MICROCHIP

# TOTEM POLE PFC DESIGN FOR E-MOBILITY - PARTNERED WITH DIGI-KEY ELECTRONICS

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**WÜRTH ELEKTRONIK** MORE THAN YOU EXPECT

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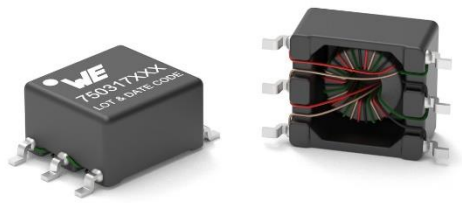
# AGENDA

- WE-PPTI Transformers
  - New parts and characteristics
  - Application in Microchip Design
- Custom PFC and New WE-TORPFC Overview
  - Product family and characteristics
  - Specification and measurements
- Why flat wire?
  - Skin and proximity effects
  - Round vs Flat wire measurements
  - Conclusion and equivalent circuit
- WCAP-FTDB Series Film Capacitors
  - Characteristics
  - Additional resources
- What WE offer

# WE-PPTI EXTENDED SERIES OVERVIEW

Push-Pull Transformers

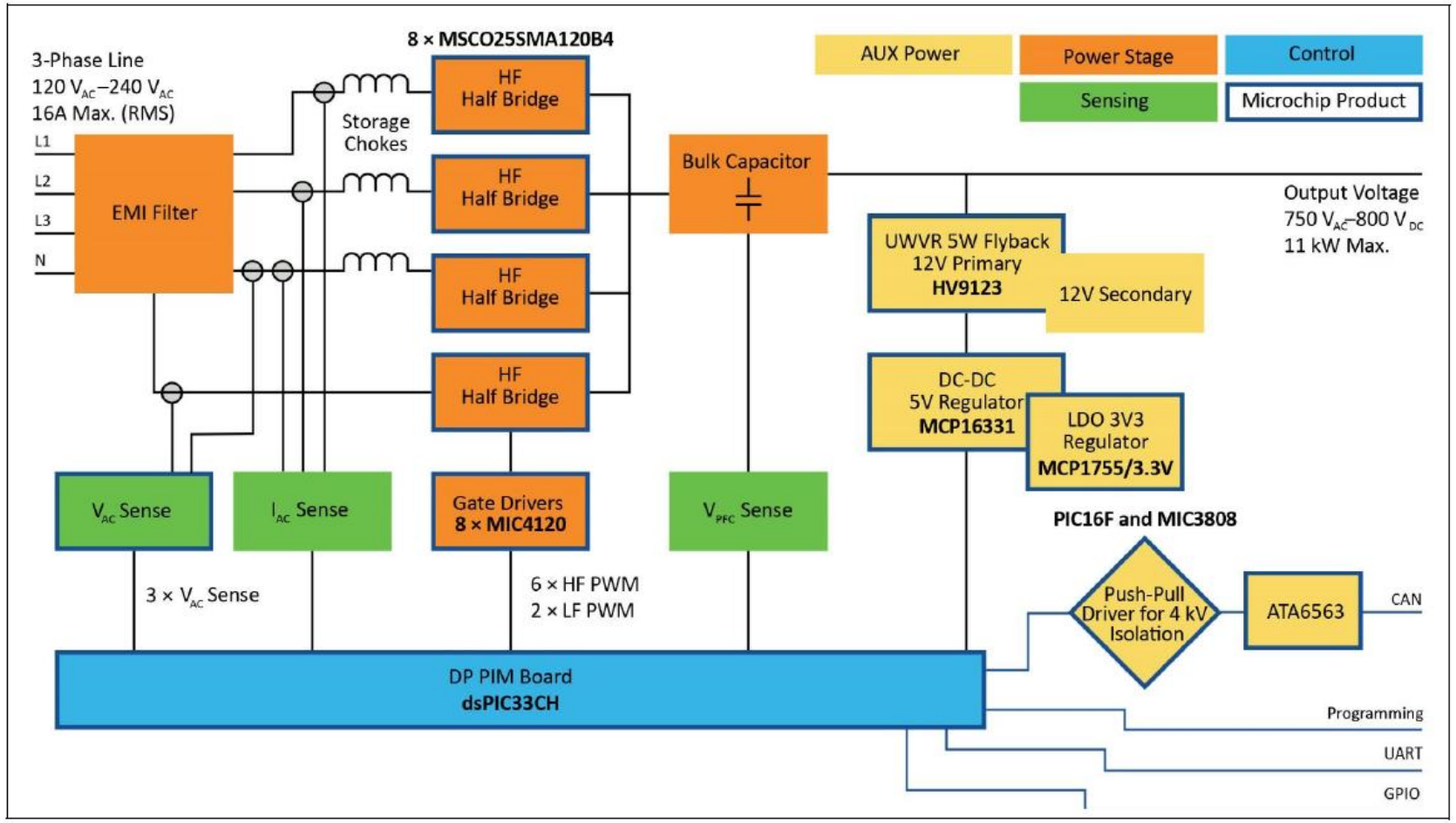
**AEC – Q200 Qualified**



- 19x Catalogue parts in stock – No MOQ
