Optimus
User Manual

Revision 2.0
July 2021

Introduction:

The Optimus Data System has been designed specifically for windtunnel applications. The Optimus System Processor, OSP, manages a configurable measurement solution having high precision and throughput of up to 2048 measurement channels. Pressure is measured with ESP Miniature pressure scanners or MicroScanners and then converted to a digital value within a Miniature Scanner Digitizer Interface, mSDI. The raw digital data is converted to Engineering Unit values within the Optimus System Processor and transmitted via Ethernet at up to one (1) Gbps.

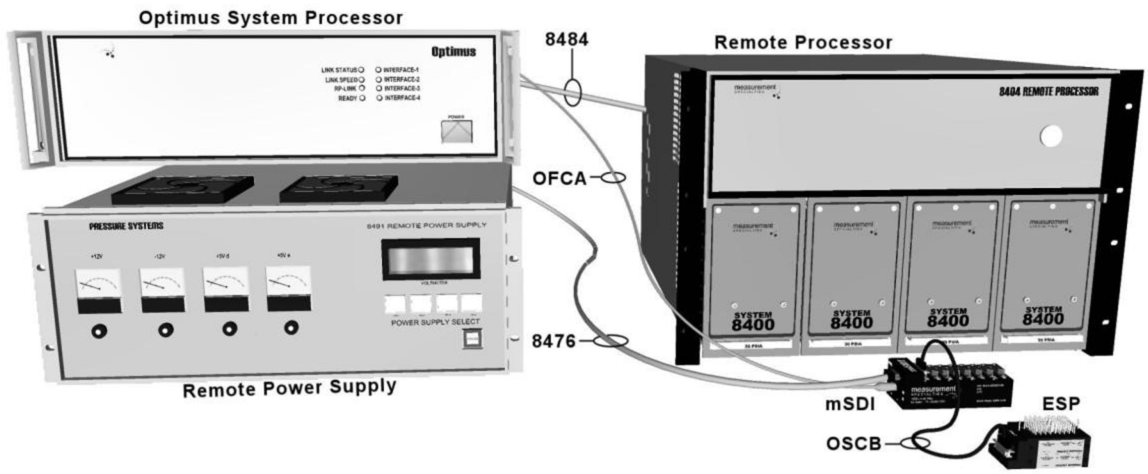


Figure 1.1: The Optimus System

As illustrated in figure 1.1, the OSP is the master, providing a standard interface through which the system is accessed. ESP pressure scanners are placed within or near the item under test and their measurement ports are attached to the pressure taps on the item under test using flexible tubing. Up to eight (8) ESP pressure scanners or MicroScanners in any combination are connected via cable to the miniature Scanner Digitizer Interface, mSDI, which can be placed within the test article, within the support structure, or at any convenient location up to a maximum of 150 feet away from the scanners. An mSDI is connected to an Optimus Fiber optic Interface, OFIU, located within the OSP, via a single multi-mode fiber optic cable. Power is supplied directly to the mSDI from a Remote Power Supply, RPS, using a separate cable. The OSP can contain up to four (4) OFIUs and thus be attached to up to four (4) mSDIs, requiring up to four (4) RPS.

Introduction: Continued

Expansion chassis can be added to the system, each capable of accommodating up to four (4) input units; pressure calibrators and pressure standards. These expansion chassis are available in two types: Remote Processors, RP, and Local Slaves, LS. An RP contains its own power supply and communicates with the OSP via a dedicated RS-485 cable. Up to three (3) RPs may be added to the system. An LS takes its power from an RP via cable and so it must be located in close proximity to an RP. An LS chassis communicates with an RP via a General Purpose Interface Bus, GPIB, independent of the OSP serial communication link. Up to seven (7) LS racks may be connected to one RP.

Input units that may be installed in either an RP or LS include: Pressure Calibration Units, PCU, which provide precise pressure calibration and performance verification information prior to start of test and Pressure Standard Units, PSU, which are read only precision pressure standards used to measure tunnel parameters having higher accuracy and precision requirements than the ESP scanners provide. It must be noted that pressure standard, PSU, and pressure generating, PCU, units each require two (2) slots and that unused slots must be occupied by dedicated Blanking Panels.

It is common to use RP and LS racks to locate PCUs and PSUs close to ESP pressure scanners in order to reduce calibration time and insure utmost accuracy. Both types of units contain secondary pressure standards that can be read periodically, and PCUs are capable of generating precision pneumatic pressures in order to calibrate ESP pressure scanners.

Individuals familiar with the legacy 8400 System may note common features and structural similarities with the Optimus. Optimus offers a convenient upgrade path for facilities having an existing 8400 System, by utilizing a common command set and re-use of 8400 components such as: 8432/8433 Pressure Calibrators, 8438/8439 Pressure Standard Units, 8491 Remote Power Supplies, 8404 Remote Processors, and ESP pressure scanners. 8400 System components that are retained for use with an Optimus system are eligible for Upgrades and Service Life Extension Plans to assure maximum performance.

Introduction: Continued

System Component Overview

The Optimus Data System provides accurate, high speed pressure data acquisition from ESP and MicroScanner pressure scanners for windtunnel test and measurement applications. The system is appropriate for use in boundary layer, low speed, transonic, supersonic, and hypersonic windtunnels with low and high channel count requirements. An Ethernet interface to the host computer offers either: Engineering Unit, EU, data, or Binary, RAW, data for users preferring to perform EU conversion within their own application. Optimus supports the latest MicroScanner and the updated Gen-2 ESP pressure scanners as well as many of the legacy ESP scanners manufactured by Pressure Systems Inc. – Now the Aerodynamic Research Group within Measurement Specialties Inc.

The Optimus System Processor

The OSP is the central data acquisition and control unit of the Optimus Data System. Configured for 19-inch rack or bench top installation, the OSP can support up to 32 - ESP pressure scanners for a total of 2048 measurement channels. An Ethernet interface allows direct host connection, and expansion beyond 2048 measurement channels.

OFIUs are installed inside the OSP and communicate with the mSDI via a single optical fiber. A minimum of one OFIU is required for system operation and up to four (4) OFIUs can be installed within one (1) OSP. The OFIUs can be factory installed at time of system production or can be easily installed by the end user.

The primary processor has two versions. The original version was manufactured by Freescale and, due to obsolescence, was replaced in new production with a processor manufactured by Compulab in early 2021. The original version was supported by firmware up to revision 4.100. The new version is identified with Ver-2 following the part number on the label and is supported by firmware starting at revision 5.000.

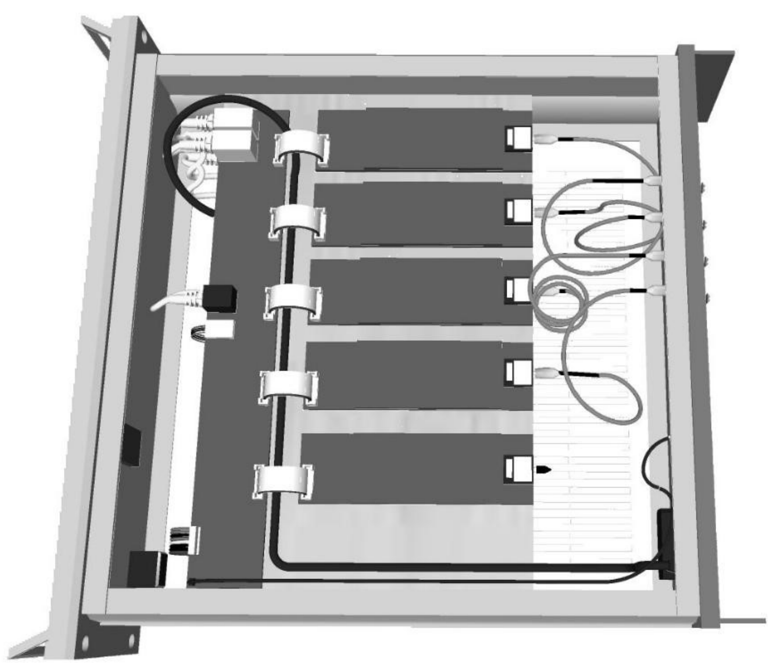


Figure 1.2: OSP with OFIU's installed

Introduction: Continued

The Optimus Fiber optic Interface Unit

The Optimus Fiber optic Interface Unit, OFIU, is installed within the OSP. This circuit board communicates with the mSDI scanner interface via a single 62.5-micron multimode fiber. The thin flexible optical cable allows placement of the mSDI within windtunnel models reducing the cabling that crosses the force balance.

An OFIU interfaces with one (1) mSDI and a minimum of one (1) OFIU is required for system operation. A maximum of four (4) OFIU slots are available inside an OSP. The OFIU fiber optic output is fed through the back panel of the OSP via industry standard ST fiber optic feed-throughs. OFIUs may be installed at time of order and can also be ordered separately and installed on site as needed.

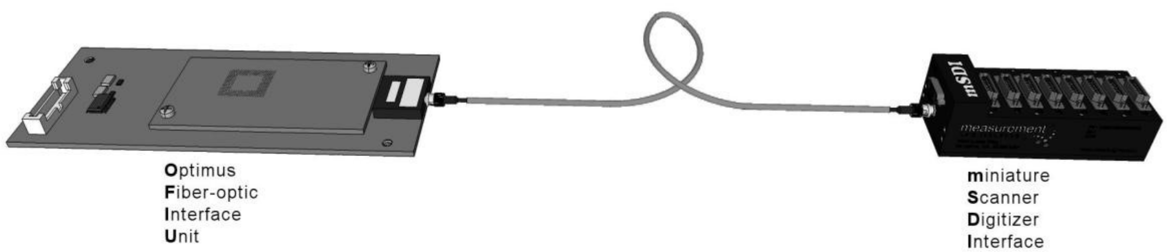


Figure 1.3: OFIU and mSDI

The miniature Scanner Digitizer Interface

The mSDI is the connection point for the cables leading to the pressure scanners. The mSDI provides power to the ESP scanners, performs excitation feedback measurement, and performs analog to digital, A/D, conversion at high data rates.

The small size and low power dissipation of the mSDI makes it ideal for mounting inside windtunnel models. The cross-sectional area matches the ESP 64HD scanner, allowing the mSDI to be placed in line with the pressure scanners for maximum channel density.

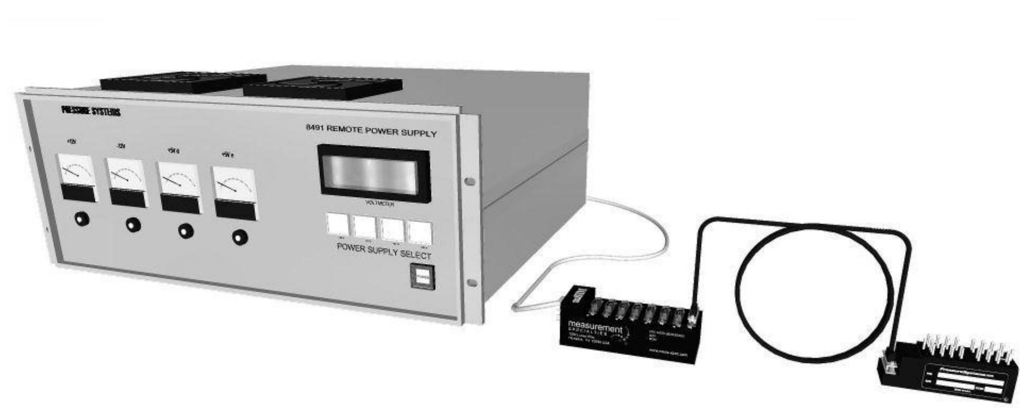


Figure 1.4: mSDI with Scanner and OSCB attached and also RPS via power cable.

Introduction: Continued

Data transport from the mSDI to the OFIU is via fiber optic cable terminated with industry standard ST connectors. Power is provided by a RPS and in turn is distributed to the pressure scanners attached to the mSDI. The pressure scanners are connected to the mSDI with an Optimus Scanner Cable, OSCB, which can be purchased in lengths ranging between six (6) inches and one hundred fifty (150) feet. OSCB cables having a length greater than thirty (30) feet are only supported when using Gen-2 DTC pressure scanners or MicroScanner pressure scanners. Within that constraint, any combination of pressure scanners attached with varied length OSCB cables may be connected to mSDI simultaneously. OSCB cables utilize standard micro D 15 pin connectors to mate with any vintage of ESP pressure scanners.

The Remote Power Supply

The RPS is configured for 19 inch rack mount installation or bench mount use and provides precision regulated power to the mSDI which in turn distributes the power to the connected ESP pressure scanners. The RPS connects to an mSDI via an 8476 cable which can be purchased in a range of lengths between ten (10) and three hundred (300) ft. The RPS uses voltage sense feedback, constantly monitoring and adjusting power delivered to the mSDI in response to varying conditions. Though multiple RPS are REQUIRED for installations having more than two (2) mSDI, an optional “Y” cable, OPCY, is available and permits a single RPS to power two (2) separate mSDI having a maximum separation of six (6) feet.

Facilities having an existing 8400 System with a legacy RPS must upgrade the RPS for Optimus compatibility.

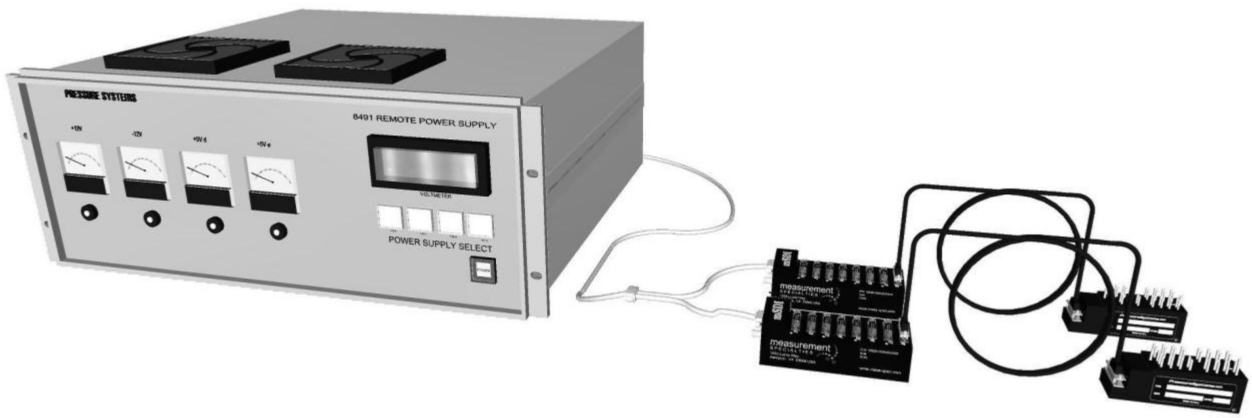


Figure 1.5: RPS with Y cable and two mSDI.

Introduction: Continued

Pressure Scanners

ESP Pressure scanners are classified as either miniature or micro scanners. The scanners are connected to an mSDI through OSCB which can be purchased in a variety of lengths ranging between 6 inches and 150 feet. Note that OSCB cables having a length greater than thirty (30) feet are only supported when using Gen-2 ESP DTC pressure scanners or MicroScanner pressure scanners.

The pressure scanners interface with the pressure taps on the item under test via flexible tubing, typically made of polyurethane. The scanners are commonly mounted in close proximity to the pressure taps within the test article. In some cases, the MicroScanner can be mated directly to a test component, without need of flexible tubing, reducing the volume required for the installation.

Optimus also supports legacy ESP scanners, including products which are no longer manufactured or supported. The performance achievable with these scanners is comparable with the current product data sheets within limits. Those limits include the maximum OSCB cable length and data throughput rate limits for non GEN-2 scanners.

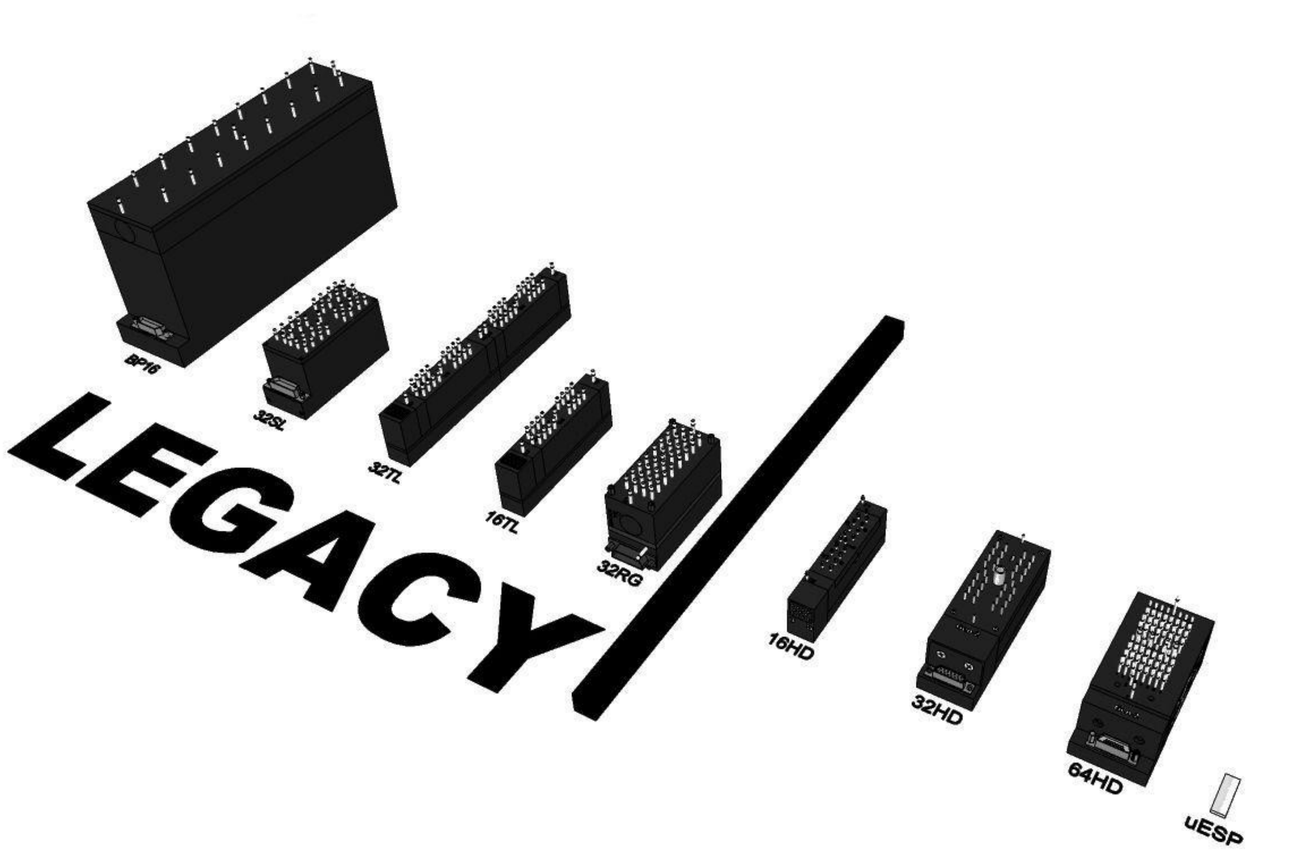


Figure 1.6: A variety of ESP scanners, from 16HD to legacy and MicroScanner

Expansion Chassis: Remote Processor and Local Slave

The RP and LS are rack mounted interfaces for the PCU and PSU. They provide complete pneumatic, electrical and communications interface for these input units. Up to four (4) input units can be mounted within one expansion chassis. All pneumatic connections are routed through a pneumatic backplane within the chassis, allowing convenient and automatic pressure connection from the units input and output ports through to the pressure scanners.

An RP contains its own AC power supply and communicates to the OSP via a serial RS-485 cable. Up to three RP's can be connected to one OSP for a total capacity of 12 PCUs and / or PSUs.

An LS can be connected to an RP, expanding the number of PCUs supported by the system. An LS receives power from the RP, communicates through the RP, and must be located in close proximity to the RP.

These chassis may be sited near the OSP, or remotely near the pressure scanners. Locating the RP and LS chassis closer to the pressure scanners reduces the length of the pressure calibration and control lines which can improve calibration speed due to reduced volume within the pneumatics.

Users with existing 8400 Systems considering upgrading to Optimus can use properly operating RP and LS without modification. Although the 8400 System is being phased out, these chassis were expected to be a part of the Optimus Data System. It is recommended that the chassis be serviced and verified to be leak free to ensure that performance goals are achieved.

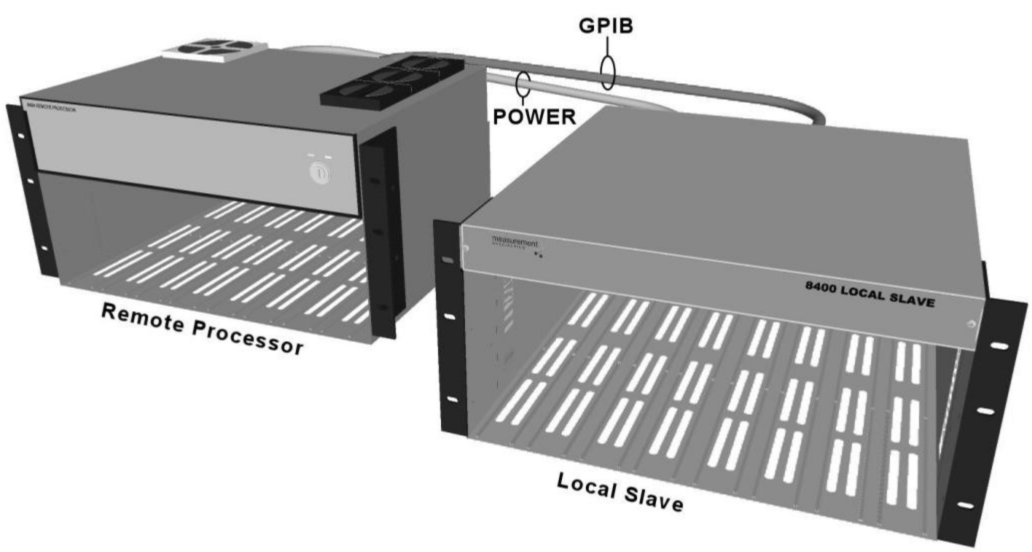


Figure 1.7: Remote Processor and Local Slave

Introduction: Continued

Pressure Calibrate Units

A PCU incorporates pneumatic valves, a pressure servo controller, and a high accuracy pressure standard. Under OSP control, the PCU facilitates the process of calibrating ESP scanners. PCUs generate pneumatic control signals which translate the calibration valve within the ESP scanners and also generate arbitrary precision pressure outputs.

PCUs can only be installed in RPs or LSs and are required for operation of the system. Owners of legacy 8400 systems may choose to refurbish their 8433/8432 PCUs for use with a new Optimus System.

Pressure Standard Units

A PSU has the same physical dimensions and appearance as a PCU and incorporates the same high accuracy measurement sensor but lacks the pressure control hardware. The purpose of the PSU is to measure and continuously monitor important wind tunnel pressures which may not associated with the primary item under test. Barometric pressure, tunnel static pressure and tunnel wall pressure are examples of measurements made with PSU's.

PSUs can only be installed in RP or LS. PSUs are an optional component of the Optimus system and are not required for operation of the system. Owners of legacy 8400 systems may choose to refurbish their PSUs for use with a new Optimus System.

Figure 1.8: PCU / PSU

Theory of Operation:

The Optimus Data System is simple to configure and operate. It is controlled by a host computer via Ethernet as part of a distributed data acquisition system. After sending the Optimus System a series of simple human readable setup commands, a continuous stream of data is returned to the host. The Optimus System's design uses a highly parallel approach to data acquisition in which data is acquired by separate input units, each having its own microprocessor. An input unit operates on a unique data acquisition profile, producing time-tagged data records which are then inserted into the system data stream. This parallel, concurrent, scanning methodology provides unprecedented acquisition speed and control capability.

All input unit processors communicate with the OSP via Ethernet or serial data links. The OSP coordinates and controls each input unit, off-loading many tasks, such as calibration and data acquisition, allowing them to be performed independently. The OSP is free to do the other functions for which it is best suited for example: process coordination and scheduling, Engineering Unit data conversion, and host communications.

A basic Optimus System configuration will contain:

1) An Optimus System Processor, OSP, having a minimum of one (1) Optimus Fiber optic Input Unit, OFIU, installed
2) A miniature Scanner Digitizer Interface, mSDI, which routes power, performs logical control, and digitizes the output of ESP pressure scanners.
3) An ESP scanner that samples multiple pressure taps on a windtunnel model.
4) A Remote Power Supply, RPS, which supplies power to the mSDI and the ESP scanners attached to it.
5) A Remote Processor, RP, providing power and pneumatic interface for Pressure Calibrate Units and / or Pressure Standard Units.
6) A Pressure Calibrate Unit, PCU, for performing calibration and verification of the ESP Scanner performance.
7) Sufficient Pneumatic Blanking Units, PBUs, which are installed in the unused slots of the RP, sealing the unused pneumatic interfaces.
8) Interconnection cables for power and communication.
9) A host computer and application software which configures the Optimus and stores the data returned from it.

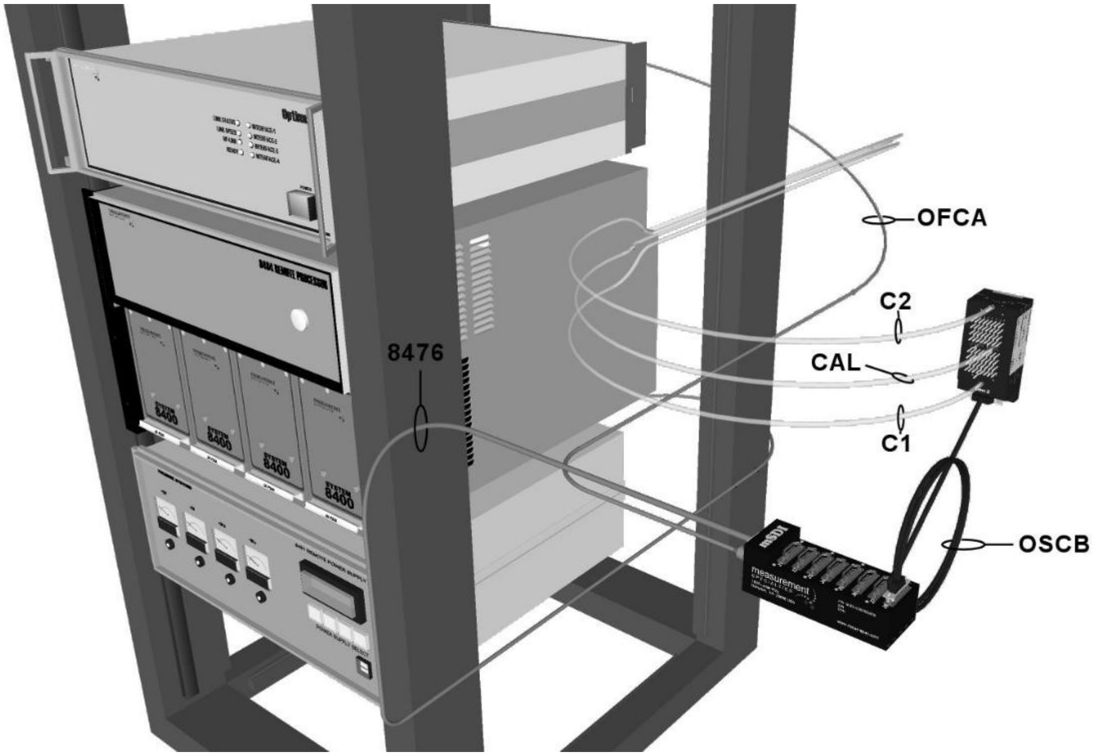


Figure 2.1: Optimus Basic System

System Component Overview

The Optimus System Processor

The OSP incorporates a Freescale MPC8308 32-bit microprocessor and integral Gb Ethernet switch, supporting an internal distributed Ethernet architecture. All input unit and expansion chassis communication is accomplished via this isolated internal network. The system application runs upon the Linux operating system which offers long term viability and upgradability of the application and the opportunity to quickly incorporate advanced features in response to customer requirements. See Appendix Z for FOSS licensing information.

Though the OSP application runs under the Linux kernel, the OFIUs are built upon Real Time Operating System, RTOS, applications that ensure deterministic data acquisition. RPs, LSs, and PCUs utilize state machines; embedded applications that perform singular tasks. The analog ESP scanner data acquisition is performed by the OFIUs. The OSP application: accepts commands from the data acquisition host computer, configures the internal system components, coordinates the operation of the system components, time-tags the data packets being acquired by the OFIUs, performs floating point conversion of the Engineering Unit data, and manages data transmission.

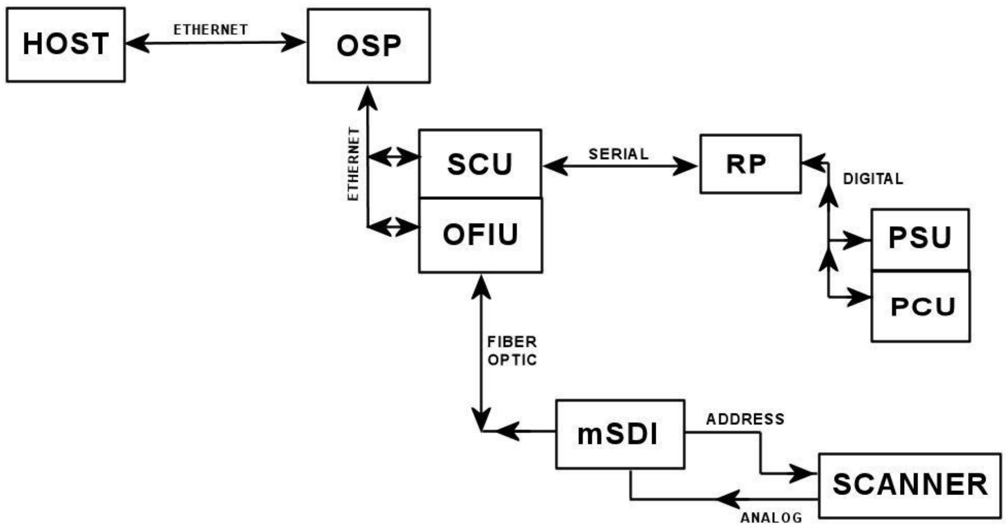


Figure 2.2: Communication path Block Diagram

The OFIU is a plug-in module located within the Optimus System Processor. Up to four (4) OFIUs may be installed within an OSP. An OFIU communicates via a single fiber optic cable with a miniature Scanner Digitizer Interface, the mSDI. The OFIU and mSDI work together to address, and digitize the output of, the pressure ports of ESP scanners connected to the mSDI. The fiber optic cable connecting the OSP and OFIU and the mSDI can be up to one thousand (1000) meters in length. The mSDI requires that a Remote Power Supply, RPS, be located within one hundred (100) meters.

An OFIU and mSDI can accommodate up to eight (8) ESP pressure scanners having a maximum aggregate channel count of 512 channels. The OFIU and mSDI scan and digitize all pressure ports of the attached scanners using one (1) of four (4) predetermined channel scan lists or Tables. The host application can switch quickly from one Table to another without being required to re-transmit and execute individual configuration commands.

OFIU and mSDIs are fully backwards compatible, supporting both conventional and DTC ESP scanners. ESP miniature scanners are typically located within, on, or near the test model and are connected to the mSDI via cables designated OSCB. Conventional ESP scanners provide a pressure output voltage per channel and require a full multipoint calibration in order to output engineering unit data. The need for a full multipoint calibration when using Conventional ESP scanners explicitly requires an RP and Pressure Calibrate Units, PCUs. Conventional ESP scanner pressure coefficients are not stored within the Optimus and must be either: saved externally by the host application or recreated every time the scanners are used. DTC ESP scanners not only provide pressure output but also temperature and excitation voltage of the scanner. This data is utilized in conjunction with factory determined, permanent, pressure conversion coefficients for each pressure port, stored on an EEPROM within the DTC ESP scanner itself. This feature allows DTC ESP scanners to operate accurately over large temperature ranges without having to regularly perform full pneumatic pressure calibrations. The OFIU uploads the DTC coefficients to the OSP on start up, and is then ready to acquire data and convert it to Engineering Units.

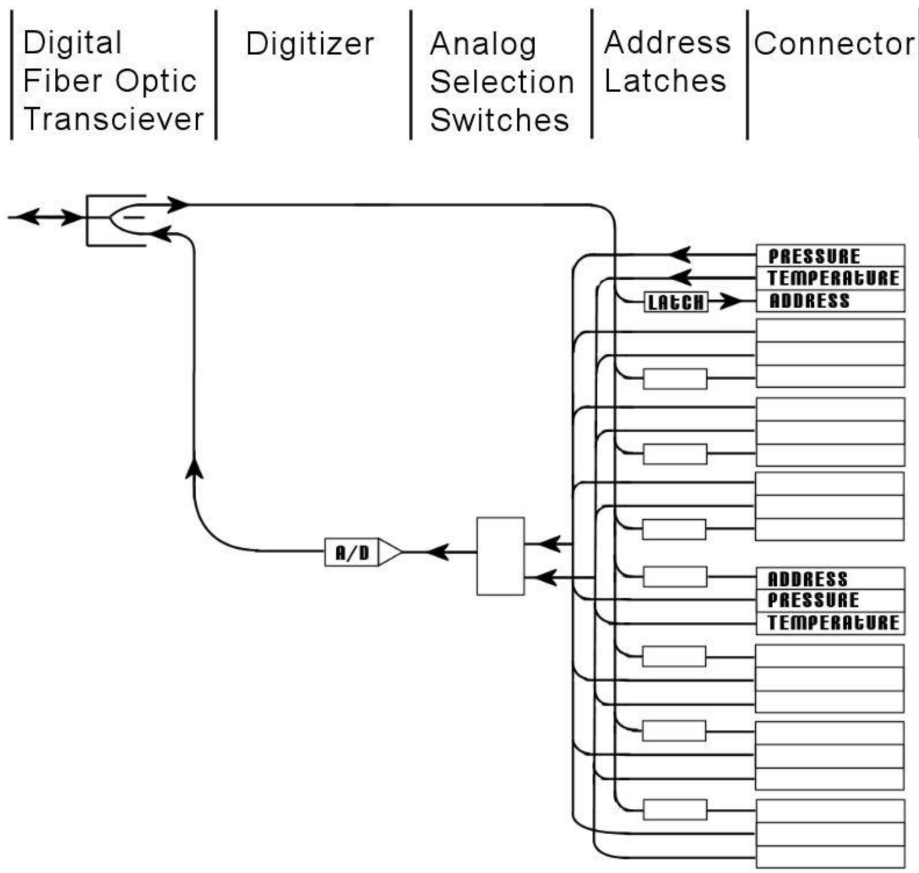


Figure 2.3: mSDI Block Diagram

The major blocks of the mSDI are: Analog to Digital Converter (ADC), Address and Control Logic, eight (8) channel analog multiplexer, instrumentation Amplifier, and Fiber Optic communications channel to the OFIU. The ADC's digital output is a 16-bit unsigned binary number with values in the range 0-65535 (0000-FFFF Hex). Zero volts is digitized to an "offset" value in the middle of this range, 32768 or 0x8000, in order to obtain bipolar voltage measurements.

Theory of Operation: Continued

When raw data are output to the host, the OSP converts them to signed short integers, in the range -32768 to +32767, or equivalent voltages approximating -5.0000 to +5.0000 volts. In addition, averaged raw data, 24-bit unsigned integer partial sums not yet divided by the number of samples per average, may also be output.

OFIU and mSDI are interconnected via a high-speed fiber-optic link that only transmits digital data. A single mSDI can connect to and scan up to 8 DTC or Conventional ESP scanners. A separate power cable connected between the Remote Power Supply, RPS, and mSDI powers the attached scanners and the mSDI itself. An optional “Y” cable, OFCY, permits a single RPS to supply power for two (2) mSDI.

Expansion Chassis: Remote Processor, RP, and Local Slave, LS.

An Optimus System Processor supports 12 pressure ranges, but has no rack or pneumatic interfaces in which to install PCUs or PSUs. Remote Processors and Local Slaves provide the racks for installing these units and have a pneumatic manifold for routing the necessary calibration, reference, and control lines.

The Optimus System can be expanded using RPs, to a maximum of three (3), and or LSs, to a maximum of seven (7) per RP, and each of these chassis contains eight (8) slots for PCUs or PSUs. These expansion chassis are linked to the OSP via a serial interface, providing control and data communication for a maximum of twelve (12) input units.

