1. Introduction

This manual describes a universal input, 19.5 V, 4.62 A single output power supply using TEA1751T and TEA1791T devices from NXPsemiconductor's GreenChip III and GreenChip-SR family. It contains the power supply specifications, circuit diagram, component list to build the supply, PCB layout and component positions, PFC choke and transformer documentation, along with test data and oscilloscope pictures of the most important waveforms.

The GreenChip III combines the control and drive functions for both the PFC and the flyback stages into a single device. The TEA1751T provides complete SMPS control functionality to comply with the IEC61000-3-2 harmonic current emission requirements, obtain a significant reduction of components, save PCB space and give a cost benefit. It also offers extremely low power consumption in no-load mode, which makes it suitable for the low-power consumer markets. The special built-in green functions allow a high efficiency at all power levels which results in a design that can easily meet all existing and proposed energy efficiency standards such as Code of Conduct (Europe), Energy Star (US), California Energy Commission, Minimum Energy Performance Standards (Australian & New Zealand) and China Energy Conservation Program.

The GreenChip SR is the only synchronous rectification control IC available that needs no external components for tuning of the timing. Used in notebook adapter designs, the GreenChip SR offers a wide VCC operation range of 8.5 V to 38 V, minimizing the number of external components required and enabling simpler designs. In addition, the high driver output voltage (10 V) makes the GreenChip SR compatible with all brands of MOSfets.

Fig 1. 90 W TEA1751T and TEA1791T demo board

2. Specification

- Mains input voltage: 90 V to 264 V, 47 Hz to 63 Hz
- DC output: 19.5 V, 2 %
- Maximum continuous output current: 4.62 A
- Peak output current: 7.5 A
- Efficiency: > 87 % at maximum load
- CEC active mode efficiency: > 90 %
- No load power consumption: < 0.3 W
- Dynamic load response: < +1 V / −0.5 V
- Output ripple and noise: 100 $mV_{p-p(max.)}$
- CISPR22 class B conducted EMI
- EN61000-4-2 immunity against ESD
- EN61000-3-2 A14 (harmonics) compliance
- Short Circuit Protection (SCP) and output Over-Current Protection (OCP); input power < 3 W at both SCP and OCP test
- Latched output Over Voltage Protection (OVP): < 25 V
- Latched Over Temperature Protection (OTP)
- Fast Latch Reset (FLR): < 3 sec.

3. Performance data

3.1 Test setup

3.1.1 Test equipment

- Programmable AC Source: Chroma, Model 61503
- Power HiTester: Hioki, Model 3332
- DC Electronic Load: Chroma, Model 63030
- Digital Oscilloscope: Tektronix, Model TDS5104B
- Current Probe/Amplifier: Tektronix, Model TCP305/TCPA300
- 100 MHz, High Voltage Differential Probe: Tektronix, Model P5205
- 6-Digit Multimeter: Agilent, Model 34401A
- EMC receiver Rohde & Schwarz ESPI-3 + LISN ENV216

3.1.2 Test conditions

- Unit on the lab-table with the heat sinks downwards
- No casing was present on the unit
- Lab temperature between 20 °C and 25 °C
- Measurements were made after stabilization of temperature according “test method for calculating the efficiency of single-voltage external AC-DC and AC-AC power supplies” of Energy Star

3.2 Efficiency

3.2.1 Efficiency PFC plus flyback stage

Test conditions:

- Before any measurements were recorded, the unit was set to maximum load and well pre-heated so that stabilization of the input and output meter readings was achieved.

Remark: The output voltage was measured at the end of the output cable.

Criteria to pass:

- The efficiency must be > 87 % at the maximum continuous output load.

