Wireless Instrumentation System
WIS™

INVOCON, INC.

TECHNOLOGY PROFILE – MARCH 2003

Features

Spread Spectrum Radio Communications

Self-Configuring, Relaying Network

"Sliced" Architecture provides Increased System Flexibility and Low-cost Upgrades

Synchronized Distributed Network for use in Modal Analysis

Powerful On-board 16-bit Microcontroller and 24-bit DSP

Wide Variety of Standard and Custom Data Acquisition Modules Available

Windows®95/98 Graphical User Interface Software

Advanced Power Saving Features for Extended Battery Life

Operating Temperature Range –40°C to 60°C

System Description

The Wireless Instrumentation System (WIS) is a highly integrated remote data acquisition system for use in a wide variety of distributed sensor applications. Typical applications include modal analysis, condition-based maintenance, structural monitoring and manufacturing process control.

The system was designed for NASA Johnson Space Center to monitor critical temperatures during the assembly of the International Space Station (ISS), and to verify structural dynamics models for the ISS on-orbit.

The relaying network is automatically configured by the embedded system software, which provides for simple installation and consistent operation in almost any environment. The ability to relocate the data acquisition electronics near the sensors decreases setup costs and reduces "noise" induced on analog signals by long wires.

Each WIS unit provides asynchronous two-way, spread-spectrum radio communications, data processing, signal conditioning and 24-bit A/D conversion for up to 16 simultaneously sampled analog channels.

Data acquisition modules are currently available for voltage, current, and resistive output sensors. Custom modules for interfacing with alternate analog or digital transducers may be readily developed and integrated into the existing system.

All network commands are issued from a Personal Computer (PC), and digital data may be stored on the PC hard-drive in any user-defined format.

System specifications may vary depending on application
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www.invocon.com   Phone: 281-292-9903, Fax: 281-298-1717   email: ivc@invocon.com

The Wireless Instrumentation System (WIS) consists of Remote Sensor Units (RSUs), a Network Control Unit (NCU), and a PC. Each RSU is capable of receiving commands from the NCU and downloading data to the NCU via RF communication. Each RSU contains all the electronics needed for acquiring analog signals from sensors, amplifying/filtering the sensor analog signals, converting the analog signals to digital, storing the digital data, processing the digital information for data reduction, and transmitting the data via the network to a central location. In addition to the data acquisition and transmission capabilities, each RSU has the capability to act as a relay for any other RSU in the network. In this way, data is gathered from network locations and is routed to the NCU, which transfers the data to the PC for storage and/or further processing.

The sensors acquiring the data may be located internally or externally to the RSU, depending on the type of sensor used and the data required. In those instances when the sensor is located external to the RSU, the interface to the RSU consists of a custom made cable.

