

# High Inductance Ferrite Supporting Wide Temperature-range For 100/1000 Base-T Pulse Transformers, DNW45 material

## Conforming to RoHS Directive

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

With the wide temperature range of  $-40$  to  $+85^{\circ}\text{C}$ , a superb DC superposition characteristic was achieved, surpassing that of the previous top-specification material, DN45, by 23%.

This revolutionary specification will take the downsizing and cost-saving potential of 100/1000 Base-T pulse transformers one step further.

## Requirements of 100Base-T for pulse transformers

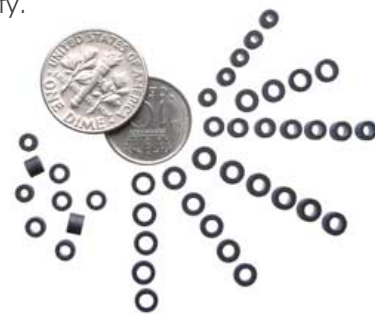
In general, the pulse transformers applied to high-speed LAN modems are required to have reduced insertion losses in a wide range between 0.1 and 100MHz. Improvement of the core's inductance characteristic in the low frequency range, and reduction of coil resistance by decreasing coil turns and the control of leakage flux through optimization of core shapes, and the method of turning coils in the middle and high frequency ranges will be the main themes of the project. In particular, the pulse transformers for 100Base-T modems require an inductance value of  $350\mu\text{H}$  or higher (ANSI X3.263-1995(R2000) standard) where an 8mA DC bias current is superimposed. In typical LAN environments such as the office, SOHO, and home, this desired value must be met between 0 and  $70^{\circ}\text{C}$ .

## Physical properties of core materials for downsizing and improved performance

Generally, a core with gaps is used to improve the DC superposition characteristic of transformers with ferrite cores. But cores with gaps significantly degrade the inductance and, inevitably, the coil turns have to be increased. Therefore, this solution can't be applied to pulse transformers used for devices which seek cost-saving and downsizing such as 100 Base-T modems.

In short, the core materials for this particular purpose require, on the premise of a toroidal-shaped small

In short, the core materials for this particular purpose require, on the premise of a toroidal-shaped small core with no leakage flux, a "physical property" that can improve "transformer performance" under DC superposition; that is, a B-H characteristic with sufficient inductance in a wide temperature range where an 8mA DC bias current (DC field  $H_{dc}=20$  to  $40\text{A/m}$ ) is superimposed, and, as well, a high initial permeability.



## Maintaining superb DC superposition characteristics in a wide temperature range

Requests for new core materials which maintain sufficient inductance in even smaller shapes under DC superposition, and which possess superb characteristics in a wide temperature range for expanding high-speed LAN environments like industrial uses, have increased. To respond to these demands swiftly, TDK has extensively reevaluated and modified the previous ultimate specification material, HP5, and developed DN45. Powerful DC superposition charac-

teristics, which surpassed existing limitations between 0 and 70 °C, were realized. Also, downsizing and reduced coil turns of 100Base-T pulse transformers have been working to cut costs. Now this "phenomenal material", that even surpasses the advantages of DN45, has been developed, and mass production has begun.

## The shift of trend from DN45 to DNW45

### Behind the scenes of cutting-edge material DNW45 development

100 Base-T has become the mainstream of high-speed LAN. Not to mention its use in diverse industrial devices and production lines, it has rapidly expanded its application to distribution/transference systems typified by POS systems; security systems for building maintenance, diverse measuring/monitoring systems, including medical devices, and so forth. The shift to the faster 1000Base-T(Gigabit Ethernet) has been fully developed.

This diversification of LAN applications, and significant acceleration of standard speeds, require transmitting pulse transformers, which are vital for network stability, for further improvement in general, including characteristics, size, price, and so forth.

Major components for industrial uses such as controller IC have been required to have characteristics based on the environmental temperature range of -40 - +85°C. The temperature range of this application is becoming a basic factor in the characteristic evaluation of high-speed LAN pulse transformers as well.

