RF Chokes

Roger Harrison takes a close look at what's in the different styles of RF choke now available.

RADIO FREQUENCY chokes are used to prevent the passage of radio energy (hence the term 'choke') while allowing direct current or lower-frequency signals (eg, audio) to pass. This sort of application is principally one of decoupling; that is, isolating the RF–carrying portions of a circuit by providing a high RF impedance between two portions of the circuit. The principle also applies in RF interference suppression applications. For example, in reducing RF 'hash' from SCR or Triac motor speed controllers, light dimmers,

RF chokes are also used widely in a variety of filter applications, eg, low-pass and high-pass filters. They are also used in pulse-forming networks and as frequency compensation components in wideband amplifiers (eg, video amplifiers).

RF chokes are also referred to as 'minichokes', 'microchokes' and 'video peaking chokes', etc.

CONSTRUCTION

The general range of construction styles employed are illustrated in Figure 1. The different winding styles have particular advantages and characteristics on which I will elaborate shortly. RF chokes are generally made in values according to the preferred series, in tolerances of 5%, 10% and 20%.

Regardless of the form of the winding or the encapsulation, RF chokes are wound on bobbins consisting either of a phenolic or plastic material (non-magnetic), powdered iron or ferrite material. The last two materials, because of their high permeability increase the inductance of the winding effecting a decrease in the number of turns required as well as in[illegible]cing the other characteristics of the [illegible]e – which I will discuss shortly.

The bobbin generally has integral pigtail leads moulded into the material to which the winding is terminated. Axial leads are the most common form although radial-lead RF chokes are obtainable – principally intended for printed-circuit mounting.

A form of construction that reduces the external magnetic field of the choke to negligible proportions is illustrated in Figure 2. This form of construction completely encloses the winding with the result that it has a very weak stray field, reducing 'crosstalk', or coupling, between the choke and adjacent components. In fact, two chokes can be mounted so that they touch each other over the full length of the bobbin – and crosstalk attenuation is quoted as 60 dB.

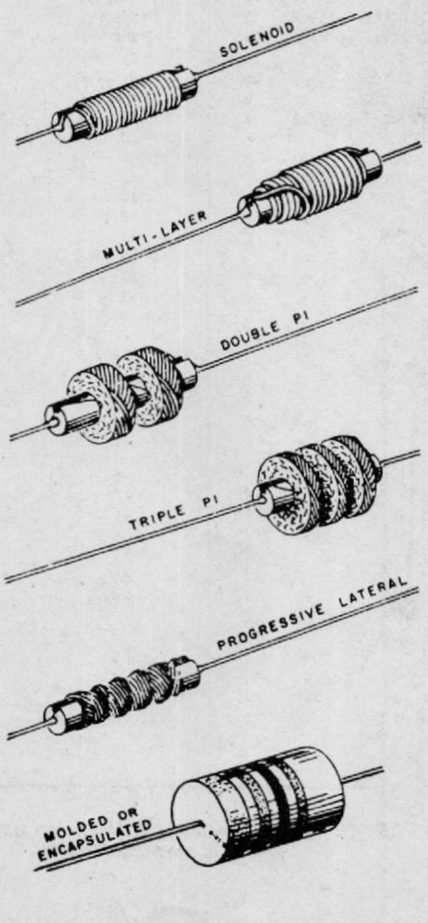


Fig. 1. General range of constructor styles of RF chokes. The particular style employed depends on the required or allowable component. Size, the inductance, the application and the required characteristics.

Low inductance RF chokes are usually 'solenoid' wound, whereby a single layer of wire is closewound on the bobbin. Chokes in the range 0.1 μH to 200 μH are generally solenoid-wound. The very low inductance types below 10 μH are generally wound on a non-magnetic bobbin. Powdered iron bobbins are generally used for chokes between about 5 μH and 100 μH, ferrite for the higher inductances to 200 μH or so.

Higher inductance chokes are obtained by overlapping several closewound layers on the bobbin. There is a limitation to this as the self-capacitance of the winding increases, decreasing the frequency range over which the choke is effective. This is discussed later. Chokes in the range 20 μH to 10 mH are often multilayer wound, generally on powdered iron or ferrite bobbins.

