R2A20134EVB-TINW

R19AN0027EJ0100
Rev.1.00
Sep 27, 2013

R2A20134 Evaluation Board for LED Tube Lamp

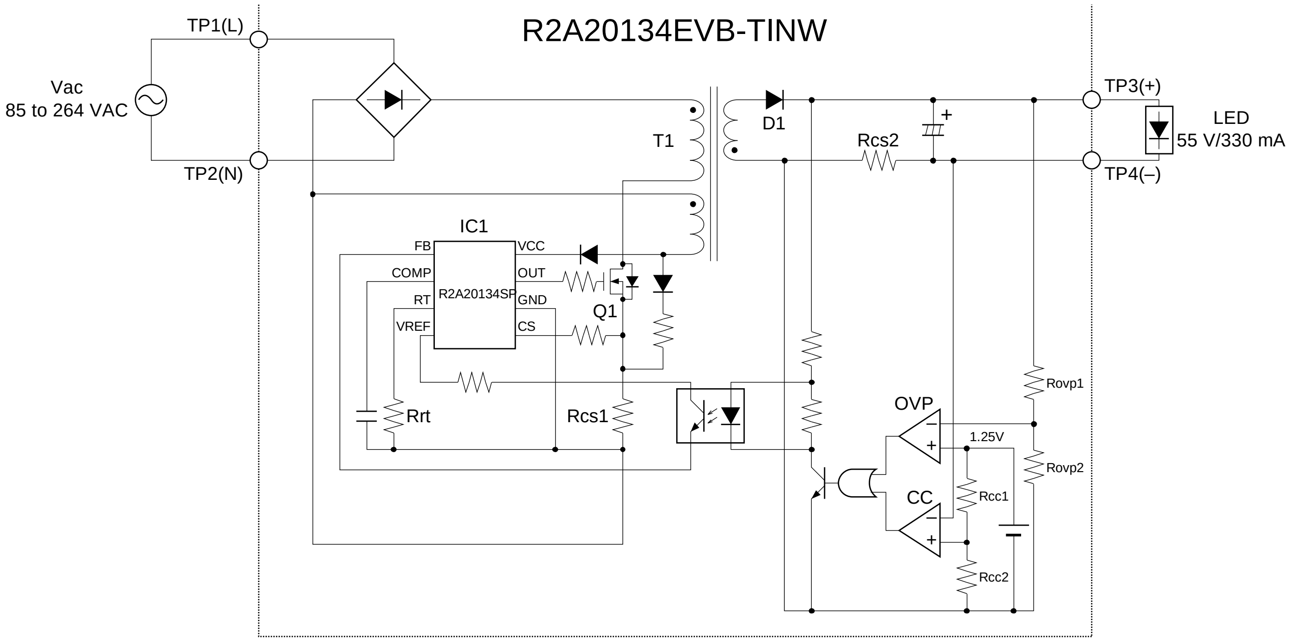
1. Overview

The R2A20134EVB-TINW is an LED driver IC evaluation board for LED tube lamp. All the components to control LED lighting system are onboard, it is easy to start evaluation by supplying power and connecting LED load.
The board has a step-down flyback circuit, operates in constant current mode, and features high efficiency, high power factor, low THD, low ripple voltage, and low noise. It complies with harmonic current limitation (IEC 61000-3-2 Class C).
For evaluating this board, please refer to the R2A20134SP data sheet as well.

2. Specification

No.	Item	Specification
1	Input voltage range	85 to 264 VAC (single phase 47 to 63 Hz)
2	Output power	18 W (max.)
3	Output voltage	55 V (typ.)
4	Output current	330 mA (typ.)
5	Efficiency	85% or more (when Vin = 100 to 240 VAC)
6	Power factor	0.95 or more (when Vin = 100 to 240 VAC)
7	Switching frequency	Variable (minimum switching frequency: 50 kHz)
8	Operation mode	Critical Conduction Mode
9	Board	Two layers / glass epoxy (FR4) / dual-sided mount
10	Size (W ´ D ´ H)	425 mm ´ 20 mm ´ 10 mm (component side)

3. Board System Diagram and Connection



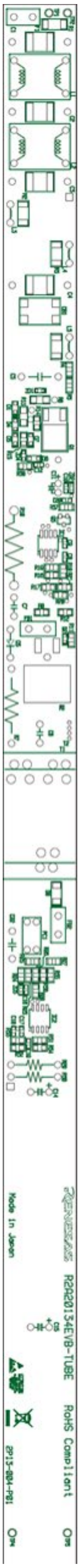
Connection Method

(1) Connect LED load (VF = 55 V/330 mA) between TP3 (+) and TP4 (–). Take care of the polarity.
(2) Connect an AC power supply to TP1 and TP2.

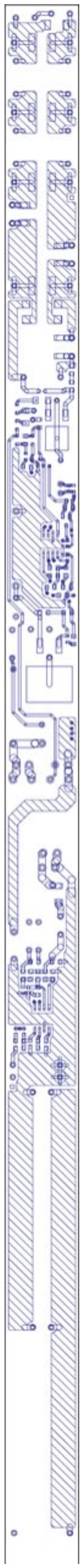
⚠ While the board is energized, in parts of the board could be at high voltage. Take care to handle the board.
Turn the AC power supply on with LED load connected between TP3 (+) and TP4 (–).

4. PCB Layout

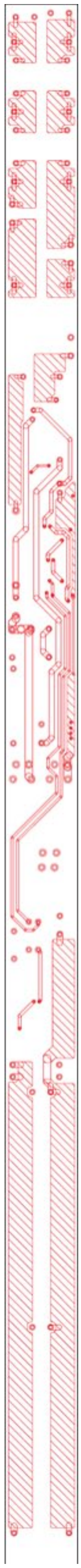
- Components mounting



- Layout pattern (Top)



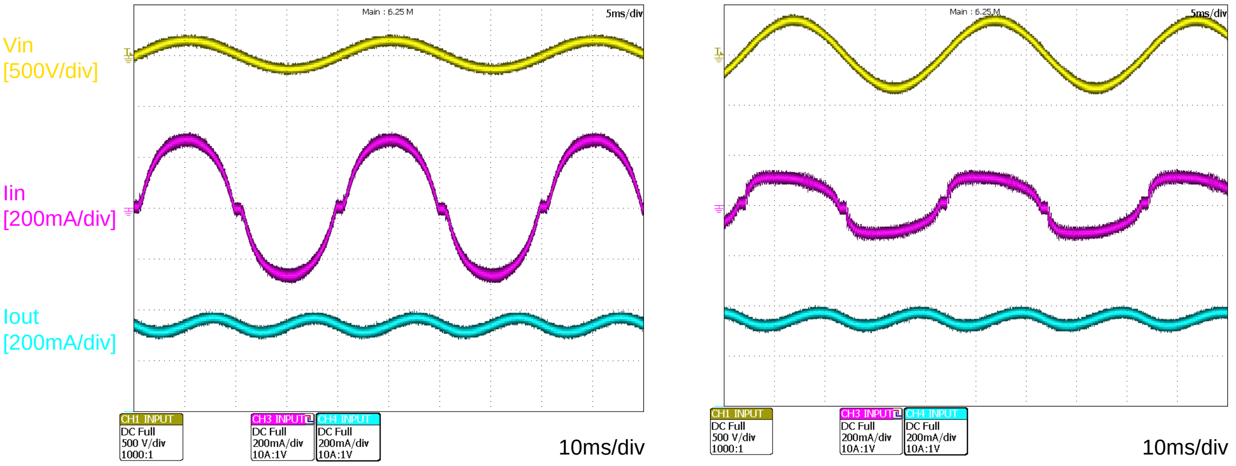
- Layout pattern (Bottom)



