PHILIPS

Data handbook

Electronic
components
and materials

Components and materials

Part 5 March 1982

Ferroxcube for power, audio/video and accelerators

COMPONENTS AND MATERIALS

PART 5 – MARCH 1982

FERROXCUBE FOR POWER, AUDIO/VIDEO AND ACCELERATORS

See Part 4 for potcores, square cores and cross cores

DATA HANDBOOK SYSTEM

Our Data Handbook System is a comprehensive source of information on electronic components, subassemblies and materials; it is made up of four series of handbooks each comprising several parts.

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

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

Where ratings or specifications differ from those published in the preceding edition they are pointed out by arrows. Where application information is given it is advisory and does not form part of the product specification.

If you need confirmation that the published data about any of our products are the latest available, please contact our representative. He is at your service and will be glad to answer your inquiries.

ELECTRON TUBES (BLUE SERIES)

The blue series of data handbooks is comprised of the following parts:

T1	**Tubes for r.f. heating**
T2	**Transmitting tubes for communications**
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, image intensifiers**
T11*	**Microwave components and assemblies**

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* Will become available in the course of 1982.

SEMICONDUCTORS (RED SERIES)

The red series of data handbooks is comprised of the following parts:

S1	**Diodes** Small-signal germanium diodes, small-signal silicon diodes, voltage regulator diodes(< 1,5 W), voltage reference diodes, tuner diodes, rectifier diodes
S2	**Power diodes, thyristors, triacs** Rectifier diodes, voltage regulator diodes (> 1,5 W), rectifier stacks, thyristors, triacs
S3	**Small-signal transistors**
S4	**Low-frequency power transistors and hybrid IC modules**
S5	**Field-effect transistors**
S6	**R.F. power transistors and modules**
S7	**Microminiature semiconductors for hybrid circuits**
S8	**Devices for optoelectronics** Photosensitive diodes and transistors, light-emitting diodes, displays, photocouplers, infrared sensitive devices, photoconductive devices.
S9	Taken into handbook T11 of the blue series
S10	**Wideband transistors and wideband hybrid IC modules**

INTEGRATED CIRCUITS (PURPLE SERIES)

The purple series of data handbooks is comprised of the following parts:

IC1	**Bipolar ICs for radio and audio equipment**
IC2	**Bipolar ICs for video equipment**
IC3*	**Digital ICs for radio, audio and video equipment**
IC4	**Digital integrated circuits** LOCMOS 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 circuits**

* These handbooks will be available in the course of 1982.

COMPONENTS AND MATERIALS (GREEN SERIES)

The green series of data handbooks is comprised of the following parts:

C1	**Assemblies for industrial use** PLC modules, PC20 modules, HNIL FZ/30 series, NORbits 60-, 61-, 90-series, input devices, hybrid ICs, peripheral devices
C2	**FM tuners, 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	**Electric motors and accessories** Permanent magnet synchronous motors, stepping motors, direct current motors
CM7a	**Assemblies** (will not be reprinted) Circuit blocks 40-series and CSA70(L), counter modules 50-series, input/output devices
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, variable capacitors**
C16	**Piezoelectric ceramics, permanent magnet materials**

GENERAL PROPERTIES OF MANGANESE ZINC AND NICKEL ZINC FERRITES

A

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 extrusions, 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.

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* 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 for electron-beam-deflection systems,
3B	rods and tubes
3B7	potcores and square cores
3B8	potcores, square cores and cross cores (with d.c. polarization)
3C2	yoke rings for electron-beam-deflection systems, and L cores
3C6	U cores, rods and tubes
3C8	E, EC, U and I 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
4B1	frames for i.f. transformers, rods and tubes
4C1	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,
4E1	tubes and rods
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.
8A3, 8C1, 8E1, 8E2, 8X1	cores 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.

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
$A_{CP\ min}$	mm^2	minimum cross-sectional area of centre pole.
A_e	mm^2	effective cross-sectional area.
$A_{e\ min}$	mm^2	minimum effective cross-sectional area.
A_L	nH	1. initial inductance factor L/N^2.
	H	2. inductance factor L/N^2. Note: unless otherwise stated, in this Handbook, A_L is the initial induction 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 actual change in the value of inductance measured over an interval $t_1 - t_2$ after demagnetization. $D = D_F \mu_e \log \frac{t_1}{t_2}$
D_F	–	disaccommodation factor: decrease in initial permeability as measured at t_1 and t_2 demagnetization. $D_F = \frac{\mu_i\,t1 - \mu_i\,t2}{\mu^2{}_i\,t_1 \log(t_2/t_1)}$ 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 measured open circuit.
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	°C	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 coefficient 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: $\eta_B = \frac{\Delta R_h}{\Delta\hat{B}\mu_c\, 2\pi f L}$ 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.
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

$A_L = 10^6 \mu_e \mu_0 / C_1$	(nH)	initial induction factor.
$\hat{B} = E/(4{,}44 f N A_e)$	(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.
$\tan\delta_h = \mu\hat{B}\eta_B$		hysteresis loss factor

TECHNICAL DATA

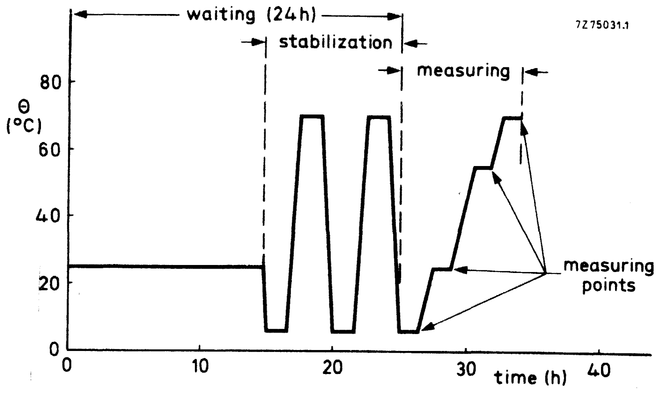
Ferroxcube data are given in the tables on the following pages in accordance with the recommendations of IEC401, and using symbols defined in the previous section.

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.



	unit	3B	3B3
Initial permeability μ_i			
at $\hat{B} \leqslant 0,1$ mT, $\theta = 25$ °C		900 ± 20%	900 ± 20%
at $\hat{B} = 0,7\text{-}1$ mT, $\theta = 10\text{-}70$ °C			
at $\hat{B} = 0,7\text{-}1$ mT, $\theta = 25\text{-}70$ °C			
Induction B, ballistically measured at			
H = 250 A/m, $\theta = 25$ °C	mT		
$\theta = 100$ °C	mT		
H = 800 A/m, $\theta = 25$ °C	mT	~ 345	
$\theta = 70$ °C	mT		
$\theta = 100$ °C	mT	~ 230	
Eddy current and residual loss factor			
$\frac{\tan \delta}{\mu_i}$ at $\hat{B} \leqslant 0,1$ mT, $\theta = 25$ °C,			
f = 4 kHz	x 10^{-6}		$\leqslant 7$
f = 50 kHz	x 10^{-6}		
f = 100 kHz	x 10^{-6}		$\leqslant 15$
f = 250 kHz	x 10^{-6}		$\leqslant 27$
f = 450 kHz	x 10^{-6}	$\leqslant 50$	$\leqslant 50$
f = 500 kHz	x 10^{-6}		
f = 1000 kHz	x 10^{-6}		
Power loss P at 16 kHz, $\hat{B} = 200$ mT			
$\theta = 25$ °C	kW/m³ (= mW/cm³)		
$\theta = 50$ °C	kW/m³ (= mW/cm³)		
$\theta = 100$ °C	kW/m³ (= mW/cm³)		
Hysteresis material constant,			
η_B at $\hat{B} = 0,3\text{-}1,2$ mT, f = 100 kHz, $\theta = 25$ °C	x 10^{-3} T^{-1}		
$\hat{B} = 1,5\text{-}3,0$ mT, f = 4 kHz, $\theta = 25$ °C	x 10^{-3} T^{-1}		$\leqslant 7,4$
d.c. sensitivity constant β_F at			
$\frac{\mu_e \cdot NI_o}{l_e} = 1,20 \cdot 10^5$ A/m			
$= 1,80 \cdot 10^5$ A/m			
$= 2,60 \cdot 10^5$ A/m			
Resistivity ρ measured with d.c. current	Ωm	$\geqslant 0,2$	$\geqslant 1$
Disaccommodation factor D_F, between 10 and 100 min after demagnetization at $\hat{B} \leqslant 0,1$ mT, $\theta = 25 \pm 1$ °C	x 10^{-6}	$\leqslant 10$	$\leqslant 11$
Temperature factor of permeability			
α_F at $\hat{B} \leqslant 0,1$ mT, $\theta = +5$ to $+25$ °C	x 10^{-6}/K		
$+25$ to $+55$ °C	x 10^{-6}/K	0 to + 3	0 to + 2
$+25$ to $+70$ °C	x 10^{-6}/K		
Curie point	°C	$\geqslant 150$	$\geqslant 150$
Mass density	kg/m³	4700-4900	4700-4900

3B7	3B8	3C2	3C6	3C7	3C8
2300 ± 20%	2300 ± 20%	900 ± 25%	1700 ± 25%	2400 ± 20%	2000 ± 25%
			⩾ 290	⩾ 330	⩾ 330
~ 430	~ 490	~ 350			
~ 345					
	~ 380	~ 245			
⩽ 1	⩽ 1,2				
⩽ 5	⩽ 5				
			⩽ 170		⩽ 110
			⩽ 160		
			⩽ 140	⩽ 140	⩽ 100
⩽ 1,1	⩽ 1,0				
	⩽ $120 \cdot 10^{-6}$				
	⩽ $300 \cdot 10^{-6}$				
⩽ 1,8	⩽ $1000 \cdot 10^{-6}$				
⩾ 1	⩾ 0,6	⩾ 0,1	⩾ 1	⩾ 1	⩾ 1
⩽ 4,3	⩽ 8				
	0 to + 4				
	0 to + 4	0 to + 4,5		0 to + 5	
−0,6 to + 0,6					
⩾ 170	⩾ 200	⩾ 150	⩾ 190	⩾ 190	⩾ 200
4700-4900	4700-4900	4700-4900	4750-4850	4750-4850	4750-4850

	unit	3D3	3E1
Initial permeability μ_i			
at $B \leqslant 0{,}1$ mT, $\theta = 25$ °C		750 ± 20%	3800 ± 20%
at $B = 0{,}7\text{-}1$ mT, $\theta = 10\text{-}70$ °C			
at $B = 0{,}7\text{-}1$ mT, $\theta = 25\text{-}70$ °C			
at $B \leqslant 0{,}1$ mT, $\theta = 5\text{-}70$ °C			
Induction B, ballistically measured at			
$H = 250$ A/m, $\theta = 100$ °C	mT		
$H = 800$ A/m, $\theta = 25$ °C	mT	~ 350	~ 350
$\theta = 70$ °C	mT		~ 270
Eddy current and residual loss factor $\frac{\tan\delta}{\mu_i}$ at $B \leqslant 0{,}1$ mT, $\theta = 25$ °C			
$f = 4$ kHz	x 10^{-6}		$\leqslant 2{,}5$
$f = 30$ kHz	x 10^{-6}		
$f = 50$ kHz	x 10^{-6}		
$f = 100$ kHz	x 10^{-6}	$\leqslant 8$	$\leqslant 20$
$f = 500$ kHz	x 10^{-6}	$\leqslant 12$	$\leqslant 200$
$f = 1000$ kHz	x 10^{-6}	$\leqslant 24$	
Power loss P at 16 kHz, $B = 200$ mT,			
$\theta = 25$ °C	kW/m³ (= mW/cm³)		
$\theta = 50$ °C	kW/m³ (= mW/cm³)		
$\theta = 100$ °C	kW/m³ (= mW/cm³)		
Hysteresis material constant			
η_B at $B = 0{,}3\text{-}1{,}2$ mT, $f = 100$ kHz, $\theta = 25$ °C	x $10^{-3}\,T^{-1}$	$\leqslant 1{,}8$	
$B = 1{,}5\text{-}3{,}0$ mT, $f = 4$ kHz, $\theta = 25$ °C	x $10^{-3}\,T^{-1}$		$\leqslant 1{,}1$
$B = 1{,}5\text{-}3{,}0$ mT, $f = 30$ kHz, $\theta = 25$ °C			
$B = 1{,}5\text{-}3{,}0$ mT, $f = 100$ kHz, $\theta = 25$ °C			
Resistivity ρ measured with d.c. current	Ωm	$\geqslant 1{,}5$	$\geqslant 0{,}3$
Disaccommodation factor D_F, between 10 and 100 min after demagnetization at $B \leqslant 0{,}1$ mT, $\theta = 25 \pm 1$ °C	x 10^{-6}	$\leqslant 12$	$\leqslant 4{,}3$
Temperature factor of permeability			
α_F at $B \leqslant 0{,}1$ mT, $\theta = +5$ to $+25$ °C	x 10^{-6}/K		1 ± 1
$= +25$ to $+55$ °C	x 10^{-6}/K		1 ± 1
$+25$ to $+70$ °C	x 10^{-6}/K	0 to + 2	1 ± 1
Curie point	°C	$\geqslant 150$	$\geqslant 125$
Mass density	kg/m³	4500-4900	4700-4900

3E2	3E3	3E4	3E5	3H1	3H2	3H3	
		4700 ± 20%	10 000 ± 20%	2300 ± 20%	2300 ± 20%	2000 ± 20%	
	⩾ 10 000						
⩾ 5000							
			⩾ 8000				
~ 355	~ 380		~ 380	~ 360	400		
~ 260	~ 280		~ 280	~ 280			
⩽ 2,5	⩽ 2,5	⩽ 2,5	⩽ 3	⩽ 1	⩽ 1		
			⩽ 25			1,2 ± 0,4	
	⩽ 20						
⩽ 15	⩽ 50	⩽ 20	⩽ 75	⩽ 5	⩽ 5	2 ± 0,5	
		⩽ 200					
⩽ 1,1	⩽ 1,1	⩽ 0,85	⩽ 0,85	⩽ 0,85	⩽ 1,1		
						⩽ 0,5	←
						⩽ 0,6	←
⩾ 0,1	⩾ 0,05	⩾ 0,3	⩾ 0,01	⩾ 1	⩾ 1		
⩽ 1,9	⩽ 1,9	⩽ 4,3	⩽ 2	⩽ 4,3	⩽ 4,3	⩽ 3,0*	
		1 ± 1	0,4 ± 0,6	1 ± 0,5		0,7 ± 0,3	←
		1 ± 1	0,6 ± 0,6	1 ± 0,5	1,2 ± 0,6	0,7 ± 0,3	
		1 ± 1	0,6 ± 0,6	1 ± 0,5	1,2 ± 0,6	0,7 ± 0,3	
⩾ 130	⩾ 125	⩾ 125	⩾ 120	⩾ 130	⩾ 160	⩾ 160	
4700-4900	4800-4950	4700-4900	4800-5000	4700-4900	4700-4900		

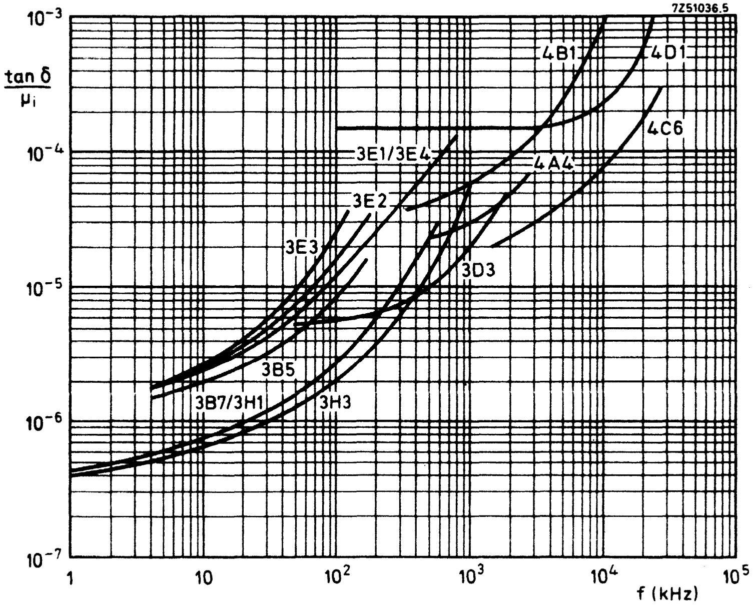
* At any temperature between 25 and 70 °C

	unit	4A4	4B1
Initial permeability μ_i at $\hat{B} \leqslant 0,1$ mT, $\theta = 25$ °C		500 ± 20%	250 ± 20%
Induction B, ballistically measured at			
H = 800 A/m, $\theta = 25$ °C	mT	~ 270	
$\theta = 70$ °C		~ 210	
H = 1600 A/m, $\theta = 25$ °C			~ 325
$\theta = 100$ °C			~ 260
H = 2000 A/m, $\theta = 25$ °C			
$\theta = 70$ °C			
H = 2400 A/m, $\theta = 25$ °C			
$\theta = 70$ °C			
$\theta = 100$ °C			
H = 3200 A/m, $\theta = 25$ °C			
$\theta = 100$ °C			
H = 4800 A/m, $\theta = 25$ °C			
$\theta = 100$ °C			
Eddy current and residual loss factor $\frac{\tan \delta}{\mu_i}$ at $\hat{B} \leqslant 0,1$ mT, $\theta = 25$ °C			
f = 500 kHz	$\times 10^{-6}$	$\leqslant 30$	
f = 700 kHz			$\leqslant 70$
f = 1 MHz			$\leqslant 90$
f = 1,5 MHz		$\leqslant 40$	$\leqslant 140$
f = 2 MHz		$\leqslant 70$	
f = 3 MHz			
f = 5 MHz			
f = 10 MHz			
f = 25 MHz			
f = 40 MHz			
Hysteresis material constant, η_B at $\hat{B} = 0,3$-$1,2$ mT, f = 100 kHz, or $\theta = 25$ °C	$\times 10^{-3}\,\mathrm{T}^{-1}$	$\leqslant 1,8$	
Resistivity ρ measured with d.c. current	Ωm	$\geqslant 10^3$	$\geqslant 10^3$
Dielectric constant ϵ at 1 MHz, $\theta = 25$ °C		15-20	
Disaccommodation factor D_F, $\hat{B} \leqslant 0,1$ mT, $\theta = 25 \pm 1$ °C	$\times 10^{-6}$	$\leqslant 5$	
Temperature factor of permeability α_F at $\hat{B} < 0,1$ mT, $\theta = +5$ to $+25$ °C			
$= +25$ to $+55$ °C	$\times 10^{-6}$/K		0 to + 8
$+25$ to $+70$ °C		10 ± 5	
Curie point	°C	$\geqslant 135$	$\geqslant 250$
Mass density	kg/m^3	4700-5100	4400-4800

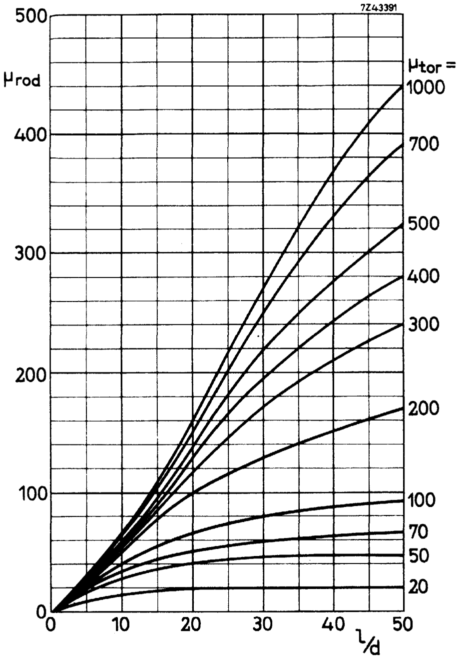
4C1	4C6	4D1	4D2	4E1
125 ± 20%	120 ± 20%	50 ± 20%	60 ± 10%	15 ± 20%
~ 275	~ 380			
	~ 350			
~ 245				
		~ 240		
		~ 220		
				~ 175
				~ 165
≤ 120	≤ 40			
≤ 160		≤ 180		
≤ 300		≤ 210		
	≤ 100	≤ 300	≤ 100	≤ 300
			≤ 200	
			≤ 600	≤ 360
	≤ 6,2			
≥ 10^3	≥ 10^3	≥ 10^3	≥ 10^3	≥ 10^3
	10-15			
	≤ 10			
	1 ± 3			
0 to + 12	3 ± 3	0 to + 15		0 to + 15
			0 to + 15	
≥ 350	≥ 350	≥ 400	≥ 350	≥ 500
4200-4600	4000-5000	4000-4400		3500-4000

CHARACTERISTIC CURVES

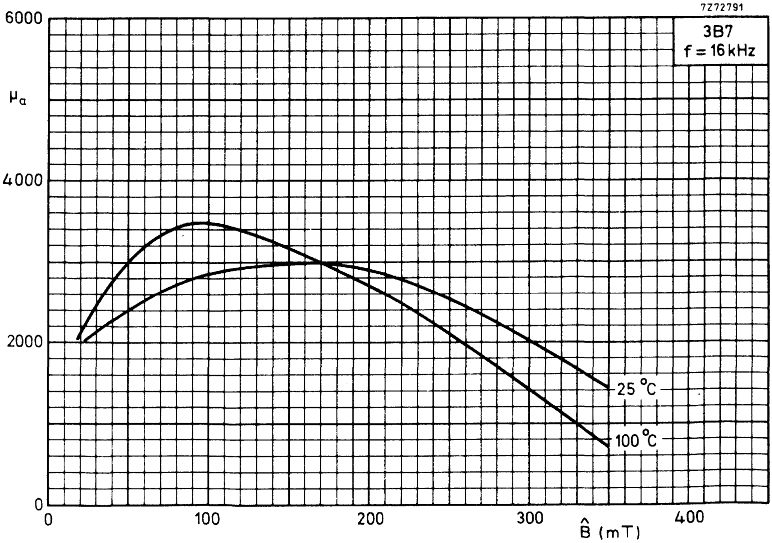
The curves are valid for toroids of not too small dimensions and should be considered as a guide. For guarantees on products, refer to the pages on the relevant products.



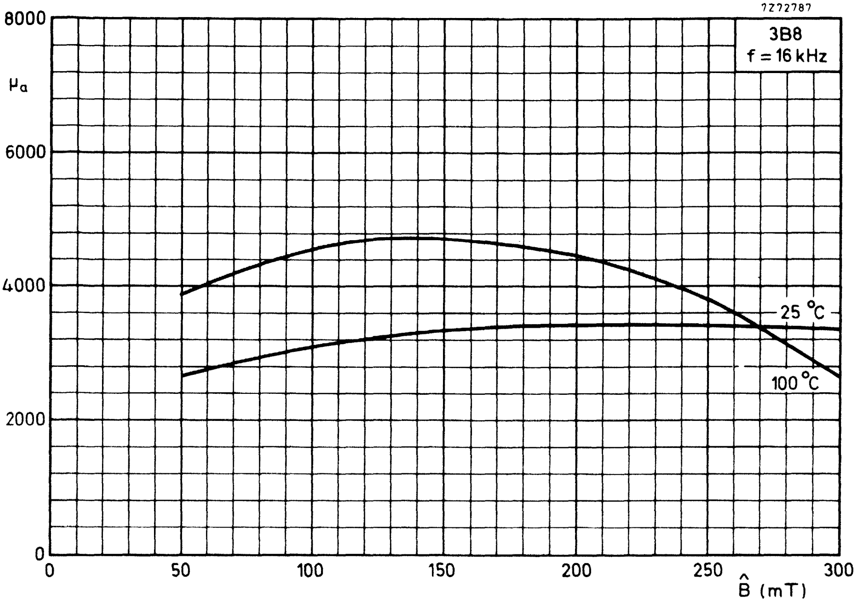
Eddy current losses and residual losses as a function of the frequency at low induction level.

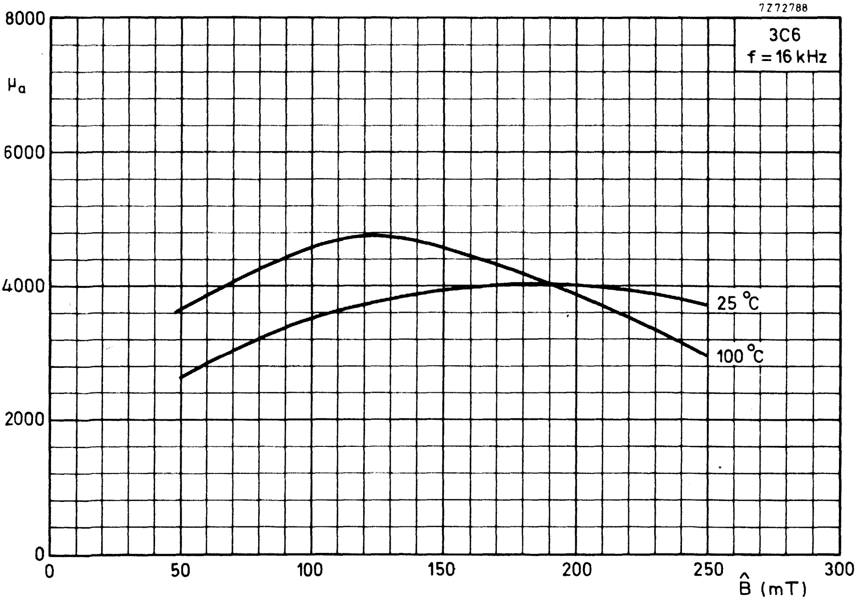


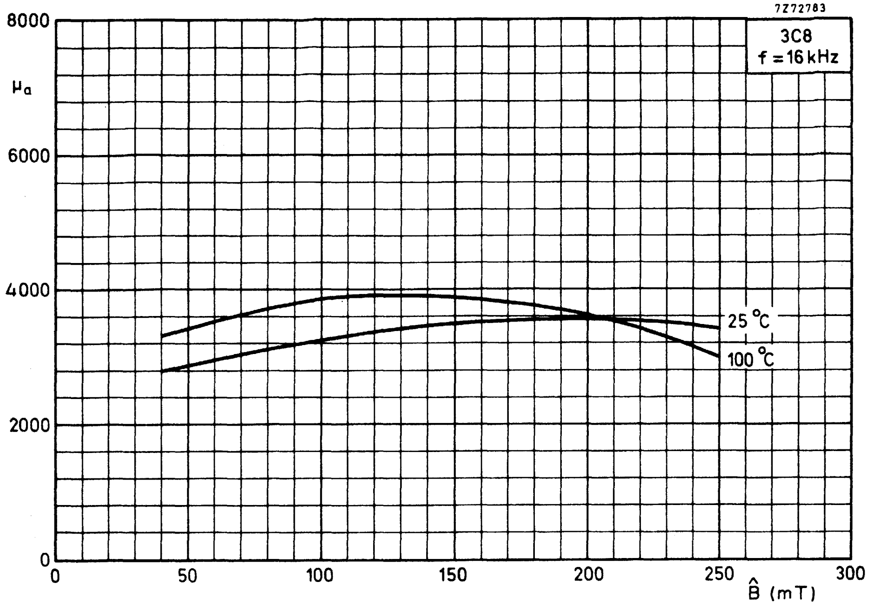
Rod permeability as a function of the ratio l/d with the relative initial permeability of a toroidal core as parameter

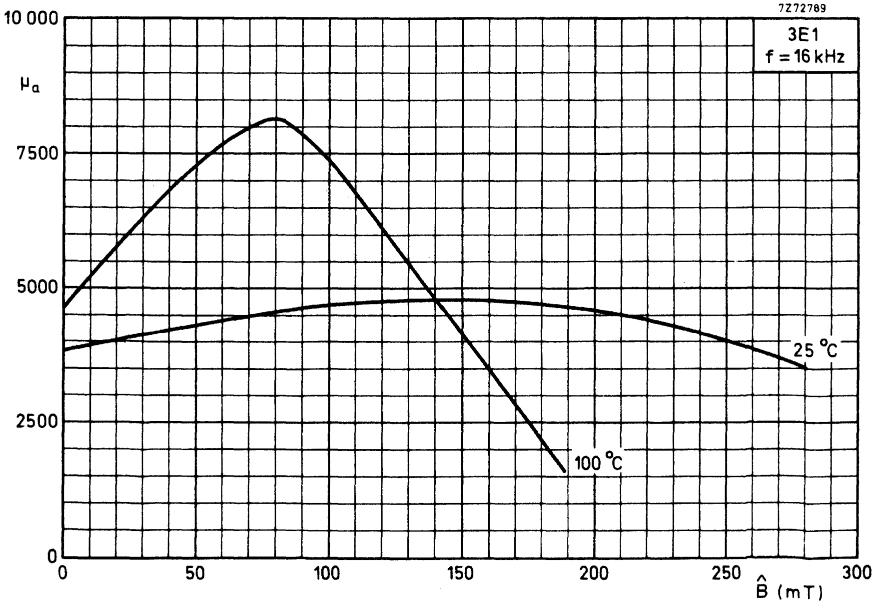


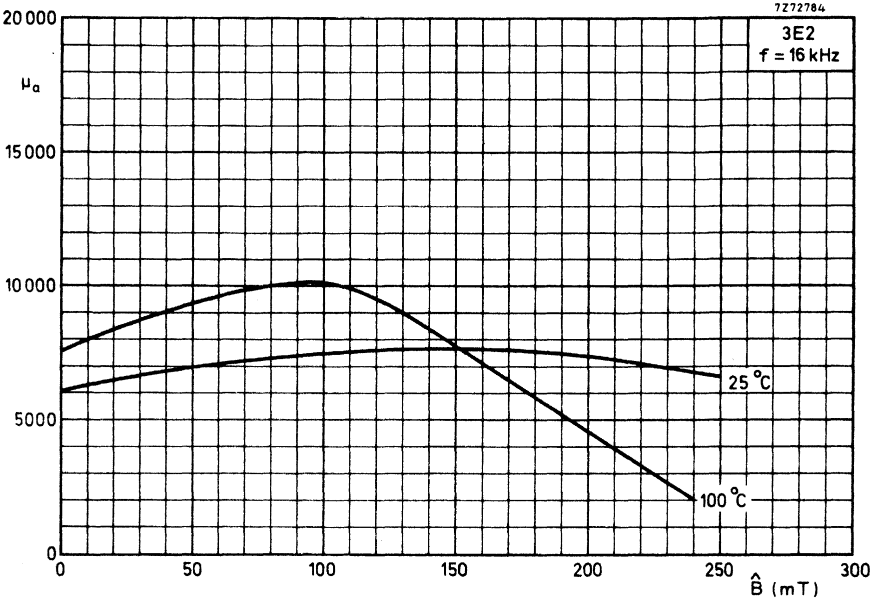
Amplitude permeability as a function of the induction.

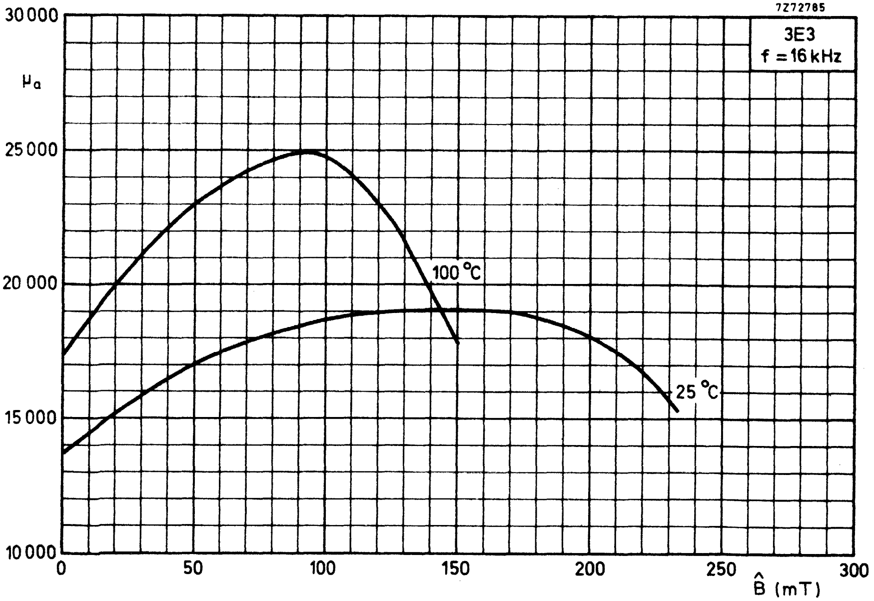

7Z72787
3B8
f = 16 kHz
μa
8000
6000
4000
2000
0
0
50
100
150
200
250
300
B̂ (mT)
25 °C
100 °C

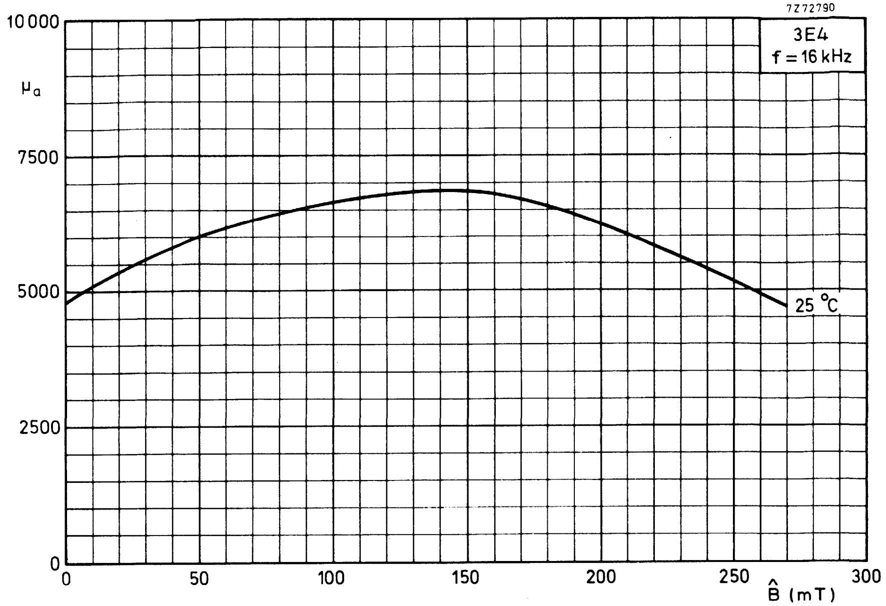

7Z72788
3C6
f = 16 kHz
μa
8000
6000
4000
2000
0
0
50
100
150
200
250
300
B̂ (mT)
25 °C
100 °C

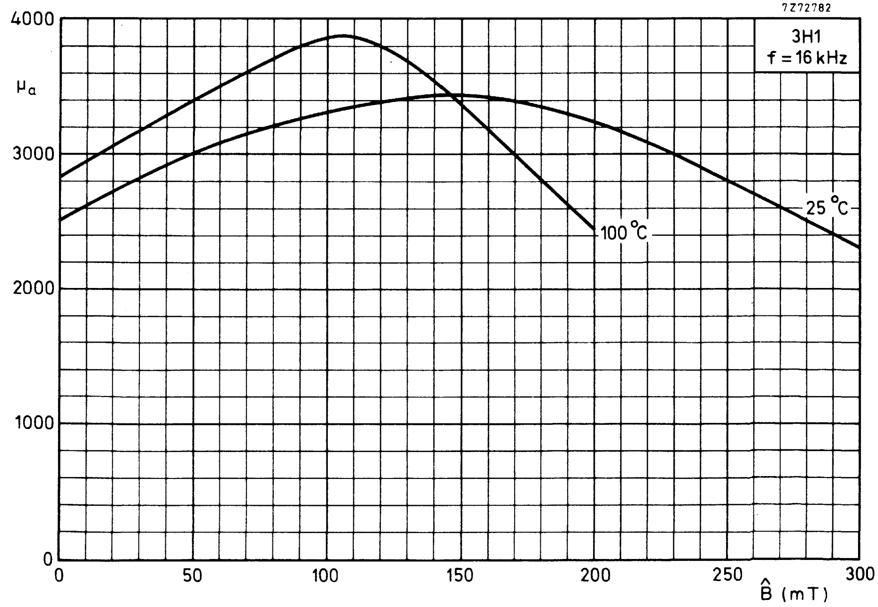

7Z72783
3C8
f = 16 kHz
μ_a
8000
6000
4000
2000
0
0
50
100
150
200
250
300
$\hat{B}$ (mT)
25 °C
100 °C

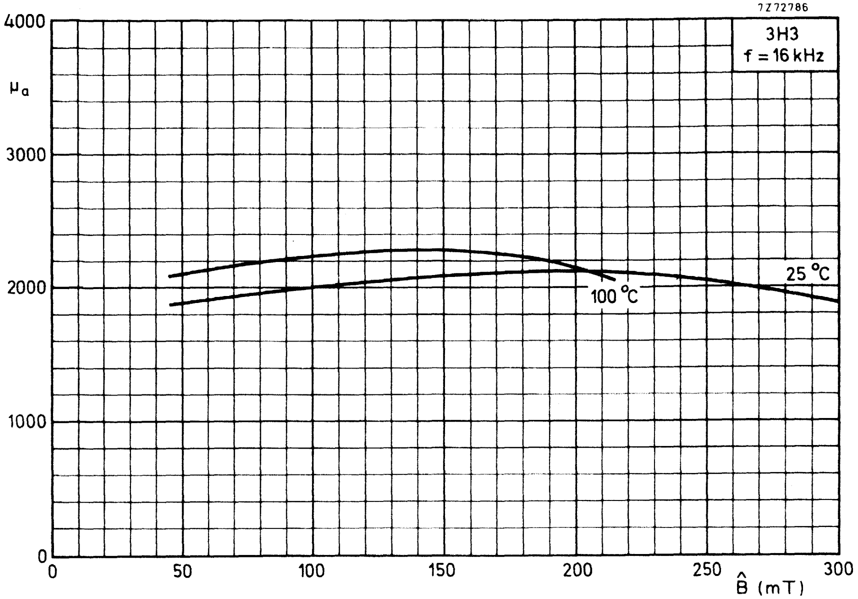

7Z72789
3E1
f = 16 kHz
μ_a
10 000
7500
5000
2500
0
0
50
100
150
200
250
300
$\hat{B}$ (mT)
25 °C
100 °C

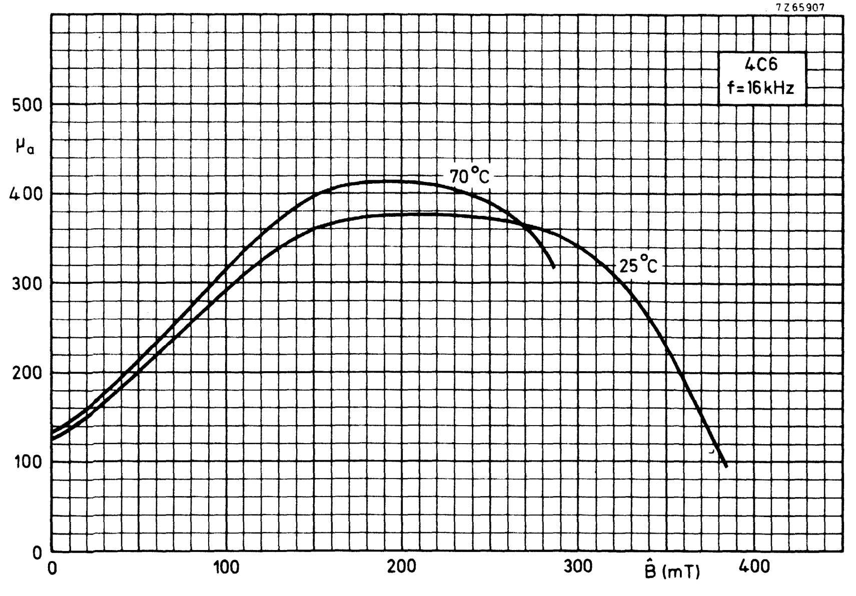

7Z72784
3E2
f = 16 kHz
μ_a
20 000
15 000
10 000
5000
0
0
50
100
150
200
250
300
$\hat{B}$ (mT)
25 °C
100 °C


7Z72785
3E3
f = 16 kHz
μ_a
30 000
25 000
20 000
15 000
10 000
0
50
100
150
200
250
300
$\hat{B}$ (mT)
100 °C
25 °C

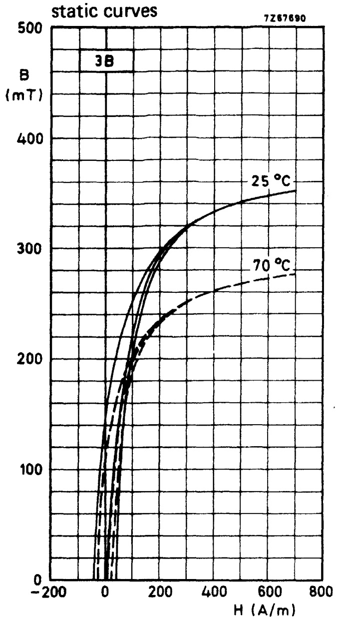

7Z72790
3E4
f = 16 kHz
10 000
7500
5000
2500
0
μ_a
25 °C
0
50
100
150
200
250
300
$\hat{B}$ (mT)

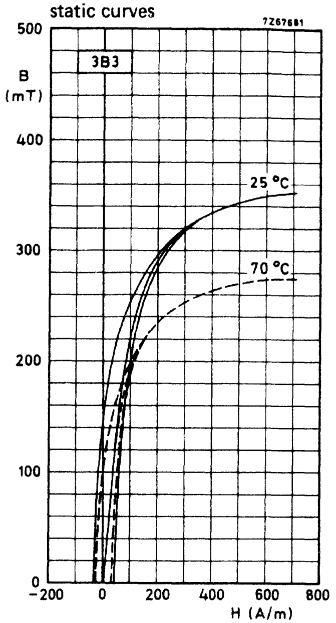

7Z72782
3H1
f = 16 kHz
4000
3000
2000
1000
0
μ_a
100 °C
25 °C
0
50
100
150
200
250
300
$\hat{B}$ (mT)

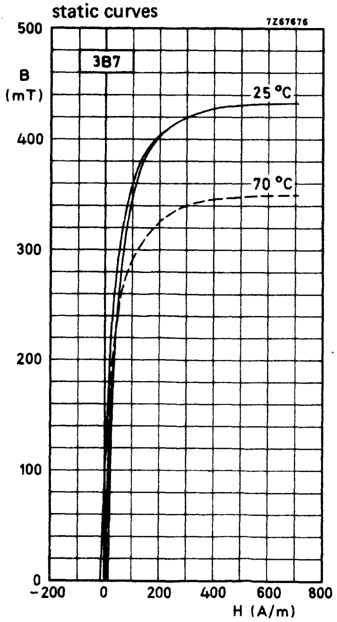

7Z72786
3H3
f = 16 kHz
4000
μ_a
3000
2000
1000
0
0
50
100
150
200
250
300
$\hat{B}$ (mT)
25 °C
100 °C

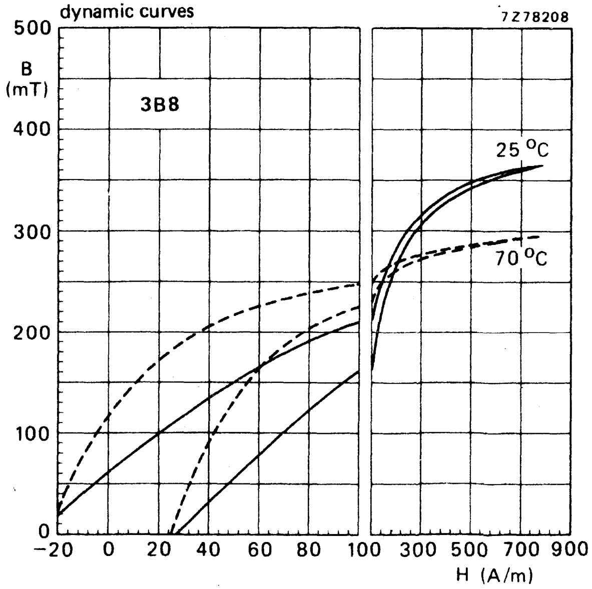

7Z65907
4C6
f=16kHz
500
μ_a
400
300
200
100
0
0
100
200
300
400
$\hat{B}$ (mT)
70 °C
25 °C

TYPICAL BH-CURVES (measured ballistically)

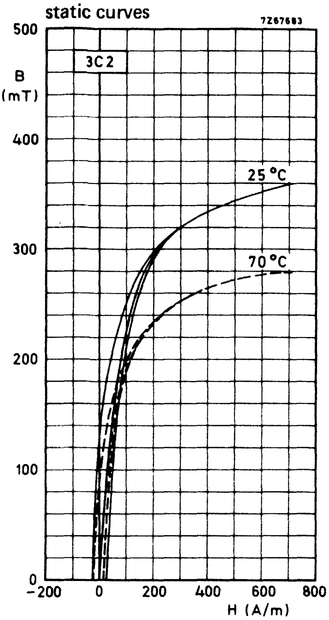




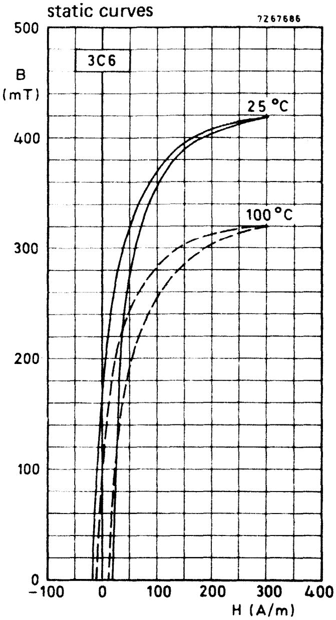




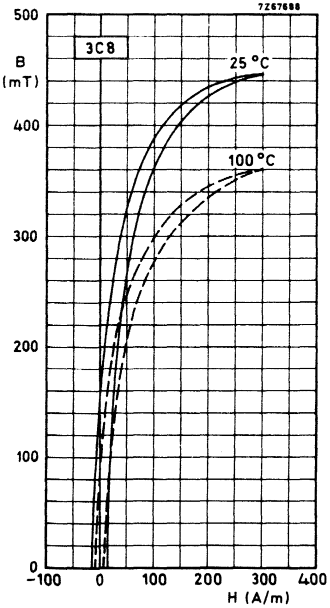
static curves



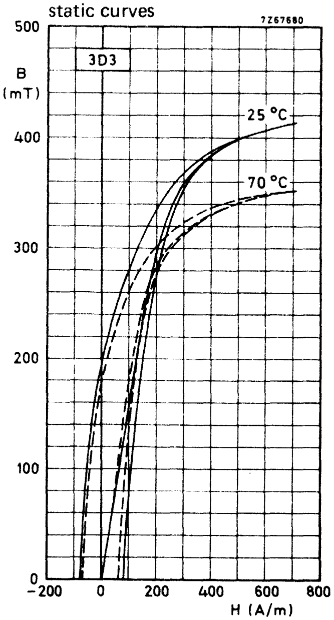
static curves

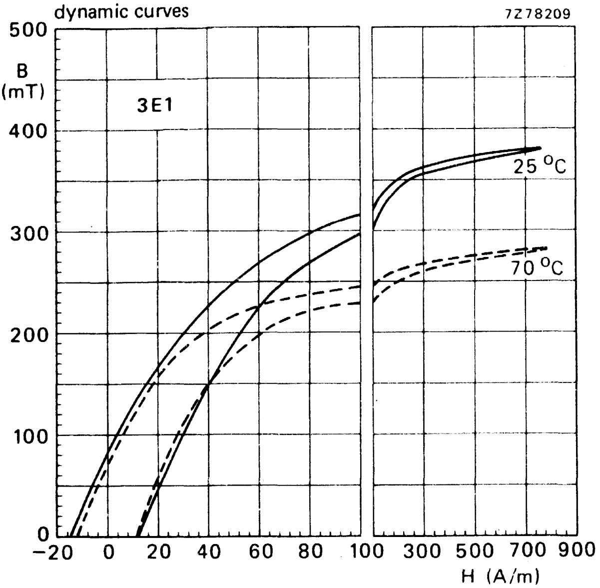


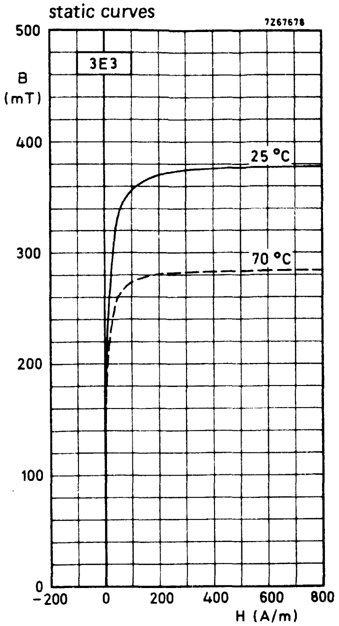
static curves

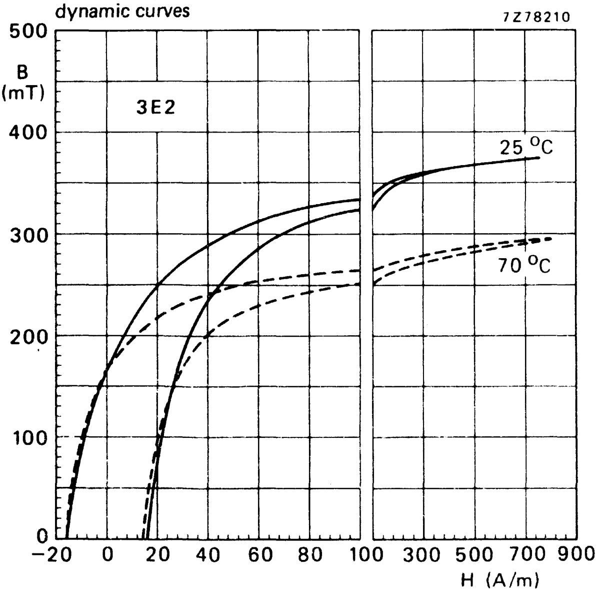


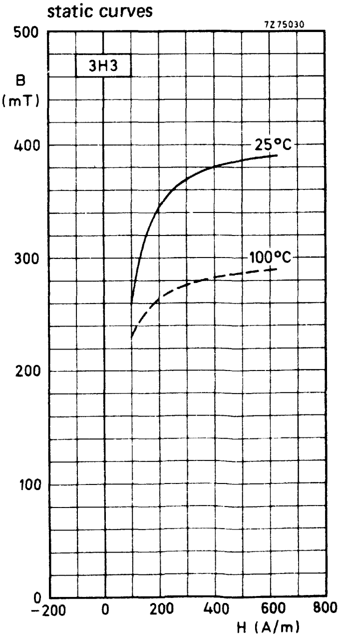
static curves

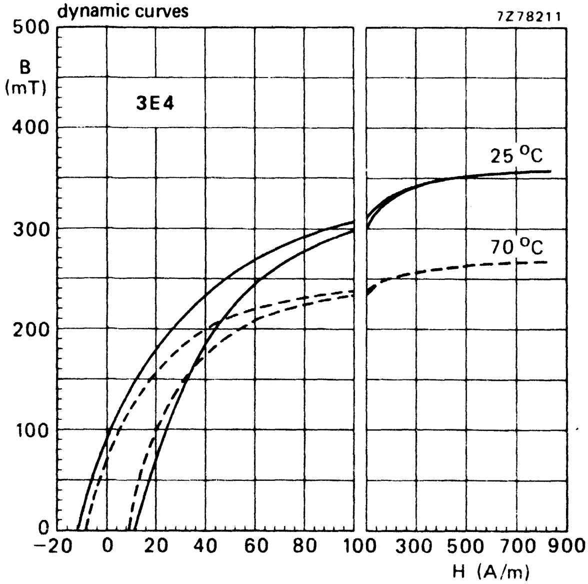


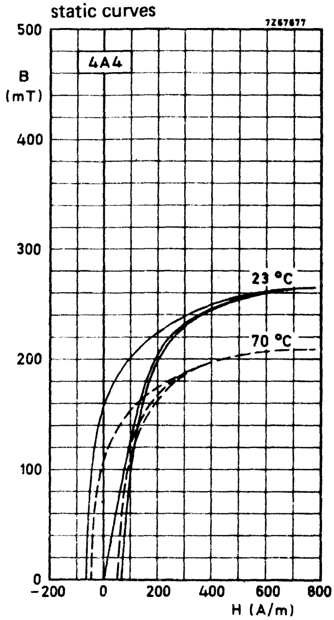

dynamic curves

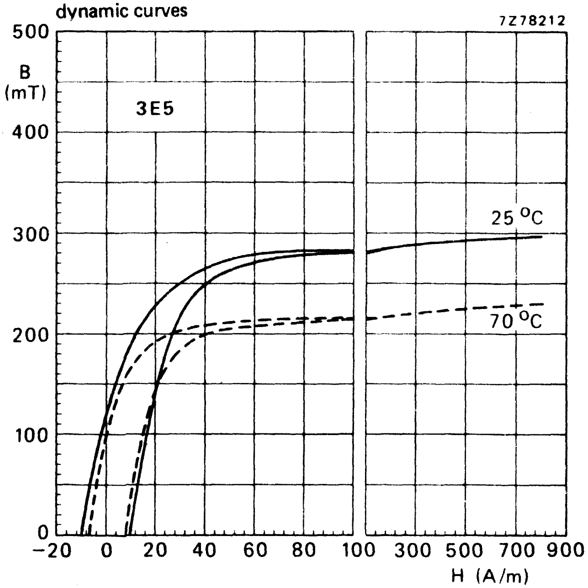

static curves

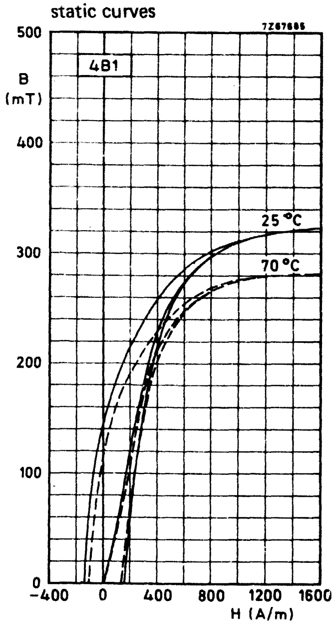

dynamic curves

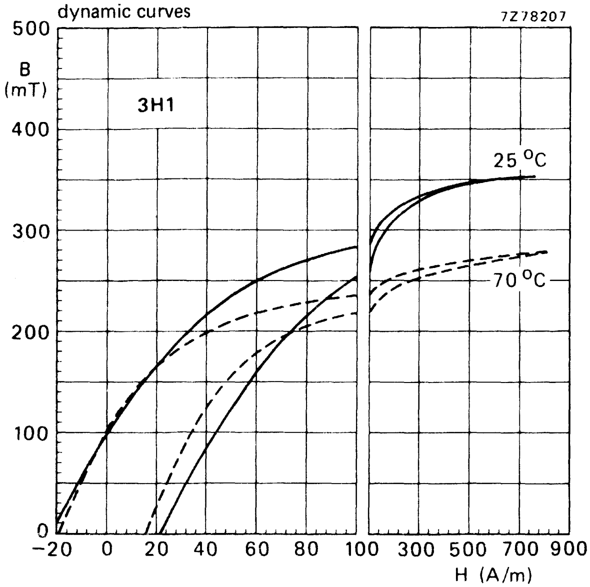

static curves

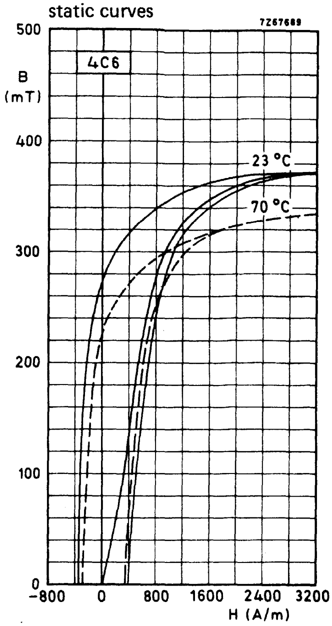

dynamic curves

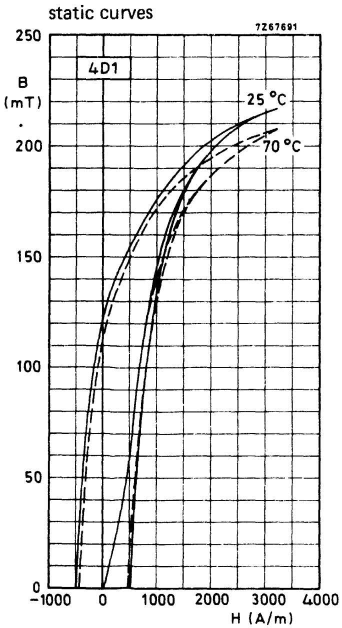

static curves

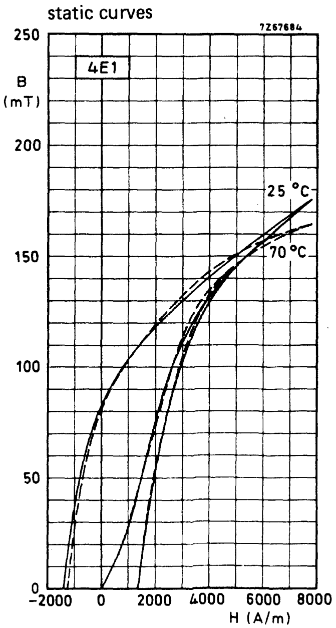

dynamic curves


static curves

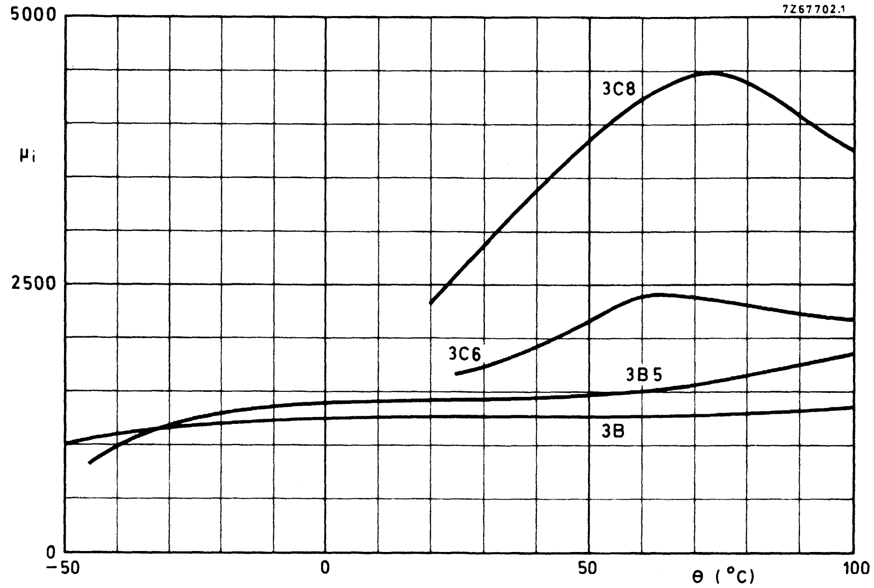

dynamic curves
7Z78207
3H1
B (mT)
500
400
300
200
100
0
−20
0
20
40
60
80
100
300
500
700
900
H (A/m)
25 °C
70 °C

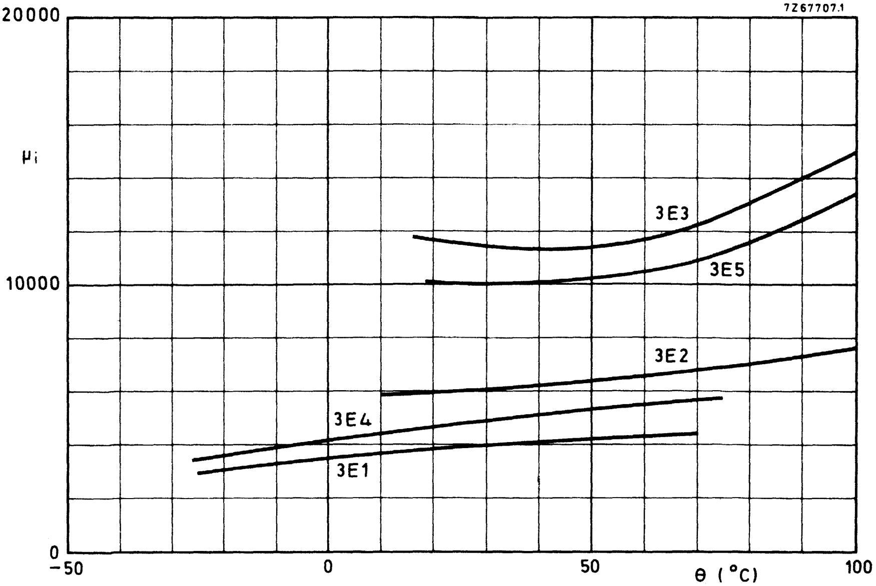

static curves
7Z67689
4C6
B (mT)
500
400
300
200
100
0
−800
0
800
1600
2400
3200
H (A/m)
23 °C
70 °C

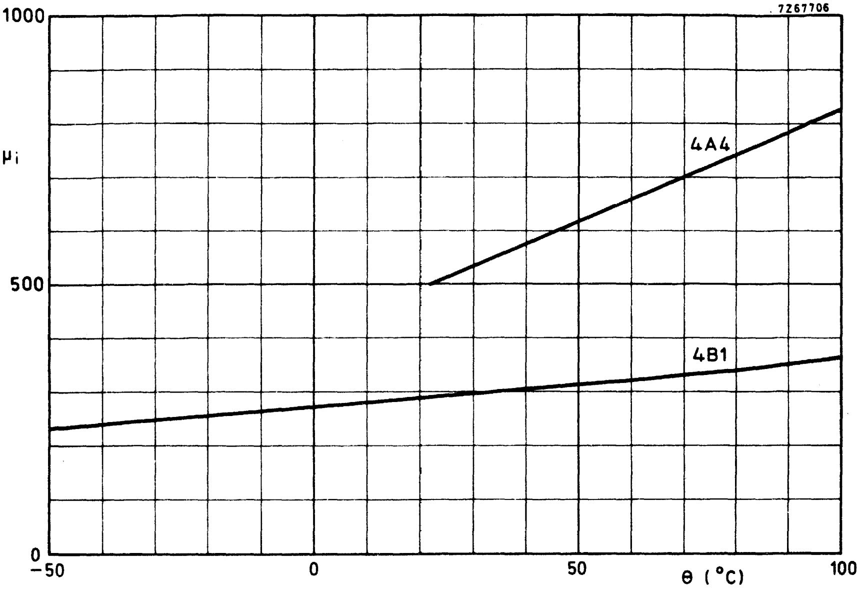

static curves
7Z67691
4D1
B (mT)
250
200
150
100
50
0
−1000
0
1000
2000
3000
4000
H (A/m)
25 °C
70 °C

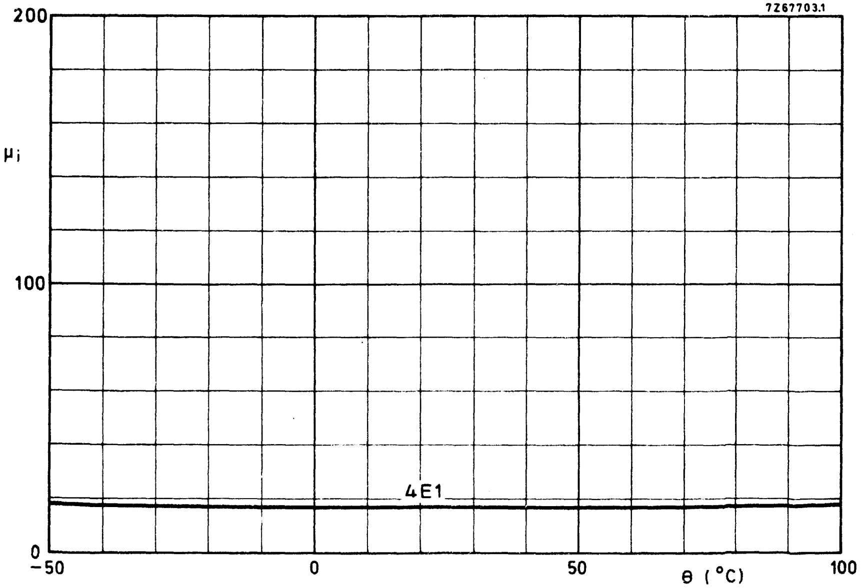

static curves
7Z67684
4E1
B (mT)
250
200
150
100
50
0
−2000
0
2000
4000
6000
8000
H (A/m)
25 °C
70 °C

