10W WPC Wireless Transmitter Evaluation Module Using NU15XX and NU1009

The evaluation module (EVM) is a 4V-12V input and 10W output, high efficiency WPC wireless power transmitter using NU15XX controller and NU1009 power stage. It is fully compliant with WPC V1.2.4, and yet can be easily customized for any customer-requested solutions. Therefore, the EVM design can communicate with any WPC compliant receivers and guarantee 10W output.

Content

1 Applications

The NU15XX and NU1009 evaluation module is a complete solution for 10W wireless transmitter compliant with WPC V1.2.4. The features and key performance of this EVM are as following:

- Input voltage: 4V to 12V, connecting to adapter which can support QC3.0
- Work with any WPC compliant 10W EPP receivers
- Efficiency over 82% at 10W
- Foreign Object Detection (FOD)
- Over temperature protection (OTP)
- Short-circuit protection (SCP)
- Input under-voltage lockout (UVLP)
- Input over-voltage lockout (OVP)
- Test points to facilitate measuring waveform and evaluating performance
- Standard WPC MPA11-type transmitter coil
- 2 LED for indicating power on, power transferring or fault conditions

2 Schematic and Bill of Materials

2.1 Schematic

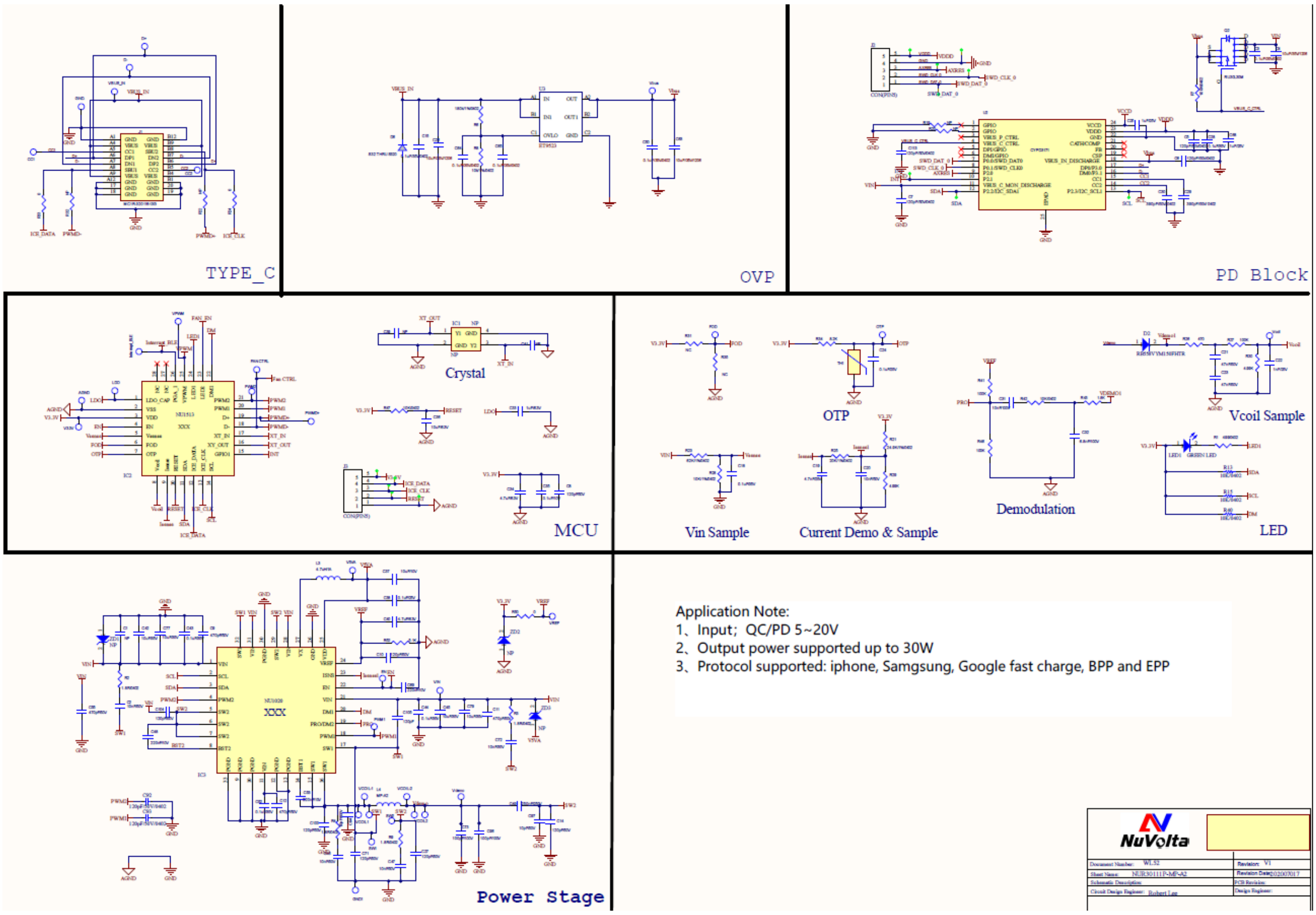


Figure 1： Schematics of NU15XX and NU1009 EVM

2.2 Bill of Materials

Table 1: Bill of Materials

Designator	Comment	LibRef	Quantity
C3, C19, C43, C44	10nF/0402	Cap	4
C6	68nF/50V/0402	Cap	1
C7, C20, C25	100nF/25V/0402	Cap	3
C8, C18	22uF/16V/0805	Cap	2
C10	4.7nF/25V/0402	Cap	1
C11	10nF/16V/0402/1%	Cap	1

