Eight Discipline Report (8D Report)

To:**	8D report No.: **
From:：**Chicony Power Technology**	RMA claim No.: **
CC：	Chicony Power P/N: **A085A001P**
	Customer P/N:**
Submit date: **	Product description: **85W adapter**
Receive date: **	

Subject：EMI Issue

Keywords/關鍵字：EMI(CE)、Diode

D1.) 問題解決成員:Use Team Approach

主持者 (Team Leader)： **Wade_Lo**

內部成員 (Internal Team Members):

CQS: Maria Chen

QE: Nono Cheng

MFG: Xiaohui Du

PE: Yong Liu

Sales: Kedy_Chang

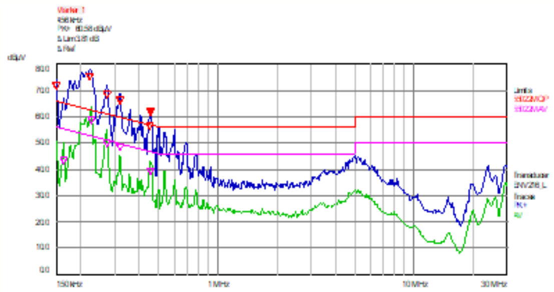
外部成員 (External Team Member):

D2.)問題說明:Problem Description:

(**Note**: Use **who**, **what**, **when**, **where**, **why**, **how**, **how many** to specify the Customer's problem.)

- **There are total 11pcs EMI Conduction testing failures happen in Jul.2021.**
- **CPT find more Lots ADP samples to do the EMI Conduction testing，a few samples of the Lots still failed.**

NG Sample : 3749B
Input :100Vac/60Hz
Load : 5A
EMI: +11.17dB



Trace	Frequency	Level	Limit	Delta Limit	Comment
	(MHz)	(dBμV)	(dBμV)	(dB)	
1 QP	0.15	70.21 *	66.00	4.21	L1 on
2 AV	0.1635	41.93	55.28	-13.35	L1 on
1 QP	0.222	73.91 *	62.74	11.17	L1 on
2 AV	0.2265	57.29 *	52.58	4.71	L1 on
1 QP	0.2715	67.03 *	61.07	5.96	L1 on
2 AV	0.2715	48.61	51.07	-2.46	L1 on
1 QP	0.3165	64.98 *	59.80	5.18	L1 on
2 AV	0.3165	47.02	49.80	-2.78	L1 on
1 QP	0.4515	55.12	56.85	-1.73	L1 on
2 AV	0.456	38.15	46.77	-8.62	L1 on

Lot	NG数/测定数	NG S/N
19X	0/10	
203	0/5	
204	0/5	
205	1/5	6532AM120505747A
206	0/5	
207	1/5	6532AM120708240A
208	3/5	6532AM120816470A 6532AM120811751A 6532AM120816501A
以下为R3改善后（TJ厂生产）数据：		
2021.04	5/10	1.PS端退回4pcs不良 2.另有7pcs不良仍在客户PS端

D3.)內部或客戶的暫時解決辦法及實施日期:Implement and Verify Containment Action:

(Note: Internal / external containment action effectiveness and date.**)**

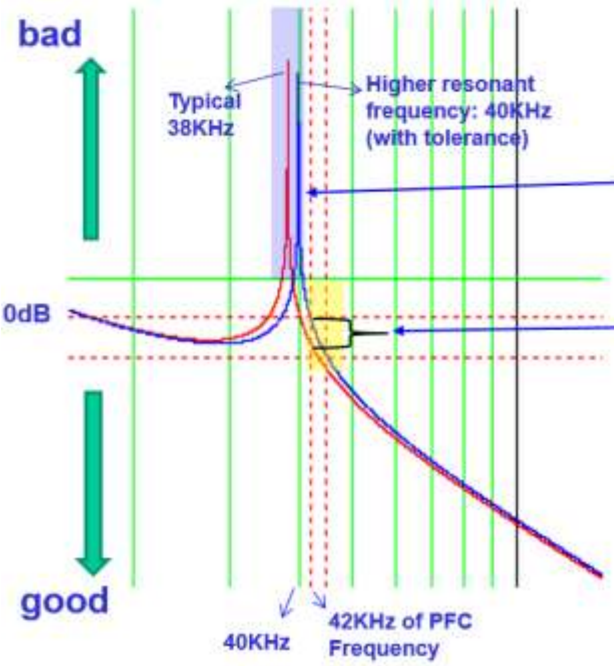
Production has been halted to investigate the root cause of defects and implement corrective actions.

