Gapped ferrite toroids for power inductors
Gapped ferrite toroids for power inductors

Contents

Introduction 1
Features 1
Applications 1
Type number structure 1
Product range and specifications 2
$A_L$ versus DC bias curves 3
Influence of winding position 6
$P_v$ versus temperature curves 6
Comparison with metal powder cores 7
$I^2L$ versus $A_L$ curves 10
Product performance calculation 11
Example 11
Note on power loss measurement 12
**Introduction**

Toroids are well known for their magnetic properties. They achieve the highest inductance per unit of volume due to the uniform cross-section and a fluent magnetic path without corners. The latter means that not only the cross-section, but also the flux density is uniform, which is especially important to fully exploit the material saturation level. Also stray flux is very low for a toroid.

FERROXCUBE has introduced a range of gapped ferrite toroids, intended primarily for power inductor applications. They are made from toroids in the high flux, frequency stable material 3C20 by precision machining a small gap. Finally, the core is completely coated with nylon and ready for winding as if it were ungapped.

The gap helps to avoid saturation in applications where there is a large current. This can be either a DC bias current or an AC current swing. For every size of toroid there is a range of gaps, providing a range of \( A_L \) values to fit the required inductance value. The high flux, frequency stable material 3C20 has very low power losses, outperforming in this respect iron powder and all metal alloy powders. Even if a slightly larger core is required, ferrite could beat certain metal alloys on price.

**Features**

- Simple economic shape
- Available in high flux, frequency stable material 3C20
- Range of toroid sizes and \( A_L \) values
- Compact and robust product

**Applications**

These products will mainly be found as power inductors. These carry larger currents and a gap is required to avoid saturation. There are many types of power inductors, in accordance with many types of power converters:

- Output filter inductor in forward or push-pull converter (DC bias)
- Resonant inductor in half or full bridge converter (AC swing)
- Buck or boost inductor in DC voltage converter (DC bias)
- Power factor correction choke (AC bias)
- Differential filter inductor (DC of AC bias)

A possible application is also a flyback transformer. For practical reasons, it is often difficult however to realize with a toroid. There can be more than one output winding and the electrical isolation between primary and secondary side must guarantee a distance of separation.

**Type number structure**

Gapped toroids can be named quite easily. The general type number structure is explained in figure 1 below.

The inner diameter is determined by the outer diameter, because only standard toroid sizes are used that already exist without gap. In such a way, all too long type numbers are avoided when the toroid is gapped.

---

**Fig. 1 : Type number structure**

```
<table>
<thead>
<tr>
<th>core type</th>
<th>coating type</th>
</tr>
</thead>
<tbody>
<tr>
<td>T N 237.5 - 3C20 - A106 - X</td>
<td>- N - polyamide 11 (nylon)</td>
</tr>
</tbody>
</table>
```

```latex
\begin{itemize}
  \item special version
  \item \( A_L \) value (nH)
  \item gapped
  \item core material
  \item core size D / H
  \begin{itemize}
    \item (ungapped core dimensions)
  \end{itemize}
\end{itemize}
```

Ferroxcube
Product range and specifications

The cores are coated with polyamide 11 (PA11), flame retardant in accordance with "UL94V-2", UL file number E45228 (M). The inner and outer diameters apply to the coated toroid.

Contacts are applied on the edge of the toroid for isolation voltage test, which is also the critical point for the winding operation.
**$A_L$ versus DC bias curves**

These curves show the stability of $A_L$ versus DC bias current. The saturating field $H_{DC}$ depends on the number of Ampere-turns ($H_{DC} = n.I_{DC}/L_e$). The lower the $A_L$ value, the larger the gap and the more DC bias capability the toroid shows.
$A_L$ versus DC bias curves (continued)
$A_L$ versus DC bias curves (continued)
Influence of winding position

All curves above are for a winding, evenly distributed over the circumference of the toroid. The place of the winding has considerable influence on induction. Non-biased induction is maximum when the winding is placed opposite to the gap. This is due to the increase of stray flux compared to a distributed winding. The decrease of inductance with DC bias will be faster, however. The reverse effect occurs with a winding on the gap. Inductance and stray flux are minimized.

