NEOSID

MAGNETIC COMPONENTS

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NEOSID

Magnetic Materials

Catalogue of magnetic and plastics components

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Contents

Contents *Page*

SOFT FERRITES

Soft Ferrites
General Information

1. Basic Concepts and Definitions

1.1 Ferromagnetism

Under the influence of an external magnetic field, magnetization occurs in ferromagnetic materials. Upon removal of the external field the material returns immediately to its normal, demagnetized state. This property is referred to as ferromagnetism.

Ferromagnetic material is subdivided into a great number of magnetic domains (elementary magnets) having dimensions in the order of 1 μm. In the normal state, i.e., no external magnetic field, these domains are randomly orientated and it is not possible to detect any magnetic effects by measurement.

Ferromagnetism in metals is due to exchange forces on the atomic level which align in parallel the adjacent electron spins to create very strong magnetic fields within the body. This makes the magnetic moments of the atoms additive over a relatively large area of a single domain.

When an external magnetic field is applied to a ferromagnetic material the individual domains tend to align themselves to the direction of this field. Some of the randomly orientated domains are capable of aligning themselves with the external field by rotation, even if the field is very weak. Others require much stronger fields as their direction is such that they have to collapse and re-emerge with the orientation nearly opposite to the original one. Yet others expand dimensionally at the expense of less favourably orientated neighbours.

Strictly speaking, ferrites are not ferromagnetic as not all the electrons within a domain are spinning in the same direction; in fact, there are two classes of electrons spinning in opposite directions which results in the overall magnetic moment of a domain being weakened. All soft ferrites having practical applications (with the exception of microwave ferrites) have a spinel lattice crystalline structure, the opposite magnetic systems being located in adjacent lattice planes. However, the numerical relationship between these two classes is such that ferrites can be, and usually are, treated as ferromagnetic materials. The strict nomenclature calls the substances such as ferrites "ferrimagnetic".

1.2 Permeability

Permeability is generally defined as the ratio between the induced magnetic flux density in the material and the external magnetic force that causes it. In practice, the applications of ferrite cores have led to several concepts of 'permeability' which are associated with the method of measurement.

1.2 (a) Intrinsic permeability (μ_i)

Intrinsic permeability is the ratio between the flux density created and the applied magnetic field strength, measurements being recorded at very low field strength on a toroidal ring manufactured from the material being examined. The inductance from a single-layer winding closely wound on the toroid is measured and the intrinsic permeability is calculated from the known inductance and the dimensions of the toroid, using the following formula,

$$\mu_i = \frac{L}{n^2} \cdot \sum \frac{\ell}{A} \cdot \frac{10}{4\pi}$$

where L is in nH,
$\sum \frac{\ell}{A}$ is in mm^{-1},
n is the number of turns.

The geometric core constant, $\sum \frac{\ell}{A}$, is calculated taking into account the variation of the magnetic path length in the radial direction and the associated changes in flux density and hysteresis losses.

The intrinsic permeability of the material is also known as the initial permeability, by reference to the B-H magnetization curve and as toroidal permeability due to the method of measurement.

1.2 (b) Amplitude permeability (μ_a)

When a relatively high, alternating magnetic field is applied, as in the case of power transformers, the shape of the B-H curve causes the permeability to vary during the cycle and the concept of permeability as an invariant ceases to be significant. The definition of permeability which is of greater use to the designer of the component is the ratio of the flux density in the material and the applied field strength at a specified flux density, e.g., 200 mT or 400 mT, which is usually the peak value of the flux density during the cycle. This permeability, which is known as amplitude or alternating field permeability, must always be specified with reference to the peak flux density reached during measurement of the mean reactive voltage drop across the core (toroidal ring) winding and the peak current in the winding. Since the voltage drop is proportional to the flux density and the current is proportional to the field strength, their quotient, including some constants, is the permeability.

1.2 (c) Effective permeability (μ_e)

In most cases, ferrite cores are not closed magnetic circuits but contain air gaps, either deliberately introduced or caused by the imperfections of a butt joint between two mating surfaces. In the case of pot cores, E cores, U cores, etc., where the gaps are relatively small (even when deliberate), some of the applied magnetomotive force is lost in overcoming the reluctance of the air gap. This results in the permeability of the core being lower than that of the material; the lowered permeability which is calculated from the measurement of the inductance of a winding on the core concerned, is called the 'effective' or 'gapped' permeability. It represents the intrinsic permeability of a perfectly closed core which would produce the same inductance, if it were of exactly the same configuration and dimensions, except for non-existence of the gap.

The same argument applies to amplitude permeability which, as already discussed, is determined from measurements on a toroidal winding. When the same type of measurement is carried out on the winding of a gapped core, the result is defined as an 'effective' amplitude permeability. However, in the first instance, the difference between the intrinsic and effective amplitude permeabilities is not indicated when the amplitude permeability for U and E cores is given.

The effective permeability is used in the calculations of losses, temperature coefficient and disaccommodation.

1.2 (d) Rod permeability (μ_{rod})

Many ferrite cores, of which aerial rods and screw cores are typical examples, are used in such a manner that the ferrite material only occupies a part of the path of the magnetic lines generated by the current flowing through the winding. The magnetic circuit is then virtually open and very strong demagnetizing fields appear at the end faces of the core. Depending on the configuration of the magnetic core, usually expressed as length-to-diameter ratio in the case of cylindrical cores, the permeability (known in this case as the rod permeability) can be calculated from the intrinsic permeability of the material. Such a calculation would be very complex in the general case but is relatively easy for cylindrical cores that are approximated to ellipsoids.

For aerial rods, the rod permeability expresses the ability of the rod to concentrate the field lines arriving from a distant transmitter and is, therefore, one of the factors determining the pickup voltage. This permeability varies along the core having its highest value in the mid-section and its lowest at the end faces.

It is very rare for open-circuit cores to operate at substantial flux densities and rod permeabilities are always associated with very low field conditions.

Because of the nature of the magnetic circuit, rod permeability is always very much lower than the intrinsic permeabilities of the material and the difference between these permeabilities increases as the length-to-diameter ratio decreases.

It should be noted that there is no known method for physically measuring values of rod permeability.

1.2 (e) Coil permeability (μ_{coil})

Even when the winding of a coil used with a ferrite core is in the most intimate contact with the core, only some of the magnetic lines generated by the current flowing in the winding pass through the core. The contribution of the core towards the inductance of the coil is therefore much smaller than might be expected if the permeability (intrinsic in the case of closed toroids, effective in the case of air-gapped cores, and rod permeability in the case of open-circuit cores) was uncritically taken as the basis for calculation. In other words, the ratio of the inductance of coil with a core and the inductance of the same coil with the core removed is much smaller than the intrinsic, effective or rod permeability of the core itself. This ratio is termed the coil permeability and is particularly significant for the design of open-circuit components where it gives, for example, a direct indication of the range of variation of inductance of the coil with a screw core adjuster.

For an open magnetic circuit the coil permeability is a function of the geometry of the winding (as in the case of aerial rods, screw cores, etc.) and the coil permeability decreases if the winding is further removed from the core, e.g., if a thick former is used or the winding consists of several layers. In the case of closed or small-gap magnetic circuits, the geometry of the winding has virtually no influence on the inductance; hence the inductance of a winding with a pot core does not really depend on the position of the winding with respect to the spigot (although this position may be significant for other properties of the coil) but the coil permeability will still vary because the inductance of the winding without the core depends upon its geometry. When the winding occupies most of the available space within a pot core, the coil permeability is of the order of one third of the effective permeability of the core.

1.3 Inductance

In order to facilitate the design of inductors based on toroidal, pot, E, and U cores, it is usual to provide information on the expected inductance when using a specific core (specified by material grade, configuration, dimensions and size of air gap if any). This information is given in the form of the so-called A_L factor expressing the inductance of a one-turn coil in nH. Actual calculation of A_L is carried out by measuring the inductance of a coil with n turns and dividing the result by n^2.

When calculating the inductance of the coil, it must be remembered that it is proportional to the square of the number of turns.

2. Physical Properties of Ferrites

2.1 General Manufacturing Processes

Commercially used ferrites suitable for applications in inductors, transformers, tuned circuits, etc., fall into two classes, manganese-zinc ferrites and nickel-zinc ferrites. Both are ceramic materials made of metal oxides. These oxides are intimately mixed to facilitate a reaction when pre-fired at a temperature of the order of 1000°C (a process also referred to as 'calcining') where the ferrite structure is partially formed, i.e., the reaction is not complete at this stage. The pre-fired material is broken down, pulverized and, with the addition of bonding materials, formed into granules suitable for automatic presses or into a form to facilitate extrusion. Pressing or extrusion results in shapes similar to those finally required but dimensions at this stage are significantly larger, as subsequent sintering at temperatures of the order of 1200°C-1350°C causes substantial shrinkage of all dimensions. The ferrite is now fully formed and the physical structure of the material is crystalline with cubic crystal cells, this structure being called a spinel lattice.

2.2 Chemical Composition

The composition of different grades of ferrite varies with the properties required but, generally speaking, about 50% (molecular) of the material is Fe_2O_3, and the other 50% is divided between NiO and ZnO, or MnO and ZnO. Other components may also be introduced in fairly small amounts when it is found that they are beneficial to certain properties that may be required.

2.3 Physical Shrinkage

The shrinkage that occurs during sintering of a ferrite core is a function of many manufacturing parameters and it is not possible to avoid its variations even within a single production batch, let alone from batch to batch. The dimensional tolerances therefore of 'as-sintered' bodies are fairly large. If this is not acceptable for the ferrite component concerned, the only way to obtain finer tolerances is by grinding, ferrite being too hard for any other finishing process. It is advisable to make due allowance in the design of components with ferrite cores to have maximum possible dimensional tolerances, thus keeping finishing and grinding costs to a minimum.

2.4 Distinctive Properties of Mn-Zn and Ni-Zn Ferrites

Although there is an overlap of properties between the manganese-zinc and nickel-zinc classes of ferrites, some general distinctive features are apparent.

The manganese-zinc ferrites are characterized by rather high intrinsic permeability (from 600 upwards) and losses that rise rapidly at relatively low frequencies. Their resistivity is low, although much greater than in metals and metal alloys. The Curie point is also low, generally decreasing as permeability increases. Manganese-zinc ferrites are mainly used for low-frequency applications although there are some exceptions to this rule. Nickel-zinc ferrites are of lower permeability, but their losses at higher frequencies are lower which makes them more usable at frequencies up to, say, 200-250 MHz, when maintaining low losses is vital. Their resistivity is higher by several orders of magnitude, and the Curie point is also higher.

Both classes of ferrites are sub-divided into several grades having different compositions. The ratio of manganese to zinc or nickel to zinc constituents to a large extent, determines the grade of ferrite. Other differences include small changes in the minor constituents and in the manufacturing techniques particularly sintering. The grades of ferrite are usually classified in accordance with their intrinsic permeability but, obviously, other parameters will also differ. It should be pointed out in this context that, because of the complexity of the manufacturing process, even within a single batch of ferrite cores a spread of properties such as permeability and losses will be encountered. The inevitable variation in dimensions has already been mentioned.

3. Parameters of Ferrite Materials

3.1 Permeability

Various definitions of permeability are discussed in Section 1. Information published by manufacturers of ferrites usually gives values for the intrinsic (toroidal, initial) permeability of the material, either as a nominal value with a specified tolerance of ±20% or 25%, or as a bottom limit with the top limit unspecified. The symbol for intrinsic permeability is μ_i.

For ferrites used in power applications, information generally includes the bottom limit of the amplitude (alternating field) permeability (μ_a), at a stated room temperature and the highest rated temperature, for one or more values of the peak flux density in the measuring cycle. The symbol for amplitude permeability is μ_a.

Published values of the permeability (intrinsic or amplitude) are derived from measurements on pressed toroids having an outside diameter of approximately 30 mm. Under production conditions and with inspection methods adapted to the shape and expected application of the ferrite cores, it is not always possible to ensure that the intrinsic (or amplitude) permeability of a specific core is exactly the same as that of specially made toroids, used for batch process control of ferrite powders from which such cores are made. The differences in some instances can be considerable, particularly if the cores are small, because the sintering conditions of a small body are obviously different from those of a larger body with a greater thermal capacity or, in the case of extruded cores, different powder preparations are employed for different shapes or, in the general case, when the cores are not expected to be wound toroidally. Screw cores, for example, with through holes are not intended to be wound as toroids and are measured for coil permeability in standard coils.

3.2 Losses

3.2 (a) General comments

When an alternating field is applied to a ferrite core, a certain amount of energy is expended in making the magnetic state of the material follow the changes in the field during each cycle and in generating eddy currents which flow in the material itself.

Because of the hysteresis of the magnetization loop ($B=f(H)$), a specific amount of energy, related to the loop area, is expended during each cycle. If the field strength is very low, this energy is very small and may almost be considered negligible except in materials which have otherwise very low losses.
The power losses, caused by hysteresis, are obviously proportional to the number of cycles but even the loss per cycle tends to increase slightly with frequency.

Although the resistivity of ferrite materials is relatively high, some eddy currents are still induced in them and become a source of power loss. This is proportional to the square of the frequency of the applied alternating field. The eddy current losses are the main reason why metallic cores, however thinly laminated, were superseded by ferrite cores especially for the higher frequencies. Nonetheless, eddy current losses still do occur in ferrites, more so in manganese-zinc types than in nickel-zinc types, as the resistivity of the nickel-zinc ferrites is much higher.

Even at very low field strength, changes of magnetic state occur in the ferrite materials (if it were not so, the material would be defined as inert). These changes are accompanied by subsidiary effects such as the resonance of domain rotation, relaxation of domain walls (least energy state is always aimed at) and other phenomena concerning the fundamental structure of ferrites. The power expended on all these effects is usually referred to as the residual losses (also called 'after-effect' losses, magnetic viscosity or the German word 'Nachwirkung'). At very low field strengths, these residual losses are the main component of the total sum of losses, especially if the frequency is not very high.

3.2 (b) Definitions

The losses associated with a coil wound on a ferrite core can be represented by the resistive component of its impedance at any given frequency and any field strength. If the total loss resistance is divided into its main parts, we have the following equation,

$$Z = R_{wind} + R_h + R_r + R_e + j\omega L$$

where,

R_{wind} represents the losses in the resistance of the winding (DC and AC)
R_h represents the hysteresis loss in the core
R_r represents the residual losses in the core
R_e represents the eddy current losses in the core
$\omega = 2\pi f$ where f is the frequency
L is the inductance of the assembly

R_{wind} can be found by winding an identical coil without a ferrite core and measuring its loss resistance at the desired frequency. This is not rigorously accurate as the presence of the core affects the flux distribution and the losses in the winding but this approach is still used for lack of a more accurate method of direct measurement excluding laborious calculations.

R_r and R_e are usually measured together by means of a bridge or Q-meter, taking care to maintain the field strength at a very low level to avoid hysteresis losses.

R_h is easily separated from other loss resistances by making two measurements of total loss resistance at two different field strengths (5 and 20 mA/cm).

For individual grades of ferrite the information regarding losses is usually given in the form of so-called loss factors (residual+eddy currents and hysteresis) normalized to unit (intrinsic) permeability. This facilitates a calculation of loss coefficients of gapped ferrite cores (especially pot cores); it is assumed that the loss coefficient is always proportional to the effective permeability of such cores. It is worth pointing out that in open-circuit cores the loss coefficient cannot be assumed to be proportional to the rod permeability.

Thus, the residual+eddy current loss factor at an angular frequency ω is,

$$LF_{(r+e)} = \frac{R_{(r+e)}}{\omega L} \cdot \frac{1}{\mu_i} = \frac{\tan \delta_{(r+e)}}{\mu_i} = \frac{1}{Q_{(r+e)}\,\mu_i}$$

where $Q_{(r+e)}$ is the value of Q which would be measured if residual and eddy current losses were the only losses in existence (i.e., no losses in the winding and no hysteresis losses in the core). For a given effective permeability of a gapped core (μ_e) the residual+eddy current loss coefficient is

$$\frac{\tan\delta_{(r+e)}}{\mu_i}\cdot\mu_e$$

Similarly the value of $Q_{(r+e)}$ is increased by a factor equal to μ_i divided by μ_e.
The problem associated with the use of normalized hysteresis loss coefficients is rather more complex since it is necessary to normalize not only to unit permeability but also to unit flux density (or field strength). There are several definitions of such normalized hysteresis loss coefficients as follows,

(i) IEC (International Electrotechnical Commission, Publications 125 and 218) hysteresis coefficient is defined as,

$$\eta_B=\frac{\tan\delta_h}{\mu_i\ B_{max}}\quad(\mathrm{mT}^{-1}\times10^{-6})$$

where $\tan\delta_h=R_h/\omega L$ and B_{max} is the peak value of the flux density.

(ii) DIN (German Standards Institution specification 41280) specifies the normalized hysteresis coefficient as h/μ_i^2 where,

$$h=\frac{R_h}{f.L.\triangle H_{rms}}$$

or

$$h=\frac{2\pi.\ \tan\delta_h}{\triangle H_{rms}}\quad(\mathrm{cm.A}^{-1}\ 10^{-6})$$

(iii) Legg (Bell System research worker) specified the normalized hysteresis coefficient as,

$$a=\frac{R_h}{f.L.\mu_i\ B_{max}}$$
$$=\frac{2\pi.\ \tan\delta_h}{\mu_i\ B_{max}}\quad(\mathrm{gauss}^{-1}.10^{-6})$$

To convert the IEC coefficient to the Legg coefficient we multiply by $2\pi/10$. The DIN coefficient is equal to the IEC coefficient multiplied by $1{\cdot}12\times10^{-3}$.

All the above coefficients represent intrinsic properties of the material as measured on toroids.

In some instances the term 'hysteresis factor' (F_h) is used to describe the property of a core and is written as follows,

$$F_h=\frac{2\pi.\ \tan\delta_h}{I_{rms}\sqrt{L}}$$

According to the IEC definition, 'hysteresis core constant' is defined by,

$$\eta_i=\frac{\tan\delta_h}{I_{peak}\sqrt{L}}$$

The hysteresis factor, F_h, can be calculated from the DIN intrinsic hysteresis coefficient, h/μ_i^2, as follows,

$$F_h=\frac{h}{\mu_i^2}\cdot\mu_e^2\left[\frac{n}{\ell_e\sqrt{L}}\right]$$

where μ_e is the effective permeability
n is the number of turns
ℓ_e is the magnetic length
L is the inductance in Henrys

When the A_L factor is introduced the above formula can be re-written,

$$F_h = \frac{h}{\mu_i^2} \cdot \mu_e^2 \left[\frac{1}{\ell_e \sqrt{A_L}} \right]$$

These expressions are frequently encountered when dealing with gapped cores.

The above hysteresis loss factors and coefficients can only be applied when the flux density in the core is relatively low (up to, say, 20 mT) and where the Rayleigh law is valid. When the flux density is high, as in power applications, the losses are specified as the power loss density (i.e., total power losses per unit volume or unit weight of the core) at a given frequency and given flux density. In this case, the losses are primarily due to hysteresis effects, but they are not normally separated into various categories; they are however specified at two or more temperatures including the highest expected working temperature.

An interesting case is represented by the so-called dimensional resonance losses. In some manganese-zinc ferrites the dielectric constant and the permeability of the material are so high that the wavelength in the material (which is inversely proportional to $\sqrt{\mu\varepsilon}$) may become comparable with the dimensions of the core. This – as in a waveguide – causes additional losses which can be prevented only by subdividing the offending dimension. This is the reason why some grades of ferrite aerial rods are fluted.

3.2 (c) General notes relating to the data sheets

Regarding the information provided in the data sheets, the nickel-zinc ferrites (mainly used in open-circuit configurations) are described by loss factors corresponding to the sum of the residual and eddy current losses. The grades of manganese-zinc ferrites mainly developed for power applications are characterised by the power loss density under specific conditions. Other manganese-zinc ferrites, especially those used in low frequency telecommunication applications, are characterised by both the residual+eddy current and the hysteresis loss factors and coefficients.

Information given for individual grades of ferrite specify the typical or maximum loss factors (residual+ eddy current losses) for a range of frequencies in the area where these losses remain fairly low. Generally speaking, these loss factors increase with the frequency at a steady rate, slower than frequency at first until a certain end frequency is reached and then rapidly increasing to overtake the frequency rise. The point at which this accelerated rate of increase of loss factors occurs depends, for a given ferrite composition, upon the sintering conditions and may vary between batches of cores, even if their behaviour at the normal recommended frequencies (lying well within the range of relatively low losses) remains virtually unchanged. At frequencies well outside their normal range of application, all ferrites exhibit high loss characteristics, so much so in fact, that in the form of beads threaded on conductors they can be used for suppression purposes, as if they were resistors inserted in series with the conductors.

4. Q (magnification) Factor

It is a well established practice to describe the quality of an inductor (or tuned transformer winding) used in a resonant circuit by means of its Q factor (the ratio of reactance and resistance at a given frequency). There are two reasons for doing this, (a) the Q of a circuit, which is usually approximately equal to the Q of the inductor as the Q of capacitors is very much higher, determines the selectivity of the resonant circuit, Q being equal to the ratio of the centre frequency and the spacing between 3dB points on the resonance curve, and (b) it is very easy to measure by means of simple Q meters.

The inductors used in resonant circuits may be based on closed, air-gapped or open-circuit cores in various configurations. In all these cases it is assumed that the field strength in the core is so low that hysteresis losses are negligible and only residual and eddy current losses occur in the core. In special cases, dimensional resonance losses may also exist.

In cores which represent closed magnetic circuits the relationship between the value of Q and the loss factors (residual+eddy current losses) is basically simple because $Q=1/\tan\delta$. Provided losses in the winding can be neglected, and this is frequently the case in high-permeability closed magnetic circuits,

$$Q=\frac{1}{\tan\delta}=\frac{1}{\mu_i\,.\,\text{loss factor}}$$

When the core is gapped, its effective permeability is lower and it may not be possible to neglect the a.c. resistance of the winding. However, when it is possible to neglect this resistance,

$$Q=\frac{1}{\mu_e\,.\,\text{loss factor}}$$

Finally, in cores having open-circuit configurations, it is generally not possible to neglect the resistance of the winding and the simple formula is not usable; moreover, expressing the losses in such cores in terms of intrinsic loss factors and rod permeabilities is not feasible, and applying coil permeabilities would lead to even more fallacious results.

Hence, in open-circuit cores, the true Q value is directly dependent on the properties of the ferrite material and shape and size of the core and can only be found by measuring the Q value of the combined coil and core (Q_{total}), removing the core, measuring the Q of the winding at the same frequency (Q_{wind}) and calculating the a.c. resistance of the winding. Therefore,

$$R_{total}=R_{ferrite}+R_{wind}$$
$$=\frac{\omega L}{Q_{total}}$$

where L is the inductance of the coil with the core.

$$R_{wind}=\frac{\omega L}{\mu_{coil}.Q_{wind}}$$

as the inductance of the winding without a core is reduced by a factor of μ_{coil}.

$$R_{ferrite} = \frac{\omega L}{Q_{total}} - \frac{\omega L}{\mu_{coil} . Q_{wind}}$$

$$= \omega L \cdot \frac{\mu_{coil} . Q_{wind} - Q_{total}}{\mu_{coil} . Q_{wind} . Q_{total}}$$

That is, the Q that would be obtained if there were no losses in the winding is,

$$Q_{ferrite} = \frac{\mu_{coil} . Q_{total} . Q_{wind}}{\mu_{coil} . Q_{wind} - Q_{total}}$$

The above derivation is based on the assumption that the presence of the core does not affect the losses in the winding; however, this is not strictly true as the flux distribution in the winding is bound to change.

In practical applications the construction of the winding and its conductor are invariant and when Q_{total} is measured, its variations reflect the variations in the intrinsic properties of the core material. This is also true of the manufacturer's inspection methods for many types of cores which are based on the use of specially made test coils.

For a specific core and winding, the measured value of Q varies with the measuring frequency. When this frequency is low the reactance is also relatively low, whereas the a.c. resistance of the winding may be appreciable and Q is low. As the frequency of measurement is increased, the reactance rises much more rapidly than the resistance of the winding and Q rises with the frequency, in spite of the general trend of ferrite losses increasing with frequency. Finally, when the frequency is fairly high and the capacitance required to tune the measured inductance is low, the self-capacitance of the winding begins to affect the measurement and lower the value of Q, due to its very presence and its dielectric losses.

Thus the Q of an inductor is a function of the capacitance used for its tuning, or, in other words, there is an optimum value of inductance for any given frequency.
Finally, it must be pointed out that direct comparison of the values of Q is only possible when all conditions of measurement are strictly invariable.

5. Frequency Range

The range of frequencies in which a particular grade of ferrite material may be usefully applied depends upon the specific conditions of the application and on the configuration of the core itself.

Sometimes the limits of the range are arbitrarily defined as those frequencies at which the value of Q of inductors wound on toroidal rings drops to 50 or, in other cases, to 20. Yet another definition of the upper limit of the range is based on the rapid rise of loss factor at and above a certain frequency, this point being easily measured for any given core; however, it should be borne in mind that this frequency will vary appreciably from batch to batch and it seems inadvisable to base any expectation of performance on its constancy.

If the core is to be used for a transformer, the circumstances are different. It is not only the loss in the core and winding that is significant but the relationship between the shunt reactance of the transformer winding and the impedance of the source or load circuit is also of fundamental importance. There is also the leakage inductance which largely determines the losses in the transformer at the high-frequency end of its working range. An ideal transformer would have an infinitely high parallel (shunt) inductance, such that its low-frequency response is perfect, and an infinitely low series (leakage) inductance so that its high-frequency limit is not curtailed. High-permeability grades of ferrite are therefore most suitable for transformer applications, because high shunt inductances with a small number of turns giving rise to low leakage inductances can be obtained. In fact, there is no reason to abstain from using a ferrite which has extremely high losses at the high-frequency end of the working range of the transformer because the shunt reactance will be so high that these losses become inconsequential.

The general rule in all applications is to use the grade of ferrite with the highest permeability and with losses not exceeding the level which can be tolerated.

It must be clearly stated that manufacturers test their products at frequencies specified in their publications and the behaviour of ferrite material outside these frequencies cannot be guaranteed.

If a certain level of losses (or Q) is expected at a certain frequency, it is necessary to select the grade which is tested close to or above the frequency in question and not to rely on the results of measurements carried out on samples.

6. Curie Point and Temperature Coefficient

As the temperature of a ferromagnetic material rises, thermally enhanced motion of domains and molecules becomes more violent. This greater mobility makes it easier for the domains to follow the variations of magnetic field induced by current flowing through a coil. The intrinsic permeability therefore will also increase with temperature, that is, the temperature coefficient of inductance of coils based on ferrite cores is nearly always positive. The exception to this rule occurs with certain manganese-zinc ferrites, the permeabilities of which reach a maximum, decrease over a relatively narrow range of temperature, and then begin to rise again. In these cases, which are few among the many commercially available ferrites, the temperature coefficient is negative over a certain temperature interval.

Permeability rises with temperature until a point is reached where the random thermal motion becomes so violent that the applied field is incapable of enforcing any ordering within the ferrite, that is, the induction ceases to be related to the field strength and the permeability drops to near unity. The temperature at which this effect occurs is very clearly defined and depends primarily on the composition of the sintered ferrite. This temperature is known as the Curie Point and is usually defined as that temperature at which the intrinsic permeability has dropped to 10% of its original value. If the core and its thermal capacity are small or the temperature rise in the oven in which the measured core is kept, is very slow, the Curie Point can be determined very accurately as the decrease in inductance at this point is extremely rapid.

The intrinsic temperature coefficient of permeability (inductance) is measured by winding a toroidal core of about 30 mm diameter and measuring its inductance over a specified temperature range (usually +20°C to +55°C, +60°C or +70°C). The temperature coefficient is then calculated as the average value of the inductance rise ($\triangle L/L$ or $\triangle \mu/\mu$) per °C. However, this expression for the temperature variation of permeability will only give guidance to the behaviour of inductors using toroidal cores.

It is generally assumed that the temperature coefficient of an inductor using a gapped core is less than its intrinsic (toroidal) value in the same proportion as the effective permeability has been reduced from its intrinsic value. It is customary therefore, to present information on the value of the temperature coefficient normalized to unit (intrinsic) permeability, this value being expressed in parts per million and being referred to as the temperature factor.

Temperature factor

$$= \frac{\text{temperature coefficient}}{\text{intrinsic permeability}}$$

$$= \frac{\triangle \mu}{\mu_i \ \triangle T} \Big/ \mu_i$$

$$= \frac{\triangle \mu}{\triangle T \ \ \mu_i^2} \text{ in parts per million/°C}$$

The temperature range wherein the value of the temperature factor remains valid is always clearly stated.

To find the temperature coefficient of an inductor using a gapped core, the temperature factor of the relevant material is multiplied by the value of the effective permeability.

The situation becomes far more complicated in the case of open-circuit core configurations and it is not possible to calculate the temperature coefficient of inductors using such cores, simply by multiplying the temperature factor by the rod or coil permeability. The actual value can only be ascertained by the direct measurement in each specific case.

The temperature coefficient of cores used at high flux density is rarely of interest as the coils wound on them are generally not tuned. The main temperature effect in such cores is the change in their saturation induction.

7. Saturation Induction

In principle, saturation induction is that value which is reached when the ordering of domains under the influence of the applied field cannot proceed any further and the value of magnetization increases only by virtue of an increasing applied field strength. This is so as total flux density is composed of the flux density induced in the material because of its permeability and the flux density equal to the field strength itself.

The saturation induction is a very important parameter in the design of power transformers and is generally specified for ferrite grades used in such applications. In Great Britain it is usually given as the value of flux density obtained when the field strength is 8 A/cm (approx. 10 oersted). In Germany the field strength standardized for this measurement is 30 A/cm (approx. 38 oersted) which gives a slightly higher figure.

The actual value of the saturation induction for commercially available ferrites developed for power applications is generally quoted for room temperature as between 400 and 480 mT. The saturation induction is substantially lower in the temperature range between 80°C to 100°C where the cores for power transformers may be expected to operate. Apart from being specified as an intrinsic property, the saturation induction is also indirectly specified for transformer cores as the expected amplitude permeability at 400 mT at room temperature and at a lower flux density at the elevated working temperature.

The measurement of amplitude permeability at very high flux density is carried out by measuring the voltage across the wound core (calculated by the usual transformer equation relating voltage to flux density and dimensions of the core) and the current flowing through the winding, both these values being peak values. Complications can sometimes arise in these measurements.

In the region of the $\mu=f(B)$ characteristic where the above measurement is carried out, the slope of the curve is very steep because of the near approach to saturation induction. Hence, even small errors of the measurement (especially when establishing the value of peak current) may lead to very large errors in the measured value of the amplitude permeability. An underestimation of the current by 5% may change the value of the permeability by a factor of, say, 2. This means that these measurements must be carried out using a specially built and frequently calibrated instrument, or by standard reference methods.

Voltage measurement as discussed above is used to obtain a value for flux and, subsequently, flux density and permeability. However, as it is essentially a flux measurement, its translation into flux density and permeability is only valid if all the parts of the measured magnetic circuit have the same dimensions. If this is not the case, the flux densities in various parts of the magnetic circuit are not equal and, while endeavouring to measure at, say, 400 mT, the conditions elsewhere may actually correspond to, say, 430 mT. This inaccuracy can be disastrous as the lower permeability in the relevant part of the circuit may easily become the dominant factor determining the total permeability of the circuit.

It must be pointed out that the measurement of amplitude permeability at, say, 200 mT (as sometimes specified) can be much more accurate as the $\mu=f(B)$ curve at mid-values of the flux density is fairly flat and the errors in the result are directly related to the errors of the measuring system thus excluding the above described catastrophic magnification.

Some users advocate the measurement of low-field permeability (intrinsic in the case of the ring cores and effective for gapped cores) as the optimum criterion. This practice, based on the convenience and availability of suitable test instruments, should be deprecated since it establishes as a merit figure a parameter that is meaningless in the context of application, and bears an indeterminate relation to the parameters that really matter.

8. Disaccommodation

After a ferrite core has been subjected to shock, thermal (change of temperature), mechanical (application of stress inducing force) or magnetic (application of magnetic field even as weak as in standard measurement techniques) its permeability abruptly increases and immediately begins to drift downwards continuing to do so for a very long time. The reasons for this phenomenon have not yet been satisfactorily explained but it is generally accepted that some relaxation effects occur on the atomic level. Some investigators believe that the main reason for this effect is the cation vacancies, but it is fairly well established in general that it is related to the sintering and cooling conditions under which the cores are manufactured, especially regarding the presence of ferrous ions (Fe^{++}) which occurs in ferrites (particularly manganese-zinc ferrites of overstoichiometric composition) where the molecular percentage of Fe_2O_3 in the composition is greater than 50%. The partial pressure of oxygen in the protective atmosphere in which manganese-zinc ferrites are usually sintered and cooled appears to exert some influence. Unfortunately, the manufacturing conditions which reduce this instability may be in direct conflict with those required for obtaining optimum values of other parameters and in practice a compromise solution has to be found, dependent on which of the core properties are regarded as the most important.

The form of instability described above is usually referred to as disaccommodation. Although its origins are obscure the effect itself is governed by simple laws of behaviour. The most interesting of these is the fact that the decrease in permeability is linear when plotted against a logarithmic time scale, that is, we can write,

$$D = \frac{\mu_2 - \mu_1}{\mu_1 . \log_{10} t_2/t_1}$$

where μ_1 is the permeability (intrinsic if measured on a toroid, which is the usual practice) at the time t_1 and μ_2 is the permeability at the time t_2. This law has been derived empirically and is valid throughout all time except for the initial brief period following the shock. This means that the relative inductance drop in the period 1 to 10 hours after the shock is the same as in the period 1 to 10 years, so that a long-term instability of the inductance can be predicted from measurements over a relatively short interval of time following a complete demagnetization of the core or its rapid heating to a temperature above the Curie Point. Both these methods are in current use.

Similarly to other ferrite parameters the disaccommodation is measured on toroids and expressed as the disaccommodation normalized to unit permeability and defined as follows,

Disaccommodation factor

$$= \frac{\mu_2 - \mu_1}{\mu_2^{\,2}} \cdot 10^{-6}$$

(In practice, $t_2 = 10.t_1$ thus, $\log_{10} t_2/t_1 = 1$ and disappears from the equation)

Actual values of t_1 and t_2 are standardised for practical manufacturing purposes and they are usually 10 and 100 minutes respectively.

Knowing the disaccommodation factor it is possible to predict the disaccommodation coefficient of an inductance based on a gapped core. This coefficient (in ppm) will be equal to the disaccommodation factor multiplied by the effective permeability of the core. The relationship in the case of open-circuit cores is not so simple and it is generally not possible to predict the actual value of their disaccommodation coefficients.

All disaccommodation measurements must be carried out at a perfectly constant temperature to prevent the disturbing influence of the temperature coefficient. The disaccommodation factor itself varies with temperature.

9. Resistivity

Ferrites are semiconducting materials and their resistivity depends upon their composition, that is it varies with the grade of ferrite. For nickel-zinc ferrites the resistivity is of the order of 10^5 to 10^7 ohm cm. For manganese-zinc ferrites it is appreciably lower, say 10^1 to 10^3 ohm cm, but nevertheless remaining very much higher than the resistivity of metals and metallic alloys.

The measurement of resistivity is carried out with direct current on specially prepared samples. The results are to some extent affected by the current density and the choice of metallic electrodes, and to a very great extent by the temperature. The resistivity of ferrites falls as the temperature increases.

10. Dielectric Constant

Manganese-zinc ferrites have high values of dielectric constant which in some cases may approach 10^6 at a frequency of 1 kHz. The value of the dielectric constant drops with the frequency, not very rapidly at first but then more and more steeply until at very high frequencies it approaches a value of 10.

Combined with the high permeability, the very high dielectric constant causes the wavelength in the material to be reduced to such an extent that it may become comparable to the physical dimensions of the core and cause dimensional resonance and associated losses.

Because of the high value of the dielectric constant the ferrite cores, especially manganese-zinc cores, should never be wound directly but should incorporate an insulating layer separating the wire from the core, thus avoiding losses from the otherwise resulting increased self-capacitance.

11. Physical Parameters

Exact values of the physical parameters of ferrites depend upon the composition and manufacturing conditions, especially the sintering temperature, and the values given below should be taken as indicating the order of magnitude only. If precise values are required, they should be measured on the cores in question.

Tensile strength	2 kg/mm^2
Compressive strength	10 kg/mm^2
Hardness	1000 kg/mm^2 (Vickers HV15)
Linear expansion coefficient	10.10^{-6}/°C at room temperature
Youngs Modulus	15000 kg/mm^2
Thermal conductivity	0·01 cal/cm sec °C
Density	4 to 5 gm/cm^3

The low coefficient of linear expansion may become the reason for very high stresses generated in ferrite cores encapsulated in epoxy resins or surrounded with plastics parts moulded directly upon them. Such stresses, if they occur, are usually detrimental to the electrical characteristics of the cores, besides causing the more mundane problem of cracking.

Results of Mechanical Stressing

Mechanical stressing of soft ferrite cores takes place above all in three commonly used technological processes:

grinding of ferrite surfaces,
clamping of pairs of cores,
(U, E, pot cores),
encapsulation in synthetic resins.

Although some efforts have been made to evaluate the effects of all three processes, the analytical difficulties are so great that, as yet, no general method has been found and established. All that can be said with any degree of certainty is that generally the compression, beyond an ill-defined limit, causes a decrease in effective permeability at low flux density of U and E cores with no intentional air gap and of ungapped (toroidal) cores, and an increase in the losses (loss factors at low flux density and power losses at high flux density). Similar effects occur also in metallic alloy cores (stampings or spiral wound tapes).

During grinding of multicrystalline ferrites, stresses are applied to the surface and underlying layers resulting in permanent deformation of the structure. Since ferrite is brittle, the removal of the surface material takes place by ploughing and chipping; the result is a roughness the degree of which depends on the grinding conditions.

The force applied during the grinding is a function of the depth of the cut. The greater the force, the greater is the affected depth of the material and the greater is the effect on the characteristics of the finished core. For economic reasons, the process of grinding must end long before a perfect finish is achieved, except in some cases of small-size extremely high μ cores.

Clamping of a pair of cores is another of those processes in which the quantitative parameters are at some point drastically changing the quality. When the clamping is relatively light and the applied force is properly directed along the axis of the mating cores, the effect is beneficial: the permeability is increasing and the losses are reduced.

This is because the roughness of the mating surfaces is great enough to allow a more intimate contact, when some pressure is applied. In other words, the effective gap which always exists between the mating surfaces, unless mirror polished, is decreasing as the peaks are crushed.

However, when the clamping force is great, this peak crushing process cannot continue indefinitely and the layers of material under the mating surfaces are subjected to high stresses which are changing their electromagnetic characteristics, invariably towards lower quality. Apart from this, a high clamping force may cause structural damage to the core; any multicrystalline structure is bound to have some weaker points or areas between crystallites which may give rise to internal cracks, not always visible, and they decrease the effective permeability by acting as air gaps — if the applied force is high enough.

Encapsulation of the assembled cores in a resin which has a shrinkage coefficient higher than that of the ferrite (which is a common fact) acts in the same manner as the clamping, possibly worse because:

a. the cracks are invisible however great they are,
b. the entire surface area and not only the mating surfaces are subjected to stresses, so that the affected part of the core material is even greater,
c. the beneficial effect of better mating of gapped cores is weakened or absent, since the pressure exerted by the shrunk resin envelope is rarely along this direction.

We could, of course, finish this discussion of compression effects by simple don't rules:

don't overclamp,
don't choose a resin with a high shrinking factor and requiring high curing temperature; add a fraction of inorganic material (silica, glass fibre etc.) to reduce the shrinkage.

However, as a matter of general interest, we shall try to explain in a simplified manner what are the reasons for a deleterious effect of all forms of mechanical stressing. For this purpose we have to examine the mechanism of magnetization of ferromagnetic cores, ferrite or metallic alloys.

When an alternating current, however small, flows through the winding on a ferromagnetic core, the core finds itself in a magnetic field,created by the current, and the magnetic induction in the core material tries to follow the periodic changes in the field (current). The word "tries" is used deliberately, because:

a. there is a time lag between the magnetic induction and the magnetic field force,
b. there are conditions when the induction cannot follow the field since saturation has been already reached.

The relation between the induction and the field strength is usually described by a hysteresis loop.

Current theories of magnetization of ferromagnetic materials make use of two macroscopic concepts: the ferromagnetic material consists of spontaneously created elementary units (magnets), called domains, which have finite dimensions; the polarity changes gradually from one domain to another neighbouring one, over a finite thickness of so-called domain (or Bloch) walls.

When the magnetic field is applied to the material, the tendency to align this structure of the material must lead to some changes in the direction of the pole axes of domains and/or virtual movement in the domain walls. Such changes, at least partly, must involve a degree of mobility within the material. It stands to reason that mechanical stressing of the material will affect this mobility.

To take an obvious example, admittedly outside the scope of our discussion but nevertheless very illustrative, the external magnetic field, required to magnetize (i.e. align the domains) an anisotropic ceramic permanent magnet material, has to be increased when the material is under external pressure. It is practically impossible to produce an anisotropic pressed magnet body, if the field is applied only when it is fully compacted, and in practice this field is applied, when the material is in a dispersed form in a liquid (wet pressing) or when it is still loosely powdered (dry pressing), in both cases while the internal mobility of the domains is unhampered.

For soft ferrites, the process of magnetization consists of several stages, overlapping in most ferrites (in square loop memory ferrites there is a distinct area of transition from one stage to another.) The individual stages correspond to different slopes of the virginal magnetization curve B = f(H) for a completely demagnetized sample. In the first stage in which the permeability is virtually constant, the magnetization is mainly caused by the "elastic" domain wall movement – the domains which happen to be more or less aligned with the field grow at the expense of their less fortunate neighbours. In the second stage, the magnetization takes place because some domain walls move, also at the expense of their neighbours as in the first stage, but since the field is now stronger, they can move against, and overcome, some mechanical impediments. Thus, they "click in" in their new positions. In other words, these domain wall movements are irreversible (which means not easily reversible in contradistinction to the movements in the first stage).

In the same stage there is also a certain amount of rotation of individual domains which may also be irreversible, if they become wedged against other domains. This is the stage in which Barkhausen noise occurs, caused by jumps of individual domains. The permeability in this stage, which includes the inflection point of the virginal magnetization curve, is not quite constant.

In the third stage, the magnetization occurs mainly by the reversal of the magnetization vector of individual domains which first collapse and then regenerate, but in such a manner as to agree with the polarity of the applied magnetic field. In this stage the permeability is already below its maximum and decreases as the applied field is increasing.

The fourth stage corresponds to saturation – some rise in magnetization still occurs – up to a point – because the applied field overcomes the random thermal effects on the (microscopic) spin moments.

The total energy required to bring a demagnetized sample to saturation is greater than that required to drive the sample along the hysteresis loops in an alternating field (taking only the first quadrant of this loop), because the energy, spent on irreversible movement of domains and domain walls, keeps being returned to the source as the sample is forcibly demagnetized.

The above described process of magnetization and its associated energy (power losses of the core) does not include the effects of eddy currents, but it does include the so-called residual losses. However, in the case of high flux densities, both residual losses and eddy current losses are normally small compared with the losses caused by the continuous magnetization and demagnetization along the hysteresis loop. It would not be so at low flux densities, when the residual losses (elastic movement of domain walls) and eddy current losses are the main effects in the energy balance, because hysteresis is very small (for perminvar ferrites, the ease of the domain wall movement in the trenches surrounding the domains causes the permeability ferrites and, of course, reduces the residual losses – hence, their very good loss factors).

When an external mechanical force is applied to the ferrite core, all processes based on mobility are bound to be made more difficult, i.e. more energy consuming or requiring a higher magnetic field. Thus, for a given field the number of domains participating in the process of alignment and cannibalization of their neighbours by the wall movement, will be reduced.

When the permeability (inductance) is measured at very low fields, it must decrease under mechanical stress, because the number of participating domains is reduced and their wall movement is more impeded. When the field is strong, the energy consumed on elastic wall movements and nucleation (collapse and rebirth of domains with a reversed magnetization vector) is greater, i.e. the hysteresis (and residual) losses are increased.

The shape of the hysteresis loop is changed by compression; if the magnetostriction is negative (NiZn ferrites), the loop becomes more square, i.e. the remanent induction is increased; if the magnetostriction is positive, the loop becomes less square.

Finally, when the core is gapped, all effects of stressing are greatly diminished, unless the length of the air gap is directly affected.

Characteristics of Soft Ferrite Materials

Ferrites are polycrystalline ceramics and are manufactured from metal oxides which are homogeneously mixed and subsequently sintered. Nearly all grades of ferrite contain about 50 (mol) % of iron oxide whilst the remainder consists of manganese oxide and zinc oxide or, nickel oxide and zinc oxide. Other constituents are often introduced into the mixture for manufacturing reasons or to influence certain electrical characteristics.

Manganese-zinc ferrites are generally used at lower frequencies. Their permeability is high but their resistivity is low (in the order of 10^1 to 10^3 ohm cm). Nickel-zinc ferrites are used for high frequencies in the range extending from a few hundred kHz to 200 MHz. Their permeability is lower and their resistivity is several decades higher than that of manganese-zinc ferrites.

The characteristics of a specific grade of ferrite depend upon its initial chemical composition, the shape and dimensions of the finished component and the manufacturing conditions. All information given in this section refers to the intrinsic values for the materials which are derived from measurements on pressed toroids having approximate dimensions of 30 mm outer diameter and 18 mm inner diameter with a height of 6 mm. It should be recognised that in actual components the characteristics may be different since they are dependent upon shapes and dimensions, thus the initial permeability may be substantially lower for smaller or extruded cores due to the different preparation of powder and the compacting, sintering and finishing processes.

For each individual grade of ferrite the information given refers to characteristics that are relevant to normal applications. Values for initial permeability (the permeability at very low field strength), Curie temperature, resistivity and the saturation induction are given in all cases.

For ferrite grades used in tuned circuits operating under low field strength conditions, the information on loss factors covers the residual and eddy current losses, hysteresis losses being very low when the flux density is low. From the values of loss factor given it is possible to calculate the value of Q of an inductor wound on a toroid,

$$Q = \frac{10^6}{\mu_i \ . \ \text{loss factor}}$$

It is assumed here that the winding itself does not introduce any losses which, of course, cannot be true; the true value of Q is therefore lower to an extent that is dependent upon the winding. It should also be noted that the value of Q calculated as above will only be true if the inductance is not excessively high or low, i.e., if it tunes with a capacitance of 100 to 400 pF at frequencies of 0.5 to 5 MHz or with a lower value of capacitance at higher frequencies.

In tuned circuits the temperature coefficient of inductance is also of interest.

Characteristics and Applications

The values given for the temperature factor in this catalogue are calculated as

$$\frac{1}{\mu_i^2} \cdot \frac{\Delta \mu}{\Delta T} \text{ parts per million per °C}$$

(within the 25-55°C range)

The value of the temperature coefficient of an inductance wound on a toroid is,

μ_i . temperature factor . 10^{-6} per °C

When a magnetic circuit contains a small air gap, as in the case of pot cores, E cores, etc., the values of Q and the temperature coefficient are calculated by substituting the effective permeability for the initial permeability in the above formulae.

Unfortunately there are no simple methods for predicting the values of Q and the temperature coefficient of cores used in open magnetic circuits – they have to be measured under actual application conditions.

Ferrites suitable for use at higher flux densities have values of amplitude permeability (i.e., B_{max}/H_{max}) given for three values of the flux density. The total core loss per cubic centimetre is given for frequencies of 16 and 25 kHz and 200 mT at 25°C and 100°C. As other core losses are much smaller under these conditions and can be neglected, this is essentially the hysteresis loss.

The values of saturation induction given for high-flux ferrites correspond to a magnetizing field strength of 796 A/m (10 Oe).

For ferrites used in telecommunications applications, information is given for the loss factors associated with residual and eddy current losses at selected frequencies and for hysteresis loss coefficients measured at 20 kHz between 0.5 and 2.0 A/m. Information on disaccommodation factors is also given which expresses the change of inductance over a decade of time following the initial shock.

Perminvar Ferrites

Perminvar ferrites are essentially nickel-zinc ferrites having the following manufacturing characteristics,

(a) Cobalt is added in small amounts.
(b) The basic composition contains an excess of Fe_2O_3, i.e., they are overstoichiometric.
(c) Annealing is essential to obtain the specified electrical properties.

Electrically, perminvar ferrites are characterized by very low losses at relatively high frequencies and they can be used to obtain high values of Q at the high frequency end of their spectrum of application. When perminvar ferrites are compared with non-perminvar nickel-zinc ferrites of similar permeability, it becomes apparent that a higher value of Q is obtainable for the same permeability.

The very low losses of perminvar ferrites are due to the fact that cobalt ferrite has an anisotropy constant of opposite sign to nickel and zinc ferrites and a very much higher one. There is, therefore, a possibility of mutual cancellation and the resultant anistropy energy can be greatly reduced by a small addition of cobalt. The significance of anistropy is that it impedes the rotation of domains in certain directions, which results in energy being spent on making the ferrite structure follow the direction of the applied field. If the anisotropy can be made lower, less energy needs to be spent during each cycle and the losses are consequently lower.

In extremely weak fields the magnetization of ferrite is carried out by the domains which are favoured directionally, i.e., that are in full or partial alignment with the field vector. These domains expand at the expense of their less favoured neighbours which results in movement of the domain walls and expenditure of energy to make them move. In perminvar ferrite, individual domains can be imagined as being surrounded by low-energy trenches in which domain walls can move very easily with minimum expense of energy; however, when the field becomes too strong, the walls are ejected from the trenches and the perminvar structure is destroyed.

The structure of a perminvar ferrite consists of the usual spinel lattice with cobalt ions in some of the unoccupied octahedral sites to form an orderly independent sub-lattice. The ions of cobalt are brought into these sites by the internal forces of the main lattice very slowly and gradually, and there is no known way of accelerating this process of migration. This leads to the requirement for annealing. When ferrite is heated beyond its Curie point, the whole structure is disorganized and when the temperature drops below the Curie point, the lattice reforms again and its internal magnetization forces begin to move the cobalt ions to their ultimate sites in a regular pattern, i.e., the cobalt sub-lattice. This must happen because it corresponds to the least energy state of ferrite and all matter tends towards this state of minimum energy. As the temperature is below the Curie point and relatively low, the mobility of the ions is also low and the process of migration requires a long time.

To facilitate the migration of cobalt ions to their ultimate stations, the ferrite must have a large number of empty sites (vacancies) thus enabling cobalt ions to jump from stage to stage towards their goals. Empty sites exist if the oxygen content in the sintering atmosphere is high, i.e., firing of perminvar ferrites must be in air. This leads also to a relatively small number of divalent iron molecules in the ferrite, the resistivity of which is high. As the properties of perminvar ferrites depend upon the existence of their regular structure, anything which can possibly disturb this structure is dangerous. An adverse influence may be exerted by the application of a strong magnetic field (proximity of permanent magnets or excessive current through the winding), heating without slow cooling or a strong mechanical pressure which causes dislocations of the crystalline structure (grinding is one example of such a pressure and ultrasonic cleaning may be another). Under such influences the permeability increases and Q is lowered, especially at the higher frequencies, although the changes in Q at the lower frequencies may be very small.

TABLE 1
Nickel-Zinc Ferrites for Entertainment and Industrial Applications

Parameter	Symbol	Standard Conditions of Test	Unit	F13	F14	F16	F25*	F29*
Initial Permeability (±20%)	μ_i	B →0 25°C 1 MHz	—	650	220	125	50	12
Saturation Flux Density	B_{sat}	H = 796 A/m = 10 Oe 25°C	mT	320	350	340	—	—
Loss Factor (maximum)	$\frac{\tan \delta_{r+e}}{\mu_i}$	B →0 25°C 250 kHz	10^{-6}	50	—	—	—	—
		500 kHz		65	40	—	—	—
		1 MHz		130	42	60	50	—
		2 MHz		—	50	—	50	—
		3 MHz		—	—	—	55	—
		5 MHz		—	—	65	65	—
		10 MHz		—	—	100	75	100
		15 MHz		—	—	—	100	—
		20 MHz		—	—	—	125	—
		40 MHz		—	—	—	300	—
		100 MHz		—	—	—	—	200
		200 MHz		—	—	—	—	1000
Temperature Factor	$\frac{\Delta \mu}{\mu_i^2 \cdot \Delta T}$	B < 0.25 mT +25°C to +55°C 10 kHz	$10^{-6}/°C$	1.5 (av'ge)	12–30	20–50	10–15	50 (av'ge)
Curie Temperature (minimum)	θ_c	B < 0.25 mT 10 kHz	°C	180	270	270	450	500
Resistivity (typical)	ρ	1 V/cm 25°C	ohm cm	3.10^4	10^5	10^5	10^5	10^5

* These are perminvar ferrites and undergo irreversible changes of characteristics (μ increases and loss factors become much greater, especially at higher frequencies) if subjected to strong magnetic fields or mechanical shocks.

TABLE 2
Manganese-Zinc Ferrites for Entertainment and Industrial Applications

Parameter	Symbol	Standard Conditions of Test	Unit	F4	F5	F6	F8	F9	F10
Initial Permeability (minimum)	μ_i	B<0.1 mT 25°C 10kHz	—	2000 —	1600 —	1200 —	1200 —	3500 —	5000 —
Saturation Flux Density (minimum)	B_{sat}	H=796 A/m =10 Oe 25°C 100°C	mT	470 350	470 —	450 —	380 —	380 —	400 285
Loss Factor (maximum)	$\frac{\tan \delta_{r+e}}{\mu_i}$	B<0.1 mT 25°C 100 kHz 250 kHz 500 kHz	10^{-6}	10 — —	— — —	— — —	— 30 110	15 — —	15 — —
Hysteresis Material Constant (maximum) (IEC)	ηB	B from 1.5 to 3 mT 25°C 10 kHz	10^{-6}/mT	1.5	—	—	—	1.4	1.4
Temperature Factor	$\frac{\Delta \mu}{\mu_i^2 . \Delta T}$	B<0.1 mt +25°C to +55°C 10 kHz	10^{-6}/°C	—	—	—	0 to +2	0 to +2	−1 to +1
Amplitude Permeability (minimum)	μ_a	400 mT 25°C 320 mT 100°C	—	2400 1825	2400 1825	1200 1200	— —	— —	— —
Total Power Loss Density (maximum)	Pv	200 mT 16 kHz 25°C 16 kHz 60–100°C 25 kHz 60–100°C	mW/cm³	— 110 190	**120** 110 190	150 150 —	—	—	—
Curie Temperature (minimum)	θ_c	B<0.1 mT 10 kHz	°C	**210**	200	180	130	135	155
Resistivity (typical)	ρ	1 V/cm 25°C	ohm-cm	100	100	100	100	50	50

TABLE 3
Manganese-Zinc Ferrites — Telecommunication Grades

Parameter	Symbol	Standard Conditions of Test		Unit	P10	P11	P12
Initial Permeability ±20%	μ_i	$B \to 0$ 25°C	10 kHz	—	2000	2250	2000
Loss Factor (maximum)	$\frac{\tan \delta_{r+e}}{\mu_i}$	$B \to 0$ 25°C	10 kHz 100 kHz	10^{-6}	6 15	1.5 5	0.8 2.5
Hysteresis Material Constant (maximum) (IEC)	ηB	B from 1.5 to 3 mT 25°C	10 kHz	10^{-6}/mT	2.4	0.8	0.45
Disaccommodation Factor (maximum)	$\frac{\Delta \mu}{\mu_i^2 . \log_{10} t_2/t_1}$	$B < 0.25$ mT 50°C 10 to 100 mins	10 kHz	10^{-6}	8	4	3
Temperature Factor	$\frac{\Delta \mu}{\mu_i^2 . \Delta T}$	$B < 0.25$ mT +25°C to +55°C	10 kHz	10^{-6}/°C	0 to +2	+0.5 to +1.5	+0.45 to +0.95
Curie Temperature (minimum)	θ_C	$B < 0.25$ mT	10 kHz	°C	150	150	150
Resistivity (typical)	ρ	1 V/cm 25°C		ohm cm	100	100	100

SI/CGS Unit Conversions

1 A/m = 0.012566 oersted
1 Oe = 79.557 ampere/metre

1 Wb = 1 Vs = 10^8 maxwell
1 Mx = 10^{-8} weber

1 T = 1 Wb/m^2 = 10^4 gauss
1 Gs = 0.1 millitesla

Applications

Component	Grade of Ferrite
Pot cores — IEC range R.M. cores	P10, P11, P12
Low power and pulse transformer cores	F8, F9, F14, P10
Balun cores	F14,
High power transformer cores	
– E cores, U cores and toroids	F5, F6, F8
Suppressors	
– E cores, U cores and toroids	F6, F8, F9, F10
Suppression beads	F8, F14
Pot cores and cup cores	F8, F14, P10
Bobbins	F8, F14, F16, F29
Toroids	All grades
Aerial rods	
– long and medium waves	F11, F14
– short waves	F16
Screw cores, rods, pins, and tubes	F8, F14, F16, F25, F29
High frequency welding impeders	F6, F11, F14

Where cores are used for inductors in tuned circuits, the top end of the frequency range in which a particular grade of ferrite can be used to optimum advantage is the highest frequency for which the value of loss factor is given. It must be noted that the manufacturing conditions particularly affect the higher frequency behaviour of the ferrites and the performance cannot be guaranteed beyond the above mentioned limits. Performance evaluation on the basis of samples above the specified frequency limits may be very misleading as the losses in this region increase very rapidly and there is no guarantee that another batch of cores will behave in an identical fashion. If a guaranteed value of Q is required, a grade of ferrite should be chosen for which the desired frequency lies within the range of the published loss factors. For example, if the value of Q is to be ensured at 5 MHz, grade F14 should not be used but rather grade F16, the loss factors of which are specified up to 10 MHz.

Where the cores are used in untuned circuits and the value of Q is not the primary consideration, individual grades may be usefully employed well beyond the range of frequencies for which the loss factors are specified. This particularly applies to all transformer applications where high permeability makes it possible to reduce the number of turns required for a specified shunt inductance, thus decreasing the leakage inductance which is usually the limiting factor at the high frequency end.

Transformer Design

Ferrite cores are used for both low-power and high-power transformers, the line of discrimination between the two classes corresponding to the flux density induced in the cores.

Low power transformers

In these transformers the core material may, to a close approximation, be regarded as remaining in the Rayleigh region in which the area of the hysteresis loop is very small and the permeability may be considered invariant throughout the cycle of the applied current. Such transformers, which are used at RF and VHF frequencies and in pulse circuits, may be tuned, or not tuned, depending on the requirements of the particular application. They can be based on a wide variety of core shapes and configurations – open-circuit, gapped and toroidal.

If the transformer is to be tuned it is obvious that the choice of ferrite for its core must be determined by the frequency of tuning, i.e. the material must be so chosen as to provide the optimum (or required) value of Q at the specified frequency. The core configuration depends upon the required value of the inductance of the winding, demand for adjustment facilities, space requirements and expected selectivity, taking into account the loading etc. Typical examples of such transformers occur in radio and television IF circuits and in filter circuits. All these transformers are used to transmit a relatively narrow band of frequencies.

Untuned transformers usually serve to transmit relatively wide bands of frequencies, stretching from the low repetition frequency to the high edge-forming frequencies in the case of pulse transformers. Loss of power, expressed in dB, is usually the main criterion of quality, and it is required that it be as small as possible over a very wide spectrum of frequencies. The lowest frequency at which the loss does not exceed some specified value is determined by the shunt inductance of the winding, i.e., the value of the inductance measured with the secondary winding open-circuited. The highest frequency that can be tolerated for a given loss depends upon the leakage inductance, i.e., the value of the inductance measured with the secondary winding short-circuited. While the shunt inductance is a function of the coil permeability in the magnetic circuit, the leakage inductance is not affected by the core and depends only on the configuration, number of turns and the proximity of the windings.

To obtain a shunt inductance as high as possible for a given number of turns, which is specified for a maximum permissible leakage inductance, it is necessary to use a ferrite of the highest permeability and in a configuration ensuring the minimum dilution of the permeability, i.e., in the form of a toroidal core or, if the winding cost is regarded as unacceptable, in the form of pot cores, E cores, etc. In this context it is often considered that the losses of high-permeability ferrites at the higher frequencies are excessive; to explain why this is not usually important it is necessary to analyse the nature of the losses occurring in a wide-band transformer.

As a first approximation, a transformer can be regarded in the lower frequency region of its spectrum as an inductance and resistance connected in parallel between the source and the load. The inductance is the shunt inductance of the winding and the resistance is the total loss resistance, i.e., the DC and AC resistance of the winding and the resistance representing the losses in the core at the relevant frequency. The loss resistance of the winding equals its reactance multiplied by Q (parallel circuit).

To simplify this concept without in any way limiting its general validity, it can be assumed that the source and load impedances are the same, i.e., the ratio of the transformer is 1:1.

At the low frequency end of the spectrum, the shunt reactance is usually designed to be several times higher than the source or load impedance. Taking the ratio of the shunt reactance to source impedance as m, we have the following values of transformer loss (in dB), neglecting at this point the losses due to the resistance of the transformer,

m	Loss (dB)
0.5	3.0
0.75	1.6
0.9	1.17
1.0	0.97
1.1	0.79
1.9	0.29
2.0	0.26
2.1	0.24
3.0	0.12
4.0	0.04
5.0	0.03

Even if the transformer loss of 0.97 dB can be tolerated and easily compensated by additional gain in the system, it is obvious that using the shunt reactance to circuit impedance ratio of 1 would lead to serious changes in the loss when the permeability of the core (and the shunt reactance) vary within normal tolerances. This is one of the prime reasons for keeping the shunt reactance appreciably higher than the circuit impedance, say, 3 to 5 times higher, the loss due to the shunt reactance being then so small that the expected changes in this reactance become insignificant from the loss point of view.

Another important aspect of transformer design is the transformer loss resistance. At the low frequency end of the spectrum the value of Q will still be reasonable but in an exaggerated condition it could be assumed that it is only 3. This would mean that at the frequency for which the shunt reactance is, say, 3 times as high as the circuit impedance, the loss resistance is 9 times as high as this impedance. The losses caused by the presence of the transformer resistance, expressed again by the loss resistance/circuit impedance ratio, n, are as follows,

n	Loss (dB)
1	3.5
3	1.3
6	0.68
9	0.46
10	0.42
20	0.20
40	0.10

In the case where the loss resistance is nine times higher than the circuit impedance, the loss introduced by it is 0.46 dB and it can be seen that it does not vary greatly with the expected variations of the permeability and Q.

At any frequency higher than the bottom limit of the spectrum the ratio of the shunt reactance to the circuit impedance is higher than the value chosen for the lowest frequency, as reactance is proportional to frequency, and similarly the ratio of the loss resistance to the circuit impedance is also improving, in spite of the rising losses in the ferrite core.

This state of affairs continues until the frequencies are reached where the leakage inductance becomes significant to ultimately become the dominant factor. As previously mentioned, the leakage inductance is not affected by the core, neither is the loss associated with it. The value of leakage reactance that equals one half of the circuit impedance causes a loss of 0.26 dB which increases to 1 dB when the leakage reactance is equal to the circuit impedance. The losses caused by the resistance associated with the leakage inductance are not likely to be very significant.

Power Transformers

Power transformers with ferrite cores can handle relatively large powers and the cores may operate at flux densities approaching the saturation induction level of the material. Typical applications are found in ultrasonic generators, inverters serving to transform low voltage DC into higher voltage AC and in television receivers. The normal frequency range is 2 to 50 kHz but there is no direct limitation to either end of the range.

The design of the operational conditions for the core follows the general procedure developed over many years for the design of small power transformers.

If the input voltage is sinusoidal, the peak flux density in a core of uniform cross-sectional area can be calculated from the following, equation,

$$B_{max} = \frac{V_{pk}}{2\pi fNA_e} \text{ (unit: tesla)}$$

$$\text{or } B_{max} = \frac{V_{pk}}{2\pi fNA_e} \cdot 10^4 \text{ (unit: gauss)}$$

where,

N is the number of turns of the winding.

A_e is the cross-sectional area in m^2

f is the frequency in Hz,

V_{pk} is the peak value of the input voltage in volts.

The choice of operational flux density depends upon many factors of which the temperature rise due to core losses is probably the most important. The output waveform and the cooling conditions must also be considered. The ferrite losses at higher flux densities are mainly caused by hysteresis and can be approximately taken as proportional to the 2.2 power of flux density and 1.2 power of frequency.

The cores used for frequencies below 20 kHz are generally operated at 200 to 250 mT and occasionally up to 300 mT. For higher ambient temperatures the operational flux density must be at a lower level. This is also the case at the higher operational frequencies.

Values of power loss density, i.e., the power loss per cm^3 of the core volume, are given for a B_{max} of 200 mT at 16 kHz and/or 25 kHz.

The number of turns is important, not only as a factor determining the operational flux density (as shown in the above equation) but also because it determines the amplitude of the magnetizing current for a given core. Obviously, the magnetizing current must be kept low since it affects the losses in the winding. The insertion loss also increases when the number of turns, i.e., the shunt reactance, is low. However, if the number of turns is high the leakage inductance increases, approximately proportional to the square of this number and may cause poor regulation. In some instances, as in the case of inverters, high leakage inductance is responsible for spikes in the current waveform. Thus, the number of turns must be determined as a result of judicious compromise between conflicting factors and is best achieved by trials and careful investigation of all results of measurement.

The core temperature rise depends to a great extent upon the heat dissipation and ambient temperature. Ferrites have a low thermal conductivity of only 0.01 cal/cm. sec. °C and dissipation area of no less than 10 cm^2 per watt is required if the temperature rise is not to exceed 40°C. This figure is obviously affected if the heat dissipation is impeded or alternatively made particularly efficient.

In most applications a small air gap in the magnetic circuit of the core is used to control the inductance and temperature coefficient or to prevent saturation by DC current flowing in the winding. Non-magnetic spacers may be used for this purpose or the centre limb of the core may be ground back. In both cases the consistency of the inductance value obtained for a given number of turns is greatly improved compared with that of an ungapped magnetic circuit but it is associated with a lower level of inductance per turn.

Aerial (Antenna) Rods
General Information

Aerial rods are manufactured in various grades of ferrite that are most suitable for the wavebands to be covered.

Long and Medium Wavebands – Grades F11 and F14

Long, Medium and Short Wavebands – Grade F16

The properties of these materials are given in the tables on pages 26 and 27.

The measured coil permeability (inductance ratio) depends upon the initial permeability of the material, length-to-diameter ratio of the rod, the spacing between the coil and the rod, the position of the coil on the rod and the type and geometry of the winding.

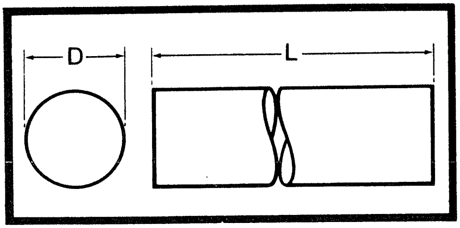
The pick-up sensitivity is a function of the initial permeability of the material, length-to-diameter ratio, position of the coil, its number of turns and the loaded value of Q in the circuit.

The losses and temperature coefficient for a given winding on a rod depend upon the intrinsic properties of the ferrite, length-to-diameter ratio of the rod and the position of the coil. The values of Q and temperature coefficient cannot be easily determined analytically.

