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Data handbook

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Ferroxcube for power, audio/video and accelerators

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FERROXCUBE FOR POWER, AUDIO/VIDEO AND ACCELERATORS

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DATA HANDBOOK SYSTEM

Our Data Handbook System comprises more than 60 books with specifications on electronic components, subassemblies and materials. It is made up of four series of handbooks:

ELECTRON TUBES	BLUE
SEMICONDUCTORS	RED
INTEGRATED CIRCUITS	PURPLE
COMPONENTS AND MATERIALS	GREEN

The contents of each series are listed on pages iv to viii.

The data handbooks contain all pertinent data available at the time of publication, and each is revised and reissued periodically.

When ratings or specifications differ from those published in the preceding edition they are indicated with arrows in the page margin. Where application information is given it is advisory and does not form part of the product specification.

Condensed data on the preferred products of Philips Electronic Components and Materials Division is given in our Preferred Type Range catalogue (issued annually).

Information on current Data Handbooks and on how to obtain a subscription for future issues is available from any of the Organizations listed on the back cover.
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ELECTRON TUBES (BLUE SERIES)

The blue series of data handbooks comprises:

T1 **Tubes for r.f. heating**

T2a **Transmitting tubes for communications, glass types**

T2b **Transmitting tubes for communications, ceramic types**

T3 **Klystrons, travelling-wave tubes, microwave diodes**

ET3 **Special Quality tubes, miscellaneous devices** (will not be reprinted)

T4 **Magnetrons**

T5 **Cathode-ray tubes**
Instrument tubes, monitor and display tubes, C.R. tubes for special applications

T6 **Geiger-Müller tubes**

T7 **Gas-filled tubes**
Segment indicator tubes, indicator tubes, dry reed contact units, thyratrons, industrial rectifying tubes, ignitrons, high-voltage rectifying tubes, associated accessories

T8 **Picture tubes and components**
Colour TV picture tubes, black and white TV picture tubes, colour monitor tubes for data graphic display, monochrome monitor tubes for data graphic display, components for colour television, components for black and white television and monochrome data graphic display

T9 **Photo and electron multipliers**
Photomultiplier tubes, phototubes, single channel electron multipliers, channel electron multiplier plates

T10 **Camera tubes and accessories**

T11 **Microwave semiconductors and components**

T12 **Vidicons and Newvicons**

T13 **Image intensifiers**

T14 **Infrared detectors**

SEMICONDUCTORS (RED SERIES)

The red series of data handbooks comprises:

S1 **Diodes**
Small-signal germanium diodes, small-signal silicon diodes, voltage regulator diodes (< 1,5 W), voltage reference diodes, tuner diodes, rectifier diodes

S2a **Power diodes**

S2b **Thyristors and triacs**

S3 **Small-signal transistors**

S4a **Low-frequency power transistors and hybrid modules**

S4b **High-voltage and switching power transistors**

S5 **Field-effect transistors**

S6 **R.F. power transistors and modules**

S7 **Microminiature semiconductors for surface mounting**

S8 **Devices for optoelectronics**
Photosensitive diodes and transistors, light-emitting diodes, displays, photocouplers, infrared sensitive devices, photoconductive devices.

S9 **Power MOS transistors**

S10 **Wideband transistors and wideband hybrid IC modules**

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The purple series of data handbooks comprises:

EXISTING SERIES

IC1 **Bipolar ICs for radio and audio equipment**

IC2 **Bipolar ICs for video equipment**

IC3 **ICs for digital systems in radio, audio and video equipment**

IC4 **Digital integrated circuits**
CMOS HE4000B family

IC5 **Digital integrated circuits — ECL**
ECL10 000 (GX family), ECL100 000 (HX family), dedicated designs

IC6 **Professional analogue integrated circuits**

IC7 **Signetics bipolar memories**

IC8 **Signetics analogue circuits**

IC9 **Signetics TTL logic**

IC10 **Signetics Integrated Fuse Logic (IFL)**

IC11 **Microprocessors, microcomputers and peripheral circuitry**

NEW SERIES

IC01N	**Radio, audio and associated systems** Bipolar, MOS	
IC02N	**Video and associated systems** Bipolar, MOS	
IC03N	**Telephony equipment** Bipolar, MOS	
IC04N	**HE4000B logic family** CMOS	
IC05N	**HE4000B logic family uncased integrated circuits** CMOS	(published 1984)
IC06N	**PC54/74HC/HCU/HCT logic families** HCMOS	
IC07N	**PC54/74HC/HCU/HCT uncased integrated circuits** HCMOS	
IC08N	**10K and 100K logic family** ECL	
IC09N	**Logic series** TTL	(published 1984)
IC10N	**Memories** MOS, TTL, ECL	
IC11N	**Analogue - industrial**	
IC12N	**Semi-custom gate arrays & cell libraries** ISL, ECL, CMOS	
IC13N	**Semi-custom integrated fuse logic** IFL series 20/24/28	
IC14N	**Microprocessors, microcontrollers & peripherals** Bipolar, MOS	
IC15N	**Logic series** FAST TTL	(published 1984)

Note

Books available in the new series are shown with their date of publication.

COMPONENTS AND MATERIALS (GREEN SERIES)

The green series of data handbooks comprises:

C1 **Assemblies for industrial use**
PLC modules, PC20 modules, HNIL FZ/30 series, NORbits 60-, 61-, 90-series, input devices, hybrid ICs

C2 **Television tuners, video modulators, surface acoustic wave filters**

C3 **Loudspeakers**

C4 **Ferroxcube potcores, square cores and cross cores**

C5 **Ferroxcube for power, audio/video and accelerators**

C6 **Synchronous motors and gearboxes**

C7 **Variable capacitors**

C8 **Variable mains transformers**

C9 **Piezoelectric quartz devices**
Quartz crystal units, temperature compensated crystal oscillators, compact integrated oscillators, quartz crystal cuts for temperature measurements

C10 **Connectors**

C11 **Non-linear resistors**
Voltage dependent resistors (VDR), light dependent resistors (LDR), negative temperature coefficient thermistors (NTC), positive temperature coefficient thermistors (PTC)

C12 **Variable resistors and test switches**

C13 **Fixed resistors**

C14 **Electrolytic and solid capacitors**

C15 **Film capacitors, ceramic capacitors**

C16 **Permanent magnet materials**

C17 **Stepping motors and associated electronics**

C18 **D.C. motors**

C19 **Piezoelectric ceramics**

C20 **Wire-wound components for TVs and monitors**

GENERAL PROPERTIES OF MANGANESE-ZINC AND NICKEL-ZINC FERRITES

INTRODUCTION

The Ferroxcube* range of manganese-zinc and nickel-zinc magnetically soft ferrites are intended for use as core material in coils and transformers operating over a wide range of frequencies. Ferroxcube is a ceramic material, manufactured from high-grade raw materials of controlled composition; the composition defines the electrical and mechanical properties.

Ferroxcube products are made by a sequence of ceramic techniques: mixing, pre-firing, milling, drying, shaping by pressing or extruding, sintering and machining. The finished products have a stable structure and high electrical resistivity. This electrical resistivity allows them to be used at high frequencies without the eddy current losses becoming prohibitively high. Ferroxcube is made in a wide range of permeabilities.

Ferroxcube cores are available in convenient shapes such as potcores, square cores, E and I-cores, EC-cores, X-cores, U-cores, toroids, aerial rods, yoke rings, screw cores, rods, tubes, beads, cores for magnetic recording and special materials for proton accelerators.

Potcores, square cores, E and I-cores and X-cores enable well-defined air gaps to be used without introducing appreciable stray fields. In this way the permeability of the material may be reduced to an effective value at which core and copper losses are matched. The dependence of the permeability on temperature and time is furthermore reduced to values that guarantee correct operation of the equipment.

This section contains comprehensive data on manganese-zinc and nickel-zinc ferrites and their various grades.

When ordering cores, please quote the 12-digit catalogue number for the core in question given in the data sheet. ←

* Our trade name for magnetically soft ferrites.

APPLICATIONS

The various grades of Ferroxcube, the forms in which they are available and their principal applications are listed in the table below.

grade	core shapes and some preferred applications
• 2A2	yoke rings
• 3B	rods and tubes
3B7	potcores and square cores
• 3B8	potcores, square cores and cross cores (power applications)
• 3C2	yoke rings
3C6	rods and tubes
• 3C8	E, EC, ETD, U and I cores, square cores (power applications)
• 3D3	potcores, square cores, screw cores
3E1	E and I cores, toroids, potcores, square cores
• 3E2	H cores and toroids
• 3E4	potcores and square cores
3E5	square cores
• 3H1	potcores, square cores, cross cores
3H2	tubes, rods, toroids
• 3H3	potcores, square cores
4A4	frames for i.f. transformers, rods and tubes
• 4B1	frames for i.f. transformers, rods and tubes
• 4C6	potcores, square cores, toroids, frames for i.f. transformers, rods and tubes
4D1, 4D2	frames for i.f. transformers, screw cores, rods and tubes
4E1	rods and tubes
3H22, 3F1, 4E2, 4L2, 4M2, 8C11, 8C12	special-purpose NiZn ferrites developed for resonant cavities for particle accelerators. A technical discussion is usually necessary to determine the correct material for this type of application.
8A5, 8C1, 8E1, 8E2, 8E21, 8X1	cores and structural material for magnetic recording heads.

Note

When ordering cores, please quote the 12-digit catalogue number for the core in question given in the data sheet.

• Preferred material.

SYMBOLS, TERMS, DEFINITIONS AND BASIC FORMULAE

This list of symbols is based on the recommendations of IEC Publications 50, 125 and 401. Where symbols or formulae are used in connection with one application, material or core only, they are explained in the relevant section or data sheet.

symbol	units	definition
A_{min}	mm^2	nominal value of the minimum cross-sectional area.
A_e	mm^2	effective cross-sectional area.
$A_{e\ min}$	mm^2	minimum effective cross-sectional area.
A_L	nH	inductance factor = L/N^2. Note: unless otherwise stated in this Handbook, A_L is the inductance factor in nH.
AT	A	ampere-turns.
B	T	flux density.
B_s	T	saturation flux density.
B_r	T	remanence: flux density remaining after magnetization to saturation and removal of the external field.
$\hat{B}$	T	peak flux density.
C_1	mm^{-1}	core constant: $C_1 = \Sigma(\ell/A)$.
D	—	disaccommodation: the fractional change of permeability of a magnetic material measured at a constant temperature over a period of time after cessation of a disturbance $D = \dfrac{\mu_1 - \mu_2}{\mu_1}$
D_F	—	disaccommodation factor: obtained by dividing D by the first measured relative permeability (at t_1) and the logarithm of the ratio of the measuring times $D_F = \dfrac{\mu_1 - \mu_2}{\mu_1{}^2 \log(t_2/t_1)}$ Times t_1 and t_2 are given in the core data.
E_1	V	voltage at fundamental frequency.
E_3	V	voltage at third harmonic.
f_{Cu}	—	space (copper) factor: proportion of the winding cross section occupied by conductor.
f	Hz	frequency.
H	A/m	magnetic field strength.
H_c	A/m	coercivity: the value of the external field strength for which the flux density is zero after the material has been magnetized to saturation.

$\hat{H}$	A/m	peak magnetic field strength.
I_0	A	direct current.
ℓ_e	mm	effective magnetic path length.
L	H	inductance.
N	—	number of turns.
P	kW/m^3	specific power loss in core material.
Q	—	inductance quality factor.
R_h	Ω	effective series resistance of an inductor due to hysteresis losses in the core.
T_c	^oC	Curie temperature: the temperature at which a ferromagnetic material becomes paramagnetic.
V_e	mm^3	effective volume of a core: the volume of an ideal toroid of the same material and having the same magnetic properties: $V_e = \frac{\Sigma(\ell/A)^3}{\Sigma(\ell/A^2)^2}$.
α	—	turns factor: number of turns for an inductance of 1 mH.
→ α_F	K^{-1}	temperature factor of a core without air gap. The original definition in IEC 133 $\alpha_F = \frac{\mu_\theta - \mu_{ref}}{\mu^2_{ref}(\theta - \theta_{ref})} = \frac{0,4\pi(A_{L\theta} - A_{L\ ref})}{A^2_{L\ ref}\ C_1\ (\theta - \theta_{ref})}$ where θ is the applied temperature, was superseded in 1976 by the definition in IEC 367-1: $\alpha_F = \frac{\mu_\theta - \mu_{ref}}{\mu_\theta \mu_{ref}\ (\theta - \theta_{ref})} = \frac{0,4\pi(A_{L\theta} - A_{L\ ref})}{A_{L\theta} A_{L\ ref}\ C_1\ (\theta - \theta_{ref})}$ The second definition is required for new, close-tolerance products, and for products whose properties are guaranteed over a wide temperature range.
α_μ	K^{-1}	temperature coefficient of a core with an (ground) air gap. Where μ_e is the effective permeability of the core, $\alpha_\mu \simeq \alpha_F \mu_e$. Alternatively, $\alpha_\mu \simeq \alpha_F\ C_1 A_L/\mu_0$. These approximations hold for fairly small changes in μ_e or A_L over the temperature range considered.

β_F	–	d.c. sensitivity constant for a core: $$\beta_F = \frac{\mu_e - \mu_{e\Delta}}{\mu_e \mu_{e\Delta}}$$ where $\mu_{e\Delta}$ is the relative incremental permeability of the core.
$\frac{\tan\delta}{\mu_i}$		eddy-current and residual loss constant at a given frequency, measured at $\hat{B} \leqslant 0{,}1$ mT. The corresponding R/L value is given by $$R/L = 2\pi f \mu \frac{\tan\delta}{\mu_i}$$
Δ	mm	air-gap length.
η_B	T^{-1}	hysteresis constant: $$\eta_B = \frac{\Delta R_h}{\Delta\mu_e 2\pi f L}$$ where $\Delta\hat{B} = \hat{B}_2 - \hat{B}_1$ and $\Delta R_h = R_{\hat{B}2} - R_{\hat{B}1}$. (That is, series resistance $R_{\hat{B}1}$ is measured at $\hat{B}_1$ and then $R_{\hat{B}2}$ at $\hat{B}_2$.)
θ	°C	temperature.
μ_a	–	relative amplitude permeability for a signal of amplitude greater than that for μ_Δ so that the value is dependent on flux density B: $$\mu_a = \frac{1}{\mu_0} \cdot \frac{B}{H}$$
μ_e	–	relative effective permeability: the permeability of a core with an air gap $$\mu_e = \frac{C_1}{\Sigma \ell/A} \text{ or } \frac{l}{\mu_e} \cdot \frac{L}{N^2} C_1$$
μ_i	–	relative initial permeability: measured on a core without air gap for a small field change $\Delta H \rightarrow 0$. $$\mu_i = \lim_{(H \rightarrow 0)} \mu_a$$
μ_{rem}	–	relative incremental permeability about remanence.
μ_Δ	–	relative incremental permeability of a polarized core: at a given d.c. applied field, the permeability observed when a small alternating field is superimposed. $$\mu_\Delta = \frac{\Delta B}{\mu_0 \Delta H}$$ Here, $\Delta B \leqslant 0{,}2$ mT and f = 4 kHz.
μ_θ	–	relative permeability at a given temperature.
ρ	Ωm	specific resistance for direct current.

FORMULAE

$L = \frac{\mu_o \mu_e N^2 \times 10^{-3}}{C_1}$	H	inductance.
$A_L = 10^6 \mu_e \mu_o / C_1$	(nH)	initial induction factor.
$B = E/(4{,}44 f N A_e) \times 10^{-6}$	(T)	peak flux density.
$E_3/E_1 = 0{,}6 \tan \delta_h$		3rd harmonic distortion.
$N = \sqrt{(10^9 L/A_L)} = \alpha\sqrt{(10^3 L)}$	(turns)	number of turns.
$Q = 1/\tan \delta_{tot}$		quality factor.
$\tan \delta_h = \mu B \eta_B$		hysteresis loss factor
1 mT = 10 Gauss		
1 Oe = 79,6 A/m		

TECHNICAL DATA

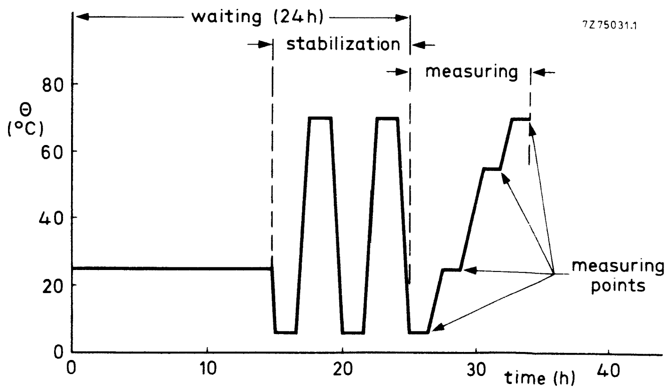
Ferroxcube data are given in the tables on the following pages in accordance with the recommendations of IEC 401, and using symbols defined in the previous section.

GENERAL PROPERTIES

Specific heat at 25 °C	
MnZn ferrites (FXC 3--)	1100 J/(kgK)
NiZn ferrites (FXC 4--)	750 J/(kgK)
Thermal conductivity from 25 °C to 85 °C	3,5 to 4,3 W/(mK)
Coefficient of linear expansion	10 to 12 x 10^{-6}/K
Modulus of elasticity	15 x 10^4 N/mm^2
Ultimate tensile strength	18 N/mm^2
Crushing strength	73 N/mm^2

NOTES TO THE DATA TABLES

- The data given apply to medium-sized toroids and should be taken as a guide. Cores that are small or have other shapes will have slightly different properties that cannot readily be predicted on the basis of toroid properties. For this reason, product characteristics are guaranteed for the products themselves and are given on the appropriate data sheets.
- The temperature coefficient α_F is measured on circuits without a (ground) air gap, with the exception of 3B7 products, for which α_F is measured on toroidally-wound core halves. For FXC 3-- products, the measuring sequence is that shown in the figure. The measurement circuits for FXC 3H3 and FXC 4-- products are thermally demagnetized by being heated to 25 °C above their Curie temperature, after which they are cooled slowly to room temperature and left for 24 h.



		materials for deflection units		
	unit	•2A2	•3C2	
Initial permeability μ_i at $\hat{B} \leqslant 0{,}1$ mT, $\theta = 25\,°C$		350 ± 20%	900 ± 25%	
Induction B, ballistically measured at	mT			
H = 500 A/m $\theta = 100\,°C$				
H = 800 A/m $\theta = 20\,°C$		≈ 200		
H = 800 A/m $\theta = 25\,°C$			≈ 350	
H = 800 A/m $\theta = 70\,°C$				
H = 800 A/m $\theta = 100\,°C$		≈ 140	≈ 245	
H = 1600 A/m $\theta = 25\,°C$				
H = 1600 A/m $\theta = 100\,°C$				
H = 3200 A/m $\theta = 25\,°C$				
H = 3200 A/m $\theta = 100\,°C$				
H = 4800 A/m $\theta = 25\,°C$				
H = 4800 A/m $\theta = 100\,°C$				
Coercivity Hc $\theta = 20\,°C$	A/m	60		
Eddy current and residual loss constant $\frac{\tan\delta}{\mu_i}$ at $\hat{B} \leqslant 0{,}1$ mT, $\theta = 25\,°C$	$\times 10^{-6}$			
f = 100 kHz		≈ 50		
f = 450 kHz				
f = 500 kHz				
f = 700 kHz				
f = 1 MHz				
f = 1,5 MHz				
f = 2 MHz				
f = 3 MHz				
f = 5 MHz				
f = 10 MHz				
f = 20 MHz				
f = 25 MHz				
f = 40 MHz				
Hysteresis constant η_B at $\hat{B} = 0{,}3 - 1{,}2$ mT f = 100 kHz	$\times 10^{-3}\ T^{-1}$			
Power loss at f = 16 kHz and	kW/m^3			
B = 50 mT $\theta = 20\,°C$		≈ 70		
B = 400 mT $\theta = 25\,°C$				
B = 400 mT $\theta = 50\,°C$				
B = 400 mT $\theta = 100\,°C$				
Resistivity ρ measured with d.c.	Ωm	$\geqslant 10^6$	$\geqslant 0{,}1$	
Dielectric constant at f = 1 MHz. $\theta = 25\,°C$				
Temperature factor α_F	$\times 10^{-6}/K$			
$\theta = +25$ to $+55\,°C$			0 to +4,5	
$\theta = +25$ to $+70\,°C$		≈ 35		
Disaccomodation factor D_F between 10 and 100 min after demagnetization, $\hat{B} \leqslant 0{,}1$ mT, $\theta = 25 \pm 1\,°C$	$\times 10^{-6}$		⩽ 10	
Curie temperature	°C	⩾ 150	⩾ 150	
Mass density	kg/m^3	≈ 4300	4700-4900	
Core shapes		yoke rings		

• preferred material

		materials for small parts				
•3B	3C6	4A4	•4B1	4D1	4D2	4E1
900 ± 20%	1700 ± 25%	500 ± 20%	250 ± 20%	50 ± 20%	60 ± 10%	15 ± 20%
≈ 345 ≈ 230	⩾ 290	≈ 270 ≈ 210	≈ 325 ≈ 260	≈ 240 ≈ 220		≈ 175 ≈ 165
⩽ 50		⩽ 30 ⩽ 40 ⩽ 70	⩽ 70 ⩽ 90 ⩽ 140	⩽ 180 ⩽ 210 ⩽ 300	⩽ 100 ⩽ 200 ⩽ 600	⩽ 300 ⩽ 300 ⩽ 360
		⩽ 1,8				
	⩽ 170 ⩽ 160 ⩽ 140					
⩾ 0,2		⩾ 10^5	⩾ 10^5	⩾ 10^3	⩾ 10^3	⩾ 10^3
		15-20				
0 to +3		+5 to +15	0 to +8	0 to +15	0 to +15	0 to +15
⩾ 150	⩾ 190	⩾ 135	⩾ 250	⩾ 400	⩾ 350	⩾ 500
4700-4900	4750-4850	4700-5100	4400-4800	4000-4400		3500-4000
tubes and rods		frames for i.f. transformers, tubes and rods		frames for i.f. transformers, screw cores, tubes and rods		tubes and rods

	unit	high level transformer materials (power materials)	
		•3B8	•3C8
Initial permeability μ_i			
at $\hat{B} \leqslant 0{,}1$ mT, $\theta = 25\,^\circ C$		2300 ± 20%	2000 ± 25%
at $\hat{B} \leqslant 0{,}1$ mT, $\theta = 100\,^\circ C$			
at $\hat{B} \leqslant 1$ mT, $\theta = 5$ to $70\,^\circ C$			
at $\hat{B}$ 0,7 – 1 mT, $\theta = 25$ to $70\,^\circ C$			
Induction B ballistically measured at	mT		
H = 50 A/m, $\theta = 100\,^\circ C$			
H = 250 A/m, $\theta = 25\,^\circ C$			
$\theta = 100\,^\circ C$			
H = 800 A/m, $\theta = 25\,^\circ C$		≈ 490	⩾ 330
$\theta = 70\,^\circ C$			
$\theta = 100\,^\circ C$		≈ 380	
Eddy current and residual loss constant $\frac{\tan\delta}{\mu_i}$ at $\hat{B} \leqslant 0{,}1$ mT, $\theta = 25\,^\circ C$	$\times 10^{-6}$		
f = 4 kHz		⩽ 1,2	
f = 30 kHz			
f = 100 kHz		⩽ 5	
f = 500 kHz			
Hysteresis constant η_B at $\hat{B} = 1{,}5 - 30$ mT, f = 4 kHz	$\times 10^{-3}\ T^{-1}$	⩽ 1,0	
Power loss at f = 16 kHz and $\hat{B}$ = 200 mT	kW/m³		
$\theta = 25\,^\circ C$		⩽ 100	⩽ 110
$\theta = 100\,^\circ C$		⩽ 110	⩽ 100
Resistivity ρ measured with d.c.	Ωm	⩾ 0,6	⩾ 1
Temperature factor α_F	$\times 10^{-6}$/K		
$\theta = +5$ to $+25\,^\circ C$		0 to +4	
$\theta = +25$ to $+55\,^\circ C$		0 to +4	
$\theta = +25$ to $+70\,^\circ C$			
Disaccomodation factor D_F between 10 and 100 min after demagnetization, $\hat{B} \leqslant 0{,}1$ mT, $\theta = 25 \pm 1\,^\circ C$	$\times 10^{-6}$	⩽ 8	
Curie temperature	°C	⩾ 200	⩾ 200
Mass density	kg/m³	4700-4900	4750-4850
D.C. sensitivity constant $\beta_F = \frac{\mu_i - \mu_{i\Delta}}{\mu_i\ \mu_{i\Delta}}$	$\times 10^{-6}$		
at $\mu_e \times \frac{N \times I_o}{l_e} = 1{,}20 \times 10^5$ A/m		⩽ 120	
$1{,}80 \times 10^5$ A/m		⩽ 300	
$2{,}60 \times 10^5$ A/m		⩽ 1000	
Core shapes		potcores, square cores	E, EC, ETD, U and I, square cores

• preferred material

low level transformer materials (broadband materials)				
3E1	•3E2	•3E4	3E5	3H2
3800 ± 20%	≥ 5000	4700 ± 20%	10000 ± 20% ≥ 8000	2300 ± 20%
≈ 350 ≈ 270	≈ 355 ≈ 260		≈ 380 ≈ 280	≈ 400
≤ 2,5 ≤ 20 ≤ 200	≤ 2,5 ≤ 15 ≤ 90	≤ 2,5 ≤ 20 ≤ 200	≤ 3 ≤ 25 ≤ 75	≤ 1 ≤ 6
≤ 1,1	≤ 1,1	≤ 0,85	≤ 0,85	≤ 0,85
≥ 0,3	≥ 0,1	≥ 0,3	≥ 0,01	≥ 1
1 ± 1 1 ± 1 1 ± 1		1 ± 1 1 ± 1 1 ± 1	0,4 ± 0,6 0,6 ± 0,6 0,6 ± 0,6	
≤ 4,3	≤ 1,9	≤ 4,3	≤ 2	≤ 4,3
≥ 125	≥ 130	≥ 125	≥ 120	≥ 160
4700-4900	4700-4900	4700-4900	4800-5000	4700-4900
E and I cores, toroids potcores square cores	toroids	potcores, square cores	square cores	toroids tubes and rods

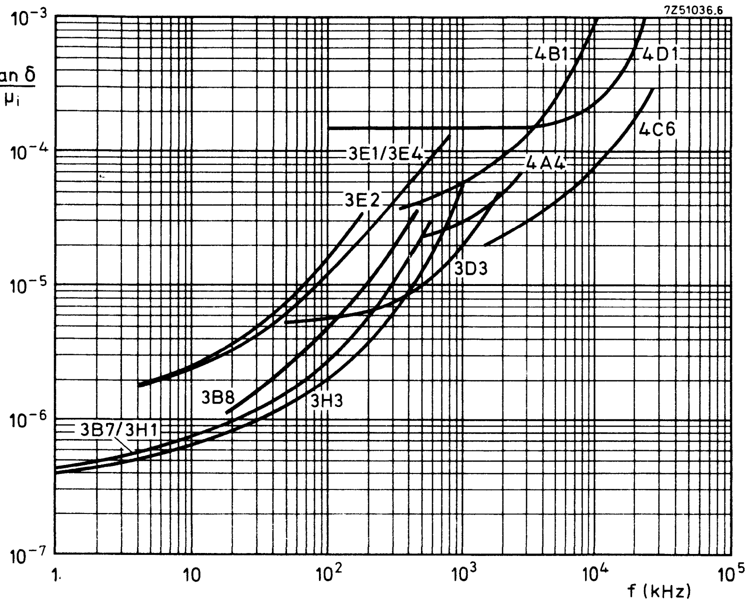
	unit	
Initial permeability μ_i at $\hat{B} \leqslant 0{,}1$ mT $\theta = 25\,°C$		
Induction B ballistically measured at H = 800 A/m $\theta = 25\,°C$ $\theta = 70\,°C$ H = 2400 A/m $\theta = 25\,°C$ $\theta = 70\,°C$	mT	
Eddy current and residual loss constant $\frac{\tan\delta}{\eta_i}$ at $\hat{B} \leqslant 0{,}1$ mT, $\theta = 25\,°C$ f = 4 kHz f = 30 kHz f = 100 kHz f = 500 kHz f = 1 MHz * f = 2 MHz f = 10 MHz	$\times 10^{-6}$	
Hysteresis constant η_B at $\hat{B} = 0{,}3 - 1{,}2$ mT f = 100 kHz at $\hat{B} = 1{,}5 - 3$ mT f = 4 kHz at $\hat{B} = 1{,}5 - 3$ mT f = 100 kHz	$\times 10^{-3}\ T^{-1}$	
Resistivity ρ measured with d.c.	Ωm	
Temperature factor α_F θ = +5 to +25 °C θ = +25 to +55 °C θ = +25 to +70 °C	$\times 10^{-6}$/°C	
Disaccomodation factor D_F between 10-100 min after demagnetization, $\hat{B} \leqslant 0{,}1$ mT $\theta = 25 \pm 1\,°C$ between 24 and 48 h after thermal demagnetization, $\hat{B} \leqslant 0{,}1$mT $\theta \leqslant 35\,°C$	$\times 10^{-6}$	
Curie temperature	°C	
Mass density	kg/m^3	
Core shapes		

* 3D3 at 700 kHz $\leqslant 12 \times 10^{-6}$.

materials for tuned circuits				
3B7	•3D3	•3H1	•3H3	•4C6
2300 ± 20%	1000 ± 20%	2300 ± 20%	2000 ± 20%	120 ± 20%
≈ 430 ≈ 345	≈ 350	≈ 360 ≈ 280	≈ 400	≈ 380 ≈ 350
≤ 1,0 ≤ 5,0	≤ 3 ≤ 8 ≤ 30 *	≤ 1,0 ≤ 5,0	1,2 ± 0,4 2 ± 0,5	≤ 40 ≤ 100
≤ 1,1	≤ 0,5	≤ 0,85	≤ 0,6	≤ 6,2
≥ 1	≥ 7	≥ 1		≥ 10^5
0 ± 0,6	1 ± 0,5 1 ± 0,5 1 ± 0,5	1 ± 0,5 1 ± 0,5 1 ± 0,5	0,7 ± 0,3 0,7 ± 0,3 0,7 ± 0,3	1 ± 3 3 ± 3
≤ 4,3	≤ 8	≤ 4,3	≤ 3	≤ 10
≥ 170	≥ 180	≥ 130	≥ 160	≥ 350
4700-4900	4300-4500	4700-4900		4000-5000
potcores, square cores	potcores, square cores, screw cores	potcores, square cores, cross cores	potcores, square cores	potcores square cores, toroids, frames for i.f. transformers, rods and tubes

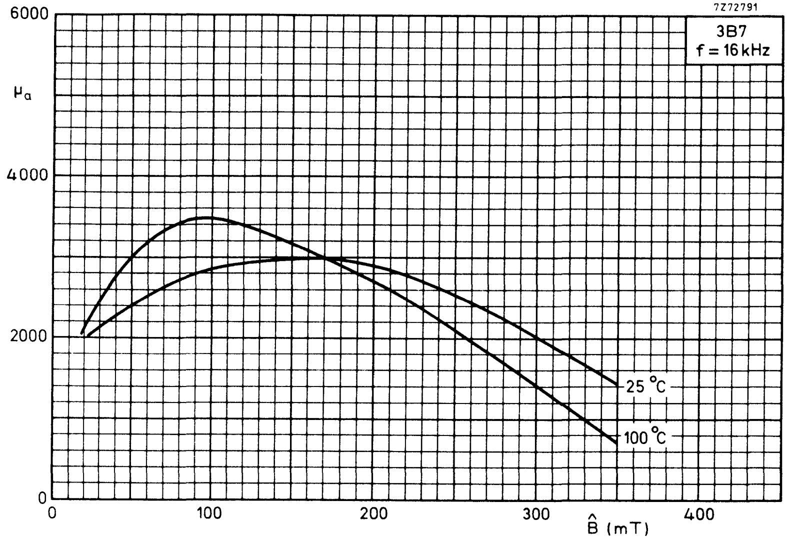
CHARACTERISTIC CURVES

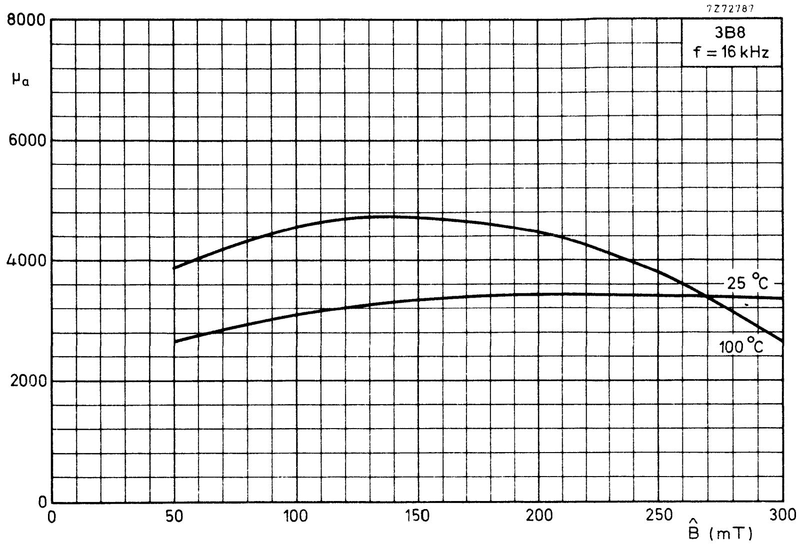
The curves are valid for toroids of not too small dimensions and should be considered as a guide. For guarantees on products, refer to the pages on the relevant products.

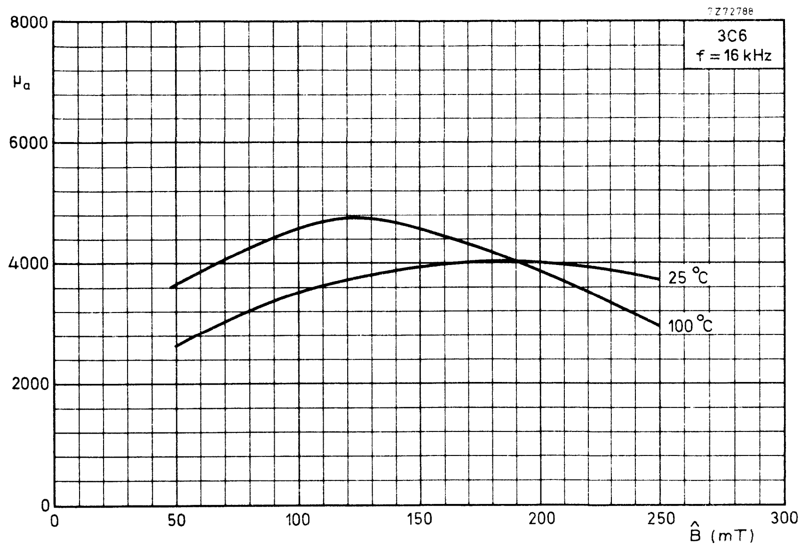


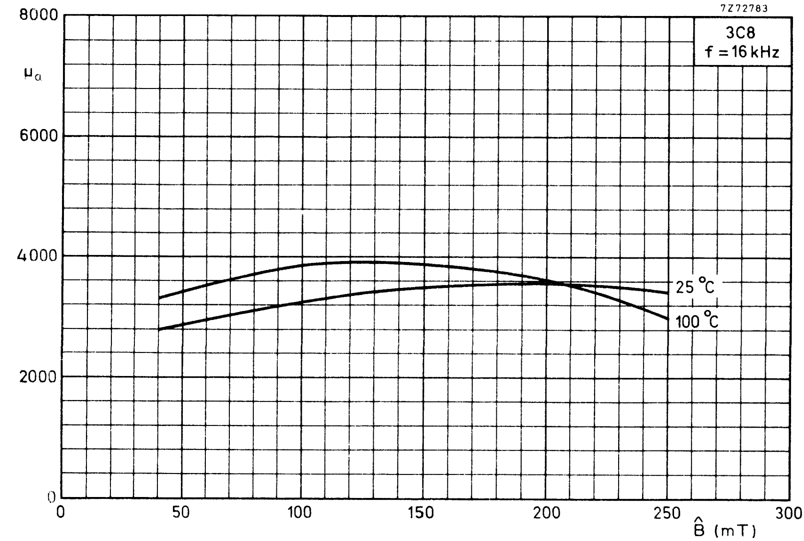
Eddy current losses and residual losses as a function of the frequency at low induction level.

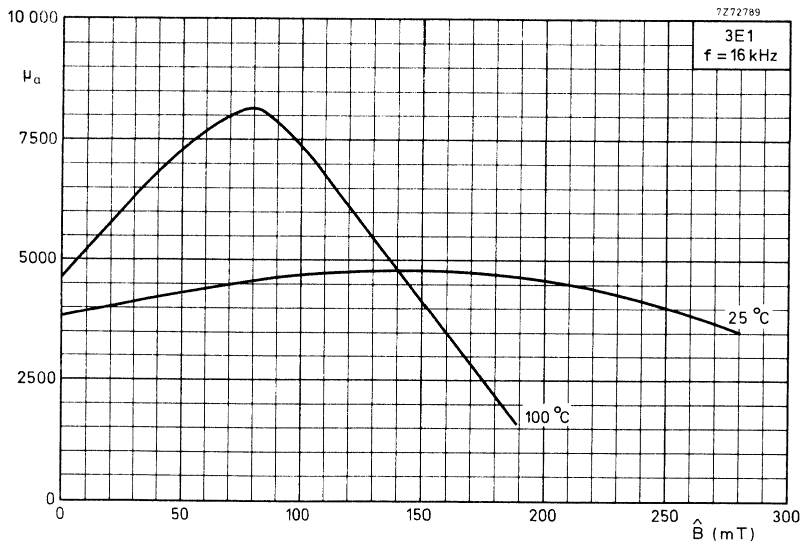
Amplitude permeability as a function of the induction.

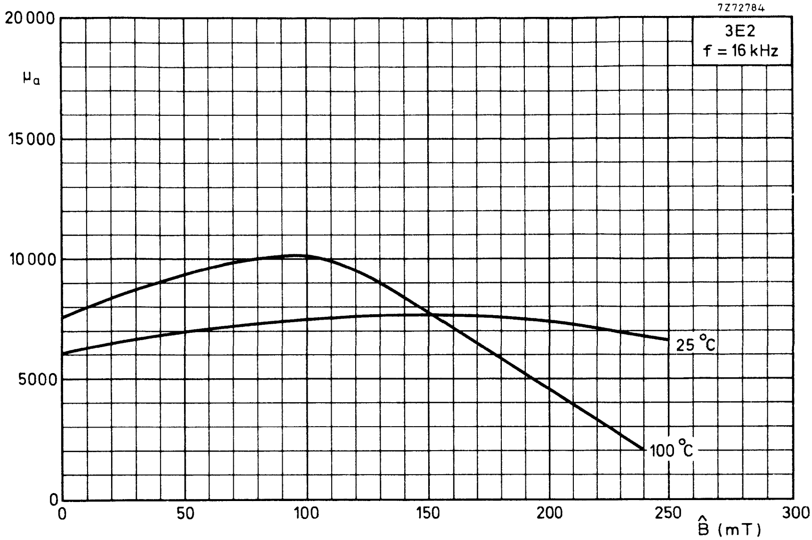


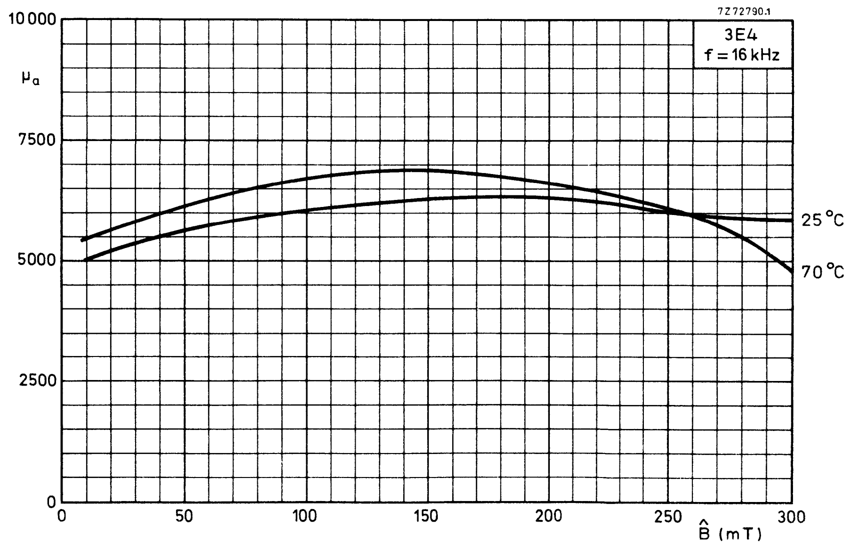

7Z72787
3B8
f = 16 kHz
8000
μa
6000
4000
2000
0
0
50
100
150
200
250
300
B̂ (mT)
25 °C
100 °C

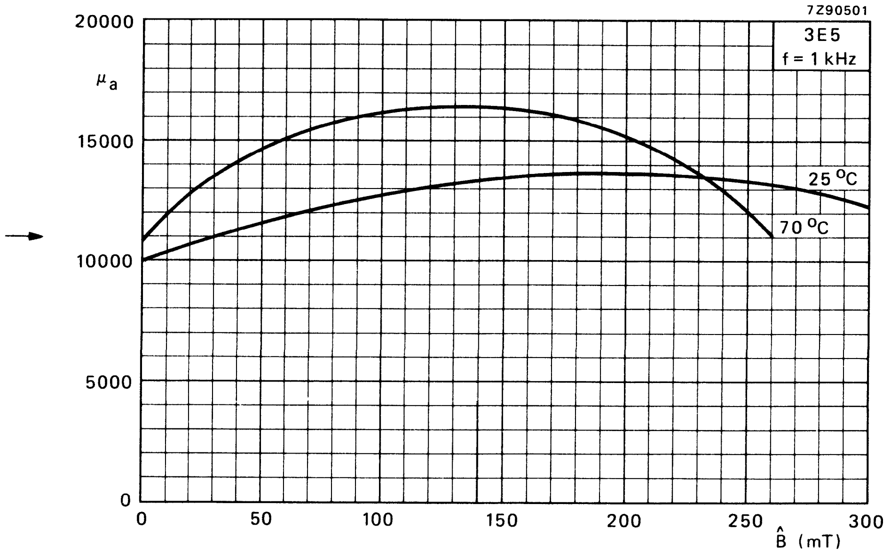

7Z72788
3C6
f = 16 kHz
8000
μa
6000
4000
2000
0
0
50
100
150
200
250
300
B̂ (mT)
25 °C
100 °C

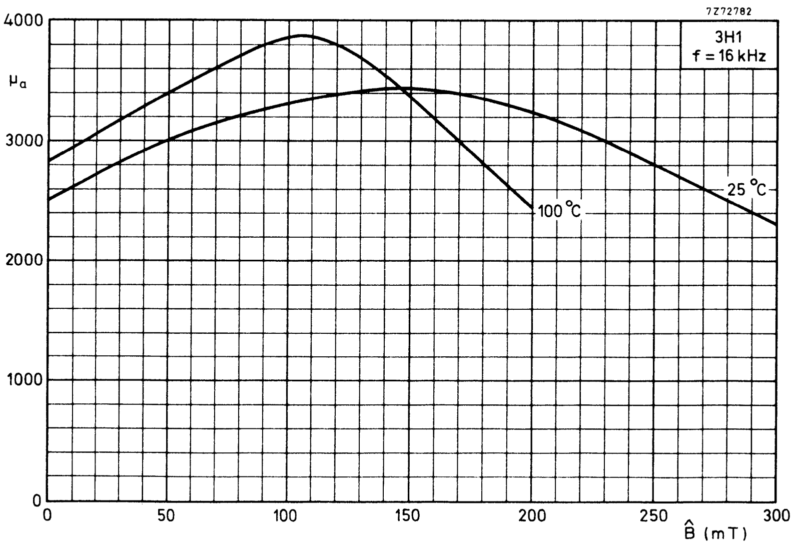

7Z72783
3C8
f = 16 kHz
μa
8000
6000
4000
2000
0
0
50
100
150
200
250
300
B̂ (mT)
25 °C
100 °C

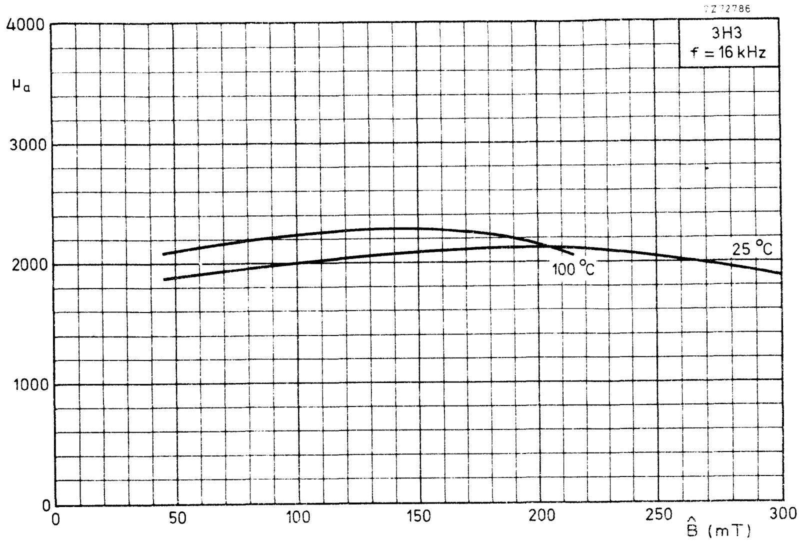

7Z72789
3E1
f = 16 kHz
μa
10 000
7500
5000
2500
0
0
50
100
150
200
250
300
B̂ (mT)
25 °C
100 °C

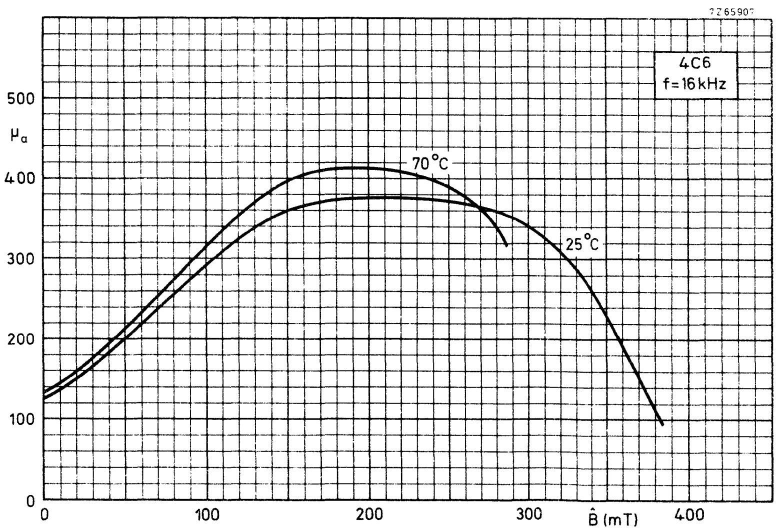

7Z72784
3E2
f = 16 kHz
20 000
15 000
10 000
5000
0
μ_a
0
50
100
150
200
250
300
$\hat{B}$ (mT)
25 °C
100 °C


7Z72790.1
3E4
f = 16 kHz
10 000
7500
5000
2500
0
μ_a
0
50
100
150
200
250
300
$\hat{B}$ (mT)
25 °C
70 °C


7Z90501
3E5
f = 1 kHz
20000
15000
10000
5000
0
μ_a
25 °C
70 °C
0
50
100
150
200
250
300
$\hat{B}$ (mT)

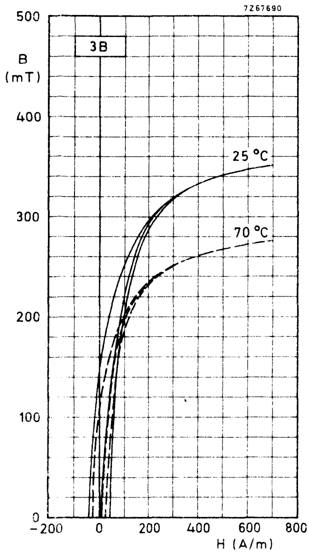

7Z72782
3H1
f = 16 kHz
4000
3000
2000
1000
0
μ_a
100 °C
25 °C
0
50
100
150
200
250
300
$\hat{B}$ (mT)


7Z72786
3H3
f = 16 kHz
4000
μa
3000
2000
1000
0
0
50
100
150
200
250
300
B̂ (mT)
25 °C
100 °C

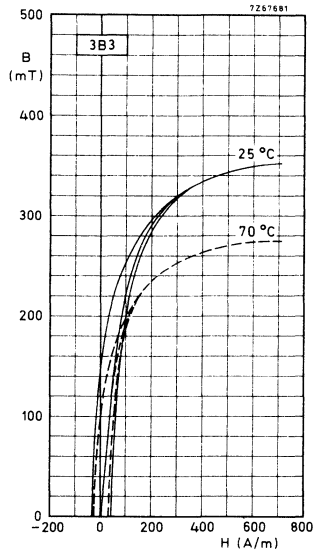

7Z65907
4C6
f=16kHz
500
μa
400
300
200
100
0
0
100
200
300
B̂ (mT)
400
70°C
25°C

TYPICAL BH-CURVES (measured ballistically)

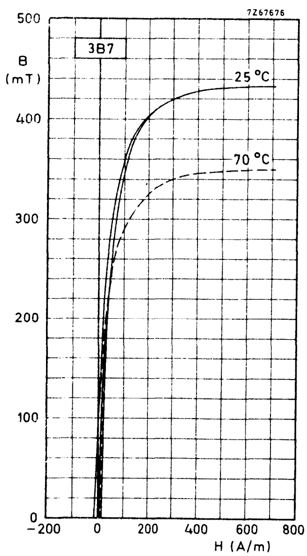
ballistic curves



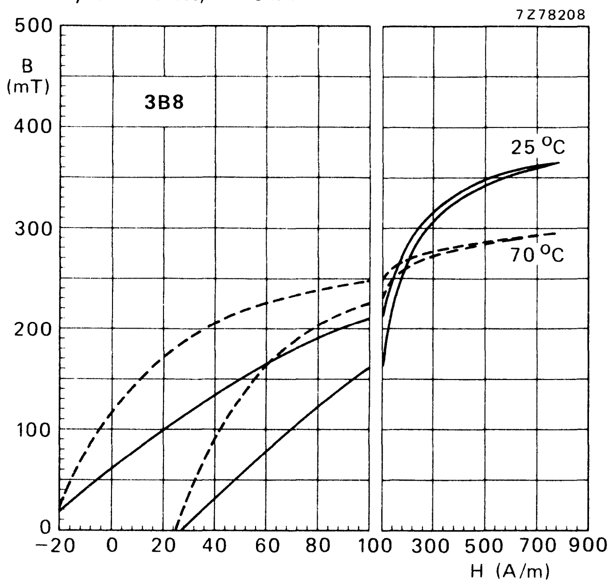
ballistic curves



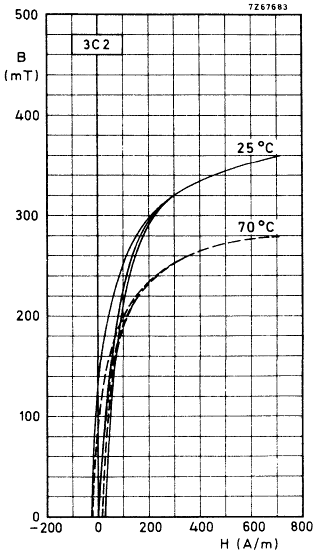
ballistic curves



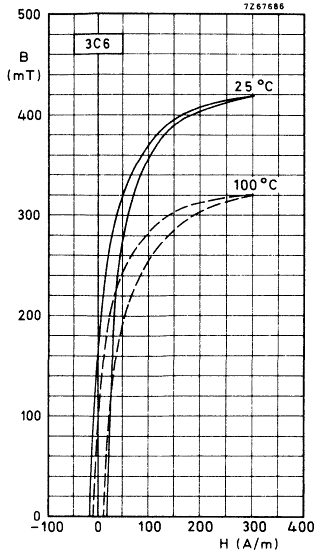
dynamic curves, f = 10 kHz



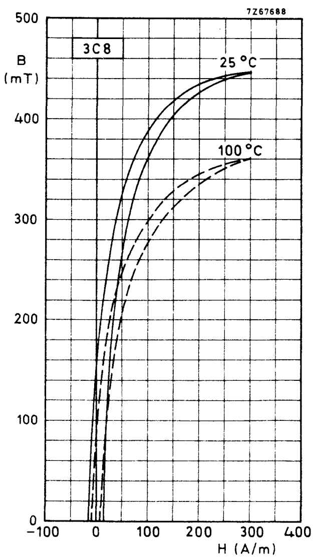
ballistic curves



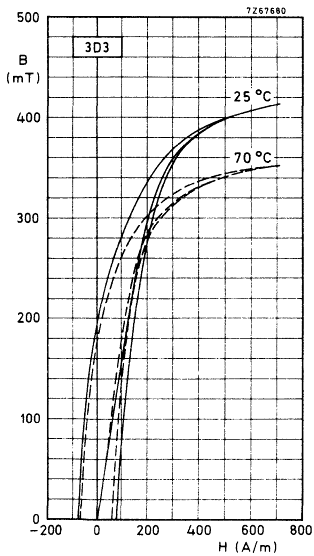
ballistic curves



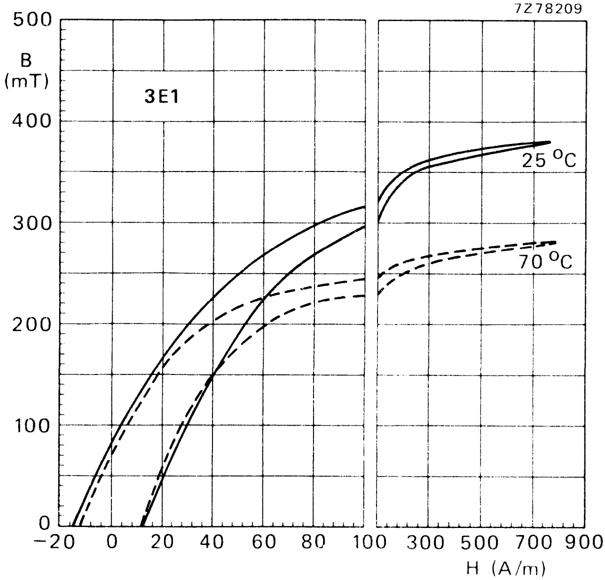
ballistic curves



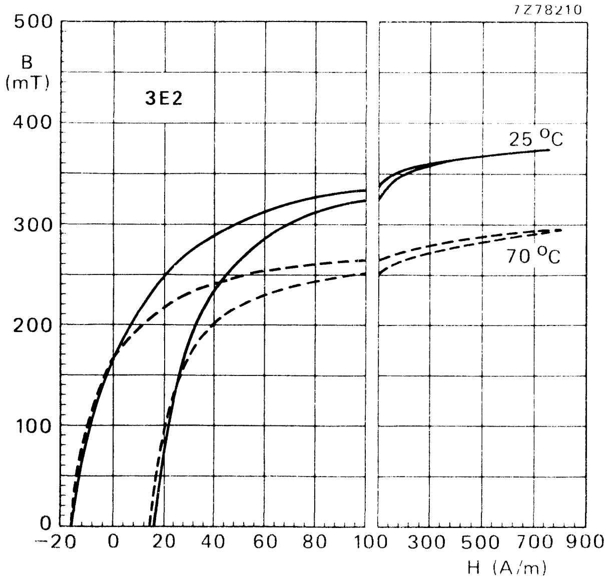
ballistic curves



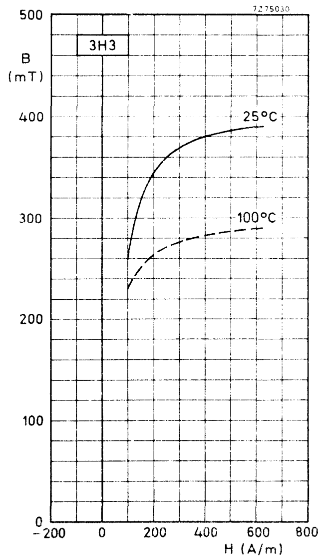
→ dynamic curves, f = 10 kHz



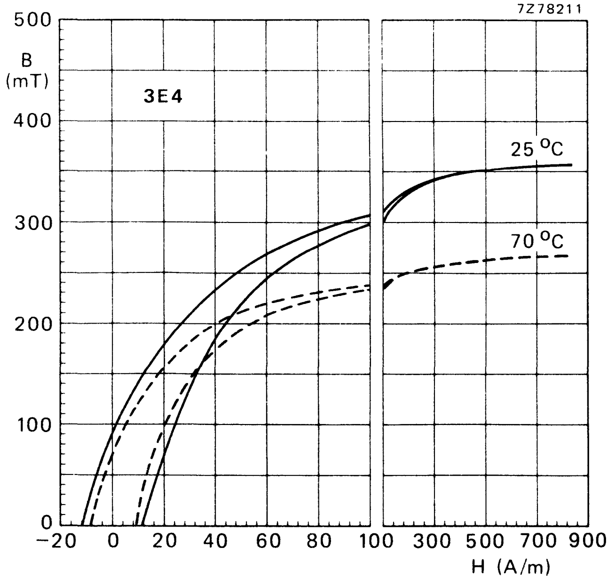
→ dynamic curves, f = 10 kHz



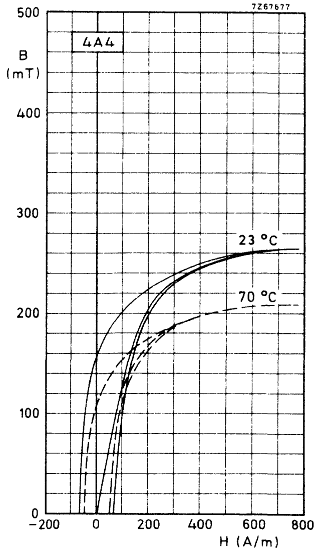
ballistic curves



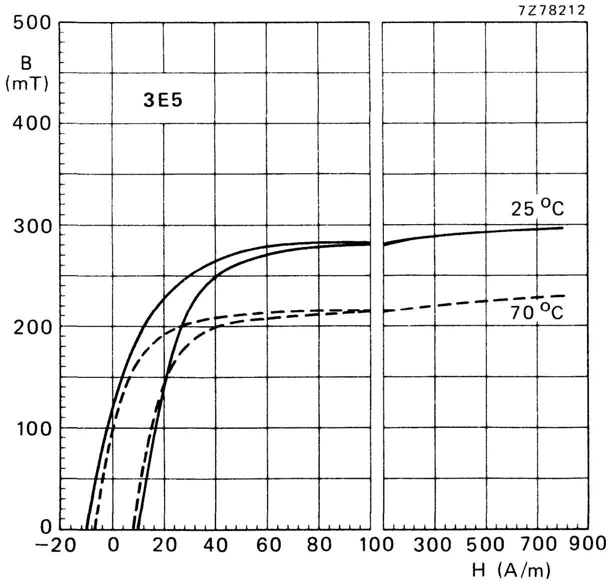
dynamic curves, f = 10 kHz



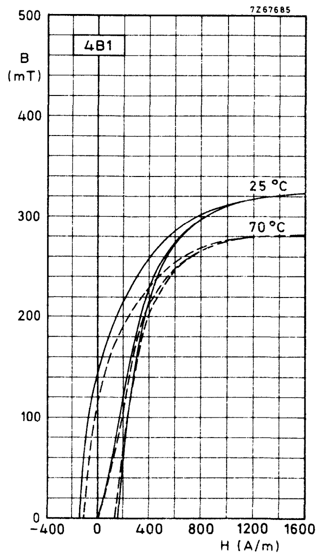
ballistic curves



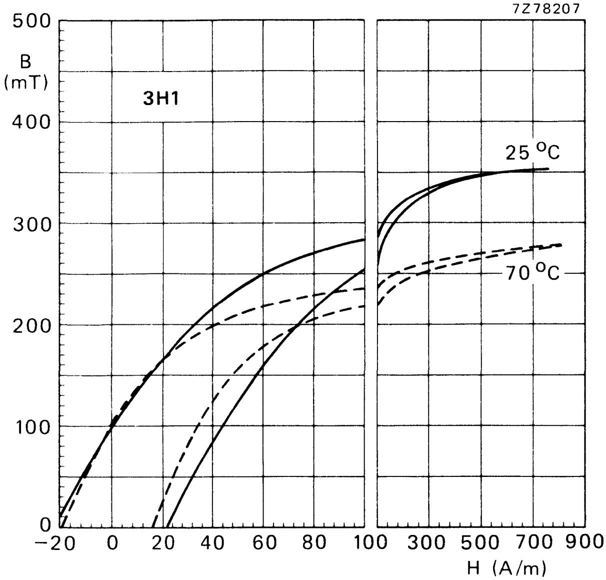
dynamic curves, f = 10 kHz



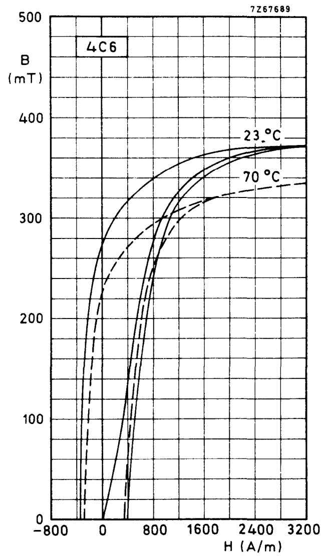
ballistic curves



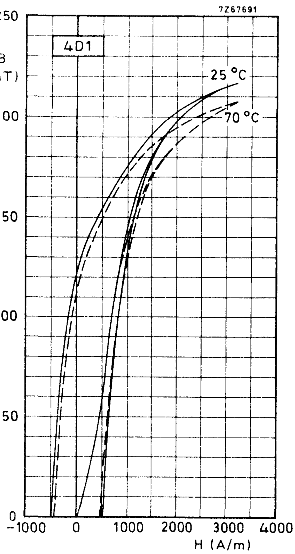
→ dynamic curves, f = 10 kHz



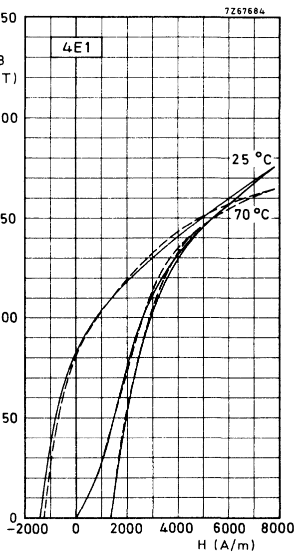
ballistic curves



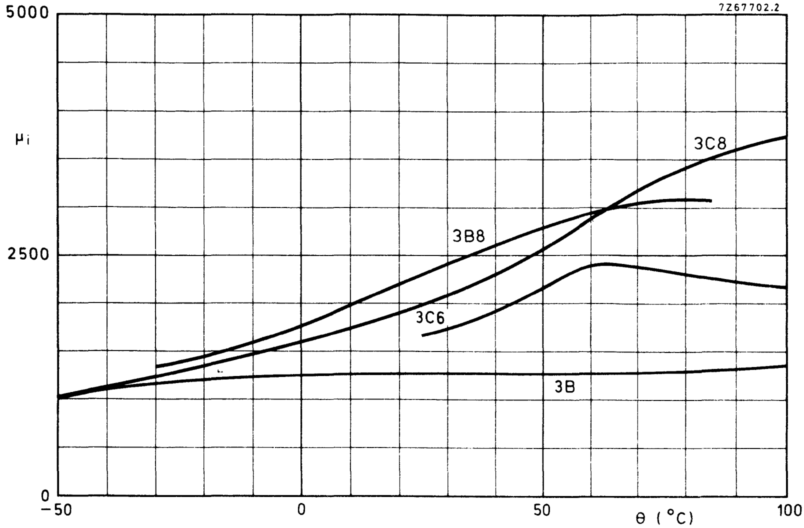
→ ballistic curves

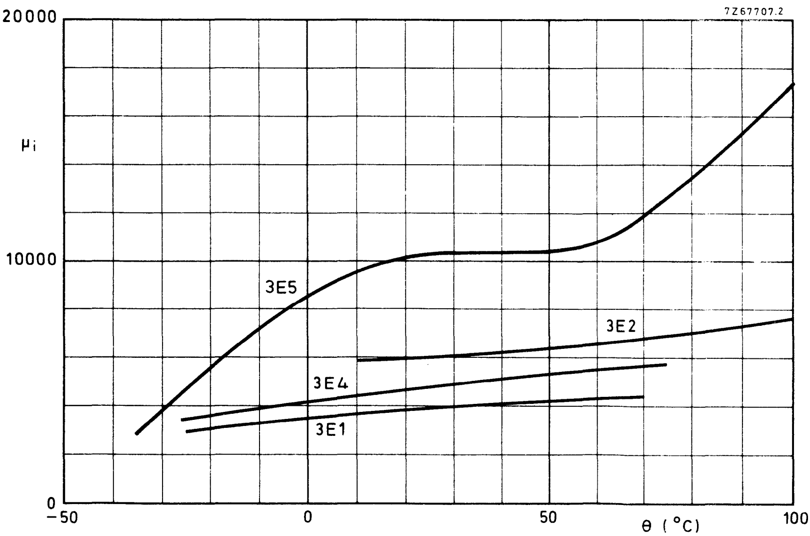


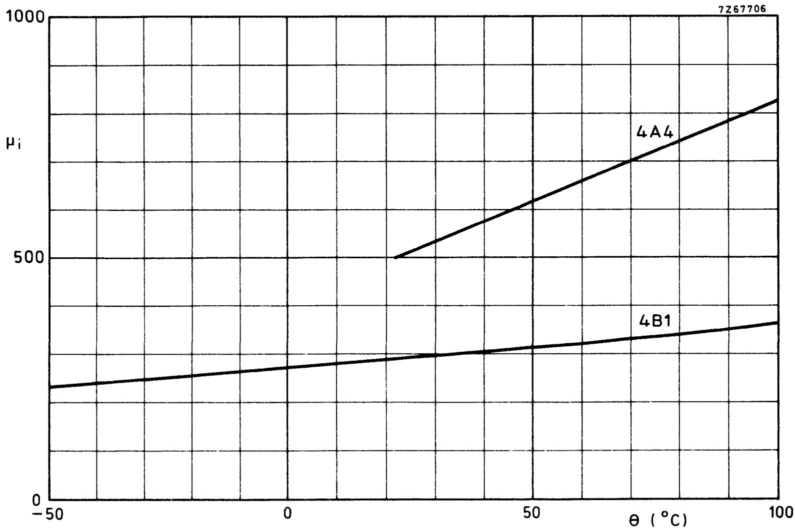
ballistic curves

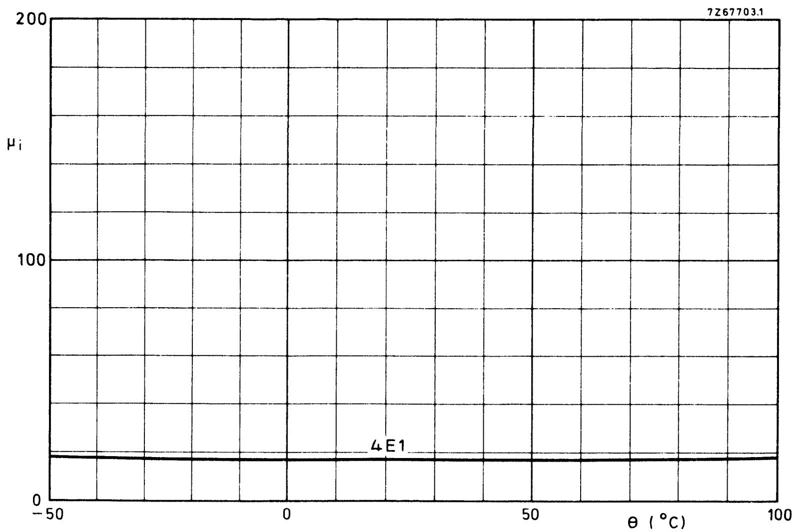


Relative initial permeability as a function of the temperature

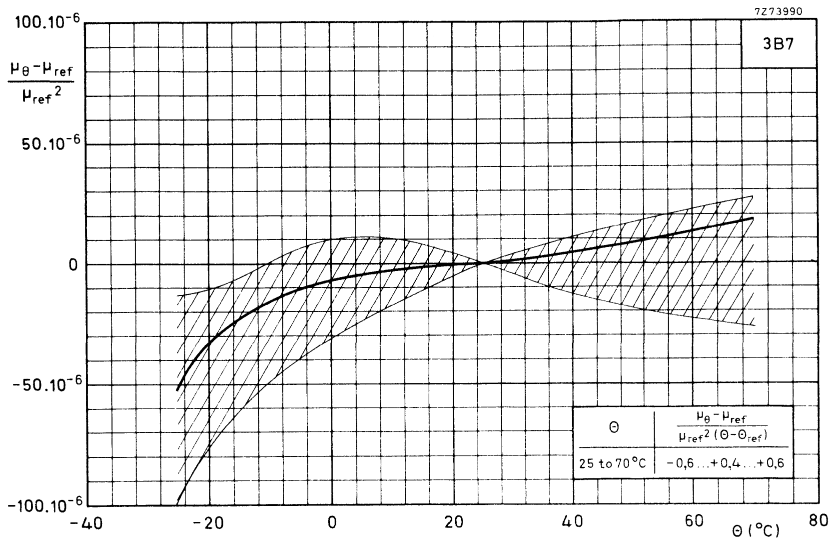


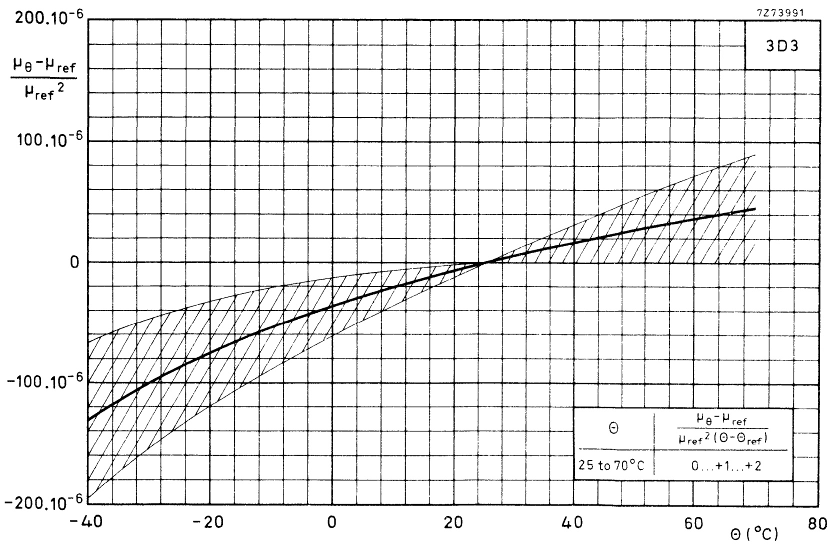


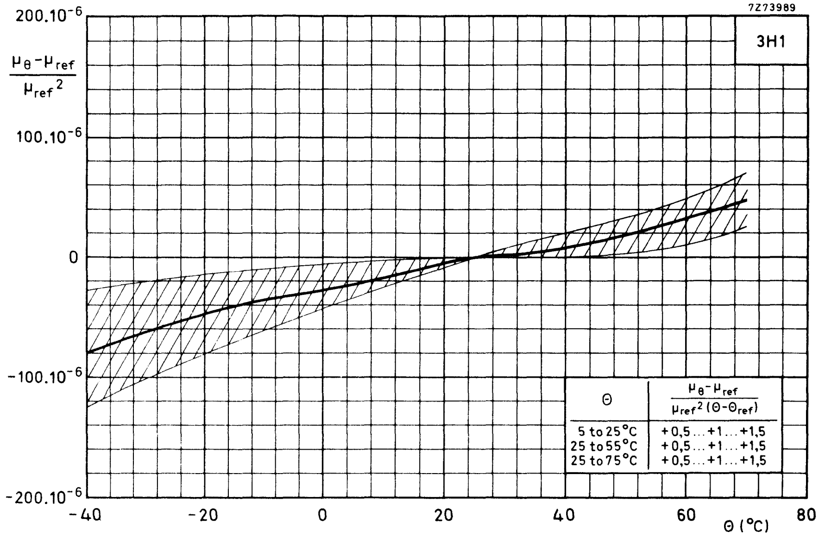

7Z67706
1000
500
0
μ_i
4A4
4B1
−50
0
50
100
θ (°C)

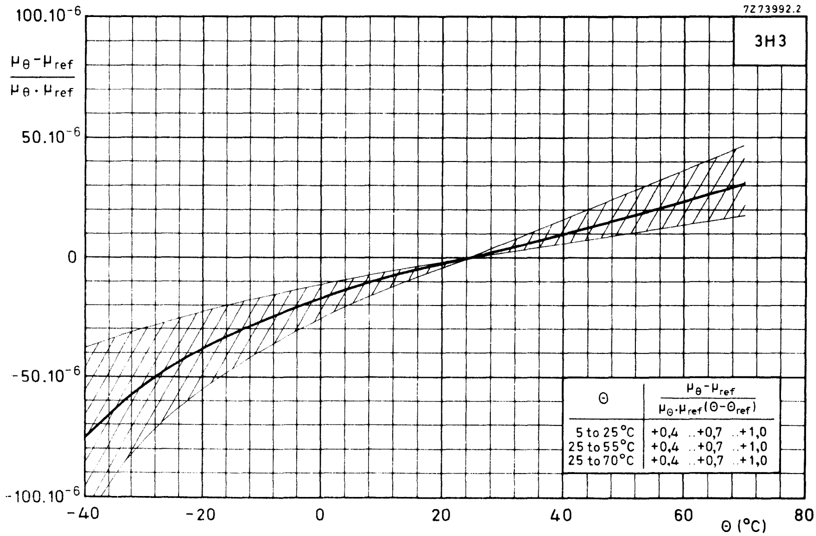

7Z67703.1
200
100
0
μ_i
4E1
−50
0
50
100
θ (°C)

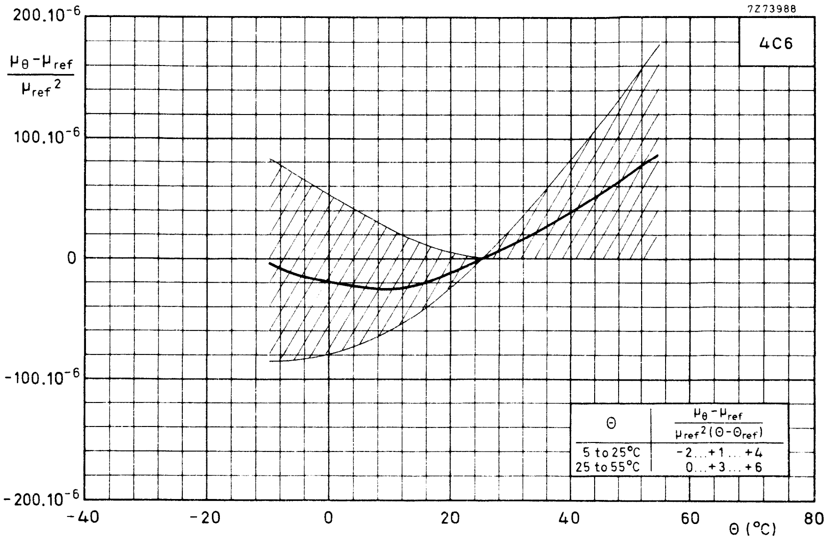
Permeability factor as a function of the temperature



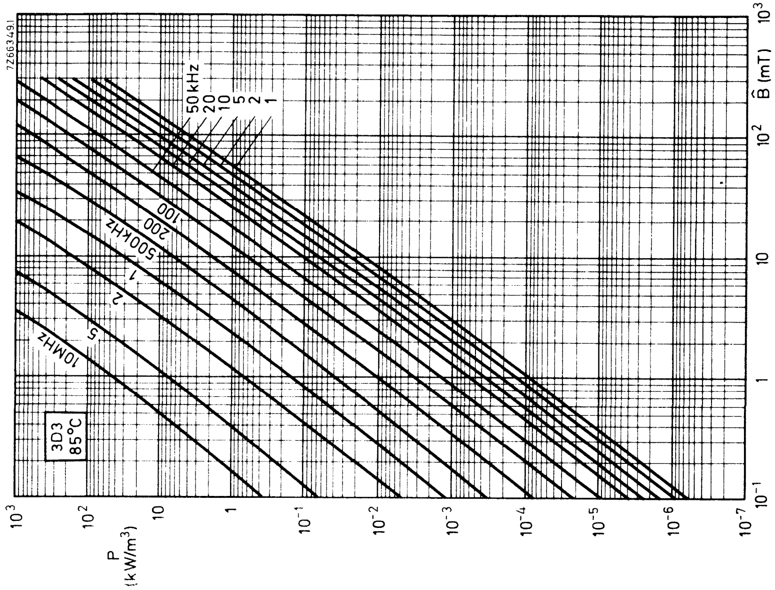


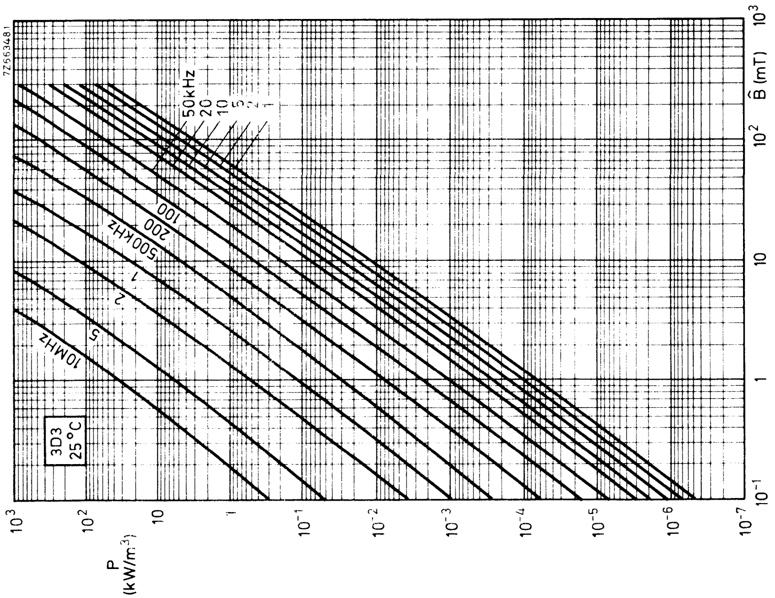

7Z73989
3H1
200.10^{-6}
$\frac{\mu_\theta - \mu_{ref}}{\mu_{ref}^2}$
100.10^{-6}
0
-100.10^{-6}
-200.10^{-6}
-40
-20
0
20
40
60
80
Θ (°C)
Θ
$\frac{\mu_\theta - \mu_{ref}}{\mu_{ref}^2 (\Theta - \Theta_{ref})}$
5 to 25°C
+0,5 ... +1 ... +1,5
25 to 55°C
+0,5 ... +1 ... +1,5
25 to 75°C
+0,5 ... +1 ... +1,5

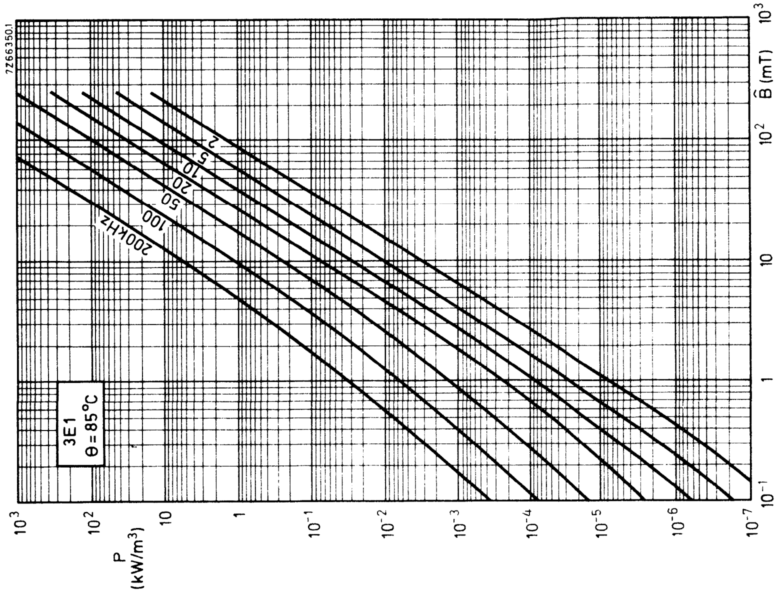

7Z73992.2
3H3
100.10^{-6}
$\frac{\mu_\theta - \mu_{ref}}{\mu_\theta \cdot \mu_{ref}}$
50.10^{-6}
0
-50.10^{-6}
-100.10^{-6}
-40
-20
0
20
40
60
80
Θ (°C)
Θ
$\frac{\mu_\theta - \mu_{ref}}{\mu_\Theta \cdot \mu_{ref} (\Theta - \Theta_{ref})}$
5 to 25°C
+0,4 .. +0,7 .. +1,0
25 to 55°C
+0,4 .. +0,7 .. +1,0
25 to 70°C
+0,4 .. +0,7 .. +1,0

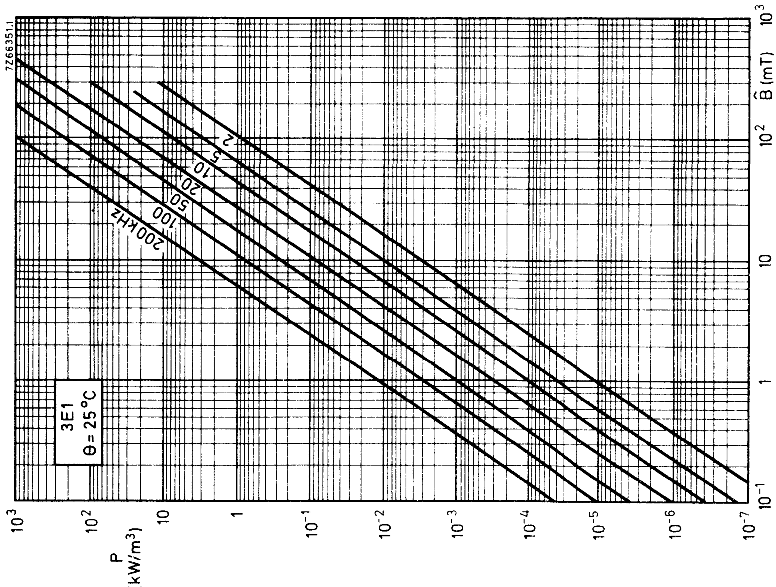

7Z73988
4C6
$\frac{\mu_\theta - \mu_{ref}}{\mu_{ref}^2}$
200.10^-6
100.10^-6
0
-100.10^-6
-200.10^-6
-40
-20
0
20
40
60
80
Θ (°C)
Θ | $\frac{\mu_\theta - \mu_{ref}}{\mu_{ref}^2(\Theta - \Theta_{ref})}$
5 to 25°C | -2 ... +1 ... +4
25 to 55°C | 0 ... +3 ... +6

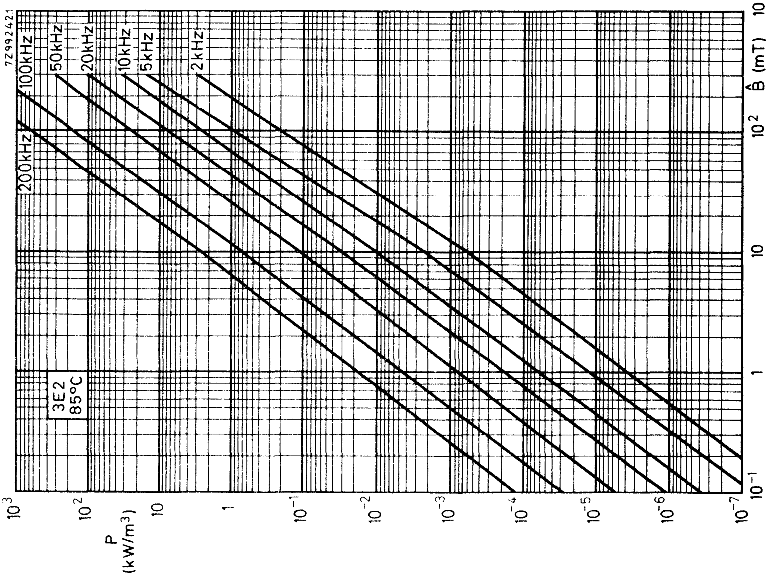
Power loss as a function of the induction

