Power factor correction IC: FA1B00N
Power supply design example: 390 V / 150 W

Reference Design

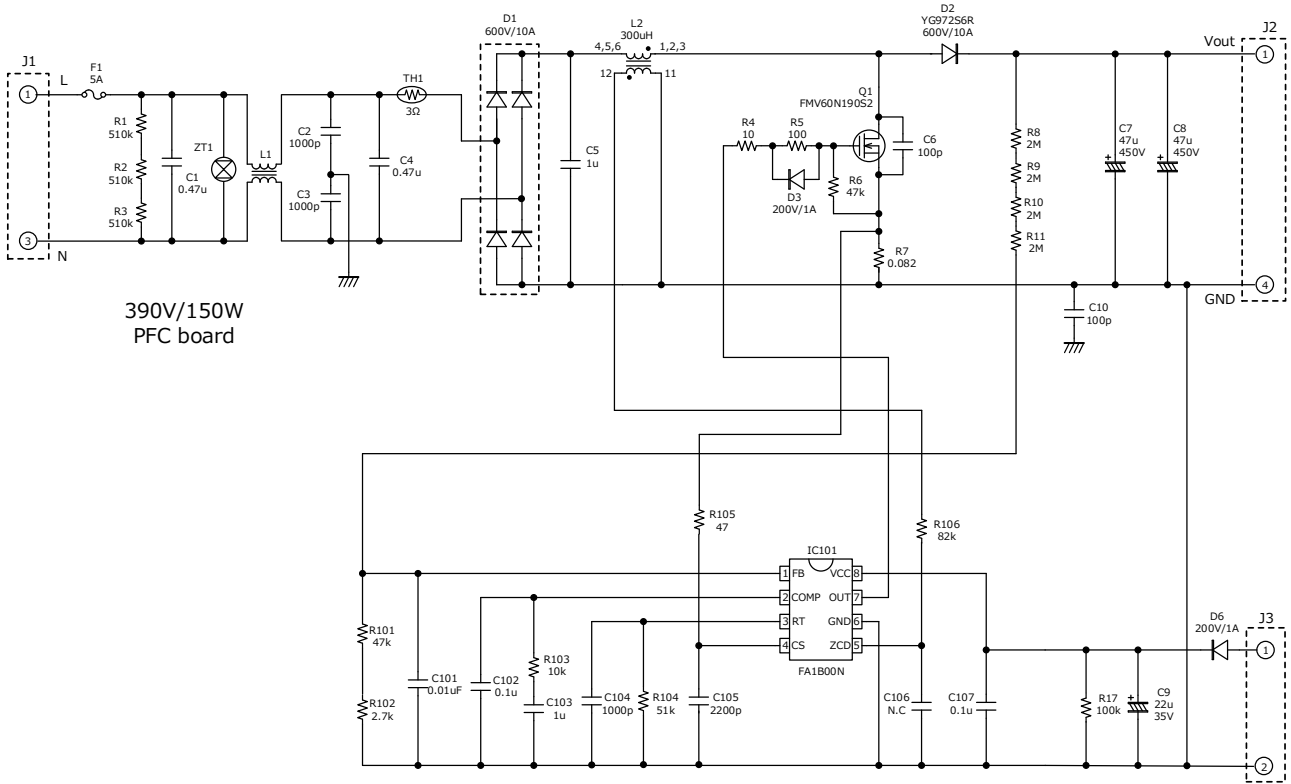
1. Overview

This document is a design example of PFC circuit using FA1B00N, critical conduction mode power factor correction IC. The rating output is 390V/150W.

2. Features of FA1B00N

- ✓ Very Low Standby Power by disusing Input Voltage Detection Resistors
- ✓ High-precision over current protection: 0.65 V ± 2 %
- ✓ Improved power efficiency at light load due to Maximum Frequency Limitation
- ✓ No Audible Noise at Startup by overshoot reduction circuit
- ✓ Low current consumption by CMOS process
- ✓ Start-up : 300 µA (max.), Operating : 1.2 mA (typ.)
- ✓ Enabled to drive power MOSFET directly
  Output peak current, source : 0.5 A, sink : 1 A
- ✓ Open/short protection at feedback (FB) pin
- ✓ Under-voltage Lockout, 13 V ON / 9 V OFF
- ✓ External signal-linked ON/OFF function built in FB pin

3. Circuit diagram



※ An external regulated power supply is connected to connector J3 and the supply voltage to VCC is 15 V.