  - Voltage second product up to 41 Vµs
  - Switching Frequency up to 620 KHz
  - AEC-Q200 Grade 1
- Characteristics
  - Small size
  - Surface mount
  - Low profile
  - Operating temp: -40°C to 125°C
  - Standards detail: IEC60950-1, EN60950-1/CSA60950-1 and AS/NZS609501.1
- Applications
  - Isolated interface power supply for CAN, RS-485, RS-422, RS-232, SPI, I2C, lower-power LAN
  - Isolated gate driver power supplies
  - AC motor drives
  - Polyphase energy meters

# WE-PPTI EXTENDED SERIES OVERVIEW

## Push-Pull Transformers

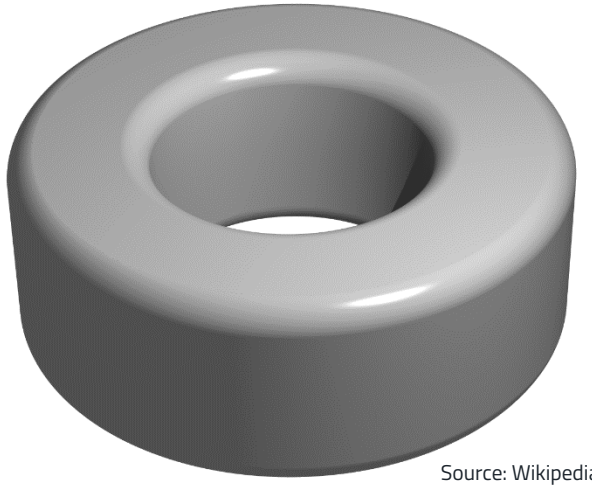



Source: Microchip

# CUSTOM MPP CORE PFC CHOKES

Magnetics Molypermalloy Powder (MPP): Mo-Ni-Fe

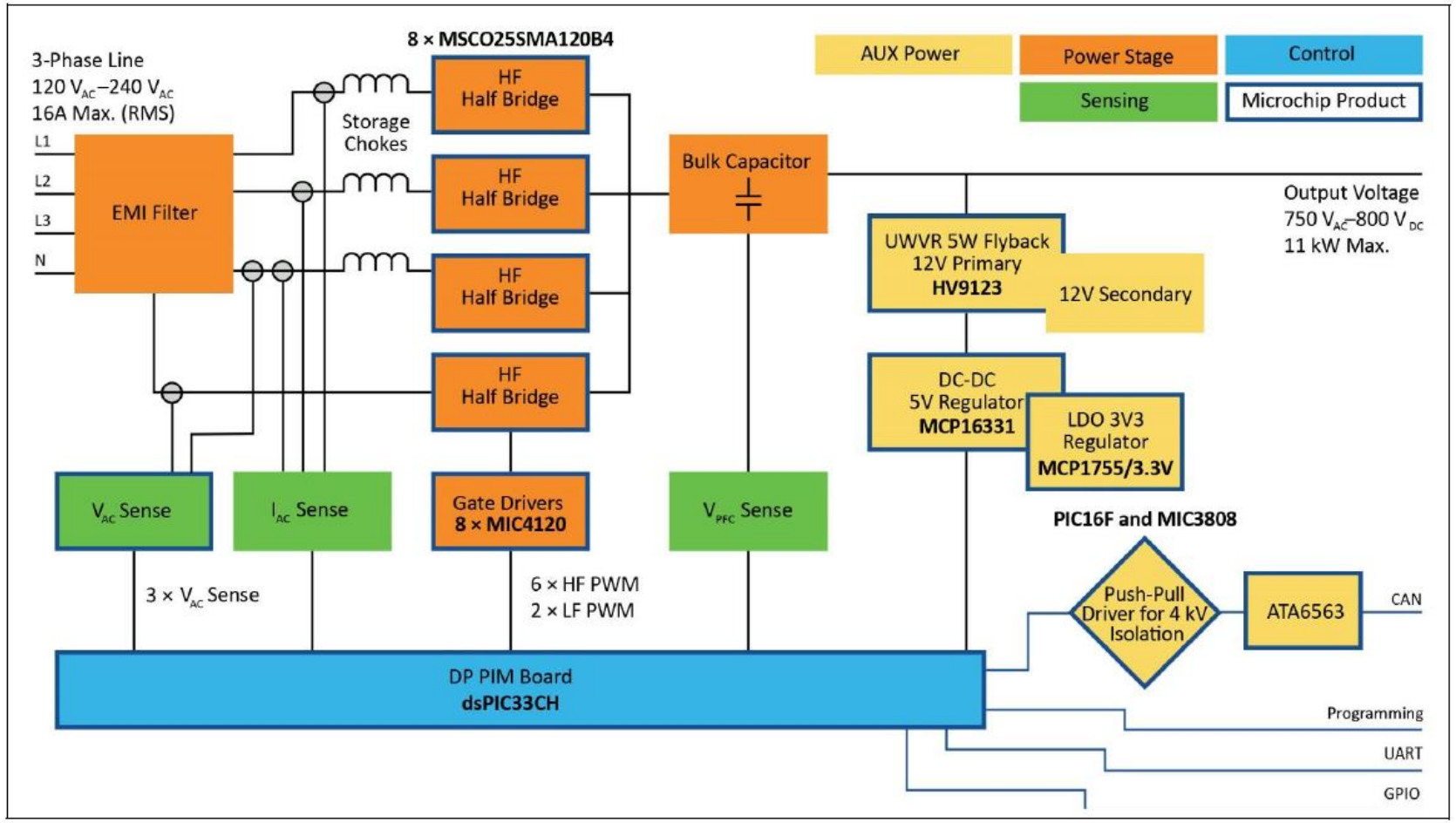
- Lowest core loss among all the powder materials.
- Best temperature stability. Under 1%.
- The maximum saturation flux density is 8000 gauss (0.8 tesla)
- High Cost



