

## Do Not Forget the Temperature Dependence of the Specific Resistivity!

### Advanced

The discovery of high temperature superconductors in **1986** immediately lead to proposals to use these materials for interconnects on chips instead of the **Al** that was common then (and for about **15** more years).

- The reason was that the finite resistivity of **Al** together with parasitic capacitances (e.g. between two conducting lines on a chip) limits the maximum frequency to

$$f_{\max} = \frac{1}{R \cdot C}$$

- With **R** = resistance of the longest connection line on the chip and **C** = parasitic capacitance "seen" by this line.
- For **R = 0 Ω** as we have it for a superconductor, the maximum frequency is no longer limited by **R · C**, no matter how large the parasitic capacitances are. Instead, the limit comes from  $f_{\max} = (L \cdot C)^{-1/2}$  with **L** = inductance of the line, and this is just another way of saying that the signal propagation is limited by the speed of light.

$$f_{\max} = (L \cdot C)^{-1/2}$$

Given the resistivity of **Al** (at room temperature!), a sizeable advantage was seen for the integrated circuits then envisioned.

- However, comparing the performance of a chip run with **Al** at room temperature to a chip run at liquid **N<sub>2</sub>** temperature (**77 K**), is not the right comparison. After all, you can cool down the conventional chip, too - and that will decrease **R<sub>Al</sub>** by a factor of **6 - 8**.
- The comparison then is quite different. The graph shows the minimum switching time  $\tau = 1/f_{\max}$  as a function of the length of a standard interconnect line about **1 μm<sup>2</sup>** cross section.

Whereas superconductors would already make an interesting difference for lengths of a few **mm** (typical line length) in the **wrong** comparison, the correct comparison only shows an advantage for about **1 cm** and larger - line lengths easily avoided by clever design.