The Philips series of 'micro-chokes' cover the inductance range from 0.1 μH to 100 mH and employ solenoid or multilayer windings on the en-

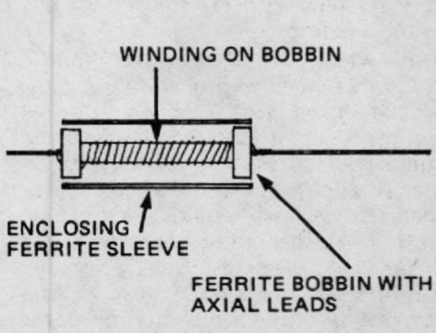


Fig. 2. Construction of fully-enclosed style of RF choke. Philips' make this style.

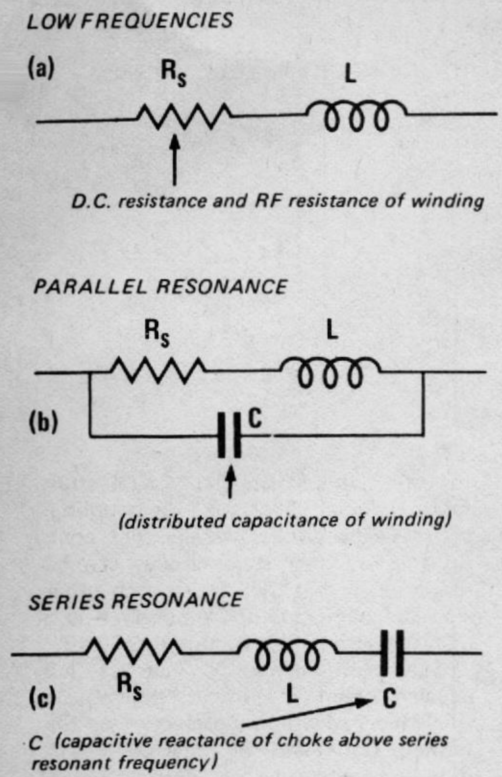


Fig. 3. Equivalent circuits of an RF choke over wide frequency range.

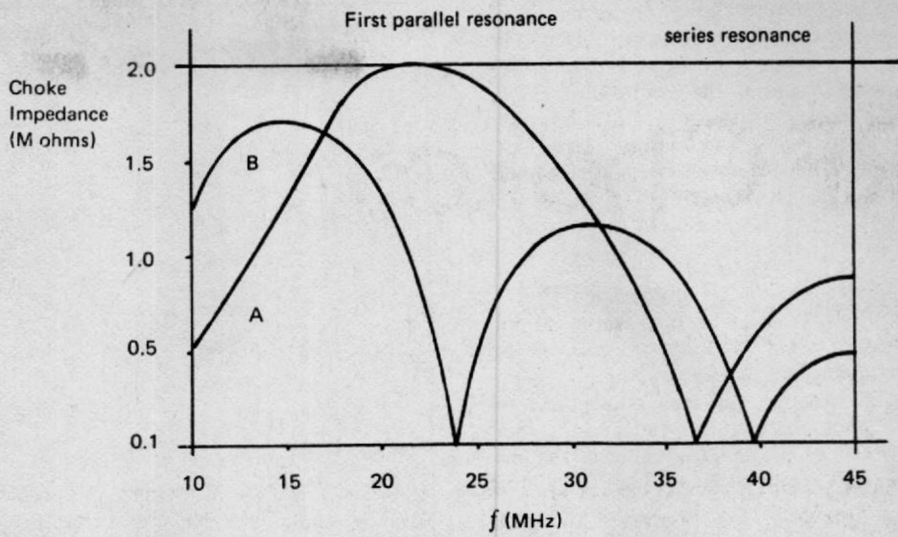


Fig. 4. Typical behavior of two RF chokes (A = around 10 μH, B = around 40 μH) over a range of frequencies.

