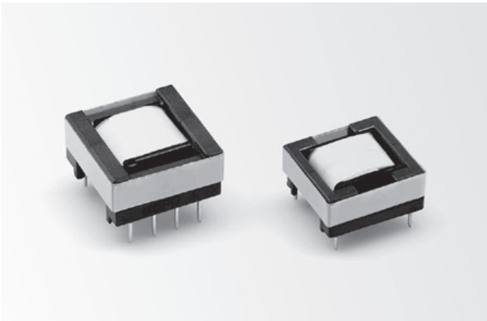
Electronic Components
TOKIN
A KEMET Company

Transformer



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INTRODUCTION

As semiconductor devices become ever more advanced, the demand for thinner, more compact devices with higher efficiency and functionality are increasing. Owing to technologies such as high-density mounting for the switching power supplies, requirements for transformers and chokes are becoming increasingly rigorous. Under the motto "Reliability based on high quality material," TOKIN uses selected excellent materials to provide diverse transformers and choke coils that can meet the requirements for a wide range of applications, such as small toroidal structure types with little heat effect and minimal emission noise to peripheral parts.

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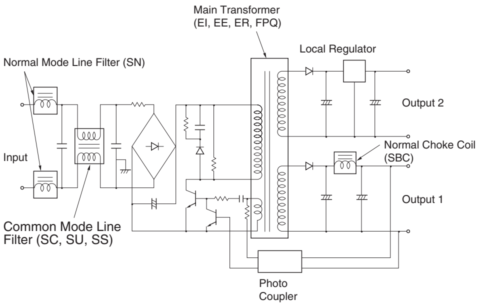
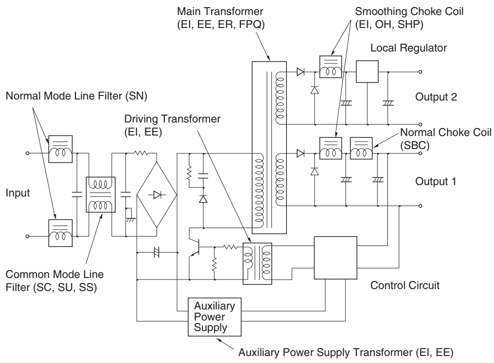
Example of Use

Flyback Method



Forward Method



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Materials for Design

Design Method

At present, there are two major types of circuits for the typical switching power supply units: the forward converter method and the flyback method. (See Figure 1.)
The following section introduces the design method of the high frequency transformers for each of the two types mentioned above.

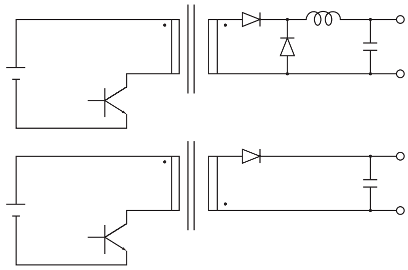

Figure 1 Circuit Method of Switching Power Supply

(1)Forward Converter Method
1)Transformers

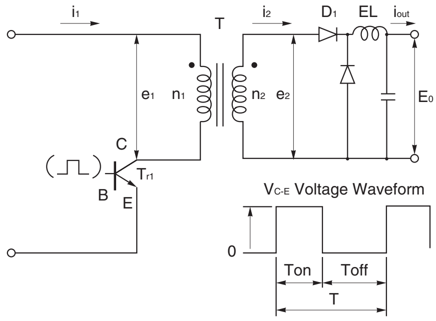

Figure 2 Circuit Diagram of Forward Converter

Figure 2 is the basic circuit diagram of the forward converter method.
When the bias (pulse) of forward direction is applied to the base of the switching transistor (Tr_1), Tr_1 is ON, e_1 (V) is impressed to the primary windings n_1 of the transformer "T", and at the same time the voltage as found by the following formula is generated to the secondary windings n_2:

$$e_2 = \frac{n_2}{n_1} \times e_1(V) \quad \text{......①}$$

e_1: Input voltage of transformer
e_2: Output voltage of transformer
n_1: Number of primary windings
n_2: Number of secondary windings

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Therefore, the output voltage is found by the ratio of n_1 and n_2.
Also, from the law of equal ampere turns, the following formula is obtained:

$$i_2 = \frac{n_1}{n_2} \times i_1 \text{ (A)} \quad \text{......②}$$

The primary winding is determined by the following formula:

$$n_1 = \frac{e_1 \times Ton}{\Delta B \times Ae} \times 10^4 \quad \text{......③}$$

Ton : Transistor (Tr_1) "on" time (sec)
ΔB : Usage magnetic flux density (T)
Ae : Core effective cross-section (cm^2)

At this point it is important to be aware of the value of ΔB. It must be set especially carefully, because when the magnetic flux is saturated, the inductance drops abruptly, in addition to the core loss and temperature rise. The magnetic flux density available for use is within the range from effective saturation magnetic flux density (Brms) to the effective saturation residual coercive force (Brms). However, it is necessary to set this value ΔB as shown below, considering the inevitable factors such as calorific value of the core:

1. Set the upper limit of allowable temperature of core heat.
2. The energy (Wattage) equivalent to the core loss at that time (set in the previous step 1).
3. The next time that same loss occurs and at what value (T).

