Building a Common Vision for the UK Microelectronic Community

Vision statement on “Analogue VLSI”
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The theme of this “vision statement” is the proposal for a broad research programme on analogue VLSI systems, towards combining the methodologies of digital VLSI systems with the potential benefits of speed, size, and power that can be gained by processing data using analogue circuits. This can be interpreted on various levels: from attempting to emulate the architectures of digital systems and digital design techniques using analogue circuits, to research on novel computing paradigms well suited to analogue circuit implementation.

Information processing is nowadays done almost exclusively in the digital domain, one of the main reasons are the flexibility of this solution, high-level programmability and ease to develop robust systems. Consequently, analogue circuits have been marginalised: used for signal conditioning, simple filters and A/D converters, while digital signal processors are responsible for most of the signal processing. But, it is well-known that processing data in the analogue domain can offer advantages in terms of implementation: high speed, low power consumption and small size. The problem is – exploiting these advantages, and at a scale of a multi-million transistor chip, is not very easy. But, while the noise immunity of the digital solution is its great strength, the other advantages of the digital technology – e.g. programmability, ability to design and build fairly complex systems, etc. – are not essentially due to the digital (e.g. binary) signal representation, but rather these advantages stem from the architectural concepts, coupled with the development of structured design methodologies and supporting EDA & software tools.

The architectures of analogue VLSI systems could be modelled on existing digital solutions. Software-programmable “analogue microprocessors”, massively parallel processor arrays, reconfigurable analogue systems, analogue “gate-arrays”, etc. might provide an alternative implementation fabric (hardware) or general-purpose computing engines (software) to many problems solved today in the digital domain. At the same time, higher level of abstraction would enable more structured approach to the design of analogue systems, up to a high-level software design. Technically, a number of challenges exist. New, robust analogue techniques, and architectural concepts are required, that will enable the design of systems at a higher level of abstraction. Building-blocks, or analogue-processors, must provide robust and well characterised behaviour, the dependence on the particular fabrication technology must be reduced (the physics cannot be ignored, but the overall methodology, architectural structures & processing techniques should enable transferability of designs between technologies). On the design tools front, “analogue software” simulators and “analogue synthesis” tools need to account for noise/accuracy, etc.

A more radical approach is to look for alternative computing paradigms. Biological systems may provide architectural inspiration - information processing could be modelled on dynamic processes occurring in the brain. Analogue circuits could be an ideal vehicle for implementing neural-like computation, where massive arrays of spiking neurons, exhibiting complex spatio-temporal dynamics may be required, and where noise and inaccuracies of individual elements can be tolerated. This can open up possibilities of developing general-purpose “processors”, as well as providing methodologies for designing special-purpose devices, e.g. associative memories, controllers, etc.

It is unlikely, that analogue solutions will provide alternatives for mainstream computing, but could provide a solution where miniature, low-power, yet computationally powerful machines are needed (portable devices, autonomous robots, sensor/processor integration, etc.). Particular applications of major impact and general public appeal are neural implants (retinal prosthesis, neuro-stimulators as a cure for epilepsy, Parkinson’s disease etc. or general brain-interfaced devices) - analogue programmable circuits combining adaptability with low-power and small size might provide an ideal vehicle for implementing signal processing required in these devices.

A number groups working on field-programmable analogue arrays, neural analogue VLSI, general-purpose analogue processors, EDA tools for analogue design, etc. are active in the UK, a coordinated research programme could be established, with a goal to provide next-generation analogue implementation fabrics and methodologies (reconfigurable, structured) and analogue computers (signal processing arrays, neural architectures). The programme of research might be split into several sub-sections and smaller projects, under the overarching theme of “analogue VLSI”.

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