Another EMC resource
from EMC Standards

EMC Design for Switching Power Converters

Helping you solve your EMC problems

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EMC design of switching power converters

DC/DC, DC/AC, AC/DC and AC/AC, milliwatts to Megawatts in *all* applications, including cellphones, computers, hybrid & electric vehicles, green power (solar, wind, tidal, etc.), etc.

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Very brief introduction to EMI and EMC

- What is EMC?
- EMC Standards and Regulations
- Why Switch-Mode converters have emissions problems
- All cables are “accidental antennas”
- Use good EMC engineering to reduce financial risks

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What is EMC?

- The science and engineering discipline that is concerned with controlling electromagnetic interference (EMI)...
  - is called electromagnetic compatibility (EMC)
- EMC is concerned with ensuring that emissions of EMI are low enough not to upset other equipment...
  - and that immunity to EMI is high enough for equipment to operate well-enough in its electromagnetic environment (EME)...
    - i.e. the totality of all the EM phenomena that can exist at the location(s) where the equipment can be used

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There are standards and regulations on EMC...

- in most countries, worldwide, at least limiting conducted and radiated emissions to protect radio broadcasting/communications spectrum

- **Unless good EMC design/construction practices are used...**
  - switch-mode power converters will fail emissions tests...
    - at least conducted emissions
- **This course will not discuss EMC standards, test methods or regulations...**
  - just good EMC design and construction techniques

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Why switch-mode power converters cause high levels of EMI emissions

- **All power switching generates a great deal of electrical "noise"...**
  - from the switching frequency, to radio frequencies (RF)
- **This noise "leaks out" into the unit's cables, causing high levels of conducted emissions...**
  - and because cables act as "accidental antennas" some of their noise leaks into the air as radiated emissions...
  - also, leaked noise currents flowing in the earth/ground structure, causes "earth/ground voltage noise"

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Why switch-mode power converters cause high levels of EMI emissions continued...

- **Plus, mains-frequency-related and low-frequency noise current emissions can damage the mains distribution network....**
  - **e.g. by overheating cables and transformers (fire is a possibility)...**
  - **– and distort the mains distribution voltage waveform so it isn't a sinewave...**
    - **possibly interfering with other equipment connected to the same network**

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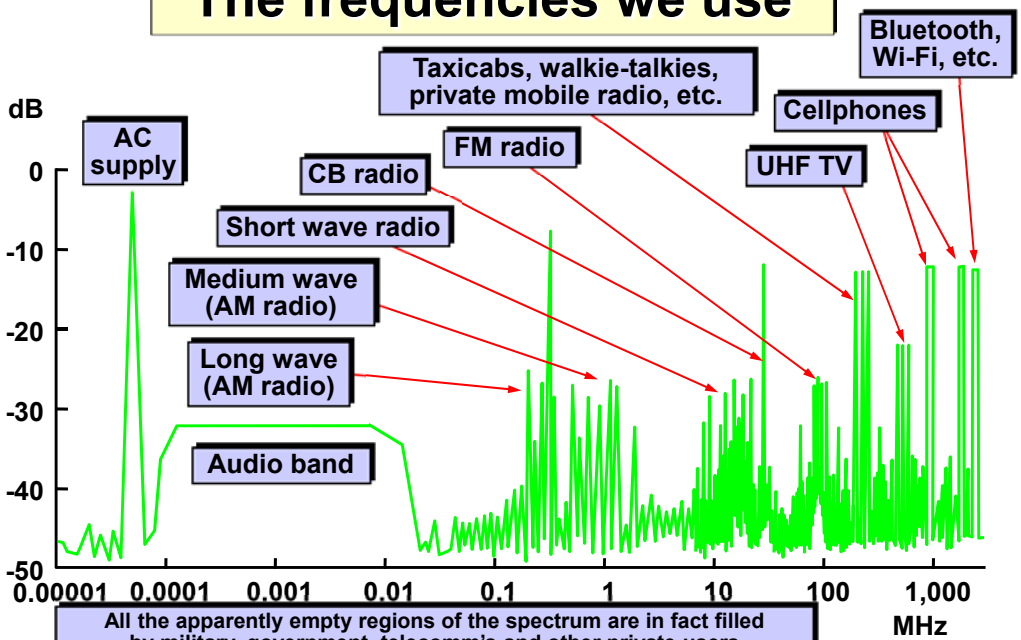
The frequencies we use



