GNP2130TEC-1-EVK-001
User's Guide

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User’s Guide

＜High Voltage Safety Precautions＞

◇ Read all safety precautions before use

Please note that this document covers only the **GaN power devices** evaluation board (**GNP2130TEC-1-EVK-001**) and its functions. For additional information, please refer to the datasheet.

To ensure safe operation, please carefully read all precautions before handling the evaluation board

Depending on the configuration of the board and voltages used,

Potentially lethal voltages may be generated.

Therefore, please make sure to read and observe all safety precautions described in the red box below.

Before Use

[1] Verify that the parts/components are not damaged or missing (i.e. due to the drops).
[2] Check that there are no conductive foreign objects on the board.
[3] Be careful when performing soldering on the module and/or evaluation board to ensure that solder splash does not occur.
[4] Check that there is no condensation or water droplets on the circuit board.

During Use

[5] Be careful to not allow conductive objects to come into contact with the board.
[6] **Brief accidental contact or even bringing your hand close to the board may result in discharge and lead to severe injury or death.**
Therefore, DO NOT touch the board with your bare hands or bring them too close to the board.
In addition, as mentioned above please exercise extreme caution when using conductive tools such as tweezers and screwdrivers.
[7] If used under conditions beyond its rated voltage, it may cause defects such as short-circuit or, depending on the circumstances, explosion or other permanent damages.
[8] Be sure to wear insulated gloves when handling is required during operation.

After Use

[9] The ROHM Evaluation Board contains the circuits which store the high voltage. Since it stores the charges even after the connected power circuits are cut, please discharge the electricity after using it, and please deal with it after confirming such electric discharge.
[10] Protect against electric shocks by wearing insulated gloves when handling.

This evaluation board is intended for use only in research and development facilities and should by handled **only by qualified personnel familiar with all safety and operating procedures.**
We recommend carrying out operation in a safe environment that includes the use of high voltage signage at all entrances, safety interlocks, and protective glasses.

GaN Power Device

GNP2130TEC-1-EVK-001 User’s Guide

Overview

This user’s guide describes how to use evaluation board (EVK) to evaluate GaN power devices for DFN8080.
In order to take advantage of good switching performance and heat dissipation for GaN power devices, it is necessary to evaluate them under various drive conditions, but these evaluations are not easy.
The EVK has been released to evaluate the switching performance.

Features

- Compact size 100W PFC + LLC converter
  (104 mm x 53mm x 23mm)
- High power density: 1.18 W/cc = 19.5 W/inch3
- Peak efficiency: 95.0% with V_{IN}=230V
- No-load power consumption: <0.3W

Application

- Telecom
- Industry
- Robot

1. EVK appearance and topology

The EVK appearance is shown in Figure 1.

The GaN power devices are connected to the daughter board shown in the red frame of the Figure 1.

In addition, the GaN power devices are connected with the cold plate to cool GaN, but a cooling fan is not used.

As shown in Figure 2., the EVK topologies are two blocks (a diode bridge PFC and an LLC circuit).

To optimize the efficiency, the transformer secondary of the LLC circuit is a synchronous rectifier.

Figure 1. EVK appearance

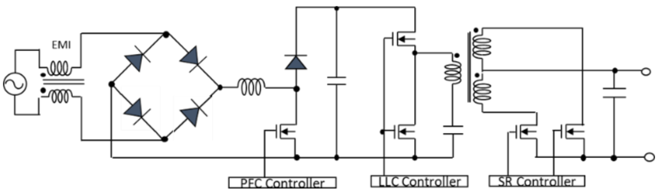


Figure 2. Circuit topology

2. EVK specification

The EVK specifications are shown in table 1.

The input AC voltage is covered world-wide value, and the load regulation of output voltage is stabilized.

For operation up to 150 W, a separate fan for forced air cooling is required.

Table 1. EVK specifications

Spec.	Value
Input voltage	90 – 264 Vac
Output Voltage	24V
Max power	150W (forced air)
	100W (convection)
Size	104 mm x 53mm x 23mm
Power Density	1.18 W/cc = 19.5 W/inch3
No-load power consumption	< 0.3 W

3. Circuit diagram

The motherboard circuit diagram on the EVK is shown in Figure 3., and the daughterboard circuit diagram is shown in Figure 4.

Control IC is on the motherboard and gate drive circuit is on the daughterboard.

The motherboard and daughterboard are connected by solder. (CB1)

The drain, gate and source of the GaN power devices (Q301, Q401, Q402) are connected with the motherboard, and gate drive circuits have speedup capacitor, (C11, C401, C402) gate protection circuits and gate voltage clamp circuits.

To protect thermal issue, the daughterboard has thermal protection part (NTC3).

To adjust the gate resistance, please change R11, R13, R401, R402, R403, R404.

Note: If the gate resistance is made too small, there is concerns regarding circuit malfunction and control IC loss.

The zener diode ZD, ZD401, ZD402 are connected to clamp gate voltage.

The Gate clamp voltage Vz can be modified by changing the zener diode.

If Vz is changed to a larger one, the voltage between gate and source is applied beyond the breakdown voltage of 6V.

