R2A20134EVB-NNWE

R2A20134 Evaluation Board

R19AN0017EJ0200
Rev.2.00
Jul 30, 2013

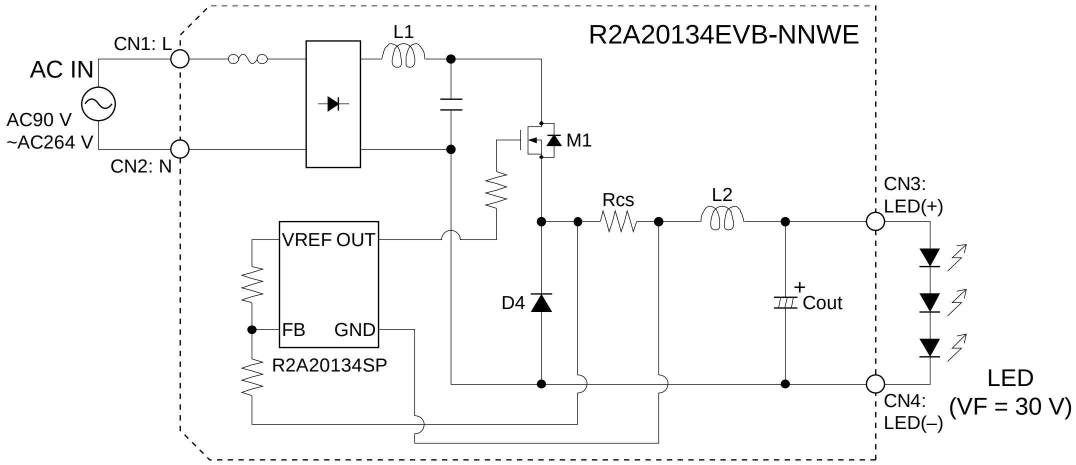
1. General Description

R2A20134EVB-NNWE is evaluation tool for evaluating LED control IC R2A20134. As all of the parts and the peripheral circuit which are necessary for LED lighting control are built on this evaluation board, R2A20134 can be evaluated by just only supplying AC power source and connecting LED load.
Since this evaluation board is composed as Step-down/High-side (non-isolated), it achieves high efficiency, high power factor, low THD (Total Harmonic Distortion) and low output current ripple with world-wide input voltage range. For using this board, please also refer the R2A20134SP datasheet and application note.

2. Specifications

No.	Item	Specification
1	Input voltage range	AC90 V to 264 V (single phase 47 to 63 Hz)
2	Output power	8 W (typ.)
3	Output voltage (VF)	DC30 V
4	Output current	267 mA (typ.)
5	Efficiency	Not less than 85% (@Vin = AC100 V to 240 V)
6	Power factor	Not less than 0.9 (@Vin = AC100 V to 240 V)
7	Switching frequency	65 kHz
8	Operational mode	Discontinuous current mode (fixed switching frequency)
9	PCB	Single layer / Glass epoxy (FR4) / Single-side mount
10	Size (W × D × H)	36 mm × 36 mm × 25 mm (Top layer)

3. System Diagram & Connection



Connecting steps:
(1) Connect AC mains to CN1 and CN2.
(2) Connect LED load (VF = 30 V, current rating over 267 mA) to CN3 and CN4 with caring LED polarity.

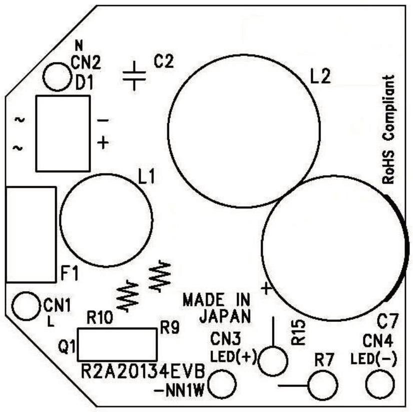
Note: Operating this evaluation board, LED load MUST be connected to CN3 & CN4. Without LED load, output voltage will be unstable and parts on the board may be damaged in the worst case.

⚠ High voltages are produced in parts of the board. Take care of this point when using the board.

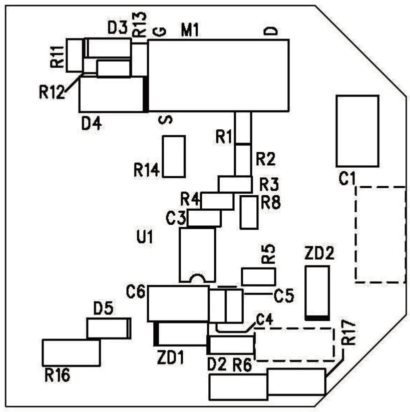
4. PCB Layout

4.1 Parts Layout

Mounting side

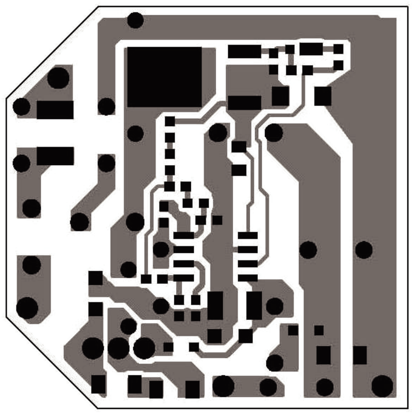


Soldering side



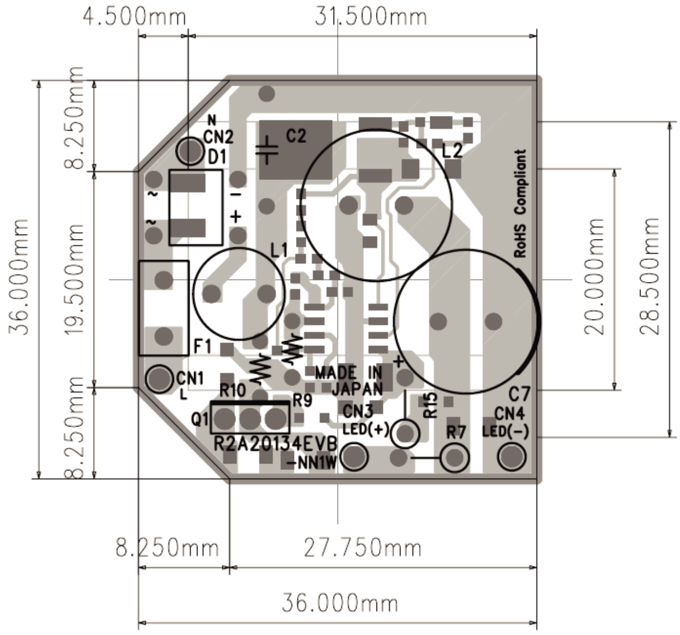
4.2 PCB Layout

Circuit pattern



* This evaluation board is single side layout.

