

25 Watt DC/DC converter using integrated Planar Magnetics



Let's make things better.

25 Watt DC/DC converter using integrated Planar Magnetics

Contents

Introduction	2
Converter description	3
Converter specification	4
Performance of the converter	4
Design of planar magnetics	6
PCB layout	8
Circuit diagram	11
Components list	12



*25 Watt DC/DC converter using integrated Planar Magnetics
(designed in cooperation with PEI Technologies, Ireland)*

Introduction

Planar magnetics are an attractive alternative to conventional core shapes when a low profile of magnetic devices is required. Basically this is a construction method of inductive components whose windings are fabricated using printed circuit tracks or copper stampings separated by insulating sheets, or constructed from multilayer circuit boards. These windings are placed in low profile ferrite EE-or E/PLT-core combinations. Planar devices can be constructed as stand alone components or integrated into a multilayer board with slots cut to accept the ferrite E-core (fig.1).

The aim of this demonstration board is to demonstrate the capability of Philips' planar E cores (see Data Handbook MA01). One of these cores is used in the design of a high frequency 25 W DC/DC converter. A 6 layer PCB is used to facilitate the integration of the transformer and output inductor windings into the multilayer PCB structure.

The board demonstrates the advantages over standard wire wound solutions in terms of cost, size, simplicity and reliability. It will also show that the electrical performance of the converter is excellent.

Features such as input filtering, output voltage and long term short circuit protection have been omitted from the design as the use of planar magnetics does not have an impact on these features.

The chosen topology is the forward converter with resonant reset. A basic description of the operation of a forward converter can be found in most textbooks on switch-mode power supplies.

Converter description

The schematic for the forward converter with resonant reset is shown on page 10. This converter design differs from a standard design in two ways:

- It employs a resonant reset technique to reset the power transformer, T1
- It uses synchronous rectifiers Q2 and Q3, low voltage, low R_{ds(on)} MOSFETS on the secondary side of the transformer for rectification.

In a standard forward converter a separate winding can be used to reset the transformer to ensure the flux returns to zero on each cycle. The resonant reset technique allows for the elimination of this winding which is an attractive benefit when using planar magnetics. Reset is achieved during the off time by imposing a resonant voltage on the primary winding using parasitic circuit elements.

The frequency of this resonance is approximately equal to:

$$f_{\text{res}} \approx \frac{1}{2\pi\sqrt{L_p \cdot C_{Q1}}}$$

where L_p is the transformer primary inductance and C_{Q1} is the MOSFET parasitic capacitance.

The advantage of this technique is that it is easy to implement at low cost. The disadvantage is that it is a lossy solution compared to soft switching techniques. This loss is not dramatic at voltages lower than 100V, and will lead to a decrease in efficiency of approximately 1% at 48V input and 2% at 72V input voltage.

The second difference in comparison with a conventional converter is the implementation of synchronous rectification. This is cost competitive with Schottky diodes at a current rating of less than 10A.

At 48V input, synchronous rectification will increase the efficiency by approximately 3% to 6% depending on the R_{ds(on)} of the MOSFETS used and the switching frequency. Low R_{ds(on)} MOSFETS increase efficiency but are more expensive.

Increased frequency will reduce the efficiency of the synchronous rectifiers due to the charging of the input capacitance once every cycle.

To keep the circuit simple and low cost, the synchronous rectifiers are self driven. This means that they are driven directly with the voltage from the transformer secondary. This is not the most efficient solution particularly when the 'dead' time is large as at high input voltage. To counteract this, diode D1 is added in parallel to Q3. This diode will conduct during the 'dead' time.

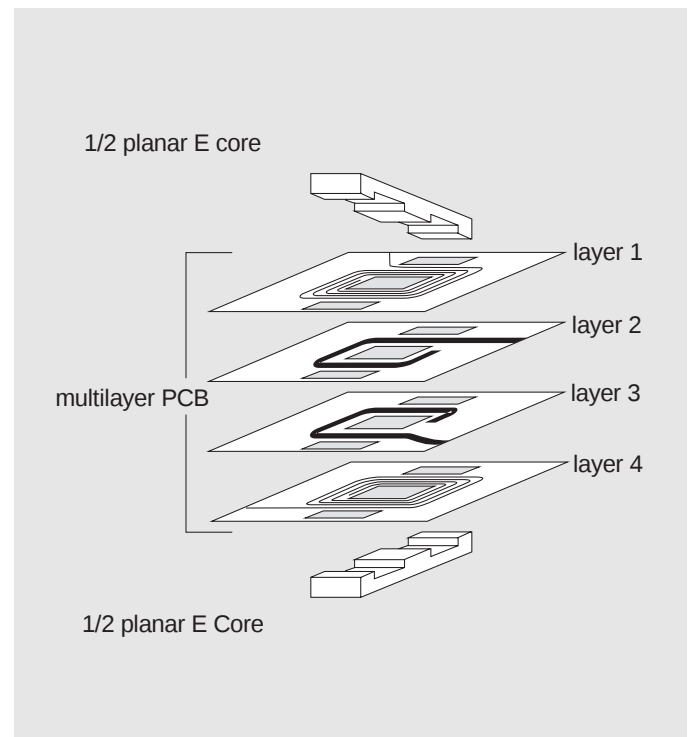


Fig. 1 Exploded view of a PCB transformer

Converter specification

Low-profile DC/DC converter (25 W)

Featuring:

- planar ferrite E cores
- multilayer FR4 printed circuit board(6layers)
- integrated windings for transformer and output choke.

Input voltage	36-72V
Max input current (no load)	50 mA
Max input current (full load)	620 mA
Output voltage	5VDC $\pm$ 1%
Output current (min)	0 A
Output current (max)	5 A
Output ripple and noise	50 mVpp
Efficiency	85 % typ
Line regulation	$\pm$ 0.1 %
Load regulation	$\pm$ 1 %
Isolation voltage	500 VDC
Switching frequency	420 kHz
Operating temperature-	25 °C to50 °C

All Specifications are typical at nominal line voltage(48V), full load and 25 °C unless otherwise stated.

Input capacitor required for operation: 10 μ F , 100V.