C12	1nF/16V/0402	Cap	1
C13, C14	10uF/16V/0805	Cap	2
C16	500nF/100V/CBB	Cap	1
C17, C22, C48, C54	150pF/16V/0402/C0G	Cap	4
C21, C24	1uF/6.3v/0402	Cap	2
C26, C33, C39	100nF/16V/0402	Cap	3
C28	2.2uF/6.3V/0603	Cap	1
C29	10uF/10V/0603	Cap	1
C30	100nF/10V/0402	Cap	1
C31	4.7uF/10V/0603	Cap	1
C35, C37	10pF/16V/0402/COG	Cap	2
C42, C46, C47	220nF/16V/0402	Cap	3
D1, D4, D5, D6	BAS516	Diode 1N4934	4
J5	MC1R-320116-13G	USB_TYPE-C_20_R	1
LED1, LED2	LED	LED0	2
R1, R9	1K/0402	Res1	2
R2, R3, R43, R45, R51	5.1k/0402	Res1	5
R4, R7, R8, R12, R39	10K/0402	Res1	5
R5, R6, R31, R32	1.8R/0603	Res	4
R10	NTC/10K/1%	Res1	1
R11, R44	1.2K/0402	Res1	2
R15	49.9k/0402/1%	Res1	1
R16	20k/0402/1%	Res1	1
R19	10k/0402/1%	Res1	1
R20	5.1k/0402/1%	Res1	1
R22	1.5k/0402	Res1	1
R24	25k/0402/1%	Res1	1
R26	8.2k/0402	Res1	1
R29	82K/0402	Res1	1
R34	0/0603	Res1	1
R37, R38	100k/0402	Res1	2
R40	30k/0402	Res1	1
R41	470/0402	Res1	1
U1	NU1509	MCU	1
U2	NU1009	Power stage	1
Y1	Crystal 22.999MHz	CRYSTAL	1

The venders of passive components can be different, but the value and accuracy should be same as shown in table.

3 PCB Layout

3.1 Layout Guidelines

EVM is a 2 layer, 1-oz board. All components except the coil are on the top side. The main Power track is on the top and bottom side. The ground on both top and bottom layer is separated into PNGD (on the left side) and AGND(on the right side) in order to avoid the interference from power to signal. The detail suggestions of PCB layout can be found on "layout guideline" of NU1009 data sheet.

The following figures are the reference PCB design of EVM.

- Layer 1: Component placement, major routing and as much ground plane as possible
- Layer 2: A clean PGND plane under NU1009 and AGND

Additionally, here are the guidelines to follow:

- Make routing loop as small as possible, especially the power loop, to minimize EMI noises.
- Place power and signal traces on the top to avoid noise coupling.
- Widen the copper between SW1, SW2 and LC tank, because high current in the LC tank can cause power losses on the traces and hence low efficiency. Moreover, the Vin routing should be as wide as possible.

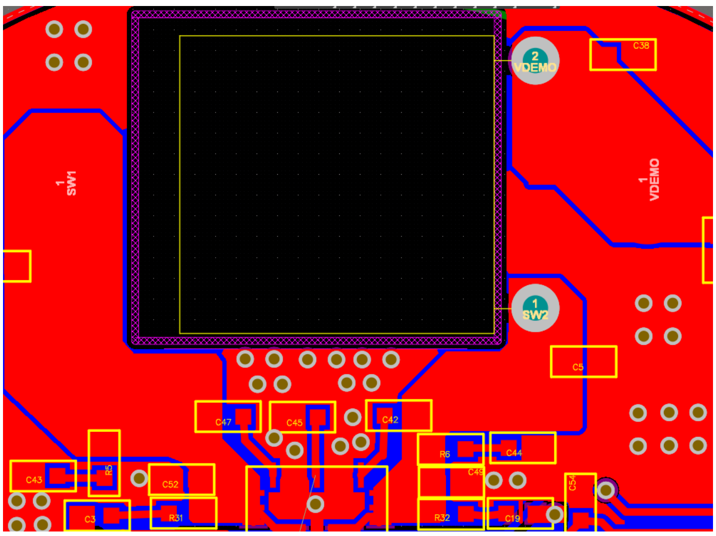


Figure 2： SW1, SW2 and LC tank *part of NU1020 EVM*

- It's better to have a symmetrical power input routing of NU1009.

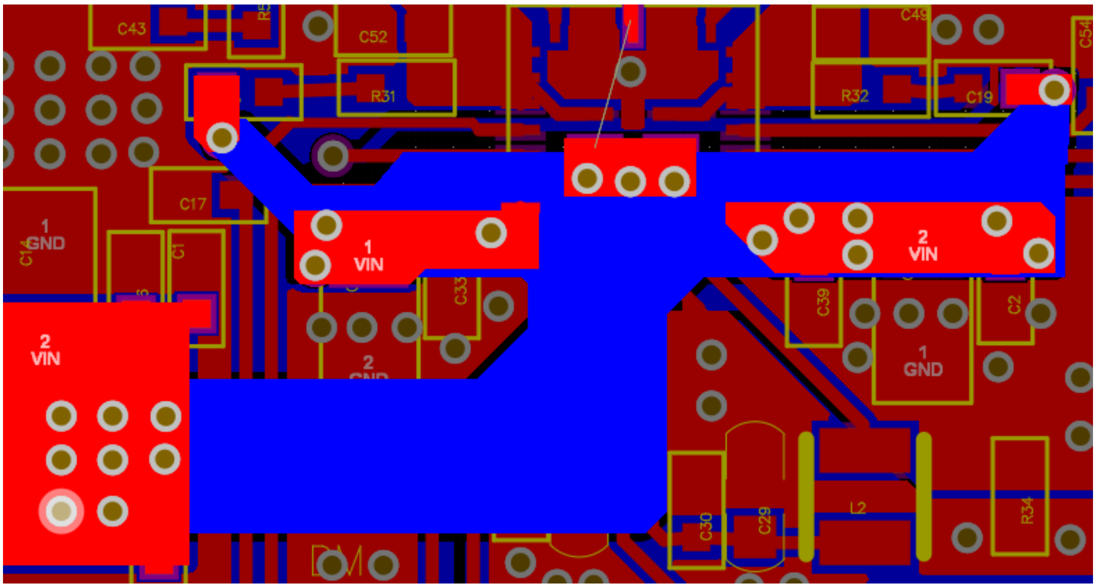


Figure 3: *VIN part of NU1020 EVM*

- Separate the analog-ground plane from the power-ground plane and use only one point to join them. Please refer to the R34 of Figure 1.
- The full-bridge power stage is integrated in NU1009, so thermal Vias are needed to provide a thermal path for the NU1009.