D4.)不良原因確認: Define and Verify Root Causes:

(Note: Identify and verify all suspect causes, which needs explain why the problem occurred.**)**

- **Root Causes**

Pi filter's resonant frequency design didn't consider component tolerance. It causes EMI issue if PFC switching frequency is very close to resonant frequency.



Red Trace L2:54uH **Blue Trace= L2:49uH**

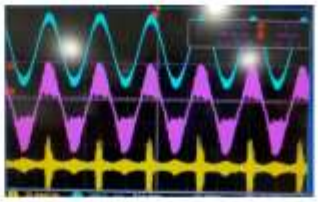
If PFC switching frequency operated at resonant frequency (40KHz), the noise would be amplified.

If PFC switching frequency is very close to resonant frequency of pi filter. It will cause filter capability reduction. For this case, The 54uH and 49uH have 7dB gap at same switching frequency

Simulation condition

When L2 over about 2A, the EMI will be happened EMI issue as bottom picture.

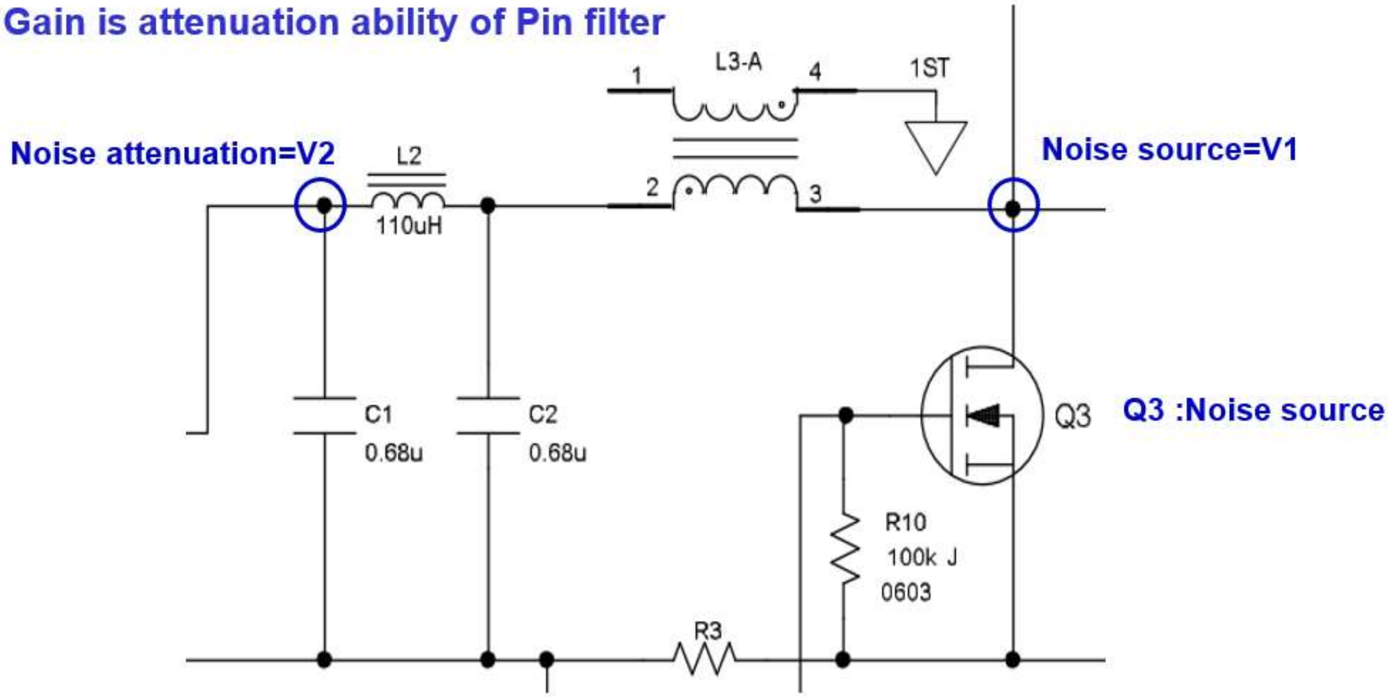
Item	0A	0.5A	1A	1.5A	2A
	uH	uH	uH	uH	uH
RD_NG-2	100	86	73	60	49
Magnetic_1	103	93	80	66	54
Magnetic_2	112	98	82	67	54



