LLC Resonance Power Transformers

Pin terminal type

SRX series

Type: **SRX45EM(Drop-in)**
SRX38EM(Drop-in)
SRX43EM(Drop-in/Through hole)
SRX30ER(Through hole)
SRX35ER(Through hole)
SRX38ER(Through hole)
SRX48EM(Through hole)
SRX40ER(Through hole)

Issue date: September 2010

- All specifications are subject to change without notice.
- Conformity to RoHS Directive: This means that, in conformity with EU Directive 2002/95/EC, lead, cadmium, mercury, hexavalent chromium, and specific bromine-based flame retardants, PBB and PBDE, have not been used, except for exempted applications.

LLC Resonance Power Transformers
SRX Series

Contents Page

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TDK

LLC Resonance Power Transformer
SRX Series

Conformity to RoHS Directive

Development Concept

Compliant with worldwide safety standards, this is a small and thin transformer with the advantages of effective use of low-loss ferrite material.

■MATERIAL

Optimized materials and core shapes have been developed. The necessary power can be transmitted with a small number of windings.
While optimizing materials, TDK has further improved its proprietary core shape to develop a new-type ECO core.
The transformer has been downsized considerably, and its temperature increase has also been curbed.

■MANUFACTURING METHOD

Since the ECO Series supports automatic winding, the product is of a high quality and can be manufactured stably.
It is designed to support automatic winding, which enables a remarkable reduction in the loss generated to achieve a proficient in manual winding until stable production.
In addition, the characteristic variations of the winding wire and creepage tape have largely been removed, stabilizing the transformer's characteristics.

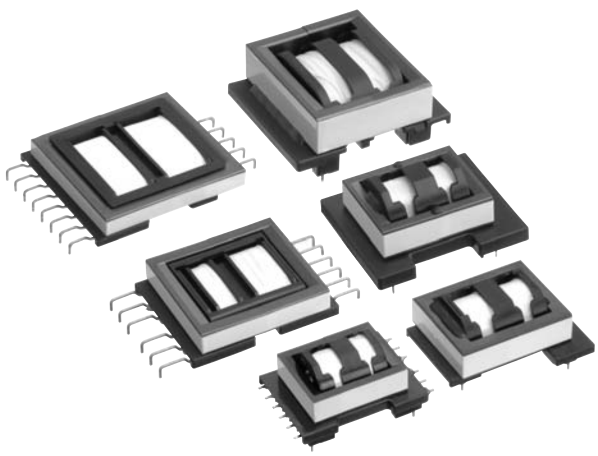
■OPTIMIZATION DESIGN

Using design tools developed with TDK's comprehensive know-how, high-precision design has been achieved in a short period of time.

1) For optimization design and high-quality stable production, customers can use a specification request form.
   If you provide the necessary information in the form, you will receive the optimization design in a short time.
2) TDK recommends design with a standard core gap (AL-value) for optimization and shorter trial and mass production lead time.
   Design is simple as each shape retains its GAP, AL-value, and K parameters beforehand.

■ENVIRONMENT

The SRX series is RoHS directive-compliant product.



- Ferrite cores, bobbins, cases, etc. are not sold individually.

- Conformity to RoHS Directive: This means that, in conformity with EU Directive 2002/95/EC, lead, cadmium, mercury, hexavalent chromium, and specific bromine-based flame retardants, PBB and PBDE, have not been used, except for exempted applications.

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LLC Resonance Power Transformer
SRX Series

Conformity to RoHS Directive

TDK now provides a characteristically thin resonance LLC resonance power transformer. In order to develop this transformer, TDK made effective use of low loss performance (which is a feature of the PC47 family), optimized the structure of the core and the bobbin, and utilized its proprietary automatic winding industrial method.

FEATURES

- A low height (8 to 31.5mm in height) is achieved.
- Large power is achieved in a small shape.
- The automatic winding industrial method is adopted.
- It is a product conforming to RoHS directive.

APPLICATIONS

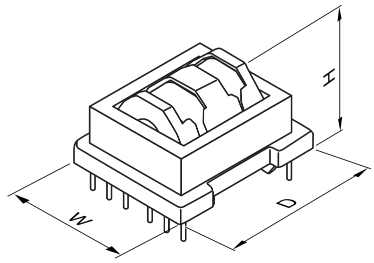
AV equipment, digital consumer electronic

PRODUCT IDENTIFICATION

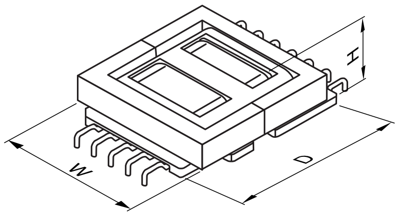
SRX	30ER	-	P	□□□□□	□□□□□
(1)	(2)		(3)	(4)	(5)

(1) Series name
(2) Core size
(3) Input voltage code
(4) Output voltage code
(5) Internal control code

THROUGH HOLE TYPE



DROP-IN TYPE



ELECTRICAL CHARACTERISTICS

Part No.	Mount method*1	Height H (mm)	Frequency (kHz)min.	Maximum output power (W)max.	Number of outputs	D (mm)	W (mm)	Lead space F (mm)	Number of pins(pieces) Primary side	Secondary side
SRX45EM	Drop-in	7.7*2	120	180	2	57	46.5	69.6	5	7
SRX38EM	Drop-in	10	120	125	2	50	40	65.5	6	6
SRX43EM	Drop-in	10	100	180	2	53	52	60	5	7
						53	46	65.2		
	Through hole	15	100	180	2	55	46	37.5	5	7
					3	58	46	37.5	6	8
SRX30ER	Through hole	27	100	180	2	57	41.5	40	6	6
	Through hole	25			3	52	45.5	35	8	8
	Through hole	27			2	45	37.5	35	6	6
SRX35ER	Through hole	25	80	250	3	55	53	35	6	9
SRX38ER	Through hole	27	60	250	3	58	53	40	6	9
SRX48EM	Through hole	25	60	300	3	58	51	35	6	8
SRX40ER	Through hole	31.5	60	300	3	54	43	35	8	8

*1 When applying flow solder to a drop-in transformer, be careful to ensure that only the terminals come into contact with the solder.
*2 Typical dimensions(maximum dimensions may vary depending on the specifications.)

