DATA SHEET

Introduction and Applications for Coaxial Resonators and Inductors (300 MHz–6.0 GHz)

Features

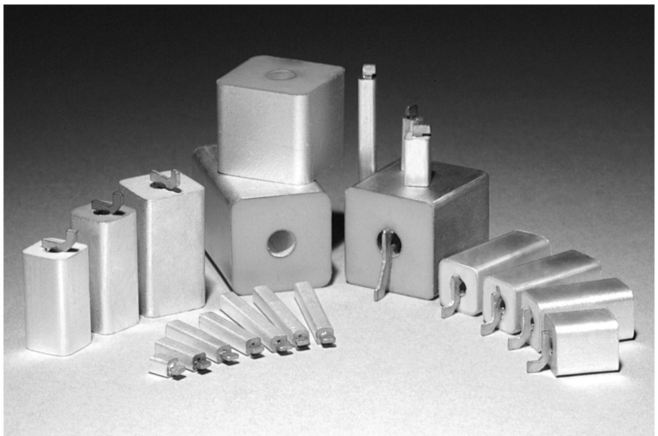
- Frequency tuned to 0.5% and 1%
- High dielectric constant
- Rugged construction
- Low loss silver
- Act as parallel resonant circuit or a high quality inductor

Benefits

- Circuit miniaturization
- Eliminate microphonics
- Repeatability of design
- Negligible aging effects
- Excellent solderability
- Improved circuit Q
- High resonant impedance
- Automation compatible

Typical Applications

- Low phase noise VCOs
- DRO/VCO oscillators
- Narrow band filters
- Nationwide pagers
- Duplexers
- Global positioning systems
- UHF tuned potential amplifiers
- Wireless communications
- Tuned oscillators



Introduction

Trans-Tech Inc., a wholly-owned subsidiary of Skyworks Solutions Inc., offers ceramic coaxial line elements in seven sizes and four dielectric constants to span applications from 300 MHz to 6 GHz. The VHF/UHF frequency bands are traditionally awkward for realizing discrete inductors and capacitors. Metallized ceramics provide an attractive alternative, since the wireless communication market now forces a continuous trade-off between performance and miniaturization.

Trans-Tech ceramic solution offers advantages of high Q, reduced size, better shielding, and temperature performance superior to that obtainable from conventional L-C circuits or microstrip construction.

Two types of coaxial resonators are offered by Trans-Tech, a quarter-wave short ($\lambda/4$) and a half-wave open ($\lambda/2$). The quarter-wave has thick-film silver applied to one end. The half-wave has both ends unmetallized.

Trans-Tech four dielectric materials are briefly summarized in Figure 1.1 along with their recommended frequencies of use. The Material Properties Chart (Figure 1.2) can be used to determine the optimum material necessary for an application.

Trans-Tech
Ceramics and Advanced Materials

Figure 1.1 Material Selection Chart

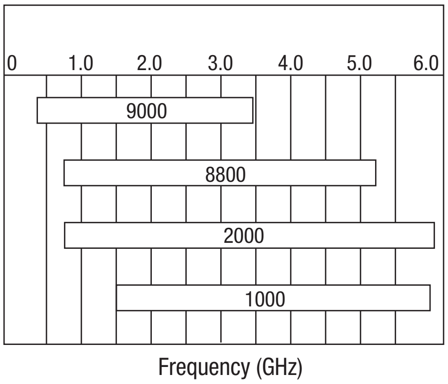


Figure 1.2 Material Properties

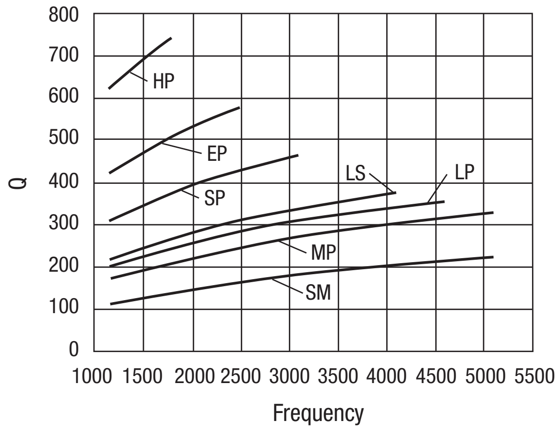
	Material Type			
	1000	2000	8800	9000
Dielectric constant	10.5 ± 0.5	20.6 ± 1.0	39 ± 1.5	90 ± 3
Temperature coefficient of resonant frequency τ_F (ppm °C)	0 ± 10	0 ± 10	+4 ± 2	0 ± 10

Properties given for the ceramic materials used to produce the coaxial line elements are measured for internal quality control purposes. The electrical quality factor (Q) of the coaxial line elements is determined primarily by the metallization. Typical properties of the coaxial line elements are listed in the Coaxial Resonator Quality Factor Specifications tables.