Source: Wikipedia

# WE-PPTI EXTENDED SERIES OVERVIEW

## Push-Pull Transformers




Source: Microchip

# NEW SERIES OVERVIEW

Introducing WE-TORPFC (High Flux cores: Ni-Fe, Sendust: Al-Si-Fe)

**AEC – Q200 Qualified**

- 17x Catalogue parts in stock – No MOQ
  - Inductance: 118uH up to 720uH
  - Voltage: up to 1000VDC
  - High saturation current up to 105A
  - Temperature: -40°C up to 155°C
  - Outer diameter sizes: 53mm – 99mm
  - Height sizes: 28mm – 62mm
  - AEC-Q200 Grade 1
- Flat Wire Windings
  - Very low intra-winding capacitance
  - Minimized Skin Effect
  - Lower DCR
  - Mechanically stable
- Applications
  - External EV Chargers
  - Solar Inverters
  - Industrial/Medical AC-DC
  - Telecom PSU

# NEW SERIES OVERVIEW

P/Ns and Values

- Typical Inductance values
- Specification of rated current with airflow
- Smaller parts for same inductance and current compared to competition

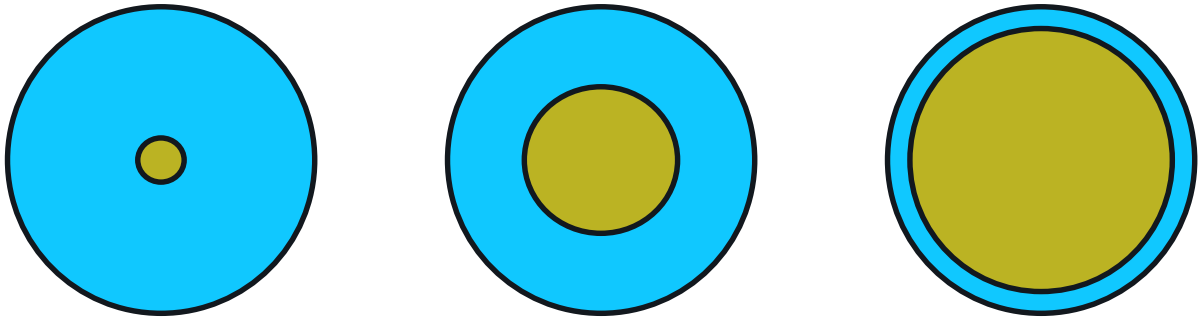
| Part Number | Max O.D. (mm) | Max Height (mm) | Inductance (±20%) | Max DCR (mΩ) | Rated Current (40°C Temp Rise) | | | | Saturation Current (30% ΔL) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | No Air Flow | 1 m/s Air Flow | 2 m/s Air Flow | 4 m/s Air Flow | |
| 760800401 | 53 | 28 | 118µH | 22 | 13.9A | 19.7A | 23.4A | 27.5A | 9.5A |
| 760800403 | 53 | 47 | 355µH | 35 | 12.3A | 18.6A | 22A | 24.7A | 9.5A |
| 760800101 | 60 | 34 | 255µH | 36 | 11.2A | 16.1A | 18.3A | 21.7A | 10.5A |
| 760800102 | 60 | 54.5 | 510µH | 55 | 9.8A | 15A | 17.4A | 20.8A | 10.5A |
| 760800201 | 72 | 31 | 194uH | 40 | 12.5A | 16.5A | 18.4A | 21.9A | 19A |
| 760800202 | 72 | 45 | 389µH | 50 | 11.5A | 16.1A | 18.2A | 20A | 19A |
| 760800203 | 72 | 60 | 584µH | 65 | 11.8A | 16.8A | 19.5A | 22A | 19A |
| 760800301 | 99 | 62 | 180µH | 20 | 24.5A | 34A | 42A | 48A | 43A |
| 760801401 | 53 | 28 | 118µH | 22 | 13.9A | 19.7A | 23.4A | 27.5A | 23A |
| 760801403 | 53 | 47 | 355µH | 35 | 12.3A | 18.6A | 22A | 24.7A | 23A |
| 760801101 | 60 | 34 | 255µH | 36 | 11.2A | 16.1A | 18.3A | 21.7A | 24A |
| 760801102 | 60 | 54.5 | 510µH | 55 | 9.8A | 15A | 17.4A | 20.8A | 24A |
| 760801201 | 72 | 31 | 194µH | 40 | 12.5A | 16.5A | 18.4A | 21.9A | 37A |
| 760801202 | 72 | 45 | 389µH | 50 | 11.5A | 16.1A | 18.2A | 20A | 37A |
| 760801203 | 72 | 60 | 584µH | 65 | 11.8A | 16.8A | 19.5A | 22A | 37A |
| 760801301 | 99 | 62 | 180µH | 20 | 24.5A | 34A | 42A | 48A | 105A |
| 760801321 | 99 | 62 | 720uH | 42 | 17A | 23A | 25.5A | 32A | 38A |