5. Performance Data

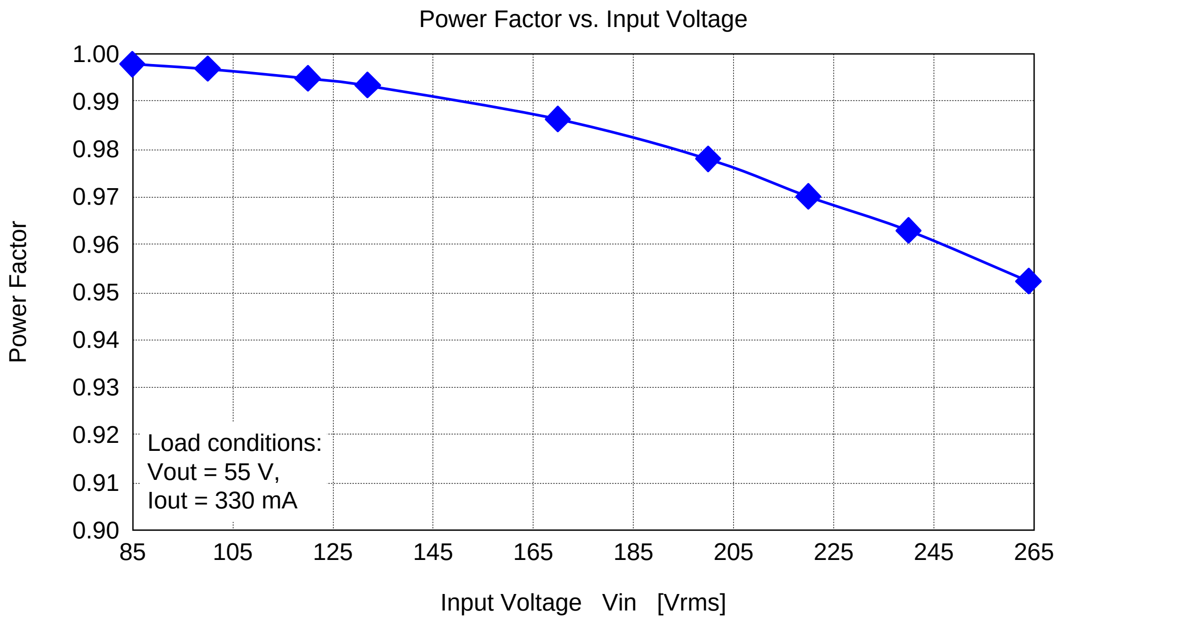
5.1 Operation Waveform

• Vin = 100 VAC, Vout = 55 V, Iout = 330 mA • Vin = 240 VAC, Vout = 55 V, Iout = 330 mA

