Applied Magnetics Laboratory

Soft Magnetic Materials and Their Application

Derac Son[1*]

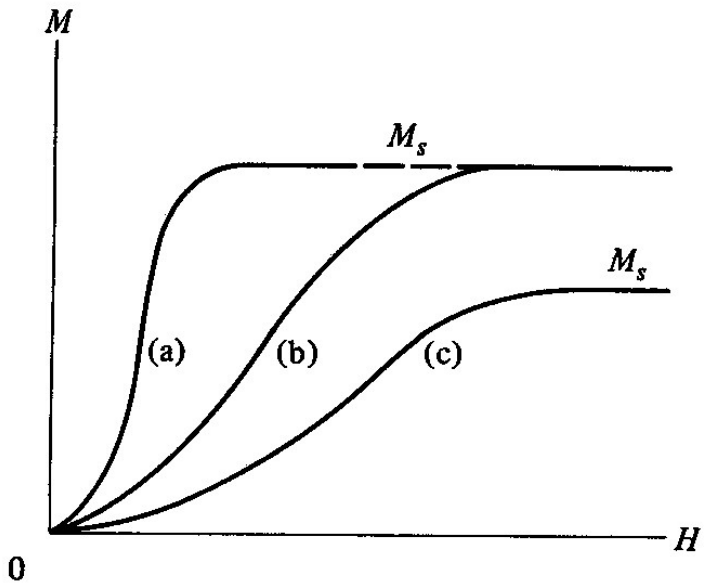
[1]*Department of Optics and Electromagnetics, Hannam University, Korea*

한남대학교 Hannam University

Classification of ferri- and ferro-magnetic materials in engineering point of view; soft and hard magnetic materials.

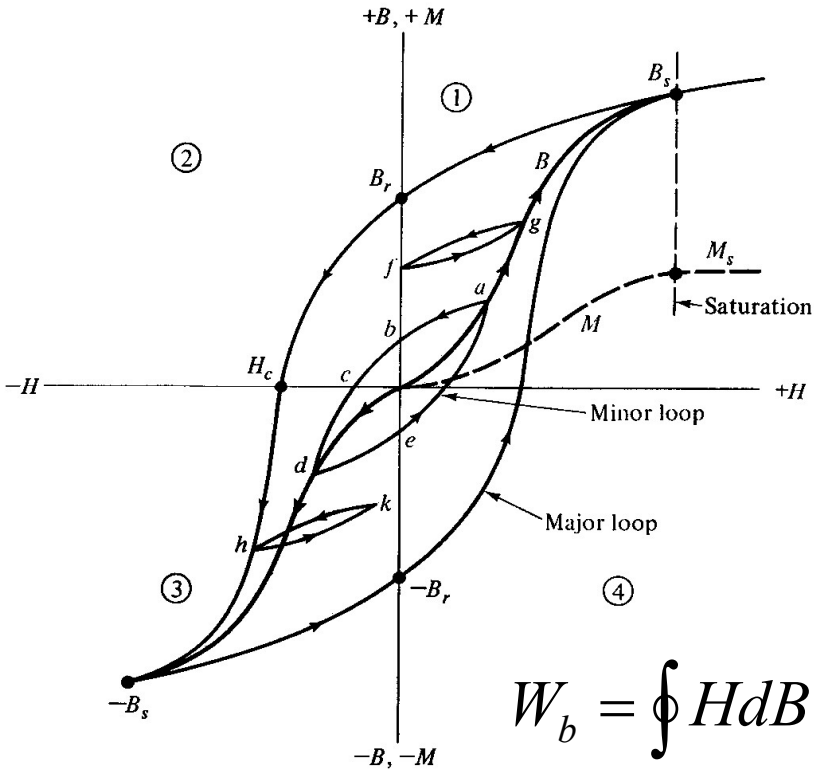
Soft magnetic materials (a)
- Material can be easily magnetized
- Permeability is high
- Used for transformer and inductor core materials
- Used for electromagnet materials

Hard magnetic materials (c)
- Material can not be easily magnetized
- High magnetic energy is stored
- Materials are used for permanent magnet



Soft magnetic materials are classified as coercivity of ferromagnetic or ferrimagnetic materials lower than 1 000 A/m in IEC standard IEC60404-1.

Magnetization curves and hysteresis loops
(자화곡선과 자기이력곡선)



$$W_b = \oint H dB$$

$$B = \mu_o (H + M)$$

$$B = \mu_o H + J \quad \text{or} \quad B = \mu_o H + B_i$$

B_s : Saturation magnetic induction

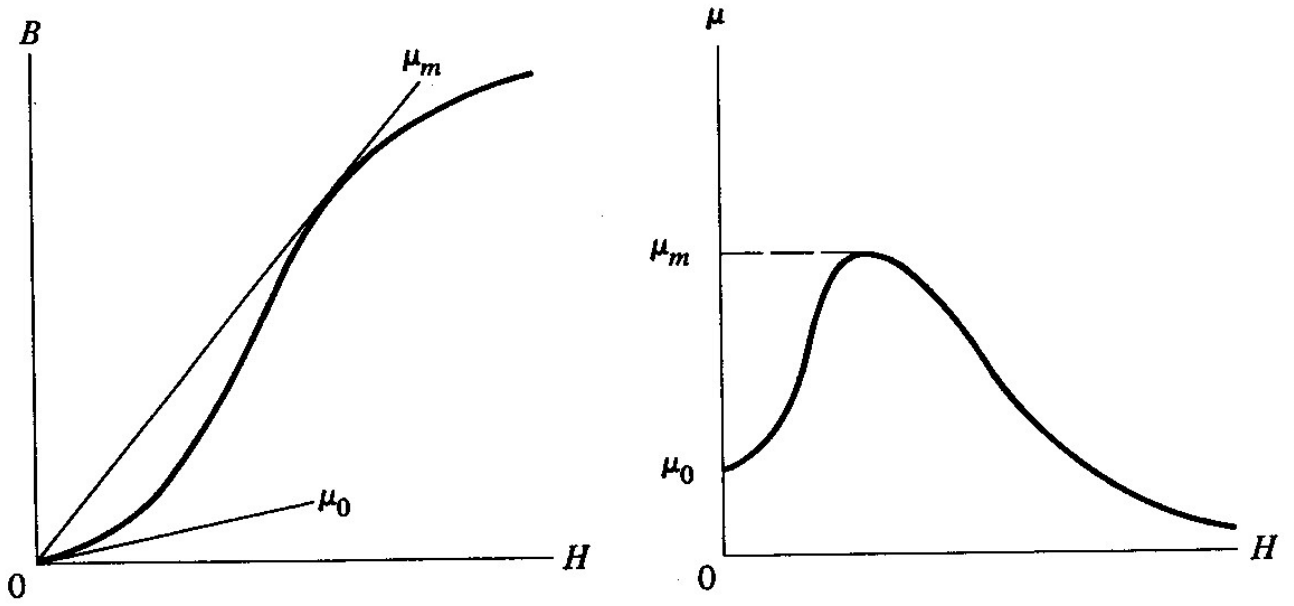
M_s : Saturation magnetization

B_r : Residual magnetic induction

H_c : Coercive field strength

Soft magnetic materials are classified as coercivity of ferromagnetic or ferrimagnetic materials lower than 1 000 A/m in IEC standard IEC60404-1.

Soft magnetic material



μ_o : **Initial permeability**

μ_m : **Maximum permeability**

μ_i : **Incremental permeability**

μ_D : **Differential permeability**

Standards related to the IEC/TC 68

규격번호	규격명(영문)	발행일	Working group
IEC 60404-1 Ed. 2.0 b	Magnetic materials - Part 1: Classification	2000-08-30	1
IEC 60404-1-1 Ed. 1.0 b	Magnetic materials - Part 1-1: Classification - Surface insulations of electrical steel sheet, strip and laminations	2004-04-20	
IEC 60404-2 Ed. 3.0 b	Magnetic materials - Part 2: Methods of measurement of the magnetic properties of electrical steel sheet and strip by means of an Epstein frame	1996-03-28	2
IEC 60404-3 Amd.1 Ed. 2.0 b	Amendment 1 - Magnetic materials - Part 3: Methods of measurement of the magnetic properties of magnetic sheet and strip by means of a single sheet tester	2002-09-25	
IEC 60404-3 Ed. 2.1 b	Magnetic materials - Part 3: Methods of measurement of the magnetic properties of magnetic sheet and strip by means of a single sheet tester	2002-10-29	
IEC 60404-4 Amd.1 Ed. 2.0 b	Amendment 1 - Magnetic materials - Part 4: Methods of measurement of d.c. magnetic properties of iron and steel	2000-07-31	
IEC 60404-4 Ed. 2.1 b	Magnetic materials - Part 4: Methods of measurement of d.c. magnetic properties of magnetically soft materials	2000-11-28	2
IEC 60404-5 Ed. 2.0 b	Magnetic materials - Part 5: Permanent magnet (magnetically hard) materials - Methods of measurement of magnetic properties	1993-10-21	2
IEC 60404-6 Ed. 2.0 b	Magnetic materials - Part 6: Methods of measurement of the magnetic properties of magnetically soft metallic and powder materials at frequencies in the range 20 Hz to 200 kHz by the use of ring specimens	2003-06-24	2
IEC 60404-7 Ed. 1.0 b	Magnetic materials. Part 7: Method of measurement of the coercivity of magnetic materials in an open magnetic circuit	1982-01-01	2

