SRI PMD

Operations and Maintenance Manual

Enhanced Series 500e
Digital Telemetry Equipment

Solving Measurement Challenges – with – Advanced Technology Solutions

Prepared by:
SRI/PMD – Melbourne, FL

Document Number: 70-SS510-00 O&M
October 2007

SRI/PMD • 751 NORTH DRIVE • MELBOURNE, FLORIDA 32934
(321) 254-2580 • FAX (321) 254-2492 • Internet : www.summationresearch.com • Email : info@summationresearch.com

SRI/PMD SERIES 500e DIGITAL TELEMETRY SYSTEMS

LIMITED WARRANTY

SRI/PMD warrants that the receiver and accessory equipment of its manufacture as identified within this document shall, at the time of shipment to the original purchaser, be free from defects in material and workmanship and conform to the specifications at time of purchase (incorporated herein) for a period of one (1) year from the date of original shipment. Encapsulated transmitters and batteries shall be covered under these same warranty terms for a period of 90 days from the date of original shipment.

This warranty applies only to equipment installed, operated, and maintained in accordance with SRI/PMD recommendations, and such warranty does not apply where SRI/PMD determines that any claimed defect has been caused by installation or repair, alteration, accident, or excessive deterioration due to environmental contamination.

SRI/PMDs obligation under this warranty is limited to repairing, or replacing, exclusive of cost of installation and labor charges, any part that SRI/PMD determines to be defective, provided that such part is received at SRI/PMDs principal office, freight prepaid. All equipment must receive prior approval for return to SRI for warranty repair, and must be sent prepaid. If they are returned collect, they will not be accepted.

This warranty is subject to any existing conditions of supply which may directly affect SRI/PMDs ability to obtain materials or manufacture replacement parts.

SRI/PMD makes no warranty that the equipment shall be merchantable or fit for any particular purpose; nor does SRI make other warranties, express or implied, by operation of law or otherwise, except such as are expressly set forth herein. SRI/PMD shall not be liable to buyer, or to any third persons for any incidental, consequential, special or contingent damages for breach of any warranty.

IMPORTANT NOTICE

FCC ID: VPT-ST540E

THIS DEVICE COMPLIES WITH PART 15.249 OF THE FCC RULES. OPERATION IS SUBJECT TO THE FOLLOWING TWO CONDITIONS:

(1) THIS DEVICE MAY NOT CAUSE HARMFUL INTERFERENCE, AND

(2) THIS DEVICE MUST ACCEPT ANY INTERFERENCE RECEIVED, INCLUDING INTERFERENCE THAT MAY CAUSE UNDESIRED OPERATION.

SRI PMD, INC. IS NOT RESPONSIBLE FOR ANY RADIO OR TV INTERFERENCE CAUSED BY UNAUTHORIZED MODIFICATIONS TO THIS EQUIPMENT. SUCH MODIFICATIONS COULD VOID THE USER'S AUTHORITY TO OPERATE THE EQUIPMENT.

CHANGES OR MODIFICATIONS NOT EXPRESSLY APPROVED BY SRI PMD, INC. COULD VOID THE USER'S AUTHORITY TO OPERATE THE EQUIPMENT.

TO MAINTAIN COMPLIANCE WITH FCC'S RF EXPOSURE GUIDELINES, THIS EQUIPMENT SHOULD BE INSTALLED AND OPERATED WITH MINIMUM DISTANCE 20 CM BETWEEN THE RADIATOR AND YOUR BODY. USE ONLY THE SUPPLIED ANTENNA.

RECORD OF CHANGES

REVISION	DATE	TITLE OR BRIEF DESCRIPTION
A	November 2006	New document for Series 500e system.
B	March 2007	Added Sample Rate and Throughput Delay Table Added SS-580 Model Number Added Paragraph About Calibration Files Update for Software Release 2.03 Added new sensor type descriptions Clarified gain/offset processing description
C1	December 2007	Updated M&C Application overview Update for Software Release 2.05

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF TABLES

SECTION 1 INTRODUCTION

The Series 500 Digital Telemetry Equipment represents one of the most versatile of SRI/PMD's Wireless Link products. Due to a unique mixture of high technology RF, analog and digital circuitry, a highly versatile measurement capability is provided in a compact package fully supporting applications requiring low power consumption and high reliability while still being offered at an affordable price.

Figure 1-1 SRI/PMD Wireless Link Product

Supporting anywhere from 1 to 8 sensor channel inputs, all Series 500e products provide both highly accurate analog and high-speed digital measurement outputs for a wide variety of sensor types and measurement ranges.

1.1 Scope

This manual describes the SRI/PMD Series 500e Digital Telemetry Product Line, including both transmit and receive processing units. The manual includes specifications, design description, installation, and operation instructions along with routine maintenance requirements for these products.

1.2 Product Overview

SRI/PMD has been designing and producing ruggedized wireless telemetry systems for over 30 years. An old slogan in the instrumentation community states that "Measurement is the beginning of knowledge". Previous versions of SRI/PMD's **Wireless Link** product have assisted customers in gaining insight into operational parameters which were, at best, difficult to acquire with any amount of reliability or longevity, if not totally unobtainable.

With the advent of the new, fully digital, SRI/PMD **Wireless Link** products, potential users are being offered an improved solution that not only provides better technology for existing customers and applications, but also significantly expands the possible uses of these designs. By offering:

• lower cost, • improved measurement accuracy,
• true "hands-off" operation, and
• more robust and user selectable wireless communications methods,

These products offer a cost effective and timely solution to a multitude of here-to-fore "hard-wired" applications.

In a nutshell, telemetry can encompass the entire process by which a measurement value is obtained, possibly quantified, qualified, or processed in other ways, and then transmitted via some mechanism to the "end user" for final processing or response actions. The "end user" in this case may be a human for manual interpretation and analysis or, more often, a machine for automated processing functions. The phrase "Digital Telemetry" simply specifies that the methodology utilized to obtain, process, and transmit the measurement data incorporates digital techniques, a highly efficient and more reliable means of handling data processing and transmission.

Typical measurements which telemetry can provide access to include:

temperature, speed, direction, motion,
location, distance, displacement, strain,
torque, energy, power, pressure,
humidity, density, ...

Furthermore, many applications require access to multiple and/or a variety of these measurements at the same time to allow for meaningful interpretation of the data. One of the significant benefits of digital telemetry is that it can be easily and readily customized to the end user requirements, allowing various measurement (or sensor) inputs to be sampled nearly simultaneously, cross correlated if need be, and presented as parallel analog or digital outputs to the end user. For certain implementations, the sampling and correlation algorithms can be configured in real-time, providing for adaptive measurement and response requirements.

1.3 Product Description

Versions of the Series 500e products are available in the versatile 915 MHz ISM frequency band, the 868 MHz European band, or the 433 MHz band. Consult the factory for alternate frequency bands. Based on the exact end-user requirements, an optimized product choice can be found to provide extremely robust wireless communications, even in indoor environments where building structures may obstruct a direct line-of-site transmission or in contaminated environments such as inside engine compartments.

The following diagram presents a simplified overview of the latest generation SRI/PMD Wireless Link system.

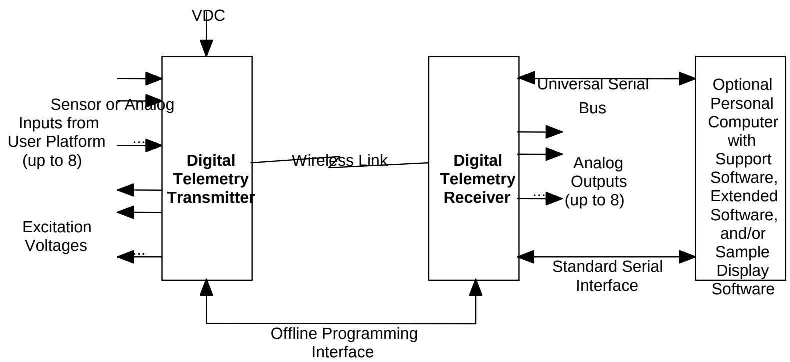


Figure 1-2 System Overview

As shown, the system consists of the following major elements:

1) The Digital Telemetry Transmitter is a miniaturized and ruggedized radio frequency (RF) transmitter providing the interface circuitry to select and sample up to 8 sensor or analog inputs, condition the signals and transmit the detected readings in digital format over the Wireless Link.

2) The Digital Telemetry Receiver provides the logic to recover the transmitted data, detect and account for errors which might have been introduced via the transmission path, and output error free and digitally compensated samples of the sensor data in both analog and digital output formats. The receive system also supports an optional interface to a standard personal computer for status, control, and analysis functions.

3) The optional Personal Computer can be utilized to execute a support software package. The support software provides for:

   a) Monitoring general system health, communications performance, and sensor gain/offset calibration functions.
   b) Editing of sensor definitions including type, sampling frequency, filtering, measurement ranges, and so forth.
   c) Sample capture/display software for storing measurement data to the PC disk or displaying real time data in graphical/scope type formats.

The transmitter circuitry of the series is typically packaged in a hermetically sealed compound, contained within a ruggedized housing measuring 2 x 1.5 x 0.8 inches. The design also readily supports custom packaging for unique end user applications.

The unit is designed to operate under FCC Part 15.249 in DTS (digital modulation) mode.

The receiver is offered as a stand-alone bench top enclosure configuration. Alternate packaging configurations, such as a 19” rack mountable chassis, are available on a custom basis.

1.4 Model Numbers

Each version of the Series 500e is assigned a model number. Transmitters for this series are always designated as an ST-5xx where xx defines the exact model type. Similarly, receivers are designated as an SR-5xx. The entire system, including both the transmitter and receiver, are referred to as the SS-5xx. The following tables provide an overview of each of the available standard models for this series.

Table 1-1 Series Part Number Descriptions

Part Number Sequence : S a - 5 b c – d – ef - g

S - Common designation for SRI/PMD Wireless Link product.

a Component type designator as follows:
- T Transmitter module only
- R Receiver module only
- S Complete telemetry system (both transmitter and receiver)

5 Series product designator

b Communications options as follows:
- 4 915MHz ISM wideband version
- 5 868MHz ISM wideband version
- 8 433MHz ISM wideband version

c Packaging and/or type designator:
- 0e Standard package

d Number of sensor channels:
- 1, 4, or 8

e Receiver Power Supply Line Voltage
- D 120VAC/60Hz (standard)
- I 220-250VAC/47-63Hz

f Transmitter Power Input Voltage Range
- L 1 to 4VDC external (consult Factory)
- H 7 to 14VDC external (standard)

g Transmitter Temperature Calibration Range
- N 0° to 85°C
- X -32° to 85°C

1.5 Technical Specifications

A summary of the technical specifications and characteristics of the referenced telemetry equipment is presented in the paragraphs that follow.

1.5.1 Transmitter Specifications

The specifications indicated in the following table apply to the Digital Telemetry Transmitter.

Table 1-2 Transmitter Specifications

PARAMETER	SPECIFICATION
OUTPUT FREQUENCIES	ST-540 – 905 to 925 MHz in 5 MHz Steps ST-550 – 868 to 870 MHz in 500 KHz Steps ST-580 – 433 to 435 MHz in 500 KHz Steps
MODULATION FORMATS	Frequency Shift Keyed (FSK)
NUMBER OF SENSOR INPUTS	Up to 8
INPUT SENSOR LEVEL RANGE	Programmable within the range of ±625 uVDC to ±45 mVDC differential, unipolar or bipolar.
SENSOR EXCITATION	Optional sensor excitation voltage driven during sensor sampling period. Excitation voltage is 5 VDC.
TYPICAL SENSOR TYPES	Strain Gages (1 to 4 active arms) Type J/K Thermocouples Thermistor Bridges Accelerometers Pressure Transducers Generic Analog Voltages Custom
NUMBER OF ANALOG INPUTS	Up to 4 single ended or 2 differential, replacing sensor channels 1 through 4 respectively
INPUT ANALOG LEVEL RANGE	Programmable within the range of: ±45 mVDC to ±2.5 VDC differential, 0-50 mVDC to 0-5 VDC single ended.
MEASUREMENT RESOLUTION	16, 12, or 8 bit
SAMPLING RATE	Up to 17+ K samples per second
TTL INPUTS	Up to 3
TTL SAMPLING RATES	Up to 250+ sps
OPERATIONAL MODES	Continuous sampling Burst Transmit/Sleep Mode
EMISSION DESIGNATOR/TYPE	508K0F1D, DTS operation under 15.249
INPUT POWER	+7VDC to +14 VDC Custom
POWER CONSUMPTION	<70 mA of 5VDC excluding sensor loads on excitation. <2 mA of 5VDC during sleep period. 80% power conversion efficiency typical.
OPERATING TEMPERATURE	Industrial 0 to +85°C Extended -35 to +85°C
ACCELERATION	5,000 g Rotational Typical

1.5.2 Receiver Specifications

The specifications indicated in the following table apply to the Digital Telemetry Receiver.

Table 1-3 Receiver Specifications

PARAMETER	SPECIFICATION
RECEIVE/DEMODULATION CAPABILITIES	Compatible with transmitter waveform
NUMBER OF ANALOG OUTPUTS	Up to 8
	0 to 5 VDC, ±5 VDC, 0 to 10 VDC or ±10 VDC
ANALOG OUTPUT RESOLUTION	16 bits
DIGITAL OUTPUT	Streaming output mode available on USB port
	Samples output mode available on serial port
ERROR DETECTION	Data checksum capable of detecting error rates of up to 1 in 100
DATA COMPENSATION	Transmitter gain/offset temperature drift dynamically compensated for by RX.
	Dynamic compensation for sensor drift due to temperature, such as thermocouples.
	Factory calibration of above characteristics provides for better than 0.5% measurement accuracy, typical.
DATA PROCESSING OPTIONS	Infinite Impulse Response or Sample Averaging (K = 2, 4, 8, 16, 32, 64, 128 or 256)
	Samples in error output inhibit/enable
	Custom
INPUT POWER	+12 VDC (AC/DC Wall Plug Standard)
POWER CONSUMPTION	< 12 Watt typical
PACKAGING OPTIONS	9” x 4” x 1.5” Bench Top Enclosure
	Custom
OPERATING TEMPERATURE	Industrial - 0 to +85°C

SECTION 2 DIGITAL TELEMETRY SYSTEM DESCRIPTION

Wireless Link Digital Telemetry Systems are accomplished with an optimum mix of analog and digital circuitry in order to provide a low-cost, flexible system capable of handling a wide variety of telemetry requirements. Utilization of state-of-the-art design technology combined with a latest generation micro-controller allows the design to meet requirements of a high performance, high reliability communications link for transferring measurement data while still maintaining a highly cost-effective price.

2.1 Transmitter Details

The following figure presents a more detailed overview of a Digital Telemetry Transmitter.

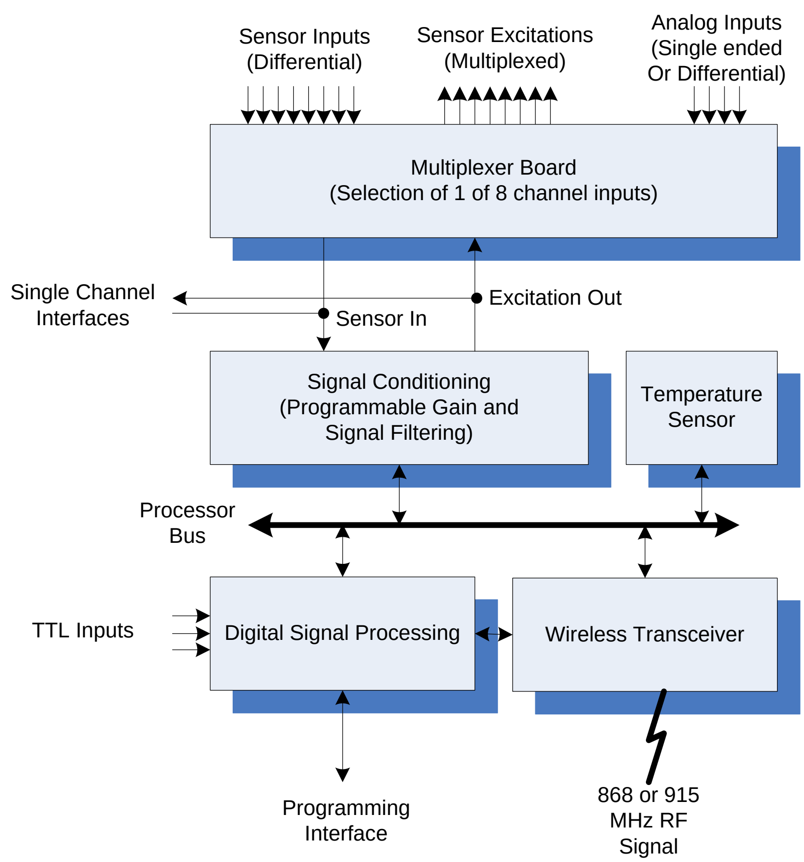


Figure 2-1 Transmitter Block Diagram

At the heart of the transmitter design is a high-speed processor with analog to digital conversion capabilities. Execution processing of the processing logic is determined via configuration data stored within electronically erasable programmable read-only-memory (EEPROM). The configuration tables contained within this memory dictates operational characteristics such as the number of input sensor channels, the type of each input, output RF frequency selection, and so forth.

EEPROM memory space within the transmitter, including both configuration tables and executable program space, can be reprogrammed via the external programming interface to the Digital Telemetry Receiver. As such, all significant operational characteristics of the Transmitter can be readily modified or customized, even for fielded units.

For transmitters limited to a single input sensor channel, onboard circuitry is available to process the input measurement data through signal conditioning circuitry. When the number of input sensor channels exceeds one (1), an optional multiplexer card is provided. This card includes up to an eight (8) to one (1) multiplexer to support connecting multiple sensor channels to the single input of the main board. All sensor-input logic also includes associated excitation voltage output circuitry that may be utilized to drive sensors requiring an input voltage, such as balanced bridges.

Operation of the signal conditioning logic is controlled via the processor to establish appropriate gain settings. This powerful feature of the design allows the same circuitry to be reprogrammed to support a wide variety of potential input sensor types. Furthermore, because the sensor type information is also included in the EEPROM configuration tables, these settings can be changed for various user requirements on a sensor by sensor basis.

Series 500e systems also include programmable filtering. This allows for configurable settings of the sensor input filtering based on sample rates through the ADC as well as signal multiplexing requirements for multiple channel systems.

In addition to sensor inputs, multiple channel systems also include analog channel inputs. These four (4) inputs are typically pre-conditioned signals ranging up to 0-5 VDC for single ended inputs. Alternatively, the analog inputs can be paired to provide two (2) differential inputs with ranges up to ±2.5 VDC. When activated, these channels replace the corresponding channels of sensor inputs.