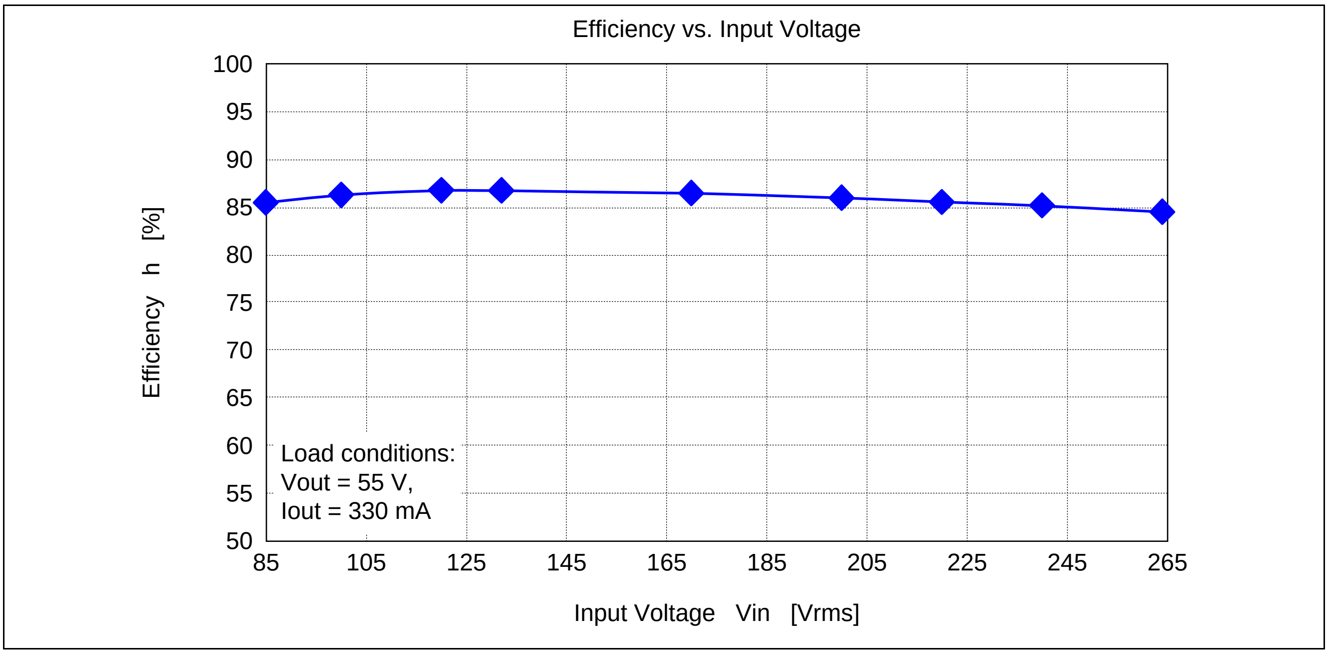


* Vin: Input voltage, Iin: Input current, Iout: Output current

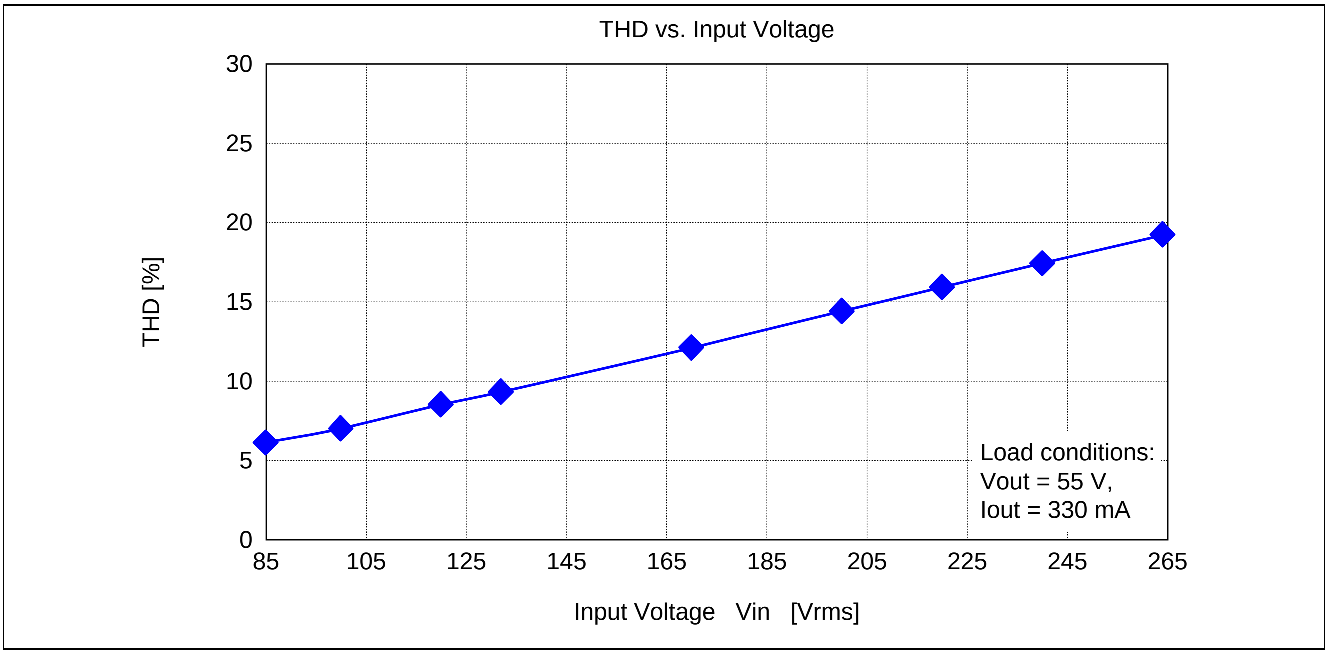
5.2 Power Factor



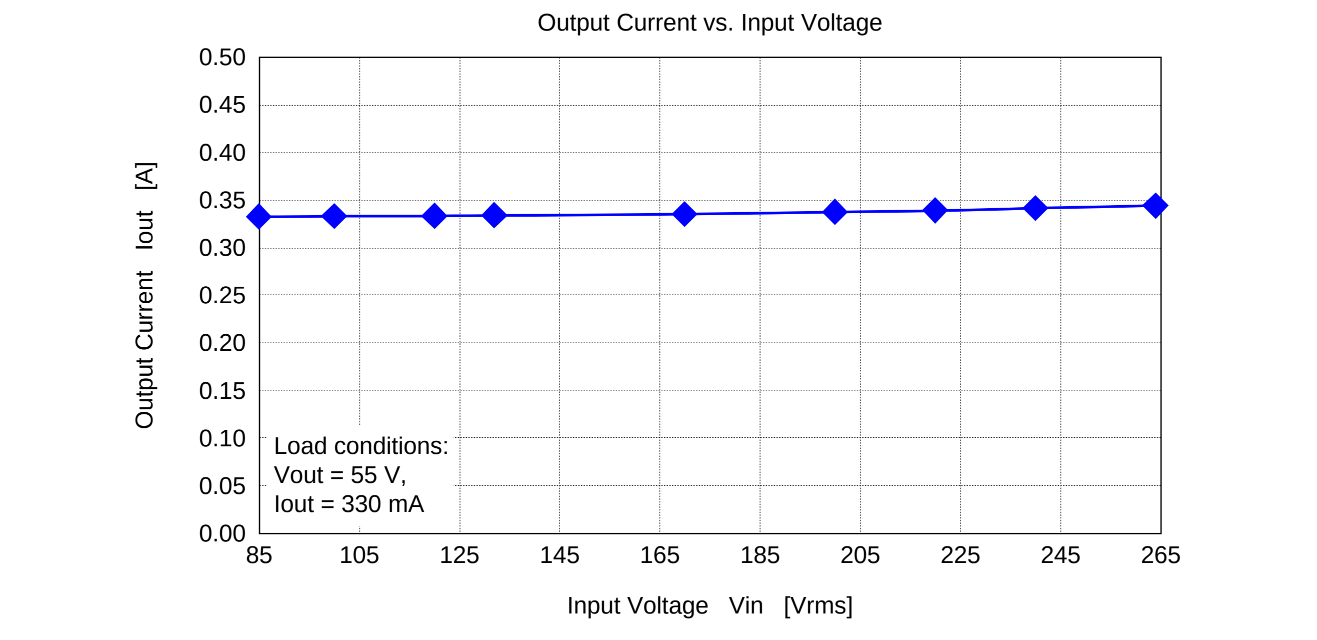
5.3 Efficiency



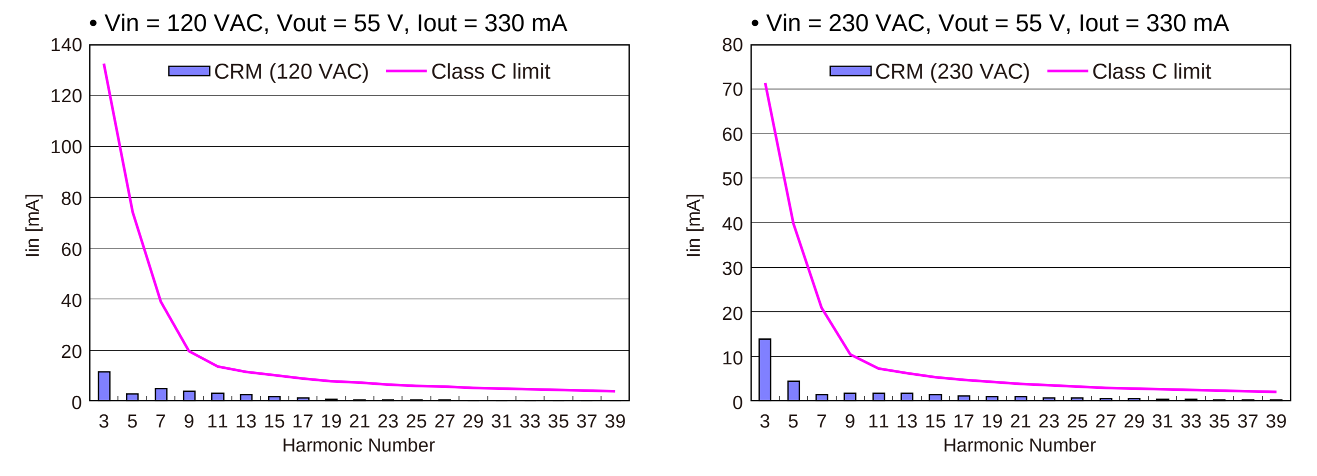
5.4 THD (Total Harmonic Distortion)