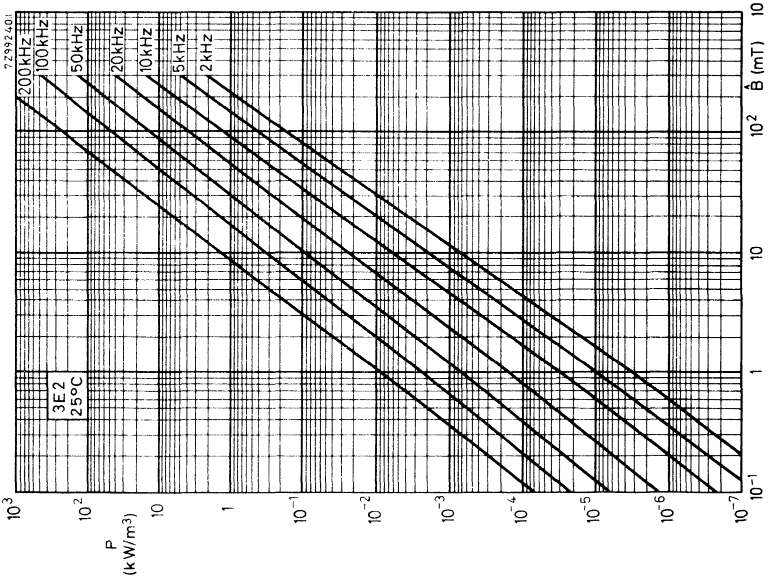


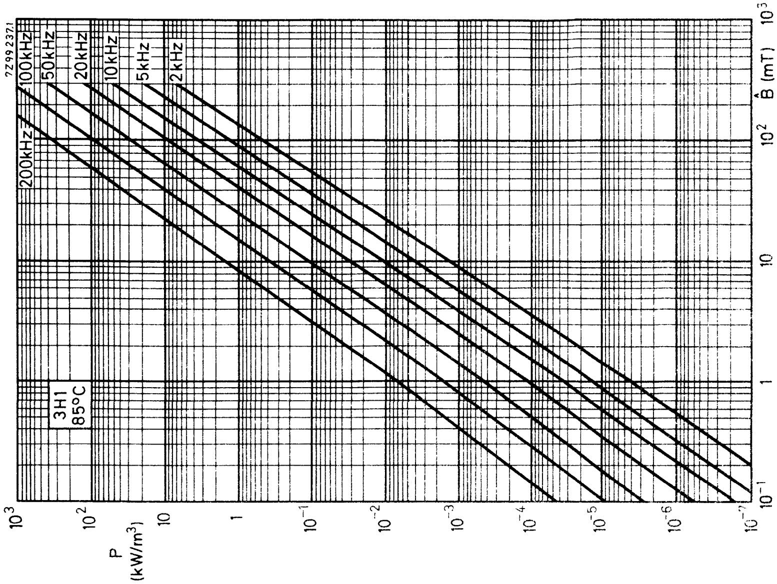


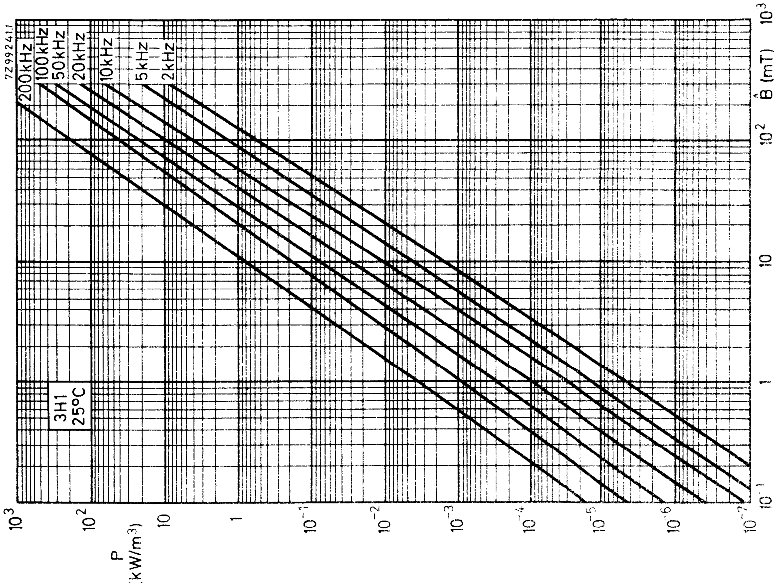

7Z66350.1
3E1
θ = 85°C
P (kW/m³)
B̂ (mT)
2
5
10
20
50
100
200kHz

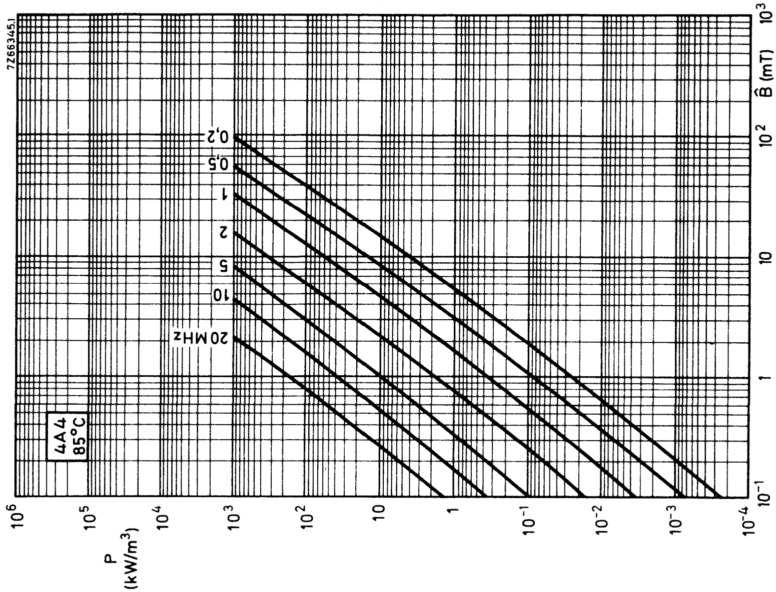

7Z66351.1
3E1
θ = 25°C
P (kW/m³)
B̂ (mT)
2
5
10
20
50
100
200kHz

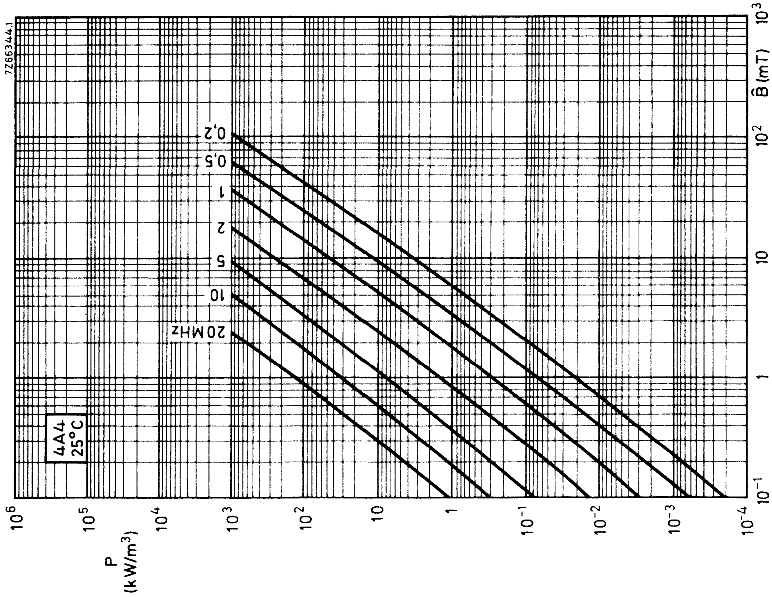

7Z99242.1
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
3E2
85°C
P
(kW/m³)
B̂ (mT)
10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷

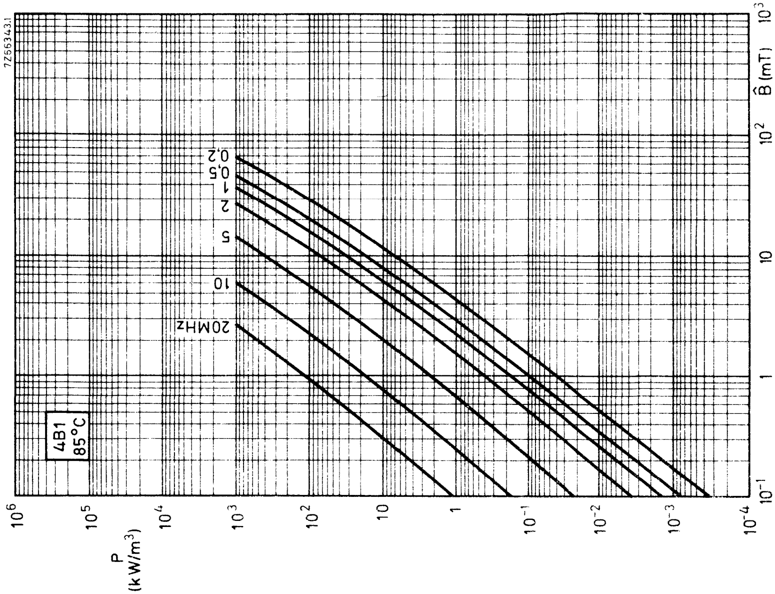

7Z99240.1
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
3E2
25°C
P
(kW/m³)
B̂ (mT)
10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷

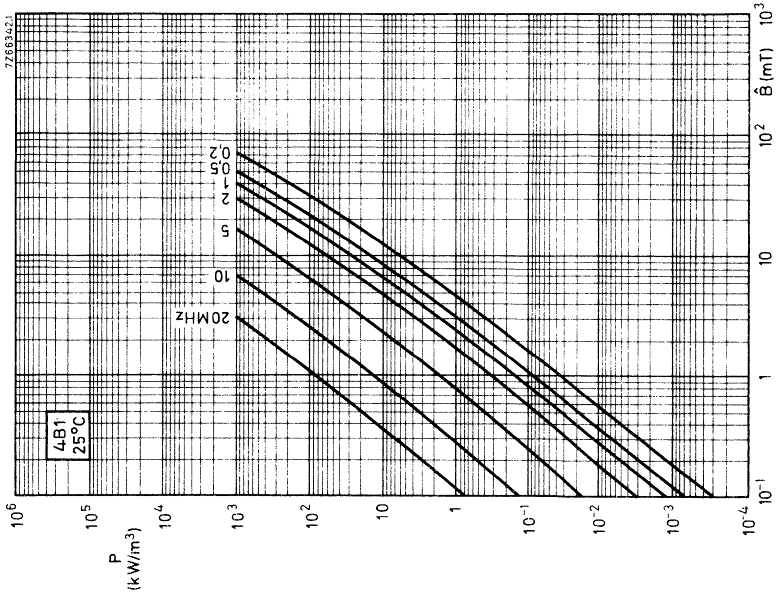

7Z99237.1
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
200kHz
3H1
85°C
P
(kW/m³)
B̂ (mT)

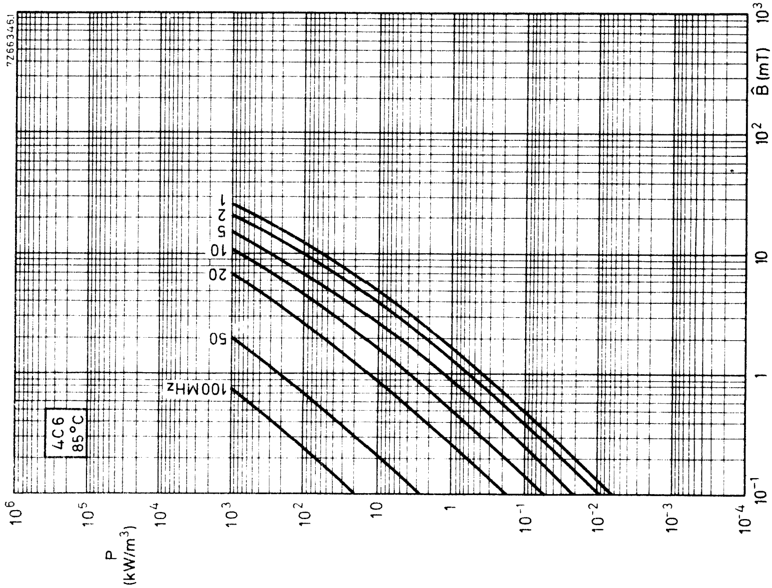

7Z99241.1
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
3H1
25°C
P
(kW/m³)
B̂ (mT)

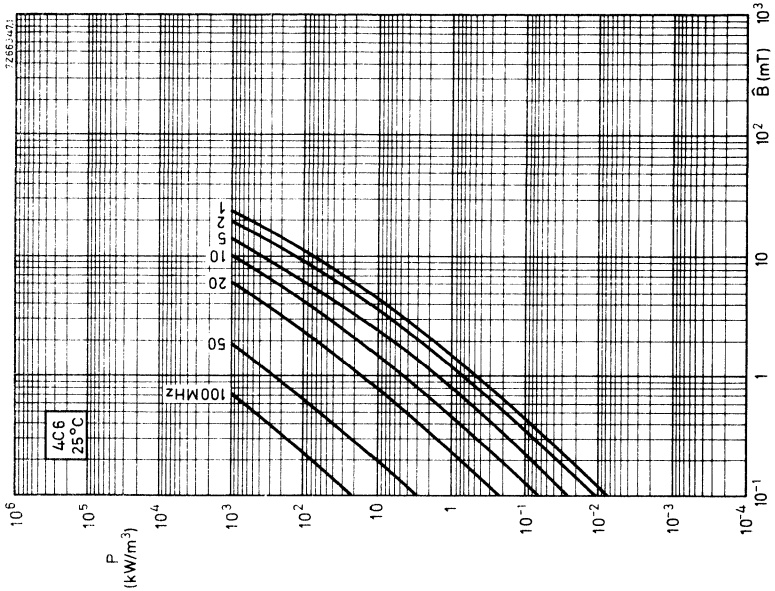

7Z66345.1
4A4
85°C
0,2
0,5
1
2
5
10
20 MHz
P
(kW/m3)
B̂ (mT)
10^6
10^5
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-1
1
10
10^2
10^3


7Z66344.1
4A4
25°C
0,2
0,5
1
2
5
10
20 MHz
P
(kW/m3)
B̂ (mT)
10^6
10^5
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-1
1
10
10^2
10^3

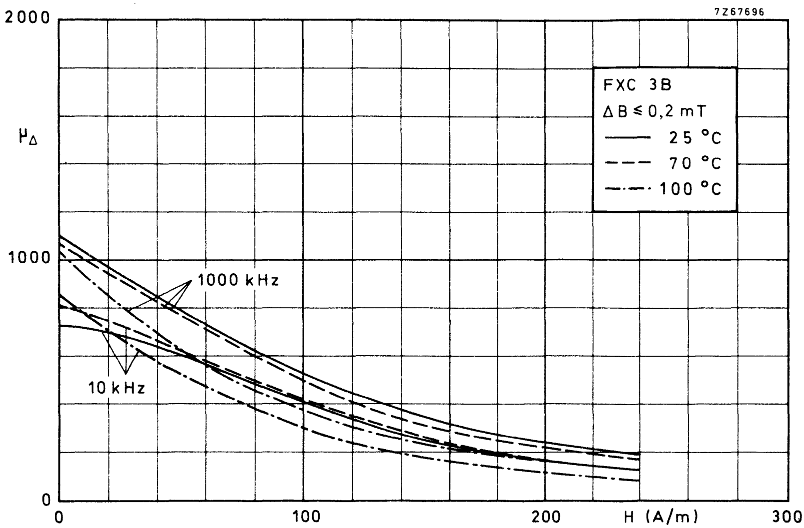

7Z56343.1
4B1
85°C
P
(kW/m³)
B̂ (mT)
20MHz
10
5
2
1
0,5
0,2

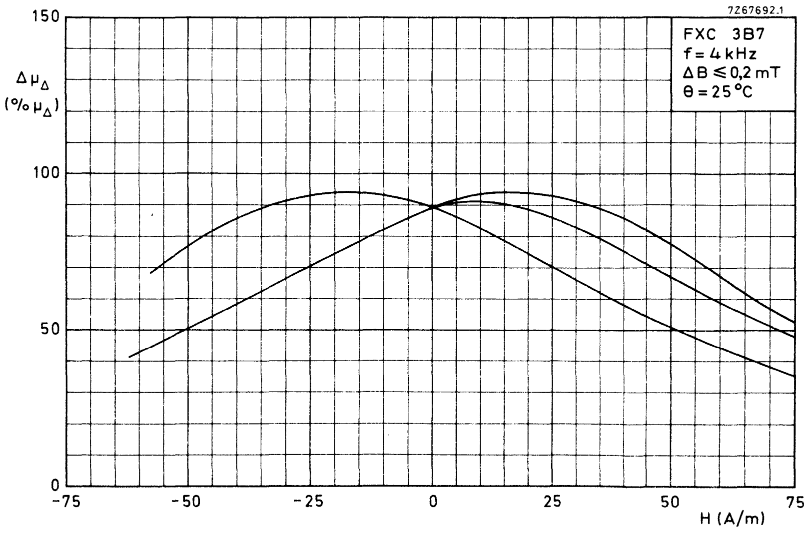

7Z66342.1
4B1
25°C
P
(kW/m³)
B̂ (mT)
20MHz
10
5
2
1
0,5
0,2

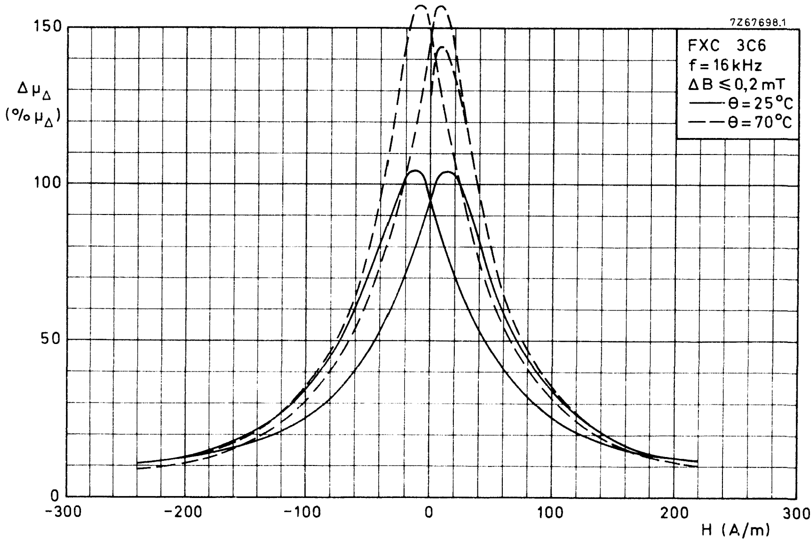

4C6
85°C
100MHz
50
20
10
5
2
1
P
(kW/m3)
B̂ (mT)

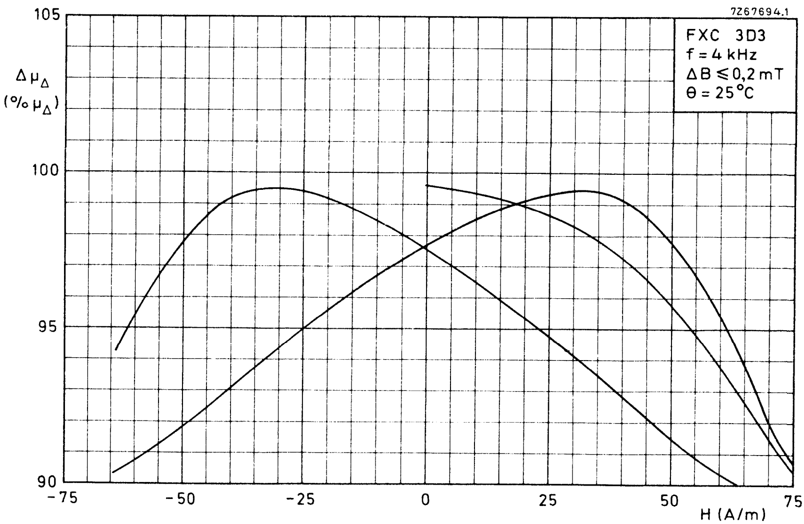

4C6
25°C
100MHz
50
20
10
5
2
1
P
(kW/m3)
B̂ (mT)

Incremental permeability as a function of the field strength






7Z67698.1
FXC 3C6
f = 16 kHz
ΔB ≤ 0,2 mT
θ = 25 °C
θ = 70 °C
Δμ_Δ
(% μ_Δ)
150
100
50
0
−300
−200
−100
0
100
200
300
H (A/m)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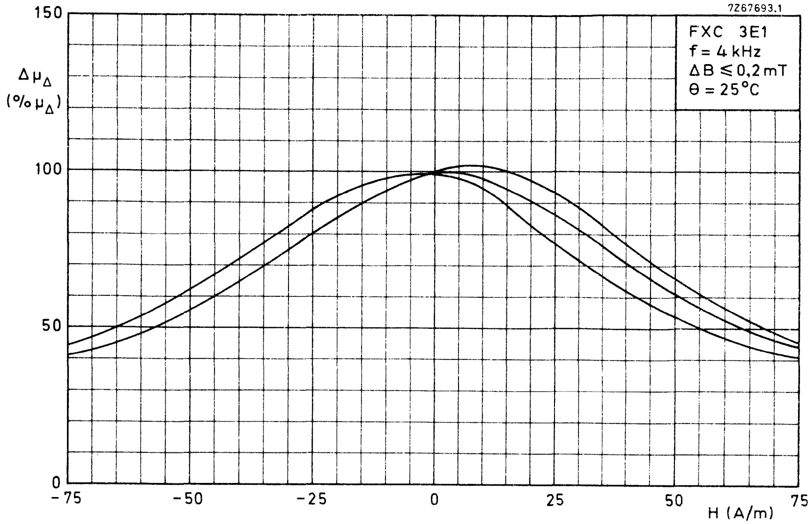
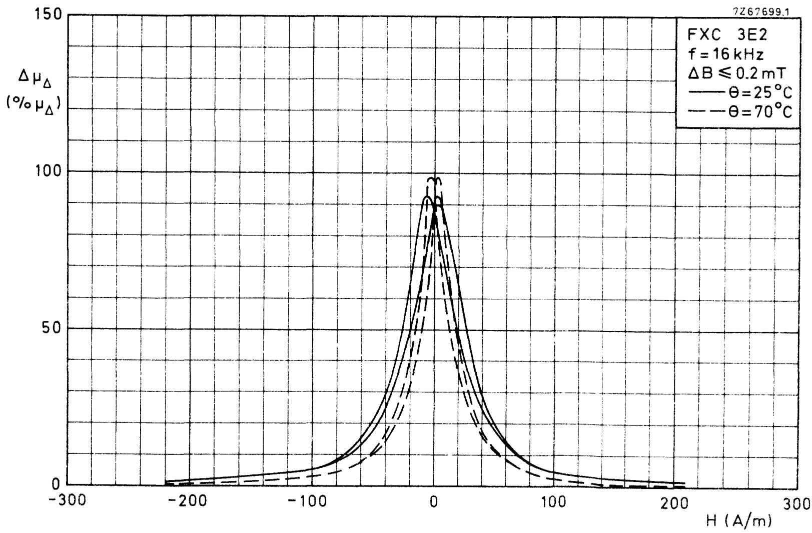
FXC 3D3
f = 4 kHz
ΔB ≤ 0,2 mT
θ = 25 °C
Δμ_Δ
(% μ_Δ)
105
100
95
90
−75
−50
−25
0
25
50
75
H (A/m)


7Z67693.1
FXC 3E1
f = 4 kHz
ΔB ≤ 0,2 mT
θ = 25°C
Δμ_Δ (% μ_Δ)
150
100
50
0
-75
-50
-25
0
25
50
75
H (A/m)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FXC 3E2
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ΔB ≤ 0.2 mT
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θ = 70°C
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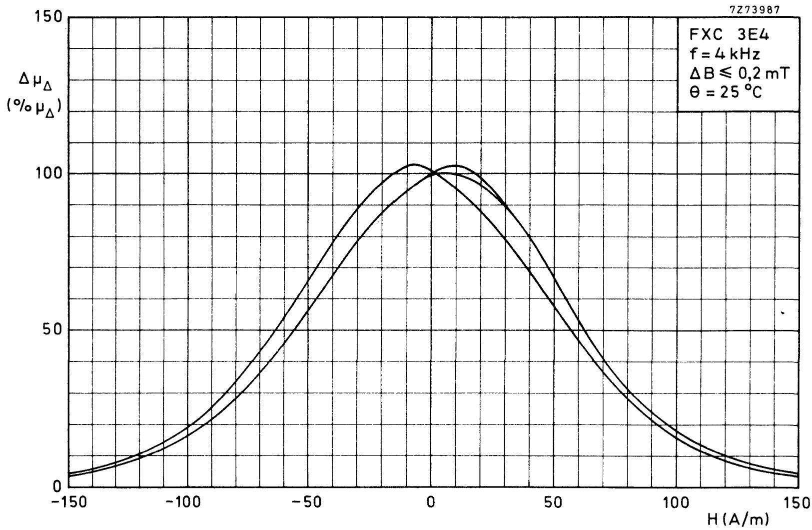
100
50
0
-300
-200
-100
0
100
200
300
H (A/m)


7Z73987
FXC 3E4
f = 4 kHz
ΔB ≤ 0,2 mT
θ = 25 °C
Δμ_Δ
(% μ_Δ)
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100
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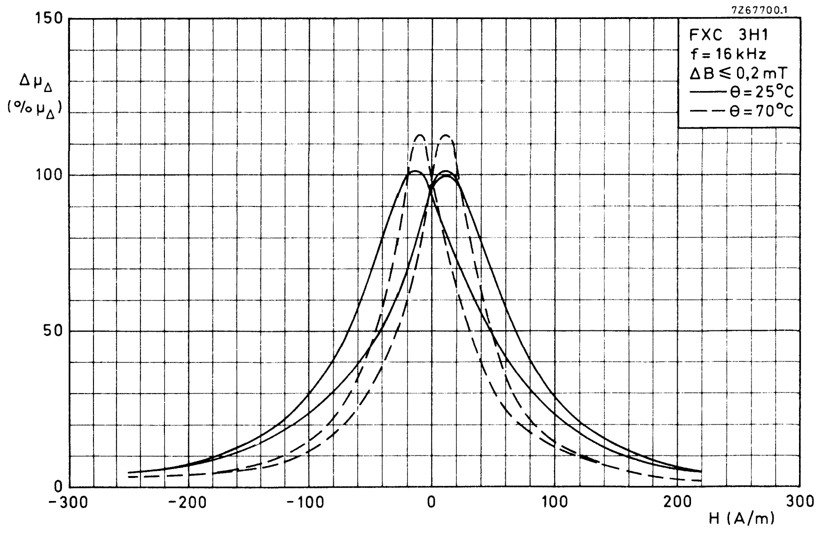
0
−150
−100
−50
0
50
100
150
H (A/m)


7Z67700.1
FXC 3H1
f = 16 kHz
ΔB ≤ 0,2 mT
θ = 25°C
θ = 70°C
Δμ_Δ
(% μ_Δ)
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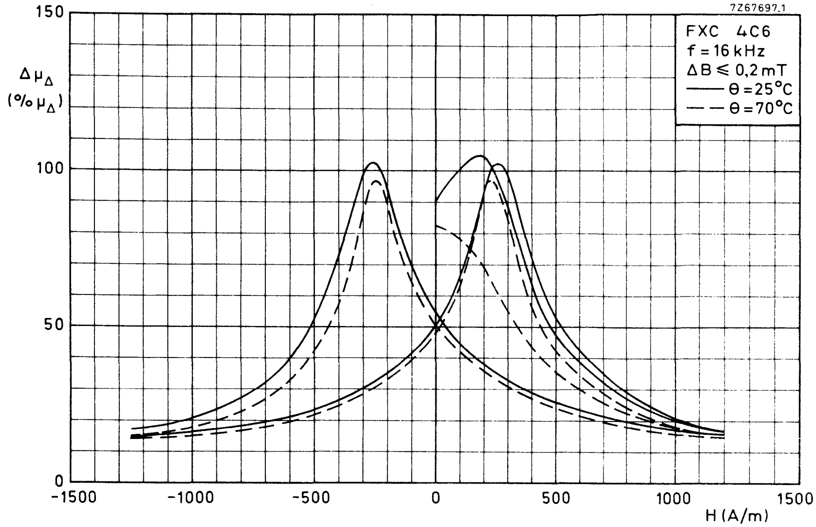
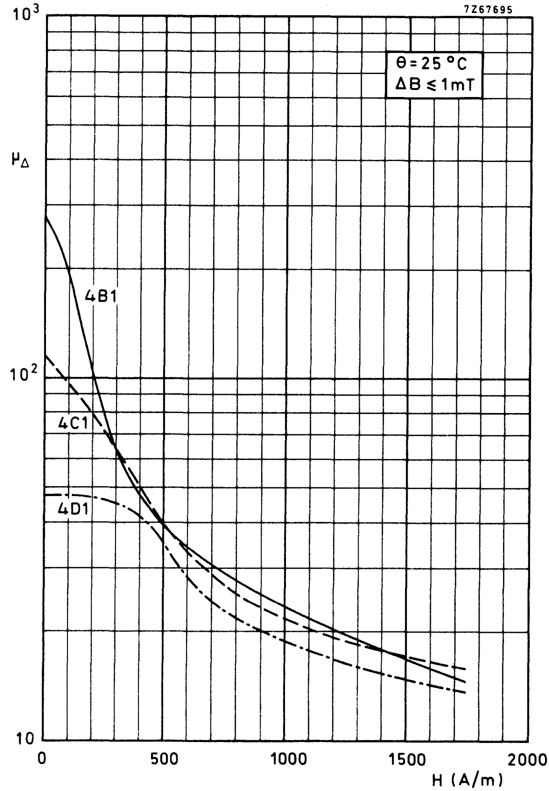
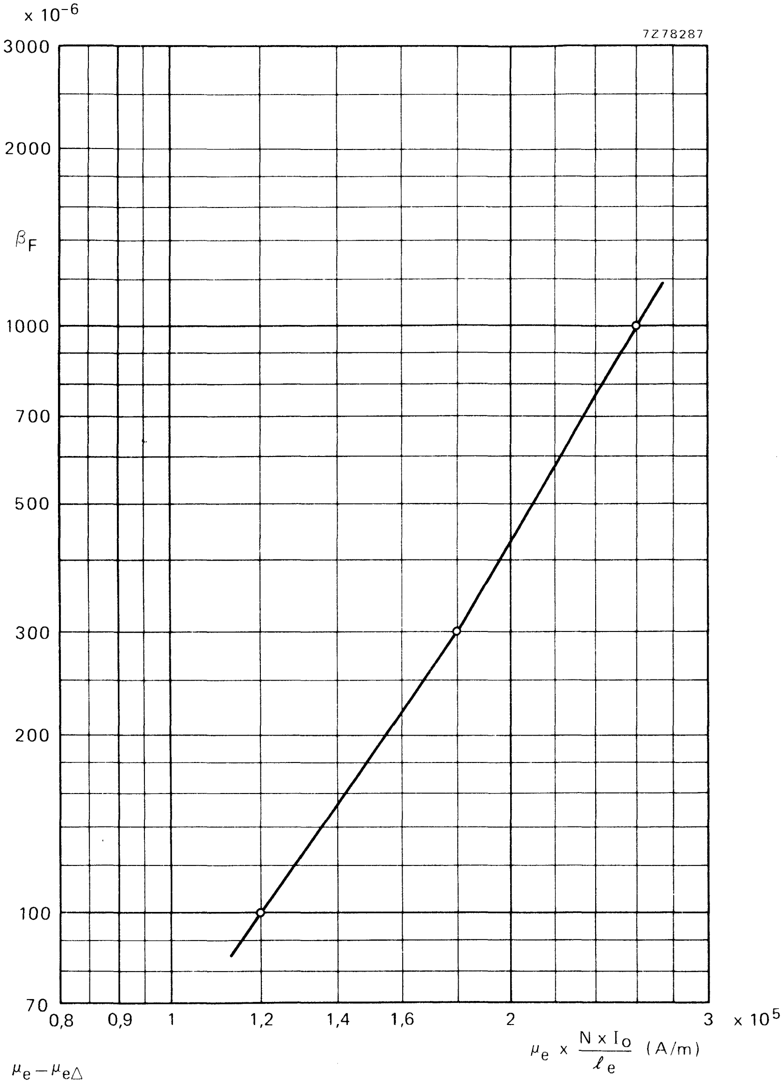
100
50
0
−300
−200
−100
0
100
200
300
H (A/m)


7Z67697.1
FXC 4C6
f = 16 kHz
ΔB ≤ 0,2 mT
—— θ = 25°C
– – θ = 70°C
Δμ_Δ (% μ_Δ)
150
100
50
0
−1500
−1000
−500
0
500
1000
1500
H (A/m)


7Z67695
θ = 25 °C
ΔB ≤ 1mT
10^3
μ_Δ
10^2
10
4B1
4C1
4D1
0
500
1000
1500
2000
H (A/m)

D.C. sensitivity

material grade: 3B8



$$\beta_F = \frac{\mu_e - \mu_{e\Delta}}{\mu_e \times \mu_{e\Delta}}$$

Inductance variation as a function of d.c. polarization. The measured values are situated in the area to the right of the curve.

YOKE RINGS

YOKE RINGS FOR USE IN DEFLECTION COILS FOR PICTURE TUBES

Survey of types

application	FXC grade	catalogue number	page
B/W			
90° (Tiny vision)	2A2	3122 134 91680	54
110°	2A2	3122 134 91940	55
110°	3C2	3122 104 93840	51
110°	3C2	3122 134 90750	52
Colour			
90°	2A2	3122 134 91610	53
90°	2A2	3122 134 92510	57
90°	2A2	3122 134 92600	58
110° (30AX)	3C2	3122 134 92500	56

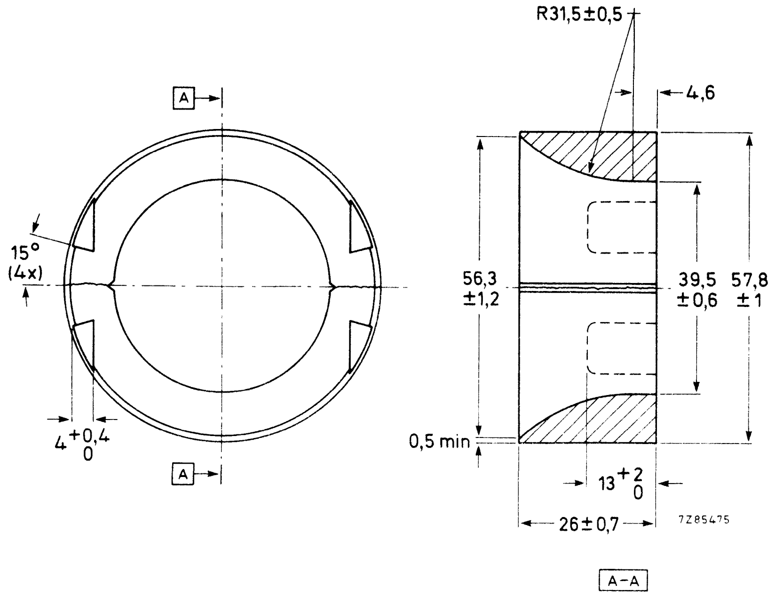
The data on these yoke rings are arranged on the following pages in order of catalogue number.

YOKE RING FOR 110° B/W TUBES

- Material grade FXC 3C2
- Mass 135 g
- Catalogue number 3122 104 93840

Spring clips for assembling can be supplied, catalogue number 3122 101 06340.

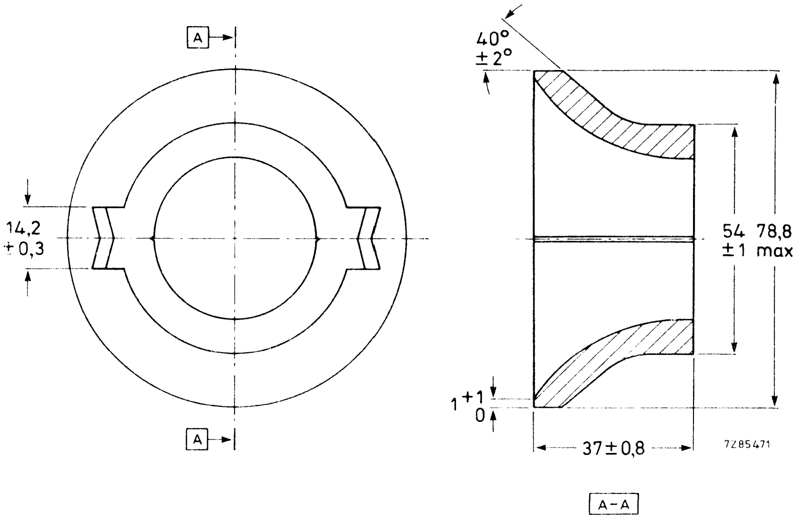
Dimensions in mm



YOKE RING FOR 110° B/W TUBES

- Material grade FXC 3C2
- Mass 227 g
- Catalogue number 3122 134 90750

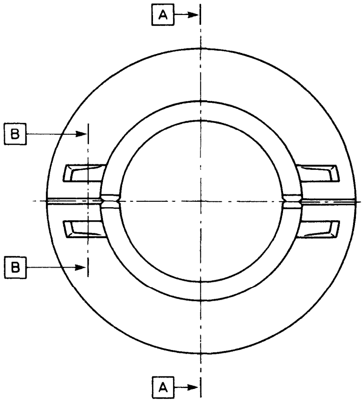
Dimensions in mm

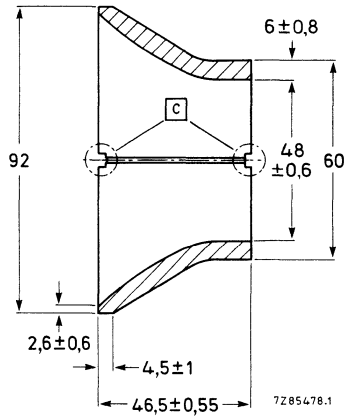


YOKE RING FOR 90° COLOUR TUBES

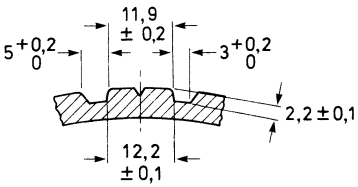
- Material FXC 2A2
- Mass 268 g
- Catalogue number 3122 134 91610

Dimensions in mm

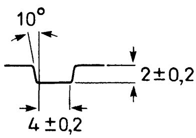




A–A



B–B

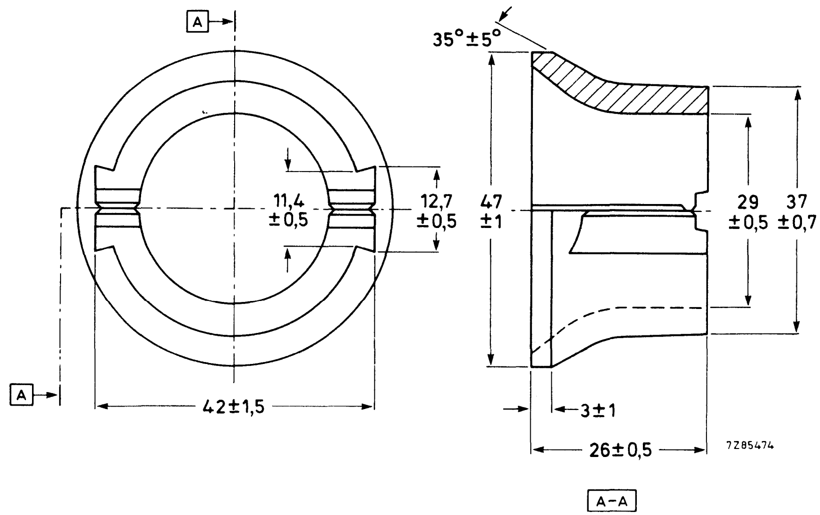


C

YOKE RING FOR 90° B/W TINY VISION TUBES

- Material grade FXC 2A2
- Mass 62 g
- Catalogue number 3122 134 91680

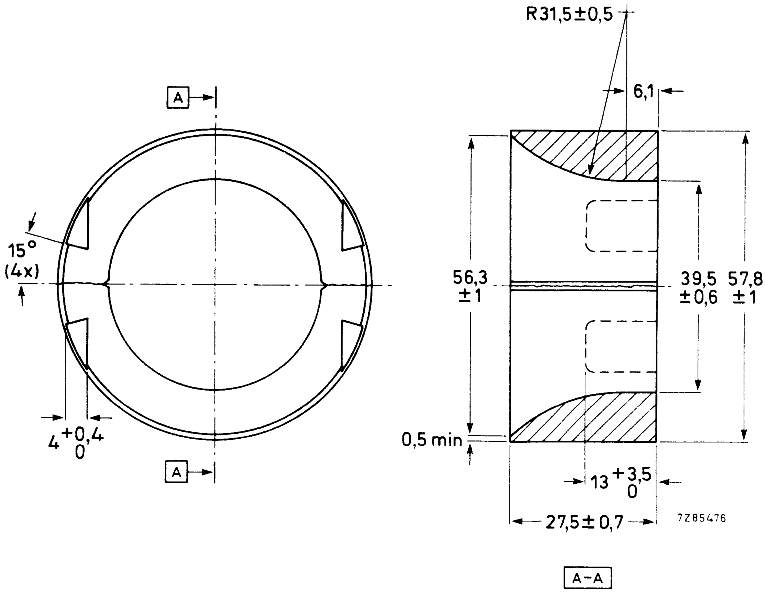
Dimensions in mm



YOKE RING FOR 110° B/W TUBES

- Material grade FXC 2A2
- Mass 135 g
- Catalogue number 3122 134 91940

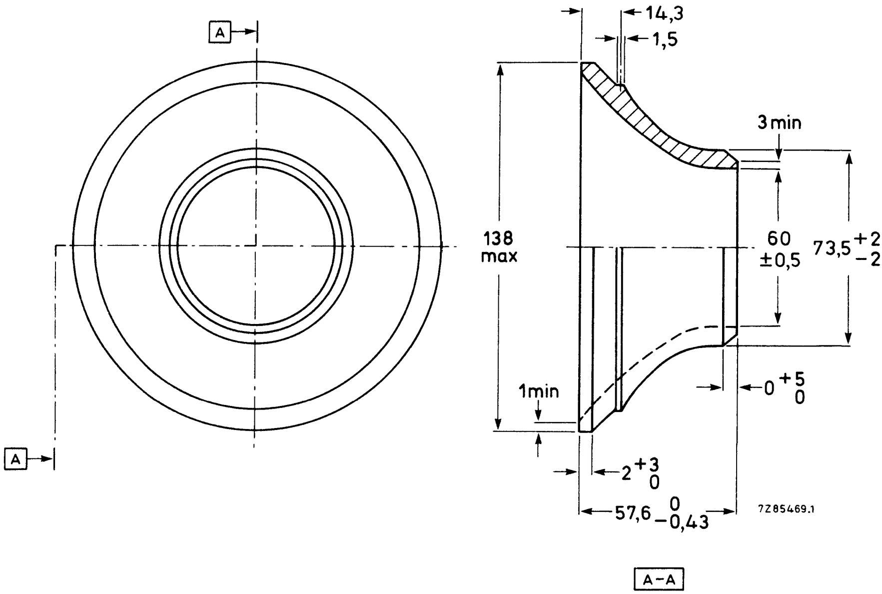
Dimensions in mm



YOKE RING FOR 110° COLOUR TUBES
30AX SYSTEM

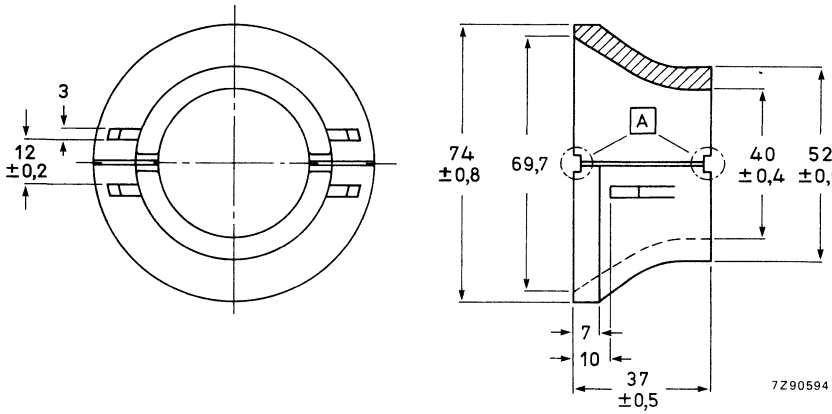
- Material grade — FXC 3C2
- Mass — 530 g
- Catalogue number — 3122 134 92500 silanated

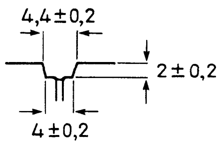
Dimensions in mm



YOKE RING FOR 90° COLOUR TUBES

- Material grade FXC 2A2
- Mass 135 g
- Catalogue number 3122 134 92510



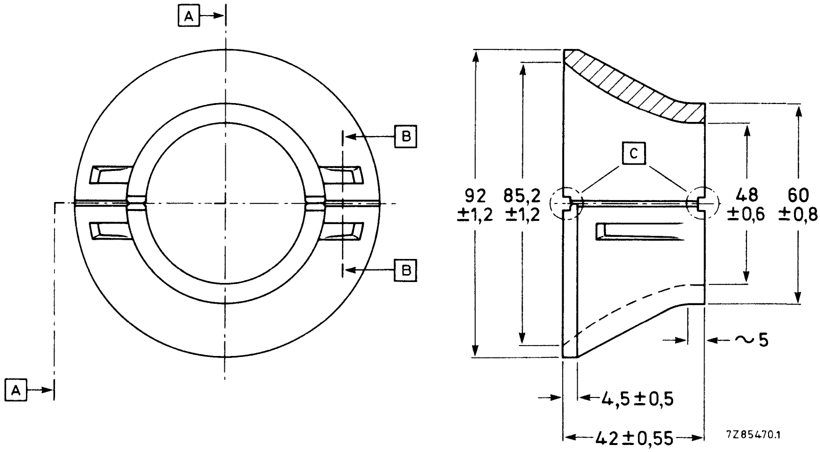


A

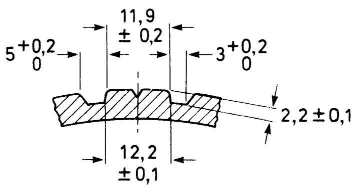
YOKE RING FOR 90° COLOUR TUBES

- Material grade FXC 2A2
- Mass 268 g
- Catalogue number 3122 134 92600

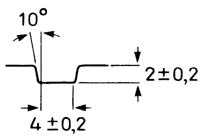
Dimensions in mm



A–A



B – B



C

E/EC/ETD/U/I CORES

INTRODUCTION

CORE TYPE AND MATERIAL GRADE SELECTION GUIDE

The range of applications of ferrite transformer and choke cores is very wide. This applications survey concentrates on the more popular, and more typical, applications so that these can be used as a guide to other, similar requirements. However, even where a clear indication in the Selection Guide is given for a given core and material, cost/performance trade-offs might be possible, especially where large quantities are involved. Intending users of ferrite cores are always recommended to consult us during equipment development, before a final core selection is made.

Using the selection guide

Starting with the paragraph Applications, below, find the application description that most closely resembles the intended application. Note the number or numbers of the application category. Proceed to the paragraph Application Categories and refer to the Category number obtained previously.

If the description of the application conditions fits the intended application, consult the tables or charts of core types indicated to select the most suitable core and material grade.

Applications

application	application category
Chokes, power	1
suppression	3
Driver transformers	2
Line-output transformers	1
Matching transformers	2
Power-supply transformers, inverters	1
Converters	1
Switched-mode	1

Application categories

1. High power, high flux density, minimum size

Preferred material: Ferroxcube 3C8.

The design of transformers where maximum throughput power is required in the minimum of volume requires careful balancing of core and winding dissipation. For details, refer to the section Cores for switched-mode power supplies. Selection charts for power transformer cores for switch-mode power supplies are also given in this section.

Ferroxcube 3C8 has been developed for optimum performance in power applications, and is the ideal material where transformer or choke volume is a principal consideration. All EC, E and U cores are available in Ferroxcube 3C8, but coil formers for U cores and some E cores are not listed here. Power-choke core selection and design is considered in detail in the section Power Choke Design.

Round-section U core type U64 in Ferroxcube 3C8 material was developed primarily for line-output transformers in colour TV receivers. A number of other round-section U cores suitable for line-output transformers is available, see section 'Cores for line-output Transformers'.

Small, square-section U cores in Ferroxcube 3C8 material are especially suitable for small-power-supply applications, such as inverters. The effective magnetic dimensions of pairs of the cores are listed in the following table.

core type	effective dimensions		
	l_e (mm)	A_e (mm^2)	V_e (mm^3)
U10/8/3	38,4	8,63	331
U15/11/6	48	30	1 440
U20/16/7	68	56	3 800
U25/20/13	86	100	8 600
U30/25/16	111	157	17 400

Very large cores for transformers in the kilowatt power range can be assembled from larger, square-section U cores of types U93/52/30 and U100/57/25: either in combination with matching I cores, or by stacking. Please consult us on the properties of large stacks.

2. Minimum loss, low operating flux density

Preferred material: Ferroxcube 3E1.

A wide range of E cores, including DIN E cores, is available in Ferroxcube 3E1. These cores are also available with a ground air gap. The table below gives winding window area and induction factor A_L for the E cores with coil formers used in pairs. The induction factor A_L has a tolerance of 25% for cores selected at random and pressed together.

Small U cores in Ferroxcube 3C8 material often prove more attractive for driver transformers. These are listed under category 1.

core type	winding window area (mm^2)	A_L (nH)
EE20/20/5	27	2 405
EE30/30/7	80	3 330
EE42/42/15	178	7 555
EE55/55/21	250	11 937
EE65/65/13	394	15 450

3. Suppressor chokes

The small, square-section U cores listed under category 1 are ideal for use as cores for suppressor chokes in higher-current applications. Where there is a d.c. component of the line current, a spacer should be used. The data given in the section Power Chokes, together with curves in the data sheets should be used for selecting cores and designing suppressor chokes (see pages C18 to C21).

CORES FOR SWITCHED-MODE POWER SUPPLIES

Ferroxcube grade 3C8 was developed specifically to meet the stringent demands placed on power supply chokes and transformers, especially those in switched-mode power supplies, operating at 10 kHz or higher. At these high frequencies the eddy current losses are very low due to the high bulk resistivity of Ferroxcube 3C8, whose permeability remains the same as at low frequencies. In general, therefore, this means a much smaller transformer can be designed than with laminated iron cores.

Ferroxcube 3C8 is a manganese-zinc ferrite which meets the main magnetic requirements for power transformer cores:

– high maximum flux density (B) and high relative amplitude permeability (μ_a).
– high resistivity (ρ) to ensure low eddy current losses.
– high Curie point, so that magnetic properties are retained at high temperature (up to 200 °C).
– in the operating temperature range (up to 100 °C), losses fall as temperature increases.

Switched-mode power supply circuits

The basic arrangement of a switched-mode power supply (SMPS) is shown in Fig. 1. In this system, the power input is rectified and filtered and the resulting d.c. voltage is chopped at a high frequency by a switch. The chopped waveform is applied to the primary of a transformer and the secondary output is rectified and filtered to give the required d.c. output. The output voltage is sensed by a control circuit which supplies a correction signal to the drive circuit to vary the ON-OFF time of the switched waveform and compensate for any change at the output. This same system can operate from a battery or any other d.c. input.

There are numerous circuit designs that can be used to convert d.c. input voltage to the required d.c. output voltage. But some preliminary design selection will have to be made as to the type of converter circuit to use. Since the emphasis here is on the design of the magnetic components used in switched-mode power supplies, the many different designs are considered from a magnetics point of view. Analysing available circuits this way, three broad basic converter designs can be distinguished, based upon the magnetic converting device: flyback, forward and push-pull converters.

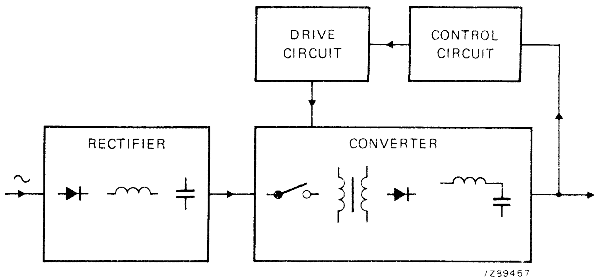
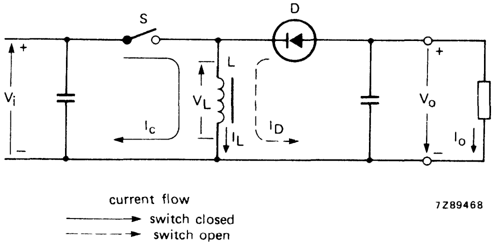


Fig. 1 Block diagram of switched-mode power supply.

Flyback converter

Figure 2 shows the basic circuit of a flyback converter and the associated waveforms. When the switch is closed (transistor conducts), the supply voltage is connected across the inductor and the output diode is non-conducting: current rises linearly, storing energy, until the switch is opened. When this happens the voltage across the inductor reverses and the stored energy is transferred into the output capacitor and load. By varying the conduction time of the transistor at a given frequency, the amount of energy stored in the inductor during each ON cycle can be controlled. This is a way of controlling and changing the output of a switched-mode power supply.



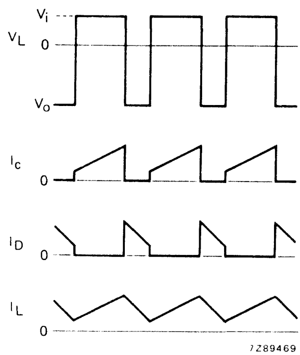


Fig. 2 Basic circuit of a flyback d.c. to d.c. converter with associated waveforms.

In Fig. 3, the basic circuit of Fig. 2 is developed into a practical circuit using an inductor with two windings. The progression from Fig. 3a via 3b to 3c can easily be understood. In a flyback converter all the energy to be transferred to the output capacitor and load is first stored in the inductor. It is therefore possible to obtain line isolation by adding a secondary winding to the inductor. (Although an inductor with more than one winding appears in schematic diagrams as a transformer, it is referred to as an inductor in accordance with its function.) Another advantage of the flyback converter is the fact that no smoothing choke is required in the output circuit. This is important in high-voltage supplies and in power supplies with a number of output circuits (see Fig. 4). A disadvantage of this type of converter is that the output capacitor is charged only during the transistor OFF cycle. Hence the output capacitor ripple current is high when compared with the other types of converters. Another disadvantage of the flyback converter relates to the energy storage in the inductor. The inductor is driven in one direction only, which requires a larger core in a flyback design than for an equivalent design using a forward or push-pull converter.

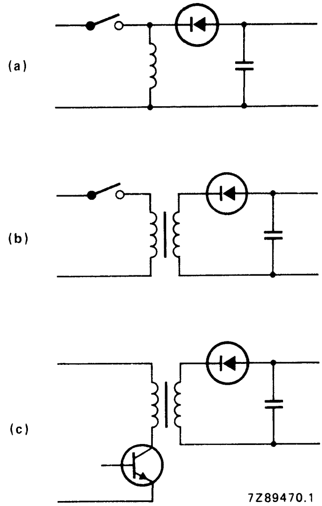


Fig. 3 Development of practical flyback converter circuit.

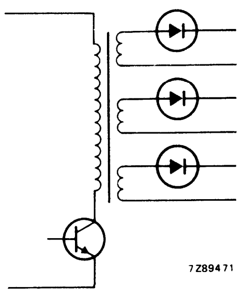


Fig. 4 Multiple output flyback converter circuit.

Forward converter

Figure 5 gives the basic circuit of the forward converter, along with the associated voltage and current waveforms. When the switch is closed (transistor conducts), the current rises linearly and flows through the inductor into the capacitor and the load. During this ON cycle, energy is both transferred to the output and stored in the inductor L. When the switch is opened the energy stored in the inductor causes the current to continue to flow to the output via the diode.

As in the flyback converter, the amount of energy stored in the inductor can be varied by varying the ON-OFF cycles. This gives a method of controlling the output of the forward converter.

Figure 6 shows a more practical forward converter circuit with a line-isolation transformer. The need for a separate transformer for line isolation is an obvious disadvantage of this converter circuit when compared with the flyback converter. A major advantage of the forward converter in comparison with the flyback converter is the lower ripple voltage at the output. This is due to the fact that the high-frequency ripple current feeding into the smoothing capacitor is limited by the inductor. This advantage is of particular interest for low-voltage supplies.

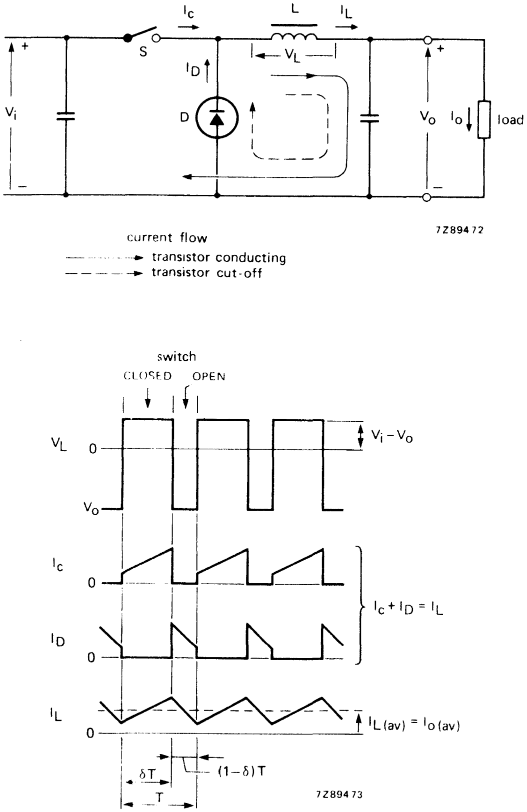


Fig. 5 Basic circuit of a forward d.c. to d.c. converter with associated waveforms.

Multiple outputs in a forward converter can be obtained by using more secondary windings on the transformer. Each of these windings, however, will have to have the two diodes, an inductor and capacitor. This method can cause regulation difficulties and is expensive.

Under certain conditions, a better approach is to use a combination of forward and flyback converters. (A dual output converter where this principle is demonstrated is shown in Fig. 7). Here the energy is stored in the inductor, to power another output. At the end of the transistor conduction cycle the voltage across the inductor is equal to the output voltage V_{o1}. Therefore, if V_{o1} is stabilized, V_{o2} will also be stabilized. The amount of energy that can be stored in the inductor is clearly limited. However, this circuit is a practical alternative in cases where a constant-load second output is required that is 30 per cent or less of the main output.

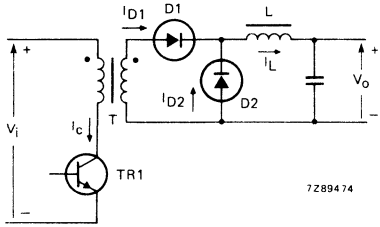


Fig. 6 Forward converter with line isolation transformer.

In Fig. 7 the transformer is shown with a tertiary winding and a diode in series. The purpose of the additional winding and diode is as follows: during the conduction cycle of the transistor, the magnetizing current increases linearly to some final value. As soon as the transistor is turned off, this magnetizing current is transferred, via the additional winding and diode, back to the d.c. supply. This demagnetizing winding should be tightly coupled with the primary winding to avoid voltage spikes during the switching of the transistors. The demagnetizing winding and diode ensure a return of the transformer's magnetic energy back to the d.c. supply and also limits the transistor collector voltage to twice the d.c. input voltage.

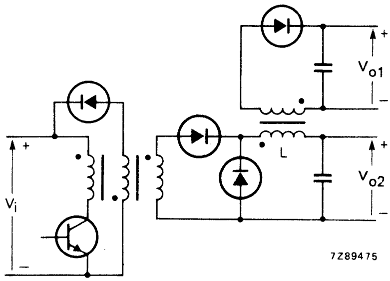


Fig. 7 Dual-output forward converter.

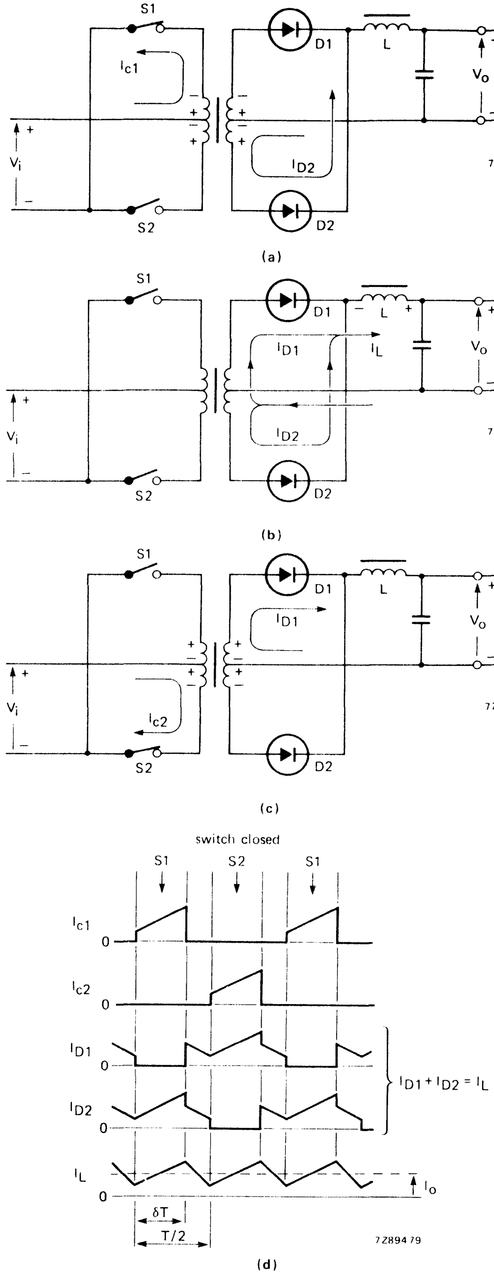


Fig. 8 Basic circuit of a push-pull d.c. to d.c. converter with associated waveforms.

Push-pull converter

Figure 8 gives the basic circuit of the push-pull converter, with voltage and current waveforms. The push-pull converter is, in fact, an arrangement of two forward converters operating in antiphase (push-pull action). With switch S_1 closed (Fig. 8a) diode D_2 conducts and energy is simultaneously stored in the inductor and supplied to the load. With S_1 and S_2 open (Fig. 8b), the energy stored in the inductor will continue to support the load current by the parallel diodes D_1 and D_2, which are now acting as flywheel diodes. When switch S_2 closes (Fig. 8c), diode D_1 will continue to conduct, diode D_2 will stop conducting and the process will repeat itself.

In Fig. 9 a practical push-pull converter circuit is shown. A push-pull converter circuit doubles the frequency of the ripple current in the output filter and, therefore, reduces the output ripple voltage. A further advantage of the push-pull operation is that the transformer core is excited alternately in both directions in contrast to both the forward and flyback converters. Therefore, for the same operating conditions and power throughput, a push-pull converter design can use a smaller transformer core.

Multiple outputs can be constructed by using several secondary windings, each with its own output diodes, inductor and smoothing capacitor. The method that relies on the energy stored in the output choke can also be used here (see Fig. 7, under Forward Converters).

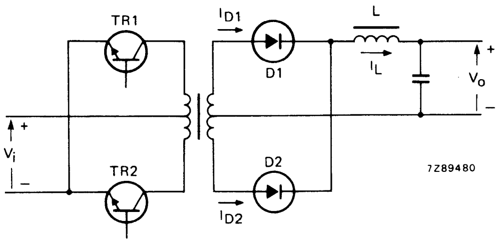


Fig. 9 Conventional push-pull converter circuit.

Converter selection

In each of the three basic converter designs there are several different circuit possibilities. In the flyback and forward converters, single and two-transistor designs can be used. If two transistors are used, they will switch simultaneously. This type of circuit preference is determined by the allowable collector emitter voltage and collector current of the transistor. In push-pull converter designs, the primary of the transformer can be connected in several ways (see Fig. 10). Depending upon how the transformer primary is driven, it is possible to differentiate between single-ended (Fig. 10a), push-pull (Fig. 10b) and full-bridge circuits (Fig. 10c). Again, decisions on circuit details are determined by the transistor capabilities.

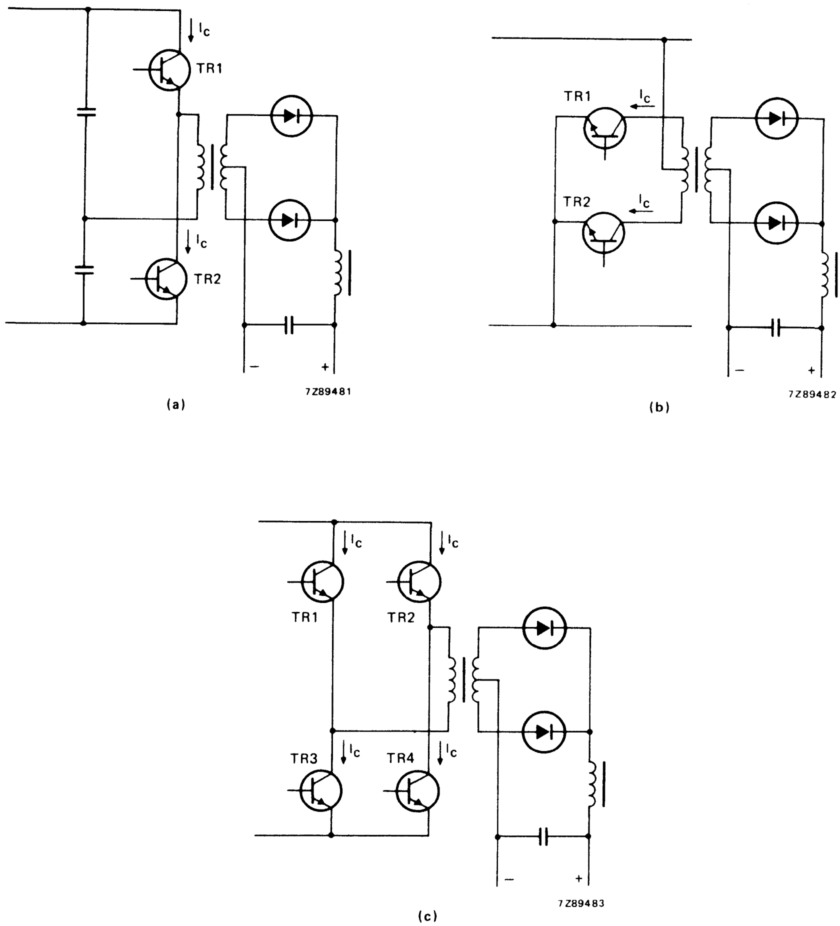


Fig. 10 Several push-pull converter circuits.

For a particular converter design, the first selection that should be considered is obviously the type of converter circuit. To aid in this initial converter circuit selection, Fig. 11 offers a rough guide to the type of converter, its output voltage and power capability. This selection has to be considered along with other requirements such as line isolation, ripple content, overall efficiency, multiple outputs, etc. Table 1 summarizes the most significant properties of a converter design. It shows the relative strengths and weaknesses of the three types of converters with regard to these characteristics.

For a high performance, high power, single output supply, where ripple requirement is well below 1%, the push-pull design is the obvious choice. For smaller power versions of this type of supply, the forward or double forward converter provides a useful alternative to the push-pull converter.

In high-voltage supplies, the flyback converter is the most suitable circuit and should be considered first.

In multiple-output supplies, again, the flyback converter is normally the first choice because it avoids the necessity of providing a number of output windings on the inductor, together with a single diode and capacitor for each.

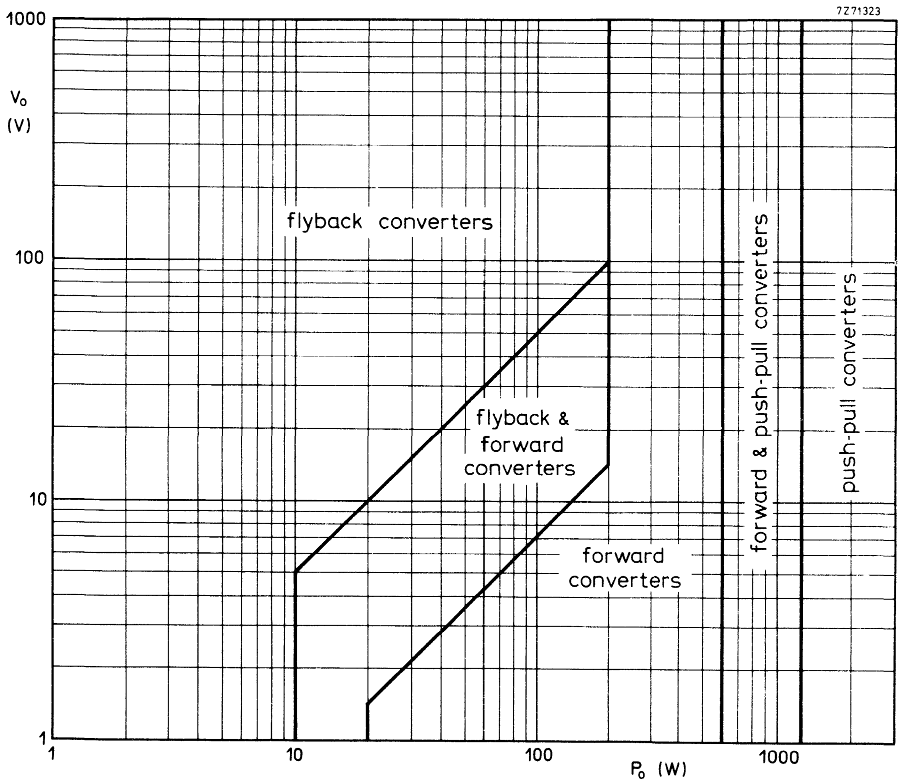


Fig. 11 Converter circuit selection as a function of output voltage and throughput power.

Table 1

	type of converter circuit		
	flyback	forward	push-pull
Circuit simplicity	+	0	–
Number of components	+	0	–
Drive circuitry	+	0	–
Output ripple	–	0	+
Choke volume	–	0	+
Transformer volume	not required	0	+
Mains isolation	+	–	+
High power	–	0	+
High voltage	+	0	0
Multiple outputs	+	0	0

\+ Favourable
0 Average
– Unfavourable

Core selection curves

When designing a transformer, use the following charts to select a core whose indicated throughput power under the desired operating conditions is equal to, or greater than, the power required.

The power-handling capability of a given core is determined by its geometry and available winding area, which are fixed, and by the following factors which depend on the specific application.

Winding configuration

In the derivation of the curves for three-winding transformers it has been assumed that each winding occupies one third of the winding area. This would apply when the third winding is bifilar wound with the primary and uses the same gauge of wire. However, because the third winding carries only magnetizing current in forward converters, or current spikes caused by leakage inductance in flyback converters, the current in the winding is normally low. Therefore, the third winding may be wound with thinner wire and may occupy less than one third of the winding area. In this case, the throughput power can be increased by up to about 20% when it would equal that for a two-winding curve.

When multiple secondaries are used to supply a number of different output-rectifier circuits, the total number of secondary windings should be regarded as a single secondary. The area of this single secondary should then be divided between the individual secondaries in proportion to the power to be delivered by each winding.

Operating frequency

The preferred operating frequency of a switched-mode power supply is greater than 20 kHz to avoid audible noise from the transformer.

Ambient temperature

Ambient temperature, together with the maximum core temperature (see next paragraph), determines the maximum temperature rise, which in turn fixes the permissible total power dissipation in the transformer. Curves of temperature rise versus power dissipation are included in the published data for each core. In the construction of the core selection curves, a maximum ambient temperature of 60 °C has been assumed. This allows a 40 °C temperature rise from the ambient to the centre of the transformer for a maximum core temperature of 100 °C.

Core temperature

Core temperature determines the maximum flux density, or flux for a given core, to avoid saturation. Curves of maximum recommended flux against temperature are given in the published data for each core. In the construction of the core selection curves, a maximum core (hot spot) temperature of 100 °C has been assumed because this is acceptable for a wide range of applications and does not exceed the maximum temperature rating of generally-available enamelled wire.

Flux density (see relevant graphs on following pages) ←

To avoid saturation in the cores the flux density in the minimum cross-section must not exceed the saturation flux density of the material at 100 °C. The allowable total flux is the product of this flux density and the bottom-limit minimum core area and must not be exceeded even under transient conditions: when a load is suddenly applied at the power supply output, and maximum duty factor occurs together with maximum supply voltage. Under steady-state conditions, where maximum duty factor occurs with minimum supply voltage, the flux is reduced from its absolute maximum permissible value by the ratio of the minimum-to-maximum supply voltage. (At all higher supply voltages the voltage control loop reduces the duty factor and keeps the steady-state flux constant.)

In the construction of the core selection curves, the minimum-to-maximum supply voltage ratio has been taken as 1 : 1,72, this being typical for most applications. The minimum supply voltage assumed in the curves is defined as that voltage which would correspond to a duty factor δ of 0,5. If in practice the maximum duty factor is limited to less than 0,5, then the practical minimum supply voltage would be increased proportionately; for example, by 10% if δ_{max} = 0,45.

Winding-window utilization

In the construction of the core selection curves, the gaps of 4 mm on each side of the windings (see Figs 12 and 13) are to comply with IEC 435 mains isolation requirements. If these gaps are omitted, the maximum throughput power is increased to P' where:

$$P' = P\sqrt{\left(\frac{\text{full winding width}}{\text{full winding width} - 8\ \text{mm}}\right)}$$

that is, by about 25% for small cores and about 10% for large cores.

The maximum percentage of copper in the available winding area is generally about 50%, corresponding to windings of circular cross-section and insulation equal to 25% of the wire diameter.

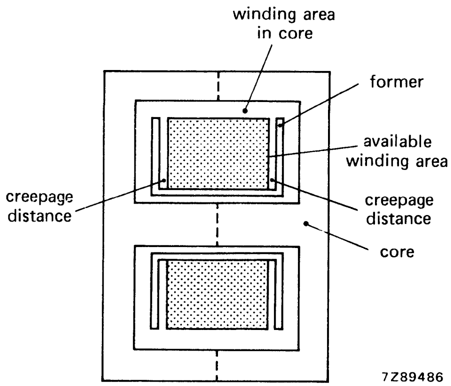


Fig. 12 To allow for creepage distance for 230 V mains isolation, a gap of 4 mm is left at each side of the winding.

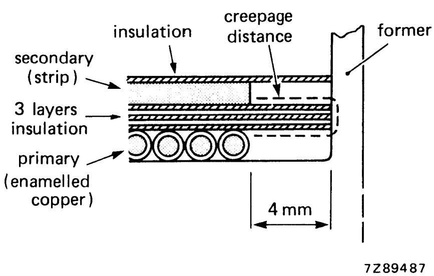


Fig. 13 Detailed section of winding showing how creepage distance is used.

Ratio F_W/F_R

The term F_W is the winding copper factor and is defined as:

$$F_W = \frac{A_{Cu}}{A_W} \qquad \frac{\text{total cross-sectional area of copper in windings}}{\text{available winding area}}$$

and F_R is defined as:

$$F_R = \frac{\text{a.c. resistance of winding}}{\text{d.c. resistance of winding}}$$

Both F_W and F_R depend on the conductor sizes and winding configuration employed in any particular transformer design, and these will depend on the required input and output voltages, etc. Achievable F_W/F_R ratios for normal solid wire and strip conductors depend on the particular transformer specification and can only be assessed for particular cases. However, the experience of a number of transformer designers, employing various cores and operating frequencies, has produced information on the values of F_W/F_R that can usually be achieved. This information has been used in the construction of the core-selection charts.

Ratio γ (flyback converters)

This is the ratio of minimum-to-maximum load current over which good output-voltage regulation is required, and over which duty factor remains roughly constant for a fixed input voltage.

Push-pull converter balance

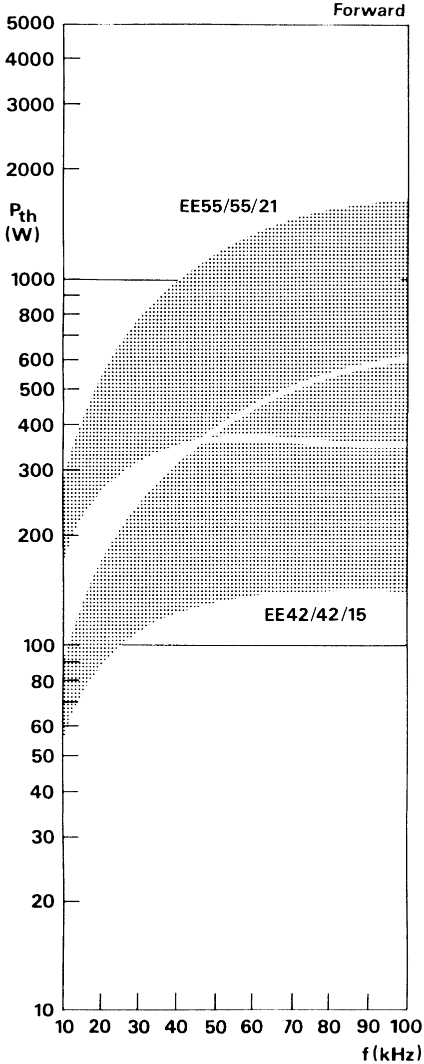
Two sets of selection charts are given for push-pull converters. One applies to converters in which precautions have been taken to ensure balanced operation so that there is no d.c. component of core flux. Here the value of α is taken as at least 1,72. The other applies to converter designs where there is a possibility of d.c. core polarization. The value of α used, 3,44, allows for operation on one half of the hysteresis loop only and is thus a worst-case value.

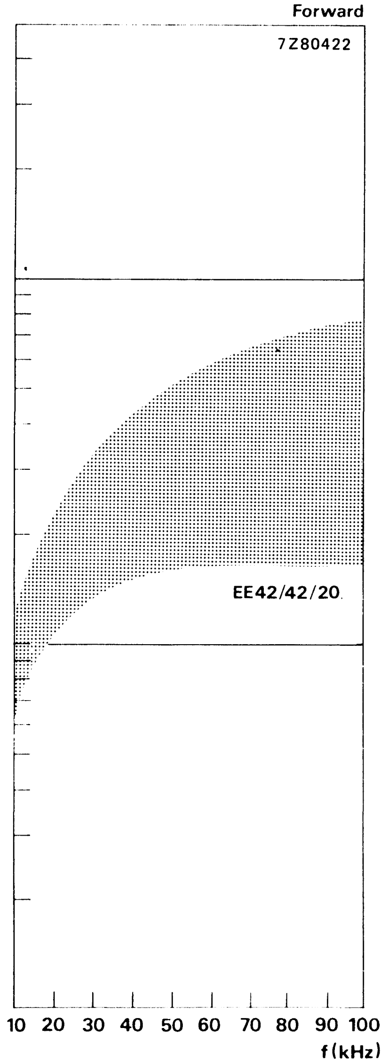
Using the selection charts

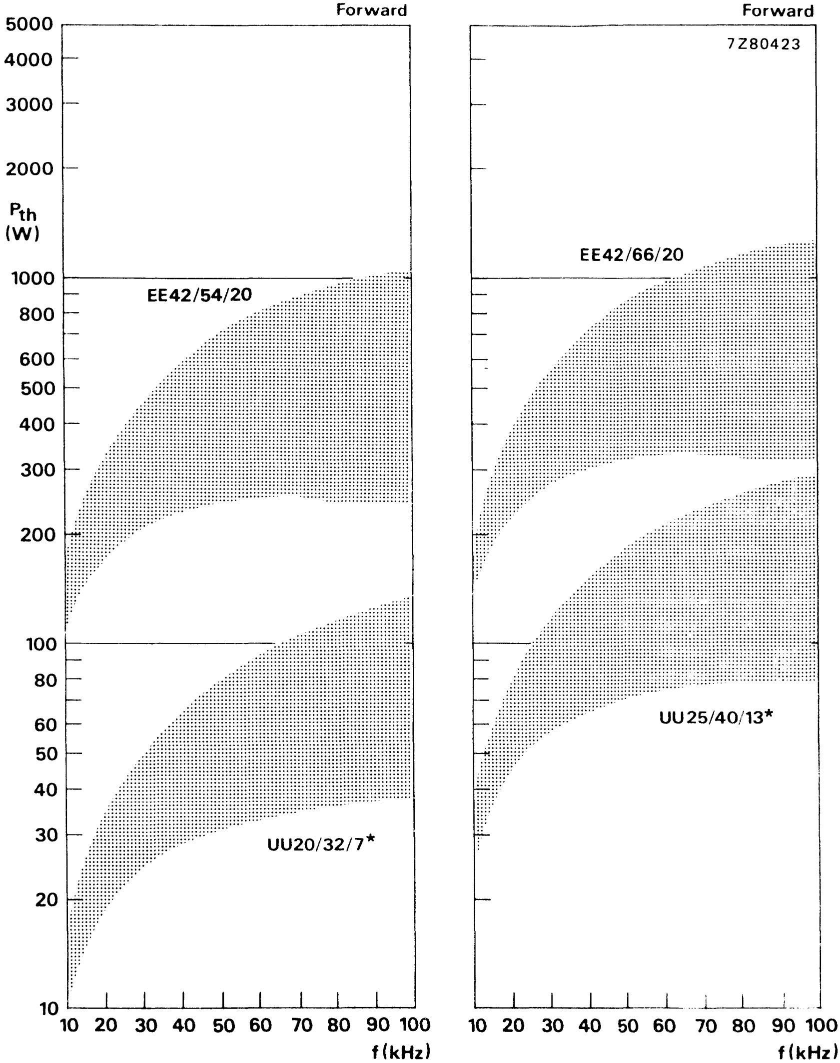
These charts are intended as a guide only: the choke selection procedure, based on stored energy, should be used to make the choice of core. These charts can be used to check that choice. See 'Power choke design'.

On the charts, each core type is represented by a shaded area. The upper limit of this area is a curve of throughput power against frequency obtainable under the best possible conditions: no creepage distance, thus maximum winding window; flux density reduced below that for α = 1,72 at higher frequencies; and a ratio of F_W/F_R = 0,5, which is just attainable at the lower frequencies with bunched (Litz) wire windings. The lower limit of the core area is a curve of throughput power against frequency for a basic transformer design: simple, but optimized, solid-wire windings, 8 mm creepage distance for IEC mains isolation, and optimum flux density sweep is assumed.

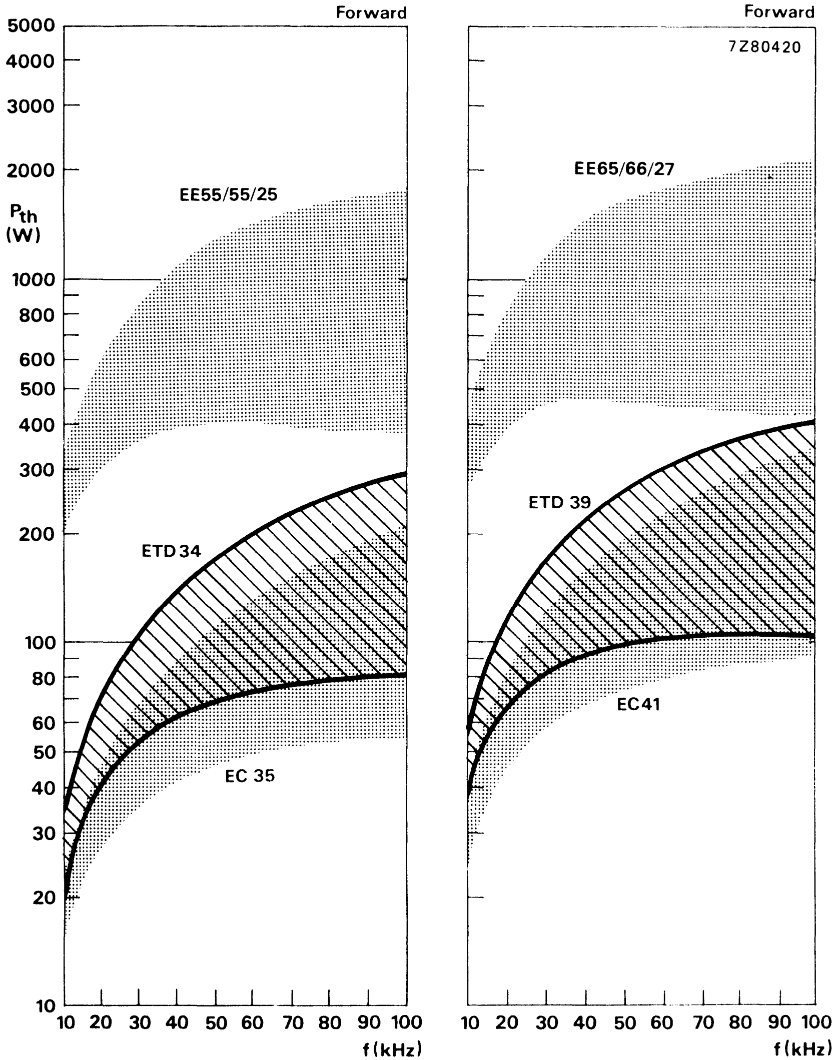
To select the best core for the application, draw a line on the chart for the desired converter type at the required throughput power. Possible cores for the transformer are those for which this power line is within or below the operating area at the desired operating frequency. The proximity of the core operating point to the upper boundary of its area will depend on the degree to which the design is to be elaborated.

