Application Note
Philips Magnetic Products

Planar E Cores

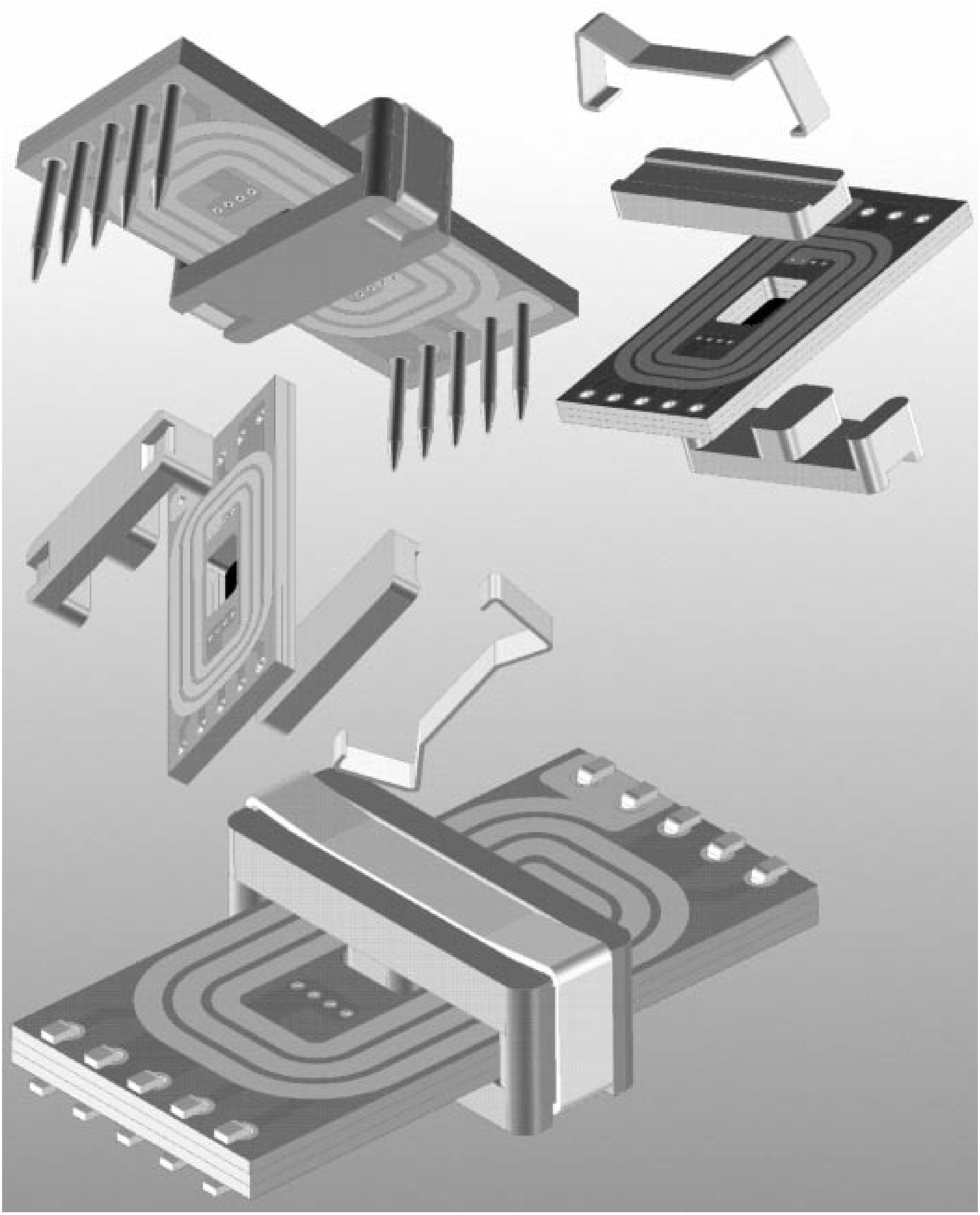
Let's make things better.

Philips Components

PHILIPS

Planar E Cores

Contents



Planar E core transformers

1. Introduction

Planar magnetics offer an attractive alternative to conventional core shapes when low profile magnetic devices are required. Basically this is a construction method of inductive components with windings made of printed circuit tracks or copper stampings separated by insulating sheets or constructed with multi-layer circuit boards. These windings are placed between low-profile ferrite cores. Planar devices can be constructed in several ways. The closest to conventional devices is a stand-alone component to replace components on a mono-layer or any other circuit board. The height of a stand-alone component can be reduced by sinking the core through a slot in the mother board until its windings rest on the mother board. One step further is a hybrid type, where part of the windings are in the mother board while others are joined as a separate multi-layer circuit board. The mother board must have slots cut out to accept the ferrite core. The last version is achieved by total integration in a multi-layer mother board.

Just like for wire-wound components, the core halves can be assembled either by gluing or by clamping, depending on the capabilities and preferences of the manufacturer. Philips Components manufacture a range of planar E cores, which is presented in this brochure. In addition, a whole range of low profile RM cores is available. For more information, please consult our DATA HANDBOOK MA01 or Product Selection Guide.

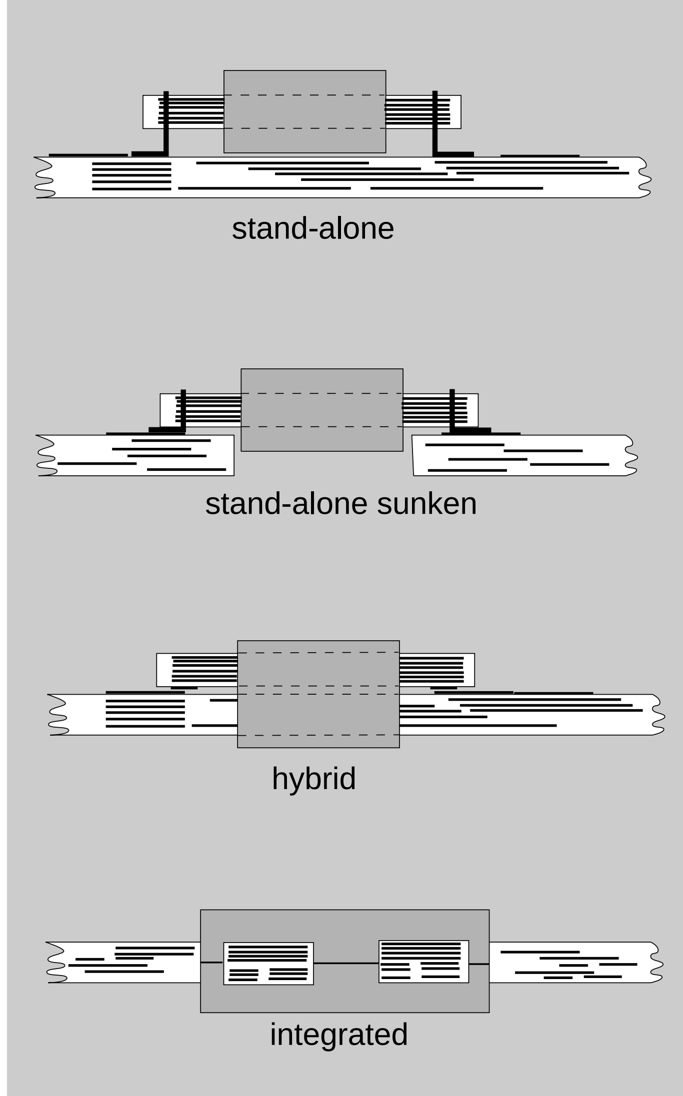


Fig.1 Several types of planar devices

2.Advantages of planar technology

There are many advantages of planar magnetic technology over conventional wire-wound inductive components. An obvious advantage is a very low build height, which promotes planar in dense rack-mount and portable equipment.

Planar magnetics are very well suited for design of high performance switch-mode power converters. Low AC copper losses and good coupling increase conversion efficiency. Levels higher than 95 % can be achieved, provided that the core is ungapped or only has a moderate air gap. In addition, low leakage inductance reduces voltage spikes and oscillations that can damage MOSFETs and increase interference emission.

Good heat management leads to very high throughput power density, up to twice the value for conventional transformers. Very good repeatability of parasitics enables high switching frequencies and resonant topologies. Cores are available in material 3F4 for switching frequencies up to 3 MHz.

