40W WPC Wireless Transmitter Evaluation Module Using NU15XX and NU1020

The evaluation module (EVM) is a 5V-20V input and supports up to 40W output, high efficiency WPC wireless power transmitter using NU15XX controller and NU1020 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 40W output.

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1 Applications

The NU15XX and NU1020 evaluation module is a complete solution for 40W wireless transmitter compliant with WPC V1.2.4. The features and key performance of this EVM are as following:

- Input voltage: 5V to 20V, connecting to adapter which can support QC3.0/PD
- Work with any WPC compliant 15W EPP or 40W(Private Protocal)
- Efficiency up to 86.5%
- 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 MPA2-type transmitter coil
- 1 LED for indicating power on, power transferring or fault conditions
- 1 GPIO for fan extended

2 Schematic and Bill of Materials

2.1 Schematic

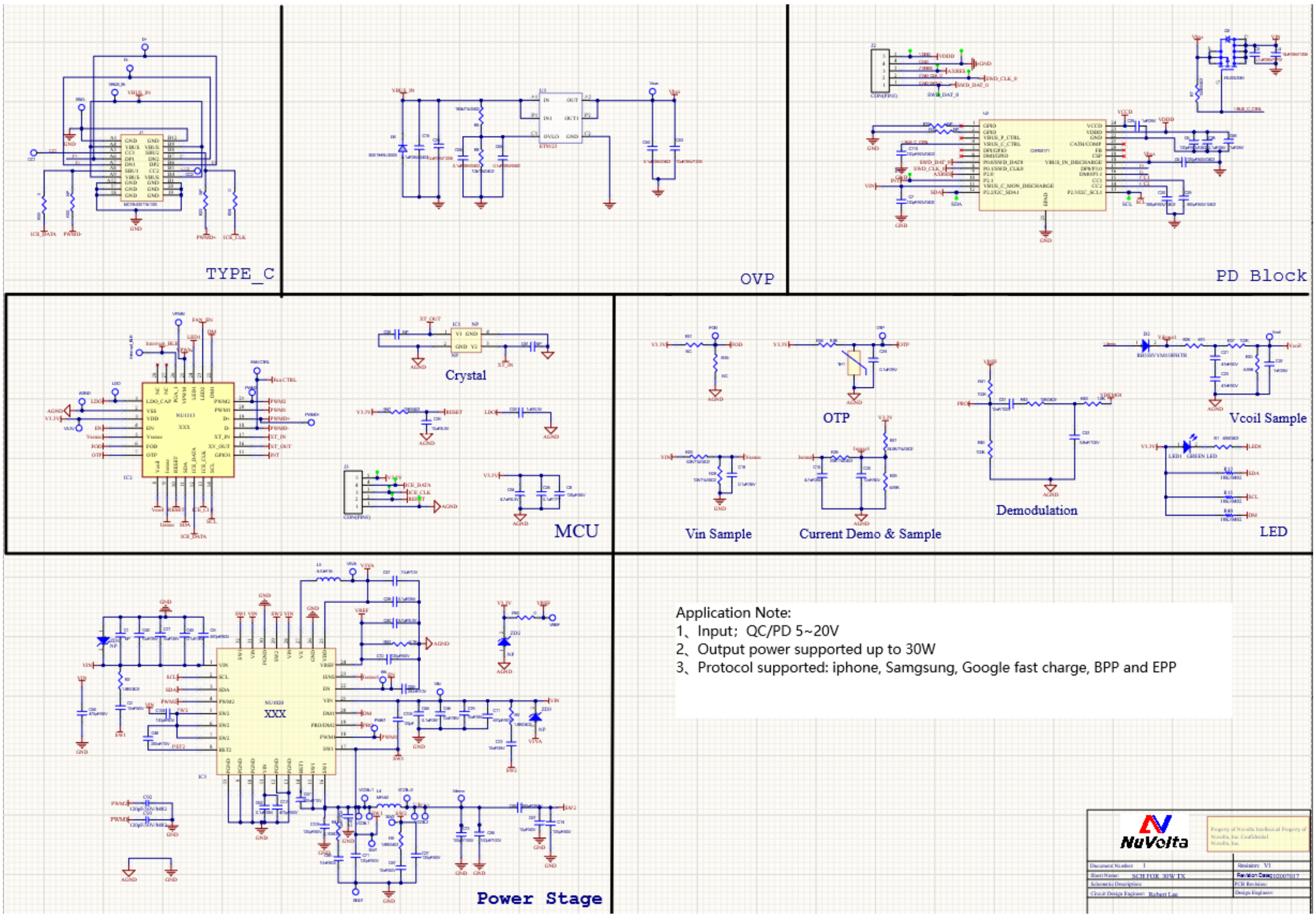


Figure 1： Schematics of NU15XX and NU1020 EVM

2.2 Bill of Materials

Table 1: Bill of Materials

Designator	Description	Quantity
C39 C41 C97 C94	CAP CER/10pF/50V/5%/C0G/0402	3
C13 C73 C95 C96 C106 C107 C108 C109	CAP CER/100pF/100V/5%/C0G/0402	8

