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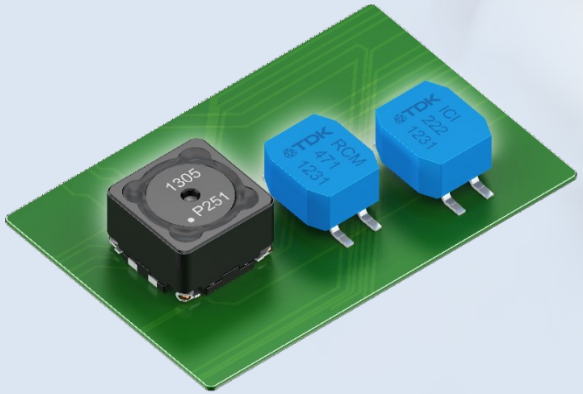
TDK

Single Pair Ethernet (SPE) in Industrial Applications

Inductor solutions for 10BASE-T1L



TDK Electronics AG
Magnetics Business Group • MAG IN PM
Munich, Germany
April 2024

Single Pair Ethernet
Motivation & Terminology

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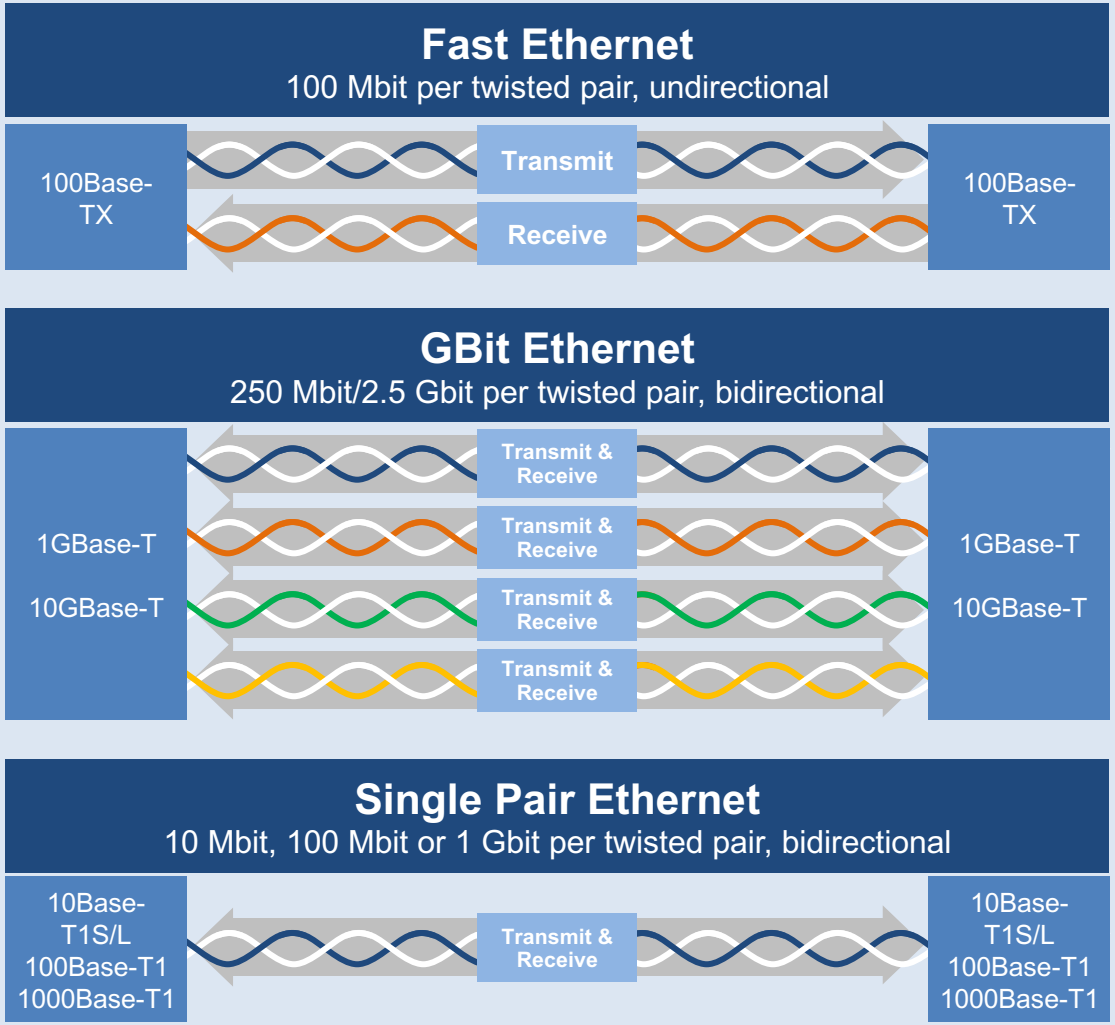
Motivation