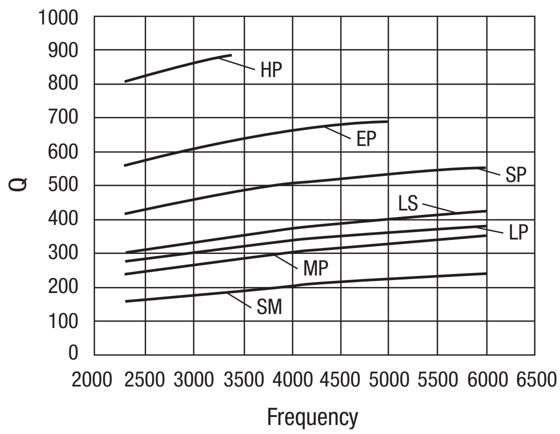
Quality Factor (Q) Specification — 1000 & 2000

The quality factors for various resonator profiles are shown in in the following charts. The resonators are grouped by wavelength type (λ/4 & λ/2), material (1000 & 2000), and profile (HP, EQ, SP, LS, MP, SM). The listed Q value on each curve is the value guaranteed for the lowest operating frequency of each component type. The Q increases approximately as the square root of increasing frequency. Typical Qs are 10% to 15% higher.

1000 Series Q Curves

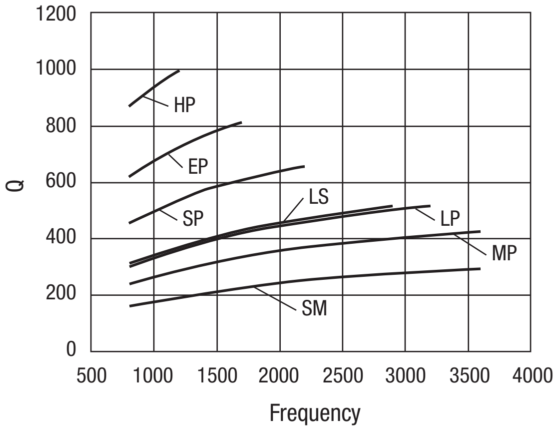


D1000 Quarter-Wave Q Curves

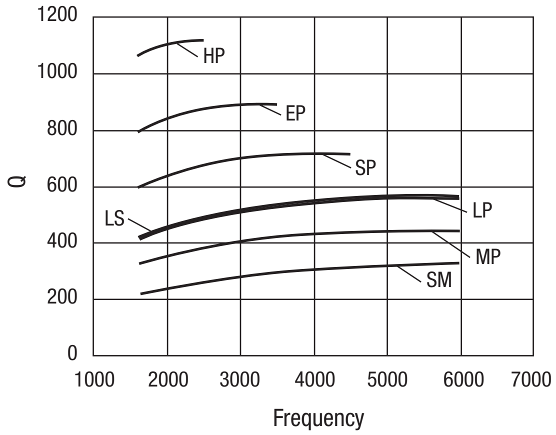


D1000 Half-Wave Q Curves

2000 Series Q Curves



D2000 Quarter Wave Q Curves

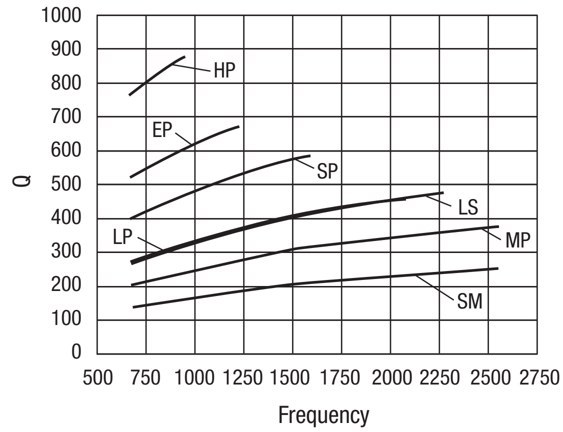


D2000 Half-Wave Q Curves

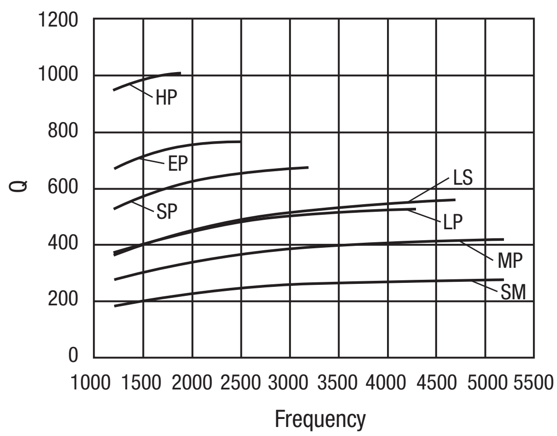
Quality Factor (Q) Specification — 8800 & 9000

The specified quality factors of the various resonator components offered are shown in the following charts. The resonators are grouped by wavelength type (λ/4 & λ/2), material (8800 & 9000), and profile (HP, EP, SP, LP, LS, MP, SM). The listed Q value on each curve is the minimum value for the lowest operating frequency of each component type. The Q increases approximately as the square root of increasing frequency. Typical Qs are 10% to 15% higher.