# WHY FLAT WIRE?

Theory and measurements

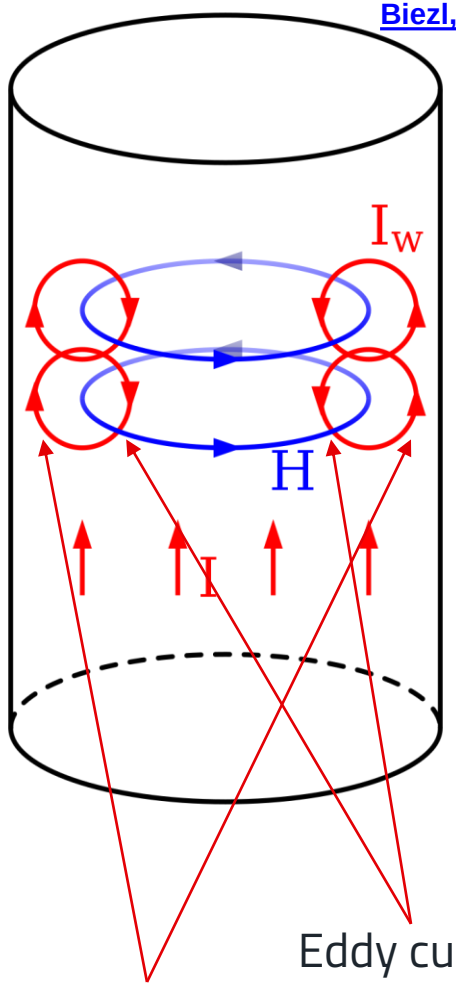
- Skin Effect
  - Tendency of the current density in alternating current to become distributed towards the surface of the conductor
  - The higher the frequency, the more the current is pushed towards the surface
  - Effective cross-section is reduced resulting in higher AC resistance
  - Skin Depth – the depth at which current density is 37% of the value at the surface

