Arm and PragmatIC create history with non-silicon chip

Cambridge partners Arm and PragmatIC have collaborated to achieve the first fully functional non-silicon Arm processor.

In terms of realising the full potential of the Internet of Things, PlasticArm is one of the most significant technology breakthroughs in memory.

Flexible electronics can seamlessly integrate with everyday objects through a combination of ultra-thin form-factor, conformability, extreme low-cost and potential for mass-scale production, enabling incredible innovation.

Arm Research and PragmatIC have been pioneering research in this area with the PlasticArm project, and has shared exciting new detail on progress in a paper published in Nature.

John Biggs, Distinguished Engineer, Arm Research, says: “As ultra-low-cost microprocessors become commercially viable, all sort of markets will open with interesting use cases such as smart sensors, smart labels and intelligent packaging.

“Products using these devices could help with sustainability by reducing food waste and promote the circular economy with smart life-cycle tracking. Personally, I think that the biggest impact could be in healthcare – this technology really lends itself to building intelligent disposable health monitoring systems that can be applied directly to the skin.”

PlasticArm is a 32-bit Arm microprocessor developed with metal-oxide thin-film transistor technology on a flexible substrate.

The potential for this technology is beyond significant. PlasticArm is bringing the possibility of seamlessly embedding billions of extremely low-cost, ultra-thin, conformable microprocessors into everyday objects – a significant leap forward in realising the Internet of Things.

Arm says chips have undergone “an unbelievable period of transformation across just a few decades.” The world’s first commercially produced processor was a modest 4-bit central processing unit (CPU) with 2,300 transistors.

It was fabricated in 10µm process technology in silicon and capable only of simple arithmetic calculations. Nowadays, state-of-the-art silicon 64-bit microprocessors have 30 billion transistors – such as the AWS Graviton2 microprocessor fabricated using a 7nm process.

Such sophisticated technology has enabled the development of powerful devices for large and small-scale applications across many industries. But could there be instances where this silicon is unsuitable?

Millions of everyday objects, such as food packaging, clothing, and bandages could benefit from having intelligence embedded into them. While microprocessors are at the heart of every electronic device, and unit costs have been dramatically reduced over time, silicon microprocessor costs can be one of the challenges for certain high volume applications.

Arm says designers need to consider alternative methods and materials in order to realise the full potential of the Internet of Things.

Flexible electronic devices, unlike conventional semiconductor devices, are built on alternative substrates such as paper, plastic, or metal foil. Using thin film semiconductor materials such as organics, metal oxides or amorphous silicon, they offer a number of advantages over silicon, including thinness, conformability, and low manufacturing costs.

Thin-film transistors (TFTs) can be fabricated on flexible substrates at a significantly lower processing cost than metal–oxide–semiconductor field-effect transistors (MOSFETs) fabricated on crystalline silicon wafers.

While some flexible components, such as sensors, memories, light-emitting diodes, and more have been prototyped, until now a flexible microprocessor has been a major blocker to the realisation of fully flexible electronics.

Arm Research, together with PragmatIC, began exploring the feasibility of an Arm-based flexible processor back in 2013, starting off by building prototype circuits, including ring oscillators, counters and shift register arrays. By 2015 the first PlasticArm was built, and shown on-stage at TechCon by Mike Muller, Arm's CTO at the time.

Unfortunately, despite the best efforts of the teams involved, technology, and fabrication limitations meant that it was not possible to produce a fully working part at that time.

Instead, the team shifted their focus to their PlasticArmPit project, a collaboration with industrial and academic partners aimed at producing an 'e-nose' capable of detecting particular odours.

Through this project, the teams worked through a Design Technology co-optimisation process. They made informed decisions at every level of the implementation flow from the routing grid and with overlaps down to the standard cell architecture and process design rules.

A few years later, PragmatIC's FlexLogIC® manufacturing system became available. Together with the advances made in the PlasticArmPit project, which uses the same cell library, tool flow and process technology, all the pieces of the puzzle fell into place.

The team decided the time was right to give it another try and the world's first fully functional non-silicon Arm processor, PlasticARM, was produced as a result.

Although PlasticArm is an ultra-minimalist Cortex-M0-based SoC, with just 128 bytes of RAM and 456 bytes of ROM, it is 12 times more complex than the previous state-of-the-art flexible electronics.