C5 C6 C7 C8 C10 C14 C27 C61 C71 C92 C93 C98 C99 C103 C104 C105 C113	CAP CER/120pF/50V/5%/C0G/0402	19
C29 C30	CAP CER/390pF/50V/10%/X7R/0402	2
C9 C11 C12 C55	CAP CER/470pF/50V/5%/C0G/0402	4
C22	CAP CER/1nF/25V/10%/X7R/0402	1
C19	CAP CER 4.7nF 25V X7R 10% 0402	1
C32	CAP CER 6.8nF 100V 5% COG 0603	1
C2 C20 C46 C47 C72	CAP CER 10nF 50V 10% X7R 0402	5
C31	CAP CER 10nF 100V 10% X7R 0603	1
C21 C23	CAP CER 47nF 50V 10% X7R 0402	2
C24 C35 C38	CAP CER 100nF 25V 10% X7R 0402	3
C3 C15 C18 C28 C43 C44 C50 C52 C64 C65	CAP CER 100nF 35V 10% X7R 0402	10
C48 C53 C69	CAP CER 220nF 50V 10% X5R 0603	3
C25 C33 C68	CAP CER 1uF 25V 10% X5R 0402	3
C34 C40	CAP CER 4.7uF 25V 10% X5R 0603	2
C36 C37	CAP CER 10uF 25V 20% X5R 0603	2
C4 C26 C42 C45 C63 C77 C79	CAP CER 10uF 50V 10% X5R 1206	7
C49	250nF/250V/CBB	1
R24 R33 R50	RES 0R 0402 5%	3
R2 R3 R4 R9	RES 1.8R 0603 1%	4
R26	RES 470R 0402 1%	1
R1	RES 499R 0402 1%	1
R43	RES 1.8K 0402 1%	1
R29 R30	RES 4.99K 0402 1%	2
R52	RES 5.1K 0402 1%	1
R34	RES 8.2K 0402 1%	1
R8 R13 R15 R28 R40 R42 R47	RES 10K 0402 1%	7
R25 R53	RES 20K 0402 1%	2
R21	RES 24.9K 0402 1%	1
R23	RES 62K 0402 1%	1
R7 R27 R41 R46	RES 100K 0402 1%	4
R6	RES 180K 0402 1%	1

L3	4.7uH/1A 0805 SPH3015H6R8MT_2	1
LED1	Green LED 20mA,70mW,130mcd 0603	1
U3	ET9523 BGA1.36*0.96	1
U4	SY6884 BGA1.36*0.96	1
U2	CYPD3171	1
D2	Diode Schottky 0.2W 150V 0.2A RB558VYM150FHTR SMA	1
D6	DIO SW 150mA 100V S32 THRU S320 SMA	1
Q2	RU30L30M P-CH 30V 30A DFN3X3	1
	NTC/10k/B=3380	1
L4	MP A2 L=10uH	1
J1	16PIN 6.4MM	1
IC1	Crystal 3225SMD 24MHZ 12PF 10PPM	1
IC2	NU1513	1
IC3	NU1020	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 4 layer, 1-oz board. All component are on the top side. The signal and Power tracks are on both top and layer3 side. The more complete ground placed on the layer 2 and bottom side to avoid noise and to dissipated heat.

The following is the reference PCB design of EVM.

- Layer 1: Component placement, major routing and as much ground plane as possible
- Layer 2: a clean analog-ground plane under NU15XX and power-ground plane as possible
- Layer 3: major routing, power trace and as much ground plane as possible
- Layer 4: a clean power-ground plane under NU1020

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.
- Try to place power routing symmetrically from Vbus to Vin of NU1020.
- Keep analog-ground plane and power-ground plane low impedance. Use as much copper as possible and an appropriate number of Vias.
- Separate the analog-ground plane from the power-ground plane and use only one point to join them. Or use two layers for two grounds and take vias as close as possible.

- 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. Refer to figure 2.

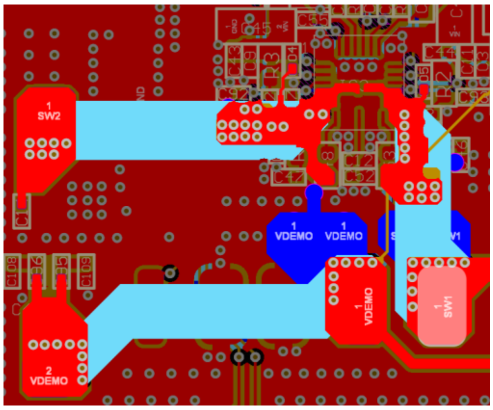


Figure 2： SW2 part of NU1020 EVM

- The full-bridge power stage is integrated in NU1020, so thermal Vias are needed to provide a thermal path for the NU1020. Refer to figure 3.

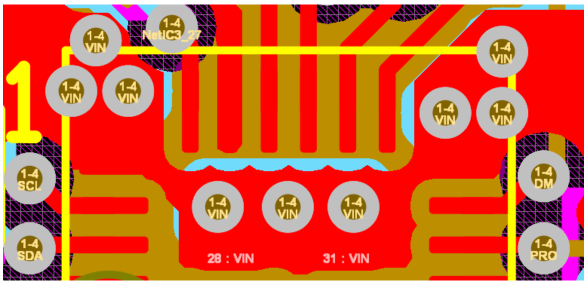


Figure 3： VIN part of NU1020 EVM

- Place small capacitor close to the coil pad to minimize EMI noises. Refer to figure 4.