5.5 Output Current

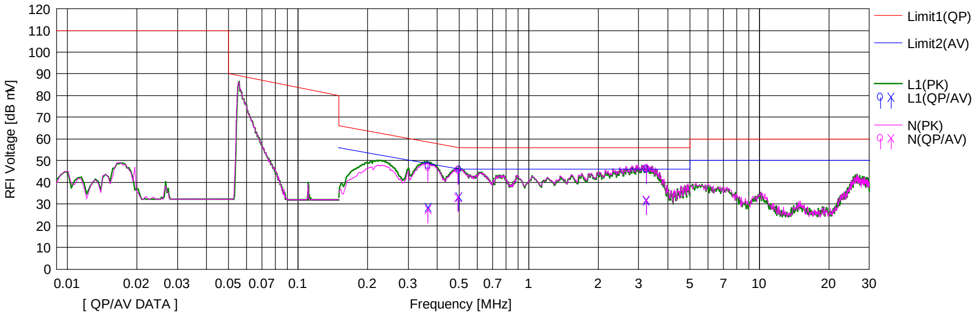


5.6 Harmonic Current



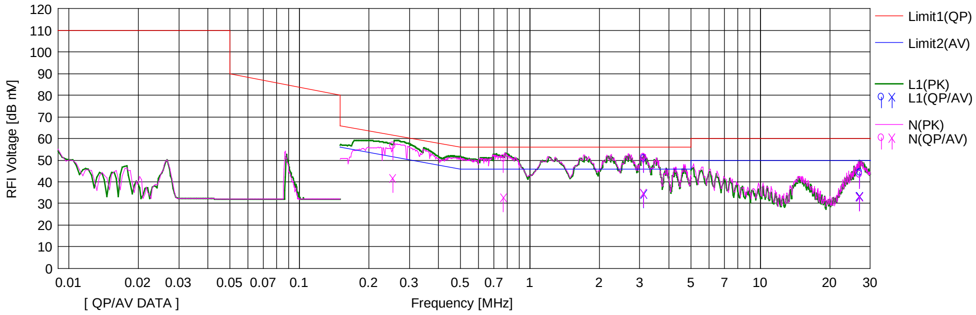
5.7 Conducted EMI (CISPR15)

- Vin = AC100 V, 50 Hz, LED load (VF = 55 V), Iout = 330 mA



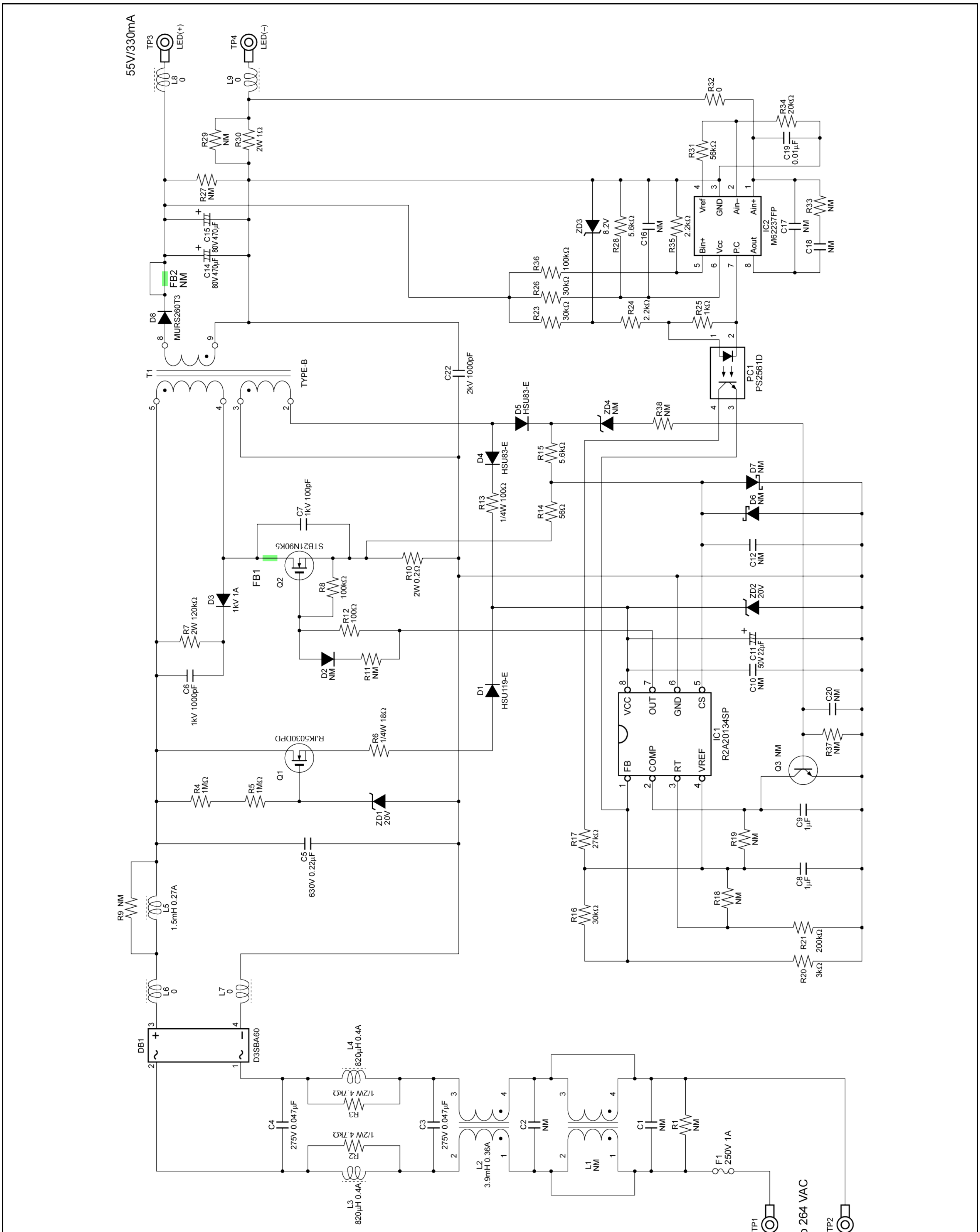
No.	Frequency [MHz]	Reading QP [dBmV]	Reading AV [dBmV]	C.Fac [dB]	Result QP [dBmV]	Result AV [dBmV]	Limit QP [dBmV]	Limit AV [dBmV]	Margin QP [dB]	Margin AV [dB]	Phase
1	0.36631	27.7	8.4	19.9	47.6	28.3	58.5	48.5	10.9	20.2	L1
2	0.49816	25.8	13.4	19.9	45.7	33.3	56	46	10.3	12.7	L1
3	3.23605	25.6	11.3	20.2	45.8	31.5	56	46	10.2	14.5	L1
4	0.36618	26.9	7.5	19.9	46.8	27.4	58.5	48.5	11.7	21.1	N
5	0.49355	25.5	13	19.9	45.4	32.9	56.1	46.1	10.7	13.2	N
6	3.23327	26.1	11.7	20.2	46.3	31.9	56	46	9.7	14.1	N