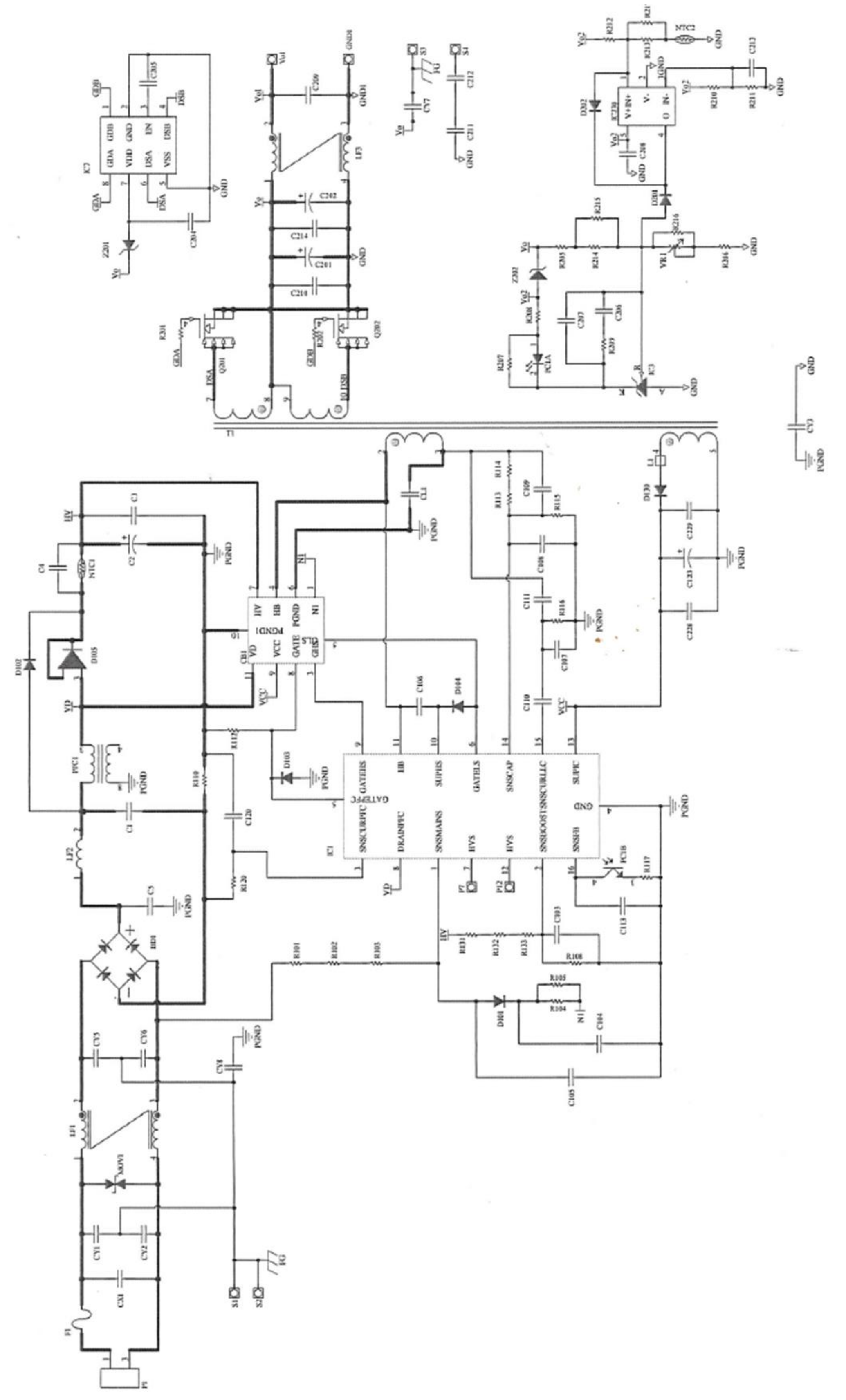


Figure 3. Motherboard circuit diagram

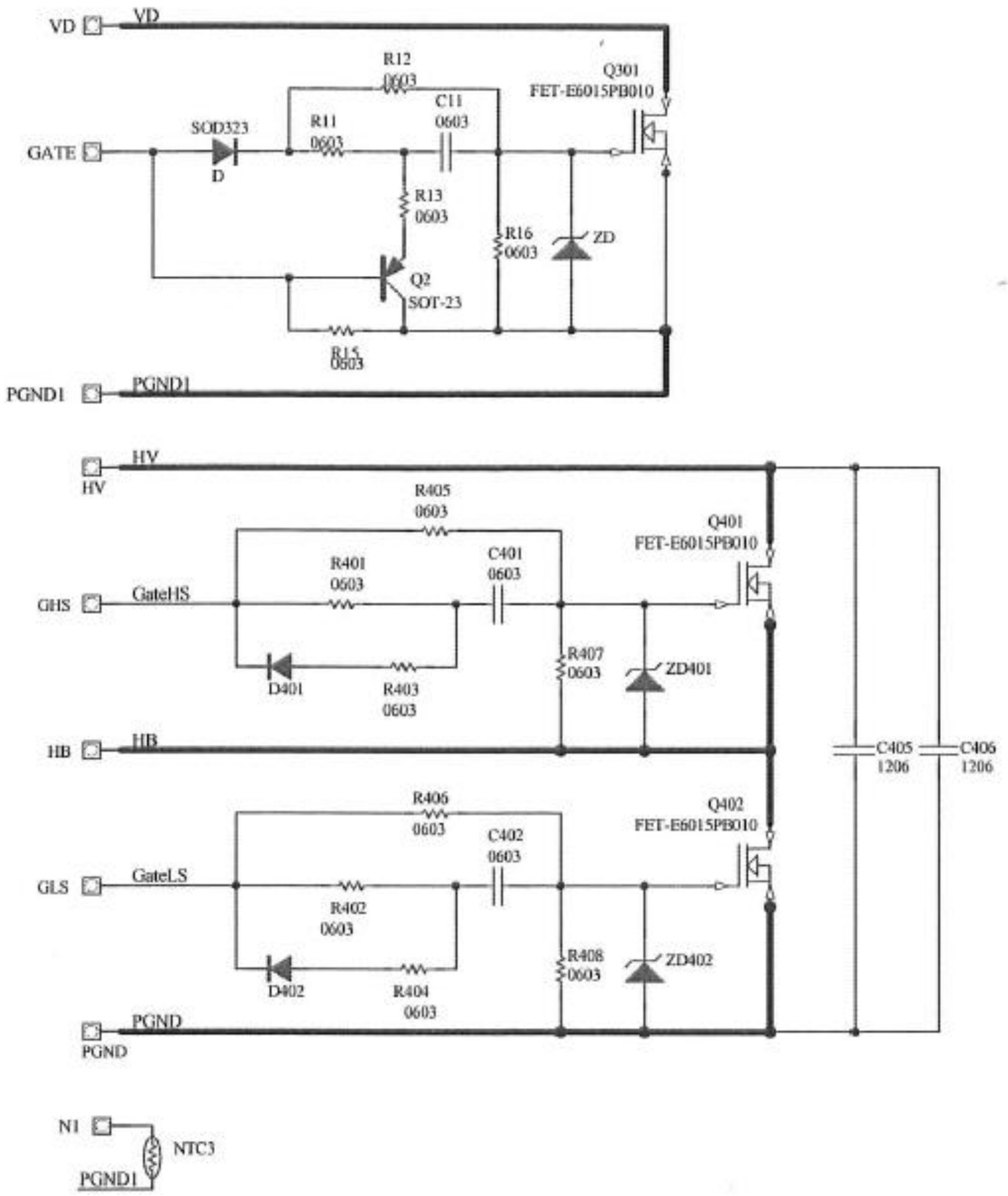


Figure 4. Daughterboard circuit diagram

4. BOM lists

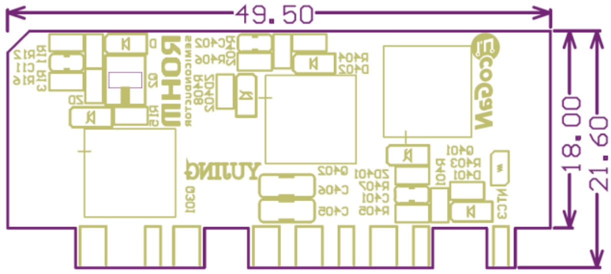
Table 2. and Table 3. show BOM lists for the motherboard and daughterboard.

