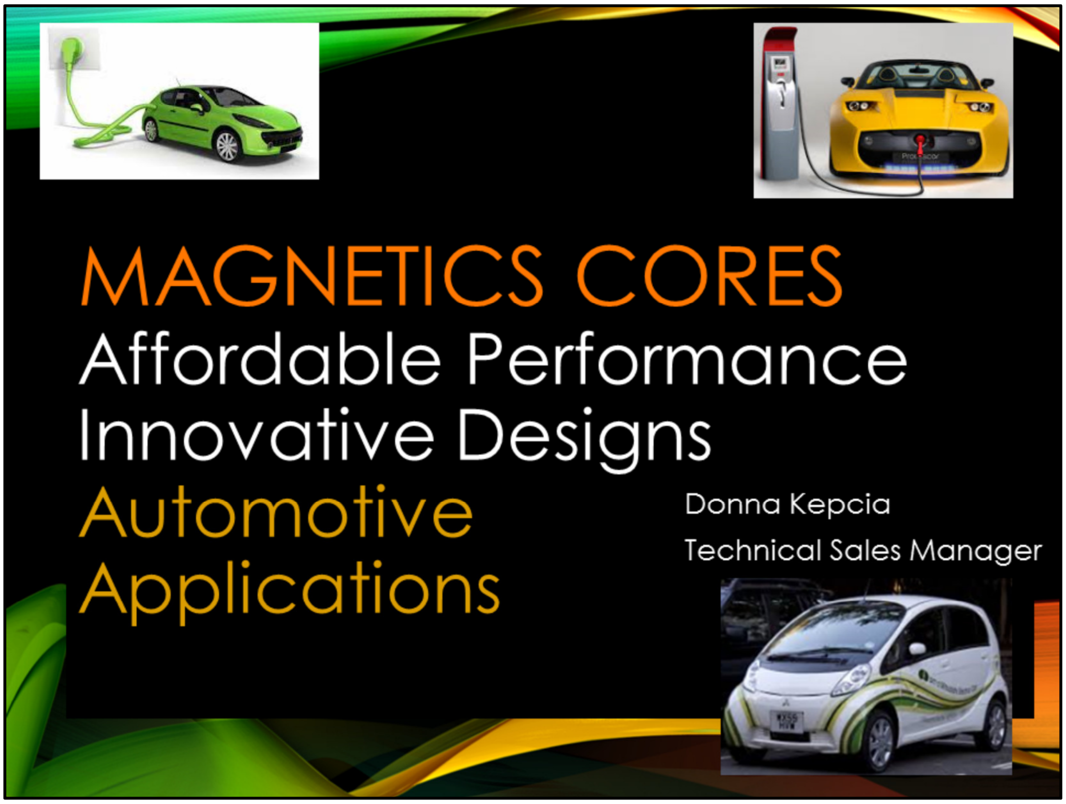


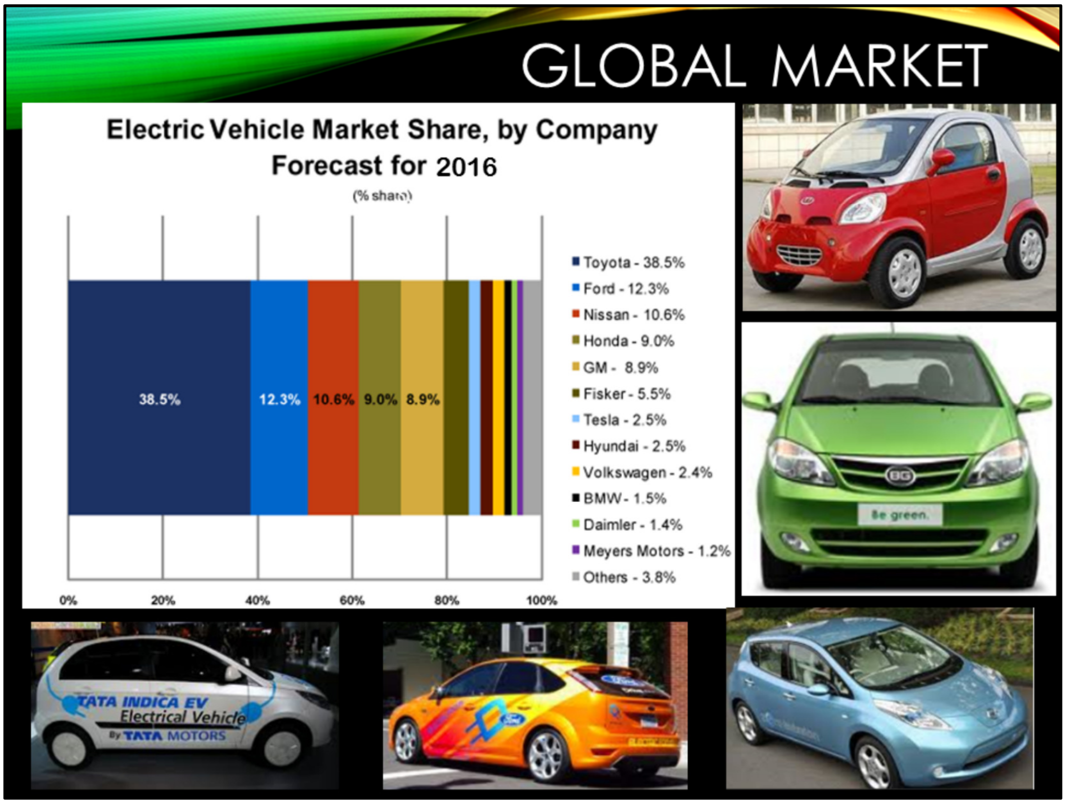
Welcome and thank you for coming to our presentation of Magnetics Powder Cores for Automotive applications—The introduction of Electric and Hybrid vehicles requires engineers to develop new design methods using a variety of materials and methods of circuit design. The industry is compelled to take a different approach to the electronic circuits in a vehicle.