P_v versus temperature curves

These curves give the loss per unit of volume, how it varies with temperature, depending on frequency and flux density. There is a minimum value, defining the optimum working temperature.
Comparison with metal powder cores

Several other material categories are used for power inductors. Metal powders form an important group. The metal can be pure iron or an alloy. In the form of a powder they have a distributed gap and don’t need to be gapped as a core.

- **Pure iron**
  Composition: Fe 100%
  Permeability: up to 90
  Highest saturation flux density
- **Molybdenum Permalloy Powder (MPP)**
  Composition: Ni 80% − Fe 20%, some substitution by Mo
  Permeability: up to 550 (because of the high intrinsic permeability of permalloy)
  Power loss volume density closest to ferrite

- **High Flux**
  Composition: Ni 50% − Fe 50%
  Permeability: up to 160
  Highest saturation flux density of metal alloys
- **Sendust (sold under various brand names)**
  Composition: Fe 85% − Si 10% − Al 5%
  Permeability: up to 125
  Saturation flux density & power loss volume density intermediate

Ferrite comes into the picture where the limiting condition is power loss rather than saturation, so especially for high frequency and also for resonant inductors (large AC swing). For a certain set of application conditions, the limiting condition for metal powder can well be the power loss, while for ferrite it is the saturation. Even if that leads to a slightly larger core size, the gapped ferrite toroid could be more economical than expensive materials like MPP or high flux.

3C20 has an improved saturation level which makes it well-suited as an inductor material.

**Fig. 3**: Relative position of materials
Pure iron, high flux and sendust have a soft saturation curve due to the distributed gap. The permeability starts dropping early, but the slope doesn’t increase fast. MPP has a much more abrupt saturation curve due to the very high intrinsic permeability of permalloy. The hysteresis loop is therefore extremely sheared.

Ferrite toroids have a single gap and the fringing effect compensates the slow intrinsic permeability drop until real saturation occurs. The stability with frequency is better for gapped ferrite, which is an advantage if linearity is a requirement, e.g. in class D audio amplifiers.

In the following graph we can see a comparison between a gapped ferrite toroid (TN26/11-3C20-A201) and a powder core (MPP, 26.9x14.7x11.2mm, A201). We can see the frequency behavior of the different pieces. The stability with frequency is still better for gapped ferrite than for MPP.

Below 2 graphs comparing the saturation behavior between a gapped ferrite toroid (TN13/5-3C20-A79) and a powder core (MPP, 12.7x7.6x4.8 mm, A79) for the first graph and TN23/7.5-3C20-A90 and MPP, 22.9 x 14 x 7.6, A90 for the second. For not too high current, the stability is better for gapped ferrite. For the highest currents however, saturation flux density prevails.
Finally, 2 graphs comparing the core losses of a gapped ferrite toroid (TN13/7.5/5-3C20) and a powder core (MPP, 12.7 x 7.6 x 4.8 mm), at 50 and 100 °C. The difference is at least a full decade, showing that where losses are premium, ferrite is the best material choice.
$I^2L$ versus $A_L$ curves

These curves give the maximum energy storage value, depending on $A_L$ value. The larger $A_L$, the smaller the gap and the lower the energy value, which is used to calculate the minimum toroid size for an output inductor. There are more sizes and $A_L$ values available and custom products can be made upon request.
Product performance calculation

With the aid of the foregoing $I^2L$ graphs, the minimum required core size can be calculated. The loss graphs serve to determine the total core loss.

- The required inductance (at maximum load) and the maximum load current determine the energy storage:
  \[ E_{\text{min}} = I_{\text{load}}^2 L_{\text{min}} \]

- The minimum energy storage determines the minimum core size and the maximum $A_L$ value of the core. Choose a core size of which the corresponding $I^2L$ graph reaches the required minimum of energy storage $E_{\text{min}}$. Choose an $A_L$ value in the graph that reaches this level.

