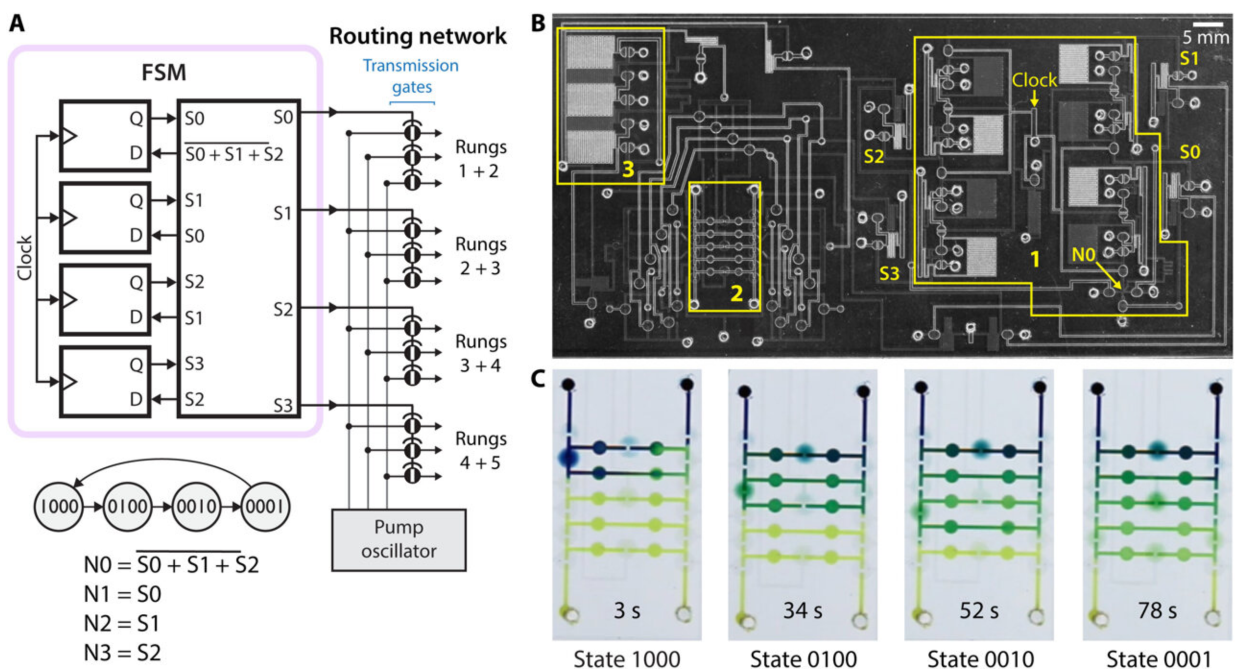
Finite state machine implemented as pneumatic circuit using microfluidic valves to create lab-on-a-chip

June 5 2023, by Bob Yirka



Autonomous control of serial dilution. (A) System-level diagram of the autonomous dilution ladder. A 4-bit FSM controls routing of peristaltic waveforms from the pump oscillator to the appropriate rungs of the dilution ladder. (B) Annotated image of microfluidic chip: FSM (box 1), dilution ladder (box 2), and ring oscillator (box 3). The pump control routing network makes up the remainder of the chip. (C) Time-lapse images of the 1:1 serial dilution process. Peristaltic pumping around each loop is driven by three valves actuated in a ripple pattern: one valve in the middle of a rung and another two on the far left and right. During each dilution step, additional unactuated valves along the far left and right seal off the rest of the rungs to create a closed loop between the two active rungs. The two smaller circles along each rung are not actuated but instead provide flexible windows to allow rung volume to expand and contract in response to peristalsis. Credit: *Science Advances* (2023). DOI: 10.1126/sciadv.adg0201

A group of biochemical engineers, Siavash Ahrar, Manasi Raje, Irene Lee and Elliot Hui at the University of California, Irvine, has developed a finite state machine (FSM) implemented as a pneumatic circuit using microfluidic valves to build a lab-on-a-chip. Their work is published in the journal *Science Advances*.

Over the past several years, biochemical and mechanical engineers have been working toward the goal of automating many of the chemical process that are currently done by hand—trained lab technicians using pipettes to determine the concentration of a chemical dissolved in a liquid, for example. Automating such tasks would not only make them less expensive, it could speed things up, potentially offering medical lab results in minutes rather than hours. To that end, engineers have been working toward building what they call a lab-on-a-chip. In this new effort, the research team has applied pneumatics to the problem.

Many chemical processes involve the movement of liquids. The researchers sought to use water pressure instead of electricity when building circuits for use on a potential lab-on-a-chip. They created a tiny sandwich comprising panes of glass as the bread and a sheet of silicone as the interior. But before making their sandwich, they etched the glass panes to allow a liquid to pass through and poked holes in the silicone sheet to connect the channels in the glass panes.

To represent the familiar zeroes and ones used in FSMs, the team used pressure—regular atmospheric pressure represented a zero and vacuum induced pressure represented a one. The coding programs were accomplished by poking holes in the silicone sheet reminiscent of the punch cards used in the early days of computers.

The team then tested their idea by creating a simple four-bit lab-on-a-chip, programmed to conduct serial dilution—determining the concentration of a chemical in a solution. The team showed that microfluidic devices like theirs could someday be used for such purposes as testing blood not just for viruses like SARS-CoV-2, but their concentrations.

More information: Siavash Ahrar et al, Pneumatic computers for embedded control of microfluidics, *Science Advances* (2023). DOI: 10.1126/sciadv.adg0201