Electeng 311

Electronics Systems Design

Flyback transformer design

Seho Kim

Contents

- Transformer losses from B-H curves and Steinmetz equations
- Eddy currents – skin effect and proximity effect in the winding
- Flyback transformer design example
- Overview of finite element analysis

Learning outcomes

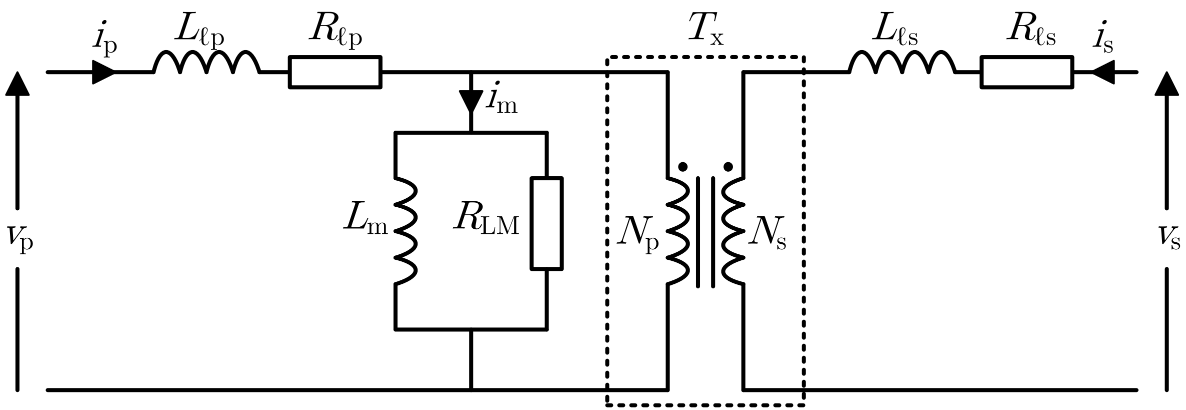
- Understand the practical loss components of transformers.
- Understand skin effect and proximity effect and be able to select a wire size.
- Able to calculate the parameters regarding the flyback transformer.
- Understand the concept of finite element analysis

Magnetics

Losses

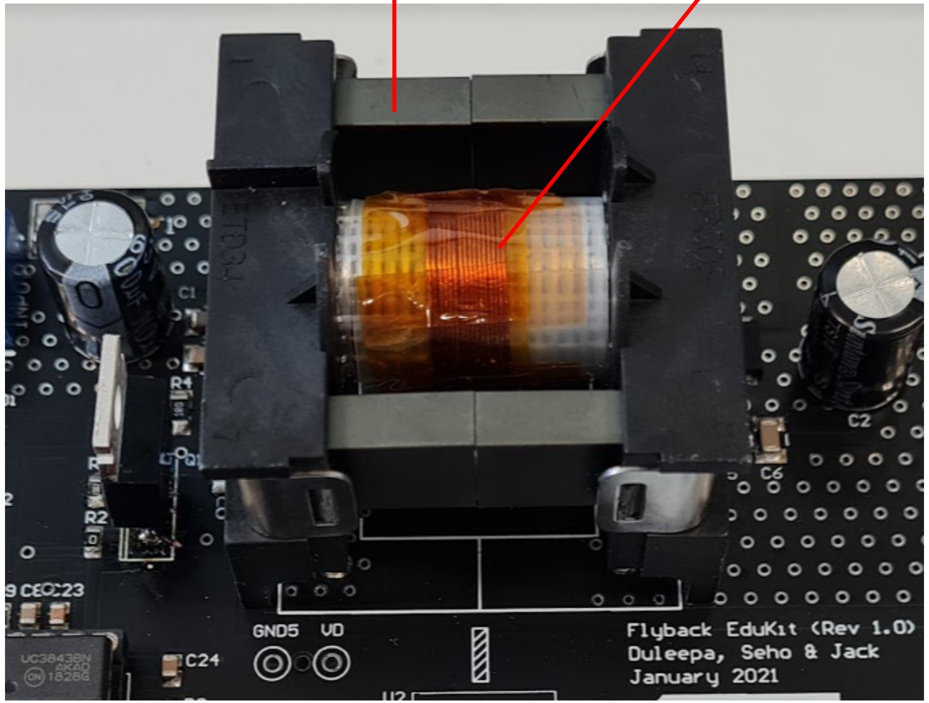
Magnetics – losses

- A transformer is designed to be without loss as much as possible, but some amount of loss always exists in the core and the winding.



- Transformer model with losses.

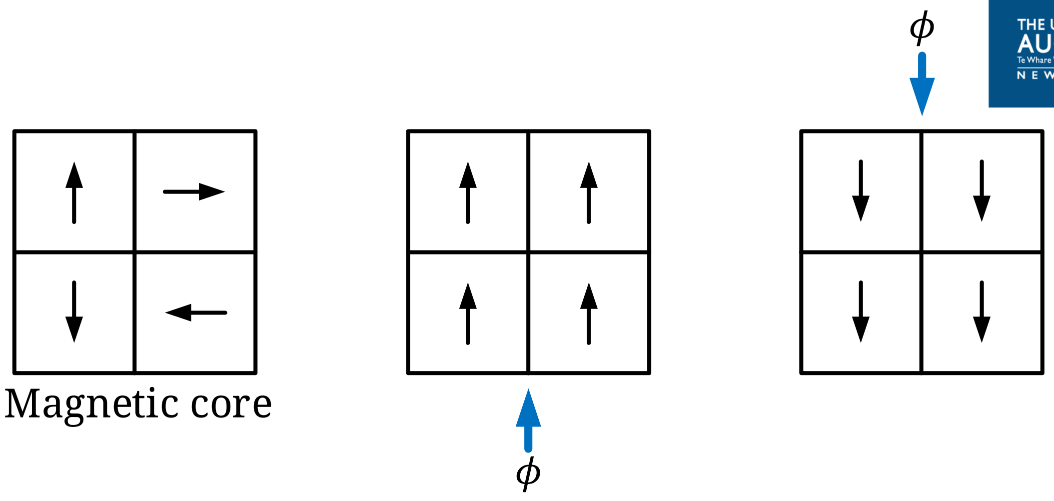
Core
Winding



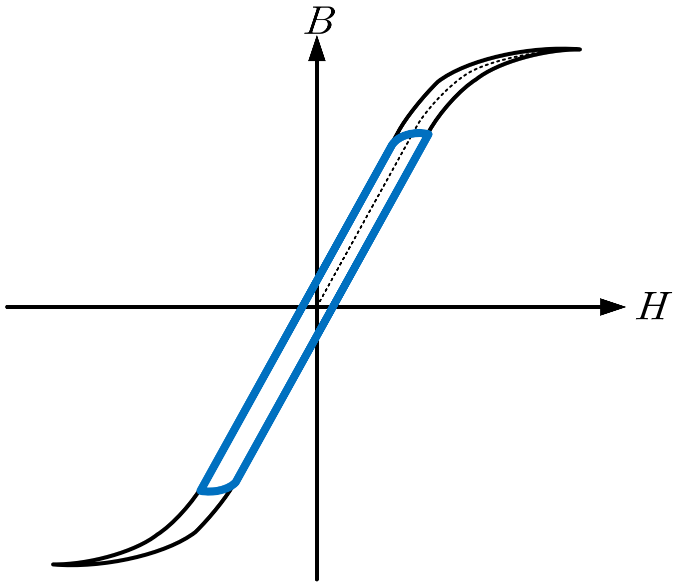
- An example transformer for the 311 project

Magnetics – core loss

- As the AC magnetic flux passes through the core of the transformer, the magnetisation of the core material changes.
- Some of the energy is lost as heat during the changes in the magnetisation of the core material.
- At higher frequencies, the losses are increased as the core undergoes more changes in the domain per second.
- The B-H curve often has a hysteresis included in it to show this core loss.
- The area inside the B-H curve can be calculated to find the hysteresis loss.



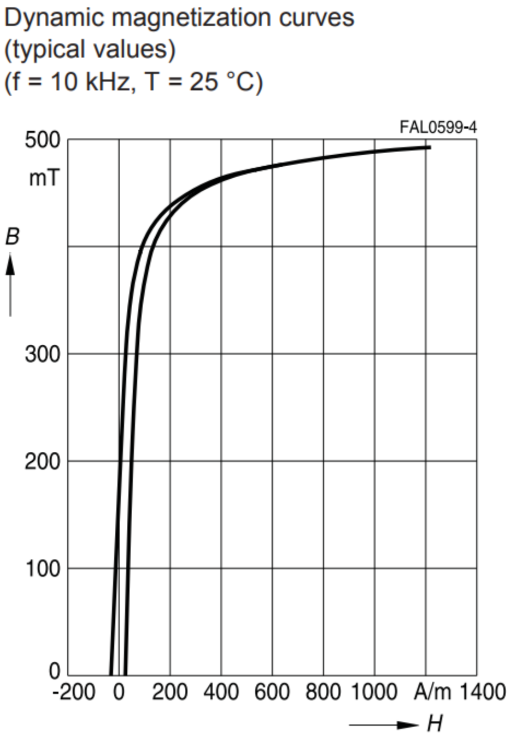
- Changes in the magnetic domain due to magnetising flux

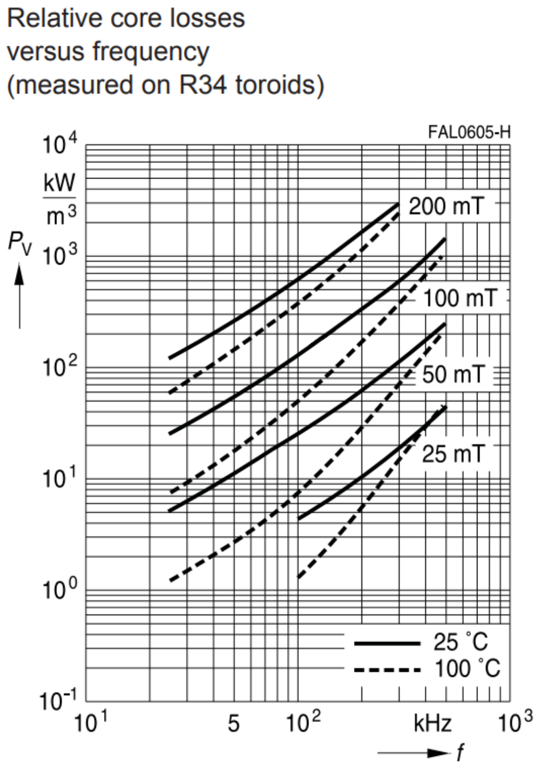


- B-H curve with hysteresis

Magnetics – Steinmetz equation

- B-H curve provides useful information about core characteristics, but changes with frequency and temperature.
- Datasheets will only show a few example B-H curves.
- **Steinmetz equation** is used to find the core loss using empirically determined values.
- $P_{\mathrm{v}} = k_{fe} f^{\alpha} B^{\beta}$
- At f = 100KHz, B = 100mT and T = 40℃, TDK N87 has Steinmetz coefficients of k_{fe} = 1.4241, α = 1.4768 and β = 2.5003 [1] :
- $P_{\mathrm{v}} = 1.4241 \times 100000^{1.4768} \times 0.1^{2.5003}$
- $P_{\mathrm{v}} = 108.96\ \mathrm{kW/m^3}$
- P_{v} is the power per unit volume in.
- If our core was 10000mm^3,
- $P = P_{\mathrm{v}} \times V = 1.09\mathrm{W}$



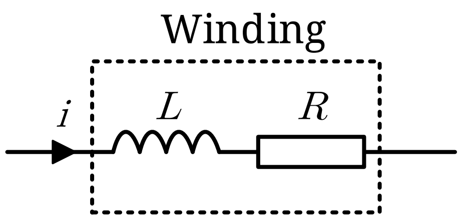


- B-H curve and core loss characteristics in TDK N87 datasheets [2]

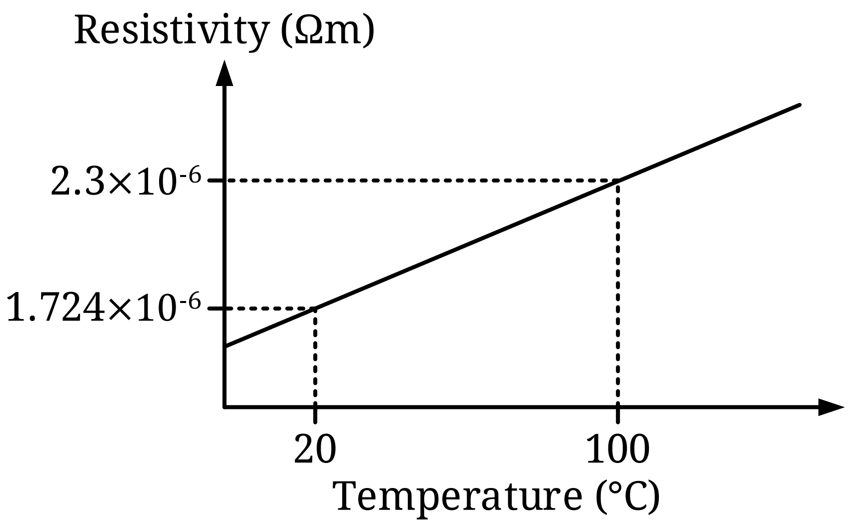
[1] https://tools.tdk-electronics.tdk.com/mdt/index.php
[2] https://www.tdk-electronics.tdk.com/download/528882/71e02c7b9384de1331b3f625ce4b2123/pdf-n87.pdf

Magnetics – copper loss

- Another source of loss in the transformer is the winding.
- At low frequency, the windings in the transformers have losses that can be calculated by:
- $P_w = I^2 R$
- The resistance is given by: $R = \rho \frac{\ell}{A}$
- Copper has a resistivity of 1.724×10^{-8} Ωm at 20°C. The copper resistivity rises with temperature linearly.
- Having a larger cross sectional area of copper helps to minimise the losses in the winding.



