Pot Cores
Low Level Applications

The information contained in this section is primarily concerned with the design of linear inductors for high frequency LC tuned circuits using ferrite pot cores. Magnetics has arranged the data in this section for ease in (1) determining the optimum core for these LC circuits and (2) ordering the items necessary for any particular Pot Core assembly.

Featured are magnetic data, temperature characteristics, core dimensions, accessories, and other important design criteria. *Standard Q curves are available on special request, contact Magnetics Application Engineering.*

The data presented in this section are compiled mainly for selecting cores for high Q resonant LC circuits. However, much of this information can also be used to design pot cores into many other applications, including high frequency transformers, chokes, and other magnetic circuit elements.

POT CORE ASSEMBLY

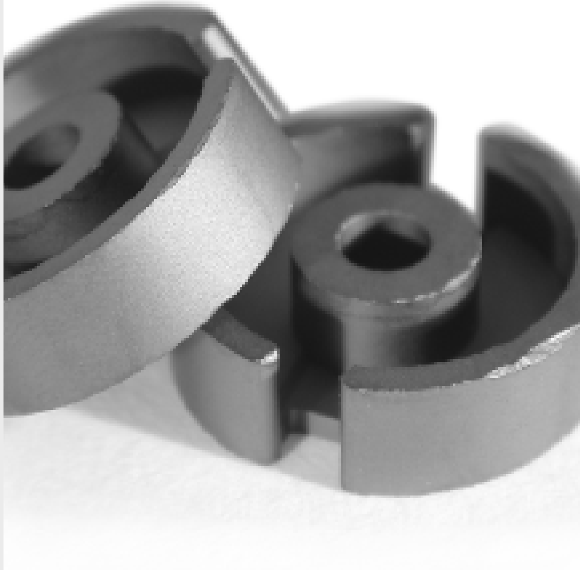
A ferrite pot core assembly includes the following items:

1. TWO MATCHED POT CORE HALVES
2. BOBBIN ON WHICH THE COILS ARE WOUND
3. TUNING ASSEMBLY
4. A CLAMP FOR HOLDING THE CORE HALVES TOGETHER

The pot core shape provides a convenient means of adjusting the ferrite structure to meet the specific requirements of the inductor. Both high circuit Q and good temperature stability of inductance can be obtained with these cores. The self-shielded pot core isolates the winding from stray magnetic fields or effects from other surrounding circuit elements.

The effective permeability (μ_e) is adjusted by grinding a small air gap in the center post of the pot core. For transformers and some inductors, no ground air gap is introduced, and the effective permeability is maximized. The effective permeability of the pot core will always be less than the material initial permeability (μ_i) because of the small air gap at the mating surfaces of the pot core halves. For other inductors where stability of inductance, Q, and temperature coefficient must be closely specified, a controlled air gap is carefully ground into the center post of one or both of the pot core halves. When fitted together, the total air gap then will determine the effective permeability and control the magnetic characteristics of the pot core. Finer adjustment of the effective permeability (gapped pot core inductance) can be accomplished by moving a ferrite cylinder or rod into the air gap through a hole in the center post.

Magnetics ferrites are available in various initial permeabilities (μ_i) which for filter applications cover frequency ranges into the megahertz region. Magnetics produces a wide variety of pot core sizes which include fourteen (14) international standard sizes*. These range from 7 x 4 mm to 42 x 29 mm, these dimensions representing OD and height of a pair. Each pot core half is tested and matched with another half to produce a core with an inductance tolerance of ± 3% for most centerpost ground parts.



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*IEC Publication No. 133 (1961).

Advantages of Pot Core Assemblies

ADVANTAGES OF POT CORE ASSEMBLIES

- SELF-SHIELDING
  Because the wound coil is enclosed within the ferrite core, self-shielding prevents stray magnetic fields from entering or leaving the structure.

- COMPACTNESS
  Self-shielding permits more compact arrangement of circuit components, especially on printed circuit boards.

- MECHANICAL CONVENIENCE
  Ferrite pot cores are easy to assemble, mount, and wire to the circuit.

- LOW COST
  As compared to other core materials, ferrites are easier to make in unusual configurations (such as pot cores), resulting in a lower cost component. In addition, winding a pot core is usually quick and inexpensive because coils can be pre-wound on bobbins. When other costs of assembly, mounting, wiring, and adjustment are added, the total cost is often less than with other core materials or shapes.

