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Amorphous Magnetic Parts

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2K1412

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Amorphous Magnetic Materials and their Applications

There is a magnetic metal material with very unique characteristics that does not have a crystalline structure. At Toshiba Materials, we focused on the excellent magnetic characteristic of this amorphous magnetic alloy and started research and development years ago, anticipating future applications and need for such a product. This Amorphous alloy was called "alloy of dreams" at the time when we started our research but in recent years, it has and is finding application in electrical products (desk top computer, copying machine, printer etc.) Amorphous magnetic parts make it possible to reduce energy consumption, and minimize electronic circuit noise for electrical products with a product considered environmentally friendly (RoHS).

Amorphous Ribbon

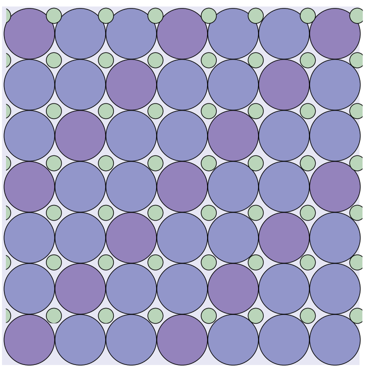
Amorphous Alloy

Amorphous alloy is a general term for a metal with a non-crystalline structure of atoms.

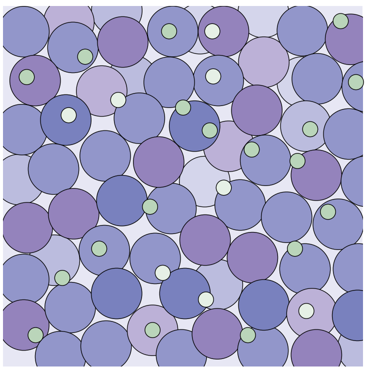
Regular alloys have a uniformly formed metallic crystalline structure, but for amorphous alloys, the atoms are distributed randomly. As a result of this random atomic distribution, the magnetic properties of amorphous alloys are anisotropic. Also, in addition to an increase of electrical resistivity, thin ribbons are made so that the eddy current losses will be small and the magnetic characteristics will be significantly improved.

At Toshiba Materials, we manufacture a Cobalt based amorphous alloy by the liquid rapid cooling method. This method of rapid cooling, at a rate of about 1 million degrees per second, prevents the metal from solidifying in an amorphous structure rather than in its normal ordered crystalline structure.

Models of Atomic Arrangement



Regular Alloy
(Crystalline Structure)

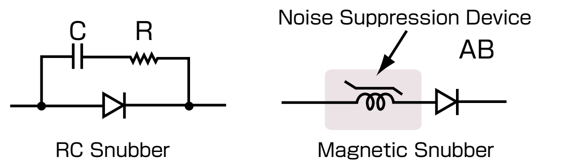


Amorphous Alloy
(Non Crystalline Structure)

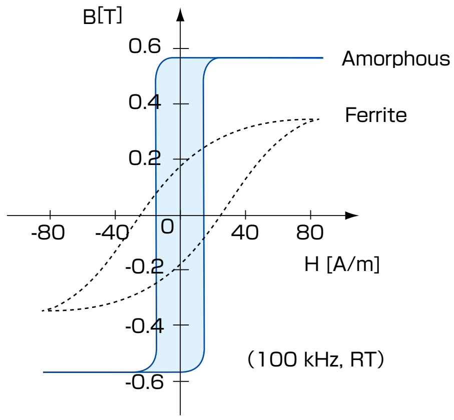
1. Noise Suppression Devices AMOBEADS™

An amorphous noise suppression device is unique and completely different from conventional noise filters. Conventional noise prevention products focus on somehow minimizing the noise after it's been created, by typically trying to absorb the noise, and so their effectiveness in noise reduction is directly influenced by frequency of the circuit. Amorphous noise suppressing devices, on the other hand, focus on the source of the noise and work to prevent or minimize the noise before it has a chance to develop. The source of the electronic circuit noise is the rapid change of current or voltage, and the effectiveness of the amorphous cores in eliminating this noise is independent of frequency.

An amorphous noise suppression device is a product that takes full advantage of the unique magnetic characteristics of the cobalt based amorphous alloy. Toshiba Materials offers two noise suppression devices, "AMOBEADS™ " and "SPIKE KILLERS™ ". AMOBEADS™ " deliver excellent noise suppression results and are convenient to use by simply being slipped over the leads of the semiconductor device. "AMOBEADS™ " are also available with a lead thru and in a surface mount configuration. "SPIKE KILLERS™ ", which are larger in size than "AMOBEADS™ ", most often are wire wound and are effective in eliminating or minimizing higher noise levels.



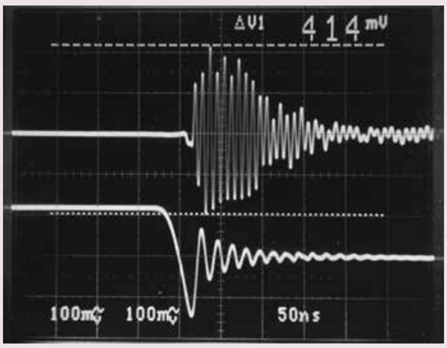
Basic Snubber Circuit Diagram



B-H Curve (typical)

Example for Noise Suppressing Effect (Chopper Converter)

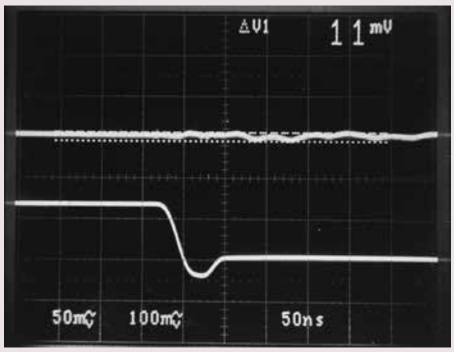
With an excellent saturable characteristic, "AMOBEADS™ " suppress the reverse recovery current of the diode and decrease the noise that is occurring. When the current for diode reverses and tries to go into the recovery condition, the "AMOBEADS™ " displays a large inductance and oppose the generation of the recovery current. In this instance, a soft recovery is possible for core material with a smaller coercive force.



Without Countermeasure

Output Noise

Diode Current
1A/div



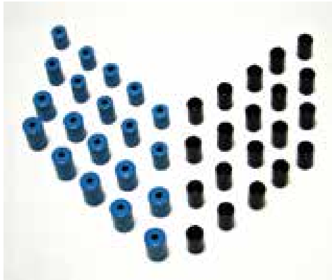
With AMOBEADS™
(AB4×2×8W)

Standard Specifications

AMOBEADS™

W series

Type No.	Finished Dimensions [mm]			Core Size [mm]*1			Total Flux*2	AL value*3	Insulating Cover	Packing Unit
	O.D. max	I. D. min	H.T. max	O.D.	I. D.	H.T.	ϕc[μWb] min	L[μH] min		
AB3X2X3W	4.0	1.5	4.5	3.0	2.0	3.0	0.9	3.0	PBT case Blue	2,000 [pcs/box]
AB3X2X4.5W	4.0	1.5	6.0	3.0	2.0	4.5	1.3	5.0		
AB3X2X6W	4.0	1.5	7.5	3.0	2.0	6.0	1.8	7.0		
AB4X2X4.5W	5.0	1.5	6.0	4.0	2.0	4.5	2.7	9.0		
AB4X2X6W	5.0	1.5	7.5	4.0	2.0	6.0	3.6	12.0		
AB4X2X8W	5.0	1.5	9.5	4.0	2.0	8.0	4.8	16.0		



W series DY sereis

DY series (low price)

(Recommend for big demand, 10,000pcs/lot)

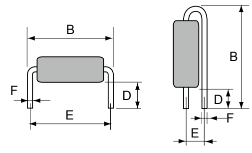
Type No.	Finished Dimensions [mm]		Total Flux*7	Insulating Cover	Packing Unit
	O.D.	H.T.	ϕc[μWb]		[pcs/bag]
AB2.8X4.5DY	4.0±0.2	5.7±0.3	0.9min	PBT Black	10,000
AB3X2X3DY	4.0±0.2	4.2±0.3	0.9min	PBT Black	10,000
AB3X2X4.5DY	4.0±0.2	5.7±0.3	1.3min	PBT Gray	10,000
AB4X2X6DY	5.0±0.2	7.2±0.3	3.6min	PBT Black	5,000
AB5X4X3DY	5.95±0.2	4.2±0.3	0.45min	PBT Black	5,000

※Inner diameter can pass through a 1.2X0.7mm lead.
However, Inner diameter of AB5x4x3DY can pass through a 2.5x0.7 mm lead.

AMOBEADS™ with lead

Bulk type

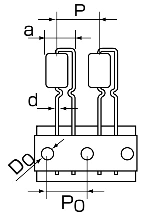
Type No.	Finished Dimensions [mm]				Current*4	Total flux*2	AL Value*3	Insulating Cover	Packing Unit
	B	D	E	F	[A]	ϕc[μWb]	L[μH]		
LB4X2X8F	16.0max	4.2±0.5	14.0±1.0	ϕ1.25±0.1	(8.0)	4.8 min	16.0 min	PBT case Black	1,000 [pcs/box]
LB4X2X8U	20.0max	4.0±0.5	5.0±1.0	ϕ1.25±0.1					



LB4X2X8F LB4X2X8U

Radial taping

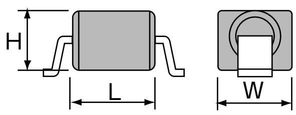
Type No.	P [mm]	Po [mm]	Do [mm]	a [mm]	d [mm]	Current*4 I [A]	Total Flux*7 ϕc[μWb]	Packing Unit
LB2.8X4.5U	12.7	12.7	ϕ4.0	9.0max	ϕ0.8	(5)	0.9min	3,000 [pcs/box]

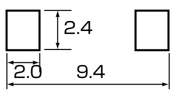


SMD Type AMOBEADS™

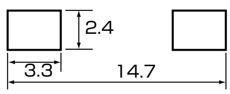
Type No.	Finished Dimensions [mm]			Lead	Io*4	Total Flux*2	AL value*3	Insulating Cover	Packing Unit
	width	length	height	width x thickness	[A]	ϕc[μWb]	L[μH]		[pcs/reel]
AB3X2X3SM	5.0±0.3	5.0±0.3	4.0±0.3	(1.8×0.35)	(6.0)	0.9 min	3.0	LCP case Black	2,000
AB4X2X6SM	6.0±0.3	8.0±0.3	5.0±0.3	(1.8×0.52)	(9.0)	3.6 min	12.0		1,000

Recommended Land Pattern (mm)





AB3X2X3SM



AB4X2X6SM

*1 Reference Value *2 Minimum Guarantee on Measuring Condition : 50kHz､80A/m(sine wave), R.T.
*3 Measuring Condition:50kHz, 1V, 1turn, R.T.
*4 Typical Value, using a cross section of lead
*5 Measuring Condition:100kHz, 80A/m(sine wave), R.T. *6 Tolerance ±0.2[mm]
*7 Converted from Inductance Value L_1 at 1kHz､100mA(sine wave)､R.T.
ϕc(μWb)=0.282 x L_1(μH)

☆"AMOBEADS™ " sample kits are available. Please ask sales department.
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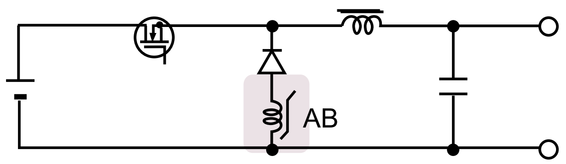
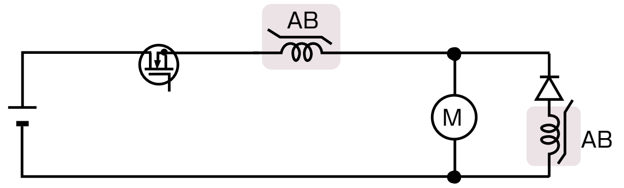
☆"AMOBEADS™ " and "SPIKE KILLER™ " : Resistered in U.S.A., France, Germany, U.K., Japan.