Pin	Pin connection
J1	Vin +
J2	Vin -
J3	+ Output
J4	- Output

Dimensions: 60 $\times$ 57 $\times$ 6 mm

Performance of the converter

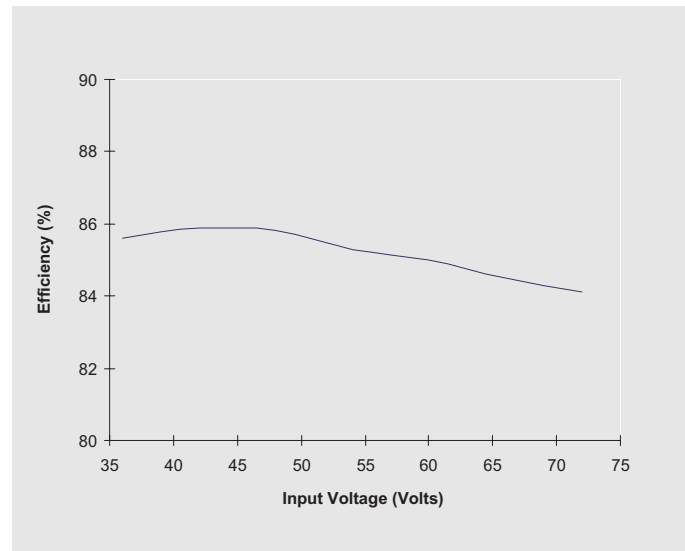


Fig.2 Efficiency as a function of input voltage at full load

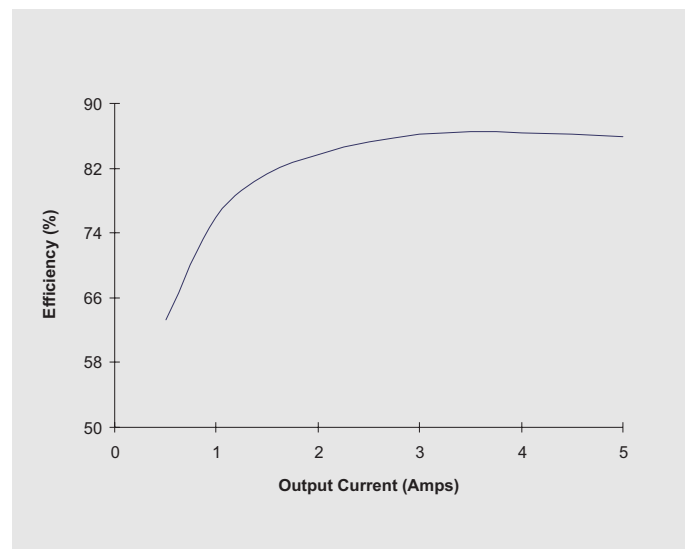


Fig.3 Efficiency as a function of output current ($V_{in}=48V$)

Oscillograms

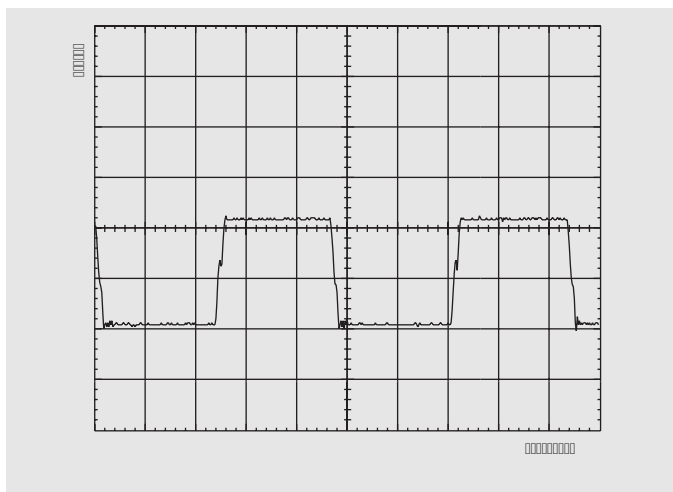


Fig.4 Primary MOSFET (Q1) gate voltage(TP6)

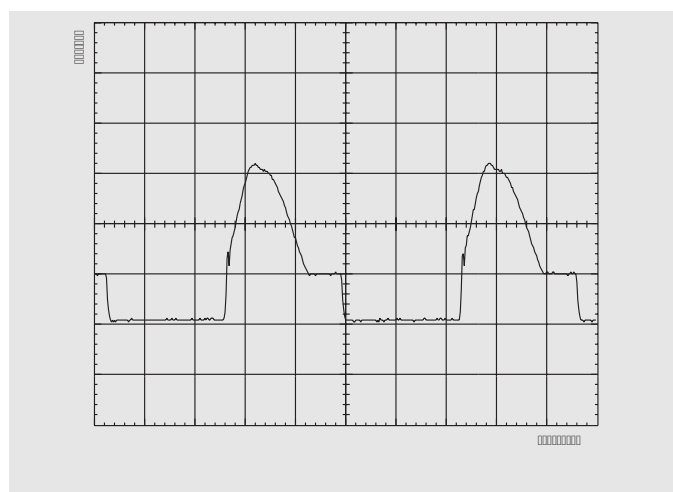


Fig.5 Primary MOSFET (Q1) drain voltage(TP2)

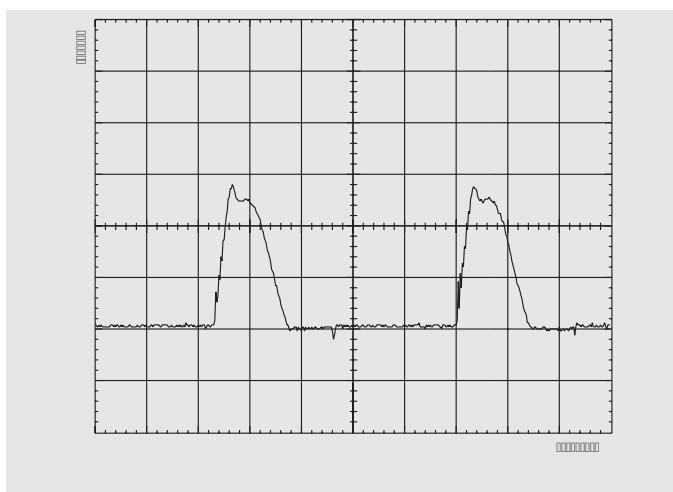


Fig.6 Synchronous rectifier (Q2) drain voltage (TP3)

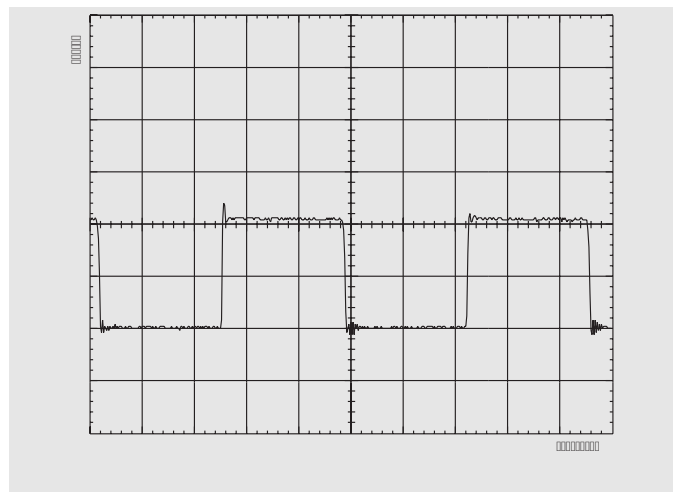


Fig.7 Synchronous rectifier (Q3) drain voltage (TP4)

