General PWM-IC FA5604N
Power supply design example
: Forward circuit, 24V/150W

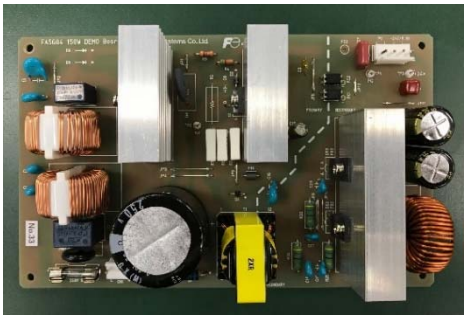
Reference Design

1. Overview

This document describes the design example of forward converter using the general PWM-IC FA5604. The input is 85Vac to 132Vac and the output is 24V/150W.
The FA5604N/05N/06N/07N is the PWM type switching power supply control IC that can directly drive power MOSFET. This IC realizes the low power consumption with reducing the switching frequency at light load(FA5604N,05N,06N).
This IC contains many functions in a small 8-pin package. With this IC, a high-performance and compact power supply can be created because not many external discrete components are needed.

2. Features

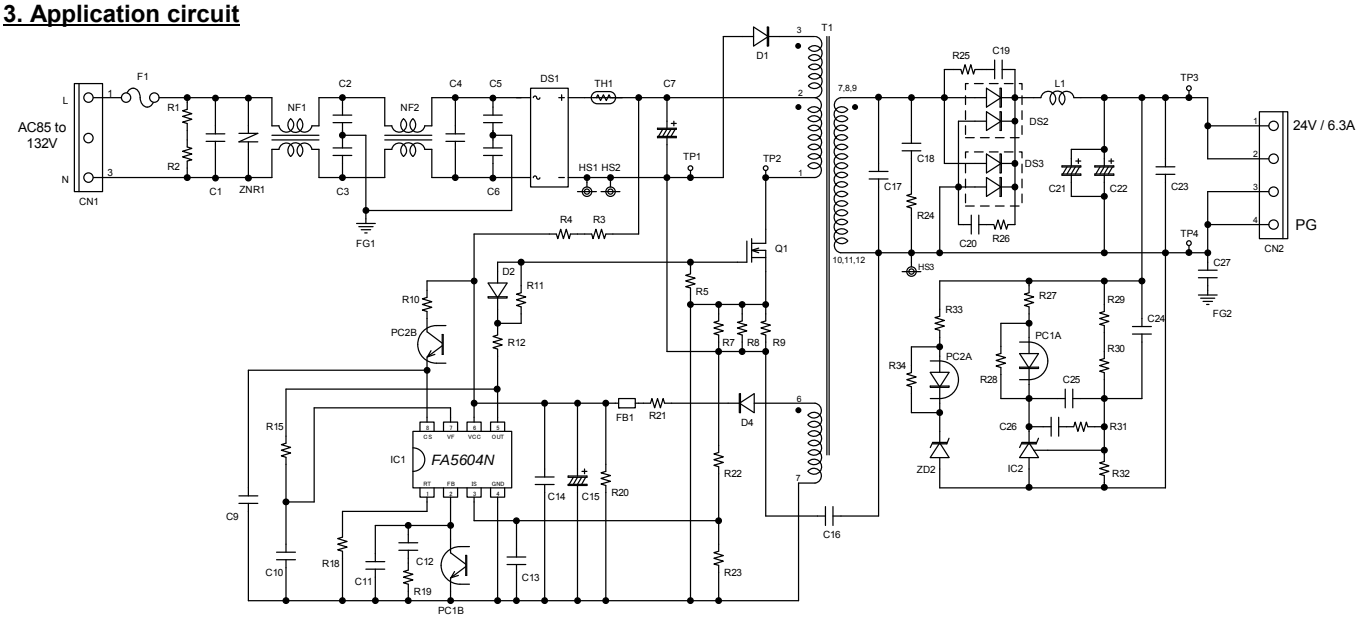
- Voltage mode control
- Systems organized by circuit methods
  FA5604N: Applied to forward power supplies (maximum duty cycle = 46%)
  FA5605N/FA5606N/FA5607N: Applied to flyback power supplies (maximum duty cycle = 70%)
- Automatically reduces the switching frequency to suppress loss in stand-by mode
- The switching frequency can be set (RT pin)
- A drive circuit for connecting a power MOSFET directly
- Output peak current: +1.0A / -0.5A
- Overcurrent of primary side limiting function (IS pin negative voltage sense)
- Overload protection function (switching frequency control by VF pin)
- Overload protection function (CS pin)
- Built-in output overvoltage latch protection
  (stopping the latch by pulling up the CS terminal by external signals)
- Undervoltage lockout function (17.5V ON / 9.7V OFF)
- 8-pin package (SOP-8)