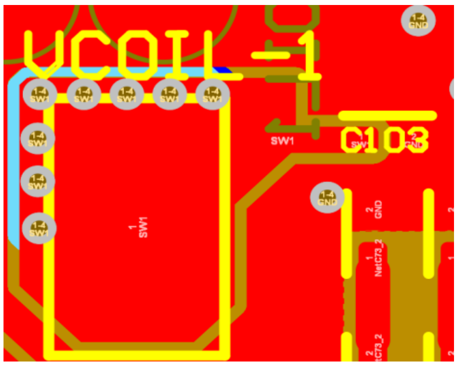


Figure 4： Little capacitor C103 near coil pad

- [1]~[11]Place small-size input capacitors as close as possible between the Vin pin and PGND pin besides the NU1020. These capacitors can effectively filter out high-frequency noises due to their low ESR and ESL. Please refer to C1 C42 C77 C43 C9 C52 C12 C44 C45 C79 and C11 in Figure 4.

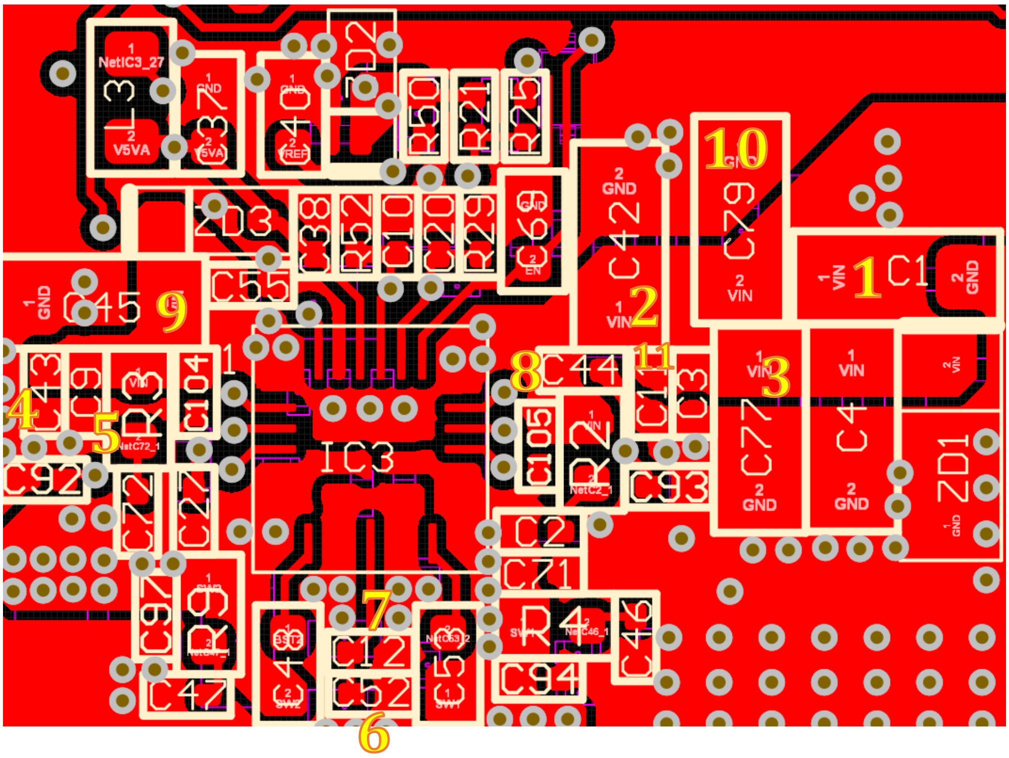


Figure 5: Capacitor location around NU1020

- [12]~[19]Make the snubber loop as small as possible. Please refer to R4 C46, R9 C47, R2 C2 and R3 C72 in Figure 6.