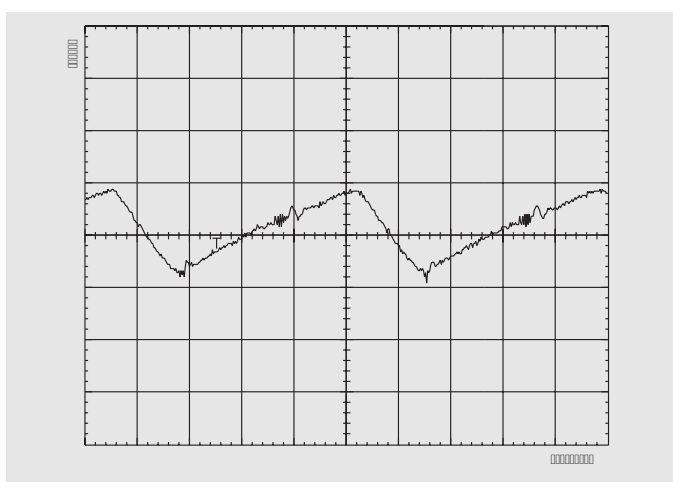


Fig.8 Control IC oscillator (TP5)

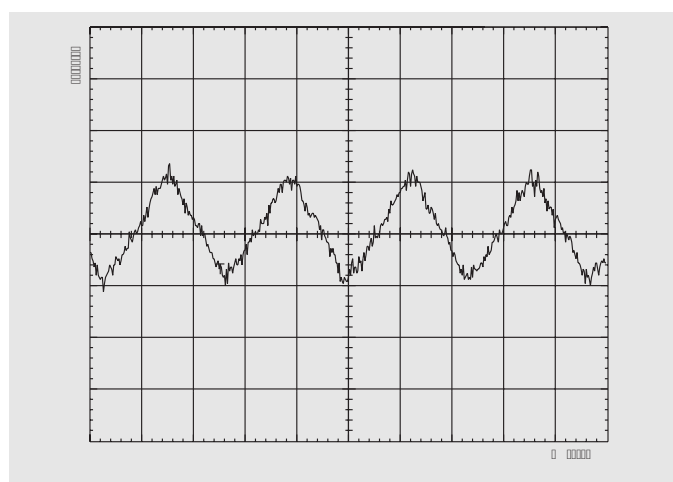


Fig.9 Output voltage ripple and noise (bandwidth 20 Mhz)

Design of planar magnetics

Transformer design (T1)

In designing the power transformer the optimisation of a number of design parameters has been investigated. These are discussed here.

The primary to secondary turns ratio should be approximately 4.5:1 to guarantee a secondary voltage of 5V at a minimum input voltage of 36V using a forward converter operating at a maximum duty cycle of 70%. Three turns ratios have been investigated (4:1, 4.5:1, 5:1) in order to determine the minimum transformer losses. The number of primary turns has been selected on the basis of a trade off between minimising core losses and copper losses. Consideration was also given to being able to accommodate the transformer windings in a 6-layer PCB construction. Hence three values of primary turns were investigated (5, 8 and 9 turns).

Copper losses in the transformer have been calculated for DC only, which appears to be accurate enough for this application. Methods to predict AC losses will be treated in a separate application note on the winding design for planar transformers.

Ferrite core: E18/4/10-3F3 + PLT18/10/2-3F3				
Turns ratio	9:2	8:2	5:1	
Track width (mm)				
primary	1.0	1.0	2.0	
secondary	4.5	4.5	4.5	
Number of PCB layers				
primary	3 or 4	3 or 4	3 or 4	
secondary	2	2	1	
auxiliary	1 or 2	1 or 2	1 or 2	
Total	6 to 8	6 to 8	5 to 7	
DC resistance (mΩ)				
primary	110	110	30	
secondary	6	6	3	
Primary inductance (μH)	243	192	75	

table1

Note 1: 2 oz copper (70 μm) is used in all cases.

The primary windings can be split in such a manner that the secondary is embedded between two primary windings. This technique, known as sandwiching or interleaving, reduces leakage inductance.

Transformer losses

Losses in the ferrite core and windings are estimated for a switching frequency of 400 kHz and an output current of 5 A.

Turns ratio	9:2	8:2	5:1
Primary current	0.8	0.85	0.75
Primary resistance	0.11	0.11	0.03
Primary loss	0.07	0.08	0.017
Secondary current	3.61	3.39	3.77
Secondary resistance	0.006	0.006	0.003
Secondary loss	0.08	0.07	0.043
Total copper loss	0.15	0.15	0.06
Core loss	0.56	0.77	2.1
Total losses (W)	0.71	0.91	2.15

table 2

The lowest overall losses are predicted for the turns ratio of 9:2, which is chosen for the design.

Optimisation of switching frequency

The choice of a switching frequency close to 400 kHz follows from an estimation of the total loss balance between semiconductors and magnetics. A higher frequency increases the loss in the switches, but ferrite losses are lower. A higher frequency also reduces the ripple current in the output inductor.

f (kHz)	Vin (V)	Semicond. losses (W)	Magnetics losses (W)	Total (W)
300	36	2.11	1.34	3.45
	48	2.38	1.27	3.65
	72	3.19	1.19	4.38
400	36	2.13	1.20	3.33
	48	2.52	1.13	3.65
	72	3.58	1.05	4.63
500	36	2.33	1.16	3.49
	48	2.67	1.09	3.76
	72	3.98	1.01	4.99
600	36	2.61	1.22	3.83
	48	2.84	1.15	3.99
	72	4.39	1.07	5.46
700	36	3.05	1.22	4.27
	48	3.01	1.15	4.16
	72	4.81	1.07	5.88

table 3

Design of planar inductor (L1)

The peak-to-peak ripple current in the output inductor is designed to be approximately 20% of the full load output current for the nominal input voltage of 48V.