Theory of Operation: Continued

Pressure Calibrate Unit, PCU, and Pressure Standard Unit, PSU.

PCUs and PSUs occupy two (2) slots within an RP or LS chassis. The PCU is a general purpose, digitally controlled, pneumatic calibration source and pressure generator. It generates pressure by modulating a pressure supply against a pressure sink; the vacuum inputs or vent ports. The supply, sink, output, and reference pressures enter and exit the PCU via a pneumatic manifold incorporated into the RP or LS chassis. A PSU is a PCU without the ability to generate pressure but still incorporating a high accuracy pressure standard transducer. PCUs and PSUs are available in a variety of pressure ranges. Each PCU is “keyed” to output its generated pressure through one port, assigned by the pressure range. Two PCUs keyed for the same port cannot be placed in the same chassis. In installations where two or more PCUs of the same range are required, it is possible to either add a separate expansion chassis or to modify the output port assigned to one of the instruments to prevent conflict.

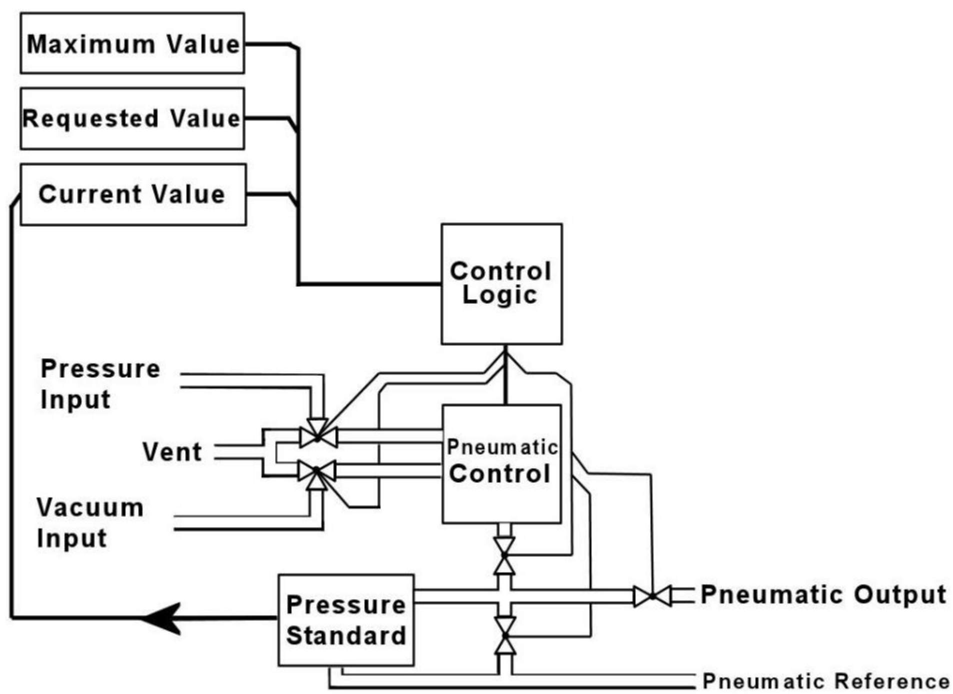


Figure 2.4 PCU and PSU Block Diagram

Measurement Specialties has produced a variety of PCUs and PSUs, including low pressure absolute, differential with high line pressure capability, and temperature compensated resonant quartz versions. All of these legacy instruments are compatible with Optimus and are eligible for service life extension programs.

Pressure Blanking Unit, PBU

All of the slots within an Expansion chassis must be sealed for the system to operate correctly. Slots that are unoccupied by PCUs or PSUs must be filled using PBUs. These units are passive, taking no part in data acquisition.

The Optimus Boot Process

The Optimus, in addition to being a chassis containing necessary components, is an embedded application residing within non-volatile storage on the system processor board.

Simultaneous to and separate from the Linux boot process, the OFIUs boot up, determine that an mSDI is attached to their fiber optic interfaces, and also whether any ESP DTC scanners are connected to the mSDI. If the OFIU determines that ESP DTC scanners are connected to the mSDI, it will immediately begin extracting the temperature and pressure correction coefficients from within the DTC Scanner internal memory. Once the OFIU has completed this process it will wait for a TCP/IP connection from the Optimus application, resident on the OSP main circuit board.

After the Linux kernel has completed the boot process, the front panel LED display is configured; displaying network link status and rate, and whether the Optimus application is operating. Optimus searches the internal, to the OSP, network, establishes a TCP/IP connection to each of the installed OFIUs, and also to the Remote Processor communication server. The status of the OFIUs and the RP communication link are indicated on the front panel LED display. Optimus is now prepared for a TCP/IP connection from a host PC, which must configure the Optimus for data acquisition. Optimus cannot begin data acquisition autonomously, nor will it automatically discover PCUs or PSUs.

The Data Acquisition Process

Before describing the configuration of the system, it is necessary to generally describe the manner in which data is acquired and its treatment or manipulation while being assembled for transmission to the controlling host application. This short section presents terms and concepts that, while not complete, are necessary to understand the system configuration.

Optimus is a scanned, multiplexed data system meaning that each of the ports on the attached ESP scanners, and in turn each of the individual ESP scanners, is selected by a digital word or Address. An address word list, a Scan List, is created that defines the order in which each port of every ESP scanner is sampled.

The Scan List is created and maintained within the OFIUs in response to the OFIU configuration commands sent by the host application. When the system is Triggered, commanded to acquire data, the address words stored in the Scan List are applied, in sequence, to the address input pins of the ESP scanners cable connector, selecting the analog voltage output of the ESP scanners port. The voltage output is digitized, and the resulting Single Point value is stored in memory in preparation of being manipulated mathematically. The stored array of values resulting from a single traversal of the Scan List is referred to as a single Frame of data.

Averaging of a number of Frames may also be performed in order to increase resolution and reduce random noise. The resulting Frame of data, whether it is an average derived from several traversals of the Scan List or a single data point, is referred to as a Measurement Set; an array of data containing a single value for each port of every ESP scanner that is physically attached to the mSDI.

When the Optimus is Triggered, Frames are acquired and assembled into Measurement Sets, and a specified number of Measurement Sets are transmitted to the host application. The number of Measurement Sets transmitted can be continuous, started and stopped by an explicit command, or bounded, begun by an explicit command and ceasing after a specific number of Measurement Sets has been acquired and transmitted. The internal operation of Optimus favors streaming data continuously and host applications must utilize this method in order to optimize throughput.

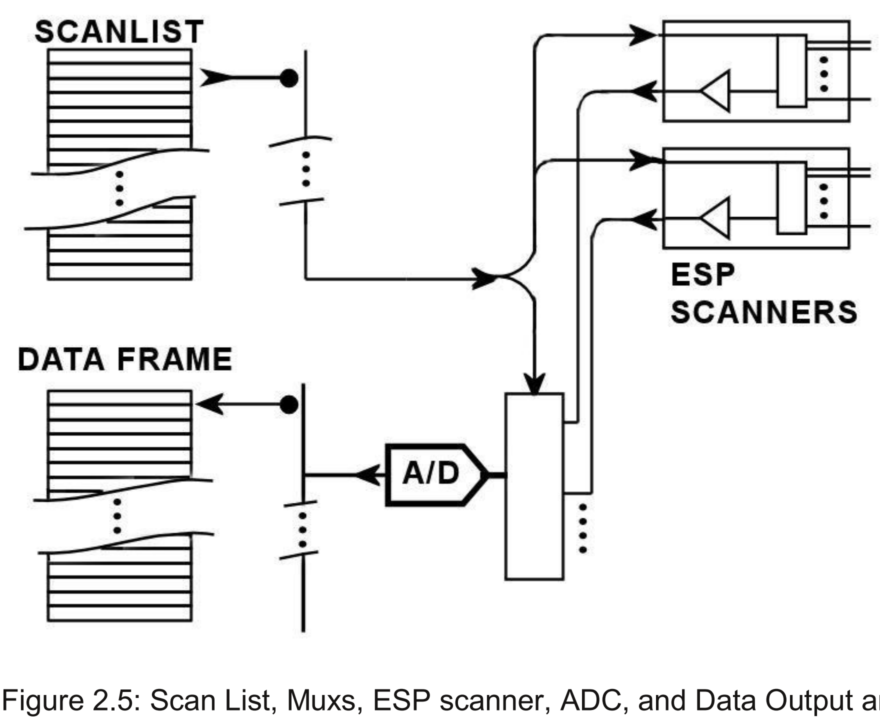


Figure 2.5: Scan List, Muxs, ESP scanner, ADC, and Data Output array.

Theory of Operation: Continued

The Optimus Configuration Process

A basic Fiber Input Unit, OFIU, Configuration

The Optimus Data System must be explicitly configured for the desired data acquisition profile before it will begin acquiring and transmitting data. In addition, the user application must continuously maintain the TCP/IP socket connection to Optimus until such time as it is no longer required to acquire and transmit data. Though there are a wide range of functional parameters available, which may be manipulated to control the acquisition process in fine detail, a reasonable acquisition profile can be quickly established using a subset of the commands listed in later sections of this manual.

> **Note:** A data acquisition profile, a Table, must be explicitly defined, immediately after a TCP/IP connection is established. Default values for functional parameters are the exception and profiles are not stored across re-boots or between TCP/IP connections.

Configuration of Optimus for a data acquisition profile, a Table, is accomplished by defining the following.

1) The number of ESP scanners connected to the system.
2) The number of Ports contained within each ESP scanner.
3) The OFIU and mSDI to which each ESP scanner is connected.
4) The channel, connector, on the mSDI to which each ESP scanner is connected.
5) The number of samples, Frames, which will be averaged to derive each Measurement Set.
6) The Rate at which the Frames will be acquired.
7) The Rate at which the Measurement Sets will be transmitted by the System to the host application.
8) The number of Measurement Sets that will be transmitted.
9) The number of total ESP scanner ports that will be included in the Measurement Sets transmitted to the host application.

The parameters, above, are defined by three discrete commands, which must be sent to an OFIU to which ESP scanners are connected. Following is a description of the ‘SDx’, Scanner Digitizer, configuration commands. Some details, necessary for understanding the calibration of ESP scanners and expansion to encompass multiple OFIUs, will be lightly touched upon and omitted where necessary to avoid over complication of the concepts presented.

Theory of Operation: Continued

Definitions:

LRN – Logical Range Number; an arbitrary number, value ranged from one (1) to twelve (12), used to associate an ESP scanner with a PCU, Pressure Calibrate Unit, in support of calibration of the ESP scanners.

CRS – Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Frame – A collection of data, containing values for the individual ports of a group of ESP pressure scanners.

Measurement Set – A Data Structure created using one or more Frames and transmitted to the host computer connected to the Optimus Data System.

Table – A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

In the listing of parameters that must be defined, items 1 – 4 are set using the 'SD1' command, items 5 – 8 are set using the 'SD2' command, and item 9 is set using the 'SD3' command.

By convention, the first command to be issued is the 'SD1'. This command applies to an OFIU and its mSDI installed at a specific location within the system chassis, defined by the CRS, Cluster, Rack, and Slot number. Each ESP scanner, attached via an OSCB cable to the mSDI, is listed in the body of the 'SD1' command indicating: the number of the mSDI connector to which it is attached, the number of ports on the ESP scanner, and the LRN, Logical Range Number, of the PCU with which it will be calibrated.

The form of the 'SD1' command, from the Programmers Reference chapter of this User Manual is:

"SD1 CRS (Scnr Nports LRN) (Scnr Nports LRN) …;"

Where:

Scnr – The mSDI connector to which the ESP scanner is connected.

Nports – The number of pressure measurement ports on the ESP scanner.

For example, for a system configuration having two (2) ESP DTC 32 port scanners attached to connectors 1 and 2 of an mSDI, and that mSDI connected with the first OFIU in an Optimus System Processor, the 'SD1' command is:

"SD1 111 (1 32 1) (2 32 1);"

To re-cap; this command specifies that "The ESP scanner attached to connector number one (1), of the mSDI associated with the OFIU at system chassis location CRS 111, has 32 pressure ports and is to be calibrated by the PCU identified as Logical Range LRN one (1). The ESP scanner attached to connector number two (2), of the mSDI associated with the OFIU at system chassis location CRS 111, has 32 pressure ports and is to be calibrated by the PCU identified as Logical Range LRN one (1).".

Theory of Operation: Continued

The parameters of this ‘SD1’ command explicitly state that there are two ESP scanners, that they have 32 pressure ports each, and that they are attached to connectors numbered one (1) and two (2) on the mSDI. It also implies that both ESP scanners have a full scale pressure range that is, if not identical, certainly compatible because they are both assigned to use the same Pressure Calibrate Unit; LRN one (1).

After issuing the ‘SD1’ command, the acquisition profile of this Table is set using the ‘SD2’ command. The ‘SD2’ command applies to a single OFIU and its mSDI at a specific location within the system chassis, specified by the CRS, Cluster, Rack, and Slot number. The ESP scanners are not indicated in this command. Only the collection parameters for a single Table of this OFIU are set including: the number of Frames that will be averaged to generate a Measurement Set, the total number of Measurement Sets to be transmitted, the rate at which Measurement Sets will be delivered, and the Trigger event that will drive acquisition of the Measurement Sets.

The form of the ‘SD2’ command, from the Programmers Reference chapter of this User Manual is:

“SD2 CRS sTBL (nFR FRd) (nMS MSd) (TRIG SCNm) OCf;”

Where:

sTBL – The number of the Table being defined.

nFR – The number of Frames to be averaged.

FRd – The Amount of time between each Frame, in microseconds.

nMS – The total number of Measurement Sets to be output.

MSd – The interval at which the Measurement Sets will be output.

TRIG – The trigger event that will start the acquisition.

SCNm – The Scan Mode for acquiring data.

OCf – The data Output and Conversion Format.

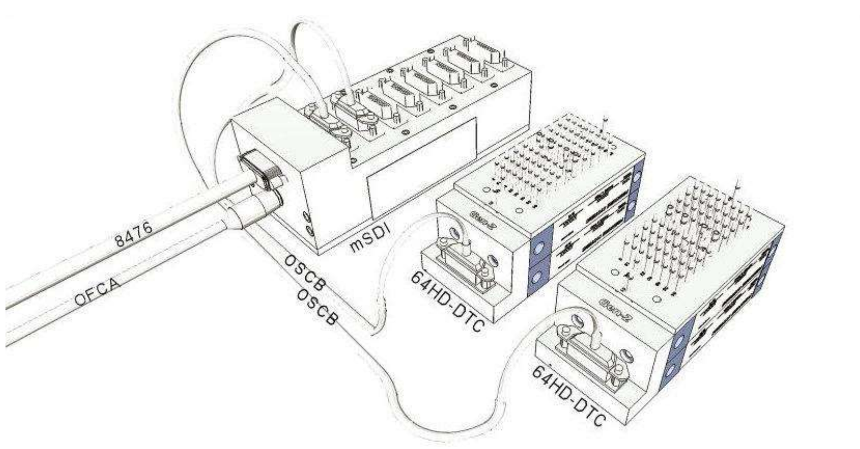


Figure 2.6: Two ESP scanners connected to mSDI connectors 1 and 2

Theory of Operation: Continued

For example, continuing the configuration described earlier, in order to use Table one (1) to acquire Measurement Sets continuously at ten (10) Hz, each Measurement Set being the average of ten (10) Frames, with the Format of the Measurement Set being an array of IEEE floating point values, the ‘SD2’ command is:

“SD2 111 1 (10 0) (0 100) (FREE PAM) 2;”

To re-cap; this command specifies that “When commanded to start acquiring data using Table one (1) for the ESP scanners indicated in the ‘SD1’ command of the OFIU and mSDI at chassis location CRS 111; acquire 10 Frames of data and calculate the average value for each of the scanner port values, calculate the Engineering Unit value for each of the port data values in the averaged Frames, Structure the Measurement Set data as an array of Floating Point values, Transmit the Measurement Set to the host computer, and repeat the process every one hundred (100) milliseconds until commanded to stop.”.

The ‘SD2’ command is not dependent on the number of ESP scanners or the number of ports on those scanners. In this example the Measurement Set will have 64 values contained within it, one (1) for each of the ports of the ESP scanners specified in the ‘SD1’ command, and each port value will be the average of ten (10) samples, Frames, acquired as rapidly as the OFIU can traverse the Scan List. The Measurement Sets will be transmitted on one hundred (100) millisecond intervals.

Once the ‘SD1’ and ‘SD2’ commands have been sent the ‘SD3’ command completes the configuration of the OFIU. The ‘SD3’ command applies to a single OFIU and its mSDI at a specific location within the system chassis, specified by the CRS, Cluster, Rack, and Slot number. ‘SD3’ specifies the order of ESP scanner port data contained within the Measurement Sets being transmitted by the Optimus. Though one can direct that the ESP scanners port data be returned in any order, it is typically returned in an array having the first value being the first port of the first ESP scanner progressing incrementally through the last port of the last ESP scanner.

Theory of Operation: Continued

The form of the ‘SD3’ command, from the Programmers Reference chapter of this User Manual is:

“SD3 CRS sTBL sPort [sPort] ...;”

Where:

sPort – The three (3) digit number indicating the mSDI connector number and the port number of the scanner to be placed at this Measurement Set index. The first digit is the connector number on the mSDI to which the scanner is attached and the final two digits are the port of the scanner. Ex; 101 is Scanner 1 port 01.

Note: This command permits entry of an implicit range of ESP scanners and their ports as well as a list of individual ports from an arbitrary group of ESP scanners.

Continuing the earlier example of two ESP scanners attached to the first two connectors of the mSDI, we specify that data from all of the ports of both ESP scanners will be placed in the Measurement Set in the order; first port of the first scanner through the last port of the last scanner. This is accomplished by separating the two sPort numbers with a hyphen “-“. The ‘SD3’command is:

“SD3 111 1 101-232;”

To re-cap; this command specifies that “When creating the measurement Set for Table number one (1), place the data from the 32 ports of the ESP scanner attached to mSDI connector number one (1) into array indices 1 through 32 and place the data from the 32 ports of the ESP scanner attached to mSDI connector number two (2) into array indices 33 through 64.”.

Once the three commands, ‘SD1’, ‘SD2’, and ‘SD3’, have been executed the Optimus can be triggered to acquire data using Table number one (1). According to the Table, the data will be transmitted at ten (10) Hz, everyone hundred (100) milliseconds, in Engineering Units; Volts if the ESP scanners are conventional or Pounds per Square Inch Differential, PSID, if the ESP scanners are Digital Temperature Compensated, DTC.

Optimus can incorporate between one (1) and four (4) OFIUs, each having an mSDI connected to it. If an OFIU and mSDI pair have ESP scanners attached it must be configured using an ‘SD1’, ‘SD2’ and ‘SD3’ command sequence. It is expected that each OFIU and mSDI is configured using the same Table number, for example Table one (1). In this way all of the connected Input Units will acquire and output data in response to the same command and trigger.

Pressure Calibrate Unit, PCU, Configuration

DTC ESP scanners contain non-volatile memory which holds conversion coefficients for temperature and pressure correction. The non-volatile memory is read during the OFIU boot process and the coefficient values are stored in memory for use. DTC ESP scanners are, in general, ready for use as soon as the warm up interval has passed, as the OSP will use the coefficients to generate Engineering Unit values from the voltage output by the DTC SEP scanners. Conventional ESP scanners do not contain non-volatile memory. In order to output Engineering Unit data for conventional ESP scanners the Optimus System must calibrate them. This is accomplished by applying a sequence of pressures to the scanners, recording the voltage output in response to the applied pressure sequence, and performing a linear regression on the pressure and voltage data. The resulting coefficients are held in memory for use and can be adjusted periodically by performing a new calibration. DTC ESP scanners also benefit from calibration resulting in an accuracy improvement of 40% over Conventional scanners having the same pressure range.

PCUs are the instruments utilized to set and measure the precision pressure signals for the calibration of ESP scanners. Like the OFIU they are independently configurable and operate under direct OSP control. Configuration of PCUs defines the following.

1) The Operating Mode of the PCU.
2) The Full-Scale pressure range of the PCU.
3) The Logical Range Number assignment.
4) The sequence of pressures that will be set when calibrating ESP scanners.

The parameters, above, are defined by two discrete commands, which must be sent to all installed PCUs via the OSP. Following is a description of the ‘PCx’, Pressure Calibrator, configuration commands. Some details necessary for understanding extended functions and features of PCU operation will be lightly touched on and omitted where necessary to avoid over complication of the concepts presented.

Definitions:

LRN – Logical Range Number; an arbitrary number, value ranged from one (1) to twelve (12), used to associate an ESP scanner with a PCU, Pressure Calibrate Unit, in support of calibration of the ESP scanners.

CRS – Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Absolute pressure – a measurement referenced, or relative, to a hard vacuum.

Differential pressure – a measurement referenced, or relative, to some other pressure.

In the listing of parameters that must be defined, items 1 – 3 are set using the ‘PC1’ command and item 4 is set using the ‘PC2’ command.

Theory of Operation: Continued

By convention, the first command to be issued is the ‘PC1’. This command applies to a PCU installed at a specific location within a Remote Processor, RP, or Local Slave, LS, chassis, defined by the CRS, Cluster, Rack, and Slot number. The PCUs LRN, Pressure operating Mode, pressure Setting Tolerance, and Maximum settable Pressure are listed in the body of this command.

The form of the ‘PC1’ command, from the Programmers Reference chapter of this User Manual is:

“PC1 CRS LRN, PrM, STol, MaxP;”

Where:

PrM – The Pressure operating Mode, either Absolute or Differential.

STol – The pressure Setting Tolerance, in Pounds per Square Inch.

MaxP – The Maximum settable Pressure, the maximum settable pressure in Pounds per Square Inch.

For example, continuing the earlier OFIU and OSP system configuration for the two ESP scanners on an mSDI, we will state that an RP is connected to the OSP and that a PCU is installed in the first slot of the RP chassis. The PCU is a Differential pressure controller with a Full Scale pressure range of 45 psiD. We will use it to calibrate the two ESP scanners that are connected to the first OFIU in the OSP. In order to logically link the PCU with the ESP scanners we use the Logical Range Number used in the OFIU ‘SD1’ command with which we defined the ESP scanners. The ‘PC1’ command for configuring the PCU in the manner listed above is:

“PC1 211 1, DIFF, 0.0045, 45;”

To re-cap; this command specifies that “The PCU located at Remote Processor chassis location CRS 211, is declared as the calibrator used for Logical Range LRN 1, will generate and measure Differential Pressures, will set requested pressures to within ±0.0045 psi, and will not set any pressures greater than 45 psiD.

The parameters of this ‘PC1’ command explicitly state that the PCU is located in the first two slots of the first Remote Processor chassis, that it will be used to calibrate all ESP scanners assigned to LRN 1, that it will set Differential pressures and all data returned by this unit will be Differential pressure values, and it will not act upon any request to set pressure greater than 45 psiD.

After issuing the ‘PC1’ command, the PCU is ready to operate but the ‘PC2’ command is required before ESP scanners can be calibrated. The ‘PC2’ command applies to a single PCU and specifies the values for, and sequence of, the Calibration Pressures that the PCU will generate during calibration of ESP scanners assigned to the PCUs LRN. The Calibration Pressures are selected based on the full scale range of the ESP scanners being calibrated and the maximum pressure must not exceed the full scale range of the ESP scanners. The Calibration Pressure values, the interval between them, and the order are selected based on best practice which is described in the body of the ‘PC2’ command section of the Programmers Reference in this User Manual.

The form of the ‘PC2’ command, from the Programmers Reference chapter of this User Manual is:

“PC2 CRS CalP CalP [CalP [CalP [CalP]]];”

Where:

CalP – A Calibration set Pressure. A minimum of two (2) and a maximum of five (5) Calibration Pressures may be entered in the ‘PC2’ command.

For example, continuing the earlier OFIU and OSP system configuration for the two ESP scanners on an mSDI, a PCU has been installed in a Remote Processor expansion chassis and it has been designated to calibrate all ESP scanners that are assigned to Logical Range LRN 1. In order to accomplish the calibration a sequence of pressures must be generated by the PCU while recording the resulting voltage output by the ESP scanners in response to each of the pressures. The ‘PC2’ command for configuring the Calibration Pressure sequence is:

“PC2 211 0.0 11.25 22.5 33.75 45.00;”

To re-cap; this command specifies that “The PCU located at Remote Processor chassis location CRS 211, will set the listed pressures in the specific order, when a calibration of ESP scanners is requested.”.

The parameters of this ‘PC2’ command explicitly state that the PCU is located in the first two slots of the first Remote Processor chassis, and lists the ESP scanner Calibration Pressure values and the sequence in which they will be set.

The ESP scanner Calibration Process

After the Optimus has been configured, having received appropriate 'SD1', 'SD2', and 'SD3' commands for each of the OFIUs and also 'PC1' and 'PC2' commands to each PCU, the system is ready to be calibrated; deriving fresh coefficients for each pressure port of the ESP scanners in preparation for data acquisition.

Both DTC and Conventional ESP scanners are calibrated using PCUs, though the requirements for each differ slightly. Conventional ESP scanners require a full calibration using the 'CA3' command in order to calculate the necessary pressure conversion coefficients. DTC ESP scanners contain factory derived calibration coefficients which compensate their data over both pressure and temperature, only requiring an offset calibration using the 'CA2' command in order to achieve accuracy equivalent to the Conventional scanners. In this section, the full calibration process will be described in order to further illustrate the operation of the Optimus System. Description of the ESP scanner coefficients may be found in Appendix B.

Calibrations are requested for Logical Ranges, groups of ESP scanners associated with a single PCU. One calibration command, either a 'CA2' or a 'CA3', can operate on multiple Logical Ranges simultaneously. All Tables must be completely defined, having completed execution of an 'SD1', 'SD2', 'SD3', 'PC1', and 'PC2' commands, before a Calibration command will execute.

Definitions:

LRN – Logical Range Number; an arbitrary number, value ranged from one (1) to twelve (12), used to associate an ESP scanner with a PCU, Pressure Calibrate Unit, in support of calibration of the ESP scanners.

The form of the 'CA3' command, from the Programmers Reference chapter of this User Manual is:

"CA3 [LRN] ...;"

Where:

LRN – A list of the Logical Ranges to be calibrated.

For example, continuing the earlier system configuration, two ESP scanners are attached to an mSDI and an RP is connected to the OSP with a PCU installed in the first slot. The PCU is linked to the ESP scanners using Logical Range Number one (1). The 'CA3' command for calibrating the scanners described is:

"CA3 1;"

After issuing the 'CA3' command, the system will not respond to commands until after the requested calibration completes.

Theory of Operation: Continued

During a calibration the system performs a set sequence of operations in order to acquire the data necessary to derive the coefficients for each scanner port. The sequence of events necessary for calibration is:

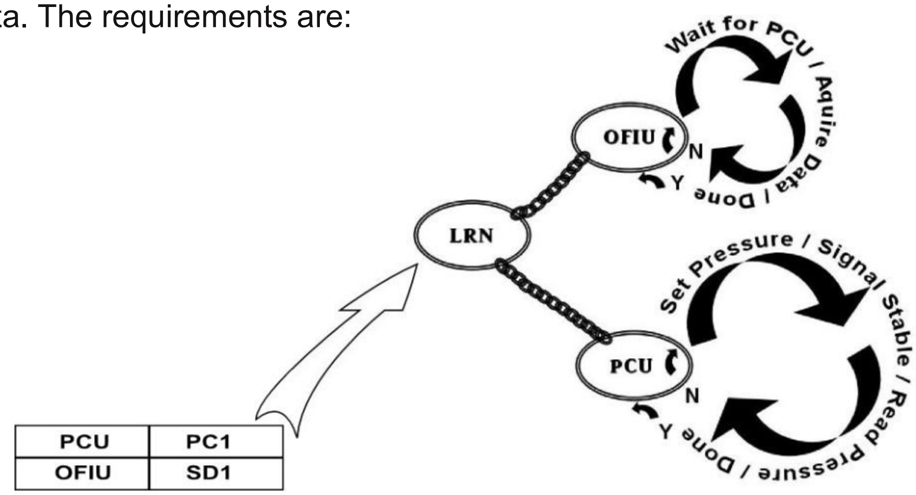
1. Receive the ‘CA3’ command
2. Instruct the PCUs to set the C1 control pressure.
   a. This places the ESP scanners into a state that permits the calibration pressure to be applied to the individual transducers simultaneously.
3. Do in the order defined by the ‘PC2’ command.
   a. Instruct the PCUs to set the next pressure from their ‘PC2’ command.
   b. Instruct the PCUs to return the value of the pressure that is set.
   c. Instruct the OFIU and mSDI to acquire data from the ESP scanners associated with the LRN.
   d. Repeat until all data points have been recorded.
4. Use the acquired data to derive conversion coefficients and store them for use.
5. Instruct the PCUs to set the C2 control pressure
   a. This places the ESP scanners into a state such that the individual transducers are physically isolated from one another.
6. Send the ‘CA3’ completion message

After completion of the ‘CA3’ command, the system is ready to acquire and transmit data to the host. It is also possible to extract the coefficients that were derived for examination or storage using the ‘OP3’ command. The data used to derive the coefficients, the pressures set by the PCUs and the voltages output by the scanner ports, may be retrieved using the ‘OP4’ and ‘OP1’ commands respectively.

Theory of Operation: Continued

The Data Acquisition Process

The Optimus requires that its components be configured correctly before it will acquire data. The requirements are:



1. The OFIUs and mSDIs must be defined correctly
   a. The ESP scanners attached must be described and assigned to LRNs in preparation for calibration.
2. The PCUs must be defined correctly, regardless of whether there are ESP scanners assigned to their LRNs.

Note: Calibration of the connected ESP scanners is not required in order to acquire data. Data for un-calibrated Conventional ESP scanners will be output in volts, scaled according to their full scale pressure range. DTC ESP scanners will have their factory coefficients present in the system but they will not achieve their specified accuracy until an offset calibration is performed using the ‘CA2’ command.

Data is typically acquired in response to an ‘AD2’ which acquires and outputs data according to a Table defined by the ‘SD1’, ‘SD2’, and ‘SD3’ commands. The data is transmitted in Stream Data packets, which are described in Appendix A.

The form of the ‘AD2’ command, from the Programmers Reference chapter of this User Manual is:

“AD2 sTBL;”

Where:

sTBL – The number of the Table for which data is being acquired.

As an example, we will consider the configuration that has been described throughput this chapter. A single OFIU and mSDI have been configured, having two (2) DTC ESP scanners connected. A single PCU is present in an RP, which is linked to the scanners through the LRN specified in the 'PC1' and 'SD1' commands. A calibration has been performed, meaning that the system data will be within the defined accuracy specification. Data will be requested for Table one (1), which is configured to acquire and output averaged data at a ten (10) Hz rate. Data will continue to be acquired and output at this rate until the system is explicitly instructed to stop, using the 'AD0' command. The 'AD2' command for starting data acquisition is:

"AD2 1;"

The host is required to continue reading the data output by the Optimus. When the data stream is no longer required the stream is stopped by issuing an 'AD0' command.

"AD0;"

Installation and Setup

This chapter covers the unpacking, assembly, and installation of the Optimus System. The Optimus System has many components that can be purchased as an entire system, or as individual pieces of equipment. Before assembling the System, use the shipping bill as a reference to ensure all parts have arrived. Measurement Specialties, Meas, takes no responsibility for equipment damaged during shipping. If containers appear broken, ripped, or damaged, contact the transportation carrier. If the equipment is damaged, contact Measurement Specialties and ask for Customer Service.

> **WARNING! All system, mains, power should be off during installation or when removing any components from the Optimus System! Failure to shut off power prior to installation may cause physical injury or component failure.**

Optimus System

The Optimus System consists of many components that operate together under the control of the Optimus System Processor, OSP. The user can control the OSP using the free setup software, which can be installed on a host computer. Optimus is based on a parallel processing concept in order to achieve its high throughput. Because it is also modular, the system can be easily expanded from modest, less than 64 channels, to large, more than 1,000 channels, by simply adding compatible components.

This chapter presents the information necessary to configure and connect each piece of equipment. To prevent hardware damage this work must be completed before applying power to the Optimus System.

The Optimus System consists of five (5) groups of equipment:

- System Processor, OSP
- Expansion Chassis
  - Remote Processor, RP
  - Local Slave, LS
- Input Units
  - Fiber optic Interface Unit, OFIU
  - Pressure Calibrate Unit, PCU
  - Pressure Standard Unit, PSU
- ESP Scanner Interfaces
  - Miniature Scanner Digitizer Interface, mSDI
  - Remote Power Supply, RPS
- ESP pressure scanners
  - DTC
  - Conventional
  - Micro

Installation and Setup: Continued

Descriptions:

System Processor, OSP

The OSP controls all components, Remote Processors, Pressure Calibrate Units, and Fiber Interface Units, while simultaneously providing an interface to the host computer.

Figure 3.1: OSP

Remote Processor, RP, and Local Slave, LS

The RP and LS provide pneumatic and electrical interface for one or more Pressure Calibrate Units, PCUs. They are typically located near to the ESP pressure scanners requiring calibration by those PCUs. The RP has an internal power supply, and connects to the OSP via an RS-485 multi-drop serial interface. An LS draws its power from and communicates through an RP, providing slots for installing an additional four (4) PCUs. Up to three (3) RPs can be simultaneously connected to a single OSP. Each RP can have up to seven (7) LS attached simultaneously.

Figure 3.2: RP

Installation and Setup: Continued

Input Units

Input Units provide the data acquisition and control functions for the Optimus System. Self-contained, having their own microprocessors, each IU to operates independently to perform their tasks. The following IUs are available for the Optimus System:

Fiber optic Interface Unit, OFIU

The OFIU is an expansion board, installed within the OSP, which connects to a miniature Scanner Digitizer Interface, mSDI, via a fiber optic cable connected to the rear panel of the OSP.

If your OSP was ordered with more than one OFIU they will have already been installed at the factory. If you have previously purchased an OSP and have now procured a new OFIU the installation kit will include installation documentation.

Pressure Calibrate Unit, PCU

A PCU is a general purpose, digitally controlled, pneumatic calibration source incorporating a precision pressure transducer. The PCU provides the valve control, reference compensation, and calibration pressures for the ESP scanners. The following table shows available full-scale PCU ranges, suitable for calibrating any of Measurement Specialties' pressure scanners.

PCUs occupy two slots within an RP or LS. A single RP or LS can contain up to four (4) PCUs. The OSP has no pneumatic interfaces and so cannot contain a PCU. PCUs provide calibration and control pressure to calibrate Conventional and DTC ESP scanners.

PCU Range Assignments	
Pressure Scanner Range	Suggested PCU Range
± 10" or ± 20" H2O, ± 1 psi	1 psid
± 2.5, ± 5.0 psi	5 psid, 23 psia
± 10, ± 15 psi	30 psia
± 30 psi, ± 50 psi	65 psia
+ 100 psi	100 psia
+ 150 psi	300 psia

Table 3.1

Pressure Standard Unit, PSU

A PSU is a single-channel, high-accuracy pressure transducer for measuring Barometric or reference pressure. Generally a PSU is a PCU with the pressure-generating circuitry removed. Refer to the PCU range table above for available full-scale ranges.

PSUs occupy two slots within an RP or LS. A single RP or LS can contain up to four (4) PSUs. The OSP has no pneumatic interfaces and so cannot contain a PSU..

ESP Scanner Interfaces

miniature Scanner Digitizer Interface, mSDI

Each mSDI can accommodate up to eight (8) ESP scanners. The mSDI receives all the channel address information from the OFIU and returns the digital data to the OFIU via the fiber-optic link. The top-plate of the mSDI incorporates eight (8) connectors for OSCB cables which connect to ESP scanners. As many as four (4) mSDIs can be connected to an OSP. Power for the mSDI and the connected ESP scanners is provided by a Remote Power supply, which can be installed up to three hundred (300) feet away from the mSDI.

Figure 3.3 mSDI with OSCB Cable and ESP scanner

Remote Power Supply, RPS

An RPS provides precision supply voltages to mSDI and the attached ESP scanners. The front panel contains four analog current meters, four separate circuit breakers, a power switch, and a digital volt meter with a four position selector switch. The output current of each power supply can be continuously monitored via the analog meters.

The output voltage of any of the four supplies can be checked with the digital panel meter by selecting the desired output with the four-position selector switch. Each output is protected by a circuit breaker. The circuit breakers and their reset buttons are accessible on the front panel.