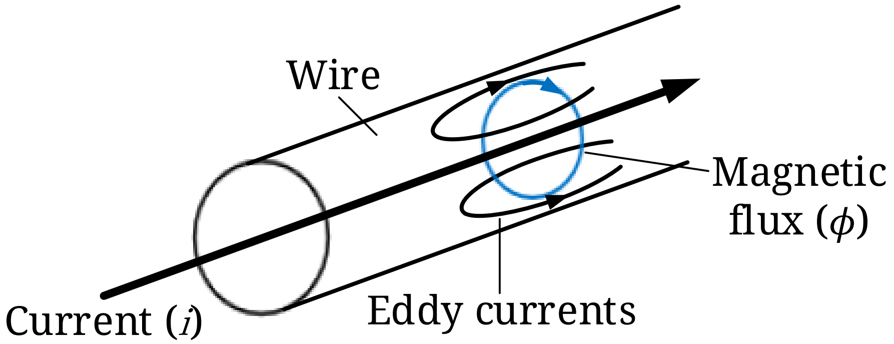
- Winding with equivalent series resistance

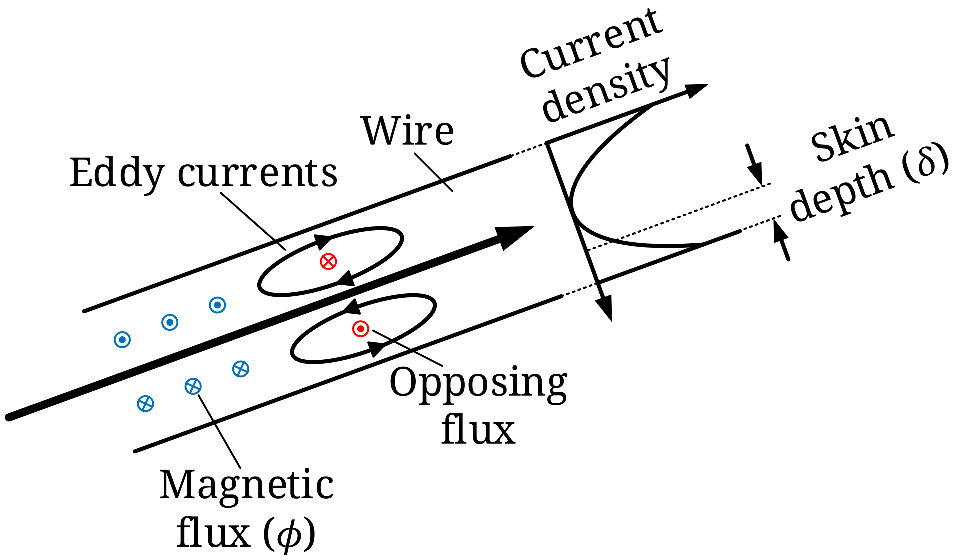


- Resistivity of copper against temperature

Magnetics – skin effect

- At higher frequencies, eddy currents are induced in the winding to result skew the current distribution in the wires.
- When a current flows into a wire, a magnetic field is formed around the current. (remember the right hand grip rule)
- Naturally, magnetic field is induced to oppose the magnetic field created by the current.
- The opposing magnetic field generates eddy currents that ‘pushes’ the current to be closer to the outer surface of the wires and this is called the **skin effect**.

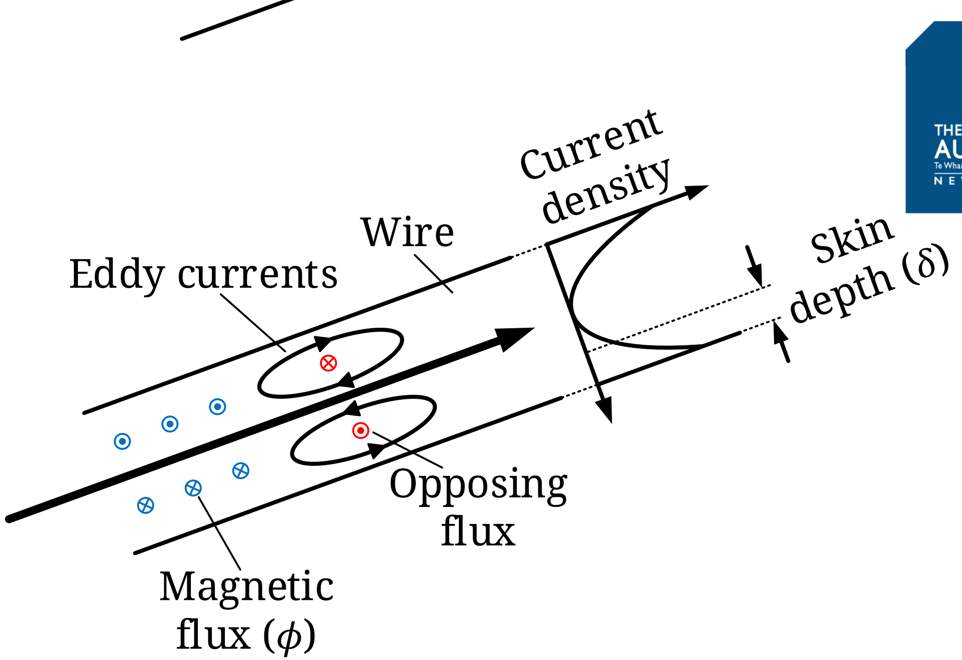


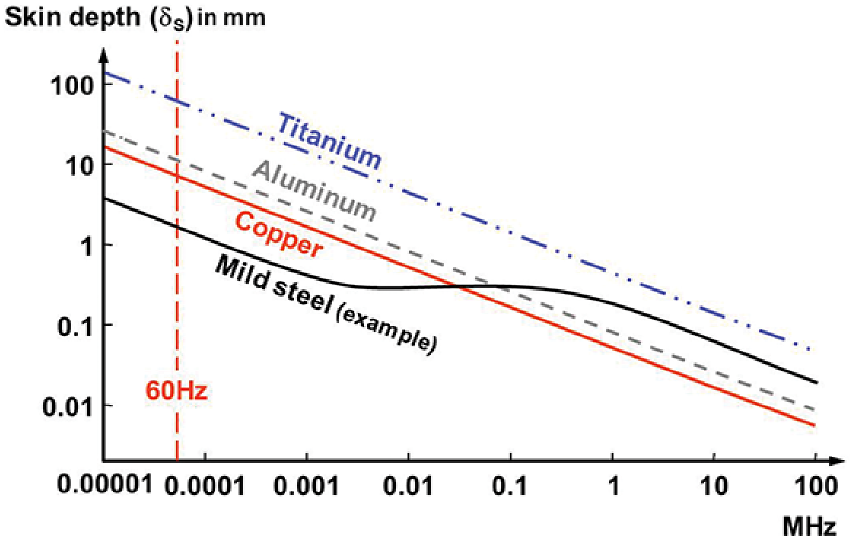


- Skin effect on a wire forcing current towards the outer surface of a wire

Magnetics – skin depth

- At high frequencies, the current travels only near outer surface of the wire and this **skin depth** is calculated by:
- $\delta = \sqrt{\frac{\rho}{\pi \mu f}}$
- For copper, relative permeability ≈ 1.
- As an example, copper wire operating at 10kHz at 20°C would have skin depth of:
- $\delta = \sqrt{\frac{\rho}{\pi \mu f}} = \sqrt{\frac{1.724\times10^{-8}}{\pi\times4\pi\times10^{-7}\times1\times10000}} = 661\mu\text{m}$
- At 50Hz,
- $\delta = \sqrt{\frac{\rho}{\pi \mu f}} = \sqrt{\frac{1.724\times10^{-8}}{\pi\times4\pi\times10^{-7}\times1\times50}} = 9.3\text{mm}$
- At high frequency operation, knowing the skin depth is useful to choose the right size of wire. Any diameter that is larger than the skin depth is wasting material.



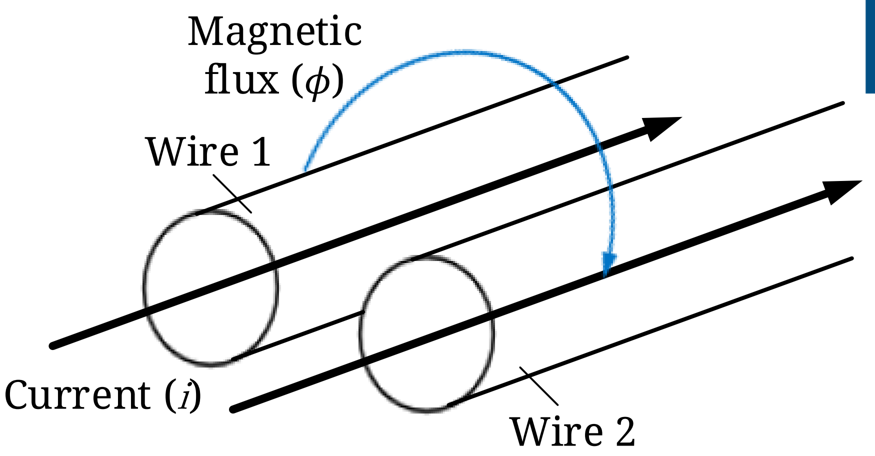


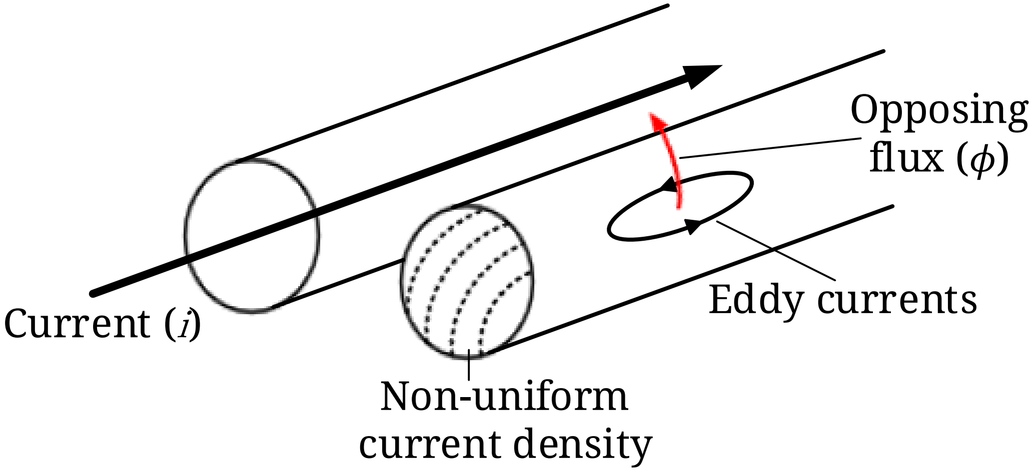
- Skin depth against frequency for different materials [3]

[3] https://incompliancemag.com/article/skin-effect-and-surface-currents/

Magnetics – proximity effect

- If two wires are side by side, the magnetic field generated by one wire affects the current distribution in the other and this is called the **<u>proximity effect</u>**.
- The effect is similar to the skin effect in the sense that an opposing magnetic field is induced in the second wire that generates eddy currents.
- The eddy currents ‘push’ the current in the second wire to be concentrated away from the first wire.
- Minimise the layers in the transformer windings to minimise proximity effect.

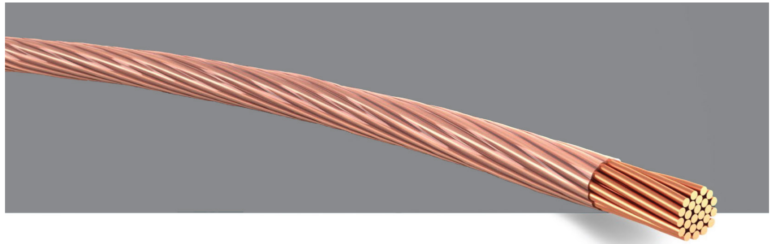




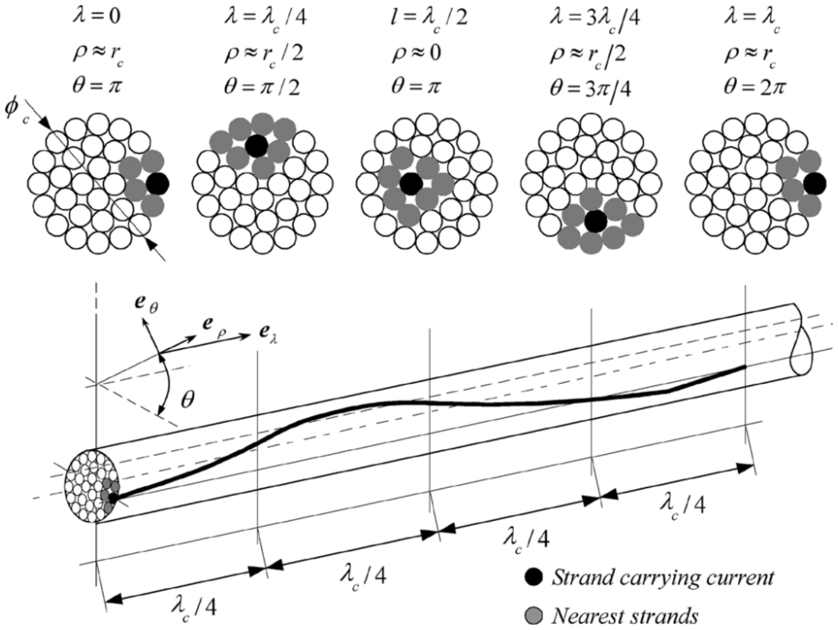
- Proximity effect causing non-uniformity in the current density

Magnetics – litz wire

- In high frequency applications, litz wires are often used to minimise the losses in the winding.
- Many individual strands of wires are twisted together and connected in parallel.
- Each strand is twisted in such a way that the strand transposes in all positions in the bundle to minimise the proximity effect.
- The strand diameter is chosen to be smaller than the skin depth.
- Litz wire often has individual coating on each strand of wire that reduces the overall copper in the cross-sectional area.
- Litz wire tends to be relatively expensive due to the manufacturing process than conventional copper wires.



