National Aeronautics and
Space Administration

John F. Kennedy Space Center

SPACEPORT
ENGINEERING AND
TECHNOLOGY

SIGNAL CONDITIONING AMPLIFIER AND RECORDER (SCAmpR)

Pedro J. Medelius, Ph.D.

Dynacs, Inc.

July 30th, 2002

2002 NASA Advanced Sensors Symposium

Agenda

- Introduction
- System Description
- Universal Signal Conditioning Amplifier (USCA)
- Advanced Data Acquisition System (ADAS)
- Signal Conditioning Amplifier and Recorder (SCAmpR)
- Conclusions

Introduction

- One of the most important goals for NASA's space program, as it moves into the new millennium, will be to lower the cost of access to space.
- One area where technology has been applied to reduce costs is the Ground Measurements System at Kennedy Space Center's (KSC) Launch Complex 39.
- The Ground Measurements System (GMS) is used to make engineering measurements at the launch pads, and in the Vehicle Assembly Building.
- During an actual Space Shuttle launch, the system monitors over two hundred pressures, strains, temperatures and vibrations throughout the Launch Pad area.

System Description

- The new Ground Measurements System, known as ADAS, for Advanced Data Acquisition System, is designed to acquire transmit, display and record measurement data from transducers in both Launch Pads and the Mobile Launch Platforms.
- It is a self-configuring system specifically designed to simplify and automate operational tasks, such as configuration control, measurement setup and system health checks.
- The GMS Upgrade was designed as a "measurement driven" data acquisition system, which means the act of plugging a transducer into the system automatically generates a sequence of events culminating in data flow to the LCC.

System Description

- The entire measurement system revolves around the contents of an external memory device called the Tag RAM, which is a tiny microcontroller and EEPROM-based device designed to be a transducer's electronic calibration sheet.
- The Tag RAM components are all installed on a small (1-inch by 1-1/4inch) printed circuit card. The Tag RAM is typically installed in the molded end of the "pigtail" cable, which adapts the transducer's connector to the USCA input connector.
- The measurement information and the transducer's calibration data is loaded into the Tag RAM prior to measurement installation using a serial data communications protocol and a PC-based setup program.

Universal Signal Conditioning Amplifier

- The Tag RAM then contains all of the information necessary to allow a USCA to configure itself for the transducer to which it is connected.
- The Universal Signal Conditioning Amplifier (USCA) is the key technology component in the Data Acquisition System.
- It automatically configures itself to match the transducer to which it has been connected. This reduces the time that is required to set up a measurement to seconds (original system required 2-4 hours).
- The USCA contains multiple programmable components that allow this automated configuration to take place.

Universal Signal Conditioning Amplifier

- A Digital Signal Processor (DSP) controls both the excitation, input, and output modules.
- The DSP performs multiple tasks to insure the accuracy of the measurement. Taking advantage of the dual channel PGA and A/D converter, the DSP performs a continuous calibration check.
- The inactive A/D channel samples a highly stable voltage reference (better than 1ppm/°C) and digital gain adjustments are made by the DSP to correct for errors. Once that A/D channel is calibrated, it is swapped with the other A/D channel so that it can be calibrated. This entire process takes place continuously and is transparent to the user. However, it does allow USCA to constantly check on its health and report any serious deviations back to the host CPU immediately.

SCAmpR

- KSC has not stopped looking for ways to improve the system further.
- All signal conditioning systems have significant analog circuitry that is critical to their operation.
- Critical measurements require continuous health check of the data acquisition system.
- Advances in Field Programmable Gate Arrays (FPGA), Flash-Memory devices, and Programmable Analog Integrated Circuits (PAIC) have opened up the possibility of designing circuits that can be dynamically reconfigured.