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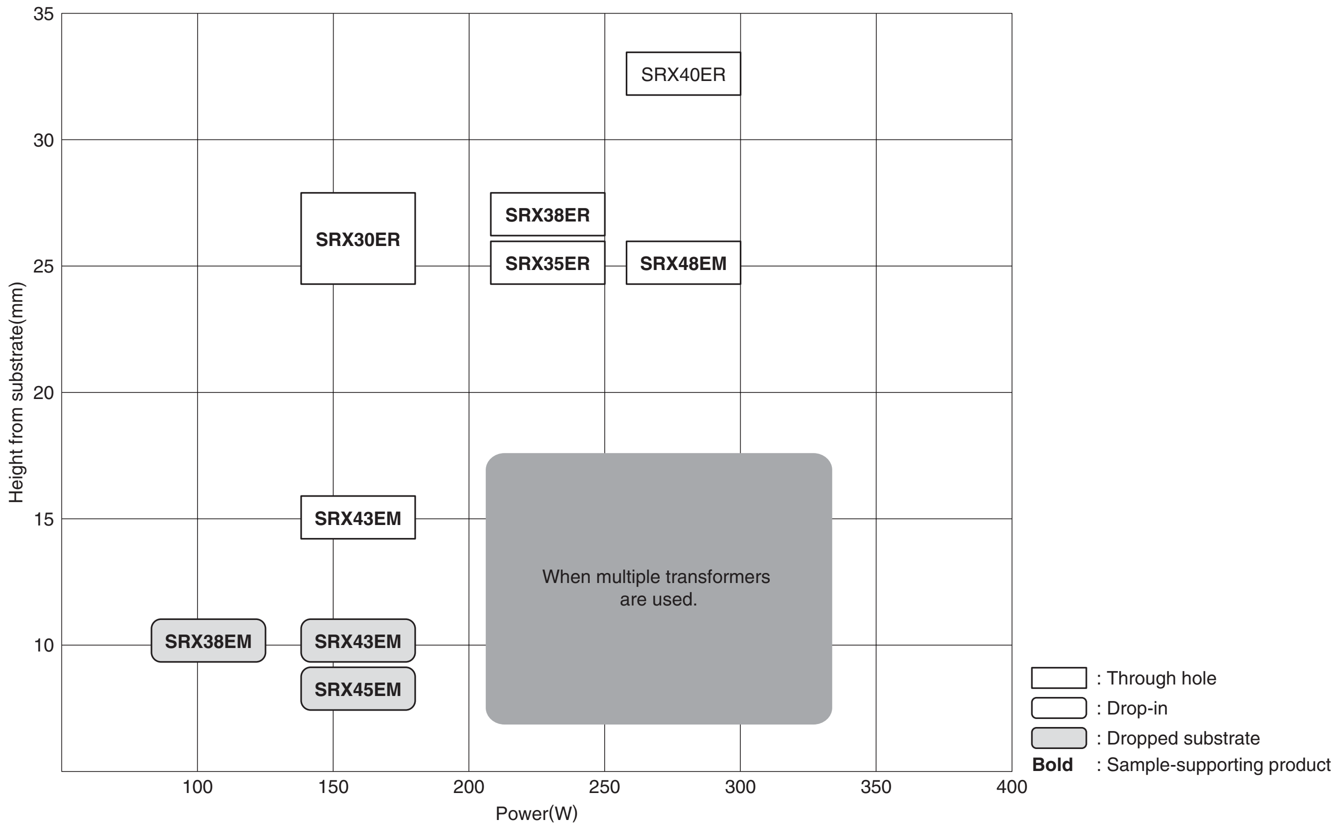
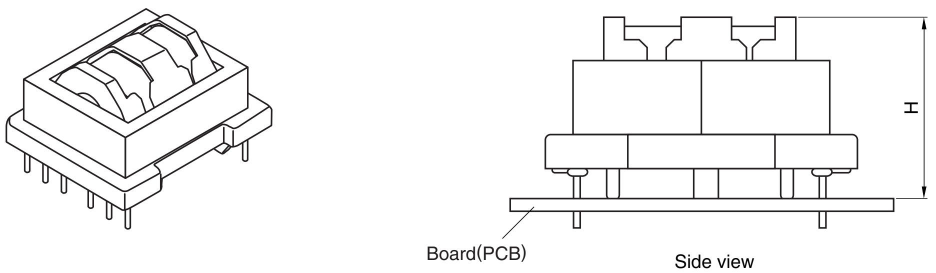
Lineup of Resonance Switching Power Transformers

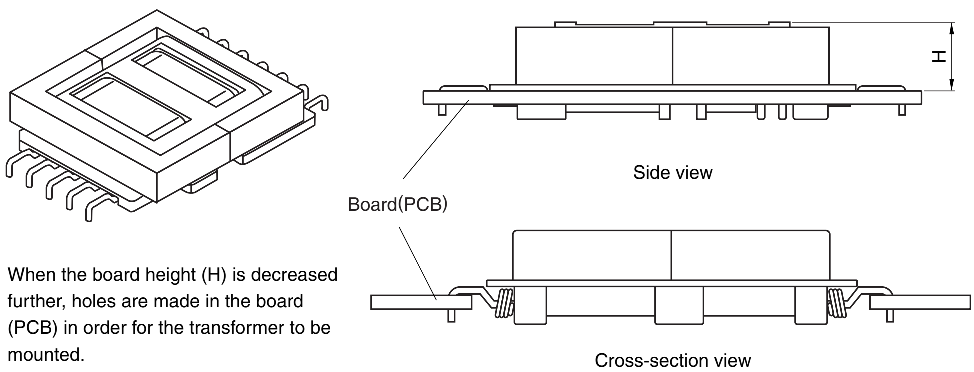


EXTERNAL SHAPES OF THROUGH HOLE AND DROP-IN TRANSFORMERS

THROUGH HOLE TYPE



DROP-IN TYPE



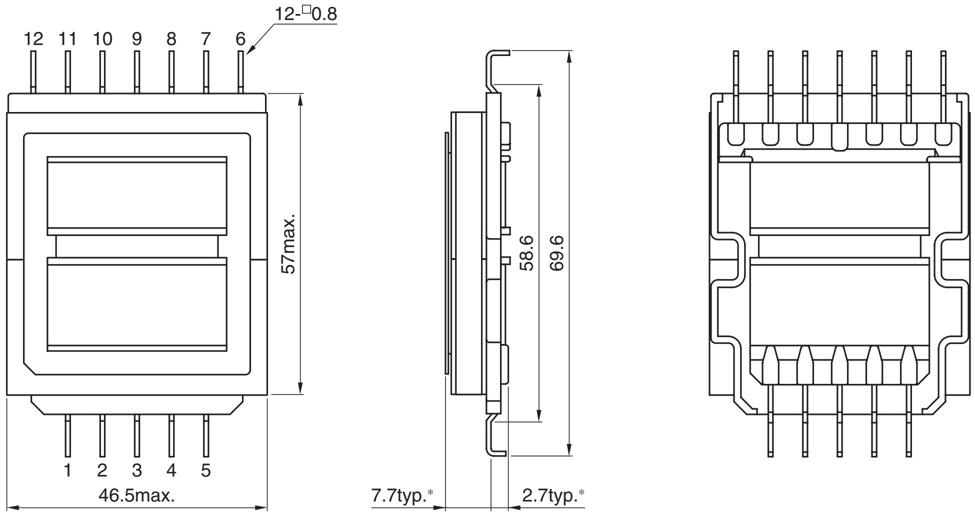
When the board height (H) is decreased further, holes are made in the board (PCB) in order for the transformer to be mounted.

• All specifications are subject to change without notice.

TDK

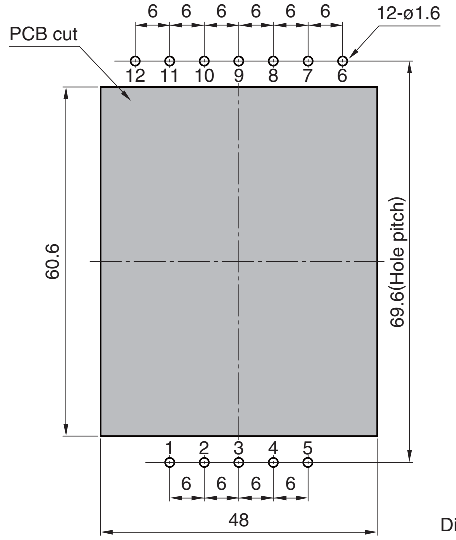
SRX45EM Series

SHAPES AND DIMENSIONS



* Maximum dimensions may vary depending on the specifications.