System Setup

The Optimus System has a variety of equipment options. It is however, important to recognize that the system is modular and that the individual modules work together to perform one task; making pressure measurements using the ESP scanners and returning the pressure data to a host computer. The installation described below is for a simplified system, beginning with the physical interconnections; pneumatic, communication, and electrical. The installation of the Optimus demonstration software will then be detailed followed by: the description of the power up sequence, the configuration of the system using the demonstration software.

WARNING! Power to the Optimus System must be off during installation.

A Basic Configuration:

The following shows a basic wind tunnel configuration. The Control room and Data center for the tunnel is sited in a room adjacent to the test section of the wind tunnel. The model for this example will be a 3 x 1 x 1 cuboid having 72 pressure taps. All tubing connecting the model pressure taps to the ESP scanner measurement ports will be equal length and the distances between the various components will be assigned arbitrary but reasonable values based on the experience of the author. The lengths of the various interconnecting cables were chosen based on the values assigned in the example and not due to any requirements imposed by the Optimus System.

Installation and Setup: Continued

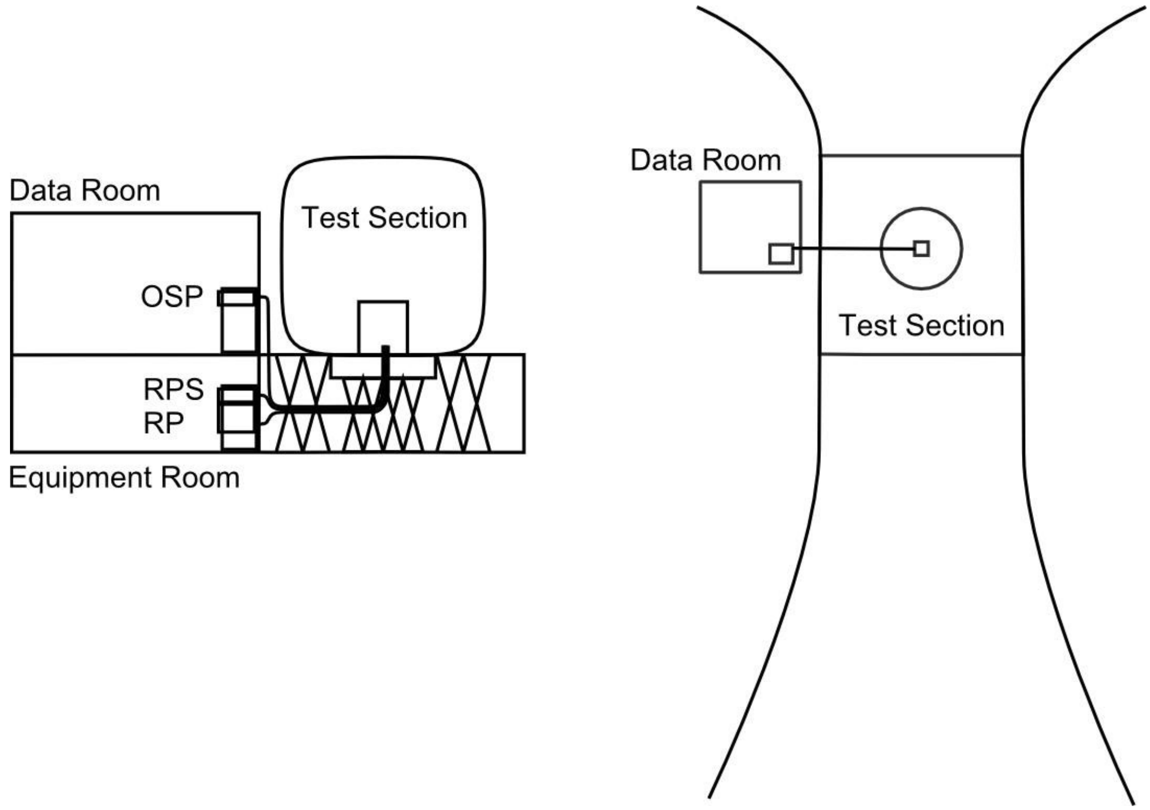


Figure 3.4 Plan diagram and side view of an arbitrary wind tunnel structure

The following list of equipment has been assembled relevant to figure 3.4.

Delivered from Measurement Specialties

System Hardware

- Qty 1, OSP
- Qty 1, OFIU, pre-installed in the OSP at CRS 111.
- Qty 1, mSDI
- Qty 200 Ft, OFIU to mSDI Fiber Optic cable.
- Qty 1, RPS
- Qty 30 Ft, RPS to mSDI cable.
- Qty 1, RP
- Qty 200 Ft, OSP to RP communication cable.
- Qty 1, PCU, having a Full Scale Range 1 psid.
- Qty 6, Pneumatic Blanking Panels.
- Qty 2, DTC ESP scanners, each scanner having 64 pressure ports, each pressure port having an Outer Diameter of 0.04”, and both scanners having a full scale range of ± 0.36 psiD.
- Qty 2, OSCB cables, 10 Ft length.
- Qty 1, Optimus Tool Kit.

Installation and Setup: Continued

Consumable Supplies

Qty 500 Ft, 0.040” polyurethane tubing

Qty 500 Ft, 0.063” Nylon tubing

Qty 500 Ft, 0.25” polyurethane tubing

Qty 10, 0.063” ‘T’s

Qty 10, 0.063” to 0.040” reducers

Qty 10, 0.125” to 0.063” reducers

The OSP, RP, and RPS, have rack-mount flanges for installation into a standard 19" instrument cabinet. These items are mounted in racks at the locations indicated using a number of screws equal to the number of panel attachment pockets.

The OSP’s front panel incorporates indicator LED’s and a covered power switch. These LED indicators present system status in a readily identifiable manner and should be kept visible during normal operation. The power, Ethernet, and mSDI fiber optic cable connectors are located on the rear panel of the OSP. It is necessary that the rack containing the OSP chassis allow access for these connectors as well as maintaining a minimum one (1) Rack Unit (1U) clearance above and below the OSP chassis.

The RP back panel must also be accessible for configuration and maintenance. In addition, PCU’s retained within the RP will vent gas from the ‘VENT’ ports located at the rear of the RP during normal operation. A modest amount of noise is generated in the process and should be expected. The front panel access door for this rack must allow for the installation and removal of the PCUs. In addition, the RP chassis of the RP must have a minimum one (1) Rack Unit (1U) of clearance above and below within the rack.

Only a few simple tools are needed to assemble and install the Optimus System. Measurement Specialties recommends and / or supplies the tools listed below:

3/32" Hex Driver

5/32" Hex Driver

*Offset Wrench 3/8” and 7/16"

*Offset Wrench 1/2” and 9/16"

Straight Slot Screwdriver

Phillips Head Screwdriver

Tubing Pliers

* Supplied with a Optimus System - OSP

Installation and Setup: Continued

Line Voltage and Fuse Holder

The OSP contains a universal power supply and can be operated on line voltage around the world by simply changing the power cord for the local standard plug. An RP does not contain a universal power supply. An RP must be explicitly ordered, and will be delivered configured for, 100, 120, or 240 VAC at 50Hz or 60Hz. Before installing the power cord in an RP, check the line voltage setting. The power line setting is indicated by labels on the RP chassis and on a circuit card located under the fuse holder. If the line power configuration labels are not present or are damaged; remove the power cord from the power entry module and slide the plastic fuse cover toward and over the power cord socket, then look for the numeric value for the line voltage etched on the circuit card. The circuit card displays the number 100, 120, or 240. The RP chassis are fused for 12 amps using a “Type 3AG, slow blow” fuse at 120 volt A.C. operation or 8 amps, a “Type 3AG, slow blow” fuse for 240 volt A.C. operation.

Important: One of the RP cooling fans is powered directly by the AC Line. If the RP chassis must be powered with line voltage other than the original configuration, that fan must also be changed. Consult Meas for details.

OSP J1 – J3 Connectors

Connector J1 is the Ethernet Host port which is capable of operating at
10 Mb/100 Mb/1000 Mb.

Note: Connecting the OSP to a 10 Mb Ethernet device is not advisable as the system will not be able to achieve maximum data rates. Utilizing a 100 Mb connection is reasonable for modest systems, not requiring the full throughput capability. For maximum throughput a 1 Gb Ethernet connection is required.

Connector J2 is for RS-485 Remote Processor communications. The communications cable must be connected prior to power on.

Connector J3 is the optional trigger input. When the OSP is configured to respond to a trigger signal, it is applied through this connector.

OSP F/O Connectors

ConnectorsF/O 1 throughF/O 4 are the fiber optic connectors for attaching mSDI to the four OFIU slots within the OSP chassis.

RP and LS Electronic Connectors

J1 - J8 Connectors

These connectors may not be installed. They provide external valve support function for the C1 and C2 pneumatic control lines and are not normally required. If the connector is populated then a cable will be present to interface with an external valve assembly, PN 84SA. A PCU must be located within the slot to which this connector is routed. For example, if connector J2 is populated, a PCU must be installed in the first slot of the RP.

RP J9 Connector

The J9 connector is labeled “Local IEEE 488”. It is not a standard GPIB interface and cannot be used to control the chassis or input units directly. It is used to provide local communication to Local Slaves that may be connected to the RP.

RP J10 Connector

The J10 connector is labeled serial interface RS-485. It is attached to connector J2 of the OSP using a serial cable and provides control for the RP chassis and the PCUs within its slots. Up to three (3) RPs can be connected via a single, daisy-chained, RS-485 cable for system expansion.

RP J12 and J12A Connectors

These connectors are labeled as Remote Power. They are used to attach Local Slaves to the Optimus System Remote Processor.

RP J13, J14, J15, J16, J17, and J18 Connectors

These connectors are unused by the Optimus System.

RP and LS Pneumatic Interconnections

Pneumatic interface connections are essential and critical for proper operation of PCUs and PIUs.

There are four (4) classes of pneumatic interconnection:

> **Attention:** Verify all input connections paying particular attention to the High Pressure supply inputs. Incorrect pressure connection can permanently damage the PCUs in the chassis.

Supply:

Source and Sink ports; the vacuum and positive pressure inputs with which the PCUs create the requested calibration pressures.

500 psig Input

Connects the user's clean, dry, high-pressure source for PCU ranges greater than 100 PSI. Input pressure should be set to 515 ±5 psig. Maximum pressure is 650 psig (49 Bar).

100-125 Input

Connects the user's supply pressure to the chassis. This pressure source should be clean and dry. It generates the C1 and C2 control pressures necessary to control the calibration valves. It also is the source for generating pressures from the PCUs with ranges 100 psia or less. Maximum pressure is 125 psig.

Vacuum Input

Supplies the necessary vacuum input. Required when setting sub-atmospheric pressures and pressures just above atmosphere (less than 5 psid) with the PCU. A partial vacuum pump with a 160-liters-per-minute flow capacity, such as a Sergeant Welch Scientific Model Number 1402 or equivalent is recommended.

Aux Vacuum Input

"Aux Vac" is the vacuum input for setting all pressures on the 5 and 10 psia full scale PCUs. A1/8 inch port for this input increases the vacuum capacity required by these low range absolute PCUs.

Installation and Setup: Continued

The Sources for the Supply inputs, 100-125 psig and 500 psig, must be maintained according to ISO 1873.1; A2, B2, C4.

Dew Point -40 C minimum

Total Oil (Aerosol, Liquid, and vapour), 5 mg/m3

Maximum number of Particles per m3

1-5 micron: 10

0.5-1 micron: 1,000

0.1-0.5 micron: 100,000

The source pressure must be stable in order to prevent fluctuations that can cause errors during the calibration process

The Vacuum and Aux Vacuum inputs connect vacuum sources to all PCUs ranged less than or equal to 100 psig and 100 psia. This allows the PCU to set sub-atmospheric pressures. A vacuum pump must also be connected for the best PCU performance calibrating ESP scanners ranged ±10 inches H2O, ±20 inches H2O, ±1 psi, and ±5 psi. This is true even when the ESP scanner will only be calibrated positive relative to atmosphere. By convention, the vacuum input is used by PCU ranges 100 psia and below and the Aux Vacuum supplies the 5 and 10 psia range PCUs only.

The Vacuum input should be supplied from a partial vacuum pump with a capacity of 160 liters/minute or greater.

The Aux Vacuum input should be supplied from a high capacity pump capable of maintaining 100 Torr.

Control:

Actuation signals used to drive or motivate mechanical components of the system; specifically within the ESP scanners.

C1 Output

The 100-125 psig pressure output by each PCU to switch the electronic pressure scanner’s calibration valve to the calibrate position.

C2 Output

The 100-125 psig pressure output by each PCU to switch the electronic pressure scanner’s calibration valve to the run position.

Installation and Setup: Continued

Calibration:

Providing a mechanism for derivation or adjustment of the EU conversion coefficients for the ESP scanners.

Cal Output one (1) through eight (8)

Each PCU is keyed, configured at manufacturing time, to a specific calibration output. PCUs can reside in any slot within a Remote Processor and their output will be routed to the assigned output.

RP Calibration Port Assignment	
Port	**PCU Range**
Cal 1	Alternate
Cal 2	1 psid, 1 psia
Cal 3	5 psid, 23 psia,5 psia
Cal 4	15 psia, 30 psia,10 psia, 15 psid,20 psid
Cal 5	45 psia, 65 psia,50 psid
Cal 6	100 psia, 100 psid
Cal 7	200 psia, 250 psia, 300 psia
Cal 8	500 psia, 600 psia, 750 psia

Table 3.2

Note: Placing two PCUs having the same pressure range in a single Remote Processor will result in incorrect operation, potentially damaging components of the system. If two PCUs having the same Full Scale pressure range are required for a given system they may be specially ordered such that their Calibration Output is routed to an alternate output.

Installation and Setup: Continued

Reference:

An input for the given PCU, the reference pressure of the ESP scanner during calibration of that scanner.

Cal Ref Input

The Cal Reference port is unused in Optimus. Do not connect any pneumatic tubing to the Cal Ref port.

Run Ref one (1) through eight (8)

PCU Pressure Standards utilize the ODD numbered Reference ports, one (1), three (3), five (5), and seven (7) as the reference pressure measurement point. Differential units set their requested pressures relative to the absolute pressure sampled from these ports and Absolute units can be configured to measure the pressure on this port for the same purpose.

Note: DO NOT Block the EVEN numbered Reference Ports two (2), four (4), six (6), and eight (8); They MUST BE left open for proper PCU operation. The EVEN numbered Reference Ports are used by the PCU pneumatic controller as an exhaust and inlet during operation.

Tubing length and diameter affect the system’s pneumatic settling time. Greater tubing length on the Cal 1 - Cal 8 lines results in longer stabilization time for a re-zero or multipoint calibration.

When adapting the control, calibrate, and reference pressures to miniature pressure scanners, nylon tubing with retaining springs should be used.

Important: The entire Optimus System should be checked for leaks before acquiring data. Leaks will degrade system performance.

Interconnection Process:

The following description uses the materials and components documented earlier in this chapter. The process is written from the perspective of inspection of a newly arrived system. As such, the narrative is intended to suggest rather than recommend and generalizes some points that may deserve more consideration.

Some components must be acquired from a source other than Measurement Specialties, such as a regulated source of filtered compressed gas and a vacuum pump. The location in which the system will be set up should be appropriate for the purpose, having sufficient space to effectively work around the large components of the system.

A counter or table is desirable for placement of system components at a height that is comfortably accessible.

A computer and Ethernet switch are required for operation of the Optimus as a data acquisition system. Test and validation software is provided free of charge allowing the user to verify the operation of the system. The documentation of that software is separate from this user manual. Operation and configuration of the free software will be generalized, referencing the functions performed. Details pertaining to the configuration of those functions necessarily depend on the current software revision as well as the specific combination of hardware being tested.

Please contact Measurement Specialties Aerospace Research group directly if assistance is required.

Installation and Setup: Continued

Unpacking:

Remove each of the components and place them on a bench top or table in a manner that is convenient and comfortable to work around the system. Check each component against the shipping documentation to assure all line items are present.

No component should be connected to mains power until the end of these instructions.

Optimus System Processor:

Front Panel Description:

The Front Panel of the OSP incorporates eight (8) LEDs and one illuminated power switch. The Indicator LEDs are listed in Table 3.3, below.

Locate the Fiber Optic interface connectors, labeled F/O 1 through F/O 4, on the rear panel of the unit. Optimus Fiber Input Units that are ordered with a system are installed in numerical order, lowest to highest number, corresponding to CRS locations 111 through 114. In this example, since only one OFIU was ordered with the OSP, the unit is installed in CRS 111 and is attached to connector F/O 1.

Identify the OFIU to mSDI Fiber Optic cable and attach one end to the OSP connector F/O 1. The cable contains a single multi-mode fiber having identical 'ST' connectors on each end and is not polarized; it may be connected in either orientation. Connect the remaining end of the fiber cable to the Fiber Optic connector of the mSDI.

Locate the OSP to RP communication cable and note that it has identical 'D' shell connectors on each end. This cable is not polarized and may be connected in either orientation. Attach one end to the OSP connector J2 and the other to Remote Processor connector J10.

Connect an Ethernet cable between the Ethernet Switch and connector J1 of the OSP.

OSP LED Indicators					
LED Color	Link Status	Link Speed	RP Link	Ready	Interface
Off	Disconnected	Disconnected	No RP	Off	Not Installed
Red	Half Duplex	10 Mb	Fault	Fault	Fault
Green	Full Duplex	100 Mb	On Line	Ready	Ready
Blue		1000 Mb			

Table 3.3

Installation and Setup: Continued

Remote Processor and Pneumatics:

Inspect the PCU and Pneumatic Blanking Panels. Examine the o-ring seals on the pneumatic interface of each component, confirming both that they are present and that they are undamaged.

Examine the Remote Processor paying attention to the rack slots and rails; the location where the PCU and Blanking Panels are to be mounted. Slide the PCU into the left slot, CRS location 211, within the remote Processor rack. Using the 5/32” Hex Driver, smoothly tighten the Locking Rods to no more than 25 in/lbs. Place the Blanking Panels into the remaining slots one at a time using the 5/32” Hex Driver to tighten the locking rods to no more than 25 in/lbs.

Connect a regulated 100 psig pressure supply to the pneumatic port labeled “100-125 psig Input” using 0.25” polyurethane tubing. Connect a vacuum pump to the pneumatic port labeled “Vacuum” using 0.25” polyurethane tubing.

Locate the 0.125” to 0.063” reducers and remove three (3) from the package. The “barrel”, the body, of the reducers is 0.25” OD. Place one reducer into each of the following three (3) ports on the back panel of the Remote Processor: C1, C2, and Cal 2. The 0.063” bulged tube should be exposed and the 0.125” bulged tube should be inside the ports. Tighten the ferruled connectors onto the body of the reducers; verify that the ferrule has properly engaged the body of the reducer.

Remote Power Supply:

Inspect the RPS, examining the indicators, connectors, and buttons. Note that the unit is powered off and do not connect the mains power. Locate the RPS to mSDI power cable and inspect both ends. The power cable is not polarized and may be connected in either orientation. Attach one end to the RPS output and the other end of the cable to the mSDI. Carefully tighten the connector mounting screws; do not over tighten.

Miniature Scanner Digitizer Interface and DTC ESP scanners:

Remove the DTC ESP scanners from their protective enclosures, placing them next to the mSDI on the work bench. Remove the protective covers from the first two connectors on the mSDI, placing them in a container or protective bag for re-use. Locate the two (2) OSCB cables and remove the protective covers from the end connectors, again retaining them for re-use.

Attach the OSCB cables between the mSDI and ESP scanners. For this exercise, the selection of one scanner versus another is irrelevant. Carefully tighten the connector retaining screws to both the mSDI and the ESP scanners: Ensure that the connector is tightened evenly and gently. Do not over tighten.

ESP Scanner Pneumatic connections:

Note: Mark all tubing described in the following paragraph. Use either wire markers or masking tape and pen. Be clear and concise with your notation. Failure to document the pneumatic interconnects can cause tubing misconnection which will result in permanent damage to the ESP scanners.

When testing on a bench, it is convenient to keep pneumatics relatively short. Cut three (3) individual pieces of 0.063” tubing, each being approximately one (1) meter in length. Attach one length of tubing to the bulged tubes extending from each of the following connectors on the rear panel of the Remote Processor: C1, C2, and Cal 2. Label each of the tubes according to the pneumatic connector to which they are attached.

Attach a 0.063” ‘T’ fitting to each of the labeled lengths of tubing. Cut six (6) additional pieces of the 0.063” tubing, each approximately 10 cm in length. Attach the 10 cm pieces of tubing to the remaining bulged tubes of the 0.063” ‘T’ fittings.

Attach one 0.063” to 0.040” reducer to each of the free 0.063” tubes extending from the 0.063” ‘T’ fittings. Cut six (6) pieces of the 0.040” tubing, each approximately 10 cm in length. Attach the 10 cm pieces of tubing to the 0.040” bulged tubes of reducers.

Noting the labels on each of the pneumatic assemblies, attach the tubing to the correct ports on the ESP scanners: C1, C2, and Cal. The Run and Cal Ref ports of the scanners must remain open and unobstructed.

Take the time to verify that the tubing and connections are correctly assigned and attached.

Computer:

Install the test and validation software on the computer. Attach an Ethernet cable between the computer and the Ethernet switch. Configure the software and computer per the software documentation.

Power On:

Plug the mains cords into the AC outlet and turn on the Optimus System components in the following order.

1) Remote processor
2) Remote Power Supply
3) Optimus System Processor.

Host Operation and Programming

Programmer's Introduction

Once the Optimus System is installed and power is applied it is ready to operate under host computer control. This chapter deals only with control by the host computer, hereafter referred to simply as the host. While reading this chapter, you should memorize any words shown in “**bold**”. These words are important terminology, needed to utilize the Optimus System effectively as a programmer.

Commands are simple ASCII strings that begin with a three (3) character operation code, followed by simple numeric or word parameters delimited by spaces. In order to make our discussion of commands more concise, there are several conventions used.

1. Items like the operation code are capitalized meaning that you should enter them exactly as shown.
2. Parameters are shown as abbreviations.
   a. For example, the commonly used input unit address “Cluster, Rack, Slot” is abbreviated **CRS** in a command description.
      i. These parameters are place holders, meant to be replaced with actual values.
   b. Optional parameters are enclosed in square brackets.
      i. E.g. “**[** sPort **]**”
   c. Repeatable parameters are followed by an ellipsis
      i. E.g. “**...**”
3. Single isolated ASCII characters are referred to directly by their long names, e.g. **COMMA** or **SEMICOLON**, or by their actual keyboard key label enclosed within angular brackets, e.g. “< **,** >” for COMMA or “< **;** >” for SEMICOLON.
   a. Notice that extra spaces separate the label from the brackets to make the label more readable. When not isolated, as when they are part of a longer string, these same characters will not be surrounded by angular brackets.
4. If an ASCII character is unprintable or has a symbolic label not easily shown within normal text it is shown using standard ASCII character set abbreviations enclosed within angular brackets; e.g. “<**SP**>” for “SPACE” which is ASCII code 0x20, or “<**NUL**>” for “NULL” which is ASCII code 0x00.
   a. Such symbols are always capitalized and are not surrounded by blanks. You are expected to enter only that one character not the brackets or the letters inside when you see this construct. The “ENTER” key typically generates a “Carriage-Return” ASCII code 0x0D, and will be indicated as “**<CR**>”.

The Optimus System Processor, hereafter referred to as the OSP, may be accessed from any host having an Ethernet card and configured with a compatible TCP/IP address.

Host Commands/Responses

To operate the OSP, the host sends a series of commands to which the OSP responds with acknowledgments, errors, and data. These commands are simple ASCII strings, which may have mixed lower or upper case alphabetic characters. Internally, the OSP firmware converts lower-case alphabetic characters to upper-case however; it is a good habit to ensure that all commands are converted to upper-case before transmission to the OSP.

Host Command Format

Each command begins with an operation code, consisting of two alphabetic characters and one numerical character, e.g. AD1 for “Acquire Data by method 1” or SD1 for “Scanner Digitizer operation code 1”. One or more parameters may follow the operation code as required. Punctuation is allowed but optional, presuming that all command elements are separated by at least one SPACE. Numeric parameters may require specific formats including: signed integers, e.g. 111, -1234, signed fixed-point or exponential values, e.g. 66.6, -1.2345, -3.33E-10, or a range of integers, e.g. 101-132 with the HYPHEN < - > indicating continuous range inclusive of the terminals. A range of values, when range entry is permitted, is treated as a single parameter. There must be no embedded SPACEs on either side of the connecting < - > character.

Word parameters, parameters starting with an alphabetic character, are permitted in some commands and those constants will be described in the command documentation. However, alphabetic constants also have numeric value equivalents. You may use either the alphabetic constant or its numeric equivalent in host commands.

Parameters must be separated from each other, and from the operation code, by one or more white space characters, including: SPACE <SP>, TAB <HT>, COMMA < , >, left parenthesis < (>, right parenthesis <) >, and combinations of these characters.

White space characters are all ignored by the internal command parser as long as they are used as separators. They may NOT be embedded within parameters or operation codes, but may surround them. Leading blanks may precede the operation code. The COMMA < , > and PARENTHESIS < ( ) > characters, or multiple SPACEs <SP>, may be useful in making lengthy commands more readable.

For example, the command

“SD1 111 101-104 32 1 105-108 16 2;”

may also be written

“SD1 111 (101-104, 32, 1) (105-108, 16, 2);”

to make repeating parameter groups more easily discernible. Most examples in this document use the later method, with parenthesis as parameter group separators, to clearly show group repetition; note that the extra parentheses are optional.

Host Operation and Programming: Continued

Each command must end with an explicit termination character, including:

SEMICOLON < **;** >

CARRIAGE-RETURN <**CR**>

LINE-FEED <**LF**>

NULL <**NUL**>

You may pack multiple host commands together in a single string with each command in the string separated by termination characters. The SEMICOLON is the most commonly used terminator for this purpose. This group of packed commands may be transmitted to the OSP in a single operation.
For very long command strings, or large strings containing packed commands, the host may insert trailing continuation characters including:

BACK-SLASH < **** >

PLUS<**+**>

and the word “**MORE**”

The command fragment is then transmitted normally to the OSP. The OSP will allocate internal buffers large enough the hold a worst case system command. As each continued fragment is received, it is appended to the previous fragment, while discarding all continuation characters and replacing them with SPACEs. The OSP continues this process of assembling a command until a fragment is received which contains a trailing termination character. The OSP then executes the command and then de-allocates the buffer. Continued commands are useful when assembling complex, custom scan lists; as noted in the SD3 command documentation.

Blank lines, ones containing only white-space characters and terminator characters in any combination, will be ignored by the system. A line that contains unrecognized characters or character groups will be flagged as an illegal or unrecognized command. Comments within commands are not permitted.

Whether the host receives a normal, packed, or continued command, it will parsed to obtain single commands which will be executed in sequence.

OSP Responses

OSP responses to commands, including error responses, are structures designed to be decoded using Case or Switch statements. Since the Optimus is a Big-endian system you will be required to convert the structure members to the correct format for your host PC. Details and recommendations will be offered in **Appendix A**, detailing the data conversion algorithms.

Every command response begins with a standard 8-byte header followed by the structured payload; the header and payload structures are documented in **Appendix A**.

The first four (4) bytes of every packet emitted from the OSP contain, in order: A single byte Response Code, a single byte Response Type, and a short integer Message Length.

The Response Code indicates the command or operation that generated the packet.
The Response Type indicates the structure of the data embedded within the packet.
The Message Length is the total length of this packet, including the four byte header, in bytes.

The data structure will be one of the following as indicated by the Response Type:

1) Confirmation or Error Packet

   One Confirmation or Error Packet is sent to the host for every command received, except for those returning the other types listed. It indicates that the particular command was successfully executed or contained an error and was NOT executed. A Confirmation or Error Packet also follows a stream of data packets, called measurement sets, marking the logical end of the stream. The SC2 command may be used to optionally disable these responses from most commands.

2) Single Value Packet

   Single Value Packets contain status words or single values such as the firmware version of the OSP or its input units.

3) Array Data Packet

   Array Data Packets contain two dimensional arrays; data structures such as scan lists, calibration coefficients, calibration voltages, calibration pressures, etc.

4) Data Stream Packet

   Stream Data Packets contain single dimension arrays, the time-stamped measurement sets from input units. These data packets are created by the Data Acquisition process and configured through one of three (3) tables; data acquisition profiles maintained within the OSP. Since each input unit emits its own data at its own independently configured rate, data packets will typically arrive at the host as a continuous stream. Measurement sets from very high-speed input units will be interleaved between those from slower units.

Host Operation and Programming: Continued

Host to OSP Communication Protocol

The factory assigned TCP/IP address is engraved on the identification label, located on the back panel of the OSP, near the power entry module. The client software may change the TCP/IP address of the system but must first CONNECT to the OSP using the currently configured TCP/IP Address on TCP port 8400. The client must either: change its TCP/IP address to be compatible with the OSPs address or modify its routing table to permit communication. Of course, after the TCP/IP address of the system has been changed, the client must document the new system address or use another method to determine the OSP TCP/IP Address.

In order to facilitate system discovery, the Optimus System Processor can emit a broadcast system status packet which contains the OSPs TCP/IP address and other useful information; for example whether it is currently connected to another client via TCP. The OSP discovery packets are broadcast on the local network and are directed to UDP port 7001. Clients can cause the OSP to emit a discovery packet by broadcasting a discovery request command directed to UDP port 7000 on the local network. This mechanism allows the host application to quickly discover and select any Optimus System on the local network without requiring manual intervention,

An Ethernet host is a client to the OSP server. The client must connect to the OSP server on TCP port 8400 before commands and responses can be exchanged. The client shall only disconnect from the OSP server after all data acquisition has been completed. Only one TCP/IP connection is permitted and attempting to establish a second connection will be rejected by the OSP. It is important to remember that should the host disconnect for any reason the system will stop acquiring data and require a new TCP connection and re-initialization.

Because Ethernet packets are limited to approximately 1500 bytes, the data packet may be broken into additional packets. They will be reassembled by the TCP/IP stack of the hosts' operating system without requiring any intervention by the application. The point to the above statement is that, when a TCP/IP connection is established the operating system allocates a relatively small amount of buffer space for the receive buffer of the connection. If the receive buffer is filled with responses from the OSP, the hosts' operating system will instruct the OSP to hold off sending any more packets until more buffer space is available. Under normal circumstances, the host application, the application you are writing to control and acquire data from the OSP, will read from the receive buffer allowing the operating system to receive more data. The buffer space allocated by the operating system as a receive buffer is not to be used as data storage. If the OSP is unable to send data to the host for an extended period of time, the OSP will assume that the host has become disabled for some reason and will drop the TCP/IP connection. When the TCP/IP connection is dropped, read requests for data will fail with a socket closed error, requiring the establishment of a new TCP/IP connection and re-configuration of the OSP.

Legal Command String Examples

The following are examples of legal commands:

Single commands with word parameters, parentheses and extra blanks are ignored:

SD2 111 1 (1 0 32 0) ITRIG PAM 1;
sd2 111 1 (1 0 32 0) ATRIG PAM 1;
sd2 111 1 (1 0 32 0) 1 2 1;

Various termination characters, parentheses and commas are ignored:

sd1 111 (1, 32, 1);
sd1 111 (1, 32, 1)<NUL>
sd1 111 (1, 32, 1)<CR>
sd1 111 (1, 32, 1)<LF>
sd1 111 (1, 32, 1)<CR><LF>

Packed command string, with 2 commands, single and multiple terminators:

SP0 1; SP2 2;SP0 1;;;; SP2 2<CR><LF>

Long fragmented command with ranges and various continuation characters:

SD1 111 more
(1-4, 16, 1) more
(5-6, 32, 2) more
(7-8, 16, 3);

SD1 111 \
(1-4, 16, 1) \
(5-6, 32, 2) \
(7-8, 16, 3)<CR>

SD1 111+
(1-4, 16, 1)+
(5-6, 32, 2)+
(7-8, 16, 3);

Each command string or fragment of a continued command must be additionally terminated; encapsulated per its particular link driver.

Command Overview

Host commands are listed below, first in alphabetical order, then by purpose. Each command shows the section of this chapter where it is fully defined.

Host Commands - Alphabetical By Operation Code

AD0 - Stop High-Speed (DA) Data Acquisition
AD1 - Acquire and Store Data
AD2 - Acquire and Output Data to Host

CA0 - Stop Pneumatic Pressure Calibration/Generation
CA1 - Generate Arbitrary Output Pressure
CA2 - Start Zero-Only Pneumatic Pressure Calibration
CA3 - Start Full Pneumatic Pressure Calibration

CP1 - Set Pneumatic Pressure Calibration Valve Mode
CP2 - Set Pneumatic Pressure Calibration Stabilization Time
CP3 - Set Post Extra SRQs Per Calibration Point

CV0 - Turn a PCU's Valve(s) On/Off
CV1 - Set Calibration Valve Position For All Scanners

LA1 - Look At a DAU’s 1st-Stage Datum
LA2 - Look At a DAU’s EU Datum
LA3 - Look At a PCU's or PSU’s Various Data
LA4 - Look At any Input Units Type & Firmware Version or Look At the Current system Date/Time

OD0 - Clear All Acquired Data Stored in OSP Memory
OD1 - Output All Stored Data to Host
OD2 - Output Selected Stored Data to the Host
OD4 - Output Measurement Set Size in Bytes
OD9 - Define Host’s Data Output Format

OP0 - Clear Tables for Pneumatic Pressure Calibration
OP1 - Output a Tables Calibration Voltages
OP2 - Output a Tables Coefficients; Adjustable
OP3 - Output a Tables Coefficients; All
OP4 - Output the Actual Pressures Generated by PCUs

OP5 - Output a Scan List of a Table
OP6 - Output a PCUs or PSUs Internal Coefficients
OP7 - Output a PCUs Internal S100 Table OP9 -
Define Hosts Table Data Format

PC1 - Configure a PCU's Pressure-Generation Parameters
PC2 - Define a PCU’s Calibration Pressures PC3 - Modify a
PCU’s Internal Coefficients PC4 - Change a PCU’s
Pressure Units PC5 - Build a PCU’s Internal S100 Table

PS1 - Configure a PSU or PCU for DAU Operation PS2
- Define a PCUs or PSUs DAU Setup Parameters PS3
- Modify a PSUs Internal Coefficients PS4 - Change a
PSUs Pressure Units

SC1 - Set SRQ/EOI Mode for Host Data & Specify IP-Address or RESET
SC2 - Enable/Disable Host Responses from Selected Commands SC4 -
Enable/Disable Host Command Echo & Specify Subnet Mask

SD1 - Configure an OFIUs Scanners
SD2 - Define an OFIUs Setup Parameters
SD3 - Define an OFIUs Scan List
SD4 - Manually enter an OFIUs EU Conversion Coefficients
SD5 - Load or Store OFIU DTC-Scanners EEPROM Coefficients or Force an OFIU to treat DTC ESP Scanners as Conventional ESP Scanners or Turn OFIU Temperature Sets Off, On, or Periodic

SP5 - Display/Set Date-Time
SP6 - Set / Enable the Preferred NTP/PTP Server
SP7 - Set the OSP Internal Switch Delay for the OFIUs
SP8 - Set the IP Address resolution Method
SP10 - Display/Set OFIU Timer Synchronization Coefficients and Update Interval

Host Operation and Programming: Continued

Host Commands - By Purpose

INPUT UNIT INITIALIZATION COMMANDS

SD1 - Configure an OFIUs Scanners

SD2 - Define an OFIUs Setup Parameters

SD3 - Define an OFIUs Scan List

SD4 – Manually enter an OFIUs EU Conversion Coefficients

SD5 – Load or Store OFIU DTC-Scanners EEPROM Coefficients or Force an OFIU to treat DTC ESP Scanners as Conventional ESP Scanners or Turn OFIU Temperature Sets Off, On, or Periodic

PC1 - Configure a PCU's Pressure-Generation Parameters

PC2 - Define a PCU's Calibration Pressures PC3 - Modify a

PCU's Internal Coefficients PC4 - Change a PCU's

Pressure Units PC5 - Build a PCU's Internal S100 Table

PS1 - Configure a PSU or PCU for DAU Operation PS2

- Define a PCUs or PSUs DAU Setup Parameters PS3

- Modify a PSUs Internal Coefficients PS4 - Change a

PSUs Pressure Units

PNEUMATIC PRESSURE CALIBRATION OPTION COMMANDS

CP1 - Set Pneumatic Pressure Calibration Valve Mode

CP2 – Set Pneumatic Pressure Calibration Stabilization Time

CP3 – Set Post Extra SRQs Per Calibration Point

PNEUMATIC PRESSURE CALIBRATION CONTROL COMMANDS

CA0 - Stop Pneumatic Pressure Calibration/Generation

CA1 - Generate Arbitrary Output Pressure

CA2 - Start Zero-Only Pneumatic Pressure Calibration

CA3 - Start Full Pneumatic Pressure Calibration

OUTPUT PNEUMATIC PRESSURE CALIBRATION DATA

OP0 - Clear Tables for Pneumatic Pressure Calibration

OP1 - Output a Tables Calibration Voltages

OP2 - Output a Tables Coefficients: Adjustable

OP3 - Output a Tables Coefficients: All

OP4 - Output the Actual Pressures Generated by PCUs

OP5 - Output a Scan List of a Table

OP6 - Output a PCUs or PSUs Internal Coefficients

OP7 - Output a PCUs Internal S100 Table

OP9 - Define Hosts Table Data Format

HIGH-SPEED DATA ACQUISITION (DA) CONTROL COMMANDS

AD0 - Stop High-Speed (DA) Data Acquisition

AD1 - Acquire and Store Data

AD2 - Acquire and Output Data to Host

CLEAR/OUTPUT STORED DATA COMMANDS

OD0 - Clear All Acquired Data Stored in OSP Memory

OD1 - Output All Stored Data to Host

OD2 - Output Selected Stored Data to the Host

OD4 - Output Measurement Set Size in Bytes

OD9 - Define Host's Data Output Format

LIVE-ACTION (LOOK-AT) DATA ACQUISITION COMMANDS

LA1 - Look At a DAU's 1st-Stage Datum

LA2 - Look At a DAU's EU Datum

LA3 - Look At a PCU's or PSU's Various Data

LA4 - Look At any Input Unit's Type & Firmware Version or Look At Current Date/Time

VALVE CONTROL COMMANDS

CV0 - Turn a PCU's Valve(s) On/Off

CV1 - Set Calibration Valve Position For All Scanners

SYSTEM COMMUNICATION (HOST PROTOCOL) COMMANDS

SC1 - Set SRQ/EOI Mode for Host Data & Specify IP-Address or RESET

SC2 - Enable/Disable Host Responses from Selected Commands SC4 -

Enable/Disable Host Command Echo & Specify Subnet Mask

Host Operation and Programming: Continued

SYSTEM PROCESSOR CONTROL COMMANDS

SP5 - Display/Set Date-Time

SP6 - Set / Enable the Preferred NTP / PTP Server

SP7 - Set the OSP Internal Switch Delay for the OFIUs

SP8 - Set the IP Address resolution Method

SP10 - Display/Set OFIU Timer Synchronization Coefficients and Update Interval

Host Operation and Programming: Continued

System Start-Up

Before starting your Optimus System, **Chapter** 3 should be read carefully, and all electrical & pneumatic connections made for your configuration. Lift the cover of and push the power switch on the front panel.