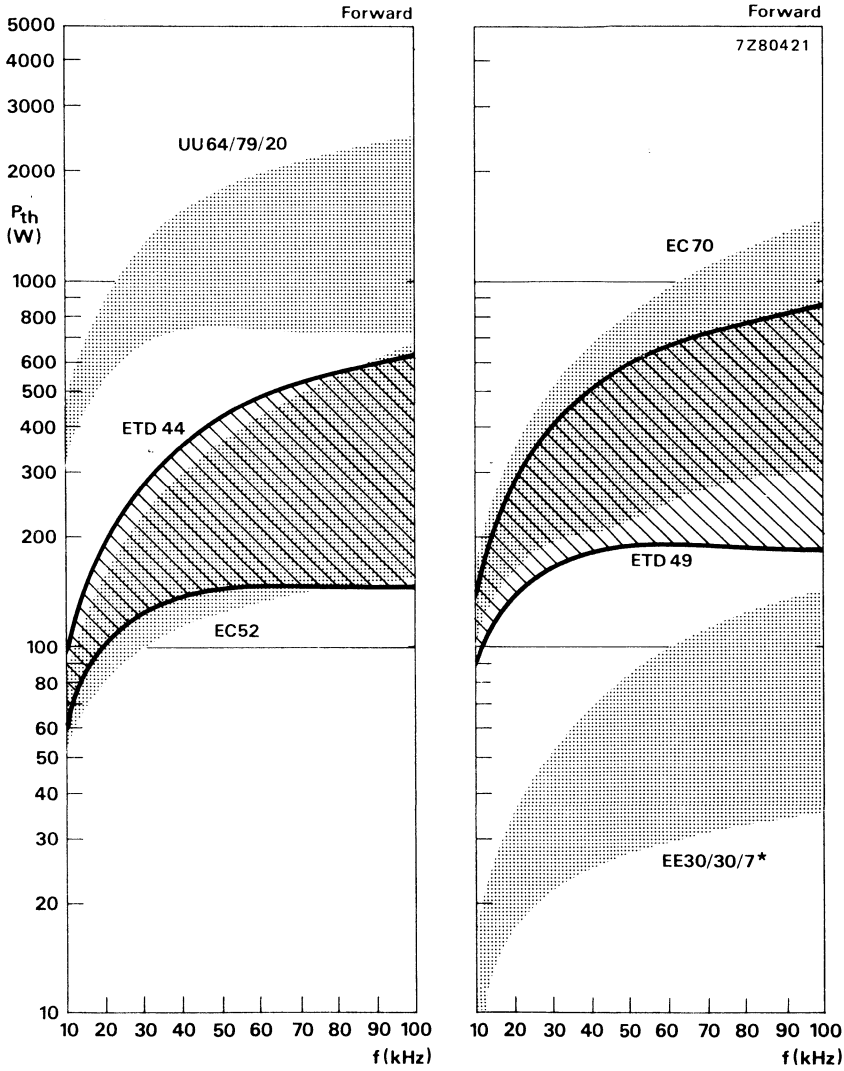

Forward
5000
4000
3000
2000
P_{th}
(W)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
EE55/55/21
EE42/42/15
10 20 30 40 50 60 70 80 90 100
f (kHz)


Forward
7Z80422
EE42/42/20
10 20 30 40 50 60 70 80 90 100
f (kHz)

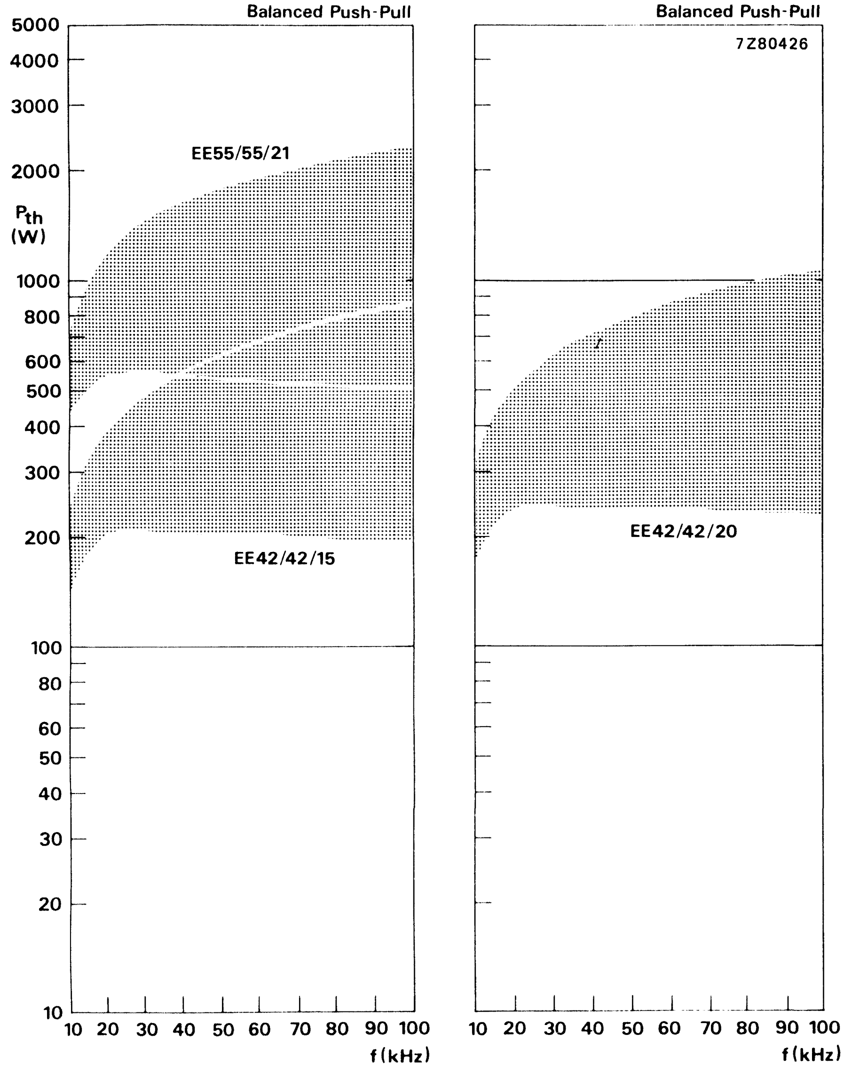


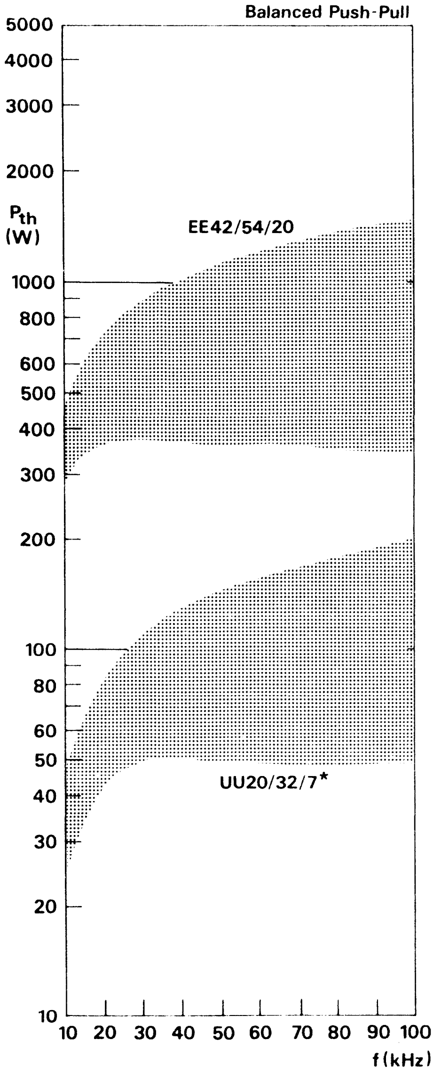
* Without creepage allowance.

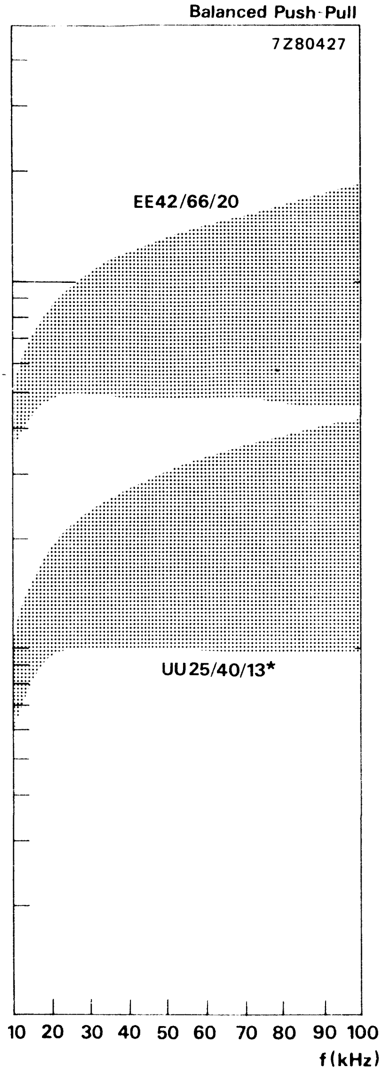

Forward
5000
4000
3000
2000
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
P_{th} (W)
EE55/55/25
ETD 34
EC 35
10 20 30 40 50 60 70 80 90 100
f (kHz)
Forward
7Z80420
EE65/66/27
ETD 39
EC41
10 20 30 40 50 60 70 80 90 100
f (kHz)



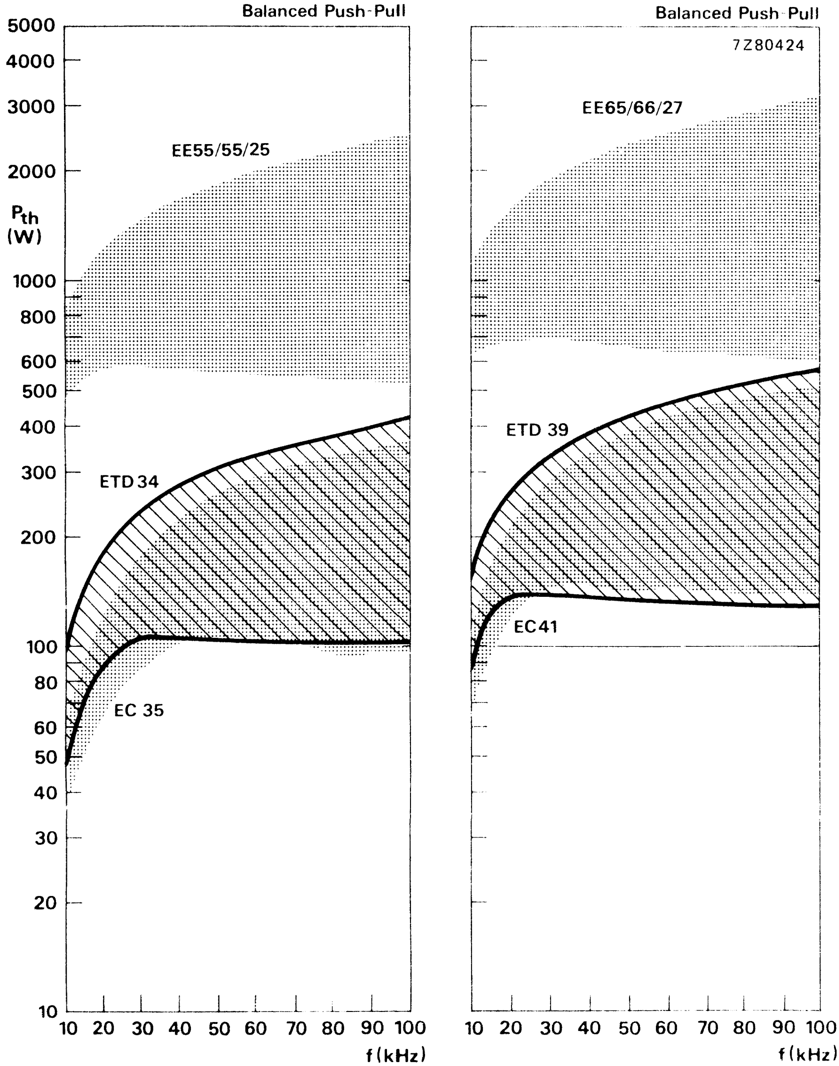
* Without creepage allowance.

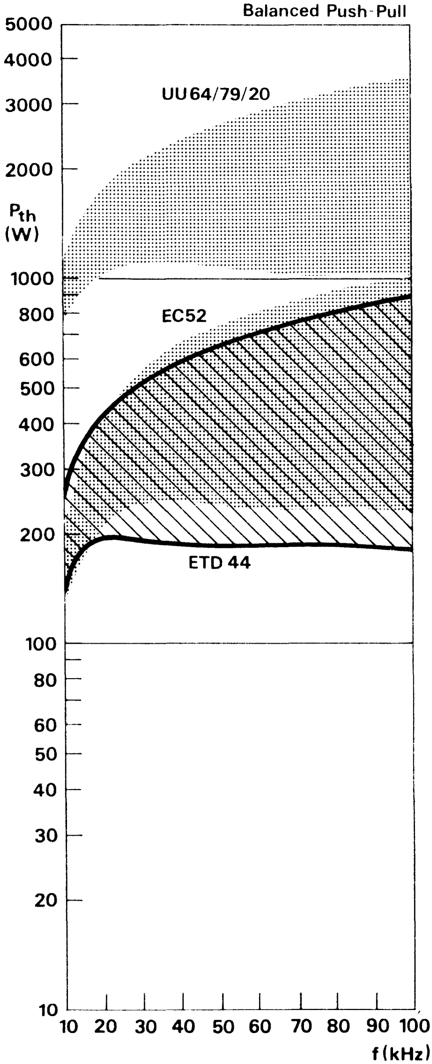

Balanced Push-Pull
Balanced Push-Pull
7Z80426
5000
4000
3000
2000
Pth
(W)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
EE55/55/21
EE42/42/15
EE42/42/20
10 20 30 40 50 60 70 80 90 100
f (kHz)
10 20 30 40 50 60 70 80 90 100
f (kHz)

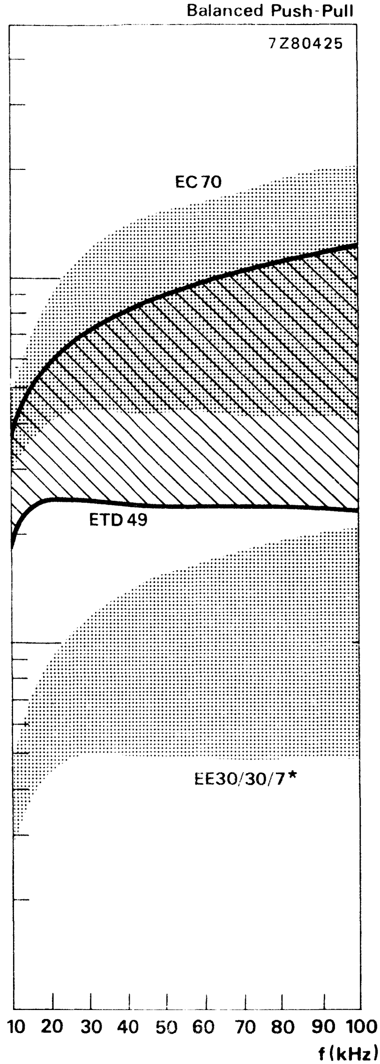




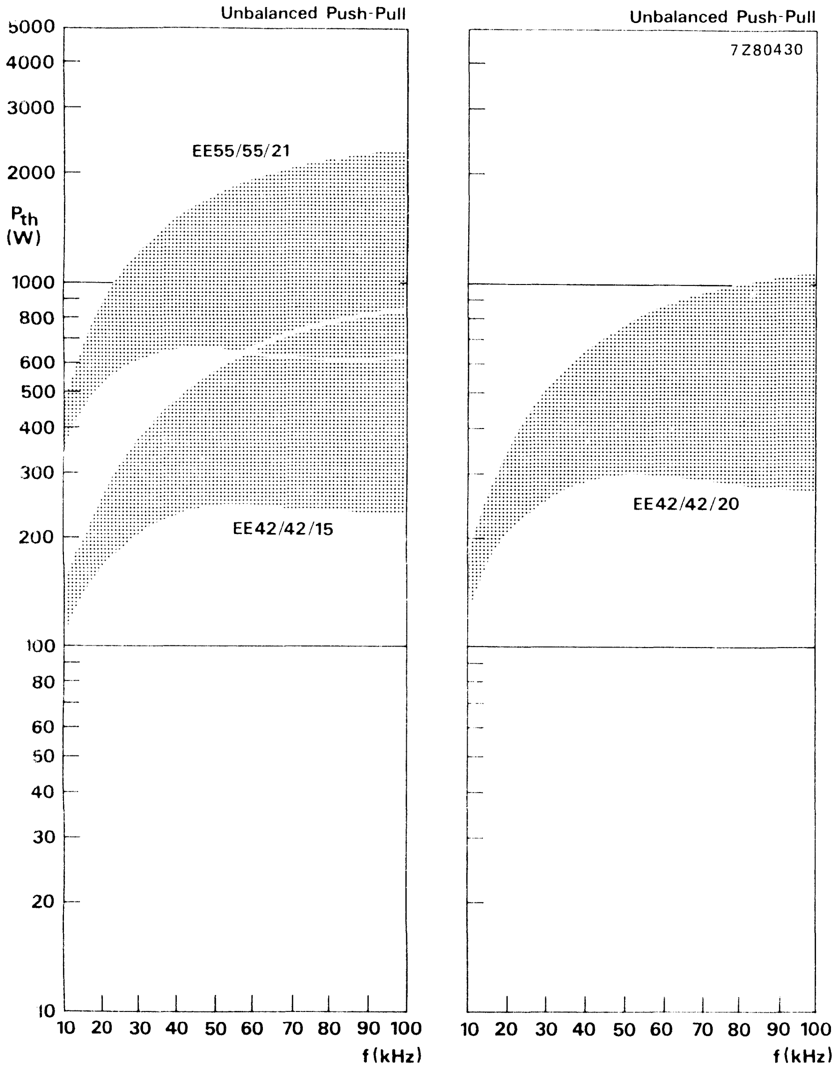
* Without creepage allowance.

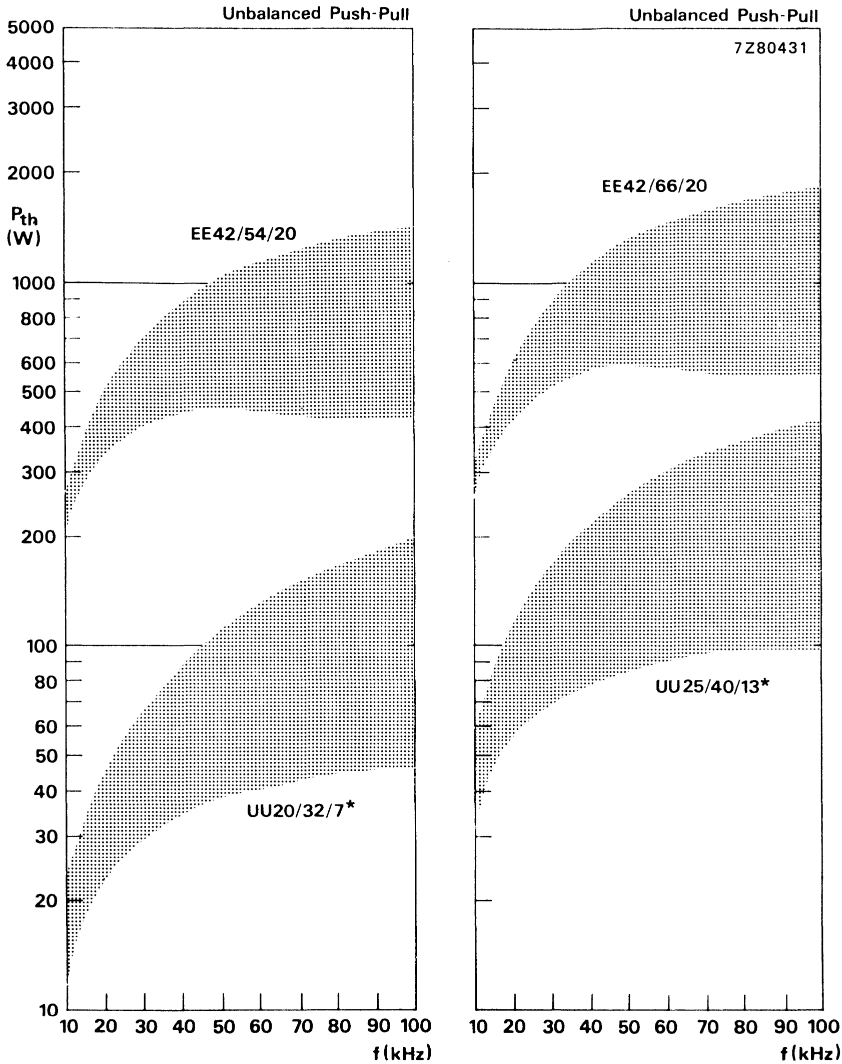

Balanced Push-Pull
Balanced Push-Pull
7Z80424
5000
4000
3000
2000
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
Pth (W)
EE55/55/25
ETD 34
EC 35
EE65/66/27
ETD 39
EC41
10 20 30 40 50 60 70 80 90 100
f (kHz)
10 20 30 40 50 60 70 80 90 100
f (kHz)



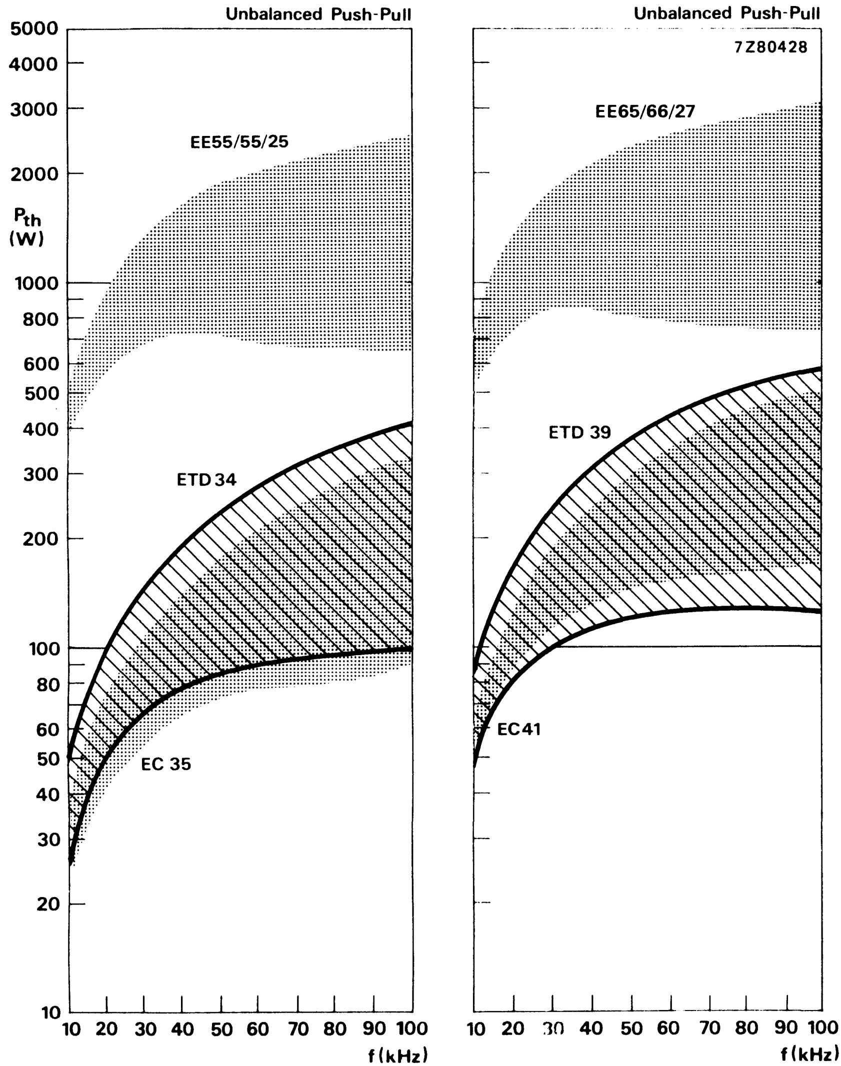


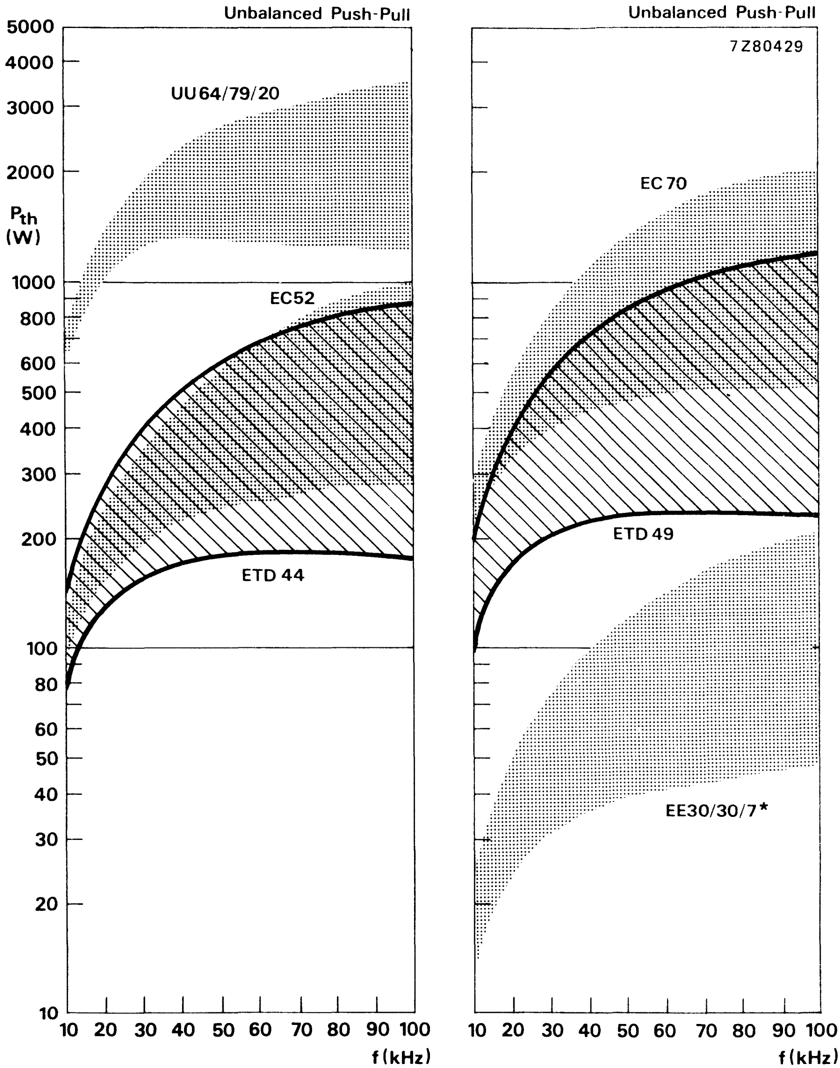
* Without creepage allowance.


Unbalanced Push-Pull
5000
4000
3000
2000
P_{th}
(W)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
EE55/55/21
EE42/42/15
10 20 30 40 50 60 70 80 90 100
f (kHz)
Unbalanced Push-Pull
7Z80430
EE42/42/20
10 20 30 40 50 60 70 80 90 100
f (kHz)



* Without creepage allowance.


Unbalanced Push-Pull
5000
4000
3000
2000
Pth (W)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
EE55/55/25
ETD 34
EC 35
10 20 30 40 50 60 70 80 90 100
f (kHz)
Unbalanced Push-Pull
7Z80428
EE65/66/27
ETD 39
EC41
10 20 30 40 50 60 70 80 90 100
f (kHz)



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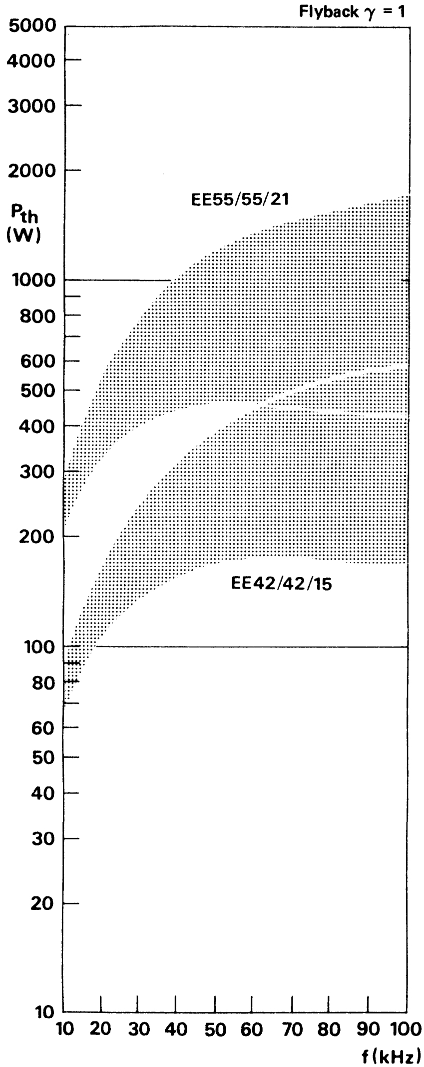
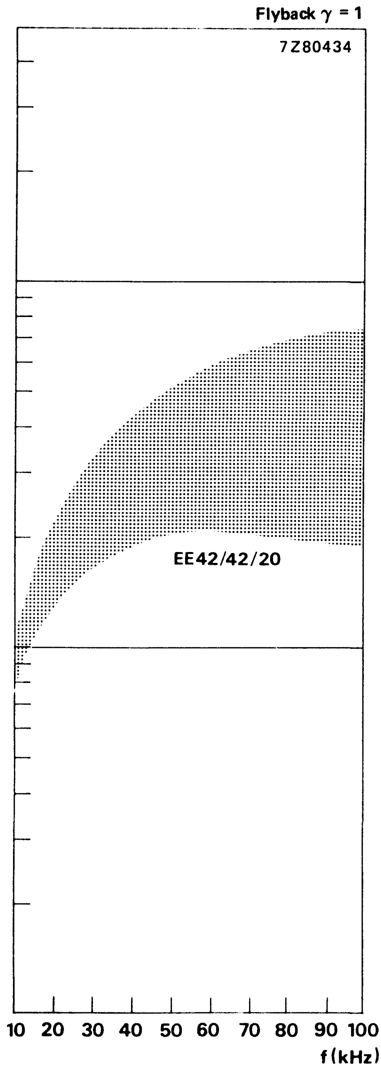
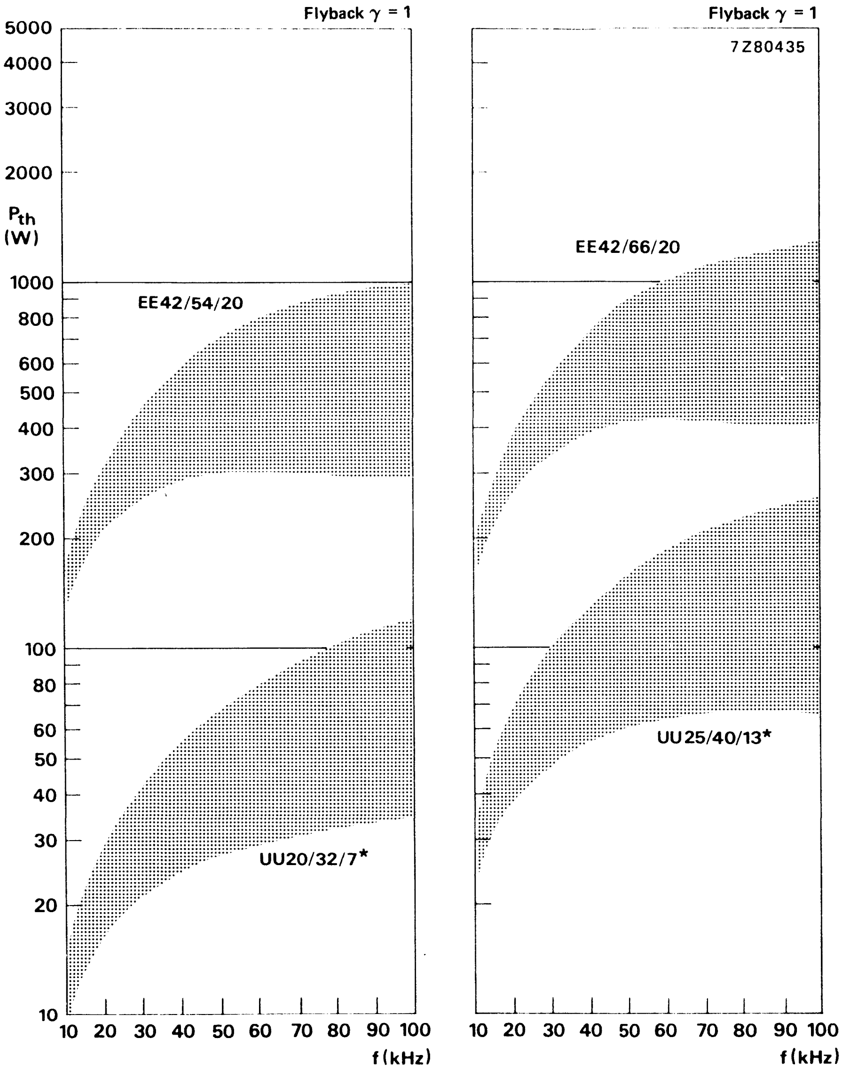
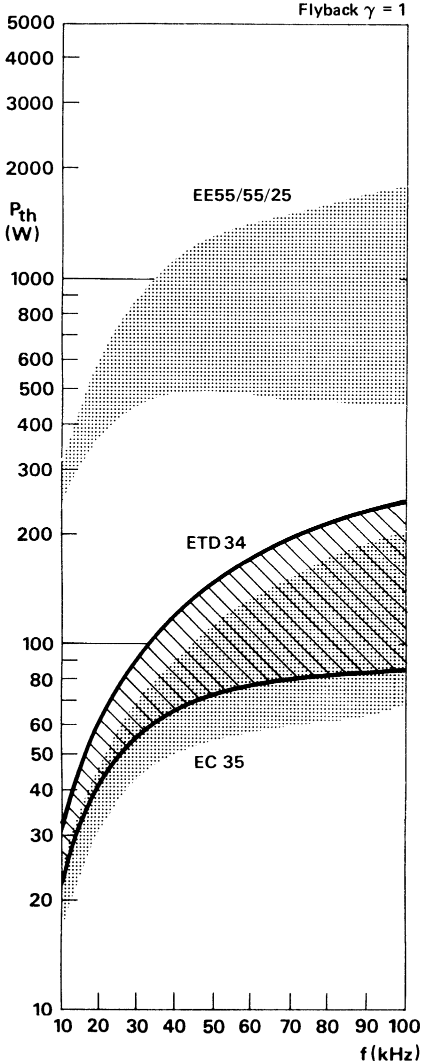
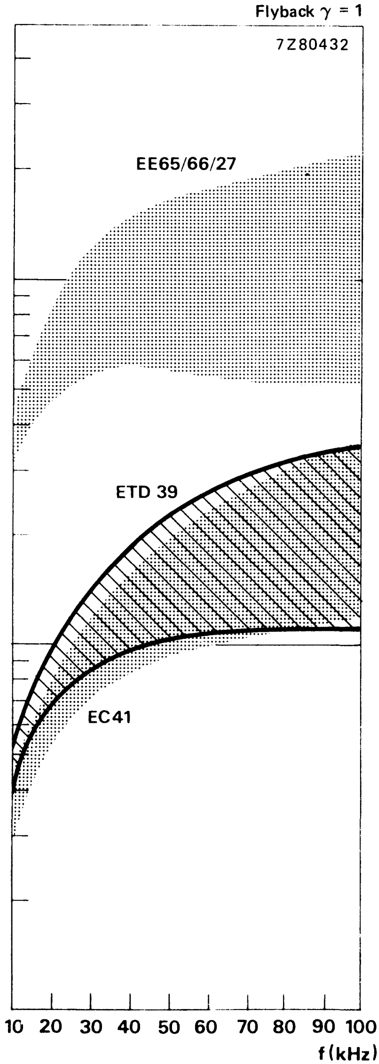

Flyback γ = 1
5000
4000
3000
2000
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
P_{th}
(W)
EE55/55/21
EE42/42/15
10
20
30
40
50
60
70
80
90
100
f(kHz)

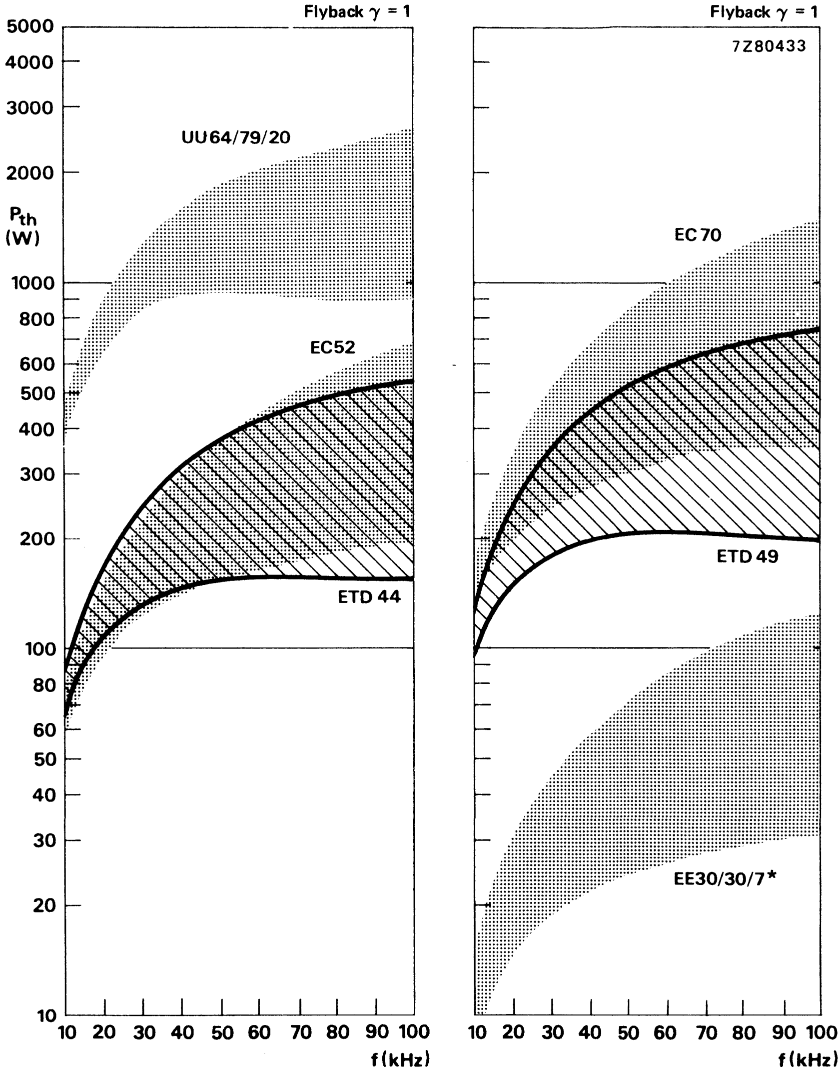

Flyback γ = 1
7Z80434
EE42/42/20
10
20
30
40
50
60
70
80
90
100
f(kHz)



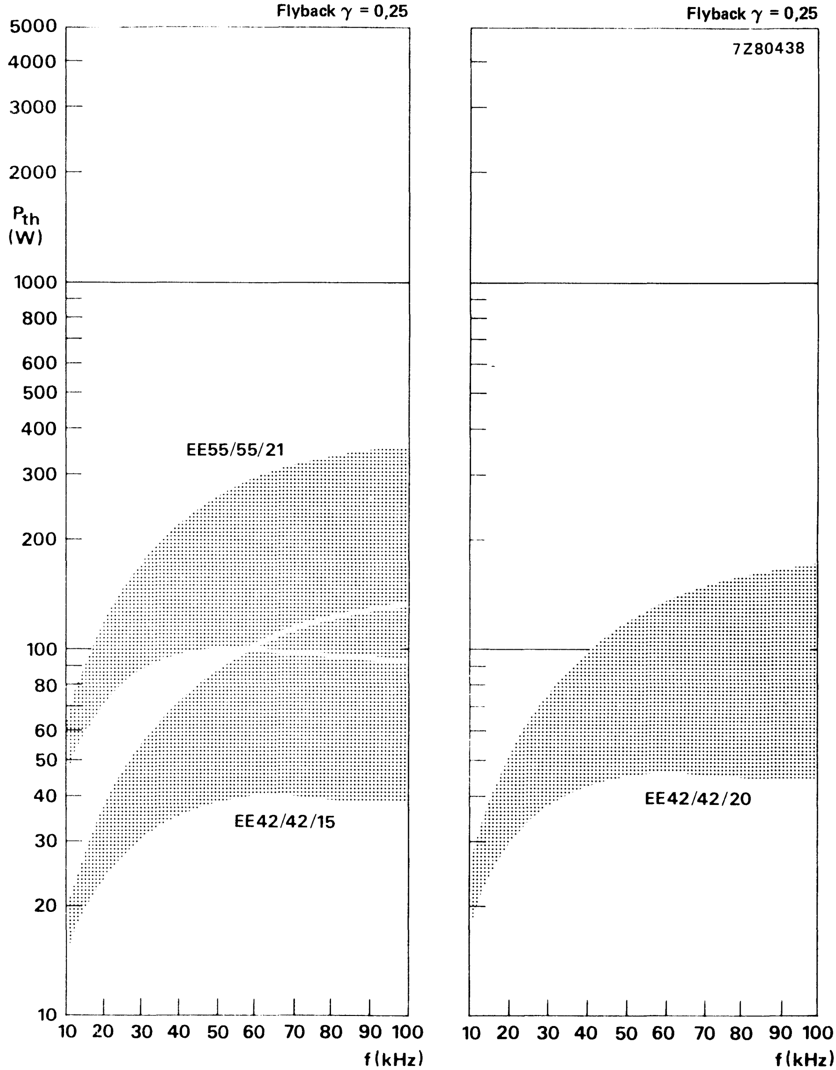
* Without creepage allowance.

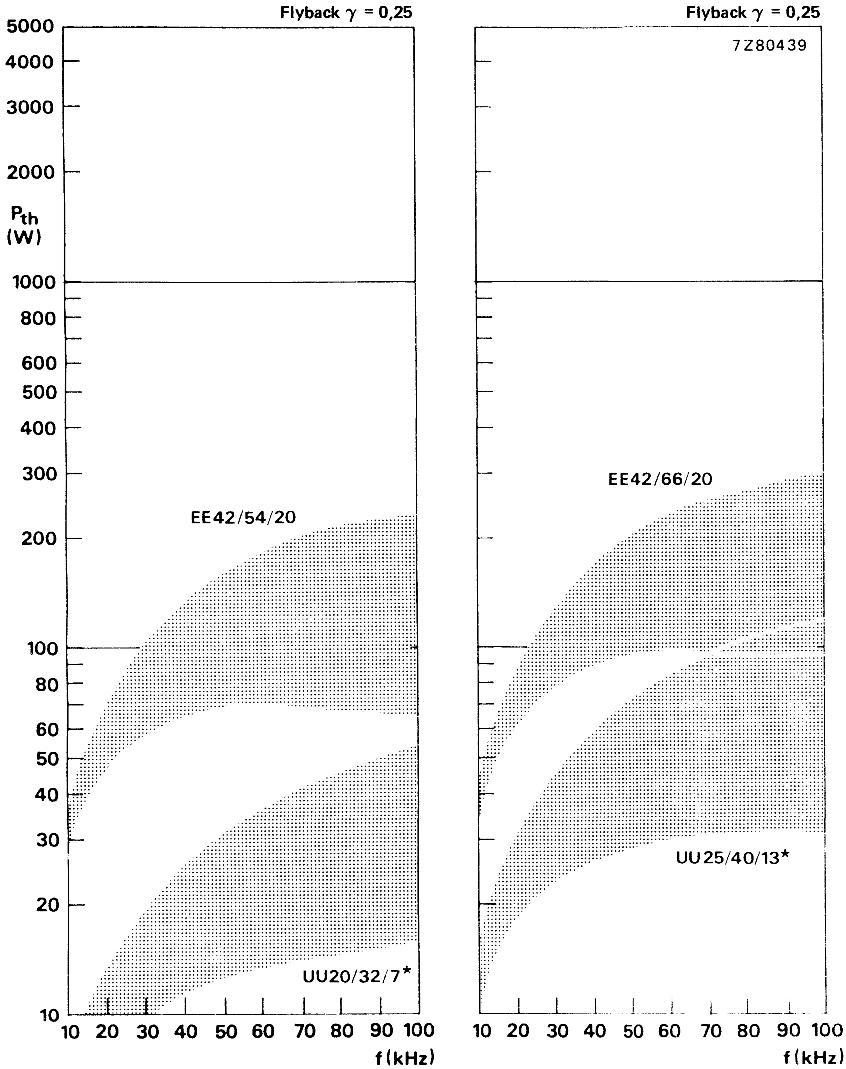

Flyback γ = 1
5000
4000
3000
2000
Pth
(W)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
EE55/55/25
ETD 34
EC 35
10 20 30 40 50 60 70 80 90 100
f (kHz)


Flyback γ = 1
7Z80432
EE65/66/27
ETD 39
EC41
10 20 30 40 50 60 70 80 90 100
f (kHz)

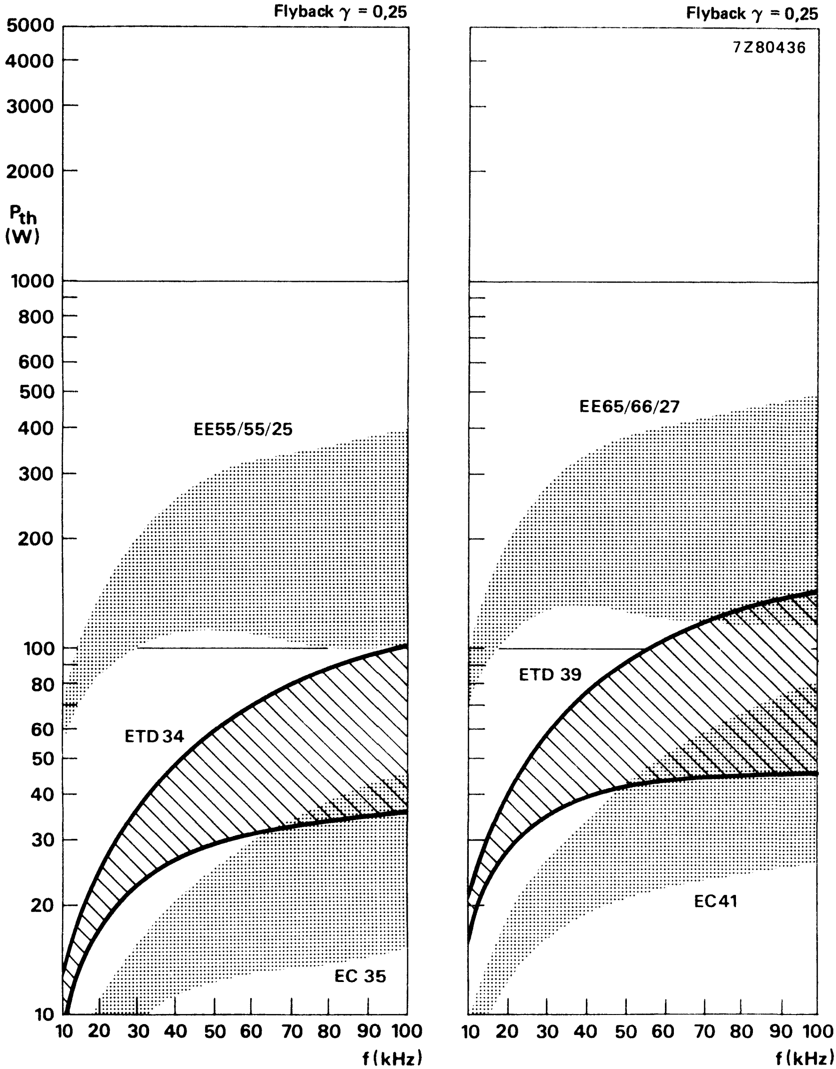


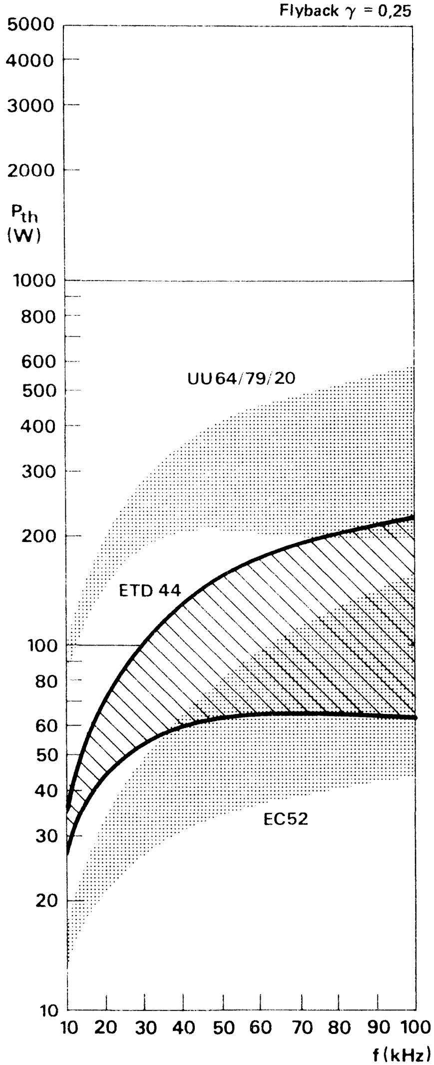
* Without creepage allowance.

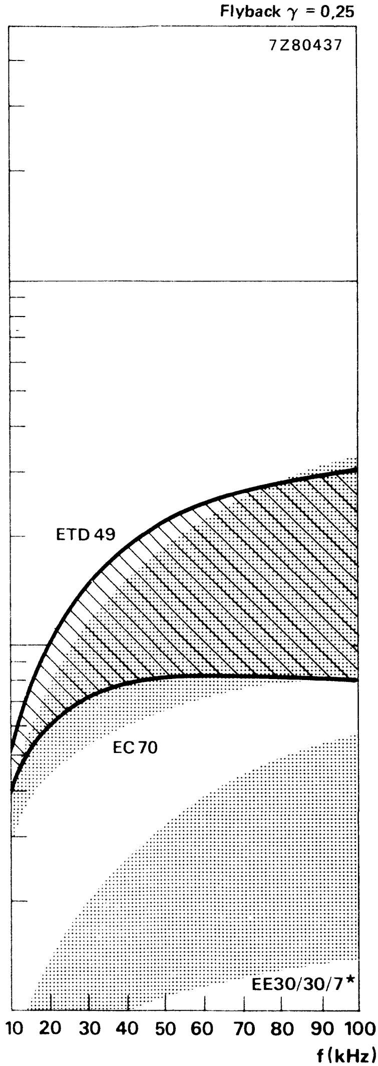

Flyback γ = 0,25
5000
4000
3000
2000
P_{th}
(W)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
EE55/55/21
EE42/42/15
10 20 30 40 50 60 70 80 90 100
f(kHz)
Flyback γ = 0,25
7Z80438
EE42/42/20
10 20 30 40 50 60 70 80 90 100
f(kHz)



* Without creepage allowance.


Flyback γ = 0,25
Flyback γ = 0,25
7Z80436
5000
4000
3000
2000
Pth
(W)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
EE55/55/25
ETD 34
EC 35
EE65/66/27
ETD 39
EC41
10 20 30 40 50 60 70 80 90 100
f (kHz)
10 20 30 40 50 60 70 80 90 100
f (kHz)

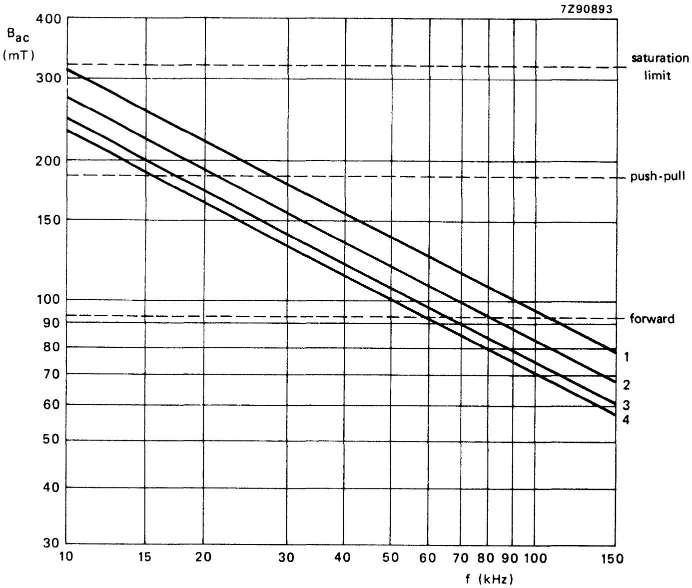




* Without creepage allowance.

Optimum flux density

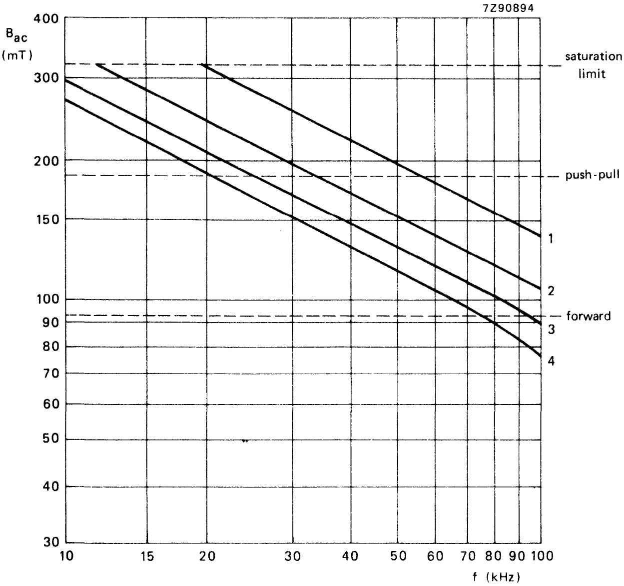
Optimum flux density excursion (half the peak-to-peak value) giving maximum throughput power for a variety of cores for SMPS applications.



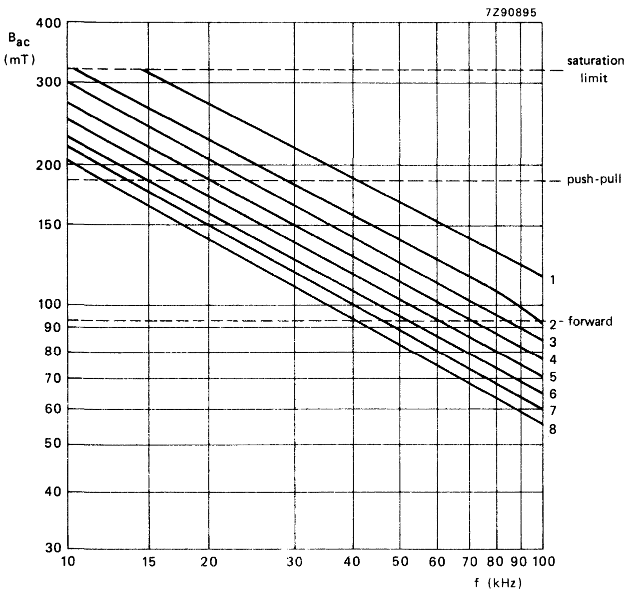
curve 1 ETD34
curve 2 ETD39
curve 3 ETD44
curve 4 ETD49

The two lower broken horizontal lines in the graphs indicate the maximum flux values for converters without feed forward, to allow for transient conditions. The intersections of these horizontal lines with the optimum-sweep curves gives the transition frequencies* for the respective cores.

* Transition frequency is the frequency at which the design changes from 'saturation limited' to 'core loss limited'.



1. UU15/22/6
   EE20/20/5
2. UU20/32/7
   EE25/25/7
   EE30/30/7
3. UU25/40/13
4. UU30/50/16



1. EC35
2. EC41, EC52
3. EE42/42/15
4. EC70
5. EE42/42/20
   EE42/54/20
   EE42/66/20
6. EE55/55/21
7. EE55/55/25
   UU64/79/20
8. EE65/66/27

POWER CHOKE DESIGN

Ferroxcube grade 3C8 is the natural choice for cores for power chokes operating at ultrasonic frequencies, such as those in switched-mode power supplies (SMPS). The data for the cores in this section include design charts that greatly simplify the design of these power chokes. Starting with the peak current I_M (Fig. 14) that the choke shall pass without saturating the core, and the minimum inductance required L_{min} the designer obtains all the information required for the construction of the choke directly. Core size, spacer thickness, number of turns, and winding geometry are derived in straightforward procedures. Note that the magnetic properties of the core do not enter into the design process. The ratio of the a.c. and d.c. current components may be small (smoothing chokes) to large (push-pull converter chokes). Parameter spreads due to manufacturing and temperature variations are taken into account in the construction of the design charts. The design procedures allow for spacer tolerances.

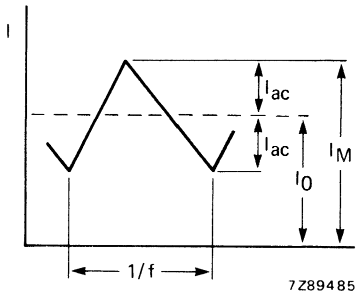


Fig. 14 Choke waveform showing symbols for currents are full load.

Operating conditions

The charts are constructed for cores of Ferroxcube 3C8 operating at a hot-spot temperature of 100 °C. Operation at lower temperatures leads neither to core saturation nor to inductances lower than L_{min}. The design peak flux density is 0,32 T. However, the charts can be used for a lower value B_M by designing for a peak current 0,32 I_M/B_M.

Applications

For the purposes of this design process, applications are divided into three classes:

I $I_{ac}/I_0 < 0,3$
Examples: smoothing chokes, and converter chokes in flyback-type SMPS without complete demagnetization.

II $I_{ac}/I_0 \approx 1$
Example: flyback-converter chokes with complete demagnetization (ringing-choke converters).

III $I_{ac}/I_0 > 2$
Example: converter chokes in push-pull-type SMPS (symmetrical excitation) as used for fluorescent-lighting.
Core loss rather than saturation is usually the limiting factor in this class of application. Thus, the peak flux density must be lower than 0,32 T by an amount that depends on operating frequency. The special treatment of class III designs given in the following procedures generally yield satisfactory results.

Core selection

The cores are grouped according to shape: EC, EE, ETD, UI, UU.

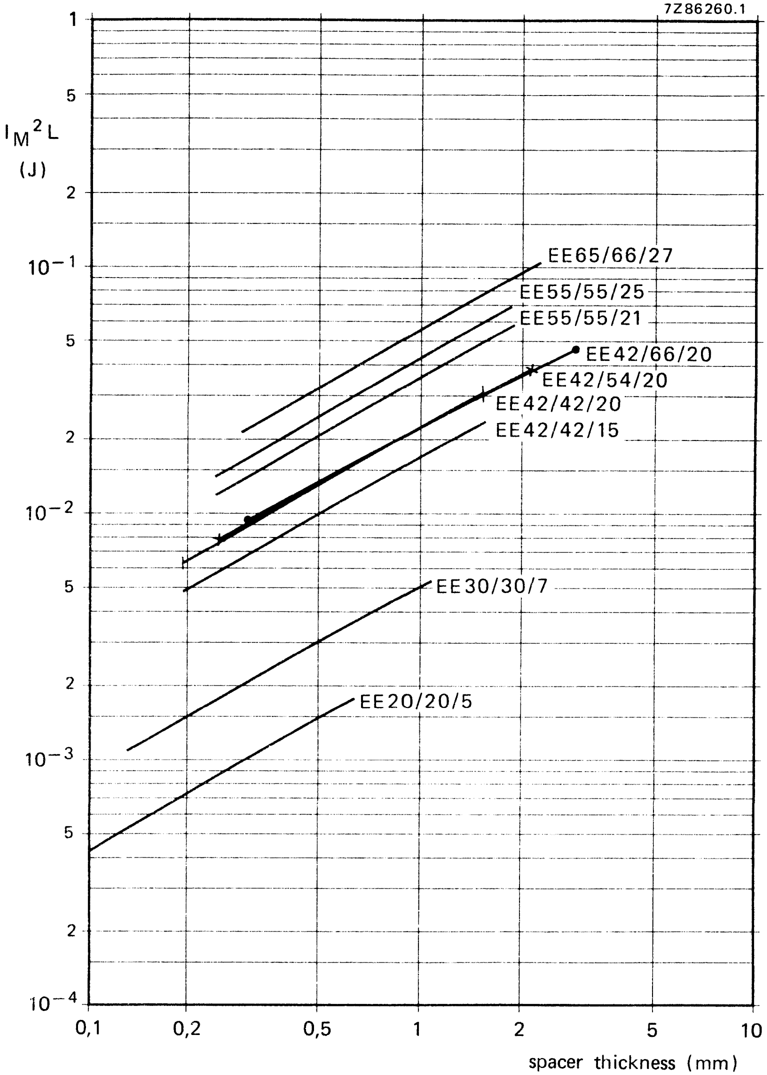
Selection procedure

- Knowing the values of peak choke current I_M and minimum required inductance L_{min}, calculate the value of $I_M^2 L_{min}$.
- Choose – at least provisionally – the shape of core (EE, EC, ETD, UU or UI) and draw a horizontal line $I_M^2 L_{min}$ across the selection chart for that core shape. For class II designs at frequencies beyond 40 kHz use a value of $I_M^2 L_{min}$ equal to f/40 times the actual value of $I_M^2 L_{min}$, for class III designs at frequencies beyond 10 kHz use a value of $I_M^2 L_{min}$ equal to 0,1 f times the actual value of $I_M^2 L_{min}$, where f is the operating frequency in kHz.
- A core whose curve intersects this horizontal line can be used for the application. The spacer thickness or centre pole gap size corresponding to the intersection is only an indication of the final value.

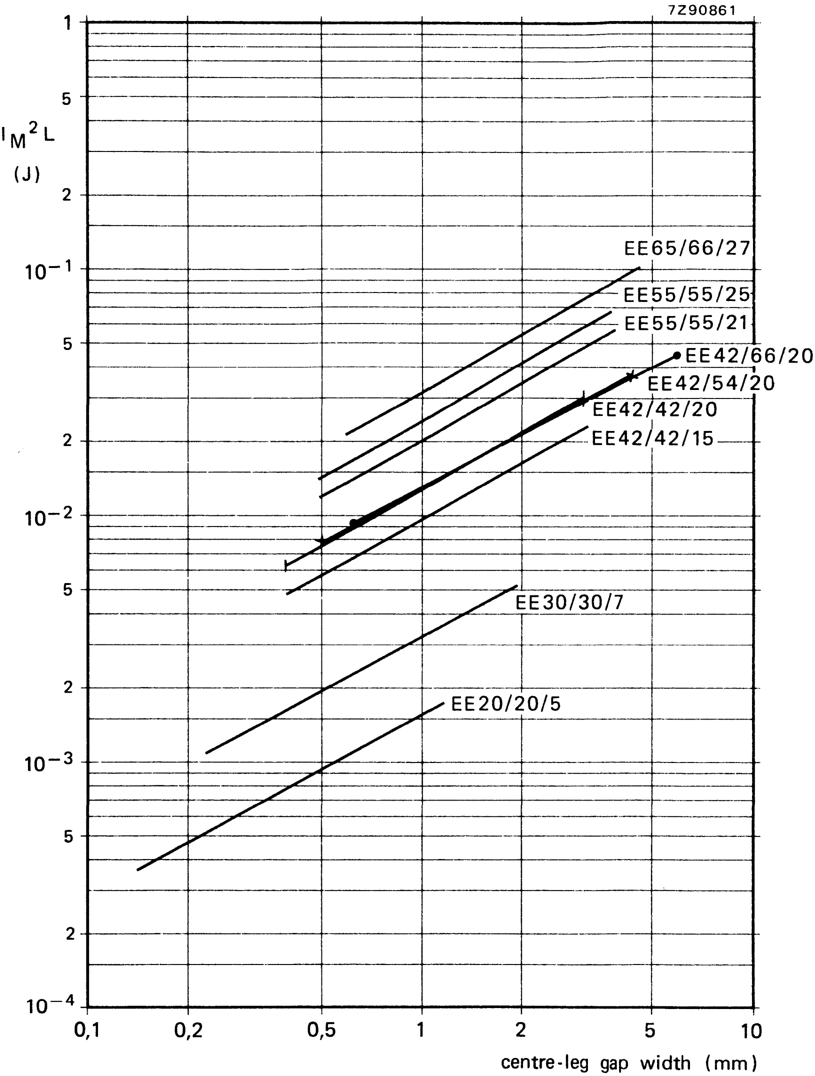
Effect of core size

Where, as is usual, more than one core could be used, the final choice may be governed by the consideration that operation near the right-hand end of the curves carries the risk of overheating.

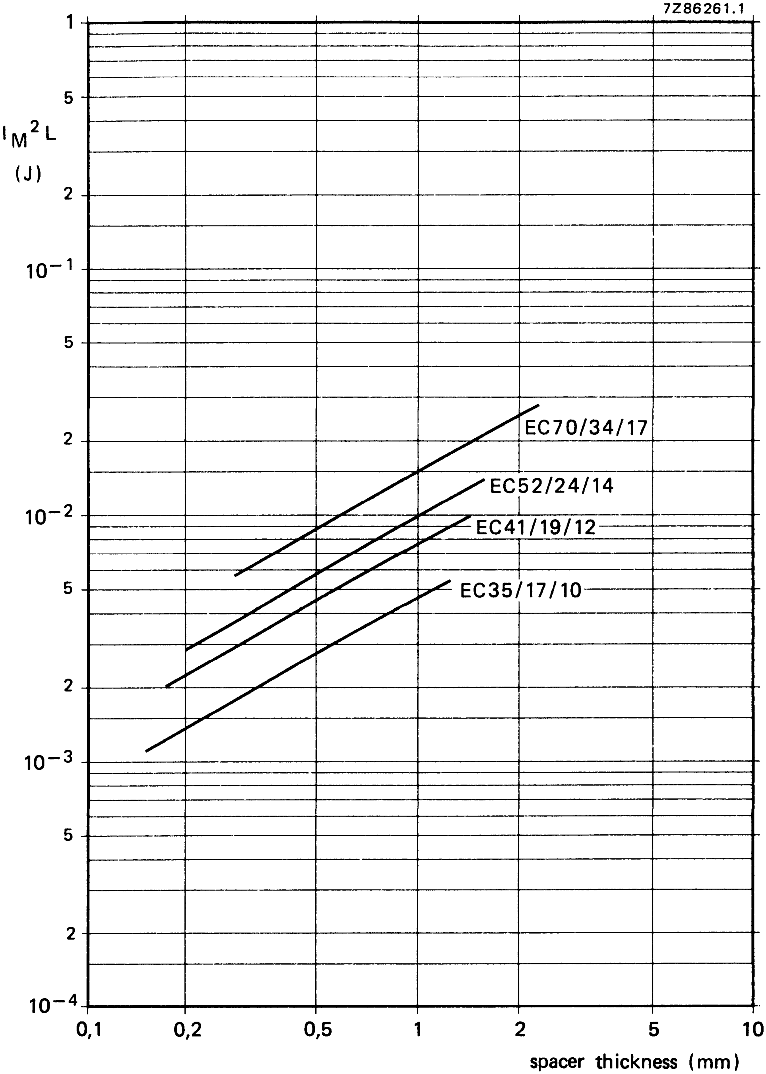
Selection of a larger core will generally result in a more conservative, efficient design than one based on a core that is marginally large enough.



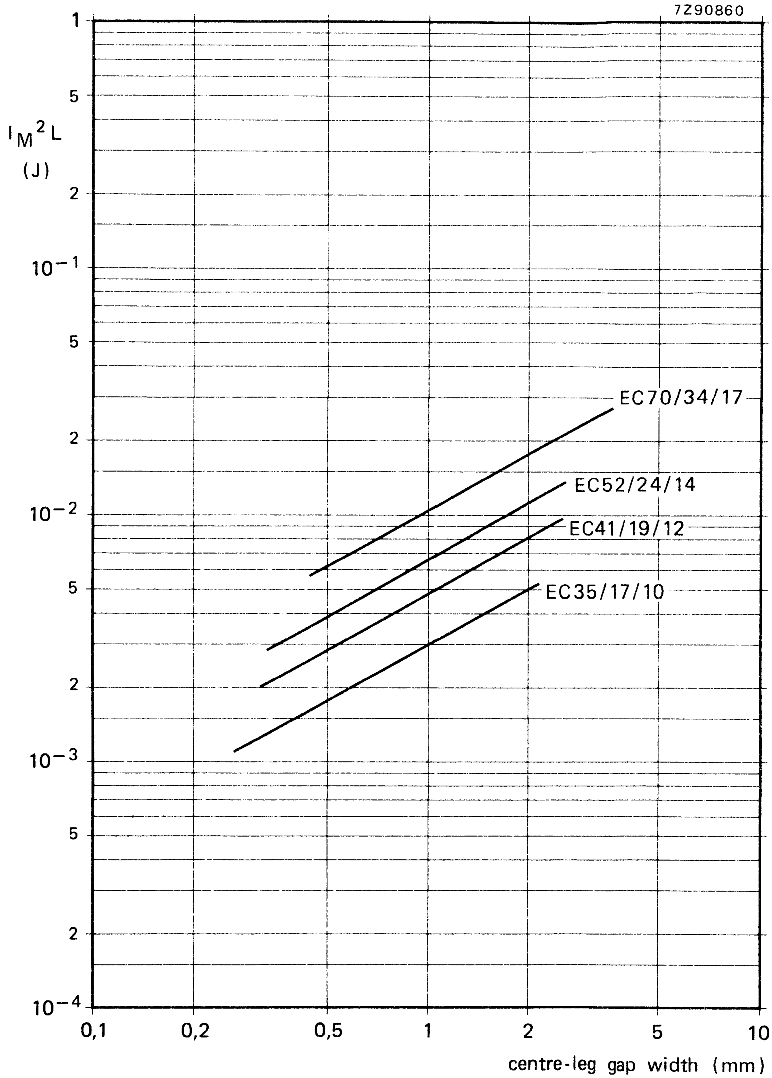
Choke core selection chart for EE cores.



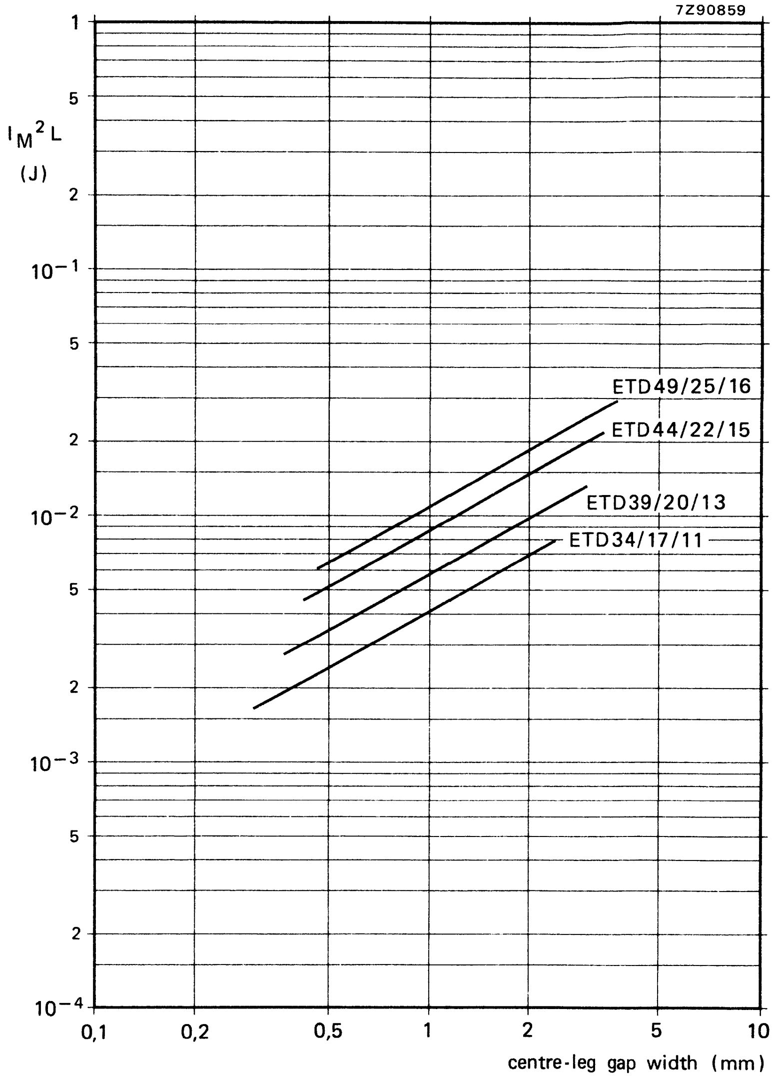
Choke core selection chart for EE cores.



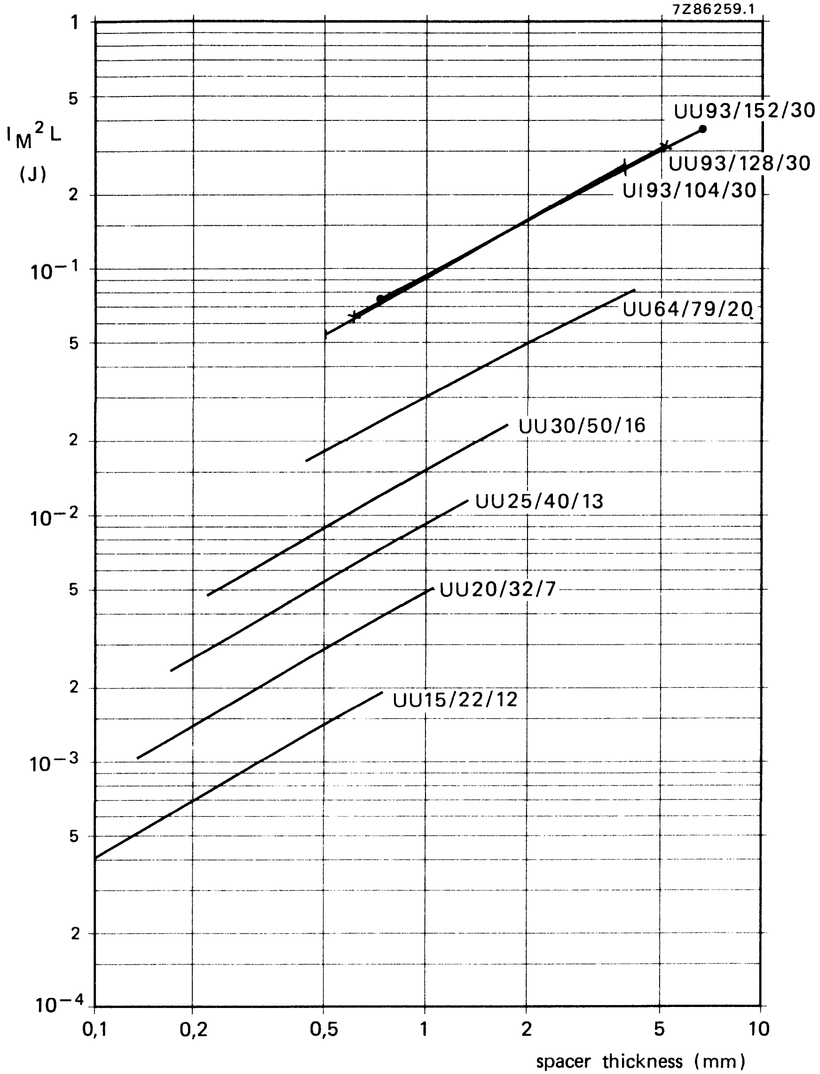
Choke core selection chart for EC cores.



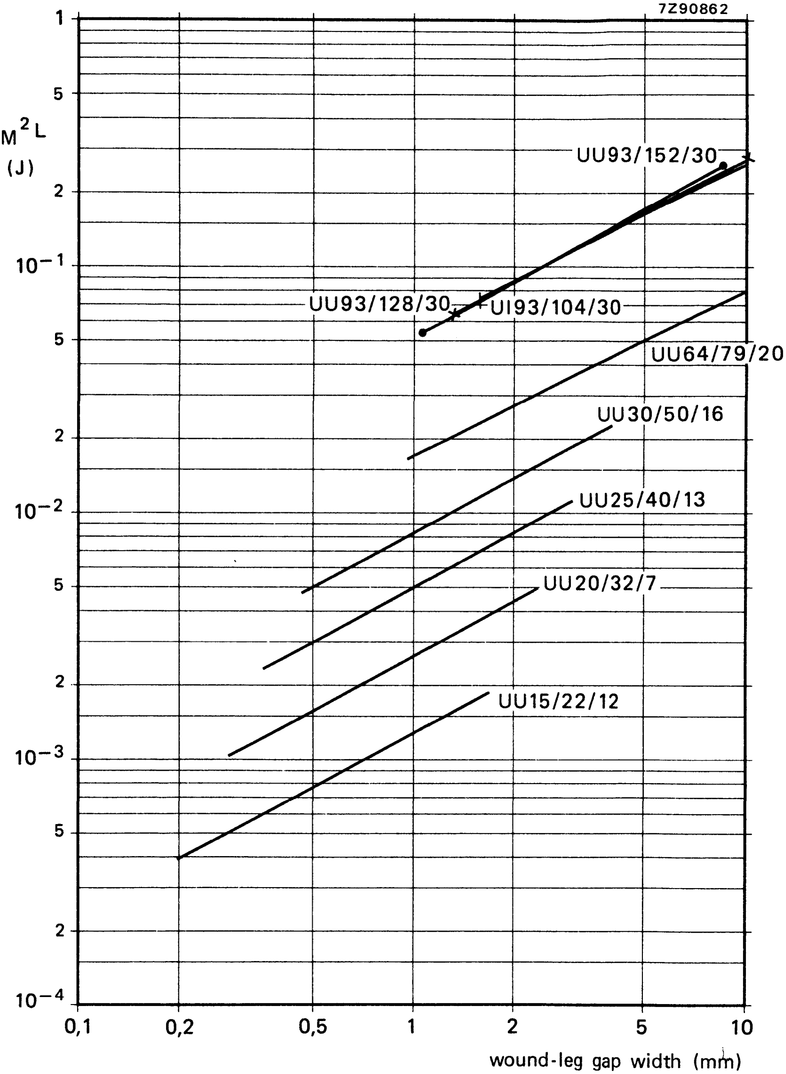
Choke core selection chart for EC cores.



Choke core selection chart for ETD cores.



Choke core selection chart for UU/UI cores.



Choke core selection chart for UU/UI cores.

Gap size (spacer thickness or centre leg gap width) **and number of turns**

For ETD cores consult the tables given on the relevant pages. For the other cores turn to the data for the core type selected and refer to the chart giving $(I_M^2 L)_{max}$ and A_L as functions of gap sizes. *(Note: A_L for these power cores is the inductance factor in henry.)*

The charts comprise a pair of curves of $(I_M^2 L)_{max}$ and A_L for each of the three application classes. Use the pair of curves for the appropriate class of application in the following design procedure.

1. On the chart, draw the horizontal line $I_M^2 L_{min}$, as used for core selection, see under 'Core selection'. The working point of the core must lie above this line and below the $(I_M^2 L)_{max}$ curve for the core. That is, between lines SQ and SP in Fig. 15.
2. Select a suitable gap size, nominal width s. Draw vertical lines s_{min} and s_{max} on the chart, where $s_{max} - s_{min}$ is the tolerance field on the centre pole gap size or thickness of the spacer and the associated adhesive films. (Epoxy adhesive films vary in thickness from about 10 µm to about 20 µm.) Ensure that the horizontal distance between the intersection and s_{min} (a in Fig. 15) is greater than the distance from s_{min} to s_{max} (b in Fig. 15).
3. For s_{min}, read values of $(I_M^2 L)_{max\,1}$ and $A_{L\,1}$ from the chart. The maximum number of turns allowed to avoid saturation is

   $$N_{max} = \sqrt{\frac{(I_M^2 L)_{max\,1}}{I_M^2 A_{L\,1}}}$$

   for class II beyond 40 kHz,

   $$N_{max} = \sqrt{\frac{(I_M^2 L)_{max\,1}}{f/40 \times I_M^2 A_{L\,1}}},$$

   for class III beyond 10 kHz,

   $$N_{max} = \sqrt{\frac{(I_M^2 L)_{max\,1}}{0{,}1\,f \times I_M^2 A_{L\,1}}},$$

   where f is expressed in kHz.

   Note: The upper left-hand corner of the shaded area of the figure is the most critical point regarding number of turns and core saturation.
4. For s_{max}, read the value of $A_{L\,2}$. The minimum number of turns, for inductance L_{min}, is

   $$N_{min} = \sqrt{\frac{L_{min}}{A_{L\,2}}}$$

   Note: The lower right-hand corner of the shaded area is the most critical for number of turns and L_{min}.
5. Select an integral number of turns N between N_{min} and N_{max}.

   Note: If a was taken to be only marginally greater than b (see Fig. 15), the design attempt might fail since such an integer would not exist. Taking $a < b$ makes $N_{max} < N_{min}$.
6. Establish the winding geometry using the winding-design procedure, given later.

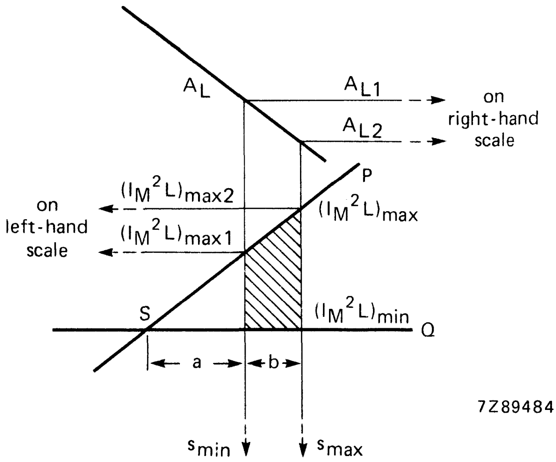


Fig. 15 Graphical design process using core design charts.

Winding design

Because the eddy-current losses in a winding carrying a.c. increase rapidly with conductor size (for wire, with d^4, whereas d.c. loss increases with d^{-2}), there is a certain "ideal" conductor size for minimum loss. This may set an upper limit to conductor size at the ultrasonic frequencies at which SMPS chokes operate. The procedures that follow allow the ideal number of layers and wire size, or the thickness of strip, to be determined for chokes with an operating-current waveform of the form shown (Fig. 14). They also indicate the course of action when the available winding window will not accommodate the ideal winding.

Copper conductors are assumed; operating temperature is 100 °C, so that conductor resistivity is 1/45 $\Omega mm^2/m$ (30% higher than that at 20 °C). Symbols used in the formulae are as follows. (Note: subscript id indicates an ideal (lowest loss) value).

b_w	mm	winding (layer) breadth
d	mm	nominal wire diameter
d_o	mm	overall wire diameter
f	kHz	frequency
f_e	kHz	effective frequency (see text)
F_R	–	resistance factor R_{ac}/R_{dc}
h	mm	thickness of foil conductor
H	mm	winding height
H_a	mm	available winding height
i	mm	thickness of interleaving
I_e	A	r.m.s. current at full load
I_0	A	d.c. component of current at full load (see Fig. 14)
I_{ac}	A	a.c. component of current at full load (see Fig. 14)
I_M	A	peak value of current at full load (see Fig. 14)
N	–	number of turns in a winding
p	–	number of layers
P_w	W	winding loss
R_{ac}	Ω	a.c. resistance
R_{dc}	Ω	d.c. resistance

Effective frequency f_e and effective current I_e

For sinusoidal currents, effective frequency f_e is equal to actual frequency f. This remains the case for small amounts of waveform distortion and small d.c. components.

For the waveform shown in Fig. 14, and provided that the rise and fall times are between 15% and 85% of the repetition period,

$$f_e = \frac{1{,}3f}{\sqrt{\{1 + 3\,(I_0/I_{ac})^2\}}}.$$

In designs for applications in class I, f_e may be only a few kilohertz. Eddy-current effects are then negligible and windings can be designed as if they carry d.c. Use the correct value of d.c. resistivity (given below).

For the waveform shown,

$$I_e^2 = I_0^2 + I_{ac}^2/3.$$

but for sinusoidal currents with a significant d.c. component

$$I_e^2 = I_0^2 + I_{ac}^2/2.$$

Multi-layer wire windings (solid round wire)

It is assumed that all layers have equal breadth; a difference in number of turns per layer of one is permitted where N/p is not an integer.

1. $d_{id} = 2,6\{b_w/(Nf_e)\}^{1/3}$.
2. Select the nearest standard wire size (for d and d_o) from a table such as that for IEC grade-1 winding wires.
3. $p_{id} = N/\{(b_w/d_o)-1\}$. Note: this expression is valid only for d_o from step 2.
   - If $p_{id} \geq 1,5$, and current density in wire d_{id} is too high, make a new design using a larger core.
   - If $p_{id} \leq 1,5$, consider a foil or strip winding.
   - If $p_{id} \leq 1$, the expression for d_{id} in step 1 is not valid: go to the single-layer winding procedure.

   Find p by rounding p_{id} to the next highest integer. Due to this rounding, there will be some space between turns.
4. $H = p(d_o + i)$.
5. If H exceeds H_a, or if current density is low:
   - reduce p by one layer,
   - select thickest wire for which $d_o \leq pb_w/(N + p)$,
   - repeat from step 4, even if p = 1.
6. $F_R = 1 + ½(d/d_{id})^6$. Note: $F_R = 1,5$ for $d = d_{id}$; $F_R \simeq 1$ if $d/d_{id} < 0,7$.
7. $P_w = I_e^2R_{ac} = I_e^2 F_R R_{dc}$. Note: d.c. wire resistance $0,0283/d^2\ \Omega/m$. For I_e, see previous page.

Single-layer wire windings (solid round wire)

1. Select thickest wire for which $d_o \leq b_w/(N + 1)$.
2. $F_R = 0,33\ df_e^{½}N/(N + 1)$. Note: valid only if $p_{id} \leq 1$ (see above).
3. $P_w = I_e^2R_{ac} = I_e^2 F_R R_{dc}$. Note: wire resistance $0,0283/d^2\ \Omega/m$. For I_e see previous page.

Bunched (Litz) wire windings

Eddy-current effects negligible: no special design procedure required. Copper density and thermal conductivity of winding low. Might be attractive if the ideal solid-conductor winding fills less than half the available height. Remember the 30% higher resistance at 100 °C.

Foil or strip windings

Here b_w is the width of the strip.

1. $h_{id} = 3,1\ (Nf_e)^{-½}$.
2. $h_{min} = 0,8h_{id}/\sqrt{N}$.
3. $h_{max} = (H_a/N) - i$ (choose a value for i that is appropriate to a strip of thickness about H_a/N). If $h_{max} < h_{min}$, try a wire winding.
4. Select from available materials a conductor of thickness h such that $h_{min} < h < h_{max}$. Aim for $h = h_{id}$.
5. $F_R = 1 + (h/h_{id})^4/3$. For $h = h_{id}$, $F_R = 1,33$. For $h < 0,6h_{id}$, $F_R \simeq 1$.
6. $P_w = I_e^2R_{ac} = I_e^2 F_R R_{dc}$. Resistance of foil is $1/(45b_wh)\ \Omega/m$. For I_e see previous page.