Data transmission across the wireless link is accomplished with dual data channels known as the primary and the background channels respectively. The primary data channel is allocated in excess of 90% of the transmit bandwidth and includes the input sensor data measurement information. The background channel is relatively low rate and contains information required for receive side frame synchronization and error detection.

Another key feature to the design is that the background channel is also utilized to transmit data pertaining to the current transmitter operating temperature. This information is utilized to support real-time temperature based compensation of sensor data samples through the receive chain. The background channel also includes lower rate sampling of discrete TTL inputs.

Series 500e systems support transmit frame formats compatible with either 16-bit, 12-bit or 8-bit ADC sensor sampling. This programmable feature provides for higher sampling rates when in 8-bit mode, while supporting enhanced measurement resolution at slightly lower sampling rates when in 12 bit or 16 bit modes.

2.2 Receiver Details

Figure 2-2 presents a more detailed overview of the Series 500e Digital Telemetry Receivers.

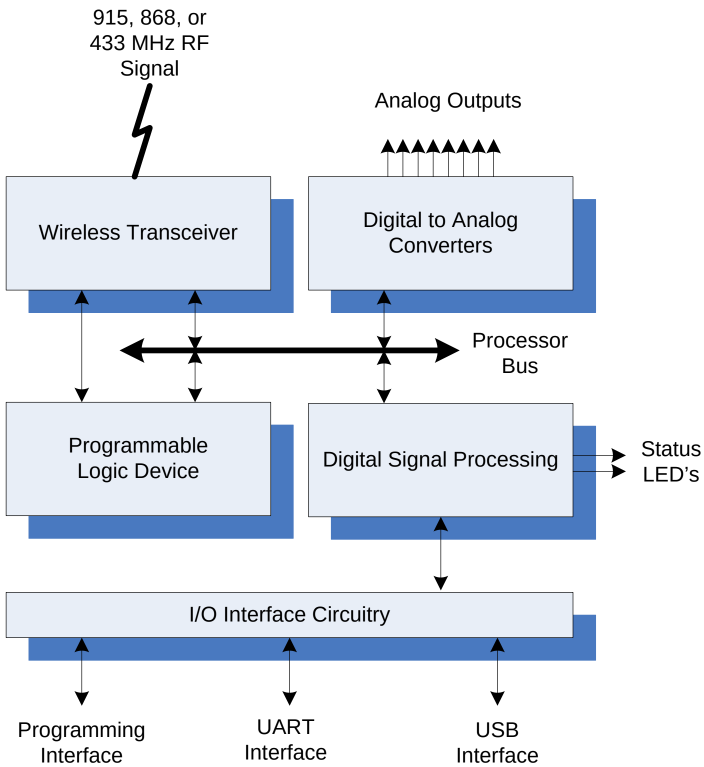


Figure 2-2 Receiver Block Diagram

The receiver incorporates a high-speed digital signal processor to provide for full real time processing of incoming measurement samples. Logic within the processor interfaces with the Wireless Link receiver via a high speed programmable logic device (PLD) to recover bit, byte, word, and frame synchronization with the incoming data stream. The process of achieving this level of synchronization is known as the acquisition process and is in-turn reflected on the front panel "SYNC" indicator. Once frame synchronization has been achieved, the "SYNC" indicator is illuminated.

After proper acquisition, the processor begins performing error detection functions via embedded checksums within the incoming data. All received data samples during a frame detected to have an error within it are flagged as error samples.

The data samples are processed through configurable data processing prior to outputting the data to analog and digital output channels. Data processing, in this case, may include standard gain adjustment multiplication, offset addition, transmitter temperature dependent data compensation, as well as alternate data averaging and or filtering functions.

Program execution of the processor is directed via code and configuration tables stored in EEPROM memory space resident within the device. The contents of this memory space can be loaded via the remote control RS-232 interface to a standard personal computer. This feature allows fielded Digital Telemetry Receiver systems to be upgraded to new releases of executable firmware, or modified to support new transmitters or alter the processing characteristics of existing transmitters.

The minimum configuration of a Digital Telemetry Receiver supports eight (8) analog output channels. These onboard channels, designated as Analog Channels 1 through 8, support 16 bits of data resolution and can be programmed to cover an entire output voltage range of -10 to +10 VDC.

2.3 System Data Processing Overview

The Series 500e products can be configured to process input sensor measurements anywhere within the range of 0 to 5VDC. Typically, instrumentation sensors do not utilize this entire measurement range. For instance, a single active arm, 350Ω strain gage with 5V excitation will only produce a ±1.25 millivolt DC (mVDC) signal for strain levels of ±500 microstrain (uE). Obviously, these signal levels are not overly useful to most end-user processing equipment.

To create a useful signal, the product line provides programmable gain, offset, and data filtering functions on the input sensor signals. The following sections describe this processing in more detail.

2.3.1 Gain and Offset Processing

The Digital Telemetry process applies various stages of gain to the input signal such that the configured measurement input levels of the sensor end up corresponding to a specified output analog voltage range (e.g., -10 to +10VDC). For the strain gage example, this implies a gain of x 8000 in order to translate -1.25 mVDC to -10 VDC and +1.25 mVDC to +10 VDC.

A gain of this magnitude is never 100% accurate. Furthermore, small errors introduced by the exact mechanical installation of the sensor, ground differentials, cabling losses, or transmitter sensor input to digital measurement processing circuitry end up causing additional errors. These errors are reflected as incorrect gain or variations in offset (i.e., where a 0 reading does not correspond to a 0 output).

In order to compensate for these factors, the Digital Telemetry System provides programmable gain and offset controls that are invoked at various stages within the system. The following figure provides a very simplistic overview of this process.

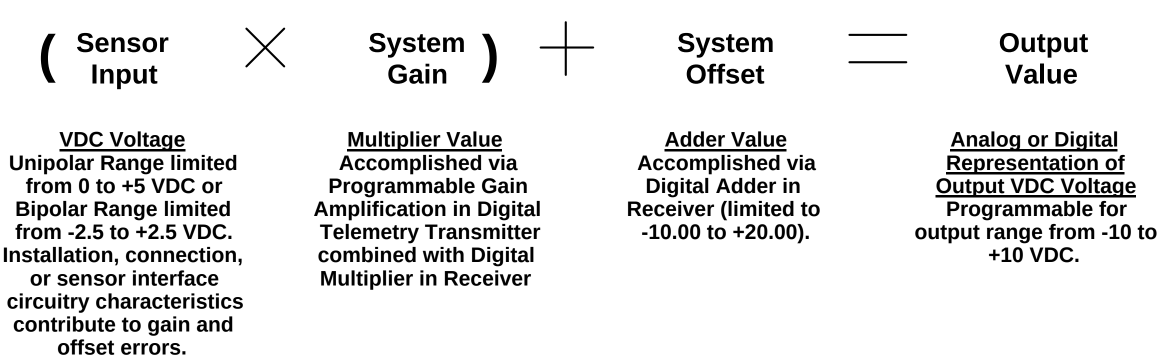


Figure 2-3 Data Processing Overview

The system gain and offset values are set to not only translate the input measurement signal range to the desired analog output voltage range, but are also utilized to account for the gain and offset errors discussed above.

The following figure presents a more detailed view of the entire signal processing of the Digital Telemetry System.

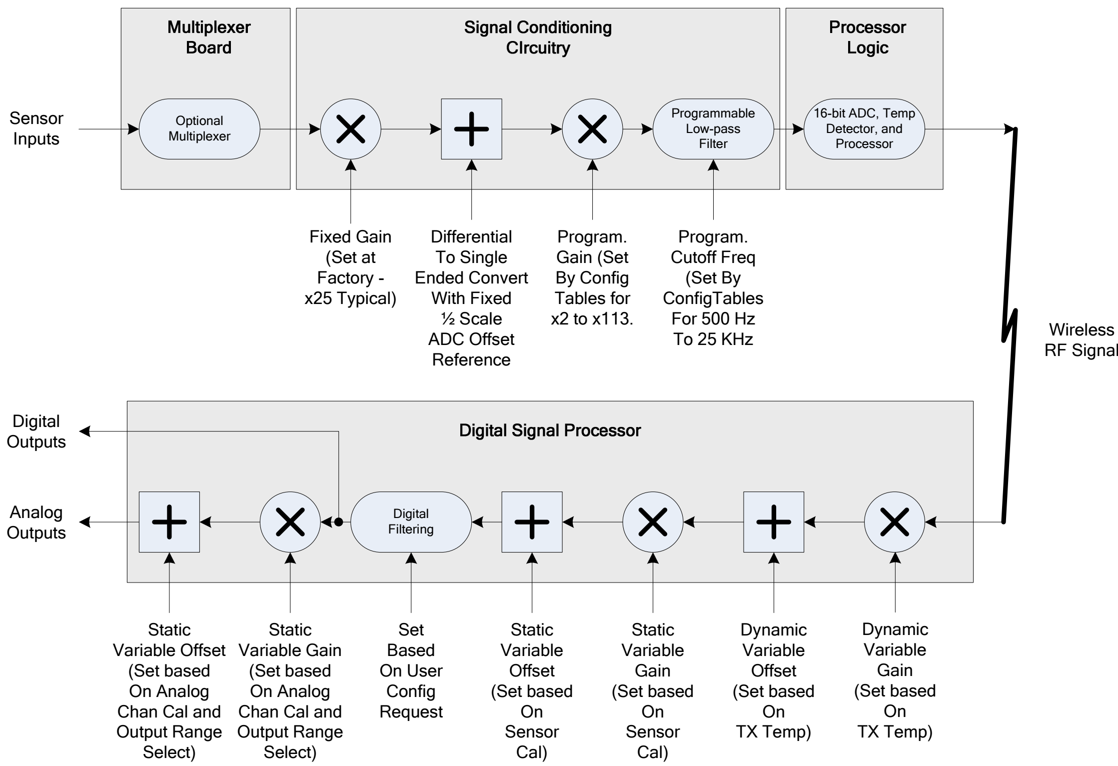


Figure 2-4 Data Processing Details

Normal sensor inputs are processed through three (3) stages of conditioning prior to digitization. All input signals through this path are treated as differential inputs. As such, for sensor inputs with a grounded negative lead, the sensor ground must be left floating with respect to the transmitter ground.

The first stage applies a fixed gain, typically set for x25. On a custom basis, this fixed gain may range anywhere from x1 to x50 based on end user requirements. The fixed gain is accomplished with a low noise, differential instrumentation amplifier, thus providing enhanced conditioning performance through the transmit system, including high common mode rejection.

The next stage establishes the offset to the input signal, bringing it to the center point of the analog to digital converter (ADC) range. This process also converts the differential signal to its single ended equivalent.

The next process provides a programmable gain stage. With a gain varying from x2 to x113, this stage provides the final amplification to the required input range for the ADC. Typically, transmit side gain is limited to cover 90% of the ADC range, which precludes sensor gain and offset errors from saturating the ADC.

All programmable logic on the transmit side may change on a per channel basis for multi-sensor channel systems. This allows for freely mixing sensor types or measurement ranges with the same transmitter product. However, these settings are classified as static in that they are established by the PC control software and downloaded into the transmitters EEPROM space. While the transmit logic will change these settings for each channel, they are not changed in response to any other dynamic conditions, such as transmitter temperature.

The receive side provides the final gain and offset processing of the system. This gain/offset is not only utilized to convert the signal to the selected output range of the digital to analog conversion (DAC) for analog channels (0-5, 0-10, ±5, or ±10 VDC), but also accounts for gain/offset errors of the input sensor signal, as well as dynamic characteristics of the transmitter system.

The first part of the processing through the receive side is dependent upon the transmitter operational temperature at the time of the measurement. The transmitter logic monitors its own temperature and periodically reports this value across the wireless link. This allows the receive side to dynamically compensate for gain/offset variations of the transmitter due to temperature. A highly accurate factory calibration of each transmitter product across temperature provides the means for precise measurements in the field.

For sensor data which varies with temperature (e.g., thermocouples), the dynamic gain/offset compensation feature is utilized to modify the receiver gain multiplier and offset adder to compensate for these real time variations. Thus, the system automatically provides the 0 reference junction for these types of devices.

This dynamic gain/offset processing is followed by additional static logic which is controlled by PC software sensor calibration processing logic. This feature is utilized to correct installation specific errors of the individual sensors. For example, an offset error in the installation of a strain gage would be compensated for by this level of static gain/offset corrections.

Digital samples output from the receiver via either the RS-232 serial or the USB port are limited to these corrections only. Digital samples are always represented as 16 bit signed outputs and thus range from -32768 to +32767. The -32768 will always correlate to the minimum configured measurement value for the sensor, while +32767 will correlate to the maximum configured measurement value.

A final stage of static corrections is applied to account for analog channel output errors. This process is controlled by analog channel calibration logic of the PC control software combined with the operator selected output range of the channel (i.e. 0-5V, ±5 V, 0-10 V, or ±10 V). This mechanism provides for highly accurate outputs for either digital or analog sample formats.

Analog input signals to the transmitter (i.e., 0-5 VDC single ended or ±2.5 VDC differential signals as opposed to <±45 mV sensor inputs) are processed directly into the ADC through a voltage divider, bypassing the entire discrete signal conditioning circuitry. Since these signals are not buffered, they exhibit high source impedance and typically require an external driver. The analog input signals can be grouped to form a pair of differential input analog inputs through the ADC. After digitization, all remaining gain/offset logic through the receive logic is identical to normal sensor inputs.

2.3.2 Data Filtering

In addition to offset and gain processing, the transmit logic supports low pass filtering which typically provides anti-aliasing protection through the digital sampling process. However, for multiplexed sensor system, the cutoff frequency through the filter must be increased to provide for the required switching speed of the multiplexer, thus allowing some minimal amount of aliasing be passed. The PC support software automatically sets the cut-off frequency of this filter based on the requested data rate and channel configuration of the transmitter.

The receive side processing supports digital data filtering of the measurement samples. Filtering may be utilized to eliminate high frequency noise from the sensor inputs which may be present due to power supply noise or other equipment operating near the telemetry system.

The first type of filter which may be applied is known as an “Infinite Impulse Response” (or IIR) filter, since any given input sample affects all future outputs. The formula for this filter is:

```
OUT(n) = (K x IN(n)) + ((1-K) x OUT(n-1))
```

In this formula, OUT(n) implies the output value to the analog channel for time period “n”, while IN(n) implies the new measurement sample for the analog channel during time period “n”. K is a simple constant that may be programmed to be equal to 1/2 to 1/256 in denominator multiples of 2.

The second type of filter which may be applied is known as an averaging filter. In this case, multiple samples are accumulated and then the average of the accumulation is output after a fixed sample period. The sample period may be set to 2 to 256 samples in multiples of 2.

2.3.3 Sample Rate and Throughput Delays

The sampling rate of the sensor channels inputs is dependent upon:

a) Wireless Link Transmit Data Rate
b) Configured Resolution of ADC Samples (i.e., 8, 12, or 16)
c) Number of Active Sensor Channels

These same factors affect the fixed system throughput delay (i.e. time from sensor sampling through corresponding output on the receivers digital or analog ports. The following table summarizes these timing characteristics of the Digital Telemetry System.

Table 2-1 Sample Rate and Throughput Delay Characteristics

TX Data Rate (bps)	ADC Resolution (bits)	# of Active Sensor Channels	Sensor Sample Rate (Hz)	Throughput Delay (approx. msec)
152300	8	1	16922	3.90
152300	8	2	8461	4.02
152300	8	4	4231	4.25
152300	8	8	2115	4.73
152300	12	1	9519	3.57
152300	12	2	4759	3.78
152300	12	4	2380	4.20
152300	12	8	1190	5.04
152300	16	1	8461	4.02
152300	16	2	4231	4.25
152300	16	4	2115	4.73
152300	16	8	1058	5.67
76150	8	1	8461	7.80
76150	8	2	4231	8.04
76150	8	4	2115	8.51
76150	8	8	1058	9.46
76150	12	1	4759	7.14
76150	12	2	2380	7.56
76150	12	4	1190	8.40
76150	12	8	595	10.09
76150	16	1	4231	8.04
76150	16	2	2115	8.51
76150	16	4	1058	9.46
76150	16	8	529	11.35
38075	8	1	4231	15.60
38075	8	2	2115	16.07
38075	8	4	1058	17.02
38075	8	8	529	18.91
38075	12	1	2380	14.29
38075	12	2	1190	15.13
38075	12	4	595	16.81
38075	12	8	297	20.17
38075	16	1	2115	16.07
38075	16	2	1058	17.02
38075	16	4	529	18.91
38075	16	8	264	22.69
19037.5	8	1	2115	31.20
19037.5	8	2	1058	32.15
19037.5	8	4	529	34.04
19037.5	8	8	264	37.82
19037.5	12	1	1190	28.58
19037.5	12	2	595	30.26

TX Data Rate (bps)	ADC Resolution (bits)	# of Active Sensor Channels	Sensor Sample Rate (Hz)	Throughput Delay (approx. msec)
19037.5	12	4	297	33.62
19037.5	12	8	149	40.34
19037.5	16	1	1058	32.15
19037.5	16	2	529	34.04
19037.5	16	4	264	37.82
19037.5	16	8	132	45.38

2.4 Digital Telemetry Control Software

Each Digital Telemetry System is delivered with Control Software compatible with running on a standard Personal Computer (PC) operating under the Windows operating system. This software provides a number of critical functions for the system, including the following:

- Communications Analysis Functions
  - On-line monitoring of communications performance
  - Analysis of communications frequencies

- System Calibration
  - Modifications to system gain and offset settings
  - Calibration of output analog channels

- Table Control Functions
  - Edit functions of currently defined Digital Telemetry Systems
  - Download functions to update or restore EEPROM memory space

(this page intentionally blank)

SECTION 3 RECEIVING, INSPECTION AND INSTALLATION

3.1 Unloading and Unpacking

NOTE

If shipping carton is damaged upon receipt, request carrier's agent be present during unpacking and inspection of the system.

Upon receipt of the equipment, inspect the shipping container for damage. If the container or the cushioning material is found damaged, they should be kept until the contents of the shipment have been verified for completeness and the equipment has been inspected for mechanical and electrical defects. If the contents are incomplete or if there is a mechanical or electrical defect, please notify:

SRI/PMD
751 North Drive
Melbourne, Florida 32934

3.2 Receiving Documentation

Each Digital Telemetry System is shipped with a copy of this manual and a packing slip. The packing slip should be carefully checked against the contents of the shipping container.

3.3 Installation and Connection Requirements

Users should be aware that the Digital Telemetry Receiver and the Digital Telemetry Transmitter contain sensitive electronic components. Proper "Electrostatic Discharge" (ESD) handling procedures should be utilized for this equipment as with any other electronic apparatus.

The transmitter may be delivered in a variety of standard or custom molds based on the actual end application of the telemetry system. The available connections and pin locations will vary based on the packaging style and purchased configuration. The receiver is typically delivered as a stand-alone bench or desktop enclosure

3.4 Transmitter Interfaces

3.4.1 Signal Definitions and Characteristics

This section describes the standard connector interfaces of the Digital Telemetry Transmitter, including the definition and associated requirements of all signals.