Diagram of System Operation
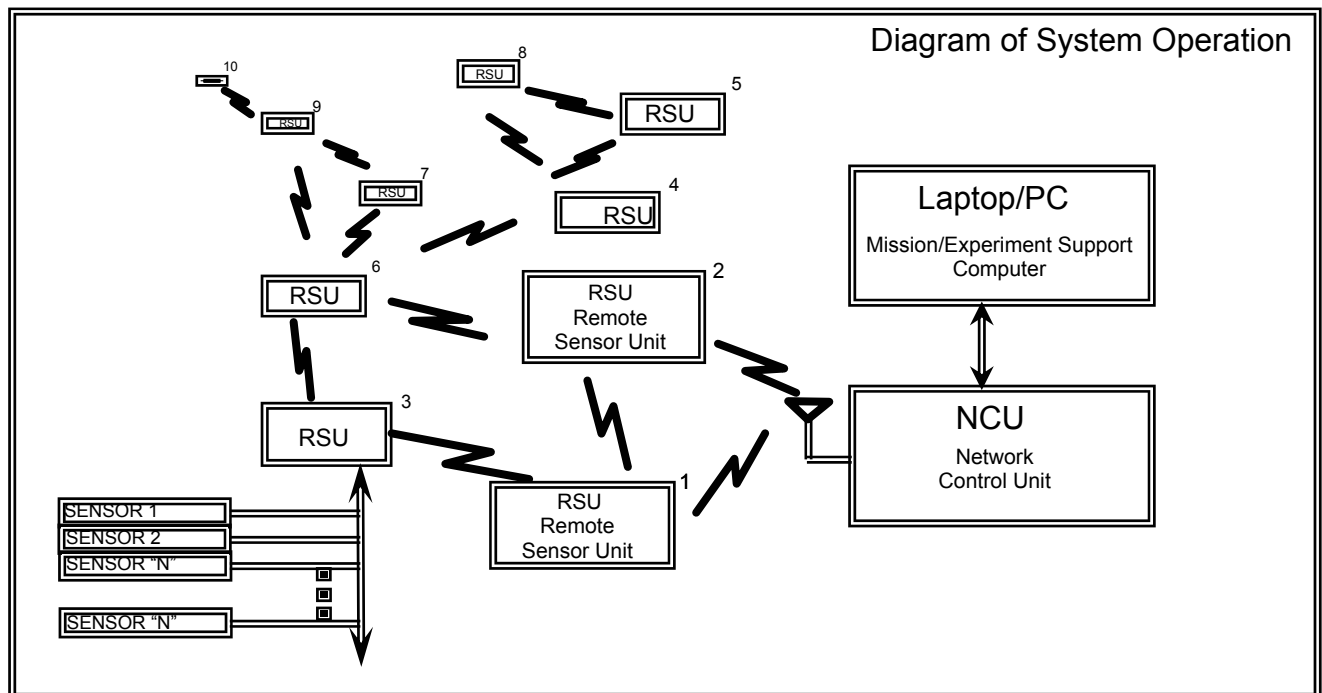
HARDWARE ARCHITECTURE

Both the RSU and NCU have a unique "sliced" or modular architecture design, which provides long-term benefits to the overall system such as flexibility, reusability, and low cost upgrades.

All modules within a given RSU or NCU are connected by means of a parallel bus, which provides for data transfer, power control, and synchronization between modules. The approximate dimensions of the enclosure are 4.25 in. x 6 in. x 5.2 in., and the approximate weight are 5 pounds. (Dimensions may vary with application specific requirements that dictate different connectors, surfaces and antenna configurations.) Both units have the same basic physical package. However, as the sensor interface unit, the RSU is the only unit that contains the data acquisition modules. Furthermore, the RSU is expandable to accommodate additional data acquisition modules to interface with different sensors.
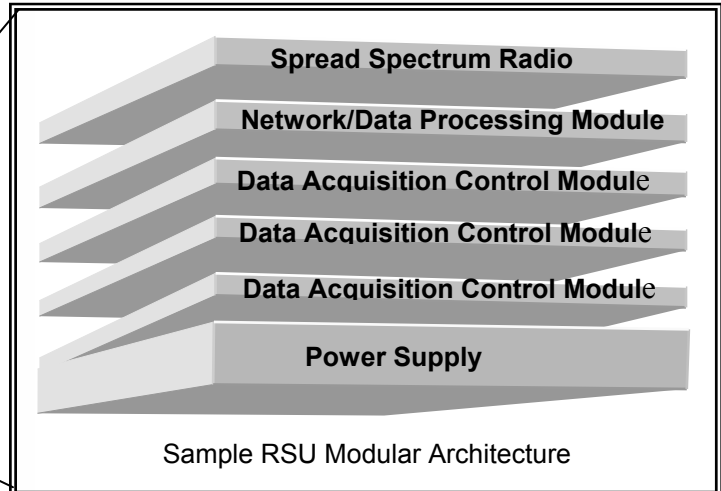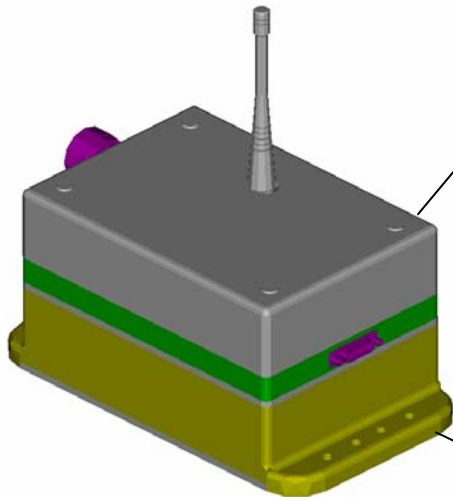
Remote Sensor Unit Package and Specifications