Examples of Applied Circuits and their Characteristics

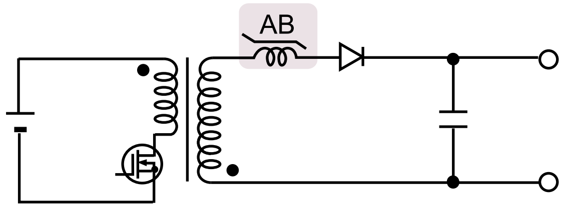
Application of Amorphous Noise Suppression Devices



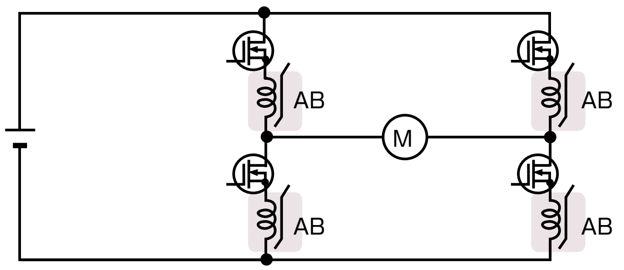
Chopper Converter



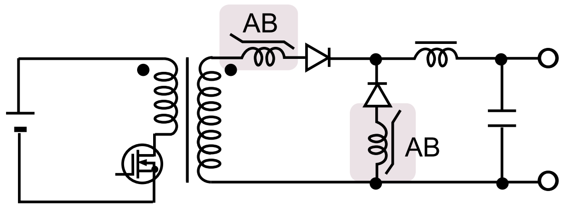
Control Circuit for Motor



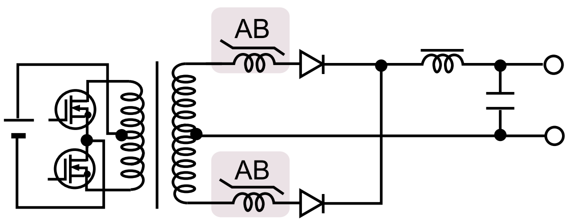
Flyback Converter



Motor Driving Circuit

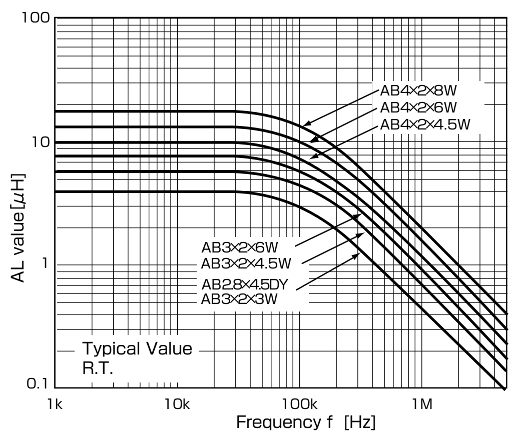


Forward Converter

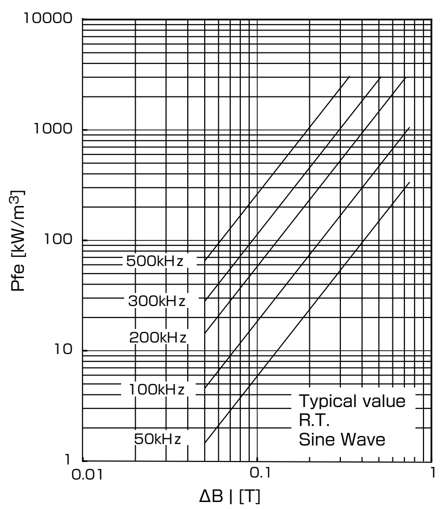


Push-pull Converter

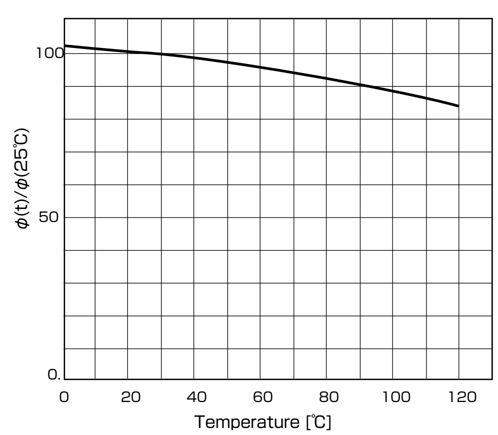
Characteristics (Typical value)



Frequency Characteristics of Inductance



Coreless Characteristic [AMOBEADS™]



Flux(φ) Decline Ratio vs. Temperature

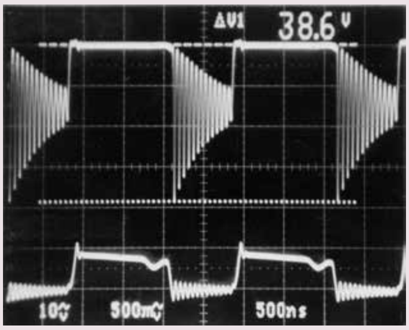
Effects of Noise Suppression by AMOBEADS™

Spike Voltage Suppression

Spike voltage can be reduced and ringing phenomena can also be prevented by AMOBEADS. Also Schottky barrier diode (SBD) can be protected from over voltage.

Frequency:500kHz
Output Voltage - Current :5V-20A

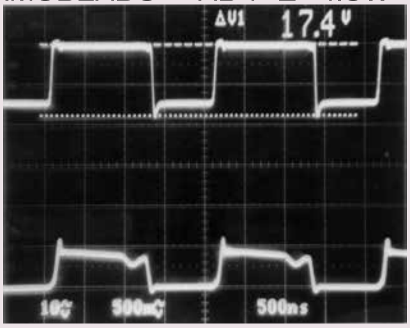
Without Countermeasure



Diode Voltage V_D 10V/div

Diode Current I_D 5A/div

AMOBEADS™ "AB4×2×4.5W"

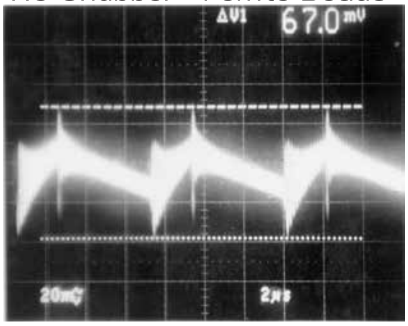


Output Noise Reduction

When the ferrite is replaced by AMOBEADS at the secondary output diode (FRD) of the forward converter circuit, the output noise can be tremendously reduced, not only the noise peak level but also the amplitude range.

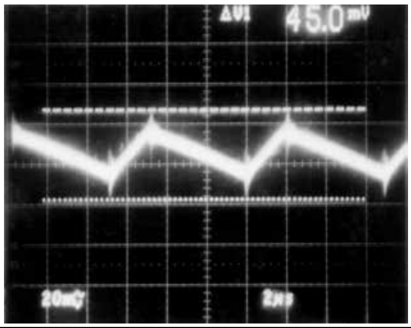
Frequency:150kHz
Output Voltage - Current :15V-10A

RC Snubber +Ferrite Beads



Output Noise V_N 20mv/div

AMOBEADS™ "AB4×2×4.5W"

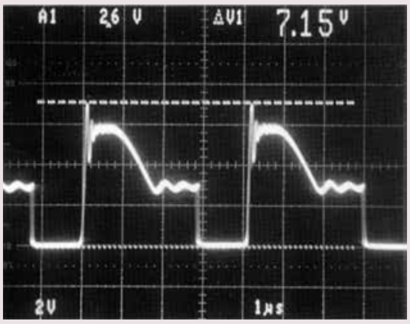


Primary Surge Voltage

When the ferrite is replaced by AMOBEADS at the secondary output diode (SBD) of the forward converter circuit, the output noise and harmful influence to the primary stage can be reduced. These effects are based on the inclination of the actual BH curves between amorphous and ferrite materials.

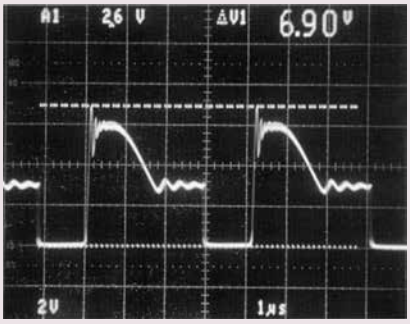
Frequency:250kHz
Output Voltage - Current :5V-15A

Ferrite Beads 4×2×4

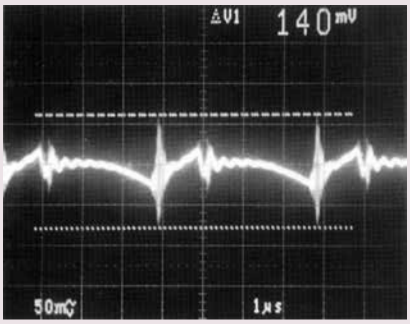


MOS-FET Drain-Source Voltage V_{DS} 200V/div

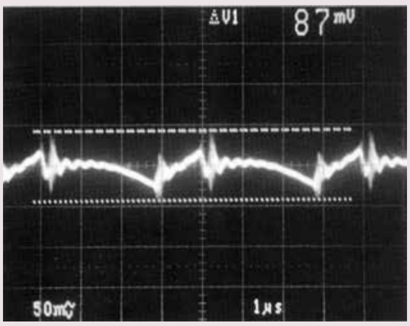
AMOBEADS™ "AB4×2×4.5W"



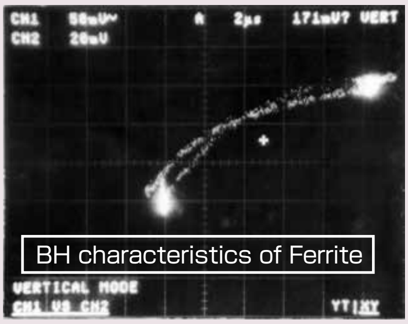
Output Noise



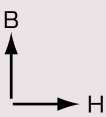
Output Noise V_N 50mv/div

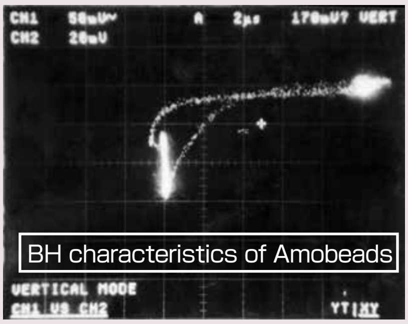


Actual BH Curve



BH characteristics of Ferrite





BH characteristics of Amobeads

Standard Specifications

SPIKEK KILLER™

Type No.	Finished Dimensions [mm]*1 O.D.	Finished Dimensions [mm]*1 I.D.	Finished Dimensions [mm]*1 H.T	Core Size [mm]*2 O.D.	Core Size [mm]*2 I.D.	Core Size [mm]*2 H.T	Effective core cross section Ae[mm2]*2	Mean Flux Path Length Lm [mm]*2	Total Flux φc[μWb]min *3	Coercive Force *3 Hc[A/m]	Rectangular Ratio *3 Br/Bm[%]	Insulating Cover
SS7X4X3W	9.1	3.3	4.8	7.5	4.5	3.0	3.38	18.8	3.15			
SS10X7X4.5W	11.5	5.8	6.6	10.0	7.0	4.5	5.06	26.7	4.73	22max	90min	PET case Black
SS14X8X4.5W	15.8	6.8	6.6	14.0	8.0	4.5	10.1	34.6	9.46			

*1 Tolerance ±0.2[mm] *2 Reference value
*3 Measuring condition:100kHz、80A/m (sine wave), R.T.