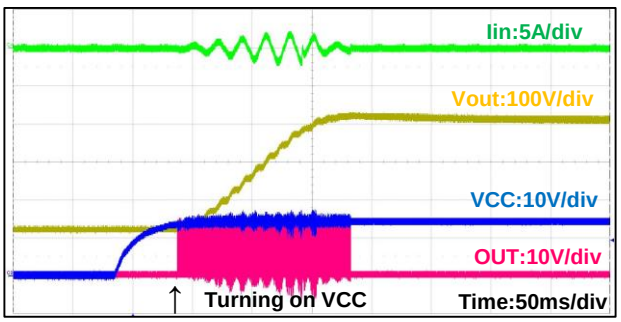
4. Power supply specifications

Item	Value	Unit
Input voltage	90 to 264	Vac
Output voltage	390	Vdc
Output power	150	W
VCC supply voltage	15	V
Protection function	◆Overcurrent limiting of power MOSFET【CS pin】 ◆Overvoltage limiting【FB pin】 ◆Open/Short protection at FB pin ◆Overshoot reduction function【COMP pin】	

5. Start up characteristics of Power supply

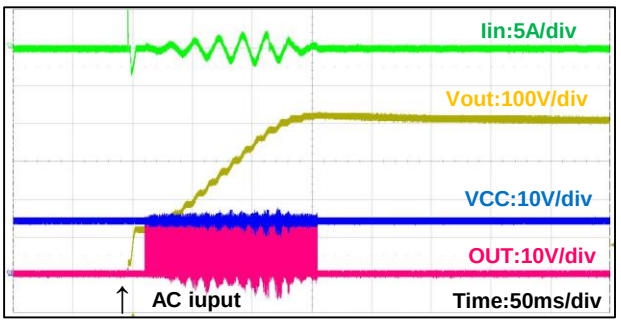
This reference board improves the power factor by driving the IC with an external power supply. There are two ways to start it. ①Reference board is started up by turning on VCC after AC line is turned on. ② Reference board is started up by turning on AC line voltage after VCC is turned on.

① Startup by turning on VCC



※IC operation started by VCC pin function

② Startup by turning on AC input

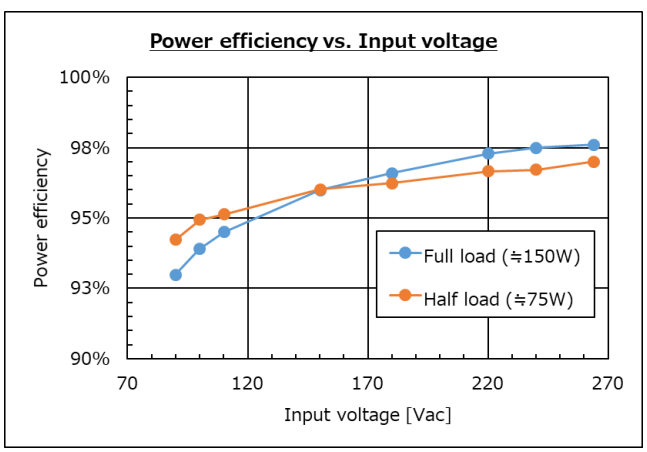


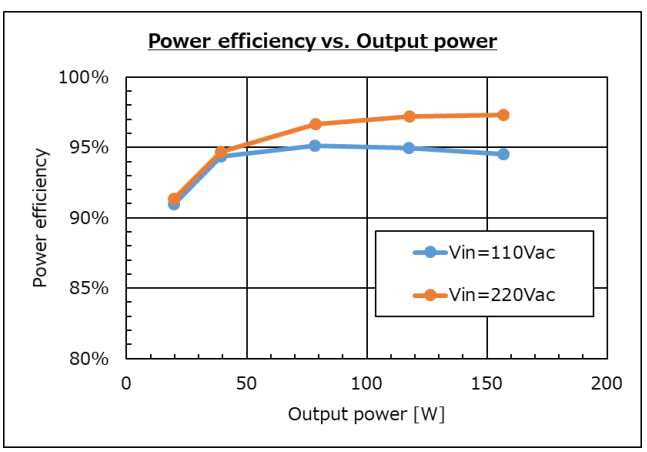
※IC operation started by FB pin function

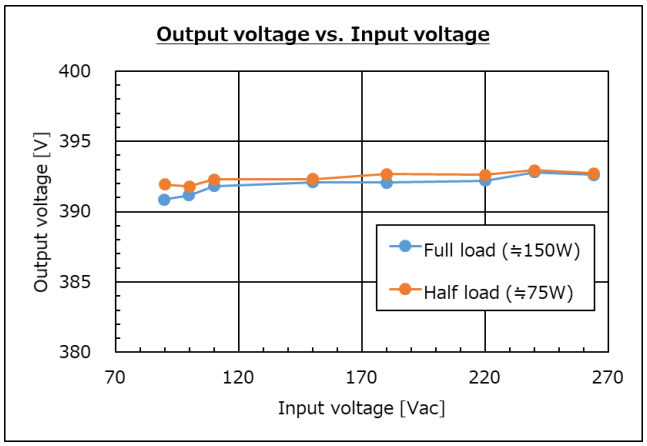
Vac: 90V / 50Hz, Iin: input current, Vout: output voltage, VCC: voltage at VCC pin, OUT: voltage at OUT pin