Sample RSU Modular Architecture

Parameter	Specification
SIZE	4.25" x 6" x 5.2"
WEIGHT	Approx. 5 lbs.
OPERATING TEMPERATURE RANGE	-40°C - 60°C
NUMBER OF CHANNELS	3 – 6 plus sensor temperature
ACCELEROMETERS	Honeywell Q-flex® Series
ACCELEROMETER FULL SCALE RANGE	Variable up to $\pm$ 25g
STRAIN GAUGE CONFIGURATIONS	¼ bridge, ½ bridge, or full bridge
STRAIN ACCURACY	$\pm$ 5$\mu\varepsilon$
STRAIN RESOLUTION	< 0.25$\mu\varepsilon$
RTD TEMPERATURE ACCURACY (UP TO 50' CABLE)	$\pm$ 2°C

MODULAR STRUCTURE AND DETAIL

Network/Data Processing Module

The Network/Data Processing Module includes the following features:

- High-speed 32-bit Microprocessor
- 2 Megabit/sec serial bus and Direct Memory Access (DMA) for high data transfer rates
- Programmable clock speeds enabling power consumption to be matched to the demands placed on the system
- Sleep, Doze, and Stop modes for periods of reduced utilization demand

The Real Time Clock and Power Control circuitry are vitally important for extending battery life while providing powerful system versatility and synchronization. As with the Wireless Data Acquisition System (WDAS) system flown on STS-83 and STS-94 (NASA Shuttle), the processor and all unnecessary circuitry can be completely powered down when not needed. The clock circuitry in each unit may be programmed via the PC to wake the processor at certain intervals ranging from once a second to once a day to "listen" for a network command. In addition, a schedule may be uploaded to each unit specifying desired data acquisition parameters over the course of the entire mission.
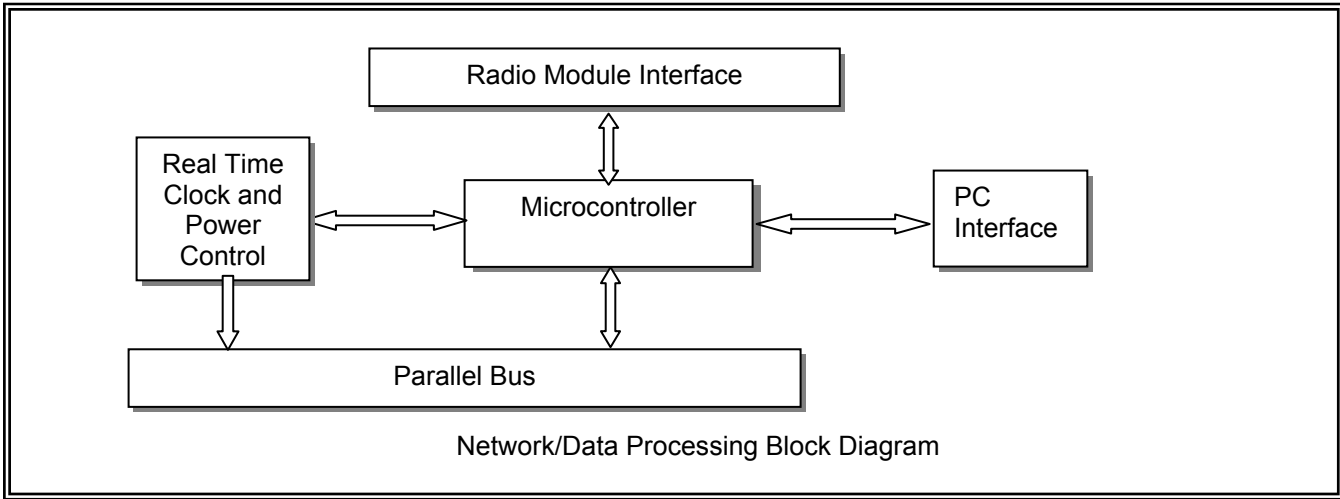
Network/Data Processing Block Diagram