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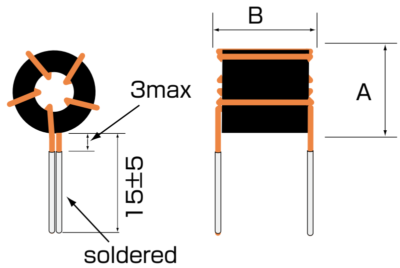
☆ "SPIKE KILLER™ " : Resistered in U.S.A., France, Germany, U.K., Japan.

Wired SPIKE KILLER™ and AMOBEADS™

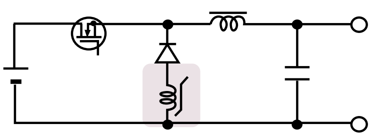
Type No.	Core No.	Current*1 [A]	Wire Dia. [φmm]	N [turn]	Flux*2 [uWb]	Dimensions[mm] A max	Dimensions[mm] B max
AB44DY0305	AB4x2x4.5DY	0.5	0.3	5	13.5	7	9
AB44DY0307	AB4x2x4.5DY	0.5	0.3	7	18.9	7	9
SS07S0309	SS7x4x3W	0.5	0.3	9	28.3	12	8
AB34DY0402	AB3x2x4.5DY	1.0	0.4	2	2.6	6	9
AB34DY0403	AB3x2x4.5DY	1.0	0.4	3	3.9	6	9
AB44DY0402	AB4x2x4.5DY	1.0	0.4	2	5.4	7	9
AB44DY0403	AB4x2x4.5DY	1.0	0.4	3	8.1	7	9
AB44DY0404	AB4x2x4.5DY	1.0	0.4	4	10.8	7	9
SS07S0507	SS7x4x3W	1.5	0.5	7	22.1	12	8
SS07S0510	SS7x4x3W	1.5	0.5	10	31.5	12	8
SS07S0515	SS7x4x3W	1.5	0.5	15	47.3	12	8
SS10S05105	SS10x7x4.5W	1.5	0.5	5	23.7	14	10
SS10S05107	SS10x7x4.5W	1.5	0.5	7	33.1	14	10
SS10S05110	SS10x7x4.5W	1.5	0.5	10	47.3	14	10
SS10S09110	SS10x7x4.5W	5	0.9	10	47.3	15	11
SS14S09108	SS14x8x4.5W	5	0.9	8	75.7	20	11
SS14S09205	SS14x8x4.5W	10	0.9x2	5	47.3	20	11



Type of wire:1UEW

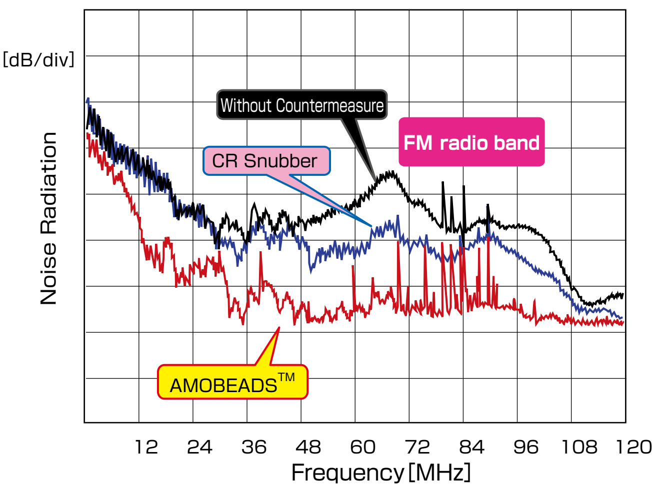
*1: Typical Value, using a cross section of winding wire
*2:Total Flux of core × turn

Example of applied circuit and it's characterisitic



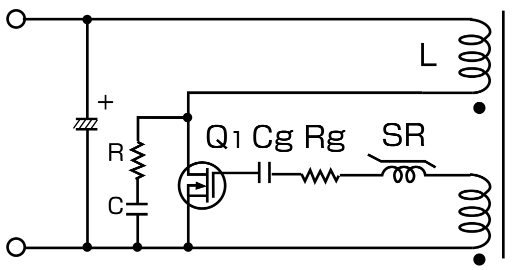
Chopper Converter

Testing Condition of Radiant Noise Measurment	
Input	20[V]
Output	12[V]/2[A]
Frequency	90kHz
Rectifier	FRD
Detector	Simple Loop Antenna



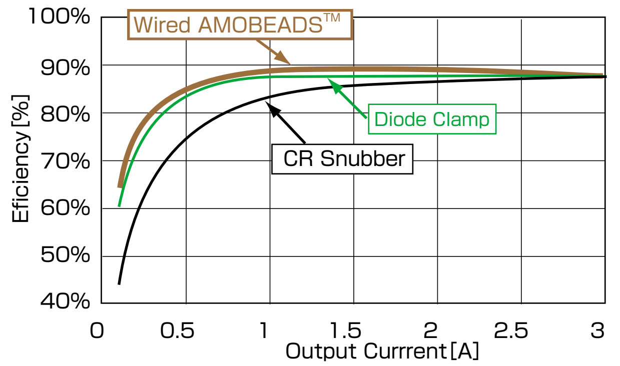
Examples of Applied Circuits and Effects of Noise Suppression

Example Circuit:Self-Exiting Single Flyback(RCC)



SR:Wired AMOBEADS™

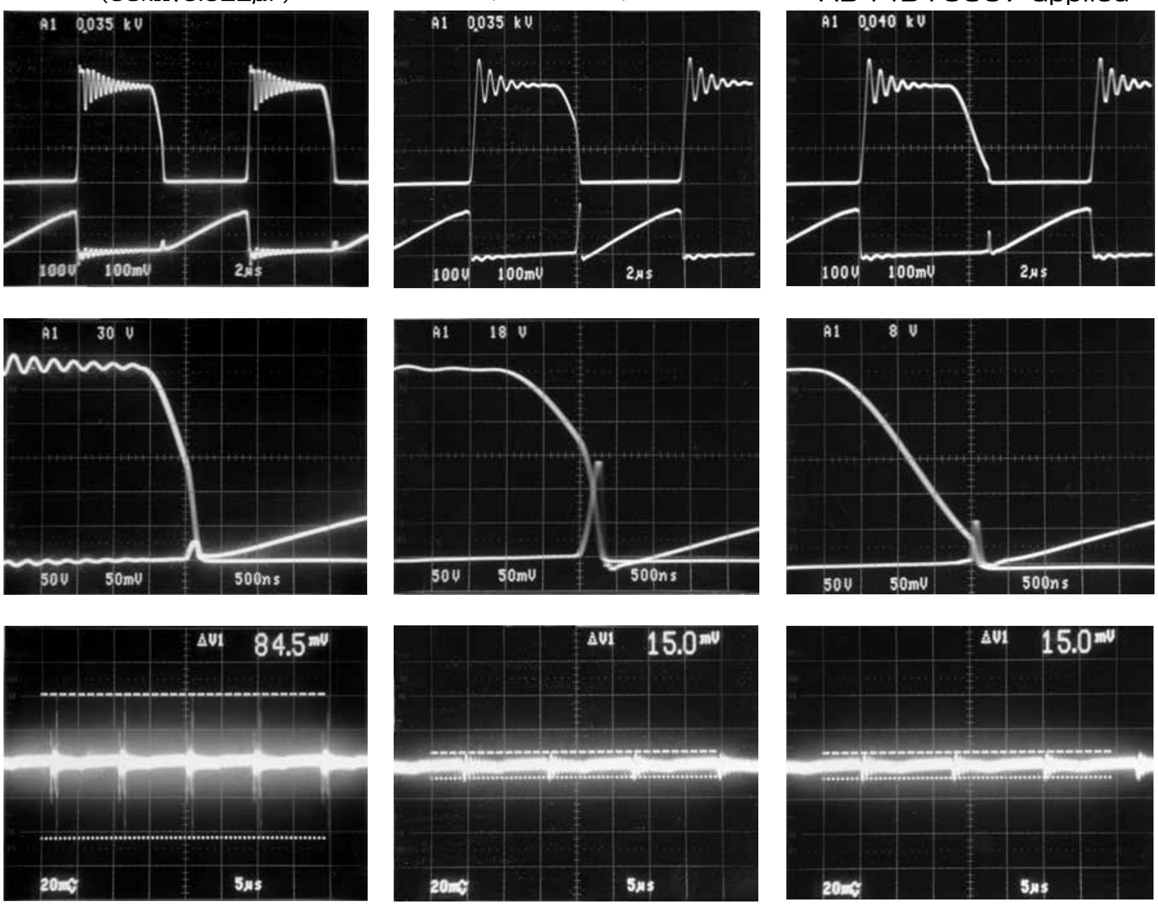
JPN.P. No. 3190775 Toshiba Materials Co. Ltd.
USP No. 5745353 〃



Power Supply Efficiency (Vin:DC140V, Vo:24V)

Example of Effects (Delaytor)

	Diode Clamp (68kΩ、0.022μF)	CR Snubber (10Ω、1500pF)	Wired AMOBEADS™ AB44DY0307 applied
Swirching Waveform Vds 100V/div Id 1A/div			
Turn-on Waveform Vds 100V/div Id 0.5A/div			
Output Voltage Noise Vn 20mV/div			



Wired AMOBEADS™ delay the turn-on time of the MOSFET when they are inserted between the gate of the MOSFET and drive winding on the primary side of the self-exiting single flyback (RCC). The wired AMOBEADS™ reduce both noise, due to surge current and switching loss, by turning on the switching element at the point when the voltage of the transformer becomes low, utilizing the the LC resonance phenomenon induced by inductance L of the primary winding of the transformer and a snubber capacitor C.

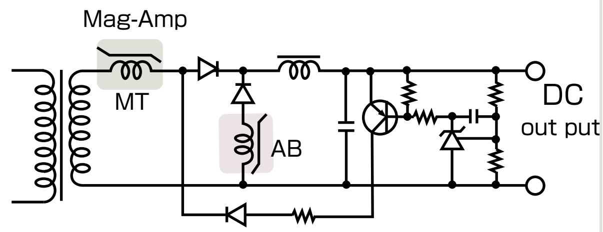
Note : The diode clamp circuit has a tendency to increase the out put noise.