Table 2. EVK motherboard BOM list

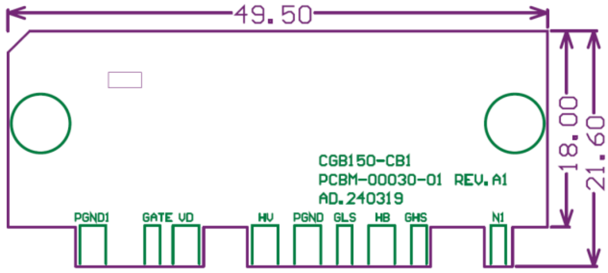
Part Description	Specification	Part No
SMPS,ROHM	CGB150-024-000 (24V@6.25A)	
SMGS,ROHM	CGB150-024-000 (24V@6.25A)	
DUMMY SEMI,ROHM	CGB150-1X	
PCB-FR4,ROHM#FR-4,@A1,DE-LI,SM#R-500 3R	CGB150,104.14*53.34mm,1.2T,2L,2oz,TG≧130°C	PCB1
CONNECTOR,DONG SHUN#A3963WV2-3P-D	NYLON_66,94V-0,p7.92mm,NATURAL,-25~85°C,E144544	P1
FUSE-TL-BOX,LITTELFUSE#39213150000	T3.15A/250V,8.5*4*8mm,-40~125°C,E67006	F1
CAP-X2,NISTRONICS#MPR0310K684C3000000	0.68uF/310V,18*18.5*7.5mm,p15mm,±10%,-40~110°C,E338685	CX1
MOV,TKS#TVR10511KLM	320VAC/410VDC,φ10mm,92J,-40~125°C,E314979	MOV1
CHOKE-C,AITIOU#YJ02T1495A1210140,@4.0	T1495A121-01,2.8mH,φ0.6mm,35.5T,2P,CLAPBOARD,CLASS B	LF1
DIODE-BG,SHINDENGEN#US8KB80R-7000,D6K	8A/800V,sg200A,-55~150°C	BD1
CHOKE-D,YJ#13261-101V300210,@1.0	DS127125,169uH,φ0.6mm,58T,1P,CLASS B,E237684	LF2
CAP-MEF,NISSEI#MPA0450K1550A460000	1.5uF/450V,18*15.4*9mm,p15mm,±10%,-40~105°C	C1
CHOKE-P,YJ#11261-386V500111,@1.1	QE20-19V(8P),L~240uH±10%,CLASS B,E237684	PFC1
DIODE-GN,LISION#S3MG,SMC	3A/1000V,-55~150°C	D102
HEATSINK,YJ#AL,@A1,TEYEN	ILB150-HS1,50*16*2mm	HS1
SCREW-ISOF,BIFU#WH MS+N3X4-D5.2T0.8	M3*0.5*4mm-D5.2T0.8,NI,SW,130°C	FOR CB1&HS1
INS-SC,YJ#SI5117,@A,KANG YANG	50.8*17*0.3mm,E153203	FOR HS1
SMGS,ROHM,CB1	CGB150-PFC+LLC MOS,CB1	CB1
PCB-FR4,ROHM#FR-4,@A1,DE-LI,SM#R-500 3R	CGB150-CB1,49.5*21.6mm,1.2T,2L,2oz,TG≧130°C	PCB-CB1
DIODE-FT,LISION#1SS355G,SOD-323	100mA/80V,4nS,-55~150°C	D,D401,D402
RES-SMD,TA-I TECH#RM06FTN1000,0603	100Ω,±1%,75V,1/10W,-55~155°C	R11,R401,R402
RES-SMD,WALSIN#WR06X6201FTL,0603	6.2KΩ,±1%,75V,1/10W,-55~155°C	R12,R405,R406
RES-SMD,TZAI_YUAN#SMD08055R1F,0805	5.1Ω,±1%,150V,1/8W,-55~155°C	R13,R403,R404
CAP-SMD,HEC#C0603X332K050T,0603	332/50V,0603,X7R,±10%,-55~125°C	C11,C401,C402
BJT-PNP,LISION#MMBT2907AG-T3R,SOT-23	-600mA/-60V,-55~150°C	Q2
DIODE-ZN,NEXPERIA#PZU5.6B2,SOD323F	5.6V(5.49~5.73V)/0.31W,-65~150°C	ZD,ZD401,ZD402
RES-SMD,TA-I TECH#RM06FTN1803,0603	180KΩ,±1%,75V,1/10W,-55~155°C	R16,R407,R408
MOSFET-N,ROHM#GNP2130TEC-Z,DFN8080CK	13.5A/650V,130mΩ,150°C	Q301,Q401,Q402
CAP-SMD,YAGEO#CC1206KKX7RCBB103,1206	103/1KV,1206,X7R,±10%,-55~125°C	C405,C406
THERMISTOR-NTC,TKS#TSM1A104F4101HZ	100KΩ,±1%,0603,SMD,-40~150°C	NTC3
DIODE-SK,HESTIA POWER#H3D065S008,TO-252-2L	11A/650V,-55~175°C	D105
THERMISTOR-NTC,TKS#SCK102R55AMSY	2.5Ω,Imax~5A,±20%,φ10mm,p5mm,E138827	NTC1
CAP-E,ELITE#MJ2W680MNN1625M	68uF/450V,φ16*25mm,rc0.98A,10000h,-40~105°C	C2
CAP-SMD,HEC#C1206X471K102T,1206	471/1KV,1206,X7R,±10%,-55~125°C	C3,C4,C111
RES-SMD,RALEC#LR251222R040F4,2512	40mΩ,±1%,2W,-55~170°C	R110
RES-SMD,YAGEO#RC0805FR-07180KL,0805	180KΩ,±1%,150V,1/8W,-55~155°C	R112
CAP-SMD,HEC#C0603X222K050T,0603	222/50V,0603,X7R,±10%,-55~125°C	C110,C120
RES-SMD,RALEC#RTT051000FTP,0805	100Ω,±1%,150V,1/8W,-55~155°C	R120
RES-SMD,TZAI_YUAN#SMD12066M8F,1206	6.8MΩ,±1%,200V,1/4W,-55~155°C	R101,R102,R103,R131,R132,R133
DIODE-FT,LISION#1SS355G,SOD-323	100mA/80V,4nS,-55~150°C	D101
CAP-SMD,WALSIN#0603N471J500CT,0603	471/50V,0603,NPO,±5%,-55~125°C	C105,C113
CAP-SMD,YAGEO#CC0603JRNPO9BN681,0603	681/50V,0603,NPO,±5%,-55~125°C	C104
RES-SMD,TZAI_YUAN#SMD0603130KF,0603	130KΩ,±1%,50V,1/10W,-55~155°C	R108
IC-LLC+PFC,NXP#TEA2016AAT,SO16	19.0V,500KHz,RESONANT-HB,-40~150°C	IC1
CAP-SMD,YAGEO#CC0805KKX7R9BB474,0805	474/50V,0805,X7R,±10%,-55~125°C	C106,C228
DIODE-SF,SIRECT#ES1006FL,SOD-123S	1A/600V,35nS,-55~150°C	D104,D130
CAP-SMD,HEC#C0603X103K050T,0603	103/50V,0603,X7R,±10%,-55~125°C	C107