Function list by type

type	Max. duty cycle(typ)	Frequency reduction mode at light-load	Hiccup operation at overload	Overcurrent detection	Package
FA5604N	46%	FB voltage: 1.8 V/1.95 V	Operation period: shutdown period = 1:7	Negative voltage detection	SOP-8
FA5605N	70%		Operation period: shutdown period = 1:15		
FA5606N		FB voltage: 1.55 V/1.65 V	Operation period: shutdown period = 1:7		
FA5607N		—			

3. Application circuit



4. Specifications of the Power supply

Item	Value	Unit
Input voltage	85 to 132	Vac
Output voltage	24	Vdc
Output current	6.3	A

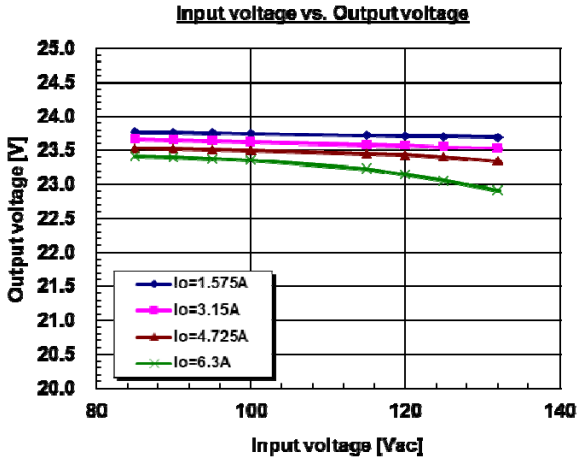
5. Efficiency

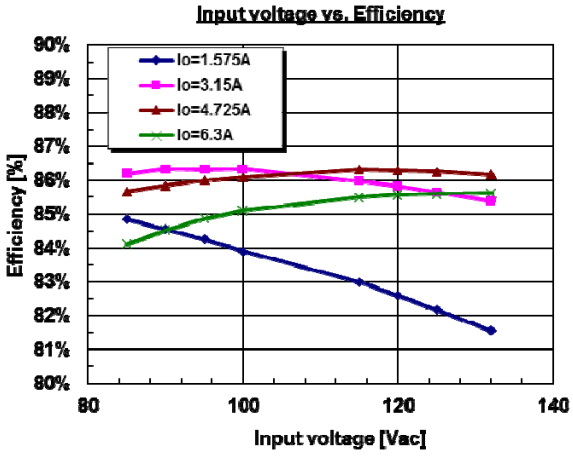
Load (%)	25	50	75	100	Ave.
Efficiency at 85Vac (%)	84.8	86.2	85.7	84.1	**85.2**
Efficiency at 100Vac (%)	83.9	86.3	86.1	85.1	**85.4**
Efficiency at 132Vac (%)	81.6	85.4	86.2	85.6	**84.7**

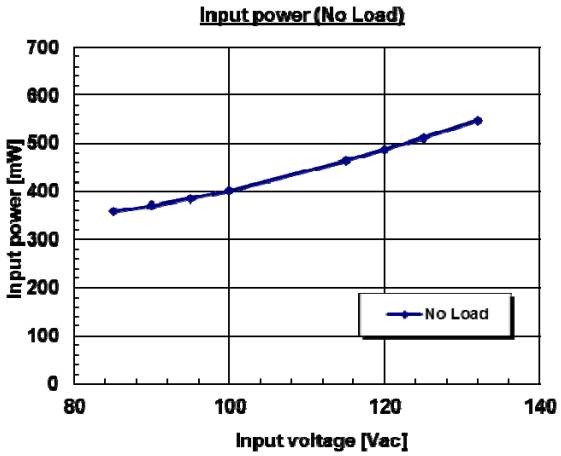
Measured using cable with a length (L) =1.4m and a diameter (Φ) =1.5mm.