IEC 60404-8-1 Amd.1 Ed. 2.0 b	Amendment 1 - Magnetic materials - Part 8-1: Specifications for individual materials - Magnetically hard materials	2004-05-06	
IEC 60404-8-1 Ed. 2.1 b	Magnetic materials - Part 8-1: Specifications for individual materials - Magnetically hard materials	2004-07-14	5
IEC 60404-8-10 Ed. 1.0 b	Magnetic materials - Part 8: Specifications for individual materials - Section 10: Specification for magnetic materials (iron and steel) for use in relays	1994-11-16	1,JWG
IEC 60404-8-3 Ed. 3.0 b	Magnetic materials - Part 8-3: Specifications for individual materials - Cold-rolled electrical non-alloyed and alloyed steel sheet and strip delivered in the semi-processed state	2005-08-11	
IEC 60404-8-4 Ed. 2.0 b	Magnetic materials - Part 8-4: Specifications for individual materials - Cold-rolled non-oriented electrical steel sheet and strip delivered in the fully-processed state	1998-05-20	1,JWG
IEC 60404-8-5 Ed. 1.0 b	Magnetic materials. Part 8: Specifications for individual materials. Section Five: Specification for steel sheet and strip with specified mechanical properties and magnetic permeability	1989-05-30	1,JWG
IEC 60404-8-6 Ed. 2.0 b	Magnetic materials - Part 8-6: Specifications for individual materials - Soft magnetic metallic materials	1999-04-28	4
IEC 60404-8-7 Ed. 2.0 b	Magnetic materials - Part 8-7: Specifications for individual materials - Cold-rolled grain-oriented electrical steel sheet and strip delivered in the fully-processed state	1998-05-20	1,JWG
IEC 60404-8-8 Ed. 1.0 b	Magnetic materials - Part 8: Specifications for individual materials - Section 8: Specification for thin magnetic steel strip for use at medium frequencies	1991-09-15	1,JWG
IEC 60404-8-9 Ed. 1.0 b	Magnetic materials - Part 8: Specifications for individual materials - Section 9: Standard specification for sintered soft magnetic materials	1994-08-30	4
IEC 60404-9 Ed. 1.0 b	Magnetic materials. Part 9: Methods of determination of the geometrical characteristics of magnetic steel sheet and strip	1987-09-15	2

IEC 60404-10 Ed. 1.0 b	Magnetic materials. Part 10: Methods of measurement of magnetic properties of magnetic sheet and strip at medium frequencies	1988-08-30	2
IEC 60404-11 Amd.1 Ed. 1.0 b	Amendment 1 - Magnetic materials - Part 11: Method of test for the determination of surface insulation resistance of magnetic sheet and strip	1998-07-24	
IEC 60404-11 Ed. 1.1 b	Magnetic materials - Part 11: Method of test for the determination of surface insulation resistance of magnetic sheet and strip	1999-01-21	
IEC 60404-12 Ed. 1.0 b	Magnetic materials - Part 12: Guide to methods of assessment of temperature capability of interlaminar insulation coatings	1992-11-30	2
IEC 60404-13 Ed. 1.0 b	Magnetic materials - Part 13: Methods of measurement of density, resistivity and stacking factor of electrical steel sheet and strip	1995-09-20	2
IEC 60404-14 Ed. 1.0 b	Magnetic materials - Part 14: Methods of measurement of the magnetic dipole moment of a ferromagnetic material specimen by the withdrawal or rotation method	2002-06-27	2
IEC/TR 61807 Ed. 1.0 b	Magnetic properties of magnetically hard materials at elevated temperatures - Methods of measurement	1999-10-20	2
IEC/TR 62331 Ed. 1.0 en	Pulsed field magnetometry	2005-02-23	
IEC/TR 62383 Ed. 1.0 en	Measurement, modelling and calculation methods for the determination of magnetic loss under magnetic polarization waveforms which include higher harmonic components	2006-01-12	

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TECHNICAL REPORT

IEC TR 62383

First edition
2006-01

Determination of magnetic loss under magnetic polarization waveforms including higher harmonic components – Measurement, modelling and calculation methods

Reference number
IEC/TR 62383:2006(E)

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Work Programme for TC 68

Project Reference	Current Code	Document Reference	Init. Date	Current Stage	Next Stage	Pub. Stage
IEC 60404-2 Ed. 4.0	AMW	68/302/MCR	04-10	04-10	05-04	
WGs : 02				Project Leader : M. Yabumoto		
Magnetic materials - Part 2: Methods of measurement of magnetic properties of electrical steel sheet and strip by means of an Epstein frame						
IEC 60404-5 A1 Ed. 2.0	CDM	68/311/CD	03-12	05-09	05-11	
WGs : 02				Project Leader : Y.Ogata		
Amendment 1 to IEC 60404-5: Magnetic materials - Part 5: Permanent magnet (magnetically hard) materials - Methods of measurement of magnetic properties						
IEC 60404-8-6 A1 Ed. 2.0	CDM	68/308/CD	02-03	05-07	05-11	
WGs : 04				Project Leader : K. Tamaki		
Amendment 1 to IEC 60404-8-6: Magnetic materials - Part 8-6: Specifications for individual materials - Soft magnetic metallic materials						
IEC 60404-8-7 Ed. 3.0	1CD	68/314/CD	03-12	05-07	05-11	
WGs : 01				Project Leader : B. Creton		
Magnetic materials - Part 8-7: Specifications for individual materials - Cold-rolled grain-oriented electrical steel sheet and strip delivered in the fully-processed state						
IEC 62383 TR Ed. 1.0	APUB	68/309/DTR	03-07	05-07	05-09	
WGs : 02				Project Leader : D. Son		
Measurement, modelling and calculation methods for the determination of magnetic loss under magnetic polarization waveforms including higher harmonic components						

Web page generated: 22 October 2005

Standards related to the IEC/TC 51

규격번호	규격명(영문)	발행일	Working group
IEC 60133 Ed. 4.0 b	Dimensions of pot-cores made of magnetic oxides and associated parts	2000-12-21	WG1
IEC 60205 Ed. 2.0 b	Calculation of the effective parameters of magnetic piece parts	2001-04-10	WG1
IEC 60205 Ed. 2.0 b Cor.1	Corrigendum 1 - Calculation of the effective parameters of magnetic piece parts	2002-11-15	
IEC 60329 Ed. 2.0 b	Strip-wound cut cores of grain oriented silicon-iron alloy, used for electronic and telecommunication equipment	1984-09-30	(WG5)
IEC 60392 Ed. 1.0 b	Guide for the drafting of specifications for microwave ferrites	1972-01-01	(WG7)
IEC 60401-1 Ed. 1.0 b	Terms and nomenclature for cores made of magnetically soft ferrites - Part 1: Terms used for physical irregularities	2002-12-13	WG1
IEC 60401-2 Ed. 1.0 b	Terms and nomenclature for cores made of magnetically soft ferrites - Part 2: Reference of dimensions	2003-04-16	WG1
IEC 60401-3 Ed. 1.0 b	Terms and nomenclature for cores made of magnetically soft ferrites - Part 3: Guidelines on the format of data appearing in manufacturers' catalogues of transformer and inductor cores	2003-10-08	WG1
IEC 60424-1 Ed. 1.0 b	Ferrite cores - Guide on the limits of surface irregularities - Part 1: General specification	1999-05-31	WG1
IEC 60424-2 Ed. 1.0 b	Guidance of the limits of surface irregularities of ferrite cores - Part 2: RM-cores	1997-10-09	WG1
IEC 60424-3 Ed. 1.0 b	Ferrite cores - Guide on the limits of surface irregularities - Part 3: ETD-cores and E-cores	1999-06-09	WG1
IEC 60424-4 Ed. 1.0 b	Ferrite cores - Guide on the limits of surface irregularities - Part 4: Ring-cores	2001-02-22	WG1