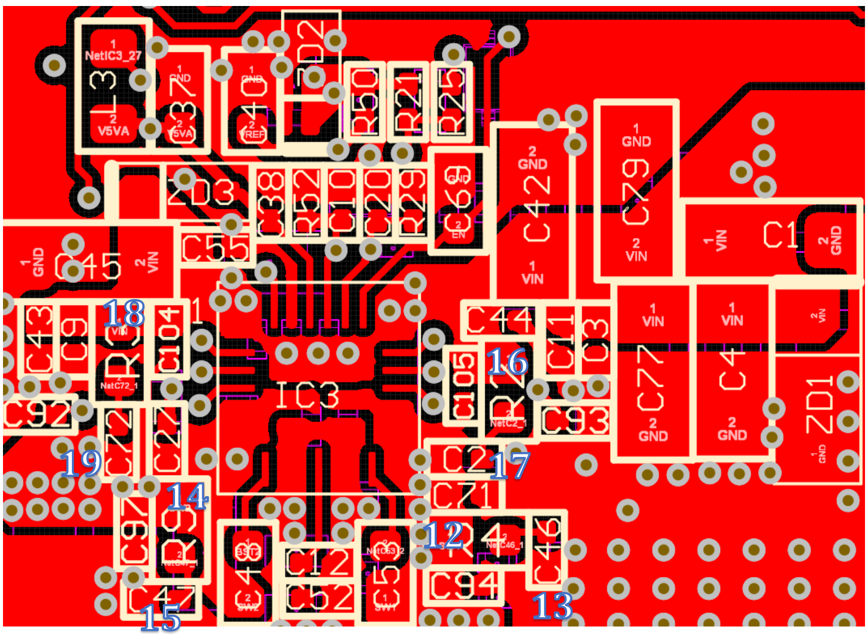


Figure 6: Capacitor location around NU1020

3.2 SMT Examples

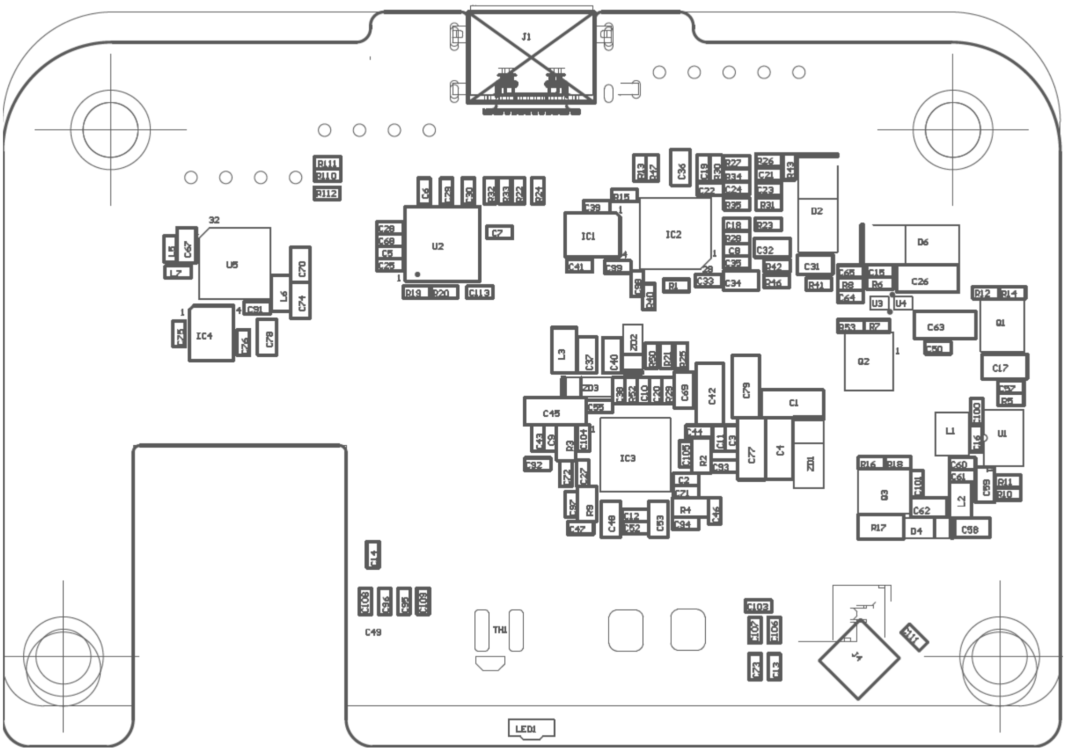


Figure 7: Top layer

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
VUSB_IN	USB Type-C Connector of Input	Vcoil	Vcoil sense input of MCU
VIN	Input of NU1020	Vbus	Input voltage after OVP IC
INT	PD IC interrupt	ICE_CLK	Reuse Debug Pin
D+/D-	QC Control Signal	ICE_DATA	Serial Wired Debugger Data
CC1/CC2	PD Control Signal	SW1/SW2	The Middle Point of Bridge
RESET	External Reset Input	VBUS	Input Voltage of Power Stage NU1020
OTP	Thermal Protection Voltage	EN	Power Stage NU1020 Enable
PWM1/2	PWM Signal of Power Stage's Driver	VREF	Bias voltage for sampling
V5VA	VCC of NU1020	VCOIL	The Voltage of LC Tank
V3.3V	VCC of NU15XX	VCOIL1	SW1(The Middle Point of Bridge)
GND	Power Ground	VCOIL2	The Voltage of LC Tank

5 Electrical Performance Specifications

Table 3 is a summary of the NU1020 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
PD Adaptor	20V PD Adapter
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 20V from 0 to 2.5A load. The limited current must be over 2.5A.

The equipment is used to simulate the application environment of the EVM. The key performance of the EVM can be evaluated and captured by using the equipment system. All the electronic equipment must be well grounded in order 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. Green LED1 should flash 3 times then turn off.
Observe the current value on the Power Source or multi-meter to check the standby input current.

6.2.2 Power Transfer

Keep the adapter 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.
• Typical output voltage is about 19 V, and the output current is from 0 mA to 2.5 A.
• Probe waveform with oscilloscope on the test point SW1 or SW2 when power transfer is active; the frequency should be between 110 kHz and 145 kHz and the switching duty cycle must be within 40% to 50% in all 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 and stop charging when the error happens.

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^{o}C(0.45v), the over-temperature protection is enabled, and the PWM outputs are disabled. The system will restart when the temperature drops below 45^{o}C(1.15v).

6.2.5 Efficiency

TEST CONDITION:
Adapter: XIAOMI-AD65G

Power receiver : RX: EVM110 V3.0 Coil : 9uH 253mΩ(100kHz) Vout : 19V

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 84.1% with full load, and the highest efficiency is over 86% when load is 1.82A.