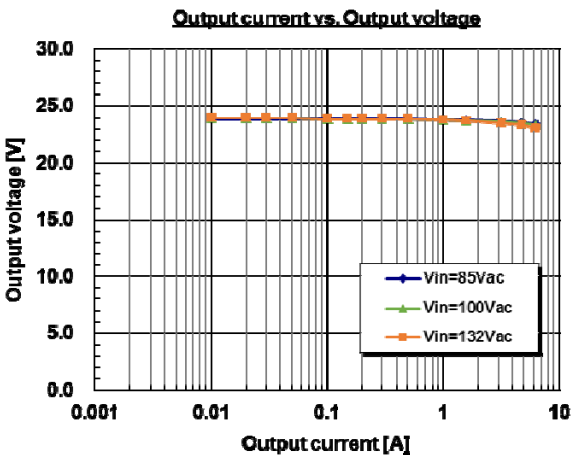
Input voltage	85Vac	100Vac	132Vac
Input power at NO Load	358mW	402mW	548mW

6. Characteristics curves

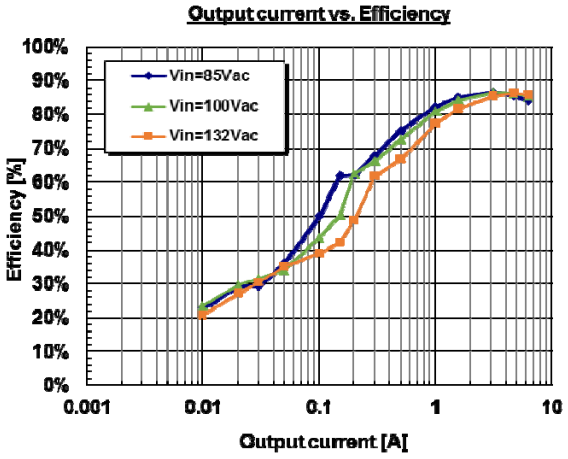


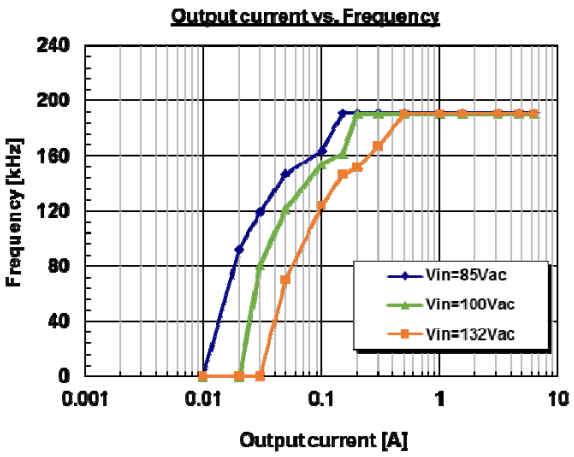


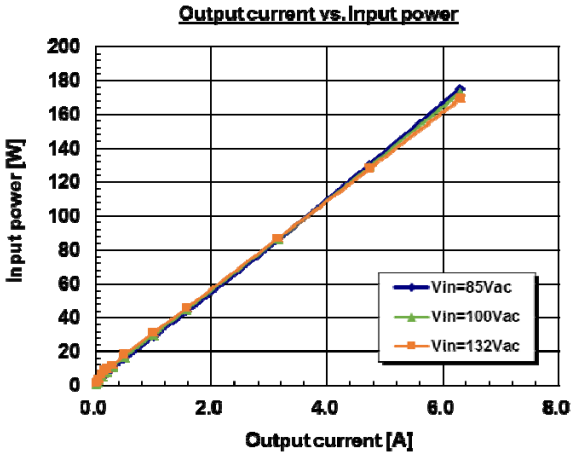


