Simple ECGs are just a heartbeat away

Plessey Semiconductor has developed an electrical potential sensor that can be used to take an ECG using dry-contact electrodes, with some very exciting future applications. Sally Ward-Foxton reports.

Sensors have long been used to measure electrical signals generated by the body. The heart is in fact a fully functioning electrical device, producing an electrical signal in the range of a few tenths of a millivolt with every beat. The brain's signals can also be measured, notching up a few tens of microvolts, and even the movement of muscles produces an electrical signal in the order of a few millivolts (Figure 1).

Measuring the electrical signals produced by the heart produces an electrocardiogram, or ECG. The normal method involves taking measurements from each of the patient's arms and legs with up to a further 6 sensors on the chest. 10 sensors are required for a full 12-lead ECG (where a 'lead' refers to one circuit through the body that reveals a certain characteristic of the heart). Applying the sensors requires application of a conductive gel between the sensor and the body for a good connection, and normally means shaving patches of body hair too. The sensors have to be disposed of every time and cost around $2 a set.

Plessey Semiconductor - based in Plymouth, UK - has developed an electrical potential sensor using technology licensed from the University of Sussex, which promises to make ECG measurements much simpler. The company has developed an IC form of the sensor and its circuit which it calls EPIC (electrical potential integrated circuit).

EPIC is essentially an exceptionally sensitive solid-state electrometer. The basics of this technology have been around for more than a hundred years whereby a simple conductive plate was connected to a high impedance amplifier to measure electric potential differences/electric fields. Researchers at the University of Sussex developed some clever screening and bootstrapping techniques which have vastly increased the sensitivity and also done away with the need for time consuming calibration.

"They needed to measure electrical potential at very low temperatures, so they needed something that didn't require calibration", explains Derek Rye, Marketing Director at Plessey Semiconductor. "After that, they realised that [the technology] had many other

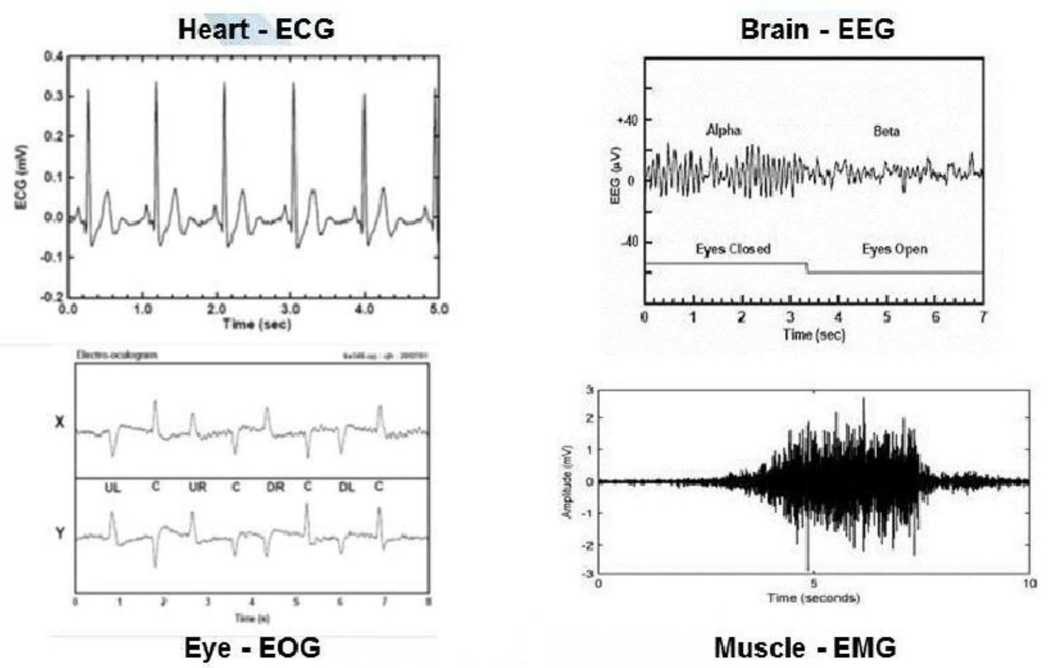

Figure 1: Examples of electrical signals produced by the body.

Figure 2: An ECG taken by the Plessey demonstrator system, and the demonstrator itself.

applications." Plessey licensed the technology in December 2010 and announced in September that it had developed an IC based on the University's work.

The technology recently won the National Microelectronics Institute's annual R&D Achievement award and Plessey has developed demonstrators that provide as good as or better resolution than conventional ECG electrodes (Figure 2).

The EPIC ECG demonstrator requires a pair of sensors which are held in each hand. EPIC is dry contact; no conductive gels and no shaving of body hair is required. And unlike conventional disposable ECG sensors, the EPIC sensors can simply be cleaned between uses, saving money and reducing waste.