CAP-SMD,YAGEO#CC0603KRX7R9BB472,0603	472/50V,0603,X7R,±10%,-55~125°C	C108
RES-SMD,YAGEO#RC0603FR-0720KL,0603	20KΩ,±1%,75V,1/10W,-55~155°C	R115
RES-SMD,TZAI_YUAN#SMD12062M4F,1206	2.4MΩ,±1%,200V,1/4W,-55~155°C	R113,R114
CAP-SMD,YAGEO#CC1206JKNPOCBN330,1206	33p/1KV,1206,NPO,±5%,-55~125°C	C109
CAP-E,NCC#ELE-500ELL470MF111	47uF/50V,φ6.3*11mm,rc0.19A,10000h,-40~105°C	C123
RES-SMD,YAGEO#RC0603FR-070RL,0603	0Ω,±1%,75V,1/10W,-55~155°C	L1
IC-OPTO,EVERLIGHT#EL1018-VG,4PLSOP	130~260CTR,-55~110°C,E214129	PC1
TERMINAL,KANG YANG#PCB-26,TIN PLATED BRASS	15A,M3*0.5P,7.9*13.2*0.8	Vo1,GND1
SCREW-ISOP,BIFU#PH MS+FS+N 3X8-D6	M3*0.5*8mm-D6,NI,SW+FW,130°C	FOR Vo1,GND1
CAP-Y1,TDK#CD70-B2GA221KYAKA/#CD70-B2GA221KYPKA	220pF/400V,±10%,p10mm,-40~125°C,E37861	CY1,CY2,CY5,CY6
CAP-Y1,TDK#CD70ZU2GA102MYPKA	1000pF/400V,±20%,p10mm,-40~125°C,E37861	CY3,CY8
CAP-PEF,KEMET#R76QI2180DQ40J	0.018uF/1KV,18*11*5mm,p15mm,±5%,-55~105°C	CL1
RES-SMD,TZAI_YUAN#SMD080518KF,0805	18KΩ,±1%,150V,1/8W,-55~155°C	R104
RES-SMD,TZAI_YUAN#SMD0805200KF,0805	200KΩ,±1%,150V,1/8W,-55~155°C	R105
RES-SMD,TZAI_YUAN#SMD060315RF,0603	15Ω,±1%,50V,1/10W,-55~155°C	R116
CAP-SMD,YAGEO#CC0603JRNPO9BN681,0603	681/50V,0603,NPO,±5%,-55~125°C	C103
RES-SMD,TZAI_YUAN#SMD0805510RF,0805	510Ω,±1%,150V,1/8W,-55~155°C	R117
XFMR-LLC,YJ#11261-385V500211,@1.1	QE23C-19V(10P),L~820uH±10%,LK~110uH±10%,CLASS B,E237684 (150W-24V)	T1
MOSFET-N,FETek#FKBA8048,PRPAK5X6	60A/80V,6.5mΩ,-55~150°C	Q201,Q202
RES-SMD,YAGEO#RC0805FR-072RL,0805	2Ω,±1%,150V,1/8W,-55~155°C	R201,R202
CAP-FE,UNICON#UPL1V221M0812	220uF/35V,φ8*12mm,rc2.95A,2000h,-55~125°C	C201,C202
CHOKE-C,AITIOU#YJ01T1495C0144,@4.4	T1495C-01,10uH,φ0.8mm,5.5T,2P,CLASS B	LF3
IC-SY,MPS#MP6922DSE-LF-Z,SOIC8	8~24V,-40~125°C	IC7
DIODE-ZN,LISION#BZT52-B3V6G,SOD-123	3.6V(3.53~3.67V)/0.5W,-55~150°C	Z201
DIODE-ZN,LISION#BZT52-B12G,SOD-123	12V(11.76~12.24V)/0.5W,-55~150°C	Z202
CAP-SMD,YAGEO#CC0805KKX7R9BB474,0805	474/50V,0805,X7R,±10%,-55~125°C	C204
CAP-SMD,YAGEO#CC0805JRNPO9BN102,0805	102/50V,0805,NPO,±5%,-55~125°C	C205
CAP-SMD,HEC#C0603X103K050T,0603	103/50V,0603,X7R,±10%,-55~125°C	C206
RES-SMD,YAGEO#RC0805FR-0791KL,0805	91KΩ,±1%,150V,1/8W,-55~155°C	R205
RES-SMD,WALSIN#WR08X9101FTL,0805	9.1KΩ,±1%,150V,1/8W,-55~155°C	R214
RES-SMD,RALEC#RTT031601FTP,0603	1.6KΩ,±1%,75V,1/10W,-55~155°C	R216
RES-SMD,YAGEO#RC0603FR-0710KL,0603	10KΩ,±1%,75V,1/10W,-55~155°C	R206
RES-SMD,TZAI_YUAN#SMD08055K1F,0805	5.1KΩ,±1%,150V,1/8W,-55~155°C	R207
RES-SMD,YAGEO#RC0805FR-072KL,0805	2KΩ,±1%,150V,1/8W,-55~155°C	R208
CAP-SMD,YAGEO#CC0603JRNPO9BN470,0603	47p/50V,0603,NPO,±5%,-55~125°C	C207
IC-REG,LISION#H431CG-T3R,SOT-23	2.495V,±0.5%,-40~125°C	IC3
DIODE-FT,LISION#1SS355G,SOD-323	100mA/80V,4nS,-55~150°C	D201,D202
CAP-SMD,HEC#C0603X104K050T,0603	104/50V,0603,X7R,±10%,-55~125°C	C208,C213
IC-OP,LISION#PS321G-T5L,SOT-23-5L	30V,-40~105°C	IC230
RES-SMD,YAGEO#RC0603FR-0720KL,0603	20KΩ,±1%,75V,1/10W,-55~155°C	R210,R211,R212,R213
RES-SMD,RALEC#RTT038202FTP,0603	82KΩ,±1%,75V,1/10W,-55~155°C	R209,R217
THERMISTOR-NTC,TKS#TSM1A104F4101HZ	100KΩ,±1%,0603,SMD,-40~150°C	NTC2
CAP-Y1,TDK#CD90ZU2GA222MYAKA/#CD90ZU2GA222MYPKA	2200pF/400V,±20%,p10mm,-40~125°C,E37861	CY7
CAP-SMD,HEC#C1206X472K102T,1206	472/1KV,1206,X7R,±10%,-55~125°C	C211
RES-SMD,YAGEO#RC1206FR-0710ML,1206	10MΩ,±1%,200V,1/4W,-55~155°C	C212
CORE-B,CORETECH#K5A RH	φ3.5*1.5*3mm,130°C	FOR C1*2
CORE-B,CORETECH#K5A RH	φ3.5*1.7*3mm	FOR CY1,CY2,CY5,CY6,CY8*2,NTC1*2
LABEL,ROHM,@A	CGB150-024-000 (24V@6.25A)	FOR T1