Table 3-1 Transmitter Signal Definitions And Characteristics

SIGNAL	DESCRIPTION
PROGRAMMING INTERFACE SIGNALS	
PROG_VCC	Alternate 5 VDC power supplied to Transmitter when it is being reprogrammed from the Receiver
PROG_GND	Ground signal utilized with the Programming Cable
PROG_RESET*	Micro-controller reset line utilized with the Programming Cable
PROG_DATA	Data line utilized to reprogram EEPROM space of the Transmitter
PROG_CLOCK	Clock line utilized to reprogram EEPROM space of the Transmitter
PROG_ENAB	Enable line utilized to program EEPROM space of the Transmitter
COMMON SIGNALS	
PRIM_VCC	Primary VDC power for the transmitter during normal operation. The primary VDC is typically 6 to 14 VDC, or other custom versions. Excessively noisy characteristics on this input line may be reflected in poor measurement accuracy results. The primary power source must be able to support a minimum 60 mA load on this input line.
GND	Primary ground for the transmitter. Excessively noisy ground characteristics on an input ground line may be reflected in poor measurement accuracy results.
EXC+COM	Excitation output +V common. Output will always be at the positive excitation voltage (typically +5 VDC) and should be connected to any sensor channel requiring excitation voltages. The output should be common to all sensors requiring this capability. Each sensor on this line may exhibit a minimum load impedance of 150 Ω. Note additional current draw on the primary VCC due to sensor utilization of this output is not included in the <60 mA max current spec.
NC	No connection
SENSOR/MEASUREMENT INPUT INTERFACE SIGNALS	
SEN+x	Positive sensor signal input for Channel X where X is valid for the populated number of available Sensor Channels (1 through 8 or simply “COM” for a single channel system). This input should provide the positive side of the measurement value for differential sensor signals. Absolute maximum voltage rating on this input is 0 to 4.0 VDC. Maximum valid signal measurement range depends on selected configuration and may be varied via configuration tables. A typical maximum signal measurement range is ±50 mVDC differential.
SEN-x	Negative sensor signal input for Channel X where X is valid for the populated number of available Sensor Channels (1 through 8 or simply “COM” for a single channel system). This input should provide the negative side of the measurement value for differential signals. Other signal characteristics and restrictions for this input are identical to SIG+X.
EXC-x	Negative excitation output voltage for Channel X where X is valid for the populated number of available Sensor Channels (1 through 8 or simply “COM” for a single channel system). This output will be equal to EXC+COM when the channel is not being sampled or equal to Gnd during an active measurement period. This output should only be connected to the corresponding sensor providing the SIG+X and SIG-X inputs.

ANLG+x	Positive analog signal input for Channel X where X is valid for 1 through 4 on Single Ended Analog inputs or 1 through 2 for Differential Analog Inputs. Analog inputs are only available on multi-channel system configurations. This input should provide the positive side of the measurement value for differential analog signals. Absolute maximum voltage rating on this input is 0 to 6.0 VDC. See important notes below for the use of Analog input channels.
ANLG-x	Negative analog signal input for Channel X where X is valid for 1 through 2 for Differential Analog inputs. Analog inputs are only available on multi-channel system configurations. This input should provide the negative side of the measurement value for differential analog signals. Absolute maximum voltage rating on this input is 0 to 6.0 VDC. See important notes below for the use of Analog input channels.
TTLx	TTL signal inputs for Channel X where X is valid for 1 through 3. These inputs are sampled as a High (> 2.0 VDC) or a Low (< 0.8 VDC) at a low periodic sampling rate.
SHUNT+	Positive side of shunt resistor connection for bridge auto-cal capabilities.
SHUNT-	Negative side of shunt resistor connector for bridge auto-cal capabilities.

Important notes on these interfaces are as follows:

1) Analog inputs supporting 0 to 5 VDC levels are non-buffered and require ***low source impedance.*** Sensor inputs are immediately buffered through a low noise instrumentation amp and do not exhibit this requirement.
2) When Analog Input Channel 1 is configured as active, whether as a differential or single ended signal, Sensor Input Channel 1 will not be sampled. The same applies for Analog Input Channel 2 with respect to Sensor Input Channel 2.
3) If Analog Input Channel 3 is configured as active for single ended input, Sensor Input Channel 3 will not be sampled. The same applies for Analog Input Channel 4 with respect to Sensor Input Channel 4.
4) If Analog Input Channel 1 is configured as a differential input, Analog Input Channel 4 is utilized as the negative input signal and thus is not available. The same applies for Analog Input Channel 2 with respect to Analog Input Channel 3.
5) If Analog Input Channel 4 is being used as the negative input side for a differential measurement on Analog Input Channel 1, Sensor Input Channel 4 is still available for sampling. The same applies for Analog Input Channel 3 with respect to Analog Input Channel 2 and Sensor Input Channel 3.
6) For multi-channel configurations, the SEN+COM and SEN-COM signals ***should not be used***. Connecting these signals may interfere with the performance of the other sensor input channels.

3.4.2 Connector Definitions

The following figure depicts the standard transmitter housing and its connectors and approximate locations. The lowest and highest numbered pin assignments are noted on the drawing. Note that not all connectors or pins are used and certain connections should not be used based on the delivered configuration as outlined above.

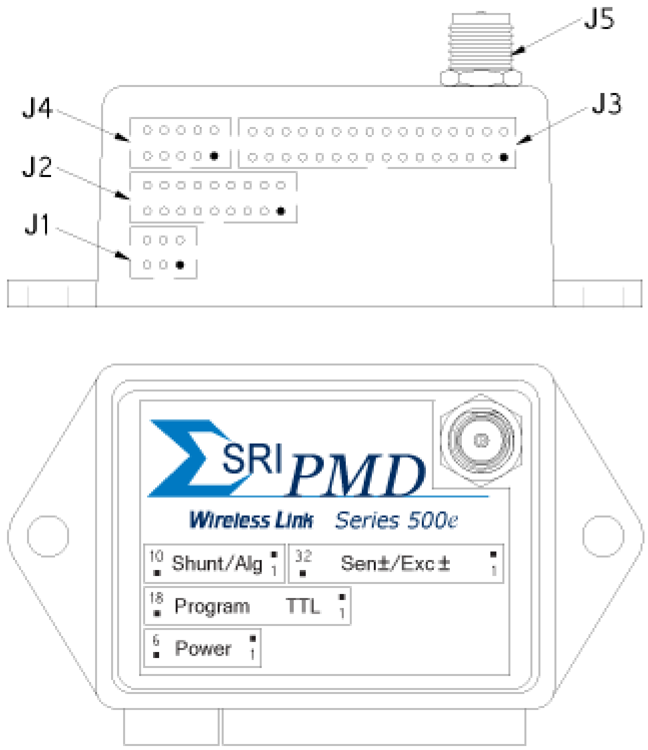


Figure 3-1 Series 500e Connector Locations

3.4.2.1 Input Power Connector

The following tables present the pin assignments for the Input Power Connector (J1). The mating connector for this interface is a DF11-6DS-2 from Hirose Electric Group.

Table 3-2 Power Connector Pin Assignments

Pin	Signal	Pin	Signal
1	GND	2	PRIM_VCC
3	GND	4	PRIM_VCC
5	NC	6	NC

3.4.2.3 Programming and Single Channel Connector

The following tables present the pin assignments for the Programming and Single Channel Connector (J2). The mating connector for this interface is a DF11-18DS-2 from Hirose Electric Group.

Table 3-3 Program/Single Channel Connector Pin Assignments

Pin	Signal	Pin	Signal
1	EXC+COM	2	SEN+COM
3	EXC-COM	4	SEN-COM
5	TTL1	6	TTL2
7	TTL3	8	GND
9	NC	10	NC
11	PROG_VCC	12	PROG_DATA
13	PROG_RESET*	14	GND
15	NC	16	PROG_CLOCK
17	PROG_ENAB	18	NC

3.4.2.4 Multi-Channel Sensor Connector

The following tables present the pin assignments for the Multi-Channel Sensor Connector (J3). The mating connector for this interface is a DF11-32DS-2 from Hirose Electric Group.

Table 3-4 Sensor Channel Pin Assignments

Pin	Signal	Pin	Signal
1	SEN+1	2	SEN-1
3	EXC+COM	4	EXC-1
5	SEN+2	6	SEN-2
7	EXC+COM	8	EXC-2
9	SEN+3	10	SEN-3
11	EXC+COM	12	EXC-3
13	SEN+4	14	SEN-4
15	EXC+COM	16	EXC-4
17	SEN+5	18	SEN-5
19	EXC+COM	20	EXC-5
21	SEN+6	22	SEN-6
23	EXC+COM	24	EXC-6
25	SEN+7	26	SEN-7
27	EXC+COM	28	EXC-7
29	SEN+8	30	SEN-8
31	EXC+COM	32	EXC-8

3.4.2.5 Analog Channel Connector

The following tables present the pin assignments for the Analog Channel Connector (J3). The mating connector for this interface is a DF11-10DS-2 from Hirose Electric Group.

Table 3-5 Analog Channel Pin Assignments

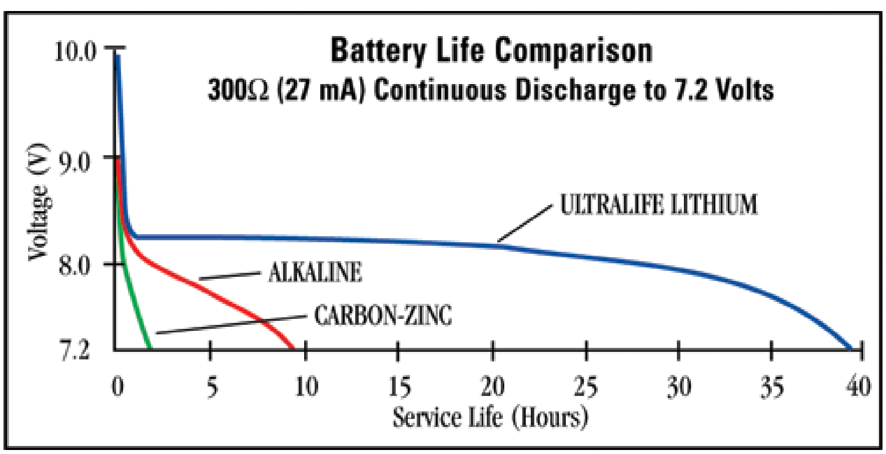
Pin	Signal	Pin	Signal
1	GND	2	ANLG+3 -or- ANLG-2
3	GND	4	ANLG+1
5	GND	6	ANLG+4 -or- ANLG-1
7	GND	8	ANLG+2
9	SHUNT-	10	SHUNT+

3.4.3 Transmitter Power Recommendations

Series 500e transmitters are powered by a DC voltage whose range is determined at time of order. Typically systems are designed for an input supply of 6 to 14 VDC, although custom interfaces can be accommodated.

Although designed for low-power draw, extended operation, the choice of power source is important to the satisfactory operation of the Series 500 Wireless Link systems. In the standard mode of operation an ST-500 unit is constantly transmitting a signal and placing a load on the power source, most often a battery. The actual load will depend on the bit rate and transmit power level settings. Power draw will also increase if excitation power is provided to any attached sensors. Each channels Excitation voltage output (EXC+/EXC-) is switched and only applied during the actual measurement of the channel, however current draw of any attached sensors must be taken into account when calculating total current draw and battery life.

SRI/PMD recommends the use of Lithium or similar primary (non-rechargeable) cells for maximum life. Secondary (rechargeable) batteries may be used however they are usually a lower capacity than primary cells, thus limiting transmission time. Alkaline and Carbon/Zinc batteries are not recommended for operation longer than a few hours due to their quick discharge under load.



(figure courtesy of the Ultralife Batteries, Inc.)

Figure 3-2 Battery Life Comparison

A typical series 500e transmitter unit will draw approximately 70 mA with a 5VDC regulated supply or 35 mA from a 9 V battery (~80% efficiency). A common Li 9 V cell might provide 1000 mAH, operating the transmitter for in excess of 28 hours, excluding sensor load.

Consult factory for additional information and recommendations regarding transmitter power.

3.4.4 Transmitter Antenna Recommendations

Series 500e transmitters are applied in a wide variety of applications. Specific installation issues may affect the use or choice of a transmit antenna. Standard ST-500e transmitters include reverse polarized (RP) SMA connections for connecting external antennas. The system is typically shipped with a quarter-wave stub antenna suitable for most applications.

Typical transmission paths where the transmitter and receiver are separated by 50-100 feet will often not require an additional antenna. Use over longer distances may require a half-wave balanced or similar antenna depending on the distance to be covered, data rate and power level to be used, and local structural and/or microwave interference. Consult factory for additional information and recommendations regarding antenna considerations.

3.5 Transmit RP-SMA Connector Orientation Options

Series 500e Transmitters include an RF Out, RP-SMA jack connector for transmit power output. An antenna is typically attached to this connector. The standard position has the connector oriented "up" related to the base of the transmitter. For low-profile or other applications, the transmitter can be ordered with the RF Out connector positioned in either of the two sides of the case. This option is noted by additional options in the extended part number as follows:

(-RFZ-) Standard orientation, not explicitly included in part number
-RFX- Connector oriented in the "X" direction
-RFY- Connector oriented in the "Z" direction

Refer to Figure 3-3 for position references.

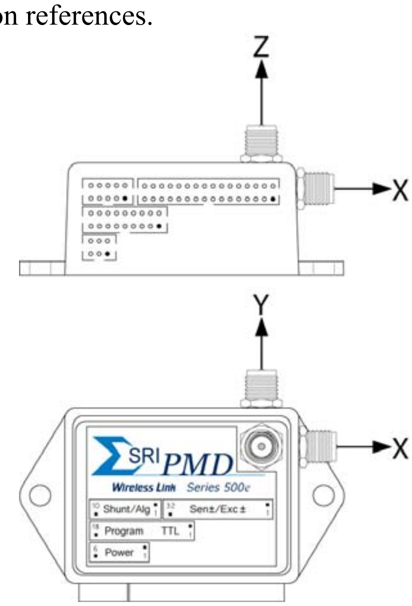


Figure 3-3 Antenna Orientation Options

3.6 Receiver Indicators, Controls, and Connector Interfaces

This section describes the status, control, and connector interfaces of the Digital Telemetry Receiver, including the types of connectors used and the definition of the signals associated with each. In general, these connectors are identical for all models of the Series 500e Receivers, although the connector locations may vary.

3.6.1 Antenna Input

The Antenna input is a bulkhead mount type SMA jack located on the rear panel and labeled "ANT". The Digital Telemetry Receiver is typically provided with a small antenna.

Characteristics of this input signal are as indicated in the following table.

Table 3-6 RF Input Characteristics

INPUT CENTER FREQUENCY	915 MHz Programmable (SR-540)
	868 MHz Programmable (SR-550)
	433 MHz Programmable (SR-580)
INPUT BANDWIDTH	±15 MHz RF Bandwidth
MAXIMUM INPUT SIGNAL LEVEL	+10 dBm Continuous Without Damage
	(Note: Proper Operation Up To -10 dBm ONLY)
INPUT IMPEDANCE	50 Ω
VSWR	2.0:1 MAXIMUM

3.6.2 VDC Input

The power input to the receiver is a standard DC power jack located on the rear panel and labeled "VDC". This input is compatible with the AC-to-DC wall plug unit supplied with the receiver.

Characteristics of the input power signal are as indicated in the following table.

Table 3-7 Input Power Characteristics

INPUT VOLTAGE	10 TO 14 VDC
	(Analog Outputs will clip <12 VDC)
CAPACITY	2 Amp (MINIMUM)

3.6.3 Remote Status/Control (RS-232)

The remote status/control input/output is a serial interface compatible with the EIA Standard RS-232 (MIL-STD-188, Section 114, Unbalanced). The connector for this interface is a commercial standard 9 position D-type. The Digital Telemetry Receiver provides the female side of this connector and as such the user interface cable must provide the male side.

The Digital Telemetry Receiver operates utilizing the signal definitions defined in the following table.

Table 3-8 Remote Status/Control Pin Assignments

RECEIVER DB-9 PIN (DTE)	SIGNAL	PC DB-9 PIN (DCE)
3	TD - TRANSMIT DATA	3
2	RD - RECEIVE DATA	2
5	GND - GROUND	5

The standard product does not support hardware handshaking via the CTS and RTS signals.

3.6.4 Remote Status/Control/Data Logging (USB)

The USB 1.1 port can achieve all the functions of the RS-232, plus the receiver can output measurement data real-time from this port. This connection is a 4 pin standard USB Type B style connector located on the rear panel and labeled “USB”. NOTE: the SR-500e is NOT compatible with any other devices sharing the USB port.

3.6.5 Digital Telemetry Transmitter Programming Interface

The receiver provides a programming interface connection for the Digital Telemetry Transmitter. This connection is a 5 pin DIN style connector located on the front panel and labeled “PROGRAM”.

This interface should only be utilized with the programming cable supplied with the Digital Telemetry System. Section 4 of this manual describes the proper utilization of this interface via the programming cable.

3.6.6 Analog Outputs

The analog outputs for channels 1 through 8 are provided via a 16 pin connector located on the rear panel and labeled “ANALOG”. As depicted in the following figures, the receiver provides the male side of this connector and the user interface cable mates to the male side (Weidmuller part number 1748220000).