OVERVIEW

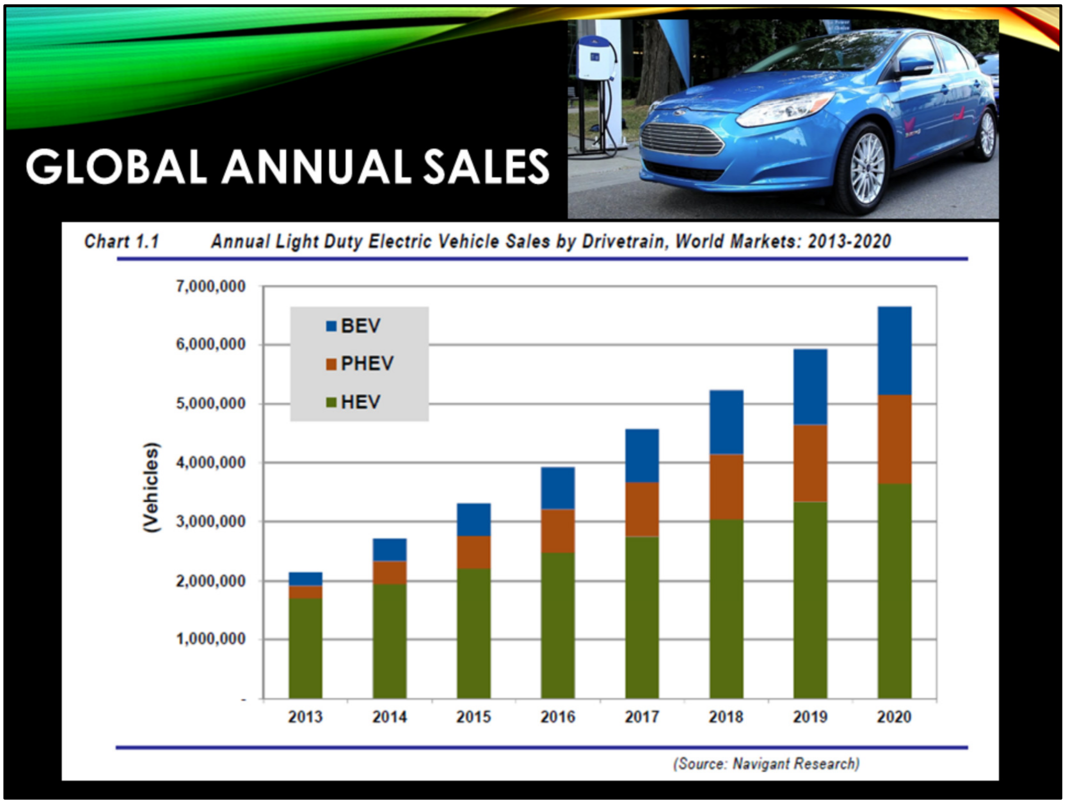
- Global Automotive Markets
- OEMs--EVs, HEV, BEV
- Regulations
  ISO TS16949, GADSL, IMDS
- Magnetics Products
  for Automotive Applications
  Differential Mode Filters
  for busbar applications
  PFC, and Output chokes
- Electric Vehicle Charging

1914 Detroit Electric

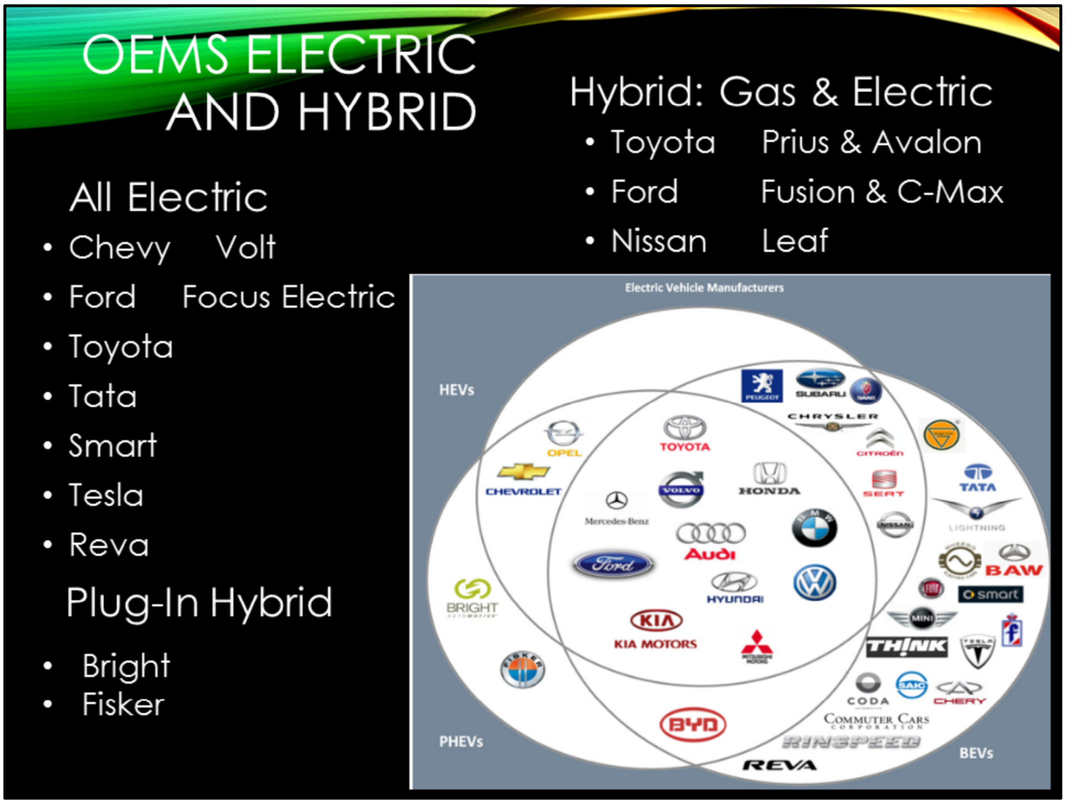
2013 Tesla Roadster



According to ABI Research, Global sales of Electric vehicles and hybrid electric vehicles are expected to increase roughly 48% each year from now until 2020. Countries across Europe are installing more charging stations and some cities are providing electric cars available to rent for the day to drive around town.

