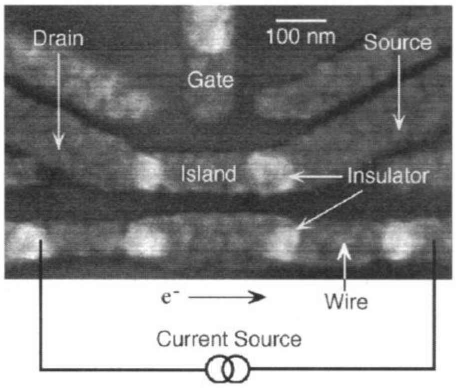
NANOELECTRONICS

The Fastest Counter of the Smallest Beans

Imagine a device that could nestle close to a current-carrying wire and eavesdrop on individual electrons as they speed through it. The makings of such a device exist already: transistors so small that they deal in individual electrons. Such single-electron devices could serve as the heart of futuristic computer chips (*Science*, 17 January 1997, p. 303). But they could also serve as the most sensitive and accurate detectors of electrical current around, because the influence of individual charges passing through a nearby wire is enough to switch them on and off. So far, however, investigators haven't been able to exploit that promise, because they have lacked an amplifier fast enough to capture the rapid-fire signals from the transistor.



SOURCE: SCHOELKOPF ET AL.

Current counter. A single-electron transistor counts electrons passing through a wire.

Now a team of U.S. and Swedish researchers has developed a new single-electron transistor (SET) architecture that includes an amplifier capable of recording the passage of electrons 1000 times faster than the previous record holder and about 1 million times faster than conventional SETs. The device, which the team describes on page 1238 of this issue, has drawn some rapid attention of its own, as it's likely to be fast enough to register individual charges in a current. "It's a real breakthrough in terms of speed," says John Martinis, a physicist at the National Institute of Standards and Technology (NIST) in Boulder, Colorado. Martinis says he and his NIST colleagues are working to define a new common standard for electric current by counting the number of electrons flowing through a device each second. "This certainly will help us," he says.

To come up with their high-speed SET, the transatlantic team, led by physicists Rob Schoelkopf of Yale University and Peter Wahlgren of Chalmers University of Technology in Göteborg, Sweden, modified a standard SET design. Conventional SETs are themselves an offshoot of ordinary transistors, which switch the flow of electrons through a semiconducting channel on and off by applying a voltage to a "gate" electrode above it. SETs replace the semiconducting channel with insulating material, except for a tiny semiconducting or metallic island halfway along. Now electrons must hop first through the insulator to the island and then hop to the other side. But if an electron is already on the island, its negative charge will repel subsequent electrons, in essence keeping them where they are.

A tiny voltage applied to a gate electrode over the island can increase the current through an SET, however. The voltage lowers the repulsive barrier felt by subsequent electrons, allowing them to jump onto the island and the resident electron to jump off. As a result, a stream of electrons passes through the channel, hopping one by one onto the island and off it again.

The same setup can be used as an electrometer to detect tiny amounts of current flowing through a wire. To do so, researchers simply place a wire next to the SET's channel so that it runs past where the gate would normally be. As electrons whiz down the wire past the gate's usual position, each one creates a tiny voltage increase that acts like voltage on the gate. These minute voltage fluctuations from the wire switch the SET on and off, allowing tiny amounts of current to flow through its channel—each burst of current registering the passage of an electron along the wire. The problem is that the rate at which electrons flow down the wire can be extremely fast, and conventional electronic amplifiers are too slow to register the SET's tiny signals.

To get around this problem, Schoelkopf and his colleagues connected an SET to a circuit known as a resonant amplifier. While the wire provides the voltage that turns the SET on and off, the resonant amplifier provides the impetus that pushes the electrons along the channel. An electromagnetic field that resonates at microwave frequencies within a circuit at the heart of the amplifier interacts with electrons to move them along. When the SET turns from off to on, this microwave energy pushes electrons through the channel, and the intensity of the microwave field resonating in the circuit drops—a change that is easy, and fast, to measure.

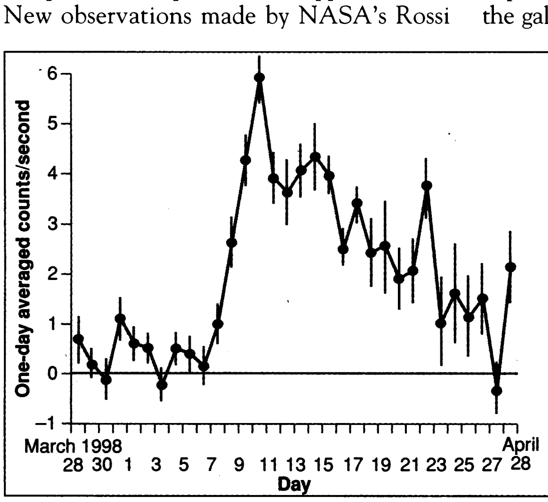
The resonator is able to detect signals from the SET at a rate of 150 million cycles per second. The group has yet to measure individual electrons flowing down a wire. But Schoelkopf is hopeful: "We can put this on a chip next to something we want to study and watch electrons as they flow by in real time."

–Robert F. Service

ASTRONOMY

A Neutron Star That Got Revved Up

Astronomers have discovered a "missing link" that could explain the formation of the bizarre celestial beacons called millisecond radio pulsars. Neutron stars that spin hundreds of times a second and give off a radio blip with each rotation, millisecond pulsars are thought to acquire their high revs when material torn from a companion star spirals in and applies a twist. New observations made by NASA's Rossi X-ray Timing Explorer (XTE) satellite seem to show just that: a neutron star that has spun up like a top and is spewing out x-rays as infalling material spirals down onto its surface.



SOURCE: ALL SKY MONITOR/ROSSI XTE

Outburst. X-rays from a neutron star surged in April.

Rudy Wijnands and Michiel van der Klis of the University of Amsterdam analyzed XTE observations of an x-ray beacon that lies perhaps 12,000 light-years away in the direction of the galactic center, captured shortly after the satellite saw the object brightening around 9 April. XTE's detectors, sensitive to rapid x-ray flickers, showed that x-rays from the object slightly dim and brighten every 2.5 milliseconds, or thousandths of a second. The variation probably arises as the "hot spot" from infalling material whirls around with the neutron star.

"The missing link has now been found," says Frederick Lamb, a theorist at the University of Illinois, Urbana-Champaign. "It's kind of a dream come true." Wijnands and Van der Klis have reported their result in International Astronomical Union (IAU) Circulars and in scientific talks. Van der Klis declined