Reference

Jongsma, J. 1978. Minimum-loss transformer windings for ultrasonic frequencies. *E.A.B.* **35**: 146 – 163 (no. 3) and 211 – 226 (no. 4).

E CORES (without air gap)*

type number	material grade FXC 3C8 catalogue number of one core	material grade FXC 3E1 catalogue number of one core
E13/7/4	4312 020 34470	
E20/10/5	● 4312 020 34070	● 4322 020 34830
E25/13/7	4312 020 34020	
EI25/25/7	3122 134 90960	
E30/15/7	4312 020 34550	4322 020 34840
E42/21/15	● 4312 020 34110	● 4322 020 34850
I42/7/15		4322 020 37320
E42/21/20	● 4312 020 34120	
E42/33/20	4312 020 34190	
E55/28/21	● 4312 020 34100	● 4322 020 34900
E55/28/25	3122 134 90210	
E65/32/13		● 4322 020 34910
E65/32/27	● 4312 020 34380	

EC CORES (without air gap)*

type number	material grade FXC 3C8 catalogue number of one core
EC35/17/10	● 4322 020 52500
EC41/19/12	● 4322 020 52510
EC52/24/14	● 4322 020 52520
EC70/34/17	● 4322 020 52530

ETD CORES

type number	material grade FXC 3C8		
	air gap mm	A_L approx. nH	catalogue number
ETD34/17/11	–	2400	● 4312 020 37000
	0,1	800	37010
	0,2	480	37020
	0,5	230	37030
	1,0	140	37040
ETD39/20/13	–	2700	● 4312 020 37050
	0,1	1000	37060
	0,2	600	37070
	0,5	295	37080
	1,0	170	37090

● Preferred types.
* Cores with air gap are available on request.

ETD CORES (continued)

type number	material grade FXC 3C8		
	air gap mm	A_L approx. nH	catalogue number
ETD44/22/15	–	3300	● 4312 020 37100
	0,2	800	37110
	0,5	400	37120
	1,0	230	37130
	1,5	170	37140
ETD49/25/16	–	3700	● 4312 020 37150
	0,2	1000	37160
	0,5	480	37170
	1,0	270	37180
	2,0	150	37190

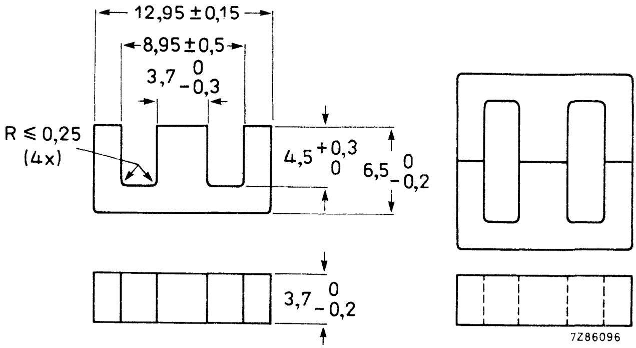
U AND I CORES

type number		material grade FXC 3C8 catalogue number of one core
U10/8/3		● 3122 134 91160
U15/11/6		● 3122 134 90690
	I15/3/3	3122 134 90730
U20/16/7		● 3122 134 90200
	I20/6/5	3122 134 90720
U25/20/13		● 3122 134 90460
	I25/7/7	3122 134 90620
U30/25/16		● 3122 134 90760
U46/33/11		3122 104 90480
	I46/10/11	3122 104 90470
U52/27/11		● 3122 134 90480
U57/28/16		4312 020 33190
U58/45/16		3122 104 94760
	I58/13/16	3122 104 94770
U64/40/20		3122 134 91390
U70/33/17		3122 104 93950
U93/52/30		4312 020 33580
U93/76/30		4312 020 33570
	I93/28/30	4312 020 33590
U93/76/16		4312 020 33550
	I93/28/16	4312 020 33560
U100/57/25		4312 020 33600
	I100/25/25	4312 020 33610

The data on these cores are arranged on the following pages in order of type number.

● Preferred types.

E-CORE



Mass approx. 0,83 g

MAGNETIC DATA

Guaranteed values measured at 16 kHz for a core pair EE13/13/4, pressed together with a force of 30 N.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	catalogue number of one E core
3C8	25 105	≥ 140 ≥ 330	50 250	4312 020 34470

Magnetic dimensions

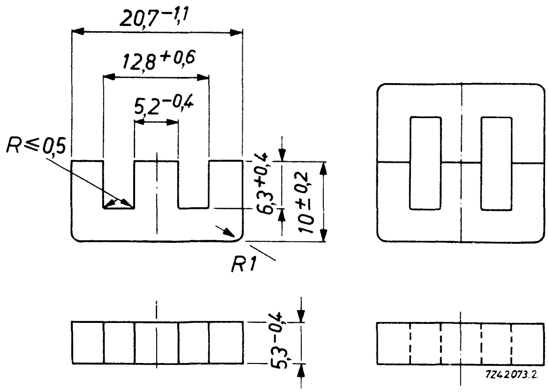
l_e = 29,6 mm

A_e = 13 mm²

V_e = 384 mm³

The core is available with air gap on request.

E-CORES



Dimensions according to DIN 41295

Mass approx. 4 g

MAGNETIC DATA

Guaranteed values for a core pair EE20/20/5, pressed together with a force of 55 N, air gap $\Delta = 0$.

	freq. kHz	temperature °C	$\hat{B}$ mT	grade 3E1	grade 3C8
A_L	100	25 ± 10	≤ 0,1	1920 to 2890	
μ_e	100	25 ± 10	≤ 0,1	2100 to 3155	
μ_e	100	23 to 70	≤ 0,1	≥ 2100	
$\frac{\tan\delta}{\mu_i} \times 10^6$	4	25 ± 10	≤ 0,1	≤ 2,5	
	100	25 ± 10	≤ 0,1	≤ 20	
	500	25 ± 10	≤ 0,1	≤ 200	
$\eta_B \times 10^3$	4	25 ± 10	1,5 to 3	≤ 1,8	
P(W)	16	25	200		≤ 0,3
	16	100	200		≤ 0,25
$\hat{H}$ (A/m)	16	100	≥ 275		250

Catalogue number of one E core without air gap*, grade 3E1 ● 4322 020 34830
3C8 ● 4312 020 34070

Magnetic dimensions, according to IEC 205:

l_e = 42,8 mm $C_1 = \Sigma \frac{l}{A} = 1,37\ mm^{-1}$

A_e = 31,2 mm^2 V_e = 1340 mm^3

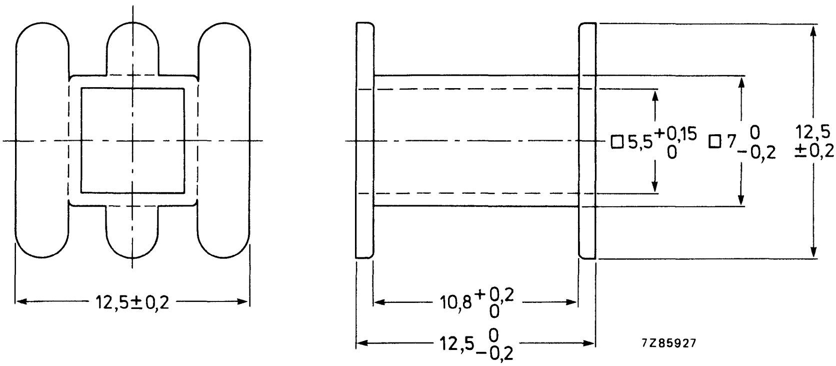
* The cores are available with air gap on request.

● Preferred type.

COIL FORMERS

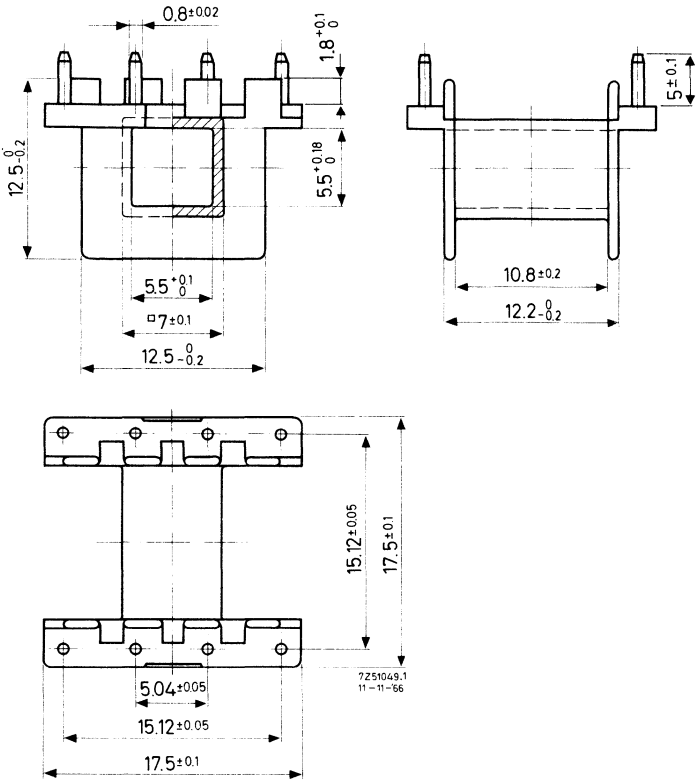
for shell type transformer EE20/20/5 (M20)

Without pins.



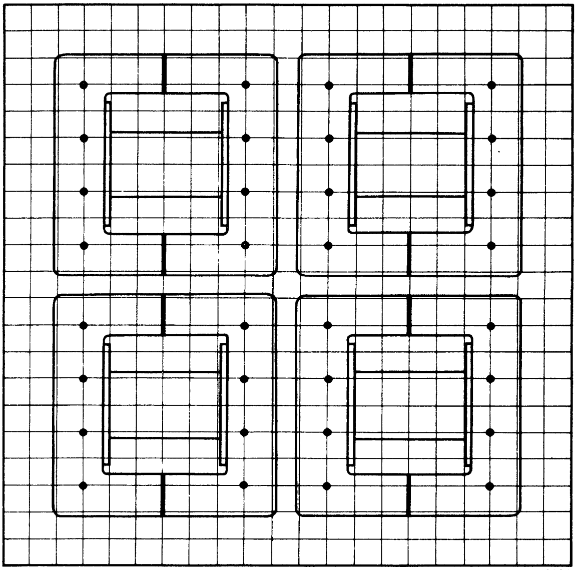
catalogue number	4312 021 28430
→ material	polyamide 6,6, glass fibre reinforced
minimum window area	27 mm^2
mean length of turn	38 mm
approximate mass	0,5 g
maximum working temperature	130 °C

With 8 soldering pins.



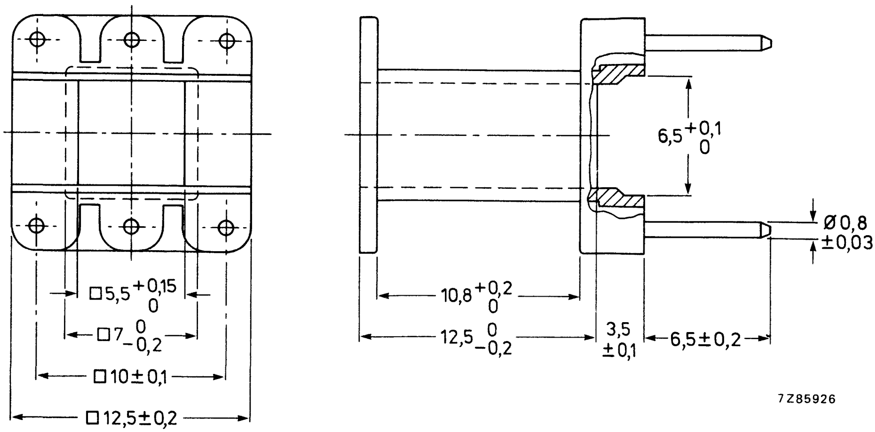
catalogue number	4322 021 20240
material	phenolformaldehyde reinforced with glass fibre; brass dip-solder pins
minimum window area	27 mm²
mean length of turn	38 mm
approximate mass	3 g
maximum temperature for dip-soldering during 5-6 s	280 °C
maximum working temperature	130 °C

The coil former fits a shell type transformer EE20/20/5 (M20). The soldering pins will fit printed-wiring boards with a grid of 0,1 inch as well as 2,5 mm. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1,3 ± 0,1 mm diameter.



7Z49836.1

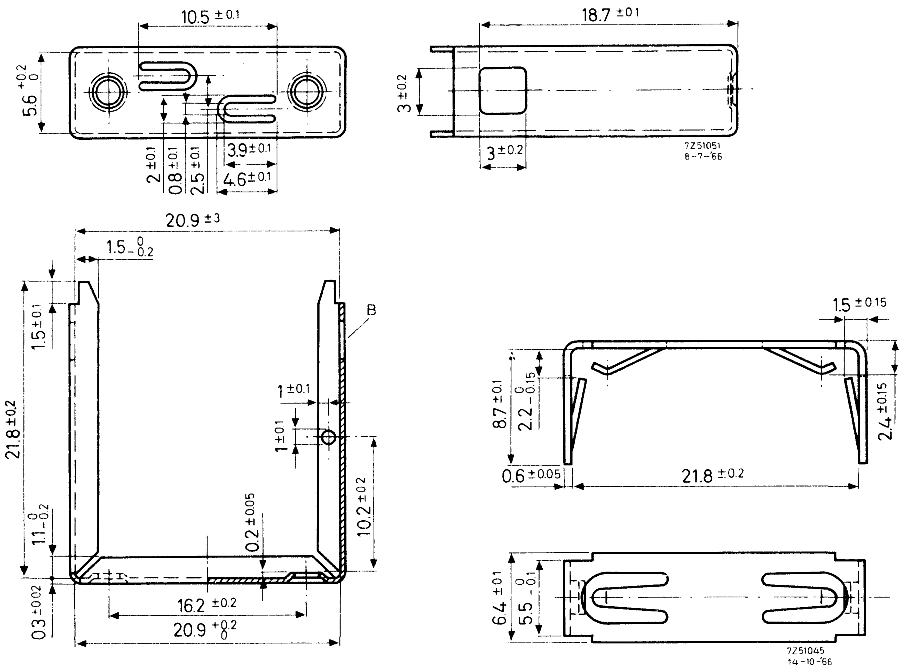
With 6 soldering pins.



catalogue number	4322 021 20290
material	polyamide 6,6, glass fibre reinforced; copper nickel soldering pins
minimum window area	27 mm^2
mean length of turn	38 mm
approximate mass	3 g
maximum working temperature	130 °C

The coil former fits a shell type transformer EE20/20/5 (M20). The soldering pins will fit printed-wiring boards with a grid of 0,1 inch as well as 2,5 mm. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1,3 ± 0,1 mm diameter.

MOUNTING PARTS



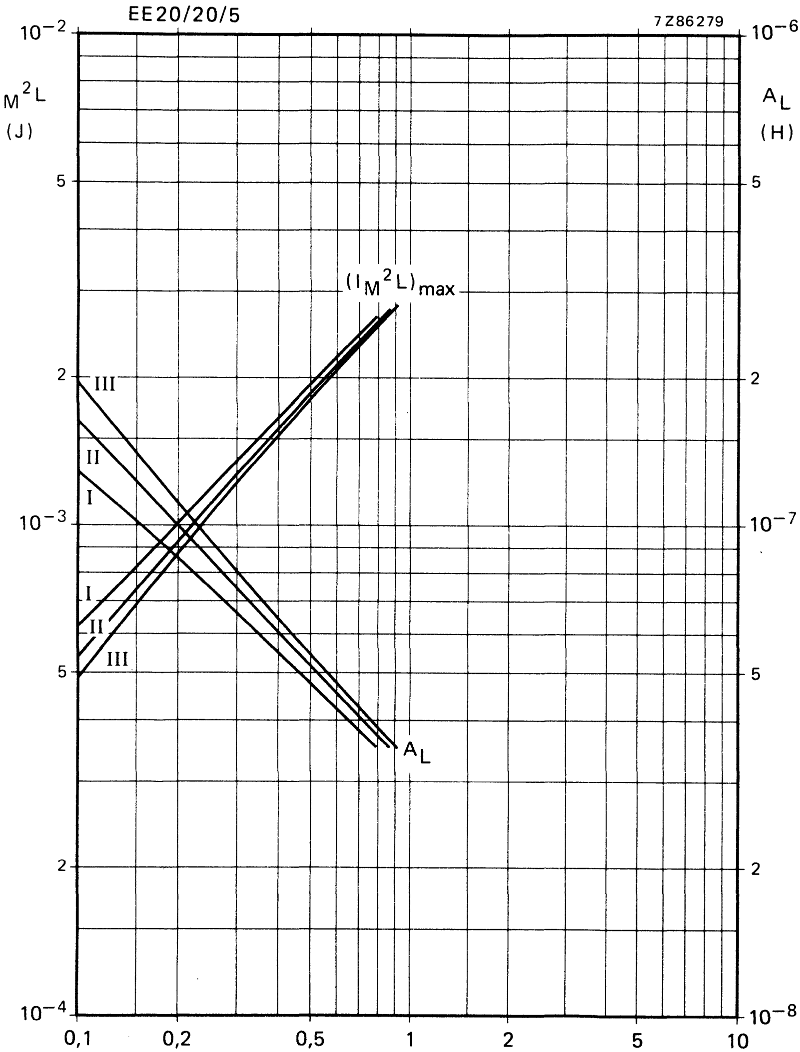
(1). Clasp 4322 021 20160.
Material: brass, tin-plated.

(2). Spring 4322 021 20220.
Material: phosphor-bronze, tin-plated.

The construction is mounted by pushing the spring over the clasp in such a way that the lips A of the spring catch in the square holes B of the clasp. The mechanical pressure, required to keep the two E-cores together is exercised by means of two lips on top of the spring. No special tool is required for mounting the construction.

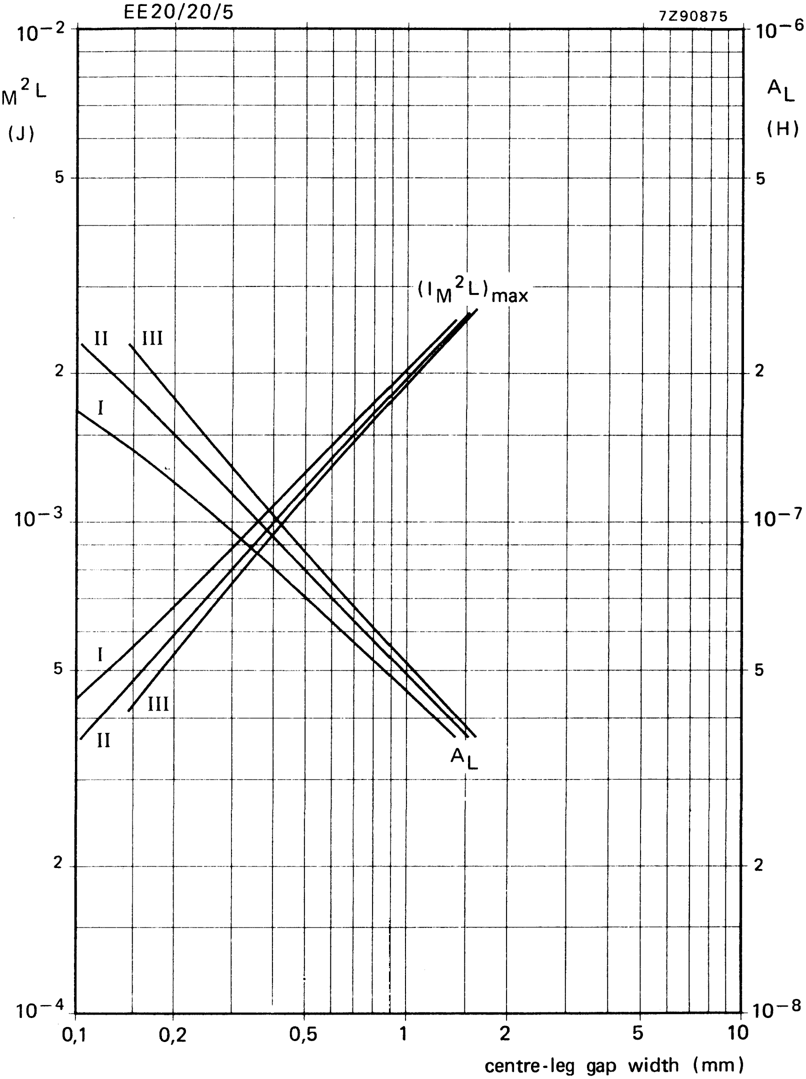
The construction can be used in the horizontal and vertical positions. If the construction is used in the vertical position, the lips C of the clasp must be bent. The dimensions and mutual distance of these lips are chosen in such a way that they fit printed-wiring boards with a grid of 0,1 " as well as those with a grid of 2,50 mm. If used in a horizontal position the clasp can be earthed by means of a copper wire soldered in hole D.

CHARACTERISTIC CURVES



Choke design chart.

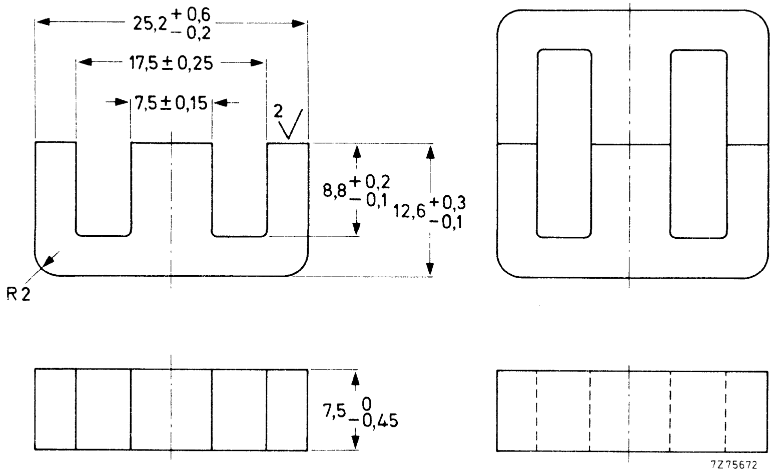
For application classes I, II and III see 'Power choke design' in the Introduction.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

E-CORES



Mass 8,1 g

MAGNETIC DATA

Guaranteed values measured at 16 kHz for a core pair EE25/25/7, pressed together with a force of 60 N.

grade	temperature °C	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one E-core
3C8	25	200		≤ 0,4	
	100	≥ 330	250		• 4312 020 34020
	100	200		≤ 0,35	

Magnetic dimensions, according to IEC 205:

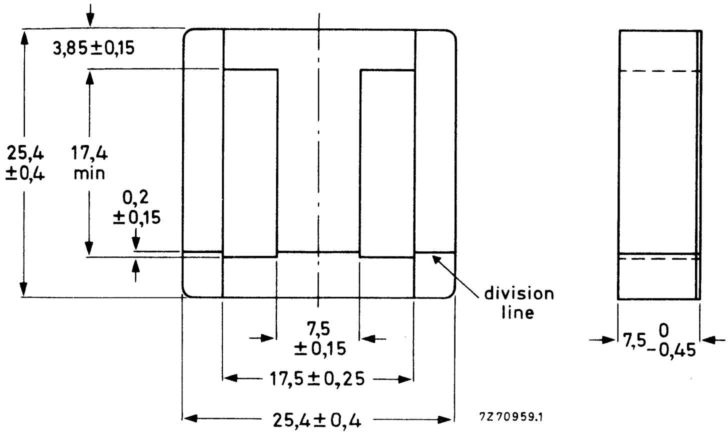
l_e = 57,5 mm

A_e = 52,5 mm^2

$$C_1 = \Sigma \frac{l_e}{A_e} = 1{,}095\ mm^{-1}$$

V_e = 3020 mm^3

• Preferred type.



MAGNETIC DATA

Guaranteed values measured at 16 kHz, for an E-and an I core pressed together with a force of 60 N.

grade	temperature °C	$\hat{B}$ mT	H A/m	losses W	catalogue number
3C8	25 25 100	200 ≥ 380 ≥ 100	 250 50	≤ 0,65	3122 134 90960

Magnetic dimensions

l_e = 57,5 mm

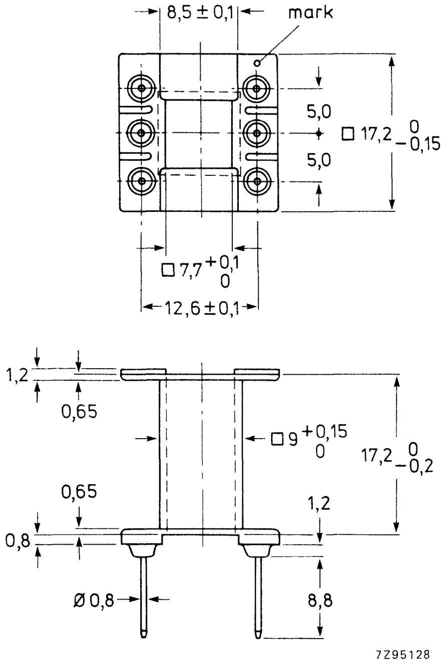
A_e = 52,5 mm^2

V_e = 3020 mm^3

COIL FORMERS

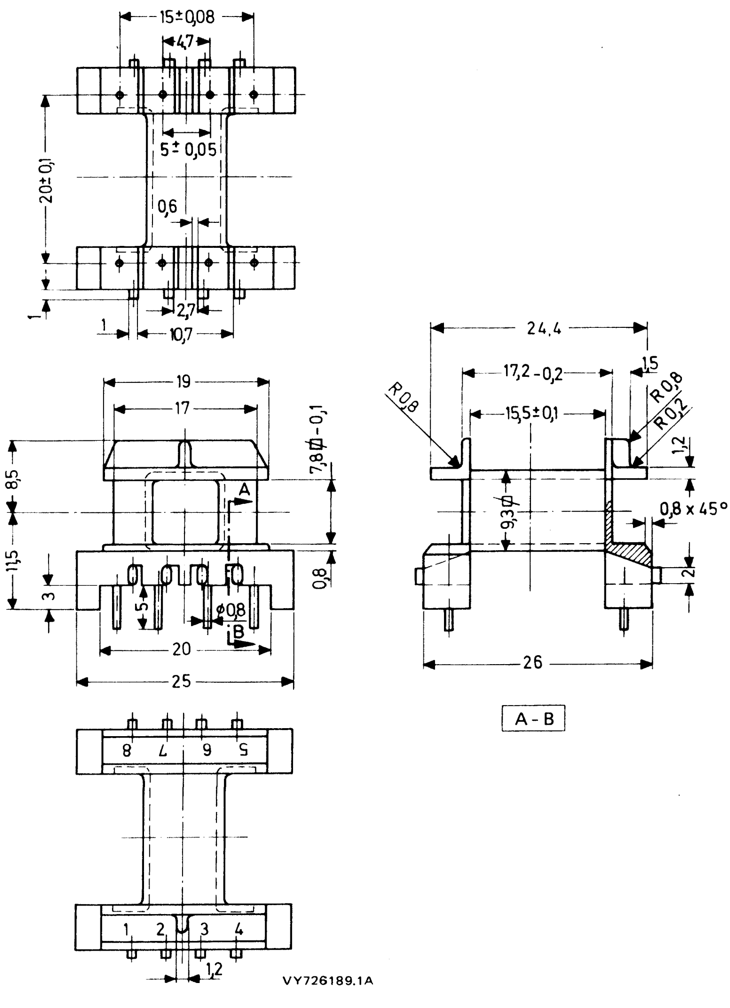
for shell type transformers EE25/25/7
and EI25/25/7

With 6 soldering pins.



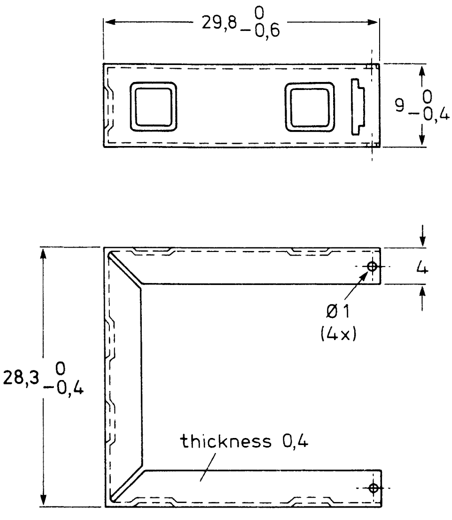
catalogue number	4312 021 28540
material	polyamide 6,6 glass fibre reinforced
minimum window area	61 mm²
mean length of turn	49 mm
approximate mass	4 g
maximum working temperature	130 °C

With 8 soldering pins.



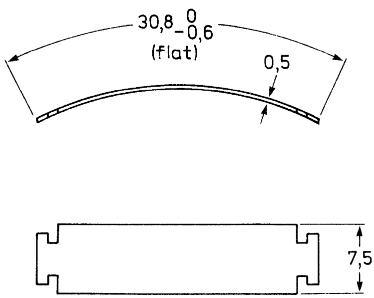
catalogue number	4312 021 28750
material	polyamide 6,6 glass fibre reinforced
soldering pins	phosphor bronze dip-soldered
minimum window area	61 mm²
mean length of turn	49 mm
approximate mass	4 g
maximum working temperature	130 °C

MOUNTING PARTS



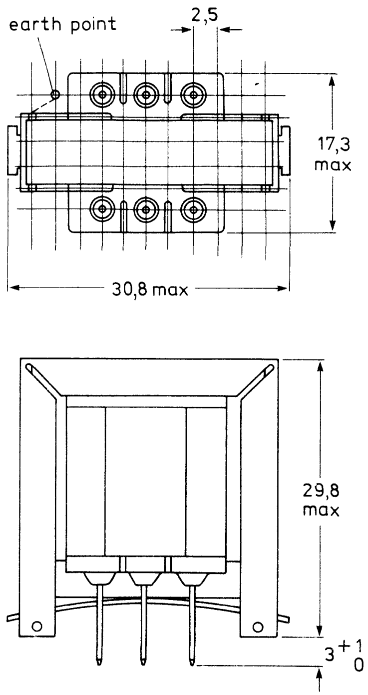
7Z95130

(1) Clasp.
material: nickel plated steel
catalogue number: 4312 021 28490



7Z95129

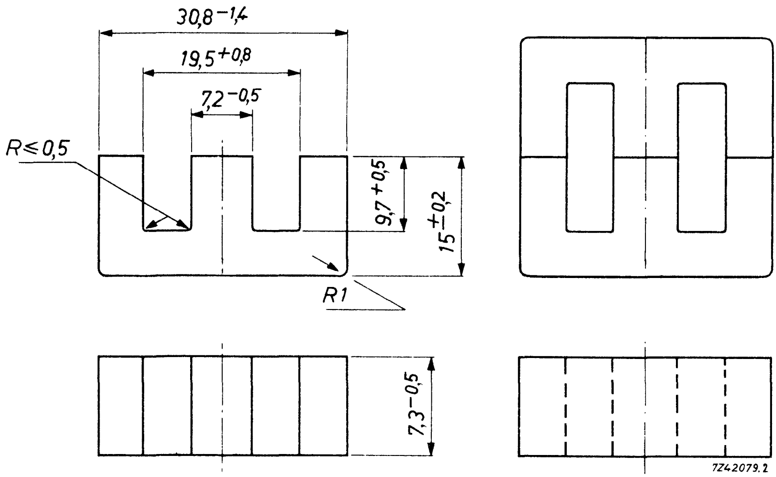
(2) Spring.
material: stainless steel
catalogue number: 4312 021 28500



7Z95127

Maximum dimensions of the set.

E-CORES



Mass approx. 11 g
Dimensions according to DIN 41295

MAGNETIC DATA

Guaranteed values for a core pair EE30/30/7, pressed together with a force of 110 N, air gap Δ = 0

	freq. kHz	temperature °C	$\hat{B}$ mT	grade 3E1	grade 3C8
A_L	100	25 ± 10	≤ 0,1	2660 to 4000	
μ_e	100	25 ± 10	≤ 0,1	2375 to 3565	
μ_e	100	23 to 70	≤ 0,1	≥ 2375	
$\frac{\tan\delta}{\mu_i} \times 10^6$	4	25 ± 10	≤ 0,1	≤ 2,5	
	100	25 ± 10	≤ 0,1	≤ 20	
	500	25 ± 10	≤ 0,1	≤ 200	
$\eta_B \times 10^3$	4	25 ± 10	1,5 to 3	≤ 1,8	
P (W)	16	25	200		≤ 0,48
	16	100	200		≤ 0,44
$\hat{H}$ (A/m)	16	100	≥ 330		250

Catalogue numbers of one E-core without air gap:*
Ferroxcube grade 3E1 ● 4322 020 34840
3C8 ● 4312 020 34550

Magnetic dimensions according to IEC 205:

l_e = 66,9 mm

A_e = 59,7 mm

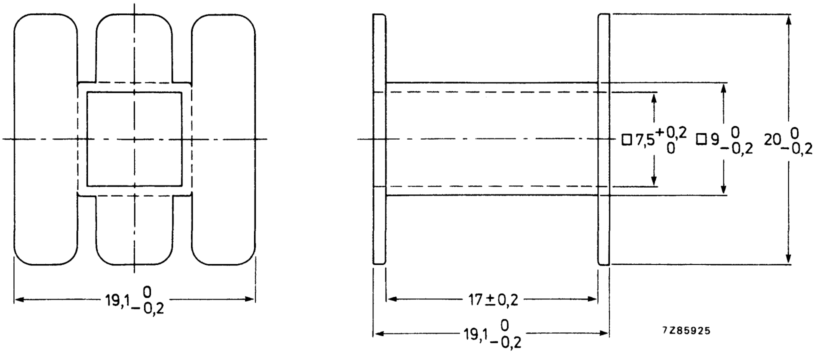
$C1 = \Sigma \frac{l}{A} =$ 1,12 mm^{-1}

V_e = 4000 mm^3

* Cores with air gap are available on request.
● Preferred type.

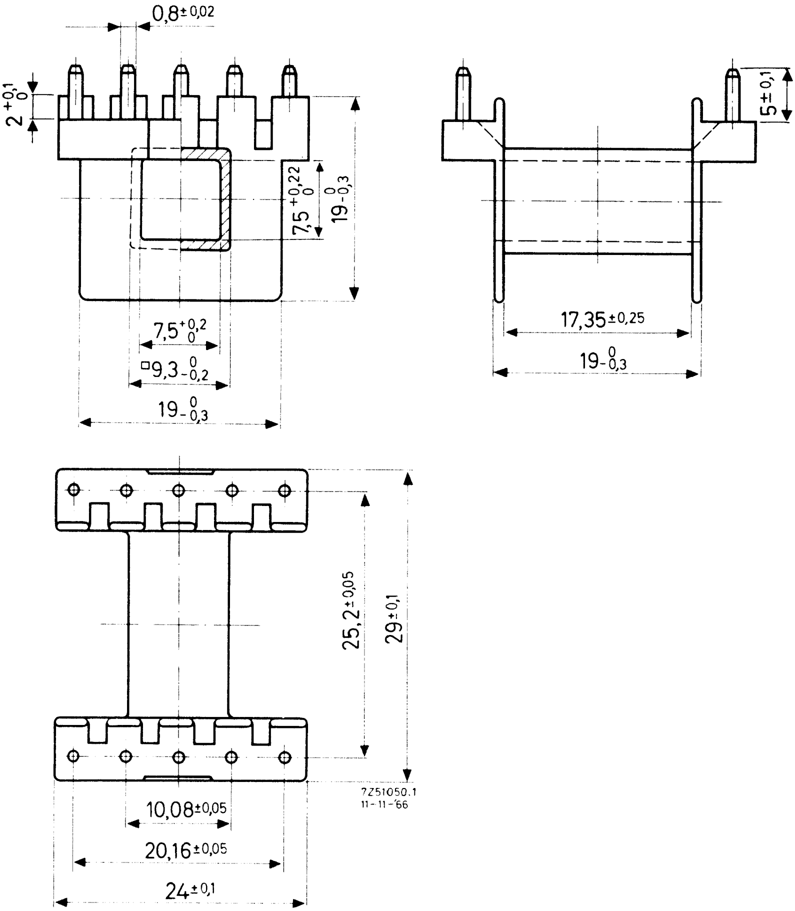
COIL FORMERS

for shell type transformer EE30/30/7 (M30)



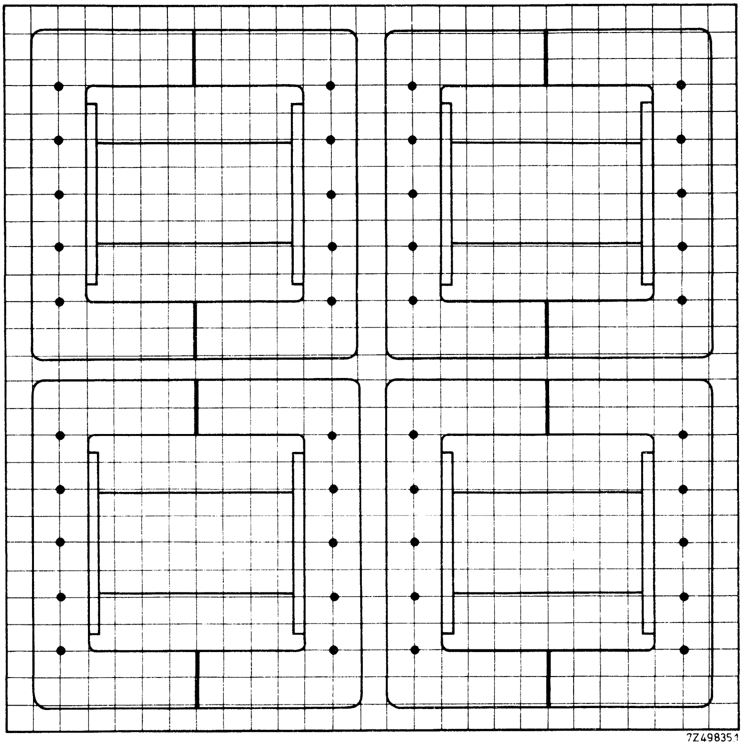
catalogue number	4312 021 28550
material	polyamide 6,6 glass fibre reinforced
minimum window area	80 mm^2
mean length of turn	56 mm
approximate mass	1,3 g
maximum working temperature	130 °C

With soldering pins.



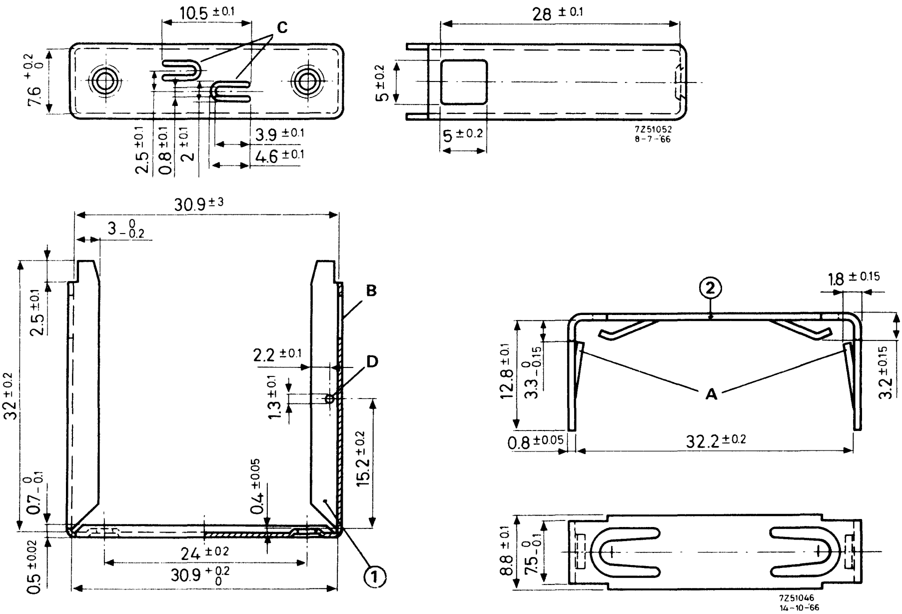
catalogue number	4322 021 20250
material	phenolformaldehyde reinforced with glass fibre; brass dip-solder pins
minimum window area	80 mm^2
mean length of turn	56 mm
approximate mass	3 g
maximum temperature for dip-soldering during 5-6 s	280 °C
maximum working temperature	130 °C

The coil former fits a shell type transformer EE30/30/7 (M30). The soldering pins will fit printed-wiring boards with a grid of 0,1 inch as well as 2,5 mm. The pin length is sufficient for a board thickness up to 3 mm. The board should be provided with holes of 1,3 ± 0,1 mm diameter.



7Z49835.1

MOUNTING PARTS



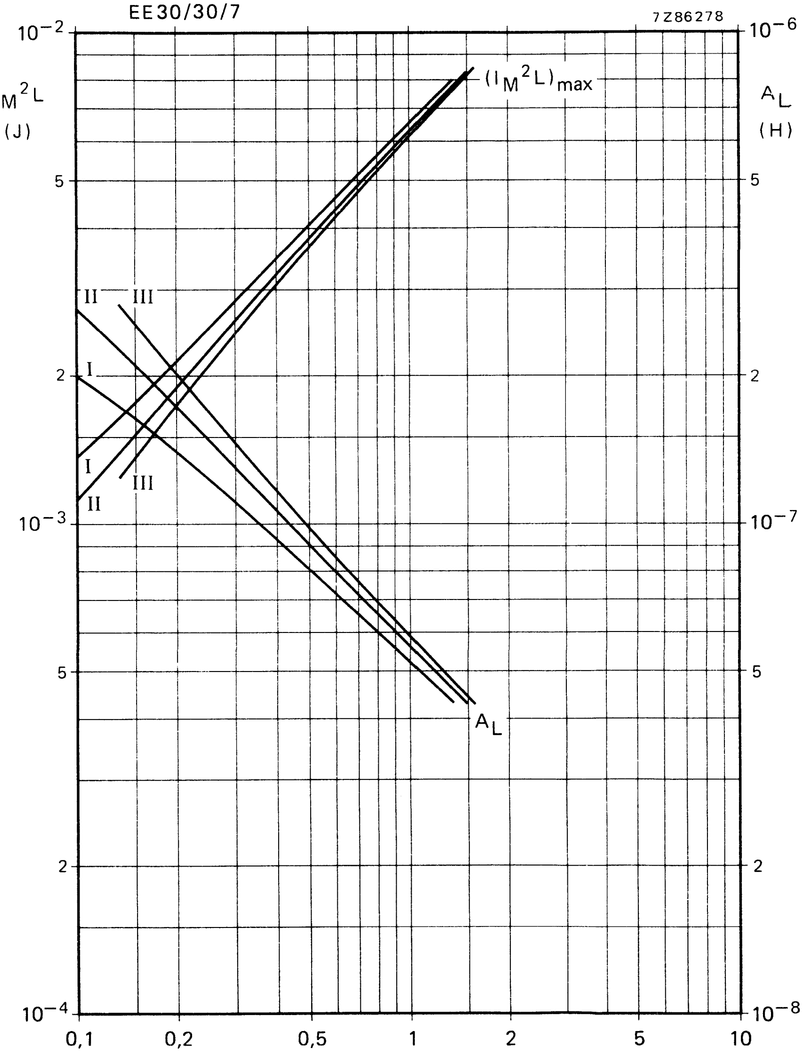
(1). Clasp 4322 021 20170
Material: brass, tin-plated.

(2). Spring 4322 021 20230
Material: phosphor-bronze, tin-plated.

The construction is mounted by pushing the spring over the clasp in such a way that the lips A of the spring catch in the square holes B of the clasp. The mechanical pressure, required to keep the two E-cores together is exercised by means of two lips on top of the spring. No special tool is required for mounting the construction.

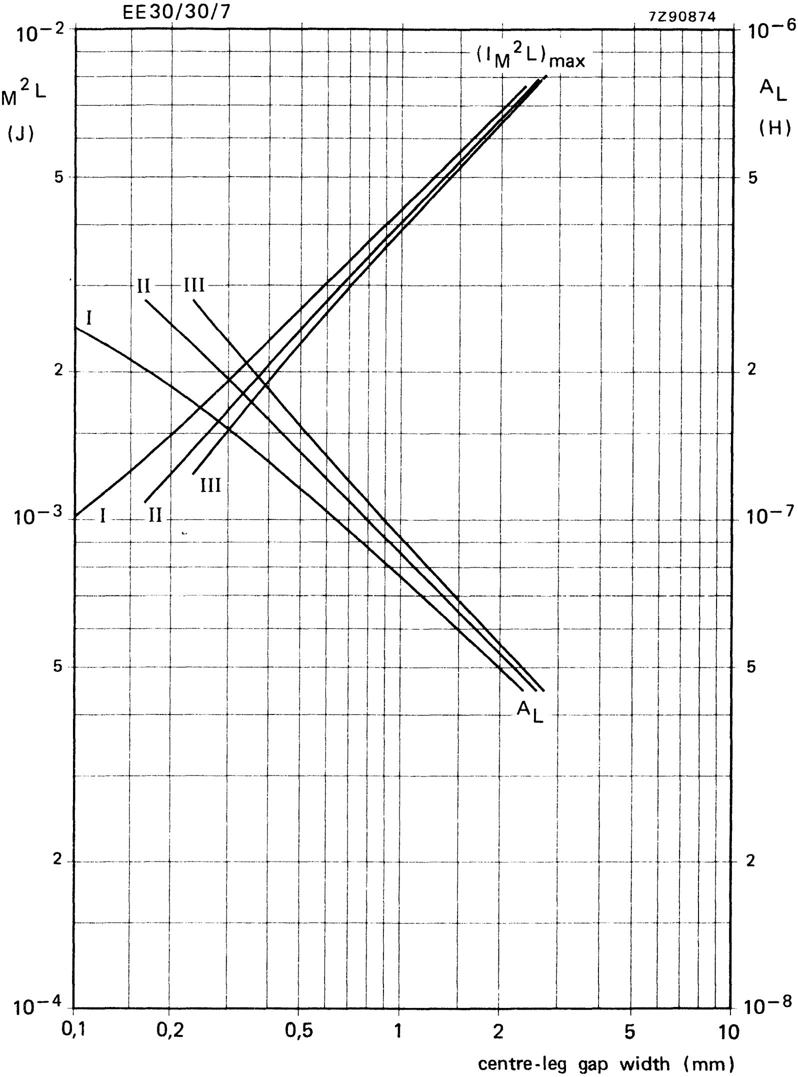
The construction can be used in the horizontal and vertical positions. If the construction is used in the vertical position, the lips C of the clasp must be bent. The dimensions and mutual distance of these lips are chosen in such a way that they fit printed-wiring boards with a grid of 0,1" as well as those with a grid of 2,50 mm. If used in a horizontal position the clasp can be earthed by means of a copper wire soldered in hole D.

CHARACTERISTIC CURVES



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

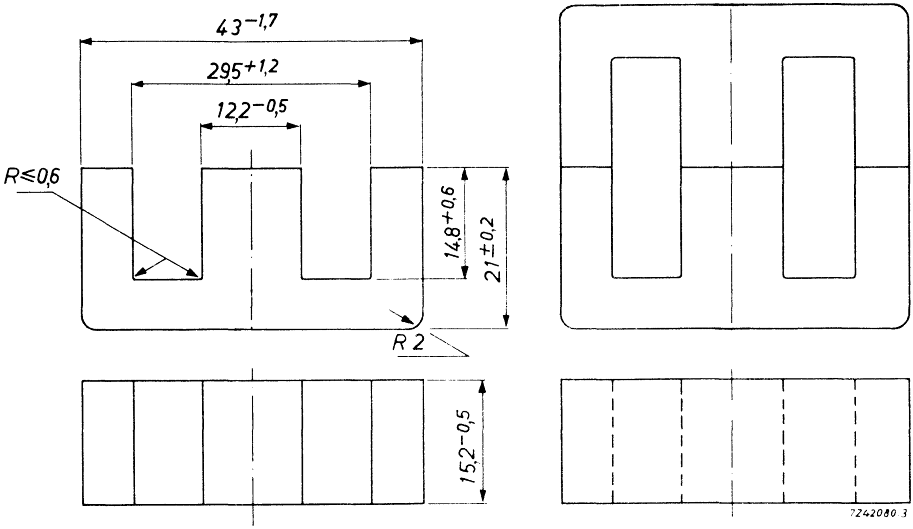


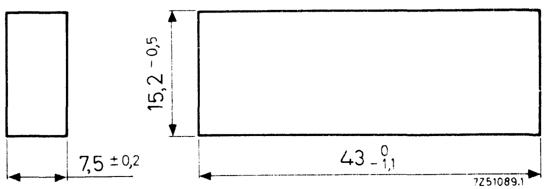
Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

E- AND I-CORES

Dimensions according to DIN 41295.





Mass approx. 42 g

Catalogue numbers

	3E1	3C8
Ferroxcube grade	3E1	3C8
Catalogue number of E-core, without air gap*	● 4322 020 34850	● 4312 020 34110
Catalogue number of I-core	4322 020 37320	

* Cores with air gap are available on request.
● Preferred type.

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer EE42/42/15 composed of two cores type E42/21/15 or the E-I combination EI42/29/15.

Magnetic dimensions according to IEC 205:

		EE42/42/15	EI42/29/15
Effective magnetic path length	l_e =	97,0 mm	67,2 mm
Effective cross-sectional area	A_e =	182 mm²	183 mm²
Core constant	$C_1 = \Sigma \frac{l_e}{A_e} =$	0,534 mm^{-1}	0,367 mm^{-1}
Effective core volume	V_e =	17600 mm³	12300 mm³

MAGNETIC DATA

Guaranteed values for a core pair EE42/42/15 or EI42/29/15, pressed together with a force of 280 N, air gap $\Delta = 0$.

Magnetic properties at 25 ± 10 °C for grade 3E1

	EE42/42/15	EI42/29/15
μ_e =	2570-3855*	2400-3600
A_L =	6040-9070	8210-12320

At 4 kHz and $\hat{B}$ between 1,5 and 3 mT: $\eta_B \times 10^3 \leqslant 1{,}8\ T^{-1}$

at 4 kHz and $\hat{B} \leqslant 0{,}1$ mT: $\frac{\tan\delta}{\mu_i} \times 10^6 \leqslant 2{,}5$

At 100 kHz and $\hat{B} \leqslant 0{,}1$ mT: $\frac{\tan\delta}{\mu_i} \times 10^6 \leqslant 20$

Magnetic properties for grade 3C8

At 16 kHz, B = 200 mT and θ = 100 °C: $P \leqslant 2$ W

At 16 kHz, $B \geqslant 315$ mT and θ = 100 °C: $\hat{H}$ = 250 A/m

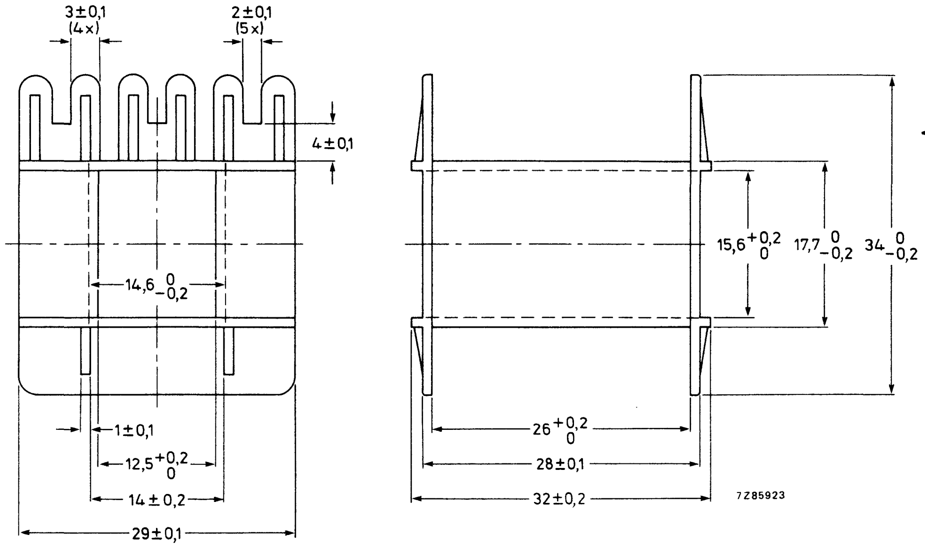
At 16 kHz, $B \geqslant 90$ mT and θ = 100 °C: $\hat{H}$ = 50 A/m

* In the temperature range + 23 to + 70 °C $\mu_e \geqslant 2575$.

COIL FORMERS

for shell type transformer EE42/42/15 (M42)

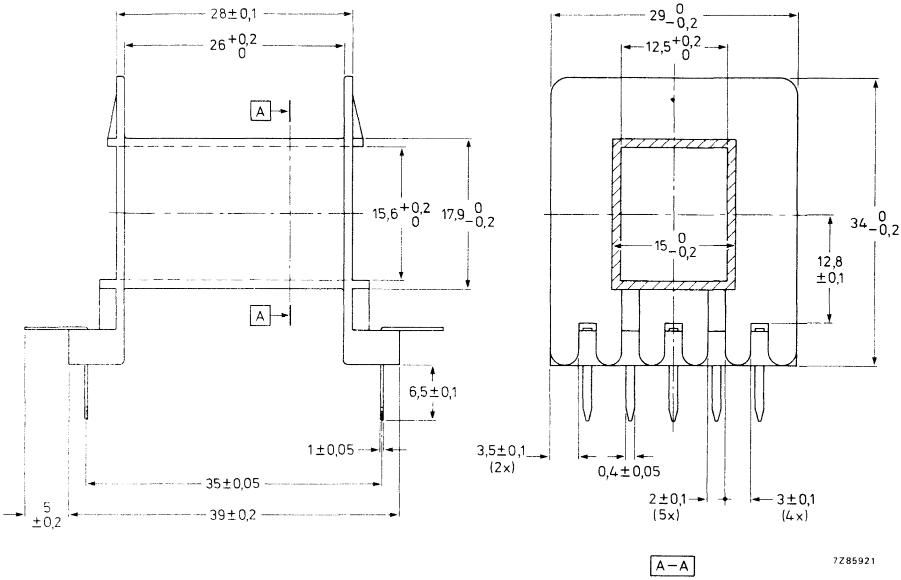
Without soldering pins.

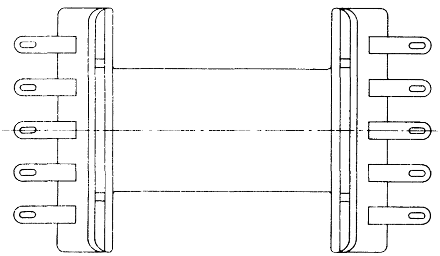


catalogue number	4312 021 28620
material	polyamide 6,6 glass fibre reinforced
minimum window area	178 mm^2
mean length of turn	93 mm
approximate mass	4 g
maximum working temperature	130 °C

The dimensions are practically according to German specification DIN 41305.

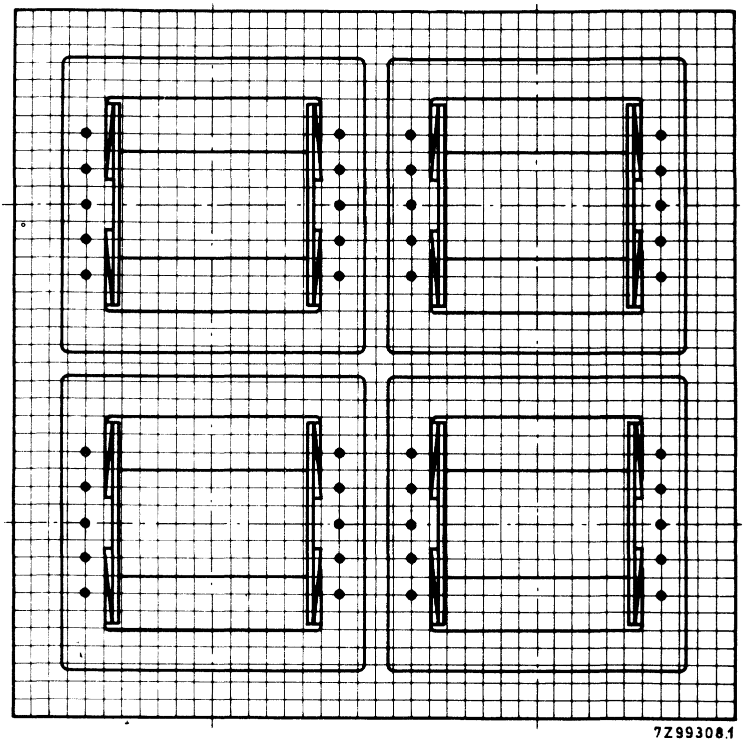
With 10 soldering pins.





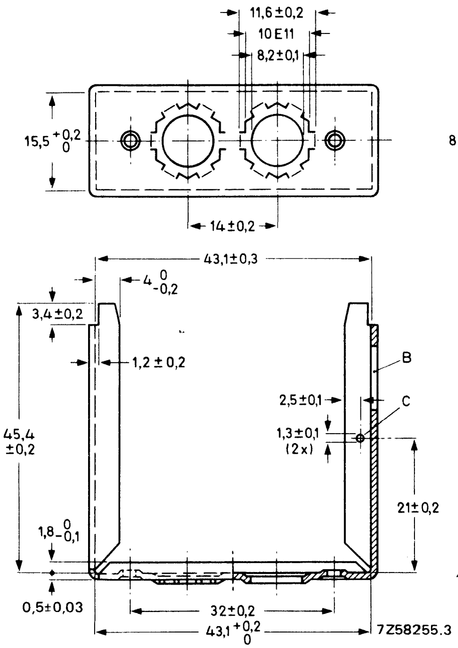
catalogue number	4322 021 31830
material minimum window area mean length of turn approximate mass maximum working temperature	reinforced polyamide with brass dip-soldered pins 178 mm² 93 mm 4 g 130 °C

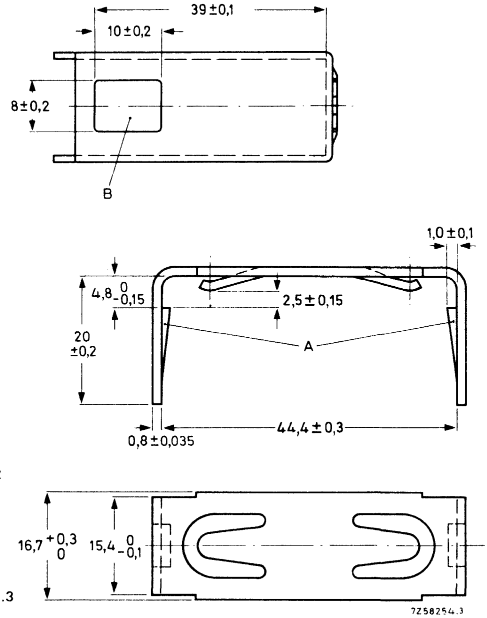
The coil former fits a shell type transformer EE42/42/15 (M42). The soldering pins will fit printed-wiring boards with a grid of 0,1 inch as well as 2,5 mm. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1,3 ± 0,1 mm diameter.



7Z99308.1

MOUNTING PARTS





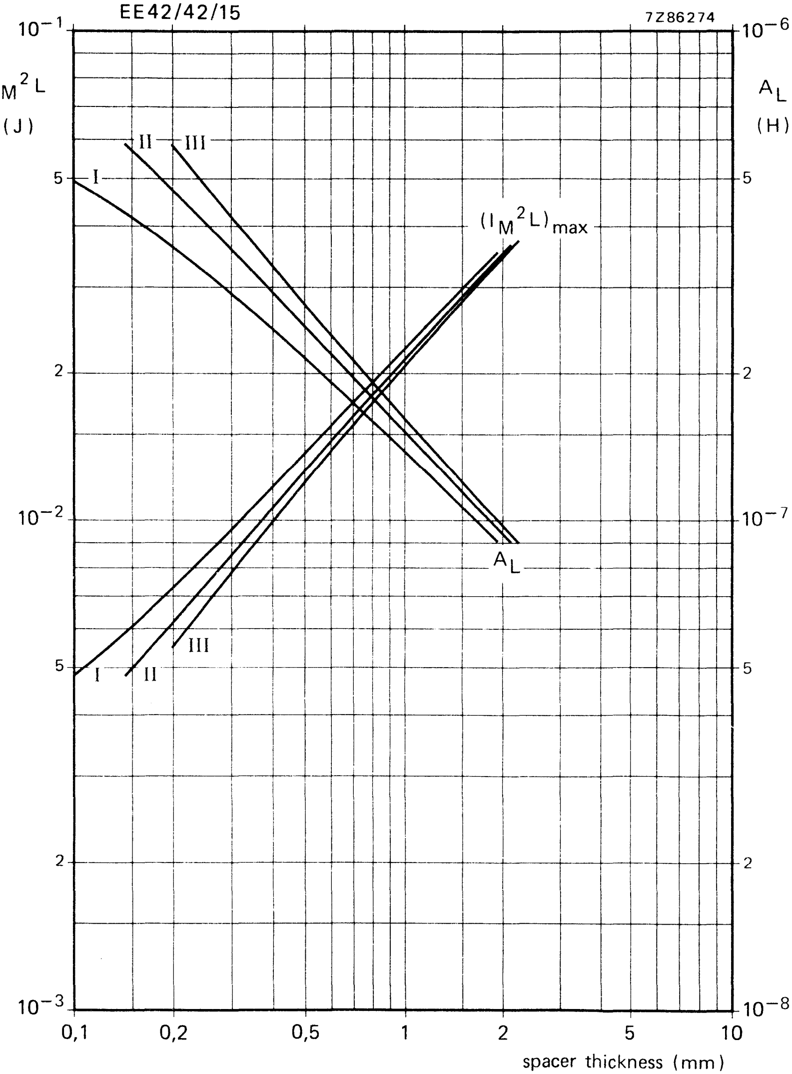
Clasp 4322 021 31910
Material: chromium nickel steel.

Spring 4322 021 31920
Material: chromium nickel steel.

The construction is mounted by pushing the spring over the clasp in such a way that the lips A of the spring catch in the square holes B of the clasp. The mechanical pressure, required to keep the two E-cores together is exercised by means of two lips on top of the spring. No special tool is required for mounting the construction.

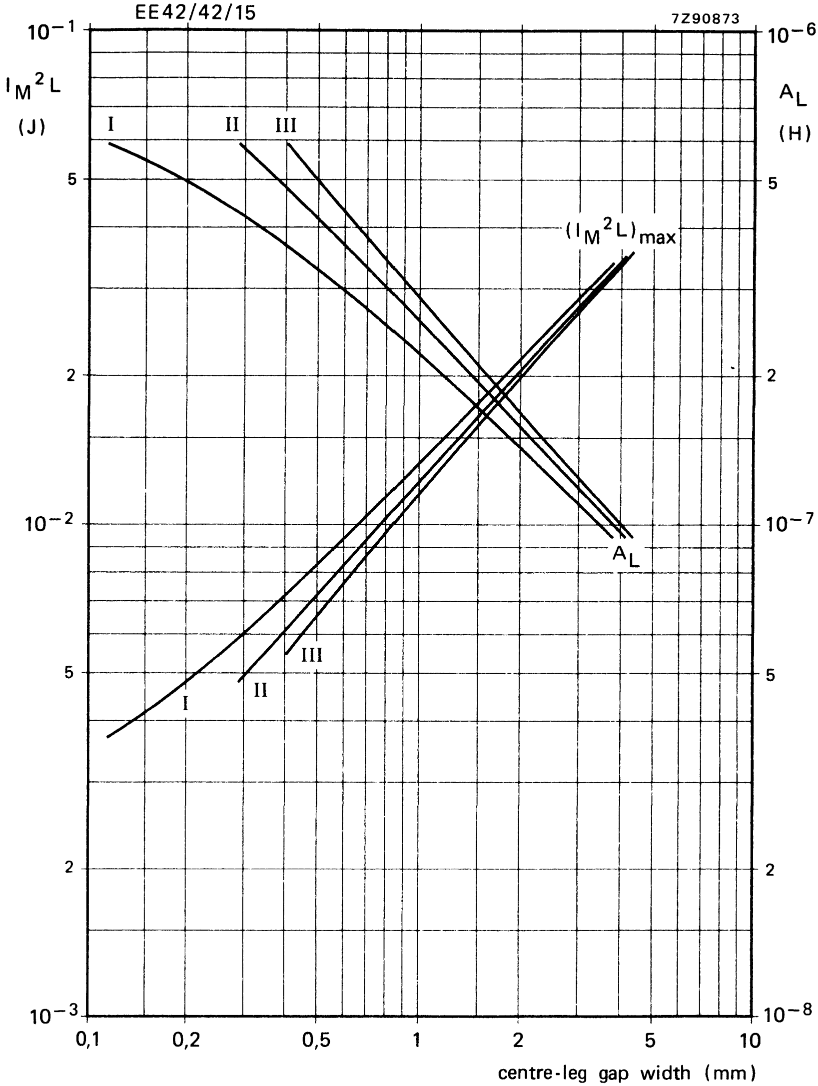
The construction can be used in the horizontal and vertical positions. If the construction is used in the vertical position, two fixing bushes 4322 021 30720 with nuts 4322 021 30710 must be applied in the holes of the clasp. If used in a horizontal position the clasp can be earthed by means of a copper wire soldered in hole C.

CHARACTERISTIC CURVES



Choke design chart.

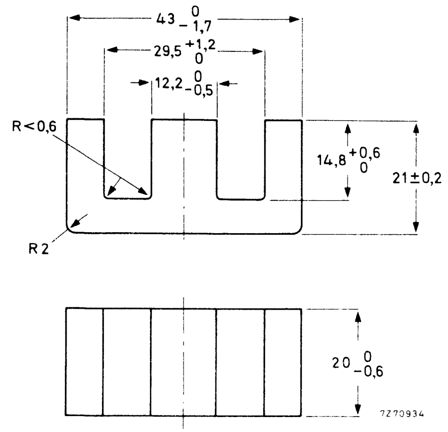
For application classes I, II and III see 'Power choke design' in the Introduction.



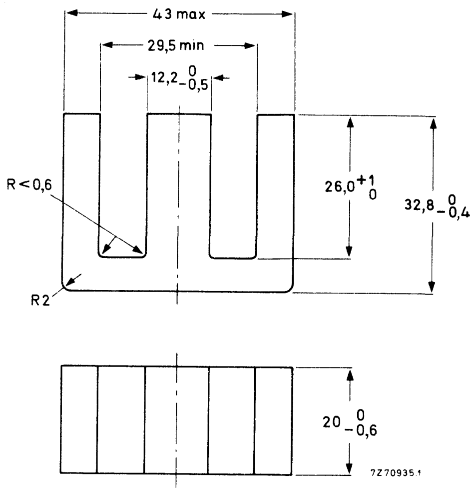
Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

E-CORES



E42/21/20



E42/33/20

Mass 56 g

Mass 82 g

Catalogue numbers

Ferroxcube grade 3C8

Catalogue number of core E42/21/20 without air gap*	● 4312 020 34120
Catalogue number of core E42/33/20 without air gap*	4312 020 34190
Catalogue number of combination of cores E42/21/20 + E42/33/20	4312 020 34170

SHELL TYPE TRANSFORMERS EE42/42/20 AND EE42/54/20

A transformer core can be built up by combining an even number of E-cores. Shapes that are often chosen are the shell type transformer EE42/42/20 composed of two cores E42/21/20, and shell type transformer EE42/54/20 composed of one core E42/21/20 and one core E42/33/20.

● Preferred type.
* Cores with air gap are available on request.

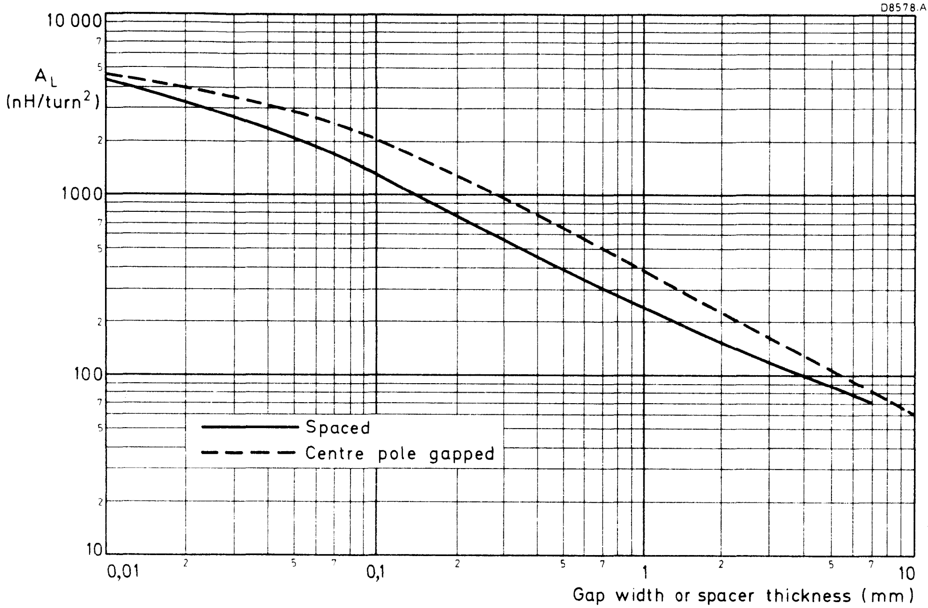
Magnetic dimensions according IEC 205:

		EE42/42/20	EE42/54/20
l_e	=	98 mm	122 mm
A_e	=	236 mm^2	236 mm^2
$C_1 = \Sigma \frac{l_e}{A_e}$	=	0,415 mm^{-1}	0,517 mm^{-1}
V_e	=	23100 mm^3	28800 mm^3

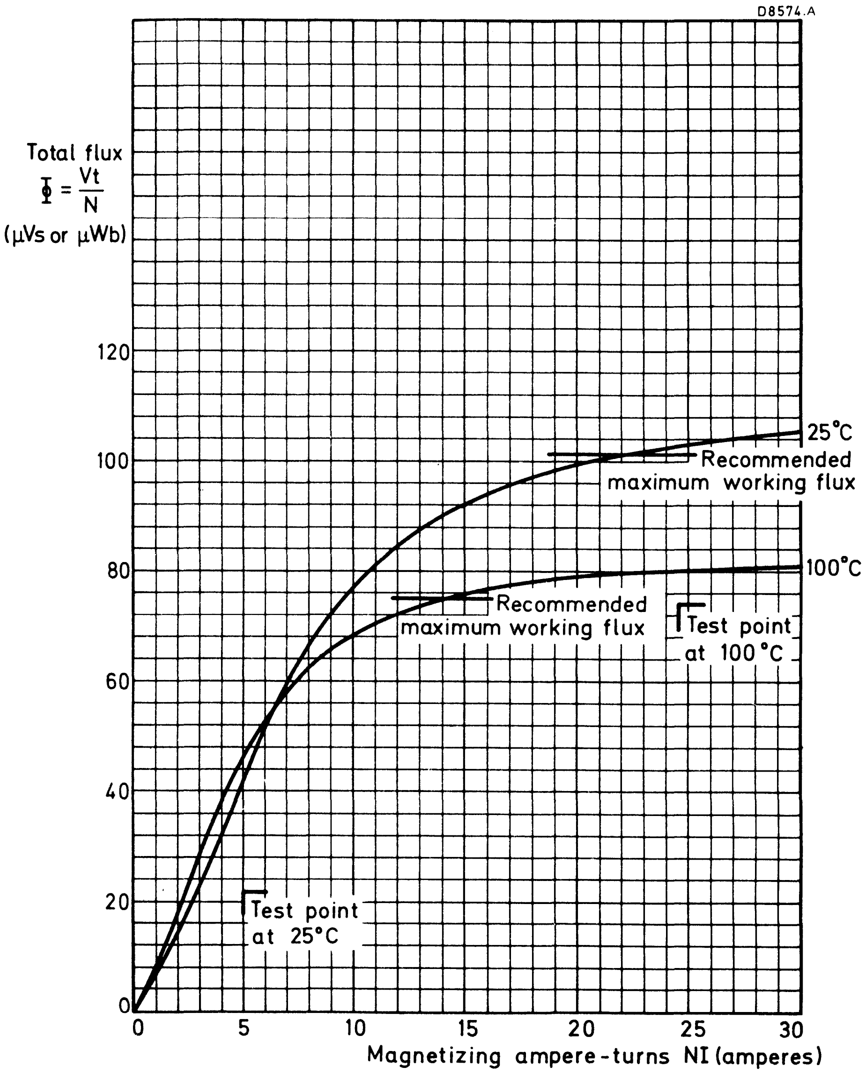
MAGNETIC DATA

			EE42/42/20	EE42/54/20
At f = 16 kHz, $\hat{B}$ = 200 mT, θ = 25 °C	P			$\leqslant$ 3,5 W
θ = 100 °C	P	$\leqslant$	2,6 W	$\leqslant$ 3,2 W
At f = 16 kHz, $\hat{B} \geqslant$ 90 mT, θ = 100 °C	$\hat{H}$	=	50 A/m	
$\hat{B} \geqslant$ 315 mT, θ = 100 °C	$\hat{H}$	=	250 A/m	250 A/m

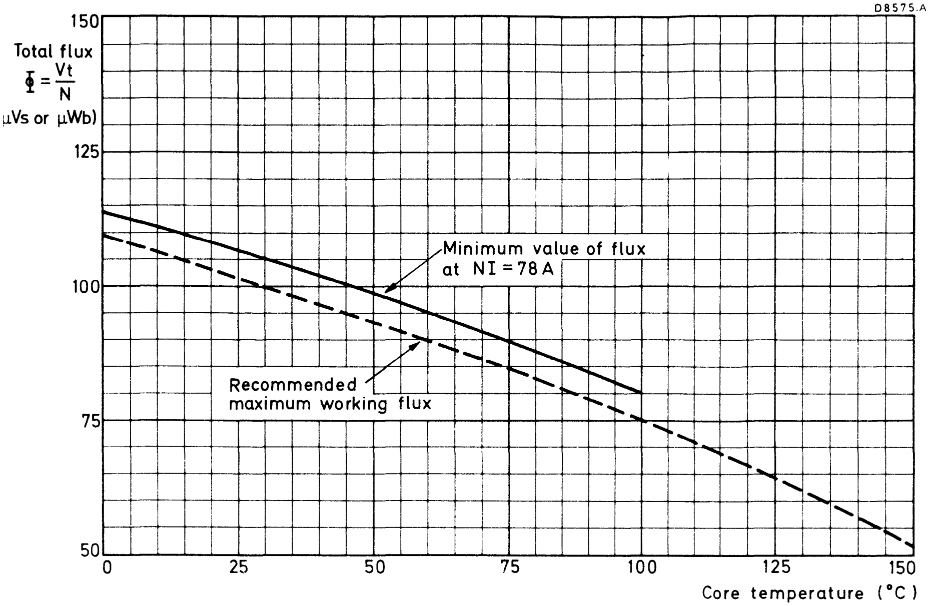
CHARACTERISTIC CURVES



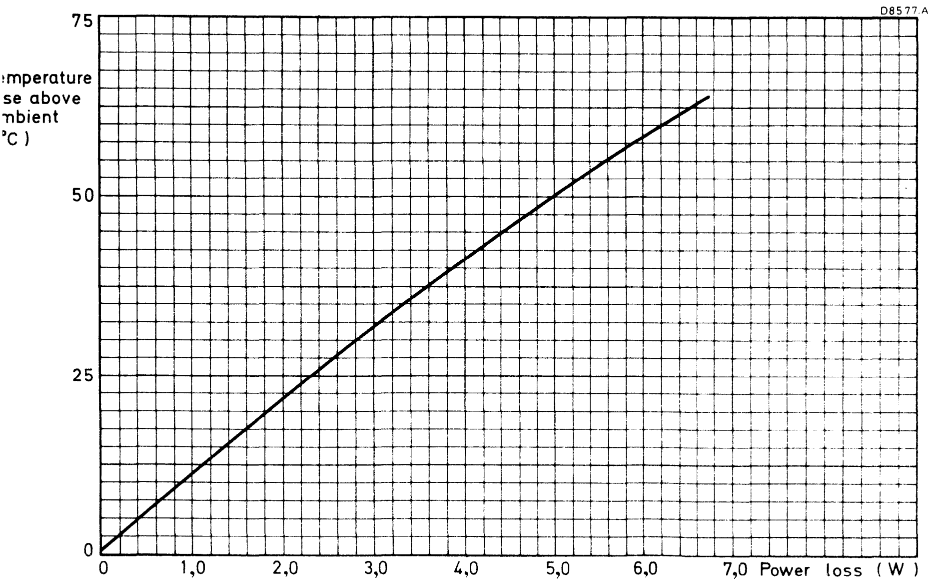
A_L based on a typical initial permeability of 2000 as a function of spacer thickness.



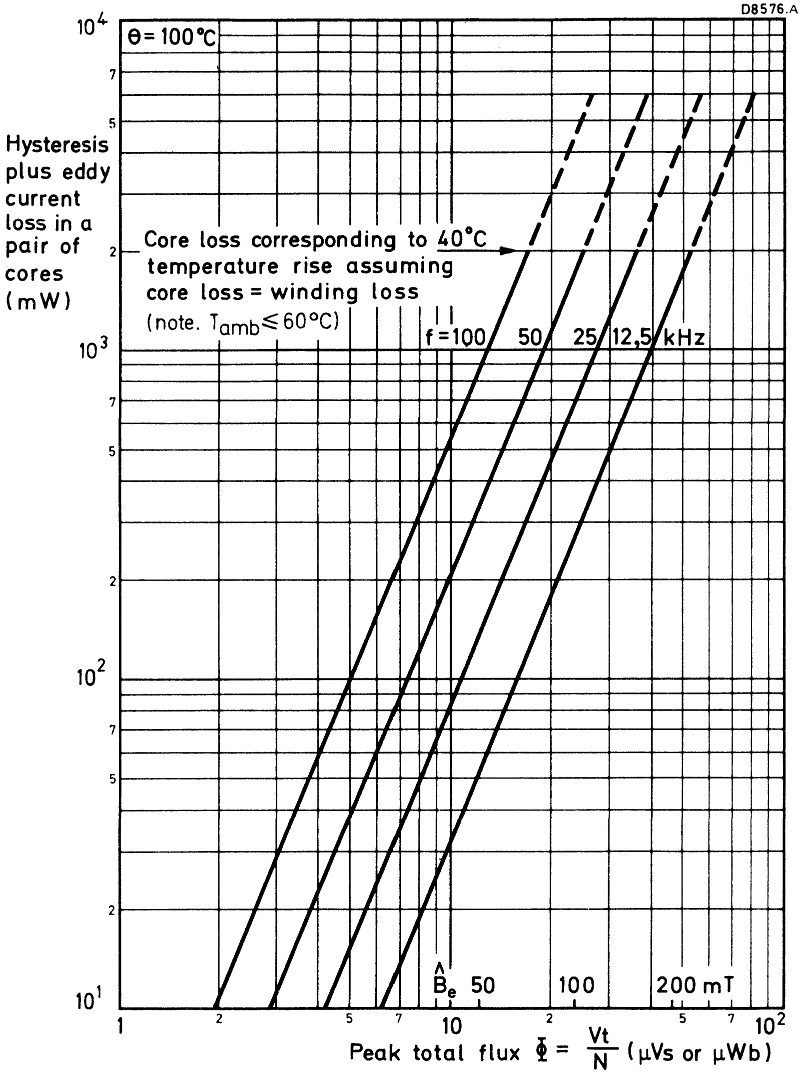
Typical magnetization curves for a pair of cores, in 3C8, with ambient temperature as parameter.



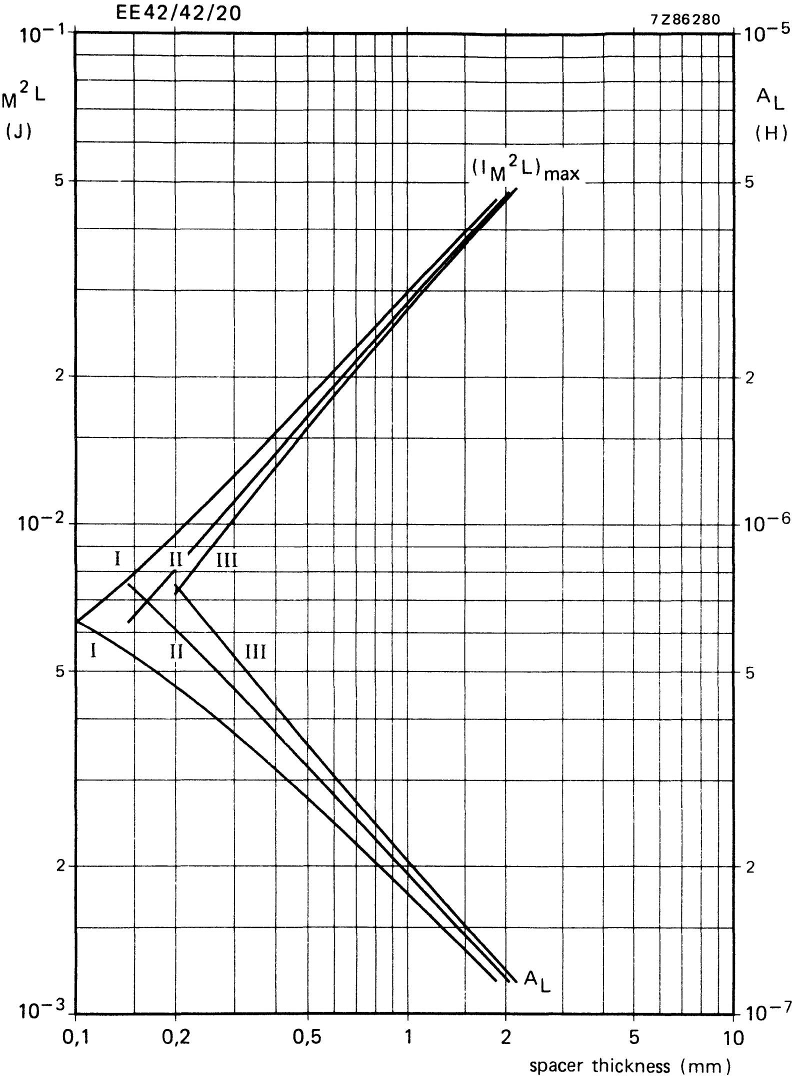
Total flux as a function of core temperature.



Typical transformer temperature rise as a function of total transformer loss in free air conditions.

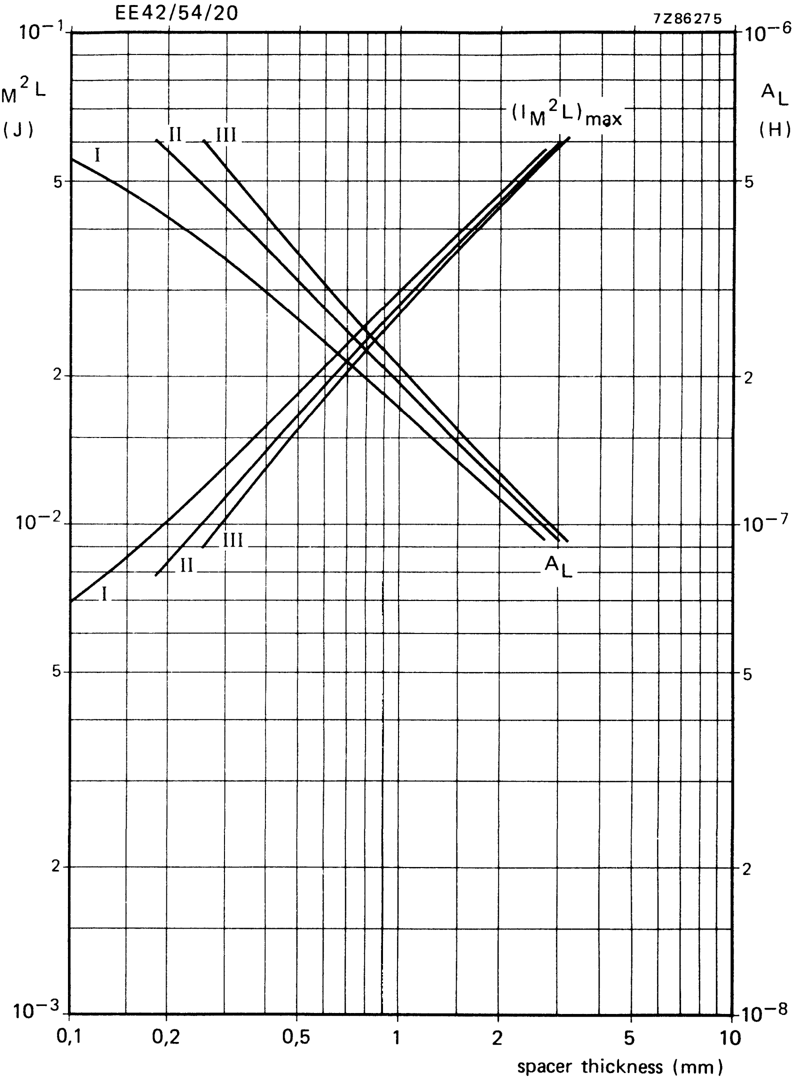


Core loss as a function of total flux at 100 °C with frequency as parameter.