SPE fulfills one of the essential requirements for IoT and Industry 4.0 applications: Continuous intelligent networking across all levels

- **Consistent:** Uniform Ethernet-based communication from the sensor to the cloud
- **Future-proof:** Comprehensive key technology for Industry 4.0 and IoT
- **Simple:** Reduced cabling effort by reducing to only one pair of wires
- **Flexible:** Can be used across applications with ranges of up to 1,000 m and transmission speeds of up to 10 Gbit/s

Terminology

- **SPE** = Single Pair Ethernet, alternative standard to regular LAN, data rates up to Gbit/s with one pair of cables
- **PoDL** = Power-over-DataLine, working with one-pair PHYs and cable length of up to 1,000 m
- **SPoE** = Single Pair Power over Ethernet, different naming for PoDL
- **PoE** = Power-over-Ethernet, working with 2-pair and 4-pair PHYs
- **10BASE-T1L** = Physical layer standard (IEEE Standard 802.3cg), data rate 10 Mbit/s



Single Pair Ethernet
Product Line-up

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Common-Mode Choke (CMC)

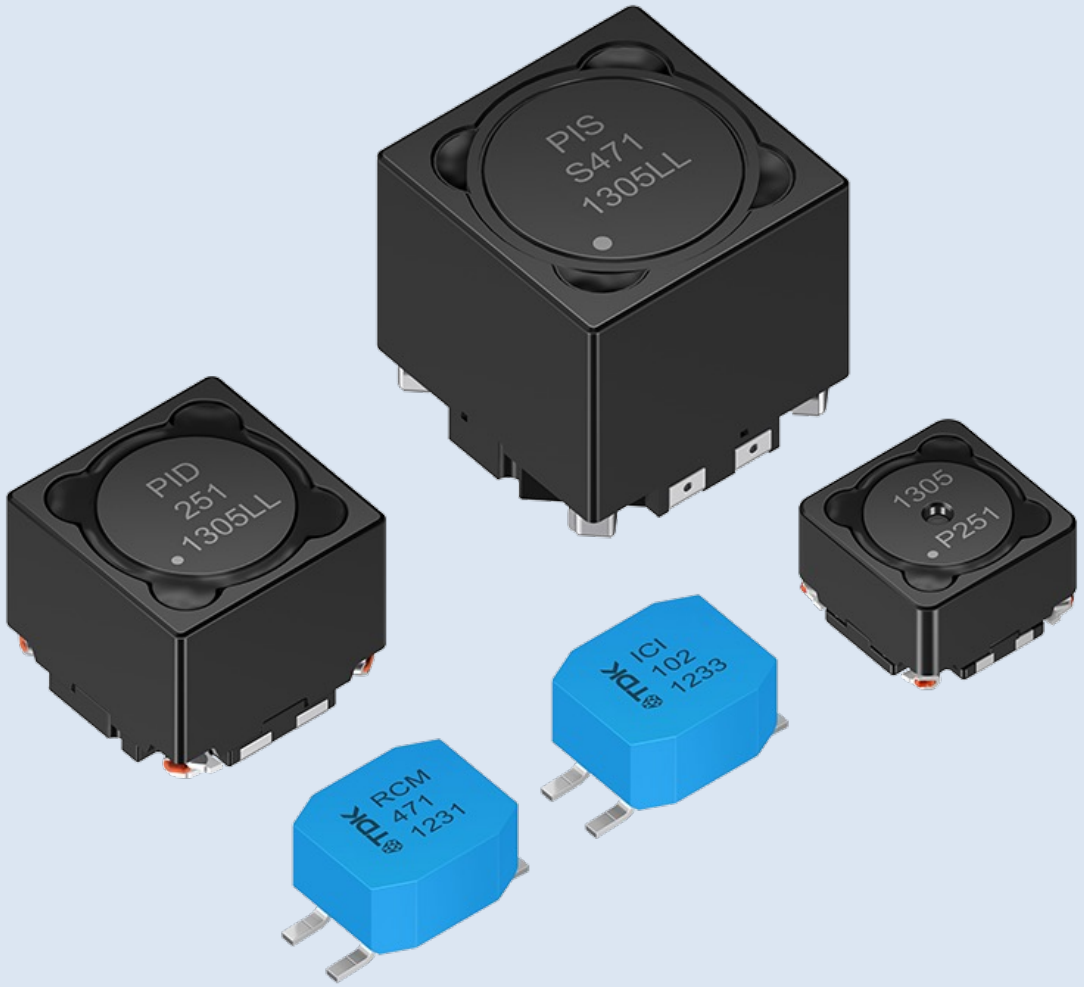
- Used for suppression of asymmetrical interference
- Rated inductance of 470 µH
- Rated current up to 700 mA ideally for PHY side injection up to (IEEE power class 15)