Aerial rods are checked for coil permeability (inductance ratio) and Q at selected frequencies within the range of intended application; standard coils are used and the results compared with standard rods. It should be noted that deviations from the nominal values depend upon the coil and, if different coils are used, measured results may also differ.

Reference rods can be supplied on request and it is advisable to use these rods for evaluation at the design stage and to make allowance for manufacturing tolerances.

Aerial (Antenna) Rods
Plain



General Description

Aerial rods that generally comply with IEC Publication 223 can be supplied in Grades F14 and F16.

Dimensional Data

Diameter –

IEC standard rods have diameters of 8 or 10 mm.

Rods are also manufactured to diameters originally expressed in Imperial units.

The preferred diameters covering both ranges are,

8 and 10mm.
Tolerance +0 −5%
6.4, 9.5 and 12.7 mm.
Tolerance ±3%

Length –

Rods can be supplied up to a maximum length of,

6.4 and 8 mm diameter - 160 mm
9.5, 10 and 12.7 mm diameter – 200 mm.
Tolerance ±2%

Straightness –

All rods pass through a gauge having a bore 0.64 mm greater than the maximum diameter of the rod and a length of 80 mm.

Preferred Sizes

Diameter	Length	Diameter	Length
8	110 125 140 160	6.4	150
		9.5	140 150 180 200
10	140 160 180 200	12.7	150 170

Electrical Specification

Coil permeability ±10%
Q −10% +30%

These tolerances apply to measurements in standard test coils. Rods of F14 grade are checked at a frequency of 1 MHz and F16 grade at 10 MHz.

Nominal and limit rods can be supplied upon request.

Applications

Long and medium wavebands	F14
Long, medium and short wavebands up to 12 MHz	F16

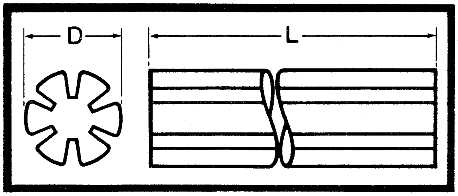
Ordering Information

Diameter, length and grade of material must be stated, for example 8 × 140/F14

A seven digit part number will be advised on the order acknowledgement.

NEOSID

Aerial (Antenna) Rods
Slotted



General Description

Slotted aerial rods to IEC Publication 223 are available only in grade F11 material which is a manganese zinc ferrite. Its high permeability enhances the pick-up sensitivity. To obtain high values of Q the rods must be slotted (see page 9 where dimensional resonance losses are discussed).

Dimensional Data

Diameter –

8 mm
Tolerance +0 −0.4 mm
10 mm.
Tolerance +0 −0.5 mm

Length –
Rods can be supplied up to a maximum length of,

8 mm diameter	160 mm
10 mm diameter	200 mm

Tolerance ±2%

Straightness –
All rods pass through a gauge having a bore 0.64 mm greater than the maximum diameter of the rod and a length of 80 mm.

Electrical Specification

Coil Permeability ±10%
Q −10% +30%

These tolerances apply to measurements in standard test coils at a frequency of 1 MHz.

Nominal and limit rods can be supplied upon request.

Preferred Sizes

Diameter	Length	Diameter	Length
8	110	10	140
	125		160
	140		180
	160		200

Applications

Long and medium waves only.

Ordering Information

Diameter and length of rod must be stated, for example, 10 × 200/F11. A seven digit part number will be advised on the order acknowledgement.

Welding (Impeder) Rods and Tubes

General Description

Ferrite welding rods are used for flux concentration in the continuous R.F. welding process of steel tubes. The parameters that influence the efficiency and speed of the process are,

a) Initial permeability of the ferrite which determines the degree of flux concentration.

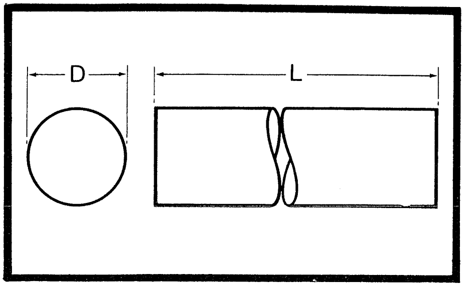
b) Curie temperature at which the ferrite material ceases to act as flux concentrator due to loss of ferromagnetic properties.

c) Saturation induction which determines the maximum field under which the ferrite can usefully perform.

These parameters are measured during production on specially made test toroids from each batch of material.

Welding rods can be supplied in plain cylindrical, slotted or tubular form. Slotted and tubular rods provide better cooling facilities.

The losses in ferrite materials, even under high flux density and high frequency conditions, are insignificant compared to the total heat generated by the welding process itself.

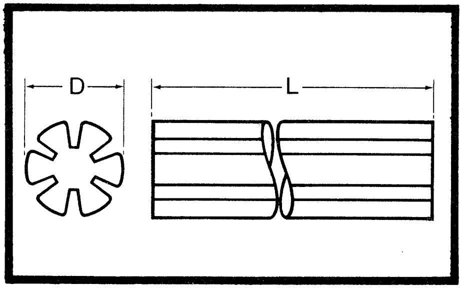


Dimensional Data (Plain Rods)

Diameter –
6, 8,10, 12.7 and 16 mm.
Tolerance ±3%.

Length –
Rods can be supplied up to a maximum length of,

6 and 8 mm diameter - 150 mm
10 mm diameter and above - 200 mm
Tolerance ±2%



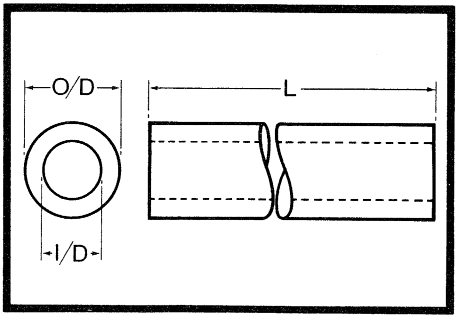
Dimensional Data (Slotted Rods)

Diameter –
8, 10, 12.7 and 16 mm.
Tolerance ±3%

Length –
Rods can be supplied up to a maximum length of,

8 mm diameter - 150 mm
10 mm diameter and above - 200 mm
Tolerance ±2%

Welding (Impeder) Rods and Tubes



Dimensional Data (Tubes)

Outer Diameter	Inner Diameter
10	5
12	5
14	7
16	7

Tolerance on all diameters ±3%.

Length –
Tubes can be supplied up to a maximum length of 200 mm. Tolerance ±2%.

Electrical Specification

Listed below are the values of the main parameters of the three grades of ferrite used for welding impeders.

Parameter	F6	F11	F14
Initial permeability	1500	600	220
Curie temperature (°C)	>180	>220	>270
Saturation induction (mT)	>450	>380	>350

Material

Plain cylindrical and tubular rods, F6 and F14.

Slotted rods, F6 and F11.

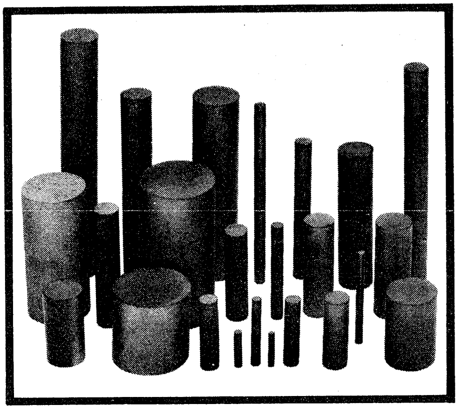
Ordering Information

Diameter(s), length and grade of material must be stated, for example,

10 × 200/F6 (welding).
10 × 200/F11 slotted (welding).
12 × 5 × 180/F14 tubular (welding).

A seven digit part number will be advised on the order acknowledgement.

Small Rods
(Up to 100 mm in length)



General Description

Small rods that generally comply with IEC Publication 220 can be supplied in all grades of ferrites. Tools are available to provide an extensive selection of sizes within the range of diameters specified.

Dimensional Data

Outer Diameter –

The table below lists preferred sizes. All tolerances are for rods which are not centreless ground.

Dimension	Tolerance	Max. length	Remarks
1.0	±0.06	13	Intermediate diameters carry proportional tolerances
1.5*	±0.08	25	
1.6*	±0.08	30	
2.0*	±0.10	30	
2.5	±0.12	50	
4.0	±0.17	100	
6.35*	±0.25	100	
7.90*	±0.27	100	
9.50*	±0.29	100	
12.7*	±0.38	100	

The most widely used diameters are marked thus, *

Length –

Tolerance ±3% of length or ±0.5 mm, whichever is the greater.

Straightness –

Rods pass a full length gauge having bore equal to maximum diameter plus 0.75% of length.

Ground Rods –

Ground rods are normally supplied with a diameter tolerance of ±0.05 mm. Grinding to closer tolerances can be carried out if required. Due to various factors it is not always practical to grind rods having diameters below 2.3 mm and such cases should be discussed in detail before an order is placed.

Electrical Tolerances (measured in standard test coils)

Coil Permeability (inductance ratio) –

The tolerance on coil permeability is ±5%. (This figure may increase to ±8% when length to diameter ratio is greater than 6 and to ±10% when this ratio is greater than 10).

Q-Value –

The tolerances on Q-value are −10% +30% and apply to measurements under our standard test conditions. Other tolerances and test conditions can be arranged.

Materials

All grades of ferrite.

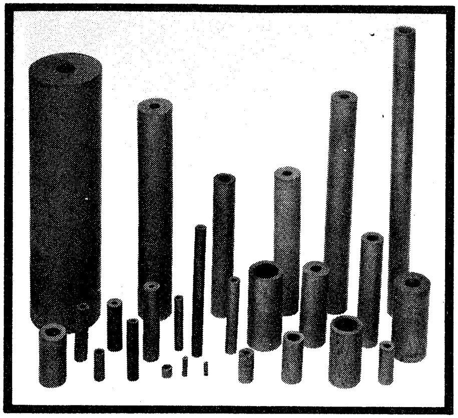
Ordering Information

Nominal diameter, nominal length and grade of material must be stated.

Example: 4×38/F8.

A seven digit part number will be advised on the acknowledgement of order.

Tubes



General Description

Ferrite tubes that generally comply with IEC Publication 220 can be supplied in all grades of ferrite materials. Tools are available to provide a very wide range of outer and inner diameters. The preferred sizes are listed opposite.

Dimensional Data

The table below gives tolerances for tubes which are not centreless ground.

Outer Diameter –

Dimension	Tolerance	Remarks
2.5	±0.12	Intermediate diameters carry proportional tolerances
3.5	±0.16	
5.3	±0.20	
5.8	±0.23	
6.2	±0.24	
9.5	±0.29	
12.7	±0.38	

Inner Diameter –

Dimension	Tolerance	Remarks
0.6	+0.20	Intermediate diameters carry proportional tolerances
3.0	+0.20	
5.0	+0.50	

Length –

The maximum practical length is limited and depends on the outer diameter and whether or not the tube is to be centreless ground.
Tolerance is ±3% of the length or ±0.5 mm, whichever is the greater.

Straightness –

Tubes pass a full length gauge having bore equal to maximum permissible outer diameter plus 0.75% of length.

Preferred Sizes –

3.5 × 1.2
4.0 × 1.5
4.0 × 2.0
5.3 × 1.5
5.3 × 2.4
5.8 × 2.4
6.2 × 2.4
9.5 × 3.2
12.7 × 3.7

Note – The first figure denotes the outer diameter and the second figure the inner diameter.

Ground Tubes –

Ground tubes are normally supplied with an outer diameter ground to a tolerance of ±0.05 mm. Grinding to closer tolerances can be carried out if required.

Inserts –

Threaded brass inserts (stems) can be fitted into the tubes if required. Threaded plastic inserts can also be supplied, subject to special arrangements.

Electrical Tolerances (measured in standard test coils)

Coil Permeability (inductance ratio) –
The tolerance on coil permeability is ±5%. (This figure may increase to ±8% when length to diameter ratio is greater than 6 and to ±10% when this ratio is greater than 10.)

Q-Value –
The tolerances on Q-value are –10% + 30% and apply to measurements under our standard test conditions. Other tolerances and test conditions can be arranged.

Material

All grades of ferrite.

Ordering Information

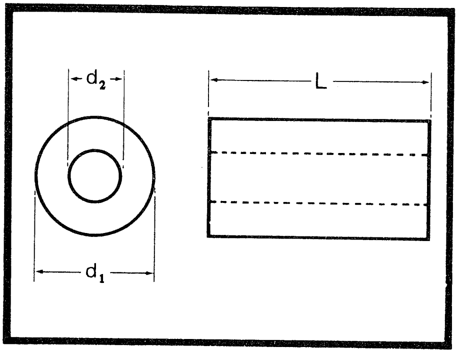
Nominal outer diameter, minimum inner diameter, nominal length and grade of material must be stated.

Example, 5.3 × 1.5 × 16/F14

A seven digit part number will be advised with the order acknowledgement.

NEOSID

Screening (Suppression) Beads



Dimensional Data

d_1 nominal	d_2 minimum	L nominal	Material Grade
3.5	1.2	3.0	F8
4.0	1.5	9.5	
4.0	2.0	5.0	
4.0	2.0	9.5	
3.5	1.2	3.0	F14
4.0	1.5	5.0	
4.0	1.5	5.5	
4.0	2.0	4.0	

General Description

Beads manufactured from relatively high permeability ferrites are threaded on wire leads and, at frequencies well beyond the normal range of application, provide a series impedance, the resistive component of which acts as a fictitious resistor in series with the circuit being protected, while the reactive component serves as a series choke. Beads are used in this manner to prevent high frequency leakage from screened boxes or parasitic oscillations arising from spurious feedback and for suppression of interference. This form of protection is possible because, at frequencies far removed from the normal range of application, the losses in ferrites are very high.

A ferrite bead threaded on a lead produces no noticeable direct effect on the operation of the equipment because, at low frequencies, the series impedance is very low. Although the bead does not cause a voltage drop at low frequencies, it acts as a suppressor at very high frequencies due to the resistance, representing the losses in the ferrite, being high and the reactance which generally increases with frequency in spite of a gradual loss of permeability. This decrease in permeability becomes noticeable at frequencies 10 to 20 times higher than the upper limit of the normal range of application.

To illustrate these effects, results are given below of measurements carried out on a 12.7 mm length of 0.9 mm diameter copper wire with a single bead threaded on it. The results are shown in the form of a series impedance, as befits the application.

Type of Bead	R + jX		
	50 MHz	100 MHz	200 MHz
4.0 × 1.5 × 9.5/F8	75 + j 19	75 + j 12	75 + j 15
4.0 × 1.5 × 5.0/F14	23 + j 19	35 + j 30	45 + j 34

Screening (Supression) Beads

It will be noticed that the bead manufactured from ferrite grade F8 (which is a high permeability, low frequency ferrite) is already well settled at 50 MHz, while both components of the impedance of the F14 bead are still increasing over the range of 50 to 200 MHz.

It must be stressed that no direct conclusion can be drawn from the above results regarding the variation of permeability with frequency. Such conclusions can only be made when the impedance is presented in the parallel configuration, i.e., reactance shunted by resistance.

The series impedance of the wire threaded through the bead is proportional to the length of the bead or the number of the beads used. Alternatively, several turns of wire can be wound toroidally on the bead to produce a higher impedance.

The beads can also be used for small pulse and wideband transformers and for other purposes where a small ring core is required.

Material

Ferrite grades F8 and F14.

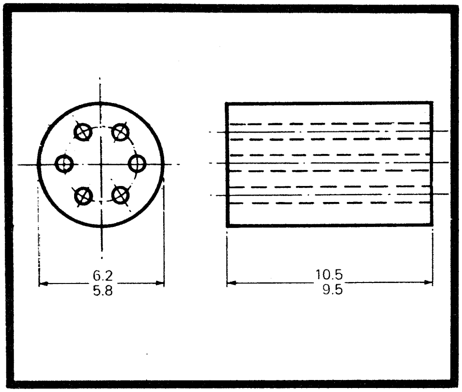
Ordering Information

Nominal outer diameter, minimum inner diameter, length and the grade of material must be stated.

Example, 4.0 × 1.5 × 9.5/F14.

A seven digit part number will be advised on the order acknowledgement.

Suppression Beads
6 Holes



Dimensional Data

There are 6 holes of 0.9 ± 0.15 mm diameter with the centres evenly spaced on a 3.66 mm diameter.

General Description

For an explanation of the phenomena occurring in ferrites at higher frequencies and the operation of suppression beads, see pages 43 and 9, Section 3.2 (C).

The 6-hole suppression beads are usually wound with 2½ turns (a single wire threaded through 5 holes) or with 2 x 1½ turns (one conductor threaded through 3 holes and the other conductor through the other 3 holes).

Frequency	Impedance R + jx
5 MHz	—
12 MHz	5 + j135
20 MHz	75 + j225
50 MHz	270 + j250
100 MHz	420 + j275
150 MHz	510 + j225

The Table shows some typical results of impedance measurements on a 2½ turns winding at various frequencies. (A Boonton R-X meter type 250A was used in these measurements).

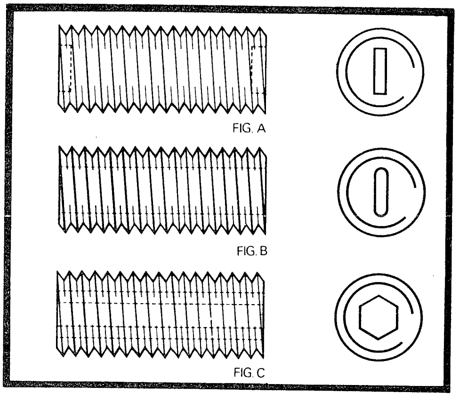
Material

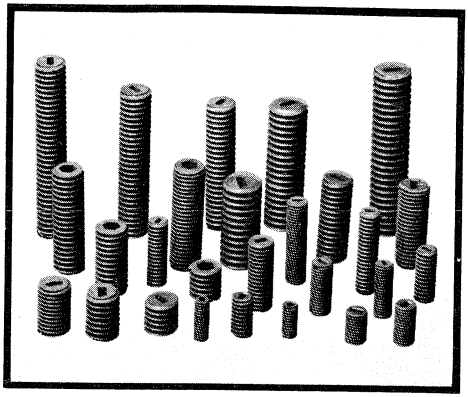
Ferrite F14

Ordering Information

Part Number 35–001–31

Screw Cores
Metric Thread





Dimensional Data

The types of screw cores in the table below are designated by their nominal diameter and pitch of thread.

Type	Standard Length									Major Diam.		Slots	Material Grade				
										min.	max.						
3×0.5	6	7.5		10						2.70	2.75	A		F14	F16	F25	F29
3.5D×0.5		7.5		10						3.25	3.30	A				F25	F29
4D×0.5	6			10	13					3.67	3.72	A		F14	F16	F25	F29
4D×0.75				10	13					3.67	3.72	A		F14	F16	F25	F29
4×0.5	6	7.5		10	13					3.84	3.89	A		F14	F16	F25	F29
4×0.75		7.5		10	13					3.84	3.89	A		F14	F16	F25	F29
5D×0.75				10	13	16				4.60	4.65	A		F14	F16	F25	F29
5×0.75				10	13	16				4.72	4.80	A		F14	F16	F25	F29
6D×1						16	20	25		5.65	5.70	B	F8	F14			
6×0.75					13	16				5.79	5.87	A	F8	F14			
6×1			9		13	16	20	25	30	5.79	5.87	A or B	F8	F14			
H6×0.75					13	16				5.79	5.87	C	F8	F14		F25	
H6×1		7.5			13	16				5.79	5.87	C	F8	F14		F25	
7.35×1.25						16		25		7.32	7.39	A	F8	F14			
8×1.25								25		7.67	7.75	A	F8	F14			

Tolerances on Length –

Up to 17 mm ± 0.4 mm
Above 17 mm ± 0.75 mm

Trimming Slots

Ferrite cores are manufactured with either a full length (through) slot or with a slot at each end, depending upon the length to diameter ratio of the core. The slots and holes are to IEC recommendations and detailed drawings can be supplied upon request.

Trimming Tools

See page 293.

Core Retention

Self-locking screw cores can be supplied which have a retention deposit (core brake) already applied, suitable for the former in which the core is to be used. Alternatively, rubber string of appropriate size can be supplied when this method of retention is preferred.

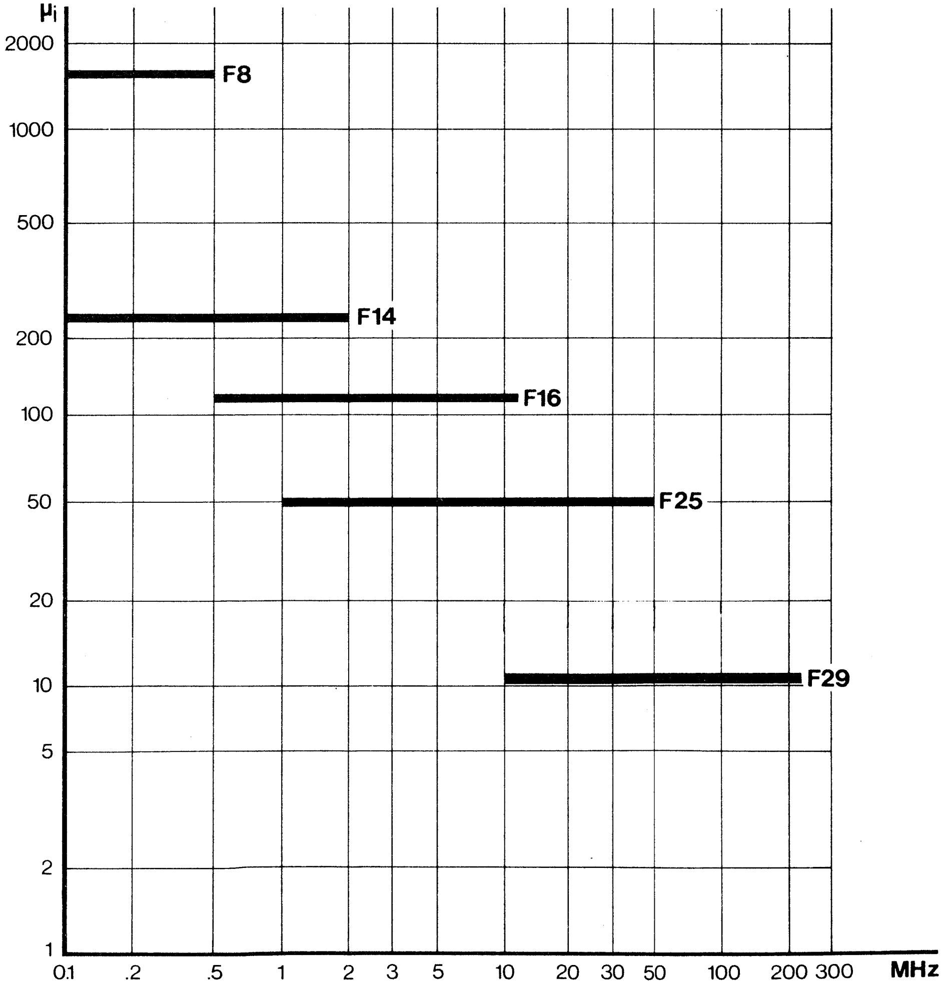
Non-standard Cores

Screw cores other than in the standard sizes quoted can be supplied by arrangement, subject to quantity justifying manufacture.

Electrical Specification

Working Frequency –

The optimum choice of the grade of material for a given frequency can be ascertained from the graph.



Optimum frequency ranges

Permeability –
The tolerance on coil permeability (inductance ratio) is ±5%. This figure relates to measurements under our standard test conditions.

Material

The choice of the material for a particular application should be based upon the intended frequency range and, to a lesser degree, upon the required inductance adjustment. A magnetic circuit that contains only a screw core produces a very low coil permeability (i.e., the ratio of inductances with and without the core) as compared with the initial permeability of the core material, particularly when high permeability grades are used. The degree of permeability dilution increases as length-to-diameter ratio decreases; it also increases as the initial permeability increases. This is illustrated by the following example:

Screw cores type 6 × 1 × 13 mm were measured in a typical single layer coil. The results were as follows:

Initial permeability

12	50	200	525	875

Coil permeability

2.9	4.0	4.5	4.6	4.65

It is obvious from this that Q considerations are more important than permeability.

Ordering information

To order a screw core the type, length and grade of material need to be quoted, e.g., 6 × 0.75 × 13 – Grade F14.

A seven digit part number will be advised on the order acknowledgement.

Ring Cores
Calculation of Inductance

The minimum value of the inductance of a winding of n turns, wound on a ring core with a minimum permeability of μ_i (at low flux densities and at room temperature), is

$$L = A_L \,.\, n^2 \ \text{nH} \tag{1}$$

where A_L is the inductance factor, i.e. the inductance of a single turn (wire threaded through the centre of a ring core).

$$A_L = \frac{0.4\,\pi\,\mu_i}{\sum \frac{\ell}{A}} \ \text{nH} \tag{2}$$

$\sum \frac{\ell}{A}$ is a dimensional factor calculated for a ring core with a rectangular cross section and dimensions D (outside diameter), d (inside diameter) and h (height), all in mm, as

$$\sum \frac{\ell}{A} = \frac{2\pi}{h.\ln D/d} \ \text{mm}^{-1} \tag{3}$$

When we substitute (3) into (2), we obtain:–

$$A_L = 0.2 \,.\, h \,.\, \ln D/d \,.\, \mu_i \ \text{nH} \tag{4}$$

This shows that the inductance factor and the inductance itself do not depend on the absolute values of D and d, only on the natural logarithm of their ratio and, of course, on the height of the core and its permeability.

Taking the value of h as 1 mm (unit height core), we can calculate the corresponding values of A_L for various grades of materials. When minimum values of initial permeability (shown in the catalogue for individual grades) are taken, we can tabulate the minimum A_L values of ring cores having various D/d ratios, and unit height. The results are shown in the Table opposite.

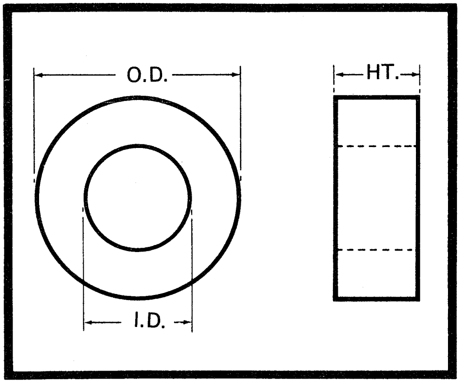
Ring Cores
Calculation of Inductance

A_L min (nH) of ring cores of 1 mm height

D/d	F29 μ_i = 9.6	F25 μ_i = 40	F14 μ_i = 176	F8 μ_i = 1200	F9 μ_i = 3500	F10 μ_i = 5000
1.2	0.350	1.460	6.418	43.76	127.6	182.3
1.25	0.428	1.784	7.850	53.55	156.2	223.1
1.3	0.504	2.100	9.240	62.97	183.7	262.4
1.35	0.576	2.400	10.56	72.03	210.1	300.1
1.4	0.646	2.692	11.84	80.75	235.5	336.4
1.45	0.713	2.972	13.08	89.18	260.1	371.6
1.5	0.779	3.244	14.27	97.31	283.8	405.4
1.55	0.842	3.508	15.44	105.2	306.8	438.3
1.6	0.902	3.760	16.54	112.8	329.0	470.0
1.65	0.962	4.008	17.64	120.2	350.5	500.7
1.7	1.018	4.244	18.67	127.4	371.4	530.6
1.75	1.074	4.476	19.69	134.3	391.7	559.6
1.8	1.129	4.704	20.70	141.1	411.5	587.9
1.85	1.181	4.920	21.65	147.6	430.6	615.1
1.9	1.233	5.136	22.60	154.0	449.3	641.9
1.95	1.283	5.344	23.51	160.3	467.5	667.9
2.0	1.331	5.544	24.39	166.4	485.2	693.1
2.05	1.379	5.744	25.27	172.3	502.5	717.9
2.1	1.425	5.936	26.12	178.1	519.4	742.0
2.15	1.470	6.124	26.95	183.7	535.8	765.4
2.2	1.514	6.308	27.76	189.2	551.9	788.4
2.25	1.557	6.488	28.55	194.6	567.7	811.0
2.3	1.599	6.664	29.32	199.9	583.0	832.9
2.4	1.681	7.004	30.82	210.1	612.8	875.4
2.5	1.760	7.332	32.26	219.9	641.4	916.3
2.6	1.835	7.644	33.63	229.3	668.9	955.6
2.7	1.908	7.948	34.97	238.4	695.3	983.3
2.8	1.977	8.236	36.24	247.1	720.7	1029.6
2.9	2.044	8.516	37.47	255.5	745.3	1064.7
3.0	2.109	8.788	38.67	263.7	769.0	1098.6

Example: Calculate the minimum inductance of a winding of 80 turns on a ring core having nominal dimensions: D = 25 mm, d = 15 mm, h = 16 mm, made of ferrite grade F9.
The value of D/d = 25/15 = 1.6667 which in the F9 column of the Tables shows (by interpolation) A_L min = 357.5 nH.
$L_{min} = 357.5 \,.\, 16 \,.\, 80^2 = 36\,608\,000$ nH = 36.61 mH.

Ring Cores



Dimensional Data

All dimensions given in the tables are nominal and are given in mm for uncoated cores. For nylon coated cores allow approximately 0.5 mm for thickness of coating.

Finish

Cores can be supplied uncoated, enamel coated, or nylon coated. Nylon coating is not available on cores having an outside diameter of less than 12.7 mm and an inner diameter of less than 6.35 mm. Toroids in grades F25 and F29 cannot be supplied with nylon coating.

Material Grades

The tables indicate ferrite grades generally available for each size of toroid and show a minimum A_L value in appropriate grade column. Cores can be manufactured in other grades of ferrite, provided the quantity is sufficiently high. Cores, but not necessarily all types, are normally available in the following grades – F5, F6, F8, F9, F10, F14, F16, F25, F29, P10, P11.

Effective Geometric Parameters

These are given for each type of toroid as follows:

Effective magnetic path length	ℓ_e in mm
Effective area of magnetic path	A_e in mm^2
Effective volume	V_e in mm^3
Dimensional factor $\sum\frac{\ell}{A}$	C_1 in mm^{-1}

Electrical Specification

The inductance of a winding wound on a ring core can be calculated from the formula $L = A_L . n^2$ where
A_L is the inductance of 1 turn in nH and
n is the number of turns
A_L is calculated from the minimum initial permeability of the material (as given below) and the dimensional factor C_1.

$$A_L = \frac{0.4 \pi \mu_i}{C_1} \ \text{nH}$$

N.B. A_L of nylon coated cores can be up to 20% lower in value than the figure quoted in the table.

Ordering information

The five-digit part numbers given in the tables must be followed by a further two digits denoting the grade of material. Type of coating is indicated by the first of the three middle digits: 0 for plain (i.e. uncoated), 5 for enamel coated, and 6 for nylon coated.

Example: A nylon coated 28-034-core in F9 material has the part number 28-634-36.

Ferrite Grade	Code	μ_i (minimum)
F5	25	1600
F6	26	1200
F8	28	1200
F9	36	3500
F10	37	5000
F14	31	176
F16	32	100
F25*	34	40
F29*	35	9.6
P10	40	1600
P11	41	1800

* These are perminvar ferrites and should not be used in power or pulse applications.

Ferrite Ring Cores 5.1 mm to 12.7 mm outside diameter

	Dimensions			Effective Geometric Parameters				Minimum A_L values in nH for uncoated cores in preferred grades										
Part Number	O.D.	I.D.	HT.	ℓ_e	A_e	V_e	C_1	F5	F6	F8	F9	F10	F14	F16	F25	F29	P10	P11
28-051-	5.1	1.3	2.54	7.49	4.14	31.0	1.81	—	—	—	—	—	—	—	—	—	1115	—
28-058-	6.20	2.36	3.0	11.56	5.33	61.7	2.17	—	—	—	—	—	—	—	23.2	5.6	—	—
28-001-	6.35	3.18	1.52	13.80	2.31	31.9	5.97	—	—	252	736	—	37	21.1	8.4	2.0	—	—
28-004-	6.35	3.18	3.00	13.80	4.57	62.88	3.02	—	—	499	—	—	—	—	—	—	—	—
28-002-	6.35	3.18	3.96	13.80	6.03	83.0	2.29	—	—	658	1920	—	96	—	21.9	5.2	—	—
28-003-	6.35	3.18	7.92	13.80	12.06	166.0	1.14	—	—	1322	3856	—	193	—	44	10.5	—	—
28-070-	9.52	4.75	3.18	20.7	7.29	151	2.84	—	—	—	1543	2212	—	—	—	—	—	—
28-011-	12.7	6.35	3.18	27.60	9.68	268	2.86	—	—	527	1537	—	77	—	17.5	4.2	—	—
28-014-	12.7	6.35	5.59	27.60	17.05	472	1.62	—	934	—	—	—	—	—	—	—	—	—
28-012-	12.7	6.35	6.35	27.60	19.36	536	1.43	—	—	1054	3074	—	154	—	35.0	8.5	—	—
28-013-	12.7	6.35	9.52	27.60	29.04	804	0.95	—	—	—	4627	—	232	—	52.8	—	—	—
28-017-	12.7	7.1	5.0	29.4	13.61	400	2.17	—	—	—	2088	—	—	—	—	—	—	—
28-015-	12.7	7.1	9.5	29.4	25.86	761	1.14	—	—	—	3966	—	—	—	—	—	—	—

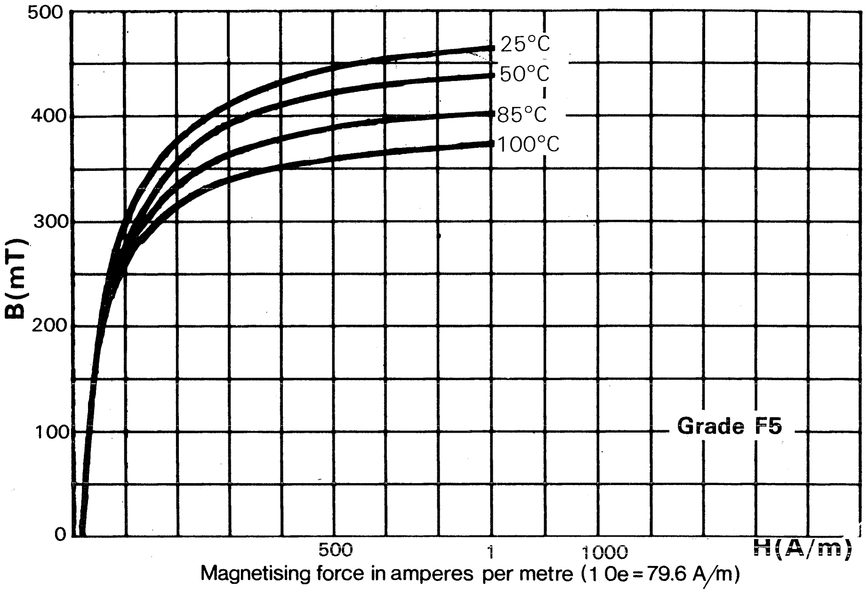
Ferrite Ring Cores 16.0 mm to 25.4 mm outside diameter

	Dimensions			Effective Geometric Parameters				Minimum A_L values in nH for uncoated cores in preferred grades										
Part Number	O.D.	I.D.	HT.	ℓ_e	A_e	V_e	C_1	F5	F6	F8	F9	F10	F14	F16	F25	F29	P10	P11
28-052-	16.0	9.6	2.54	38.5	7.95	306	4.84	—	—	—	—	—	—	—	—	—	415.4	—
28-059-	16.0	9.6	5.0	38.5	15.66	603	2.46	—	—	—	1788	—	—	—	—	—	—	—
28-021-	19.05	12.7	3.18	48.5	9.96	483	4.87	—	—	—	—	—	45	—	10.3	—	—	—
28-022-	19.05	12.7	6.35	48.5	19.92	966	2.43	—	—	620	1809	—	91	—	20.7	—	—	—
28-023-	19.05	12.7	9.52	48.5	29.88	1449	1.62	—	—	930	2713	—	—	—	—	—	—	—
28-057-	20.0	10.0	10.0	43.55	48.05	2092	0.51	—	2957	—	—	—	—	—	—	—	—	—
28-055-	24.0	12.0	12.0	52.36	69.2	3616	0.755	—	—	—	—	—	—	—	—	—	—	2996
28-035-	25.0	15.0	7.0	60.2	34.3	2065	1.75	—	—	—	2503	—	—	—	—	—	—	—
28-034-	25.0	15.0	10.0	60.2	49.0	2950	1.23	—	—	—	3575	—	—	—	—	—	—	—
28-080-	25.0	15.0	10.0	60.2	49.0	2950	1.23	—	—	—	4000	—	—	—	—	—	—	—
28-036-	25.0	15.0	16.0	60.2	78.4	4720	0.77	—	—	—	5720	—	—	—	—	—	—	—
28-081-	25.0	15.0	20.0	60.2	98.0	5900	0.615	—	—	—	7150	—	—	—	—	—	—	—
28-031-	25.4	19.05	4.75	68.9	15.0	1040	4.58	—	—	329	960	—	—	—	10.9	—	—	—
28-032-	25.4	19.05	9.52	68.9	30.0	2080	2.29	—	—	—	—	—	96	—	21.8	—	—	—
28-033-	25.4	19.05	14.30	68.9	45.0	3120	1.53	—	—	985	2880	—	144	—	32.8	—	—	—

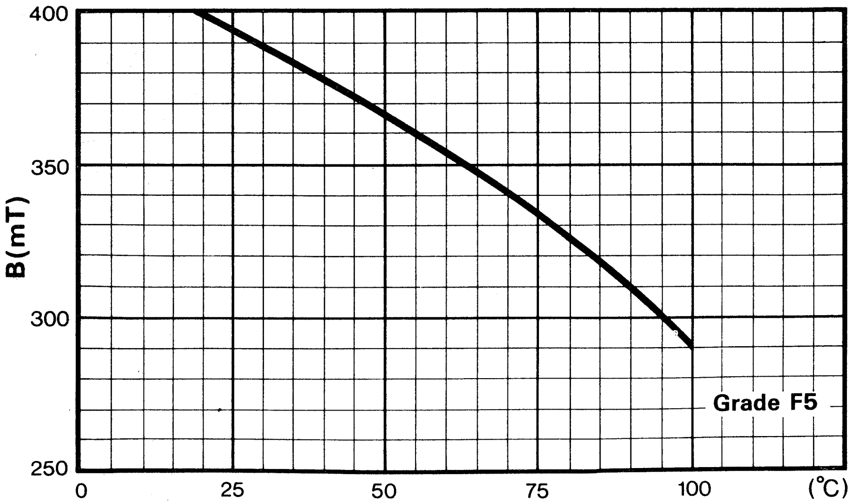
Ferrite Ring Cores 31.5 mm to 63.0 mm outside diameter

	Dimensions			Effective Geometric Parameters				Minimum A_L values in nH for uncoated cores in preferred grades										
Part Number	O.D.	I.D.	HT.	ℓ_e	A_e	V_e	C_1	F5	F6	F8	F9	F10	F14	F16	F25	F29	P10	P11
28-060-	31.5	19.0	7.0	76.04	42.83	3257	1.775	—	—	—	2553	—	—	—	—	—	—	—
28-056-	31.5	19.0	12.5	76.04	76.48	5816	0.994	—	—	—	4434	—	—	—	—	—	—	—
28-054-	36.0	13.0	12.7	65.11	134.05	8728	0.486	—	—	—	—	—	—	258	—	—	—	—
28-041-	38.1	25.4	6.35	97.10	39.80	3860	2.44	—	—	618	1802	—	90	—	20	—	—	—
28-042-	38.1	25.4	12.7	97.10	79.60	7720	1.22	—	—	1236	3604	—	181	—	41	—	—	—
28-044-	38.1	25.4	15.87	97.10	99.41	9647	0.976	—	—	—	4504	—	—	—	—	—	—	—
28-045-	38.1	25.4	16.0	97.10	100.22	9728	0.969	2075	—	—	—	—	—	—	—	—	—	—
28-043-	38.1	25.4	19.05	97.10	119.40	11580	0.81	—	—	1861	5427	—	272	155	62	—	—	—
28-062-	63.0	27.0	17.0	125.77	288.33	36264	0.436	—	—	—	—	—	—	288	—	—	—	—
28-053-	63.0	27.0	19.0	125.77	322.25	40530	0.390	—	—	—	—	—	567	322	—	—	—	—
28-061-	63.0	38.0	25.0	152.09	305.93	46530	0.497	4045	—	—	8850	—	—	—	—	—	—	—

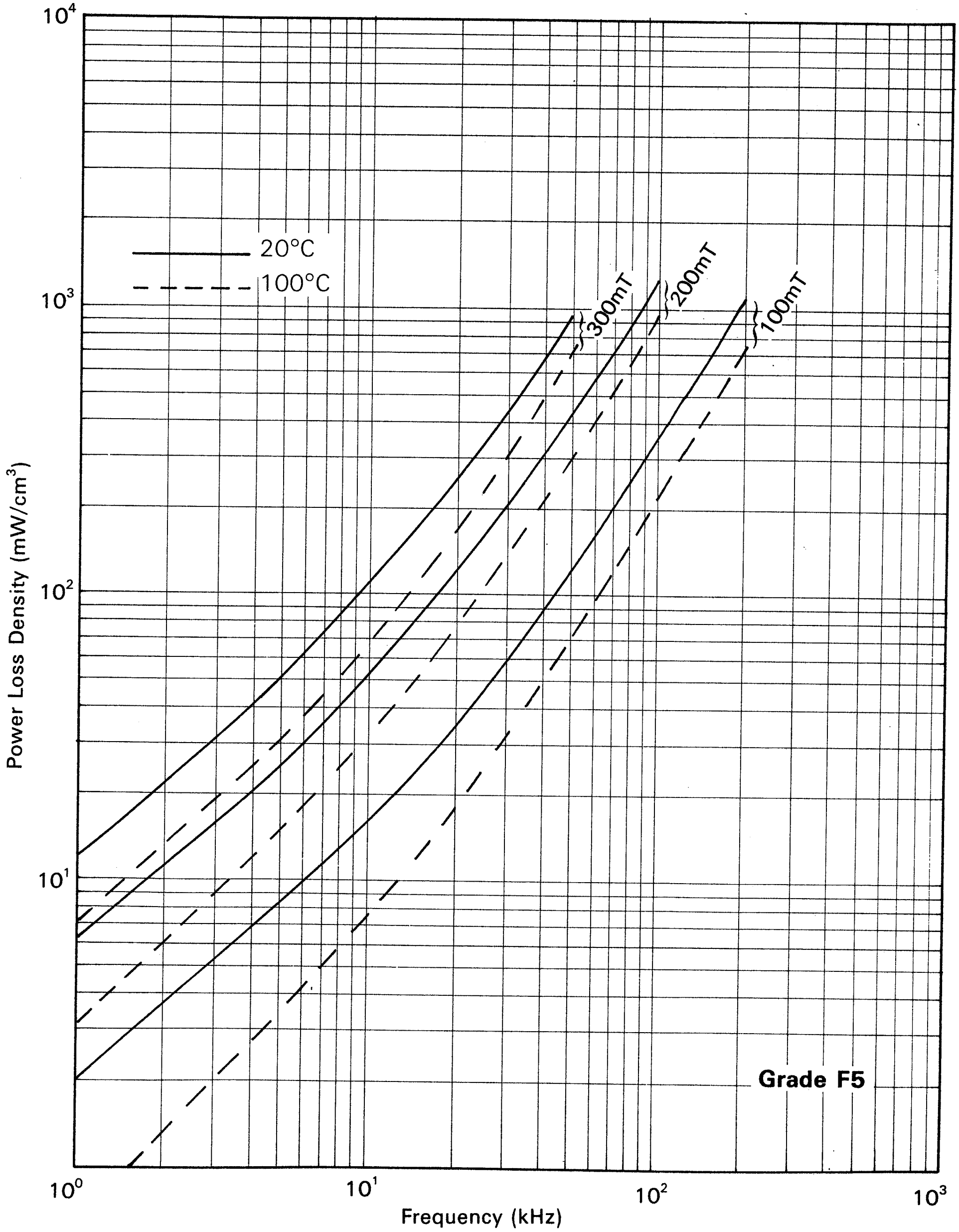
U, E and I Cores
Material and Characteristics



Flux density as a function of temperature



Maximum peak working flux density as a function of temperature



Power loss density versus frequency

U, E and I Cores
Effect of an air gap

A method is described below for approximate evaluation of the effective permeability, μ_e, of gapped U and E cores, at low flux densities. The A_L values, which are of even greater direct interest to the user, are related to μ_e by the formula:

$$A_L = \frac{0.4\,\pi.\,\mu_e}{\sum\frac{\ell}{A}} \quad \text{or} \quad \mu_e = \frac{A_L \sum\frac{\ell}{A}}{0.4\,\pi} \tag{1}$$

where A_L (the inductance of one turn) is in nH,
$\sum\frac{\ell}{A}$ (given in the catalogue sheets for specific cores) is in mm^{-1}.

The demagnetizing effect of magnetic poles on both sides of an air gap makes the effective permeability of a gapped core assembly lower than the initial (intrinsic) permeability of the core material. The extent of this reduction in value depends on the magnetic reluctance of the flux path in the ferromagnetic material of the core and on the reluctance of the air gap. It can be written that:

$$\mu_e = \frac{R_m}{R_m + R_{gap}} \cdot \mu_i \tag{2}$$

where R_m is the reluctance of the flux path in the core and R_{gap} is the reluctance of the air gap.

The value of R_m can be calculated from the published geometric parameters of the core and the knowledge of the initial permeability of the core material.

$$R_m = \frac{\ell_e}{A_e} \cdot \frac{1}{\mu_i} \tag{3}$$

where ℓ_e is the effective length of the magnetic path and A_e is the effective cross-sectional area of magnetic path (both values are given in the catalogue sheets).

Taking the published ℓ_e value for the above expression is not strictly justified; the length of the gap should be really subtracted from ℓ_e which is always given for an ungapped core, but the error is small because the gap length is usually small compared with ℓ_e.

The value of R_{gap} is:

$$R_{gap} = \frac{\ell_{gap}}{A_{gap}} \quad (\mu \text{ of air is } 1) \tag{4}$$

While the total length of the air gap, ℓ_{gap}, presents no problems, the cross-sectional area of the gap, A_{gap}, is more difficult to ascertain, because the lines of the magnetic flux between the pole faces on both sides of the gap are not strictly contained within the perimeter of the poles. The magnetic lines barrel out and, therefore, the cross-sectional area of the gap reaches its maximum half-way between the poles.

This effect can be taken into account by introducing a correction factor k (greater than 1):

$$A_{gap} = k \, . \, A_{pole} \tag{5}$$

where A_{pole} is the area of this part of the core where the gap is situated.

In the design of U and E cores, the general tendency is to maintain the same cross-sectional area in all core parts through which the magnetic flux flows, so that the same flux density is maintained and the losses are not increased in the narrower parts (power losses increase with the 2.2 power of the flux density). Nevertheless, A_{pole} is not necessarily identical with A_e. However, to simplify the calculations, it can be taken that $A_{pole} = A_e$ although this introduces a certain error.

Thus, for an EE42 core (32-110-25), $A_e = 181 \text{ mm}^2$, $A_{pole} = 178.7 \text{ mm}^2$;
for E core 56 x 37 x 19 (32-620-25), $A_e = 211 \text{ mm}^2$, $A_{pole} = 201 \text{ mm}^2$;
for U core 65 x 35 x 19 (34-510-25), $A_e = 241 \text{ mm}^2$, $A_{pole} = 248 \text{ mm}^2$.

Formula (4), with the above qualifications, can now be written as follows:—

$$R_{gap} = \frac{\ell_{gap}}{k . A_e} \tag{6}$$

Introducing expressions (3) and (6) into (2), we obtain finally:—

$$\mu_e = \frac{\ell_e \, . \, \mu_i}{\ell_e + \frac{\ell_{gap}}{k} \, . \, \mu_i} \tag{7}$$

The value of k can be determined only experimentally and not very accurately. In an approximate calculation, the following values may be taken:—

gap length	mm	0.1	0.2	0.5	1.0	2.0	3.0	4.0
k		1.1	1.2	1.3	1.4	1.5	1.65	1.8
$\frac{\ell_{gap}}{k}$	mm	0.09	0.17	0.38	0.71	1.33	1.82	2.22

If the total gap consists of two gaps, located in different parts of the magnetic circuit, the value of k should be taken which corresponds to the half-length of the total gap.

Formula (7) can be rearranged to show directly the value of ℓ_{gap}/k as a function of μ_e and μ_i:

$$\frac{\ell_{gap}}{k} = \ell_e\left(\frac{1}{\mu_e} - \frac{1}{\mu_i}\right) \quad \text{or in terms of } A_L \quad \frac{\ell_{gap}}{k} = \ell_e\left(\frac{0.4\,\pi}{A_L \,.\, \sum\frac{\ell}{A}} - \frac{1}{\mu_i}\right) \qquad (8)$$

Since the value of k depends on the ℓ_{gap}, some trial calculations may be needed before the physical length of the air gap is calculated for a required value of A_L; the third row of figures in the Table relating ℓ_{gap} and k will help these calculations.

When the magnetic circuit of E or U cores has no intentional air gaps, the roughness of the mating surfaces and the impossibility of establishing contact in every point of these surfaces, even with the most advanced grinding methods, produce an effect equivalent to the existence of a very small gap. The length of this gap is of the order of 0.01 mm for U cores and 0.015 mm for E cores (which have more contact areas). For this length of the gap, k is obviously 1.

Since the initial permeabilities of ferrite grades used for U and E cores are of the order of 1500-2000, even very small gaps seriously reduce the effective permeability, as the following example will show:

assume $\ell_{gap} = 0.015$ mm, $\mu_i = 2000$, $\ell_e = 50$ mm

$$\mu_e = \frac{50 \,.\, 2000}{50 + 0.015 \,.\, 2000} = 1250$$

Obviously, the larger is the core (and its ℓ_e), the higher will be μ_e, other conditions remaining unchanged.

It should be pointed out once more that the above method for evaluating the effect of the air gap is only approximate and can be used only for preliminary calculations, but not as a source of exact design data, which can be obtained only by careful measurements of experimentally gapped cores.

The method can be used also for preliminary evaluation of the amplitude permeability at high flux densities, although the errors will be even greater because the determination of the reluctance under the conditions of large cyclic variations of the magnetizing field strength is even more difficult than when the flux density is very low.

Gapped Cores
DC Loading

A coarse approximate method is described below for finding the length of the air gap, required to ensure that the inductance, L, remains constant when a DC current, I, flows through the winding on a given type of core (E-core, U-core, pot core or gapped ring core). Conversely, the method can be used to determine the DC loading, compatible with constant inductance, when the length of the air gap in a given type of core is known.

The greatest difficulty in calculations of this type is that, for a given type of core, both the total DC loading (ampere-turns) and the number of turns, required for a given inductance, vary with the length of the air gap. To be successful, a method for such calculations must bring both these quantities into one equation which should relate the value of the permissible DC current, the value of the required inductance, the type of the core and the length of the gap. The derivation of such an equation is shown.

With a current, I, flowing through n turns of the winding, the total magnetomotive force, applied to the magnetic circuit (I.n ampere-turns), generates a magnetic flux which flows through the core and through the air gap. The current causes, therefore, the material of the core to be moved to a point on its B-H curve, in which the slope of minor loops (dB/dH) corresponding to the small AC current, used for inductance measurement, may cease to be identical with that obtained when no DC magnetization is present, i.e. with the effective permeability (which is measured with no DC loading and at very low current amplitude). The point on the B-H curve, at which the change in the slope of the minor loop begins, marks the limit of the permissible DC loading.

For a given type of core, the flux density in the material of the core is directly proportional to the flux, so although the above remarks pertained to the flux density, we may talk about the flux instead.

The flux produced by DC current in a gapped magnetic circuit is:

$$\Phi = \frac{\text{magnetomotive force}}{\text{reluctance of the core} + \text{reluctance of the air gap}}$$

$$= \text{const.} \quad \frac{I.n}{R_{\text{core}} + R_{\text{gap}}} \qquad (1)$$

We can re-write equation (1) as:

$$(I.n)_{total} = \text{const.} \left(R_{core} + R_{gap}\right) \cdot \Phi \qquad (2)$$

In other words, the total magnetomotive force (I.n) can be divided into two parts: one $(I.n)_{core}$ required to overcome the reluctance of the core path and the other $(I.n)_{gap}$ required to overcome the reluctance of the air gap.

Since the reluctance of any path is proportional to its length and inversely proportional to its cross-sectional area and permeability, we have the means to separate the above two parts of the magnetomotive force:—

$$(I.n)_{core} = (I.n)_{total} \cdot \frac{R_{core}}{R_{core} + R_{gap}} \qquad (3)$$

$$(I.n)_{gap} = (I.n)_{total} \cdot \frac{R_{gap}}{R_{core} + R_{gap}} \qquad (4)$$

If one could assume that the cross-sectional areas of the core and of the gap are the same, the separation of the magnetomotive force would only require the knowledge of the respective lengths and of the ferrite permeability. However, the cross-sectional areas cannot be regarded as identical because of the barrelling effect in the air gap, which effectively increases the cross-sectional area of the gap compared with the surface area of the core faces. Neither is it strictly true that the surface area of the core faces bordering on the gap is identical with the value of A_e, published for each individual core. Nevertheless, we shall take this area as equal to A_e, because the error is not very great and the method cannot pretend to be accurate anyway.

The barrelling effect in the gap, i.e. the increase in the cross-sectional area of the gap, is expressed by a factor k (cf pages 59 and 60) the value of which increases with the length of the gap. The reluctance of the air gap is, therefore, decreased by the same factor and it does not matter whether we talk about the increase in the gap area or a decrease in the gap length.

The magnetomotive force for the air gap can now be written as follows:—

$$(I.n)_{gap} = (I.n)_{total} \cdot \frac{\ell_{gap}/k.A_e}{\ell_e/A_e \cdot \mu_i + \ell_{gap}/k.A_e}$$

$$= (I.n)_{total} \cdot \frac{\ell_{gap}/k}{\ell_e/\mu_i + \ell_{gap}/k}, \qquad (5)$$

where μ_i is the intrinsic (initial) permeability of the core material.

An inductance of L requires $n = 1000\sqrt{L/A_L}$ turns, where L is in mH and A_L in nH.

The value of $A_L = \dfrac{0.4\,\pi.\,\mu_e}{\Sigma\ell/A} = \dfrac{0.4\,\pi\,.\,\mu_e}{\ell_e/A_e}$ nH,

where ℓ_e is in mm and A_e in mm², as given in the data sheets, and μ_e is the effective permeability the value of which (cf B3-02, equation 7) is:

$$\mu_e = \frac{\ell_e \cdot \mu_i}{\ell_e + \mu_i.\ell_{gap}/k},$$

so that

$$A_L = \frac{0.4.\,\pi}{\ell_e/A_e} \cdot \frac{\ell_e\,.\,\mu_i}{\ell_e + \mu_i.\,\ell_{gap}/k} = \frac{0.4.\,\pi\,.\,A_e}{\ell_e/\mu_i + \ell_{gap}/k}. \qquad (6)$$

Using the above formula for the calculation of the number of turns (n), required for an inductance of L mH, equation (5) for the $(I.n)_{gap}$ becomes after some re-arrangements, substitution of 0.892 for the square root of $1:(0.4\,\pi)$ and V_e for $A_e.\ell_e$:

$$(I.n)_{gap} = 1000.I \cdot \frac{\ell_{gap}/k}{\ell_e/\mu_i + \ell_{gap}/k} \cdot \sqrt{\frac{L}{0.4.\,\pi.\,A_e} \cdot (\ell_e/\mu_i + \ell_{gap}/k)}$$

$$= 892.I \cdot \frac{\ell_{gap}}{k} \sqrt{\frac{L}{V_e} \cdot \frac{\mu_i}{1 + \mu_i \,.\, \dfrac{\ell_{gap}}{\ell_e\,.\,k}}} \qquad (7)$$

The magnetic field strength in the gap, H, is:

$$H_{gap} = \frac{(I.n)_{gap}}{\ell_{gap}} = \frac{10\,(I.n)_{gap}}{\ell_{gap}} \quad \frac{A}{cm},$$

where ℓ_{gap} is in mm, or when equation (7) is combined with the above,

$$H_{gap} = 8920\ I\,.\,\frac{1}{k} \sqrt{\frac{L}{V_e} \cdot \frac{\mu_i}{1 + \mu_i \,.\, \dfrac{\ell_{gap}}{\ell_e\,.\,k}}} \quad \frac{A}{cm} \qquad (8)$$

The above equation gives the relation between the DC loading current, the type of the core (V_e and ℓ_e), the required inductance and the length of the air gap.

The survey of various available data for the permissible DC loading shows that for typical ferrite grades with an intrinsic permeability of about 2000 (nominal) and saturation induction of 4000 or higher, the inductance (measured at a very low AC flux density in the core) hardly varies until the loading with DC current brings the core material to a flux density of about one half of the saturation induction, i.e. to 2000 gauss or even more. The flux density in the gap, as has been already discussed, is somewhat lower than in the core, because of the apparently expanding cross-sectional area.

We shall take, therefore, a more conservative value and assume that the flux density in the air gap must not exceed 1700 gauss. Since the flux density in the air, when expressed in gauss, is equal to the magnetic field strength, expressed in oersted, we may say that the maximum permitted field strength in the air gap is 1700 gauss or 1350 A/cm.

Putting this value into (8), taking μ_i = 2000 and transforming the equation so as to show the maximum permitted DC current, we obtain:

$$I_{max} = 0.00338\ k \sqrt{\frac{V_e}{L}\left(1 + 2000 \cdot \frac{\ell_{gap}}{\ell_e\ .\ k}\right)} \qquad (9)$$

where, to repeat, I is in amperes, V_e in mm^3, L in mH, ℓ_{gap} and ℓ_e in mm.

To facilitate the calculations, we shall also present the number of turns, required for L mH, in another form, starting from equation (6),

$$n = 1000 \sqrt{\frac{L}{0.4\pi\ .\ V_e/\ell_e} \cdot \ell_e \left(\frac{1}{\mu_i} + \frac{\ell_{gap}}{\ell_e . k}\right)}$$

$$= 19.95\ \ell_e \sqrt{\frac{L}{V_e}\left(1 + 2000 \cdot \frac{\ell_{gap}}{\ell_e\ .\ k}\right)} \qquad (10)$$

Let us point out that equation (9) gives only a very approximate value of the maximum DC loading permitted if the measured inductance is to remain constant, and that equation (10) gives a rather smaller number of turns for a given L than the number which can be guaranteed, taking into account the bottom limit of the intrinsic permeability of the material with a nominal value of 2000.

Using equations (9) and (10), I_{max} and n have been calculated for some types of cores, used more frequently with DC loading, with various air gaps. The results are shown in the Table, based on L = 1 mH. For E – cores which have, nearly always, only one gap in the centre leg, factor k has been taken as shown on page 60.

Obviously, if the considered value of inductance is LmH and not 1 mH, the value of I shown in the Table must be divided by $\sqrt{L}$, while the number of turns, n, must be multiplied by $\sqrt{L}$. The product (I.n) = magnetomotive force remains constant, being a function only of the effective magnetic path length of the core, ℓ_e, of the length of the air gap and, of course, of the intrinsic permeability of the core material.

For design examples see following pages.

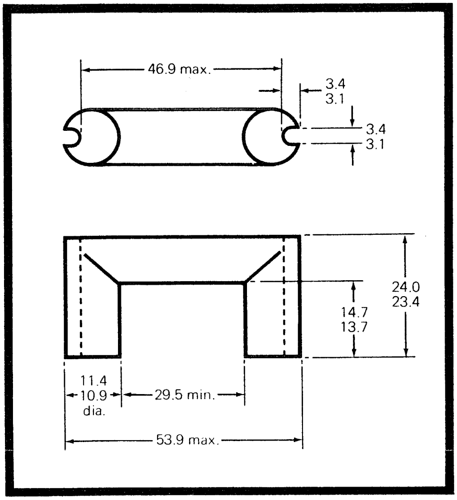
Gapped Cores
DC Loading

Permissible DC current (A) and number of turns required for 1 mH

Assumptions:
1. intrinsic permeability – 2000,
2. area of core faces bordering on the air gap = A_e,
3. maximum permitted field strength in the air gap = 135000 A/m,
4. effective magnetic path length of the cores not changed by the introduction of the gaps,
5. numerical values of the factor k expressing the barrelling effect of flux lines in the gap.

gap mm	E 42/15		E 42/20		E 55/21		E 55/25		E 65	
	I	n	I	n	I	n	I	n	I	n
0.05	0.68	21	0.78	18	1.02	16	1.08	14	1.27	13
0.1	0.87	25	1.00	21	1.27	19	1.33	17	1.55	16
0.15	1.01	28	1.16	24	1.46	21	1.57	19	1.81	17
0.2	1.13	31	1.30	27	1.63	23	1.78	21	2.05	19
0.25	1.25	34	1.44	29	1.79	25	1.95	22	2.24	20
0.3	1.35	36	1.56	31	1.94	27	2.12	24	2.42	22
0.4	1.56	40	1.79	35	2.22	29	2.42	27	2.76	24
0.5	1.74	44	2.00	38	2.47	32	2.70	29	3.07	26
0.6	1.91	47	2.19	41	2.70	34	2.95	31	3.34	28
0.7	2.06	50	2.37	44	2.92	36	3.18	33	3.61	30
0.8	2.21	53	2.54	46	3.12	38	3.41	35	3.86	31
0.9	2.35	56	2.71	49	3.32	40	3.62	37	4.10	33
1.0	2.49	58	2.86	51	3.51	42	3.83	38	4.33	34
1.1	2.62	60	3.02	53	3.70	44	4.02	40	4.54	36
1.2	2.75	63	3.17	54	3.88	45	4.20	41	4.74	37
1.3	2.87	65	3.30	56	4.04	47	4.38	43	4.94	38
1.4	2.98	67	3.43	58	4.20	48	4.55	44	5.13	40
1.5	3.09	69	3.56	60	4.36	50	4.72	45	5.32	41
1.6	3.20	71	3.68	62	4.51	51	4.88	47	5.50	42
1.8	3.42	74	3.94	64	4.82	53	5.20	49	5.86	44
2.0	3.62	77	4.17	67	5.10	56	5.51	51	6.20	46

U Cores
52 × 24 × 11



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameter of the coil former must be 11.9 mm.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	148 mm
Effective area of magnetic path	A_e	93 mm^2
Effective volume	V_e	13800 mm^3
$\sum \frac{\ell}{A}$	C_1	1.59 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1000
,, ,, (100°C)		50 Hz	320	>1000
Effective total core loss (25°C)	P	16 kHz	200	<1.65W
,, ,, ,, ,, (100°C)		16 kHz	200	<1.5W

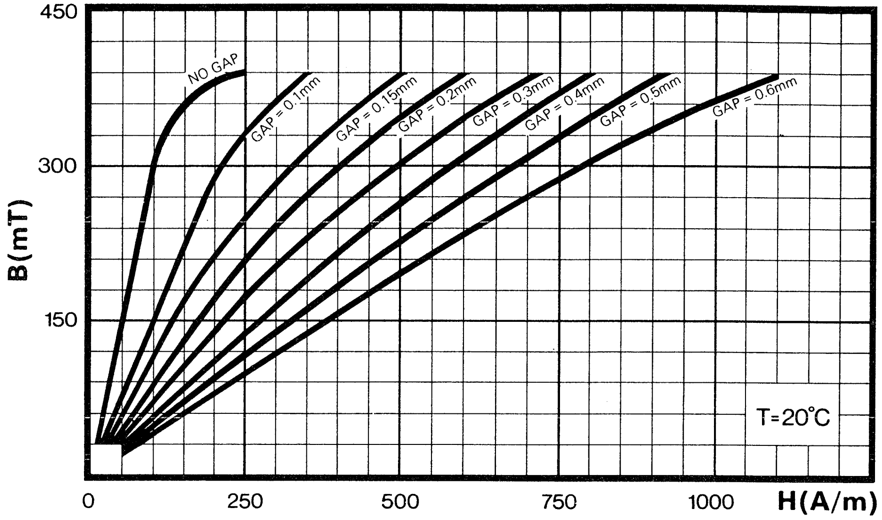
Material

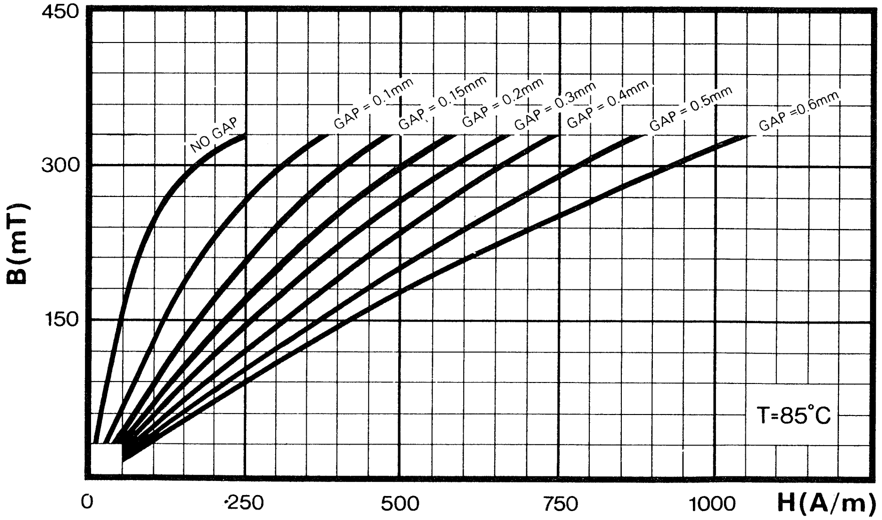
Ferrite F5

Part Number

34-513-25

U Cores
52 × 24 × 11

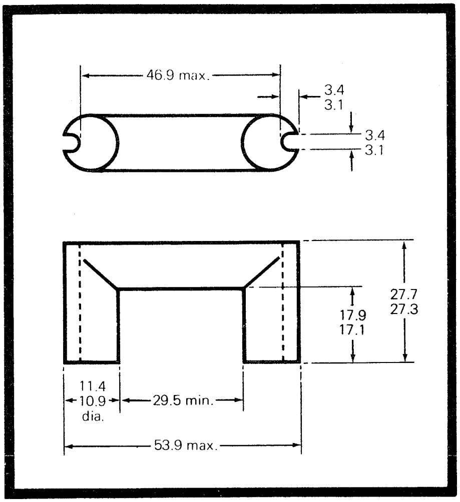




Flux density as a function of field strength for different gaps

NEOSID

U Cores
52 × 28 × 11



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameter of the coil former must be 12 mm.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	162 mm
Effective area of magnetic path	A_e	93 mm^2
Effective volume	V_e	15100 mm^3
$\sum \frac{\ell}{A}$	C_1	1.74 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1000
,, ,, (100°C)		50 Hz	320	>1000
Effective total core loss (25°C)	P	16 kHz	200	<1.8W
,, ,, ,, ,, (100°C)		16 kHz	200	<1.7W

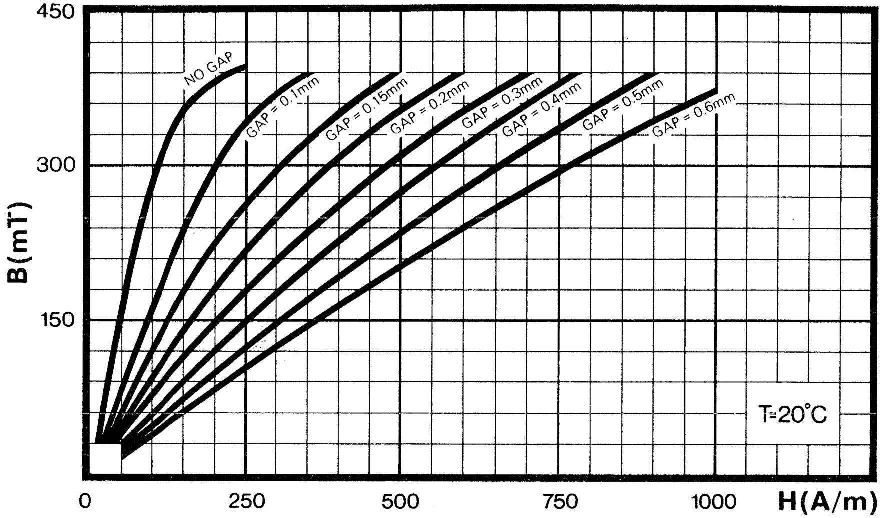
Material

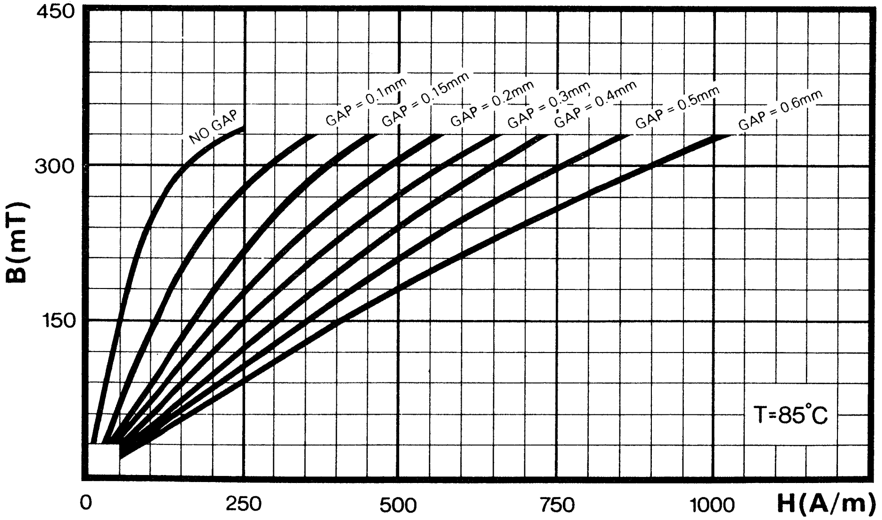
Ferrite F5

Part Number

34-514-25

U Cores
52 × 28 × 11

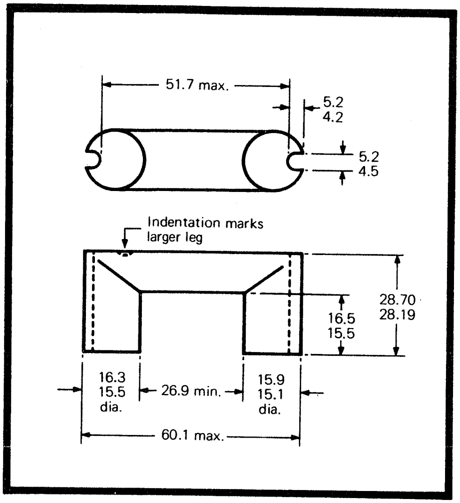




Flux density as a function of field strength for different gaps

NEOSID

U Cores
60 × 29 × 16



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameters of the coil formers must be 16.4 mm and 16.8 mm respectively.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	164 mm
Effective area of magnetic path	A_e	171 mm^2
Effective volume	V_e	28000 mm^3
$\sum \frac{\ell}{A}$	C_1	0.957 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				F5	F6
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1000	>1000
,, ,, (100°C)		50 Hz	320	>1000	>1000
Effective total core loss (25°C)	P	16 kHz	200	<3.4W	<4.2W
,, ,, ,, ,, (100°C)		16 kHz	200	<3.1W	<4.2W

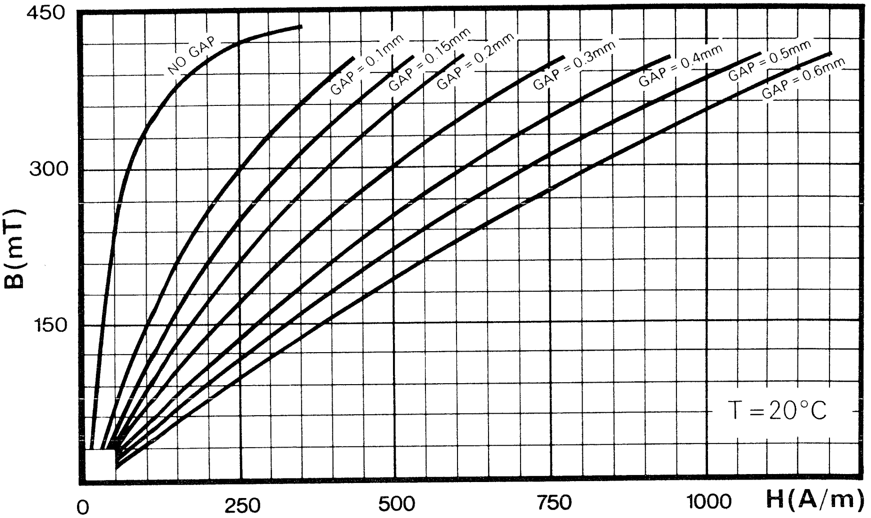
Material

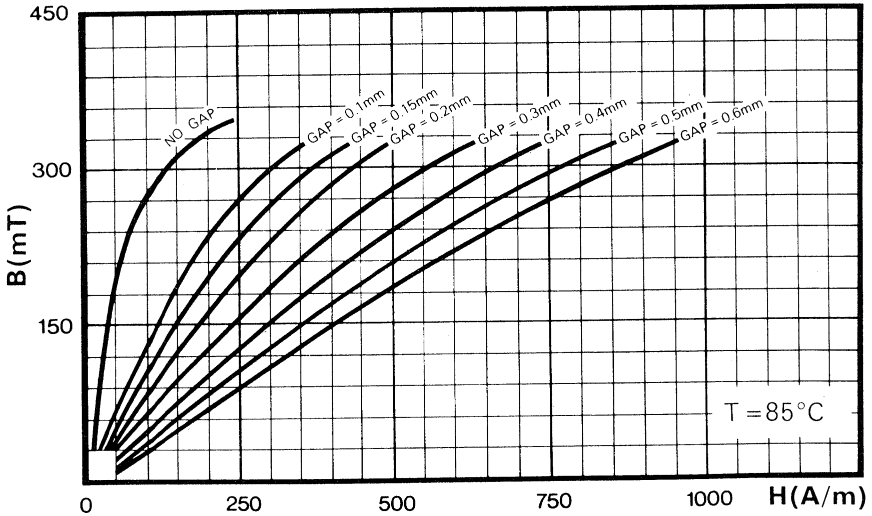
Ferrites F5 and F6.