Planar technology is straight forward and reliable in production. Advantages and limitations are listed in following tables.

2.a. Design advantages

Feature	*stand-alone*	*Integrated*
● Mechanical characteristics		
Very low profile	x	x x
Compact and rigid construction	x	x x
● Electrical characteristics		
Little skin and proximity effect in flat copper tracks	x	x
Good coupling of closely stacked transformer windings	x	x x
Excellent repeatability due to fixed winding layout	x	x
● Heat management		
High core surface (cooling) to volume (dissipation) ratio	x	x
Compact coil with good heat conduction	x	x
Large core surface for heat sink contact	x	x

2.b. Manufacturing advantages

Feature	*stand-alone*	*Integrated*
● Forward integration		
No coil former required	x	x
No separate windings required		x
No pinning / leads required		x
Independence of component assembler		x
● Manufacturability		
No winding operation	x	x
No soldering operation		x
Compatible with SMD technology	x	x
● Reliability		
No winding errors / short circuit	x	x
No solder contact problems		x

2.c. Limitations

Feature	*Stand-alone*	*Integrated*
● General		
Only if multi-layer mother board		x
Cost of planar windings versus copper wire (1)	x	
Design & production knowledge needed by board assembler		x
Every design needs its own prefab winding	x	x x
● Design		
Low copper cross-section to window area ratio	x	x x
Parasitic capacitance limits winding design possibilities	x	x x
Designs with large air gap are unfavourable	x	x
● Manufacturing		
The batch to batch spread can't be compensated with the turns	x	x

Note (1) The price of multi-layer PCB is coming down. Overall cost : no coil former and smaller core.

2.d. Integrated versus stand-alone

Integrated planar components are used if the complexity of the surrounding circuitry already demands for multi-layer PCB. Typical applications can be found in low power conversion and signal processing and use mostly E / plate combination of the small sizes. Main design considerations for planar here are flatness and high frequency electrical characteristics.
Stand-alone components are used otherwise. Typical applications can be found in high power conversion and use mostly E / E combination of the large sizes. Main design consideration for planar here is heat management.
The type of windings depends partly on the current rating.

Low : multi-layer PCB (most compact) or stacked mono-layer PCB (standard windings)
Medium : stacked flex foil leadframes (thick tracks) or ceramic substrates (good heat conduction)
High : self-supporting leadframes (nut & bolt type)

Sunken stand-alone components reduce the build height without changing component layout.
Hybrid components make use of the mother board tracks to reduce the number of stand-alone tracks, whereas these are completely eliminated with an integrated component.
Combinations of the foregoing types are also possible. For example, a power converter could have the primary winding and mains filter choke (fixed) in the mother board and the secondary winding and output choke (custom) in stand-alone PCB's (see Fig. 2).

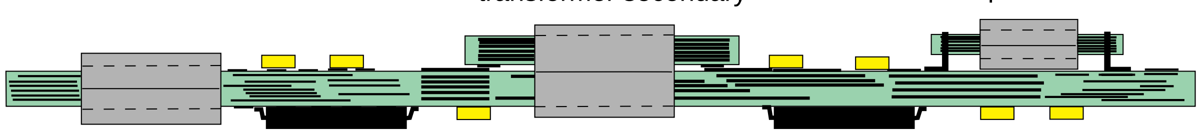


Fig.2 Hybrid design with planar magnetics.

2.e. Gluing versus clamping

The choice between gluing and clamping depends mainly on the capabilities and preferences of the manufacturer, but also the application requirements can favour one of the two.

- Reasons for gluing
  Simple production automation
  Uniform core cross-section (saturation)
  Low build height (no clamp arc)
  Smaller PCB cut-out (integrated version)
  Fixation of cores to the PCB (no rattle/noise)

- Reasons for clamping
  Clean assembly process
  No environmental influence on assembly process
  No problems in high temperature application
  No increase of parasitic gap (high permeability)

3. Applications

The first applications for planar E cores were in power conversion. Correspondingly, material grades were medium and high frequency power ferrites. The inductance of the mains filter choke can be increased by substituting the power ferrite for a high permeability grade. In pulse transmission, a wideband transformer between pulse generating IC and cable provides isolation and impedance matching. For an S or T-interface, this should also be a high permeability ferrite. Cores in the high permeability material 3E6 have been added to our range. A listing of applications, likely to profit from planar, is given below.

3.a. Power conversion

- Components
  power transformer, output or resonant choke(s), mains filter choke
- AC/DC converter (mains-fed power supply)
  Stand-alone SMPS
  Battery charger (mobile phone, portable computers)
  Instrumentation & control
- DC/DC converter (distributed or battery-fed power supply)
  Power converter modules
  Telecommunications network switch (distributed supply)
  Mobile phone (main power supply)
  Portable computer (main power supply)
  Electric car (traction voltage to 12 V down converter)
- AC/AC converter (mains-fed power supply)
  Compact fluorescent lamps
  Induction heating, welding
- DC/AC inverter (battery-fed power supply)
  Mobile phone (LCD backlighting)
  Portable computer (LCD backlighting)
  Gas discharge car headlamp (ballast)
  Car rear window heating (step-up converter)

3.b. Pulse transmission

- Component
  wideband transformer
  S_0 interface (subscriber telephone line)
  U interface (subscriber ISDN line)
  T1/T2 interface (trunk line between network switches)
  ADSL interface (Asynchronous Digital Subscriber Line)
  HDSL interface (High Digital Subscriber Line)

4. Product range

Philips Components offer an extensive product range of planar E cores. Sizes range from 14 to 64 mm. The cross-sectional area is always uniform for the basic version for gluing to make optimum use of the ferrite volume. Every size has an E core and corresponding plate (PLT). A core set consists of either an E core and a plate or two E cores, in which case the winding window height doubles. The smallest 3 sizes also have an E/PLT version for clamping. The E core has recesses (E/R) while the plate has a slot (PLT/S). A clamp (CLM) snaps into the recesses and provides a firm grip, pressing the plate on two points. The slot prohibits the plate from sliding out even in case of strong shocks or vibrations and provides alignment. For the E / E combination there are no clips.

All sizes are available in power materials 3F3 (frequencies up to 500 kHz) and 3F4 (500 kHz - 3 MHz). The largest 5 sizes are also available in 3C85 (frequencies up to 200 kHz), as large cores are often used in low frequency, high power applications. The smallest 3 sizes are available in high permeability 3E6 (μ_i12000) as well for mains filter chokes and wideband transformers.

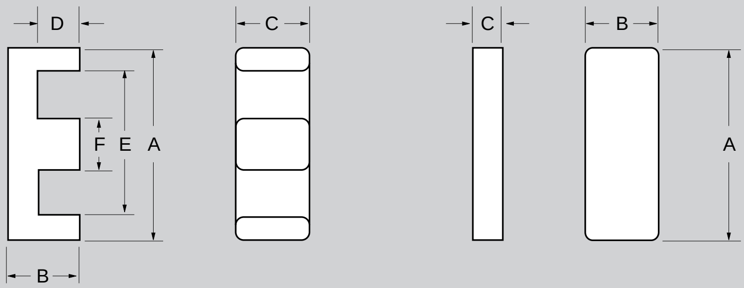
All E cores in power materials can be gapped, preferably in a standard range of A_L values. Every A_L value corresponds to 2 slightly different gaps, depending on whether the mating part is another E core or a plate (P). Default is asymmetric gap (A) ; the mating part is a plate or an ungapped E core. The largest 5 sizes have their largest gaps symmetrical (E) ; the mating part is an identical gapped E core.

For an overview of the type number system :
see section 8.