IEC 60556 Amd.1 Ed. 1.0 b	Amendment 1 – Measuring methods for properties of gyromagnetic materials intended for application at microwave frequencies	1997-07-30	
IEC 60556 Amd.2 Ed. 1.0 b	Amendment 2 – Measuring methods for properties of gyromagnetic materials intended for application at microwave frequencies	2004-09-28	
IEC 60556 Ed. 1.0 b	Measuring methods for properties of gyromagnetic materials intended for application at microwave frequencies	1982-01-01	
IEC 60635 Amd.1 Ed. 1.0 b	Amendment 1 – Toroidal strip-wound cores made of magnetically soft material	1997-10-09	
IEC 60635 Ed. 1.0 b	Toroidal strip-wound cores made of magnetically soft material	1978-01-01	(WG5)
IEC 60647 Ed. 1.0 b	Dimensions for magnetic oxide cores intended for use in power supplies (EC-cores)	1979-01-01	WG1
IEC 60732 Ed. 1.0 b	Measuring methods for cylinder cores, tube cores and screw cores of magnetic oxides	1982-01-01	WG1
IEC 60740-1 Ed. 1.0 en	Laminations for transformers and inductors – Part 1: Mechanical and electrical characteristics	2005-08-09	
IEC 60740-2 Ed. 1.0 b	Laminations for transformers and inductors for use in telecommunication and electronic equipment – Part 2: Specification for the minimum permeabilities of laminations made of soft magnetic metallic materials	1993-06-18	(WG5)
IEC 60852-1 Ed. 1.0 b	Outline dimensions of transformers and inductors for use in telecommunication and electronic equipment. Part 1: Transformers and inductors using YEI-1 laminations	1986-07-30	
IEC 60852-2 Ed. 1.0 b	Outline dimensions of transformers and inductors for use in telecommunication and electronic equipment – Part 2: Transformers and inductors using YEx-2 laminations for printed wiring board mounting	1992-05-15	

IEC 60852-3 Ed. 1.0 b	Outline dimensions of transformers and inductors for use in telecommunication and electronic equipment – Part 3: Transformers and inductors using YUI-1 laminations	1992-07-01	
IEC 60852-4 Ed. 1.0 b	Outline dimensions of transformers and inductors for use in telecommunication and electronic equipment – Part 4: Transformers and inductors using YUI-2 laminations	1996-07-03	
IEC 60852-5 Ed. 1.0 b	Outline dimensions of transformers and inductors for use in telecommunication and electronic equipment – Part 5: Transformers and inductors using the series Q of C-cores	1994-04-25	
IEC 61007 Ed. 2.0 b	Transformers and inductors for use in electronic and telecommunication equipment – Measuring methods and test procedures	1994-09-30	WG9
IEC 61021-1 Ed. 1.0 b	Laminated core packages for transformers and inductors used in telecommunication and electronic equipment – Part 1: Dimensions	1990-08-31	(WG5)
IEC 61021-2 Ed. 1.0 b	Laminated core packages for transformers and inductors for use in telecommunication and electronic equipment – Part 2: Electrical characteristics for cores using YEE2 laminations	1995-05-11	(WG5)
IEC 61185 Ed. 2.0 en	Ferrite cores (ETD-cores) intended for use in power supply applications – Dimensions	2005-06-10	
IEC 61246 Amd.1 Ed. 1.0 b	Amendment 1 – Magnetic oxide cores (E-cores) of rectangular cross-section and associated parts – Dimensions	2002-07-10	WG1
IEC 61246 Ed. 1.1 b	Magnetic oxide cores (E-cores) of rectangular cross-section and associated parts – Dimensions	2002-10-09	WG1
IEC 61247 Ed. 1.0 b	PM-cores made of magnetic oxides and associated parts – Dimensions	1995-05-11	
IEC 61248-1 Ed. 1.0 b	Transformers and inductors for use in electronic and telecommunication equipment – Part 1: Generic specification	1996-06-06	

IEC 61248-2 Ed. 1.0 b	Transformers and inductors for use in electronic and telecommunication equipment - Part 2: Sectional specification for signal transformers on the basis of the capability approval procedure	1996-06-06	WG9
IEC 61248-3 Ed. 1.0 b	Transformers and inductors for use in electronic and telecommunication equipment - Part 3: Sectional specification for power transformers on the basis of the capability approval procedure	1996-06-06	WG9
IEC 61248-4 Ed. 1.0 b	Transformers and inductors for use in electronic and telecommunication equipment - Part 4: Sectional specification for power transformers for switched mode power supplies (SMPS) on the basis of the capability approval procedure	1996-06-06	WG9
IEC 61248-5 Ed. 1.0 b	Transformers and inductors for use in electronic and telecommunication equipment - Part 5: Sectional specification for pulse transformers on the basis of the capability approval procedure	1996-06-06	WG9
IEC 61248-6 Ed. 1.0 b	Transformers and inductors for use in electronic and telecommunication equipment - Part 6: Sectional specification for inductors on the basis of the capability approval procedure	1996-06-06	WG9
IEC 61248-7 Ed. 1.0 b	Transformers and inductors for use in electronic and telecommunication equipment - Part 7: Sectional specification for high-frequency inductors and intermediate frequency transformers on the basis of the capability approval procedure	1997-06-24	WG9
IEC 61332 Ed. 2.0 en	Soft ferrite material classification	2005-09-23	
IEC 61333 Ed. 1.0 b	Marking on U and E ferrite cores	1996-03-07	WG1
IEC 61596 Ed. 1.0 b	Magnetic oxide EP-cores and associated parts for use in inductors and transformers - Dimensions	1995-05-11	WG1
IEC 61605 Ed. 2.0 b	Fixed inductors for use in electronic and telecommunication equipment - Marking codes	2005-06-13	
IEC 61609 Ed. 1.0 b	Microwave ferrite components - Guide for the drafting of specifications	1996-02-07	(WG7)

IEC 61631 Ed. 1.0 b	Test method for the mechanical strength of cores made of magnetic oxides	2001-06-27	WG1
IEC 61797-1 Ed. 1.0 b	Transformers and inductors for use in telecommunication and electronic equipment – Main dimensions of coil formers – Part 1: Coil formers for laminated cores	1996-10-17	(WG5)
IEC 61830 Ed. 1.0 b	Microwave ferrite components – Measuring methods for major properties	1997-11-28	(WG7)
IEC 61843 Ed. 1.0 b	Measuring method for the level of intermodulation products generated in a gyromagnetic device	1997-04-28	
IEC 61860 Ed. 1.0 b	Dimensions of low-profile cores made of magnetic oxides	2000-07-31	
IEC 62024-1 Ed. 1.0 b	High frequency inductive components – Electrical characteristics and measuring methods – Part 1: Nanohenry range chip inductor	2002-05-29	
IEC 62025-1 Ed. 1.0 b	High frequency inductive components – Non-electrical characteristics and measuring methods – Part 1: Fixed, surface mounted inductors for use in electronic and telecommunication equipment	2002-05-28	
IEC 62025-2 Ed. 1.0 b	High frequency inductive components – Non-electrical characteristics and measuring methods – Part 2: Test methods for non-electrical characteristics	2005-01-28	
IEC 62044-1 Ed. 1.0 b	Cores made of soft magnetic materials – Measuring methods – Part 1: Generic specification	2002-05-28	
IEC 62044-2 Ed. 1.0 b	Cores made of soft magnetic materials – Measuring methods – Part 2: Magnetic properties at low excitation level	2005-03-07	
IEC 62044-3 Ed. 1.0 b	Cores made of soft magnetic materials – Measuring methods – Part 3: Magnetic properties at high excitation level	2000-12-21	
IEC 62211 Ed. 1.0 b	Inductive components – Reliability management	2003-10-10	

IEC 62317-4 Ed. 1.0 en	Ferrite cores - Dimensions - Part 4: RM-cores and associated parts	2005-09-23	
IEC 62317-7 Ed. 1.0 en	Ferrite cores - Dimensions - Part 7: EER-cores	2005-09-23	
IEC 62323 Ed. 1.0 en	Dimensions of half pot-cores made of ferrite for inductive proximity switches	2005-06-10	
IEC 62358 Ed. 1.0 b	Ferrite cores - Standard inductance factor (AL) and its tolerance	2004-05-12	
IEC/TR 61604 Ed. 1.0 b	Dimensions of uncoated ring cores of magnetic oxides	1997-07-03	
IEC/TS 62398 Ed. 1.0 en	Ferrite cores - Technology approval schedule (TAS)	2004-10-12	

Publication of KS C IEC

- 산업현장에서 (자성)재료의 규격은 필수적이다.

- (자성)재료 및 측정에 관한 규격에 대하여 대학 교육과정에 없으며, 학회차원에서 활동도 미흡하다.

- 산업경쟁력 강화를 위하여 좋은 연구결과를 국제규격화 하여야 한다

INTERNATIONAL STANDARD

IEC 60404-1

Magnetic materials - Part 1: Classification

Clause

2.1 Class A -Irons

2.1.1 General

These materials are covered by IEC 60404-8-6 and IEC 60404-8-10.

