Analog ASICs in industrial applications

Customised IC solutions for sensor interface applications in industrial electronics – the requirements and the possibilities

Synopsis

Industrial electronics creates special challenges for analog ICs. For example, on one hand highly demanding sensor amplifiers and A/D converters are necessary, while on the other the ICs are frequently exposed to sharp voltage transients and varied loads. Standard ICs do not generally satisfy all the requirements and additional complex external circuitry is therefore needed. Customised ICs (ASICs) often offer a cost-effective and space-saving alternative, particularly for large quantities.

Introduction

Typical for many applications is a power supply usually with an unregulated voltage, perhaps nominally 24V, on which however transients of over 50V may occur. It is similar for applications in equipment construction and domestic goods, where supply voltages are often higher.

An example will show how the use of an ASIC offers advantages for the application.

What is an ASIC?

An ASIC is an IC developed and manufactured in response to an order and according to a specification received from a customer.

The generic term ASIC embraces field-programmable ICs (e.g. FPGAs), mask-programmable ICs (e.g. Gate Arrays), standard-cell ICs (e.g. ASSPs) and fully customised ICs designed at the transistor level. Since the requirements for analog circuits are very diverse and necessitate widely varying solutions, in the majority of cases fully customised developments provide the most appropriate answers.

What advantages do customised analog ASICs offer?

- Saving of space and costs through the reduction of numerous standard ICs to one component
- More functionality possible than with standard ICs
- Product copies are not possible since customised ASICs are not obtainable on the electronics market
- Higher reliability through fewer components and soldered connections
- Greater security of supply, since supply guarantees can be agreed with the manufacturer
- Protective circuitry as desired can be integrated in the ASIC

The following will demonstrate, using an example ASIC, the functions that can be integrated in an analog ASIC and the advantages that such customised circuits offer in the industrial field.

The term "analog bipolar ASIC" does not necessarily imply that only analog circuit elements are contained. With modern bipolar processes, like the ModuS U-6 Process from PREMA (see box), digital components can also be integrated, such as for example a serial interface, process control or A/D converter.

Power supply and integrated power management

Typical power supply voltages in industry and automation equipment are in the range of 20V to 30V, sometimes higher. This means selecting a process for the ASIC that provides satisfactory voltage stability. This is offered for example by the ModuS U6 Process from PREMA, as described in the box.

Power supply voltages in the industrial field are mostly not ideal. On the other hand integrated precision amplifiers, for example, make high demands on the internal supply voltage of the IC. Thus a voltage controller is needed that effectively suppresses power supply fluctuations. In the simplest case a linear regulator can be used.

For larger currents however a step-down converter can be integrated in the ASIC, as in the application indicated, which only calls for the addition of a capacitor and an inductance to the external components. This serves primarily for powering external components; in the example application a CMOS microcontroller is supplied with 3.3V as well as further peripheral units. Additionally a voltage monitor is incorporated, which in the event of the voltage falling below a defined value transmits a "Save" signal to the microcontroller. A Power-On-Reset ensures the correct conditions are set in the analog ASIC after a voltage drop-out.

Sensor signal amplifier for demanding requirements

To register sensor signals (e.g. from photodiodes, pressure and temperature sensors), interfaces can be integrated in ASICs from PREMA (see circuit block diagram Sensor Interface). A typical sensor application is the conversion of inputs from pressure or temperature sensors. To amplify these signals which are generally very small and interference-sensitive, precision or instrument amplifiers are used, characterised by low noise, limited quiescent-state input currents and small offset voltages – under 100μV is necessary in the example. To suppress thermal voltages at the connections, the polarity of the signal inputs is periodically reversed. Additionally, the sensors often need to be fed from a constant voltage or current source. Here an integrated bandgap voltage source with controllable accuracy within 1% gives good service as a precise and temperature-stable voltage reference.

Photodiodes or phototransistors represent a special case. The Modus U6 Process makes it possible to integrate these on the chip. Photosensors therefore need no longer be externally mounted. This can be very advantageous especially for applications in equipment construction, enabling electronics and sensor technology to be accommodated together in the smallest space. To process the signals, current-voltage conversion is initially necessary, effected with transimpedance converters.

For the conversion of the sensor signals, high-grade A/D converters are available, which enable direct connection over an integrated SPI interface to the microcontroller.

Digital blocks with current-saving CCL gates

To implement digital functions, the Constant-Current Logic (CCL) of the Modus U6 Process is available. It operates current-controlled; this has – in contrast to CMOS logic, which entails high pulse-shaped current flows – the great advantage of not generating interference affecting the somewhat sensitive analog blocks.

An example of the use of CCL gates is the integration of clock generators. Thus a ring oscillator, say, can be constructed with few gates. In the same way a serial interface (SPI) for communication with a microcontroller can be integrated.

Drivers for LEDs and relays

On the output side of an ASIC, drivers are often required for LEDs, maybe to indicate functional status. The ASIC can provide a constant current output for these, guaranteeing their brightness will be independent of the power supply voltage without additional circuitry.

A further task for analog ASICs in the industrial field is the switching of resistive, capacitive or inductive loads. Here inductive loads, such as for example relays, make the highest demands on account of the overvoltages and overcurrents arising in switching. For these applications there are components available in the PREMA design library enabling switching at up to 70V.

Fault detection and protective circuitry

An ASIC enables the implementation of protective circuitry that is adapted to and tailored for the application, providing reliable protection of electronic circuits against, for example, excessive voltages on the inputs or the power supply, excessive temperatures, or excessive currents. ASICs can detect specific faults such as short circuits on inputs or outputs, or sensor failures, and react appropriately.

The ASIC shown combines numerous protective measures.