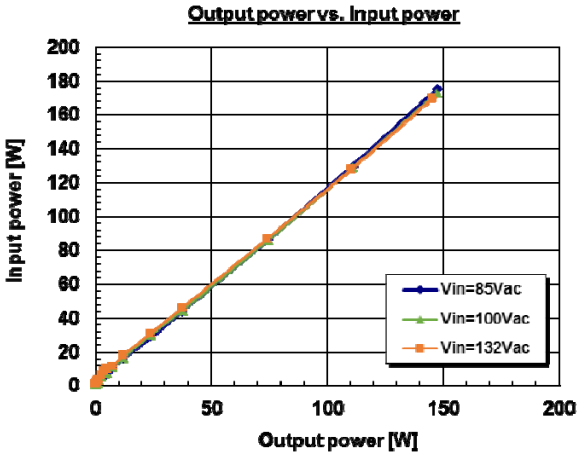


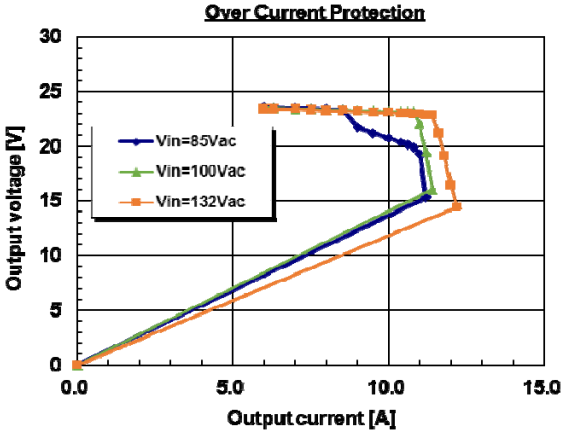
6. Characteristics curves



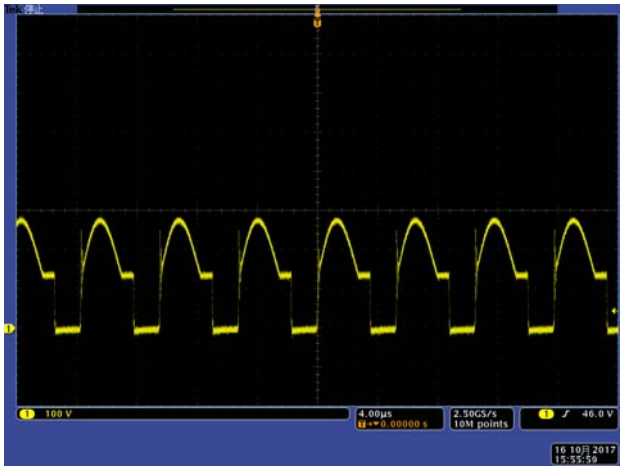
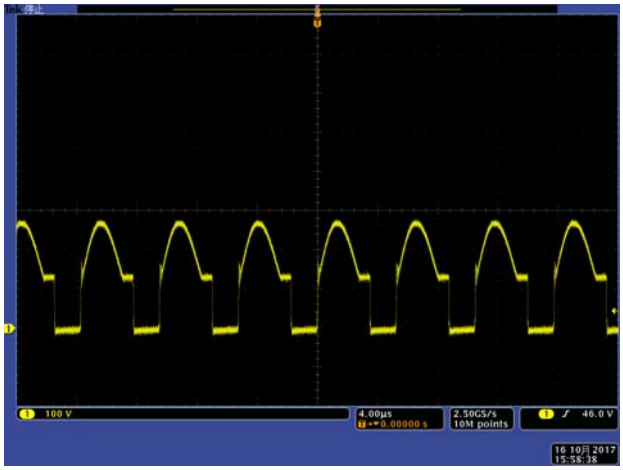
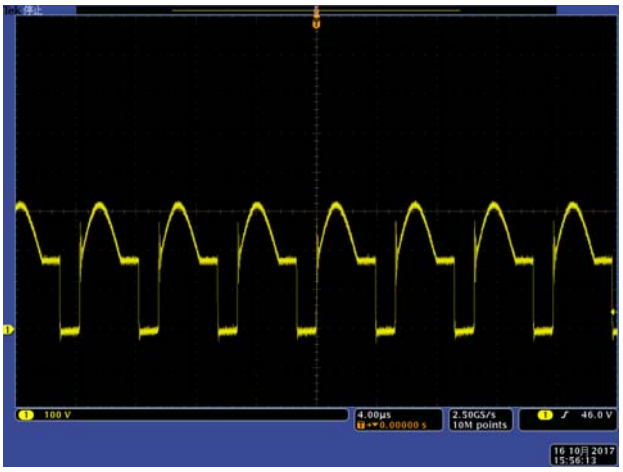
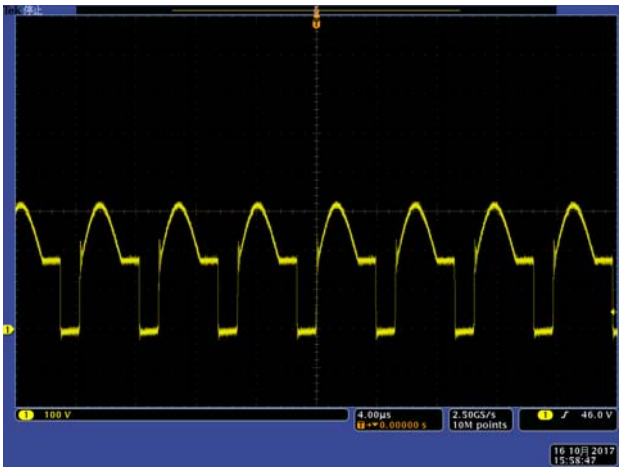