Table 3. EVK daughterboard BOM list

Part No.	Part Name	Value	Part Description	Manufacture	Size [mm]
R11	WR06X1000FTL	100ohm	RES SMD 1/10W	WAISIN	0603
R12	WR06X6041FTL	6.04kohm	RES SMD 1/10W	WAISIN	0603
R13	RC0606FR-074R75L	4.75ohm	RES SMD 1/10W	YAGEO	0603
R14	WR06X1002FTL	10kohm	RES SMD 1/10W	WAISIN	0603
R15	WR06X1003FTL	100kohm	RES SMD 1/10W	WAISIN	0603
R16	WR06X1000FTL	100ohm	RES SMD 1/10W	WAISIN	0603
R401	WR06X1000FTL	100ohm	RES SMD 1/10W	WAISIN	0603
R402	WR06X1000FTL	100ohm	RES SMD 1/10W	WAISIN	0603
R403	RC0606FR-074R75L	4.75ohm	RES SMD 1/10W	YAGEO	0603
R404	RC0606FR-074R75L	4.75ohm	RES SMD 1/10W	YAGEO	0603
R405	WR06X6041FTL	6.04kohm	RES SMD 1/10W	WAISIN	0603
R406	WR06X6041FTL	6.04kohm	RES SMD 1/10W	WAISIN	0603
R407	WR06X1003FTL	100kohm	RES SMD 1/10W	WAISIN	0603
R408	WR06X1003FTL	100kohm	RES SMD 1/10W	WAISIN	0603
C11	0603B332K500	3300pF	CAP MC SMD 50V K X7R	WAISIN	0603
C401	0603B332K500	3300pF	CAP MC SMD 50V K X7R	WAISIN	0603
C402	0603B332K500	3300pF	CAP MC SMD 50V K X7R	WAISIN	0603
C405	CL31B333KHHSFNE	33nF	CAP MC SMD 630V K X7R	SAMSUNG	1206
C406	CL31B333KHHSFNE	33nF	CAP MC SMD 630V K X7R	SAMSUNG	1206
D	1N4148WS-7-F	V_F=1V (I_F=50mA)	DIO SBD 300mA 100V SOD-323-2P SMD	DIODES	2.9×2.3
D401	1N4148WS-7-F	V_F=1V (I_F=50mA)	DIO SBD 300mA 100V SOD-323-2P SMD	DIODES	2.9×2.3
D402	1N4148WS-7-F	V_F=1V (I_F=50mA)	DIO SBD 300mA 100V SOD-323-2P SMD	DIODES	2.9×2.3
ZD	PZU5.6B2,115 (SOD323F)	V_Z=5.6V	DIO ZEN 0.55W 5.6V SOD-323 SMD	Nexperia	1.25×2.5
ZD401	PZU5.6B2,115 (SOD323F)	V_Z=5.6V	DIO ZEN 0.55W 5.6V SOD-323 SMD	Nexperia	1.25×2.5
ZD402	PZU5.6B2,115 (SOD323F)	V_Z=5.6V	DIO ZEN 0.55W 5.6V SOD-323 SMD	Nexperia	1.25×2.5
Q2	PBSS5240T,215	$V_{CE(sat)}$=-55mV (I_C=-100mA)	TR -40V -2A SOT-23-3P 350 SMD	Nexperia	2.9×2.3
Q301	GNP2130TEC	$R_{DS(on)}$=130mohm	GaN 650V DFN88-8P SMD	ROHM	8.0×8.0
Q401	GNP2130TEC	$R_{DS(on)}$=130mohm	GaN 650V DFN88-8P SMD	ROHM	8.0×8.0
Q402	GNP2130TEC	$R_{DS(on)}$=130mohm	GaN 650V DFN88-8P SMD	ROHM	8.0×8.0
NTC3	TKS#TSM1A104F4101HZ	100kohm	THRMISTOR-NTC SMD 1/10W	Thinking	0603