8800 Series Q Curves

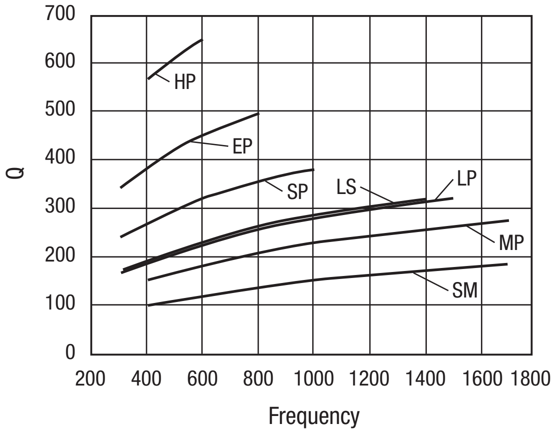


D8800 Quarter Wave Q Curves

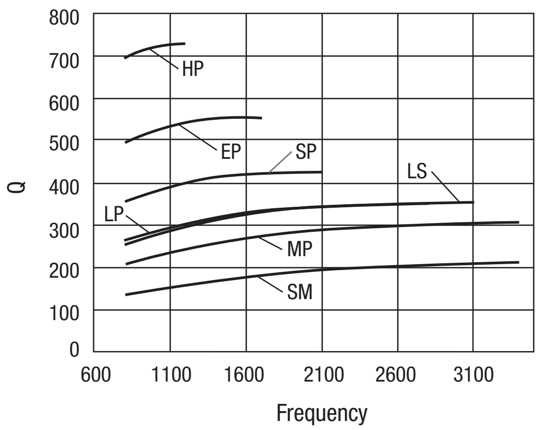


D8800 Half-Wave Q Curves

9000 Series Q Curves



D9000 Quarter Wave Q Curves



D9000 Half-Wave Q Curves

Dimensions & Configurations

Trans-Tech coaxial resonator components are available in the frequency range of 300 MHz to 6 GHz. Seven mechanical profiles are offered to give the designer the greatest flexibility in selecting the electrical quality factor (Q). The high profile (HP) has the highest Q and size. The enhanced Q profile (EP) offers a high Q and wide frequency offering. The standard profile (SP) offers a compromise of electrical Q and size, and should be considered the component of choice for most applications.

Trans-Tech offers four smaller profiles for occasions when available space is restricted. The low profile (LP), large profile (LS), miniature profile (MP), and sub-miniature profile (SM) provide the designer with a trade-off between electrical Q and compact size. Trans-Tech low profile (LP) and large profile (LS) both have the same outer physical dimensions. They differ in the dimension of the inner diameter, which allows for different characteristic impedances, and increases the options available to designers. Overall comparisons can be determined from the given Q curves or by utilizing Trans-Tech COAX Program.

These components are available in square configurations with dimensions shown in Figure 1.3a–1.3g.

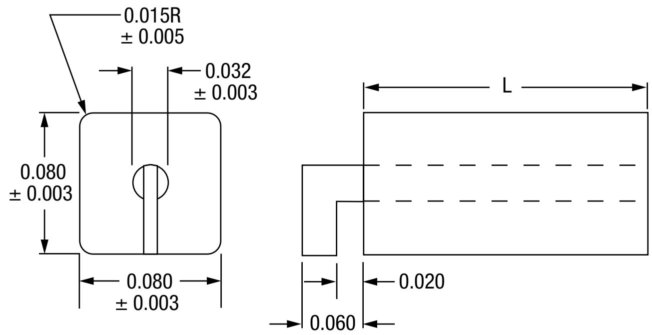


Figure 1.3a. SM – Sub-Miniature Profile (2 mm)

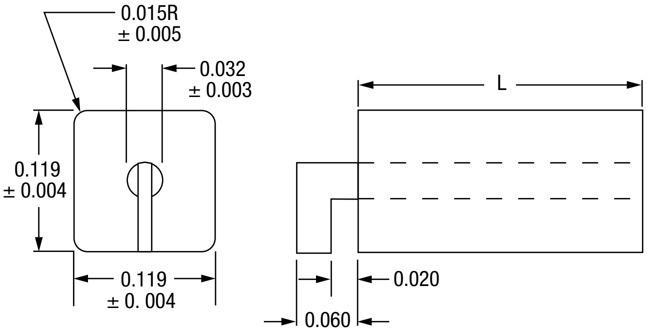


Figure 1.3b. MP – Miniature Profile (3 mm)