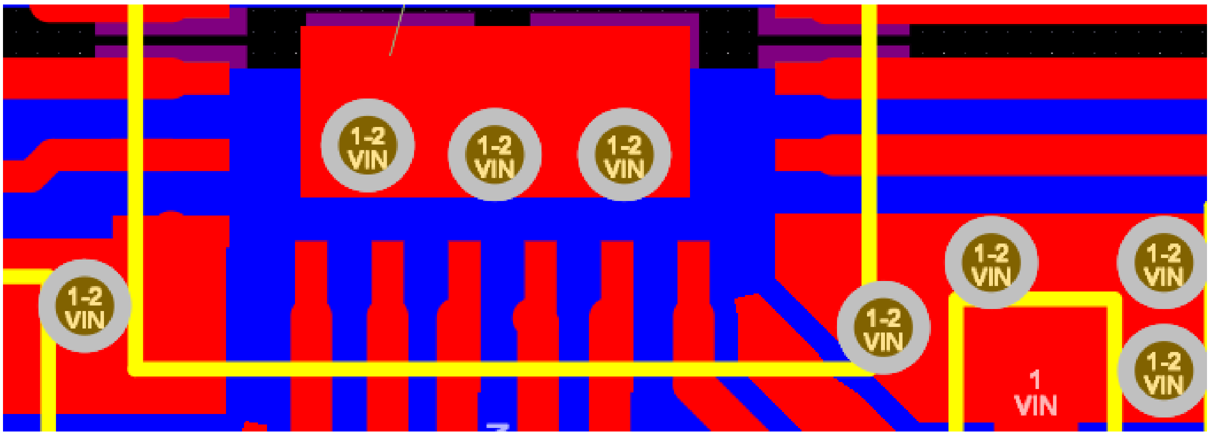


Figure 4: Thermal path *of NU1020 EVM*

- [1]~[4]Place small-size input capacitors as close as possible between the Vin pin and PGND pin besides the NU1009. These capacitors can effectively filter out high-frequency noises due to their low ESR and ESL. Please refer to C33, C39, C1, C45 in Figure 5.

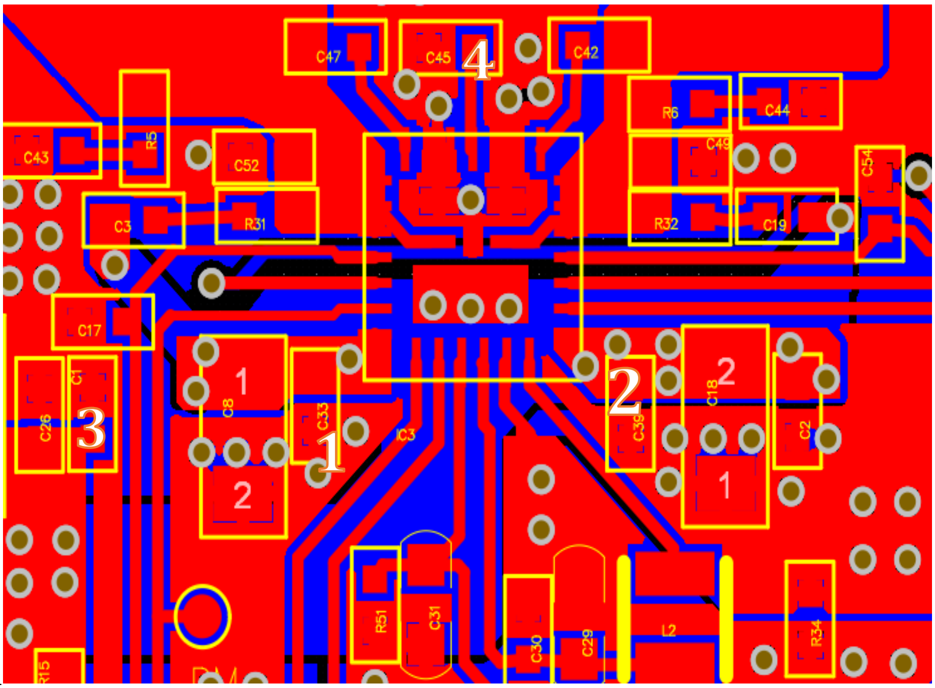


Figure 5： Capacitor location around NU1009

- Keep analog-ground plane and power-ground plane low impedance. Use as much copper as possible and an appropriate number of Vias.
- [5]~[12]Make the snubber loop as small as possible. Please refer to R32 C19, R31 C3, R6 C44 and R5 C43 in Figure 6**.**