- The required inductance determines the number of turns:
  \[ n = \sqrt{\frac{L_{\text{min}}}{A_L}} \]
  This is rounded to an entire number.

- Voltage and frequency determine the flux density
  for sinusoidal flux and voltage variation:
  \[ B_{\text{max}} = \frac{V_{\text{rms}}}{\sqrt{2}} \sqrt{\pi n f A_e}, \quad V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \]
  for triangular flux and rectangular voltage variation:
  \[ B_{\text{max}} = \frac{V_{\text{rms}}}{4} (4 n f A_e), \quad V_{\text{rms}} = V_{\text{max}} \]

- Core loss follows from flux density and frequency:
  \[ P = P_v(B_{\text{max}} f) V_e \]

Example

Required: output choke with inductance > 5 $\mu$H at a maximum load current 15 A.

The minimum energy storage:
\[ E_{\text{min}} = I_{\text{load}}^2 (5 \times 10^{-6}) = 1125 \mu J. \]

The smallest toroid reaching this level is TN20/6.4, where only $A_L = 68$ nH exceeds this level.

The number of turns is now:
\[ n = \sqrt{\frac{5000}{68}} \rightarrow 9 \text{ turns} \rightarrow n I_{\text{load}} = 135 \text{ A.turns.} \]

In the $A_L$ vs. DC bias graph of TN20/6.4 one can check that no significant saturation occurs.

$A_L$ value 109 nH could reduce the turns to 7 to achieve 5 $\mu$H, but would not comply with 15 A load.

Suppose the choke is driven by a rectangular voltage of 4 V amplitude, switching at 200 kHz.

Taking into account the core effective cross-section 30.5 mm$^2$ of TN20/6.4, peak flux density will be:
\[ B_{\text{max}} = \frac{4 \times 9 \times 200 \times 10^3 \times 30.5 \times 10^{-6}}{18.2 \text{ mT}} \]

Ignoring the influence of bias current and non-sinusoidal waveforms, the graphs of $P_v(T)$ can be taken as reference.

Even for lower temperatures the loss density will be below 10 mW/cm$^3$.

With an effective volume of 1.33 cm$^3$, the core loss will only be in the order of 10 mW.

Remark

An output choke can also carry a large AC current instead of a small ripple current and a large DC bias current. This is the case in output filters of audio amplifiers.

For detailed design information, see our brochure:
9930 030 00011, Class D audio amplifier with Ferroxcube gapped toroid output filter.
Note on power loss measurement

Power losses as presented in this brochure have been measured on ungapped ferrite toroids, as is common practice for paired core shapes like EFD etc. Gapped cores have a much lower loss tangent $\tan\delta$ which reduces the loss measurement accuracy and increases the amplifier load:

- **Lower loss tangent**

  \[
  \frac{\tan\delta}{\mu_e} = \tan\delta / \mu \\
  \frac{\tan\delta}{\mu_e} = \tan\delta / \mu \\
  \tan\delta_e = (\mu_e / \mu) \cdot \tan\delta
  \]

  As $\mu_e / \mu < 1$, the loss tangent is reduced by a gap.

- **Lower measurement accuracy**

  \[
  P = V.I.\cos\phi = V.I.\sin\delta \\
  dP/d\delta = V.I.\cos\delta \\
  \Delta P/P = (dP/d\delta) \cdot \Delta \delta / P = 2\pi f \Delta t / \tan\delta
  \]

  $\mu$ = permeability without gap
  $\tan\delta$ = loss tangent without gap
  $\tan\delta / \mu$ = loss factor without gap
  $\mu_e$ = permeability with gap
  $\tan\delta_e$ = loss tangent with gap
  $(\tan\delta / \mu)_e$ = loss factor with gap

  For a given time accuracy $\Delta t$ (equipment), the relative loss error $\Delta P/P$ increases proportional with frequency $f$ and inversely proportional with loss tangent $\tan\delta$ (or proportional to quality factor $Q$).

  The above linear calculation holds for small signals, but qualitatively the result is the same for large signals and hysteresis loops.