According to the above stated procedure, the appropriate ΔB can be set.
The characteristics of the TOKIN BH2 compound are shown in Figures 3 and 4.
Then, determine the output voltage "e_2" of the transformer from the desired output voltage "Eo".

$$e_2 : \frac{Eo}{duty} + (ed + el) \quad \text{......④}$$

duty : Ton / T T = Ton + Toff
ed : Output rectification diode loss voltage (V)
el : Line loss voltage (V)

The number of secondary windings is determined by formula ①

$$n_2 = \frac{e_2 \bullet n_1}{e_1}$$

When the number of secondary windings is determined, again modify the value of "n_1", the number of primary windings:

$$n_1 = \frac{e_1 \bullet n_2}{e_2} \quad \text{......⑤}$$

At that time, it may be very convenient if the values ΔB, core loss and temperature rise of core are found.
Then determine the current i_2 applied to the secondary windings:

$$i_2 = \frac{iout}{duty} \quad \text{......⑥}$$

The primary current is determined by formula w.

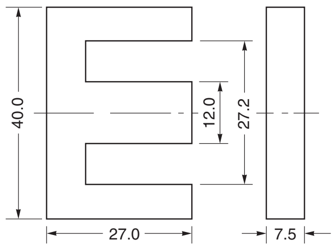
$$i_1 = \frac{n_2 \bullet i_2}{n_1}$$

The material of windings is determined by the following formula:

$$d\o = \sqrt{\frac{4 \bullet i}{\delta \bullet \pi}} \quad \text{...⑦}$$

dø : Diameter of winding (mmø)
δ : Density of current (A/mm^2)
i : Average current (A)

When the current is large, the winding becomes very thick. Considering the bobbin structure and the efficiency of work, it is more convenient to use numerous windings with the diameter not exceeding 1.0. The higher the frequency used, the greater the loss by the skin effect of the windings. Therefore, applying many of the thinner windings instead of using the single thick winding is recommended.



Core Constant	Σℓ/A	cm^{-1}	5.19
Effective Cross-section Area	Ae	cm^2	1.48
Effective Magnetic Circuit Length	ℓe	cm	7.68
Effective Volume	Ve	cm^3	11.4
Cross-section Area of Middle Leg	Acp	cm^2	1.36
Core Frame Area	Acw	cm^2	1.63
Weight		g/set	61.0
AL		nH	4750

Figure 3 FEI40 (BH2) Core Constant

Figure 4 FEI40 core loss - temperature characteristics

2)Choke coils

Because the switching regulator's secondary side choking circuit is superimposed with direct current, a choke coil with good direct current superimposition characteristics must be selected to prevent saturation of the core. Therefore, for designing choke coils the data on the relationship between the gap and AL value is required.
For example, if the gap of the FEI40 (BH2) is 0.2 mm, then from Figure 5 showing the relationship of the FEI40's air gap AL, the AL value is 800nH. In this case, from the direct current superimposition characteristics it is understood that the range in

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which the direct current magnetic field's magnetic permeability does not decrease is 40AT. For making a choke coil, the following formula must apply between the actual number of windings N_1 and the maximum direct current superimposition current Io:

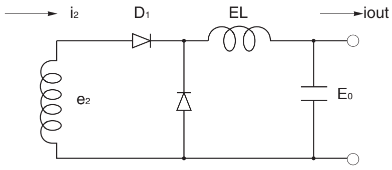
$$NI > N_1Io \quad ⑧$$

Thus, in this case the number of windings and current capacity are selected according to $40AT > N_1Io$.
On the other hand inductance is represented by the following formula:

$$L = AL \bullet N^2 \bullet 10^{-9} \text{ [H]} \quad ⑨$$

$$N = \sqrt{\frac{L \bullet 10^9}{AL}} \text{ (Turn)} \quad ⑩$$

When choosing the choke with the switching regulator, considering from the previous example :



$$eL = e_2 - ed - Eo$$

$$= L \frac{di}{dt}$$

$$\therefore L = \frac{eLdt}{di} = \frac{eL \bullet Ton}{iout}$$

Here, on account of the ripple and dummy load of iout, general guidelines for the inductance of the output choke are derived using the following formula:

$$L = \frac{5Eo \bullet Ton}{iout\ (max)} \text{ [H]}$$

When a 0.1 mm gap is placed in the core's middle leg, the total gap is 0.1 mm, but when a 0.1 mm gap material is inserted overall, the total gap amount becomes 0.2 mm.

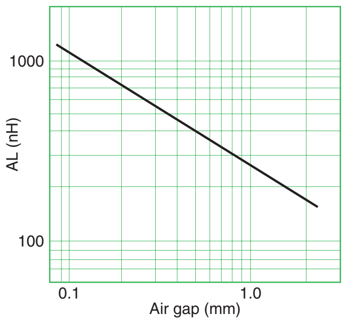


Figure 5 Air gap-AL characteristics (FEI40, BH2)

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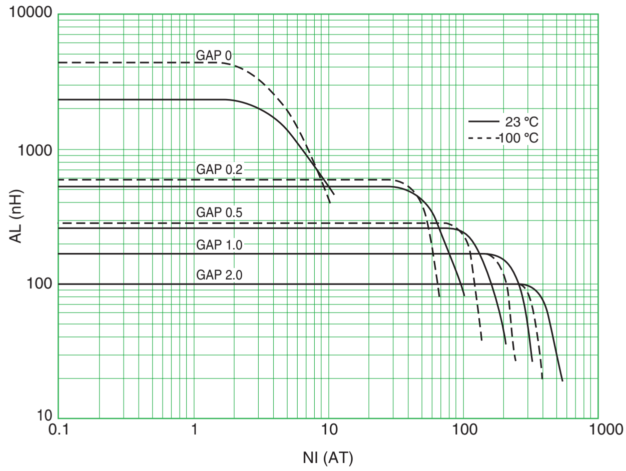