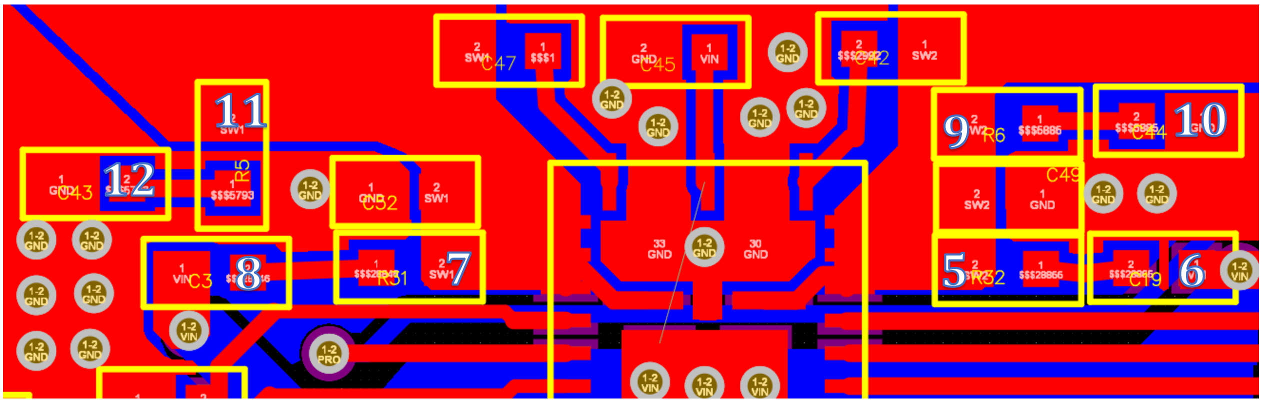


Figure 6： Capacitor location around NU1020

3.2 SMT Examples

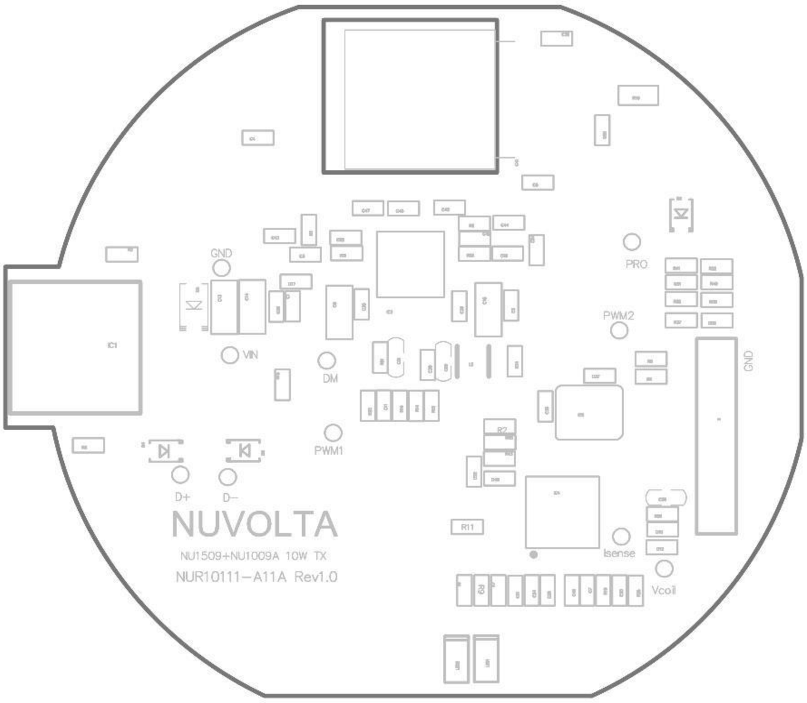


Figure 6: SMT location drawing

4 Connector and Test Point Descriptions

Multiple test points are placed to probe the waveform and debug performance easily. The test points are described in the following table.

Table 2: Connector and Test Point Description

Name	Description	Name	Description
USB1	USB Type-C Connector of Input.	VIN	Input voltage of the NU1009
D+/D-	QC Control Signal	DM	Demodulation Signal
PWM1/2	PWM Signal of Power Stage’s Driver	Isense	Current Sense Signal
PRO	Debug test point for demodulation		

5 Electrical Performance Specifications

Table 3 is a summary of the NU1009 EVM performance specifications. All specifications are given with NU15XX receiver when the ambient temperature is 25°C.

6 EVM Evaluation

6.1 Test Equipment

Table 3: Equipment

Equipment	Description
QC3.0 Adaptor	QC3.0 Adaptor
Multi-meter	The Multi-meter can monitor both voltage and current.
Oscilloscope	An oscilloscope is used to probe the ripple of output.
Electronic Load	The load must be required at 10V from 0 to 1.3 A load. The limited current must be over 1.5A.

The equipment is used to simulate the application environment of the EVM. The key performance of the EVM can evaluated and captured using the equipment system. All the electronic equipment must be well grounded to avoid the electrical shock hazard.

6.2 EVM Test Procedure

Connect the Adaptor and Type C with EVM to provide the power for EVM.

6.2.1 Power on with No Receiver

Connect the adaptor supplier to EVM with no receiver.
Observe the status of LED1. Red LED1 should be on first.
Observe the current value on the Power Source or multi-meter to check the standby input current.

6.2.2 Power Transfer

Keep the adaptor on and place the receiver on the top of the transmitter coil. Align the centers of the receiving and transmitting coils and observe the following performance of the EVM.

- The LED on green light during power transfer.
- The LED will blink if an error happens, or Foreign Object is Detected.
- Probe waveform with oscilloscope on the test point SW1 or SW2 when power transfer is active; the frequency should be between 120 kHz and 130 kHz and the switching duty cycle may be adjusted in light load conditions.

6.2.3 Over Current Protection (OCP)

Increase the load current from 1A and observe the output voltage through multi-meter. Mark the value of load current when the output voltage drops from 9V to close zero. The LED will blink when OCP is triggered.

6.2.4 Over Temperature Protection (OTP)

The over-temperature condition is detected by an NTC connected to the Pin TEMP of NU15XX. The recommended NTC is 10K and the value of R34 is 8.2K. When the temperature exceeds 75°C(Real voltage is 0.69v), the over-temperature protection is enabled, and the PWM outputs are disabled. The system will restart when the temperature drops below 45℃(real voltage is 1.23v).

6.2.5 Efficiency

TEST CONDITION:
Adapter: XIAOMI-AD65G

Power receiver : RX: EVM110 V3.0   Coil : 9uH 253mΩ(100kHz) Vout : 10V

The output voltage (Vo), the output current (Io), input voltage (Vin), and input current (Iin) should be recorded by multi-meter to calculate efficiency as the ratio of the output power to the input power. The input voltage and output voltage must be tested on the PCB to avoid the voltage drop on the cable of input and output.

The efficiency (η) of EVM can be calculated by the following equation:

$$\eta = {(Vo * Io)}/{(Vin * Iin)}$$

The Figure 7 and table 5 shows the 15W efficiency of EVM with the receiver (NuVolta EVM) under different load condition. The efficiency is over 82% with full load, and the highest efficiency is over 82% when load is 1A.