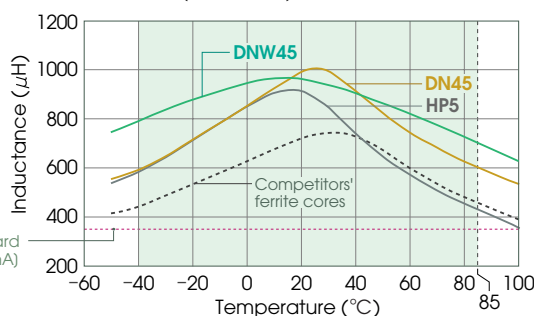
Of course a small pulse transformer, which meets the DC superposition characteristic required by ANSI, and provides the latest requirements, can be realized using DN45 material. However, to increase the stability of a high-speed LAN system, such as 1000Base-T, for which a shift from the backbone is in progress, further stabilization of transmission characteristics is vital, and coil count, which holds the key to the improvement of high-frequency characteristics and cost-saving, has to be reduced.

### Application merits of DNW45 material

Based on the basic composition of DN45 material, the most-advanced DNW45 material, created through a new sintering profile with compositional control by ion substitution and a reevaluated fine structure, is probably the world's first ferrite material that can respond to the technical requirements of the next-generation Ethernet, such as 1000Base-T, and to the needs of industrial uses.

#### Example of inductance vs. temperature characteristics

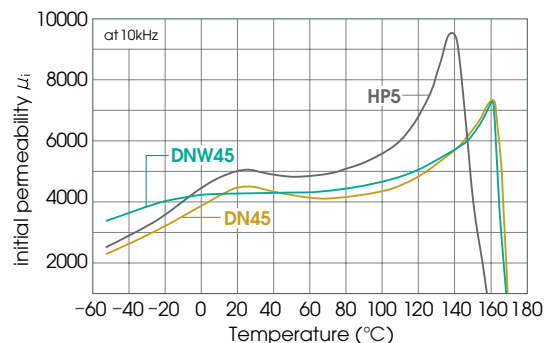
○ Toroidal core  
External diameter 3.05 x internal diameter 1.27 x Height 2.54mm)  
DC bias current = 8mA(H<sub>bc</sub>=32.1A/m),100kHz,100mV,N=24Ts



### Realizing further downsizing while the transmission characteristic is reinforced

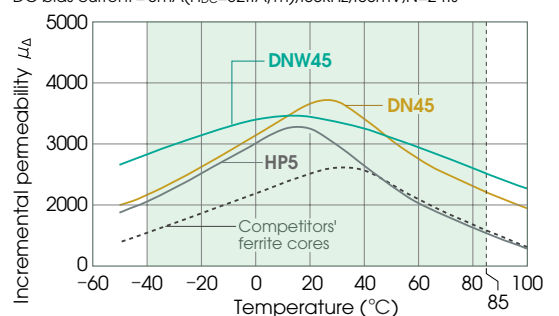
By reinforcing the initial permeability  $\mu_i$  between -40 - 0°C, the temperature change rate is greatly reduced while maintaining a high-level incremental permeability  $\mu_\Delta$ , the deciding factor of effective performance of LAN pulse transformers, and realizing a superb DC superposition characteristic that's even greater by 23% than the high-inductance characteristic of DN45 material, which is still in the industry's top bracket. As a result, if a similar characteristic to pulse transformers using existing materials is sought, a reduced core cubic volume of about 36%, and a downsizing effect can be achieved, and if a similar shape, in addition to a similar characteristic, is used, the coil count can be reduced by as much as 20%. Of course with 1000 Base-T pulse transformers outstanding miniaturization and inexpensive design, as well as improved transmission reliability, can be obtained.