Table 1. Efficiency PFC plus flyback stage

Efficiency total converter (at full load) as a function of the mains input

Input Voltage V / Hz	I_{IN} RMS (A)	P_{OUT} (W)	P_{IN} (W)	Efficiency (%)	Power factor
90/60	1.134	88.43	99.98	88.45	0.991
100/50	1.016	88.45	99.41	88.96	0.990
115/60	0.883	88.45	98.59	89.72	0.984
230/50	0.468	88.42	97.84	90.37	0.924
264/50	0.414	89.27	97.58	90.46	0.907

3.2.2 Energy Star efficiency

To market adapters sold as stand-alone adapters, and adapters supplied with notebooks as Energy Star efficient, they have to pass the active mode and no-load criteria as stated in the Energy Star standard for External Power Supplies; EPS2.0. The minimum active-mode efficiency is defined as the arithmetic average efficiency at 25 %, 50 %, 75 % and 100 % of the rated output power as printed on the name plate of the adapter.

3.2.2.1 Active mode efficiency

Test Conditions:

- The unit was set to maximum load and well pre-heated until temperature stabilization was achieved.
- Temperature stabilization was established for every load step before recording any measurements.

Remark: The output voltage was measured at the end of the output cable.

Criteria to pass:

- To comply with Energy Star EPS2.0, the arithmetic average of the four efficiency measurements must be greater than, or equal to, 87 %.
- Universal mains adapters have to pass the criteria at both 115 V / 60 Hz and 230 V / 50 Hz.

Table 2. Active mode efficiency at 115 V / 60 Hz

Load percentage	I_{OUT} (A)	V_{OUT} (V)	P_{OUT} (W)	P_{IN} (W)	Efficiency (%)	Power factor
100	4.624	19.130	88.45	98.59	89.72	0.984
75	3.468	19.198	66.58	73.47	90.63	0.973
50	2.312	19.266	44.53	49.05	90.80	0.950
25	1.156	19.329	22.35	24.61	90.83	0.452
Average	-	-	-	-	90.49	-

Table 3. Active mode efficiency at 230 V / 50 Hz

Load percentage	I_{OUT} (A)	V_{OUT} (V)	P_{OUT} (W)	P_{IN} (W)	Efficiency (%)	Power factor
100	4.624	19.124	88.42	97.84	90.37	0.924
75	3.468	19.195	66.57	73.76	90.25	0.901
50	2.312	19.262	44.53	50.18	88.74	0.880
25	1.157	19.330	22.36	24.59	90.94	0.379
Average	-	-	-	-	90.08	-

3.2.2.2 No-load input power

Test Conditions:

- The unit was set to maximum load and preheated.
- After 5 minutes the load was removed.
- The no-load input power measurements were recorded after stabilization of the input power reading.

Criteria to pass:

- To comply with Energy Star EPS2.0, the input power shall be less than 0.5 W.
- Universal mains adapters have to pass the criteria at both maximum input voltages (115 V / 60 Hz and 230 V / 50 Hz).

Table 4. No-load input power

No-load input power as a function of the mains input voltage

V / Hz	90 / 60	115 / 60	132 / 60	180 / 50	230 / 50	264 / 50
Input power P_{IN} (W)	0.124	0.130	0.137	0.158	0.186	0.200