4.a. Material grades

PARAMETER	SYMBOL	UNIT	TEST CONDITIONS	3C85	3F3	3F4	3E6
Initial permeability	μ_i	-	f = ≤10 kHz, B < 0.1mT, T = 25 ^oC	2000	1800	900	12000
Saturation flux density	B_s	mT	f = 10 kHz, T = 25 ^oC	≈500	≈500	≈450	≈400
at Field strength	H	A/m		3000	3000	3000	250
Remanence	B_r	mT	T = 25 ^oC	≈160	≈150	≈150	≈100
Coercivity	H_c	A/m	T = 25 ^oC	≈15	≈15	≈60	≈4
Power loss density (typical, sinewave excitation)	P_v	kW/m^3	f = 25kHz, B = 200mT, T = 100 ^oC	100	70	-	-
			f = 100kHz, B = 100mT, T = 100 ^oC	120	50	200	-
			f = 500kHz, B = 50mT, T = 100 ^oC	-	180	180	-
			f = 1MHz, B = 30mT, T = 100 ^oC	-	300	140	-
			f = 3MHz, B = 10mT, T = 100 ^oC	-	-	240	-
Curie temperature	T_c	^oC	-	≥200	≥200	≥220	≥130
Resistivity (DC)	ρ	Ωm	T = 25 ^oC	≈2	≈2	≈10	≈0.5
Density		g/cm^3	T = 25 ^oC	≈4.8	≈4.8	≈4.7	≈4.9

4.b. Cores for gluing (without recess)



E core (E)

plate (PLT)

Core type	dimensions (mm)						effective core parameters				
	A	B	C	D	E	F	core factor Σ l/A (mm^{-1})	eff. volume V_e (mm^3)	eff. length l_e (mm)	eff.[1] area A_e (mm^2)	mass of core half (g)
E14/3.5/5 (E-E combination)	14 ± 0.3	3.5 ± 0.1	5 ± 0.1	2 ± 0.1	11 ± 0.25	3 ± 0.05	1.43	300	20.7	14.5	≈ 0.6
PLT14/5/1.5 (E-PLT combination)	14 ± 0.3	5 ± 0.1	1.5 ± 0.05	-	-	-	1.16	240	16.7	14.5	≈ 0.5
E18/4/10 (E-E combination)	18 ± 0.35	4 ± 0.1	10 ± 0.2	2 ± 0.1	14 ± 0.3	4 ± 0.1	0.616	960	24.3	39.5	≈ 2.4
PLT18/10/2 (E-PLT combination)	18 ± 0.35	10 ± 0.2	2 ± 0.05	-	-	-	0.514	800	20.3	39.5	≈ 1.7
E22/6/16 (E-E combination)	21.8 ± 0.4	5.7 ± 0.1	15.8 ± 0.3	3.2 ± 0.1	16.8 ± 0.4	5 ± 0.1	0.414	2550	32.5	78.5	≈ 6.5
PLT22/16/2.5 (E-PLT combination)	21.8 ± 0.4	15.8 ± 0.3	2.5 ± 0.05	-	-	-	0.332	2040	26.1	78.5	≈ 4
E32/6/20 (E-E combination)	31.75 ± 0.64	6.35 ± 0.13	20.32 ± 0.41	3.18 ± 0.13	24.9 min	6.35 ± 0.13	0.323	5380	41.7	129	≈ 13
PLT32/20/3 (E-PLT combination)	31.75 ± 0.64	20.32 ± 0.41	3.18 ± 0.13	-	-	-	0.278	4560	35.9	129	≈ 10
E38/8/25 (E-E combination)	38.1 ± 0.76	8.26 ± 0.13	25.4 ± 0.51	4.45 ± 0.13	30.23 min	7.62 ± 0.15	0.272	10200	52.6	194	≈ 25
PLT38/25/4 (E-PLT combination)	38.1 ± 0.76	25.4 ± 0.51	3.81 ± 0.13	-	-	-	0.226	8460	43.7	194	≈ 18
E43/10/28 (E-E combination)	43.2 ± 0.9	9.5 ± 0.13	27.9 ± 0.6	5.4 ± 0.13	34.7 min	8.1 ± 0.2	0.276	13900	61.7	225	≈ 35
PLT43/28/4 (E-PLT combination)	43.2 ± 0.9	27.9 ± 0.6	4.1 ± 0.13	-	-	-	0.226	11500	50.8	225	≈ 24
E58/11/38 (E-E combination)	58.4 ± 1.2	10.5 ± 0.13	38.1 ± 0.8	6.5 ± 0.13	50 min	8.1 ± 0.2	0.268	24600	81.2	305	≈ 62
PLT58/38/4 (E-PLT combination)	58.4 ± 1.2	38.1 ± 0.8	4.1 ± 0.13	-	-	-	0.224	20800	68.3	305	≈ 44
E64/10/50 (E-E combination)	64.01 ± 1.27	10.2 ± 0.13	50.80 ± 1.02	5.1 ± 0.13	53.80 ± 1.07	10.2 ± 0.2	0.156	40700	79.7	511	≈ 100
PLT64/50/5 (E-PLT combination)	64.01 ± 1.27	50.8 ± 1.02	5.08 ± 0.13	-	-	-	0.136	35500	69.6	511	≈ 78

1) $A_{min} = A_e$

	Core type	E14/3.5/5	E18/4/10	E22/6/16	E32/6/20	E38/8/25	E43/10/28	E58/11/38	E64/10/50
	Matching plates	PLT14/5/1.5	PLT18/10/2	PLT22/16/2.5	PLT32/20/3	PLT38/25/4	PLT43/28/4	PLT58/38/4	PLT64/50/5
core HALVES for use in combination with an ungapped E core or plate	3C85				E160 - E A160 - P E250 - E A250 - P A315 - E A315 - P A400 - E A400 - P A630 - E A630 - P 6425 / 7350	E250 - E A250 - P E315 - E A315 - P E400 - E A400 - P A630 - E A630 - P A1000 - E A1000 - P 7940 / 9290	E250 - E A250 - P E315 - E A315 - P E400 - E A400 - P A630 - E A630 - P A1000 - E A1000 - P 8030 / 9250	E315 - E A315 - P E400 - E A400 - P E630 - E A630 - P A1000 - E A1000 - P A1600 - E A1600 - P 8480 / 9970	E630 - E A630 - P E1000 - E A1000 - P A1600 - E A1600 - P A2500 - E A2500 - P A3150 - E A3150 - P 14640/16540
	3F3	A63 - E A63 - P A100 - E A100 - P A160 - E A160 - P 1100 / 1300	A100 - E A100 - P A160 - E A160 - P A250 - E A250 - P A315 - E A315 - P 2700 / 3100	A160 - E A160 - P A250 - E A250 - P A315 - E A315 - P A400 - E A400 - P A630 - E A630 - P 4300 / 5000	E160 - E A160 - P E250 - E A250 - P A315 - E A315 - P A400 - E A400 - P A630 - E A630 - P 5900 / 6780	E250 - E A250 - P E315 - E A315 - P E400 - E A400 - P A630 - E A630 - P A1000 - E A1000 - P 7250 / 8500	E250 - E A250 - P E315 - E A315 - P E400 - E A400 - P A630 - E A630 - P A1000 - E A1000 - P 7310 / 8700	E315 - E A315 - P E400 - E A400 - P E630 - E A630 - P A1000 - E A1000 - P A1600 - E A1600 - P 7710 / 9070	E630 - E A630 - P E1000 - E A1000 - P A1600 - E A1600 - P A2500 - E A2500 - P A3150 - E A3150 - P 13300/15050
	3F4	A63 - E A63 - P A100 - E A100 - P A160 - E A160 - P 650/780	A100 - E A100 - P A160 - E A160 - P A250 - E A250 - P A315 - E A315 - P 1550 / 1800	A160 - E A160 - P A250 - E A250 - P A315 - E A315 - P A400 - E A400 - P A630 - E A630 - P 2400 / 2900	E160 - E A160 - P E250 - E A250 - P A315 - E A315 - P A400 - E A400 - P A630 - E A630 - P 3200 / 3700	E250 - E A250 - P E315 - E A315 - P E400 - E A400 - P A630 - E A630 - P A1000 - E A1000 - P 3880 /4600	E250 - E A250 - P E315 - E A315 - P E400 - E A400 - P A630 - E A630 - P A1000 - E A1000 - P 3870 / 4660	E315 - E A315 - P E400 - E A400 - P E630 - E A630 - P A1000 - E A1000 - P A1600 - E A1600 - P 4030 / 4780	E630 - E A630 - P E1000 - E A1000 - P A1600 - E A1600 - P A2500 - E A2500 - P A3150 - E A3150 - P 6960 / 7920
high µ halves	3E6	5600 / 6400	13500 / 15500	22000 / 26000					

E160 - E	gapped core half with symmetrical gap (E). A_L = 160 nH measured in combination with an Equal-gapped E core half.
A25 - E	gapped core half with asymmetrical gap (A). A_L = 25 nH in combination with an ungapped E core half.
A25 - P	gapped core half with asymmetrical gap (A). A_L = 25 nH in combination with a plate.
1100/1300	ungapped core half. A_L = 1100/1300 nH measured in combination with an ungapped half / plate.