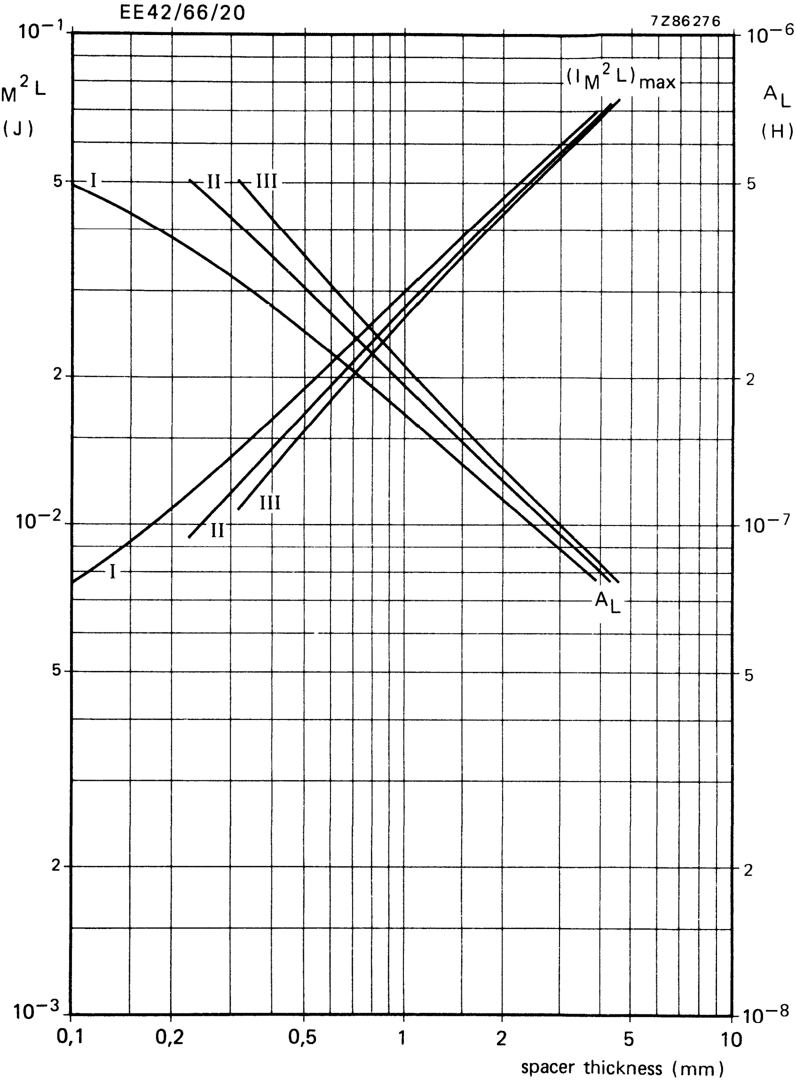
Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.



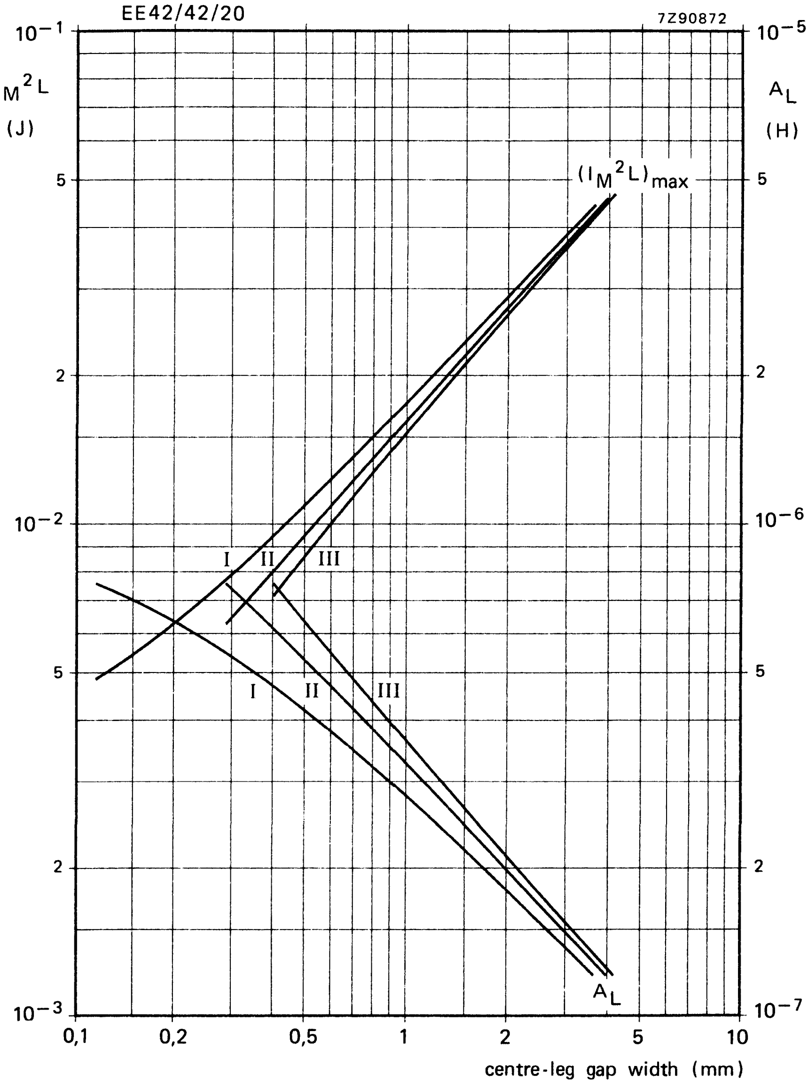
Choke design chart.

→ For application classes I, II and III see 'Power choke design' in the Introduction.



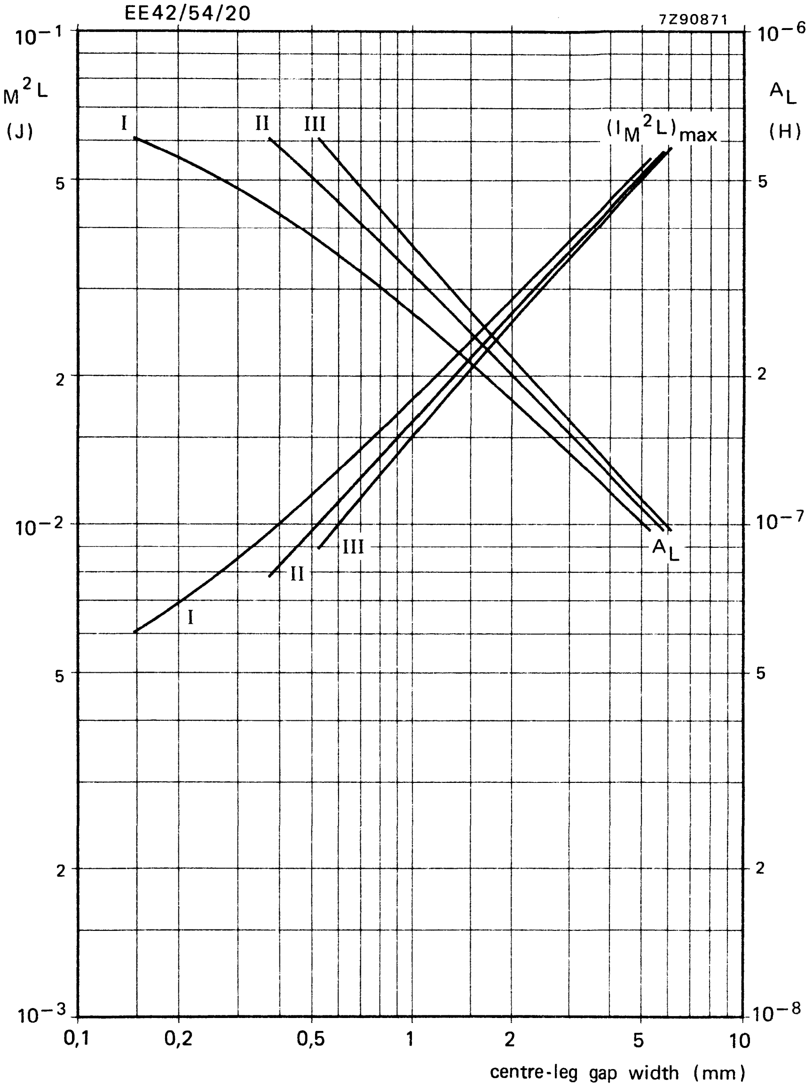
Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.



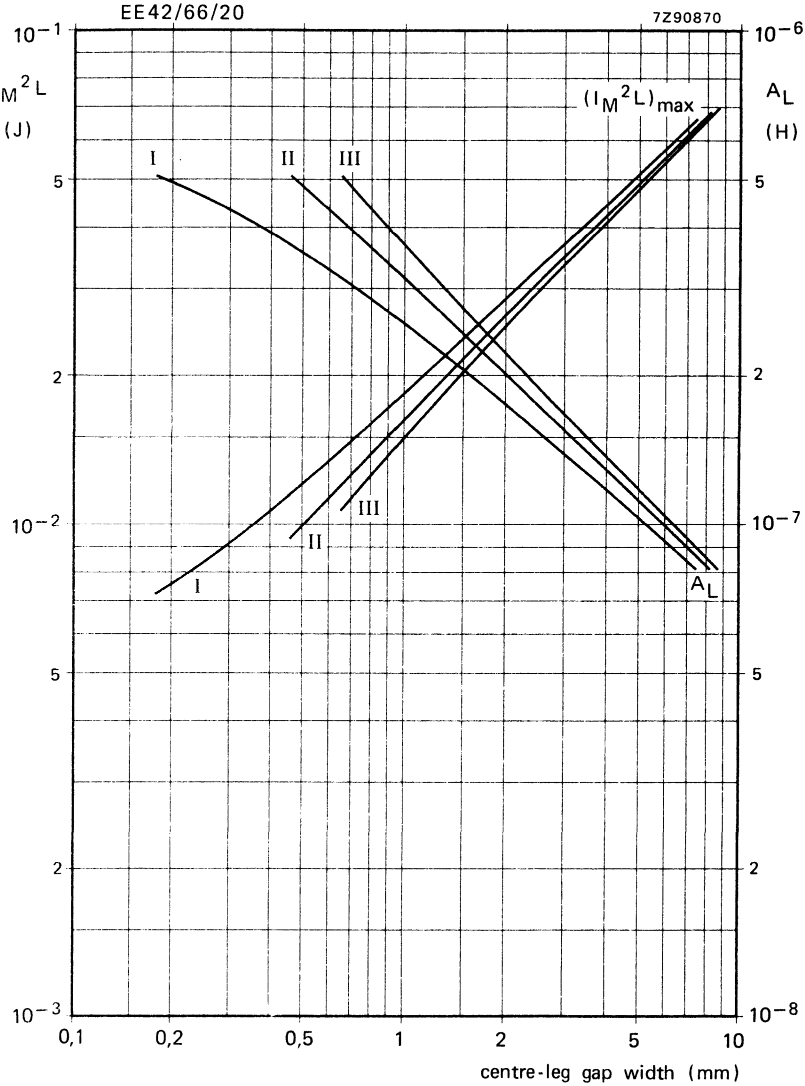
Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.



Choke design chart.

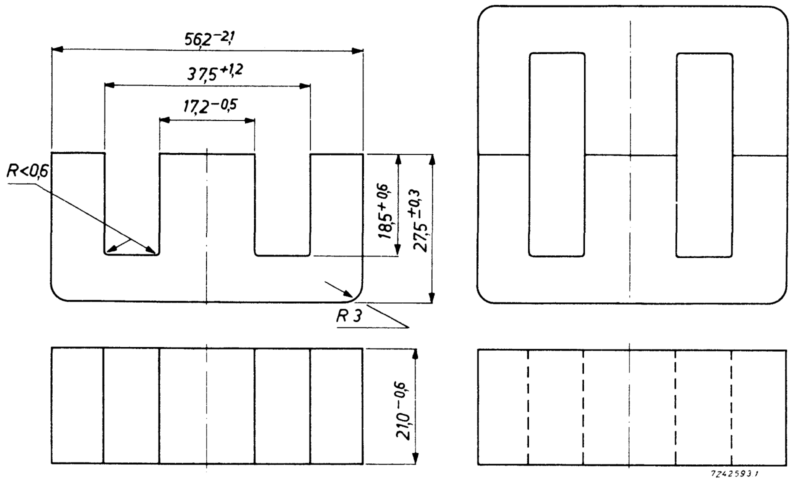
For application classes I, II and III see 'Power choke design' in the Introduction.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

E-CORES



The dimensions are according to DIN 41295.

Mass approx. 115 g

Catalogue numbers

Ferroxcube grade 3E1, no air gap*	● 4322 020 34900
Ferroxcube grade 3C8, no air gap*	● 4312 020 34100

SHELL TYPE TRANSFORMER EE55/55/21

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer EE55/55/21 composed of two cores type EE55/28/21.

* Cores with air gap are available on request.

● Preferred type.

Magnetic dimensions according to IEC 205:

l_e = 123 mm

A_e = 354 mm^2

$C_1 = \Sigma \frac{l_e}{A_e} = 0{,}348\ mm^{-1}$

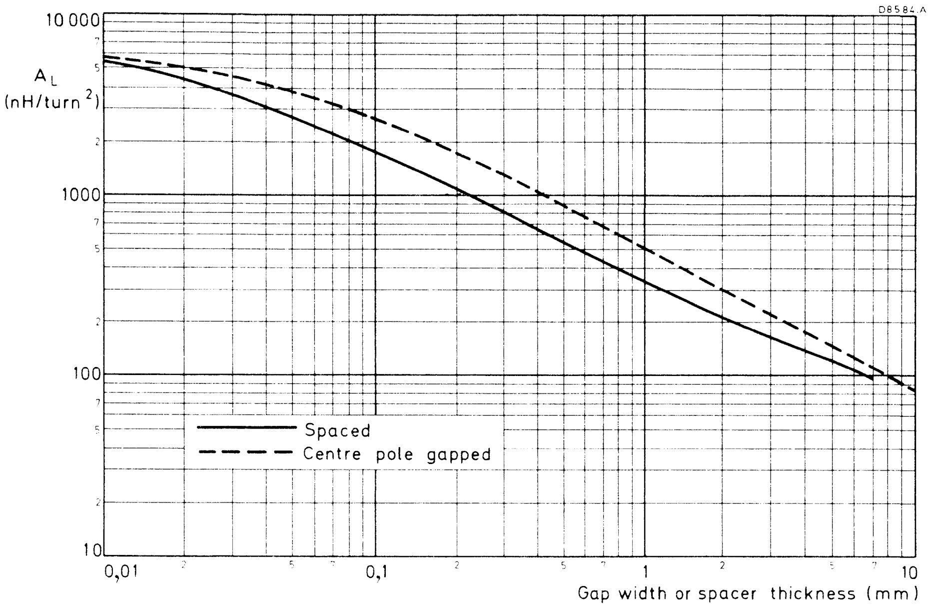
V_e = 43700 mm^3

MAGNETIC DATA

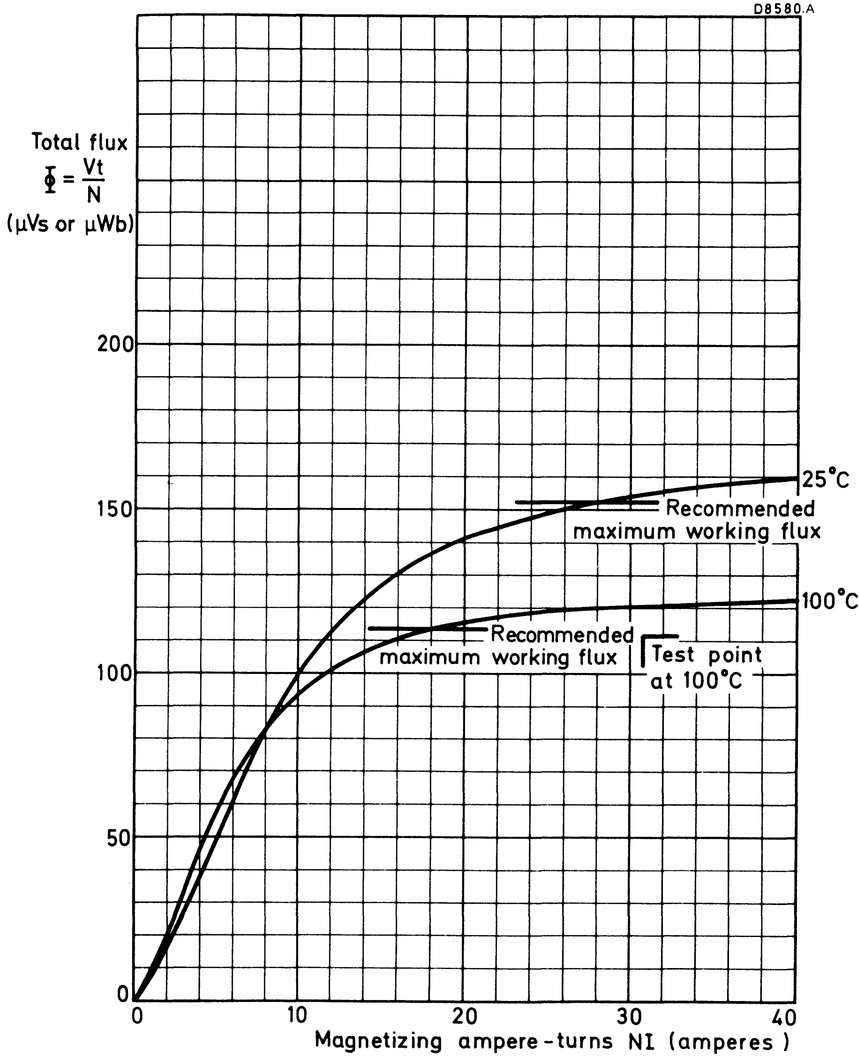
Guaranteed values for a core pair EE55/55/21, pressed together with a force of 550 N, air gap Δ = 0.

	freq. kHz	temp. °C	$\hat{B}$ mT	grade 3E1	grade 3C8
A_L	100	25 ± 10		9545 to 14330	
μ_e	100	25 ± 10		2645 to 3970	
$\eta_B \times 10^3$	4	25 ± 10	1,5 to 3	⩽ 2,5	
P (W)	16	25	200		⩽ 5,5
	16	100	200		⩽ 5,0
$\hat{H}$ (A/m)	16	100	315		250

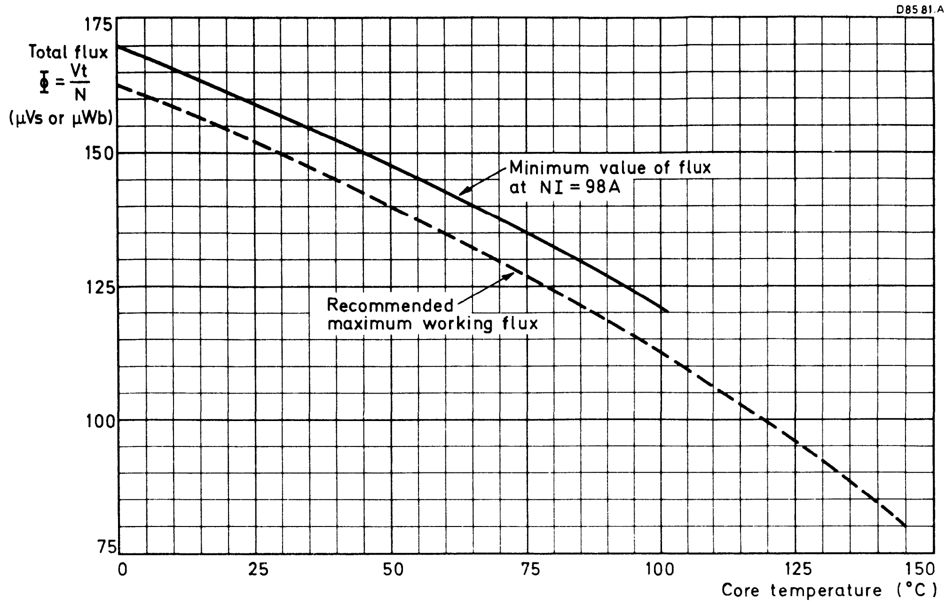
CHARACTERISTIC CURVES



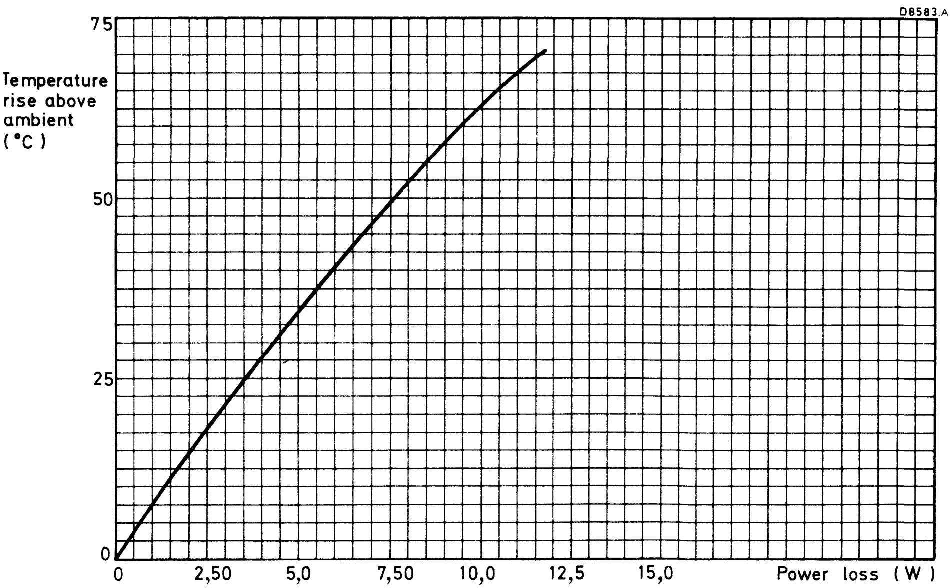
A_L based on a typical initial permeability of 2000 as a function of spacer thickness.



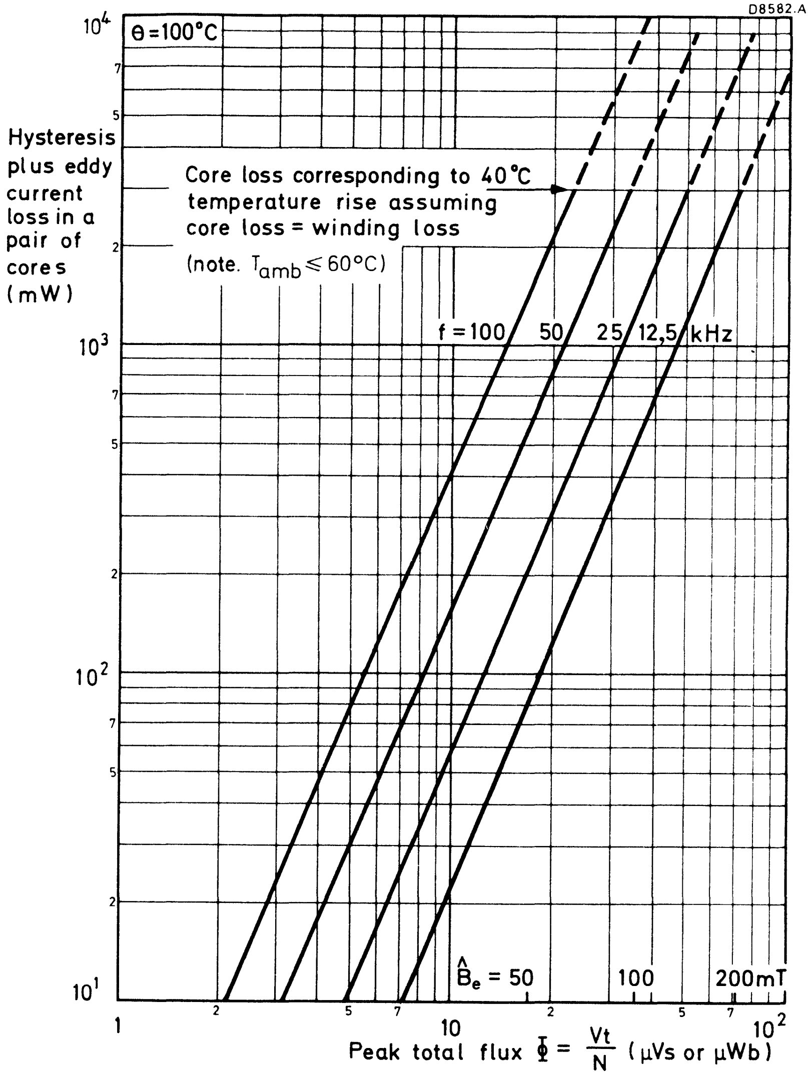
Typical magnetization curves for a pair of cores with ambient temperature as parameter, FXC 3C8.



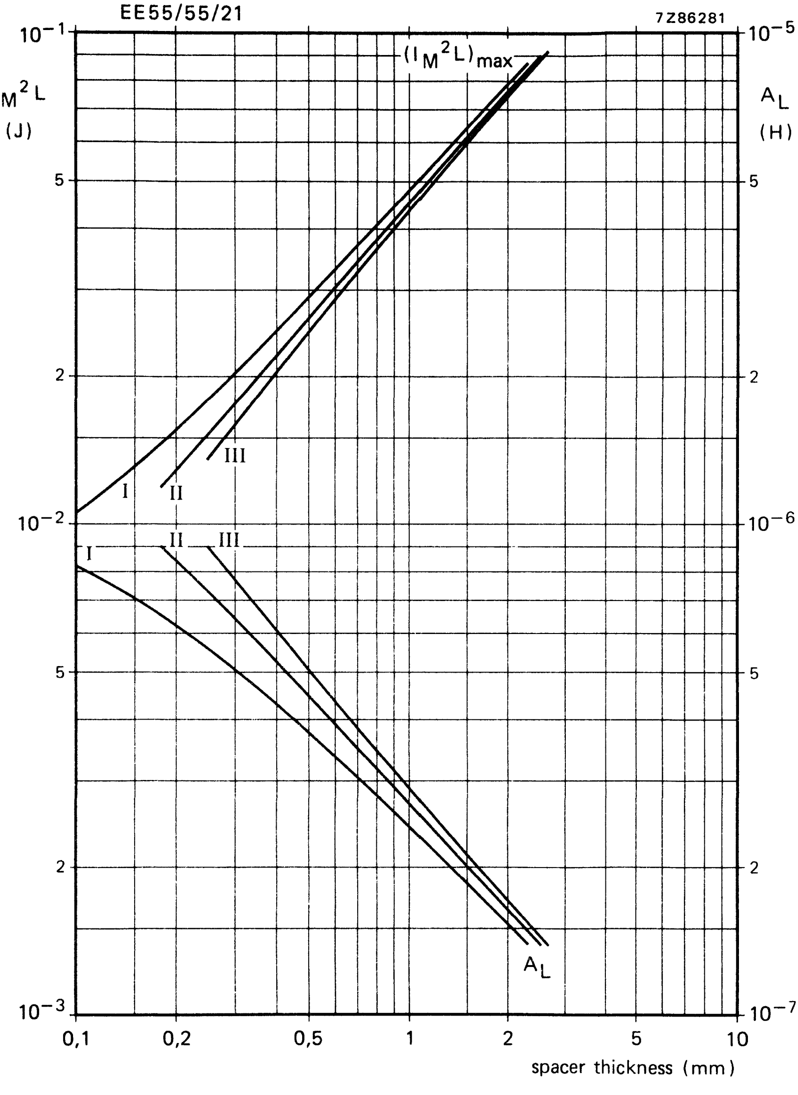
Total flux as a function of core temperature.



Typical transformer temperature rise as a function of total transformer loss in free air conditions.

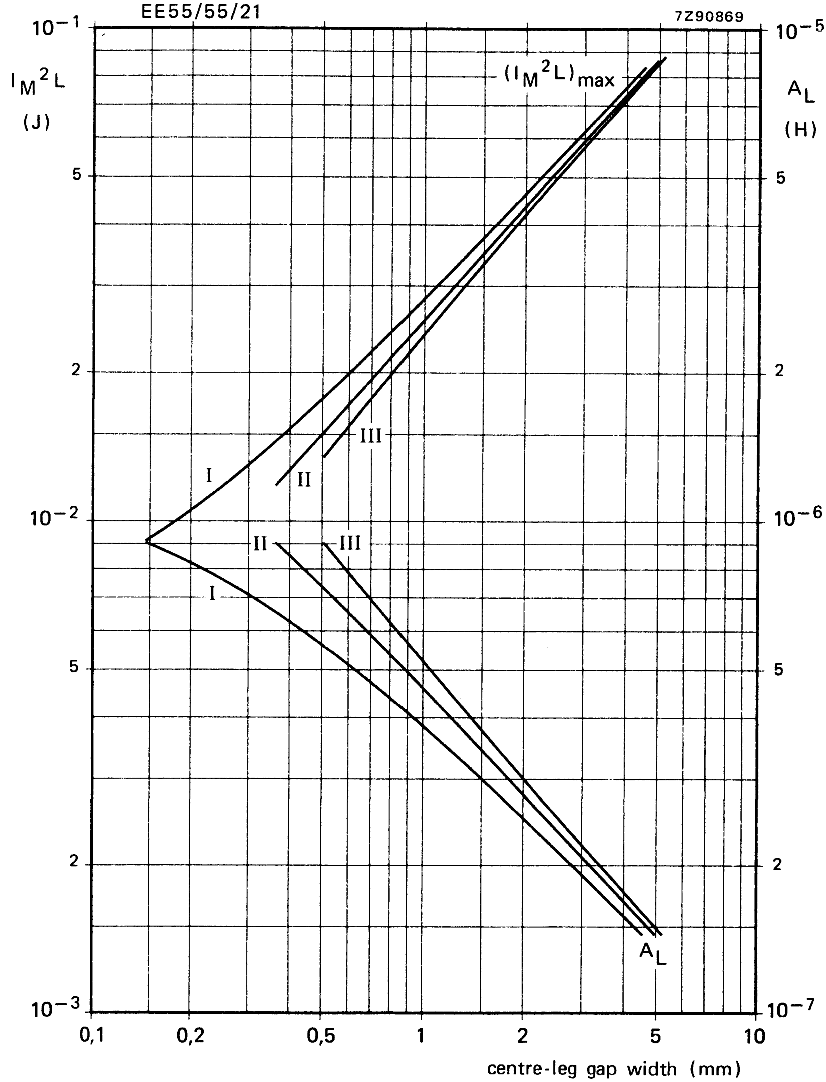


Core loss as a function of total flux at 100 °C with frequency as parameter, FXC 3C8.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

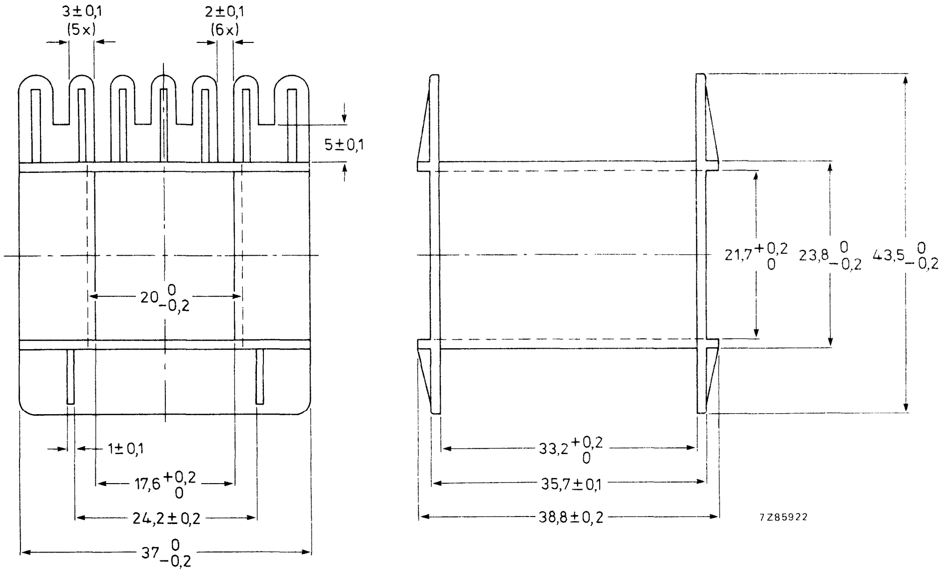


Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

COIL FORMER

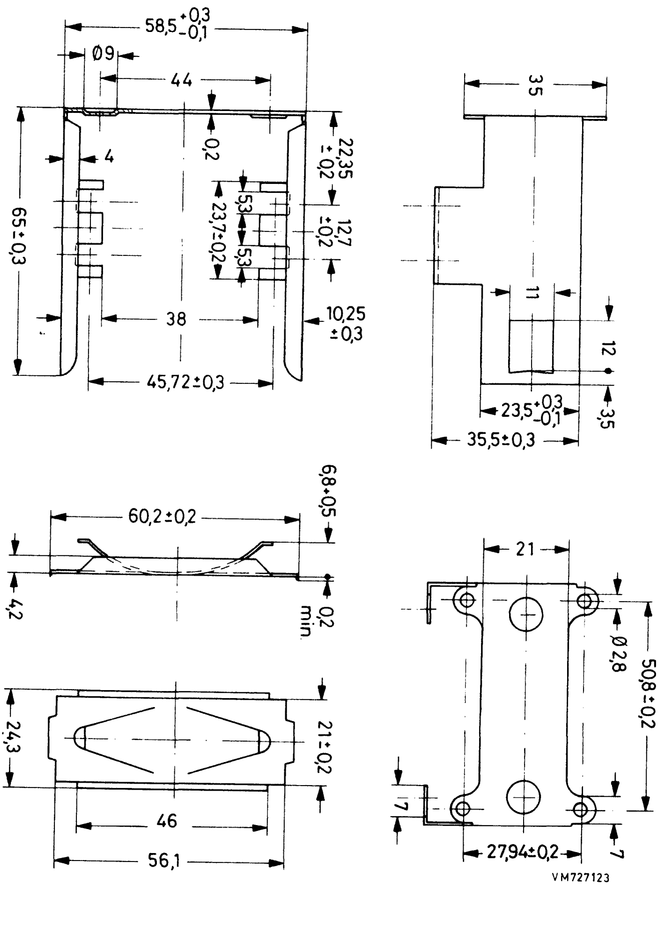
for shell type transformer EE55/55/21



catalogue number	4312 021 28710
material	polyamide 6,6 glass fibre reinforced
minimum window area	250 mm^2
mean length of turn	116 mm
approximate mass	9 g
maximum working temperature	130 °C

The dimensions are according to German specification DIN 41305.

MOUNTING PARTS

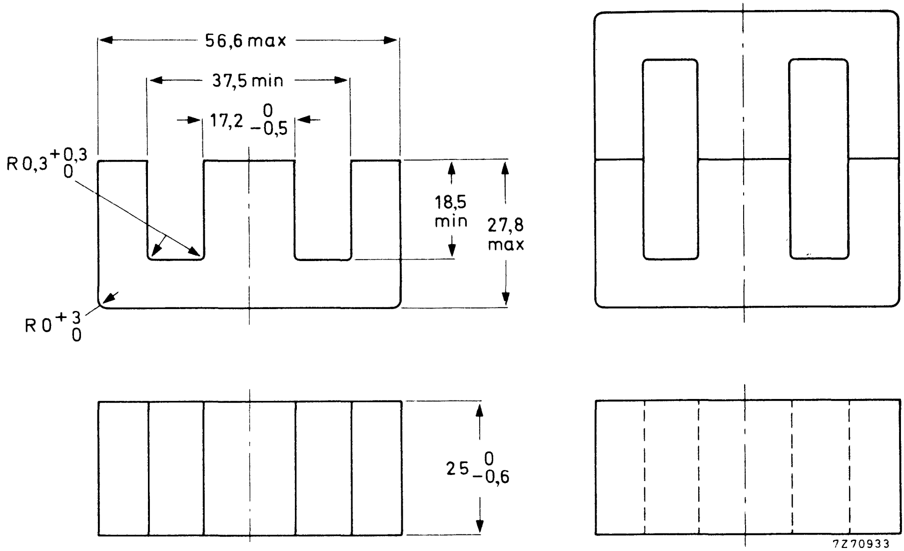


Spring.
Material: zinc plated stainless steel, bichromated.

Clasp.
Material: zinc plated steel, bichromated.

Catalogue number of clasp and spring 4312 021 26090.

E-CORES



Mass approx. 130 g

Catalogue numbers

Ferroxcube grade 3C8
Catalogue number of E-core without air gap* 3122 134 90210

SHELL TYPE TRANSFORMER EE55/55/25

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer EE55/55/25 composed of two cores type EE55/28/25.

Magnetic dimensions according to IEC 205:

l_e = 123 mm

A_e = 420 mm^2

$C_1 = \Sigma \frac{l_e}{A_e} = 0,293 \text{ mm}^{-1}$

V_e = 52000 mm^3

Magnetic properties; $\Delta = 0$

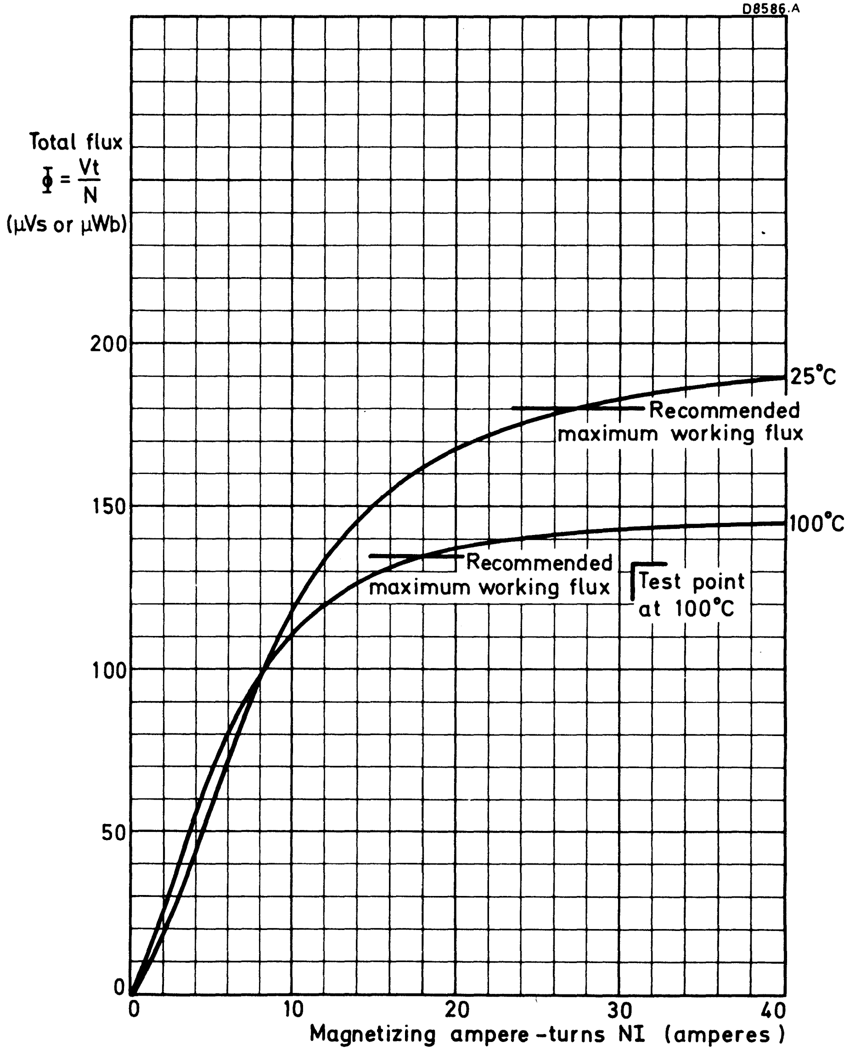
At f = 16 kHz, $\hat{B}$ = 200 mT, θ = 25 °C — P $\leqslant$ 6,2 W

θ = 100 °C — P $\leqslant$ 5,7 W

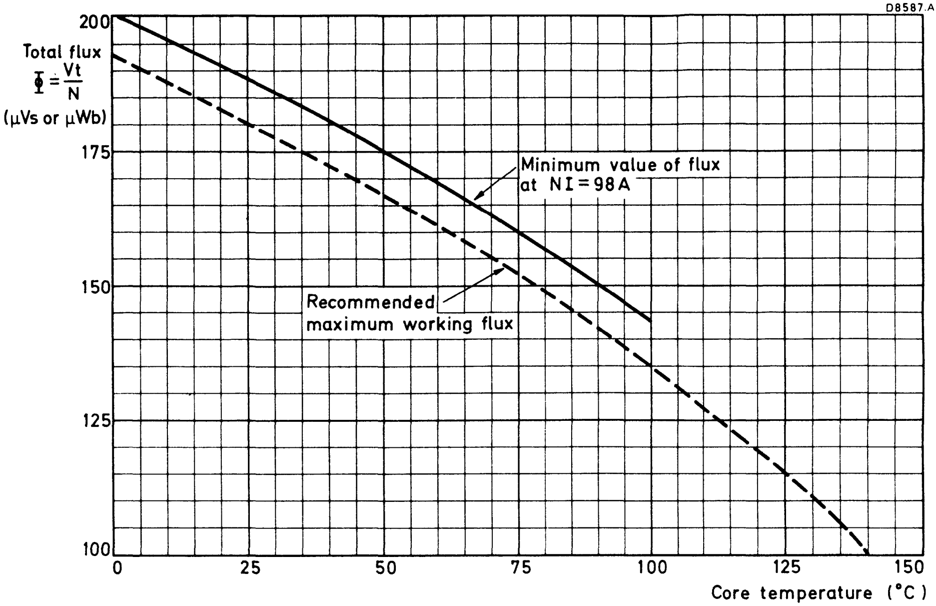
At f = 16 kHz, $\hat{B} \geqslant$ 315 mT, θ = 100 °C — $\hat{H}$ = 250 A/m

* Cores with air gap are available on request.

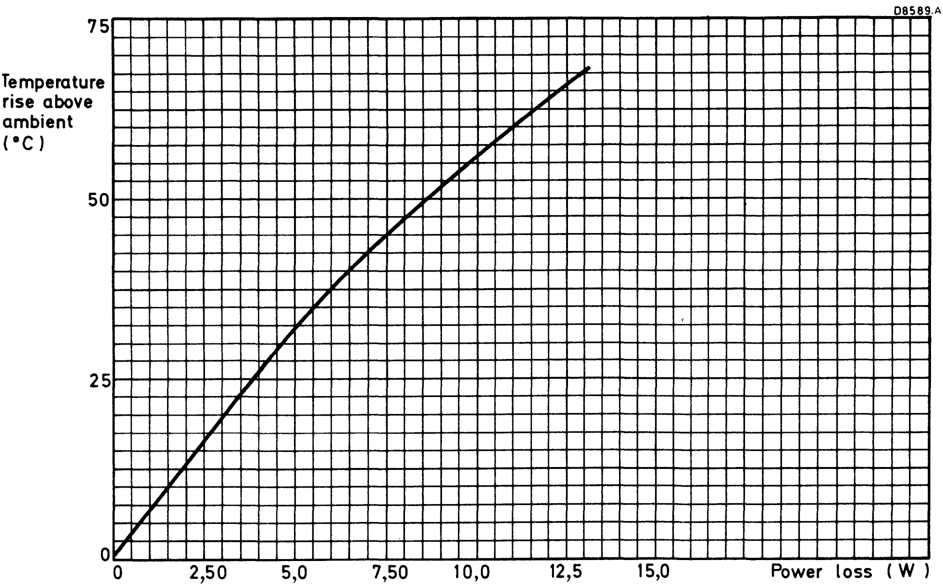
CHARACTERISTIC CURVES



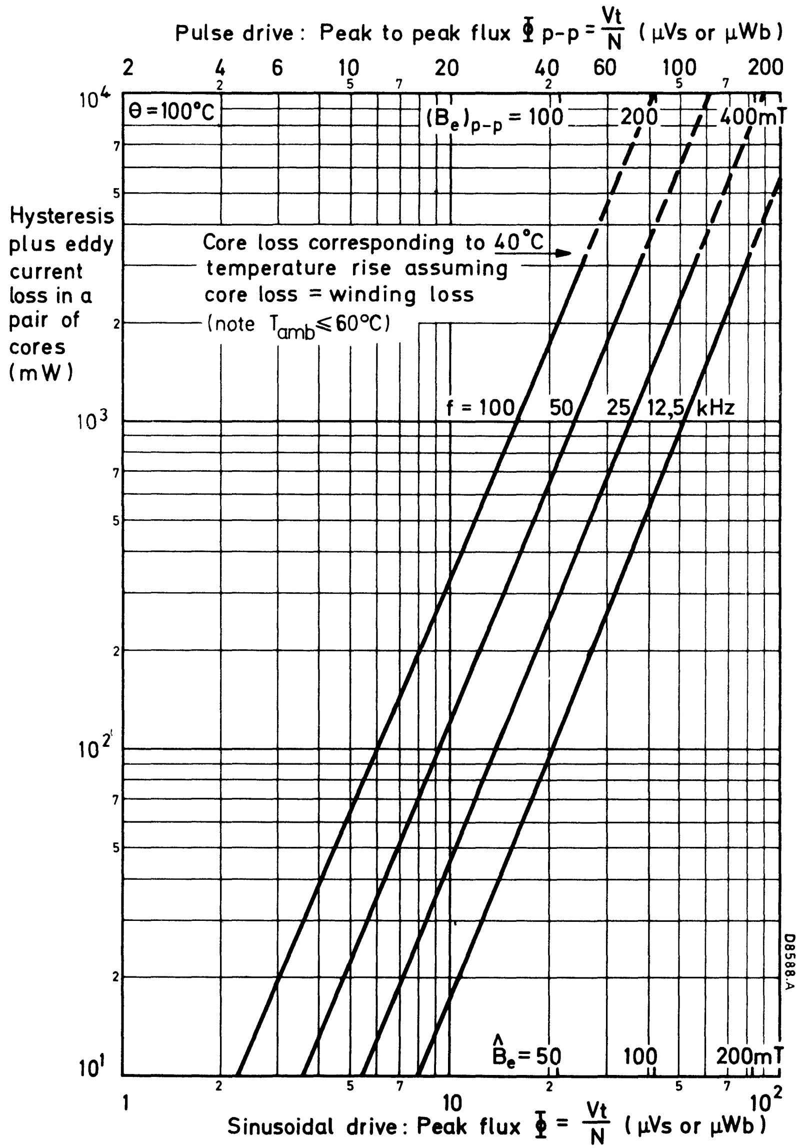
Typical magnetization curves for a pair of cores with ambient temperature as parameter.



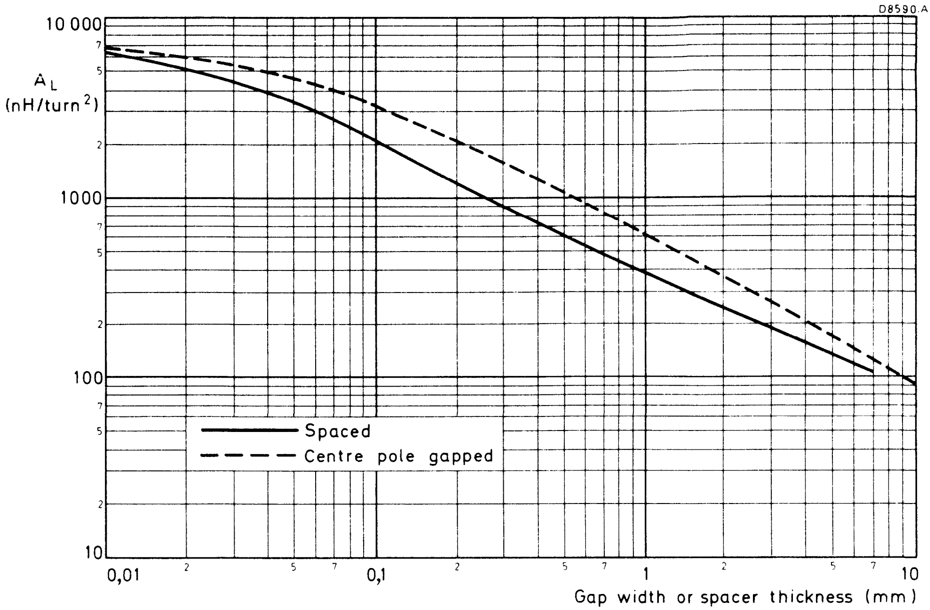
Total flux as a function of core temperature.



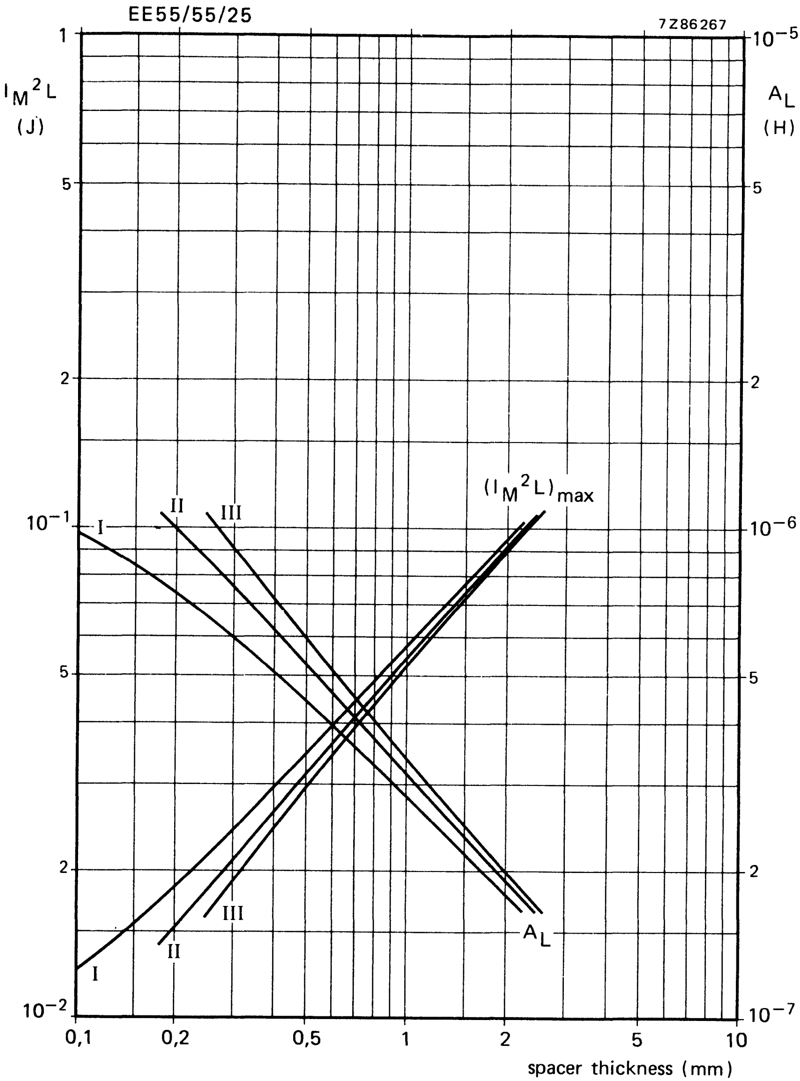
Typical transformer temperature rise as a function of total transformer loss in free air conditions.



Core loss as a function of total flux at 100 °C with frequency as parameter.

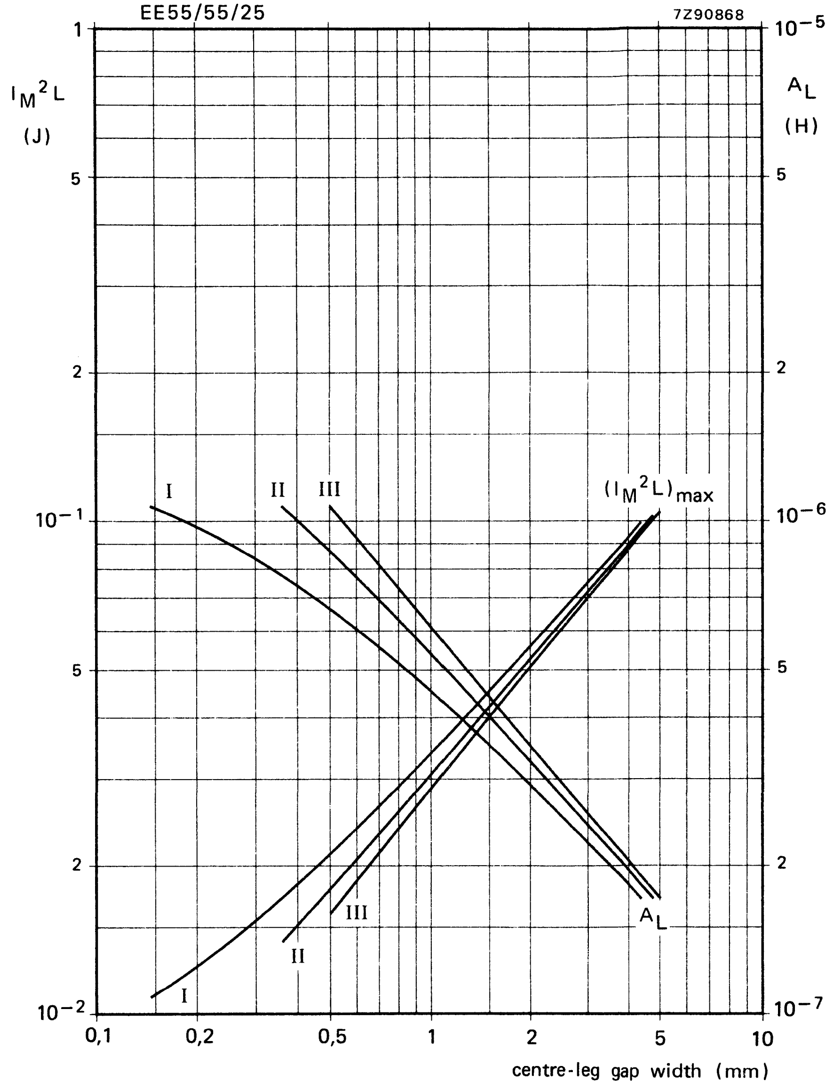


A_L based on a typical permeability of 2000 as a function of spacer thickness.



Choke design chart.

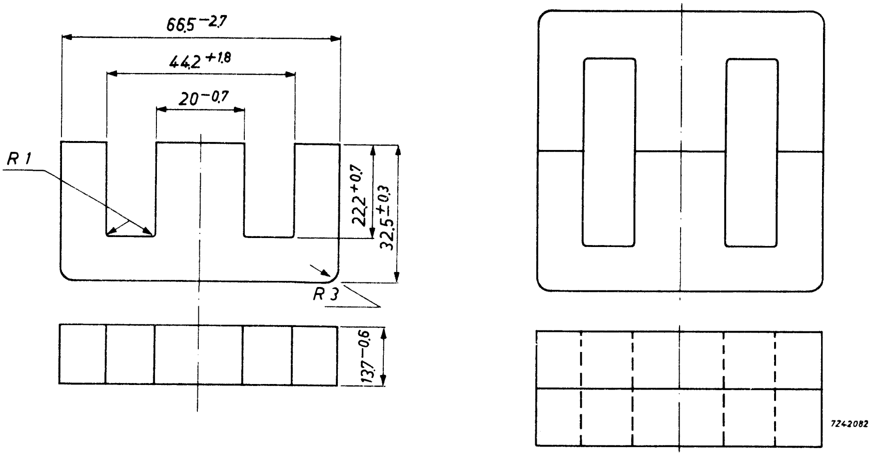
For application classes I, II and III see 'Power choke design' in the Introduction.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

E-CORES



The dimensions are according to DIN 41295

Mass approx. 103 g

Catalogue number

Ferroxcube grade 3E1

Catalogue number of E-core ● 4322 020 34910

SHELL TYPE TRANSFORMER 65/65/27

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer 65/65/27 composed of **four** cores type E65/32/13.

Magnetic dimensions according to IEC 205:

l_e = 147 mm; A_e = 532 mm^2; $C_1 = \Sigma \frac{l_e}{A_e}$ = 0,275 mm^{-1}; V_e = 78200 mm^3

MAGNETIC DATA

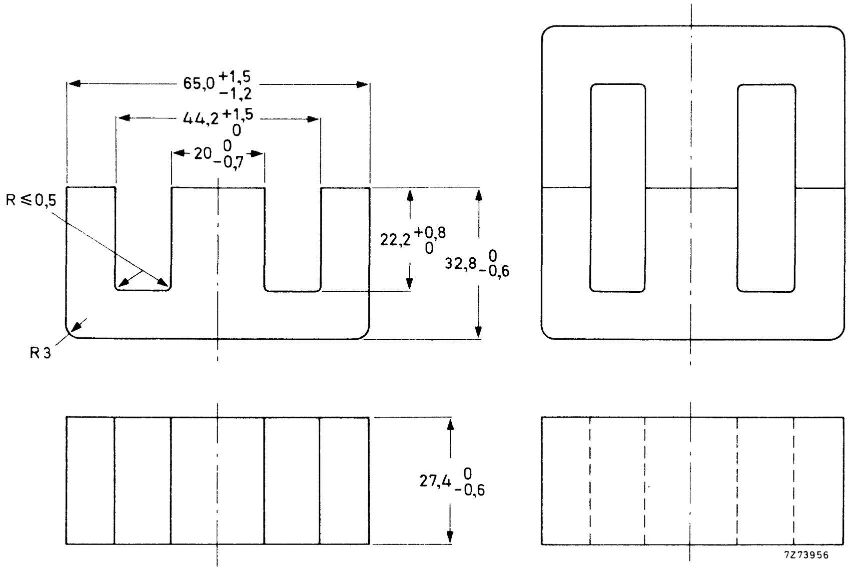
Guaranteed values for a combination of four E-cores, pressed together with a force of 400 N, air gap $\Delta = 0$. *

	freq. kHz	temp. °C	$\hat{B}$ mT	
A_L	100	25 ± 5		12355 to 18545
μ_e	100	25 ± 5		2705 to 4060
$\eta_B \times 10^3$	4	25 ± 5	1,5 to 3	⩽ 4,3

* Cores with air gap are available on request.

● Preferred type.

E-CORES



Mass	approx. 203 g
Ferroxcube grade	3C8
Catalogue number of E-core, without air gap*	● 4312 020 34380

SHELL TYPE TRANSFORMER EE65/66/27

A transformer core can be built up by combining an even number of E-cores. A shape that is often chosen is the shell type transformer EE65/65/27 composed of two cores type E65/32/27.

Magnetic dimensions according to IEC 205:

l_e = 147 mm

A_e = 532 mm^2

$C_1 = \Sigma \frac{l_e}{A_e}$ = 0,275 mm^{-1}

V_e = 78200 mm^3

Magnetic properties; $\Delta = 0$

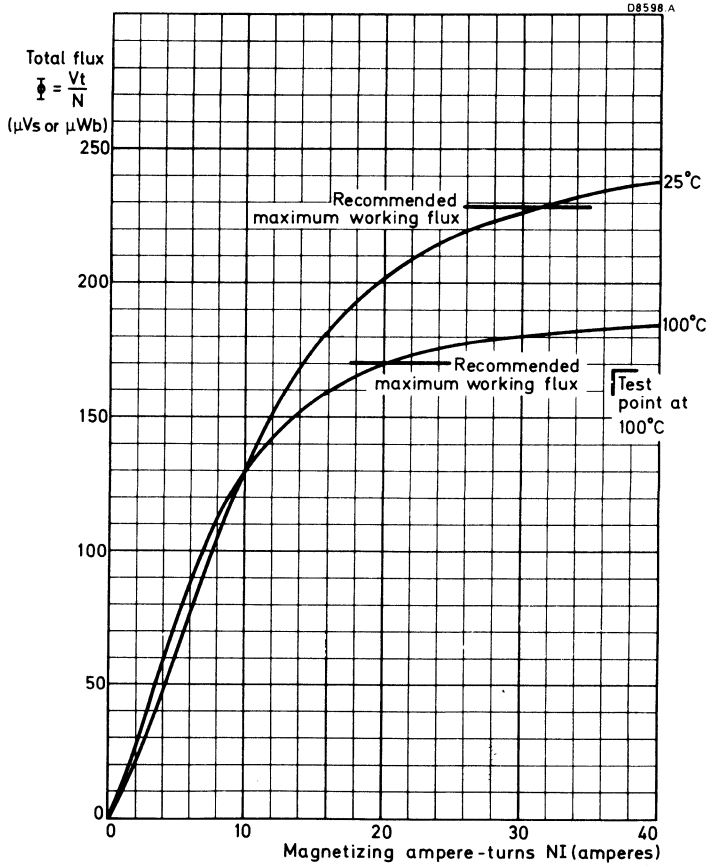
At f = 16 kHz, $\hat{B}$ = 200 mT, θ = 25 °C	P ≤ 9,5 W
θ = 100 °C	P ≤ 8,7 W
At f = 16 kHz, $\hat{B} \geq$ 315 mT, θ = 100 °C	$\hat{H}$ = 250 A/m

* Cores with air gap are available on request.

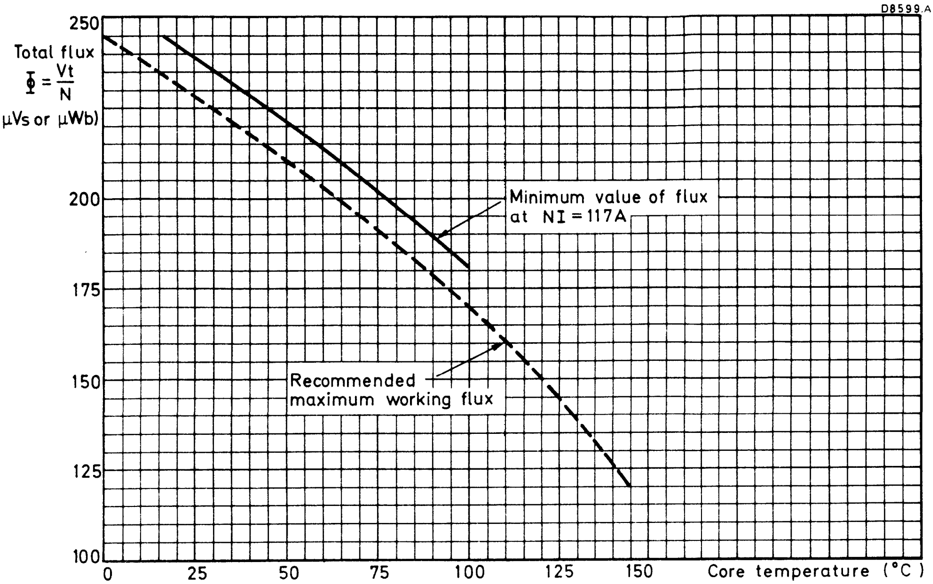
● Preferred type.

CHARACTERISTIC CURVES

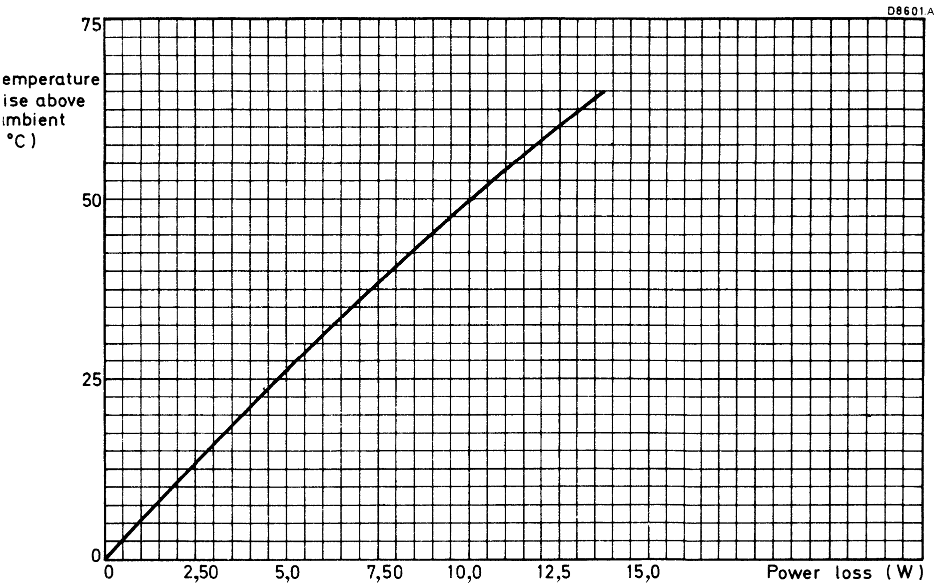
Note: The curves shown on the following pages represent typical characteristics for a pair of E65 cores in 3C8.



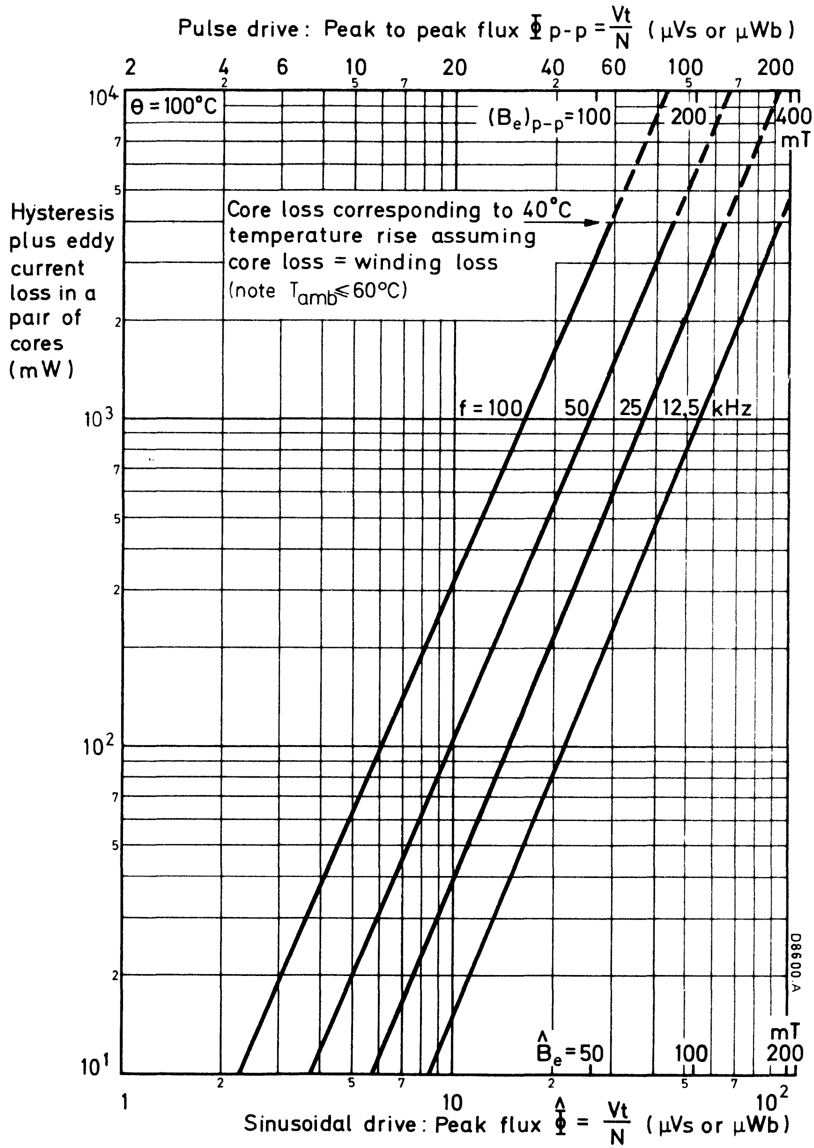
Typical magnetization curves for a pair of cores with ambient temperature as a parameter.



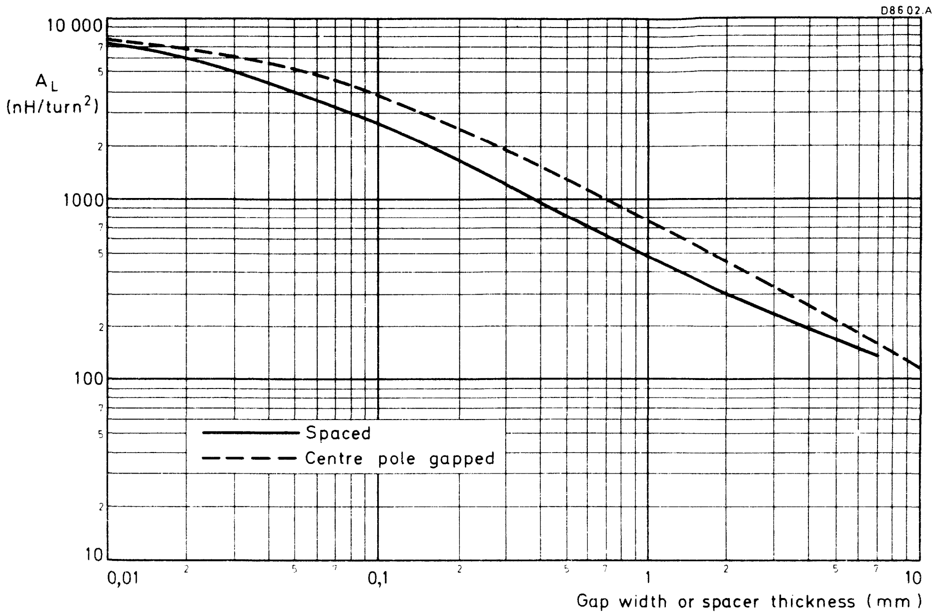
Total flux as a function of core temperature.



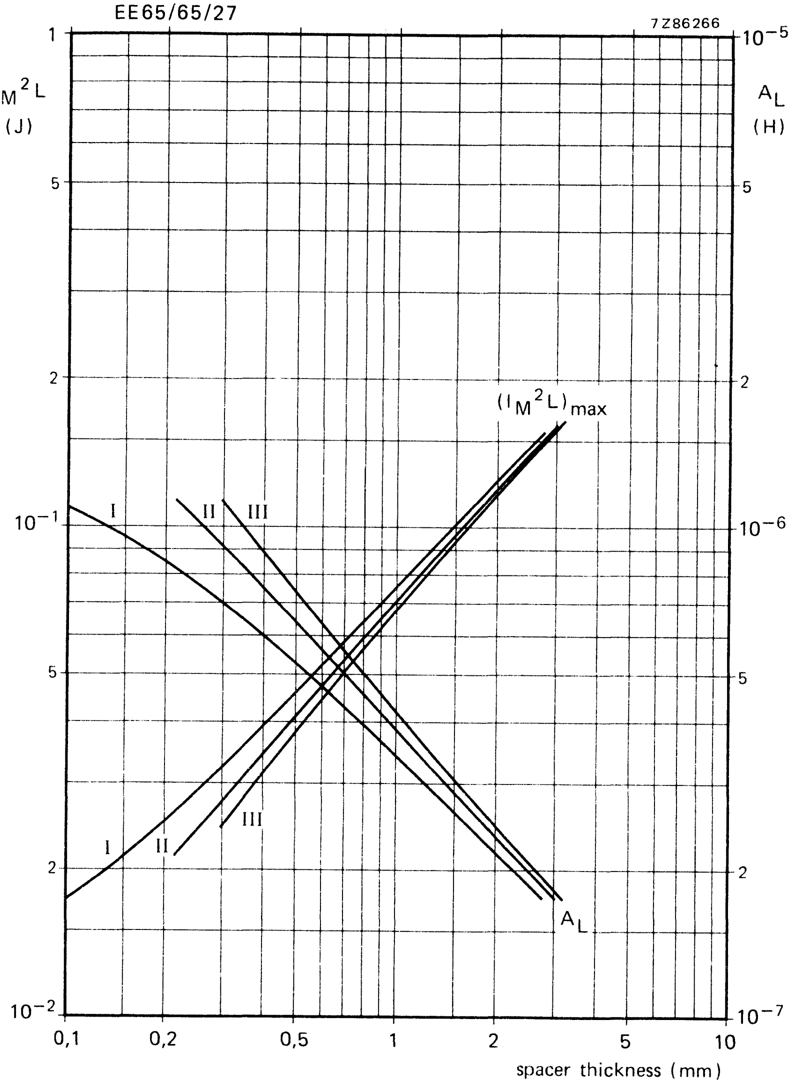
Typical transformer rise as a function of total transformer loss in free air conditions.



Core loss as a function of total flux at 100 °C with frequency as parameter.

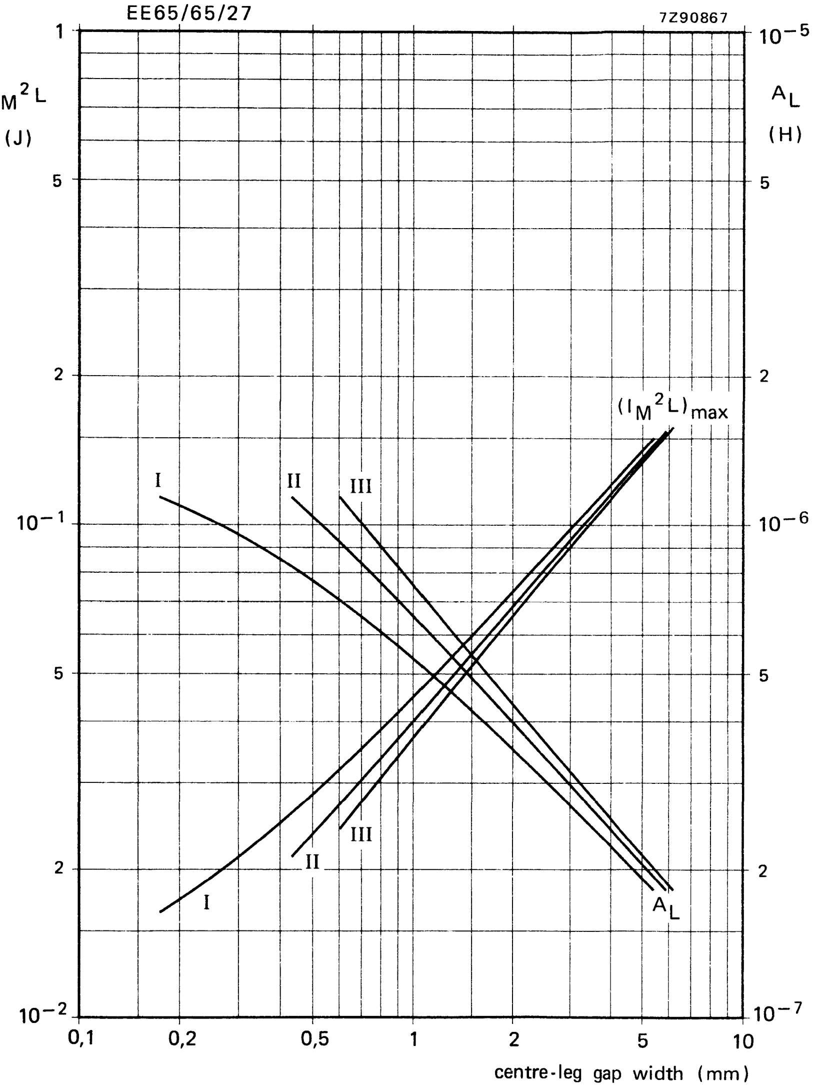


A_L based on a typical initial permeability of 2000 as a function of spacer thickness.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

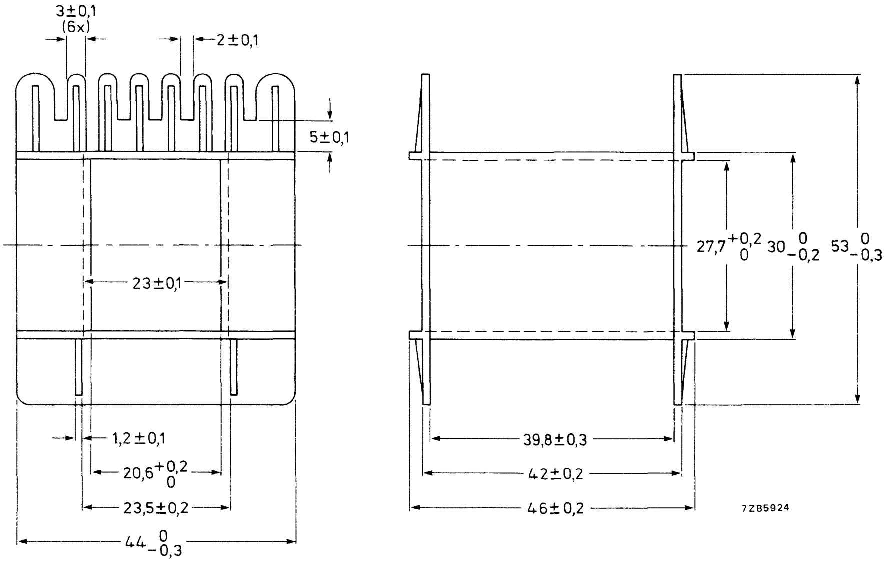


Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

COIL FORMER

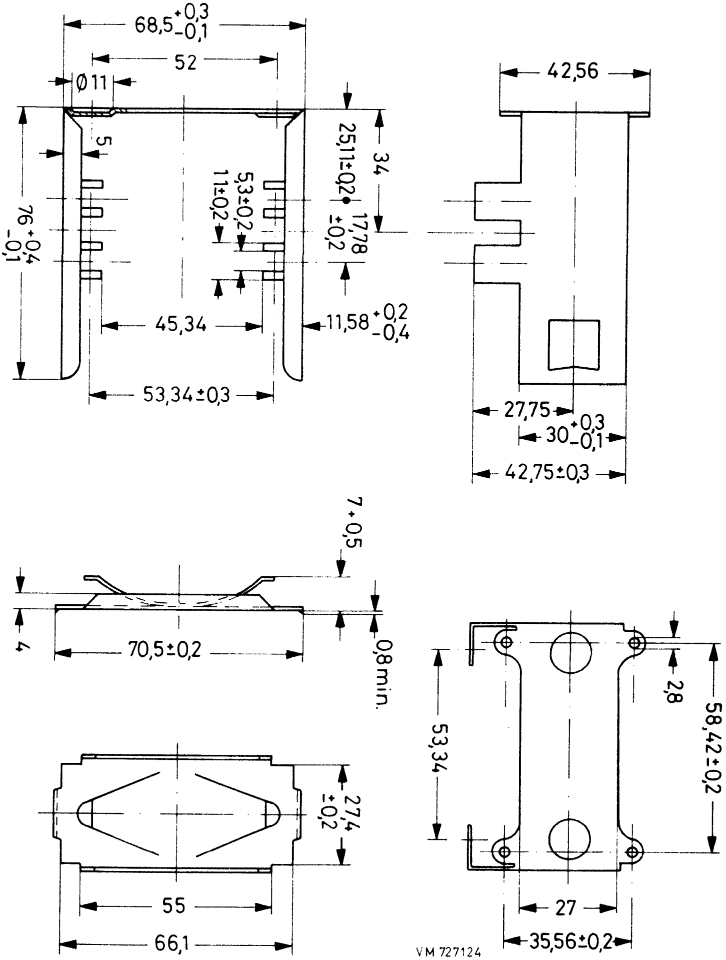
for shell type transformer 65/65/27 (M65)



catalogue number	4312 021 28720
material	polyamide 6,6 glass fibre reinforced
minimum window area	394 mm^2
mean length of turn	150 mm
approximate mass	13 g
maximum working temperature	130 °C

The dimensions are according to German specification DIN 41305.

MOUNTING PARTS

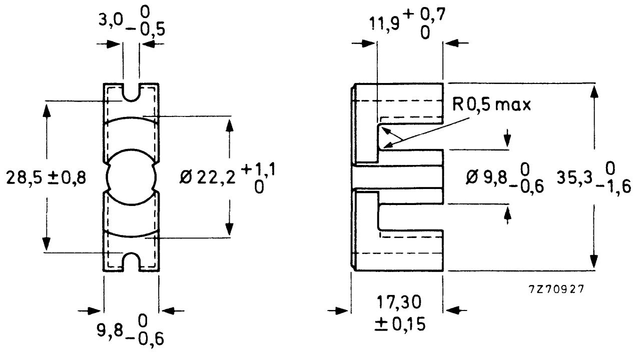


Spring.
Material: zinc plated stainless steel, bichromated.

Clasp.
Material: zinc plated steel, bichromated.

Catalogue number of clasp and spring 4312 021 26110.

EC-CORE



Mass	approx. 18 g
Ferroxcube grade	3C8
Catalogue number of EC-core without air gap*	● 4322 020 52500

DIMENSIONAL PARAMETERS FOR A PAIR OF CORES

(Assuming nominal dimensions, unless otherwise stated).

Core constant**	C_l	= 0,918 mm^{-1}
Minimum cross-sectional centre pole area	A_{CPmin}	= 66,5 mm^2
Cross-sectional centre pole area	A_{min}	= 71,0 mm^2
Back and leg cross-sectional area	A_b	= 96,0 mm^2
Centre pole volume	V_{CP}	= 1740 mm^3
Back and leg volume	V_b	= 6040 mm^3
Total core volume	V_f	= 7780 mm^3
Effective magnetic path length**	l_e	= 77,4 mm
Effective cross-sectional area**	A_e	= 84,3 mm^2
Effective core volume**	V_e	= 6530 mm^3

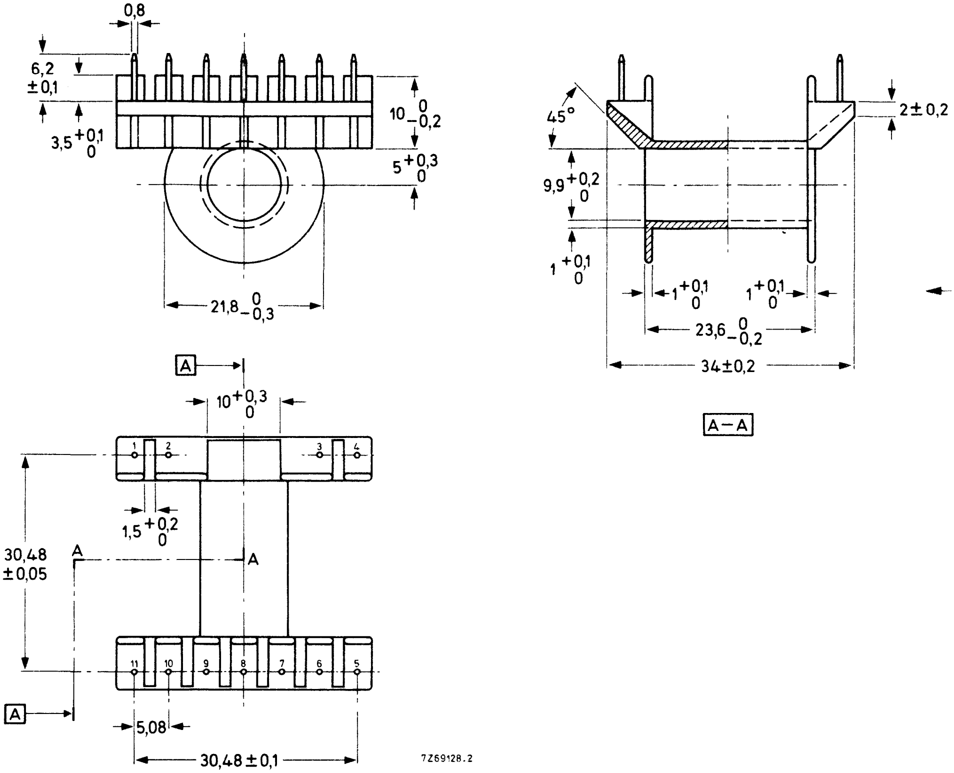
* Cores with air gap are available on request.
** According to IEC 205.
● Preferred type.

MAGNETIC PROPERTIES FOR A PAIR OF CORES WITHOUT AIR GAP

Relative amplitude permeability (μ_a) at θ = 100 °C, $\hat{B}$ = 320 mT in A_{CPmin}	> 1000
Permissible induction in centre pole ($\hat{B}$) with min. cross-sectional area, at θ = 100 °C	≤ 320 mT
Resistivity (ρ), measured with d.c. current	≥ 1 Ωm
Curie point	≥ 200 °C
→ Effective total core loss (P) referred to A_e at f = 25 kHz, θ = 100 °C, $\hat{B}$ = 160 mT	≤ 1,1 W
Inductance factor A_L at f < 100 kHz, θ = 25 °C, $\hat{B}$ < 0,1 mT	> 1600

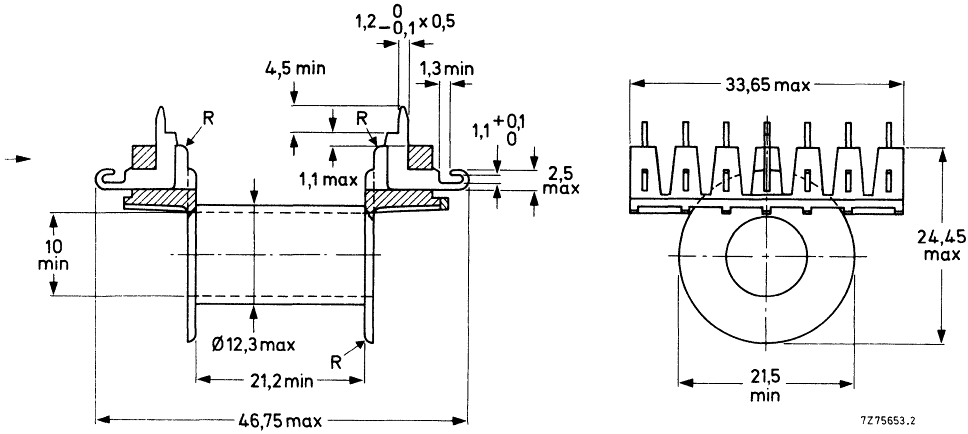
COIL FORMERS

Style 1

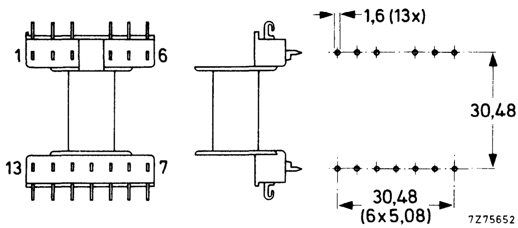


Material	phenolformaldehyde reinforced with glass fibre; brass dip-solder pins
Mounting	horizontal
Minimum window area	97,5 mm^2
Mean length of turn	50 mm
Mass	approx. 6 g
Maximum temperature	140 °C
Catalogue number (coil former with pins)	4322 021 33410

Style 2



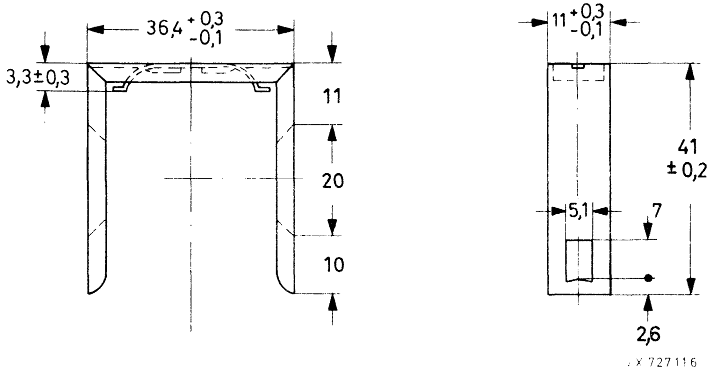
Tag arrangement



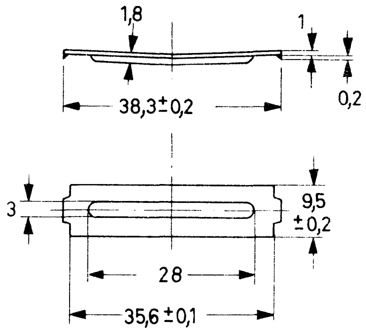
Material	polyteraphthalate, glass fibre reinforced, 13 solder-plated brass tags are inserted.
Mounting	horizontal
Minimum window area	97 mm^2
Mean length of turn	53 mm
Mass	7 g
Flammability	according to UL 94 V-0
Catalogue number *	4322 021 33310

* Catalogue number of coil former, style 2, without tags: 4322 021 33000.