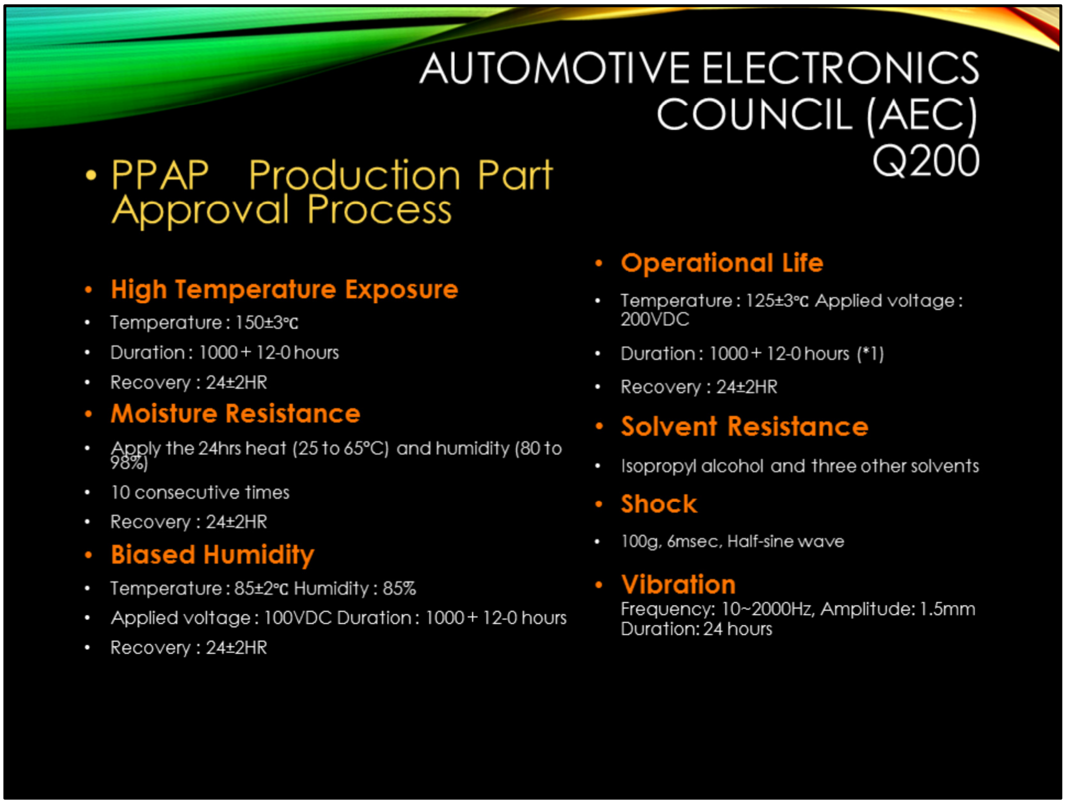


HEV Hybrid generate all their energy onboard. PHEV Plug-In Hybrids store energy from the grid but also have an engine on board for recharging. BEV Battery or All-electric vehicles get their energy from the grid and store it in batteries. At prices from $28-42,000 conservatively speaking. We're looking at a 140 billion dollar industry.



To be an approved supplier to the Automotive Industry requires the manufacturer to be familiar with the regulations that pertain to the Automotive Industry. The universally-accepted certification to be a supplier to the automotive industry is ISOTS16949.

ISOTS16949. This Quality Management System takes the ISO9001 certification a step farther aiming for continual improvement, analyzing the production data and preventing any movement away from the spec requirements. Certification bodies across the globe have been authorized to complete audits and have the authority to grant the ISOTS16949 certification. GADSL is the complete list of the Substances of Very High Concern that may not appear in any component part of an automobile. This list includes the substances banned under RoHS, and the 168 substances that appear on the REACH, Registration, Evaluation, Authorization and Restriction of Chemicals created by the European Chemicals Agency. Also included are chemicals listed under JIG 101, Joint Industry Guide 101. IMDS—International Material Data System components are entered into the database and broken down into their elemental parts to ensure that no banned substances are included in their composition.



The AEC is an organization that sets qualification standards for the supply of components in the automotive electronics industry. The AEC Q-200 was based on MIL-STD-202 Test Methods for Electronic and Electrical Parts.

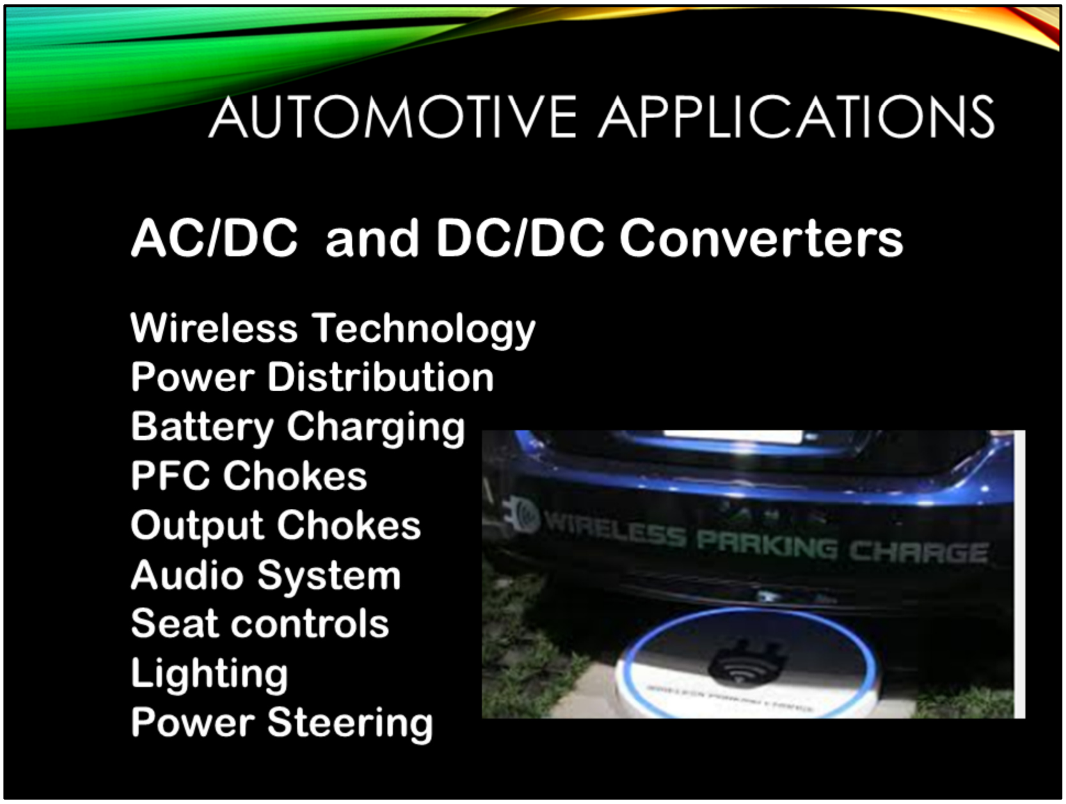
The Production Part Approval Process (**PPAP**) is a standardized process created by the (AEC) for the automotive and aerospace industries. The PPAP details the test methods and qualification standards for manufacturers. The AEC-Q200 is the regulation for passive components such as capacitors, inductors, etc.