Table 1 - Ranges of chemical composition

C %	Si %	Mn %	P %	S %	Al %	Ti %	V %
Up to 0.03	Up to 0.1	0.03 to 0.2	Up to 0.015*	Up to 0.03*	Up to 0.08	Up to 0.1	Up to 0.1
*For improved free machining capability, the upper limits for P and S may be higher than indicated in the table.							

Table 2 - Ranges of specified values for magnetic properties

Maximum coercivity	Minimum magnetic polarization for H =			Minimum saturation magnetic polarization*
	300 A/m	500 A/m	4000 A/m	
A/m	T	T	T	T
12 to 240	1,30 to 1,15	1,40 to 1,30	1,60	2,10 to 2,16
* Value not specified but typical.				

2.1.3 Main applications

The main applications are in d.c. relays, loudspeakers, electromagnets, magnetic clutches, brakes, parts for magnetic circuits in instruments and control apparatus, as well as for pole pieces and other c.c. parts for generators and motors.

2.2 Class B - Low carbon mild steels

2.2.1 Class B.1 -Bulk material

2.2.1.1 General
some of these materials are covered by IEC 60404-8-10.

Table 3 - Ranges of typical values of magnetic and mechanical properties

Yield strength	Elongation (L_0 =5 d_0)	coercivity	Magnetic polarization at H =		
			2500 A/m	5000 A/m	10000 A/m
N/mm^2	%	A/m	T		
100 to 180			1,65 to 1,55	1,75 to 1,65	1,85 to 1,75

2.2.1.3 Main applications

The materials are used for large d.c. magnets where no mechanical strength is required. for example deflection magnets in elementary particle physics and for relay applications.

2.2.2 Class B.2 - Flat material

Table 4 - Ranges of specified values of maximum specific total loss

Nominal Thickness	Frequency	Ranges of specific total loss at ĵ =1.5 T
mm	Hz	W/kg
0,50 0,65	50 50	6,6 to 10,5 8,0 to 12,0
0,50 0,65	60 60	8,4 to 13,4 10,2 to 15,3

2.2.2.3 Main applications

The materials are used in the manufacture of laminated cores for electrical apparatus and especially small machines and for relay applications.

2.3 Class C - Silicon steels

2.3.1 Class C.1 - Bulk materials

Some of these materials are covered by IEC 60404-8-6 and IEC 60404-8-10.

Table 5 - Ranges of specified values for magnetic and electric properties

Silicon content *	Resistivity *	Coercivity	Minimum magnetic polarization at H =			
			100 A/m	300 A/m	500 A/m	4000 A/m
%	μΩm	A/m	T			
2 to 4,5	0,35 to 0,60	48 to 12	0,6 to 1,2	1,1 to 1,3	1,2 to 1,35	1,5

∗ Value not specified but typical.

2.3.1.3 Main applications

The main applications are for the magnetic circuits of relays, magnetic clutches, magnetic pole pieces, stepping motors and gyro housings.

2.3.2 Class C. - Flat material

2.3.2.1 Class C.21 - Isotropic* (non-oriented) steels for use at power frequencies

2.3.2.1.1 General

These materials are covered by IEC 60404-8-2, IEC 60404-8-4, IEC 60404-8-8 and IEC 60404-8-10.

2.3.2.1.1.1 Chemical composition

The main alloying element is silicon, whose content may be between 0,5 % and 5 %.

Table 6 - Range of specified valued of maximum specific total loss

Nominal thickness	Frequency	Ranges of specific total loss at
mm	Hz	W/kg
0.35	50	2.3 to 3.6
0.50	50	2.5 to 10
0.65	50	3.1 to 10
1.00	50	6.0 to 13
0.35	60	2.9 to 4.6
0.50	60	3.2 to 11.9
0.65	60	4.1 to 12.8
1.00	60	8.1 to 17.3

2.3.2.1.3 Main application

These materials are used mainly in the magnetic circuits of electrical apparatus, particularly in the parts of rotating machines in which the flux is not unidirectional. They may also be used in electromagnetic relays, small transformers, chokes for fluorescent tubes, electrical meters, shielding and magnetic poles of electron and proton synchrotrons.

2.3.2.2 Class C.22 - Anisotropic* (oriented) steels for use at power frequencies

2.3.2.2.1 General

These materials are covered by IEC 60404-8-7.

Magnetic measurements are made in accordance with IEC 60404-2 or IEC 60404-3.

2.3.2.1.1.1 Chemical composition

The basic constituent of these materials is iron and the main alloying element is silicon (approximately 3 %),

Table 7 - Range of specified values of maximum specific total loss

Nominal thickness	Regular material		Material with high permability	
	Maximum specific total loss at			
	50 Hz	60 Hz	50 Hz	60 Hz
mm	W/kg	W/kg	W/kg	W/kg
0.23	1.20 to 1.27	1.57 to 1.65	0.90 to 1.00	1.21 to 1.32
0.27	1.30 to 1.40	1.68 to 1.85	1.03 to 1.10	1.35 to 1.45
0.30	1.40 to 1.50	1.83 to 1.98	1.05 to 1.17	1.38 to 1.54
0.35	1.50 to 1.65	1.98 to 2.18	1.25 to 1.35	1.64 to 1.77

Table 8 - Range of typical values of maximum specific loss

Nominal thickness	Domain-refined material	
	Maximum specific total loss at	
	50 Hz	60 Hz
mm	W/kg	
0.23	0.80 to 0.90	1.08 to 1.21
0.27	0.85 to 0.95	1.12 to 1.25

2.3.2.2.3 Main applications

These materials are used mainly for the manufacture of magnetic cores in which the magnetic flux paths are substanially parallel to the direction of cold-rolling, as for example in transformer cores.

2.3.2.3. Class C.23 - Thin silicon steels

2.3.2.3.1 General

These materials are covered by IEC 60404-8-8.

2.3.2.3.1.1 Chemical composition

The basic constituent of these materials is iron. The main alloying element is silicon, whose content may be between 2 % and 4 %.

Table 9 - Specified values of maximum specific total loss

Type	Nominal thickness	Maximum specific total loss at		Frequency
		1 T	1.5 T	
	mm	W/kg		Hz
Grain-oriented	0.05	24	-	1000
	0.1	-	15	400
	0.15	-	16	400
Non-oriented	0.05	45	-	1000
	0.1	13	-	400
	0.15	14	-	400
	0.2	15	-	400

2.3.2.3.3 Main application

These materials are mainly used in magnetic circuits of transformers and rotating machines operating at frequncies above 100 Hz.

2.3.2.4 Class C.24-Steels with specified mechanical properties and specific total loss

2.3.2.4.1 General

2.3.2.4.1.1 Chemical composition

The basic constituent of these materials is irons. The main alloying element is silicon whose content may be between 2 % and 5 %.

Table 10-Typical values of mechanical and magnetic properties for the thickness of 0.50 mm

Yield strength	Specific total loss at and	Magnetic polarization at	Stacking factor
(L)	(L+C)	(L+C)	
	W/kg	T	%
470	4.6	1.69	98.0
620	6.7	1.63	98.0
NOTE L = parallel to rolling direction;			
C = perpendicular to rolling direction			

2.3.2.4.3 Main applications

These materials are generally used under conditions of alternating flux for the stressed parts of magnetic circuits such as rotors of high-speed rotating electric machines.

2.3.2.5 Class C.25-6.5 % silicon steels

2.3.2.5.1 General

These materials are not covered by an IEC publication.

2.3.2.5.1.1 Chemical composition

The basic constituent of these materials is iron. The main alloying element whose content may be between 6 % and 7 %.

Table 11 - Typical values of magnetic properties

Nominal thickness	Maximum specific total loss at		Magnetostriction (peak to peak) at 1.0 T and 400 Hz
mm	W/kg	Hz	
0.05	20.0	1000	1.2
0.10	6.0	400	1.2
0.20	8.0	400	1.2
0.30	10.0	400	1.2

Specific total loss is determined in accordance with IEC 60404-10, using sheared specimens consisting of half the strip taken parallel and half taken perpendicular to the axis of rolling.

2.3.2.5.3 Main applications

These materials are generally used in magnetic circuits of the electrical apparatus operating at frequencies above 100 Hz, which require low noise output and low core loss at higher frequency, such as high-frequency transformers, reactors and the motors used in portable electrical apparatus.

2.4 Class D - Other steels

2.4.1 Class D.1 - Bulk material

2.4.1.1 Class D.11 - Cast solid steels

2.4.1.1.1 General

These materials are not covered by an IEC publication.

2.4.1.1.1.1 Chemical composition

The basic constituent of these materials is iron containing unavoidable imporities. The main alloying elements are carbon, whose content is lower than 0.45 %, and other elements (namely chromium, nickel, manganese, molybdenum and silicon) which may be necessary to develop the required properties.

