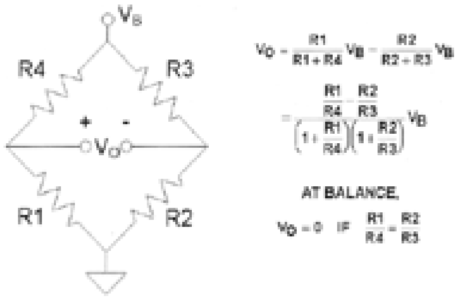
Integrating Functions on Mixed-Signal SoCs

System complexity, escalating cost pressures, shrinking available silicon and more restrictive quality requirements are among the increasing demands placed on ASIC designers.

By Herve Branquart

There are sensors throughout the electronic equipment you use on a daily basis. These components report various states and conditions, usually as analog signals, for



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processing by a central controller. Other signals that operate in the analog domain are the commands controlling analog components such as motors or lamps. Those types of signals are often generated as outputs of a central computing system and require higher voltages than those used by the processors. However, most of the electronics world, and specifically microcontrollers, comprises digital components. It is then necessary to generate interface circuitry to correctly and reliably handle those incoming and outgoing analog signals that connect to the digital world.

With the trend to shrink electronic systems and get more content for less money, it is important to reduce the number of components a system needs and also to reuse the system's IP when possible. This trend also applies to interface circuitry where it is often advantageous to combine input and output interface functions in the same electronic component. The idea makes sense, but requires a specific technology able to handle analog and digital signals as well as voltages higher than those used by the processing chip. This article will discuss the challenges and limitations of this type of integration approach.

Sensors and Sensor Interfaces

The raw signals that come from sensors are not clean &#151 they are often buried in electronic noise that hides the original signals. It is therefore important to have a robust system to filter, decode or even amplify these analog signals. This is what an interface chip does.

A sensor is a device that produces an electric signal reflecting a measurement within a specific domain. There are six different kinds of domains: thermal, mechanical, electric, magnetic, radiation and chemical. A transducer is a device that converts a signal from one domain to another. An example of a transducer would be a thermocouple that converts temperature (thermal domain) to voltage (electric domain). Input transducers are called sensors or detectors while output transducers are called actuators.

There is a wide range of signals that may be sensed, including temperature, pressure, force, rotational position, level, speed, acoustic level, magnetic field, chemical and RF. On the other hand, the list of available electrical signals is limited: voltage, current, charge, resistance, capacitance, inductance and impedance. One common way of measuring small changes in the resistance of a transducer, which would indicate a signal change in a domain, is with a Wheatstone Bridge (Figure 1).

Any signals coming from a sensor need to be “conditioned” by an interface circuit before being sent to the digital processing portion of the system.

A/D Integration of the Interface

Interface system designers often separate the digital section of the interface circuitry from the analog section for a variety of reasons, including the lack of availability of both analog and digital circuits on the same component, high complexity of the digital part of the circuit, or that the digital section is available as a standard product.

However, integrating the analog and digital interface circuits in an integrated circuit lets the system designer optimize the cost of the entire interface module. This integration approach is usually difficult to implement for advanced markets such as telecommunication or computer. On the other hand, it makes sense to utilize analog/digital integration for more mature or conservative markets such as automotive, medical and industrial. For most of the applications in these markets, digital functions are finding their way onto what were once pure analog designs.

Adding digital functions to an analog design is enabled in part by the development of new process technologies that can handle both short-channel, fast-switching digital transistors as well as high-voltage analog transistors. For example, all AMIS mixed-signal process technologies provide digital and analog integration capabilities on the same design platform. The CMOS 0.35 &#181m mixed-signal technology family is the most widely used to develop sensor interface chips. This technology might be considered “old” from a purely digital chip designer’s point of view, but it is at the forefront for the automotive, industrial and medical markets.