5. Schematic diagram

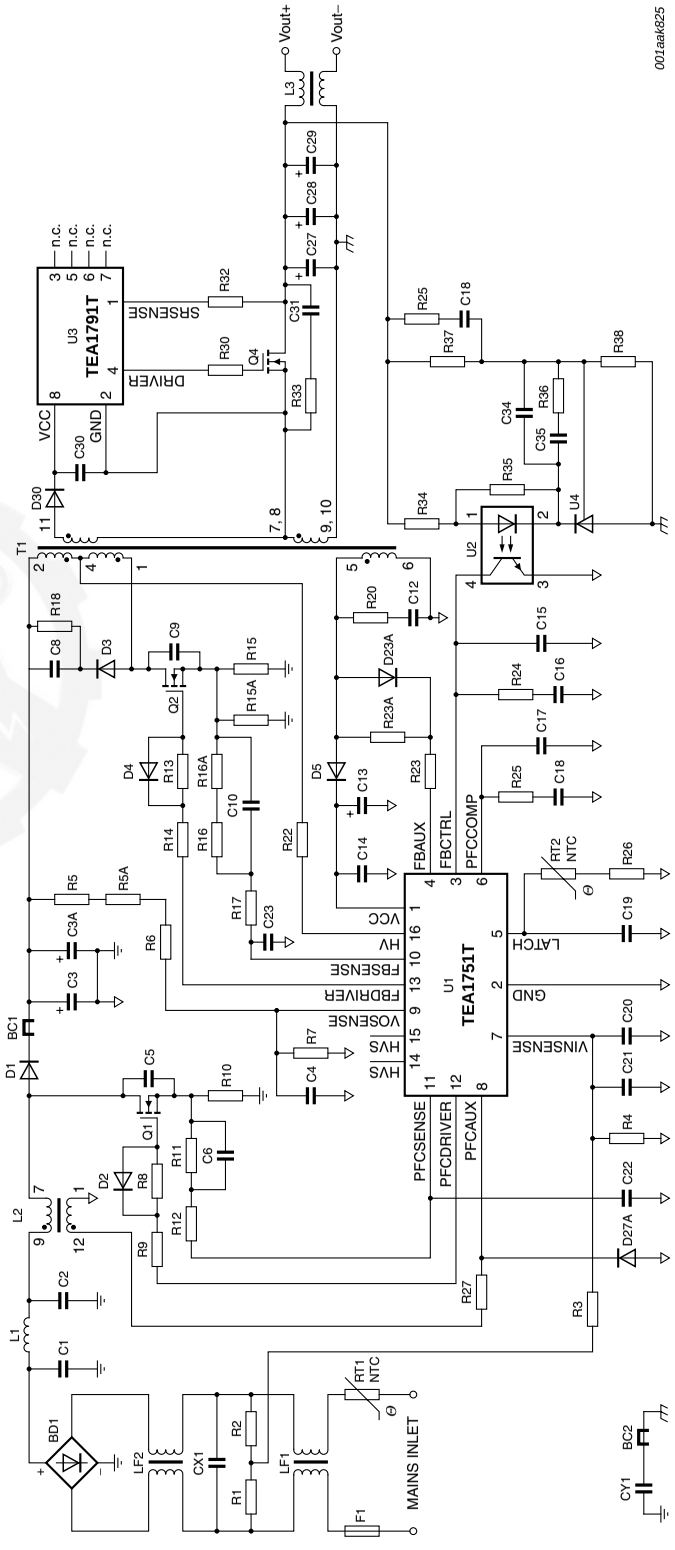

Fig 20. Schematic of 90 W TEA1751T and TEA1791T adapter solution

6. Bill of materials

Table 13. Default bill of materials for a 90 W TEA1751T and TEA1791T adapter solution

Reference	Component	Package	Remark
R1	2 MΩ, 1 %	1206	
R2	2 MΩ, 1 %	1206	
R3	560 kΩ, 1 %	1206	
R4	47 kΩ, 1 %	0603	
R5	3.3 MΩ, 1 %	1206	
R5A	3.3 MΩ, 1 %	1206	
R6	2.7 MΩ, 1 %	1206	
R7	60.4 kΩ, 1 %	0603	
R8	10 Ω, 5 %	0805	
R9	10 Ω, 5 %	0805	
R10	0.1 Ω, 5 %, 1 W	Axial	metal oxide film
R11	15 kΩ, 5 %	0603	
R12	1 kΩ, 5 %	0805	
R13	10 Ω, 5 %	0805	
R14	10 Ω, 5 %	0805	
R15	0.1 Ω, 5 %, 1 W	Axial	metal oxide film
R15A	0.3 Ω, 1 %	RL1632	
R16	27 kΩ, 5 %	0603	
R16A	750 Ω, 5 %	0603	
R17	1 kΩ, 5 %	0603	
R18	43 kΩ, 5 %	1206	
R19	43 kΩ, 5 %	1206	
R20	47 Ω, 5 %	0805	
R21	0 Ω	0805	
R22	10 kΩ, 5 %	0805	
R23	82 kΩ, 1 %	0603	
R23A	47 kΩ, 1 %	0603	
R24	39 kΩ, 5 %	0603	
R25	39 kΩ, 5 %	0603	
R26	10 kΩ, 5 %	0603	
R27	5.1 kΩ, 5 %	1206	
R30	10 Ω, 5 %	0805	
R32	1 kΩ, 5 %	0805	
R33	Not Mounted		
R34	1 kΩ, 5 %	0603	
R35	2.7 kΩ, 5 %	0603	
R36	10 kΩ, 5 %	0603	
R37	35.7 kΩ, 1 %	0603	
R38	5.23 kΩ, 1 %	0603	