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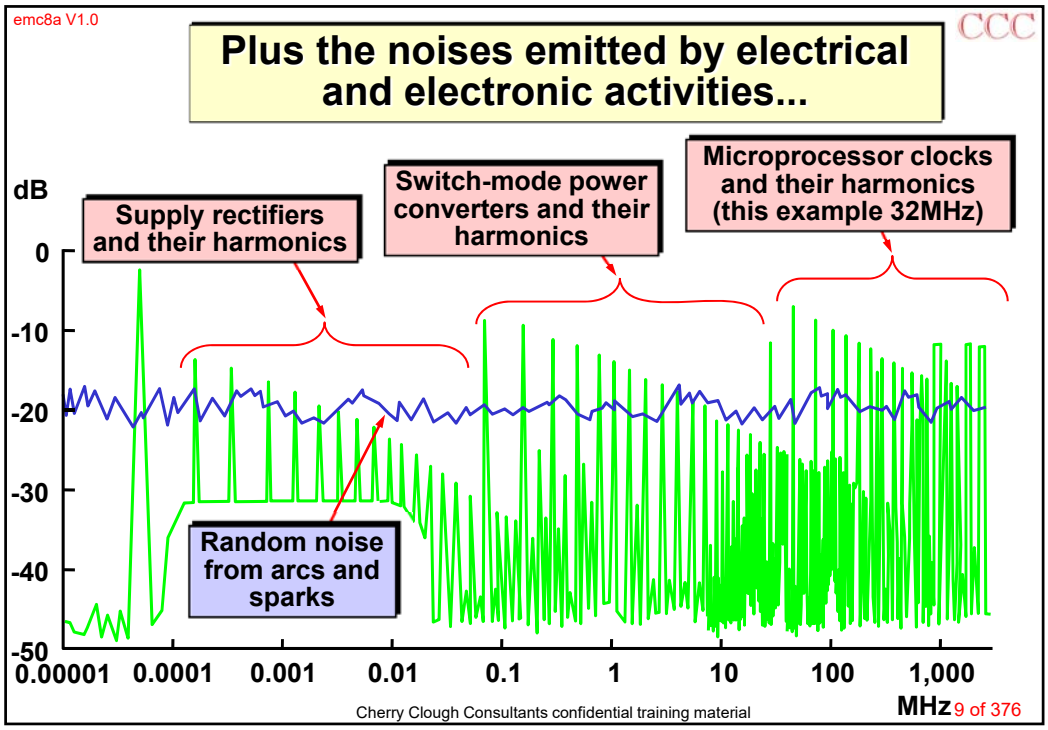
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Plus the noises emitted by electrical and electronic activities...
dB
0
-10
-20
-30
-40
-50
Supply rectifiers and their harmonics
Switch-mode power converters and their harmonics
Microprocessor clocks and their harmonics (this example 32MHz)
Random noise from arcs and sparks
0.00001
0.0001
0.001
0.01
0.1
1
10
100
1,000
MHz
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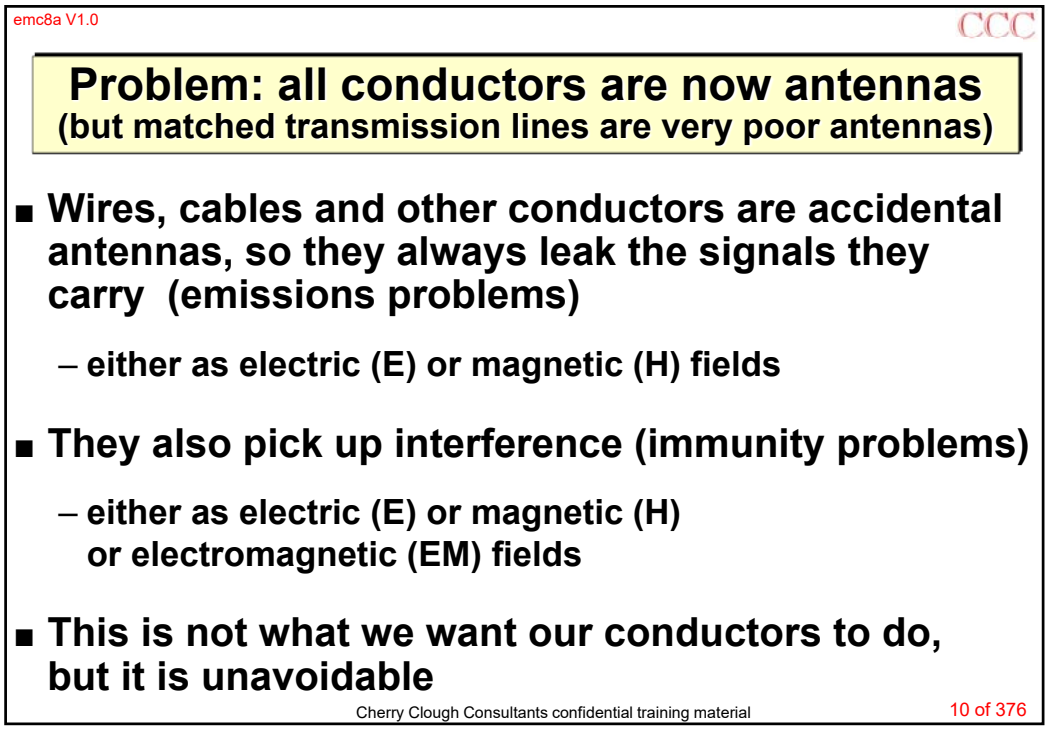
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Problem: all conductors are now antennas
(but matched transmission lines are very poor antennas)
■ Wires, cables and other conductors are accidental antennas, so they always leak the signals they carry (emissions problems)