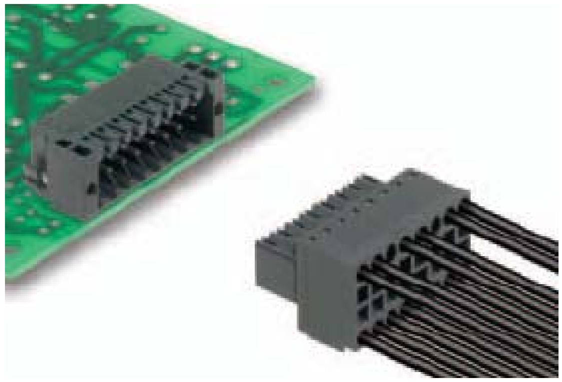


Figure 3-4 Analog Output Connector

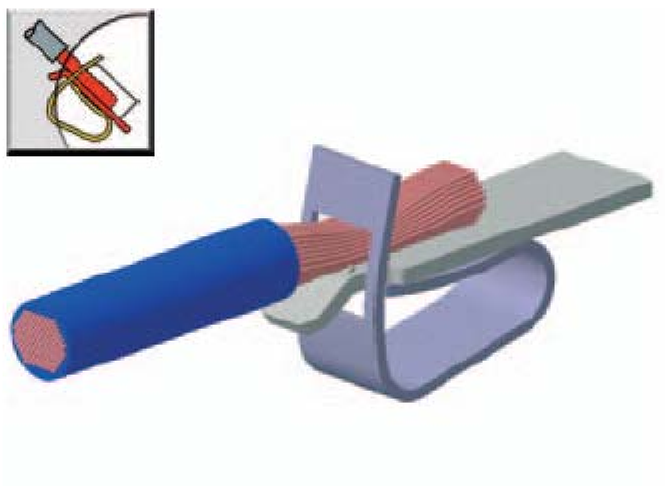


Figure 3-5 Wire Insertion to Analog Connector

Characteristics of these output analog signal are as shown in the following table:

Table 3-9 Analog Output Signal Characteristics

FREQUENCY RESPONSE	DC TO 10 KHz
VOLTAGE RANGE	-10 to +10 VDC (USER SELECTABLE)
LOAD IMPEDANCE	1K Ω MINIMUM

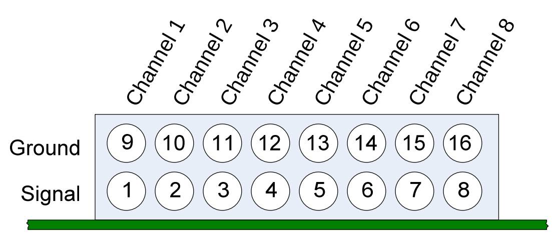


Figure 3-6 Analog Output Connector Pin Layout

The pin assignments for this connector are as follows:

Table 3-10 Analog Output Pin Assignments

PIN	SIGNAL (BOTTOM ROW)	PIN	SIGNAL GND (TOP ROW)
1	ANALOG 1	9	ANALOG 1 GND
2	ANALOG 2	10	ANALOG 2 GND
3	ANALOG 3	11	ANALOG 3 GND
4	ANALOG 4	12	ANALOG 4 GND
5	ANALOG 5	13	ANALOG 5 GND
6	ANALOG 6	14	ANALOG 6 GND
7	ANALOG 7	15	ANALOG 7 GND
8	ANALOG 8	16	ANALOG 8 GND

3.6.7 Power On/Off Switch

The Power On/Off switch is a standard toggle switch located on the front panel of the receiver with positions labeled for “ON” and “OFF” settings. Before making any connections for the receiver, the user should ensure this switch is in an “OFF” position.

3.6.8 Front Panel LED Indicators

There are four (4) front panel LED indicators on each receiver system. The labels, colors, and meaning of each of these indicators are presented in the following table.

Table 3-11 LED Indicator Descriptions

LED LABEL	"ON" COLOR	DESCRIPTION
POWER	GREEN	When illuminated, indicates that the front panel power switch is in an "ON" position and that valid 12VDC power is applied at the rear panel "VDC" connection.
SYNC	GREEN	When off, indicates the system has not acquired frame synchronization with the currently configured transmitter. When illuminated, indicates that the system is properly receiving data from the selected transmitter sufficient to achieve frame synchronization.
ERROR	Red	Illuminated when an error is detected in the data contained within a receive frame. Turned off when no errors are detected in a frame. The error LED is also illuminated briefly during receive acquisition processing if a valid signal is not detected within ~8 seconds. This is utilized to inform the operator that the system is still searching for a valid telemetry signal.
FAULT	Red	Illuminated when an internal fault condition is detected within the receiver.

Note that all front panel LEDs illuminate when the receiver is actively being programmed via the remote serial port interface. This is not a failure condition.

SECTION 4 BASIC OPERATION

The Series 500e Digital Telemetry Product Line has been designed to provide a user friendly interface environment while minimizing the amount of operator interaction which must be taken to achieve proper measurement transmission functions. In general, the system design is oriented towards a "hands-off" philosophy while still supporting the necessary interfaces and capabilities to allow detailed status and control of the unit if required for specific applications.

The following paragraphs describe the procedures for verifying the basic operation of the system and altering system parameters. **Users should be aware that the Digital Telemetry System contains sensitive electronic components. Proper "Electrostatic Discharge" (ESD) handling procedures should be utilized for this equipment as with any other electronic apparatus.**

4.1 Getting Started

Each delivery typically includes a CD ROM disk which provides control software for the system. Directions on the CD ROM should be followed to properly install this software onto a personal computer (PC) operating with the Windows operating system. The installation procedure creates a program on the PC called "SRIPMD Control Software.exe" as well as associated data and support files to fully define the equipment. The program is also referred to as the Digital Control Program within the context of this document.

The software provides the interface from the PC to the Digital Telemetry System. This software supports standard Windows type operation, including menu based selection processes. Throughout the remaining portions of this document, a reference such as "select ***aaaa : bbbb***" indicates a Windows type menu selection process where ***aaaa*** is the text name which appears at the top of the active "Digital" program screen and ***bbbb*** is the submenu item displayed once the ***aaaa*** menu is selected.

The Digital Control Program has been developed utilizing standard Windows small fonts settings. Systems that deviate from these standard settings may produce undesirable display results. If the program exhibits these characteristics, locate the current display font settings by following the Windows path for "***Start : Settings : Control Panel : Display*** : ***Settings : Advanced***" and ensure small fonts is selected. Furthermore, the minimum Desktop Area setting should be 800 by 600 pixels.

All of the screens associated with the Digital Control Program support online help functions. This display of information can be activated by selecting "***Display Online Help Window***" within the menu of the main program screen. By moving the mouse over the field of interest, the help window will depict a description of any control or display field on the displays.

To get started with the control software, take the following steps:

1. Unpack and validate the contents of the shipping package.
2. Install the Digital Telemetry System Control Software on a PC as directed from the received CD ROM.

3. Connect the Digital Telemetry Receiver to one of the PCs serial ports or to an available USB port. For serial ports, the connection should be via a standard RS-232 serial port cable (9 pin D to 9 pin D). The cable should connect to the "REMOTE" connection on the receiver. For USB connection, the connection should be via a standard USB cable to the USB connector on the receiver.
4. Connect the AC to DC wall plug to the "VDC" input on the rear panel of the receiver and then to an AC wall socket (110VAC, 50 to 70 Hz).
5. Power up the receiver from its power on/off switch after all of the above connections have been established.
6. Verify during power up that all LEDs on the receiver momentarily illuminate, and then all except the power LED turn off.
7. Start the control program on the PC from the installed program directory.
8. Select "***General : Communications Port***" and select the appropriate COM or USB port selection.

At this point, the Digital Telemetry Transmitter can be activated. Paying careful attention to the pinouts shown in the preceding section of this document, appropriate primary power should be applied to the transmitter. Once this has been accomplished, the front panel "SYNC" indicator should illuminate within a maximum of 5 seconds. This indicates that the Digital Telemetry Receiver has successfully recognized the output signal from the transmitter at a sufficiently low error rate to achieve synchronization. In a close proximity set up such as this, the "ERROR" LED should never illuminate, thus indicating error free reception of the data.

If any of the above indications are not true, the user should validate proper connections at all points in the set-up. If all of the above has been verified and the basic Digital Telemetry System communications test still fails, SRI/PMD should be contacted for further assistance.

4.2 Setting the System Configuration

The following sections describe how to change, save, and restore all configurable parameters associated with the digital telemetry system.

4.2.1 Changing Configuration Settings

To modify any user configurable parameter of the telemetry system, take the following steps:

1. Establish normal connections between the Digital Telemetry Receiver and the PC.
2. For configuration changes that affect operation of the Digital Telemetry Transmitter, connect the transmitter to the receiver via the custom programming cable.
3. At the PC, select "***Table Control : Edit System Definition***".

Once activated, a new screen similar to the following will appear showing the current receiver and model for the connected system. This information cannot be modified on this screen. The top part of the screen also depicts the currently assigned transmitter serial number. For users who own multiple transmitters, a special menu selection item invoked by "**Tools : Assign a Different Transmitter to this Receiver**" can be used to change this assignment.

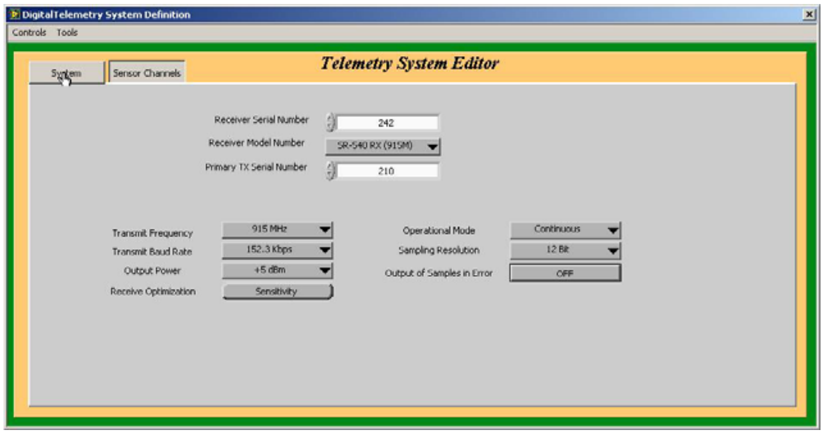


Figure 4-1 Main Configuration Screen

Information contained at the bottom part of this screen, as well as sensor information which can be displayed by selecting the "Sensor Channels" tab at the top of the screen can be modified by any user. All fields within these screens are either menu based selection parameters, 2-way toggle switches, or numeric fields with adjacent increment/decrement controls. Standard Windows based edit mechanisms should be employed to alter the settings.

4.2.1.1 General System Parameters

System parameters are displayed with the "System" tab is selected at the top of the screen and includes the following:

- **Transmit Frequency** – menu selection of the frequency on which the wireless transmission will occur. See subsequent sections for recommendations on how to establish optimum transmit frequency selection.
- **Transmit Baud Rate** – menu selection of the over the air data rate for transmit operation. Slower data rates will yield better communications performance, but slower sensor sample update rates.
- **Output Power** – menu selection of the transmit power for the wireless link. High output power will yield better communications performance at the cost of increased transmitter power supply draw.
- **Receiver Optimization** – toggle switch selection to optimize the receiver performance for sensitivity (longer range communications), or linearity (sometimes better for high interference environments).
- **Operational Mode** – future selection to support burst mode of system operation.
- **Sampling Resolution** – selects whether sensor samples are digitized to 8, 12, or 16 bits of resolution. Using higher resolution will provide increased system measurement accuracy at the price of slower sample update rates.
- **Output of Samples in Error** – toggle switch selection which enables or disables the outputting of recovered sensor samples by the receiver during frames which have a detected checksum error.

4.2.1.2 Sensor Channel Parameters

Sensor channel parameters are displayed with the “Sensor Channel” tab that can be selected at the top of the screen. This will cause the display to change to something similar to the following.

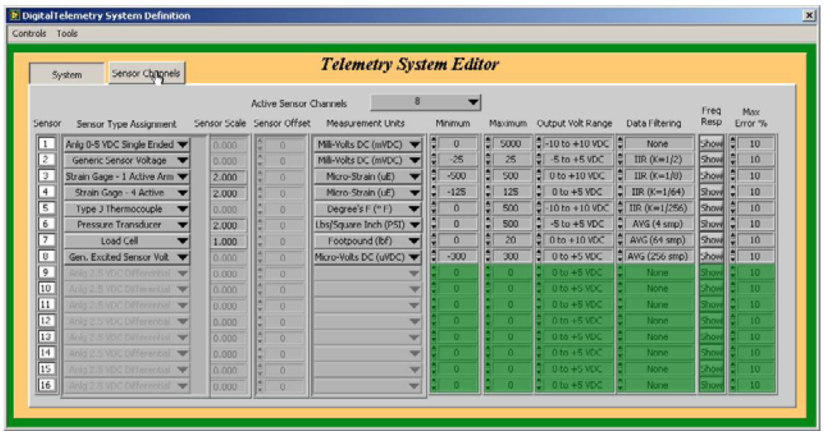


Figure 4-2 Sensor Configuration Screen

The top of this screen shows the number of active sensor channels. This is a menu based selection from 1 to 16, limited to the number of channels configured for the specific transmitter.

The remainder of the page includes the following for each active sensor channel. Subsequent paragraphs within this section provide more sensor type specific information on each field.

- **Sensor Type Assignment** – menu selection of the type of sensor which will be connected to the channel, including Analog Voltages, Generic Sensor Voltages, Strain Gages (1 to 4 active arms), Thermocouples, Accelerometers, and so forth.
- **Sensor Scale -** a numeric field which changes based on the type of sensor selected, but provides sensor specific information. For instance, on strain gages, this field provides what is known as the Gage Factor, which is typically 2.0 for common strain gages.
- **Sensor Offset -** a numeric field which changes based on the type of sensor selected.
- **Measurement Units –** menu selection which selects the measurement units over which the input sensor range will be defined. The supported values change with each sensor type. For example, thermistors can be Degrees C or F, while for strain gages are limited to microstrain.
- **Minimum** and **Maximum** – numerical fields which define the minimum and maximum input levels for the sensors in the predefined measurements units value. Measurement ranges do not need to be bi-polar or even balanced.
- **Output Volt Range** – a menu selection which selects the output voltage range for the receiver analog channels which will be utilized to represent the sensor output levels. Hence, for a –10 to +10 VDC output range selection, the minimum sensor measurement unit will be output as -10 VDC, while the maximum will be output as +10 VDC.
- **Data Filtering** – a menu selection to invoke optional digital filtering on the sensor samples, and configure for various levels of IIR or averaging.

- **Freq Response** – a toggle field which activates an additional screen for the specific sensor which shows the anticipated frequency response for the sensor measurement given current values of sample rates and data filtering settings.
- **Max Error %** - the maximum anticipated error in the input levels due to sensor calibration errors. This value must be set low enough to allow the system calibration logic to fully account for all sensor induced gain or offset errors.

The table that follows presents all the various sensor types currently supported by the digital telemetry system, along with the supported measurement units setting for each. Corresponding to each possible setting of these values is an explanation of what the corresponding sensor scale and sensor offset values mean, along with what measurement units apply to the minimum/maximum range setting of the sensor definition.

(this page intentionally blank)

Sensor Type Name	Measurement Units Selection	Sensor Scale Definition	Sensor Offset Definition	Units of Min/Max Range
Anlg 2.5 VDC Differential	millivolt DC (mVDC)	N/A	N/A	mVDC
Anlg 0-5 VDC Single Ended	millivolt DC (mVDC)	N/A	N/A	mVDC
Generic Sensor Voltage	millivolt DC (mVDC)	N/A	N/A	mVDC
	microvolts DC (uVDC)	N/A	N/A	uVDC
Strain Gage – 1 Active Arm	microstrain (uE)	Gage Factor	N/A	uE
Strain Gage – 2 Active Arm	microstrain (uE)	Gage Factor	N/A	uE
Strain Gage – 4 Active Arm	microstrain (uE)	Gage Factor	N/A	uE
Type J Thermocouple	Degree F (°F)	N/A	N/A	°F
	Degree C (°C)	N/A	N/A	°C
Type K Thermocouple	Degree F (°F)	N/A	N/A	°F
	Degree C (°C)	N/A	N/A	°C
Pressure Transducer	Lbf per Square Inch (PSI)	Sensitivity as mV / (1000 PSI)	N/A	PSI
	Metric (kg/cm^2)	Sensitivity as mV / (kg/cm^2)	N/A	kg/cm^2
	High Sensitivity (PSI)	Sensitivity as mV / (1 PSI)	N/A	PSI
	Bar	Sensitivity as mV / (1 Bar)	N/A	bar
Accelerometer	Gravitational Force (g)	Sensitivity as mV / (100g)	N/A	g
	High Sensitivity (g)	Sensitivity as mV / (1g)	N/A	g
	m/s^2	Sensitivity as mV / (1m/s^2)	N/A	m/s^2
Thermistor	Degree F (°F)	Sensitivity as mV / (1°F)	°F corresponding to 0 measurement	°F
	Degree C (°C)	Sensitivity as mV / (1°C)	°F corresponding to 0 measurement	°C
Load Cell	pound force (lbf)	Sensitivity as mV / (100 lbf)	N/A	lbf
	High Sensitivity (lbf)	Sensitivity as mV / (1 lbf)	N/A	lbf
	Newton (N)	Sensitivity as mV / (1 N)	N/A	N
	kilonewton (kN)	Sensitivity as mV / (1 kN)	N/A	kN
Gen. Excited Sensor Volt	millivolt DC (mVDC)	N/A	N/A	mVDC
	microvolts DC (uVDC)	N/A	N/A	uVDC

Table 4-1 Sensor Type, Measurement Units, Scale, And Offset Definitions

(This page intentionally blank

4.2.1.2.1 Analog Input Voltages

As previously stated, Analog inputs are those voltages not requiring input amplification and conditioning through the transmit circuitry. They are typically in the range of 0 to 5 VDC, or ±2.5 VDC, but may be any voltages the user wishes to invoke recognizing that the only gain that will be applied is on the receive side. These channels are only available on multi-channel systems. When selected, the user input pins for these channels switch from the Sensor input connector to the Analog input connector.

There are two possible selections under the “Sensor Type Assignment” utilized to define Analog input voltages. These are “Anlg 2.5 VDC Differential” and “Anlg 0-5 VDC Single Ended”. The first selection is only available for Channels 1 and 2, while the second one is available for Channels 1 through 4.

The “Anlg 2.5 VDC Differential” measures up to ±2.5 VDC differentially between the two (2) assigned input pins. The “Anlg 0-5 VDC Single Ended” measures up to 5VDC on the single assigned input pin. The input levels for either type of analog voltage are referenced to the ground source of the Transmitter power supply.

The “Measurement Units” for these type channels are limited to mVDC and the minimum and maximum range values can be set anywhere from -2500 to 2500 or 0 to 5000 mVDC for differential/single ended respectively. Setting the minimum and maximum range values to other than these ranges simply causes the RX gain setting to be increased and does not affect the measurement resolution through the transmitter logic. Sensor Scale/Sensor Offset fields have no meaning for this sensor type.

4.2.1.2.2 Sensor Input Voltages

The “Generic Sensor Voltage” selection measures a differential voltage range between the Signal+ and Signal– on the Sensor Input connection pins. The measurement units may be specified as mVDC or micro-volts DC (uVDC). The minimum and maximum range values can be set anywhere from -45 to +45 for mVDC and –32768 to +32768 for uVDC although this may be further limited by the minimum gain settings of the Transmitter. Scale/Sensor Offset have no meaning for this sensor type.

4.2.1.2.3 Strain Gages

There are three (3) possible selections under the “Sensor Type Assignment” utilized to define strain gage sensor types. These are “Strain Gage – 1 Active Arm”, “Strain Gage – 2 Active Arms”, and “Strain Gage – 4 Active Arms”. The proper selection is determined by the balanced bridge configuration utilized for the implementation of the strain gage. Reference appendices of this document for further information on balanced bridge configurations.

Regardless of the number of active arms, the “Sensor Scale” field for a strain gage defines what is known as the gage factor. Most strain gages incorporate a gage factor of 2.0, although custom sensors may vary from this setting. The range of gage factors supported by this field is 0.0 to 255.996 in approximately 0.004 count increments. The Sensor Offset field has no meaning for this sensor type.