Table 13. Default bill of materials for a 90 W TEA1751T and TEA1791T adapter solution *…continued*

Reference	Component	Package	Remark
R39	not mounted		
RT1	Jumper		
RT2	NTC 100 kΩ, D = 5 mm	Radial lead	TTC050104
C1	Film capacitor 0.47 μF / 450 V, 10 %		
C2	Film capacitor 0.47 μF / 450V, 10 %		
C3	Electrolytic capacitor 100 μF / 400V, 105 °C	Radial 16x30 mm	
C3A	10 nF / 1 kV, Z5U	Disk 11.5 mm	
C4	10 nF / 25 V, X7R	0603	
C5	220 pF / 630 V, NP0	1206	
C6	0.1 μF / 25 V, X7R	0603	
C8	3300 pF / 630 V	1206	
C9	100 pF / 630 V, NP0	1206	
C10	0.1 μF / 25 V, X7R	0805	
C12	220 pF / 100 V, NP0	0805	
C13	Electrolytic capacitor 47 μF / 35V, 105 °C	Radial 5 x 11 mm	low impedance type
C14	1 μF / 50 V, Y5V	0805	
C15	10 nF / 25 V, X7R	0603	
C16	0.33 μF / 10 V, X7R	0603	timing capacitor; review tolerance
C17	0.33 μF / 10 V, X7R	0603	
C18	0.47 μF / 10 V, X7R	0603	
C19	10 nF / 25 V, X7R	0603	
C20	2.2 μF / 10 V, Y5V	0603	
C21	2.2 μF / 10 V, Y5V	0603	
C22	220 pF / 50 V, NP0	0603	10 V is permitted
C23	220 pF / 50 V, NP0	0603	10 V is permitted
C27	Electrolytic capacitor 470 μF / 25V, 105 °C	Radial 10 x 12.5 mm	low impedance type
C28	Electrolytic capacitor 470 μF / 25V, 105 °C	Radial 10 x 12.5 mm	low impedance type
C29	Electrolytic capacitor 470 μF / 25V, 105 °C	Radial 10 x 12.5 mm	low impedance type
C30	1 μF / 50 V, Y5V	0805	
C31	Not mounted		
C34	0.1 μF / 25 V, X7R	0603	
C35	10 nF / 25 V, X7R	0603	
C36	Not mounted		
CX1	0.33 μF / 275 V AC, X2	MKP	
CY1	1000 pF / 400 V AC, Y1	Pitch 10 mm	

Table 13. Default bill of materials for a 90 W TEA1751T and TEA1791T adapter solution *…continued*

Reference	Component	Package	Remark
BD1	GBU806, 8 A / 600 V	Flat / mini	
D1	MUR460, 4 A / 600 V	DO-201AD	Vishay
D2	1N4148W	SOD-123	
D3	S2M	SMB	
D4	1N4148W	SOD-123	
D5	BAS21	SOT23	NXP, BAS20 is permitted
D23A	BAS21	SOT23	NXP, BAS20 is permitted
D27A	1N4148W	SOD-123	
D30	BAS21	SOT23	NXP
Q1	2SK3568	TO220F	
Q2	2SK3569	TO220F	
Q4	PSMN015-100P	TO220	NXP
U1	TEA1751T	SO16	NXP, GreenChip III PFC + flyback controller
U2	LTV817B	DIP4-W	CTR 130-260, spacing 10.16 mm
U3	TEA1791T	SO8	NXP, GreenChip-SR controller
U4	AP431SR	SOT-23R	diodes
T1	Flyback transformer 450 μH	PQ3220	see specification
L1	Inductor 210 μH	T50-52	
L2	PFC inductor 250 μH	RM10	see specification
L3	Inductor CM 200 μH	T12*6*4	
LF1	Inductor CM 500 μH	T12*6*4	
LF2	Inductor CM 12.8 MH	T16*12*18	
BC1	Bead core R5B/XP N4/AMAX	RH 4*6*2	placed at cathode of D1
BC2	Bead core S6H/JK N6/AMAX	RH 3.5*4.2*1.3	placed at lead of CY1
F1	Fuse T3, 15 A / 250 V	LT5	