Figure 6 Direct current superimposition characteristics (FEI40, BH2)

(2)Flyback Method

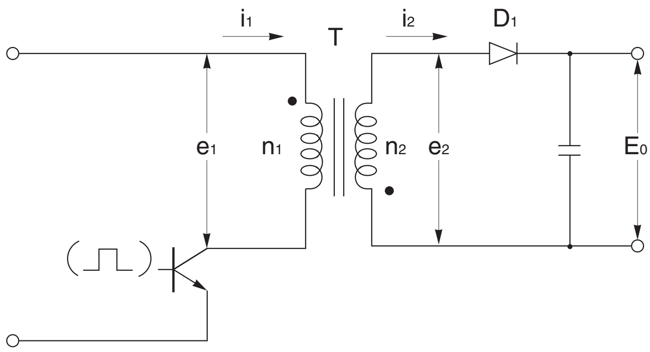

Figure 7 Circuit diagram of flyback method

The above Figure 7 is the circuit diagram of the flyback method. It is almost the same as the previous Figure 2 except for the polarity of the transformer. As the diode D_1 is located in the backward direction on the secondary output circuit, nothing is output when the switching transistor Tr_1 is turned ON. At that time, the following amount of energy is charged in the transformer T.

$$E = 1/2\ Li_1^2 \quad \text{......} ⑪$$

L: Primary inductance (H)

The above energy is emitted to the load R by way of the secondary diode D_1 when Tr_1 is turned OFF.
Determine the primary average current.

$$i_1 = \frac{Eo \bullet Io}{e_1 \bullet \eta} \quad \text{......} ⑫$$

Eo : Output voltage
Io : Output current
η : Energy conversion rate

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Determine the primary peak current i1 max. by the following formula:

$$i_1\ max. = \frac{2 \bullet i_1 \bullet T}{Ton} \quad ⑬$$

T: Driving cycle of switching (sec)

The inductance "Lp" necessary for the primary windings "n_1" is determined by the following formula:

$$Lp\ min. = \frac{e_1\ min. \bullet Ton\ max.}{i_1\ max.}\ [H] \quad ⑭$$

The number of primary windings "n_1" is determined by the following formula:

$$n_1 = \frac{Lp\ min. \bullet i_1\ max.}{Ae \bullet \Delta B} \bullet 10^4 \quad ⑮$$

In this case, a certain Gap is provided by the core. Therefore, its hysteresis curve becomes linear, unlike the nonlinear one for Gap = 0, and the value ΔB can be kept somewhat larger than the case using the forward method.
The number of secondary windings "n_2" is determined by the following formula:

$$n_2 = \frac{n_1 \bullet (Eo + ed + el)}{e_1} \bullet \frac{Toff}{Ton} \quad ⑯$$

ed : Secondary side diode loss voltage (V)
el : Line loss voltage (V)

In the RCC method, the feedback winding is determined by the voltage "Ez" of the driving voltage, as shown in the following formula:

$$nd = \frac{Ez + E_{BE}}{e_2 \bullet n_2} \quad ⑰$$

The designing procedure has been completed by the above steps. However, a slight correction is actually required because of the differences from the various conditions initially set together with the linkage inductance of the transformer, floating capacity and transformer connecting conditions.
In recent years, the driving frequency has risen.

$$Np = \frac{e_1 Ton}{\Delta B \bullet Ae} \times 10^4 \quad ⑱$$

The higher it becomes, the fewer windings are required to enable the transformer to be downsized, as shown in the above formula. However, loss could increase by the skin effect of the winding material, as it does for the high frequency. In addition, it might be difficult to cope with the safety standards of each country. Therefore, it is necessary to select the method that is the most appropriate for the various conditions required for each transformer when selecting the winding materials, winding order, winding method and insulation structure.
To select the core, attention must be paid to the following items.

1. The magnetic flux density is to be high.
2. The core loss is to be low.

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3. The magnetic permeability is not to decrease within the driving frequency range.
4 The Curie temperature is to be high.
5 The saturation magnetic flux density is not to be abruptly changed by the temperature.

Table 1 shows the material characteristics of TOKIN's ferrite cores.

Table 1 Ferrite Core Material Characteristics

Material Characteristics				Unit	BH1	BH2
Applied Frequency Range				MHz	<0.3	<0.3
Initial Permeability		μ_i			2300±20%	2300±20%
Effective Saturation Magnetic Flux Density (Approx.1200 A/m)		Bms	23˚C	mT	520	510
			100˚C		410	400
Effective Retentivity		Brms	23˚C		100	100
			100˚C		55	55
Effective Coercivity		Hcms	23˚C	A/m	13	14.3
			100˚C		5	
Curie Temperature		T_c		˚C	220	220
Core Loss	100kHz 200mT	P_{cv}	23˚C	kW/m³	550	600
			60˚C		350	450
			100˚C		250	410
	500kHz 200mT	P_{cv}	23˚C			
			60˚C			
			100˚C			
	1MHz 50mT	P_{cv}	60˚C			
			100˚C			
Density		d		kg/m³	4.8 × 10³	4.8 × 10³