Part Number

Grade F5 – **34-511-25**
Grade F6 – **34-511-26**

U Cores
60 × 29 × 16

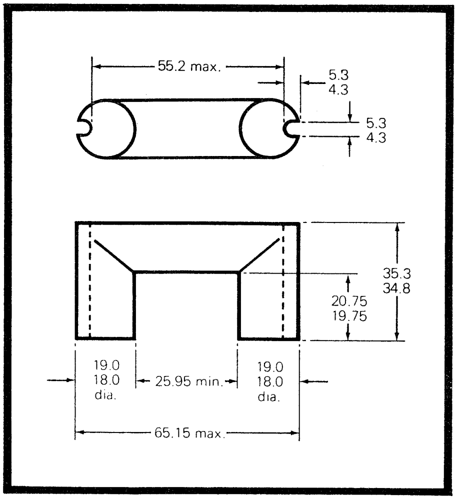




Flux density as a function of field strength for different gaps

NEOSID

U Cores
65 × 35 × 19



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameter of the coil former must be 19.7 mm.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	188 mm
Effective area of magnetic path	A_e	241 mm^2
Effective volume	V_e	45400 mm^3
$\sum \frac{\ell}{A}$	C_1	0.783 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				F5	F6
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1000	>1000
,, ,, (100°C)		50 Hz	320	>1000	>1000
Effective total core loss (25°C)	P	16 kHz	200	<5.5W	<6.8W
,, ,, ,, ,, (100°C)		16 kHz	200	<5.0W	<6.8W

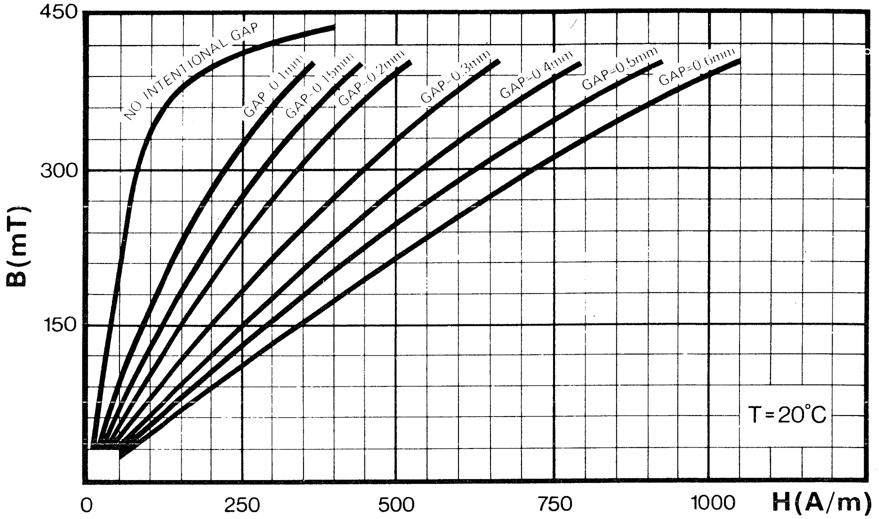
Material

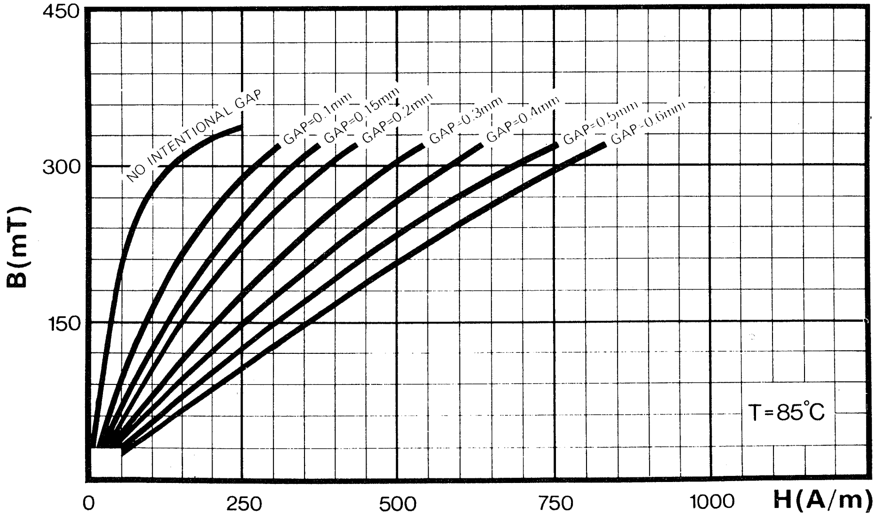
Ferrite F5 and F6

Part Number

Grade F5 – **34-510-25**
Grade F6 – **34-510-26**

U Cores
65 × 35 × 19

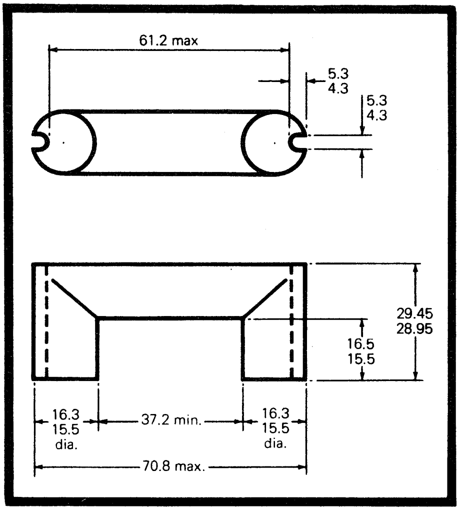




Flux density as a function of field strength for different gaps

NEOSID

U Cores
70 × 29 × 16



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameter of the coil former must be 16.8 mm.

Effective geometric parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	184 mm
Effective area of magnetic path	A_e	181 mm^2
Effective volume	V_e	33300 mm^3
$\sum \frac{\ell}{A}$	C_1	1.02 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1000
" " (100°C)		50 Hz	320	>1000
Effective total core loss (25°C)	P	16 kHz	200	<4.0 W
" " " " (100°C)		16 kHz	200	<3.7 W

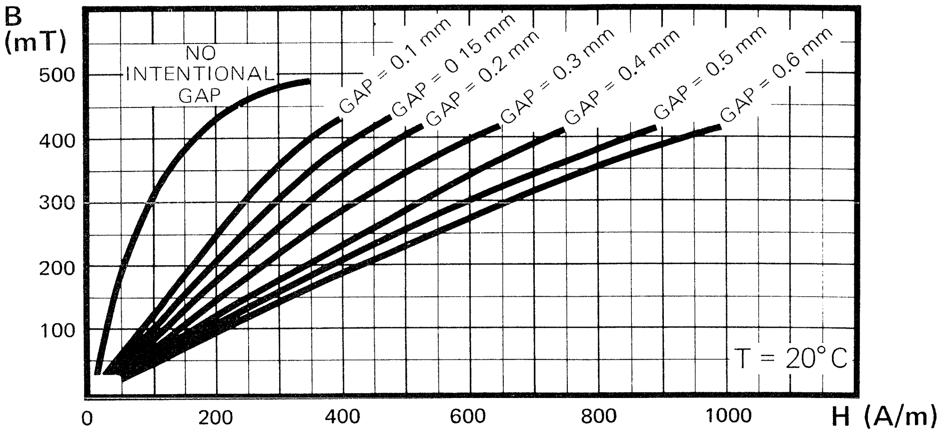
Material

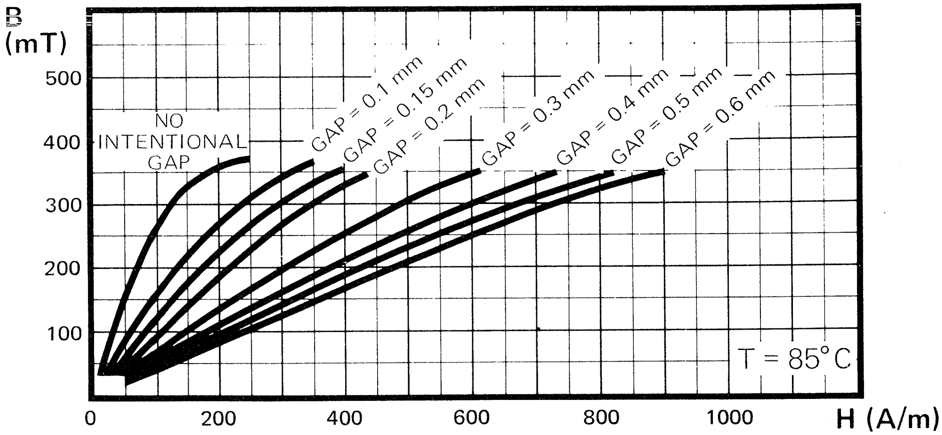
Ferrite F5

Part Number

34-515-25

U Cores
70 × 29 × 16

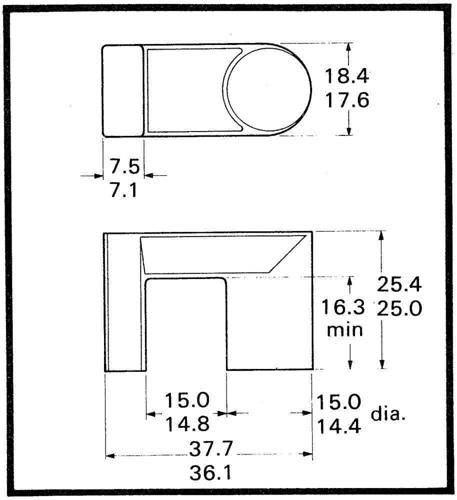




Flux density as a function of field strength for different gaps

NEOSID

U Cores
37 × 25 × 18



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameter of the coil former must be 15.1 mm

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	125 mm
Effective area of magnetic path	A_e	150 mm^2
Effective volume	V_e	18750 mm^3
$\sum \frac{\ell}{A}$	C_1	0.833 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value
Amplitude permeability (25°C)	μ_a	50 Hz	400	> 1200
,, ,, (100°C)		50 Hz	320	> 1200
Effective total core loss (100°C)	P	16 kHz	200	< 2.1W

Material

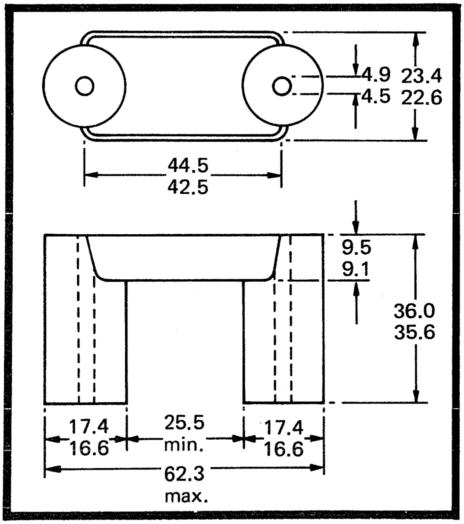
Ferrite F5

Part Number

34-521-25

NEOSID

U Cores
60 × 36 × 23



All information on this sheet is given for a pair of cores (zero gap)

Dimensional Data

Minimum inside diameter of coil former must be 18.5 mm.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	189 mm
Effective area of magnetic path	A_e	210 mm^2
Effective volume	V_e	39700 mm^3
$\sum \frac{\ell}{A}$	C_1	0.90 mm^{-1}

Electrical Specification

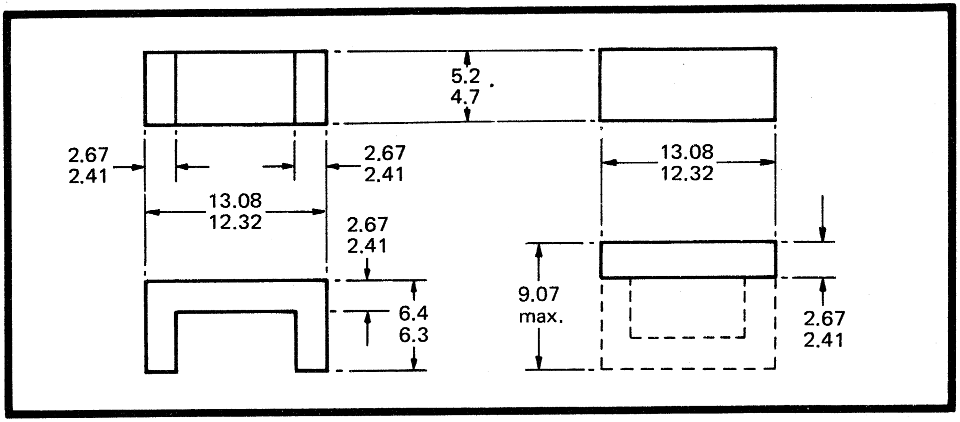
Parameter	Symbol	Test Frequency	Flux Density mT	Value
Amplitude permeability (25° C)	μ_a	50 Hz	400	> 1000
" " (100° C)		50 Hz	320	> 1000
Effective total core loss (25° C)	P	16 kHz	200	< 4.75W
" " " " (100° C)		16 kHz	200	< 4.35W

Material Ferrite F5

Part number 34-520-25

NEOSID

U and I Cores
12.7 × 8.9 × 4.95



All information on this sheet is given for a pair of cores (zero gap).

Effective Geometric Parameters

Parameters	Symbol	Value U + I
Effective magnetic path length	ℓ_e	33 mm
Effective area of magnetic path	A_e	12.6 mm²
Effective volume	V_e	416 mm³
$\sum \frac{l}{A}$	C_1	2.62 mm⁻¹

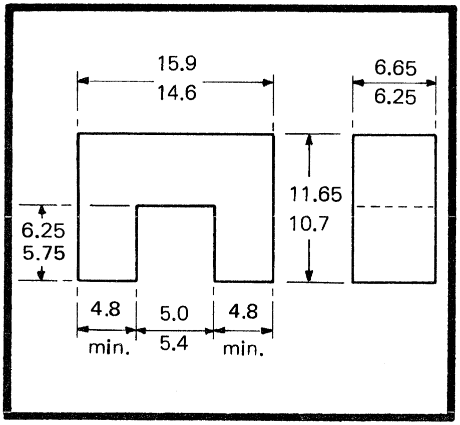
Electrical Specification

Parameters	Symbol	Value U + I
Minimum effective permeability	μ_e	1670
Maximum turns for 1 mH	α	36
Inductance factor (nH for 1 turn)	A_L min.	800

The above parameters are measured at an effective peak flux density <0.1 mT at 25°C.

Material	**Part Numbers**
Ferrite F9	U core **34-490-36**
	I core **33-490-36**

U Cores
15 × 11 × 6.5



All information on this sheet is given for a pair of cores (zero gap)

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	48 mm
Effective area of magnetic path	A_e	32 mm^2
Effective volume	V_e	1540 mm^3
$\sum \frac{\ell}{A}$	C_1	1.5 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value
Amplitude permeability (25° C)	μ_a	50Hz	400	>1000
" " (100° C)		50Hz	320	>1000
Effective total core loss (25° C)	P	16kHz	200	<0.23W
" " " " (100° C)		16kHz	200	<0.23W

Material

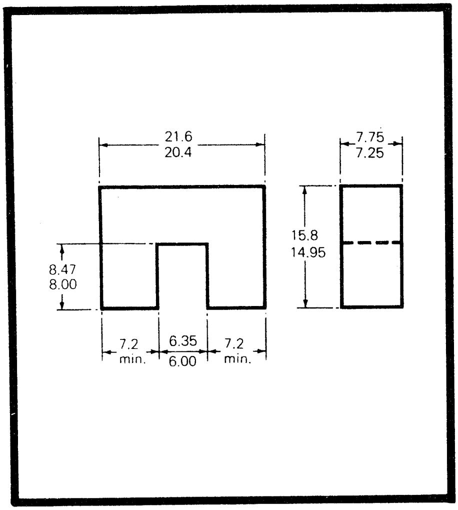
Ferrite F6

Part Number

34-010-26

NEOSID

U Cores
21 × 15 × 7.5



All information on this sheet is given for a pair of cores (zero gap).

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	68.0 mm
Effective area of magnetic path	A_e	54.9 mm^2
Effective volume	V_e	3730 mm^3
$\sum \frac{\ell}{A}$	C_1	1.24 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1000
" " (100°C)		50 Hz	320	>1000
Effective total core loss (25°C)	P	16 kHz	200	<0.6 W
" " " " (100°C)		16 kHz	200	<0.6 W

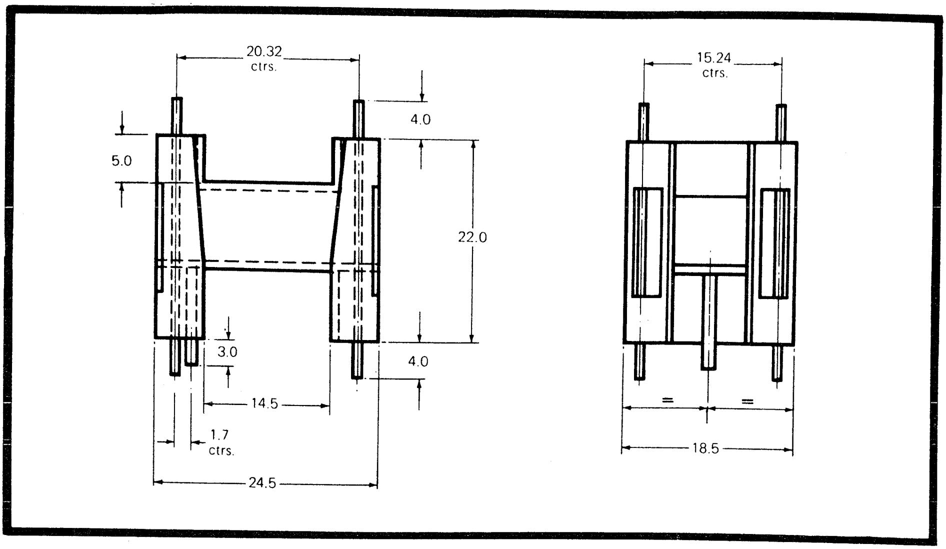
Material

Ferrite F6

Part Numbers

U Core – **34-012-26**
Former – **59-100-66**

U Core Former
21 × 15 × 7.5



Dimensional Data

Mounting holes to be suitable for 1.0 mm diameter pins and for the 1.4 mm square plastics location peg.

Material

Pins –
Hard brass, hot-dip tinned

Pin solderability –
To BS 2011 Part 2T

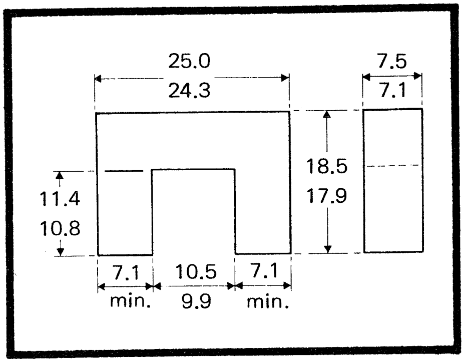
Former –
Glass-filled nylon AD197 SE1

Part Number

59-100-66

NEOSID

U Cores
25 × 18.5 × 7.5



All information on this sheet is given for a pair of U cores (zero gap).

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	87 mm
Effective area of magnetic path	A_e	54 mm^2
Effective volume	V_e	4700 mm^3
$\sum\frac{\ell}{A}$	C_1	1.61 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				34-018-25	34-018-36
Amplitude permeability 25°C	μ_a	50 Hz	400	>1000	–
" " " 100°C		50 Hz	320	>1000	–
Effective total core loss 25°C	P	16 kHz	200	<0.57W	–
" " " 100°C		16 kHz	200	< 0.52W	–
Minimum inductance factor (nH)	A_L min	1000Hz	<1	1150	2500

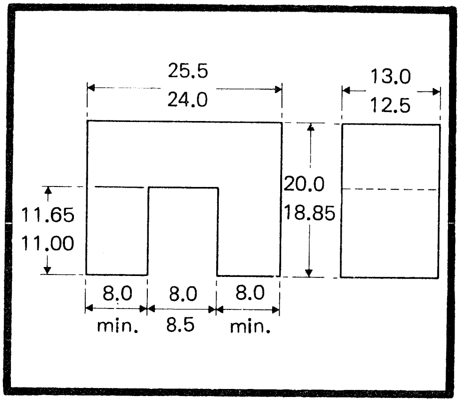
Material

Ferrite F5 and F9.

Part Numbers

Grade F5 **34-018-25** (single core).
Grade F9 **34-018-36** (single core).

U Cores
25 × 20 × 13



All information on this sheet is given for a pair of cores (zero gap)

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	86 mm
Effective area of magnetic path	A_e	105 mm²
Effective volume	V_e	9030 mm³
$\sum \frac{\ell}{A}$	C_1	0.82 mm⁻¹

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value
Amplitude permeability (25° C) " " (100° C)	μ_a	50Hz 50Hz	400 320	>1000 >1000
Effective total core loss (25° C) " " (100° C)	P	16 kHz 16 kHz	200 200	<1.1W <1.0W
Inductance factor (nH for 1 turn)	A_L min	1000Hz	<1	1900

Material

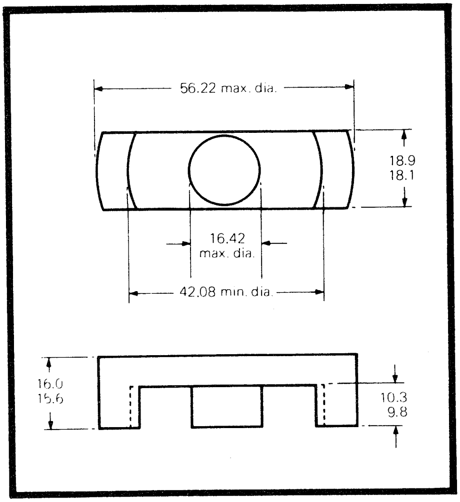
Ferrite F5

Part Number

34-015-25 (single core).

NEOSID

E Cores
56 × 32 × 19



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameter of the coil former must be no less than 16.5 mm.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	86.2 mm
Effective area of magnetic path	A_e	211 mm^2
Effective volume	V_e	18200 mm^3
$\sum \frac{\ell}{A}$	C_1	0.408 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				F5	F6
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1000	>1000
,, ,, (100°C)		50 Hz	320	>1000	>1000
Effective total core loss (25°C)	P	16 kHz	200	<2.2W	<2.7W
,, ,, ,, ,, (100°C)		16 kHz	200	<2.0W	<2.7W

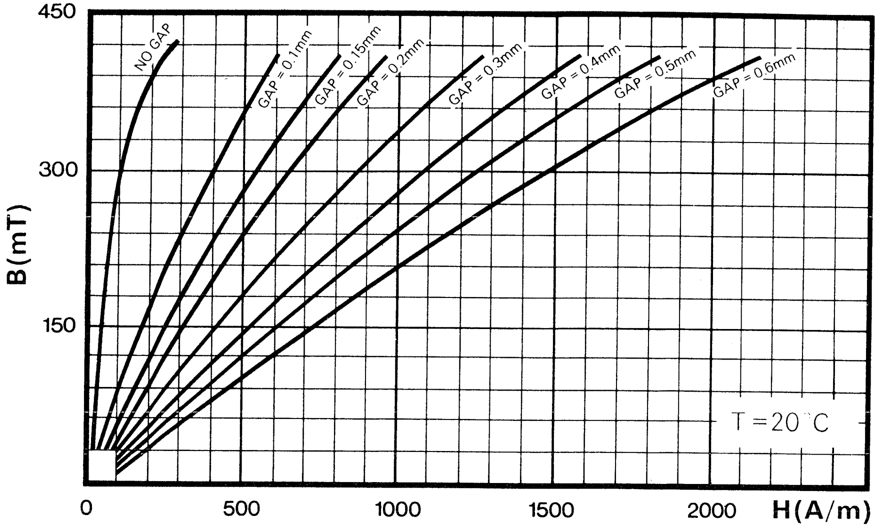
Material

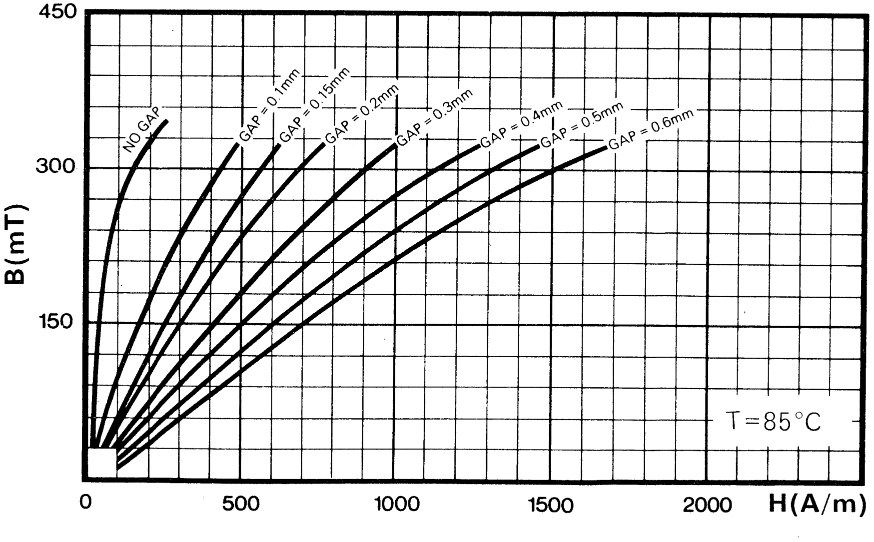
Ferrites F5 and F6

Part Number

Grade F5 **32-630-25** (single core).
Grade F6 **32-630-26** (single core).

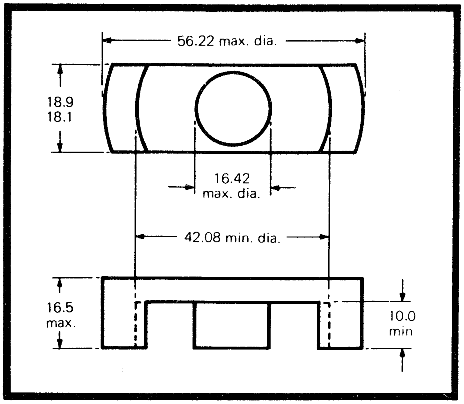
E Cores
56 × 32 × 19





Flux density as a function of field strength for different gaps

E Cores
56 × 33 × 19



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameter of the coil former must be no less than 16.5 mm.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	87.2 mm
Effective area of magnetic path	A_e	211 mm^2
Effective volume	V_e	18400 mm^3
$\sum \frac{\ell}{A}$	C_1	0.418 mm^{-1}

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				F5	F6
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1000	>1000
,, ,, (100°C)		50 Hz	320	>1000	>1000
Effective total core loss (25°C)	P	16 kHz	200	<2.2W	<2.8W
,, ,, ,, ,, (100°C)		16 kHz	200	<2.0W	<2.8W

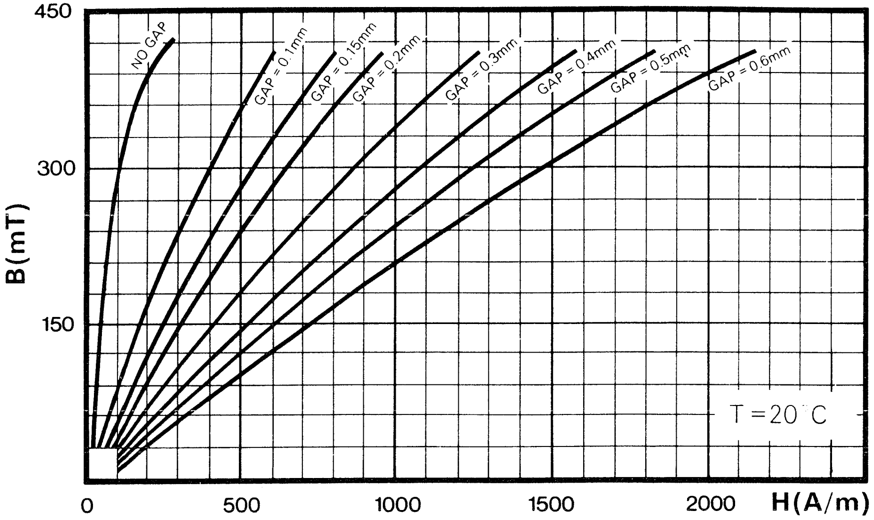
Material

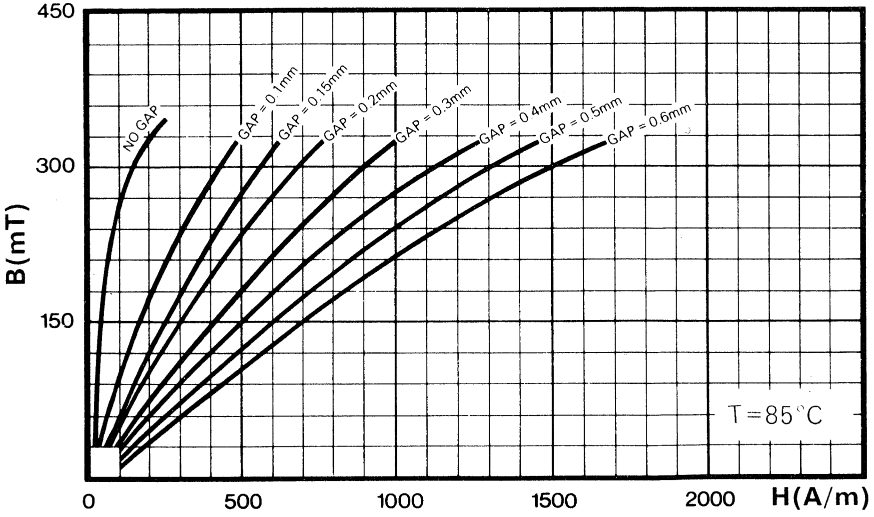
Ferrites F5 and F6.

Part Numbers

Grade F5 **32-610-25** (single core).
Grade F6 **32-610-26** (single core).

E Cores
56 × 33 × 19

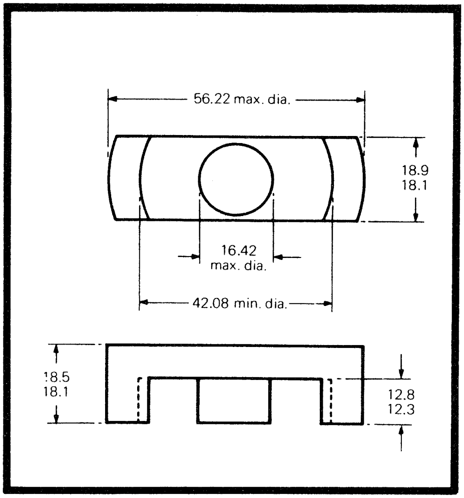




Flux density as a function of field strength for different gaps

NEOSID

E Cores
56 × 37 × 19



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

Minimum inside diameter of the coil former must be no less than 16.5 mm.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	95.8 mm
Effective area of magnetic path	A_e	211 mm^2
Effective volume	V_e	20200 mm^3
$\sum \frac{\ell}{A}$	C_1	0.455 mm^{-1}

Electrical Specification

Parameter		Symbol	Test Frequency	Flux Density mT	Value	
					F5	F6
Amplitude permeability	(25°C)	μ_a	50 Hz	400	>1000	>1000
,, ,,	(100°C)		50 Hz	320	>1000	>1000
Effective total core loss	(25°C)	P	16 kHz	200	<2.4W	<3.0W
,, ,, ,, ,,	(100°C)		16 kHz	200	<2.2W	<3.0W

Material

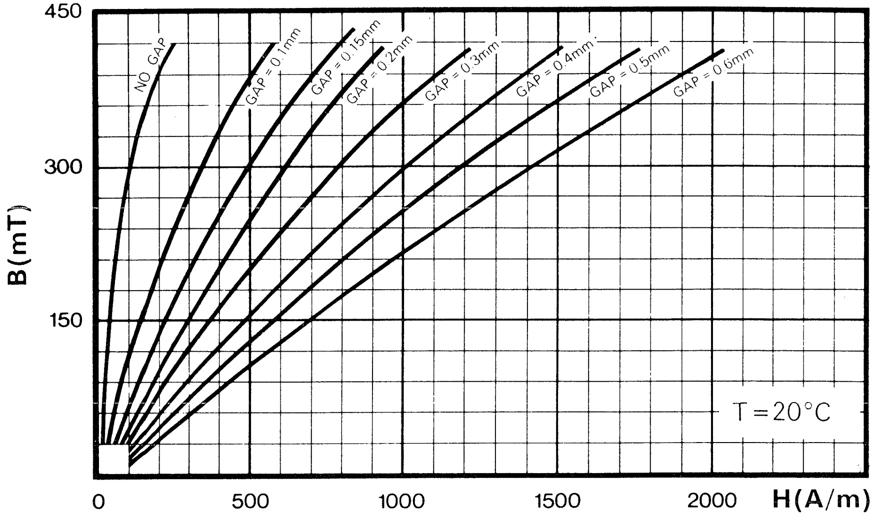
Ferrites F5 and F6.

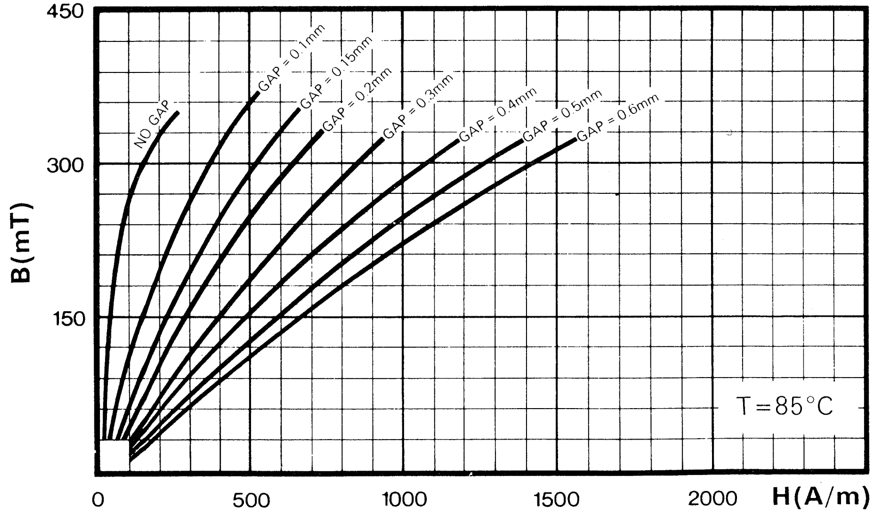
Part Number

Grade F5 **32-620-25** (single core).
Grade F6 **32-620-26** (single core).

E Cores

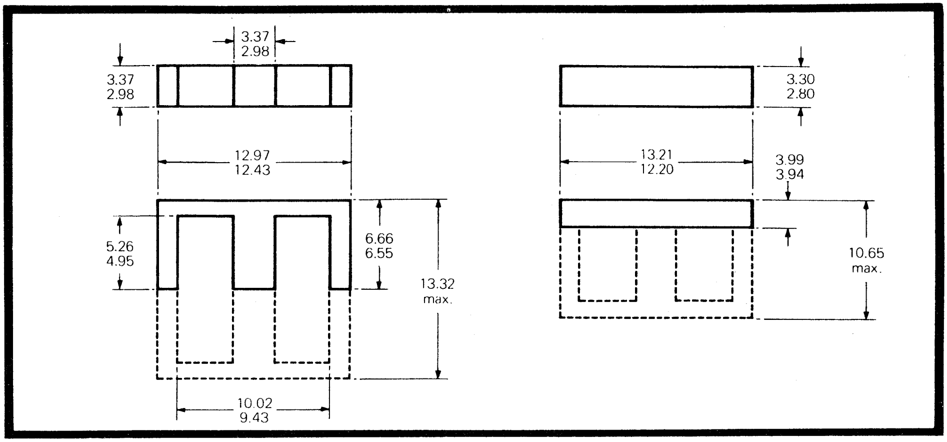
56× 37 × 19





Flux density as a function of field strength for different gaps

E and I Cores
13 × 13 × 3
13 × 11 × 3



All information given on this sheet is for a pair of cores (zero gap).

Dimensional Data

To BS 4257 Ref. 2 (E Core)
Ref. 14 (I Core)

Window Area

2 × E – 30.0 mm^2 (minimum)
E + I – 15.0 mm^2 (minimum)

Effective Geometric Parameters

Parameter	Symbol	Value	
		2 × E	E + I
Effective magnetic path length	ℓ_e	31.7 mm	21.7 mm
Effective area of magnetic path	A_e	9.68 mm^2	10.7 mm^2
Effective volume	V_e	307 mm^3	232 mm^3
$\sum \frac{\ell}{A}$	C_1	3.28 mm^{-1}	2.03 mm^{-1}

Electrical Specification

Parameter	Symbol	2 × E	E + I
Minimum effective permeability	μ_e	1000	1000
Maximum turns for 1 mH	α	51.2	40.3
Inductance factor (nH for 1 turn)	A_L min	382	618

The above parameters are measured at an effective peak flux density <0.1 mT at 25°C.

Material

Ferrite F8

Part Numbers

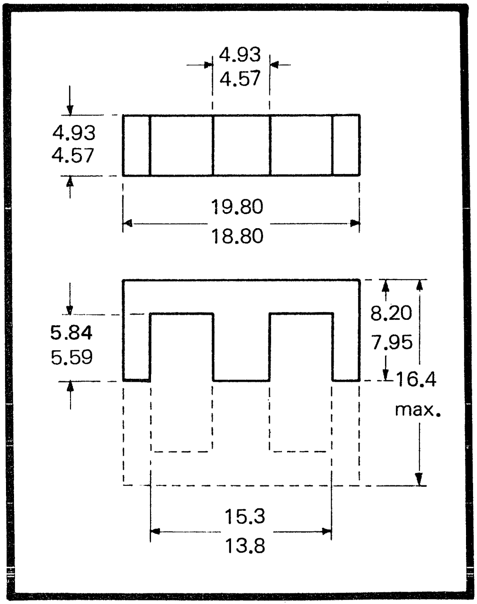
E core **32-040-28** (single core).
I core **33-040-28** (single core).

Formers

2 × E – **59-040-66** (2 off)
E + I – **59-040-66** (1 off)
(see page 107)

NEOSID

E Cores
19 × 16 × 4.75



All information on this sheet is given for a pair of cores (zero gap)

Effective geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	40 mm
Effective area of magnetic path	A_e	22.5 mm²
Effective volume	V_e	900 mm³
$\sum\frac{\ell}{A}$	C_1	1.78 mm^{-1}

Electrical Specification

Parameter	Symbol	Test frequency	Flux density mT	Value		
				Grade F4	Grade F6	Grade F9
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1500	>1000	—
" " (100°C)		50 Hz	320	>1250	>1000	—
Effective total core loss (25°C)	P	16 kHz	200	—	<.14W	—
" " " " (60–100°C)		16 kHz	200	<.1W	<.14W	—
" " " " (60–100°C)		25 kHz	200	<.17W	—	—
Minimum inductance factor (nH)	A_L min.	1000 Hz	<1	1050	750	1730

E Cores
19 × 16 × 4.75

Gapped Cores

E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required A_L value can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

Material

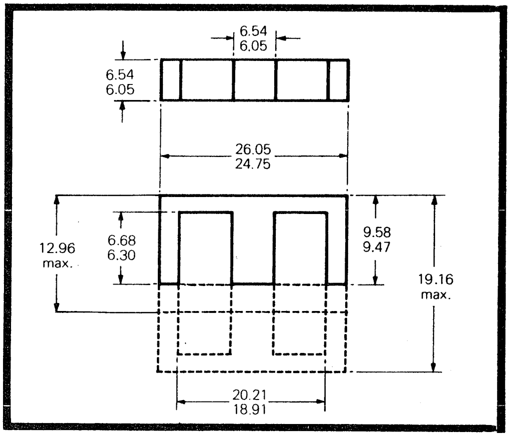
Ferrite F4, F6 and F9

Part Numbers (single cores)

Grade F4	**36-160-45**
Grade F6	**32-160-26**
Grade F9	**32-160-36**

NEOSID

E and I Cores
25 × 19 × 6
25 × 13 × 6



All information on this sheet is for a pair of cores (zero gap).

These cores can also be supplied gapped to specified A_L values.

Dimensional Data

To BS 4257 Ref. 5 (E Core)
Ref. 15 (I Core)

Window Area

2 × E – 77.93 mm^2 (minimum)
E + I – 38.96 mm^2 (minimum)

Effective Geometric Parameters

Parameter	Symbol	Value	
		2 × E	E + I
Effective magnetic path length	ℓ_e	48.7 mm	35.9 mm
Effective area of magnetic path	A_e	38.1 mm^2	38.7 mm^2
Effective volume	V_e	1860 mm^3	1390 mm^3
$\sum \frac{\ell}{A}$	C_1	1.28 mm^{-1}	0.927 mm^{-1}

Electrical Specification

Parameter	Symbol	Test frequency	Flux density mT	Value		
				F4	F6	F8
				2 × E	2 × E	2 × E
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1500	>1000	—
" " (100°C)		50 Hz	320	>1250	>1000	—
Effective total core loss (25°C)	P	16 kHz	200	<.2W	<.28W	—
" " " " (60–100°C)		16 kHz	200	<.2W	<.28W	—
" " " " (60–100°C)		25 kHz	200	<.35W	—	—
Minimum inductance factor (nH)	A_L min.	1000 Hz	<1	1600	1130	1130

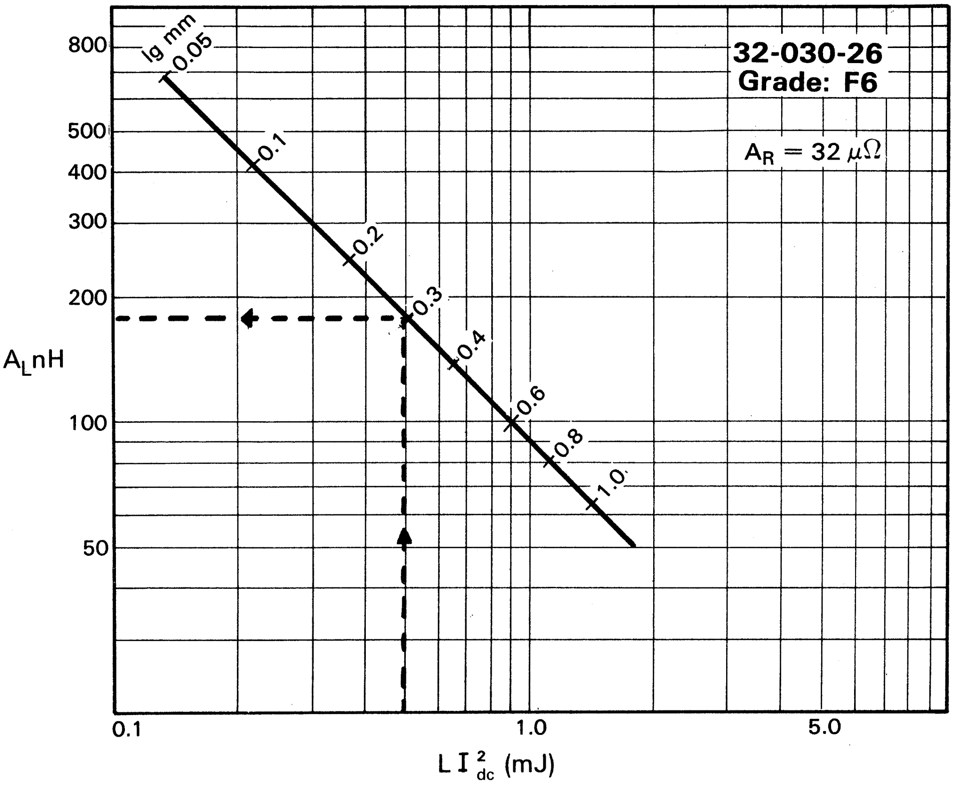
Material
Ferrites F4, F6 and F8.
Part Numbers (single cores).

	F4	F6	F8
E core	**32-030-45**	**32-030-26**	**32-030-28**
I core	—	**33-030-26**	**33-030-28**

Former 2 × E **59-030-66** (see page 106).

NEOSID

E Cores
25 × 19 × 6



Design of Inductors carrying d.c. (energy storage chokes).

Design Example

$L = 1.0$ mH
$I_{dc} = 0.7$ amps.

1. Calculate $L I^2_{dc}$

   $= 1 \times 0.7^2 = 0.49$ mJ

2. Read A_L corresponding to 0.49 mJ

3. Select the nearest A_L value = 180

4. Calculate number of turns

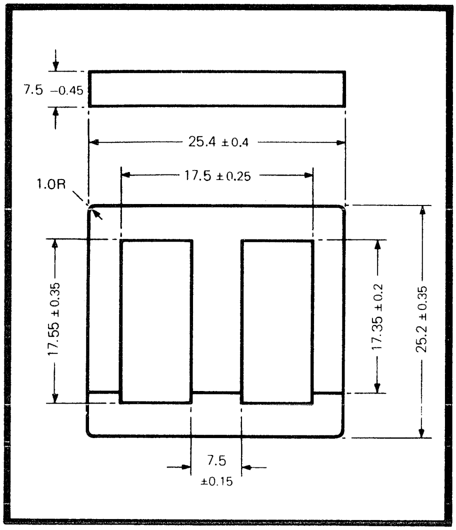
   $$N = 10^3 \sqrt{\frac{L\ \text{mH}}{A_L}}$$

   $$= 10^3 \sqrt{\frac{1}{180}} \quad = 75 \text{ turns}$$

5. Calculate $Rdc = A_R \times N^2$
   $= (32 \times 75^2)\ 10^{-6}$
   $= 0.18$ ohms

NEOSID

E and I Cores
25 × 25 × 7.7



For colour television transductor applications

All information on this sheet is given for a pair of E and I cores (zero gap).

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	57 mm
Effective area of magnetic path	A_e	56 mm^2
Effective volume	V_e	3200 mm^3
$\sum \frac{\ell}{A}$	C_1	1.02 mm^{-1}

Electrical Specification

Parameter	Symbol	Value
Inductance factor (nH for 1 turn)	A_L	2400±20%

The inductance factor is measured at an effective peak flux density <0.1 mT at 25°C.

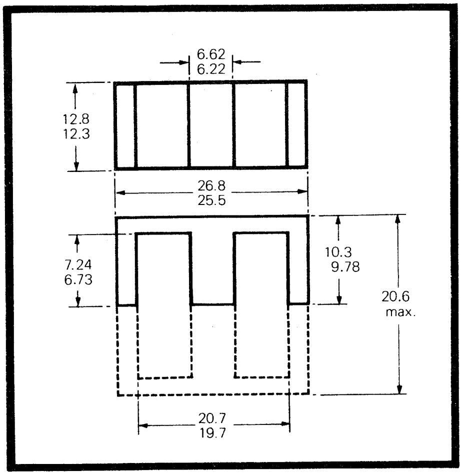
Material

Ferrite F6.

Part Numbers

E core – **32-090-26**
I core – **33-090-26**

E Cores
25 × 20 × 12.5



All information on this sheet is for a pair of cores (zero gap).

These cores can also be supplied gapped to specified A_L values.

Dimensional Data

Window Area
2 × E – 88.0 mm^2 (minimum)

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	51 mm
Effective area of magnetic path	A_e	77 mm^2
Effective volume	V_e	3930 mm^3
$\sum \frac{\ell}{A}$	C_1	0.663 mm^{-1}

Electrical Specification

Parameter	Symbol	Value
Minimum effective permeability	μ_e	1150
Maximum turns (for 1 mH)	α	21.4
Inductance factor (nH for 1 turn)	A_L min	2180
Effective total core loss 25°C	P	0.59W
" " " " 100°C		0.59W

μ_e, α and A_L are measured at an effective peak flux density <0.1 mT at 25°C. Effective total core loss is measured at 16 kHz and a flux density of 200 mT.

Material

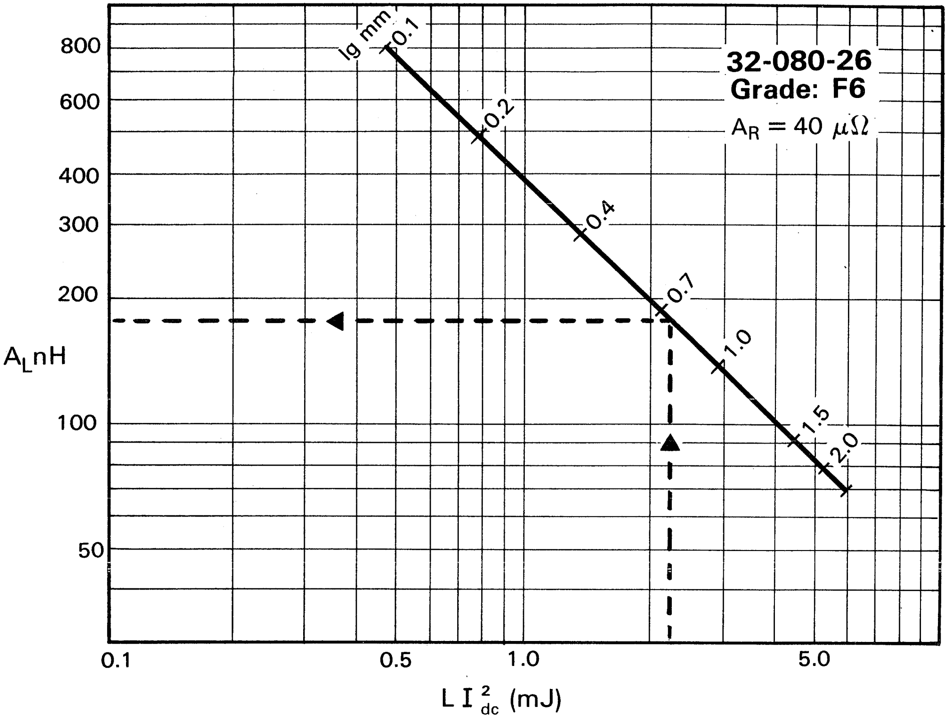
Ferrite F6.

Part Numbers

E core **32-080-26** (single core)
Former **59-080-66** (see page 107)

NEOSID

E Cores
25 × 20 × 12.5



Design of Inductors carrying d.c. (energy storage chokes).

Design Example

$L = 1.0$ mH
$I_{dc} = 1.5$ amps.

1. Calculate LI^2_{dc}

   $= 1 \times 1.5^2 = 2.25$ mJ

2. Read A_L corresponding to 2.25 mJ
3. Select the nearest A_L value = 170
4. Calculate number of turns

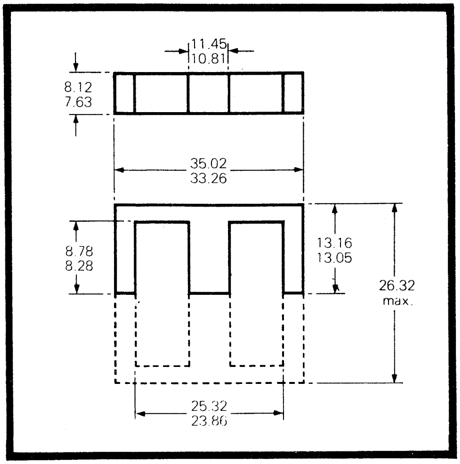
   $$N = 10^3 \sqrt{\frac{L\ \text{mH}}{A_L}}$$

   $$= 10^3 \sqrt{\frac{1}{170}} \quad = 77 \text{ turns}$$

5. Calculate Rdc $= A_R \times N^2$
   $= (33 \times 77^2)10^{-6}$
   $= 0.2$ ohms

NEOSID

E Cores
34 × 26 × 8



All information on this sheet is for a pair of cores (zero gap).

These cores can also be supplied gapped to specified A_L values.

Dimensional Data
To BS 4257 Ref. 8

Window Area
102.7 mm^2 (minimum)

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	62.5 mm
Effective area of magnetic path	A_e	77.4 mm^2
Effective volume	V_e	4840 mm^3
$\sum \frac{\ell}{A}$	C_1	0.808 mm^{-1}

Electrical Specification

Parameter	Symbol	Value
Minimum effective permeability	μ_e	1150
Maximum turns for 1 mH	α	24
Inductance factor (nH for 1 turn)	A_L min	1790
Effective total core loss 25° C F6 " " " " 100°C only	P	0.73W 0.73W

μ_e, α and A_L are measured at an effective peak flux density <0.1 mT at 25°C.
Effective total core loss is measured at 16 kHz and a flux density of 200 mT.

Material

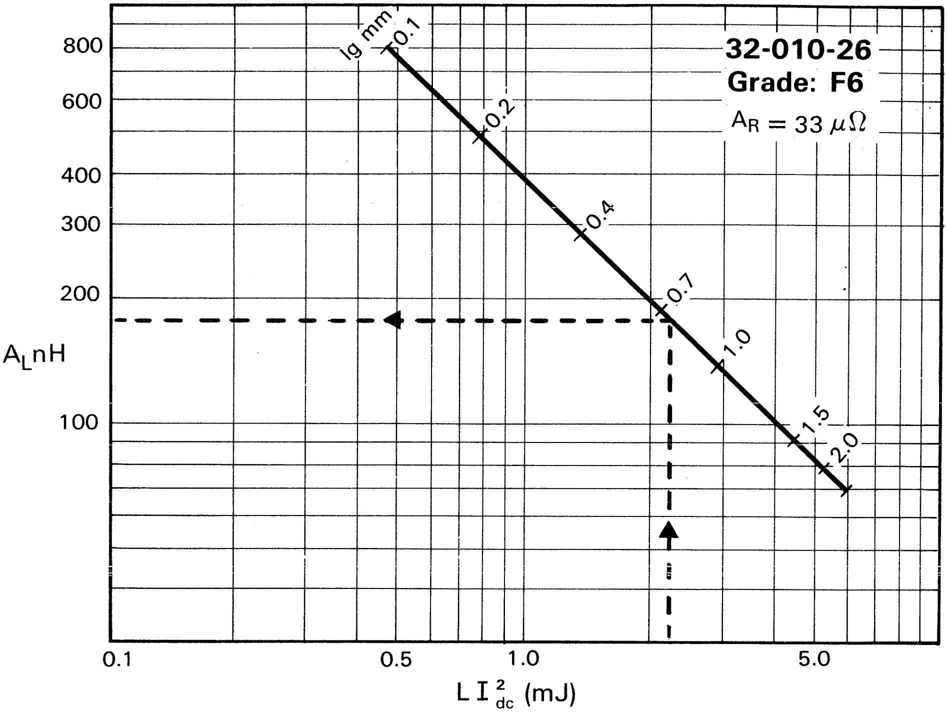
Ferrites F6 and F8

Part Numbers (single cores)

Grade F6	**32-010-26**	Former	**59-010-66** (single section)
Grade F8	**32-010-28**		**59-011-66** (double section)

(see page 106)

E Cores
34 × 26 × 8



Design of Inductors carrying d.c. (energy storage chokes).

Design Example

$L = 1.0$ mH
$I_{dc} = 1.5$ amps.

1. Calculate LI^2_{dc}

   $= 1 \times 1.5^2 = 2.25$ mJ

2. Read A_L corresponding to 2.25 mJ
3. Select the nearest A_L value = 170
4. Calculate number of turns

$$N = 10^3 \sqrt{\frac{L\ \text{mH}}{A_L}}$$

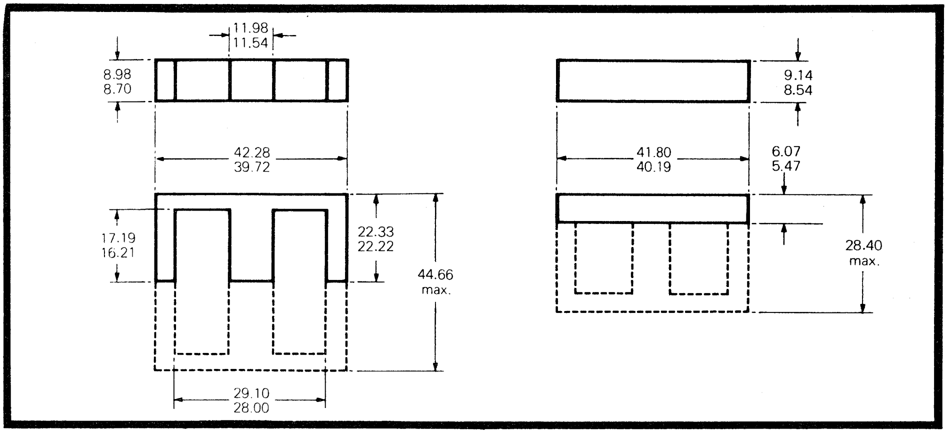
$$= 10^3 \sqrt{\frac{1}{170}} = 77 \text{ turns}$$

5. Calculate $Rdc = A_R \times N^2$

$= (40 \times 77^2)\ 10^{-6}$

$= 0.22$ ohms

E and I Cores
41 × 44 × 9
41 × 28 × 9



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

To BS 4257 Ref. 9 (E Core)
Ref. 17 (I Core)

Window Area

2×E – 259.6 mm² (minimum)
E+I – 129.8 mm² (minimum)

Effective Geometric Parameters

Parameter	Symbol	Value	
		2×E	E+I
Effective magnetic path length	ℓ_e	102 mm	68.5 mm
Effective area of magnetic path	A_e	105 mm²	104 mm²
Effective volume	V_e	10600 mm³	7140 mm³
$\sum \frac{\ell}{A}$	C_1	0.973 mm⁻¹	0.658 mm⁻¹

Electrical Specification

Parameter	Symbol	Value	
		2×E	E+I
Minimum effective permeability	μ_e	1150	1150
Maximum turns for 1 mH	α	25.9	21.3
Inductance factor (nH for 1 turn)	A_L min	1490	2200
Effective total core loss 25°C F6 " " " " 100°C only	P	1.6W 1.6W	1.1W 1.1W

μ_e, α and A_L are measured at an effective peak flux density <0.1 mT at 25°C.
Effective total core loss is measured at 16 kHz and a flux density of 200 mT.

E and I Cores
41 × 44 × 9
41 × 28 × 9

Gapped Cores

E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required A_L value can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

Material

Ferrite F6 and F8

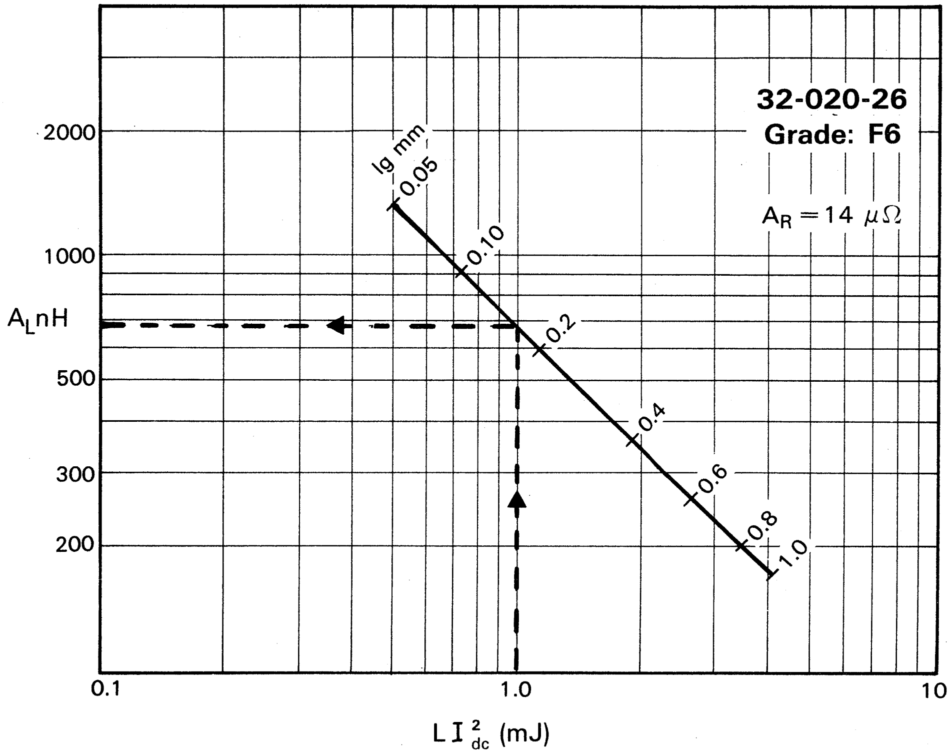
Part numbers (single cores)

	F6	F8
E core —	**32-020-26**	**32-020-28**
I core —	**33-020-26**	**33-020-28**

Formers

2×E — **59-020-66** (2 off)
E× I — **59-020-66** (1 off) (see page 106)

E Cores
41 × 44 × 9



Design of Inductors carrying d.c. (energy storage chokes).

Design Example

$L = 1.0$ mH
$I_{dc} = 1.0$ amps.