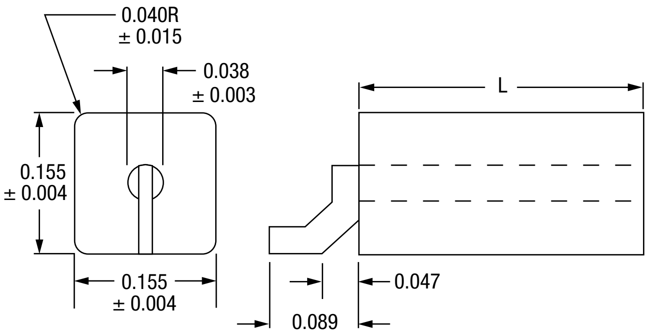


Figure 1.3c. LP – Low Profile (4 mm)

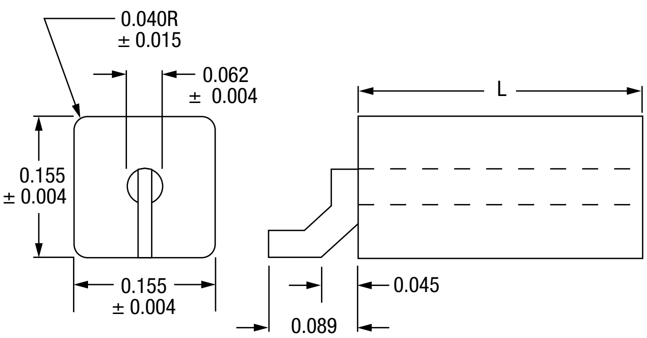


Figure 1.3d. LS – Large Diameter (4 mm)

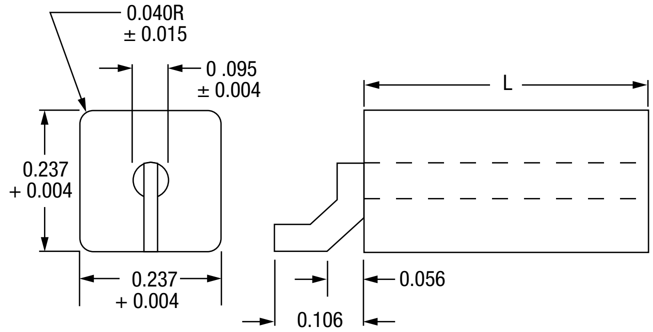


Figure 1.3e. SP – Standard Profile (6 mm)

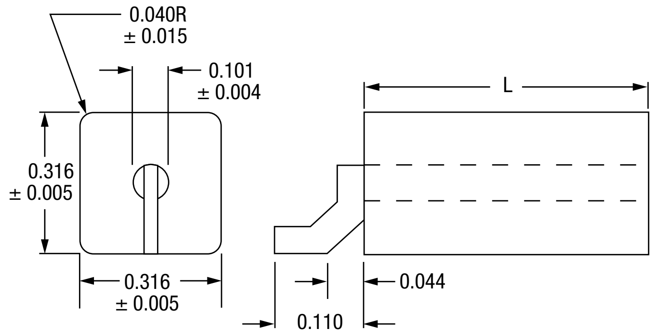


Figure 1.3f. EP – Enhanced Q Profile (8 mm)

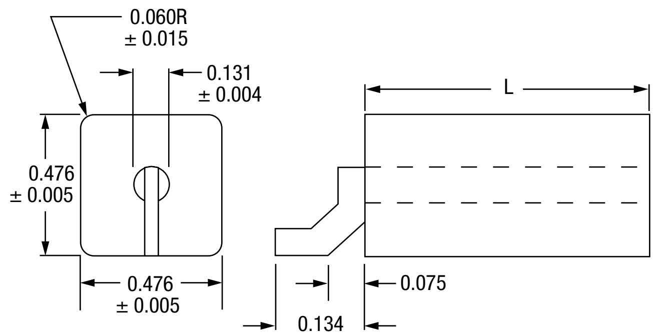


Figure 1.3g. HP – High Profile (12 mm)

Ceramic Coaxial Resonators*

The various profiles, materials and types available for the Trans-Tech coaxial TEM mode resonators are summarized in the following charts. You have a choice of two types, four materials and seven profiles. This range of component variables should meet most circuit design requirements. While the component is manufactured to frequency, a formula is given so that the approximate length can be determined. The selected resonant frequency is available with two standard frequency tolerances of ± 0.5% and ± 1.0%. The minimum tolerance is ± 2 MHz. Please note that the ordered value of f_0 will be set according to our measurement procedure. The f_0 in your circuit may vary due to stray reactance. This offset can be corrected by changing the ordered value of f_0.