MOUNTING PARTS



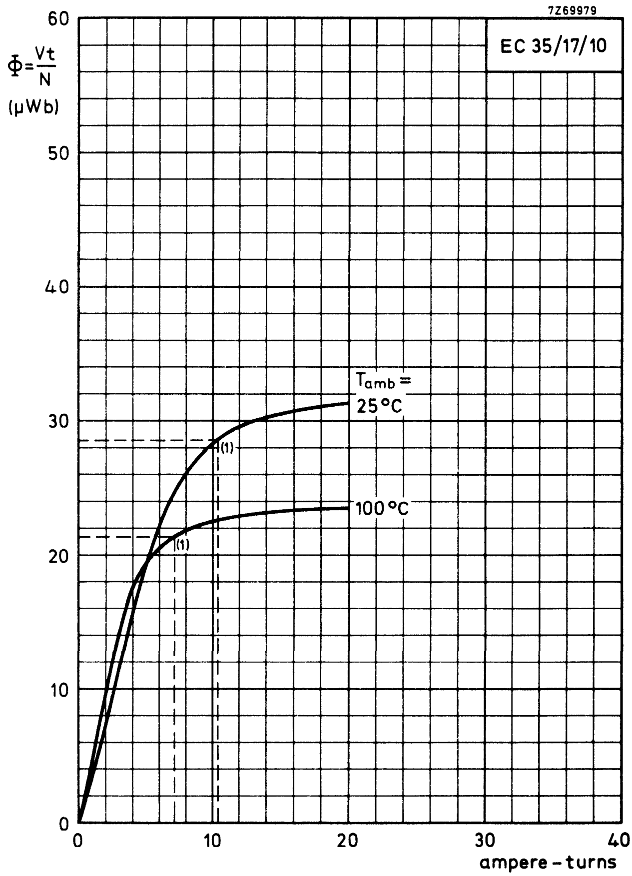
Clasp.
Material: zinc plated steel, bichromated.



Spring.
Material: zinc plated steel, bichromated.

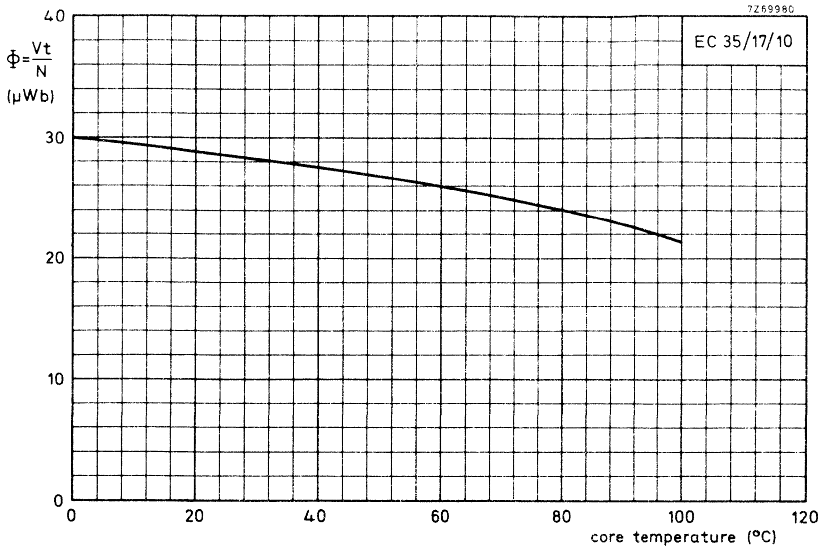
Catalogue number of clasp with spring: 4312 021 26010.

CHARACTERISTIC CURVES

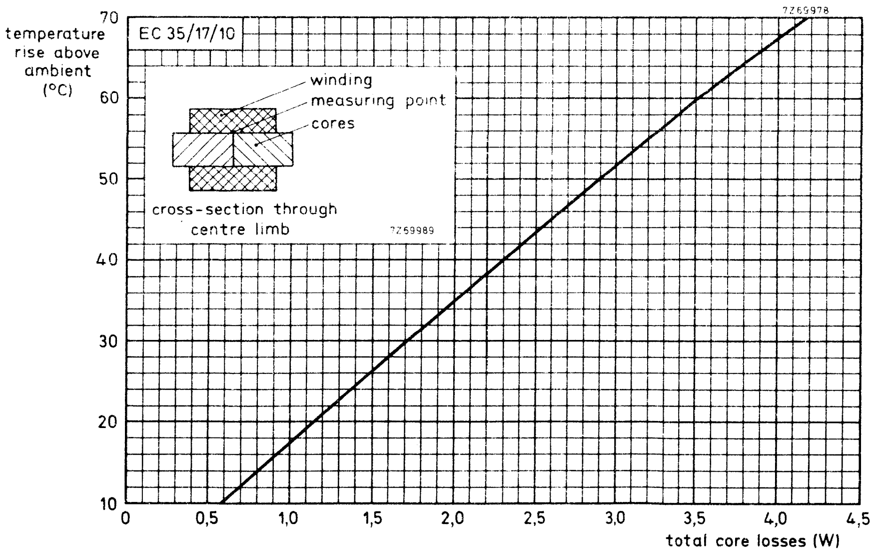


(1) Recommended maximum working flux.

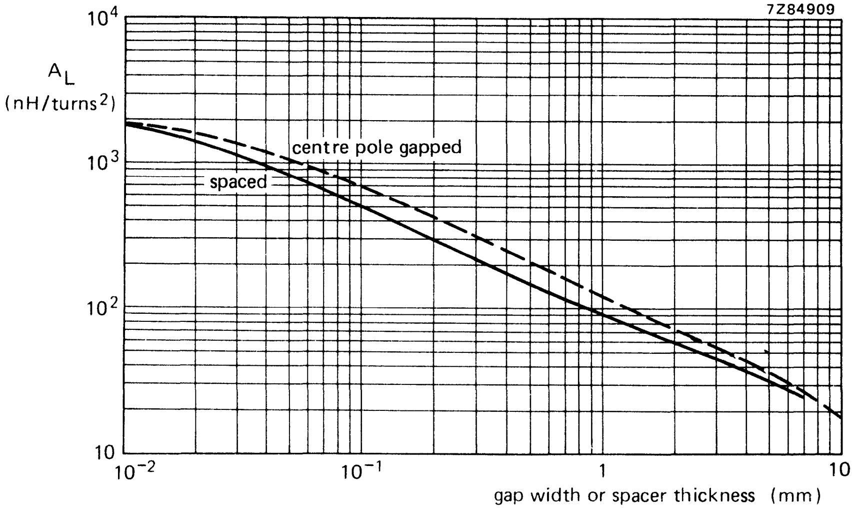
Total flux as a function of ampere-turns.

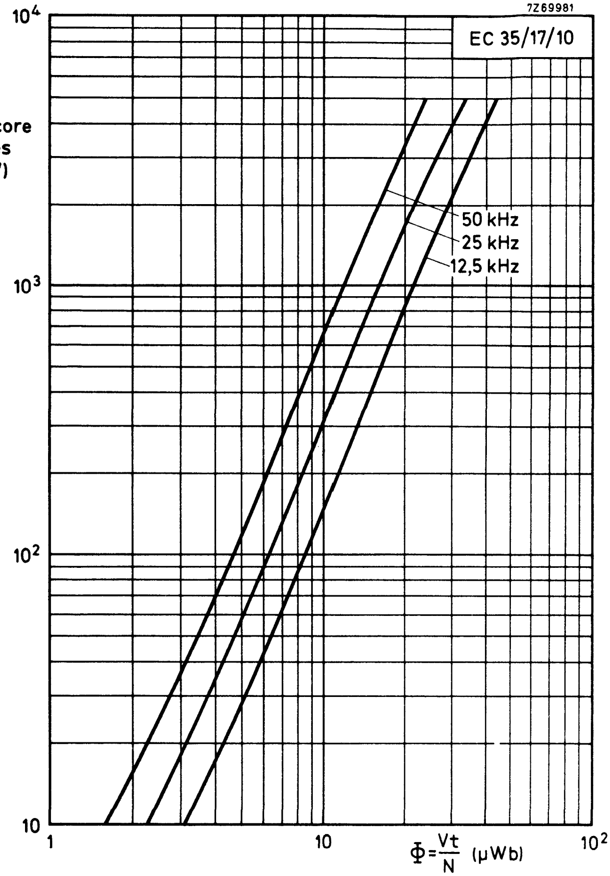


Recommended maximum working flux as a function of core temperature.

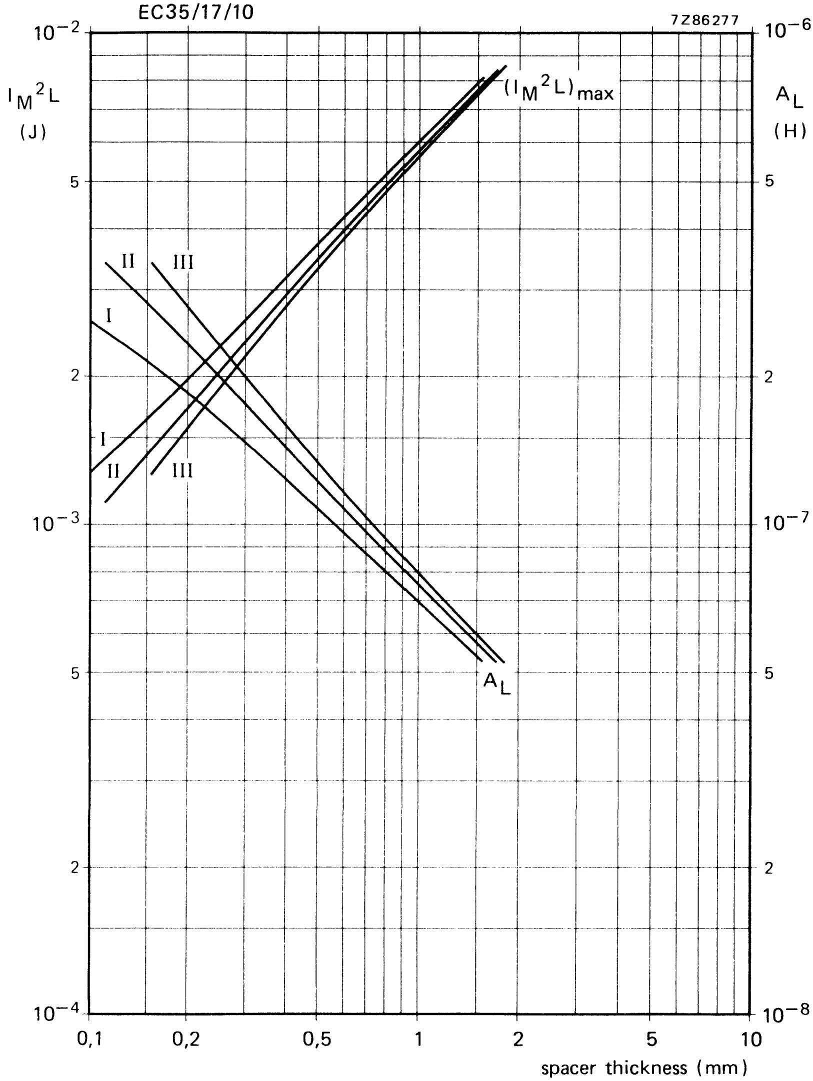


Transformer temperature rise as a function of total core losses, in free air conditions, without heatsink.

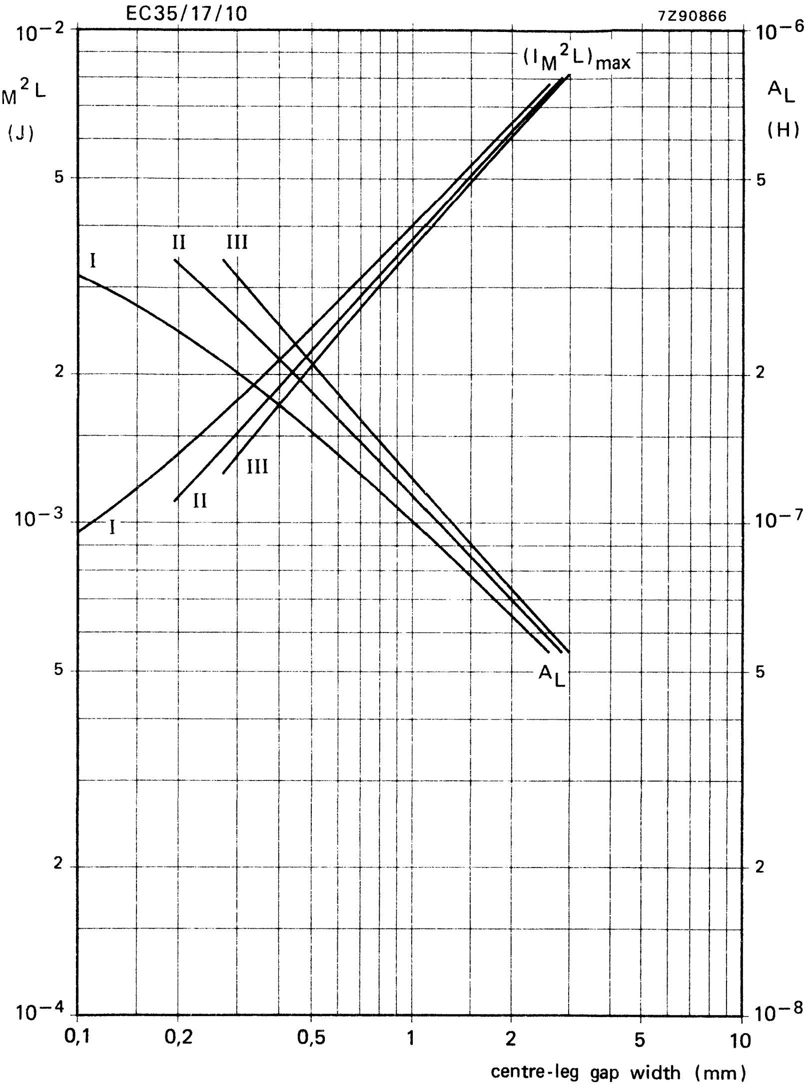

7Z84909
A_L
(nH/turns^2)
10^4
10^3
10^2
10
centre pole gapped
spaced
10^{-2}
10^{-1}
1
10
gap width or spacer thickness (mm)



Total core losses as a function of total flux at hot-spot core temperature.



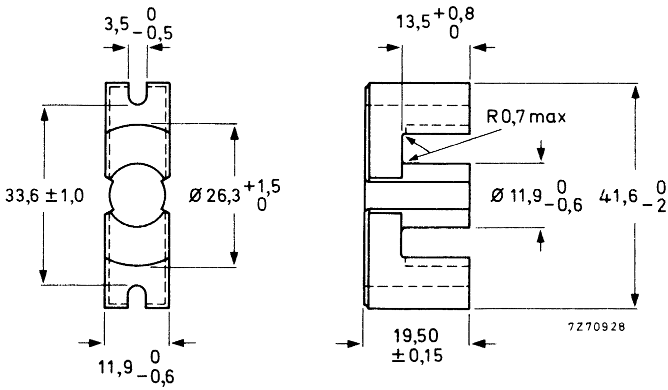
Choke design chart.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

EC-CORE



Mass	approx. 26 g
Ferroxcube grade	3C8
Catalogue number of EC-core without air gap*	● 4322 020 52510

DIMENSIONAL PARAMETERS FOR A PAIR OF CORES

(Assuming nominal dimensions, unless otherwise stated.)

Core constant **	C_1	= 0,735 mm^{-1}
Minimum cross-sectional centre pole area	A_{CPmin}	= 100,3 mm^2
Cross-sectional centre pole area	A_{min}	= 106 mm^2
Back and leg cross-sectional area	A_b	= 130 mm^2
Centre pole volume	V_{CP}	= 2950 mm^3
Back and leg volume	V_b	= 9650 mm^3
Total core volume	V_f	= 12600 mm^3
Effective magnetic path length **	l_e	= 89,3 mm
Effective cross-sectional area **	A_e	= 121 mm^2
Effective core volume **	V_e	= 10800 mm^3

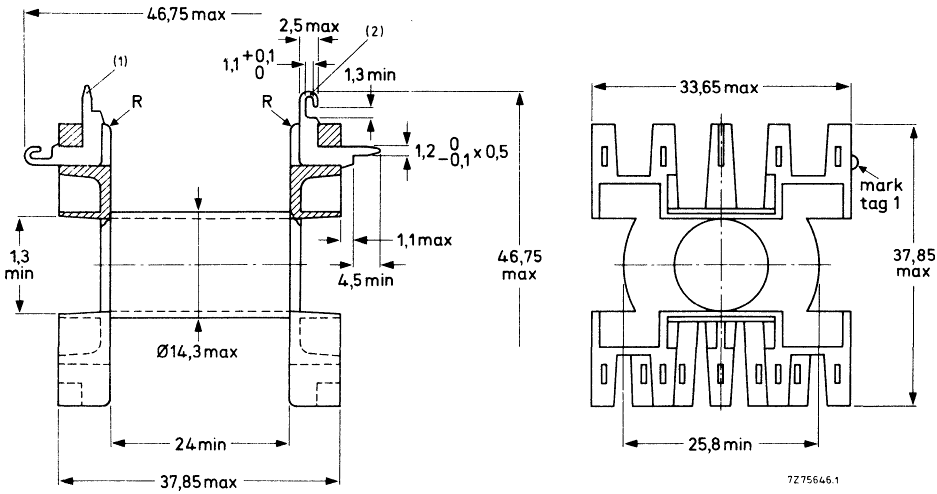
* Cores with air gap are available on request.
** According to IEC 205.
● Preferred type.

MAGNETIC PROPERTIES FOR A PAIR OF CORES WITHOUT AIR GAP

Relative amplitude permeability (μ_a) at θ = 100 °C, $\hat{B}$ = 320 mT in A_{CPmin}	> 1000
Permissible induction in centre pole ($\hat{B}$) with min. cross-sectional area, at θ = 100 °C	≤ 320 mT
Resistivity (ρ), measured with d.c. current	≥ 1 Ωm
Curie point	≥ 200 °C
Effective total core loss (P) referred to A_e at f = 25 kHz, θ = 100 °C, $\hat{B}$ = 160 mT	≤ 2,2 W
Inductance factor A_L at f < 100 kHz, θ = 25 °C, $\hat{B}$ < 0,1 mT	> 2000

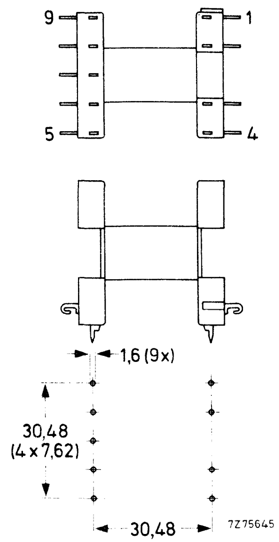
COIL FORMERS

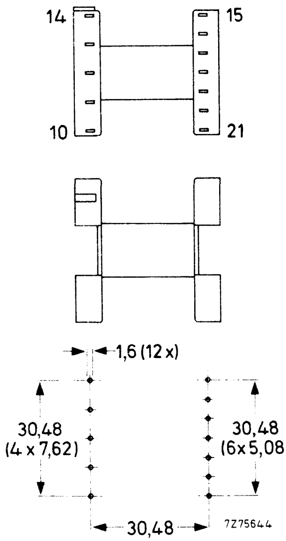
Material	glass-fibre-filled polyteraphthalate; solder-plated brass tags
Minimum window area	138 mm^2
Mean length of turn	62 mm
Mass, 9 tags inserted	10 g
Flammability	according to UL 94 V-0
Mounting	horizontal and vertical
Catalogue number	see next page
Tag arrangement	see next page

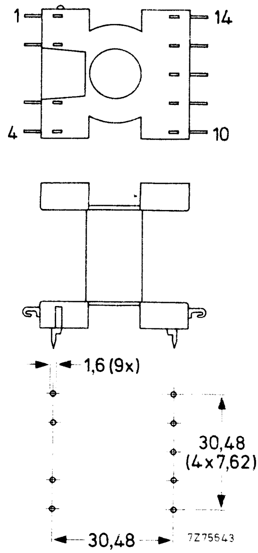


Tag arrangement

Horizontal mounting		Vertical mounting
9 tags inserted	12 tags inserted	9 tags inserted
catalogue number 4322 021 33320	catalogue number 4322 021 33480	catalogue number 4322 021 33350

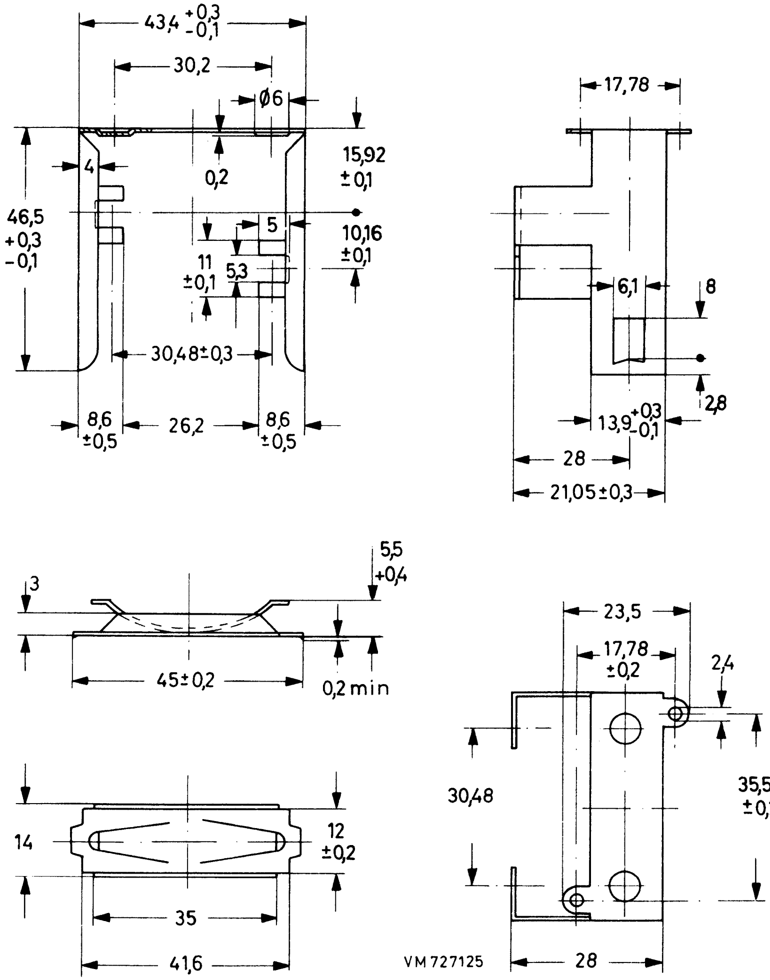






Catalogue number of coil former with 21 tags: 4322 021 33490
Catalogue number of coil former without tags: 4322 021 33010
Catalogue number of tag: 4322 021 33060

MOUNTING PARTS



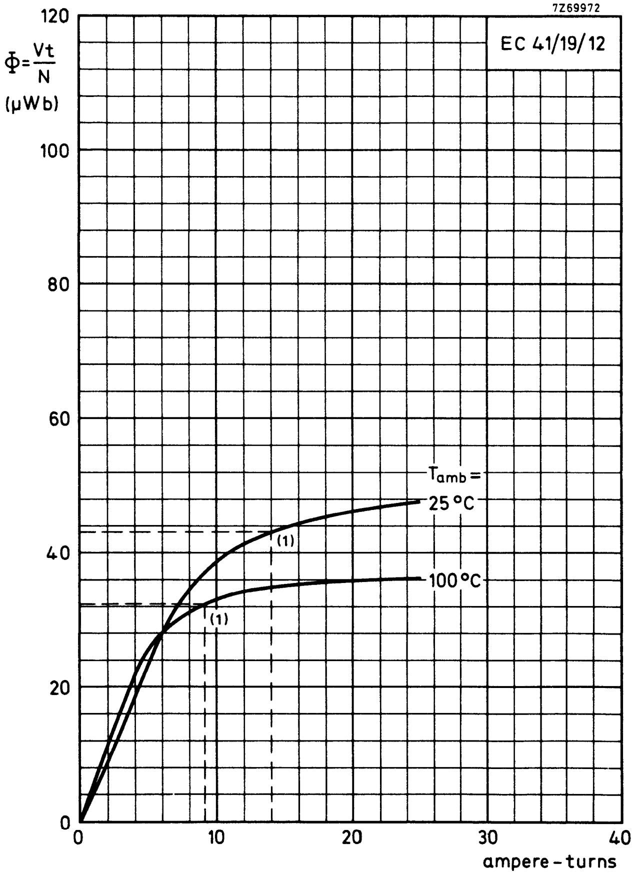
Spring.
Material: zinc plated steel, bichromated.

Clasp.
Material: zinc plated steel, bichromated.

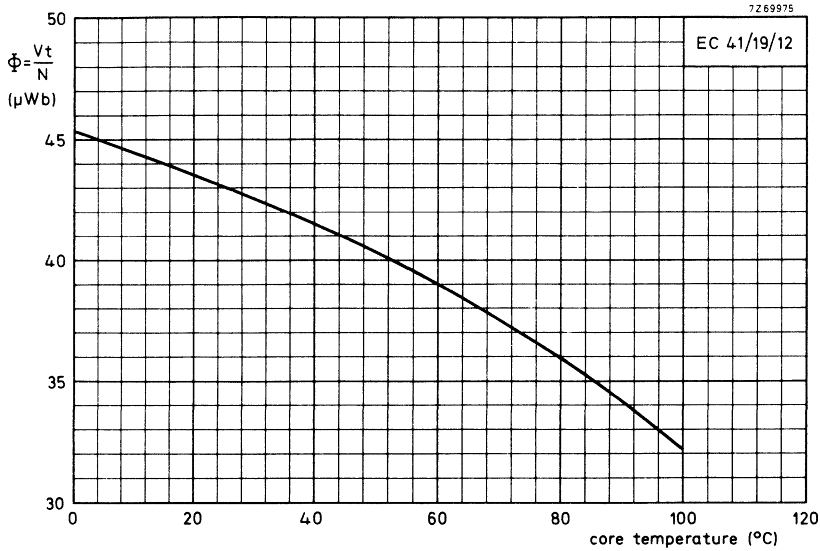
Catalogue number of clasp and spring

without mounting stud	4312 021 26020
with mounting stud	4312 021 26030.

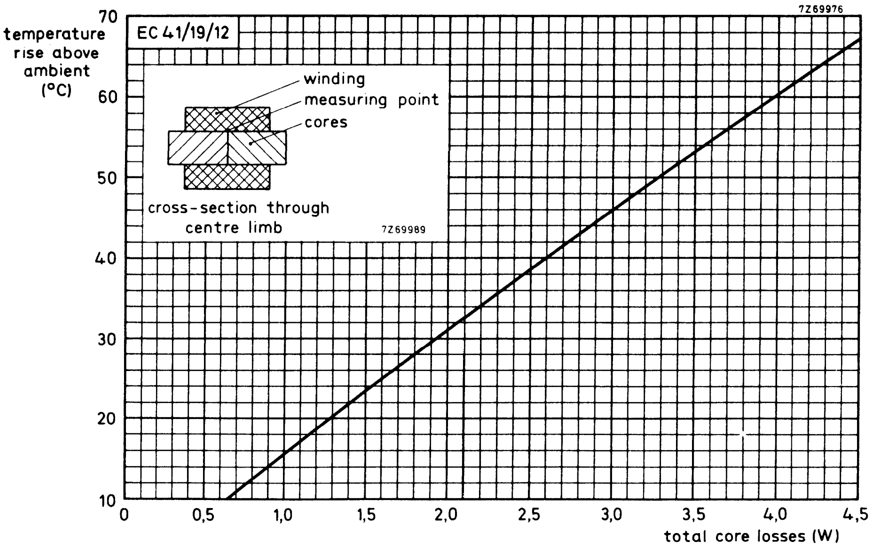
CHARACTERISTIC CURVES



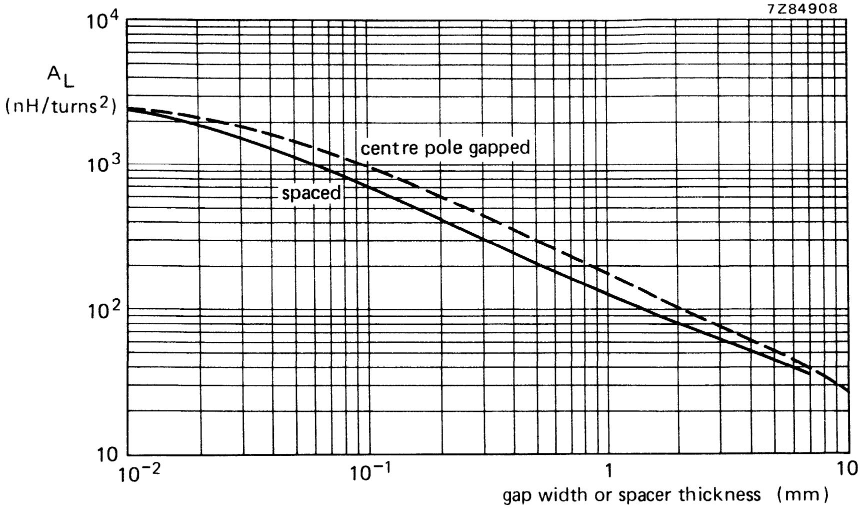
(1) Recommended maximum working flux.
Total flux as a function of ampere-turns.

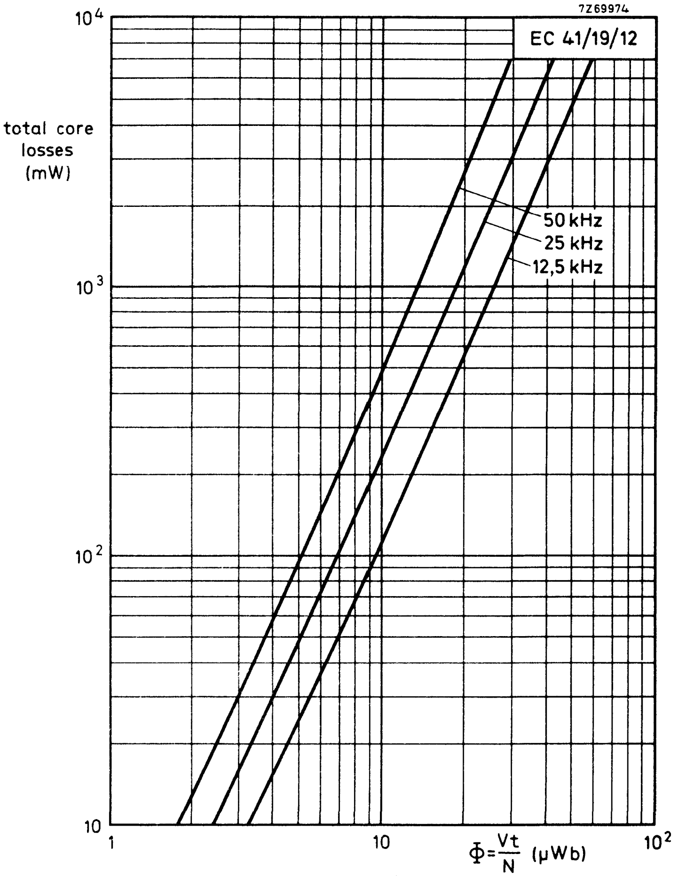


Recommended maximum working flux as a function of core temperature.

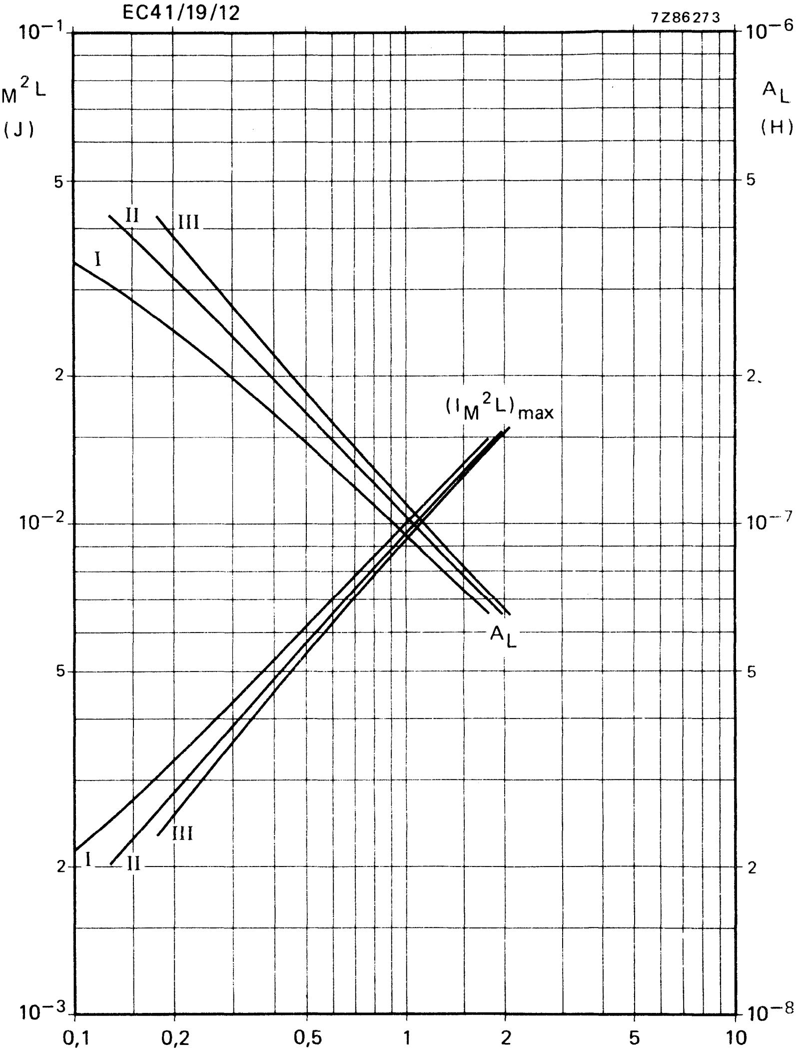


Transformer temperature rise as a function of total core losses, in free air conditions, without heatsink.


7Z84908
10^4
A_L
(nH/turns^2)
10^3
10^2
10
10^{-2}
10^{-1}
1
10
centre pole gapped
spaced
gap width or spacer thickness (mm)

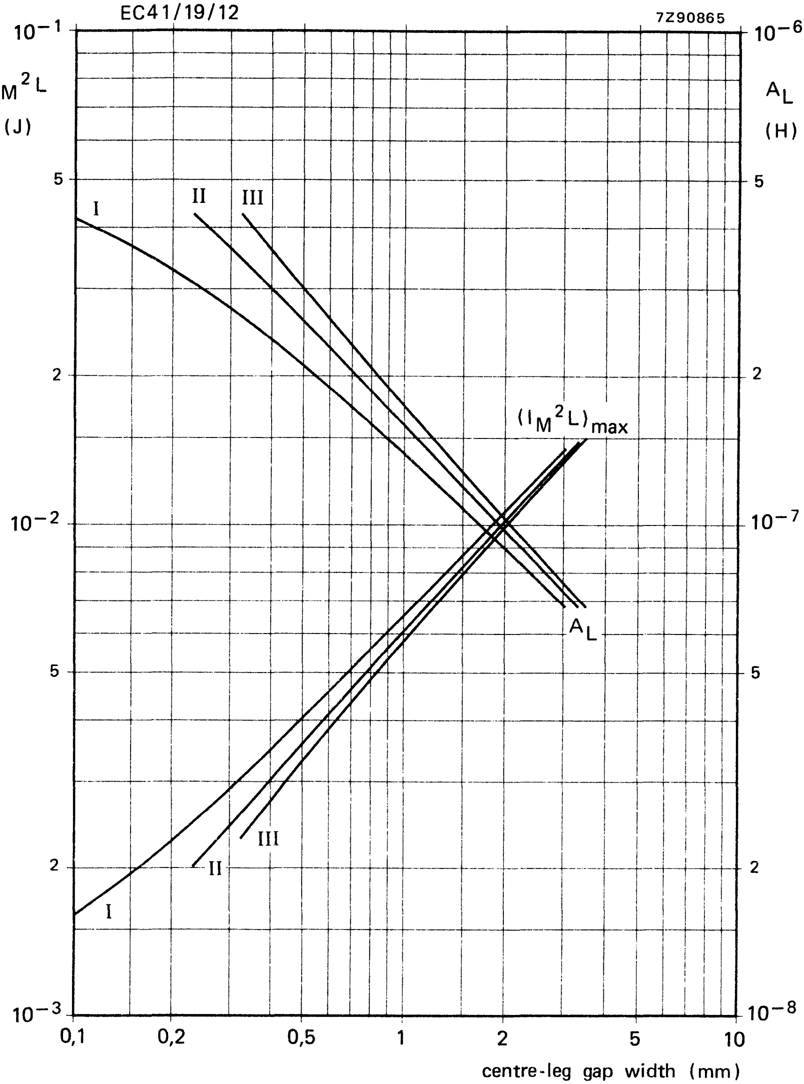


Total core losses as a function of total flux at hot-spot core temperature.



Choke design chart.

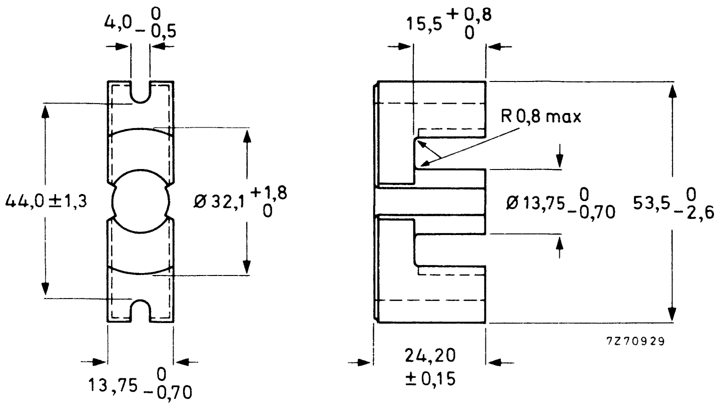
For application classes I, II and III see 'Power choke design' in the Introduction.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

EC-CORE



Mass	approx. 55,5 g
Ferroxcube grade	3C8
Catalogue number of EC-core without air gap*	● 4322 020 52520

DIMENSIONAL PARAMETERS FOR A PAIR OF CORES

(Assuming nominal dimensions, unless otherwise stated.)

Core constant **	C_l	$= 0,581\ mm^{-1}$
Minimum cross-sectional centre pole area	A_{CPmin}	$= 133,8\ mm^2$
Cross-sectional centre pole area	A_{min}	$= 141,0\ mm^2$
Back and leg cross-sectional area	A_b	$= 222,0\ mm^2$
Centre pole volume	V_{CP}	$= 4480\ mm^2$
Back and leg volume	V_b	$= 19820\ mm^3$
Total core volume	V_f	$= 24300\ mm^3$
Effective magnetic path length **	l_e	$= 105\ mm$
Effective cross-sectional area **	A_e	$= 180\ mm^2$
Effective core volume **	V_e	$= 18800\ mm^3$

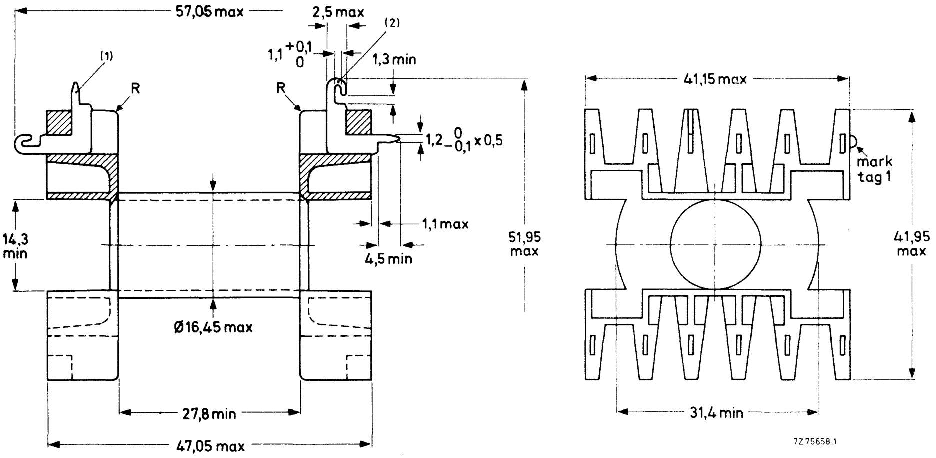
* Cores with air gap are available on request.
** According to IEC 205.
● Preferred type.

MAGNETIC PROPERTIES FOR A PAIR OF CORES WITHOUT AIR GAP

Relative amplitude permeability (μ_a) at θ = 100 °C, $\hat{B}$ = 320 mT in A_{CPmin}	> 1000
Permissible induction in centre pole ($\hat{B}$) with min. cross-sectional area, at θ = 100 °C	⩽ 320 mT
Resistivity (ρ), measured with d.c. current	⩾ 1 Ωm
Curie point	⩾ 200 °C
→ Effective total core loss (P) referred to A_e at f = 25 kHz, θ = 100 °C, $\hat{B}$ = 160 mT	⩽ 2,7 W
Inductive factor A_L at f < 100 kHz, θ = 25 °C, $\hat{B}$ < 0,1 mT	> 2550

COIL FORMER

Material	glass-fibre-filled polyteraphthalate; solder-plated brass tags
Minimum window area	210 mm²
Mean length of turn	70 mm
Mass, 11 tags inserted	18 g
Flammability	according to UL 94 V-0
Mounting	horizontal and vertical
Catalogue number	see next page
Tag arrangement	see next page

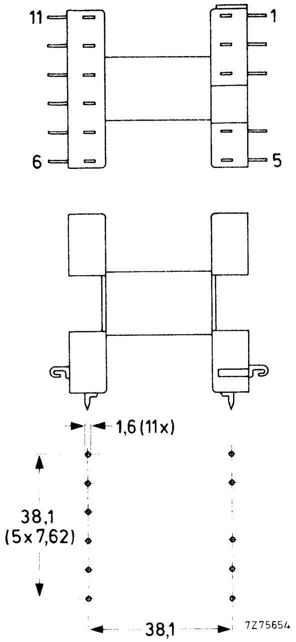


Tag arrangement

Horizontal mounting

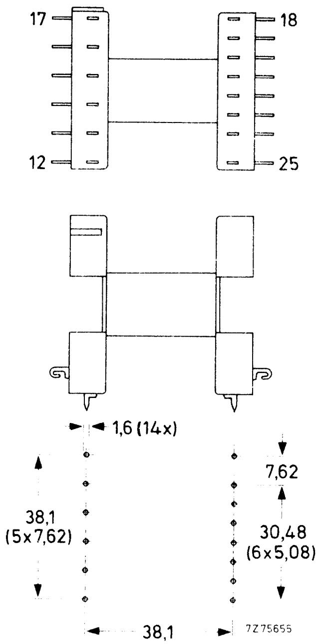
11 tags inserted

catalogue number
4322 021 33330



14 tags inserted

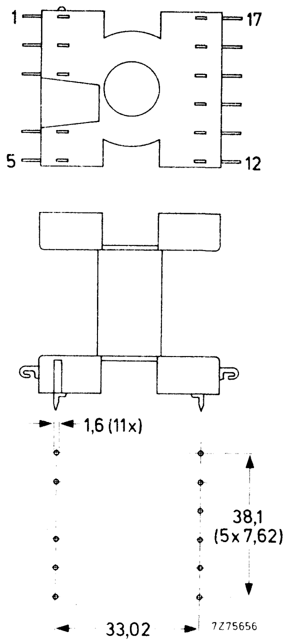
catalogue number
4322 021 33500



Vertical mounting

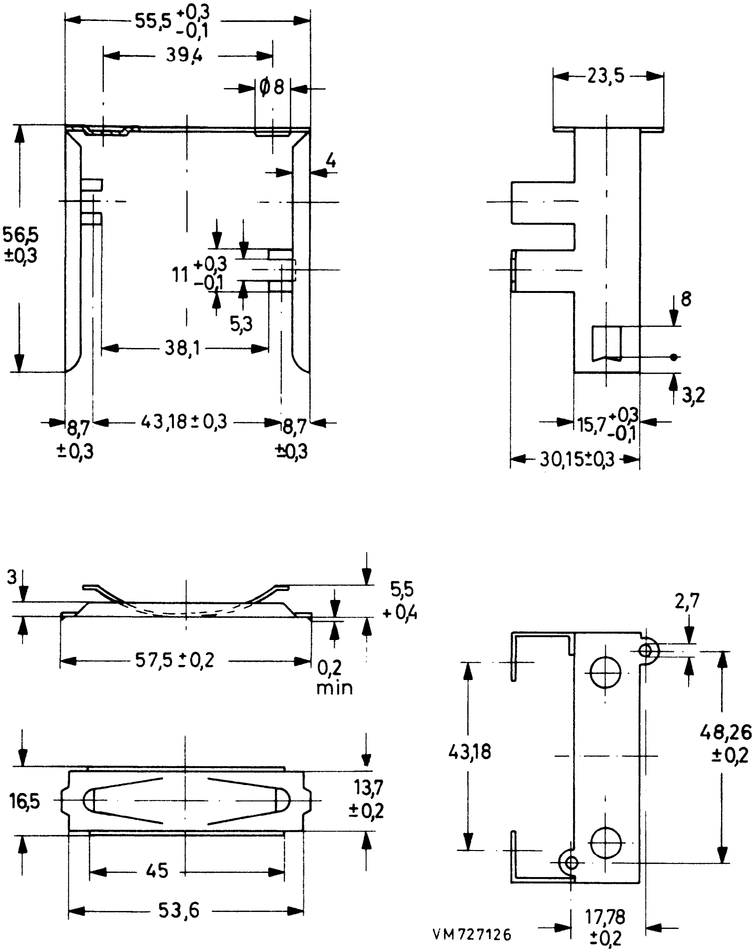
11 tags inserted

catalogue number
4322 021 33360



Catalogue number of coil former without tags: 4322 021 33030
Catalogue number of tag: 4322 021 33070

MOUNTING PARTS



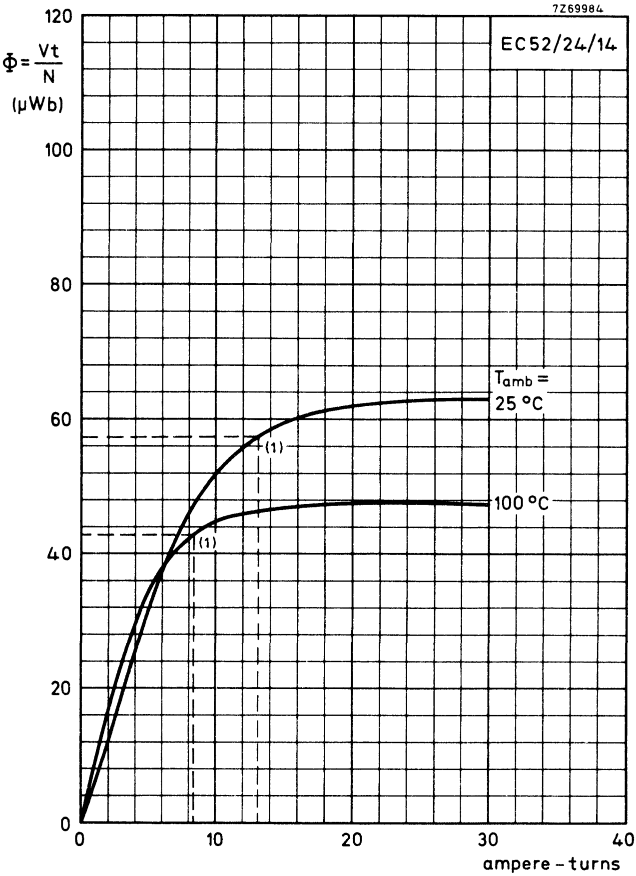
Spring.
Material: zinc plated steel, bichromated.

Clasp.
Material: zinc plated steel, bichromated.

Catalogue number of clasp and spring

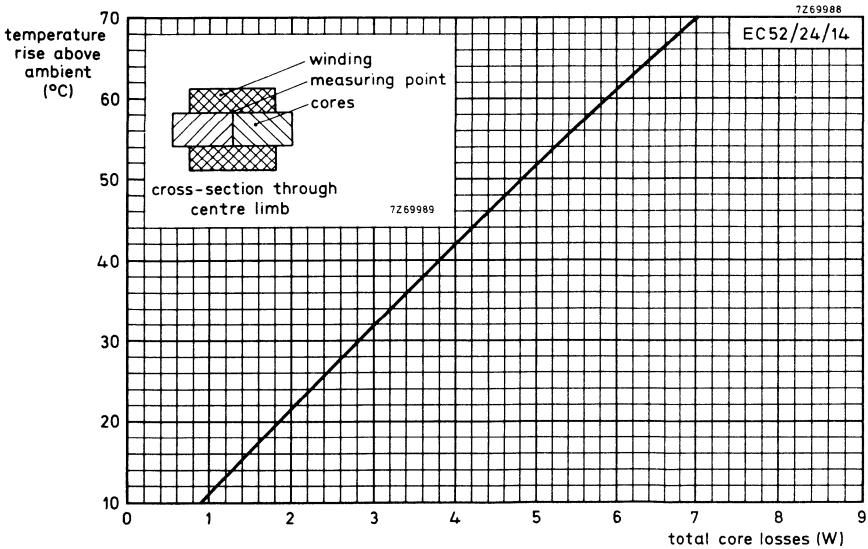
without mounting stud	4312 021 26040
with mounting stud	4312 021 26050.

CHARACTERISTIC CURVES

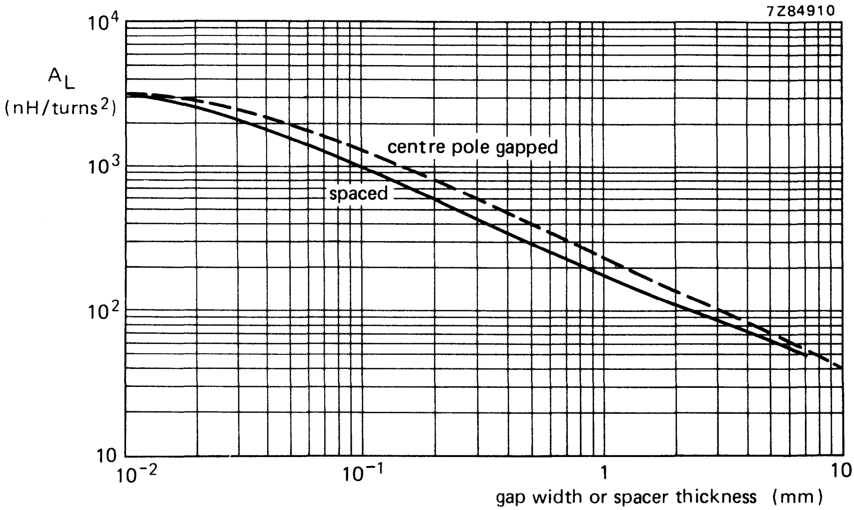


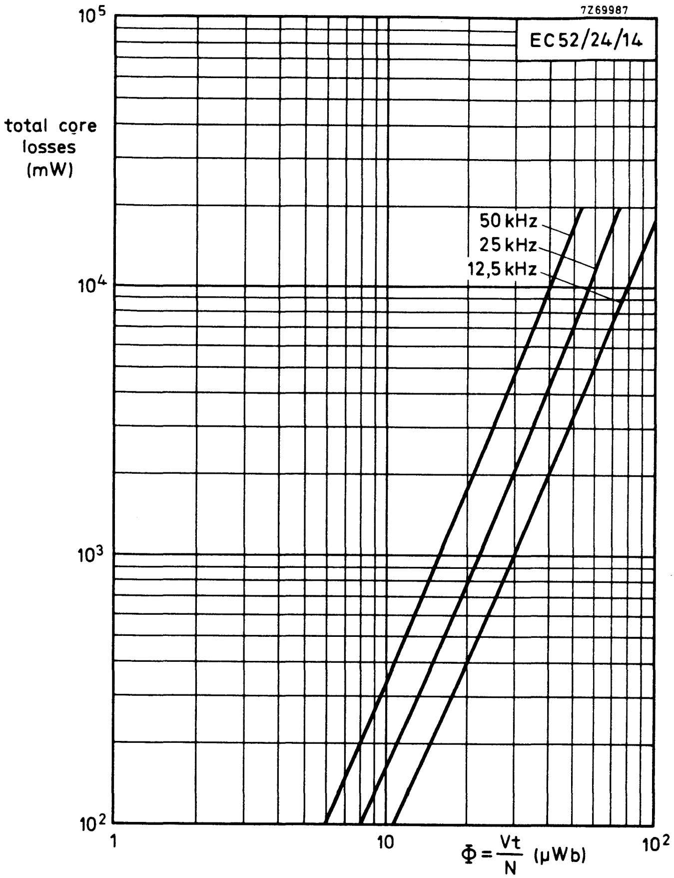
(1) Recommended maximum working flux.
Total flux as a function of ampere-turns.

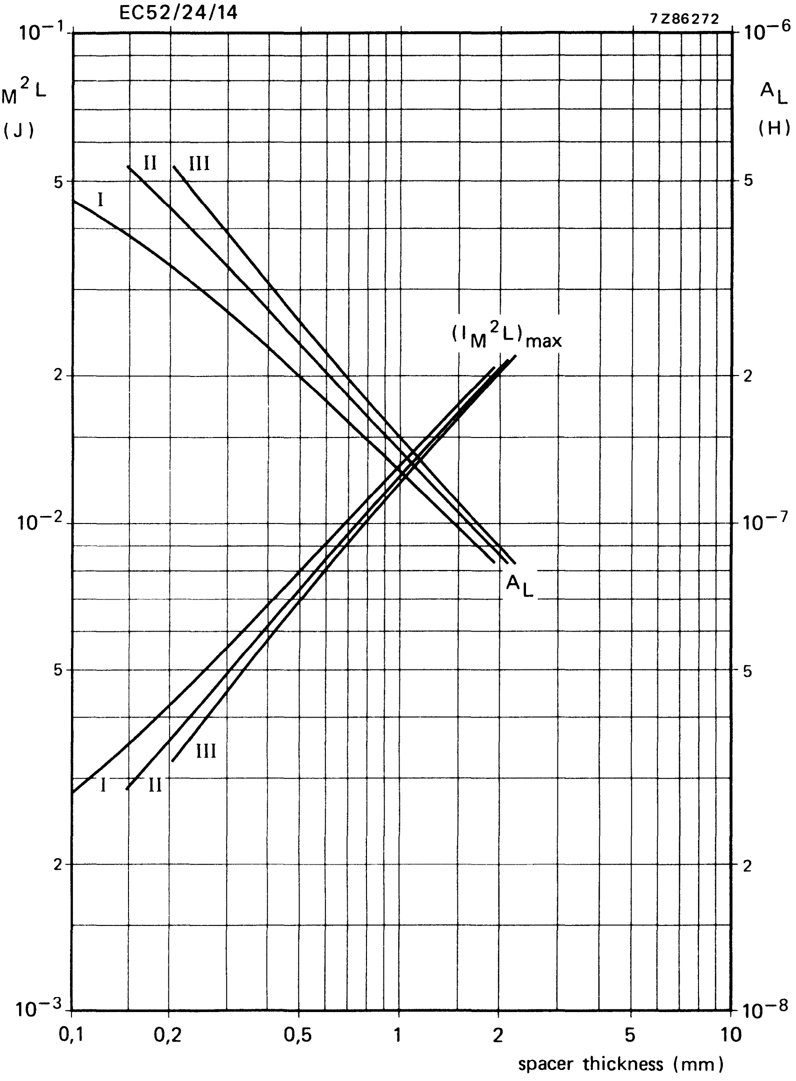
Recommended maximum working flux as a function of core temperature.



Transformer temperature rise as a function of total core losses, in free air conditions, without heatsink.

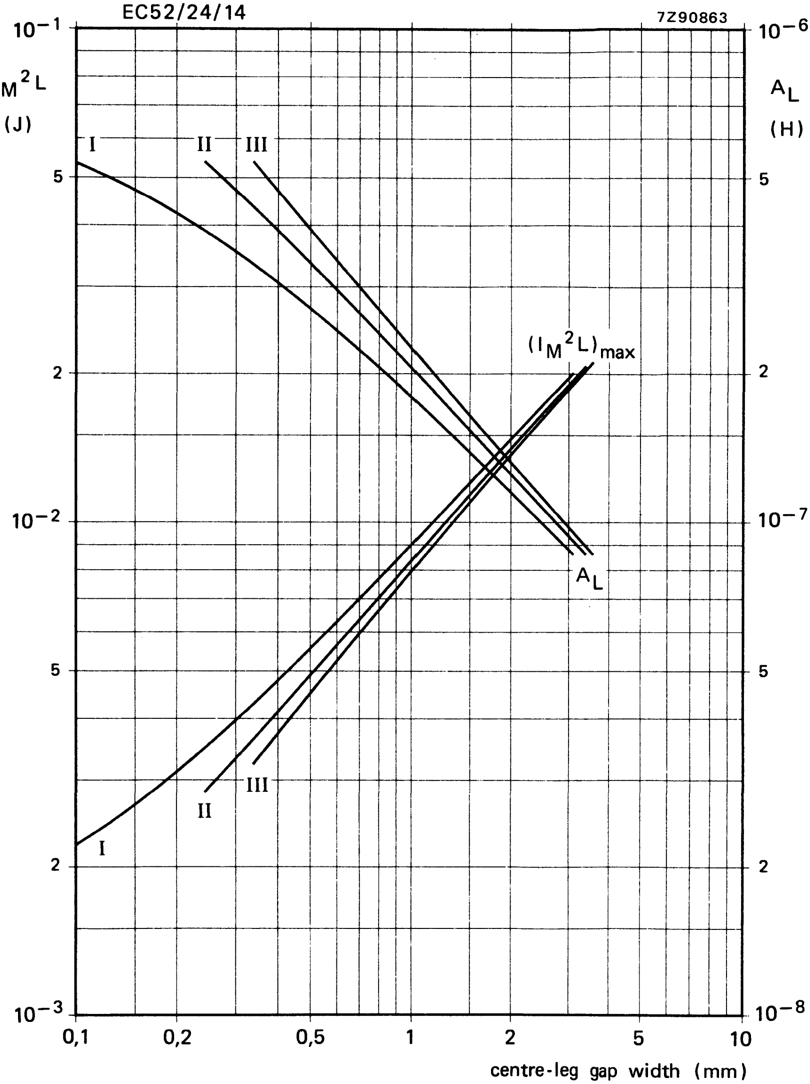

7Z84910
10^4
A_L
(nH/turns^2)
10^3
10^2
10
10^{-2}
10^{-1}
1
10
centre pole gapped
spaced
gap width or spacer thickness (mm)


7Z69987
EC52/24/14
total core losses (mW)
10^5
10^4
10^3
10^2
50 kHz
25 kHz
12,5 kHz
1
10
10^2
$\Phi = \frac{Vt}{N}$ (μWb)



Choke design chart.

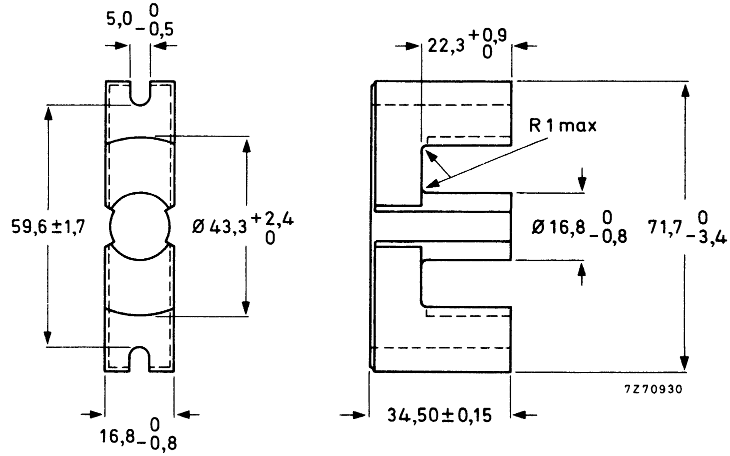
For application classes I, II and III see 'Power choke design' in the Introduction.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

EC-CORE



Mass	approx. 126,5 g
Ferroxcube grade	3C8
Catalogue number of EC-core without air gap*	● 4322 020 52530

DIMENSIONAL PARAMETERS FOR A PAIR OF CORES

(Assuming nominal dimensions, unless otherwise stated.)

Core constant **	C_l	= 0,514 mm^{-1}
Minimum cross-sectional centre pole area	A_{CPmin}	= 201,1 mm^2
Cross-sectional centre pole area	A_{min}	= 211,0 mm^2
Back and leg cross-sectional area	A_b	= 386,0 mm^2
Centre pole volume	V_{CP}	= 9600 mm^3
Back and leg volume	V_b	= 46000 mm^3
Total core volume	V_f	= 55600 mm^3
Effective magnetic path length **	l_e	= 144 mm
Effective cross-sectional area **	A_e	= 279 mm^2
Effective core volume **	V_e	= 40100 mm^3

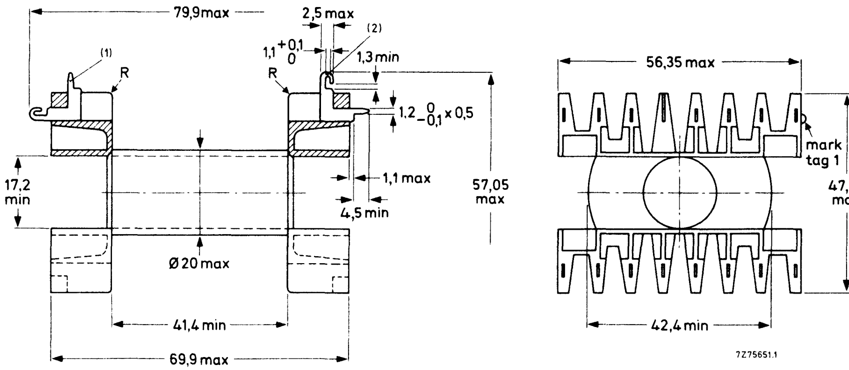
* Cores with air gap are available on request.
** According to IEC 205.
● Preferred type.

MAGNETIC PROPERTIES FOR A PAIR OF CORES WITHOUT AIR GAP

Relative amplitude permeability (μ_a) at θ = 100 °C, $\hat{B}$ = 320 mT in A_{CPmin}	$>$ 1000
Permissible induction in centre pole ($\hat{B}$) with min. cross-sectional area, at θ = 100 °C	$\leqslant$ 320 mT
Resistivity (ρ), measured with d.c. current	$\geqslant$ 1 Ωm
Curie point	$\geqslant$ 200 °C
Effective total core loss (P) referred to A_e at f = 25 kHz, θ = 100 °C, $\hat{B}$ = 160 mT	$\leqslant$ 5 W
Inductance factor A_L at f $<$ 100 kHz, θ = 25 °C, $\hat{B}$ $<$ 0,1 mT	$>$ 2900

COIL FORMERS

Material	glass-fibre-filled polyteraphthalate; solder-plated brass tags
Minimum window area	464 mm^2
Mean length of turn	96 mm
Mass, 15 tags inserted	approx. 36 g
Flammability	according to UL 94 V-0
Mounting	horizontal and vertical
Catalogue numbers	see next page
Tag arrangement	see next page

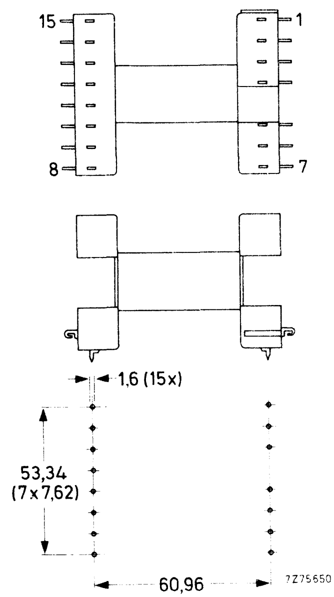


Tag arrangement

Horizontal mounting

15 tags inserted

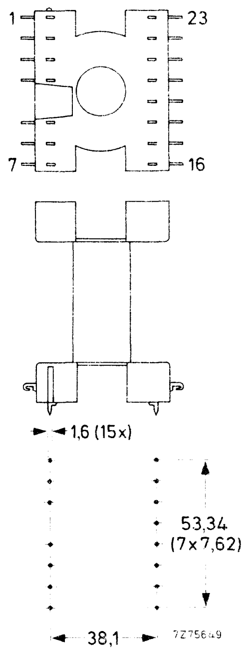
catalogue number
4322 021 33340



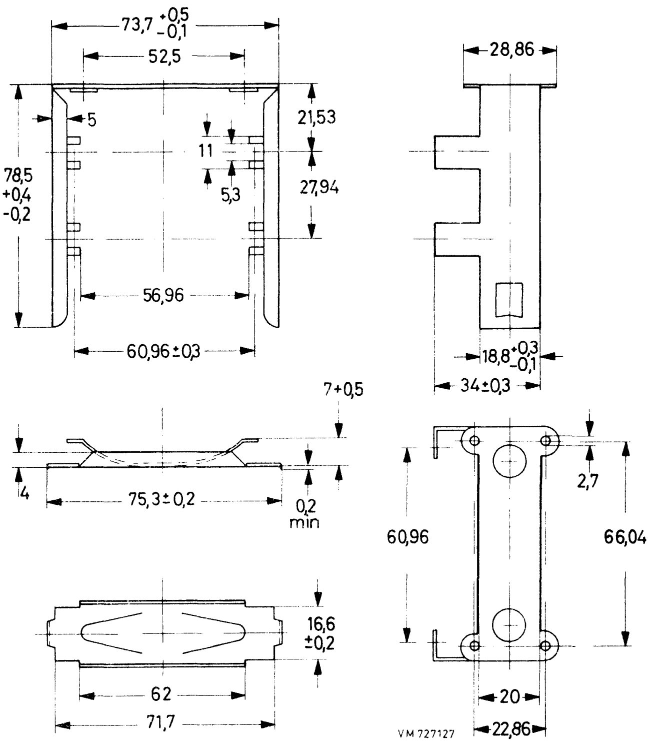
Vertical mounting

15 tags inserted

catalogue number
4322 021 33370



MOUNTING PARTS



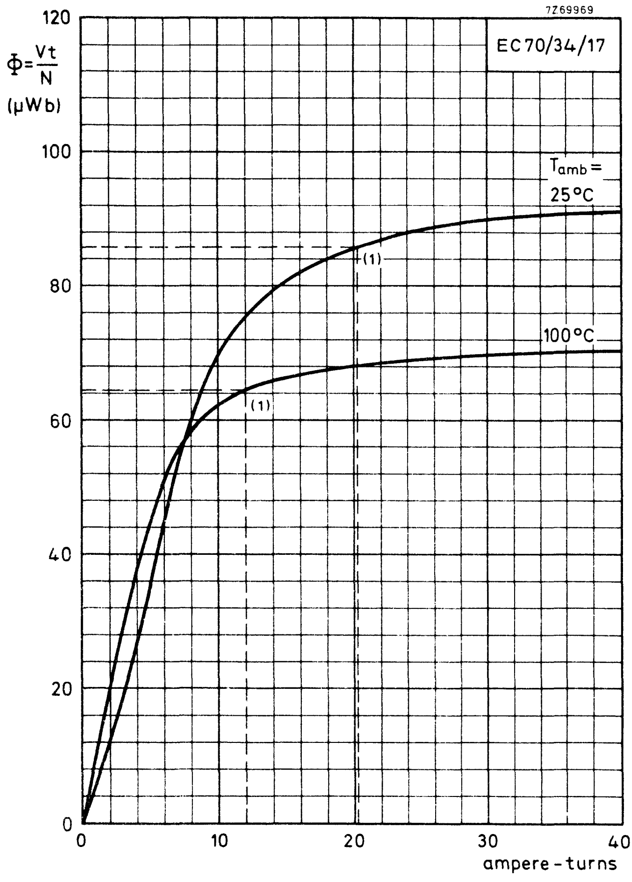
Spring.
Material: zinc plated steel,
bichromated.

Clasp.
Material: zinc plated steel,
bichromated.

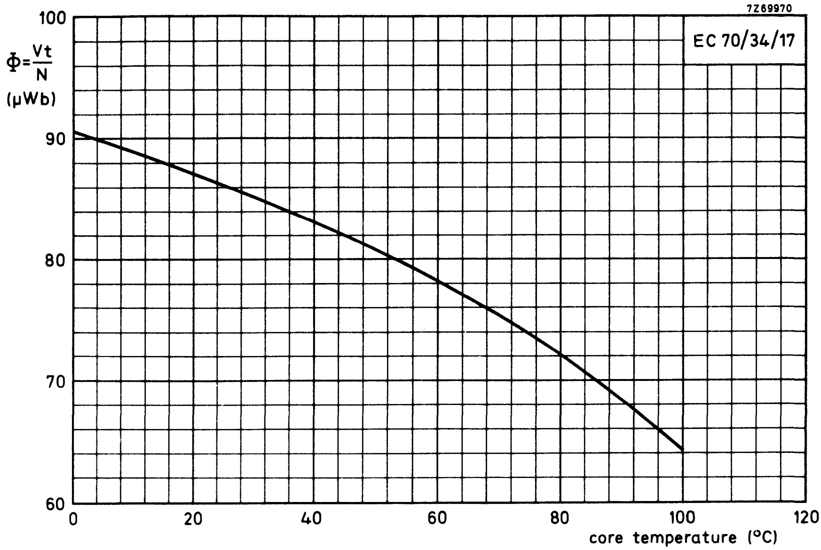
Catalogue number of clasp and spring

without mounting stud	4312 021 26060
with mounting stud	4312 021 26070.

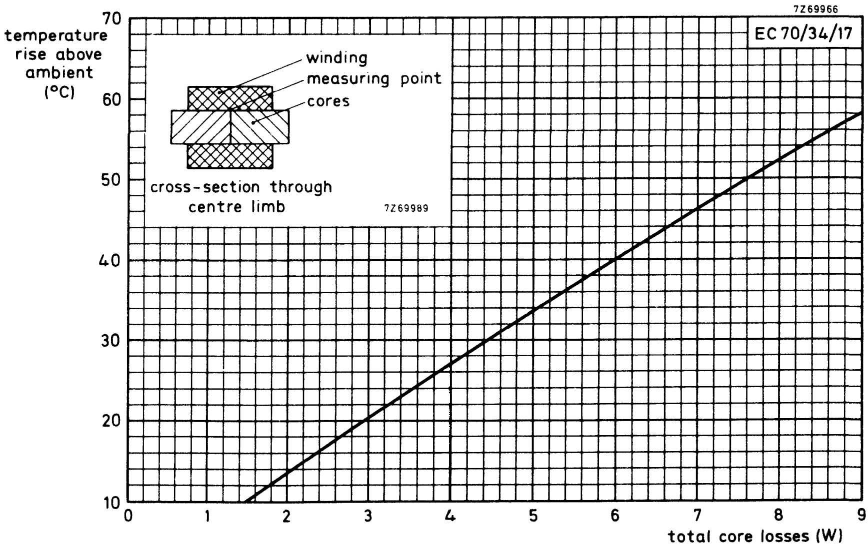
CHARACTERISTIC CURVES



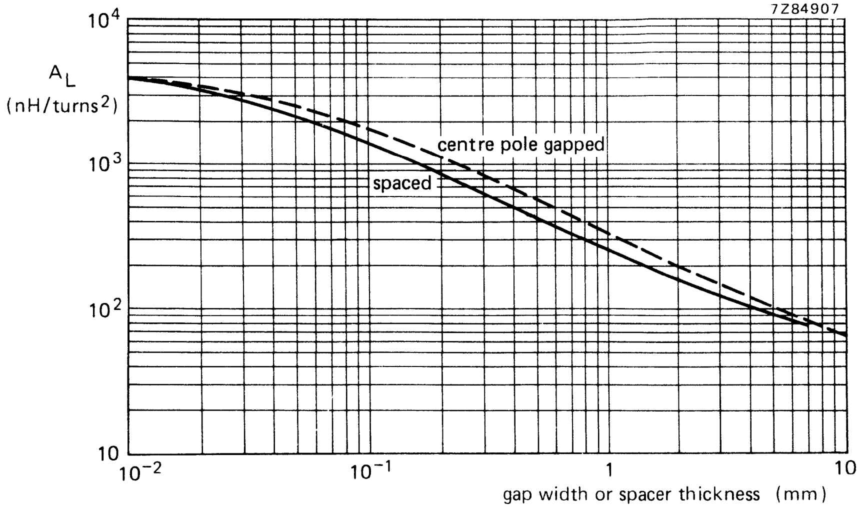
(1) Recommended maximum working flux.
Total flux as a function of ampere-turns.

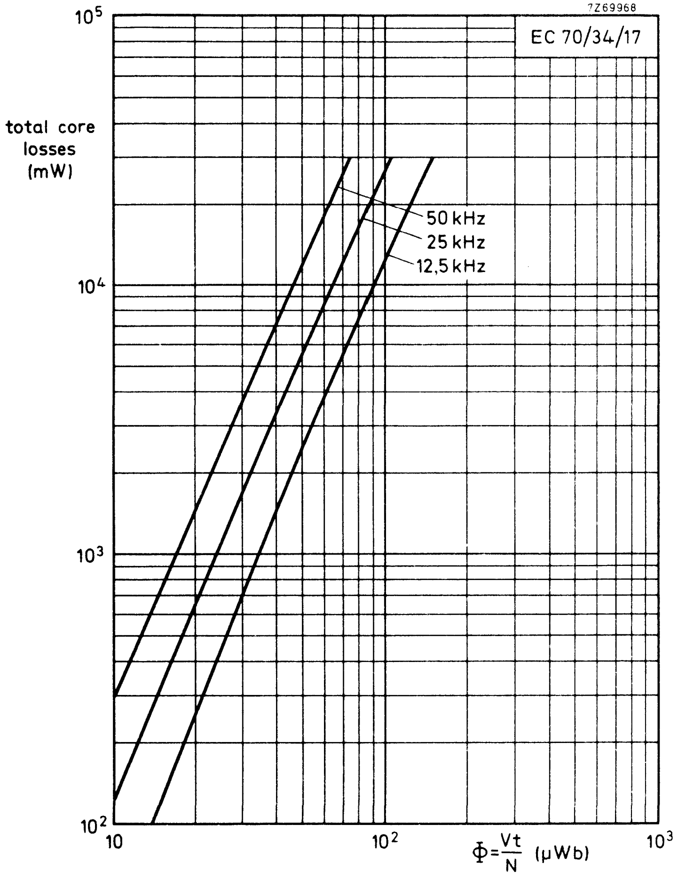


Recommended maximum working flux as a function of core temperature.

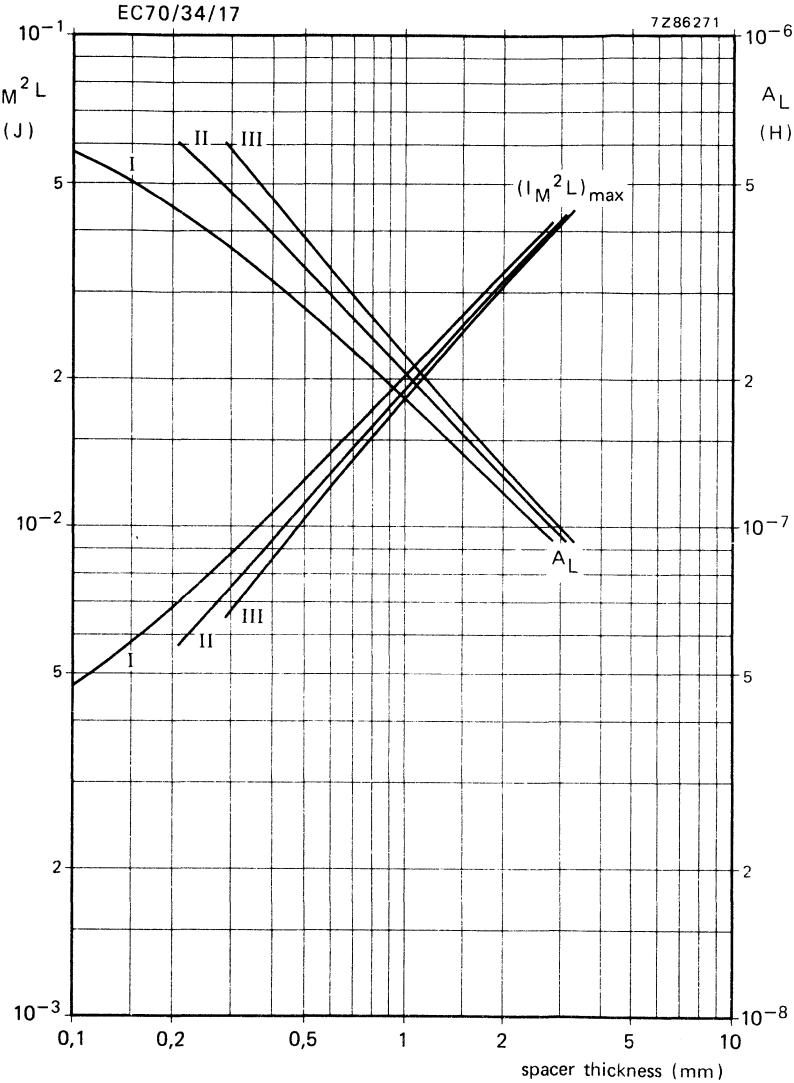


Transformer temperature rise as a function of total core losses, in free air conditions, without heatsink.


7Z84907
10^4
A_L
(nH/turns^2)
10^3
10^2
10
10^{-2}
10^{-1}
1
10
centre pole gapped
spaced
gap width or spacer thickness (mm)

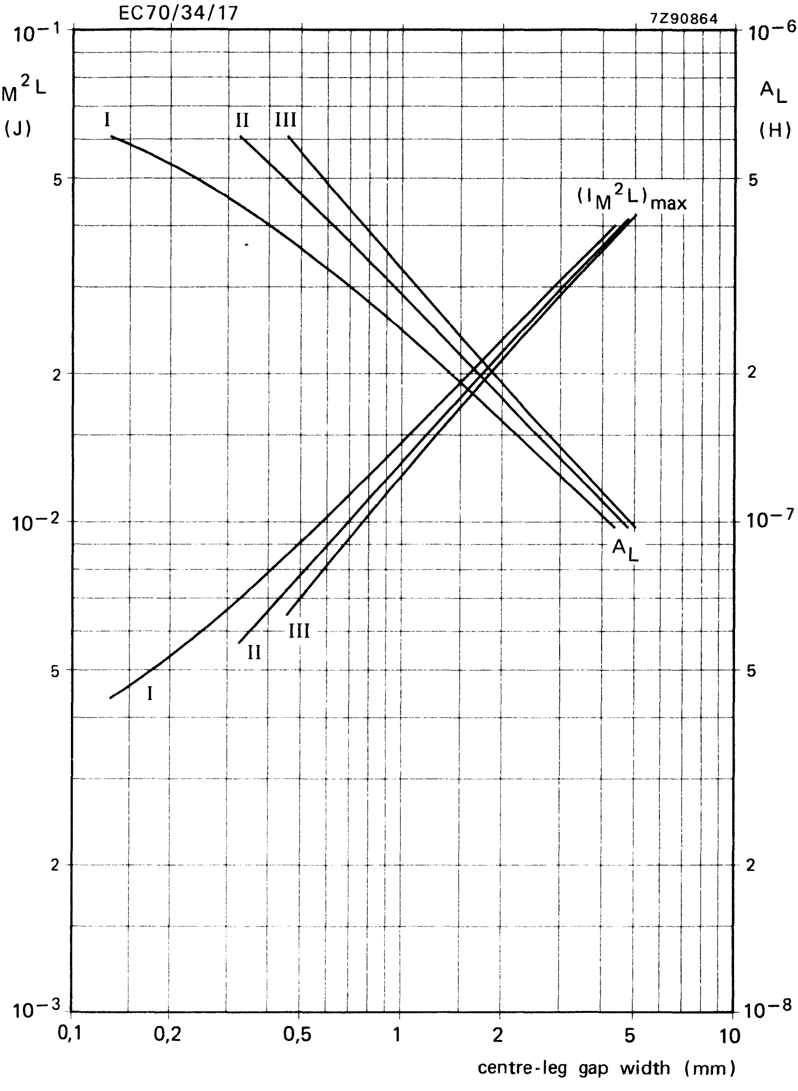


Total core losses as a function of total flux at hot-spot core temperature.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

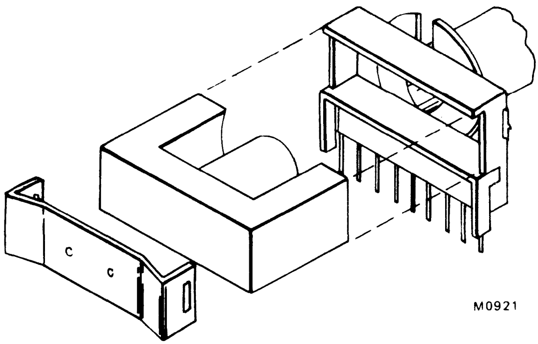
INTRODUCTION

The Economic Transformer Design (ETD) series consists of a number of high-frequency power cores in Ferroxcube 3C8 ferrite, which has been optimized to meet the current requirements of switched-mode power supplies. The cores are available for assembly as ungapped or gapped versions, with a range of four nominal A_L values for the gapped cores.

Features

- Round centre pole for minimum conductor length.
- Maximum throughput power in the frequency range 20 to 150 kHz.
- Minimum core weight due to constant cross-sectional area and proper choice of transition frequency*.
- Winding breadth sufficient for full IEC mains isolation in specified configurations.
- Sufficient winding height for minimum loss windings.

Assembly and mounting



Coil former assembly operation.

The polyteraphthalate coil former is suitable for single spindle or automatic machine winding. It is terminated, after winding, to integral pins. The two cores are assembled to the coil former in one operation, as shown in the figure.

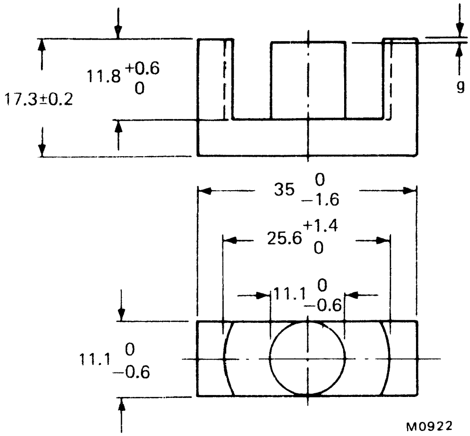
Two stainless steel clips retain the cores in the coil former assembly, maintaining adequate pressure at the mating pole faces.

The complete assembly is suitable for mounting on a printed-wiring board.

* Transition frequency is the frequency, at which the design changes from 'saturation limited' to 'core loss limited'.

ETD34 SYSTEM

FERROXCUBE CORE



Material: Ferroxcube grade 3C8

Mass per core: 20 g

gap width	nominal A_L (nH)	catalogue number
≙ 0	2400	● 4312 020 37000
0.1 ± 0.02	800	4312 020 37010
0.2 ± 0.03	480	4312 020 37020
0.5 ± 0.05	230	4312 020 37030
1.0 ± 0.1	140	4312 020 37040

The A_L values shown above apply to the gapped core indicated, assembled with an ungapped core.

● Preferred type.