3. Saturable Cores for Mag-Amps

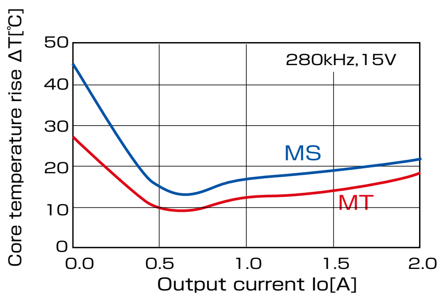
The Mag-amp method is one of several output voltage regulation methods used in switching power supplies. A saturable core is used in the secondary side of the main transformer to regulate voltage by magnetic pulse width modulation (PWM). The Mag-amp method is especially effective and economically attractive in low voltage/high current circuits and is frequently used in power supplies for information processing equipment, such as desktop PCs and computer servers, in power supplies for office equipment such as photocopy machines and printers, and in power supplies for communication equipment, such as mobile phone stations.

Miniaturization, high efficiency, low noise, high reliability, and high precision can be easily realized by adopting the Mag-amp method.

Utilizing the unique magnetic characteristics of cobalt-based amorphous alloys, we have realized low loss at high frequencies which cannot be realized using other materials. Our lineup consists of MS series cores, which are well suited for general purpose applications, and MT cores, which have lower loss than the MS series.

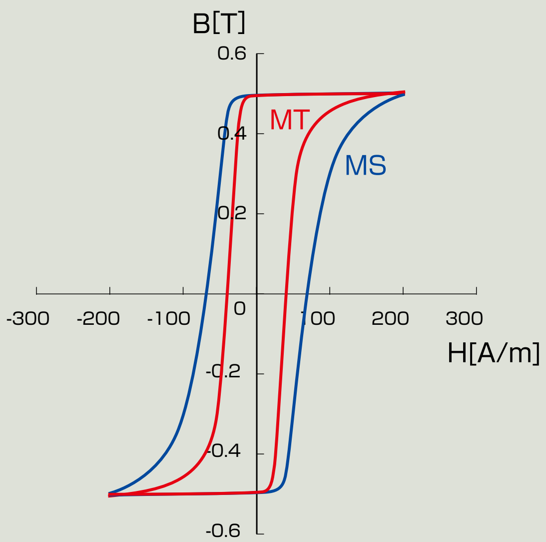


Basic Circuit Diagram of Mag-Amp method

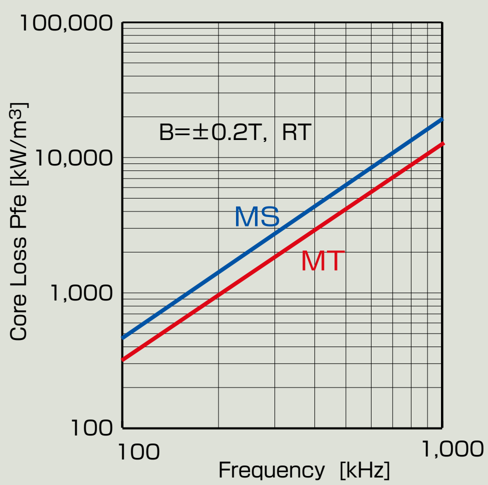


Comparison of Core Temperature Rise in a Power Supply

Basic Characteristics (Typical Value)



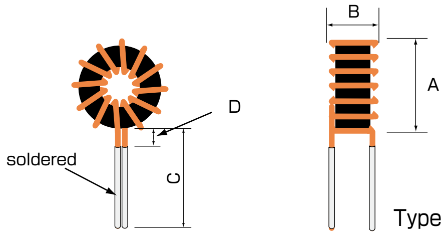
B-H Curve (500kHz, RT)



Core Loss

RoHS compliant products

Standard Specifications



Type of wire:1UEW

MT Standard Wired Series

Type No.	Core Type No.	Wire Diameter ϕ[mm]	Parallel Number	N [turn]	Flux*1*2 [μWb]	Example of Circuit (150kHz)*3 Vo [V]	Example of Circuit (150kHz)*3 Io [A]	Finished Dimensions [mm] A max	Finished Dimensions [mm] B max	Lead Length C [mm]	Length of Non Solder D [mm]	Package
MT12S115	MT12X 8X4.5W	1.0	1	15	94.7	5	6	20	13	20±5	3 max	1,000 [pcs in a box]
MT12S208		0.9	2	8	50.5	3.3	10	20	13			
MT15S125	MT15X10X4.5W	1.0	1	25	197	12	6	25	15			
MT15S214		0.9	2	14	110	5	10	25	15			
MT18S130	MT18X12X4.5W	1.0	1	30	284	15	6	28	15			
MT18S222		0.9	2	22	208	12	10	28	15			
MT21S134	MT21X14X4.5W	1.0	1	34	375	24	6	32	15			
MT21S222		0.9	2	22	243	15	10	32	15			

MT Series

Type No.	Finished Dimensions*4 [mm] O.D.	I.D.	H.T.	Core Size*5 [mm] O.D.	I.D.	H.T.	Effective Core Cross Section Ae [mm²] *5	Mean flux Path Length Lm [mm]*5	Total Flux*2 ϕc[μWb]min	Coercive Force *2 Hc[A/m]	Rectangular Ratio *2 Br/Bm[%]	ϕc·AW [μWb·mm²]	Insulating Covers *6
MT10X7X4.5W	11.5	5.8	6.6	10	7	4.5	5.06	26.7	4.73	20 max	94 min	116	A
MT12X8X4.5W	13.8	6.	6.6	12	8	4.5	6.75	31.4	6.31			215	A
MT14X8X4.5W	15.8	6.8	6.6	14	8	4.5	10.1	34.6	9.46			323	A
MT15X10X4.5W	16.8	8.8	6.6	15	10	4.5	8.44	39.3	7.88			457	A
MT16X10X6W	17.8	8.3	8.1	16	10	6.0	13.5	40.8	12.6			649	B
MT18X12X4.5W	19.8	10.8	6.6	18	12	4.5	10.1	47.1	9.46			834	A
MT21X14X4.5W	22.8	12.8	6.6	21	14	4.5	11.8	55.0	11.0			1371	A
MT12X8X3W	13.7	6.4	4.8	12	8	3.0	4.50	31.4	4.20			126	C
MT15X10X3W	16.7	8.4	4.8	15	10	3.0	5.63	39.3	5.25			277	C

MS Series

Type No.	Finished Dimensions*4 [mm] O.D.	I.D.	H.T.	Core Size*5 [mm] O.D.	I.D.	H.T.	Effective Core Cross Section Ae [mm²] *5	Mean Flux Path Length Lm [mm]*5	Total Flux*2 ϕc[μWb]min	Coercive Force *2 Hc[A/m]	Rectangular Ratio *2 Br/Bm[%]	ϕc·AW [μWb·mm²]	Insulating Covers *6
MS7X4X3W	9.1	3.3	4.8	7.5	4.5	3.0	3.38	18.8	3.15	25 max	94 min	23	A
MS10X7X4.5W	11.5	5.8	6.6	10	7	4.5	5.06	26.7	4.73			116	A
MS12X8X4.5W	13.8	6.8	6.6	12	8	4.5	6.75	31.4	6.31			215	A
MS12X8X4.5W-HF	13.8	6.8	6.6	12	8	4.5	6.75	31.4	6.31			215	D
MS14X8X4.5W	15.8	6.8	6.6	14	8	4.5	10.1	34.6	9.46			323	A
MS15X10X4.5W	16.8	8.8	6.6	15	10	4.5	8.44	39.3	7.88			457	A
MS16X10X6W	17.8	8.3	8.1	16	10	6.0	13.5	40.8	12.6			649	B
MS18X12X4.5W	19.8	10.8	6.6	18	12	4.5	10.1	47.1	9.46			834	A
MS21X14X4.5W	22.8	12.8	6.6	21	14	4.5	11.8	55.0	11.0			1371	A
MS26X16X4.5W	29.5 max	13.0 min	8.0 max	26	16	4.5	16.9	65.9	15.8			2097	B
MS12X8X3W	13.7	6.4	4.8	12	8	3.0	4.50	31.4	4.20			126	C
MS15X10X3W	16.7	8.4	4.8	15	10	3.0	5.63	39.3	5.25			277	C

*1 The amount of magnetic flux is equal to (N) ×(ϕc).
*2 Measuring condition : 100kHz, 80A/m (sine wave), R.T.
*3 Recommend for designing (note : A design of a transformer in the case may be unable to use this data. Please set up the operating magnetic flux 70% or less of the magnetic flux.)
*4 Dimensions of the Finished Insulating Covers ; Tolerance : ±0.2mm *5 Reference value
*6 Insulating cover is made with UL94V-0 approved material A : Black PET, B : Black PBT, C : Red LCP, D : Halogen-free

☆ Those other than standard winded articles can be manufactured. Please ask to sales department.
☆ MT sample kits are prepared. Please ask to sales department.

Merits of the Mag-Amp Method

Since the Mag-amp method uses saturable cores to regulate voltage, there is a big advantage that cannot be achieved by semiconductor-based regulation methods. The advantage is especially clear when there are large changes in the current.

Miniaturization (Downsizing)	Large currents can be handled by small size cores. Also, there is no need for a heat sink and the number of parts as the regulation circuit is small. This results in a smaller mount area compared to semiconductor-based methods.
Power Saving	Because cobalt-based amorphous alloy is used, the operating loss at high frequencies is small. Also, the power needed for control of the Mag-amp is smaller, enabling power to be saved.
Low Noise	The noise from the output diode is small because the Mag-amp is connected in series with the output diode. In semiconductor-based methods, since the number of switching elements increases, so also does the noise.
High Reliability	Since Mag-amps are magnetic parts, the cores are not destroyed by surges in voltage and current. For this reason, they have been used in power supplies requiring reliability such as those for electricity or large computers.
High Precision	The Mag-amps realize precise output voltage because the secondary side of the main transformer is directly controlled. It is possible to conduct voltage torelance with high precision (±1%), from no-load conditions to full-load conditions.

As seen above, when the Mag-amp method is used in regulating output voltage of switching power supplies, excellent characteristics can be achieved in size, efficiency, noise, reliability, and precision. Advantages in cost performance are especially realized in low voltage / high current circuits (example: 3.3V-5A).

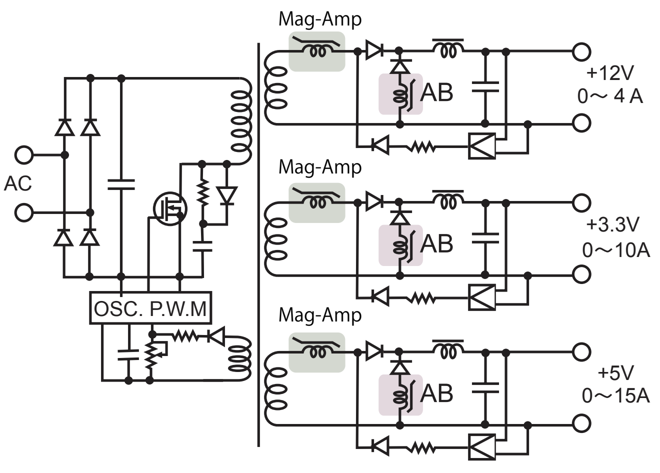
Full Mag-Amp Method

The simple Mag-amp method is used mainly for voltage control of the post circuit in power supplies, called the cross-regulation (master-slave) method. This cross-regulation method stabilizes the output voltage by feedback of the main circuit to the primary side. Therefore, the post circuit output is affected by the situation of the load in the main circuit (cross regulation error). There is also the problem that power supplies do not operate unless some current (minimum current) is sent through the main circuit.