1. Calculate LI^2_{dc}

   $= 1 \times 1 = 1$ mJ

2. Read A_L corresponding to 1 mJ

3. Select the nearest A_L value = 680

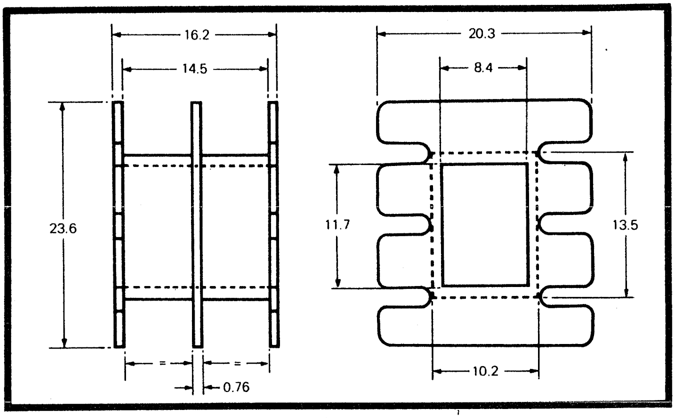
4. Calculate the number of turns

$$N = 10^3 \sqrt{\frac{L\ \text{mH}}{A_L}}$$

$$= 10^3 \sqrt{\frac{1}{680}} = 38 \text{ turns}$$

5. Calculate $Rdc = A_R \times N^2$
   $= (14 \times 38^2)10^{-6}$
   $= 0.02$ ohms (approx)

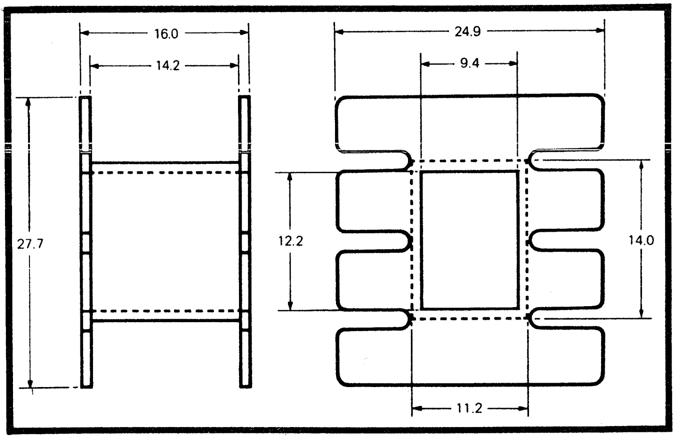
E Cores
Formers



Part Numbers
59-010-66
(centre flange ommitted)
59-011-66 (as shown)

For use with E cores
part numbers
32-010-28
32-010-26

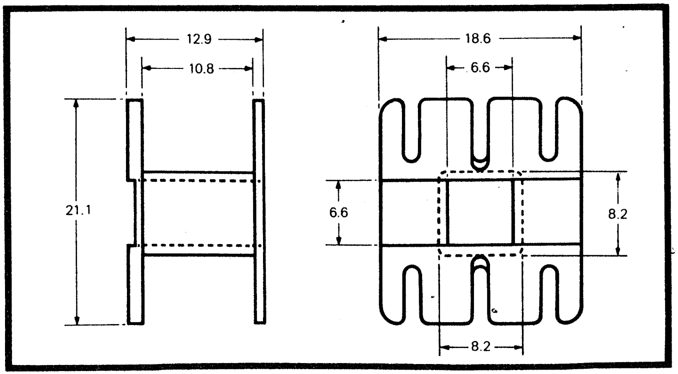
Material
Nylon, type 66



Part Number
59-020-66

For use with E cores
part numbers
32-020-28
32-020-26

Material
Nylon, type 66

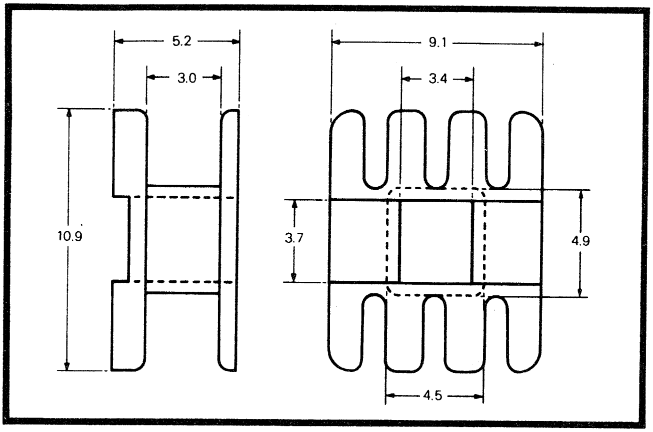


Part Number
59-030-66

For use with E cores
part numbers
32-030-28
32-030-26
32-030-25

Material
Nylon, type 66

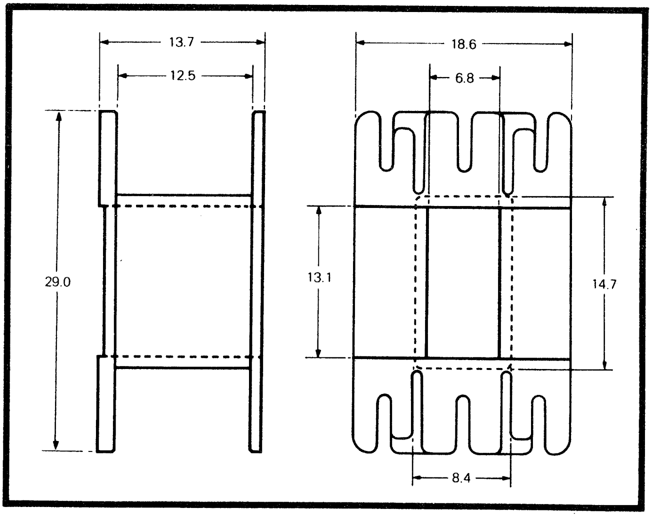
E Cores
Formers



Part Number
59-040-66

For use with E core and I core part numbers
32-040-28
33-040-28

Material
Nylon, type 66

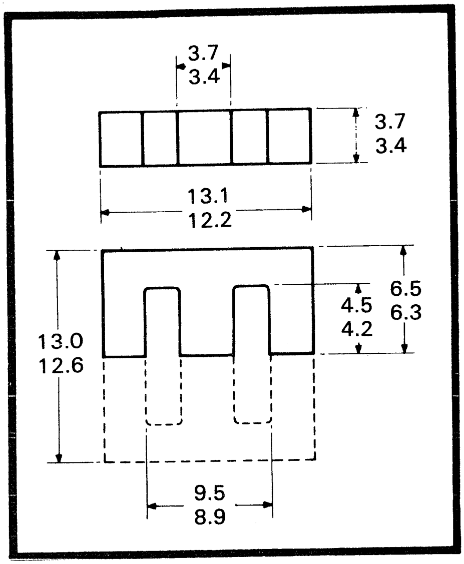


Part Number
59-080-66

For use with E core and I core part numbers
32-080-26
33-080-26
32-080-28
33-080-28

Material
Glass filled nylon type 66 SE1

E Cores
EF 12.6



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

The dimensions of these E cores are in accordance with German Standard DIN 41985.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path	l_e	29.6 mm
Effective area of magnetic path	A_e	13.0 mm^2
Effective volume	V_e	384 mm^3
$\sum\frac{l}{A}$	C_1	2.28 mm^{-1}

Material

Ferrite F5 and F9

Part Numbers

Grade F5 **32-200-25** (single core)
Grade F9 **32-200-36** (single core)

E Cores
EF 12.6

Electrical Specification

Parameter	Symbol	Value	
		32–200–25	32–200–36
Minimum effective permeability	μ_e	1160	1810
Maximum turns for 1 mH	α	39	33
Inductance factor (nH for 1 turn)	A_L min	640	1000

The above parameters are measured at an effective peak flux density <0.1 mT at 25°C.

It should be pointed out that the dimensions of these E cores are such that the cross-sectional area of the centre leg is substantially smaller than that of other parts of the magnetic circuit. The flux densities in different parts of the magnetic circuit are, therefore, not the same. Under these conditions, the usual methods for determining the amplitude permeability and core losses must be considered with circumspection.

The number of turns required to obtain an inductance L is given by the formula:—

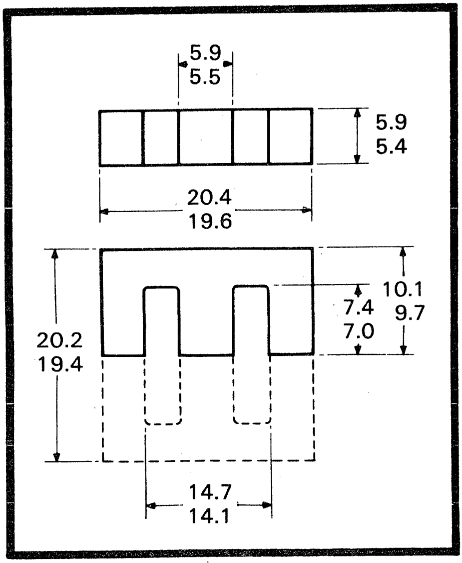
$$n = 1000\sqrt{\frac{L}{A_L}}$$

where L is in mH,
A_L is in nH.

Gapped Cores

These E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required value of A_L can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven-digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

E Cores
EF 20



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data
The dimensions of these E cores are in accordance with German Standard DIN 41295.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path	ℓ_e	44.9 mm
Effective area of magnetic path	A_e	33.5 mm^2
Effective volume	V_e	1500 mm^3
$\sum \frac{\ell}{A}$	C_1	1.34 mm^{-1}

Material
Ferrite F5 and F9

Part Numbers
Grade F5 **32-180-25** (single core)
Grade F9 **32-180-36** (single core)

E Cores
EF 20

Electrical Specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				32-180-25	32-180-36
Effective total core loss (25°C) (100°C)	P	16kHz 16kHz	200 200	165 mW 165 mW	– –
Minimum inductance factor (nH)	A_L min.	1000Hz	<1	1050	2000
Minimum effective permeability	μ_e	–	–	1110	2140

The number of turns required to obtain an inductance L is given by the formula:–

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

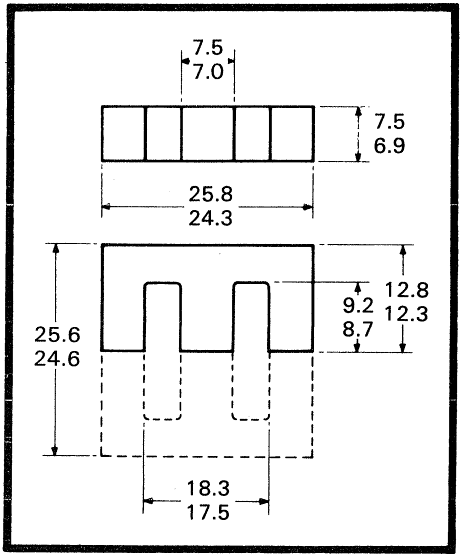
where L is in mH,
A_L is in nH.

Gapped Cores

These E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required value of A_L can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven-digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

NEOSID

E Cores
EF 25



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data
The dimensions of these E cores are in accordance with German Standard DIN 41985.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path	ℓ_e	57.5 mm
Effective area of magnetic path	A_e	52.5 mm^2
Effective volume	V_e	3020 mm^3
$\sum \frac{\ell}{A}$	C_1	1.09 mm^{-1}

Material
Ferrite F5 and F9

Part Numbers
Grade F5 **32-190-25** (single core)
Grade F9 **32-190-36** (single core)

E Cores
EF 25

Electrical specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				32–190–25	32–190–36
Effective total core loss (25°C) (100°C)	P	16kHz 16kHz	200 200	330mW 330mW	– –
Minimum inductance factor (nH)	A_L min.	1000Hz	<1	1400	2480
Minimum effective permeability	μ_e	–	–	1220	2160

It should be pointed out that the dimensions of these E cores are such that the cross-sectional area of the centre leg is substantially smaller than that of other parts of the magnetic circuit. The flux densities in different parts of the magnetic circuit are, therefore, not the same. Under these conditions, the usual methods for determining the amplitude permeability and core losses must be considered with circumspection.

The number of turns required to obtain an inductance L is given by the formula:–

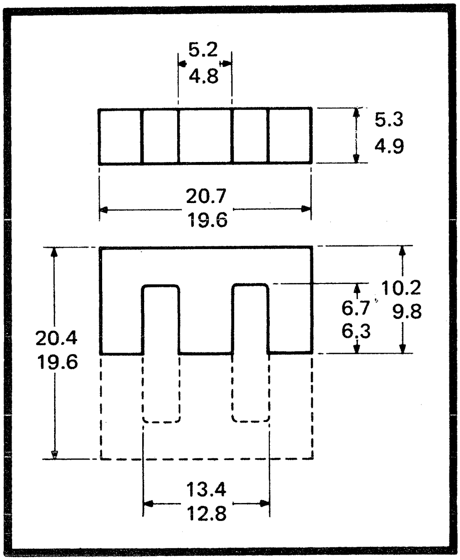
$$n = 1000\sqrt{\frac{L}{A_L}}$$

where L is in mH,
A_L is in nH.

Gapped Cores

These E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required value of A_L can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven-digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

E Cores
E 20



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data
The dimensions of these E cores are in accordance with German Standard DIN 41295.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path	ℓ_e	43 mm
Effective area of magnetic path	A_e	31 mm²
Effective volume	V_e	1330 mm³
$\sum \frac{\ell}{A}$	C_1	1.37 mm⁻¹

Material
Ferrite F6 and F9

Part Numbers
Grade F6 **32-140-26** (single core)
Grade F9 **32-140-36** (single core)

Electrical specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				32–140–26	32–140–36
Effective total core loss (25°C) (100°C)	P	16kHz 16kHz	200 200	200mW 200mW	– –
Minimum inductance factor (nH)	A_L min.	1000Hz	<1	1050	2000
Minimum effective permeability	μ_e	–	–	1145	2180

It should be pointed out that the dimensions of these E cores are such that the cross-sectional area of the centre leg is substantially smaller than that of other parts of the magnetic circuit. The flux densities in different parts of the magnetic circuit are, therefore, not the same. Under these conditions, the usual methods for determining the amplitude permeability and core losses must be considered with circumspection.

The number of turns required to obtain an inductance L is given by the formula:—

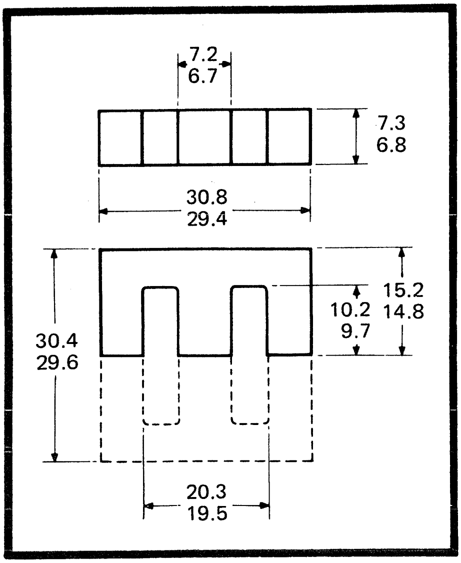
$$n = 1000 \sqrt{\frac{L}{A_L}}$$

where L is in mH,
A_L is in nH.

Gapped Cores

These E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required value of A_L can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven-digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

E Cores
E 30



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data
The dimensions of these E cores are in accordance with German Standard DIN 41295.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path	ℓ_e	67 mm
Effective area of magnetic path	A_e	60 mm^2
Effective volume	V_e	4000 mm^3
$\sum\frac{\ell}{A}$	C_1	1.12 mm^{-1}

Material
Ferrite F6 and F9

Part Numbers
Grade F6 **32-130-26** (single core)
Grade F9 **32-130-36** (single core)

E Cores
E 30

Electrical specification

Parameter	Symbol	Test Frequency	Flux Density mT	Value	
				32–130–26	32–130–36
Effective total core loss (25°C) (100°C)	P	16kHz 16kHz	200 200	600mW 600mW	– –
Minimum inductance factor (nH)	A_L min.	1000Hz	<1	1440	2640
Minimum effective permeability	μ_e	–	–	1280	2350

It should be pointed out that the dimensions of these E cores are such that the cross-sectional area of the centre leg is substantially smaller than that of other parts of the magnetic circuit. The flux densities in different parts of the magnetic circuit are, therefore, not the same. Under these conditions, the usual methods for determining the amplitude permeability and core losses must be considered with circumspection.

The number of turns required to obtain an inductance L is given by the formula:–

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

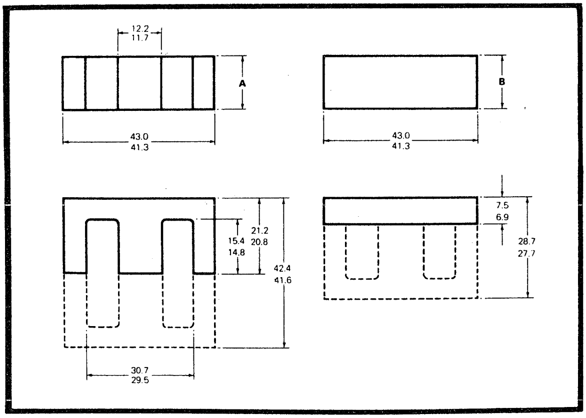
where L is in mH,
A_L is in nH.

Gapped Cores

These E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required value of A_L can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven-digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

NEOSID

E and I Cores
E 42 Cores
EI 42 Cores



All information on this sheet is given for a pair of cores (zero gap).

Dimensional Data

The dimensions of these E cores are in accordance with German standard DIN 41 295.

Effective Geometric Parameters

Parameter	Symbol	2 x E 15 mm	2 x E 20 mm	E + I 15 mm	E + I 20 mm
Effective magnetic path length	ℓ_e	97 mm	97 mm	68 mm	68 mm
Effective area of magnetic path	A_e	181 mm^2	240 mm^2	186 mm^2	243 mm^2
Effective volume	V_e	17600 mm^3	23300 mm^3	12600 mm^3	16500 mm^3
$\sum\frac{\ell}{A}$	C_1	0.535 mm^{-1}	0.405 mm^{-1}	0.365 mm^{-1}	0.280 mm^{-1}

Electrical Specification

Parameter	Symbol	Test frequency	Flux density mT	Value					
				Grade F4		Grade F5			
				2 x E 15mm	2 x E 20mm	2 x E 15mm	2 x E 20mm	E + I 15mm	E + I 20mm
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1500	>1500	>1250	>1250	>1250	>1250
" " (100°C)		50 Hz	320	>1250	>1250	>1250	>1250	>1250	>1250
Effective total core loss (25°C)	P	16 kHz	200	<1.95W	<2.6W	<2.2W	<2.8W	<1.5W	<2.0W
" " " " (60–100°C)		16 kHz	200	<1.95W	<2.6W	<1.95W	<2.6W	<1.4W	<1.8W
" " " " (60–100°C)		25 kHz	200	<3.35W	<4.5W	<3.5W	<4.5W	<2.4W	<3.1W
Minimum inductance factor (nH)	A_L min.	1000 Hz	<1	4100	5400	2800	3700	4000	5300

E and I Cores
E 42 Cores
EI 42 Cores

The number of turns required to obtain an inductance L is given by the formula

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

where L is in mH.
A_L is in nH.

Gapped Cores

E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required value of A_L can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

Material

Ferrite F4 Code – 45
F5 Code – 25

Part Numbers

E cores

Part number	Grade	Dimension A
32-110-25	F5	14.7 to 15.2mm
32-110-45	F4	14.7 to 15.2mm
32-120-25	F5	19.2 to 20.0mm
32-120-45	F4	19.2 to 20.0mm

I cores

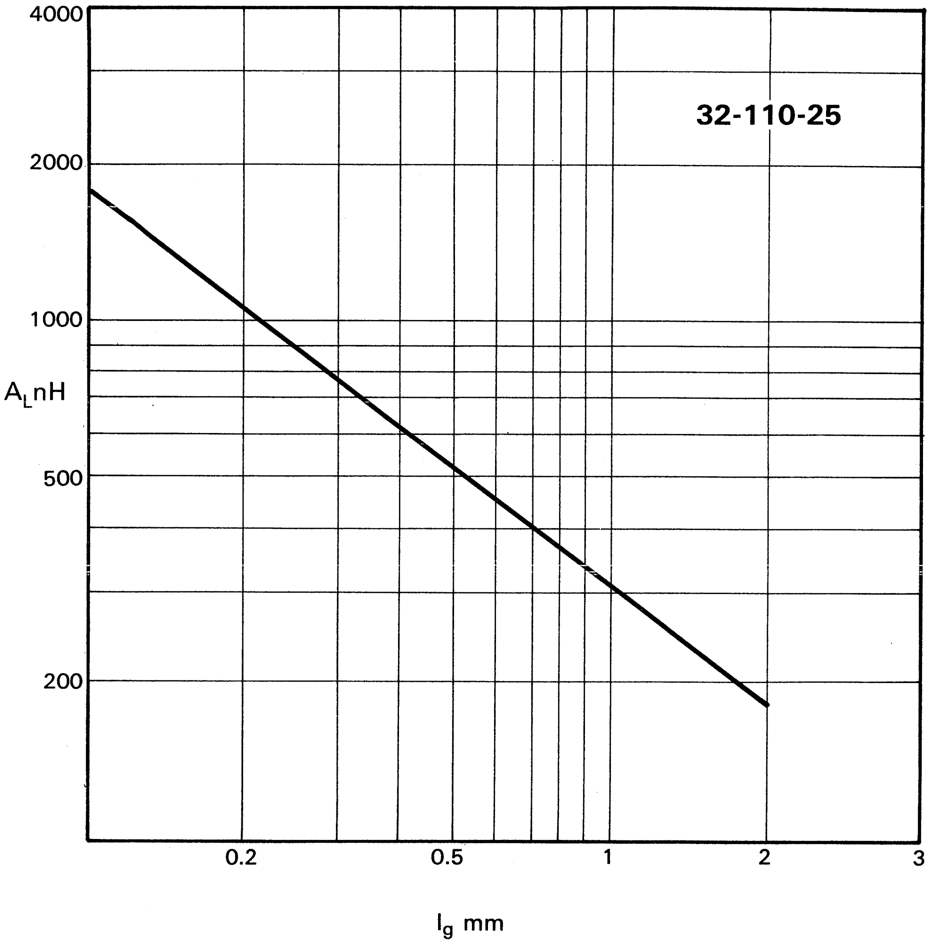
Part number	Grade	Dimension B
33-110-25	F5	14.7 to 15.2mm
33-120-25	F5	19.2 to 20mm

Formers see page 122.

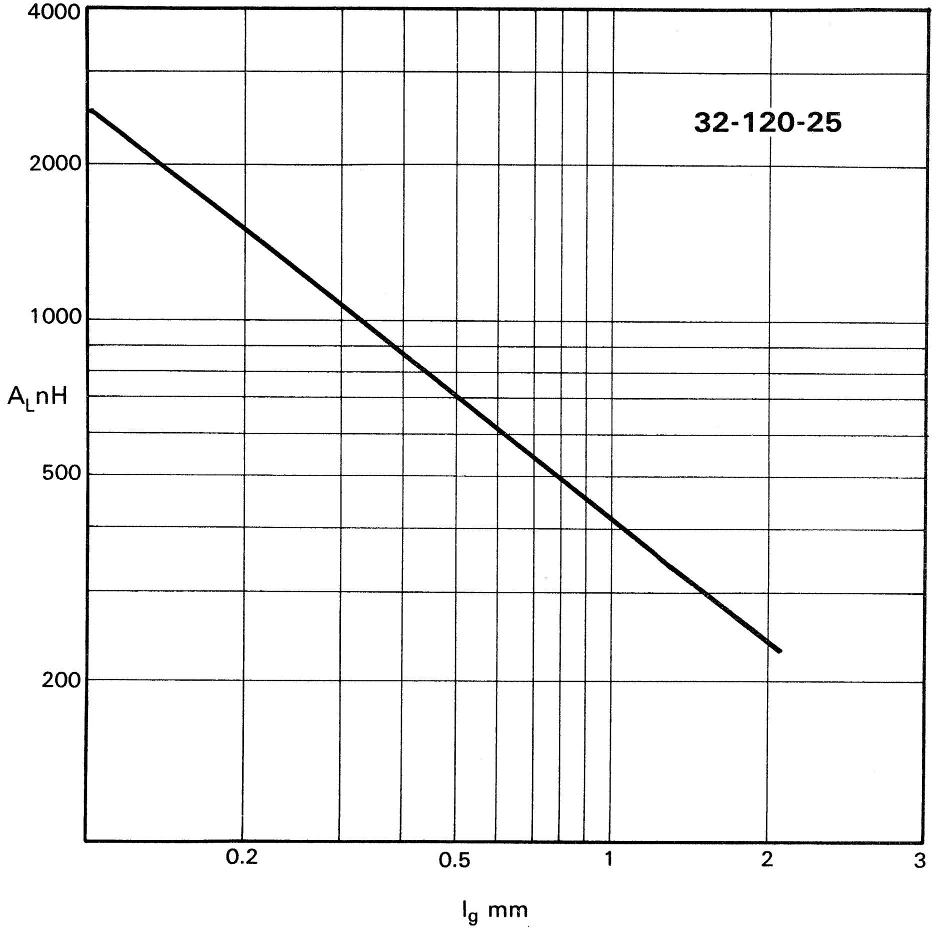
Note:

See page 130 for design of inductors carrying d.c.

E Cores
E 42/15



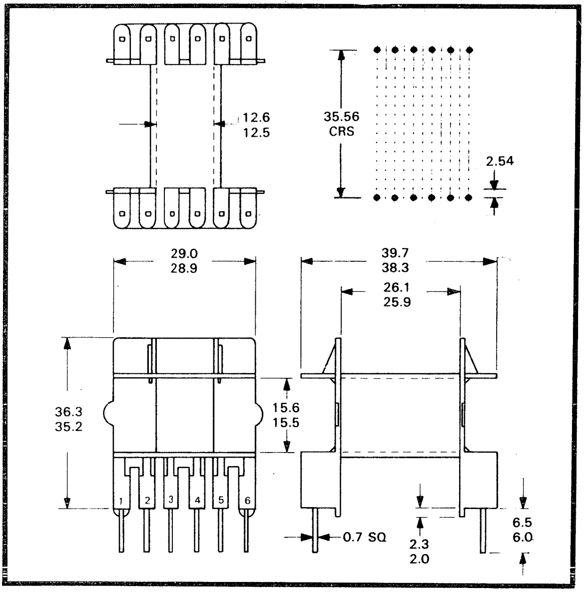
A_L value versus total air gap



A_L value versus total air gap

NEOSID

E Cores
E 42/15 Former



General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Winding Area mm²	Length of Mean Turn mm	A_R $\mu\Omega$
180	88	17

Approximate DC resistance of winding is $A_R \cdot n^2$ $\mu\Omega$ for a fully wound former with a copper factor of 0.5.

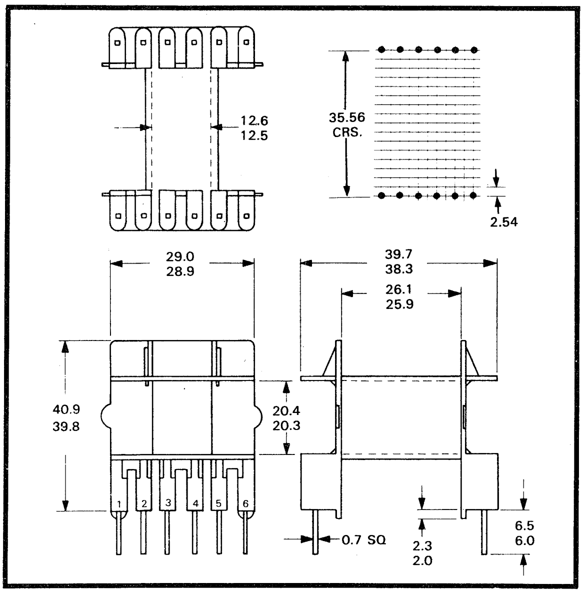
Material

Glass filled nylon ULV94 VO

Part Number
59-113-66

NEOSID

E Cores
E 42/20 Former



General Description
Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data
Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Winding Area mm²	Length of Mean Turn mm	A_R $\mu\Omega$
180	98	21

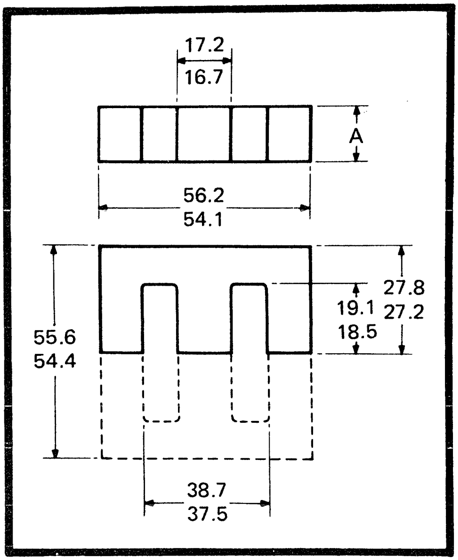
Approximate DC resistance of winding is $A_R.n^2$ $\mu\Omega$ for a fully wound former with a copper factor of 0.5.

Material
Glass filled nylon ULV94 V0

Part Number
59-120-66

NEOSID

E Cores
E55



All information on this sheet is given for a pair of cores (zero gap).

Dimensional data

The dimensions of these E cores are in accordance with German Standard DIN 41295.

Effective Geometric Parameters

Parameter	Symbol	2 x E 21mm	2 x E 25mm
Effective magnetic path length	ℓ_e	123 mm	123mm
Effective area of magnetic path	A_e	355 mm²	420 mm²
Effective volume	V_e	43700 mm³	52000 mm³
$\sum \frac{\ell}{A}$	C_1	0.35 mm⁻¹	0.293 mm⁻¹

Electrical Specification

Parameter	Symbol	Test frequency	Flux density mT	Value			
				Grade F4		Grade F5	
				2 × E 21 mm	2 × E 25 mm	2 × E 21 mm	2 × E 25 mm
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1500	>1500	>1250	>1250
" " (100°C)		50 Hz	320	>1250	>1250	>1250	>1250
Effective total core loss (25°C)	P	16 kHz	200	<4.8W	<5.7W	<5.2W	<6.2W
" " " " (60–100°C)		16 kHz	200	<4.8W	<5.7W	<4.8W	<5.7W
" " " " (60–100°C)		25 kHz	200	<8.3W	<9.8W	<8.3W	<9.8W
Minimum inductance factor (nH)	A_L min.	1000 Hz	<1	7100	8450	4640	5510

E Cores
E 55

The number of turns required to obtain an inductance L is given by the formula

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

where L is in mH.
A_L is in nH.

Gapped Cores

E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required value of A_L can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

Material

Ferrite F4 Code – 45
F5 Code – 25

Part Numbers

Part number	Grade	Dimension A
32-150-25	F5	20.4 to 21 mm
32-150-45	F4	20.4 to 21 mm
32-170-25	F5	24.4 to 25 mm
32-170-45	F4	24.4 to 25 mm

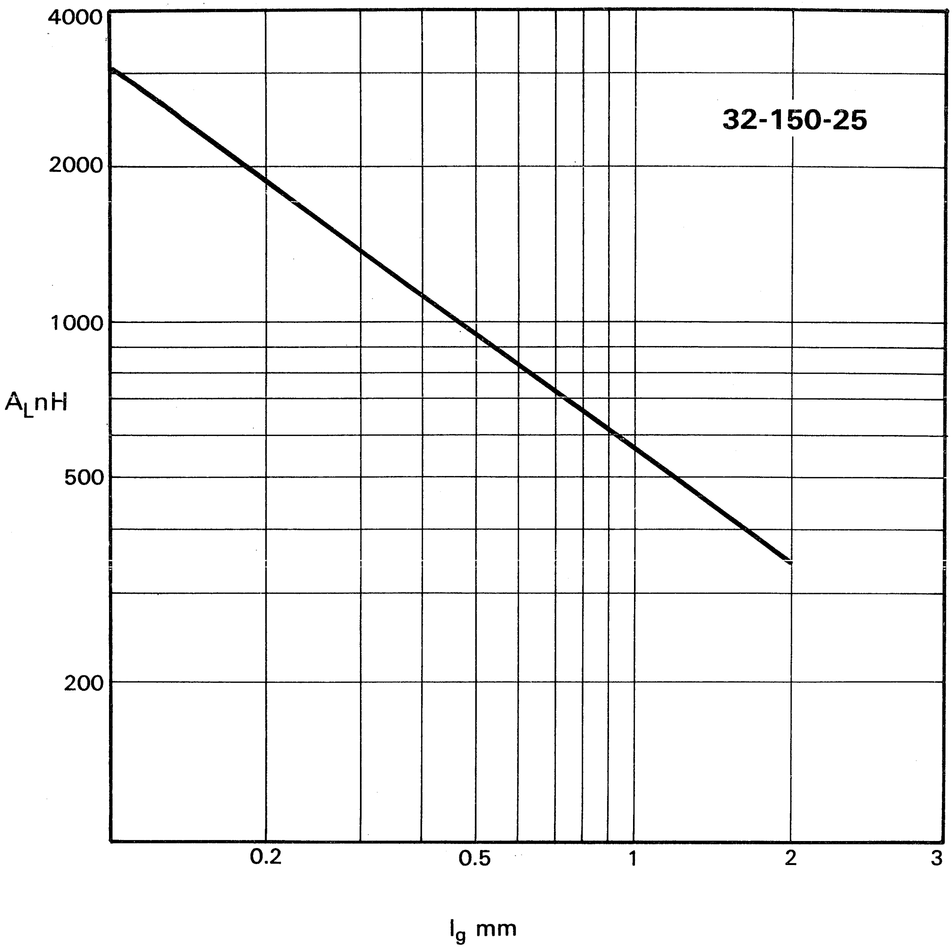
Above part numbers are for single cores.

Formers see pages 128 and 129.

Note:

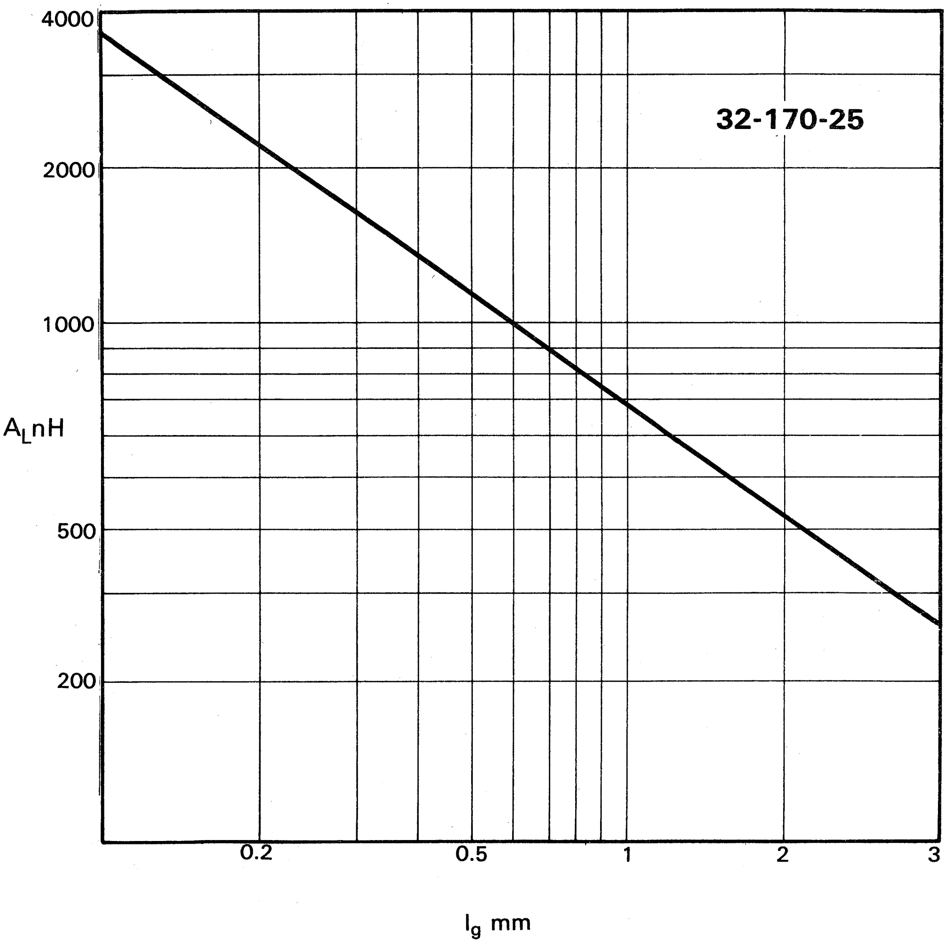
See page 130 for design of inductors carrying d.c.

E Cores
E 55/21



A_L value versus total air gap

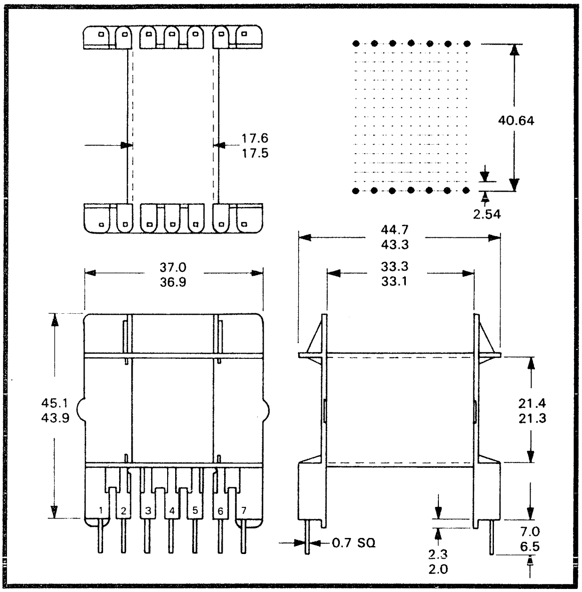
E Cores
E 55/25



A_L value versus total air gap

NEOSID

E Cores
E 55/21 Former



General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Winding Area mm^2	Length of Mean Turn mm	A_R $\mu\Omega$
280	110	14

Approximate DC resistance of winding is $A_R.n^2 \mu\Omega$ for a fully wound former with a copper factor of 0.5.

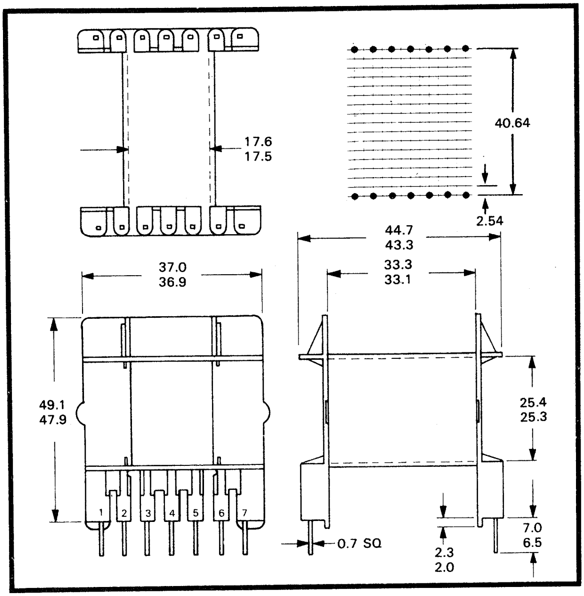
Material

Glass filled nylon UL94 VO

Part Number

59-150-66

E Cores
E 55/25 Former



General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Winding Area mm²	Length of Mean Turn mm	A_R μΩ
280	117	16

Approximate DC resistance of winding is $A_R.n^2$ μΩ for a fully wound former with a copper factor of 0.5.

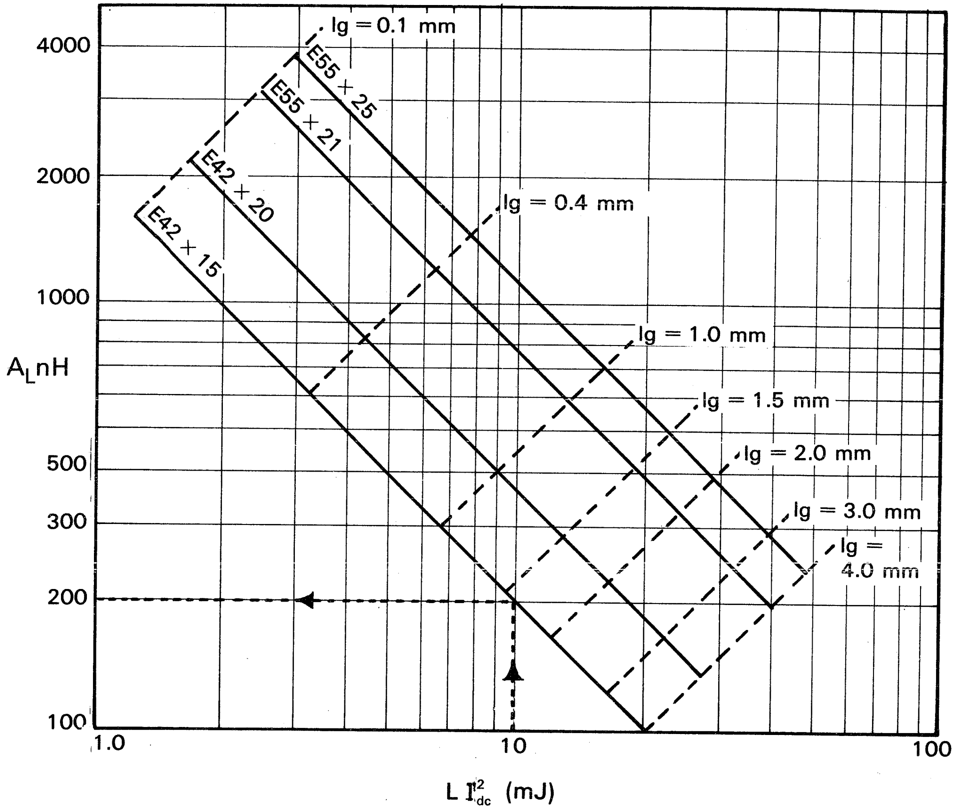
Material

Glass filled nylon UL94 VO.

Part Number

59-170-66

E Cores
E 42/E 55



Design of Inductors carrying d.c. (energy storage chokes).

Design Example

1. Calculate L I^2_{dc} in mJ (mH & Amp^2).
2. Select a core as a first trial.
3. Read A_L & lg as shown in graph.
4. Calculate the number of turns

$$N = 1000\sqrt{\frac{L\,mH}{A_L}}$$

5. Calculate $Rdc = A_R \times N^2$

Example:

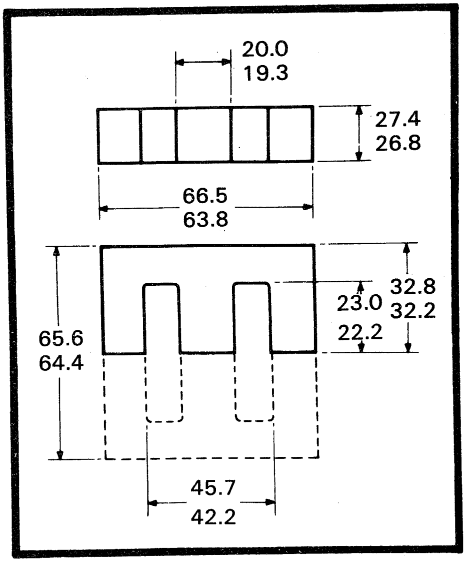
$L = 10$ mH
$I_{dc} = 1.0$ A
$L I^2_{dc} = 10$ mJ

Select E42 × 15
$A_L = 200$
Total Airgap lg = 1.6 mm

N = 224 turns
Rdc = 0.55 ohms

NEOSID

E Cores
E 65



All information on this sheet is given for a pair of cores (zero gap).

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path	ℓ_e	147 mm
Effective area of magnetic path	A_e	532 mm^2
Effective volume	V_e	78200 mm^3
$\sum \frac{\ell}{A}$	C_1	0.275 mm^{-1}

Electrical Specification

Parameter	Symbol	Test frequency	Flux density mT	Value	
				Grade F4	Grade F5
Amplitude permeability (25°C)	μ_a	50 Hz	400	>1500	>1250
〃 〃 (100°C)		50 Hz	320	>1250	>1250
Effective total core loss (25°C)	P	16 kHz	200	<8.6W	<9.4W
〃 〃 〃 〃 (60–100°C)		16 kHz	200	<8.6W	<8.6W
〃 〃 〃 〃 (60–100°C)		25 kHz	200	<14.8W	<14.8W
Minimum inductance factor (nH)	A_L min.	1000 Hz	<1	8200	6200

Gapped Cores

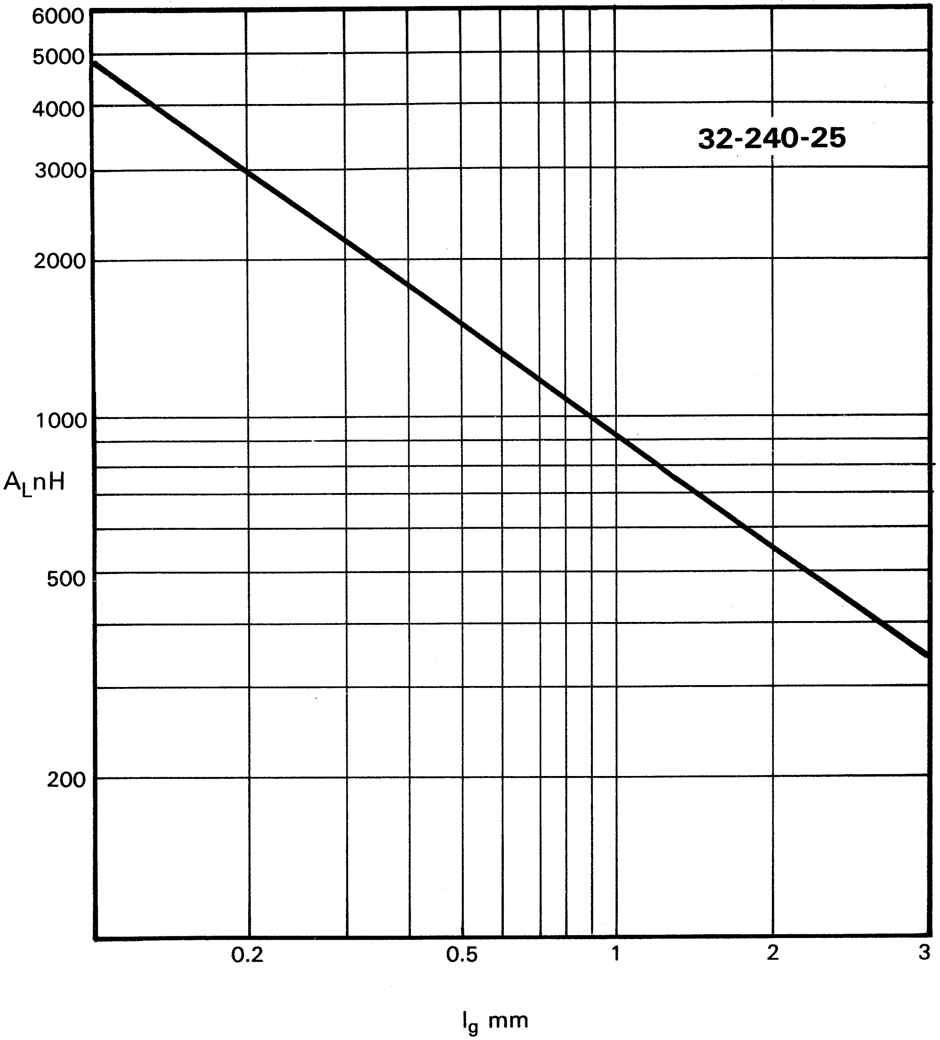
E cores can also be supplied with an air gap in the centre leg. Either the length of the air gap or the required A_L value can be specified. The tolerance of A_L value will be between ± 10% for large gaps (i.e. low A_L values) and ± 20% for small gaps (i.e. high A_L values). A seven digit part number will be advised with the order acknowledgement for cores ordered with an air gap.

Material

Ferrite F4 Code **-45**
F5 Code **-25**

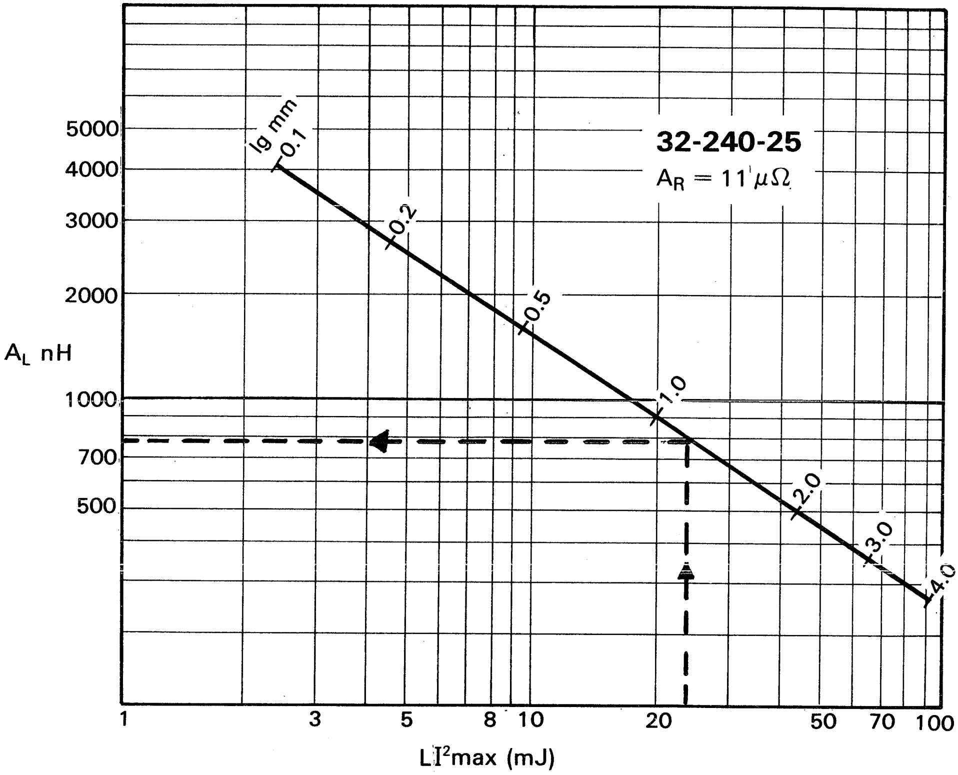
Part Number

Grade F4 **32-240-45** (single core)
Grade F5 **32-240-25** (single core)



A_L value versus total air gap

E Cores
E 65



Design of Inductors carrying d.c. (energy storage chokes).

Design Example

1. Calculate LI^2max in mJ (mH and Amp^2) and read corresponding A_L and lg as shown.
2. Calculate the number of turns

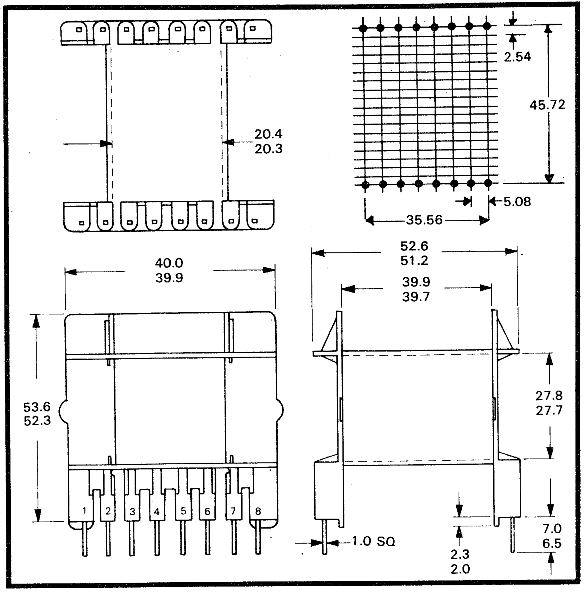
$$N = 1000\sqrt{\frac{LmH}{A_L}}$$

3. Calculate $Rdc = A_R \times N^2$

Example:
$L = 100\,\mu H$, $Imax = 15$ Amps
$LI^2max = 22.5$ mJ
$A_L = 780$ nH
$N = 11$ turns
$lg = 1.2$mm
$Rdc = 11 \times 10^{-6} \times 11^2 = 1.33$ m. ohms approx.

NEOSID

E Cores
E 65 Former



General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Winding Area mm²	Length of mean turn mm	A_R $\mu\Omega$
414	134	11

Approximate DC resistance of winding is $A_R.n^2 \mu\Omega$ for a fully wound former with a copper factor of 0.5.

Material

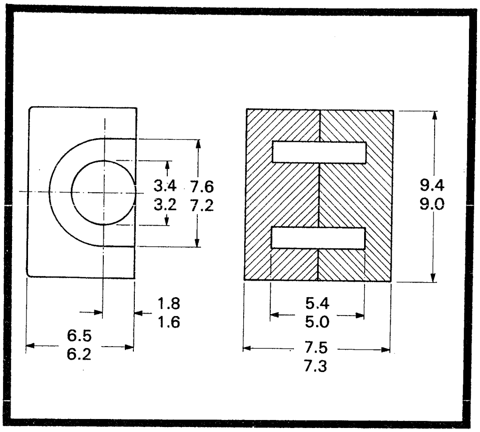
Glass filled nylon UL94 VO

Part Number

59-240-66

NEOSID

EP Cores
EP 7



All information on this sheet is given for a pair of cores (zero gap).

General Description

EP cores are manufactured from high permeability materials and are suitable for the design of high inductance coils and transformers at a high packing density.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	15.7 mm
Effective area of magnetic path	A_e	10.3 mm^2
Effective volume	V_e	162 mm^3
$\sum \frac{\ell}{A}$	C_1	1.52 mm^{-1}

Electrical Specification

Parameter	Symbol	Value	
		F9	F10
Minimum effective permeability	μ_e	1940	3450
Maximum turns for 1 mH	α	25	19
Inductance factor (nH for 1 turn)	A_L min	1600	2840

The above parameters are measured at an effective peak flux density <0.1 mT at 25°C.

Material

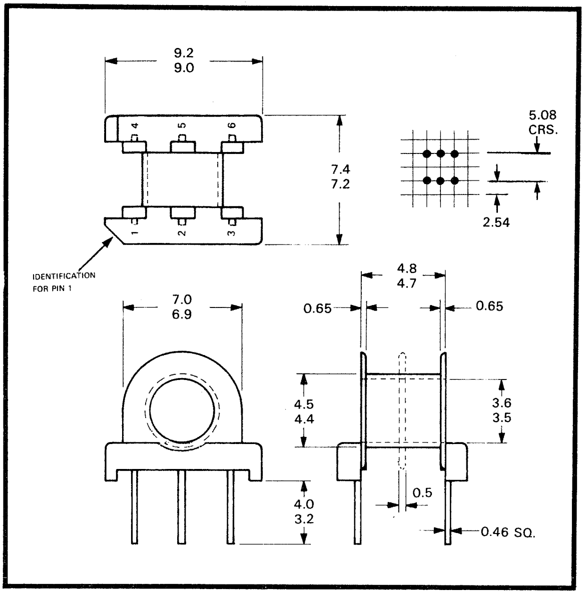
Ferrites F9 and F10.

Part Number

Grade F9 – **32-810-36** (single cores)
Grade F10 – **32-810-37** (single cores)

NEOSID

EP Cores
EP 7 Former



General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm^2	Length of Mean Turn mm	A_R $\mu\Omega$
1	3.7	17.9	166
2	1.6		192

Material

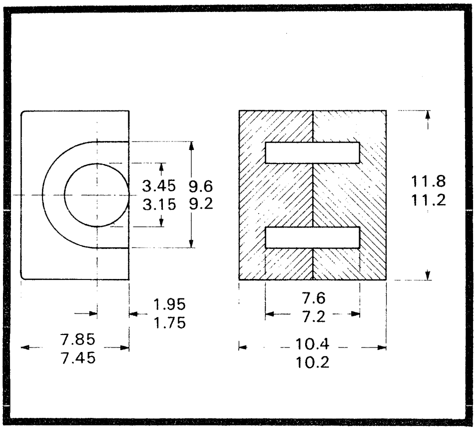
G.P. Phenolic glass filled.

Part Numbers

1 Section – **59-810-64**
2 Section – **59-811-64**

NEOSID

EP Cores
EP 10



All information on this sheet is given for a pair of cores (zero gap).

General Description

EP cores are manufactured from high permeability materials and are suitable for the design of high inductance coils and transformers at a high packing density.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	19.2 mm
Effective area of magnetic path	A_e	11.3 mm^2
Effective volume	V_e	217 mm^3
$\sum \frac{\ell}{A}$	C_1	1.7 mm^{-1}

Electrical Specification

Parameter	Symbol	Value	
		F9	F10
Minimum effective permeability	μ_e	2160	3460
Maximum turns for 1 mH	α	25	20
Inductance factor (nH for 1 turn)	A_L min	1590	2560

The above parameters are measured at an effective peak flux density <0.1 mT at 25°C.

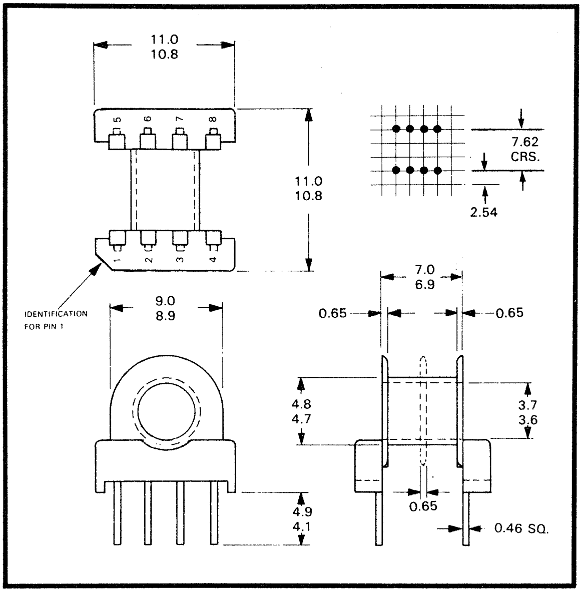
Material

Ferrite F9 and F10.

Part Number

Grade F9 – **32-820-36** (single cores)
Grade F10 – **32-820-37** (single cores)

EP Cores
EP 10 Former



General Description
Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data
Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

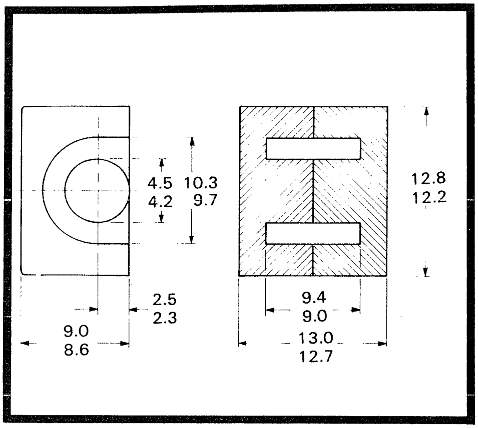
Winding Data

Number of Sections	Winding Area Per Section mm^2	Length of Mean Turn mm	A_R $\mu\Omega$
1	11.4	21.5	65
2	5.0		74

Material
G.P. Phenolic glass filled.

Part Numbers
1 Section – **59-820-64**
2 Section – **59-821-64**

EP Cores
EP 13



All information on this sheet is given for a pair of cores (zero gap).

General Description

EP cores are manufactured from high permeability materials and are suitable for the design of high inductance coils and transformers at a high packing density.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	24.2 mm
Effective area of magnetic path	A_e	19.5 mm^2
Effective volume	V_e	472 mm^3
$\sum \frac{\ell}{A}$	C_1	1.24 mm^{-1}

Electrical Specification

Parameter	Symbol	Value	
		F9	F10
Minimum effective permeability	μ_e	2200	3470
Maximum turns for 1 mH	α	21	17
Inductance factor (nH for 1 turn)	A_L min	2230	3520

The above parameters are measured at an effective peak flux density <0.1 mT at 25°C.

Material

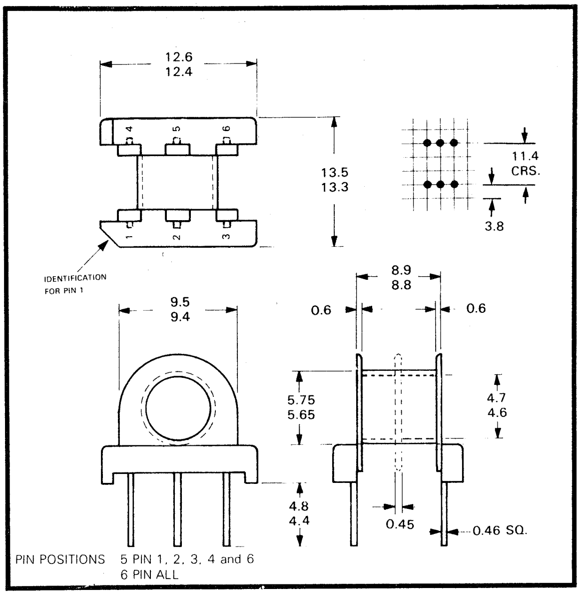
Ferrite F9 and F10.

Part Number

Grade F9 – **32-800-36**
Grade F10 – **32-800-37**

NEOSID

EP Cores
EP 13, 5 & 6 Pin Former



PIN POSITIONS 5 PIN 1, 2, 3, 4 and 6
6 PIN ALL

General Description
Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data
Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm²	Length of Mean Turn mm	A_R μΩ
1	13.8	23.8	59.4
2	6.5		63.2

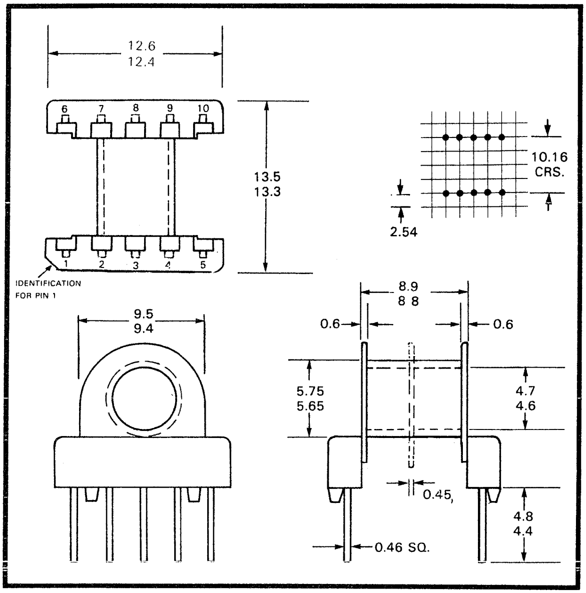
Material
G.P. Phenolic glass filled.

Part Numbers
1 Section 5 pin-**59-800-64**
1 Section 6 pin-**59-801-64**
2 Section 5 pin-**59-802-64**
2 Section 6 pin-**59-803-64**

NEOSID

EP Cores

EP 13 10 Pin Former



General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm²	Length of Mean Turn mm	A_R μΩ
1	13.8	23.8	59.4
2	6.5		63.2

Material

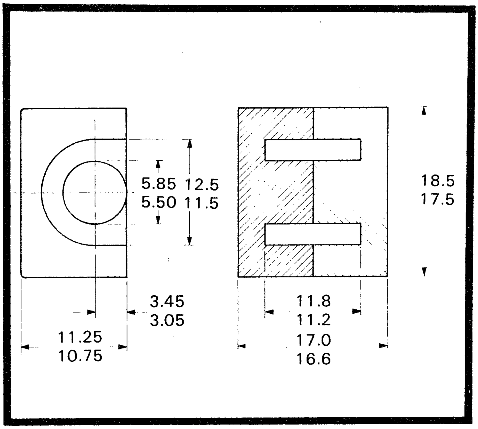
G.P. Phenolic glass filled.

Part Numbers

1 Section 10 pin-**59-805-64**
2 Section 10 pin-**59-806-64**

NEOSID

EP Cores
EP 17



All information on this sheet is given for a pair of cores (zero gap).

General Description

EP cores are manufactured from high permeability materials and are suitable for the design of high inductance coils and transformers at a high packing density.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	28.5 mm
Effective area of magnetic path	A_e	33.9 mm^2
Effective volume	V_e	966 mm^3
$\sum \frac{\ell}{A}$	C_1	0.84 mm^{-1}

Electrical Specification

Parameter	Symbol	Value				
		F4	F5	F9	F10	P11
Minimum effective permeability	μ_e	1400	1200	2300	3680	1250
Maximum turns for 1 mH	α	22	24	17	14	23
Inductance factor (nH for 1 turn)	A_L min	2100	1795	3450	5500	1900

The above parameters are measured at an effective peak flux density <0.1 mT at 25°C.

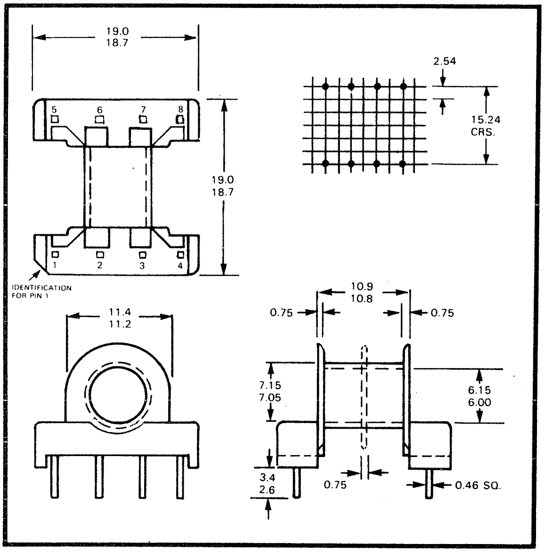
Material

Ferrite F4, F5, F9, F10 and P11.

Part Number

Grade F4 – **32-830-45**
Grade F5 – **32-830-25**
Grade F9 – **32-830-36**
Grade F10 – **32-830-37**
Grade P11 – **32-830-41**

EP Cores
EP 17 Former



General Description

Pin and Clip solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm²	Length of Mean Turn mm	A_R μΩ
1 2	18.8 8.85	28.8	52.7 55.9

Material

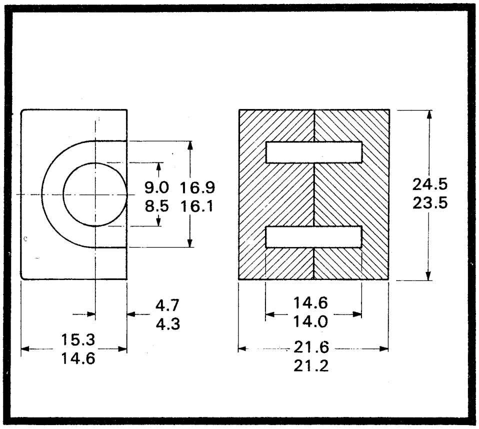
G.P. Phenolic glass filled.

Part Numbers

1 Section **59-830-64**
2 Section **59-831-64**

NEOSID

EP Cores
EP 20



All information on this sheet is given for a pair of cores (zero gap).

General Description

EP cores are manufactured from high permeability materials and are suitable for the design of high inductance coils and transformers at a high packing density.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	40 mm
Effective area of magnetic path	A_e	78 mm^2
Effective volume	V_e	3120 mm^3
$\sum \frac{\ell}{A}$	C_1	0.51 mm^{-1}

Electrical Specification

Parameter	Symbol	Value				
		F4	F5	F9	F10	P11
Minimum effective permeability	μ_e	1500	1200	2180	3640	1250
Maximum turns for 1 mH	α	16	18	14	11	18
Inductance factor (nH for 1 turn)	A_L min	3800	2955	5360	8950	3080

The above parameters are measured at an effective peak flux density <0.1 mT at 25°C.