Relative initial permeability as a function of the temperature

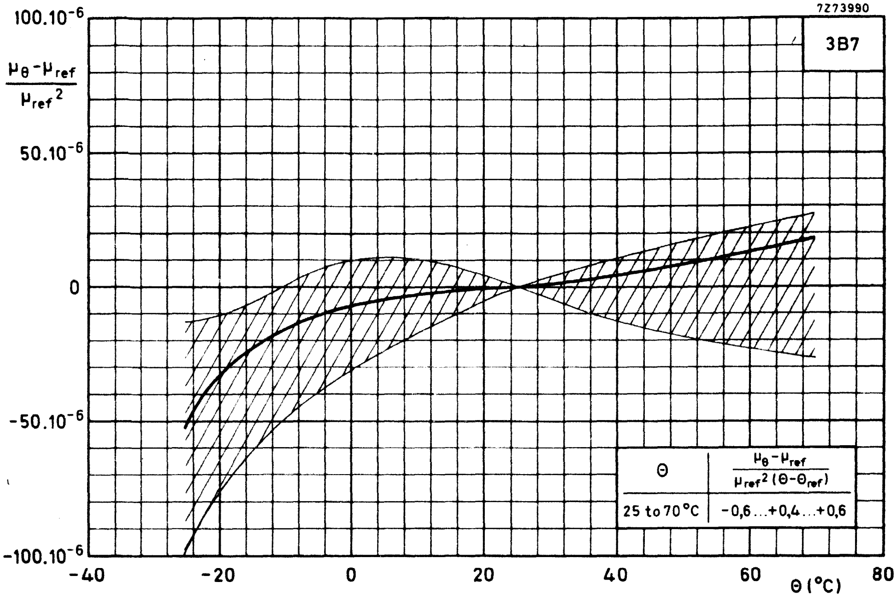




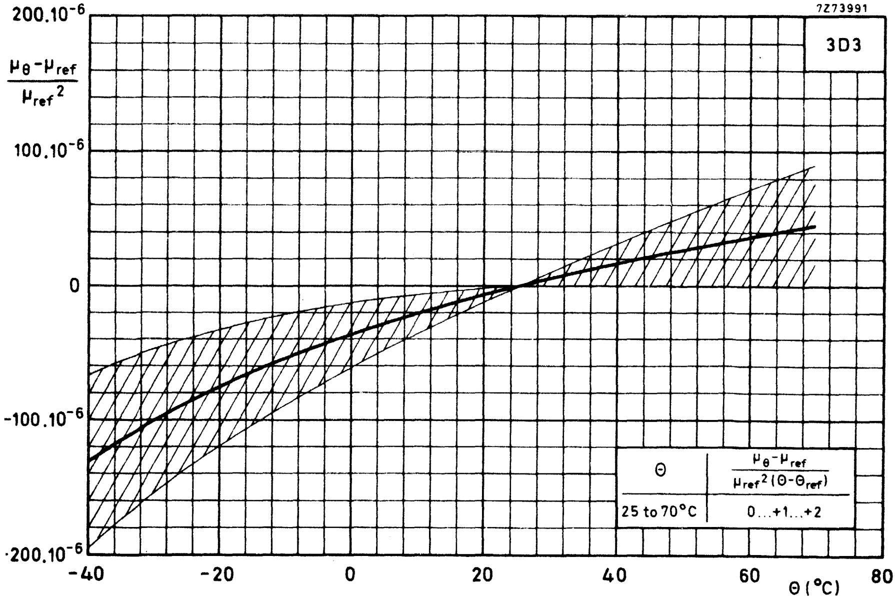

7Z67706
1000
μi
500
0
4A4
4B1
−50
0
50
100
θ (°C)


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

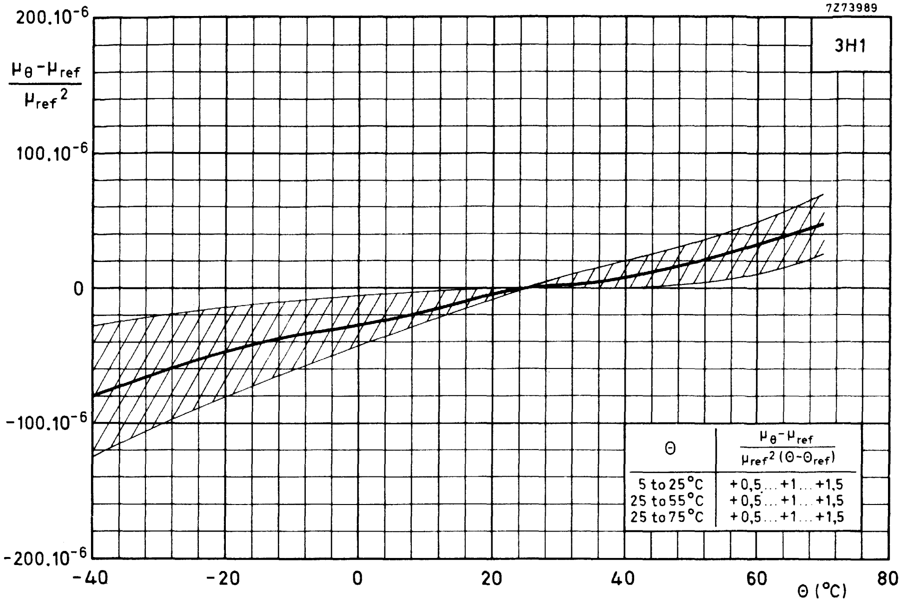
Permeability factor as a function of the temperature



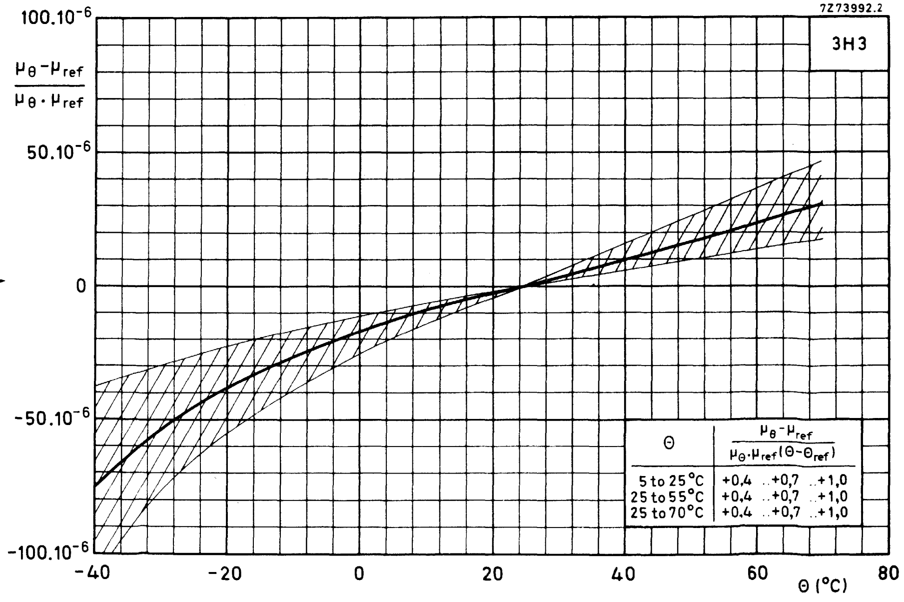
Θ	$\frac{\mu_\theta - \mu_{ref}}{\mu_{ref}^2 (\Theta - \Theta_{ref})}$
25 to 70 °C	−0,6 ... +0,4 ... +0,6



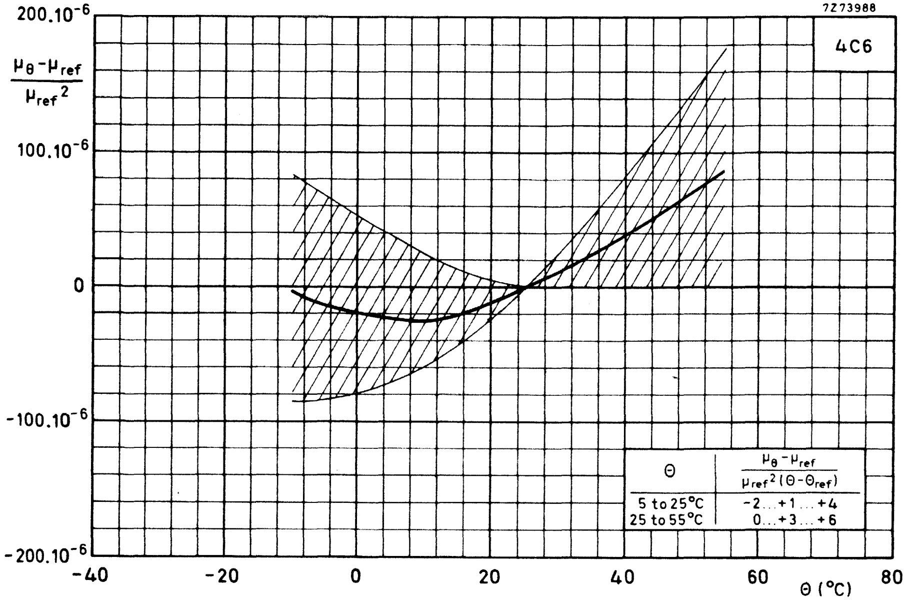
Θ	$\frac{\mu_\theta - \mu_{ref}}{\mu_{ref}^2 (\Theta - \Theta_{ref})}$
25 to 70 °C	0 ... +1 ... +2



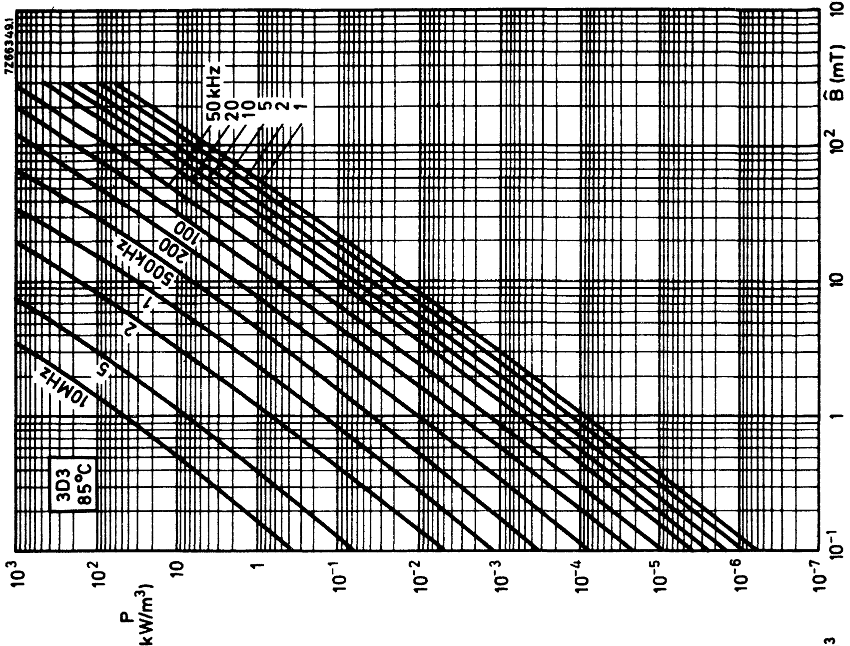
Θ	$\frac{\mu_\theta-\mu_{ref}}{\mu_{ref}^2(\Theta-\Theta_{ref})}$
5 to 25°C	+0,5 ... +1 ... +1,5
25 to 55°C	+0,5 ... +1 ... +1,5
25 to 75°C	+0,5 ... +1 ... +1,5

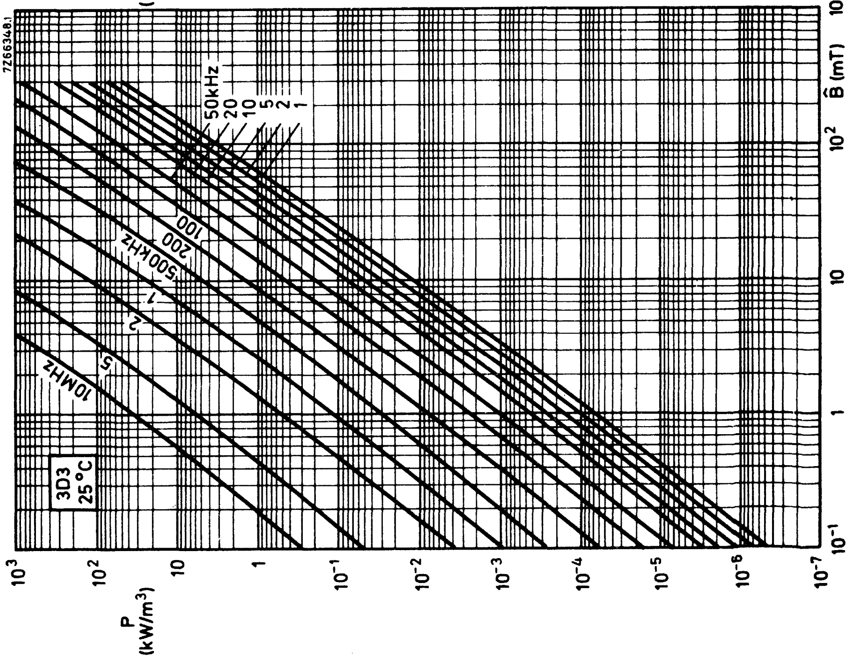


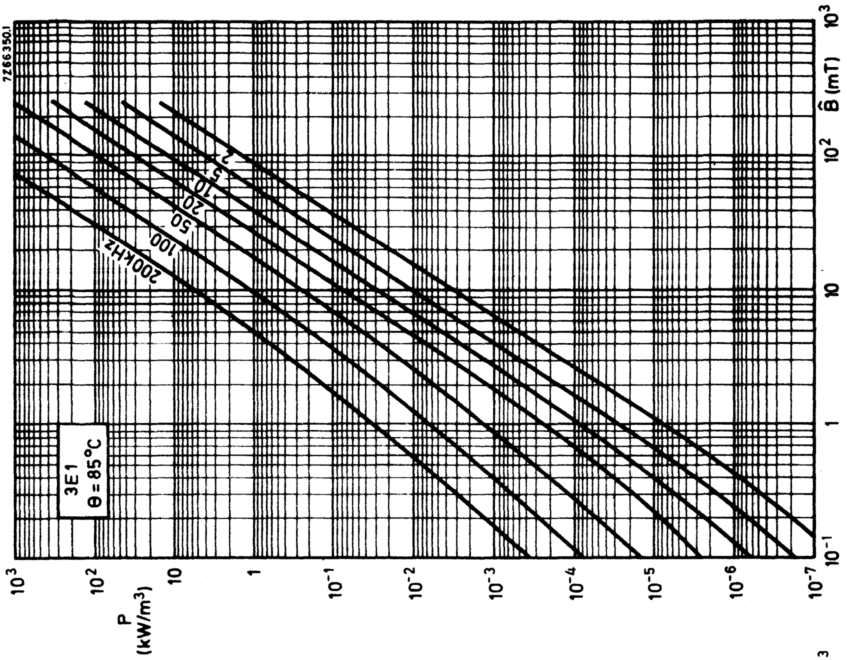
Θ	$\frac{\mu_\theta-\mu_{ref}}{\mu_\Theta \cdot \mu_{ref}(\Theta-\Theta_{ref})}$
5 to 25°C	+0,4 ..+0,7 ..+1,0
25 to 55°C	+0,4 ..+0,7 ..+1,0
25 to 70°C	+0,4 ..+0,7 ..+1,0

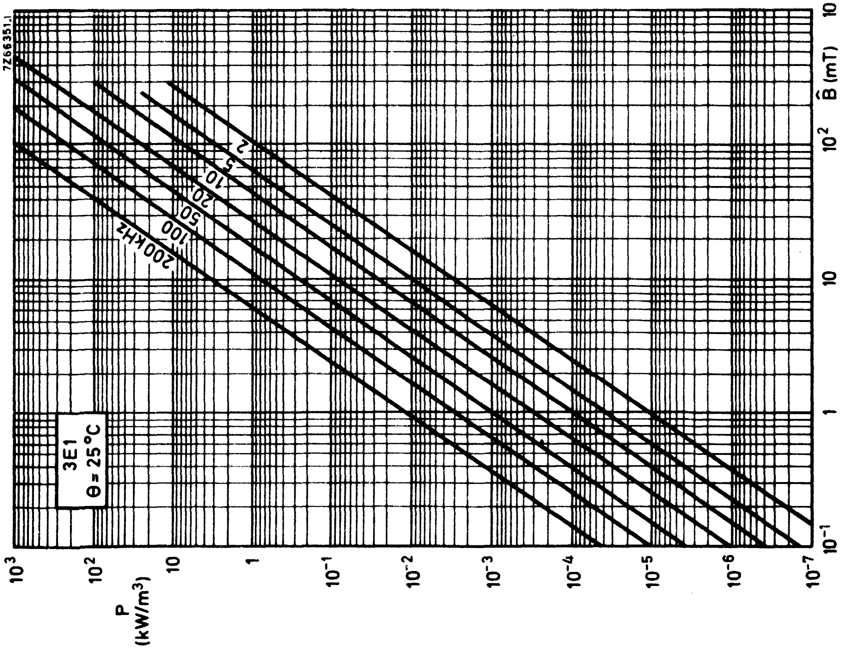

7Z73988
4C6
$\frac{\mu_\theta - \mu_{ref}}{\mu_{ref}^2}$
200.10^{-6}
100.10^{-6}
0
-100.10^{-6}
-200.10^{-6}
-40
-20
0
20
40
60
80
Θ (°C)
Θ
$\frac{\mu_\theta - \mu_{ref}}{\mu_{ref}^2(\Theta - \Theta_{ref})}$
5 to 25°C
-2 ... +1 ... +4
25 to 55°C
0 ... +3 ... +6

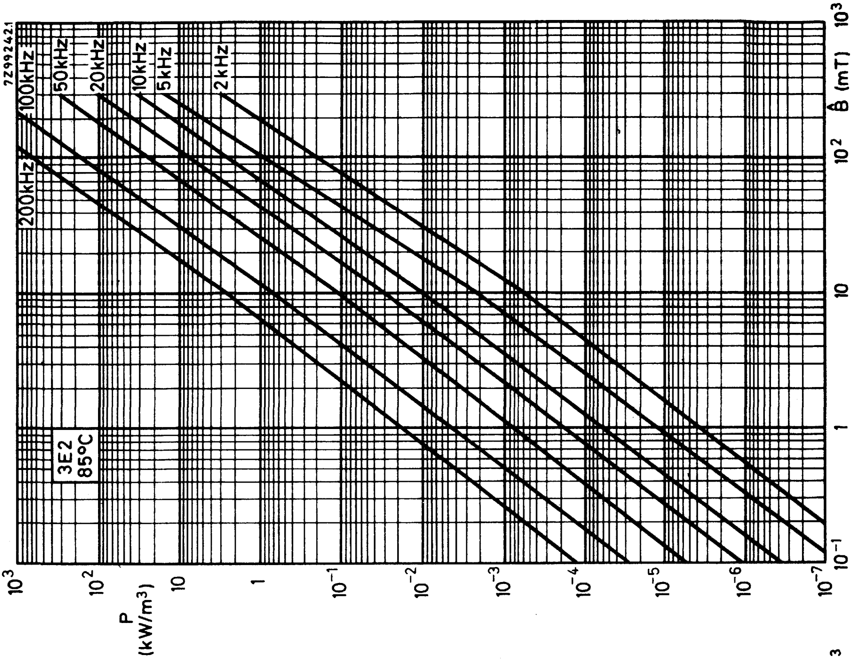
Power loss as a function of the induction

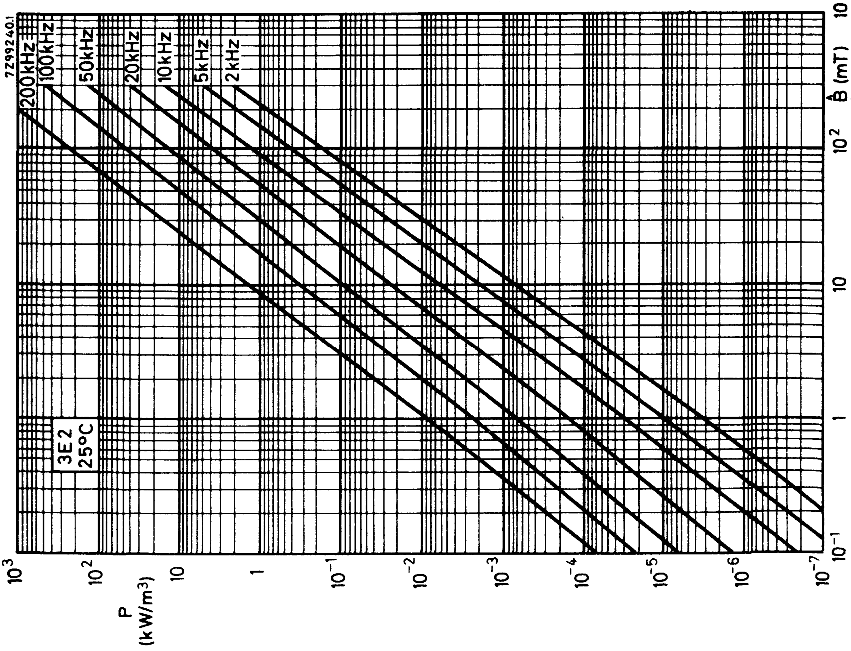


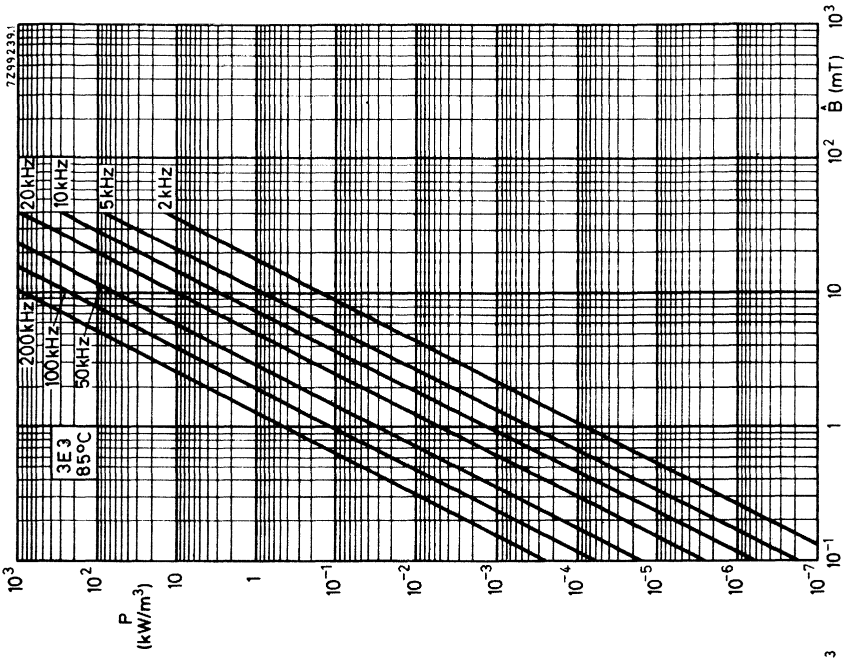


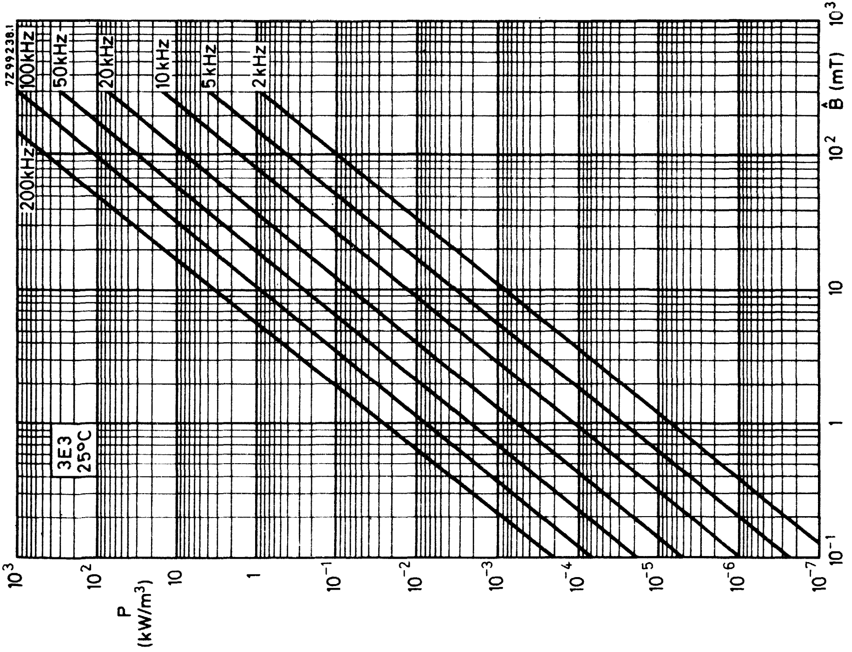

7Z66350.1
3E1
θ = 85°C
200 kHz
100
50
20
10
5
2
P (kW/m³)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
B̂ (mT)
10^{-1}
1
10
10^2
10^3

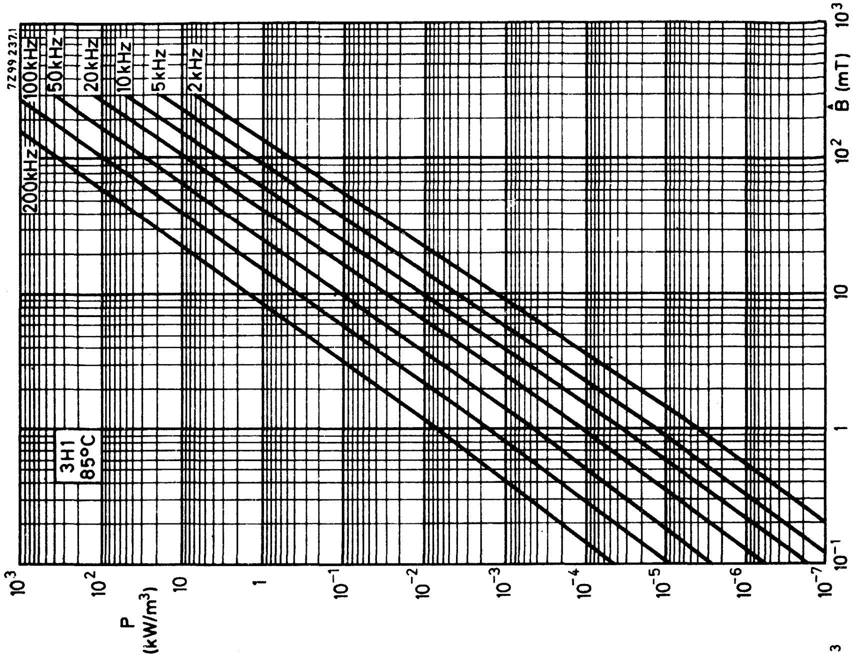

7Z66351.1
3E1
θ = 25°C
200 kHz
100
50
20
10
5
2
P (kW/m³)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
B̂ (mT)
10^{-1}
1
10
10^2
10^3

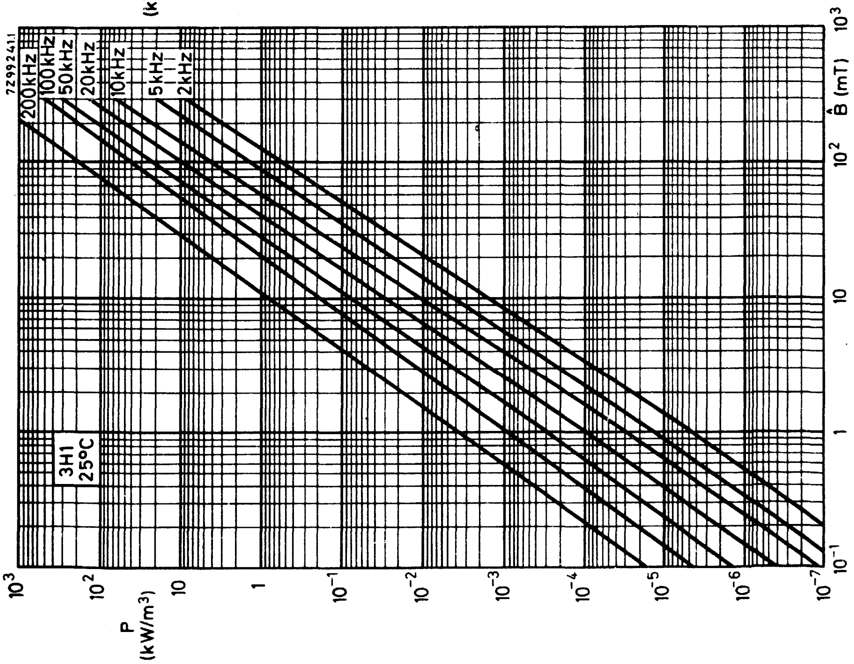

7Z99242.1
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
200kHz
3E2
85°C
$\hat{B}$ (mT)
10^3
10^2
10
1
10^{-1}
P
(kW/m^3)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}

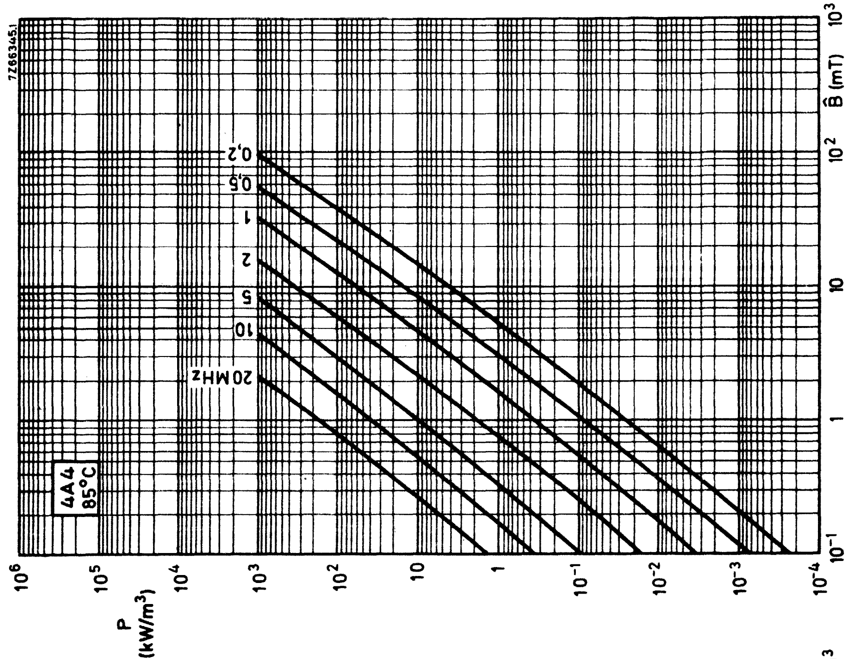

7Z99240.1
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
3E2
25°C
$\hat{B}$ (mT)
10^3
10^2
10
1
10^{-1}
P
(kW/m^3)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}

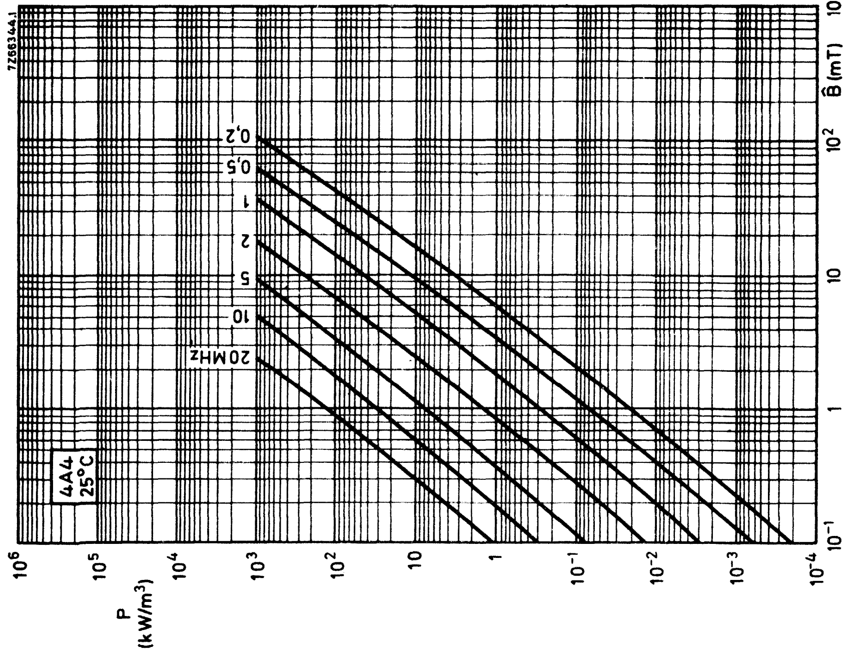

7Z99239.1
3E3
85°C
20kHz
10kHz
5kHz
2kHz
200kHz
100kHz
50kHz
P
(kW/m^3)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
$\hat{B}$ (mT)
10^{-1}
1
10
10^2
10^3

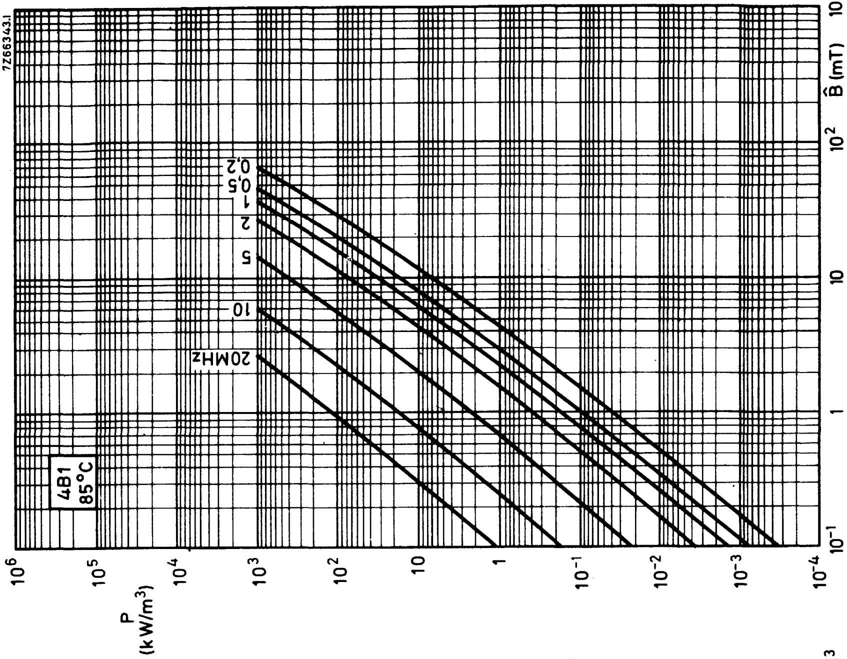

7Z99238.1
3E3
25°C
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
200kHz
P
(kW/m^3)
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
$\hat{B}$ (mT)
10^{-1}
1
10
10^2
10^3

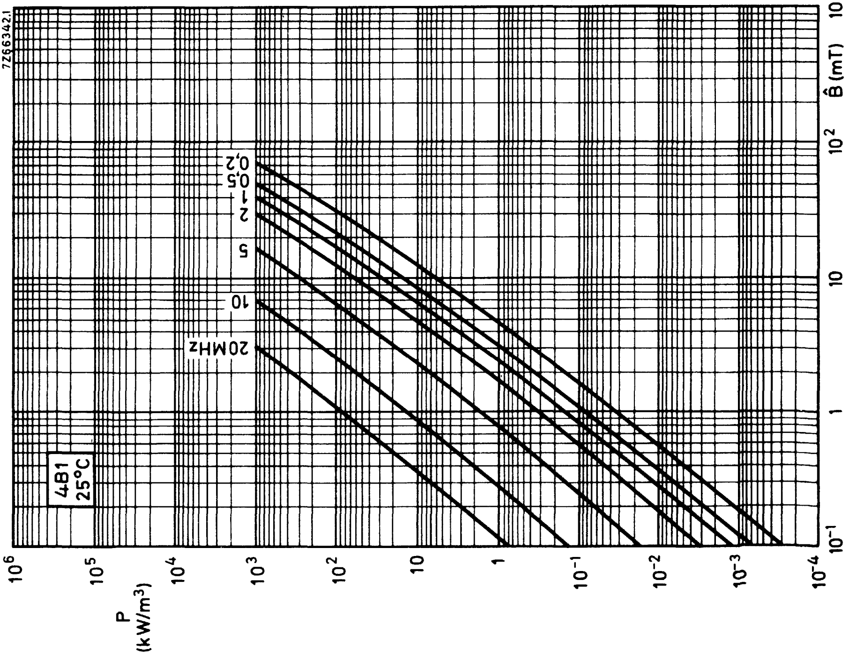

7Z99237.1
3H1
85°C
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
P
(kW/m³)
10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
B̂ (mT)
10⁻¹
1
10
10²
10³

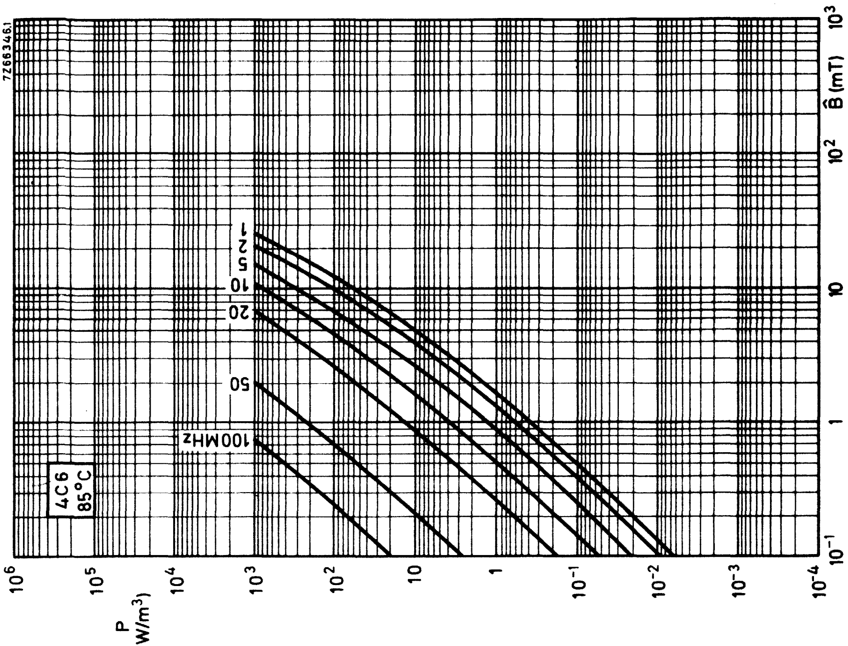

7Z99241.1
3H1
25°C
200kHz
100kHz
50kHz
20kHz
10kHz
5kHz
2kHz
P
(kW/m³)
10³
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
B̂ (mT)
10⁻¹
1
10
10²
10³

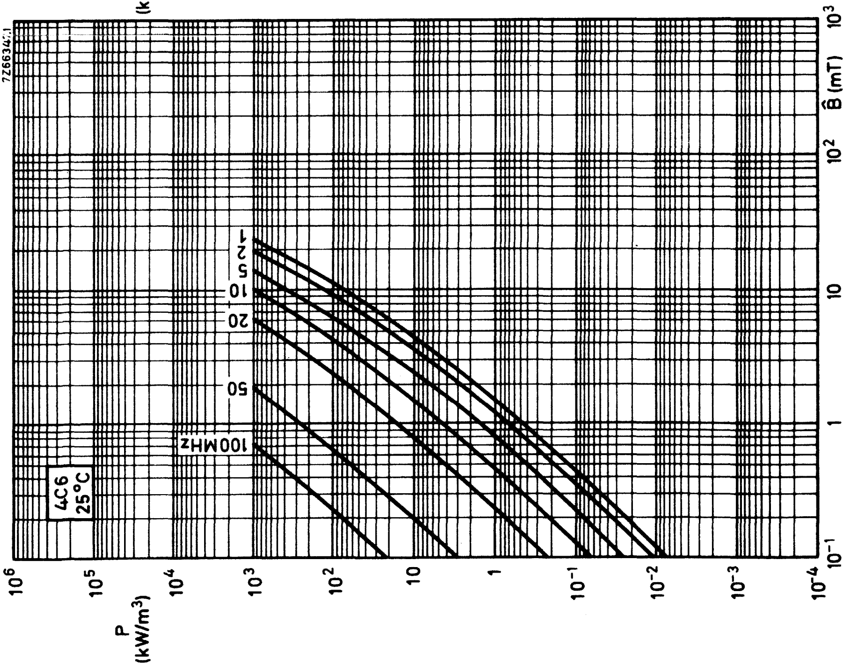

7Z86345.1
4A4
85°C
0,2
0,5
1
2
5
10
20 MHz
$\hat{B}$ (mT)
10^{-1}
1
10
10^2
10^3
P
(kW/m^3)
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}


7Z86344.1
4A4
25°C
0,2
0,5
1
2
5
10
20 MHz
$\hat{B}$ (mT)
10^{-1}
1
10
10^2
10^3
P
(kW/m^3)
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}

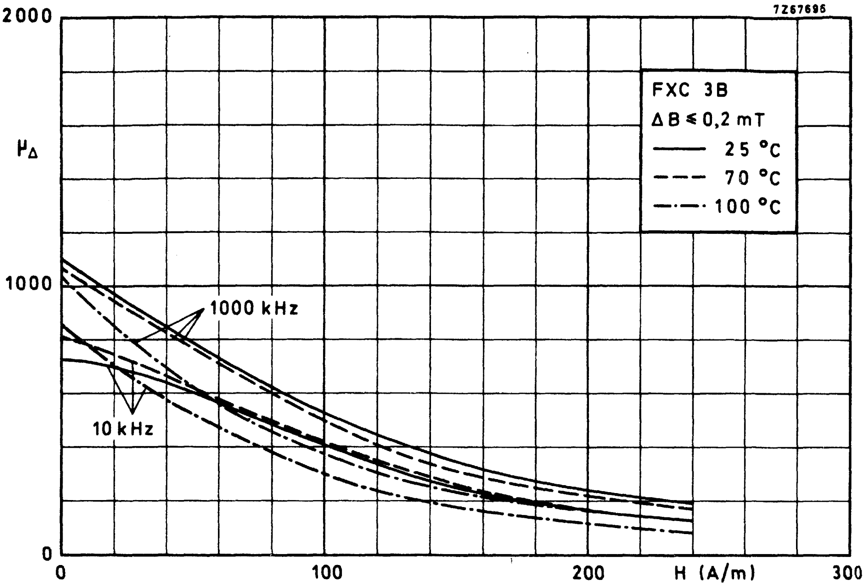

7Z66343.1
4B1
85°C
0,2
0,5
1
2
5
10
20MHz
B̂ (mT)
10^3
10^2
10
1
10^-1
P
(kW/m^3)
10^6
10^5
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4

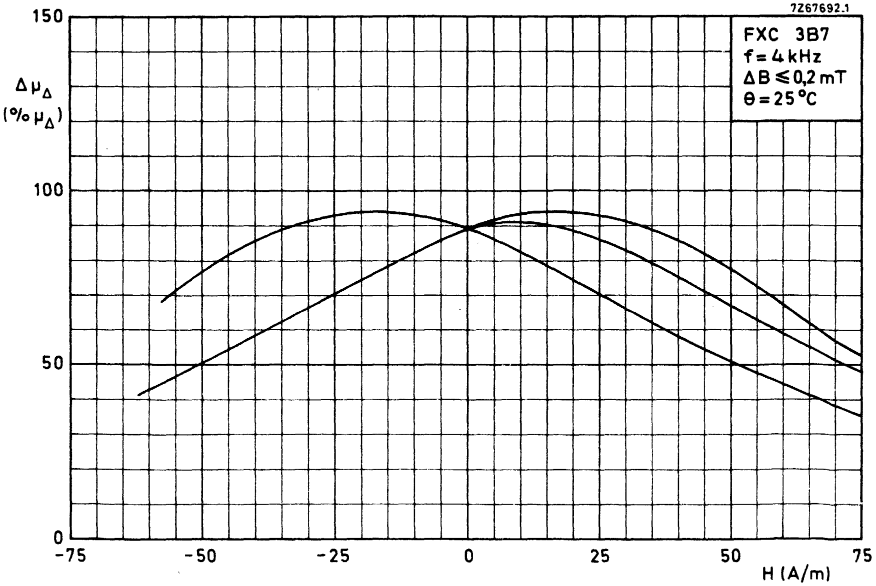

7Z66342.1
4B1
25°C
0,2
0,5
1
2
5
10
20MHz
B̂ (mT)
10^3
10^2
10
1
10^-1
P
(kW/m^3)
10^6
10^5
10^4
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4


7Z66346.1
4C6
85°C
100 MHz
50
20
10
5
2
1
P
(kW/m^3)
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\hat{B}$ (mT)
10^{-1}
1
10
10^2
10^3


7Z66347.1
4C6
25°C
100 MHz
50
20
10
5
2
1
P
(kW/m^3)
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\hat{B}$ (mT)
10^{-1}
1
10
10^2
10^3

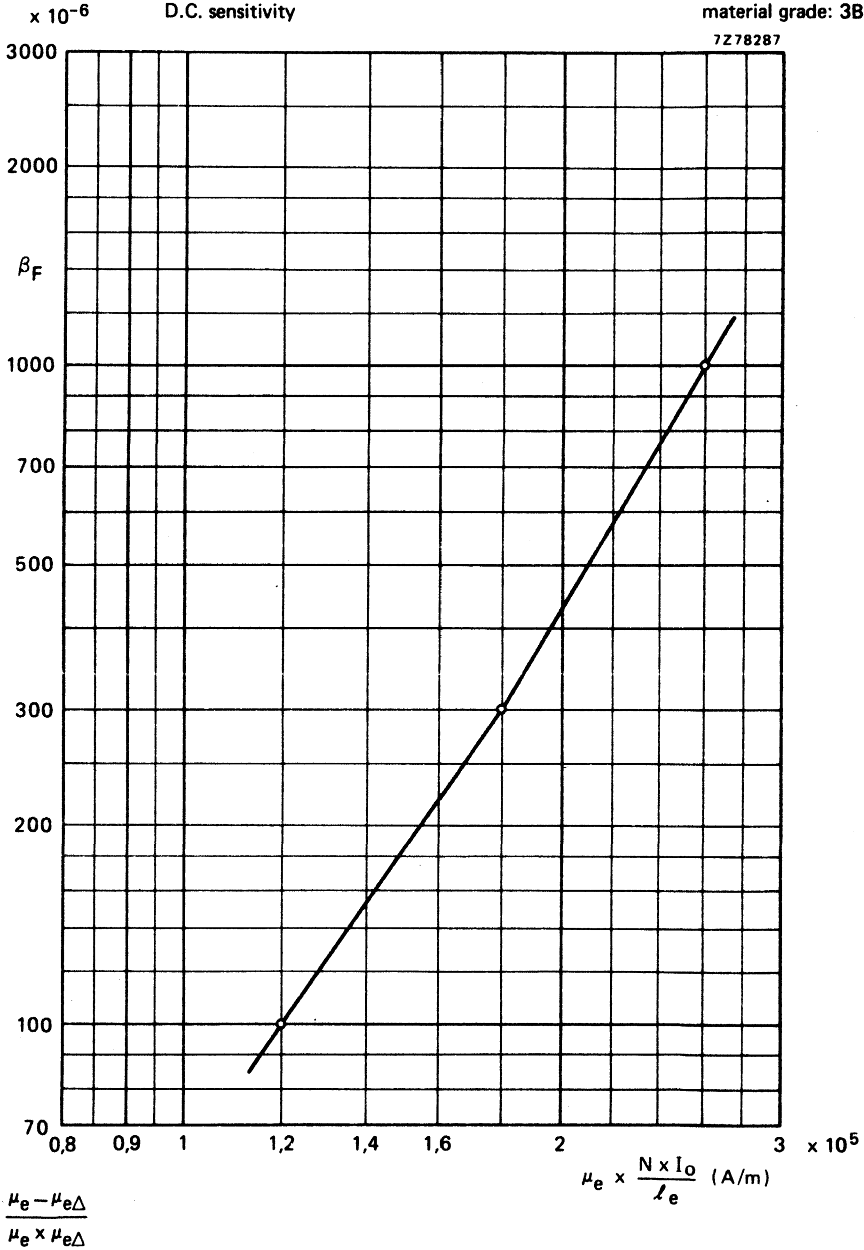
Incremental permeability as a function of the field strength





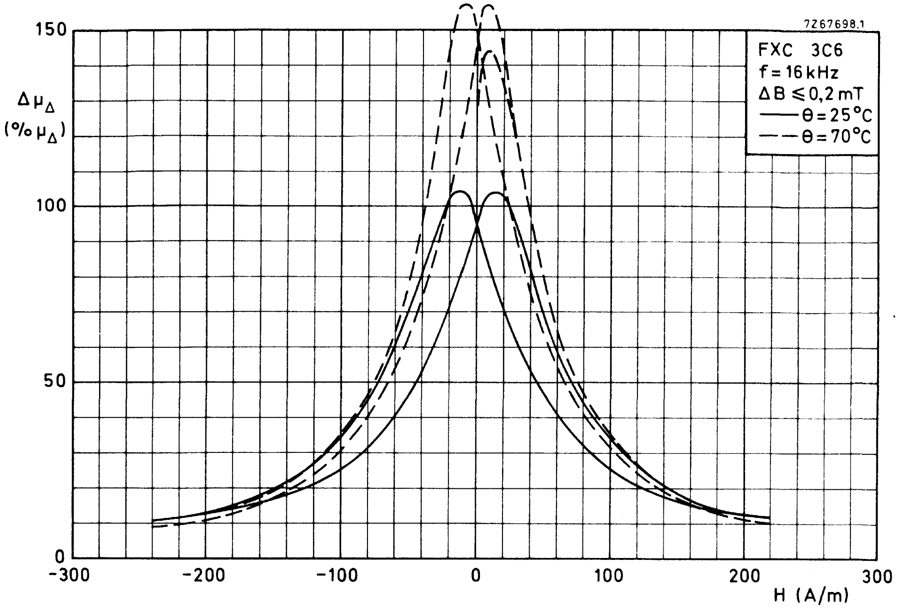
D.C. sensitivity

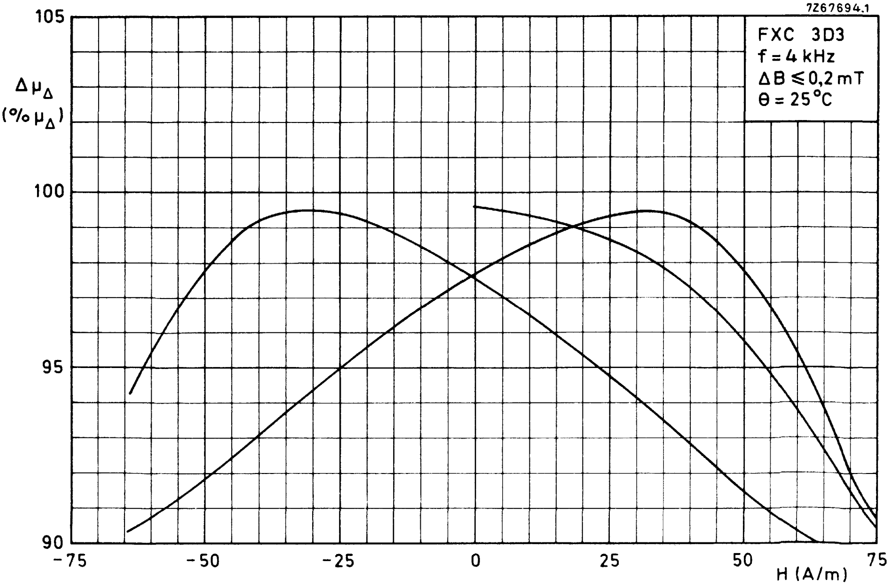
material grade: 3B8

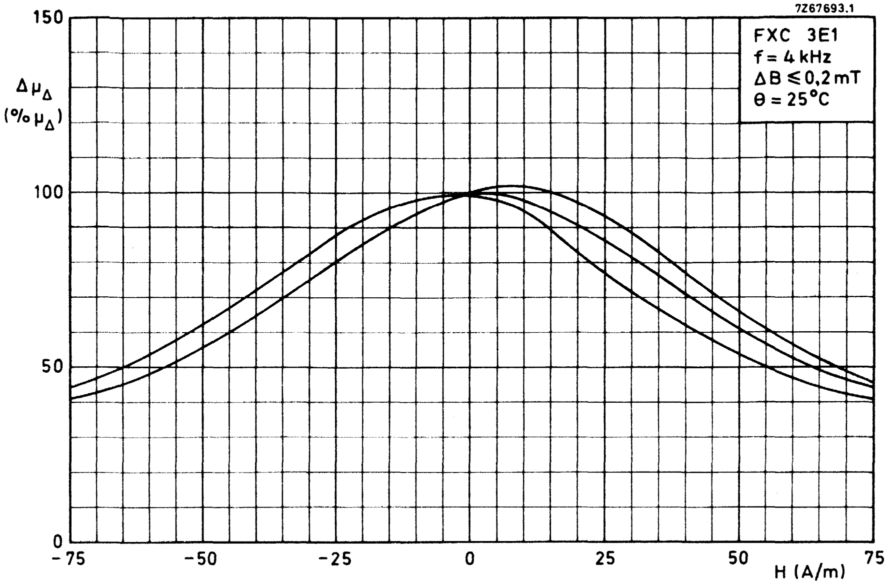


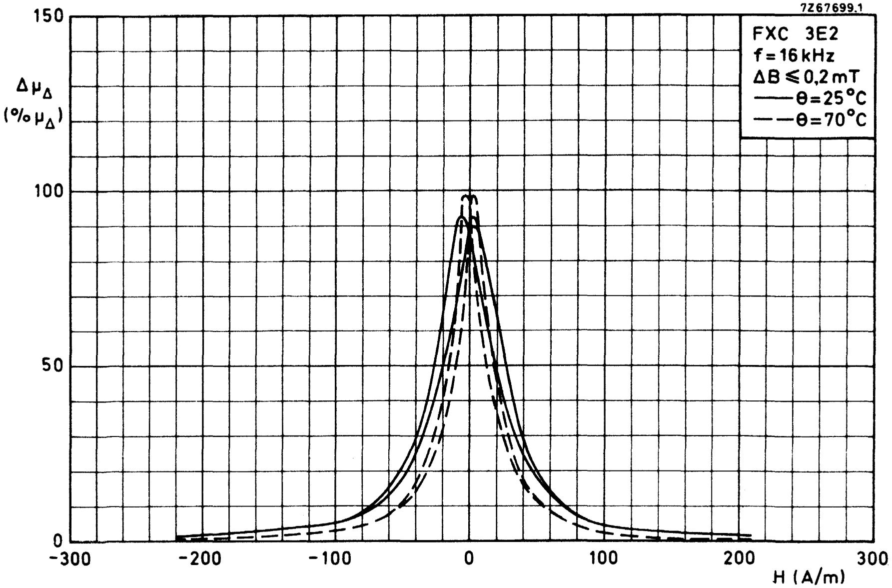
$$\beta_F = \frac{\mu_e - \mu_{e\Delta}}{\mu_e \times \mu_{e\Delta}}$$

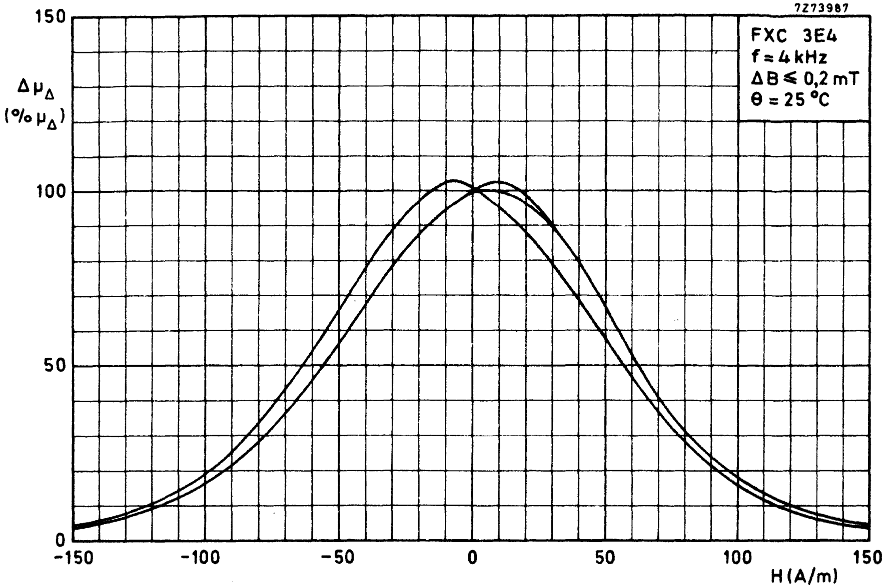
Inductance variation as a function of d.c. polarization. The measured values are situated in the area to the right of the curve.

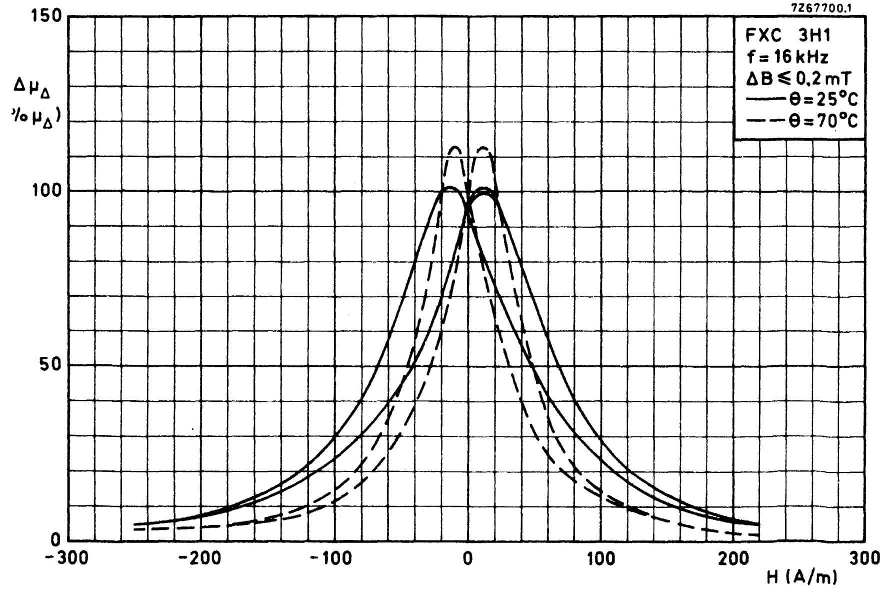

7Z67698.1
FXC 3C6
f = 16 kHz
ΔB ≤ 0,2 mT
θ = 25°C
θ = 70°C
Δμ_Δ
(% μ_Δ)
150
100
50
0
−300
−200
−100
0
100
200
300
H (A/m)

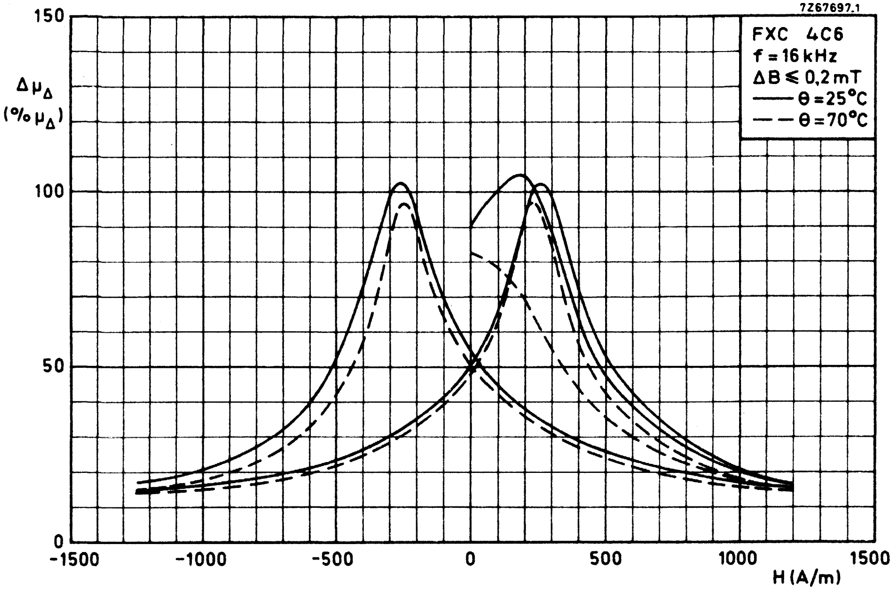

7Z67694.1
FXC 3D3
f = 4 kHz
ΔB ≤ 0,2 mT
θ = 25°C
Δμ_Δ
(% μ_Δ)
105
100
95
90
−75
−50
−25
0
25
50
75
H (A/m)

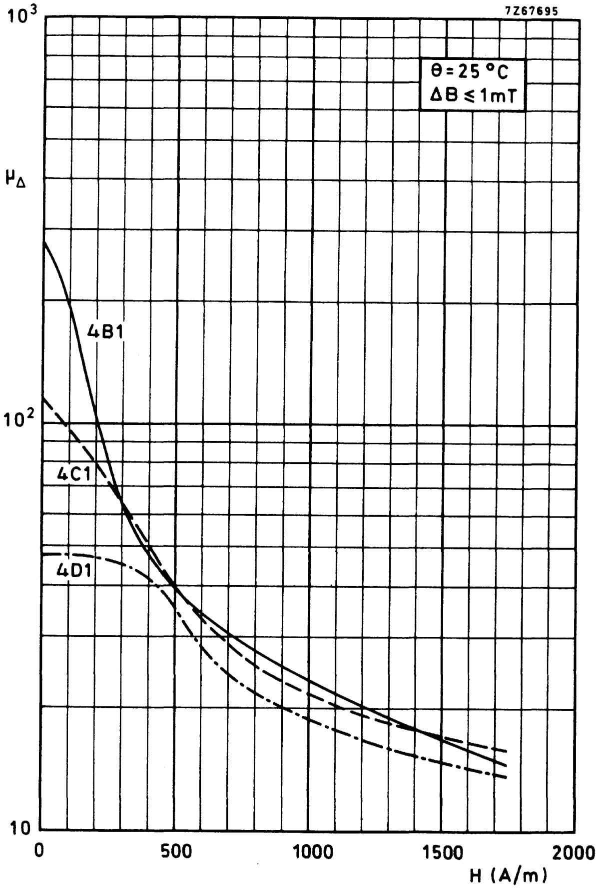

7Z67693.1
FXC 3E1
f = 4 kHz
ΔB ≤ 0,2 mT
θ = 25°C
Δμ_Δ (% μ_Δ)
150
100
50
0
−75
−50
−25
0
25
50
75
H (A/m)


7Z67699.1
FXC 3E2
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)


7Z73987
FXC 3E4
f = 4 kHz
ΔB ≤ 0,2 mT
θ = 25 °C
Δμ_Δ
(% μ_Δ)
150
100
50
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)
150
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
μ_Δ
10^3
10^2
10
4B1
4C1
4D1
0
500
1000
1500
2000
H (A/m)

YOKE RINGS

B

YOKE RINGS FOR USE IN DEFLECTION COILS FOR PICTURE TUBES

Survey of types

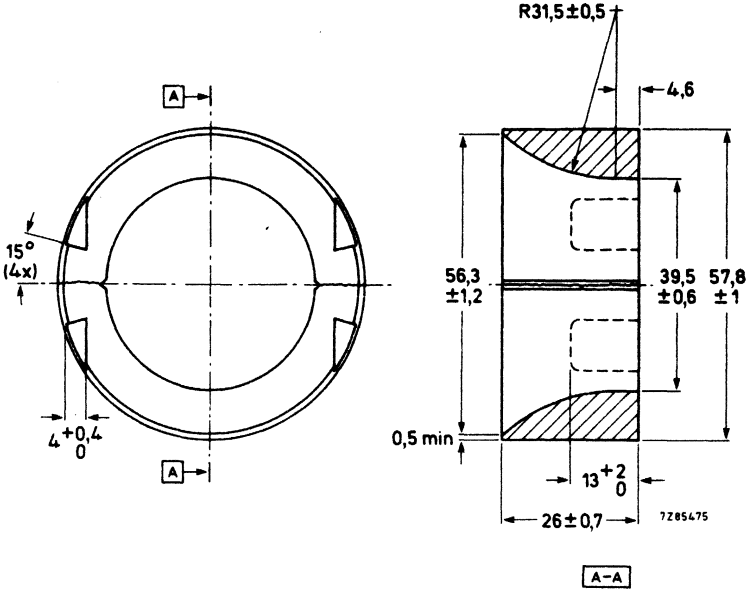
catalogue number	for tubes	FXC grade
3122 104 93840	110° B/W	3C2
3122 134 91940	110° B/W	2A2
3122 134 91280	110° B/W Tiny Vision	2A2
3122 134 90750	110° B/W	3C2
3122 134 91680	90° B/W Tiny Vision	2A2
3122 134 91610	90° Hybrid 20" colour	2A2
3122 134 91440	90° Hybrid 14-16-18" colour	2A2
3122 134 91620	110° 20-22-26" 30AX colour	3C2
3122 134 92270	110° 20-22-26" 30AX colour	3C2
3122 134 92140	90° 20" colour	2A2
3122 134 92230	90° Hybrid 14-16-18" colour	2A2

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.