  Measuring with the same flux density $B$ still leads to the same power loss $P$ as for gapped ferrite toroids, apart from the core volume factor $V_g / V_e = (A_e \cdot (l_e - l_g)) / (A_e \cdot l_e) = 1 - l_g / l_e \approx 1$. Another deviation is the influence of stray flux, which also depends on the place of the winding. In the above calculation, the flux is supposed to cross the gap straight. Measuring on a gapped core has a second problem, apart from the loss of accuracy. Low effective permeability (compared to a non-gapped toroid) means low inductance and high load current. After all, the voltage has to be the same as for a non-gapped toroid to keep the same flux density $B$.

  In the case of metal powder cores, it’s impossible to measure without the (distributed) gap, but the accuracy is much higher due to the higher loss tangent $\tan\delta$. 

Fig. 4: Output inductor in forward configuration.

Fig. 5: SAMPLEBOX15 - 4330 032 22151
# Ferroxcube America Sales Offices

## USA State

<table>
<thead>
<tr>
<th>State</th>
<th>Sales Office</th>
<th>Phone</th>
<th>Fax</th>
<th>E-mail / Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona, Arkansas, Colorado</td>
<td>Ferroxcube USA, El Paso TX</td>
<td>(915) 599 2616</td>
<td>(915) 599 2555</td>
<td><a href="mailto:ken.blasor@ferroxcube.com">ken.blasor@ferroxcube.com</a></td>
</tr>
<tr>
<td>Illinois, Missouri, Montana</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iowa, Kansas, Louisiana</td>
<td>Ferroxcube USA, Sudbury, MA</td>
<td>(978) 579 7932</td>
<td>(978) 579 9457</td>
<td><a href="mailto:david.longden@ferroxcube.com">david.longden@ferroxcube.com</a></td>
</tr>
<tr>
<td>Missouri, Nebraska, Nevada</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nevada</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Mexico, Oklahoma, Texas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wisconsin (excl Western)</td>
<td>Tempest Technical Sales, Carmel, IN</td>
<td>(317) 844 9236</td>
<td>(317) 844 9019</td>
<td>CherylO@TempestTechSales.</td>
</tr>
<tr>
<td>Wyoming</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorado</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Massachusetts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Hampshire</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Carolina</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pennsylvania (Eastern)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhode Island, South Carolina</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vermont, Virginia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alabama, Connecticut, Delaware</td>
<td>Ferroxcube USA, San Diego, CA</td>
<td>(619) 207 0061</td>
<td>(619) 207 0062</td>
<td><a href="mailto:joel.salas@ferroxcube.com">joel.salas@ferroxcube.com</a></td>
</tr>
<tr>
<td>Arizona, Arkansas, Colorado</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idaho, Oregon, Utah, Washington</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alaska, California, Hawaii,</td>
<td>ECS, Eden Prairie, MN</td>
<td>(952) 914 7212</td>
<td>(952) 946 9052</td>
<td><a href="mailto:shauschild@ecs-sales.com">shauschild@ecs-sales.com</a></td>
</tr>
<tr>
<td>Mexico (Baja), Oregon, Utah,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minnesota, North Dakota, South Dakota, Wisconsin (Western)</td>
<td>Tempest Technical Sales, Carmel, IN</td>
<td>(317) 844 9236</td>
<td>(317) 844 9019</td>
<td>CherylO@TempestTechSales.</td>
</tr>
<tr>
<td>Indiana, Kentucky, Michigan, Ohio, Pennsylvania (Western), West Virginia</td>
<td>Tempest Technical Sales, Carmel, IN</td>
<td>(317) 844 9236</td>
<td>(317) 844 9019</td>
<td>CherylO@TempestTechSales.</td>
</tr>
</tbody>
</table>

## Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Sales Office</th>
<th>Phone</th>
<th>Fax</th>
<th>E-mail / Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Ferroxcube USA, Sudbury, MA</td>
<td>(978) 579 7932</td>
<td>(978) 579 9457</td>
<td><a href="mailto:david.longden@ferroxcube.com">david.longden@ferroxcube.com</a></td>
</tr>
<tr>
<td>Brazil (Rio De Janeiro)</td>
<td>Richardson Electronics do Brazil</td>
<td>55 21 521 4004</td>
<td>55 21 521 5193</td>
<td><a href="http://www.rell.com">www.rell.com</a></td>
</tr>
<tr>
<td>Brazil (Sao Paulo)</td>
<td>Richardson Electronics do Brazil</td>
<td>55 11 3845 6199</td>
<td>55 11 3845 6199</td>
<td><a href="http://www.rell.com">www.rell.com</a></td>
</tr>
<tr>
<td>Colombia</td>
<td>Richardson Electronics Colombia</td>
<td>57 1 636 1028</td>
<td>57 1 636 1005</td>
<td><a href="http://www.rell.com">www.rell.com</a></td>
</tr>
<tr>
<td>Mexico (excl Baja)</td>
<td>RV Componentes, Guadalajara, MX</td>
<td>52 33 3641 9595</td>
<td>52 33 3641 9898</td>
<td>javier.reynoso@rvcomponent</td>
</tr>
<tr>
<td>All others in America</td>
<td>Ferroxcube USA, El Paso (TX)</td>
<td>(915) 599 2513</td>
<td>(915) 599 2555</td>
<td><a href="mailto:salesusa@ferroxcube.com">salesusa@ferroxcube.com</a></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(915) 599 2328</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Internet address:** www.ferroxcube.com
Ferroxcube - your global partner

Australia: Contact Ferroxcube Taiwan
Tel: +886 2 86650099, Fax: +886 2 86650145

Austria: Contact Ferroxcube Germany
Tel: +43 (040) 527 28 305, Fax: +43 (040) 527 28 306

Benelux: Contact Ferroxcube Germany
Tel: +43 (040) 527 28 302, Fax: +43 (040) 527 28 306

Bosnia: Contact Ferroxcube China
Tel: +86 10 68665009, Fax: +86 10 686650145

Brazil: Contact Ferroxcube China
Tel: +86 10 68665009, Fax: +86 10 686650145

Bulgaria: Contact Ferroxcube China
Tel: +86 10 68665009, Fax: +86 10 686650145

Canada east: Contact Ferroxcube USA
Tel: +1 978 579 7932, Fax: +1 978 579 9457

Canada west: Contact Ferroxcube USA
Tel: +1 619 207 0061, Fax: +1 619 207 0062

China: Ferroxcube Hong Kong
Tel: +852 2319 2740, Fax: +852 2319 2757
Ferroxcube South of China
Tel: +86 137 0242 1270, Fax: +86 137 0242 1271
Ferroxcube Suzhou
Tel: +86 137 0242 1270, Fax: +86 137 0242 1271

Colombia: Contact Ferroxcube Poloneza
Tel: +57 1 636 1028, Fax: +57 1 636 1005

Croatia: Contact Ferroxcube Italy
Tel: +39 02 241131 1, Fax: +39 02 241131 11

Czech Republic: Contact Ferroxcube Poland
Tel: +48 46 834 00 07, Fax: +48 46 834 00 35

Denmark: Contact Ferroxcube Sweden
Tel: +46 8 580 119 74, Fax: +46 8 580 121 60

Finland: Contact Ferroxcube Sweden
Tel: +46 8 580 119 74, Fax: +46 8 580 121 60

France: Ferroxcube France, NANTERRE
Tel: +33 (01) 5551 8422, Fax: +33 (01) 5551 8423

Germany: Ferroxcube Germany, HAMBURG
Tel: +49 (040) 527 28 302, Fax: +49 (040) 527 28 306

Greece: Contact Ferroxcube Italy
Tel: +39 02 241131 1, Fax: +39 02 241131 11

Hungary: Contact Ferroxcube Poland
Tel: +48 46 834 00 07, Fax: +48 46 834 00 35

Indonesia: Contact Ferroxcube Singapore
Tel: +65 6244 7815, Fax: +65 6449 0446

Ireland: Contact Ferroxcube UK
Tel: +44 1706 830723, Fax: +44 1706 222638

Israel: Arrow/Arpac Ltd., PETCHIK TIKVA
Tel: +972 3 9203480, Fax: +972 3 9203443

Italy: Ferroxcube Italy, SESTO S. GIOVANNA (MI)
Tel: +39 02 241131 1, Fax: +39 02 241131 11