The inductance to achieve this can be calculated from the formula:

$$L = \frac{V_{\text{sec}} \cdot t_{\text{on}}}{\Delta I} = \frac{10.66 \cdot 1.38 \mu\text{s}}{1} = 14.7 \mu\text{H}$$

where

$$V_{\text{sec}} = \text{Peak secondary voltage} = N_s / N_p \cdot V_{\text{in}} \\ = 2/9 \cdot 48 \text{ V} = 10.66 \text{ V}$$

$$t_{\text{on}} = \text{Primary MOSFET on time} = 1.38 \cdot 10^{-6} \text{ s}$$

$$\Delta I = \text{Inductor ripple current}$$

So ideally the inductance value should be 14.7 μH .

With 5 turns this means an inductance per turn of:

However, a check on the flux density shows that with a peak current of 5.5 A this is too high, since:

$$A_L = \frac{L}{N^2} = \frac{14.7 \cdot 10^{-6}}{25} = 588 \text{ nH}$$

Using the standard core E18/4-3F3-A315-P, a check on the flux density shows that with a peak current of 5.5A, the maximum value is:

$$B_{\text{max}} = \frac{N \cdot I_p \cdot A_L}{A_e} = \frac{5 \cdot 5.5 \cdot 588 \cdot 10^{-9}}{39.5 \cdot 10^{-6}} = 409 \text{ mT}$$

where

I_p = Peak inductor current

B = Maximum flux density

N = Number of turns

A_L = Inductance per turn

A_e = Cross sectional area of core

This maximum flux density of 388 mT is excessive for 3F3 material. To reduce the maximum flux density using the same core, the air-gap needs to be increased.

Consequently, the maximum flux density is set to 300 mT. Using this figure and working backwards to calculate the required A_L with $N=5$ turns and $I_p=5.5$ A gives:

$$A_L = \frac{B \cdot A_e}{N \cdot I_p} = \frac{0.3 \cdot 39.5 \cdot 10^{-6}}{5 \cdot 5.5} = 431 \text{ nH}$$

$$L = A_L \cdot N^2 = 431 \cdot 10^{-9} \cdot 25 = 10.8 \mu\text{H}$$

The increased ripple current will cause an increase in ΔB which will lead to somewhat higher losses in the output inductor.

Output capacitor design

Output ripple voltage is calculated using the formula:

$$\Delta V_o = \frac{1}{C} \int dI_L dt + \Delta I_L \cdot \text{ESR}$$

where ΔI_L is the ripple current in the output inductor and ESR is the equivalent series resistance of the output capacitors.

The first term is much smaller than the second due the high capacitance of the output capacitors so that the ripple voltage can be expressed as:

$$\Delta V_o = \Delta I_L \cdot \text{ESR}$$

The worst case will be at maximum input voltage.

$$V_{\text{sec}} = 2/9 \cdot 72 \text{ V} = 16 \text{ V}$$

$$L = 10.8 \mu\text{H}$$

Maximum ripple current follows from:

$$\Delta I_{\text{max}} = \frac{V_{\text{sec}} \cdot t_{\text{on}}}{L} = \frac{16 \cdot 0.92 \mu\text{s}}{10.8 \cdot 10^{-6}} = 1.35 \text{ A}$$

For a ripple voltage of less than 40 mV, the equivalent ESR should be less than 30m Ω . The capacitors chosen meet this requirement.

PCB layout

The multilayer FR4 PCB with 70 μm of copper comprises all windings of the transformer and output inductor.

These windings are divided over the separate layers in the following way:

transformer
primary (9turns): -5 turns in layer 1
 -4 turns in layer 6

secondary (2 turns): -1 turn in layer 2
 -1 turn in layer 5

sense (2 turns): -1 turn in layer 3
 -1 turn in layer 4

output inductor
 -1 turn in layer 1
 -1 turn in layer 2
 -1 turn in layer 3
 -1 turn in layer 4
 -1 turn in layer 5