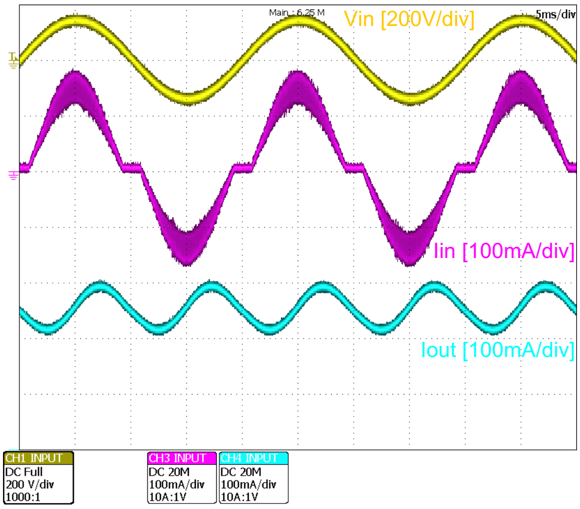
4.3 PCB Size



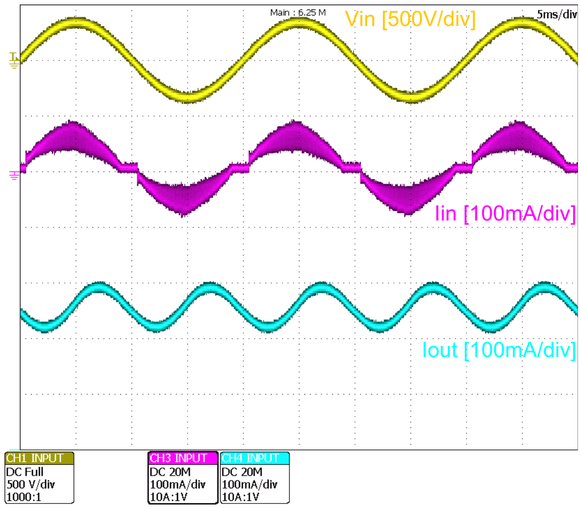
5. Performance Characteristics

5.1 Waveforms

Vin = AC100 V, VF = 30 V, Iout = 267 mA

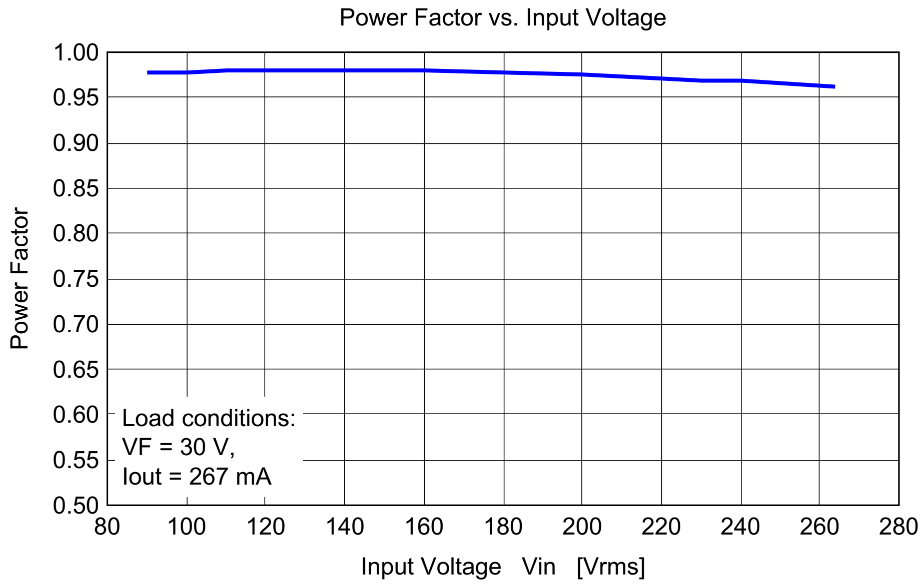


Vin = AC240 V, VF = 30 V, Iout = 267 mA

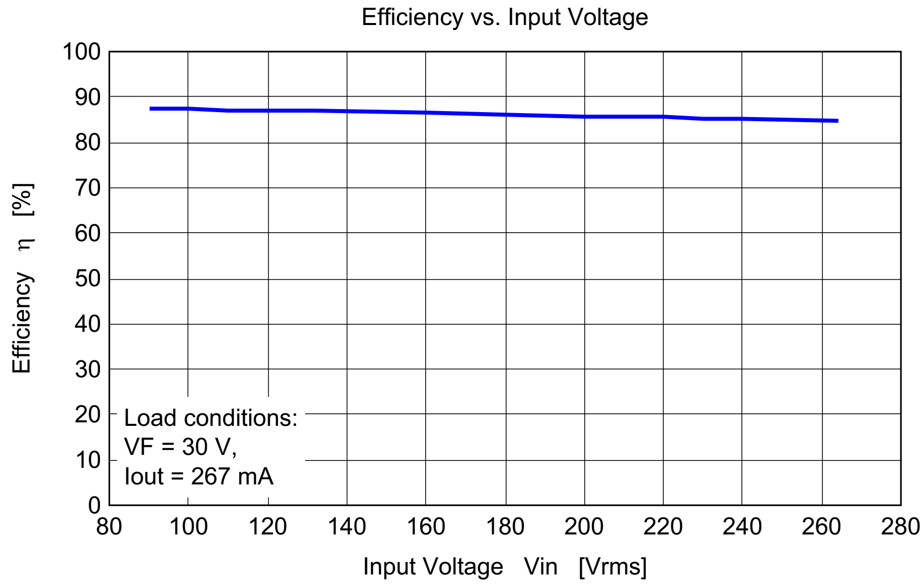