$$R \approx \frac{l\rho}{\pi D \delta}$$



60Hz 1000Hz 400kHz

Biezl, Wikipedia



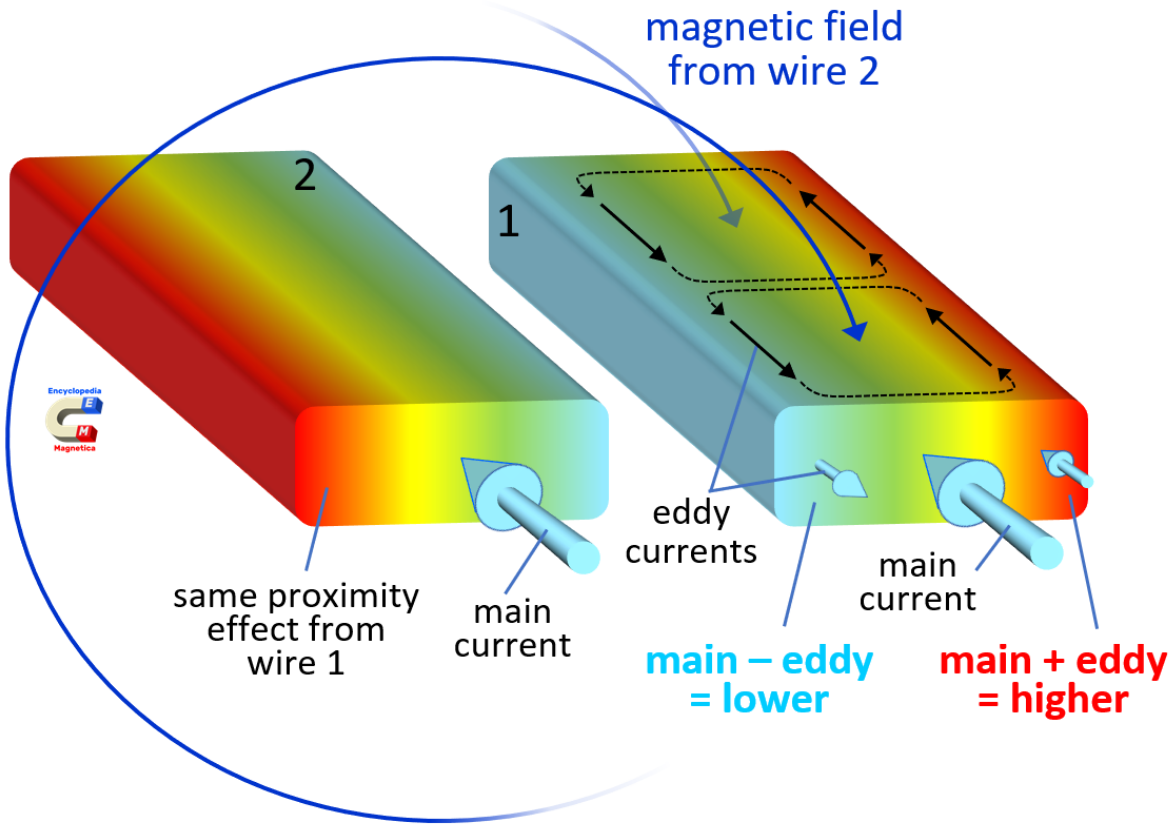

Current flow reinforced towards outer surface

Eddy currents cancel current flow in center

# WHY FLAT WIRE?

Theory and measurements

- Proximity effect
  - Current redistribution in conductors running in parallel and carrying alternating current
  - Conductors carrying current in same direction have current density distributed to the opposite sides
  - Conductors carrying current in opposite direction have current density distributed to the neighboring sides
  - Increase in AC resistance
  - Increased effect with higher frequency




Stan Zurek, Encyclopedia Magnetica

# WHY FLAT WIRE?

Theory and measurements

- For this testing, 760800201 standard flat wire part was used and then hand wound a similar round wire sample. To wind a similar round wire part, the same core as 760800201 was used, same number of turns, and used equivalent sized round wires to obtain a similar DCR.

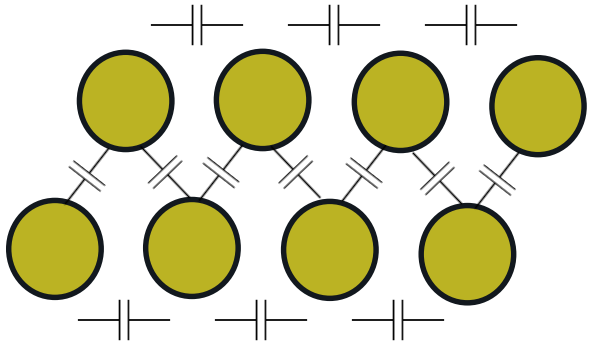
| Characteristics | Round Wire | Flat Wire | 760800201 Datasheet Specifications |
|---|---|---|---|
| Inductance (uH) | 204 | 197 | 194 |
| DCR (mΩ) | 27.7 | 27.1 | 40mΩ max |
| Interwinding Cap (pF) | 154 | 2.99 | - |
| Rated I. ΔT=40K | 11 | 12.4 | 12.4 |

# WHY FLAT WIRE?

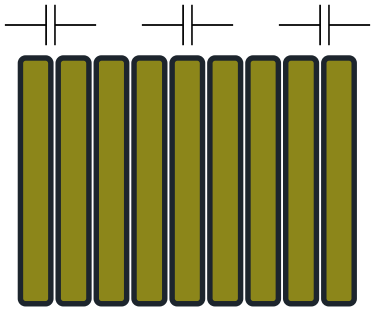
Capacitance matters

- Round conductor normal winding with all the parasitic capacitances shown – Parasitic capacitances are not just between adjacent horizontal layers, but also between vertical layers as well and between multiple inductors