Isolation Inductors (Isolation)

- Used for galvanic isolation or 1:1 coupling of data signal
- Rated inductance of 1.0 mH or 2.2 mH
- Voltage strength up to 2.250 V DC

Differential Mode Inductors (DMI)

- Used to enable power over DataLine (PoDL)
- Suitable for both IEEE 802.3cg and APL power classes
- Rated inductance with 56 µH, 65 µH or 250 µH per winding
- Functional isolation up to 500 V
- Sizes depending on current transmission from 7.5 x 7.5 up to 15.5 x 15.5 mm



Single Pair Ethernet System Considerations

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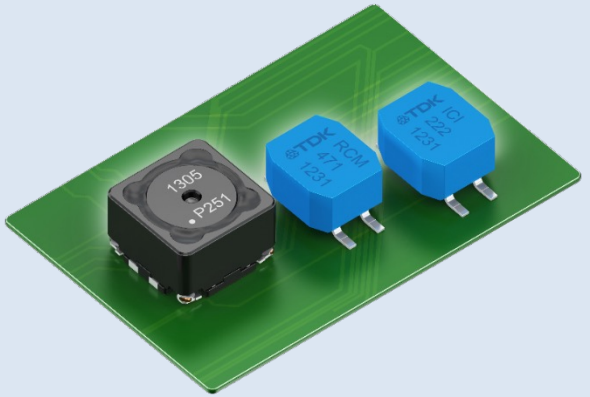
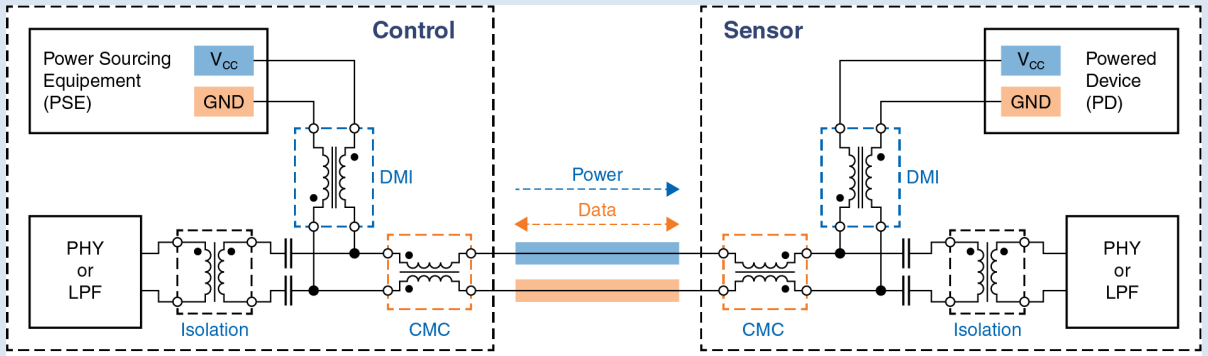
V_{PSE} max. ($V_{PSE\ OC}$ max.)	30 V (20 V)			58 V (40 V)		
Class	Class 10	Class 11	Class 12	Class 13	Class 14	Class 15
I_{PI} max.	**92 mA**	**240 mA**	**632 mA**	**231 mA**	**600 mA**	**1579 mA**
P_{class} min. (P_{PD} max.)	1.85 W (1.23 W)	4.8 W (3.2 W)	12.63 W (8.4 W)	11.54 W (7.7 W)	30 W (20 W)	79 W (52 W)
V_{PD} min.	14 V	14 V	14 V	35 V	35 V	35 V
Cable AWG/length	18/1000 m	14/1000 m	24/300 m	18/1000 m	14/1000 m	24/300 m