* Vin: Input line voltage, Iin: Input line current, Iout: Output current

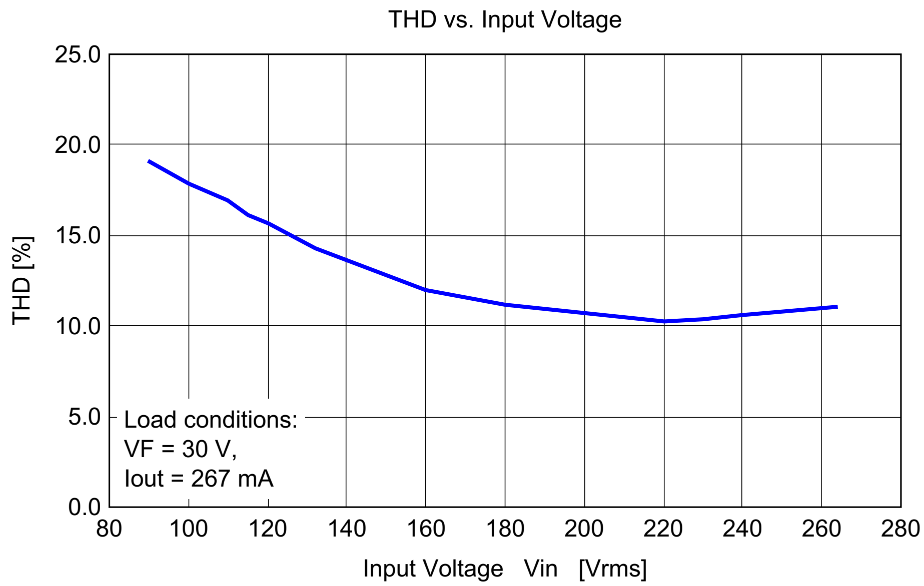
5.2 Power Factor



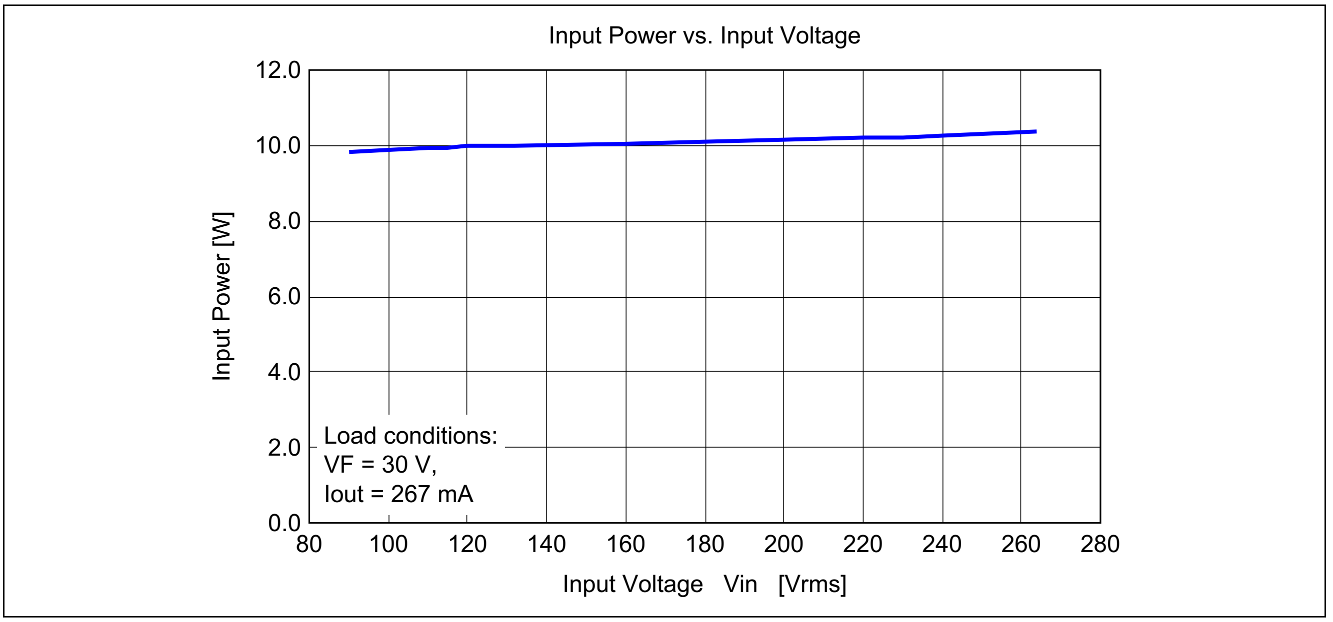
5.3 Efficiency



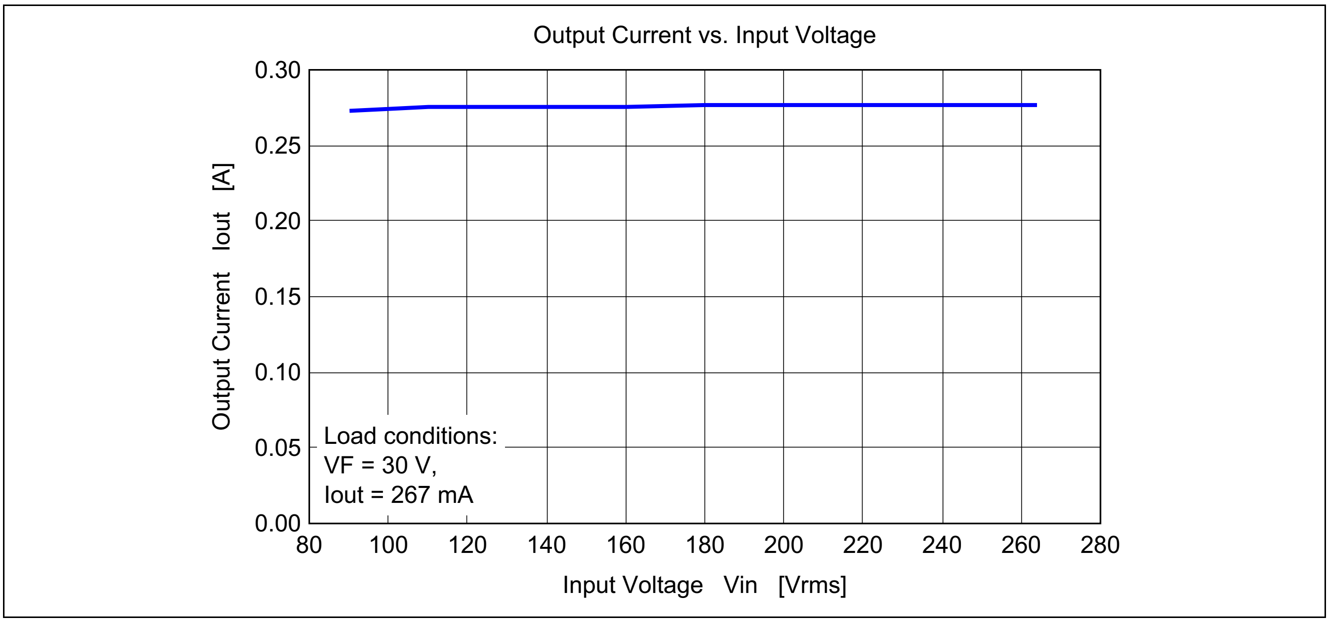
5.4 THD (Total Harmonic Distortion)



