APEC 2018 – San Antonio

Advanced ferrite technology
Distributed air-gap cores improve performance of power electronics
Air gaps increase power handling capability and allow higher currents

Limiting factors of solutions with only one air gap
- Fringing flux close to the air gap induces eddy currents
- Additional proximity losses occur in high-frequency magnetics
- Fringing flux losses are proportional to the average of the square of the local flux density in the winding ($B^2$)
Effect of different air gaps in ferrite cores

No air gap
- Low energy storage
- Highest inductance
- Lowest copper
- Lowest loss

Small air gap
- Nominal energy storage
- Lower inductance
- Low copper
- Nominal fringing flux
- Moderate loss

Big air gap
- High energy storage
- Low inductance
- Higher copper
- Highest fringing flux
- Highest loss

Distributed air gaps
- High energy storage
- Low inductance
- Low copper
- Nominal fringing flux
- Moderate loss

Distributed air gaps combine the advantages of small and big air gaps
Distributed air gaps lower loss due to fringing flux

Simulation of fringing flux losses with E 55/28/25 cores

Loss due to fringing flux get decreased in proportion to $B^2$ with an increasing number of identical air gaps
Identically distributed air gaps delay core saturation

The delayed core saturation is realized due to the lower temperature rise which is around $\frac{1}{3}$rd for wire coil.
Identically distributed air gaps improve the performance/cost ratio

Simulation of fringing flux losses with E 55/28/25 cores

- Proximity losses decrease as the number of smaller air gaps increases
- Identical distributed air gaps are more efficient than non-identical air gaps

The best performance/cost ratio is achieved with three identical air gaps

ΔP = reduction of proximity losses
Distributed air gaps improve the temperature increase

Measurement of temperature after 60 min of $5 \ A_{pp} \ @ \ 50 \ kHz$ with ETD 29/16/10 cores in N87 with three distributed air gaps (left) and single air gap (right) with wire coils

Temperature increase improves with distributed air gap cores
Distributed air gaps improve significantly the temperature increase with wire coils

Measurement of temperature increase for 60 min of 5 $A_{pp}$ @ 50 kHz with ETD 29/16/10 cores in N87

- Temperature increase can be reduced by the factor 3 for wire coils
- Effect of temperature difference is already noticeable at low frequencies for wire coils

Proximity losses can be reduced by the factor 3 for wire coils
Wide range of core types with distributed air gaps

- **E cores**
  Sizes: E 42 to 100
- **EQ cores**
  Sizes: EQ 25 to 30
- **ER cores**
  Sizes: ER 28 to 54
- **PQ cores**
  Sizes: PQ 32 to 50
- **ETD cores**
  Sizes: ETD 29 to 59
- **PM cores**
  Sizes: PM 50 to 114

All core types are available in all materials.
Customer benefits

Distributed air gaps

- Reduce proximity losses by up to 70%
- Enable use of a larger winding area by reducing the fringing flux
- Lower winding losses than with a single large air gap for the factor 3
- Enable reduction of the core size by one class thanks to lower winding losses, e.g.
  - E 65 to E 55
  - ETD 59 to ETD 54
- Offer significantly increased power density

Identical air gaps increase the efficiency of applications