The Q200 tests recognize that demands placed on passive components in an automotive environment relate to a very high resistance to temperature and vibration and to protection against short circuiting. Recognition is given to the fact that temperature conditions in automobiles can vary greatly, with the most demanding locations being in the engine, transmission and brake systems. Engine and transmission temperatures are typically less than 200°C, but some of the wheel-mounted components can reach 250°C. Consequently, the appropriate component needs to be selected not just for the application in question—automotive-- but for a specific function and location, too. AEC recommends that car parts be classified for the engine area and the passenger area based on the intended location of use, and because the intrinsic heat requirements of these parts are different, different test temperatures are recommended.

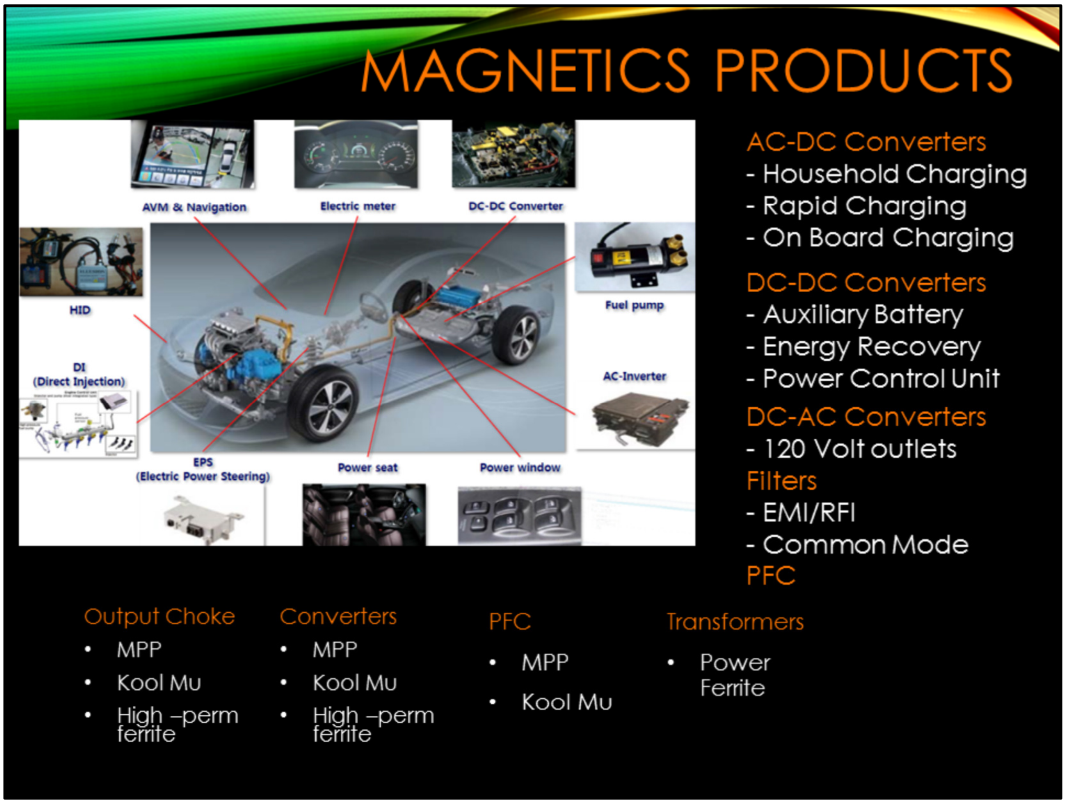
Large and rapid temperature changes also can occur when components are mounted on a PCB, and this can induce stress as a result of different material CTE (Coefficient of Thermal Expansion) rates. The difference in material (PCB, ceramic, solder) expansion rates can induce cracks within components that cause them to electrically fail.

For all of these reasons there are five temperature range grades defined in AEC-Q200:

Grade 0: Minimum/maximum temperature range is -50°C to +150°C. Applicable parts include flat chip ceramic resistors and X8R ceramic capacitors
Grade 1: -40°C to +125°C (mostly under hood applications). Parts include capacitor networks, resistors, Inductors, transformers, thermistors, resonators, crystals and varistors, all other ceramic and tantalum capacitors.
Grade 2: -40°C to +105°C (mostly passenger compartment applications). e.g., aluminum electrolytic capacitors.
Grade 3: -40°C to +85°C film capacitors, ferrites, R/R-C networks and trimmer capacitors
Grade 4: 0°C to +70°C: (non-automotive)
It is well accepted that the AEC-Q200 specification includes the most stringent stress tests for passive components, which are tested and audited to a much greater extent than for other commercial applications, primarily with respect to stability under high temperatures and temperature changes, resistance to humidity, mechanical stress (shock, vibration, board flex)



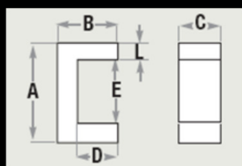
Two main forces are driving cars to multivoltage systems--the quest for ever-greater fuel economy and the introduction of new power-hungry automotive equipment. Electrical equipment that was considered a luxury in the past will become standard over time. This will double or triple the required electrical power from 1.5 kwatts in a sedan to 3.4 kWatts in an electrical vehicle to potentially 10 kWatts in the near future. That amount of power can be more effectively distributed and utilized at voltages much higher than the older 12 V DC model.