- Vin = AC240 V, 50 Hz, LED load (VF = 55 V), Iout = 330 mA



No.	Frequency [MHz]	Reading QP [dBmV]	Reading AV [dBmV]	C.Fac [dB]	Result QP [dBmV]	Result AV [dBmV]	Limit QP [dBmV]	Limit AV [dBmV]	Margin QP [dB]	Margin AV [dB]	Phase
1	3.11971	30.5	14.1	20.2	50.7	34.3	56	46	5.3	11.7	L1
2	26.89302	22.8	12.5	20.7	43.5	33.2	60	50	16.5	16.8	L1
3	26.94462	23.7	12.4	20.7	44.4	33.1	60	50	15.6	16.9	L1
4	0.25419	36.8	21.6	19.9	56.7	41.5	61.6	51.6	4.9	10.1	N
5	0.76813	30.8	12.6	20	50.8	32.6	56	46	5.2	13.4	N
6	3.10281	31	14.4	20.2	51.2	34.6	56	46	4.8	11.4	N
7	26.89461	22.9	12.4	20.5	43.4	32.9	60	50	16.6	17.1	N

6. Schematic



Note: The values of circuit constants may be changed to improve the circuit characteristics.

7. Bill of Materials

Symbol	Parts Name	Catalog No.	Q	Rating		Manufacturer
IC1	Control IC	R2A20134SP	1			Renesas Electronics
IC2	Constant voltage/current control IC	M62237FP	1			Renesas Electronics
C1	X Capacitor	Not Mount	1			
C2	X Capacitor	Not Mount	1			
C3	X Capacitor	LE473	1	275V	0.047mF	Okaya Electric
C4	X Capacitor	LE473	1	275V	0.047mF	Okaya Electric
C5	Ceramic Capacitor	RDED72J224K5B1	1	630V	0.22mF	Murata Manufacturing
C6	Ceramic Capacitor	DESD33A102KN2A	1	1000V	1000pF	Murata Manufacturing
C7	Ceramic Capacitor	DESD33A101KN2A	1	1000V	100pF	Murata Manufacturing
C8	Chip Capacitor	GRM188R71E105KA12D	1	25V	1mF	Murata Manufacturing
C9	Chip Capacitor	GRM188R71E105KA12D	1	25V	1mF	Murata Manufacturing
C10	Chip Capacitor	Not Mount	1			
C11	Electrolytic Capacitor	PX	1	50V	22mF	Rubycon
C12	Chip Capacitor	Not Mount	1			
C13	Unused number					
C14	Electrolytic Capacitor	TXW	1	80V	470mF	Rubycon
C15	Electrolytic Capacitor	TXW	1	80V	470mF	Rubycon
C16	Chip Capacitor	Not Mount	1			
C17	Chip Capacitor	Not Mount	1			
C18	Chip Capacitor	Not Mount	1			
C19	Chip Capacitor	GRM188R11H103KA01D	1	25V	0.01mF	Murata Manufacturing
C20	Chip Capacitor	Not Mount	1			
C21	Unused number					
C22	Ceramic Capacitor	DEBF33D102ZD1B	1	2000V	1000pF	Murata Manufacturing
Q1	MOSFET	RJK5030DPD	1	500V	5A	Renesas Electronics
Q2	MOSFET	STB21N90K5	1	900V	18.5A	ST Micro
Q3	Transistor	Not Mount	1			
L1	Common mode choke coil	Not Mount	1			
L2	Common mode choke coil	LF1290NP-392	1	0.36A	3.9mH	Sumida
L3	Radial lead inductor	10RHT2	1	0.4A	820mH	TOKO
L4	Radial lead inductor	10RHT2	1	0.4A	820mH	TOKO
L5	Radial lead inductor	10RHT2	1	0.27A	1.5mH	TOKO
L6	Chip resistor	CRCW12060000Z0EA	1		0W	VISHAY
L7	Chip resistor	CRCW12060000Z0EA	1		0W	VISHAY
L8	Chip resistor	CRCW12060000Z0EA	1		0W	VISHAY
L9	Chip resistor	CRCW12060000Z0EA	1		0W	VISHAY
T1	Transformer	TYPE-B	1	600mH		SMI
PC1	Photo coupler	PS2561D-1	1			Renesas Electronics
DB1	Bridge diode	S1NB60	1	600V	1A	Shindengen Electric
D1	Rectifying diode	HSU119-E	1	80V	100mA	Renesas Electronics
D2	Schottky barrier diode	Not Mount	1			
D3	Fast recovery diode	D1NK100	1	1kV	1A	Shindengen Electric
D4	High voltage diode	HSU83-E	1	250V	100mA	Renesas Electronics
D5	High voltage diode	HSU83-E	1	250V	100mA	Renesas Electronics
D6	Zener diode	Not Mount	1			
D7	Zener diode	Not Mount	1			
D8	Fast recovery diode	MURS260T3	1	600V	2A	ON Semiconductor
ZD1	Zener diode	RKZ20B2KJ	1	150mW	20V	Renesas Electronics
ZD2	Zener diode	RKZ20B2KJ	1	150mW	20V	Renesas Electronics
ZD3	Zener diode	RKZ8.2B2KJ	1	150mW	8.2V	Renesas Electronics
ZD4	Zener diode	Not Mount	1			
R1	Chip resistor	Not Mount	1			
R2	Chip resistor	MCR50JZHJ472	1	1/2W	4.7kW	ROHM
R3	Chip resistor	MCR50JZHJ472	1	1/2W	4.7kW	ROHM
R4	Chip resistor	RK73B2ATTD105J	1	1/8W	1MW	KOA
R5	Chip resistor	RK73B2ATTD105J	1	1/8W	1MW	KOA
R6	Chip resistor	RK73B2BTTD180J	1	1/4W	18W	KOA
R7	Metal oxide film resistor	MO2C	1	2W	120kW	KOA
R8	Chip resistor	RK73B2ATTD104J	1	1/8W	100kW	KOA
R9	Chip resistor	Not Mount	1			
R10	Wire-wound resistor	NKN200JT-73-0R2	1	2W	0.2W	Yageo
R11	Chip resistor	Not Mount	1			
R12	Chip resistor	RK73B2ATTD101J	1	1/8W	100W	KOA
R13	Chip resistor	RK73H2BTTD1000F	1	1/4W	100W	KOA
R14	Chip resistor	RK73B2ATTD560J	1	1/8W	56W	KOA
R15	Chip resistor	Not Mount	1			
R16	Chip resistor	RK73B2ATTD303J	1	1/8W	30kW	KOA
R17	Chip resistor	RK73B2ATTD273J	1	1/8W	27kW	KOA
R18	Chip resistor	Not Mount	1			
R19	Chip resistor	Not Mount	1			
R20	Chip resistor	RK73B2ATTD302J	1	1/8W	3kW	KOA
R21	Chip resistor	RK73B2ATTD204J	1	1/8W	200kW	KOA
R22	Unused number					
R23	Chip resistor	RK73B2ATTD303J	1	1/8W	30kW	KOA
R24	Chip resistor	RK73B2ATTD222J	1	1/8W	2.2kW	KOA
R25	Chip resistor	RK73B2ATTD102J	1	1/8W	1kW	KOA
R26	Chip resistor	RK73B2ATTD303J	1	1/8W	30kW	KOA
R27	Chip resistor	Not Mount	1			
R28	Chip resistor	RK73B2ATTD562J	1	1/8W	5.6kW	KOA
R29	Metal film resistor	MOSX1C	1	1W	1W	KOA
R30	Metal film resistor	Not Mount	1			
R31	Chip resistor	RK73B2ATTD563J	1	1/8W	56kW	KOA
R32	Chip resistor	RK73Z2ATTD	1	1A	0W	KOA
R33	Chip resistor	Not Mount	1			
R34	Chip resistor	Not Mount	1			
R35	Chip resistor	RK73B2ATTD222J	1	1/8W	2.2kW	KOA
R36	Chip resistor	RK73B2ATTD104J	1	1/8W	100kW	KOA
R37	Chip resistor	Not Mount	1			
R38	Chip resistor	Not Mount	1			
F1	Fuse	39211000440	1	250V	1A	Littelfuse
FB1	Ferrite bead	BL02RN2R1M2B	1			Murata Manufacturing
FB2	Ferrite bead	Jumper	1			