Spread Spectrum Transceiver Module

All WIS units are linked via spread spectrum radio modules, which consist of a transceiver and either an integral or external antenna. Current options include, but are not limited to, the following:

- ISM band transceiver
  * Frequency: 915 MHz
  * Baseband data rate: 2 Mbit/sec

Radio modules are chosen to match the specific requirements of the application.

Data Acquisition Control Modules

The modular architecture implementation provides for very flexible, yet powerful data acquisition capabilities. Additional Data Acquisition Control Modules (DACM) may be added for an unlimited variety of sensor or actuator applications.
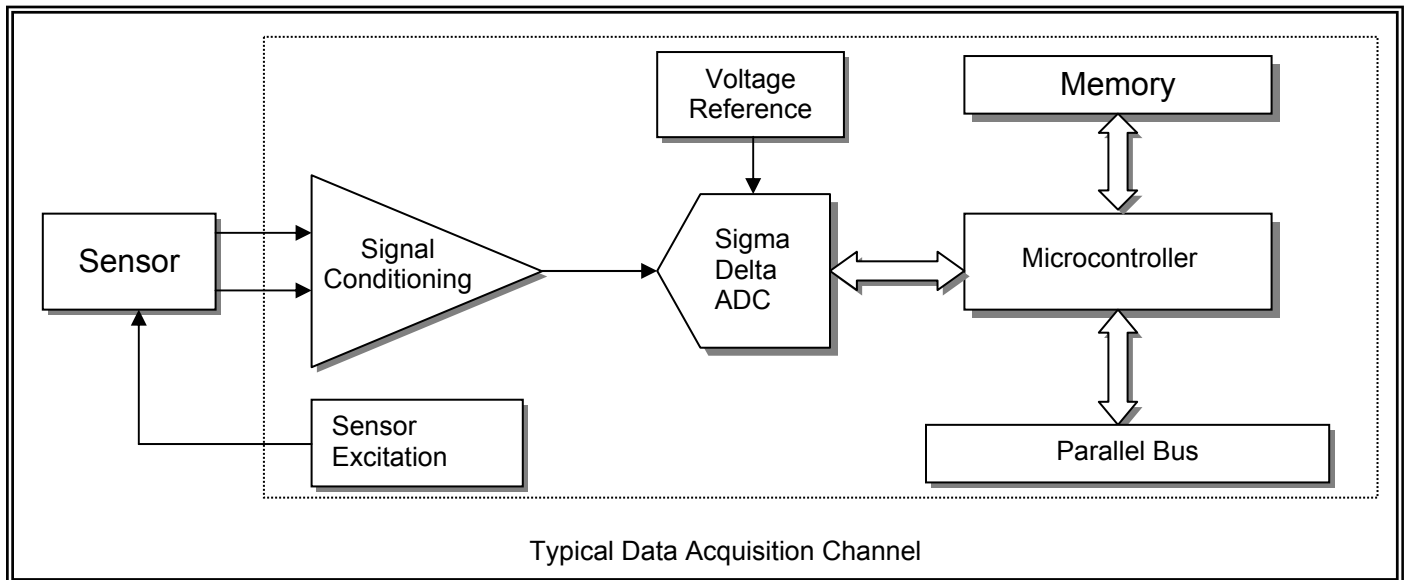
Typical Data Acquisition Channel

Each Data Acquisition Control Module (DACM) utilizes an 8-bit microcontroller to handle data buffering, synchronization, and parallel communications with the Network/Data Processing Module (NDPM. Calibration capabilities, as well as sensor fault detection capabilities, are provided for all modules.

