Daniel Schinkel

A centimetre may seem like nothing, but on a microchip it easily becomes an insurmountable distance. In order to transmit gigabits of data over this distance, Daniel Schinkel has had to pull out all the stops. Analog and digital technology come together in the Integrated Circuit Design group, which recently became part of the CTIT.

Gigabits through a slow wire

‘It sounds like a contradiction: as microchip transistor speed continues to increase, the transmission speed of microchip wires continues to decrease. As a result, they will represent a real barrier to speed, capacity and reliability. The problem has shifted over time. First, modems for telephone cables became more and more sophisticated, then you had to put all the effort in the pc motherboard, and now the problem is the microchip. We are just lucky that copper is now used to make the connections; the performance of aluminium wires was even worse.’

‘You need to take special measures if you want to transmit three gigabits per second over a one-centimetre connection at rates in line with current clock speeds. If you fail to do so, you can pretty much call it a day at 500 megabits per second. Although technology is available to “clean up” the signal along the way, it takes up too much of the microchip’s surface. A large microchip already has 30,000 of these repeaters. There is something wrong if they take up too much of the microchip’s surface.’

‘The problem is rooted in the wires’ electrical resistance and capacity, which reduce speed and consume energy. Solutions to this may be found in a new architecture requiring shorter connections or finding a way to remove the energy-hungry clock signal and minimizing communication on the microchip. Together with my colleague Eisse Mensink, I am approaching the problem from the other side. We want existing technology to use the slow wire more efficiently. With clever circuitry, we can really achieve the three gigabits per second rate.’

‘To make this happen, we are looking at combining solutions. For instance, the manner in which the signal is transmitted through the wire can be adjusted. The pulse representing a “one” develops an enormous tail due to the delay. The end of this tail remains in the picture long after the next pulse arrives. As a result, there is a risk that it will no longer be possible to keep the bits apart. That tail can be removed by using a brief negative pulse after the initial pulse of information. While this may be a well-known technique, the innovation rests in the fact that we are playing with the duration of the negative pulse. The benefits could prove enormous.’

‘I like the fact that the simplest solutions are often the most powerful. You will know soon enough if it is too complex, as it takes up too much surface space or requires too much energy. One simple solution focusing on the wire involves, for instance, placing a small resistor at the end. The way in which a charge moves through the wire can be compared to a diffusion process. Diffusion is accelerated when the charge has another way out. In this case, the resistor offers a way out. It is like opening up another valve.’

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‘Another thing we can address is the wires’ design. A wire can pick up signals from other wires placed next to them: this cross talk generates delays as well. This can be prevented by twisting the wires. It may sound complex, but there are relatively simple manufacturing methods for this. A more challenging problem is when wires are placed on top of one another, but we have solutions for that as well.’

‘While each of these solutions on their own offers substantial improvements, combining them proves formidable. Although calculations on paper have already demonstrated this, we have also had the opportunity to have a test microchip made and to conduct performance measurements. The initial results support the theory fairly well. We might be able to increase the solutions’ energy efficiency, but we will leave that for the next version.’

‘As newcomer to CTIT, we are collaborating with the CADTES group, which designs embedded systems and conceives new architectures. Even though they address the problem from the other side, their approach does not necessarily contradict ours. On the contrary, you want to ensure that a new type of system maximises the connections’ potential. The exciting part is that this represents the meeting of the analog and digital world. While we feel this research focuses heavily on the “digital”, the system architects see our work as quite “analog”. However, as we are working on the frontiers of the potential of this type of system, we need each other.’