Note: The components may be changed to improve the circuit characteristics.

8. Design Guide

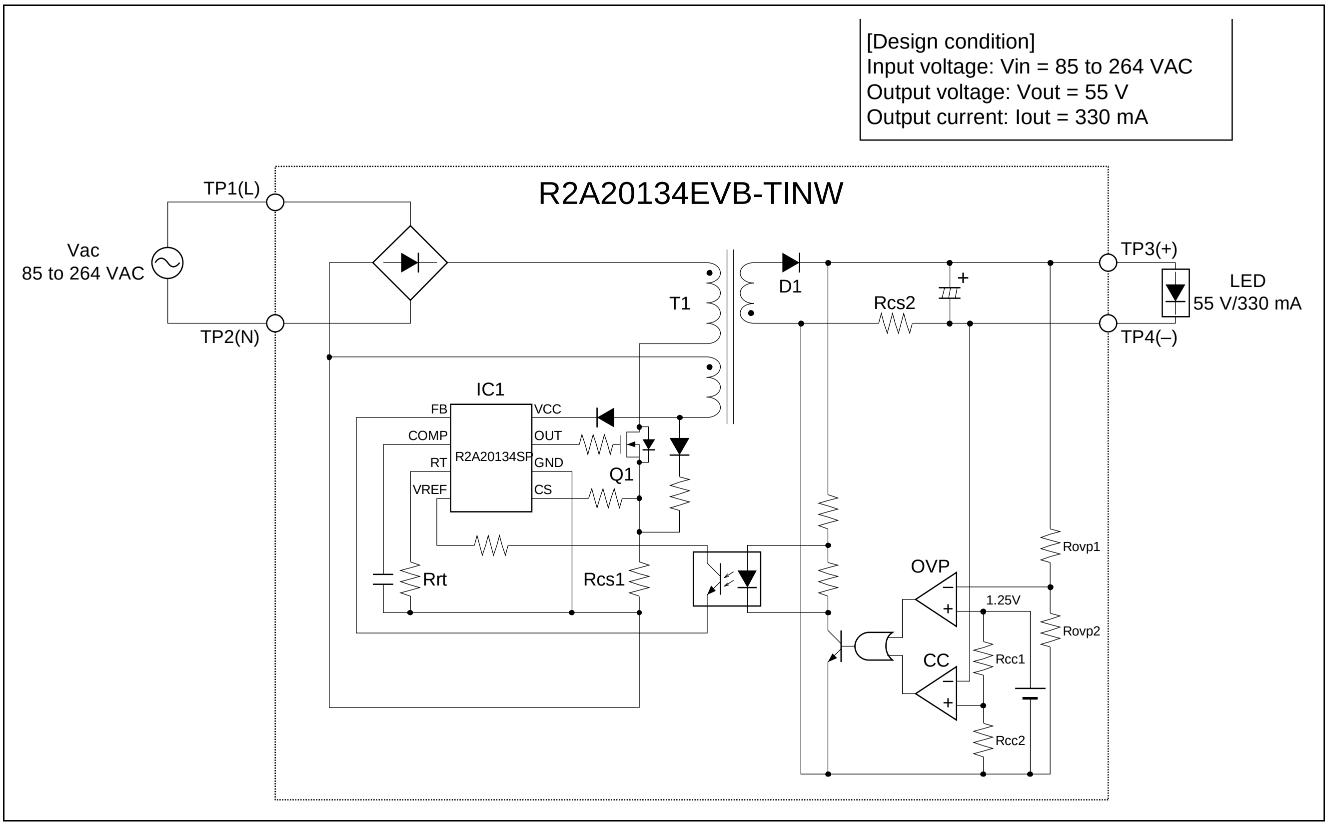


Figure 8.1 R2A20134EVB-TINW Circuit

This evaluation board operates in constant current (CC) mode. The board controls the output current Iout to be constant. Iout and the COMP pin voltage are constant, so current I1, which flows into the primary side of transformer T1, is proportional to input voltage Vin. The input current Iin is generated by smoothing I1, so Iin is also proportional to Vin. This leads to the good power factor and THD (total harmonic distortion) characteristics (refer to Figure 8.3).

8.1 Setting Switching Frequency

The frequency is generally in the range from 20 to 100 kHz, both in consideration of efficiency and so that it is not in the range of audible frequencies.
The minimum oscillation frequency is set to 50 kHz on this evaluation board.

8.2 Selection of Switching Frequency Setting Resistance Rrt

When the evaluation board operates in current critical mode, the RT pin is pulled down to GND by the Rrt resistor with a value of several hundred kW. The value of Rrt on the board is 200 kW.

8.3 Selection of Transformer (T1)

8.3.1 Design Example of Transformer

1. The peak value of the current in the primary-side transformer, I1, and the peak value of the current in the secondary-side transformer, I2, are calculated.

$$I_1(\text{peak}) = \frac{2}{\text{Don}} \times \text{Iin(peak)} = \frac{2\sqrt{2}\,\text{Pout}}{\text{Don Vin(min) h}}\,[\text{A}] = \frac{2 \times \sqrt{2} \times 18}{0.45 \times 80 \times 0.85} = 1.66[\text{A}]$$

$$I_2(\text{peak}) = \frac{2}{\text{Doff}} \times \text{Is(peak)} = \frac{2}{\text{Doff}} \times \frac{2 \times \text{Pout}}{(\text{Vout} + V_F)}\,[\text{A}] = \frac{2}{0.55} \times \frac{2 \times 18}{(55 + 1)} = 2.34[\text{A}]$$

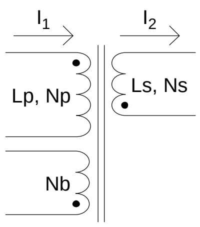


Figure 8.2 Transformer Circuit

2. The inductance of the primary-side transformer, LP, is calculated. The calculation formula is as follows in current critical mode:

$$\text{Lp} = \frac{\sqrt{2}\,\text{Vin(min) Don}}{I_1(\text{peak})\,\text{fout}}\,[\text{H}] = \frac{\sqrt{2} \times 80 \times 0.45}{1.66 \times 50 \times 10^3}\,[\text{H}] = 613[\text{mH}]$$

A value of 600 mH is selected for inductance in accordance with the result of the calculation.