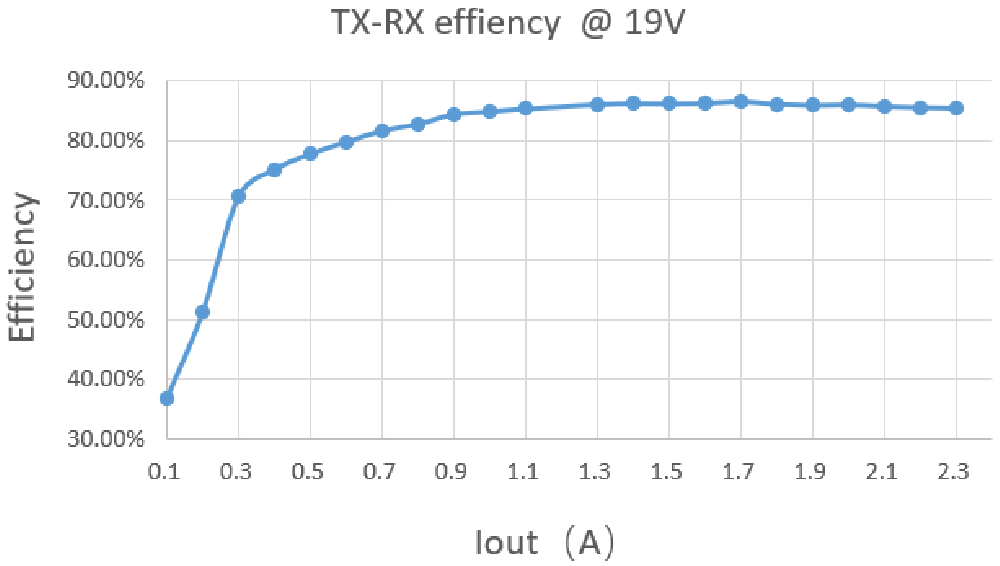


Figure 6: 40W Efficiency of NU15XX and NU1020 EVM

Table 4: Efficiency Test Result

dz/mm	Vin/V	Iin/A	Vout/V	Iout/A	Po/W	η/100%
4mm	17.130	0.297	18.710	0.1	1.871	36.78%
4mm	17.630	0.411	18.560	0.2	3.712	51.23%
4mm	16.980	0.467	18.650	0.3	5.595	70.56%
4mm	17.610	0.564	18.650	0.4	7.460	75.11%
4mm	17.910	0.670	18.650	0.5	9.325	77.71%
4mm	18.120	0.775	18.660	0.6	11.196	79.73%
4mm	18.210	0.879	18.660	0.7	13.062	81.60%
4mm	18.340	0.984	18.660	0.8	14.928	82.72%
4mm	18.460	1.081	18.700	0.9	16.830	84.34%
4mm	18.540	1.187	18.660	1.0	18.660	84.79%
4mm	18.600	1.292	18.630	1.1	20.493	85.28%
4mm	18.740	1.503	18.630	1.3	24.219	85.99%
4mm	18.810	1.608	18.620	1.4	26.068	86.19%
4mm	18.870	1.717	18.600	1.5	27.900	86.11%
4mm	19.000	1.820	18.630	1.6	29.808	86.20%
4mm	19.050	1.919	18.600	1.7	31.620	86.50%
4mm	19.130	2.035	18.610	1.8	33.498	86.05%
4mm	19.210	2.142	18.590	1.9	35.321	85.84%
4mm	19.280	2.245	18.600	2.0	37.200	85.94%
4mm	19.360	2.352	18.580	2.1	39.018	85.69%
4mm	19.430	2.456	18.550	2.2	40.810	85.52%

6.2.6 Current Sense Accuracy

NU1020 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 multimeters to capture the real input current and the ISNS pin voltage which represents the current sense without calibration through an equation. The Figure 7 and table 5 shows the 15W efficiency of EVM with the receiver (NuVolta EVM) under different load condition.

Table 6: Current Sense Accuracy Test

Iin: Input Current;
Isense: The sense current through NU1020;

Iin(A)	Isense (A)	Pout(W)	err (A)
0.207	0.189	0.62	-8.70%
0.305	0.285	2.25	-6.56%
0.404	0.386	3.84	-4.46%
0.506	0.48	6.35	-5.14%
0.608	0.583	8.28	-4.11%
0.705	0.677	10.02	-3.97%
0.803	0.778	11.76	-3.11%
0.901	0.878	13.46	-2.55%
1.002	0.979	15.2	-2.30%
1.105	1.08	16.98	-2.26%
1.204	1.18	18.7	-1.99%
1.303	1.284	20.44	-1.46%
1.403	1.385	22.07	-1.28%
1.505	1.492	23.96	-0.86%
1.602	1.584	25.53	-1.12%
1.703	1.691	27.36	-0.70%
1.803	1.791	29.04	-0.67%
1.901	1.887	30.66	-0.74%
2.001	1.987	32.44	-0.70%
2.105	2.097	34.18	-0.38%
2.207	2.198	35.96	-0.41%
2.306	2.288	37.64	-0.78%
2.406	2.4	39.53	-0.25%
2.442	2.437	40.11	-0.20%