SCAmpR

- The SCAmpR is a self configuring, constantly calibrating signal conditioning amplifier.
- It time-stamps and stores data on non-volatile memory.
- Data transfer and control is conducted via Ethernet TCP/IP standard network protocol.
- Development of a new Smart Signal Conditioning Amplifier which takes advantage of this technology, has reached the prototype stage of development.
- The low cost per channel will result in increased benefits to satisfy the aerospace industry's need to reduce operations cost, to accelerate processing time and to provide reliable hardware at a reasonable cost.

SCAmpR - Features

- The SCAMPR provides for internal data storage, thus allowing for fast data sample bursts without the requirement of large bandwidth communication links.
- The SCAMPR utilizes standard data communication protocols, thus enabling its use with most computer platforms.
- Instructions can be downloaded to the SCAMPR for execution at future times. i.e. switching to fast data rates, returning to slow sampling rates, switching to exception-reporting mode, etc.
- The SCAMPR is continuously calibrated, using a single analog channel.

SCAmpR - Features

- The use of the SCAMPR provides for a dynamically re-configurable system.
- The use of standard interfaces, combined with the internal data processing and storage makes the configuration of the data acquisition system completely flexible.
- The SCAMPR will be an integral component of the design of the Ground Measurement System (GMS) Phase 2 Data Acquisition System.
- The SCAMPR system meets the performance requirements established by the GMS. In addition, it is designed to greatly improve reliability and significantly reduce cost of ownership.

SCAmpR - Benefits

Several features of the SCAMPR make it unique in its class:

- The capability of internally storing a large amount of data is important to prevent the loss of critical launch data in case of a communication failure.
- The design of a remotely-controlled calibration module results in increased confidence in the system, while minimizing costs associated with periodic maintenance and calibration procedures.
- A modular design permits the customization of the SCAMPR for specific requirements, reducing the additional cost of a one-fits-all instrument.

SCAmpR Architecture

- A modular approach on the design has resulted in three distinct, although closely interfaced, functional sections: Analog, digital, and power management.
- The architecture of the SCAMPR is comprised of a DSP controller and a variety of peripheral circuitry for performing analog and digital functions.
- The digital section includes scalable non-volatile memory for data storage to be used in case data communication is lost, when network congestion is detected, or redundantly when critical data is being monitored (i.e., T-5 to T+5 minutes).
- Interface circuitry for the VME bus and for TCP/IP communication is also provided.