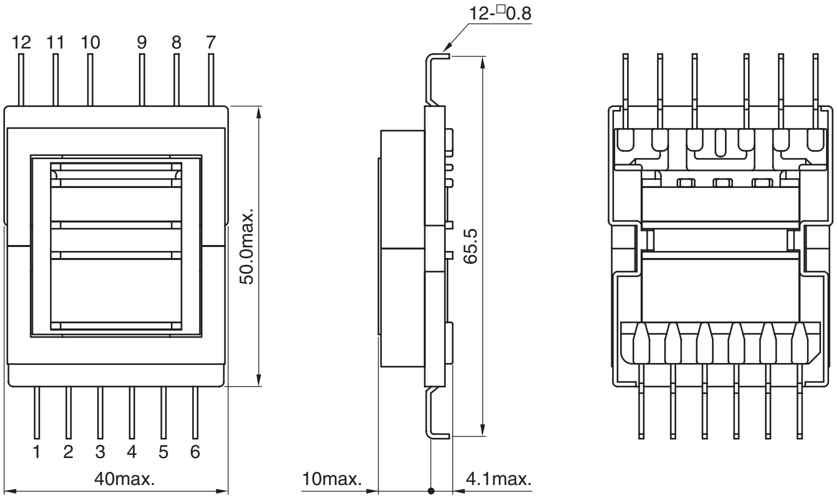
RECOMMENDED BASE MATERIAL OPENING SIZE



Dimensions in mm

SRX38EM Series

SHAPES AND DIMENSIONS



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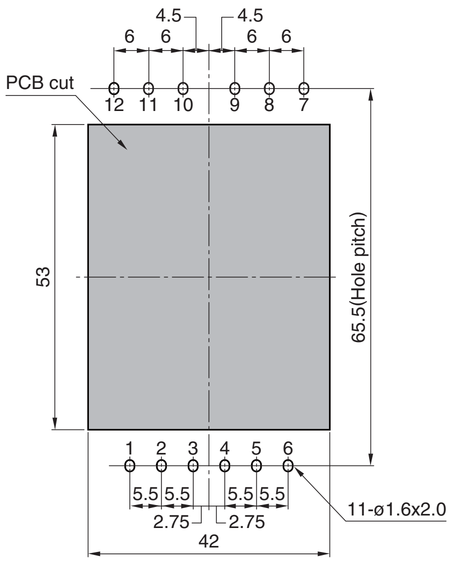
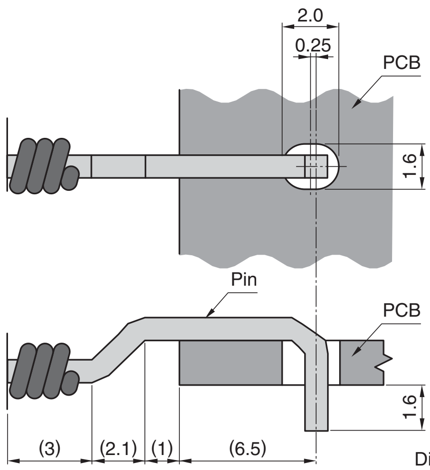