(a) Top side view

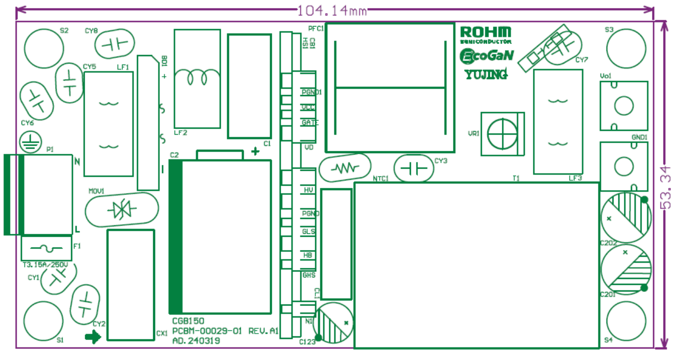


(b) Bottom side view

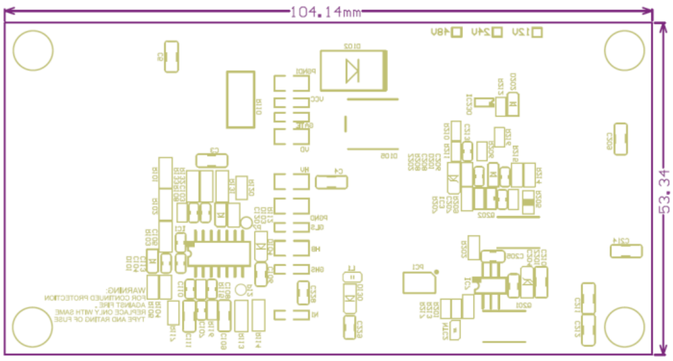
Figure 6. EVK PCB (daughterboard)

5. EVK PCB

Figure 5. shows PCB of motherboard and Figure 6. Shows PCB of daughterboard.



(a) Top side view



(b) Bottom side view

Figure 5. EVK PCB (motherboard)

6. Operation method of EVK

Section 6 describes operation method of EVK to use safety.

6-1. How to connect of EVK

Connect AC input wire and DC output wire.

Please refer to Figure 7, connect the four wires with input AC on the left and output DC on the right.

On the AC input side, the upper terminal is "L" (ungrounded side) and the lower terminal is "N" (grounded side).

Also on the DC output side, the upper terminal is "Positive (OUT side)" and the lower terminal is "Negative (GND side)".

Figure 7. Wiring diagram of EVK

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6-2. ON sequence and OFF sequence

ON sequence and OFF sequence are shown in Figure 8.
To prevent over current in case of short circuit, electric load should be no-load state before turning on the AC input.
No need for another power supply to start up.

After applying the AC voltage of 90 V or higher, confirm that the DC voltage is 24 V.
If the output voltage is swinging from 0V to 24V, the EVK is not operating correctly.

Since poor connection of GaN power devices, poor connection of wiring, or failure of control IC are suspected, please check the EVK.

In OFF sequence, the electronic load is turned off first, and then the AC input is turned off, then a voltage of 380 V is stored in the output electrolytic capacitor C3 of the PFC circuit, thus touching the EVK may cause an electric shock.
Make sure to discharge the C3 with a discharging jig before touching the EVK.

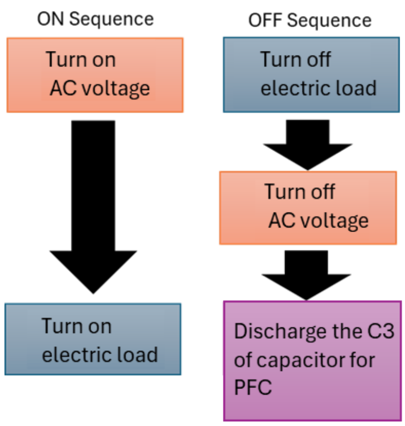


Figure 8. ON sequence and OFF sequence

7. EVK characteristic

7-1. Load regulation

After confirming the wiring and sequence, start measuring the characteristic.
Figure 9. Is shown the road regulation for the EVK.

In output current from 0A to 4.17A (Output power from 0W to 100W), delta-V_{OUT}=0.2V was confirmed.
delta- V_{OUT} is output voltage variation.

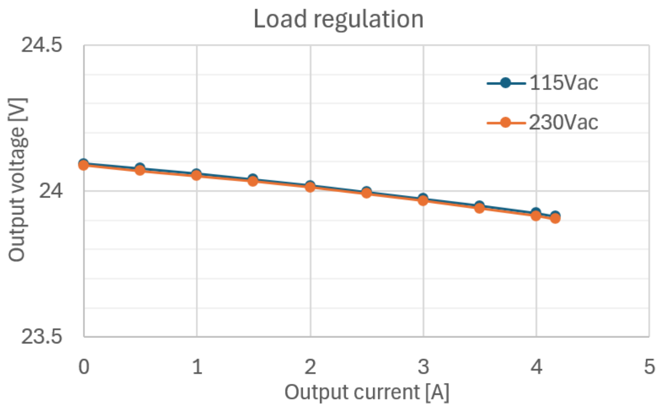
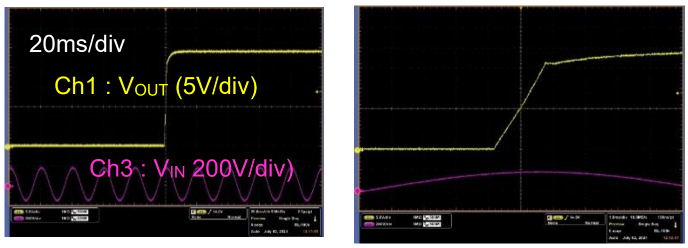


Figure 9. Load reguration

7-2. Startup waveforms

The startup waveforms for an input AC voltage of 115V are shown in Figure 10. (a), (b).
At no-electric load, t_r=1.6ms for the output voltage after the applying of the input voltage.
t_r is the time for the output voltage to rise from 0% to 100%.