The measurement units for a strain gage is limited to microstrain (uE). The minimum and maximum range values can be set anywhere from -32768 to +32768, although this may be further limited by the minimum and maximum gain settings of the Transmitter.

4.2.1.2.4 Thermocouples

There are two (2) possible selections under the "Sensor Type Assignment" utilized to define thermocouple sensor types. These are "Type J Thermocouple", and "Type K Thermocouple". The Sensor Scale/Sensor Offset fields have no meaning for these sensor types.

The measurement units for a thermocouple may be selected between "Degree C (°C)" and "Degree F (°F)" corresponding to Celsius and Fahrenheit respectively. The minimum and maximum range values can be set anywhere from -32768 to +32768, although this may be further limited by the minimum and maximum gain settings of the Transmitter as well as limitations of the specified thermocouple type.

4.2.1.2.5 Pressure Transducers

The "Sensor Type Assignment" can also be set to "Pressure Transducer". The measurement units for a pressure transducer may be selected between "Pounds per Square Inch (PSI)" or "kilograms per Square Centimeter (kg/cm^2)", "PSI (High Sensitivity)" or "Bar". The minimum and maximum range values can be set anywhere from -32768 to +32768, although this may be further limited by the minimum and maximum gain settings of the Transmitter as well as limitations of the specified transducer type.

The "Sensor Scale" field for a pressure transducer defines the output voltage range of the sensor based on the selected measurement units. If the measurement units field is selected to "Pounds per Square Inch (PSI)" the sensor scale specifies this voltage range in terms of mVDC/(1000 PSI). For "kilograms per Square Centimeter (kg/cm^2)", the range is defined as mVDC/(1000 kg/cm^2). For "PSI (High Sensitivity)", this range is defined in terms of mVDC/(10 PSI). For "Bar", the range is defined in terms of mVDC/(1 Bar). For example, a pressure transducer which outputs a 10mVDC level for 500 PSI which has been selected to "Pounds per Square Inch (PSI)" measurement units would have a "Sensor Scale" field of 20.0.

The range of "Sensor Scale" factors supported by this field is 0.0 to 255.996 in approximately 0.004 count increments. The Sensor Offset field has no meaning for this sensor type.

4.2.1.2.6 Accelerometers

The "Sensor Type Assignment" can be set to "Accelerometer". The measurement units for an accelerometer are "Gravitational Force (g)", "High Sensitivity (g)", or "m/s^2". The minimum and maximum range values can be set anywhere from -32768 to +32768, although this may be further limited by the minimum and maximum gain settings of the Transmitter as well as limitations of the specified accelerometer type.

The "Sensor Scale" field for an accelerometer defines the output voltage range of the sensor based on the selected measurement units. If the measurement units field is selected to "Gravitational Force (g)", the sensor scale should reflect the output mVDC/(100 g). If the measurement units field is selected to "High Sensitivity (g)", the sensor scale should reflect the output mVDC/(1 g). If the measurement units field is selected to "m/s^2", the sensor scale should reflect the output mVDC/(1 m/s^2). For example, an accelerometer which outputs a 25 mVDC level for 5 g would have a "Sensor Scale" field of 5.0 if the measurement units was selected to "High Sensitivity (g)".

The range of "Sensor Scale" factors supported by this field is 0.0 to 255.996 in approximately 0.004 count increments. The Sensor Offset field has no meaning for this sensor type.

Note that certain accelerometers (as well as other transducers) that output a DC offset or bias (e.g., 2.5 VDC or 1/2 Excitation Voltage) are considered Analog signals (see Section 4.2.1.2.1) due to input voltage levels in excess of 45 mV.

4.2.1.2.7 Thermistors

The "Sensor Type Assignment" can be selected to "Thermistor". The measurement units for a thermistor may be selected between "Degree C (°C)" and "Degree F (°F)" corresponding to Celsius and Fahrenheit respectively. The minimum and maximum range values can be set anywhere from -32768 to +32768, although this may be further limited by the minimum and maximum gain settings of the Transmitter as well as limitations of the thermistor circuit implementation.

Thermistors are typically incorporated into a balanced bridge configuration or a simpler voltage divider circuit. Reference appendices of this document for further information on thermistor sensor implementations.

The "Sensor Scale" field for a thermistor defines the output voltage range of the sensor in terms of mVDC/(°C) or mVDC/(°F) based on which measurement units have been selected for the channel. The range of "Sensor Scale" supported by this field is 0.0 to 255.996 in approximately 0.004 count increments.

The "Sensor Offset" field defines the °C or °F which are represented by a 0 differential input voltage been the Signal+ and Signal– inputs to the Transmitter. The range of the "Sensor Offset" field for a thermistor is –32768 to +32768.

For example, a thermistor circuit which produces a +10 mVDC output for 100°C input and a 0 mVDC output for a 50°C input would have a "Sensor Offset" value of 50 and a "Sensor Scale" field of 5.0.

4.2.1.2.8 Load Cells

The "Sensor Type Assignment" can be selected to "Load Cell". The measurement units for a Load Cell are "pound-force (lbf)", "High Sensitivity (lbf)", "Newton(N)", and "kilonewton (kN)". The minimum and maximum range values can be set anywhere from -32768 to +32768, although this may be further limited by the minimum and maximum gain settings of the Transmitter as well as limitations of the specified accelerometer type.

The "Sensor Scale" field for a Load Cell defines the output voltage range of the sensor based on the selected measurement units. If the measurement units field is selected to "pound-force (lbf)", the sensor scale should reflect the output mVDC/(100 lbf). If the measurement units field is selected to "High Sensitivity (lbf)", the sensor scale should reflect the output mVDC/(1 lbf). If the measurement units field is selected to "Newton (N)", the sensor scale should reflect the output mVDC/(1 N). And if the measurement units field is selected to "kilonewton (kN)", the sensor scale should reflect the output mVDC/(1kN). For example, a Load Cell which outputs a 5 mVDC level for 100lbf would have a "Sensor Scale" field of 5.0 if the measurement unit was selected to "pound-force (lbf)".

The range of "Sensor Scale" factors supported by this field is 0.0 to 255.996 in approximately 0.004 count increments. The Sensor Offset field has no meaning for this sensor type.

4.2.1.2.9 Generic Excited Sensor Input Voltages

The “Gen Excited Sensor Volt” selection measures a differential voltage range between the Signal+ and Signal– on the Sensor Input connection pins identically to the “Generic Sensor Voltage” previously discussed. However, for the “Gen Excited Sensor Volt” selection, calibration corrections are applied to the input measurement corresponding to drifts of the +5 VDC excitation voltage across temperature. This allows for of the use of generic sensors where the output voltage varys in proportion to the provided output excitation voltage. The measurement units may be specified as mVDC or micro-volts DC (uVDC). The minimum and maximum range values can be set anywhere from -45 to +45 for mVDC and –32768 to +32768 for uVDC although this may be further limited by the minimum gain settings of the Transmitter. Scale/Sensor Offset have no meaning for this sensor type.

4.2.2 Invoking Changed Settings

Once all changes have been accomplished, the user should select “**Tools : Update System Definition**”. This will cause the program to download the changed tables to the receiver and, if necessary, the transmitter. The screen will then close and return to the main control screen.

If the user elects to not change any settings, the configuration window may be exited by clicking in the Close Window “X” box. If changes have been made but not downloaded to the system, the user will be queried as to whether it is acceptable to discard these changes.

4.2.3 Saving/Restoring Configuration Settings

The system allows the user to save configuration settings to the PC disk and restore them at later time. Thus, multiple sensor configurations can be utilized with the telemetry transmitter and easily invoked for future requirements.

To save the current configuration settings, the user should:

1. Establish normal connections between the Digital Telemetry Receiver and the PC.
2. From the main control screen, select “***Table Control : Files : Save System Definition to File***”.

The program will query the user as to the desired file name to be utilized for saving the information, and then copy the appropriate tables from the receiver to the disk. The transmitter does not need to be connected to the receiver for this operation to occur.

To restore this configuration at a later point in time, the user should:

1. Establish normal connections between the Digital Telemetry Receiver and the PC.
2. Connect the transmitter to the receiver via the custom programming interface cable.
3. From the main control screen, select “***Table Control : Files : Restore System Definition from File***”.

4.2.4 Transmitter EEPROM Updates

On rare occasions, a telemetry transmitter may stop operating due to corrupted executable or table space within its circuitry. This can occur due to unexpected primary power fluctuations during operation or other noise induced EMC type of situations. To account for these occurrences, the system supports forced loading of the transmitter EEPROM space from the receiver via the following procedure:

1. Establish normal connections between the Digital Telemetry Receiver and the PC.
2. Connect the transmitter to the receiver via the custom programming interface cable.
3. From the main control screen, select "***Table Control : Transmitter Control : Update TX Configuration Tables***".
4. If the problem persists after the above action, the user should select "***Table Control : Transmitter Control : Update TX Executable Code***". This action will take the user to a file selection process for a file ending with the file acronym of ".encexe" for encrypted executable. Usually users will only have one such file for the system and should simply select that file.

4.3 Determining Wireless Link Communications Settings

It is imperative that the settings for the Wireless Link operation be optimized for each end-user application. To assist in this process, the Digital Telemetry Control Program provides easy-to-use functions that monitor and/or alter the characteristics of the link. The following paragraphs detail the operation of this portion of the software.

4.3.1 Scanning the Available Communications Channels

In certain cases, select RF frequencies (or channels) may not be as robust as others based on interfering signals or susceptibility to other external elements. By default, each Digital Telemetry System is delivered from the factory set to a link frequency utilized for factory test. Based on experimentation or data gathered from other sources, the operator may elect to change the RF frequency to other available channels.

To assist in this process, the control program provides an RF spectrum analysis function. This process can be utilized to scan all available communications frequencies and detect potential sources of interference.

To activate the RF spectrum analysis process, take the following steps:

1. Connect the antenna input that will be utilized during actual operation of the system to the "ANT" port on the Digital Telemetry Receiver. **Do not power on any digital telemetry Transmitter during this process. Also, insure potential sources of interfering signals which will not be present during actual operation are not active.**

2. With an active receiver, select "***Tools : Scan Input Frequency Spectrum***" from the control program.

Once activated, the available communications channels (or frequencies) will be scanned and plotted on a graph similar to the following figure. Note that in this example case, a telemetry transmitter was active during the sample capture.

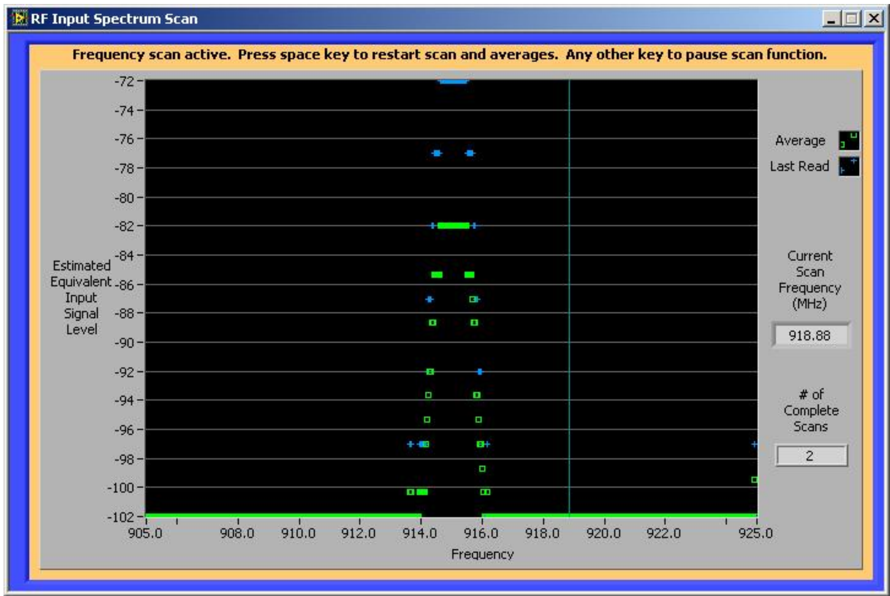


Figure 4-3 Scan Input Spectrum

The user may leave this function running as long as desired and the available channels will be repetitively scanned from the lowest to the highest. The graph will depict both individual measurement samples for the frequency as well as the cumulative averages as multiple samples are accumulated.

Typically, the optimum frequency selection is the channel that exhibits the lowest background noise level. Once a complete scan of the input spectrum has been completed, the program indicates this channel by placing a red line at that frequency setting. Some interpretation by the operator may be required if channels of significant interfering signal levels surround the selected lowest background noise channel.

When sufficient samples have been collected, the user may close the frequency scan window by clicking in the Close Window "X" box. Procedures discussed below can then be utilized to change the frequency.

4.3.2 Monitoring Online Communications Performance

The Digital Telemetry Control Software supports full real-time monitoring of the communications link performance. This feature allows operators to accurately assess signal levels and resulting communications error rates in order to determine if the wireless link is providing acceptable measurement transfer functions. Although ideally, the wireless link will provide error free operation, in reality, any communications link is susceptible to periodic errors.

To activate online communications performance analysis, take the following steps:

1. Establish normal operation of the Digital Telemetry Receiver and Transmitter and connections to the PC.
2. From the control program, select "***Windows : Receiver Status***".

Once activated, a new screen will appear showing text, numeric and graphical data similar to that shown in the following figure.

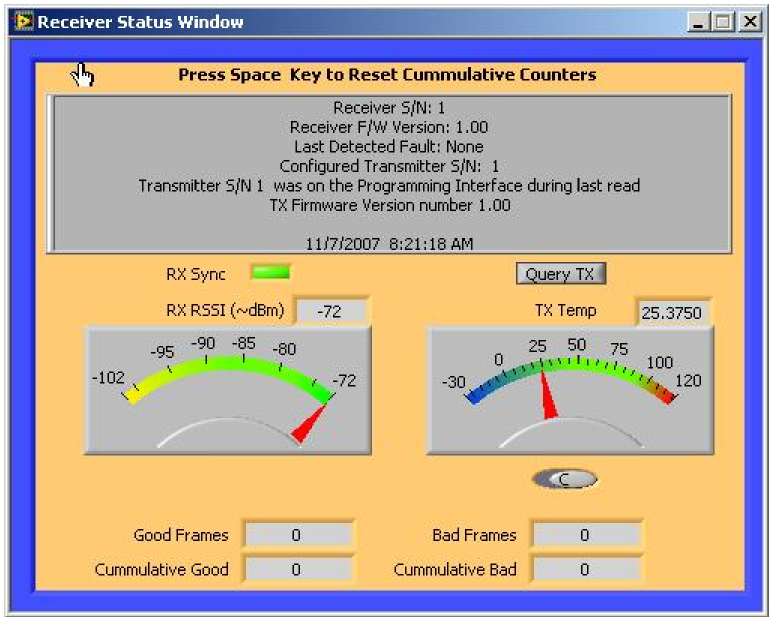


Figure 4-4 Receiver Status

The text information depicts miscellaneous operational information, such as what receiver is connected to the PC and what transmitter from which it is configured to receive data. A receiver in-sync indicator is also provided to indicate whether data is actively being received from the transmitter.

The numeric fields will indicate the number of digital telemetry data frames received, and how many of these frames had errors detected during the reception process. Numeric values are provided for the last sample period (approximately 1 second) as well as cumulative figures since the start of the monitoring process. At any time during window operation, pressing the space bar will cause the cumulative figures to reset to 0.

The graphs depict the measured input signal level expressed in approximate dBm levels and the current reported transmitter operational temperature in either °C or °F.

A data frame is 32 sensor sample periods long for 8 bit sampling or 16 sensor sample periods for 12 bit or 16 bit sampling operation. Any frames in error result in the loss of 32 or 16 consecutive sensor samples. Although ideally no frames in error will ever be detected, some installations can accept a certain error rate as long as sufficient data is being recovered to support accurate analysis functions.

Pertaining to signal levels, typically any reading above -90 dBm is considered a high quality signal, although reception can typically be to as low as -100 dBm input level. These figures are not absolute in that the reported signal level reflects signal AND noise, where noise can be any external interfering signals or simply background thermal noise. As such, reported signal levels as high as 0 dBm may still yield no usable data if signals or noise other than the desired wireless link telemetry signal is driving the input level.

The user may close the receiver status window by clicking in the Close Window “X” box.

4.4 Sensor Data Processing

The Digital Telemetry Control Software supports real-time monitoring of the sensor measurement levels which includes the capabilities to display the data and save recovered samples to a file utilizing various formatting capabilities.

4.4.1 Displaying the Sensor Data

To activate displaying of sensor channel data, take the following steps:

1. Establish normal operation of the Digital Telemetry Receiver and Transmitter and connections to the PC.
2. From the control program, select "***Windows : Sensor Display***".

Once activated, a new screen will appear similar to the following showing a plot chart, menu, and various status indicators.

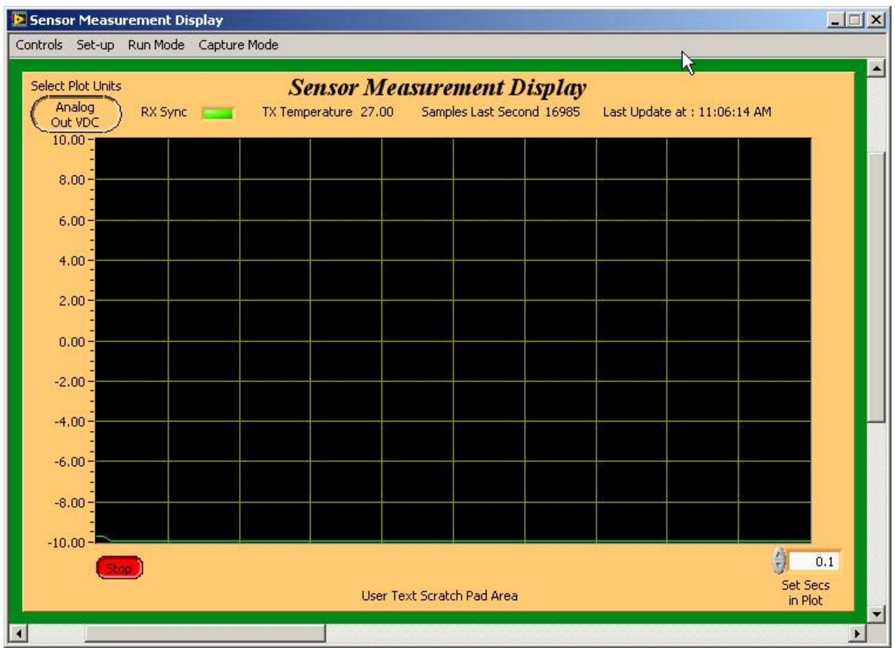


Figure 4-5 Sensor Measurement Display

By default, the system always attempts to bring this screen up in the same configuration as was being utilized the last time the window was closed.

4.4.1.1 Assigning Plot Channels

To assign what sensor channels are being displayed, the user can select "***Setup : Assign Plot Channels : Activate Plotting of All Sensor Channels***". This will activate the display for plotting all active sensor channels for the transmitter in consecutive channel order.

Alternatively, the user may select "***Setup : Assign Plot Channels : Assign Individual Channels***" which will bring up a secondary screen allowing the user to only activate plots for specific user selected channels.

Figure 4-6 Assigning/Activating Plot Channels

Selecting any of the "Current Assignment" lines will bring up a menu selection of all available sensor channels or "[Not Assigned]" to deactivate plotting of that channel. This display will also allow the user to select the plot color associated with each activated channel by selecting the "Plot Color" field. Closing the window causes the new assignments to go into effect.

4.4.1.2 Selecting Plot Display Mode and Scaling Options

The sensor display will show captured data in either time or frequency modes. When the current mode is time display, the user can switch to frequency display mode by selecting "***`Setup : Display Options : Switch to Frequency Mode`***". When in frequency mode, the user can switch to time display mode by selecting "***`Setup : Display Options : Switch to Time Mode`***".

4.4.1.2.1 Time Display Mode

When in time mode, the digital display on the far end of the X (or bottom) scale is labeled "Set Secs in Plot". This field controls the amount of time which the plot reflects from the far left of the display to the far right. It may be set as low as 10 mSec (i.e. 0.01) or as high as 100 seconds. The control can be changed by manually entering a number into the numeric selection field. Note that regardless of this setting the display is always updated at a fixed 1 second rate. For display time scales less than 1 second, the unused data is lost.

The Y (or side) axis in this mode provides a select button up at the top which allows the display to be shown as the equivalent output analog voltage from the receiver (true when button select indicates Analog Out VDC) or as equivalent sensor measurement units (true when button select indicates Sensor Meas Units). The first selection sets the output axis range to ±10, ±5, 0-5 or 0-10 depending on the configured output of the receiver analog output for the first plotted sensor channel. The second selection sets it to the selected range of the defined units of the first plotted sensor channel.

4.4.1.2.2 Frequency Display Mode

When in frequency mode, the digital display on the far end of the X scale is labeled "Set Max Freq (Hz)". This field controls the maximum frequency which the plot reflects at the far right of the display. It may be set as low as 1 Hz or as high as 10 KHz. The control can be changed by manually entering a number into the numeric selection field.

The Y (or side) axis in this mode provides a select button up at the top which allows the display to be shown as the equivalent output analog voltage peak to peak from the receiver (true when button select indicates Analog Out VPP) or as db below full scale output (true when button select indicates dBc from

Full Scale). The first selection sets the output axis range to 20, 10, or 5 depending on the configured output of the receiver channel. The second selection sets it to 0 to -96 dBc (i.e., maximum dBc for lsb of a 16 bit resolution value).

4.4.1.3 Setting Other Display Options

To set other user controllable characteristics of the plot display, the user should select "Setup : Display Options : " and then one of the menu items below it. Controllable display items under this menu include:

- Selecting whether a legend is included within the plot area for each active sensor channel with "***: Display Legend***" or not with "***: Hide Legend***".
- Selecting whether a corresponding digital value is included within the plot area for each active sensor channel with "***: Display Digital Data***" or not with "***: Hide Digital Data***".
- Selecting whether the plot area includes a grid with "***: Display Grids***" or not with "***: Hide Grids***".
- Selecting whether the plot area is shown against a black background "***: Dark Background***" or a white background with "***: Light Background***".

The light background setting is particularly useful when printing the displayed plot as described below.

4.4.1.4 Operational Run Modes

The display logic also supports four modes of run operation as identified herein.

4.4.1.4.1 Continuous Run Mode

This mode is selected by "***Run Mode : Run Continuously***". When active the display is constantly updating with new data being added to the right of each plot line and, when the display fills to the entire time period, old data is dropped from the left of each plot.

4.4.1.4.2 Run/Stop Button Mode

This mode is selected by "***Run Mode : Run/Stop Button***". When active the display includes a button which is green and states "Run" when plotting is not active. By selecting the button it toggles to Red and states "Stop" and plotting is active as in continuous run mode. Selecting the button again suspends all plotting and returns the button to the green state.

4.4.1.4.3 Single Sweep After Run Mode

This mode is selected by "***Run Mode : Single Sweep After Run***". When active the display includes a button which is green and states "Run" when plotting is not active. By selecting the button it temporarily disappears and plotting is active on all channels. When sufficient data has been processed such that the display is filled to the right hand side of the plot area, plotting is suspended and the green "Run" state button reappears.

4.4.1.4.4 Trigger Mode

This mode is selected by "***Run Mode : Set Trigger Mode***". When activated, an additional screen appears as follows:

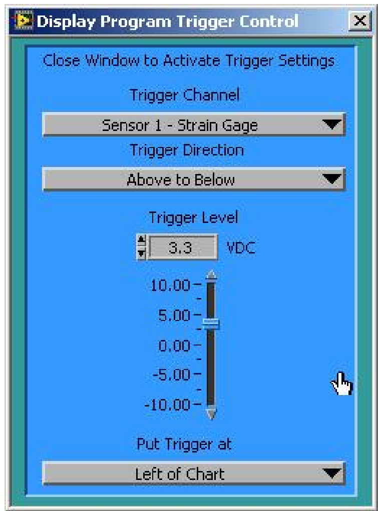


Figure 4-7 Trigger Mode Control

This mode allows the user to set a condition that must me met to activate the plotting function. Via the "Trigger Channel" menu selection, the user may select any sensor channel from those which are actively being plotted which should be monitored for a trigger condition. The "Trigger Direction" specifies whether a trigger should occur when the sensor channel goes from "Above to Below" the trigger level, or "Below to Above". The "Trigger Level" establishes the trigger point within the range of the plotted data. This value can be set directly via the digital display or with the slide bar control. Finally, the user may locate where the trigger point is plotted with respect to the time axis as being at the "Left of Chart", "Center of Chart", or "Right of Chart".

Closing the window causes the new assignments to go into effect.

4.4.1.4.5 Printing the Plot Window

Standard print functions exist for the plot window. The printer settings may be established by selecting "***Controls : Page Setup***". The page area itself can then be printed by selecting "***Controls : Print Page***". For better results, a white background display setting is usually advised for printing. Also, a user "scratch pad" area is provided at the bottom of the plots which provides a mean for the user to enter text to identify the plot information.

4.4.2 Capturing the Sensor Data

The control software also supports capturing sensor data to a disk file. This process is accessible whenever the sensor display window is being displayed. To activate capturing of sensor channel data, take the following steps:

1. Establish normal operation of the Digital Telemetry Receiver and Transmitter and connections to the PC.
2. From the control program, select "***Windows : Sensor Display***".
3. From the main sensor display window, select "***Capture Mode : Activate Capture Mode***".

Once activated, a new screen will appear similar to that shown in Figure 4-6.

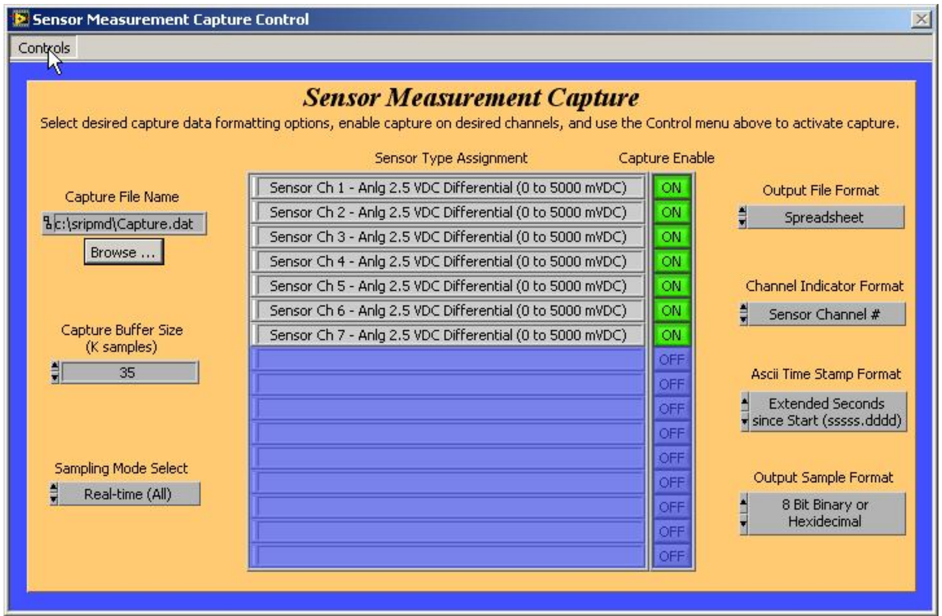


Figure 4-8 Sensor Measurement Capture

The various controls on this screen provide for the saving of sensor data in various file and content formats as described in the following paragraphs.

4.4.2.1 Channel and Timing Selection Controls

When first activated, the screen will show all configured sensor channels for the system and the "Capture Enable" control button will indicate "OFF" for each one. By selecting the corresponding control for the various sensors, the "Capture Enable" changes to "ON" thus enabling the capture of data for that channel.

The "Sampling Mode Select" determines how samples are selected. When the menu is set to "Real-time (All)", all samples for enabled channels will be captured to disk. When switched to "Samples per Second" a secondary control will be shown allowing the operator to select a discrete number of samples which should be captured for each second.

The "Capture Buffer Size (K samples)" controls how many K samples (K = 1024) will be saved for the total capture function. This control combined with Sampling Mode Select and number of active sensor channels determines the entire length of the capture period.

The "Capture File Name" control should be used to select what file name to be assigned to the capture data. A "Browse" control is provided for users wishing to use existing files.

4.4.2.2 Output File Formatting

The capture function allows samples to be stored as binary, ASCII, or spread sheet compatible formats.

4.4.2.2.1 Binary Formats

When the "Output File Format" control is selected to "Binary", data is output to the file as a continuous string of 8, 16, 32, or 48 bit numeric fields depending on the other selections.

The first data output in this mode represents the time of the captured sample if enabled. When the "Binary Time Stamp Format" is selected to "None", no data is output for the time. When selected to "Relative Time from Start", the time stamp is output as a 32 bit field representing the number of milliseconds since the start of the capture at which the sample was recorded. When selected to "Absolute Date Time", the time stamp is output as a 48 bit field representing number of seconds since 12:00 AM January 1, 1904 UTC.

Immediately following the time field is the channel indicator field. When "Channel Indicator Format" is set to "None", no data is output for the channel number. This should only be utilized for single channel operation. When selected to "Sensor Channel #", the corresponding sensor channel which produced the sample will be output as an 8 bit value limited to 1 through 8.

The final data output is the actual capture sample data. When "Output Sample Format" is selected to "8 Bit Binary or Hexadecimal", a single byte of data is output for the sample. This byte represents the upper 8 bits of the captured data if the transmitter is operating in 12 or 16 bit sampling mode. When selected to "16 Bit Binary or Hexadecimal", two (2) bytes of data are output ordered as the MSB and then the LSB of the captured sample. Data is lsb 0 filled if the transmitter is operating in 12 or 8 bit sampling mode. When selected to "Floating Point Analog Value" the data is represented as an ANSI/IEEE Standard 754-1985 single precision 32 bit floating point number indicating the corresponding analog output voltage of the receiver channel within the range of $\pm$10 VDC. When selected to "Integer Measurement Value", the data is output as a 16 bit integer number corresponding to the selected measurement units for the sensor channel and limited to the selected measurement range of the sensor.

4.4.2.2.2 ASCII and Spread Sheet Formats

When the "Output File Format" control is selected to "ASCII", data is output to the file as a continuous string of ASCII characters delimited by a carriage return and line feed character for each sample. A similar format is used for a selection of "Spreadsheet" with the differences as explained below.

The first data output in these modes represents the time of the captured sample. When the "ASCII Time Stamp Format" is selected to "Time of Day (hh:mm:ss)" a total of 8 ASCII characters are output as indicated in the selection indicating the local computers time of day at which the sample was capture. When selected to "Extended Time of Day (hh:mm:ss.dddddd)", a total of 15 ASCII characters are output as indicated in the selection thus providing millisecond resolution. When selected to "Time Since Start (sssss)" a total of 5 ASCII characters are output as indicated in the selection indicating the number of seconds since the start of capture at which the sample was recorded.. Finally, when selected to "Extended Time Since Start (sssss.dddddd)", a total of 12 ASCII characters are output as indicated in the selection thus providing millisecond resolution.

Immediately following the time field is a sensor channel indicator represented as 1 through 8 tabs. This allows the data to be viewed as columns of the corresponding sensors.

The final data output is the actual capture sample data. When "Output Sample Format" is selected to "8 Bit Binary or Hexadecimal", four ASCII characters are output for the sample formatted as "0xYY" where yy is replaced with the 8 bit hexadecimal representation of the data. This byte represents the upper 8 bits of the captured data if the transmitter is operating in 12 or 16 bit sampling mode. When selected to "16 Bit Binary or Hexadecimal", six ASCII characters are output for the sample formatted as "0xYYYY". Data is lsb 0 filled if the transmitter is operating in 12 or 8 bit sampling mode. When selected to "Floating Point Analog Value" the data is represented as up to 7 characters of data to represent the range of ±10.000 VDC with the correspond sign indication. When selected to "Integer Measurement Value", the data is output as a 5 character number corresponding to the selected measurement units for the sensor channel and limited to the selected measurement range of the sensor.

When the output is selected to ASCII mode, the capture data sample is followed by one space and then the appropriate units for the representation. In either hexadecimal mode, this field is blank. For analog value it is always "VDC". For sensor measurement units, it is the selected units for the corresponding sensor definition.

4.4.2.3 Starting and Stopping Captures

After all the above indicated controls have been appropriately configured, the user should select ***"Controls : Start Sample Capture***". A file output status will appear at the bottom of the display showing the progression of the capture process versus the allocated sample capture buffer. Once the capture buffer is full, all samples are output to disk. If the user wishes to terminate the capture process, select ***"Controls : Cancel Sample Capture".*** The file will still be saved to disk even if the capture is cancelled.

4.5 System Shut-Down

In order to shutdown the Digital Telemetry Receiver, simply place the two position power switch into the "OFF" position. The front panel power LED should immediately turn off indicating shut down completion. Exercising prudent care of electronic equipment, a power-on sequence from the front panel should not be attempted for five (5) seconds after a system shutdown.

4.6 Calibration Files

A unique Calibration, or "CAL", file is created during factory testing and installed with the supplied Monitor & Control application. In general the CAL files correct for nonlinearities resulting from the wide operating temperature range of SRI PMD systems. Each transmitter has a unique CAL file that can be found in the directory into which the M&C application was installed. These files are about 10kb in size and can be identified by the transmitter serial number included in the filename. For example, a calibration file named "TX00305.cal" will correspond with an ST-540 Transmitter serial number 00305.

When using the M&C application a warning will be displayed if the CAL file corresponding to the connected or configured transmitter is not found. To correct this condition verify that the CAL file corresponding to the attached transmitter is located in the application directory, by default "C:\Program Files\SRI_PMD Series 500e Control".

Occasionally a new or updated CAL file is required due to factory repair. These are generally supplied either on a CD with the returned transmitter or via email directly to the user. To install the new CAL file, simply copy it into the SRI PMD application directory. It is not necessary to delete CAL files for other transmitters, however if the transmitter serial number has not changed, for example due to a repair, any old CAL files will need to be replaced.

For convenience the most current CAL files are maintained on the SRI web site and are accessible through your SRI PMD Sales or Technical contact.

(This page intentionally blank)

SECTION 5 REMOTE STATUS/CONTROL

The remote status/control interface supports control and status functions for the Digital Telemetry Receiver across the “REMOTE” RS-232 interface or a standard USB interface. The following paragraphs describe the protocol associated with these ports.

5.1 RS-232 Serial Remote Interface

The asynchronous RS-232 remote status/control interface link is capable of operating at rates up to 19200 bps and can support even, odd, or no parity. The following sections describe this interface in more detail.

5.1.1 Basic Frame Format

As shown in the following figure, each data byte is transferred asynchronously, least significant bit first, and is surrounded by one (1) start bit, one (1) stop bit, and one (1) parity bit (when parity is used). **The default operating parameters for the interface is 9600 bps, 1 start bit, 1 stop bit, and no parity.** Additional interface characteristics are available upon request.

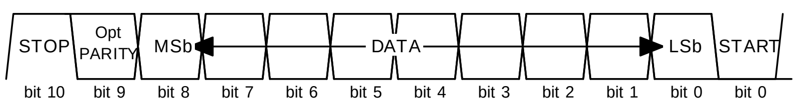


Figure 5-1 Remote Status/Control Byte Format

The interface is a byte oriented bus (eight (8) bits). Bytes are grouped together to form frames which constitute an entire message. All transfers are accomplished starting with byte 0 and ending with the last byte of the frame (frame checksum).

Frame formats are the same for both sides of the interface (i.e., input and/or output to the Digital Telemetry Receiver). All frames are composed of three (3) fields as shown in this figure.

	b7	b6	b5	b4	b3	b2	b1	b0
B0	FRAME BYTE COUNT FIELD							
B1	FIRST BYTE OF DATA FIELD							
B2	SECOND BYTE OF DATA FIELD							
	...							
	...							
B N-1	LAST BYTE OF DATA FIELD							
B N	FRAME CHECKSUM FIELD							

Figure 5-2 Remote Status/Control Frame Format

The byte count field contains a count of the total number of bytes in the frame, including the byte count field.

The data field bytes contain the commands on the input side of the receiver and provide the status on the output side from the receiver. Subsequent sections below describe the contents of this field.

A frame checksum field is included on all frames and is used to verify that no errors occurred during the frame transfer. The checksum is calculated by performing a twos compliment addition of all frame bytes preceding the checksum field, truncating the result to eight (8) bits, and performing a twos complement negate of the result. On the receive side, the checksum is verified by adding all bytes together including the checksum byte and verifying that the result is zero (0). The parity, start, and stop bits are not included when calculating the frame checksum.

When a command is received, the receiver validates the byte count and checksum, and then attempts to process the command, invoke any necessary configuration changes, and respond with an appropriate status message. Invalid byte counts, checksums, or data field parameters result in a negative acknowledgment. In order to accommodate this entire process, a minimum three (3) second time-out waiting for response should be incorporated after any command is issued to the receiver.

