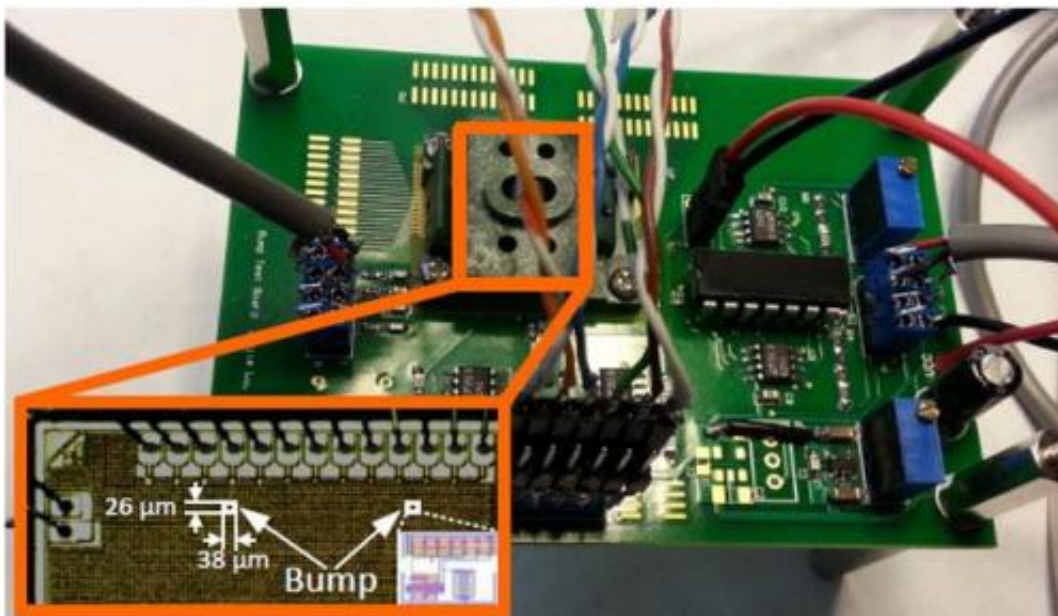


A bump circuit with flexible tuning ability that uses 500 times less power

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Experimental setup and chip micrograph.

A bump circuit with flexible tuning ability that uses 500 times less power and is smaller than previous circuits has been demonstrated by researchers at the University of Tennessee in the US.

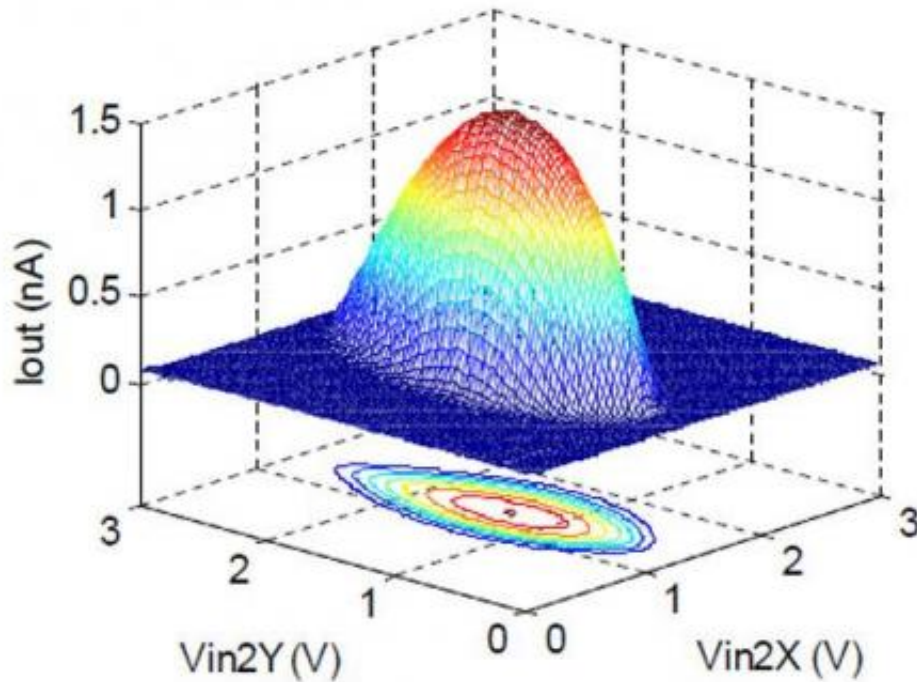
"The challenges and requirements of the analogue deep-learning system inspired us to come up with this radically new design," said Junjie Lu,