PIN DETAILS

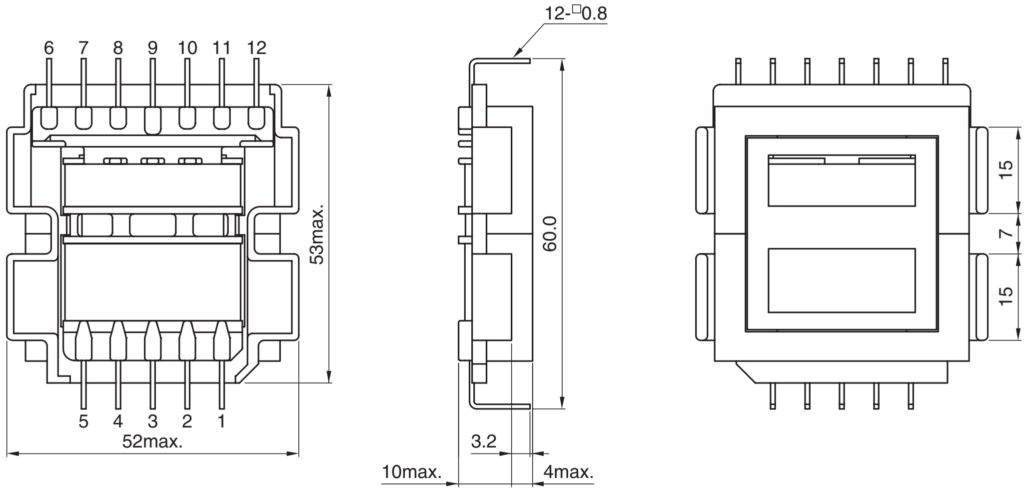


Dimensions in mm

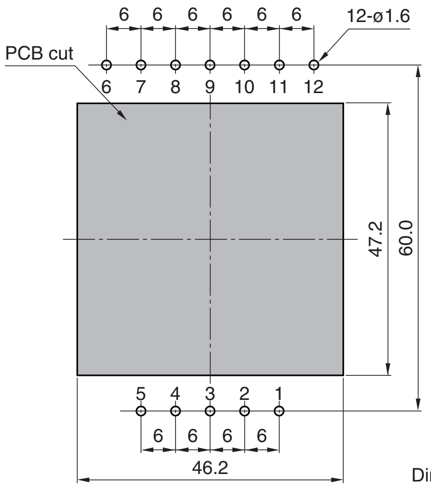
TDK

SRX43EM Series

SHAPES AND DIMENSIONS



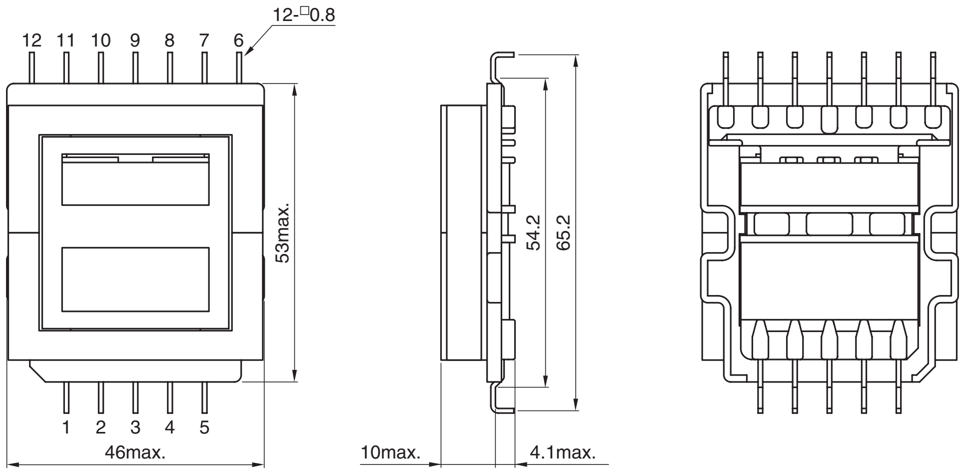
RECOMMENDED BASE MATERIAL OPENING SIZE



Dimensions in mm

SRX43EM Series

SHAPES AND DIMENSIONS



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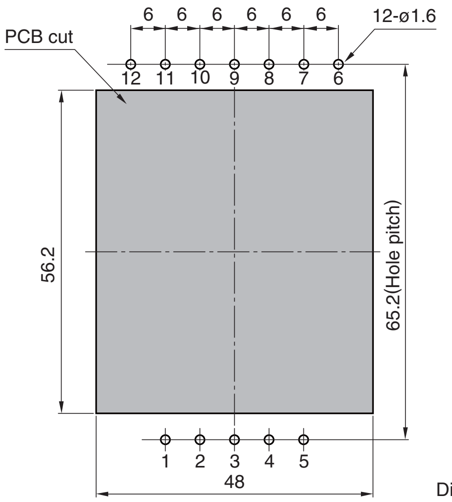
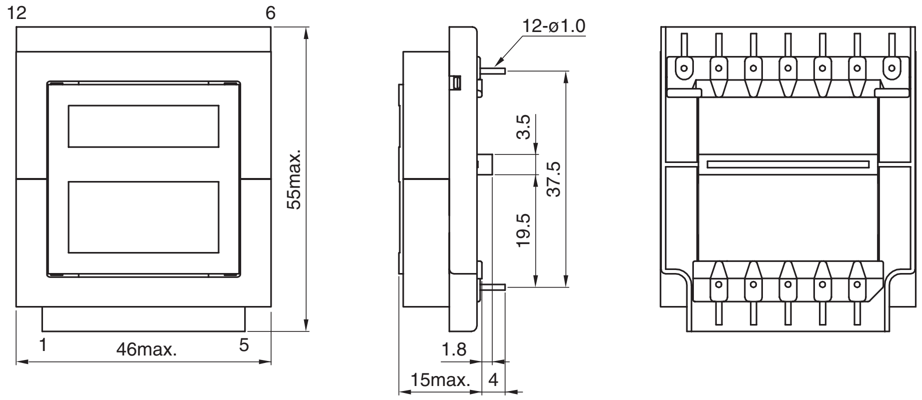


Dimensions in mm

SRX43EM Series

SHAPES AND DIMENSIONS



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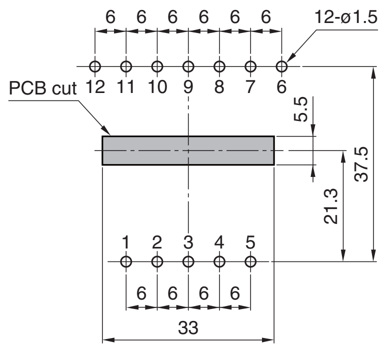
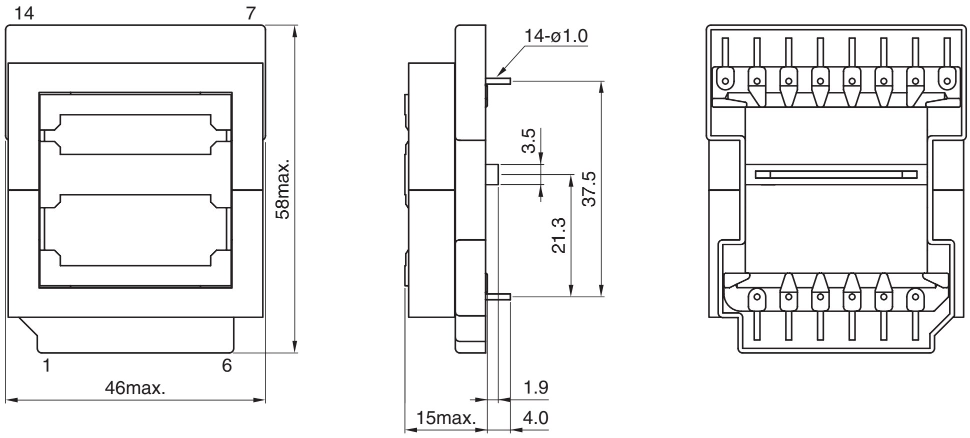


Dimensions in mm

TDK

SRX43EM Series

SHAPES AND DIMENSIONS



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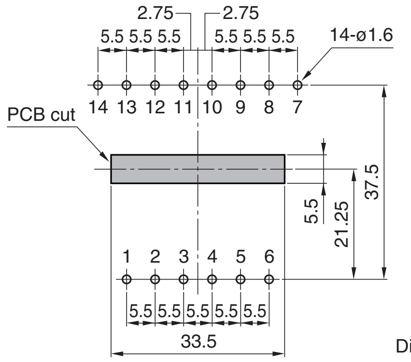
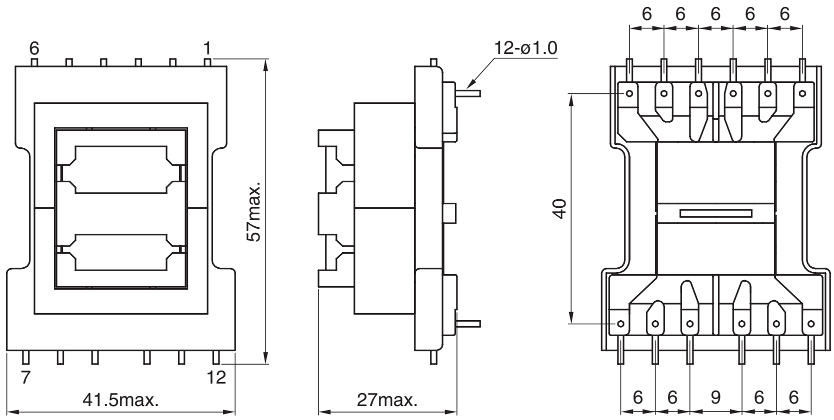