- A depiction of litz wire [3]



- Transposition of a strand of litz wire [4]

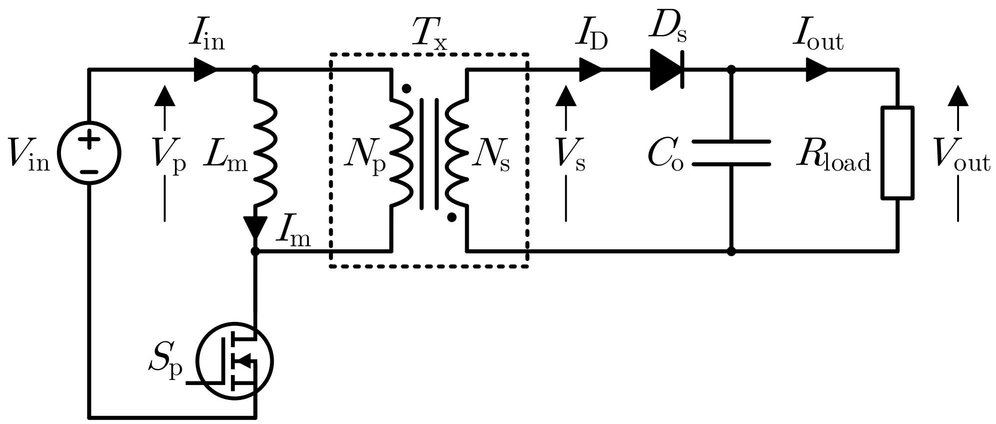
[3] https://www.elektrisola.com/ru/Products/Litz-Wire/Products/Smartbond
[4] J. Acero, R. Alonso, J. M. Burdio, L. A. Barragan and D. Puyal, "Frequency-dependent resistance in Litz-wire planar windings for domestic induction heating appliances," in IEEE Transactions on Power Electronics, vol. 21, no. 4, pp. 856-866, July 2006

Flybback transformer

Design examples

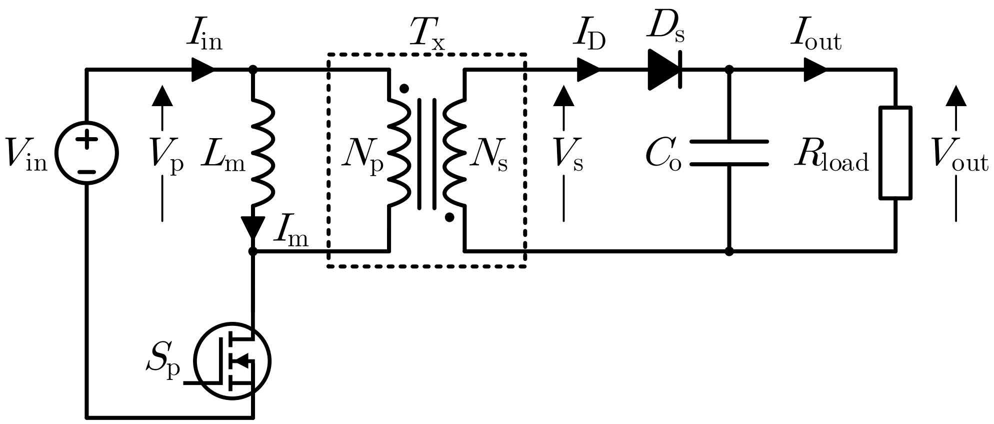
Flyback transformer

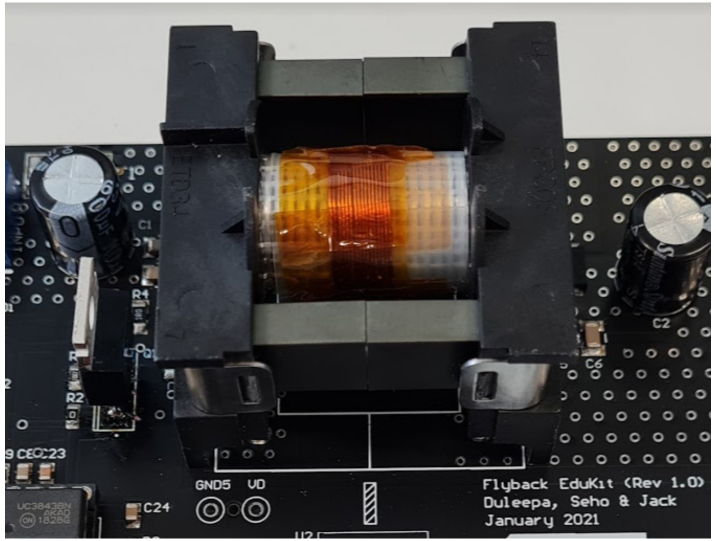
- Ideal transformers do not store energy. All energy is passed through with a small amount of losses.
- Flyback transformers are not really fitting the classical definition of 'transformers', but rather two closely coupled inductors as flyback transformers are deliberately designed to store energy as magnetic field.
- Transformers are large, bulky and expensive and careful design can minimise these factors.



Flyback transformer design – example

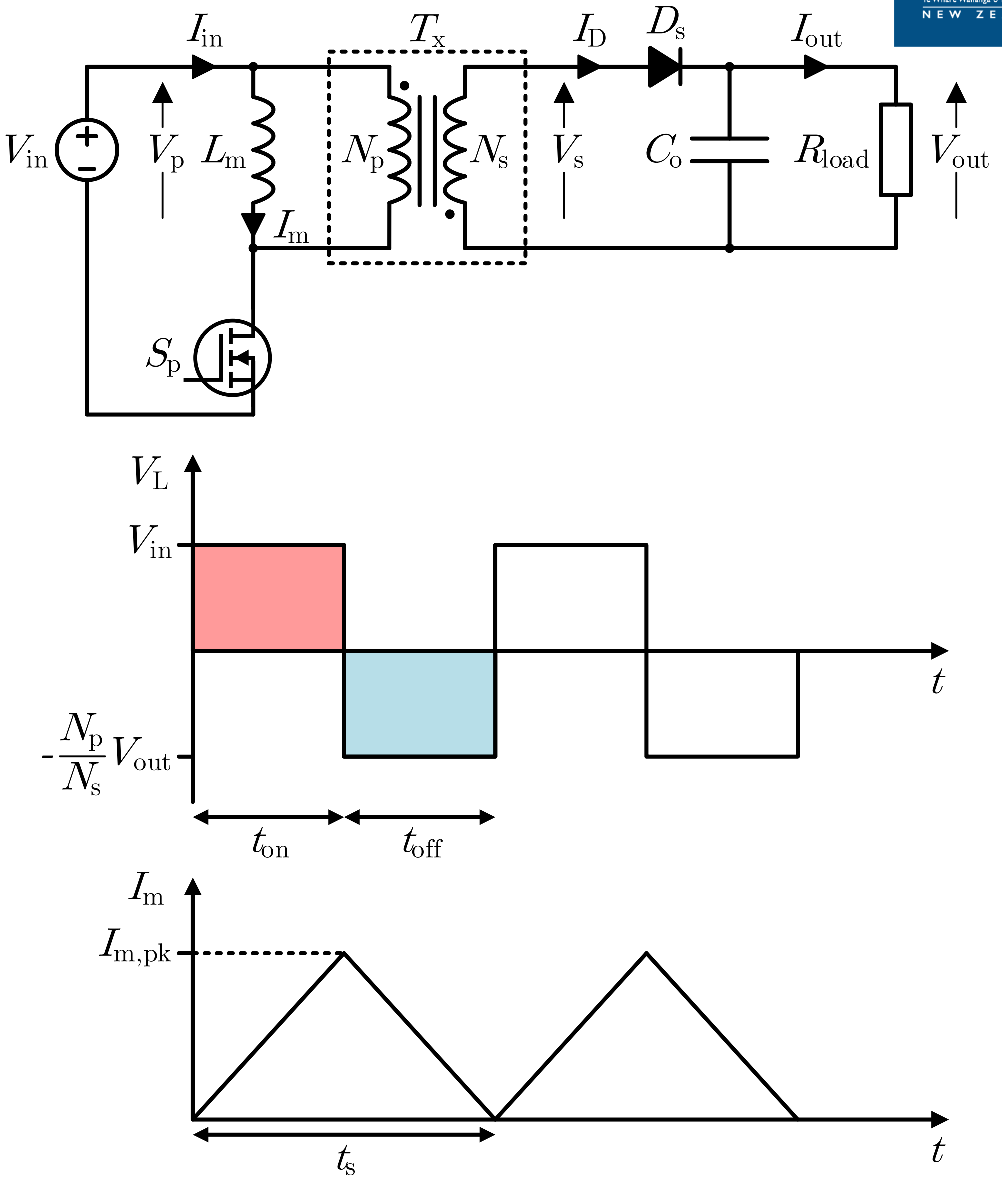
- Example parameters:
  - Input voltage: 50V
  - Output voltage: 50V
  - Maximum power output: 50W
  - Operating frequency: 100kHz
  - Max. duty cycle: 0.5
  - Coupling factor = 1
  - Discontinuous conduction mode
- Calculate the primary inductance.
- Calculate the turns ratio.
- Calculate the secondary inductance.
- Select ferrite core, air gap and winding turns.
- Calculate the peak primary and secondary currents.
- Calculate the peak magnetic flux density in the core.
- Calculate the transformer losses.





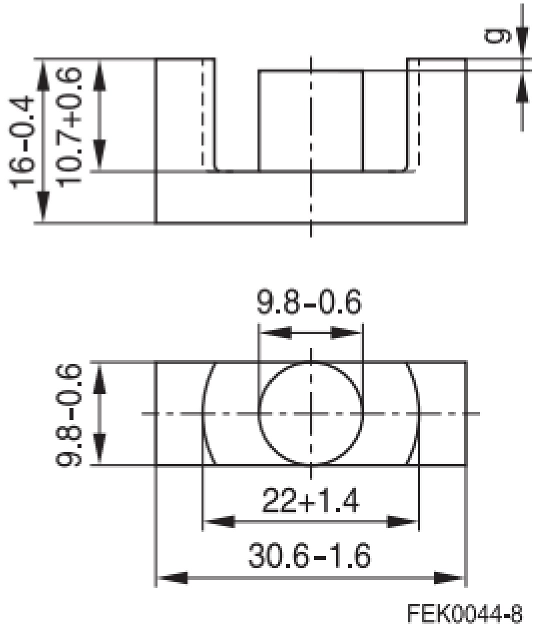
Flyback transformer design – example

- In discontinuous conduction mode, all of the energy within the primary winding is transferred out in a cycle.
- Since $k = 1$ in this example, $L_m = L_p$.
- In the previous lectures, the primary inductance required to transfer power at maximum duty cycle was given as:
- $L_{p(req)} \leq \frac{V_{in}^2 D_{max}{}^2}{2 f_s P} = \frac{(50\times0.5)^2}{2\times100000\times50} = 62.5\mu H$
- The flyback transformer turns ratio required to operate in discontinuous conduction mode is found as:
- $\frac{N_p}{N_s} \geq \frac{V_{in} D}{V_{out}(1-D)} = \frac{50\times0.5}{50(1-0.5)} = 1$
- The turns ratio is selected to be 1.
- Since turns ratio is 1, the secondary inductance is identical to the primary inductance.
- $\therefore L_p = L_s$



Flyback transformer design – example

- Example design using ETD 29/16/10 core [6].
- Effective core length (ℓ_e) = 70.4mm
- Effective core area (A_e) = 76mm^2
- Core permeability (μ_r) = 1610
- $N_p = \sqrt{\frac{L\ell_e}{\mu_0\mu_r A}} = \sqrt{\frac{62.5\mu\times0.0704}{4\pi\ \times10^{-7}\times1610\times0.000076}} = 5.35$
- Select N_p to be 5 turns since 6 turns would exceed L_p of 62.5µH.
- $L_p = \frac{\mu_0\mu_r {N_p}^2 A}{\ell_e} = \frac{4\pi\ \times10^{-7}\times1610\times5^2\times0.000076}{0.0704} = 54.6\mu H$
- $L_s = L_p = 54.6\mu H$