- ADJUSTABILITY
  Final adjustment is accomplished by moving a threaded core in and out of the centerpost, and adjustment in the field is relatively easy as compared to any other type of construction.

- IMPROVED TEMPERATURE STABILITY AND Q
  Air gaps inserted between the mating surfaces of the centerposts provide good temperature stability and high Q.

- WIDE CORE SELECTION
  Many combinations of materials, physical sizes, and inductances offer the design engineer a large number of choices in core selection.

- LOW LOSSES AND LOW DISTORTION
  Since ferrites have high resistivities, eddy current losses are extremely low over the applicable frequency range and can be neglected. Hysteresis losses can be kept low with proper selection of material, core size, and excitation level.

SPECIAL ADVANTAGES OF MAGNETICS POT CORE ASSEMBLIES

- UNIQUE ONE PIECE CLAMP
  Provides simple assembly of the two core halves. Easy bending action allows insertion of the core assembly into the clamp, and spring tension holds the assembly rigidly and permanently in place. Rivet, screw, or circuit board tab mounting is available.

- CHOICE OF LINEAR OR FLAT TEMPERATURE CHARACTERISTICS
  Provides a close match to corresponding capacitors.

- CONSISTENCY AND UNIFORMITY
  Modern equipment with closely controlled manufacturing processes produce ferrite pot cores that are magnetically uniform, not only within one lot but from lot to lot.

Important Considerations

The selection of a pot core for use in LC resonant circuits and high frequency inductors requires a careful analysis of the design, including the following:

- OPERATING FREQUENCY.
- INDUCTANCE OF THE WOUND POT CORE ASSEMBLY.
- TEMPERATURE COEFFICIENT OF THE INDUCTOR.
- Q OF THE INDUCTOR OVER THE FREQUENCY RANGE.
- DIMENSIONAL LIMITATIONS OF THE COIL ASSEMBLY.
- MAXIMUM CURRENT FLOWING THROUGH THE COIL.
- LONG TERM STABILITY.

The important characteristics which strongly influence the above requirements are:

1. Relative loss factor - $\frac{1}{\mu_i Q}$. This factor reflects the relative losses in the core and varies with different ferrite materials and changes in operating frequency. When selecting the proper material, it is best to choose the one giving the lowest $\frac{1}{\mu_i Q}$ over the range of operating frequencies. In this way, the highest circuit Q can be expected. In a situation where the $\frac{1}{\mu_i Q}$ curves may cross over or coincide at various frequencies, each ferrite material should be considered in view of all circuit parameters of importance, including size, temperature coefficient, and disaccommodation, as well as Q. With this analysis, little doubt is left concerning the optimum selection of a proper core material.

2. Inductance factor (A_L). The selection of this parameter is based on a logarithmic progressive series of values obtained by dividing a logarithmic decade into 5 equal parts (International Standardization Organization R5 series of preferred numbers). Since the (A_L) values for the various core sizes are standard, they may be graphed or charted for ease of determining the required turns (N) to give the value of inductance needed. Pot cores with various (A_L) values are obtained by grinding closely-controlled air gaps in the centerposts of the cores. Small gaps are processed by gapping one core half. For larger gaps, both halves are gapped.

3. Temperature Coefficient (TC_e). The temperature coefficient of the pot core is important in LC tuned circuits and filters when attempting to stabilize the resonant frequency over a wide range of temperatures. This temperature coefficient (TC_e) is determined by the properties of the ferrite material and the amount of air gap introduced. Ferrite materials have been designed to produce gapped pot core temperature coefficients that balance the opposite temperature characteristics of polystyrene capacitors, or match similar flat temperature coefficients of silvered mica capacitors. Therefore, careful selection of both capacitors and pot cores with regard to temperature coefficient will insure the optimum temperature stability.

4. Quality Factor (Q)*. The quality factor is a measure of the effects of the various losses on circuit performance. From the designer's point of view, these losses should include core losses, copper losses, and winding capacitive losses. Therefore, Q will be affected greatly by the number and placement of the turns on the bobbin, and the type and size of wire used. At higher frequencies, litz wire would reduce the eddy current losses in the windings and produce a higher Q than solid wire. Q data include the effects of winding and capacitive losses, which, if removed, would produce significantly higher calculated Q values. Consequently, the Q curves represent more realistically the actual Q values that would be obtained from circuit designs.