Material

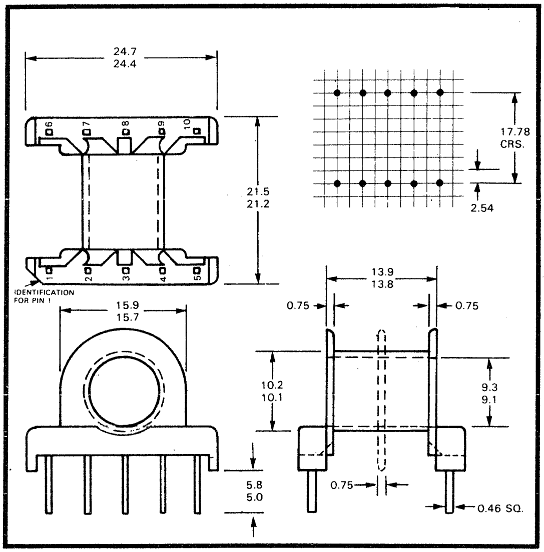
Ferrite F4, F5, F9, F10 and P11.

Part Number

Grade F4 – **32-840-45**
Grade F5 – **32-840-25**
Grade F9 – **32-840-36**
Grade F10 – **32-840-37**
Grade P11 – **32-840-41**

NEOSID

EP Cores
EP 20 Former



General Description

Pin and Clip solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm^2	Length of Mean Turn mm	A_R $\mu\Omega$
1	33.8	38.9	39.6
2	15.9		42.1

Material

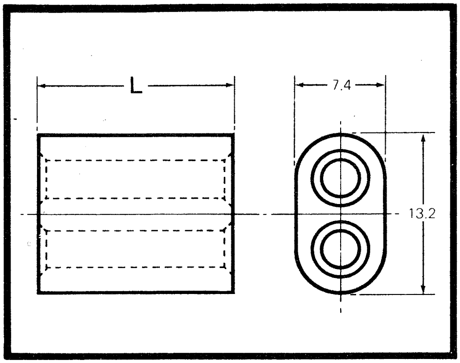
G.P. Phenolic glass filled.

Part Numbers

1 Section **59-840-64**
2 Section **59-841-64**

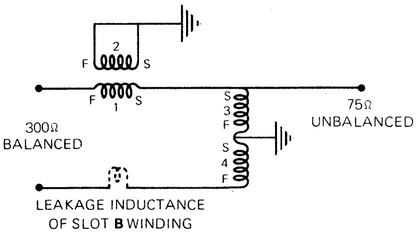
NEOSID

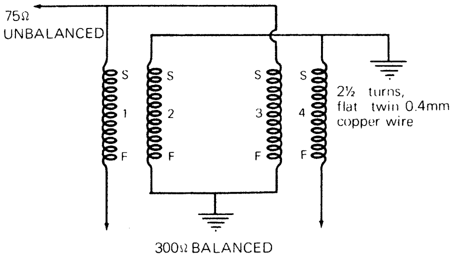
Transformer (Balun) Cores



Electrical Specification

The insertion loss of transformers, wound on cores manufactured from ferrite grade F14 and connected according to the information presented in the diagrams, is approximately 0.5 dB between 40 and 220 MHz; above 220 MHz the insertion loss gradually increases, reaching 1 dB at 800 MHz.





General Description

Originally designed for balun transformers, matching balanced to unbalanced circuits in the television frequency spectrum, these cores are also used for wideband and pulse transformers and for interference suppression.

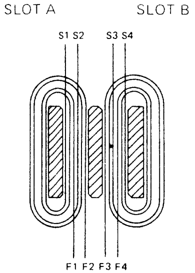
The drawing below illustrates the winding arrangements and the circuit diagrams show the connections of a balun transformer designed to match a balanced 300 ohm impedance to an unbalanced 75 ohm impedance. It will be noticed that the only purpose of windings 1 and 2 is to introduce an inductance to balance the leakage inductance of windings 3 and 4 which form a centre-tapped auto-transformer.

Material

Ferrite grade F14

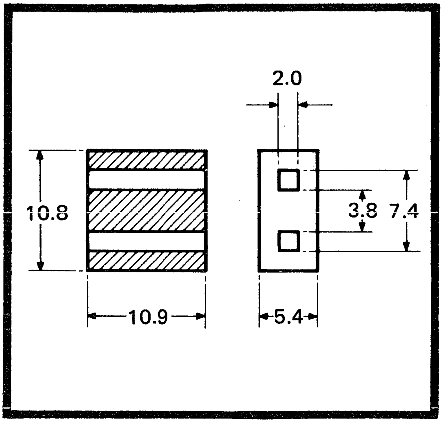
Part Numbers

Part Number	L
42-001-31	13.5 mm
42-002-31	6.6 mm



NEOSID

Double Aperture Cores



Dimensional Data

Nominal dimensions are shown in the diagram.

General Description

These cores are used in high frequency wide band and pulse transformers.

All data given below apply when the coil is wound through the two apertures.

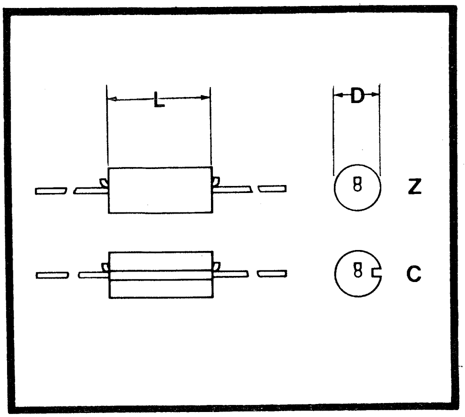
Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	13 mm
Effective area of magnetic path	A_e	38 mm^2
Effective volume	V_e	495 mm^3
$\sum \frac{\ell}{A}$	C_1	0.34 mm^{-1}

Electrical Specification

Part Number	Material Grade	A_L Value (nH) min.
42—003—30	F13	1900
42—003—36	F9	12500
42—003—41	P11	6500

Choke Cores



General Description

These cores are used for self-supporting radio frequency coils, chokes and interference suppressors. Cores can be supplied plain or with slots to facilitate the lead out of the winding. The various styles are shown in the diagram.

Dimensional Data

A wide range of diameters, lengths and wire terminations is available, as shown in the Table. Other sizes can be supplied on request.

D	L	Notch Style	Wire Type Dia. x Length
1.78	6.35 8.25	Z	0.5 x 38.1
3.18	12.7	C	0.6 x 25.4
4.04	9.5 11.1 12.7 19.0 25.4	CZ	0.6 x 25.4 0.6 x 38.1
5.33	16.0 19.0 38.1	CZ	0.6 x 25.4 0.6 x 38.1 0.7 x 25.4
6.35	16.0 25.4	Z	0.6 x 25.4 0.6 x 38.1 0.7 x 25.4
7.92	25.4 31.8	Z	1.22 x 51
12.7	50.8	Z	1.22 x 51

NEOSID

Choke Cores

Standard Cores (ex stock)

Part Numbers	Description
43–021–31	4.04 x 9.5/Z/0.6 x 25.4/F14
43–023–31	4.04 x 9.5/C/0.6 x 25.4/F14
43–051–31	5.33 x 16.0/Z/0.6 x 25.4/F14
43–053–31	5.33 x 16.0/C/0.6 x 25.4/F14
43–081–31	6.35 x 16.0/Z/0.7 x 25.4/F14

Dimensional Tolerances

Diameter	
1.78	± 0.10
3.18	± 0.14
4.04	± 0.17
5.33	± 0.20
6.35	± 0.25
7.92	± 0.27
12.7	± 0.38

Length	
up to 12.7	± 0.5
up to 19.0	± 0.57
up to 25.4	± 0.76
up to 31.8	± 1.0
up to 50.8	± 1.5

Electrical Tolerances (measured in standard test coils)
Coil Permeability (inductance ratio):
the tolerance on coil permeability is ± 5%.

Q Value:
the tolerance on Q value is -10% +30% and applies to measurements under our standard test conditions.

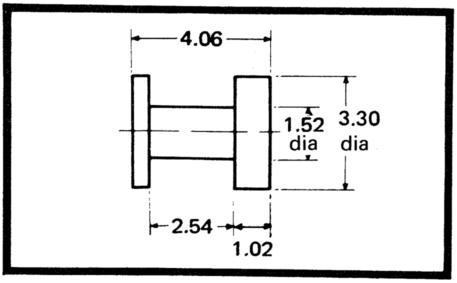
Material

Ferrite – Grade F14. Other ferrite grades can be supplied on request.
Wire – tinned copper.

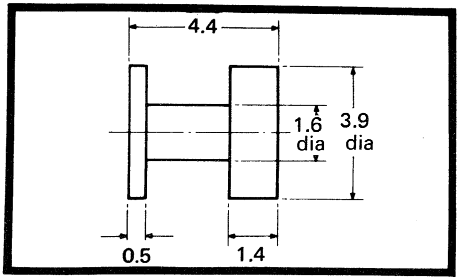
Ordering Information

Core diameter, length, style of notch, type of wire and grade of material must be stated, for example:
5.33 x 16.0/C/0.6 x 25.4/F14
A seven digit Part Number will be advised on the order acknowledgement.

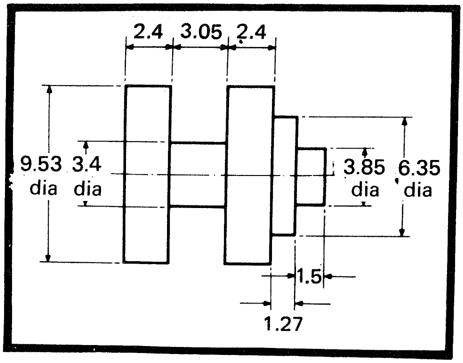
Bobbins



Part numbers
41-001-31 (grade F14)
41-001-32 (grade F16)
Material
Grades F14 and F16
A$_L$ values
Approximately: grade F14 12nH.
grade F16 10nH.

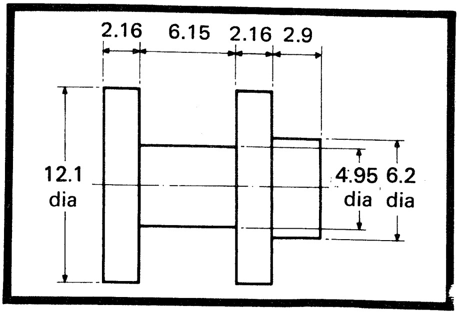


Part Number
41-002-31
Material
Grade F14
A$_L$ value
Approximately 15nH.



Part Number
41-002-31
Material
Grade F14
A$_L$ value
Approximately 45nH.

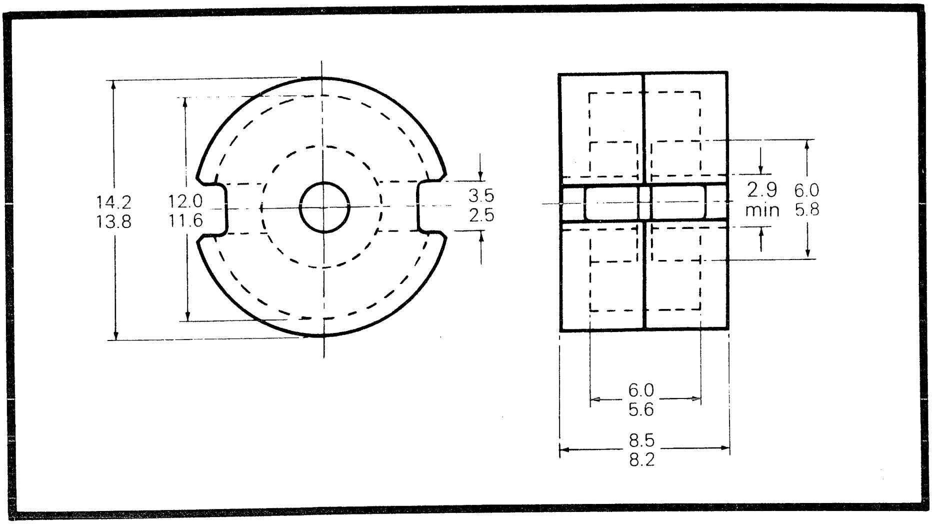
Note: This bobbin can be supplied mounted on a 6 pin base. Assembly 47–001–31.



Part number
41-005-31
Material
Grade F14
A$_L$ value
Approximately 45nH.

NEOSID

Transformer Pot Cores
IEC 14 × 8



General Description

These transformer pot cores comply with IEC Publication 133 and also satisfy the requirements of British Standard BS 4061 Range 2 and German Standard DIN 41293.

Cores are normally supplied ungapped but they can also be supplied gapped to a specified A_L value. Typical examples are given in the Electrical Specification.

All information below is given for a pair of pot cores.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	20 mm
Effective area of magnetic path	A_e	25 mm^2
Effective volume	V_e	500 mm^3
$\sum \frac{\ell}{A}$	C_1	0.789 mm^{-1}

Electrical Specification Grade P10

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-451-40	zero	2100 −20% + 30%	1320
29-452-40	<0.05	630 ±10%	395
29-453-40	0.05	400 ±5%	251

Transformer Pot Cores
IEC 14 × 8

Electrical Specification Grade F4

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-451-45	Zero	2500 −20% +30%	1570

Cores are always supplied in pairs. The A_L values are measured with a pair of pot cores subjected to a clamping force of 40 newtons.
μ_e is calculated by the formula,

$$\mu_e = 0.628\, A_L \text{ (nH)}$$

Number of Turns –
The number of turns required for an inductance L can be calculated from the formula,

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

where L is in mH
A_L is in nH.

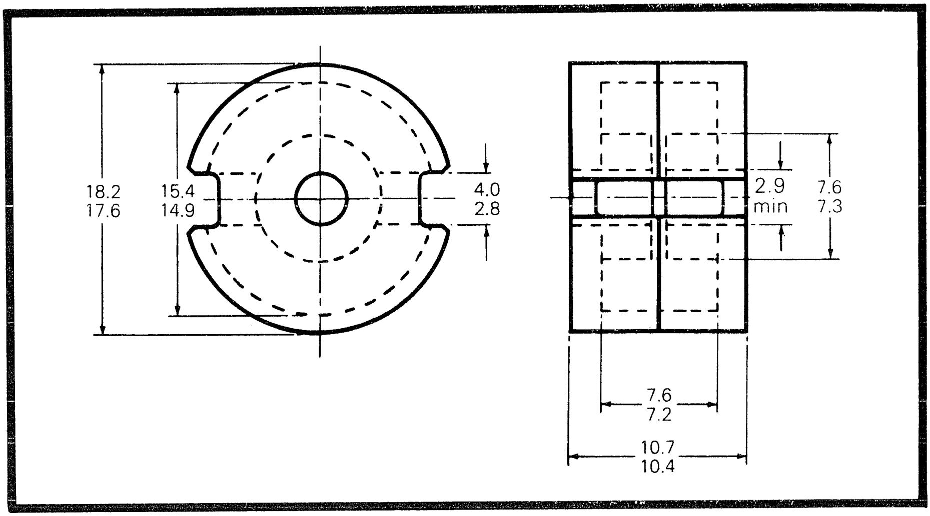
Part Numbers
As specified in Electrical Data.

Material
Ferrite P10 (see page 28)
F4 (see page 27)

Ordering Information
Pot core pairs –
State the part number. If not tabulated, state the A_L value; a seven-digit number will be advised on the order acknowledgement.
Coil formers –
(see page 164 for details)
Single section –
Part number **60-451-72**
Double section –
Part number **60-452-72**

NEOSID

Transformer Pot Cores
IEC 18 × 11



General Description

These transformer pot cores comply with IEC Publication 133 and also satisfy the requirements of British Standard BS 4061 Range 2 and German Standard DIN 41293.

Cores are normally supplied ungapped but they can also be supplied gapped to a specified A_L value. Typical examples are given in the Electrical Specification.

All information below is given for a pair of pot cores.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	26 mm
Effective area of magnetic path	A_e	43 mm^2
Effective volume	V_e	1120 mm^3
$\sum \frac{\ell}{A}$	C_1	0.597 mm^{-1}

Electrical Specification Grade P10

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective Permeability μe
29-501-40	zero	2800 −20% + 30%	1330
29-502-40	<0.05	1000 ± 10%	475
29-503-40	0.05	630 ± 10%	300
29-504-40	0.1	400 ± 5%	190

Transformer Pot Cores
IEC 18 × 11

Electrical Specification Grade F4

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-501-45	Zero	3625 –20% +30%	1720

Cores are always supplied in pairs.

The A_L values are measured with a pair of pot cores subjected to a clamping force of 50 newtons.

μ_e is calculated by the formula,

$$\mu_e = 0.475\ A_L\ (\text{nH})$$

Number of Turns –

The number of turns required for an inductance L can be calculated from the formula,

$$n = 1000\sqrt{\frac{L}{A_L}}$$

where L is in mH
A_L is in nH.

Part Numbers

As specified in Electrical Data

Material

Ferrite P10 (see page 28)
F4 (see page 27)

Ordering Information

Pot core pairs –

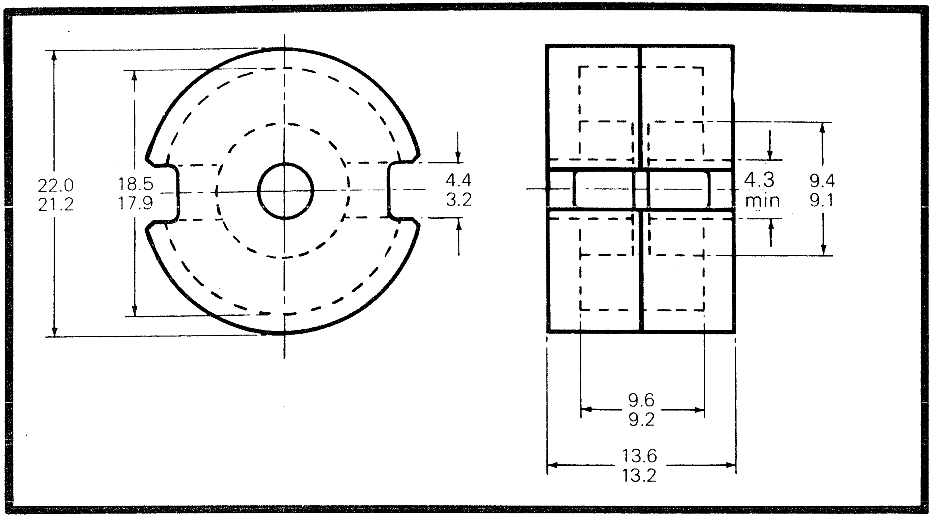
State the part number. If not tabulated, state the A_L value; a seven-digit number will be advised on the order acknowledgement.

Coil formers –

(see page 164 for details)
Single section –
Part number **60-501-72**
Double section –
Part number **60-502-72**

NEOSID

Transformer Pot Cores
IEC 22 × 13



General Description

These transformer pot cores comply with IEC Publication 133 and also satisfy the requirements of British Standard BS 4061 Range 2 and German Standard DIN 41293.

Cores are normally supplied ungapped but they can also be supplied gapped to a specified A_L value. Typical examples are given in the Electrical Specification.

All information below is given for a pair of pot cores.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	31.5 mm
Effective area of magnetic path	A_e	63 mm^2
Effective volume	V_e	2000 mm^3
$\sum \frac{\ell}{A}$	C_1	0.497 mm^{-1}

Electrical Specification Grade P10

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-551-40	zero	3800 −20% + 30%	1505
29-552-40	0.05	1000 ±10%	395
29-553-40	0.1	630 ±5%	250
29-554-40	0.15	400 ±5%	160

NEOSID

Transformer Pot Cores
IEC 22 × 13

Electrical Specification Grade F4

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-551-45	Zero	4625 −20% +30%	1840

Cores are always supplied in pairs. The A_L values are measured with a pair of pot cores subjected to a clamping force of 70 newtons. μ_e is calculated by the formula,

$$\mu_e = 0.396\ A_L\ (\text{nH})$$

Number of Turns –
The number of turns required for an inductance L can be calculated from the formula,

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

where L is in mH
A_L is in nH.

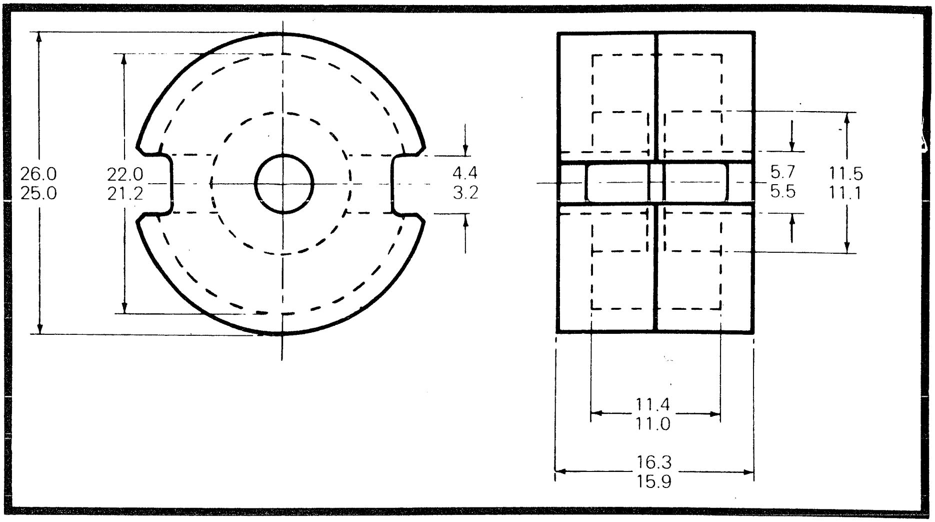
Part Numbers
As specified in Electrical Data.

Material
Ferrite P10 (see page 28)
F4 (see page 27)

Ordering Information
Pot core pairs –
State the part number. If not tabulated, state the A_L value; a seven-digit number will be advised on the order acknowledgement.

Coil formers –
(see page 164 for details)
Single section –
Part number **60-551-72**
Double section –
Part number **60-552-72**

Transformer Pot Cores
IEC 26 × 16



General Description

These transformer pot cores comply with IEC Publication 133 and also satisfy the requirements of British Standard BS 4061 Range 2 and German Standard DIN 41293. Cores are normally supplied ungapped but they can also be supplied gapped to a specified A_L value. Typical examples are given in the Electrical Specification.

All information below is given for a pair of pot cores.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	37.5 mm
Effective area of magnetic path	A_e	94 mm^2
Effective volume	V_e	3520 mm^3
$\sum \frac{\ell}{A}$	C_1	0.400 mm^{-1}

Electrical Specification Grade P10

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-601-40	zero	4900 −20% + 30%	1560
29-602-40	0.1	1000 ±10%	318
29-603-40	0.15	630 ± 5%	200
29-604-40	0.25	400 ± 5%	127

Transformer Pot Cores
IEC 26 × 16

Electrical Specification Grade F4

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-601-45	Zero	6000 –20% +30%	1910

Cores are always supplied in pairs. The A_L values are measured with a pair of pot cores subjected to a clamping force of 100 newtons. μ_e is calculated by the formula,

$$\mu_e = 0.318\, A_L \text{ (nH)}$$

Number of Turns –
The number of turns required for an inductance L can be calculated from the formula,

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

where L is in mH
A_L is in nH.

Part Numbers

As specified in Electrical Data.

Material

Ferrite P10 (see page 28)
F4 (see page 27)

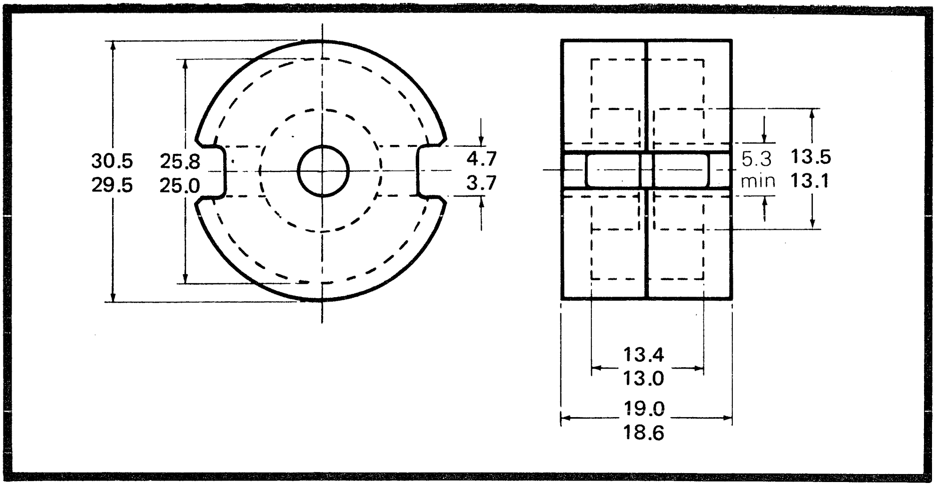
Ordering Information

Pot core pairs –
State the part number. If not tabulated, state the A_L value; a seven-digit number will be advised on the order acknowledgement.

Coil formers –
(see page 164 for details)
Single section –
Part number **60-601-72**
Double section –
Part number **60-602-72**

NEOSID

Transformer Pot Cores
IEC 30 × 19



General Description

These transformer pot cores comply with IEC Publication 133 and also satisfy the requirements of British Standard BS 4061 Range 2 and German Standard DIN 41293.

Cores are normally supplied ungapped but they can also be supplied gapped to a specified A_L value. Typical examples are given in the Electrical Specification.

All information below is given for a pair of pot cores.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	45 mm
Effective area of magnetic path	A_e	136 mm²
Effective volume	V_e	6120 mm³
$\sum \frac{\ell}{A}$	C_1	0.33 mm⁻¹

Electrical Specification Grade P10

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-621-40	zero	6200 20% + 30%	1630
29-622-40	0.1	1250 ± 10%	328
29-623-40	0.25	630 ± 5%	165
29-624-40	0.4	400 ± 5%	105

NEOSID

Transformer Pot Cores
IEC 30 × 19

Electrical Specification Grade F4

Part Number	Total approximate air gap (mm)	A_L value (nH)	Nominal effective permeability μ_e
29-621-45	Zero	7500 –20% +30%	1970

Cores are always supplied in pairs. The A_L values are measured with a pair of pot cores subjected to a clamping force of 120 newtons. μ_e is claculated by the formula,

$$\mu_e = 0.26\, A_L \text{ (nH)}$$

Number of Turns—

The number of turns required for an inductance L can be calculated from the formula,

$$n = 1000\sqrt{\frac{L}{A_L}}$$

where L is in mH
A_L is in nH.

Part Numbers

As specified in Electrical Data

Material

Ferrite P10 (see page 28)
F4 (see page 27)

Ordering Information

Pot core pairs

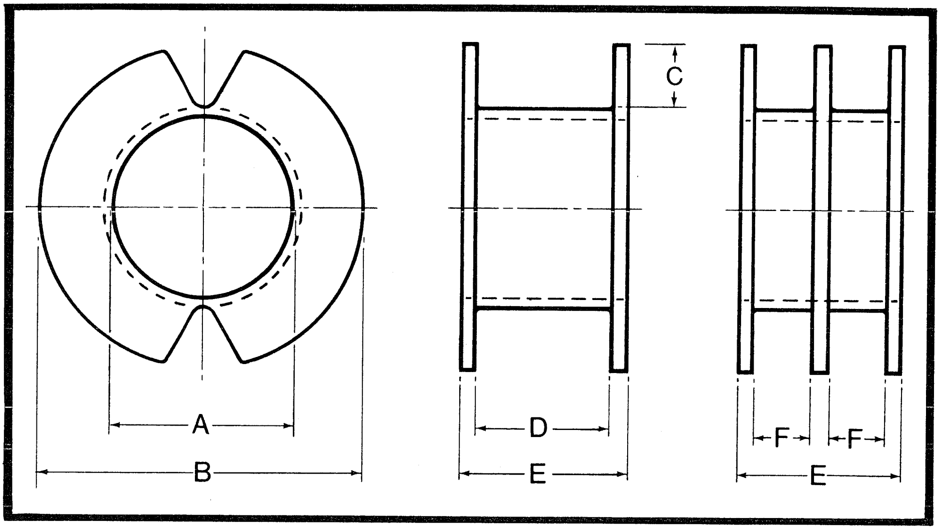
State the part number. If not tabulated, state the A_L value; a seven-digit number will be advised on the order acknowledgement.

Coil formers—

(see page 164 for details)

Single section—
Part number **60-621-72**
Double section—
Part number **60-622-72**

IEC Pot Core Formers



Dimensional Data

Only those dimensions that determine the assembly and winding of the formers are shown in the table below. Other dimensions and/or complete drawings of formers can be supplied upon request.

Part Number	Pot Core	Number of Sections	A	B	C min	D min	E	F min
60-451-72	14 x 8	1	6.1 to 6.2	11.3 to 11.5	2.05	4.3	5.3 to 5.4	–
60-452-72		2	6.1 to 6.2	11.3 to 11.5	2.05	–	5.3 to 5.4	1.95
60-501-72	18 x 11	1	7.7 to 7.8	14.6 to 14.8	2.9	5.9	6.9 to 7.0	–
60-502-72		2	7.7 to 7.8	14.6 to 14.8	2.9	–	6.9 to 7.0	2.75
60-551-72	22 x 13	1	9.6 to 9.75	17.6 to 17.8	3.4	7.7	8.85 to 9.0	–
60-552-72		2	9.6 to 9.75	17.6 to 17.8	3.4	–	8.85 to 9.0	3.6
60-601-72	26 x 16	1	11.7 to 11.85	20.7 to 20.9	3.95	9.5	10.65 to 10.8	–
60-602-72		2	11.7 to 11.85	20.7 to 20.9	3.95	–	10.65 to 10.8	4.45
60-621-72	30 x 19	1	13.7 to 13.9	24.5 to 24.7	4.75	11.2	12.6 to 12.8	–
60-622-72		2	13.7 to 13.9	24.5 to 24.7	4.75	–	12.6 to 12.8	5.25

General Description

These formers comply with IEC Publication 133

Material

Polyacetal

NEOSID

IEC Pot Core Formers

Winding Data

Pot core	Number of sections	Winding area per section mm^2	Length of mean turn mm	A_R $\mu\Omega$
14 x 8	1 2	8.6 3.9	28 28	113 124
18 x 11	1 2	16.8 7.8	36 36	74 80
22 x 13	1 2	25.0 11.5	44 44	61 66
26 x 16	1 2	35.0 16.0	52 52	51 56
30 x 19	1 2	51.0 23.5	60 60	41 44

The length of the mean turn is given for a fully wound former.

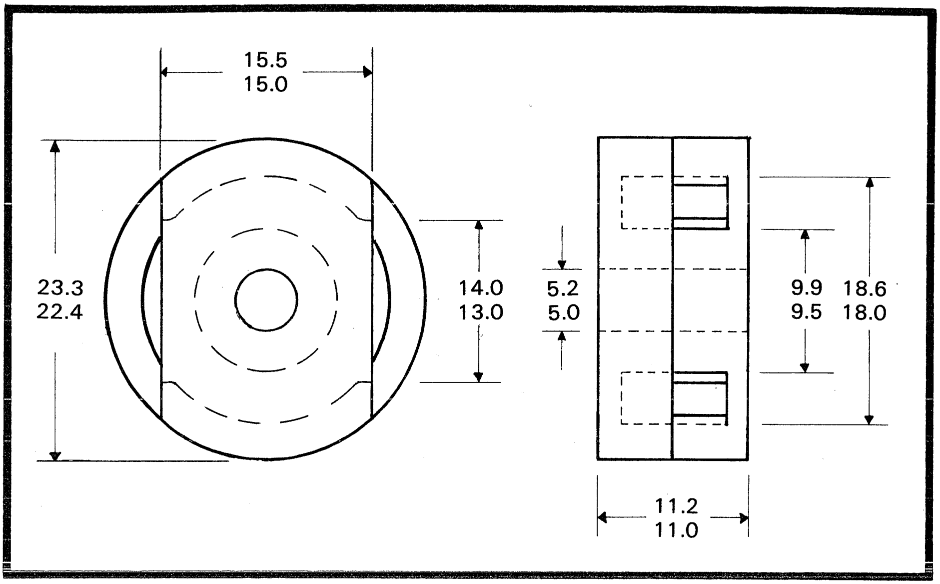
The value of the resistance factor, A_R, is calculated for a copper factor of 0.5, i.e. the sum of the cross-sectional areas of all turns in a fully wound bobbin equals one half of the available winding space. If the anticipated copper factor is different from 0.5, the value of A_R must be changed because A_R is inversely proportional to the copper factor.

The DC resistance of the winding is $A_R.n^2$ in micro-ohms, where n is the number of turns. This is an approximate value intended only for use in preliminary design evaluations.

Part Numbers

As specified under Dimensional Data

Touch Tone Pot Cores
23/15 × 11



General Description

These pot cores are used extensively in telecommunications and converter power supply circuits. The wide slot in the lower half of the assembly enables a large number of connections to be brought out.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	27 mm
Effective area of magnetic path	A_e	56 mm^2
Effective volume	V_e	1510 mm^3
$\sum\frac{\ell}{A}$	C_1	0.48 mm^{-1}

Touch Tone Pot Cores
$23/15 \times 11$

Electrical Specification

Part Number	Material Grade	Air Gap	A_L value (nH) Min.	Minimum effective permeability μ_e
29–632–45	F4	Zero	3900	1490
29–632–25	F5	Zero	3200	1220
29–632–36	F9	Zero	5760	2200

Cores are always supplied in pairs. Gapped cores in F4 and F5 material can be supplied to specified A_L values.

Material

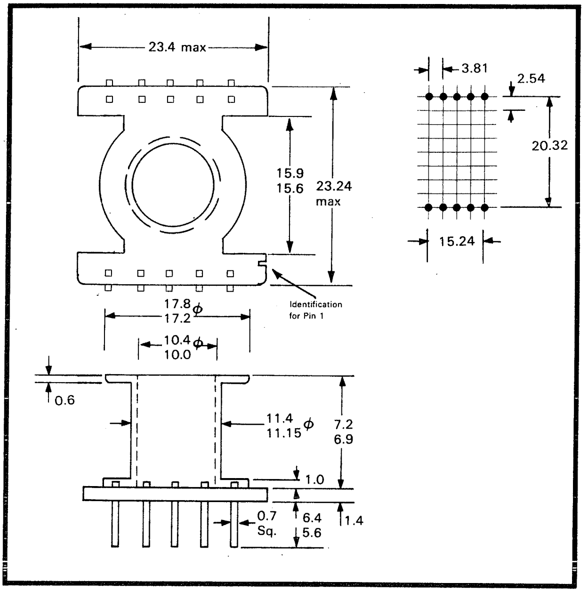
Ferrite F4, F5 and F9

Part Numbers

As specified in Electrical Specification.

NEOSID

Touch Tone Pot Core Former
23/15 × 11



General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C. 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area	Length of Mean Turn mm	A_R $\mu\Omega$
1	14	44.8	110

Approximate DC resistance of winding is $A_R.n^2$ $\mu\Omega$ for a fully wound former with a copper factor of 0.5.

Material

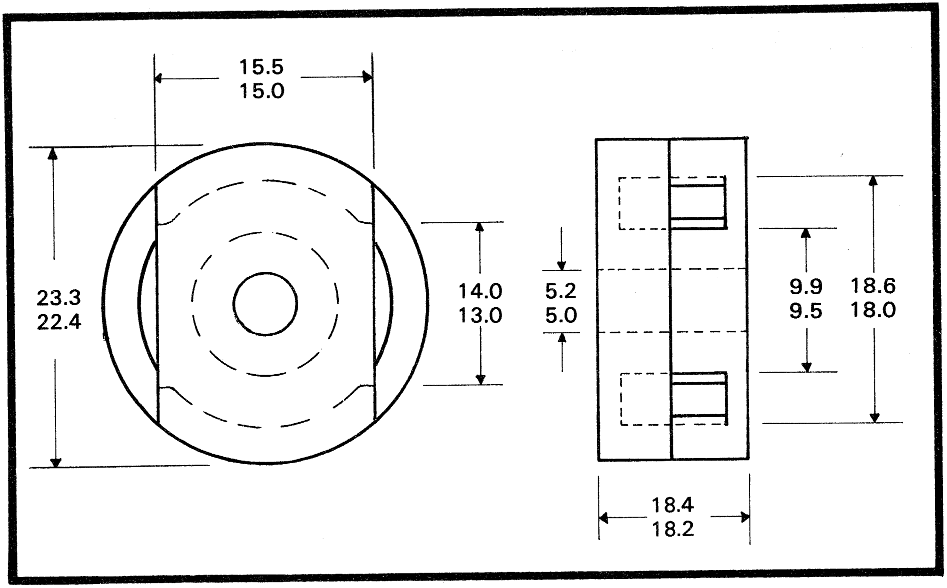
Glass filled nylon UL94 VO

Part Number

60-632-66

NEOSID

Touch Tone Pot Cores
23/15 × 18



General Description

These pot cores are used extensively in telecommunications and converter power supply circuits. The wide slot in the lower half of the assembly enables a large number of connections to be brought out.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	41 mm
Effective area of magnetic path	A_e	56 mm^2
Effective volume	V_e	2300 mm^3
$\sum \frac{\ell}{A}$	C_1	0.73 mm^{-1}

Touch Tone Pot Cores
23/15 × 18

Electrical Specification

Part Number	Material Grade	Air Gap	A_L value (nH) Min.	Minimum effective permeability μ_e
29–635–45	F4	Zero	3000	1740
29–635–25	F5	Zero	2000	1160
29–635–36	F9	Zero	3840	2230

Cores are always supplied in pairs. Gapped cores in F4 and F5 material can be supplied to specified A_L values.

Material

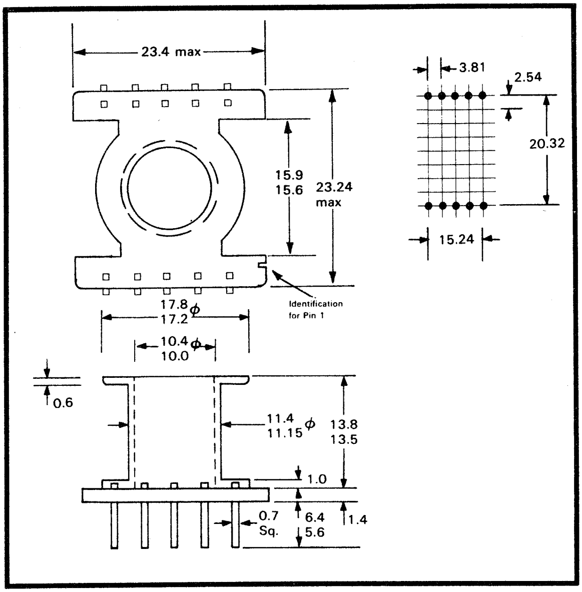
Ferrite F4, F5 and F9

Part Numbers

As specified in Electrical Specification.

NEOSID

Touch Tone Pot Core Former
23/15 × 18



General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C. 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm²	Length of Mean Turn mm	A_R $\mu\Omega$
1	35.6	44.8	43.4

Approximate DC resistance of winding is $A_R.n^2$ $\mu\Omega$ for a fully wound former with a copper factor of 0.5.

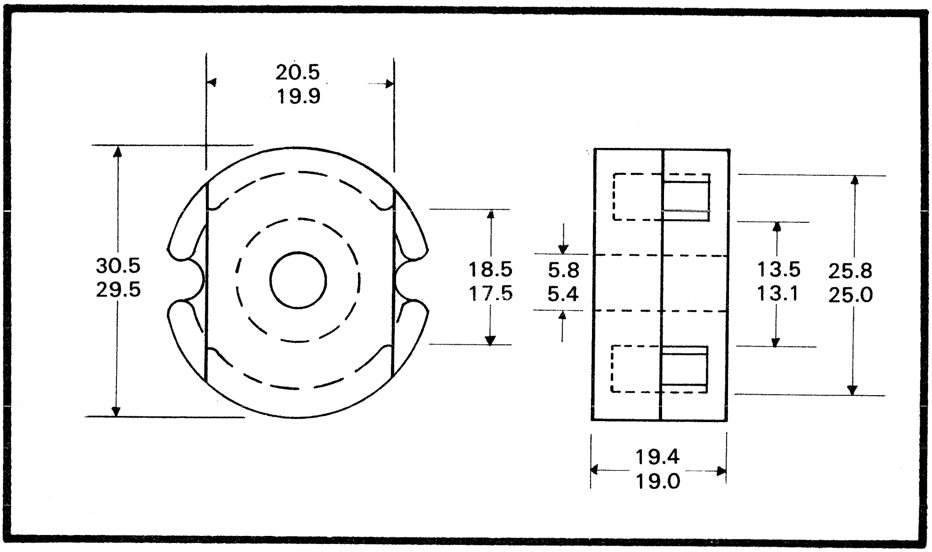
Material

Glass filled nylon UL94 VO

Part Number

60-632-66

Touch Tone Pot Cores
30/20 × 19



General Description

These pot cores are used extensively in telecommunications and converter power supply circuits. The wide slot in the lower half of the assembly enables a large number of connections to be brought out.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	45 mm
Effective area of magnetic path	A_e	100 mm^2
Effective volume	V_e	4500 mm^3
$\sum \frac{\ell}{A}$	C_1	0.45 mm^{-1}

Touch Tone Pot Cores
30/20 × 19

Electrical Specification

Part Number	Material Grade	Air Gap	A_L value (nH) Min.	Minimum effective permeability μ_e
29–637–45	F4	Zero	4300	1540
29–637–25	F5	Zero	3760	1345
29–637–36	F9	Zero	6400	2300

Cores are always supplied in pairs. Gapped cores in F4 and F5 material can be supplied to specified A_L values.

Material

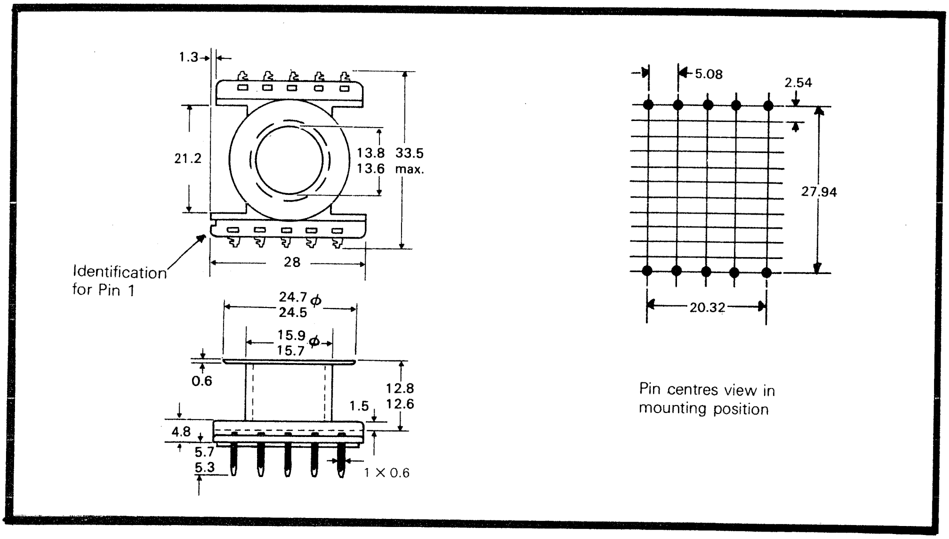
Ferrite F4, F5 and F9.

Part Numbers

As specified in Electrical Specification.

NEOSID

Touch Tone Pot Core Former
30/20 × 19



Pin centres view in mounting position

General Description

Pin solderability to BS2011 Part 2T and IEC 68-2-20B, Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm²	Length of Mean Turn mm	A_R µΩ
1	48	60	43

Approximate DC resistance of winding is $A_R.n^2$ µΩ for a fully wound former with a copper factor of 0.5.

Material

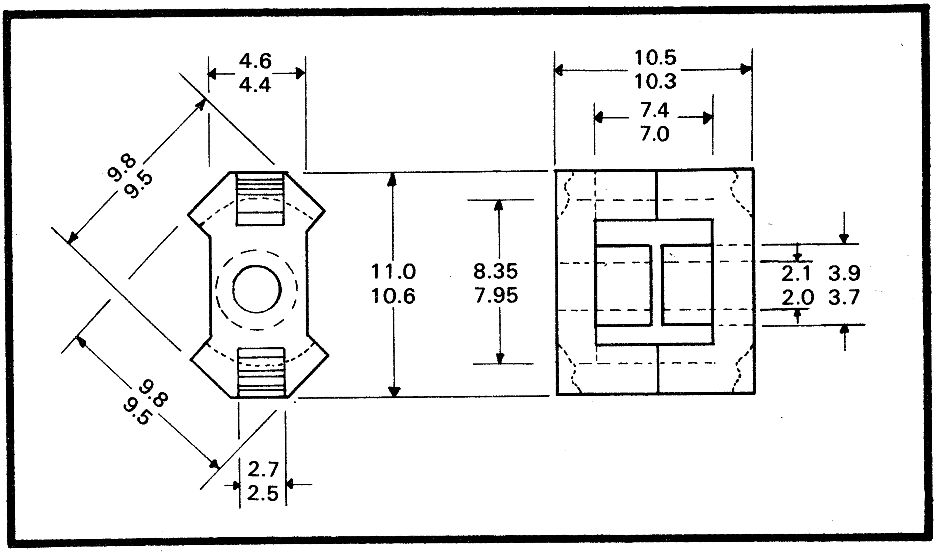
Glass filled nylon UL94 VO.

Part Number

60-636-66

NEOSID

Inductor RM Cores
IEC RM 4



General Description

These RM inductor cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are supplied in pairs, gapped to A_L values specified in the Electrical Specification. If the gap is smaller than 0.2mm, one half core is gapped and bears all the marking data, the other half is then not marked. If the total gap is greater than 0.2mm, the gap is evenly distributed between the two half cores, one or both being marked. The marking indicates the A_L value and grade of ferrite.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	21.0 mm
Effective area of magnetic path	A_e	11.0 mm^2
Effective volume	V_e	232 mm^3
$\sum\frac{\ell}{A}$	C_1	1.9 mm^{-1}

Inductor RM Cores
IEC RM 4

Electrical Specification

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective Permeability μ_e
29–903–	0.06	160 ± 3%	242
29–904–	0.04	250 ± 3%	378

The above A_L values are measured without the adjuster, while the pair of cores is subjected to a clamping force of 40 newtons.

The value of effective permeability μ_e cannot be directly measured and is calculated from the formula

$$\mu_e = 0.66 A_L \text{(nH)}$$

It should be noted that μ_e is not equal to the ratio of the inductance of the coil placed in the core assembly and the inductance of the same coil without core. Usually μ_e is about three times greater than the above ratio.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

where L is in mH,
A_L is in nH.

The use of the adjuster can only increase the value of A_L given in the Table, and the target value of A_L with the adjuster should be taken when calculating μ_e and n.

Material

Ferrite P11 and P12.
For electrical characteristics see page 28.

Material Code Numbers

P11 – **41**
P12 – **42**

Inductor RM Cores
IEC RM 4

Material Grade P11

Electrical Parameters for Core Assemblies

Parameter	Symbol	Frequency kHz	A_L Values nH	
			160	**250**
Effective Permeability	μ_e	10	242	378
Turns Factor (Turns for 1 mH)	α	–	79	63
Residual and Eddy Current Loss Tangent	$\tan \delta_{r+e}$	100	$<1.42 \times 10^{-3}$	$<2.22 \times 10^{-3}$
Hysterisis Loss Tangent $\Delta\hat{B} = 1.5$ mT	$\tan \delta_h$	10	$<0.35 \times 10^{-3}$	$<0.52 \times 10^{-3}$
Temperature Coefficient (ppm per °C) 25–55°C	α_L	10	125 to 370	211 to 614

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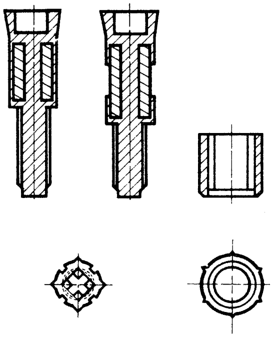
Inductor RM Cores
IEC RM 4

Material Grade P12

Electrical Parameters for Core Assemblies

Parameter	Symbol	Frequency kHz	A_L Values nH	
			160	250
Effective Permeability	μ_e	10	242	378
Turns Factor (Turns for 1 mH)	α	–	79	63
Residual and Eddy Current Loss Tangent	$\tan\delta_{r+e}$	100	$<0.98 \times 10^{-3}$	$<1.54 \times 10^{-3}$
Hysterisis Loss Tangent $\Delta\hat{B} = 1.5$ mT	$\tan\delta_h$	10	$<0.24 \times 10^{-3}$	$<0.38 \times 10^{-3}$
Temperature Coefficient (ppm per °C) 25–55°C	α_L	10	98 to 246	154 to 384

Inductor RM Cores
IEC RM 4



Adjustment

The adjustment system consists of a plastics splined nut and a plastics threaded adjuster, carrying a ferromagnetic sleeve. The dimensions and the material of the sleeve, listed in the Table, are chosen so as to produce a reasonably wide range of inductance adjustment, combined with an ease of accurate adjustment. If a wider range of adjustment is required, an adjuster specified in the Table for a higher A_L value can be used. Conversely, an adjuster corresponding in the Table to a lower A_L value can be used, if more accurate adjustment is desired, but the range of adjustment will then be reduced. Generally, any adjuster can be used for any A_L value.

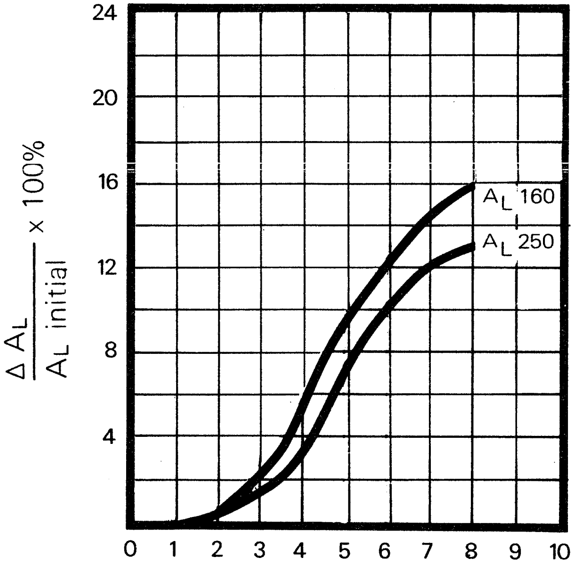
Adjuster Table

Adjuster Part Number	Sleeve Size diameter x length	Sleeve material grade	Used for A_L (nH)	Colour Code	Total adjustment range %	Number of turns
64–020–66	1.81 x 2.7	P10	160	Red	16	8
64–021–66	1.85 x 3.4	P10	250	Clear	13	8

Cores are supplied with nut inserted.

Inductor RM Cores
IEC RM 4

The graphs illustrate the increase of the initial A_L value (without the adjuster) as a function of the effective adjuster turns, for various A_L values.



Inductance adjustment curves

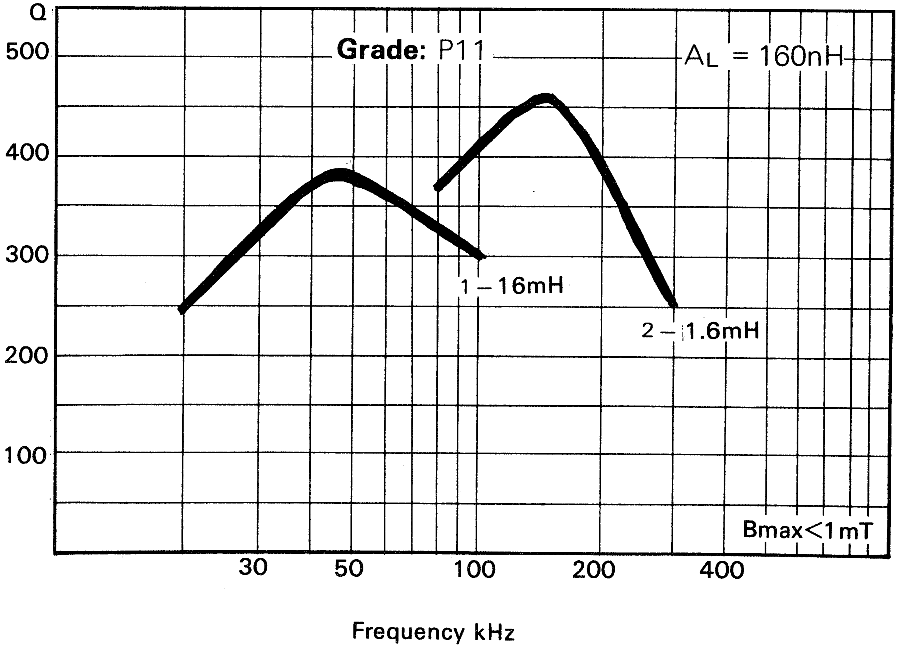
Inductor RM Cores
IEC RM 4

Typical curves of Q as a function of the frequency

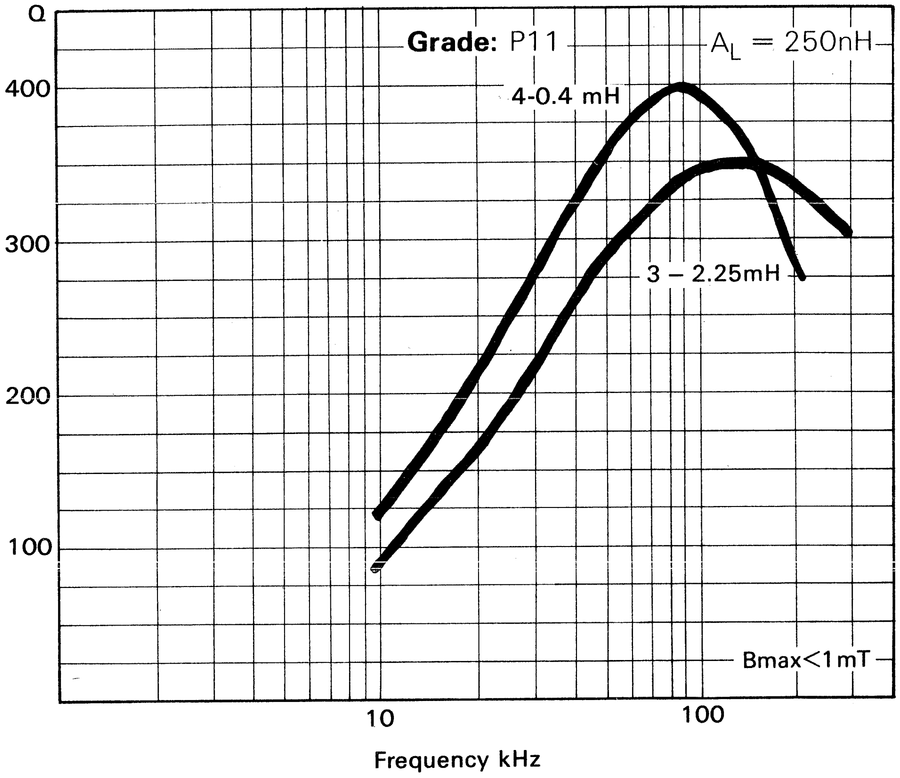
The graphs illustrate the values of Q easily obtainable with inexpensive windings. These curves are not intended to show the highest values of Q, obtainable by a careful choice of the number of turns and of the type of wire. The windings were chosen which seemed likely to represent practical extremes for the most popular A_L values.
The former was wound with a few turns of polystyrene tape, building up to less than 0.2mm thickness, before winding the coil, in order to reduce the disturbing influence of the fringe effects around the gap.

Winding data

1. 316 turns 0.14 EnCu
2. 100 turns 30 × 0.04 EnCu covered bunched wire
3. 90 turns 24 × 0.04 EnCu covered bunched wire
4. 41 turns 50 × 0.04 EnCu covered bunched wire



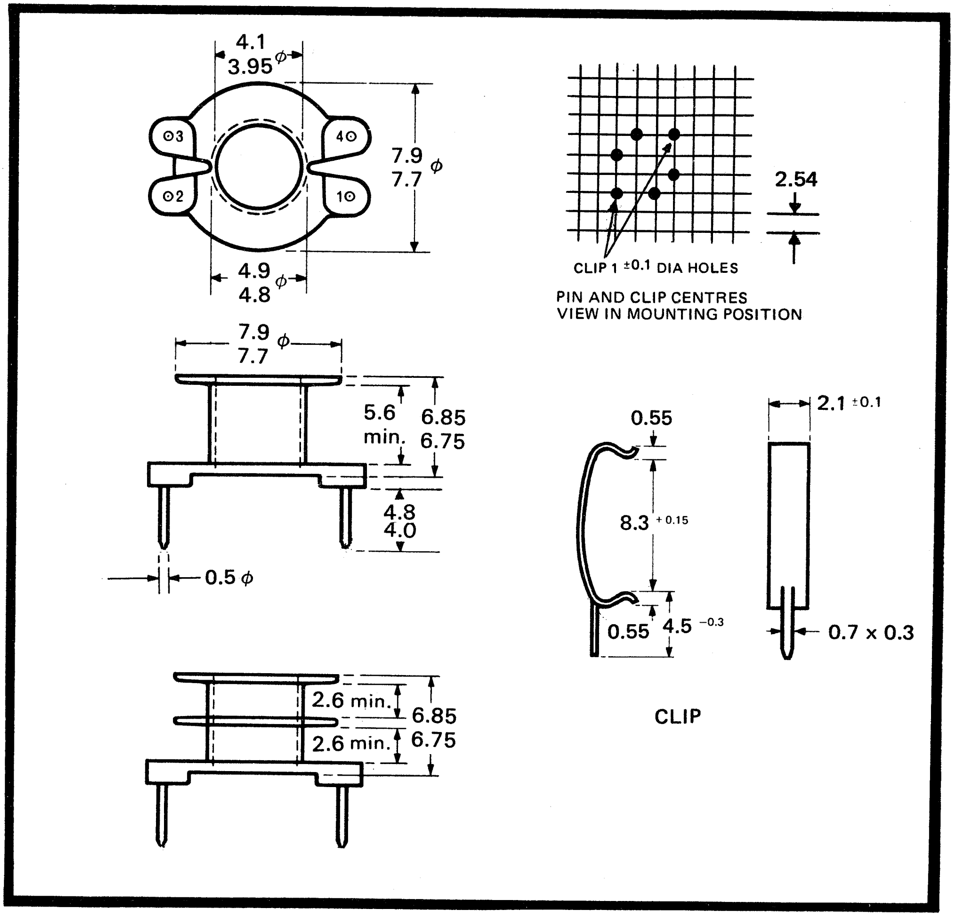
Inductor RM Cores
IEC RM 4



NEOSID

RM Core Former and Clip

IEC RM 4 4 Pin



Material

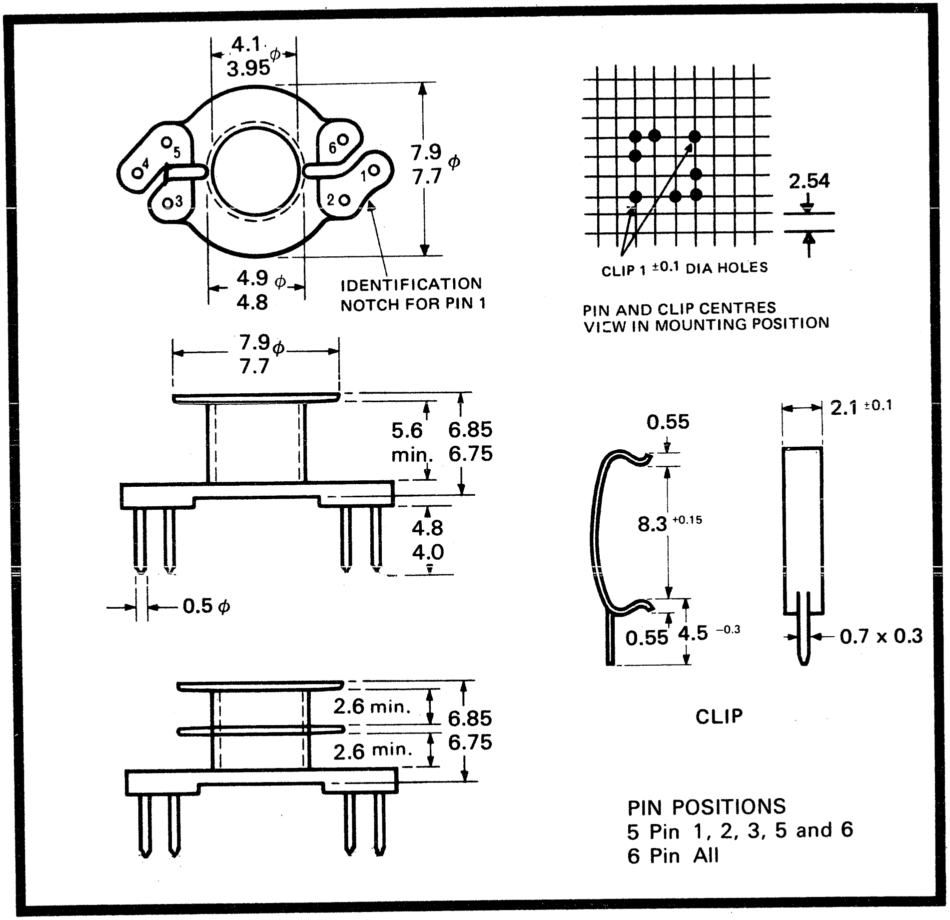
Former	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section	**60-901-64**
	2 Section	**60-904-64**
Clip		**76-024-95**

NEOSID

RM Core Former and Clip
IEC RM 4 5 & 6 Pin



PIN POSITIONS
5 Pin 1, 2, 3, 5 and 6
6 Pin All

Material

Former	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section 5 pin	**60-902-64**	2 Section 5 pin	**60-905-64**
	1 Section 6 pin	**60-903-64**	2 Section 6 pin	**60-906-64**
Clip		**76-024-95**		

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RM Core Former and Clip IEC RM 4

General Description

These formers comply with IEC Publication 431B and German Standard DIN 41981.
Pin and Clip solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm²	Length of Mean Turn mm	A_R $\mu\Omega$
1	7.7	20	89
2	3.65		94

The length of the mean turn is given for a fully wound former. The value of the resistance factor, A_R, is calculated for a copper factor of 0.5, i.e. the sum of the cross sectional areas of all turns in a fully wound former equals one half of the available winding space. If the anticipated copper factor is different from 0.5, the value of A_R must be changed; A_R is inversely proportional to the copper factor.
The DC resistance of the winding is $A_R.n^2$ in $\mu\Omega$, where n is the number of turns. This is an approximate value intended only for use in preliminary design evaluations.

Ordering information (example)

To order 1000 complete RM inductor core assemblies in grade P11 with an A_L value of 160 nH and single section 4 pin formers, the details are as follows:

1000	RM4 inductor cores (pairs) A_L 160 nH Part Number 29–903–41
1000	adjusters Part Number 64–020–66
1000	coil formers Part Number 60–901–64
2000	clips Part Number 76–024–95

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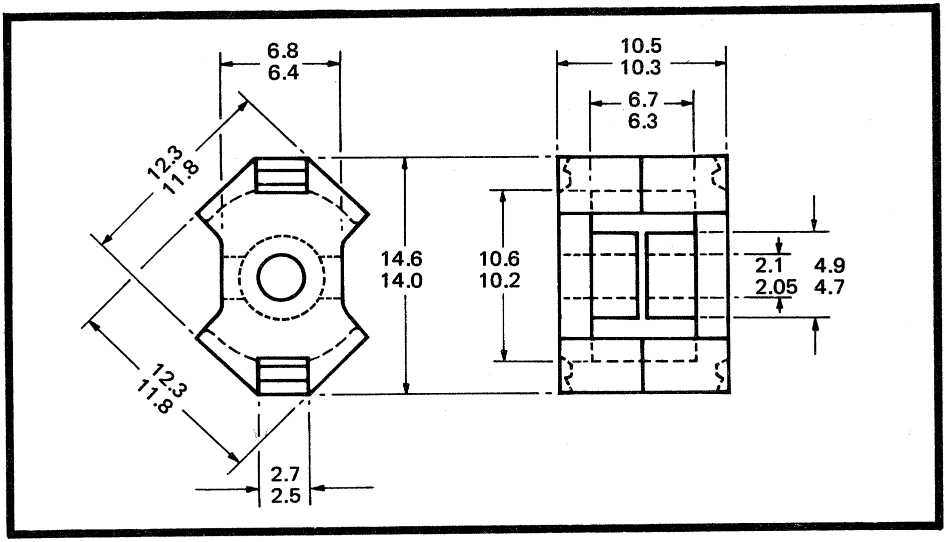
Inductor RM Cores
IEC RM 5



General Description

These RM inductor cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are supplied in pairs, gapped to A_L values specified in the Electrical Specification. If the gap is smaller than 0.2mm, one half core is gapped and bears all the marking data, the other half is then not marked. If the total gap is greater than 0.2mm, the gap is evenly distributed between the two half cores, one or both being marked. The marking indicates the A_L value and grade of ferrite.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	20.8 mm
Effective area of magnetic path	A_e	20.8 mm^2
Effective volume	V_e	430 mm^3
$\sum \frac{\ell}{A}$	C_1	1.0 mm^{-1}

Inductor RM Cores
IEC RM 5

Electrical Specification

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective Permeability μ_e
29–701–	0.18	100 ± 3%	80
29–702–	0.12	160 ± 3%	128
29–703–	0.06	250 ± 3%	200

The above A_L values are measured without the adjuster, while the pair of cores is subjected to a clamping force of 40 newtons.

The value of effective permeability μ_e cannot be directly measured and is calculated from the formula

$$\mu_e = 0.80\,A_L\,(\mathrm{nH})$$

It should be noted that μ_e is not equal to the ratio of the inductance of the coil placed in the core assembly and the inductance of the same coil without core. Usually μ_e is about three times greater than the above ratio.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000\sqrt{\frac{L}{A_L}}$$

where L is in mH,
A_L is in nH.

The use of the adjuster can only increase the value of A_L given in the Table, and the target value of A_L with the adjuster should be taken when calculating μ_e and n.

Material

Ferrite P11 and P12
For electrical characteristics see page 28.