### Example of initial permeability vs. temperature characteristics



### Example of incremental permeability vs. temperature characteristics

○ Toroidal core  
External diameter 3.05 x internal diameter 1.27 x Height 2.54mm)  
DC bias current = 8mA(H<sub>bc</sub>=32.1A/m),100kHz,100mV,N=24Ts



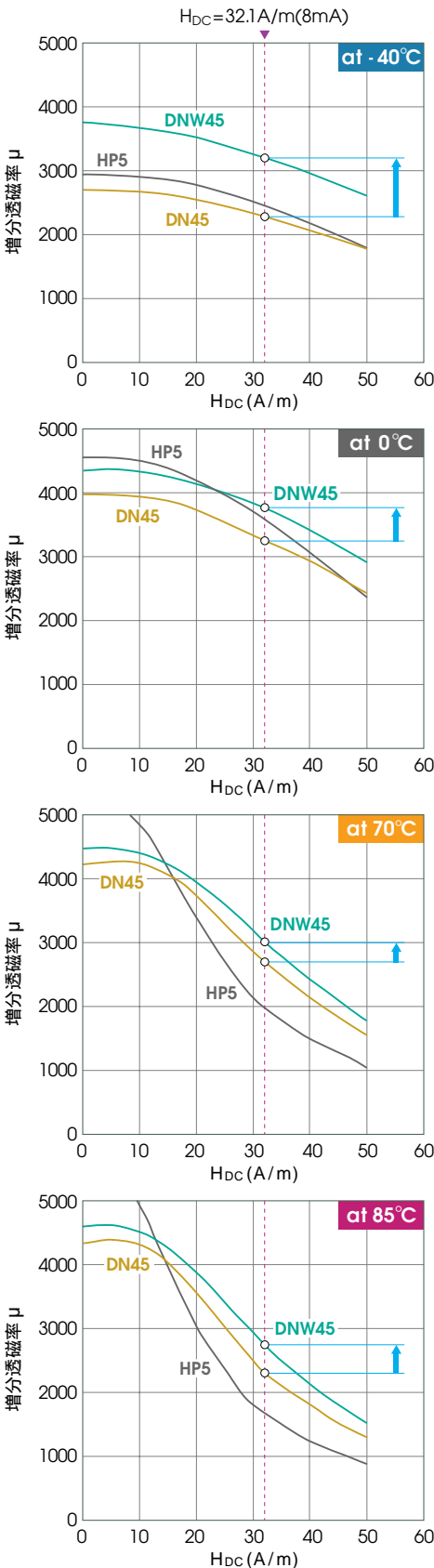
# First-rate specification exceeding the existing highest level in the industry