Mechanical and non-destructive tests are made in accordance with the appropriate ISO standards. Coercivity is measured in accordance with IEC 60404-7, other magnetic properties in accordance with IEC 60404-4.

Table 12-Typical ranges of magnetic and mechanical properties.

Yield strength	Tensile strength	Elongation	Impact values	Magnetic polarization at		
				2500 A/m	5000 A/m	10000 A/m
		%	J	T		
200 to 500	350 to 700	25 to 12	50 to 20	1.50 to 1.30	1.65 to 1.50	1.80 to 1.85

2.4.1.1.3 Main applications

These materials are used in magnetic circuits of electrical apparatus, where a certain mechanical strength is required, particularly in parts of rotating machinery such as rotors, pole pieces, pressure plates and magnet frames.

2.4.1.2 Class D.12 - Forged solid steel

2.4.1.2.1 General

These materials are not covered by an IEC publication.

2.4.1.2.1.1 Chemical composition

The basic constituent of these materials is iron . The main alloying elements are carbon, whose content may vary from 0.15 % to 0.5 % and other alloying elements such as nickel (up to 4 %), chromium (up to 1.8 %), molybdenum (up to 0.5 %), vabadium (up to 0.12 %) and manganese (up to 1.9 %), depending on the mechanical properties required and the size of the forgings. The material also contains unavoidable impurities together with a low content of other elements (Si, Al) which may arise from additions necessitated during the manufacturing process.

Mechanical and non-destructive tests are made in accordance with the appropriate ISO standards. Magnetic properties are measured in accordance with IEC 60404-4.

Table 13 - Typical ranges of mechanical properties

Yield strength	Tensile strength	Elongation	Impact values V-notch test
		%	J
200 to 800	300 to 100	20 to 12	136 to 16

2.4.1.2.3 Main applications

These materials are used in magnetic circuits of electrical apparatus, particularly in the stressed parts of rotating machines such as shafts for rotating machines, pole shoes, pole bodies and pole endplates.

2.4.2 Class D.2 - Flat material

2.4.2.1 Class D.21 - High strength steels - Steel with specified mechanical preperties and permability

2.4.2.1.1 General

These naterials are covered by IEC 60404-8-5.

2.4.2.1.1.1 Chemical composition

The basic constituent of these materials is iron. Alloying elements may be carbon or others, for example silicon. The material also contains unavoidable impurities and a low level of other elements which may arise from additions necessitated during the manufacturing process.

Table 14 - Ranges og specified valued of mechanical and magnetic characteristics of hot-rolled products

Minimum 0.2 % proof stress	Minimum tensile strength	Minimum elongation after fracture	Minimum magnetic poarization at	
			5000 A/m	15000A/m
		%	T	
250 to 700	350 to 800	22 to 10	1.60 to 1.46	1.80 to 1.78

Table 15 - Ranges og specified valued of mechanical and magnetic characteristics of cold-rolled products

Minimum 0.2 % proof stress	Minimum tensile strength	Minimum elongation after fracture	Minimum magnetic poarization at	
			5000 A/m	15000A/m
		%	T	
250 to 400	325 to 450	16 to 10	1.60 to 1.50	1.83 to 1.80

2.4.2.1.3. Main application

These materials are generally used under conditions of d.c. magnetization for the stressed parts of the magnetic circuits of rotating machines, particularly spiders, rims and poles.

2.4.3 Class D.3 - Stainless steels

2.4.3.1 General

Theses materials are presently not covered by an IEC publication.

2.4.3.1.1 Chemical composition

Grade	Cr	Si	Mo	Mn	C	S*
	%					
D31-01	11 to 13	Up to 1.5	Up to 0.5	Up to 0.8	Up to 0.065	Up to 0.025
D31-02	11 to 13	Up to 1.5	Up to 0.5	Up to 0.8	Up to 0.065	0.25 to 0.40
D31-03	16.5 to 18.5	Up to 1.5	Up to 0.5	Up to 0.8	Up to 0.065	Up to 0.065
D31-04	16.5 to 18.5	Up to 1.5	Up to 0.5	Up to 0.8	Up to 0.065	0.25 to 0.40
D31-05	16.5 to 18.5	Up to 1.5	1.0 to 2.5	Up to 1.0	Up to 0.065	Up to 0.03
D31-06	16.5 to 18.5	Up to 1.5	1.0 to 2.5	Up to 1.0	Up to 0.065	0.25 to 0.40
*Selenium and lead may be added instead or in addition to sulphur.						

2.4.3.3 Main application

These materials are used in magnetic cores and other parts requiring a high-permeability stainless steel having low coercive force and low residual magnetism: magnetic solenoid valves and automotive electromechanical devices such as fuel injectors and anti-lock braking systems.

N/mm^2 mm

Table 17 - Typical magnetic properties of materials in the fully processed state

Grade	Resistivity	Maximum permeability	Coercivity	Magnetic polarization at			
				300 A/m	500 A/m	1 kA/m	8 kA/m
	μΩm		A/m	T			
D31-01	0.55	2000	200	1.2	1.3	1.35	1.6
D31-02	0.55	2000	200	1.2	1.3	1.35	1.6
D31-03	0.75	2000	200	0.95	1.1	1.2	1.45
D31-04	0.75	2000	200	0.95	1.1	1.2	1.45
D31-05	0.75	1300	240	0.5	0.6	0.8	1.1
D31-06	0.75	1300	240	0.5	0.6	0.8	1.1

2.5 Class E - Nickel-iron alloys

2.5.1 Class E.1 - Nickel content 72 % to 83 %

2.5.1.1 General

Theses materials are covered by IEC 60404-8-6.

Table 18 - Specified magnetic properties of material with a round hysteresis loop

Grade1)	Maximum Coercivity2)	Minimum amplitude permeability3) at	Magnetic polarization at				
			20A/m	50 A/m	100 A/m	500 A/m	4000 A/m
	A/m		T				
E 11	1 to 4	100 to 30	0.50	0.65	0.70	0.73	0.75
1) Improved grades with minimum amplitude permeability up to 250000 at are available							
2) Only for thickness							
3) Only for thickness							

Table 19 - Typical magnetic properties of material with a flat hysteresis loop

Saturation magnetic polarization	Remanent magnetic polarization	Measuring point amplitude of magnetic field strength	Amplitude of magnetic polarization	Static excursion range of magnetic polarization
T	T	A/m	T	T
0.74	0.2	1.5	0.22	0.18
0.74	0.15	5	0.44	0.35
0.74	0.1	10	0.44	0.38

Table 20 - Typical magnetic properties of material with a rectangular hysteresis loop

Sturation magnetic polartization	Coercivity	Remanent magnetic polarization	Maximum amplitude permeability
T	A/m	T	
0.8	0.8	0.73	250000

2.5.1.3. Main application

The materials are used where high permeability at low magnetic field strength in combination with remanent or saturation magnetic polarization is required.

a) Round hysteresis loop: measuring instruments, current transformer, low-power transformer, relay parts, transducers, protective ground-fault circuit brakers, rotor and stator laminations, magnetic shielding;
b) Flat hysteresis loop: pulse transformers, thyristor protective chokes, protective ground-fault circuit-breaker;
c) Rectangular hysteresis loop: magnetic amplitude, a.c./d.c converters, saturable inductors, pulse transformer cores.

2.5.2 Class E.2 - Nickel content 54 % to 68 %

2.5.2.1. General

These materials are covered by IEC 60404-8-6

Table 21 - Typical magnetic properties of materials with a round hysteresis loop

Grade	Coercivity A/m	Amplitude permeability at	Maximum magnetic permeability
E21	1.2	50000	110000

Table 22 - Typical magnetic properties of material with a flat hysteresis loop

Coercivity	Saturation magnetic polarization	Static excursion range of magnetic polarization	Remanent magnetic polarization
A/m	T	T	T
5 to 7	1.5 to 1.25	0.8	0.2 to 0.1

2.5.2.3 Main applications

The materials are used where high permeability at low magnetic field strength is required.

a) Round hysteresis loop: protective ground-fault circuit-breakers, transducers, measuring transformers;

b) Flat hysteresis loop: protective ground-fault circuit-breakers, pulse transformers, thyristor protective choke.

2.5.3 Class E.3 - Nickel content 45 % to 50 %

2.5.3.1 General

These materials are covered by IEC 60404-8-6.