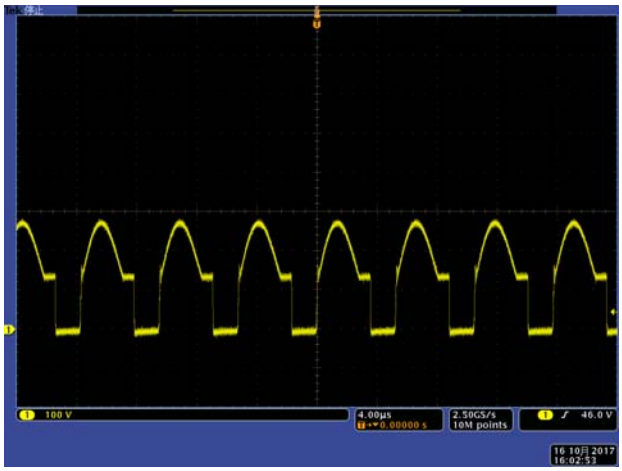
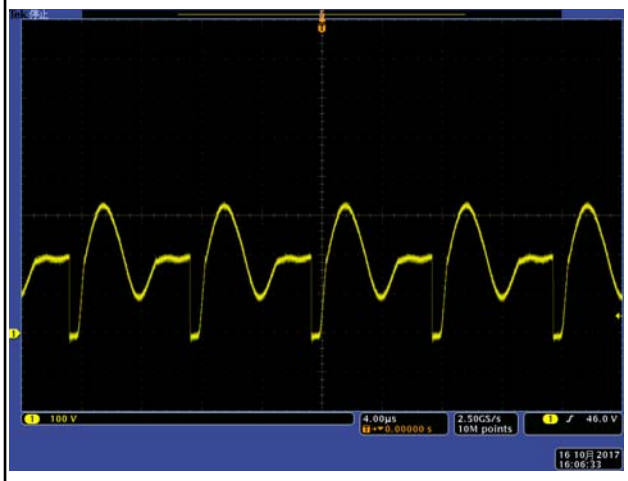