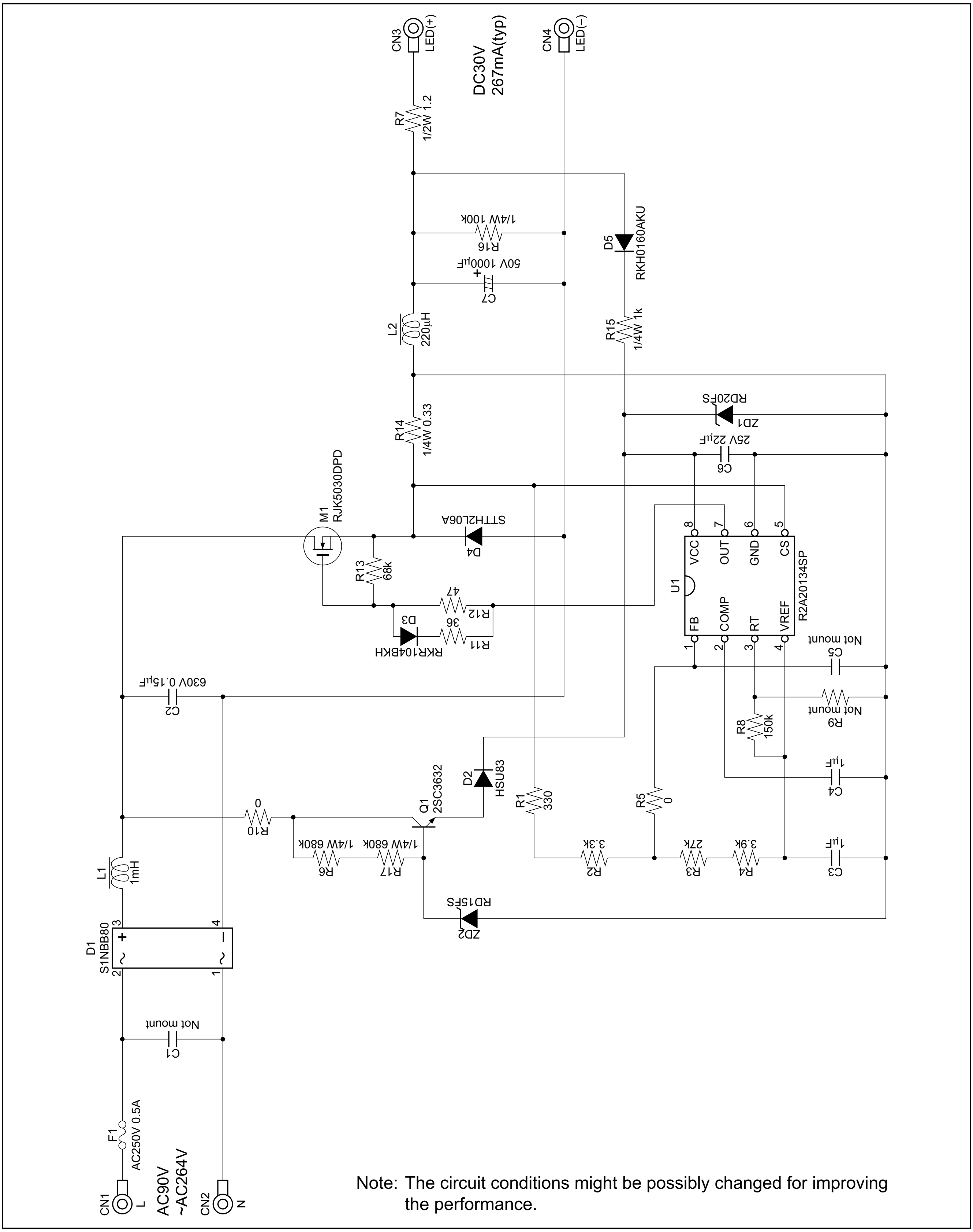
5.5 Input Power



5.6 Output Current



6. R2A20134EVB-NNWE Schematic



7. Bill of Materials

Symbol	Parts Name	Catalog No.	Q	Rating		Manufacturer	Note
PWB	Printed-wiring board	PW018	1			Renesas Electronics	
U1	IC	R2A20134SP	1			Renesas Electronics	SOP-8
M1	FET	RJK5030DPD	1	500 V	5 A	Renesas Electronics	MP-3A
Q1	Transistor	2SC3632	1	600 V	1 A	Renesas Electronics	TO-251
D1	Bridge Diode	S1NBB80	1	800 V	1 A	Shindengen	1NA(THD)
D2	Diode	HSU83	1	250 V	300 mA	Renesas Electronics	URP
D3	SBD	RKR104BKH	1	40 V	1 A	Renesas Electronics	TURP-FM
D4	FRD	STTH2L06A	1	600 V	2 A	ST Micro	SMA
D5	Diode	RKH0160AKU	1	600 V	600 mA	Renesas Electronics	TURP
ZD1	Zener diode	RD20FS	1	20 V		Renesas Electronics	
ZD2	Zener diode	RD15FS	1	15 V		Renesas Electronics	
R1	Resistor	MCR03EZPFX3300	1	1/10 W	330	Rohm	1608
R2	Resistor	MCR03EZPFX3301	1	1/10 W	3.3 k	Rohm	1608
R3	Resistor	MCR03EZPFX2702	1	1/10 W	27 k	Rohm	1608
R4	Resistor	MCR03EZPFX3901	1	1/10 W	3.9 k	Rohm	1608
R5	Resistor	MCR03EZPJ000	1	1/10 W	0	Rohm	1608
R6, 17	Resistor	MCR18EZPF6803	2	1/4 W	680 k	Rohm	3216
R7	Resistor	MF1/4LCVT1R2F	1	1/4 W	1.2	KOA	Leaded
R8	Resistor	MCR03EZPFX1503	1	1/10 W	150 k	Rohm	1608
R9		Not mount					Leaded
R10	Resistor	J1/6ZCMTA	1		0	KOA	Leaded
R11	Resistor	MCR03EZPFX36R0	1	1/10 W	36	Rohm	1608
R12	Resistor	MCR03EZPFX47R0	1	1/10 W	47	Rohm	1608
R13	Resistor	MCR03EZPFX6802	1	1/10 W	68 k	Rohm	1608
R14	Resistor	RL1220S-R33-F	1	1/4 W	0.33	susumu	2012
R15	Resistor	CFP1/4CVT102J	1	1/4 W	1 k	KOA	Leaded
R16	Resistor	MCR18EZPF1003	1	1/4 W	100 k	Rohm	3216
C1		Not mount					
C2	Ceramic capacitor	RDER72J154K5B1C13B	1	630 V	0.15 μF	murata	Leaded
C3, 4	Ceramic capacitor	GRM188B31E105KA75B	2	25 V	1 μF	murata	1608
C5	Ceramic capacitor	Not mount					1608
C6	Ceramic capacitor	GRM32EB31E226ME15B	1	25 V	22 μF	murata	3225
C7	Electrochemical capacitor	UVK1H102MHD	1	50 V	1000 μF	nichicon	ϕ12.5 × 25
L1	Inductor	RCR-875D-102K	1		1 mH	SUMIDA	
L2	Inductor	RCP1317NP-221L	1		220 μH	SUMIDA	
F1	Fuse	HTS 500 mA	1	AC250 V	0.5 A	Skygate	

8. Design Guide

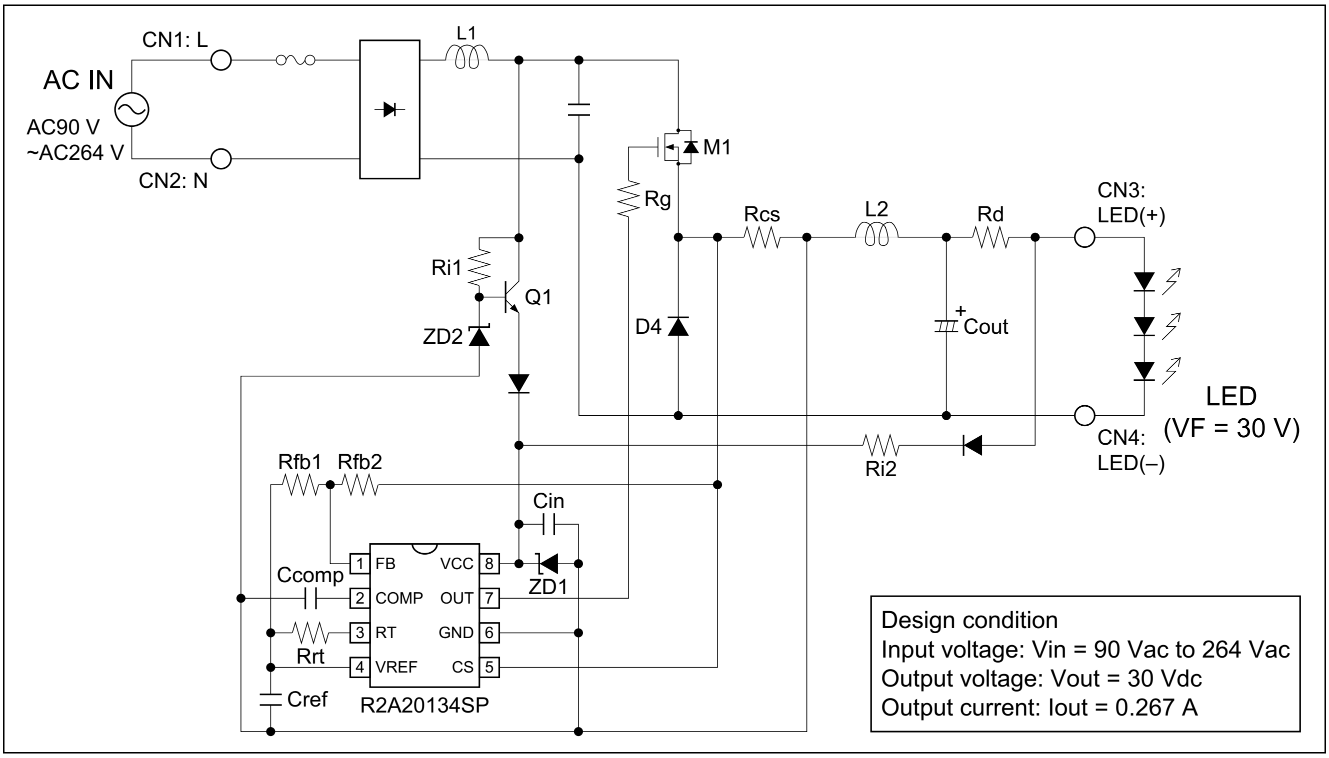


Figure 8.1 R2A20134EVB-NNWE Schematic

With fixed switching frequency and average current control, the system is controlled to keep constant output power. With this control method, current flow through the inductor L2 is discontinuous as is shown in figure 8.2, and input current is proportional to inductor current.
Therefore, power factor and THD (Total Harmonic Distortion) are improved.