Table 23 - Specific magnetic properties of materials with a round hysteresis loop

Grade	Maximum Coercivity	Minimum amplitude permeability at	Magnetic polarization at				
			20A/m	50 A/m	100 A/m	500 A/m	4000 A/m
	A/m		T				
E31	6 to 12	10 to 4	0.5	0.9	1.1	1.35	1.45
1) Only for thickness 2) Only for thickness							

Table 24 - Typical magnetic properties of material with a flat hysteresis loop

Coercivity	Saturation magnetic polarization	Static excursion range of magnetic polarization	Remanent magnetic polarization
A/m	T	T	T
7	1.52	1.1	0.08 to 0.23

Table 25 - Typical magnetic properties of materials with a rectangular hysteresis loop

Sturation magnetic polartization	Coercivity	Remanent magnetic polarization	Maximum amplitude permeability
T	A/m	T	
1.55 to 1.60	12 to 8	1.5 to 1.57	50000 to 70000

2.5.3.3 Main applications

The materials are used where high permeability at low magnetic field strength in combination with high remanent or saturation magnetic polarization is required.

a) Round hysteresis loop: measuring instruments, current transformer, low-power transformer, relay parts, transducers, protective ground-fault circuit brakers, rotor and stator laminations, magnetic shielding;

b) Flat hysteresis loop: pulse transformers, thyristor protective chokes, protective ground-fault circuit-breaker;

c) Rectangular hysteresis loop: magnetic amplitude, a.c./d.c converters, saturable inductors, pulse transformer cores.

2.5.4 Class E.4 - Nickel content 35 % to 40 %

2.5.4.1 General

These materials are covered by IEC 60404-8-6.

Table 26 - Specific magnetic properties of materials in the fully processed state

Grade	Maximum Coercivity	Minimum amplitude permeability at	Magnetic polarization at				
			20A/m	50 A/m	100 A/m	500 A/m	4000 A/m
	A/m		T				
E 41-02	-	2200	-	-	-	-	-
E 41-03	24	2900	0.20	0.45	0.70	1.00	1.18
1) Only for thickness 2) Only for thickness 3) Improved grades with minimum amplitude permeability up to 9000 at are available							

2.5.4.3 Main applications

The materials are used for high-frequency and pulse applications, telecommunication translators, high-frequency filters or transformers, blocking transformers, pulse transformers, magnetic shields.

2.5.5 Class E.5 - Nickel content 29 % to 33 %

2.5.5.1 General

These materials are not covered by an IEC publication.

Table 27 - Typical magnetic properties

Curie temperature	Magnetic polarization at 0 °C and at $H = 10$ kA/m	$\Delta B/\Delta T$ at $H = 10$ kA/m
°C	T	T/K
30 to 120	0.15 to 0.7	-0.005 to -0.007

2.5.5.3 Main applications

Temperature compensators (magnetic shunts) for permanent magnet measuring devices espescially for electric current (watt-hour) meters and automotive voltage regulators.

2.6 Class F - Iron-cobalt alloys

2.6.1 Class F.1 - Cobalt content 47 % to 50 %

2.6.1.1 General

These materials are covered by IEC 60404-8-6.

Table 28 - Range of specified magnetic properties of materials with a round hysteresis loop

Grade	Maximum coercivity	Minimum magnetic polarization at				
		300 A/m	800 A/m	1600 A/m	4000 A/m	8000 A/m
	A/m	T				
F 11	60 to 240	1.8 to 1.4	2.1 to 1.7	2.2 to 1.9	2.25 to 2.05	2.25 to 2.15

Table 29 - Typical magnetic properties of materials with a rectangular hysteresis loop

Grade	Coercivity	Remanence
	A/m	T
F 12	20 to 40	1.90 to 2.10

2.6.1.3 Main applications

Isotropic materials are used in applications involving extremely high magnetic polarizations in low or medium magnetic fields such as transformers, relays, electromagnetic and electromechanical devices for aeronautical or aerospace equipment, telephone membranes, pole pieces for electromagnets, magnetic lenses and magnetic bearings.

Anisotropic materials are used for space-saving highly loaded magnetic amplifiers and specialpurpose transformers.

2.6.2 Class F.2 - Cobalt content 35 %

2.6.2.1 General

These materials are covered by IEC 60404-8-6.

Table 30 - Specified magnetic properties

Grade		Maximum coercivity	Minimum magnetic polarization at			
			800 A/m	1600 A/m	4000 A/m	8000 A/m
		A/m	T			
F 21	Bulk material	300	1.2	1.3	-	-
	Strip or sheet		1.6	1.6	2.0	2.2

2.6.2.3 Main applications

The materials are mainly used for applications involving either extremely high magnetic polarizations or unusually high temperatures and as pole pieces for electromagnets.

2.6.3 Class F.3 - Cobalt content 23 % to 27 %

2.6.3.1 General

These materials are covered by IEC 60404-8-6.

Table 31 - Specified magnetic properties

Grade		Maximum coercivity	Minimum magnetic polarization at	
			4000 A/m	8000 A/m
		A/m	T	
F 31	Bulk material	300	1.1	1.75
	Strip or sheet		1.85	2.0

2.6.3.3 Main applications

These materials are mainly used for applications involving either extremely high magnetic polarizations or particularly high temperatures, such as for electromagnetic and electromechanical devices for aeronautical or aerospace equipment, especially when subjected to mechanical load in service such as liquid metal pumps and magnetic bearings. They are also used for pole pieces for electromagnets.

2.7 Class G - Other alloys

2.7.1 Class G.1 - Aluminium-iron alloys

2.7.1.1 General

These materials are not covered by an IEC publication.

2.7.1.3 Main applications

The materials are used in the manufacture of laminated cores for magnetic heads and ultrasonic transducers or as structural parts of magnetic circuits.

2.7.2 Class G.2 - Aluminium-silicon-iron alloys

2.7.2.1 General

These materials are not covered by an IEC publication.

2.7.2.3 Main applications

The materials are used for the parts of magnetic circuits, magnetic heads and as semiprocessed products, for example, powder.

2.8 Class H - Magnetically soft materials made by powder metallurgical techniques

2.8.1 Class H.1 - Soft ferrites

2.8.1.1 General

These materials are covered by IEC 60401.

Table 32 - Typical properties for Mn-Zn ferrites

initial permeability	Relative loss factor at	Hysteresis material constant	Temperature coefficient of permeability	Disaccom-modation at 40 ℃	Magnetic polarization at	Curie temperature	Resistivity
					mT	K	Ωm
700 to 10000	1 to 20	0.8 to 2	0 to 8	2 to 10	300 to 480	390 to 470	0.05 to 5
* Between 20 ℃ to 55 ℃							

Table 33 - Typical properties for Ni-Zn ferrites

initial permeability	Relative loss factor at	Hysteresis material constant	Temperature coefficient of permeability	Disaccom-modation at 40 ℃	Magnetic polarization at	Curie temperature	Resistivity
					mT	K	Ωm
10 to 250	100 to 400	10 to 40	0 to 30	<60	50 to 400	520 to 770	to
* Between 20 ℃ to 55 ℃							

2.8.1.3 Main applications

Among the most important applications are the following:

-cores for inductors and transformers operating at frequencies in the range from audio frequency to several hundreds of megahertz;
- cores for pulse transformers up to several hundred megahertz; aerial rods;
-cores for power transformers operating at frequencies in the range from about 5 kHz to about 30 MHz;
- ring cores and multiaperture cores for data storage devices;
- cores for recording heads;
- cores for deflection coils on cathode-ray tubes;
- cores for reciprocal and non-reciprocal microwave devices;
- beads for RF decoupling and attenuation of unwanted signals.

$H = 80000$ A/m

2.8.2 Class H.2 - Magnetically soft sintered materials

2.8.2.1 General

These materials are covered by IEC 60404-8-9.

Table 34 - Ranges of specified properties

Material	Minimum density	Maximum coercivity
		A/m
Fe	6400 to 7300	150 to 175
FeP	6800 to 7300	110 to 150
FeNi	7600 to 8300	8 to 20
FeCo	7700	100 to 200
FeSi	7200 to 7400	50 to 80
With special precautions, lower coercivities are possible.		

Table 35 - Typical physical and magnetic properties

Material	Porosity	Magnetic polarization at	Magnetic polarization at	Maximum relative permeability minimum values	Vickers hardness	Resistivity
	%	T	T		HV5	μΩm
Fe	6 to 18	0.7 to 1.3	1.55 to 1.85	2000 to 5500	50 to 70	0.12 to 0.15
FeP	5 to 10	1.05 to 1.35	1.65 to 1.85	3400 to 6900	95 to 105	0.18 to 0.20
FeNi	3 to 7	0.75 to 1.30	0.80 to 1.55	20000 to 74500	70 to 95	0.45 to 0.60
FeCo	3	1.50 to 1.55	2.15 to 2.20	2000 to 3900	190 to 240	0.10 to 0.35
FeSi	2 to 4	1.35 to 1.40	1.85 to 1.95	8000 to 9500	170 to 180	0.45

2.8.2.3 Main application

The materials are used as structural parts in magnetic circuits.

2.8.3 Class H.3 - Powder composites

2.8.3.1 General

These materials are not covered by an IEC publication.

2.8.3.1.1 Chemical composition and manufacturing method

Powder composite materials consist of a basic magnetic powder and inorganic or organic electrically insulating additives and binders.