L	Q @ F(MHz)		SELF-RESONANT FREQUENCY	DC RESISTANCE (Ω)	MAX. DC CURRENT	CONSTRUCTION & SIZE
0.1 μH	45	25	≈450 MHz	0.7	2.9 A	
0.15	45	25	≈400 MHz	0.12	2.8A	4 mm dia
0.22	45	25	≈350 MHz	0.14	2.7 A	by
0.33	45	25	≈300 MHz	0.17	2.6 A	10 mm long
0.47	45	25	≈270 MHz	0.21	1.7 A	* wound on
0.68	45	25	≈220 MHz	0.25	1.6 A	ferrite bobbin
1.0 μH	45	25	≈200 MHz	0.31	1.5 A	with ferrite
1.5	40	8	≈110 MHz	0.38	1.2 A	sleeve and
2.2	40	8	80	0.45	1.1 A	encapsulated.
3.3	40	8	60	0.53	900 mA	
4.7	40	8	55	0.63	650 mA	
6.8	40	8	45	1.0	500 mA	
10 μH	40	8	38	1.7	300 mA	
15	40	2	30	0.55	250 mA	
22	40	2	26	0.7	150 mA	
33	40	2	25	0.9	120 mA	
47	40	2	19	1.35	110 mA	
68	40	2	15	1.6	100 mA	
100μH	40	2	12	1.9	60 mA	
150	45	0.8	10	3.5	60 mA	
220	45	0.8	7.5	6.5	50 mA	
330	45	0.8	6.5	11	40 mA	
470	50	0.8	6.0	20	35 mA	
680	50	0.8	5.0	41	35 mA	
1 mH	50	0.8	4.0	48	25 mA	
1.5	50	0.25	3.1	25	100 mA	6.5 mm dia
2.2	50	0.25	2.9	30	100 mA	by
3.3	45	0.25	2.6	50	70 mA	10 mm long
4.7	45	0.25	2.4	60	60 mA	* same
6.8	40	0.25	2.3	75	50 mA	construction
10 mH	40	0.1	2.0	90	40 mA	as above.
15	40	0.1	1.4	110	20 mA	
22	40	0.1	1.3	130	15 mA	
33	35	0.1	1.3	130	15 mA	
33	35	0.1	1.3	275	12 mA	
47	35	0.1	1.2	400	10 mA	
68	30	0.1	1.1	470	9 mA	
100 mH	25	0.1	1	720	8 mA	
0.1						

TABLE 1 Typical characteristics of encapsulated microchokes wound on ferrite bobbins as made by Philips.

closed ferrite bobbins as illustrated in Figure 2.

RF chokes from around 47 μH through to 100 mH are often 'pie-wound'. This is a form of winding where the wire is zig-zagged around the circumference of the bobbin and built up in many layers. The individual turns are not colinear — lying alongside the adjacent turns — but the wires cross at an angle due to the zig-zag winding, thus reducing the total self-capacitance of the coil. A multilayer winding wound in this way is termed a 'pie', the method of winding is also referred to as 'universal' winding.

Pie-wound RF chokes may have 1, 2, 3 or as many as 5 or 6, pies making up the inductance. Generally the pies are of the same width, diameter and number of turns but some types for special applications, or where special characteristics are required, are wound with a number of pies, each having a smaller diameter but a greater width than the preceding pie. This ...ieves a more uniform impedance ...racteristic over the desired frequency range.

A variation on the pie winding is the 'progressive lateral' type where the zig-zag winding is progressively moved along the bobbin rather than building a high, multilayer pie. This technique reduces the inherent self-capacitance of the winding and provides a more uniform impedance characteristic across the required frequency range.

Encapsulated chokes are generally of solenoid or multilayer construction, and are encapsulated in an epoxy or other suitable material. Pie-wound chokes are sometimes encapsulated although they are more usually wax-impregnated. Heat-shrink tubing is also used to enclose and protect RF chokes.

CHARACTERISTICS

RF chokes are an inductance that is required to have a high value of impedance over a wide range of frequencies.

In practice, an RF choke has inductance, distributed capacitance, and resistance. At low frequencies, the distributed capacitance has negligible effect and the electrical equivalent of the choke will be as shown in Figure 3(a). With increasing frequency the effect of the distributed capacitance becomes more evident until at some particular frequency it becomes a parallel resonant circuit. The equivalent circuit at and around this frequency is illustrated in Figure 3(b). At frequencies beyond this the overall reactance of the choke becomes capacitive and eventually the choke becomes a series resonant circuit, as shown in Figure 3(c).