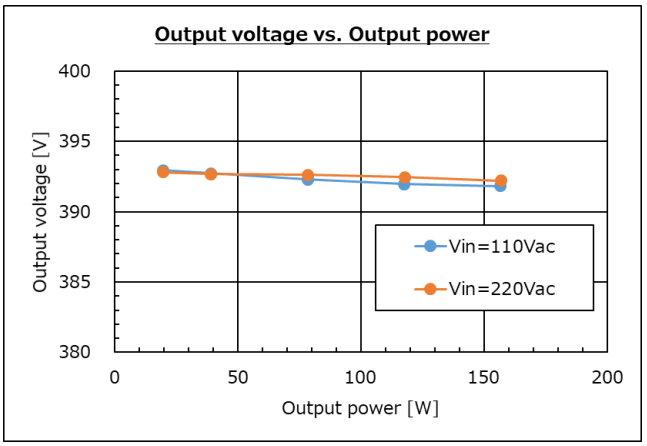
6. Electrical characteristics

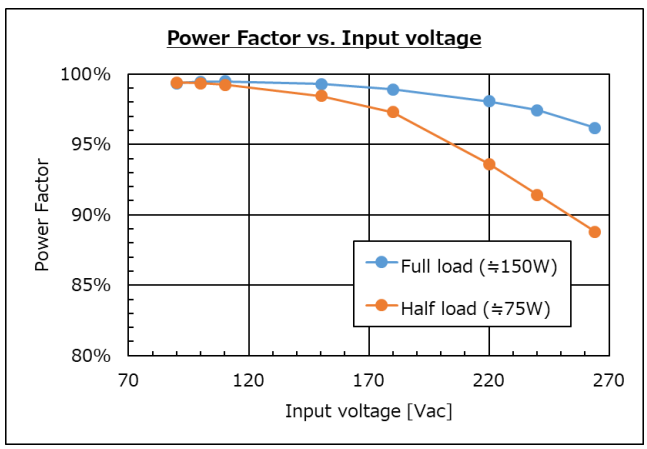
The input / output characteristics of the reference board are as follows.
An 15V external regulated power supply is connected to connector J3. It is supplied to VCC pin of the IC.