Ungapped

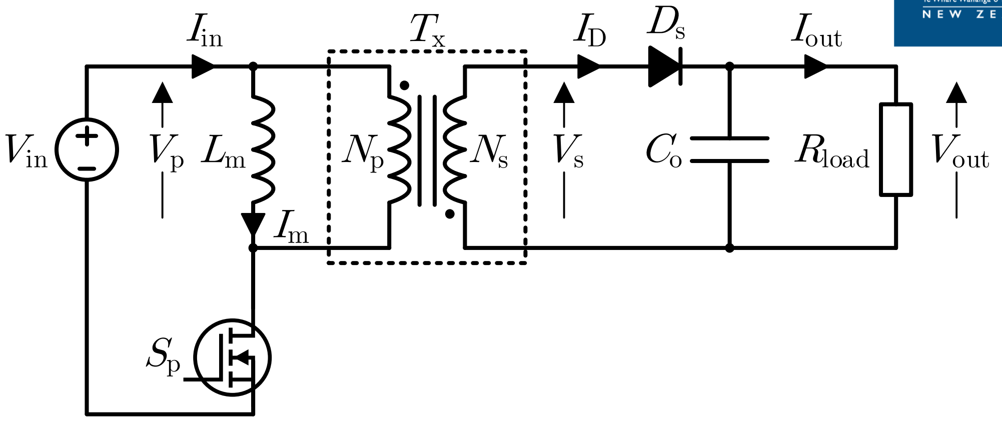
Material	A_L value nH	μ_e	P_V W/set
N27	2000 +30/–20%	1470	< 1.04 (200 mT, 25 kHz, 100 °C)
N87	2200 +30/–20%	1610	< 2.80 (200 mT, 100 kHz, 100 °C)
N97	2250 +30/–20%	1670	< 2.40 (200 mT, 100 kHz, 100 °C)

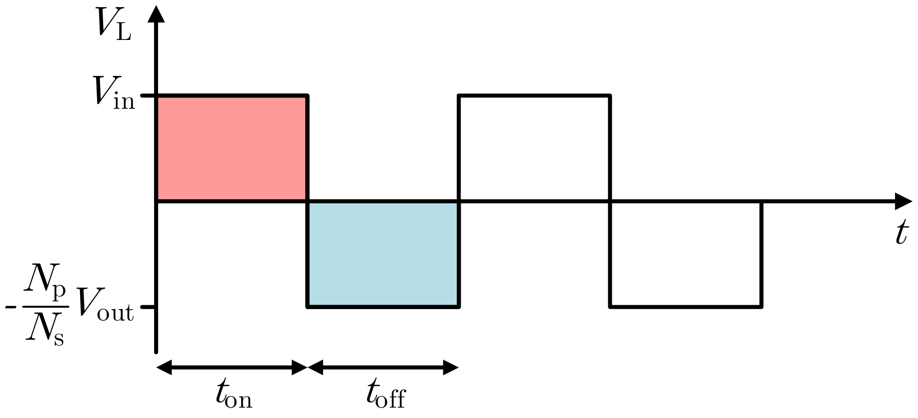
- ETD 29/16/10 core dimensions and properties [5]

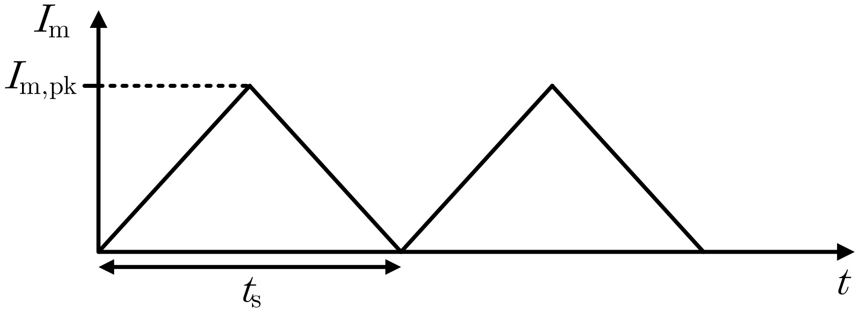
[6] https://www.tdk-electronics.tdk.com/inf/80/db/fer/etd_29_16_10.pdf

Flybatransformer design – example

- The operating duty cycles are given by:
- $D = \sqrt{\frac{2Pf_sL_p}{V_{\text{in}}^2}} = \sqrt{\frac{2\times50\times100000\times54.6\mu}{50^2}} = 0.467$
- $D' = \frac{V_{\text{in}}D}{V_{\text{out}}}\frac{N_s}{N_p} = \frac{50\times0.467}{50}\times1 = 0.467$
- Given the inductances and the turns ratio, the peak currents in the primary and the secondary windings can be calculated.
- $\text{I}_{\text{m,peak}} = \text{I}_{\text{p,peak}} = \frac{V_{\text{in}}}{L_p}D_{\max}t_s = \frac{50\times0.418}{100000\times43.6\mu} = 4.28\text{A}$
- $\text{I}_{\text{s,peak}} = \frac{N_p}{N_s}\text{I}_{\text{p,peak}} = 1\times4 = 4.28\text{A}$

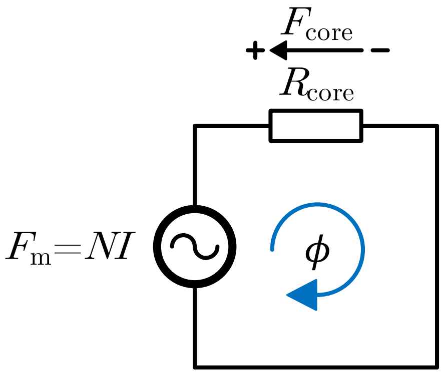


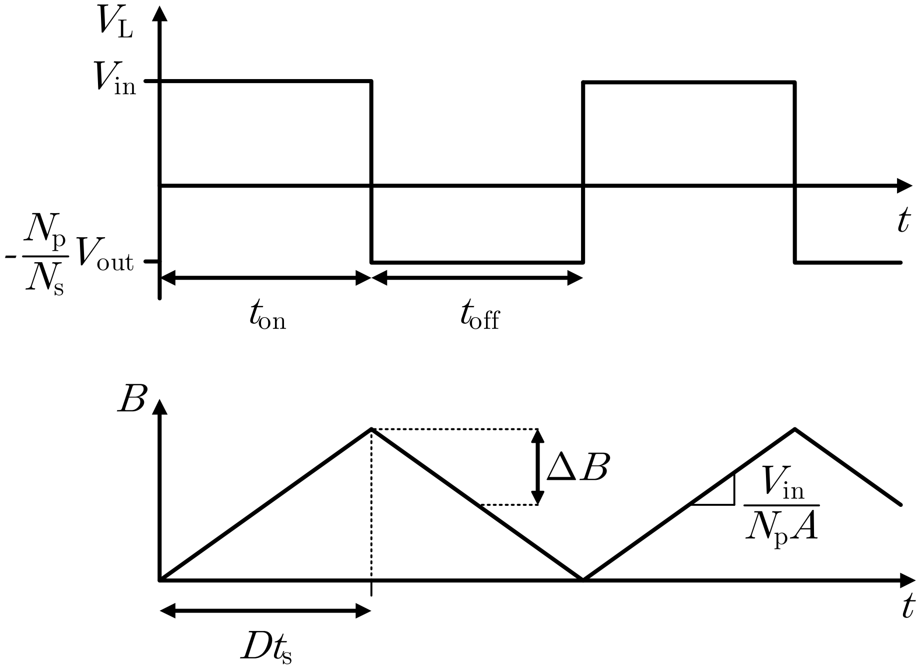




Flybook transformer design – example

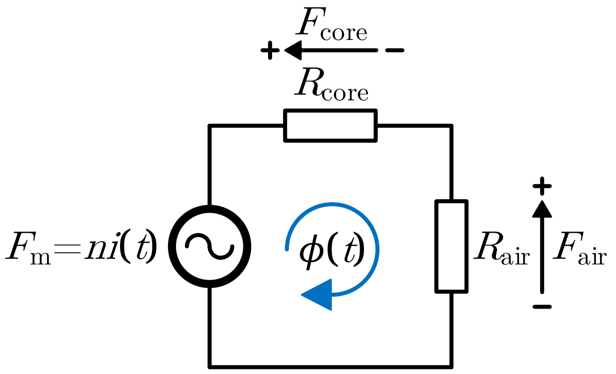
- In order to find the magnetic flux density (B) in the core, the magnetic field strength (H) needs to be found.
- $H = \frac{N_p I_{Lpeak}}{\ell_e} = \frac{5\times4.28}{0.0704} = 304\text{Am}^{-1}$
- The B field within the core is found as:
- $B = \mu_0\mu_e H = 4\pi \times 10^{-7} \times 1610 \times 304 = 0.615\text{T}$
- $B_{SAT} \approx 0.3\text{T}$
- The magnetic flux density is too high and needs to be reduced.

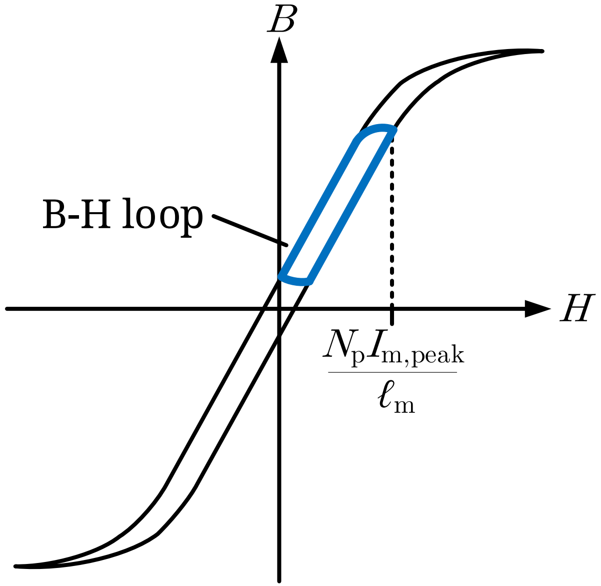


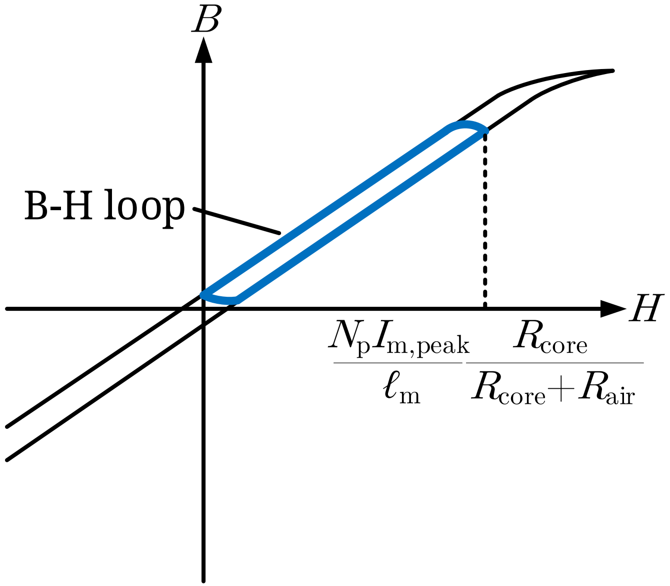


Flyback transformer design – example

- The peak current in the flyback transformer correlates to the stored energy.
- In discontinuous conduction mode, the peak current tends to be significant so a high magnetic field strength (H) is generated.
- An air gap is used to lower the effective reluctance of the flyback transformer so a small transformer can withstand a higher current without the core saturating due to high magnetic flux density (B).
- $F_{\text{core}} = F_{\text{m}} \frac{R_{\text{core}}}{R_{\text{core}}+R_{\text{air}}}$
- H in the core (H_{core}) is:
- $H_{core} = \frac{N_{\text{p}} I_{\text{Lpeak}}}{\ell} \frac{R_{\text{core}}}{R_{\text{core}}+R_{\text{air}}}$

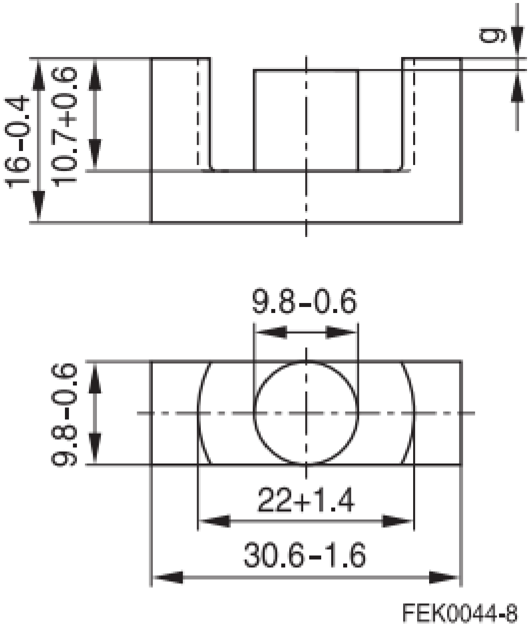






Flyback transformer design – example

- Example design using ETD 29/16/10 core [6].
- Effective core length (ℓ_e) = 70.4mm
- Effective core area (A_e) = 76mm^2
- Core permeability (μ_r) = 1610
- Air gap = 0.2mm
- Core reluctance (R_{core}) = $\frac{\ell}{\mu_0 \mu_r A}$ =
- Air reluctance (R_{air}) = $\frac{\ell}{\mu_0 A}$ =
- Effective reluctance (R_e) =
- Effective permeability (μ_e) =
- $N_p = \sqrt{\frac{L\ell_m}{\mu_0 \mu_e A}} =$
- $L_p = \frac{\mu_0 \mu_r {N_p}^2 A}{\ell_e} =$