(a)Startup waveform (b) Startup waveform

Figure 10. Startup waveforms (V_{IN}=115Vac, I_{OUT}=0A)

7-3. Shutdown waveforms

The shutdown time t_r is defined by the following equation.

$$I_C = I_{OUT} = C_{OUT} * dV_{OUT} / t_f \quad (1)$$

$$t_f = C_{OUT} * dV_{OUT} / I_{OUT} \quad (2)$$

where I_C is the capacitor current; C_{OUT} is the output capacitor C201 and C202; I_{OUT} is the output current; dV_{OUT} is the output voltage
variation; t_f is the time for the output voltage to fall from 100% to 0%.

Calculated with I_{OUT}=0.1A,
t_f=440*10[6]*24/0.1≈106ms

The measurement t_f=110ms with I_{OUT}=0.1A. (Figure 11.)

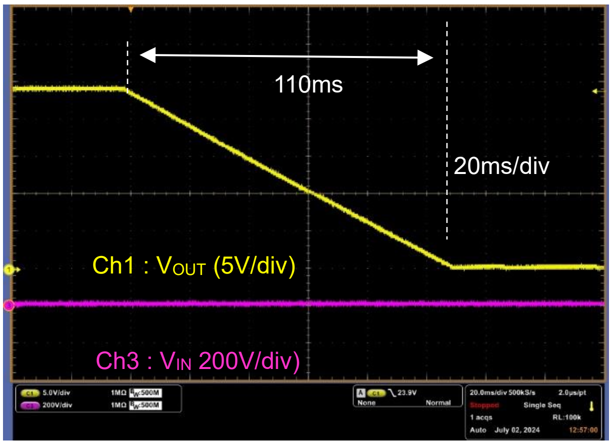


Figure 11. Shutdown waveform (V_{IN}=115Vac, I_{OUT}=0.1A)

7-4. Efficiency

The maximum efficiency of EVK is 95%, as shown in Figure 12.

The average efficiencies are 92.6% for V_{IN}= 115V and 93.4% for V_{IN}= 230V, both of them satisfying the requirement of 88% of standard.

Also, the no-load power is less than 0.3W, satisfying the requirement of 0.5W of standard.

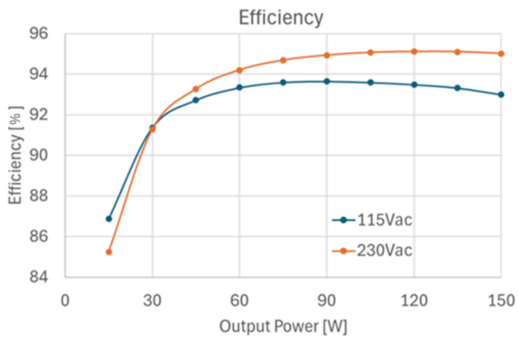


Figure 12. Efficiency of EVK

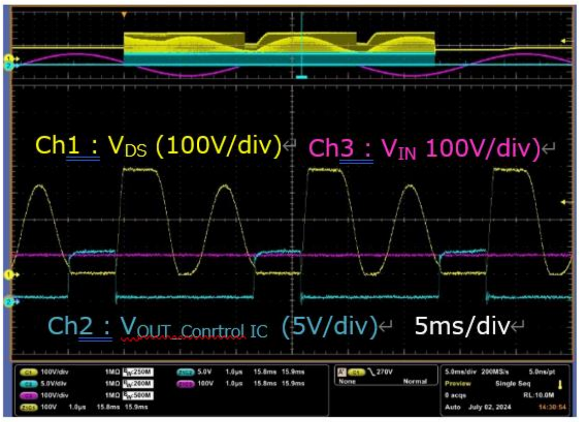
7-5. Switching waveforms

Figure 14. and Figure 15 show the switching waveforms for the PFC circuit.

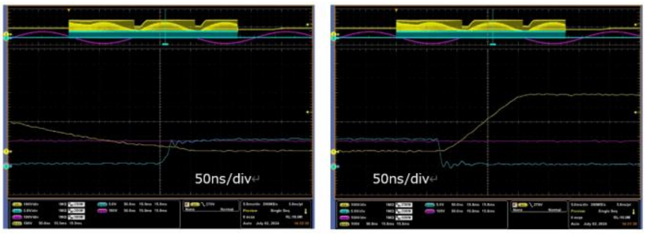
Figure 14. are waveforms of no-load power, there are operating as burst mode

This EVK is decreased the switching loss (turn on loss) since control IC has bottom switching function.

The slew rate dV_{DS}/dt in VDS at no load is dV_{DS}/dt=4V/ns, indicating fast switching at no load.



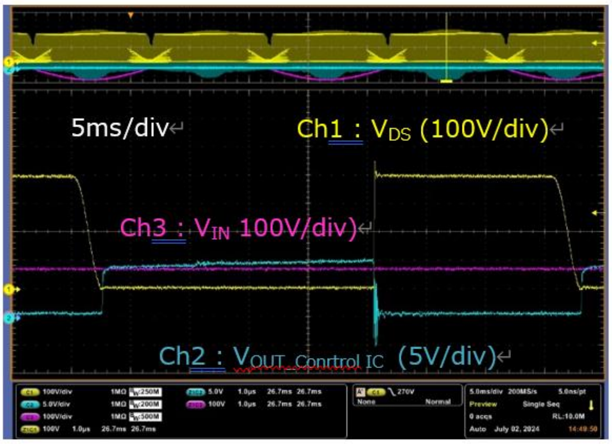
(a) Switching waveform for the PFC circuit



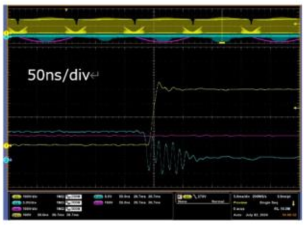
(b) Turn on wave form (c) Turn-off waveform

Figure 14. Switching waveforms for the PFC circuit
(V_{IN}=115Vac, I_{OUT}=0A)

Figure 15. shows switching waveforms of the PFC circuit for 100W power.
Burst mode has been shifted to continuous switching, but bottom switching is still used to reduce switching loss.
The slew rate dV_{DS}/dt in V_{DS} at 100W load is dV_{DS}/dt=47V/ns.