This diagram shows just a few of the applications in a vehicle that require voltage conversion. We're going to take a look at the types of cores that are needed for some of these new applications.

EMI FILTERING
DIFFERENTIAL MODE CHOKE
PLANAR POWDER CORES U CORES

Custom sizes available
Coated for direct application to bus bar



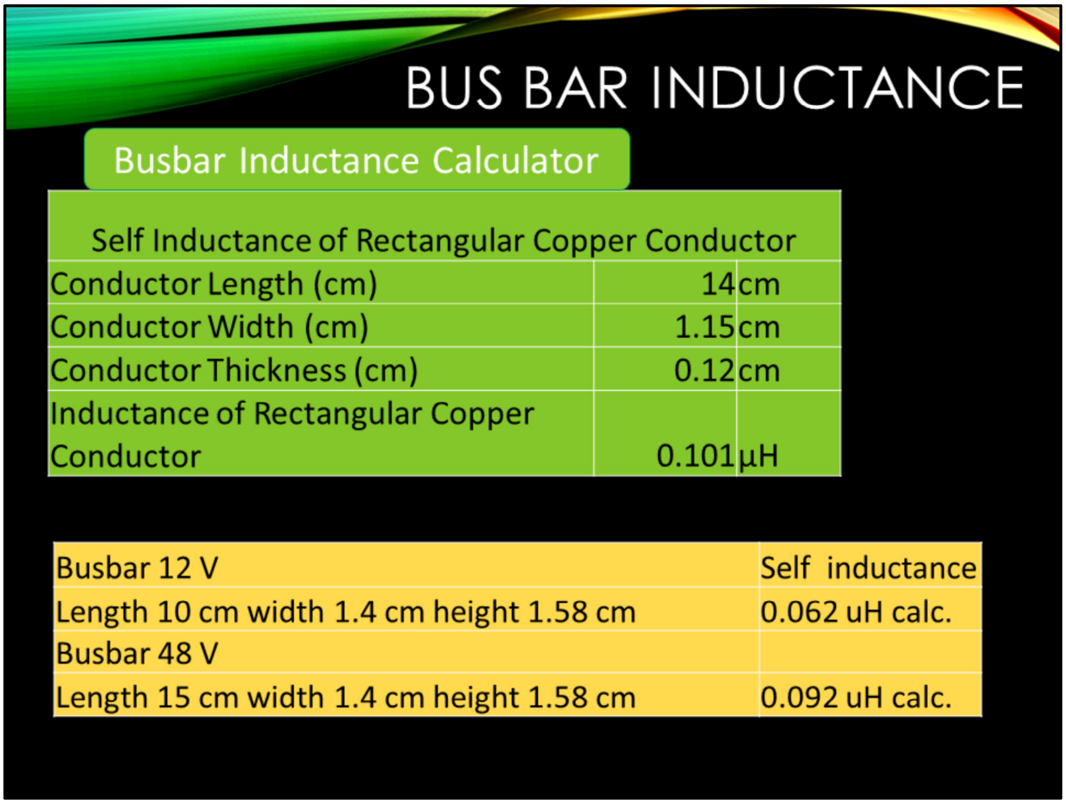
PART NO		A	B	C	D(min)	E(min)	L(nom)
00K3112U***	mm	31.24±0.51	11.2±0.26	12.1±0.39	2.54	14.2	8.26
	in	1.230±0.020	0.440±0.010	0.475±0.015	0.100	0.560	0.325
00K4110U***	mm	40.64±0.51	11.2±0.51	9.53±0.39	2.54	23.6	8.38
	in	1.600±0.020	0.440±0.020	0.375±0.015	0.100	0.930	0.330
00K4111U***	mm	40.64±0.51	11.2±0.26	12.1±0.39	2.54	23.6	8.38
	in	1.600±0.020	0.440±0.010	0.475±0.015	0.100	0.930	0.330
00K4119U***	mm	40.64±0.51	11.2±0.26	19.1±0.39	2.54	23.6	8.38
	in	1.600±0.020	0.440±0.010	0.750±0.015	0.100	0.930	0.330

First we'll take a look at cores that will be effective for differential mode choke applications—both for the standard 12 V bus bar and the 48 V bus bar. Kool Mu U cores have the right dimensions to unobtrusively fit onto a bus bar. There are four sizes tooled up. Custom shapes are easily created to fit any bus bar.

DIFFERENTIAL MODE CHOKE FOR BUSBAR APPLICATIONS PLANAR POWDER U CORES

				Testing at 10 kHz.				
Copper Bus Bar Dimensions					No-load Inductance			
Length	Width	Height			Calculated Busbar		Measured on Busbar	
100.55 mm	12.8 mm	1.58 mm			0.064 µH		0.094 µH	
	Core Set	Dimensions L X W X H			Inductance/A_L		With Busbar	Core contribution
Core Set		Length	Width	Height				
00K3112U090		31.24 mm	12.1 mm	22.4 mm	179 +/- 8%		0.274 µH	0.180 µH
00K3112U090 coated 0.0015", 0.381 mm.							0.122 µH	0.028 µH
00K3112U060		31.24 mm	12.1 mm	22.4 mm	111 +/- 8%		0.199 µH	0.105 µH
00K3112U060 coated 0.0015", 0.381 mm.							0.110 µH	0.016 µH
00K4110U090		40.64 mm	9.53 mm	22.4 mm	109 +/- 8%		0.208 µH	0.114 µH
00K4110U090 coated 0.0015", 0.381 mm.							0.131 µH	0.037 µH
00K4111U090		40.64 mm	9.53 mm	24.2 mm	138 +/- 8%		0.237 µH	0.143 µH
00K4111U090 coated 0.0015", 0.381 mm.							0.143 µH	0.049 µH
00K4119U090		40.64 mm	9.53 mm	38.2 mm	218 +/- 8%		0.288 µH	0.194 µH
00K4119U090 coated 0.0015", 0.381 mm.							0.165 µH	0.071 µH
Multiple coated cores on one Busbar					Expected sum	Actual sum		
00K4119U090+00K4111U090					0.214 µH	96%	0.205 µH	0.111 µH
00K4119U090+00K4111U090+00K4110U090					0.251 µH	101%	0.255 µH	0.161 µH
Conclusion: Multiple cores on the Busbar impacts the leakage flux and the self-inductance of the busbar slightly.								