EFFECTIVE PARAMETERS

For calculating the magnetic properties of a pair of cores, the following parameters should be used.

parameter	symbol	value	unit
effective magnetic path length	ℓ_e	78.6	mm
effective area of magnetic path	A_e	97.1	mm^2
effective magnetic volume	V_e	7640	mm^3
core factor $\sum \frac{\ell}{A}$	C_1	0,8096	mm^{-1}

NOMINAL DESIGN DATA FOR A PAIR OF CORES

parameter	symbol	value	unit
centre pole area	A_{min}	91,6	mm^2
length of the mean turn	ℓ_w	60	mm

ELECTRICAL AND MAGNETIC PROPERTIES OF A PAIR OF CORES

property	temperature (°C)	frequency (kHz)	parameter	value	unit
total power loss (P)	60–100	25	$\hat{B}$ = 200 mT*	<1.6	W
saturation induction ($\hat{B}_{max}$)	100	25	H = 250 A/m	>320	mT

$$*\hat{B} = \frac{\sqrt{2}\,U}{\omega A_{min} N}$$

CHOKE DESIGN CHART

For application classes I, II and III see 'Power choke design' in the Introduction.

class I			class II*			class III**			centre leg gap width	core halves ▲ catalogue number 4312 020 followed by
I_M^2L	$N_{max} \times I_M$	A_{L2}	I_M^2L	$N_{max} \times I_M$	A_{L2}	I_M^2L	$N_{max} \times I_M$	A_{L2}		
mJ	A	nH	mJ	A	nH	mJ	A	nH	mm	
1,09	55,6	354	0,71	36,2	541	0,47	24,1	803	0,1	37000 & 37010
1,43	72,8	270	1,04	53,2	368	0,79	41,0	472	0,2	37010 & 37010
1,86	90,9	225	1,46	71,1	289	1,21	58,8	350	0,3	37010 & 37020
2,26	108	194	1,86	88,0	240	1,61	75,7	281	0,4	37020 & 37020
2,85	127	176	2,45	108	212	2,20	95,1	244	0,5	37000 & 37030
3,11	141	157	2,71	121	185	2,46	109	208	0,6	37010 & 37030
3,47	156	143	3,06	136	166	2,81	123	185	0,7	37020 & 37030
4,55	199	115	4,15	179	130	3,90	166	141	1,0	37030 & 37030
4,77	210	108	4,37	190	121	4,11	178	130	1,1	37010 & 37040
5,08	223	102	4,67	203	114	4,42	190	122	1,2	37020 & 37040
6,04	260	89	5,63	240	98	5,38	228	104	1,5	37030 & 37040
7,38	316	74	6,97	296	80	6,72	284	84	2,0	37040 & 37040

Calculate N_{max} with $N_{max} = (N_{max} \times I_M)/I_M$

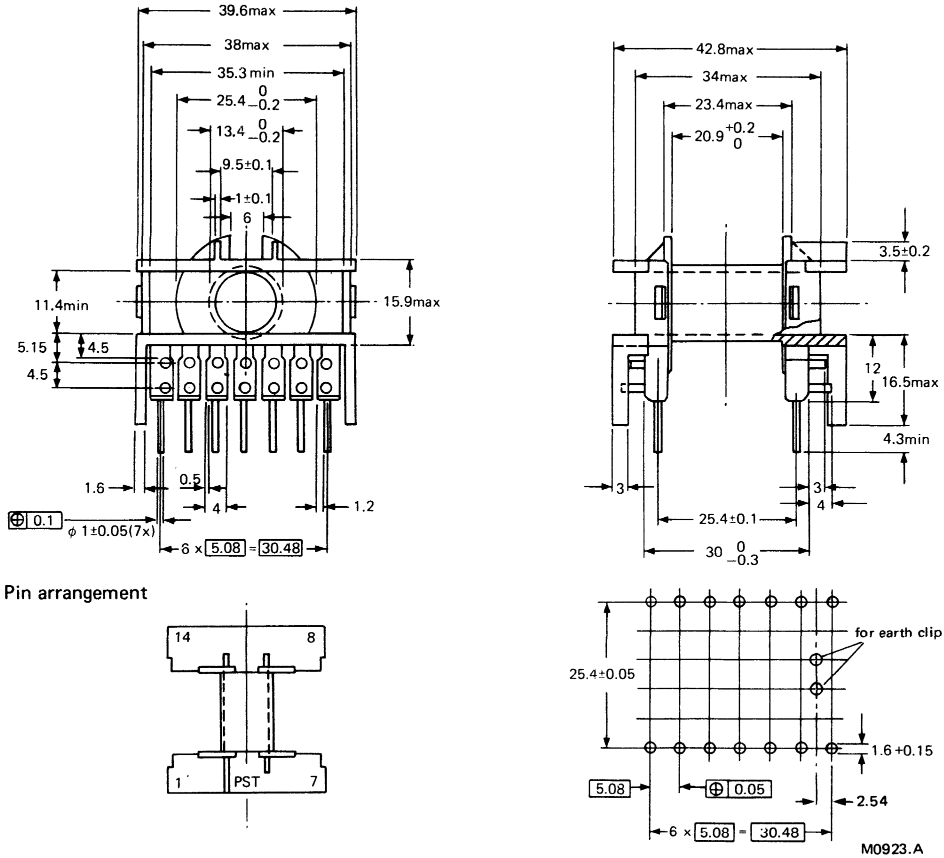
Calculate N_{min} with $N_{min} = \sqrt{L_{min}/A_{L2} \times 10^{-9}}$

▲ Preferred combinations.

* For frequencies beyond 40 kHz enter the table at $f/40 \times I_M^2L$ and calculate $N_{max} = (N_{max} \times I_M)/I_M \times \sqrt{f/40}$ (f in kHz).

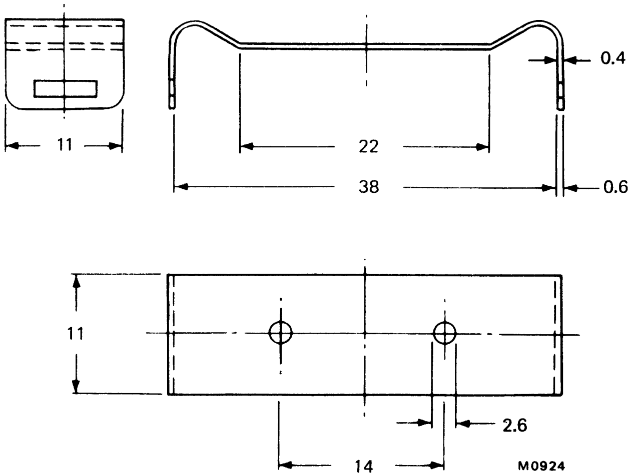
** For frequencies beyond 10 kHz enter the table at $0{,}1\ f \times I_M^2L$ and calculate $N_{max} = (N_{max} \times I_M)/I_M \times \sqrt{0{,}1\ f}$ (f in kHz).

COIL FORMER

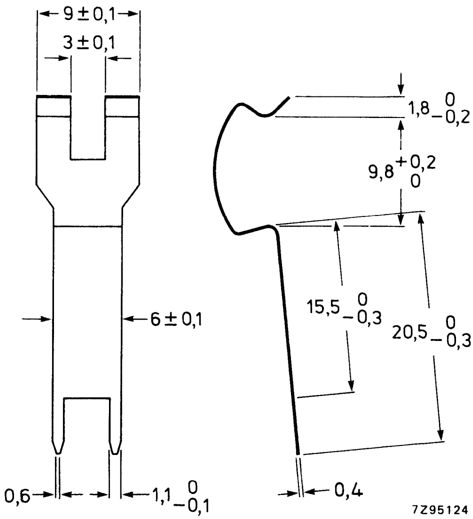


Material	glass-fibre-filled polyteraphthalate; 14 copper-nickel alloy pins are inserted
Minimum window area	123 mm^2
Mean length of turn	60 mm
Flammability	according to UL94 V-0
Solderability	400 ^{o}C for 4 s
Catalogue number	4322 021 33850

MOUNTING PARTS



Assembly clip.
Material stainless steel
Catalogue number 4322 021 33890

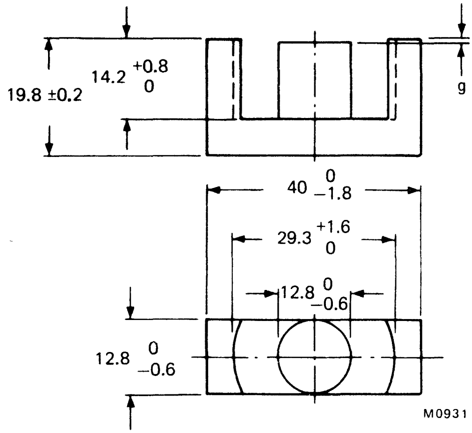


Earth clip.
Material nickel silver
Terminations hot tinned
Catalogue number 4322 021 33940

Both core halves can be connected to earth by means of this clip.

ETD39 SYSTEM

FERROXCUBE CORE



Material: Ferroxcube grade 3C8

Mass per core: 30 g

gap width	nominal A_L (nH)	catalogue number
≏ 0	2700	• 4312 020 37050
0.1 ± 0.02	1000	4312 020 37060
0.2 ± 0.03	600	4312 020 37070
0.5 ± 0.05	295	4312 020 37080
1 ± 0.1	170	4312 020 37090

The A_L values shown above apply to the gapped core indicated, assembled with an ungapped core.

• Preferred type.

EFFECTIVE PARAMETERS

For calculating the magnetic properties of a pair of cores, the following parameters should be used.

parameter	symbol	value	unit
effective magnetic path length	ℓ_e	92.2	mm
effective area of magnetic path	A_e	125	mm^2
effective magnetic volume	V_e	11 500	mm^3
core factor $\sum \frac{\ell}{A}$	C_1	0,7373	mm^{-1}

NOMINAL DESIGN DATA FOR A PAIR OF CORES

parameter	symbol	value	unit
centre pole area	A_{min}	123	mm^2
length of the mean turn	ℓ_w	69	mm

ELECTRICAL AND MAGNETIC PROPERTIES OF A PAIR OF CORES

property	temperature (°C)	frequency (kHz)	parameter	value	unit
total loss (P)	60–100	25	$\hat{B}$ = 200 mT*	<2.2	W
saturation induction ($\hat{B}_{max}$)	100	25	H = 250 A/m	>320	mT

$$*\hat{B} = \frac{\sqrt{2}\,U}{\omega A_{min} N}$$

CHOKE DESIGN CHART

For application classes I, II and III see 'Power choke design' in the Introduction.

class I			class II*			class III**			centre leg gap width	core halves ▲ catalogue number 4312 020 followed by
I_M^2L	$N_{max} \times I_M$	A_{L2}	I_M^2L	$N_{max} \times I_M$	A_{L2}	I_M^2L	$N_{max} \times I_M$	A_{L2}		
mJ	A	nH	mJ	A	nH	mJ	A	nH	mm	
1,70	64,2	413	1,07	40,4	655	0,67	25,6	1022	0,1	37050 & 37060
2,17	81,8	324	1,53	57,8	457	1,12	42,8	610	0,2	37060 & 37060
2,76	100	274	2,11	76,2	363	1,69	61,1	453	0,3	37060 & 37070
3,32	118	239	2,66	93,6	304	2,24	78,5	365	0,4	37070 & 37070
4,15	138	217	3,49	114	270	3,07	98,6	316	0,5	37050 & 37080
4,51	152	195	3,85	128	236	3,43	113	270	0,6	37060 & 37080
5,01	168	178	4,34	143	212	3,92	128	240	0,7	37070 & 37080
6,53	212	145	5,86	188	167	5,44	172	183	1,0	37080 & 37080
6,84	224	136	6,17	200	155	5,75	184	169	1,1	37060 & 37090
7,27	237	129	6,60	213	146	6,18	197	158	1,2	37070 & 37090
8,62	277	113	7,94	252	125	7,53	237	135	1,5	37080 & 37090
10,51	335	94	9,84	310	102	9,42	295	108	2,0	37090 & 37090

Calculate N_{max} with $N_{max} = (N_{max} \times I_M)/I_M$

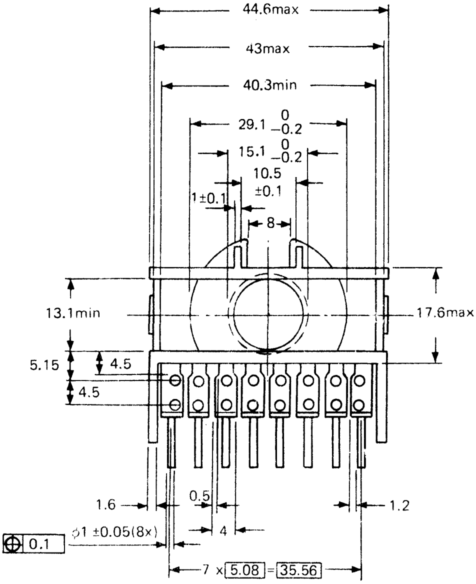
Calculate N_{min} with $N_{min} = \sqrt{L_{min}/A_{L2} \times 10^{-9}}$

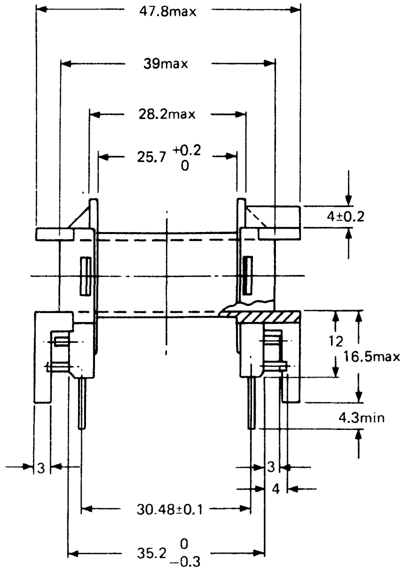
▲ Preferred combinations.

* For frequencies beyond 40 kHz enter the table at f/40 x I_M^2L and calculate $N_{max} = (N_{max} \times I_M)/I_M \times \sqrt{f/40}$ (f in kHz).

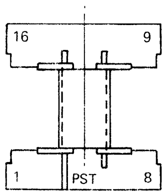
** For frequencies beyond 10 kHz enter the table at 0,1 f x I_M^2L and calculate $N_{max} = (N_{max} \times I_M)/I_M \times \sqrt{0,1\,f}$ (f in kHz).

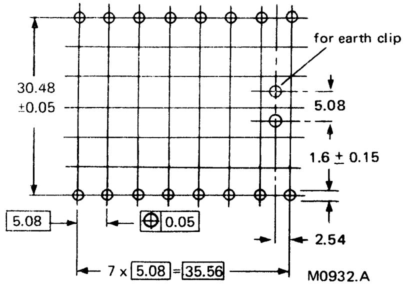
COIL FORMER





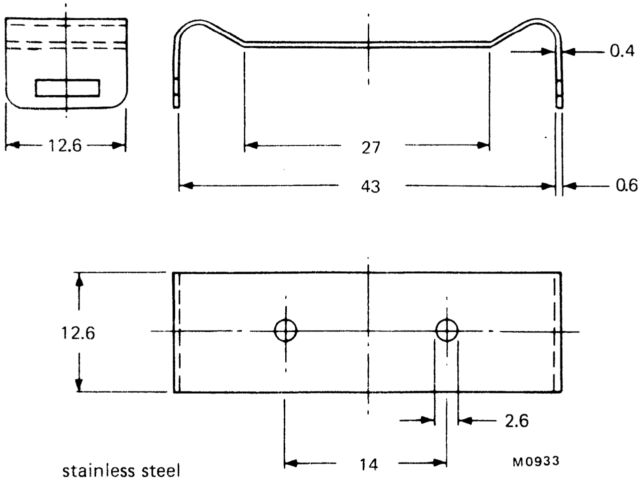
Pin arrangement



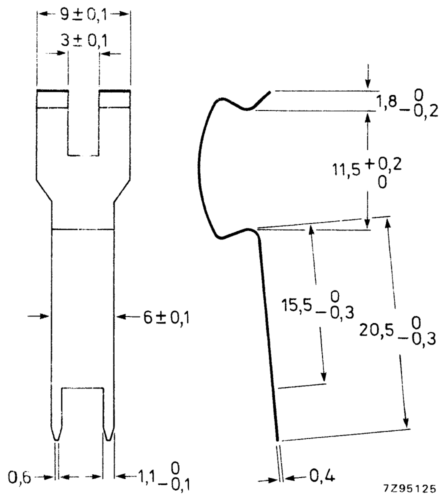


Material	glass-fibre-filled polyteraphthalate; 16 copper-nickel alloy pins are inserted
Minimum window area	177 mm²
Mean length of turn	69 mm
Flammability	according to UL94 V-0
Solderability	400 °C for 4 s
Catalogue number	4322 021 33860

MOUNTING PARTS



Assembly clip.
Material stainless steel
Catalogue number 4322 021 33900

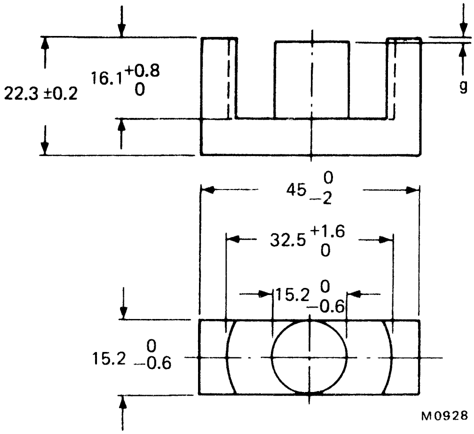


Earth clip.
Material nickel silver
Terminations hot tinned
Catalogue number 4322 021 33950

Both core halves can be connected to earth by means of this clip.

ETD44 SYSTEM

FERROXCUBE CORE



Material: Ferroxcube grade 3C8

Mass per core: 47g

gap width	nominal A_L (nH)	catalogue number
≏ 0	3300	• 4312 020 37100
0.2 ± 0.03	800	4312 020 37110
0.5 ± 0.05	400	4312 020 37120
1.0 ± 0.1	230	4312 020 37130
1.5 ± 0.15	170	4312 020 37140

The A_L values shown above apply to the gapped core indicated, assembled with an ungapped core.

• Preferred type.

EFFECTIVE PARAMETERS

For calculating the magnetic properties of a pair of cores, the following parameters should be used.

parameter	symbol	value	unit
effective magnetic path length	ℓ_e	103	mm
effective area of magnetic path	A_e	173	mm^2
effective magnetic volume	V_e	17 800	mm^3
core factor $\sum \frac{\ell}{A}$	C_1	0,5886	mm^{-1}

NOMINAL DESIGN DATA FOR A PAIR OF CORES

parameter	symbol	value	unit
centre pole area	A_{min}	174	mm^2
length of the mean turn	ℓ_w	77	mm

ELECTRICAL AND MAGNETIC PROPERTIES OF A PAIR OF CORES

property	temperature (^oC)	frequency (kHz)	parameter	value	unit
total loss (P)	60–100	25	$\hat{B}$ = 200 mT*	<3.6	W
saturation induction ($\hat{B}_{max}$)	100	25	H = 250 A/m	>320	mT

$$*\hat{B} = \frac{\sqrt{2}\,U}{\omega A_{min} N}$$

CHOKE DESIGN CHART

For application classes I, II and III see 'Power choke design' in the Introduction.

class I			class II*			class III**			centre leg gap width	core halves ▲ catalogue number 4312 020 followed by
I_M^2L	$N_{max} \times I_M$	A_{L2}	I_M^2L	$N_{max} \times I_M$	A_{L2}	I_M^2L	$N_{max} \times I_M$	A_{L2}		
mJ	A	nH	mJ	A	nH	mJ	A	nH	mm	
3,63	91,7	431	2,56	63,9	626	1,89	46,7	866	0,2	37100 & 37110
5,10	127	317	4,01	98,8	410	3,32	81,4	501	0,4	37110 & 37110
6,33	148	289	5,24	120	364	4,56	102	435	0,5	37100 & 37120
7,62	179	238	6,52	151	287	5,82	133	329	0,7	37110 & 37120
9,91	226	194	8,81	198	225	8,12	180	250	1,0	37120 & 37120
11,0	253	172	9,93	225	197	9,23	207	216	1,2	37110 & 37130
13,1	295	151	12,0	266	169	11,3	249	183	1,5	37120 & 37130
14,1	319	139	13,0	291	154	12,3	273	165	1,7	37110 & 37140
16,0	357	125	14,9	329	138	14,2	311	147	2,0	37130 & 37130
18,7	416	108	17,6	387	117	16,9	369	124	2,5	37130 & 37140
21,2	470	96	20,1	442	103	19,4	424	108	3,0	37140 & 37140

Calculate N_{max} with $N_{max} = (N_{max} \times I_M)/I_M$

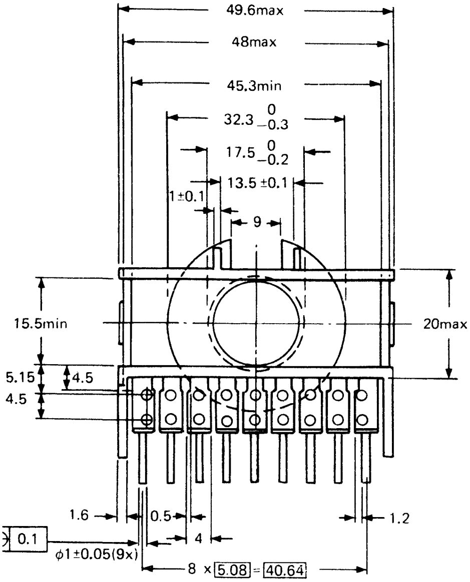
Calculate N_{min} with $N_{min} = \sqrt{L_{min}/A_{L2} \times 10^{-9}}$

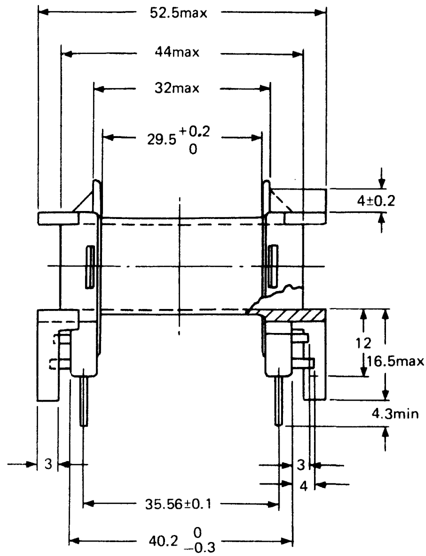
▲ Preferred combinations.

* For frequencies beyond 40 kHz enter the table at $f/40 \times I_M^2L$ and calculate $N_{max} = (N_{max} \times I_M)/I_M \times \sqrt{f/40}$ (f in kHz).

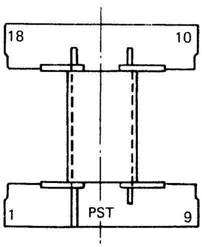
** For frequencies beyond 10 kHz enter the table at $0,1\ f \times I_M^2L$ and calculate $N_{max} = (N_{max} \times I_M)/I_M \times \sqrt{0,1\ f}$ (f in kHz).

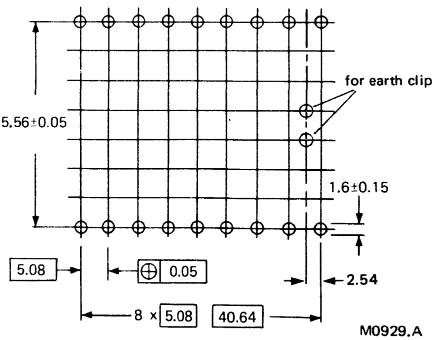
COIL FORMER





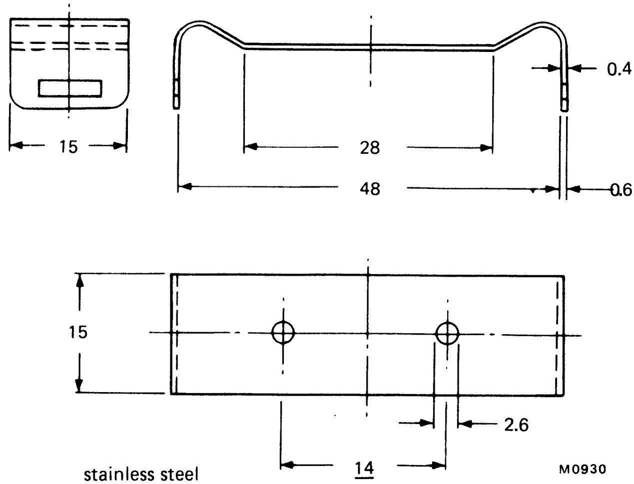
Pin arrangement



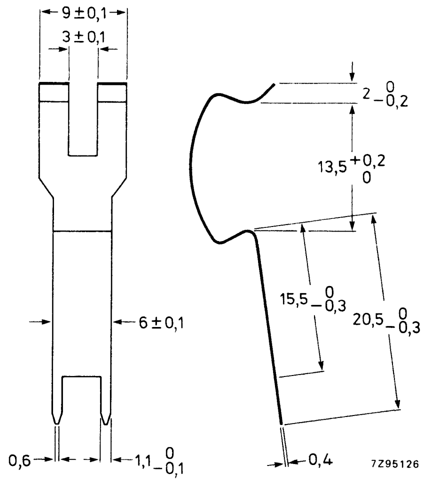


Material	glass-fibre-filled polyteraphthalate; 18 copper-nickel alloy pins are inserted
Minimum window area	214 mm^2
Mean length of turn	77 mm
Flammability	according to UL94 V-0
Solderability	400 ^{o}C for 4 s
Catalogue number	4322 021 33870

MOUNTING PARTS



Assembly clip.
Material stainless steel
Catalogue number 4322 021 33910

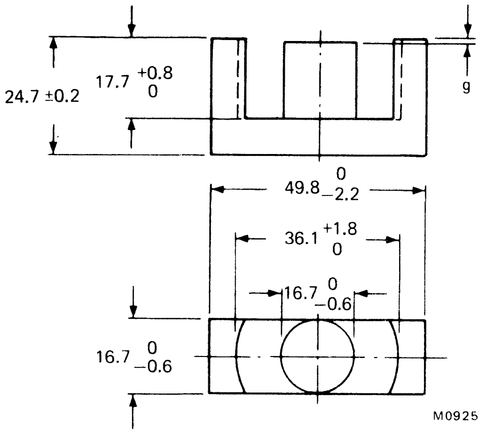


Earth clip.
Material nickel silver
Terminations hot tinned
Catalogue number 4322 021 33960

Both core halves can be connected to earth by means of this clip.

ETD49 SYSTEM

FERROXCUBE CORE



Material: Ferroxcube grade 3C8

Mass per core: 62g

gap width	nominal A_L (nH)	catalogue number
≏ 0	3700	● 4312 020 37150
0.2 ± 0.03	1000	4312 020 37160
0.5 ± 0.05	480	4312 020 37170
1.0 ± 0.1	270	4312 020 37180
2.0 ± 0.2	150	4312 020 37190

The A_L values shown above apply to the gapped core indicated, assembled with an ungapped core.

● Preferred type.

EFFECTIVE PARAMETERS

For calculating the magnetic properties of a pair of cores, the following parameters should be used.

parameter	symbol	value	unit
effective magnetic path length	ℓ_e	114	mm
effective area of magnetic path	A_e	211	mm^2
effective magnetic volume	V_e	24 000	mm^3
core factor $\sum \frac{\ell}{A}$	C_1	–	mm^{-1}

NOMINAL DESIGN DATA FOR A PAIR OF CORES

parameter	symbol	value	unit
centre pole area	A_{min}	211	mm^2
length of mean turn	ℓ_w	85	mm

ELECTRICAL AND MAGNETIC PROPERTIES OF A PAIR OF CORES

property	temperature (°C)	frequency (kHz)	parameter	value	unit
total loss (P)	60–100	25	$\hat{B}$ = 200 mT*	<4.6	W
saturation induction ($\hat{B}_{max}$)	100	25	H = 250 A/m	>320	mT

$$^*\hat{B} = \frac{\sqrt{2}\,U}{\omega A_{min} N}$$

CHOKE DESIGN CHART

For application classes I, II and III see 'Power choke design' in the Introduction.

class I			class II*			class III**			centre leg gap width	core halves ▲ catalogue number 4312 020 followed by
I_M^2L	$N_{max} \times I_M$	A_{L2}	I_M^2L	$N_{max} \times I_M$	A_{L2}	I_M^2L	$N_{max} \times I_M$	A_{L2}		
mJ	A	nH	mJ	A	nH	mJ	A	nH	mm	
4,68	97,5	492	3,25	66,9	727	2,35	47,8	1026	0,2	37150 & 37160
6,50	133	366	5,04	102	481	4,12	83,1	596	0,4	37160 & 37160
8,02	155	334	6,57	124	428	5,65	105	516	0,5	37150 & 37170
9,63	187	276	8,15	155	337	7,33	136	390	0,7	37160 & 37170
12,5	235	226	11,0	204	265	10,1	184	297	1,0	37170 & 37170
13,9	263	201	12,4	231	232	11,5	212	256	1,2	37160 & 37180
16,5	306	176	15,0	274	199	14,1	255	216	1,5	37170 & 37180
20,1	370	147	18,6	339	162	17,7	319	173	2,0	37180 & 37180
21,3	394	137	19,8	362	151	18,9	342	161	2,2	37160 & 37190
23,5	430	127	22,0	399	138	21,1	379	146	2,5	37170 & 37190
26,7	487	113	25,2	455	122	24,3	436	128	3,0	37180 & 37190
32,7	593	93	31,2	561	99	30,2	542	103	4,0	37190& 37190

Calculate N_{max} with $N_{max} = (N_{max} \times I_M)/I_M$

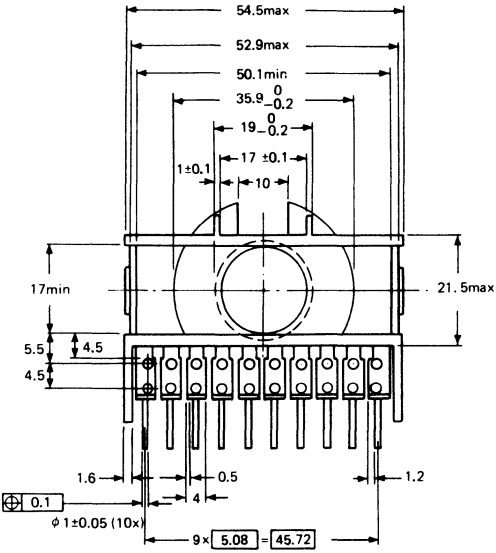
Calculate N_{min} with $N_{min} = \sqrt{L_{min}/A_{L2} \times 10^{-9}}$

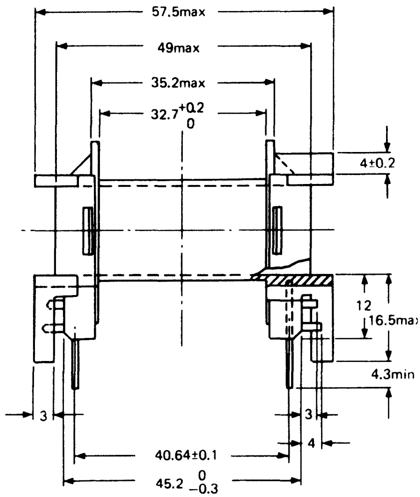
▲ Preferred combinations.

* For frequencies beyond 40 kHz enter the table at f/40 x I_M^2L and calculate $N_{max} = (N_{max} \times I_M)/I_M \times \sqrt{f/40}$ (f in kHz).

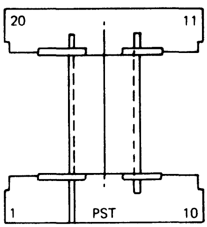
** For frequencies beyond 10 kHz enter the table at 0,1 f x I_M^2L and calculate $N_{max} = (N_{max} \times I_M)/I_M \times \sqrt{0,1\ f}$ (f in kHz).

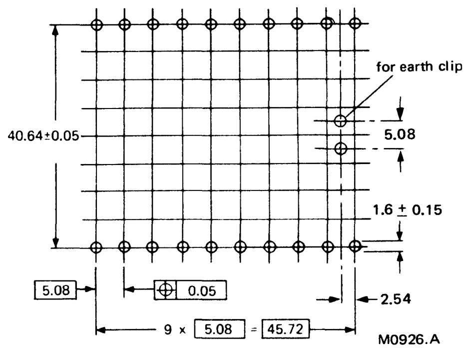
COIL FORMER





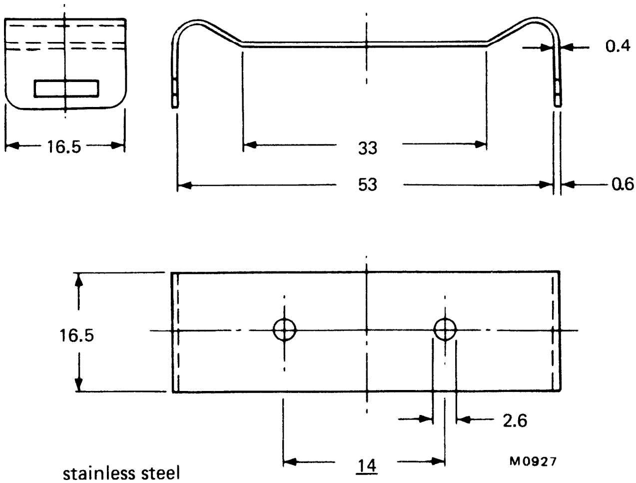
Pin arrangement



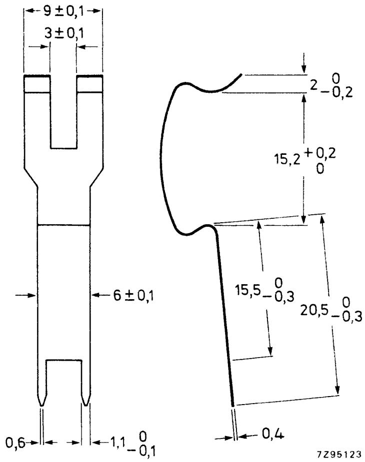


Material	glass-fibre-filled polyteraphthalate; 20 copper-nickel alloy pins are inserted
Minimum window area	273 mm^2
Mean length of turn	85 mm
Flammability	according to UL94 V-0
Solderability	400 °C for 4 s
Catalogue number	4322 021 33880

MOUNTING PARTS



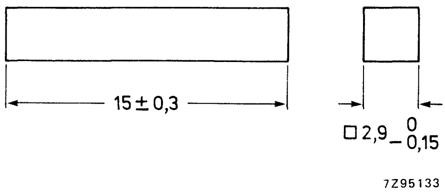
Assembly clip.
Material stainless steel
Catalogue number 4322 021 33920



Earth clip.
Material nickel silver
Terminations hot tinned
Catalogue number 4322 021 33970

Both core halves can be connected to earth by means of this clip.

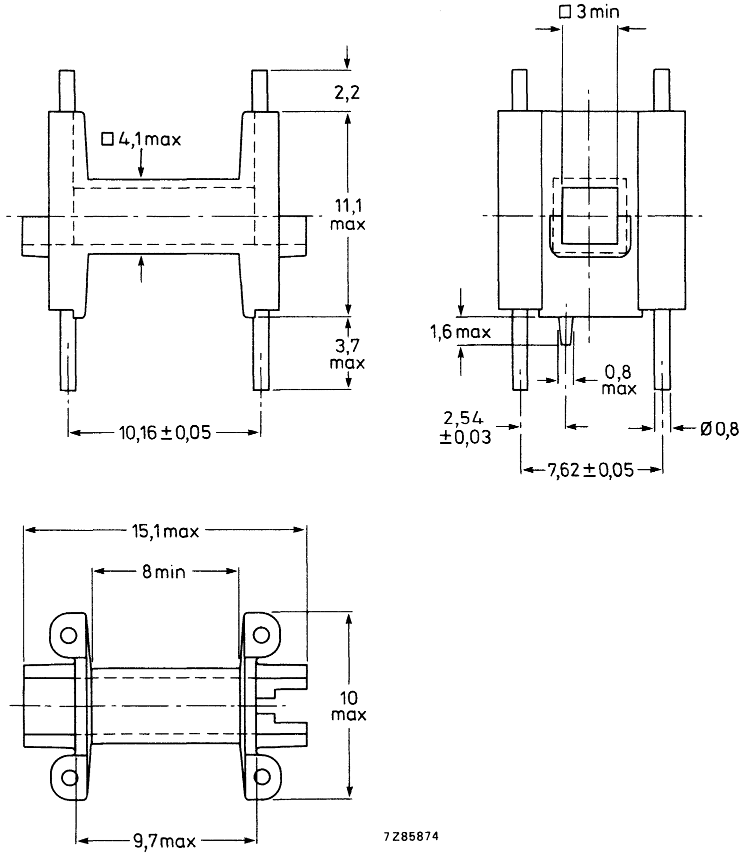
I-CORE



Ferroxcube grade	3C8
Catalogue number	3122 134 90730

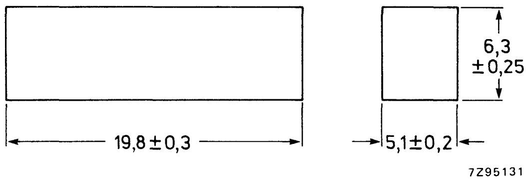
COIL FORMER

suited for one core I-15/3/3



Catalogue number 3122 134 02590

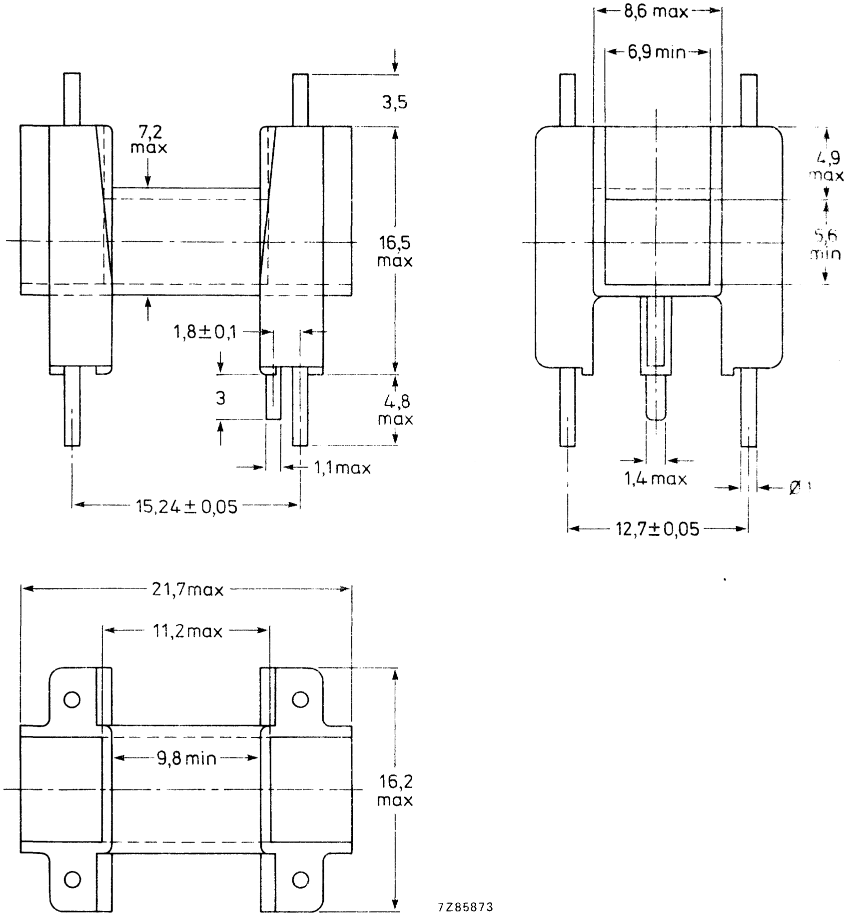
I-CORE



Ferroxcube grade	3C8
Catalogue number	3122 134 90720

COIL FORMER

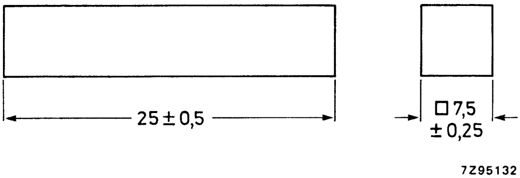
suited for one core I-20/6/5



7Z85873

Catalogue number 3122 134 02540

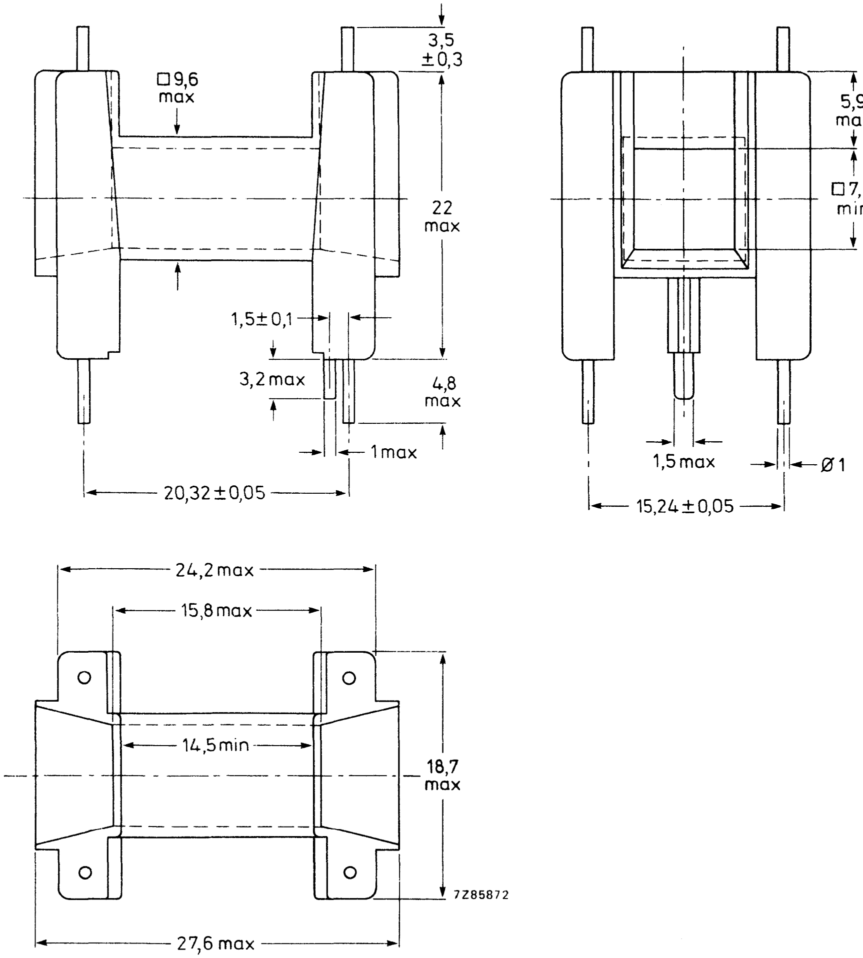
I-CORE



Ferroxcube grade	3C8
Catalogue number	3122 134 90620

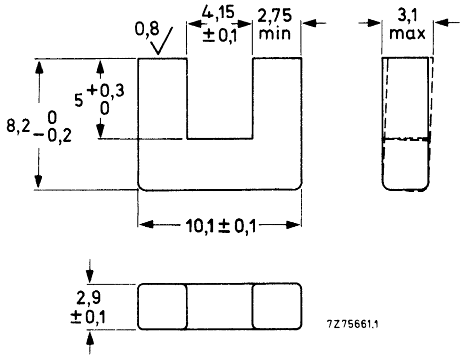
COIL FORMER

suited for one core I-25/7/7



Catalogue number 3122 137 64140

U-CORE



Mass 0,85 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-10/16/3.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	catalogue number of one U-core
3C8	25 100	⩾ 140 ⩾ 315	50 250	• 3122 134 91160

Magnetic dimensions

l_e = 38,4 mm

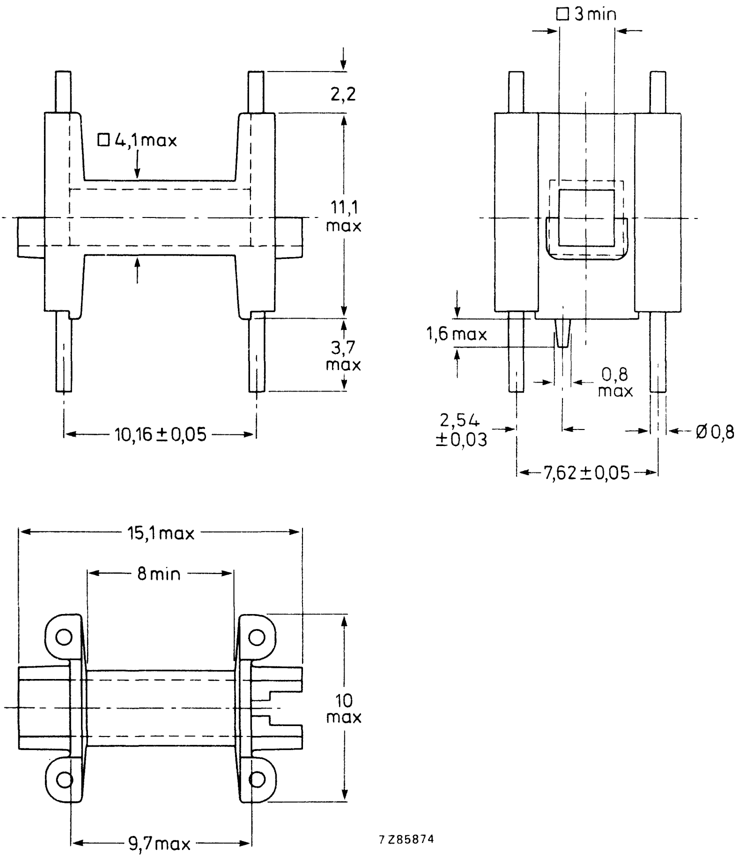
A_e = 8,6 mm^2

V_e = 330 mm^3

• Preferred type.

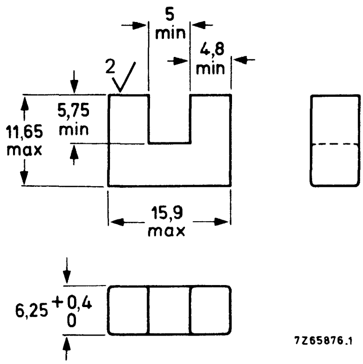
COIL FORMER

suited for two cores U-10/8/3



Catalogue number 3122 134 02590

U-CORE



Mass 4,35 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-15/22/6.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	≤ 0,18	● 3122 134 90690
	100	200	–	≤ 0,16	
	100	≥ 315	250	–	

Magnetic dimensions

l_e = 48 mm

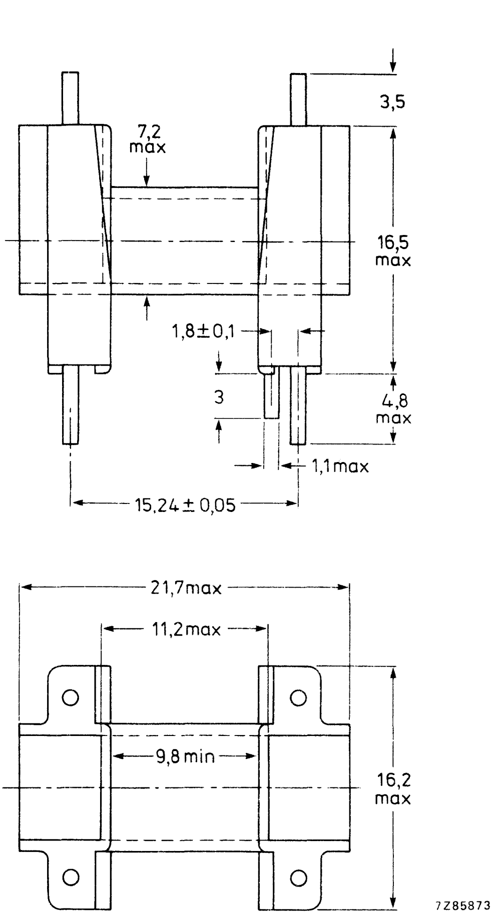
A_e = 30 mm^2

V_e = 1440 mm^3

● Preferred type.

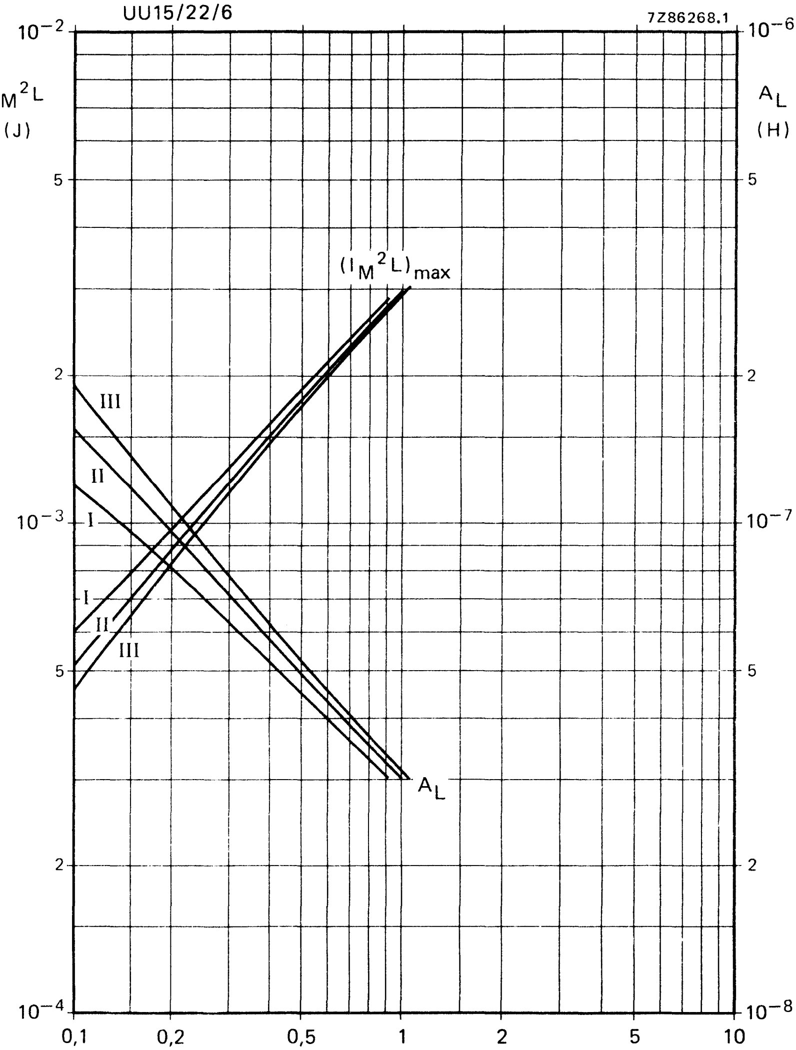
COIL FORMER

suited for two cores U-15/11/6



Catalogue number 3122 134 02540

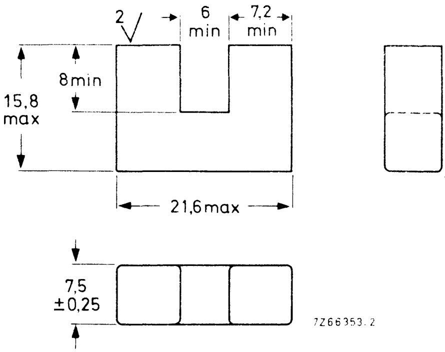
CHARACTERISTIC CURVES



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

U-CORE



Mass 9 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-20/32/7.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	⩽ 0,46	● 3122 134 90200
	100	200	–	⩽ 0,42	
	100	⩾315	250	–	

Magnetic dimensions

l_e = 68 mm

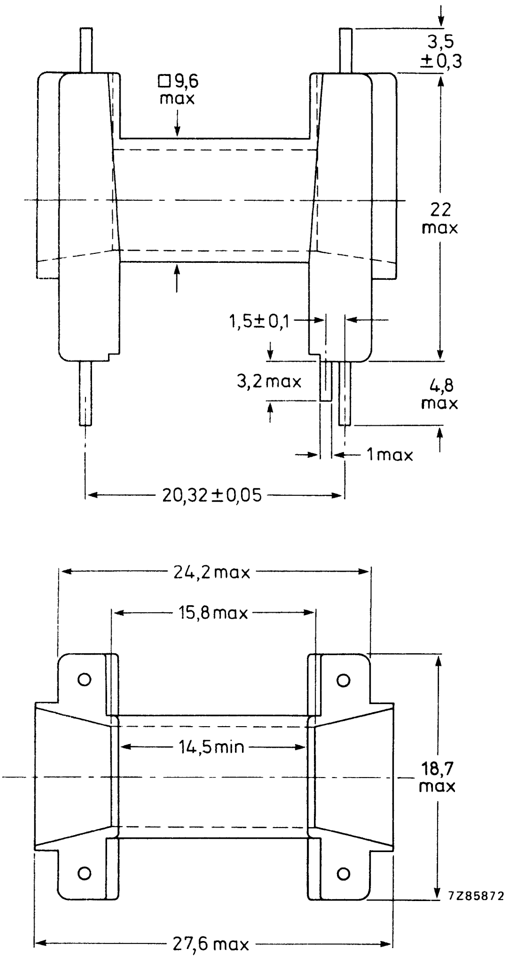
A_e = 56 mm^2

V_e = 3800 mm^3

● Preferred type.

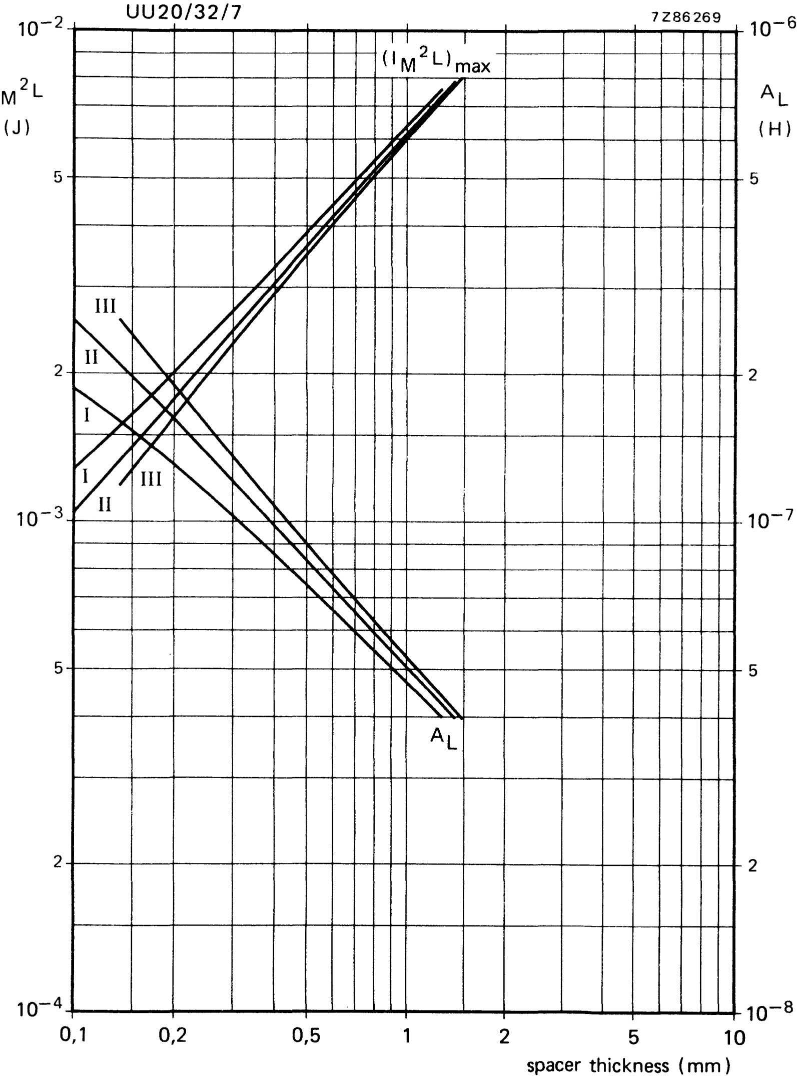
COIL FORMER

suited for two cores U-20/16/7



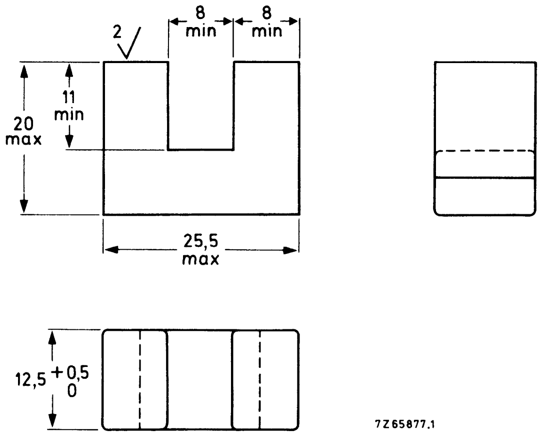
Catalogue number 3122 137 64140

CHARACTERISTIC CURVES



Choke design chart.
For application classes I, II and III see 'Power choke design' in the Introduction.

U-CORE



Mass 21 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-25/40/13.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	⩽ 1,1	• 3122 134 90460
	100	200	–	⩽ 1,0	
	100	⩾ 315	250	–	

Magnetic dimensions

l_e = 86 mm

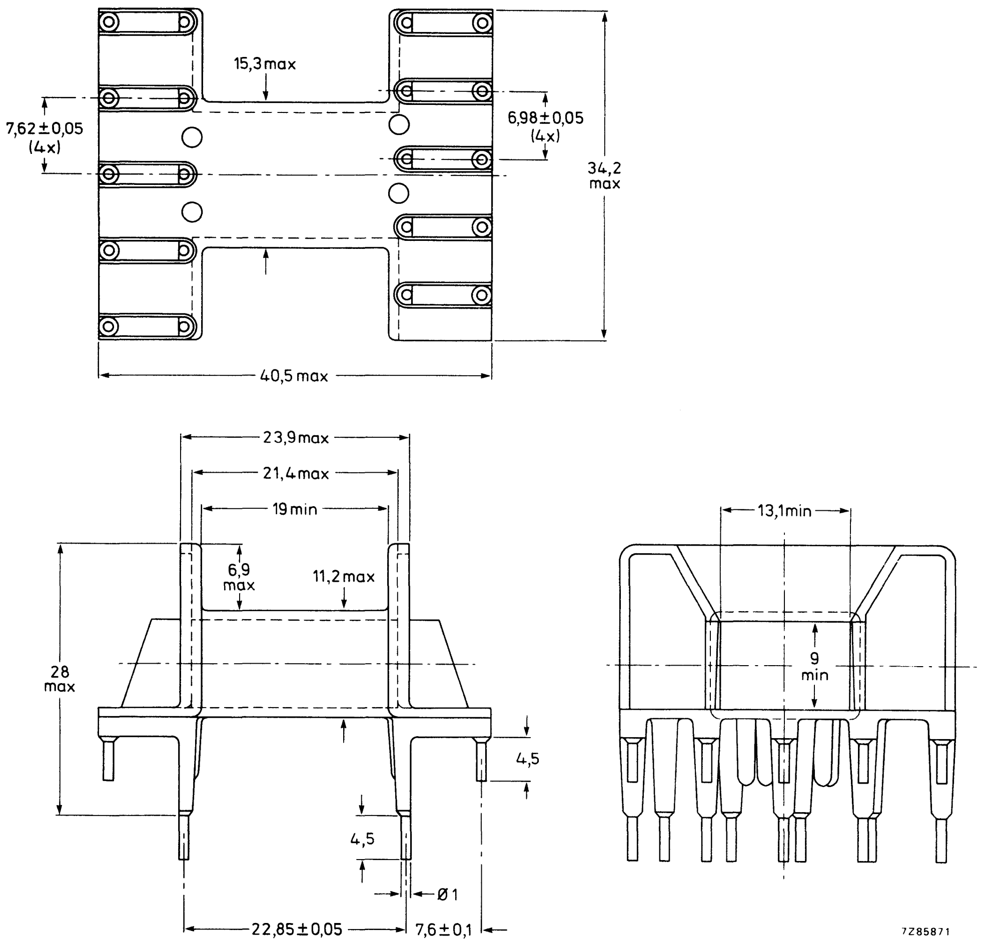
A_e = 100 mm^2

V_e = 8600 mm^3

• Preferred type.

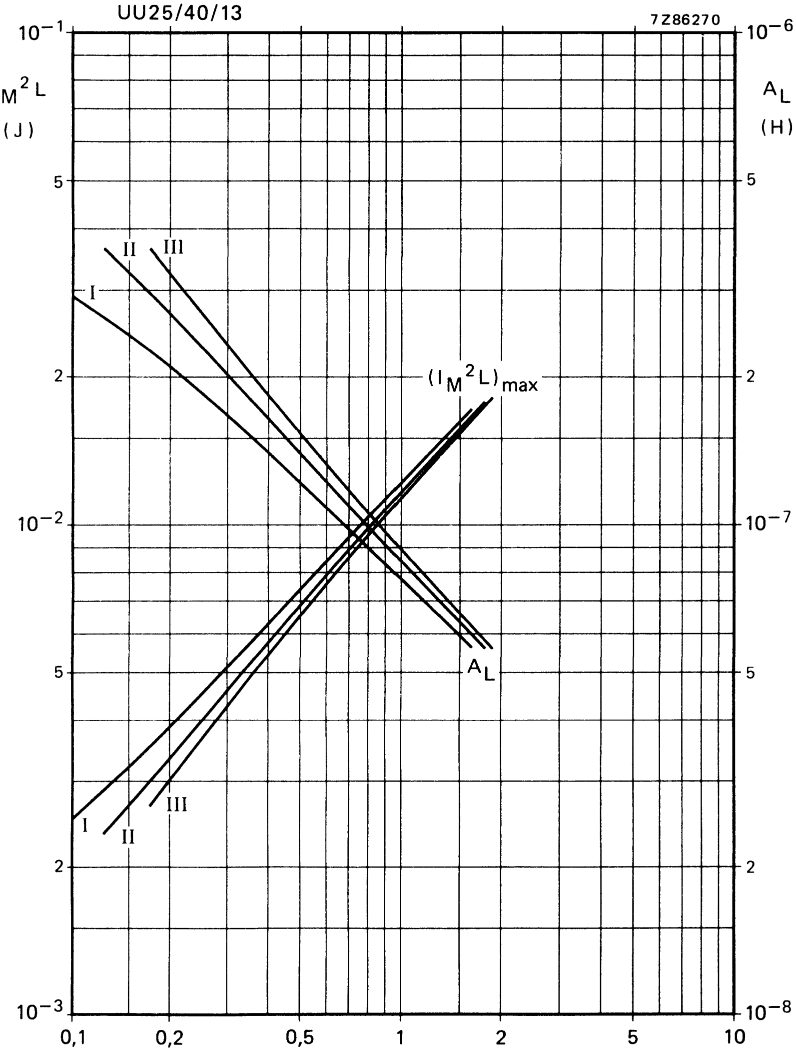
COIL FORMER

suited for two cores U-25/20/13



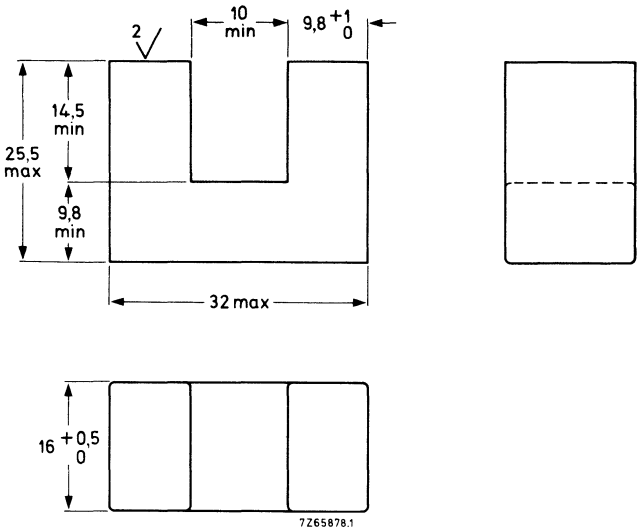
Catalogue number 3122 137 61910

CHARACTERISTIC CURVES



Choke design chart.
For application classes I, II and III see 'Power choke design' in the Introduction.

U-CORE



Mass 48 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-30/50/16.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	⩽ 2,4	● 3122 134 90760
	100	200	–	⩽ 2,0	
	100	⩾ 335	400	–	

Magnetic dimensions

l_e = 111 mm

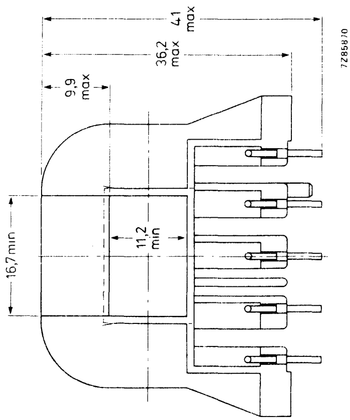
A_e = 157 mm²

V_e = 17400 mm³

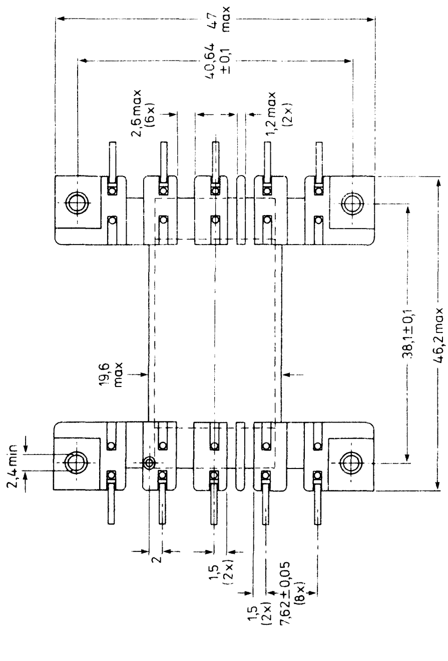
● Preferred type.

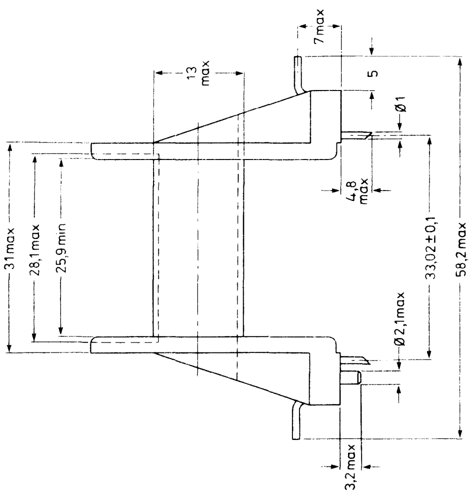
COIL FORMER

suited for two cores U-30/25/16

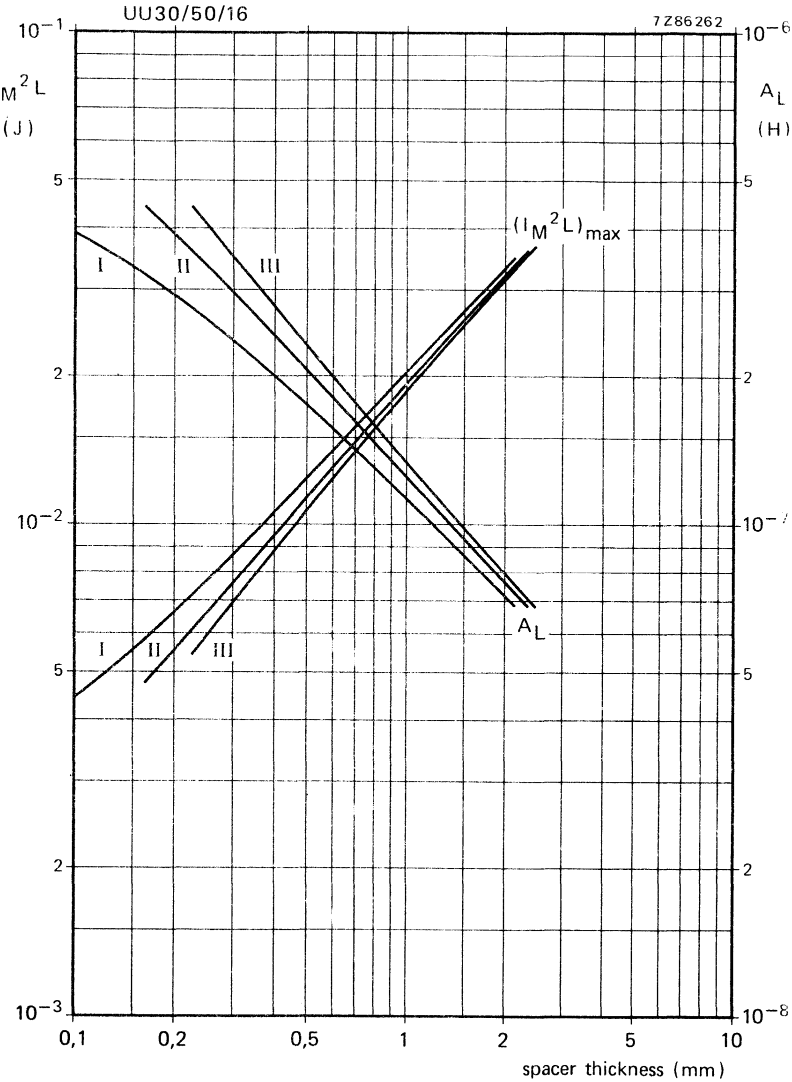


Catalogue number 3122 137 55360



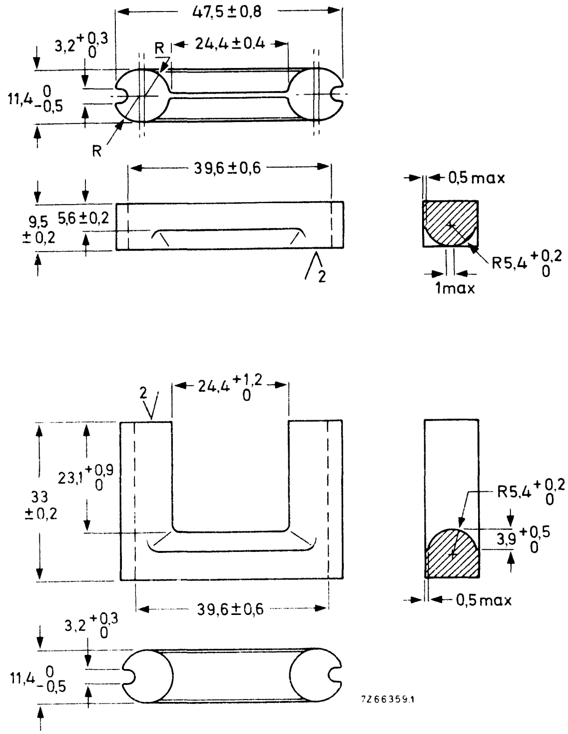


CHARACTERISTIC CURVES



Choke design chart.
For application classes I, II and III see 'Power choke design' in the Introduction.

UI-CORES



Mass U-core 38 g
I-core 20 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UI-46/43/11.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C8	25	200	–	≤ 1,97	U	3122 104 90480
	100	200	–	≤ 1,62	I	3122 104 90470
	100	≥ 290	250	–		

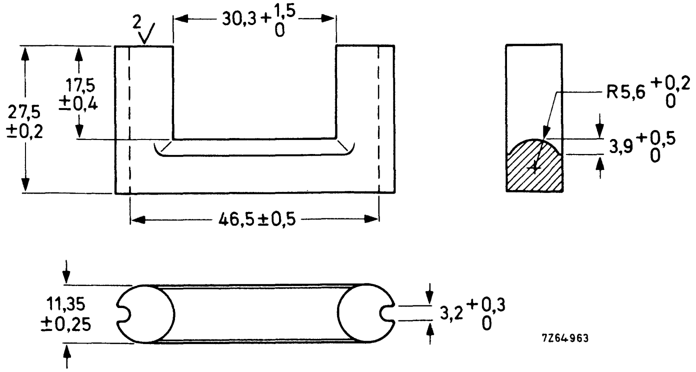
Magnetic dimensions

l_e = 129 mm

A_e = 88 mm^2

V_e = 11600 mm^3

U-CORE



Mass 40 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-52/56/11.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number one U-core
3C8	25	200	–	⩽ 1,9	• 3122 134 90480
	100	200	–	⩽ 1,75	
	100	⩾ 330	250	–	

Magnetic dimensions

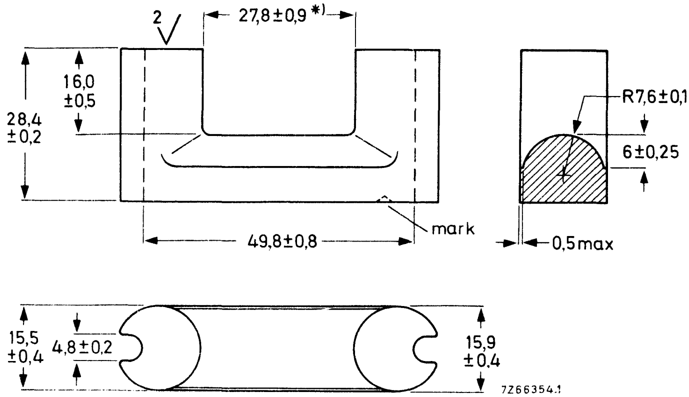
l_e = 165 mm

A_e = 95 mm^2

V_e = 15700 mm^3

• Preferred type.

U-CORE



Mass 70 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-57/57/16.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	≤ 3,3	4312 020 33190
	100	200	–	≤ 3,05	
	100	≥ 330	250	–	

Magnetic dimensions

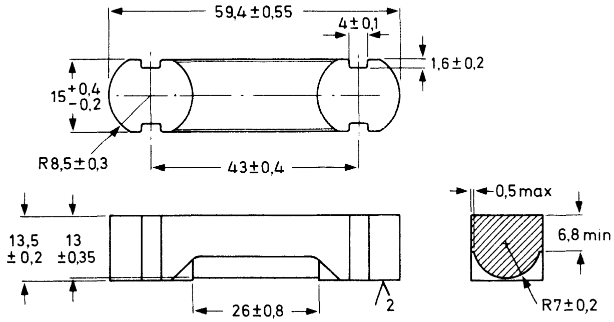
l_e = 163 mm

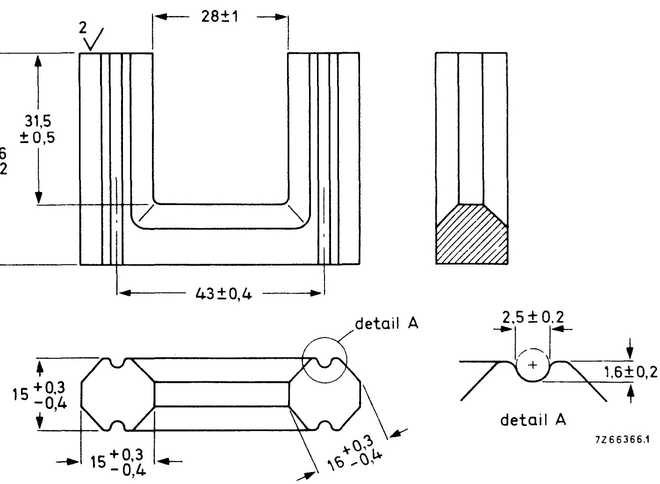
A_e = 171 mm²

V_e = 27500 mm³

* The difference in splay between two U-cores, taken at random from one packing, will never exceed 0,8 mm.

UI-CORES





Mass U-core 98 g
I-core 50 g

MAGNETIC DATA

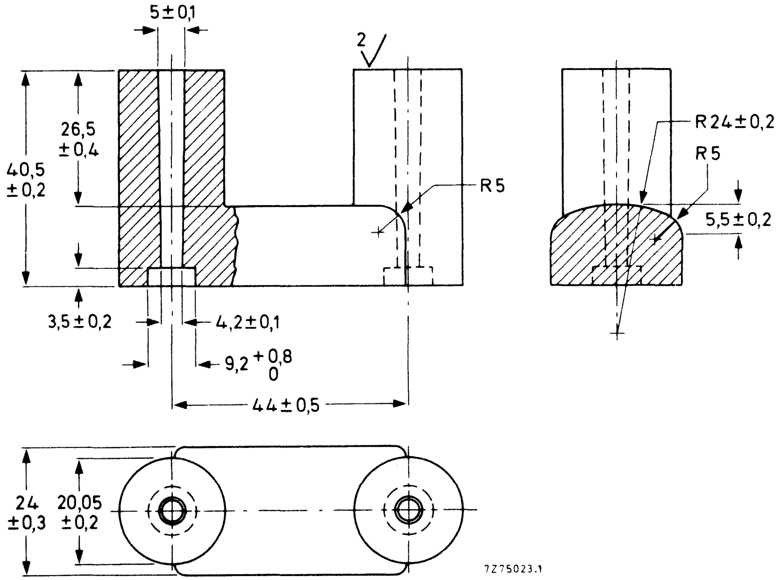
Guaranteed values, measured at 16 kHz, for a core-pair UI-58/58/16.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C8	25	200	–	⩽ 3,5	U	3122 104 94760
	100	200	–	⩽ 3,2	I	3122 104 94770
	100	⩾ 330	250	–		

Magnetic dimensions

l_e = 164 mm; A_e = 175 mm^2; V_e = 28 800 mm^3.

U-CORE



Mass 155 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-64/79/20

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength H (A/m)	losses W	catalogue number of one U-core
3C8	25 100 100	200 200 ⩾ 330	– – 250	⩽ 8,5 ⩽ 7,0 –	3122 134 91390

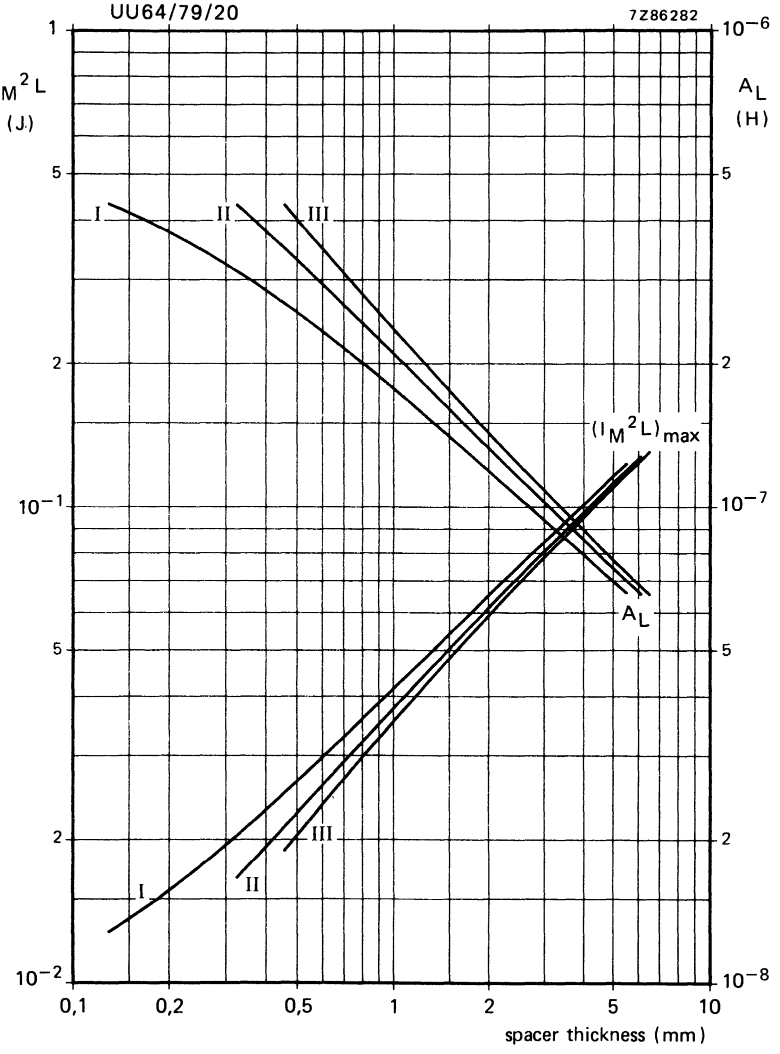
Magnetic dimensions

l_e = 210 mm

A_e = 290 mm²

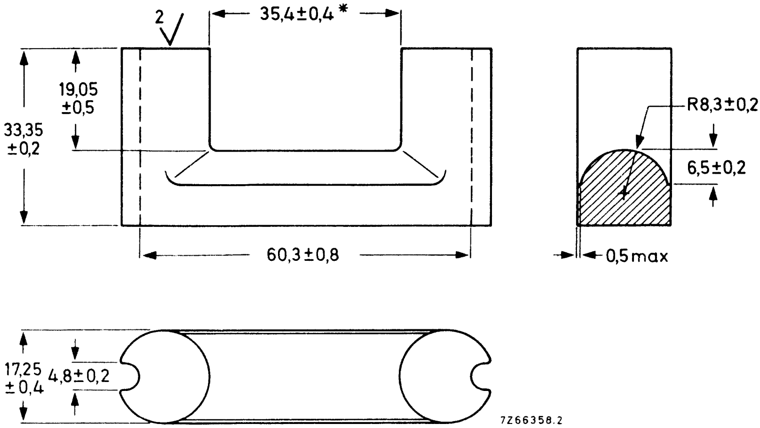
V_e = 61000 mm³

CHARACTERISTIC CURVES



Choke design chart.
For application classes I, II and III see 'Power choke design' in the Introduction.

U-CORE



Mass 108 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-70/67/17.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	≤ 5,3	3122 104 93950
	100	200	–	≤ 5,0	
	100	≥ 330	250	–	

Magnetic dimensions

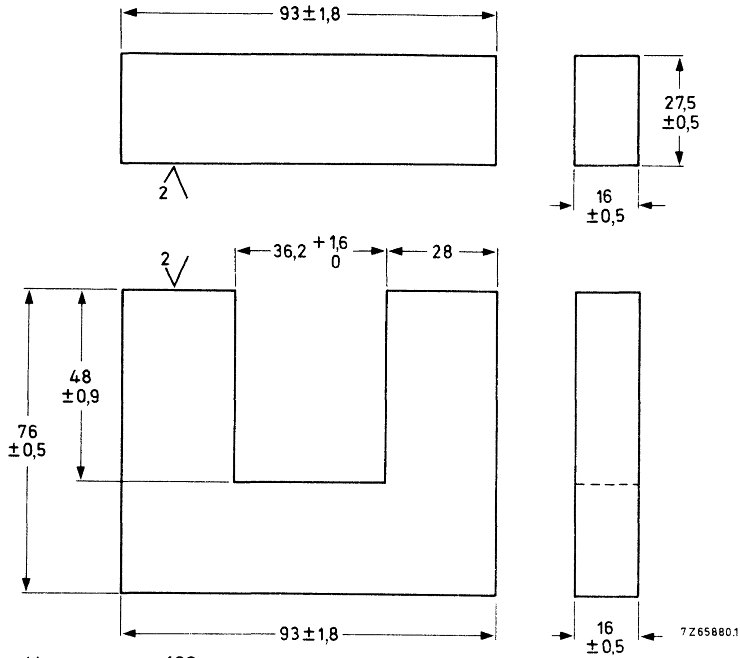
l_e = 197 mm

A_e = 214 mm²

V_e = 43800 mm³

* The difference in splay between two U-cores taken at random from one packing will never exceed 1 mm.

UI-CORES



Mass	U-core	403 g
	I-core	194 g

MAGNETIC DATA

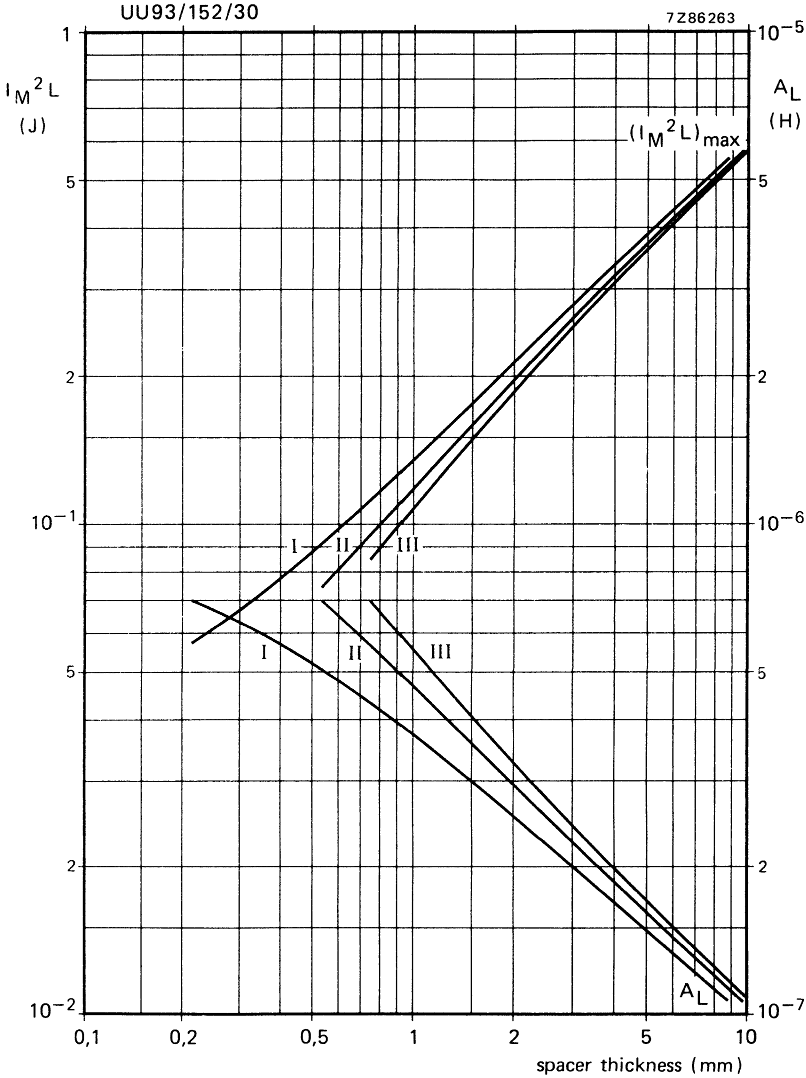
Guaranteed values, measured at 16 kHz, for core-pairs UI-93/104/16 and UU-93/152/16.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C8	25 100 100	200 200 ⩾ 330	– – 250	⩽ 12,8 ⩽ 11,8 –	UI	4312 020 33550 4312 020 33560
3C8	25 100 100	200 200 ⩾ 290	– – 250	⩽ 17,6 ⩽ 16,2 –	UU	4312 020 33550

Magnetic dimensions

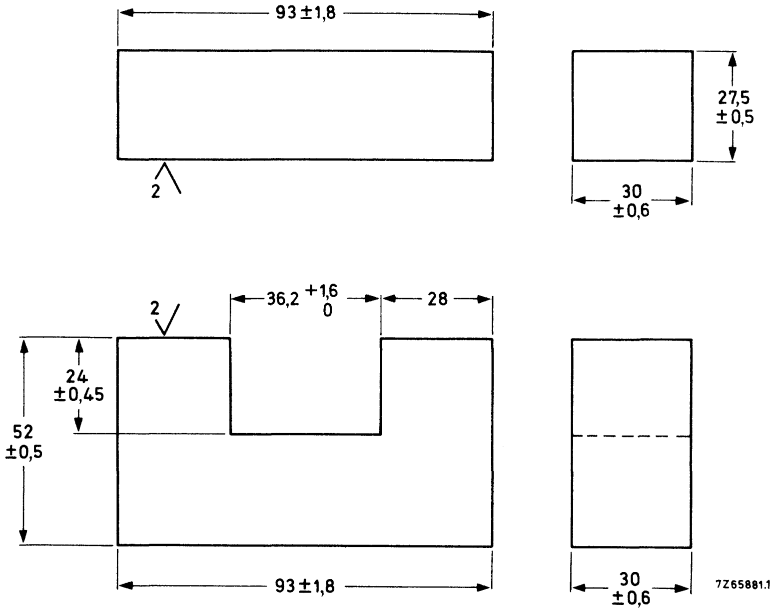
	UI-93/104/16	UU-93/152/16	
l_e	254	350	mm
A_e	420	450	mm^2
V_e	107 000	147 000	mm^3

CHARACTERISTIC CURVES



Choke design chart.
For application classes I, II and III see 'Power choke design' in the Introduction.