inductance characteristic under DC superposition and explanation of concept

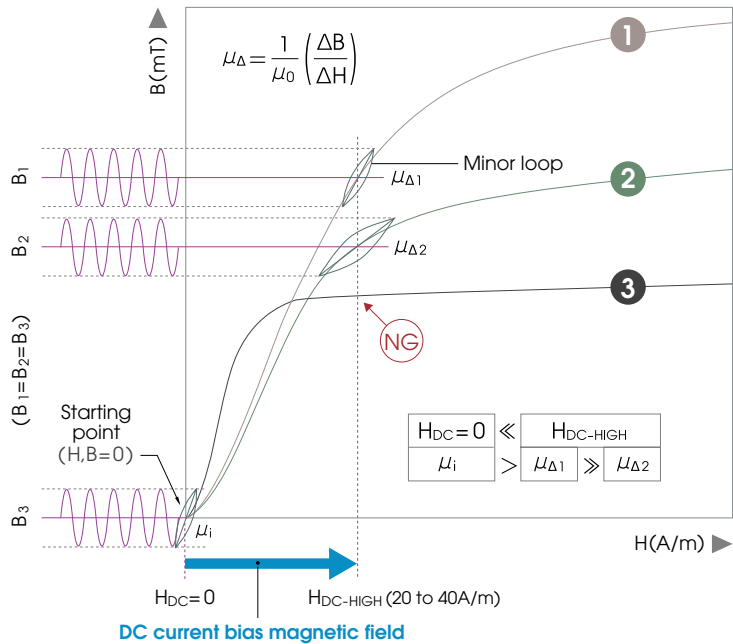


DNW45 material

## Incremental permeabilities vs. DC superposition magnetic field characteristics by temperature



## Relationship between magnetization curve and DC superposition characteristic



Similar to the definition of inductance, the incremental permeability  $\mu_{\Delta}$  is shown as the slope of the magnetization curve in the minor loop. The inductance of a transformer where direct current is impressed depends on the slope of the minor loop, and as the slope starts to level off (beginning of magnetic saturation), the inductance plunges.

High- $\mu$  cores applied to general transmission transformers use the inductance on the initial permeability level at the origin of the B-H loop (the  $\mu_i$  shown in the B-H characteristics ③ above). But with the transmission transformers for 100Base-T, a bias magnetic field of about 20-40A/m (depending on the shape and coil turns) is impressed because 8mA DC current is superposed ( $H_{DC-HIGH}$  in the same chart).

Therefore, if a core with a magnetization curve similar to ② is used under this condition, the inductance at this point ( $\mu_{\Delta 2}$ ) will decline significantly compared to that at the origin of the B-H loop because the actual driving part of the magnetization curve has great curvature (that is, flux density B is close to saturation).

The high- $\mu$  core model 3, which shows the largest inductance ( $\mu_i$ ) at the origin, also reaches near complete saturation at this  $H_{DC-HIGH}$  point, losing the function as a magnetic core.

What is required here is the magnetization curve ① based on DNW45 material.

Although the rise at the origin is still not as sharp as that of the high- $\mu$  core model ③, the linearity is well maintained under a bias magnetic field on the 20-40A/m level, and therefore has a superb transmission characteristic with much greater inductance ( $\mu_{\Delta 1}$ ) than core ②

# Comparison of material characteristics

## Electrical characteristics of standard-shaped products

Demand for small pulse transformers supporting a wide range of LAN environments, including security and industrial fields, as well as the ever-accelerating next-generation high-speed Ethernet, at low cost... These world-first small ferrite cores can fulfill such demand immediately.

### Material characteristic

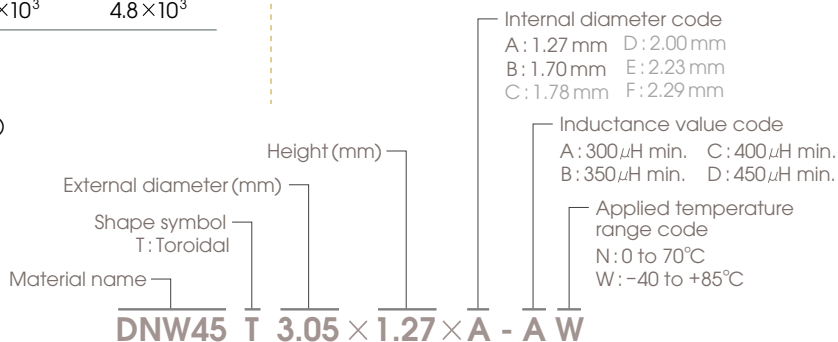
comparative example with conventional materials

Material name	DNW45	Conventional material	
		DN45	HP5
Initial permeability*1 $\mu_i$	4200±25%	4500±25%	5000±25%
Loss coefficient*2 $\tan\delta/\mu_i$	<3.5×10 <sup>-6</sup>	<3.5×10 <sup>-6</sup>	<3.5×10 <sup>-6</sup>
Saturation magnetic flux density*3 Bs (mT)	450	460	400
Curie temperature Tc (°C)	150min.	150min.	140min.
Volume resistivity*1 $\rho_V$ ( $\Omega\cdot m$ )	0.65	0.3	0.15
Bulk density db (kg/m <sup>3</sup> )	4.85×10 <sup>3</sup>	4.85×10 <sup>3</sup>	4.8×10 <sup>3</sup>

\*1. at 25°C \*2. at 25°C/10kHz \*3. at 25°C/H=1000A/m  
 Operating temperature range: -30 to +85°C  
 Operating humidity range: 0 to 90%RH  
 (Maximum wet-bulb temperature: 38°C/Non-condensing)

DNW45 material

### Nominal designations of the products



## Electrical characteristic of standard-shaped products (1)



The red letters in the chart show the coil turns needed to achieve a similar inductance using the same-shaped DN45 material (comparative referential amount).