Recommended Frequencies 1000 Series (ε_R = 10.5 ± 0.5, T_F = 0 ± 10)

Type	Profile	Recommended Range f_0 (MHz)	Nominal Length (in.) ± 0.030 in.	Nominal Length Range (in.)	Characteristic Impedance (Ω)
λ/4 Quarter wave length	HP	800–1150	L = 911/f_0 (MHz)	0.506–0.792	25.3
	EP	1150–2500		0.364–0.792	22.5
	SP	1150–3100		0.294–0.792	18.3
	LS	1150–4600		0.198–0.792	18.4
	LP	1150–4100		0.222–0.792	27.4
	MP	1150–5100		0.179–0.792	25.7
	SM	1150–5100		0.179–0.792	18.4
λ/2 Half wave length	HP	2300–3400	L = 1821/f_0 (MHz)	0.536–0.792	25.3
	EP	2300–5000		0.364–0.792	22.5
	SP	2300–6000		0.304–0.792	18.3
	LS	2300–6000		0.304–0.792	18.4
	LP	2300–6000		0.304–0.792	27.4
	MP	2300–6000		0.304–0.792	25.7
	SM	2300–6000		0.304–0.792	18.4

Recommended Frequencies 2000 Series (ε_R = 20.6 ± 1, T_F = 0 ±10)

Type	Profile	Recommended Range f_0 (MHz)	Nominal Length (in.) ± 0.030 in.	Nominal Length Range (in.)	Characteristic Impedance (Ω)
λ/4 Quarter wave length	HP	800–1200	L = 650/f_0 (MHz)	0.542–0.813	18.1
	EP	800–1700		0.382–0.813	16.1
	SP	800–2200		0.296–0.813	13.1
	LS	800–3200		0.203–0.813	13.1
	LP	800–2900		0.224–0.813	19.6
	MP	800–3600		0.181–0.813	18.4
	SM	800–3600		0.181–0.813	13.1
λ/2 Half wave length	HP	1600–2500	L = 1300/f_0 (MHz)	0.520–0.813	18.1
	EP	1600–3500		0.372–0.813	16.1
	SP	1600–4500		0.289–0.813	13.1
	LS	1600–6000		0.217–0.813	13.1
	LP	1600–6000		0.217–0.813	19.6
	MP	1600–6000		0.217–0.813	18.4
	SM	1600–6000		0.217–0.813	13.1

Recommended Frequencies 8800 Series (ε_R = 39 ± 1.5, T_F = 4 ± 2)

Type	Profile	Recommended Range f_0 (MHz)	Nominal Length (in.) ± 0.030 in.	Nominal Length Range (in.)	Characteristic Impedance (Ω)
λ/4 Quarter wave length	HP	600–900	L = 472/f_0 (MHz)	0.525–0.787	13.1
	EP	600–1200		0.394–0.787	11.7
	SP	600–1600		0.295–0.787	9.5
	LS	600–2300		0.205–0.787	9.5
	LP	600–2100		0.225–0.787	14.2
	MP	600–2600		0.182–0.787	13.3
	SM	600–2600		0.182–0.787	9.5
λ/2 Half wave length	HP	1200–1900	L = 945/f_0 (MHz)	0.497–0.787	13.1
	EP	1200–2500		0.378–0.787	11.7
	SP	1200–3200		0.295–0.787	9.5
	LS	1200–4700		0.201–0.787	9.5
	LP	1200–4300		0.220–0.787	14.2
	MP	1200–5200		0.182–0.787	13.3
	SM	1200–5200		0.182–0.787	9.5

Recommended Frequencies 9000 Series (ε_R = 90 ± 3, T_F = 0 ± 10)

Type	Profile	Recommended Range f_0 (MHz)	Nominal Length (in.) ± 0.030 in.	Nominal Length Range (in.)	Characteristic Impedance (Ω)
λ/4 Quarter wave length	HP	400–600	L = 311/f_0 (MHz)	0.518–0.778	8.6
	EP	300–800		0.389–1.037	7.7
	SP	300–1000		0.311–1.037	6.3
	LS	300–1500		0.207–1.037	6.3
	LP	300–1400		0.222–1.037	9.4
	MP	400–1700		0.183–0.778	8.8
	SM	400–1700		0.183–0.778	6.3
λ/2 Half wave length	HP	800–1200	L = 622/f_0 (MHz)	0.518–0.778	8.6
	EP	800–1700		0.366–0.778	7.7
	SP	800–2100		0.296–0.778	6.3
	LS	800–3100		0.201–0.778	6.3
	LP	800–2800		0.222–0.778	9.4
	MP	800–3400		0.183–0.778	8.8
	SM	800–3400		0.183–0.778	6.3

Coaxial Resonator Order Information

An Order Example

SR 8800 SP Q 1300 B Y E

- **E** — **Green, lead (Pb)-free, RoHS-compliant, conform to the EIA/EICTA/JEITA Joint Industry Guide (JIG) Level A guidelines, and are free from antimony trioxide and brominated flame retardants.**
- **Y** — **Tab:** Y = Yes, N = No
- **B** — **Frequency Tolerance:** B = +1.0%, A = 0.5%
- **1300** — **Resonant Frequency:** State in MHz
- **Q** — **Type:** Q for λ/4, H for λ/2
- **SP** — **Profile:** HP, EP, SP, LP, LS, MP, SM
- **8800** — **Material:** 8800, 9000, 1000, 2000
- **SR** — **Product Code:** SR - square coaxial resonator

Ceramic Coaxial Inductors*

Trans-Tech coaxial inductors are most frequently used in the resonant circuit of voltage-controlled oscillators (VCOs), where a varactor provides the tuning capability. The designer is usually confronted with trade-offs between high Q for best phase noise and component size versus circuit board real estate. An algorithm for selecting the correct Trans-Tech part follows. In addition, Trans-Tech COAX Program can provide valuable assistance for determining the correct Trans-Tech part. Application notes and references give example circuits, basic principles, and some helpful hints.