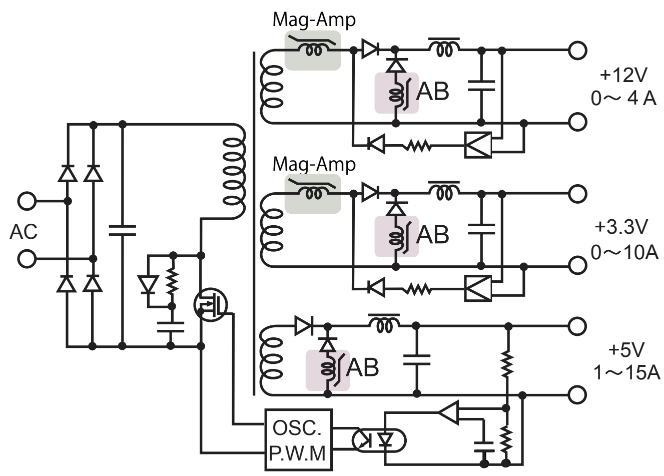
The Full Mag-amp method is a way to solve this problem.

The Full Mag-amp method controls each output at the secondary side. Therefore, there is no need for feedback to the primary side, and each output can be controlled from no-load conditions. Also, since each output operates independently, the optimization of the winding ratio for the main transformer and high efficiency can be realized compared to the cross-regulation method.

Furthermore, since each output is independent in the Full Mag-amp method, it is only necessary to adjust the circuit where the specification was changed. Therefore, time can be saved in the process of a design change.



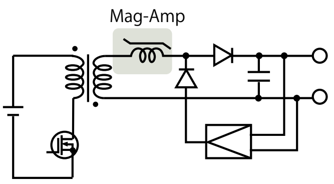
Full Mag-Amp Method



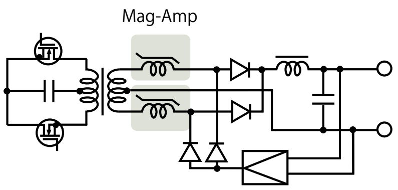
Cross-Regulation (Master-Slave) Method

Examples of Circuits and Characteristics

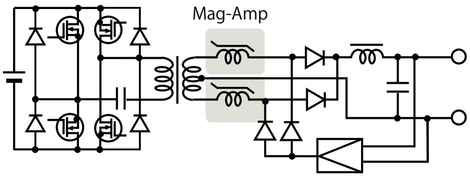
Examples of Circuit



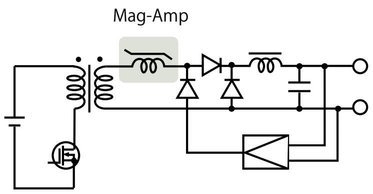
Flyback converter (ON-OFF Type)
Ringing choke converter (RCC)



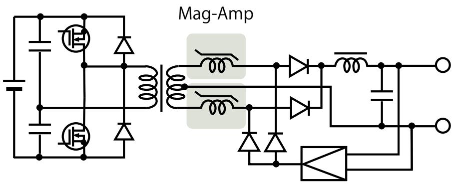
Push-pull converter (Center tap type)



Full bridge converter

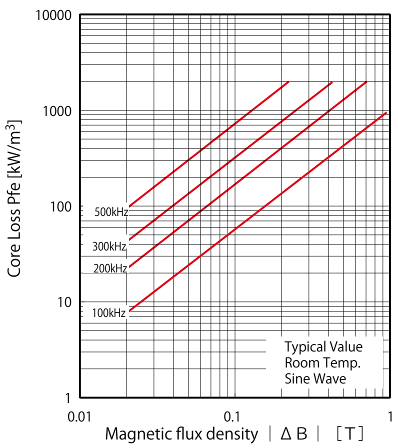


Forward Converter (ON-ON Type)

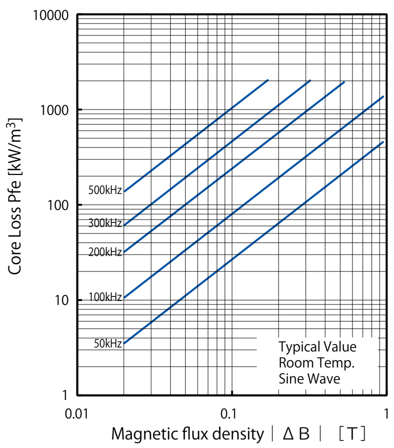


Half Bridge Converter

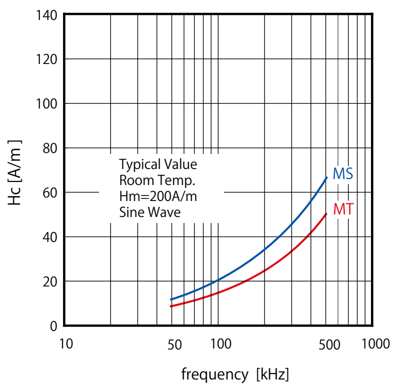
Characteristics (Typical Value)



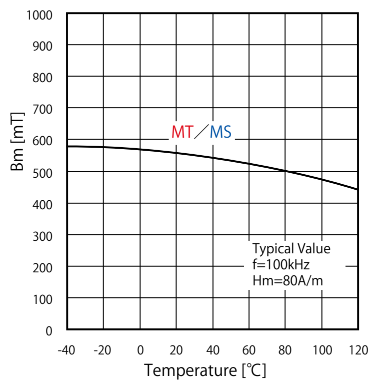
Saturable Core MT Core Loss



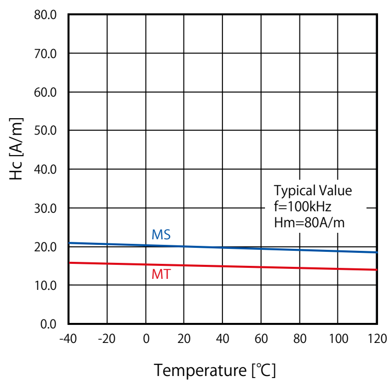
Saturable Core MS Core Loss



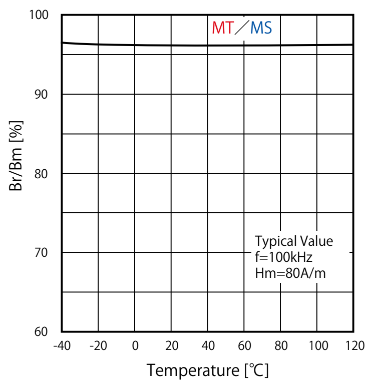
Hc vs. Frequency



Bm vs. Temperature



Hc vs. Temperature



Br/Bm vs. Temperature

Examples of a use other than Mag-Amp :
Resonancer for Switching Power Supply (Partial Resonace Element), CT Magnetic Sensor,
Transformer Core for Self-Invertor Oscillator, High Frequency Saturable Core for Current Delay or Timing Control

4.High Magnetic Permeability Cores for Pulse Transformer

After suitable heat treatment has been done, cobalt base amorphous material shows excellent magnetic properties. TOSHIBA MATERIALS has developed new high permeability core 'FS Series' with this material.

FS series maintain high initial permeability μi especially at the high frequency zone, and are suitable for Pulse Transformers, Noise Filter and Cores for Sensors. High permeability enables electronic parts to be smaller and have higher performance.

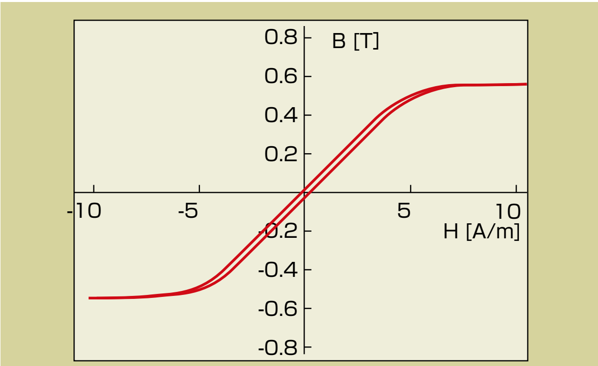
High Permeability : μ_i at 10kHz is 100,000 it changes inductance module smaller and higher performance.

Low Loss : Smaller core loss, higher exchange efficiency, lower self heat of core can be obtained.

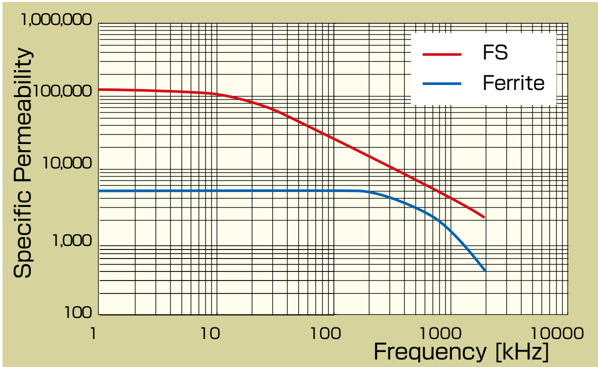
Constant Permeability : Small **permeability** change depending on magnetic field.

Thin and Small Core : Small miniature core enables to mount in a PC-card.

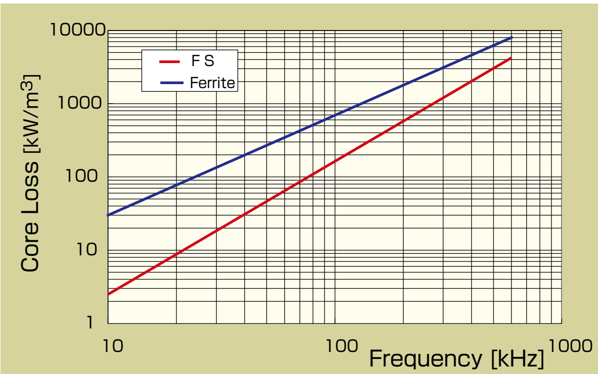
Characteristics (Typical Value)