- **Calculation Condition：**

V1=△410V **V2 = Gain * V1**

Gain is attenuation ability of Pin filter



● Formula of Pi filter Design：

Pi L-C Filter Analysis:

$$C1\_old := 0.68\cdot 10^{-6}F \qquad C2\_old := 0.68\cdot 10^{-6}F$$

$$L2\_old := 110\cdot 10^{-6}H \qquad L3\_old := 300\cdot 10^{-6}H$$

$$Xc1\_old(fsw) := \frac{1}{i\,\omega(fsw)\cdot C1\_old} \qquad Xc2\_old(fsw) := \frac{1}{i\,\omega(fsw)\cdot C2\_old}$$

$$XL2\_old(fsw) := i\,\omega(fsw)\cdot L2\_old \qquad XL3\_old(fsw) := i\,\omega(fsw)\cdot L3\_old$$

Gain=V2/V1

$$Gain\_old(fsw) := \frac{\dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw)+Xc1\_old(fsw))}{Xc2\_old(fsw)+XL2\_old(fsw)+Xc1\_old(fsw)}}{XL3\_old(fsw)+\dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw)+Xc1\_old(fsw))}{Xc2\_old(fsw)+XL2\_old(fsw)+Xc1\_old(fsw)}}\cdot\frac{Xc1\_old(fsw)}{Xc1\_old(fsw)+XL2\_old(fsw)}$$

$$Gain\_old\_dB(fsw) := 20\cdot\log(|Gain\_old(fsw)|)$$

● EMI Performance Relation with Pi Filter and Switching frequency

Below table is calculation result with different conditions.

From table we can find if L2 inductance is higher, then Pi filter can have good attenuation.

Different source of bridge diode will cause just a little increasing in PFC switching frequency.

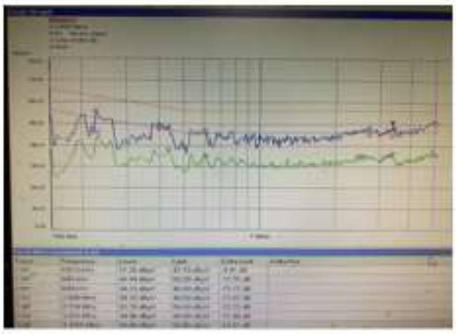
Condition	Switching Frequency	L2 Inductance	Pi Filter Gain	V1	V2
EMI OK (BD1 with LITEOM)	41.6KHz	54uH	-14.22dB	52.25dB	38.03dB
EMI NG (BD1 with LITEOM)	40.2KHz	49uH	+12.71dB	52.25dB	64.96dB
EMI NG Change BD1 from LITEON to TSC	41.1KHz	49uH	-3.35dB	52.25dB	48.90dB
EMI NG Change BD1 from LITEON to SHINDENGEN	41.4KHz	49uH	-5.64dB	52.25dB	46.61dB

PS:
1, Compare #1 and #2, we can find L2 Inductance change a little, but the result have big deviation.
2, Compare #3 and #4, we can find BD1 just impact a little in V2

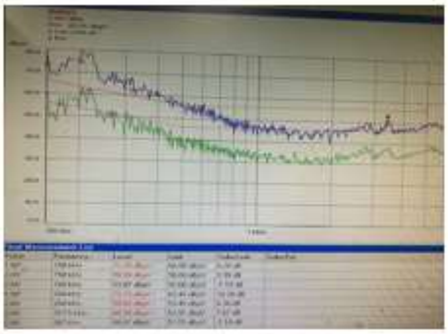
EMI Performance Relation with V2 and EMI result

Condition	V2	EMI Result
EMI OK (BD1 with LITEON)	38.03dB	-9.91dB
EMI NG (BD1 with LITEON)	64.96dB	+10.28dB
EMI NG Change BD1 from LITEON to TSC	48.90dB	-6.28dB
EMI NG Change BD1 from LITEON to SHINDENGEN	46.61dB	-7.4dB

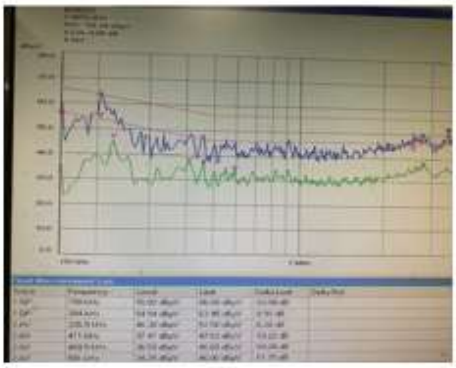
-9.91dB



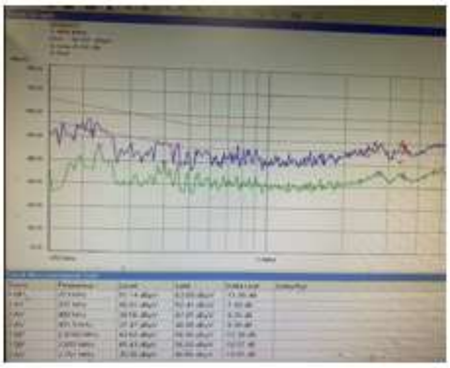
+10.28dB



-6.28dB



-7.4dB



● Calculated EMI ok unit

EMI OK (BD1 with Liteon Diode)