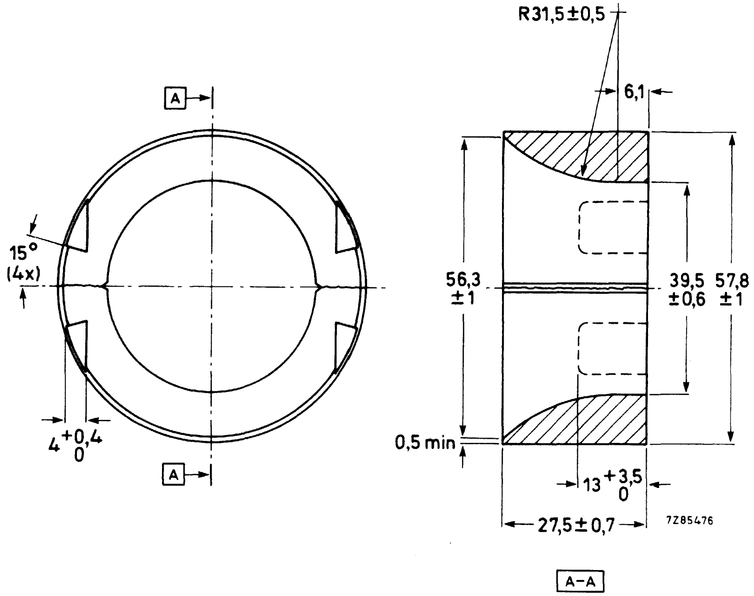
Dimensions in mm



YOKE RING FOR 110° B/W TUBES

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

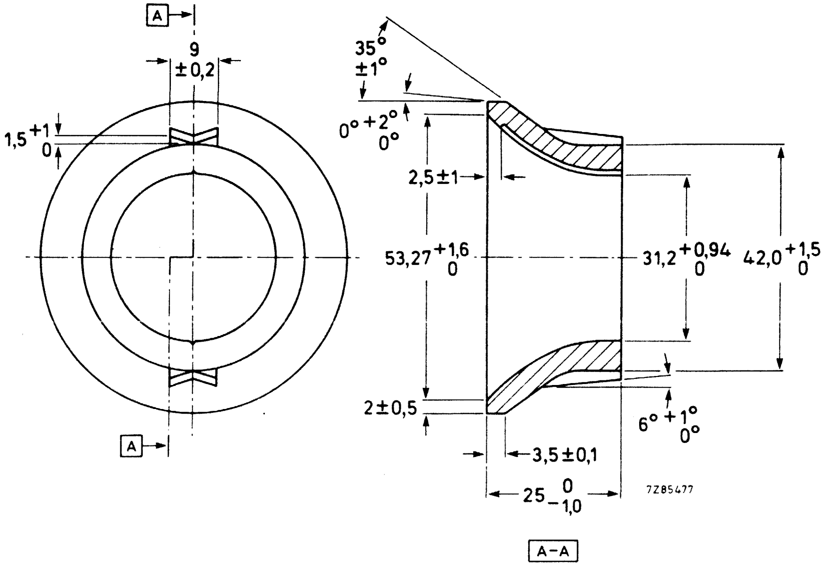
Dimensions in mm



YOKE RING FOR 110° B/W TINY VISION TUBES

● Material grade	FXC 2A2
● Mass	90 g
● Catalogue number	3122 134 91280

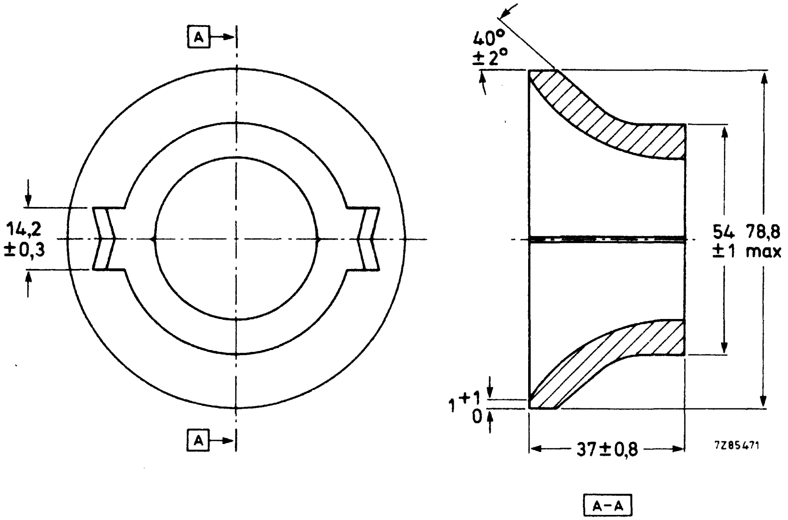
Dimensions in mm



YOKE RING FOR 110° B/W TUBES

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

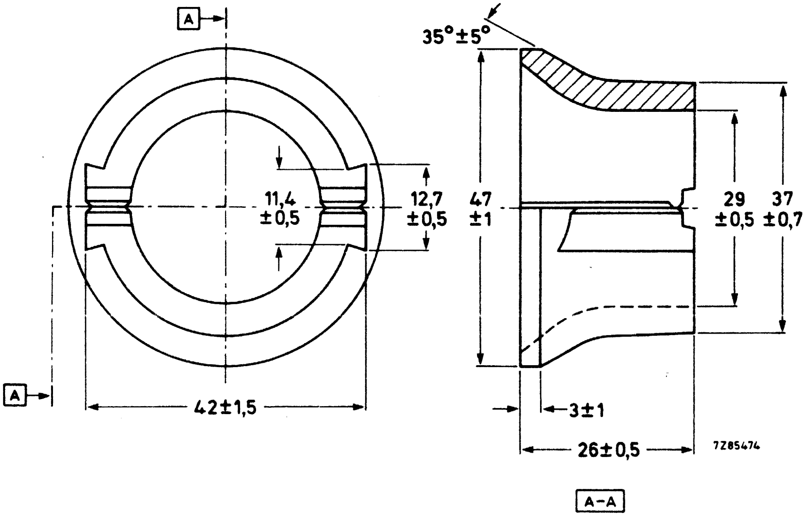
Dimensions in mm



YOKE RING FOR 90° B/W TINY VISION TUBES

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

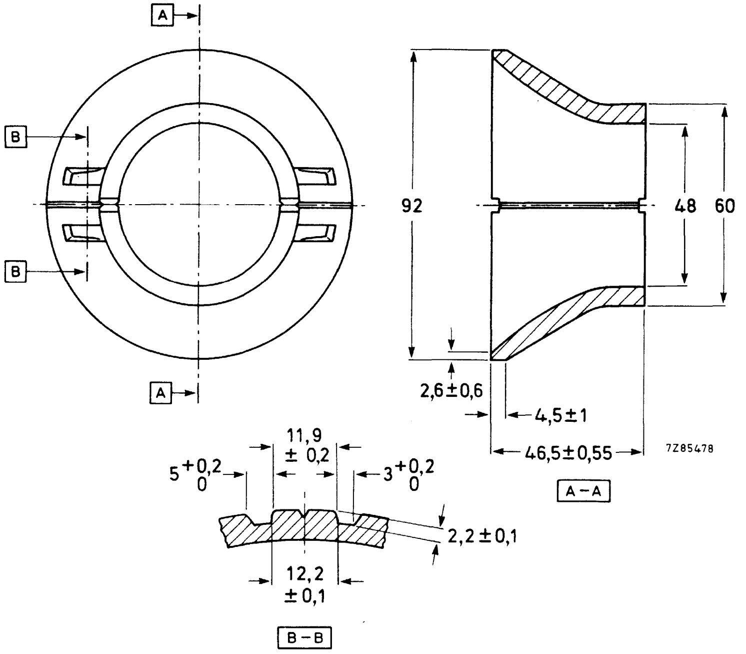
Dimensions in mm



YOKE RING FOR 90° HYBRID 20 INCH COLOUR TUBES

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

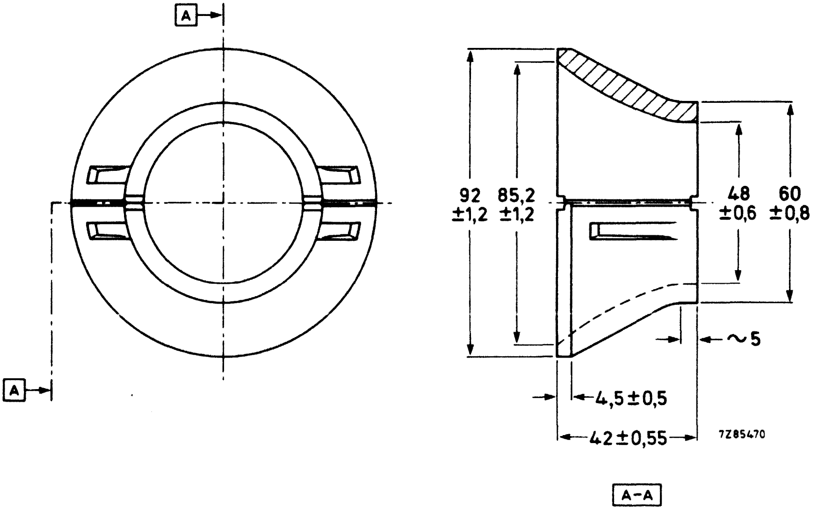
Dimensions in mm



YOKE RING FOR HYBRID 90° 14, 16, 18 INCH COLOUR TUBES

● Material grade	FXC 2A2
● Mass	268 g
● Catalogue number	3122 134 91440

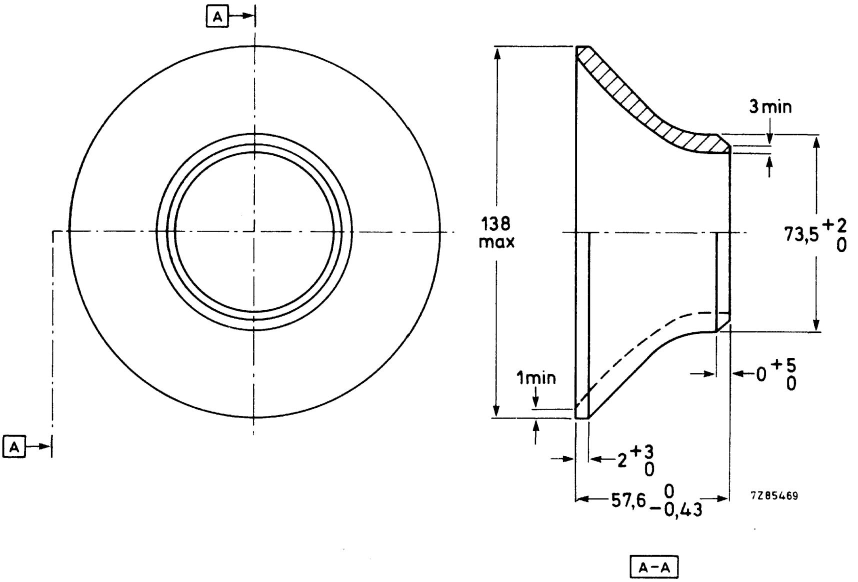
Dimensions in mm



YOKE RINGS FOR 20, 22, 26 INCH 110° COLOUR TUBES
30AX SYSTEM

● Material grade	FXC 3C2
● Mass	530 g
● Catalogue numbers	3122 134 91620 standard in 3C2 3122 134 92270 silanated in 3C2

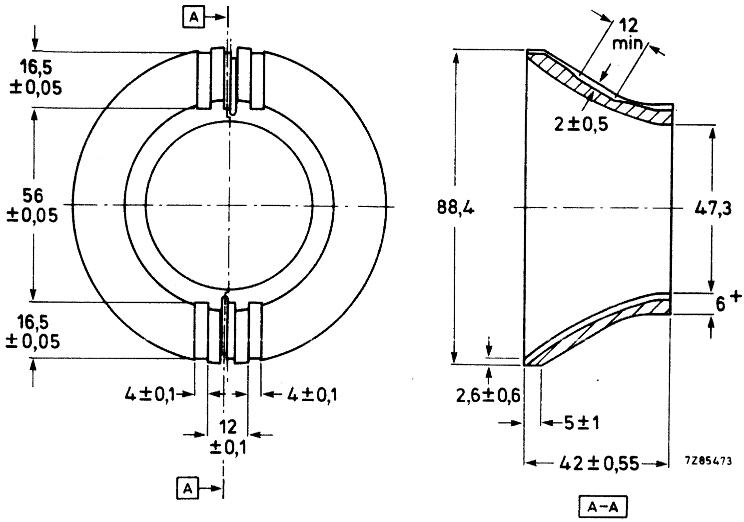
Dimensions in mm



YOKE RING FOR 20 INCH 90° COLOUR TUBES

- Material grade FXC 2A2
- Mass ~ 275 g
- Catalogue number 3122 134 92140

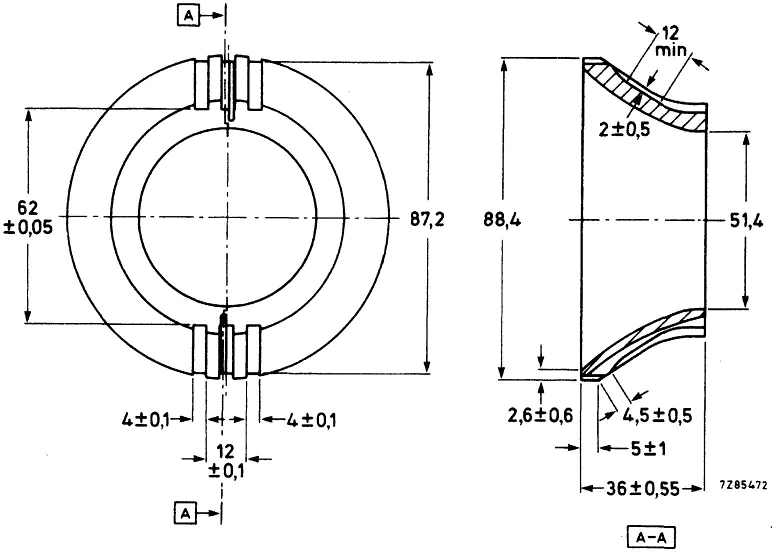
Dimensions in mm



YOKE RING FOR 90° HYBRID 14, 16, 18 INCH COLOUR TUBES

- Material grade FXC 2A2
- Mass ~ 275 g
- Catalogue number 3122 134 92230

Dimensions in mm



U/I/E/EC CORES C

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 given on pages C18 to C22.

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.

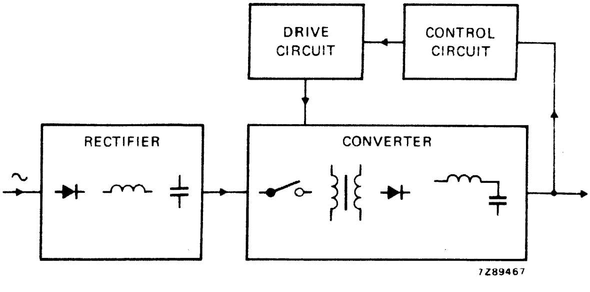


Fig. 1 Block diagram of switched-mode power supply.

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.

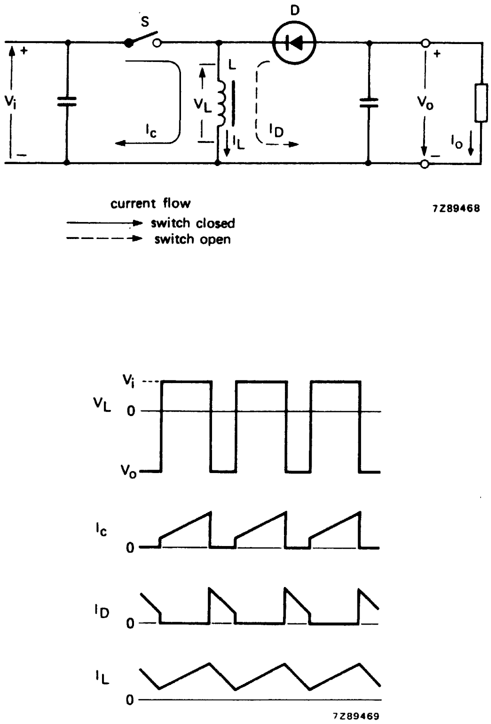


Fig. 2 Basic circuit of a flyback d.c. to d.c. converter with associated waveforms.

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.

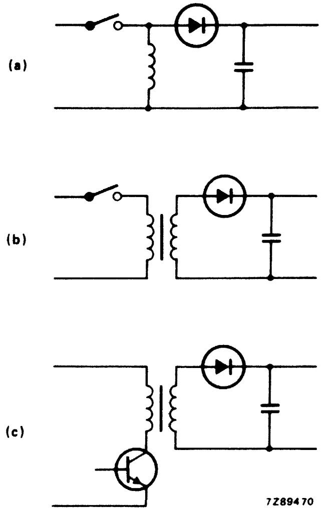


Fig. 3 Development of practical flyback converter circuit.

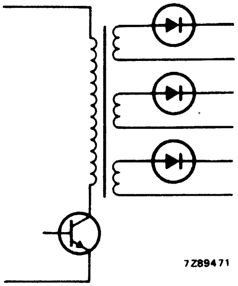


Fig. 4 Multiple output flyback converter circuit.

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.

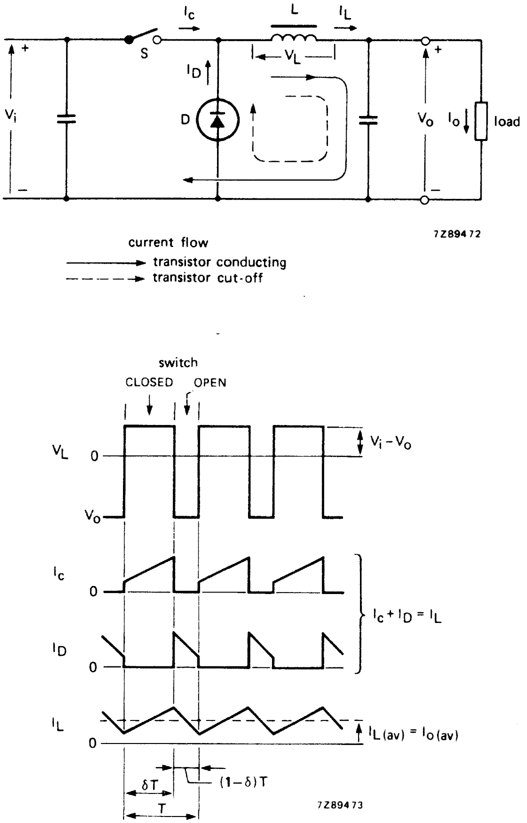


Fig. 5 Basic circuit of a forward d.c. to d.c. converter with associated waveforms.

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.

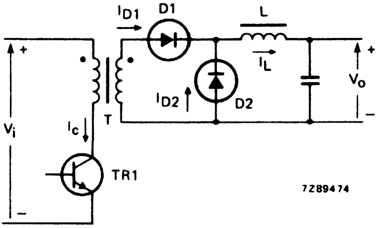


Fig. 6 Forward converter with line isolation transformer.

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.

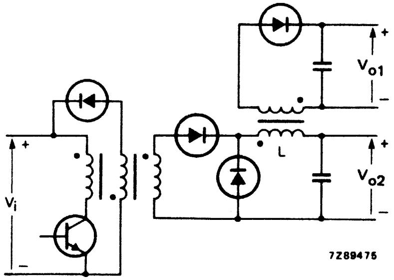
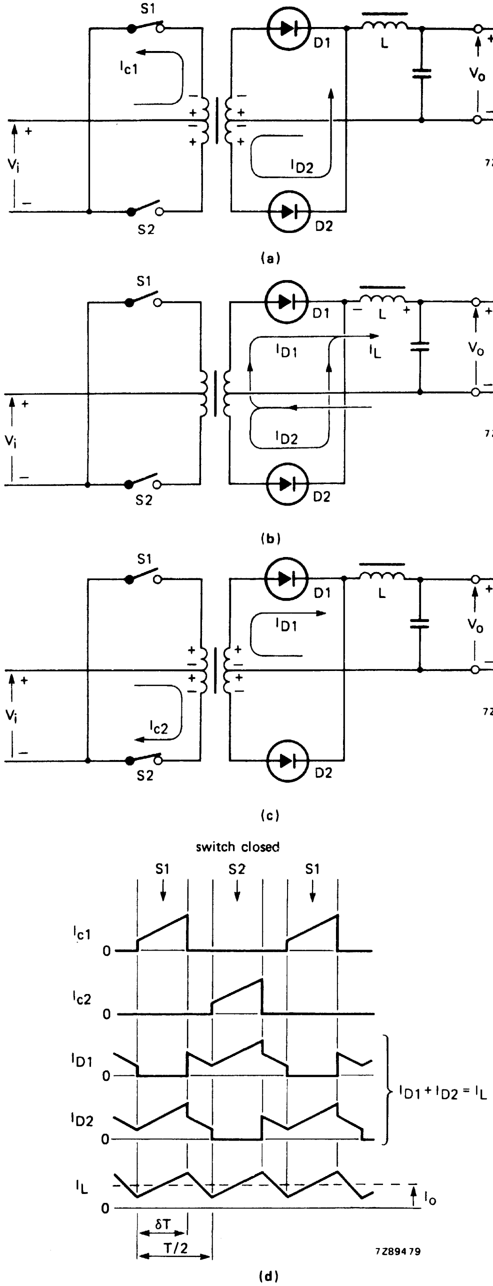


Fig. 7 Dual-output forward converter.



(a)

(b)

(c)

(d)

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).

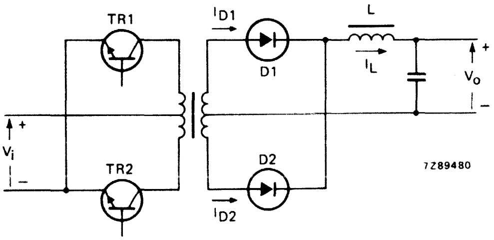
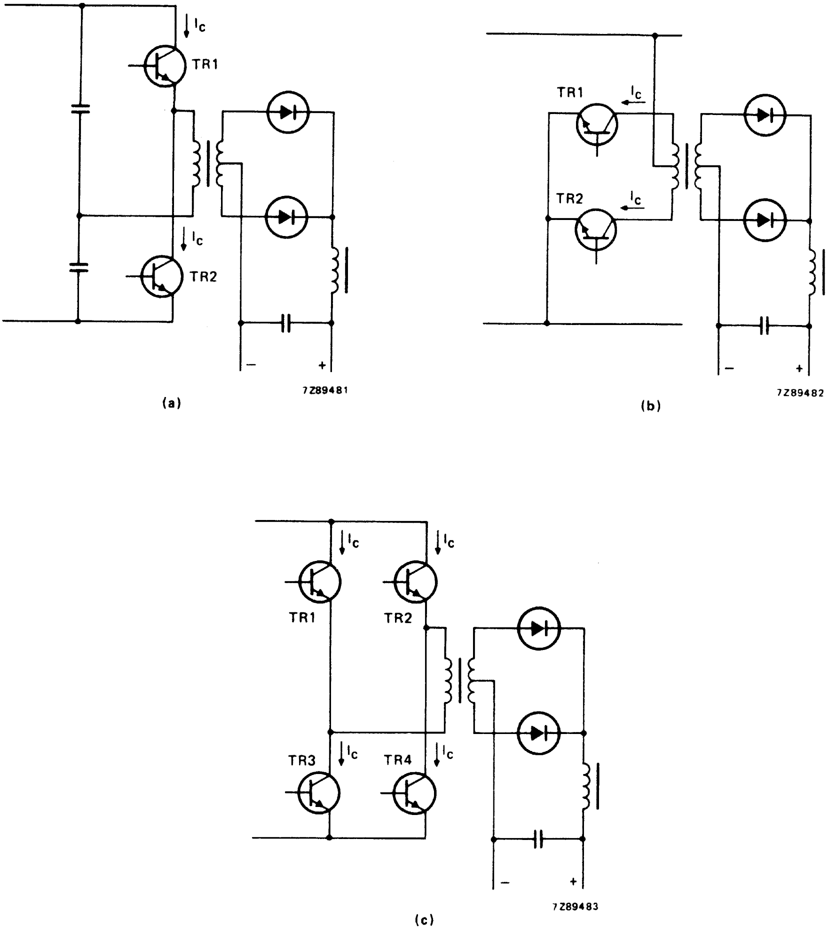


Fig. 9 Conventional push-pull converter circuit.

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.



(a)

(b)

(c)

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 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.

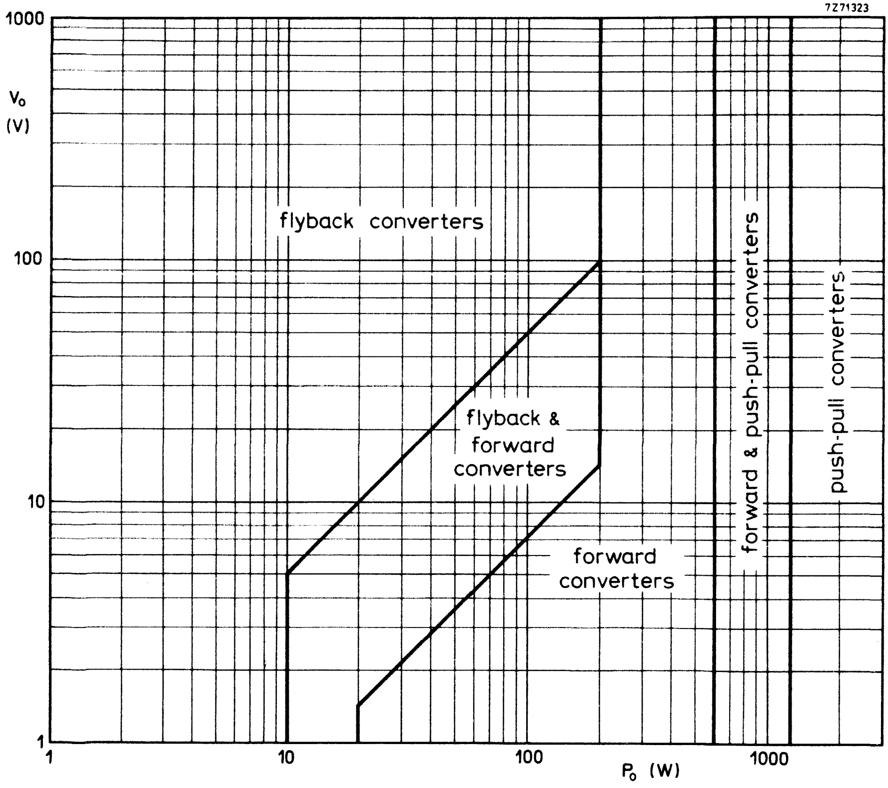


Fig. 11 Converter circuit selection as a function of output voltage and throughput power.

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

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 $\delta_{max} = 0{,}45$.

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 415 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.

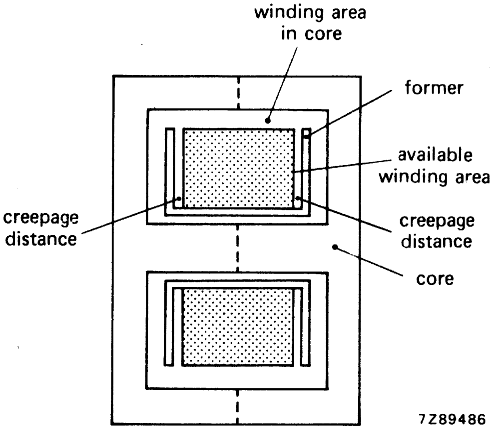


Fig. 12 To allow for creepage distance for 230 V mains isolation, a gap of 4 mm is left at each side of the winding.

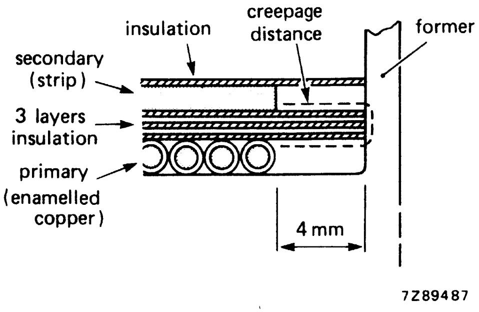


Fig. 13 Detailed section of winding showing how creepage distance is used.

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

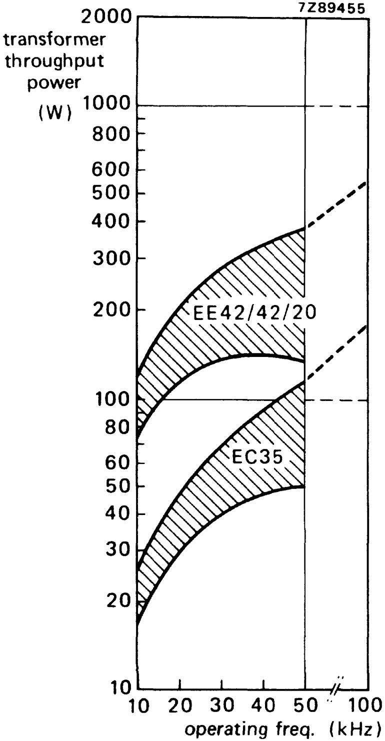
On the charts, each core type is represented by a shaded area. The upper limit of this area is a curve of throughput power against frequency obtainable under the best possible conditions: no creepage distance, thus maximum winding window; flux density reduced below that for $\alpha = 1{,}72$ at higher 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 a constant operating flux density at all frequencies so that α remains at 1,72.

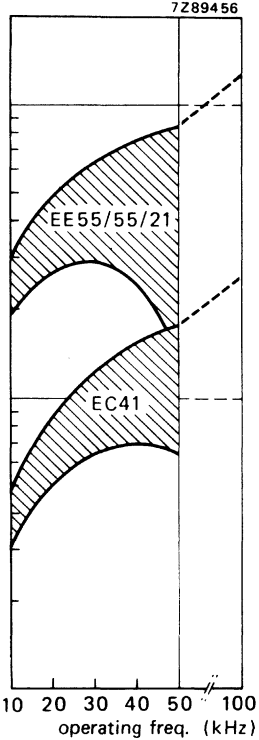
It is evident from the charts that some optimization of operating flux density is necessary for larger cores at higher frequencies.

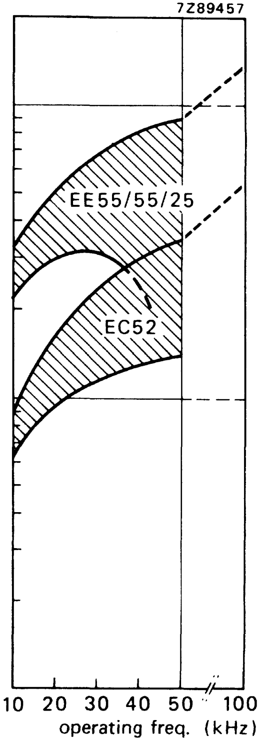
To select the best core for the application, draw a line on the chart for the desired converter type at the required throughput power. Possible cores for the transformer are those for which this power line is within or below the operating area at the desired operating frequency. The proximity of the core operating point to the upper boundary of its area will depend on the degree to which the design is to be elaborated. Where full mains isolation is required, cores should be operated about 25% below the upper limit, even where bunched conductors are to be used.

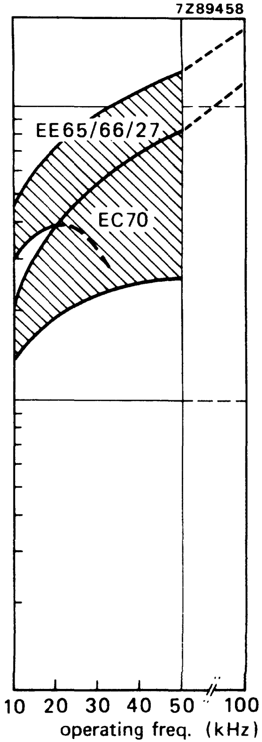
Selection charts

Forward converter SMPS $\alpha \geqslant 1,72$

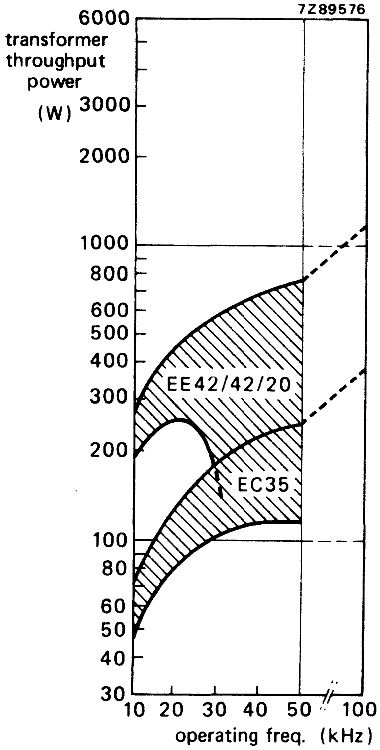


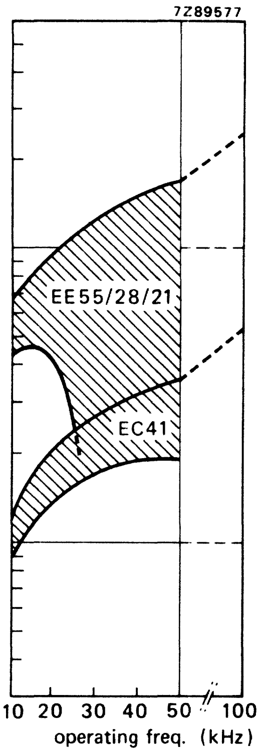


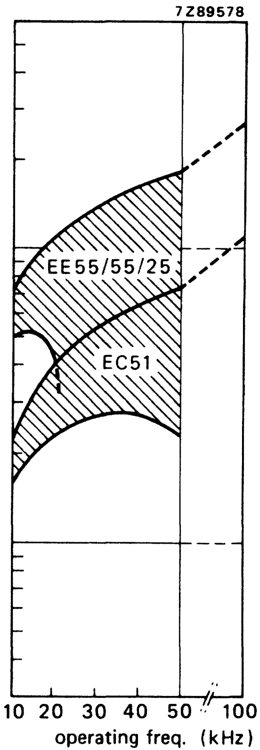


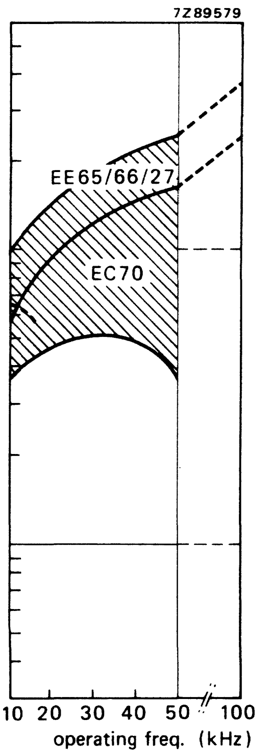


Balanced push-pull $\alpha \geqslant 1,72$

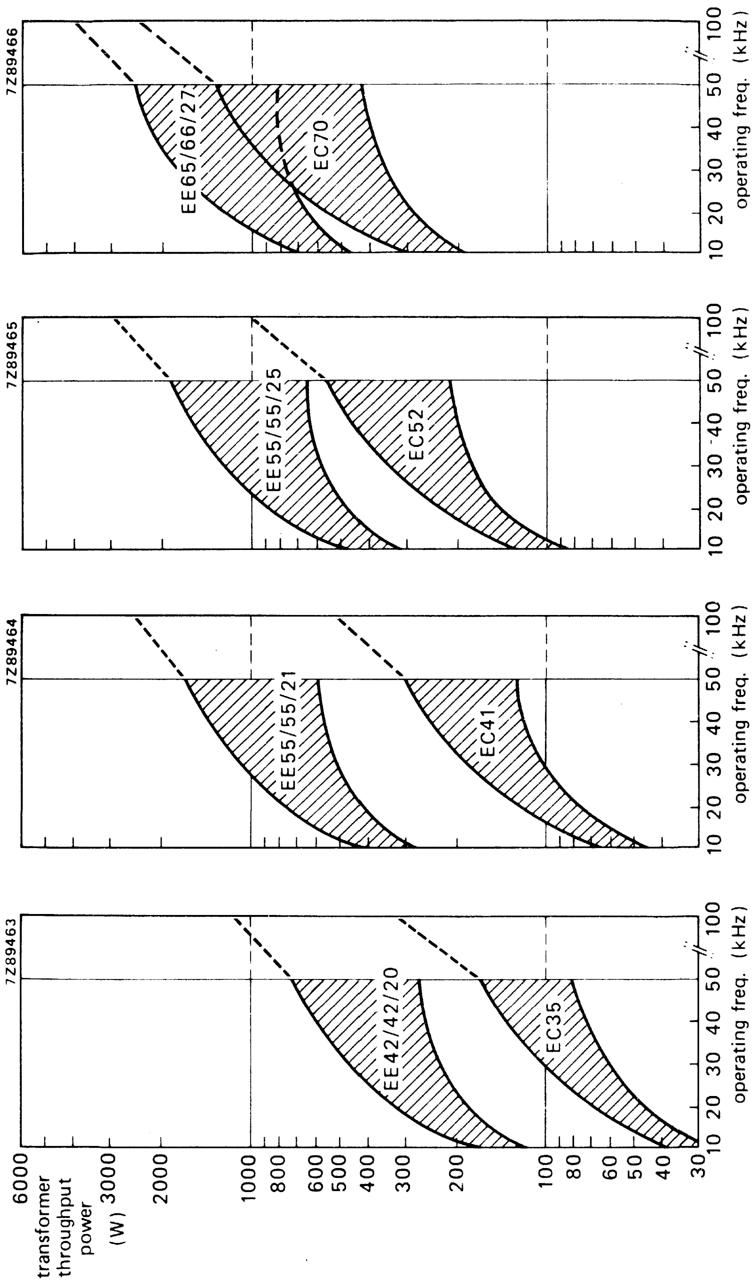




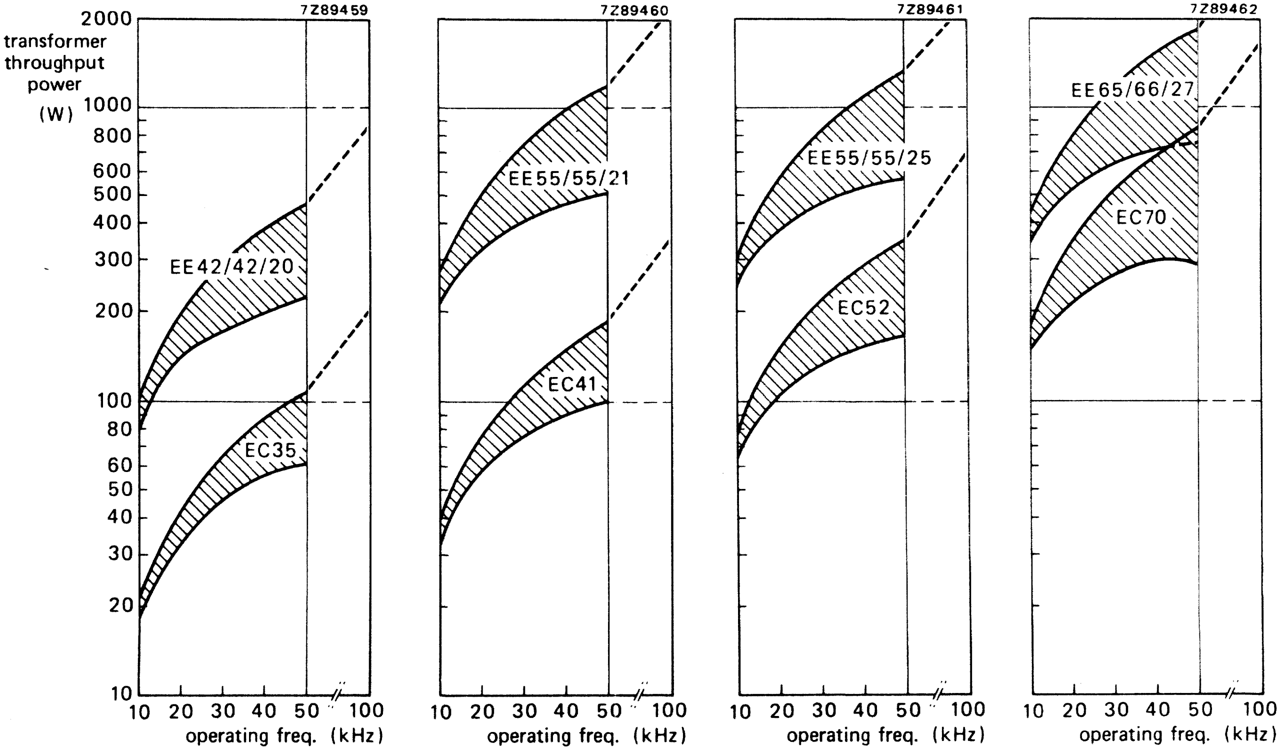




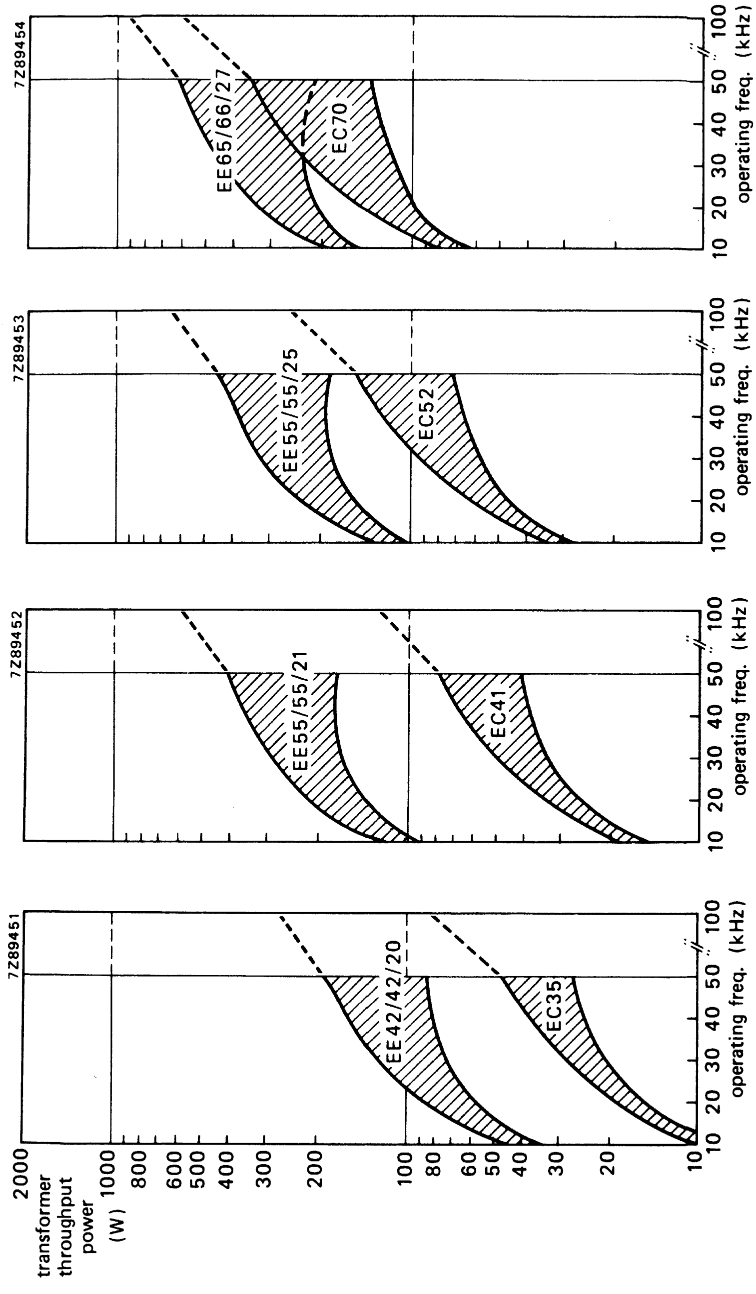
Unbalanced push-pull SMPS $\alpha \geqslant 3{,}44$



Flyback converter SMPS (ringing choke) $\alpha \geqslant 1{,}72 \quad \gamma = 1$



Flyback converter SMPS $\alpha \geqslant 1{,}72$ $\gamma = 0{,}25$



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.

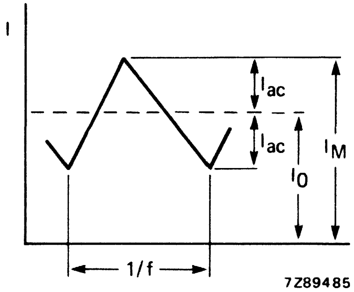


Fig. 14 Choke waveform showing symbols for currents are full load.

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:

- UU and UI cores comprising, respectively, two U cores or a U and an I core, generally give designs with with the lowest ferrite cost. However, production coil formers for them are not listed in this Handbook.
- EE cores, a pair of E cores, may be preferred where other considerations dominate, such as availability of coil formers.
- EC cores, although designed primarily for transformers, might perhaps be chosen because their use for both transformers and chokes in an SMPS reduces component type count.

Three core selection charts are given (on the following pages), each containing all of the core types in one group. These charts should be used to select a suitable core for the intended application before a full design is made using the design chart accompanying the core data.

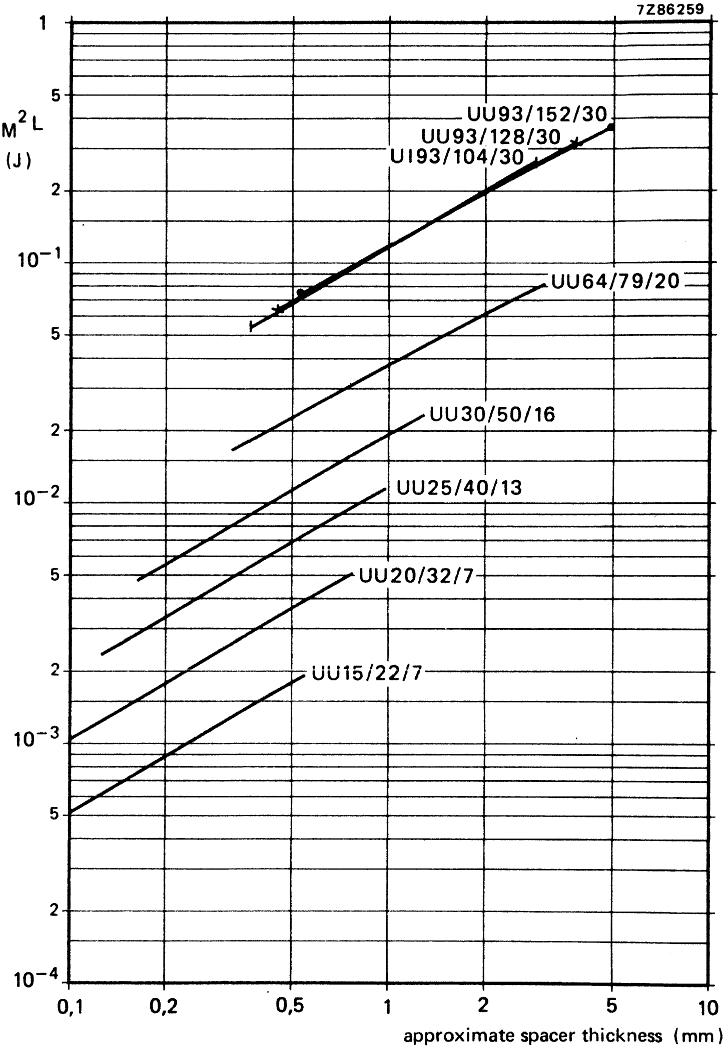
Selection procedure

- 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 (UU/UI, EE or EC) and draw a horizontal line $I_M^2 L_{min}$ across the selection chart for that core shape. For class III designs 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 corresponding to the intersection is only an indication of the final value.

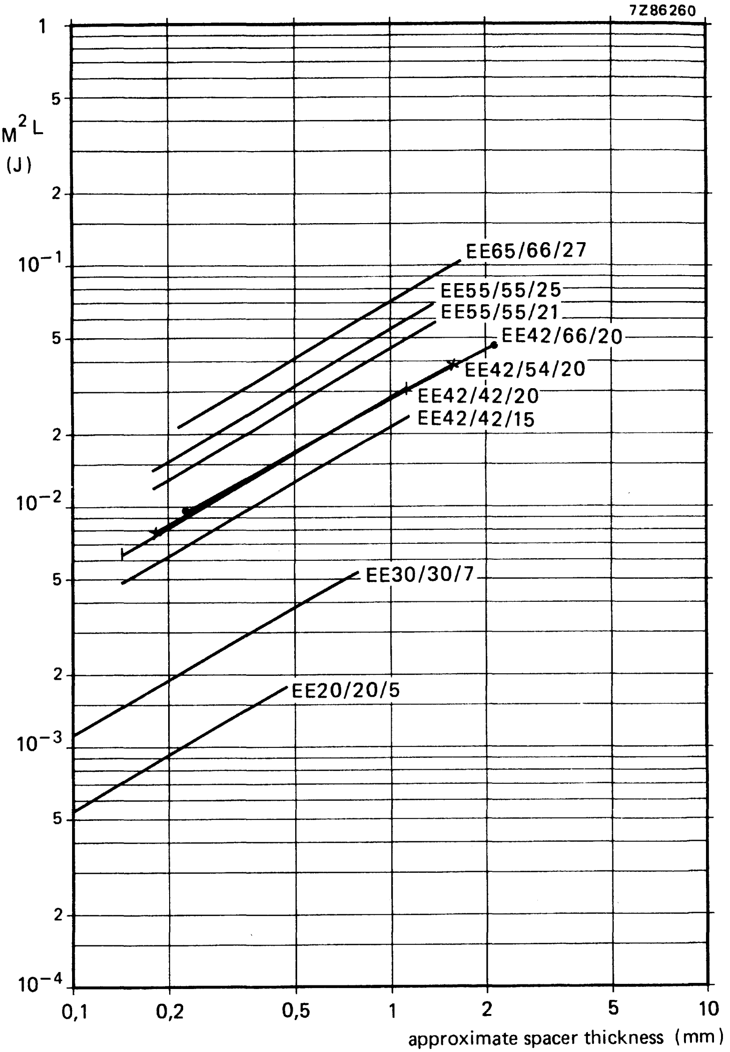
Effect of core size

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.

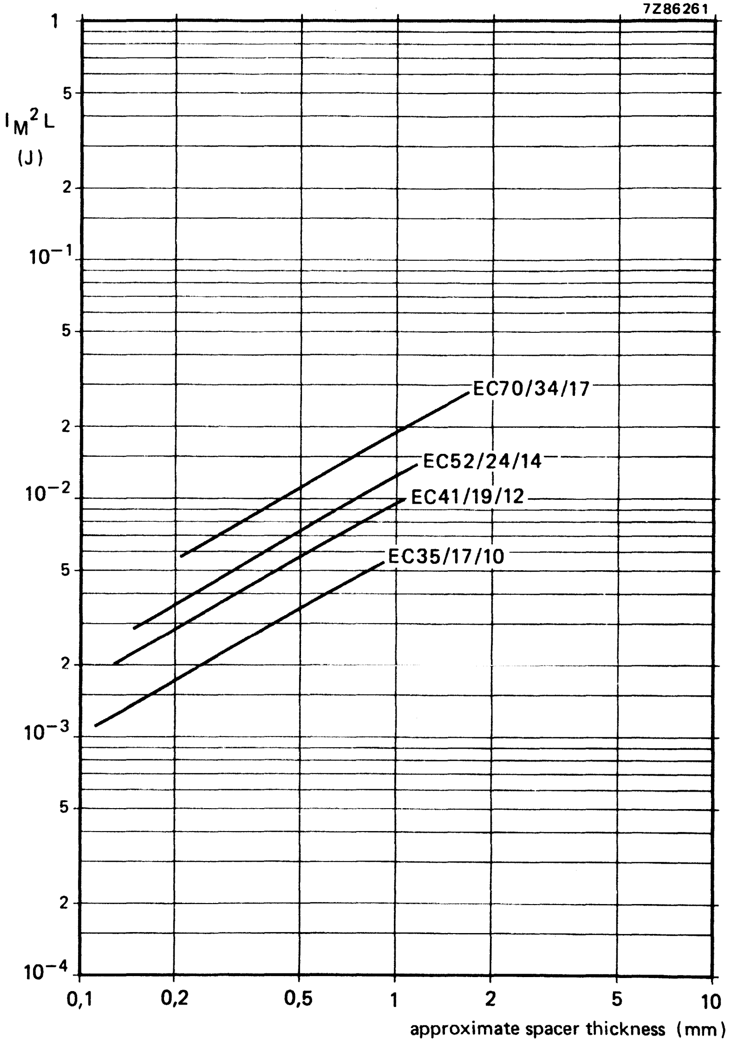
Selection of a larger core will generally result in a more conservative, efficient design than one based on a core that is marginally large enough.



Choke core selection chart UU/UI group.



Choke core selection chart EE group.



Choke core selection chart EC cores.

Spacer thickness and number of turns

Turn to the data for the core type selected and refer to the chart giving $(I_M^2L)_{max}$ and A_L as functions of spacer thicknesses. *(Note: A_L for these power cores is the inductance factor in henry.)*

The charts comprise a pair of curves of $(I_M^2L)_{max}$ 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 $I_M^2L_{min}$ (or 0,1 f $I_M^2L_{min}$ for class III), as used for core selection. The working point of the core must lie above this line and below the $(I_M^2L)_{max}$ curve for the core. That is, between lines SQ and SP in Fig. 15.
2. Select a suitable spacer, nominal thickness s. Draw vertical lines s_{min} and s_{max} on the chart, where $s_{max} - s_{min}$ is the tolerance field on the 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 $(I_M^2L)_{max\ 1}$ and $A_{L\ 1}$ from the chart. The maximum number of turns allowed to avoid saturation is

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

   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.

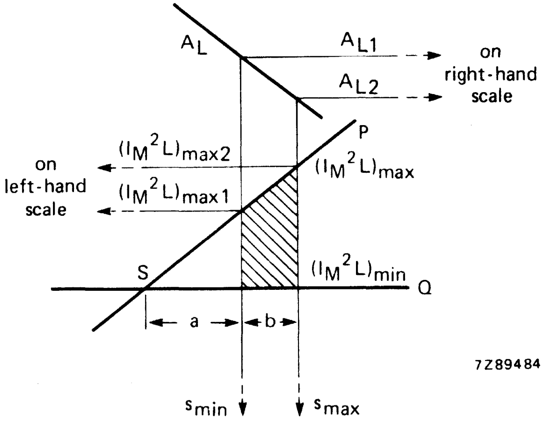


Fig. 15 Graphical design process using core design charts.

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,

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

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 $p_{id} \geqslant 1{,}5$, and current density in wire d_{id} is too high, make a new design using a larger core.
   - If $p_{id} \leqslant 1{,}5$, consider a foil or strip winding.
   - If $p_{id} \leqslant 1$, 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 $d_o \leqslant pb_w/(N + p)$,
   - repeat from step 4, even if p = 1.
6. $F_R = 1 + \frac{1}{2}(d/d_{id})^6$. 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 $0{,}0283/d^2\,\Omega/\text{m}$. For I_e, see previous page.

Single-layer wire windings (solid round wire)

1. Select thickest wire for which $d_o \leqslant b_w/(N + 1)$.
2. $F_R = 0{,}33\, df_e^{1/2}N/(N + 1)$. Note: valid only if $p_{id} \leqslant 1$ (see above).
3. $P_w = I_e^2R_{ac} = I_e^2 F_R R_{dc}$. Note: wire resistance $0{,}0283/d^2\,\Omega/\text{m}$. 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. $h_{id} = 3{,}1\,(Nf_e)^{-1/2}$.
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 $1/(45b_wh)\,\Omega/\text{m}$. 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).

1. E CORES

type number	material grade FXC 3C8			material grade FXC 3E1		
	air gap Δ mm	catalogue number one core	page	air gap Δ mm	catalogue number one core	page
E13/7/3	–	4322 020 34510*	C33			
E13/7/4	–	4312 020 34470	C34			
E20/10/5	–	4312 020 34070	C35	–	4322 020 34830	C35
				0,15	4322 020 34550	C35
				0,2	4322 020 34980	C35
E25/9/6				–	4322 020 34560	C42
				0,12	4322 020 34580	C42
E25/13/7	–	4312 020 34020	C43			
E30/15/7	–	4312 020 34550	C44	–	4322 020 34840	C44
	1,5	4312 020 34630	C44	0,15	4322 020 34650	C44
				0,3	4322 020 34660	C44
				0,5	4322 020 34990	C44
				1,1	4322 020 52570	C44
E42/21/15	–	4312 020 34110	C50	–	4322 020 34850	C50
	0,7	4312 020 34640	C50	0,25	4322 020 34740	C50
	0,8	4312 020 34370	C50	0,5	4322 020 34750	C50
	0,9	4312 020 34650	C50			
	1,4	4312 020 34280	C50			
	2,0	4312 020 34490	C50			
I42/7/15				–	4322 020 37320	C50
E42/21/20	–	4312 020 34120	C57			
	0,9	3122 134 91810	C57			
	1,25	4312 020 34660	C57			
	1,7	3122 134 91360	C57			
	2,0	4312 020 34360	C57			
	2,8	4312 020 34260	C57			
E42/33/20	–	4312 020 34190	C57			
	1,0	4312 020 34670	C57			
	2,2	4312 020 34510	C57			
E55/28/21	–	4312 020 34100	C65	–	4322 020 34900	C65
	0,36	4312 020 34580	C65			
	1,75	4312 020 34730	C65			
	2,0	4312 020 34710	C65			
	2,2	4312 020 34720	C65			
E55/28/25	–	3122 134 90210	C72			
	1,4	3122 134 90940	C72			
	2,3	4312 020 34740	C72			
E65/32/13				–	4322 020 34910	C78
E65/32/27	–	4312 020 34380	C85			
	1,75	4312 020 34750	C85			

* FXC 3H2.