While there is no physical distinction between a coaxial resonator and a coaxial inductor, the selection of an inductor for a VCO begins by first knowing (from analysis or experiment) the equivalent inductance that the active circuit, including the varactor, must see. In general, the VCO active circuit loads the resonator, lowering the resonator's self-resonant frequency (SRF). The situation is analogous to externally capacitively loading a discrete parallel resonant L-C circuit.

While there is an approximate equivalent L-C circuit for the coaxial resonator close to resonance, this model has limited application.

The coaxial resonators and inductors are more accurately modeled as a transmission line. Our application notes and references delve further into this topic.

Values of inductance that can be achieved depend upon the separation between the VCO frequency and the SRF of the coaxial line element. Values less than 1 nH are not practical since the metal connection tab itself has an equivalent inductance of this order.

In our experience, equivalent inductances in the range of 3–20 nH have been popular among designers of VCOs for wireless equipment.

Call for availability, utilize the Inductor Selection Guide, use the COAX Program, or refer to the application notes for assistance with ordering the correct part.

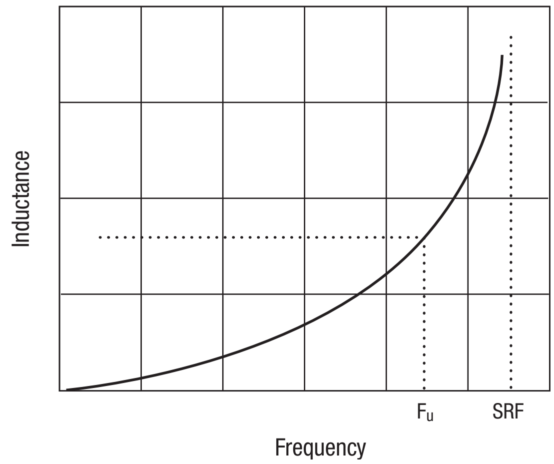


Figure 1. Frequency of Use vs. Inductance

Coaxial Inductor Order Information

An Order Example

SI 8800 LP Q 0450 Y 6.3

- **6.3 — Inductance:** (see Figure 1) Available in 0.01 nH increments
- **Y — Tab:** Y = Yes, N = No
- **0450 — Frequency of Use (F_u):** (see Figure 1 for definition)
- **Q — Type:** Q for $\lambda/4$ standard
- **LP — Profile:** HP, EP, SP, LP, LS, MP, SM
- **8800 — Material:** 1000, 2000, 8800, 9000
- **SI — Product Code:** SI - square coaxial inductor

Coax Line Properties vs. Profile and Material

Profile	1000	2000	8800	9000	Tab Inductors
HP	25.3 Ω	18.1 Ω	13.1 Ω	8.6 Ω	1.8 nH
EP	22.5 Ω	16.1 Ω	11.7 Ω	7.7 Ω	1.0 nH
SP	18.3 Ω	13.1 Ω	9.5 Ω	6.3 Ω	1.0 nH
LS	18.4 Ω	13.1 Ω	9.5 Ω	6.3 Ω	0.9 nH
LP	27.4 Ω	19.6 Ω	14.2 Ω	9.4 Ω	1.0 nH
SP	25.7 Ω	18.4 Ω	13.3 Ω	8.8 Ω	0.6 nH
SM	18.4 Ω	13.1 Ω	9.5 Ω	6.3 Ω	0.6 nH

Wavelength (λg) in Dielectric

Material	ε_R	Wavelength Formula for λ_G (inches)
1000	10.5 ± 0.5	$3642 / f_0$
2000	20.6 ± 1.0	$2601 / f_0$
8800	39.0 ± 1.5	$1890 / f_0$
9000	90.0 ± 3.0	$1244 / f_0$

Figure 2.

Inductor Selection Guide

1) Select one of Trans-Tech four dielectric materials.
2) Determine the VCOs operating frequency (f_{VCO}).
3) Determine the desired inductance or circuit impedance (Z_{IN}). Note: Convert inductances to impedances by using: $Z_{IN} = 2*\pi * f_{VCO} * L_{IN}\ \Omega$
4) Calculate the effect of the tab. Tab inductances are given in Figure 9. Use the formula ($Z_{IN} = 2*\pi * f_{VCO} * L_{TAB}\ \Omega$) to convert the tab inductances to impedances.
5) Determine the input impedance by subtracting off the effect of the tab using: $Z_{INPUT} = Z_{IN} – Z_{TAB}$
6) Calculate the wavelength (λ_G) of the part in the dielectric (see Figure 2 for appropriate formula).
7) Determine the characteristic impedance (Z_0) of the part (see Figure 3)
8) Calculate the physical length of the part using the formula: $l = (\lambda_G /2 * \pi) \tan^{-1} (Z_{INPUT}/Z_0)$ inches
9) Determine the SRF of this part using: $SRF = (\lambda_G * f_{VCO}) / (4 * l)$ MHz
10) Check the Recommended Frequency Chart for the appropriate material to ensure a valid part.