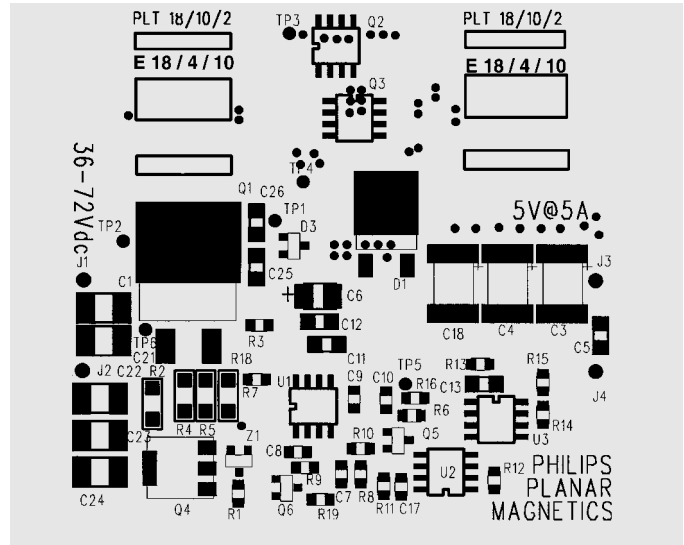


Fig.10 Component location

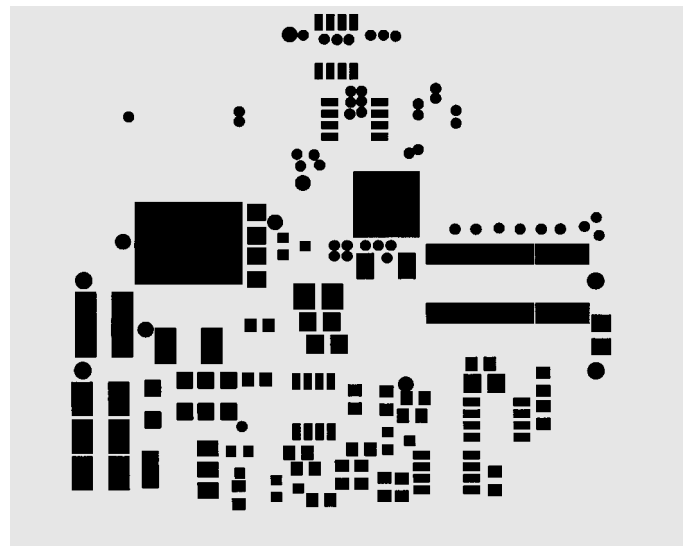


Fig.11 Solder mask layer 1

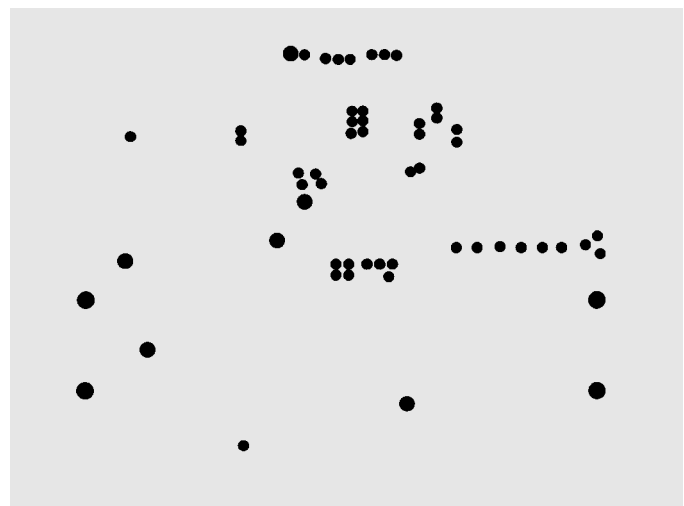


Fig.12 Solder mask layer 6

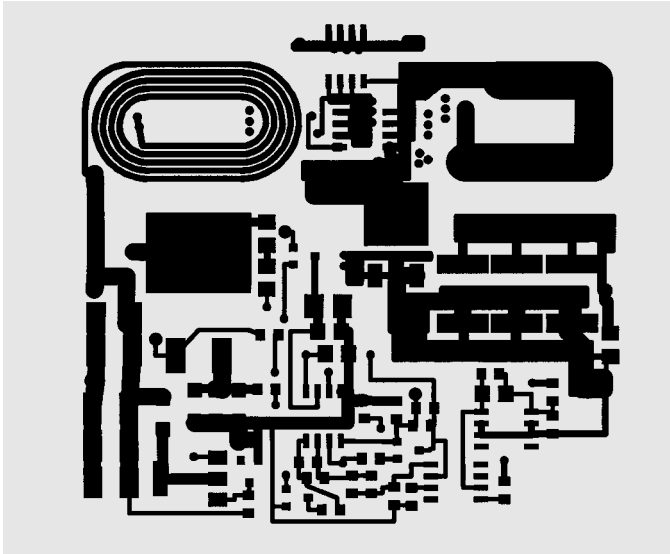


Fig.13 PCB layer 1

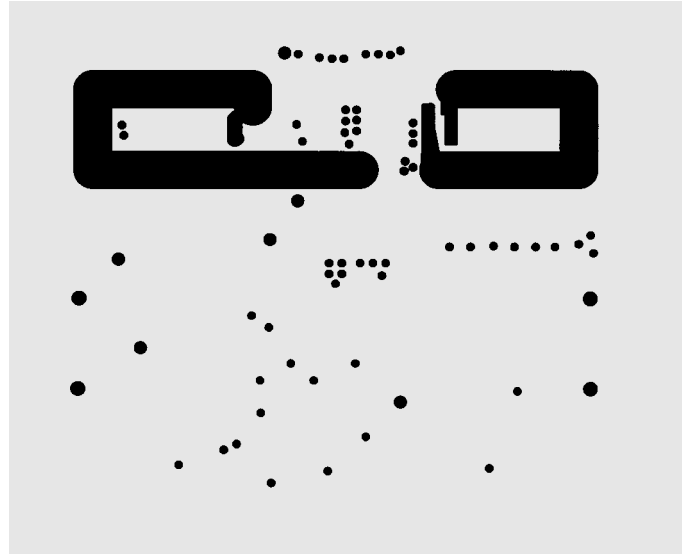