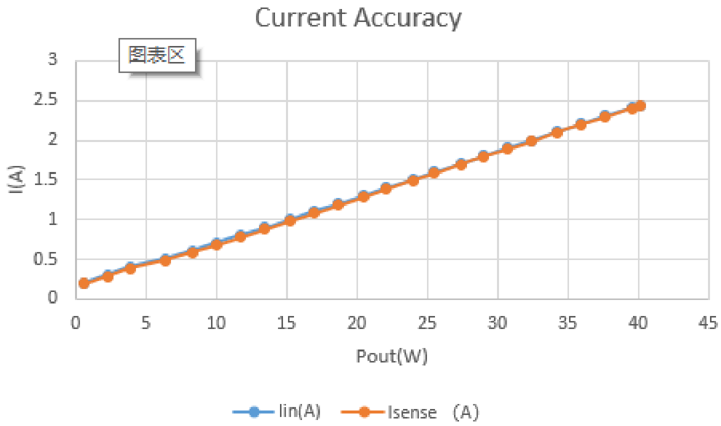


Figure 8: Current Sense Curve under Full Load Range

6.2.7 Foreign Object Detection (FOD)

The NU15XX and NU1020 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 preset in NU15XX, the power transfer will be stopped.

Here, it measures the Q value under different condition. Open means no objects above the EVM, and FO#1 0.5 RMB coin, FO#2 1 RMB coin. Test condition: PD 65W adapter with Z=2mm(distance between FO and coil).

Table 6: Q Detection under Different Condition

Condition	Q Value
OPEN	84
FO#1	20
FO#2	11

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.
NU1020 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 9 and Figure 10 captures the deadtime between the primary FETs under open load and full load conditions.

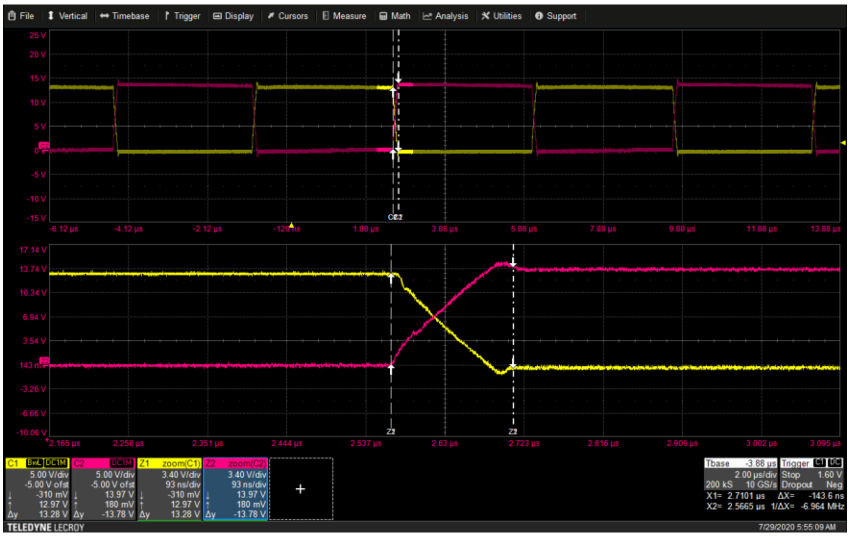


Figure 9: Deadtime under RX Vout 19V/0A Condition

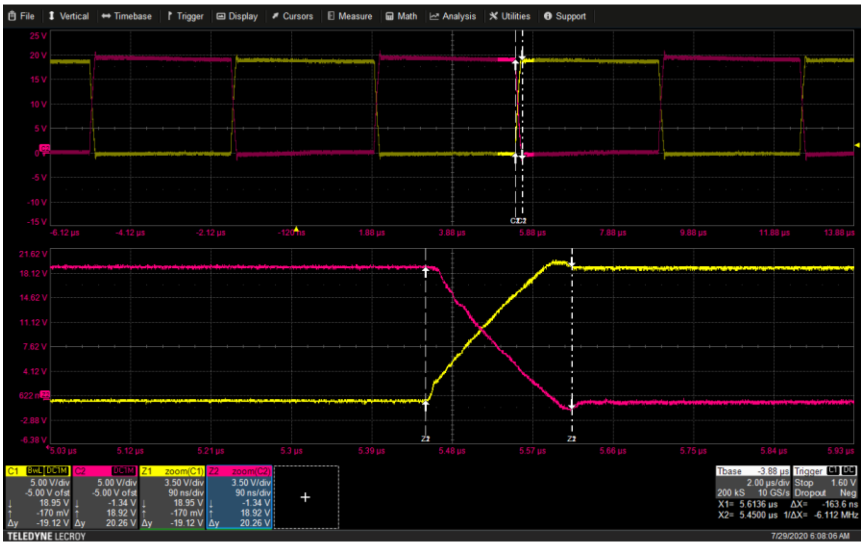


Figure 10: Deadtime under 19Vout/2.2A Condition

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”.