> ***Important:*** *If any Remote Processors, RPs, are connected to the Optimus System they must be powered on before applying power to the Optimus System Processor, OSP.*

When powered and warmed up at least for one hour, the OSP and all its input units are ready to operate accurately. You can, of course, operate the system earlier when absolute accuracy is not your immediate concern.

Full understanding of input unit Initialization commands requires knowledge of the Data Acquisition processes within the OSP. Please read the **Data Acquisition** Review in Chapter 2 if you have not already done so.

Host Operation and Programming: Continued

Input Unit Initialization Commands

The entire OSP and input unit Initialization commands may be stored in Default Storage so that, if you have enabled the AUTO-Initialize function, they can be copied into Application Memory and optionally transmitted to the appropriate input units. The initialization parameters have to be entered by the host application. Later the initialization parameters may require modification when your test configuration changes, for example when input units are moved to different slots or chassis.

Initialize OFIUs

Definitions:

LRN = Logical Range Number; an arbitrary number, value ranged from one (1) to twelve (12), used to associate an ESP scanner with a PCU, Pressure Calibrate Unit, in support of calibration of the ESP scanners.

CRS = Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Frame = A collection of data, containing values for the individual ports of a group of ESP pressure scanners.

Measurement Set = A Data Structure created using one or more Frames and transmitted to the host computer connected to the Optimus Data System.

Table = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple devices.

The SDx commands define parameters that identify all OFIUs in a system and specify the configuration of all ESP pressure scanners connected to the OFIUs. The SDx commands also associate groups of similarly ranged ESP pressure scanners with a Pressure Calibrate Unit, PCU, using a Logical Range Number, LRN. This number logically links a PCU capable of generating suitable pressures to calibrate a groups range during a pneumatic pressure calibration.

Conventional ESP scanners must have had a full five (5) point pneumatic calibration before any EU data can be output. At the end of this process the EU conversion coefficients are calculated for every Conventional ESP scanner port. It is understood that performing a full calibrations periodically for Conventional ESP scanners can be time consuming and so, once a full calibration has been performed, a shorter re-zero pneumatic calibration process can quickly eliminate the largest component of error in the Conventional ESP scanners.

Host Operation and Programming: Continued

DTC ESP scanners, being factory calibrated and Digitally Temperature Compensated, do not require a full five (5) point pneumatic calibration before operation. Instead a set of compensation coefficients are uploaded for each DTC ESP scanner port from non-volatile storage inside each DTC ESP scanner. Once the DTC pressure and temperature coefficients have been read from the DTC ESP scanners internal non-volatile memory, the system is ready to acquire and output EU data. The pneumatic calibration process still exists, however it is simpler, faster, and is performed less frequently, only adjusting the two lowest order DTC coefficients, Zero $\mathbf{C}_z$ and Span $\mathbf{C}_s$, for each scanned port using a short two (2) point pneumatic calibration. These adjustable DTC coefficients, in combination with dynamically calculated DTC coefficients, and the permanently stored DTC coefficients are used to convert raw pressure data into engineering units.

The Optimus OFIU is capable of acquiring data from both DTC and Conventional ESP scanners simultaneously. It should be noted that, if a mixture of DTC and Conventional scanners are to be used, it is best to put all DTC ESP scanners on one OFIU and mSDI and to put all Conventional ESP scanners on a separate OFIU and mSDI. It is also recommended that no Logical Ranges Numbers are shared between the two scanner types. When this separation is maintained, pneumatic calibration of both ESP scanner types can be performed independently.

OFIUs running in their normal Full OFIU Mode acquire and output sensor Pressure data, sensor Temperature data, sensor Excitation data, and Analog to Digital converter Zero offset data. The sensor Pressure data is referred to as a Pressure or Press-Set going forward. The sensor Temperature, sensor Excitation, and A / D converter Zero offset data are referred to generally as compensation or Comp-Sets, and individually as Temp-Sets and EZ-Sets respectively. Comp-sets are used internal to the OSP to dynamically compensate the pressure data as it is converted into EU. The individual Comp-Sets can also be passed to the host application, which can be useful in some instances for troubleshooting. One Ez-Set is generated at the start of a data stream, immediately before the first Temp-Set. By default, a Temp-Set is acquired for every Press-Set to ensure rapid response to temperature changes. In practice, once the ESP scanners have stabilized in their environment, the rate of sensor temperature change will be moderated by the surrounding insulating material and the ratio of Temp-Sets to Press-Set can be increased significantly. It is common practice that, at a 10 Hz Press-Set rate, Temp-Set to Press-Set ratios of 1/150 or larger are sufficient to maintain the specified accuracy of the system

SD1 - Configure an OFIUs Scanners

This command defines all characteristics of ESP scanners connected to an OFIU and mSDI including: The mSDI connector to which a scanner is attached, The number of pressure ports in each scanner, and The Logical Range Number to which a scanner is assigned. For DTC ESP scanners, the SD1 also specifies whether the Sensitive Mode, a high gain output setting permitting increased resolution, will be enabled.

When the SD1 command is executed the OFIU interrogates each of the scanners listed in the command parameters. Conventional ESP scanners will not respond to that interrogation and the OFIU will return a warning response for those scanners. The OFIU will continue to operate in the Full FIU mode, meaning that all detected DTC ESP scanners will operate as expected and any indicated Conventional ESP scanners will require a pressure calibration before Engineering Unit data can be calculated. If no DTC ESP scanners are present, or if the operator does not require DTC operation, the OFIU may be instructed to operate in Conventional mode only, requiring a full calibration of all connected scanners whether DTC or Conventional.

Response:

Confirmation / Error Packet

Format:

“SD1 CRS (Scnr Nports LRN) (Scnr Nports LRN) …;”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114

The isolated groups of three (3) parameters each are repeated as necessary to define all scanners connected to the OFIU and mSDI. The scanners may be specified individually, or in contiguous ranges of scanners having the same number of pressure ports and the same calibrator LRN. The individual parameters of each group are specified as follows:

Scnr = The Scanner number; the connector on the mSDI to which the scanner is attached. For DTC ESP scanners, a negative number may be used to indicate that the scanner should be configured in Sensitive mode.

May be specified as a contiguous range by separating the two terminals of the range with a hyphen; for example "1-4" indicates the contiguous range of scanners attached to mSDI connectors one (1) through four (4) inclusive.

Contiguous ranges of scanners must have the same number of pressure ports and be assigned to the same PCU LRN for calibration.

Range: ± (1 to 8).

Nports = The Number of pressure ports possessed by the scanner.

Value = 16, 32, 48, and 64; Defined by legacy and standard ESP pressure scanner configurations.

LRN = The Logical Range Number; A numeral associating ESP scanners and Pressure Calibrate Units, supporting pressure calibration of the ESP scanners, in addition to PSUs acquiring precision single pressure values. The PCU and PSU LRN is specified in the PC1 and PS1 commands.

Range: 1 to 12

Since all scanners connected to an OFIU must be defined by this one command, you may need to use continuation characters to break up a long SD1 command.

Example 1:

A System is configured with one (1) OFIU and its mSDI Interface, eight (8) identical 16-port Conventional ESP scanners, and one (1) PCU appropriate for calibrating those scanners is assigned to LRN 1. The OFIU SD1 command is:

"SD1 111 (1-8, 16, 1);"

Which states; "The OFIU at OSP slot location 111 has scanners attached to each of its mSDI connectors. Each of the eight scanners has 16 pressure ports and they will be calibrated by the PCU designated as LRN 1.".

Host Operation and Programming: Continued

Example 2:

A System is configured with one OFIU and its mSDI Interface, two (2) identical 48-port legacy Conventional ESP scanners which will be calibrated using a PCU assigned to LRN 1, and four (4) 32-port Conventional ESP scanners which will be calibrated by a PCU assigned to LRN 2.

“SD1 111 (1-2, 48, 1) (3-6, 32, 2);”

Which states; “The OFIU at OSP slot location 111 has scanners attached to mSDI connectors 1 through 6. The scanners attached to mSDI connectors 1 and 2 have 48 pressure ports each and will be calibrated by the PCU designated as LRN 1. The scanners attached to mSDI connectors 3 through 6 have 32 pressure ports each and will be calibrated by the PCU designated as LRN2.”.

Example 3:

A System is configured with one OFIU and its mSDI Interface, one (1) 64-port DTC ESP scanner and two (2) 32-port DTC ESP scanners will use their normal range and be calibrated using a PCU assigned to LRN 1, three (3) 32-port Conventional ESP scanners will be calibrated by a PCU assigned to LRN 2, and one (1) 64-port DTC ESP scanner will use its sensitive range and be calibrated by a PCU assigned to LRN 3.

“SD1 111 (1, 64, 1) (2-3, 32, 1) (4-6, 32, 2) (--7, 64, 3);”

Which states; “The OFIU at OSP slot location 111 has scanners attached to mSDI connectors 1 through 7. The scanner attached to mSDI connector 1 has 64 pressure ports and the scanners attached to mSDI connectors 2 and 3 have 32 pressure ports. The three scanners attached to mSDI connectors 1 through 3 will be calibrated by the PCU designated as LRN 1. The scanners attached to mSDI connectors 4 through 6 have 32 pressure ports each and will be calibrated by the PCU designated as LRN 2. The scanner attached to mSDI connector 7 has 64 pressure ports, is to be configured in its sensitive mode, and will be calibrated by the PCU designated as LRN 3.”.

Example 4:

A System is configured with two OFIUs and each has an mSDI Interface. On the mSDI of the OFIU at CRS 111, four (4) 32-port DTC ESP scanner will use their normal range and be calibrated using a PCU assigned to LRN 1 and four (4) 64-port DTC ESP scanners will use their normal range and be calibrated using a PCU assigned to LRN 3. On the mSDI of the OFIU at CRS 112, three (3) 32-port Conventional ESP scanners will be calibrated by a PCU assigned to LRN 2, one (1) 64-port DTC ESP scanner will use its sensitive range and be calibrated by a PCU assigned to LRN 4, and two (2) 64- port DTC ESP scanners will use their normal range and be calibrated by a PCU assigned to LRN 1.

"SD1 111 (1-4, 32, 1) (5-8, 64, 3);"

"SD1 112 (1-3, 32, 2) (-4, 64, 4) (5-6, 32, 1);"

Which states; "The OFIU at OSP slot location 111 has scanners attached to mSDI connectors 1 through 8. The scanners attached to mSDI connectors 1 through 4 have 32 pressure ports each and will be calibrated by the PCU designated as LRN 1. The scanners attached to mSDI connectors 4 through 8 have 64 pressure ports each and will be calibrated by the PCU designated as LRN 3. The OFIU at OSP slot location 112 has scanners attached to mSDI connectors 1 through 6. The scanners attached to mSDI connectors 1 through 3 have 32 pressure ports each and will be calibrated by the PCU designated as LRN 2. The scanner attached to mSDI connector 4 has 64 pressure ports, is to be configured in its sensitive mode, and will be calibrated by the PCU designated as LRN 4. The scanners attached to connectors 5 and 6 have 32 pressure ports each and will be calibrated by the PCU designated as LRN 1.".

SD2 - Define an OFIUs Table Parameters

This command defines data acquisition Tables, profiles which set: the Number of Frame samples averaged to derive a Measurement Set, the Frame Delay interval between those Frame samples, the Number of Measurement Sets that will be acquired, the Measurement Set Delay interval between each Measurement Set, the Scanning Mode in which the scanner channels are sampled, and the Format in which the data will be transmitted. Up to three (3) independent Tables may be set for each OFIU. However, only one of the three tables can be actively controlling data acquisition at any one time.

Response:

Confirmation / Error Packet

Format:

“SD2 CRS sTBL (nFR[-nFRez] FRd) (nMS MSd) (TRIG SCNm) OCf;”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 4

The following six parameters, isolated by parenthesis in the template above, are unique pairs and are not repeated in the manner of the SD1 scanner definition. The use of parentheses in the Format is only to illustrate the pairing of these parameters.

nFR[-nFRez] = The Number of Frames which dictates the number of frames averaged to derive a Temp-Set and Press-Set.

The optional nFRez modifier may be included, which applies in the same manner to OFIU Ez-Sets.

A value of one (1) specifies that no frame averaging will be performed. Larger values result in that number of frames being summed within the OFIU and then transmitted to the OSP. The summed frames will be divided by nFR, and or nFRez, inside the OSP or host, prior to the application of EU coefficients.

Range: 1 to 127; Nfrez Default Value = 64

FRd = The Frame Delay, interval between the beginning of scanned frames

A value of zero (0) specifies no delay between. This parameter is ignored if the value of nFR = one (1).

Range: 0 to 65000 microseconds

nMS = The Number of pressure Measurement Sets to be acquired when the Optimus is commanded to acquire data. The Measurement Sets are acquired and emitted to the host at Measurement Set Delay intervals.

A value of zero (0) specifies that the OFIU will acquire data continuously, without bounds, when triggered until explicitly commanded to stop acquiring data.

A non-zero value specifies that number ‘n’ Measurement Sets will be acquired and output when triggered, after which the system must be triggered again.

Note: The value for nMS can be overridden by the command which starts the data acquisition process. See the ADx commands for additional details.

Range: 0 to 65000

MSd = The Measurement Set Delay the interval between pressure Measurement Sets.

Note: Specifying a value less than or equal to the time required to acquire a pressure Measurement Set will cause this parameter to be ignored.

Range: 0 to 600000 milliseconds (10 minutes)

TRIG = The Trigger Mode specifies the hardware or software event which will trigger the acquisition of data.

This parameter accepts either the mnemonic or numeric values listed below.

FREE (0) = Free Trigger. Data will be acquired according to the (nFR[-nFRez] FRd) (nMS MSd) parameters.

Note: The following two values for TRIG require a digital signal edge transition to be applied to the Trigger In BNC connector located on the back panel of the OSP. The ADx command must have been executed prior to the trigger input edge for the trigger to be active.

ITRIG (1) = Trigger the Initial Measurement Set and continue acquiring data as specified by the (nFR[-nFRez] FRd) (nMS MSd) parameters.

ATRIG (2) = Trigger Every Measurement Set explicitly using the (nFR[-nFRez] FRd) parameters to create the Measurement Sets. MSd is irrelevant. nMS is still valid.

Note: Impact on System Performance

For an OFIU in Full OFIU mode, an Ez-Set will be acquired before the trigger starts acquisition of the Press-Set and Temp-Set pairs. The Ez-Set compensates for excitation variations and A / D converter offset errors taking a relatively large amount of time compared to pressure and temperature data acquisition. This delay will significantly reduce system throughput if the application designer chooses to repeatedly poll the system for single data points. It is recommended, and more efficient, to configure a stream of data to be delivered at an appropriate data rate continuously, either using the FREE trigger or one of the two Hardware trigger options for trigger mode. This avoids a time delay inherent in repeatedly acquiring an Ez-Set.

Value = FREE (0), ITRIG (1), ATRIG (2)

SCNm = The Scan Mode specifies the method by which the mSDIs multiplexers and A / D converter perform the selection and digitizing of individual ports of the ESP scanners.

This parameter accepts either the mnemonic or numeric values listed below.

SEQ (0) = Sequential Address Mode addresses and samples the scanner ports in the order they are declared in the SD3 scan list.

PAM (1) = Parallel Address Mode addresses and samples the scanner ports in parallel to achieve higher data throughput. The data is output in the order declared by the SD3 scan list.

See the Timing Diagram for a detailed description of Sequential and Parallel Address modes.

Value = SEQ (0), PAM (1)

OCf = The Output and Conversion Format for Measurement Sets specifies which data, the Temperature, Pressure, and Excitation and Zero set are delivered as well as the format in which they are delivered. All Optimus Responses contain a four (4) byte header indicating: the source of the data, which command evoked it, the format of the data, the structure, and the number of bytes contained within the data packet.

1 = The Raw Format returns raw Measurement Sets generated by the OFIU.

The raw Measurement Sets are arrays of two (2), three (3), or four (4) byte integers, depending on whether one or more frames are averaged. The data structure is indicated by the Response Type value embedded within the data packet. Single point data, created if the nFR parameter of the SD2 command is equal to one (1), are returned as signed short integers. Averaged data, created if nFR is greater than one (1), is returned as either a three (3) or four (4) byte integer sum which must be divided by nFR to derive the average value.

An OFIU, operating in Full OFIU Mode, will deliver a single raw Ez-Set and then deliver a raw Temp-Set preceding each raw Press-Set specified by nMS. Each Temp-Sets raw temperature array is scanned and assembled according to the scan list for the active Table defined in the SD3 command.

The Ez-Set differs from the Temp-Set and Press-Set by having a single Excitation value for each ESP scanner defined in the SD1 command and a single Zero Offset value for the A_/_D converter within the mSDI. The Excitation data will be present for scanners even if they are not referenced in the SD3 command.

2 = The Engineering Unit Format returns Pressure Measurement Sets generated by the OFIU. The EU Measurement Sets are arrays of 32 bit IEEE 754 floating point values in Big Endian order. The data structure is indicated by the Response Type value embedded within the data packet. The values have been processed and are the result of Frame Averaging specified in the nFR parameter.

OFIUs operating in Full OFIU Mode do acquire Excitation, Zero offset, and Temperature sets from DTC ESP scanners but do not transmit them to the host. The DTC ESP scanner data is fully compensated for temperature.

The Engineering Units default to PSI if DTC or Conventional ESP scanners have coefficients resident in memory. Other units can be specified using the PC4 command. Conventional ESP scanners that have not been calibrated and DTC ESP scanners which conversion coefficients have been read into memory will output data in volts. Coefficients may be created as a result of calibration using the CA2 or CA3 commands or loaded into memory using the SD4 or SD5 commands.

3 = The Engineering Unit and Compensation Set Format returns Pressure, Temperature, and the Compensation Measurement Sets generated by the OFIU. The Measurement Sets are arrays of 32 bit IEEE 754 floating point values in Big Endian order. The data structure is indicated by the Response Type value embedded within the data packet. The values have been processed and are the result of Frame Averaging specified in the nFR parameter.

OFIUs operating in Full OFIU Mode acquire Excitation, Zero offset, and Temperature sets from DTC ESP scanners. The Excitation and Zero Offset, Ez-Set, data is transmitted to the host immediately after a data acquisition command is received, followed by a Temperature, Temp-Set, data and then the Pressure, Press-Set. The Optimus then continues acquiring and emitting Press-Set and Temp-Set data according to the nFR, nMS, and MSd parameters. Temp-Set data is in ºC by default and the Ez-Set data is in Volts.

Example 1:

Configure Table 1 for the OFIU at OSP CRS 111 to acquire Measurement Sets continuously at 10 Hz, each Measurement Set being the average of 10 Frames, with the Format of the Measurement Set being an array of IEEE floating point values. The internal timer will be used to trigger each Measurement set. Only the Pressure data in Engineering Units are to be transmitted. No Compensation sets will be returned to the host.

"SD2 111 1 (10 0) (0 100) (FREE PAM) 2;"

When the Data acquisition command is received the OFIU / Optimus will begin taking data at 100 millisecond intervals with the interval timer inside the OFIU controlling the data rate. Each data point transmitted by the system will be a Pressure Measurement Set, the average of 10 frames of pressure data that has been converted into temperature compensated Engineering Unit values.

Example 2:

Configure Table 1 for the OFIU at OSP CRS 111 to acquire an unbounded number of Measurement Sets in response to a digital edge transition applied to the Trigger Input BNC connector, each Measurement Set being the average of 10 Frames, with the Format of the Measurement Set being an array of IEEE floating point values. The trigger signal for each Measurement set will be generated by an external signal generator at an arbitrary rate. An Ez-Set, The Temp-Sets, and The Press-Sets will be returned to the host in EU format.

"SD2 111 1 (10 0) (0 0) (ATRIG PAM) 3;"

When the Data acquisition command is received the OFIU / Optimus will begin acquire and transmit an Excitation and Zero Offset, EZ-Set, packet and then wait for an edge transition on the Trigger Input BNC connector. When a trigger signal occurs, the OFIU will acquire a Pressure Measurement Set and a Temperature Measurement Set each being the average of 10 frames of the scan list. The Pressure Measurement Set has been converted into temperature compensated Engineering Unit values. The system will then wait for another digital transition on the Trigger Input BNC.

SD3 - Define an OFIUs Scan List

The SD3 command defines the scan list, the order in which the pressure ports of the Table are addressed and sampled. Measurement Sets, Pressure and Temperature data, as well as calibration coefficients and the calibration voltage data are all returned in this Scan List order. The Compensation, Ez-Set, is scanned in a static order and is unaffected by the scan list.

After transmitting the scan list for each Table, the system must then either create or retrieve engineering unit coefficients for all pressure ports defined in the scan list. This can be accomplished by:

1) Execute an SD5 command to retrieve the DTC ESP scanner coefficients from their embedded non-volatile storage.
2) Execute a CA3 command to perform a full pressure calibration on the ESP scanners.
3) Execute a sequence of SD4 commands to explicitly write pressure port coefficients into the coefficient tables.

Option one (1) is only valid for DTC ESP scanners and may be omitted under some circumstances; see the documentation for the SD5 command. If the DTC coefficients are not extracted from DTC ESP scanners then they will be treated as Conventional ESP scanners and will not be temperature compensated. Options two (2) and three (3) may be used for all scanner types though they are most applicable to Conventional ESP scanners.

Response:

Confirmation / Error Packet

Format:

“SD3 CRS sTBL sPort [sPort] ...”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 4

sPort = The three (3) digit number indicating the mSDI connector number and the port number of the scanner to be placed at this Measurement Set index. The first digit is the connector number on the mSDI to which the scanner is attached and the final two digits are the port of the scanner. Ex; “101” is Scanner 1 port 01.

The SD3 command permits entry of an implicit range of ESP scanners and their ports, as well as an arbitrary list of individual ports from a group of ESP scanners.

Ex: “101-132” is the inclusive range of scanner one (1) port one (01) through scanner one (1) port thirty-two (32) and “101-832” is the inclusive range of scanner one (1) port one (01) through scanner eight (8) port thirty-two (32) implicitly including all channels of the intervening six (6) scanners that may be defined in the SD1 command.

The sPort parameter is either repeated or configured as one or more contiguous ranges that include all scanners and pressure ports that are desired in this scan list. For complicated scan lists, it may be necessary to use command line continuation methods such as the keyword MORE.

Example 1:

Configure the scan list of Table 1 for the OFIU at OSP CRS 111 to scan and output the data for eight (8) ESP scanners. The ESP scanners attached to mSDI connectors 1, 2, and 3 have 16, 32, and 32 ports respectively. The remaining five (5) ESP scanners, attached to connectors 4 through 8, have 64 ports each.

“SD3 111 1 (101-864);”

Scan all ports of the ESP scanners referenced in the SD1 command for Table 1 connected to the OFIU and mSDI at OSP CRS 111 in the order; first port of the first scanner through the last port of the last scanner.

Example 2:

There are two OFIU in the OSP, and each OFIU has an mSDI attached. The first OFIU and mSDI are at OSP CRS 111 and have three – 16 port ESP scanners attached to connectors 1, 2, and 3. The second OFIU and mSDI are at OSP CRS 112 and have eight - 32 port ESP scanners attached.

Configure the scan lists for Table 1 to scan and output ports 1 through eight of each of the three ESP scanners attached to OFIU and mSDI at CRS 111, and also port 32 of each of the eight ESP scanners attached to OFIU and mSDI at CRS 112.

“SD3 111 1 (101-108) (201-208) (301-308);”

“SD3 112 1 (132) (232) (332) (432) (532) (632) (732) (832);”

Scan the ports of the ESP scanners referenced in the SD1 command for Table 1 of the OFIU and mSDI at CRS 111 attached to connectors 1, 2, and 3 in order: scanner 1 port 1 through scanner 1 port 8, then scanner 2 port 1 through scanner 2 port 8, and then scanner 3 port 1 through scanner 3 port 8. Simultaneously, scan the ports of the ESP scanners referenced in the SD1 command for Table 1 of the OFIU and mSDI at CRS 112 attached to connectors 1 through 8 in the order: scanner 1 port 32, scanner 2 port 32, scanner 3 port 32, scanner 4 port 32, scanner 5 port 32, scanner 6 port 32, scanner 7 port 32, and scanner 8 port 32.

SD4 – Manually Enter an OFIUs EU Conversion Coefficients

This command manually enters EU data conversion coefficients to an SP, for each scanner port scanned by each Table. It is normally used only when coefficients are not obtainable from either the DTC ESP scanner non-volatile memory or a full pressure calibration. It is also used to load the factory supplied DTC coefficients to into the non-volatile memory of DTC ESP scanner. This command will overwrite coefficients in the specified Table. An extensive discussion of the derivation and use of both DTC and Conventional ESP scanner coefficients can be fou nd in Appendix B.

Response:

Confirmation / Error Packet

Format:

“SD4 CRS [-]sTBL sPort [Coef] ... ;”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer.

The SD4 command writes calibration coefficients into the indicated Tables coefficient array. There are two types of coefficients handled by this command, corresponding to the two types of ESP scanners; DTC and Conventional.

Calibration of a Conventional ESP scanner is performed in-situ, at the time the ESP scanner is to be used. The coefficients are valid for the current state of the scanners and must be updated periodically to ensure accurate measurements. The Conventional calibration process will derive a set of coefficients for an ‘n-1’ order polynomial equation, with ‘n’ being the number of calibration pressure points specified for the ESP scanners. These coefficients may be stored on the host computer and re-loaded during configuration to reduce the time required before taking data; however, this process does not guarantee the system performance specification. It is still necessary to perform an offset calibration using a CA2 command if this optional procedure is used.

Calibration of DTC ESP Scanners is performed at the factory during production. The DTC calibration process requires application of multiple pressures across a number of temperatures. After the calibration data is reduced, the coefficients are stored in the scanners non-volatile memory and never require modification for the life of the scanner. In addition to being placed in the DTC scanner non-volatile memory, the coefficients are delivered on a CD accompanying the scanner. These coefficients are to be stored as a local record and can be reloaded into the DTC scanner using this command in conjunction with the SD5 command.

An in-situ pressure calibration of DTC ESP scanners may be performed as well. The in-situ calibration derives a first order pressure adjustment, having only an offset and span correction term, that is applied after the DTC temperature and pressure corrections have been made. These values, the DTC Adjustable Group coefficients, can also be stored into the DTC scanner non-volatile memory, although they may require adjustment at intervals.

The sign of the sTBL value selects the type of coefficients which will be written to the Table coefficient arrays. A negative Table value writes the factory coefficients for the DTC scanners into the OSP coefficient array and a positive Table value writes the Conventional scanner coefficients as well as DTC scanner Adjustable Group coefficients into the OSP coefficient array. The coefficients are written into temporary memory and will be erased if the power is cycled or overwritten if a subsequent SD4 command is executed for that Table and scanner port. If multiple Tables reference the scanner ports then the coefficients must be written to all Tables individually.

Range: -4 to -1, for DTC coefficients

Range: 1 to 4, for Conventional coefficients and DTC Adjustable Group coefficients

sPort = The three (3) digit number indicating the mSDI connector number and the port number of the scanner to which the coefficients will be applied. The first digit is the connector number on the mSDI to which the scanner is attached and the final two digits are the port of the scanner. Ex; “101” is Scanner 1 port 01.

Value = A single connected Scanner and Port number. The port for which the coefficients to be transmitted are valid.

Coef = For positive Table values, Coef specifies between two (2) and five (5) EU conversion coefficients entered from lowest to highest degree. For Negative Table Values Coef specifies a total of twenty three (23) floating point values in nine (9) coefficient groups. The Coef values may be written as Fixed Point, Floating Point, Scientific, Engineering, or Exponential notation.

Value = Between 2 and 5 values, Conventional, or 23 values, DTC, in Fixed Point, Floating Point, Scientific, Engineering, or Exponential notation.

Host Operation and Programming: Continued

Example 1:

After configuring the scan list of Table 1 for the OFIU and mSDI at OSP CRS = 111, load the pressure coefficients for Conventional scanner one (1) port one (01) through scanner one (1) port thirty two (32).

The coefficient list for Conventional ESP scanner 1, by port number, is:

Port #	C0	C1	C2	C3	C4
01	0.15968	1.14263	0.00080	0.00011	-0.00000
...					
...					
...					
32	0.05109	1.15475	0.00035	0.00013	0.00001

"SD4 111 1 101 (0.15968, 1.14263, 0.00080, 0.00011, -0.00000);"

…

"SD4 111 1 132 (0.05109, 1.15475, 0.00035, 0.00013, 0.00001);"

Load the five coefficients, C0 through C4, for scanner one (1) port one (01) into the Coefficient array for Table 1 of the OFIU and mSDI at OSP CRS 111. Incrementally load the five coefficients, C0 through C4, for the remaining thirty one (31) ports of scanner one (1) into the coefficient array for Table 1 of the OFIU and mSDI at OSP CRS 111.

Example 2:

In preparation of re-writing Coefficients to non-volatile memory within a DTC ESP scanner attached to connector 1 of the OFIU and mSDI at OSP CRS = 111, write the scanners coefficients to Table 1. The coefficients will be written to the scanner using the SD5 command.

The coefficient list for DTC ESP scanner 1, by port number, is:

Port #	Group	Term 1	Term 2	Term 3	Term 4
01	Adjustable	0.00000	1.00000		
	P_x A	-16.22416055	-72.29816174	-104.93503733	-50.12542169
	P_x B	12.44525447	8.72096582	11.43406642	8.38368705
	P_x C	0.21483914	0.19328543		
	P_x D	0.10589883	0.06644576		
	T_x Q	-0.00013973	0.99985718		
	T_x R	-0.00118181	0.00156580		
	T_x S	0.00015803	0.00043320		
	T_x T	694.28893801	985.21905227	70.69070065	

Put each of the nine (9) coefficient groups on a separate command line within parentheses and using continuation marks for better readability.

```
"SD4 112 -1 101 +
(    0.00000000     1.00000000) +
(    -16.22416055 -72.29816174    -104.93503733  -50.12542169) +
(   12.44525447     8.72096582      11.43406642      8.38368705) +
(    0.21483914     0.19328543) +
(    0.10589883     0.06644576) +
(   -0.00013973     0.99985718) +
(   -0.00118181     0.00156580) +
(    0.00015803     0.00043320) +
(  694.28893801   985.21905227      70.69070065);"
```

SD5 – Perform DTC scanner specific Functions

This command performs three functions specific to DTC ESP scanners and the manner in which the OFIU acquires the DTC scanner temperature data.

1) Load or Store DTC ESP scanner Coefficients
2) Enable, Disable, or Periodically acquire DTC Temperature Data
3) Enable or Disable DTC ESP scanner function

Load or Store DTC ESP scanner Coefficients

The most common use for the SD5 command is to move the DTC ESP scanner coefficients between the non-volatile memory within the scanner and the OSP memory. The SD5 is executed to read the coefficients into OSP memory immediately after the SD1, SD2, and SD3 commands are executed. This operation, of necessity, takes a relatively long time however it only needs to be performed once when the system is power cycled or if scanners are moved on the mSDI.

There are five (5) operations which can be performed on the non-volatile memory within DTC ESP scanners.

1) Read all DTC coefficients from the scanner
2) Write All DTC coefficients to the scanner
3) Write the Adjustable coefficients to the scanner
4) Verify all DTC coefficients in the scanner against the coefficients in the OSP memory.
5) Erase the non-volatile memory in the scanner.

These functions are performed using a positive Table number. Care should be taken when performing coefficient writes and memory erase operations. Ensure that there is a backup copy of the coefficients and only initialize one scanner at a time to avoid unfortunate incidents.

When performing a Verify operation, it is important to realize that the verification also applies to the Adjustable Coefficients, the offset and span coefficients modified by the pressure calibration routines CA2 and CA3. To avoid a false Verify failure, read all of the coefficients from non-volatile and then perform the Verification. Since the Adjustable coefficients can be written back to non-volatile memory within the scanner it is reasonable to limit that write operation to the calibration lab. This would ensure that the scanner memory contents can be verified against a known copy of the coefficients.

Note: The Erase adjustable coefficients operation writes the default offset and span correction terms, zero (0) and one (1) respectively, to these memory locations.

Enable, Disable, or Change the period of DTC Temperature Data acquisition

The second most common use for the SD5 command is used to Enable, Disable, or change the interval of acquisition of a Temperature Data Set during Pressure Data Acquisition. When an OFIU is configured and DTC ESP scanners are detected, the default Temperature Data rate is identical to the specified Pressure Data rate. This ensures that a fresh temperature value is acquired for each pressure value allowing continuous compensation for changes in temperature. The Pressure and Temperature data sets are acquired in the OFIU concurrently, interleaved temperature for a port and then pressure for the same port. This default rate will not permit full throughput and is not required to achieve the stated system accuracy.

The ratio of temperature data sets to pressure data sets can safely be reduced, such that temperature is refreshed once a minute or even longer if the temperature of the DTC ESP scanner is stabile. Once a ratio of temperature to pressure data is set it will remain until it is explicitly changed, either through issuing a new SD5 command or by a power cycle or reset of the Optimus. The temperature compensation coefficients are updated every time a new temperature data point is acquired.

In some instances, for example if the highest data rate is desired for short intervals, it is necessary to turn the continuous or periodic temperature updates off. In this case, since the data acquisition is at a high rate and the data stream duration is short, it is presumed that the initial temperature data point will be sufficient. A single temperature data point is always acquired upon a data acquisition request immediately after the Excitation and Zero Offset Compensation set is acquired.