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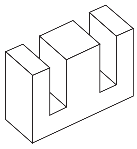
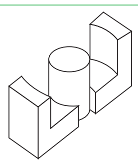
Transformers/Choke Coils Series [RoHS Compliant]

Series	Shape of Core	Output Wattage			
		Forward Method		Flyback Method	
		50kHz(W)	100kHz(W)	50kHz(W)	100kHz(W)
FEI・FEE	**FEI12.5**	3 ~ 8	4 ~ 10	2 ~ 5	3 ~ 6
	FEI16 **FEE16**	10 ~ 15	13 ~ 19	3 ~ 8	4 ~ 10
	FEI19 **FEE19**	12 ~ 18	15 ~ 23	5 ~ 10	6 ~ 13
	FEI22 **FEE22**	15 ~ 20	19 ~ 26	8 ~ 15	10 ~ 19
	**FEI22S**	15 ~ 20	19 ~ 26	8 ~ 15	10 ~ 19
	FEI25	20 ~30	26 ~ 39	10 ~ 20	13 ~ 26
	FEI28	30 ~ 50	40 ~ 65	20 ~ 30	25 ~ 40
	FEI30 **FEE30**	50 ~ 70	65 ~ 90	30 ~ 40	40 ~ 50
	FEI33 **FEE33**	80 ~ 130	100 ~ 165	35 ~ 50	45 ~ 65
	FEI35S	80 ~ 130	100 ~ 165	35 ~ 50	45 ~ 65
	FEI40	100 ~ 150	130 ~ 195	45 ~ 75	60 ~ 95
	FEE40	90 ~ 140	115 ~ 180	40 ~ 70	50 ~ 90
FEER	**FEER25.5**	20 ~ 30	26 ~ 39	10 ~ 20	13 ~ 26
	**FEER28**	35 ~ 45	45 ~ 55	20 ~ 30	26 ~ 39
	FEER28L	40 ~ 60	50 ~ 80	30 ~ 40	40 ~ 50
	FEER35	70 ~ 100	90 ~ 130	40 ~ 50	50 ~ 65
	FEER35L	100 ~ 150	130 ~ 195	50 ~ 65	65 ~ 80

Note:The output wattage is specified for conditions using TOKIN's BH2 material and the temperature rise of the transformer bein $\Delta T < 45$℃ within range of the operating flux density.

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List of Core Set Shapes

Ordering Code System

EB 40 - P 12 12 - F
① ② ③ ④ ⑤ ⑥

① Series
EB ...... Bobbins for FEI and FEE Cores
ERB ... Bobbins for FEER Cores
② Size of Core
③ Type of Pin
④ Type of Placing 11: Horizontal Type, 12: Vertical Type
⑤ Number of Pins
⑥ Material F: Phenor Resin

Description of Abbreviations

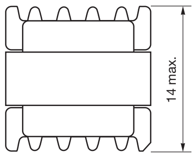
Ae : Section Area of Core (cm^2)
W : Weight of Core (g/Set)

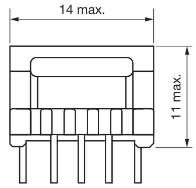
The dimension without the specification of tolerance in-dicates the typical value.

Outline drawing

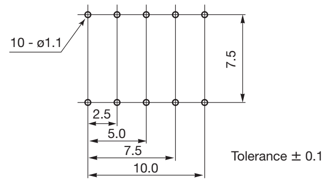
[mm] as the unit for dimensions not specified otherwise.
The top view is shown for the pin pattern dimensions not specified otherwise.

Core			Bobbin
article name	Ae	W	
FEI12.5	0.15	1.9	EB12.5-P1210-F



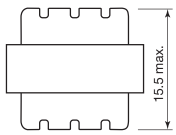


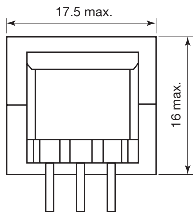
Recommended pin pattern dimensions



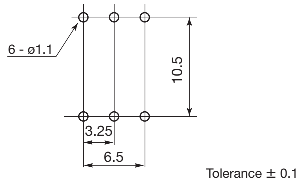
Core			Bobbin
article name	Ae	W	
FEI16	0.19	3.2	EB16-P1206-F, EB16-P1210-FA
FEE16	0.19	3.3	