Material Code Numbers

P11 – **41**
P12 – **42**

Inductor RM Cores
IEC RM 5

Material Grade P11

Electrical Parameters for Core Assemblies

Parameter	Symbol	Frequency kHz	A_L Values nH		
			100	**160**	**250**
Effective Permeability	μ_e	10	79.6	128	200
Turns Factor (Turns for 1 mH)	α	–	100	79.06	63.24
Residual and Eddy Current Loss Tangent	$\tan \delta_{r+e}$	100	$<0.48 \times 10^{-3}$	$<0.8 \times 10^{-3}$	$<1.3 \times 10^{-3}$
Hysterisis Loss Tangent $\Delta\hat{B} = 1.5$ mT	$\tan \delta_h$	10	$<0.11 \times 10^{-3}$	$<0.17 \times 10^{-3}$	$<0.27 \times 10^{-3}$
Temperature Coefficient (ppm per °C) 25–55°C	α_L	10	44 to 128	70 to 203	110 to 320

Inductor RM Cores
IEC RM 5

Material Grade P12

Electrical Parameters for Core Assemblies

Parameter	Symbol	Frequency kHz	A_L Values nH		
			100	**160**	**250**
Effective Permeability	μ_e	10	79.6	128	200
Turns Factor (Turns for 1 mH)	α	–	100	79.06	63.24
Residual and Eddy Current Loss Tangent	$\tan \delta_{r+e}$	100	$<0.3 \times 10^{-3}$	$<0.48 \times 10^{-3}$	$<0.76 \times 10^{-3}$
Hysterisis Loss Tangent $\Delta\hat{B} = 1.5$ mT	$\tan \delta_h$	10	$<0.072 \times 10^{-3}$	$<0.114 \times 10^{-3}$	$<0.18 \times 10^{-3}$
Temperature Coefficient (ppm per °C) 25–55°C	α_L	10	32 to 80	51 to 127	80 to 199

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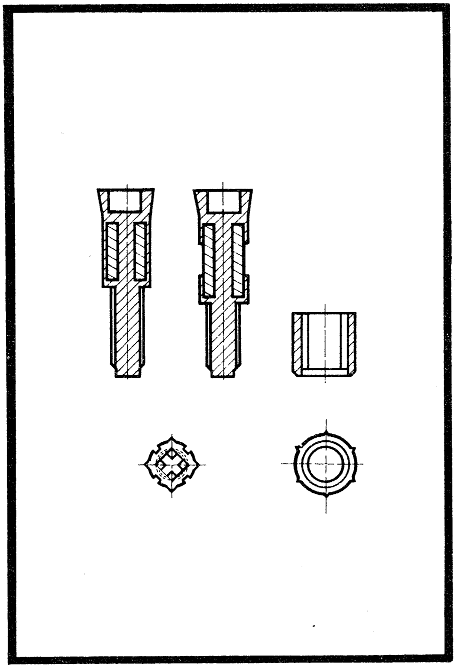
Inductor RM Cores
IEC RM 5



Adjustment

The adjustment system consists of a plastics splined nut and a plastics threaded adjuster, carrying a ferromagnetic sleeve. The dimensions and the material of the sleeve, listed in the Table, are chosen so as to produce a reasonably wide range of inductance adjustment, combined with an ease of accurate adjustment. If a wider range of adjustment is required, an adjuster specified in the Table for a higher A_L value can be used. Conversely, an adjuster corresponding in the Table to a lower A_L value can be used, if more accurate adjustment is desired, but the range of adjustment will then be reduced. Generally, any adjuster can be used for any A_L value.

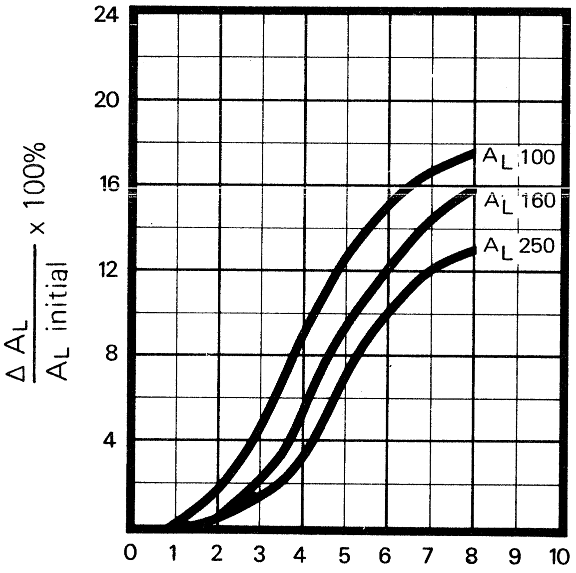
Adjuster Table

Adjuster Part Number	Sleeve Size diameter x length	Sleeve material grade	Used for A_L (nH)	Colour Code	Total adjustment range %	Number of turns
64–020–66	1.81 x 2.7	P10	100	Red	16	8
64–020–66	1.81 x 2.7	P10	160	Red	15	8
64–021–66	1.85 x 3.4	P10	250	Clear	12	8

Cores are supplied with nut inserted.

Inductor RM Cores
IEC RM 5

The graphs illustrate the increase of the initial A_L value (without the adjuster) as a function of the effective adjuster turns, for various A_L values.



Inductance adjustment curves

NEOSID

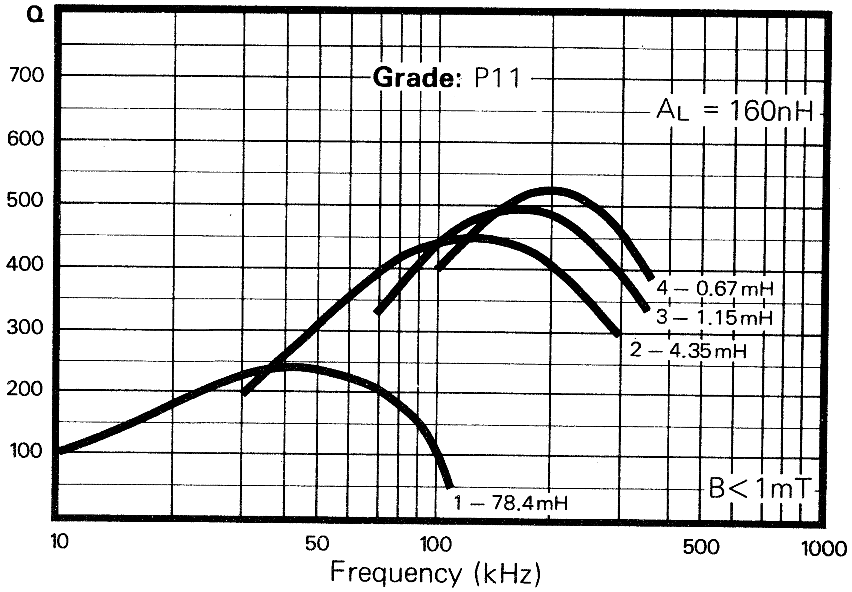
Inductor RM Cores
IEC RM 5

Typical curves of Q as a function of the frequency

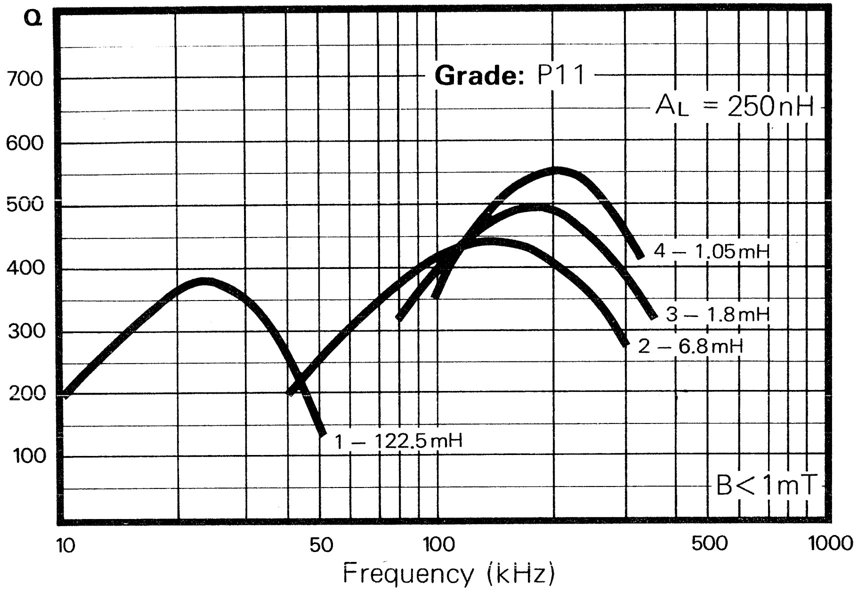
The graphs illustrate the values of Q easily obtainable with inexpensive windings. These curves are not intended to show the highest values of Q, obtainable by a careful choice of the number of turns and of the type of wire. The windings were chosen which seemed likely to represent practical extremes for the most popular A_L values.
The former was wound with a few turns of polystyrene tape, building up to less than 0.2mm thickness, before winding the coil, in order to reduce the disturbing influence of the fringe effects around the gap.

Winding data

1.	700	turns	0.1 EnCu
2.	165	turns	10 x 0.05 EnCu covered bunched wire
3.	85	turns	30 x 0.04 EnCu covered bunched wire
4.	65	turns	45 x 0.04 EnCu covered bunched wire



Inductor RM Cores
IEC RM 5



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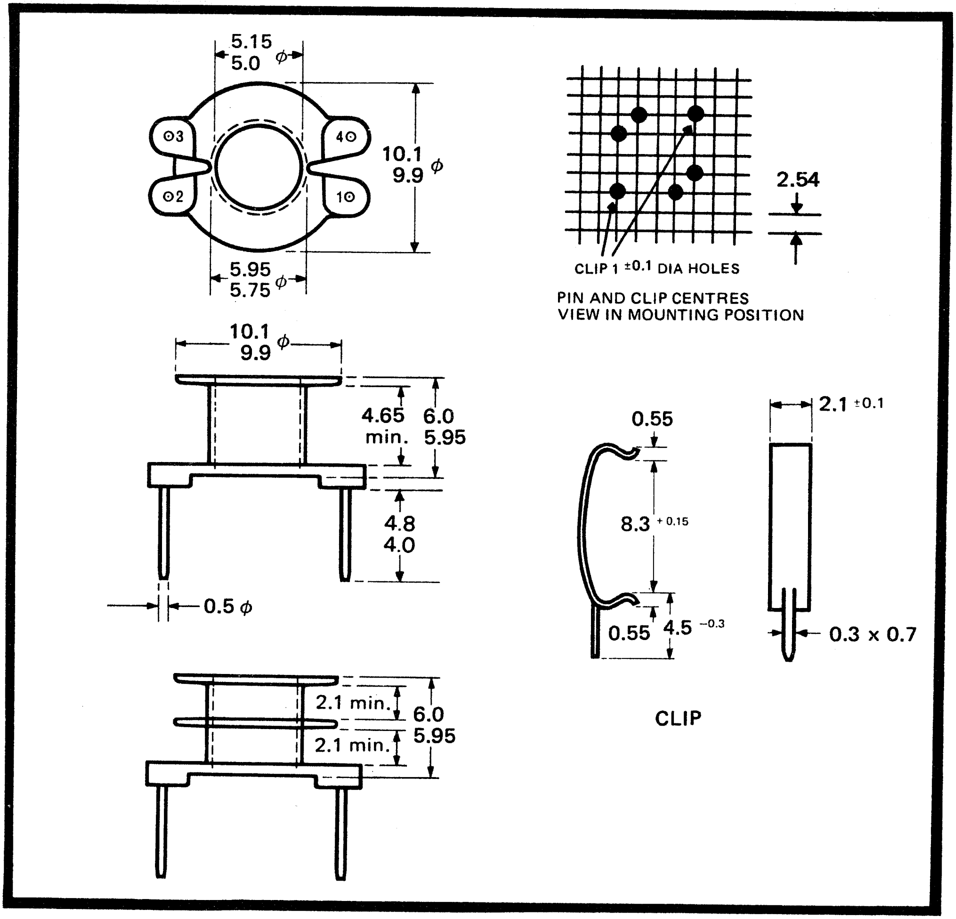
RM Core Former and Clip
IEC RM 5 4 Pin



Material

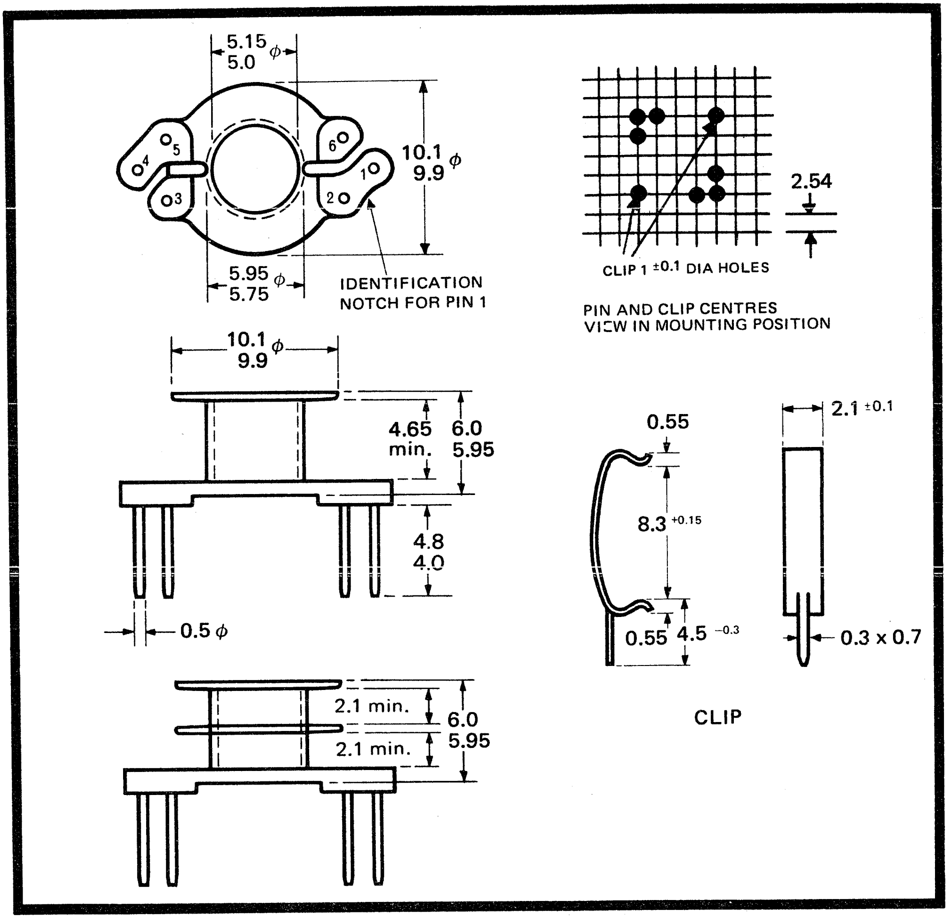
Former	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section	**60–701–64**
	2 Section	**60–703–64**
Clip		**76–024–95**

NEOSID

RM Core Former and Clip
IEC RM 5 6 Pin



Material

Former	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section	**60–702–64**
	2 Section	**60–704–64**
Clip		**76–024–95**

NEOSID

RM Core Former and Clip
IEC RM 5

General Description

These formers comply with IEC Publication 431B and German Standard DIN 41981.
Pin and Clip solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm^2	Length of Mean Turn mm	A_R $\mu\Omega$
1 2	9.5 4.35	25	90 94

The length of the mean turn is given for a fully wound former. The value of the resistance factor, A_R, is calculated for a copper factor of 0.5, i.e. the sum of the cross sectional areas of all turns in a fully wound former equals one half of the available winding space. If the anticipated copper factor is different from 0.5, the value of A_R must be changed; A_R is inversely proportional to the copper factor.
The DC resistance of the winding is $A_R.n^2$ in $\mu\Omega$, where n is the number of turns. This is an approximate value intended only for use in preliminary design evaluations.

Ordering information (example)

To order 1000 complete RM5 inductor core assemblies in grade P11 with an A_L value of 160 nH and single section 4 pin formers, the details are as follows:

1000	RM5 inductor cores (pairs) A_L 160 nH Part Number 29–702–41
1000	adjusters Part Number 64–020–66
1000	coil formers Part Number 60–701–64
2000	clips Part Number 76–024–95

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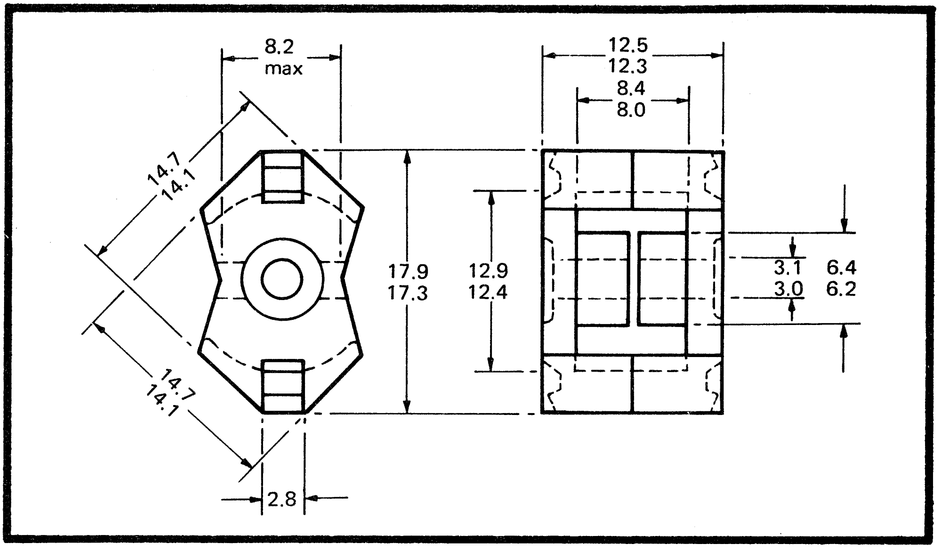
Inductor RM Cores
IEC RM 6



General Description

These RM inductor cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are supplied in pairs, gapped to A_L values specified in the Electrical Specification. If the gap is smaller than 0.2 mm, one half core is gapped and bears all the marking data, the other half is then not marked. If the total gap is greater than 0.2 mm, the gap is evenly distributed between the two half cores, one or both being marked. The marking indicates the A_L value and grade of ferrite. Manufacturing code marking can also be included, if requested.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	27 mm
Effective area of magnetic path	A_e	31 mm^2
Effective volume	V_e	840 mm^3
$\sum \frac{\ell}{A}$	C_1	0.87 mm^{-1}

Inductor RM Cores
IEC RM 6

Electrical Specification

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective permeability μ_e
29-731-	0.5	100 ± 3%	69
29-732-	0.2	160 ± 3%	111
29-733-	0.11	250 ± 3%	173
29-734-	0.08	315 ± 3%	218
29-735-	0.05	400 ± 3%	277

The above A_L values are measured without the adjuster, while the pair of cores is subjected to a clamping force of 50 newtons. The value of the effective permeability μ_e cannot be directly measured and it is calculated from the formula

$$\mu_e = 0.693\,A_L\ (\mathrm{nH})$$

It should be noted that μ_e is not equal to the ratio of the inductance of the coil placed in the core assembly and the inductance of the same coil without core. Usually the μ_e is about three times greater than the above ratio.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000\sqrt{\frac{L}{A_L}}$$

where L is in mH,
A_L is in nH.

The use of the adjuster can only increase the value of A_L given in the Table, and the target value of A_L with the adjuster should be taken into account when calculating μ_e and n.

Material

Ferrite P11 and P12.
For electrical characteristics see page 28.

Material Code Numbers

P11 – **41**   P12 – **42**

Inductor RM Cores
IEC RM 6

Material Grade P11

Electrical Parameters for Core Assemblies

Parameter	Symbol	Frequency kHz	A_L Values nH				
			100	**160**	**250**	**315**	**400**
Effective Permeability	μ_e	10	69	111	173	218	277
Turns Factor (Turns for 1 mH)	α	–	100	79.06	63.24	56.34	50
Residual and Eddy Current Loss Tangent	$\tan\delta_{r+e}$	100	$<0.36 \times 10^{-3}$	$<0.58 \times 10^{-3}$	$<0.90 \times 10^{-3}$	$<1.15 \times 10^{-3}$	$<1.38 \times 10^{-3}$
Hysterisis Loss Tangent $\Delta\hat{B} = 1.5$ mT	$\tan\delta_h$	10	$<0.09 \times 10^{-3}$	$<0.14 \times 10^{-3}$	$<0.22 \times 10^{-3}$	$<0.27 \times 10^{-3}$	$<0.36 \times 10^{-3}$
Temperature Coefficient (ppm per °C) 25–55°C	α_L	10	38 to 109	60 to 164	94 to 274	119 to 346	151 to 439

NEOSID

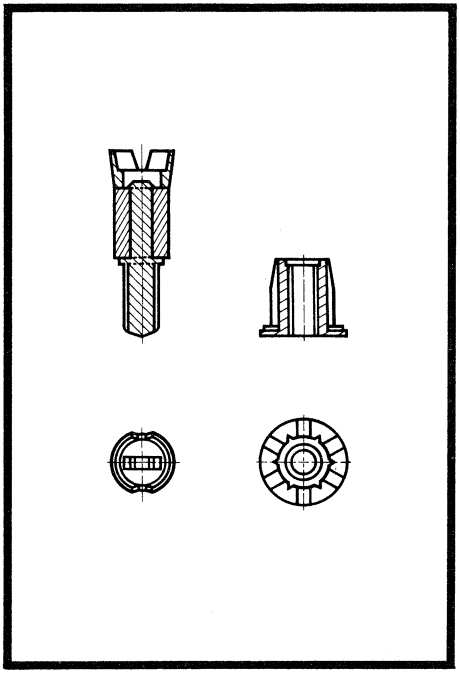
Inductor RM Cores
IEC RM 6

Material Grade P12

Electrical Parameters for Core Assemblies

Parameter	Symbol	Frequency kHz	A_L Values nH				
			100	**160**	**250**	**315**	**400**
Effective Permeability	μ_e	10	69	111	173	218	277
Turns Factor (Turns for 1 mH)	α	–	100	79.06	63.24	56.34	50
Residual and Eddy Current Loss Tangent	$\tan\delta_{r+e}$	100	$<0.26 \times 10^{-3}$	$<0.414 \times 10^{-3}$	$<0.65 \times 10^{-3}$	$<0.82 \times 10^{-3}$	$<1.04 \times 10^{-3}$
Hysterisis Loss Tangent $\Delta\hat{B} = 1.5$ mT	$\tan\delta_h$	10	$<0.061 \times 10^{-3}$	$<0.098 \times 10^{-3}$	$<0.15 \times 10^{-3}$	$<0.19 \times 10^{-3}$	$<0.25 \times 10^{-3}$
Temperature Coefficient (ppm per °C) 25–55°C	α_L	10	27 to 68	44 to 109	68 to 171	86 to 216	110 to 274

Inductor RM Cores
IEC RM 6



Adjustment

The adjustment system consists of a plastics splined nut and a plastics threaded adjuster, carrying a ferromagnetic sleeve. The dimensions and the material of the sleeve, listed in the Table, are chosen so as to produce a reasonably wide range of inductance adjustment, combined with an ease of accurate adjustment. If a wider range of adjustment is required, an adjuster specified in the Table for a higher A_L value can be used. Conversely, an adjuster corresponding in the Table to a lower A_L value can be used, if more accurate adjustment is desired, but the range of adjustment will then be reduced. Generally, any adjuster can be used for any A_L value.

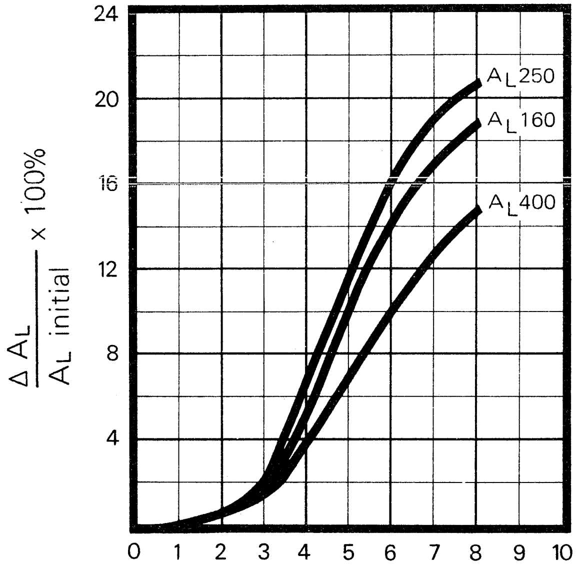
Adjuster Table

Adjuster Part Number	Sleeve Size diameter x length	Sleeve material grade	Used for A_L (nH)	Colour Code	Total adjustment range %	Number of turns
64–025–66	2.6 x 3.0	P11	100	Yellow	17	8
64–025–66	2.6 x 3.0	P11	160	Yellow	15	8
64–026–66	2.76 x 3.6	P11	250	Natural	18	8
64–027–66	2.8 x 3.75	P11	315	Beige	15	8
64–027–66	2.8 x 3.75	P11	400	Beige	12	8

The nut is supplied already fitted into the RM core.

Inductor RM Cores
IEC RM 6

The graphs illustrate the increase of the initial A_L value (without the adjuster) as a function of the effective adjuster turns, for various A_L values.



Inductance adjustment curves

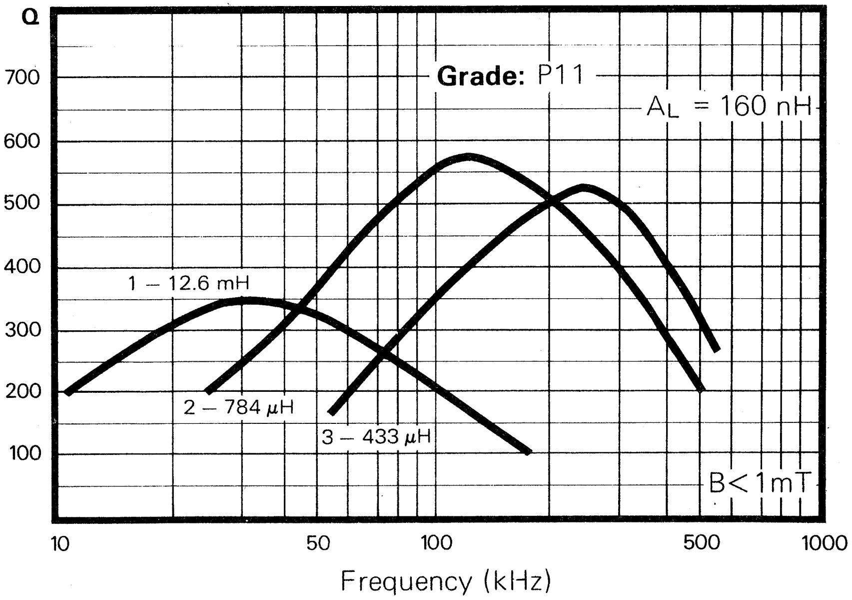
Inductor RM Cores
IEC RM 6

Typical curves of Q as a function of the frequency

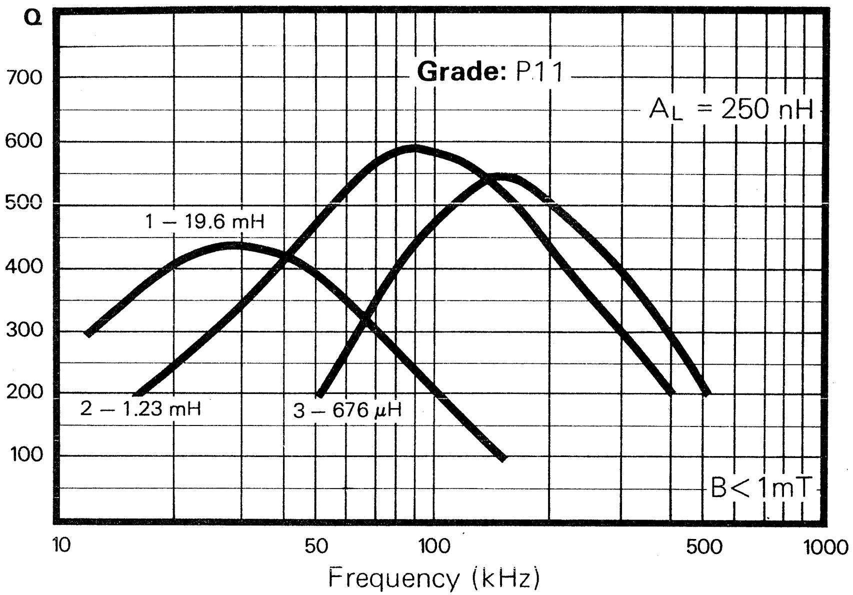
The graphs illustrate the values of Q easily obtainable. These curves are not intended to show the highest values of Q, obtainable by a careful choice of the number of turns and of the type of wire. The windings were chosen which seemed likely to represent practical extremes for the most popular A_L values.
The former was wound with a few turns of polystyrene tape, building up to less than 0.2mm thickness, before winding the coil, in order to reduce the disturbing influence of the fringe effects around the gap.

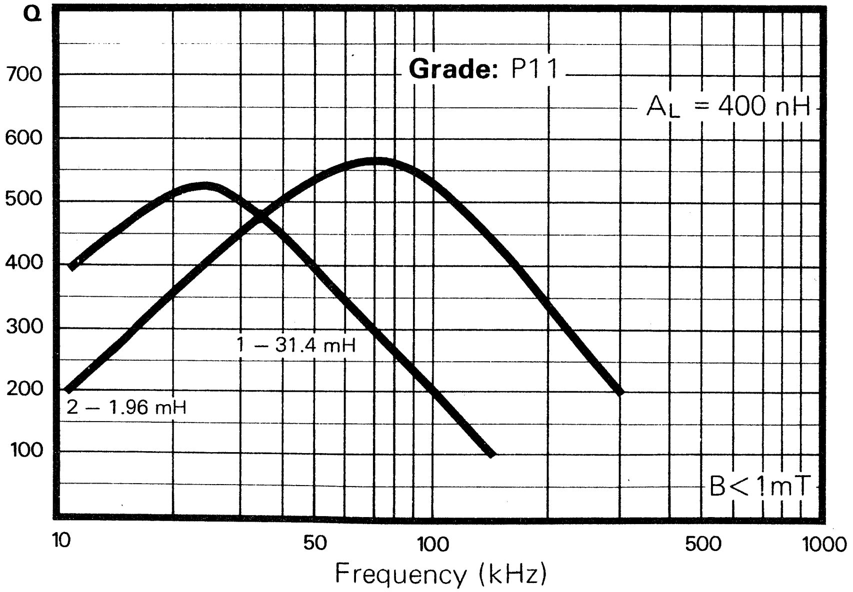
Winding data

1 – 280 turns, 0.2 EnCu wire
2 – 70 turns, 50 x 0.04 EnCu covered bunched wire
3 – 52 turns, 30 x 0.04 EnCu covered bunched wire

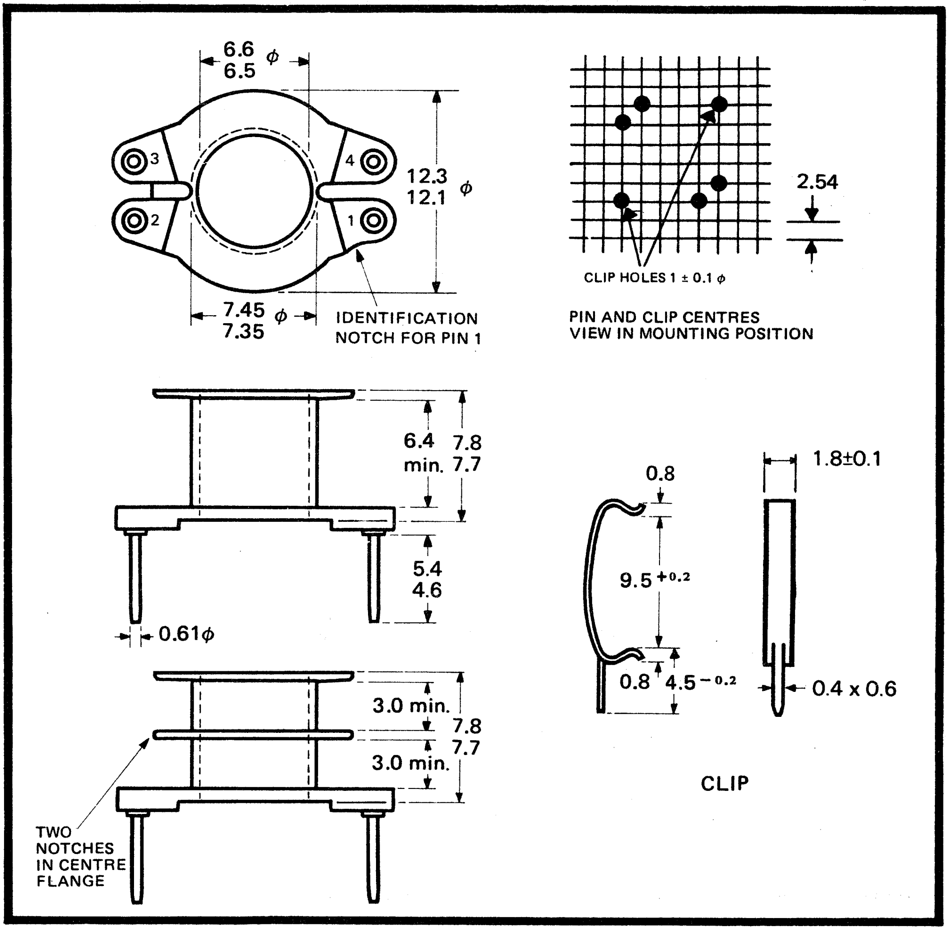


Inductor RM Cores
IEC RM 6





RM Core Former and Clip
IEC RM 6 4 Pin



Material

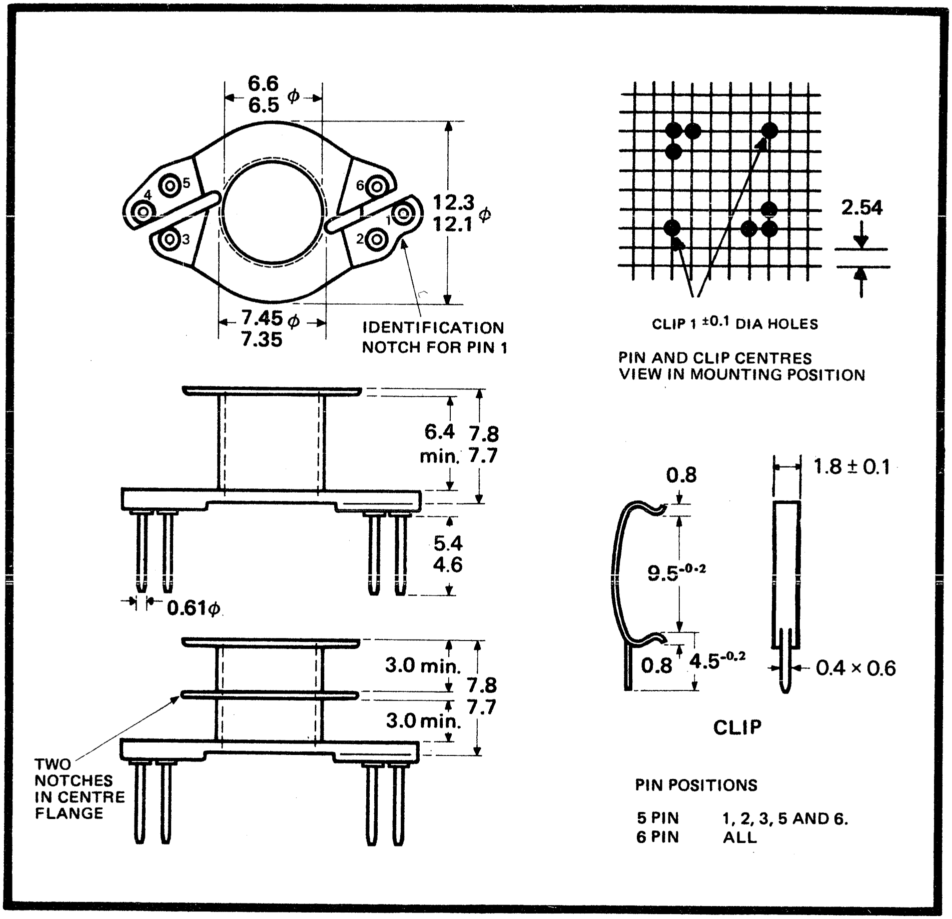
Formers	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section	**60-731-64**
	2 Section	**60-734-64**
Clip		**76-020-95**

RM Core Former and Clip

IEC RM 6 5 & 6 Pin



PIN POSITIONS

5 PIN	1, 2, 3, 5 AND 6.
6 PIN	ALL

Material

Former	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section 5 pin	**60-732-64**	2 Section 5 pin	**60-735-64**
	1 Section 6 pin	**60-733-64**	2 Section 6 pin	**60-736-64**
Clip		**76-020-95**		

NEOSID

RM Core Former and Clip IEC RM 6

General Description

These formers comply with IEC Publication 431B and German Standard DIN 41981.
Pin and Clip solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400° C, 2 sec.
Pin configurations, other than those listed can be made available subject to special arrangements taking into account the quantities required.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm^2	Length of Mean Turn mm	A_R $\mu\Omega$
1	15	30	69
2	7		74

The length of the mean turn is given for a fully wound former. The value of the resistance factor, A_R, is calculated for a copper factor of 0.5, i.e. the sum of the cross sectional areas of all turns in a fully wound former equals one half of the available winding space. If the anticipated copper factor is different from 0.5, the value of A_R must be changed; A_R is inversely proportional to the copper factor.
The DC resistance of the winding is $A_R.n^2$ in $\mu\Omega$, where n is the number of turns. This is an approximate value intended only for use in preliminary design evaluations.

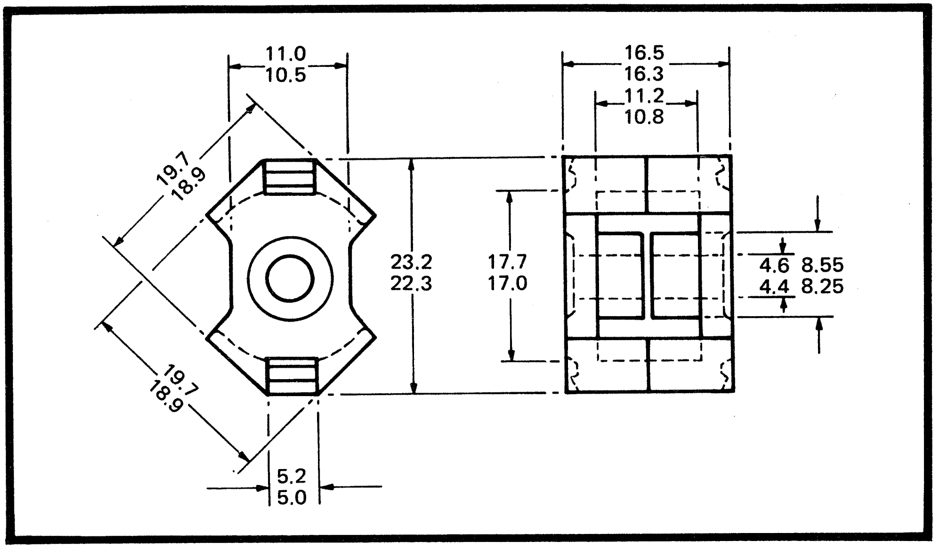
Ordering information (example)

To order 1000 complete RM6 inductor core assemblies in grade P11 with an A_L value of 250 nH and single section 6 pin fromers, the details are as follows:

1000	RM6 inductor cores (pairs) A_L = 250 nH Part Number 29–733–41
1000	adjusters Part Number 64–026–66
1000	coil formers Part Number 60–733–64
2000	clips Part Number 76–020–95

NEOSID

Inductor RM Cores
IEC RM 8



General Description

These RM inductor cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are supplied in pairs, gapped to A_L values specified in the Electrical Specification. If the gap is smaller than 0.2 mm, one half core is gapped and bears all the marking data, the other half is then not marked. If the total gap is greater than 0.2 mm, the gap is evenly distributed between the two half cores, one or both being marked. The marking indicates the A_L value and grade of ferrite. Manufacturing code marking can also be included, if requested.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	35.5 mm
Effective area of magnetic path	A_e	52 mm^2
Effective volume	V_e	1850 mm^3
$\sum \frac{l}{A}$	C_1	0.68 mm^{-1}

Electrical Specification

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective Permeability μ_e
29-791-	0.9	100 ± 3%	54
29-792-	0.55	160 ± 3%	86
29-793-	0.25	250 ± 3%	135
29-794-	0.2	315 ± 3%	170
29-795-	0.15	400 ± 3%	216
29-796-	0.1	630 ± 3%	341

The above A_L values are measured without the adjuster, while the pair of cores is subjected to a clamping force of 70 newtons.

The value of effective permeability μ_e cannot be directly measured and is calculated from the formula

$$\mu_e = 0.542 \ A_L \ (nH)$$

It should be noted that μ_e is not equal to the ratio of the inductance of the coil placed in the core assembly and the inductance of the same coil without core. Usually μ_e is about three times greater than the above ratio.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

where L is in mH,
A_L is in nH.

The use of the adjuster can only increase the value of A_L given in the Table, and the target value of A_L with the adjuster should be taken when calculating μ_e and n.

Material Ferrite P11 and P12

For electrical characteristics see page 28.

Material Code Numbers P11 – **41** P12 – **42**

Inductor RM Cores
IEC RM 8

Material Grade P11

Electrical Parameters for Core Assemblies

Parameter	Symbol	Frequency kHz	A_L Values nH					
			100	**160**	**250**	**315**	**400**	**630**
Effective Permeability	μ_e	10	54	86	135	170	216	341
Turns Factor (Turns for 1 mH)	α	–	100	79.06	63.24	56.34	50	39.84
Residual and Eddy Current Loss Tangent	$\tan \delta_{r+e}$	100	$<0.31 \times 10^{-3}$	$<0.50 \times 10^{-3}$	$<0.78 \times 10^{-3}$	$<0.98 \times 10^{-3}$	$<1.25 \times 10^{-3}$	$<1.95 \times 10^{-3}$
Hysterisis Loss Tangent $\Delta\hat{B} = 1.5$ mT	$\tan \delta_h$	10	$<0.07 \times 10^{-3}$	$<0.11 \times 10^{-3}$	$<0.18 \times 10^{-3}$	$<0.22 \times 10^{-3}$	$<0.29 \times 10^{-3}$	$<0.44 \times 10^{-3}$
Temperature Coefficient (ppm per °C) 25–55°C	α_L	10	29 to 85	47 to 136	73 to 215	92 to 270	117 to 341	185 to 538

NEOSID

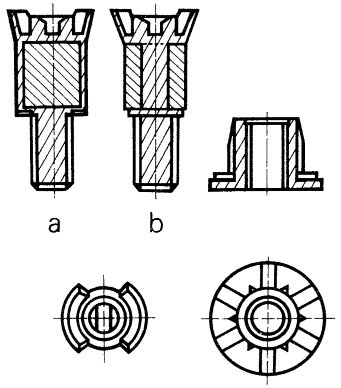
Inductor RM Cores
IEC RM 8

Material Grade P12

Electrical Parameters for Core Assemblies

Parameter	Symbol	Frequency kHz	A_L Values nH					
			100	**160**	**250**	**315**	**400**	**630**
Effective Permeability	μ_e	10	54	86	135	170	216	341
Turns Factor (Turns for 1 mH)	α	–	100	79.06	63.24	56.34	50	39.84
Residual and Eddy Current Loss Tangent	$\tan \delta_{r+e}$	100	$<0.20 \times 10^{-3}$	$<0.32 \times 10^{-3}$	$<0.51 \times 10^{-3}$	$<0.64 \times 10^{-3}$	$<0.81 \times 10^{-3}$	$<1.27 \times 10^{-3}$
Hysterisis Loss Tangent $\Delta\hat{B} = 1.5$ mT	$\tan \delta_h$	10	$<0.048 \times 10^{-3}$	$<0.078 \times 10^{-3}$	$<0.12 \times 10^{-3}$	$<0.15 \times 10^{-3}$	$<0.2 \times 10^{-3}$	$<0.3 \times 10^{-3}$
Temperature Coefficient (ppm per °C) 25–55°C	α_L	10	21 to 53	34 to 85	53 to 133	67 to 168	85 to 213	134 to 336

Inductor RM Cores
IEC RM 8



Type a A_L 100, 160
Type b A_L 250, 315, 400, 630

Adjustment

The adjustment system consists of a plastics splined nut and a plastics threaded adjuster, carrying a ferromagnetic sleeve. The dimensions and the material of the sleeve, listed in the Table, are chosen so as to produce a reasonably wide range of inductance adjustment, combined with an ease of accurate adjustment. If a wider range of adjustment is required, an adjuster specified in the Table for a higher A_L value can be used. Conversely, an adjuster corresponding in the Table to a lower A_L value can be used, if more accurate adjustment is desired, but the range of adjustment will then be reduced. Generally, any adjuster can be used for any A_L value.

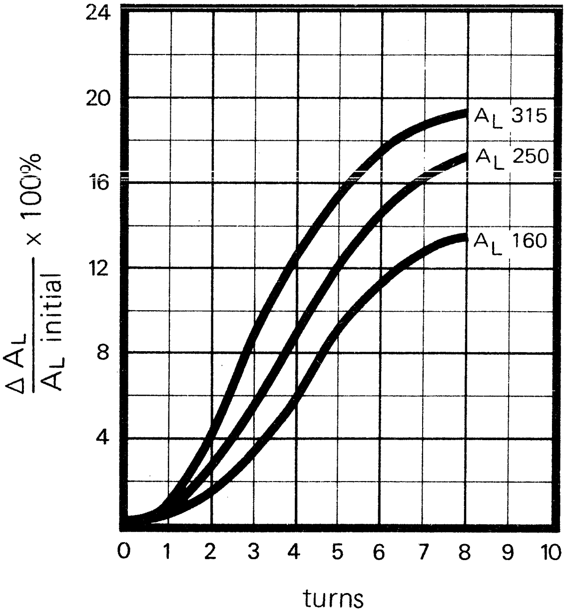
Adjuster Table

Adjuster Part Number	Sleeve Size diameter x length	Sleeve material grade	Used for A_L (nH)	Colour Code	Total adjustment range %	Number of turns
64–040–66	3.5 x 3.15	F22	100	Blue	20	8
64–041–66	3.5 x 3.8	P11	160	Black	12	8
64–042–66	3.85 x 4.3	P11	250	Yellow	15	8
64–043–66	4.1 x 4.3	P11	315	Red	18	8
64–044–66	4.13 x 5.7	P11	400	White	18	8
64–045–66	4.19 x 5.7	P11	630	Grey	14	8

The nut is supplied already fitted into the RM core.

Inductor RM Cores
IEC RM 8

The graphs illustrate the increase of the initial A_L value (without the adjuster) as a function of the effective adjuster turns, for various A_L values.



Inductance adjustment curves

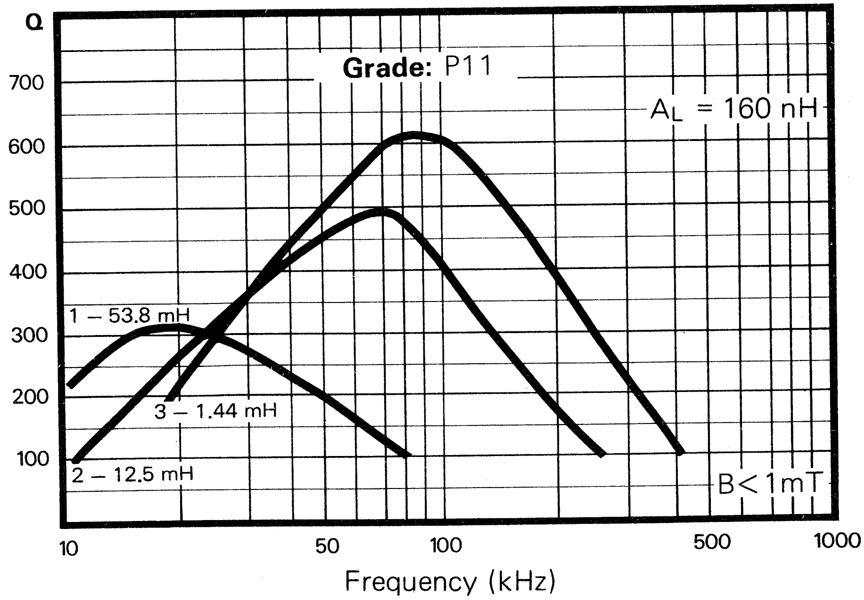
Inductor RM Cores
IEC RM 8

Typical curves of Q as a function of the frequency

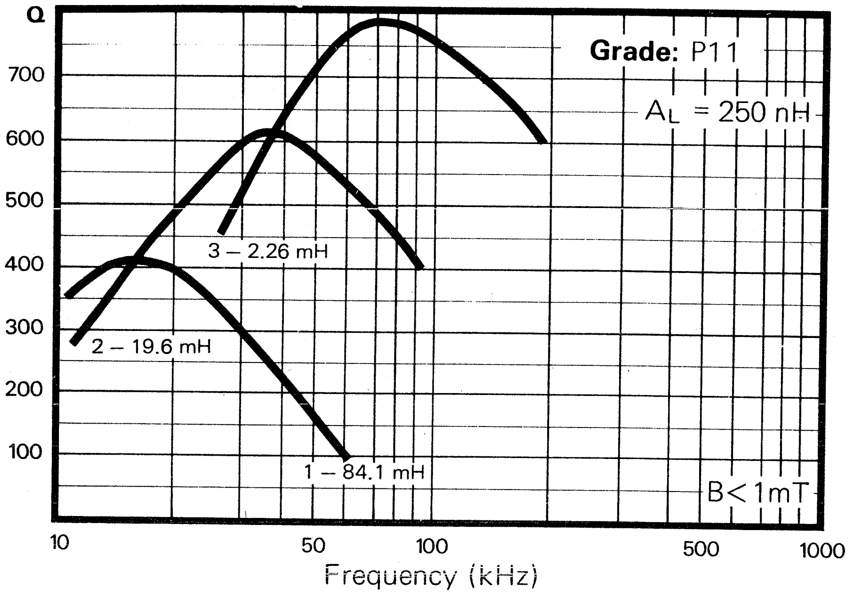
The graphs illustrate the values of Q easily obtainable. These curves are not intended to show the highest values of Q, obtainable by a careful choice of the number of turns and of the type of wire. The windings were chosen which seemed likely to represent practical extremes for the most popular A_L values.
The former was wound with a few turns of polystyrene tape, building up to less than 0.2mm thickness, before winding the coil, in order to reduce the disturbing influence of the fringe effects around the gap.

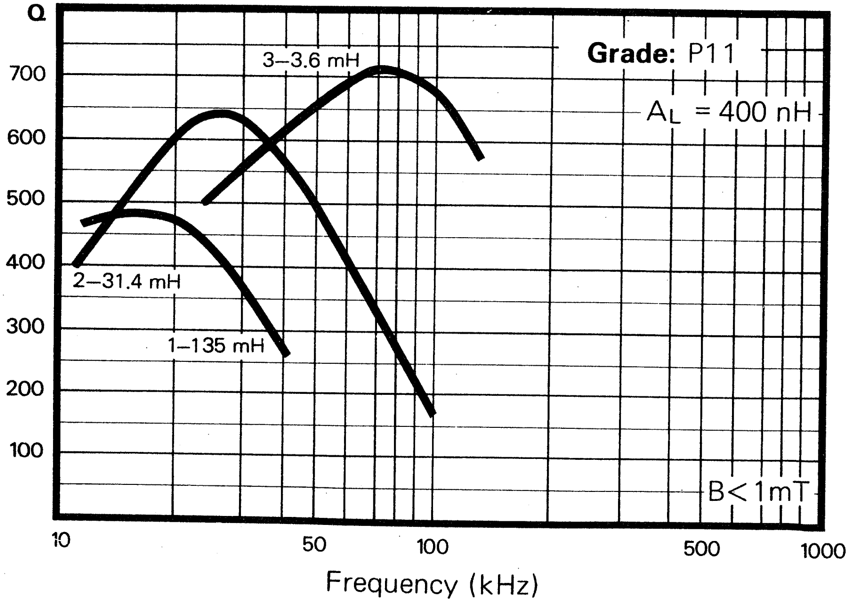
Winding data

1 – 580 turns, 0.2 EnCu wire
2 – 280 turns, 20 x 0.05 EnCu covered bunched wire
3 – 95 turns, 50 x 0.04 EnCu covered bunched wire



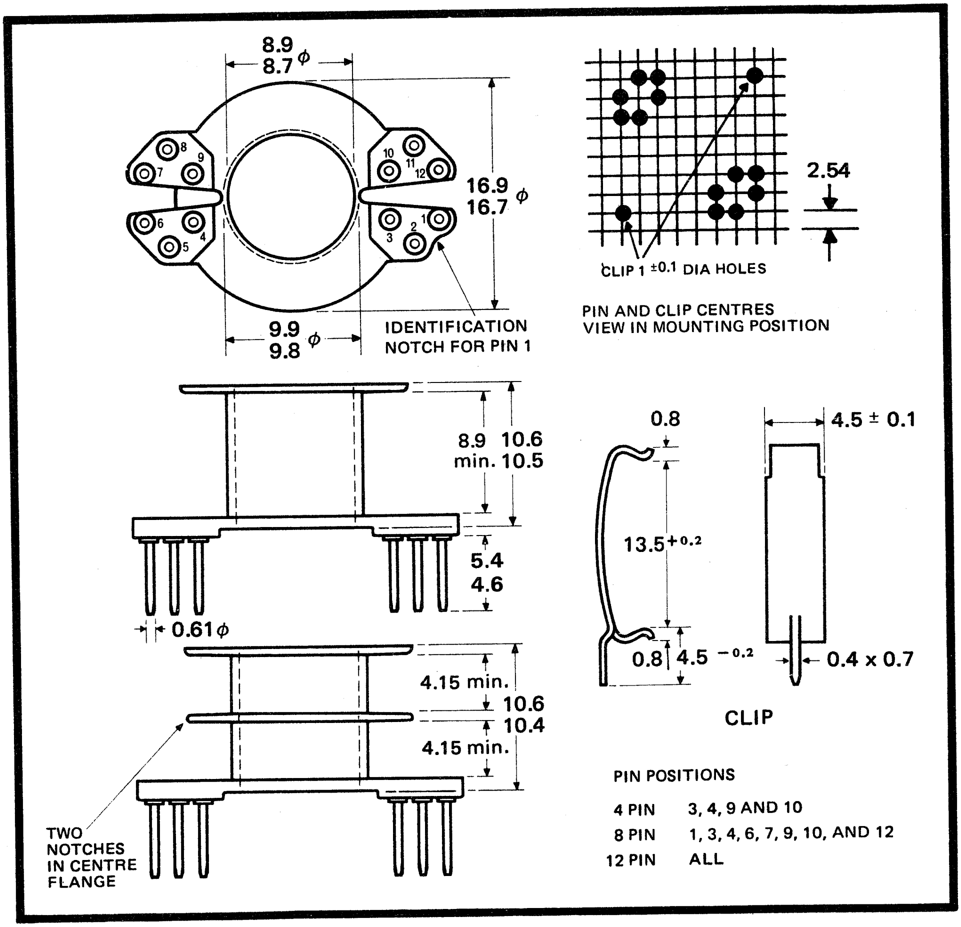
Inductor RM Cores
IEC RM 8





NEOSID

RM Core Former and Clip
IEC RM 8



PIN POSITIONS

4 PIN	3, 4, 9 AND 10
8 PIN	1, 3, 4, 6, 7, 9, 10, AND 12
12 PIN	ALL

Material

Former	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section 4 pin	**60-791-64**	2 Section 4 pin	**60-794-64**
	1 Section 8 pin	**60-792-64**	2 Section 8 pin	**60-795-64**
	1 Section 12 pin	**60-793-64**	2 Section 12 pin	**60-796-64**
Clip		**76-022-95**		

RM Core Former and Clip IEC RM 8

General Description

These formers comply with IEC Publication 431B and German Standard DIN 41981.
Pin and Clip solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400° C, 2 sec.
Pin configurations, other than those listed can be made available subject to special arrangements taking into account the quantities required.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

Number of Sections	Winding Area Per Section mm^2	Length of Mean Turn mm	A_R $\mu\Omega$
1 2	30 14	42	47 50

The length of the mean turn is given for a fully wound former. The value of the resistance factor, A_R, is calculated for a copper factor of 0.5, i.e. the sum of the cross sectional areas of all turns in a fully wound former equals one half of the available winding space. If the anticipated copper factor is different from 0.5, the value of A_R must be changed; A_R is inversely proportional to the copper factor.
The DC resistance of the winding is $A_R.n^2$ in $\mu\Omega$, where n is the number of turns. This is an approximate value intended only for use in preliminary design evaluations.

Inductor RM Cores
IEC RM 8

Ordering Information (example)

To order 1000 complete RM8 inductor core assemblies in grade P11 with an A_L value of 160 nH and single section 8 pin formers; the details are as follows:

1000	RM8 inductor cores (pairs) A_L = 160 nH Part Number 29–792–41
1000	adjusters Part Number 64–041–66
1000	coil formers Part Number 60–792–64
2000	clips Part Number 76–022–95

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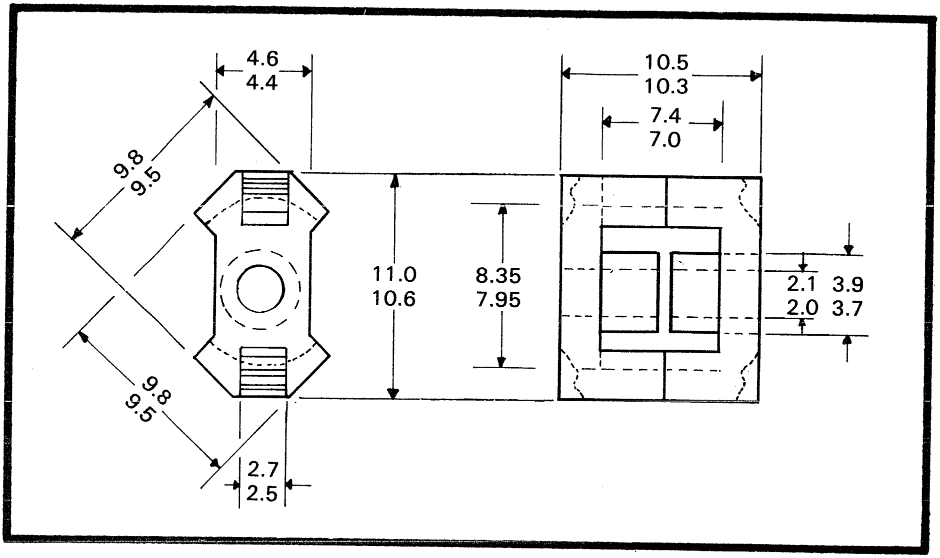
Transformer RM Cores
IEC RM 4



General Description

These transformer cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are normally supplied without gap but can be supplied gapped to a specified A_L value as shown overleaf.

All information below is given for a pair of RM cores.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	l_e	21.0 mm
Effective area of magnetic path	A_e	11.0 mm²
Effective volume	V_e	232 mm³
$\sum \frac{l}{A}$	C_1	1.9 mm^{-1}

Transformer RM Cores
IEC RM 4

Electrical Specification

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective permeability μ_e
29–901–41	0.16	63 ± 3%	95
29–902–41	0.10	100 ± 3%	154
29–903–41	0.06	160 ± 3%	242
29–904–41	0.04	250 ± 3%	378
29–900–41*	Zero	650 min	980 min
29–900–36*	Zero	1390 min	2100 min

* These part numbers refer to single half cores

The above A_L values are measured while the pair of cores is subjected to a clamping force of 40 newtons.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000\sqrt{\frac{L}{A_L}}$$

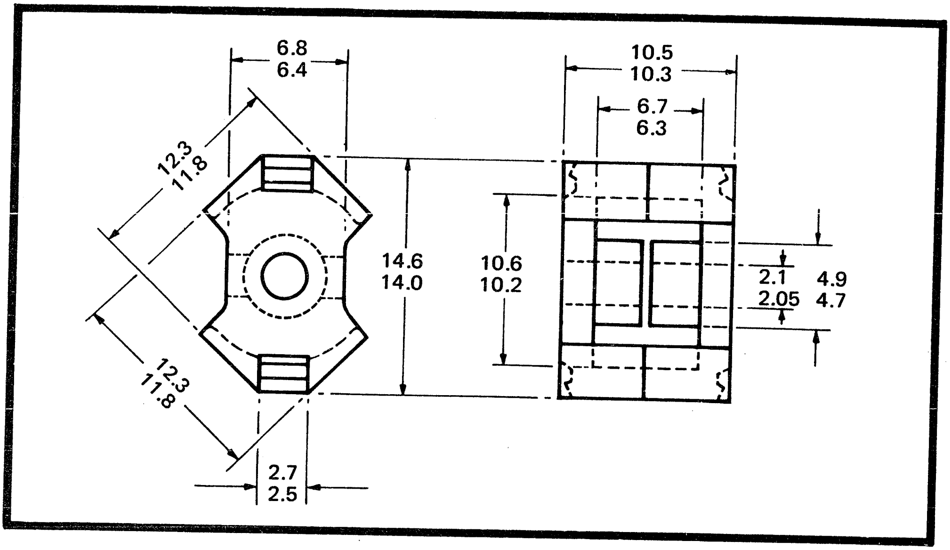
where L is in mH,
A_L is in nH.

Material Codes are

P11 – **41**
F9 – **36**
For electrical characteristics see pages 27 and 28.

NEOSID

Transformer RM Cores
IEC RM 5



General Description

These transformer cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are normally supplied without gap but can be supplied gapped to a specified A_L value as shown.

All information below is given for a pair of RM cores.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	l_e	20.8 mm
Effective area of magnetic path	A_e	20.8 mm^2
Effective volume	V_e	430 mm^3
$\sum \frac{l}{A}$	C_1	1.0 mm^{-1}

Transformer RM Cores
IEC RM 5

Electrical Specification

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective Permeability μ_e
29–711–41	0.18	100 ± 3%	80
29–712–41	0.12	160 ± 3%	128
29–713–41	0.06	250 ± 3%	200
29–714–41	0.03	315 ± 5%	255
29–700–41*	Zero	1470 min	1170 min
29–700–36*	Zero	2560 min	2040 min
29–700–37*	Zero	3840 min	3060 min

*These part numbers refer to single half cores.

The above A_L values are measured while the pair of cores is subjected to a clamping force of 40 newtons.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

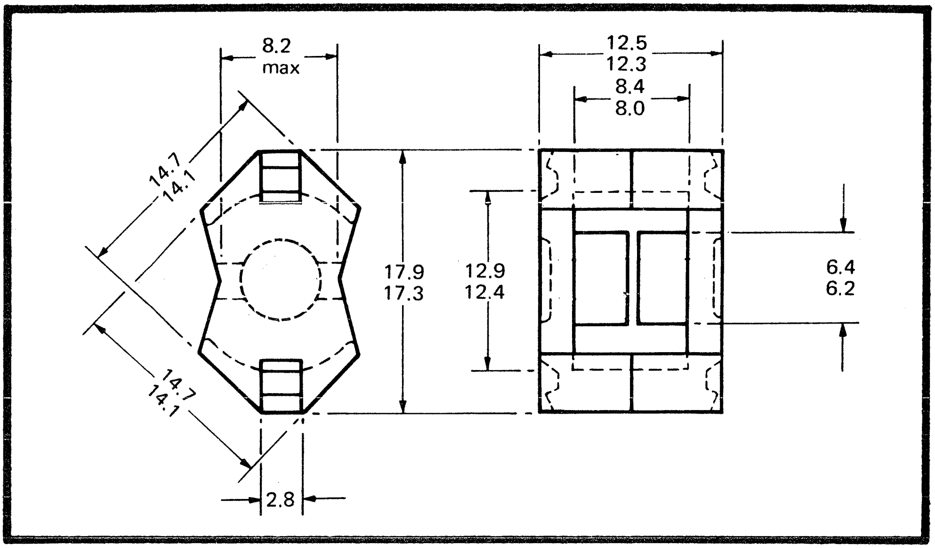
where L is in mH,
A_L is in nH.

Material Codes are

P11 – **41**
F9 – **36**
F10 – **37**
For electrical characteristics see pages 27 and 28.

NEOSID

Transformer RM Cores
IEC RM 6



General Description

These transformer cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are normally supplied without gap but can be supplied gapped to a specified A_L value as shown.

All information below is given for a pair of RM cores.

Effective Geometric Parameters

Parameter	Symbol	Value	
		with centre hole	without centre hole
Effective magnetic path length	l_e	27 mm	29 mm
Effective area of magnetic path	A_e	31 mm^2	37 mm^2
Effective volume	V_e	840 mm^3	1090 mm^3
$\sum \frac{l}{A}$	C_1	0.87 mm^{-1}	0.78 mm^{-1}

Transformer RM Cores
IEC RM 6

Electrical Specification (with centre hole)

Part Number	Total approximate air gap (min)	A_L (nH)	Nominal effective Permeability μ_e
29–741–41	0.5	100 ± 3%	69
29–742–41	0.2	160 ± 3%	111
29–743–41	0.11	250 ± 5%	173
29–744–41	0.08	315 ± 5%	218
29–745–41	0.05	400 ± 5%	277
29–730–41*	Zero	1600 min	1100 min

Electrical Specification (without centre hole)

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal Effective permeability μ_e
29–751–25	0.5	100 ± 3%	62
29–752–25	0.2	160 ± 3%	99
29–753–25	0.11	250 ± 5%	155
29–754–25	0.08	315 ± 5%	197
29–755–25	0.05	400 ± 5%	248
29–750–25*	Zero	1800 min	1120 min
29–750–36*	Zero	3440 min	2140 min
29–750–37*	Zero	4960 min	3080 min

*These part numbers refer to single half cores.

The above A_L values are measured while the pair of cores is subjected to a clamping force of 50 newtons.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000\sqrt{\frac{L}{A_L}}$$

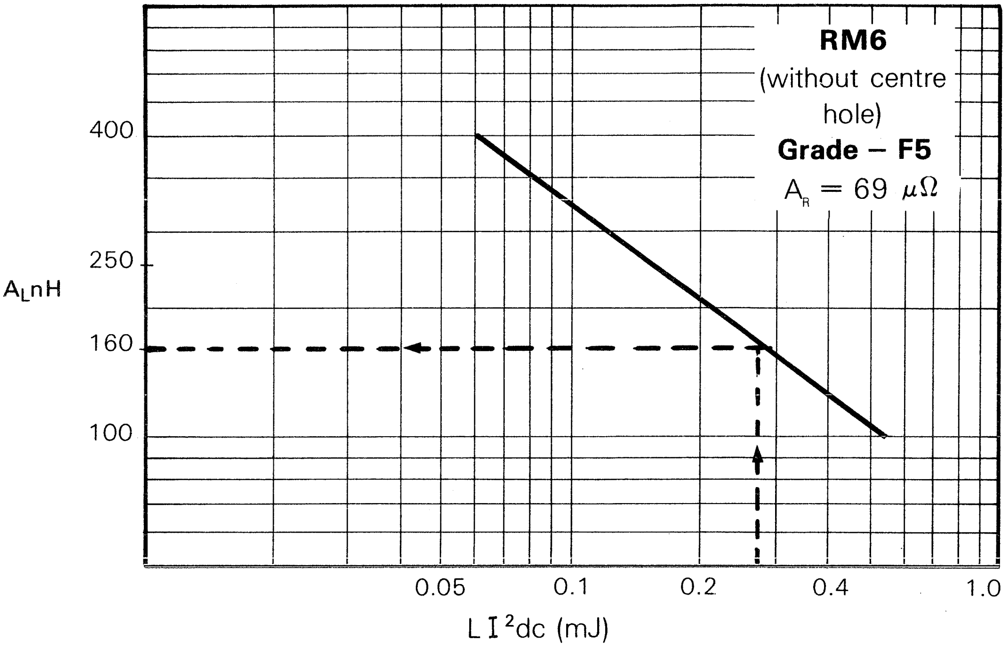
where L is in mH,
A_L is in nH.

Material Codes are

P11 – **41** F9 – **36**
F5 – **25** F10 – **37**
For electrical characteristics see pages 27 and 28.