Part No.	Inductance value code/Inductance*1 min.				Applied temperature range (°C)	A <sub>i</sub> -value*2 (nH/N <sup>2</sup> )		
	A:300 µH	B:350 µH	C:400 µH	D:450 µH				
	<b>DNW45T3.05 × 1.27 × A-AW</b>	30Ts	-	-	-40 to +85	930±25%		
	DNW45T3.05 × 1.27 × A-AN	26Ts(32Ts)	-	-	0 to 70			
	DNW45T3.05 × 1.27 × A-BN	-	30Ts	-	-			
	<b>DNW45T3.05 × 2.54 × A-AW</b>	16Ts	-	-	-40 to +85	1870±25%		
	<b>DNW45T3.05 × 2.54 × A-BW</b>	-	18Ts	-				
	<b>DNW45T3.05 × 2.54 × A-CW</b>	-	-	20Ts			-	
	<b>DNW45T3.05 × 2.54 × A-DW</b>	-	-	-			22Ts	
	DNW45T3.05 × 2.54 × A-AN	16Ts(18Ts)	-	-			-	
	DNW45T3.05 × 2.54 × A-BN	-	18Ts(20Ts)	-			-	0 to 70
DNW45T3.05 × 2.54 × A-DN	-	-	-	20Ts(24Ts)	-			
	<b>DNW45T3.4 × 1.5 × B-AW</b>	26Ts	-	-	-40 to +85	870±25%		
	<b>DNW45T3.4 × 1.5 × B-BW</b>	-	28Ts	-				
	<b>DNW45T3.4 × 1.5 × B-CW</b>	-	-	32Ts			-	
	DNW45T3.4 × 1.5 × B-AN	24Ts(28Ts)	-	-			-	
	DNW45T3.4 × 1.5 × B-BN	-	26Ts(32Ts)	-			-	0 to 70
	DNW45T3.4 × 1.5 × B-CN	-	-	30Ts(36Ts)			-	-
DNW45T3.4 × 1.5 × B-DN	-	-	-	32Ts	-			

\*1. 1.00kHz, 100mVrms, 8mAdc \*2. 1.00kHz, 100mVrms, 10Ts, 0Adc, 25°C






## DNW45 material

## Electrical characteristic of standard-shaped products (2)

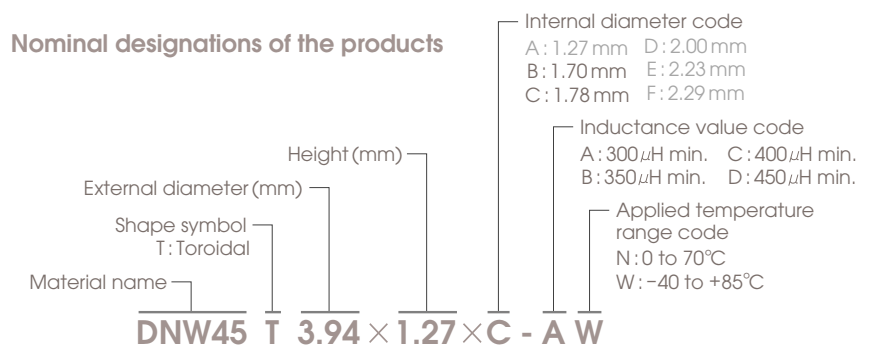


The **red letters** in the chart show the coil turns needed to achieve a similar inductance using the same-shaped DN45 material (comparative referential amount).