A_L value (nH) measured at $\hat{B} \leq 0.1$ mT, $f \leq 10$ kHz, T = 25°C

A_L tolerance: ± 3% | ± 5% | ± 8% | ± 10% | ± 25% | + 40% − 30%

Properties under power conditions

Core combination	B(mT) at 250 A/m 10 kHz 100 ºC	core loss (W) 25 kHz 200 mT 100 ºC	100 kHz 100 mT 100 ºC	400 kHz 50 mT 100 ºC	1 MHz 30 mT 100 ºC	3 MHz 10 mT 100 ºC
E+E14-3F3	≥300	–	≤0.033	≤0.060	–	–
E+PLT14-3F3	≥300	–	≤0.027	≤0.048	–	–
E+E14-3F4	≥250	–	–	–	≤0.090	≤0.11
E+PLT14-3F4	≥250	–	–	–	≤0.072	≤0.088
E+E18-3F3	≥300	–	≤0.11	≤0.19	–	–
E+PLT18-3F3	≥300	–	≤0.092	≤0.16	–	–
E+E18-3F4	≥250	–	–	–	≤0.29	≤0.35
E+PLT18-3F4	≥250	–	–	–	≤0.24	≤0.29
E+E22-3F3	≥300	–	≤0.28	≤0.50	–	–
E+PLT22-3F3	≥300	–	≤0.23	≤0.40	–	–
E+E22-3F4	≥250	–	–	–	≤0.77	≤0.90
E+PLT22-3F4	≥250	–	–	–	≤0.62	≤0.72
E+E32-3C85	≥320	≤0.84	≤0.97	–	–	–
E+PLT32-3C85	≥320	≤0.71	≤0.82	–	–	–
E+E32-3F3	≥320	–	≤0.59	≤1.00	–	–
E+PLT32-3F3	≥320	–	≤0.50	≤0.85	–	–
E+E32-3F4	≥250	–	–	–	≤1.60	≤2.00
E+PLT32-3F4	≥250	–	–	–	≤1.36	≤1.70
E+E38-3C85	≥320	≤1.60	≤1.80	–	–	–
E+PLT38-3C85	≥320	≤1.35	≤1.50	–	–	–
E+E38-3F3	≥320	–	≤1.20	≤2.00	–	–
E+PLT38-3F3	≥320	–	≤1.00	≤1.65	–	–
E+E38-3F4	≥250	–	–	–	≤3.00	≤3.50
E+PLT38-3F4	≥250	–	–	–	≤2.50	≤2.90
E+E43-3C85	≥320	–	≤2.50	–	–	–
E+PLT43-3C85	≥320	–	≤2.10	–	–	–
E+E43-3F3	≥320	–	≤1.60	≤2.70	–	–
E+PLT43-3F3	≥320	–	≤1.35	≤2.25	–	–
E+E43-3F4	≥250	–	–	–	≤4.20	≤5.00
E+PLT43-3F4	≥250	–	–	–	≤3.50	≤4.15
E+E58-3C85	≥320	–	≤4.40	–	–	–
E+PLT58-3C85	≥320	–	≤3.75	–	–	–
E+E58-3F3	≥320	–	≤2.70	≤4.70	–	–
E+PLT58-3F3	≥320	–	≤2.30	≤4.00	–	–
E+E58-3F4	≥250	–	–	–	≤7.40	≤8.00
E+PLT58-3F4	≥250	–	–	–	≤6.25	≤6.80
E+E64-3C85	≥320	–	≤7.30	–	–	–
E+PLT64-3C85	≥320	–	≤6.40	–	–	–
E+E64-3F3	≥320	–	≤4.50	≤7.80	–	–
E+PLT64-3F3	≥320	–	≤3.95	≤6.80	–	–
E+E64-3F4	≥250	–	–	–	≤12.0	≤15.0
E+PLT64-3F4	≥250	–	–	–	≤10.5	≤13.0

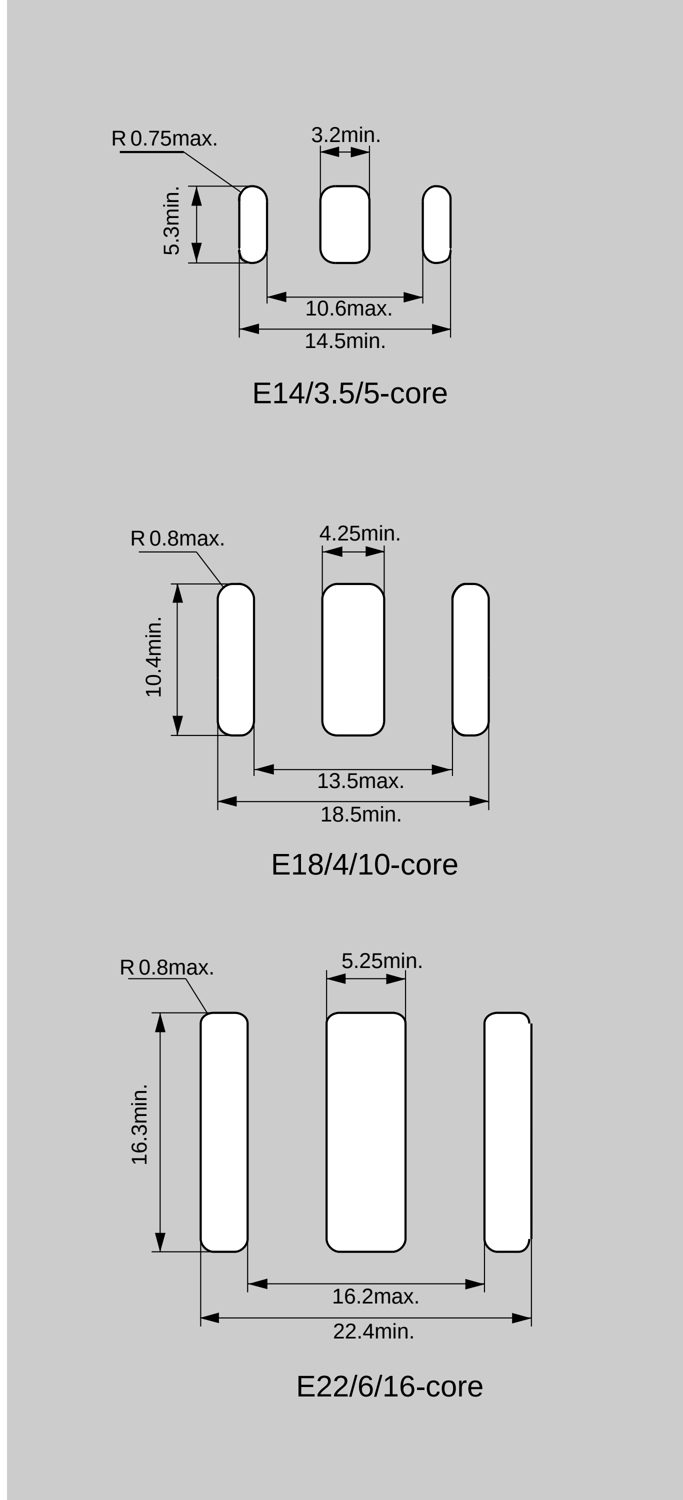
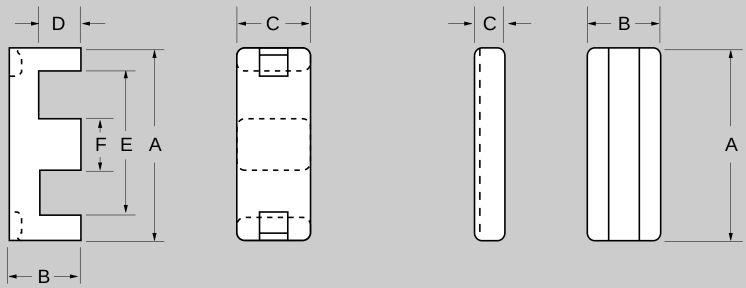