- Flat wire, due to winding nature only has series parasitic capacitance

Series and parallel parasitic capacitance

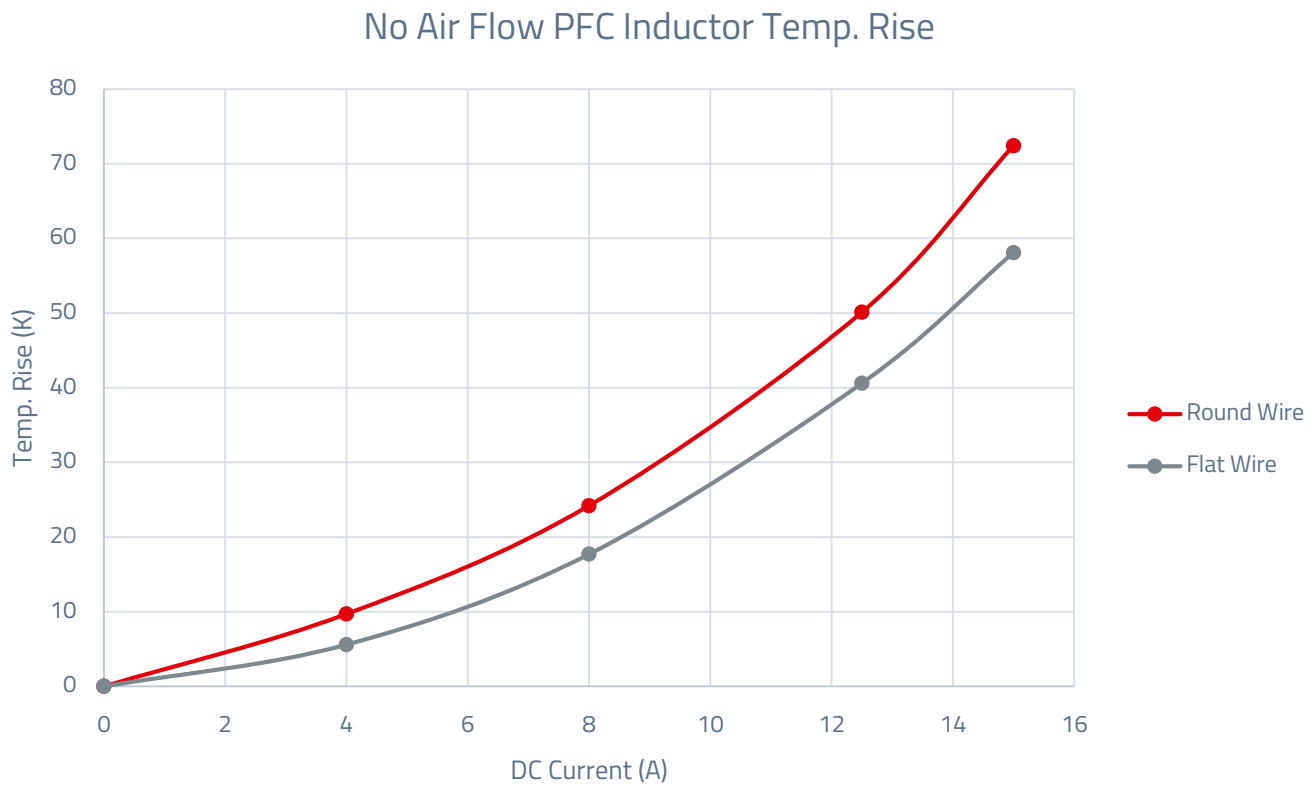


Cpar = C/n

# WHY FLAT WIRE?

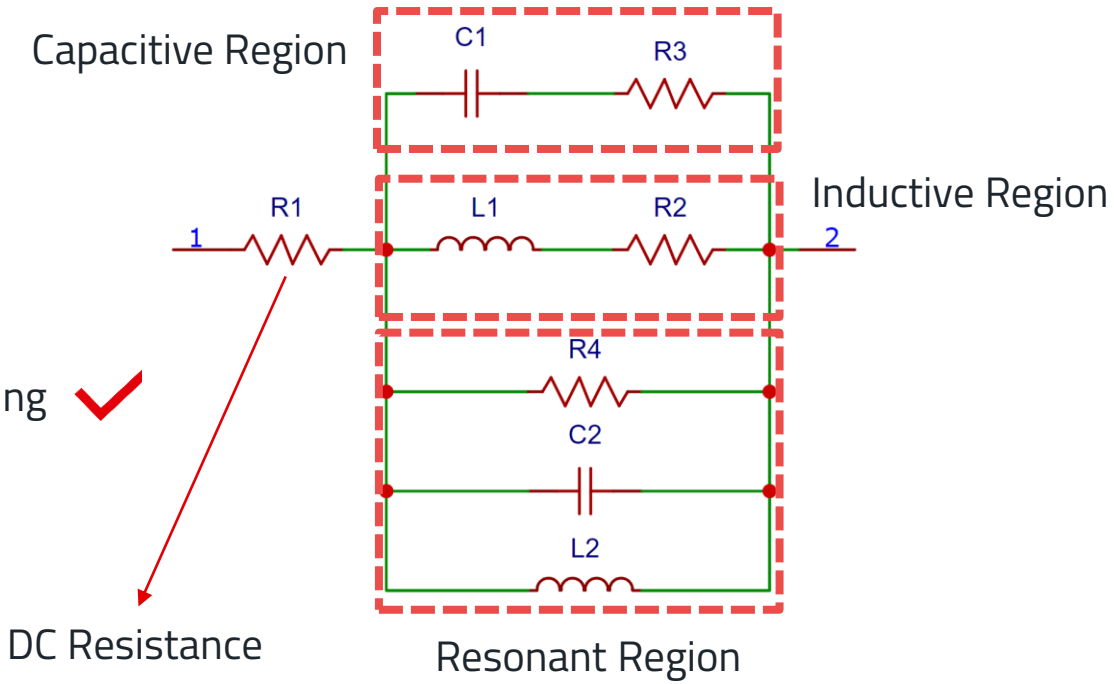
Theory and measurements

- For something as small as 0.6mΩ difference in DCR, at 15A we have 14.3 degrees difference.
- The difference comes from the better heat dissipation capabilities of the flat wire increased surface area.



# FLAT WIRE CONCLUSION

- Less interwinding capacitance – higher frequency ✓
- Lower DCR – lower losses ✓
- Skin effect reduced – reduced AC losses ✓
- Space between windings – proximity effect reduced + better cooling ✓