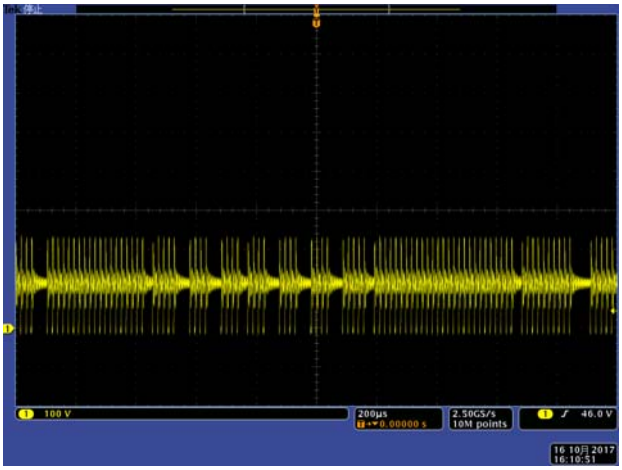
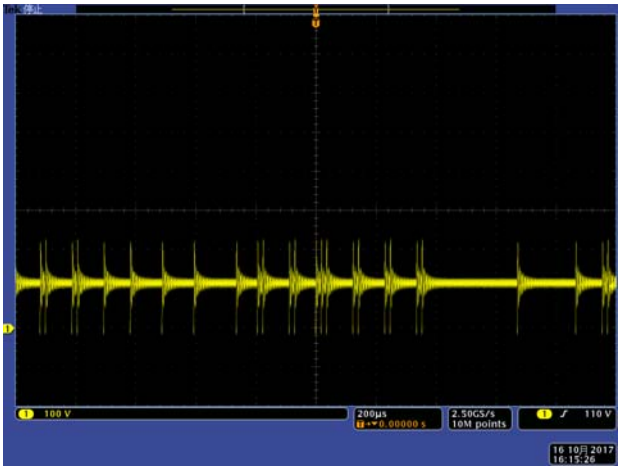
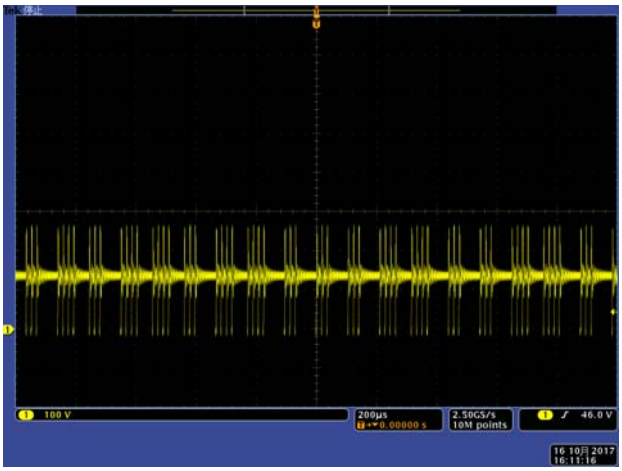
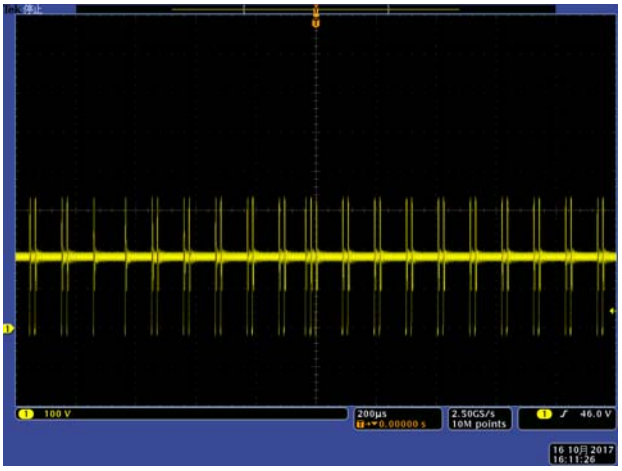
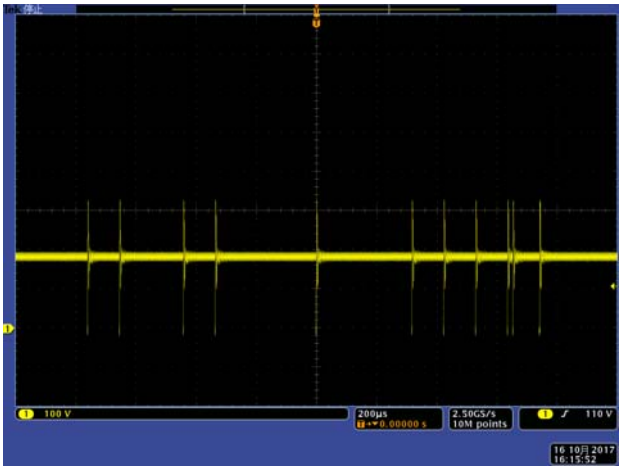
7. Switching waveforms