NEOSID

Transformer RM Cores
IEC RM 6



Design of Inductors carrying d.c. (energy storage chokes)

Design example

$L = 0.25$ mH
$I_{dc} = 1$ amp.

1. Calculate LI^2_{dc}

   $= 0.25 \times 1 = 0.25$ mJ
2. Read A_L corresponding to 0.25 mJ
3. Select the nearest standard A_L value
4. Calculate number of turns

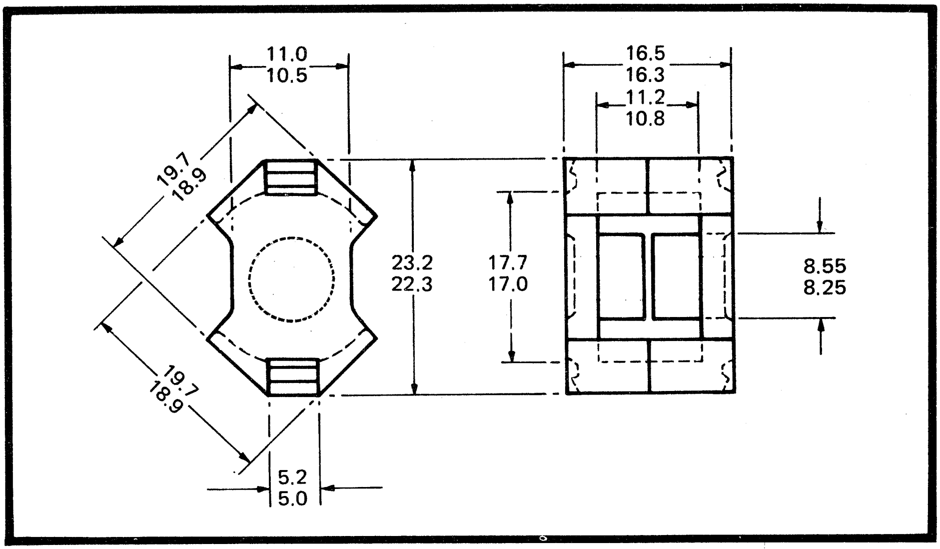
   $$N = 10^3 \cdot \sqrt{\frac{L\ \text{mH}}{A_L}}$$

   $$= 10^3 \sqrt{\frac{0{:}25}{160}} = 40 \text{ turns}$$
5. Calculate $R_{dc} = A_R \times N^2$

   $= (69 \times 1600)\ 10^{-6}$

   $= 0.11$ ohms (approx.)

Transformer RM Cores
IEC RM 8



General Description

These transformer cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are normally supplied without gap but can be supplied gapped to a specified A_L value as shown.

All information below is given for a pair of RM cores.

Effective Geometric Parameters

Parameter	Symbol	Value	
		with centre hole	without centre hole
Effective magnetic path length	ℓ_e	35.5 mm	38 mm
Effective area of magnetic path	A_e	52 mm^2	64 mm^2
Effective volume	V_e	1850 mm^3	2430 mm^3
$\sum \frac{l}{A}$	C_1	0.68 mm^{-1}	0.59 mm^{-1}

NEOSID

Transformer RM Cores
IEC RM 8

Electrical Specification (with centre hole)

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective Permeability μ_e
29–801–41	0.9	100 ± 3%	54
29–802–41	0.55	160 ± 3%	86
29–803–41	0.25	250 ± 5%	135
29–804–41	0.2	315 ± 5%	170
29–805–41	0.15	400 ± 5%	216
29–806–41	0.1	630 ± 5%	341
29–790–41*	Zero	2000 min	1060

Electrical Specification (without centre hole)

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal Effective permeability μ_e
29–811–25	1.5	100 ± 3%	40
29–812–25	0.9	160 ± 3%	64
29–813–25	0.55	250 ± 5%	100
29–814–25	0.28	315 ± 5%	125
29–815–25	0.21	400 ± 5%	160
29–816–25	0.13	630 ± 5%	250
29–810–25*	Zero	2400 min	1120 min
29–810–36*	Zero	4560 min	2140 min
29–810–37*	Zero	6700 min	3150 min
29–810–45*	Zero	3200 min	1500 min

*These part numbers refer to single half cores.

The above A_L values are measured while the pair of cores is subjected to a clamping force of 70 newtons.

Number of turns

The number of turns required for an inductance L is calculated from the formula

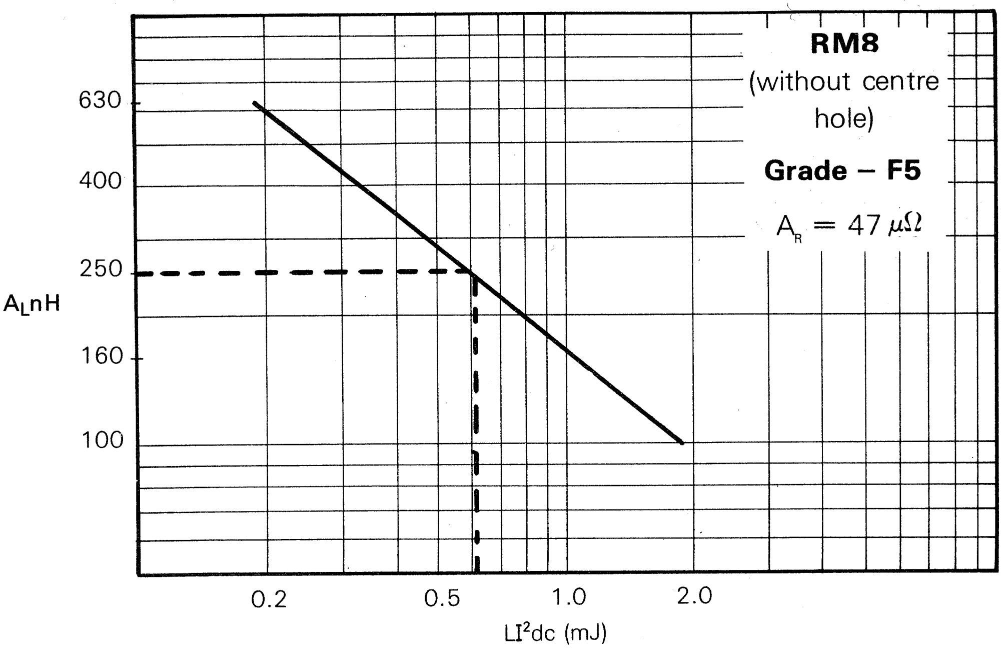
$$n = 1000\sqrt{\frac{L}{A_L}} \qquad \text{where } L \text{ is in mH, } A_L \text{ is in nH.}$$

Material codes are

P11 – **41** F4 – **45** F5 – **25** F9 – **36** F10 – **37**

NEOSID

Transformer RM Cores
IEC RM 8



Design of Inductors carrying d.c. (energy storage chokes)

Design example

$L = 2.5$ mH
$I_{dc} = 0.5$ amps.

1. Calculate $L\,I^2_{dc}$

   $= 2.5 \times 0.25 = 0.63$ mJ

2. Read A_L corresponding to 0.63 mJ

3. Select the nearest standard A_L value

4. Calculate number of turns

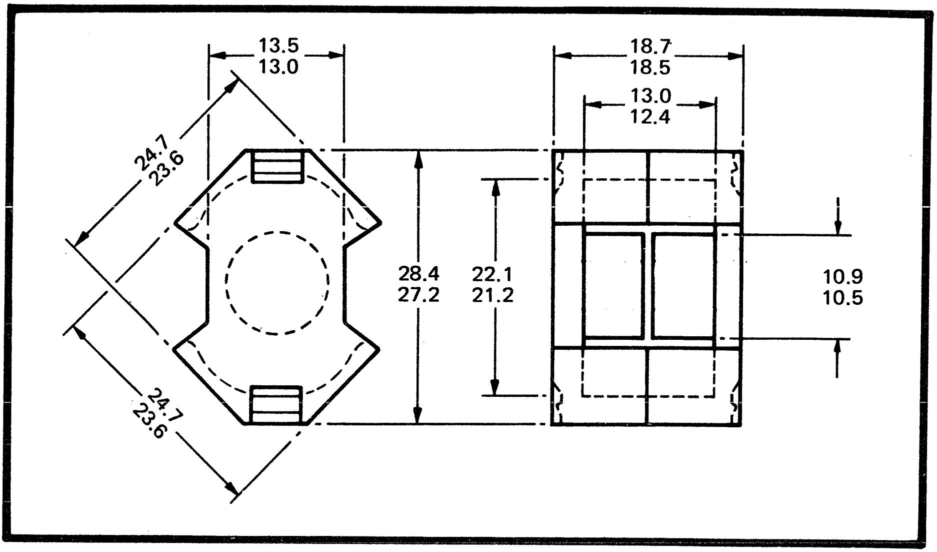
   $$N = 10^3\sqrt{\frac{L\ \text{mH}}{A_L}}$$

   $$= 10^3\sqrt{\frac{2.5}{250}} = 100 \text{ turns}$$

5. Calculate Rdc $= A_R \times N^2$
   $= (47 \times 10^4)\ 10^{-6}$
   $= 0.5$ ohms (approx.)

NEOSID

Transformer RM Cores
IEC RM 10



General Description

These transformer cores comply with IEC Publication 431 and German Standard DIN 41980.

Cores are normally supplied without gap but can be supplied gapped to a specified A_L value as shown.

All information below is given for a pair of RM cores.

Effective Geometric Parameters

Parameter	Symbol	Value	
		with centre hole	without centre hole
Effective magnetic path length	ℓ_e	42 mm	44 mm
Effective area of magnetic path	A_e	83 mm^2	98 mm^2
Effective volume	V_e	3470 mm^3	4310 mm^3
$\sum \frac{l}{A}$	C_1	mm^{-1}	0.45 mm^{-1}

Transformer RM Cores
IEC RM 10

Electrical Specification (with centre hole)

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective Permeability μ_e
29–831–41	1.5	100 ± 3%	40
29–832–41	0.9	160 ± 3%	64
29–833–41	0.55	250 ± 5%	100
29–834–41	0.28	315 ± 5%	125
29–835–41	0.21	400 ± 5%	160
29–836–41	0.13	630 ± 5%	250
29–830–41*	Zero	3170 min	1260 min

Electrical Specification (without centre hole)

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal Effective permeability μ_e
29–861–25	1.5	100 ± 3%	36
29–862–25	0.9	160 ± 3%	57
29–863–25	0.55	250 ± 5%	90
29–864–25	0.28	315 ± 5%	115
29–865–25	0.21	400 ± 5%	143
29–866–25	0.13	630 ± 5%	225
29–850–25*	Zero	3200 min	1150 min
29–850–36*	Zero	6100 min	2185 min
29–850–37*	Zero	8800 min	3150 min
29–850–45*	Zero	4300 min	1540 min

*These part numbers refer to single half cores.

The above A_L values are measured while the pair of cores is subjected to a clamping force of 100 newtons.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

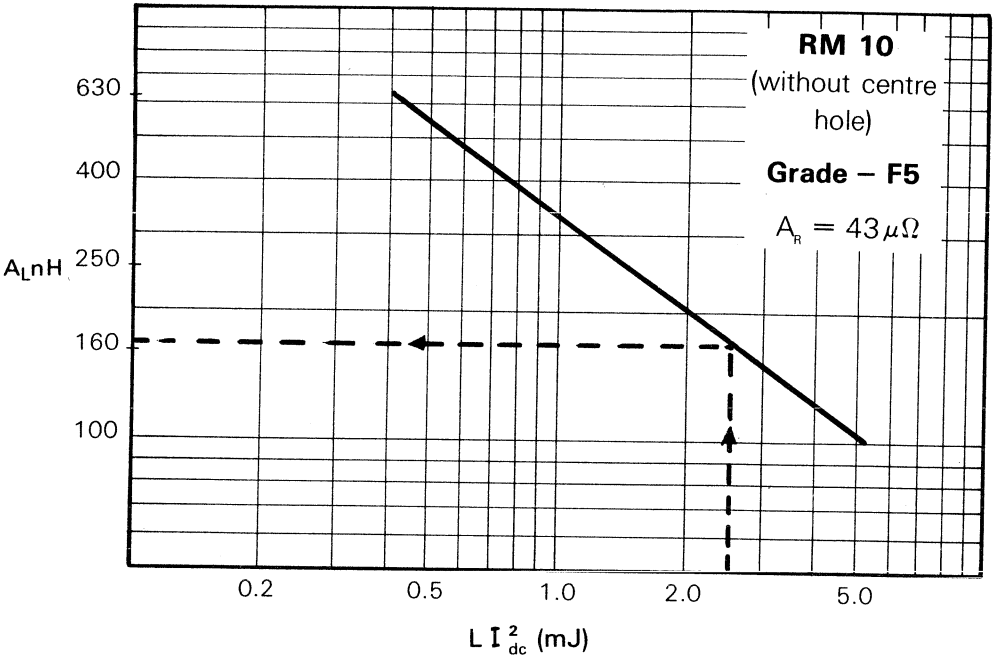
where L is in mH,
A_L is in nH.

Material codes are

P11 – **41** F4 – **45** F5 – **25** F9 – **36** F10 – **37**
(For electrical characteristics see pages 27 and 28).

NEOSID

Transformer RM Cores
IEC RM 10



Design of Inductors carrying d.c. (energy storage chokes)

Design example

$L = 0.1$ mH
$I_{dc} = 5$ amps.

1. Calculate $L I_{dc}^2$

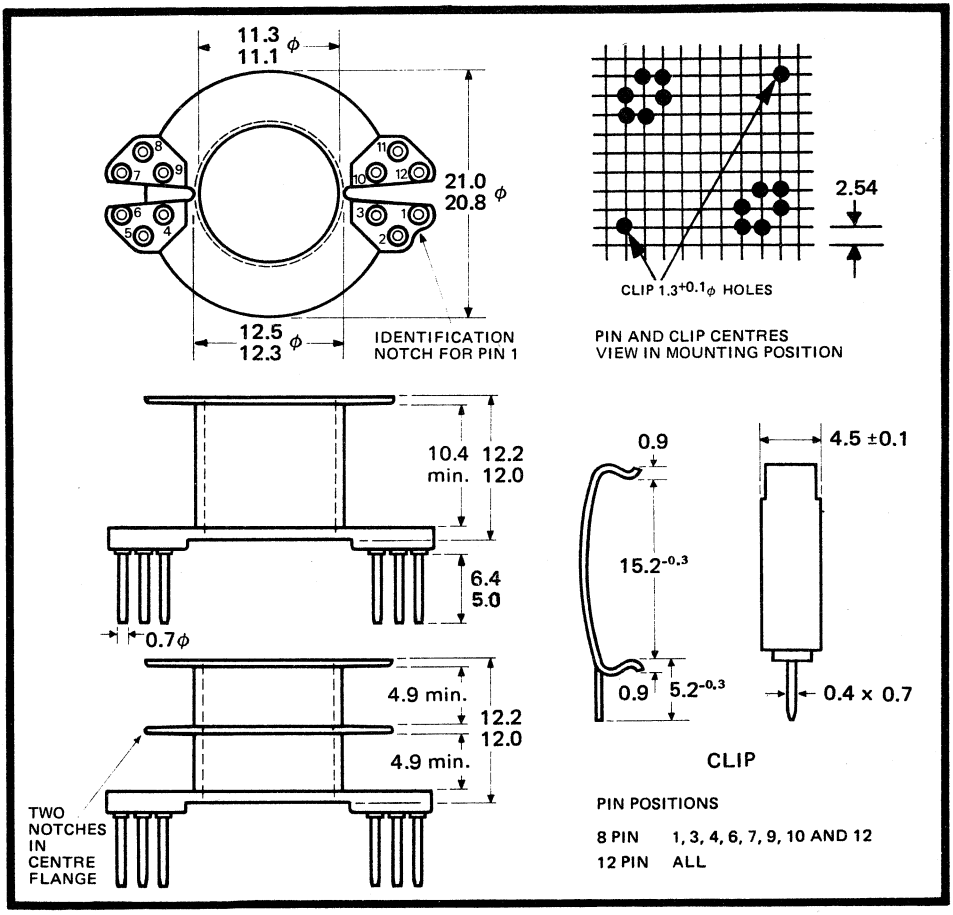
   $= 0.1 \times 25 = 2.5$ mJ
2. Read A_L corresponding to 2.5 mJ
3. Select the nearest standard A_L value
4. Calculate number of turns

   $$N = 10^3 \sqrt{\frac{L\ \text{mH}}{A_L}}$$

   $$= 10^3 \sqrt{\frac{0.1}{160}} = 25 \text{ turns}$$
5. Calculate $\text{Rdc} = A_R \times N^2$
   $= (43 \times 625) 10^{-6}$
   $= 0.027$ ohms.

NEOSID

RM Core Former and Clip
IEC RM 10



Material

Former	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section 8 pin	**60-822-64**	2 Section 8 pin	**60-825-64**
	1 Section 12 pin	**60-823-64**	2 Section 12 pin	**60-826-64**
Clip		**76-023-95**		

NEOSID

RM Core Former and Clip
IEC RM 10

General Description

These formers comply with IEC Publication 431B and German Standard DIN 41981.

Pin and Clip solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400°C, 2 sec.

Pin configurations, other than those listed can be made available subject to special arrangements taking into account the quantities required.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

Winding Data

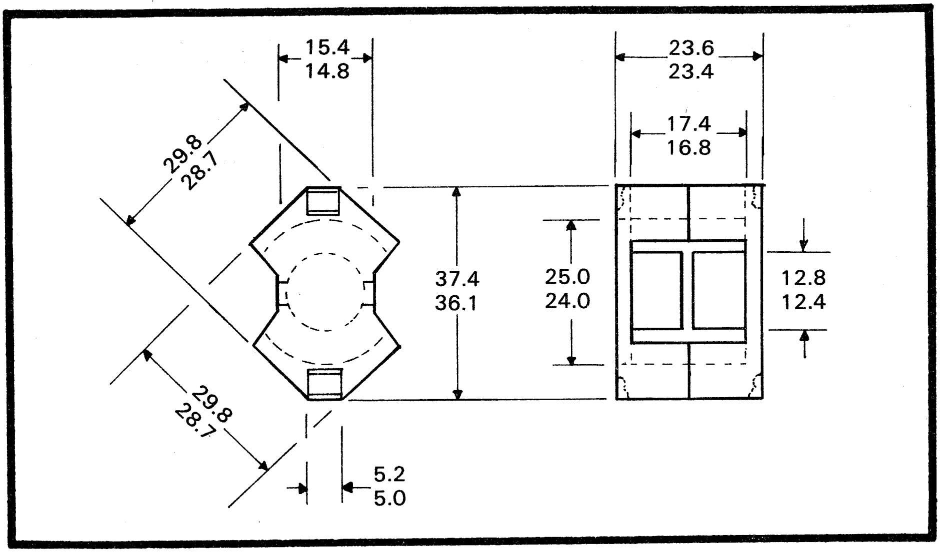
Number of Sections	Winding Area Per Section mm^2	Length of Mean Turn mm	A_R $\mu\Omega$
1	41.5	52	43
2	19.5		46

The length of the mean turn is given for a fully wound former. The value of the resistance factor, A_R, is calculated for a copper factor of 0.5, i.e. the sum of the cross sectional areas of all turns in a fully wound former equals one half of the available winding space. If the anticipated copper factor is different from 0.5, the value of A_R must be changed; A_R is inversely proportional to the copper factor.

The DC resistance of the winding is $A_R . n^2$ in $\mu\Omega$, where n is the number of turns. This is an approximate value intended only for use in preliminary design evaluations.

NEOSID

Transformer RM Cores
RM 12



Effective Geometric Parameters

All information below is given for a pair of RM cores.

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	56.9 mm
Effective area of magnetic path	A_e	140 mm^2
Effective volume	V_e	7960 mm^3
$\sum\frac{l}{A}$	C_1	0.40 mm^{-1}

Electrical Specification (ungapped cores)

Part Number	Material Grade	Air Gap	A_L value (nH) Min.	Minimum effective permeability μ_e
29–930–25	F5	Zero	3500	1120
29–930–36	F9	Zero	6720	2140
29–936–37	F10	Zero	9840	3130

The part numbers listed in the Table refer to a single half core.

Transformer RM Cores
RM 12

Electrical Specification (gapped cores)

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective permeability μ_e
29–931–	1.5	160 ± 3%	51
29–932–	0.9	250 ± 3%	80
29–933–	0.5	400 ± 5%	127
29–934–	0.28	630 ± 5%	200
29–935–	0.14	1000 ± 5%	320

The above A_L values are measured while the pair of cores is subjected to a clamping force of 120 newtons.

Number of turns

The number of turns required for an inductance L is calculated from the formula

$$n = 1000 \sqrt{\frac{L}{A_L}}$$

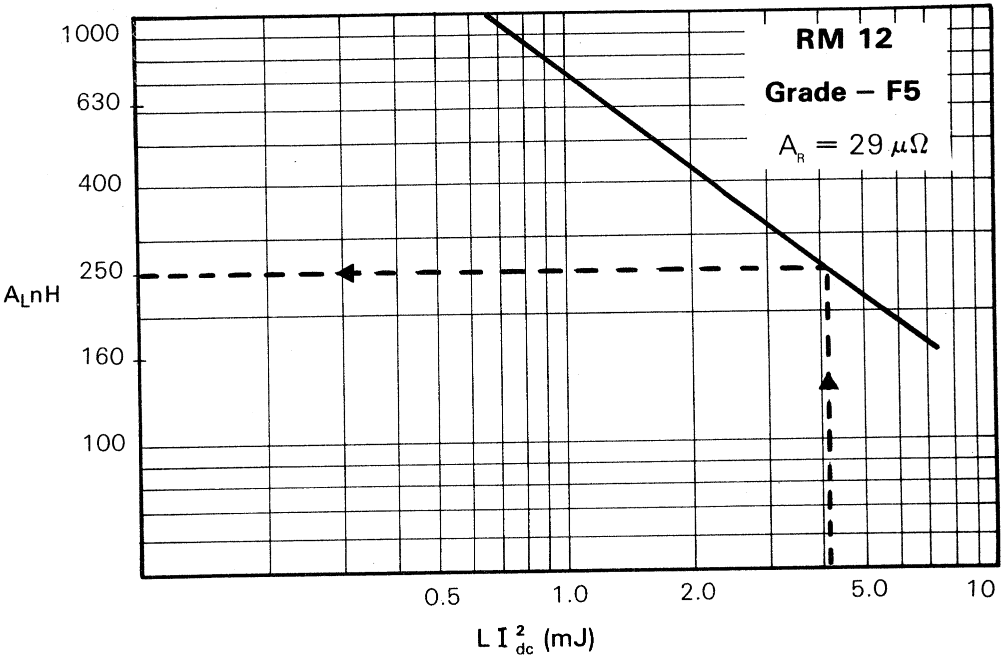
where L is in mH,
A_L is in nH.

Material codes are

F5 – **25**
F9 – **36**
F10 – **37**

(For electrical characteristics see pages 27 and 28).

Transformer RM Cores
RM 12



Design of Inductors carrying d.c. (energy storage chokes)

Design example

$L = 0.1$ mH
$I_{dc} = 6.5$ amps.

1. Calculate $L\,I_{dc}^2$

   $= 0.1 \times 42.25 = 4.3$ mJ

2. Read A_L corresponding to 4.3 mJ
3. Select the nearest A_L value
4. Calculate number of turns

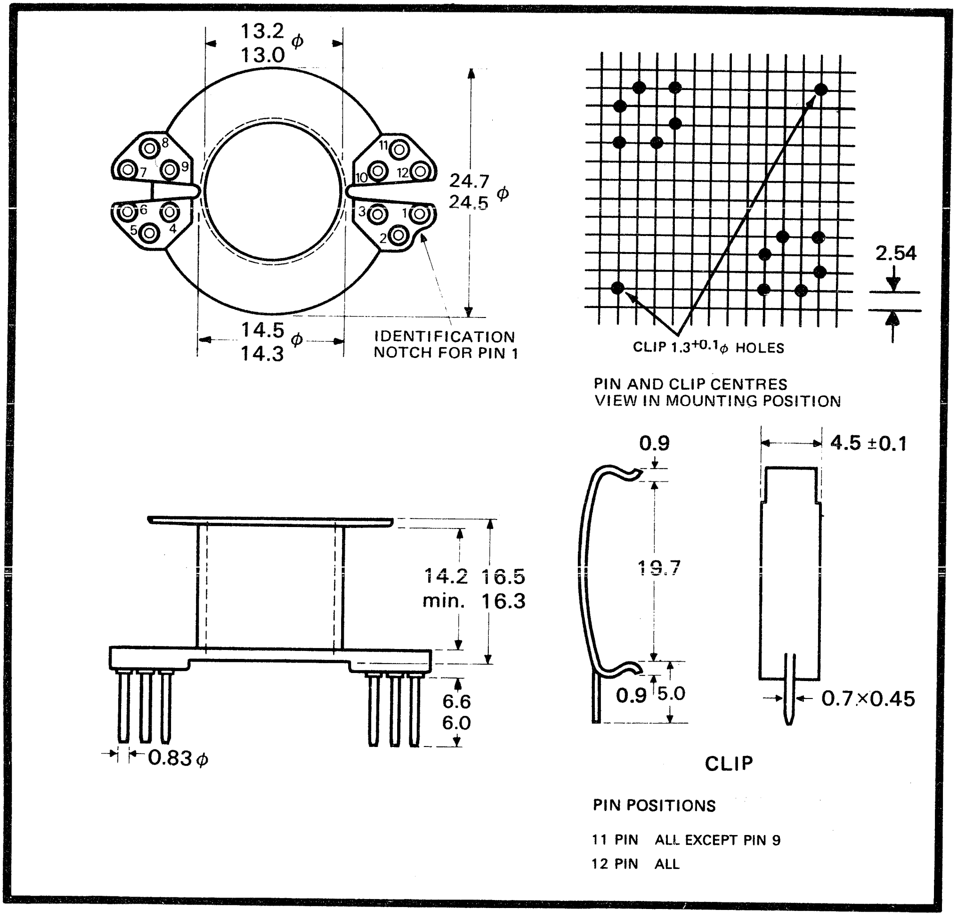
   $$N = 10^3 \sqrt{\frac{L\ \text{mH}}{A_L}}$$

   $$= 10^3 \sqrt{\frac{0.1}{250}} = 20 \text{ turns}$$

5. Calculate $R_{dc} = A_R \times N^2$
   $= (29 \times 400)10^{-6}$
   $= 0.017$ ohms.

NEOSID

RM Core Former and Clip
RM 12



PIN POSITIONS

11 PIN	ALL EXCEPT PIN 9
12 PIN	ALL

Material

Former	G.P. Phenolic glass filled.
Clip	Spring steel hot tin dipped.

Part Numbers

Former	1 Section 11 pin	**60-931-64**
	1 Section 12 pin	**60-930-64**
Clip		**76-030-95**

NEOSID

RM Core Former and Clip
RM 12

General Description

Pin and Clip solderability to BS2011 Part 2T and IEC 68-2-20B Part 2 test T. Former, maximum soldering temperature 400° C, 2 sec.
Pin configurations, other than those listed can be made available subject to special arrangements taking into account the quantities required.

Dimensional Data

Only those dimensions that determine the assembly and winding of the former are given. Other dimensions and/or complete drawings can be supplied on request.

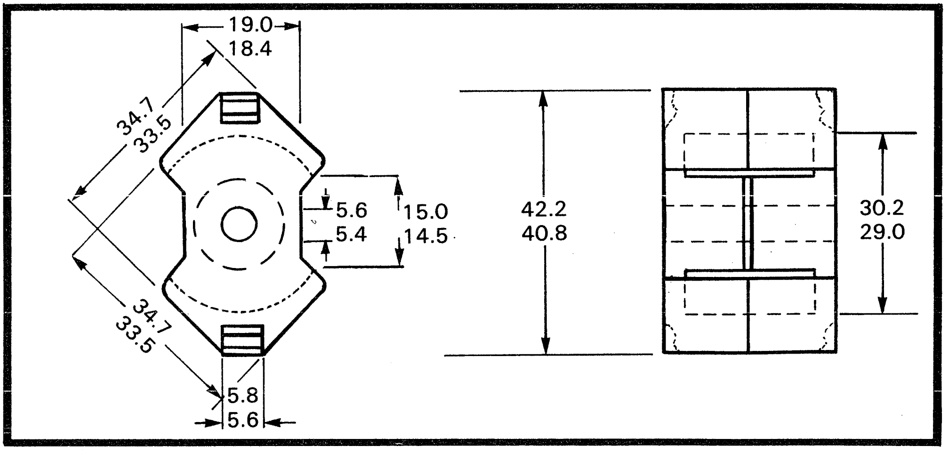
Winding Data

Winding Area mm²	Length of mean turn mm	A_R $\mu\Omega$
74	60	29

The length of the mean turn is given for a fully wound former. The value of the resistance factor, A_R, is calculated for a copper factor of 0.5, i.e. the sum of the cross sectional areas of all turns in a fully wound former equals one half of the available winding space. If the anticipated copper factor is different from 0.5, the value of A_R must be changed; A_R is inversely proportional to the copper factor.
The DC resistance of the winding is $A_R . n^2$ in $\mu\Omega$, where n is the number of turns. This is an approximate value intended only for use in preliminary design evaluations.

NEOSID

Transformer RM Cores
IEC RM 14



General Description

These RM transformer cores comply with IEC Publication 431 and German Standard DIN 41980. All information is given for a pair of RM cores.

Effective Geometric Parameters

Parameter	Symbol	Value
Effective magnetic path length	ℓ_e	71 mm
Effective area of magnetic path	A_e	178 mm^2
Effective volume	V_e	12600 mm^3
$\sum \frac{\ell}{A}$	C_1	0.40 mm^{-1}

Electrical Specification

Part Number	Total approximate air gap (mm)	A_L (nH)	Nominal effective Permeability μ_e
29-880-25*	-NIL-	3600 (min)	1140 min
29-886-25	1.9	160 ± 3%	51
29-881-25	1.0	250 ± 3%	80
29-882-25	0.50	400 ± 3%	127
29-883-25	0.30	630 ± 3%	201
29-884-25	0.15	1000 ± 3%	318

* This part number refers to a single half core.

Transformer RM Cores
IEC RM 14

Parameter	Symbol	Test Frequency	Flux Density mT	Value.
Amplitude permeability(25° C)	μ_a	50 Hz	400	>1250
" " (100° C)		50 Hz	320	>1250
Effective total core loss (60°C)	P	25 KHz	200	2.5 W
" " " " (100° C)		25 KHz	200	2.5 W

Material

Ferrite F5

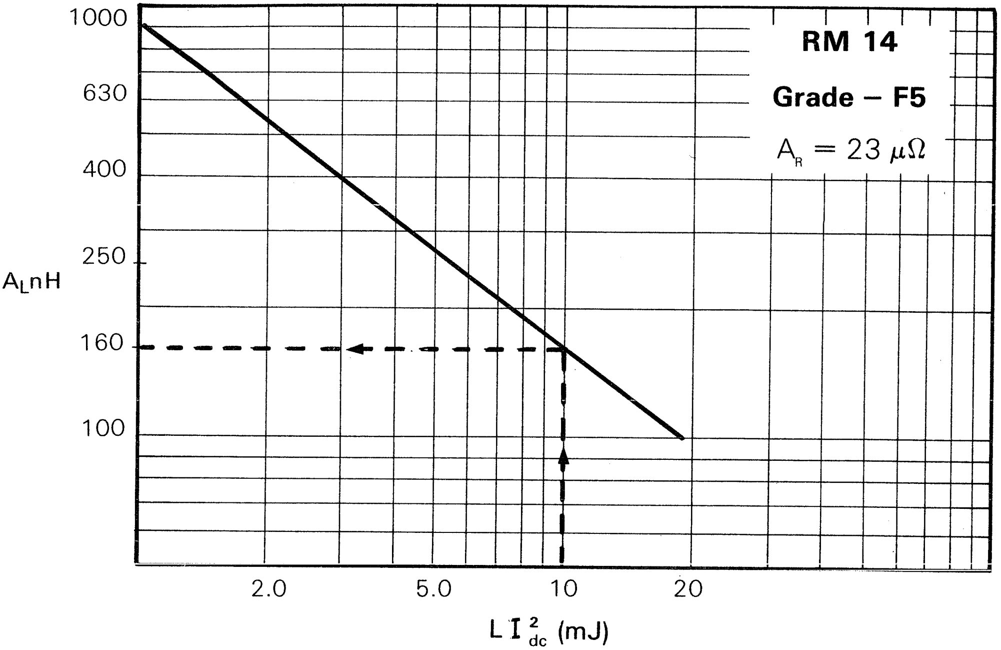
(For electrical characteristics see page 27).

Part Numbers

As given under electrical specification.

NEOSID

Transformer RM Cores
IEC RM 14



Design of Inductors carrying d.c. (energy storage chokes)

Design example

$L = 0.1$ mH
$I_{dc} = 10$ amps.

1. Calculate LI_{dc}^2

   $= 0.1 \times 100 = 10$ mJ
2. Read A_L corresponding to 10 mJ
3. Select the nearest standard A_L value
4. Calculate number of turns

   $$N = 10^3 \sqrt{\frac{L\ \mathrm{mH}}{A_L}}$$

   $$= 10^3 \sqrt{\frac{0.1}{160}} = 25 \text{ turns}$$
5. Calculate $R_{dc} = A_R \times N^2$

   $= (25 \times 625)10^{-6}$
   $= 0.016$ ohms (approx.)

NEOSID

Iron Powder Materials Characteristics and Applications

Characteristics of Iron Powder Materials

Iron powder cores are pressed from very fine carbonyl iron mixed with a bonding material. High resistivity is required to reduce the eddy current losses and for this purpose the iron powder is subjected to an acid treatment to produce an insulating oxide layer on the surface of each individual particle. An unfortunate corollary is that minute gaps appear between the particles and the permeability of the material is severely reduced, the highest obtainable value being approximately 30. Because of these gaps it is difficult to saturate iron powder cores, especially those operating in an open magnetic circuit.

The optimum frequency ranges and initial permeabilities of the grades of iron powder are given overleaf.

The frequency range for which a particular grade of material is the most suitable depends upon the application, the shape of the core and the configuration of the magnetic circuit. For optimum values of Q the frequency range is clearly indicated. In untuned conditions, for example, suppressor and transformer applications, individual grades of iron powder are successfully used well above the frequency limits indicated.

TABLE 4
Iron Powder Materials

Parameter	Symbol	Standard Conditions of Test	Unit	100	500	900	901	910
Initial Permeability (typical)	μ_i	B →0 25°C	—	22	12	10	5	4.5
Loss Factor (typical)	$\frac{\tan \delta_{r+e}}{\mu_i}$	B →0 25°C 100 kHz	10^{-6}	400	—	—	—	—
		1 MHz		600	70	50	—	—
		2 MHz		800	80	60	160	210
		10 MHz		—	250	130	200	220
		50 MHz		—	—	600	700	230
		100 MHz		—	—	—	2000	240
Temperature Factor (typical)	$\frac{\Delta \mu}{\mu_i^2 \cdot \Delta T}$	B<0.25 mT +25°C to +55°C	10^{-6}/°C	20	12	12	12	50

Characteristics and Applications

All figures in Table 4 were derived from measurements on toroids, the loss factors (residual plus eddy current) being determined by winding the test toroids with a number of turns suitable for the required frequency and measuring at a low flux density. The temperature factors of permeability were measured between 25 and 55°C.

For inductances wound on toroids, the value of Q obtainable at any frequency with a 'lossless' winding is;

$$Q = \frac{10^6}{\mu_i \,.\, \text{loss factor}}$$

Similarly, the value of the temperature coefficient of inductance per °C is,

Temperature coefficient
$= \mu_i \,.\, \text{temperature factor}. \ 10^{-6}$ per °C.

There is no simple formula for predicting the value of Q or the temperature coefficient of inductors using iron powder cores in open magnetic configurations.

The values given in Table 4 are approximate only, as in each case the characteristics of the core depend upon the manufacturing conditions. These conditions have to be adapted to achieve not only the desired electrical characteristics but also the required mechanical strength.

Applications

Grade 100 is used in permeability tuners and pot cores and, generally, whenever high permeability is one of the main considerations.

Grade 500 is the most popular grade for tuned applications up to frequencies of 10 MHz or higher, if optimum values of Q are not particularly important.

Grade 900 is used to obtain values of Q higher than those obtainable with grade 500 at frequencies between 5 and 60 MHz.

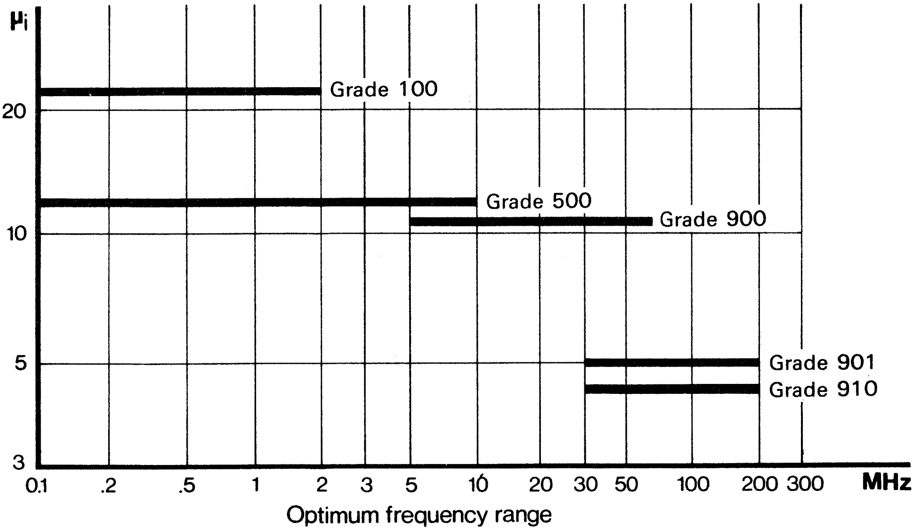
Grade 901 is generally used at frequencies between 30 and 200 MHz.

Grade 910 is generally used at frequencies above 100 MHz.

Threaded cores are made in Grades 500, 900, 901 and 910.

When the choice of grade is motivated by the desired degree of variation of inductance as is frequently the case with threaded cores or permeability tuner cores, it should be understood that an increase in the length of the core may be much more effective than the use of a higher permeability grade and may lead to a higher value of Q.

The bonding material used for iron powder cores limits the maximum ambient temperature to 110°C.



Optimum frequency range

Screw Cores
Metric Thread

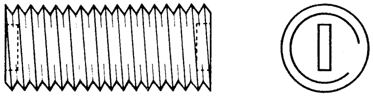


FIG. A

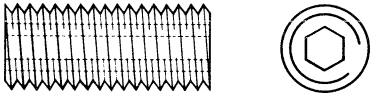
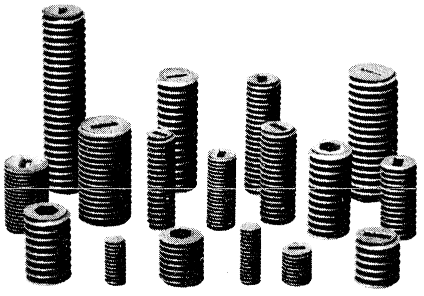


FIG. B



Dimensional Data

The types of screw cores in the table below are designated by their diameter and pitch of thread.

Type	Standard Length									Major Diam.		Slots
										min.	max.	
3×0.5	6	7.5								2.70	2.75	A
3.5D×0.5	6	7.5		10						3.25	3.30	A
4D×0.5				10	13					3.67	3.72	A
4D×0.75				10	13					3.67	3.72	A
4×0.5	6	7.5		10	13					3.84	3.89	A
4×0.75		7.5		10	13					3.84	3.89	A
5D×0.75				10	13					4.60	4.65	A
5×0.75				10	13	16				4.72	4.80	A
6D×1					13	16				5.65	5.70	A
6×0.75					13	16				5.79	5.87	A
6×1	6		9		13	16		25		5.79	5.87	A
H6×0.75			9		13	16				5.79	5.87	B
H6×1			9		13	16				5.79	5.87	B
8×1.25							17		30	7.67	7.75	A

All screw cores in the above table are manufactured in Grades 500, 900 and 901.

Tolerances on length –
Up to 17 mm ±0.25 mm
Above 17 mm ±0.40 mm

Trimming Slots

Iron powder screw cores have trimming slots at both ends except type B which have a full length hexagonal hole through the centre of the core. The slots are to IEC recommendations and detailed drawings can be supplied upon request. The dimensions of the slots depend upon the size of core.

Trimming Tools

See page 293

Screw Cores

Core Retention

Self-locking screw cores can be supplied which have a retention deposit (core brake) already applied, suitable for the former in which the core is to be used. Alternatively, rubber string of an appropriate size can be supplied when this method of retention is preferred.

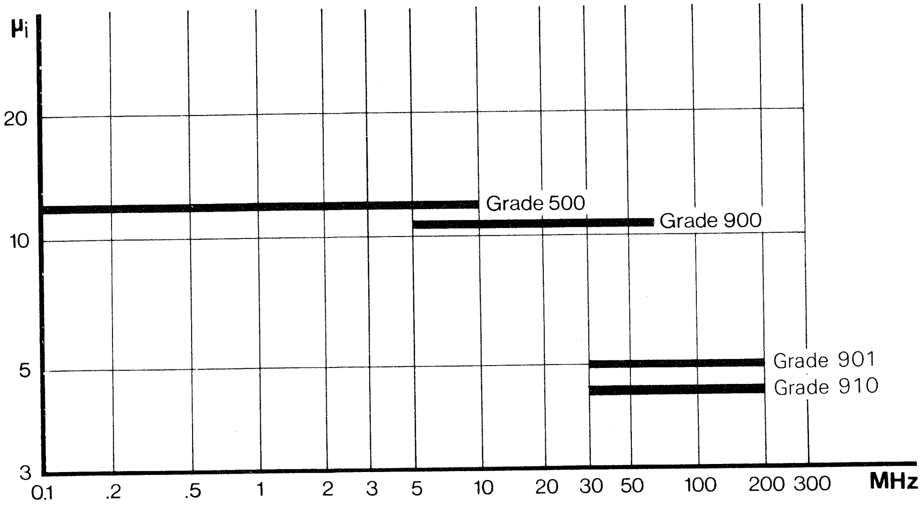
Non-standard Cores

Screw cores other than in the standard sizes quoted can be supplied by arrangement, subject to quantity justifying manufacture.

Electrical Specification

Working Frequency –

The optimum choice of the grade of material for a given frequency can be ascertained from the graph.



Optimum frequency ranges

Permeability –

The tolerance on coil permeability (inductance ratio) is ±3%. This figure relates to measurements under our standard test conditions.

Material

The cores listed in the table can be supplied in iron powder Grades 500, 900, 901 and 910

The choice of the material for a particular application should be based upon the intended frequency range and, to a lesser degree, the required inductance adjustment.

A magnetic circuit that contains only a screw core produces a low coil permeability (i.e. the ratio of inductances with and without the core) as compared with the initial permeability of the core material. The degree of permeability dilution increases as length-to-diameter ratio decreases; it also increases as the initial permeability increases.

This is illustrated by the following example.

Screw cores type 6 × 1 × 13 mm were measured in a typical single layer coil. The results were as follows:

Initial permeability

5	12

Coil permeability

1.65	2.9

It is obvious from this that Q considerations are more important than permeability.

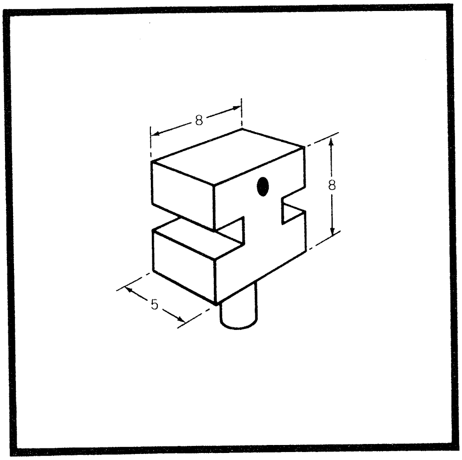
Ordering Information

To order a screw core the type, length and grade of material need to be quoted, e.g. 6 × 0.75 × 13 – Grade 500.

A seven digit part number will be advised on the order acknowledgement.

NEOSID

Transformer Core
FM Aerial Matching



General Description

This core is particularly suitable for a fixed tuned broad-band aerial coupling transformer in FM (88-108 MHz) radio receivers, and similar applications.

The core is made of thermoplastic magnetic material to facilitate easy fixing to a printed circuit board. The spigot of the core is put through a hole in the board and heat-riveted. A marker point is provided on one face for winding reference purposes.

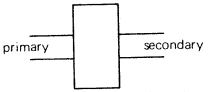
Dimensional Data

8 × 5 × 8 mm
Spigot diameter, 2.4 mm

Electrical Specification

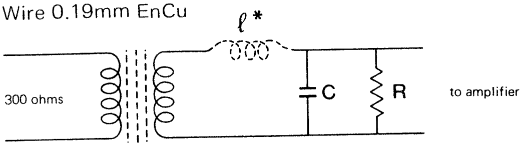
Example of winding for 88-108 MHz.

Primary (outer)
5 turns; Lp ≃ 0.5 μH



Secondary (inner)
4 turns; Ls ≃ 0.35 μH

Wire 0.19mm EnCu



Leakage inductance ℓ* ≃ 0.08 μH. Unloaded Q = 20

The value of C must be so chosen that, together with stray capacitance, the leakage inductance resonates in the centre of the frequency band.

The value of R (taking into account amplifier input resistance) must be chosen to provide the required bandwidth.

The leakage inductance (which can be measured at the secondary winding with the primary short-circuited) is a function only of the geometry of the windings and the number of turns. Winding specification and production should therefore be carefully controlled.

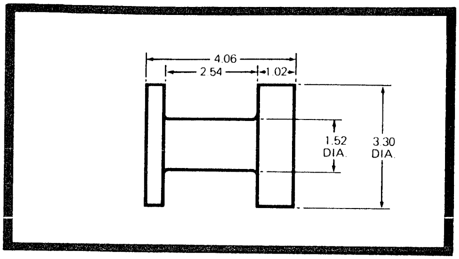
Material

Thermoplastic Grade M5A

Part Number

27-001-16

Bobbins



Part Numbers

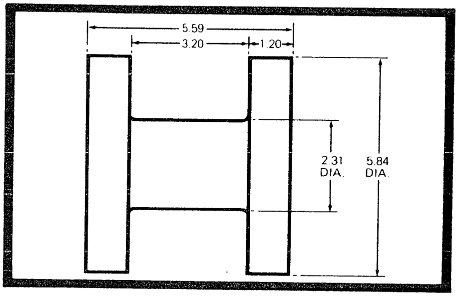
22-001-12 (Grade 500)
22-001-13 (Grade 900)

Material

Grades 500 and 900

A_L Value

Approximately 4.5 nH (Grade 500)
4.0 nH (Grade 900)



Part Number

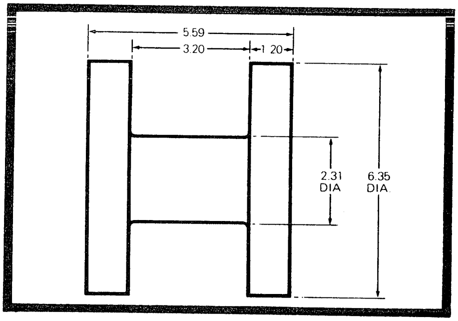
22-002-12

Material

Grade 500

A_L Value

Approximately 8 nH



Part Number

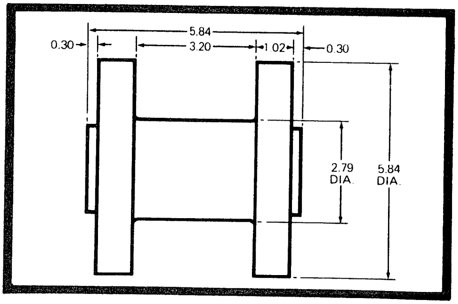
22-003-12

Material

Grade 500

A_L Value

Approximately 8.3 nH



Part Number

22-004-12

Material

Grade 500

A_L Value

Approximately 9 nH

The A_L values quoted are for bobbins fully wound with 0.08 EnCu wire and are only intended for guidance.

Neofer Iron Powder Materials
High Permeabilty

Characteristics and Applications

Cores are made by a specially developed manufacturing process in several grades, using selected types of iron powders.

Grades 1001 and 1003

The cores are characterized by relatively high permeability and high losses in the interference spectrum. RFI suppresion of light dimmers and motor speed controllers employing thyristors or triacs, and switched mode power supplies, can be achieved to the levels specified in BS 800 and VDE 0871 by using these grades.

Grade 1004

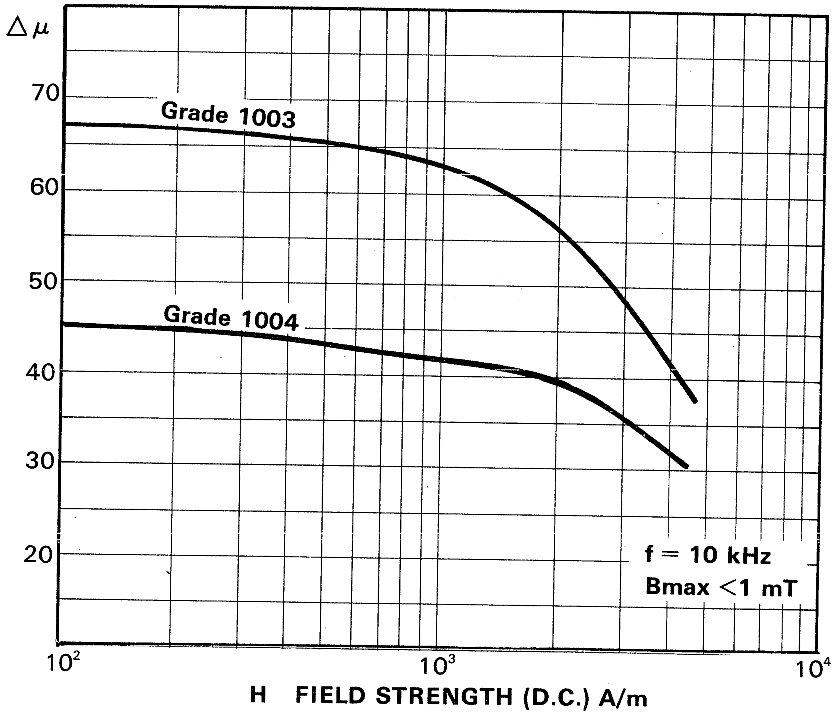
Cores made from this powder are used in energy storage choke applications for switched mode power supplies.

TABLE 5
Iron Powder Materials

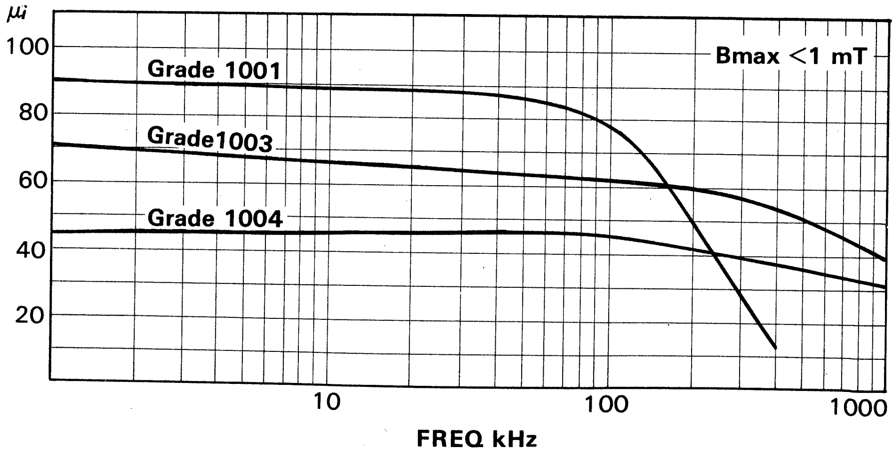
Parameter	Symbol	Standard Conditions of Test	Unit	1001	1003	1004
Initial Permeability (typical)	μ_i	B —0 25°C 10 kHz	—	85	60	45

Neofer Iron Powder Materials

High Permeability



INCREMENTAL PERMEABILITY VERSUS FIELD STRENGTH



INITIAL PERMEABILITY VERSUS FREQUENCY

NEOFER IRON POWDER RING CORES FOR RADIO FREQUENCY INTERFERENCE SUPPRESSION AND ENERGY STORAGE CHOKES.

RFI Suppression Requirements

The limits of interference voltage, imposed by the British Standard BS800:1977 or the corresponding International CISPR recommendations for household appliances, are as follows:-

Frequency range	Interference Voltage Limit	
MHz	dB (µV)	mV
0.15 – 0.50	66	2
0.50 – 5	60	1
5 – 30	66	2

When semiconductor switches are used for the phase-control of the mains current, the interference is generated because of the fast rise of the load current at the instant of switching, i.e. when the switch (triac, thyristor) is triggered. In practice, since the amplitudes of harmonics of a step waveform generally decrease with their order, meeting the interference limit at 150 kHz is the most difficult.

The interference suppression by a commonly used inductance-capacitance filter can be imagined to consist of two separate processes:-

1. the presence of an inductance in a phase-controlled mains circuit causes the current to rise slower at the trigger instant and this means that the generation of harmonics is lowered;
2. the filter action of the LC circuit reduces the propagation of the generated harmonics along the mains leads.

It is difficult to estimate how these two processes contribute numerically to the total interference suppression. If the inductance is high at the instant of switching, the current step deviates more from vertical rise, so less is required from the LC filtering. If – on the other hand – the inductance at the instant of triggering is relatively low, more LC filtering is required.

However, the inductance at the triggering instant is not identical with the inductance effective at the frequencies in the spectrum to be protected. Because of the eddy currents, the inductance drops as the frequency rises, and it might happen that even a very high inductance at the triggering point is too low to produce sufficient filtering at, say, 150 kHz, which is a function of L multiplied by C.

Thus, the frequency response of the inductance of the suppressor coil (i.e. the permeability of its core) is a very important point.

In practice, the higher is the permeability at low frequencies, for instance in purely metallic cores, the more rapidly it drops with the frequency. Hence, a compromise has to be struck; the core permeability has to be as high as possible at the triggering instant, while its fall with the frequency must be as slow as possible.

It should be clearly said that the permeability (inductance) values measured at low flux density (bridge and similar methods) are by no means identical with the values, effective when the relatively low interference currents are superimposed on a high mains current, interrupted at each half-cycle, but experience shows that there is a close correlation between this low flux density inductance and the results of interference measurements: the higher the inductance at, say, 150 kHz, the better the suppression.

The importance of high losses in the core material at higher frequencies needs some explanation. Whereas the filters, composed of low loss inductors and capacitors in the low pass band configuration, work by reflecting the high frequencies back to the generating source, the use of high loss inductors allows the unwanted frequencies to be absorbed in the core. In other words, high losses make the filters behave as an RC filter, except at mains frequencies where the value of "R" is negligible. In some applications, for instance, light dimmers, if the losses in the cores are not high enough, i.e. Q of the inductor is high, self oscillations following the instant of switching are not sufficiently damped, which gives rise to the so-called "flicker effect". Typically, Q of grades 1001 and 1003 at 150 kHz is less than 5.

Since relatively high mains current flows through the winding on the suppressor core, mains hum can become audible, if insufficient provisions are made to prevent any mechanical movement arising from the variation of the current, especially since phase-control causes abrupt changes in the instantaneous value of the current intensity. As an analogy, the hum of mains transformers, in which the stampings are not rigidly clamped, may be mentioned.

The mains current flowing through the suppressor winding causes a power loss in the winding and a power loss in the core. Of these two, the loss in the winding is more important. It is, therefore, necessary to reduce the resistance of the winding to reasonable minimum, by reducing the number of turns and increasing the cross-sectional area of the wire. The power losses at mains frequency in the core material, although less important, should also be kept low. In addition, attention should be paid to the distributed capacitance which causes self resonance and increases the apparent impedance of the series member of the LC circuit. If possible, this should occur in the lower range of the frequency spectrum (150 kHz – 500 kHz). Normally this frequency band is most difficult to suppress.

Specification for the core material, grades 1001 and 1003

The above discussion leads directly to the conclusion that the permeability, or the inductance for a given number of turns, should be as high as possible, because then the number of turns can be reduced for a given inductance value and, with a specified winding area, the cross-section of the wire can be increased. The losses at a relatively high flux density induced by the mains current must be kept low.

Grades 1001 and 1003 can operate at high flux densities. Saturation flux density is approximately 15,000 gauss and 10,000 gauss is reached when the field strength is 42A/cm. For example, using a 33 × 20 × 8 toroid wound with 120 turns, and a mains current of 3A pk (2.1A. r.m.s.) flowing through the winding, flux density is 10,000 gauss. The total core loss at this flux density is 50 mW/cc.

Grade 1004

The design of inductors carrying d.c. is not always straightforward. When laminations or ferrites are used, it is necessary to introduce an air gap to prevent saturation. Presence of such an air gap, which can be several mm long, gives rise to flux fringing around the gap. This effect could be objectionable from the electromagnetic interference point of view. Ring cores in grade 1004 are made in a specially blended iron powder, where each particle is insulated, thus introducing microscopic air gaps. Although this reduces the permeability, it makes it possible to operate ring cores at a high d.c. magnetization level.

FILTER INDUCTOR DESIGN

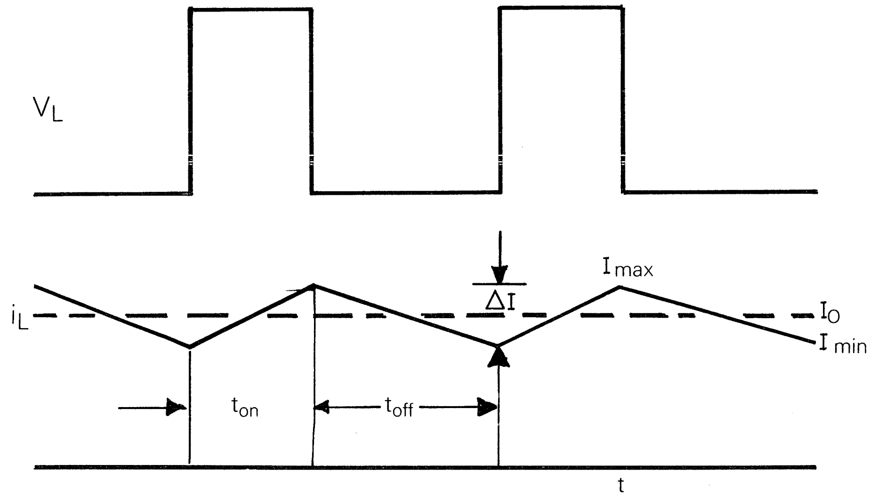


Fig 1

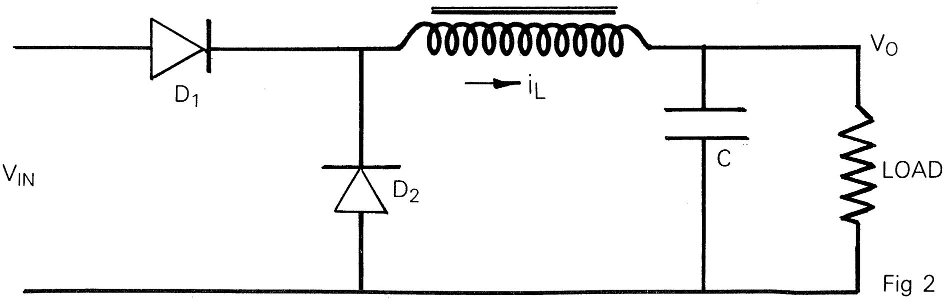


Fig 2

v_L = Instantaneous voltage across the inductor.

i_L = instantaneous current through the inductor.

I_o = mean d.c. current.

V_o = output voltage (d.c.)

ΔI = peak to peak ripple current.

Fig 1 shows typical wave forms of voltage and current through the filter inductor (see fig. 2) in a forward converter. For a given switching frequency, the turn off time, t_{off}, can be calculated from the formula

$$t_{off} = \frac{1}{f}(1 - V_O/V_{in}) \quad --- \quad (1)$$

where f is the switching frequency

V_O = output voltage

V_{in} = input voltage

A definite LC product is necessary to reduce the ripple voltage to a required value. This can be achieved over a wide range of LC products, but there are several practical considerations to be taken into account before the values of L and C can be determined.

The value of inductance has to be a compromise between the high value required to minimize the ripple voltage, and the low value desirable for rapid response to load changes. In addition, large values of inductance increase the size of the inductor, and hence its cost. It is, therefore, desirable to keep L as low as possible and C high. In practice ΔI (peak to peak ripple current) dictates the value of the inductance which can be calculated from the equation.

$$L = \frac{(V_O + V_d)\, t_{off}}{\Delta I} \quad \text{H} \quad --- \quad (2)$$

where V_d is the voltage drop across D_2

This value of inductance must be maintained under all possible operating conditions.

DESIGN EXAMPLE:- $V_O = 5$ volts $\quad$ $I_O = 5$ A

$t_{off} = 17.5\ \mu$ sec $\quad$ Max $\Delta I = 25\%$ of I_O

1. Calculate $\Delta I = \frac{5}{4} = 1.25$ amps

2. Calculate $L = \frac{(V_O + V_d)\, t_{off}}{\Delta I} = \frac{(5 + 0.6)\, 17.5}{1.25}\ \mu H$
   $= 80\ \mu H$

3. Calculate the energy product $L I^2$ max (mJ)
   (L in mH, I in amps)
   $= 80 \times 10^{-3} \times (5.625)^2 = 2.53$ mJ
   Note: $I\,\max = I_O \times \frac{\Delta I}{2}$

4. Select a toroid of nearest $L I^2$ max figure from electrical specification table (page 262).
   17-630-23   24.7 × 12.7 × 9.7
   $A_L = 54$ nH

5. Calculate number of turns $n = 10^3 \sqrt{\frac{L\ mH}{A_L}}$ . . . (3)

$$= 10^3 \sqrt{\frac{80 \times 10^{-3}}{54}} = 39 \text{ turns}$$

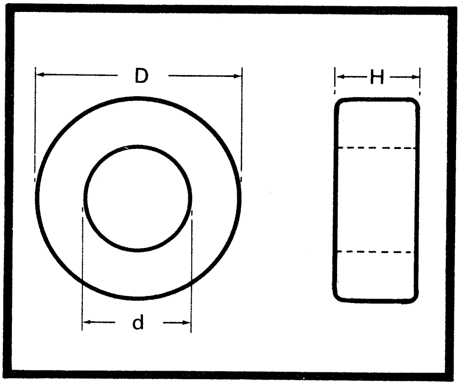
It must be remembered that under operating conditions, i.e. d.c. with a substantial ripple current superimposed, the flux conditions and, therefore, permeability differ from the figures given in the table. A_L values given in the table have been measured on a bridge at 10 kHz and Bmax a.c. less than 1mT. It is found that A_L values measured under "Pulse" condition are at least 50% higher than the A_L values tabulated. In the above example, therefore, taking a pulse A_L of 80 the revised number of turns are

$$n = 10^3 \sqrt{\frac{80 \times 10^3}{80}} = 32 \text{ turns}$$

Inductance with 32 turns measured on a bridge will obviously be less than 80 µH but under pulse conditions the value is approximately 80 µH. It is recommended that in the first instance a trial is made by measuring the actual inductance with an oscilloscope and displaying the current through the inductor. Turn off time and V_O can also be measured and L can be calculated by using formula (2). The exact number of turns can then be calculated to obtain the inductance required.

NEOSID

Ring Cores



General Description

Nominal dimensions for plain cores are shown in the table below.

Dimensional Data and Effective Geometric Parameters

Part Number	D	d	H	ℓ_e	A_e	V_e	$\sum\frac{\ell}{A}$
	mm			mm	mm^2	mm^3	mm^{-1}
17-649-	13.2	7.8	5.4	33	14.5	479	2.28
17-632-	14.8	8.0	6.35	34	20.0	680	1.70
17-630-	24.7	12.7	9.7	54	54	2916	1.0
17-638-	33	20	6	80	37	2960	2.17
17-640-	33	20	8	80	50	4000	1.61
17-642-	33	20	10	80	63	5040	1.28
17-645-	44	24	16.5	101	155	15655	0.65
17-647-	44	24	8.5	101	80	8080	1.26

The part numbers given are for nylon coated ring cores. Nominal thickness of coating is 0.25 mm.

Ring Cores

Electrical Specification

Part Number	Minimum A_L values in nH *			LI^2 max. (mJ) **
	Grade 1001	Grade 1003	Grade 1004	Grade 1004
17-649-	47	33	24	0.5
17-632-	63	44	32	0.71
17-630-	107	75	54	3.0
17-638-	50	35	25	3.1
17-640-	67	47	34	4.2
17-642-	84	59	42	5.1
17-645-	164	116	82	16.0
17-647-	85	60	43	8.4

* Measured at 10 KHz. $B_{max} < 1$ mT.
** LmH × Amps^2.

The number of turns required to obtain an inductance L is given by the formula

$$n = 1000\sqrt{\frac{LmH}{A_L}}$$

Ordering Information

The five-digit part numbers given in the Tables must be followed by a further two digits denoting the grade of the material.

Material codes are,

Grade 1001 – **10**
Grade 1003 – **22**
Grade 1004 – **23**

Example –

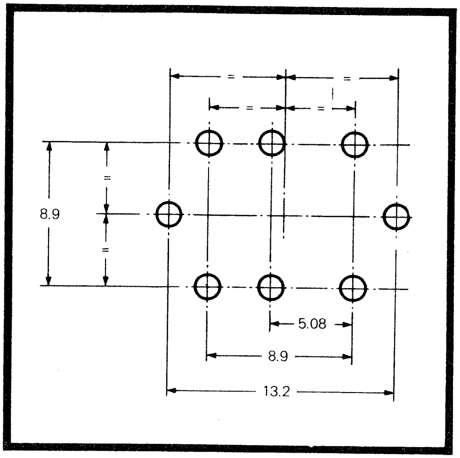
A ring core 14 × 8 × 6.35 in Grade 1003 material has the part number **17-632-22**

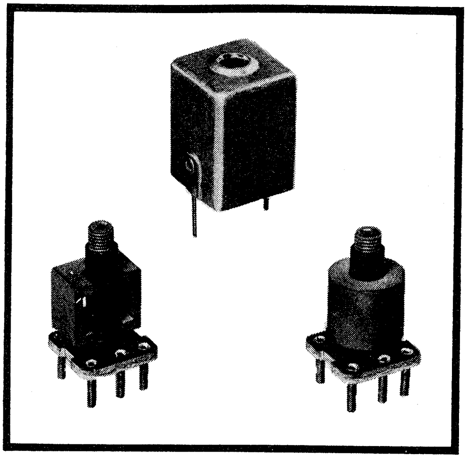
Part Numbers

As specified under Dimensional Data.

NEOSID

Adjustable Inductance Assembly
Type A 12.7 × 12.7 × 18.4





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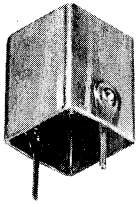

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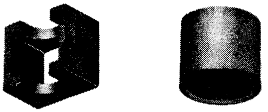

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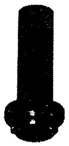

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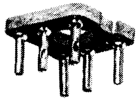


Dimensional Data

Mounting holes to be suitable for pillar lugs 1.32 mm diameter and rectangular lugs 0.48 × 1.14 mm.