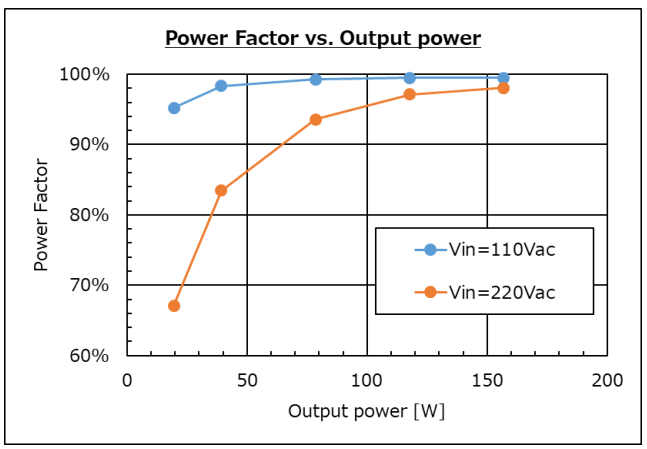


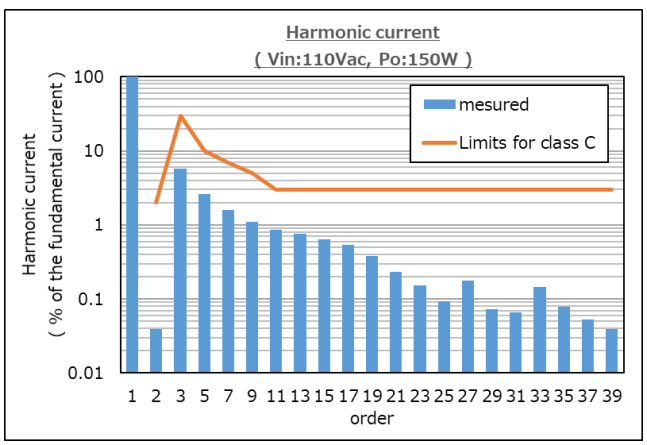


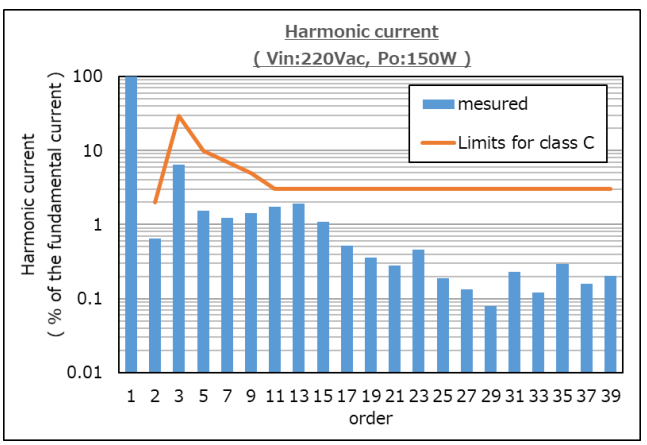




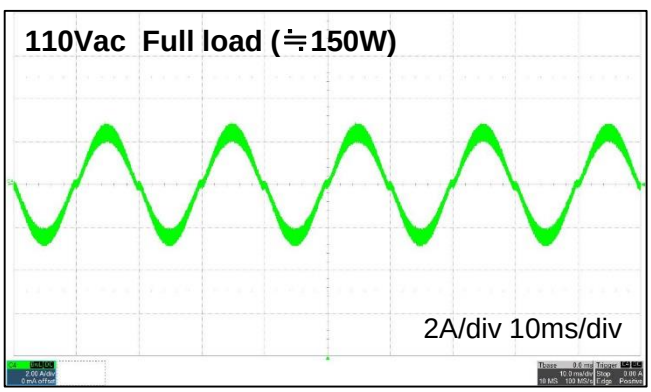


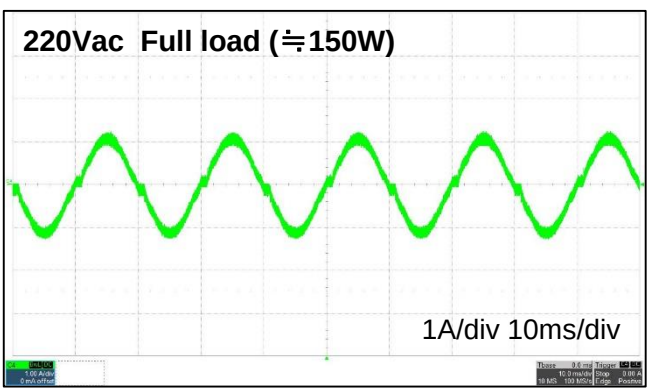






7. Waveforms (AC input current)





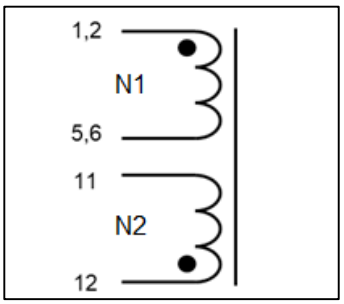
8. Parts list

Component	Item	Value	Parts No.	Maker
C1,4	Film capacitor	0.47u	LE474-MX	OKAYA
C10	Ceramic capacitor	470p	DE2B3KY471KA3BM02F	MURATA
C101	Ceramic capacitor	0.01u		
C102,107	Ceramic capacitor	0.1u		
C103	Ceramic capacitor	1u		
C104	Ceramic capacitor	1000p		
C105	Ceramic capacitor	2200p		
C2,3	Ceramic capacitor	2200p	DE1E3KX222MN4AN01F	MURATA
C5	Film capacitor	450V/1u		
C7,8	Electrolytic capacitor	450V/47u		
C9	Electrolytic capacitor	35V/22u		
D1	Bridge Diode	600V/10A		
D2	Diode	600V/10A	YG972S6R	Fuji
D3,6	Diode	200V/1A		
F1	Fuse	250V/5A		
IC101	PFC IC		FA1B00N	Fuji
J1	Connector	3pin	B2P3-VH(LF)(SN)	JST
J2	Connector	4pin	B4P-VH(LF)(SN)	JST
J3	Connector	2pin	B2B-EH(LF)(SN)	JST
L1	Inductor	2A/12mH		
L2	Inductor	300uH		
Q1	MOSFET	600V/190mΩ	FMV60N190S2HF	Fuji
R1,2,3	Resistor	510k		
R102	Resistor	2.7k		
R103	Resistor	10k		
R104	Resistor	51k		
R105	Resistor	47		
R106	Resistor	82k		
R17	Resistor	100kΩ		
R4	Resistor	10		
R5	Resistor	100		
R6,101	Resistor	47k		
R7	Resistor	0.082		
R8,9,10,11	Resistor	2MΩ		
TH1	Thermistor	3Ω		
ZT1	Transient/Surge Absorber	470V		