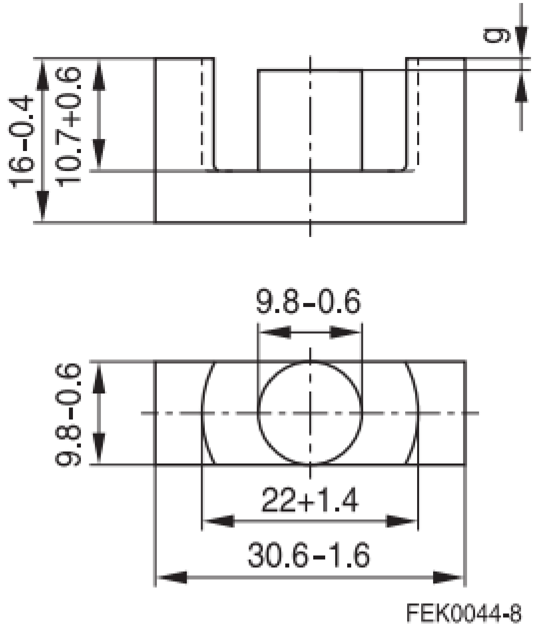
Gapped (A_L values/air gaps examples)

Material	g mm	A_L value approx. nH	μ_e
N27, N87	0.10 ±0.02 0.20 ±0.02 0.50 ±0.05 1.00 ±0.05	621 383 201 124	457 281 148 91

- ETD 29/16/10 core dimensions and properties [5]

Flyback transformer design – example

- Example design using ETD 29/16/10 core [6].
- Effective core length (ℓ_e) = 70.4mm
- Effective core area (A_e) = 76mm^2
- Core permeability (μ_r) = 1610
- Air gap = 0.2mm
- Core reluctance (R_{core}) $= \frac{\ell}{\mu_0 \mu_r A} = \frac{0.0704}{4\pi \times 10^{-7} \times 1610 \times 0.000076} = 458\text{kH}^{-1}$
- Air reluctance (R_{air}) $= \frac{\ell}{\mu_0 A} = \frac{0.0002}{4\pi \times 10^{-7} \times 0.000076} = 2.09\text{MH}^{-1}$
- Effective reluctance (R_e) = 458k+2.09M= 2.55M
- Effective permeability (μ_e) $= \frac{\ell}{\mu_0 R_e A} = \frac{0.0704}{4\pi \times 10^{-7} \times 2550000 \times 0.000076} = 289$
- $N_{p,max} = \sqrt{\frac{L\ell_e}{\mu_0 \mu_e A}} = \sqrt{\frac{62.5\mu \times 0.0704}{4\pi \times 10^{-7} \times 289 \times 0.000076}} = 12.6$
- Select N_p to be 12 turns since 13 turns would exceed L_p of 62.5μH.
- $L_p = \frac{\mu_0 \mu_r {N_p}^2 A}{\ell_e} = \frac{4\pi \times 10^{-7} \times 289 \times 12^2 \times 0.000076}{0.0704} = 56.4\mu\text{H}$



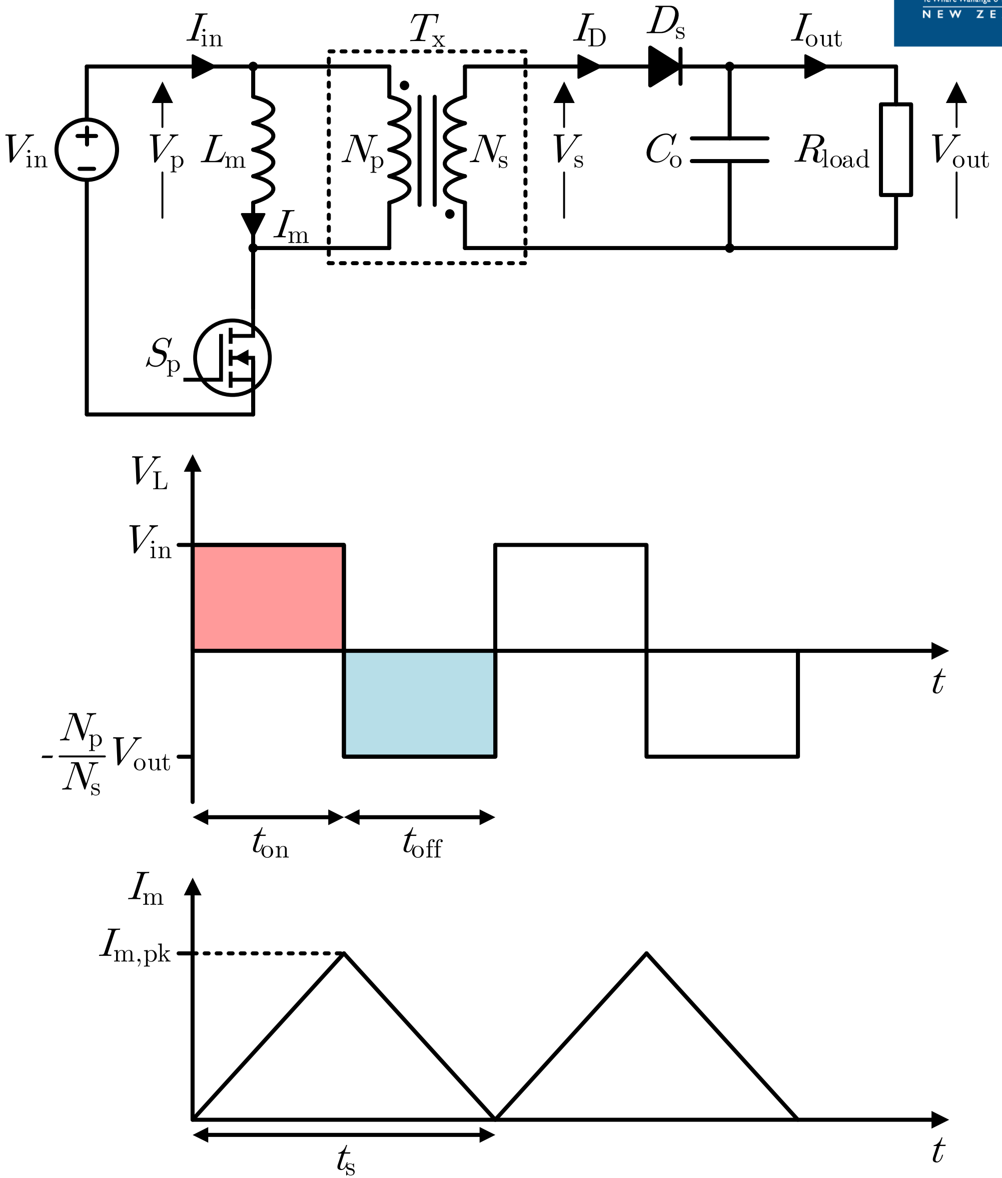
Ungapped

Material	A_L value nH	μ_e	P_V W/set
N27	2000 +30/–20%	1470	< 1.04 (200 mT, 25 kHz, 100 °C)
N87	2200 +30/–20%	1610	< 2.80 (200 mT, 100 kHz, 100 °C)
N97	2250 +30/–20%	1670	< 2.40 (200 mT, 100 kHz, 100 °C)

- ETD 29/16/10 core dimensions and properties [5]

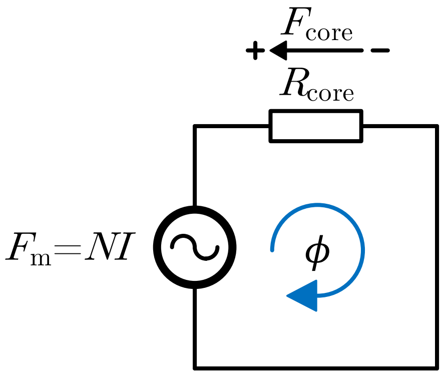
Flybeck transformer design – example

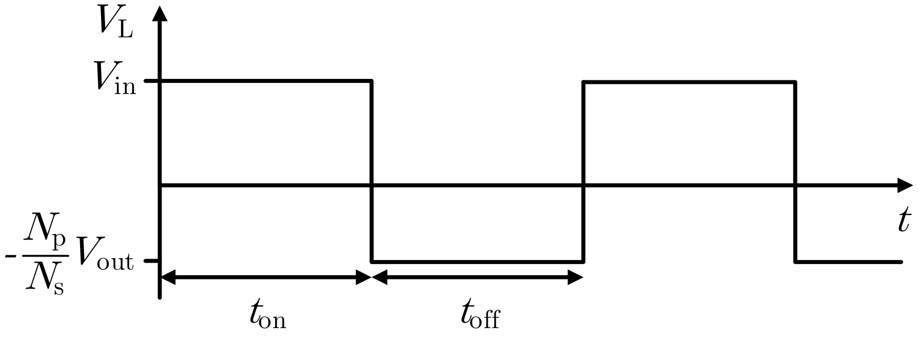
- The operating duty cycles are given by:
- $D = \sqrt{\frac{2Pf_s L_\mathrm{p}}{V_\mathrm{in}^2}} = \sqrt{\frac{2\times 50\times 100000\times 56.4\mu}{50^2}} = 0.475$
- $D' = \frac{V_\mathrm{in} D}{V_\mathrm{out}} \frac{N_\mathrm{s}}{N_\mathrm{p}} = \frac{50\times 0.475}{50} \times 1 = 0.475$
- Given the inductances and the turns ratio, the peak currents in the primary and the secondary windings can be calculated.
- $\mathrm{I_{m,peak}} = \mathrm{I_{p,peak}} = \frac{V_\mathrm{in}}{L_\mathrm{p}} D_\mathrm{max} t_s = \frac{50\times 0.418}{100000\times 43.6\mu} = 4.21\mathrm{A}$
- $\mathrm{I_{s,peak}} = \frac{N_\mathrm{p}}{N_\mathrm{s}} \mathrm{I_{p,peak}} = 1 \times 4 = 4.21\mathrm{A}$

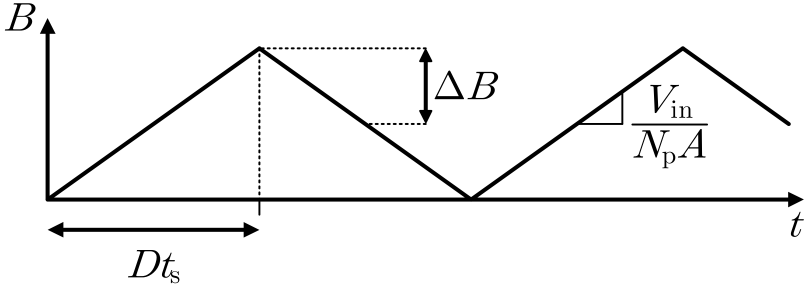


Flybeck transformer design – example

- In order to find the magnetic flux density (B) in the core, the magnetic field strength (H) needs to be found.
- $H = \frac{N_\text{p} I_\text{Lpeak}}{\ell_e} =$
- The magnetic field strength has almost doubled as the current stayed almost constant, but the number of turns doubled.
- Then the B field within the core is found as:
- $B =$

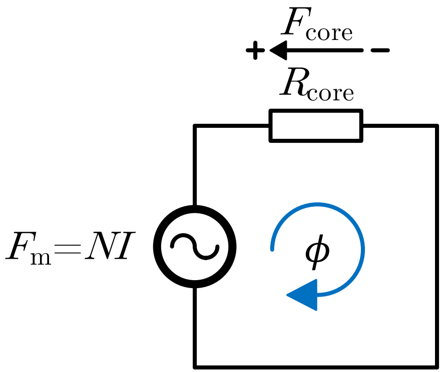


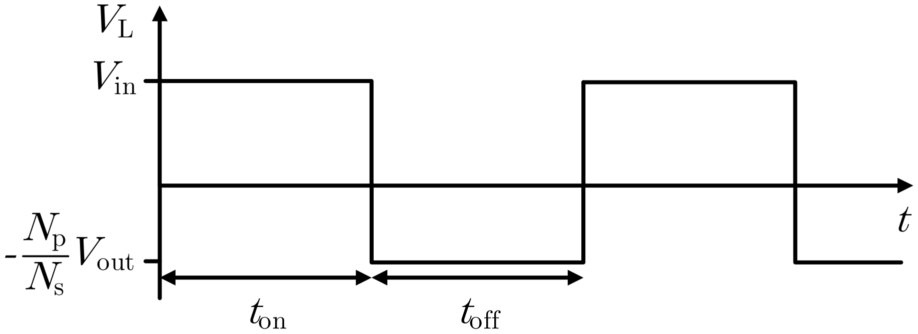


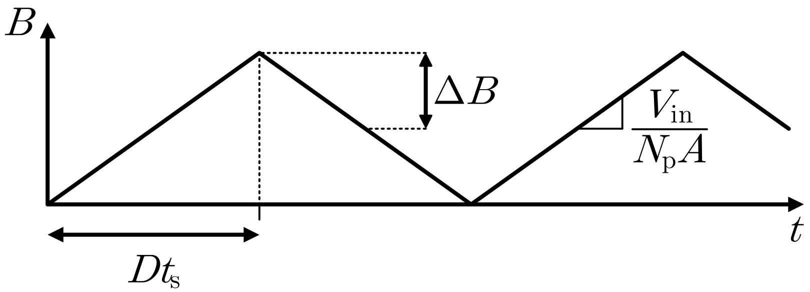


Flybck transformer design – example

- In order to find the magnetic flux density (B) in the core, the magnetic field strength (H) needs to be found.
- $H = \frac{N_p I_{Lpeak}}{\ell_e} = \frac{12\times 4.21}{0.0704} = 718\text{Am}^{-1}$
- The magnetic field strength has almost doubled as the current stayed almost constant, but the number of turns doubled.
- Then the B field within the core is found as:
- $B = \mu_0 \mu_e H = 4\pi \times 10^{-7} \times 289 \times 718 = 0.261\text{T}$
- Same core operating similarly as before, but the small air gap has significantly reduced the magnetic flux density.