General Description

This assembly has been designed for printed circuit applications and is suitable for use up to 200 MHz.
It consists of the following components:

1. Copper screening can tinned.
2. Screw core, self-locking if required.
3. (a) Yoke core or (b) Cup core.
4. Former.
5. Baseplate fitted with 4, 5 or 6 lugs as required.

Items 1, 4 and 5 are common to all types of assembly.

NEOSID

Adjustable Inductance Assembly

Type A

Assemblies Available and Q-values

The table below shows the recommended types of magnetic components and grades of material for the specified frequency ranges and the approximate unloaded Q-values.

Part Number	Ref	Frequency range	Screw core	Cup core	Cup core	Yoke core	c	Unloaded Q (approximate)
99-001-96	A1	50 to 2000 kHz	F14	—	500	—	6.4	130 @ 470 kHz
99-002-96	A2		F14	F14	—	—	5.8	150 @ 470 kHz
99-003-96	A3		F14	—	—	F14	5.7	170 @ 470 kHz
99-004-96	A4	2 to 7.5 MHz	500	—	500	—	10.5	130 @ 5.75 MHz
99-005-96	A5		F16	F16	—	—	6.3	150 @ 5.75 MHz
99-005-96	A5	7.5 to 12 MHz	F16	F16	—	—	6.3	120 @ 10.7 MHz
99-006-96	A6		900	—	—	—	11.8	110 @ 10.7 MHz
99-006-96	A6	12 to 50 MHz	900	—	—	—	11.8	140 @ 40 MHz
99-007-96	A7		F29	—	—	—	10.7	170 @ 40 MHz
99-007-96	A7	50 to 200 MHz	F29	—	—	—	10.7	200 @ 100 MHz
99-008-96	A8		910	—	—	—	13.5	160 @ 100 MHz

Frequently, values of Q lower than those indicated may be acceptable or indeed required. Such values can be obtained using other, possibly lower-priced, grades of material or fewer magnetic parts. Suggestions concerning specific requirements will be offered upon request.

Electrical Specification

Examples of Windings –

Part Number	Ref	Frequency	n	Wire	Winding
99-002-96	A2	470 kHz	150	3×0.06 EnCu	wave
99-005-96	A5	5.75 MHz	27	3×0.06 EnCu	close
99-006-96	A6	10.7 MHz	27	0.15 EnCu	spaced
99-007-96	A7	40 MHz	10	0.23 EnCu	spaced
99-007-96	A7	100 MHz	6	0.38 EnCu	spaced

Note. The Q values shown in the table were obtained using the above coils.

Number of Turns –

The approximate number of turns required to obtain the inductance of L (expressed in μH) is $n=c\sqrt{L}$. The value of c is shown in the table.

Inductance –

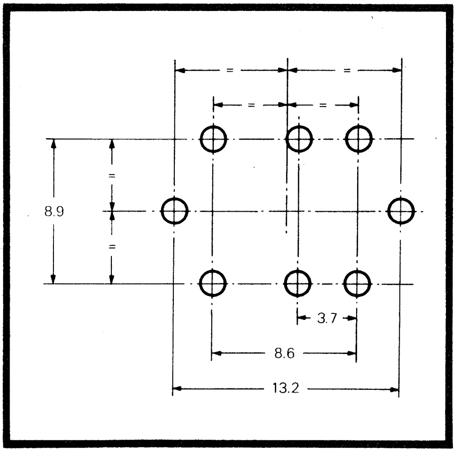
The inductance adjustment range is not less than ±15%.

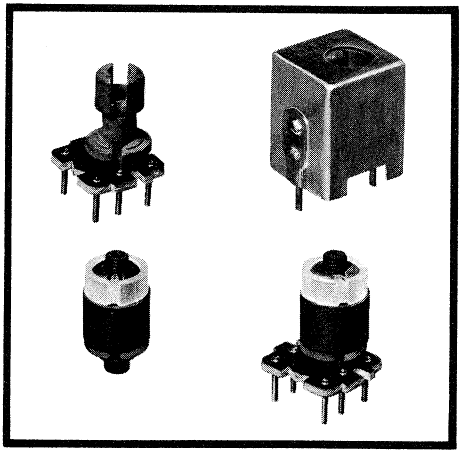
Part Numbers

As indicated in the table for Assemblies Available.

NEOSID

Adjustable Inductance Assembly
Type E 12.7 × 12.7 × 17.8





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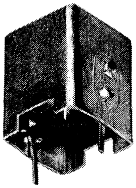

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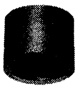

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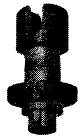

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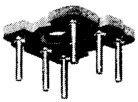


United Kingdom Patent 1,011,377. Patents in other countries.

Dimensional Data

Mounting holes to be suitable for pins 0.92 mm diameter and rectangular lugs 0.56 × 1.12 mm.

General Description

The assembly consists of the following components,

1. Copper screening can tinned.
2. Screw core
3. Retaining ring
4. Cylindrical shell
5. Bobbin
6. Baseplate

Parts 1, 3 and 6 are common to all types of this assembly while parts 2, 4 and 5 are supplied in grades of material which are most suitable for the frequency of the application.

NEOSID

Adjustable Inductance Assembly Type E

This assembly is suitable for use in the frequency range 0.05 to 50 MHz. The magnetic component parts used depend on the frequency of the application.

The assembly has been developed essentially for printed circuit board applications. The bobbin is made of thermoplastic material. The spigot fits into a hole in the base plate or printed circuit board and is heat-riveted. The angular positioning is ensured by a key on the side of the spigot. If required the bobbin can be supplied riveted to the base plate. The mounting position of the bobbin is offset to allow a capacitor to be fitted inside the can.

Assemblies Available and Q-values

The table below shows the recommended types of magnetic components and the grades of material for the specified frequency ranges and approximate unloaded Q-values.

Part Number	Ref	Frequency range	Screw Core	Shell	Bobbin	c	Unloaded Q (approximate)
99-011-96	E1	50 to 2000 kHz	F14	F14	M5B	6.1	155 @ 470 kHz 250 @ 1 MHz
99-012-96	E2	2 to 7.5 MHz	F16	F16	M5B	5.8	155 @ 5.75 MHz
99-013-96	E3	7.5 to 12 MHz	F16	900	M9B	6.25	150 @ 10.7 MHz
99-014-96	E4	12 to 50 MHz	F29	900	M9B	7.6	125 @ 40 MHz
99-015-96	E5		F25	900	M9B	7.0	135 @ 40 MHz
99-016-96	E6		F29	900	Polystyrene	14.0	140 @ 40 MHz

Electrical Specification

Example of Windings –

Part Number	Ref	Frequency	n	Wire	Winding
99-011-96	E1	470 kHz	140	3 × 0.06 EnCu	layer
99-011-96	E1	1 MHz	52	24 × 0.04 DS EnCu	layer
99-012-96	E2	5.75 MHz	17	3 × 0.06 EnCu	close
99-013-96	E3	10.7 MHz	10	30 × 0.04 DS EnCu	close
99-014-96	E4	40 MHz	4	0.38 EnCu	spaced
99-015-96	E5	40 MHz	4	0.38 EnCu	spaced
99-016-96	E6	40 MHz	7	0.38 EnCu	spaced

Note. The values of Q shown in the table for Assemblies Available were obtained using the above coils.

Adjustable Inductance Assembly

Type E

Number of Turns –
The approximate number of turns is $n = c\sqrt{L}$ where c is the constant listed in the table and L is the required value of inductance in microhenries. Maximum inductance for E1 assembly when wound with 0.08 EnCu is 9.9 mH.

Inductance Adjustment –
Not less than ±15% for assemblies E1, E2, E3 and E5. Not less than ±7% for assembly E4 and not less than ±12% for assembly E6.

Temperature Coefficient –
The value for the E1 assembly is approximately $+150 . 10^{-6}/°C$.

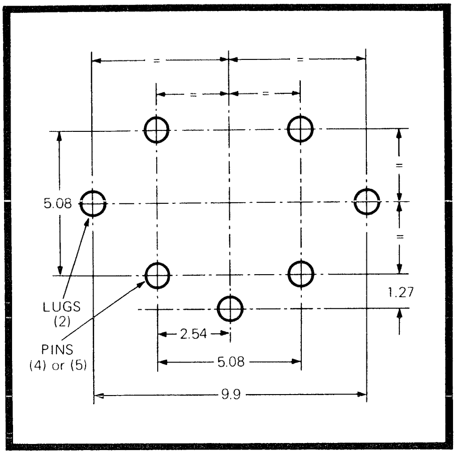
Part Numbers

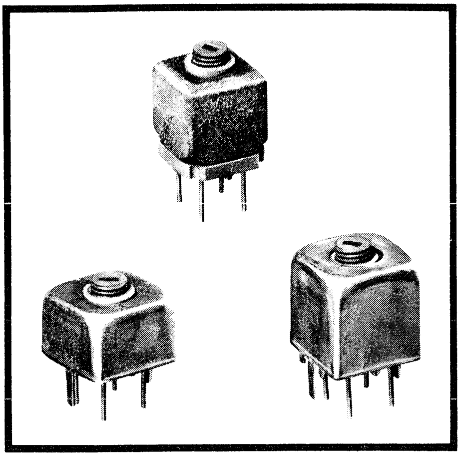
As indicated in the table for Assemblies Available.

NEOSID

Adjustable Inductance Assembly

Type H 10.2 × 10.2 × 11–HA
10.2 × 10.2 × 7–HB





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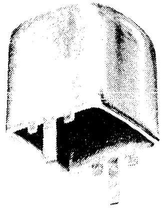

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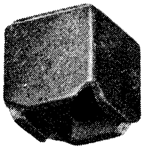

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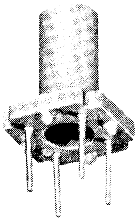


Dimensional Data

Mounting holes to be suitable for square pins 0.7 mm across diagonal and for lugs 0.33×1.35 mm.

General Description

This assembly has been designed for use in professional applications where a high degree of stability is required. There are two versions that differ in height but have identical pin centres and areas. The assemblies are suitable for use up to 200 MHz within the temperature range, −55°C to +100°C.

The assemblies consist of the following components:

1. Copper screening can, tinned.
2. Screw core (iron powder).
3. Shell (iron powder).
4. Former, 4 or 5 pins (glass filled phenolic).

NEOSID

Adjustable Inductance Assembly
Type H

Assemblies Available

The table below lists the assemblies recommended for use in the specified frequency ranges.

4 – pin Base

Part number	Assembly type	Frequency range
99-041-96 **99-042-96**	HA1 HB1	0 to 1 MHz
99-043-96 **99-044-96**	HA2 HB2	0 to 10 MHz
99-045-96 **99-046-96**	HA3 HB3	5 to 70 MHz
99-047-96 **99-048-96**	HA4 HB4	30 to 200 MHz

5 – pin Base

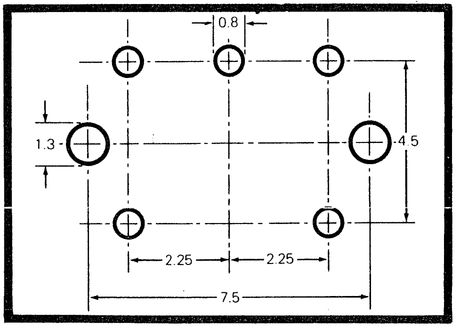
Part number	Assembly type	Frequency range
99-051-96 **99-052-96**	HA1 HB1	0 to 1 MHz
99-053-96 **99-054-96**	HA2 HB2	0 to 10 MHz
99-055-96 **99-056-96**	HA3 HB3	5 to 70 MHz
99-057-96 **99-058-96**	HA4 HB4	30 to 200 MHz

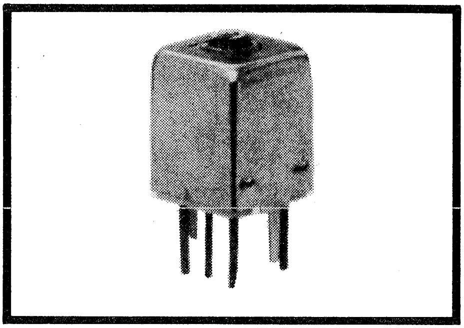
Part Numbers

As indicated in the table for Assemblies Available.

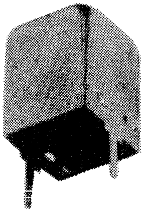
NEOSID

Adjustable Inductance Assembly
Type K 7.5 × 7.5 × 10



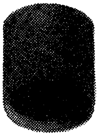


1.

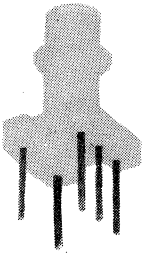


2.

3.



4.



Dimensional Data

Mounting holes to be suitable for pins 0.45 mm square, taking into account the increase in diameter due to the wire termination.

General Description

This assembly has been designed for printed circuit applications and is suitable for use up to 200 MHz. For the optimum value of Q a cup core has to be used to prevent the damping effect of the can. The former is designed to be a 'push fit' into the can. The assembly consists of the following components,

1. Copper screening can.
2. Ferrite screw core (self-locking)
3. Ferrite cup core
4. Former (glass-filled polybutyleneterephtalate)

NEOSID

Adjustable Inductance Assembly Type K

Assemblies Available and A_L values

The table below shows the recommended types of magnetic components and grades of ferrite for the specified frequency ranges.

Part Number	Ref.	Frequency range	Screw Core	Cup Core	A_L values (nominal)
99-071-96	K1	0.1 to 1 MHZ	F11	F11	8.5 nH
99-072-96	K2	0.1 to 5 MHz	F14	F14	8 nH
99-073-96	K3	5 to 12 MHz	F16	F16	8 nH
99-074-96	K4	12 to 20 MHz	F25	F25	6.5 nH
99-075-96	K5	20 to 60 MHz	F25	F25	6 nH
99-076-96	K6	60 to 200 MHz	F29	F29	5.5 nH

Electrical Specification

Number of Turns –

The approximate number of turns can be calculated from the formula,

$$L = A_L . n^2 \text{ nH}$$

The cross-sectional area available for the winding is 3.5 mm^2 and the mean length of the turn is 12.5 mm.

Inductance Adjustment –

Not less than ± 12% for all assemblies.

Temperature Coefficient

The value of the temperature coefficient is greatly affected by the structure of the winding and reliable data can only be obtained from measurement of coils wound under production conditions.

Typical values are,

K1, K2 and K3 + $300 . 10^{-6}$ /°C

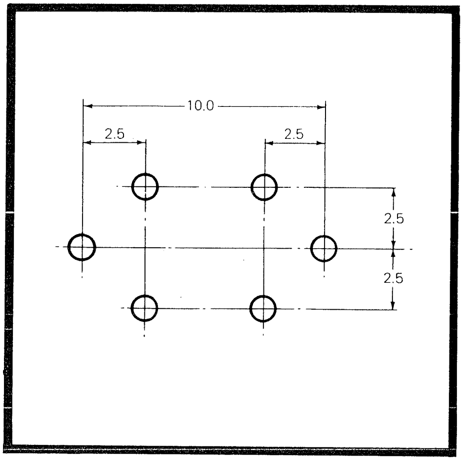
K4, K5 and K6 + $200 . 10^{-6}$ /°C

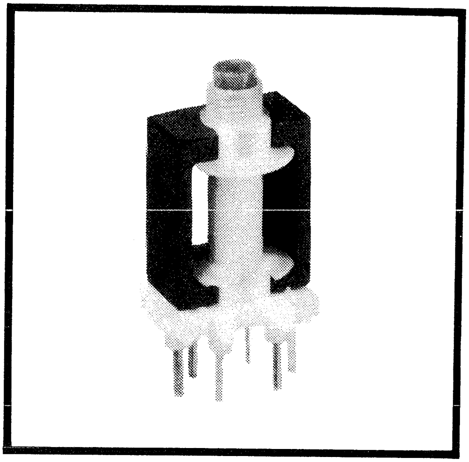
Part Numbers

As indicated in the table for Assemblies Available.

NEOSID

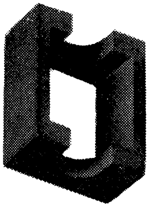
Adjustable Inductance Assembly
Type L 12.7 × 9.5 × 20.4



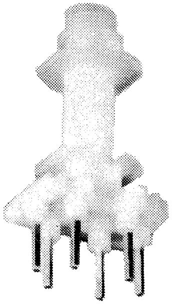


1.

2.



3.



Dimensional Data

Mounting holes to be suitable for pins 0.6 mm square taking into account the increase in diameter due to the wrapped wire termination.

General Description

This assembly has been designed for application in the frequency range from 1 to 500 kHz. High values of inductance and Q can be obtained.

The assembly consists of the following components,

1. Square ferrite yoke.
2. Adjuster core (a plain cylindrical ferrite core with plastics self-threading head).
3. Former provided with 6 pins.

Adjustment can be performed from top or bottom.

NEOSID

Adjustable Inductance Assembly
Type L

Electrical specification

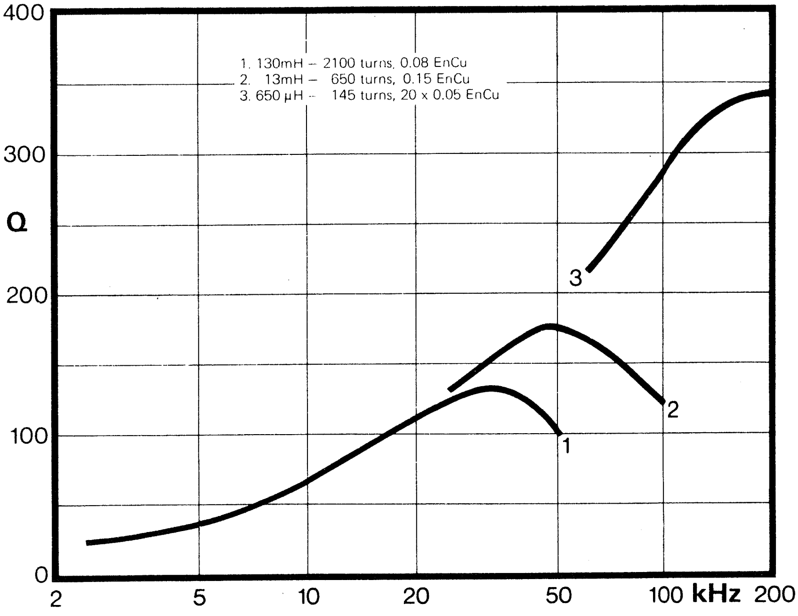
Winding Details–
The winding space is 15 mm² and the mean length of one turn in a fully wound bobbin is 19 mm.

Number of Turns –
The average value of A_L is 31 nH, so that the approximate number of turns required for an inductance L (mH) is $180\sqrt{L}$.

Inductance Adjustment –
Not less than ± 12%.

Temperature Coefficient –
The value of the temperature coefficient in the range 0 to + 70°C is 100 ± 150. 10^{-6} /°C

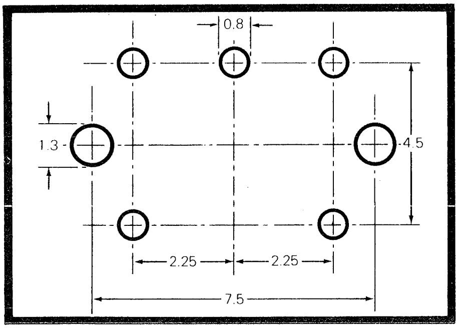
Q-values –
The values of Q measured on typical windings are shown in the graph below.

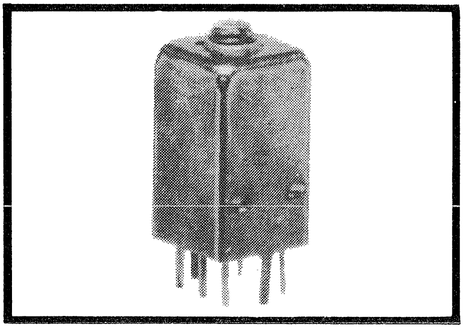


Part Number
99-061-96

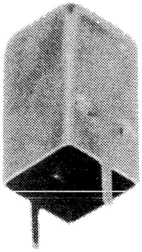
NEOSID

Adjustable Inductance Assembly
Type S 7.5 × 7.5 × 13

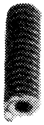




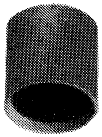
1.



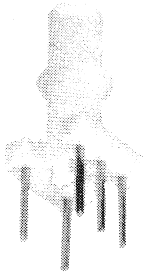
2.



3.



4.



Dimensional Data

Mounting holes to be suitable for pins 0.45 mm square, provided the soldered wire termination extends no more than 1.5 mm below the base.

General Description

This assembly has been designed for printed circuit applications and is suitable for use up to 200 MHz. The former is designed to be a 'push fit' into the can. The assembly consists of the following components,

1. Copper screening can
2. Ferrite screw core (self-locking)
3. Ferrite cup core
4. Former (glass-filled polybutylene-terephtalate)

The two projections at the base of the former prevent the screw core from falling out when adjustment is made from the top of the assembly.

NEOSID

Adjustable Inductance Assembly Type S

Assemblies Available and A_L Values

The table below shows the recommended types of magnetic components and grades of ferrite for the specified frequency ranges.

Part Number	Ref.	Frequency range	Screw Core	Cup Core	A_L values (nominal)
99-081-96	S1	0.1 to 1 MHz	F11	F11	14 nH
99-082-96	S2	0.1 to 5 MHz	F14	F14	13 nH
99-083-96	S3	5 to 12 MHz	F16	F16	12 nH
99-084-96	S4	12 to 20 MHz	F25	–	6.5 nH
99-085-96	S5	20 to 60 MHz	F25	–	5.5 nH
99-086-96	S6	60 to 200 MHz	F29	–	4.5 nH

Electrical Specification

Number of Turns –

The approximate number of turns can be calculated from the formula,

$$L = A_L . n^2 \text{ nH}$$

The cross-sectional area available for the winding is 3.5 mm^2 and the mean length of the turn is 12.5 mm.

Inductance Adjustment –

Not less than ±15% for all assemblies.

Temperature Coefficient

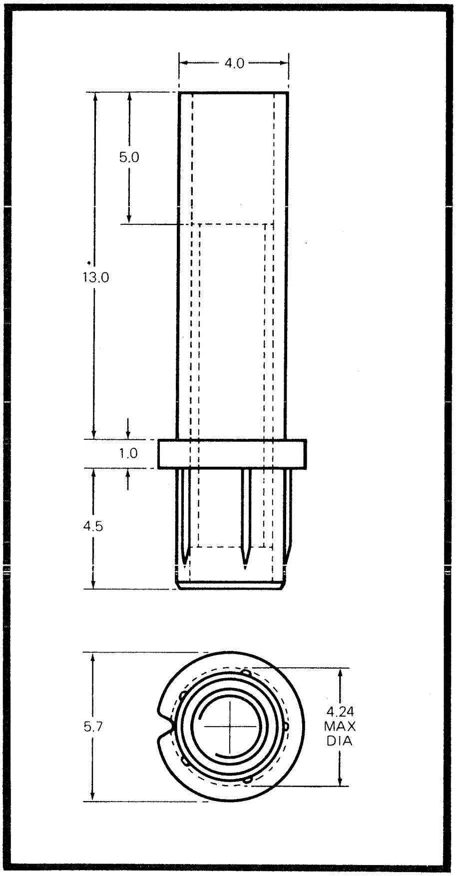
The value of the temperature coefficient is greatly affected by the structure of the winding and reliable data can only be obtained from measurement of coils wound under production conditions.

A typical value for all assemblies is $+ 200. 10^{-6} / ^\circ C$

Part Numbers

As indicated in the table for Assemblies Available.

Coil Formers
Internal Thread
3.0 × 0.5 mm



Dimensional Data

The mounting hole to be suitable for acceptance of splines with a maximum diameter of 4.24 mm.

General Description

This former has been designed to plug directly into printed circuit boards.

Material

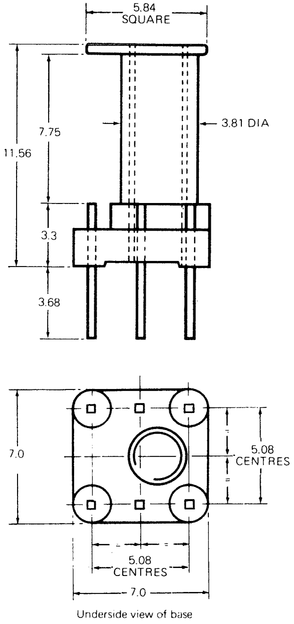
Polycarbonate

Part Number

56-020-67

NEOSID

Coil Formers
Internal Thread
3.0 × 0.5 mm



Dimensional Data

Mounting holes should be suitable for square pins 0.56 mm across diagonal.
Pin solderability – to BS 2011 Part 2T.

General Description

This former can be used in conjunction with a screening can part no. 73-001-92. As the former is offset there is space for a capacitor to be fitted inside the can.
See page 289.

Material

Phenolic (glass filled).

Part Number

50-020-64

NEOSID

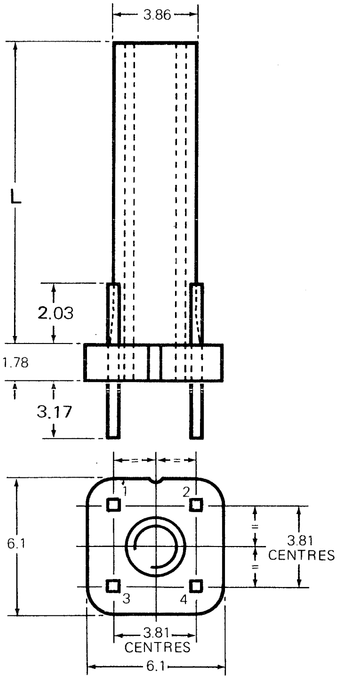
Coil Formers
Internal Thread 3.0 × 0.5 mm

Dimensional Data

Mounting holes to be suitable for square pins 0.70 mm across diagonal.
Pin solderability – to BS 2011 Part 2T.

General Description

These formers are for use in printed circuits.



Underside view of base

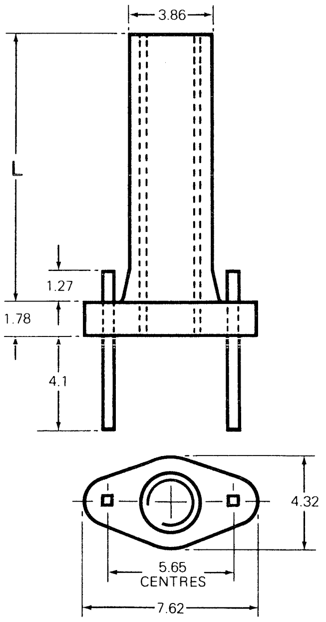
Pin numbers on base are for reference only and do not appear on moulding

Material

Phenolic (glass filled)

Part Numbers

Part Number	Dimension L
50-001-64	15.90
50-002-64	25.40
50-003-64	19.05
50-004-64	12.70
50-005-64	9.80



Underside view of base

Material

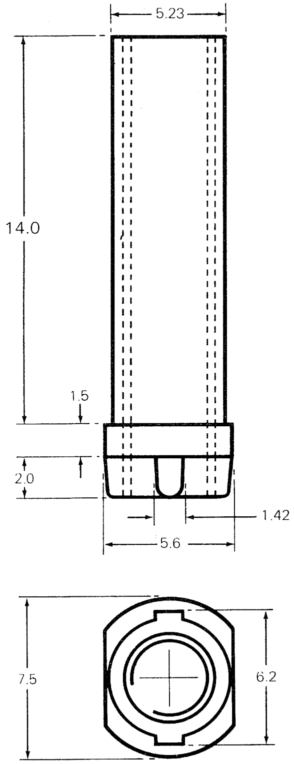
Phenolic (glass filled)

Part Numbers

Part Number	Dimension L
50-041-64	14.0
50-042-64	8.9

* This former can be used in conjunction with a screening can part number **73-007-92** or **73-001-92**. See page 289.

Coil Formers
Internal Thread 4.0 × 0.5 mm



Underside view of base

General Description

This former can be used in conjunction with base plate, part number 70-001-97, or as a direct plug-in former for printed circuit boards. See page 292.

Material

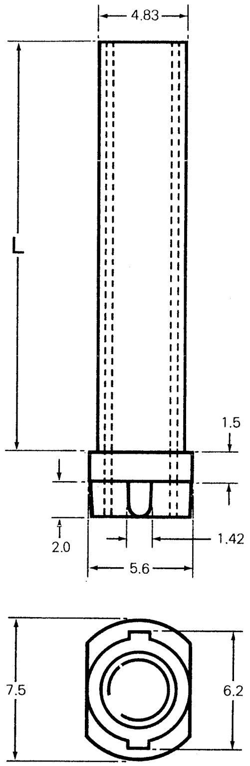
Polycarbonate

Part Number

Part Number
52-021-67

NEOSID

Coil Formers
Internal Thread
4.0 × 0.5 mm



Underside view of base

General Description

These formers can be used in conjunction with base plate, part number 70-001-97, or as a direct plug-in former for printed circuit boards. See page 292.

Material

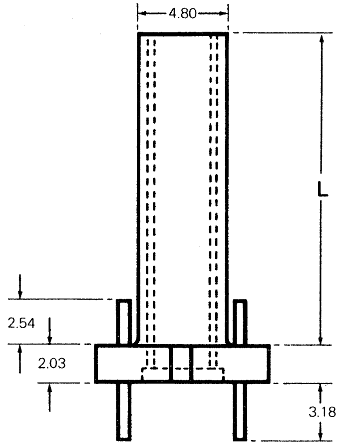
Phenolic

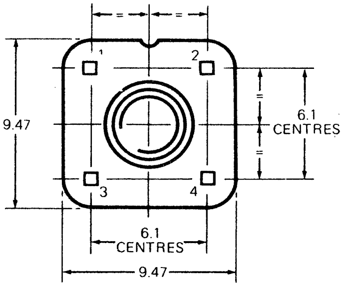
Part Numbers

Part Number	Dimension L
52-001-60	14.0
52-002-60	15.9
52-003-60	20.5
52-004-60	27.2
52-005-60	33.0

NEOSID

Coil Formers
Internal Thread
4.0 × 0.5 mm





Underside view of base

Pin numbers on base are for reference only and do not appear on moulding

Dimensional Data

Mounting holes to be suitable for square pins 0.9mm across diagonal. Although normally fitted with 4 pins, other combinations can be supplied.
Pin solderability – to BS 2011 Part 2T.

General Description

This former is for use in printed circuits.

Material

Phenolic (glass filled).

Part Numbers

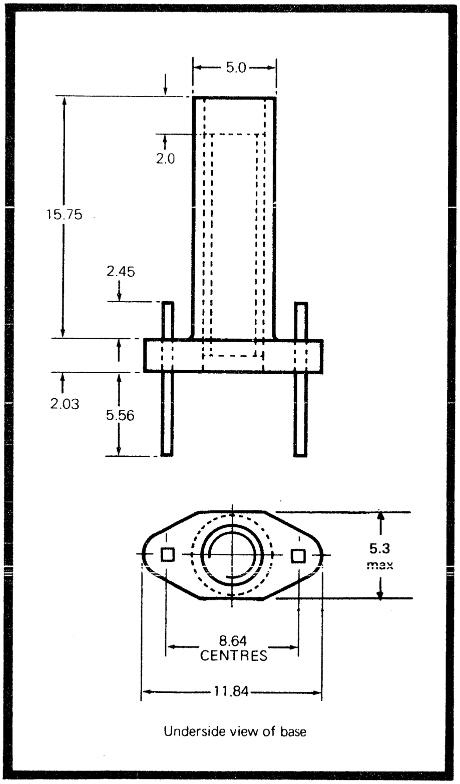
Part Number	Dimension L
52-041-64	19.05
52-051-64	15.90
52-061-64	13.90
52-071-64	11.30
52-081-64	9.90

Former, part number 52-071-62, can be fitted into screening can, part number 73-006-92.

See page 290.

NEOSID

Coil Formers
Internal Thread 4.0 × 0.5



Underside view of base

Dimensional Data

Mounting holes to be suitable for square pins 0.9mm across diagonal.
Pin solderability – to BS 2011 Part 2T.

General Description

This former is for use in printed circuits.

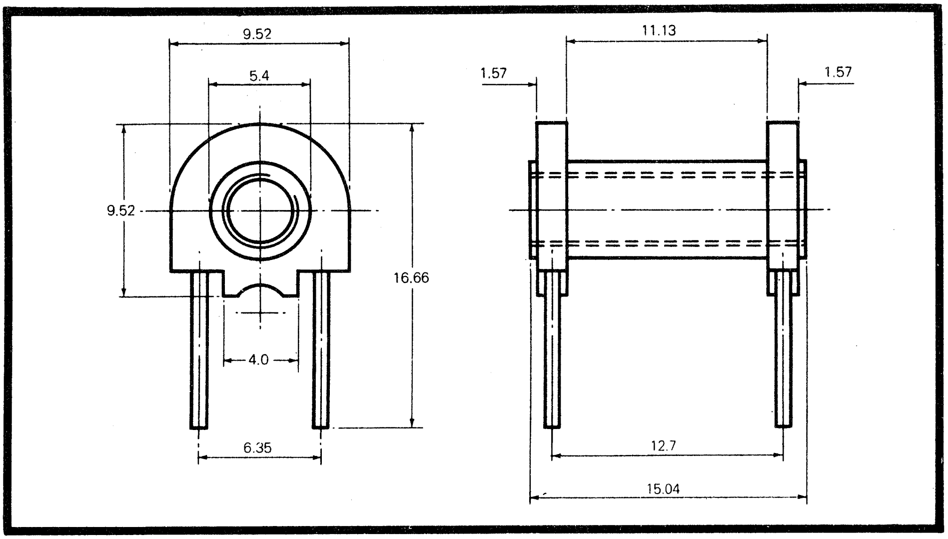
Material

Glass filled nylon Type 66

Part Number

52-030-66

Coil Formers
Horizontal Mounting
Internal Thread 4.0 × 0.5 mm



Dimensional Data

Mounting holes to be suitable for square pins 0.76 mm across diagonal.
Pin solderability – to BS 2011 Part 2T.

General Description

This former is for use in printed circuits where low-profile horizontal mounting of the coil is desired, together with a reasonable distance between the winding and the printed circuit board.

Material

Phenolic (glass filled).

Part Number

52-130-64

NEOSID

Coil Formers
Internal Thread 6 × 1 mm

Dimensional Data

Mounting holes to be suitable for rectangular tags 0.61 x 1.1 mm.

These formers are normally fitted with five tags as shown but other combinations can be supplied.

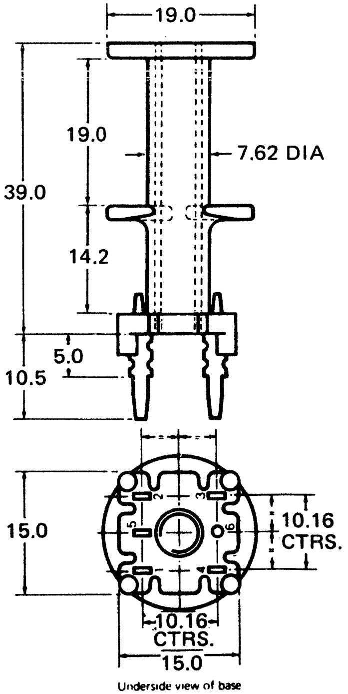
Tag spacing – on a 5.08 mm grid.

Tag positions – 1, 2, 3, 4 and 5.

Tag solderability – to BS 2011 Part 2T.

General Description

This former has been designed for use in colour television convergence circuits.



Material

Glass filled nylon type 66 SE1

Part Number

55-150-66

NEOSID

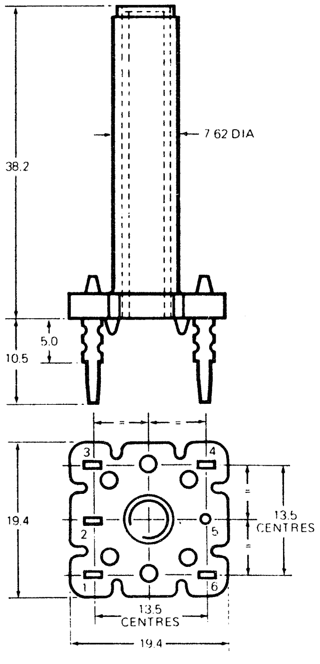
Coil Formers
Internal Thread 6 × 1 mm

Dimensional Data

Mounting holes to be suitable for rectangular tags 0.61 x 1.1 mm.
These formers are normally fitted with five tags as shown but other combinations can be supplied.
Tag spacing – on a 6.75 mm grid.
Tag positions – 1, 2, 3, 4 and 6.
Tag solderability – to BS 2011 Part 2T.

General Description

This former is for use in printed circuits.



Underside view of base

Material

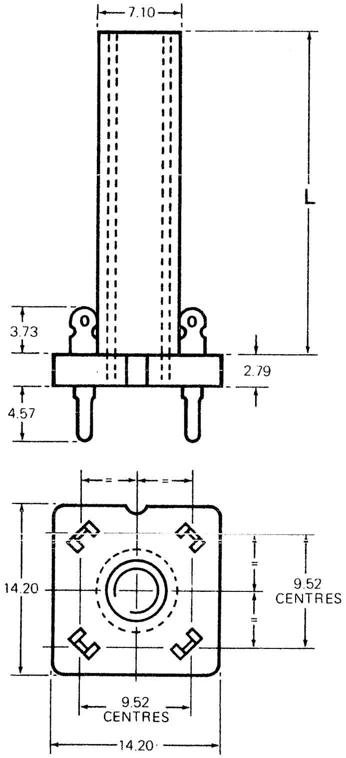
Glass filled nylon type 66 SE1

Part Number

55-081-66

NEOSID

Coil Formers
Internal Thread 6.0 × 1.0 mm
6.0 × 0.75 mm



Underside view of base

Dimensional Data

Mounting holes to be suitable for rectangular tags 0.28×0.90 mm.
Tag solderability – to BS 2011 Part 2T.

General Description

This former is for use in printed circuits.

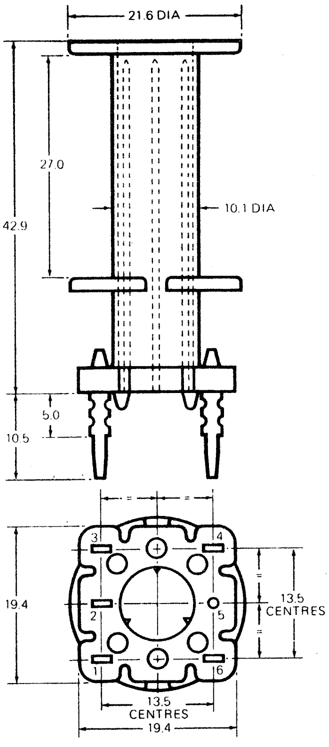
Material

Polyphenylene Oxide

Part Numbers

Part Number	Internal Thread	Dimension L
54-001-68	6.0×0.75	25.4
55-060-68	6.0×1.0	25.4

Coil Formers
Internally Splined



Underside view of base

Screw core 7.35 × 1.25 mm is used with this former.

Dimensional Data

Mounting holes should be suitable for rectangular tags 0.61 × 1.1 mm. These formers are normally fitted with five tags as shown but other combinations can be supplied.

Tag spacing – on a 6.75 mm grid.

Tag solderability – to BS 2011 Part 2T.

General Description

This former has been designed for colour television applications where the ferrite core is working under high flux conditions. The internal splines are tapped by the screw core and provide a self-locking facility.

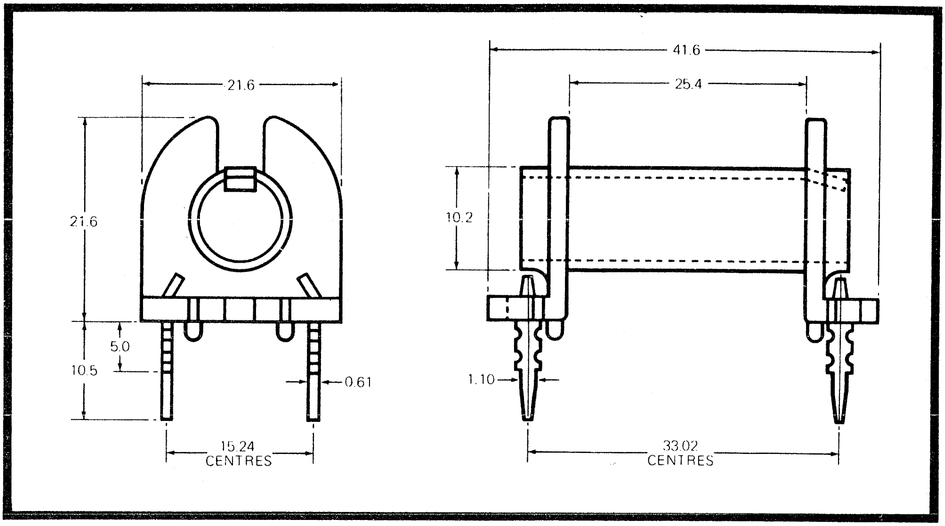
Material

Glass filled nylon type 66 SE1.

Part Number

56-001-66

Coil Formers
Horizontal Mounting



Dimensional Data

Mounting holes to be suitable for rectangular tags 0.61 × 1.1 mm.
Tag solderability – to BS 2011 Part 2T.

General Description

This former has been designed primarily for line shift chokes in colour television applications. It is used in conjunction with a 7.92 × 38.1, Grade F8 ferrite rod. The angled tab at the end of the former provides a self-locking facility for the rod.

Electrical Specification

Inductance

The maximum inductance for a fully wound former using 0.19 EnCu wire is 400 mH and the nominal A_L value is 43.3 nH.

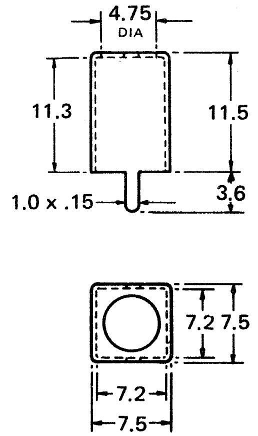
Material

Glass filled nylon type 66 SE1.

Part Number

57-001-66

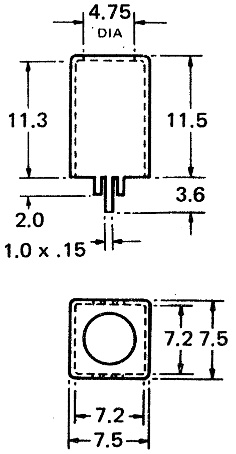
Screening Cans



7 mm square.

Material: brass, nickel plated.

Part Number
73-007-92
Can be used with Formers
50-005-64 and 50-020-64.
See pages 277 and 278.



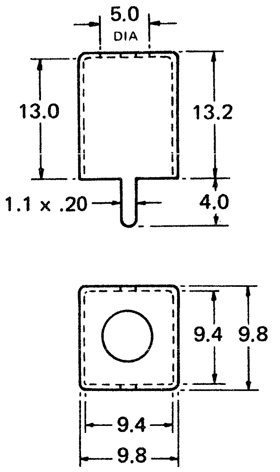
7 mm square.

Material: brass, nickel plated.

Part Number
73-001-92
Can be used with Former
50-020-64.
See page 277.

NEOSID

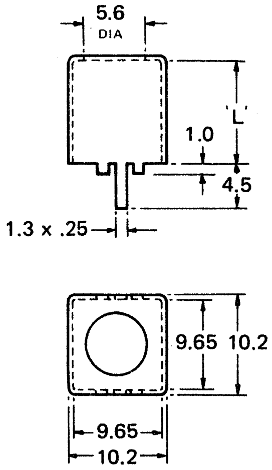
Screening Cans



10 mm square.

Material: brass, nickel plated.

Part Number
73-006-92
Can be used with Former
52-071-64.
See page 281.



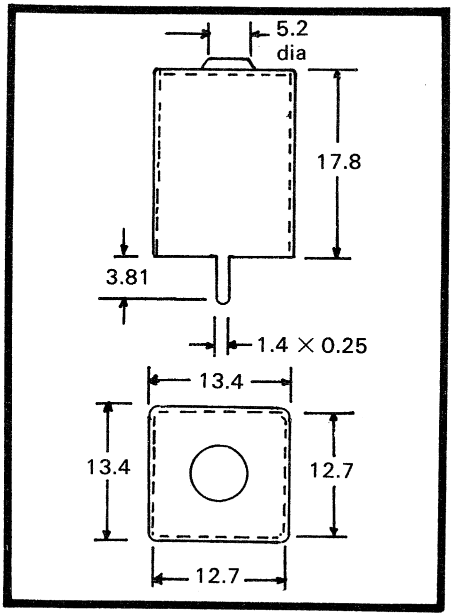
10 mm square.

Material: copper, tinned.

Part Number	Dimension L
73-008-93	7.0
73-009-93	10.9

73-008-93 to be used with HB assemblies.
73-009-93 to be used with HA assemblies.
See page 268.

Screening Cans



12.7 mm square.

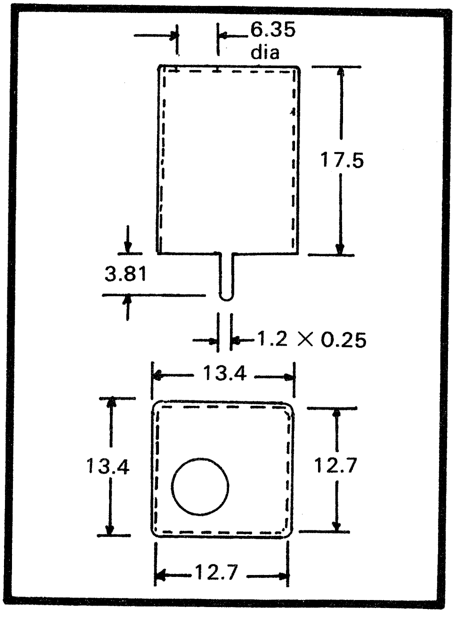
Material

Copper, tinned

Part Number

73-019-93

To be used with type A assemblies
See page 263.



12.7 mm square.

Material

Copper, tinned.

Part Number

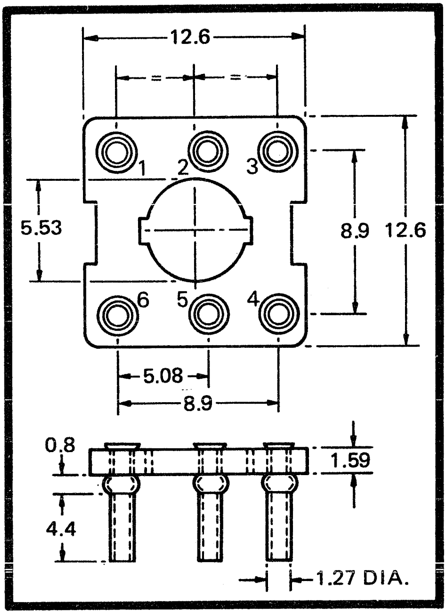
73-023-93

To be used with type E assemblies.
See page 265.

NEOSID

Baseplates for Inductance Assemblies
Type A

12.7 mm square



Tag numbers are for reference only and do not appear on the baseplate.

Description
For use with type A assembly (see page 263), screening can 73-019-93 (see page 291) and former 52-001-60 (see page 280), also former 52-021-67 (see page 279).

Material

Base – S.R.B.P. (synthetic resin bonded paper) Grade 1 or Commercial grade.

Hollow tags – Brass, hot tin dipped, minimum inside diameter 0.6 mm.
Solderability – BS 2011 Part 2T.

Part Numbers

70-001-90	Grade 1	tag positions	all six
70-001-97	Commercial	" "	all six
70-002-90	Grade 1	" "	1,2,3,4,6
70-003-90	Grade 1	" "	1,3,4,6

NEOSID

Trimming Tools for Screw Cores

T.T.5 For 3 mm screw cores.

T.T.1 For 4 mm screw cores.

T.T.2 For 4 and 6 mm screw cores.

H.S.3 For H6 screw cores.

Part Numbers

Reference	Part Number
T.T.5	**74-005-94**
T.T.1	**74-001-94**
T.T.2	**74-002-94**
H.S.3	**74-003-66**

NEOSID

Magnetic Materials Group
Permanent Magnet Products

Introduction

Through both Neosid Ltd., and other operating subsidiaries, the Group offer a comprehensive and extensive range of permanent magnet products, embracing both established and latest technology materials.

These magnet products are classified into two main groups: metal alloy and hard ferrites, which then sub-divide dependent on the method of manufacture, i.e., casting, sintering, plastic or resin bonding. The magnets in each group can normally be supplied with either isotropic or anisotropic properties, and any limitations to be avoided during manufacture are discussed in the text.

This wide range of permanent magnet materials enables the designer to meet the electrical and mechanical requirements of different magnetic systems and configurations, with the most cost effective design solution.

Full information and technical data on the various materials is available from the individual manufacturing divisions of the Group, and a brief survey of the permanent magnet products of each of the operating divisions is given in the following pages. This is supplemented with a product tree showing the main divisions and sub-divisions of the materials within our range.

These include both isotropic and anisotropic hard ferrite grades, cast and sintered aluminium–nickel–cobalt alloys, and the latest technology rare-earth magnets in sintered and matrix bonded form.

NEOSID

Magnetic Materials Group
Permanent Magnet Products

Manufacturing/Operating Subsidiaries:

1. Isotropic Ceramic Ferrite Magnets

Neosid Ltd.,
Eduard House,
Brownfields,
Welwyn Garden City,
Herts. AL7 1AN

Telephone:
Welwyn Garden (07073) 25011
Telex: 25423

2. Aluminium-Nickel-Cobalt Alloy Magnets
Anisotropic Ceramic Ferrite Magnets

Swift Levick Magnets Ltd.,
Foremost Works,
Grange Mill Lane,
Wincobank,
Sheffield. S9 1HW

Telephone:
Rotherham (0709) 550099
Telex: 54160

3. Rare-Earth Alloy Magnets

Swift Levick Supermagloy Ltd.,
Unit 7,
Headlands Trading Estate,
Swindon. SN2 6JQ

Telephone:
Swindon (0793) 694221
Telex: 444407

4. Group Small Order Magnet Stockist/Special Products

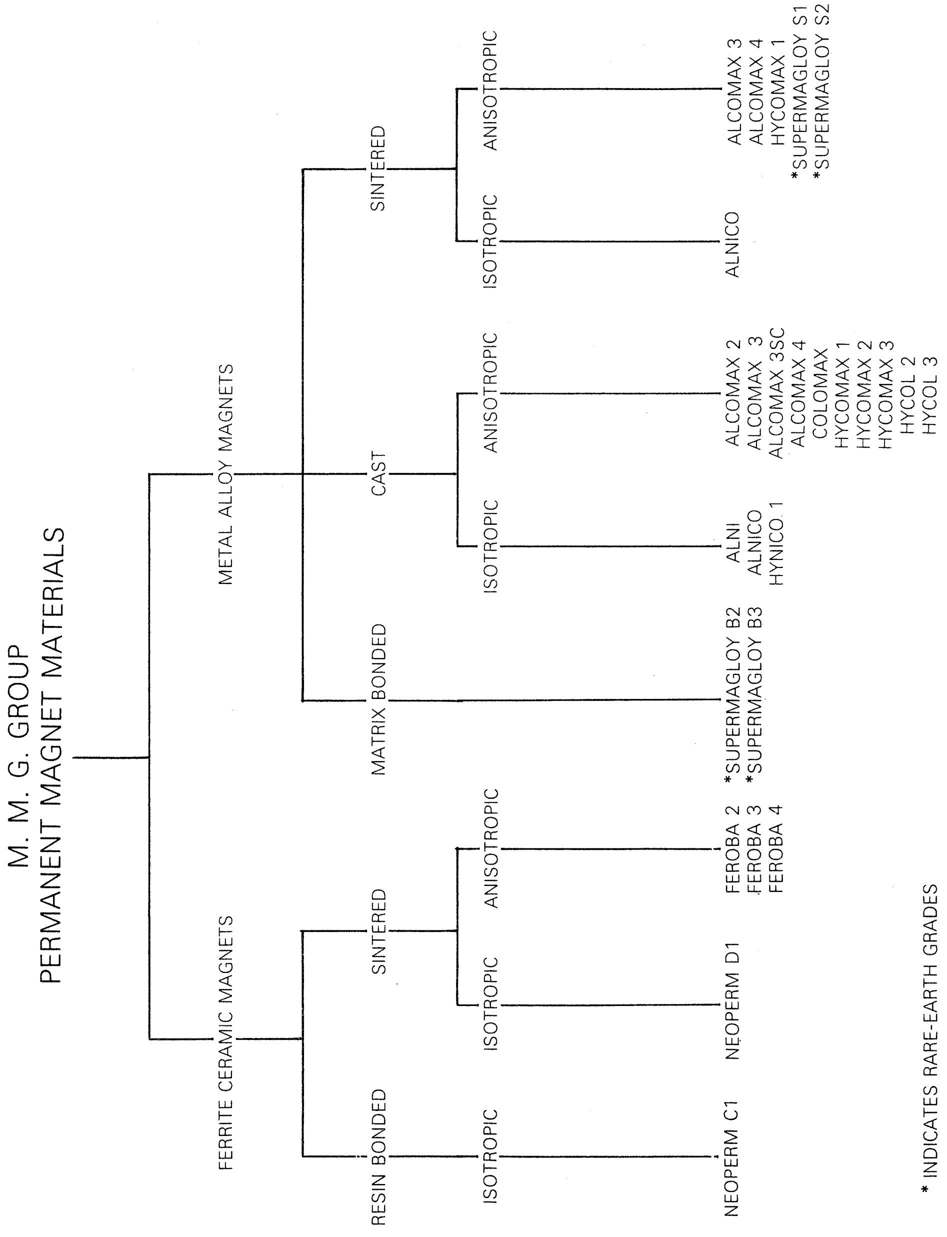
Magnet Developments Ltd.,
Unit 7,
Headlands Trading Estate,
Swindon. SN2 6JQ

Telephone:
Swindon (0793) 33212
Telex: 444407 MAGDEV G

NEOSID

Magnetic Materials Group
Permanent Magnet Products

Product Tree



* INDICATES RARE-EARTH GRADES

Cast Alloy Permanent Magnets

Swift Levick Magnets Ltd., manufacture and market a wide range of internationally compatible aluminium–nickel–cobalt alloy magnets under many different brand names. Typical magnetic properties are given under Table 1.

The alloys shown include both isotropic and anisotropic grades – the anisotropy being produced by a complex heat treatment operation which consists of cooling at a controlled rate in a magnetic field in the preferred direction of magnetisation.

The properties in the preferred direction may be further enhanced in certain shapes and alloys by crystal orientation during casting which can improve the properties by up to 40%.

The cast alloy magnets provide high field strength at medium cost, and have a low mean reversible temperature flux loss of –0,02%°C. Their high maximum operating temperature of around 500°C and Curie temperatures of between 760°C and 865°C make them eminently suitable for applications requiring permanent magnets which will operate over a very wide temperature range or where magnets are required to be die cast into aluminium or zinc based alloy housings.

The alloys are hard and brittle and lend themselves to grinding operations only. This grinding should be kept to a minimum to avoid unnecessary costs.

Cast alloy magnets are normally supplied unmagnetised to avoid losses and to facilitate assembly. The magnets can be readily magnetised to saturation after assembly using field strengths of 250–500kA/m (3000 – 6000 Oe) dependent on the coercive force of the material to be used.

Magnetic assemblies to customers' specifications can be supplied magnetised and stabilised as required.

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Magnetic Materials Group
Permanent Magnet Products

Cast Alloy Permanent Magnets

TABLE 1
Typical Magnetic Performance Data

Material	Energy Product		Remanence		Coercive Force		Opt. Static Working Point				I–Isotropic A–Anisotropic C–Crystal Orientated
	BH_{max}		Br		$_BH_C$		B_d		H_d		
	kJ/m^2	G.O$_e$ × 10^6	Tesla	Gauss	kA/m	Oersted	Tesla	Gauss	kA/m	Oersted	
Alcomax III	42	5.3	1.27	12700	52	650	1.00	10000	42	530	A
Alcomax III SC	47	5.9	1.29	12900	56	700	1.04	10400	45	560	AC
Columax	60	7.5	1.35	13500	59	740	1.17	11700	51	640	AC
Alcomax II	44	5.5	1.32	13200	48	600	1.08	10800	41	510	A
Alnico	14	1.7	0.77	7700	45	560	0.46	4600	30	370	I
Hynico I	14	1.7	0.65	6500	50	620	0.43	4300	32	400	I
Alni	10	1.25	0.60	6000	44	550	0.39	3900	26	325	I
Alcomax IX	41	5.2	1.22	12200	57	710	0.90	9000	46	575	A
Hycomax I	26	3.3	0.95	9500	65	815	0.63	6300	42	525	A
Hycomax II	32	4.0	0.85	8500	96	1200	0.53	5300	60	750	A
Hycomax III	45	5.7	0.90	9000	128	1600	0.55	5500	83	1030	A
Hycol II	56	7.0	1.05	10500	100	1250	0.75	7500	76	950	AC
Hycol III	64	8.0	1.04	10400	128	1600	0.67	6700	96	1200	AC

Sintered Alloy Permanent Magnets

Swift Levick Magnets Ltd., by using powder metallurgy techniques, also produce small and complex shaped alloy magnets with good surface finish, and close tolerances in all directions except that of pressing, resulting in a minimum of grinding where this is necessary. Holes can also be accurately included in the magnet – a great advantage compared with small cast alloy magnets in which small holes of less than 5 mm diameter are virtually a practical and economical impossibility.

The materials are shown in Table 2. It can be seen from the properties that the remanence and energy product of sintered alloy magnets are slightly lower than those of cast alloy magnets due to the reduced physical density (about 7 gm/cm^3). However, this is compensated by the increased mechanical strenth due to the finer crystal structure.

Anisotropy where applicable is produced by heat treatment and cooling in a magnetic field to achieve optimum performance in a preferred direction.

Typical 'As Sintered' Tolerances

Dimension	Size mm	Tolerance mm
Depth of pressing	Below 3.18 3.18–7.62 7.62–12.7	±0.13 ±0.25 ±0.38
Outline of die cavity	Below 12.7 12.7–25.4 25.4–38.1	±0.19 ±0.25 ±0.38
Diameter of holes	2.54–7.62 7.62–12.7	±0.13 ±0.25

Sintered Alloy Permanent Magnets

TABLE 2

Typical Magnetic Performance Data

Material	Energy Product		Remanence		Coercive Force		Opt. Static Working Point				I—Isotropic A—Anisotropic
	BH_{max}		Br		$_BH_C$		B_d		H_d		
	kJ/m^2	G.O$_e$ $\times 10^6$	Tesla	Gauss	kA/m	Oersted	Tesla	Gauss	kA/m	Oersted	
Alnico	13	1.6	0.72	7200	44	550	0.45	4550	28	350	I
Alcomax III	34	4.3	1.13	11300	52	650	0.86	8600	40	500	A
Alcomax IX	32	4.0	1.03	10300	58	720	0.80	8000	40	500	A
Hycomax I	20	2.5	0.80	8000	66	820	0.50	5000	40	500	A

Sintered Rare Earth Cobalt Magnets

Swift Levick Supermagloy Ltd., manufacture and market a range of Rare Earth Cobalt magnets, with extrememly high energy products and exceptional coercive field strength, combined with high remanence and good thermal stability.

Sintered Supermagloy S1 and S2 grades are alloys of cobalt and samarium, which develop high permanent magnetic properties compared to conventional metal alloy and ferrite magnets.

Produced by powder metallurgy techniques, Supermagloy magnets have a preferred magnetic axis created by a magnetic field applied during the pressing operation.

Components may either be die pressed to size or cut from larger blocks, dependent upon quantity required. Sintered Rare Earth Cobalt is extremely brittle and must always be handled with care – especially in the magnetised condition.

Single blocks up to 50 × 50 × 25 mm with the preferred magnetic axis along the 25 mm dimension are available. For larger pieces a number of blocks can be bonded together. Ring shaped components should have sufficient wall thickness to prevent breakage during production.

Typical tolerances for cut parts – ±0.1 mm. Typical tolerance for die pressed parts – in pressed direction ±0.35 mm – perpendicular to pressed direction ±0.25 mm. Additional grinding operations are required on any faces requiring closer tolerances than those shown.

Supermagloy magnets exhibit good temperature stability up to 250°C. However, it is advisable to consult our technical staff when continuous temperatures above 175°C are to be encountered. Rises in magnet temperature lead to reversible and irreversible losses of magnetisation. Reversible losses are expressed by the temperature coefficient of remanence and averages −0.04%°C over the range −20°C to +100°C.

Irreversible losses occur when the magnet operates at higher temperatures, dependent upon the magnet working point (B/μ_0H) being used. At B/μ_0H of −1, typical losses are 5% for a temperature rise to 150°C, 8% for a rise to 200°C and 15% for a rise to 250°C. Irreversible losses can be allowed for by cycling the magnetised magnet to a temperature equal to or greater than the ultimate operating temperature. All irreversible losses are restored by remagnetisation.

To obtain full benefit from the outstanding magnetic properties of Supermagloy magnets, whether for a new design, or to replace other materials, it is essential that the magnetic circuit is designed specifically for this material. Frequently, the maximum advantages can only be achieved by completely redesigning the device.

The higher energy product of Supermagloy combined with its coercive force allows designers to operate their devices in adverse stray field conditions. The virtual straight line demagnetisation characteristic also enables magnets to be removed and replaced into their magnetic circuits without noticeable loss.

TABLE 3
Typical Magnetic Performance

Material	Energy Product		Remanence		Coercive Force		Intrinsic Coercive Force	
	BH_{max}		Br		$_BH_C$		$_JH_C$	
	kJ/m^3	$G.O_e \times 10^6$	Tesla	Gauss	kA/m	Oersted	kA/m	Oersted
Supermagloy S1	120	15	0.80	8000	610	7650	>1200	>15000
	135	17	0.84	8400	640	8000		
Supermagloy S2	145	18	0.85	8500	660	8250	>1400	>18000
	175	22	0.93	9300	700	8750		

Bonded Rare Earth Cobalt Magnets

Swift Levick Supermagloy Ltd., also manufacture and market matrix bonded rare earth cobalt magnets. These bonded Supermagloy magnets offer lower cost solutions to many applications requiring the high energy and high coercive force characteristics of the rare earth Cobalt alloys.

Apart from the advantage of using moulding techniques to produce finished magnets to close dimensional tolerances without subsequent machining, the bonded magnets have lower density, can be economically produced in larger sizes and have higher mechanical strength than sintered rare earth Cobalt magnets.

Bonded Supermagloy can be readily machined using normally available machine tooling although precautions must be taken by using coolants to avoid the formation of dust which can cause fire and/or atmosphere contamination.

As with all bonded magnets, there are maximum temperature constraints of around +120°C due to the bonding material used. However bonded Supermagloy is not recommended for continuous use above +60°C.

For optimum performance redesign will probably be necessary to utilise fully the outstanding properties of this material.

Where material is likely to be used in highly abrasive conditions special coatings may be applied.

Bonded Supermagloy is moulded in the presence of a high magnetic field to provide anisotropic magnets with a preferred axis in the direction of the applied field.

Wherever possible, the use of magnets produced from existing tooling is recommended since samples for development work can be supplied at short notice and rapid delivery of large quantities is possible.

Intermediate sizes can be readily machined from standard size magnets, either by the customer or by ourselves provided full details are given. For economic production of large quantities in sizes other than those available, it is recommended that special tooling is produced.

Bonded Rare Earth Cobalt Magnets

TABLE 4
Typical Magnetic Performance Data

Material	Energy Product		Remanence		Coercive Force		Intrinsic Coercive Force	
	BH_{max}		Br		$_BH_C$		$_JH_C$	
	kJ/m³	G.Oe × 10⁶	Tesla	Gauss	kA/m	Oersted	kA/m	Oersted
Supermagloy B2	48	6	0.55	5500	360	4500	720	9000
Supermagloy B3	64	8	0.59	5900	420	5250	800	10000

NEOSID

Magnetic Materials Group
Permanent Magnet Products

Hard Ferrite Ceramic Magnets

Swift Levick Magnets Ltd., in conjunction with **Neosid Ltd.,** and jointly marketed by both companies, offer a wide range of hard ferrite ceramic permanent magnets, sold under the trade names of Neoperm and Feroba.

The range includes both isotropic and anisotropic grades, and the Group factories have extensive experience in the production of ferrite magnets in a wide range of shapes and sizes, for an extended field of application.

The magnets are essentially barium or strontium iron oxide compounds, with small quantities of other constituents added to influence certain characteristics. Ferrite magnets have a relatively low remanent induction, high coercive force, and a very low recoil permeability, coupled with low density (60% of weight of metal magnets for a given volume). Their electrical resistivity is so high they may be regarded as insulators, and they are not significantly affected by the majority of organic compounds. In common with all ceramics, however, hard ferrite magnets are hard and brittle and can only be finished to close tolerances by grinding.

There are three main categories of Neoperm and Feroba materials:

Resin Bonded	–	Neoperm Grade C1
Sintered Isotropic	–	Neoperm Grade D1
Sintered Anisotropic	–	Feroba Grades F2, F3, F4.

The characteristics of magnets manufactured from any particular grade depend primarily on the intrinsic properties of the material, and the manufacturing conditions, which are adapted to the shape and size of the magnet and its particular application. The nominal values of the main parameters as measured on standard test samples is given below:

TABLE 5

Typical Magnetic Performance Data

Parameter	Symbol	C.G.S. Unit	Neoperm		Feroba		
			C1	D1	F2	F3	F4
Remanence	B_r	gauss	1475	2200	3900	3700	3400
Coercivity	H_c	oersted	1050	1600	2200	3000	3300
Maximum Energy Density	$(BH)_{max}$	10^6 gauss oersted	0.4	1.0	3.6	3.3	2.8
Temp, Coeff (Neg).	—	% per °C	0.15	0.2	0.2	0.2	0.2
Curie Temperature	—	°C	—	450	450	450	450

NEOSID

Magnetic Materials Group
Permanent Magnet Products

Applications of Permanent Magnets

Permanent magnets of whatever group or type, are normally classified according to their magnetic function.

This depends whether they are used to convert mechanical energy into electrical energy, electrical energy into mechanical energy, mechanical energy into another form of mechanical energy, or mechanical energy into heat. In addition there are certain special effect application areas such as nuclear magnetic resonance, magnetic resistance, etc.

Applications of modern permanent magnets include:

- Attraction and Repulsion
- Alternators
- Arc Quenchers
- Balances
- Beam Deflection
- Biasing Magnets
- Bicycle Dynamos
- Clock and Timer Motors
- Chucks (and other mechanical devices)
- Door Catches
- Electric Stringed Instruments
- Holding and Lifting Magnets
- Ion Traps
- Isolators and Circulators
- Loudspeakers
- Magnetos
- Marker Boards
- Magnetrons
- Magnetic Filters
- Magnetic Gaskets
- Magnetic Detectors
- Magnetic Suspension
- Moving Coil Instruments
- Microphones
- Mass Spectrometers
- Motors and Generators
- Nuclear Magnetic Resonance
- Phono Pick-up Heads
- Relay Latching
- Separators
- Speedometers
- Television Picture Correction
- Television Transductor Biasing
- Telephone Ringers
- Travelling Wave Tubes
- Thermostats
- Torque Couplings
- Toys
- Watt-Hour Meters

Design and Advisory Service

Technical assistance on the design and application of permanent magnets is available from the individual manufacturing division, and magnets can be either selected from the wide range of preferred types and standards, or ordered to a customers own design (subject to product feasibility and manufacturing technique being acceptable).

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