	Rated Load (24V/6.3A)	Middle Load (24V/3.15A)
	100V/div ,4msec/div	100V/div ,4msec/div
Vin=85Vac		
Vin=100Vac		
Vin=132Vac		

7. Switching waveforms

	Light load (24V/1.575A)	Light load (24V/0.1A)
	100V/div ,4msec/div	100V/div ,4msec/div
Vin=85Vac		
Vin=100Vac		
Vin=132Vac		

7. Switching waveforms

	Light load (24V/0.01A)	No load (24V/0A)
	100V/div ,200msec/div	100V/div ,200msec/div
Vin=85Vac		
Vin=100Vac		
Vin=132Vac		

8. Bill of material

Component	Item	Value	Part. No	Maker	Note
T1	Transformer		Y11FE12T1		H:35mm
NF1,NF2	Line filter	10mH,5A	SFC-2510—05103	SEKISIN INDUSTRY	
L1	Choke coil		PDS-T15A-08151	SEKISIN INDUSTRY	
FB1	Ferrite beads		B-20F-38	NEC TOKIN	
C1	Film capacitor	275V,0.47uH	LEM474-M	OKAYA ELECTRIC	
C2,C3	Ceramic capacitor	1000pF	DE2E3KH102M	MURATA	
C4	Film capacitor	275V,0.22uF	LEM224-M	OKAYA ELECTRIC	
C5,C6	Ceramic capacitor	2200pF	DE2E3KH222M	MURATA	
C7	Electrolytic capacitor	250V,1000uF	LXG2E102MELC35	NICHICON	
C9	Film capacitor	50V,0.033uF	QYX1H333KTP	NICHICON	
C10,C12,C14	Ceramic capacitor	50V,0.1uF	GRM188R11H104K	MURATA	
C11,C13	Ceramic capacitor	50V,1000pF	GRM188B11H102K	MURATA	
C15	Electrolytic capacitor	50V,47uF	UPJ1H470MDD	NICHICON	
C16	Ceramic capacitor	2200pF	DE1E3KX222M_L01	MURATA	
C17,C19,C20	Ceramic capacitor	1kV,220pF	DEHR33A221K	MURATA	
C18	Ceramic capacitor	1kV,1000pF	DEHR33A102K	MURATA	
C21,C22	Electrolytic capacitor	35V,2200uF	UHE1V222MHD	NICHICON	
C23	Film capacitor	50V,1uF	ECQV1H105JL	PANASONIC	
C24,C26	Ceramic capacitor	50V,0.1uF	GRM188R11H104K	MURATA	
C27	Film capacitor	630V,0.047uF	ECQE6473KF	PANASONIC	
R1,R2	Chip resistor	680kΩ,1/8W			
R3	Carbon resistor	47kΩ,1/2W			
R4	Carbon resistor	51kΩ,1/2W			
R5	Chip resistor	47kΩ,1/8W			
R7	Cement resistor	0.1Ω,2W	BPR28CFR10K	KOA	
R8	Cement resistor	0.15Ω,2W	BPR28CFR15K	KOA	
R9	Cement resistor	0.12Ω,2W	BPR28CFR12K	KOA	
R10	Chip resistor	33kΩ,1/8W			
R11	Chip resistor	22Ω,0.33W			
R12	Chip resistor	10Ω,0.33W			
R15,R31	Chip resistor	10kΩ,1/8W			
R18	Chip resistor	12kΩ,1/8W			
R19	Chip resistor	33Ω,1/8W			
R20	Chip resistor	30kΩ,1/4W			
R21	Chip resistor	2.2Ω,1/4W			
R22	Chip resistor	680Ω,1/8W			
R23	Chip resistor	2.4kΩ,1/8W			
R24,R25,R26	Metal oxide film resistor	47Ω,2W			
R27	Chip resistor	2.4kΩ,1/4W			
R28,R34	Chip resistor	1kΩ,1/8W			
R29	Chip resistor	15kΩ,1/8W			
R30	Chip resistor	5.6kΩ,1/8W			
R32	Chip resistor	2.4kΩ,1/8W			
R33	Chip resistor	470Ω,1/8W			