3. After selected the transformer core, the number of turns in the winding of the primary-side transformer, Np, is calculated.

$$\text{Np} = \frac{\sqrt{2}\,\text{Vin(min) Don}}{\text{fsw DB Ae}} \times 10^8[\text{T}] = \frac{\sqrt{2} \times 80 \times 0.45}{50 \times 10^3 \times 2400 \times 0.55} \times 10^8 = 77.1[\text{T}]$$

A value of 80 turns is selected for Np in accordance with the result of the calculation.

4. The inductance of the secondary-side transformer, LS, is calculated.

$$\text{Ls} = \frac{(\text{Vout} + V_F)}{I_2(\text{peak})} \times \frac{\text{Doff}}{\text{fout}}\,[\text{H}] = \frac{55 + 1}{2.34} \times \frac{0.55}{50 \times 10^3}\,[\text{H}] = 263.2[\text{mH}]$$

An value of 220 mH is selected for inductance in accordance with the result of the calculation.

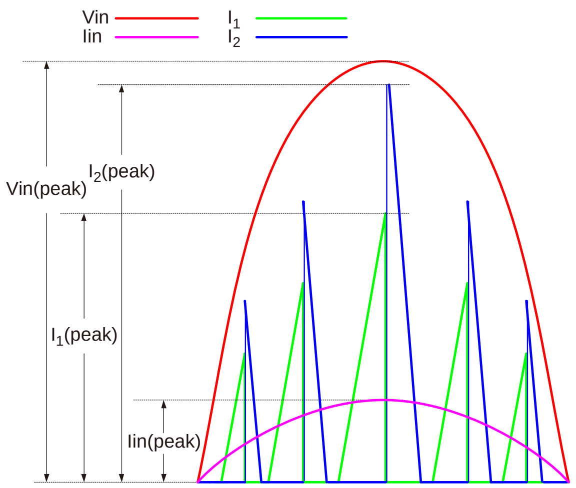


Figure 8.3 Relationship between Transformer Current, Input Current, and Input Voltage

5. The number of turns in the winding of the secondary-side transformer, NS, is calculated.

$$Ns = \sqrt{\frac{Ls}{Lp}}\,Np[T] = \sqrt{\frac{220m}{600m}} \times 80[T] = 48.4[T]$$

A value of 48 turns is selected for Ns in accordance with the result of the calculation.

6. The number of turns in the winding of the auxiliary transformer, Nb, is calculated.

$$Nb = \frac{Vb}{Vout + V_F}\,Ns[T] = \frac{20}{55 + 1} \times 48[T] = 17.1[T]$$

A value of 17 turns is selected for Nb in accordance with the result of the calculation.

Vin(min):	Minimum input voltage (actual value)	Iin(peak):	Peak value of input current	Don:	On-time duty
Vin(peak):	Peak value of input voltage	Ae:	Effective cross-sectional area of the core [cm^2]	Doff:	Off-time duty
Vout:	Output voltage	DB:	Core magnetic flux density variation [G]	Pout:	Output power
V_F:	Diode forward voltage	fout:	Switching frequency		
Vb:	Voltage across auxiliary winding	h:	Efficiency of conversion		

8.4 Selection of MOSFET (Q1)

Firstly, Drain-Source voltage of MOSFET, Vds, should be calculated. At the moment of MOSFET turning off, that is Vds reaching to maximum voltage, surge voltage Vk derived from transformer leakage inductance arises in addition to Vin and fly-back voltage Vf. When VK is 200 V, Vds (max.) when the MOSFET is turned off is calculated as follows:

$$Vds(max) = \sqrt{2}\,Vin(max) + Vf + V_K = \sqrt{2} \times 264 + \frac{80}{48} \times (55 + 1.5) + 200 = 667.5[V]$$

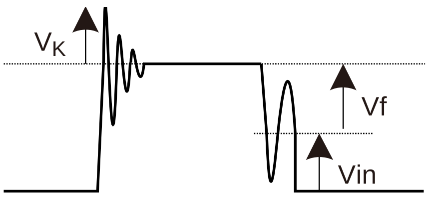


Figure 8.4 Vds Waveform of MOSFET

The peak drain current, I1(peak), at minimum input voltage is calculated as follows:

$$I_1(peak) = \frac{\sqrt{2}\,Vin(min)\,Don}{Lp\,fout} = \frac{\sqrt{2} \times 80 \times 0.45}{600 \times 10^{-6} \times 50 \times 10^{3}} = 1.7[A]$$

Based on the result of the calculation, the MOSFET with voltage rating of 900 V and a rated current of 18.5 A is selected so that it operates within a range of safe operation.

Note: Please confirm if selected components' rating meet to actual operation.

8.5 Selection of Current Detection Resistor (Rcs1)

The overcurrent detection resistor Rcs1 for the primary-side overcurrent protection (OCP) is calculated as follows: Considering that the OCP threshold of IC1, Vocp, is 0.6 V (typ.) and I1(peak) is calculated as above, the OCP threshold is set to 3.0 A.

$$Rcs1[W] = \frac{V_{OCP}}{I_1(peak)} = \frac{0.6}{3.0} = 0.2[W]$$

A value of 0.2 W(rated power of 2W) is selected for current detection resistor RCS in accordance with the result of the calculation.

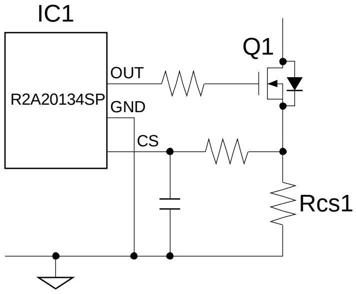


Figure 8.5 Current Detection Resistor

8.6 Selection of Output Current Setting Resistor

The resistor used to set the output current Iout, Rcs2, is calculated.
Rcc1 and Rcc2 are determined so that the formula is satisfied.

$$Rcs2[W] = \frac{Rcc2}{Rcc1 + Rcc2} \times \frac{Vref}{Iout}$$

The charge control IC2 allows the use of a reference voltage Vref (A) for the error amplifier of 1.25 V or less through the addition of an external resistor. Because the reference voltage of the IC2, Vref, is 1.25 V, Vref (A) is 0.33 V when Rcc1 is 56 kWand Rcc2 is 20 kW. Because the target for the output current Iout is 0.33 A, a value of 1 Wis selected for current detection resistor Rcs2.