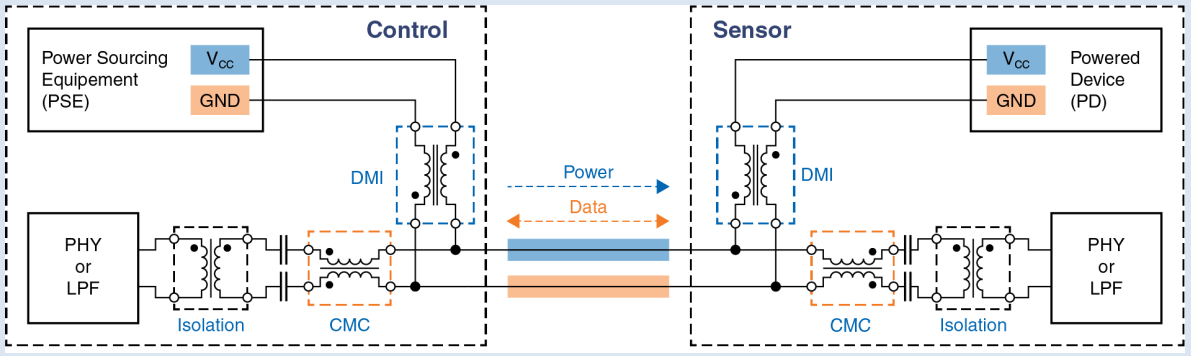
OC: Open circuit voltage
PI: Power interface



PHY side injection for power classes 10-14



Line side injection for power class 15



TDK Solutions for 10BASE-T1L
Common-mode Choke RCM70CGI

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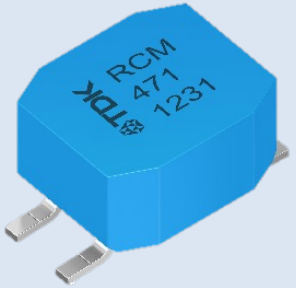
Features

- Temperature range -40 to +125 °C (incl. self-heating)
- Suitable for lead-free reflow soldering as referenced in JEDEC J-STD 020E
- High current rating