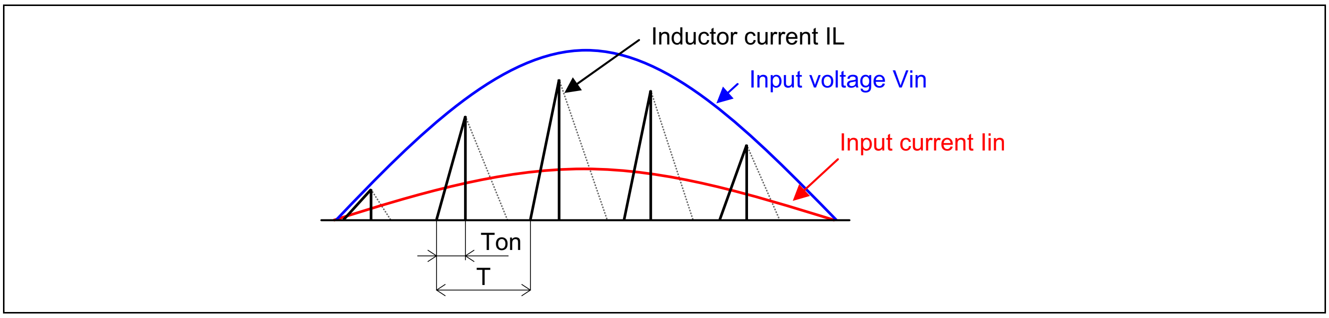


Figure 8.2 Input Current & Inductor Current

8.1 Setting Fixed Switching Frequency

To avoid audio frequency band and reduce switching loss, the switching frequency should be set from 20 kHz to 100 kHz. In this case, the switching frequency is set to 65 kHz with considering above.

8.2 Setting Rrt which Sets Switching Frequency

From following formula, Rrt is calculated Rrt = 149 kΩ. From this result, 150 kΩ resistor will be selected for Rrt. In this condition, the switching frequency is set to 64.7 kHz.

$$Rrt\,[k\Omega] = \frac{(1/fout[kHz]) - (450 \times 10^{-6})}{100 \times 10^{-9}}$$

8.3 Selecting Inductor L

As inductor current is discontinuous in constant input current operation, firstly, it is necessary that inductance is calculated in the critical conduction mode operation condition.
Then, inductor will be selected based on this calculated result; the inductor whose inductance is smaller than above calculated inductance will be selected.
When the most severe condition is given as minimum Vin is 90 Vac and Vout is 30 V, on duty D_{ON} will be calculated;

$$D_{ON} = Vout / (Vin \times \sqrt{2}) = 30 / (90 \times \sqrt{2}) = 0.236$$

Note: In case that D_{ON} is over 0.5 in the minimum Vin & Vout condition, D_{ON} is assumed as 0.5.

As the switching frequency is 62.7 kHz, on period Ton will be calculated;

$$Ton = D_{ON} / fout = 0.236 / 62.7\ kHz = 3.76\ \mu s$$

Now, in critical conduction mode, the relationship between input current, inductor current and output current is as below;

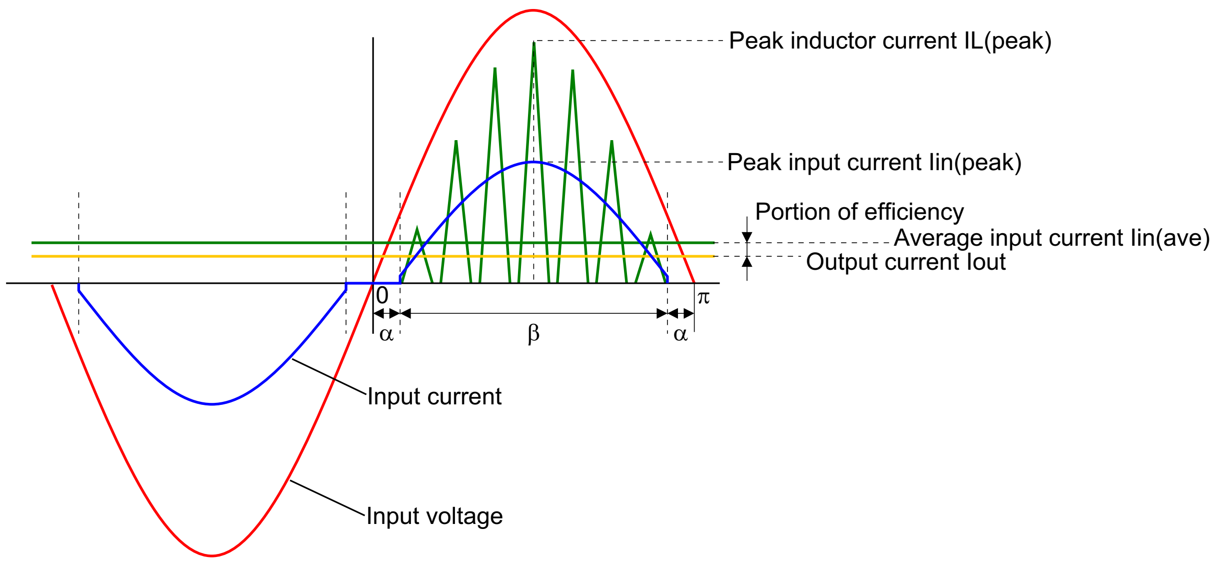


Figure 8.3 Input Current, Inductor Current, and Output Current

Output current is the value which is subtracted efficiency from average input current that the input current at conduction angle β is integrated over the range of zero to π. When output current Iout is 267 mA and efficiency η is 85%, average input current Iin(ave) will be calculated as below;

$$Iin(ave) = \frac{Iout}{\eta} = \frac{267\ mA}{0.85} = 314\ mA$$

and, peak input current Iin(peak) will be

$$Iin(peak) = \frac{\frac{\pi}{2} \times Iin(ave)}{\theta} = \frac{\frac{\pi}{2} \times 314\ mA}{0.849} = 581\ mA$$

θ: conduction ratio of half cycle

$$\theta = \frac{\beta}{\pi} \qquad \beta = \pi - (\alpha \times 2) \qquad \alpha = Asin\ (Vout / (Vin \times \sqrt{2}))$$

$$\theta = \frac{\pi - (Asin\ (30 / (90 \times \sqrt{2})))}{\pi} = 0.849$$

Inductor current IL(peak) will be doubled from above in critical conduction mode;

$$IL(peak) = Iin(peak) \times 2 = 581\ mA \times 2 = 1.16\ A$$

Thus,

$$L = (Vin \times \sqrt{2} - Vout) \times Ton / IL(peak) = (90 \times \sqrt{2} - 30) \times 3.76\ \mu s / 1.16 = 314\ \mu H$$

In case the inductance is smaller than above calculated value, the system will be in discontinuous operation. As for this, 220 μH inductor will be selected from standard line-up with considering tolerance.