Dimensions in mm

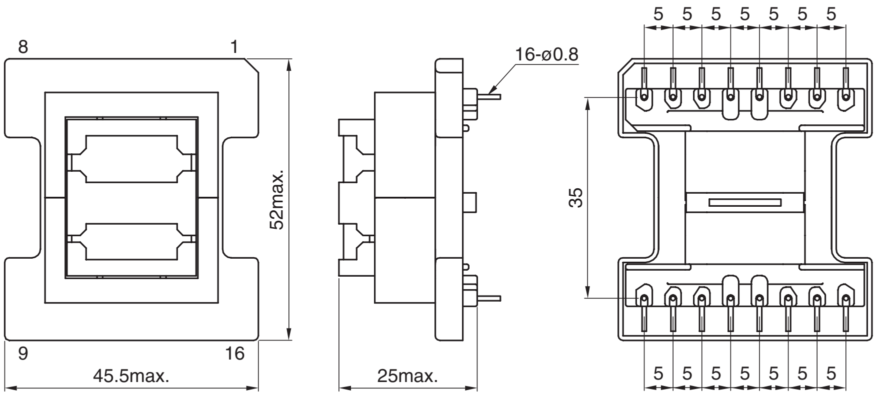
SRX30ER Series

SHAPES AND DIMENSIONS

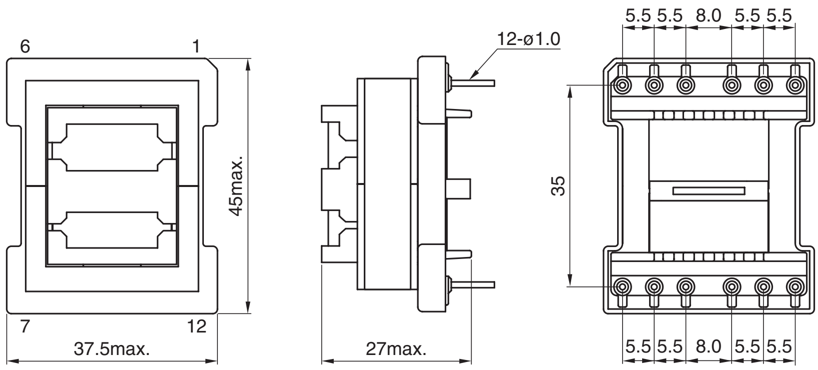
TYPE A



TYPE B



TYPE C

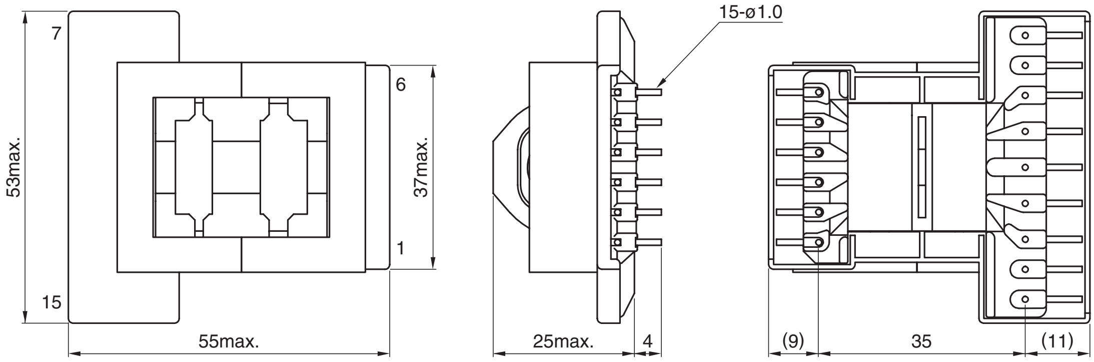


Dimensions in mm

TDK

SRX35ER Series

SHAPES AND DIMENSIONS



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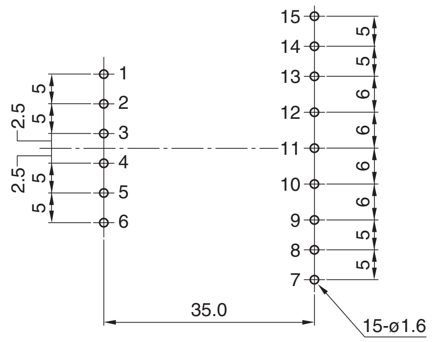


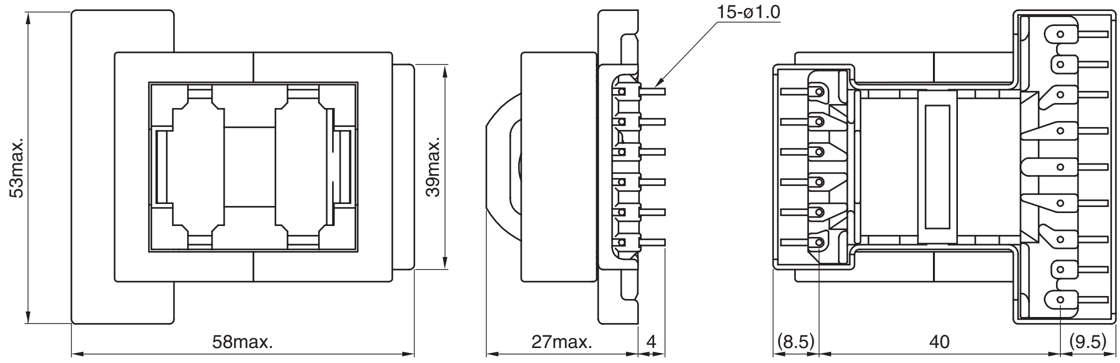
Dimensions in mm

• All specifications are subject to change without notice.

TDK

SRX38ER Series

SHAPES AND DIMENSIONS



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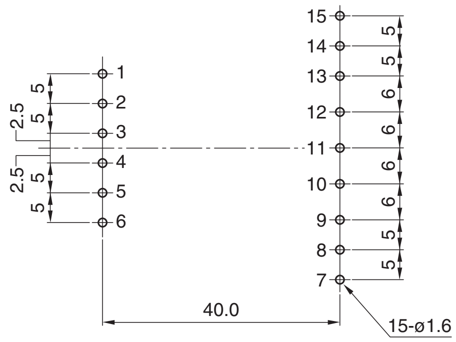
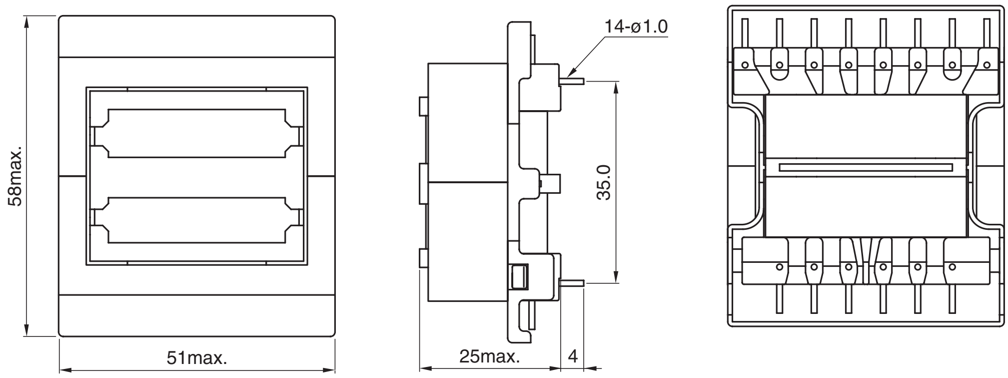