Applications

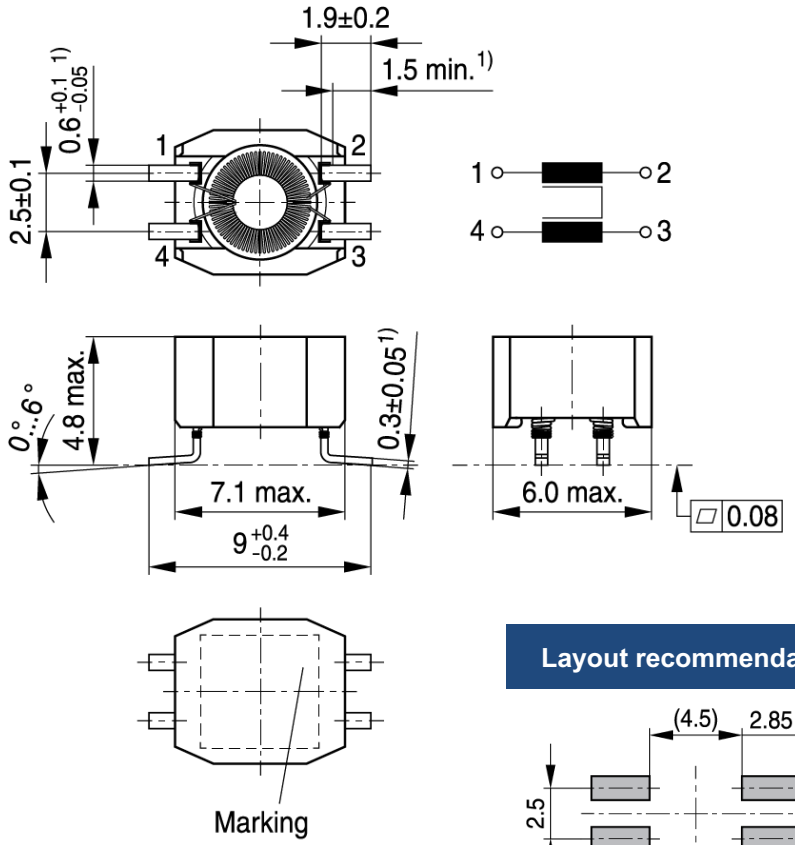
- Industrial Single Pair Ethernet (SPE)
- Common-mode choke for 10BASE-T1L (IEEE 802.3cg)

Electrical characteristics

Part #	L_R [µH]	Tol. [%]	$L_{stray, typ}$ [nH]	$R_{DC, typ}$ [Ω]	$I_{R, typ}$ [mA]	V_{test} [V] 2 seconds
RCM70CGI-471	470	+/-30	110	0.17	700	250

DC resistance R_{DC}: Specified per winding
Rated current I_R: Based on the temperature increase (40 K by self-heating); ambient temperature: 85 °C

Dimensional drawing and pin configuration



Layout recommendation

TDK Solutions for 10BASE-T1L
Isolation Inductors ICI70CGI

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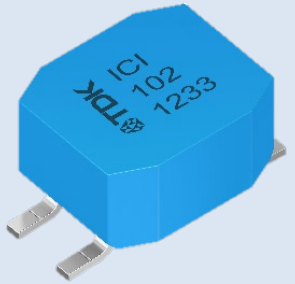
Features

- Temperature range -40 to +125 °C (incl. self-heating)
- Suitable for lead-free reflow soldering as referenced in JEDEC J-STD 020E
- High isolation capability