Bus bars inherently have a self inductance which includes a leakage inductance. I realize this slide is a little dense with numbers. What I am illustrating here is the inductance achieved with both the fully-coated bus bar cores and the bus bar cores that are not coated on the mating surface. The bus bar was calculated to have an inductance due to the geometry of the copper bar. We calculated 64 uH. We actually measure 94 uH which includes some leakage inductance. When the U cores with uncoated mating surfaces are added to the bus bar the inductance added to the bar correlates well with the anticipated measurement based upon the AL value of the core. When the coating is applied to the entire U core, an additional gap the thickness of the coating is introduced, reducing the inductance of the unit by a substantial amount. Adding additional U cores to the bus bar adds inductance from the core, but the self-inductance of the bus bar is altered due to the change in the leakage flux. The inductance realized by adding additional cores to the bus bar is altered slightly. Actual measurements should be taken with cores and the bus bar.



We have an Excel file that has been developed for estimating the self inductance of the bus bar. As always, actual measurements should be taken with the bar and the cores.

Magnetics has retooled their toroid cores to take advantage of the additional cross sectional area of the core and the relatively smaller path length which results in increased inductance.

EASY PART NUMBERING

{Std P/N} + {"HT"} + {Max Hgt}

Example:

00 - 77 930 - A7 - HT- 15

Grading Code
C0 – 2% Inductance Bands
00 – Not Graded

Material
77=Kool Mμ
55=MPP
58=High Flux
78=XFlux

Catalog Number
Designates Size and Permeability

Core Finish Code
A7=Kool Mu & XFlux
A2=MPP & High Flux

Tall Height Designation

Coated Height Maximum (mm)

14

PFC BOOST WITH TALL TOROIDS PHEV—INTERLEAVED PFC

- 3.3 kWatt 70 kHz 15 A 2 A p-p Ripple 400 μH
- Suggested cores:

Part number	Perm	Finished OD	Finished HT	Temp Rise
0077111A7HT30	26	72.5 mm	44.2 mm	57 °C
0077192A7HT32	60	67.5 mm	41.9 mm	58 °C
0077189A7HT32	40	72.3 mm	46.6 mm	45 °C
0078439A7HT38	60	57.1 mm	47.5 mm	58 °C

For PHEV applications, the accepted approach involves using an on-board charger . The most common charger power architecture includes an AC-DC converter with power factor correction (PFC) followed by an isolated DC-DC converter.
An onboard 3.3 kW charger can charge a depleted 16 kWh battery pack in PHEVs to 95% charge in about four hours from a 240V supply.

TALL TOROID AVAILABILITY

Diameter (mm)	Example P/N (125μ)	Standard Height (mm)	Height available up to…
16.5	77120	6.35	**14 mm**
17.3	77380	6.35	**19 mm**
20.3	77206	6.35	**14 mm**
22.9	77310	7.62	**23 mm**
23.6	77350	8.89	**27 mm**
26.9	77930	11.2	**32 mm**
33.0	77548	10.7	**32 mm**
39.9	77254	14.5	**20 mm**
46.7	77438 / 77089	18.0 /15.2	**42 mm**
57.2	77195 / 77109	15.2 /14.0	**42 mm**

Can also supply at heights below standard

Can supply in all Kool Mμ perms

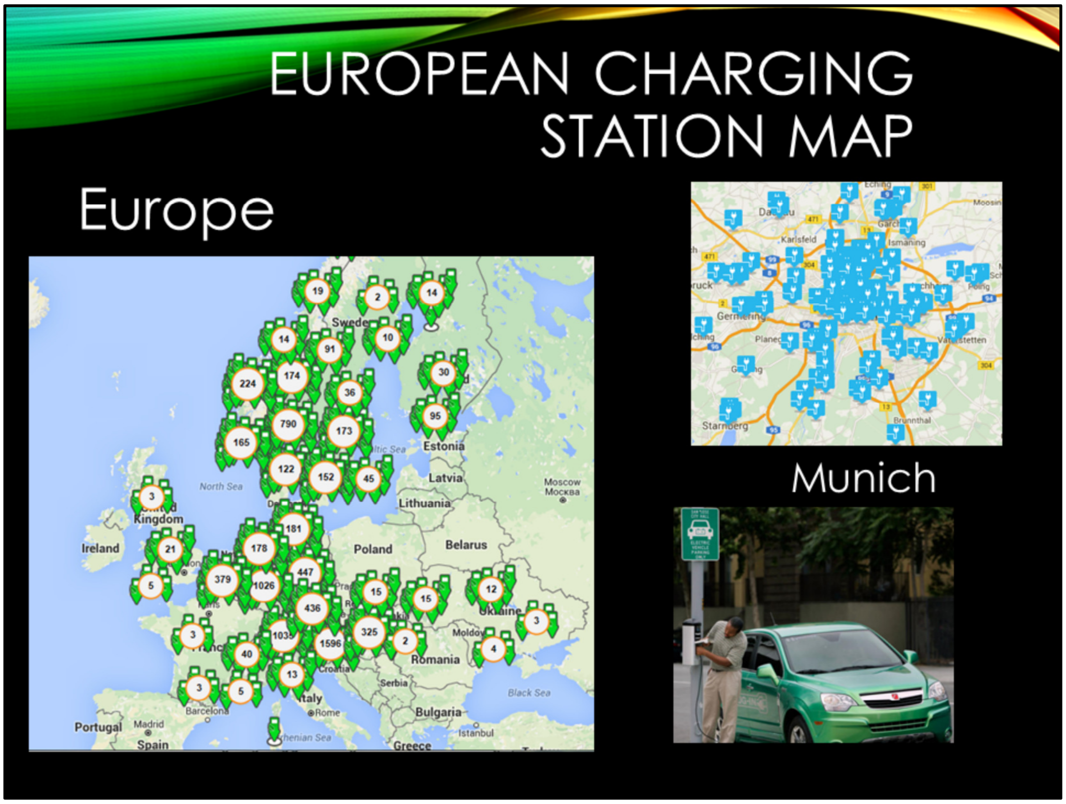
(14, 26, 40, 60, 125)