Fig.3 PCB cut out proposal for glued cores

4.c. Cores for clamping



E core with recess (E/R)

plate with slot (PLT/S)

	Core type	E14/3.5/5/R	PLT14/5/1.5/S (E-PLT combination)	E18/4/10/R	PLT18/10/2/S (E-PLT combination)	E22/6/16/R	PLT22/16/2.5/S (E-PLT combination)
effective core parameters	core factor Σ l/A(mm^{-1})	-	1.15	-	0.498	-	0.324
	eff. volume V_e (mm^3)	-	230	-	830	-	2100
	eff. length l_e (mm)	-	16.4	-	20.3	-	26.1
	eff. area A_e (mm^2)	-	14.2	-	40.8	-	80.4
	min. area A_{min} (mm^2)	-	10.9	-	35.9	-	72.6
	mass of core half (g)	≈ 0.6	≈ 0.5	≈ 2.4	≈ 1.7	≈ 6.5	≈ 4
dimensions (mm)	A	14 ± 0.3	14 ± 0.3	18 ± 0.35	18 ± 0.35	21.8 ± 0.4	21.8 ± 0.4
	B	3.5 ± 0.1	5 ± 0.1	4 ± 0.1	10 ± 0.2	5.7 ± 0.1	15.8 ± 0.3
	C	5 ± 0.1	1.8 ± 0.05	10 ± 0.2	2.4 ± 0.05	15.8 ± 0.3	2.9 ± 0.05
	D	2 ± 0.1	-	2 ± 0.1	-	3.2 ± 0.1	-
	E	11 ± 0.25	-	14 ± 0.3	-	16.8 ± 0.4	-
	F	3 ± 0.05	-	4 ± 0.1	-	5 ± 0.1	-
mounting parts	CLM		E14/PLT14		E18/PLT18		E22/PLT22

Core type		E14/3.5/5/R	E18/4/10/R	E22/6/16/R
Matching plates		PLT14/5/1.5/S	PLT18/10/2/S	PLT22/16/2.5/S
core HALVES for use in combination with a plate	3F3	A63-P	A100-P	A160-P
		A100-P	A160-P	A250-P
		A160-P	A250-P	A315-P
		1300	A315-P	A400-P
			3100	A630-P
				5000
	3F4	A63-P	A100-P	A160-P
		A100-P	A160-P	A250-P
		A160-P	A250-P	A315-P
		780	A315-P	A400-P
			1800	A630-P
				2900
	3E6	6400	15500	26000

A_L value (nH) measured at $\hat{B} \leq 0.1$ mT, f ≤ 10 kHz, T = 25°C

A_L tolerance: ± 3% | ± 5% | ± 8% | ± 25% | + 40% − 30%

A63-P — gapped core half with asymmetrical gap (A), A_L = 63 nH measured in combination with a plate.

1280 — ungapped core half, A_L = 1280 nH measured in combination with a plate.

Properties under power conditions

Core combination	B(mT) at 250 A/m 10 kHz 100 °C	Core loss (W) at 25 kHz 200 mT 100 °C	100 kHz 100 mT 100 °C	400 kHz 50 mT 100 °C	1 MHz 30 mT 100 °C	3 MHz 10 mT 100 °C
E+PLT14-3F3	≥300	–	≤0.032	≤0.058	–	–
E+PLT14-3F4	≥250	–	–	–	≤0.086	≤0.11
E+PLT18-3F3	≥300	–	≤0.12	≤0.20	–	–
E+PLT18-3F4	≥250	–	–	–	≤0.30	≤0.37
E+PLT22-3F3	≥300	–	≤0.29	≤0.52	–	–
E+PLT22-3F4	≥250	–	–	–	≤0.80	≤0.93

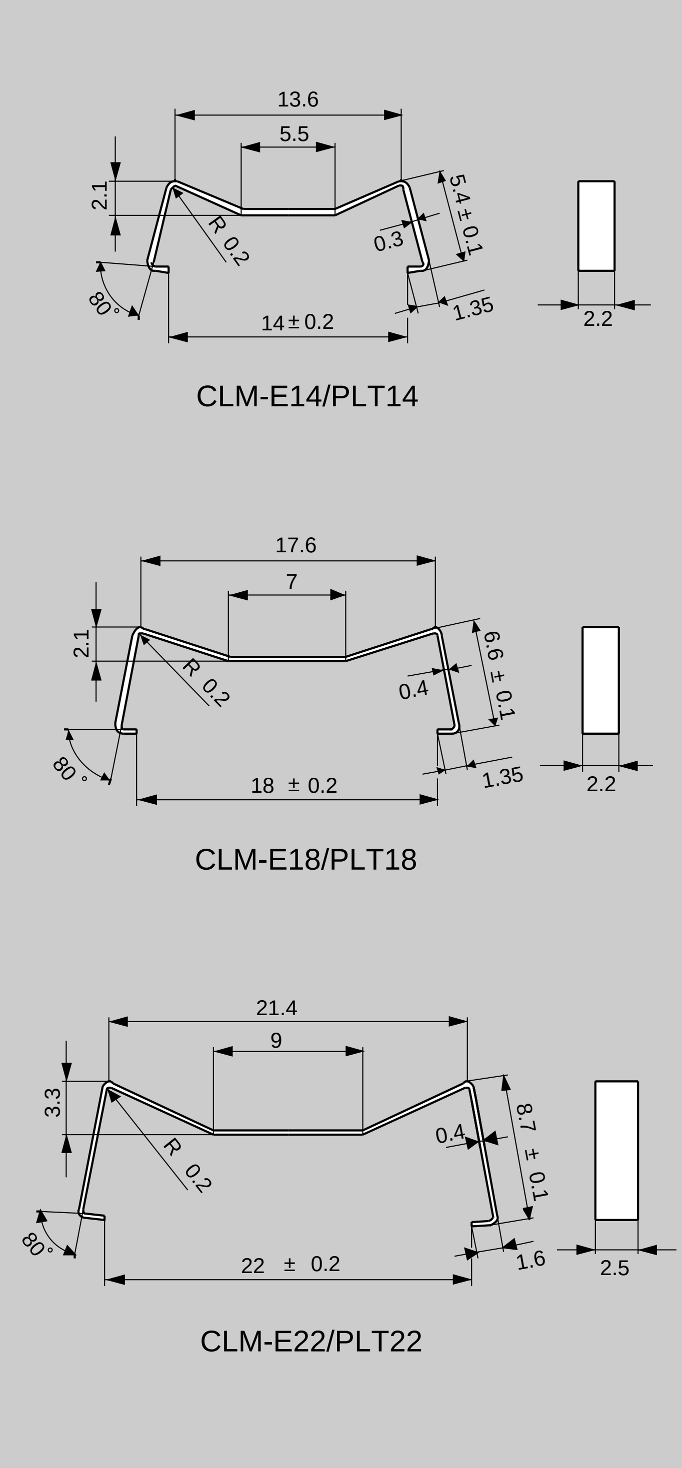


Fig.4 Clamps for E/PLT combinations.