Modes of operation

The EPIC sensor has two modes of operation. The first is 'contact mode', where the sensor is in direct contact with the patient (Figure 3). This is the mode used for the ECG application and for other body measurements such as respiration and muscle movement measurements.

"We see a lot of potential applications in the sports/fitness market", Rye says. "The EPIC sensor has the edge [over other heart rate sensor technologies] as it produces a much higher quality ECG-like readout."

Rye said that automotive manufacturers were also interested in the technology, using the second of the two modes of operation – remote mode – in which the EPIC sensor does not require an electrical contact with the person/patient. It is

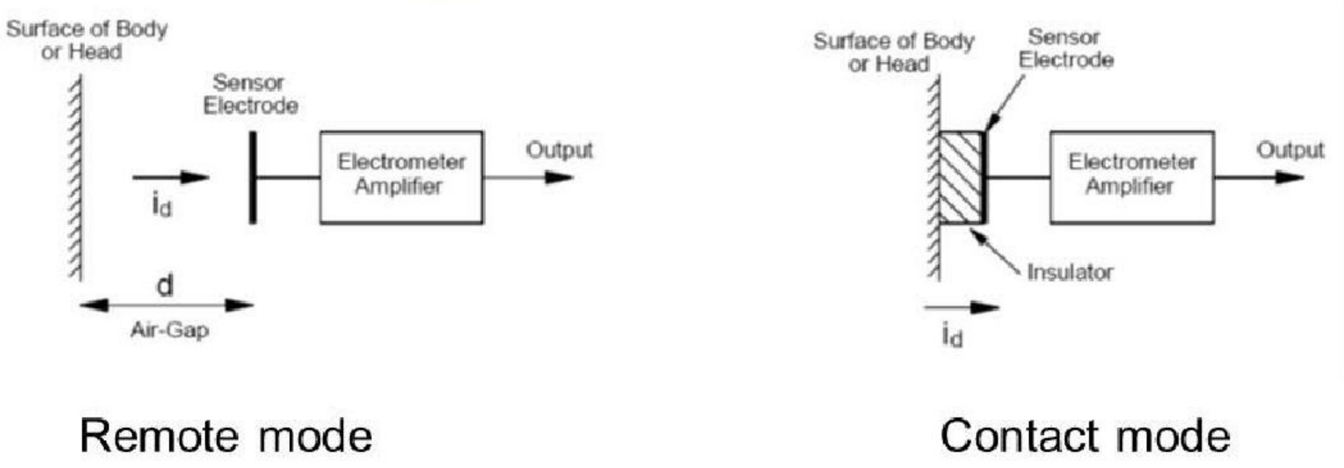

Figure 3: The two modes of operation of the EPIC sensor.

Figure 4: EPIC technology can be used to measure the electric charge pattern left behind by a finger when it touches a non-conductive surface.

sensitive enough to detect these electrical signals through clothing. As an example, the sensor could be built in to a seatbelt or seat back to measure the driver's respiration rate and sound an alarm if it drops below a certain rate to stop the driver falling asleep. This is not a straightforward application however, since clothes and fabrics can become charged with movement, generating static electricity.

"The sensor can pick up muscular activity as you breathe as well as heart activity, since muscles also generate electrical signals", Rye said. "Since breathing is much slower than the heart rate, you effectively see the two signals superimposed. With appropriate filtering, you can get the heart rate and respiration rate from the same sensors."

Other applications

The exceptional sensitivity of the EPIC sensor makes many other applications possible. For example, it can be used to detect the presence of a person from a few metres away. The Earth's electric field is distorted around a conductive object like a person, and a person's movements change the electric field in a way that can be detected by EPIC.

"This could be used for basic gesture control, or presence detection for security and safety applications", Rye says, adding that the range of the current sensor is 20m for detecting the presence of a person, and it can detect through walls so long as they are not conductive, giving it an advantage over commonly used PIR sensors which detect the infrared emitted by a person. Rye speculates that since EPIC is not blocked by physical barriers it could potentially be used to detect people in a smoke filled room before a firefighter opens the door, provided they are moving.

In fact, potential applications for this technology are as far spread as monitoring the vital signs of racehorses during the night, to measuring the stress in rocks to predict earthquakes.

CSI Plymouth?

