0603KRX7R7BB334	Yageo	2	Ceramic Capacitor
C9, C11, C14, C62	4.7uF	10V	LMK107BJ475KAHT	Taiyo Yuden	4	Ceramic Capacitor
C12, C13	15pF	50V			2	Ceramic Capacitor
C15, C20, C23, C31, C46	1uF	50V	UMK212B7105MGHT	Taiyo Yuden	5	Ceramic Capacitor
C16, C19, C22, C48, C57, C63, C80, C87, C94, C103, C111	10nF	50V			11	Ceramic Capacitor
C17, C18, C21, C96	100pF	50V			4	Ceramic Capacitor
C24, C25, C26, C47	10uF	25V	TMK316AB7106KLHT	Taiyo Yuden	4	Ceramic Capacitor
C27, C28, C29, C59	10uF	25V	TMK316AB7106KLHT	Taiyo Yuden	4	Ceramic Capacitor
C30, C34, C35, C81, C88, C95, C98	100nF	50V	GCM155R71H104KE02J	Murata	7	Ceramic Capacitor
C32, C33, C55, C56, C112	10uF	10V	LMK212ABJ106KGHT	Taiyo Yuden	5	Ceramic Capacitor
C36, C37, C39, C40, C117	1nF	50V	GCM155R71H102KA37D	Murata	5	Ceramic Capacitor
C38, C44	470nF	16V	GCM188R71C474KA55J	Murata	2	Ceramic Capacitor
C49, C50, C51, C52, C53	10uF	10V	LMK316AB7106KLHT	Taiyo Yuden	5	Ceramic Capacitor
C54	22nF	16V	EMK105B7223MVHF	Taiyo Yuden	1	Ceramic Capacitor
C58, C99	1uF	10V	LMK107B7105KAHT	Taiyo Yuden	2	Ceramic Capacitor
C60, C61	10uF	25V	GRM21BR61E106KA73L	Murata	2	Ceramic Capacitor
C65, C67, C68, C71, C74	100nF	50V	CGA5L2C0G1H104J160AA	TDK	5	Ceramic Capacitor
C66, C72	47nF	50V	CGA5H2C0G1H473J115AA	TDK	2	Ceramic Capacitor
C76, C77, C83, C84, C90, C91	100nF	100V	CGA5L1C0G2A104J160AC	TDK	6	Ceramic Capacitor
C102, C105	2.2nF	25V	AC0402KRX7R8BB222	Yageo	2	Ceramic Capacitor
C104, C106	2.2nF	200V	C0805C222J1GAC7800	Kemet	2	Ceramic Capacitor
C108, C109	220pF	50V			2	Ceramic Capacitor
D1			APHBM2012SURKCGKC	Kingbright	1	LED Dual Color
D2, D3, D8, D9	60V		NRVTS260ESFT1G	ON Semi	4	Diode Schottky
D4, D5, D6, D7	20V		PMEG2005EGWJ	Nexperia	4	Diode Schottky
D10	30V		BAT54GWJ	Nexperia	1	Diode Schottky
D11	12V		SZMMSZ5242BT1G	ON Semi	1	Diode Zener
D14, D15, D16, D19, D20, D23, D24, D27			BAS16GWJ	Nexperia	8	Diode
D17, D18, D21, D22, D25, D26, D29	10V		MM3Z10VST1G	ON Semi	7	Diode Zener