Enable or Disable DTC ESP scanner function

When an OFIU is initialized with the list of scanners using the SD1 command, it will determine if any or all of the scanners attached to its mSDI are DTC ESP scanners. If any scanners identified in the SD1 command do not respond as DTC scanners, the OFIU will issue a warning that it either, has a combination of DTC and Conventional scanners attached, or that there were no DTC ESP scanners identified on the mSDI. Some reduction in performance can be expected when combinations of DTC and Conventional ESP scanners are present on a single OFIU and mSDI. In such cases where it is critical to achieve full throughput the DTC and Conventional scanners may be segregated, connected to separate OFIU and mSDI in the same OSP. The OFIU and mSDI having the Conventional scanners attached, can turn off the DTC specific features of that OFIU, simplifying the configuration of the overall system and reducing the time required for system initialization.

In some applications, it may be advantageous to operate the DTC scanners as Conventional scanners, configuring the OFIU such that it will ignore the presence of DTC scanners. In these cases, the DTC scanner retains one feature available through the SD1 command; the ability to engage the Sensitive Mode of operation with increased resolution. If this feature is enabled, it is important to account for the increased sensitivity by reducing the calibration pressures specified within the PC2 command for the LRN calibrating that scanner.

Response:

Confirmation / Error Packet

Format:

"SD5 CRS sTBL [actx] [x.x];"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer.

The SD5 command reads calibration coefficients into the indicated Tables coefficient array. This command is only applicable to DTC scanners and the operation of the OFIU when DTC scanners are connected.

Range: -2, -1, 0 to 4

-2 = Disable the DTC function of the OFIU. All scanners attached are treated as if they were Conventional ESP scanners. DTC ESP scanners that are configured for Sensitive mode of operation remain in sensitive mode until a new SD1 command is issued. After the DTC function is disabled the SD5 command will return an error until the system is reset and re-initialized.

The optional parameters [actx] [x.x] are ignored if present and are not necessary.

-1 = Set the ratio of Temperature data sets to Pressure Data Sets during data acquisition. The Ratio is defined by the actx parameter as follows.

actx = 0, Turn off Temperature data sets. Only acquire one Temperature set at the start of data acquisition.

actx ≥ 1, A Temperature data set will be acquired every actx pressure data sets. Ex, an actx value of 2 indicates that the OFIU must acquire one (1) Temperature data set for every two (2) Pressure data sets.

The optional parameter [x.x] is ignored if present and is not necessary.

0 through 4 = The Table for which the Verify, Read, Write, or Erase coefficients operation will be valid. Zero (0) specifies to read the DTC coefficients from all connected DTC ESP scanners, and place them into all three (3) Tables. If the Table is set to zero (0) and a write to DTC ESP scanner non-volatile memory is requested, the first table containing coefficients will be written to the scanners and ports defined by the SD1 and SD3 commands.

The parameter [actx] indicates the operation to perform as follows:

actx = 1, Verify All of the coefficients in the DTC ESP scanner non-volatile memory against the coefficients in the Table indicated by sTBL.

actx = 0, Read All of the coefficients from the DTC ESP scanner non-volatile memory into the Table indicated by sTBL.

actx = -1, Write the Adjustable Group coefficients for all ports from the indicated Table into the DTC ESP scanner non-volatile memory.

When **actx = -1**, a value of one (1.0) for the optional [x.x] parameter is used to clear the Adjustable coefficients to their default values of zero (0) and one (1) for Cz Offset and Cs Span correction respectively.

When **actx = -2**, Write All of the coefficients for all ports in the indicated sTBL into the DTC ESP scanner non-volatile.

When **actx = -3**, Erase All completely erase the non-volatile memory within the scanner or scanners defined in the indicated table. It is important to clear the Table and re-initialize the system, such that only the one scanner to be erased are defined in the SD1 and SD3 commands, before erasing non-volatile memory. Failure to include only one scanner in the scan list will erase all scanners in the scan list. The most common use is to identify bad data during a erase, write, read, and verify operation sequence.

The ***optional [x.x] parameter*** is not normally used for actx, except to modify or read the scanner Header, port zero [0.0], or Trailer, scanner last port + 1, data. Ex: To read the Trailer data on a 32 port DTC ESP scanner specify port [33.0] with actx = 1.

A CD containing the factory coefficient update files is provided with each DTC ESP scanner. These files contain OFIU command scripts that can restore the DTC ESP scanner to its original state. This operation is not performed except in the case of an accidental erasure of the scanner non-volatile memory.

DTC ESP scanner coefficients apply to both normal and sensitive range. A gain factor coefficient that applies to all DTC-scanner ports is used with the standard coefficient set. The gain factor and other data, such as the serial number and other identifying information, in the header and trailer sections of the non-volatile memory, addressed as port 0, the Header, and scanner last port + 1. The header and trailer data are read into the OSP during the execution of the SD1 command.

Example 1:

Disable the OFIU DTC ESP scanner functions so that it handles every scanner as a Conventional ESP scanner.

Configure the scan list of Table 1 for the OFIU and mSDI at OSP CRS 111 to scan and output data for two (2) ESP scanners. The ESP scanner attached to mSDI connector 1 has 16 pressure ports, a full scale pressure range of ± 1 psid, and is a Conventional scanner. The ESP scanner attached to mSDI connector 2 has 64 pressure ports, a full scale pressure range of ± 5 psid, and is a DTC ESP scanner. The DTC ESP scanner will be configured for Sensitive Mode operation before disabling the DTC scanner features.

“SD1 111 (1 16 1) (-2 64 2);”

“SD5 111 -2;”

“SD2 111 1 (1 0) (100 0) (FREE PAM) 2;”

“SD3 111 1 101-116 201-264;”

Since the Conventional ESP scanner and the DTC ESP scanner are treated in the same manner, a full calibration is required before EU data can be output. A PC1, PC2, and CA3 command would follow these SDx commands to complete the required configuration.

In order to re-enable the DTC function, a full System Reset is required.

Example 2

Change the ratio of Temperature data sets to Pressure data sets. This is a global change, affecting all Tables.

Configure the scan list of Table 1 for the OFIU and mSDI at OSP CRS 111 to scan and output data for two (2) ESP scanners. The ESP scanner attached to mSDI connector 1 has 32 pressure ports, a full scale pressure range of ± 1 psid, and is a DTC scanner. The ESP scanner attached to mSDI connector 2 has 64 pressure ports, a full scale pressure range of ± 5 psid, and is a DTC ESP scanner. Table 1 will be set to acquire one thousand (1000) un-averaged, single frame, measurement sets at 10 millisecond intervals. The Temperature data set for all DTC scanner ports will be updated every one hundred (100) Pressure Sets; effectively once per second.

“SD1 111 (1 32 1) (2 64 2);”

“SD2 111 1 (1 0) (1000 10) (FREE PAM) 2;”

“SD3 111 1 101-264;”

“SD5 111 -1 100;”

The Temperature data set to Pressure data set ratio ensures that, if temperature is changing over the ten (10) second window, it will be accounted for.

Example 3:

Restore factory DTC coefficients to a single DTC ESP scanner with 32 pressure ports.

Note: The following sequence of commands will configure a Table and then Erase, Write, and Verify the DTC coefficients for that Table. These functions are applied to the Scan List that is defined for the Table and not specifically a single ESP scanner attached to a single connector of an mSDI. It is prudent to remove any DTC scanners which are not the direct target of the operations to be performed so that unintentional effects are avoided.

A single DTC ESP scanner will be attached to connector 1 of the OFIU and mSDI located at OSP CRS 111. No other ESP scanners will be connected to the mSDI during the Erase, Write, and Verify operation. The single DTC scanner will be defined in Table 1 as it would for data acquisition. The DTC functions must not be disabled.

Step 1: Configure a Table including only the first port of the DTC scanner.

"SD1 111 (1, 32, 1);"
"SD2 111 1 (1 0) (1 0) (FREE SEQ) 1;"
"SD3 111 1 101;"

Step 2: Write the DTC scanner Header information into the Table using the SD4 command.

Note: Observe the use of continuation characters to concatenate the long command line.

"SD4 111 -1 101 +"
"(0.33333 0.0) +"
"(24422.0 2223.0 32.0 15.0) +"
"'MOD=ESP-32-DTC ' +"
"'SER=64267 ' +"
"'DOM=1997/03/31 ' +"
"'EOH=';"

Step 3: Write the Header data to the Header non-volatile memory at port '0.0' of the DTC scanner.

"SD5 111 1 -2 0.0;"

After writing the Header, the Trailer data is written.

Step 4: Modify the Table scan list to only include the Last port of the DTC scanner. In this case, the scanner has thirty two (32) pressure ports.

"SD3 111 1 132;"

Step 5: Write the DTC scanner Trailer information into the Table using the SD4 command.

Note: Observe the use of continuation characters to concatenate the long command line.

"SD4 111 -1 132 +"
"'DOC=1997/03/31 ' +"
"'MOC=HP1234-XYZ ' +"
"'SEC=J163456-X-2345 ' +"
"'EOT=';"

Step 6: Write the Trailer data to the Trailer non-volatile memory at port '33.0' of the DTC scanner.

"SD5 111 1 -2 33.0;"

Once the header and Trailer data has been written, write the individual port coefficients to non-volatile memory one at a time.

Step 7: Modify the Table scan list to include the all ports of the DTC scanner. In this case, the scanner has thirty two (32) pressure ports.

"SD3 111 1 101-132;"

Step 8: Write the DTC scanner port coefficients into the Table using the SD4 command.

Note: Observe the use of continuation characters to concatenate the long command line and that the Coefficient titles are used in this example to illustrate the process. In practice the titles would be replaced with floating point values; the actual values of the coefficients.

"SD4 111 -1 101 +"
"(C_Z C_S) +"
"(A_0 A_1 A_2 A_3) (B_0 B_1 B_2 B_3) (C_0 C_1) (D_0 D_1) +"
"(Q_0 Q_1) (R_0 R_1) (S_0 S_1) (T_0 T_1 T_2);"

Repeat the above for each port; scanner 1 port 02 through scanner 1 port 31.

Step 39: Write the final port coefficients into the Table.

“SD4 111 1 132 +”

“(C_Z C_S) +”

“(A_0 A_1 A_2 A_3) (B_0 B_1 B_2 B_3) (C_0 C_1) (D_0 D_1) +”

“(Q_0 Q_1) (R_0 R_1) (S_0 S_1) (T_0 T_1 T_2);”

Step 40: Write the entire Table of coefficients to the DTC scanner non-volatile memory.

“SD5 111 1 -2;”

In Step 1 through Step 3, a single 32 - port DTC scanner is initialized and the scan list is set to scan only port one (1) of the DTC ESP scanner attached to connector 1 of the OFIU and mSDI at OSP CRS 111. This enables writing the Header to port zero (0.0), the scanners header memory location. The scanner header data is written into the Table using the SD4 command. The SD5 command then writes the Header data from the Table to the scanner non-volatile memory.

In Step 4 through Step 6, the scan list is changed to scan only the last port, thirty two (32) in this example, of the scanner. This enables writing the Trailer to port thirty three (33.0), the scanners trailer memory location. The scanner trailer data is written into the Table using the SD4 command. The SD5 command then writes the Trailer data from the Table to the scanner non-volatile memory.

In Step 7 through Step 40, the Table scan list is changed again; all of the scanner ports are included in the scan list. The individual port coefficients are written to the Table using the SD4 command. When all coefficients for every port are loaded the entire body of the Table is written to the scanners non-volatile memory.

Step 41: Verify the contents of the scanner non-volatile memory against the data in the Table.

“SD5 111 1 1;”

While the responses to all commands must be evaluated to confirm they executed without error, it is very important to confirm that the memory verification completes without error at this point.

Step 42: Read the coefficients from the scanners non-volatile memory into the Table for use.

“SD5 111 1 0;”

Step 43: Data acquisition commands should not return engineering unit values; psi by default. The following command causes all scanner coefficients to be sent to the host PC.

“OP3 111 -1;”

The 42 step operation illustrated above is exactly the process documented within the coefficient data file provide with every DTC ESP scanner. The coefficient file is created as the final step of scanner production and is stored permanently at our facility.

This example, and in fact all factory DTC coefficient files are written such that the target scanner is expected to be attached to the first connector of the first OFIU and mSDI in the Optimus System. This is done by convention to ensure a common configuration to which all users can refer. There is however no limitation placed on the connector through which this process can be accomplished. Changing the scanner number to five (5) throughout this example would permit the scanner to be attached to mSDI connector 5 instead of mSDI connector 1. The reader is strongly advised to adhere to the conventions documented in the DTC ESP scanner coefficient files and this manual.

Host Operation and Programming: Continued

Initialize PCUs and PSUs

Definitions:

LRN = Logical Range Number; an arbitrary number, value ranged from one (1) to twelve (12), used to associate an ESP scanner with a PCU, Pressure Calibrate Unit, in support of calibration of the ESP scanners.

CRS = Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis. PCUs and PSUs are two slots wide and are installed with their left edge located within an ODD slot.

Frame = A collection of data, containing single values from a PSU.

Measurement Set = A Data Structure created using one or more Frames and transmitted to the host computer connected to the Optimus Data System.

Table = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple devices.

Host Operation and Programming: Continued

The PCx commands define parameters that identify and configure all PCUs and PSUs in the system. The PCx commands also: assign a sequence of calibration pressures to be used for a group of ESP scanners, enable streaming of high precision pressure measurements, and change the Units of Measurement for a Table.

Pressure Calibrate and Pressure Standard units, PCUs and PSUs respectively, are both highly accurate single channel pressure measurement instruments. They may participate in the normal Data Acquisition process, and are linked to a Table just as an OFIU and mSDI.

PCUs are capable of generating accurate pressures for calibrating ESP scanners during the Pneumatic Pressure Calibration process. PSUs have no pneumatic controls and are incapable of generating pressures. Both devices may also be configured as precision read only devices. They can be assigned to a Table along with any ESP scanners attached to an OFIU and mSDI and will acquire and output data in response to the same Acquire Data command.

When configuring a PCU or PSU, it is important to keep the functional differences firmly in mind to avoid operational confusion. There is a long standing convention that Calibrators shall be placed in Remote Processor slots, CRS location, ordered according to their maximum pressure range and that the LRN assigned to them will be likewise ordered from lowest pressure range to highest within the system.

For example, in a system having three (3) PCUs installed within an RP designated as Cluster two (2), the PCUs would be installed in slots one (1), three (3), and five (5) of the first rack of that RP according to their pressure range. The LRN selection would then assign LRN 1 to the PCU at CRS 211, LRN 2 to the PCU at CRS 213, and LRN 3 to the PCU at CRS 215.

The corresponding convention for Standards dictates that they be placed in Remote Processor Slots, CRS locations, above the Calibrators and that their LRNs will assigned in reverse order; beginning with LRN 12 and decreasing.

Extending the example above for a system having three PCUs installed at RP CRS 211, 213, and 215 respectively, a PSU is added at CRS 217, filling the RP rack. The PCUs are installed according to their pressure range, the lowest in the first CRS 211 is designated as LRN 1, the second at CRS 213 is designated LRN 2, and the third at CRS 215 is designated LRN 3. The PSU at CRS 217 is to be isolated, by both convention and capability, and is designated as LRN 12. Additional PSUs would be assigned decrementing LRNs.

> **Note:** LRNs must be unique and it should be noted that PCUs can be configured both as PCU and PSU simultaneously. When this is desired, the same LRN is used in both the PC and PS commands for that Calibrator.

The command descriptions incorporate both the Pressure Calibrate and Pressure Standard version of each command along with examples for each usage.

The command descriptions below are valid for PCUs having a firmware revision greater than or equal to 2.39 and for PSUs having a firmware revision greater than or equal to 8.19

PC1 and PS1 Commands

The PC1 and PS1 command both identify the location of the instrument within the system chassis and also assign a Logical Range Number, LRN, which for PCUs links the calibrator with a group of ESP scanners to facilitate the scanner calibration process. The PC1 command extends the configuration by defining the precision to which the pressure will be controlled, the maximum pressure which can be set, and whether the values being set and reported will be in Absolute or Differential pressure units.

PC1 - Configure a PCUs Pressure Generation parameters

The PC1 command describes each PCU's location, operating mode, and pressure generation parameters. If the PCU will also have its secondary pressure standard scanned by the Data Acquisition process, it must also be initialized as a using the PS1 and PS2 commands after it has been initialized by this PC1 command (and subsequent PC2 command).

A PSU will not be defined by this command.

Response:

Confirmation / Error Packet

Format:

“PC1 CRS LRN, PRm, Stol, maxP;”

Where:

CRS = Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Range: Dependent on the Chassis in which the PCU is installed. Typical values are 211, 213, 215, and 217 for an RP.

LRN = The Logical Range Number, a number between 1 and 12 that identifies a specific PCU, associating it with a group of ESP scanners to be calibrated by it. The LRN must be unique for every PCU and PSU in the system.

Range: 1 to 12

PRm = The Pressure operating Mode; whether the pressures will be specified and reported as Absolute or Differential units. Specifying Differential operating mode for an Absolute PCU instructs the unit to subtract a, typically Atmospheric, reference pressure from the measured pressure value during operation. Differential PCUs cannot be configured as Absolute and will ignore this value if set inappropriately.

This parameter accepts either the mnemonic or numeric values listed below.

Valid Values:

ABS (0) = Absolute Pressure values will be expected as command parameters and returned as data.

DIFF (1) = Differential Pressure values will be expected as command parameters and returned as data.

Stol = The Set pressure Tolerance for Calibration pressures; always specified in psi. Setting this parameter too tight will only increase the time to a valid pressure set indication without improving calibration quality.

Range: 0.0001 psi to the recommended value: 0.01% of the PCU full scale pressure range.

maxP = The Maximum Pressure a PCU will set; always specified in psi.

Range: ≤ the actual maximum pressure range of the PCU pressure standard. For Differential PCUs it is specified as the positive full scale pressure range and the negative complementary capability is assumed. For example; a 5 psid PCU would be specified as having a MaxP of 5.

Example 1:

Configure an absolute PCU located in Slot 5 of an RP. The instrument will operate in Differential Mode, and be designated as LRN 1 for calibrating ESP scanners. The PCU is capable of setting pressures up to 30 psia and will use a Set pressure Tolerance of 0.005 psi to qualify its pressure output stability.

“PC1 215 1, DIFF, 0.005, 30;”

The PCU located at RP CRS 215 is designated as LRN 1, can set pressures as great as 30 psia. The instrument will measure the current barometric pressure through its reference port and store it for use as a TARE value. The reference pressure will be subtracted from all pressure data and will be added to the value that is to be set. The intention is that this unit will emulate a differential PCU with a true range of ±15 psia: maxP of 30 less the atmospheric reference value.

PS1 - Configure a PSU or PCU for streaming data Operation

The PS1 command describes each PSUs chassis location within the system and its Logical Range Number. This command is issued in preparation of configuring the instrument to stream data in the same manner as an OFIU.

Response:

Confirmation / Error Packet

Format:

“PS1 CRS LRN;”

Where:

CRS = Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Range: Dependent on the Chassis in which the PCU is installed. Typical values are 211, 213, 215, and 217 for an RP.

LRN = The Logical Range Number, a number between 1 and 12 that identifies a specific PCU, associating it with a group of ESP scanners to be calibrated by it. The LRN must be unique for every PCU and PSU in the system.

Range: 1 to 12

If the unit is a true PCU, and it will be used to perform ESP scanner calibration, then the PS1 LRN must match the LRN assigned in the PC1 command. Otherwise, convention states that the first PSU will be designated as LRN 12 and LRNs will be assigned to additional PSUs in descending order.

Example 1:

Define a PSU or PCU in OSP Chassis Slot 3 as a DAU only.

“PS1 113 12;”

PC2 or PS2 Commands

The PC2 command is used by PCUs only and the PS2 commands are used to specify data acquisition parameters for either PCUs or PSUs that will stream data for a Table.

PC2 - Define PCU's Calibration Pressures

The PC2 command sets the calibration pressures a PCU will generate during the Full Pneumatic Pressure Calibration process (CA3). A PC1 command must have been executed prior to execution of the PC2 command. PSUs, or PCUs used only to stream data and will not be used to generate calibration pressures, should not use this command. The number of calibration pressures entered depends on the type of scanners being calibrated, either conventional or DTC ESP scanners.

Response:

Confirmation / Error Packet

Format:

"PC2 CRS calP calP [calP [calP [calP]]];"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

calP = The pressure value which will be set, in sequence, during calibration of ESP scanners. These values can be specified in any order. Each point's value may be positive or negative, but the value cannot exceed the Maximum Pressure Generated; per the maxP parameter of the preceding PC1 command. The value must also be greater than the minimum pressure the PCU can set. If a PC4 command has changed the PCUs pressure units then calP must be specified in the same pressure units.

Note: The number of Calibration Points used, determines the order of the curve fit for each conventional scanner pressure port. For DTC ESP scanners, only two points are required and only the lowest and highest calibration points will be used.

When a combination of Conventional and DTC scanners are calibrated using the same LRN, it is advisable to use the maximum number of calibration pressures to assure that the conventional scanners can achieve their accuracy specifications. A minimum of two points must be set. The calP values must be in the pressure units set by the 'PC4'; PSI by default. The units must also be consistent with the mode of operation, Differential or Absolute, in the 'PC1' command.

Example 1:

Select five calibration pressures in PSI to be generated by the PCU located in RP Slot 5:

"PC2 215 -4.8, -2.4, 0.0, 2.5, 4.75;"

The PCU located at RP CRS 215 will generate the specified sequence of pressures when a 'CA3' calibration command is executed.

Example 2:

Define the same calibration pressures in PSF to be generated by the same PCU; as in Example 1:

"PC2 215 -691.2 345.6 0.0 144 684;"

"PC4 215 12;"

The PCU located at RP CRS 215 will generate the specified sequence of pressures when a 'CA3' calibration command is executed. The referenced pressure values are in PSF, Pounds per Square Foot, as defined by the 'PC4' command.

PS2 - Define PSUs or PCUs streaming data Setup Parameters

This command defines data acquisition Tables, profiles which set: the Number of Frame samples averaged to derive a Measurement Set, the Frame Delay interval between those Frame samples, the Number of Measurement Sets that will be acquired, the Measurement Set Delay interval between each Measurement Set, the Scanning Mode in which the scanner channels are sampled, and the Format in which the data will be transmitted. Up to three (3) independent Tables may be set for each PSU. However, only one of the three tables can be actively controlling data acquisition at any one time.

Response:

Confirmation / Error Packet

Format:

“PS2 CRS sTBL (nFR[-nFRez] FRd) (nMS MSd) (TRIG SCNm) OCf;”

Where:

CRS = Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Range: Dependent on the Chassis in which the PCU is installed. Typical values are 211, 213, 215, and 217 for an RP.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 3

The following six parameters, isolated by parenthesis in the template above, are unique pairs and are not repeated in the manner of the SD1 scanner definition. The use of parentheses in the Format is only to illustrate the pairing of these parameters.

nFR = PCUs and PSUs do not use this parameter since the degree of averaging is accomplished by a coefficient stored internal to the unit.

Value= one (1)

FRd = PCUs and PSUs do not use this parameter since the averaging methodology is controlled by code stored internal to the unit.

Value = one (0)

nMS = The Number of pressure Measurement Sets to be acquired when the Optimus is commanded to acquire data. The Measurement Sets are acquired and emitted to the host at Measurement Set Delay intervals.

Value = zero (0) specifies that the PCU or PSU will acquire data continuously, without bounds, when triggered until explicitly commanded to stop acquiring data.

Value > zero (0) specifies that number ‘n’ Measurement Sets will be acquired and output when triggered, after which the system must be triggered again.

Note: The value for nMS can be overridden by the command which starts the data acquisition process. See the ADx commands for additional details.

Range: 0 to 65000

MSd = The Measurement Set Delay the interval between pressure Measurement Sets.

Note: Specifying a value less than or equal to the time required to acquire a pressure Measurement Set will cause this parameter to be ignored.

Range: 0 to 600000 milliseconds (10 minutes)

TRIG = The Trigger Mode specifies the hardware or software event which will trigger the acquisition of data.

This parameter accepts either the mnemonic or numeric values listed below.

Values: FREE (0), ITRIG (1), ATRIG (2)

FREE (0) = Free Trigger. Data will be acquired according to the (nFR FRd) (nMS MSd) parameters.

Note: The following two values for TRIG require a digital signal edge transition to be applied to the Trigger In BNC connector located on the back panel of the RP. The ADx command must have been executed prior to the trigger input edge for the trigger to be active.

ITRIG (1) = Trigger the Initial Measurement Set and continue acquiring data as specified by the (nFR FRd) (nMS MSd) parameters.

ATRIG (2) = Trigger Every Measurement Set explicitly using the (nFR FRd) parameters to create the Measurement Sets. MSd is irrelevant. nMS is still valid.

Note: Impact on System Performance

SCNm = The Scan Mode specifies the method by which measurement sets are acquired or selected for return to the OSP.

This parameter accepts the numeric values listed below.

0 = Unsynchronized Scan Mode: returns measurement sets at the MSd parameter specified interval, even if the PCU or PSU has not had sufficient time to update the current value from the pressure standard. If the value is “stale”, not new, the time stamp will not have been updated. This mode may return the first measurement set from the current value table which will be no older than one data acquisition cycle prior to execution of the ADx command. An over scale value will be returned if data acquisition is started before the PCU or PSU can fill its current value table.

1 = Synchronized Scan Mode: returns only unique new scans at the specified rate. In this mode the unit will only start each scan after the specified Measurement Set delay has expired. If the MSd parameter specifies less time than is required to obtain a fresh pressure value, Measurement Sets will be delivered at a slower rate; the fastest possible. The time stamps of adjacent unique measurement sets will always be unique.

OCf = The Output and Conversion Format for all measurement set data returned to the host. The allowed entries are:

1 = Raw Data Format returns raw data in each measurement set as an array of unsigned 4-byte long integers. Uncompensated PCUs and PSUs return one (1) long integer: the pressure raw counts. Temperature compensated Quartz PCUs and PSUs return two (2) long integers: pressure raw counts and temperature raw counts. Temperature compensated HASS PCUs and PSUs return four (4) integers: pressure raw counts, temperature raw counts, reference raw counts, and zero raw counts. The equations used to convert the raw data into engineering units are described in Appendix P and the PCU and PSU Calibration instructions.

2 = EU Data Format returns one (1) 32 bit IEEE 754 floating point value in Big Endian order.

The Engineering Units default to PSI. Other units can be specified using the PS4 command.

Example 1:

When DA Setup Table # 1 is used to control the DA process, the PSU or PCU located in Slot 7 and 8 will return unique “barometer” readings continuously every 1 second in EU (pressure) format. These measurement sets, acquired in the Synchronized mode, will be placed into the overall data acquisition stream, along with the measurement sets of other units also contributing to DA Setup Table #1:

Configure Table #1 for the PSU at RP CRS 211 to acquire Measurement Sets continuously at 1 Hz, with the Format of the Measurement Set being IEEE floating point values. The internal timer will be used to trigger each Measurement set.

“PS2 211 1 (1 0) (0 1000) (0 1) 2;”

When the Data acquisition command is received the PSU or PCU will begin taking data at 1000 millisecond intervals with the interval timer inside the PCU or PSU controlling the data rate. Each data point transmitted by the system will be a Pressure Measurement set containing an array having a single indices; the current value of output by the PCU or PSU.

Example 2:

Configure Table #1 for the PCU or PSU at RP CRS 211 to acquire an unbounded number of Measurement Sets in response to a digital edge transition applied to the RP Trigger Input BNC connector, with the Format of each Measurement Set being IEEE floating point values. The trigger signal for each Measurement set will be generated by an external signal generator at an arbitrary rate. The data will be synchronous having only fresh data values.

“PS2 211 1 (1 0) (0 0) (ATRIG 1) 2;”

When the Data acquisition command is received the PCU or PSU will wait for an edge transition on the Trigger Input BNC connector. When a trigger signal occurs, the PCU or PSU will acquire a Pressure Measurement set and transmit it to the host application. The Pressure Measurement Set will have been converted into Engineering Unit values. The system will then wait for another digital transition on the Trigger Input BNC.

PC3 and PS3 Commands - Modify a PCU's or PSU's Internal Coefficients

PSUs and PCUs are both single channel pressure measuring units, and do not require a Scan List. The PC3 and PS3 commands are instead used for modifying the coefficients stored in non-volatile memory within each PCU or PSU. These commands are the same whether executed by PCUs or PSUs. Both alias command names, PC3 and PS3, are provided as a convenience.

Purpose:

PCUs and PSUs retain all operating parameters and functions used for temperature compensation and engineering unit data conversion within the unit’s firmware. The PC3 and PS3 command updates the pressure coefficients when the standard is re-calibrated in a lab, or if the firmware is changed. The factory provides coefficients in psia or psid, but they can be changed to any desired units by using an appropriate conversion factor via the PC4 or PS4.

Important: *The PCU or PSU should be calibrated at least once per year based on the manufacturers’ recommendation.*

Response:

Confirmation / Error Packet

Format:

“PC3 CRS Term Ncv;”

And

“PS3 CRS Term Ncv;”

Where:

CRS = Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Range: Dependent on the Chassis in which the PCU is installed. Typical values are 211, 213, 215, and 217 for an RP.

Term = A Term Index, the Coefficient Number, to be updated in the PCU or PSU coefficient table.

Range: 1 to 60, for High Accuracy Silicon Sensor “HASS” transducer PCUs and PSUs.

Range: 1 to 33, for Quartz or Bourdon tube transducer PCUs and PSUs.

Refer to the PCU and PSU coefficient table in Appendix D.

The actual number of coefficients and the functions which use those coefficients varies according to the transducer type. Refer to the Calibration Document supplied with your PCU or PSU to identify your unit.

Ncv = The New coefficient value for the term selected above.

Range: Floating Point; may be entered in fixed point or exponential notation.

Important: *PCU and PSU internal coefficients have been store after calibration at the factory. Use the OP6 Command to read the current values of these coefficients. This command writes to non-volatile memory without confirmation.*

Example 1:

Set term #2 of the PCU located in slot 3 of an RP to a new value of 12.3456789.

“PC3 213 2 12.3456789”

Example 2:

Set term #2 of the PSU located in slot 3 of an RP to a new value of 12.3456789.

“PS3 213 2 12.3456789”

PC4 and PS4 Commands - Change PCU's or PSU's Pressure Units

This command specifies the engineering units to which all pressure values will be converted. PSI pressure units, Pounds per Square Inch, are the system default, and will be used unless the system configuration is changed using this command.

> ***Important:*** *The PC2 command must specify its Cal Points in the units set by the PC4 command. A new PC1 and PC2 command must be executed for a PC4 units change. Issuing a PC4 prior to execution of a PC1 and PC2 requires that the LRN be specified rather than the CRS of the PCU.*

Unx	Conversion Factor	Designation	Precision
0	Undefined	[user]	Undefined
1	1.000	PSI	4
2	27.673	$inH^2 0$	5
3	6894.75	Pa	1
4	703.0696	kg/m^2	2
5	70.30696	g/cm^2	4
6	0.06804	ATM	7
7	51.7149	mmHg	5
8	703.08	$mmH^2 0$	2
9	0.0689475	Bar	7
10	6.89475	kPa	3
11	68.94757	mBar	4
12	144.0	PSF	3
13	Undefined	[user]	Undefined

Conventional ESP scanner EU conversion coefficients generated by a CA3 Full Calibration in native PSI units or in the units selected with the PC4 command executed by the PCU that calibrated the scanner. A new Full Calibration, CA3, is necessary after a PC4 command changes a calibrating PCUs’ units.

DTC ESP scanner coefficients are in PSI units. When they are uploaded into the OSP by an SD5 command the Final Units Multiplier conversion factor is changed according to the executed PC4. DTC coefficients must be uploaded again and then adjusted by a CA2 offset correction calibration or CA3 full calibration after a PC4 command changes a calibrating PCUs’ units.

Purpose:

This command selects the engineering units to which all pressure data are converted for the specified PCU or PSU. Two table entries are meant to have their conversion parameters specified entirely by the user. Other standard table entries may be used as is or modified if desired.

Response:

Confirmation / Error Packet

Format:

"PC4 CRS Unx [Fctr [Prec [UnStr]]];"

Or

"PC4 LRN Unx [Fctr [Prec [UnStr]]];"

And

"PS4 CRS Unx [Fctr [Prec [UnStr]]];"

Or

"PS4 LRN Unx [Fctr [Prec [UnStr]]];"

Where:

CRS = Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Range: Dependent on the Chassis in which the PCU is installed. Typical values are 211, 213, 215, and 217 for an RP.

Unx = The Units index, from an available table of standard pressure units and one user defined unit entry:

Two (2) unique user defined units can be specified; unx = 0 or 13 in table. After being fully defined with the parameters Fctr, Prec, and UnStr they may be assigned to any PCU or PSU.

Fctr = Specifies a conversion factor, units multiplier, that can replace the default factor in the Units Table. Fctr is always positive.

Value: A floating point number in fixed, Scientific, or Engineering format.

Prec = Specifies the precision of the units. A default precision will be chosen if not specified for the pre-defined units. Precision must be specified for user defined units, 0 and 13. A negative value of Prec is ignored.

Range: 0 to 9

UnStr = Specifies a “quoted” alphanumeric units descriptor string suitable for displaying user defined data per Fctr. The standard Units descriptor string will be displayed if UnStr is not specified.

Value = A quoted text string, less than or equal to eight characters in length.

Example 1:

Configure the PSU located at RP slot 5 for kilopascal, kPa, units.

“PS4 215 10;”

The PSU located at RP CRS 215 will output data in kilopascals.

Example 2:

Configure user defined units hectopascal, hPa, at Unx index 0. Set the PCUs and ESP scanners assigned to Logical Ranges, LRNs, one (1) and three (3) to use these units.

“PC4 1 0 0.6894757 2 “hPa”;”

“PC4 3 0;”

Any PCU designated as LRNs one (1) and three (3) and the ESP scanners that are assigned to those LRNs will output their pressure data in the User Units assigned to index 0.

PC5 - Build a PCU's Internal S100 Table

The PCUs generate pressures which are used to calibrate the attached ESP scanners via their calibrate ports. The control device within the PCUs uses a comparator circuit, DAQ, and silicon Piezo resistive pressure transducer to establish and maintain the required pressure. This command creates a lookup table, pressure to DAC setting; an initial set point from which to start the pressure output. It is important to ensure that the PCU pressure output port is “dead headed” and that both the Pressure supply and vacuum sink are attached and properly set before executing this command. This command may take some time to complete and gives no outward indication of progress. It is appropriate and recommended that a pressure gauge with digital readout be connected to the calibrator output port so that progress can be monitored.

The PC5 command builds and saves an internal PCU table, called the “S100 Table”, used by the PCU's firmware to generate a pressure efficiently. Do NOT execute this command for a PSU. Normally a new S100 Table is generated after replacement of the “S100” transducer. You may need to perform this command after PCU repair, a firmware change, or if the PCU is removed or installed within a chassis while power is applied. See Appendix C for more information on the S100 Table Build process.

The OP7 command retrieves the current table, and allows you to review these values.

Response:

Confirmation / Error Packet

Format:

“PC5 CRS Pass;”

Where:

CRS = Cluster, Rack, Slot; A numeric representation of the physical location of a PCU or OFIU within the Optimus System chassis.

Range: Dependent on the Chassis in which the PCU is installed. Typical values are 211, 213, 215, and 217 for an RP.

Pass = Specifies that you really want to Perform this operation.

Value: 1

The PCU “walks through” sixty-seven (67) different DAC settings, driving the pressure controller, and reading the set pressure on the pressure standard. This process takes between 5 and 15 minutes to execute. It is important that the Ethernet socket wait for the command completion message.

Example:

Build the “S100” Table for the PCU in RP slot 5.

“PC5 215 1;”

Create a new “S100” table for the PCU located at RP CRS 215.

Pneumatic Pressure Calibration Options

CP1 - Set the ESP scanners Calibration Valve Mode

The ESP scanner calibration process is a choreographed sequence of events requiring all components of the system to perform specific tasks within a defined time span. One of these tasks is to call for the control pressures, designated C1 and C2, to be set or unset in order to place the ESP scanner calibration valves into the desired state. The Calibration valves are physical pneumatic manifolds which translate from the Calibration to the Run state within each individual ESP scanner.

These control pressure lines must extend from the RP or RPs to the ESP scanners, which may be a significant distance. In addition, the control lines must be physically small, having Internal Diameters of as little as 0.040", which restricts the propagation of air pressure change from one end to the other. In some installations, it may be necessary to increase the amount of time that the control pressure is applied to ensure that the scanners calibration valves have completed their translation.