- Flat wire – higher mechanical stability ✓




*Real equivalent circuit of inductor*

# WCAP-FTDB: DC-LINK FILM CAPACITOR

## Introducing new series WCAP-FTDB

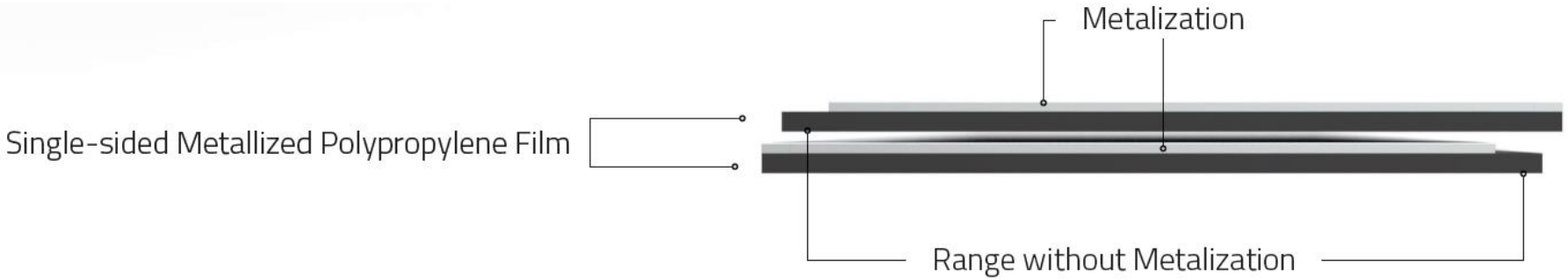

**Würth Elektronik WCAP-FTDB DC-Link Film capacitors**
Boxed THT - MKP Film Capacitors

- 24x catalogue parts in stock – no MOQ
  - Capacitance: 1 µF up to 75 µF
  - Voltage: 500 $V_{DC}$ up to 1200 $V_{DC}$
  - Temperature: -40 °C up to 105 °C
  - Pitch / Pin distance: 27.5, 37.5 and 52.5 mm

# WCAP-FTDB: DC-LINK FILM CAPACITOR

## Introducing new series WCAP-FTDB

- MKP: Polypropylene metallized film
  - High ripple current capability
  - Self-healing properties
  - Very long expected load life