– either as electric (E) or magnetic (H) fields
■ They also pick up interference (immunity problems)
– either as electric (E) or magnetic (H) or electromagnetic (EM) fields
■ This is not what we want our conductors to do, but it is unavoidable
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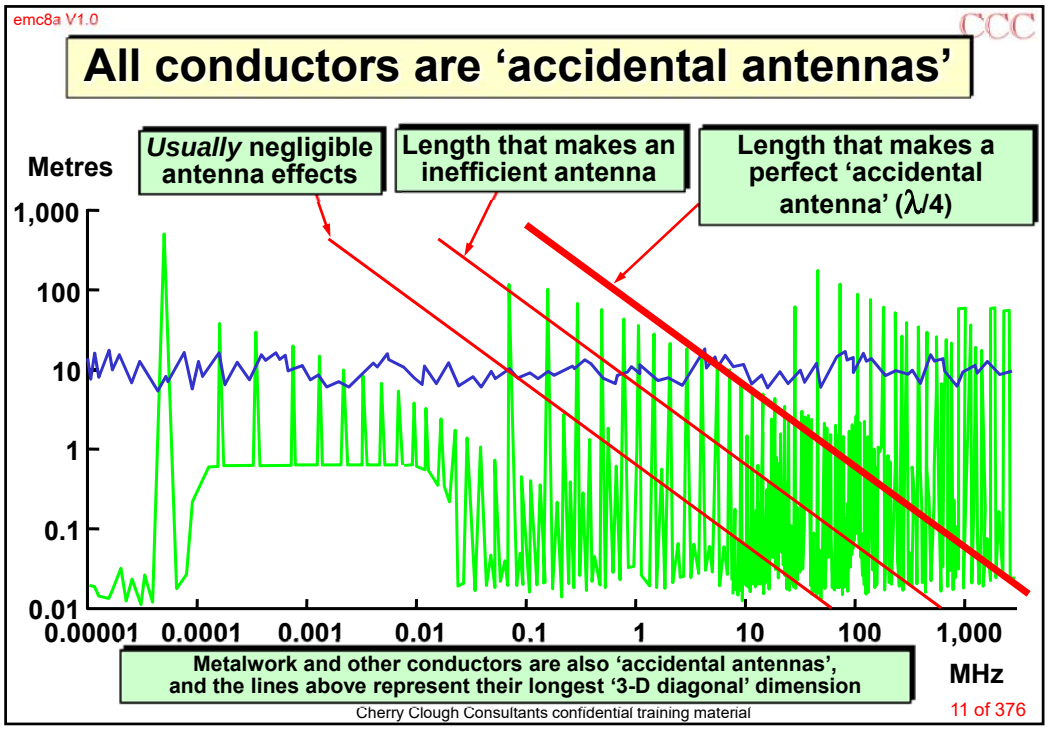
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All conductors are 'accidental antennas'
Metres
Usually negligible antenna effects
Length that makes an inefficient antenna
Length that makes a perfect 'accidental antenna' (λ/4)
1,000
100
10
1
0.1
0.01
0.00001
0.0001
0.001
0.01
0.1
1
10
100
1,000
MHz
Metalwork and other conductors are also 'accidental antennas', and the lines above represent their longest '3-D diagonal' dimension