The cycles of parallel resonance-reactance, series resonance, etc, repeat with increasing frequency, the overall impedance of the choke rapidly becoming lower past the initial cycles. This sort of characteristic is illustrated in Figure 4.

L	Q @ F(MHz)		SELF-RESONANT FREQUENCY	DC RESISTANCE (Ω)	MAX. DC CURRENT	CONSTRUCTION & SIZE
0.1 μH	50	25	500 MHz	0.027	3.5 A	4 mm dia. by 9 mm long * solenoid wound on phenolic bobbin
0.15	50	25	510	0.03	3.0 A	
0.22	50	25	415	0.035	2.6A	
0.33	50	25	350	0.065	2.0 A	
0.47	50	25	300	0.085	1.7 A	
0.68	45	25	250	0.15	1.3 A	
1.0 μH	40	25	200	0.29	930 mA	
1.5	30	8	170	0.485	700 mA	
2.2	30	8	140	0.97	505 mA	
3.3	30	8	70	0.14	1.35 A	4 mm dia. by 9 mm long * wound on powdered iron bobbin
4.7	30	8	60	0.21	1.1 A	
6.8	25	8	50	0.375	810 mA	
10 μH	30	8	42	0.605	640 mA	
15	55	2.5	30	1.2	460 mA	
22	60	2.5	24	2.2	335 mA	4 mm dia by 9 mm long * wound on ferrite bobbin.
33	60	2.5	23	1.6	360 mA	
47	60	2.5	20	2.1	340 mA	
68	60	2.5	16	2.7	320 mA	
100 μH	55	2.5	10.5	3.3	275 mA	
150	60	0.8	7.2	4.1	230 mA	
220	65	0.8	6.2	5.0	200 mA	
330	70	0.8	5.4	7.0	170 mA	
470	70	0.8	4.7	9.55	145 mA	
680	65	0.8	3.6	13.8	115 mA	
1 mH	65	0.8	2.8	18.5	70 mA	
1.5	75	0.25	2.9	10	140 mA	6.5 mm dia by 12 mm long * wound on ferrite bobbin.
2.2	70	0.25	2.2	17.5	120 mA	
3.3	70	0.25	2.2	20.5	100 mA	
4.7	65	0.25	1.9	27.5	80 mA	
6.8	55	0.25	1.5	41.5	70 mA	
10 mH	50	0.25	1.5	51.5	50 mA	

TABLE 2 *Typical characteristics of various encapsulated RF chokes, representative of those made by a variety of manufacturers.*

TABLE 3 *Typical characteristics of a variety of pie-wound RF chokes, representative of a number of manufacturers.*

L	Q af (MHz)		SELF RESOANAT FREQUENCY	DC RESISTANCE (Ω)	MAX. DC CURRENT (mA0	NUMBER OF PIES	CONSTRUCTION DETAILS	
47 μH	55	2.5	12 MHz	3	250	1	6 mm	9 mm
100	50	2.5	9.8	5.1	190	1	7.5 mm	9 mm
120	60	0.8	9	5.7	180	1	8 mm	9 mm
150	60	0.8	8	6.3	170	1	8.5 mm	9 mm
220	60	0.8	6	7.8	160	1	9 mm	9 mm
270 μH	60	0.8	5.2	9	180	2	7.5 mm	9 mm
330	60	0.8	4.5	10	170	2	8 mm	9 mm
470	60	0.8	3.5	12.4	170	2	8.5 mm	9 mm
560	60	0.8	3	14	160	2	9 mm	9 mm
470 μH	60	0.8	6.5	14	160	3	7 mm	12 mm
560	60	0.8	5.5	15.5	160	3	7.5 mm	12 mm
680	60	0.8	4.5	17.2	150	3	8 mm	12 mm
820	60	0.8	4	19	140	3	8.5 mm	12 mm
1 mH	60	0.8	3.5	21	130	3	9 mm	12 mm
1.2 mH	60	0.25	3.1	23	130	3	9.5 mm	12 mm
820 μH	60	0.8	3.2	13	190	2	9 mm	13 mm
1 mH	60	0.8	3.2	16	170	2	9.5 mm	13 mm
1.2	60	0.25	3.1	19	160	2	10 mm	13 mm
1.5	65	0.25	3	22	150	2	10.5 mm	13 mm
2.2	65	0.25	2.5	28	130	2	11 mm	13 mm
2.5 mH	65	0.25	2	30	120	2	12 mm	13 mm
2.0 mH	60	0.25	1.8	26	150	2	11.5 mm	16 mm
2.2	60	0.25	1.7	28	140	2	12 mm	16 mm
2.5	60	0.25	1.5	30	140	2	12.5 mm	16 mm
2.7	60	0.25	1.45	32	130	2	13 mm	16 mm
3.0 mH	55	0.25	1.4	34	140	3	11 mm	16 mm
3.3 mH	55	0.25	1.3	36	130	3	11.5 mm	16 mm
4.7 mH	55	0.25	1.1	45	120	3	12 mm	16 mm
5.6 mH	55	0.25	1	50	110	3	12.5 mm	16 mm
6.8 mH	55	0.25	0.95	56	110	3	13 mm	16 mm
8.2 mH	55	0.25	0.9	63	100	3	13.5 mm	16 mm
10 mH	55	0.25	0.85	71	90	3	14 mm	16 mm