The CP1 command changes the duration for which the C1 and C2 control pressures are applied. The duration may be finite or infinite depending on the value of the Pulse Duration specified.

Response:

Confirmation / Error Packet

Format:

"CP1 PulDur;"

Where:

PulDur = The Pulse Duration, in seconds, for which the control pressures C1 and C2 are applied when translation of the ESP scanner calibration valve is called for. The default Pulse Duration is 5 seconds.

Value = Integer seconds from 1 to 199. The default is five (5) seconds. A value of zero (0) designates Continuous application of the C1 and C2 control pressures.

Example:

Set C1 and C2 Pulse Duration to ten (10) seconds.

"CP1 10;"

When the Optimus is commanded to move the calibration valves within the ESP scanners the Control pressure will be applied for ten (10) seconds, after which the air pressure source will be turned off and the control line vented.

CP2 - Set the Calibration Pressure Stabilization Time

Periodically ESP scanners must be calibrated; either a simple offset correction or a longer span adjustment. The Process requires that the pneumatic output of the calibrators be connected to the measurement side of all ESP scanner transducers. This is accomplished by moving the calibration valve within the ESP scanners to the calibrate position by application of the C1 control pressure to the piston which actuates the calibration valves.

Once the ESP scanners calibration valves have been set into the correct position, the PCUs generate the desired pressures. However, as with the control pressures, the calibration pressures must propagate through the pneumatic lines connecting the PCUs in the RP to the ESP scanners; which takes a finite amount of time. In addition, fluids enclosed within tubing can surge and resonate as the pressure wave propagates through the system, which will skew the pressure calibration.

The CP2 command sets a delay, in seconds, after the PCU has achieved a stabile condition, before the PCU signals that the OSP should acquire data from the ESP scanners. This delay occurs after every pressure set point, including when a re-zero is requested.

Response:

Confirmation / Error Packet

Format:

“CP2 StbTim;”

Where:

StbTim = The Stabilization Time in seconds after each calibration point is set.

Value = From 1 to 199 seconds. The default is five (5) seconds.

Example:

Set the Calibration point stabilization time to fifteen (15) seconds.

“CP2 15;”

During calibration of ESP scanners, wait 15 seconds after each calibrator, PCU, has indicated that a stabile pressure has been achieved before acquiring the ESP scanner data and moving to the next set point.

CP3 – Set Notification at each Calibration Point

During a pressure calibration of ESP scanners the system must: translate the calibration valves located within each ESP scanner to the correct position, set each calibration pressure using the PCUs, read all ESP scanner data when the calibration pressures are stabile, and calculate the new corrections or coefficients.

Some facilities may wish to use their own pressure standards to measure the calibration pressure applied to the ESP scanners, using the system PCUs as pressure generators only. In this case the system must notify the facility application that the PCUs have achieved a stabile condition so that the external pressure standards can measure the pressure before the system acquires the ESP scanner data and then progresses to the next calibration pressure set point.

The Optimus performs a calibration of the ESP scanners and generates the scanner coefficients normally. But the facility application then extracts the ESP scanner voltages, or pressure values in the case of DTC scanners, performs the regression using the external pressure standard values instead of the system PCUs, and then writes the calculated coefficients into the Optimus memory. The Optimus calculated pressure calibration coefficients are discarded.

This command causes the system to emit an SRQ packet when the PCUs have achieved stability at the calibration set point. Acknowledging the message will allow the system to progress to the next calibration set point.

Response:

Confirmation / Error

Format:

“CP3 Opt;”

Where:

Opt = The Option, whether notification of calibration pressure state will occur.

Value = 0 or 1

0 = Default, No notification.
1 = Transmit an SRQ packet as a notification when the PCUs have achieved stability during calibration of ESP scanners.

Example 1:

Send an SRQ packet when each calibration set point has been achieved.

“CP3 1;”

Pneumatic Pressure Calibration Control

The following commands control the system calibration of ESP scanners or the active output of one or more PCUs. System initialization must have already occurred prior to using these commands.

Note: All PCUs physically installed within expansion chassis must have been initialized by a PC1 command, regardless of whether or not they are used to calibrate ESP scanners. The valves within the PCUs are coordinated during calibration of ESP scanners and un- initialized PCUs will not be properly configured. Calibration failure will occur if PCUs are not properly configured.

CA0 – Abort an ESP scanner Calibration or re-set a PCU to its default condition.

This command aborts the calibration process started by the CA2 or CA3 commands. All PCUs, except those configured as “dedicated” and are continuously generating a pressure output, are restored to their idle state. See the CA1 command for the description of “dedicated” PCUs.

Response:

Confirmation / Error Packet

Important: *The Confirmation / Error Packet from the aborted command, the CA2 or CA3 Command but not the CA1 Command, is also returned to the host computer.*

Format:

“CA0 CRS;”

Example 1:

The system has previously instructed a PCU at RP slot 1, CRS 211, to generate a pressure on its output. Return the PCU to its idle state.

“CA0 211;”

All PCUs that are not in a “Dedicated” state are returned to their idle state.

CA1 - Generate Arbitrary Output Pressure

PCUs are used to generate a series of pressures for calibration of ESP scanners. This command instructs a PCU to set an arbitrary pressure on either its reference or calibration output port. The control algorithm will maintain the pressure so long as there is supply air and a vacuum sink. Once the PCU has responded the pressure will have been set within the tolerance declared in the PC1 command.

The optional command switch, designated ‘Dedicated’, causes the PCU to ignore global commands, such as the global Reset CA0, global RE-Zero CA2, and global Multi-Point calibration CA3.

Note: A PCU will have the location of its Calibration output port etched or screen printed on its front panel. The Reference port is controlled by the slot in which the PCU resides. See the RP chassis description and PCU pneumatic logic diagram for additional information.

Use the LA3 command to read the pressure value currently being controlled by a PCU.

Important: *If a PCU is to be used as a PSU, streaming data in response to an AD2 command, it cannot be instructed to set a pressure. A CA0 command must be issued in order to restore the valve positions for PSU operation.*

Note: All PCUs physically installed within expansion chassis must have been initialized by a PC1 command, regardless of whether or not they are used to calibrate ESP scanners. The valves within the PCUs are coordinated during calibration of ESP scanners and un- initialized PCUs will not be properly configured. Calibration failure will occur if PCUs are not properly configured.

Response:

Confirmation / Error Packet

Format:

“CA1 LRN Pval OutPort [dedicate];”

Where:

LRN = The Logical Range Number, a number between 1 and 12 that identifies a specific PCU, associating it with a group of ESP scanners to be calibrated by it. The LRN must be unique for every PCU and PSU in the system.

Range: 1 to 12

Pval = The Pressure Value to be set by the PCU, in the pressure units declared by the PC4 command. Values greater than the stated Maximum Pressure, the MaxP parameter declared in the PC1 command, will be coerced to the value of MaxP.

Value = A floating point number within the range of the PCUs capability.

OutPort = One of the PCUs physical ports, directed to a physical location on the back of the chassis within which the PCU resides.

This parameter accepts either the mnemonic or numeric values listed below.

Value = CALOUT (0), The Calibration Output port

Value = REFOUT (1), The Reference Output port

Dedicate = This is an optional flag that locks the PCU to its pressure generation task. The CA0 command will not clear the dedicate flag. To clear the dedicate flag, issue the CA1 command without the dedicate parameter or with dedicate set equal to zero (0).

Value = 0, Disable; The default state if un-specified

Value = 1, Enable

Example 1:

Output 2.56 psi pressure from the Calibration output port of the PCU designated as LRN 1.

“CA1 1, 2.56, CALOUT;”

Instruct the PCU which PC1 command has defined it as LRN 1, to set 2.56 psi and emit it on its normal output port.

Example 2:

Continuously set a pressure of 250 psia on the calibration port of the PCU designated as LRN 6. Set the Dedicate flag so that the PCU will not be interrupted by calibrations of ESP scanners or PCU reset commands.

“CA1 1, 250.0, CALOUT 1;”

Instruct the PCU which PC1 command has defined it as LRN 6, to set and maintain 250 psia on its normal output port. Maintain the pressure until explicitly commanded to set another pressure value.

CA2 - Start Re-Zero ESP scanner Pressure Calibration

This command performs Re-Zero calibration for the ESP scanners associated with the specified Logical Ranges, LRNs. The ESP scanners in the specified LRNs must either: be TDC ESP scanners which coefficients have been loaded from the DTC ESP scanner non-volatile memory, or Conventional ESP scanners which have had a Full calibration, CA3, performed. The CA2 adjusts the lowest order offset coefficient term.

The command specifies none or more individual Logical Range Numbers which will be acted upon. Each LRN listing identifies a PCU and a group of ESP scanners associated with it. Specifying LRN 0, or not specifying an LRN, will imply that all configured LRNs are to perform a Zero only calibration. A maximum of seven (7) LRNs may be specified in the CA2 command line.

DTC scanners and Conventional ESP scanners should not share LRNs as it is impossible to perform both DTC and Conventional corrections within the same LRN.

The OP2 command is used to examine the new Offset correction coefficients. OP2 returns the values c0 or Cz for any and all ESP scanner pressure ports included in the Table scan list.

> ***Important:*** *When reference pressure other than atmospheric is used, pressure stability must be assured by the end user. Insufficient reference stability, or insufficient stabilization time, can result in an “poor” zero calibration.*

After a Zero only calibration involving DTC ESP scanner port, the user may copy the new offset, Cz, values back to the DTC scanners non-volatile memory. The Write Adjustable Coefficients form of the SD5 command performs this function.

> **Note:** All PCUs physically installed within expansion chassis must have been initialized by a PC1 command, regardless of whether or not they are used to calibrate ESP scanners. The valves within the PCUs are coordinated during calibration of ESP scanners and un- initialized PCUs will not be properly configured. Calibration failure will occur if PCUs are not properly configured.

Response:

Confirmation / Error Packet

Format:

“CA2 [LRN] ... ;”

Where:

LRN = The Logical Range Number, a number between 1 and 12 that identifies a specific PCU, associating it with a group of ESP scanners to be calibrated by it. The LRN must be unique for every PCU and PSU in the system.

Range: 1 to 12

Example 1:

Three PCUs are initialized to generate pressures for pneumatically calibrating several different LRNs. Perform a Zero only calibration of all scanners assigned to LRNs 1, 2, and 3.

“CA2 1-3;”

Re-Zero the ESP scanners associated with LRNs 1, 2, and 3.

Example 2:

Using the same configuration described in Example 1, perform a Zero only calibration for only LRN 2, leaving the previously adjusted coefficients for LRNs 1 and 3 unchanged.

“CA2 2;”

Re-Zero only those ESP scanners associated with LRN2.

CA3 - Start Full Pneumatic Pressure Calibration

This command performs a full pneumatic calibration of any scanners associated with the specified LRNs. For Conventional ESP scanners it calculates new offset, span, and, depending upon the number of calibration points specified in the LRNs PC2 command, up to 3 additional non-linearity coefficients. These coefficients convert raw pressure values in A / D counts directly to EU values with a single polynomial equation. The interval between calibrations of Conventional ESP scanners depends on rate of temperature change in the scanner environment. It is recommended that an initial calibration occur after system and scanner warm-up and prior to the first Data Acquisition command. For maximum accuracy, perform new calibrations at two hours intervals or more often if the temperature environment changes significantly.

DTC scanners and Conventional ESP scanners should not share LRNs as it is impossible to perform both DTC and Conventional corrections within the same LRN.

When operating on DTC ESP scanners, which DTC-coefficients have been previously uploaded, CA3 only adjusts the Group 0 DTC coefficients, Cz and Cs. If DTC ESP scanners have not been configured to operate using DTC, meaning that their coefficients have not been extracted from the non-volatile memory for use, they will be treated as, and be indistinguishable from, Conventional ESP scanners. Full DTC scanner accuracy is achieved by using a Full calibration, CA3 command. Unlike Conventional ESP scanners, DTC ESP scanners need not be re-calibrated at frequent intervals. The DTC algorithm compensates for significant changes in temperature, reducing calibration requirements to once per shift.

Note: Although the CA3 command will perform a maximum five (5) point calibration, as defined by the PC2 command, only the algebraically lowest and highest calibration points are used to adjust the Group 0 DTC coefficients.

The CA3 command specifies none or more individual Logical Range Numbers which will be acted upon. Each LRN listing identifies a PCU and a group of ESP scanners associated with it. Specifying LRN 0, or not specifying an LRN, will imply that all configured LRNs are to perform a Full Calibration. A maximum of seven (7) LRNs may be specified in the CA3.

Note: All PCUs physically installed within expansion chassis must have been initialized by a PC1 command, regardless of whether or not they are used to calibrate ESP scanners. The valves within the PCUs are coordinated during calibration of ESP scanners and un- initialized PCUs will not be properly configured. Calibration failure will occur if PCUs are not properly configured.

The OP3 command is used to inspect the coefficients that result from running a full calibration. This command displays all coefficient values, whether affected by the calibration or not. Using this information, along with the output of the OP1 and OP2 commands, it is possible to recalculate and verify all the coefficients for Conventional ESP scanners as well as the C_z and C_s coefficient adjustments for DTC ESP scanners. In addition, it is possible to acquire and convert raw data to EU data directly. This process can be used to increase throughput of the system by eliminating the internal processing required of the OSP.

> ***Important:*** *Internally, Conventional scanner coefficients are represented as units of pressure per A / D count, which are more efficient for conversion. The Conventional scanner coefficients for output are represented as units of pressure per volt. The units of DTC coefficients and fpe coefficients taken together are in units of pressure per normalized raw pressure units, both internally and externally.This is because all raw A / D count data from DTC ESP scanners are converted immediately into normalized data in a range of -1.0 < pn < +1.0 before conversion. See the description of conversion coefficients and equations in the appendices for more information.*

Response:

Confirmation / Error Packet

Format:

“CA3 [LRN] ... ;”

Where:

LRN = The Logical Range Number, a number between 1 and 12 that identifies a specific PCU, associating it with a group of ESP scanners to be calibrated by it. The LRN must be unique for every PCU and PSU in the system.

Range: 1 to 12

Example 1:

Calibrate all ports within the scan list of all configured LRNs.

“CA3;”

Calibrate all LRNs defined in the system.

Example 2:

Calibrate all scanners assigned to Logical Range 1 through 4 and then Logical Range 7.

"CA3 1-4 7;"

Calibrate the scanners assigned to LRNs 1, 2, 3, 4, and 7.

Output Pnematic Presure Calibration Data

OP0 - Clear the Pressure Calibration Coefficient Tables

Clear the calibration data for all defined Setup Tables in OSP memory. The calibration data includes: PCU set pressure values, A / D counts for Conventional scanner ports, coefficients for Conventional scanner ports, pressure values for DTC scanner ports, and the coefficients for DTC scanner ports. After execution of this command, the system will not be able to calculate Engineering Unit values for ESP scanner ports. A new pressure calibration must be performed for conventional scanners using the CA3 command and the DTC coefficients must be extracted from the DTC ESP scanners non-volatile memory using the SD5 command.

Response:

Confirmation / Error Packet

Format:

"OP0 TabTyp;"

Where:

TabTyp = the Table Type, selecting which tables are to be cleared:

Value = 0, All tables are cleared (voltages and coefficients);
Value = 1, Clear Raw Voltage Data Tables Only;

Example 1:

Clear the raw voltage data tables acquired during a Conventional ESP scanner calibration.

"OP0 1;"

Erase the calibration voltages for all conventional ESP scanners.

OP1 - Output the Table Calibration Voltages

During a full calibration, PCUs set a sequence of pressures, specified by the PCUs PC2 command, and voltage values, A / D counts, corresponding to those pressures are acquired for every ESP port. The OP1 outputs the voltage data acquired during the most recent calibration for any and all ESP scanner ports in the specified Table. The OSP uses these data to calculate new coefficients for each scanned port for Conventional scanners and to adjust the Zero, C_Z, and Span, C_S, DTC scanner coefficients.

The data will be an array of IEEE Floating point numbers having two (2) dimensions: nPorts by nPressures.

Response:

Array Data packet

Format:

"OP1 CRS sTBL sPort[-sPort]...;"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 4

sPort = The three (3) digit number indicating the mSDI connector number and the port number of the scanner to be placed at this Measurement Set index. The first digit is the connector number on the mSDI to which the scanner is attached and the final two digits are the port of the scanner. Ex: "101" is Scanner 1 port 01.

The OP1 command permits entry of an implicit range of ESP scanners and their ports, as well as an arbitrary list of individual ports from the ports defined in the SD3 command for this Table.

Ex: "101-132" is the inclusive range of scanner one (1) port one (01) through scanner one (1) port thirty-two (32) and "101-832" is the inclusive range of scanner one (1) port one (01) through scanner eight (8) port thirty-two (32) implicitly including all channels of the intervening six (6) scanners that may be defined in an SD3 command.

The sPort parameter is either repeated or configured as one or more contiguous ranges that include all scanners and pressure ports which voltage data are to be included in the output array. If any of the specified scanner ports are not in the scan list, an error will be declared and no array data will be returned.

Example:

Retrieve the voltages acquired during the most recent calibration of scanner number one (1), ports one (1) through sixteen (16), listed in Table one (1) for the OFIU located at OSP CRS 114.

"OP1 114 1, 101-116;"

Return the calibration voltages acquired for ports one (1) through sixteen (16) of the Conventional ESP scanner attached to connector one (1) of the OFIU and mSDI at OSP location CRS 114, that are listed in Table one (1).

Example 2:

Retrieve the voltages acquired during the most recent calibration for all of the ESP scanner pressure ports listed in Table one (1) for the OFIU located at OSP CRS 114.

"OP1 114 1;"

OP2 - Output the Conventional ESP scanner Zero Coefficient and the DTC ESP scanner Cz and Cs adjustable Coefficients

During a full calibration, PCUs set a sequence of pressures, specified by the PCUs PC2 command, and voltage values, A / D counts, corresponding to those pressures are acquired for every ESP port. The OP2 outputs the coefficients calculated after the most recent calibration for any and all ESP scanner ports in the specified Table. The OSP uses these coefficients to derive Engineering Unit data for each port included in the scan list for the indicated Table. If a CA3, calibration has not been performed, Conventional ESP scanners will not have coefficients available. DTC ESP scanners which have had their coefficients extracted from non-volatile memory using the SD5 command will have the nominal coefficients only until after a CA2 or CA3 calibration.

The OP2 retrieves the offset, C0, coefficient for Conventional scanners and the Final Pressure Equation zero coefficient for any DTC ESP scanners in a Table. The adjustable DTC coefficients, Cz and Cs, are retrieved by requesting a negative Table number. When indicating a negative Table number the Conventional ESP scanners defined in the Table are not included in the array data response.

The coefficients will be an array of IEEE Floating point numbers having two (2) dimensions: nPorts by Calibration Coefficient order.

Response:

Array Data Packet

Format:

“OP2 CRS [-]sTBL [sPort][-sPort] ... ;”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 4, Negated to return DTC ESP scanner adjustable coefficients C_Z and C_S.

sPort = The three (3) digit number indicating the mSDI connector number and the port number of the scanner to be placed at this Measurement Set index. The first digit is the connector number on the mSDI to which the scanner is attached and the final two digits are the port of the scanner. Ex: “101” is Scanner 1 port 01.

The OP2 command permits entry of an implicit range of ESP scanners and their ports, as well as an arbitrary list of individual ports from the ports defined in the SD3 command for this Table.

Ex: “101-132” is the inclusive range of scanner one (1) port one (01) through scanner one (1) port thirty-two (32) and “101-832” is the inclusive range of scanner one (1) port one (01) through scanner eight (8) port thirty-two (32) implicitly including all channels of the intervening six (6) scanners that may be defined in an SD3 command.

The sPort parameter is either repeated or configured as one or more contiguous ranges that include all scanners and pressure ports which coefficients are to be included in the output array. If any of the specified scanner ports are not in the scan list, an error will be declared and no array data will be returned.

Example 1:

Retrieve the Conventional or DTC Final Pressure Equation zero coefficient calculated during the most recent calibration of scanner number one (1), ports one (1) through eight (8), listed in Table two (2) for the OFIU located at OSP CRS 112.

“OP2 112 2, 101-108;”

Return the offset calibration coefficients calculated for ports one (1) through eight (8) of the Conventional or DTC ESP scanner attached to connector one (1) of the OFIU and mSDI at OSP location CRS 112, that are listed in Table two (2).

Example 2:

Retrieve the adjustable DTC coefficients, Cz and Cs, calculated during the most recent calibration of scanner number one (1), ports one (1) through eight (8), listed in Table two (2) for the OFIU located at OSP CRS 112.

“OP2 112 -2, 101-108;”

Return the adjustable Cz and Cs calibration coefficients calculated for ports one (1) through eight (8) of the DTC ESP scanner attached to connector one (1) of the OFIU and mSDI at OSP location CRS 112, that are listed in Table two (2).

Example 3:

Retrieve all of the adjustable Cz and Cs DTC coefficients calculated during the most recent calibration for all DTC ports, listed in Table two (2) for the OFIU located at OSP CRS 112.

"OP2 112 -2;"

Return all adjustable DTC coefficients for the DTC ESP scanners attached to the OFIU and mSDI at OSP location CRS 112, which are listed in Table two (2).

OP3 - Output all of the Table Coefficients

During a full calibration, PCUs set a sequence of pressures, specified by the PCUs PC2 command, and voltage values, A / D counts, corresponding to those pressures are acquired for every ESP port. The OP3 outputs the coefficients calculated after the most recent calibration for any and all ESP scanner ports in the specified Table. The OSP uses these coefficients to derive Engineering Unit data for each port included in the scan list for the indicated Table. If a CA3, calibration has not been performed, Conventional ESP scanners will not have coefficients available. DTC ESP scanners which have had their coefficients extracted from non-volatile memory using the SD5 command will have the nominal coefficients only until after a CA2 or CA3 calibration.

The OP3 retrieves all coefficients for Conventional scanners and also the Final Pressure Equation coefficients for any DTC ESP scanners in a Table. The factory coefficients, extracted from the DTC scanner non-volatile memory, are retrieved by requesting a negative Table number. When indicating a negative Table number the Conventional ESP scanners defined in the Table are not included in the array data response.

The OP3 command can also read the special DTC scanner header, port zero (0), and trailer, port scanner last physical port + one. See the special configuration required in Example 4.

The coefficients will be an array of IEEE Floating point numbers having two (2) dimensions: nPorts by Calibration Coefficient order.

Response:

Array Data Packet

Format:

“OP3 CRS [-]sTBL [sPort][-sPort] ...;”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 4, Negated to return DTC ESP scanner factory calibration coefficients.

sPort = The three (3) digit number indicating the mSDI connector number and the port number of the scanner to be placed at this Measurement Set index. The first digit is the connector number on the mSDI to which the scanner is attached and the final two digits are the port of the scanner. Ex; “101” is Scanner 1 port 01.

The OP3 command permits entry of an implicit range of ESP scanners and their ports, as well as an arbitrary list of individual ports from the ports defined in the SD3 command for this Table.

Ex: “101-132” is the inclusive range of scanner one (1) port one (01) through scanner one (1) port thirty-two (32) and “101-832” is the inclusive range of scanner one (1) port one (01) through scanner eight (8) port thirty-two (32) implicitly including all channels of the intervening six (6) scanners that may be defined in an SD3 command.

The sPort parameter is either repeated or configured as one or more contiguous ranges that include all scanners and pressure ports which coefficients are to be included in the output array. If any of the specified scanner ports are not in the scan list, an error will be declared and no array data will be returned.

Example 1:

Retrieve the Conventional or DTC Final Pressure Equation Coefficients calculated during the most recent calibration of scanner number one (1), ports one (1) through eight (8), listed in Table two (2) for the OFIU located at OSP CRS 112.

“OP3 112 2, 101-108;”

Return the calibration Coefficients calculated for ports one (1) through eight (8) of the Conventional or DTC ESP scanner attached to connector one (1) of the OFIU and mSDI at OSP location CRS 112, that are listed in Table two (2).

Example 2:

Retrieve all of the factory DTC coefficients from scanner number one (1), ports one (1) through eight (8), listed in Table two (2) for the OFIU located at OSP CRS 112.

“OP3 112 -2, 101-108;”

Return the DTC factory calibration coefficients for ports one (1) through eight (8) of the DTC ESP scanner attached to connector one (1) of the OFIU and mSDI at OSP location CRS 112, that are listed in Table two (2).

Example 3:

Retrieve all of the factory DTC coefficients calculated during the most recent calibration for all DTC ports, listed in Table two (2) for the OFIU located at OSP CRS 112.

"OP3 112 -2;"

Return all factory DTC coefficients for the DTC ESP scanners attached to the OFIU and mSDI at OSP location CRS 112, which are listed in Table two (2).

Example 4:

In order to retrieve only the DTC scanner header and trailer, a separate initialization must be performed. The Header and Trailer contain identification information for the scanner such as: the serial number, date of manufacture, and the number of pressure ports. This information can be helpful when designing or implementing a robust and potentially self configuring data system.

Note: Each step must be performed in the order presented to accomplish the header and trailer read.

For completeness, we will assume that the OFIU and mSDI at OSP CRS 111 has eight (8) 64 port DTC ESP scanners attached. We wish to read the scanner header and trailer information so that the serial number can be determined and also the Date of Factory Calibration.

First, create and execute an SD1 command for all eight scanners.

"SD1 111 (1-8 64 1);"

Then we use a standard SD2 Table configuration. The selection of Table 3 is to avoid conflict with any other Table that may be configured.

"SD2 111 3 (1 0) (1 0) FREE SEQ 1;"

A Scan List is created consisting of the first port of the first scanner.

"SD3 111 3 101;"

An SD5 command is executed to read the coefficients for port zero; the header alias.

"SD5 111 3 0 0.0;"

The coefficients for port zero, the scanner header, are read by the host application. The coefficients must be cast to a byte array and then interpreted as strings of ASCII characters.

"OP3 111 -3;"

Now, to get the Trailer, we overwrite the scan list definition. Again only a single port, the last port of the scanner, is included in the scan list.

"SD3 111 3 164;"

An SD5 command is executed to read the coefficients for port sixty five (65); the trailer alias.

"SD5 111 3 0 65.0;"

The coefficients for port sixty five, the scanner trailer, are read by the host application. The coefficients must be cast to a byte array and then interpreted as strings of ASCII characters.

"OP3 111 -3;"

OP4 - Output the Calibration Pressures Generated by the PCUs

During a full calibration, PCUs set a sequence of pressures, specified by the PCUs PC2 command, and voltage values, A / D counts, corresponding to those pressures are acquired for every ESP port. The OP4 outputs the pressure values set by the PCUs during the most recent calibration of any and all ESP scanner ports. The OSP uses these pressure values to derive the Engineering Unit coefficients for each port included in the scan list for the Table. If a CA3, calibration has not been performed, Conventional ESP scanners will not have coefficients available. DTC ESP scanners which have had their coefficients extracted from non-volatile memory using the SD5 command will have the nominal coefficients only until after a CA2 or CA3 calibration.

The pressure values will be an array of IEEE Floating point numbers having two (2) dimensions: nPCUs by nPressureValues.

Response:

Array Data Packet

Format:

"OP4 CRS [CRS] ...;"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the PCU is installed within the RP.

Range: The CRS in which the PCU is installed. PCUs occupy two (2) slots within an Optimus Expansion Chassis, such as an RP, and are always installed in the ODD numbered slots; 1, 3, 5, or 7.

Important: *This command does not accept an inclusive implied list of CRS. One cannot indicate the first CRS in a chassis followed by a hyphen and the last CRS in a chassis to read the calibration pressure values for all PCUs.*

Example:

After executing a CA3 calibration for LRNs 1, and 2, retrieve the actual pressure values set by the PCUs that were used to derive the calibration coefficients. PCUs are designated as being used for specific LRNs in their respective PC1 commands. The PCU for LRN 1 is located at RP CRS 211 and the PCU for LRN 2 is located at RP CRS 213.

“OP4 211, 213;”

Retrieve the recorded calibration pressure values from the PCUs located at RP CRS locations 211 and 213. These PCUs had been assigned to LRNs 1 and 2 by their PC1 commands.

OP5 - Output the Scan List of a Table

The OP5 command returns an array, the scan list of the Table in the order defined in the SD3 command for the Table. The values are three digit scanner and port, sPort, designations; one for every port in the scan list.

The OFIU / mSDI perform an initial survey of each connector to determine the presence, or absence, of DTC ESP scanners. If a DTC scanner is identified the coefficients are retrieved and loaded into memory as Table 5. This operation occurs prior to a TCP connection initiated by the host application. This is a significant departure from legacy systems, permitting a degree of automatic configuration, previously unavailable to the application designer.

When establishing a TCP connection with the system, the application can request the scan list of Table 5 without any knowledge of the connected population of scanners. From the array of sPort numbers provided the application can determine the number of ports per scanner and the location on the mSDI. Using the mSDI connector information, the application can then use the SD5 and OP3 commands to retrieve the DTC scanner headers. The headers contain not only the Serial Number and Model number of the scanner, but the full scale range in psi and the date of last calibration as well.

Negative scan list values return a status byte for each scanner port. The most significant bit, Bit 7, of each status byte indicates the type of port; 1 = DTC and 0 = Conventional. The remaining 7 bits are for troubleshooting internal processes and are of little or no use to the application designer.

Response:

Array Data Packet

Format:

“OP5 CRS [-]sTBL;”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 4; Table 5 is available for read and is the scan list encompassing all system discovered DTC scanners. Table 5 is not usable for data acquisition. Negative values return a status byte for each of the scanner ports.

Example 1:

Retrieve the scan list, the list of scanner ports that are included in Table two (2) for the OFIU located at OSP CRS 112.

“OP5 112 2;”

Return the scan list configured for the OFIU / mSDI at CRS 112 in Table 2.

Example 2:

Retrieve status bytes for each scanner port listed in Table two (2) for the OFIU located at OSP CRS 112.

“OP5 112 -2;”

Return the scanner port status bytes in Table 2 for the OFIU / mSDI located at CRS 112.

OP6 - Output a PCUs or PSUs Internal pressure Coefficients and operating parameters.

PCUs and PSUs are independent devices within the Optimus System, having their own internal non-volatile memory for storage of operating parameters. These parameters are normally only examined and / or modified in the process of a standards laboratory calibration. The parameters and coefficients retrievable by this command are documenting within the calibration process documentation and also the PCU coefficient list in the Appendix of this manual.

The Coefficient Table inside of a PCU or PSU takes a significant amount of time to extract. This command may not return for several seconds if a large number of Terms are being requested in one operation. Some of the Coefficient Table values are dynamically changing raw data or intermediate calculation values and may be more effectively read using the LA3 command.

Response:

Array Data Packet

Format:

“OP6 CRS Term[-Term];”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the PCU or PSU is installed within an RP chassis.

Range: 211 to 217.

Term = The Term Index, Coefficient Number, being requested as a unit value or an implied contiguous range indicated as a first and last Term separated by a hyphen.

Value = Positive non-zero Integers, Defined by the documentation for the type of instrument. The listing of available Terms is in the PCU coefficient Appendix and also the calibration process documentation.

Example:

Retrieve the Coefficient Terms 1 through 60 from a PCU located at RP CRS 211.

“OP6 211 1-60;”

Return the first sixty Coefficients from the PCU loated at CRS 211.

OP7 - Output a PCU's Internal "S100" Table

Extract the S100 Table values generated by the PC5 command from a PCUs internal non-volatile memory. The "S100" Table is a listing of Pressure values and DAC settings, used to establish an initial set point when a PCU is instructed to set a pneumatic output. This command is used to evaluate the table as a method for troubleshooting the operation of a PCU.

Response:

Array Data Packet

Format:

"OP7 CRS Term[-Term];"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the PCU or PSU is installed within an RP chassis.

Range: 211 to 217.

Term = The Term Index, lookup Table number, being requested as a unit value or an implied contiguous range indicated as a first and last Term separated by a hyphen.

Range: 1 to 67; inclusive.

Example:

Retrieve the entire "S100" Table of a PCU in RP Slot CRS 211.

"OP7 211, 1-67;"

Return the sixty seven (67) values stored in the "S100" table of the PCU in RP CRS 211.

OP9 - Define a Tables Data Format

The OP9 command sets the format of the data returned OPx commands. The format stays current until changed or the OSP is reset. The format numbers are the same as the Response Type.

> ***Important:*** *The OP5 Command returns the scan table for response types 32 and 35 in integer, but it is multiplied by 1, NOT by 1000.*

Response:

Confirmation / Error Packet

Format:

"OP9 dFmt;"

Where:

dFmt = The Data Format of OPx responses, a value or word from the list.

Value = 32 (INT), Long Integer (4 Bytes), value x1000
Value = 33 (FLOAT), IEEE Floating point (binary) numbers

Example 1:

Set Format to IEEE Floating

"OP9 33;"

Data Acquisition Commands

AD0 - Stop system Data Acquisition

The AD0 command aborts the Table data acquisition process. When it is executed each input unit that is acquiring data is commanded to stop. A Confirmation Packet is emitted for the command which is being aborted. The system waits for each input unit to report that it has stopped acquiring data. An AD0 Confirmation or Error Packet is returned within 10 seconds of issuing this command. An AD0 Error Packet is returned immediately if no data acquisition process is running.

> ***Important:*** *When the "**ATRIG**" Trigger Mode is used, data acquisition will not terminate until after the next Measurement Set is triggered.*

Response:

Confirmation / Error Packet

Format:

"AD0;"

No modifiers or additional parameters are required.

AD1 - Acquire and Store Data

The AD1 command acquires data from all input units identified in the specified Table. The OSP stores the acquired data in memory until the host applications issues an OD1 command to read the data, or an OD0 command to clear the data. The OSP must have sufficient memory available to store the acquired measurement sets.

Important: *All initialization commands for each input unit must have been completed before issuing this command. Continuous data acquisition, i.e. Measurement Sets = zero (0) is not a permitted configuration for this command.*

Response:

Confirmation/Error Packet

Format:

“AD1 sTBL [nMS];”

Where:

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 4

nMS = The Number of pressure Measurement Sets to be acquired when the Optimus is commanded to acquire data. The Measurement Sets are acquired and emitted to the host at Measurement Set Delay intervals specified in the SD2 or PS2 command for the indicated Table.

A value of zero (0) is not permitted when storing data to memory using the AD1 command.

Range: 1 to 65000

Example 1:

Acquire data from all input units defined with a Table #1. Use the number of measurement sets defined by the SD2 or PS2 command for each input unit and store the data in the OSP memory.

“AD1 1;”

Acquire and Store the Measurement Sets defined in Table #1.

Example 2:

Acquire 30 Measurement Sets using Table #2. Do not use the number of Measurement Sets defined by the SD2 or PS2 configuring Table #2.

“AD1 2 30;”

Acquire and store 30 Measurement Sets using Table #2.

AD2 - Acquire and Output Data to the host application

Acquire data from all input units units specified in the indicated Table. The Measurement Sets are immediately output to the host application as they are received from the various input units.

The number of Measurement Sets received is determined by the number of input units initialized for the specified Table and the nMS parameter defined in the SD2 or PS2 commands or the override nMS specified with the AD2 command. When the AD2 command completes, i.e. all of the requested data packets have been transmitted, a Confirmation / Error Packet is sent indicating command completion.

The Optimus data acquisition rate may be higher than the read rate of the host application. If more data is being acquired than can be received by the host application, the OSPs buffering memory may be exhausted. A buffer overflow condition can cause the Optimus to drop measurement sets, an occurrence that can be identified by the evaluation of the Measurement Set sequence numbers.

Measurement Set sequence numbers should increase monotonically. Gaps in the sequence numbers indicates that the system has lost packets and the source of the issue should be identified and resolved, either by improving the performance of the host application or by slowing the data rate of the Table.

> ***Important:*** *All initialization commands for each input unit must have been completed before issuing this command. Continuous data acquisition, i.e. Measurement Sets = zero (0), is a permitted configuration for this command.*

Response:

Stream Data Packet

Format:

“AD2 sTBL [nMS];”

Where:

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple OFIUs.

Range: 1 to 4

nMS = The Number of pressure Measurement Sets to be acquired when the Optimus is commanded to acquire data. The Measurement Sets are acquired and emitted to the host at Measurement Set Delay intervals.

Value = zero (0) specifies that the OFIU will acquire data continuously, without bounds, when triggered until explicitly commanded to stop acquiring data.