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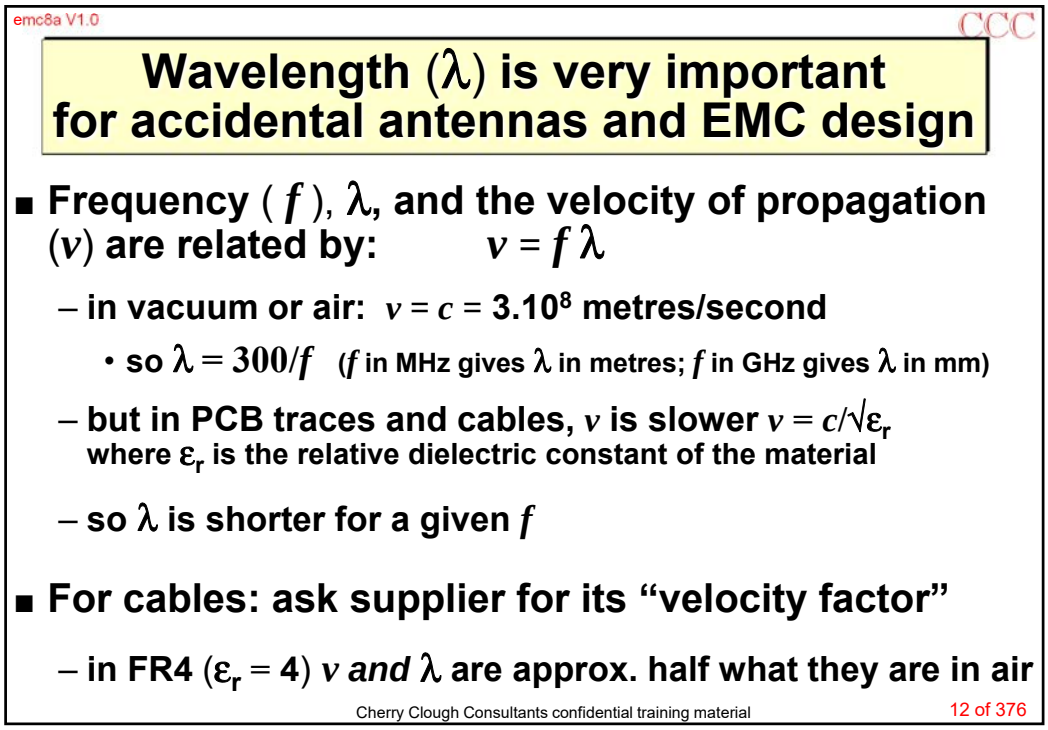
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Wavelength (λ) is very important for accidental antennas and EMC design
■ Frequency (f), λ, and the velocity of propagation (v) are related by: v = f λ
– in vacuum or air: v = c = 3.10^8 metres/second
• so λ = 300/f (f in MHz gives λ in metres; f in GHz gives λ in mm)
– but in PCB traces and cables, v is slower v = c/√εr where εr is the relative dielectric constant of the material
– so λ is shorter for a given f
■ For cables: ask supplier for its "velocity factor"
– in FR4 (εr = 4) v and λ are approx. half what they are in air
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Reduce financial risks by EMC engineering from project start