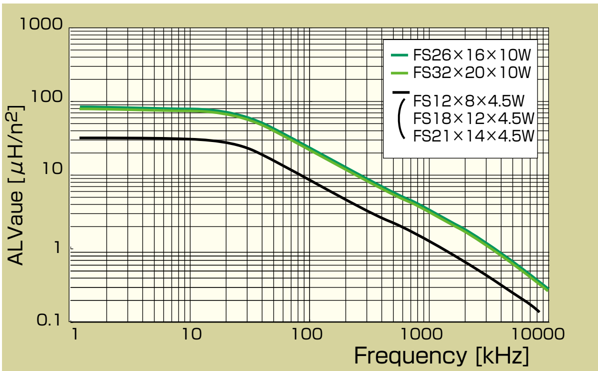
DC BH Curve



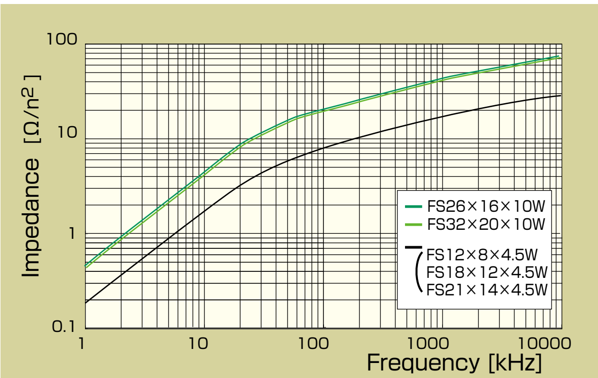
Frequency vs. Permeability



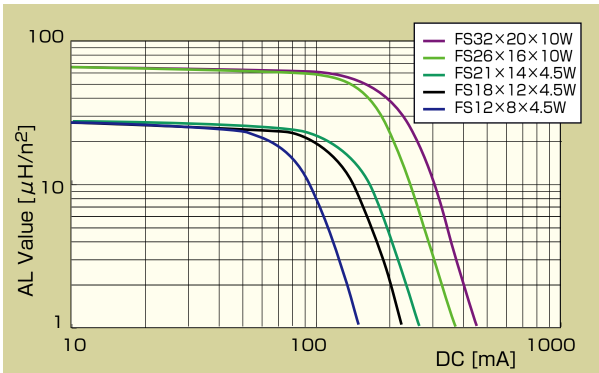
Core Loss VS. Frequency



AL Value VS. Frequency



Impedance VS. Frequency



DC Bias Characteristic

FS Series

RoHS compliant products

Standard Specifications

Type No.	Finished Dimensions [mm]			Core Size [mm] *1			Effective core *1 cross section Ae [mm²]	Mean flux *1 path length Lm [mm]	*2 *3 AL Value [μH/n²]	*4 Insulating Cover
	O.D.max	I.D.min	H.T.max	O.D.	I.D.	H.T.				
FS12X8X4.5W	14.0	6.6	6.8	12	8	4.5	6.75	31.4	27.0	A
FS18X12X4.5W	20.0	10.6	6.8	18	12	4.5	10.1	47.1	27.0	A
FS21X14X4.5W	23.0	12.6	6.8	21	14	4.5	11.8	55.0	27.0	A
FS26X16X10W	29.5	13.0	13.0	26	16	9.5	35.6	66.0	67.8	B
FS32X20X10W	35.5	17.0	13.0	32	20	9.5	42.8	81.7	65.7	B

Operating temperature has to be less than 85℃ (include self rise up)

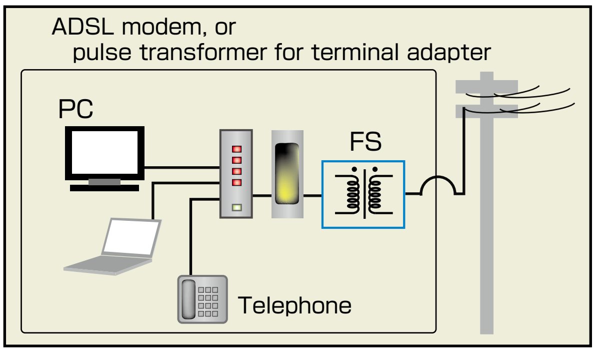
∗1 Reference value ∗2 Tolerance±30% ∗3 Measuring Condition : 10kHz,10mA, 1turn, R.T.
∗4 Insulating cover made with UL94V-0 Approved Material.
A: PET, B: PBT
Don't hesitate to ask our sales section about other size items.

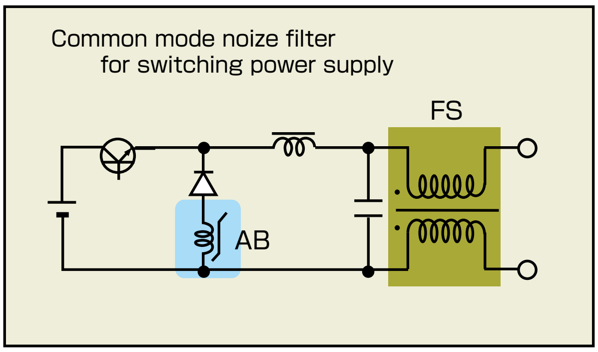
Applications

☆Magnetic core of pulse transformer
- Communication instrument (ADSL etc.)
- Small size, high density assemble

☆Magnetic core for common mode noise filter
- Switching power supply
- Communication and measuring instrument

☆Magnetic core for current transformer





How to Select the Proper Size "AMOBEADS™"

Reference

The proper size "AMOBEADS™" core is selected by calculating the necessary voltage times the time in seconds (=flux). From its operating theory, there is a need to increase the voltage used in the calculation by that which develops during the reverse recovery period of diode. The multiple of the voltage and time (voltage times second) is equal to the operating flux. Therefore, the magnetization $\Delta\phi ns$ necessary to suppress the noise is calculated by the voltage Ec[V] and time for reverse recovery of diode, that is added to "AMOBEADS™"

$$\Delta\phi_{ns}\ [Wb] = E_c \times t_{rr}\ [V \times Sec]$$

A good result is achieved when the voltage Ec added to "AMOBEADS™" is close to voltage added to diode. Please select the "AMOBEADS™" that have a larger core magnetization ϕc than the voltage times seconds that was calculated here. However, the actual noise suppression result for "AMOBEADS™" on real circuit may differ from the calculated value due to the peculiar recovery characteristics of the diode used or the circuit structure. So please confirm the effect by performing examination. "AMOBEADS™" can be also affected by things like a CR snubber, so please perform evaluation under condition without any effect of a snubber.

Since "AMOBEADS™" have high circuit voltage, sometimes an insufficient result is obtained when the reverse recovery time is long and has minimal magnetization. Under this condition, please consider a wire wound type "SPIKE KILLER™"

Example of "AMOBEADS™" Selection

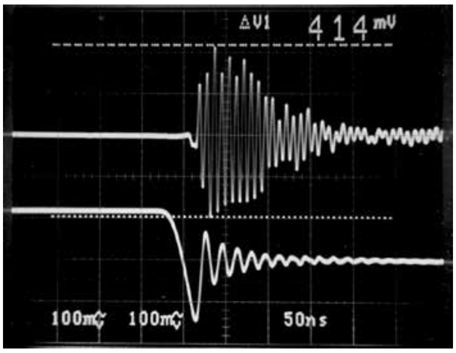
Forward Converter

trr	Output Voltage				
	3.3V	5V	12V	15V	24V
35nsec	AB3×2×3W	AB3×2×4.5W	AB3×2×6W	AB4×2×4.5W	AB4×2×6W
60nsec	AB3×2×4.5W	AB3×2×6W	AB4×2×4.5W	AB4×2×6W	SPIKE KILLER

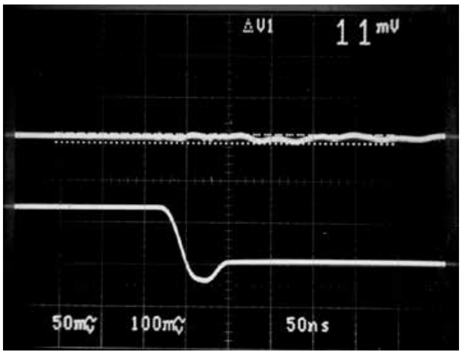
Flyback Converter

trr	Output Voltage				
	3.3V	5V	12V	15V	24V
35nsec	AB3×2×3W	AB3×2×3W	AB3×2×4.5W	AB3×2×6W	AB4×2×4.5W
60nsec	AB3×2×3W	AB3×2×4.5W	AB3×2×6W	AB4×2×4.5W	AB4×2×6W

Example of Noise Reduction



Without Countermeasure



With AMOBEADS
(AB4×2×8W)

Principle of the Noise Suppressing Device

We will explain the behavior of "AMOBEADS™" when slipped over the lead of a switching power supply output diode.

PeriodⅠ,O(When Diode is On)

During period Ⅰ, which is when the diode is in the "ON" condition and the forward current is running, the "AMOBEADS™" are in the saturated magnetic condition "Ⅰ". There will be almost no inductance under this condition. (Inductance is proportional to the slope of the B-H curve.)

PeriodⅡ(When Diode is Turn Off)

During period Ⅱ, which is when the diode current starts to turn off and the current decreases heading towards zero, the "AMOBEADS™" magnetization curve will change like "Ⅱ" in a condition of almost no inductance until the current crosses zero. Since there is no inductance during this period Ⅱ, the angle or slope of the diode current during turn off is constant, a unique characteristic of the "AMOBEADS™". If materials such as ferrite is used, inductance will occur during this period Ⅱ and the angle or slope of current during the turn off period will change and this will lead to increased of diode loss.

Period Ⅲ(Reverse Recovery Period)

During periodⅢ, a reverse recovery current tries to flow in a direction opposite to the normal direction of current flow of the diode and as a result, the magnetization curve of the "AMOBEADS™" change like "Ⅲ" and the inductance increases rapidly. At this time, the large inductance of the "AMOBEADS™" intercepts and opposes the recovery current and converts the current into a soft recovery condition. Thus by converting the sharp reverse recovery to a soft recovery condition by decreasing the rate of the current change (di/dt), the "AMOBEADS™" minimize the rapid change of current (High di/dt) and suppress the noise in the circuit.

Period Ⅳ(After Reverse Recovery Ends)

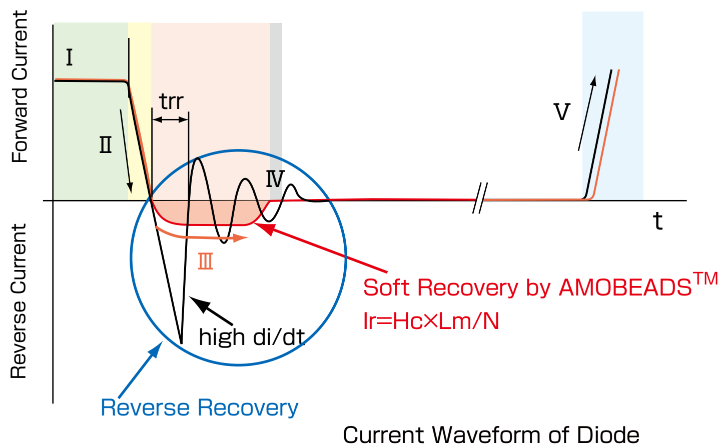
During period Ⅳ, when the reverse recovery of the diode ends, the magnetization of the "AMOBEADS™" will move parallel to the vertical axis of the magnetization curve as shown in period "Ⅳ".

Period Ⅴ (When Diode is Turn On)

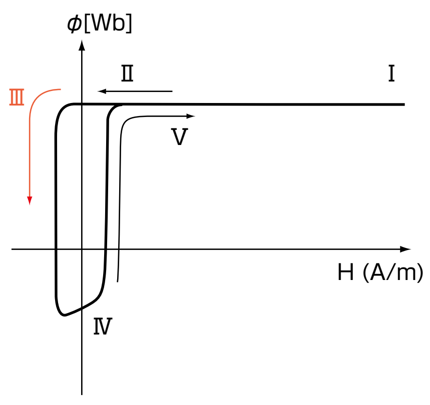
The "AMOBEADS™" magnetization will change as shown in "Ⅴ" of the magnetization curve and go back to a saturation condition. At this point, the diode will turn on and after a slight delay of the start up of current, the next current pulse will develop and the cycle described above from Period Ⅰ thru Ⅴ will repeat itself.