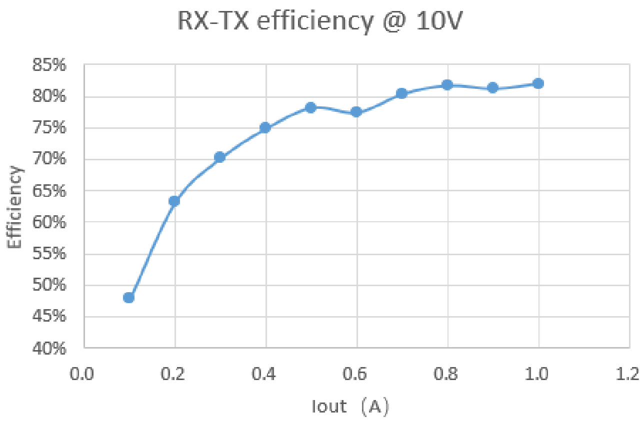


Figure 7: 10W Efficiency of NU15XX and NU1009 EVM

Table 4: Efficiency Test Result

垂直距离	输入电压	输入电流	输出电压	输出电流	输出功率	系统效率
dz/mm	Vin/V	Iin/A	Vout/V	Iout/A	Po/W	η/100%
4mm	8.680	0.263	10.940	0.1	1.094	47.92%
4mm	9.070	0.381	10.930	0.2	2.186	63.26%
4mm	9.260	0.504	10.920	0.3	3.276	70.19%
4mm	9.450	0.617	10.920	0.4	4.368	74.91%
4mm	9.430	0.738	10.880	0.5	5.440	78.17%
4mm	9.610	0.870	10.790	0.6	6.474	77.43%
4mm	9.600	0.989	10.900	0.7	7.630	80.36%
4mm	9.580	1.110	10.860	0.8	8.688	81.70%
4mm	9.760	1.236	10.880	0.9	9.792	81.17%
4mm	9.750	1.359	10.870	1.0	10.870	82.04%

6.2.6 Current Sense Accuracy

NU1009 has an unique current-sense circuit that measures the input current and reports it on the Isns pin. The output current on the ISNS pin is directly proportional to the input current, and the ratio is defined by parameter Ksns.

Here, it uses power-Z to capture the real input current and the Isense reported by MCU which represents the current sense with calibration through an equation. The Figure 5 and table 6 shows the 10W efficiency of EVM with the receiver (NuVolta EVM) under different load condition.

Table 5: Current Sense Accuracy Test

Iin(A)	Isense (A)	err (%)	Pout(W)
0.206	0.196	-4.85%	0.21
0.307	0.316	2.93%	0.88
0.401	0.417	3.99%	1.85
0.502	0.519	3.39%	3.23
0.602	0.618	2.66%	4.11
0.703	0.722	2.70%	5.01
0.806	0.829	2.85%	5.89
0.901	0.928	3.00%	6.67
1.002	1.026	2.40%	7.58
1.104	1.135	2.81%	8.44
1.203	1.249	3.82%	9.46
1.302	1.338	2.76%	10.16

Iin: Input Current;
Isense: The sense current through NU1009;

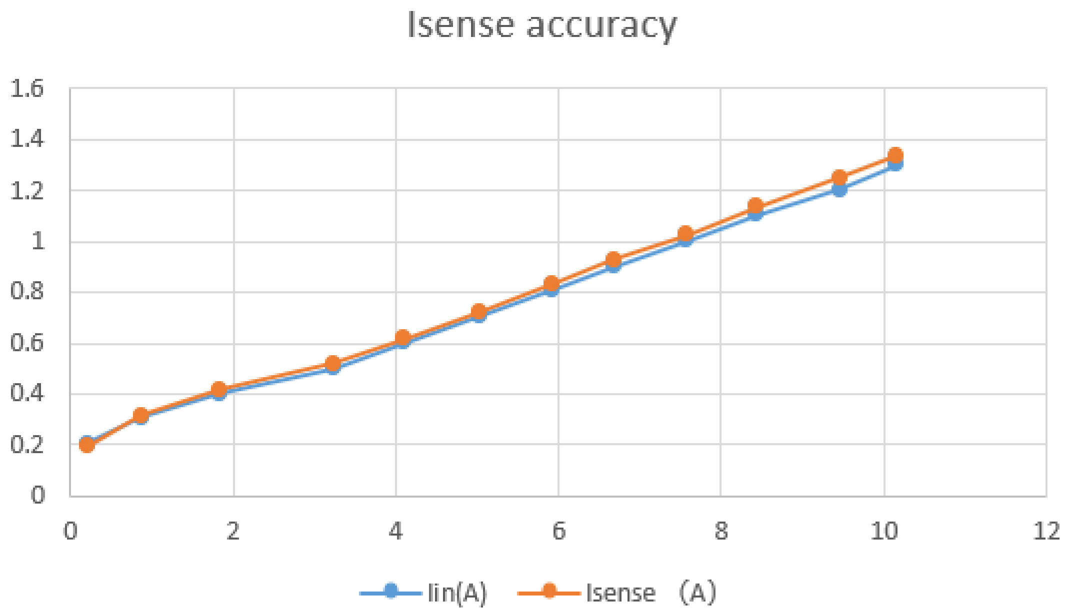


Figure 8: Current Sense Curve under Full Load Range

6.2.7 Foreign Object Detection (FOD)

The NU15XX and NU1009 EVM implements a low cost, reliable FOD algorithm to assure foreign objects detection. It calculates the power losses between transmitted power and received power reported by the receiver. If the power loss is over the limit that is presented in NU15XX, the power transfer will be stopped.

Here, it measures the Q value under different condition. Open means no objects above the EVM, 0.5 yuan RMB coin and 1 yuan RMB coin.

Table 6: Q Detection under Different Condition

Condition	Q value
Open	67
0.5 yuan	19
1 yuan	10

6.2.8 Deadtime Evaluation

Maintaining reasonable deadtime is necessary for the power transfer, it could assure the reliable operation system, and maximize the power transfer efficiency.

NU1009 is integrated full-bridge power stage IC, and the deadtime is internally controlled by the IC. SW1 and SW2 are the switch nodes of the half-bridge FETs. The interval time between SW1 and SW2 represents the deadtime of the full-bridge FETs.

Figure 6 and Figure 7 captures the deadtime between the primary FETs under full load and open load conditions.