- **Unless low-enough emissions and high-enough immunity is designed-in from the start of design/development project...**
  - **projects will take a long time before they work well enough to sell...**
  - **customers will suffer interference and downtime...**
  - **warranty costs will be high...**
  - **repeat business will suffer...**
  - ***so good EMC engineering is always required regardless of standards and regulations***

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This course does *not* address immunity to EMI...

- **because immunity design/construction is the same as for any kind of electronics...**
  - **although a lack of immunity can make power converters explode violently due to the high energies they handle**

- **However, the shielding and filtering techniques described here for reducing emissions...**
  - **are also good for improving immunity, over the same frequency ranges as the emissions they reduce...**
    - **and can be extended to higher frequencies if required**

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Applications of switch-mode power conversion

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- Building blocks for switch-mode power converters
- Non-isolating DC-DC converters
- Isolating DC-DC converters
- Non-isolating AC-DC converters
- Isolating AC-DC converters
- Non-isolating DC-AC converters
- Isolating DC-AC converters
- Non-isolating AC-AC converters
- Isolating AC-AC converters

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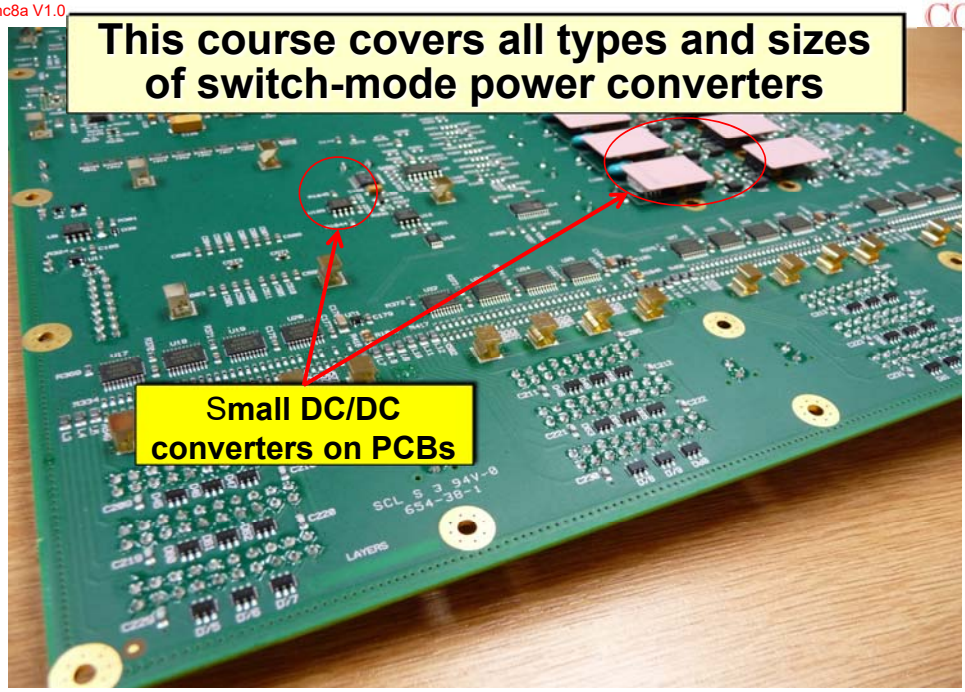
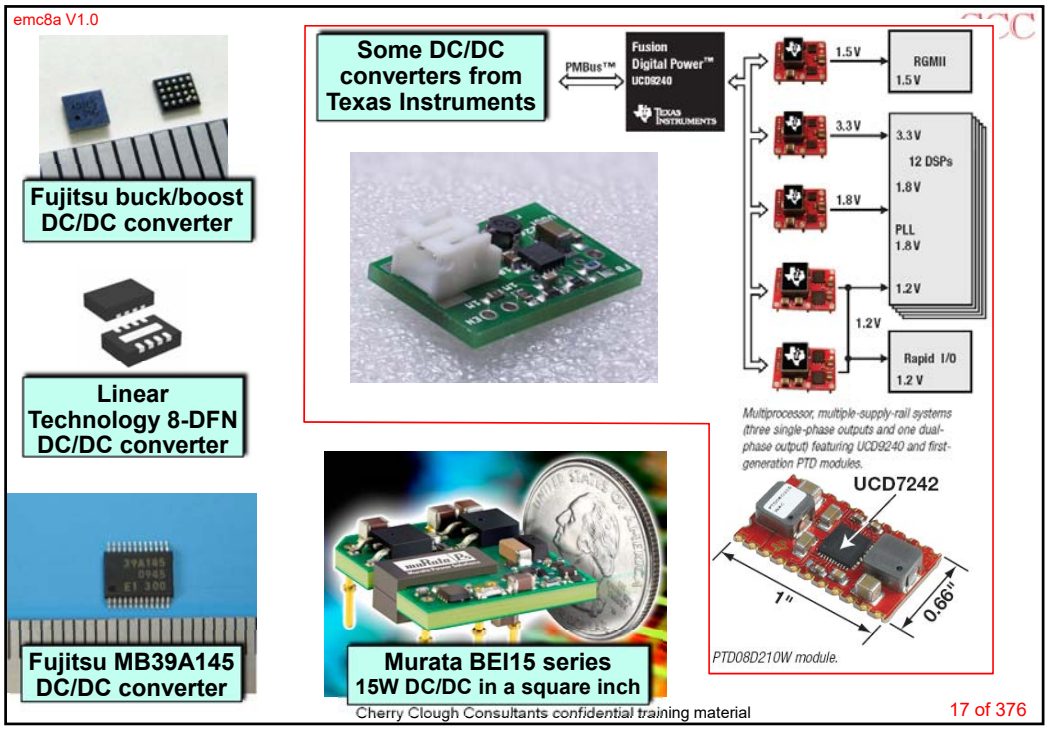
This course covers all types and sizes of switch-mode power converters