$$\boxed{fsw := 41.6\cdot 10^{3}\,Hz} \qquad V1 := 410 \qquad 20\cdot\log(|V1|) = 52.256$$

$$C1\_old := 0.671\cdot 10^{-6}\,F \qquad C2\_old := 0.675\cdot 10^{-6}\,F$$

$$\omega(fsw) := 2\cdot\pi\cdot fsw \qquad \boxed{L2\_old := 54\cdot 10^{-6}\,H} \qquad L3\_old := 298\cdot 10^{-6}\,H$$

$$Xc1\_old(fsw) := \frac{1}{i\,\omega(fsw)\cdot C1\_old} \qquad Xc2\_old(fsw) := \frac{1}{i\,\omega(fsw)\cdot C2\_old}$$

$$XL2\_old(fsw) := i\,\omega(fsw)\cdot L2\_old \qquad XL3\_old(fsw) := i\,\omega(fsw)\cdot L3\_old$$

$$Gain\_old := \frac{\dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw)+Xc1\_old(fsw))}{Xc2\_old(fsw)+XL2\_old(fsw)+Xc1\_old(fsw)}}{XL3\_old(fsw) + \dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw) + Xc1\_old(fsw))}{Xc2\_old(fsw) + XL2\_old(fsw) + Xc1\_old(fsw)}}\cdot\frac{Xc1\_old(fsw)}{Xc1\_old(fsw) + XL2\_old(fsw)} = 0.195$$

$$Gain\_old\_dB := 20\cdot\log(|Gain\_old|) = \boxed{-14.22}$$

$$V2 := V1\cdot Gain\_old \qquad 20\cdot\log(|V2|) = \boxed{38.036}$$

● Calculated EMI NG unit

EMI NG (BD1 with Liteon Diode)

$$\boxed{fsw := 40.2\cdot 10^{3}\,Hz} \qquad V1 := 410 \qquad 20\cdot\log(|V1|) = 52.256$$

$$C1\_old := 0.671\cdot 10^{-6}\,F \qquad C2\_old := 0.675\cdot 10^{-6}\,F$$

$$\omega(fsw) := 2\cdot\pi\cdot fsw \qquad \boxed{L2\_old := 49\cdot 10^{-6}\,H} \qquad L3\_old := 298\cdot 10^{-6}\,H$$

$$Xc1\_old(fsw) := \frac{1}{i\,\omega(fsw)\cdot C1\_old} \qquad Xc2\_old(fsw) := \frac{1}{i\,\omega(fsw)\cdot C2\_old}$$

$$XL2\_old(fsw) := i\,\omega(fsw)\cdot L2\_old \qquad XL3\_old(fsw) := i\,\omega(fsw)\cdot L3\_old$$

$$Gain\_old := \frac{\dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw)+Xc1\_old(fsw))}{Xc2\_old(fsw)+XL2\_old(fsw)+Xc1\_old(fsw)}}{XL3\_old(fsw) + \dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw) + Xc1\_old(fsw))}{Xc2\_old(fsw) + XL2\_old(fsw) + Xc1\_old(fsw)}}\cdot\frac{Xc1\_old(fsw)}{Xc1\_old(fsw) + XL2\_old(fsw)} = 4.321$$

$$Gain\_old\_dB := 20\cdot\log(|Gain\_old|) = \boxed{12.713}$$

$$V2 := V1\cdot Gain\_old \qquad 20\cdot\log(|V2|) = \boxed{64.968}$$

noise Increasing between OK & NG:
64.968dB-38.036dB=26.932

Calculated EMI NG and bridge change

EMI NG's BD1 change to **TSC** bridge

$\boxed{fsw := 41.1\cdot 10^3 Hz}$ $V1 := 410$ $20\cdot\log(|V1|) = 52.256$

$C1\_old := 0.671\cdot 10^{-6}F$ $C2\_old := 0.675\cdot 10^{-6}F$

$\omega(fsw) := 2\cdot\pi\cdot fsw$ $\boxed{L2\_old := 49\cdot 10^{-6}H}$ $L3\_old := 298\cdot 10^{-6}H$

$Xc1\_old(fsw) := \dfrac{1}{i\,\omega(fsw)\cdot C1\_old}$ $Xc2\_old(fsw) := \dfrac{1}{i\,\omega(fsw)\cdot C2\_old}$