8. Bill of material

Component	Item	Value	Part. No	Maker	Note
D1	Diode	600V,1.5A	S2L60	SHINDENGEN	
D2,D4	Diode	200V,1A	ERA92-02	FUJI ELECTRIC	
DS1	Diode bridge	600V,10A	D10XB60	SHINDENGEN	
DS2,DS3	Diode	200V,20A	YG906C2R	FUJI ELECTRIC	
ZD2	Zener diode	27V,200mW	HZU27B	RENESAS	
Q1	MOSFET	500V,20A,0.31Ω	FMV20N50ES	FUJI ELECTRIC	
IC1	Power supply control IC		FA5604N	FUJI ELECTRIC	
IC2	Shunt regulator		HA17432HUP	RENESAS	
PC1,PC2	Photocoupler		TLP781	TOSHIBA	
F1	Fuse	250V,5A	FBT250V5A	NIPPON SEISEN	
TH1	Power thermistor	3Ω,7A	3D2-15	SEMITEC	
ZNR1	Varistor	470V	ERZV14D471	PANASONIC	
CN1	Connector		B2P3-VH	JST	
CN2	Connector		B4P-VH	JST	

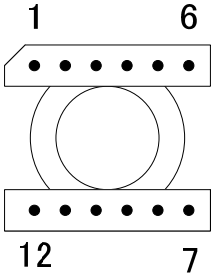
9. Transformer specifications

Bobbin	EER28L-12PN-2（TAMAGAWA ELECTRIC）
Core	PC40EER28L-Z
Gap	No gap
Inductance	5Pin ～ 4Pin * *uH ± 10%
Safety Rule	UL･CSA･IEC･PSE

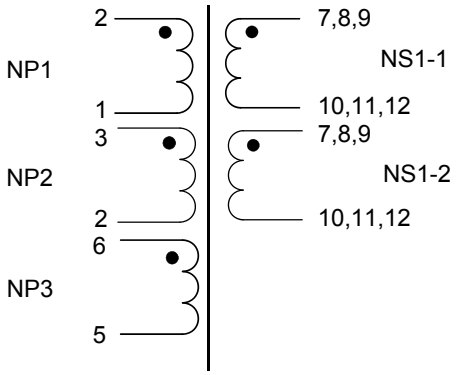
Winding order	Layer	Wire material and size	Winding Turns	Winding starting position	winding ending position	Winding type	Insulation tape	Remark
							Barrier tape	
1	NS1-1	UEW 7/Φ0.25×2	9	7,8,9	10,11,12	Solenoid	up:2.5mm/down:5mm	1layer
							22mm 3T	
2	NP2	UEW Φ0.35×2	16	3	2	Solenoid	up:2.5mm/down:5mm	1layer
							22mm 1T	
3	NP1	UEW Φ0.5×3	16	2	1	Solenoid	up:2.5mm/down:5mm	2ayers
							22mm 1T	
4	NP3	UEW Φ0.3×1	2	6	5	Space	up:2.5mm/down:5mm	1layer
							22mm 3T	
5	NS1-2	UEW 7/Φ0.25×2	9	7,8,9	10,11,12	Solenoid	up:2.5mm/down:5mm	1layer
							22mm 3T	

	Insulation Resistance (MΩ)	Withstand Voltage (kV) 1min.
Np : Ns	100	1.5
Pri. Core	100	1.5
Sec. core	100	1.5

Pin Pattern（bottom view）



Connection



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