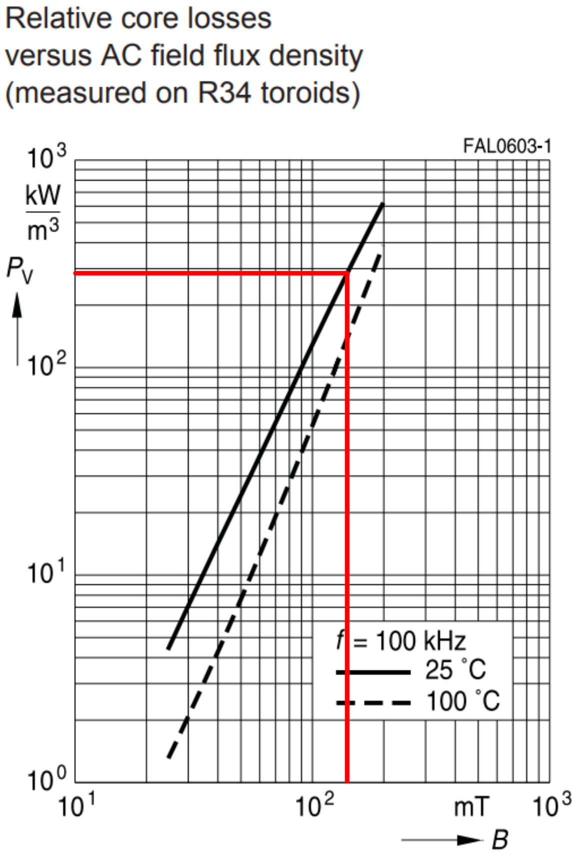


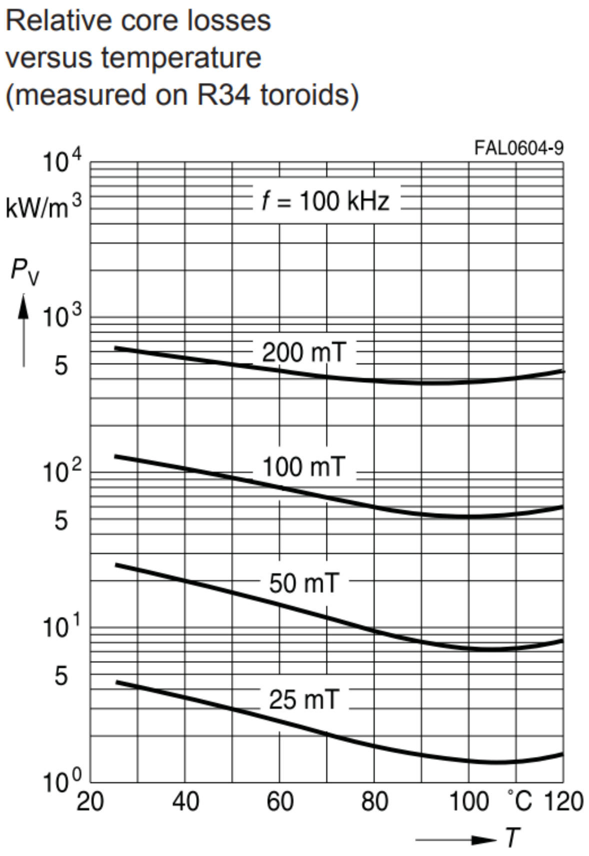




Flybtack transformer design – core loss

- Given that magnetic flux density (B) in the core is 130mT, the core losses can be found.
- Core losses are found using peak B (ΔB).
- $\Delta B = \frac{B}{2} = \frac{0.261}{2} = 130\text{mT}$
- Power per volume can be found using the graph provided in the datasheets.
- In this case $P_\text{v} \approx 300\text{kW/m}^3$
- ETD 29/16/10 core volume = 5350mm^3
- Remember there are two cores!
- $P = P_\text{v} \times V = 300 \times 10^3 \times 2 \times 5350 \times 10^{-9} = 3.21\text{W}$
- This loss is at 25°C and will change with temperature.



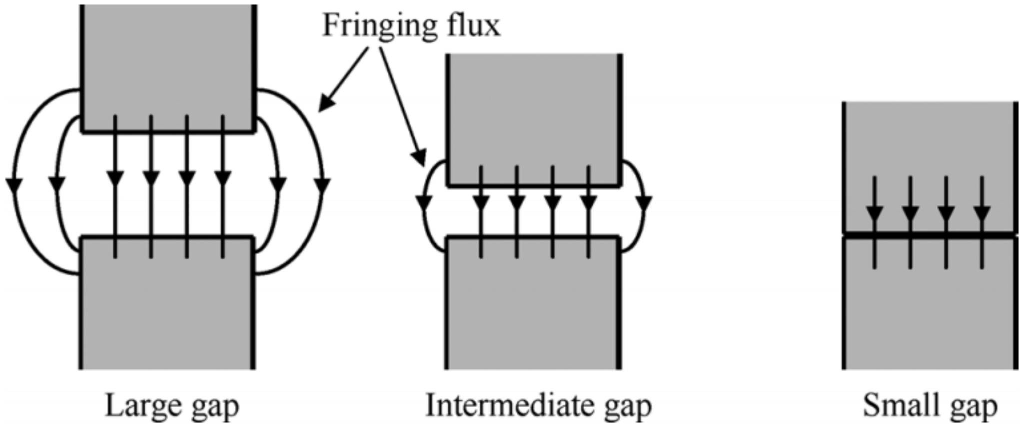


- Core loss characteristics in TDK N87 datasheets [2]

[2] https://www.tdk-electronics.tdk.com/download/528882/71e02c7b9384de1331b3f625ce4b2123/pdf-n87.pdf

Flyback transformer design

- Actual losses in the core and the winding are generally higher in practice than the calculations.
- One factor not taken into account is the **fringing effect**. Fringing effect is the spread of magnetic flux paths as an air gap is introduced in the magnetic core.
- The fringing increases the cross-sectional area of the air gap so the magnetic field density in the air gap becomes different to the rest of the core.
- Large fringing effect could make the calculation of the effective permeability (μ_e) difficult if the field path length and area is not constant.
- Fringing should be minimised to reduce any additional eddy currents in the core or proximity effect in the winding.



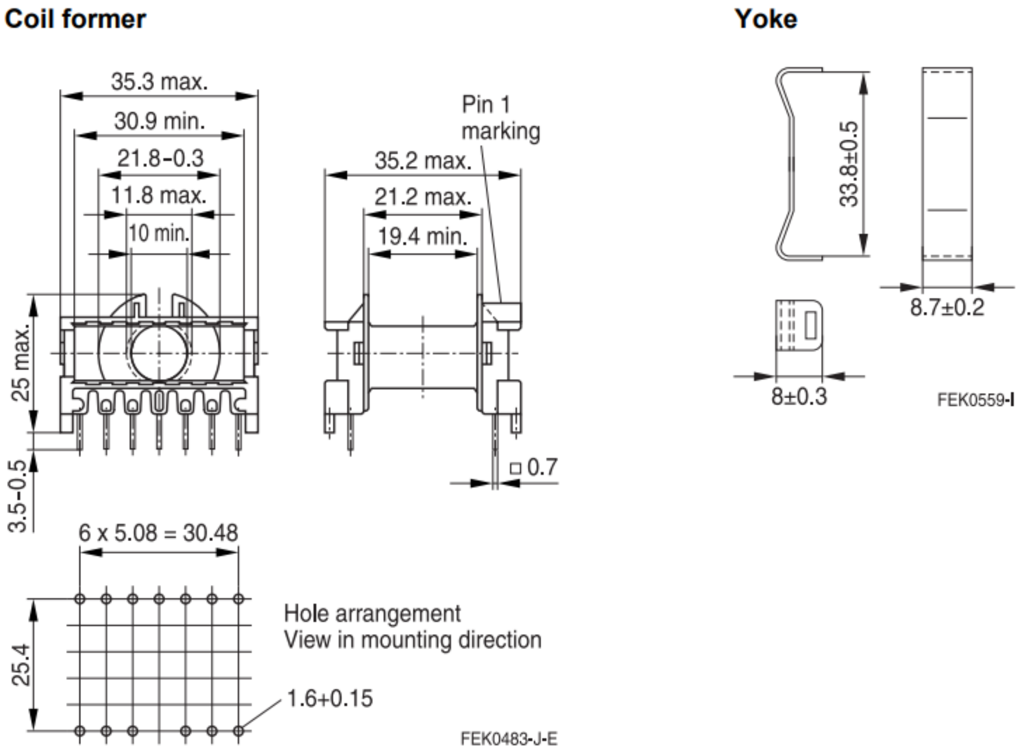
- Fringing effect in magnetic cores [7]

[7] J. Riba Ruiz, A. Garcia Espinosa and L. Romeral, "A Computer Model for Teaching the Dynamic Behavior of AC Contactors," in IEEE Transactions on Education, vol. 53, no. 2, pp. 248-256, May 2010

Flyback transformer design – winding

- As an example, copper wire operating at 100kHz at 20°C would have skin depth of:
- $\delta = \sqrt{\frac{\rho}{\pi \mu f}} = \sqrt{\frac{1.724\times10^{-8}}{\pi\times4\pi\times10^{-7}\times1\times100000}} = 209\mu\text{m}=0.2\text{mm}$
- Wire diameter selected to be 2×0.2mm to minimise any skin effect so a 0.4mm wire is chosen.
- Two wires used in parallel to improve current handling capability and reduce resistance.
- $A_{\mathrm{w}} = \pi r^2 \times 2 = \pi 0.0002^2 \times 2 = 2.51 \times 10^{-7}\ \mathrm{m}^2$
- Length of wire per turn according to datasheet [6]: 52.8mm
- $\ell_{\mathrm{w}} = 12 \times 0.0528 = 0.634\mathrm{m}$
- DC resistance of the winding given that resistivity of copper (ρ) is $1.724 \times 10^{-8}\ \Omega\mathrm{m}$ at room temperature:
- $R = \rho \frac{\ell_{\mathrm{w}}}{A_{\mathrm{w}}} = 1.724 \times 10^{-8} \frac{0.634}{25.13\times10^{-6}} = 43.5\mathrm{m}\Omega$
- $P_w = I^2 R = \left(\sqrt{\frac{0.475}{3}} \times 4.21\right)^2 \times 43.5\mathrm{m} = 0.122\mathrm{mW}$

Coil former				
Sections	A_N mm^2	l_N mm	A_R value µΩ	Pins
1	97	52.8	18.7	13



- Coil former details for ETD 29/16/10 [6]

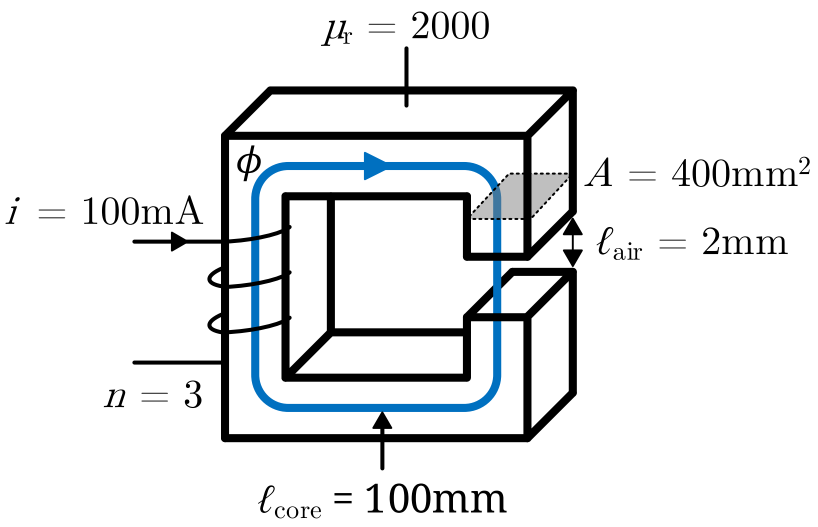
[6] https://www.tdk-electronics.tdk.com/inf/80/db/fer/etd_29_16_10.pdf

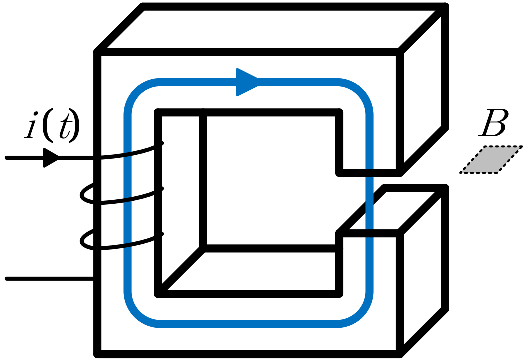
Flyback transformer

Simulations

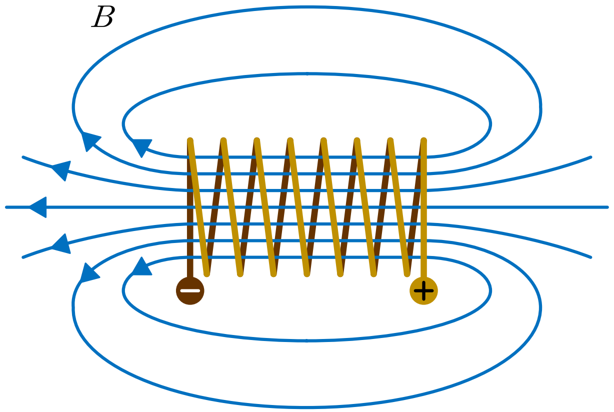
Flybacktransformer design – FEA simulations

- Once calculations are set up on spreadsheets, designs involve substituting some variables to fit the needs.
- A lot of the times, hand calculations of magnetic components like a flyback transformer has limitations.
- For example, the distribution of the magnetic field within the core is difficult to predict accurately.
- Given the problem from before, what is the magnetic field (B) around the core at different points?
- What is the magnetic field outside the core? Can we calculate the leakage magnetic fields or fringing effects?