7. Transformer and inductor specifications

7.1 Flyback transformer T1 specifications

- Primary inductance: 450 μH (±±5 %).
- Leakage inductance: 6 μH (max).
- Core / Bobbin: PQ3220.
- Core material: PC44.
- HI-POT prim - sec: 3 kV / 5 mA, 3 sec.

Manufacturer: Send Power Electronics. Co., LTD, Taiwan ROC.

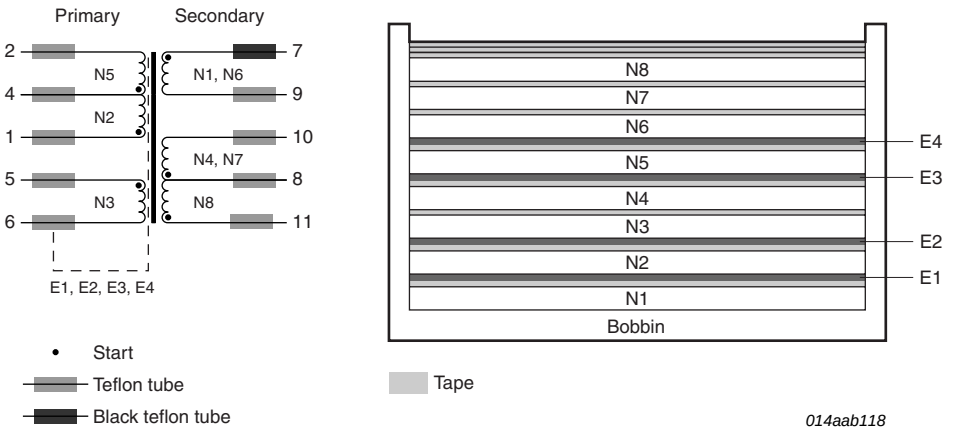

Fig 21. Flyback transformer schematic

Table 14. Flyback transformer winding details

Winding order		Pin number		Wire type	Number of wires	Number of turns		Remarks
		Start	Finish			Winding	MYLAR tape	
1:	N1	7	9	TEX-E (3L) 0.3 mm ∅	2	6	1	
2:	E1		6	Copper foil 0.025 mm x 7 mm		1	1	finished with wire 0.3 ∅
3:	N2	1	4	2-UEW 0.5 mm ∅	1	16	1	
4:	E2		6	Copper foil 0.025 mm x 7 mm		1	1	finished with wire 0.3 ∅
5:	N3	5	6	2-UEW 0.25 mm ∅	2	7	1	
6:	N4	8	10	TEX-E (3L) 0.3 mm ∅	2	6	1	
7:	E3		6	Copper foil 0.025 mm x 7 mm		1	1	finished with wire 0.3 ∅
8:	N5	4	2	2-UEW 0.5 mm ∅	1	16	1	
9:	E4		6	Copper foil 0.025 mm x 7 mm		1	1	finished with wire 0.3 ∅
10:	N6	7	9	TEX-E (3L) 0.3 mm ∅	2	6	1	
11:	N7	8	10	TEX-E (3L) 0.3 mm ∅	2	6	1	
12:	N8	11	8	TEX-E (3L) 0.3 mm ∅	1	5	3	close winding method

7.2 PFC inductor L2 specifications

7.2.1 Inductor L2 specifications

- Primary inductance: 250 μH (±10 %).
- Core / Bobbin: RM10.
- Core material: NC-2H.

Manufacturer: Send Power Electronics. Co., LTD, Taiwan ROC.