Value ≠ zero (0) specifies that number ‘n’ Measurement Sets will be acquired and output when triggered, after which the system must be triggered again.

Example 1:

Acquire and output Measurement Sets as configured in Table #1.

“AD2 1;”

Example 2:

Acquire and output 65535 Measurement Sets at the interval specified by Table #3.

“AD2 3 65535;”

Clear / Output Stored Data

OD0 - Clear All Acquired Data Stored in the OSP

The OD0 command erases all stored scan data from the OSPs volatile RAM, which was acquired and stored in response to an AD1 command.

Note: The SD1 or PS1 initialization command will also clear any previously acquired and stored Measurement Sets for a specific input unit.

Response:

Confirmation / Error Packet

Format:

"OD0 [CRS[-CRS];"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the input unit is installed within the Optimus System chassis.

Range: Any CRS in which an input unit, which had acquired and stored data in response to an AD1 command, is installed. An inclusive range of CRSs, designated as a beginning and ending CRS separated by a hyphen is also appropriate, if the range is within a single chassis.

Example 1:

Erase all data acquired in response to an Acquire and Store Data, AD1, command for Table #1.

"OD0;"

Erase all stored data.

Example 2:

Erase only the data acquired and stored for the OFIU at OSP CRS 112 in response to the AD1 command for Table #2.

"OD0 112;"

Erase the data that was acquired from the OFIU at CRS 112.

OD1 - Output All Stored Data to the Host application

The OD1 command outputs all of the data currently held in the OSPs memory that had been acquired by one or more AD1, Acquire and Store Data, commands. In the event that more than one AD1 command has been executed prior to issuing an OD1 command, the data returned can be the total amount of data in memory; the aggregate of all executed Acquire Data commands.

It is important to note that, since the resulting data from multiple acquire data commands may be stored in memory, the data may be from different Tables having different scan lists and output formats. The Table used to acquire the data packet is embedded within the Stream Data Packet header. The output of the OP5 and OP9 commands can be used to retrieve the desired scan list and data format information. The returned Measurement Sets will be formatted and structured as Stream Data packets with all of the appropriate header information for the Table with which it was acquired.

It is recommended that data acquired, using an acquire and store data command, be immediately retrieved using an OD1, reducing the complication of the host application. There is no method available to determine how many Measurement Sets remain in memory. It is prudent to issue an AD0 command after reading all data with the OD1 to ensure that there are no residual Measurement Sets remaining in memory.

Format:

"OD1 [nMS];"

Where:

nMS = The Number of pressure Measurement Sets to be output by the Optimus in response to this command.

Value = zero (0), or the absence of an nMS parameter, instructs the Optimus to return all data in memory.

Value ≠ zero (0) specifies that number 'n' Measurement Sets will be output immediately, after which the host should either issue another OD1 command or an OD0 to clear any remaining Measurement Sets from memory.

Example 1:

Output all stored measurement sets stored in response to an AD1 command.

"OD1;"

Return All Measurement Sets in Memory.

Example 2:

Output only 25 stored Measurement Sets.

"OD1 25;"

Return 25 Measurement Sets from the total in memory. There is no way to determine how many Measurement Sets remain in memory. Unless the host application has noted the number of Measurement Sets that were stored, it is wise to follow a call for a specific number of Measurement Sets with an OD0 to clear memory before acquiring more data.

OD2 - Output Selected Stored Data to the Host

The OD2 command outputs data currently held in the OSPs memory, but only from the input units at specific CRS locations.

Response:

Stream Data Packet

Format:

“OD2 CRS nMS [CRS nMS] ...;”

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the input unit is installed within the Optimus System chassis.

Value = Any CRS in which an input unit, which had acquired and stored data in response to an AD1 command, is installed. An inclusive range of CRS is not permitted. Instead include the individual CRSs and the desired number of Measurement Sets.

nMS = The Number of pressure Measurement Sets to be output by the Optimus in response to this command.

Value = zero (0), instructs the Optimus to return all data in memory.

Value ≠ zero (0) specifies that number ‘n’ Measurement Sets will be output immediately, after which the host should either issue another OD1 command or an OD0 to clear any remaining Measurement Sets from memory.

Example:

Output 25 Measurement Sets that were acquired from the OFIU at OSP CRS 111 and then output all the measurement sets that were acquired from the PSU at RP CRS 215.

“OD2 (111, 25) (215, 0);”

OD4 - Output a Tables Measurement Set Size or the available Memory in Bytes

The OD4 command outputs the number of bytes required to store one Measurement Set for the specified Table, or outputs the current size of available memory in bytes.

Response:

Single Value Packet

Format:

"OD4 CRS sTBL;"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the input unit is installed within the Optimus System chassis. The Optimus System Processor CRS is 100. Issuing the OD4 command for the OSP, CRS 100, returns the actual size of available memory. Any other value requests the size of each measurement set generated by that input unit only.

Value = Any CRS in which an input unit, which had acquired and stored data in response to an AD1 command, is installed. An inclusive range of CRS is not permitted.

sTBL = A Data Acquisition profile defining the manner in which a Measurement Set is collected and returned to the host computer. A single table can encompass multiple input units.

Range: 0 to 4

Value = zero (0) indicates that the data storage space is to be estimated in bytes each instead of Measurement Sets.

Example:

Calculate the number of Measurement Sets that can be acquired with the OFIU at OSP CRS 111 Table #2, OFIU at OSP CRS 113 Table #2, and the PSU CRS 211 Table #3.

This will require several steps.

First, output the number of bytes available in OSP memory

“OD4 100, 0;”

Next, output number of bytes used by each measurement set of the OFIU at OSP CRS 111 Table #2.

“OD4 111, 2;”

Then, output number of bytes used by each measurement set of the OFIU at OSP CRS 113 Table #2.

“OD4 113, 2;”

Finally, output number of bytes used by each measurement set of the PSU CRS 211 Table #3.

“OD4 211, 3;”

Now having all of the required information, we can calculate the total number of Measurement sets that can be acquired using each Table.

OD9 - Set the Hosts Data Output Format

Set the format of the Measurement Sets sent to the host in Stream Data Packets. The format stays current until changed by the host or until the OSP is Reset. The OD9 Command affects the output format of the OD1, OD2, and AD2 Commands. LA1, LA2, and LA3 are available in IEEE floating point formats only.

Response:

Confirmation / Error Packet

Format:

“OD9 dFmt;”

Where:

dFmt = The Data Format of Stream Data Packets as a numeric value.

Value = 0 or 17, Natural (raw) format
Value = 18, Long integer (4 bytes)
Value = 19, IEEE Floating point (binary) numbers

Example:

Set data format to be Long integers for all acquired Measurement Set data.

“OD9 18;”

Live-Action (Look At) Data Acquisition

LA1 - Look at an ESP scanners' "Raw" Data

Reads a value from a single ESP scanner port and transmits the value to the host application. The OFIU must have been initialized; having had an SD1, SD2, and SD3 command executed that includes the desired port in the scan list of the Table. The value can be pressure A / D counts or pressure volts for Conventional and DTC ESP scanners or a DTC scanners' temperature voltage, excitation voltage, A / D converter zero reference voltage, or the DTC scanner status word.

The selection of the additional DTC scanner data is performed using special "port" numbers for the given scanner. See the notes in the description of sPort, below.

Response:

Single Value Packet

Format:

"LA1 CRS [-]sPort [FrCt];"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sPort = The three (3) digit number indicating the mSDI connector number and the port number of the scanner to be placed at this Measurement Set index. The first digit is the connector number on the mSDI to which the scanner is attached and the final two digits are the port of the scanner. Ex; “101” is Scanner 1 port 01.

Positive values of sPort return the pressure A / D counts or pressure volts for Conventional and DTC ESP scanners

Negative values of sPort are used to select the temperature voltage for the given DTC ESP scanner port.

In addition to the described port data, several general data items are available using this command, through negative “virtual” port numbers. Negative port numbers 97, 98, and 99 retrieve the DTC scanner Status Byte, scanner A / D converter Zero Voltage, and the DTC scanner Excitation Voltage.

FrCt = The Frame Count used for acquiring the requested data.

Range: 1 to 255, Default is 64 if not specified.

Example 1:

Read the pressure voltage from scanner 1 port 1 connected to the OFIU at OSP CRS 111. The value returned will be an average of 32 A / D samples.

“LA1 111 101 32;”

Example 2:

Read the temperature voltage from scanner 1 port 1 connected to the OFIU at OSP CRS 111. The value returned will be an average of 32 A / D samples.

“LA1 111 -101 32;”

Example 3:

Read the Excitation voltage from scanner 1 port 1 connected to the OFIU at OSP CRS 111. The value returned will be an average of 32 A / D samples.

“LA1 111 -197 32;”

LA2 - Look at an ESP scanners' "EU" Data

Reads a value from a single ESP scanner port and transmits the value to the host application. The OFIU must have been initialized; having had an SD1, SD2, and SD3 command executed that includes the desired port in the scan list of the Table. In addition, the Table must have EU coefficients present for the scan list. The coefficients can be: uploaded using the SD4 command or through execution of a CA3 calibration command

Scanner Status byte			
Bit #	Designation	Un-Set (0)	Set (1)
7	Scanner Type	Conventional	DTC
6	Calibration Valve	Cal Position	Run Position
5	<Reserved>		
4	<Reserved>		
3	<Reserved>		
2	<Reserved>		
1	<Reserved>		
0	Gain Setting	Standard	Sensitive

for Conventional scanners, or after retrieving the DTC scanner coefficients using an SD5 command. The value can be pressure EU for Conventional and DTC ESP scanners or a DTC scanners' temperature EU, excitation voltage, A / D converter zero reference voltage, or the DTC scanner status word.

Response:

Single Value Packet

Format:

"LA2 CRS [-]sPort [FrCt];"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the OFIU is installed within the OSP.

Range: 111 to 114.

sPort = The three (3) digit number indicating the mSDI connector number and the port number of the scanner to be placed at this Measurement Set index. The first digit is the connector number on the mSDI to which the scanner is attached and the final two digits are the port of the scanner. Ex; "101" is Scanner 1 port 01.

Positive values of sPort return the pressure EU for Conventional and DTC ESP scanners.

Negative values of sPort are used to select the temperature EU for the given DTC ESP scanner port.

In addition to the described port data, several general data items are available using this command, through negative “virtual” port numbers. Negative port numbers 97, 98, and 99 retrieve the DTC scanner Status Byte, scanner A / D converter Zero Voltage, and the DTC scanner Excitation Voltage.

FrCt = The Frame Count used for acquiring the requested data.

Range: 1 to 255, Default is 64 if not specified.

Example 1:

Read the pressure EU from scanner 1 port 1 connected to the OFIU at OSP CRS 111. The value returned will be an average of 32 A / D samples.

“LA2 111 101 32;”

Example 2:

Read the temperature EU from scanner 1 port 1 connected to the OFIU at OSP CRS 111. The value returned will be an average of 32 A / D samples.

“LA2 111 -101 32;”

Example 3:

Read the Excitation voltage from scanner 1 port 1 connected to the OFIU at OSP CRS 111. The value returned will be an average of 32 A / D samples.

“LA2 111 -197 32;”

LA3 - Look at a PCUs or PSUs Data

Reads a value from a PCU or PSU and transmits that value to the host application. The PCU or PSU must have been initialized using a PC1 or PS1 command prior to execution of this command. The feature set for this command is listed in Appendix D.

Note: Feature 0 only works for PCUs with firmware version 2.39 and later and for PSUs with firmware version 8.19 and later.

The Internal valve state of a PCU is readable as an integer value bitmap and the CV0 command will set or Un-Set any and all valves within the PCU. Using the LA3 in combination with the CV0 permits a fine grained analysis of the PCU operation and can facilitate system leak testing.

Response:

Single Value Packet

Format:

"LA3 CRS Feat;"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the PCU or PSU is installed within an RP chassis.

Range: 211 to 217.

Feat = The Feature, a specific value from within the coefficient or operating parameter space of the PCU or PSU.

Reference the Features from the Table in Appendix D.

Example 1:

Read the Output Period of vibrating quartz pressure standard inside of the PCU located at RP CRS 213.

"LA3 213 2;"

Example 2:

Read the transducer temperature of a temperature compensated PCU or PSU located at RP CRS 217.

"LA3 217 -20"

LA4 - Look at Any Input Units' Type and Firmware Version or Look at the System Date and Time

The LA4 command returns the Type number and Firmware version of the Input Unit in the specified Cluster, Rack, Slot CRS location. The same information can be retrieved for an Optimus System Processor or a Remote Processor using the appropriate Cluster number with Rack and Slot numbers equal to zero (0). Issuing the command with CRS zero (0), an invalid location, returns the system Date and Time.

The Input Unit type codes are listed in Appendix A along with the Data Formats for the Responses.

Response:

Single Value Packet

Format:

"LA4 CRS;"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the input unit is installed within the Optimus System chassis.

Value = Any CRS within the system address space.

Value = zero (0) returns the system Date and Time.

Example 1:

Read input Unit type and Firmware Revision for OSP CRS location 114.

"LA4 114;"

Example 2:

Read the system Current Date and Time

"LA4 0;"

Valve Control

CV0 - Control a PCUs' internal pneumatic Valves

The CV0 command sets a PCUs' solenoid value ON or OFF. Valves are numbered according to their function; which can be found in Appendix C; the PCU and PSU operation description.

Feature zero (0) operates only on PCUs with Firmware version 2.39 and later and for PSUs with firmware version 8.19 and later.

The LA3 command reads the current PCU valve state as an integer value bitmap. The CV0 and LA3 commands can be used in combination to permit fine grained analysis of the PCUs health. Automated Leak testing of the system calibration lines and chassis is also possible,

> **WARNING:** This command sets the electric current in the valve solenoid coils, OFF and ON. The valves in **Appendix C** are illustrated in their Default state with the coils DE-ENERGIZED, which may be OPEN or CLOSED pneumatically. Take care when developing software which controls these valves. Catastrophic damage can occur to Instrumentation if inappropriate commands are sent.

Response:

Confirmation / Error Packet

Format:

"CV0 CRS [Valve [State]];"

Where:

CRS = The Cluster, Rack, Slot number; the physical location where the PCU or PSU is installed within an RP chassis.

Range: 211 to 217.

Valve = The Valve Number. When not specified, the valves are set to the default state; illustrated in Appendix C. When specified, valve number identifies an internal solenoid valves: K1 - K9. Negative valve numbers, -1 and -2, control externally linked solenoid drivers D1 and D2 which can be used for alternate functions.

Range: 0 through 9, The value zero (0) implies ALL valves, and is equivalent to not including a Valve parameter. Attempting to set ALL valves to the energized state simultaneously will return an error packet.

State = The Valve State to be set.

Value = 1 (On) or 0 (OFF), When not specified the 0 (OFF) state is assumed.

Example 1:

Set ALL valves in the PCU at RP CRS location 217 to their default state.

“CV0 217;”

Example 2:

Set the valve K2 within the PCU at RP CRS location 215 to the ON (1) state.

“CV0 115 2 1;”

CV1 - Set the ESP scanners Calibration Valve Position

The CV1 command sets the position of the Calibration valve within ESP scanner to the Calibrate or Run position. The mechanism used to motivate the calibration valves are the control pressures, C1 and C2, which are sourced from all of the PCUs installed within the system chassis.

The control pressure ports designated C1 and C2 supply motive pressure signals which physically move sliding manifold valves that are located within each of the ESP scanners. For additional details of the operation of these calibration valves, review the description of the scanner calibration process in the CA2 and CA3 commands. The control pressures are connected via pneumatic tubing which extends from the ports labeled C1 and C2 on the rear of the Remote Processors, where PCUs are installed, to the C1 and C2 control ports on each ESP scanner.

All PCUs in the system, even when located in separate chassis, are coordinated when selecting the control pressures.

This command asserts either C1 or C2 for an arbitrary duration in seconds, after which the control pressure line is vented to ambient pressure; conserving supply gas.

Response:

Confirmation / Error Packet

Format:

“CV1 ValPos, PulDur;”

Where:

ValPos = The position to which the scanner calibration valve is being driven by the control pressure; as a numeric or mnemonic value.

Value = 1 (CALPOS), the Calibrate Position

Value = 0 (RUNPOS), the Run / Acquire Data acquisition Position.

The CALPOS keyword applies pressure to the C1 control pressure and selecting RUNPOS applies pressure to the C2 control pressure.

PulDur = The Pulse Duration in seconds, the duration for which the control pressure is applied.

Range: 0 through 199 seconds. A value of zero (0) seconds causes the control pressure to be applied continuously until a new state is commanded; either with a new CV1 command or via a calibration command such as CA2 or a CA3.

Example:

Drive the scanner calibration valves to CAL position using a Pulse duration of 10 seconds:

“CV1 CALPOS, 10;”

System Communication (Host Protocol)

SC1 - Set SRQ / EOI Mode for Host Data, Specify an IP-Address, or RESET the System

The SC1 command sets if and when an SRQ IP packet will be posted by the OSP before it transmits each Measurement Set and command response to the host application. The transmission of an EOI IP packet with or after the last byte of each measurement set and command response. The default behavior of the system is to NOT transmit these packets.

The SC1 command can also configure a new TCP/IP Address, or cause the OSP to RESET immediately.

Response:

Confirmation / Error Packet

Note: No response is sent for a Reset command. The system may take up to 500 seconds to complete a reboot depending on the number of DTC scanners connected to the OFIU and mSDIs.

Format:

“SC1 SRQflg EOIflg [IPadrs];”

Where:

SRQflg = The SRQ flag which determines whether an SRQ packet is returned prior to responding to a command or returning a data value.

Range: -1 to 3

-1 = No SRQ posted before measurement sets or command responses: The system default.

0 = No SRQ posted before any measurement sets are returned

1 = SRQ posted before the first measurement set is returned

2 = SRQ posted before each measurement set is returned

3 = SRQ posted before the last measurement set is returned

EOIflg = The EOI flag which determines if and when an EOI packet is sent after Measurement Sets or command responses.

Range: -1 to 1

-1 = No EOI posted for measurement sets or command: The system default.

0 = EOI posted only with the last measurement set.

1 = EOI posted with each measurement set

IPadrs = A TCP/IP address or the value causing the system to RESET.

Value = ASCII dotted quad TCP/IP address, WWW.XXX.YYY.ZZZ

Value = -1, The value causing the system to Reset.

The Subnet Mask is set using the SC4 command. A valid Subnet Mask is required for operation.

Example 1:

Enable SRQ packets to be delivered only before the first measurement set and EOI packets to be delivered only after the last measurement set.

“SC1 1 0;”

Example 2:

Disable all SRQ / EOI packets and also save a new TCP/IP address. Then RESET the OSP so that the new TCP/IP address becomes valid.

“SC1 -1 -1 192 168 0 1;”

“SC1 -1 -1 -1;”

The host program must disconnect the current TCP socket and wait for up to 500 seconds before establishing a new socket to the Optimus System.

SC2 - Disable Host Responses for Selected Commands

The SC2 command disables or enables the Confirmation and Error responses from the OSP. Normally the OSP sends a confirmation for all non data commands and an error response for every command that has an error. It is also possible to disable the Responses to the SC2 command itself.

Response:

Confirmation / Error Packet

Format:

“SC2 CmdTyp[-CmdTyp], Mode;”

Where:

CmdTyp = The Command Type for which to disable responses. Specify one command, or a range of commands.

Value = Command Type is also the Response Code for that command, as documented in Appendix A. An inclusive range of commands may be specified using the hyphen ‘**-**‘ to separate the first and last values in the range.

1x: SDx

SDU's SDx Initialize commands

3x: PCx

PCU's PCx Initialize commands

10x: ADx

Acquire Data commands

11x: ODx
Output Data to Host commands

12x: CAx
Calibration commands

13x: OPx
Output Parameter commands

14x: CVx
Valve Control commands

16x: CPx
Calibration Parameter commands

17x: SPx
System Processor commands

18x: SCx
System Communication commands

Each command type may include up to nine (9) individual commands; the '**x**' in the command type format above can be any value, between zero (0) and nine (9) inclusive, to suppress or activate the responses from specific commands.

Mode = The Mode parameter selects whether to enable or disable Confirmation / Error responses.

Value = 0 (Disable)
Value = 1 (Enable)

Example 1:

Disable the Confirmation / Error responses for the AD2 command.

"SC2 102, 0;"

Example 2:

Disable responses to SDx commands, SD1, SD2, SD3, and SD4.

"SC2 11-14, 0;"

SC4 - Set the system Subnet Mask

The SC4 command sets the Subnet Mask for the system. The TCP/IP address is set using the SC1 command. After setting either the TCP/IP address and / or the Subnet mask, a full system reset is required. The SC1 command also performs a system reset.

Response:

Confirmation / Error Packet

Format:

"SC4 mode xtra [SubNet];"

Where:

Mode = The Legacy Front Panel Echo Function.

This parameter does not have a function and may assume either of the values below. It is maintained for legacy application compatability.

Value = 0 (Disable)
Value = 1 (Enable)

xtra = A "switch" parameter, used in legacy applications to indicate that the Subnet Mask was appended to the command. This is a required parameter in this context. :

Value = 0; Required value for this function.

SubNet = The Subnet Mask, consisting of the ASCII representation of four (4) byte values separated by "Spaces".

Example 1:

Set a Subnet Mask of 255.255.255.0 for the system.

"SC4 1 0 255 255 255 0;"

System Processor Control

SP5 - Set the system Date and Time

The SP5 command sets the system date and time within the real time clock.

Note: a system reset is required after executing this command.

Response:

Confirmation / Error Packet

Format:

"SP5 Month Day Year [hour [minute [sec]]];"

Where:

Month = The Month of the year, as a two digit numeral.

Range: 01 – 12

Day = The Day of the Month as a two digit numeral.

Range: 01 – 31: The internal clock parser will check for correctness.

Year = The last two digits of the current Year, as a two digit numeral.

Range: The system presumes that all dates begin with "20"

Hour = The current hour, in 24 hour format.

Range: 00 to 23

Minute = The current minute.

Range: 00 to 59

Second = The current second.

Range: 00 to 59

Example 1:

Set the system clock to Nov 10th, 2014, 13:34:00.

"SP5 11 10 2014 13 34;"
"SC1 1 1 -1;"

SP6 - Set / Enable the system Preferred NTP / PTP Server

The SP6 command sets the system Preferred NTP Server using either a Fully Qualified Domain name or a "dotted quad" IP v4 address or enables use of NTP or PTP time synchronization.

Response:

Confirmation / Error Packet

Format:

“SP6 FQDN;” or “SP6 IPv4Ad;”

or

“SP6 USE_NTP,” or “SP6 USE_PTP,”

Where:

FQDN = A fully Qualified Domain Name. TheOptimus must have been assigned its address through a DHCP server having a valid referrence to both DNS and a route to the specified host.

IPv4Ad = An IPv4 Address in "Dotted Quad" notation.The Optimus must either be on the same subnet as the target or have been assigned its address through a DHCP server having a valid referrence to both DNS and a default route to the specified host.

USE_NTP = Enables the system to use NTP protocol to time synchronize system. Command is nonvolatile, and system retains state after power cycle.

USE_NTP = Enables the system to use PTP protocol to time synchronize system. Command is nonvolatile, and system retains state after power cycle.

Example 1:

"SP6 192.168.1.1;"

Example 2:

"SP6 USE_PTP;"

SP7 - Set the OSP-INTERNAL-SWITCH-DELAY for the OFIU's

The SP7 command sets a delay constant for each port of the OSP internal ethernet switch. This function is used during manufacture but may be used in a service situation, such as if the main processor board of the Optimus System Processor is replaced in the field. The values for each of the five (5) switch ports are typically set to the same value.

Response:

Confirmation / Error Packet

Format:

“SP7 OFIU1, OFIU2, OFIU3, OFIU4, RPSVR;”

Where:

OFIU1, OFIU2, OFIU3, OFIU4, RPSVR = microseconds of delay.

Example 1:

"SP7 125000, 125000, 125000, 125000, 125000;"

SP8 - Set the OSP to use either Static or Dynamic Ip Address Assignment

The SP8 command configures the Optimus to use either the static TCP/IP address specified via the SC1 command or to receive its address from a local DHCP server. Active TCP connections are terminated and the system is reset.

Response:

Confirmation / Error Packet

Format:

“SP8 DHCP;”

Where:

DHCP = Whether the Optimus will receive its TCP/IP Address via DHCP

Value = 0 (Use the Static Address assigned via the SC1 command)
Value = 1 (Use a DHCP server to retrieve the TCP/IP Address)

Example 1:

"SP8 1;"

Unit will disconnect and reset.

SP10 - Display/Set OFIU Timer Synchronization Coefficients and Update Interval

The SP10 command is used to read or set the coefficients for time-syncing the internal OFIUs to the system OSP time. A coefficient for correcting the ofiu's time-base clock at room temperature, it's corresponding adjustment value for dynamic compensation, and interval for OSP to update ofius is read or set. The time-base correction coefficients are sent to each corresponding ofiu once at power-up time and is used as the starting correction. During each subsequent defined interval, updates to each ofiu will further improve the correction using the defined adjustment value coeff.

Response:
Read: Coeffs
Set: Confirmation / Error Packet

Format:
Read Command: "SP10"
Response: "D_Coeff_1 D_Coeff_2 D_Coeff_3 D_Coeff_4 Coeff_1 Coeff_2 Coeff_3 Coeff_4 Adj_1 Adj_2, Adj_3 Adj_4 Int"

Set: "SP10 Coeff_1 Coeff_2 Coeff_3 Coeff_4 Adj_1 Adj_2, Adj_3 Adj_4 Int

Where:
D_Coeff_X = The current value of the time-base correction coefficient for each OFIU.
Coeff_X = The desired starting correction coefficient at power-up for each OFIU.
Adj_X = The adjustment applied to Coeff_X at defined interval for each OFIU.
Int = The interval (in seconds) between OSP messages to each ofiu.

Example 1:
Read: "SP10"
Response: "SP10 1.00001943 1.000014675 1.00001690 1.00002047 1.00001961 1.000014625 1.00001623 1.00002012 1.0e-8 1.0e-8 1.0e-8 1.0e-8 60"

Set: "SP10 1.00001961 1.000014625 1.00001623 1.00002012 1.0e-8 1.0e-8 1.0e-8 1.0e-8 60"
Response: CONFIRMATION

Above, this example sets OFIU 111's starting coefficient to 1.00001961 and it will get adjusted either up or down by 1.0e-8 every 60-seconds. The starting coefficient is the ratio describing the OSP's clock versus the OFIU's clock. In this case the OFIU's time-base clock is slower than the OSP and is corrected by multiplying the OFIU-clock * 1.00001961.

Appendix A:

Host Response Formats

Chapter 4 of this manual described the function of each OSP command in detail. Each command response identifies within itself the command which generated it as well as the structure of the data contained within it.

The Packet Header

The starting point for deciphering Optimus response packets is the four byte packet header, the first four bytes of every response from the OSP.

The Packet Header The first four (4) bytes of every packet			
Byte 0	**Byte 1**	**Byte 2**	**Byte 3**
RespCode	RespType	MsgLength	

Table 5.1

A ‘c’ structure:

```
struct sHeader {
    char RespCode;
    char RespType;
    char MsgLength[2] ;
} ;
struct sPacket {
    struct sHeader header;
    Char *payload
}  packet;
```

Where:

RespCode = The Response Code field, the first byte of the Packet Header which identifies the command or event that generated the packet. The Response codes are listed in table 5.2.

The Response Codes Byte zero (0) of the Packet Header	
RespCode	Command Family
00 – 09	XCx – Direct Access commands
10 – 19	SDx – OFIU Initialization commands
30 – 39	PCx – PCU Initialization commands
100 – 109	ADx – Acquire Data commands
110 – 119	ODx – Output Data commands
120 – 129	CAx – Calibrate commands
130 – 139	OPx – Output calibration Parameter commands
140 – 149	CVx – Control Valve commands
150 – 159	LAx – Look At commands
160 – 169	CPx – set Calibration Parameter commands
170 – 179	SPx – System Processor commands
180 – 189	SCx – System Communication commands
250	Stream Data – DCT Compensation Set
251	Stream Data – Measurement Set
254	EOI – End Or Identify
255	SRQ – Service Request

Table 5.2

The Response code is retrieved from the header using the structure defined earlier as follows.

Rcode = packet. header. RespCode;

Note: The command mnemonic, listed in the right hand column of the Response Code table, presents the first two letters of a command group and a variable indicated with an '**x**'. By replacing the '**x**' with the units' digit of the Response Code the reader can readily determine the command which generated the Response Code.

Appendix A: Continued

RespType = The Response Type, the second byte of the header indicates the contents or meaning of the packet. The second column of the table indicates the meaning and the data type. The embedded data begins after the packet header at byte four (4); the fifth byte of the Packet.

The Response Types Byte one (1) of the Packet Header	
RespType	Data Structure and Format
0x04	Confirmation, 32 bit long integer
0x08	Single Value, 32 bit long integer
0x09	Single Value, 32 bit IEEE 754 float
0x10	Stream Data, RAW two (2) byte, short integer values
0x11	Stream Data, RAW three (3) byte, long integer values
0x12	Stream Data, RAW four (4) byte, long integer values
0x13	Stream Data, 32 bit IEEE 754 float
0x20	Array Data, 32 bit long integer
0x21	Array Data, 32 bit IEEE 754 float
0x80	Error, 32 bit long integer

Table 5.3

The Response type is retrieved from the header using the structure defined earlier as follows.

```
Rtype = packet. header. RespType;
```

MsgLength = The Message Length, bytes two (2) and three (3) the third and fourth bytes of the packet header indicate the total length of the packet including the four bytes of the header.

The Packet Header The first four (4) bytes of every packet			
Byte 0	**Byte 1**	**Byte 2**	**Byte 3**
RespCode	RespType	MsgLength MSB	MsgLength LSB

Table 5.4

The Message length is a short unsigned integer in Big Endian format.

The Message length is retrieved from the header using the structure defined above and “ntohs”, the network to host order short integer, function as follows.

```
MsgLen = ntohs(*  (unsigned short int *)                    &packet. header. MsgLength) ;
```

The Packet Payload

The Payload, the data transmitted by the Optimus, begins after the header at the fifth byte of the packet. The data is transmitted in one of three structures and one of four data types indicated by the Response Type field in the Packet Header. All Optimus data is in Big Endian order.

Generally, Optimus data is structured as one of:

1. A single value
   a. long integer
   b. IEEE 754 float
2. A one dimension array of values
   a. Two (2) byte short integer
   b. Three (3) byte long integer
   c. Long integer
   d. IEEE 754 float
3. A two dimension array of values
   a. Long integer
   b. IEEE 754 float

Optimus Data Types

Single Values

A single value is returned in four (4) of the Response Types:

1) Type 0x04, the Confirmation Packet
2) Type 0x08, the long integer value Packet
3) Type 0x09, the IEEE 754 float value Packet
4) Type 0x80, the Error Packet

In all of these packets the four bytes starting immediately after the Packet Header encode the transmitted value. All of the values are in Big Endian order and, except for type 0x09, the value is a long integer.

The Confirmation Packet value will be zero (0) indicating successful completion of a command or a positive non-zero value; a non fatal warning.

The long integer and IEEE 754 float value Packets are the returned parameter value; a direct response from the command which generated the packet.

The Error Packet is a non-zero negative value; the code describing the fault condition which has occurred. The System Error Codes can be found in Appendix F.

The Single Value Packet The four (4) bytes following the Packet Header			
Byte 4	**Byte 5**	**Byte 6**	**Byte 7**
High Byte			Low Byte

Table 5.5

Appendix A: Continued

When using the ‘c’ structures described earlier, the long integer and floating point values can be decoded using the “ntohl”, network to host order long, function as follows.

A ‘c’ structure:

```
struct sHeader {
    char RespCode;
    char RespType;
    char MsgLength[2] ;
} ;

struct sPacket {
    struct sHeader header;
    Char *payload
}  packet;

Union uSingVal {
    long lValue;
    single sValue;
}  singval;

singval. lValue = ntohl(*  (long *)          &packet. payload) ;
```

And of course the floating point value can be retrieved using:

```
singval. sValue;
```

One Dimension Array of Values

A one dimension array of values is returned in four (4) of the Response Types:

1) 0x10, the RAW Stream Data two (2) byte short integer values
2) 0x11, the RAW Stream Data three (3) byte long integer values
3) 0x12, the RAW Stream Data four (4) byte long integer values
4) 0x13, the EU Stream Data IEEE 754 float values

In all of these packets the array, and the Measurement Set it represents, are described by a Stream Data Header.

The Stream Data Header The four (4) bytes following the Packet Header			
Byte 4	**Byte 5**	**Byte 6**	**Byte 7**
Measurement Set Number		Number of Values	

Table 5.6

The Measurement Set Header follows the Stream Data Header, completing the description of the Stream Data Packet.

The Measurement Set Header The sixteen (16) bytes following the Stream Data Header			
Byte 8	**Byte 9**	**Byte 10**	**Byte 11**
Cluster	Rack	Slot	IUTyp
Byte 12	**Byte 13**	**Byte 14**	**Byte 15**
TBL	nFR	Year	Month
Byte 16	**Byte 17**	**Byte 18**	**Byte 19**
Day	Hour	Minute	Second
Byte 20	**Byte 21**	**Byte 22**	**Byte 23**
Millisecond		Cnvt	Seq

Table 5.7

Note: The Input Unit Type Measurement or Compensation Set indicates the instrument with which the data was acquired. 1x = OFIU and 30 = PCU or PSU. For the OFIU: x = 0 is Pressure Data, x = 1 is Temperature Data, x = 3 is Excitation and Zero Data.

When using the ‘c’ structure described earlier, the Stream Data Header, the

Appendix A: Continued

Measurement Set Header, and the Array of values can be decoded using the "ntohl", network to host order long, function and "ntohs", the network to host order short integer, function as follows.

A 'c' structure:

```
struct sHeader {
    char RespCode;
    char RespType;
    char MsgLength[2] ;
} ;

struct sPacket {
    struct sHeader header;
    Char *payload
}  packet;

struct sStrmDatHdr {
    char msn[2] ;
    char nVals[2] ;
    char Cluster;
    char Rack;
    char Slot;
    char IUTyp;
    char TBL;
    char nFR;
    char Year;
    char Month;
    char Day;
    char Hour;
    char Minute;
    char Second;
    char Milliseconds[2]
    char Cnvt;
    char Seq;
    char *data
}  *strmpkt;

strmpkt = (struct sStrmDatHdr *)                &packet. payload;
```

Appendix A: Continued

```
#  Create an array of the size and type needed to decode the stream data.

Unsigned short int nVals = ntohs(*  (unsigned short int *)
    &strmpkt. nVals) ;

Short unsigned int dataArray[nVals] ;
long dataArray[nVals] ;
single dataArray[nVals] ;
```

The data format is indicated by the Response type value in the Packet header and the number of values, indices, in the data array is indicated by the nVals data element of the Stream Data header structure. With that information the data element of the Stream Data header structure can be processed to extract the stream data values.

Appendix A: Continued

The Measurement Set Data

The RAW values are A/D converter values which are the result of an ADx, Acquire Data, command issued for a Table that is configured for raw data. This format is set by the output conversion format parameter of the SD2 command and also the OD9 Stream Data output format command. The three RAW formats are:

The RAW two (2) byte short integer format contains an array of unsigned short integers. Each value is an un-averaged unsigned A/D measurement. The short integers contained within the array must be converted to the host Endian format. 0xFFFF = positive full scale, 0x7FFF = Zero, and 0x0000 = negative full scale.

```
Unsigned short int nVals = ntohs(*  (unsigned short int *)
    &strmpkt. nVals) ;
Short unsigned int dataArray[nVals] ;
Unsigned int loopctl;
Char *idx;

Idx = strmpkt. data;

For(loopctl = 0; loopctl ++; loopctl < nVals) { dataArray[loopctl] = ntohs(*
    (unsigned short int *) Idx) ;


    idx += 2;
}
```

Appendix A: Continued

The RAW three (3) byte integer format contains an array of 24 bit values. Each value is the sum of a number of frames of data with the number of frames being indicated by the nFR element of the Stream Data header structure. This data format must be promoted to a four byte long integer and converted to the host Endian order before being divided by nFR to get the average counts value. Once divided by nFR the result is within the range of a short integer: 0xFFFF = positive full scale, 0x7FFF = Zero, and 0x0000 = negative full scale.

```
Unsigned short int nVals = ntohs(*  (unsigned short int *)
    &strmpkt. nVals) ;
unsigned long dataArray[nVals] ;
Unsigned int loopctl;
Char *idx,  tmp[4] ;

Idx = strmpkt. data;

For(loopctl = 0; loopctl ++; loopctl < nVals) { Memset(tmp, 0, 4 *
    sizeof(char) ) ; Memcopy(tmp + 1, idx, 3 * sizeof(char) ) ;
    dataArray[loopctl] = ntohl(* (unsigned long *) tmp) ;



    idx += 3;
}
```

Appendix A: Continued

The RAW four (4) byte integer format contains an array of signed 32 bit values. Each value has been complemented before promotion to a long. Therefore, the values are in the range 0x00007FFF = positive full scale to 0xFFFF8000 = negative full scale. In signed long integer; 32767 to -32768. The values must be converted to host Endian order.

```
Unsigned short int nVals = ntohs(*  (unsigned short int *)
    &strmpkt. nVals) ;
long dataArray[nVals] ;
Unsigned int loopctl;

Idx = strmpkt. data;

For(loopctl = 0;  loopctl ++;  loopctl < nVals)                    {
    dataArray[loopctl]          = (signed long)        ntohl(*  (unsigned long *)            tmp) ;

    idx += 4;
}
```

The IEEE 754 values are the result of a conversion of the RAW A/D values; either into volts using the analog bit weight of the A/D converter or Engineering Units using the current EU pressure coefficients. The values are complete and, presuming ideal installation and sufficient averaging, are accurate to within the system specification.