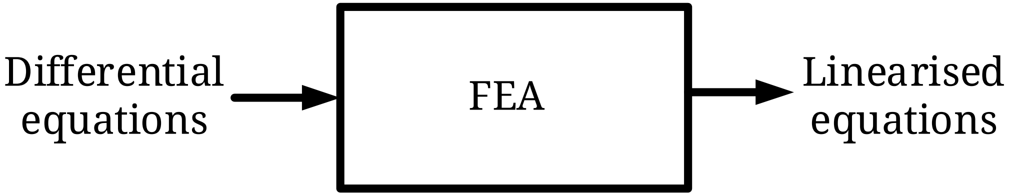


Flybback transformer design – FEA simulations



- In electromagnetics, the physics are governed by the following Maxwell's equations:
  - $\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}$
  - $\nabla \cdot \mathbf{B} = 0$
  - $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$
  - $\nabla \cdot \mathbf{B} = \mu_0 \left(\mathbf{J} + \epsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right)$
- For simple structures, analytical solutions can be found using the equations.
- For example, a solenoid can be described using analytical solution to find the magnetic field around it.
- As the shapes get more complicated, the equations become more and more complex and an analytical solution describing the model becomes almost impossible to obtain.
- **<u>Finite element analysis</u>** (FEA) can be used to approximate the solution to more complicated problems.

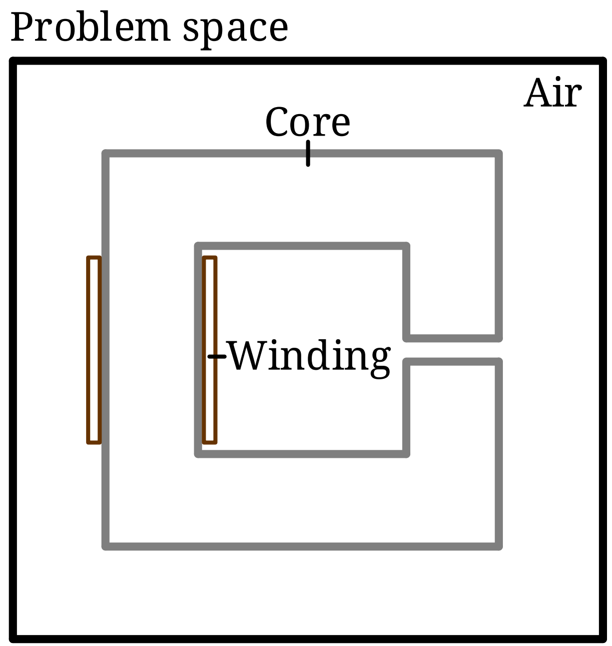
- An example transformer for power distribution [7]

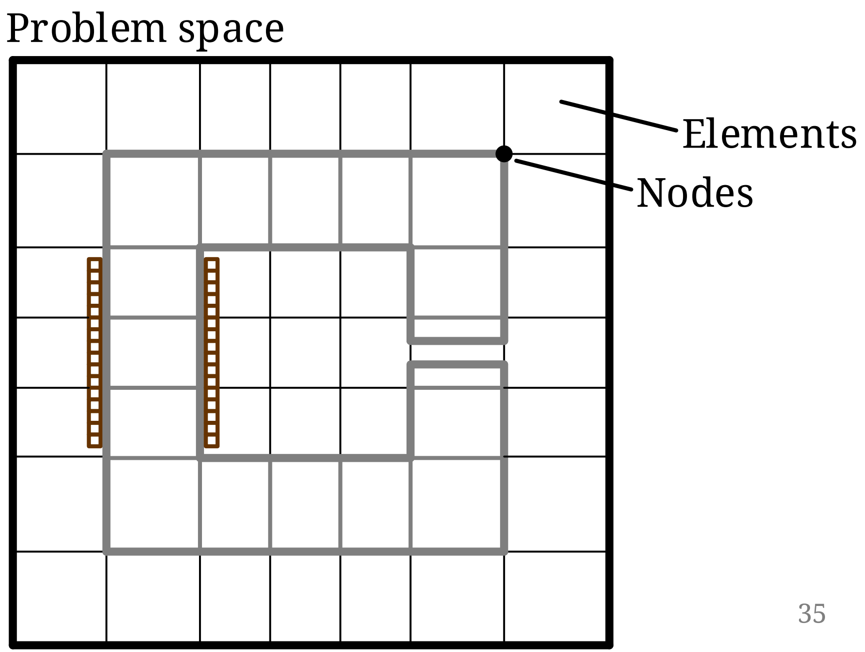


[7] https://www.servostabilizer.org.in/materials-can-be-used-for-transformer-magnetic-core/

Flyback transformer design – FEA simulations

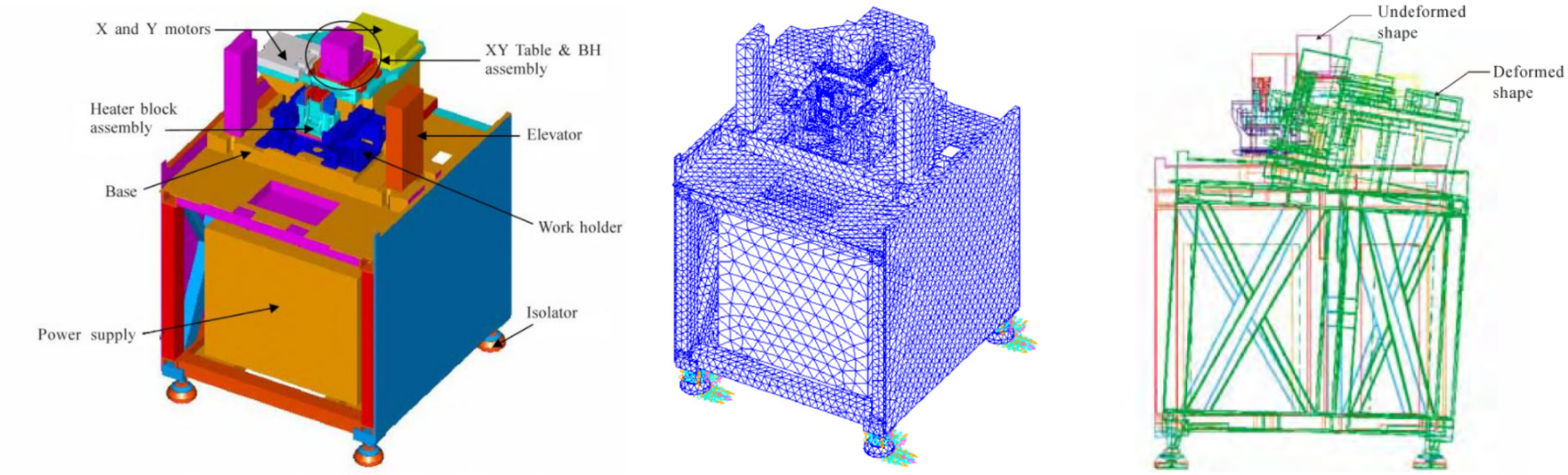
- Given the flyback transformer from before, the transformer can be translated into a 2D model.
- The geometry of the transformer is placed within some boundaries that form the problem space.
- The problem space is then divided into smaller parts called elements.
- The elements are connected to each other using nodes in the corners of each element.
- The elements can be triangular, rectangular or other shapes with more sides.
- When the problem space is divided into smaller elements, the equations for each element becomes a linearised algebraic equations that computers can solve much faster than people.
- The equation solver take into account of the initial conditions and boundary conditions.
- Once the equations for all the elements have been solved, the elements are put together to estimate the results in all of the nodes in the problem space.





Flyback transformer design – FEA simulations

- Much more complicated shapes than a transformer can be discretised into finite element models.
- The accuracy of the model improves with a finer model of elements, but the computational time increases proportionally.

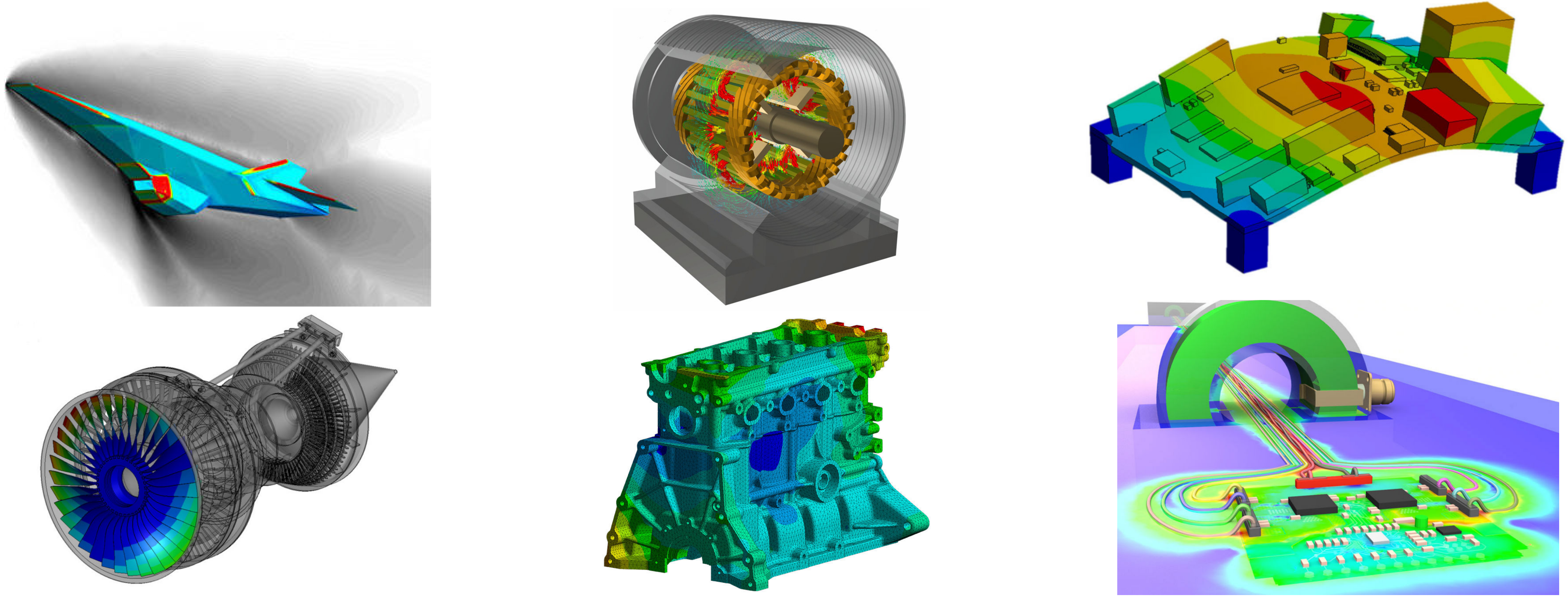


- Finite element model and deformation of a wire bonder machine [8]

[8] TEXTBOOK OF FINITE ELEMENT ANALYSIS, P. SESHU · 2004,

Flyback transformer design – FEA simulations

- FEA is often used in fluid dynamics, mechanical, structural, thermal or electromagnetic problems with complicated shapes.
- Different simulations can also be linked with each other to better emulate real life conditions.