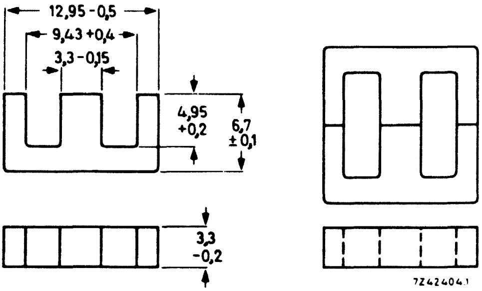
2. EC CORES

type number	material grade FXC 3C8		
	air gap Δ mm	catalogue number one core	page
EC35/17/10	–	4322 020 52500	C87
	1,0	4313 020 25610	C87
	1,4	4313 020 25590	C87
EC41/19/12	–	4322 020 52510	C96
	0,15	4322 020 52600	C96
	1,5	4313 020 25640	C96
EC52/24/14	–	4322 020 52520	C105
	2,3	4313 020 25680	C105
EC70/34/17	–	4322 020 52530	C114
	2,5	4313 020 25730	C114
	4,85	4313 020 25720	C114

3. U AND I CORES

type number		catalogue number of one core		page
		grade FXC 3C8	grade FXC 3C6	
U10/8/3		3122 134 91160		C123
U15/11/6		3122 134 90690		C124
U20/16/7		3122 134 90200		C126
U25/20/13		3122 134 90460		C128
U30/25/16		3122 134 90760		C130
U46/27/11		3122 134 91630		C132
U46/33/11		3122 104 90480		C143
	I46/10/11	3122 104 90470		C143
U52/27/11		3122 134 90480		C133
U57/28/16		4312 020 33190		C134
U58/45/16		3122 104 94760		C144
	I58/13/16	3122 104 94770		C144
U64/30/14		4312 020 33450		C135
U64/40/20		3122 134 91390		C136
U64/32/25		3122 134 91770		C139
U70/32/16		4312 020 33330		C140
U70/33/17		3122 104 93950		C141
U70/35/17		3122 134 90130		C142
U93/52/30		4312 020 33580	4312 020 33100	C147
U93/76/30		4312 020 33570	4312 020 33090	C150
	I93/28/30	4312 020 33590	4312 020 33110	C150
U93/76/16		4312 020 33550	4312 020 33070	C145
	I93/28/16	4312 020 33560	4312 020 33080	C145
U100/57/25		4312 020 33600	4312 020 33120	C151
	I100/25/25	4312 020 33610	4312 020 33420	C151

E-CORES



Mass approx. 0,83 g

MAGNETIC DATA

Guaranteed values for a core pair EE13/13/3, pressed together with a force of 30 N.

grade	temperature °C	μ_e	A_L	d	catalogue number of one E-core
3H2	25 ± 10	$\geqslant 1390$	$\geqslant 566$	$\leqslant 42{,}1$	4322 020 34510

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

Magnetic dimensions

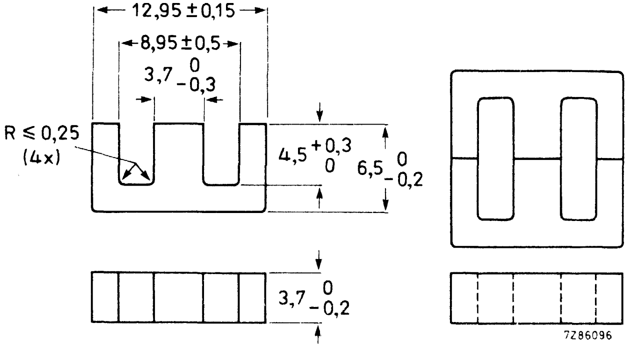
$l_e = 31{,}4$ mm

$A_e = 10{,}1$ mm^2

$C_1 = \Sigma \frac{l}{A} = 3{,}09$ mm^{-1}

$V_e = 318$ mm^3

E-CORES



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	⩾ 140	50	4312 020 34470
	105	⩾ 330	250	

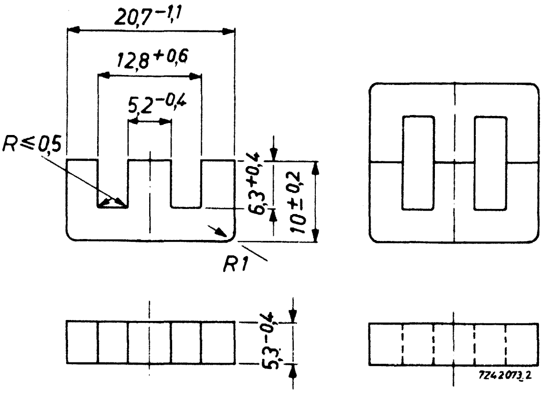
Magnetic dimensions

l_e = 29,6 mm

A_e = 13 mm^2

V_e = 384 mm^3

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	$\leqslant 0{,}1$	1920 to 2890	
μ_e	100	25 ± 10	$\leqslant 0{,}1$	2100 to 3155	
μ_e	100	23 to 70	$\leqslant 0{,}1$	$\geqslant 2100$	
$\frac{\tan\delta}{\mu_i} \times 10^6$	4	25 ± 10	$\leqslant 0{,}1$	$\leqslant 2{,}5$	
	100	25 ± 10	$\leqslant 0{,}1$	$\leqslant 20$	
	500	25 ± 10	$\leqslant 0{,}1$	$\leqslant 200$	
$\eta_B \times 10^3$	4	25 ± 10	1,5 to 3	$\leqslant 1{,}8$	
P(W)	16	25	200		$\leqslant 0{,}3$
	16	100	200		$\leqslant 0{,}25$
$\hat{H}$ (A/m)	16	100	$\geqslant 275$		250

Catalogue number of one E core ($\Delta = 0$), grade 3E1 4322 020 34830
3C8 4312 020 34070
$\Delta = 0{,}15 \pm 0{,}015$ 3E1 4312 020 34550
$\Delta = 0{,}2 \pm 0{,}015$ 3E1 4322 020 34980

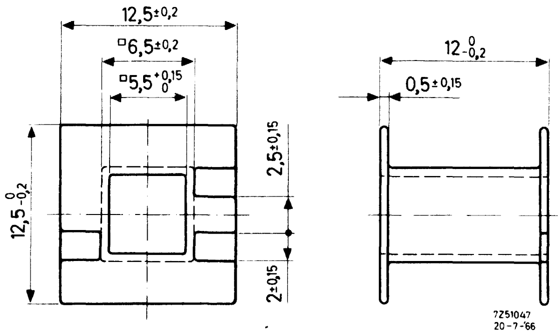
Magnetic dimensions, according to IEC 205:

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

$A_e = 31{,}2\ \text{mm}^2 \qquad V_e = 1340\ \text{mm}^3$

COIL FORMERS

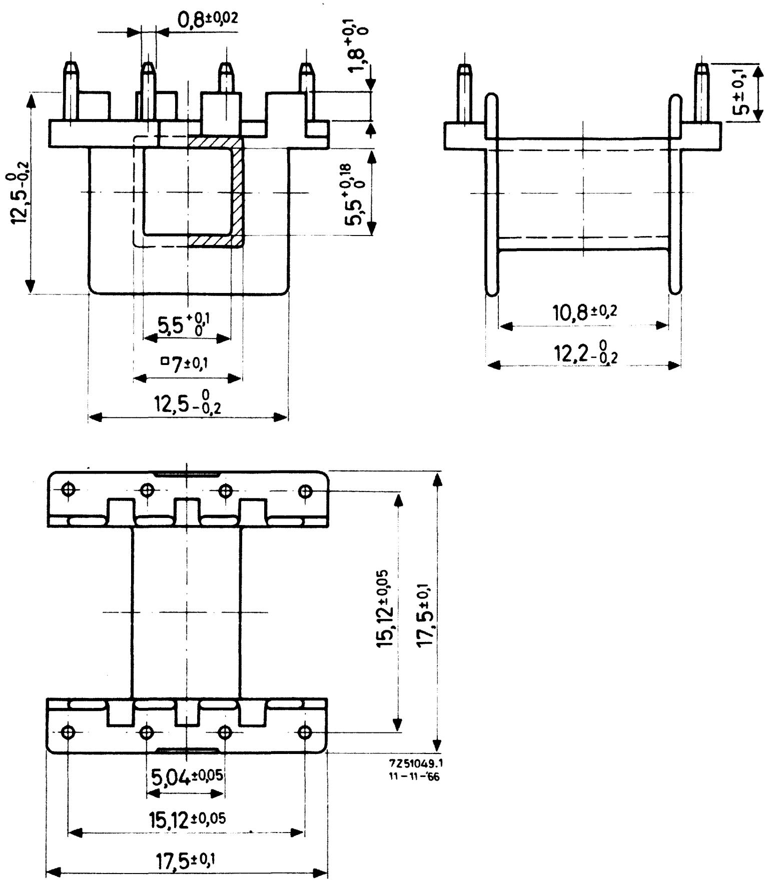
for shell type transformer EE20/20/5 (M20)



catalogue number	4312 021 28430
material	polycarbonate
minimum window area	27 mm^2
mean length of turn	38 mm
approximate mass	0,5 g
maximum temperature	130 °C

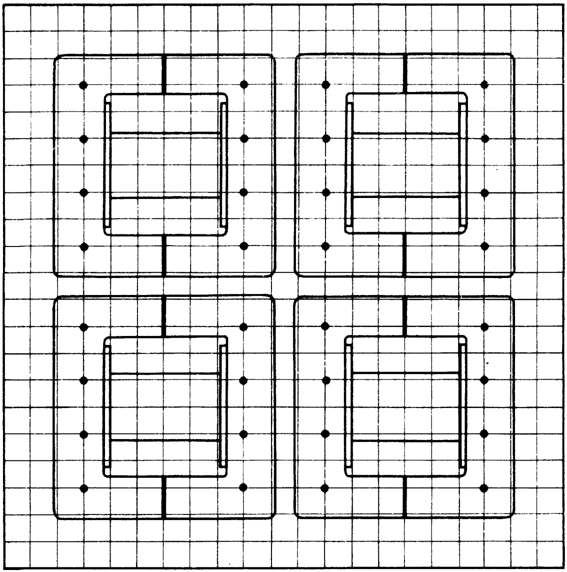
Coil formers for shell type transformer EE20/20/5 (M20)

With soldering pins.

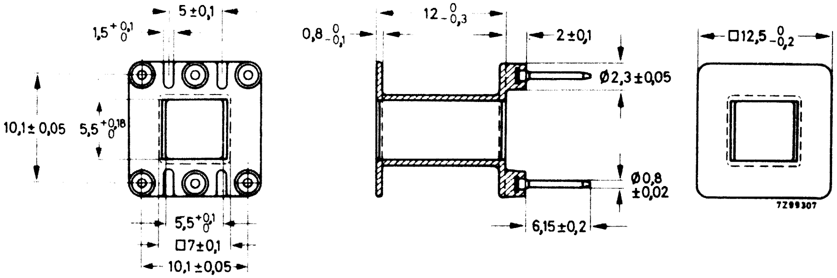


catalogue number	4322 021 20240
material	phenolformaldehyde reinforced with glass fibre; brass dip-solder pins
minimum window area	27 mm^2
mean length of turn	38 mm
approximate mass	3 g
maximum temperature for dip-soldering during 5-6 s	280 °C
maximum working temperature	130 °C

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.

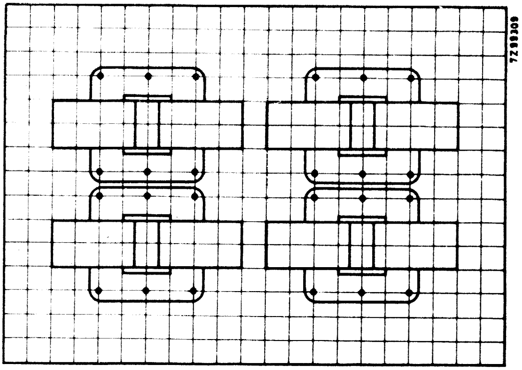


With soldering pins.

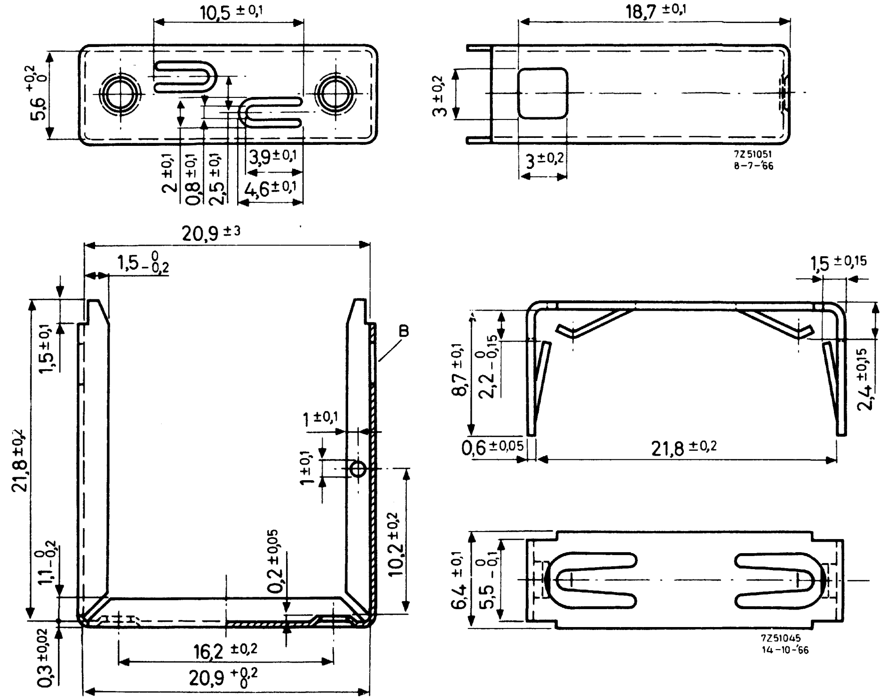


catalogue number	4322 021 20140
material	phenolformaldehyde reinforced with glass fibre; brass dip-solder pins
minimum window area	27 mm²
mean length of turn	38 mm
approximate mass	3 g
maximum temperature for dip-soldering during 5-6 s	280 °C
maximum working temperature	130 °C

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.



MOUNTING PARTS



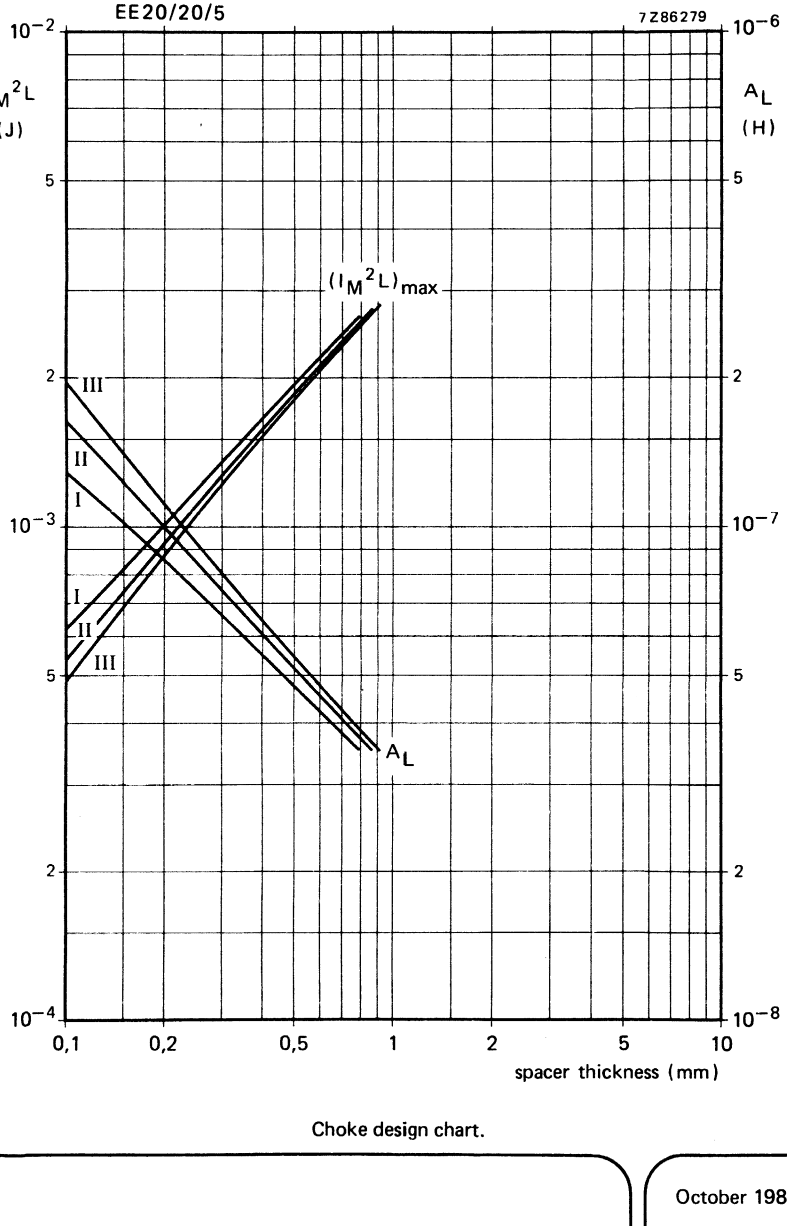
(1). Clasp 4322 021 20160.
Material: brass, tin-plated.

(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.

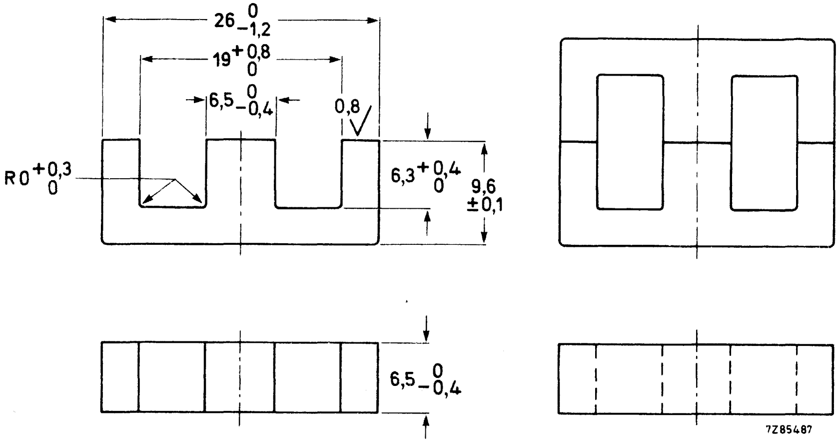
The construction can be used in the horizontal and vertical positions. If the construction is used in the vertical position, the lips C of the clasp must be bent. The dimensions and mutual distance of these lips are chosen in such a way that they fit printed-wiring boards with a grid of 0,1 " as well 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.

E-CORES



Mass approx. 4,8 g

MAGNETIC DATA

Guaranteed values for a core pair EE25/19/6, pressed together with a force of 55 N, air gap $\Delta = 0$.

grade	temperature °C	μ_e	A_L	d	catalogue number of one E-core
3E1	25 ± 10	$\geqslant 1700$	$\geqslant 1680$	$\leqslant 24,4$	4322 020 34560

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

Catalogue number of one core with air gap $\Delta = 0,12 \pm 0,015$ mm: 4322 020 34580

Magnetic dimensions, according to IEC 205:

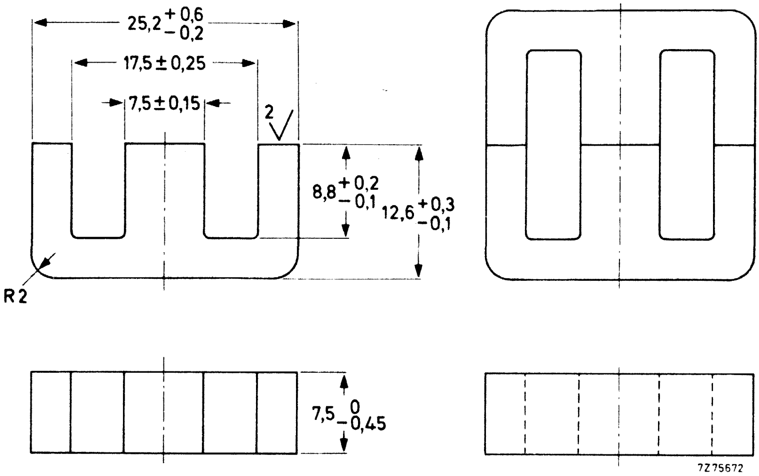
$l_e = 48,8$ mm

$A_e = 38,6\ mm^2$

$C_1 = \Sigma \frac{l}{A} = 1,27\ mm^{-1}$

$V_e = 1890\ mm^3$

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 25	200 ≥ 340	– 250	≤ 0,65 –	4312 020 34020

Magnetic dimensions, according to IEC 205:

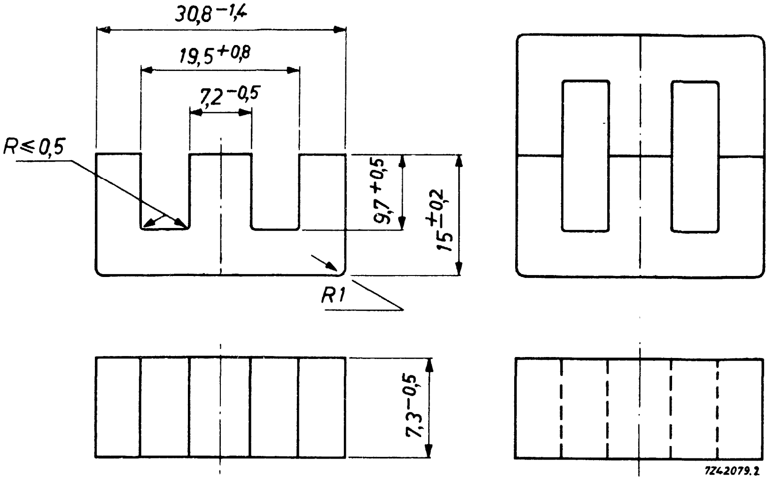
l_e = 57,5 mm

A_e = 55 mm^2

$C_1 = \Sigma \frac{l_e}{A_e} =$ 1,045 mm^{-1}

V_e = 3160 mm^3

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

Ferroxcube grade	3E1	3C8
Δ = 0	4322 020 34840	4312 020 34550
Δ = 0,15 ± 0,015	4322 020 34650	
Δ = 0,3 ± 0,05	4322 020 34660	
Δ = 0,5 ± 0,05	4322 020 34990	
Δ = 1,1 ± 0,05	4322 020 52570	
Δ = 1,5 ± 0,1		4312 020 34630

Magnetic dimensions according to IEC 205:

l_e = 66,9 mm

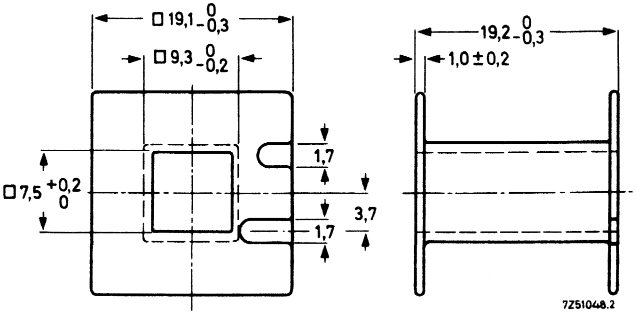
A_e = 59,7 mm

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

V_e = 4000 mm^3

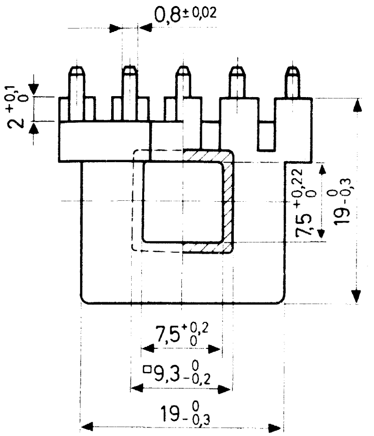
COIL FORMERS

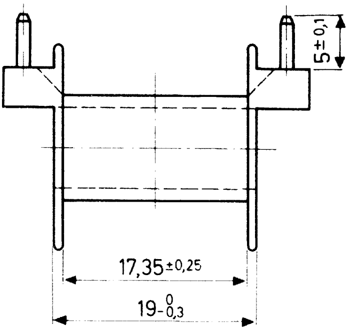
for shell type transformer EE30/30/7 (M30)

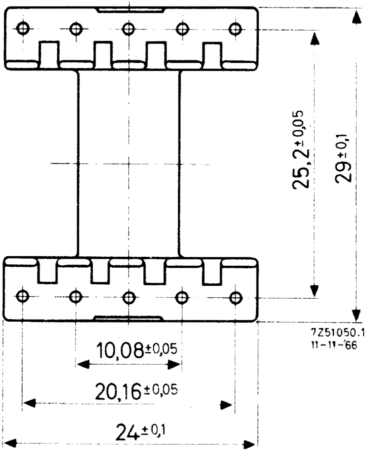


catalogue number	4312 021 28550
material	polycarbonate
minimum window area	80 mm²
mean length of turn	56 mm
approximate mass	1,3 g
maximum temperature	130 °C

With soldering pins.

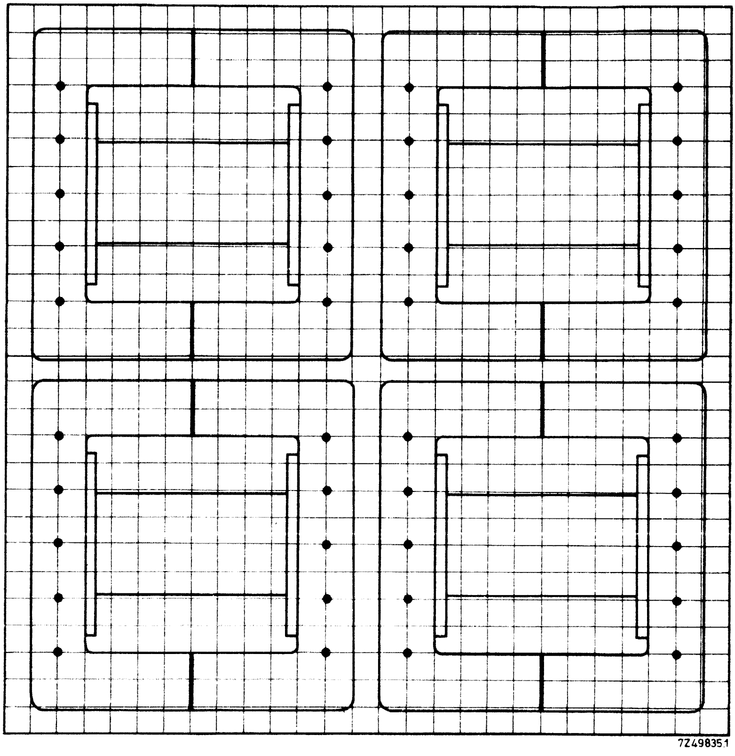




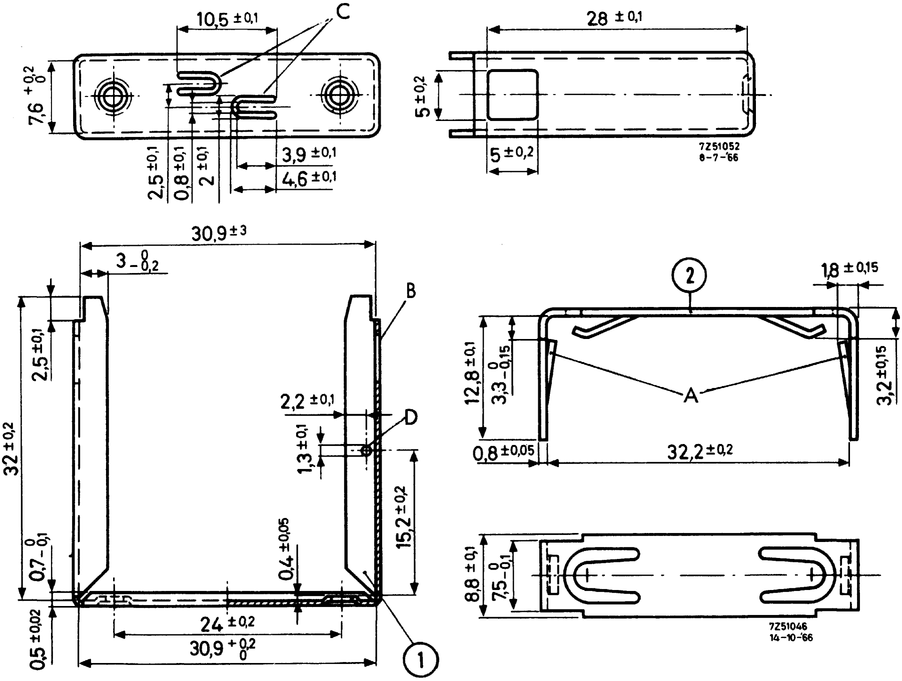


catalogue number	4322 021 20250
material	phenolformaldehyde reinforced with glass fibre; brass dip-solder pins
minimum window area	80 mm^2
mean length of turn	56 mm
approximate mass	3 g
maximum temperature for dip-soldering during 5-6 s	280 °C
maximum working temperature	130 °C

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.



MOUNTING PARTS



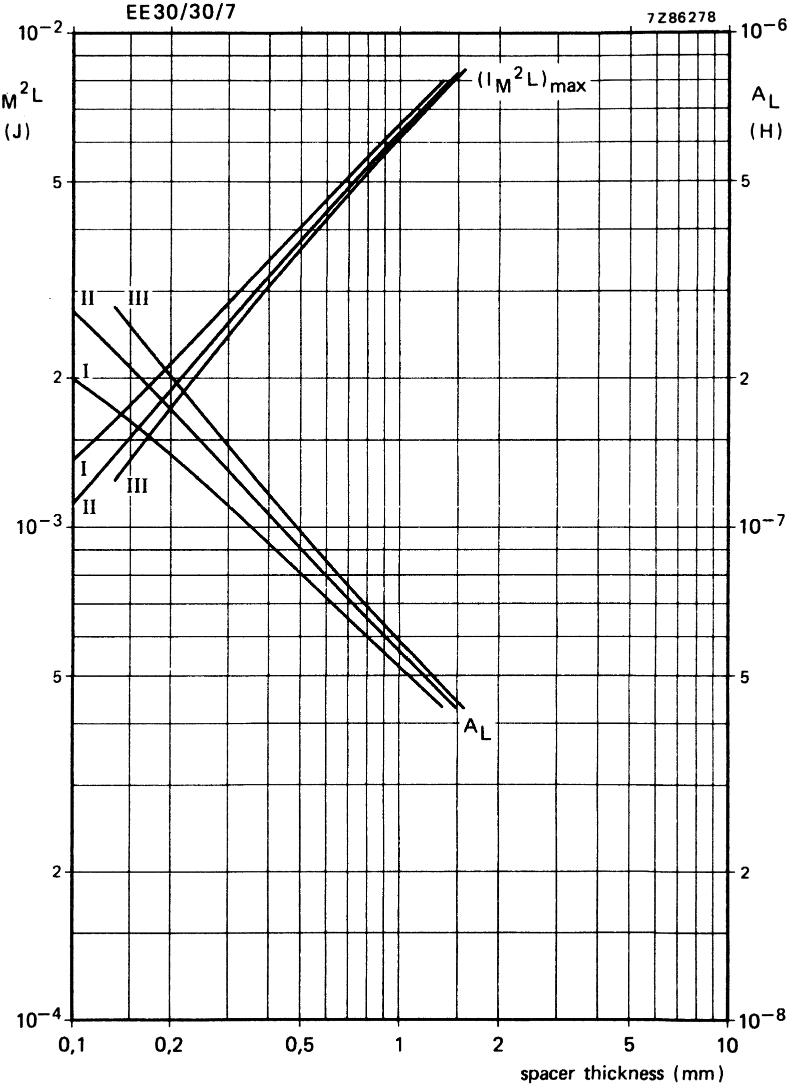
(1). Clasp 4322 021 20170
Material: brass, tin-plated.

(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.

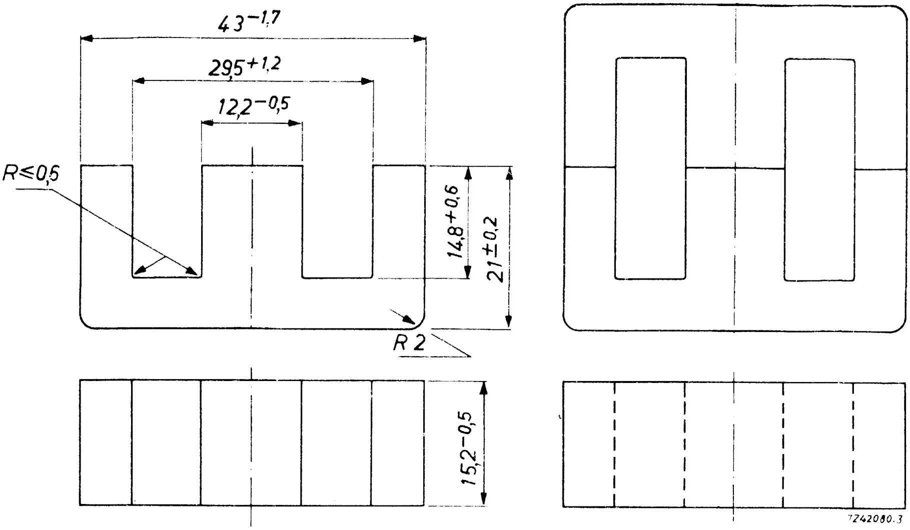
CHARACTERISTIC CURVES

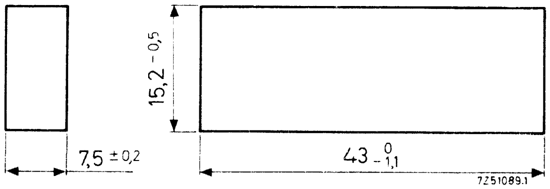


Choke design chart.

E- AND I-CORES

Dimensions according to DIN 41295.





Mass approx. 42 g

Catalogue numbers

Ferroxcube grade		3E1	3C8
Catalogue number of E-core, air gap	Δ = 0	4322 020 34850	4312 020 34110
	Δ = 0,25 ± 0,015	4322 020 34740	
	Δ = 0,50 ± 0,015	4322 020 34750	
	Δ = 1,4 ± 0,1		4312 020 34280
with air gap in one of the outer legs	0,7 ± 0,05		4312 020 34640
	0,8 ± 0,05		4312 020 34370
	0,9 ± 0,05		4312 020 34650
	2,0 ± 0,1		4312 020 34490
Catalogue number of I-core		4322 020 37320	

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 mm^2	183 mm^2
Core constant	$C_1 = \Sigma \frac{l_e}{A_e} =$	0,534 mm^{-1}	0,367 mm^{-1}
Effective core volume	$V_e =$	17600 mm^3	12300 mm^3

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
$\mu_e =$	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

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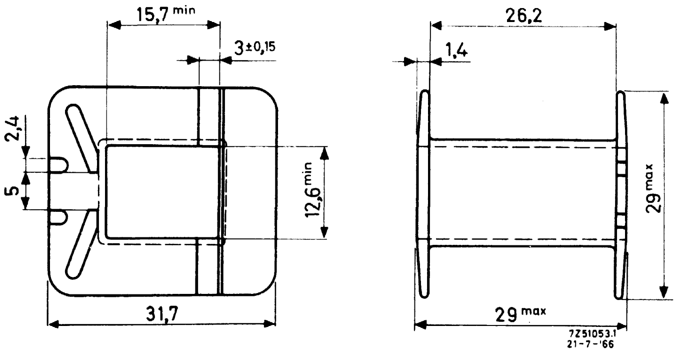
* In the temperature range + 23 to + 70 °C $\mu_e \geqslant 2575$.

COIL FORMERS

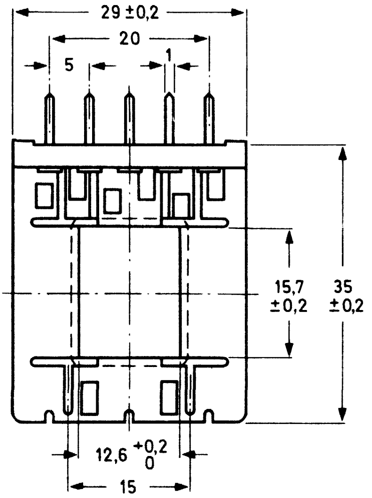
for shell type transformer EE42/42/15 (M42)

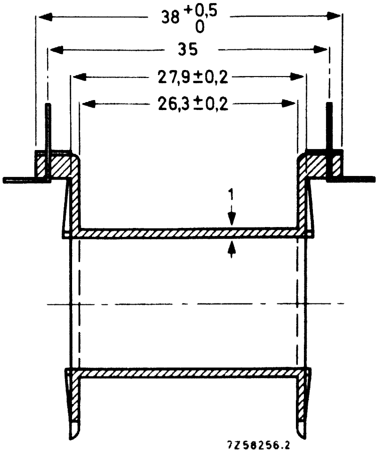


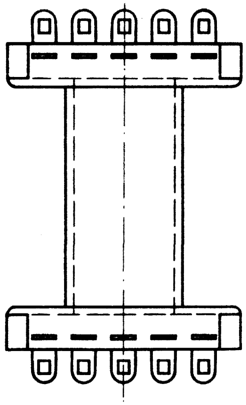
catalogue number	4312 021 28622
material	reinforced polyamide
minimum window area	178 mm²
mean length of turn	93 mm
approximate mass	4 g
maximum temperature	180 °C

The dimensions are practically according to German specification DIN 41305.

With soldering pins.

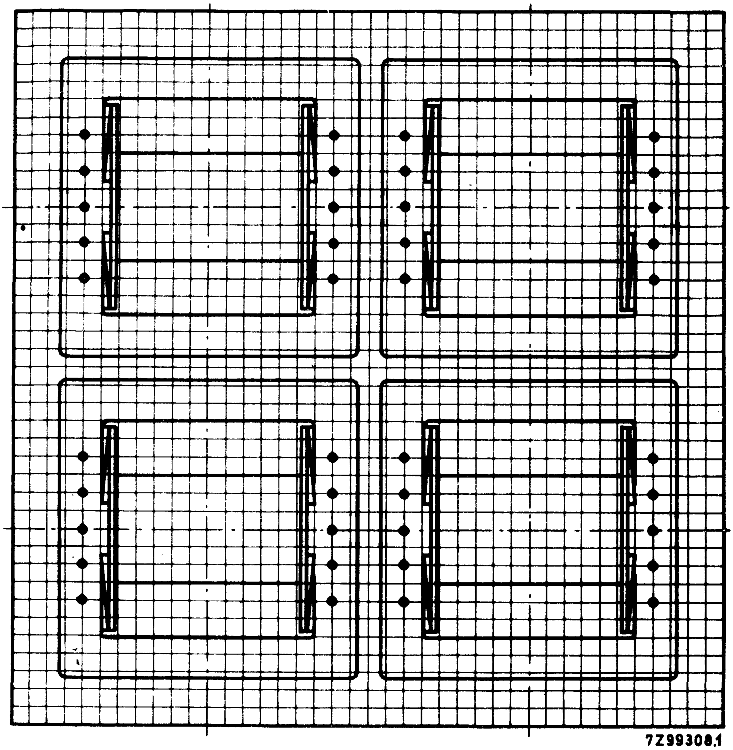




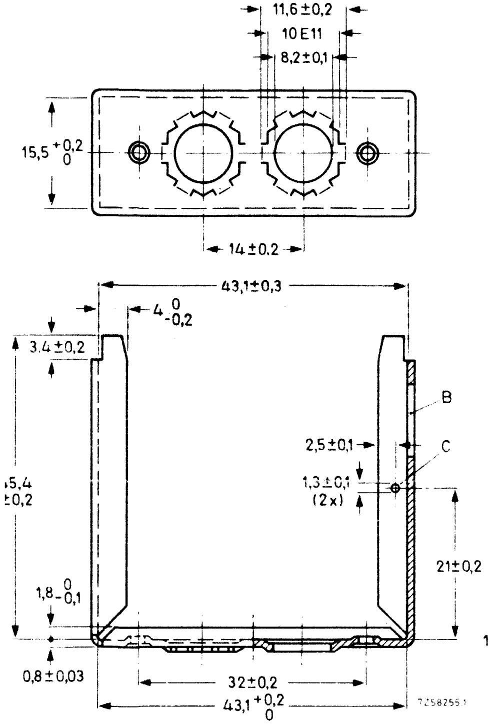


catalogue number	4322 021 31830
material	reinforced polyamide with brass dip-soldered pins
minimum window area	178 mm²
mean length of turn	93 mm
approximate mass	4 g
maximum temperature	180 °C

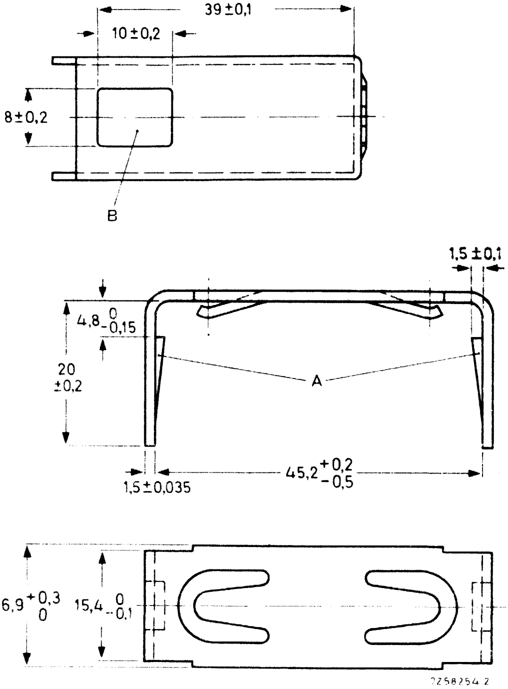
The coil former fits a shell type transformer EE42/42/15 (M42). The soldering pins will fit printed-wiring boards with a grid of 0,1 inch as well as 2,5 mm. The pin length is sufficient for a board thickness of up to 3 mm. The board should be provided with holes of 1,3 ± 0,1 mm diameter.



MOUNTING PARTS



Clasp 4322 021 31910
Material: steel, copper-plated, nickel-plated.

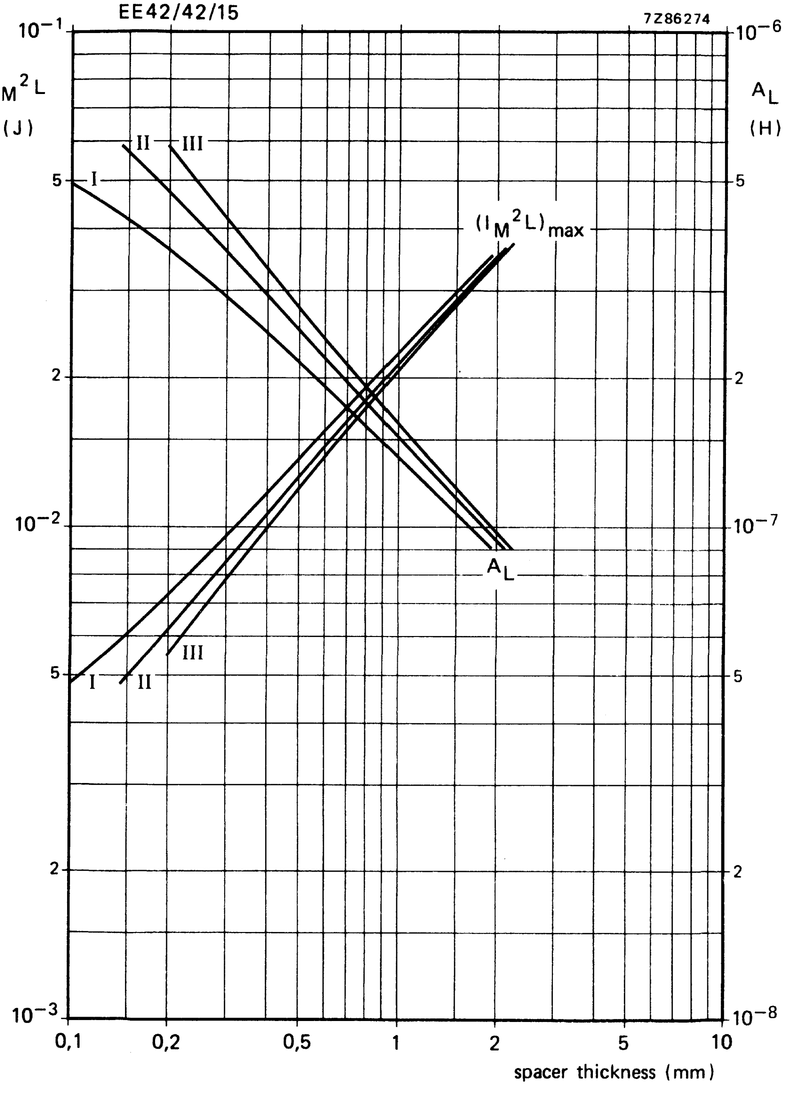


Spring 4322 021 31920
Material: phosphor-bronze,
nickel-plated.

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.

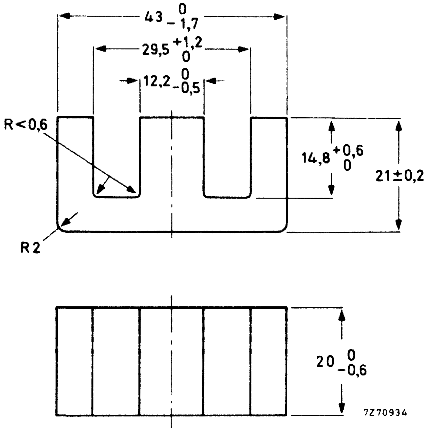
The construction can be used in the horizontal and vertical positions. If the construction is used in the vertical position, two fixing bushes 4322 021 30720 with nuts 4322 021 30710 must be applied in the holes of the clasp. If used in a horizontal position the clasp can be earthed by means of a copper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

CHARACTERISTIC CURVES

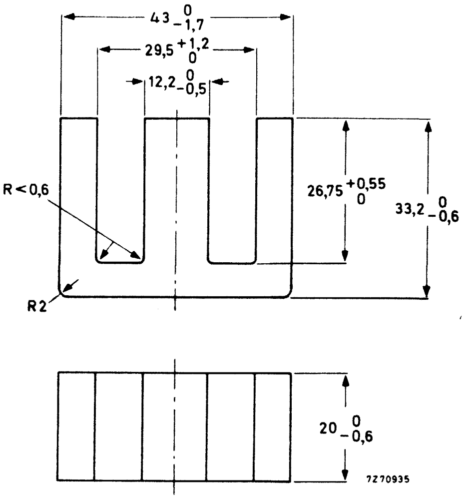


Choke design chart.

E-CORES



E42/21/20



E42/33/20

Mass 56 g

Mass 65 g

Catalogue numbers

Ferroxcube grade		3C8
Catalogue number of core E42/21/20, air gap	Δ = 0	4312 020 34120
	Δ = 2,0 ± 0,1	4312 020 34360
	Δ = 1,7 ± 0,1	3122 134 91360
	Δ = 2,8 ± 0,1	4312 020 34260
	Δ = 0,9 ± 0,05	3122 134 91810
	Δ = 1,25 ± 0,1	4312 020 34660
Catalogue number of core E42/33/20, air gap	Δ = 0	4312 020 34190
	Δ = 1,0 ± 0,1	4312 020 34670
	Δ = 2,2 ± 0,1	4312 020 34510
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.

Magnetic dimensions according IEC 205:

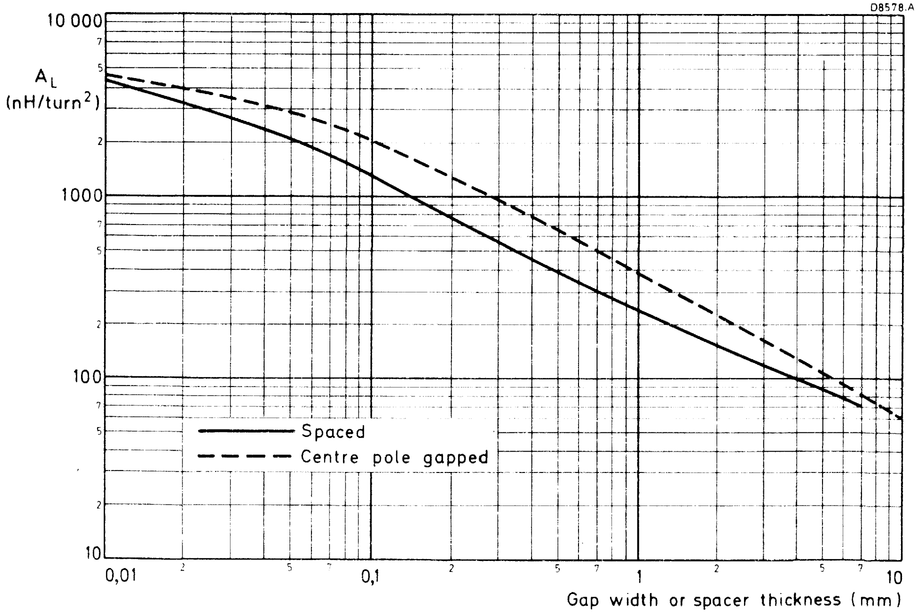
	EE42/42/20	EE42/54/20
l_e =	98 mm	122 mm
A_e =	236 mm^2	236 mm^2
$C_1 = \Sigma \frac{l_e}{A_e}$ =	0,415 mm^{-1}	0,517 mm^{-1}
V_e =	23100 mm^3	28800 mm^3

MAGNETIC DATA

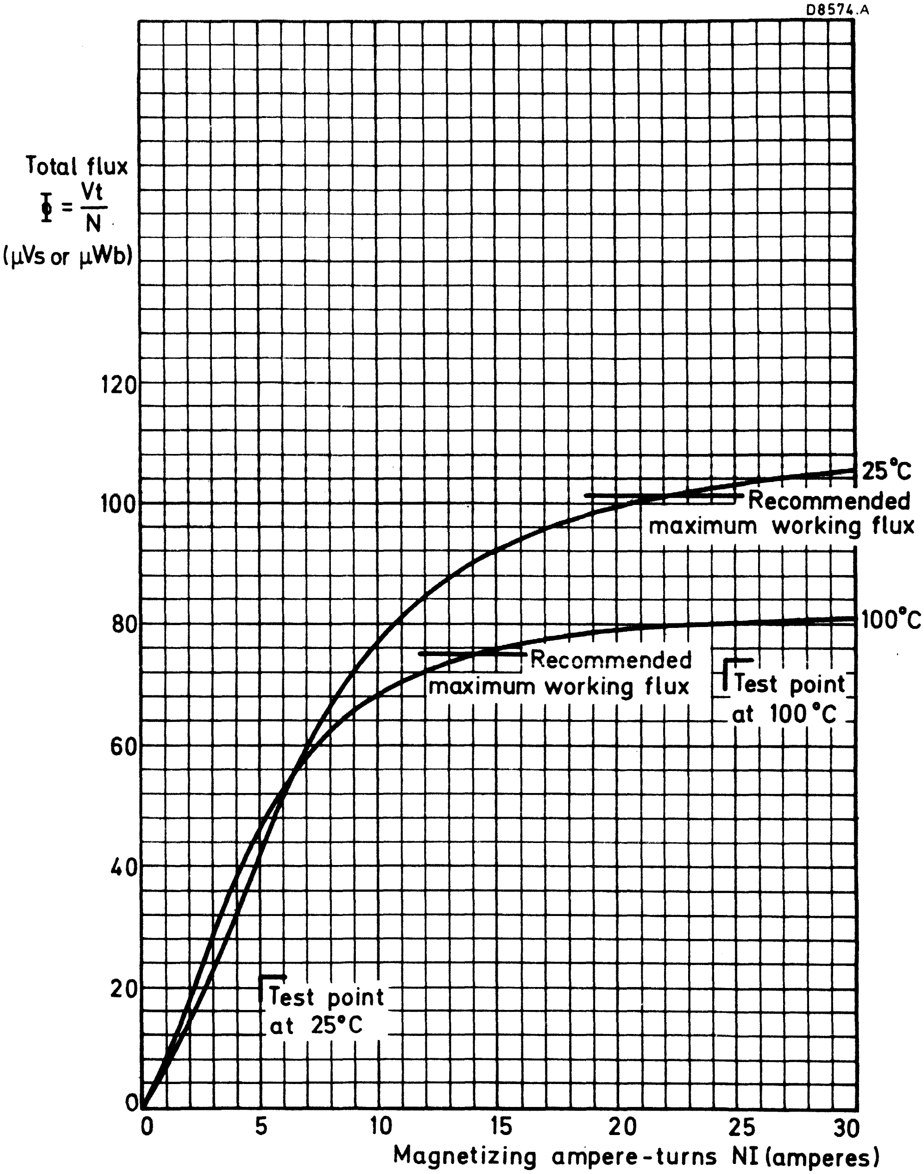
		EE42/42/20	EE42/54/20
At f = 16 kHz, $\hat{B}$ = 200 mT, θ = 25 °C	P		≤ 3,5 W
θ = 100 °C	P	≤ 2,6 W	≤ 3,2 W
At f = 16 kHz, $\hat{B} \geq$ 90 mT, θ = 100 °C	$\hat{H}$	= 50 A/m	
$\hat{B} \geq$ 315 mT, θ = 100 °C	$\hat{H}$	= 250 A/m	250 A/m

Application data for symmetrical magnetization

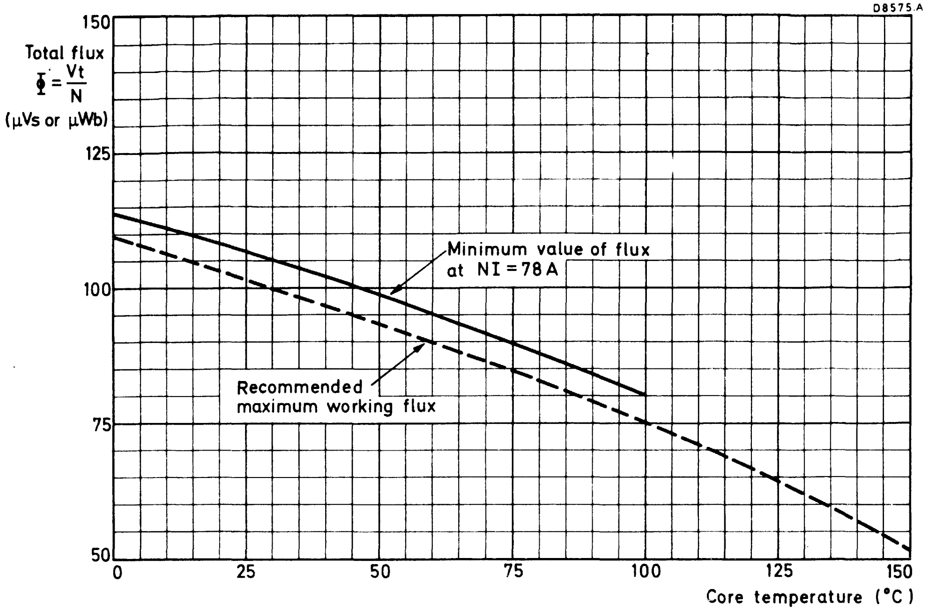
The curves shown here and on the following pages represent typical characteristics for a pair of EE42/42/20 in FXC 3C8.



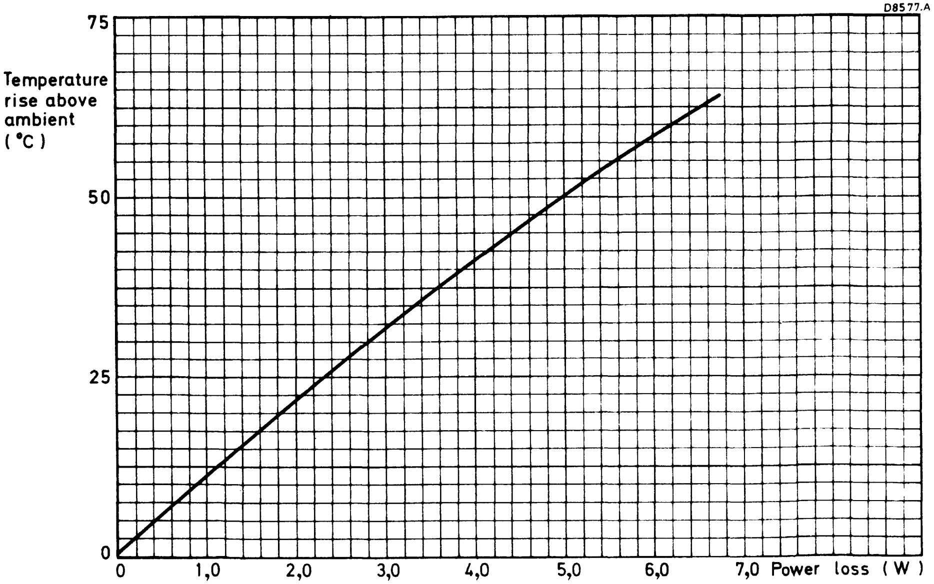
A_L based on a typical initial permeability of 2000 as a function of spacer thickness.



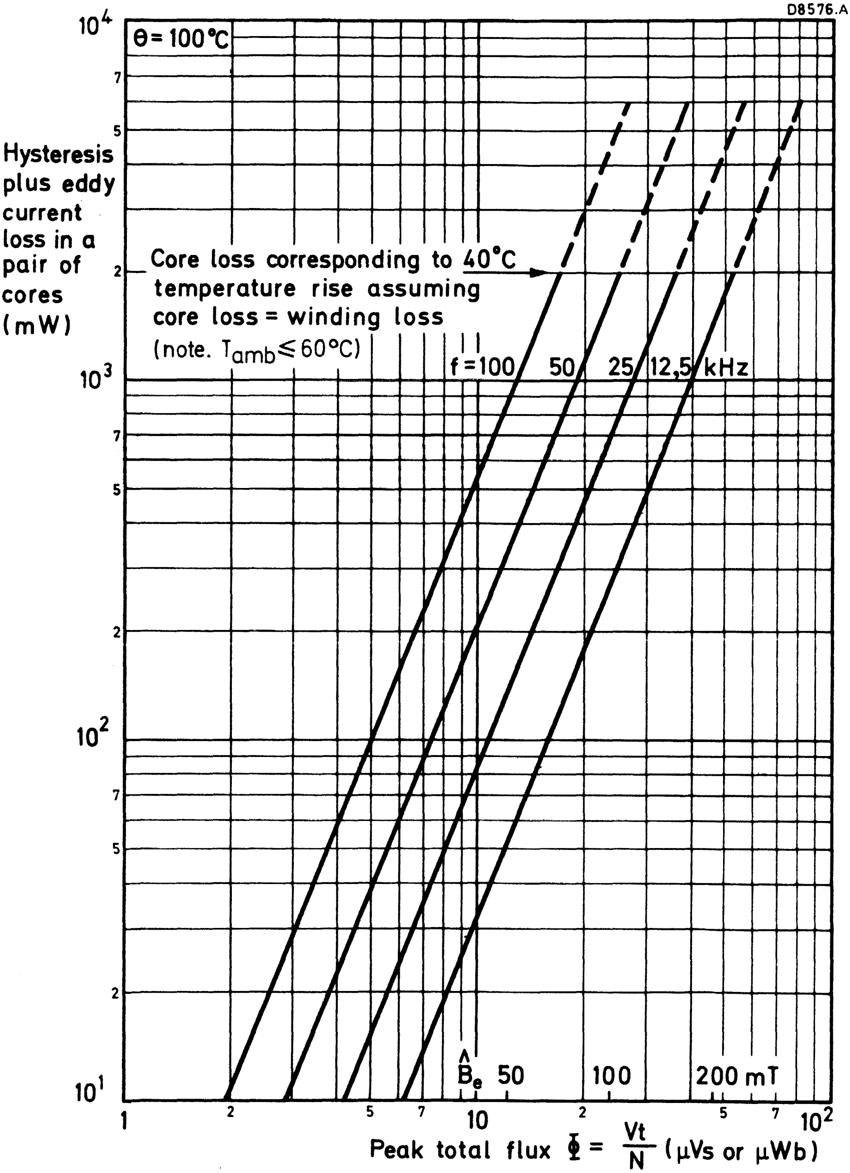
Typical magnetization curves for a pair of cores, in 3C8, with ambient temperature as parameter.



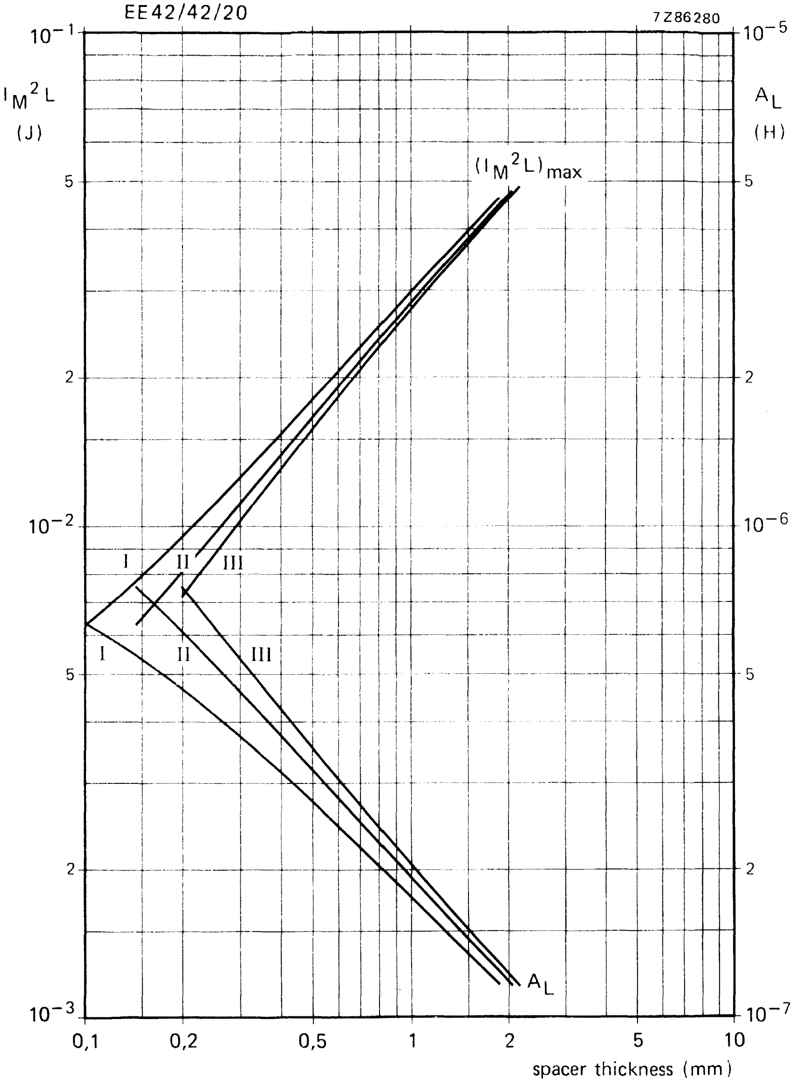
Total flux as a function of core temperature.



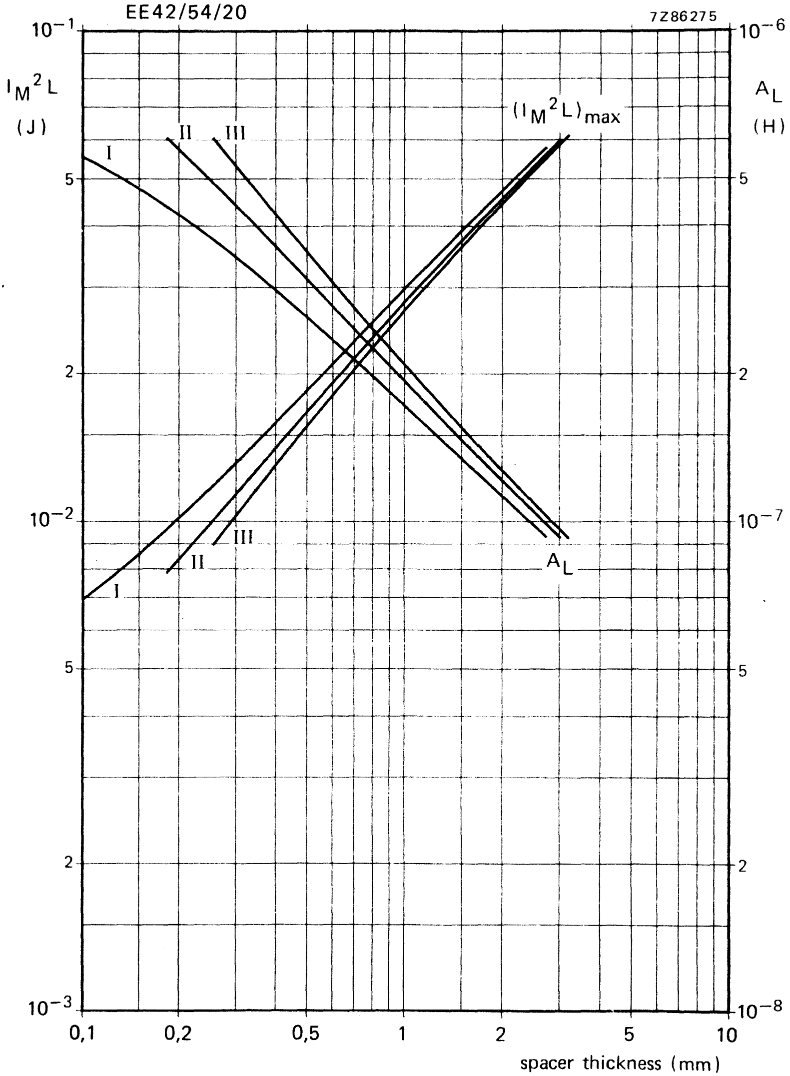
Typical transformer temperature rise as a function of total transformer loss in free air conditions.



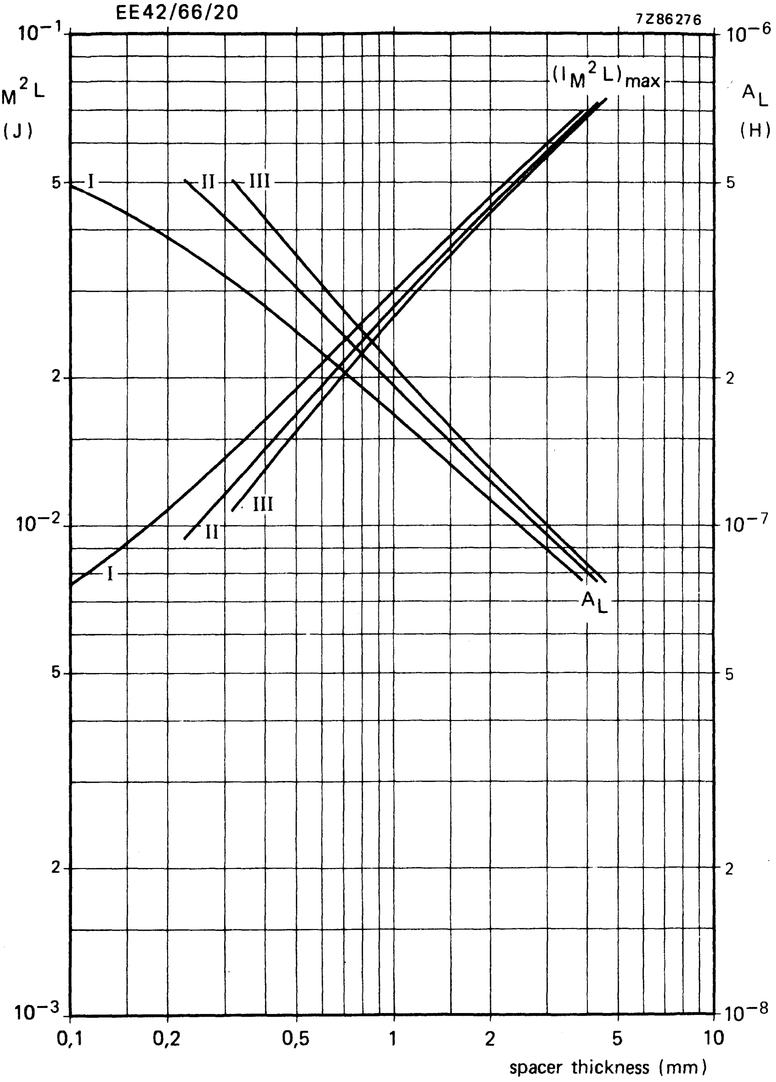
Core loss as a function of total flux at 100 °C with frequency as parameter.