Applications

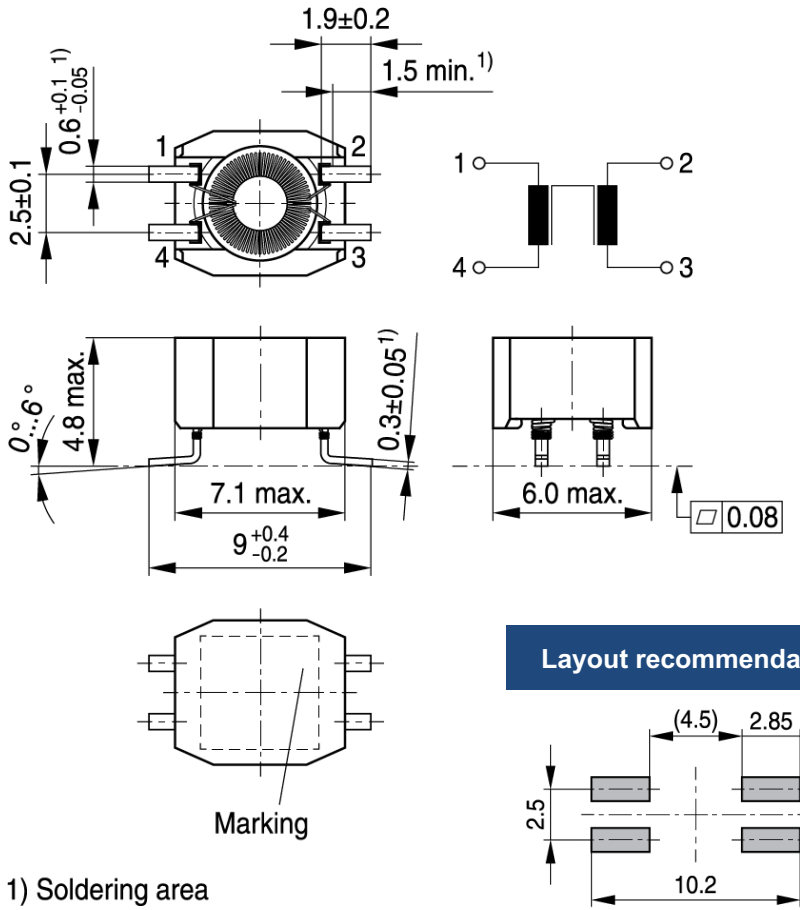
- Industrial Single Pair Ethernet (SPE)
- Isolating inductor for 10BASE-T1L (IEEE 802.3cg)

Electrical characteristics

Part #	L_R [mH]	Tol. [%]	$L_{stray, typ}$ [nH]	$R_{DC, typ}$ [Ω]	C_{typ} [pF]	V_{test} [V] 2 seconds
ICI70CGI-102	1.0	-30/+50	150	0.165	14	2250
ICI70CGI-222	2.2	-30/+50	150	0.420	18	2250

DC resistance R_{DC}: Specified per winding

Dimensional drawing and pin configuration



Layout recommendation

TDK Solutions for 10BASE-T1L (10% droop)
Differential Mode Inductors PID*-251M

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Features

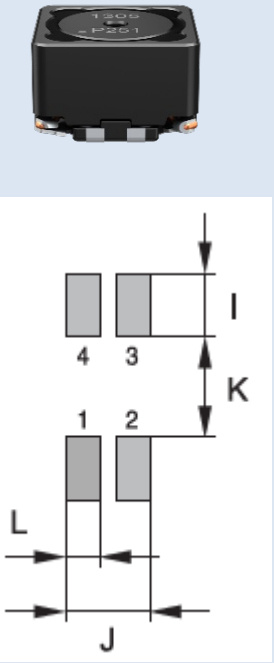
- Temperature range -40 to +150 °C (incl. self-heating)
- Suitable for lead-free reflow soldering as referenced in JEDEC J-STD 020E
- High rated current with low DC resistance
- Functional isolation up to 500 V

Applications

- Industrial Single Pair Ethernet (SPE)
- Differential mode choke for Power over Data Line (PoDL) for 10BASE-T1L (IEEE 802.3cg)

Technical data

- Rated inductance 250 µH ± 20% (per winding)
- PoDL inductance 1000 µH (equivalent inductance when both windings are connected in series (measured in 1-4 with 2-3 shorted)