Dimensions in mm

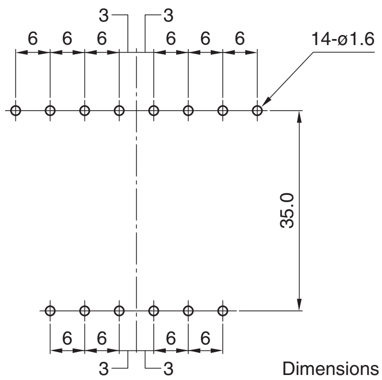
TDK

SRX48EM Series

SHAPES AND DIMENSIONS



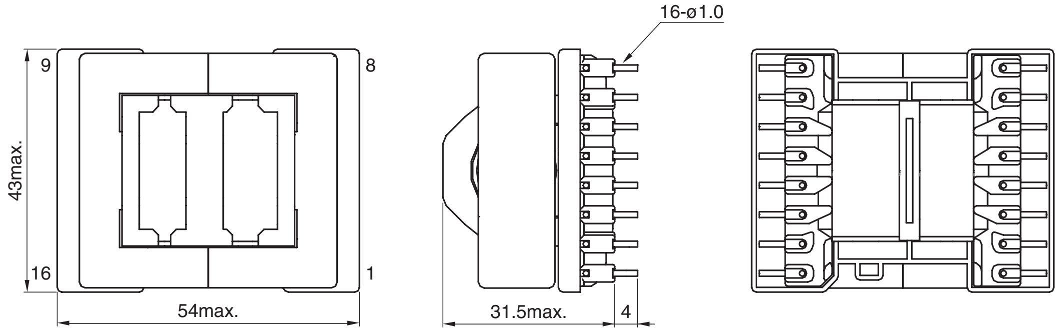
RECOMMENDED BASE MATERIAL OPENING SIZE



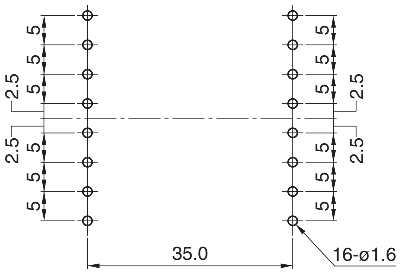
Dimensions in mm

SRX40ER Series

SHAPES AND DIMENSIONS



RECOMMENDED BASE MATERIAL OPENING SIZE



Dimensions in mm

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Design Reference for LLC Resonant Power Transformers

LLC RESONANT CONVERTER

The LLC resonant converter features low noise and high efficiency and is a circuit system suitable for relatively large power requirements. The LLC resonant converter is of SRC (Series Resonant Converter) type.

SFM(Frequency modulation control) is generally used for control of the converter.

The converter is driven by a half bridge and, because the usage rate of the core is high, low-loss core materials are recommended for the downsizing of the converter.

In addition, because its input voltage range is narrower than that of a PWM-system power supply, it is recommended that PFC be used at the front stage to stabilize input voltage. Even when PFC is not used, increasing the ratio of resonance inductance to excitation inductance can stabilize input voltage to some extent. Under such circumstances, however, optimized design and efficiency will be difficult to achieve.

It therefore follows that there are difficulties facing global design of this system.

Figure 1 Basic circuit (1) (with a resonance inductor separated)

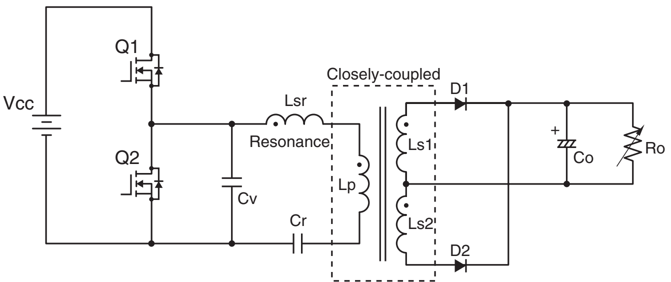
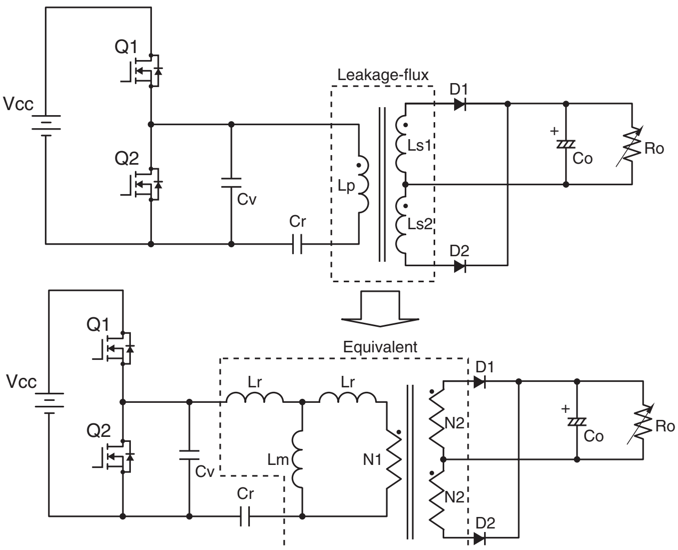


Figure 2 Basic circuit (2) (with a resonance inductor one type)



Here, the following equation applies:

$Lp = Lr + Lm$ $\quad Lr = (1-k) \times Lp$

$Lm = k \times Lp$

Lp: Primary inductance

Lm: Excitation inductance

Lr: Leakage inductance

k: Coupling coefficient

LEAKAGE-FLUX TRANSFORMER FOR LLC POWER SUPPLY

This is a transformer in which leakage inductance has been intentionally increased and the value of the inductance has been standardized. Here, when the secondary side has completely short-circuited, the primary-side inductance is handled as resonance inductance L_{LK}.

As a structure, the primary and secondary sides are separated from each other by a wall installed in the reel, which decreases the coupling. When the resonance inductance, primary inductance, and coupling coefficient are L_{LK}, Lp, and k, respectively, the equation shown below applies. L_{LK} operates as a resonance inductor.

$L_{LK} = Lp \times (1 - k^2)$

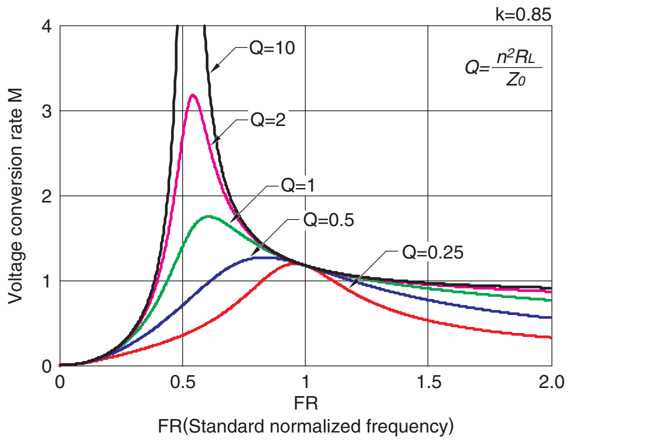
Lp is A_L-value$\times Np^2$. A_L-value is determined according to the core gap, and k is a parameter determined according to the core gap and a bobbin structure.

ABOUT TRANSFORMER DESIGN

The stationary operation condition is set so that it is near to CRM (Critical Mode). However, it may be changed to some extent in relation to the input voltage range and output voltage.

Figure 3 shows the voltage conversion rate of a leakage-flux transformer-type LLC circuit, calculated with k being 0.85 according to a theoretical formula. Initially, FR (normalized frequency) is set so that it is near 1.

Figure 3 LLC resonant circuit normalized frequency characteristics



Here, Q shows the ratio of load resistance to characteristic impedance; in many cases, it is set in the range of about 0.5 to 1.5 at stationary loading.

When k is higher, the exciting current can be decreased further. Normally, k is set at about 0.8 to 0.95. However, when the input voltage range is wide, it is set lower, and when the range is narrow, it is set higher.

The figure below is an example of a transformer designed with the following conditions: Vin=390V, Vo=24V, Io=8A, and stationary frequency=100kHz.

Shown below is a design example with the operation point near Fs.