Fig.14 PCB layer 2

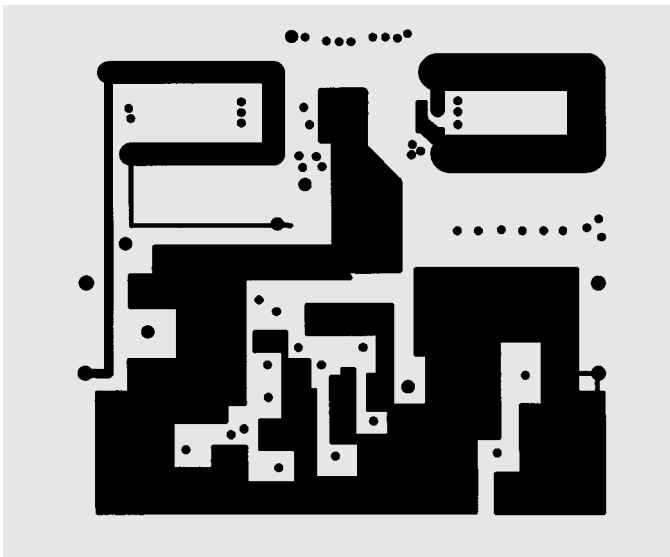


Fig.15 PCB layer 3

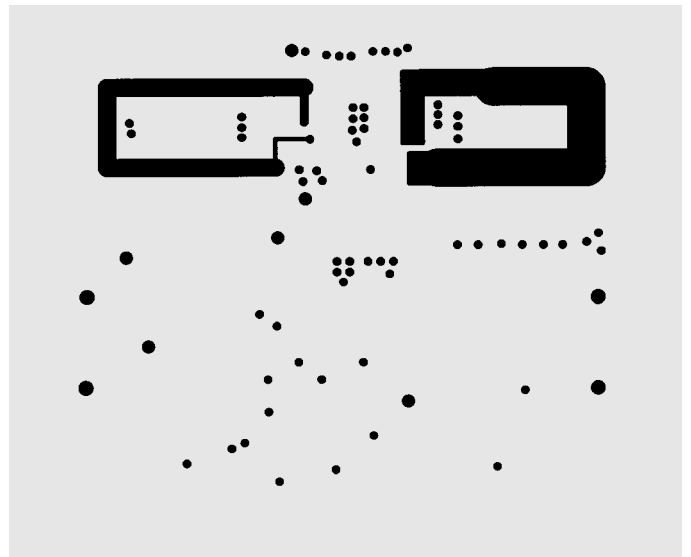


Fig.16 PCB layer 4

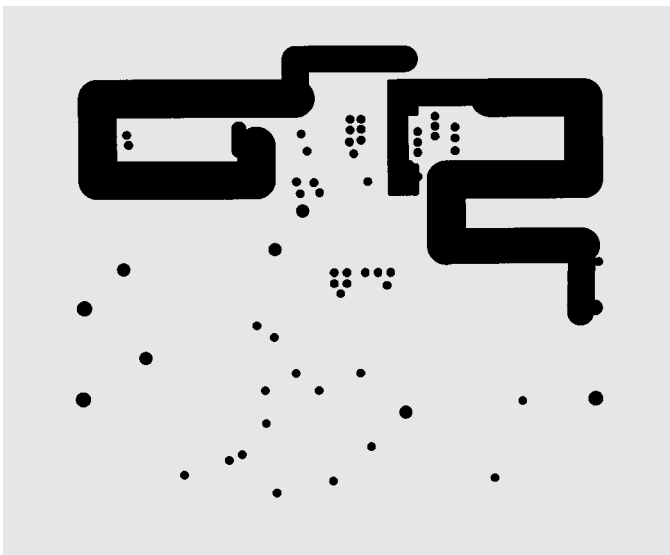


Fig.17 PCB layer 5

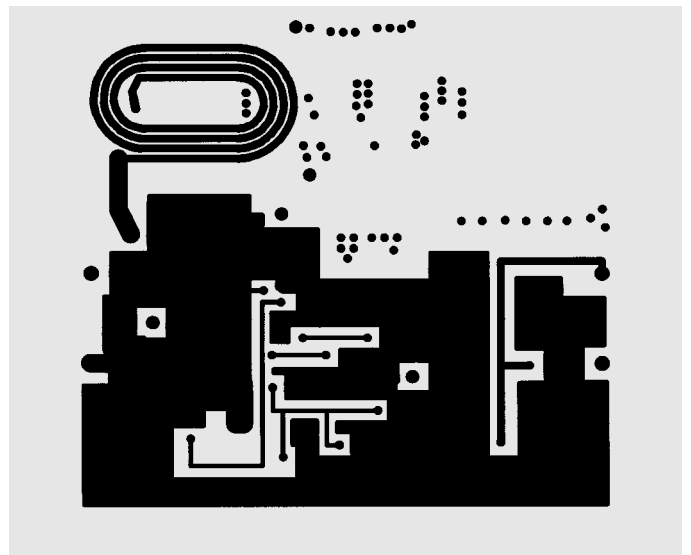
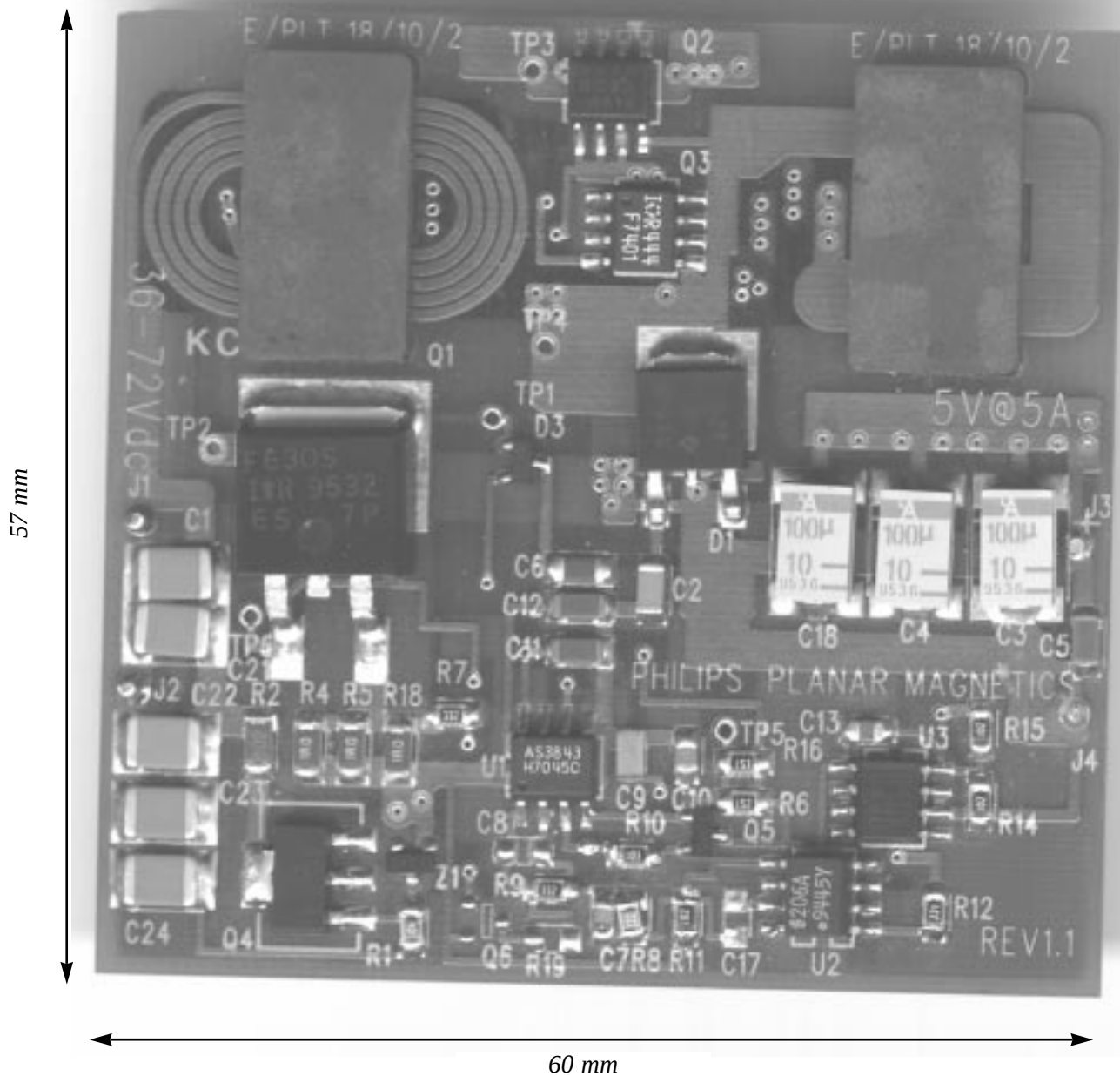