Measurement Description of Q, f_0, and L

Evaluation of Q (quality factor) and f_0 (resonant frequency) of coaxial components is made with a one-port reflection measurement on a network analyzer. The probe is moved into the inner diameter (ID) of the device until the input resistance of the device matches the terminal resistance of the network analyzer. This is indicated by a 50 Ω circle on the Smith Chart display and is known as “critical” coupling. The point on this circle where the response is purely resistive (capacitance reactance equals inductive reactance) is the point of resonance and will be defined by a complex impedance of Z = 50 + j Ω. The Q is computed by observing the frequency span between VSWR-2.616 (Z = 50 ± j50 Ω) on either side of f_0. The Q is defined as $f_0/\Delta f$.

The inductance parameter (L) is measured with an APC 7 mm connector mounted flush with a conducting plane and a full one-port calibration (open, short, broadband 50 Ω load) is performed. The inductor is then clamped into place with the tab touching the inner conductor and the metallized body touching the grounding plane. The inductance (L) is measured at the frequency of use. The impedance vector on the Smith Chart of an ANA gives the necessary information where Z = R + jwL.

Characteristic Impedance

As shown in Figure 3, the characteristic impedance (Z_0) of the coaxial TEM mode components is a function of the profile dimensions and the dielectric constant of the material. Z_0 is reduced over its air line value by the square root of the dielectric constant of the material. At one-eighth wavelength, the short-circuit line exhibits an inductive reactance while the open-circuit line exhibits a capacitive reactance equal in magnitude to Z_0.

$$Z_0 = \text{character impedance} = \frac{60}{\sqrt{\varepsilon_R}} \ln\left(1.079\ \frac{W}{d}\right)$$

where:
w = width of resonator
d = diameter of inner conductor
ε_R = dielectric constant

Profile	1000	2000	8800	9000
HP	25.3 Ω	18.1 Ω	13.1 Ω	8.6 Ω
EP	22.5 Ω	16.1 Ω	11.7 Ω	7.7 Ω
SP	18.3 Ω	13.1 Ω	9.5 Ω	6.3 Ω
LS	18.4 Ω	13.1 Ω	9.5 Ω	6.3 Ω
LP	27.4 Ω	19.6 Ω	14.2 Ω	9.4 Ω
MP	25.7 Ω	18.4 Ω	13.3 Ω	8.8 Ω
SM	18.4 Ω	13.1 Ω	9.5 Ω	6.3 Ω

Figure 3.

Ceramic Coaxial Inductors

Soldering Conditions

Trans-Tech coaxial components are compatible with standard surface mount reflow and wave soldering methods. The HP profile components may require mechanical support mounting because of the larger size. Consult the factory for details.

Use silver-bearing solder such as SN62 (62Sn-36Pb-2Ag). Trans-Tech tabs are pretinned to improve solderability. Additional attaching methods include hot air gun, infrared source, soldering iron, hot plate, vapor phase and others. The coaxial component body is a ceramic and subject to thermal shock if heated or cooled too rapidly. Figure 4 is the recommended soldering profile, not to exceed 230 °C for a duration of about 10 seconds. Repeatable results can be best achieved with air cooling only, not quenching.

Figure 5 indicates the maximum tolerance of the component planarity with respect to the datum plane.

Equation (1) Input Impedance fo

$$Z_{INPUT} = fZ_0 \tan\left(\frac{2\pi f_0}{4\ SRF}\right)$$

where: f_0 = use frequency

Equation (2) Resonant Frequency

$$\iota = \frac{c}{4\ SRF\ \sqrt{\varepsilon_R}}$$

where: c = speed of light ε_R = 39.0 8800 material
90.0 9000 material
10.5 1000 material
20.6 2000 material