Can supply in

MPP

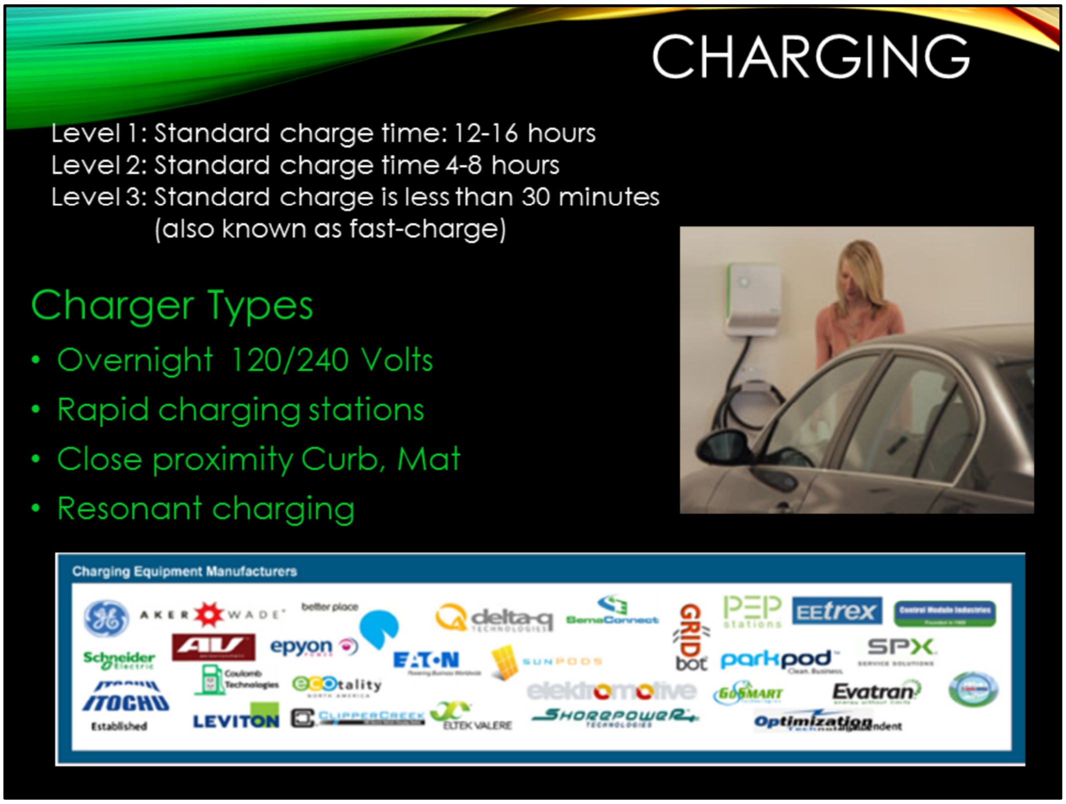
High Flux

XFLUX



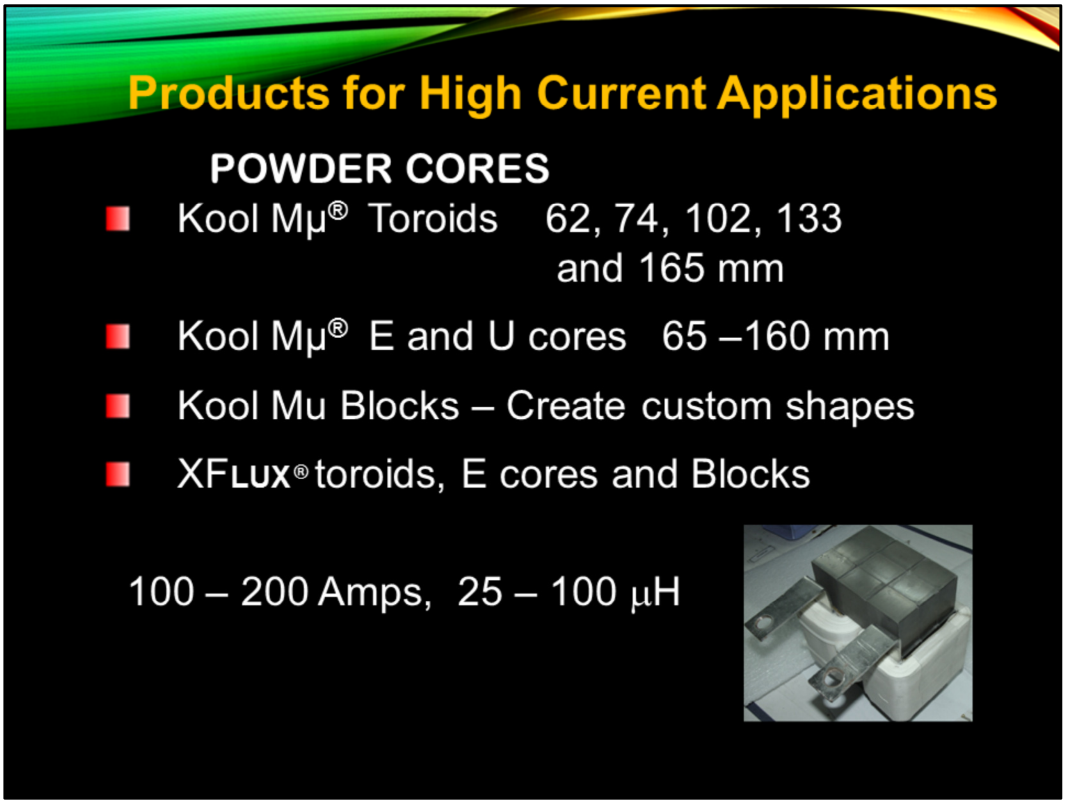
Germany is spending millions to add 200 charging stations in the Munich Region in Munich and Berlin. Countries across Europe are installing EV charging stations

Here are some of the companies installing the charging stations around the world.