In the first place the IC is passively protected against electrostatic discharge on all connections. Furthermore, the IC contains numerous active protective circuits.

For protection in case of failure, but also in case of high power dissipation in the end stages, an overtemperature protection is integrated, realised with a temperature sensor internal to the chip. Thus for the existing ambient temperature, the maximum permissible power dissipation can be utilised. The way in which the IC must react to an overtemperature, perhaps by switching off an output, by reducing the output current, or by reporting to an external control unit, is adapted to the application.

In the given example, an overvoltage detector at the outputs ensures that the transistors in the end stages, or the external load itself, do not get destroyed. Should a fault occur, the output driver switches on or off, depending on the application.

In the same way an overcurrent or short circuit protection is implemented, which initially switches off the output then periodically retests to find if the fault still exists. Here the current-sensing resistance operates in conjunction with the current-limiting block, again to control the output driver.

The advantage of the customised solution always consists in the protection being tailored to the application and implemented with the minimum of external components.

Summary:

The way to the analog ASIC

Before a customised IC can be manufactured, it must be developed. This can be done by the customer himself with existing know-how, by an independent design house, or by the semiconductor manufacturer. Which way is the most favourable depends on the individual case. By referring to the PREMA components library, development times can be reduced and existing know-how optimally exploited.

In order to ensure trouble-free functioning under all conditions of use, exhaustive testing of ASIC prototypes is undertaken before release for production. In serial production all wafer lots are initially inspected, both optically under the microscope (figure 3), and also electrically with standardised test apparatus. Further, a test rig specific to the given ASIC is developed and constructed for 100% testing of the serial ASICs. For manufacture a corresponding mask set is produced.

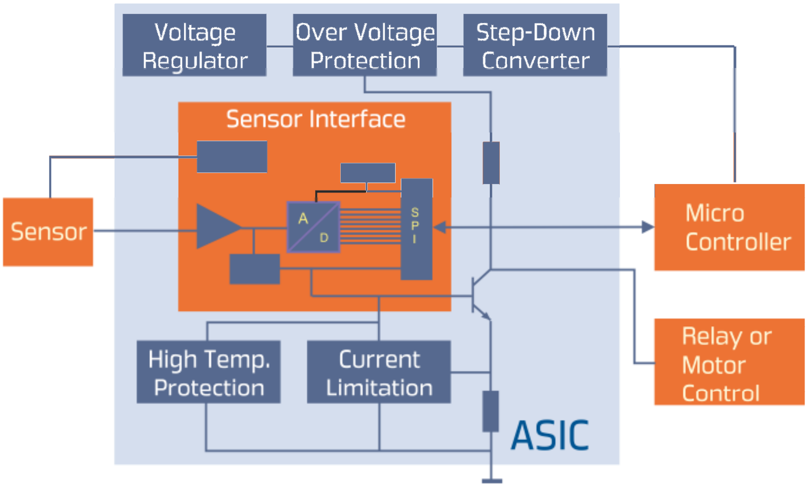
The initial and development costs incurred by an ASIC are counterbalanced by the high utility given by an analog ASIC. Moreover the high cost-saving potential that comes from the reduction in number of components to be mounted should also be considered. Security of supply over many years, protection against product withdrawals, and product quality supervised with mutually agreed serial production tests are additional arguments in favour of developing an ASIC. In many cases an ASIC is essential if only because the size of a product must be reduced. The customer can opt for the IC housing, or procure tested wafers for chip-on-board or flip-chip mounting.

The question is often raised, when does the development of an analog ASIC begin to pay off in terms of production quantities. Practical experience suggests that a sensible minimum quantity is about 100,000 ICs a year – but as the initial costs and savings potential can vary considerably, the threshold can be higher or lower according to the application.

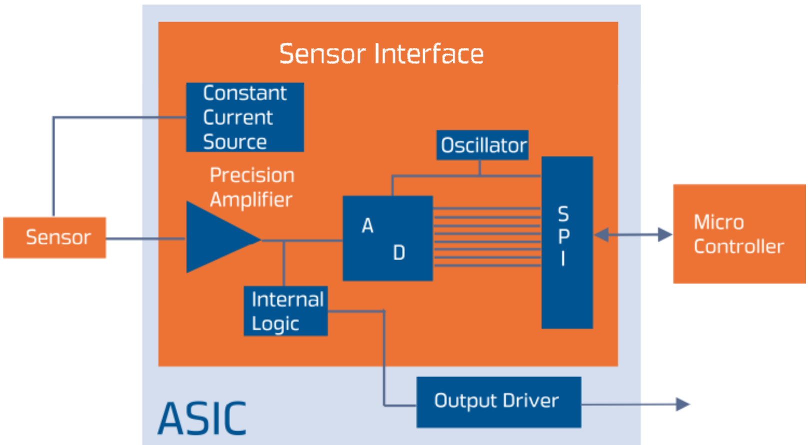
ASIC manufacturers generally offer comprehensive applications advice, and can make suggestions or put forward proposals on the basis of a product requirement specification or circuit block diagram.

PREMA-ModuS U6 Process

- full-implantation bipolar silicon process
- integration of super-beta-npn, p-channel JFET, transistors with integrated Schottky diode, super-beta phototransistors, CCL gates and other features
- Power supply voltages from 1V to 80V, dependent on the application
- Current from the pA region up to 1A (pulsed)
- Digital functions in compact Ultra-Low-Power CCL logic
- Rapid prototyping



Alongside the sensor interface, the ASIC also includes a voltage regulator, driver circuitry with various protection functions and a microcontroller interface.



The sensor is supplied with a constant current from the sensor interface. The ASIC additionally includes a sensor signal amplifier and an A/D converter, which transmits its output over the integrated SPI interface to an external microcontroller.

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