SCAmpR Architecture

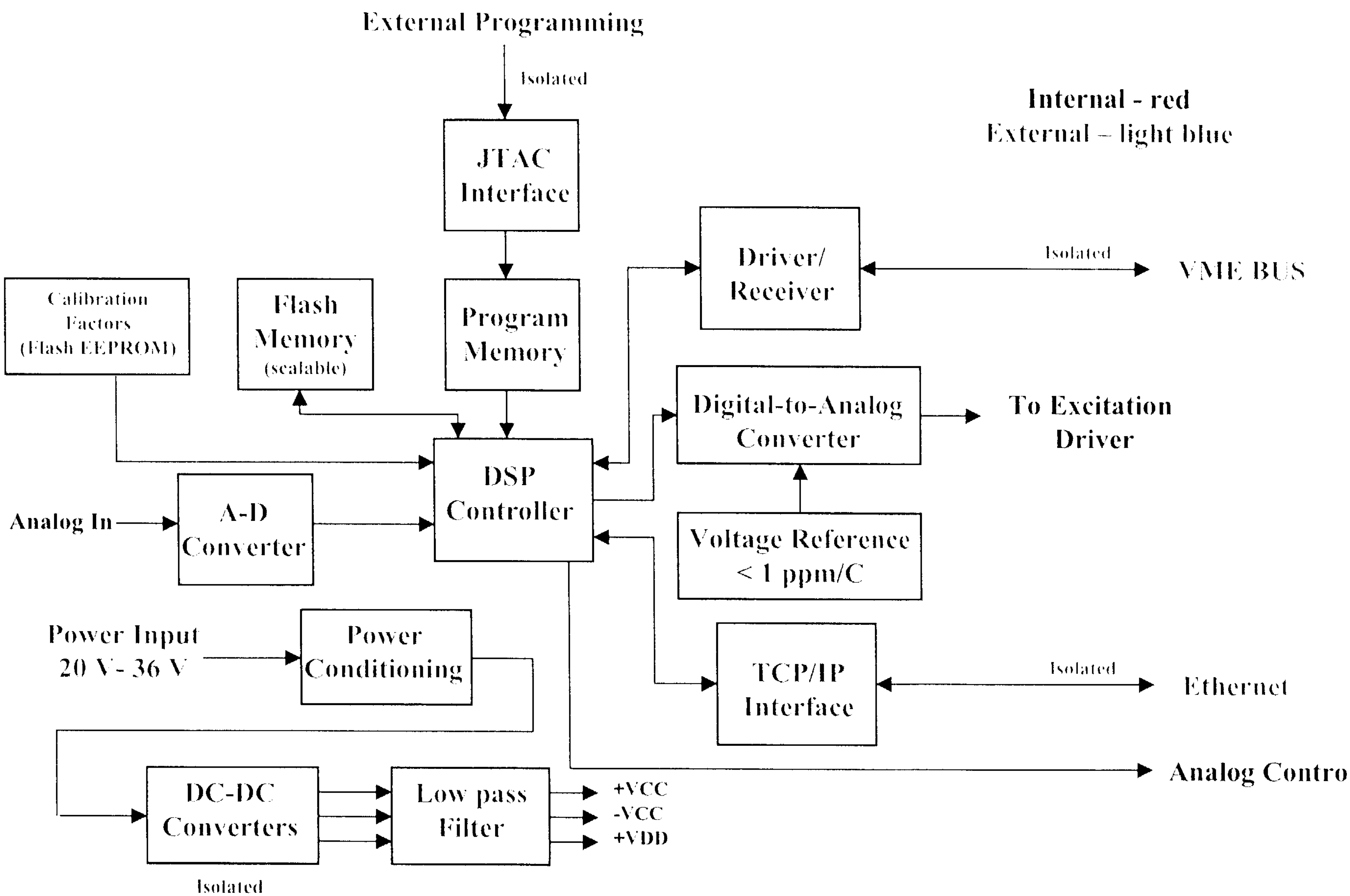
- Calibration factors for the SCAMPR as well as the configuration information are stored in a separate flash EPROM.
- A 16-bit analog-to-digital converter is provided to perform data acquisition up to a rate of 100 kilosamples per second.
- A 16-bit digital to analog converter is implemented for generating excitation voltage and/or current.
- Complete electrical isolation between the power source and the SCAMPR is achieved by means of the use of DC-DC converters, with 500-volt isolation capability.
- Isolation between the SCAMPR and the communication and control links is implemented by means of optical isolators.