Part No.	Inductance value code/Inductance*1 min.				Applied temperature range (°C)	A <sub>L</sub> -value*2 (nH/N <sup>2</sup> )	
	A:300 μH	B:350 μH	C:400 μH	D:450 μH			
	<b>DNW45T3.4 × 2.5 × B-AW</b>	18Ts	-	-	-40 to +85	1460±25%	
	<b>DNW45T3.4 × 2.5 × B-BW</b>	-	20Ts	-			
	<b>DNW45T3.4 × 2.5 × B-CW</b>	-	-	22Ts			
	<b>DNW45T3.4 × 2.5 × B-DW</b>	-	-	-	24Ts		0 to 70
	DNW45T3.4 × 2.5 × B-AN	18Ts(22Ts)	-	-			
	DNW45T3.4 × 2.5 × B-BN	-	20Ts(24Ts)	-			
	DNW45T3.4 × 2.5 × B-DN	-	-	22Ts(28Ts)			
	<b>DNW45T3.94 × 1.27 × C-AW</b>	24Ts	-	-	-40 to +85	850±25%	
	<b>DNW45T3.94 × 1.27 × C-BW</b>	-	28Ts	-			
	<b>DNW45T3.94 × 1.27 × C-CW</b>	-	-	30Ts			
	<b>DNW45T3.94 × 1.27 × C-DW</b>	-	-	-	34Ts		0 to 70
	DNW45T3.94 × 1.27 × C-AN	24Ts(28Ts)	-	-			
	DNW45T3.94 × 1.27 × C-BN	-	26Ts(30Ts)	-			
	DNW45T3.94 × 1.27 × C-CN	-	-	30Ts(34Ts)			
DNW45T3.94 × 1.27 × C-DN	-	-	-	32Ts(38Ts)			
	<b>DNW45T3.94 × 1.78 × C-AW</b>	20Ts	-	-	-40 to +85	1190±25%	
	<b>DNW45T3.94 × 1.78 × C-BW</b>	-	22Ts	-			
	<b>DNW45T3.94 × 1.78 × C-CW</b>	-	-	24Ts			
	<b>DNW45T3.94 × 1.78 × C-DW</b>	-	-	-	26Ts		0 to 70
	DNW45T3.94 × 1.78 × C-AN	20Ts(22Ts)	-	-			
	DNW45T3.94 × 1.78 × C-BN	-	22Ts(24Ts)	-			
	DNW45T3.94 × 1.78 × C-CN	-	-	24Ts(26Ts)			
DNW45T3.94 × 1.78 × C-DN	-	-	-	26Ts(28Ts)			

\*1.100kHz, 100mVrms, 8mAdc \*2.100kHz, 100mVrms, 10Ts, 0Adc, 25°C

### Nominal designations of the products





DNW45 material



## Electrical characteristic of standard-shaped products (3)

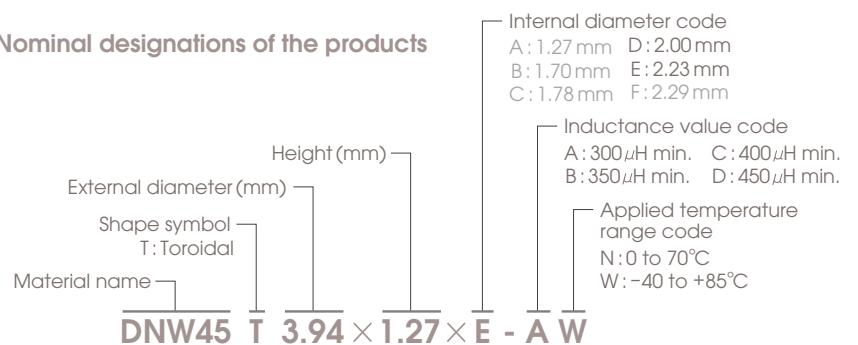


The red letters in the chart show the coil turns needed to achieve a similar inductance using the same-shaped DN45 material (comparative referential amount).