●EB16-P1206-F

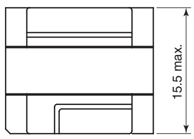


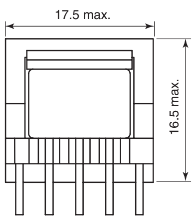


Recommended pin pattern dimensions

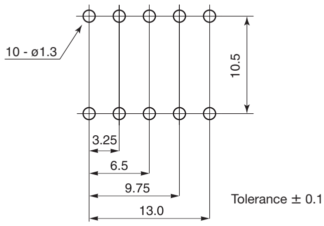


●EB16-P1210-FA

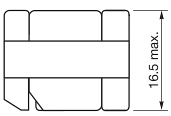


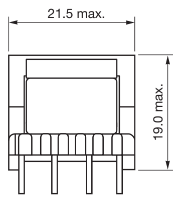


Recommended pin pattern dimensions

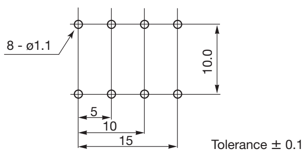


Core			Bobbin
article name	Ae	W	
FEI19	0.23	4.4	EB19-P1208-F
FEE19	0.23	4.8	

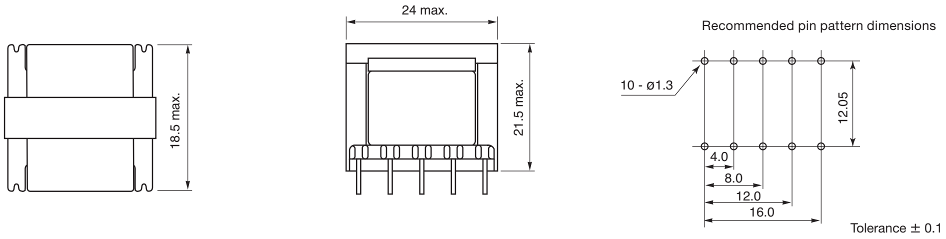




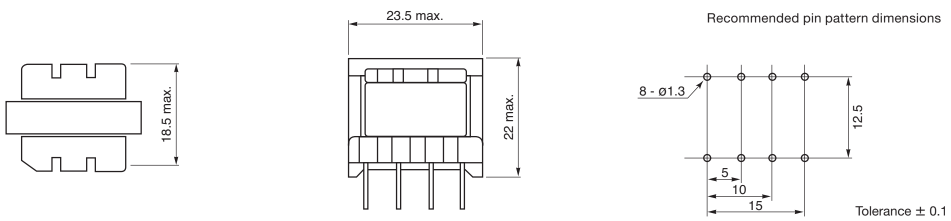
Recommended pin pattern dimensions



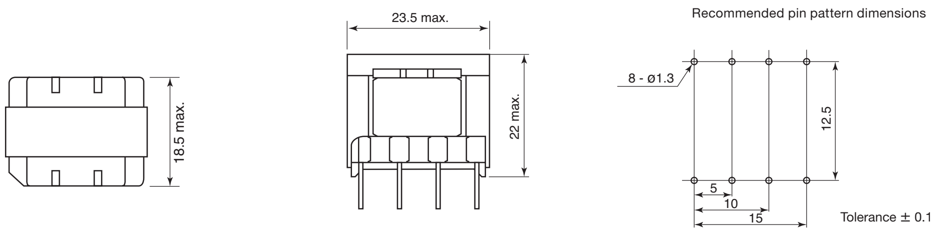
article name	Core Ae	Core W	Bobbin
FEI22	0.41	8.8	EB22-P1210-F
FEE22	0.42	8.8	



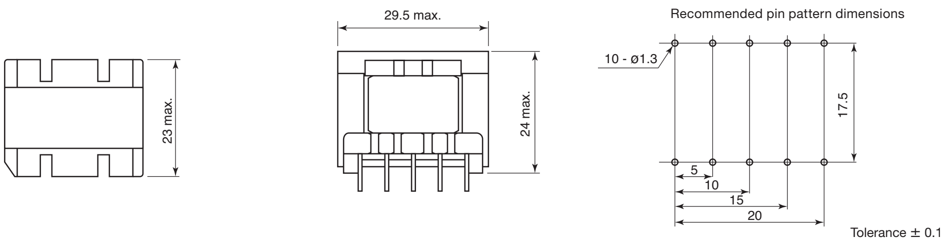
article name	Core Ae	Core W	Bobbin
FEI22S	0.36	7.7	EB22S-P1208-F



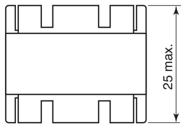
article name	Core Ae	Core W	Bobbin
FEI25	0.41	11.0	EB25-P1208-F

