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Circuits as a simple platform for the emergence of hydrodynamics in deterministic chaotic many-body systems

The emergence of hydrodynamics is one of the deepest phenomena in many-body systems. Arguably, the hydrodynamic equations are also the most important tools for predicting large-scale behaviour. Understanding how such equations emerge from microscopic deterministic dynamics is a century-old problem, despite recent progress in fine-tuned integrable systems. Due to the universality of hydrodynamics, the specific microscopic implementation should not matter. Here, we show that classical deterministic circuits provide a minimal, exact, and efficient platform that admits non-trivial hydrodynamic behaviour for deterministic but chaotic systems. By developing new techniques and focusing on 1D circuits as a proof of concept, we obtain the characteristic dynamics, including relaxation to Gibbs states, exact Euler equations, shocks, diffusion, and exact KPZ super-diffusion. Our methods can be easily generalised to higher dimensions or quantum circuits.

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