RF chokes should not be used within about ± 20 –30% of the series resonant frequency, nor more than about 1.5 times the series resonant frequency. Obviously, from Figure 4, they exhibit their greatest impedance around their parallel resonant frequency.

Tables, 1, 2 and 3 list data on typical RF chokes of several varieties and sizes – they should only be taken as a guide, consult the manufacturers' literature if the characteristics of a particular choke are required.

The lower the self capacitance of a particular style of winding, the higher will be the series resonant frequency (also referred to as the self-resonant frequency), thus allowing the choke to operate over a wide frequency range. Special windings, such as the progressive lateral, have extremely low distributed capacitance as well as less variation in impedance across the frequency range, compared to other styles. The variation in self resonant frequency versus choke inductance for three different bobbins and winding styles is illustrated in Figure 5.

The equivalent series resistance of a choke is made up of the actual dc resistance of the winding plus the RF resistance of the wire used due to 'skin effect'. The actual dc resistance of the choke may need to be taken into account in a circuit, particularly in high current circuits or with high inductance chokes. The latter may have dc resistances up to 500 or 600 ohms.

The equivalent series resistance (also called the 'apparent resistance') varies with frequency, reaching a peak before decreasing due to the shunting effect of the distributed capacitance of the winding. The variation of R_S with frequency for a range of inductances is illustrated in Figure 6.

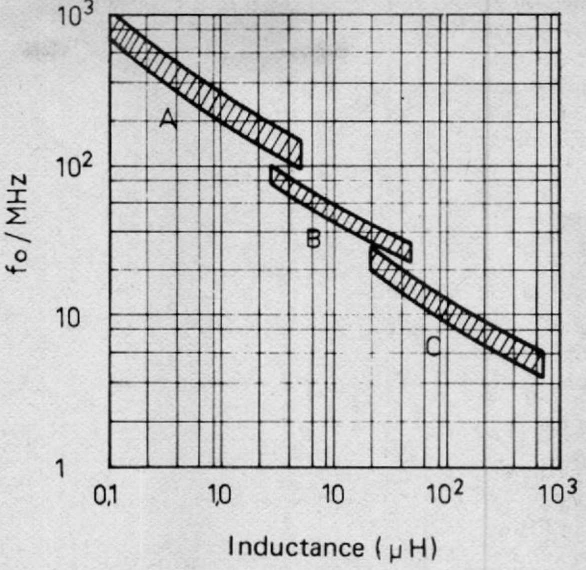


Fig. 5. Typical variation of self-resonant (or series-resonant) frequency against choke inductance for three different styles of choke construction.
A = non-magnetic bobbin
B = solenoid wound (single layer) chokes on powdered iron and ferrite bobbins
C = Multilayer chokes on powdered iron and ferrite bobbins.