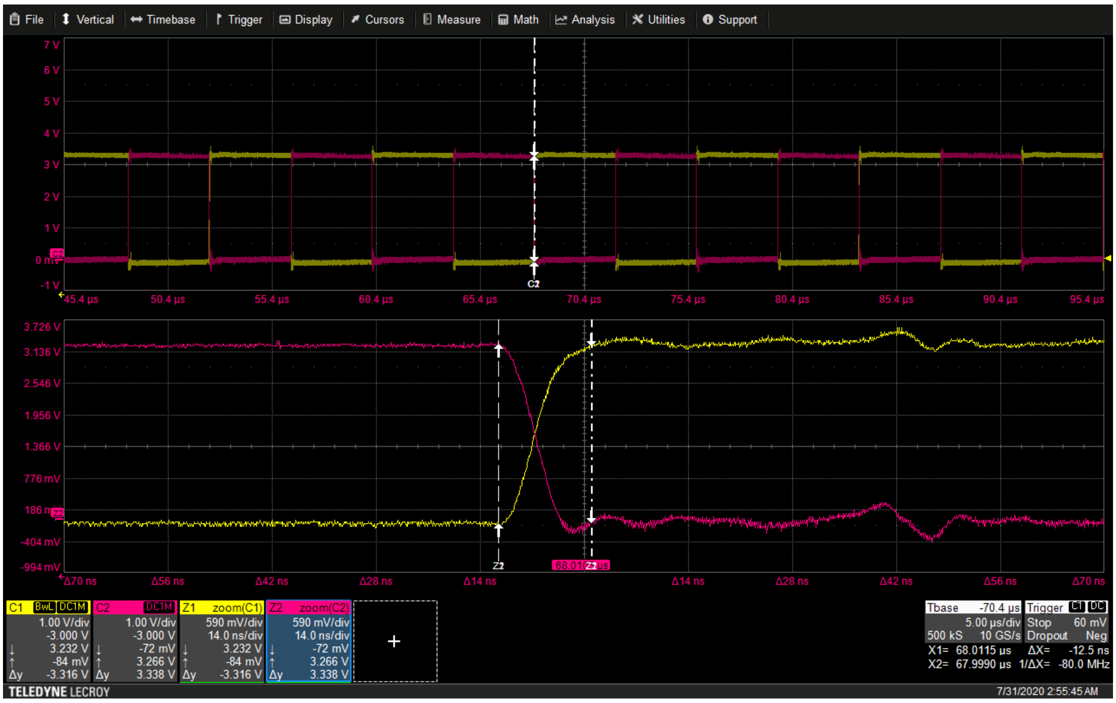


Figure 9: Deadtime under 11Vout/A Condition

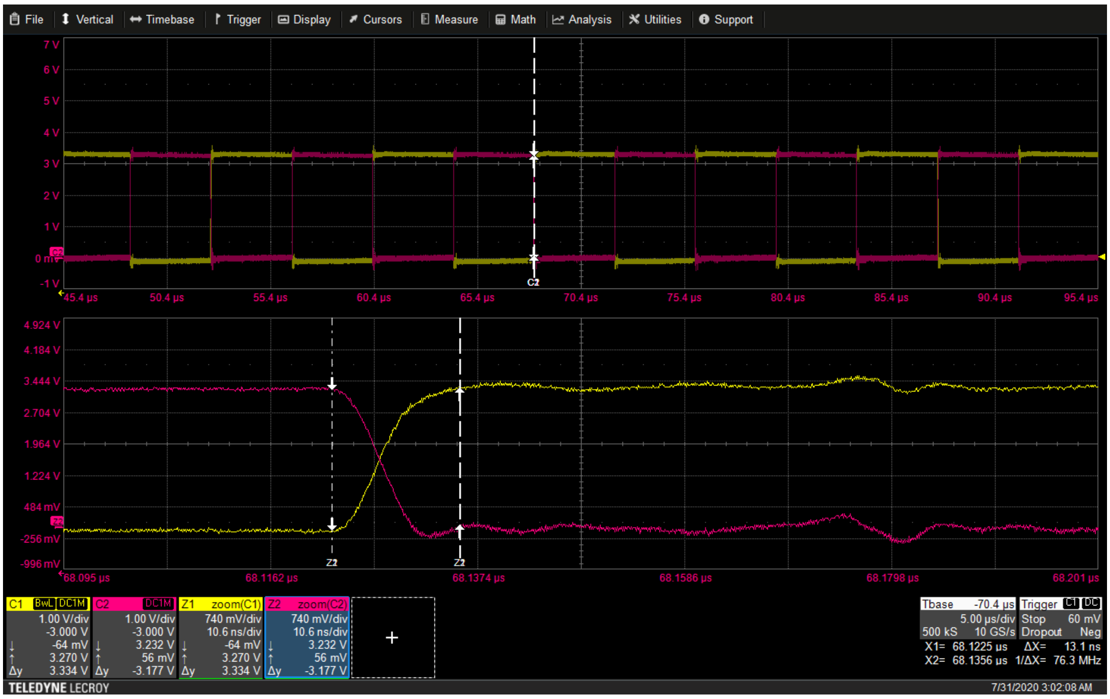


Figure 10: Deadtime under 9Vout/0A Condition

6.2.9 Demodulation

NU1020 is integrated Low-Error-Rate digital demodulation internally. It provides 3 kinds of demodulation methods. Below figures show the demodulation example, it captures the demodulation transitions of of “01”, “71”, “51”, and “03”.