D28			SBAS70-04LT1G	ON Semi	1	Diode Schottky
D30, D31, D32			BAS21GWJ	Nexperia	3	Diode
FB1, FB2, FB5, FB8, FB10	1K		BK1005HS102-T	Taiyo Yuden	5	Ferrite Bead
FB3, FB4	30	8.5A	BLM21SN300SZ1D	Murata	2	Ferrite Bead
FB6, FB7	600	500mA	MMZ1608Y751BTD25	TDK	2	Ferrite Bead
J1			FTSH-110-01-L-DV-A	Samtec	1	JTAG 20-pin Connector
J2			FTSH-105-01-L-DV-K	Samtec	1	DAP 10-pin Connector
J3			M20-9960445	Harwin	1	UART 4-pin Connector 90 Deg
J4			M20-9980445	Harwin	1	SPI 8-pin Connector
J5			PJ-051BH	CUI	1	Barrel Connector 2.5mm ID/5.5mm OD
J16			M20-9990345	Harwin	1	CAN 3-pin Connector
J17			M20-9980445	Harwin	1	FOD 8-pin Connector
L1		4A	ACM70V-701-2PL-TL00	TDK	1	Common Mode Choke
L2	10uH	7.48A	MSS1260-103 784771100	Coilcraft Wurth Elektronik	1	Inductor
L3	56uH	1.4A	SRN6045TA-560M	Bourns	1	Inductor
L4	100uH	260mA	LQH3NPZ101MMEL	Murata	1	Inductor
L5, L6	33uH	4.34A	MSS1260-333 784771330	Coilcraft Wurth Elektronik	2	Inductor
L7		7A			1	Common Mode Choke
L8	12.5uH		760308106 WT1005690-12K2-A6-G	Wurth Elektronik TDK	1	Wireless Power Coil
Q1			BC817-25,235	Nexperia	1	NPN Transistor
Q2, Q3, Q7			IPG20N04S4L11AATMA1	Infineon	3	N Channel FET
Q4, Q5, Q6, Q8			BSR606NH6327XTSA1	Infineon	4	N Channel FET
Q9			MUN5213DW1T1G	ON Semi	1	NPN/NPN Transistor
Q10			BSS138WH6433XTMA1	Infineon	1	N Channel FET
Q11, Q14, Q17, Q19			MUN5312DW1T1G	ON Semi	4	NPN/PNP Transistor
Q12, Q16, Q18			BSS7728NH6327XTSA2	Infineon	3	N Channel FET
Q13			IPD50N06S4L12ATMA2	Infineon	1	N Channel FET
Q15			IPG20N06S4L14AATMA1	Infineon	1	N Channel FET
R1, R5, R18, R91, R109, R126	1K				6	Chip Resistor
R2, R3, R10, R11, R12, R13, R31, R42, R44, R46, R50, R55, R57, R62, R65, R67, R68, R69, R71, R73, R74, R75, R77, R79, R80, R81, R89, R95, R97, R98, R100, R147, R148	10K				33	Chip Resistor
R4, R14, R51	10				3	Chip Resistor
R6, R37, R45, R131, R134	0				5	Chip Resistor
R7, R8, R43, R133	100				4	Chip Resistor
R19, R20	220				2	Chip Resistor
R21, R32	0.010	0.5W	KRL1220E-M-R010-F-T5	Susumu	2	Chip Resistor