5.1.2 Data Field Contents

The data field of the remote status/control frame contains the commands to be performed by the Digital Telemetry Receiver or the response in return from these commands. The following sections describe the contents of the data field for each message type. Please note that byte offsets shown in the following paragraphs indicate offsets within the data field as opposed to frame offsets

5.1.2.1 Report Status Command/Response

The report status command is used to request a status response from the Digital Telemetry Receiver. The command format is as follows:

B 0	COMMAND FIELD = 1

Figure 5-3 Report Status Command Format

The command field is simply set to a value of 1 to invoke this command. The command causes the receiver to respond with a status response as follows:

B 0	ECHOED COMMAND FIELD = 1
B 1	RX SERIAL NUMBER (HIGH BYTE)
B 2	RX SERIAL NUMBER (LOW BYTE)
B 3	RX SYNC STATUS (0 = NO SYNC, 1 = SYNC)
B 4	RX FAULT INDICATOR (CONTACT SRI/PMD IF NOT 0)
B 5	RX DSP VERSION NUMBER (x.y in nibbles))
B 6	ASSIGNED TX SERIAL NUMBER (HIGH BYTE)
B 7	ASSIGNED TX SERIAL NUMBER (LOW BYTE)
B 8	FUTURE
B 9	FUTURE
B 10	LAST KNOWN TX TEMPERATURE (8 BIT SIGNED DEGREE C)
B 11	LAST KNOWN FRACTIONAL TX TEMPERATURE (x/256 DEGREE C)
B 12	ESTIMATED RECEIVE SIGNAL STRENGTH (8 BIT SIGNED dBm)
B 13	RECEIVED GOOD FRAMES (SINCE LAST STATUS UPDATE)
B 14	RECEIVED BAD FRAMES (SINCE LAST STATUS UPDATE)
B 15	FUTURE
B 16	FUTURE
B 17	FUTURE
B 18	FUTURE
B 19	FUTURE

Figure 5-4 Report Status Response Format

5.1.2.2 Read Sensor Channel Command/Response

The read analog channel command causes the Digital Telemetry Receiver to respond with the last valid output value for any given sensor channel. The following figure depicts the format of this command.

B 0	COMMAND FIELD = 2
B 1	SENSOR CHANNEL SELECT (0 to 15)

Figure 5-5 Read Sensor Channel Command Format

The command field is set to a value of 2 to invoke this command. The sensor channel select is a value between 0 and 15 corresponding to sensor channels 1 through 16. All other values are invalid in this field. The response from this command is as follows:

B 0	ECHOED COMMAND FIELD = 2
B 1	LAST KNOWN SENSOR VALUE(HIGH BYTE)
B 2	LAST KNOWN SENSOR VALUE (LOW BYTE)

Figure 5-6 Read Sensor Channel Response Format

Regardless of the configured mode of operation for either bits of sampling resolution or analog output channel voltage ranges, the last known sensor value returned in this response is always a 16 bit signed value where the maximum positive value (i.e., 0x7FFF) corresponds to the maximum defined measurement value for the sensor and the maximum negative value (i.e., 0x8000) corresponds to the minimum defined measurement value for the sensor.

5.1.2.3 Negative Acknowledgment Response

The negative acknowledgment response is returned from the receiver whenever problems are encountered in processing any command. The following figure depicts the format of this response.

B 0	NAK RESPONSE (NEGATIVE NUMBER)

Figure 5-7 Negative Acknowledgment Response Format

Any negative byte 0 value (i.e., bit 7 = 1) indicates a negative acknowledgment response. The actual value in these cases indicates why the received command was considered invalid. The Digital Telemetry Receiver takes no action on any command received which results in a negative acknowledgment.

5.2 USB Remote Interface

The USB remote status/control interface link is a 1.1 compatible USB port. It can operate either as a standard command/response interface or as a high speed data streaming port for the outputting of real time samples. The USB device utilized in the receiver is an FT232BM component made by Future Technology Device International, Ltd (FTDI). Information on component specific formatting and drivers can be obtained from the vendor at www.ftdichip.com. Note that the FTDI chip inserts 2 status bytes for every 62 data bytes transferred. The following sections do not address these bytes, but are limited to only the data byte content of any transferred message.

5.2.1 Basic Status/Response Operation

The USB is a byte oriented interface capable of high speed operation. It does not have any start, stop, or parity bits as with an RS-232 interface. Standard device drivers within the PC take care of packetizing and depacketizing the byte wide data in both directions.

At power-up, the USB defaults to operating in standard command/response interface format. This mode of operation is identical to that described for the RS-232 formats. As such, the user may invoke a status response from the RX on the USB interface by sending the following byte sequence:

B 0	BYTE COUNT = 3
B 1	COMMAND FIELD = 1
B 2	CHECKSUM = 0xFC

Figure 5-8 Sample USB Report Status Command

The receiver will respond with the exact byte sequence as indicated for the RS-232 response format for this command. This applies for all supported commands and the associated responses of the RS-232 interface.

5.2.2 Data Streaming Operation

A special command is supported on the USB interface which causes the receiver to enter an output only data streaming mode. This allows all sensor samples to be output on this interface in real time. This mode of operation is invoked with command data field content as follows:

B 0	COMMAND FIELD = 6

Figure 5-9 USB Streaming Activate Command Format

As with all commands, this is surrounded by the appropriate byte count and checksum.

When received, the receiver begins streaming data out the USB until such time as any other input data is received on the USB port. Any input data will terminate this mode of operation and return the receiver to the command/response format described above.

When streaming is active, the receiver continually outputs four (4) byte packets on the USB as described in the remaining portions of this section. Each packet consists of a sync byte with a value of 0xE1 and then three (3) data bytes. The user can determine packet alignment and detect and potential lost data situation by insuring that this sync byte is present as the first value of any packet.

As each sensor sample is successfully processed through the receiver, an output packet is issued to reflect the latest measurement value. In addition, for each input frame from the transmitter (i.e., 32 8 bit samples or 16 12 bit samples), the receiver outputs one additional packet on the interface indicating background information such as transmitter temperature and so forth.

5.2.2.1 Sensor Channel Packet

For each processed sensor sample, the following packet is output on the USB:

B 0	SYNC BYTE = 0xE1
B 1	SENSOR CHANNEL NUMBER (0 to 15)
B 2	SENSOR VALUE(HIGH BYTE)
B 3	SENSOR VALUE (LOW BYTE)

Figure 5-10 USB Sensor Sample Packet Format

The sensor channel field is a value between 0 and 15 corresponding to sensor channels 1 through 16.

The format of the sensor value is a 16 bit signed value where the maximum positive value (i.e., 0x7FFF) corresponds to the maximum defined measurement value for the sensor and the maximum negative value (i.e., 0x8000) corresponds to the minimum defined measurement value for the sensor.

It should be noted that samples are only output when fully processed. Hence, for channels which have sample averaging activated, a packet will only be output for the channel when sufficient input samples from the Transmitter have been received to establish a complete averaging period.

5.2.2.2 USB Sync Packet

The first background packet output on the frame basis is just a basic USB Sync packet which is a fixed data content which allows the user to guarantee data packet alignment. The value of this packet is as follows:

B 0	SYNC BYTE = 0xE1
B 1	FIXED BYTE = 0x11
B 2	FIXED BYTE = 0x11
B 3	FIXED BYTE = 0x11

Figure 5-11 USB Sync Packet Format

Users will note that due to packet content formats, this exact data sequence cannot validly occur within any other packet of the USB in this mode of operation.

5.2.2.3 Time Sync Packet

On an every other alternate frame basis, the receiver outputs a Time Sync packet which reports a free running micro-second based counter within the receiver. Since the USB does not guarantee data delivery on a real time basis, this provides the means for the user to time-sync reported sensor data which occurs between successive Time Sync Packets. The format of this packet is as follows:

B 0	SYNC BYTE = 0xE1
B 1	TIME IND : HIGH NIBBLE = 2, LOW NIBBLE = HIGH BITS OF TIMER
B 2	MIDDLE BYTE OF TIMER
B 3	LOW BYTE OF TIMER

Figure 5-12 Time Sync Packet Format

The timer value is presented as a 20 bit unsigned value as shown and is limited to a range of 0 to 1,000,000. Hence, the counter rolls over every second and starts again.

5.2.2.4 Transmitter Temperature Packet

The last detected temperature of the transmitter is reported on a periodic basis. The format of this packet is as follows:

B 0	SYNC BYTE = 0xE1
B 1	TEMP INDICATOR : HIGH NIBBLE = 3, LOW NIBBLE = TTL BITS
B 2	TX TEMP HIGH BYTE
B 3	TX TEMP LOW BYTE

Figure 5-13 Transmitter Temperature Packet Format

The signed 16 bit temperature measurement can be converted into a fractional degrees C value by dividing it by 256. The lower nibble of the second byte reflects the current status of TTL inputs 1, 2, and 3 in bits 0, 1, and 2 respectively.

5.2.2.5 Signal Strength Packet

The estimated signal strength from the receiver is reported on a periodic basis. The format of this packet is as follows:

B 0	SYNC BYTE = 0xE1
B 1	SIGNAL STRENGTH INDICATOR = 0x40
B 2	RSSI IN dBm
B 3	RECEIVER IN SYNC = 1, OR NOT = 0

Figure 5-14 Signal Strength Packet Format

The estimated receive signal strength is an 8 bit signed value reported in approximate dBm.

5.2.2.6 Receiver Serial Number Packet

The serial number of the receiver driving the USB is reported on a periodic basis. The format of this packet is as follows:

B 0	SYNC BYTE = 0xE1
B 1	RX SERIAL NUMBER INDICATOR = 0x50
B 2	RX SERIAL NUMBER HIGH BYTE
B 3	RX SERIAL NUMBER LOW BYTE

Figure 5-15 Receiver Serial Number Packet Format

5.2.2.7 Receiver Fault Packet

Any faults detected by the receiver are reported on a periodic basis. The format of this packet is as follows:

B 0	SYNC BYTE = 0xE1
B 1	RX FAULT INDICATOR = 0x60
B 2	FAULT INDICATOR
B 3	DSP VERSION NUMBER (x.y in High Nibble/Low Nibble)

Figure 5-16 Fault Packet Format

5.2.2.8 Transmitter Serial Number Packet

The serial number of the configured transmitter for this receiver is reported on a periodic basis. The format of this packet is as follows:

B 0	SYNC BYTE = 0xE1
B 1	TX SERIAL NUMBER INDICATOR = 0x70
B 2	TX SERIAL NUMBER HIGH BYTE
B 3	TX SERIAL NUMBER LOW BYTE

Figure 5-17 Transmitter Serial Number Packet Format

5.2.2.9 Bad Frame Packet

The system will also report when a bad frame is detected by the receiver, due to bit errors or loss of frame synchronization. The format of this packet is as follows:

B 0	SYNC BYTE = 0xE1
B 1	FIXED BYTE = 0xF0
B 2	FIXED BYTE = 0xF0
B 3	FIXED BYTE = 0xF0

Figure 5-18 Bad Frame Packet Format

SECTION 6 SYSTEM CALIBRATION

A key to successful utilization of the Digital Telemetry System is to ensure that given sensor input stimuli result in known and accurate output analog or digital measurement values at the receiver. This process requires that the system is programmed for the correct offset and gain settings as previously discussed in this document.

Although all Series 500e products are calibrated at the factory to account for transmitter gain/offset characteristics, users will typically wish to calibrate the system for sensor gain/offset errors. Fortunately, the Digital Telemetry Control Software provides a simple means of performing this calibration process.

6.1 Calibration Overview

There are two (2) types of calibration relevant to the end user of Series 500 products. These are:

- Sensor Calibration – adjusts gain and/or offset values through the system processing logic to account for measurement errors caused by the specific sensor to which any given channel is connected.

- Analog Calibration – adjusts gain/offset values specific to the analog output ports of the Digital Telemetry Receiver. This calibration only affects the portion of the processing which converts the final digital output samples over to the analog equivalent values on these ports.

Sensor calibration requires that the operator can establish a known stimuli conditions for any given sensor input to the Digital Telemetry System. The "known" setting may be the defined minimum and maximum measurement values to the system, or any level in between. Regardless, the accuracy of the calibration process will be established by the accuracy of this stimulus setting. In order to correct for both gain and offset, at least 2 stimuli levels must be realized. If only a single point is available, the system will correct for offset only.

Suppliers of sensors typically provide a means of establishing these known conditions. Examples of this capability include shunt calibration resistors for balanced bridge strain or pressure gages, simulators for thermocouples, or accurate voltage references for general purpose sensors.

During system calibration, the user should attempt to establish conditions for the Digital Telemetry System as close to the actual end application environment as possible. This includes such parameters as the mounting of the Digital Telemetry Transmitter, location of the receive antenna with respect to the transmitter, utilizing the actual transmitter power source (battery, generator, etc.) which will be utilized during the telemetry process, and so forth.

The telemetry transmitter itself is calibrated at the factory for gain/offset characteristics across the entire range of operational temperatures. This will account for all temperature based drift of this circuitry. In addition, for sensor types which have a defined drift with temperature (such as thermocouples), the system will account for this drift in real time by varying the offset value of the processing logic. This allows the system to provide what is known as the "zero junction reference box" function for these types of sensors.

Actual sensor calibration is not temperature sensitive. As such, if a user is dealing with a sensor type which does have some variations with temperature, it is recommended that the stimuli conditions discussed above properly account for the typical temperature the user expects to experience during actual operation.

The analog calibration is done independently of any sensor input. This function only requires a digital volt meter (DVM) or its equivalent which can provide accurate analog voltage measurements of these receiver output channels in the end user environment. As with sensor calibration, analog calibration is not temperature sensitive. As such, the receiver should be at or near its expected end operational temperature during the calibration process.

6.2 Sensor Calibration

The following paragraphs describe how to utilize the PC and the control software to perform sensor calibration on a Digital Telemetry System.

6.2.1 Starting the Calibration Function

Once the operator has established the system configuration and test equipment as described above, the calibration process can be started from the Digital Telemetry Control Software as follows:

1. Establish normal connections between the Digital Telemetry Receiver and the PC and active wireless link operation between the transmitter and the receiver.
2. Start the control program on the PC from the installed program directory.
3. Select "***`Tools : Calibrate Sensor Channels`***".

This action will result in a screen being displayed depicting each sensor channel of the system as well as its current calibration gain/offset settings. The display will also indicate the current equivalent output VDC value for the channel which can be utilized to verify that sensor stimuli are at approximate expected values. Note that these VDC values are scaled to approximate the expected output levels at the analog channels of the receiver. As such, changing the analog output range will directly affect the reported VDC values on this screen.

6.2.2 Calibrating Sensor Channels

At the left-hand side of the screen is a column labeled "Calibrate" with a corresponding On/Off control for each channel. All channels initially start in an "Off" condition. To activate calibration on a sensor channel, the user should select this control button to change its condition to "On". Only a single channel can be calibrated at a time and, as such, activating calibration on a second channel will turn the first channel to an "Off" condition. However, any measurement data taken while a channel is in calibration mode will be maintained, even if the calibration mode switches to "Off" for that channel.

Next, the following procedures should be conducted:

1. Establish a known stimuli condition for the corresponding sensor for this channel. Also establish a stable transmitter operating temperature if temperature drift is relevant for the sensor type.

2. Invoke a measurement on the sensor channel by selecting the appropriate menu item from the "***Measurement Function***" located at the bottom of the screen. The menu selections for this item will depict text corresponding to one (1) of five (5) measurement points. These points will be dependent upon the defined sensor type, total measurement range, and measurement units and will correspond to 0, 25, 50, 75, and 100% of the measurement range for the corresponding sensor definition.

For instance, a strain gage defined to measure –200 to +200 microstrain will depict the following measurement options:

a. ***–200 Microstrain (uE)***
b. ***–100 Microstrain (uE)***
c. ***0 Microstrain (uE)***
d. ***100 Microstrain (uE)***
e. ***200 Microstrain (uE)***

Similarly, a thermocouple defined to measure 0 to 500° C will depict the following measurement options

a. ***0 Degree C (°C)***
b. ***125 Degree C (°C)***
c. ***250 Degree C (°C)***
d. ***375 Degree C (°C)***
e. ***500 Degree C (°C)***

For stimuli conditions not covered by the fixed selections described above, the user should select the last menu item under the "***Measurement Function***" element as "**User Specified**". This will activate a separate dialog box stating the question "**Input the current sensor input level for sensor** x **in terms of** y **measurement units**" where x will be the active calibration sensor channel and y will be its associate measurement units. The operator may then enter the appropriate measurement data in a digital input field and press OK to continue.

3. After establishing the menu selection, the system will indicate that a measurement is active on the channel. After the measurement has completed, the number of measurements on the main screen will increment by 1. For a single measurement point, the system cannot correct for both gain and offset. As such, it establishes a correction for offset only. This provides the means for an operator to "zero cal", or correct for an offset only if other stimulus levels cannot be realized. The "Cal'ed" indicator will turn green, indicating successful initial calibration of the channel, but users should be aware that no gain correction has been applied.

4. If more stimuli settings are available, repeat steps 1 and 2 for each different input level. After each measurement has completed, the number of measurements made should increment. New gain/offset data will also be depicted for that channel. Additional measurements beyond two will improve the calibration accuracy.

If an error is made in the setting of the stimuli or the selection of the measurement function, the operator may invoke the **Revert** control by pressing **Select** for the appropriate channel.

The calibration and measurement process outlined above **only** updates calibration data within the PCs local memory. Once the operator is satisfied with the calibration data for the channel, the ***Select***

Function at the bottom of the screen should be utilized to activate the menu selection for **Save Updated Values**. This will save all updated values to the receivers non-volatile memory.

6.2.3 Manual Calibration Adjustments

Manual alteration of the calibration gain/offset data is possible. To invoke this process, activate calibration on the specific channel as discussed above. This will enable editing of the number gain and offset fields depicted on the main screen. This floating point numbers may be modified via increment/decrement buttons adjacent to the digital fields, or by normal selection and data entry means for the field. The step size of the increment/decrement function reflects the resolution of the gain/offset correction values within the receiver.

As with computer assisted calibration, the manual process outlined above only updates calibration data within the PCs local memory. Once the operator is satisfied with the calibration data for the channel, the ***Select Function*** : **Save Updated Values** should be used to store the values to the receivers non-volatile memory.

6.3 Analog Channel Calibration

Independent of the sensor calibration discussed above, the system provides calibration support functions for the receivers analog channels. These functions may be utilized to accurately establish any analog channels output voltages from the Digital Telemetry System. This function is independent of the digital output data, thus providing the means for accurate analog outputs with their own unique gain/offset characteristics.

To enable the analog calibration support functions, use the Digital Telemetry Control Software as follows:

1. Establish normal connections between the Digital Telemetry Receiver and the PC.
2. Start the control program on the PC from the installed program directory.
3. Select "***Tools : Calibrate Receiver Analog Channels***".

This action will result in a screen being displayed depicting each analog channel of the system as well as its current calibration gain/offset settings. The left-hand side of the screen has a column labeled "Calibrate" with a corresponding On/Off control for each channel. To activate calibration on an analog channel, the user should select this control button to change its condition to "On".