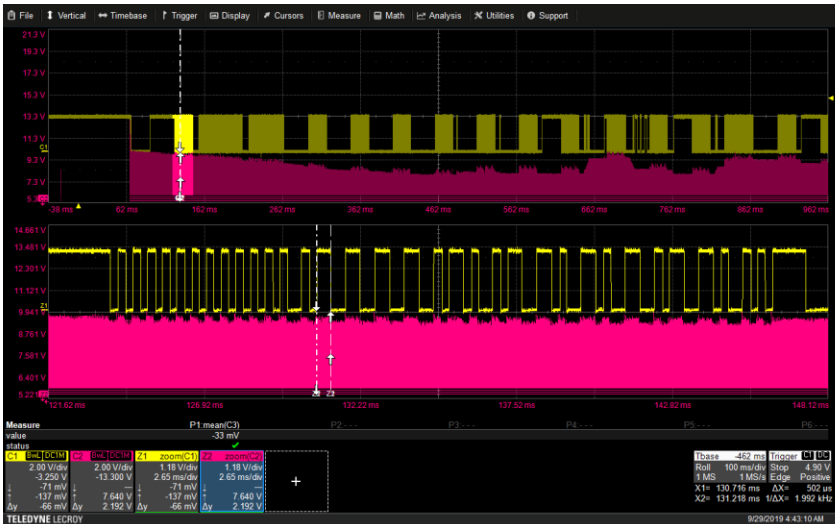


Figure 11: “01” Demodulation

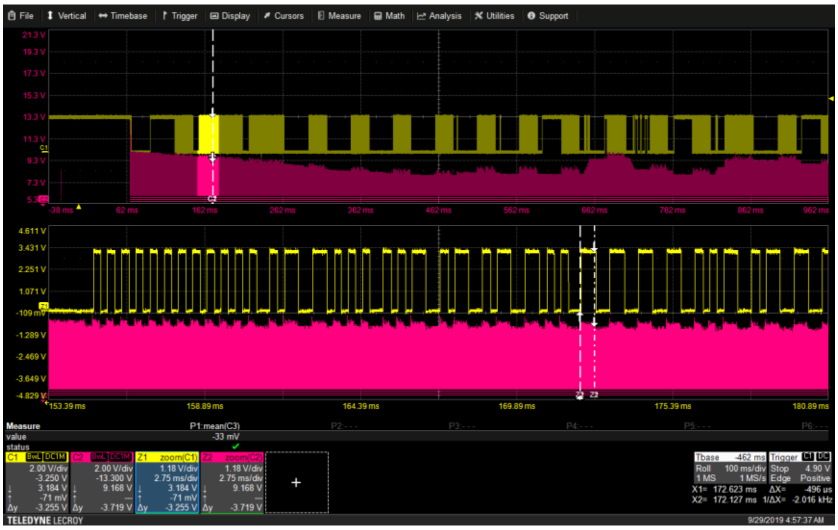


Figure 12: “71” Demodulation

Figure 13: “51” Demodulation

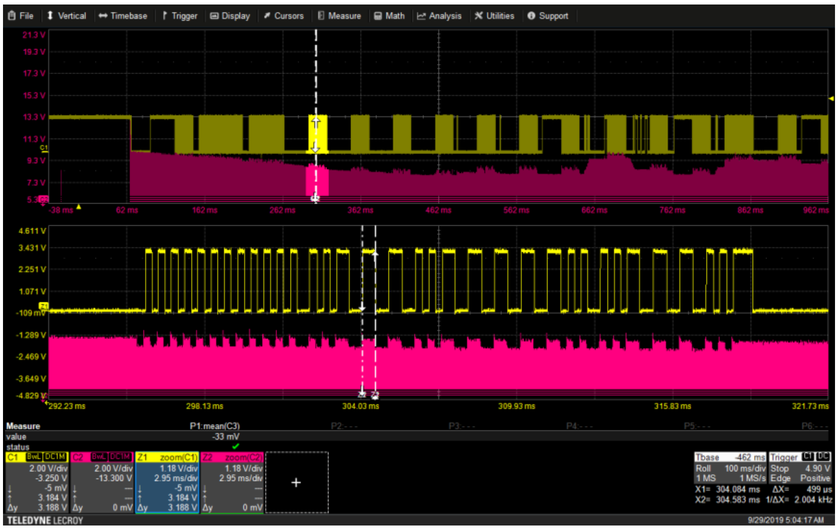
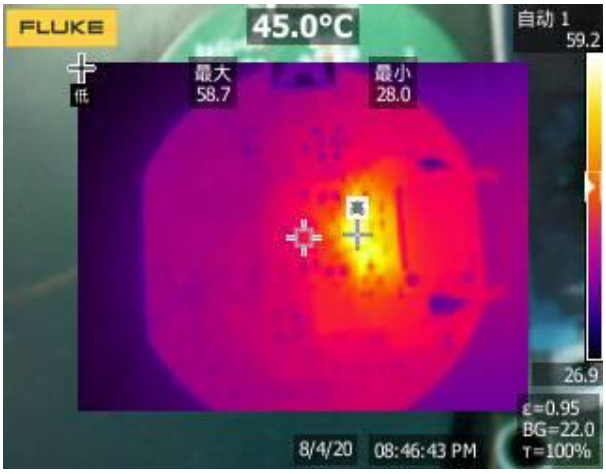


Figure 14: “03” Demodulation

6.2.9 Thermal Evaluation

Place the NU1009 EVM and Rx EVM in an environment without forced air ventilation. Align POWER RECEIVER and POWER TRANSMITTER coil center to center, separated by 4mm vertical distance.
Set the Rx with 10W full load, power on the NU1009 EVM board. Monitor the thermal performance with the thermal imager.
After operation 0.5hours, and takes the thermal photograph as below, and the hottest point 58.7℃ is the NU1009.



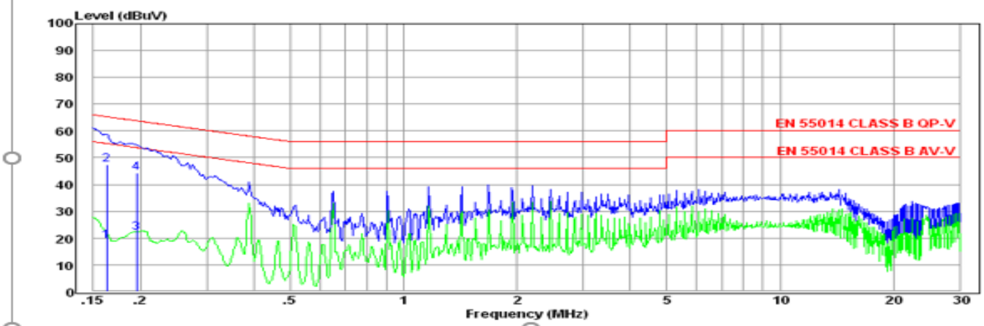
Test Condition：9.37Vin/10W/0.5 Hour, Open Frame Ambient：28℃

6.2.7 EMI

The EMI test includes conducted emission (CE) and radiated emission (RE). The following figures show the test result of the EVM with S10 PLUS.