5. Dimensional Limitations. Many circuit designs contain dimensional and weight limitations which restrict the size of the inductor and the mounting techniques used. Sometimes, minimum weight or volume is sacrificed to obtain better circuit performance.

6. Current Carrying Capacity. Inductive circuits containing ferrite pot cores are normally operated at extremely low levels of AC excitation to insure the best possible performance. However, the current flowing in the coil may be much higher than anticipated due to superimposed DC currents, or unexpected surges of AC. Therefore, the selection of the wire size used in an inductor design is influenced by both of these factors. Wire data is presented in this catalog as a guide in considering these operating conditions. - Refer to Tables 5 and 6, pages 5.8 and 5.9.

7. Long Term Stability (DF_e). In critical inductive designs, especially resonant circuits, the designer must be concerned with long term drift in resonant frequency. This stability drift (or decrease in inductance), known as disaccommodation, can be calculated for each pot core size and inductance factor (A_L). It occurs at a logarithmic rate, and the long term change of inductance may be calculated from the formula: $\frac{\Delta L}{L} = DFe \times \log \frac{t_2}{t_1}$

where $\frac{\Delta L}{L}$ is the decrease in inductance between the times t_1 and t_2, DF_e is the Effective Disaccommodation Coefficient of the core selected, and t_1 is the elapsed time between manufacture of the core (stamped on shipping container) and its assembly into the circuit, while t_2 is the time from manufacture of the core to the end of the expected life of the device. Disaccommodation starts immediately after the core is manufactured as it cools through its Curie Temperature. At any later time as the core is demagnetized, or thermally or mechanically shocked, the inductance may increase to its original value and disaccommodation begins again. Therefore, consideration must be given to increases in inductance due to magnetic, thermal or physical shock, as well as decreases in inductance due to time. If no extreme conditioning is expected during the equipment life, changes in inductance will be small, because most of the change occurs during the first few months after manufacture of the core.

*Q curves referred to here are available on special request. Contact Magnetics Applications Engineering.

Important Considerations

LIMITS ON EXCITATION

Inductors designed using pot cores are usually identified as linear magnetic components because they are operated within the range of negligible change of effective permeability with excitation. To calculate suggested maximum AC excitation levels, use the following formula:

$$B = \frac{E_{rms} \times 10^8}{4.44\, A_e N f}$$

4.44 for sine wave
4.0 for square wave

where B = 200 gausses, the suggested conservative limit.
N = turns on pot core
f = operating frequency in hertz.
A_e = effective area of the pot core in cm^2.

Because superimposed DC current also affects linearity of inductance in pot cores, consideration for DC currents must also be given. The equation shown above must be modified to include effect of DC bias. The combined equation now becomes:

$$B_{(combined)} = \frac{E_{rms} \times 10^8}{4.44\, A_e N f} + \frac{N I_{dc} A_L}{10 A_e}$$

where B = 200 gausses, the suggested conservative limit.
I_{dc} = bias current in amperes.

See pages 4.15 - 4.19 for DC bias data on Magnetics power ferrites.

Notes

Assembly Notes

Magnetics ferrite pot cores can be assembled with or without clamping hardware or tuning devices.

Mounting clamps are available for the 40905, 41107, 41408, 41811, 42213, 42616, 43019, 43622, and 44229 pot core sizes. These clamps normally eliminate the need to cement the pot core halves together. The mating surfaces of the pot core must be cleaned to remove moisture, grease, dust, or other foreign particles, before clamping or cementing.

If the cementing method is chosen, a small amount of cement is placed on the mating surface of the pot core skirt, being careful to keep the centerpost free of all cement. The pot core halves are brought together and rotated together under slight pressure to distribute the cement evenly around the skirt. The halves are separated and the wound bobbin is set in place. A small amount of cement is now placed on the exposed flange of the bobbin to bond it in the pot core assembly and thus insure no movement. The other core half is replaced, the centerpost holes and wire aperture aligned, and the unit clamped together in a pressure jig. Permanent bonding is accomplished by curing the cement at elevated temperatures according to the manufacturer's recommendations. After curing, storage for a minimum of 24 hours, and heat cycling between room temperature and 70°C may be required before final testing or tuning is completed.