Choke design chart.

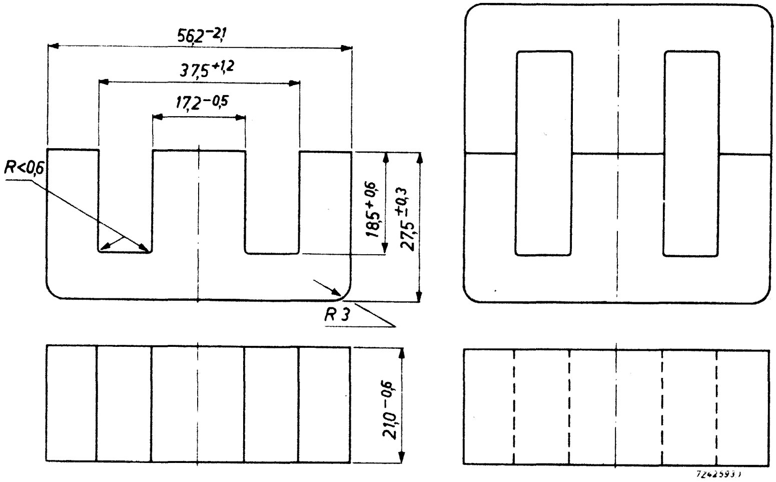


Choke design chart.



Choke design chart.

E-CORES



The dimensions are according to DIN 41295.

Mass approx. 115 g

Catalogue numbers	3E1	3C8
Ferroxcube grade air gap Δ = 0	4322 020 34900	4312 020 34100
Δ = 0,36 ± 0,1		4312 020 34580
Δ = 1,75 ± 0,15		4312 020 34730
Δ = 2,0 ± 0,1		4312 020 34710
Δ = 2,2 ± 0,15		4312 020 34720

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 E55/28/21.

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

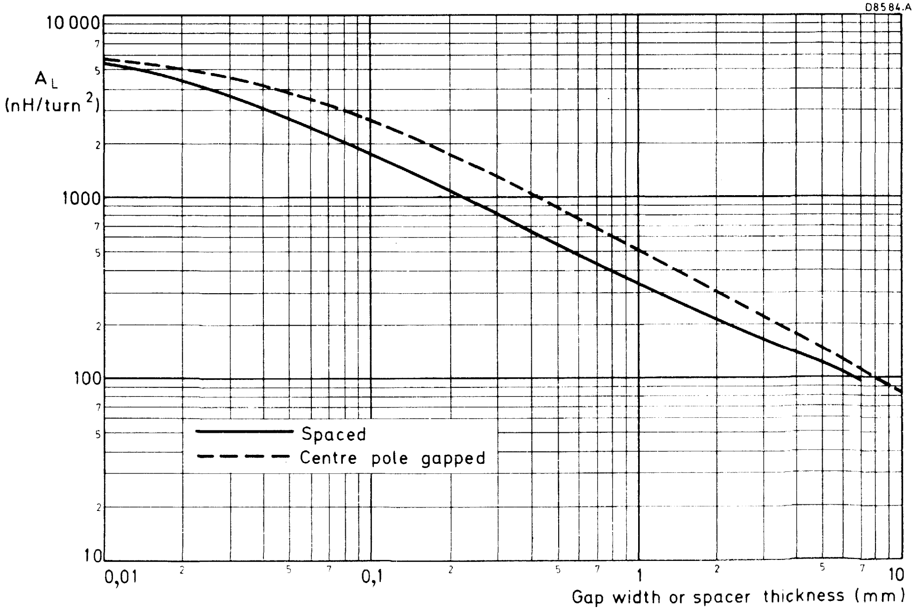
MAGNETIC DATA

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

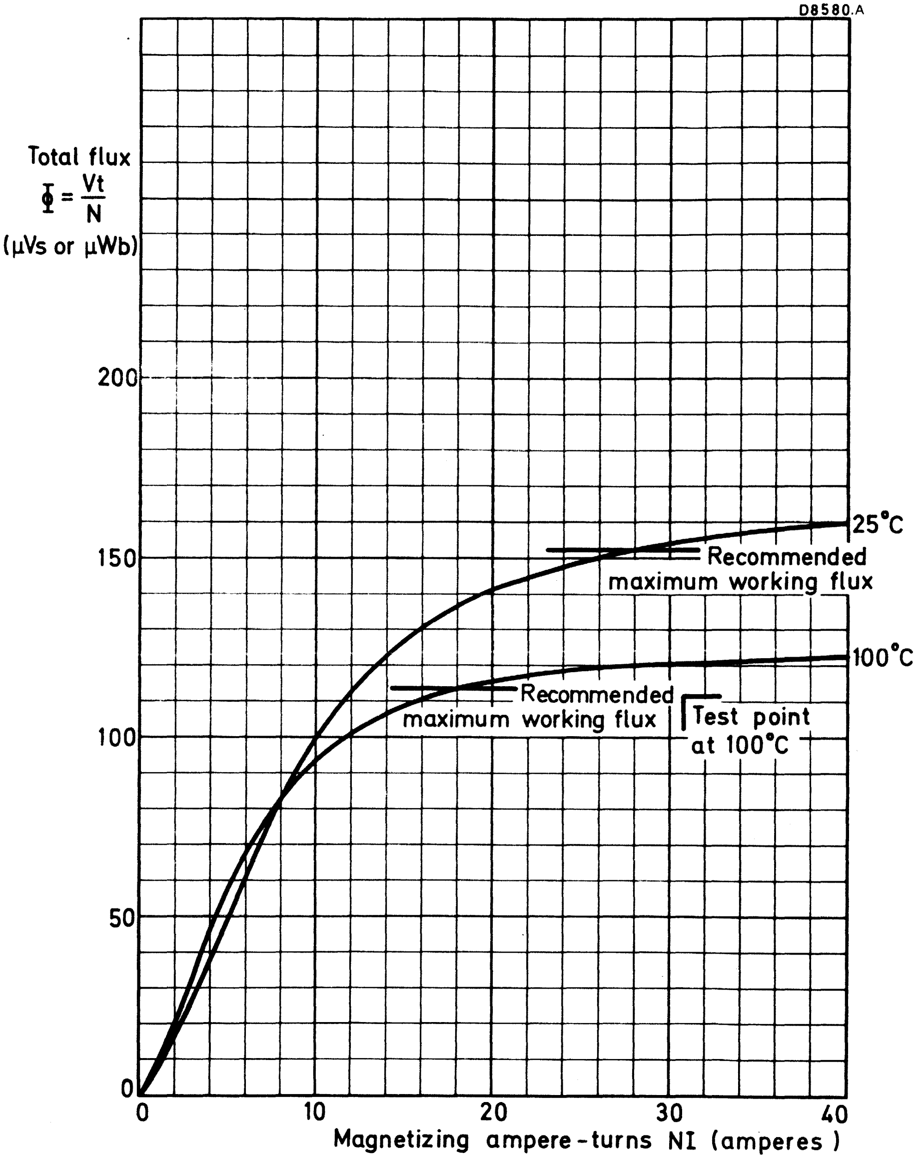
	freq. kHz	temp. °C	$\hat{B}$ mT	grade	
				3E1	3C8
A_L	100	25 ± 10		9545 to 14330	
μ_e	100	25 ± 10		2645 to 3970	
$\eta_B \times 10^3$	4	25 ± 10	1,5 to 3	$\leqslant$ 2,5	
P (W)	16	25	200		$\leqslant$ 5,5
	16	100	200		$\leqslant$ 5,0
$\hat{H}$ (A/m)	16	100	315		250

APPLICATION FOR SYMMETRICAL MAGNETIZATION

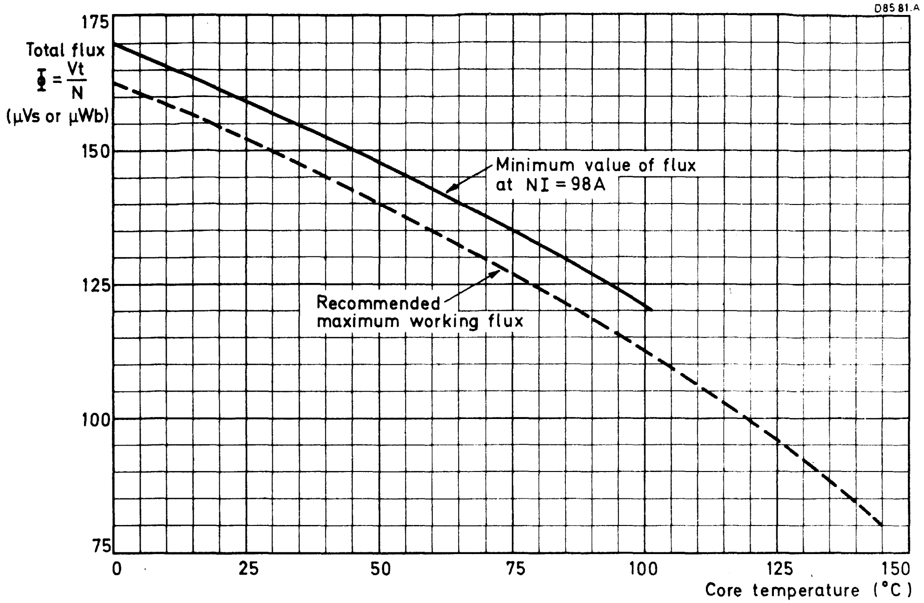
The curves shown here and on the following pages represent typical characteristics for a pair of EE55/55/21 in FXC 3C8.



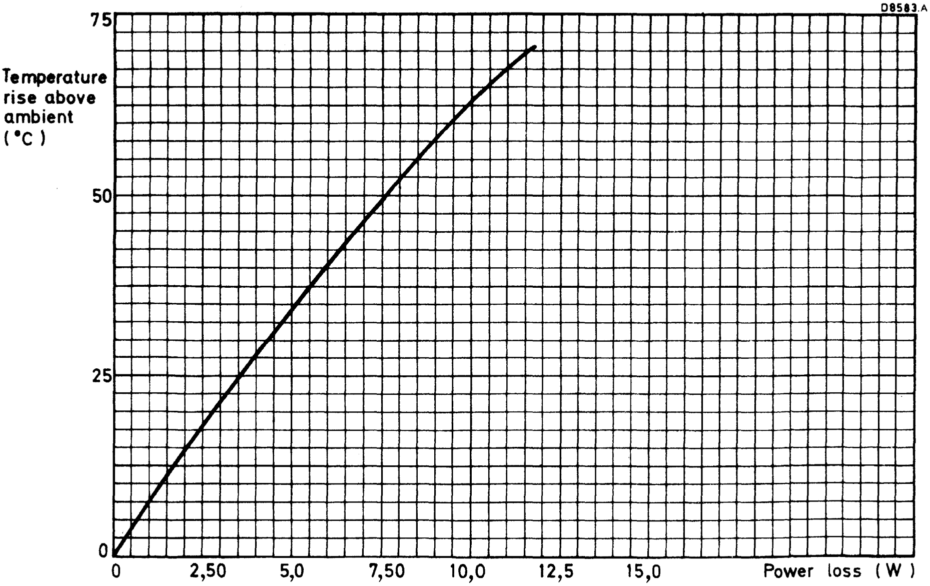
A_L based on a typical initial permeability of 2000 as a function of spacer thickness.



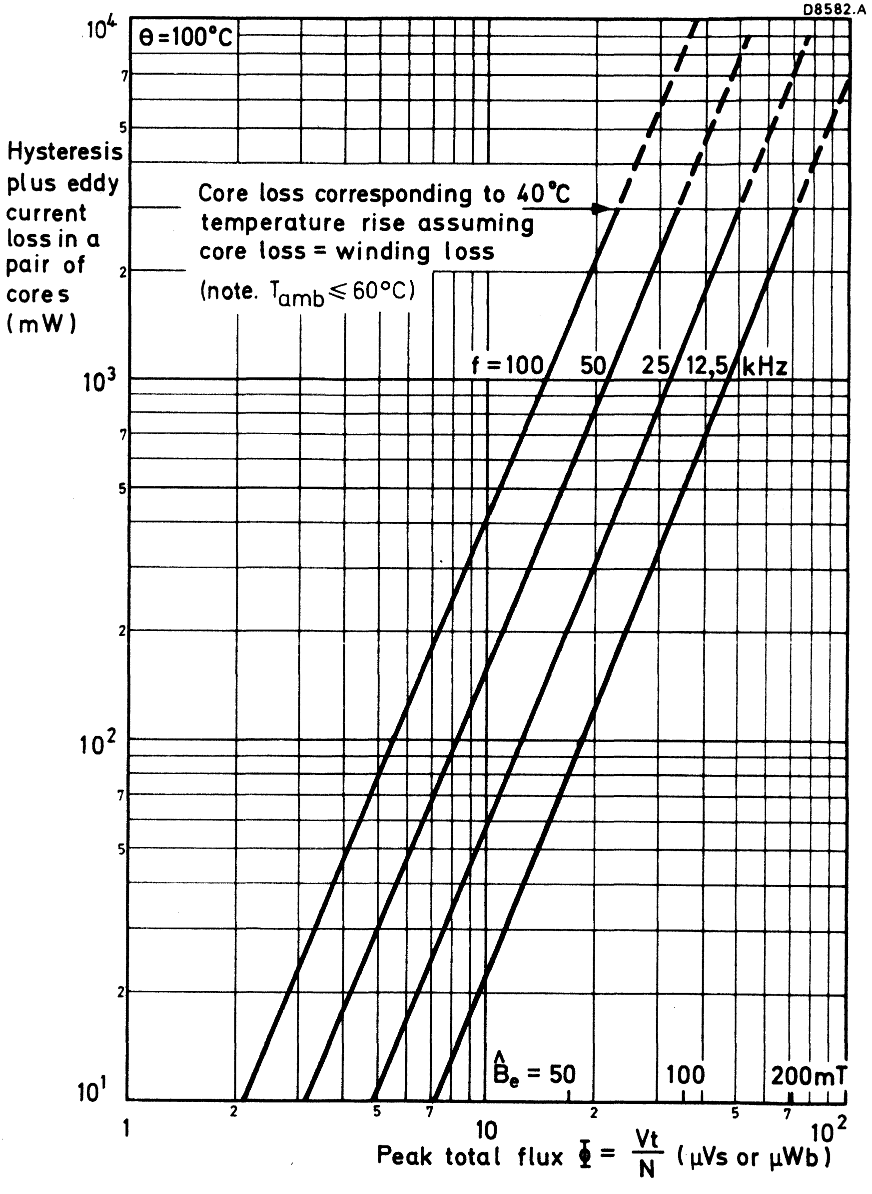
Typical magnetization curves for a pair of cores with ambient temperature as parameter, FXC 3C8.



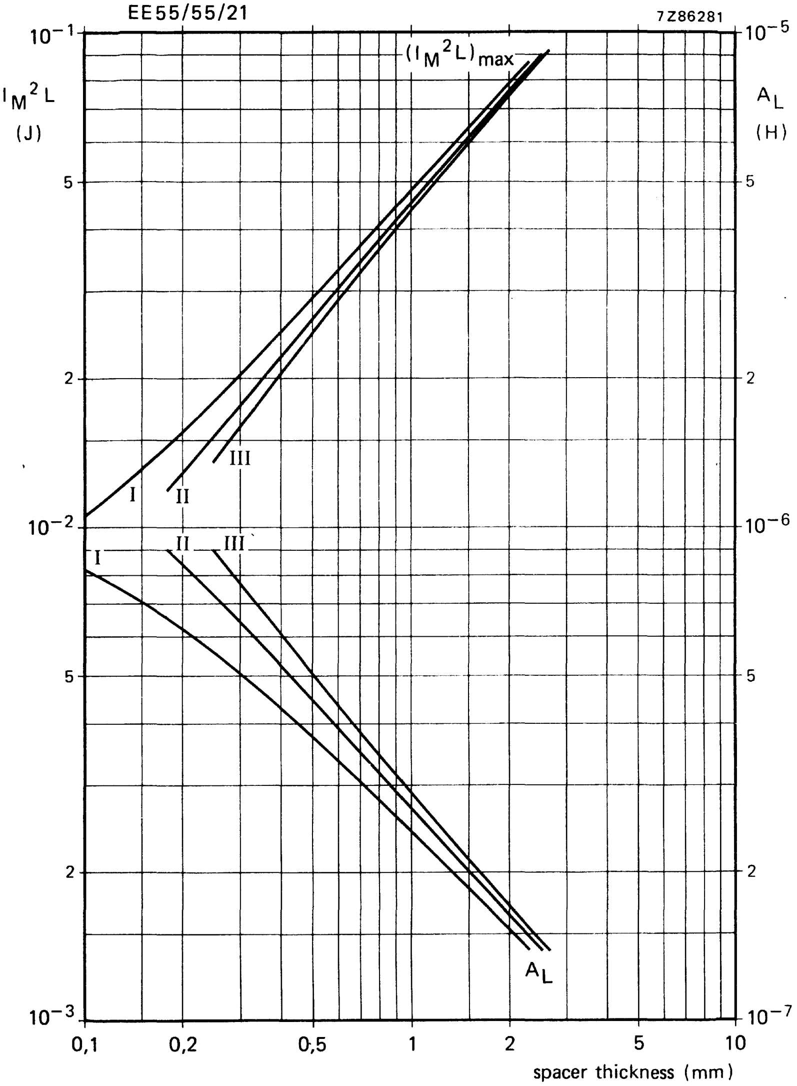
Total flux as a function of core temperature.



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



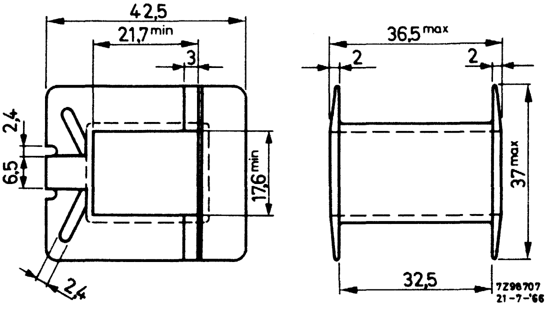
Core loss as a function of total flux at 100 °C with frequency as parameter, FXC 3C8.



Choke design chart.

COIL FORMER

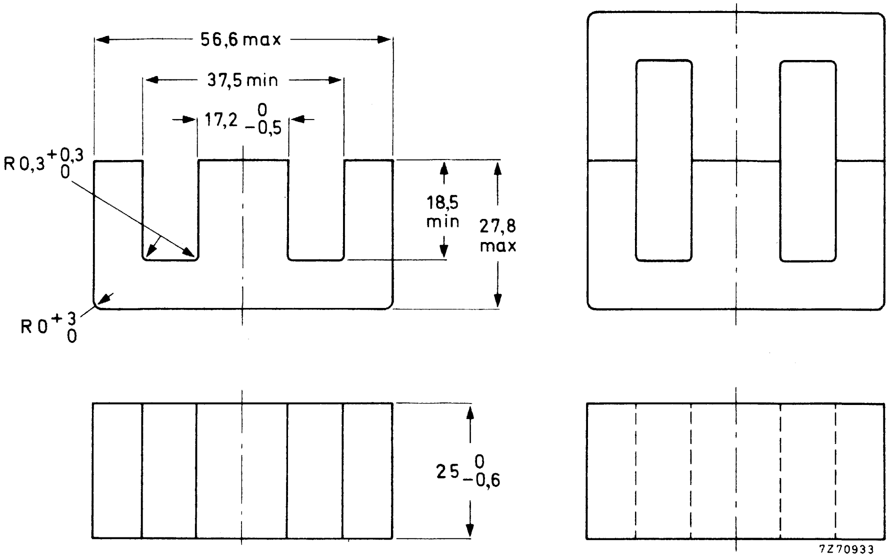
for shell type transformer EE55/55/21



catalogue number	4312 021 28711
material	reinforced polyamide
minimum window area	250 mm^2
mean length of turn	116 mm
approximate mass	9 g
maximum temperature	180 °C

The dimensions are according to German specification DIN 41305.

E-CORES



Mass approx. 130 g

Catalogue numbers

Ferroxcube grade		3C8
Catalogue number of E-core, air gap	$\Delta = 0$	3122 134 90210
	$\Delta = 1{,}4 \pm 0{,}1$	3122 134 90940
	$\Delta = 2{,}3 \pm 0{,}2$	4312 020 34740

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

$A_e = 420\ \text{mm}^2$

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

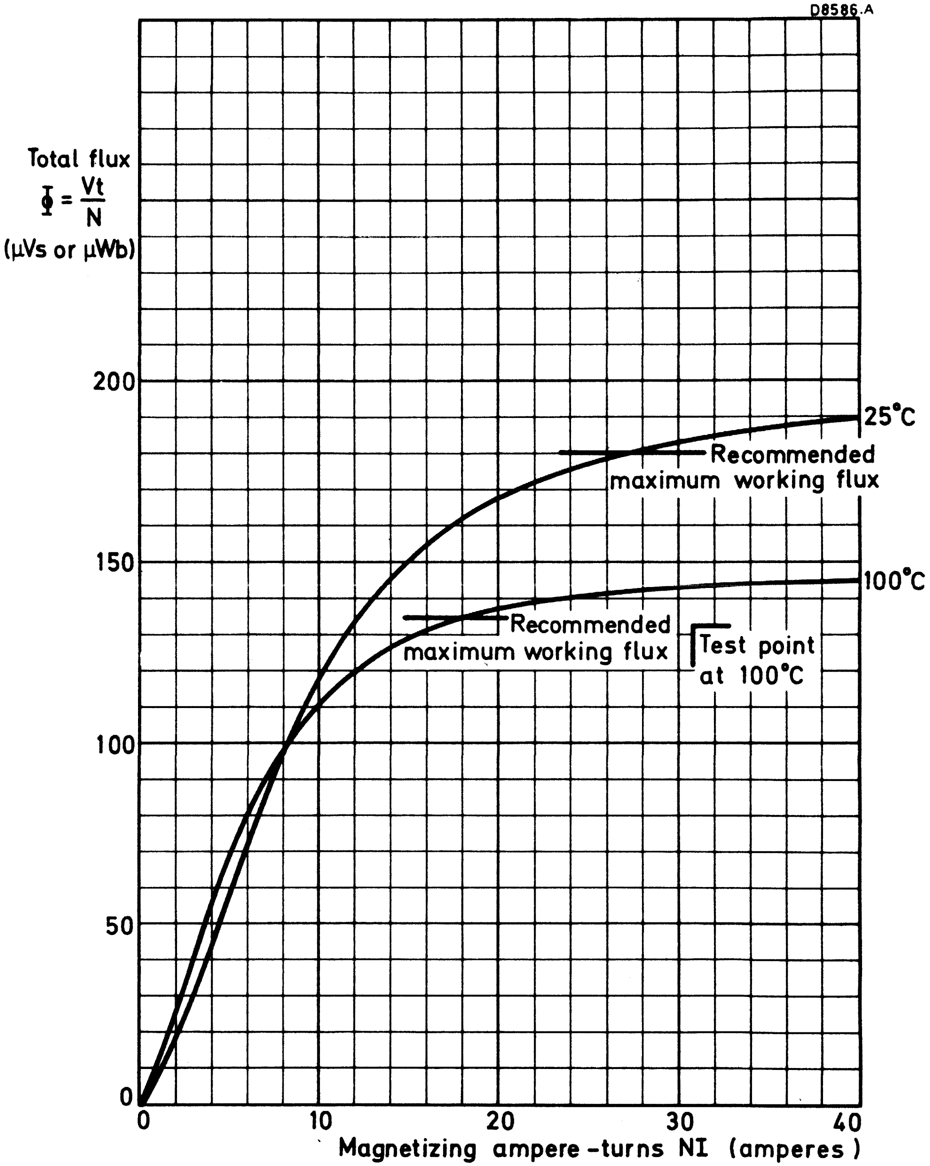
$V_e = 52000\ \text{mm}^3$

Magnetic properties; $\Delta = 0$

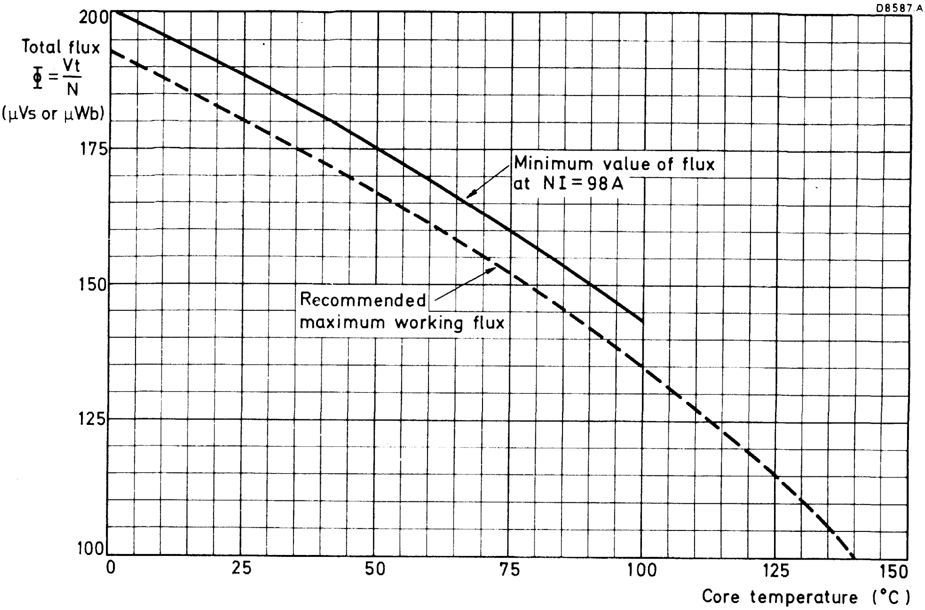
At f = 16 kHz, $\hat{B} = 200$ mT, $\theta = 25\ ^{\circ}\text{C}$	$P \leqslant 6{,}2$ W
$\theta = 100\ ^{\circ}\text{C}$	$P \leqslant 5{,}7$ W
At f = 16 kHz, $\hat{B} \geqslant 315$ mT, $\theta = 100\ ^{\circ}\text{C}$	$\hat{H} = 250$ A/m

APPLICATION FOR SYMMETRICAL MAGNETIZATION

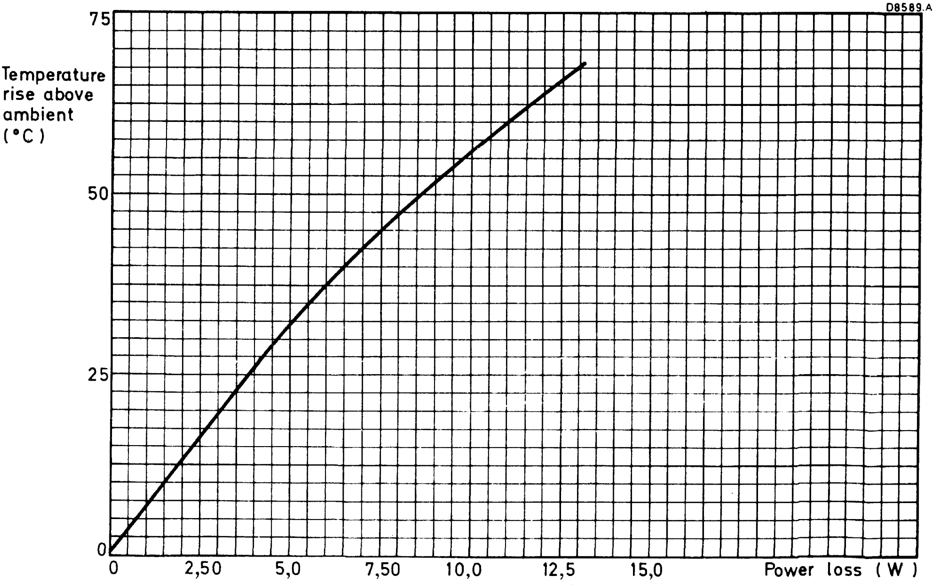
Note: The curves shown on the following pages represent typical characteristics for a pair of E55 cores in 3C8.



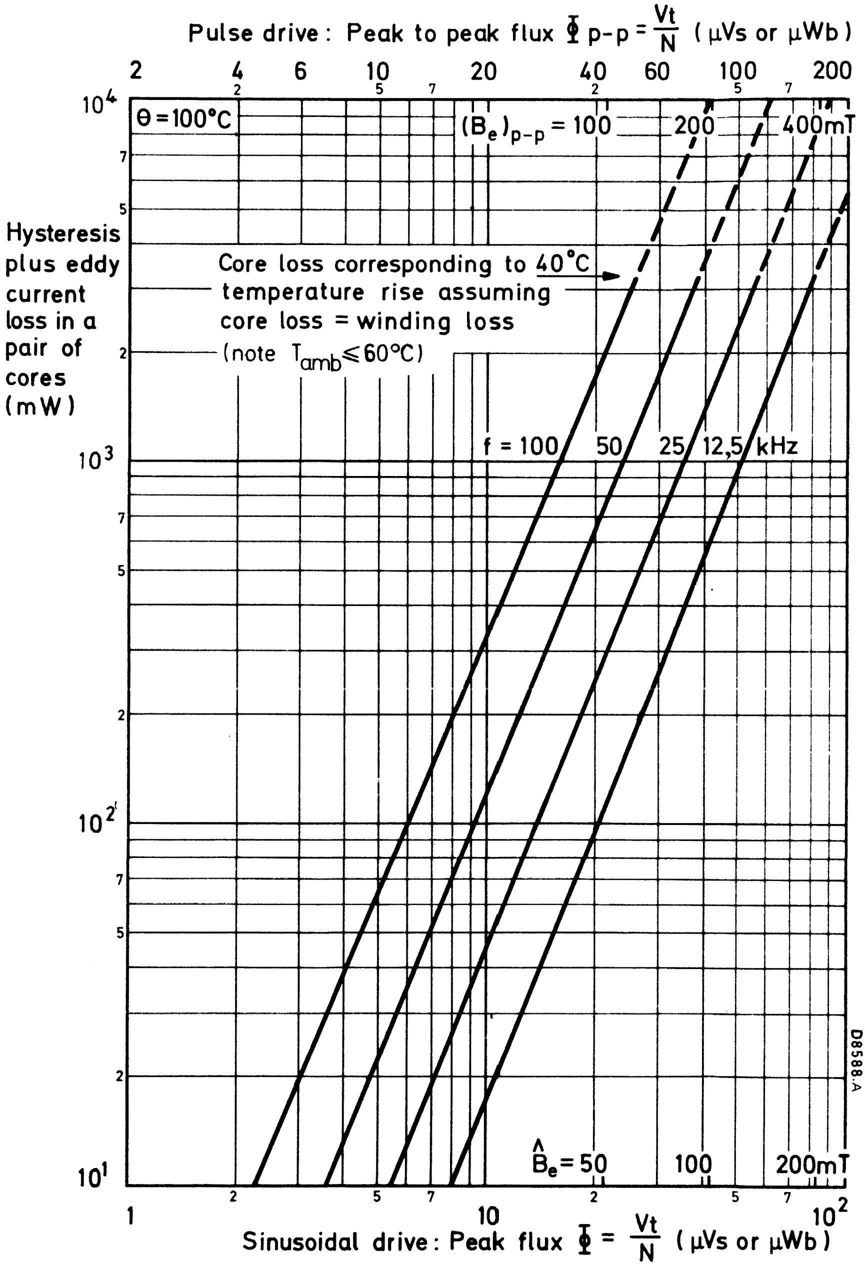
Typical magnetization curves for a pair of cores with ambient temperature as parameter.



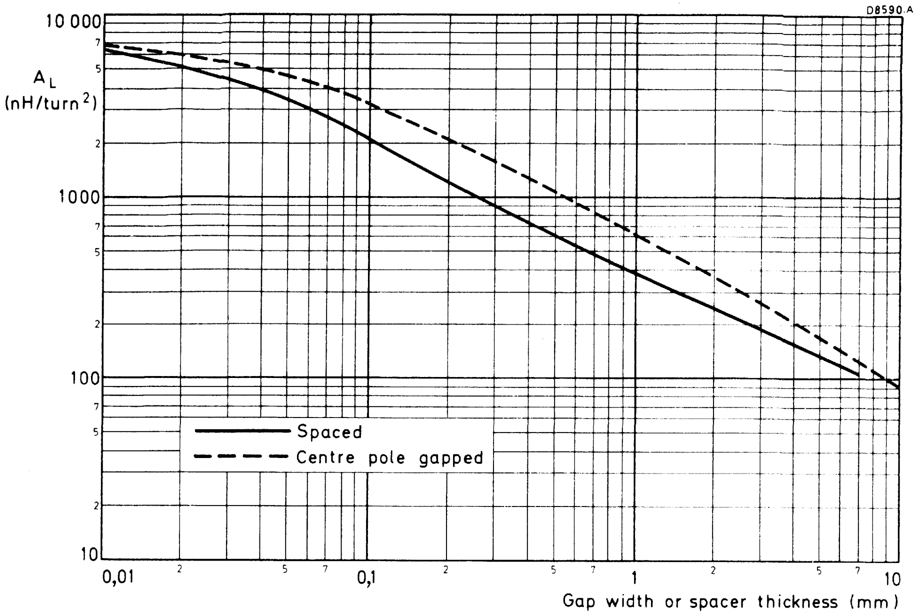
Total flux as a function of core temperature.



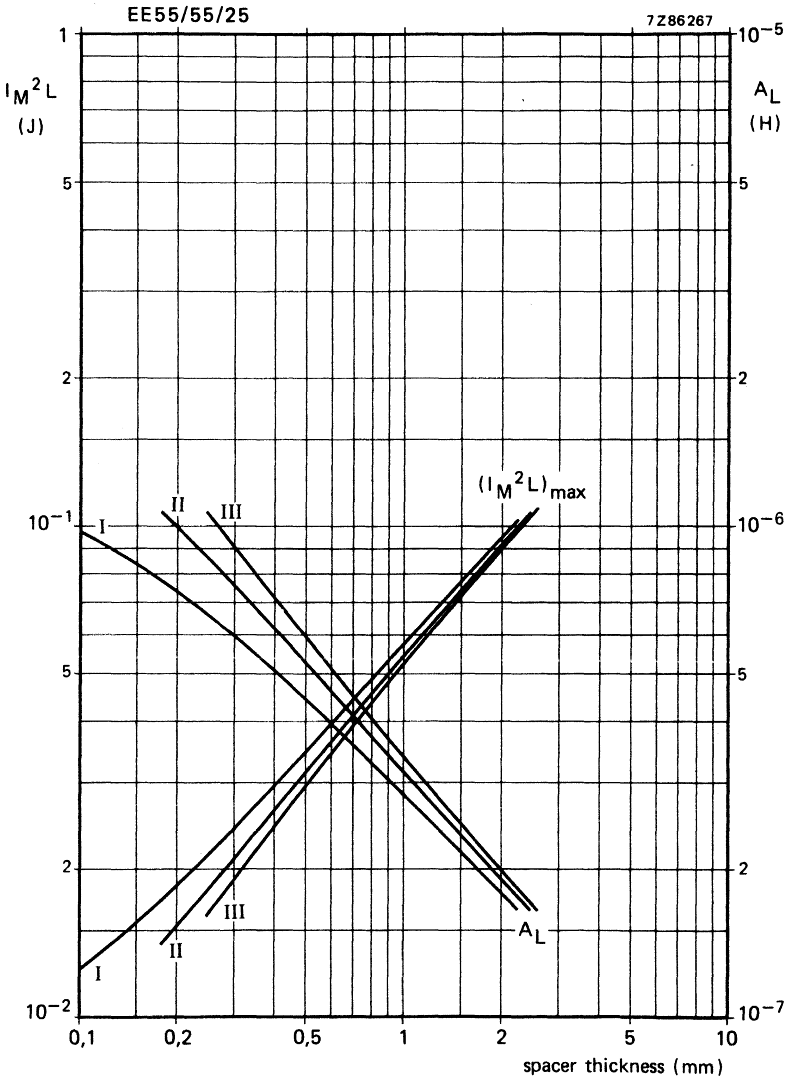
Typical transformer temperature rise as a function of total transformer loss in free air conditions.



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

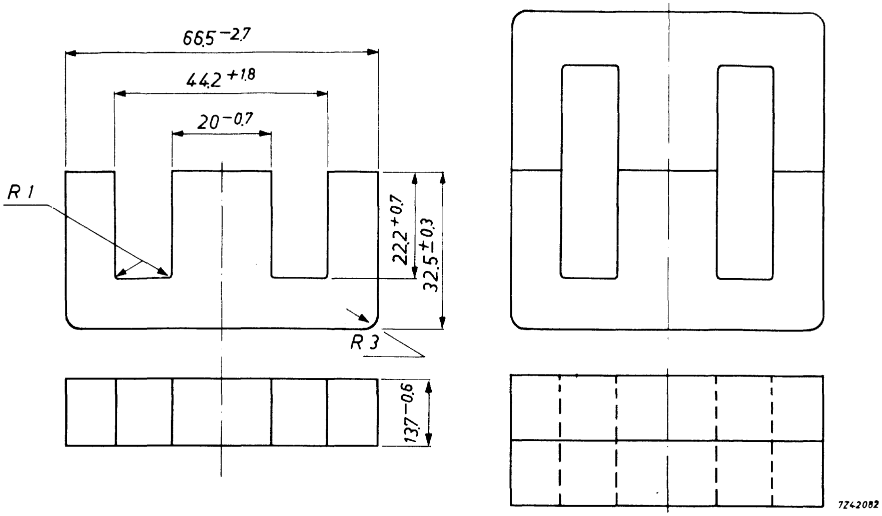


A_L based on a typical permeability of 2000 as a function of spacer thickness.



Choke design chart.

E-CORES



The dimensions are according to DIN 41295

Mass approx. 76 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:

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

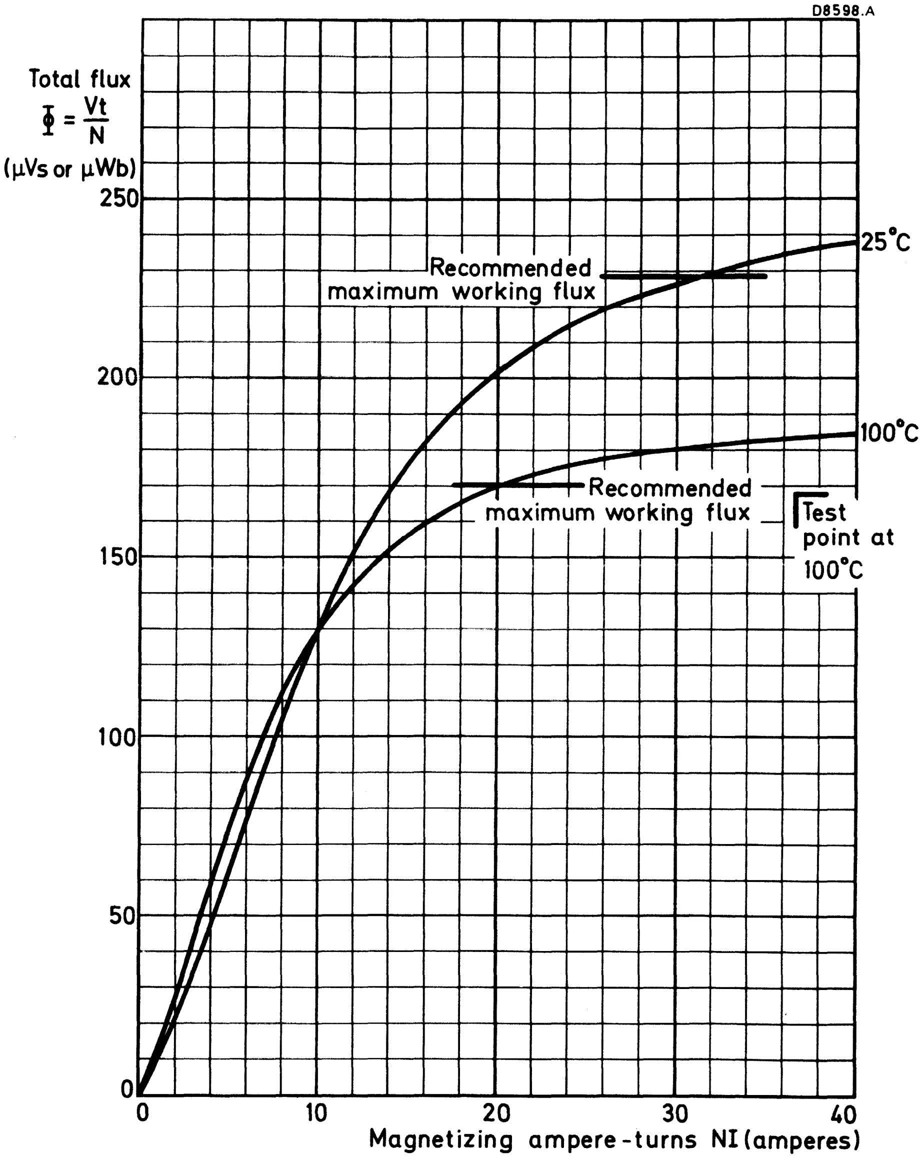
MAGNETIC DATA

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

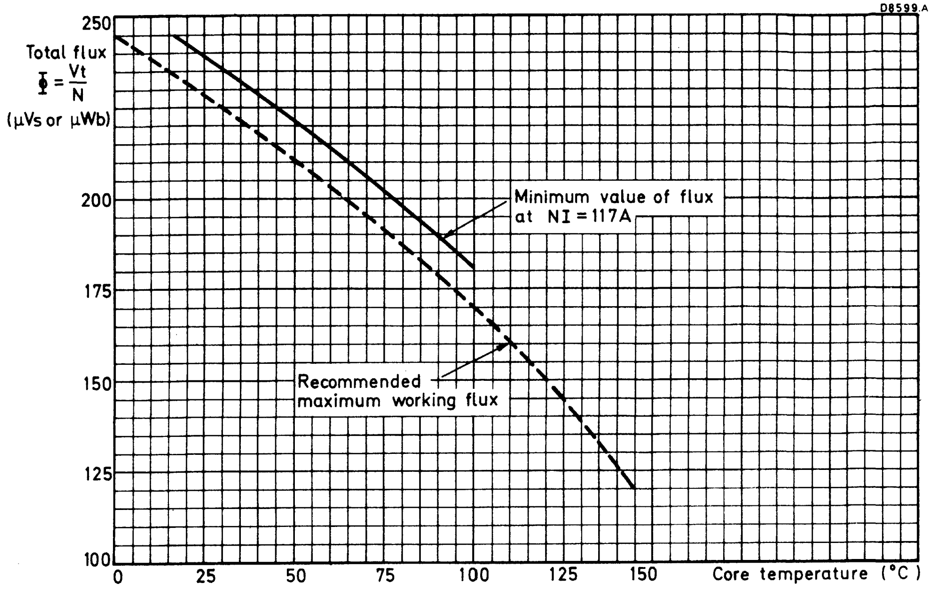
	freq. kHz	temp. °C	$\hat{B}$ mT	
A_L	100	25 ± 5		12355 to 18545
μ_e	100	25 ± 5		2705 to 4060
$\eta_B \times 10^3$	4	25 ± 5	1,5 to 3	$\leqslant 4{,}3$

APPLICATION FOR SYMMETRICAL MAGNETIZATION

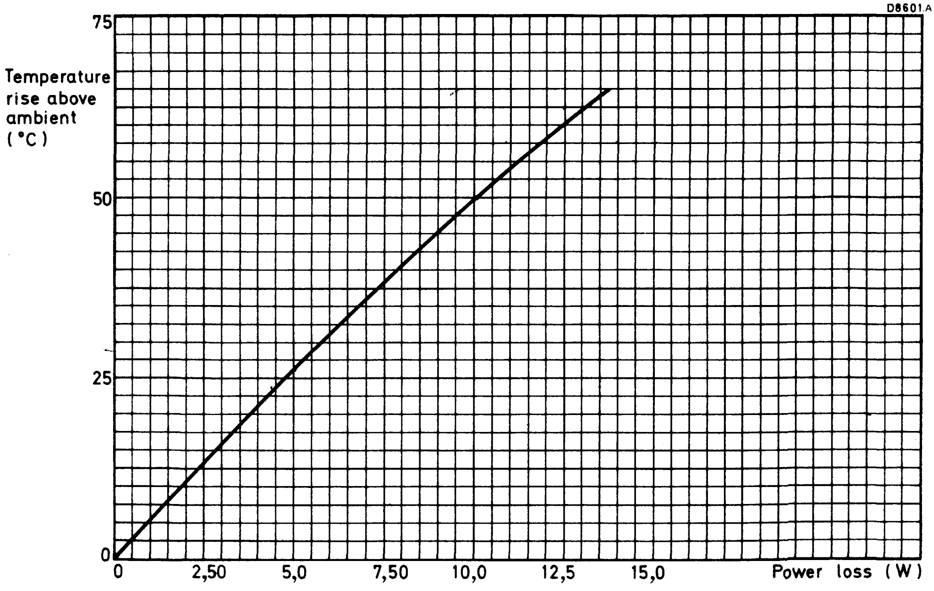
Note: The curves shown on the following pages represent typical characteristics for a pair of E65 cores in 3C8.



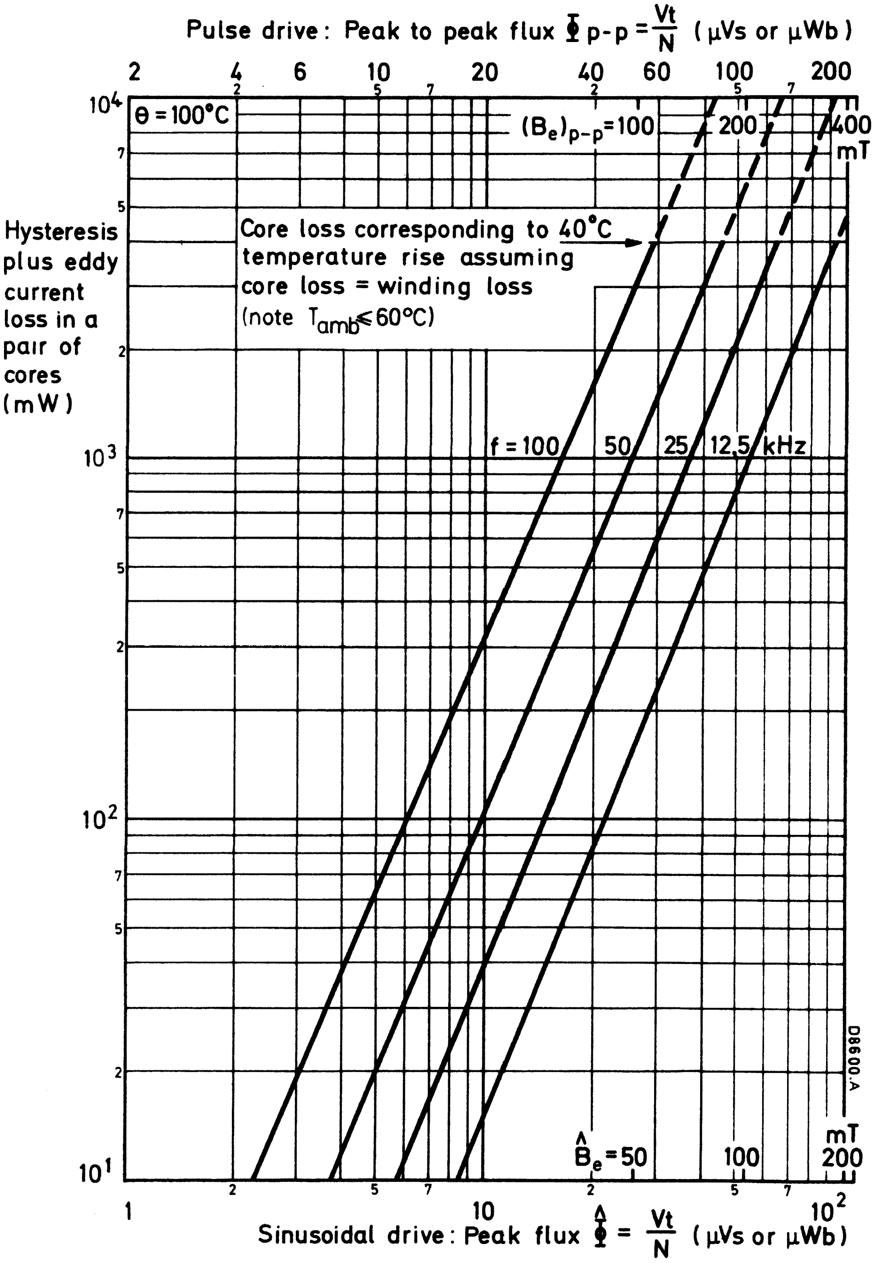
Typical magnetization curves for a pair of cores with ambient temperature as a parameter.



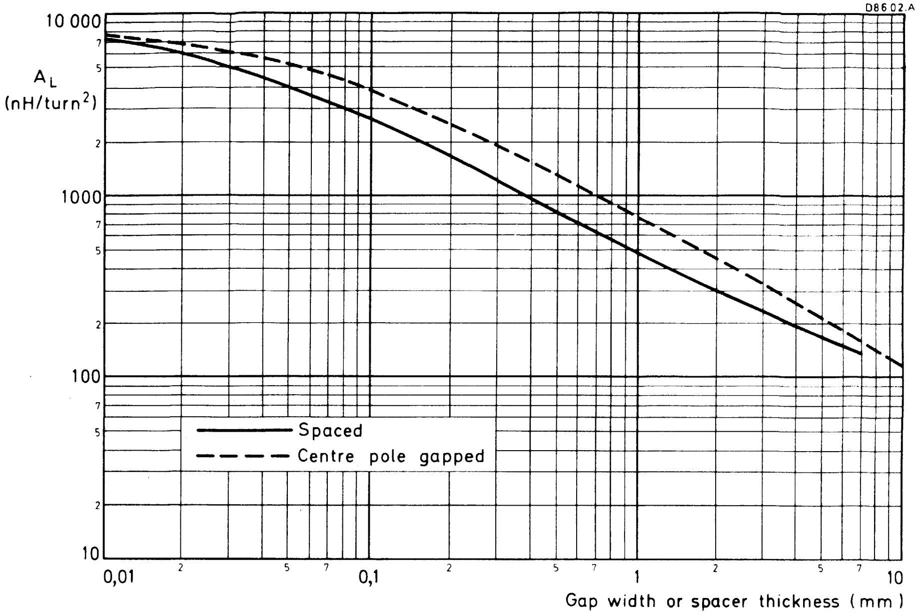
Total flux as a function of core temperature.



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



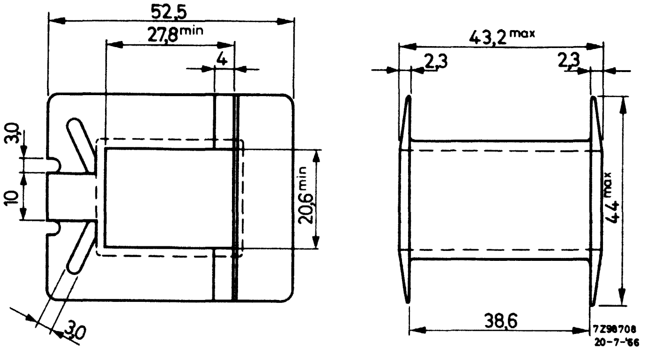
Core loss as a function of total flux at 100 °C with frequency as parameter.



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

COIL FORMER

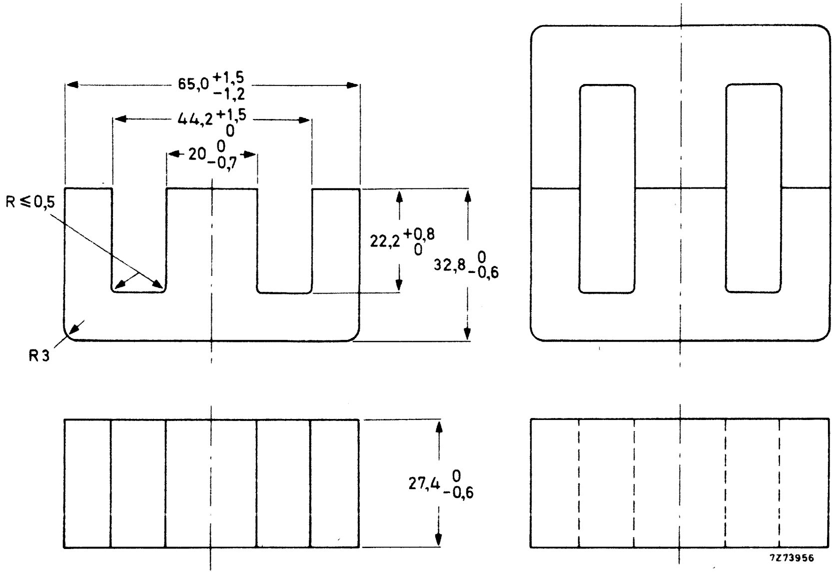
for shell type transformer 65/65/27 (M65)



catalogue number	4312 021 28720
material	reinforced polyamide
minimum window area	394 mm²
mean length of turn	150 mm
approximate mass	13 g
maximum temperature	180 °C

The dimensions are according to German specification DIN 41305.

E-CORES



Mass	approx. 203 g
Ferroxcube grade	3C8
Catalogue number of E-core, air gap $\Delta = 0$	4312 020 34380
$\Delta = 1{,}75 \pm 0{,}15$	4312 020 34750

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 EE65/66/27 composed of two cores type E65/33/27.

Magnetic dimensions according to IEC 205:

l_e = 147 mm

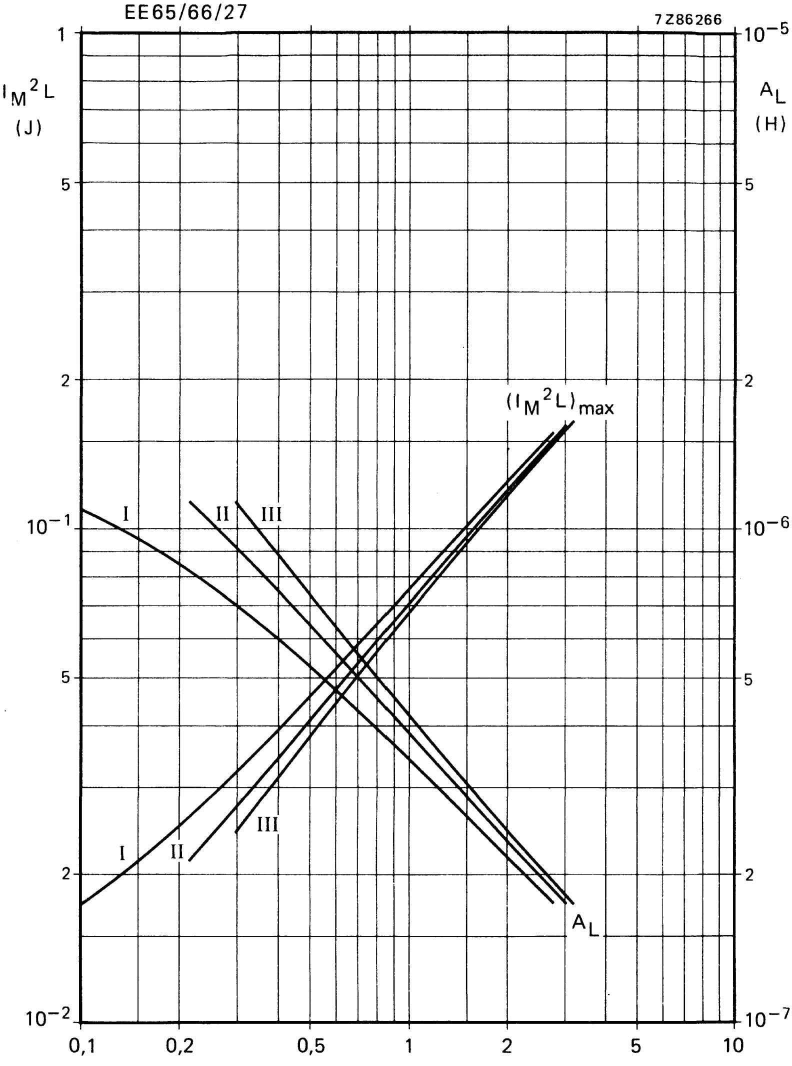
A_e = 532 mm^2

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

V_e = 78200 mm^3

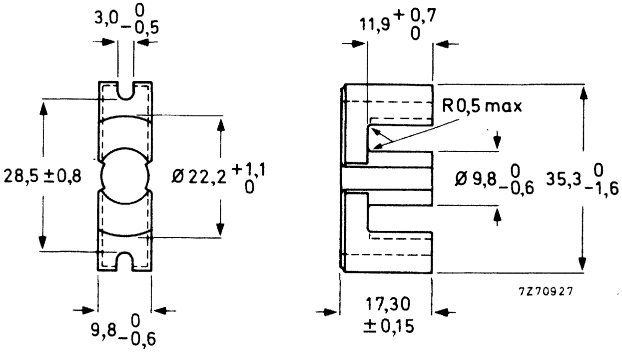
Magnetic properties; $\Delta = 0$

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



Choke design chart.

EC-CORE



Mass	approx. 18 g.
Ferroxcube grade	3C8
Catalogue number of EC-core with air gap: Δ = 0	4322 020 52500
Δ = 1,0 ± 0,1	4313 020 25610
Δ = 1,4 ± 0,2	4313 020 25590

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_{CP}	= 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

* According to IEC205.

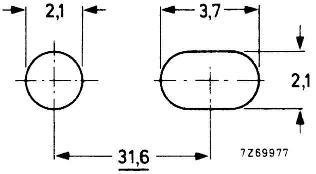
MAGNETIC PROPERTIES FOR A PAIR OF CORES WITHOUT AIR GAP

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) at f = 25 kHz, θ = 100 °C, $\hat{B}$ = 160 mT	$\leqslant$ 1,1 W
Inductance factor A_L at f $<$ 100 kHz, θ = 25 °C, $\hat{B}$ $<$ 0,1 mT	$>$ 1600

MOUNTING

The wound coil former and cores may be assembled by means of non-magnetic M2 screws or studs along the grooves provided. The use of a clamping bar is strongly recommended to ensure that the maximum clamping force of 200 N is uniformly distributed over the cross-section of the outer poles.

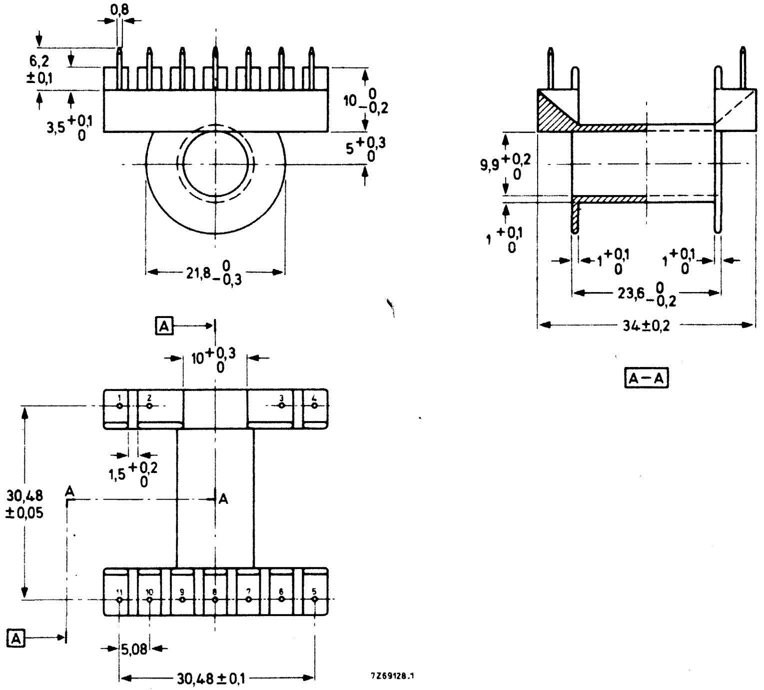
The assembly studs can be extended for mounting purposes or to support another sub-assembly.



Recommended piercing diagram.

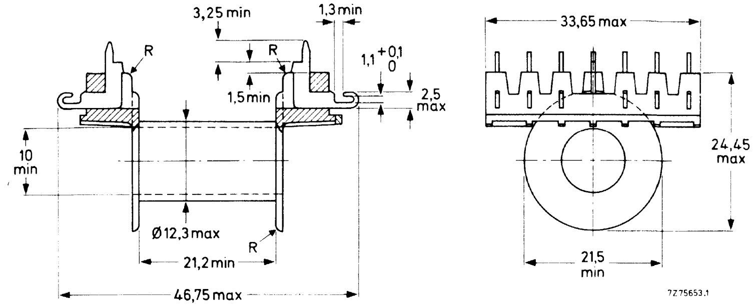
COIL FORMERS

Style 1

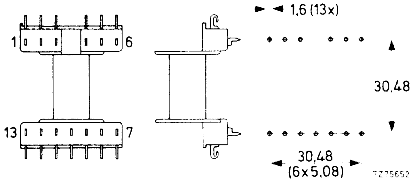


Material	phenolformaldehyde reinforced with glass fibre: brass dip-solder pins
Mounting	horizontal
Minimum window area	97,5 mm^2
Mean length of turn	50 mm
Mass	approx. 6 g
Maximum temperature	140 °C
Catalogue number (coil former with pins)	4322 021 33410

Style 2



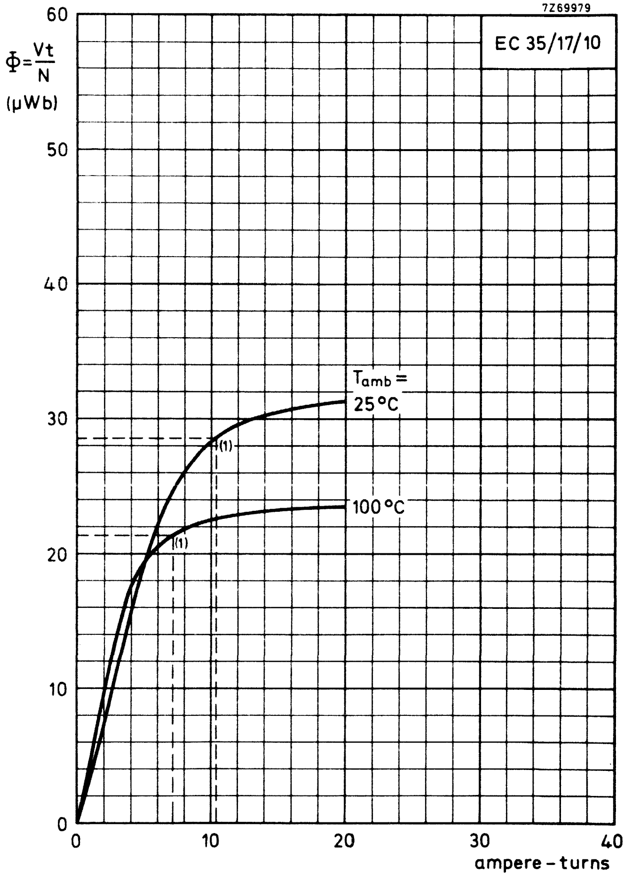
Tag arrangement



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
Flame proof	according to UL-94 V 0
Catalogue number	4322 021 33310

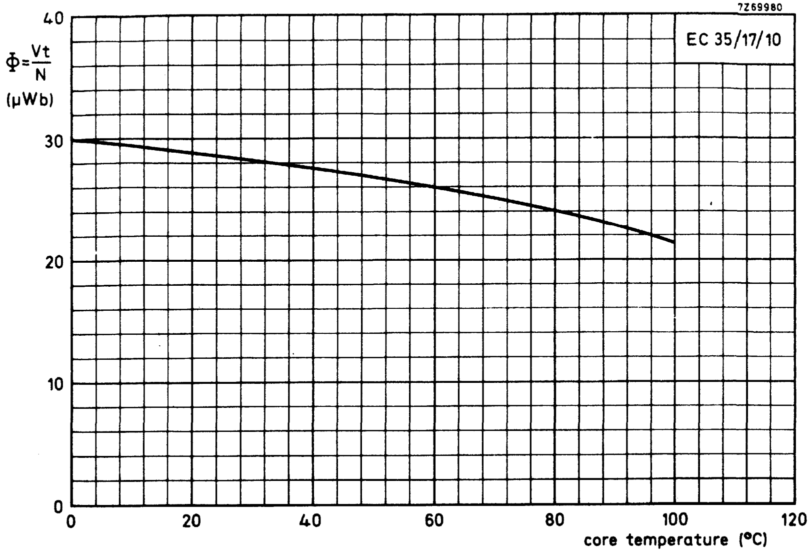
Note
Another coil former for core EC35/17/10 is available: catalogue number 4313 021 04143; information will be supplied on request.