$XL2\_old(fsw) := i\,\omega(fsw)\cdot L2\_old$ $XL3\_old(fsw) := i\,\omega(fsw)\cdot L3\_old$

$$Gain\_old := \frac{\dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw)+Xc1\_old(fsw))}{Xc2\_old(fsw)+XL2\_old(fsw)+Xc1\_old(fsw)}}{XL3\_old(fsw) + \dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw) + Xc1\_old(fsw))}{Xc2\_old(fsw) + XL2\_old(fsw) + Xc1\_old(fsw)}}\cdot\frac{Xc1\_old(fsw)}{Xc1\_old(fsw) + XL2\_old(fsw)} = 0.68$$

$Gain\_old\_dB := 20\cdot\log(|Gain\_old|)\ \boxed{= -3.35}$

$V2 := V1\cdot Gain\_old$ $20\cdot\log(|V2|)\ \boxed{= 48.906}$

noise reduced between NG + L bridge & NG + TSC bridge: 64.968dB-48.906dB=16.062dB

EMI NG's BD1 change to **SHINDENGEN** bridge

$\boxed{fsw := 41.4\cdot 10^3 Hz}$ $V1 := 410$ $20\cdot\log(|V1|) = 52.256$

$C1\_old := 0.671\cdot 10^{-6}F$ $C2\_old := 0.675\cdot 10^{-6}F$

$\omega(fsw) := 2\cdot\pi\cdot fsw$ $\boxed{L2\_old := 49\cdot 10^{-6}H}$ $L3\_old := 298\cdot 10^{-6}H$

$Xc1\_old(fsw) := \dfrac{1}{i\,\omega(fsw)\cdot C1\_old}$ $Xc2\_old(fsw) := \dfrac{1}{i\,\omega(fsw)\cdot C2\_old}$

$XL2\_old(fsw) := i\,\omega(fsw)\cdot L2\_old$ $XL3\_old(fsw) := i\,\omega(fsw)\cdot L3\_old$

$$Gain\_old := \frac{\dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw)+Xc1\_old(fsw))}{Xc2\_old(fsw)+XL2\_old(fsw)+Xc1\_old(fsw)}}{XL3\_old(fsw) + \dfrac{Xc2\_old(fsw)\cdot(XL2\_old(fsw) + Xc1\_old(fsw))}{Xc2\_old(fsw) + XL2\_old(fsw) + Xc1\_old(fsw)}}\cdot\frac{Xc1\_old(fsw)}{Xc1\_old(fsw) + XL2\_old(fsw)} = 0.522$$

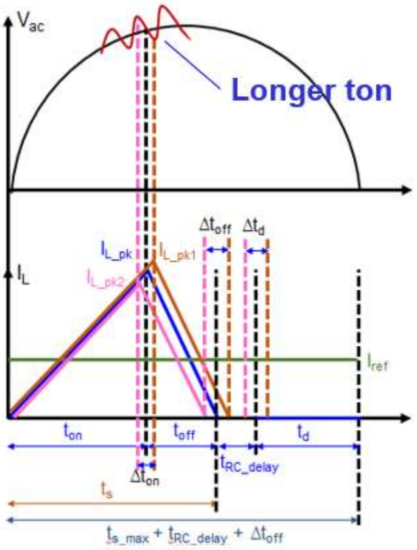
$Gain\_old\_dB := 20\cdot\log(|Gain\_old|)\ \boxed{= -5.642}$

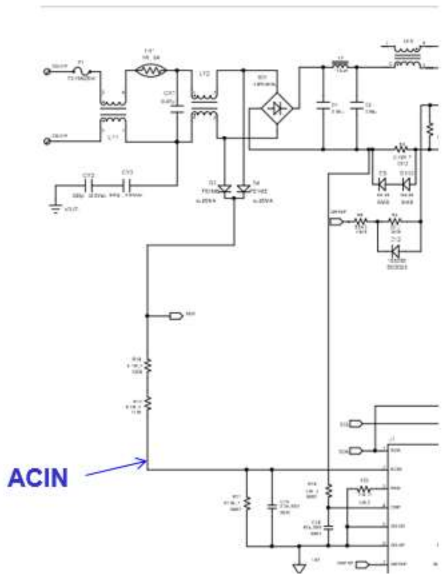
$V2 := V1\cdot Gain\_old$ $20\cdot\log(|V2|)\ \boxed{= 46.613}$

noise reduced between NG + L bridge & NG + TSC bridge: 64.968dB-46.613dB=18.355dB