SCAmpR Architecture

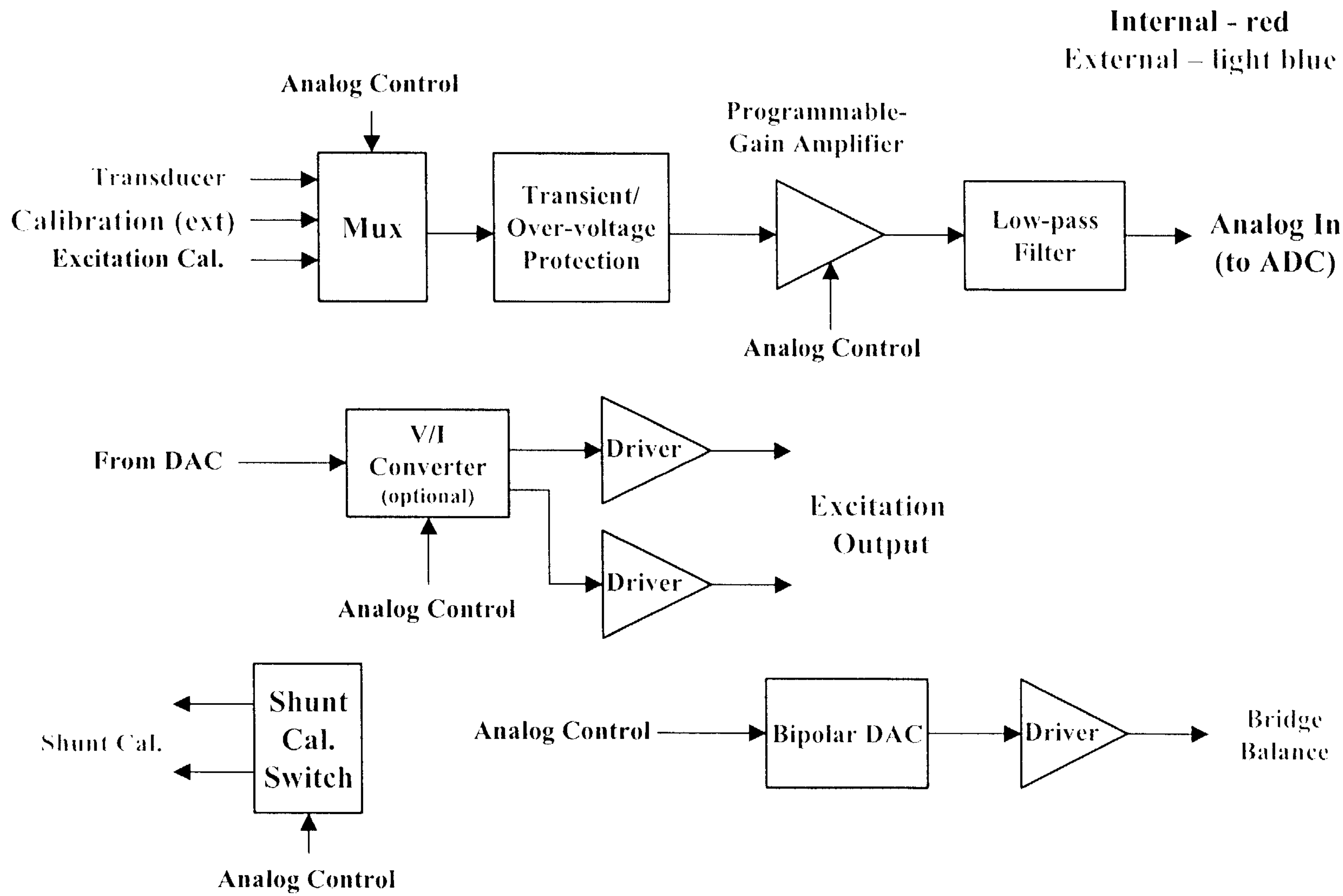
- The input circuitry in the analog section of the SCAMPR includes over-voltage and transient protection, programmable gain amplifiers, filters, and a multiplexer.
- The multiplexer is used to select the signal source for the amplifier. The sources can be selected among the transducer's output, external calibration signal, and internal calibration of the excitation circuitry.
- Capabilities such as bridge balancing and shunt calibration have also been provided in the SCAMPR.