9. Inductor (L2)

Item	Value	Note
Core size	PQ 32/20	
Inductance	300μH	1,2 pin ～5,6 pin
N1	28 turn	start 1,2 pin : end 5,6 pin
N2	3 turn	start 12 pin : end 11 pin

Wiring diagram

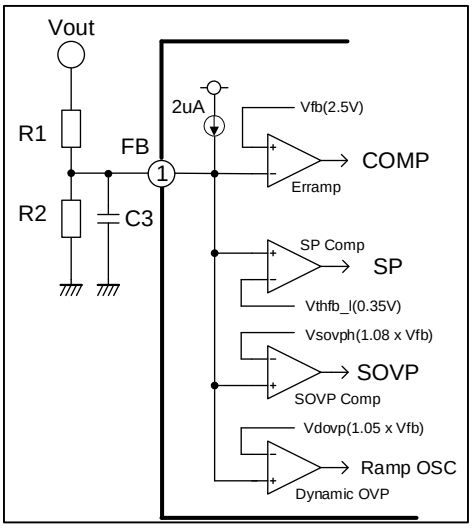


10. Parts settings around the IC

10-1. FB pin

A pull-up current Ipullup flows from the FB pin to detect the FB pin open. This current flows to GND via R2 as shown in the FB pin circuit. Therefore, when setting the output voltage Vout, calculate including this current. The recommended range of resistance for the FB pin is 1 MΩ (MIN.) To 20 MΩ (MAX.). In this reference design, R1 is 8 MΩ.

FB pin circuit



- VREF: 2.5 V (typ.)
- Ipullup: 2 μA (typ.)
- Vout: 390 V (target)
- R1: 8 MΩ

Calculate the current flowing through R1.

$$(390\mathrm{V} - 2.5\mathrm{V}) \div 8\mathrm{M\Omega} = 48.4\mu\mathrm{A}$$

Calculate the resistance value of R2.

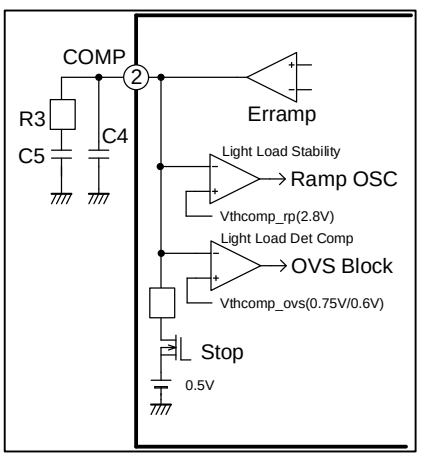
$$2.5\mathrm{V} \div (48.4\mu\mathrm{A} + 2\mu\mathrm{A}\ ) = 49.6\mathrm{k\Omega}$$

From the calculation results, the resistor R2 is selected to 47 kΩ + 2.7 kΩ. C3 is connected with a 0.01 μF ceramic capacitor to prevent malfunction due to noise.

10-2. COMP pin

The COMP pin is the output of the built-in error amplifier. Parts for phase compensation are connected to suppress the ripple component at FB pin which is twice of the AC line frequency. The time constants of R3 and C5 are set to twice the frequency of the AC line as a guide, and are adjusted by evaluation.

COMP pin circuit



- R3: 10 kΩ
- C5: 1 μF
- C4: 0.1 μF

Calculate the approximate cycle.

$$1 \div (2 \times 50\mathrm{Hz}) = 10\mathrm{ms}$$

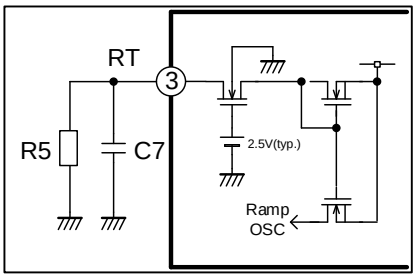
Calculate the time constants for R3 and C5.

$$10\mathrm{k\Omega} \times 1\mu\mathrm{F} = 10\mathrm{ms}$$

10-3. RT pin

For the resistor of the RT pin, set the resistance greater than the on-width required for the circuit. Each parameter used in the calculation is as follows.