As the complete cycle repeats itself at the circuit operating frequency, the "AMOBEADS™" repeatedly suppress circuit noise during period III of the cycle by eliminating the rapid change in the reverse recovery current of the diode, which is the cause of noise.

"AMOBEADS™" use a cobalt based amorphous alloy with a small coercive force under frequency and this results in excellent noise suppression.



Current Waveform of Diode



Actual BH Curve

Mag-Amp Operating Principle

Reference

The Mag-Amp method is a switching regulation method for D.C power supply in which the magnetic switch is created through using saturated area and unsaturated area of the saturable core. Voltage regulation at the secondary side of the switching supply is realized by P.W.M. (Pulse Width Modulation).

Period Ⅰ (Pulse is on)
When the "ON" pulse is from the main transformer, the flux changes as "Ⅰ" on the actual magnetization curve. At this time, the saturable core has very high inductance because the core's magnetization is in an unsaturated area. When voltage is added, it is handled at both ends of the coil and the current does not flow toward the side with the current load. During Period "Ⅰ", the voltage is blocked with the switch OFF, and the pulse width modulation is done.

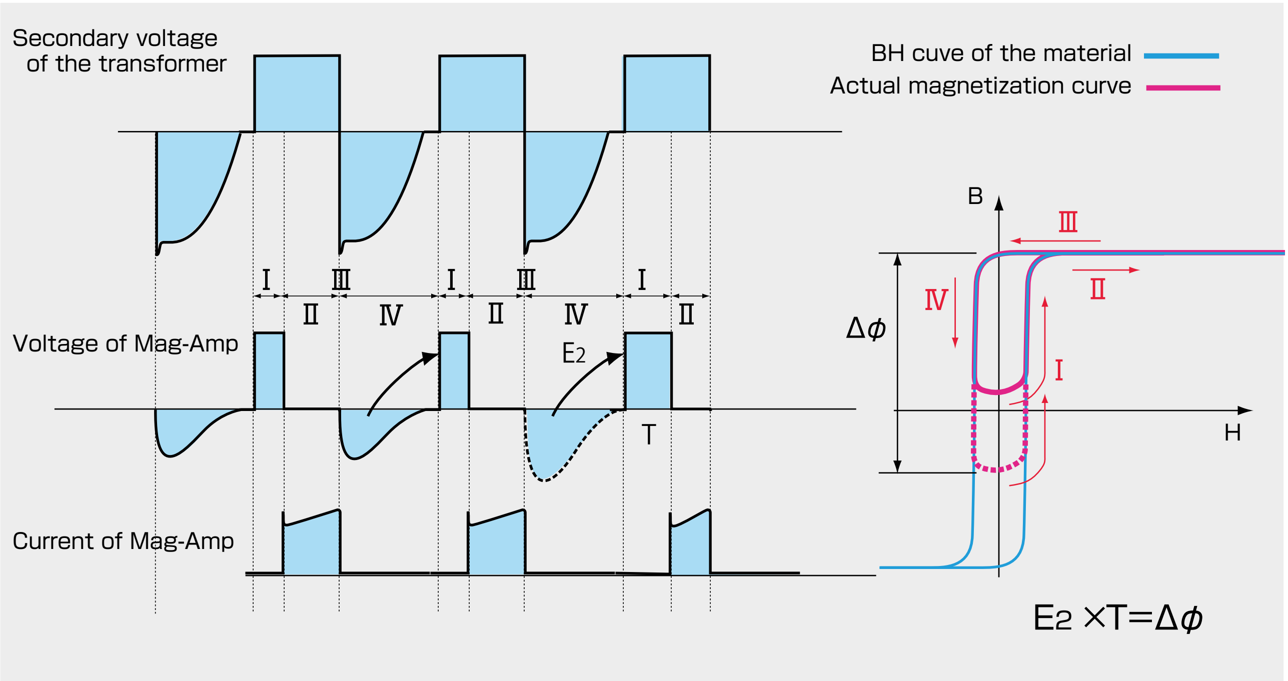
Period Ⅱ (Mag-amp is saturation)
After some time at Period Ⅰ, the saturable core becomes saturated "Ⅱ" and the inductance rapidly decreases to a minimum and the current is supplied toward the load side. The switch is ON in Period Ⅱ.

Period Ⅲ (Pulse is off)
When the pulse from the main transformer is OFF (Period Ⅲ), the magnetic curve of the saturable core changes as in Ⅲ. It rises over the magnetization axis from the effects of the reverse recovery current and leaked current of the output diode.

Period Ⅳ (Reset)
While the polarity of the pulse voltage is reversed (Period Ⅳ), there is voltage control which corresponds with the preset output voltage by the Mag-amp control circuit. The saturable core's magnetization changes (resets) itself as in "Ⅳ".

Period Ⅰ~Period Ⅳ is operated repeatedly through the operated frequency and the voltage is regulated.

The reset area at Period Ⅳ and the area at Period Ⅰ is equal. Therefore, by changing the reset amount at Period Ⅳ, the blocked area at Period Ⅰ can be changed, and it becomes possible to regulate voltage by magnetic P.W.M.



Mag-Amp Design (Forward Converter)

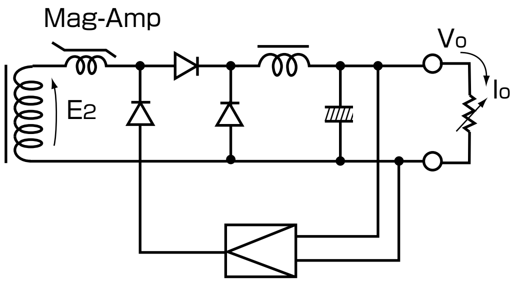
Reference

The standard methodology for designing and selecting the proper size mag-amp is to first determine the product of the secondary voltage of the transformer and the "on duty" time, measured in seconds. The proper size mag-amp can then be selected by determining which mag-amp core can adequately handle the highest product of this secondary voltage and "on duty" time, otherwise known as core flux. All calculations must be made on the condition that this on-pulse product of voltage and time is at its maximum.

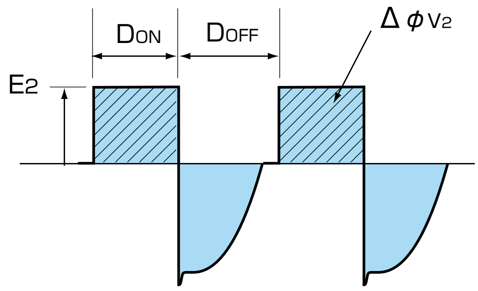
☆ On-pulse maximum product of time

The on-pulse maximum product of time $\triangle\phi_{V2}$ is calculated from the secondary voltage of the transformer (=E_2) [V] and the maximum on time duty period (=Don) and operating frequency (=f)[Hz]. For cross-regulation type circuits, the on-duty values for the main circuit at maximum load current are usually used.

$\Delta\phi_{V2}$ [Wb]=$E_2 \times D_{ON} / f$ [V×Sec]



Mag-Amp circuit of the secondary side



Transformer voltage of the secondary side

☆ Flux needed for mag-amp control

The calculation of the Voltage-time product (=Magnetic Flux) $\Delta\phi_{mag}$ differs between when the mag-amp is used for voltage regulation only and when the mag-amp is also used to protect against over currents.

(1) Voltage regulation

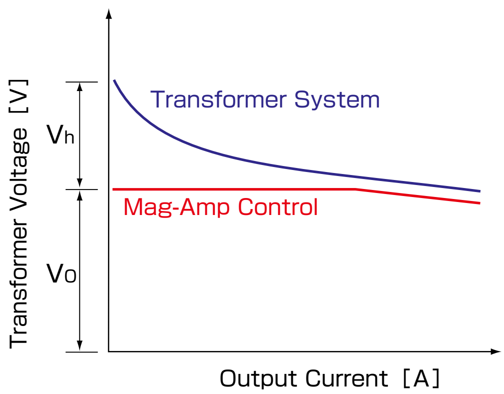
The mag-amp is designed with the standard of no load, because the flux deviation is usually largest when there is no load. The coefficient for the incremental increase in voltage at no load (Kv) is used. (Kv=<1)

$\Delta\phi_{mag} = \Delta\phi_{V2} \times Kv$ [Wb] $\left[Kv = \frac{V_h}{V_o} \right.$ see right figure $\left. \right]$

(2) Protection of over currents

When the mag-amp is also used to protect against over-currents, the on-pulse maximum voltage-time product $\Delta\phi_{V2}$ must be handled by the mag-amp. Therefore, the following calculation is applied.

$\Delta\phi_{mag} = \Delta\phi_{V2}$ [Wb]



Output Current vs. Transformer Voltage

☆Selection of core size

The core size is selected based on the flux needed to control the mag-amp, $\Delta\phi_{mag}$. The following simplified calculation is used to select core size.

$\phi C \cdot Aw \geqq \Delta\phi_{mag} \times Io/(Kf \times J)/Kt$ [Wb・mm^2]

Here, ϕC is the total flux of the core and AW is the core winding area. The values for $\phi C \cdot Aw$ are found in the standard specification chart. Kt is the design safety coefficient; Kf is the coefficient for wire winding, and J is the current density.

☆Calculation of Number of Turn

The number of turns (N) is calculated by the following equation, where N is an integer.

$N \geqq \Delta\phi_{mag} / \phi C\ min / Kt$ [turn]

☆Calculation of Diameter of the Wire

From the equation for current density J [A/mm^2], wire diameter d [mm], output current Io[A],

$Io = (d/2)^2 \times \pi \times J$ [A] → $d = 2 \times \sqrt{Io/(\pi \times J)}$ [mm]

Please always confirm operation on the actual circuit after design.

Examples of the Design

Here, we show a design example when regulating a 5V-10A circuit using a forward converter with an operating frequency of 150kHz.

☆On-pulse maximum voltage-time product

The E_2 on the secondary side of the main transformer and the maximum on duty cycle are assumed to be E_2=15[V] and D_{on}=0.4.

$\Delta\phi_{V2}=E_2\times D_{on}/f$ [V×Sec]=[Wb]

$=15\times0.4/150000$

$=40$ [μWb]

When using a Mag-amp to also protect against over currents, $\Delta\phi_{mag}=\Delta\phi_{V2}$. Here, we assume that the mag-amp only regulates voltage and set the incremental increase at the time of no current load as K_V=0.6.

$\Delta\phi_{mag}=\Delta\phi_{V2}\times K_V=40\times0.6=24$ [μWb]

☆Choice of core size

The wire winding coefficient, K_f, is the coefficient that it is possible to wind on the inside of a toroidal core. Usually, K_f=0.4 is used. The current density J is usually set as J=5～10[A/mm²]. Here, we assume J=8[A/mm²].

If the mag-amp's maximum operating temperature is assumed to be 120℃, we assume that the flux density of the core decreases to 80%. We also allow flux design space to be 70%.

$\phi_C\cdot A_W\geqq\Delta\phi_{mag}\times I_o/(K_f\times J)/K_t$

$\geqq24\times10/(0.4\times8)/(0.8\times0.7)$

$\geqq133.9$ [μWb・mm²]

From the standard specification table, MT12X8X4.5W is chosen.

☆Number of wire winding

$N\geqq\Delta\phi_{mag}/\phi_{Cmin}/K_t$ [turn]

$\geqq24/6.31/(0.8\times0.7)=6.8$

$=7$ [turn]

☆Wire diameter

When the wire diameter is over φ1.0mm, there is difficulty in the actual wire winding of the toroidal cores. Therefore, when the output current Io is over 5[A], parallel winding is used. Here, since I_o=10[A], two parallel wires are used.

$d=2\times\sqrt{I_o/2/(\pi\times J)}$ [mm]

$=2\times\sqrt{10/2/(\pi\times8)}=0.89$ [mm]

As a result, 2 parallel φ0.9mm wires are wound.

☆Results of design (Operating Frequency 150kHz, 5V-10A, Voltage Regulation)

MT12X8X4.5W, φ0.9mm, 2 parallel windings, 7[turn]

Please always confirm operation on the actual circuit after design. Since the mag-amp is a passive part, it becomes susceptible to effects from the waves of the transformer, and actual operating tests are necessary.

Design Example (Forward Converter, 150kHz operating)

	Voltage Control (at K_V=0.6)			Over Current Protection (at $E_2\times D_{ON}$ =1.2V_o)		
Current / Voltage	6A (φ1.0mm)	10A (φ0.9mm×2p.)	15A (φ0.9mm×3p.)	6A (φ1.0mm)	10A (φ0.9mm×2p.)	15A (φ0.9mm×3p.)
3.3V	MT12S115	MT12S208	MT12 : 5turn	MT12S115	MT12S208	MT15:7turn
5V	MT12S115	MT12S208	MT15 : 6turn	MT12S115	MT15S214	MT16:6turn
12V	MT15S125	MT15S214	MT18S311	MT15S125	MT18S222	MT21:16turn
15V	MT15S125	MT18S222	MT18 :14turn	MT18S130	MT21S222	MT21:20turn
24V	MT18S130	MT18S222	MT21 :19turn	MT21S134	MT21:32turn	MS26:18turn

Note) Operating flux is influenced by the main transformer of the circuit, and the value shown in the table is not necessarily applied as it is.

Evaluation of the Mag-Amp Circuit Unit

1) At no-Load

Generally, the range of the flux becomes large at no, or small current load. There is a possibility that the mag-amp may not be able to control the output voltage because there is a shortage of core flux. This problem occurs because the large range of the flux density causes saturating on the other side and there is not enough ability to control the voltage-time product. In order to set the allowances for design, the wire winding for the Mag-amp is reduced and the operating range is confirmed.

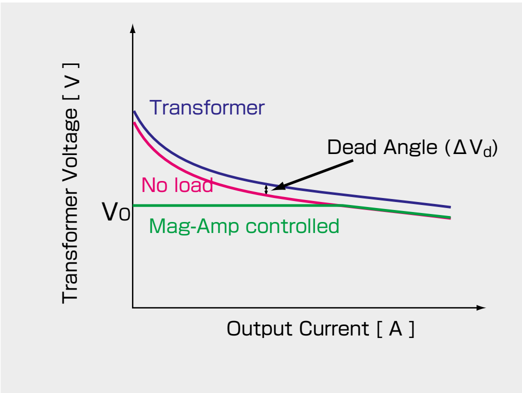
However, the core flux necessary at the time of no current load is largely influenced by such factors as the dummy current value. Therefore, when the core flux is large at no current load, such factors as the dummy current value must be adjusted, taking efficiency into account.

2) At Full-Load

Generally, the mag-amp's flux range becomes small at the full current load. There is the possibility that output voltage cannot be regulated because it is not possible to make the range any smaller. This problem is called the dead angle.

The allowances for design at full current load are confirmed by increasing the number of wire windings.

However, the dead angle value is influenced not only by the core characteristics, but also by the reverse recovery current of the output diode and leaked currents. Please select output diodes with fast recovery times. Also, when using SBD (Schottky Barrier Diode), please use one with small current leaks and stable temperature characteristics.



3) Temperature Rise

The temperature rise from no current load to full current load should be confirmed. Since the upper limit temperature for continuous use of our mag-amp saturable cores is 120℃, the mag-amp should be designed so that the sum of the surrounding temperature and core temperature rise does not exceed 120℃. Please measure core temperature rise under the condition of natural air-cooling (Without cooling fan). Generally, the mag-amp is designed calculating the temperature rise at ΔT=30℃～40℃.

With forward converters, the temperature rise at no current load is especially high. When this occurs, the wire winding should be increased and the operating flux density reduced. When the temperature rise is too high at full current load, the wire winding should be reduced and the operating magnetic field reduced.

4) Output voltage precision

It is necessary to confirm the voltage regulation characteristics (specifications) from no current load to full current load conditions. When there is a mismatch between the gain of the mag-amp and the gain of the regulated circuit, the circuit vibrates abnormally. Especially when there are sounds from the mag-amp circuit, there is a high possibility that the regulated circuit is abnormally vibrating.

5) Protection from Over currents

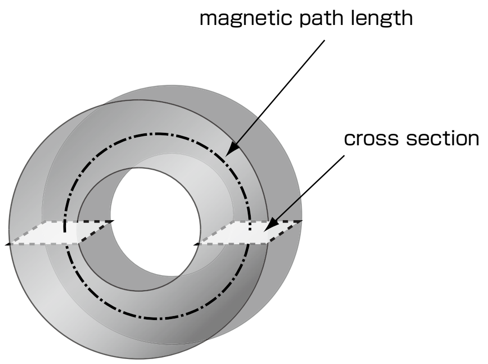
When protecting for over currents, the range of operating flux for the mag-amp becomes large. Please set the maximum flux range to be 70% of the core flux, similar to when there is no current load.

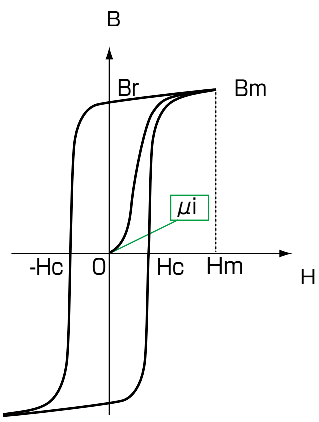
Glossary of Amorphous Magnetic Parts

Technical Terms

Saturable Core	A magnetic core can be able to saturate. These cores have a high square shape ratio, and it can use magnetic saturation and magnetic being un-saturated.
Toroidal Core	Magnetic core which has doughnut shape.
Cross Section	Effective core cross section area :Ae, Ae [m²] = ((OD[m] - ID[m]) x height HT[m] / 2) x pf
Packing Factor pf	The ratio of the absolute area of magnetic material to its geometrical area .
Magnetic Path Length Lm	Length of the magnetic circuit. In the case of the toroidal core, magnetic mean path length Lm is adopted. Lm [m] = (OD[m] + ID[m]) x $\pi/2$
Magnetic Flux Density B	Magnetic flux strength of the material, which is perpendicular magnetic flux of the unit area. B[T] = ϕ[Wb] / Ae [m²]
Magnetic Flux ϕ	ϕ[Wb = V·sec] = B[T] x Ae [m²]
Magnetic Field Strength H	H[A/m] = I [A] / Lm [m]
Permeability μ	μ = B / H. Inductance L is proportional to permeability μ.
Initial Permeability μ_i *1	First inclination of the initial growth of magnetic flux density B (see the illustration below)
Maximum Flux Density Bm	In this booklet, Bm is defined as the flux density at the magnetic field Hm. (see the illustration below)
Residual Magnetic Fux Density Br	Br is the flux density at the time the magnetic field return to H = 0 (see the illustration below)
Total Magnetic Flux ϕ_C	Total magnetic flux of the core. In this booklet, total magnetic flux ϕ_C is defined as the following equation. ϕ_C [Wb] = 2 x Bm [T] x Ae [m²]
Rectangular Ratio Br / Bm	The ratio of the Bm and Br. Greater the rectangular ratio, the more superior the magnetic saturability. Br / Bm = Br [T] / Bm [T]
Coercive Force Hc	Hc is the cross point of the BH curve and X axis. Smaller the Hc, the less the loss and the more superior the Hc. (see the illustration below)

**1 Initial permeability is out of control in the case of saturable cores, because it is unrelated to the Mag-Amp.*





Notices on Handle, Maintenance and Discontinue List

Notices of the amorphous magnetic parts on handle

Detail information are described on the technical data sheet or the specification for supply.

Maximum Operating Temperature	120℃ (include temperature rising by self-heating, under natural air cooling) (except FS series which is 85℃)
Wire Winding	Be careful at wire winding or lead insertion. Damage or deformation of the core or insulating cover has a harmful influence. Be careful to the rare short circuit.
Mounting	Make sure not to apply any stresses which will lead to deformation of the core exterior. If the product is to be impregnated, bonded, cleaned or otherwise treated, confirm that such treatment will not adversely affect the magnetic characteristics. When impregnating the core, be sure that the magnetic properties will not be influenced. Prevent radiation and conduction from high temperature components from reaching the core. Be sure to consider vibration and shock when installing these parts.
Soldering	When soldering be sure that the core exterior will not be deformed by heat conducted through the lead wire. Do not subject parts to re-flow or flow soldering. (Except the surface mounting type)
Circuit Design	Be careful, of imput voltage, rated current, ambient temperature and temperature rise. When revising the circuit, please recheck the core temperature rise. Recheck the maximum temperature or maximum loads.
Transport and Storage	Do not drop the parts. Protect the parts from water.

Discontinued List

Discontinued Type No.	Substitution (recommend)
FS10X4X1	(FS12X8X4.5W)
MA7X6X4.5X	(MS10X7X4.5W)
MA8X6X4.5X	(MS10X7X4.5W)
MA10X6X4.5X	(MS10X7X4.5W)
MA14X8X4.5X	MS14X8X4.5W
MA18X12X4.5X	MS18X12X4.5W
MA22X14X4.5W	(MS26X16X4.5W)
MA26X16X4.5W	MS26X16X4.5W
MB8X7X4.5	(MS10X7X4.5W)
MB9X7X4.5	(MS10X7X4.5W)
MB10X7X4.5	MS10X7X4.5W
MB12X8X4.5	MS12X8X4.5W
MB14X8X4.5	MS14X8X4.5W

Discontinued Type No.	Substitution (recommend)
MB15X10X4.5	MS15X10X4.5W
MB18X12X4.5	MS18X12X4.5W
MB21X14X4.5	MS21X14X4.5W
MS8X7X4.5W	(MS10X7X4.5W)
MS9X7X4.5W	(MS10X7X4.5W)
MS10X6X4.5W	(MS10X7X4.5W)
MT10X6.5W	MT10X7X4.5W
SA4.5X4X3	AB5x4x3DY
SA5X4X3	AB5x4x3DY
SA7X6X4.5	(SS7X4X3W)
SA8X6X4.5	(SS10X7X4.5W)
SA10X6X4.5	(SS10X7X4.5W)
SA14X8X4.5	SS14X8X4.5W

Attention :

Same or similar core size items are listed up for substitution. Magnetic or electric characterisitcs are changeable.
Please test substitution parts before replacing to ensure performance.
Wired parts made by these cores are also discontinued items.

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