Electrical characteristics and layout recommendation

Part #	Dimension, max [L x W x H, mm]	$R_{DC, typ}$ [Ω]	$I_{Sat, typ}$ [mA]	$I_{R, typ}$ [mA] (ambient temp.)	I	J	K	L
PID75-251M	7.5 x 7.5 x 4.8	2.25	360	270 (25 °C) 250 (85 °C) 240 (105 °C)	2.1	2.8	3.3	1.1
PID100-251M	10.4 x 10.4 x 6.3	1.13	645	460 (25 °C) 410 (85 °C) 400 (105 °C)	2.4	4.5	5.7	1.7
PID120L-251M	12.5 x 12.5 x 8.5	0.65	910	650 (25 °C) 530 (85 °C) 500 (105 °C)	3.1	5.8	6.8	2.3
PID120H-251M	12.5 x 12.5 x 10.5	0.41	1160	820 (25 °C) 675 (85 °C) 635 (105 °C)	3.1	5.8	6.8	2.3
PID150H-251M	15.5 x 15.5 x 14.5	0.27	1200	1200 (25 °C) 1070 (85 °C) 1040 (105 °C)	4.2	6.6	7.4	2.6

Circuit diagram

DC resistance R_{DC}: Specified per winding
Saturation current I_{Sat}: Based on the inductance decrease (30% below initial value)
Rated current I_R: Based on the temperature increase (40 K by self-heating); ambient temperature: 25/85/105 °C

TDK Solutions for 10BASE-T1L (10% droop)
Differential Mode Inductor PIS150H-471M

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Features

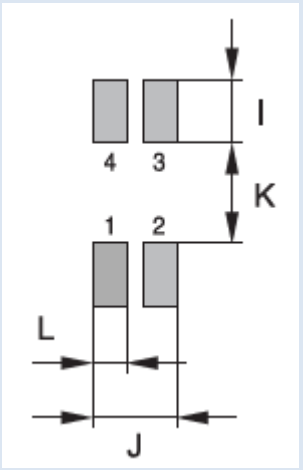
- Temperature range -40 to +150 °C (incl. self-heating)
- Suitable for lead-free reflow soldering as referenced in JEDEC J-STD 020E
- High rated current with low DC resistance
- Functional isolation up to 500 V

Applications

- Industrial Single-Pair Ethernet (SPE)
- Differential mode choke for Power over Data Line (PoDL) for 10BASE-T1L (IEEE 802.3cg)

Technical data

- Rated inductance 470 µH ±20% (per winding)



Electrical characteristics and layout recommendation

Part #	Dimension, max [L x W x H, mm]	$R_{DC, typ}$ [Ω]	$I_{Sat, typ}$ [mA]	$I_{R, typ}$ [mA] (ambient temp.)	I	J	K	L
PIS150H-471M	15.5 x 15.5 x 14.5	0.25	2300	1810 (25 °C) 1650 (85 °C) 1600 (105 °C)	4.2	6.6	7.4	2.6

DC resistance R_{DC}: Specified per winding
Saturation current I_{Sat}: Based on the inductance decrease (30% below initial value)
Rated current I_R: Based on the temperature increase (40 K by self-heating); ambient temperature: 25/85/105 °C

Circuit diagram

TDK Solutions for 10BASE-T1L (25% droop)
Differential Mode Inductors PID*-650M

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Features

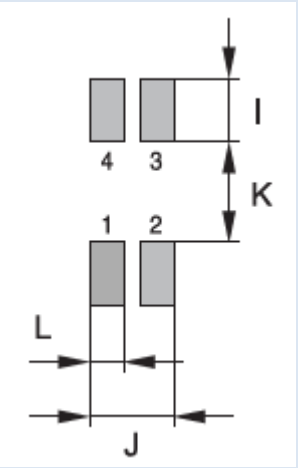
- Temperature range -40 to +150 °C (incl. self-heating)
- Suitable for lead-free reflow soldering as referenced in JEDEC J-STD 020E
- High rated current with low DC resistance
- Functional isolation up to 500 V

Applications

- Industrial Single-Pair Ethernet (SPE)
- Differential mode choke for Power over Data Line (PoDL) for 10BASE-T1L (IEEE 802.3 cg)

Technical data

- Rated inductance 65 µH ±20% (per winding)
- PoDL inductance 250 µH (equivalent inductance when both windings are connected in series (measured in 1-4 with 2-3 shorted)