Pure iron (Fe), iron-silicon (FeSi, FeSiA[) and nickel-iron (FeNi, FeNiMo) powder composites are in use. Powder metallurgical techniques such as cold-isostatic pressing, die pressing or injection moulding are used for manufacturing.

Table 36 - Typical physical and magnetic properties

Material	Initial magnetic permeability	Saturation magnetic polarization	Total loss density at and	Electrical resistivity
		T		Ωm
Fe-base	10 to 90	0.5 to 2.0	10 to 35	1 to
FeNi-base	10 to 500	0.5 to 1.5	3 to 15	1 to

2.8.3.3 Main application

The materials are used as ring-shaped powder cores for inductive components (storage chokes) and as structural parts in motor applications.

2.9 Class I - Amorphous soft magnetic materials

Amorphous alloys are non-crystalline materials which are produced via rapid solidification by casting as thin sheets or wires. Due to the lack of long-range atomic order, they have no magneto-crystalline anisotropy. Interesting soft magnetic properties are found in Fe-based alloys with relatively high saturation magnetic polarization and in Co-based alloys with near zero magnetostriction.

2.9.1 Class 1.1 - Iron-based alloys

2.9.1.1 General

These materials are not covered by an IEC publication.

Table 37 - Typical physical and magnetic properties

Material	Specific total loss at and	Speicific apparent at and	Coercivity	Magnetic polarization at	Crystalliza-tion temperatur e	Resistivity	Density	Stacking factor
	W/kg	VA/kg	A/m	T	℃	μΩm		%
$Fe_{92}Si_5B_3$	0.2	1.0	3	1.55	550	1.2	7200	80 to 85

2.9.1.3 Main applications

Variation of one property normally influences the value of various other properties. This situation gives rise to the existence of many different materials, each intended for a relatively small group of applications.

The most important ones are
- core material for distribution transformers at power frequency,
-cores for inductors and transformers operating at frequencies up to several hundred kHz, and
- theft detection tags.

2.9.2 Class 1.2 - Cobalt-based alloys

2.9.2.1 General

These materials are not covered by an IEC publication.

2.9.2.1.1 Chemical composition

The basic constituents of these materials are cobalt and iron or manganese whose content is commonly in the range of 2 % by atoms to 10 % by atoms and metalloids (silicon and boron mainly) whose content is in the range of 18 % by atoms to 30 % by atoms. Cobalt may be partly substituted by nickel. These alloys may contain additions of titanium, vanadium, chromium, zirconium, niobium, molybdenum, ruthenium, hafnium, tantalum and tungsten to improve magnetic and mechanical properties.

2.9.2.3 Main applications

Variation of one property normally influences the value of various other properties. This situation gives rise to the existence of many different materials, each intended for a relatively small group of applications.

The most important ones are
- cores for inductors and transformers operating at frequencies in the range from 50 Hz to several hundreds of kHz,
- cores for pulse transformers,
- cores for recording heads, and
- flexible magnetic shielding.

2.9.3 Class 1.3 - Nickel-based alloys

2.9.3.1 General

These materials are not covered by an IEC publication.

2.9.3.1.1 Chemical composition

The basic metallic constituents of these materials are nickel and iron in approximately equal amounts by weight and which form about 90 % of the alloy by weight. In some alloys molybdenum can be present. The principal metalloid is boron although phosphorus and silicon can also be present.

2.9.3.3 Main applications

The main applications are for article surveillance sensors and magnetic EMI shielding.

3 Magnetically hard materials (coercivity >1 kA/m)

3.1 Class Q - Magnetostrictive alloys - Rare earth iron alloys (Class Q.1)

3.2 Class R - Magnetically hard alloys

3.2.1 Class R.1 - Alloys of aluminium-nickel-cobalt-iron-titanium

3.2.2 Class R.3 - Iron-cobalt-vanadium-chromium alloys

3.2.3 Class R.5 - Rare earth cobalt (RE-Co) alloys

3.2.4 Class R.6 - Chromium-iron-cobalt alloys

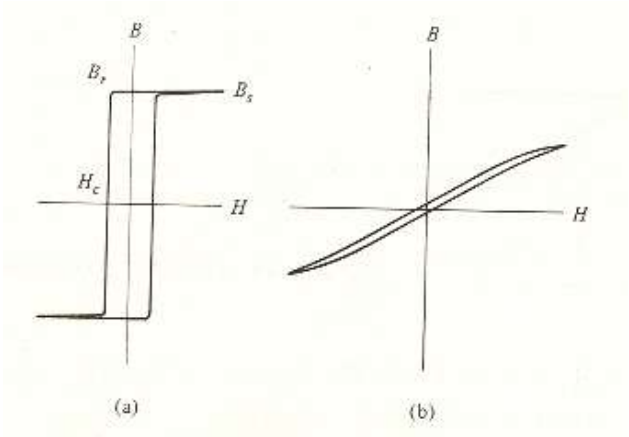
3.2.5 Class R.7 - Rare earth iron boron alloys

3.3 Class S - Magnetically hard ceramics - Hard ferrites (Class S.1)

3.4 Class T - Other magnetically hard materials - Martensitic steels (Class T.1)

3.5 Class U - Bonded magnetically hard materials

Application core materials for power management (under high frequency operation)



$$V = NA\frac{dB}{dt} \qquad \Delta V \cdot \Delta t = NA\Delta B$$

$$E_f = 4.444\ NAB_{\max}$$

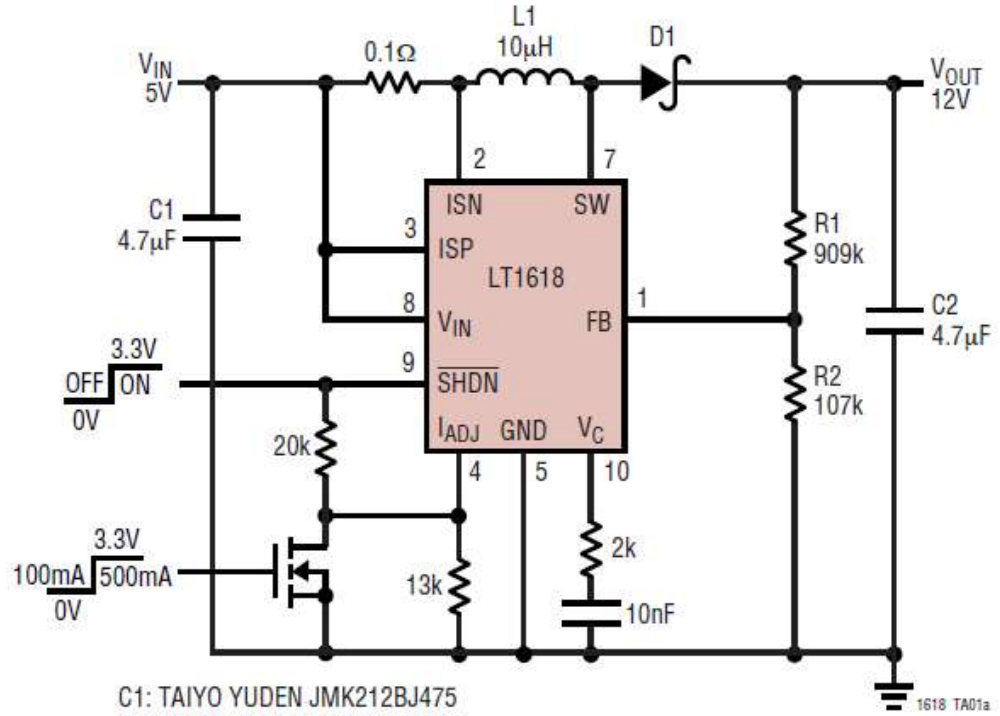
$$W(f) = W_h + W_{cl}(f) + W_{exc}(f)$$

Frequency is low : winding resistance and high induction are important
Frequency is high : Core loss is important