Sigma-Delta Analog-to-Digital Conversion

In order to satisfy wide dynamic range applications, sigma-delta A/D converters (ADCs) are used. Currently available sigma-delta ADCs typically contain the following features: up to 18 bits of dynamic range at 100 Hz analysis bandwidth, programmable gain, selectable filter cutoff frequencies, and on-chip calibration. The ADC is able to achieve such a wide dynamic range due to the sigma-delta conversion technique. The sigma-delta modulator converts the sampled input signal into a digital pulse train whose duty cycle contains the amplitude information. The output of the modulator is processed by a $sinc^3$ digital low-pass filter, which updates the output register at a user-defined rate. The actual sampling frequency is fixed at a very high value, which eases the anti-aliasing filter requirements and provides for a very flat frequency response over the entire frequency range specified. Post-processing algorithms will be developed to emulate a 4th order Bessel filter. Wider bandwidth sigma-delta converters are available that sample at greater than 100 KHz at 16 bits.

The following is a list of popular sensor interfaces for the DACM:

Strain Gage Module

The strain gage module provides 4 simultaneously sampled channels of strain gage measurements for quarter-bridge, half-bridge, and full-bridge circuit applications. Shunt calibration capabilities are provided for any two arms of the Wheatstone bridge. Software allows the user to select gain, sample rate, filter cutoff frequency, and offset. Nominal resistance, number and configuration of active gages, shunt calibration resistance values, and location of shunt calibration resistors must be determined prior to manufacture. All Wheatstone bridge components, both internal and external to the signal conditioning, must be balanced to within 50% of full-scale in order to achieve maximum resolution. Accuracy and resolution of the signal conditioning electronics is better than $5\mu\varepsilon$.

Accelerometer Module

Each accelerometer module is capable of interfacing with three (3) Q-Flex® Series accelerometers, including the three (3) temperature sensors internal to the accelerometers. The three acceleration output signals are sampled simultaneously at up to 250 samples/sec, while the internal temperatures are multiplexed into a single A/D and sampled periodically. The accelerometers are mounted orthogonally within the external Tri-axial Accelerometer Assembly (TAA), and connected to the RSU via a 12-conductor cable. The dimensions of the sensor module are 2.7 in. x 2.7 in. x 1.5 in. An additional module is available to interface with ICP piezoelectric acceleroeters.

POWER SUPPLY MODULE

The RSU or NCU may be battery-powered or connected to a 28 VDC power input. Included within the battery pack module are blocking diodes, shunting diodes, fuses, battery capacity monitoring electronics, and DC/DC converters. Power may be completely disconnected via an external locking switch. Laboratory DC power or supplemental battery power may be supplied to the circuitry through an external connector.

NETWORK STRUCTURE

WIS incorporates a self-configuring, relaying network. The network automatically chooses the optimum communication route for transferring data and commands without operator intervention. All network activity is initiated by the transfer of a high level command from the PC to the NCU. The NCU then configures the network and transfers the appropriate messages to the proper RSUs. Each RSU powers itself up periodically and enters a receive mode to detect any network activity. Only if an RSU receives a message with the proper Node ID will it acknowledge the network message. Therefore, the RSUs will "never speak unless spoken too," which eliminates the possibility of RF transmission at unwanted times. In addition, two NCUs may be set up with two PCs simultaneously to provide for redundant data paths during critical periods. Several other network protocols have been implemented and can be configured to meet other applications. Additionally, the network can be programmed for static routes.

Inquiries regarding WIS may be addressed to:
Invocon, Inc.
19221 IH 45 South, Suite 530, Conroe, TX 77385
Phone: 281-292-9903; Fax: 281-298-1717
E-mail: ivc@invocon.com
www.invocon.com