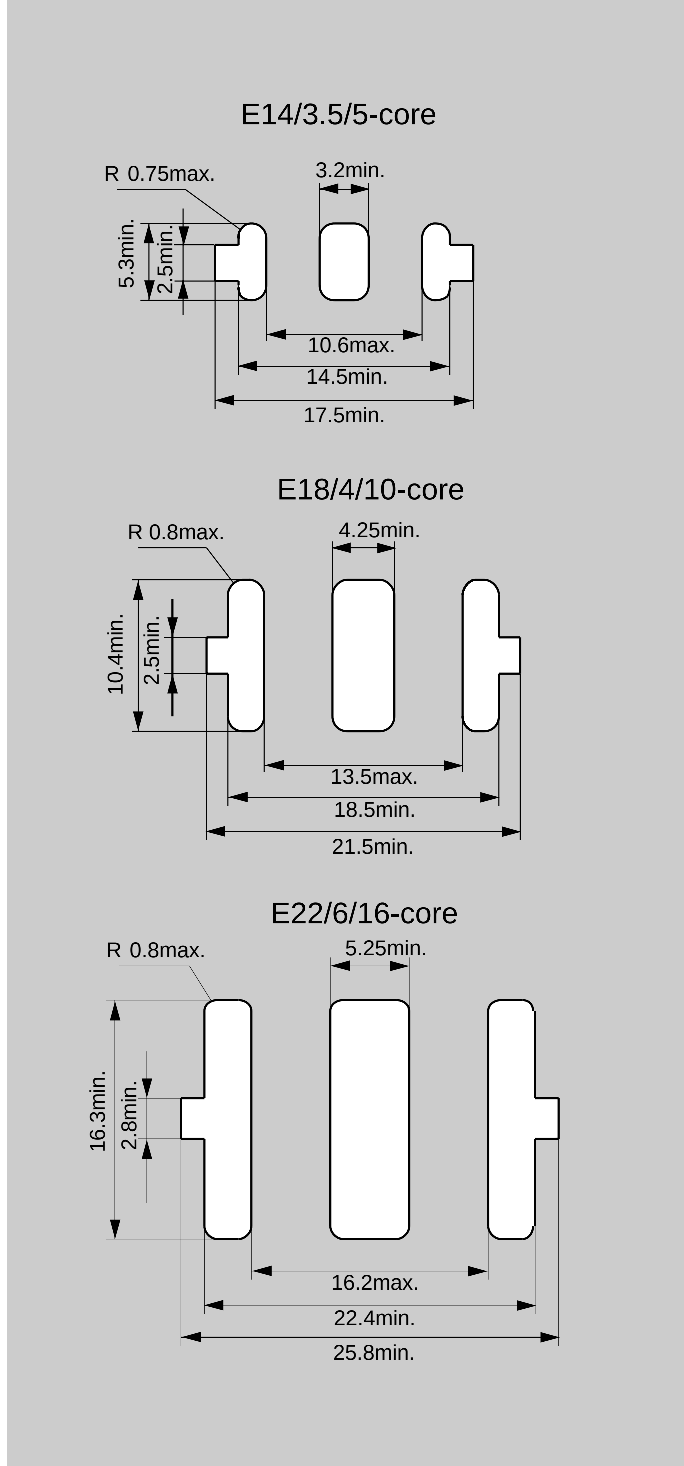


Fig.5 PCB cut out proposal for clamped cores

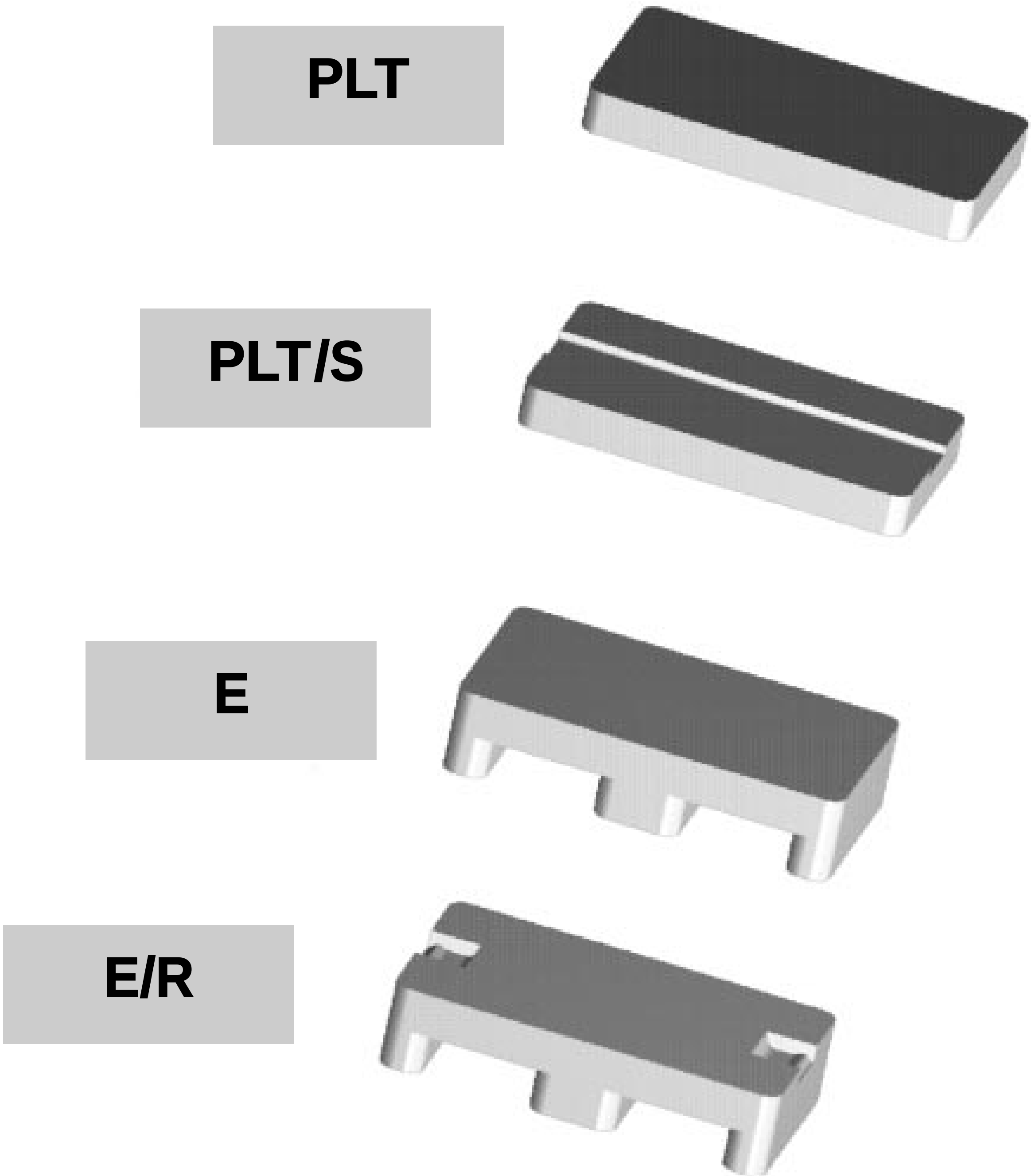


Fig.6 The different core shapes available for planar E transformers.

4.d. Packing

Standard packing for Planar E cores and Plates is a plastic blister tape. The plastic material (PET) is environmentally friendly.