Korea: Contact Ferroxcube Taiwan
Tel: +886 2 88665009, Fax: +886 2 886650145

Malaysia: Contact Ferroxcube Singapore
Tel: +65 6244 7815, Fax: +65 6449 0446

Mexico (excl. Baja): R.V. Componentes, Guadalajara, MX
Tel: +52 33 3641 9595, Fax: +52 33 3641 9898

Mexico (Baja): Contact Ferroxcube USA
Tel: +1 619 207 0061, Fax: +1 619 207 0062

New Zealand: Contact Ferroxcube Taiwan
Tel: +886 2 86650099, Fax: +886 2 86650145

Norway: Contact Ferroxcube Sweden
Tel: +46 8 580 119 74, Fax: +46 8 580 121 60

Philippines: Contact Ferroxcube Singapore
Tel: +66 6244 7815, Fax: +66 6449 0446

Poland: Contact Ferroxcube Polska, SKIERNIEWSKA
Tel: +48 46 834 00 07, Fax: +48 46 834 00 35

Portugal: Contact Ferroxcube Poloneza
Tel: +34 (949) 247 153, Fax: +34 (949) 247 146

Serbia and Montenegro: Contact Ferroxcube Italy
Tel: +39 02 241131 1, Fax: +39 02 241131 11

Singapore: Ferroxcube Singapore, SINGAPORE
Tel: +65 6244 7815, Fax: +65 6449 0446

Slovak Republic: Contact Ferroxcube Poland
Tel: +48 46 834 00 07, Fax: +48 46 834 00 35

Slovenia: Contact Ferroxcube Italy
Tel: +39 02 241131 1, Fax: +39 02 241131 11

South-Africa: Contact Ferroxcube UK
Tel: +44 1706 830723, Fax: +44 1706 822638

Spain: Contact Ferroxcube Spain, MADRID
Tel: +34 (949) 247 153, Fax: +34 (949) 247 146

Sweden: Ferroxcube Sweden, JÄRFÄLLA
Tel: +46 8 580 119 74, Fax: +46 8 580 121 60

Switzerland: Contact Ferroxcube Germany
Tel: +49 (040) 527 28 305, Fax: +49 (040) 527 28 306

Taiwan: Ferroxcube Taiwan, TAIPEI
Tel: +886 2 86650099, Fax: +886 2 86650145

Turkey: Contact Ferroxcube Italy
Tel: +39 02 241131 1, Fax: +39 02 241131 11

United Kingdom: Contact Ferroxcube UK, CROYDON
Tel: +44 870 2418759, Fax: +44 870 2418761

United States: Ferroxcube USA, EL PASO (TX)
Tel: +1 915 599 2513/2328, Fax: +1 915 599 2555

For all other countries apply to closest regional sales office:

Hamburg, Germany
Tel: +49 (040) 527 28 302, Fax: +49 (040) 527 28 306
E-mail: sales@ferroxcube.com

El Paso (TX), USA
Tel: +1 915 599 2312, Fax: +1 915 599 2555
E-mail: sales@ferroxcube.com

Taipei, Taiwan
Tel: +886 2 86650099, Fax: +886 2 86650145
E-mail: sales@ferroxcube.com

© Ferroxcube International Holding B.V. 2006

All rights are reserved. Reproduction in whole or in part is prohibited without the prior written consent of the copyright owner. The information presented in this document does not form part of any quotation or contract, is believed to be accurate and reliable and may be changed without notice. No liability will be accepted by the publisher for any consequence of its use. Publication thereof does not convey nor imply any license under patent- or other industrial or intellectual property rights.

Visit our web-site for the latest information on new products, application info as well as updated phone- and fax numbers

Internet: www.ferroxcube.com

Printed in The Netherlands Date of release: February 2007