RT pin circuit



- Lp: 300 μH (typ.)
- Pout: 150 W (target)
- Vac(min): 90 Vrms
- η: 0.9

※η is the input / output conversion efficiency of PFC, and the power factor is assumed as1.

Calculate the input current (effective value).

$$150\mathrm{W} \div 0.9 \div 90\mathrm{Vrms} = 1.85\mathrm{Arms}$$

The on-time is calculated by setting the peak value of the inductor current to twice the above input current.

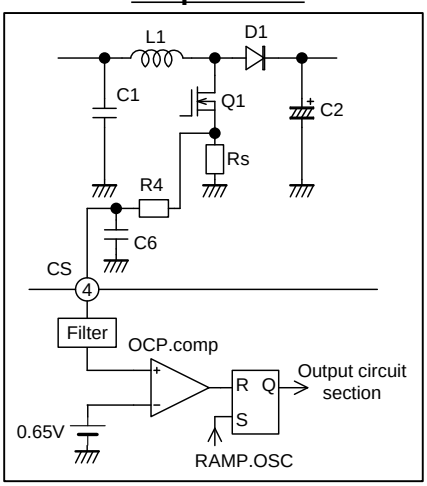
$$300\mu\mathrm{H} \times 2 \times 1.85\mathrm{Arms} \times \sqrt{2} \div \left(90\mathrm{Vrms} \times \sqrt{2}\right) = 12.3\mathrm{us}$$

From the calculation result, R5 is set to 51kΩ, because on-time is 13 us(typ.) when Rrt is 39kΩ on the data sheet. C7 is connected with a 1000 pF ceramic capacitor to prevent malfunction due to noise.

10-4. CS pin

The surge current due to drive current of MOSFET_TR1 or the discharge current of the parasitic capacitance of the circuit flow through the current sensing resistor Rs. At the CS pin, connect a CR filter to prevent the OUT pin pulse from stopping due to false detection of these currents. After setting the cutoff frequency of the CR filter to be 1 to 2 MHz, check the actual operation and adjust.

CS pin ciruit



- R4: 47 Ω
- C6: 2200 pF

Calculate the cutoff frequency.

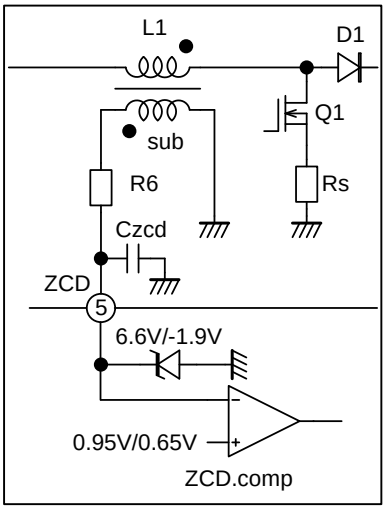
$$1 \div (2 \times \pi \times 47\Omega \times 2200\mathrm{pF}) = 1.54\mathrm{MHz}$$

10-5. ZCD pin

The ZCD pin uses the auxiliary winding voltage to detect the timing when the transformer energy is reset. The recommended current value of the internal Zener diode at the ZCD pin is ± 1.5mA. The current flowing through the Zener diode is limited by the resistor R6. The parameters used in the calculation are:

- N1: 28 turn
- N2: 3 turn
- Vac(max) :264 Vrms
- Vout: 390 V
- Zd(+): 5.6 V (MIN.)
- Zd(-): -0.6 V (MAX.)

ZCD pin circuit



Calculate the ZCD pin voltage plus side.

$$(390\mathrm{V} \times 3/28 - 5.6\mathrm{V}) \div 1.5\mathrm{mA} < \mathrm{R6}$$

$$\underline{\mathrm{R6} > 24.1\mathrm{k\Omega}}$$

Calculates the negative side of the ZCD pin voltage.

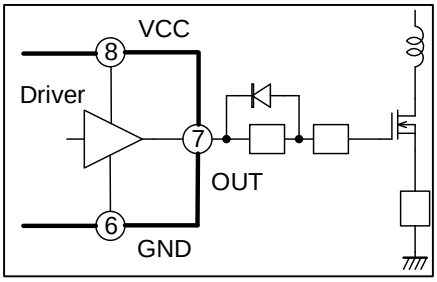
$$\left(-0.6\mathrm{V} + \sqrt{2} \times 264\mathrm{V} \times 3/28\right) \div 1.5\mathrm{mA} < \mathrm{R6}$$

$$\underline{\mathrm{R6} > 26.3\mathrm{k\Omega}}$$

From the calculation results, R17 should be set to 26.1 kΩ or higher. In this reference design, 82 kΩ is selected in consideration of adjusting the resistance value of R6. When determining the resistance value, make adjustments while checking the MOSFET turn-on timing and ZCD pin waveform in the actual evaluation. The capacitor Czcd between the ZCD pin and the GND pin is not mounted.