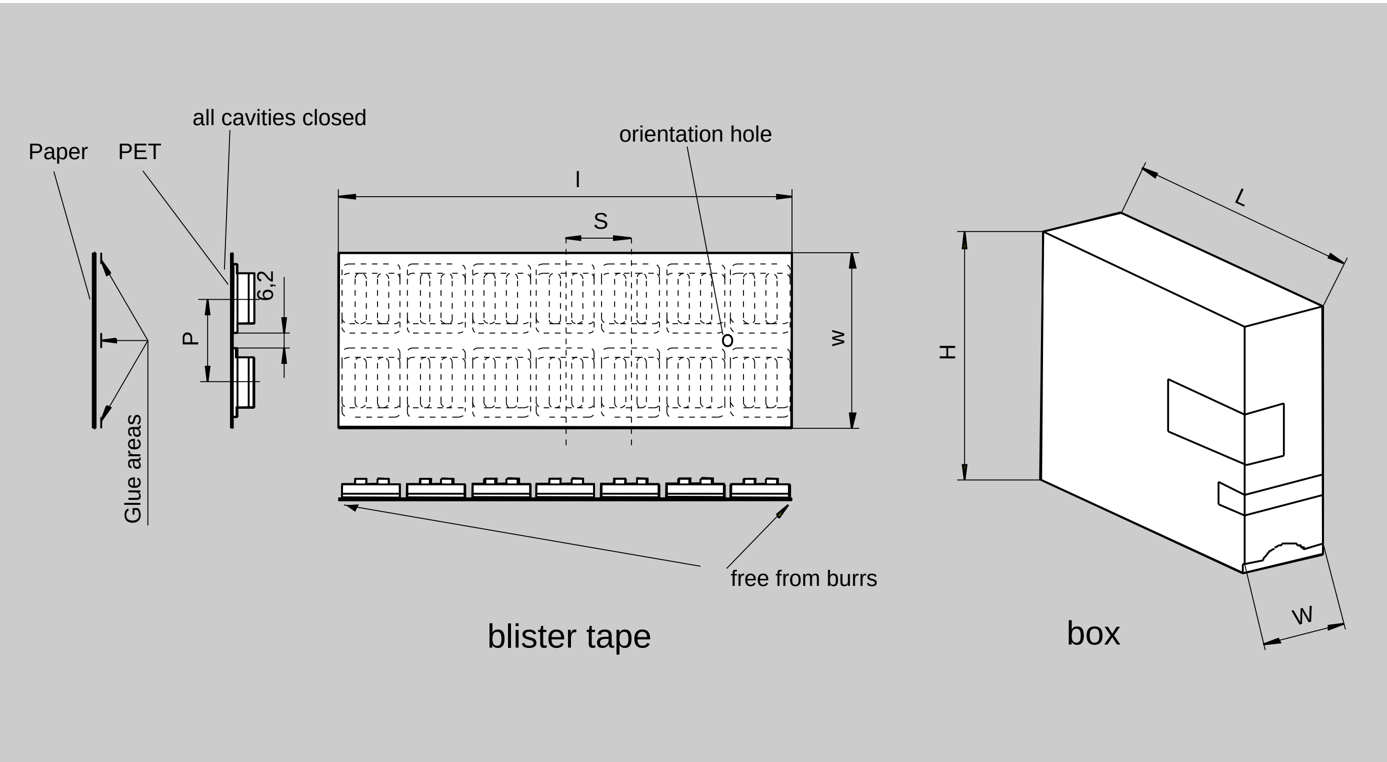


Fig.7 Blister tape packing.

Cores in blister tape

Blister size	Pitch (P)	Box size (LxWxH)	Products / blister
340 x 60 mm	27.5 mm	355 x 70 x 210 mm	40
295 x 82 mm	38.5 mm	310 x 90 x 248 mm	20

Core size	Blisters / box	Core halves / box	Blister width
E14/3.5/5	50	2000	60 mm
E18/4/10	50	2000	60 mm
E22/6/16	25	500	82 mm

Clamps in bulk

Clamp size	Box size	clamps / box
CLM-E14/PLT14	170 x 100 x 70 mm	5000
CLM-E18/PLT18	170 x 100 x 70 mm	2500
CLM-E22/PLT22	170 x 100 x 70 mm	1500

For E14/3.5/5 and E18/4/10, a prototype version of tape on reel packing has been developed to facilitate automatic mounting with SMD pick & place equipment. The packing method is in accordance with IEC-286, part 3. The plastic material (0.3 mm PET) is environmentally friendly. Plates have the same packing as the corresponding E cores.

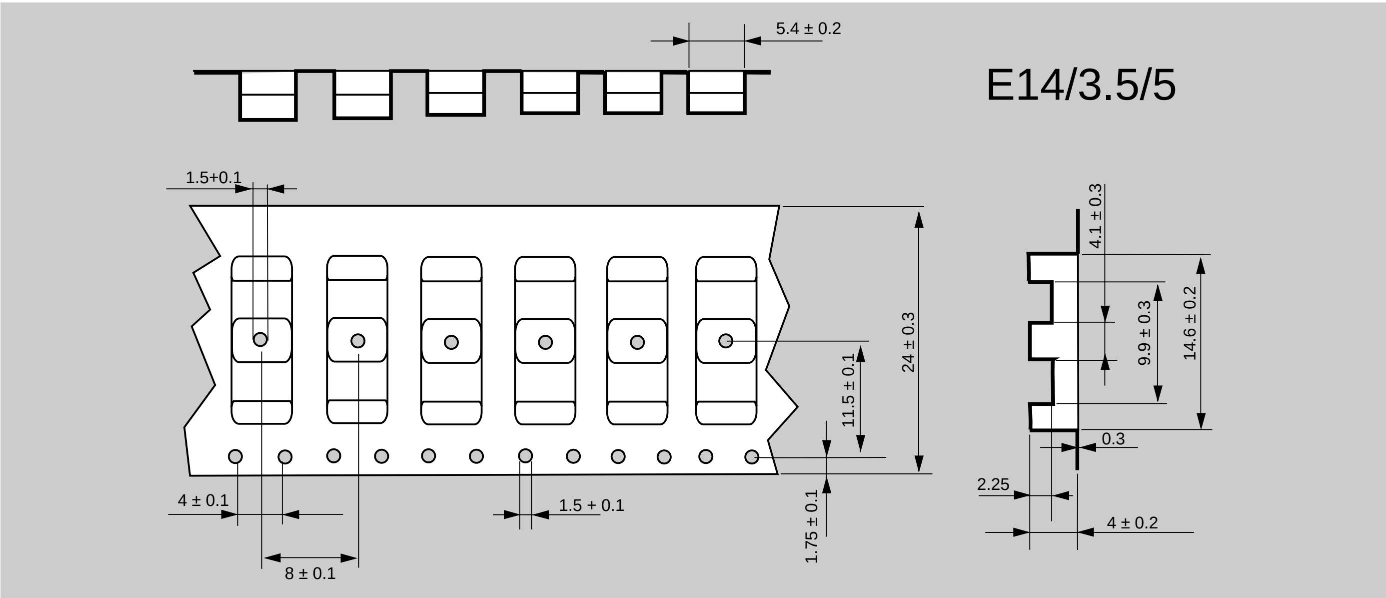


Fig.8 Tape on reel packing for E14/3.5/5.

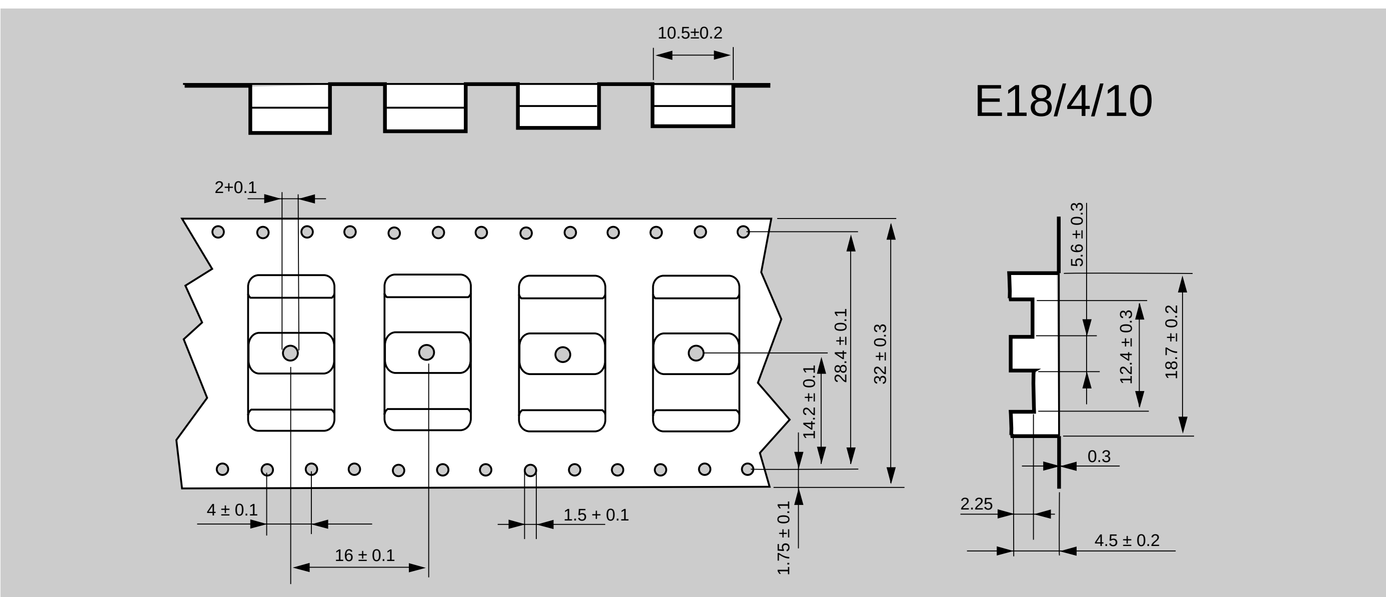


Fig.9 Tape on reel packing for E18//4/10.