Next, the following steps should be followed:

1. Establish a stable receiver operating temperature in line with the expected operational temperature during testing.

2. Invoke a measurement on the sensor channel by selecting the appropriate menu item from the "***Measurement Function***" located at the bottom of the screen. The menu selections for this item will depict text corresponding to -10, -5, 0, +5, and +10 VDC. Optionally, a ramp measurement function will cause the analog channel to be continually ramped from -10 to +10 VDC.

3. After establishing the menu selection, a separate dialog box will be presented stating "**Enter the current output level of the selected analog channel in VDC**". The operator may then enter the

appropriate measurement data from the appropriate analog channel in a digital input field and press OK to continue. This will cause the number of measurements on the main screen to increment by 1.

4. Repeat steps 2 and 3 for a different measurement level. After this has completed, the number of measurements made field should display “2”. Furthermore, the “Cal’ed” indicator will turn green, indicating successful initial calibration of the channel. Finally, new gain/offset data will be depicted for that channel.

Additional measurements beyond the 2 discussed above can be activated which will improve the accuracy of the calibration process.

If an error is made in the setting of the stimuli or the selection of the measurement function, the operator may invoke the **Revert** control by pressing on **Select** for the appropriate channel.

The gain/offset values may also be manually adjusted in the corresponding field. As changes are made, the new values will be downloaded to the receiver and will begin to affect the associated channel immediately.

Once the operator is satisfied with the calibration data for the channel, the ***Select Function*** at the bottom of the screen should be utilized to activate the menu selection for **Save Updated Values**. This will save all updated values to the receivers non-volatile memory.

(This page intentionally blank)

SECTION 7 MAINTENANCE

In order to ensure that the Digital Telemetry System is always ready for operation, it should be checked periodically such that defects may be discovered and corrected before they develop into any serious damage or system failure. A minimal preventive maintenance program will significantly increase the systems life span.

This section describes the necessary preventive maintenance checks and tests the user can perform to easily identify most defects and problems. Any other defects or problems discovered during the normal operation of the system should be noted for future corrective measures.

CAUTION

Stop the operation of the system immediately if a problem is noted during normal operation that can otherwise damage the system.

This section also describes the corrective maintenance checks that can be performed on the Digital Telemetry Systems.

7.1 Maintenance Concept

The maintenance concept for the Digital Telemetry Equipment is limited to period preventive maintenance actions as identified in the following sections.

7.2 Preventive Maintenance Requirements

The following is a recommended timetable for performing preventive maintenance checks on Series 500e Digital Telemetry Systems.

CAUTION

Power to the chassis must be turned OFF when performing preventive maintenance on the equipment.

7.2.1 Inspection

The Digital Telemetry System, chassis, and interface cables should be inspected periodically for defects or physical damage developed during operation. Inspect all the interface cables for cracks, breaks and proper seating with their mating connectors. Inspect all cables for frayed, broken or damaged wires. In addition, inspect all connections for accumulation of dirt, grease, or any foreign material that can cause a non-connection. If a cable is found damaged or non-repairable, it should be replaced before operating the system again.

Inspection should be performed at least once every month. The frequency of inspection should be increased for units exposed to dusty or heavy particulate environments.

7.2.2 Cleaning

Clean the outside surfaces and areas around the connectors periodically. Clean the surfaces with a clean, soft, lint-free cloth. Clean the areas around the connectors with a soft bristle brush. Cleaning can be done with a cloth moistened in warm soapy water after all the excess water has been squeezed out of the cloth.

To remove grease, fungus, or corrosion, use a cloth dampened in high quality electronic cleansing solution.

Cleaning should be done at least once every month. The frequency of cleaning should be increased for units exposed to dusty or heavy particulate environments.

7.3 Corrective Maintenance Requirements

SRI/PMD does not recommend any corrective maintenance actions be performed for fielded units except as specifically directed by SRI/PMD during any potential service assistance calls. In general, if a transmitter or receiver is exhibiting suspect behaviors, the operational start-up procedures discussed in section 4 of this document should be followed in an attempt to isolate potential areas of failure. Following this action, SRI/PMD should be contacted directly for further maintenance recommendations.

APPENDIX A TYPICAL SENSOR INTERCONNECTS

The Series 500e Digital Telemetry Systems are not usually provided with the actual sensors that they will telemeter. Most often, the end user of the product selects and installs the appropriate sensor and provides the interconnection to the Digital Telemetry Transmitter. This is typically accomplished either via direct solder connections or connectorized/header interfaces to the transmitter. The following sections describe some of the typical sensors which may be utilized with this product, and discusses the interconnect considerations for each type.

A.1 Balanced Bridge Sensors (Strain/Pressure/...)

Balanced bridge sensors are most often accomplished with sensors forming what is classically called the "Wheatstone Bridge Circuit". As shown in the following figure, the balanced bridge is created via four (4) nominally equal resistance values, one (1) or more of which may vary with the parameter being measured (i.e. strain, pressure, ...).

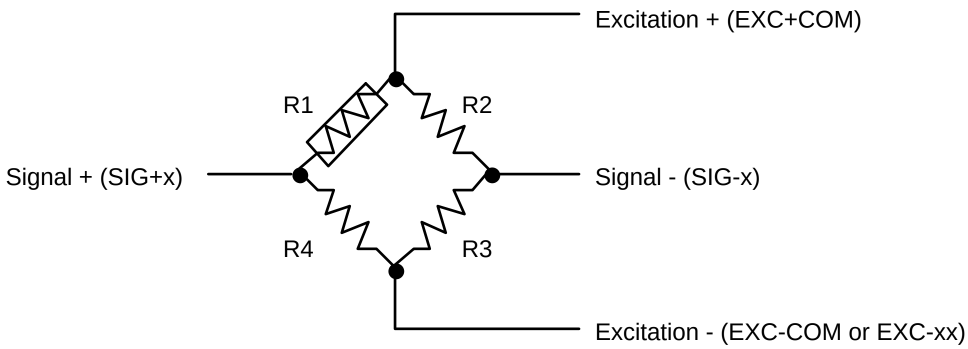


Figure A-1 Typical Balanced Bridge Circuit

The figure depicts what is known as a single active arm circuit. In this case, R1 is the only arm of the balanced bridge that varies with the measurement parameter. The R1 in this case is a single active gage, widely available from a number of sensor manufacturers. R2 through R4 are fixed resistance values (typically 120, 350, or 700 Ω each), most often formed via a bridge completion circuit. Again, bridge completion circuits are available from these same manufactures.

Under nominal (i.e., zero (0) measurement value) conditions, the circuit creates a balanced, voltage divider network. As such, the excitation voltage from the Digital Telemetry Transmitter (i.e., EXC+COM and EXC-COM or EXC-x for multi-sensor channel systems) is divided in half via the path R1 to R4. This creates the positive sensor signal back to the transmitter (i.e., SIG+x). Similarly, path R2 to R3 creates the negative sensor signal (i.e., SIG-x).

As the measurement parameter varies, the resistance of the active gage varies, thus creating a small differential voltage between Signal + and Signal -. The magnitude of this differential voltage determines the actual measurement value, which is then translated through by the Digital Telemetry System to the analog output port associated with that sensor. Each system is configured at the factory for the maximum measurement range of the sensor, which determines the maximum amount of differential voltage between the + and – Signal inputs which will correspond to the maximum and minimum voltage outputs of the analog port.

Users may also incorporate sensor configurations that utilize multiple active arms. For instance, by replacing R4 with an active gage and limiting the bridge completion circuit to R2 and R3, a two (2) active arm bridge is created. With no changes to the telemetry system, this in affect doubles the resolution of the circuit while halving the maximum measurement range. For instance, a single active arm strain gage sensor may be configured to measure ±1000 microstrain (uE), which would equate to 100 uE/VDC on a ±10 VDC analog output channel. By modifying the circuit to a two (2) active arm bridge, the analog output port will reflect 50 uE/VDC if no other parameters are modified. Similarly, a four (4) active arm system, with R1 through R4 all being accomplished via active gages with increase the resolution by 4 when compared to a single active arm system.

The Digital Telemetry System also supports selectable excitation voltage levels. This feature may be utilized to reduce the current utilization of sensors utilizing the excitation voltage. Typical sensors utilizing +5 VDC excitation will require twice as much system current as compared to a reduced excitation voltage of +2.5 VDC. However, the output differential voltage associated with any given measurement value will also be reduced by half. Although the Digital Telemetry System automatically compensates for this reduced output value by doubling the invoked gain settings, the accuracy of resulting measurements is reduced as a consequence. Note that the output excitation voltage level is a configurable parameter on a per transmitter basis. As such, this level cannot be varied for different sensor inputs to any given, single transmitter.

It is also important to note that on multi-sensor input systems, the Digital Telemetry Transmitter only activates the excitation voltage to any given sensor during the actual measurement period associated with that channel. This reduces the total power consumption of the system by eliminating current draw from sensors that are not being actively measured. The multiplexing of the excitation voltage is accomplished by allowing the excitation – voltage associated with the sensor channel (i.e., EXC-x) to float during non-active periods. In order to realize the power consumption savings of this feature, users should not incorporate sensor configurations that tie the EXC-x signal to an external ground reference.

A.2 Thermocouples

A thermocouple is a temperature measurement sensor that consists of two dissimilar metals joined together at one end (i.e., a junction) that produces a small thermoelectric voltage when the junction is heated. As shown in the following figure, this thermoelectric voltage causes a differential voltage between the signal + and – inputs (i.e., SIG+x and SIG-x) to the Digital Telemetry System for the particular sensor input channel.

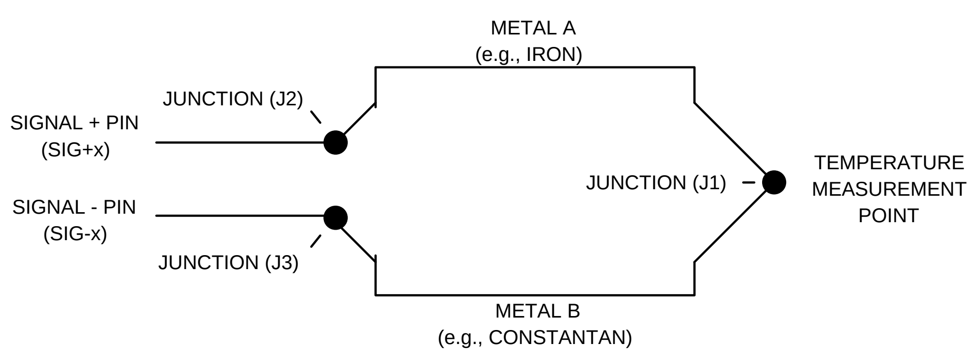


Figure A-2 Typical Thermocouple Circuit

Different types of thermocouples incorporate varying types of dissimilar metals. For instance, the Iron-Constantan version shown above is known as a type J thermocouple, while Chromel-Alumel is utilized for type K, and so forth. Each type of thermocouple provides varying levels of output differential voltages for different input measurement temperatures. When purchasing a Digital Telemetry System, the user will specify the type of thermocouple(s) being incorporated, thus allowing the factory to establish the appropriate gain settings for each sensor input.

Note that although the point labeled J1 in the diagram is the dissimilar metal junction of interest, the actual pin interconnects to the Digital Telemetry Transmitter (shown as J2 and J3 in the figure) also form dissimilar metal junctions. If the affects of junction J2 and J3 are ignored, small offsets or errors in the measurement value may be present, which will vary with the transmitters operating temperature. This may be acceptable for thermocouple applications measuring a large temperature range as compared to the variation of operating temperature for the transmitter itself.

However, the Digital Telemetry System configured for one or more thermocouple sensor inputs will automatically calibrate itself for this offset voltage. As described in the main text of this document, temperature based compensation provides the means by which the systems gain and offset values will vary with operating temperature of the transmitter. This provides the means by which the temperature varying errors produced by junctions J2 and J3 are eliminated, thus producing an accurate measurement representation at the receiver output ports. Since for thermocouples the effects of the dissimilar metal offset are predictable, the system automatically accounts for this when the sensor is defined. Furthermore, end users may perform a manual calibration process in the field via the Digital Telemetry Control Software if additional errors are present.

It should be noted that under dynamically varying transmitter operational temperature conditions, there is sometimes a minor temperature differential between the Signal + and – pins (i.e., J2 and J3 in the example figure) and the detected operational temperature of the transmitter itself. This is true since the transmitter operational temperature measurement is based on an internal sensor embedded within the transmitter mold as opposed the Signal + and – pins which are located on the exterior surface of the mold. In these cases, a slight offset in sensor measurement may be present through the telemetry system until such time as the two temperatures have stabilized and are equal.

A.3 Thermistors

Thermistors are sensors that vary in resistance based on temperature. This is similar to operation of a strain gage and, in fact, thermistors may incorporate balanced circuitry like the Wheatstone bridge to provide a differential voltage measurement to the Digital Telemetry System proportional to the thermistor temperature.

Thermistor circuits may also utilize a simpler voltage divider network as depicted in the following diagram.

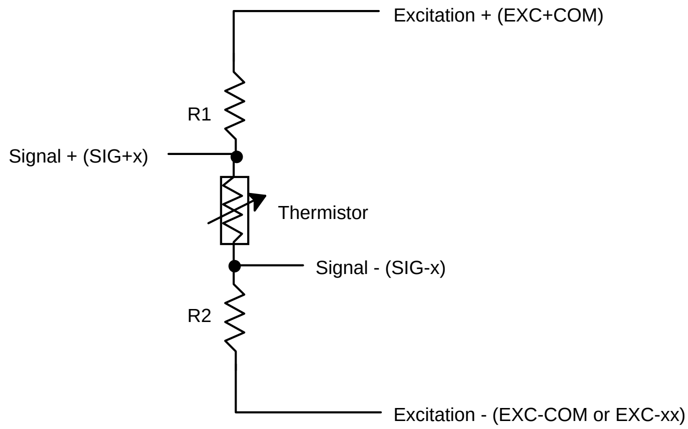


Figure A-3 Simple Thermistor Circuit

This circuit is typically less accurate than the balanced bridge approach, but may still be sufficient for some measurement applications.

The exact voltages which will be produced by a balanced bridge thermistor configuration or the simplified voltage divider network shown above depend on the resistance values implemented. This directly affects the necessary sensor definition for this input in the Digital Telemetry System. Users may contact SRI/PMD for assistance in determining these values and the corresponding sensor definition settings for the thermistor.

A.4 Accelerometers

Accelerometers are sensors that produce a differential voltage proportional to the acceleration forces on the sensor in a specific axis or direction. Multi-axis accelerometers are frequently utilized (bi-axial or tri-axial) to measure forces in more than one (1) direction. For applications incorporating multi-axis devices, the differential voltage outputs from each axis are typically interconnected to different sensor inputs on the Digital Telemetry System.

Most accelerometers are active devices, thus requiring an excitation voltage in order to produce the measurement output(s). They also typically require a significant amount of "power-on" initialization time before producing accurate results. This initialization or settling time is usually not compatible with the multiplexed excitation voltage of the Series 500 equipment.

To circumvent this limitation, the accelerometer power leads may be connected to EXC+COM output (which always produces a selectable DC output voltage) and the GROUND pin of the primary power input to the transmitter. By bypassing the multiplexed EXC-x outputs from the transmitter, power will be constantly provided to the sensor during transmitter operation. Users need to be aware of the extra current draw this places on the primary power source to the transmitter and adjust the associated power budget accordingly.

Note that certain accelerometers (as well as other transducers) that output a DC offset or bias (e.g., 2.5 VDC or 1/2 Excitation Voltage) are considered Analog signals (see Section 4.2.1.2.1) due to input voltage levels in excess of 45 mV.

A.5 Other Sensor Types

As noted within the main text of this document, the Series 500e Digital Telemetry Systems can be configured for almost any type of sensor input, ranging from those which produce micro-volt DC level inputs to 0 to +5 VDC inputs. Due to the simplicity and versatility of configuring these systems, custom sensor types can also be readily accommodated.

It is important to note that for all defined sensor types other than “Generic 0 to 5 VDC” inputs, the standard product always treats the Signal + and – inputs (i.e., SIG+x and SIG-x) as differential, bipolar signals. As such, any positive or negative relationship is allowed to exist between these input signals within the configured measurement range. However, due to this implementation, neither input should ever be tied to any ground reference of the Digital Telemetry Transmitter via any path. Establishing a direct path between the input sensor signals and the transmitter ground will cause offsets that cannot be compensated for by the telemetry system.

Certain sensors require external circuitry to make them compatible with the input/output requirements of the Series 500e equipment. For example, certain piezoelectric type sensors require an external charge amplifier to produce a compatible voltage output. Similarly, some sensors require an excitation signal from a frequency source. SRI/PMD frequently delivers custom external circuitry that can readily be connected to a standard transmitter to accomplish these adaptations.

Potential users with unique or special sensor input needs should contact SRI/PMD directly for assistance in determining the suitability of the Series 500e products for these applications.

Summation Research Inc

Summation Research, Inc Is

- ***A QUALIFIED SMALL BUSINESS VENDOR***
- ***LOCATED ON THE HIGH TECHNOLOGY SPACE COAST OF FLORIDA***
- ***DEDICATED TO PROVIDING ON-TIME AND APPROPRIATE SOLUTIONS TO THE CHALLENGES OUR CUSTOMERS PRESENT***
- ***FOUNDED ON THE FIRM BELIEVE THAT SMALL COMPANIES CAN EFFICIENTLY PROVIDE RAPID RESPONSE, LOWER COST SOLUTIONS TO LARGER COMMERCIAL CORPORATIONS OR GOVERNMENT AGENCIES.***

Summation Research, Inc Specializes In

- ***SPECIAL AND GENERAL PURPOSE COMMUNICATIONS EQUIPMENT***
- ***PRIVATE LAND MOBILE RADIOS***
- ***SATELLITE TELEMETRY AND COMMUNICATIONS EQUIPMENT***
- ***AUTOMATED PRODUCTION TEST EQUIPMENT***
- ***HIGH PERFORMANCE SPECIALIZED TEST EQUIPMENT***

Summation Research, Inc Provides

- ***ENGINEERING RESEARCH AND DEVELOPMENT SERVICES AND/OR STUDIES***
- ***PRODUCT DESIGN AND DEVELOPMENT***
- ***PROTOTYPE TO PRODUCTION ENGINEERING***
- ***FABRICATION, MANUFACTURING OR REFURBISHMENT SERVICES***

FOR MORE INFORMATION ON SRI OR ANY OF ITS PRODUCTS,
CONTACT ANY OF OUR AUTHORIZED REPRESENTATIVES
-OR-
WRITE US AT SUMMATION RESEARCH, INC., 751 NORTH DRIVE, MELBOURNE, FL 32934
-OR-
CALL US AT (321) 254-2580 OR FAX TO (321) 254-2492
-OR-
VISIT OUR INTERNET HOMEPAGE AT http://www.summationresearch.com
-OR-
EMAIL TO: info@summationresearch.com