# DC LINK CAPACITOR TECHNOLOGIES

## Film DC Link Capacitors

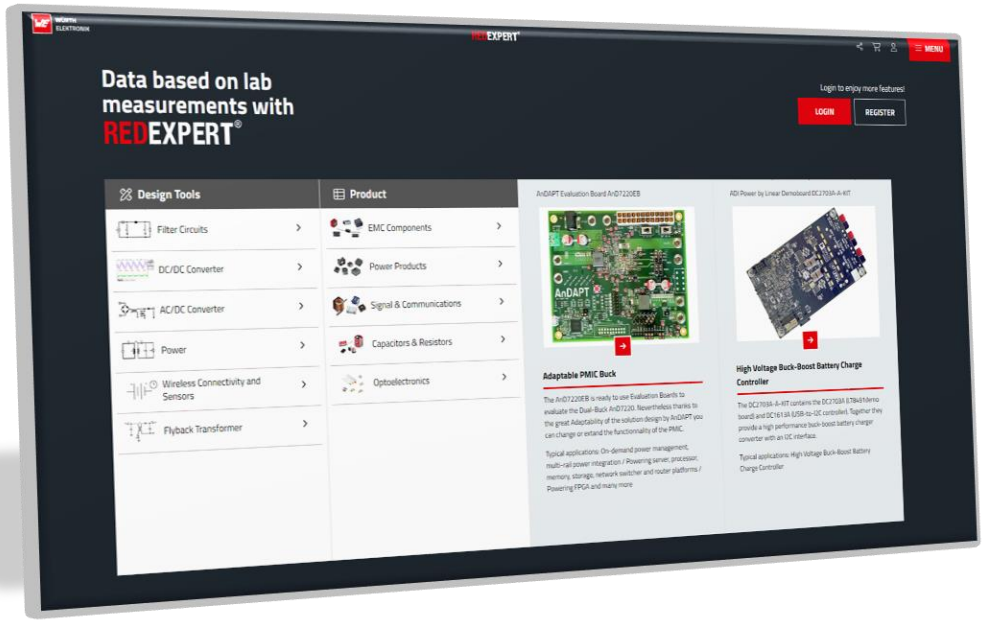

- Rated voltages up to 1,200 V
  - Perfect for SiC Modules
- Very low ESR - High RMS current capabilities
  - Ripple current: several $A_{RMS}$ per µF
- Low capacitance may cause high voltage ripple
- No liquid inside - long storage and load life
- Self-healing properties

## Aluminum Electrolytic Capacitors


- Rated voltages up to 650 V
  - Series connection necessary!
- Relatively high ESR internal resistance
  - Depends on the part 1 mA/µF…20 mA/µF or higher
- High capacitance values
  - Highest capacitance per volume (µF / mm³)
- Get large bulk capacitance for low voltage ripple

# REDEXPERT®

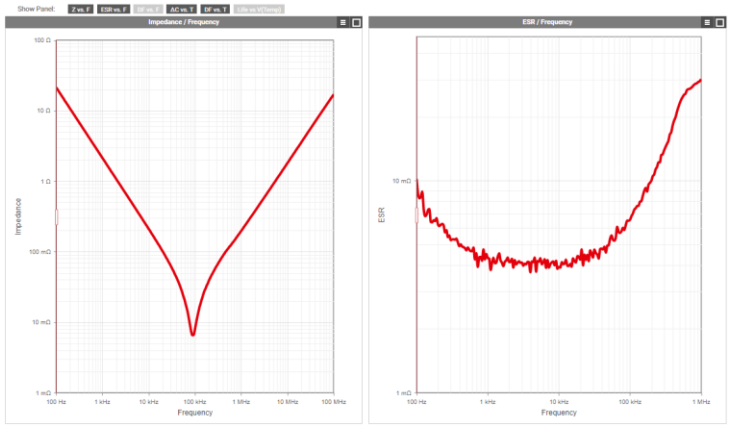
## Free browser platform optimized for component selection




Scan for DC-Link Module!

Find all standard specifications and following curves:

- Z vs Freq. (Impedance spectrum)
- ESR vs Freq.
- D (tan δ) vs Freq.
- Capacitance vs Temperature
- D (tan δ) vs Temperature
- Temperature /Voltage vs Lifetime (Derating curve)



# MORE INFORMATION

- Webinar (Youtube) - DC-Link Capacitor, Specification and Application
- Webinar (Youtube) - The Effects of Harsh Environmental Conditions on Film Capacitors
- Application Note: Impedance Spectra of Different Capacitor Technologies
  - ***Register for our next Webinar about this topic on 11.07.2023***




Scan to go to Webinar registration!

# MICROCHIP 11KW TOTEM POLE PFC

What offer?

- WE-CBF 
- WE-TI 
- WE-PD 
- WE-LHMI 
- WE-CMBNC 
- WE-PPTI 
- WE-PFC
- WE-AGDT 
- WE-FAMI 

- WCAP-CSGP 
- WCAP-FTXX 
- WCAP-CSMH 
- WCAP-ATLI 
- WCAP-FTX2 
- WCAP-AIG8 

- WL-TMRC 
- WR-TBL 
- WR-PHD 
- WR-DSUB 
- WE-VD 

- WS-TASV 
- WA-SSTIE 
- WA-SSTII 

# Questions

& Answers

Online Catalogue
WCAP-FTDB

Online Catalogue
Push Pull
Transformers

Online Catalogue
PFC Chokes