8.4 Selecting Current Sensing Resistor Rcs

The inductor current with selected inductor will become the maximum when input voltage is 264 Vac. At this point, Iin(peak) will be; (also see 8.3)

$$\text{Iin(peak)} = \frac{\frac{\pi}{2} \times \text{Iin(ave)}}{\theta} = \frac{\frac{\pi}{2} \times 314\ \text{mA}}{0.949} = 520\ \text{mA}$$

$$\theta = \frac{\pi - (\text{Asin}\ (30 / (264 \times \sqrt{2})))}{\pi} = 0.949$$

on period Ton will be;

$$\text{Ton} = \sqrt{\frac{2 \times \text{Vout} \times \text{Iin(peak)} \times \text{L}}{\text{fsw} \times \text{Vin} \times (\text{Vin} - \text{Vout})}} = \sqrt{\frac{2 \times 30 \times 0.520 \times 220\ \mu\text{H}}{62.7\ \text{kHz} \times 264 \times \sqrt{2} \times (264 \times \sqrt{2} - 30)}} = 0.924\ \mu\text{s}$$

Therefore, the peak current flow through the inductor which is selected before will be;

$$\text{IL(peak)} = (\text{Vin} - \text{Vout}) \times \text{Ton} / \text{L} = (264 \times \sqrt{2} - 30) \times 0.924\ \mu\text{s} / 220\ \mu\text{H} = 1.44\ \text{A}$$

and it is necessary that Rcs is set to the value which is tolerant for above peak current flow.
Not to detect as over current protect level.

When Over Current Protection (OCP) detection voltage is Vocp = 0.6 V with taking 20% margin, Rcs will be following;

$$\text{Rcs} = \text{Vocp} / (\text{IL(peak)} \times 1.2) = 0.6 / (1.442 \times 1.2) = 0.347\ \Omega$$

Thus, 0.33 Ω resistor is selected as Rcs from standard line-up (E12 line) and over current detection is 1.82 A.

8.5 Setting Rfb1 & Rfb2 (Setting Output Current)

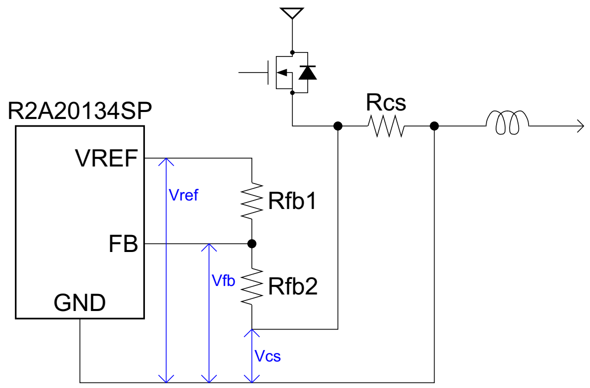


Figure 8.4 Output Current Setting Circuit

Partial voltage ratio with Rfb1 & Rfb2 should be set as following with FB terminal voltage Vfb (0.6 V), reference voltage Vref (5 V) and Rcs voltage Vcs;

$$\text{Rfb2} / (\text{Rfb1} + \text{Rfb2}) = (\text{Vfb} - \text{Vcs}) / (\text{Vref} - \text{Vcs})$$

When output power Iout is set to 0.267 A, average Rcs voltage Vcs which has been set in previous term is following;

$$\text{Vcs} = \text{Rcs} \times \text{Iout} = 0.33 \times 0.267 = 0.088\ \text{V}$$

$$\text{Rfb2} / (\text{Rfb1} + \text{Rfb2}) = (0.6\ \text{V} - 0.088\ \text{V}) / (5.0\ \text{V} - 0.088\ \text{V})$$

Thus, when Rfb1 is set to 30.9 kΩ (27 kΩ + 3.9 kΩ), Rfb2 becomes, Rfb2 = 3.63 kΩ = 3.3 kΩ + 330 Ω.

8.6 Loop Filter of Feedback Amplifier (External Circuit for FB & COMP Terminal)

Frequency characteristics of R2A20134EVB-NNWE are shown in figure 8.6.
Although this system is controlled as current mode (first-order lag system) and can operate stably, it would be recommended that Ccomp (shown in figure 8.5.) is set to make loop gain as 0 dB under 100 – 200 Hz which is double frequency of the AC mains; 50 – 60 Hz. On the evaluation board, Ccomp has been set to 1 μF. In case operation can be affected by switching noise or other effect, it is also recommended that CR filter (Cf1 & Rf1) is inserted to FB terminal.

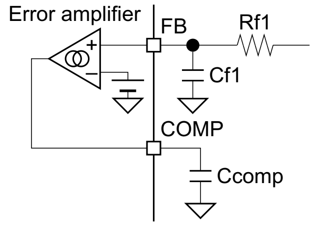


Figure 8.5 External Circuit for FB & COMP Terminals

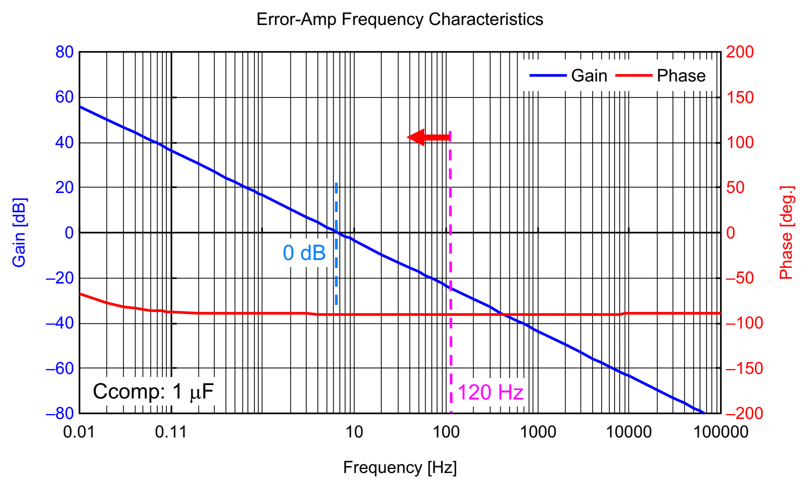
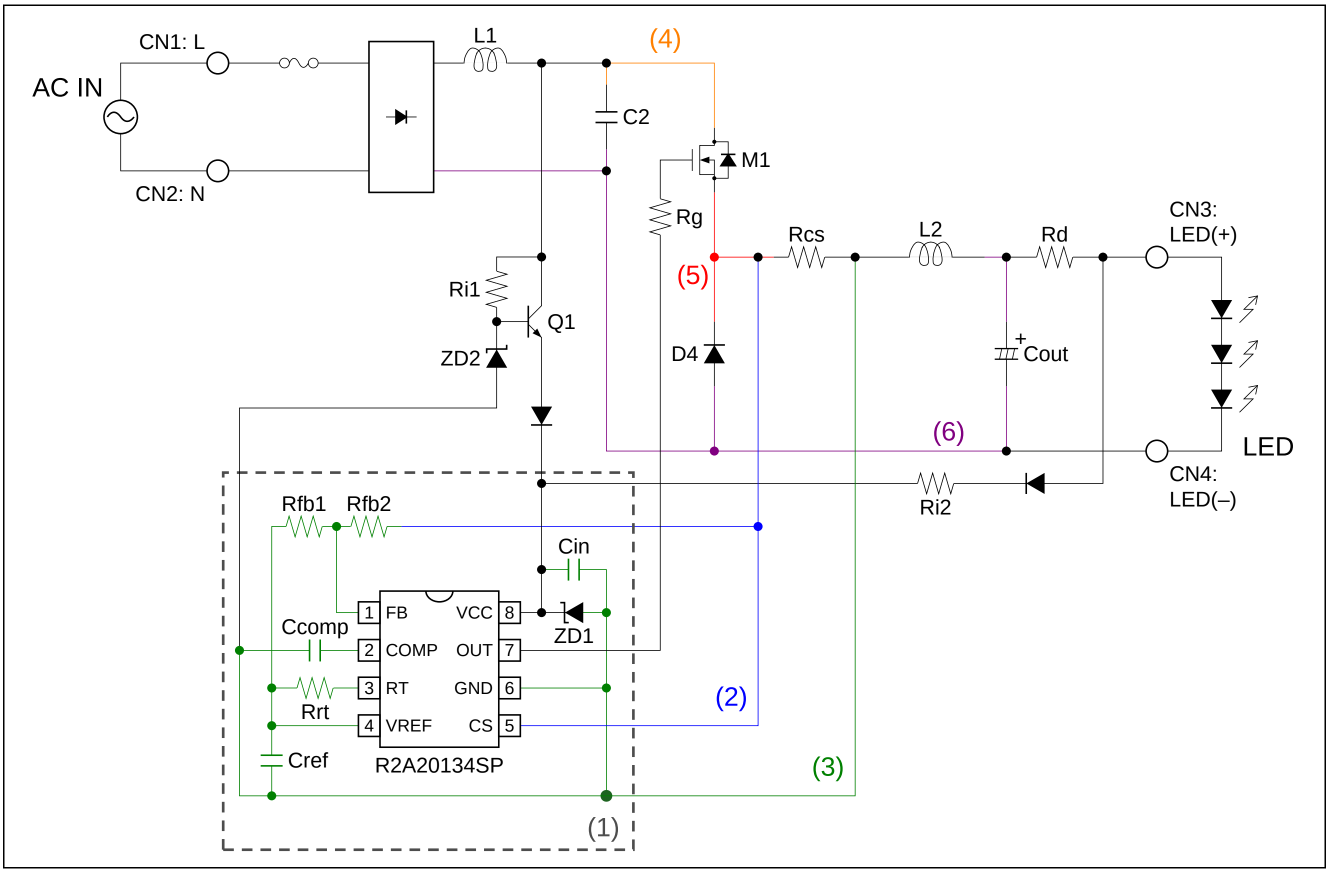