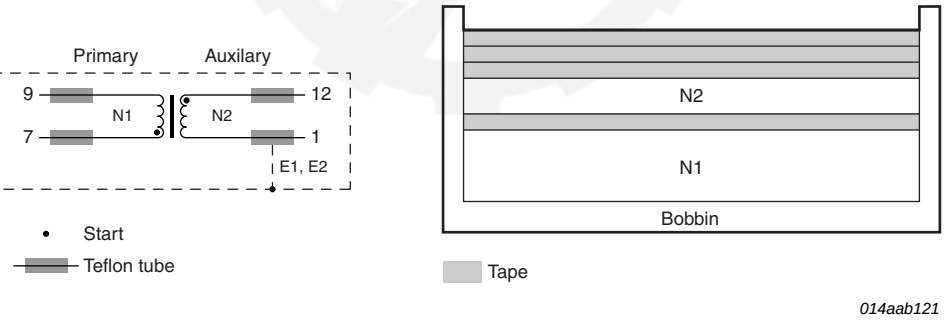

Fig 22. PFC inductor L2 schematic

Table 15. PFC inductor L2 winding details

Layer order		Pin number		Wire type	Number of wires	Number of turns		Remarks
		Start	Finish			Winding	MYLAR tape	
1:	N1	9	7	USTC 30 x 0.1 mm ∅	1	40	1	
2:	N2	12	1	2-UEW 0.22 mm ∅	2	2.5	3	

8. PCB layout

The SMPS printed circuit board is a single sided board. Dimensions are 125 mm x 59 mm.

The PCBs are produced on 1.6 mm FR2 with single sided 2 Oz. copper (70 μm).

The Gerber File set for production of the PCB is available through the local NXP sales office.

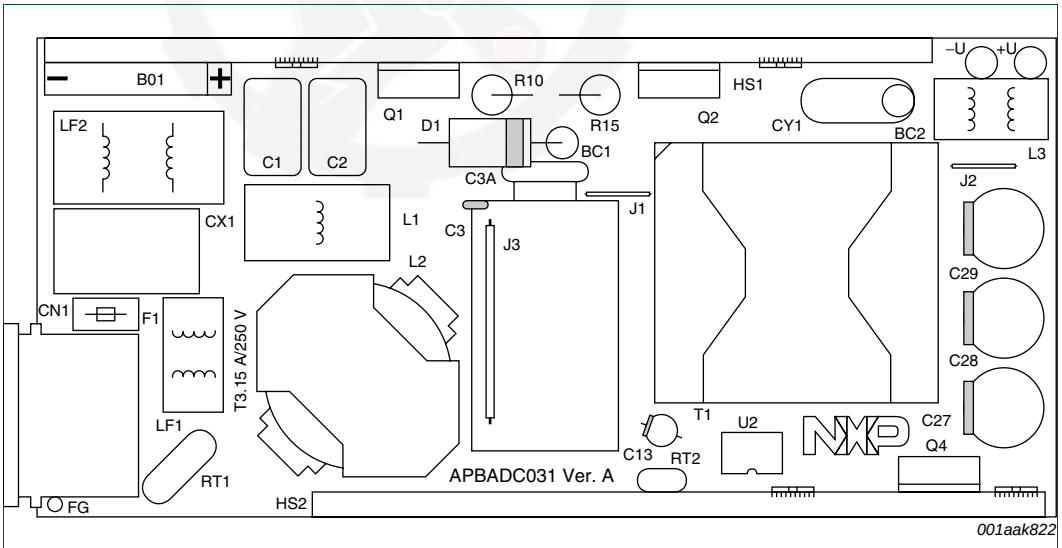

Fig 23. Demo board top silk (top view)