Fig.18 PCB layer 6



The complete converter

Components list

Reference	Part No. Series	Description	Package	Manufacturer
TR1	E18/4/10-3F3	Planar E Core		Philips
	PLT18/10/2-3F3	Plate		Philips
L1	E18/4/10-3F3	Planar E Core		Philips
	PLT18/10/2-3F3	Plate		Philips
Q1	IRF630S	200V, 0.4Ω, MOSFET	SMD-220	I.R.
Q2	Si9410DY	30V, 30mΩ, MOSFET	SO-8	Siliconix
Q3	IRF7401	20V, 22mΩ, MOSFET	SO-8	I.R.
Q4	BCP56	80V, 1A, NPN Trans.	SOT223	-
Q5	BC848A	30V, 100mA,NPN Trans	SOT23	Philips
D1	MBRD320	20V, 3A, Schottky Diode	D-Pak	Motorola
D3	BAV70	70V, 250mA Dual Diode	SOT-23	P.S.
Z1	BZX84C12	12V Zener Diode	SOT-23	P.S.
U1	AS3843	PWM Controller	SO-8	Astec
U2	IL206A	opto-isolator	SO-8	Siemens
U3	T1431	Prog. Reference	SO-8	T.I.
R1	WCR	100K, 0.1W	0805	Welwyn
R2	RC-01	1K, 0.125W	1206	Philips
R4,R5,R18	RC-01	1R, 0.25W	1206	Philips
R6	WCR	1K5, 0.1W	0805	Welwyn
R8	WCR	2K2, 0.1W	0805	Welwyn
R7,R9	WCR	3K3, 0.1W	0805	Welwyn
R11,R14,R15	WCR	1K, 0.1W	0805	Welwyn
R10	WCR	10K, 0.1W	0805	Welwyn
R12	WCR	220R, 0.1W	0805	Welwyn
R16	WCR	15K, 0.1W	0805	Welwyn
C1,C21,C22, C23,C24		100nF,100V	1812	Syfer
C3,C4,C18	TAJ	100μF, 10V	D	AVX
C5,C11,C12	CG,2R	100nF, 63V	1206	Philips
C6		220nF	1206	AVX
C7,C10		22nF	0805	Philips
C9		22pF	0805	Philips
C13		15nF	0805	Kemet
C2		10nF 500V	1206	AVX

Magnetic Products NAFTA Sales Offices

Alabama	Over and Over, Inc., Charlotte, NC	(708) 583-9100
Alaska	Eclipse Marketing Group, Redmond, WA	(206) 885-6991
Arizona	Harper and Two, Tempe, AZ	(602) 804-1290
Arkansas	Philips Components, Willoughby, OH	(440) 269-8585
California - Northern	Criterion Sales, Santa Clara, CA	(408) 988-6300
California - Southern	Harper and Two, Signal Hill, CA	(801) 264-8050
Colorado	Philips Components, Willoughby, OH	(440) 269-8585
Connecticut	Philips Components, Woburn, MA	(617) 932-4748
Delaware	Philips Components, Woburn, MA	(617) 932-4748
Florida	Over and Over, Charlotte, NC	(704) 583-9100
Georgia	Over and Over, Charlotte, NC	(704) 583-9100
Hawaii	Harper and Two, Signal Hill, CA	(310) 424-3030
Idaho - Northern	Eclipse Marketing Group, Redmond, WA	(206) 885-6991
Idaho - Southern	Electrodyne, Inc., Salt Lake City, UT	(801) 264-8050
Illinois - Northern	Philips Components, Willoughby, OH	(440) 269-8585
Illinois - Quad Cities	Lorenz Sales, Cedar Rapids, IA	(319) 377-4666
Illinois - Southern	Lorenz Sales, St. Louis, MO	(314) 997-4558
Indiana - Northern	Corrao Marsh, Fort Wayne, IN	(219) 482-2725
Indiana - Central and Southern	Corrao Marsh, Greenfield, IN	(317) 462-4446
Iowa - All except Quad Cities	Lorenz Sales, Cedar Rapids, IA	(319) 377-4666
Kansas - Northeast	Lorenz Sales, Overland Park, KS	(913) 469-1312
Kansas - All except Northeast	Lorenz Sales, Wichita, KS	(316) 721-0500
Kentucky	Corrao Marsh, Greenfield, IN	(317) 462-4446
Louisiana	Philips Components, Willoughby, OH	(440) 269-8585
Maine	Philips Components, Woburn, MA	(617) 932-4748
Maryland	Philips Components, Willoughby, OH	(440) 269-8585
Massachusetts	Philips Components, Woburn, MA	(617) 932-4748
Michigan	Philips Components, Willoughby, OH	(440) 269-8585
Minnesota	Electronic Component Sales, Minneapolis, MN	(612) 946-9510
Mississippi	Over and Over, Charlotte, NC	(704) 583-9100
Missouri - Eastern	Lorenz Sales, St. Louis, MO	(314) 997-4558
Missouri - Western	Lorenz Sales, Overland Park, KS	(913) 469-1312
Montana	Electrodyne, Inc., Salt Lake City, UT	(801) 264-8050
Nebraska	Lorenz Sales, Cedar Rapids, IA	(319) 377-4666
Nevada - Central and Northern	Criterion Sales, Santa Clara, CA	(408) 988-6300
Nevada - Southern	Harper and Two, Tempe, AZ	(602) 804-1290
New Hampshire	Philips Components, Woburn, MA	(617) 932-4748
New Jersey	Philips Components, Woburn, MA	(617) 932-4748
New Mexico	Harper and Two, Tempe, AZ	(602) 804-1290
New York - Western	Philips Components, Willoughby, OH	(440) 269-8585
New York - All other	Philips Components, Woburn, MA	(617) 932-4748
North Carolina	Over and Over, Charlotte, NC	(704) 583-9100
North Dakota	Electronic Component Sales, Minneapolis, MN	(612) 946-9510
Ohio	Philips Components, Willoughby, OH	(440) 269-8585
Oklahoma	Philips Components, Willoughby, OH	(440) 269-8585
Oregon	Eclipse Marketing Group, Beaverton, OR	(503) 642-1661
Pennsylvania - Western	Philips Components, Willoughby, OH	(440) 269-8585
Pennsylvania - Eastern	Philips Components, Woburn, MA	(617) 932-4748
Rhode Island	Philips Components, Woburn, MA	(617) 932-4748
South Carolina	Over and Over, Charlotte, NC	(704) 583-9100
South Dakota	Electronic Component Sales, Minneapolis, MN	(612) 946-9510
Tennessee	Over and Over, Charlotte, NC	(704) 583-9100
Texas	Philips Components, Willoughby, OH	(440) 269-8585
Utah	Electrodyne, Inc., Salt Lake City, UT	(801) 264-8050
Vermont	Philips Components, Woburn, MA	(617) 932-4748
Virginia	Philips Components, Willoughby, OH	(440) 269-8585
Washington	Eclipse Marketing Group, Redmond, WA	(206) 885-6991
Washington DC	Philips Components, Willoughby, OH	(440) 269-8585
West Virginia	Philips Components, Willoughby, OH	(440) 269-8585
Wisconsin	Philips Components, Willoughby, OH	(440) 269-8585
Wyoming	Electrodyne, Inc., Salt Lake City, UT	(801) 264-8050
Canada	Philips Components, Scarborough, ON	(416) 292-5161
Mexico	Philips Components, El Paso, TX	(915) 772-4020
Puerto Rico	Max Anderson Co., Caperra Heights, PR	(809) 783-6544
Virgin Islands	Max Anderson Co., Caperra Heights, PR	(809) 783-6544