Figure 8.6 R2A20134EVB-NNWE Frequency Characteristics

9. PCB Layout Guide

9.1 Wiring Pattern



(1) Make the wring around the IC as short as possible in order to reduce the switching noise influence.
(2) Connect the CS line as close as possible to Rcs to shorten the wiring.
(3) Wire the independent wide GND pattern and connect it as close as possible to Rcs (output side). Also, please place bypass capacitors (Cin, Cref) of Vcc and Vref, and the resistors of RT and FB (Rrt, Rfb1 and Rfb2) as close as possible to IC, as well as the wiring between GND of IC and the bypass capacitor (Cref) of Vref pin as short as possible.
(4) Make the wire between M1 (Drain) and C2 (+) as short and as thick as possible.
(5) Make the track between M1 (source) and D1 (cathode) as short and as thick as possible.
(6) As switching current flows, make this track as short and as thick as possible.

9.2 Parts Layout and Mount

In case the IC is affected by switching noise, it may cause IC malfunction. As for this, please care following things;

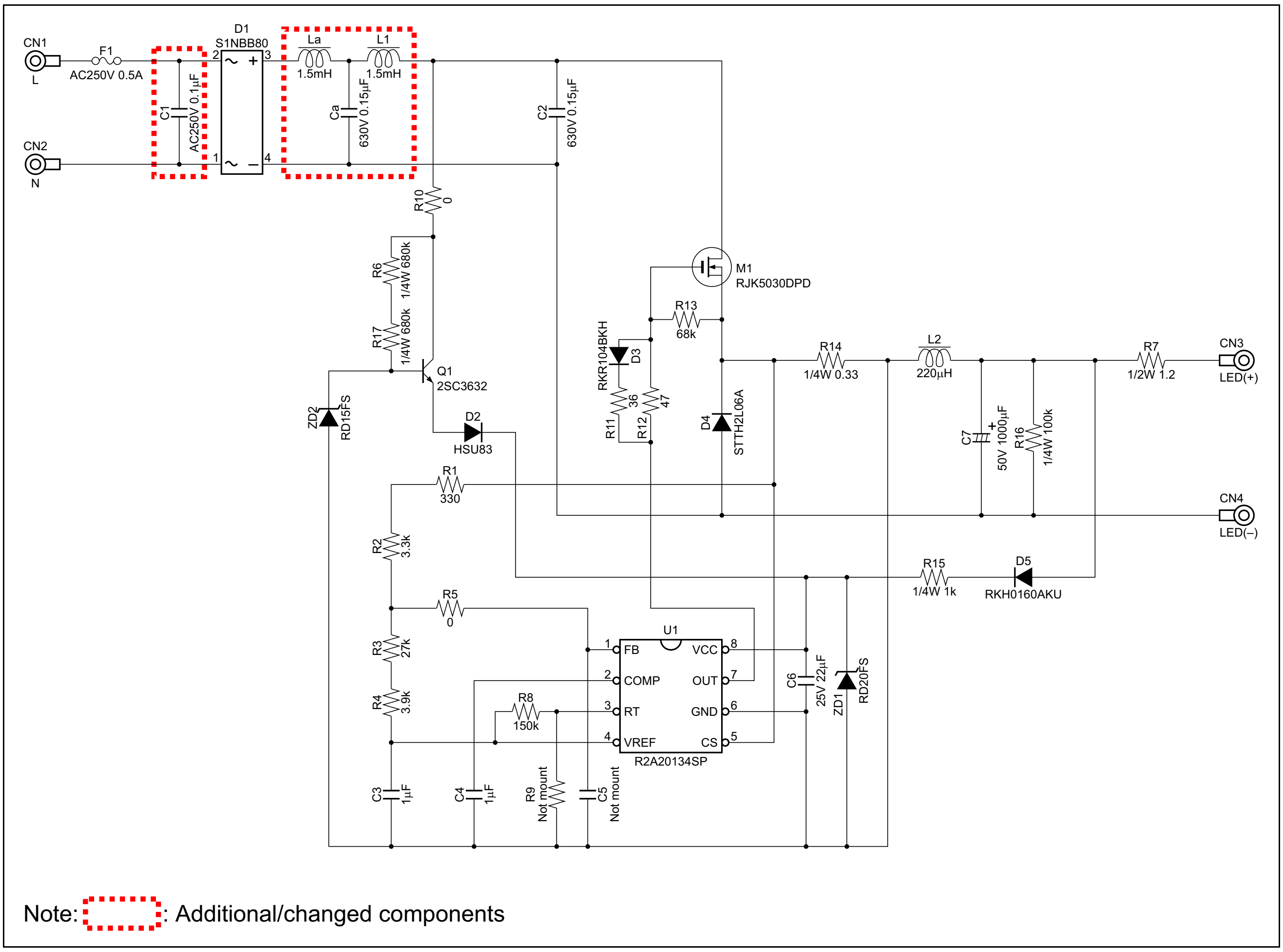
- Keep the distance of IC (R2A20134SP) and MOSFET (M1) as much as possible.
- In case capacitor is mounted as bended, it should be mounted without contact to IC.

10. Conducted Emission

10.1 Conducted Emission Standard (CISPR15) Adaptation

This evaluation board is possible to meet the conducted emission standard (CISPR15) by changing or adding some components.
However, basic characteristics such as power efficiency or power factor are trade-off for conducted emission, please adjust each components' value according to required performance.