SCAmpR Architecture

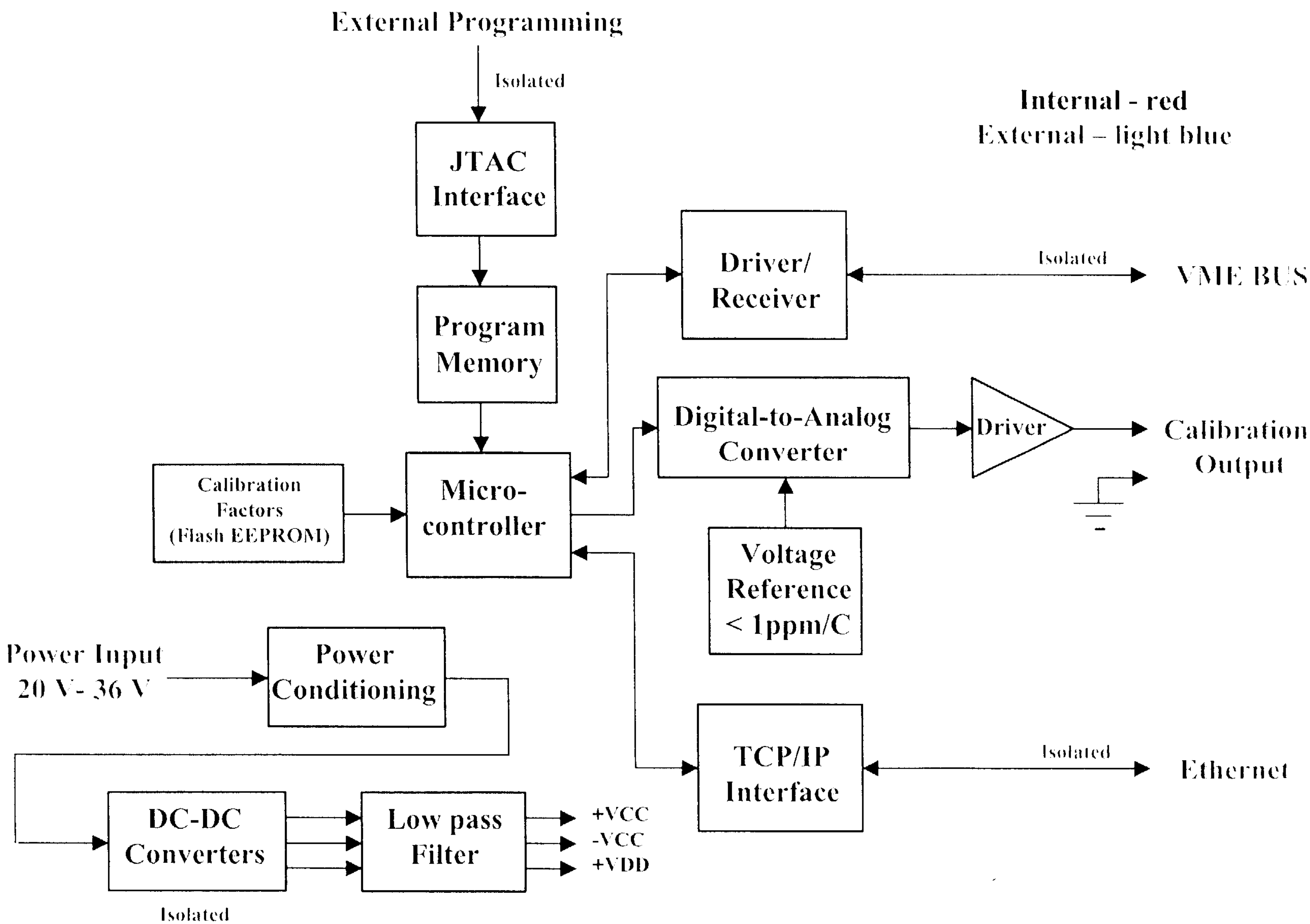
- The SCAMPRs are designed to be mounted on a multi-slot modified VME chassis.
- One of the slots will be dedicated to a calibration card which includes highly stable voltage references.
- The output of the calibration card can be applied to any of the SCAMPRs through remote commanding via the TCP/IP network.
- This allows for calibration of the SCAMPRs to be performed without the need to remove them from service.
- Traceability on the calibration card will allow for its use for certification of the SCAMPRs.



SCAMPR Block Diagram – Digital and Power



SCAMPR Block Diagram – Analog



SCAMPR – Calibration Module

Conclusions

- Design advances in Data Acquisition Systems have had a significant impact on the reduction of cost in the ground processing of human space flight missions.
- The USCA coupled with the ADAS represented a significant advancement in the state-of-the-art.
- However, new developments like the SCAmpR will help drive costs down further, while providing enhanced reliability.