Hybrid Analog-Digital Computing for Solving Nonlinear Systems

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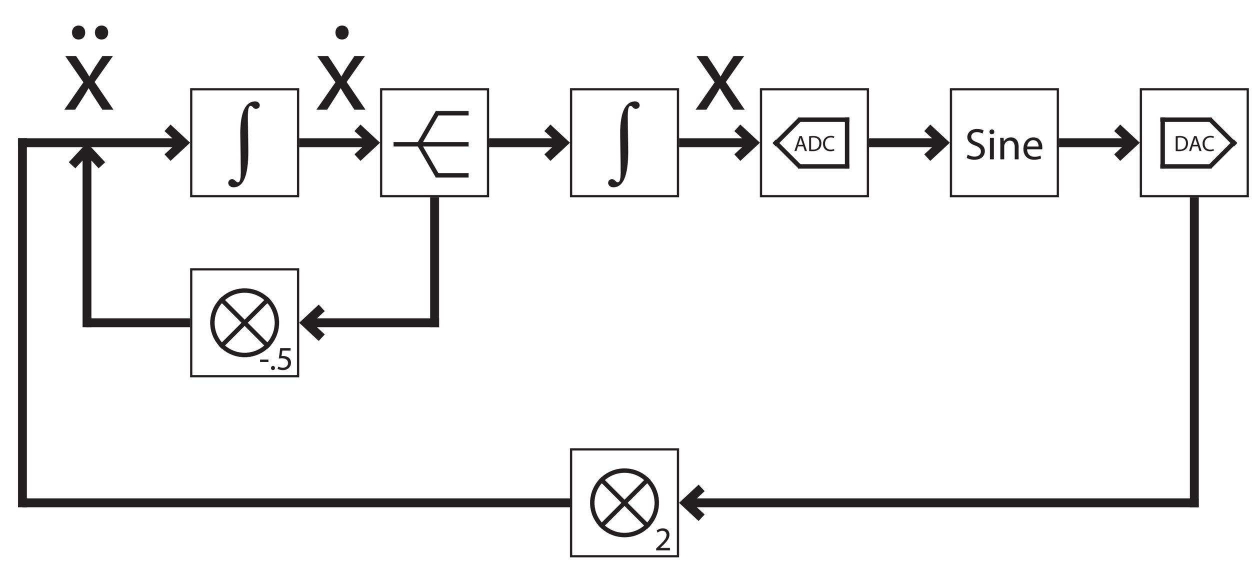
Motivation for analog in digital era

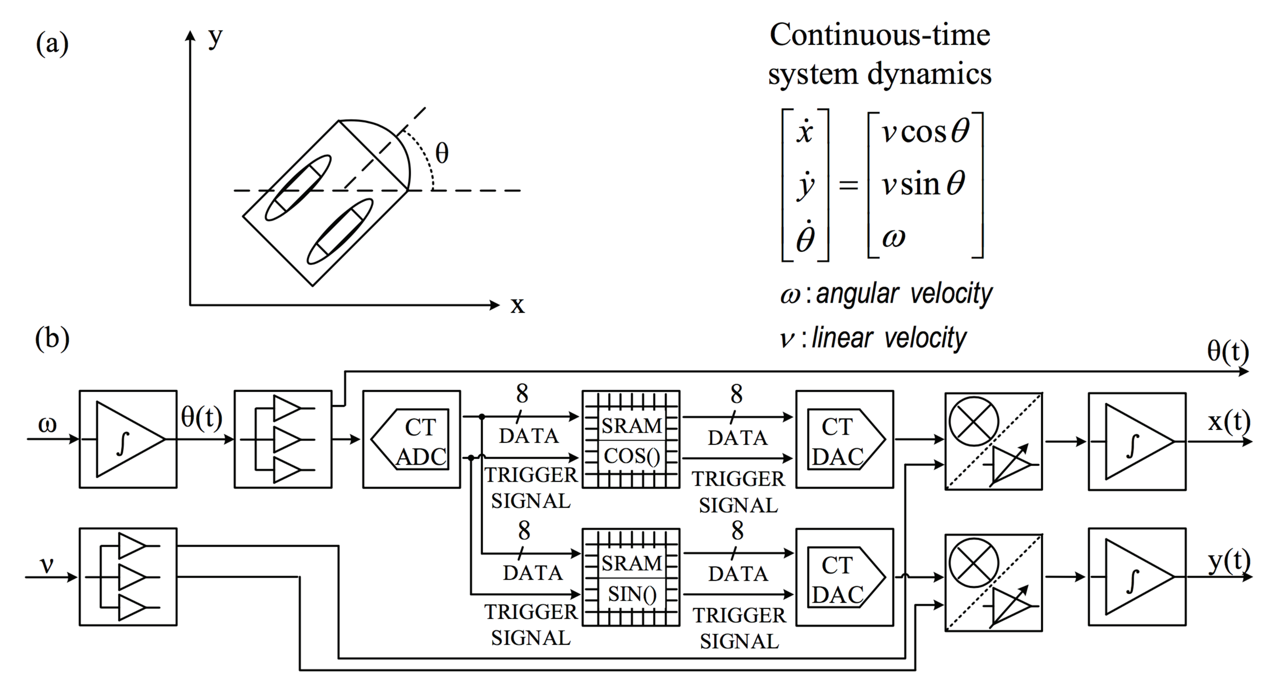
- Anticipated slowdown of speed and efficiency improvements in digital integrated circuits
- Analog circuits delivers fast and efficient computation with existing silicon technology
- Continuous-time, continuous-value hardware matches well with physical problems
- Downsides such as low precision and accuracy, limited scalability, and difficulty in programming can be mitigated
- Approximate solutions are useful in physical simulations and machine learning tasks

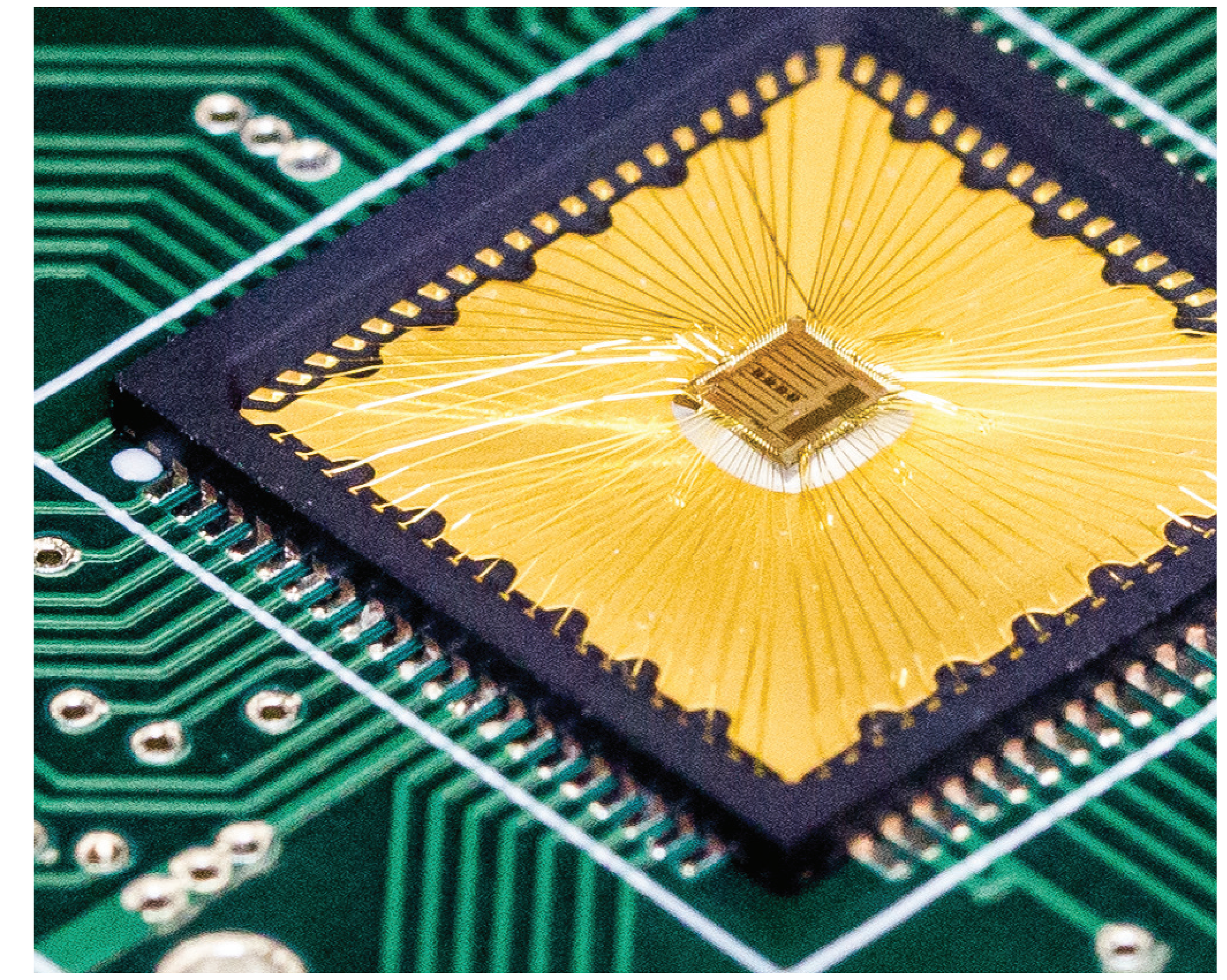
Solve an ordinary differential equation

$$\ddot{x} = -\frac{1}{2} * \dot{x} + 2 * \sin(x)$$

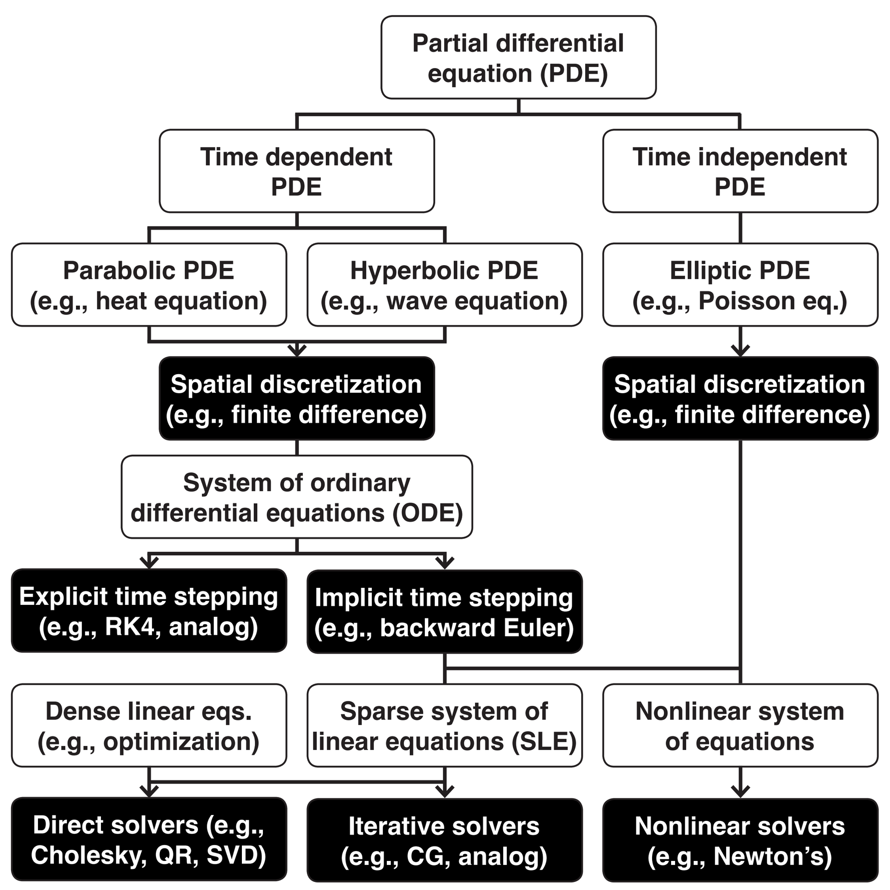


Example in robotic control

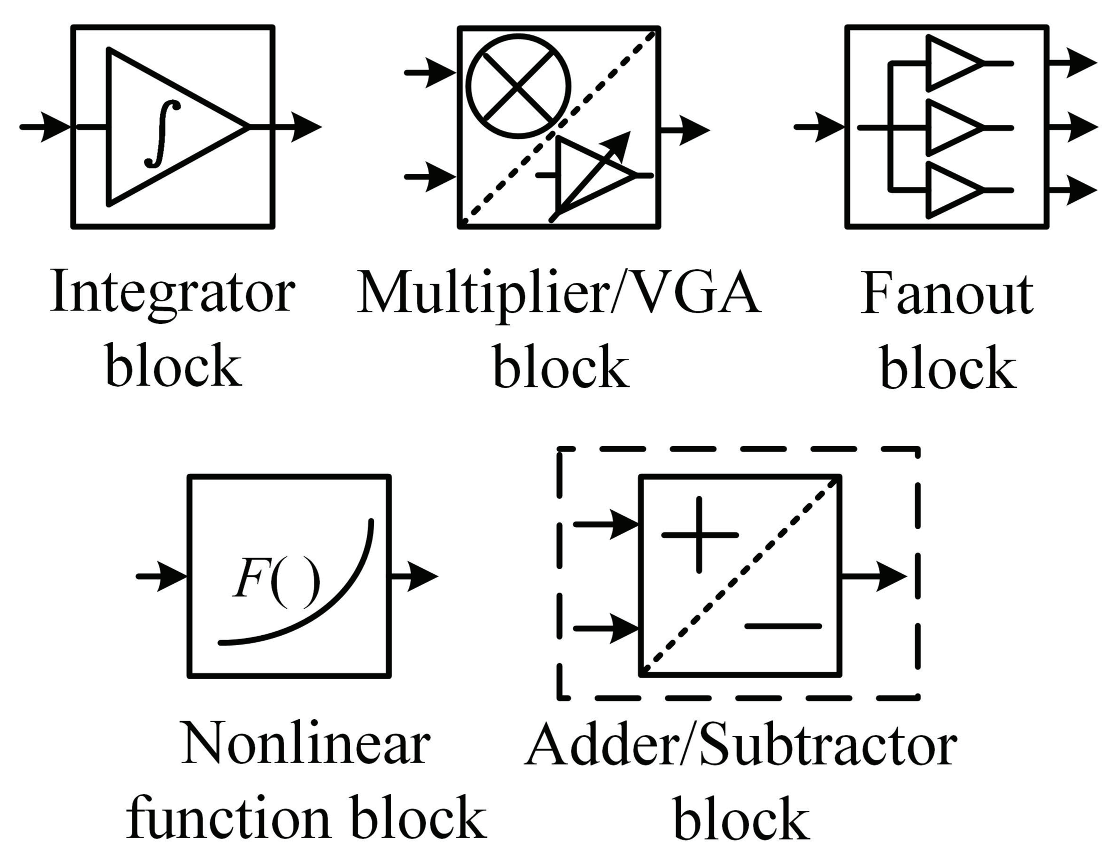




Broad applications in continuous math

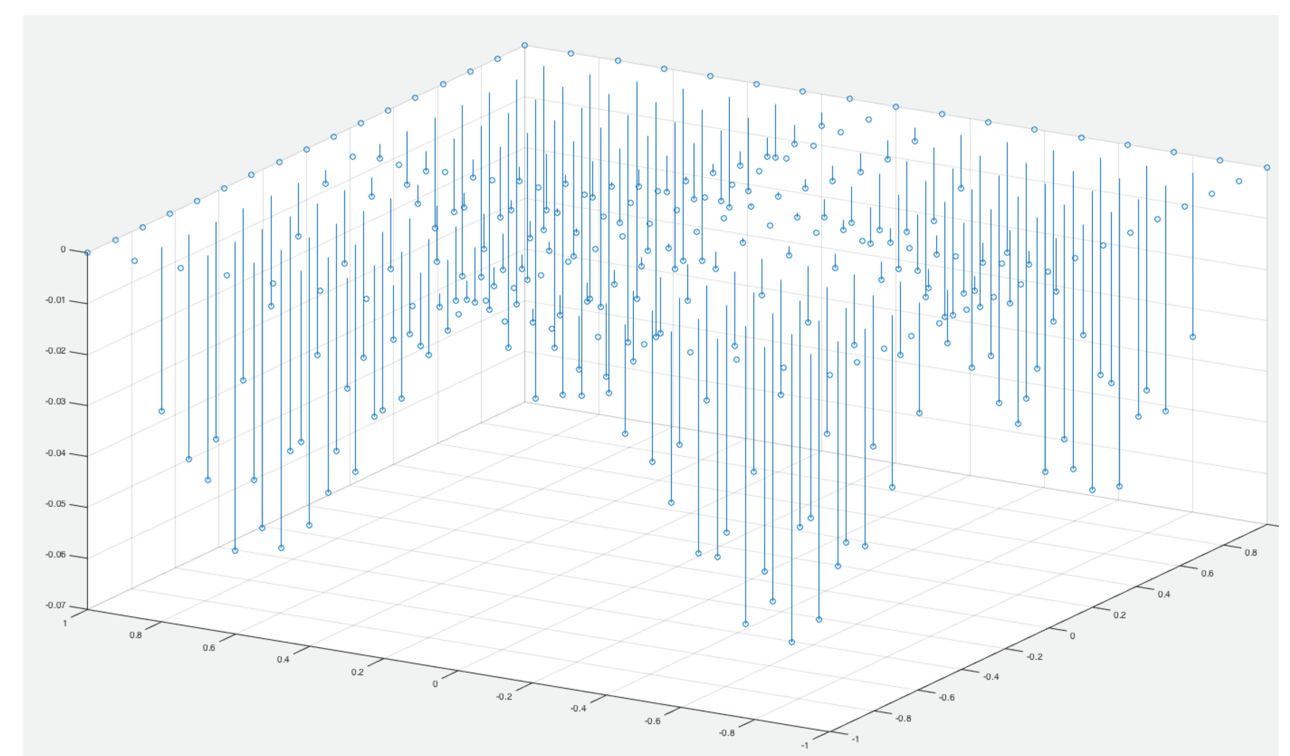


Analog computer building blocks

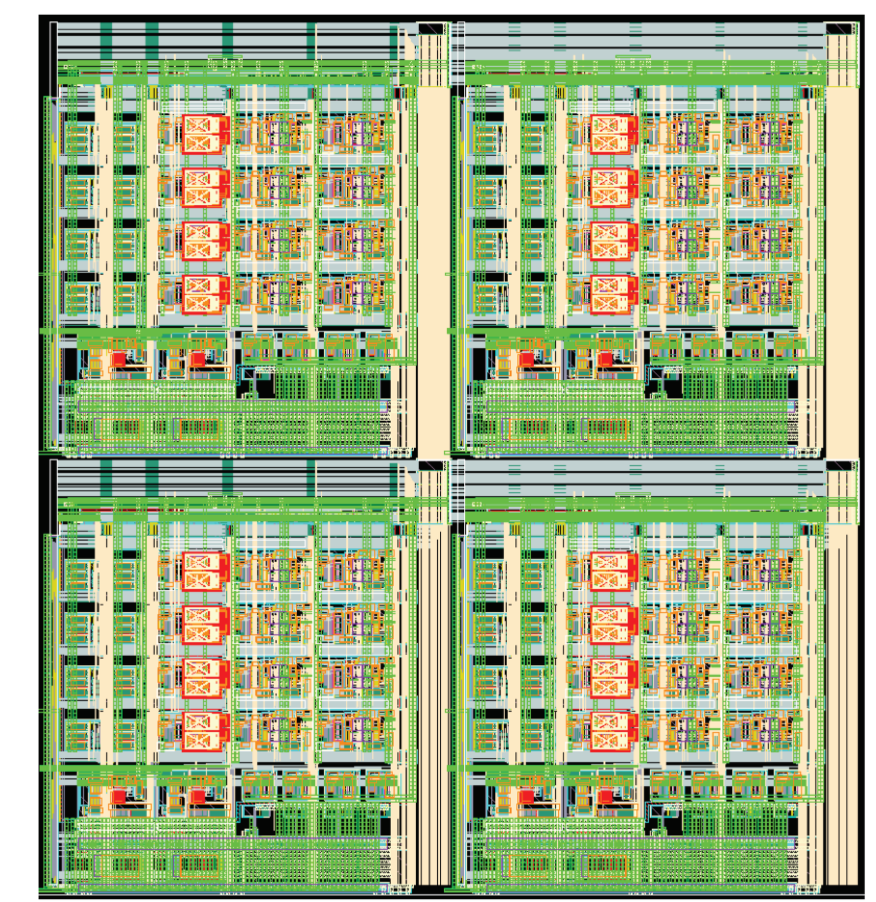


Solving partial differential equations

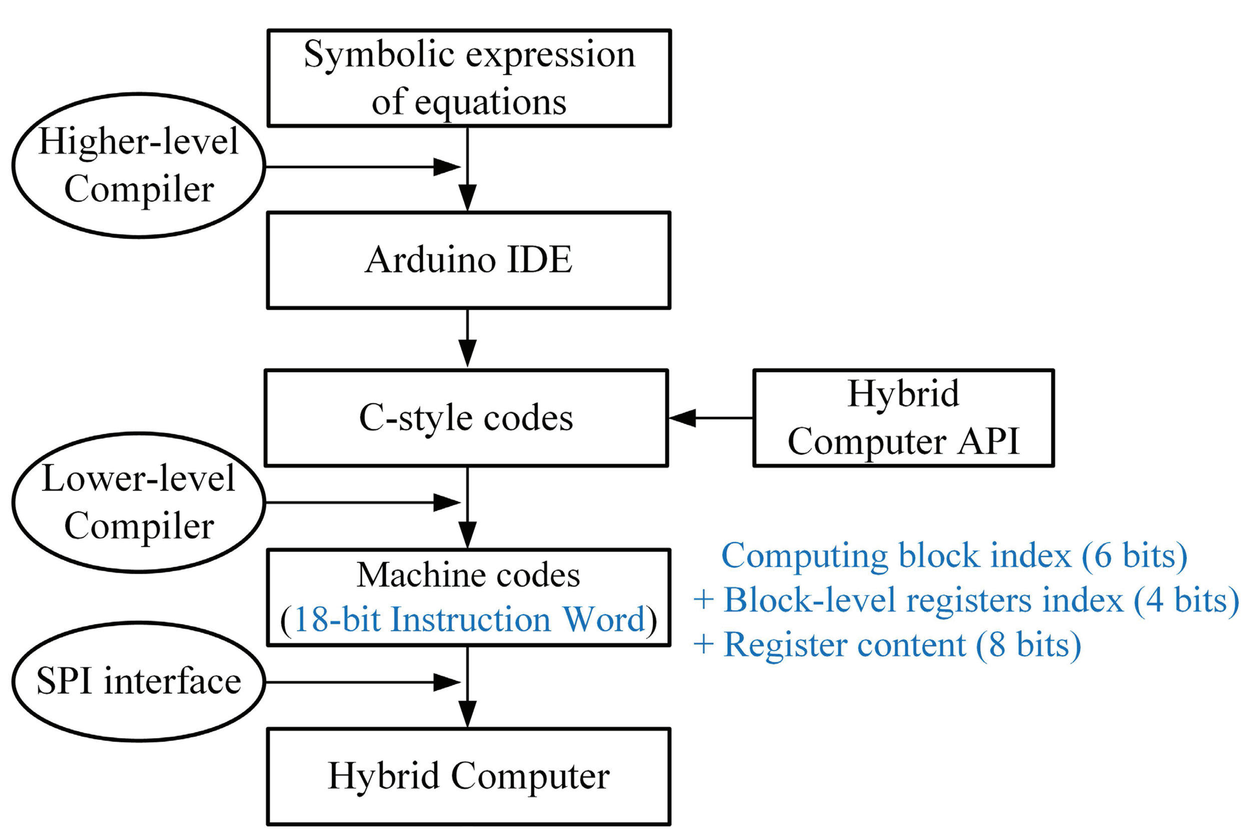
$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = b(x, y)$$