Cores in tape on reel

Core size	Pitch	Tape width	Reel diameter	Core halves / reel
E14/3.5/5	8 mm	24 mm	330 mm	2000
E18/4/10	16 mm	32 mm	330 mm	900

5. Design

In order to make full use of the advantages of planar technology, the design concept must be different from a wire-wound design. A few points are highlighted below. For a complete design procedure of planar power transformers with examples, see the brochure “ Design of Planar Power transformers”. For a completely worked-out example of a DC/DC converter, see the brochure "25 Watt DC/DC converter using integrated planar magnetics".

5.a. Core choice

Flux density

The improved heat management allows for up to twice the power loss of a conventional design with the same magnetic volume, so optimum flux density will be higher than for a conventional design.

Air gap

Large air gaps are not favourable in a planar design because of stray flux. The flux fringing factor depends on the ratio of winding window height to air gap length, which is lower for a flat core. If the window height is only a few times the gap length and the window breadth is several times the centre post width, then even considerable flux crossing between core top and bottom will occur. More flux fringing and flux crossing lead to higher eddy current loss in the winding.

5.b. Winding design

DC resistance

Often used copper track heights are 35 and 70 µm. If the copper cross-section is not enough for an acceptable DC resistance, then tracks can be connected in parallel for all or part of the turns.

AC resistance

AC copper losses due to skin and proximity effect are lower for flat copper tracks than for round wire with the same cross-sectional area. Eddy currents induced in the vicinity of a gap can be reduced by deleting a few turns where the flux density is maximum and perpendicular to the winding plane. The E / plate combination has somewhat less stray flux than the E / E combination because of the gap position.

Leakage inductance

With vertically stacked windings, the magnetic coupling will be very strong and coupling factors close to 100 % can be achieved (Fig.10a).

Parasitic capacitance

The former will lead to higher inter-winding capacitance. This capacitance can be reduced by projecting the tracks of a winding in between the tracks of the adjacent winding (Fig.10b).

Furthermore, the repeatability of the capacitance allows for either compensating it in the rest of the circuit or using it in a resonant design. In the latter case, a high capacitance could be chosen on purpose by placing the tracks of adjacent windings face to face (Fig.10c).

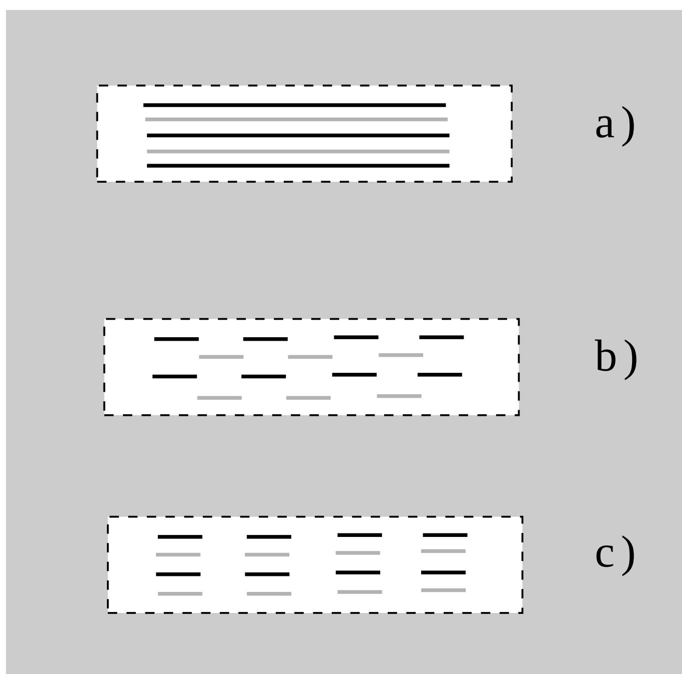


Fig.10 Different winding designs

6. Manufacturing

6.a. Assembly

Stand-alone : not essentially different from conventional. For glue and curing proposals, see the application note "Gluing of ferrite cores". The high permeability ferrite 3E6 should not be glued between the mating faces, because the parasitic gap reduces effective permeability. Glue can be applied on the sides of the outer legs (Fig. 11).
Clamping is done by first pressing the clamp into the snap-fit and then aligning the plate in transversal direction.
Integrated : assembly is combined with mounting.

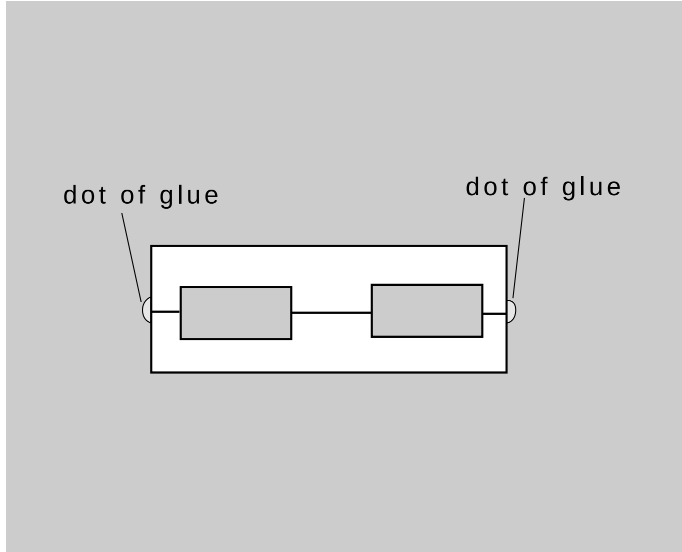


Fig.11 Gluing of planar E cores

6.b. Mounting

Stand-alone : through-hole or SMD, not essentially different from conventional.
The flat core surface is well suited for pick & place systems.
Integrated : can best be done in 2 steps.

1). Glue one core half to the PCB. The same glue can be used as for attaching SMD components and this step is logically combined with SMD mounting on the same PCB side.

2). Glue or clamp the second core half to the first one. The same remarks apply here as for stand-alone assembly.

6.c. Soldering

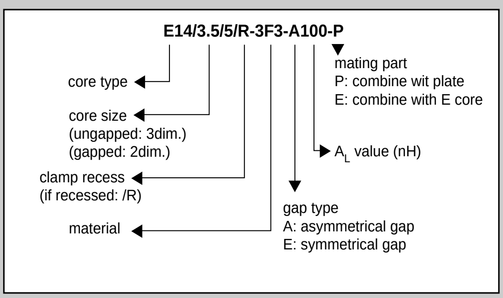
Only applicable for stand-alone transformers.
In case of reflow soldering, hot air convection is preferred over IR radiation heating, because it equalises the temperature differences. With standard IR radiation heating, the good thermal conduction of the planar component can lead to a too low solder paste temperature or there can be a too high PCB temperature if radiation power is increased. In case of IR reflow soldering, it is advised to use modified solder paste and/or PCB material.

7. Literature & sample boxes

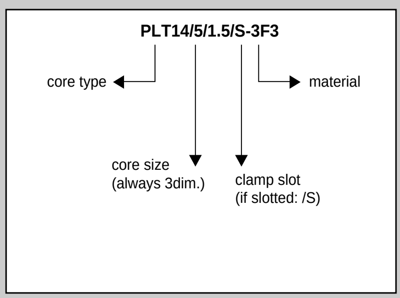
25 Watt DC/DC converter using integrated planar magnetics	9398 236 26011
Gluing of Ferrite Cores	9398 083 20011
Design of Planar Power Transformers	9398 083 39011
SAMPLEBOX7 : Small planar E cores in 3F3	4322 020 85131
SAMPLEBOX8 : Medium planar E cores in 3C85 & 3F3	4335 000 40971

8. Type number system

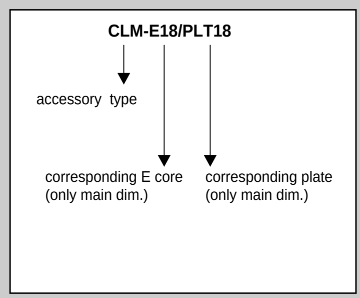
All planar core type numbers correspond to a core half. Therefore two core halves have to be ordered in the right combination. There are 4 core half types combined to 3 types of core sets :
E + E, E + PLT and E/R + PLT/S. The last one is completed with a clamp (CLM).



E core



Plate



Clamp

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
Deleware	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 - Sourthern	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 Carlolina	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
Tennesse	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.

Printed in The Netherlands

Document order number: 9398 083 40011 Date of release: 07/97

Philips Components

PHILIPS

Let's make things better.