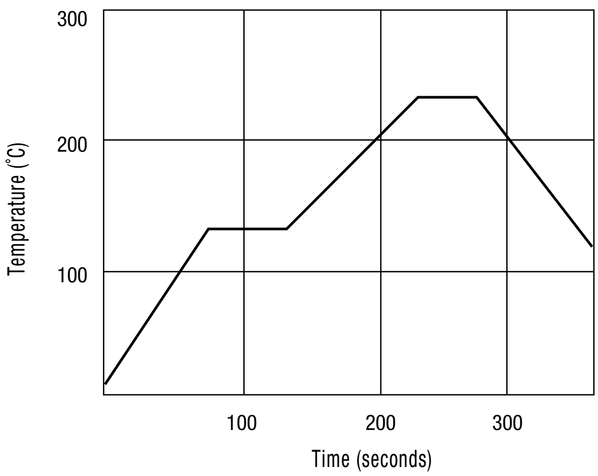


Figure 4. Soldering Profile

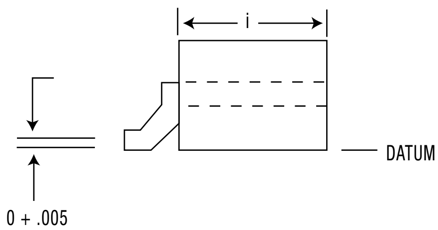


Figure 5. Surface Mount Tolerance for Components with Tabs

Packaging

Tape and reel packaging is available. Consult the factory for

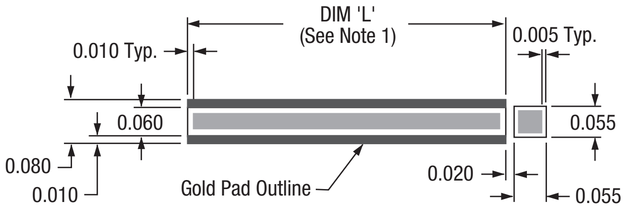
Ceramic Coaxial Inductors

Packaging

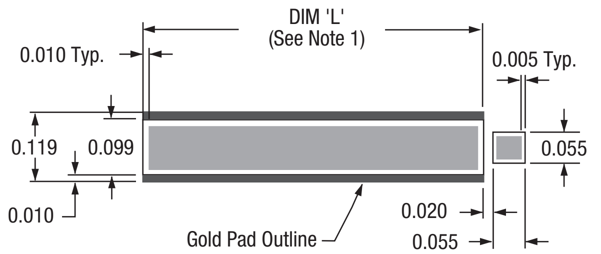
Tape and reel packaging is available. Consult the factory for details.

Notes: 1. Dimension "L" is length which depends on frequency.

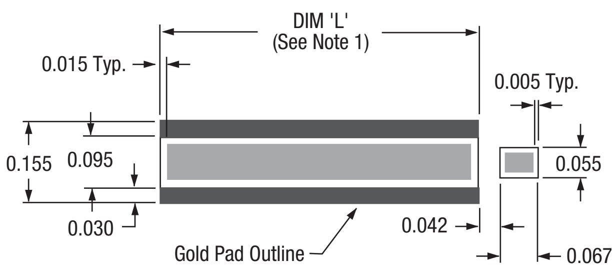
Key:
- = Solder over metallic mounting pad
- = Solder mask over metallic mounting pad
- = Exposed metallic mounting pad



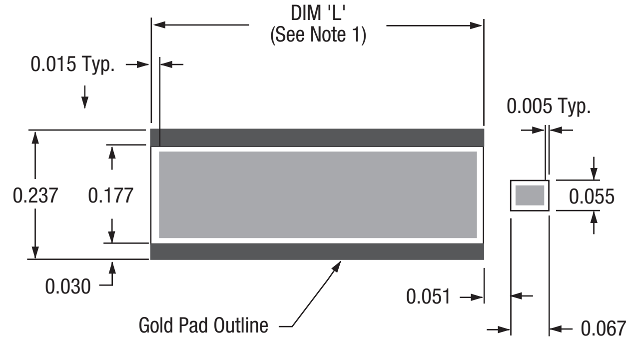
2 mm (5 m) Coaxial Resonator Footpad Dimensions



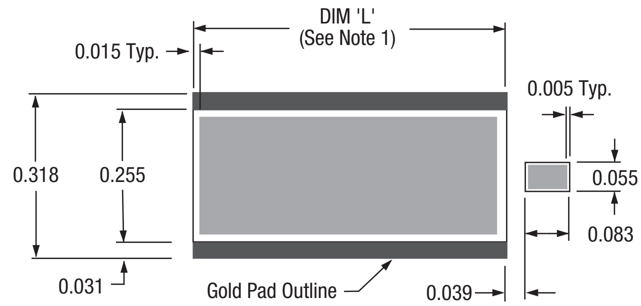
3 mm (MP) Coaxial Resonator Footpad Dimensions



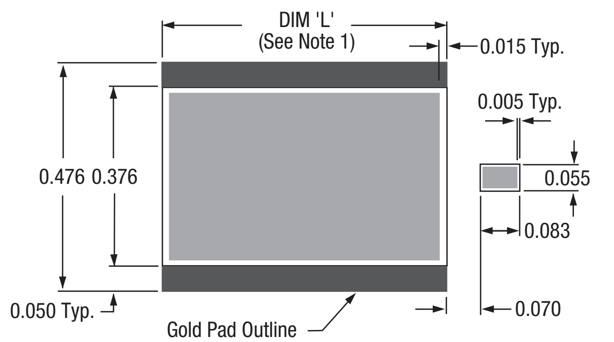
4 mm (LP/LS) Coaxial Resonator Footpad Dimensions



6 mm (SP) Coaxial Resonator Footpad Dimensions



8 mm (EP) Coaxial Resonator Footpad Dimensions



12 mm (HP) Coaxial Resonator Footpad Dimensions