$$\Delta t << \Rightarrow NA << \Rightarrow A << \text{ and } N <<$$

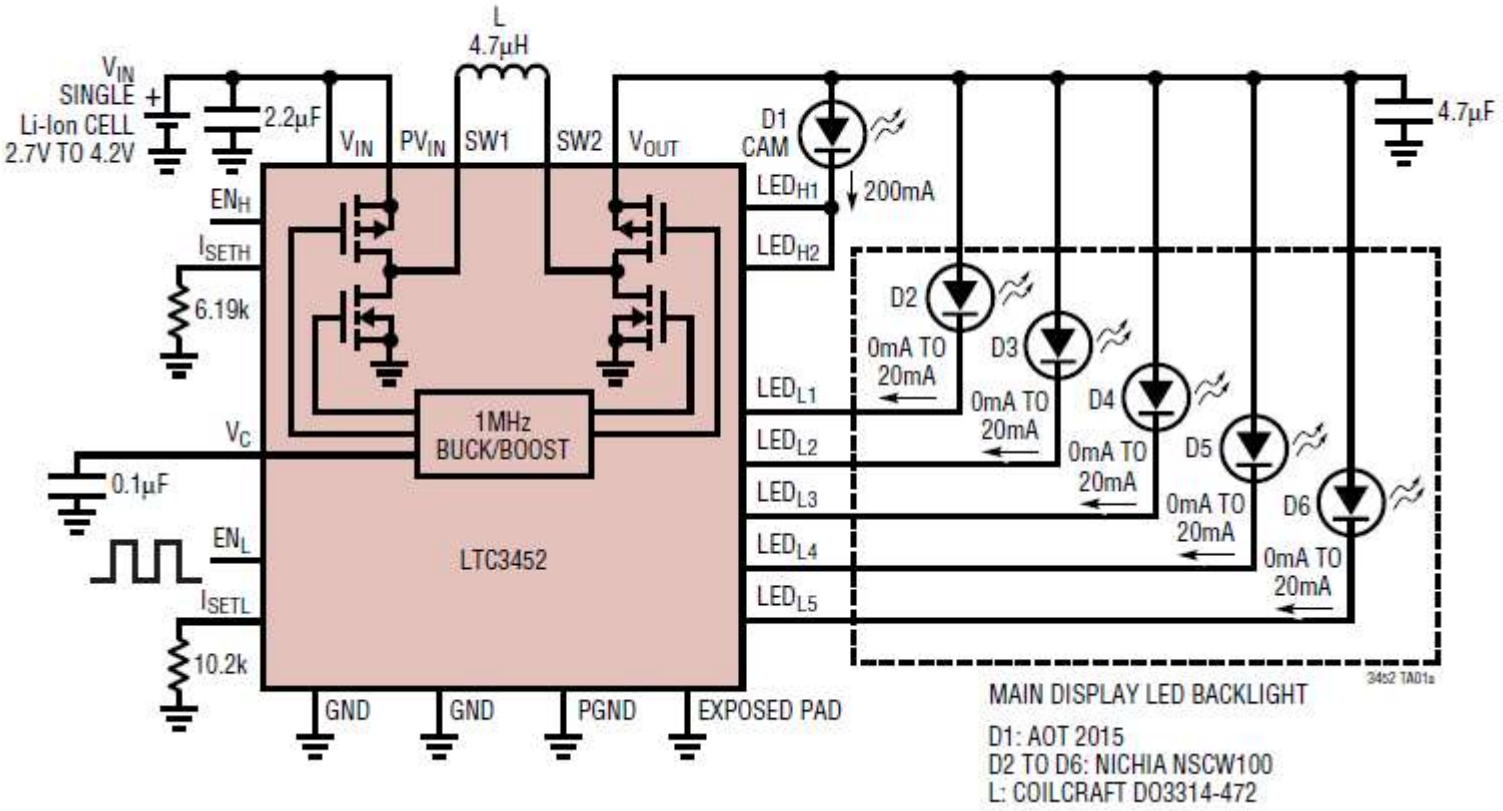
Constant-Current/
Constant-Voltage 1.4MHz
Step-Up DC/DC Converter

USB to 12V Boost Converter
(with Selectable 100mA/500mA Input Current Limit)

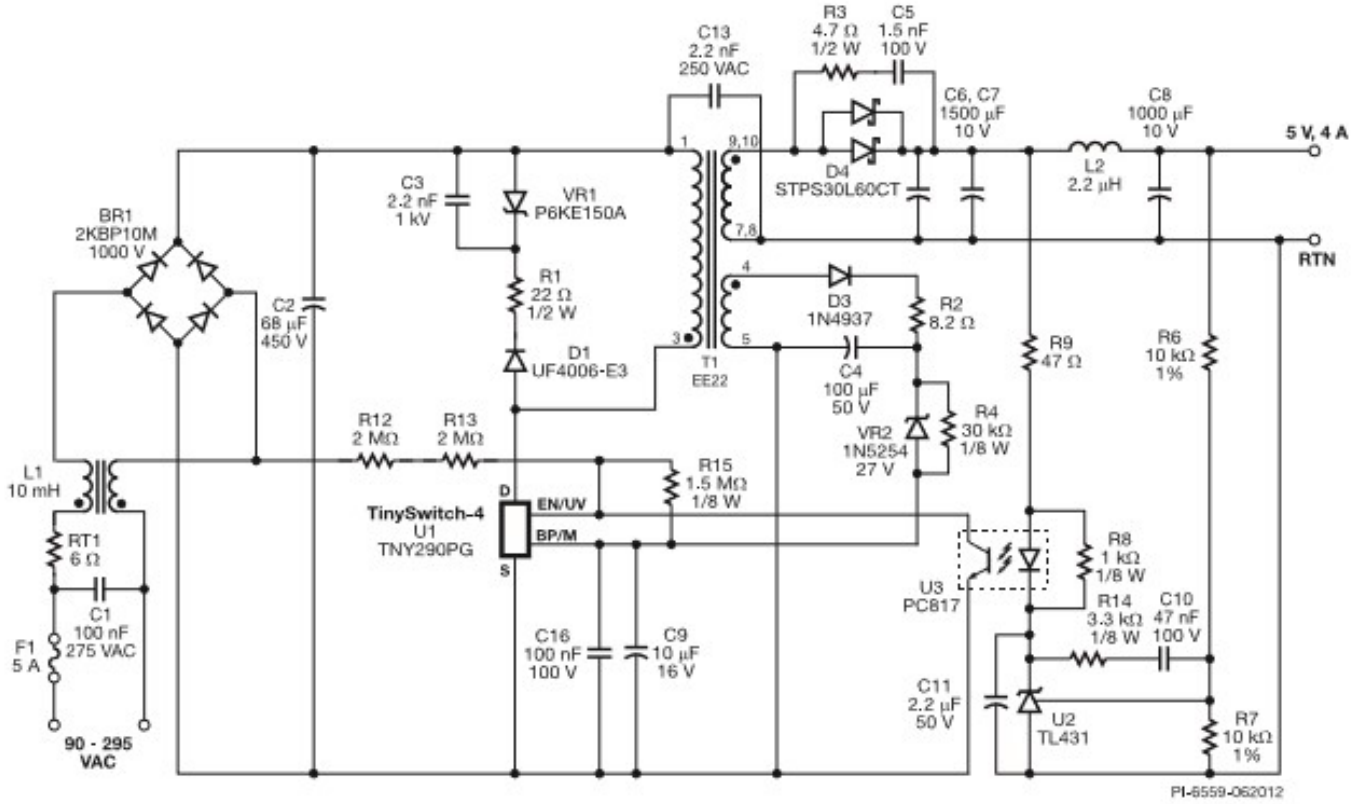


C1: TAIYO YUDEN JMK212BJ475
C2: TAIYO YUDEN EMK316BJ475
D1: ON SEMICONDUCTOR MBR0520
L1: SUMIDA CR43-100

5 × 20mA White LED Display + 200mA Camera Light Driver

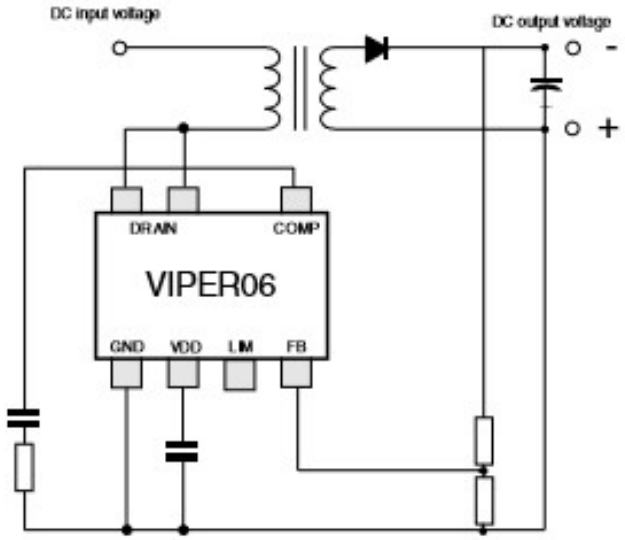


Energy-Efficient, Off-Line Switcher With Line Compensated Overload Power



In a PC standby application input stage
will be part of main power supply input

- 800 V avalanche rugged power section
- PWM operation with frequency jittering for low EMI
- Operating frequency:
  - 30 kHz for VIPER06Xx
  - 60 kHz for VIPER06Lx
  - 115 kHz for VIPER06Hx
- No need for an auxiliary winding in low-power applications
- Standby power < 30 mW at 265 VAC
- Limiting current with adjustable set point
- On-board soft-start
- Safe auto-restart after a fault condition
- Hysteretic thermal shutdown



Programmable Operating Frequency
(20kHz to 1MHz) with One External Resist