10-6. OUT pin

OUT pin circuit



The OUT pin can directly drive the power MOSFET, but it must be used within the ratings of the source and sink current of the OUT pin. Make adjustments according to the circuit actually used and the power MOSFET. As a guide, set the lower limit of the resistance value. The parameters used in the calculation are:

- Vol: 1.2 V (typ.), Isink = 200 mA
- Voh: 10 V (MAX.), Isource = 50 mA
- Vcc: 12 V (measurement condition)
- VCC: 15 V (actual VCC pin voltage)
- Io: 1000 mA (sink)
- Io: 500 mA (source)

Calculate the internal resistance Rsink of the OUT pin when sinking the current.

$$\mathrm{Rsink} = 1.2\mathrm{V} \div 200\mathrm{mA} = 6\Omega$$

Calculate the gate resistance Rg required when the power MOSFET is off.

$$15\mathrm{V} \div (6\Omega + \mathrm{Rg}) < 1000\mathrm{mA}$$

$$\underline{\mathrm{Rg} > 9\Omega}$$

Calculate the internal resistance Rsource of the OUT pin when sourcing current.

$$\mathrm{Rsource} = (12\mathrm{V} - 10\mathrm{V}) \div 50\mathrm{mA} = 40\Omega$$

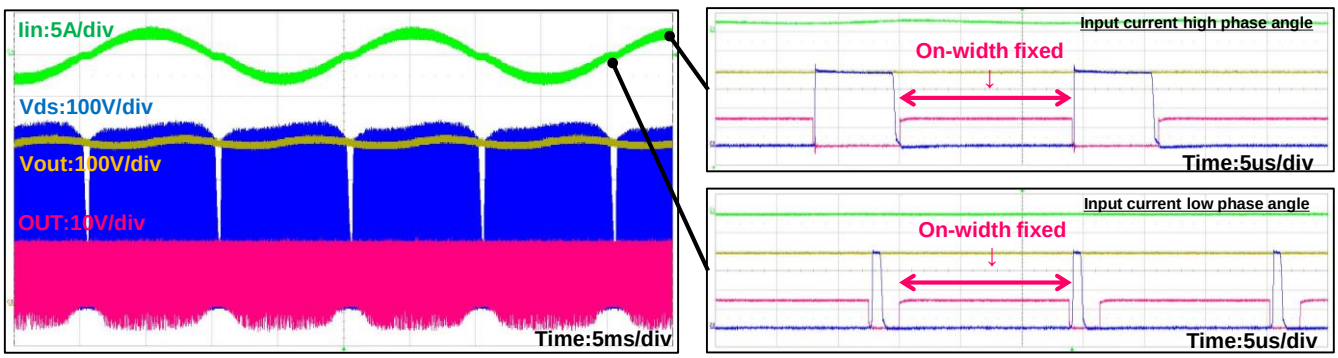
$$15\mathrm{V} \div 40\Omega = 375\mathrm{mA}$$

From the above calculation results, it was set as 10 Ω for sink and 10 Ω + 100 Ω for source. When the VCC voltage is 15 V, the output current Io does not exceed 500 mA due to the voltage drop inside the IC, but when connecting to a MOSFET, be sure to connect a resistor. Determine the resistance value by adjusting the on / off timing in the actual evaluation. If the voltage fluctuation of the VCC pin is large, set the gate resistance at the maximum VCC voltage.

11. Reference board operating waveform

11-1. On-width fixed control

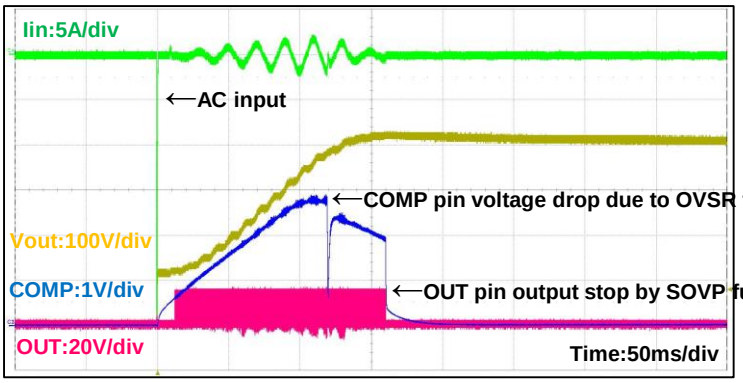
Fixed on-width control improves the power factor of the input current Iin.