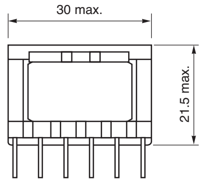


article name	Core Ae	Core W	Bobbin
FEI28	0.85	24.0	EB28-P1210-F
FEE28S	0.87	21.5	

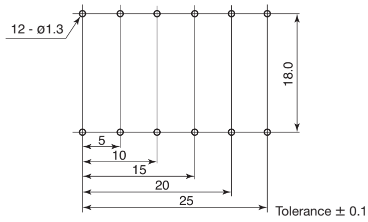


Core			Bobbin
article name	Ae	W	
FEI28	0.85	24.0	EB28-P1212-F
FEE28S	0.87	21.5	

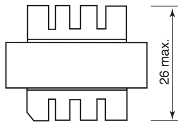


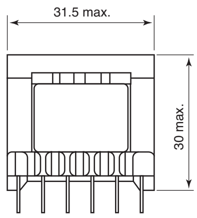


Recommended pin pattern dimensions

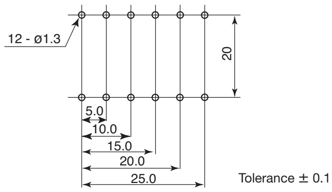


Core			Bobbin
article name	Ae	W	
FEI30	1.11	35.0	EB30-P1212-F
FEE30	1.11	33.0	

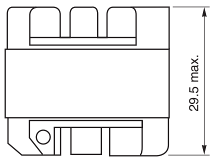


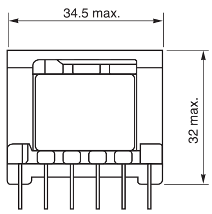


Recommended pin pattern dimensions

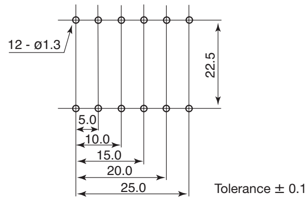


Core			Bobbin
article name	Ae	W	
FEI33	1.18	41.5	EB33-P1212-FS

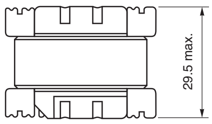


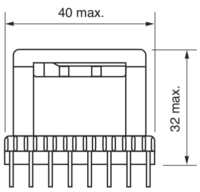


Recommended pin pattern dimensions

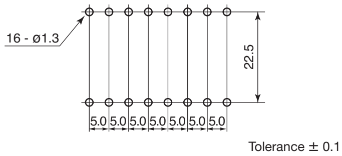


Core			Bobbin
article name	Ae	W	
FEI33	1.18	41.5	EB33-P1216-F

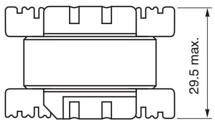


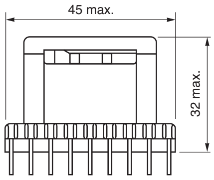


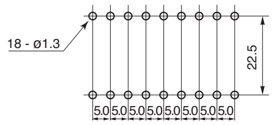
Recommended pin pattern dimensions



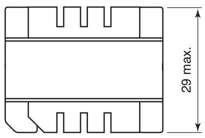
Core			Bobbin
article name	Ae	W	
FEI33	1.18	41.5	EB33-P1218-F

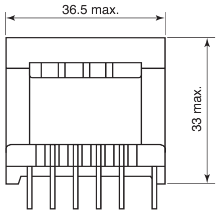


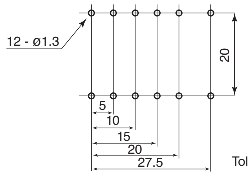




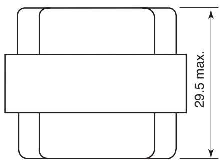
Core			Bobbin
article name	Ae	W	
FEI35S	1.2	41.5	EB35S-P1212-F

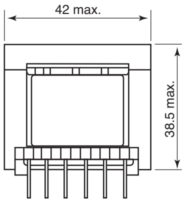


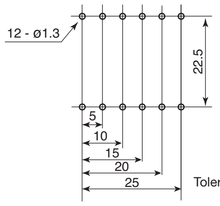




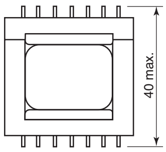
Core			Bobbin
article name	Ae	W	
FEI40	1.48	61.0	EB40-P1212-F
FEE40	1.28	51.1	

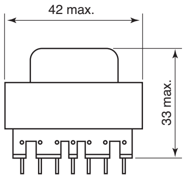


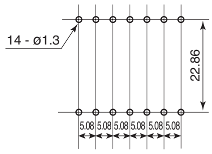




Core			Bobbin
article name	Ae	W	
FEI40	1.48	61.0	EB40-P1114-FA
FEE40	1.28	51.1	







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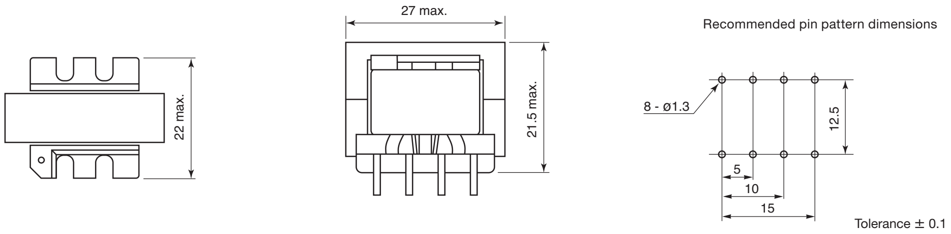
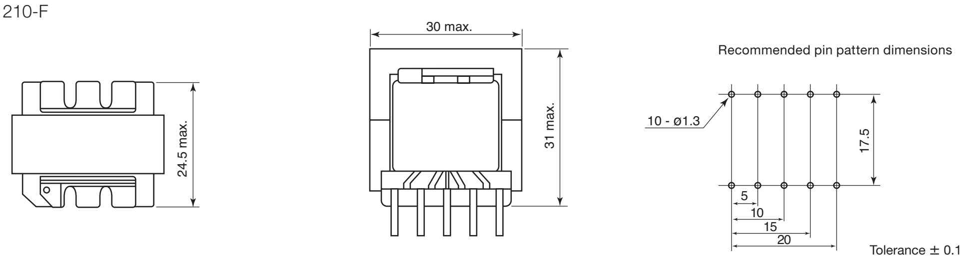
Core			Bobbin
article name	Ae	W	
FEER25.5	0.43	10.8	ERB25.5-P1208-F