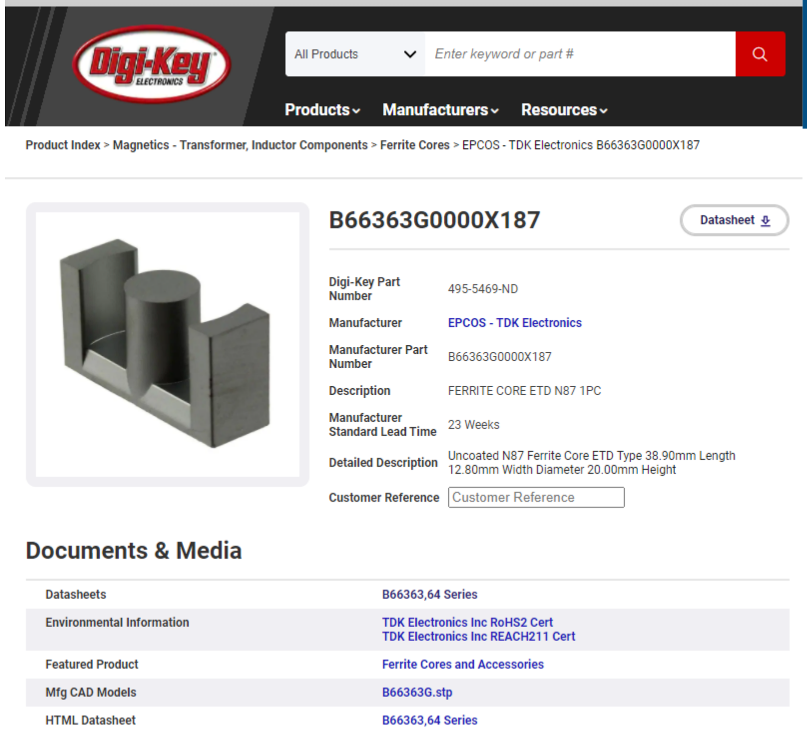


- Example of FEA used in different applications [9]

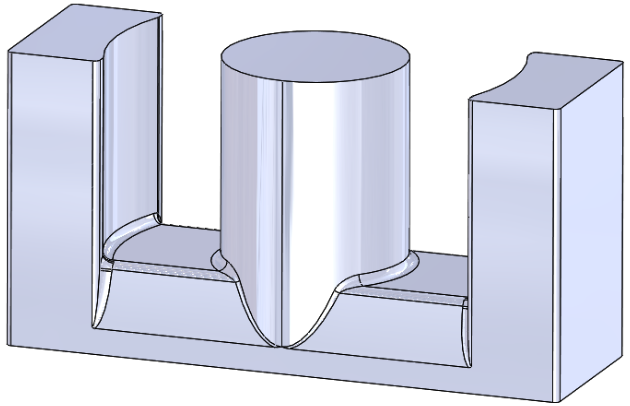
[9] https://www.ansys.com/

Flyback transformer design – FEA simulations

- FEA can be used to simulate different flyback transformers.
- Simulations reduce cost and effort of actually making individual flyback transformers.
- Simulations often provide more detailed solutions than calculations done by hand.
- To fast-track the FEA process, an example ETD 39/20/13 is downloaded from the supplier’s website.
- https://www.digikey.co.nz/product-detail/en/epcos-tdk-electronics/B66363G0000X187/495-5469-ND/3914819



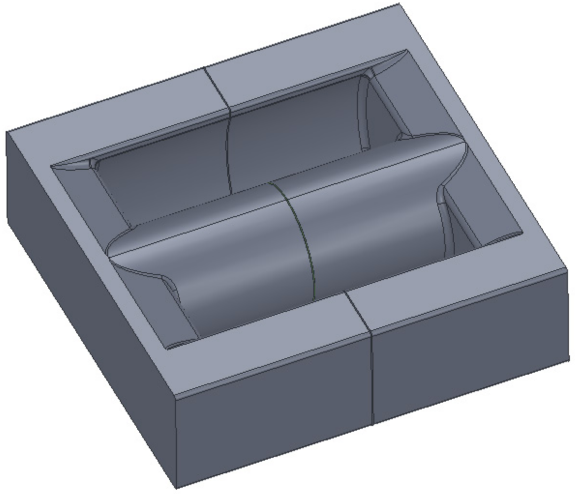
- Looking up ETD 39/20/13 on Digikey



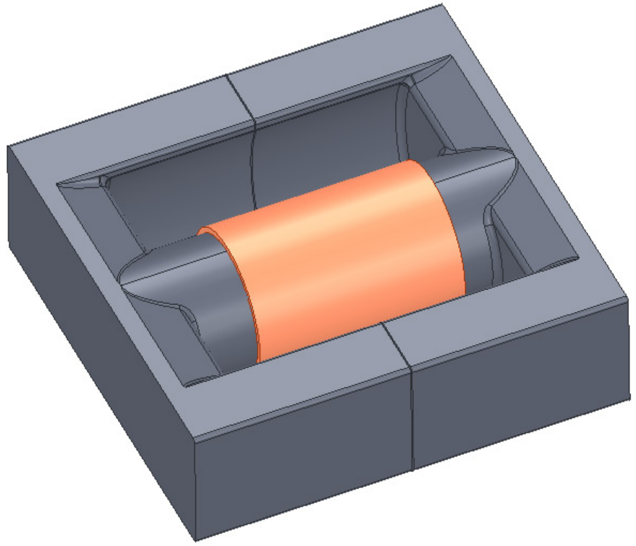
- CAD model of ETD 39/20/13

Flybeack transformer design – FEA simulations

- The geometry of the transformer is put together in the FEA software.
- The transformer is designed with no air gap.
- Windings are created around the transformer.
- Material properties are assigned to indicate ferrite cores and copper windings.
- The copper wires can be designed as individual strands for very precise accuracy, but computationally much faster to just use a simple lumped model.
- The core is set to have relative permeability of 1600.
- FEA is given the same initial conditions as calculated before of 2.235A peak current. The winding is set to be 4 turns.



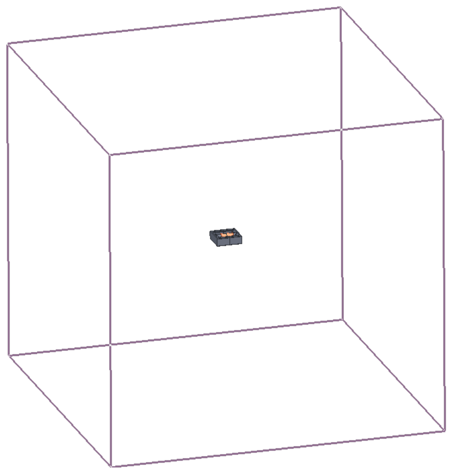
- Putting two ETD 39/20/13 together



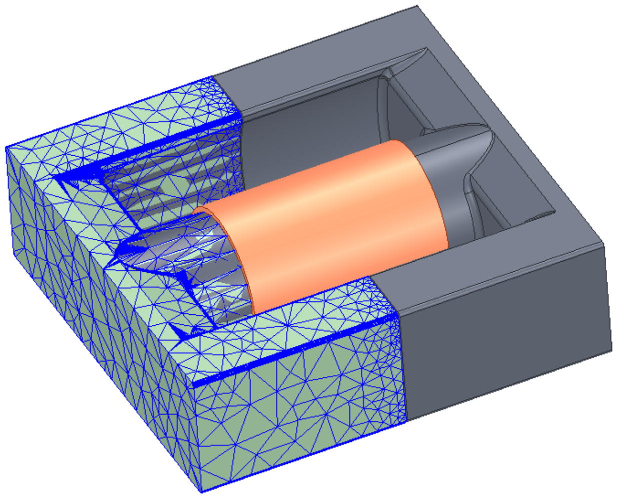
- Designing a thin copper winding in the centre

Flybalk transformer design – FEA simulations

- The flyback transformer is placed within the problem space.
- In this case, the flyback transformer is simulated as if it is suspended in vacuum.
- In more involved FEA models, entire circuits are designed with all of the components and surroundings to simulate the heat transfer and electromagnetic interference.
- Once all of the geometry are placed within the problem space, the FEA software divides the geometry into smaller finite elements.
- Smaller sized elements yield better accuracy, but increases computational time.



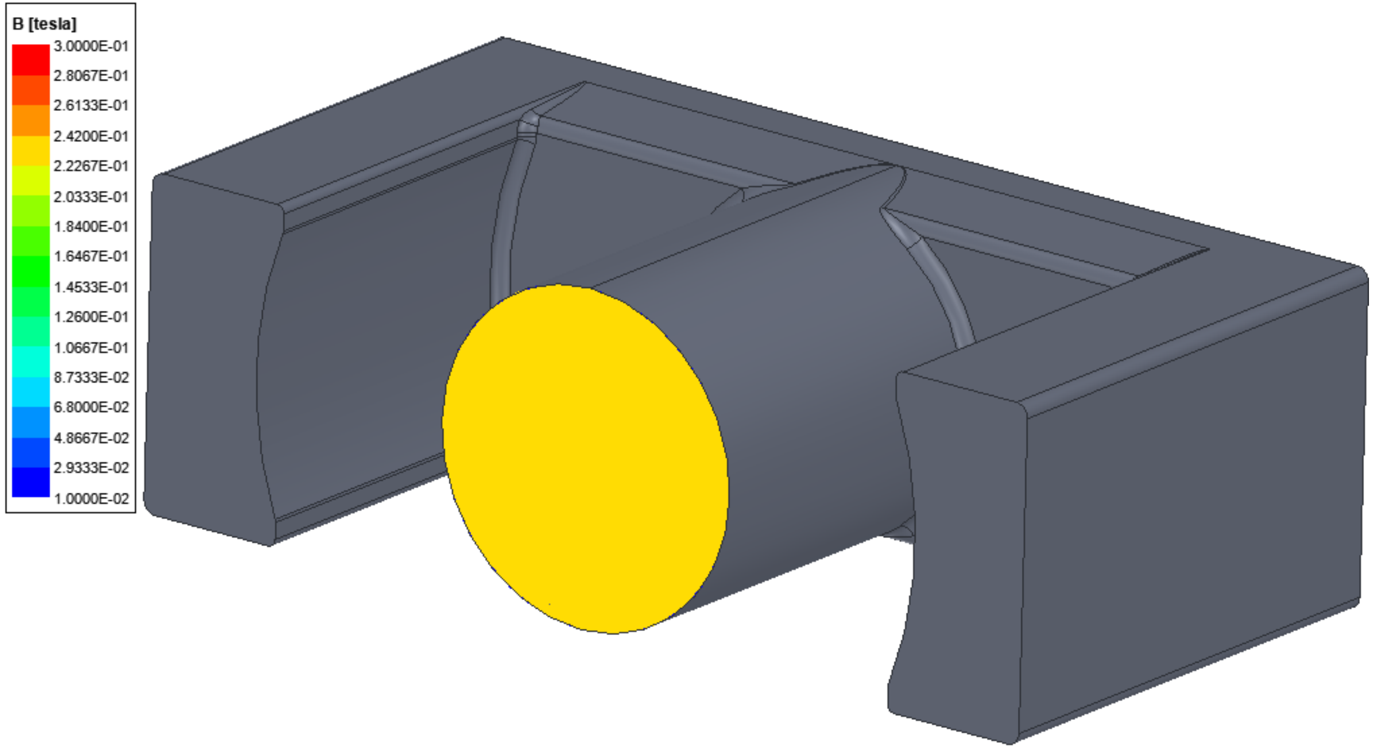
- The flyback transformer within the problem space



- The division of the geometry into small finite elements

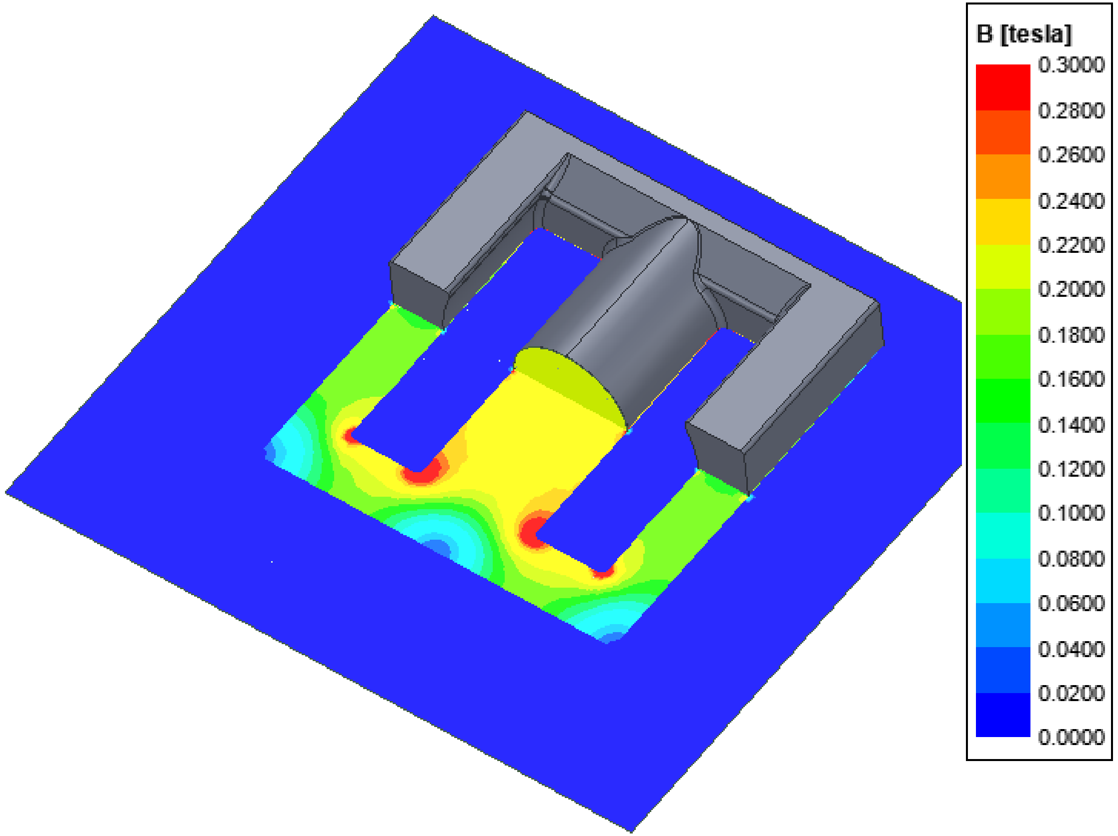
Flyback transformer design – FEA simulations

- Once the FEA solution has been found, the magnetic field within the core can be shown.
- In this simulation, the average magnetic field within the core seems to be around 222mT.
- The calculation of peak magnetic field was 209mT as shown previously.



Flyback transformer design – FEA simulations

- The magnetic field distribution across the entire core and the surrounding region can be shown using the FEA solution.
- In the simulation, air gaps or turns in the windings can be changed quickly. Other types of cores or materials can be used to check if there will be any issues with the design.
- Using this method, a number of flyback transformer designs can be investigated before building them.
- In the laboratory, you will be simulating the flyback transformers in ANSYS.
- A quick step-by-step guide to using ANSYS will be provided as well as in-person support if required.



THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND