

Generic Architecture for a Self-Powered Smart Sensor Interface in Avionic Application

Saeid Hashemi
 Polytechnique Montreal

ABSTRACT

In this paper, we present an universal architecture for a reliable self-powered Smart Sensor Interface (SSI) in avionic applications. The SSI module consists of data acquisition and signal excitation paths. The power recovery unit harvests energy from data field bus to power up the SSI module entirely. Using integrated CMOS technologies, the interface is flexible and configurable to be integrated with and fully controlled by Transducer Interface Module (TIM) introduced in IEEE1451 standard. Employing data converters within the signal paths makes the SSI well suited for full digital control over specifications of the excitation signal and data processing algorithms. The interface can be used along with various types of position sensors including legacy R/LVDT, MEMS-based and optical ones. The analog parts of the SSI are implemented using IBM 0.13 μm CMOS process while its digital modules are realized in FPGAs. The Power Conversion Chain (PCC) of the SSI is also presented and its complex components are modeled in Verilog-A using a top-down modeling approach. The models make it possible to study over power transfer and distribution throughout the SSI. Simulation results prove that the proposed power recovery scheme could procure and deliver significant amount of power to SSI which makes the structure self-powered.

CITATION: Hashemi, S., "Generic Architecture for a Self-Powered Smart Sensor Interface in Avionic Application," *SAE Int. J. Aerosp.* 5(1):2012, doi:10.4271/2012-01-2126.

INTRODUCTION

High channel count sensor and actuator devices are needed to tackle a growing number of functions in aircrafts. With Federated Avionic Architecture (FAA), connecting these devices results in bulky wiring bundles. The stringent safety standard of avionic systems requires redundant installation of all components on board, which further exacerbates the situation. Moreover, in new avionic systems, communications between devices across different application domains are also needed, which drastically increases information flow. Wiring bundles and demand for a much higher communication bandwidth raise serious challenges requiring the development of new avionic data buses.

The AFDX is the backbone of the avionic network. Recently, an improved architecture for the new avionics data network is introduced (Fig. 1), where the components in a TIM are connected to a field bus of Controller Area Network (CAN), and communicate with the AFDX network via a gateway. This network architecture can be tailored to have more or less the AFDX portion depending on the application, the cost constraint, and the performance requirement.

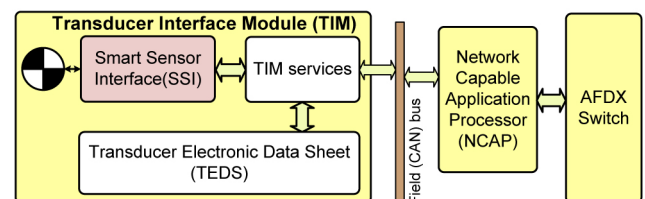


Figure 1. Architecture of modified AFDX network along with SSI.

The operation of fly-by-wire flight control systems relies heavily on position sensors for detecting pilot controls, and control surfaces movement. The sensors currently used in most systems are fully analog and passive based on electromagnetic principle. The development of sensor technology resulted in new types (optical and MEMS-based) of sensors with increasing accuracy and reliability, smaller size, contactless, less power consumption, and simplified integration possibility with electronic circuits. In order to use different sensor technologies at the same time, an interface circuits with adoptive front-end is essential.

Employing high speed data bus structures and new sensor technologies in avionics sensor networks, need a general and

configurable interface which should reduce the interconnection complexity of the network. Such interface could be implemented using CMOS technologies.

In addition, recent researches in power/data transmission have led to introducing new techniques including wireless communication [1], Power Line Communication (PLC) [2] and Power over Ethernet (data) (PoE) [3]. These techniques, however, suffer from limitations which partially outweigh their advantages and limit their applications. Compared to wired communication, wireless communication is less popular and more power hungry and subject to EMI/EMC problems, as well.