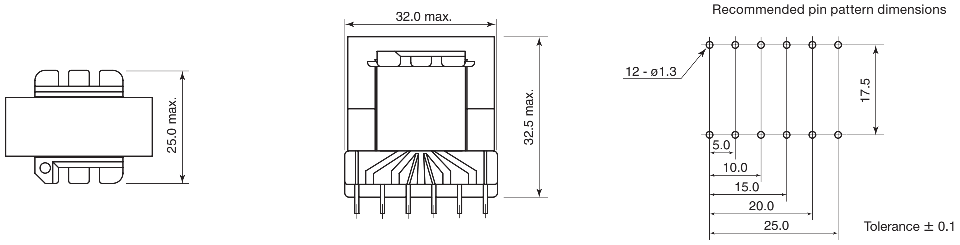


Core			Bobbin
article name	Ae	W	
FEER28	0.85	28.5	ERB28-P1210-F, ERB28-P1212-F

●ERB28-P1210-F



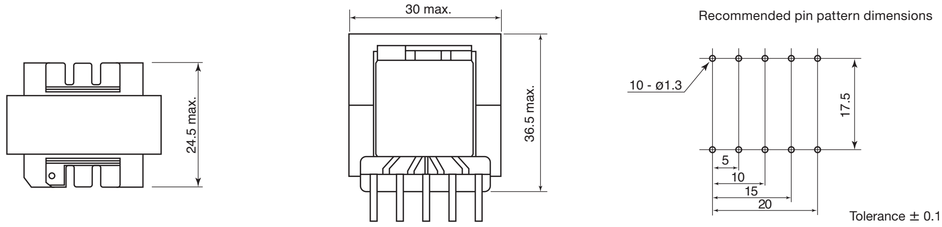
●ERB28-P1212-F



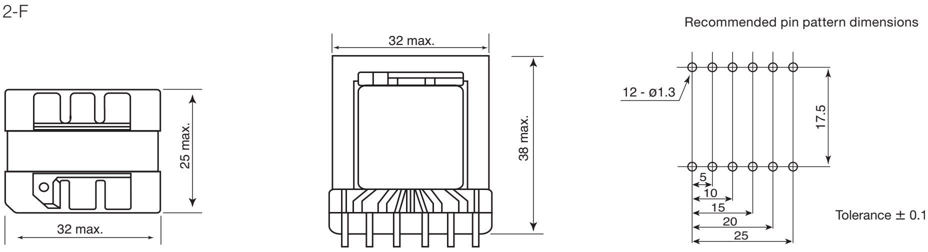
9616TRAVOL07E1704E1

article name	Core Ae	W	Bobbin
FEER28L	0.85	33.2	ERB28L-P1210-F, ERB28L-P1212-F

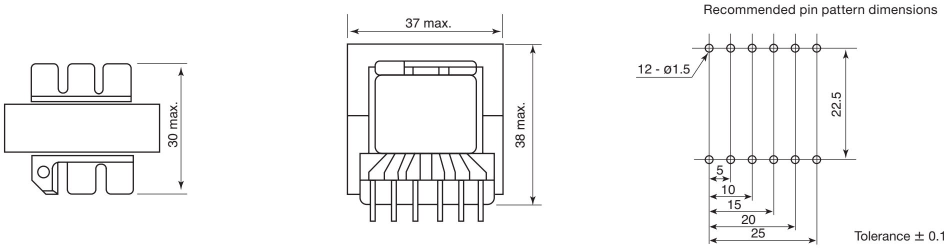
●ERB28L-P1210-F



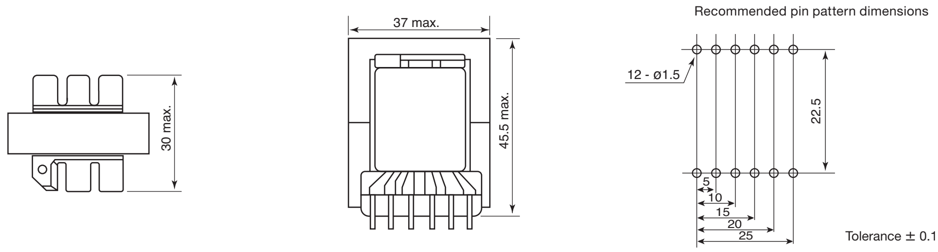
●ERB28L-P1212-F



article name	Core Ae	W	Bobbin
FEER35	1.10	45.0	ERB35-P1212-F



article name	Core Ae	W	Bobbin
FEER35L	1.08	50.7	ERB35L-P1212-F



Notes for Handling

- Confirm the required operating conditions for each product before using it.
  (Applying excess load may damage the transformer.)
- Avoid subjecting the terminals of the transformer to excessive stress.
  (This can damage the wiring.)
- Avoid handling the product while holding the transformer part after it is mounted on the board.
  (This can loosen the core or damage the wiring.)
- Never use any product that has been dropped .
  (A cracked core can cause unsatisfactory characteristics .)

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Custom transformer series (Through-hole type)

Output Wattage	Core Size	Bobbin
4W	FEY12.7 / 12 / 4	EYB12-P1107-F7
5W	FEY16 / 14.5 / 5	EYB16-P1107-F1
6W	FEE12.6	EEB12.6-P1109-F
7W	FEY16D / 14.2 / 5.5	EYB16D-P1110-F
15W	FEI22S	EB22S-P1211-F
18W	FEE22	EEHB22-P1110-F
40W	FEEH28	EHB28-P1214-F2
50W	FEY28D	EYB28-P1112-F

Circuit condition: Flyback at= 100 kHz
*Contact us indisivually regarding safety standard complied models.