Conditions: A_L=410nH/n^2 k=0.906

Vin=390V, Vo=24V, V_F=0.65V, Io=8A, Fs=100kHz, Q=0.80

1. The ratio of turns n is determined from input voltage Vin and output voltage Vo.

$$n=\frac{Vm}{2\times k\times(V_O+V_F)}=\frac{390}{2\times0.906\times24.65}=8.732$$

2. Calculation of characteristic impedance Zo

$$R_L=\frac{V_O}{I_O}=\frac{24}{8}=3.0\quad Z_O=\frac{n^2\times R_L}{Q}=\frac{8.732^2\times3.0}{0.80}=285.9\,[\Omega]$$

3. Calculation of Cr (resonance capacity) and L_{LK} (resonance inductance)

$$Z_O=\frac{k}{1-k^2}\sqrt{\frac{L_{LK}}{C_r}}$$

$$C_r=\frac{1}{2\times\pi\times\frac{1-k^2}{k}\times F_S\times Z_O}=\frac{1}{2\times\pi\times0.1978\times100000\times285.9}$$

$$=28.14\,[\text{nF}]$$

$$L_{LK}=\left(\frac{1-k^2}{k}\right)^2\times Z_O^2\times C_r=0.1978^2\times285.9^2\times28.14\times10^{-9}$$

$$=90.0\,[\mu\text{H}]$$

4. Calculation of transformer parameters

$$L_P=\frac{L_{LK}}{(1-k^2)}=\frac{90.0}{(1-0.906^2)}=502.3\,[\mu\text{H}]$$

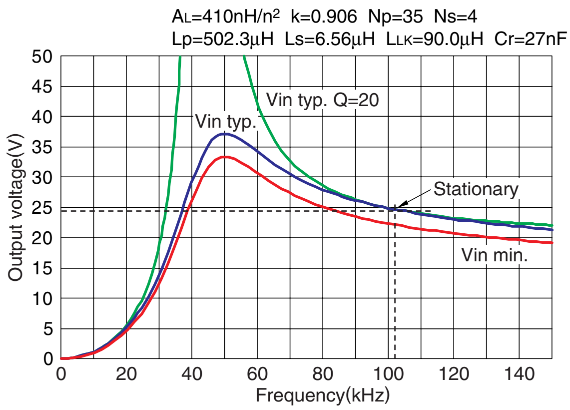
$$N_P=\sqrt{\frac{L_P}{A_L}}=\sqrt{\frac{502.3}{0.410}}=35.0\,[\text{Ts}]$$

$$N_S=\frac{N_P}{n}=\frac{35.0}{8.732}=4.0\,[\text{Ts}]$$

Repeating the above calculation several times will optimize each parameter. It is better for Ns with a smaller number of turns to be near an integer.
Design is complete when the flux, current, etc., calculated with this number of turns are within acceptable values. When they exceed the values, the frequency, Q, and transformer parameters (A_L-value and k) need to be revised.

Figure 4 shows frequency characteristics illustrated graphically, based on the results of conditions set after the aforementioned calculation results have been further optimized.

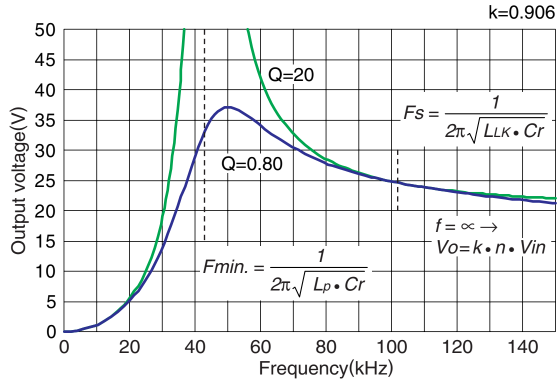
Figure 4 Example of LLC resonant circuit frequency characteristics



OPERATION POINT AND OPERATION WAVEFORM

The operation point and operation waveform are briefly explained here. Figure 5 shows frequency characteristics according to the conditions in Figure 4, above. Q=0.80 and Q=20 are characteristics at stationary loading and at light loading, respectively.
In addition, Fs and Fmin are calculated as 102.1kHz and 43.2kHz, respectively.

Figure 5 LLC resonant circuit operation point



When the operation point frequency is Fm, there are four modes available. Normally, the transformer is operated in modes other than the the off-resonance mode. Unless any special request is made, the transformer is designed so that its stationary operation condition is near to Critical Mode. In addition, when Fm is larger than Fs, the control-limit voltage is reached, which causes the voltage not to decrease.
Figures 6a and 6b show examples of operation waveforms in each mode when a circuit simulator is used. When CRM is selected, the transformer

Figure 6a Operation waveforms in each mode

Fm>Fs: Continuous Mode(CCM) Fm = Fs: Critical Mode(CRM)
Fmin<Fm<Fs: Continual Mode(DCM) Fm<Fmin: Off-resonance mode

CRM

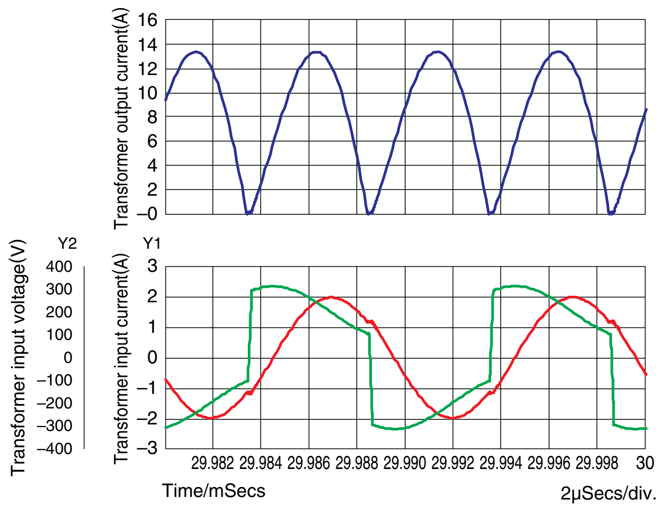
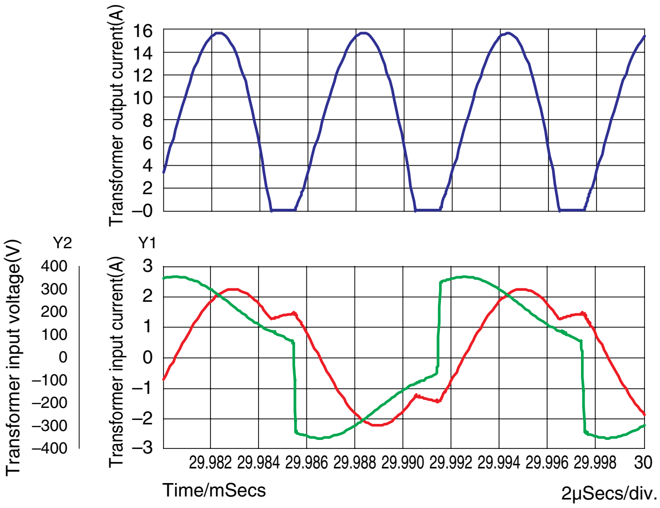
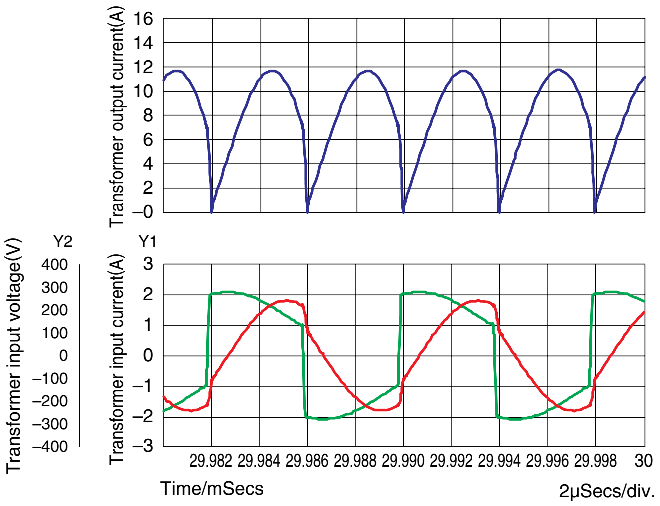