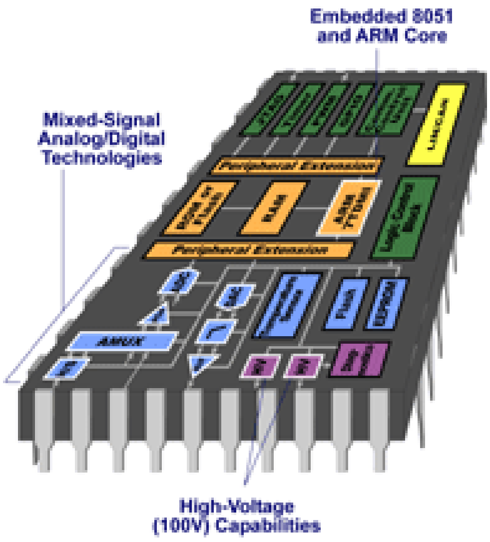
Along with its silicon processing technology expertise, AMIS has also developed a large and specialized library of IP (Intellectual Property) for the sensor interface chip market. This combination of expertise, tools and hardware is important to support customers who need leading-edge interface products.

Signal Conditioning

Signal conditioning is the common term to define the function of a sensor interface chip. Several sub-functions are often employed to condition the signal. Examples of these sub-functions include input buffering (to prevent sensor loading), amplification/attenuation, calibration (usually for gain and offset), filtering, sampling, A/D conversion, temperature compensation, isolation, linearization, output buffering and excitation. For example, if the sensor is delivering a voltage signal, the interface chip will have to integrate, at a minimum, a preamplifier, attenuator, programmable gain amplifier and Analog-to-Digital Converter (ADC). There are several kinds of ADCs that are used to meet different requirements. For high resolution applications, a Sigma Delta converter would be used, while for high frequency (&gt20 MHz) applications a pipelined version is preferred.

Once the signal is ready to go to the processing component, a state machine or microcontroller can then take control and process the function in the system. The integration of this control function can also be integrated, if the technology’s digital integration capability supports it. With a 0.35 &#181m transistor gate length, AMIS can cost effectively integrate an 8051 or an ARM7TDMi microprocessor on the chip. Several solutions are available, including integration of the signal conditioning function; integration of the controller and signal conditioning function on one piece of silicon; or integrating within the same package the standard microcontroller (often already employed in the application with its software function also embedded) and the conditioning chip as a multi-chip module (MCM).

As previously discussed, the integration of the sensor signal conditioning function can also be combined with the conditioning of the output signal, which can represent an



actuator signal input or simply a communication signal to another element of the electronic system. Actuator signals are analog, so a Digital-to-Analog Converter (DAC) is then needed. Most of the difficulty with integrating the sensor signal conditioning function with the conditioning of the output signal is due to the operating voltage of the actuators, which is often higher than the computation circuitry operating voltage. With CMOS 0.35 &#181m technology, the supply voltage is 3.3 V &#177 10%, while the actuator will often require a double-digit voltage. A voltage converter circuit is then needed to boost the 3.3 V to the required voltage for the actuator. A charge pump circuit is often used for this function.

Communication signals, on the other hand, usually rely on IP availability. USB, CAN, LIN and I2C cores are some examples of the IP needed to convert the processor’s output signal to the required format for a particular bus. Some of these bus/interface formats still require a high-voltage process capability to be embedded, for example, for CAN. Beside wired communication links, there may also be a need for an RF transceiver unit to support wireless interfaces.

Considerations of an Integrated Process

AMI Semiconductor’s I3T technology can handle signals up to 80 V. The technology supports the development of real System-on-Chip (SoC) designs that include high-voltage interfacing up to 80 V, micro-processing capabilities up to 32-bit word width, wireless capabilities up to 2.8 GHz and dense logic design up to 15K gates /mm^2. Beside those capabilities, the technology also supports NVM integration with E2PROM up to 4 Kbytes, Flash memory up to 500 Kbits, or OTP (One-Time-Programmable) cells for specific application calibration. The ability to integrate all these features on a chip gives the user the potential to be independent from the obsolescence of the standalone NVM market, which is more or less driven by the computer market. This advantage is quite important when we consider the cost of re-qualifying a module for automotive OEMs, for example. It also makes economic sense when considering the long lifetime of automotive electronic systems, industrial applications or medical self-treatment that is affordable for most patients.