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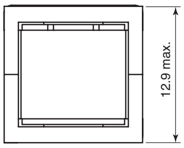
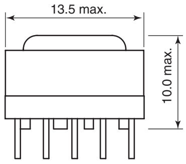
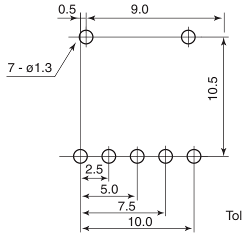
	Core		Bobbin
article name	Ae	W	
FEY12.7/12/4	0.107	1.6	EYB12-P1107-F7



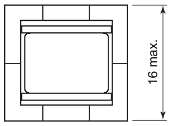


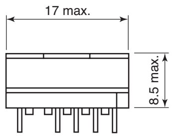
Recommended pin pattern dimensions



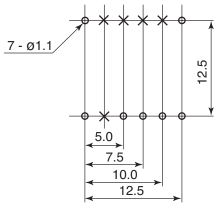
Tolerance ± 0.1

	Core		Bobbin
article name	Ae	W	
FEY16/14.5/5	0.1593	3.0	EYB16-P1107-F1



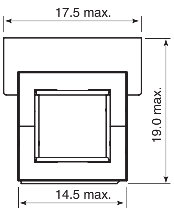


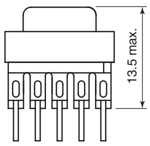
Recommended pin pattern dimensions



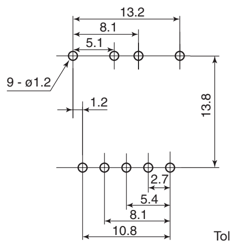
Tolerance ± 0.1

	Core		Bobbin
article name	Ae	W	
FEE12.6	0.124	2.0	EEB12.6-P1109-F



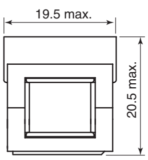


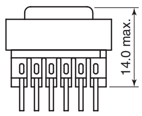
Recommended pin pattern dimensions



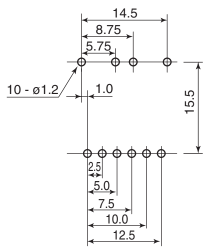
Tolerance ± 0.1

	Core		Bobbin
article name	Ae	W	
FEY16D/14.2/5.5	0.236	4.1	EYB16D-P1110-F





Recommended pin pattern dimensions



Tolerance ± 0.1

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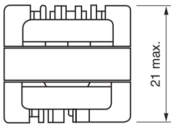
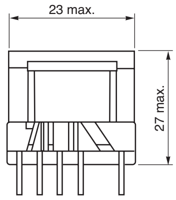
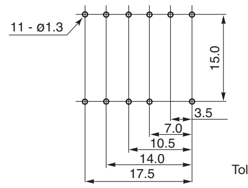
Core			Bobbin
article name	Ae	W	
FEI22S	0.36	7.7	EB22S-P1211-F



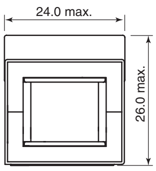


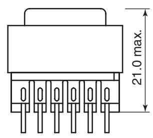
Recommended pin pattern dimensions



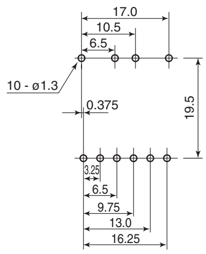
Tolerance ± 0.1

Core			Bobbin
article name	Ae	W	
FEE22	0.502	11.7	EEHB22-P1110-F



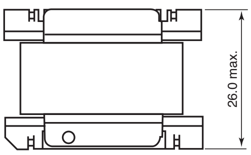


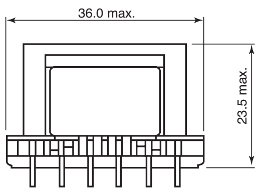
Recommended pin pattern dimensions



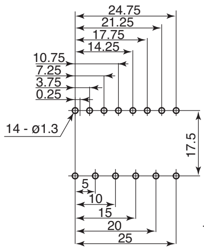
Tolerance ± 0.1

Core			Bobbin
article name	Ae	W	
FEEH28	0.844	23.8	EHB28-P1214-F2



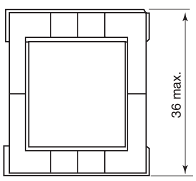


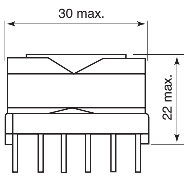
Recommended pin pattern dimensions



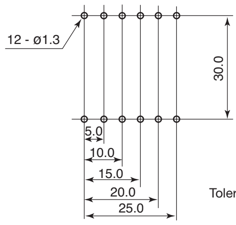
Tolerance ± 0.1

Core			Bobbin
article name	Ae	W	
FEY28D	0.75	32.0	EYB28-P1112-F





Recommended pin pattern dimensions



Tolerance ± 0.1

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●All specifications in this catalog and production status of products are subject to change without notice. Prior to the purchase, please contact TOKIN for updated product data.
●Please request for a specification sheet for detailed product data prior to the purchase.
●Before using the product in this catalog, please read "Precautions" and other safety precautions listed in the printed version catalog.

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  (This can loosen the core or damage the wiring.)
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  (A cracked core can cause unsatisfactory characteristics.)

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Precautions

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- The names of the products and the specifications in this catalog are subject to change without notice for the sake of improvement. The manufacturer also reserves the right to discontinue any of these products. At the time of delivery, please ask for specifications sheets to check the contents in order to use the products properly and safely.
- Descriptions in this catalog regarding product characteristics and quality are based solely on discrete components. When using these components, be sure to check the specifications with the component in question mounted on the products.
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