UI-CORES



Mass	U-core	562 g
	I-core	365 g

MAGNETIC DATA

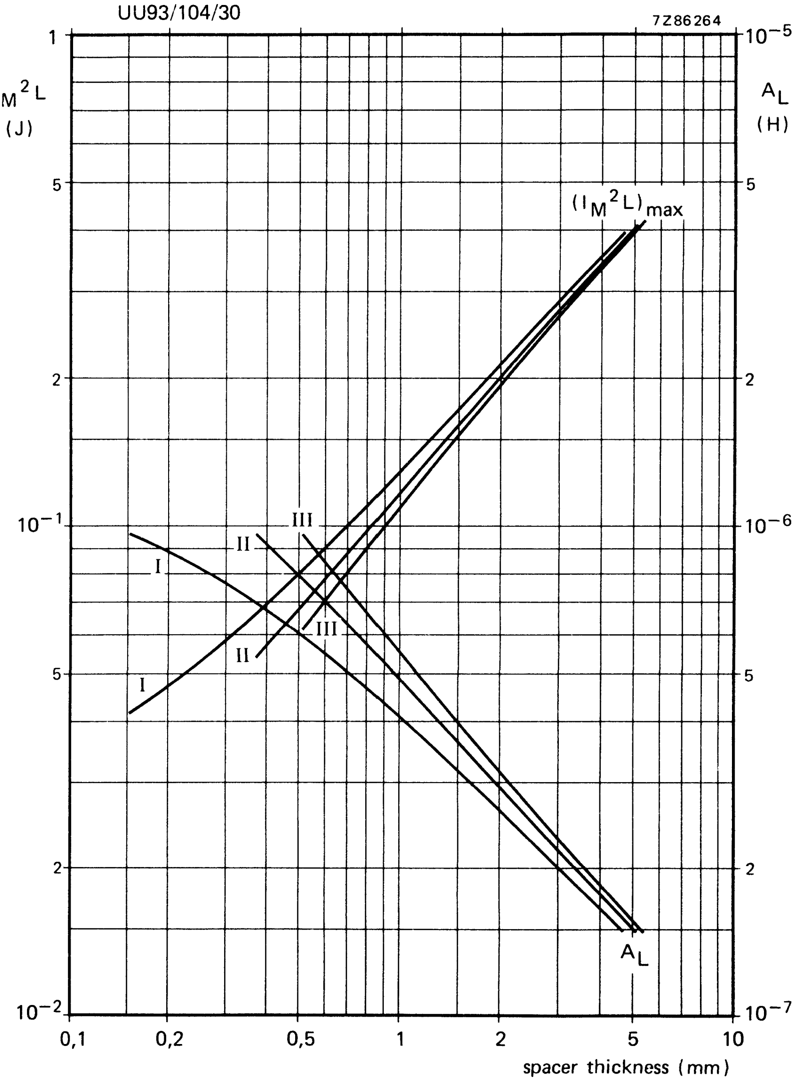
Guaranteed values, measured at 16 kHz, for core-pairs UI-93/80/30 and UU-93/104/30.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C8	25 100 100	200 200 ≥ 330	– – 250	≤ 19,0 ≤ 17,4 –	UI	4312 020 33580 4312 020 33590
3C8	25 100 100	200 200 ≥ 290	– – 250	≤ 24,0 ≤ 22,0 –	UU	4312 020 33580

Magnetic dimensions

	UI-93/80/30	UU-93/104/30	
l_e	204	254	mm
A_e	780	780	mm²
V_e	158 000	200 000	mm³

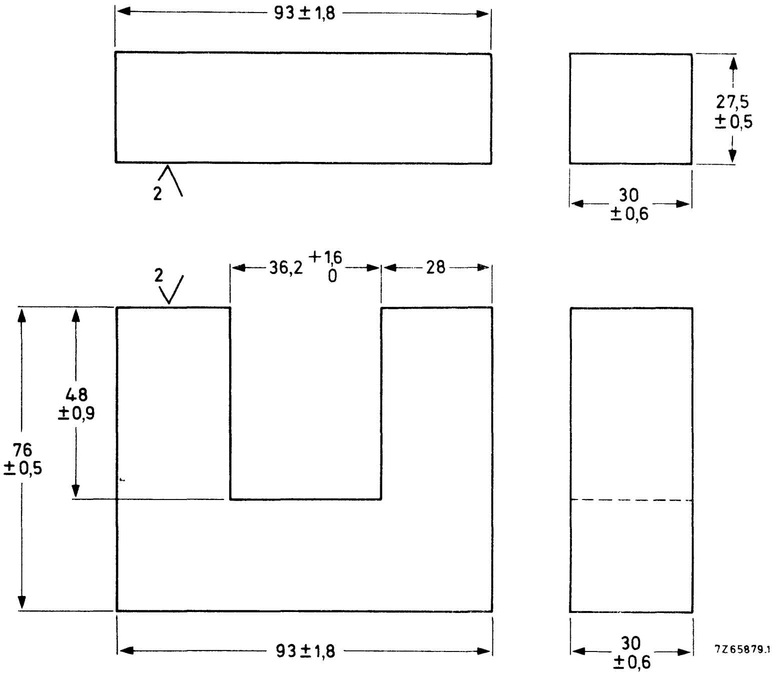
CHARACTERISTIC CURVES



Choke design chart.

For application classes I, II and III see 'Power choke design' in the Introduction.

UI-CORES



Mass	U-core	756 g
	I-core	365 g

MAGNETIC DATA

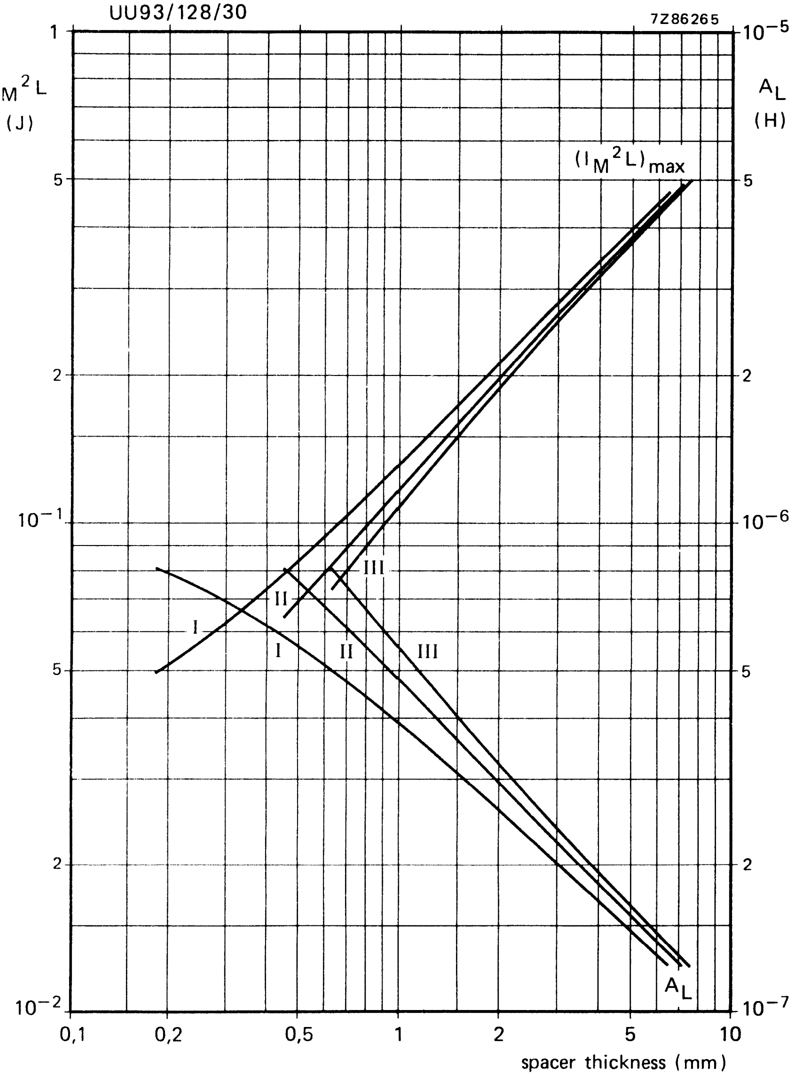
Guaranteed values, measured at 16 kHz, for core-pairs UI-93/104/30 and UU-93/152/30.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C8	25 100 100	200 200 ≥ 330	– – 250	≤ 24,0 ≤ 22,0 –	UI	4312 020 33570 4312 020 33590
3C8	25 100 100	200 200 ≥ 290	– – 250	≤ 32,8 ≤ 30,0 –	UU	4312 020 33570

Magnetic dimensions

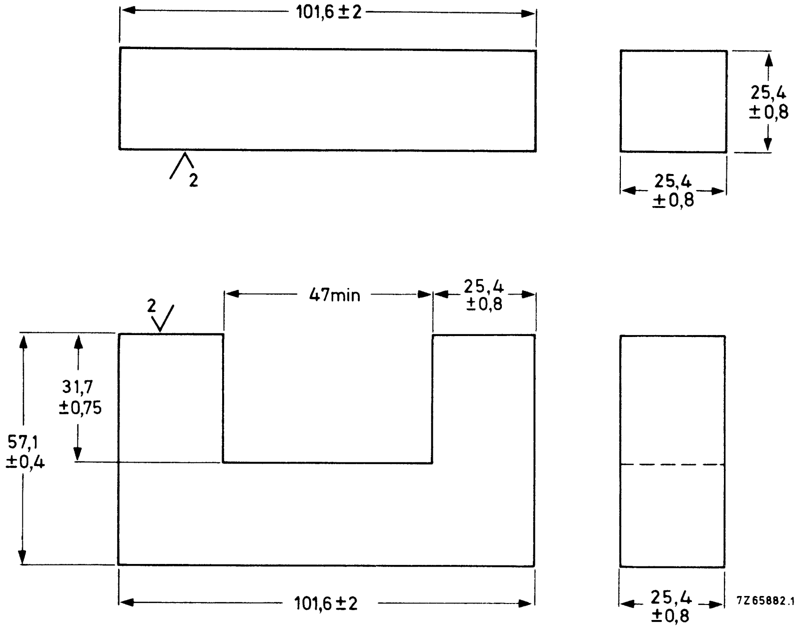
	UI-93/104/30	UU-93/152/30	
l_e	254	350	mm
A_e	780	780	mm^2
V_e	200 000	273 000	mm^3

CHARACTERISTIC CURVES



Choke design chart.
For application classes I, II and III see 'Power choke design' in the Introduction.

UI-CORES



Mass U-core 506 g
I-core 310 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for core-pairs UI-100/82/25 and UU-100/114/25.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C8	25 100 100	200 200 ≥ 330	– – 250	≤ 17,9 ≤ 16,4 –	UI	4312 020 33600 4312 020 33610
3C8	25 100 100	200 200 ≥ 290	– – 250	≤ 24,5 ≤ 20,5 –	UU	4312 020 33600

Magnetic dimensions

	UI-100/82/25	UU-100/114/25	
l_e	240	300	mm
A_e	620	620	mm^2
V_e	149 000	186 000	mm^3

MATERIALS AND CORES FOR MAGNETIC RECORDING

MATERIALS AND CORES FOR MAGNETIC RECORDING

These grades of Ferroxcube were developed primarily for the production of magnetic recording heads in audio, video and industrial and professional applications. Their high density give these materials excellent performance in these applications. The main features are the high resistance to wear and good magnetic performance resulting from the well-controlled micro-structure. This structure enables machining, lapping and high-gloss polishing. Glass or epoxy bonding may be used. The materials are available void-free in the form of bars, tiles, core configurations and cores with glass-bonded gaps. Our experience in the processing and machining of ferrite allows ferrite materials to be ground to virtually any shape with very tight tolerances.

MATERIAL DATA

FXC 8C1

This NiZn material is used for the manufacturing of recording heads for industrial and professional applications, including data processing, professional audio recorders and instrumentation recorders.

Material properties

Unless otherwise stated, all properties of the material have been measured at an atmospheric pressure of 86 to 106 kPa and at a relative humidity of 45 to 75%. Measured on a machined toroid, dimensions approx. ϕ 23 x ϕ 14 x 6 mm.

	freq. kHz	B mT	temp. °C	typical values	
initial permeability	4	< 0,1	25 ± 5	1600	
Curie point	4	< 0,1		150	°C
resistivity	d.c.		25 ± 5	1 x 10^4	Ωm
density			25 ± 5	5330	kg/m^3
hardness (Vickers) *			25 ± 5	750	Hv 0,05/30
coefficient of linear expansion, α_m				see Fig. 4	

FXC 8C1 is available in the form of bars:

140 ± 2 mm x 45 ± 2 mm x 35 + 2 mm, catalogue number 4322 020 43020 or custom-made shapes on request.

* Measured with 0,05 kg for 30 s.

8C1

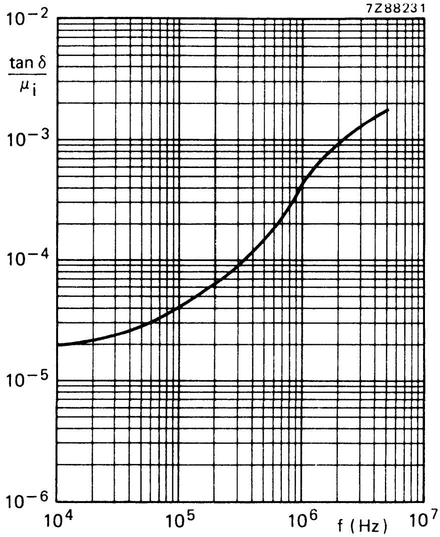


Fig. 1.

8C1

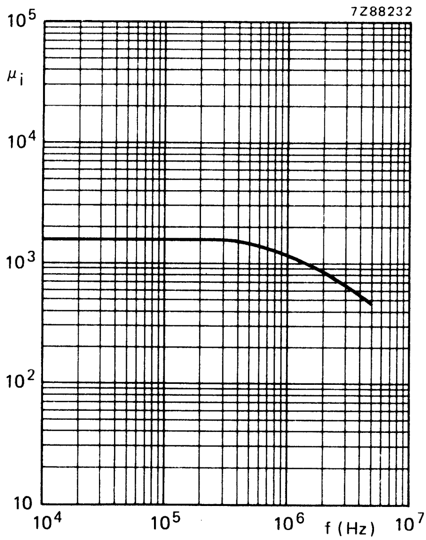


Fig. 2.

8C1

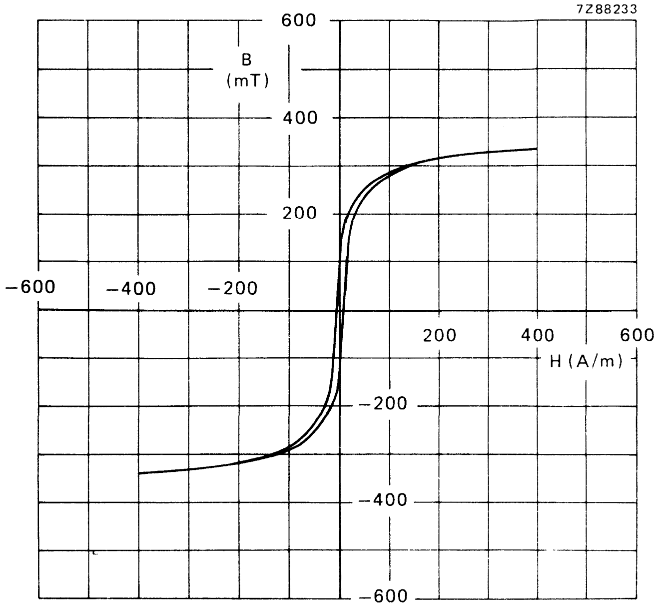


Fig. 3.

8C1

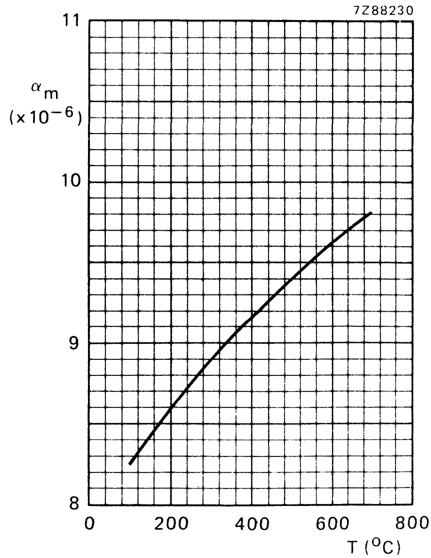


Fig. 4 Coefficient of linear expansion as a function of the temperature.

NON-MAGNETIC STRUCTURAL MATERIAL 8A5

8A5 is ideal for use in combination with FXC 8C1 as the non-magnetic component of glass-bonded structures. The matched coefficient of thermal expansion and the excellent resistance to wear give a stable and tight-toleranced tape-contact surface to the recorder head.

Material properties

Unless otherwise stated, all properties of the material have been measured at an atmospheric pressure of 86 to 106 kPa and at a relative humidity of 45 to 75%. The density has been measured on a plate, dimensions approx. 22 x 35 x 4 mm; the coefficient of expansion on a rod of approximately 2 x 2 x 10 mm.

density	typ.	4700	kg/m^3
coefficient of linear expansion α_m		see Fig. 5	
hardness (Vickers)*		1300	Hv 0,05/30

8A5 is available in the form of bars:

145 ± 5 x 35 ± 3 x 22 ± 2 mm, catalogue number 4322 020 97630
210 ± 6 x 37 ± 3 x 34 ± 3 mm, catalogue number 4322 020 97640 or custom-made shapes on request.

8A5

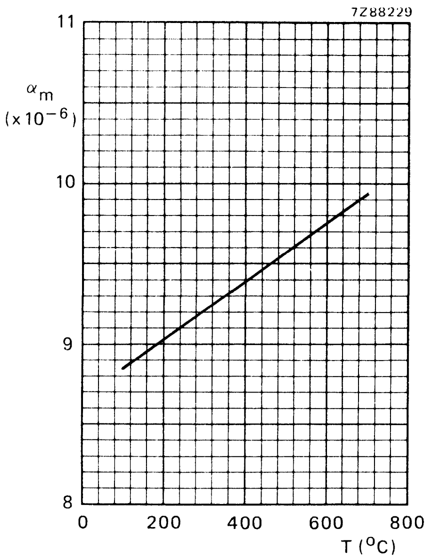


Fig. 5 Coefficient of linear expansion as a function of the temperature.

* Measured with 0,05 kg for 30 s.

FXC 8E1, 8E2 and 8E21

These manganese-zinc materials are intended for the production of erasing heads for audio and video applications. Effective erasing of magnetic tape for a low-noise level requires a high level of induction at a frequency in the range 50 to 100 kHz. Thus, for the use in erasing heads, a low eddy-current-loss core material is recommended. Low eddy current losses imply low heat dissipation and consequently less erasing power. Material FXC 8E1 is intended for erasing heads for iron-oxide or chromium dioxide tapes. Materials FXC 8E2 and 8E21 are for erasing heads for metal tapes.

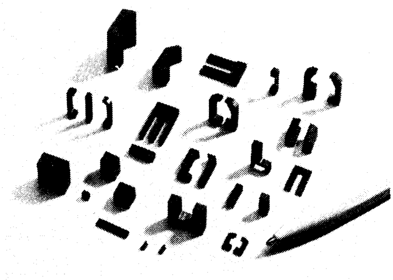
Material properties

Unless otherwise stated, all properties of the material have been measured at an atmospheric pressure of 86 to 106 kPa and at a relative humidity of 45 to 75%.

	freq. kHz	B mT	H A/m	temp. °C	grade 8E1 (typical values)	8E2	8E21	
μ_i	4	$<0,1$		25 ± 5	3200	2800	3600	
B_s	ballistic		250	25 ± 5	400	490	490	mT
$\frac{\tan \delta}{\mu_i}$	100	$<0,1$		25 ± 5	$3 \cdot 10^{-6}$	$3 \cdot 10^{-6}$	$2,5 \cdot 10^{-6}$	
η_B	100	1,5 to 3		25 ± 5	$0,5 \cdot 10^{-3}$	$0,5 \cdot 10^{-3}$	$0,5 \cdot 10^{-3}$	T^{-1}
power losses	45	100	25	25 ± 5	$40 \cdot 10^3$	$40 \cdot 10^3$	$20 \cdot 10^3$	W/m^3
				85 ± 5	$60 \cdot 10^3$	$60 \cdot 10^3$	$50 \cdot 10^3$	W/m^3
Curie temp.	4	$<0,1$			180	180	210	°C
resistivity	d.c.			25 ± 5	5*	5*	3*	Ωm
density				25 ± 5	4700	4700	4750	kg/m^3
hardness (Vickers)**					560	730	730	Hv 0,05/30
linear expansion coefficient α_m					Fig. 9	Fig. 13	Fig. 17	

Unless otherwise stated, measured on a machined toroid, dimensions approximately ϕ 23 x ϕ 14,5 x 6 mm.
Note: The properties of the products made from this material are dependent on dimensions and technology of the product. Deviations may occur.

The materials are available in the form of bars:
100 x 35 x 7,8 mm 8E2 catalogue number 4322 020 97500
100 x 28 x 12,5 mm 8E1 catalogue number 4322 020 37400
100 x 35 x 12,5 mm 8E1 catalogue number 4322 020 37480
100 x 35 x 14 mm 8E1 catalogue number 4322 020 37470
100 x 49 x 14 mm 8E1 catalogue number 4322 020 37460
215 x 39 x 37 mm 8E21 catalogue number 4322 020 97610
and in custom made shapes on request, see photograph.



780118-21-02

* Measured on a machined bar, dimensions approximately 3 x 2 x 15 mm.
** Measured with 0,05 kg for 30 s.

8E1

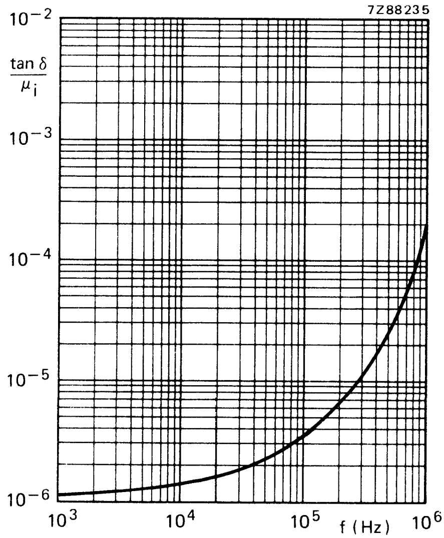


Fig. 6.

8E1

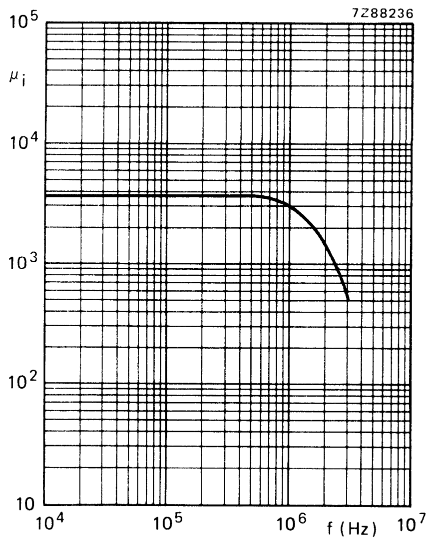


Fig. 7.

8E1

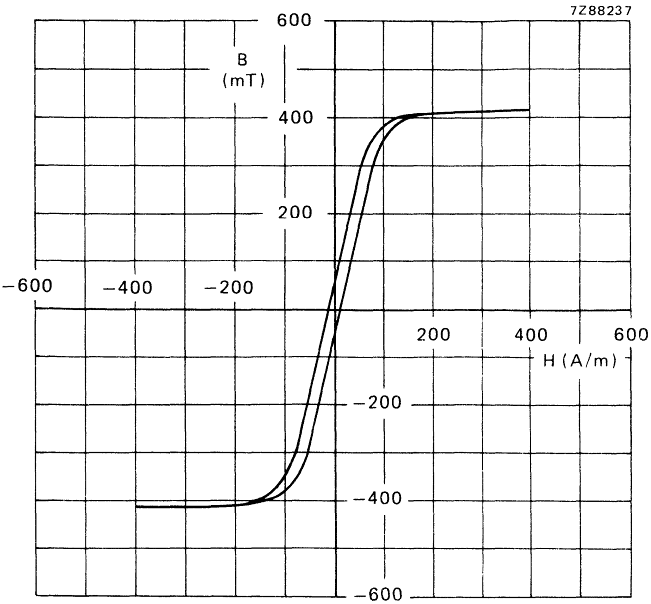


Fig. 8.

8E1

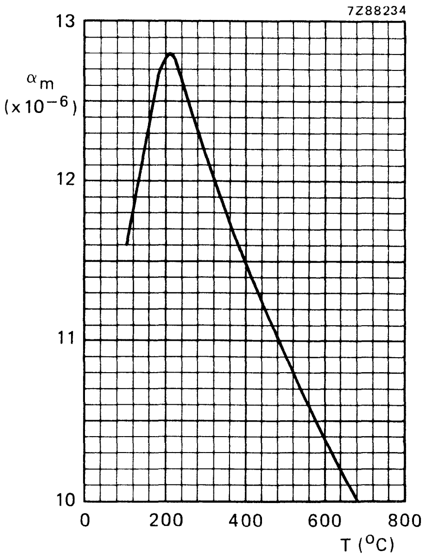


Fig. 9 Coefficient of linear expansion as a function of the temperature.

8E2

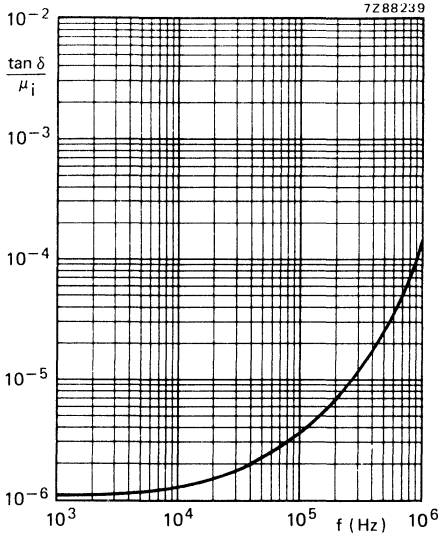


Fig. 10.

8E2

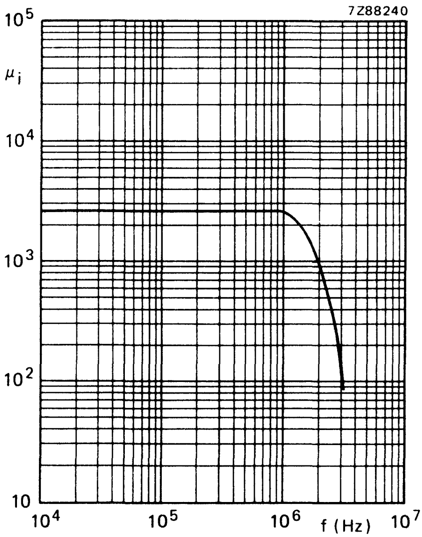


Fig. 11.

8E2

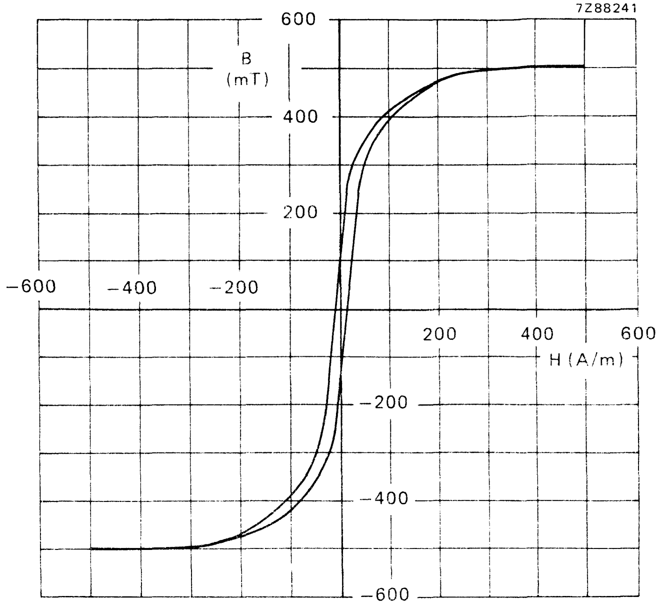


Fig. 12.

8E2

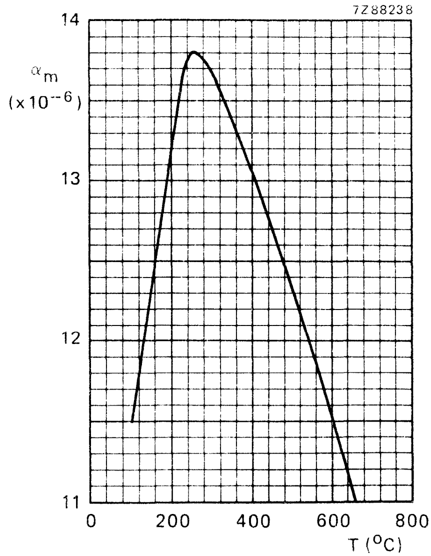


Fig. 13 Coefficient of linear expansion as a function of the temperature.

8E21

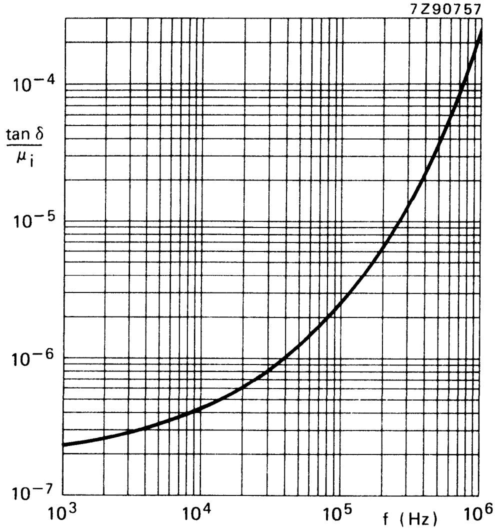


Fig. 14.

8E21

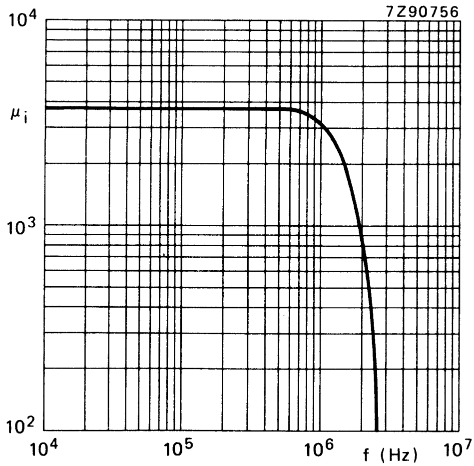


Fig. 15.

8E21

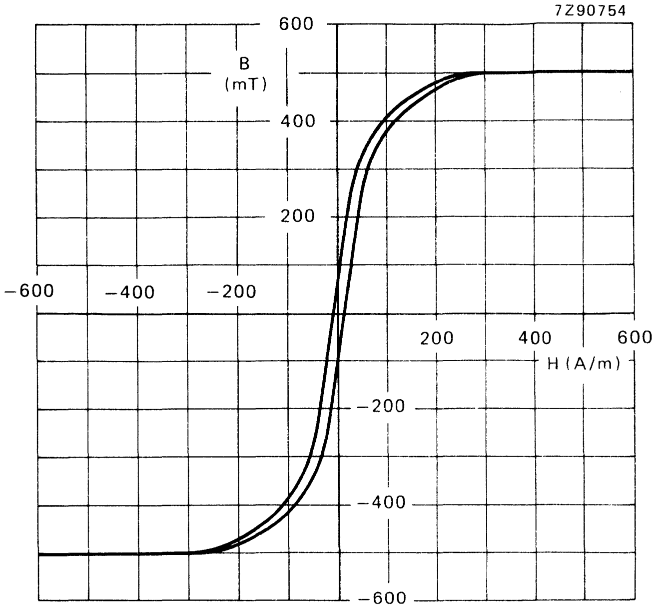


Fig. 16.

8E21

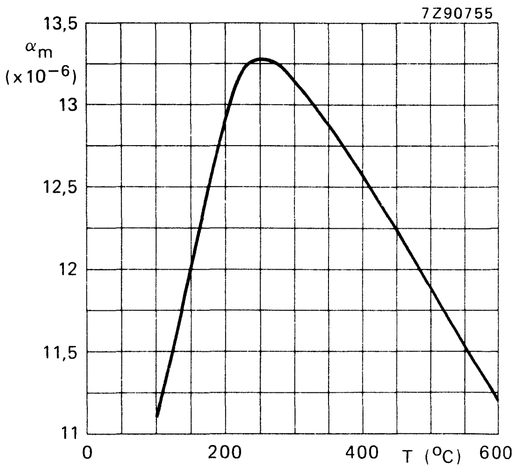


Fig. 17 Coefficient of linear expansion as a function of temperature.

FXC 8X1

This MnZn single-crystal ferrite is the basic material for the manufacture of video cassette recorder heads. The unique magnetic properties, homogeneity, outstanding wear resistance and the ability to machine this material to extremely tight tolerances, makes FXC 8X1 ideal for video use where a specified signal level with high information density on a very small track width is required.

Material properties

	freq. kHz	B mT	H A/m	typical value	
μ_i	500	$\leqslant 1$		1800	
	5000	$\leqslant 1$		600	
$\frac{\tan \delta}{\mu_i}$	5000	$\leqslant 1$		2	
B_{sat}	ballistic		800	490	mT
B_r	ballistic			140	mT
H_c	ballistic		800	3	A/m
resistivity	d.c.			$3 \cdot 10^{-3}$	Ωm
linear expansion coefficient α_m				see Fig. 21	
Curie point	< 10			180	°C
hardness (Vickers) *				730	Hv 0,05/30

The material is available in orientated tiles; one side polished to a flatness of 0,15 μm:

16 x 8 x 1,52 mm, catalogue number 4322 020 91560.

Other dimensions and orientations can be supplied on request.

* Measured with 0,05 kg for 30 s.

8X1

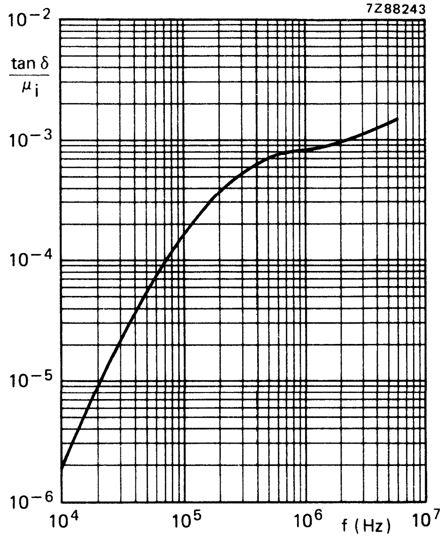


Fig. 18.

8X1

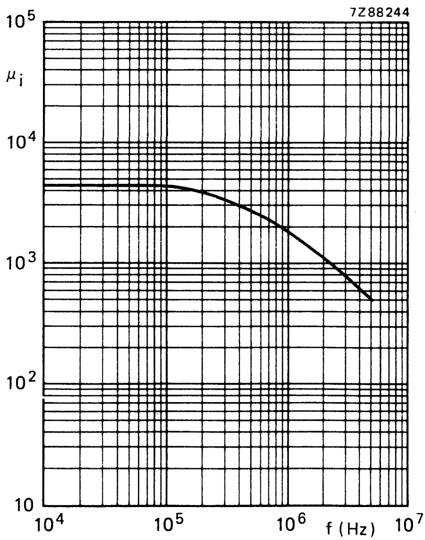


Fig. 19.

8X1

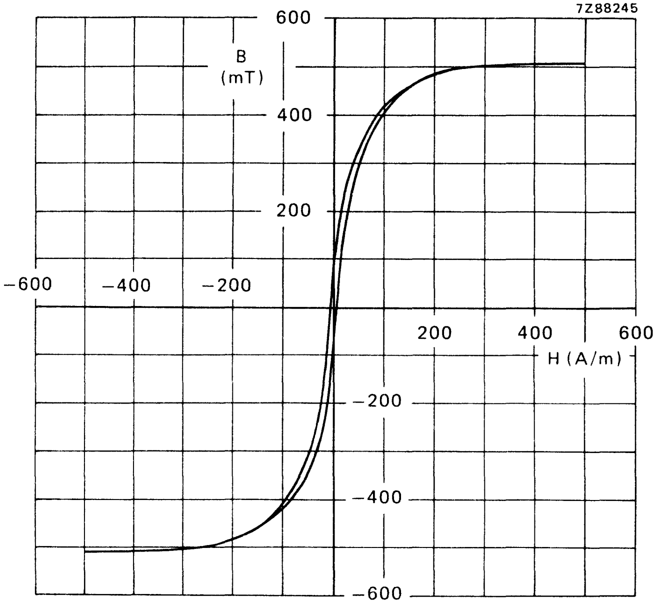


Fig. 20.

8X1

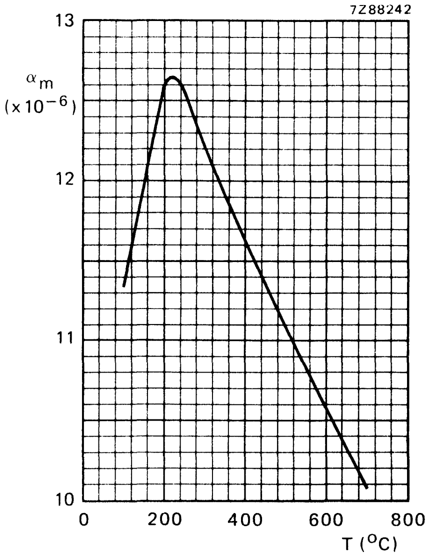


Fig. 21 Coefficient of linear expansion as a function of the temperature.

SMALL CORES AND CHOKES

TOROIDS

Toroids, having no air gap, generate only a small magnetic stray field and thus have a high permeability. In spite of the closed magnetic circuit the losses are low due to the favourable properties of Ferroxcube. They are used in small broadband transformers and pulse transformers. Toroids are also effective for interference suppression filters when they function as differential transformers offering no impedance to symmetrical line-current flow, since no flux change takes place in the core due to these currents. However, unsymmetrical current drawn unequally from either the line or the power supply will cause flux changes and the windings will acts as an impedance to this current flow. Toroids are not recommended for tuned circuits.

Toroids are available in various sizes and Ferroxcube grades. They are barrel-finished and can be obtained in nylon insulated or non-coated versions.

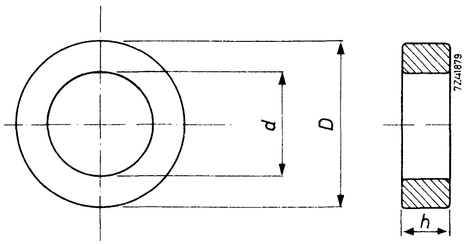


Table 1 Dimensional quantities, tolerances and mass of non-coated toroids.

D mm	d mm	h mm	l_e mm	$\Sigma \frac{l}{A}$ mm^{-1}	V_e mm^3	mass g
4 ± 0,1	2,2 ± 0,1	1,1 ± 0,1	9,46	9,56	9,37	0,045
6 ± 0,15	4 ± 0,15	2 ± 0,1	15,5	7,75	31,0	0,15
9 ± 0,2	6 ± 0,2	3 ± 0,1	23,3	5,17	105	0,50
14 ± 0,3	9 ± 0,25	5 ± 0,15	35,5	2,85	445	2,14
19 ± 0,4	10,6 ± 0,3	15 ± 0,3	44,0	0,718	2690	14
23 ± 0,5	14 ± 0,35	7 ± 0,2	57,0	1,81	1790	8,6
26 ± 0,55	14,5 ± 0,45	10 ± 0,3	60,3	1,08	3360	17
26 ± 0,55	14,5 ± 0,45	20 ± 0,45	60	0,538	6660	35
29 ± 0,5	19 ± 0,4	7,5 ± 0,2	75,0	2,01	2580	13
36 ± 0,7	23 ± 0,5	10 ± 0,2	92,0	1,42	5600	29
36 ± 0,7	23 ± 0,5	15 ± 0,3	92,0	0,942	8500	44

Notes

1. All μ-values in the following pages are determined with the $\Sigma \frac{l}{A}$ values of Table 1 at 25 °C.

   The relevant A_L values can be calculated from: $A_L = \frac{0,4\,\pi\,\mu}{\Sigma \frac{l}{A}}$. ($A_L$ in nH, $\Sigma \frac{l}{A}$ in mm^{-1}).
2. L can be calculated from the formula: $L = A_L \cdot N^2$ (L in nH).
3. The smaller a toroid, the more its properties deviate from the material properties. Therefore a straightforward translation of the material figures is not always possible.

Table 2. Dimensions and tolerances of coated toroids

D mm	d mm	h mm	derived from non-coated toroids with dimensions
4,3 ± 0,2	1,9± 0,2	1,4 ± 0,2	4 x 2,2 x 1,1
6,3 ± 0,25	3,7± 0,25	2,3 ± 0,2	6 x 4 x 2
9,4 ± 0,3	5,6 ± 0,3	3,4 ± 0,2	9 x 6 x 3
14,5 ± 0,4	8,5 ± 0,35	5,5 ± 0,25	14 x 9 x 5
23,6 ± 0,7	13,4 ± 0,55	7,6 ± 0,4	23 x 14 x 7
29,6 ± 0,7	18,4 ± 0,6	8,1 ± 0,4	29 x 19 x 7,5
36,6 ± 0,9	22,4 ± 0,7	10,6 ± 0,4	36 x 23 x 10
36,6 ± 0,9	22,4 ± 0,7	15,6 ± 0,4	36 x 23 x 10

Table 3. Grades, sizes and catalogue numbers.

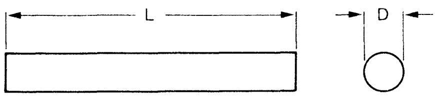
grade	μ_{tor}	colour coating	dimensions * mm	nylon coated	non-coated
				catalogue number 4322 020	
3E1	2700 ± 20% at 25 °C	green	29 x 19 x 7,5	97000	31310
			36 x 23 x 10	97010	31320
			36 x 23 x 15	97020	31330
3E2	> 5000 at +25 to +70 °C	blue	4 x 2,2 x 1,1	97030	31420
			6 x 4 x 2	97040	31430
			9 x 6 x 3	97050	31440
			14 x 9 x 5	97060	31450
			23 x 14 x 7	97070	31460
3H2	2300 to 3100 at +25 °C	grey	4 x 2,2 x 1,1	97110	31350
			6 x 4 x 2	97120	31370
	$D_F \leqslant 5 \times 10^{-6}$ at 23 ± 1 °C		9 x 6 x 3	97130	31380
			14 x 9 x 5	97140	31390
			23 x 14 x 7	97150	31400
4C6	> 100 at + 5 to + 55 °C	violet	6 x 4 x 2	97160	90750
			9 x 6 x 3	97170	90760
			14 x 9 x 5	97180	90770
			23 x 14 x 7	97190	90860
			36 x 23 x 15	97200	90870
				catalogue number 4312 020	
3C11	4000 ± 25%		19 x 10,6 x 15		36300
			26 x 14,5 x 10		36280
			26 x 14,5 x 20		36250
			36 x 23 x 15		36310

* These dimensions refer to non-coated toroids. More exact details are given in Tables 1 and 2.

RODS AND TUBES

Ferroxcube rods and tubes can be used in r.f. and h.f. coils with an open magnetic circuit such as in i.f. transformers, fixed or adjustable inductances, and filters. Not only tubes, used as beads, are suitable for interference suppression but also small rods (pins) can effectively be used because of their relatively high insensitivity for premagnetization.

The table below lists standard diameters and matching lengths of rods and tubes. On the next page details are given on length tolerances and curvature limits, followed by a type list of currently available types.



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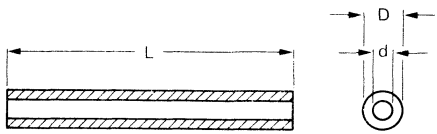

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	RODS				TUBES					
grade	dia. group mm	length group mm	dia. tol. group mm	matching length mm	outer dia. group mm	inner dia. max. mm	inner dia. tol. mm	length group mm	outer dia. tol. group mm	matching length mm
	1,6	5-30	−0,2	5-30						
			−0,05	5-8						
			−0,03	5-8						
	2,0	5-30	−0,2	5-30						
			−0,05	5-10						
			−0,03	5-10						
3B	2,5	5-30	−0,25	5-30	2,5	1,0	+0,15	3-30	−0,3	3-30
3C6			−0,1	5-20					−0,1	3-20
3D3			−0,05	5-10					−0,05	3-10
3E1	3,1	5-30	−0,25	5-30	3,1	1,5	+0,15	3-30	−0,3	3-30
3H2			−0,1	5-25					−0,1	3-25
			−0,05	5-15					−0,05	3-25
4A4	4,0	8-30	−0,3	8-30	4,0	2,0	+0,2	4-40	−0,3	4-40
4B1			−0,1	8-30					−0,1	4-30
4C6			−0,05	8-20					−0,05	4-30
4D1	5,0	10-50	−0,3	10-50	5,0	3,0	+0,2	5-50	−0,3	5-50
4D2			−0,1	10-40					−0,1	5-50
4E1			−0,05	10-30					−0,05	5-30
	6,3	10-60	−0,3	10-60	6,3	4,0	+0,3	10-60	−0,3	10-60
			−0,1	10-45					−0,1	10-50
	10,0	10,100	−0,5	10-100	10,0	6,0	+0,3	10,60	−0,4	20-60

Tolerances on length (in mm) of standard-size rods and tubes.

length	tolerance class	
	coarse	fine
< 6	0 −0,4	0 −0,2
6-8	0 −0,5	0 −0,3
8-10	0 −0,6	0 −0,6
10-13	0 −0,7	0 −0,4
13-16	0 −0,8	0 −0,4
16-20	0 −0,9	0 −0,4
> 20	0 −0,4%	0 −0,4

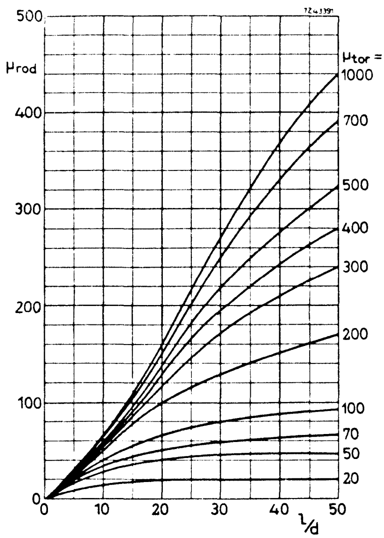
Curvature

The curvature of rods and tubes is the maximum deviation from the straight line through the end face centres. This curvature may be checked by means of a tubular gauge with dimensions as given below:

gauge inner diameter $d = d_1 + \frac{\ell_1}{100}$

gauge length $\ell = \geqslant \ell_1$

where d_1 = maximum outer dia. of the rod or tube
ℓ_1 = maximum length of the rod or tube



Rod permeability as a function of the ratio l/d with the relative initial permeability of a toroidal core as parameter.

Type list of rods

D		L		FXC grade		catalogue number
max.	tol.	max.	tol.	3	4	
1,40	−0,02	6,85	−0,20	3D3		3122 104 91920
1,60	−0,10	3,95	−0,20		4D2	3122 134 91190
1,65	−0,05	9,2	−0,4	3D3		4312 020 30160
1,65	−0,05	9,2	−0,4		4B1	3122 104 91060
1,65	−0,05	12,2	−0,4	3B		3122 104 91100
1,65	−0,05	12,2	−0,4		4B1	3122 104 91110
1,65	−0,05	25,2	−0,4	3B		3122 104 91170
1,65	−0,05	28,2	−0,4		4B1	4322 020 32090
1,70	−0,15	8,4	−0,4		4D1	3122 104 93160
1,70	−0,15	14,2	−0,4		4E1	4322 020 32060
1,70	−0,15	17,8	−1,0	3B		3122 104 92020
1,75	−0,20	12,2	−0,4		4B1	3122 104 92070
1,75	−0,20	14,2	−0,4		4B1	4312 020 30560
1,75	−0,20	18,5	−1		4B1	3122 104 91150
1,78	−0,03	8,25	−0,30		4D1	4330 030 30300
1,78	−0,03	8,95	−0,45	3D3		4322 020 39480
2,0	−0,2	12,0	−0,7		4C6	4330 030 30320
2,0	−0,2	16,5	−1,0		4B1	4330 030 30360
2,1	−0,2	9,4	−0,8		4D1	4330 030 30140
2,1	−0,2	12,5	−1,0		4B1	4330 030 30130
2,2	−0,2	16,5	−1,0		4B1	4312 020 30460
2,30	−0,05	10,2	−0,4	3D3		4312 020 30030
2,50	−0,25	16,3	−0,8		4B1	4330 030 30450
2,50	−0,25	20	−1		4B1	4312 020 30510
3,0	−0,1	14	−0,5		4B1	4330 030 30060
3,05	−0,1	16,5	−1		4C6	4330 030 30390
3,00	−0,25	20	−0,6		4B1	4330 030 30220
3,15	−0,3	16,5	−1,0		4C6	4330 030 30070
3,15	−0,3	24,35	−0,7		4B1	4312 020 30520
3,2	−0,2	11,5	−1		4B1	4330 020 30560
3,5	−0,3	17	−0,5	3B		4330 030 30400
4,0	−0,3	20	−0,6	3C6		4312 020 30320
4,0	−0,3	25	−1		4B1	4330 030 30250
4,00	−0,05	25	−1	3C6		4312 020 30290
4,1	−0,2	21	−1		4B1	4330 030 30120
4,95	−0,1	50	−0,5	3C6		3122 134 90110
5,0	−0,3	14	−0,8		4B1	4330 030 30110
5,0	−0,3	20,5	−1		4B1	4312 020 30570
5,0	−0,3	25	−1		4B1	4330 030 30080
5,0	−0,2	25,5	−1	3B		4322 020 39450
5,0	−0,3	30	−1,2		4B1	4330 030 30030
5,0	−0,2	41	−2	3B		4322 020 39470
5,3	−0,6	18,3	−0,6		4B1	4312 020 30490

Type list of tubes

D		d		L		FXC grade		catalogue number
max.	tol.	min.	tol.	max.	tol.	3	4	
2,2	−0,4	0,6	+ 0,2	3,25	−0,5		4E1	4330 030 32670
2,7	−0,4	1,2	+ 0,2	3,5	−0,5		4E1	3122 104 91690
2,8	−0,05	1,2	+ 0,2	8,4	−0,4	3B		4322 020 34340
3,10	−0,02	1,3	+ 0,2	18,8	−0,5	3B		3122 134 90770
3,5	−0,05	1,7	+ 0,2	14,2	−0,4	3B		3122 104 92800
3,6	−0,3	1,3	+ 0,2	3,5	−0,5	3B		4312 020 31050
3,7	−0,4	1,2	+ 0,2	3,5	−0,5	3B		4322 020 34400
3,7	−0,4	1,2	+ 0,2	3,5	−0,5		4A1	4322 020 34410
3,7	−0,4	1,2	+ 0,2	3,5	−0,5		4B1	4322 020 34420
3,7	−0,4	1,5	+ 0,2	3,5	−0,5	3B		4322 020 34430
3,7	−0,4	1,0	+ 0,4	5,5	−1,0		4E1	4330 030 32660
3,7	−0,4	1,0	+ 0,4	5,5	−1,0		4D1	4330 030 32630
3,7	−0,4	1,3	+ 0,2	5,5	−0,5	3B		4312 020 31060
3,7	−0,4	1,3	+ 0,2	8,0	−0,5	3B		4312 020 31330
3,7	−0,4	1,5	+ 0,2	8,0	−0,5	3B		4330 030 32650
3,7	−0,4	1,3	+ 0,2	15,2	−0,4	3B		4312 020 31320
4,05	−0,25	1,35	+ 0,3	5,7	−0,4		4B1	4313 020 15460
4,15	−0,05	2,0	+ 0,2	7,2	−0,4		4A1	4322 020 34440
4,15	−0,05	2,0	+ 0,2	12,2	−0,4		4B1	4322 020 34450
4,15	−0,05	2,0	+ 0,2	12,2	−0,4		4D1	4322 020 34470
4,15	−0,05	2,0	+ 0,2	15,2	−0,4		4B1	4322 020 34380
4,15	−0,3	2,0	+ 0,2	36,6	−1,2	3C6		4312 020 31450
4,2	−0,4	1,8	+ 0,4	5,5	−1,0	3B5		4313 020 15170
4,2	−0,1	2,0	+ 0,2	7,2	−0,4	3D3		4313 020 31220
4,2	−0,1	2,0	+ 0,2	11,2	−0,4	3D3		4312 020 31250
4,2	−0,1	2,0	+ 0,2	20,2	−0,4	3B		4312 020 31030
4,3	−0,2	2,0	+ 0,2	7,2	−0,4	3B		3122 104 92900
4,3	−0,2	2,0	+ 0,2	7,2	−0,4		4A1	4311 020 53460
4,3	−0,2	2,0	+ 0,2	7,2	−0,4		4B1	4311 020 50710
4,3	−0,2	2,0	+ 0,2	15,4	−0,8	3B		4322 020 36750
4,3	−0,2	2,0	+ 0,2	25,5	−1,0	3B		4322 020 36780
4,3	−0,2	2,0	+ 0,2	25,5	−1,0		4B1	3122 104 90810
4,3	−0,2	2,0	+ 0,2	30,5	−1,0		4B1	4311 020 54310
4,95	−0,10	1,3	+ 0,2	15,2	−0,4	3C6		3122 104 90370
4,95	−0,10	1,3	+ 0,2	23,2	−0,4	3C6		3122 104 90380
4,95	−0,10	1,3	+ 0,2	26,2	−0,5	3C6		3122 104 94030
4,95	−0,10	2,9	+ 0,2	36,0	−0,5	3C6		3122 104 93760
5,3	−0,2	3,0	−0,2	22,4	−0,8	3B		4322 020 36810
5,4	−0,4	3,3	+ 0,3	21,2	−0,4		4A1	3104 101 80630
8,0	−0,4	4,2	+ 0,6	51,4	−2,8	3B		4322 020 34310
8,5	−0,5	3,5	+ 0,3	15,3	−0,6		4B1	4312 020 31200
9,6	−0,3	7,1	+ 0,1	8,2	−0,4		4B1	3122 134 91490
9,8	−0,6	6,3	+ 0,4	17,5	−0,5	3B		4313 020 15180
10,8	−0,5	6,7	+ 0,4	19,5	−0,4		4A4	3122 134 90780
14,5	−1,0	7,3	+ 1,0	28	−6		4A1	4311 020 51880

MULTI-HOLE TUBES

Multi-hole tubes are used for small h.f. transformers for voltage or impedance matching in television, communications, data transmission, instrumentation and similar applications.

A. With two holes, "twin beads"

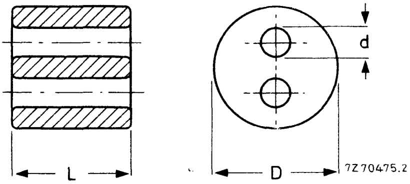


Fig. 1.

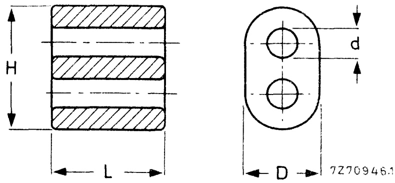


Fig. 2.

Fig.	D mm	d mm	L mm	H mm	grade	catalogue number
1	5,6 ± 0,25	0,95 + 0,15	4,5 – 0,5	–	4D1	3122 134 90800
	5,6 ± 0,15	1,5 ± 0,15	12 ± 0,2	–	4B1	4330 030 32740
	5,9 – 0,6	0,75 + 0,3	12,4 – 0,8	–	4B1	3122 104 90960
	6,6 – 0,6	1,05 + 0,3	5 ± 0,2	–	4B1	3122 104 94840
2	8,5 – 0,5	3,5 + 0,5	8 ± 0,3	14 + 0,5	4B1	4312 020 31570
	8,5 – 0,5	3,5 + 0,5	14 ± 0,4	14 + 0,5	4B1	4312 020 31520

With twin beads advantages can be taken of mutual inductance to increase inductance L and loss resistance R caused by ΔL and ΔR respectively. This is shown in Fig. 3 for a twin bead 4312 020 31520 on two straight wires. Grade 4B1 provides ample insulation between bare wires.

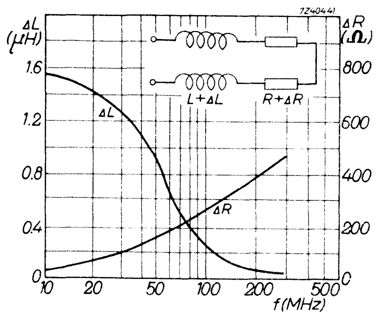


Fig. 3.

B. With six holes

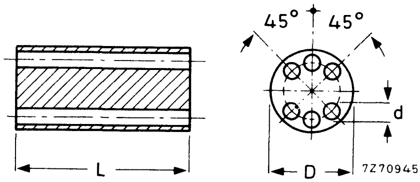


Fig. 4.

D mm	d mm	L mm	grade	catalogue number
6 ± 0,3	0,7 + 0,2	10 ± 0,5	3B	4312 020 31500
6 ± 0,3	0,7 + 0,2	10 ± 0,5	4B1	4312 020 31550

BEADS

for interference suppression

Three grades of Ferroxcube have been developed primarily for interference suppression in such applications as power supplies, radio and television receivers, and automotive and domestic equipment. These grades are FXC3S1, FXC3S2 and FXC4S3. The table on the next page lists the ferrite beads available in these three material grades, together with their dimensions and guaranteed minimum impedances. Impedances are measured with the beads threaded on a straight copper wire.

Choice of material grade

In practice, choosing the correct material grade for a given application is very simple. First, determine the frequency range of the interfering signals that are to be suppressed, then, from the graph of Fig. 1, find the most suitable material grade and, finally, using the table of impedances, determine the bead dimensions for the required attenuation.

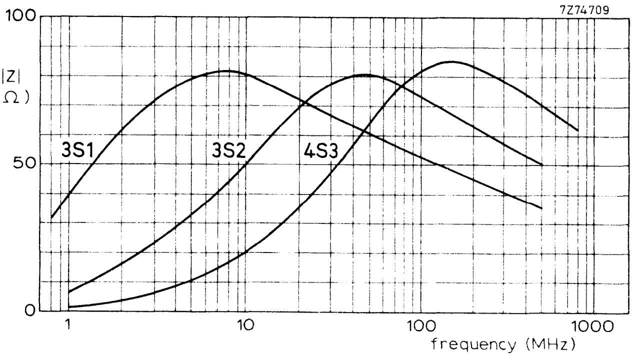


Fig. 1 Impedance of Ferroxcube grades as a function of frequency. The curves are typical for a bead size of 5 x 2 x 10 mm.

The high surface resistivity of FXC4S3 beads makes them suitable for mounting on bare wires. Increasing the surface resistivity of all grades by means of lacquer or any other insulation does not interfere with the magnetic properties of the Ferroxcube material.

The values of initial permeability μ_i and saturation flux density B_s of FXC3S1, FXC3S2 and FXC4S3 have been optimized for the following ranges of application:

- FXC3S1: a very high μ_i combined with a high B_s. Beads of this grade have a high $|Z_S|$ at frequencies from 1 MHz to 50 MHz* (maximum $|Z_S|$ occurs between 6 MHz and 10 MHz), but are easily saturated by d.c. owing to the high μ_i.
- FXC3S2: a medium μ_i and a high B_s. At frequencies greater than about 20 MHz, these beads have a higher $|Z_S|$ than those of grade 3S1. They can be used up to about 200 MHz.* Maximum $|Z_S|$ occurs between 40 MHz and 60 MHz.
- FXC4S3: a low μ_i and a high B_s. At frequencies greater than about 80 MHz, these beads have a higher $|Z_S|$ than those of grade 3S2. They can be used up to about 1 GHz.* Maximum $|Z_S|$ occurs between 100 MHz and 200 MHz.

* See "Notes".

Guaranteed minimum bead impedances $|Z_S|$ (Ω) at various frequencies.

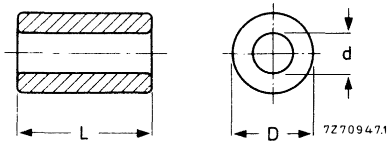


Fig. 2.

	frequency in MHz							dimensions (mm)			
	1	3	10 $\lvert Z_S\rvert(\Omega)$	30	100	300	catalogue number	D	d	L	$L \cdot l_n$ (D/d)
grade 3S1	10	18	24	20	17	15	4330 030 32180	5	2,0	4	3,7
	14	29	30	24	20	18	32120	3	1,0	4	4,4
	10	20	32	26	22	20	32160	5	1,5	4	4,8
	19	38	39	31	26	23	32100	3	0,7	4	5,8
	27	52	53	42	36	32	32140	5	0,7	4	7,9
	29	51	61	49	42	37	32190	5	2,0	10	9,2
	33	72	73	58	50	44	32130	3	1,0	10	11,0
	40	72	80	64	55	48	32170	5	1,5	10	12,0
	58	95	97	77	66	58	32110	3	0,7	10	14,5
	70	125	128	90	70	50	32150	5	0,7	10	19,7
grade 3S2	2	8	16	20	26	17	4330 030 32280	5	2,0	4	3,7
(blue)	2	8	17	22	28	18	32340	8	3,0	4	3,9
	3	9	19	25	32	20	32220	3	1,0	4	4,4
	3	10	21	27	35	22	32260	5	1,5	4	4,8
	4	11	24	31	33	26	32320	8	2,0	4	5,6
	2	8	25	32	42	27	32200	3	0,7	4	5,8
	4	14	29	38	48	31	32300	8	1,5	4	6,7
	5	16	34	44	57	37	32240	5	0,7	4	7,9
	6	19	40	51	66	43	32290	5	2,0	10	9,2
	6	20	42	55	62	45	32350	8	3,0	10	9,8
	7	23	48	61	79	51	32230	3	1,0	10	11,0
	7	25	52	68	87	55	32270	5	1,5	10	12,0
	9	28	60	77	100	64	32330	8	2,0	10	13,9
	9	30	63	81	104	67	32210	3	0,7	10	14,5
	10	34	72	93	90	77	32310	8	1,5	10	16,7
	12	40	75	110	142	91	32250	5	0,7	10	19,7
grade 4S3	1	2	7	17	32	36	4330 030 32440	5	2,0	4	3,7
(red)	1	3	8	18	34	38	32500	8	3,0	4	3,9
	1	3	9	20	38	43	32380	3	1,0	4	4,4
	1	3	9	22	41	47	32420	5	1,5	4	4,8
	1	3	11	26	49	55	32480	8	2,0	4	5,6
	1	3	11	27	50	57	32360	3	0,7	4	5,8
	1	4	13	31	57	65	32460	8	1,5	4	6,7
	2	5	16	36	68	77	32400	5	0,7	4	9,7
	2	6	18	42	80	89	32450	5	2,0	10	9,2
	2	6	19	45	85	95	32510	8	3,0	10	9,8
	2	8	21	50	95	107	32390	3	1,0	10	11,0
	2	7	23	55	104	116	32430	5	1,5	10	12,0
	2	9	27	64	121	134	32490	8	2,0	10	13,9
	2	9	28	67	126	140	32370	3	0,7	10	14,5
	3	10	32	77	145	161	32470	8	1,5	10	16,7
	4	12	38	90	170	190	32410	5	0,7	10	19,7

In many applications, leads through suppressor beads also carry a d.c. or a 50 Hz a.c. current. In such cases the impedance of grades 3S1 and 3S2 will decrease.

Figure 3 shows the effect of d.c. on the impedance of 3S1 and 3S2 beads. This is caused by partial saturation of the beads, which will, of course, be more pronounced with smaller beads, and those of lower B_S and higher μ_i material. Therefore, the effect of *d.c. on grade 4S3 is negligible.* Consequently, where high d.c. (or 50 Hz a.c.) currents flow, grades 4S3 or 3S2 should be used.

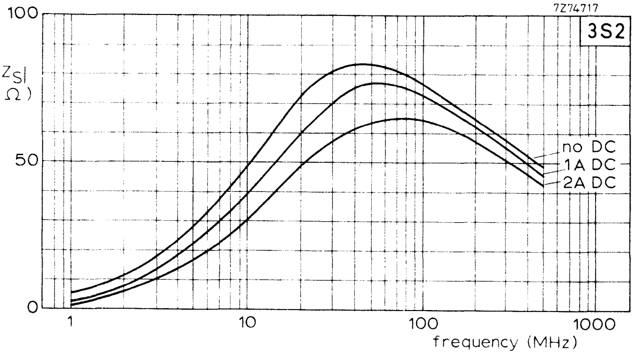


Fig. 3a Impedance $|Z_S|$ of a 5 x 2 x 10 mm bead of grade 3S2 as a function of frequency with the premagnetizing current as a parameter.

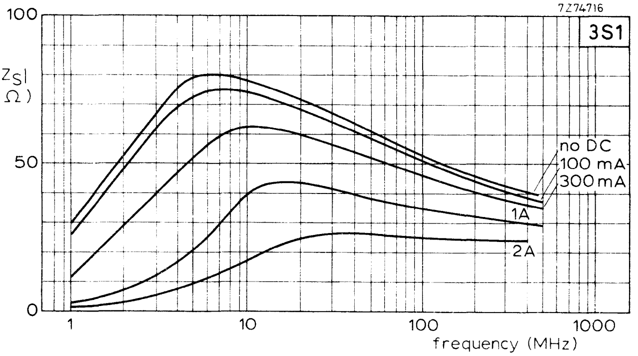


Fig. 3b Impedance $|Z_S|$ of a 5 x 2 x 10 mm bead of grade 3S1 as a function of frequency with the premagnetizing current as a parameter.

Notes

The attenuation of a given type of bead used beyond the frequency limit for its material grade may vary significantly from batch to batch. Although the attenuation will never be less than that given in the table of guaranteed minimum values, it may be much higher. However, the guaranteed minimum attenuation of a bead of the correct material grade for the frequency will always be higher than that of one beyond its frequency limit.

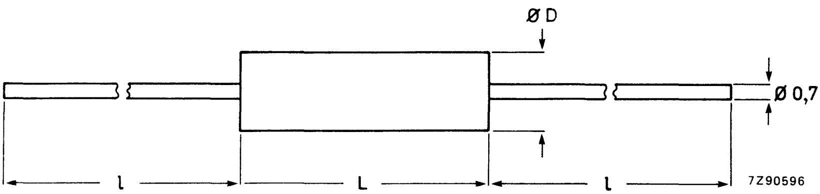
Beads used beyond the frequency limit for their grade should not be too large. This is because the possible deterioration of attenuation may become excessive for greater L.ln (D/d) values. Rather than increase L.ln (D/d) it is usually better to use several well-separated beads with smaller L.ln (D/d) values.

FERRITE COIL FORMERS

for axial coils

These cylindrical ferrites with two axial wires glued into the ferrite are very suitable to be provided with a number of turns to form a required axial coil.

Available types:



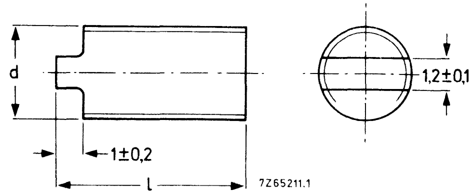
dimensions in mm D	L	l	FXC grade	catalogue number
2,7	8	28	4A4	8230 302 02080
4	14	34	4B1	4330 030 38070
6	20	28	4A4	8230 302 02170

The coil formers are also available with lead diameters of 0,5 mm and 0,6 mm.

SCREW CORES

Ferroxcube screw cores are used in adjustable inductances in r.f. and h.f. coils with an open magnetic circuit.

Stud trimming



nom. diameter x pitch	l mm	d mm	grade	catalogue number
3,5 x 0,7	10 ± 0,2	3,5 ± 0,05	3B	3122 104 90550

WOUND SIX-HOLE BEADS

Wide-band h.f. chokes are used for interference suppression, e.g. in electric motors. Double chokes are used for twin leads, in which case the advantage of mutual inductance can be utilized.

The chokes can be supplied with six axial holes through which 1,5, 2,5 or 2 x 1,5 (double chokes) turns of tinned copper wire are threaded.

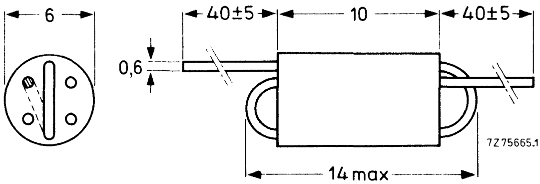


Fig. 1.

number of turns	Z_{max} kΩ	f at Z_{max} MHz	decrease of impedance		grade	catalogue number
			in the freq. range MHz	dB		
1,5	⩾ 0,3	120	10-300	⩽ 7	3B	4312 020 36630
1,5	⩾ 0,35	250	80-300	⩽ 3	4B1	4312 020 36690
2,5	⩾ 0,6	50	10-200, 30-100	⩽ 7, ⩽ 3	3B	4312 020 36640
2,5	⩾ 0,7	180	50-300, 80-220	⩽ 6, ⩽ 3	4B1	4312 020 36700
2 x 1,5	⩾ 0,7*	50	10-220, 30-100	⩽ 7, ⩽ 3	3B	4312 020 36650
2 x 1,5	⩾ 0,8*	110	50-300, 80-220	⩽ 7, ⩽ 3	4B1	4312 020 36710

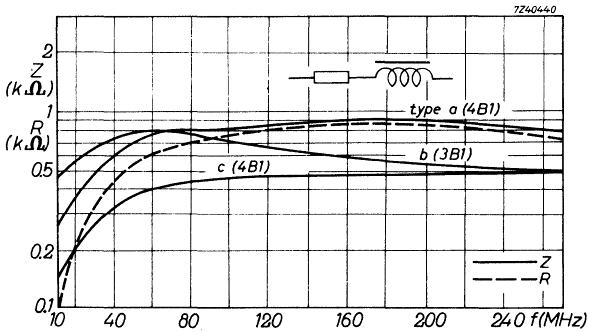


Fig. 2 Performance of three single chokes.

Type a = 4312 020 36700
b = 4312 020 36640
c = 4312 020 36690

Figure 2 shows some performance details of three single chokes. It will be noted that above approx. 80 MHz the impedance is substantially resistive and tends to be constant. Double chokes are used for twin leads, in which case the advantages of mutual inductance can be utilized. Figure 3 compares the typical obtainable performance.

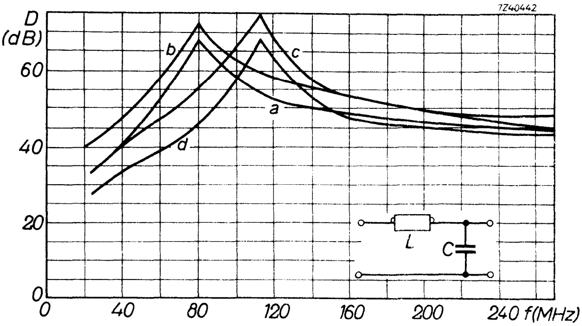


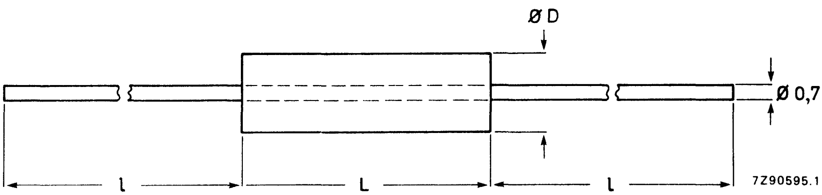
Fig. 3 Damping in an LC circuit consisting of a Ferroxcube choke and a ceramic disc capacitor.

a. L = 4312 020 36690, C = 1500 pF
b. L = 4312 020 36700, C = 1500 pF
c. L = 4312 020 36700, C = 550 pF
d. L = 4312 020 36690, C = 550 pF.

BEADS ON WIRE

For suppression of in or outgoing interferences in various applications.

Example:



D = 3,7–0,4 mm
L = 6,2–0,4 mm
l = 34 mm

Ferroxcube grade 3B, catalogue number 8230 301 03330.

This bead is supplied on tape.

Other types of bead on wire can be supplied on request.

MATERIALS FOR PARTICLE ACCELERATORS

MATERIALS FOR PARTICLE ACCELERATORS

Several grades of Ferroxcube have been developed especially for use in particle accelerators. Applications include kicker magnets for beam extraction, and accelerating stations. For kicker magnets, materials of low coercivity and low degassing rate are required. Materials for accelerating stations must have a high μQf product at the working flux density. The dynamic behaviour of the materials under pulse conditions is important for both applications.

The data given in the following table allows a preliminary selection of material grade to be made. However, consulation with the manufacturer is always advisable to establish finally the material properties and component geometries for each application.

NOTE ON DATA

Losses given in terms of μQ factors may be converted into losses in kW/m^3 (mW/cm^3) using the following expression.

$$\text{Losses in } kW/m^3 = \frac{2{,}5 \times f \times B^2}{\mu Q}$$

where f is in kHz and B in mT. For example, the losses in FXC 3F1 material at 200 kHz and 10 mT induction are

$$\frac{2{,}5 \times 200 \times 10^2}{200 \times 10^3} = 0{,}25\ kW/m^3.$$

material		3H22	8C11	3F1	8C12	4L2	4M2	4E2
μ_i		⩾ 2500	⩾ 1000	1800 ± 360	900 ± 150	250 ± 50	140 ± 30	25 ± 5
μ_{rem} approx.		2300	850	1500	600	200	130	20
B_{sat} 25° (mT, 800 A/m)		⩾ 400	⩾ 300	⩾ 400	280	240	250	250
B_{sat} 40° (mT, 800 A/m)		⩾ 350	⩾ 280	⩾ 350	250	220	220	220
H_c (A/m, after 800 A/m)		⩽ 15	⩽ 20	⩽ 20	30	90	100	500
ρ d.c. (Ω M)		> 1	> 10^3	> 10	> 10^3	> 10^3	> 10^3	> 10^3
T_c (°C)		⩾ 125	⩾ 125	⩾ 200	⩾ 125	⩾ 150	⩾ 150	⩾ 400
μQ in remanence								
200 kHz	10 mT			200.10^3	15.10^3			
	20 mT			160.10^3	9.10^3			
	50 mT			75.10^3	4.10^3			
	100 mT			30.10^3				
500 kHz	10 mT			110.10^3	10.10^3			
	20 mT			90.10^3	6.10^3			
	50 mT			40.10^3	$2{,}5.10^3$			
	100 mT			20.10^3				
1 MHz	5 mT			25.10^3	10.10^3	35.10^3	20.10^3	
	10 mT			23.10^3	$7{,}5.10^3$	26.10^3	20.10^3	
	20 mT			17.10^3	5.10^3	13.10^3	15.10^3	
	30 mT			15.10^3		7.10^3	8.10^3	
	50 mT			14.10^3				
2,5 MHz	5 mT					25.10^3	20.10^3	
	10 mT					20.10^3	20.10^3	
	20 mT					9.10^3	15.10^3	
	30 mT					5.10^3	7.10^3	
5 MHz	5 mT					15.10^3	15.10^3	
	10 mT					11.10^3	15.10^3	
	20 mT					5.10^3	10.10^3	
	30 mT					2.10^3	7.10^3	

10 MHz 5 mT 10 mT						12.10^3 10.10^3	
80 MHz 1 mT							$2{,}5.10^3$
100 MHz							2.10^3
Decrease in μQ, measured 10 ms after application of d.c. bias in % (approx.)			10	10	30	15	30
μ_Δ with d.c. bias field (approx.) 0 A/m 250 A/m 500 A/m 1000 A/m 2000 A/m 3000 A/m			1500 270 33 13 6 4	600 120 50 22 8 5,5	200 120 55 25 12 8	130 80 40 22 12 8	
Freq. range (with or without d.c. bias) in MHz			0,1–1	0,5–10	1–5	2–10	20–100
Application area and special features	Kickers	Kickers High resistance	Low freq. For large dimensions, eddy current losses have to be considered	High freq. ratio possible with d.c. bias	Rel. high μQ	Fast recovery after magnetic bias	High freq. material

INDEX OF CATALOGUE NUMBERS

The purpose of this index is to provide identification of the component type when only the catalogue number is known. Details of the particular component are given in the relevant section of this book. See also book C4.

catalogue number	page	description
3104 101 80630	308	Tube core
3122 104 90370	308	Tube core
90380	308	Tube core
90470	270	I-core
90480	270	U-core
90550	315	Screw core
90810	308	Tube core
90960	309	Multi-hole tube
91060	307	Rod core
91100	307	Rod core
91110	307	Rod core
91150	307	Rod core
91170	307	Rod core
91690	308	Tube core
91920	307	Rod core
92020	307	Rod core
92070	307	Rod core
92800	308	Tube core
92900	308	Tube core
93160	307	Rod core
93760	308	Tube core
93840	51	Yoke ring
93950	276	U-core
94030	308	Tube core
94760	273	U-core
94770	273	I-core
94840	309	Multi-hole tube
3122 134 02540	253	Coil former
02590	251	Coil former
90110	307	Rod core
90200	261	U-core
90210	167	E-core
90460	264	U-core
90480	271	U-core
90620	254	I-core
90690	258	U-core
90720	252	I-core
90730	250	I-core
90750	52	Yoke ring
3122 134 90760	267	U-core
90770	308	Tube core
90780	308	Tube core
90800	309	Multi-hole tube
90960	126	E-core
91160	256	U-core
91190	307	Rod core
91390	274	U-core
91490	308	Tube core
91610	53	Yoke ring
91680	54	Yoke ring
91940	55	Yoke ring
92500	56	Yoke ring
92510	57	Yoke ring
92600	58	Yoke ring
3122 137 55360	268	Coil former
61910	265	Coil former
64140	255	Coil former
4311 020 50710	308	Tube core
51880	308	Tube core
53460	308	Tube core
54310	308	Tube core
4312 020 30030	307	Rod core
30160	307	Rod core
30290	307	Rod core
30320	307	Rod core
30460	307	Rod core
30490	307	Rod core
30510	307	Rod core
30520	307	Rod core
30560	307	Rod core
30570	307	Rod core
31030	308	Tube core
31050	308	Tube core
31060	308	Tube core
31200	308	Tube core
31250	308	Tube core
31320	308	Tube core
31330	308	Tube core

catalogue number	page	description
4312 020 31450	308	Tube core
31500	310	Multi-hole tube
31520	309	Multi-hole tube
31550	310	Multi-hole tube
31570	309	Multi-hole tube
33190	272	U-core
33550	277	U-core
33560	277	I-core
33570	281	U-core
33580	279	U-core
33590	279	I-core
33600	283	U-core
33610	283	I-core
34020	125	E-core
34070	117	E-core
34100	157	E-core
34110	137	E-core
34170	145	E-core
34380	175	E-core
34470	115	E-core
34550	130	E-core
36250	304	Toroids
36280	304	Toroids
36300	304	Toroids
36310	304	Toroids
36630	316	Wound beads
36640	316	Wound beads
36650	316	Wound beads
36690	316	Wound beads
36700	316	Wound beads
36710	316	Wound beads
37000	230	ETD core
37010	230	ETD core
37020	230	ETD core
37030	230	ETD core
37040	230	ETD core
37050	235	ETD core
37060	235	ETD core
37070	235	ETD core
37080	235	ETD core
37090	235	ETD core
37100	240	ETD core
37110	240	ETD core
37120	240	ETD core
37130	240	ETD core
37140	240	ETD core
37150	245	ETD core
37160	245	ETD core
37170	245	ETD core
37180	245	ETD core
4312 020 37190	245	ETD core
4312 021 26010	189	Clasp and spring
26020	200	Clasp and spring
26030	200	Clasp and spring
26040	211	Clasp and spring
26050	211	Clasp and spring
26060	222	Clasp and spring
26070	222	Clasp and spring
26090	166	Clasp and spring
26110	184	Clasp and spring
28430	118	Coil former
28490	129	Clasp
28500	129	Spring
28540	127	Coil former
28550	131	Coil former
28620	139	Coil former
28710	165	Coil former
28720	183	Coil former
28750	128	Coil former
4313 020 15170	308	Tube core
15180	308	Tube core
15460	308	Tube core
31220	308	Tube core
4322 020 31310	304	Toroid
31320	304	Toroid
31330	304	Toroid
31350	304	Toroid
31370	304	Toroid
31380	304	Toroid
31390	304	Toroid
31400	304	Toroid
4322 020 31420	304	Toroid
31430	304	Toroid
31440	304	Toroid
31450	304	Toroid
31460	304	Toroid
32060	307	Rod core
32090	307	Rod core
34310	308	Tube core
34340	308	Tube core
34380	308	Tube core
34400	308	Tube core
34410	308	Tube core
34420	308	Tube core
34430	308	Tube core
34440	308	Tube core
34450	308	Tube core
34470	308	Tube core
34830	117	E-core
34840	130	E-core

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4322 020 34850	137	E-core
34900	157	E-core
34910	174	E-core
36750	308	Tube core
36780	308	Tube core
36810	308	Tube core
37320	137	I-core
37400	291	Bar
37460	291	Bar
37470	291	Bar
37480	291	Bar
39450	307	Rod core
39470	307	Rod core
39480	307	Rod core
43020	287	Bar
52500	185	EC-core
52510	196	EC-core
52520	207	EC-core
52530	218	EC-core
90750	304	Toroid
90760	304	Toroid
90770	304	Toroid
90860	304	Toroid
90870	304	Toroid
91560	298	Bar
97000	304	Toroid
97010	304	Toroid
97020	304	Toroid
97030	304	Toroid
97040	304	Toroid
97050	304	Toroid
97060	304	Toroid
97070	304	Toroid
97110	304	Toroid
97120	304	Toroid
97130	304	Toroid
97140	304	Toroid
97150	304	Toroid
97160	304	Toroid
97170	304	Toroid
97180	304	Toroid
97190	304	Toroid
97200	304	Toroid
97500	291	Bar
97610	291	Bar
4322 021 20160	122	Clasp
20170	134	Clasp
20220	122	Spring
20230	134	Spring
20240	119	Coil former

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4322 021 20250	132	Coil former
20290	121	Coil former
31830	140	Coil former
31910	142	Clasp
31920	142	Spring
33000	188	Coil former
33030	210	Coil former
33060	199	Tag
33070	210	Tag
33310	188	Coil former
33320	199	Coil former
33330	210	Coil former
33340	221	Coil former
33350	199	Coil former
33360	210	Coil former
33370	221	Coil former
33410	187	Coil former
33480	199	Coil former
33490	199	Coil former
33500	210	Coil former
33850	233	Coil former
33890	234	Assembly clip
33940	234	Earth clip
33860	238	Coil former
33900	239	Assembly clip
33950	239	Earth clip
33870	243	Coil former
33910	244	Assembly clip
33960	244	Earth clip
33880	248	Coil former
33920	249	Assembly clip
33970	249	Earth clip
4330 020 30560	307	Rod core
4330 030 30030	307	Rod core
30060	307	Rod core
30070	307	Rod core
30080	307	Rod core
30110	307	Rod core
30120	307	Rod core
30130	307	Rod core
30140	307	Rod core
30220	307	Rod core
30250	307	Rod core
30300	307	Rod core
30320	307	Rod core
30360	307	Rod core
30390	307	Rod core
30400	307	Rod core
30450	307	Rod core
32100	312	Bead

catalogue number	page	description
4330 030 32110	312	Bead
32120	312	Bead
32130	312	Bead
32140	312	Bead
32150	312	Bead
32160	312	Bead
32170	312	Bead
32180	312	Bead
32190	312	Bead
32200	312	Bead
32210	312	Bead
32220	312	Bead
32230	312	Bead
32240	312	Bead
32250	312	Bead
32260	312	Bead
32270	312	Bead
32280	312	Bead
32290	312	Bead
32300	312	Bead
32310	312	Bead
32320	312	Bead
32330	312	Bead
32340	312	Bead
32350	312	Bead

catalogue number	page	description
4330 030 32360	312	Bead
32370	312	Bead
32380	312	Bead
32390	312	Bead
32400	312	Bead
32410	312	Bead
32420	312	Bead
32430	312	Bead
32440	312	Bead
32450	312	Bead
32460	312	Bead
32470	312	Bead
32480	312	Bead
32490	312	Bead
32500	312	Bead
32510	312	Bead
32630	308	Tube core
32650	308	Tube core
32670	308	Tube core
32740	309	Multi-hole tube
38070	314	FXC coil former
8230 301 03330	318	Bead on wire
8230 302 02080	314	FXC coil former
02170	314	FXC coil former

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