Part No.	Inductance value code/Inductance* <sup>1</sup> min.				Applied temperature range (°C)	A <sub>L</sub> -value* <sup>2</sup> (nH/N <sup>2</sup> )	
	A:300 μH	B:350 μH	C:400 μH	D:450 μH			
	<b>DNW45T3.94 × 1.27 × E-AW</b>	30Ts	-	-	-40 to +85	610 ± 25%	
	<b>DNW45T3.94 × 1.27 × E-BW</b>	-	34Ts	-			
	<b>DNW45T3.94 × 1.27 × E-CW</b>	-	-	40Ts			
	DNW45T3.94 × 1.27 × E-AN	30Ts(32Ts)	-	-	0 to 70		
	DNW45T3.94 × 1.27 × E-BN	-	34Ts(36Ts)	-			
	DNW45T3.94 × 1.27 × E-CN	-	-	36Ts(40Ts)			
	DNW45T3.94 × 1.27 × E-DN	-	-	40Ts			
	<b>DNW45T3.94 × 1.78 × E-AW</b>	26Ts	-	-	-40 to +85	850 ± 25%	
	<b>DNW45T3.94 × 1.78 × E-BW</b>	-	28Ts	-			
	<b>DNW45T3.94 × 1.78 × E-CW</b>	-	-	30Ts			
	<b>DNW45T3.94 × 1.78 × E-DW</b>	-	-	-	32Ts		0 to 70
	DNW45T3.94 × 1.78 × E-AN	24Ts(28Ts)	-	-			
	DNW45T3.94 × 1.78 × E-BN	-	26Ts(32Ts)	-			
	DNW45T3.94 × 1.78 × E-CN	-	-	28Ts(34Ts)			
DNW45T3.94 × 1.78 × E-DN	-	-	30Ts(38Ts)				
	<b>DNW45T4 × 1 × D-AW</b>	32Ts	-	-	-40 to +85	580 ± 25%	
	<b>DNW45T4 × 1 × D-BW</b>	-	36Ts	-			
	DNW45T4 × 1 × D-AN	30Ts(34Ts)	-	-	0 to 70		
	DNW45T4 × 1 × D-BN	-	34Ts(40Ts)	-			
	DNW45T4 × 1 × D-CN	-	-	38Ts			

\*1.100kHz, 100mVrms, 8mAdc \*2.100kHz, 100mVrms, 10Ts, 0Adc, 25°C

### Nominal designations of the products





DNW45 material



## Electrical characteristic of standard-shaped products (4)

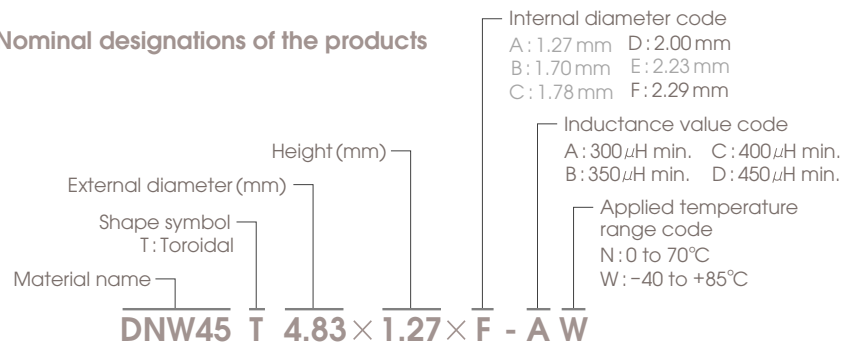


The red letters in the chart show the coil turns needed to achieve a similar inductance using the same-shaped DN45 material (comparative referential amount).