the lead author. "We implemented the bump circuit by preceding the current correlator with a novel nano-power tunable transconductor to achieve variable width and height. By significantly reducing the [power consumption](#) of the bump circuit, this work makes possible the realisation of analogue learning and signal processing systems that achieve better energy efficiency than their digital equivalents, and ultimately fully autonomous systems, which are able to get both information and energy from the environment without external intervention."

Towards flexible transfer

The bump circuit is a family of circuits with bell-shaped, non-linear transfer functions. First appearing in 1991, they are widely used to provide similarity or distance measures in analogue signal processing systems such as support vector machines, neural networks and analogue machine-learning systems.

The original bump circuit design lacked the ability to change the width of its transfer function, which is desirable in many applications to represent distributions with different variance or templates with different model parameters. A common approach to solve this is to pre-scale the input voltage, but the circuits required are physically large and consume a lot of power. Other approaches also have limitations such as complex circuitry, large physical size, and a restricted number of possible widths achievable.



The two-dimensional bump output generated by the reported bump circuit.

Hidden depths

The researchers from the University of Tennessee designed their circuit as an important building block in an analogue deep-learning machine, which is able to perform unsupervised learning and extract salient features from high-dimensional input data, with a much better power efficiency than the existing digital machine learning implementations.

Large-scale systems require the computational element, or bump circuit in this case, to be very efficient in both power and area. It is also important that the output features, which are the confidence scores that the current input belongs to each of the previous observations, take both the mean distances and probabilistic variances into account. A bump circuit that has a tunable centre for mean tuning, width for variance

tuning, and height for normalisation is therefore highly desirable, and if these three bump parameters can be individually tuned and controlled by a single signal, this would greatly help with on-chip trainability.

To achieve the variable height and width, the researchers designed and incorporated a novel transconductor, linearised using the drain resistances of saturated transistors. They adopted a pseudo-differential structure to allow operation with a low supply voltage, and designed a common mode feedback circuit to provide common mode rejection for the pseudo-differential structure to get a tunable bump height.

The whole circuit uses 18.9 nW power from 3 V supply which is 1/500th of the power of the next best bump circuit with tunable width. Implemented in 0.13 μm CMOS, it is smaller in area by 6%, and has maximum flexibility through the individual tunability of the three key bump function parameters. Another feature is that multiple bump circuits can be easily cascaded to represent multivariate probability.

A vision of the future

With power scaling in CMOS tapering off, there has been renewed interest in analogue computation recently, and the researchers expect to see some very exciting results in this area. They are currently working to integrate low-power circuits, such as their bump circuit, into larger systems for real-world applications.

"One application area we've been working on is machine vision," said Lu. "We've been working with image processing and machine vision researchers to build a complete pipeline using analogue circuits. This circuit helps to provide a path to implementing multi-dimensional kernel methods for [machine learning](#)."

Systems using the bump circuit could find application in many areas

such as healthcare monitoring, environmental monitoring, process control and battlefield surveillance. In addition, the nano-power tunable linear transconductor developed in this work, which has the advantages of ultra-low power, large input range and gm tunability, could be used in a huge range of applications such as amplifiers, filters and oscillators.

More information: "Nano-power tunable bump circuit using wide-input-range pseudo-differential transconductor" Junjie Lu; Tan Yang; M.S. Jahan; J. Holleman. *Electronics Letters*, Volume 50, Issue 13, 19 June 2014, p. 921 – 923. DOI: 10.1049/el.2014.0920 , Print ISSN 0013-5194, Online ISSN 1350-911X

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