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Analog Front End Integrated Circuits for Mixed Signal Spacecraft Applications

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Mixed signal spacecraft systems typically involve a digital processing portion to execute algorithms based on external events and the Analog Front End (AFE) that provides the interface between the benign digital processor environment and the "real world". The digital processor is typically optimized for high speed computations using a low voltage process that helps reduce the power consumption. The analog interfaces in some applications are higher voltages to minimize susceptibility to interference. The digital processing can be a sequential instruction microprocessor which realizes algorithms in software or an FPGA fabric that can simultaneously process several data streams. An analog front end (AFE) might consist of operational amplifiers, current sources, data converters, power drivers. Typical applications include telemetry for applications including attitude control, motor control and position sensing, and power control. The sensor interface is rarely compatible directly to the processor I/O so some level of buffering is necessary. Buffering is also required to support redundancy which may involve cold sparing.

There are various degrees of specialization that can be supported by an AFE; the most flexible being a design made up of single function parts that are uniquely configured for each application. The highest level of integration is a custom IC designed for a specific application; this solution affords the least degree of flexibility if the requirements change. An AFE approach that offers a high degree of integration and a high degree of flexibility would be an integrated circuit with commonly used analog interfaces that are configurable. An efficient partitioning of the analog and digital functions minimizes the hard coded logic within the AFE and moves as much of the configurability to a Hardware Description Language (HDL) defined digital part such as an FPGA. HDL based logic tends to be more intuitive than schematic based logic using LSI parts for example. A spacecraft FPGA is designed to be radiation tolerant with redundant logic paths; it uses a small geometry process to improve circuit density. The FPGA gate count can be sized to an application or a group of applications to reduce cost and increase gate utilization. When the AFE is offered as a standard prequalified part as opposed to a custom part, it has the advantage that it does not require development so non-recurring engineering is reduced and time to market and schedule risk are also reduced. While the standard part AFE may not be fully utilized in every application, the level of integration for using even a portion of the circuits is usually a reduction in size over the use of single function parts.

There are many spacecraft functions that can benefit from an AFE. Sensor arrays such as health monitoring are suitable for sequential sampling as opposed to continuous monitoring. A flexible sensor interface AFE includes an analog multiplexer, a conditioning amplifier and an analog to digital converter. Passive sensors require an exciter such as a current source and should support a "four wire"measurement for high accuracy. Maximum flexibility can be designed in by allowing each AFE I/O to serve as a current source, a differential input or a single ended input. A position sensor such as a resolver or a coil current sensor in a motor likely requires continuous sampling if the position and or current is used in a servo control system that also drives the motor coils. A sigma delta converter with oversampling works well in these applications since the sampling modulator can be implemented in the AFE and the filter can be implemented in the FPGA. The FPGA can control the degree of the decimation to obtain a flexible compromise between resolution and sample rate. The FPGA can also process multiple ADC paths simultaneously and not burden the control loop state machine with the ADC sinc3 filter processing. For power control, the non-volatile programming of an FPGA can be exploited to bring up power rails in sequence and to mitigate faults if the occur. The AFE can provide voltage and current supervision and DACs for power supply margining. The AFE can also provide linear control for slewing the output of solid state circuit breakers to reduce power bus transients and open circuits in the event of a fault.

The use of a standard integrated circuit AFE paired with a configurable FPGA takes advantage of a high level of integration when the partitioning of the analog and digital functions provides IC process optimization for the implementation of the digital and the analog functions. Higher integration reduces parts count which improves reliability and reduces size and weight of the spacecraft electronic modules. This presentation discusses the topics above and provides examples to demonstrate the concepts.

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