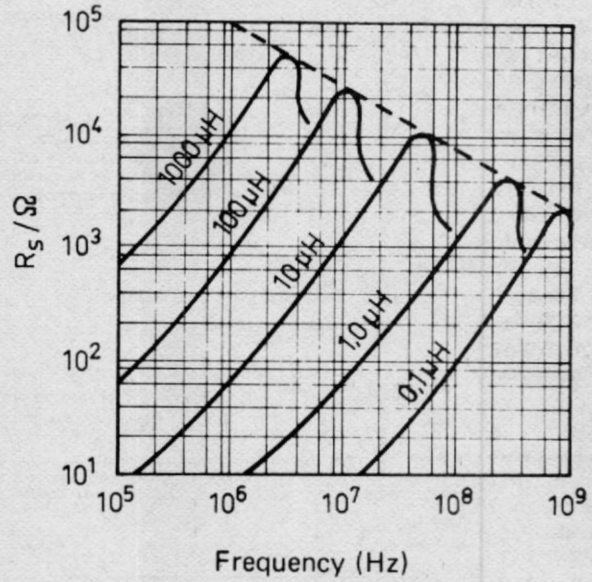
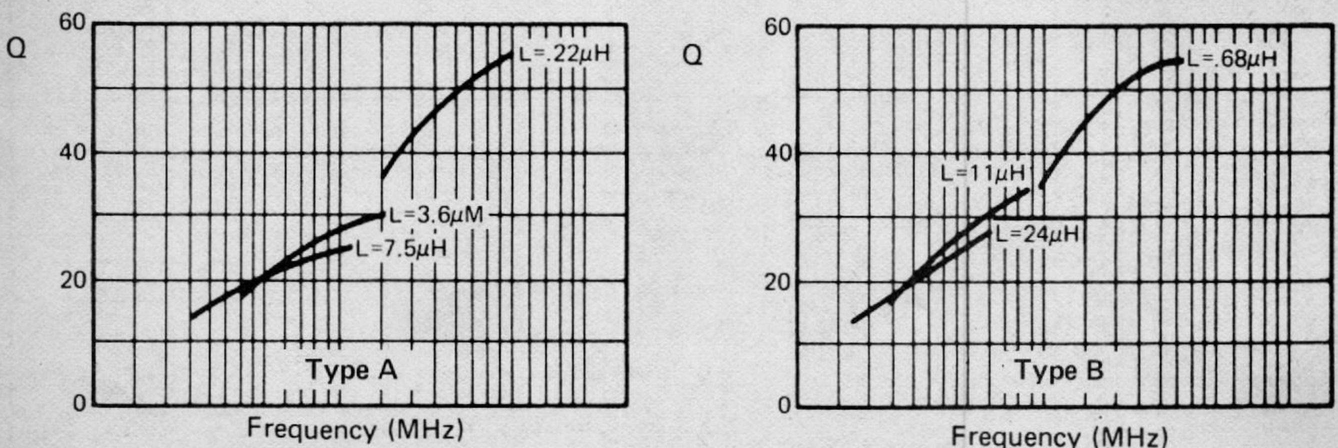


Fig. 6. Typical variation of equivalent serves resistance of a range of RF chokes against frequency.



ig. 7. Typical Q values versus frequency for several values of two different sizes of moulded RF chokes (From IRH).
= 6.4 mm dia. x 78 mm long.
= 6.4 mm dia. x 27 mm long.

RF Chokes

Naturally enough, RF chokes have a limit to the amount of dc current they can carry without either overheating or effecting a change in the inductance outside the specified tolerance limits. Manufacturers specify a maximum dc current for their chokes, the figures given in tables 2 and 3 are only a guide. Seek out the manufacturer's data if in any doubt. Special high current chokes are manufactured for specific applications, eg, for RF hash suppression in SCR and Triac ac control circuits, filament chokes for high power RF transmitting tubes, etc.

RF chokes are generally low Q components. The actual Q specified by a manufacturer is generally the minimum Q, measured at a particular frequency, generally in the manner illustrated for several values and two sizes in Figure 7.

MARKINGS

RF chokes are marked with their value and tolerance with the standard colour code or typographic code, in much the same way that resistors and some capacitors are marked.

There are several ways in which the colour code is marked on the body of the choke and these are illustrated in Figures 8, 9, 10, and 11.

The nominal inductance value is always indicated in microhenries (μH).