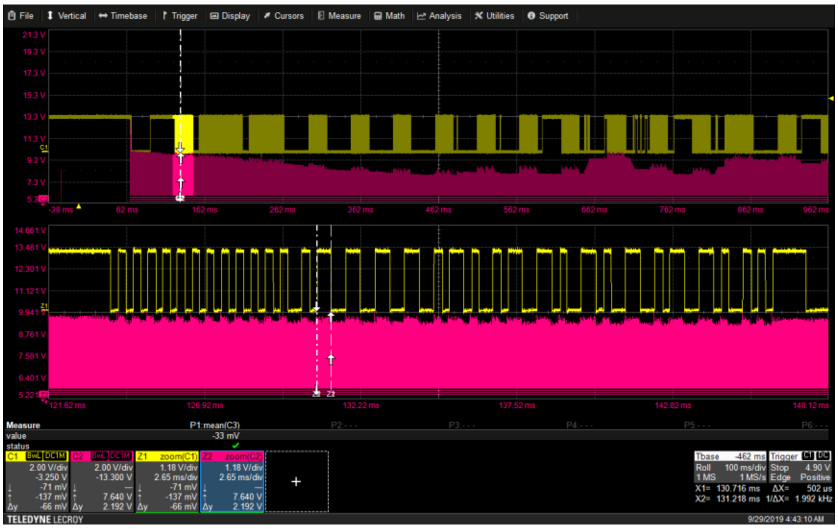


Figure 11: “01” Demodulation

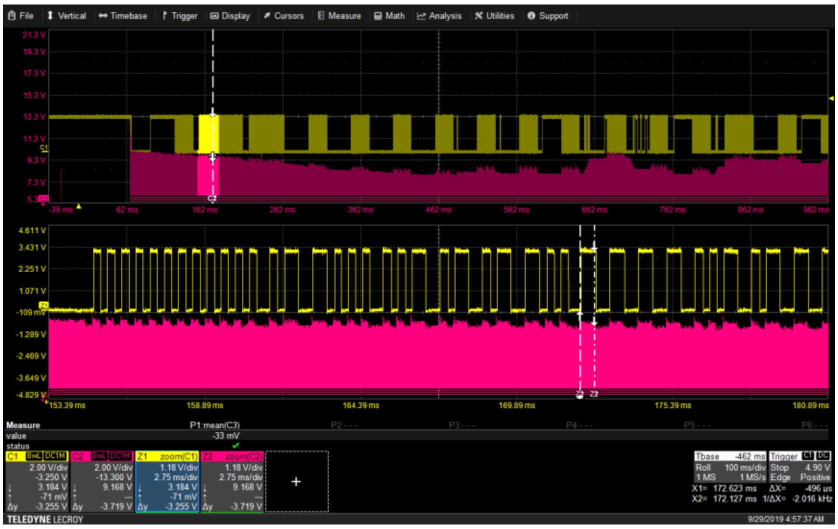


Figure 12: “71” Demodulation

Figure 13: “51” Demodulation

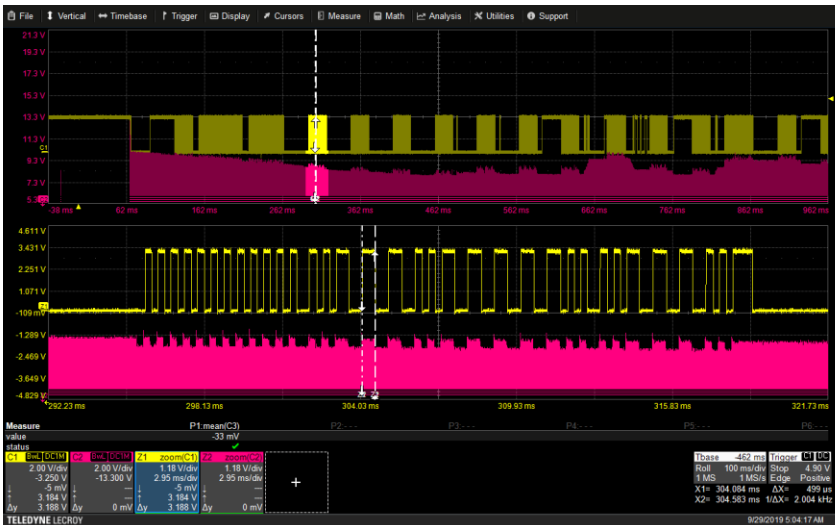
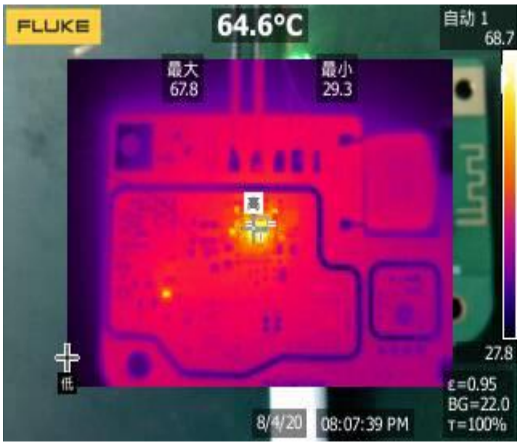


Figure 14: “03” Demodulation

6.2.9 Thermal Evaluation

Place the NU1020 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 40W full load, power on the NU1020 EVM board. Monitor the thermal performance with the thermal imager.
After operation 5min, and takes the thermal photograph as below, and the hottest point 67.8℃ is the NU1020.