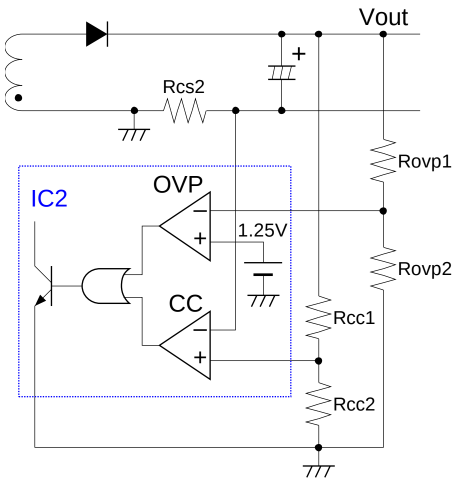


Figure 8.6 IC2 and Peripheral Circuit

8.7 Selection of Secondary-side Rectifying Diode (D1)

The maximum reverse voltage which is applied when the secondary-side rectifying diode is turn off, V_{AK}(max.), is calculated.

$$V_{AK}(\max) = Vs + Vout = \frac{Ns}{Np} \times \sqrt{2}\, Vin(\max) + Vout = \frac{48}{80} \times \sqrt{2} \times 264 + 80 = 304[V]$$

The maximum value of the forward current, I_F, is calculated.

$$I_F(\max) = \frac{2}{Doff} \times Iout = \frac{2}{0.55} \times 0.33 = 1.2[A]$$

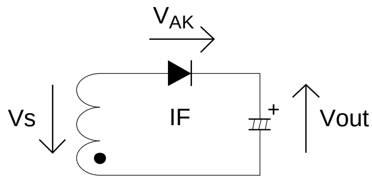


Figure 8.7 Secondary-side Rectifying Diode

Based on the above, a fast recovery diode (FRD) with rated reverse voltage of 600 V and a rated current of 2 A is selected.

Note: Please confirm if selected component's rating meet to actual operation.

8.8 Setting of Overvoltage Protection (OVP) Circuit

The constants for the overvoltage protection (OVP) circuit of the output are selected. The following is the relationship between Vovp, the voltage when the output is open circuit, and Rovp1 and Rovp2.

$$Vovp = \frac{Rovp1 + Rovp2}{Rovp2} \times Vref$$

Vovp is set to 60 V. Then, a value of 100 kW is selected for Rovp1 and a value of 2.2 kW is selected for Rovp2 so that the above formula is satisfied.

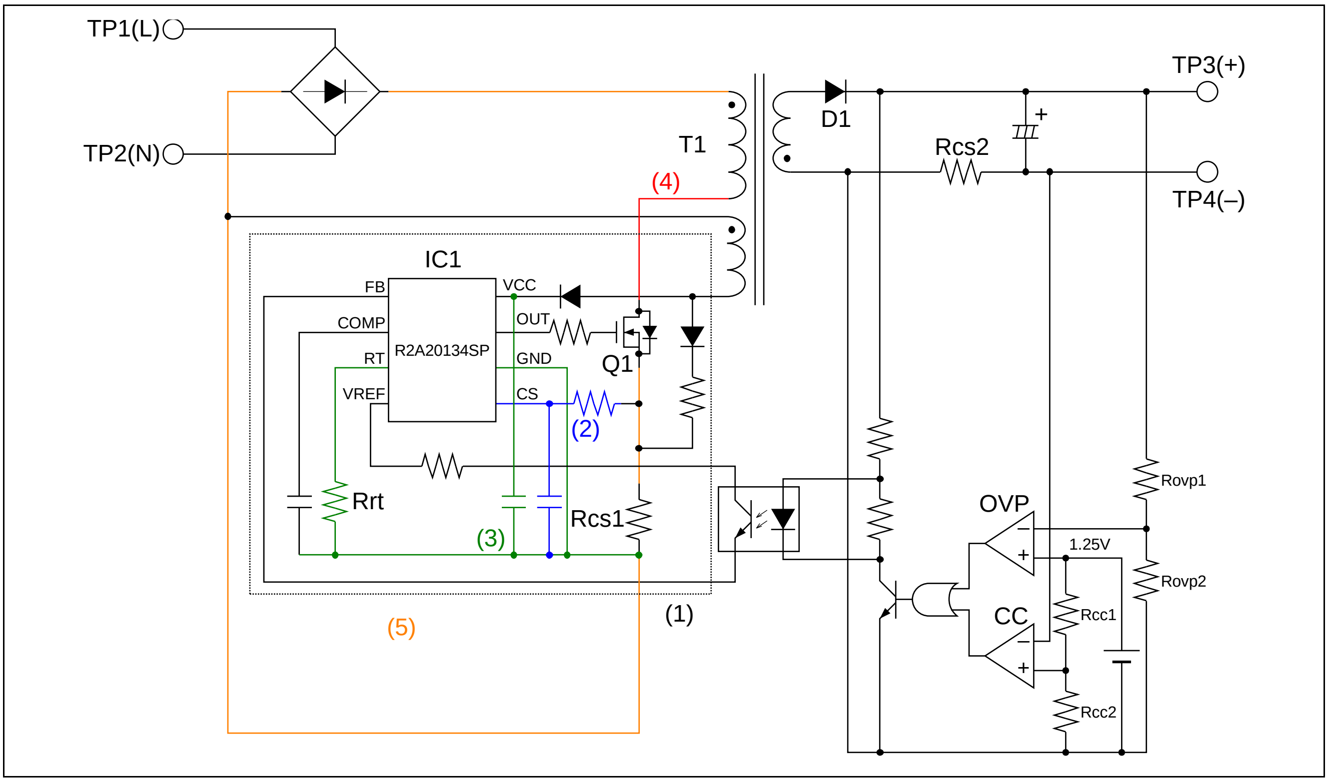
8.9 Setting of ZCD

The ZCD detection signal level is set. The voltage at the CS pin, Vcs, must be greater than or equal to Vzcd (19 mV (max.)) of IC1. In addition, current Ics (–85 mA) flowing from the CS pin into Rzcd1 and Rcs applies an offset to the voltage on the CS pin. Accordingly, for correct ZCD detection, the value of Rzcd1 must satisfy the following relationship: Ics ´ Rzcd1 < Vzcd

$$Vcs = \frac{R_{ZCD1} + R_{ZCD2}}{R_{ZCD2}} \times (Vb - V_F)$$

When Vcs is set to 0.2 V, 20 V is substituted for Vb, 0.5 V is substituted for VF, and Rzcd1 is set to 56 W, Rzcd2 is 5.6 kW in accordance with the above formula.

9. PCB Layout Guidelines



(1) Make the wiring 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. Also, please place a noise suppression filter as close as possible to IC.
(3) Wire the independent thick GND pattern of the IC as close to the Rcs1 resistor (on the output side) as possible. Also, place the VCC bypass capacitor and the RT resistor as close to the IC as possible.
(4) To decrease the parasite inductance, connect T1 and the drain of Q1 by using independent think and short pattern.
(5) Make this track as thick and short as possible because the switching current flows into the wire.

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Revision Record

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