Where a typographic code is employed it is generally of a quite simple form, similar to that used on resistors. The nominal inductance value, again, is always expressed in microhenries (μH). The value is identified as follows:–

Nominal inductance values less than 100 μH are identified with three (3) numbers representing the significant figures, the letter R being used to designate the decimal point.

eg,
0.68 μH = R680
4.7 μH = 4R70
33 μH = 33R0

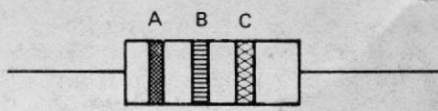
Nominal inductance values of 100 μH and above are identified by a four digit number. The first three (3) digits represent the significant figures of the value and the last digit specifies the number of the following zeroes,

eg,
680 μH = 6800
4700 μH 4701 (4.7 mH)
33000 μH 3302 (33 mH)

In addition, a single letter may be added to indicate the tolerance, as follows:

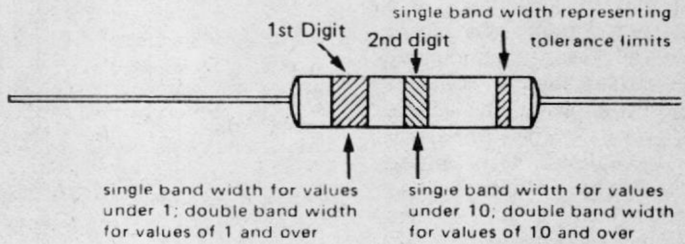
J = ± 5%
K = ± 10%
M = ± 20%

COLOUR	A & B	C
SILVER		10^{-2}
GOLD		10^{-1}
BLACK	0	1
BROWN	1	10^1
RED	2	10^2
ORANGE	3	10^3
YELLOW	4	10^4
GREEN	5	10^5
BLUE	6	10^6
VIOLET	7	10^7
GREY	8	10^8
WHITE	9	10^9



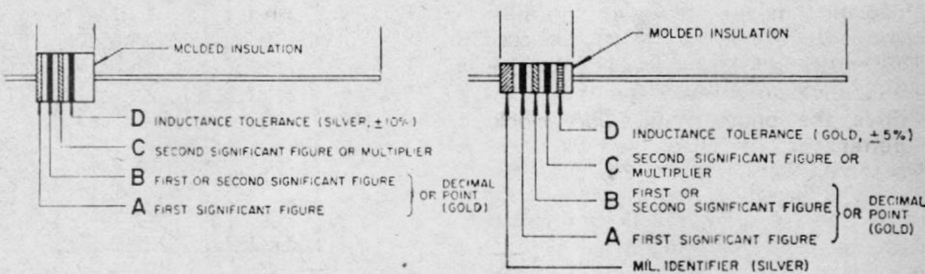
A = First digit
B = Second digit
C = Multiplier

Fig. 8. This colour code for RF chokes follows that for resistors most closely. Principally used by Philips on their 'microchoke' range.



Example: 0 – 0.91 two single bands
1.0 – 9.1 double-single
10.0 – 24.0 double-double

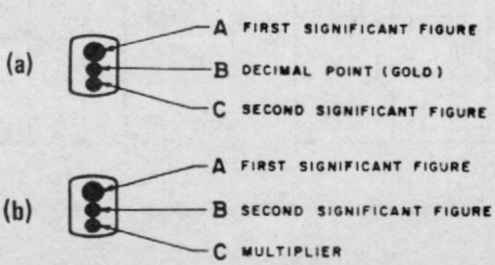
Fig. 9. This code varies the widths of the first two bands to indicate the position of the decimal point in the value. The code is read from left to right, as is conventional.



EXAMPLES

A = GOLD B = ORANGE C = ORANGE D = SILVER	0.33 μH, ±10% A = YELLOW B = GOLD C = VIOLET D = GOLD	4.7 μH, ± 5% A = BROWN B = RED C = ORANGE D = GOLD 15 mH, ± 5%

Fig. 10. This is similar to the code in figure 8 but the decimal point for values under 10μH is indicated by a gold band for bands A or B. A mil-Spec component is identified by broad silver band preceeding the value and tolerance bands. Some manufacturers use a dot to indicate the tolerance value as illustrated here.



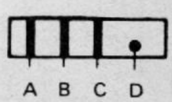


Fig. 11. Miniature radial lead RF chokes for printed circuit mounting may be colour-coded as shown here. The decimal point is indicated by a gold dot at either A or B, the value being read off in the same way as illustrated in figure 10. Note that the value is read commencing at the largest dot.