There are many different types of charging stations in development. There are many issues to be addressed. In addition to the electrical challenges, there are business considerations to be resolved as well. Considerations on how payment will be made for charging the EV must be developed that can interact with financial institutions.

Half a charge in 20 minutes, free-of-charge currently charges Tesla Models only. The latest location is in St. Augustine, FL. Others are located in Port St. Lucie and Fort Myers, FL. There are one thousand model S owners in Florida. The inverter design in these chargers uses 00K4741B060 Blocks.

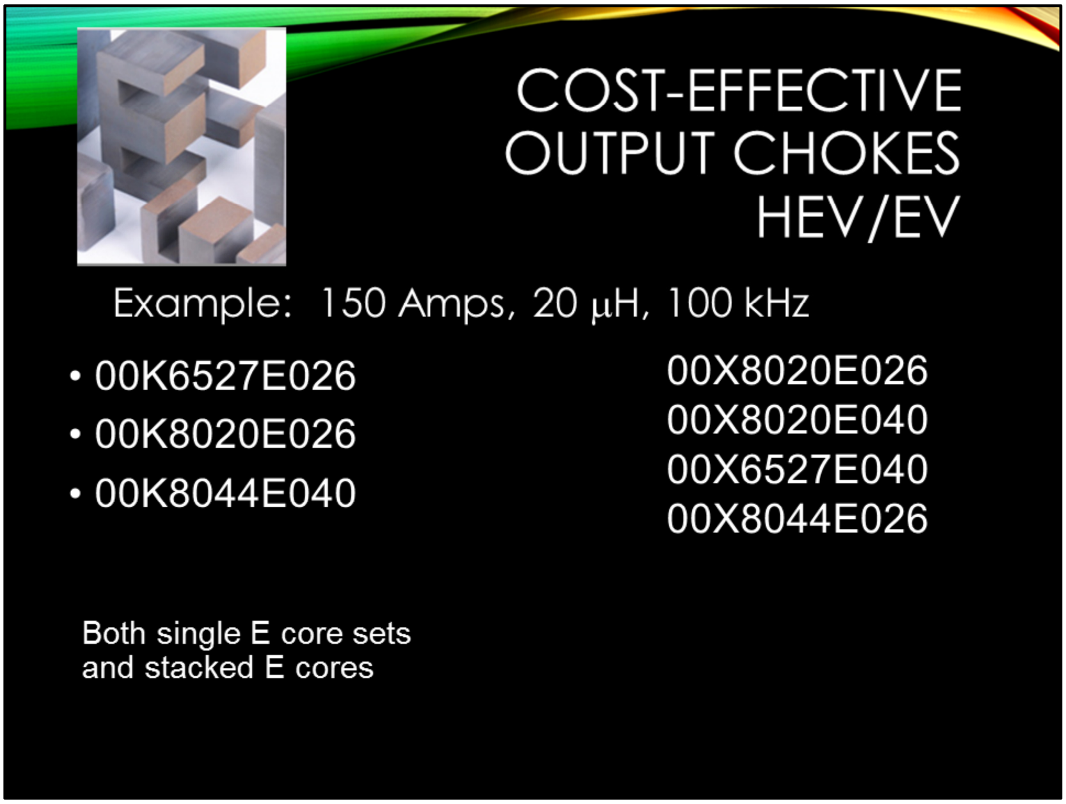


EV charging circuits require high-current inductors (a high-current application is any LI^2 value over 1000).

JUMBO TOROIDS

Part Code	Outside Diameter	Inside Diameter	Height
620	62 mm (2.44 in.)	32 mm (1.26 in.)	25 mm (0.98 in.)
740	74 mm (2.91 in.)	45 mm (1.77 in.)	35 mm (1.38 in.)
102	102 mm (4.02 in.)	57 mm (2.24 in.)	17 mm (0.67 in.)
337	133 mm (5.24 in.)	79 mm (3.11 in.)	32 mm (1.26 in.)
165	165 mm (6.50 in.)	102 mm (4.02 in.)	38 mm (1.50 in.)

I particularly like the simplicity and flexibility of the large toroids. I can make a 150 A 80 uH inductor in under fifteen minutes with a multi-strand cable and stacked toroids.

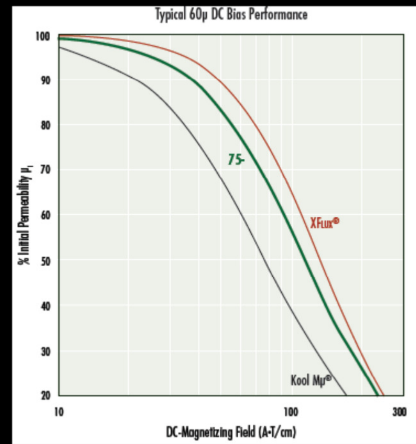


Our Kool Mu and XFlux E cores provide cost effective solutions for HEV and EV output chokes.

NEW POWDER CORE

75 Material

High DC Bias
Lower Losses



Material	Alloy Composition	DC Bias	Core Loss	Relative Cost	Saturation Flux Density	Curie Temperature	Operating Temperature Range	60μ μ flat to...
75-Series	**FeSiAl**	**Better**	**Moderate**	**Low**	**1.5 T**	**700° C**	**-55° C to 200° C**	**500 kHz**
XFlux®	FeSi	Best	High	Low	1.6 T	700° C	-55° C to 200° C	500 kHz
High Flux	FeNi	Best	Moderate	Medium	1.5 T	500° C	-55° C to 200° C	1 MHz
Kool Mμ®	FeSiAl	Good	Low	Low	1.0 T	500° C	-55° C to 200° C	900 kHz
MPP	FeNiMo	Better	Very Low	High	0.8 T	460° C	-55° C to 200° C	2 MHz

As we constantly strive to provide Magnetic materials with better characteristics, our newest powder core material, 75 Material, provides Higher DC bias than Kool Mu and has lower losses than XFlux. This material will be available for use in PFC and Output Choke applications. Anywhere small size and high DC Bias are required.

THANK YOU