- ## Parameter study of BD1

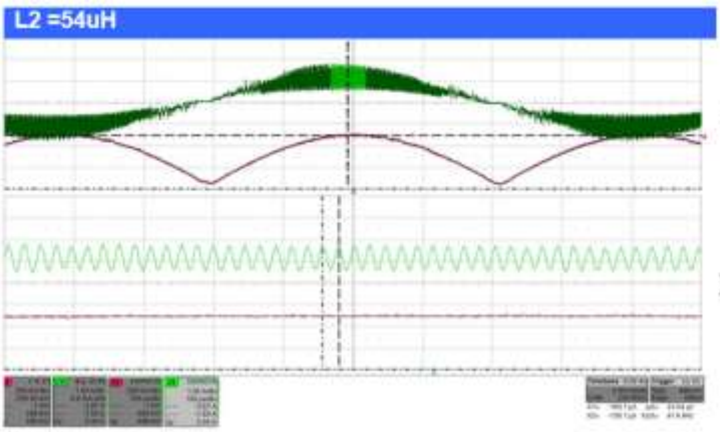
If BD1 used lower trr , it will cause higher delta Vpk in ACIN to cause sampling voltage deviation and longer ton as bottom left drawing. The longer ton will impact PFC switching frequency about 1KHz decreasing.





※Additional

Condition	Switching Frequency	L2 Inductance	Pi Filter Attenuation	V1	V2
EMI OK	41.6KHz	54uH	-12.55dB	52.25dB	39.7dB
EMI NG	40.2KHz	49uH	+12.71dB	52.25dB	64.96dB
EMI NG Change BD1 from LITEON to TSC	41.1KHz	49uH	-3.35dB	52.25dB	48.90dB
EMI NG Change BD1 from LITEON to SHINDENGEN	41.4KHz	49uH	-5.64dB	52.25dB	46.61dB



- The L2 captured frequency and ACIN pin:
  Fig.1 L2=54uH: f=41.6kHz, VACIN pin= 499mV
- Different L2 make a difference ACIN pin sensed voltage lead to a minor frequency shift.

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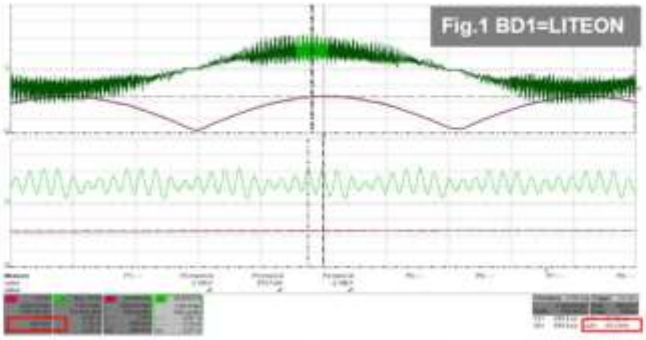
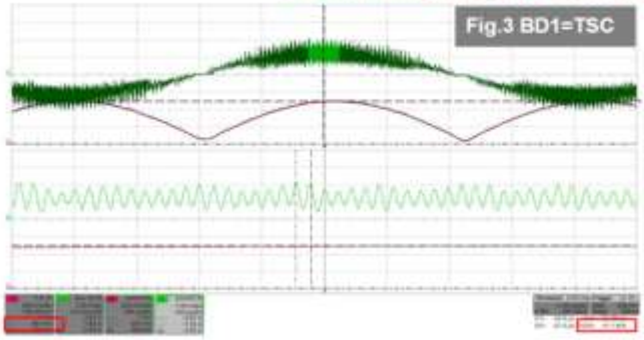
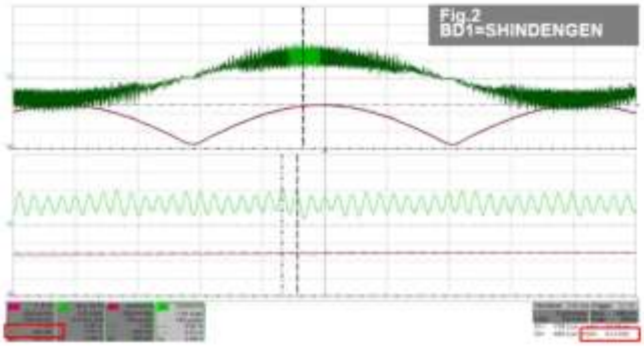
Chicony Power Technology Co., Ltd TEL: 886-2-22985636 FAX: 886-2-22985635

L2=49uH BD1 difference comparison







- The three BD1 captured frequency and ACIN pin:
  Fig.1 BD1=LITEON, f=40.2kHz,VACIN pin= 455mV
  Fig.2 BD1=SH: f=41.4kHz, VACIN pin= 493mV
  Fig.3 BD1=TSC: f=41.1kHz, VACIN pin= 491mV

- Different BD1 make a difference ACIN pin sensed voltage lead to a minor frequency shift.