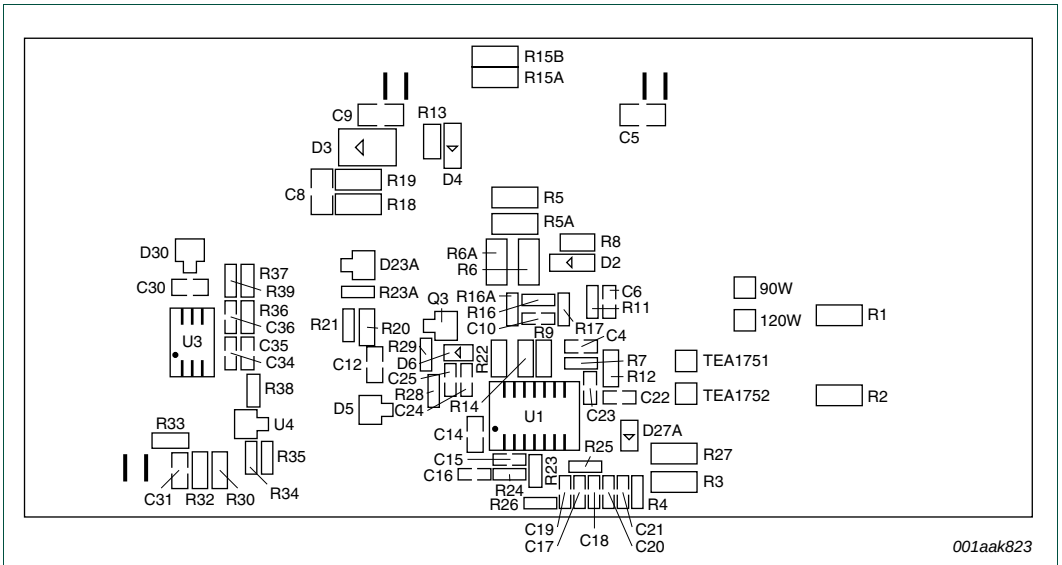

Fig 24. Demo board bottom silk (bottom view)

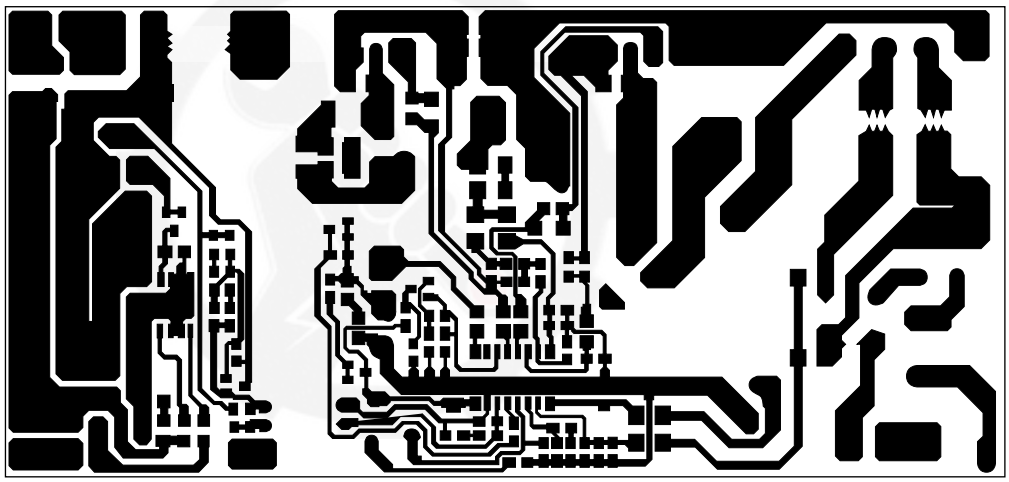

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Fig 25. Demo board bottom copper (bottom view)

9. Abbreviations

Table 16. Abbreviations table

Acronym	Description
CC	Constant Current
CR	Constant Resistance
CV	Constant Voltage
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
EMS	ElectroMagnetic Susceptibility
ESD	ElectroStatic discharge
FLR	Fast Latch Reset
LISN	Line Impedance Standardization Network
MHR	Mains Harmonic Reduction
OTP	Over Temperature Protection
OCP	Over Current Protection
OVP	Over Voltage Protection
PCB	Printed Circuit Board
PE	Protective Earth
PFC	Power Factor Correction
SCP	Short Circuit Protection
SMPS	Switched Mode Power Supply
SR	Synchronous Rectification
TIW	Triple Insulated Wire
UEW	PolyUrethane Enameled Wire
USTC	PolyUrethane Silk Tetrone Covered