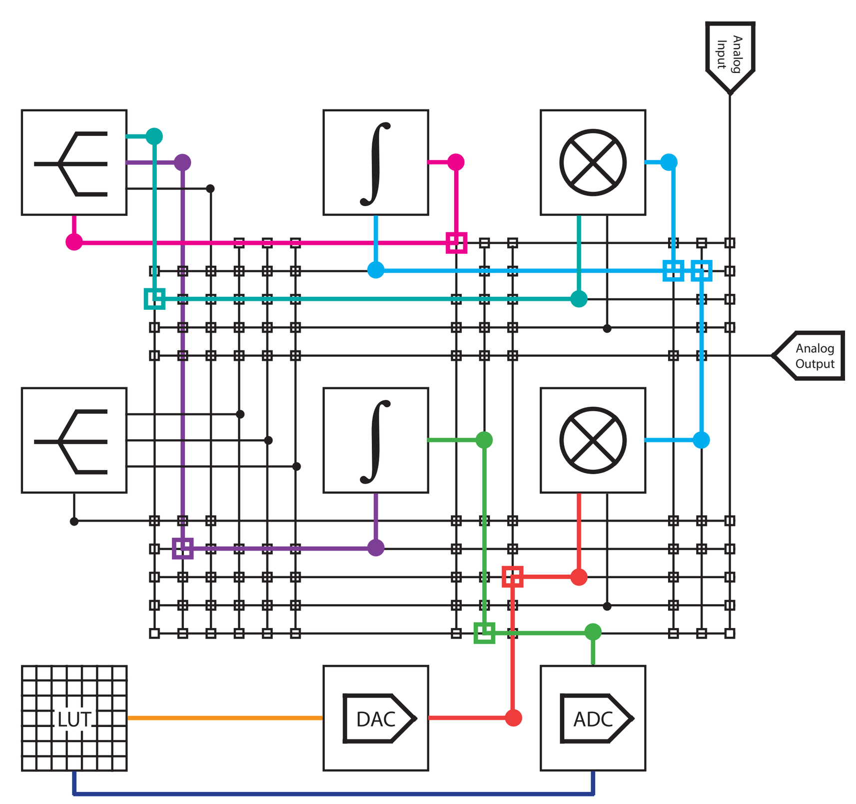
A reconfigurable analog computer



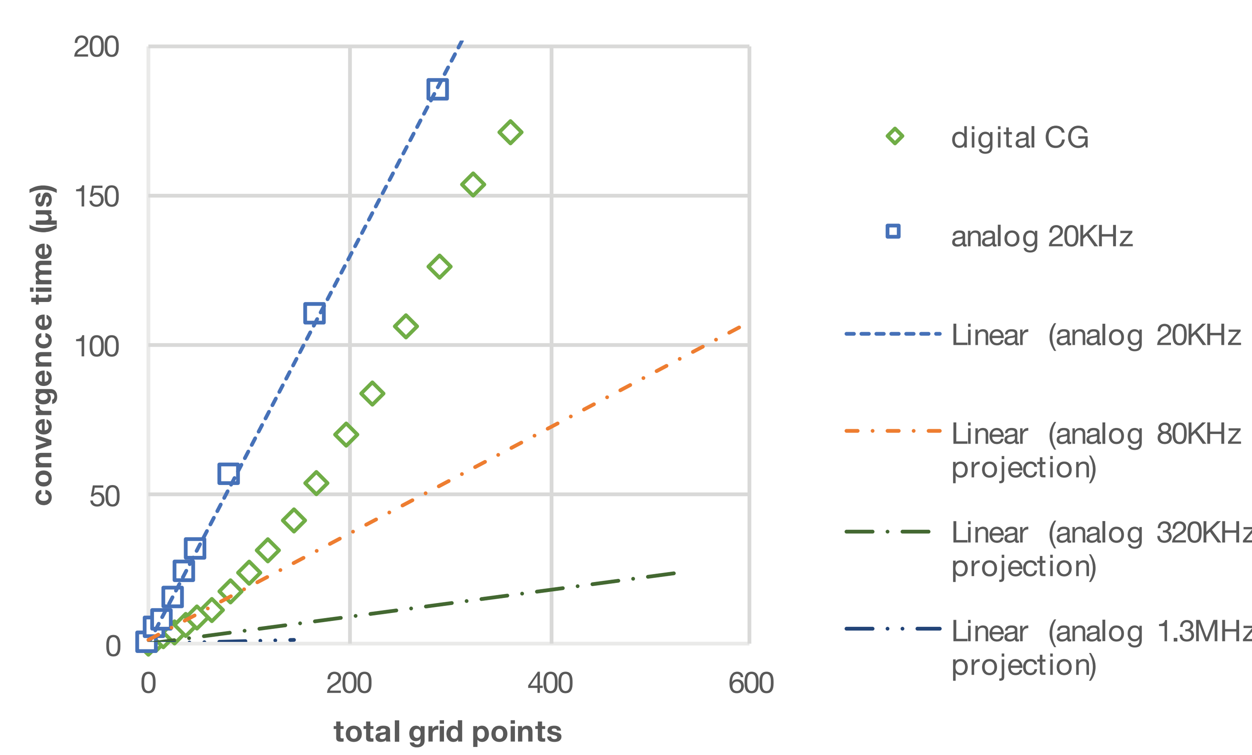
Analog-digital programming toolchain



Mapping to physical hardware



Performance comparison



Contact info & publications

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Ning Guo, Yipeng Huang, Tao Mai, Shavil Patil, Chi Cao, Mingoo Seok, Simha Sethumadhavan, Yannis Tsividis, "Continuous-Time Hybrid Computation with Programmable Nonlinearities," European Solid-State Circuits Conference (ESSCIRC), 2015.

Ning Guo, Yipeng Huang, Tao Mai, Shavil Patil, Chi Cao, Mingoo Seok, Simha Sethumadhavan, Yannis Tsividis, "Low-Energy Hybrid Analog/Digital Approximate Computation in Continuous Time," IEEE Journal of Solid-State Circuits (JSSC), 2016.

Yipeng Huang, Ning Guo, Mingoo Seok, Yannis Tsividis, Simha Sethumadhavan, "Evaluation of an Analog Accelerator," ACM/IEEE International Symposium on Computer Architecture (ISCA), 2016.

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