(a) Switching waveform for the PFC circuit



(b) Turn on waveform (c) Turn-off waveform

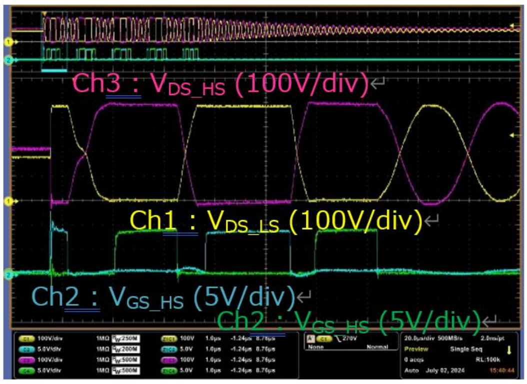
Figure 15. Switching waveforms for the PFC circuit

(V_{IN}=115V, I_{OUT}=4.17A)

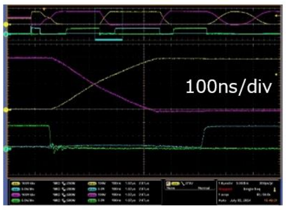
The following waveforms are regarding the LLC circuit.
Figure 16. are no-load waveforms of the LLC circuit.
The LLC circuit also operates in burst mode, just like the PFC circuit.

The slew rate dV_{DS}/dt that no-load of the LLC circuit is 0.9V/ns, this value is smaller than the PFC circuit.
However, the deadtime is 500ns, and fall time t_{f_LLC} of V_{DS} is 360ns.

Thus, the GaN power devices operates ZVS (Zero Volt Switching) in turn-on operation since the GaN power devices have high speed switching.



(a) Switching waveform for the LLC circuit

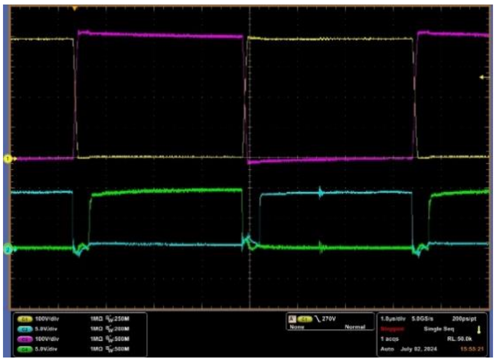


(b) Low side turn-on (c) Low side turn-off

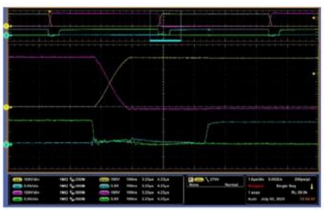
Figure 16. Switching waveforms for the LLC circuit

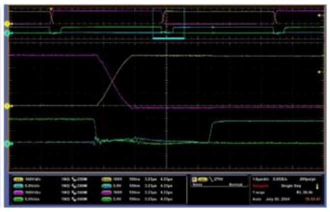
(V_{IN}=115V, I_{OUT}=0A)

Switching waveforms that I_{OUT}=4.17A are shown in Figure 17.



(a) Switching waveform for the LLC circuit





(b) Low side turn-on (c) Low side turn-off

Figure 17. Switching waveforms for the LLC circuit

(V_{IN}=115V, I_{OUT}=4.17A)

7-6. Thermal evaluation result

The thermal evaluation for the GaN power devices are shown in Figure 18. and figure 19.

The temperature that a GaN power device for the PFC circuit is 75degC.

And the temperature of the LLC circuit is 70degC.

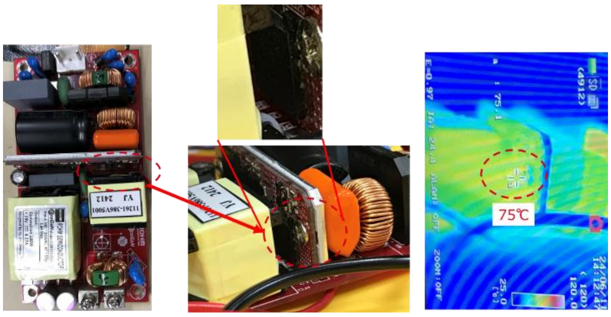


Figure 18. Temperature for the PFC circuit

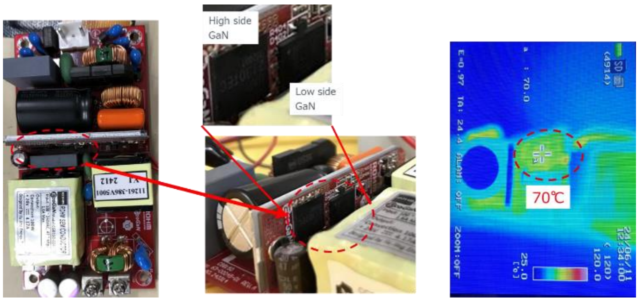


Figure 19. Temperature for the LLC circuit

7-7. Thermal evaluation result

The conduction emission (CE) and the radiation emission (RE) are shown in Figure 20. and Figure 21., CE and RE are both satisfying the noise standards.

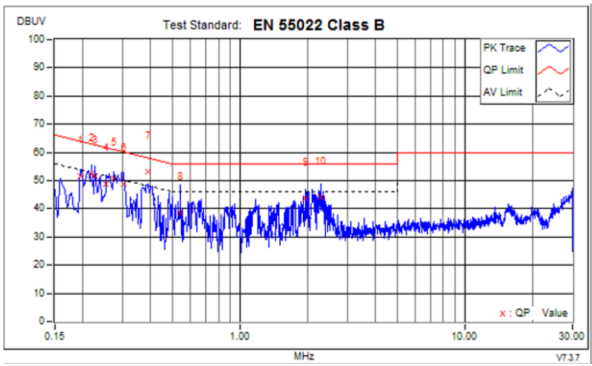


Figure 20. Conduction emission

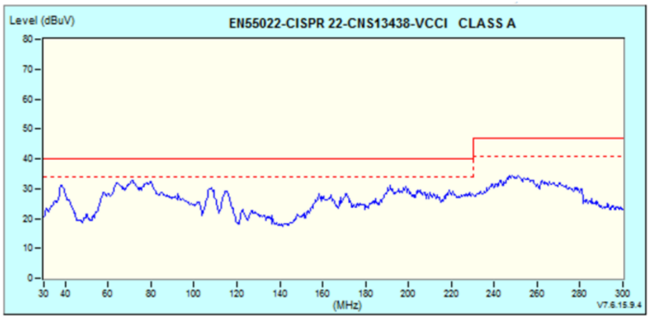


Figure 21. Radiation emission

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