CHARACTERISTIC CURVES

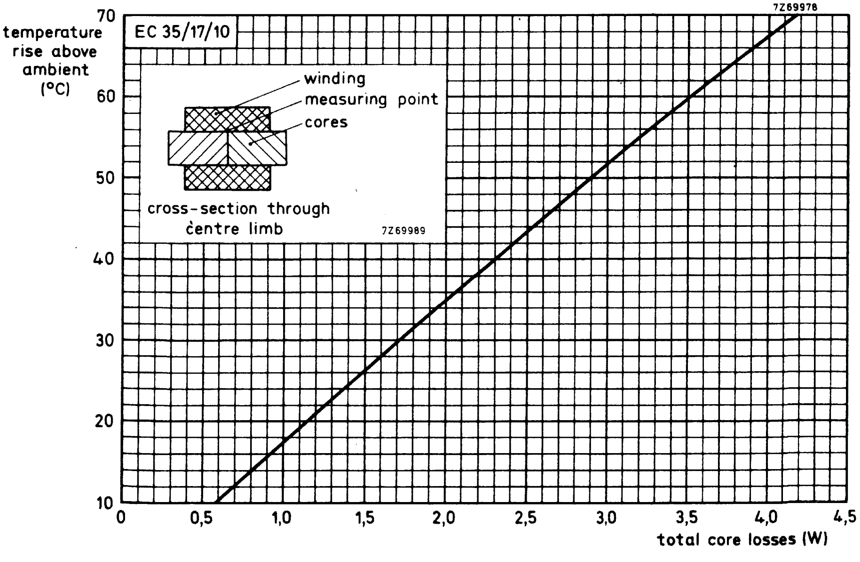


(1) Recommended maximum working flux.

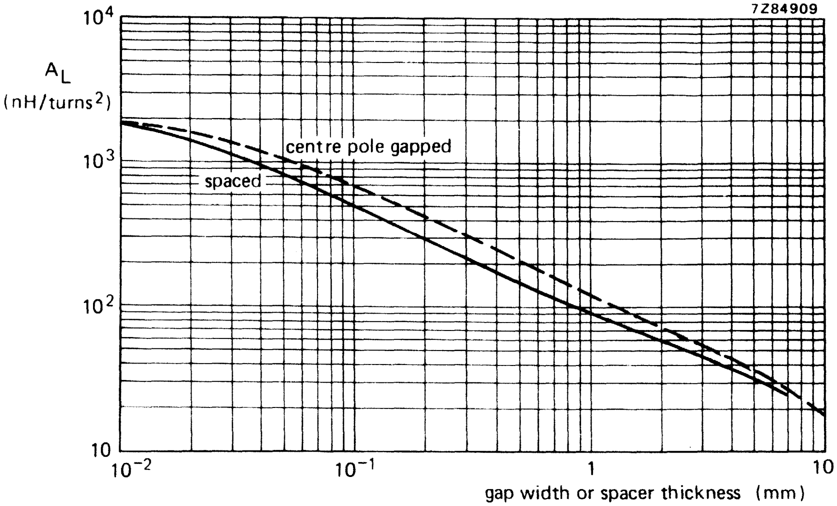
Total flux as a function of ampere-turns.

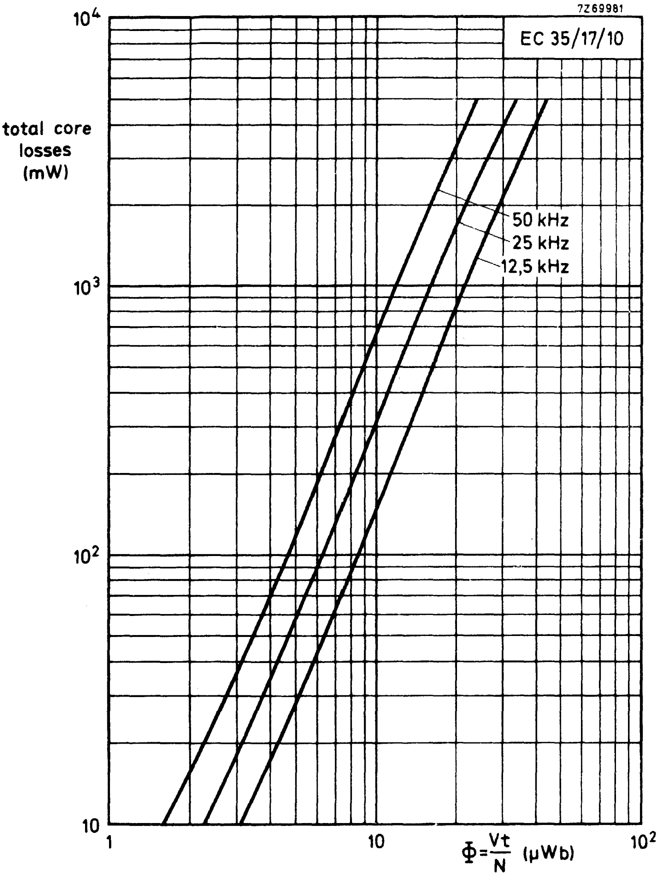


Recommended maximum working flux as a function of core temperature.

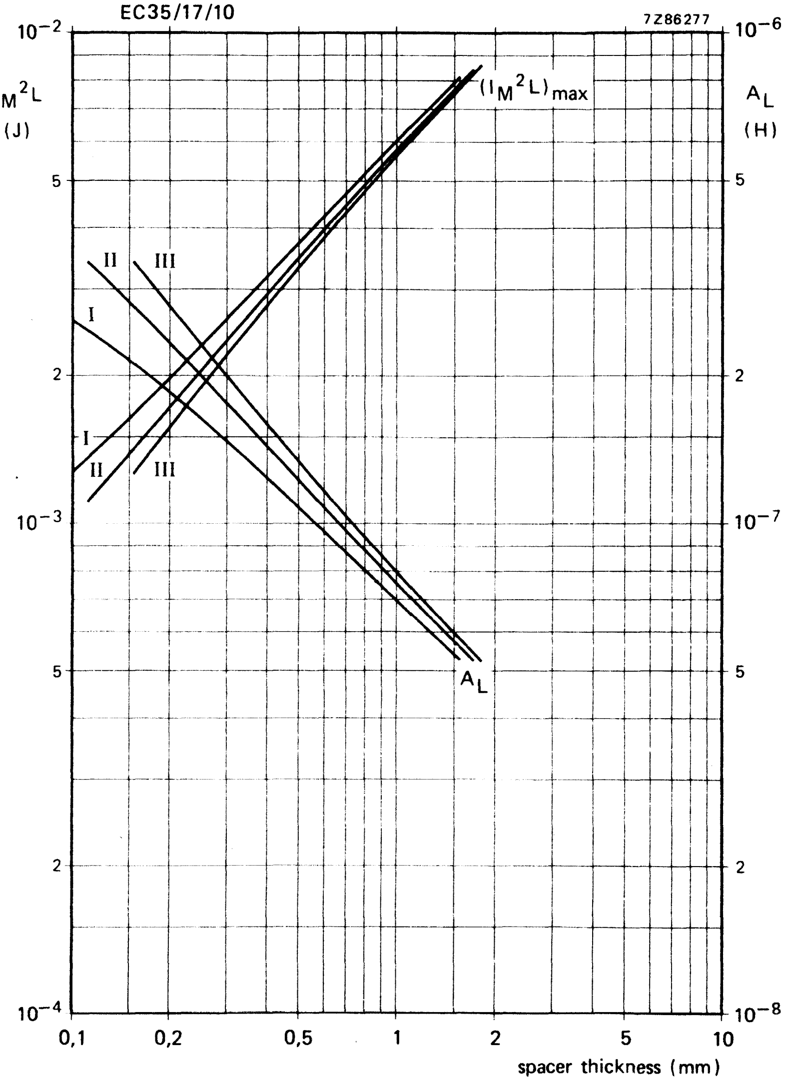


Transformer temperature rise as a function of total core losses, in free air conditions, without heatsink.


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)

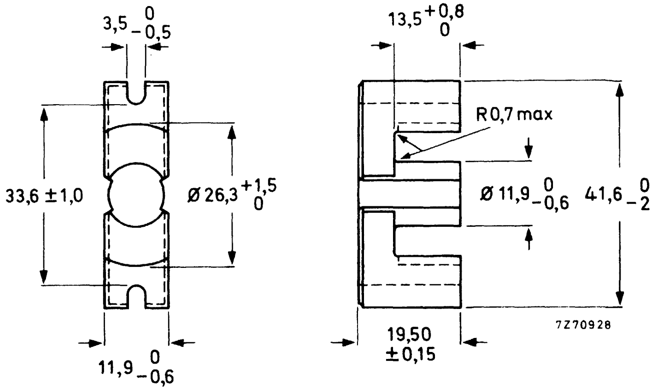


Total core losses as a function of total flux at hot-spot core temperature.



Choke design chart.

EC-CORE



Mass		approx. 26 g
Ferroxcube grade		3C8
Catalogue number of EC-core with air gap:	Δ = 0	4322 020 52510
	Δ = 0,15 ± 0,015	4322 020 52600
	Δ = 1,5 ± 0,2	4313 020 25640

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_{CP}	=	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

* According to IEC205.

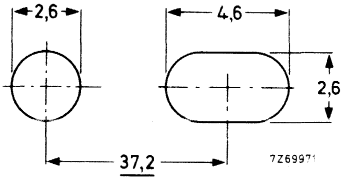
MAGNETIC PROPERTIES FOR A PAIR OF CORES WITHOUT AIR GAP

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) at f = 25 kHz, θ = 100 °C, $\hat{B}$ = 160 mT	$\leqslant$ 2,2 W
Inductance factor A_L at f $<$ 100 kHz, θ = 25 °C, $\hat{B}$ $<$ 0,1 mT	> 2000

MOUNTING

The wound coil former and cores may be assembled by means of non-magnetic M2,5 screws or studs along the grooves provided. The use of a clamping bar is strongly recommended to ensure that the maximum clamping force of 250 N is uniformly distributed over the cross-section of the outer poles.

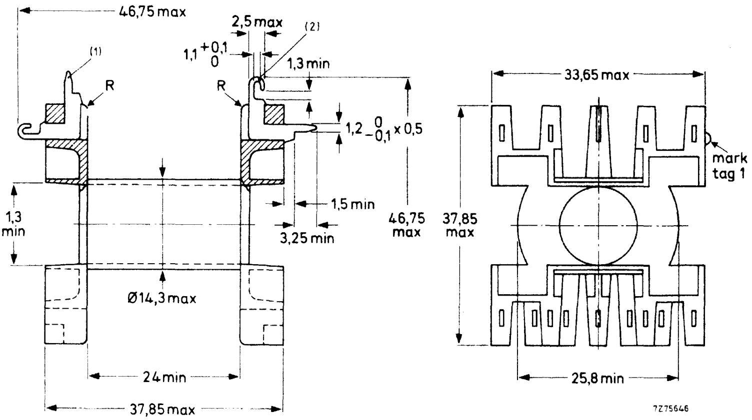
The assembly studs can be extended for mounting purposes or to support another sub-assembly.



Recommended piercing diagram.

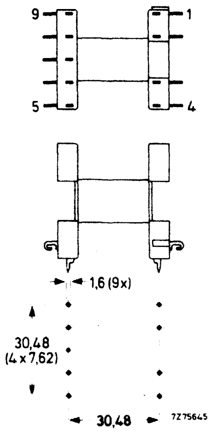
COIL FORMERS

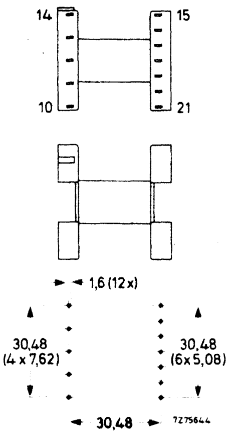
Material housing	glass-fibre-filled polyteraphthalate
Material of tags	solder-plated brass
Minimum window area	138 mm^2
Mean length of turn	62 mm
Mass, 9 tags inserted	10 g
Flame proof	according to UL-94-V 0
Mounting	horizontal and vertical
Catalogue number	see next page
Tag arrangement	see next page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

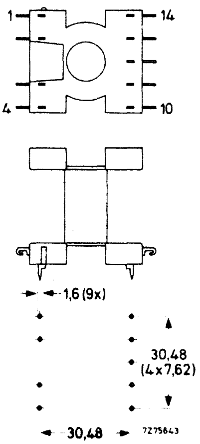


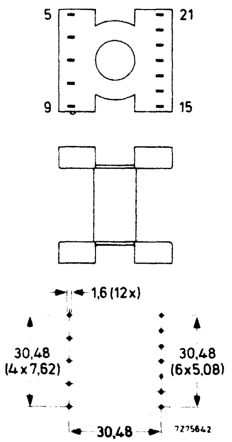
Tag arrangement

Horizontal mounting		Vertical mounting	
9 tags inserted	for 12 tags*	9 tags inserted	for 12 tags*
catalogue no. 4322 021 33320	catalogue no. 4322 021 33010	catalogue no. 4322 021 33350	catalogue no. 4322 021 33010









Note
Another coil former for core EC41/19/12 is available: catalogue number 4313 021 04153; information will be supplied on request.

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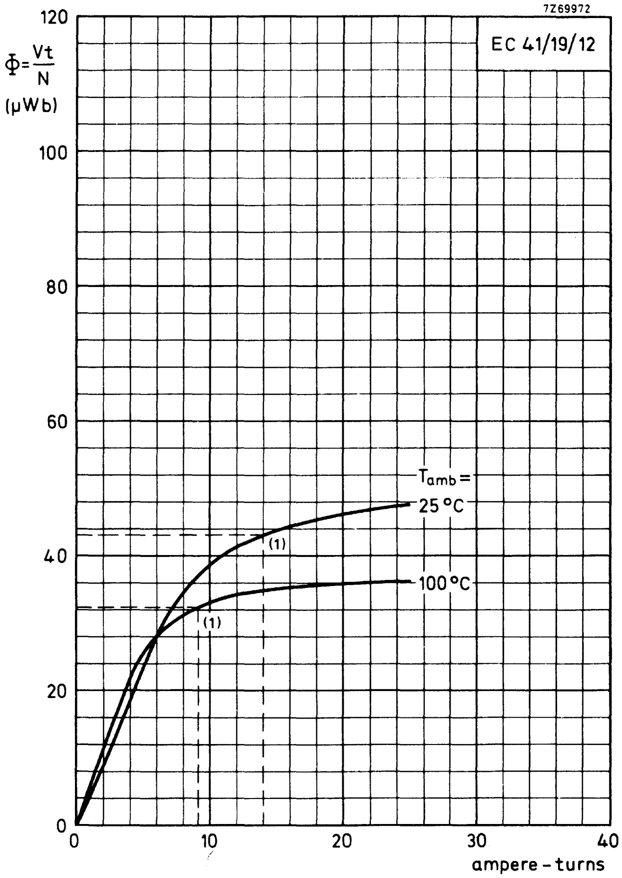
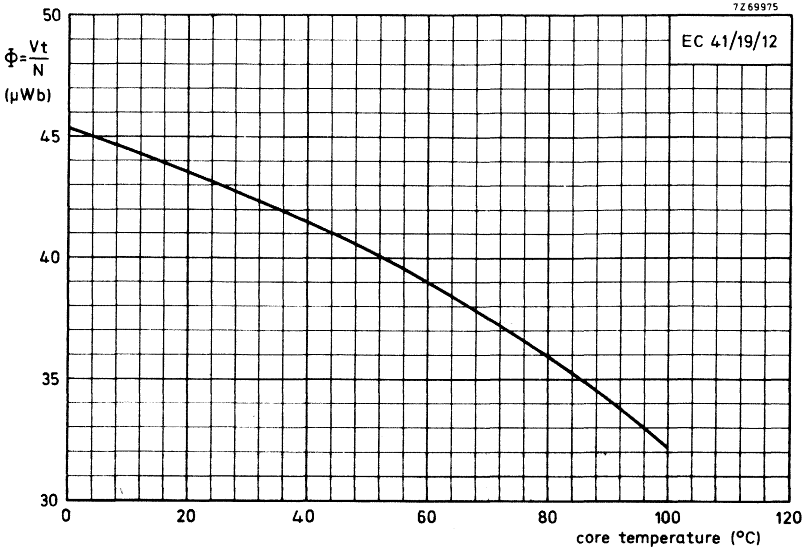
* Tags, catalogue number 4322 021 33060 should be ordered separately.

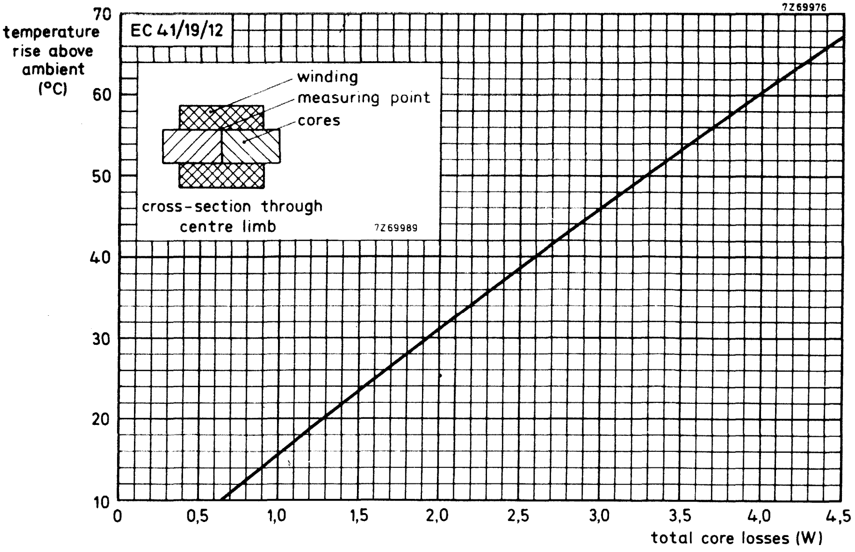
CHARACTERISTIC CURVES



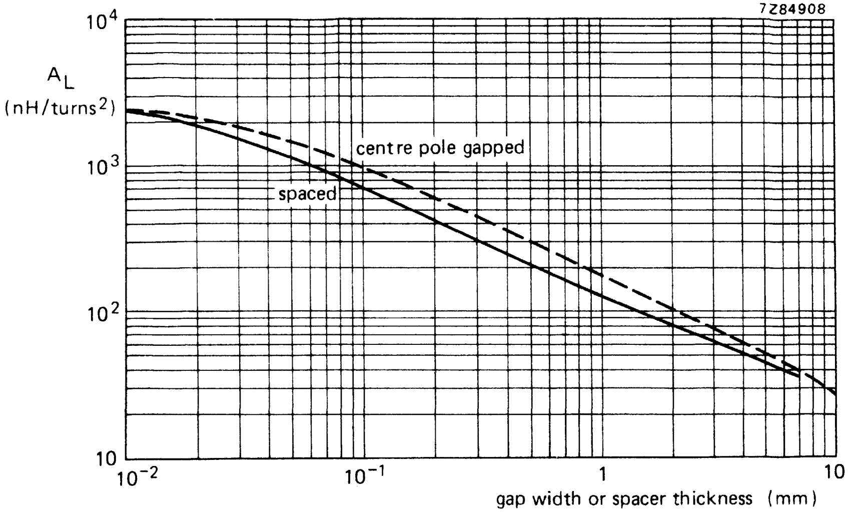
(1) Recommended maximum working flux.
Total flux as a function of ampere-turns.

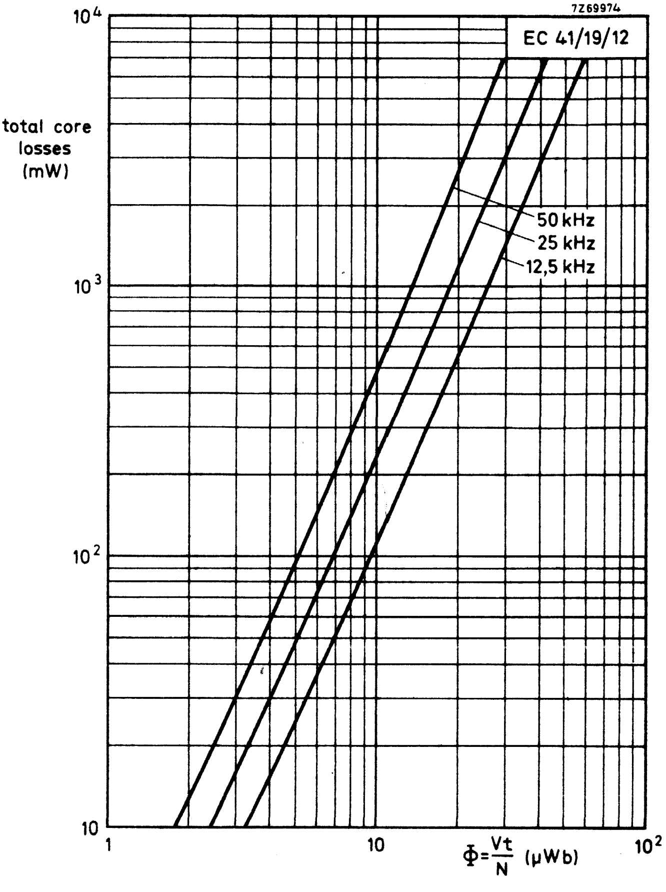


Recommended maximum working flux as a function of core temperature.

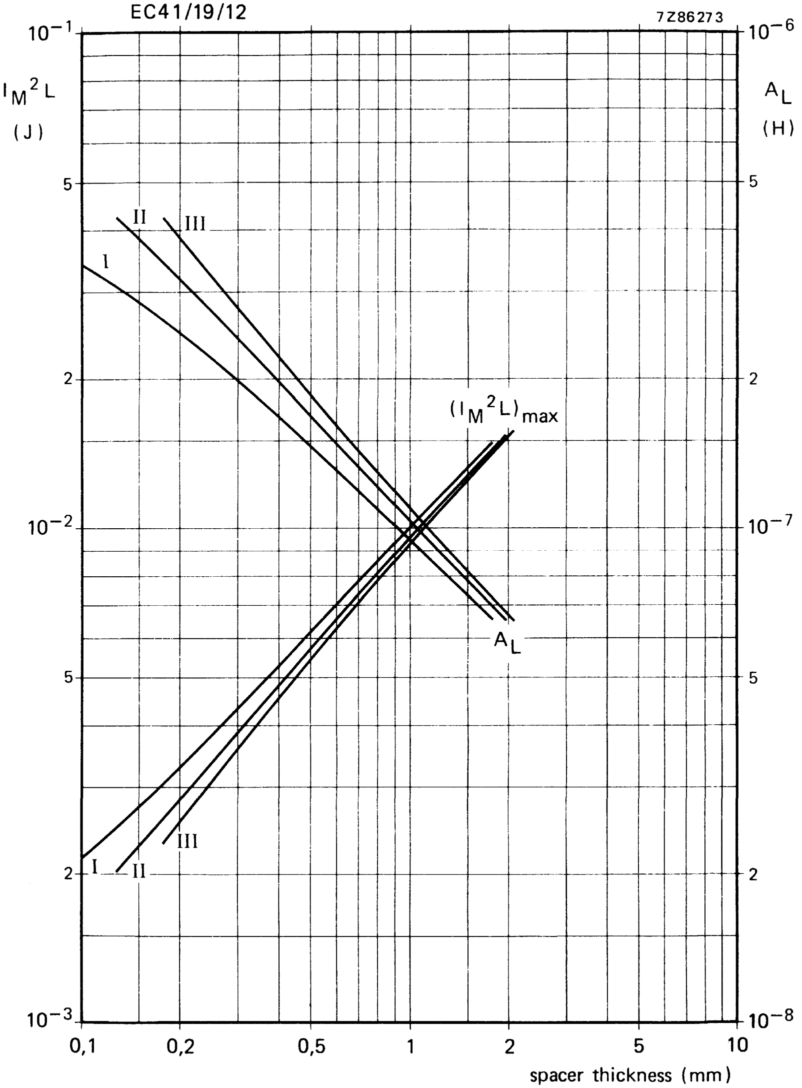


Transformer temperature rise as a function of total core losses, in free air conditions, without heatsink.


7Z84908
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)

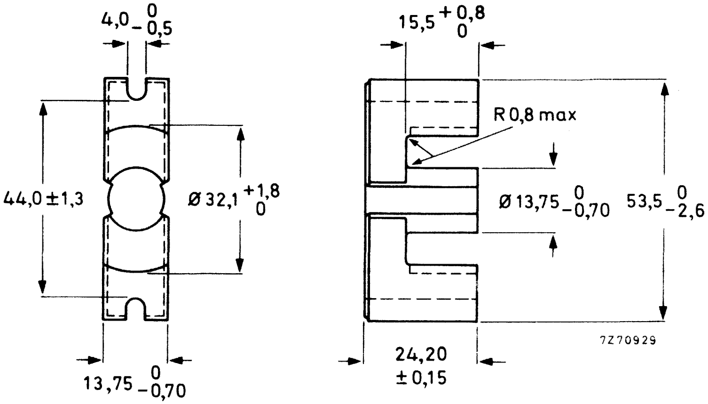


Total core losses as a function of total flux at hot-spot core temperature.



Choke design chart.

EC-CORE



Mass		approx. 55,5 g
Ferroxcube grade		3C8
Catalogue number of EC-core with air gap:	Δ = 0	4322 020 52520
	Δ = 2,3 ± 0,2	4313 020 25680

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_{CP}	= 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

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* According to IEC205.

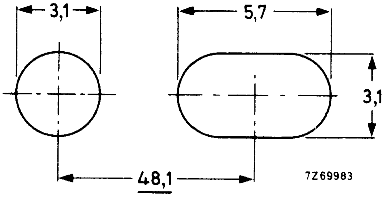
MAGNETIC PROPERTIES FOR A PAIR OF CORES WITHOUT AIR GAP

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) at f = 25 kHz, θ = 100 °C, $\hat{B}$ = 160 mT	$\leqslant$ 2,7 W
Inductive factor A_L at f $<$ 100 kHz, θ = 25 °C, $\hat{B} <$ 0,1 mT	> 2550

MOUNTING

The wound coil former and cores may be assembled by means of non-magnetic M3-screws or studs along the grooves provided. The use of a clamping bar is strongly recommended to ensure that the maximum clamping force of 400 N is uniformly distributed over the cross-section of the outer poles.

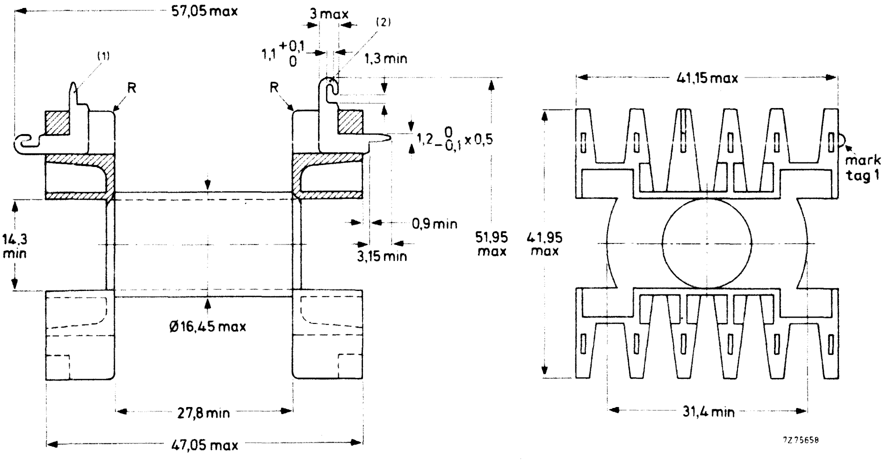
The assembly studs can be extended for mounting purposes or to support another sub-assembly.



Recommended piercing diagram.

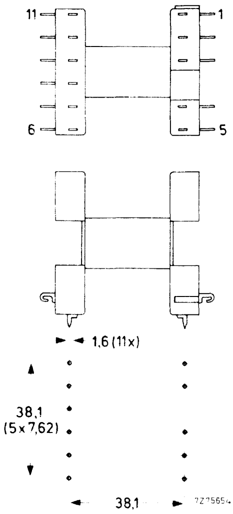
COIL FORMER

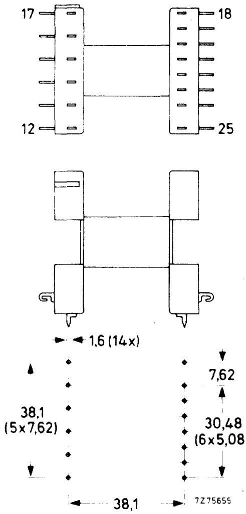
Material of housing	glass-fibre-filled polyteraphthalate
Material of tags	solder-plated brass
Minimum window area	210 mm^2
Mean length of turn	70 mm
Mass, 11 tags inserted	18 g
Flame proof	according to UL-94-V 0
Mounting	horizontal and vertical
Catalogue number	see next page
Tag arrangement	see next page
Dimensions in mm	

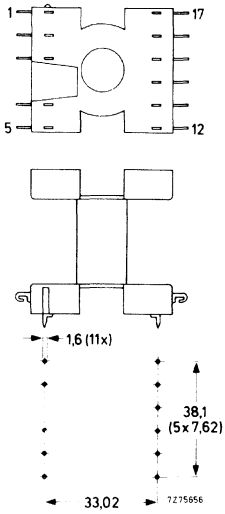


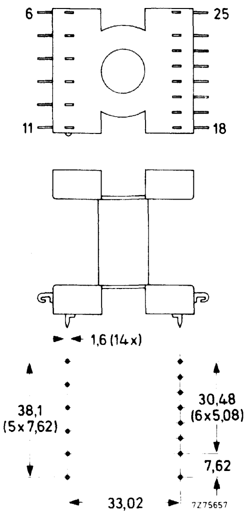
Tag arrangement

Horizontal mounting		Vertical mounting	
11 tags inserted	for 14 tags*	11 tags inserted	for 14 tags*
catalogue no. 4322 021 33330	catalogue no. 4322 021 33020	catalogue no. 4322 021 33360	catalogue no. 4322 021 33020









Note
Another coil former for core EC52/24/14 is available: catalogue number 4313 021 04163; information will be supplied on request.

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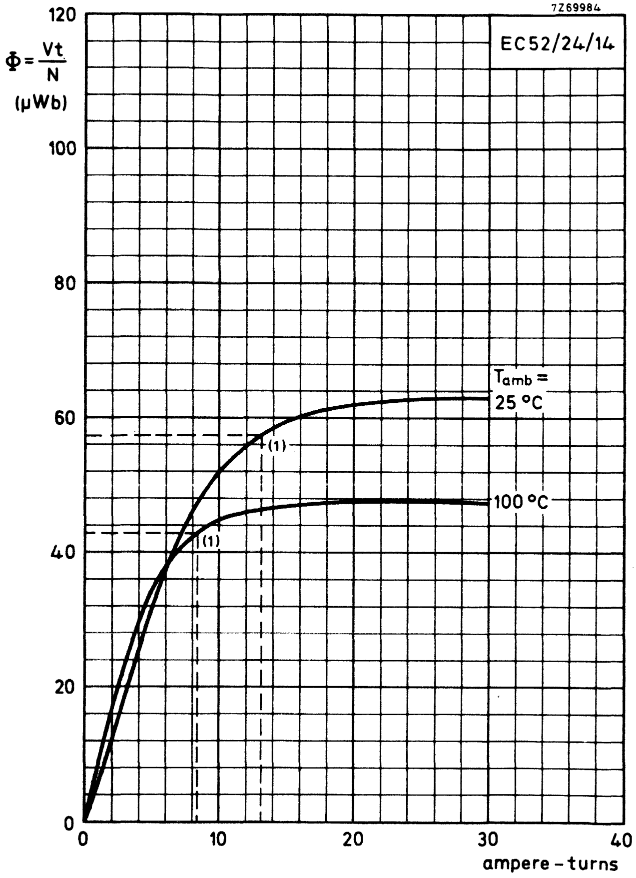
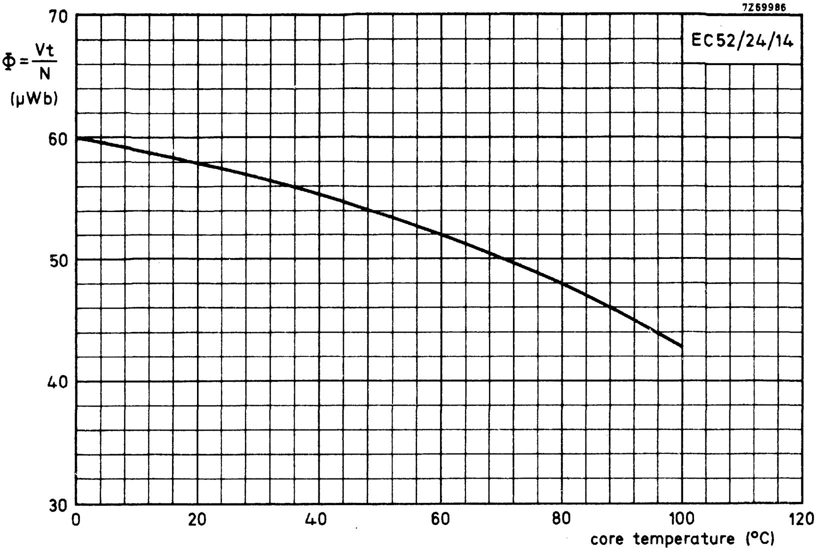
* Tags, catalogue number 4322 021 33070 should be ordered separately.

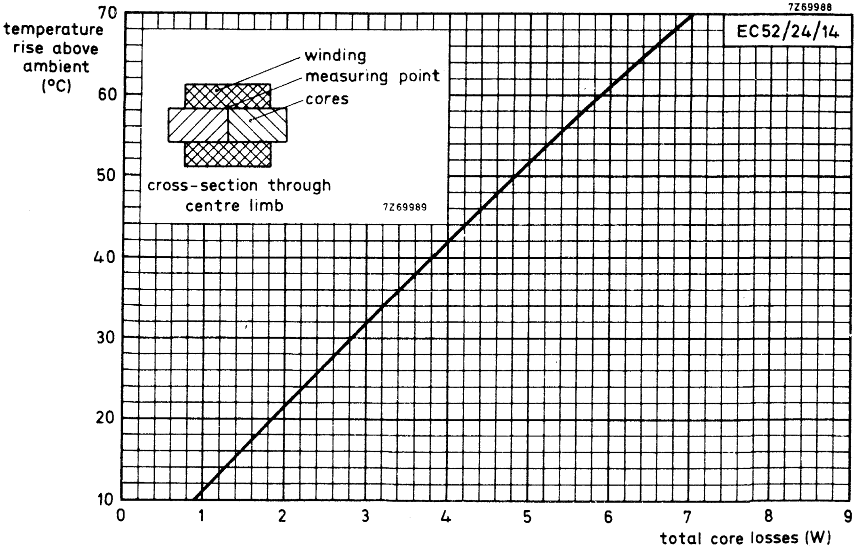
CHARACTERISTIC CURVES



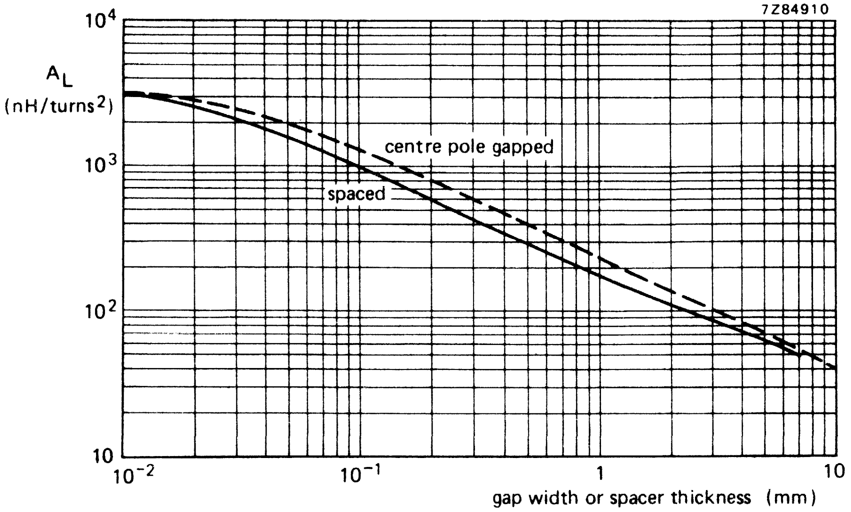
(1) Recommended maximum working flux.
Total flux as a function of ampere-turns.

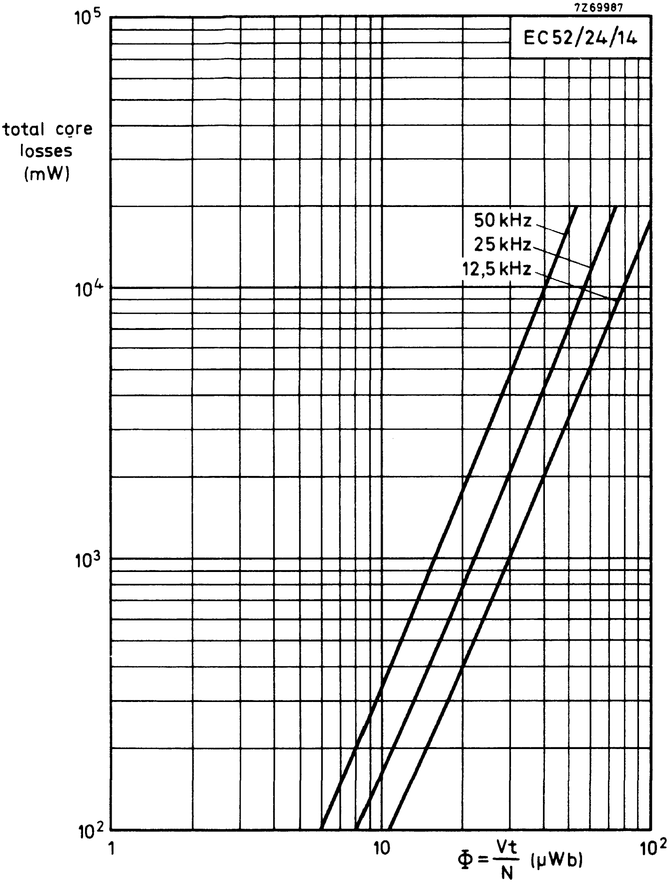


Recommended maximum working flux as a function of core temperature.

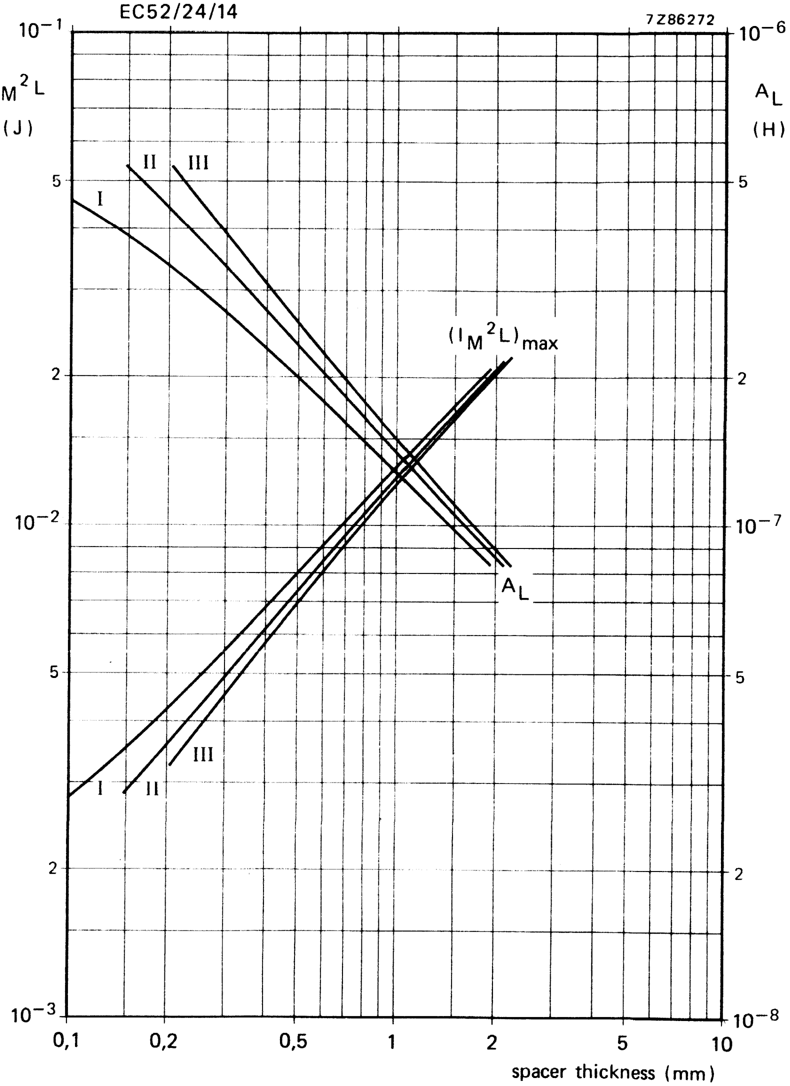


Transformer temperature rise as a function of total core losses, in free air condictions, without heatsink.


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

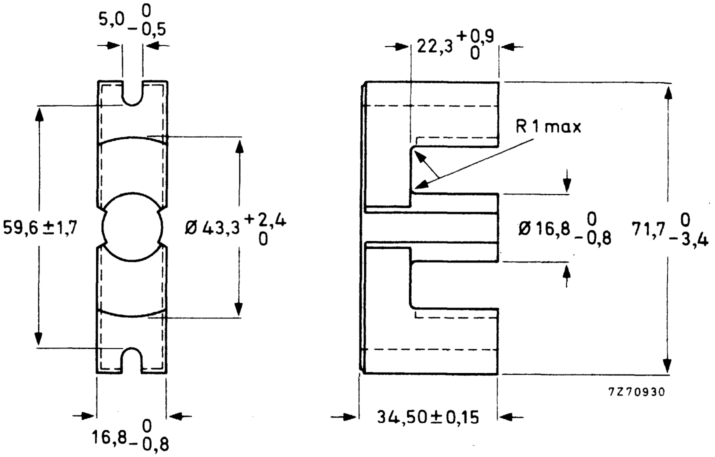


Total core losses as a function of total flux at hot-spot core temperature.



Choke design chart.

EC-CORE



Mass		approx. 126,5 g
Ferroxcube grade		3C8
Catalogue number of EC-core with air gap:	Δ = 0	4322 020 52530
	Δ = 2,5	4313 020 25730
	Δ = 4,85 ± 0,2	4313 020 25720

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_{CP} = 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

* According to IEC205.

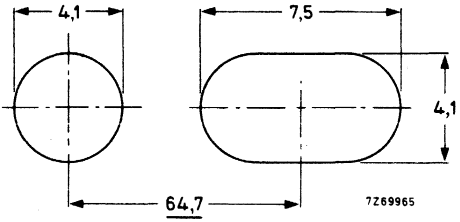
MAGNETIC PROPERTIES FOR A PAIR OF CORES WITHOUT AIR GAP

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

MOUNTING

The wound coil former and cores may be assembled by means of non-magnetic M4 screws or studs along the grooves provided. The use of a clamping bar is strongly recommended to ensure that the maximum clamping force of 600 N is uniformly distributed over the cross-section of the outer poles.

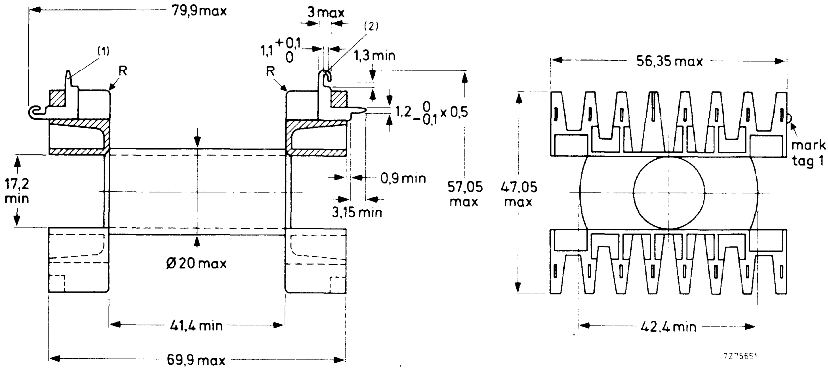
The assembly studs can be extended for mounting purposes or to support another sub-assembly.



Recommended piercing diagram.

COIL FORMERS

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



Tag arrangement

Horizontal mounting

15 tags inserted

catalogue no.
4322 021 33340

for 19 tags*

catalogue no.
4322 021 33030

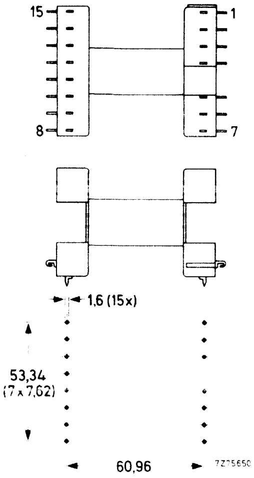
Vertical mounting

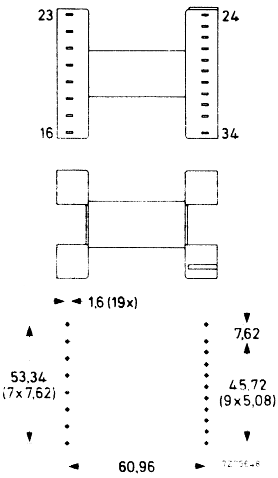
15 tags inserted

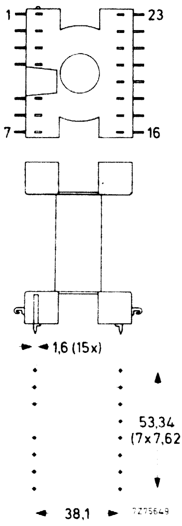
catalogue no.
4322 021 33370

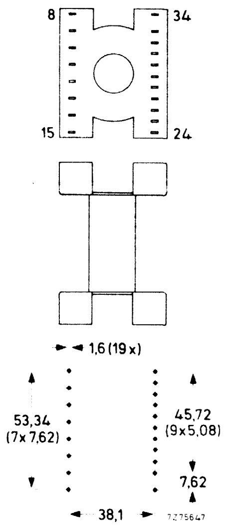
for 19 tags*

catalogue no.
4322 021 33030









Note
Another coil former for core EC70/34/17 is available: catalogue number 4313 021 04173; information will be supplied on request.

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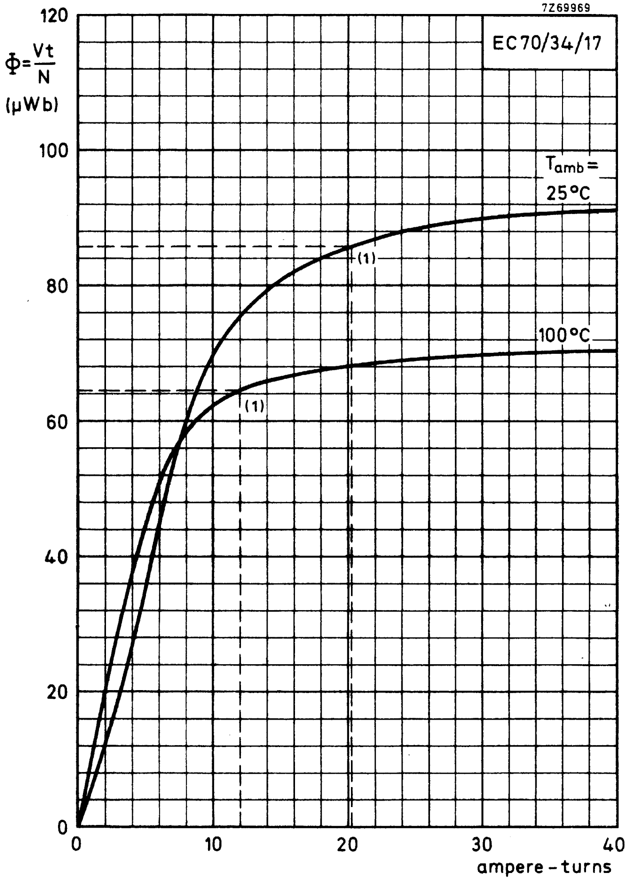
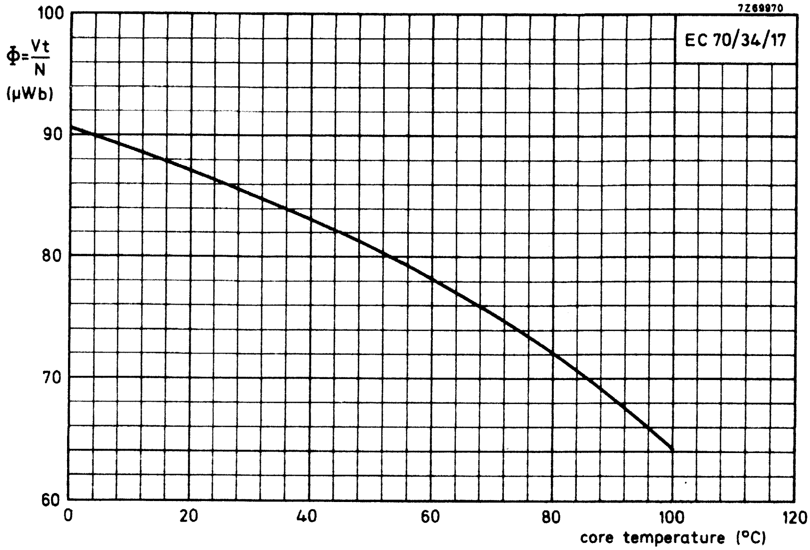
* Tags, catalogue number 4322 021 33070 should be ordered separately.

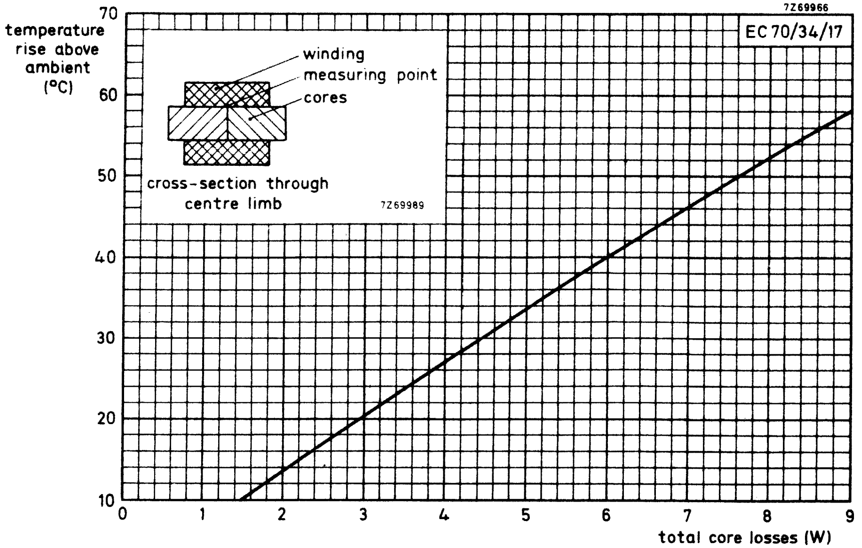
CHARACTERISTIC CURVES



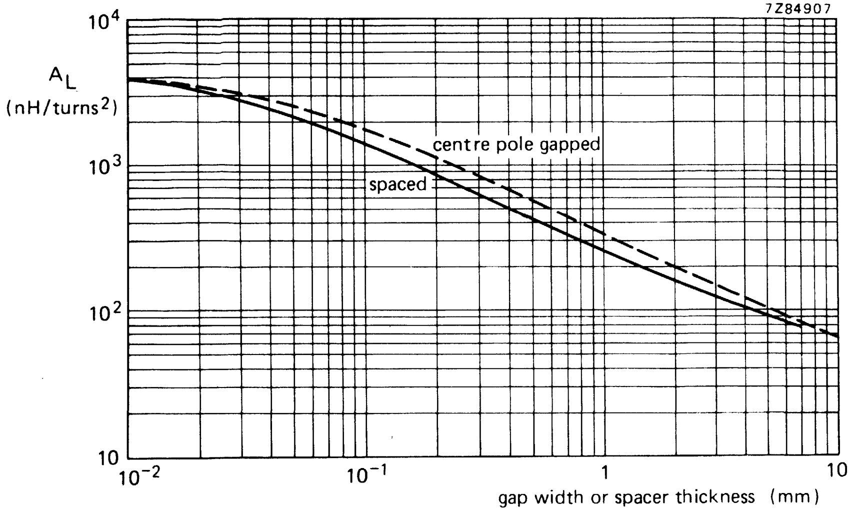
(1) Recommended maximum working flux.
Total flux as a function of ampere-turns.

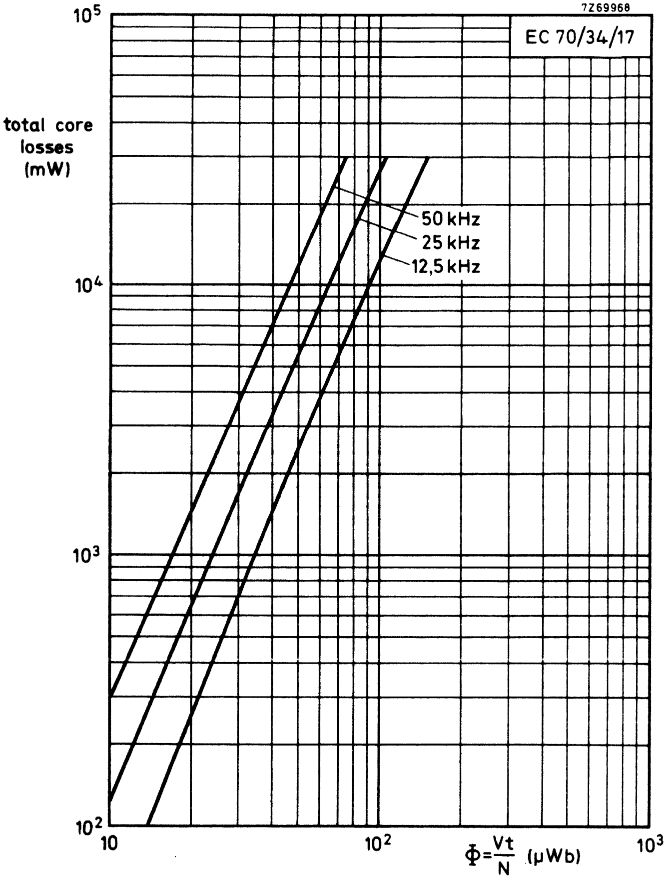


Recommended maximum working flux as a function of core temperature.

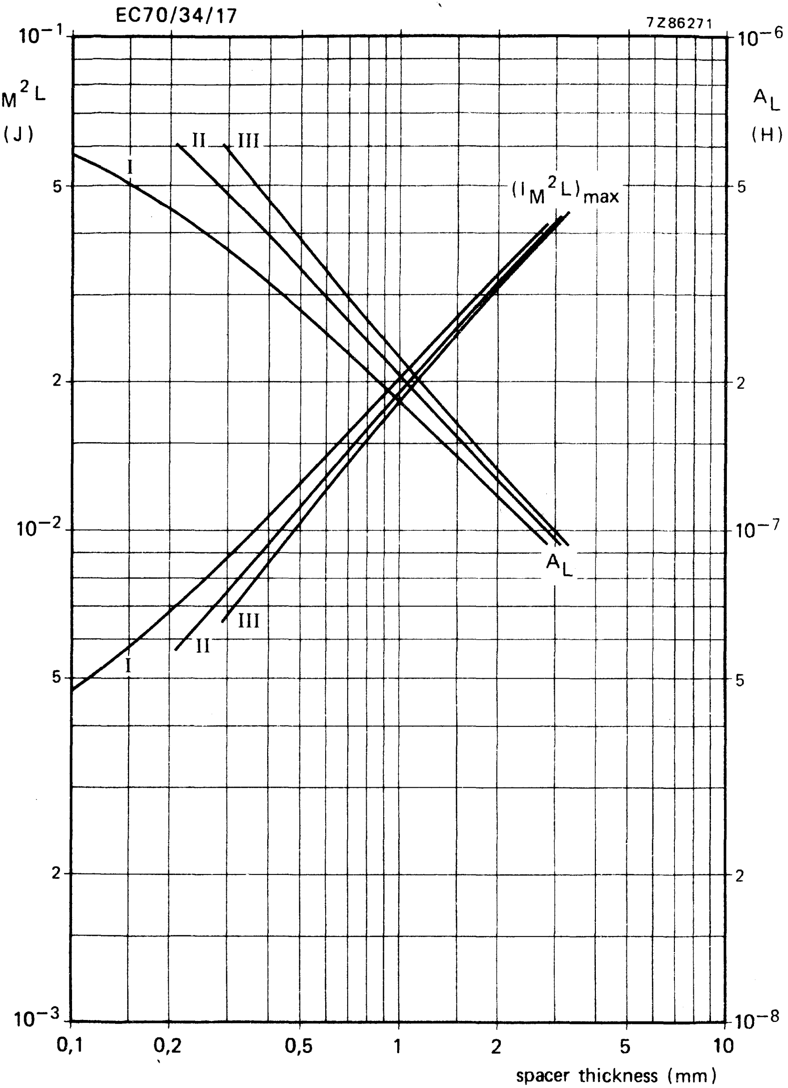


Transformer temperature rise as a function of total core losses, in free air conditions, without heatsink.


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

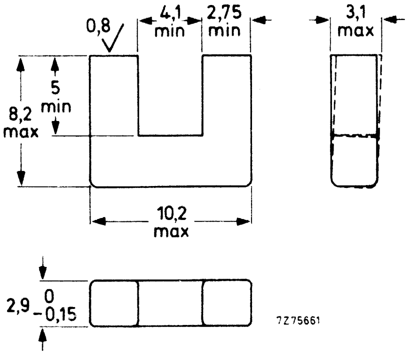


Total core losses as a function of total flux at hot-spot core temperature.



Choke design chart.

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	200	–	3122 134 91160
	25	⩾ 140	50	
	100	⩾ 200	–	
	100	⩾ 315	250	

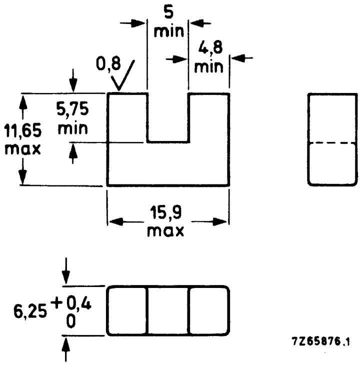
Magnetic dimensions

l_e = 40 mm

A_e = 7,9 mm²

V_e = 320 mm³

U-CORE



Mass 4,35 g

MAGNETIC DATA

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

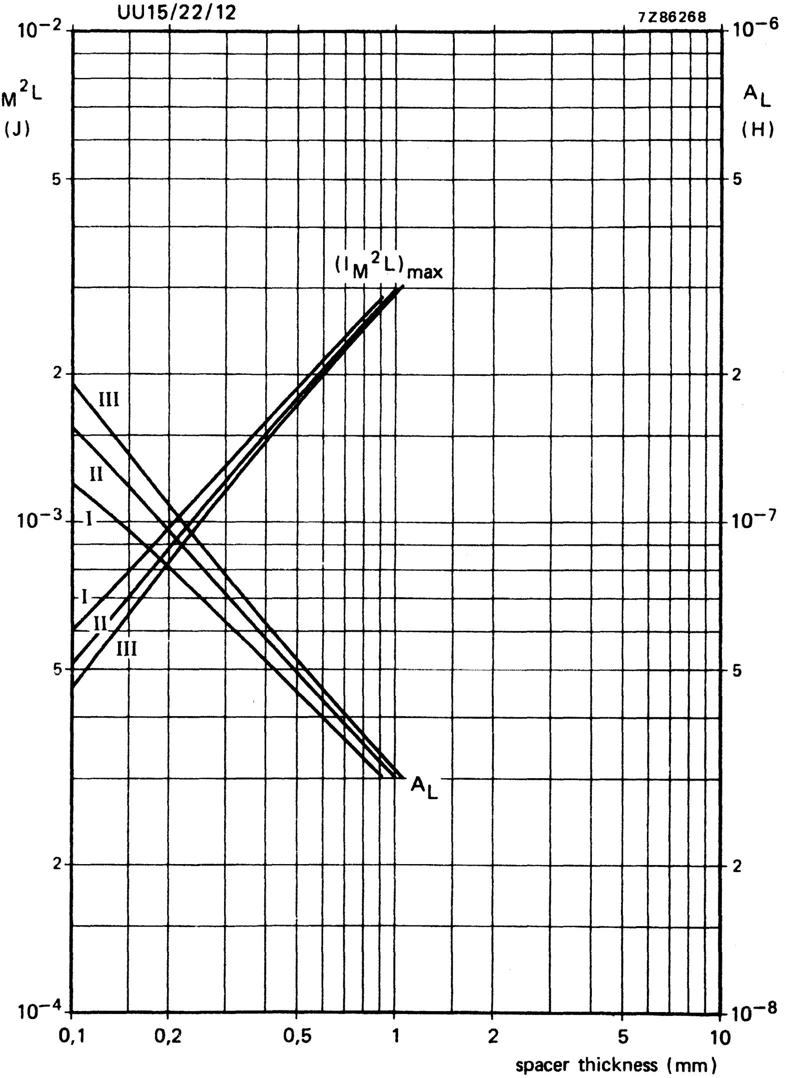
grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25 25 100 100	200 ⩾ 140 200 ⩾ 315	– 50 – 250	⩽ 0,18 – ⩽ 0,16 –	3122 134 90690

Magnetic dimensions

l_e = 48 mm

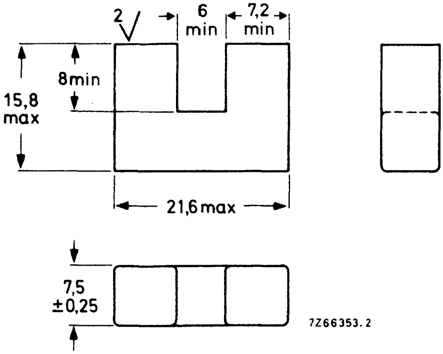
A_e = 30 mm^2

V_e = 1440 mm^3



Choke design chart.