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Some DC/DC converters from Texas Instruments
PMBus™
Fusion Digital Power™ UCD9240
Texas Instruments
1.5 V
RGMII 1.5 V
3.3 V
3.3 V 12 DSPs
1.8 V
PLL 1.8 V
1.2 V
1.2 V
Rapid I/O 1.2 V
Multiprocessor, multiple-supply-rail systems (three single-phase outputs and one dual-phase output) featuring UCD9240 and first-generation PTD modules.
UCD7242
1"
0.66"
PTD08D210W module.
Fujitsu buck/boost DC/DC converter
Linear Technology 8-DFN DC/DC converter
Fujitsu MB39A145 DC/DC converter
Murata BEI15 series 15W DC/DC in a square inch
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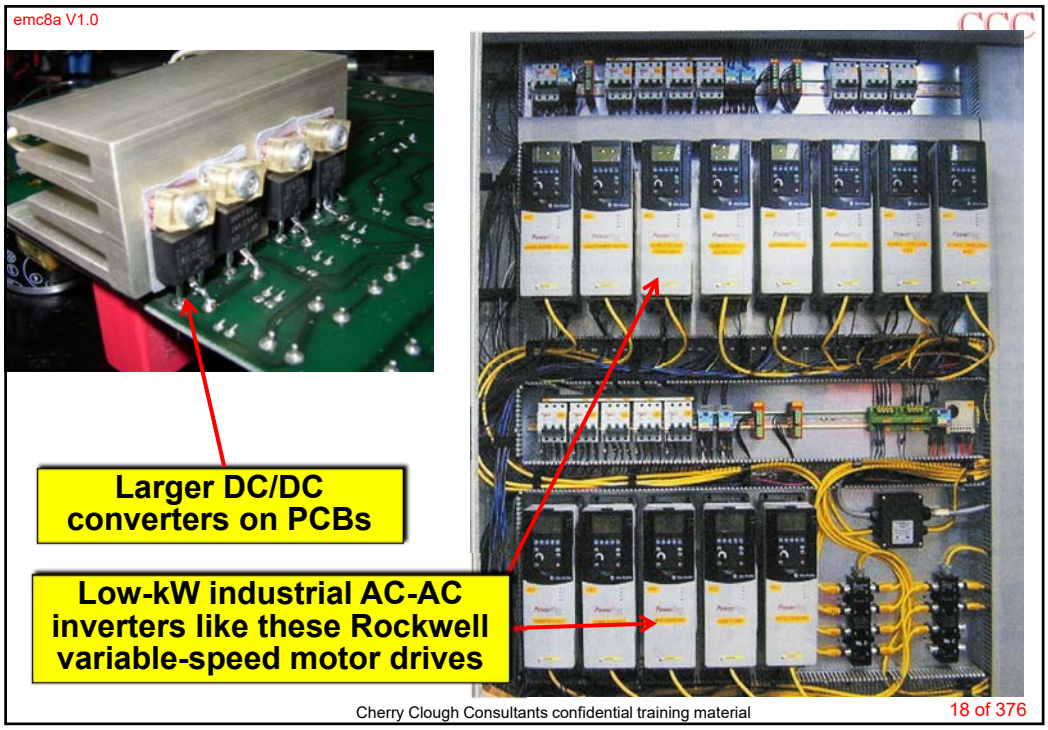
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Larger DC/DC converters on PCBs