Power lines are usually not designed to carry data, and actually behave as a very harsh and noisy transmission medium. Thus maintaining signal integrity over power lines requires robust signaling techniques and additional hardware. The researchers reported the use of PoE technique to power up End Systems in conventional Ethernet/AFDX networks. Device-level Ethernet is however too costly compared to field bus device. Therefore, it is not a desired choice to power devices through PoE technique.

To our best of knowledge, there is no published achievements on design and implementation of power recovery scheme to scavenge power from field bus, which are numerous and widespread in aircrafts.

In responding to these challenges, this project aims at developing a new universal configurable autonomous interface for avionic applications. It can be integrated with and fully controlled by TIM in IEEE1451. On the sensor side, this interface can be merged with various position sensor such as magnetic, MEMS or optical ones. The proposed interface employs a novel power harvesting technique which scavenges power from CAN bus and powers up the entire SSI circuitry. The presented technique offers the potential to significantly reduce the mass of the cables, and correspondingly decrease the cost, wiring complexity and weight, especially aiming at energy management and environment friendly avionics.

II. PROPOSED ARCHITECTURE FOR SMART SENSOR INTERFACE

The SSI is used for activating and signal conditioning of different position sensors. It interfaces the sensor and the field bus. Fig. 2 shows the proposed architecture of a single-channel SSI. Here, the SSI consists of data acquisition, excitation signal generator and power recovery paths.

The sensor output feeds forward throughout an analog signal processing scheme and then digitized using a high precision data converter and a ratio-metric unit. Afterward, the sensor data is forwarded to TIM services through Transducer Measurement Interface (TMI). The feedback path also generates the excitation signal for sensors based on the amplitude and frequency information provided by the incoming data from network and adopt its level to the operating range of the sensors. The third path harvests power

from the field bus and procures the required energy for SSI circuitry and the sensors.

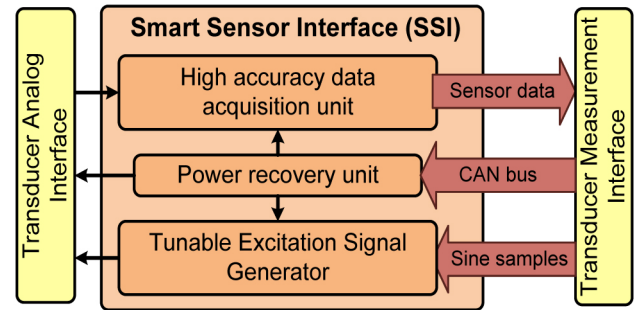


Figure 2. Architecture of proposed single-channel SSI.

A. Excitation Signal Generator Path

The excitation signal generator path links between the AFDX network and the position sensors. It generates a sinusoidal signal with

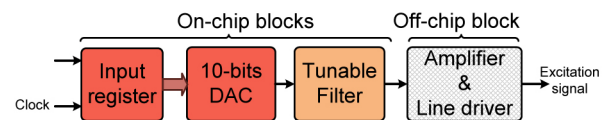


Figure 3. Block diagram of excitation signal generator.

adopted voltage levels for actuating the R/LVDT sensors. The excitation signal frequency may vary between 1.5 kHz and 10 kHz. Fig. 3 shows the block diagram of such signal generator path.

This path consists of shift registers, digital-to-analog converter, tunable filter, an amplifier and a line driver. The chain of data concerning the amplitude and frequency of a sinusoidal signal is serially received and stored in shift registers. The data are then fed to an accurate 10-bit digital-to-analog converter in parallel. A tunable filter located in the path helps to smooth the waveform and to increase the SNDR of the generated signal. The last module in this path adopts the excitation signal with sensor requirements and enhance driving capabilities.

The core of excitation signal generator path is a 10-bit digital-to-analog (DAC) converter. This resolution was found to be necessary achieving the required SNDR for data acquisition path. It uses current-steering structure with segmented layout scheme. Fig 4 shows the structure of a unit cell for DAC.