Electrical characteristics and layout recommendation

Part #	Dimension, max [L x W x H, mm]	$R_{DC, typ}$ [Ω]	$I_{Sat, typ}$ [mA]	$I_{R, typ}$ [mA] (ambient temp.)	I	J	K	L
PID75-650M	7.5 x 7.5 x 4.8	0.53	750	560 (25 °C) 505 (85 °C) 490 (105 °C)	2.1	2.8	3.3	1.1
PID100-650M	10.4 x 10.4 x 6.3	0.30	1200	880 (25 °C) 780 (85 °C) 750 (105 °C)	2.4	4.5	5.7	1.7
PID120L-650M	12.5 x 12.5 x 8.5	0.19	1800	1280 (25 °C) 1160 (85 °C) 1120 (105 °C)	3.1	5.8	6.8	2.3
PID120HS-650M	12.5 x 12.5 x 10.5	0.12	2100	1640 (25 °C) 1450 (85 °C) 1390 (105 °C)	3.1	5.8	6.8	2.3

DC resistance R_{DC}: Specified per winding
Saturation current I_{Sat}: Based on the inductance decrease (30% below initial value)
Rated current I_R: Based on the temperature increase (40 K by self-heating); ambient temperature: 25/85/105 °C

Circuit diagram

TDK Solutions for 10BASE-T1L (25% droop)
Differential Mode Inductors PID*-560M

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Features

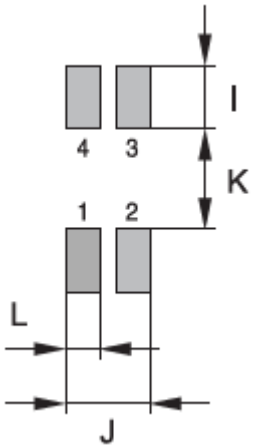
- Temperature range -40 to +150 °C (incl. self-heating)
- Suitable for lead-free reflow soldering as referenced in JEDEC J-STD 020E
- High rated current with low DC resistance
- Functional isolation up to 500 V

Applications

- Industrial Single-Pair Ethernet (SPE)
- Differential mode choke for Power over Data Line (PoDL) for 10BASE-T1L (IEEE 802.3 cg)

Technical data

- Rated inductance 56 µH ±20% (per winding)
- PoDL inductance 225 µH (equivalent inductance when both windings are connected in series (measured in 1-4 with 2-3 shorted)



Electrical characteristics and layout recommendation

Part #	Dimension, max [L x W x H, mm]	$R_{DC, typ}$ [Ω]	$I_{Sat, typ}$ [mA]	$I_{R, typ}$ [mA] (ambient temp.)	I	J	K	L
PID75-560M	7.5 x 7.5 x 4.8	0.48	800	580 (25 °C) 530 (85 °C) 500 (105 °C)	2.1	2.8	3.3	1.1
PID100-560M	10.4 x 10.4 x 6.3	0.28	1350	950 (25 °C) 790 (85 °C) 770 (105 °C)	2.4	4.5	5.7	1.7
PID120L-560M	12.5 x 12.5 x 8.5	0.17	1950	1350 (25 °C) 1200 (85 °C) 1150 (105 °C)	3.1	5.8	6.8	2.3
PID120HS-560M	12.5 x 12.5 x 10.5	0.09	2200	1900 (25 °C) 1740 (85 °C) 1680 (105 °C)	3.1	5.8	6.8	2.3

DC resistance R_{DC}: Specified per winding
Saturation current I_{Sat}: Based on the inductance decrease (30% below initial value)
Rated current I_R: Based on the temperature increase (40 K by self-heating); ambient temperature: 25/85/105 °C

Circuit diagram

Further Information and Contact

Technical information

- Data sheets
- Application note
- Product Brief & Landing page

Design support

- Sample kits
- Footprint and 3D files
- Evaluation boards

Get in contact

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