U-CORE



Mass 9 g

MAGNETIC DATA

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

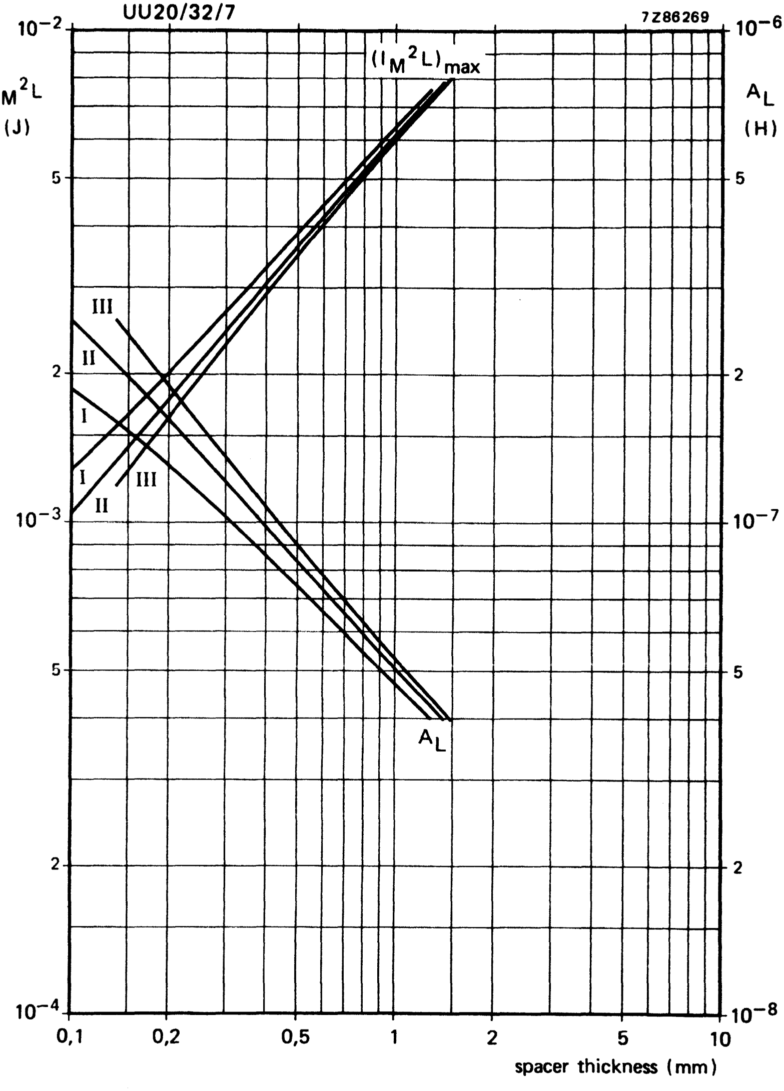
grade	temperature $^{o}C \pm 5$	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	⩽0,46	3122 134 90200
	100	200	–	⩽0,42	
	100	⩾100	50	–	
	100	⩾315	250	–	

Magnetic dimensions

l_e = 68 mm

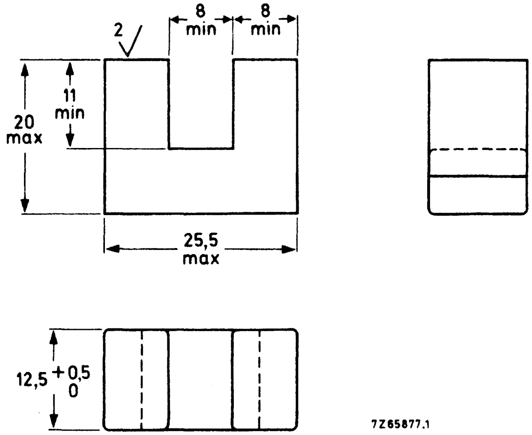
A_e = 56 mm^2

V_e = 3800 mm^3



Choke design chart.

U-CORE



Mass 21 g

MAGNETIC DATA

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

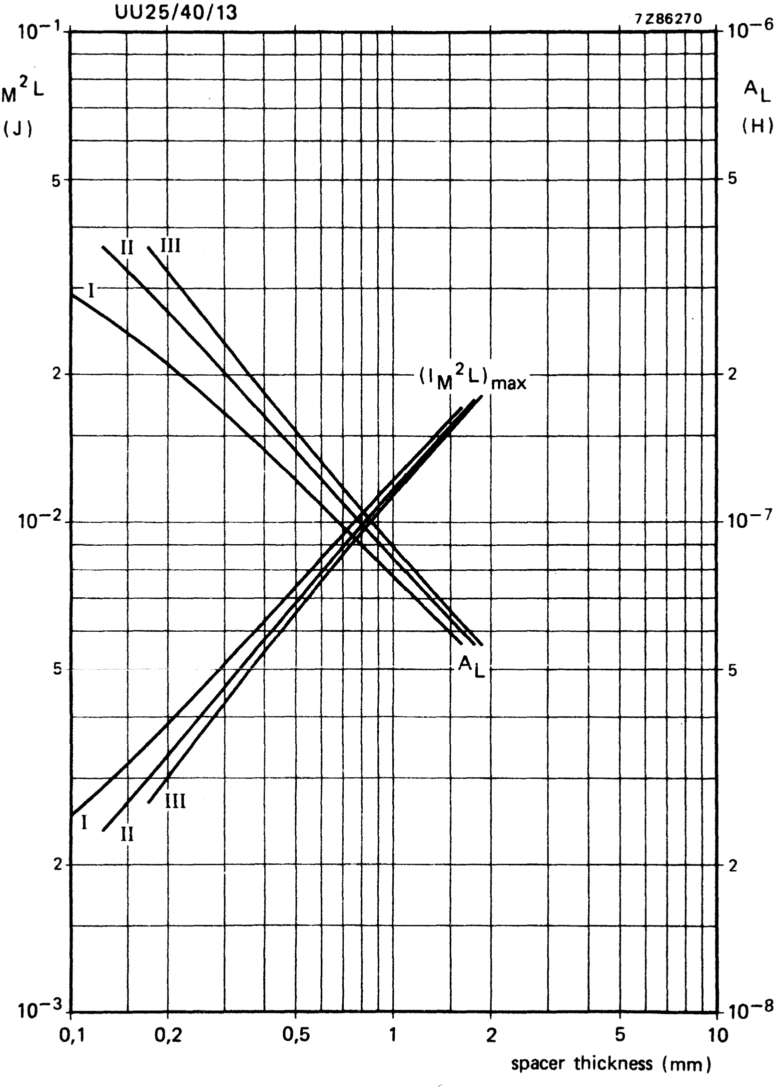
grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	⩽ 1,1	3122 134 90460
	100	200	–	⩽ 1,0	
	100	⩾ 100	50	–	
	100	⩾ 315	250	–	

Magnetic dimensions

l_e = 86 mm

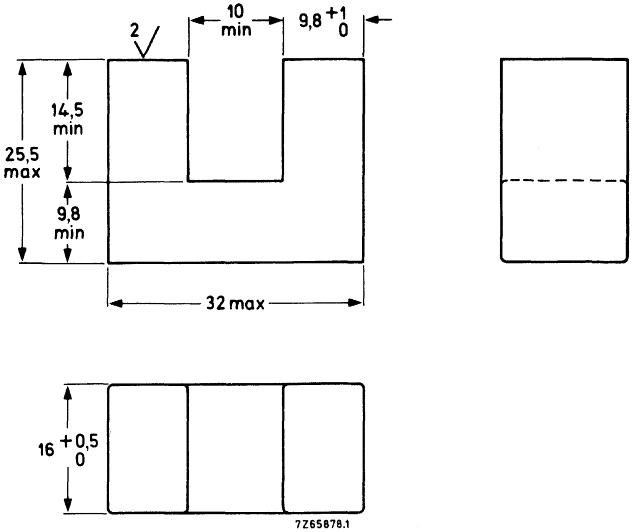
A_e = 100 mm^2

V_e = 8600 mm^3



Choke design chart.

U-CORE



Mass 48 g

MAGNETIC DATA

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

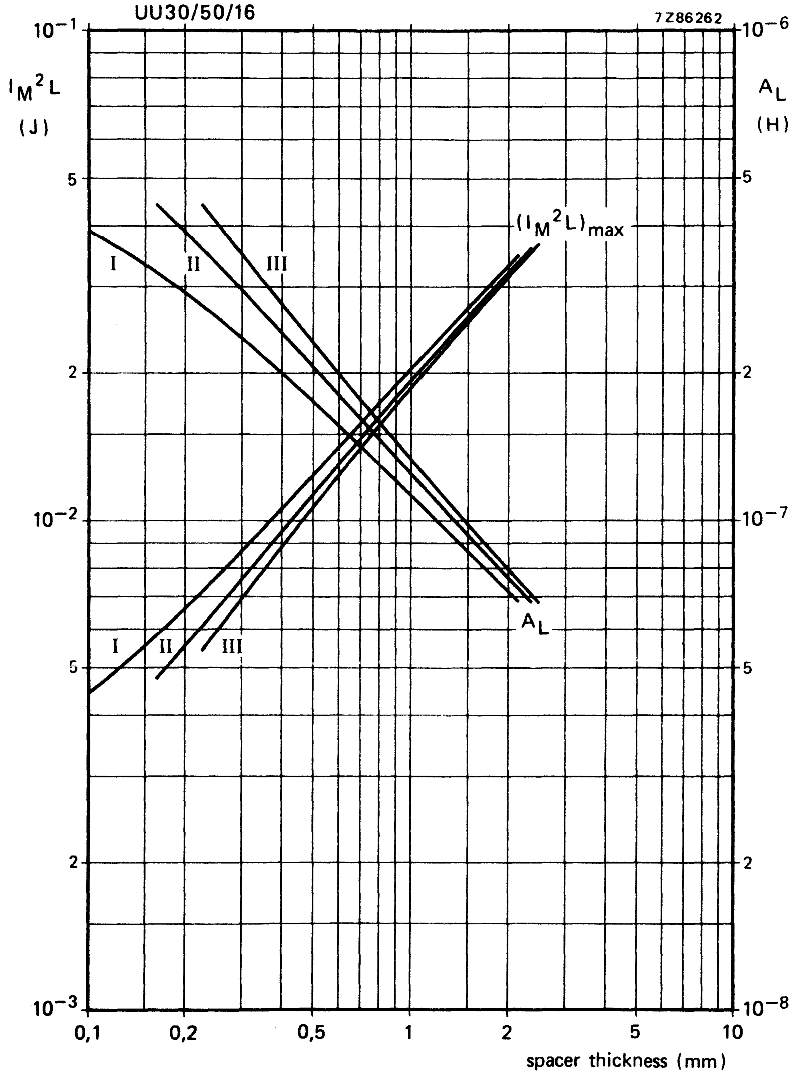
grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25	200	–	≤ 2,4	3122 134 90760
	100	200	–	≤ 2,0	
	100	≥ 335	400	–	

Magnetic dimensions

l_e = 111 mm

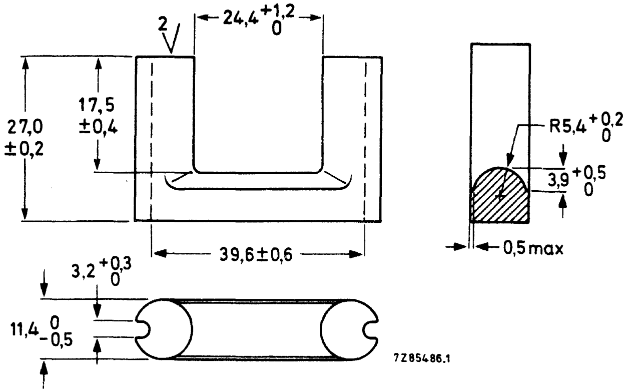
A_e = 157 mm²

V_e = 17400 mm³



Choke design chart.

U-CORE



Mass U-core 35 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-46/54/11.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)		shape	catalogue number of one core
3C8	25	200	1,65		U	3122 134 91630
	100	200	1,50			
	100	⩾ 330	250			

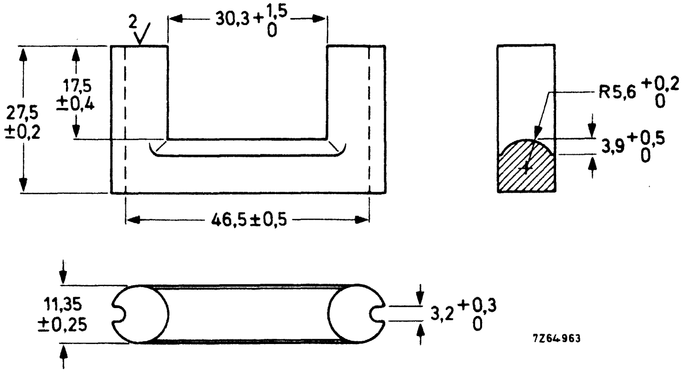
Magnetic dimensions

l_e = 152 mm

A_e = 88 mm²

V_e = 13400 mm³

U-CORE



Mass 40 g

MAGNETIC DATA

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

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

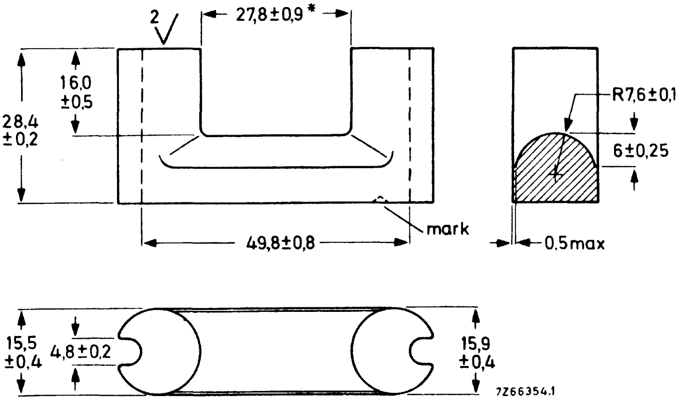
Magnetic dimensions

l_e = 165 mm

A_e = 95 mm^2

V_e = 15700 mm^3

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

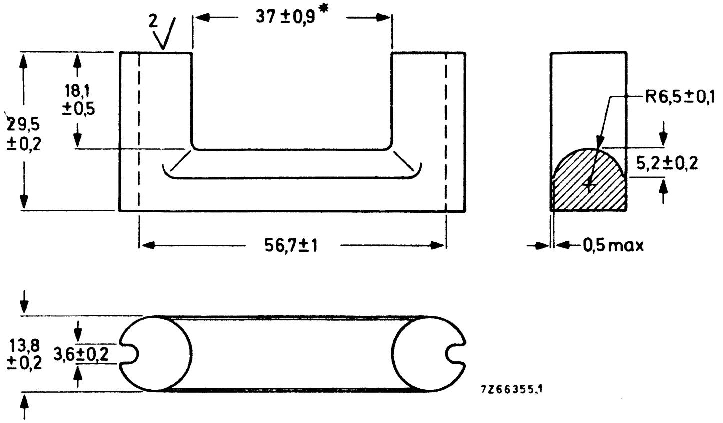
A_e = 171 mm²

V_e = 27500 mm³

---

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

U-CORE



Mass 64 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-64/59/14.

grade	temperature $^{o}C \pm 5$	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	catalogue number of one U-core
3C8	25 100 100	200 200 ⩾ 330	– – 250	⩽ 3,04 ⩽ 2,8 –	4312 020 33450

Magnetic dimensions

l_e = 185 mm

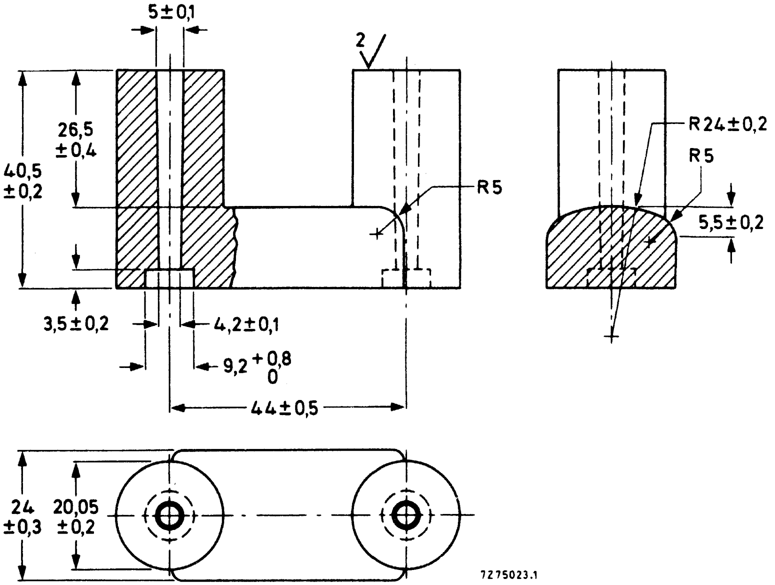
A_e = 138 mm^2

V_e = 25300 mm^3

---

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

U-CORE



Mass 155 g

MAGNETIC DATA

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

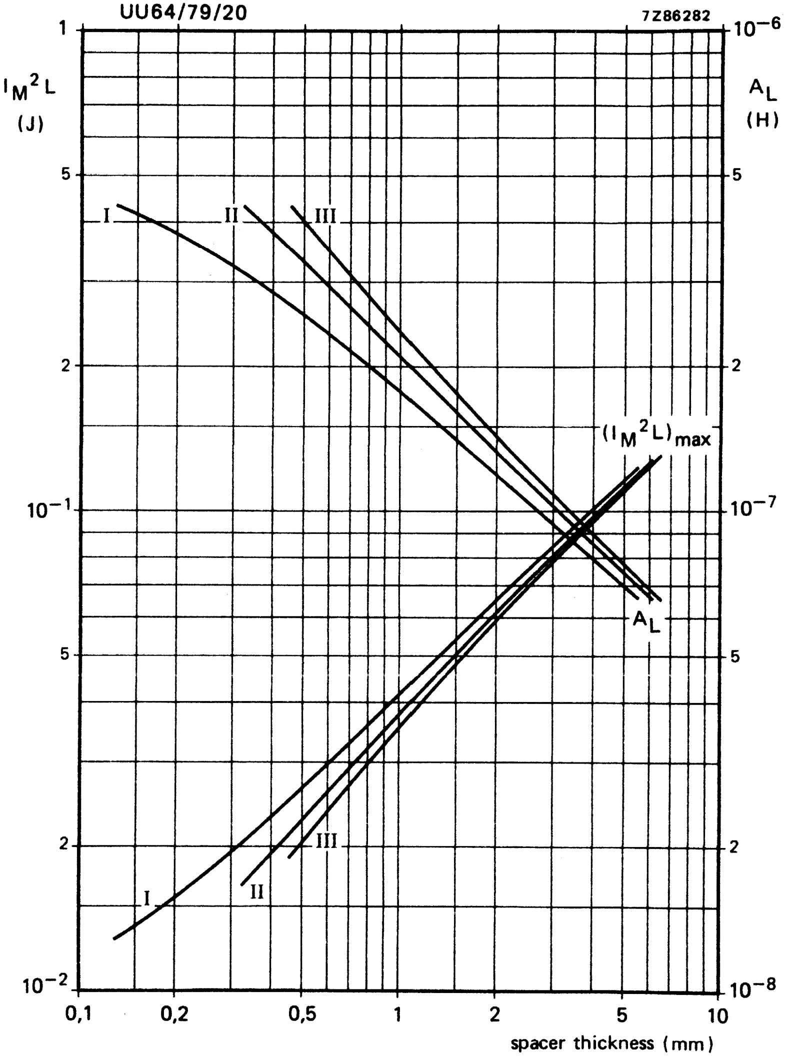
grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength H (A/m)	losses W	catalogue number of one U-core
3C8	25 100 100	200 200 ⩾ 330	– – 250	⩽ 8,5 ⩽ 7,0 –	3122 134 91390

Magnetic dimensions

l_e = 210 mm

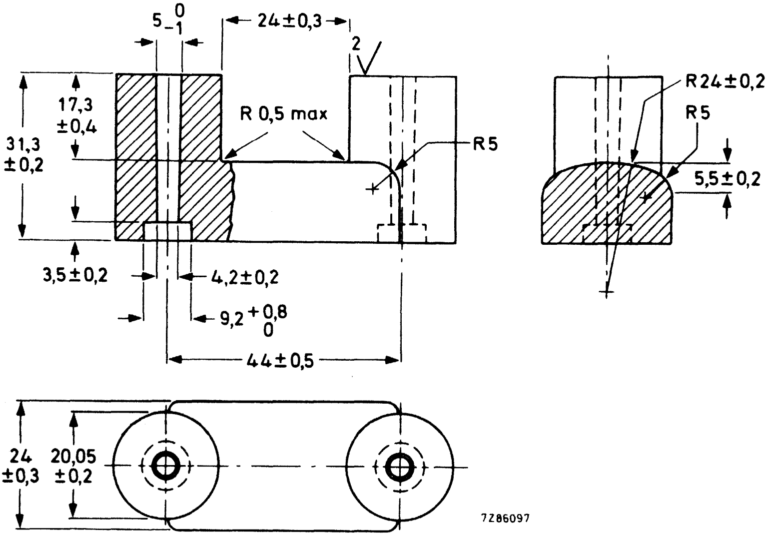
A_e = 290 mm²

V_e = 61000 mm³



Choke design chart.

U-CORE



Mass 135 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-64/63/25.

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	–	⩽ 6,16	3122 134 91770
	100	200	–	⩽ 5,65	
	100	⩾ 330	250	–	

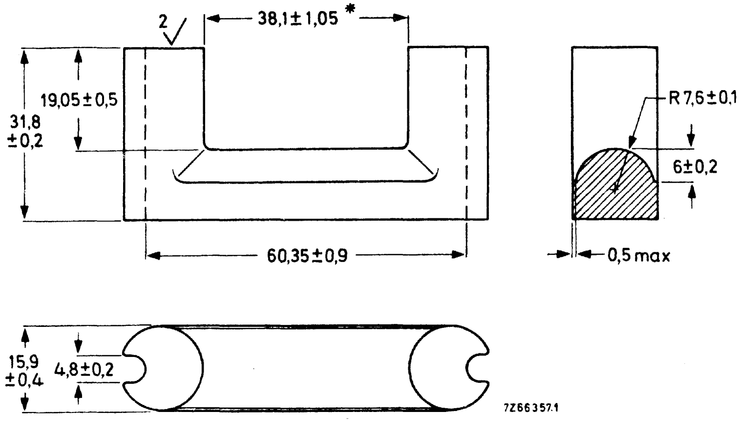
Magnetic dimensions

l_e = 177 mm

A_e = 290 mm^2

V_e = 51300 mm^3

U-CORE



Mass 87 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UU-70/64/16.

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	–	⩽ 5,86	4312 020 33330
	100	200	–	⩽ 4,83	
	100	⩾ 290	250	–	

Magnetic dimensions

l_e = 197 mm

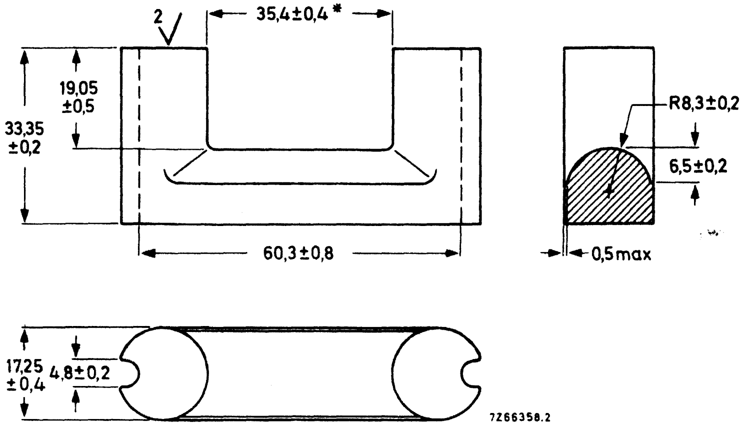
A_e = 177 mm^2

V_e = 34500 mm^3

---

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

U-CORE



Mass 108 g

MAGNETIC DATA

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

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

Magnetic dimensions

l_e = 197 mm

A_e = 214 mm^2

V_e = 43800 mm^3

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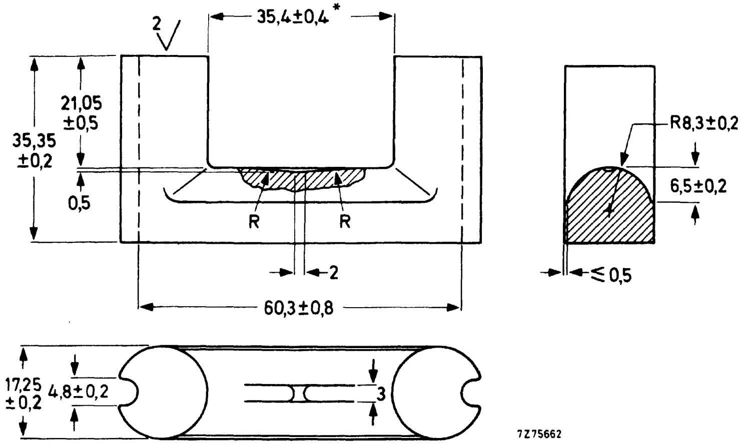
* The difference in splay between two U-cores taken at random from one packing will never exceed 1 mm.

U-CORE



Mass 120 g

MAGNETIC DATA

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

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 134 90130
	100	200		≤4,8	
	100	≥330	250	–	

Magnetic dimensions

l_e = 205 mm

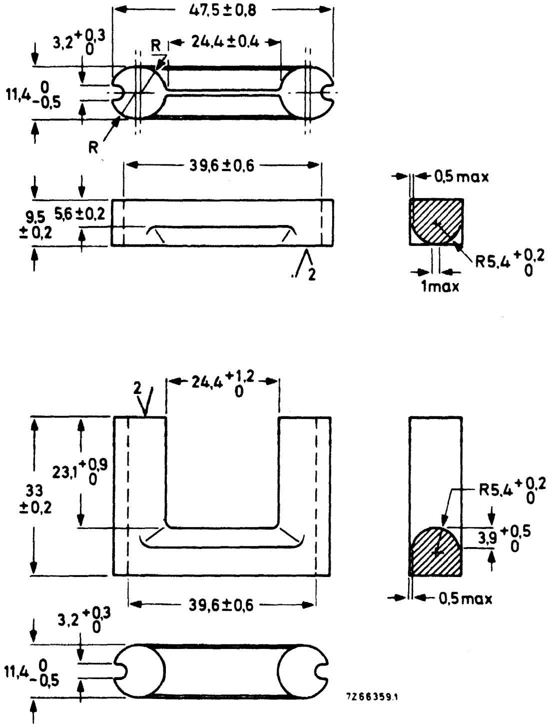
A_e = 214 mm²

V_e = 43900 mm³

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

U-46/33/11
I-46/10/11

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	–		

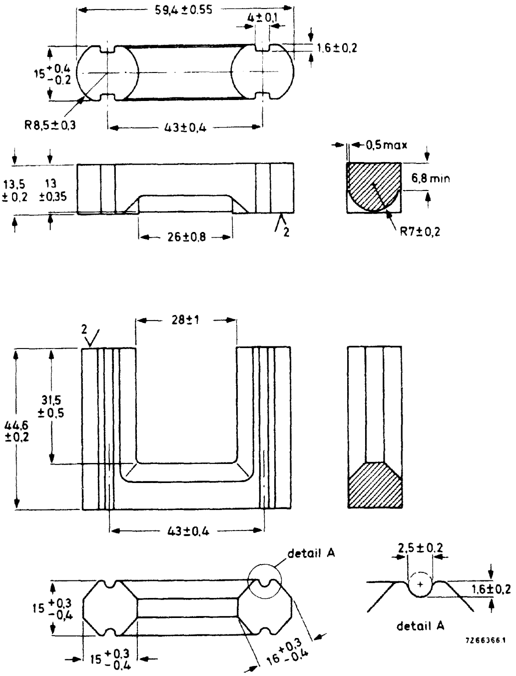
Magnetic dimensions

l_e = 129 mm

A_e = 88 mm^2

V_e = 11600 mm^3

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	25 100 100	200 200 ⩾ 330	– – 250	⩽ 3,5 ⩽ 3,2 –	U I	3122 104 94760 3122 104 94770

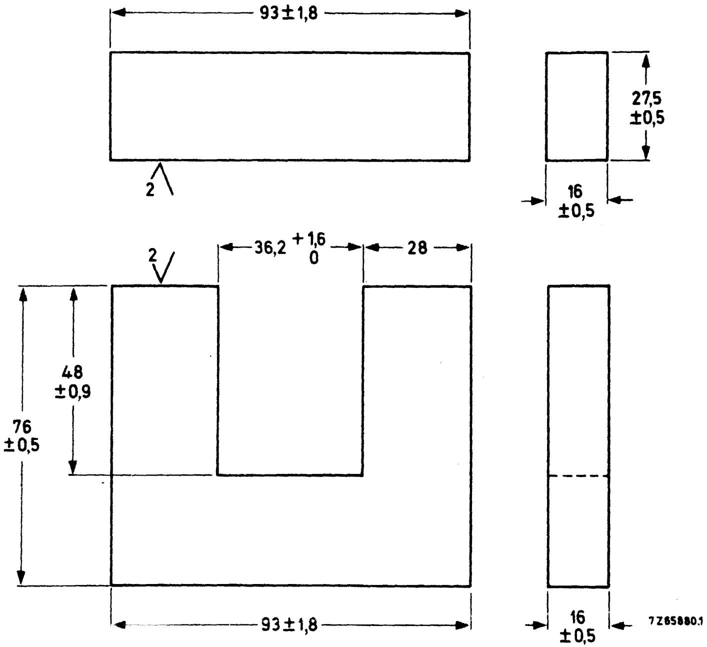
Magnetic dimensions

l_e = 164 mm

A_e = 175 mm²

V_e = 28800 mm³

UI-CORES



Mass		
Mass	U-core	403 g
	I-core	194 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UI-93/104/16.

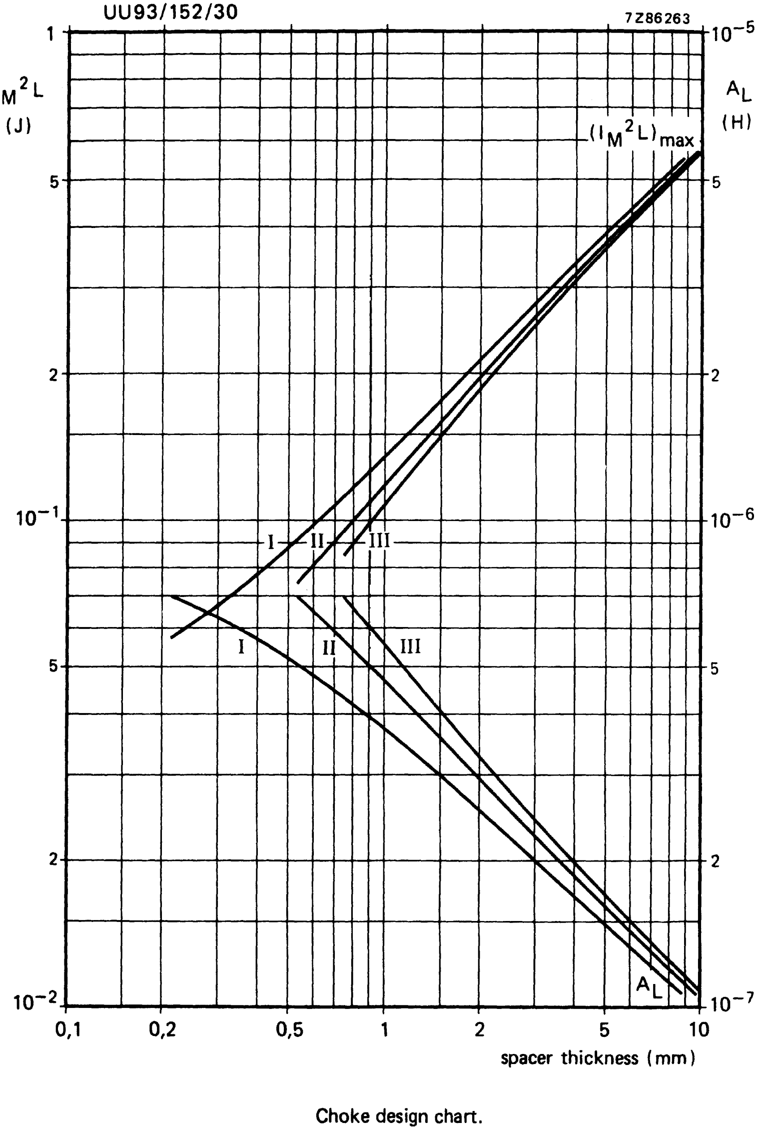
grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C6	25 100 100	200 200 ≥ 290	– – 250	≤ 18,2 ≤ 15,0 –	U I	4312 020 33070 4312 020 33080
3C8	25 100 100	200 200 ≥ 330	– – 250	≤ 12,8 ≤ 11,8 –	U I	4312 020 33550 4312 020 33560

Magnetic dimensions

l_e = 254 mm

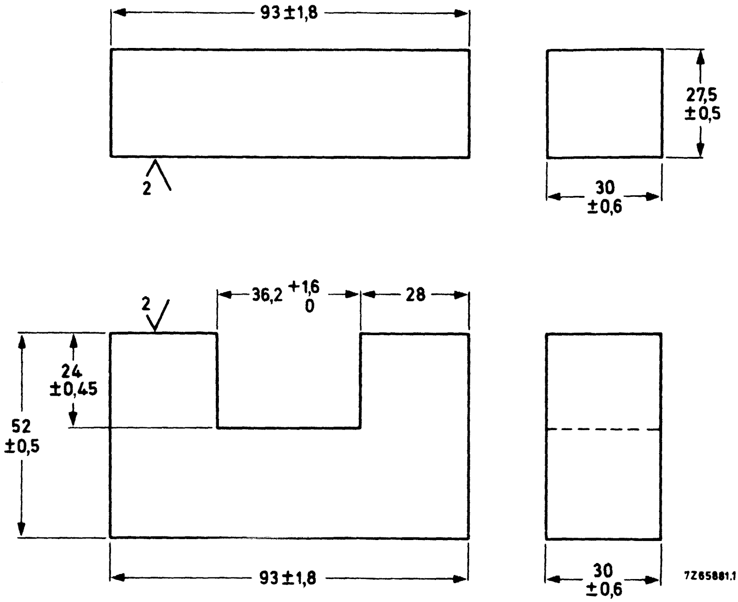
A_e = 420 mm^2

V_e = 107 000 mm^3



Choke design chart.

UI-CORES



Mass	U-core	562 g
	I-core	365 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UI-93/80/30.

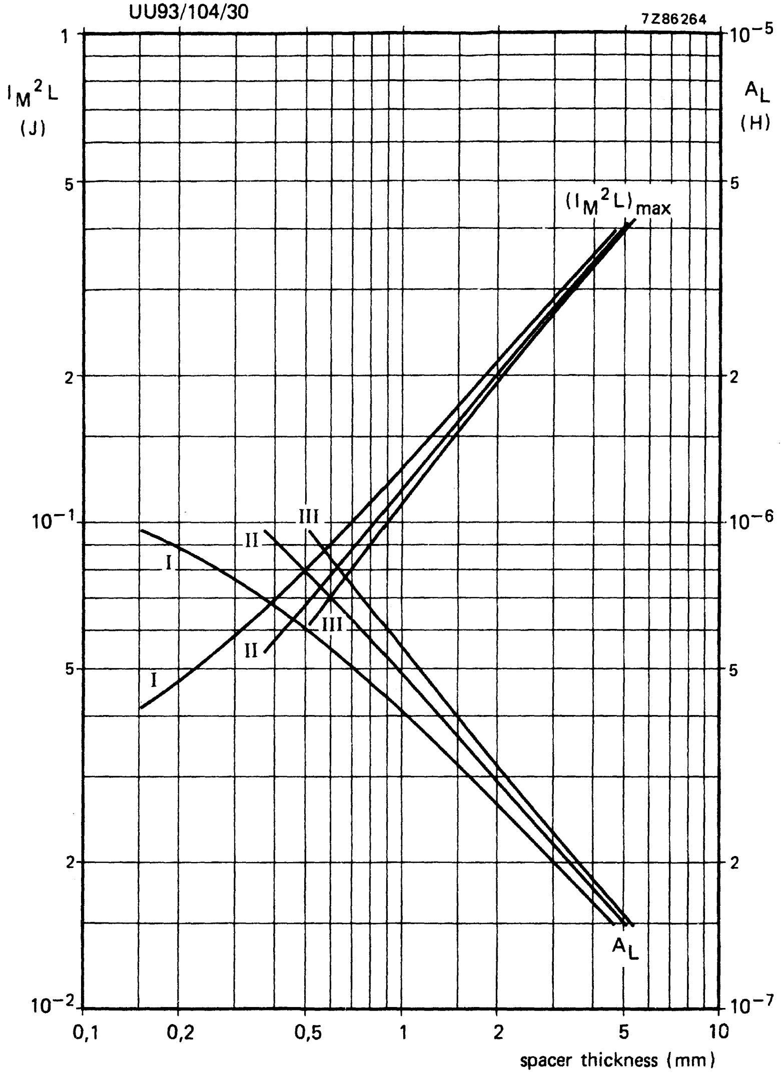
grade	temperature $^{o}C \pm 5$	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C6	25 100 100	200 200 $\geqslant$ 290	– – 250	$\leqslant$ 26,9 $\leqslant$ 22,2 –	U I	4312 020 33100 4312 020 33110
3C8	25 100 100	200 200 $\geqslant$ 330	– – 250	$\leqslant$ 19,0 $\leqslant$ 17,4 –	U I	4312 020 33580 4312 020 33590

Magnetic dimensions

l_e = 204 mm

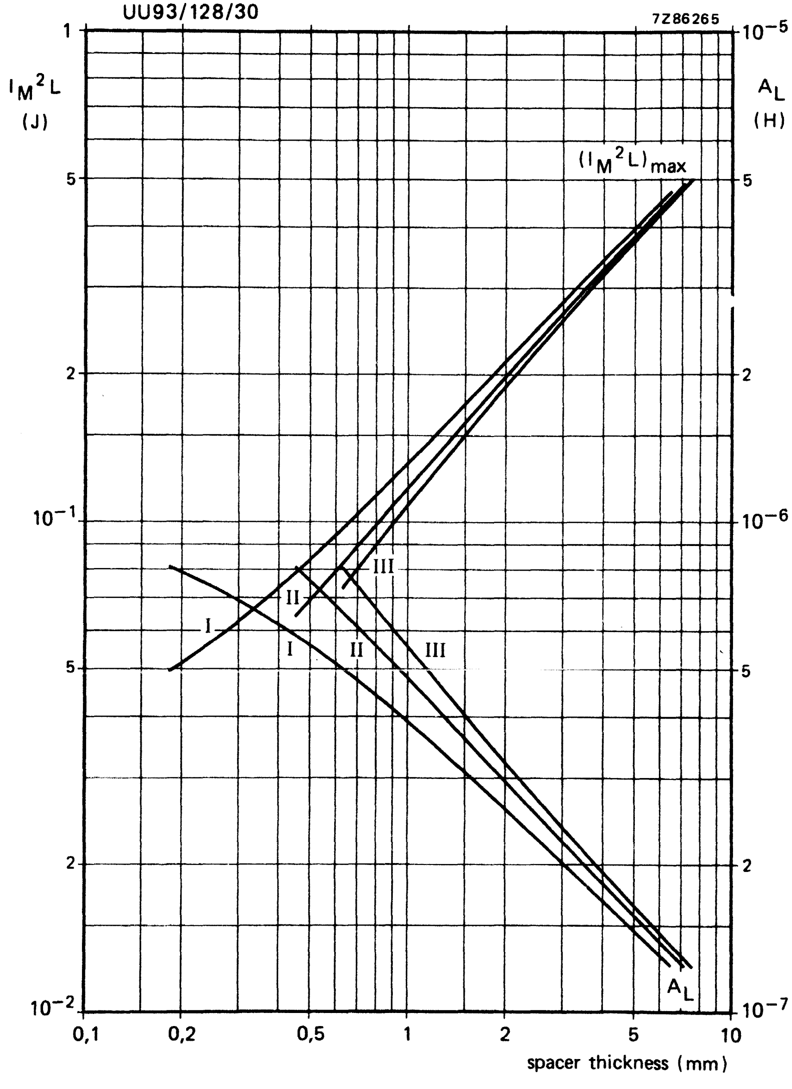
A_e = 780 mm²

V_e = 158 000 mm³



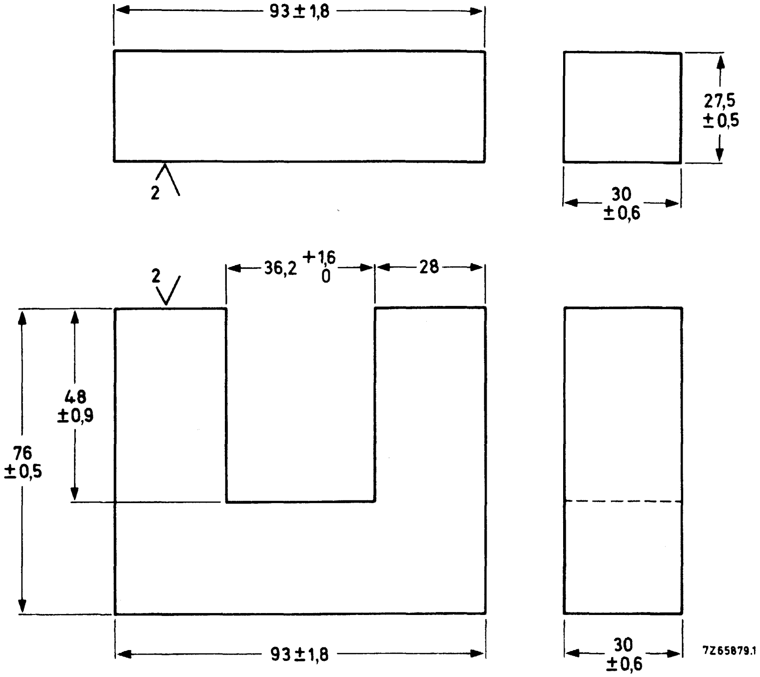
Choke design chart.

]



Choke design chart.

UI-CORES



Mass	U-core	756 g
	I-core	365 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UI-93/104/30.

grade	temperature $^{\circ}C \pm 5$	induction $\hat{B}$ (mT)	field strength $\hat{H}$(A/m)	losses W	shape	catalogue number of one core
3C6	25	200	–	≤ 34,0	U	4312 020 33090
	100	200	–	≤ 28,0	I	4312 020 33110
	100	≥ 290	250	–		
3C8	25	200	–	≤ 24,0	U	4312 020 33570
	100	200	–	≤ 22,0	I	4312 020 33590
	100	≥ 330	250	–		

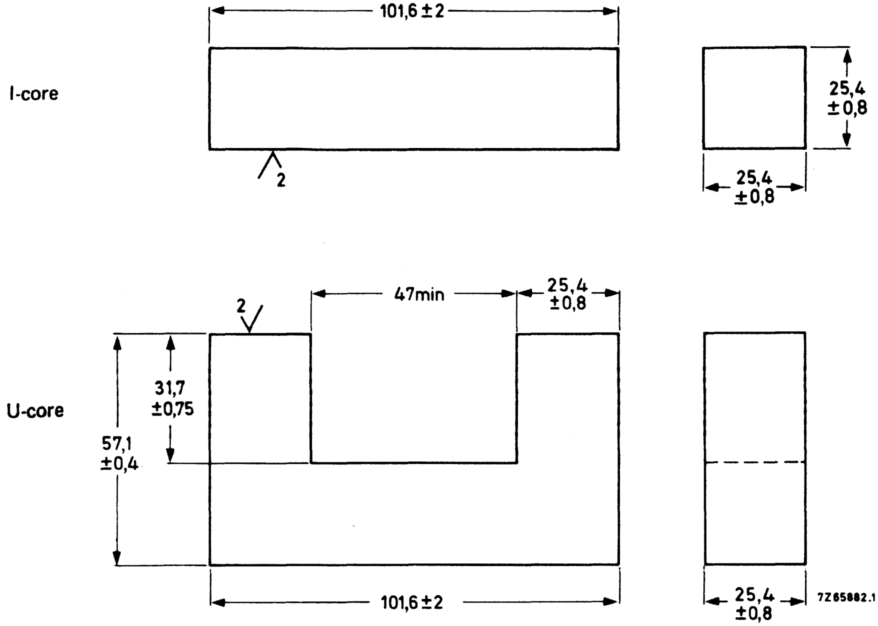
Magnetic dimensions

l_e = 254 mm

A_e = 780 mm^2

V_e = 200 000 mm^3

UI-CORES



Mass	U-core	506 g
	I-core	310 g

MAGNETIC DATA

Guaranteed values, measured at 16 kHz, for a core-pair UI-100/82/25.

grade	temperature °C ± 5	induction $\hat{B}$ (mT)	field strength $\hat{H}$ (A/m)	losses W	shape	catalogue number of one core
3C6	25 100 100	200 200 ≥ 290	– – 250	≤ 26,8 ≤ 22,1 –	U I	4312 020 33120 4312 020 33420
3C8	25 100 100	200 200 ≥ 330	– – 250	≤ 17,9 ≤ 16,4 –	U I	4312 020 33600 4312 020 33610

Magnetic dimensions

l_e = 240 mm

A_e = 620 mm^2

V_e = 149 000 mm^3

MATERIALS & CORES FOR MAGNETIC RECORDING D

FERROXCUBE 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	1×10^4	Ωm
density			25 ± 5	5330	kg/m³
hardness (Vickers)			25 ± 5	0,75	Pa
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.

8C1

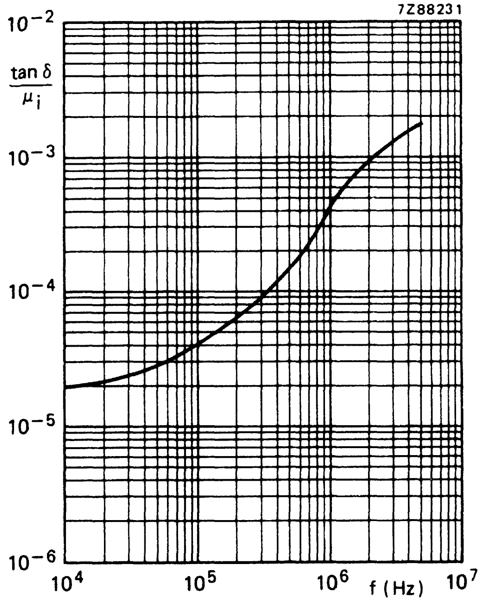


Fig. 1.

8C1

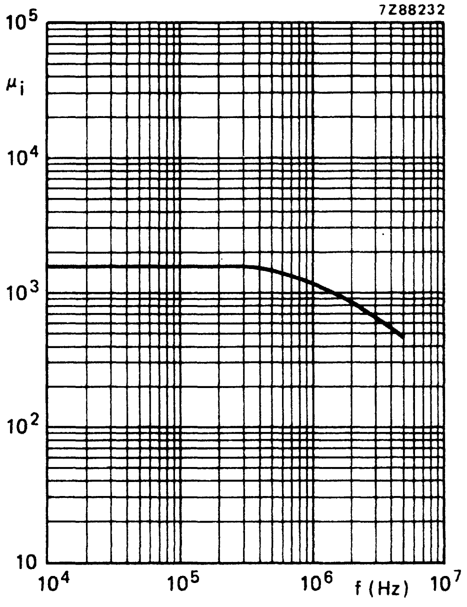


Fig. 2.

8C1

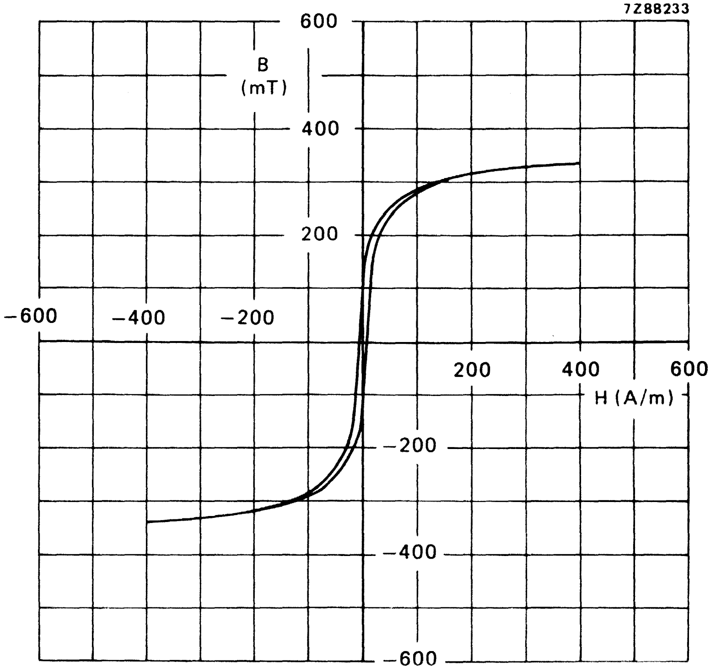


Fig. 3.

8C1

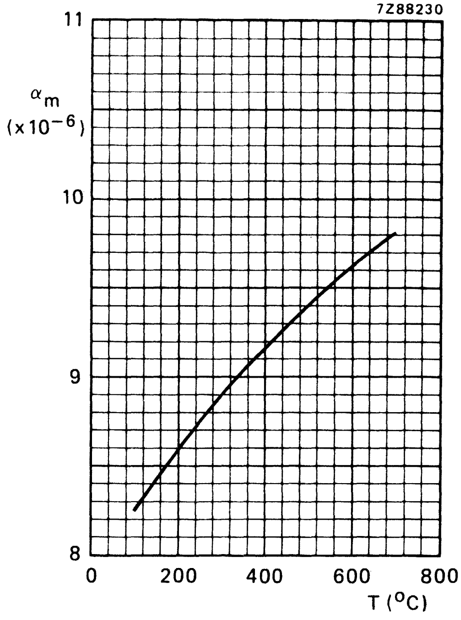


Fig. 4 Coefficient of linear expansion as a function of the temperature.

NON-MAGNETIC STRUCTURAL MATERIAL 8A3

FXC 8A3 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.

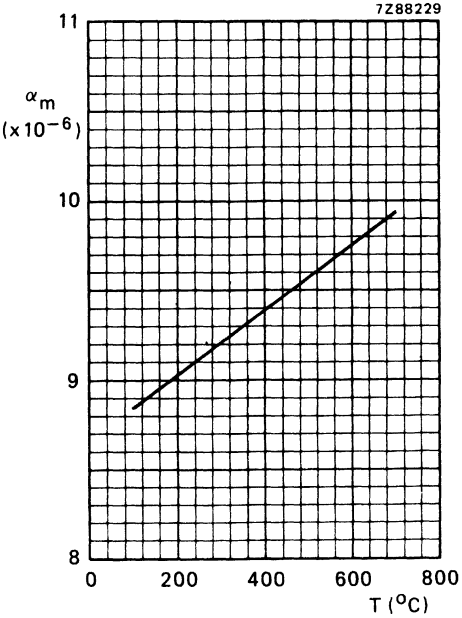
Material properties

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.	4430	kg/m^3
coefficient of linear expansion α_m		see Fig. 5	
Hardness (Vickers)		1,3	Pa

FXC 8A3 is available in the form of bars:

145 ± 5 x 35 ± 3 x 22 ± 2 mm, catalogue number 4322 020 03060 or custom-made shapes on request.



8A3

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

FXC 8E1 AND 8E2

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. Material FXC 8E2 is 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%.

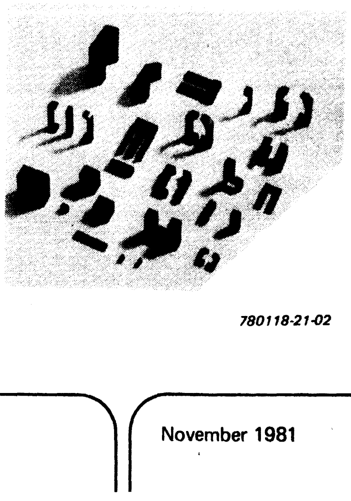
	freq. kHz	B mT	H A/m	temp. °C	grade 8E1 typical values	8E2	
μ_i	4	$<0,1$		25 ± 5	3200	2800	
B_s	ballistic		250	25 ± 5	400	490	mT
$\frac{\tan \delta}{\mu_i}$	100	$<0,1$		25 ± 5	$3 \cdot 10^{-6}$	$3 \cdot 10^{-6}$	
η_B	100	1,5 to 3		25 ± 5	$0,5 \cdot 10^{-3}$	$0,5 \cdot 10^{-3}$	T^{-1}
power losses	45	100	25	25 ± 5	$40 \cdot 10^3$	$40 \cdot 10^3$	W/m³
				85 ± 5	$60 \cdot 10^3$	$60 \cdot 10^3$	W/m³
Curie temp.	4	$<0,1$			180	180	°C
resistivity	d.c.			25 ± 5	5*		Ωm
density				25 ± 5	4700	4700	kg/m³
hardness					0,56	0,73	Pa
linear expansion coefficient α_m					see Figs 9 and 13		

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.
* Measured on a machined bar, dimensions approximately 3 x 2 x 15 mm.

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

and in custom made shapes on request.
See photograph.



780118-21-02

8E1

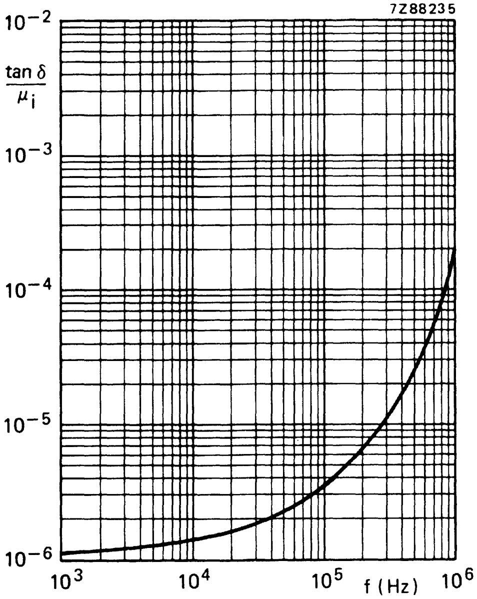


Fig. 6.

8E1

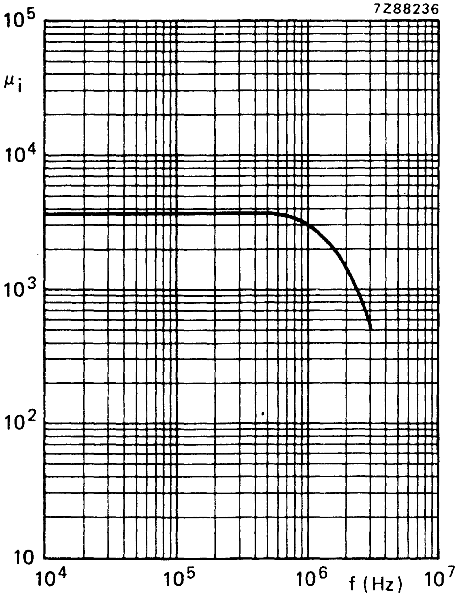
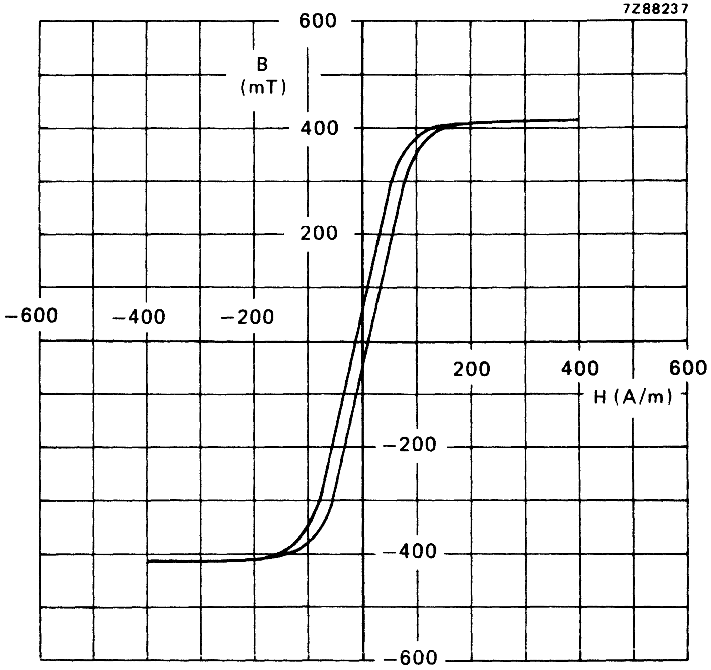


Fig. 7.



8E1

Fig. 8.

8E1

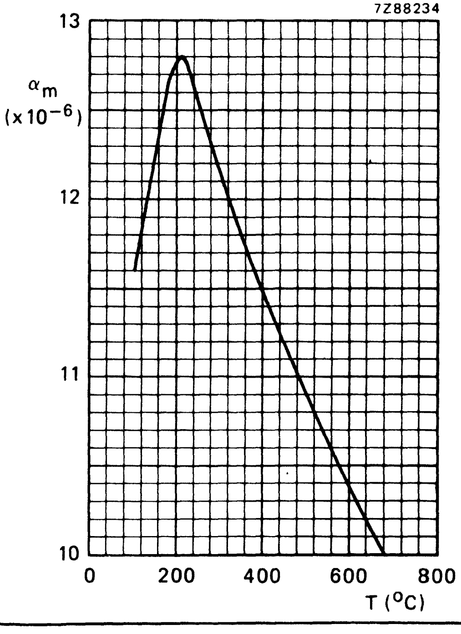


Fig. 9 Coefficient of linear expansion as a function of the temperature.

8E2

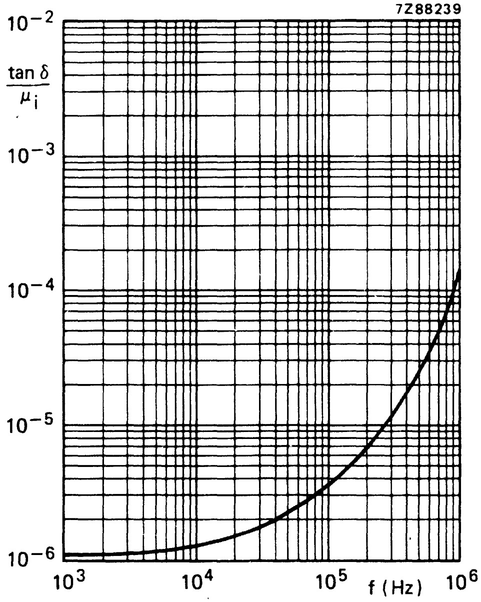


Fig. 10.

8E2

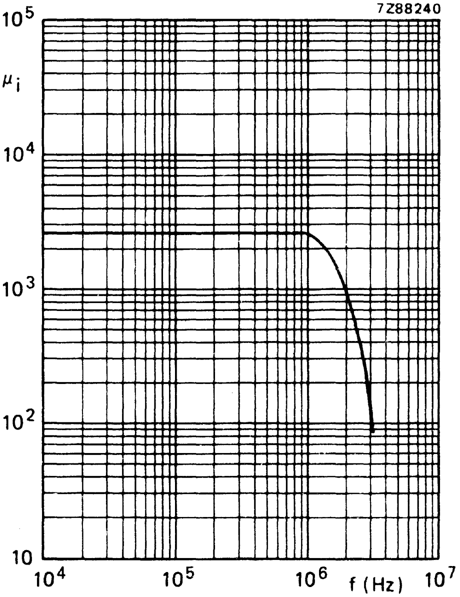


Fig. 11.

8E2

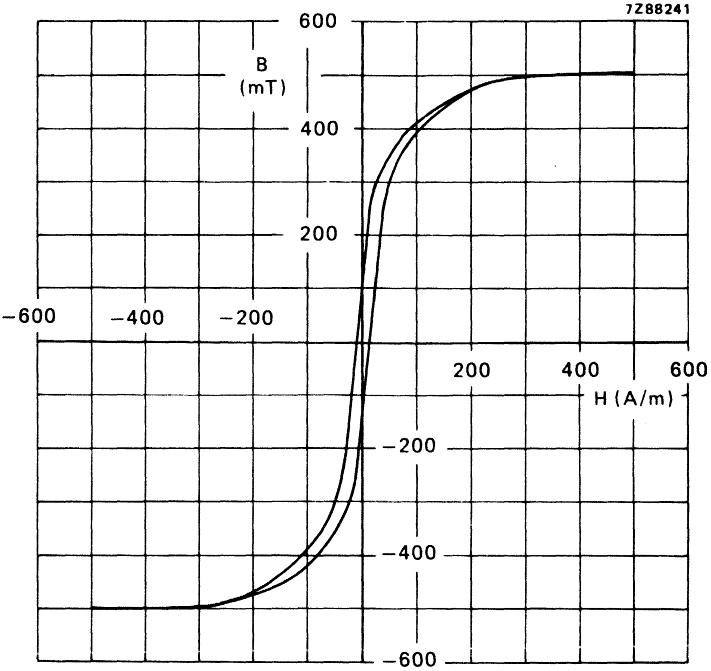


Fig. 12.

8E2

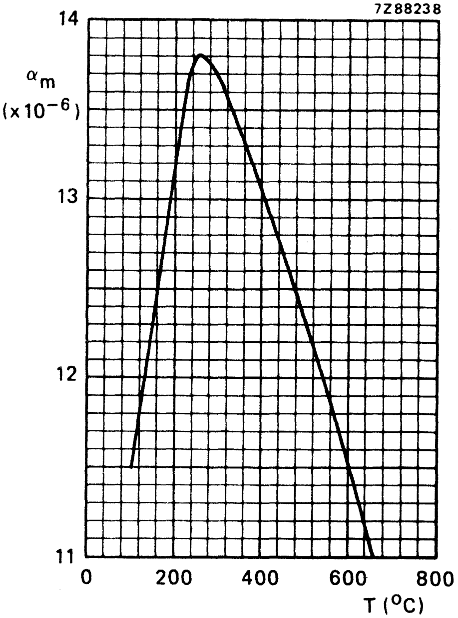


Fig. 13 Coefficient of linear expansion as a function of the temperature.

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 5000	$\leqslant 1$ $\leqslant 1$		1800 600	
$\frac{\tan\delta}{\mu_i}$	5000	$\leqslant 1$		2	
B_{sat}	ballistic		800	470	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. 17	
Curie point	< 10			180	°C
hardness (Vickers)				0,73	Pa

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.

8X1

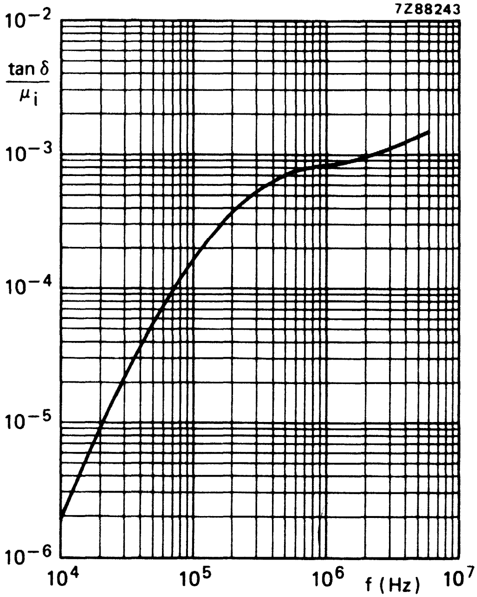


Fig. 14.

8X1

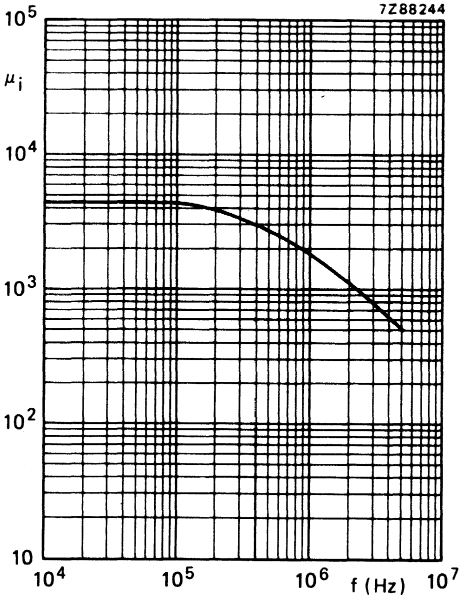


Fig. 15.