Vac: 90V / 50Hz, Po=150W, Iin: input current, Vds: drain to source voltage, Vout: output voltage, OUT: voltage at OUT pin

11-2. Overshoot reduction (OVSR) function

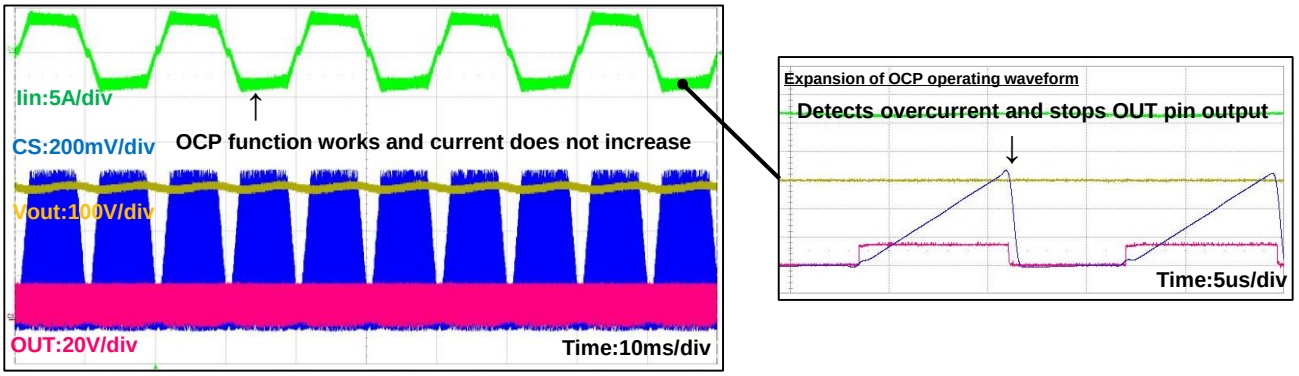
The overshoot reduction function suppresses the increase in COMP voltage at startup and narrows the on width, thereby reducing the output voltage overshoot at startup due to response delay. In addition, the overvoltage protection function built into the FB pin suppresses the rise in output voltage even after the overshoot reduction function operates.



Vac: 90V / 50Hz, Po=0W, Iin: input current, Vout: output voltage, COMP: voltage at COMP pin, OUT: voltage at OUT pin

11-3. Overcurrent Protection (OCP) Function

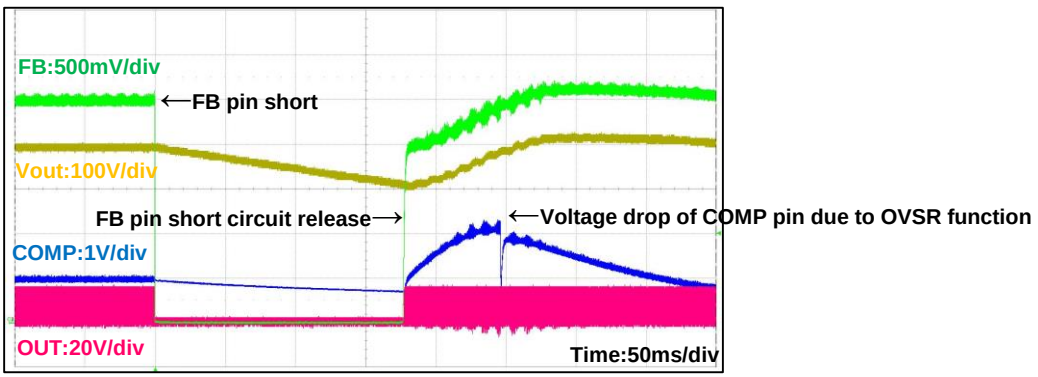
The OCP function of the CS pin can suppress the peak current of the power MOSFET. When the CS pin voltage exceeds 0.65 V (typ.), The OUT pin output stops and the power MOSFET is turned off. This OCP function operates cycle by cycle of the OUT pin. Note that, this waveform is observed by increasing the current detection resistor in order to operate the OCP function.



Vac: 90V / 50Hz, Iin: input current, Vout: output voltage, CS: voltage at CS pin, OUT: voltage at OUT pin

11-4. FB pin short circuit detection function

The FB pin has an FB pin short circuit detection function, and the OUT output is stopped when the FB pin voltage falls below 0.35V (typ.). When the FB pin short is released, the IC resumes operation and OUT output. The OVSR function also operates when the PFC circuit is turned on and off using the FB pin short-circuit detection circuit.



Vac: 90V / 50Hz, Po=20W, FB: voltage at FB pin, Vout: output voltage, COMP: voltage at COMP pin, OUT: voltage at OUT pin

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