Low-kW industrial AC-AC inverters like these Rockwell variable-speed motor drives
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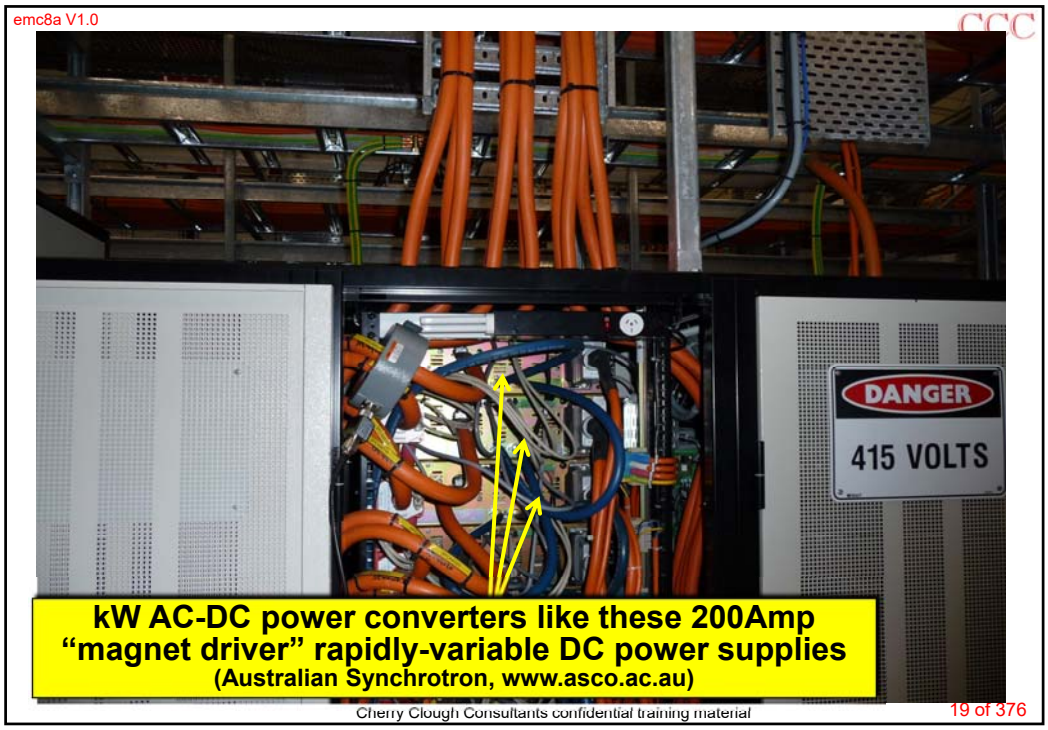
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DANGER
415 VOLTS
kW AC-DC power converters like these 200Amp "magnet driver" rapidly-variable DC power supplies
(Australian Synchrotron, www.asco.ac.au)
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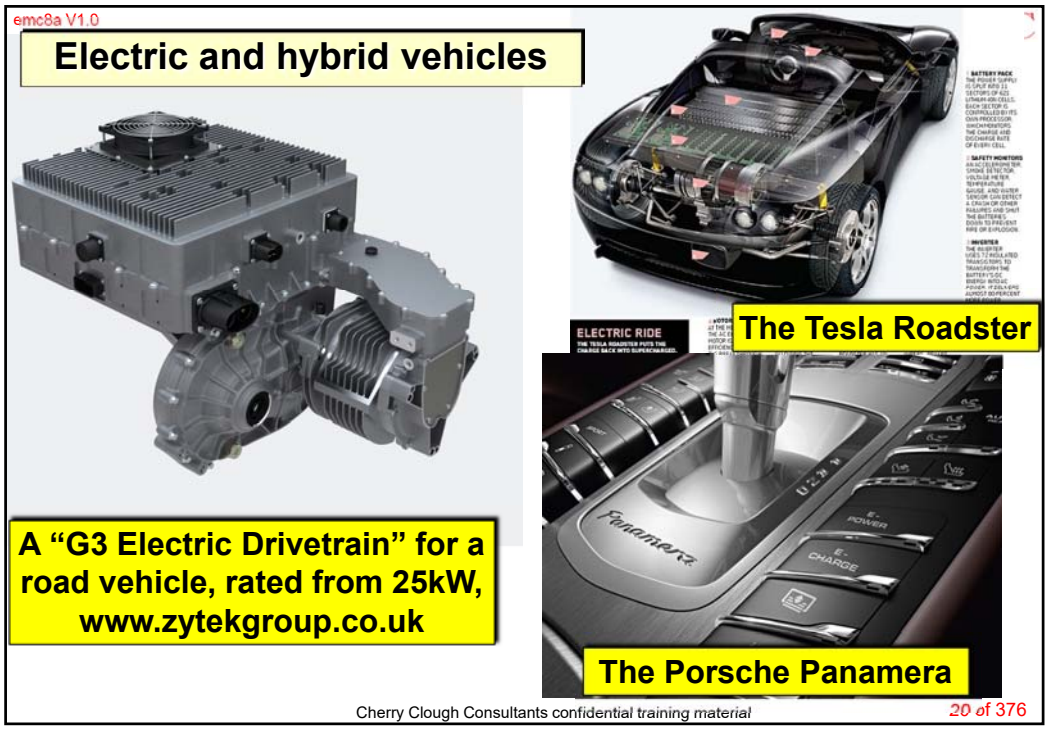
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Electric and hybrid vehicles
The Tesla Roadster
A "G3 Electric Drivetrain" for a road vehicle, rated from 25kW, www.zytekgroup.co.uk
The Porsche Panamera
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