Nevertheless, integrating all these functions on a single chip also raises issues that must be addressed by the chip development team. Clocking noise from high-speed digital circuits, for instance, often interferes with noise-sensitive analog functions. Switching currents from high-power analog functions can interfere with low-voltage digital processors. The goal is to protect low-voltage transistors from the electric-field effects of voltages that are 10 to 30 times higher.

A deep trench isolation technique can be integrated in the process technology to avoid those potential issues. The technique uses a series of isolating trenches that go deep into the IC substrate, effectively creating on-chip “pockets” where noise and power-supply parameters can be carefully controlled. In addition to its isolation advantage, the deep trench technology also helps to minimize die area by allowing dense packing of high-voltage analog pockets with low-voltage regions. Improvements in die area of 10% to 60% are possible compared to designs that use standard junction isolation techniques.

In Figure 2, the chip integrates the system functionality from the sensor to the actuator, going through some digital processing in between. Conventional mixed-signal technology allows analog control and signal-processing functions such as amplifiers, ADCs and filters to be combined with digital functions such as microcontrollers, memory, timers and logic control functions on a single, customized chip. All the signals used to process an algorithm or arithmetic calculation are digital, so conversion of analog to digital signals is necessary when sending data for comparison or processing to the microcontroller. In addition, conversion from digital output signals to analog high-voltage signals is needed to drive an actuator or load. High-voltage mixed-signal technology is particularly relevant for automotive electronics applications where higher voltage outputs &#151 to drive a motor or actuate a relay &#151 must be combined with analog signal conditioning functions and complex digital processing.

Dealing with Electromagnetic Issues

As electronic content grows, the issue of electromagnetic compatibility (EMC) becomes more and more of a design challenge for the engineer. The three key problems are:

1. How to minimize electromagnetic susceptibility (EMS) so that the electronics is protected against unwanted electromagnetic emissions (EME) caused by other electronic systems. 2. How to protect the electronics against a harsh environment that includes the potential for large supply transients or interference caused by the switching of heavy or inductive loads such as lamps and motors. 3. How to minimize EME that could have an impact on other electronic circuits.

Furthermore, these problems become increasingly challenging as system voltages increase, digital electronic content grows and frequencies rise as a result of more high-frequency electronics. In addition, many electronic modules are now expected to interface with inexpensive, low-power sensors that are characterized by low linearity and large offsets. These sensors rely on small signals and the impact of electromagnetic interference could be catastrophic on their operation.

A key point to note is that radiated emission and susceptibility are not major problems for ICs. Instead, it is the conducted emission and susceptibility to the efficient antennae of the PCB traces and cable harnesses that cause the main problems.

In developing SoC devices based on its own mixed-signal semiconductor processes, AMIS employs a number of approaches to help engineers ensure EMC compliance for their end products. In the case of EME, which is generated by the switching of DSPs, clock drivers and other sources of high-frequency currents, low power circuits are used wherever possible. These might include lower or adaptive supply voltages or architectures that spread the clocking signals over the frequency domain and thus reduce RF energy at a single frequency and its harmonics. EME can also be lowered through a reduction in the number of elements switching on a single clock cycle. In addition, applying slope control to clock and driver signals to slow down the switching edges and provide for softer switching characteristics can help to reduce EME. External and chip layouts are also rigorously examined. Differential output signals, which use ‘twisted pair’ style lines, generate less EME and are also less susceptible to EME. Ensuring that VDD and VSS are close to each other and the use of efficient supply voltage decoupling techniques are other simple ways to reduce EME.

Rectification/pumping, parasitic devices, currents and power dissipation are the most disturbing effects of high EMS. High-frequency electromagnetic power is partially absorbed in the IC and, as a result, can cause a number of disturbances.

These include delivering large high-frequency voltages into a high-impedance node and large high-frequency currents into a low-impedance node. In addressing EMC issues during the chip development phase, it is very important that the system and IC engineers collaborate closely since there is a subtle link between the end product and PCB design that needs to be addressed upfront.

About the Author

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