6.2.7.1 CE

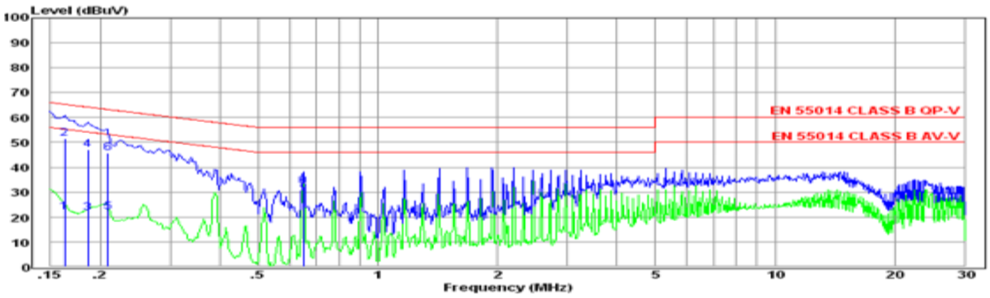
CEL



Freq MHz	Reading dBuV	C.F dB/m	Result dBuV/m	Limit dBuV/m	Margin dB	Detector
0.16	9.43	9.62	19.05	55.30	36.25	Average
0.16	37.83	9.62	47.45	65.30	17.85	QP
0.20	12.26	9.58	21.84	53.80	31.96	Average
0.20	34.89	9.58	44.47	63.80	19.33	QP

CE Neutral / RX: RX: S10 PLUS/ Adapter: QC3.0 12V

Figure 15: CE test Result (Line)

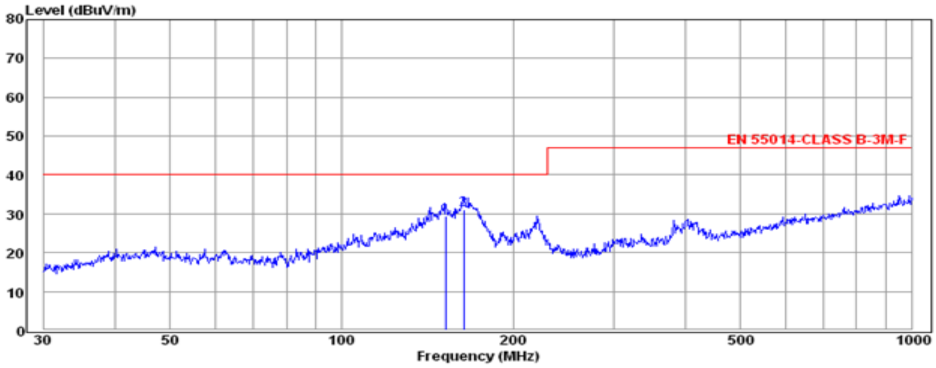


Freq MHz	Reading dBuV	C.F dB/m	Result dBuV/m	Limit dBuV/m	Margin dB	Detector
0.16	12.49	9.62	22.11	55.30	33.19	Average
0.16	42.07	9.62	51.69	65.30	13.61	QP
0.19	12.15	9.59	21.74	54.20	32.46	Average
0.19	37.59	9.59	47.18	64.20	17.02	QP
0.21	12.29	9.58	21.87	53.23	31.36	Average
0.21	36.29	9.58	45.87	63.23	17.36	QP
0.65	21.22	9.68	30.90	46.00	15.10	Average
0.65	22.65	9.68	32.33	56.00	23.67	QP

CE Neutral / RX: RX: S10 PLUS/ Adapter: QC3.0 12V

Figure 16: CE test Result (Neutral)

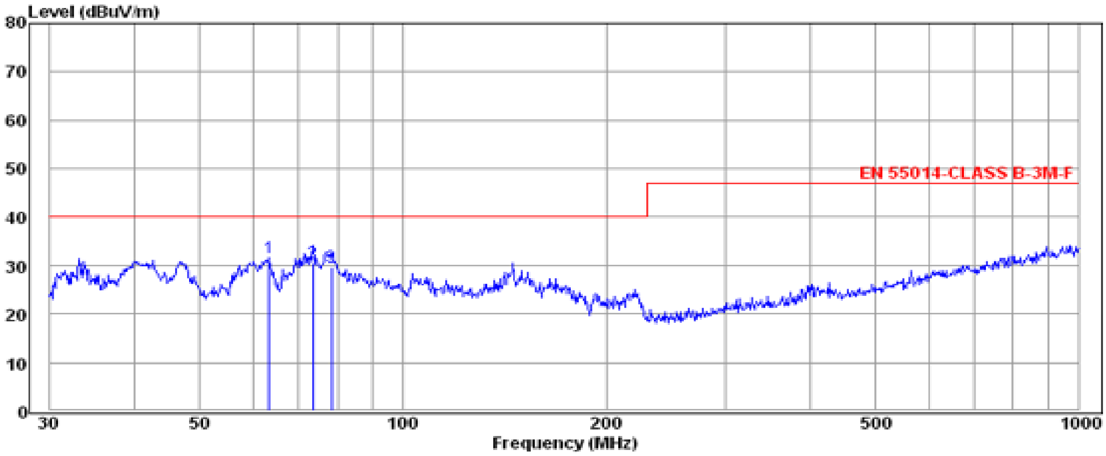
6.2.7.2 RE



Freq MHz	Reading dBuV	C.F dB/m	Result dBuV/m	Limit dBuV/m	Margin dB	Detector
152.13	18.21	11.18	29.39	40.00	10.61	QP
163.76	19.40	11.71	31.11	40.00	8.89	QP

CE Neutral / RX: RX: S10 PLUS/ Adapter: QC3.0 12V

Figure 17: RE test Result



Freq MHz	Reading dBuV	C.F dB/m	Result dBuV/m	Limit dBuV/m	Margin dB	Detector
63.31	17.43	14.08	31.51	40.00	8.49	QP
73.62	20.00	10.52	30.52	40.00	9.48	QP
78.41	19.70	10.09	29.79	40.00	10.21	QP

CE Neutral / RX: RX: S10 PLUS/ Adapter： QC3.0 12V

Figure 18: RE test Result