10.1.1 Schematic with Conducted Emission Filter

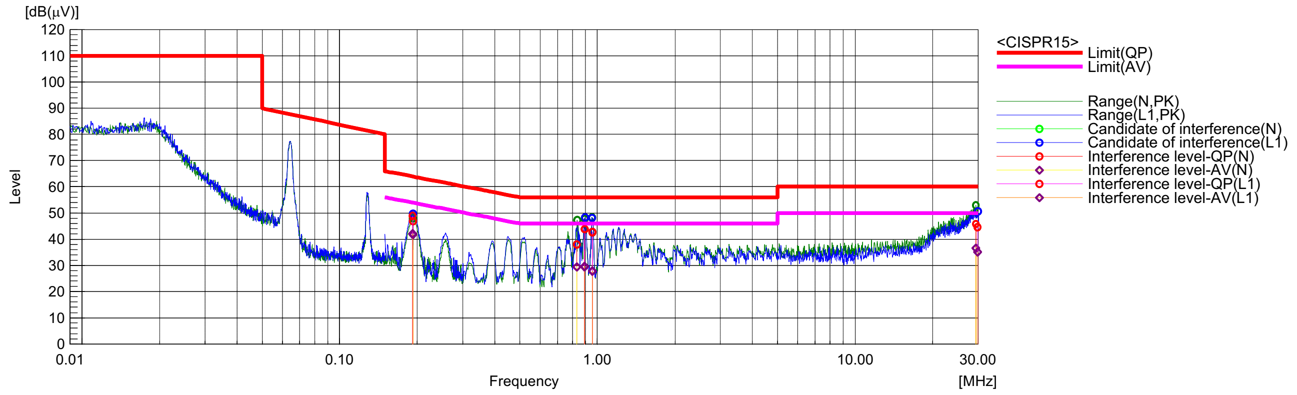


10.1.2 Additional/Changed Parts to Meet Conducted Emission Standard

Symbol	Parts Name	Catalog No.	Q	Rating		Manufacturer
C1	Ceramic capacitor	GA255DR7E2104MW01L	1	250 Vac	0.1 µF	murata
Ca	Ceramic capacitor	RDER72J154K5B1C13B	1	630 V	0.15 µF	murata
L1, La	Inductor	RCR875DNP-152K	2		1.5 mH	SUMIDA

10.2 Conducted Emission Test Results (CISPR15)

- Vin = AC100 V, 60 Hz, LED load (VF = 30 V), Iout = 267 mA



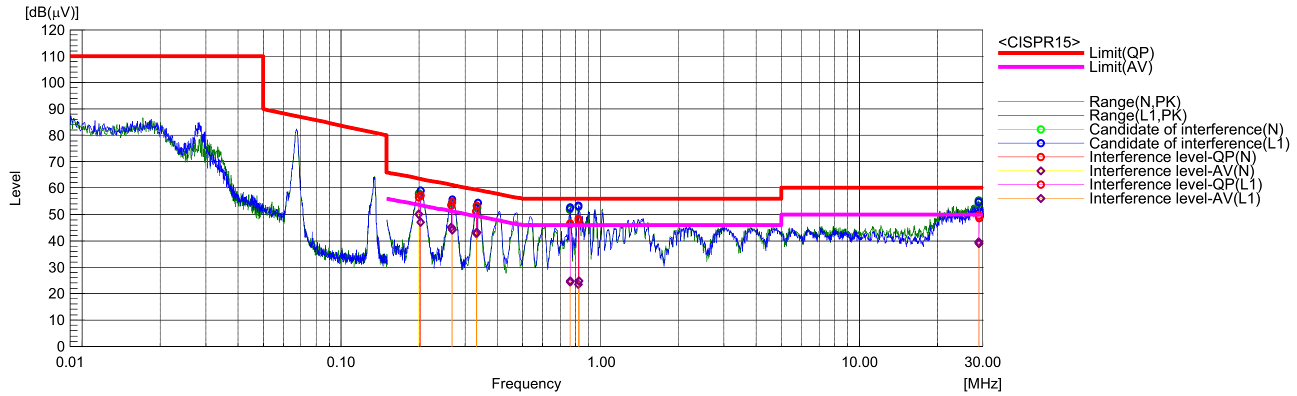
---N Phase ---

No.	Frequency [MHz]	Reading QP [dB(µV)]	Reading CAV [dB]	c.f [dB(µV)]	Result QP [dB(µV)]	Result CAV [dB(µV)]	Limit QP [dB(µV)]	Limit AV [dB(µV)]	Margin QP [dB]	Margin CAV [dB]
1	0.19227	36.8	31.7	10.1	46.9	41.8	63.9	53.9	17.0	12.1
2	0.83223	27.7	19.3	10.2	37.9	29.5	56.0	46.0	18.1	16.5
3	0.89105	33.7	19.3	10.2	43.9	29.5	56.0	46.0	12.1	16.5
4	0.95478	32.6	17.7	10.2	42.8	27.9	56.0	46.0	13.2	18.1
5	29.42104	33.4	24.1	12.4	45.8	36.5	60.0	50.0	14.2	13.5

---L1 Phase ---

No.	Frequency [MHz]	Reading QP [dB(µV)]	Reading CAV [dB]	c.f [dB(µV)]	Result QP [dB(µV)]	Result CAV [dB(µV)]	Limit QP [dB(µV)]	Limit AV [dB(µV)]	Margin QP [dB]	Margin CAV [dB]
1	0.1921	38.7	32.0	10.1	48.8	42.1	63.9	53.9	15.1	11.8
2	0.89222	33.7	19.3	10.2	43.9	29.5	56.0	46.0	12.1	16.5
3	0.95492	32.4	17.7	10.2	42.6	27.9	56.0	46.0	13.4	18.1
4	29.86914	32.3	22.9	12.3	44.6	35.2	60.0	50.0	15.4	14.8

- Vin = AC240 V, 60 Hz, LED load (VF = 30 V), Iout = 267 mA



---N Phase ---

No.	Frequency [MHz]	Reading QP [dB(µV)]	Reading CAV [dB]	c.f [dB(µV)]	Result QP [dB(µV)]	Result CAV [dB(µV)]	Limit QP [dB(µV)]	Limit AV [dB(µV)]	Margin QP [dB]	Margin CAV [dB]
1	0.19927	46.5	40.0	10.1	56.6	50.1	63.6	53.6	7.0	3.5
2	0.2668	43.3	35.1	10.1	53.4	45.2	61.2	51.2	7.8	6.0
3	0.33188	41.1	32.7	10.1	51.2	42.8	59.4	49.4	8.2	6.6
4	0.76424	36.1	14.2	10.2	46.3	24.4	56.0	46.0	9.7	21.6
5	0.82394	38.1	13.3	10.2	48.3	23.5	56.0	46.0	7.7	22.5
6	28.82505	37.1	27.1	12.4	49.5	39.5	60.0	50.0	10.5	10.5

---L1 Phase ---

No.	Frequency [MHz]	Reading QP [dB(µV)]	Reading CAV [dB]	c.f [dB(µV)]	Result QP [dB(µV)]	Result CAV [dB(µV)]	Limit QP [dB(µV)]	Limit AV [dB(µV)]	Margin QP [dB]	Margin CAV [dB]
1	0.20278	47.1	37.0	10.1	57.2	47.1	63.5	53.5	6.3	6.4
2	0.26868	44.6	34.0	10.1	54.7	44.1	61.2	51.2	6.5	7.1
3	0.33334	43.2	33.0	10.1	53.3	43.1	59.4	49.4	6.1	6.3
4	0.76403	36.4	14.6	10.2	46.6	24.8	56.0	46.0	9.4	21.2
5	0.82742	37.3	14.6	10.2	47.5	24.8	56.0	46.0	8.5	21.2
6	28.96092	36.4	26.7	12.3	48.7	39.0	60.0	50.0	11.3	11.0

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Revision Record

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