R22, R23, R24, R25, R27, R28, R29, R30, R49, R54, R56	2.2				11	Chip Resistor
R26	49.9				1	Chip Resistor
R33	422K				1	Chip Resistor
R34, R58, R59	47K				3	Chip Resistor
R35	27K				1	Chip Resistor
R36, R66, R72, R78, R123, R124, R135, R137	33K				8	Chip Resistor
R38, R41	470				2	Chip Resistor
R39, R47, R70, R76, R82, R84, R85, R86, R87, R88, R90, R92, R93, R94, R99, R136, R138, R143, R144, R145, R146, R149	100K				22	Chip Resistor
R40, R48, R139, R140	22K				4	Chip Resistor
R52, R129, R130	10K	1%			3	Chip Resistor
R53, R102	2K	1%			2	Chip Resistor
R60, R61	150	0.5W			2	Chip Resistor
R83	4.7K				1	Chip Resistor
R96, R101, R104	1K				3	Chip Resistor
R103, R110, R112, R113, R116, R118, R121	33K	1%			7	Chip Resistor
R106	200K				1	Chip Resistor
R107, R114, R117, R120, R122	820	1%			5	Chip Resistor
R108, R115, R125	100K	1%			3	Chip Resistor
R127	150K	1%			1	Chip Resistor
R128	75K	1%			1	Chip Resistor
U1			SAK-TC212S-8F133SC	Infineon	1	Wireless Power Controller
U2			TLD5190QVXUMA1	Infineon	1	Buck-Boost Controller
U3			TLE8366EV50XUMA1	Infineon	1	Buck Regulator
U4			TLS203B0LDV33XUMA1	Infineon	1	LDO (3.3V)
U5			AUIRS2301STR	Infineon	1	FET Driver (5V-20V Supply with 3.3V-5V MCU Interface)
U6			LM2904AQM8-13	Diodes	1	OPAMP (2 Channel)
U7			LMV824IYPT	ST	1	OPAMP (4 Channel)
U8, U10, U11			74LVC1G66GW-Q100,1	Nexperia	3	Analog Switch (Single)
U9			SN74HC4852PWR	TI	1	Analog Multiplexer (Dual 4-channel)
U12			TLE7250VSJXUMA1	Infineon	1	CAN Transceiver
Y1	20MHz		ECS-200-12-33Q-JES-TR	ECS	1	Crystal

APPENDIX A

Qi v1.2.4 certification document.

CERTIFICATE OF REGISTRATION QI-ID 4699

The product The Beast Automotive In-cabin Wireless Charger by Spark Connected with type number SPK-4101-3C15A is licensed to use the Qi logo on the product, on the product's packaging, and in the product's user manual.

The product passed the tests defined in the Qi wireless power specification and works correctly when used in combination with other products that are licensed to use the Qi logo.

Oct 23, 2018
Menno Treffers
Chairman

http://www.wirelesspowerconsortium.com/products/details/4699/info

APPENDIX B

CISPR-25 Class 4 certification document.

1.0 Administrative Data

1.1 References

- Spark Connected
- NTS Quote Number OP0254710-01 dated 07/10/2018 and OP0251401
- ISO/IEC 17025:2005(E), *General Requirements for the Competence of Testing & Calibration Laboratories*, May 15, 2005
- CISPR 25, *Vehicles, boats and internal combustion engines – Radio-frequency disturbance characteristics – Limits and methods of measurement for the protection of on-board receivers, Ed 3.0 2008-03*

1.2 Description of Test Item

Qty	Item	P/N	S/N
1	15 Watt 3-Coil In-Cabin Automotive Wireless Charger	SPK-4101-3C15A	NA

1.3 Test Configuration

According to CISPR 25. Car battery, artificial network, wireless power transmitter.

1.4 Test Locations and Dates

Test Category	Test Dates
Radiated Emissions	07/05/2018
Conducted Emissions	07/05/2018
Note: All testing was performed at NTS in Plano, TX	

1.5 Calibration Details

Lists of the equipment used during testing are included in each test section. This equipment is calibrated according to ISO/IEC 17025:2005(E) and calibration is traceable to the National Institute of Standards and Technology (NIST). Calibration records are maintained on file at National Technical Systems.

1.6 Test and Result Summary

The 15 Watt 3-Coil In-Cabin Automotive Wireless Charger was tested to the specified standards and to comply with all of the criteria to which it is tested:

Test	Section	Reference	Performance	Test Result
		Emissions	**Class Limit**	
Radiated Emissions	2.1	CISPR 25	Class 4	Pass
Conducted Emissions	2.2		Class 4	Pass

1.7 Mode of Operation and Power

The 15 Watt 3-Coil In-Cabin Automotive Wireless Charger was operated via 12 - 14VDC from car battery. The wireless power transmitter detects the presence of a wireless power receiver on its surface and starts the power transfer. The power level is controlled by the receiver via in-band communication data packets.

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