Analog computing with high precision and programmability enabled by memristors

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Abstract:

While digital computing dominates the technological landscape, analog computing distinguishes itself with superior energy efficiency and high throughput. However, its historical limitation in precision and programmability has confined its application to specific and low-precision domains, notably in neural networks. The escalating challenge posed by the analog data deluge calls for versatile analog platforms. These platforms must not only exhibit exceptional efficiency but also boast reconfigurability and precision.

Recent breakthroughs in analog devices, such as memristors, have laid the groundwork for unparalleled analog computing capabilities. Leveraging the multifaceted role of memristors, we introduce memristive field-programmable analog arrays (FPAAs), mirroring the functionality of their digital counterparts, field-programmable digital arrays (FPGAs). To elevate precision, we delve into the origins of reading noise, successfully mitigating it and achieving an unparalleled 2048 conductance levels in individual memristors—equivalent to 11 bits per cell, setting a record precision among diverse memory types. Acknowledging the persistent demand for single or double precision in various applications, we propose and develop a circuit architecture and programming protocol. This innovation enables analog memories to attain arbitrarily high precision with minimal circuit overhead. Our experimental validation involves a memristor System-on-Chip fabricated in a standard foundry, demonstrating significantly improved precision and power efficiency compared to traditional digital systems.

The co-design approach presented empowers low-precision analog devices to perform high-precision computing within a programmable platform. This demonstration underscores the transformative potential of analog computing, transcending historical limitations and ushering in a new era of precision and efficiency.