LINEAR ICs - A BACKDOOR ON SENSOR TECHNOLOGY

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Linear Integrated Circuits make up a large portion of the signal conditioning circuitry used to detect, amplify, demodulate, combine, compensate, linearize, digitize, and in general convert the primitive electrical output of a physical sensor or transducer into a more convenient and possibly standardized format. They are also used to provide the excitation regulation, and otherwise to control the power and stimulus applied to sensors of many kinds.

General purpose ICs such as op-amps, multipliers, and A/D converters are readily combined at board level to produce signal conditioners which are evolving toward steadily improving performance and lower costs. Collections of these functions integrated on single chips make up relatively complete signal conditioners, and the addition of the sensor to these collections seems like a desirable and very natural step.

The silicon technology used to make "Solid-State Sensors" is similar to, and in many cases identical to, silicon planar IC technology. Low cost IC manufacturing techniques are available for some of these sensors, and so the question arises : why are there so few integrated sensor/signal-conditioner chips being manufactured?

As a representative of the Linear IC design community who is keenly interested in such combinations I'd like to point out what appears to be a fundamental difficulty, in hopes of responses that will provide new vantage points from which to view and solve sensor problems. It appears to me that the same sensitivities to pressure, or chemistry, or photons, or some other phenomenon which make silicon a good transducer, makes it a bad signal conditioner Perusal of the data sheet for a typical linear IC, used in signal conditioning, reveals that its intended function is probably pretty simple. For example, an op-amp takes little signals and makes them very large, a multiplier produces an output which is proportional to the mathematical product of two input signals, and a voltage reference provides no more than a single output voltage. The data sheet generally gives only a perfunctory explanation of the basic circuit function (since the circuit is often intended to do something trivially simple) and may devote as little as one line to specifying the desired performance.

For example in the case of the voltage reference IC it may say something like "Vref = 5.000 Volts". The remaining pages of the data sheet consist mostly of an elaborate disclaimer about unwanted sensitivities of the product and a collection of so called "Applications" whioh generally enumerate all the things you must do to help this little piece of silicon if you actually expect it to produce any sort of useful result.

By the time users receive the finished and tested IC it has been probe tested, sawed, diced, die mounted, wire bonded, baked, dried, evacuated and sealed: all to take any dice which have survived the fabrication process in working condition and protect them from further disturbances in the form of strain, chemical contaimination, electric fields, photoelectric input, abrasion, and in short all possible influences except the desired electrical ones. One influence that is only slightly modified by packaging is temperature and people like me like to go to great lengths to exploit the electrical properties of silicon devices while supressing the thermal sensitivies. The data sheet then compiles long lists of how well this has all been done citing various coefficients of (in)sensitivity.

In view of all this it shouldn't be much of a surprise that silicon can be used as a sensor. It's sensitive to all manner of things in ways which are generally a nuisance but which can, on occasion, be tested in relative isolation. On of these non-surprises is that of all the possible transducer applications, temperature sensing is about the only one which has hit the big time in standard product IC form. This is the one phenomenon to which silicon circuits are sensitive and which can't be excluded by the package technology. As a result, circuit and layout designers have been forced to confront this sensitivity and understand it well in order to circumvent it in most circuits. Signal conditioning circuits can be designed to avoid expression of the inherent temperature sensitivities of silicon devices and combined monolithically with a few devices arranged to give a predicable temperature response. (1) (2).

In order to achieve similar results measuring other phenomena to which silicon devices are sensitive the co-operation of the packaging and fabrication technologists will be required. First, to devise to protect the monolithic device from unwanted exposure without excluding the measured phenomenon. And, second, to help to isolate the effect on the monolithic chip to those areas sensitized or calibrated as the sensor and away from those signal conditioning areas which would be disturbed by it.

One area where there has been some activity of this kind is in optical sensors. Something as simple as transparent lids or coatings has permitted light sensors and signal conditioning to be combined monolithically. Designs in this area include shielding the signal conditioning sections from ambient light as well as incorporating the induced photo-currents into the operation of the signal conditioning circuit. (3) (4)

Monolithic curcuits combining signal conditioning with sensors for strain or chemical effects will require packaging similarly transparent to the measured quantity but opague to other disturbances. They should also provide circuit and device designers with interesting challenges to shield portions of the chip or to design signal conditioning circuits which do not express uncalibrated sensitivities to the measured parameter.

The author will present selected topics from I.C. circuit design to illustrate the arguments presented here. And, if encouraged by questions, he will no doubt tell all (or perhaps more than) he knows of solid-state senor design.

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