Figure 6b Operation waveforms in each mode

DCM



CCM



FLUX DENSITY AND CORE LOSS

Because the transformer is a bridge-system circuit, the core is excited in two quadrants. Therefore, low-loss materials that decrease core loss are suitable for transformer downsizing.
Shown below is a rough calculation formula of Bm of the LLC resonant converter. In addition, the variation width of B is twice this. Core loss needs to be evaluated with this ΔB.

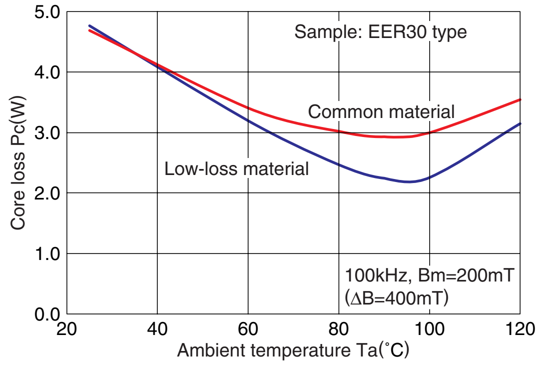
$$I_{PMAX} = \frac{Vo \times n}{4 \times k \times Lp \times Fs} \qquad Bm = \frac{Lp \times I_{PMAX}}{Np \times Ae}$$

$$\Delta B = 2 \times Bm$$

Vo: Output voltage
n: Ratio of turns
k: Coupling coefficient
Lp: Primary inductance
Np: Primary number of turns
Ae: Effective cross-sectional area
Fs: Resonance frequency

Figure 7 shows core loss temperature characteristics in common power ferrite materials and TDK's low-loss materials represented by PC47.
In an environment where the temperature of a core is 80°C or greater, low-loss materials have achieved a low loss of 20% compared with common materials, which contributes to the set's temperature decrease and downsizing.

Figure 7 Example of core loss temperature characteristics



PRECAUTIONS

About Multi-output Transformers

In design, the number of turns on the secondary side may be small. Even in such cases, multi-output is possible, but it is difficult when voltage does not correspond with the ratio of turns on the secondary side.
For example, when this winding has been optimally designed with 4Ts at Vo=24V, note that the second output can have only 24/4=6V-step voltage.

Narrower Input Voltage Range Compared with the PWM System

As described earlier, the operation-enabling input voltage range is narrow in principle; therefore, it is recommended that a circuit that improves the input range of PFC, etc., be installed at the front stage of the LLC resonant converter.

About Multi-transformer Configuration

When one transformer cannot attain the necessary power because of shape restriction, etc., combining multiple same-shape transformers enables the required power to be obtained.
Contact us for more details on transformer design methods that correspond with each wire connection.

About the Influence of Leakage Flux

There are often problems with thin resonant transformers. When the transformer has a structure in which metal plates, etc., are arranged close to each other on the upper and lower sides during operation, leakage flux generated from the transformer crosses through the metal and overcurrent loss occurs as a result.
This in turn may cause the metal plate or the transformer to generate heat.

• All specifications are subject to change without notice.

TDK

LLC Resonance Power Transformer Specification Request Form

Issued on ____ / ____ / ____

1. Company name ____

Address ____

2. Department, applicant's name

Name: ____

TEL/FAX: ____

E-mail: ____

Person in Charge from Sales Promotion Dep.: ____	Recorded Date / /
Person in Charge from Sales Dep.: ____	Recorded Date / /
Prototype No: ____	Recorded Date / /

3. Input specifications

AC input voltage: Rated ____ (V) to ____ (V) Operating range: ____ (V) to ____ (V)

DC input voltage: Rated ____ (V) to ____ (V) Operating range: ____ (V) to ____ (V)

Frequency ____ (Hz) Minimum operating input voltage: ____ (Hz)

4. Design condition

(1) Clock frequency Lowest frequency to Highest frequency: ____ to ____ (kHz)

			Min.	Typ.	Max.
(2) Secondary-side output voltage	____ (V) ±	____ (V)	____ (A) to	____ (A) to	____ (A)
	____ (V) ±	____ (V)	____ (A) to	____ (A) to	____ (A)
	____ (V) ±	____ (V)	____ (A) to	____ (A) to	____ (A)

(3) Rated output power/Maximum peak power ____ (W) / ____ (W)

(4) Overcurrent point condition (ex.: 130% of the rated output power in (3) above) ____ (%)

(5) Operating temperature range ____ (℃) to ____ (℃)

(6) Maximum temperature rise ΔT ____ (℃)

Condition in temperature evaluation (ex.: minimum input, rated load) ____

(7) Auxiliary winding (Fill in the (☐) square like this (■) to make your selection.) ☐Yes ☐No

Number of windings ____ (Windings)

Desired voltage value and current ____ (V) to ____ (mA)

Necessity of insulation (Fill in the (☐) square like this (■) to make your selection.) ☐Functional insulation ☐Reinforced insulation

(8) Circuit diagram (If you desire any pin number, attach a circuit diagram.) ☐Yes ☐No

5. Inductance value for reference

Primary-side self-inductance: ____ μ(H) Leakage inductance: ____ μ(H)

6. Desired core size and external size

Core size: ____ External size L: ____ W: ____ H(Height from the board): ____ mm max.

7. IC expected to be used

Manufacturer name: ____ Product No.: ____

8. Production quantity information

Final set name: ____ Desired price/Currency: ____

Acceptance conditions of the above price (F.O.B, C.I.F, D.D.U, D.D.P etc.): ____

Production volume: ____ k/M Production start period: ____ Production place: ____

Prototyping time: (ES1) ____ (ES2) ____ (PP1) ____ (PP2) ____ (MP1) ____

9. Sample information

Required sample quantity ____ pcs. Requested delivery time: ____

10. Note company regulations, such as safe distance and dielectric voltage strength, if there are any.

____

11. If there are any other requests (priorities in the company, size or price, etc.) or alterable items, please provide a description.

TDK Corporation Magnetics Business Group, Business Promotions Dept.
13-1, Nihonbashi 1-chome, Chuo-ku Tokyo 103-8272, Japan TEL: 81-3-5201-7229, FAX: 81-3-5201-7230

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