The difference of ACIN pin voltage

According to the "major items lead to switching frequency shift" analyze, the voltage difference on ACIN pin represent the sampling ratio (k_{in_t}) has changed. Therefore, the actual freewheeling conduction time t_{off} is changed, too.

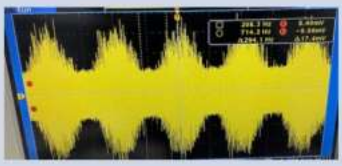
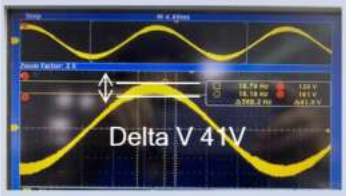
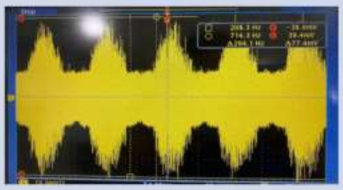
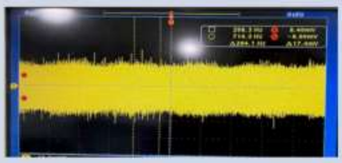
$$\Delta_{t_{off}} = \left(\frac{V_{IN}(n)}{V_O(n)-V_{IN}(n)} \times \frac{k_{out\_t} \times V_O(n) - k_{in\_t} \times V_{IN}(n)}{k_{out\_t} \times V_O(n)} - \frac{k_{in\_t} \times V_{IN}(n)}{k_{out\_t} \times V_O(n)}\right) \times T_S$$

The value Δt_{off_1} of Fig.1 = 0.3327us. The Δt_{off_2} of Fig.2 = -0.3999us. The Δt_{off_3} of Fig.3 = -0.2299us. If we use the Fig.1 frequency 40.2kHz as base.

The Fig.2 frequency shift will become: $\frac{1}{40.2kHz}$ - (Δt_{off_1}-Δt_{off_2}) = 24.143us => 41.42kHz

The Fig.3 frequency shift will become: $\frac{1}{40.2kHz}$ - (Δt_{off_1}-Δt_{off_3}) = 24.313us => 41.13kHz

Use 4 pcs separated diode with different Trr to replace bridge diode Low Trr will cause the large noise spike and cause EMI fail

Condition	Bridge waveform	EMI LISN Nosie	Result
2pcs diode = high Trr ~2uS 2pcs diode = low Trr ~ 500ns			NG
4pcs diode= low Trr ~ 500ns			NG
4pcs diode= high Trr ~ 2us			OK

BD1 Analysis :

Vendor Analysis data

	Test item	Trr (ns)	VF (V) @ 2A	VF (V) @ 4A	IR (uA) @ 10A	VR (V) @ 10uA
TSC	1	2855	0.886	0.937	0.133	1347
	2	2692	0.888	0.941	0.126	1413
	3	2728	0.886	0.939	0.128	1438
	4	2740	0.884	0.935	0.131	1413
LT 3732B	1	2617	0.881	0.932	0.344	1469
	2	2655	0.881	0.931	0.292	1564
	3	2793	0.879	0.93	0.248	1508
	4	2180	0.881	0.933	0.27	1612
LT NO.4	1	2720	0.882	0.932	0.341	1398
	2	2572	0.881	0.931	0.386	1221
	3	1834	0.884	0.938	0.403	1331
	4	1442	0.883	0.936	0.339	1529

NG Sample BD1 has lower Trr parameter

- **Found V2 Max by Simulation**

Condition	Switching Frequency	L2 Inductance	C1/C2	Pi Filter Gain	V1	V2 (Max)
EMI worst result	42.11KHz	43.6	0.68	+50.7dB	52.25dB	102.99dB

$fsw := 42.11 \cdot 10^3 Hz \quad V1 := 410 \quad 20 \cdot \log(|V1|) = 52.256$

$C1\_old := 0.68 \cdot 10^{-6} F \qquad C2\_old := 0.68 \cdot 10^{-6} F$

$\omega(fsw) := 2 \cdot \pi \cdot fsw \qquad L2\_old := 43.6 \cdot 10^{-6} H \qquad L3\_old := 300 \cdot 10^{-6} H$

$Xc1\_old(fsw) := \frac{1}{i\,\omega(fsw) \cdot C1\_old} \qquad Xc2\_old(fsw) := \frac{1}{i\,\omega(fsw) \cdot C2\_old}$