The tuning adjusters can be inserted into the pot core immediately after the cemented core halves have been cured and the assembly can then be heat cycled. Some adjusters require insertion of the base into the centerpost hole prior to assembly of the pot core into the clip when a clip is used for mounting. The adjuster is usually made in two parts - the plastic base with a threaded hole, and a ferrite cylinder imbedded in a plastic screw. The base is pressed into the centerpost of the pot core, and the plastic screw is turned into the base until the ferrite cylinder enters the air gap. Tuning is completed when the inductance of the pot core assembly reaches the proper value. If this initial adjustment is expected to be the final one, cementing is recommended to prevent accidental detuning. If precise inductance values are expected, final tuning should not be completed earlier than 24 hours after the pot core assembly has been cured or clamped.

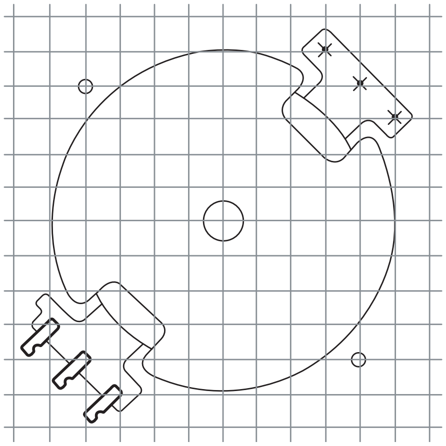
"TB-P" bases, which are polypropylene, may be etched in order to roughen the adhering surface and improve the bonding that is achieved.

Plastic screw drivers are available upon request for use in final tuning.

Tuning assemblies are available for most standard size pot cores. Contact Magnetics Application Engineering for details.

Assembly Notes

FIGURE 1



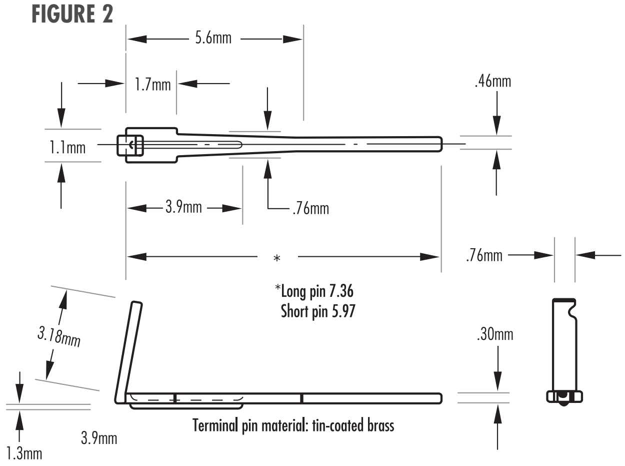
PRINTED CIRCUIT BOBBINS AND MOUNTING HARDWARE

Many sizes in the standard pot cores can be supplied with printed circuit board bobbins. The grid pattern (Figure 1) illustrates the location of 6 pin type bobbins. The soldering pins are arranged to fit a grid of 2.50 mm. The pin length is sufficient for a board thickness up to 4.75mm. Terminal pin details are illustrated in Figure 2. The board holes should be 1.17mm + .08mm in diameter (#56 drill). The bobbin should be cemented to the lower pot core half.

For some core types, printed circuit board mounting clamps are also available. A cross section of a completed core assembly using clamps is shown in Figure 3. When clamps are not available, the pot core halves must be cemented together.

Printed circuit board hardware for EP, RM and RS cores is described in the sections covering these core types.

FIGURE 2



PRINTED CIRCUIT BOBBINS SOLDERING INSTRUCTIONS

1. A solder pot should be used to solder the leads to the terminals. Preferred solder is 63/37 tin/lead eutectic. The solder temperature should be between 275°-300°C. Lower or higher temperatures will both damage the bobbin. Modern soldering techniques commonly use temperatures in excess of the softening points of all thermoplastic bobbin materials. Extreme care is required to prevent loosening of the terminals during soldering.