Philips Components – a worldwide company

Australia: Philips Components Pty Ltd., NORTH RYDE,
Tel. +61 2 9805 4455, Fax. +61 2 9805 4466

Austria: Österreichische Philips Industrie GmbH, WIEN,
Tel. +43 1 60 101 12 41, Fax. +43 1 60 101 12 11

Belarus: Philips Office Belarus, MINSK,
Tel. +375 172 200 924/733, Fax. +375 172 200 773

Benelux: Philips Nederland B.V., EINDHOVEN, NL,
Tel. +31 40 2783 749, Fax. +31 40 2788 399

Brazil: Philips Components, SÃO PAULO,
Tel. +55 11 821 2333, Fax. +55 11 829 1849

Canada: Philips Electronics Ltd., SCARBOROUGH,
Tel. +1 416 292 5161, Fax. +1 416 754 6248

China: Philips Company, SHANGHAI,
Tel. +86 21 6354 1088, Fax. +86 21 6354 1060

Denmark: Philips Components A/S, COPENHAGEN S,
Tel. +45 32 883 333, Fax. +45 31 571 949

Finland: Philips Components, ESPOO,
Tel. +358 9 615 800, Fax. +358 9 615 80510

France: Philips Composants, SURESNES,
Tel. +33 1 4099 6161, Fax. +33 1 4099 6493

Germany: Philips Components GmbH, HAMBURG,
Tel. +49 40 2489-0, Fax. +49 40 2489 1400

Greece: Philips Hellas S.A., TAVROS,
Tel. +30 1 4894 339/+30 1 4894 239, Fax. +30 1 4814 240

Hong Kong: Philips Hong Kong, KOWLOON,
Tel. +852 2784 3000, Fax. +852 2784 3003

India: Philips India Ltd., MUMBAI,
Tel. +91 22 4930 311, Fax. +91 22 4930 966/4950 304

Indonesia: P.T. Philips Development Corp., JAKARTA,
Tel. +62 21 794 0040, Fax. +62 21 794 0080

Ireland: Philips Electronics (Ireland) Ltd., DUBLIN,
Tel. +353 1 7640 203, Fax. +353 1 7640 210

Israel: Rapac Electronics Ltd., TEL AVIV,
Tel. +972 3 6450 444, Fax. +972 3 6491 007

Italy: Philips Components S.r.l., MILANO,
Tel. +39 2 6752 2531, Fax. +39 2 6752 2557

Japan: Philips Japan Ltd., TOKYO,
Tel. +81 3 3740 5135, Fax. +81 3 3740 5035

Korea (Republic of): Philips Electronics (Korea) Ltd., SEOUL,
Tel. +82 2 709 1472, Fax. +82 2 709 1480

Malaysia: Philips Malaysia SDN Berhad,
Components Division, PULAU PINANG,
Tel. +60 3 750 5213, Fax. +60 3 757 4880

Mexico: Philips Components, EL PASO, U.S.A.,
Tel. +52 915 772 4020, Fax. +52 915 772 4332

New Zealand: Philips New Zealand Ltd., AUCKLAND,
Tel. +64 9 815 4000, Fax. +64 9 849 7811

Norway: Norsk A/S Philips, OSLO,
Tel. +47 22 74 8000, Fax. +47 22 74 8341

Pakistan: Philips Electrical Industries of Pakistan Ltd., KARACHI,
Tel. +92 21 587 4641-49, Fax. +92 21 577 035/+92 21 587 4546

Philippines: Philips Semiconductors Philippines Inc.,
METRO MANILA, Tel. +63 2 816 6345, Fax. +63 2 817 3474

Poland: Philips Poland Sp. z o.o., WARSZAWA,
Tel. +48 22 612 2594, Fax. +48 22 612 2327

Portugal: Philips Portuguesa S.A.,
Philips Components: LINDA-A-VELHA,
Tel. +351 1 416 3160/416 3333, Fax. +351 1 416 3174/416 3366

Russia: Philips Russia, MOSCOW,
Tel. +7 95 755 6918, Fax. +7 95 755 6919

Singapore: Philips Singapore Pte Ltd., SINGAPORE,
Tel. +65 350 2000, Fax. +65 355 1758

South Africa: S.A. Philips Pty Ltd., JOHANNESBURG,
Tel. +27 11 470 5911, Fax. +27 11 470 5494

Spain: Philips Components, BARCELONA,
Tel. +34 93 301 63 12, Fax. +34 93 301 42 43

Sweden: Philips Components AB, STOCKHOLM,
Tel. +46 8 5985 2000, Fax. +46 8 5985 2745

Switzerland: Philips Components AG, ZÜRICH,
Tel. +41 1 488 22 11, Fax. +41 1 481 7730

Taiwan: Philips Taiwan Ltd., TAIPEI,
Tel. +886 2 2134 2900, Fax. +886 2 2134 2929

Thailand: Philips Electronics (Thailand) Ltd., BANGKOK,
Tel. +66 2 745 4090, Fax. +66 2 398 0793

Turkey: Türk Philips Ticaret A.S., GÜLTEPE/ISTANBUL,
Tel. +90 212 279 2770, Fax. +90 212 282 6707

United Kingdom: Philips Components Ltd., DORKING,
Tel. +44 1306 512 000, Fax. +44 1306 512 345

United States:

- Display Components, ANN ARBOR, MI,
Tel. +1 734 996 9400, Fax. +1 734 761 2776
- Magnetic Products, SAUGERTIES, NY,
Tel. +1 914 246 2811, Fax. +1 914 246 0487
- Passive Components, SAN JOSE, CA,
Tel. +1 408 570 5600, Fax. +1 408 570 5700

Yugoslavia (Federal Republic of): Philips Components, BELGRADE,
Tel. +381 11 625 344/373, Fax. +381 11 635 777

Internet:

- Display Components: www.dc.comp.philips.com
- Passive Components: www.passives.comp.philips.com

For all other countries apply to:

Philips Components, Building BF-1, P.O. Box 218, 5600 MD EINDHOVEN,
The Netherlands, Fax. +31-40-27 23 903.

COD19

Philips Electronics N.V. 1998

All rights are reserved. Reproduction in whole or in part is prohibited without the prior written consent of the copyright owner.

The information presented in this document does not form part of any quotation or contract, is believed to be accurate and reliable and may be changed without notice. No liability will be accepted by the publisher for any consequence of its use. Publication thereof does not convey nor imply any license under patent- or other industrial or intellectual property rights.

Printed in The Netherlands

Document order number: 9398 236 2601 I

Date of release: 03/96

**Philips
Components**



PHILIPS

Let's make things better.