Part No.	Inductance value code/Inductance*1 min.				Applied temperature range (°C)	A <sub>L</sub> -value*2 (nH/N <sup>2</sup> )
	A:300 μH	B:350 μH	C:400 μH	D:450 μH		
<b>DNW45T4 × 2 × D-AW</b>	20Ts	-	-	-	-40 to +85	1160±25%
<b>DNW45T4 × 2 × D-BW</b>	-	22Ts	-	-		
<b>DNW45T4 × 2 × D-CW</b>	-	-	24Ts	-		
<b>DNW45T4 × 2 × D-DW</b>	-	-	-	26Ts		
DNW45T4 × 2 × D-AN	20Ts(22Ts)	-	-	-	0 to 70	
DNW45T4 × 2 × D-BN	-	22Ts(24Ts)	-	-		
DNW45T4 × 2 × D-CN	-	-	24Ts(26Ts)	-		
DNW45T4 × 2 × D-DN	-	-	-	26Ts(28Ts)		
<b>DNW45T4.83 × 1.27 × F-AW</b>	26Ts	-	-	-	-40 to +85	800±25%
<b>DNW45T4.83 × 1.27 × F-BW</b>	-	28Ts	-	-		
<b>DNW45T4.83 × 1.27 × F-CW</b>	-	-	30Ts	-		
<b>DNW45T4.83 × 1.27 × F-DW</b>	-	-	-	32Ts		
DNW45T4.83 × 1.27 × F-AN	24Ts(26Ts)	-	-	-	0 to 70	
DNW45T4.83 × 1.27 × F-BN	-	26Ts(30Ts)	-	-		
DNW45T4.83 × 1.27 × F-CN	-	-	28Ts(32Ts)	-		
DNW45T4.83 × 1.27 × F-DN	-	-	-	30Ts(34Ts)		

\*1.100kHz, 100mVrms, 8mAac \*2.100kHz, 100mVrms, 10Ts, 0Aac, 25°C

### Nominal designations of the products

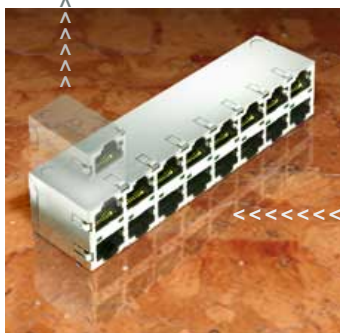
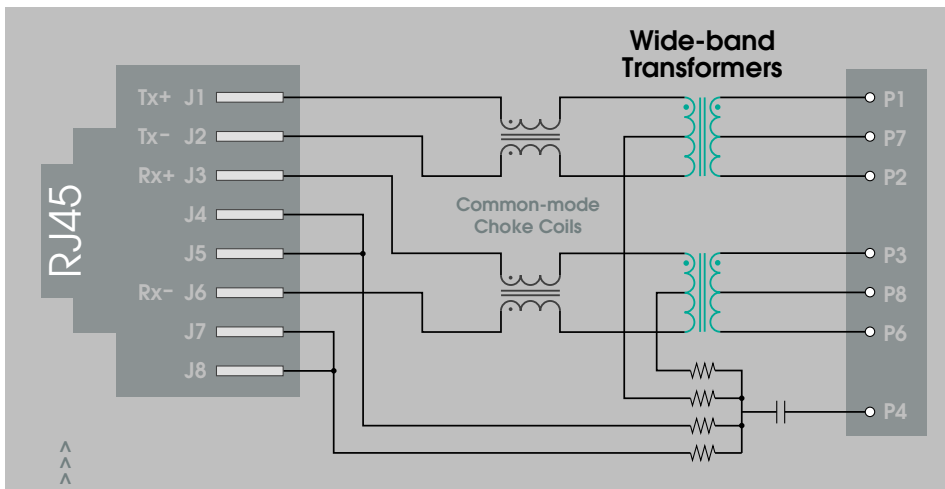


# Example of application

10/100Base-T RJ45 JACK



DNW45 material



Modular Jack

