Technical Update
#1 2016

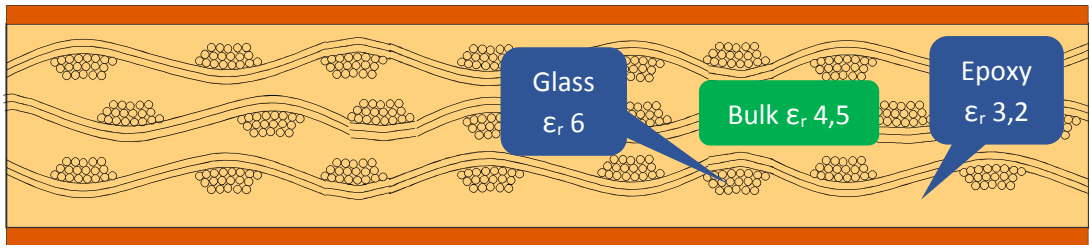
Impedance & dielectric constant

In our first technical newsletter, we will explain why the dielectric constant depends on where the tracks is positioned in the pcb and how it affects the impedance calculations.

If you ever designed with impedance controlled tracks 50 Ohm single end or 100 Ohm differential pair, you might have noticed that the dielectric constant ε_r often is set to 4,2 to 4,6.
In most cases this value works just fine for single end and stripline.
However differential pairs behave different and adding up all error tolerances in the calculations, the impedance value will differ a lot.

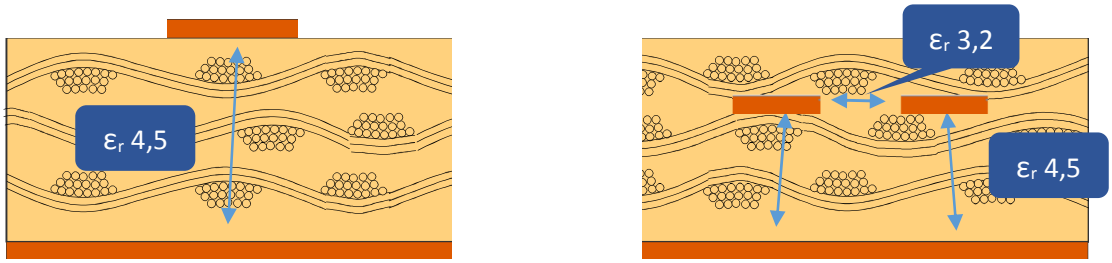
Printed circuit board base material
Multilayer boards are built with multiple layers of resin coated woven glass fiber, so called prepreg. The resin coating in FR-4 material contains mainly of epoxy.

The amount of resin will vary in the woven glass fiber, as well as the prepreg thickness between different glass fiber thicknesses and brands. Each prepreg thickness is determined by layer count, distance between each layer and the total thickness of the board. Thin material contains more epoxy, the ratio between epoxy and glass differs within the pcb, which means variations in ε_r as well.



The woven glass ε_r is approximately 6 and epoxy 3,2. The ratio between glass and epoxy in a regular double sided board is about equal parts and that ratio will end up in what we call bulk ε_r about 4,5.

It is reasonable to calculate with 4,5 for a 50 Ohm single end with reflective plane on innerlayer as shown in the left picture. However a 100 Ohm differential pair shown in the picture to the right have signals between the tracks and that part of the pcb do not contain any glass, resulting in decreased ε_r



Between tracks in differential pairs there is either epoxy with ε_r at 3,2 if they are embedded in the pcb, or covered with soldermask with ε_r at 3,5 if the pair is positioned on the outerlayer.

If the signal is spread nearly equal between the tracks and between the pair and ground plane, we should calculate on approximately 3,8 for a differential pair. In other words we will have a few % error at calculated impedance value if we still use the default value 4,2-4,6 during impedance calculation of differential pairs.

Difference in resin content

To make things a little bit more complicated, we will remind you about the fact that prepreg contains of different amounts of resin, the ratio between epoxy and glass depends on type of woven glass and its thickness. The resin content can vary from 40% up to 80%. It means that a thin layer within a 12-layer pcb or a microvia layer can have a very large amount epoxy, decreasing ε_r , while a regular double sided board made of rough woven glass have a much lower resin content, increasing ε_r .
For critical designs in multilayer boards where the impedance value need to be kept within narrow tolerances, it might be reasonable to calculate on bulk ε_r with different resin content. Some examples shown in the table below:

Thickness	Resin content	ε_r
1,52 mm laminate	42%	4,6
0,2 mm prepreg	48%	4,1
0,1 mm prepreg	55%	4,0
0,05 mm prepreg	70%	3,6