$XL2\_old(fsw) := i\,\omega(fsw) \cdot L2\_old \qquad XL3\_old(fsw) := i\,\omega(fsw) \cdot L3\_old$

$$Gain\_old := \frac{\frac{Xc2\_old(fsw) \cdot (XL2\_old(fsw)+Xc1\_old(fsw))}{Xc2\_old(fsw)+XL2\_old(fsw)+Xc1\_old(fsw)}}{XL3\_old(fsw) + \frac{Xc2\_old(fsw) \cdot (XL2\_old(fsw) + Xc1\_old(fsw))}{Xc2\_old(fsw) + XL2\_old(fsw) + Xc1\_old(fsw)}} \cdot \frac{Xc1\_old(fsw)}{Xc1\_old(fsw) + XL2\_old(fsw)} = 344.48$$

$Gain\_old\_dB := 20 \cdot \log(|Gain\_old|) = 50.743$

$V2 := V1 \cdot Gain\_old \qquad 20 \cdot \log(|V2|) = 102.999$

- **Switching frequency vs input voltage**

Input voltage for Switching frequency effect (5A)

Input Voltage	Switching frequency
90VAC	50KHz
95Vac	50KHz
100Vac	42.37KHz Close to resonance frequency
105Vac	45.45KHz
110Vac	46.3KHz

錯誤! 連結無效。

Above table show to us, at 100Vac, the switching frequency is more close to resonance frequency.

D5.)改善措施:Corrective Action Verification:

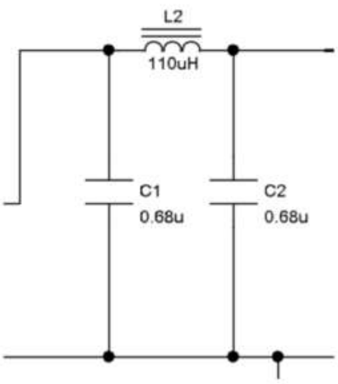
(Note: Be make sure the corrective actions is effective in process as well as able to fix the customer complaint problem**)**

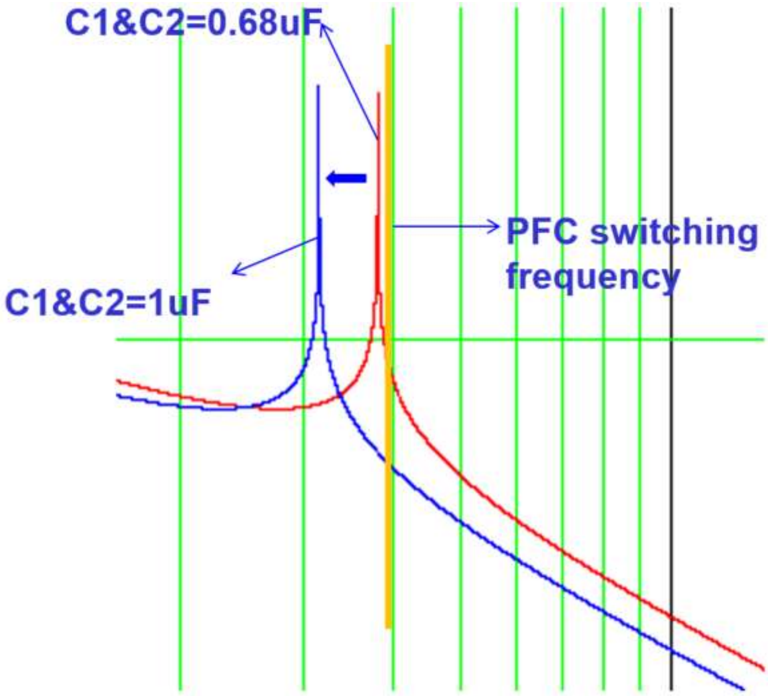
- **Chicony stop production and shipment. Chicony total Q hold 13Kpcs stocks to be screened.**
- **Increasing capacitance of C1&C2 can reduce the resonant frequency of Pi filter to keep away from PFC minimum switching frequency.**

Capacitance of C1/ C2.

As is: 0.68uF **K type**

=>To be: 1uF **J type**





D6.)改善措施實施日期:Implement Permanent Corrective Actions:

(Note: Be provide the phase-in date or lot# of corrective actions **implementation** in process**)**

immediately

D7.)預防再發生措施:Prevent Recurrence:

(Note: Modified the management, operating systems, practices, and procedures to prevent recurrence for the problems as well as lessons learned cases**.)**

Same as D5

D8.)確認並感謝問題解決成員:Check and Congratulate the Team:

(Note: Recognize the collective efforts of the team.**)**

Thanks to you all！！！

CQS: Maria Chen SQE: Nono Cheng MFG: Xiaohui Du PE: Yong Liu Sales: Kedy_Chang

Signature	**Cf_Liu**

Team Leader:	
	Name – Title
Signature by Approver:	**Wade_Lo**
	Name-Title