8X1

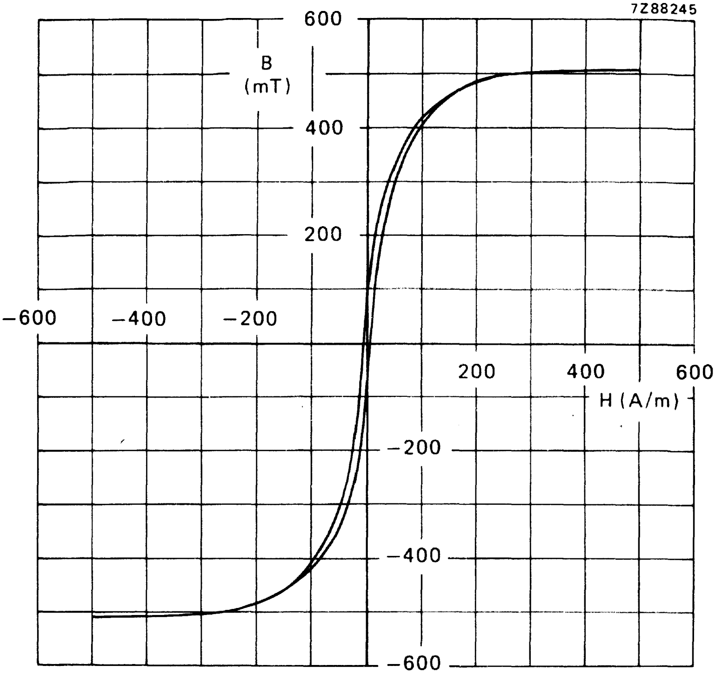


Fig. 16.

8X1

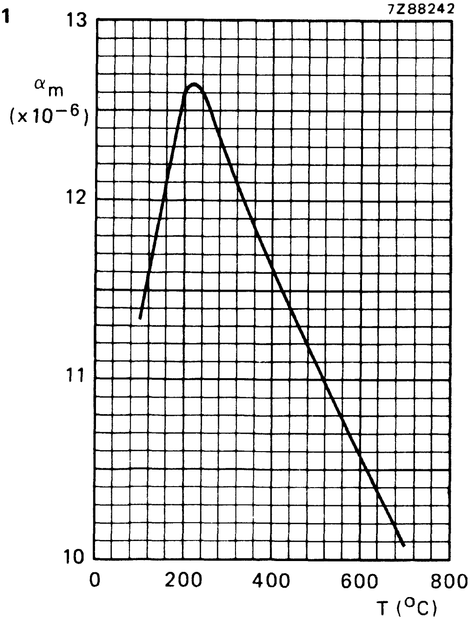


Fig. 17 Coefficient of linear expansion as a function of the temperature.

SMALL CORES

E

INTRODUCTION

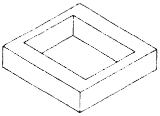
The development of ferrite magnetic materials suitable for the mass production of high-initial-permeability transformer cores has made possible considerable miniaturization of transformers without the attendant loss of performance. One problem than can still arise when miniaturizing cores is that, except for toroids, the effect of the inevitable airgap in the magnetic circuit increases as core size decreases, to the detriment of the initial permeability. The toroid core, which avoids this problem, is inconvenient and time consuming to wind and assemble.

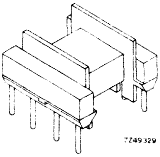
The H core for transformers overcomes the disadvantages of both the conventional EE or EI core and the toroid. It is simple to wind and assemble, and its overlapping construction greatly reduces the effect of the airgap.

The H10 core comprises a complete set of parts for the construction of a printed-wiring-board-mounting transformer. The coil former is integral with the H-shaped centre leg of the core and is provided with pin terminations set at a standard pitch.

The H10 core is supplied in FXC 3E2 ferrite, and, by virtue of its construction, has a high value of A_L. The ease of winding, small size, and high permeability result in small winding capacitances that make the H10 core eminently suitable for the construction of miniature wide-band transformers. Other applications include driver and pulse transformers.

H-CORE





The H10 core consists of an H-shaped piece of Ferroxcube with integral coil former, a Ferroxcube frame, a nickel-copper container and a phosphor-bronze spring. The pin terminations are fixed in bars of thermosetting plastic moulded together with the H-shaped core into the thermoplastic coil former.

The H10 core can be supplied only as a complete assembly.

Catalogue number of the assembly: 4322 020 33060

Approximate weight of the assembly: 2,0 g

The core material is high-permeability grade Ferroxcube 3E2. Mating surfaces are very flat and are lapped smooth.

Dimensional quantities

Effective magnetic path length:	ℓ_e	$= 22{,}5$ mm
Effective cross-sectional area:	A_e	$= 7{,}5$ mm^2
Core constant:	C_1	$= \Sigma \frac{\ell}{A} = 3$ mm^{-1}
Effective core volume:	V_e	$= 170$ mm^3

Electrical requirements, measured with 20 turns of 0,20 mm wire, at $\hat{B} = 0{,}7$ mT to 1 mT, f = 4 kHz and a mechanical force between the magnetic components of 1,5 N, in the temperature range +23 °C to + 70 °C, 24 hours after demagnetization.

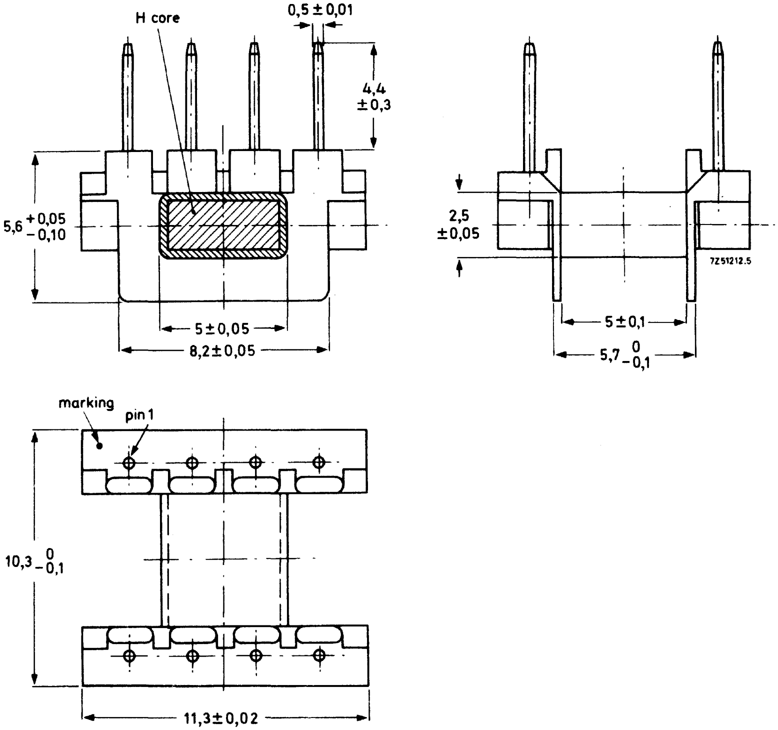
$\mu_e \geqslant 3820$

$\alpha \leqslant 25{,}0$

$A_L \geqslant 1600$

The eight pins are arranged to fit printed-wiring boards with both a 0,1 inch grid and a 2,50 mm grid. The holes provided for the pins should not be greater than 0,8 mm + 0,1 mm ϕ.

COIL FORMER



The bars in which the pins are fixed, the coil former and the Ferroxcube H shape are combined to one part.

Material of the bars	thermosetting material with phosphor bronze, nickel plated pins
Material of the coil former	polyamide
Minimum window area	7,6 mm^2
Mean turn length	21,7 mm
Maximum dip-soldering temperature	
for 5-6 s	280 °C
for 1-2 s	360-400 °C
Maximum working temperature	80 °C

To speed up soldering of the winding wire to the pins, the use of self-fluxing wire is recommended. Where a winding termination is to be connected to the container, it should be soldered to pin 1 (see illustration on preceding page).

The side of the coil former where the soldering pins protrude is asymmetrical, providing a means for numbering the connections.

In order to avoid damage, avoid applying excessive torque to the Ferroxcube H-shaped core itself.

MOUNTING

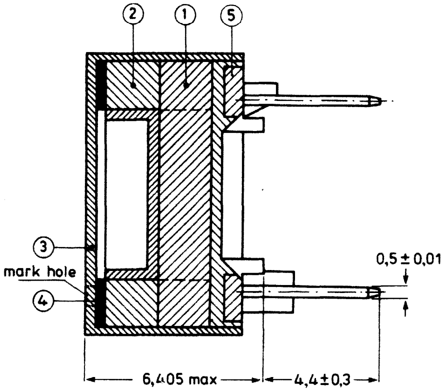


Fig. 1.

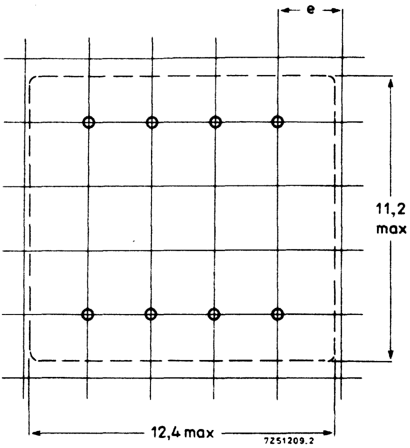


Fig. 2 Hole pattern. e = 0,1" or 2,5 mm.

Components of Fig. 1:

(1) Ferroxcube H-shaped core with polyamide coil former

(2) Ferroxcube frame

(3) Nickel-copper container.

(4) Phosphor-bronze spring.

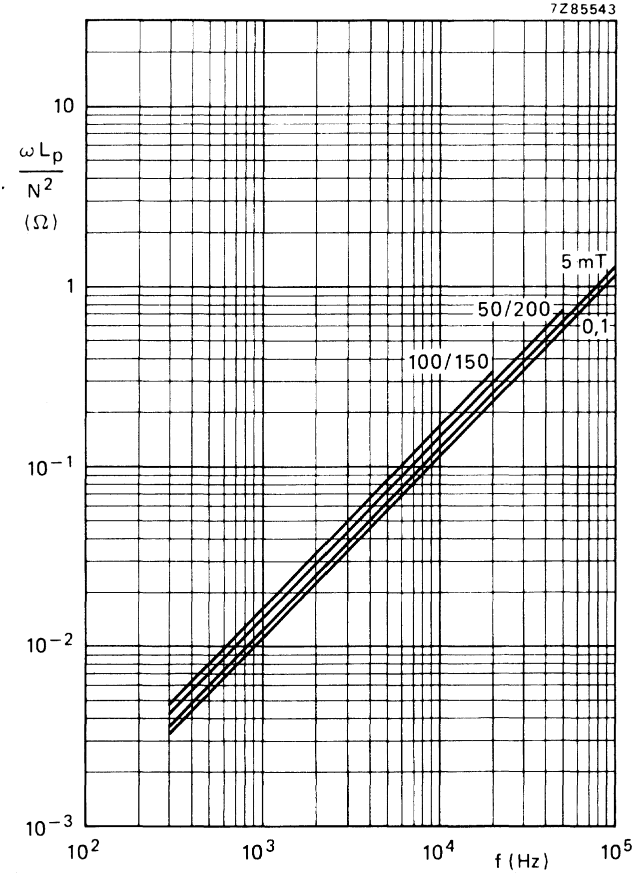
(5) Thermosetting pin bars.

Take care that the mating surfaces of the two magnetic components are very clean.

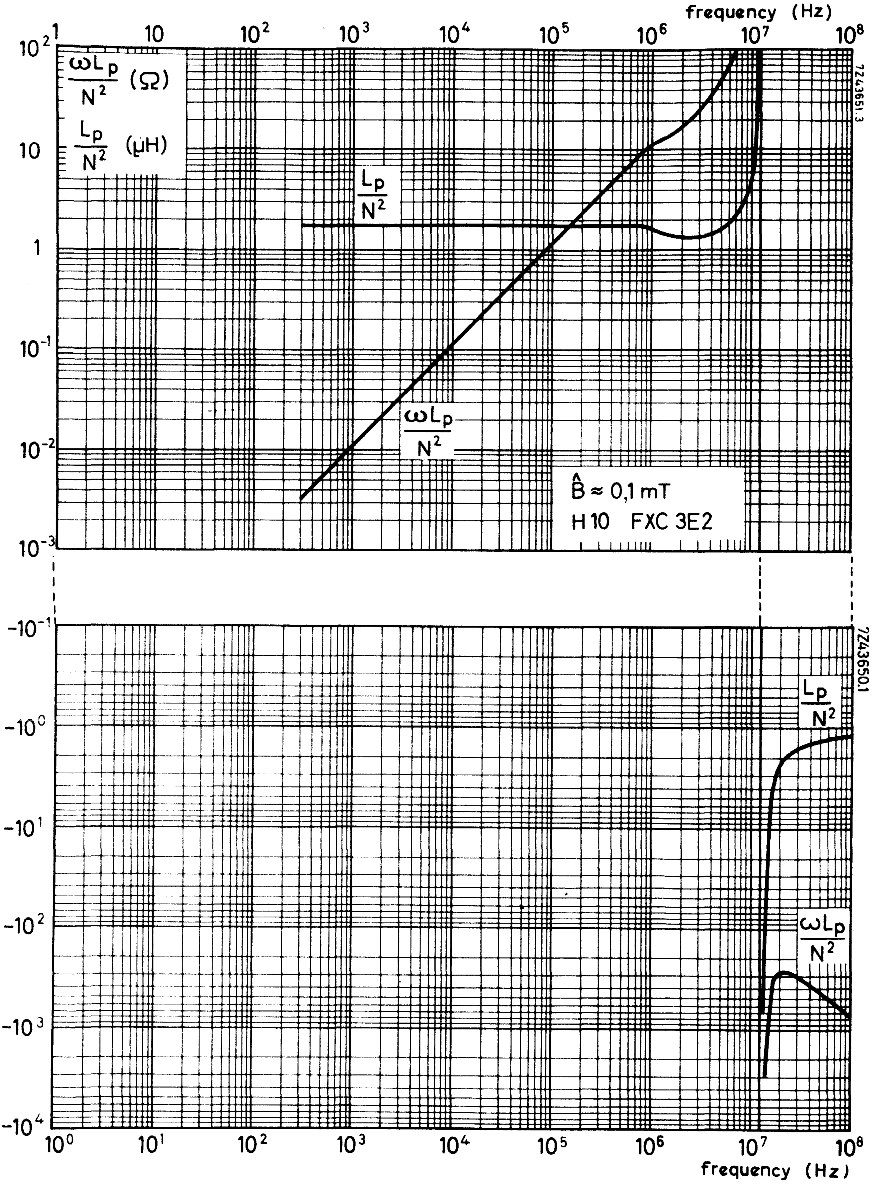
The silver reference lines on one side of the H-shaped core and on one side of the frame should coincide. If no reference lines are provided, the parts may be positioned arbitrarily.

CHARACTERISTIC CURVES

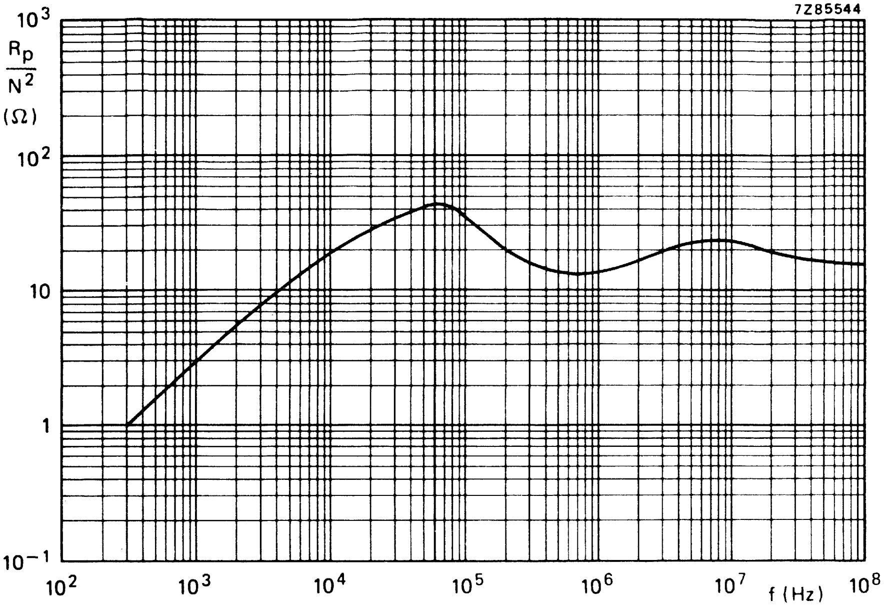
NORMALIZED IMPEDANCE AS A FUNCTION OF THE FREQUENCY (typical values)



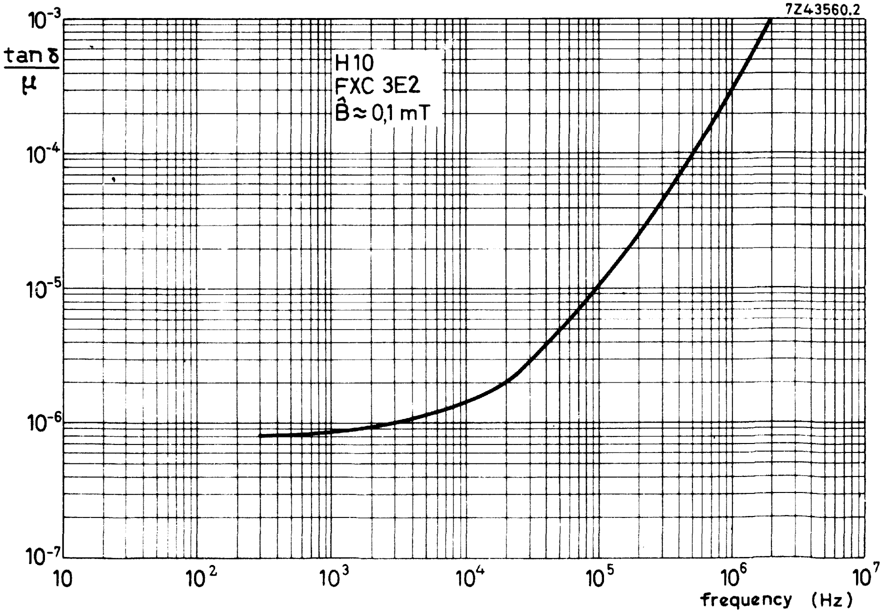
FXC grade 3E2


frequency (Hz)
1
10
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
$\frac{\omega L_p}{N^2}$ (Ω)
$\frac{L_p}{N^2}$ (μH)
$\frac{L_p}{N^2}$
$\frac{\omega L_p}{N^2}$
$\hat{B} \approx$ 0,1 mT
H 10 FXC 3E2
7Z43651.3
-10^{-1}
-10^0
-10^1
-10^2
-10^3
-10^4
7Z43650.1
$\frac{L_p}{N^2}$
$\frac{\omega L_p}{N^2}$
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
frequency (Hz)

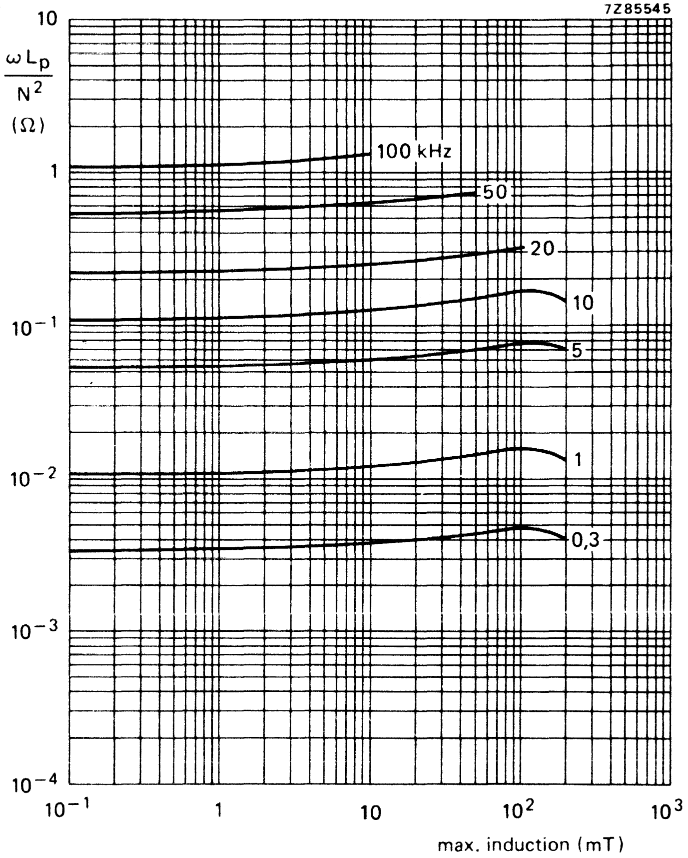
LOSSES AS A FUNCTION OF THE FREQUENCY (typical values)



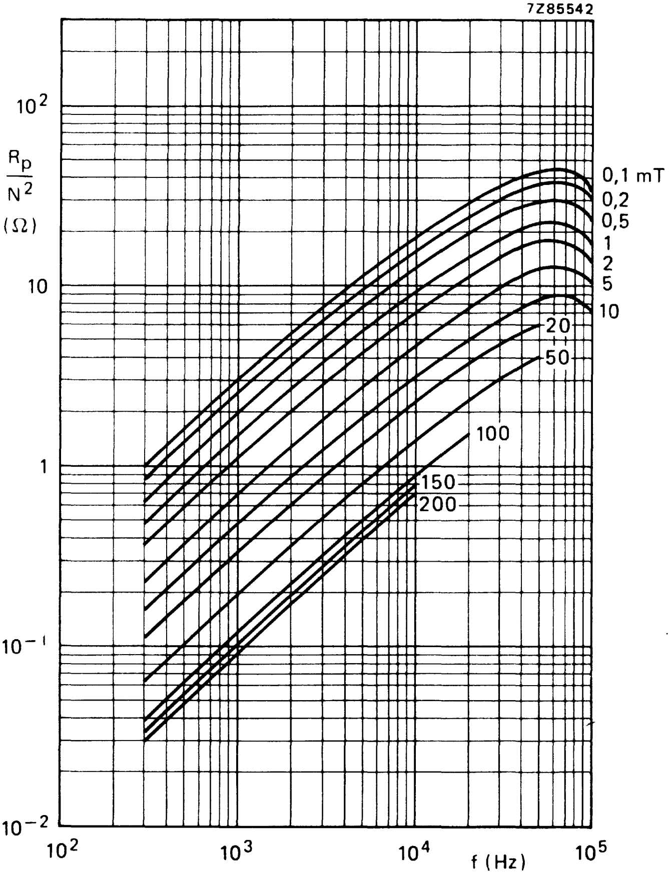
FXC grade 3E2; $\hat{B} \approx 0{,}1$ mT.



INDUCTANCE AS A FUNCTION OF THE INDUCTION (typical values)

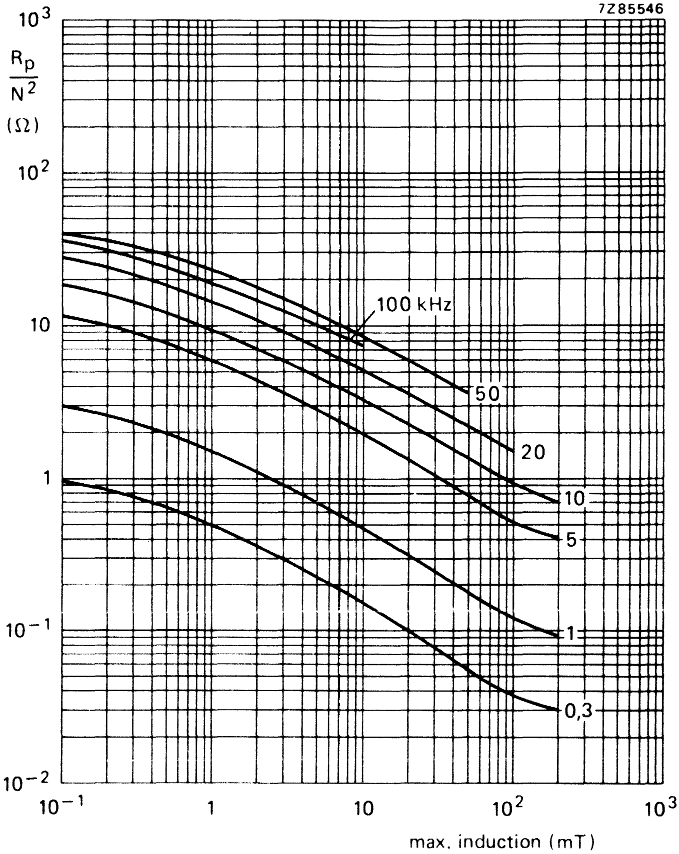


FXC grade 3E2.



FXC grade 3E2.

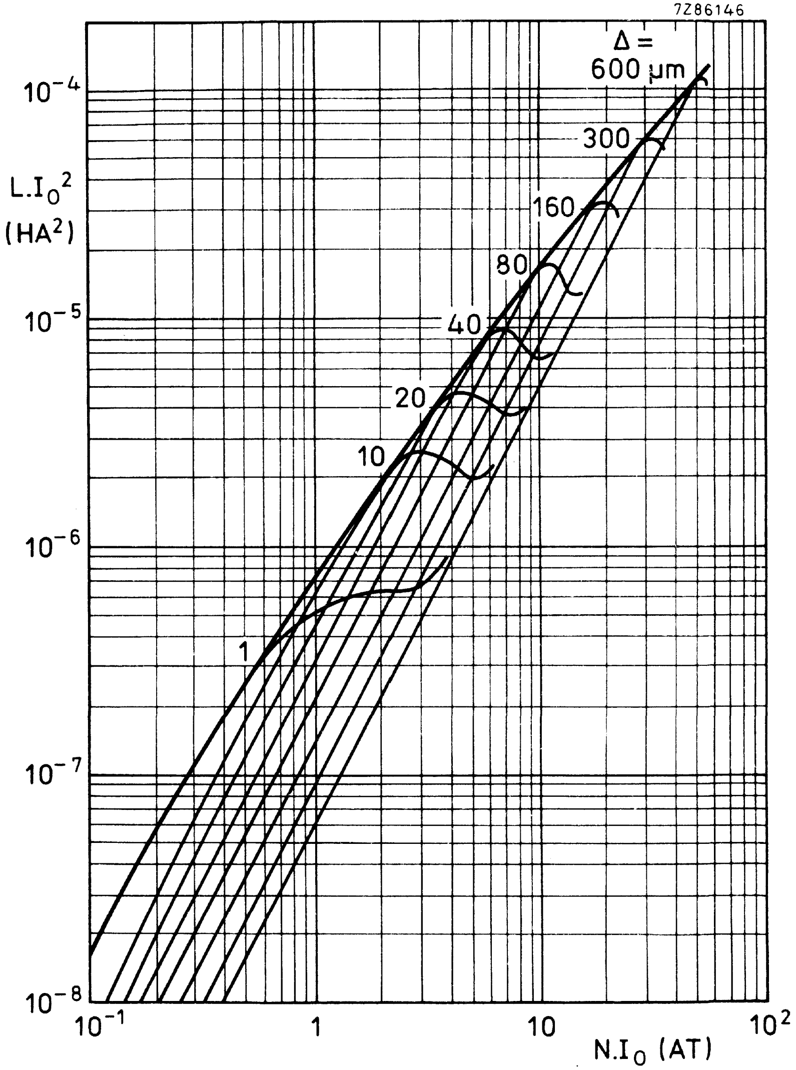
LOSSES AS A FUNCTION OF THE INDUCTION (typical values)



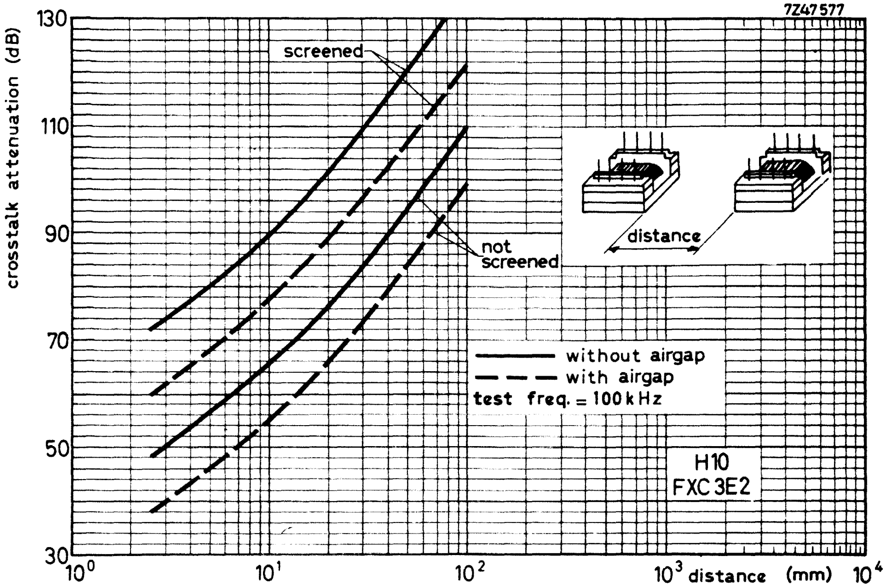
FXC grade 3E2.

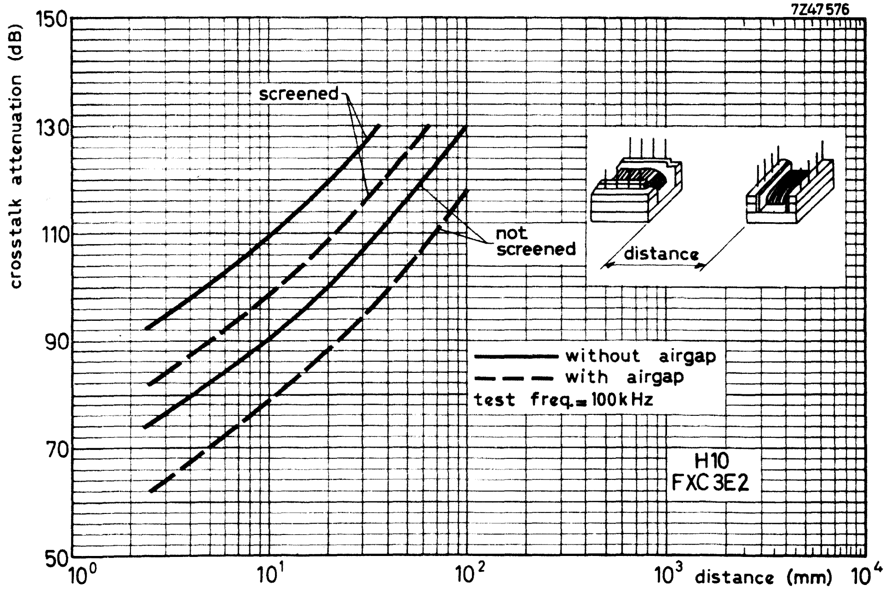
HANNA CURVE (typical values)

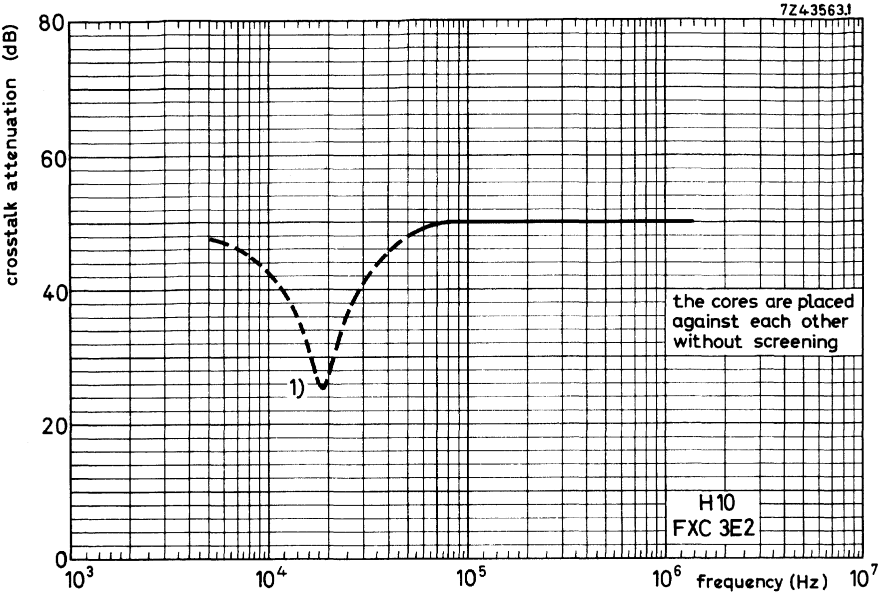
Indicating optimum inductance for a certain air gap and direct current



CROSS TALK ATTENUATION (typical values)







(1) This dip does not depend on the magnetic circuit. It is caused by resonance of the inductance and stray capacitance of the two components in the test circuit.

FERRITE 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.

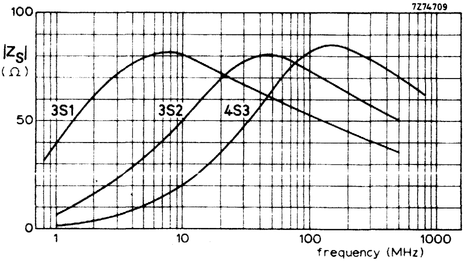


Fig. 1 Impedance of Ferroxcube grades as a function of frequency.
The curves are typical for a bead size of 5 x 2 x 10 mm.

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.

Notes, see page E18.

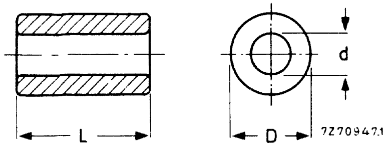


Fig. 2 Guaranteed minimum bead impedances $|Z_S|(\Omega)$ at various frequencies.

	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	15	24	24	20	17	15	4322 030 32180	5	2,0	4	3,7
	18	29	30	24	20	18	32120	3	1,0	4	4,4
	20	31	32	26	22	20	32160	5	1,5	4	4,8
	24	38	39	31	26	23	32100	3	0,7	4	5,8
	32	52	53	42	36	32	32140	5	0,7	4	7,9
	37	60	61	49	42	37	32190	5	2,0	10	9,2
	44	72	73	58	50	44	32130	3	1,0	10	11,0
	48	78	80	64	55	48	32170	5	1,5	10	12,0
	58	95	97	77	66	58	32110	3	0,7	10	14,5
	79	128	131	105	89	79	32150	5	0,7	10	19,7
grade 3S2 (blue)	2	8	16	20	26	17	4330 030 32280	5	2,0	4	3,7
	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	40	26	32320	8	2,0	4	5,6
	4	12	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	71	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	120	77	32310	8	1,5	10	16,7
	12	40	85	110	142	91	32250	5	0,7	10	19,7
grade 4S3 (red)	1	2	7	17	32	36	4330 030 32440	5	2,0	4	3,7
	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.

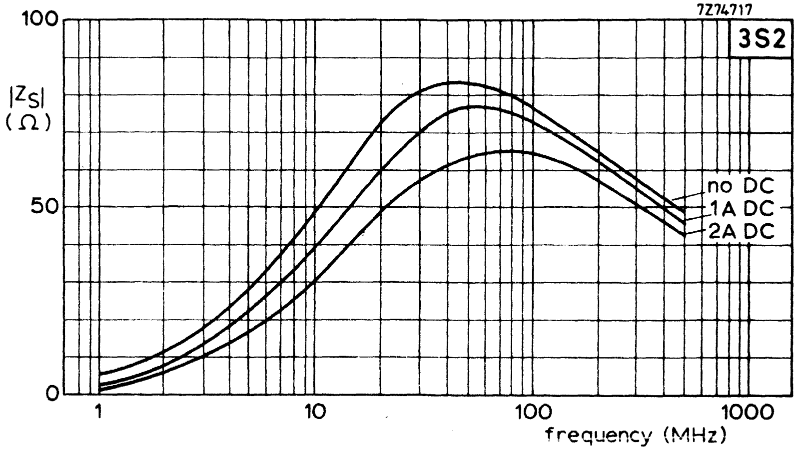


Fig. 3a Impedance $|Z_S|$ of a 5 x 2 x 10 mm bead of grade 3S2 as a function of frequency with the premagnetizing current as a parameter.

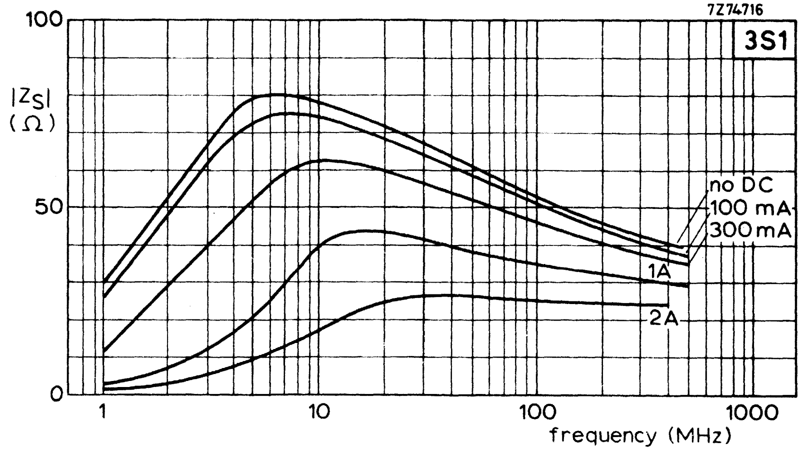


Fig. 3b Impedance $|Z_S|$ of a 5 x 2 x 10 mm bead of grade 3S1 as a function of frequency with the premagnetizing current as a parameter.

Notes

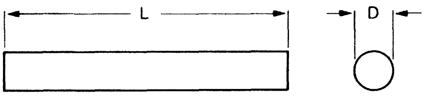
The attenuation of a given type of bead used beyond the frequency limit for its material grade may vary significantly from batch to batch. Although the attenuation will never be less than that given in the table of guaranteed minimum values, it may be much higher. However, the guaranteed minimum attenuation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

CORES FOR SMALL COILS

Ferroxcube rods, tubes and screw cores 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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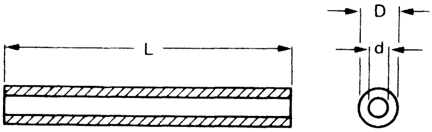

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	RODS				TUBES					
grade	dia. group mm	length group mm	dia. tol. group mm	matching length mm	outer dia. group mm	inner dia. max. mm	inner dia. tol. mm	length group mm	outer dia. tol. group mm	matching length mm
	1,6	5-30	−0,2	5-30						
			−0,05	5-8						
			−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 statndard-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

Type list of rod cores with rectangular cross section

rectangular section	length	FXC grade	catalogue number
2,9 − 0,15 x 2,9 − 0,15	15 ± 0,3	3C6	3122 134 90730
5,1 ± 0,2 x 6,3 ± 0,25	19,8 ± 0,3	3C8	3122 134 90720
7,5 ± 0,25 x 7,5 ± 0,25	25 ± 0,5	3C8	3122 134 90620

Type list of rods

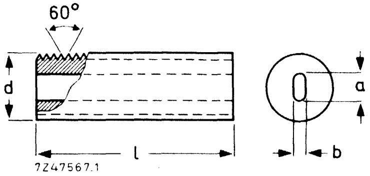
D		L		FXC grade		catalogue number
max.	tol.	max.	tol.	3	4	
1,40	−0,02	6,85	−0,20	3D3		3122 104 91920
1,60	−0,10	3,95	−0,20		4D2	3122 134 91190
1,65	−0,05	9,20	−0,40	3D3		4312 020 30160
1,65	−0,05	9,20	−0,40		4B1	3122 104 91060
1,65	−0,05	12,2	−0,40	3B		3122 104 91100
1,65	−0,05	12,2	−0,40		4B1	3122 104 91110
1,65	−0,05	14,0	−0,40		4B1	4330 020 31770
1,65	−0,05	28,2	−0,40		4B1	4322 020 32090
1,70	−0,15	7,50	−0,40		4E1	4322 020 39300
1,70	−0,15	8,40	−0,40		4D1	3122 104 93160
1,70	−0,15	10,2	−0,40		4D1	4322 020 32040
1,70	−0,15	14,2	−0,40		4E1	4322 020 32060
1,70	−0,15	17,8	−1,00	3B		3122 104 92020
1,75	−0,20	12,2	−0,40		4B1	3122 104 92070
1,75	−0,20	18,5	−1,00		4B1	3122 104 91150
1,78	−0,03	8,95	−0,45	3D3		4322 020 39480
2,10	−0,20	9,40	−0,80		4D1	4330 030 30140
2,10	−0,20	12,5	−1,00		4B1	4330 030 30130
2,20	−0,20	16,5	−1,00		4B1	4312 020 30460
2,30	−0,05	10,2	−0,40	3D3		4312 020 30030
2,50	−0,25	20,0	−1,00		4B1	4312 020 30510
3,00	−0,10	14,0	−0,50		4C6	4330 030 30270
3,00	−0,25	20,0	−0,60		4B1	4330 030 30220
3,15	−0,30	16,5	−1,00		4C6	4330 030 30070
3,20	−0,20	11,5	−1,00		4B1	4330 020 30560
4,00	−0,30	20,0	−0,60	3C6		4312 020 30320
4,00	−0,30	25,0	−1,00		4B1	4330 030 30250
4,95	−0,10	50,0	−0,50	3C6		3122 134 90110
5,00	−0,30	14,0	−0,80		4B1	4330 030 30110
5,00	−0,05	18,3	−0,60		4B1	4330 030 30240
5,00	−0,30	20,5	−1,00		4B1	4312 020 30570
5,00	−0,30	25,0	−1,00		4B1	4330 030 30080
5,00	−0,30	30,0	−1,20		4B1	4330 030 30030
5,00	−0,05	30,2	−0,40	3C6		3122 134 91120
6,00	−0,10	23,0	−0,60	3B		4330 030 30190
6,00	−0,10	46,2	−0,40	3B		3122 104 91310

Type list of tubes

D		d		L		FXC grade		catalogue number
max.	tol.	min.	tol.	max.	tol.	3	4	
2,70	–0,40	1,20	+0,20	3,50	–0,50		4E1	3122 104 91690
2,80	–0,05	1,20	+0,20	8,40	–0,40	3B		4322 020 34340
3,10	–0,02	1,30	+0,20	18,8	–0,50	3B		3122 134 90770
3,50	–0,05	1,70	+0,20	14,2	–0,40	3B		3122 104 92800
3,60	–0,30	1,30	+0,20	3,50	–0,50	3B		4312 020 31050
3,70	–0,40	1,20	+0,20	3,50	–0,50	3B		4322 020 34400
3,70	–0,40	1,20	+0,20	3,50	–0,50		4A1	4322 020 34410
3,70	–0,40	1,20	+0,20	3,50	–0,50		4B1	4322 020 34420
3,70	–0,40	1,50	+0,20	3,50	–0,50	3B		4322 020 34430
3,70	–0,40	1,30	+0,20	5,50	–0,50	3B		4312 020 31060
3,70	–0,40	1,30	+0,20	8,00	–0,50	3B		4312 020 31330
3,70	–0,40	1,30	+0,20	15,2	–0,40	3B		4312 020 31320
4,00	–0,30	1,60	+0,20	15,0	–1,00	3D3		4330 030 32570
4,05	–0,25	1,35	+0,30	5,70	–0,40		4B1	4313 020 15460
4,15	–0,05	2,00	+0,20	7,20	–0,40		4A1	4322 020 34440
4,15	–0,05	2,00	+0,20	12,2	–0,40		4B1	4322 020 34450
4,15	–0,05	2,00	+0,20	12,2	–0,40		4D1	4322 020 34470
4,15	–0,30	2,00	+0,20	36,6	–1,20	3C6		4312 020 31450
4,20	–0,40	1,80	+0,40	5,50	–1,00	3B5		4313 020 15170
4,20	–0,10	2,00	+0,20	7,20	–0,40	3D3		4313 020 31220
4,20	–0,10	2,00	+0,20	11,2	–0,40	3D3		4313 020 31250
4,30	–0,20	2,00	+0,20	7,20	–0,40	3B		3122 104 92900
4,30	–0,20	2,00	+0,20	7,20	–0,40		4A1	4311 020 53640
4,30	–0,20	2,00	+0,20	7,20	–0,40		4B1	4311 020 50710
4,30	–0,20	2,00	+0,20	7,20	–0,40		4D1	3122 104 93890
4,30	–0,20	2,00	+0,20	15,4	–0,80	3B		4322 020 36750
4,30	–0,20	2,00	+0,20	30,5	–1,00		4B1	4311 020 54310
4,95	–0,10	1,30	+0,20	15,2	–0,40	3C6		3122 104 90370
4,95	–0,10	1,30	+0,20	23,2	–0,40	3C6		3122 104 90380
4,95	–0,10	1,30	+0,20	26,2	–0,50	3C6		3122 104 94030
4,95	–0,10	2,90	+0,20	36,0	–0,50	3C6		3122 104 93760
5,40	–0,40	3,30	+0,30	21,2	–0,40		4A1	3104 101 80630
8,00	–0,40	4,20	+0,60	51,4	–2,80	3B		4322 020 34310
9,60	–0,30	7,10	+0,10	8,20	–0,40		4B1	3122 134 91490
10,8	–0,50	6,70	+0,40	19,5	–0,40		4A4	3122 134 90780
14,5	–1,00	7,30	+1,00	28,0	–6,00		4A1	4311 020 51880

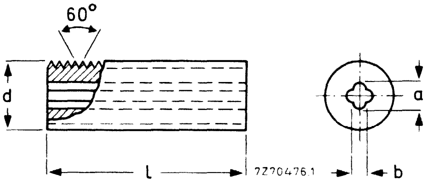
SCREW CORES

Slot trimming hole



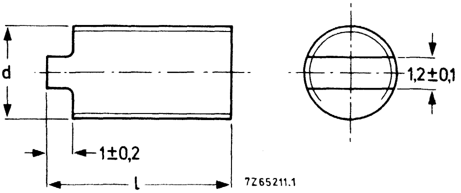
nom. dia x pitch	l mm	d mm	a mm	b mm	grade	catalogue number
5 x 1	20 ± 0,3	5 −0,1	2,35 − 0,3	1,1 ± 0,1	3D3	4312 020 32130
7,35 x 1,25	16 ± 0,5	7,35 + 0,05	3,65 ± 0,15	1,3 ± 0,1	3D3	4312 020 32110

Cross trimming hole



3,5 x 0,7	10 ± 0,25	3,5 ± 0,05	1,4 − 0,1	0,6 − 0,1	3B	3122 104 90750
3,5 x 0,7	10 ± 0,25	3,5 ± 0,05	1,4 − 0,1	0,6 − 0,1	4D2	3122 104 90770

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
3,5 x 0,7	10 ± 0,2	3,5 ± 0,05	4D1	3122 104 90590

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"

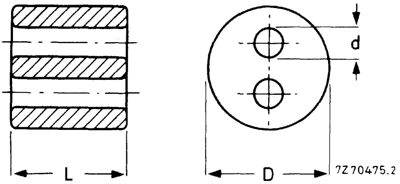


Fig. 1.

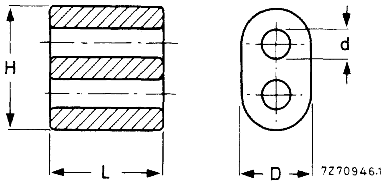


Fig. 2.

Fig.	D mm	d mm	L mm	H mm	grade	catalogue number
1	5,6 ±0,3	0,9 ±0,15	6,35 +0,4	–	4B1	4322 020 38280
	5,6 ±0,25	0,95 +0,15	4,5 −0,5	–	4D1	3122 134 90800
	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
	6,6 −0,6	1,05 +0,3	12,4 −0,8	–	4B1	3122 104 90950
	7,2 −0,4	0,7 +0,2	5,1 −0,2	–	4A1	4322 020 36840
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.

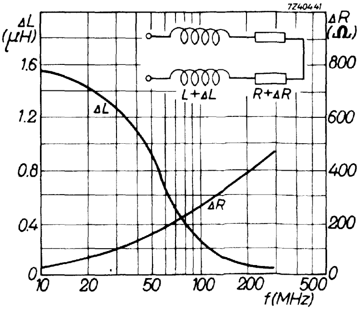


Fig. 3.

B. With six holes

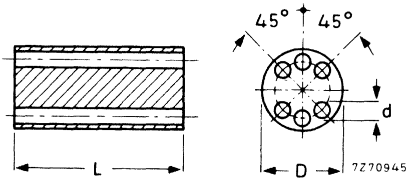


Fig. 4.

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

WIDE-BAND H.F. CHOKES

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.

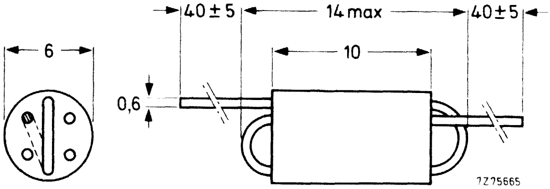


Fig. 5.

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

* Measured with the two 1,5 turn windings in series.

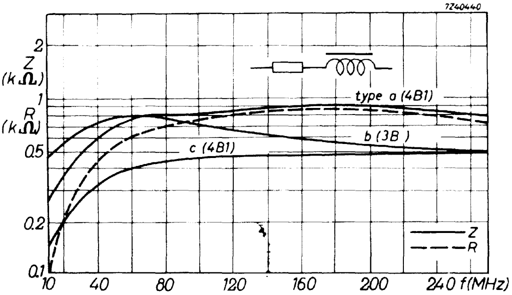


Fig. 6 Performance of three single chokes.

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

Figure 6 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 7 compares the typical obtainable performance.

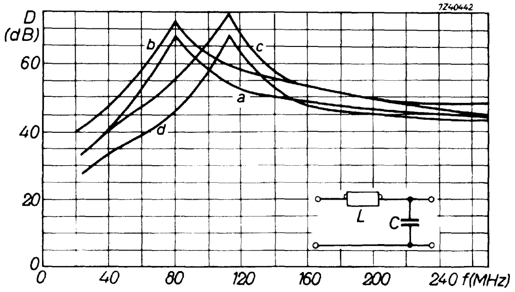
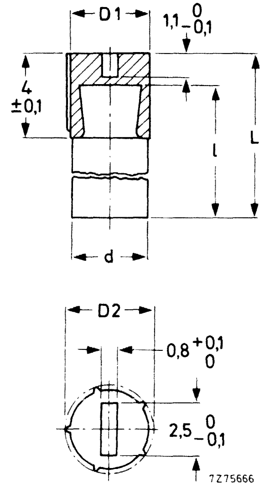


Fig. 7 Damping in an LC circuit consisting of a Ferroxcube choke and a ceramic disc capacitor.

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.

PLASTIC HEADED ADJUSTER CORES

Plastic headed adjuster cores are used for coil adjustment. With help of the ridged elastic polypropylene head the core is fixed in the threaded coil former.



d mm	l mm	D1 mm	D2 mm	L mm	grade	catalogue number
3,1	5,2	3,2 − 0,05	3,6 − 0,05	6,7 ± 0,1	4D2	3122 104 99150
3,1	10,1	3,2 − 0,05	3,6 − 0,05	11,5 ± 0,1	3B	3122 104 99200
3,1	10,1	3,2 − 0,05	3,6 − 0,05	11,5 ± 0,1	4D2	3122 104 99190
3,7	15	3,8 − 0,05	4,2 − 0,05	16,5 ± 0,1	3B	3122 104 99250
4,4	20	4,5 − 0,05	5 − 0,05	21,5 ± 0,1	3B	3122 104 99020
6,3	35	6,4 − 0,05	7,1 − 0,05	36,5 ± 0,1	3C6	3122 104 99270

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 act 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.

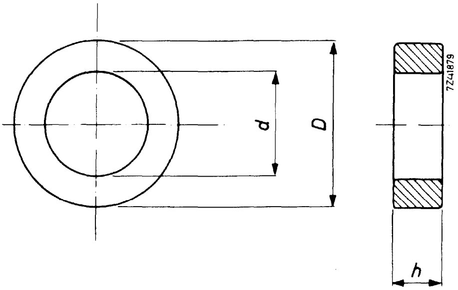


Table 1 Dimensional quantities, tolerances and mass of non-coated toroids.

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
23 ± 0,5	14 ± 0,35	7 ± 0,2	57,0	1,81	1790	8,6
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 ± 0,2	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	catalogue number 4322 020	
				nylon coated	non-coated
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

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

MISCELLANEOUS

1. FERROXCUBE RODS, TUBES AND FERROXDURE MAGNETS FOR LINEARITY-CONTROL UNITS IN TV RECEIVERS

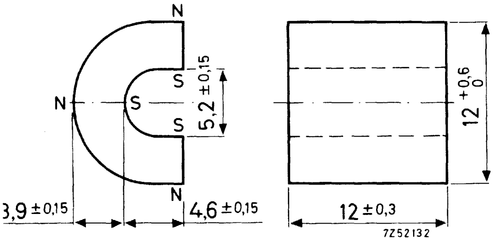
Rods

diameter mm	length mm	grade	catalogue number
4,9 ± 0,05	36 – 0,5	3C6	3122 104 90490
4,9 ± 0,05	50 – 0,5	3C6	3122 134 90110

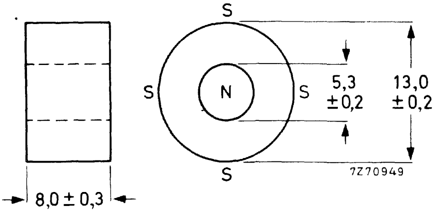
Tubes

outer diameter mm	inner diameter mm	length mm	grade	catalogue number
4,9 ± 0,05	3 + 0,1	36 – 0,5	3C6	3122 104 93760
4 ± 0,15	2 + 0,2	36 ± 0,6	3C6	4312 020 31450

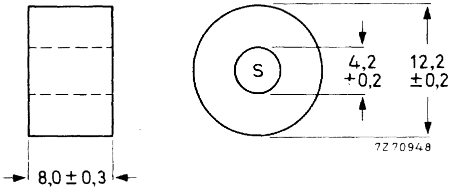
Magnets



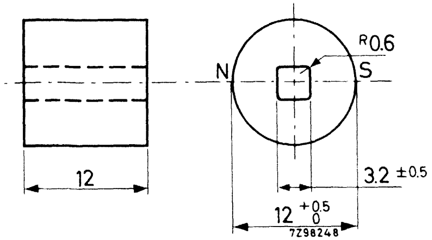
Segment magnet, radially magnetized.
Plastic bonded Ferroxdure P40.
Catalogue number 3122 104 93770.



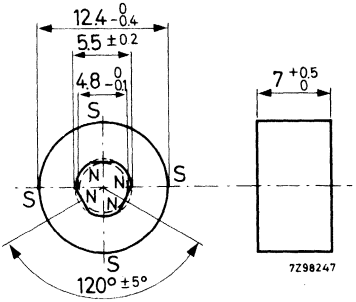
Ring magnet, radially magnetized.
Ferroxdure 100.
Catalogue number 3122 904 92670.



Ring magnet, radially magnetized.
Ferroxdure 100.
Catalogue number 4312 020 63180.



Ring magnet, diametrically magnetized.
Ferroxdure 100.
Catalogue number 3122 104 92690.



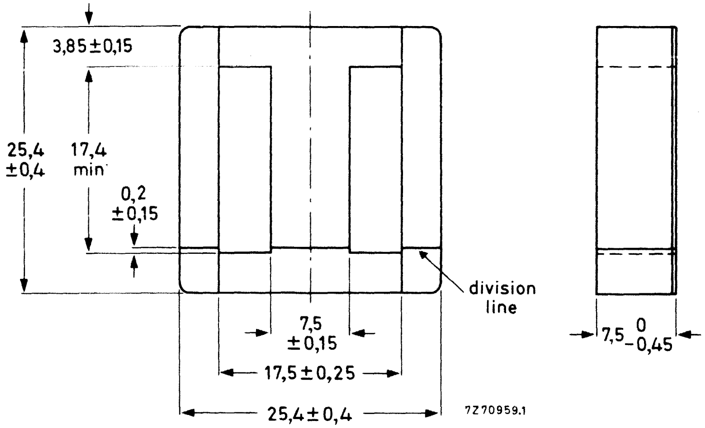
Ring magnet, radially magnetized.
Plastic bonded; Ferroxdure P40.
Catalogue number 3122 104 93530.

2. TRANSDUCTOR CORES

Ferroxcube E + I core in grade 3C7 for raster correction in TV sets.

Magnetic dimensions

l_e = 57,5 mm
A_e = 52,5 mm^2
V_e = 3020 mm^3



Magnetic data

Measured at 16 kHz

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

MATERIALS FOR PARTICLE ACCELERATORS

F

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

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

material		3H2	8C11	3F1	8C12	4L2	4M2	4E2
μ_i		$\geqslant 2500$	$\geqslant 1000$	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)		$\geqslant 400$	$\geqslant 300$	$\geqslant 400$	280	240	250	250
B_{sat} 40° (mT, 800 A/m)		$\geqslant 350$	$\geqslant 280$	$\geqslant 350$	250	220	220	220
H_c (A/m, after 800 A/m)		$\leqslant 20$	$\leqslant 20$	$\leqslant 20$	30	90	100	500
ρ d.c. (Ω M)		> 1	$> 10^3$	> 10	$> 10^3$	$> 10^3$	$> 10^3$	$> 10^3$
T_c (°C)		$\geqslant 125$	$\geqslant 125$	$\geqslant 200$	$\geqslant 125$	$\geqslant 150$	$\geqslant 150$	$\geqslant 400$
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						12.10^3	
10 mT						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			1500	600	200	130	
250 A/m			270	120	120	80	
500 A/m			33	50	55	40	
1000 A/m			13	22	25	22	
2000 A/m			6	8	12	12	
3000 A/m			4	5,5	8	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 G

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 part C4.

catalogue number	page	description
3104 101 80630	E22	Tube core
3122 104 90370	E22	Tube core
90380	E22	Tube core
90470	C143	I-core
90480	C143	U-core
90490	E30	Rod core
90550	E23	Screw core
90590	E23	Screw core
90750	E23	Screw core
90770	E23	Screw core
90950	E24	Multi-hole tube
90960	E24	Multi-hole tube
91060	E21	Rod core
91100	E21	Rod core
91110	E21	Rod core
91150	E21	Rod core
91310	E21	Rod core
91690	E22	Tube core
91910	E21	Rod core
92020	E21	Rod core
92070	E21	Rod core
92690	E31	Magnet
92800	E22	Tube core
92900	E22	Tube core
93160	E21	Rod core
93530	E31	Magnet
93760	E22	Tube core
93770	E30	Magnet
93840	B3	Yoke ring
93890	E22	Tube core
93950	C141	U-core
94030	E22	Tube core
94760	C144	U-core
94770	C144	I-core
94840	E24	Multi-hole tube
99020	E27	Adjuster core
99150	E27	Adjuster core
99190	E27	Adjuster core
99200	E27	Adjuster core
3122 104 99250	E27	Adjuster core
99270	E27	Adjuster core
3122 134 90110	E21	Rod core
90130	C142	U-core
90200	C126	U-core
90210	C72	E-core
90460	C128	U-core
90480	C133	U-core
90620	E20	Rod core
90690	C124	U-core
90720	E20	Rod core
90730	E20	Rod core
90750	B6	Yoke ring
90760	C130	U-core
90770	E22	Tube core
90780	E22	Tube core
90800	E24	Multi-hole tube
90940	C72	E-core
90960	E31	Transductor core
91120	E21	Rod core
91160	C123	U-core
91190	E21	Rod core
91280	B5	Yoke ring
91360	C57	E-core
91390	C136	U-core
91440	B9	Yoke ring
91490	E22	Tube core
91610	B8	Yoke ring
91620	B10	Yoke ring
91630	C132	U-core
91680	B7	Yoke ring
91770	C139	U-core
91810	C57	E-core
91940	B4	Yoke ring
92140	B11	Yoke ring
92230	B12	Yoke ring
92270	B10	Yoke ring
3122 904 92670	E30	Magnet

INDEX

catalogue number	page	description
4322 020 31420	E29	Toroid
31430	E29	Toroid
31440	E29	Toroid
31450	E29	Toroid
31460	E29	Toroid
32040	E21	Rod core
32060	E21	Rod core
32090	E21	Rod core
33060	E3	Core assembly
34310	E22	Tube core
34340	E22	Tube core
34400	E22	Tube core
34410	E22	Tube core
34420	E22	Tube core
34430	E22	Tube core
34440	E22	Tube core
34450	E22	Tube core
34470	E22	Tube core
34510	C33	E-core
34550	C35	E-core
34560	C42	E-core
34580	C42	E-core
34650	C44	E-core
34660	C44	E-core
34740	C50	E-core
34750	C50	E-core
34830	C35	E-core
34840	C44	E-core
34850	C50	E-core
34900	C65	E-core
34910	C78	E-core
34980	C35	E-core
34990	C44	E-core
36750	E22	Tube core
36840	E24	Multi-hole tube
37320	C50	I-core
37400	D7	Bar
37460	D7	Bar
37470	D7	Bar
37480	D7	Bar
38280	E24	Multi-hole tube
39300	E21	Rod core
39480	E21	Rod core
43020	D3	Bar
52500	C87	EC-core
52510	C96	EC-core
52520	C105	EC-core
52530	C114	EC-core
52570	C44	E-core
52600	C96	EC-core

catalogue number	page	description
4322 020 90750	E29	Toroid
90760	E29	Toroid
90770	E29	Toroid
90860	E29	Toroid
90870	E29	Toroid
91560	D12	Bar
97000	E29	Toroid
97010	E29	Toroid
97020	E29	Toroid
97030	E29	Toroid
97040	E29	Toroid
97050	E29	Toroid
97060	E29	Toroid
97070	E29	Toroid
97110	E29	Toroid
97120	E29	Toroid
97130	E29	Toroid
97140	E29	Toroid
97150	E29	Toroid
97160	E29	Toroid
97170	E29	Toroid
97180	E29	Toroid
97190	E29	Toroid
97200	E29	Toroid
97500	D7	Bar
4322 021 20140	C39	Coil former
20160	C40	Clasp
20170	C48	Clasp
20220	C40	Spring
20230	C48	Spring
20240	C37	Coil former
20250	C46	Coil former
31830	C53	Coil former
31910	C55	Clasp
31920	C55	Spring
33010	C99	Coil former
33020	C108	Coil former
33030	C117	Coil former
33060	C99	Tag
33070	C108	Tag
33310	C89	Coil former
33320	C99	Coil former
33330	C108	Coil former
33340	C117	Coil former
33350	C99	Coil former
33360	C108	Coil former
33370	C117	Coil former
33410	C89	Coil former

catalogue number	page	description
4322 030 32100	E16	Bead
32110	E16	Bead
32120	E16	Bead
32130	E16	Bead
32140	E16	Bead
32150	E16	Bead
32160	E16	Bead
32170	E16	Bead
32180	E16	Bead
32190	E16	Bead
4330 020 30560	E21	Rod core
31770	E21	Rod core
4330 030 30030	E21	Rod core
30070	E21	Rod core
30080	E21	Rod core
30110	E21	Rod core
30130	E21	Rod core
30140	E21	Rod core
30190	E21	Rod core
30220	E21	Rod core
30240	E21	Rod core
30250	E21	Rod core
30270	E21	Rod core
32200	E16	Bead
32210	E16	Bead
32220	E16	Bead
32230	E16	Bead
32240	E16	Bead
4330 030 32250	E16	Bead
32260	E16	Bead
32270	E16	Bead
32280	E16	Bead
32290	E16	Bead
32300	E16	Bead
32310	E16	Bead
32320	E16	Bead
32330	E16	Bead
32340	E16	Bead
32350	E16	Bead
32360	E16	Bead
32370	E16	Bead
32380	E16	Bead
32390	E16	Bead
32400	E16	Bead
32410	E16	Bead
32420	E16	Bead
32430	E16	Bead
32440	E16	Bead
32450	E16	Bead
32460	E16	Bead
32470	E16	Bead
32480	E16	Bead
32490	E16	Bead
32500	E16	Bead
32510	E16	Bead
32570	E22	Tube core

FERROXCUBE FOR POWER, AUDIO/VIDEO AND ACCELERATORS

See Part 4 for potcores, square cores and cross cores