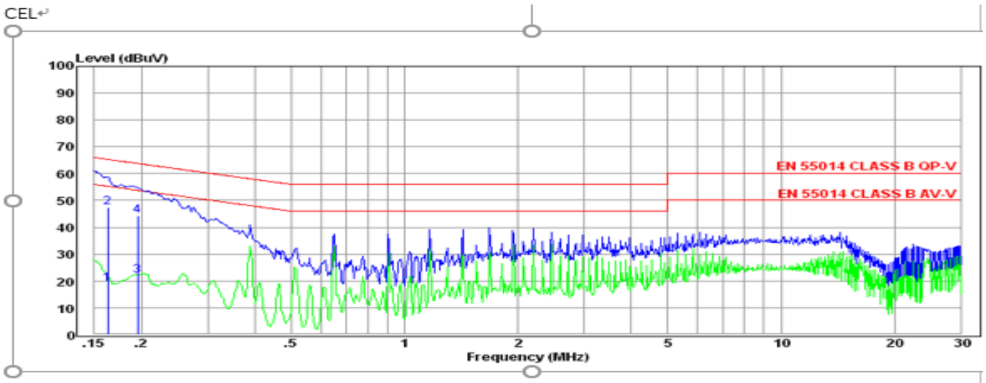


Test Condition： 20Vin/40W/5min/Z=4mm, Open Frame Ambient： 28℃

6.2.10 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.

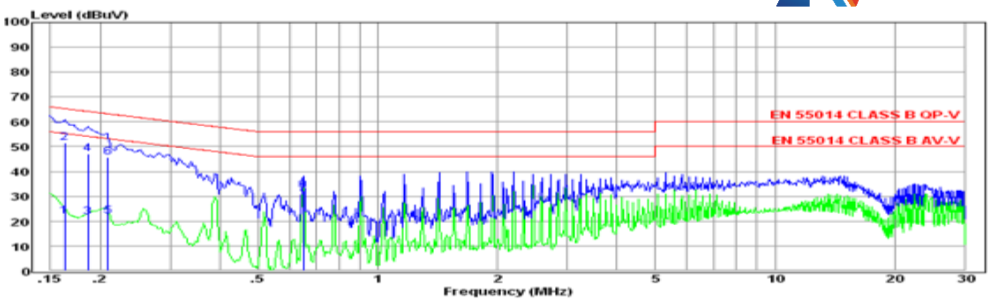
6.2.10.1 CE



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 14: CE test Result (Line)

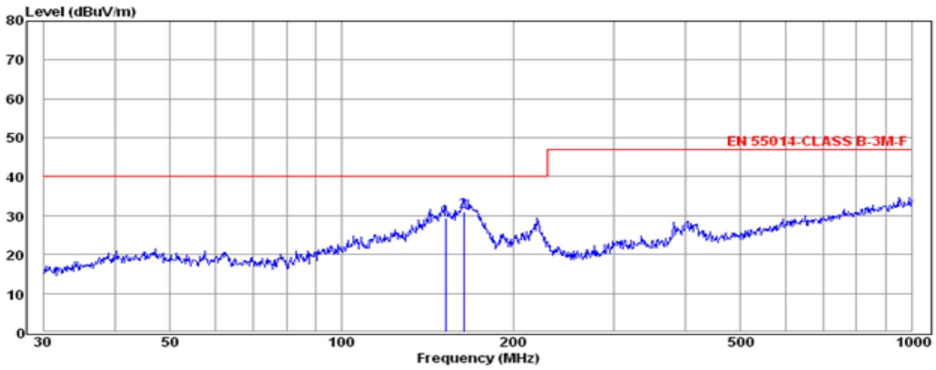


Freq MHz	Reading dBuV	C.F dB/m	Result dBuV/m	Limit dBuV/m	Margin dB	Detector
0.16	12.49	9.62	22.11	55.30	33.19	Average
0.16	42.07	9.62	51.69	65.30	13.61	QP
0.19	12.15	9.59	21.74	54.20	32.46	Average
0.19	37.59	9.59	47.18	64.20	17.02	QP
0.21	12.29	9.58	21.87	53.23	31.36	Average
0.21	36.29	9.58	45.87	63.23	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 15: CE test Result (Neutral)

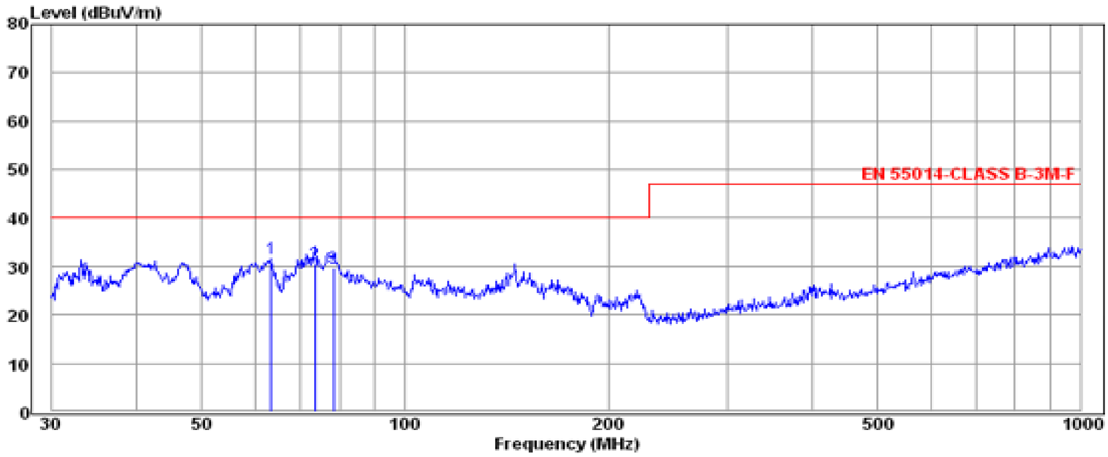
6.2.10.2 RE



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 16: 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 17: RE test Result