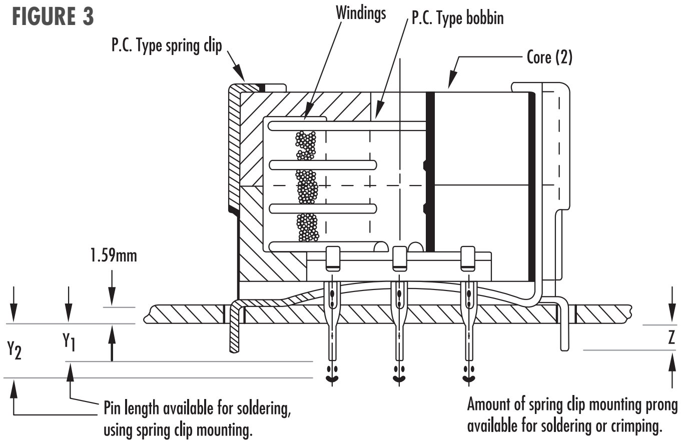
2. Insulation should be removed from the ends of the wire before soldering. This is especially important when litz wire is used. The preferred method is by burning.

3. Dip wound terminals into liquid soldering flux. A rosin based flux in alcohol solution should be used. Allow flux to air dry.

4. The bobbin should be immersed only far enough to cover the terminals.

5. The part should be immersed in the solder for 2-4 seconds, depending on the size of the wire used.

FIGURE 3



Wire Tables

TABLE 5 - MAGNET WIRE

WIRE SIZE	WIRE AREA (MAX.)* HEAVY		TURNS**	RESISTANCE	CURRENT CAPACITY (MA)	
AWG	Circular Mils	cm^2 10^{-3}	per cm^2	Ohms/1000	@750 Cir. Mil/amp	@500 Cir. Mil/amp
10	11,470	58.13	13.8	.9987	13,840	20,768
11	9,158	46.42	17.4	1.261	10,968	16,452
12	7,310	37.05	21.7	1.588	8,705	13,058
13	5,852	29.66	27.3	2.001	6,912	10,368
14	4,679	23.72	34.1	2.524	5,479	8,220
15	3,758	19.05	40.3	3.181	4,347	6,520
16	3,003	15.22	51.2	4.020	3,441	5,160
17	2,421	12.27	63.6	5.054	2,736	4,100
18	1,936	9.812	79.1	6.386	2,165	3,250
19	1,560	7.907	98.4	8.046	1,719	2,580
20	1,246	6.315	124	10.13	1,365	2,050
21	1,005	5.094	155	12.77	1,083	1,630
22	807	4.090	186	16.20	853	1,280
23	650	3.294	232	20.30	681	1,020
24	524	2.656	294	25.67	539	808
25	424	2.149	372	32.37	427	641
26	342	1.733	465	41.0	338	506
27	272	1.379	558	51.4	259	403
28	219	1.110	728	65.3	212	318
29	180	0.9123	868	81.2	171	255
30	144	0.7298	1,085	104	133	200
31	117	0.5930	1,317	131	106	158
32	96.0	0.4866	1,628	162	85	128
33	77.4	0.3923	2,015	206	67	101
34	60.8	0.3082	2,480	261	53	79
35	49.0	0.2484	3,100	331	42	63
36	39.7	0.2012	3,876	415	33	50
37	32.5	0.1647	4,961	512	27	41
38	26.0	0.1318	5,736	648	21	32
39	20.2	0.1024	7,752	847	16	25
40	16.0	0.0811	10,077	1,080	13	19
41	13.0	0.0659	12,403	1,320	11	16
42	10.2	0.0517	15,504	1,660	8.5	13
43	8.40	0.0426	19,380	2,140	6.5	10
44	7.30	0.037	23,256	2,590	5.5	8
45	5.30	0.0269	28,682	3,348	4.1	6.2

Wire Tables

TABLE 6 - LITZ WIRE

LITZ Wire Size	**TURNS***** per cm^2	**LITZ** Wire Size	**TURNS***** per cm^2
5/44	4,341	72/44	232
6/44	3,876	80/44	217
7/44	3,410	90/44	186
12/44	2,016	100/44	170
20/44	1,147	120/44	140
30/44	620	150/44	108
40/44	465	180/44	77
50/44	356	360/44	38
60/44	294		

*Areas are for maximum wire area plus maximum insulation buildup.

**Based on a typical machine layer wound coil.

*** Based on a typical layer wound coil.