In a particularly compelling potential application of the technology, a successful proof of concept has been produced for the collection of fingerprints for forensic purposes. Conventional

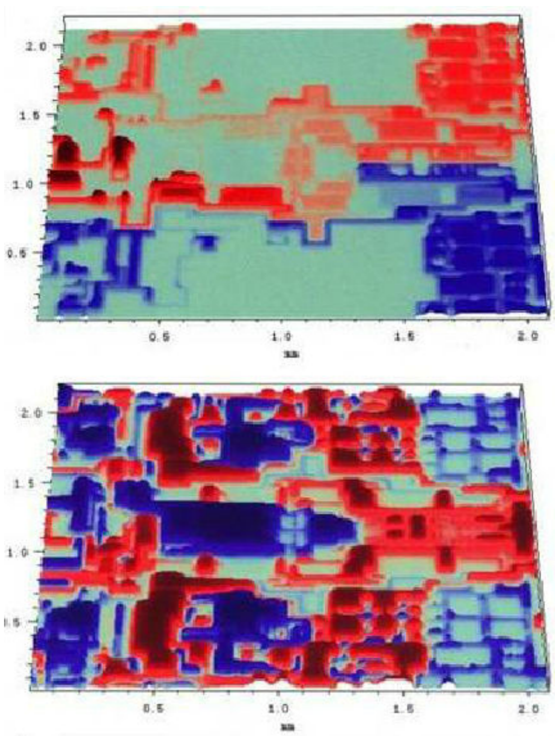

Figure 5: The top image shows a scan of an INA101 differential amplifier with 100Hz signals applied the red shows the in phase areas, the blue shows the out of phase areas. In the bottom image, 100Hz modulation was applied to the power supplies.

fingerprinting relies on a person leaving oil from their skin behind when they touch something, but in fact, each time you touch a non-conductive object, your finger will leave behind an electric charge pattern in the shape of your fingerprint.

In the lab, an EPIC sensor was moved over a non-conductive (PTFE) surface to take measurements at an array of different points with very fine resolution to reveal the electric charge pattern left behind by a finger (pictured in Figure 4). This fingerprint was measured using a smaller form of the EPIC sensor than the one developed for the ECG application. According to Rye, the electric charge pattern decays over time, typically lasting two to three weeks – in fact, if you know the electrical characteristics of the material from which the fingerprint was taken, it would be possible to say how long ago the person touched the object with quite fine granularity (in the order of hours).

In a real-life application, this would be done with an array of sensors. Rye says that with the new IC form of EPIC, the size of the sensor can be reduced and this leads the way for building arrays of 100 x 100 or larger for this type of imaging application. Other future applications for the array form of EPIC include scanning the surface of an IC for potential distribution, shown in Figure 5.

Plessey's EPIC sensor IC is currently available in two different packages. The first, dubbed PS25101, comes in the same metal or plastic circular packaging that Plessey uses for its ECG demonstrators. The second, part number PS25201, is supplied in a more compact square package with four exposed balls for surface mounting onto a PCB, measuring 10mm square and 3mm high (Figure 6).

In the future this exciting technology will no doubt enable futuristic applications like Dr 'Bones' McCoy's tricorder in Star Trek (which can read a person's – or alien's – vital signs without touching them), but the most diverse and inventive applications have probably yet to be dreamt of.

EPIC's electrical characteristics

- An ultra high input impedance amplifier, with input resistance in the range of $10^{15}\Omega$.
- Able to measure spatial electric potential or electric fields.
- Very low non-contact capacitive coupling, with input capacitance around 10^{-17} F.
- Voltage noise at the input is <30nV/√Hz (for >10Hz).
- Bandwidth from quasi-DC to >200MHz.
- Very low power consumption: first IC solution from Plessey consumes about 35mW.

Return to contents page.

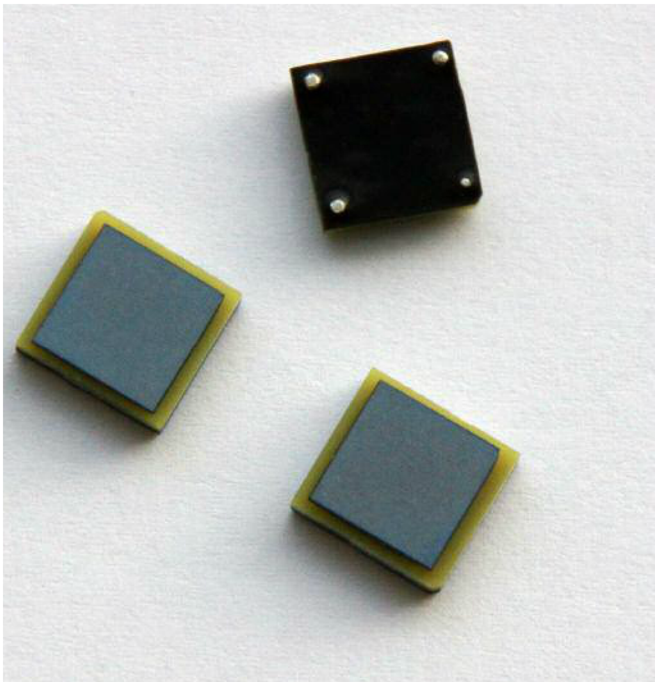

Figure 6: PS25201 can be surface mounted onto a PCB.