The IEEE 754 floating point values, from a code standpoint, are simply a modification of the RAW four (4) byte data. This is an array of single precision floating point values, the length of the array being the value of short integer conversion of the parameter strmpkt.nVals.

```
Unsigned short int nVals = ntohs(*  (unsigned short int *)
    &strmpkt. nVals) ;
single dataArray[nVals] ;
Unsigned int loopctl;

Idx = strmpkt. data;

For(loopctl = 0; loopctl ++; loopctl < nVals) { dataArray[loopctl] = (single) ntohl(*
    (unsigned long *) tmp) ;


    idx += 4;
}
```

Two Dimension Array of Values

A two dimensional array of values is returned in two (2) of the Response Types:

1) 0x20, the Array Data long integer values
2) 0x21, the Array Data IEEE 754 float values

In these packets the array dimensions, the number of columns and rows, are described by the Array Data Header.

The Array Data Header The four (4) bytes following the Packet Header			
Byte 4	**Byte 5**	**Byte 6**	**Byte 7**
Number of Rows		Number of Columns	

Table 5.8

When using the ‘c’ structure described earlier, the Array Data Header and the Array of values can be decoded using the “**ntohl**”, network to host order long, function and “ntohs”, the network to host order short integer, function as follows.

A ‘c’ structure:

```
struct sHeader {
    char RespCode;
    char RespType;
    char MsgLength[2] ;
} ;

struct sPacket {
    struct sHeader header;
    Char *payload;
}  packet;

struct sAryDatHdr {
    char nRows[2] ;
    char nCols[2] ;
    char *data;
}  *arypkt;

arypkt = (struct sAryDatHdr *)                    &packet. payload;
```

```
# Create an array of the size and type needed to decode the array data.


Unsigned short int nRows = ntohs(*  (unsigned short int *)
    &arypkt. nRows) ;
Unsigned short int nCols = ntohs(*  (unsigned short int *)
    &arypkt. nCols) ;

long dataArray[nRows] [nCols] ;
single dataArray[nRows] [nCols] ;
```

The data format is indicated by the Response type value in the Packet header and the number of values, rows and columns, in the data array is indicated by the nRows and nCols data elements of the Array Data header structure. With that information the data elements of the Array Data header structure can be processed to extract the array data values.

The Array Data

The long integer format contains an array of signed 32 bit values. Each value has been complemented before promotion to a long. Therefore, the values are in the range 0x00007FFF = positive full scale to 0xFFFF8000 = negative full scale. In signed long integer; 32767 to -32768. The values must be converted to host Endian order.

```
Unsigned short int nRows = ntohs(*  (unsigned short int *)
    &arypkt. nRows) ;
Unsigned short int nCols = ntohs(*  (unsigned short int *)
    &arypkt. nCols) ;

long dataArray[nRows] [nCols] ;
Unsigned int rowctl,  colctl;

Idx = arypkt. data;

For(rowctl = 0; rowctl++; rowctl < nRows) { For(colctl = 0;
    colctl++; colctl < nCols) {

        dataArray[rowctl] [colctl] = (signed long) ntohl(* (unsigned long *) Idx) ;


        idx += 4;
    }
}
```

The IEEE 754 values are the result of a conversion of the long integer values; either into volts using the analog bit weight of the A/D converter or Engineering Units using the current EU pressure coefficients. The values are complete and, presuming ideal installation and sufficient averaging, are accurate to within the system specification.

Appendix A: Continued

The IEEE 754 floating point values, from a code standpoint, are simply a modification of the RAW four (4) byte data. This is an array of single precision floating point values, the length of the array being the value of short integer conversion of the parameter strmpkt.nVals.

```
Unsigned short int nRows = ntohs(*  (unsigned short int *)
    &arypkt. nRows) ;
Unsigned short int nCols = ntohs(*  (unsigned short int *)
    &arypkt. nCols) ;

single dataArray[nRows] [nCols] ;
Unsigned int rowctl,  colctl;

Idx = arypkt. data;

For(rowctl = 0; rowctl++; rowctl < nRows) { For(colctl = 0;
    colctl++; colctl < nCols) {

        dataArray[rowctl] [colctl]          = (single)        ntohl(*  (unsigned long *)
            Idx) ;

        idx += 4;
    }
}
```

Appendix A: Continued

Deciphering Optimus data packets is simple. Once a TCP/IP socket is established with the Optimus from the host application, the host application transmits command strings and the responses arrive in the receive buffer.

It is however, inefficient to transmit a command and then immediately wait for the response. Socket communication is asynchronous and so if an application is written in such a manner as to wait for responses after every transmission, the application will be unable to attain the performance of which the system is capable.

Optimus responses, data packets, were conceived with asynchronous operation in mind. For this reason the developer reading this document is encouraged to write the socket read routine as an endless loop maintaining a continuously open TCP/IP socket. Once the packets are read from the socket, the data should be passed to a separate thread or process for parsing and record keeping. No processing of the data packets should take place within the socket read loop. Writes to the socket can occur in a separate thread having access to the socket handle without concern that they will interfere with the socket read process.

Appendix A: Continued

The following pseudo code simply illustrates the socket read loop, a process which is critical to the success of applications which communicate with Optimus. Be aware that there are several critical thread interlock and shared memory issues within the example.

An Optimus Read TCP/IP Socket Loop example:

Allocate a circular buffer for passing the data packets to the response parser.

```
Char *pPacketCircularBuffer[100] ,  *pPCB;
```

Allocate a pointer into the circular buffer for use within the socket read loop.

```
pPCB = pPacketCircularBuffer;

While(not exit)
{
    Char *pPacket,  Header[4] ;
    Unsigned short int MsgLen;

    #  Wait on one of the events to occur on the socket Poll(socket, Timeout
    or Socket_Error or Data_Arrival)

    If(Data_Arrival)
    {
        #  If data has arrived
        #  Clear my header array

        Memset(Header,  0,  4  *  sizeof(char) ) ;

        # Read the first four bytes of the packet.
        # It' s a good idea to verify you read four bytes.
        #  Good practice to read again to get (4  -  bytes read)  = 0
        #  I  didn' t do that here…

        Read(socket,  Header,  4) ;

        #  The message header is always in BigEndian order
        #  Network order if you wish

        #  Convert bytes three and four to a short uint in
        #  Host order

                MsgLen = ntohs(*  (unsigned short int *)       &Header[2] ) ;
```

Appendix A: Continued

```
        # Allocate memory; the amount needed to hold the
        # entire packet.

        pPacket = Malloc( sizeof(char) * MsgLen) ; # Copy the
        Header into the Packet

        Memcopy(Packet, Header, sizeof(char)        * 4) ;

        # Read the remainder of the packet
        # Again, good practice you should verify
        # you' ve received what you expect

        Read(socket, (char *)       &Packet[4] , MsgLen – 4) ;

        # Put the packet into the circular buffer
        # So we can process it outside of this critical
        # Performance loop

        *pPCB = Packet;

        # Increment the pointer to the circular buffer. pPCB++;


    }
    Elseif(Socket_Error)
    {
        Exit = true;
    }
}
```

Appendix A: Continued

Response Packets

Confirmation and Error Responses

Every command executed confirms its completion, either with a Confirmation packet or with the requested data; for example an LA1 command confirms its proper completion by transmitting a Single Value packet containing the requested value.

Every command which encounters an error responds with an Error response.

Though every command returns a response, it is possible to inhibit and / or modify these responses. The SC2 command can be used to inhibit the confirmation and error responses for any and all commands. This feature reduces traffic over the Ethernet link, though at the expense of qualification of command execution and error checking. Eliminating the Confirmation / Error responses does little to improve throughput in today's network environment and the ability to do so is only retained for backwards code compatibility.

SRQ and EOI Responses

An SRQ packet indicates that the OSP has a response packet available for host to read. An EOI packet is sent after the response packet is transmitted. The SRQ and EOI response packets are a legacy application support feature. They were conceived of as a way to ease the transition of existing facility software from GPIB to Ethernet communications. The intention was to provide an Ethernet message having a meaning synonymous with GPIB signals, conveniently linking in the new system with a minimum of software modification. The SC1 command will enable these messages which are transmitted prior to and after a command response or data packet. The use of this mechanism should be avoided, as the additional packets complicate the communication process with little to no benefit.

Note: The SRQ and EOI packets have a message length of 4 bytes, having no additional data or ASCII comments appended to them.

The following four response packet types contain binary data returned in response to data acquisition commands.

Single Value Response

A packet containing a single value encoded as four bytes, either a long integer or IEEE 754 single precision float. The receipt of a single value packet is synonymous with a Confirmation Packet; the command succeeded if you received the data.

Stream Data Response

Stream data is exclusively the result of an ADx, Acquire Data, or an ODx, Output Data, command. Receipt of Stream packets is not necessarily a confirmation that a command has completed execution nor is their absence necessarily an error; though it can be presumed that, if your application requested data and none is forthcoming, some type of error has occurred. Acquire Data and Output Data commands send a Confirmation packet upon completion of acquiring or transmission of the Tables' nMS, the Number of Measurement Sets. If the Table is configured to continuously acquire and output data, it must be terminated using an AD0 command. In this event the continuous stream of data will terminate with an Error response and the AD0 command, which stops the stream, will send a confirmation packet.

Note: There are two (2) different response codes for which stream data responses are transmitted. The OSP, when sending data for DTC scanners, may send a Compensation data set containing excitation and zero values for the DTC scanners and the A/D converter in the mSDI. This data can be used in conjunction with the DTC coefficients to perform the Engineering Unit conversion within the host application. This may be done for a number of reasons, the most common being a desire to increase system throughput.

Array Data Response

The array data type is used to transmit tabular data; calibration coefficients, calibration data, and configuration information for any of the Input Units present in the system. Review the discussion of ESP scanner coefficients in Appendix B for clarification of the manner in which the coefficients are used.

Note: DTC ESP scanner coefficients are returned by the OP3 command as an array of twenty three (23) single precision floating point numbers. However, when a DTC scanners' header and trailer are read, some values are single floating point values while others must be interpreted as ASCII strings. The DTC scanner Header coefficients begin with six (6) floats and the remaining seventeen (17) coefficients are ASCII strings. The collection of strings is concatenated to realize key / value pairs. Each has a three (3) character keyword followed by an equivalency "=" character and a variable length string value with at least one trailing Space 0x20, Tab 0x09, or NULL 0x00 character. The entire trailer is a single ASCII string.

Appendix B

ESP scanner EU Pressure Conversion Equations:

Conventional Coefficients

Once the physical connections, pneumatic and electrical, have been accomplished and the Optimus has been configured and initialized, Conventional ESP scanners must be calibrated. The purpose of this calibration is to derive the coefficients necessary to calculate pressure from the voltage output by the sensors embedded within the scanners.

Conventional ESP scanner calibration coefficients are derived by polynomial regression of data points, scanner port voltage and calibrator pressure, measured by an OFIU and mSDI in conjunction with a PCU during a calibration. Conventional scanners are not compensated for temperature changes and so it is important to be aware of this limitation and reduce its effects by performing either a re-zero calibration or a new full calibration at intervals during system operation.

> **Note:** DTC ESP scanners may also be calibrated in this fashion and users do so for a variety of reasons. The details of why one would use a DTC scanner without taking advantage of the inherent temperature compensation are unimportant in this context. It is sufficient that one be aware that such an option is available. When operating in this conventional mode, DTC scanners are not compensated for temperature changes.

The Conventional scanner Polynomial Equation calculates pressure as a function of measured voltage, output by the sensor of a scanner port. Every port included in a Table scan list has its own, unique, set of coefficients. The coefficients may be created as a result of execution of a CA3 full calibration, a CA2 offset adjustment calibration, or written into system memory using an SD4 command. Regardless of the method of creation, the system does not permanently retain conventional coefficients.

The Pressure equation has the form:

$$P = C_0 + C_1V + C_2V^2 + C_3V^3 + C_4V^4$$

This equation can be factored for more efficient processing as follows.

$$P = (((C_4V + C_3)V + C_2)V + C_1)V + C_0$$

Where:

P = EU Pressure
V = scanner port Voltage
C_0 = Offset Coefficient
C_1 = Span or Slope Coefficient
$C_2 \ldots C_4$ = Linearity Coefficients

When the coefficients, C_0 through C_4, are retrieved via an SD4 command or output by the system via an OP3, they are expressed as pressure units per volt as shown here. Internal to the Optimus however, the coefficients are stored as pressure units per A/D converter count. The raw data from which these coefficients are derived can be retrieved using the OP1 and OP4 commands respectively; note that the OP1 command returns volts and so the OP3 coefficients can be directly and consistently compared for validation. The system pressure units can be selected by changing the units for the PCU which calibrates a given LRN by using the PC4 command.

DTC Coefficients

DTC ESP scanners, in contrast to Conventional scanners, do not require a full calibration to generate Engineering Unit coefficients. During manufacture the sensors within the scanner are characterized over the temperature and pressure range. This process also accounts for potential variations of the sensor excitation and A/D converter offset drift. Ultimately, eight (8) groups of coefficients are derived for each port of a DTC scanner, to convert the sensor output voltage into temperature compensated Engineering Unit values. The remainder of this section presents the Coefficient Groups stored for each DTC scanner port within the scanner non-volatile memory, the Measured Parameters, the calculated Coefficients, and the Final Values; the EU output of the equations.

The DTC Coefficient Groups: Per scanner port

Group Zero: Adjustable

- C_z – The Zero correction in EU
- C_s – The Span correction

Groups One through Four: Pressure

- (A_0, A_1, A_2, A_3)
- (B_0, B_1, B_2, B_3)
- (C_0, C_1)
- (D_0, D_1)

Groups Five through Seven: Temperature

- (Q_0, Q_1)
- (R_0, R_1)
- (S_0, S_1)

Group Eight: EU Temperature

- (T_0, T_1, T_2)

Measured Parameters

- E_r – The Scanners Excitation Voltage
- Z_r – The mSDI A/D converter zero reference
- T_r – Sensor Raw Temperature Voltage
- P_r – Sensor Raw Pressure Voltage

Appendix B: Continued

Intermediate Parameters

T_n – Sensor Normalized Temperature Voltage
P_n – Sensor Normalized Pressure Voltage
q, r, s – Coefficients: Temperature
T_c – Sensor Corrected Temperature Voltage
a, b, c, d – Coefficients: Pressure

Output Values

P – Sensor EU Pressure
T – Sensor EU Temperature

The DTC equations solve for the Engineering Unit Pressure as a function of two interrelated variables; the temperature of the sensor and the force applied to the sensor. The following is a step by step description of the process of solving those equations.

The first step of the process requires that the Optimus normalize the raw temperature and pressure voltage data for sensor Excitation and A/D converter offset error. This is accomplished by instructing the DTC scanner to gate the excitation voltage through the temperature voltage output pin of the DTC scanner connector. The scanner excitation voltage is then digitized by the A/D converter located in the mSDI. Next the system measures the A/D converter offset; the value output by the device when its differential input is shunted within the mSDI. These functions are performed just prior to making the first measurement when starting a stream of Measurement Set data for a Table. The result is the Excitation and Zero values: E_r and Z_r.

> **Note:** An Excitation and Zero Measurement Set is only acquired at the beginning of a stream of data.

After acquiring the Excitation and Zero, the Optimus acquires a pressure and temperature voltage data set for all scanner ports in the scan list defined by the active Table. That data is then normalized for the excitation and zero.

$$T_n = (T_r - Z_r)/(E_r - Z_r)$$
$$P_n = (P_r - Z_r)/(E_r - Z_r)$$

The Normalized Temperature voltage, T_n, is used to generate the Temperature coefficients: q, r, and s.

$$q = Q_0 + Q_1 T_n$$
$$r = R_0 + R_1 T_n$$
$$s = S_0 + S_1 T_n$$

Appendix B: Continued

The Corrected Temperature voltage, Tc, is now calculated as a function of the Normalized Pressure voltage, Pn, using Temperature Coefficients: q, r, and s.

$$T_c = q + rP_n + sP_n^{\,2}$$

Note: Tc is only calculated for one of two events: At the start of a stream of data, immediately after an Excitation and Zero data point is acquired, and when a new temperature voltage Measurement Set is acquired. Temperature Voltage Measurement Sets are acquired at intervals while a stream of data is being acquired. The interval between Temperature Measurements is controlled by the SD5 command and is configured to acquire one Temperature Measurement Set for each Pressure Measurement Set by default.

Now the Pressure Coefficients a, b, c, and d, are calculated using the Corrected Temperature Voltage, Tc.

$$a = A_0 + A_1T_c + A_2T_c^{\,2} + A_3T_c^{\,3}$$
$$b = B_0 + B_1T_c + B_2T_c^{\,2} + B_3T_c^{\,3}$$
$$c = C_0 + C_1T_c$$
$$d = D_0 + D_1T_c$$

Note: Since Tc is only calculated when a new Temperature Measurement Set is acquired, the coefficients a, b, c, and d, are also not re-calculated until a there is a new value for Tc.

The Engineering Unit values for Pressure can now be calculated using the Normalized Pressure Voltage as well as the EU Correction coefficients: Cz and Cs.

$$P = C_z + C_s(a + bP_n + cP_n^{\,2} + dP_n^{\,3})$$

The Equation above can be rearranged using the Distributive Property to more closely resemble the Conventional ESP scanner equation.

$$C_0 = C_s(a) + C_z$$
$$C_1 = C_s(b)$$
$$C_2 = C_s(c)$$
$$C_3 = C_s(d)$$
$$C_4 = 0$$

$$P = C_0 + C_1P_n + C_2P_n^{\,2} + C_3P_n^{\,3} + C_4P_n^{\,4}$$

This equation can be factored for more efficient processing as follows.

$$P = (((C_4P_n + C3)P_n + C_2)P_n + C_1)P_n + C_0$$

Although the arrangement provides correct results, there is a single difference that can cause difficulties when operating on DTC and Conventional scanner data in the same function. The final coefficient, C_4, is not used in the DTC calculation; in this case the inner C_4P_n term is set to zero and skipped. However, the Optimus will return a non-zero C_4 value in response to an OP3 command issued for DTC scanners. This is due to storage of the DTC Units Multiplier, the EU Conversion Factor, in the memory location of the C4 coefficient for DTC scanners. That factor is applied when the output units are changed using the PC4 command.

For DTC scanners only, if the C_4 coefficient is not equal to 1 and not equal to zero the value is applied as a unit's conversion factor.

$$P=PC_4$$

DTC scanner port EU temperature

The final operation, though not required or relevant for the calculation of DTC Pressure data, is offered as a convenience. The Corrected Temperature voltage, T_c, can be used to derive the EU temperature of the individual scanner sensors. This operation is performed using the Group 8 coefficients; T_0, T_1, and T_2.

$$T=T_0+T_1T_c+T_2T_c^2$$

Calibrating DTC ESP scanners

Although the factory DTC coefficients do not require periodic update, ESP scanners are subject to the rigors of use. Physical damage from excessive force, pressure exceeding the specified burst pressure, can cause span and or offset shifts. To compensate for any deviations from ideal performance, the system is capable of calculating and storing first order corrections which will be automatically applied to the Factory DTC coefficients. These Adjustable Group Zero coefficients, designated C_z and C_s, can be written to the DTC scanner non-volatile memory through use of the SD5 command.

The adjustment of these coefficients is accomplished by performing a pressure calibration using either the CA2 or CA3 commands, after which the SD5 command is used to save the Group Zero coefficients.

Appendix C

PCU / PSU Operation

As stated in earlier sections of this document, PCUs and PSU are single sensor precision pressure measurement devices. PSUs are strictly measurement only devices and are often used to monitor the reference pressure for the ESP scanners. PCUs contain pressure control and generation circuitry and can provide precision pressures for the calibration of ESP scanners. Both PCUs and PSUs are capable of sourcing data in a manner similar to the OFIU and mSDI; however the throughput of these instruments is significantly lower than the rate specified for ESP scanners.

PCUs are a required component of the Optimus System, being the instrument which calibrates the ESP scanners. PCUs are semi autonomous, capable of maintaining a stabile output pressure for extended periods of time. This capability has been used to accomplish a number of tasks which can be difficult to achieve with any other device.

In order to operate as a pressure controller a PCU must be configured with a “PC1” command. The PCU can then be commanded to set a pressure and maintain it continuously. The PCU may also be commanded to return the instantaneous value of the pressure being set, though it should be noted that the control loop is interrupted while the pressure is being calculated by the microprocessor in the unit, potentially causing some variation in the output for short intervals. In order to enable calibration of ESP scanners, a “PC2” command is also required.

Whether a PCU is being used to generate an arbitrary pressure or a sequence of pressures to calibrate ESP scanners, the control logic within the unit operates in the same manner. The unit utilizes a lookup table to set an initial pressure and then uses readings from the pressure standard to close on the requested value. Once the pressure is within the requested tolerance, a comparator circuit continually corrects the output of the controller.

Appendix C: Continued

Terminology:

1. Pressure Standard
   a. The precision sensor within the instrument.
2. DH Transducer
   a. A control sensor used to actively sense the output of the Servo Controller. The output of this sensor is passes to the comparator along with the output of the DAC.
3. DAC
   a. A Digital to Analog converter, the output of which is passes to the input of the comparator along with the output of the DH Transducer.
4. Comparator
   a. The comparator receives input from the DH Transducer and the DAC. The output of the comparator is drives the Servo Valve, controlling the pressure generated by the PCU.
5. S100 Table
   a. A lookup table containing DAC digital words indexed by pressure output by the Servo Controller, as measured by the Pressure Standard. The S100 Table is used to quickly achieve an approximation of the requested pressure. The S100 Table is built internal to the PCU by the "PC5" command.
6. Servo Controller
   a. The pressure controller; it modulates the flow of gas between the input supply and the vacuum input or vent in order to generate a pressure at the Cal Output port. The output is monitored by the DH Transducer and also measured by the Pressure Standard. The Servo is driven directly by the comparator output, an "error" signal which is the difference between the DAC output and the DH Transducer output.
7. C1 and C2
   a. Control pressure signals which translate the Calibration Valves located within ESP scanners between the Run and Calibrate positions. These signal pressures are actuated by all of the PCUs in a system, in parallel. They are required as a part of the calibration of ESP scanners and automatically applied during the execution of the "CA2" and "CA3" commands. They are normally actuated aside from the context of calibrating scanners using the "CV1" command.

Appendix C: Continued

For the purpose of clarity, the description of operation will begin with the PCU at “Rest”; the condition in which it is placed when first powered on or after receipt of a “CA0” or “CV0” command. Included in this discussion is the state of the individual solenoid valves within the PCU.

> **Note:** The Valve state illustrations show the valves in the relaxed or quiescent state. Within the text description, the valve state will be noted as either “Closed”, permitting flow through the valve, or “Open”, blocking flow through the valve. The valve state referenced by the “LA3” and “CV0” commands are the “Energized” and “De-Energized” state of the electrical circuit controlling the valve. Be aware that valve logic differs between each of the individual types of PCUs: the Low Range Absolute, High Range Absolute, and Differential. Developing software which can control the PCU to a high degree is useful in a troubleshooting context as well as when performing calibrations of the PCU or for special purpose; however, there is a possibility that incorrect, unintended, or inappropriate combinations of valves can damage equipment and potentially injure bystanders. There is no inherent protective monitoring of the valve states when they are explicitly set using the “CV0” command. All permutations are available.

The Normal Operation of a PCU:

To begin, a request for the PCU to set a pressure is received. From the initial quiescent state the microprocessor evaluates the value of the request to determine which supply inputs are required to achieve the necessary output level.

PCUs have a similar logic for required inputs regardless of range: If the absolute value of the requested pressure is less than or equal to 3.5 psi for differential PCUs and within 3.5 psia of one standard atmosphere for absolute PCUs then both the pressure and vacuum supply valves will be closed. Above that range, only the pressure supply valve will be closed and below that range only the vacuum supply valve will be closed. The vent for the PCU will be used as the source or sink of the pneumatic controller in this context. Once the appropriate supply valves are set, the output valve will be closed, gating the pressure being set to the port on the back panel of the Remote Processor.

Having set the internal valves appropriately, the microprocessor selects a value from the S100 lookup table, less than or equal to the requested pressure value, and latches the associated digital word into the DAC. The comparator generates an “error” signal, the difference between the DAC output and the output of the DH Transducer, which drives the Servo controller pressure toward the desired value. The pressure generated by the Servo Controller operating on the DH Transducer reduces the rate of change for the Servo Controller, closing on a stabile value.

Upon achieving stability at the initial set point, the pressure standard is used to measure the pressure value. If the pressure is not within the desired tolerance, the DAC setting is changed proportional to the difference between the desired set point and the current value. The process iteratively closes upon the desired value.

Upon successfully setting the requested pressure, the PCU notifies the caller of the success and continues to track and hold the requested pressure.

Example:

Since this is an example of the operation of PCU, the OFIU and ESP scanner configuration will be generalized. For the following text, presume that the ESP scanners are correctly configured and that they are operating in correctly.

A PCU having a Full Scale pressure range of 30 psia is identified as Logical Range one (1) by its “PC1” command and located in the first slot of the first Remote Processor; Cluster, Rack, Slot, address 211. It is assigned to the group of ESP scanners having a full scale pressure range of ± 10 psid. Since ESP scanners are differential pressure measurement devices, the PCU is configured to operate as a differential pressure controller. This is accomplished by measuring Atmospheric pressure through Run Reference port and storing the value as the absolute reference relative to which it will set all requested pressure values. The sequence of pressures to be applied during the calibration of Logical Range one (1) is defined as differential by the “PC2” command.

“PC1 211 1, DIFF 0.001 30;”

“PC2 211 -10 -5 0.0 5 10;”

Note: An Absolute PCU will always measure and set pressure as an Absolute value. When it is operated in Differential mode it accepts the requested pressure value and adds the measured reference value to calculate an Absolute value to be set. During an ESP scanner calibration sequence, PCUs are commanded to take a new measurement of the reference pressure, ensuring that a current value for the absolute reference pressure is used.

A calibration is requested and, since the PCU is configured in Differential mode, it receives an instruction to prepare for that process by measuring the Absolute value of Atmospheric pressure. The PCU “Opens” the supply valves, ‘K3’, ‘K8’, and ‘K9’, to vent the Servo Controller and then “Closes” ‘K4’ to expose the Pressure Standard to the current Atmospheric pressure as applied to the “Run Ref” port on the back of the Remote Processor. The PCU measures that pressure value and stores it as the current Zero Offset value. For this example the value of one Standard Atmosphere is assumed: 14.7 psia.

The PCU is then instructed to generate the “C1” control pressure, in order to move the calibration valves within the ESP scanners to the Calibrate position. The PCU “Closes” the ‘K1’ valve to apply the supply pressure to the scanners via the ‘C1’ port on the back of the Remote Processor. The System may be configured to only apply the control pressures for a finite period of time. If this is the case, the PCU will receive a command to “Open” ‘K1’ and then change the state of ‘K2’ to vent the pneumatic lines connecting the Remote Processor to the control ports of the attached ESP scanners.

The command is then sent by the Optimus System Processor to generate the first of the sequence of calibration pressure that had been defined in the “PC2” command. The PCU examines the first calibration pressure stored in the calibration pressure array and adds the current Zero Offset value to derive the actual Absolute pressure to be set. Using the example “PC2” command sequence the first pressure to be set is “-10” psi, which when summed with the previously measured offset value of 14.7 psia results in an Absolute pressure requested being 4.7 psia.

The requested pressure, 4.7 psia, is more than 3.5 psi away from one Standard Atmosphere and is negative relative to that level, so the vacuum input is required and not the positive pressure input. Valve ‘K9’ is “Closed” applying the vacuum supply to the system, valve ‘K8’ is “Opened” passing Atmospheric pressure into the system. Valves ‘K3’ and ‘K5’ are “Closed” and valve ‘K4’ is “Opened”; routing the generated pressure through the “Cal” port on the back of the Remote Processor.

Once the pneumatic circuit is correctly gated using the solenoid valves the microprocessor searches the S100 Lookup Table for the closest pressure point to the one being requested. The paired digital word, the DAC setting, is applied to the DAC. The Comparator then emits an error voltage that drives the Servo Valve to modulate the flow rate between the vacuum supply port via ‘K9’ and the Atmospheric vent via ‘K8’. As the pressure within the pneumatic system changes, the DH Transducer senses that change and applies a signal to the Comparator which slows the rate of change for the Servo Valve. Once the output of the DAC equals the output of the DH Transducer, the PCU acquires data using the Pressure Standard and uses that value to adjust the DAC, driving the Servo Controller closer to the requested set point.

Upon achieving the set point pressure, the PCU continues to monitor the pressure using the Pressure Standard. The pressure will be held until a new pressure is requested or some other event interrupts the control loop. Calibration of ESP scanners would, of course, require the system to complete the remainder of the pressure sequence. Description of the process is redundant in this context.

The Normal Operation of a PSU:

A PSU, unlike a PCU, does not contain a pressure control circuit, however the solenoid valves within the unit can cause it to be isolated from the ports located on the back of the Remote Processor. A PCU can be configured as a PSU, via execution of a “PS1” and “PS2” command, allowing it to continuously emit data in a manner similar to that described for the OFIU and ESP scanners. When a PCU is configured to operate as a PSU, it cannot be used to calibrate ESP scanners nor can it be used to set or control pressures using its control loop and servo valve system. For detailed description of the configuration of the PSU, refer to the “PS1” and “PS2” command descriptions in the Programmers Reference section of this manual.

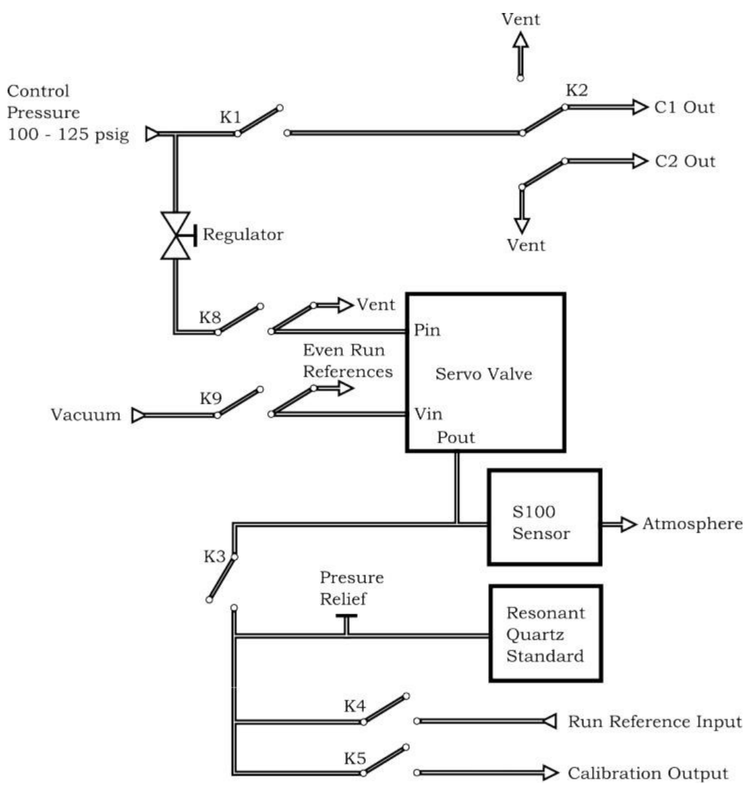


Figure 7.1: Pneumatics of a Low Pressure Range Absolute PCU

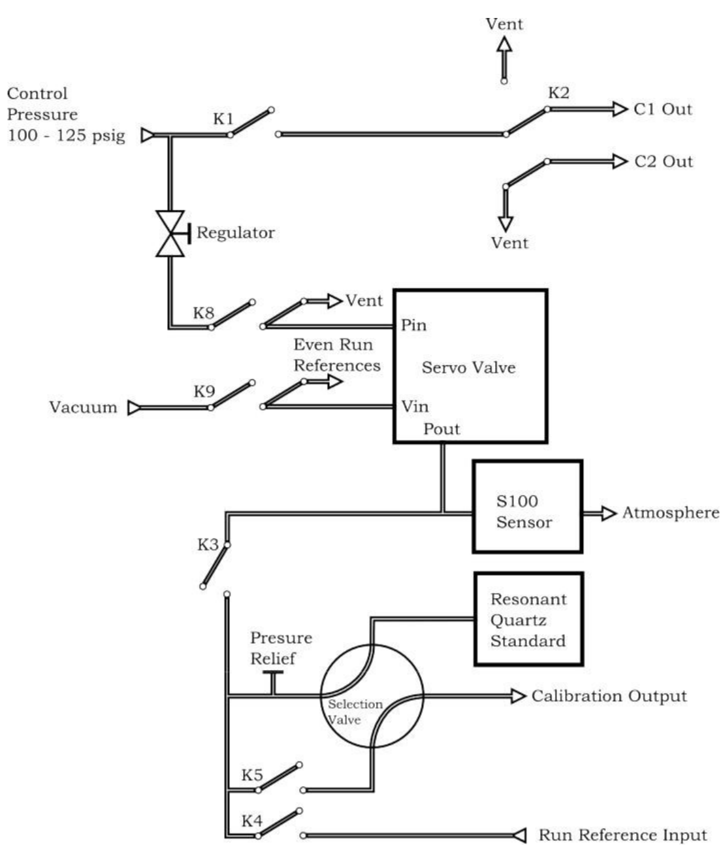


Figure 7.2: Pneumatics of a High Pressure Range Absolute PCU

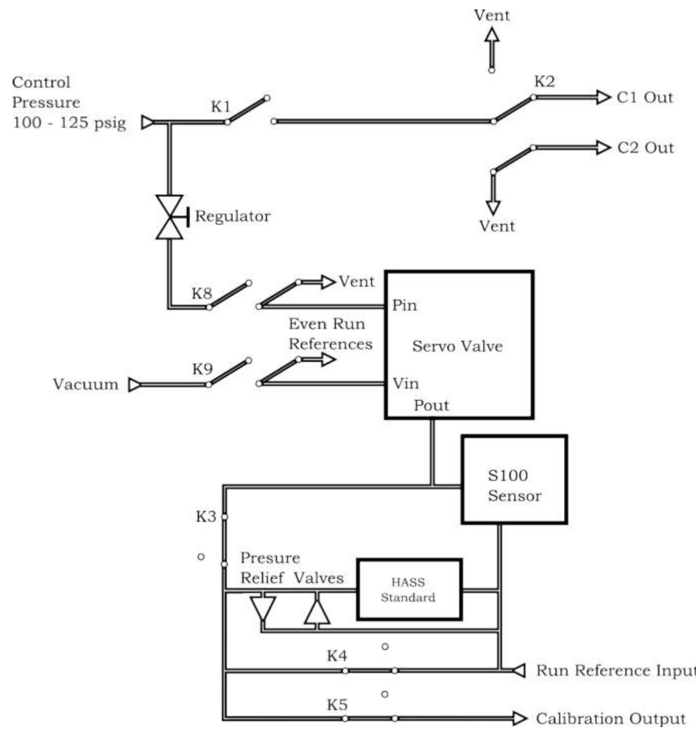


Figure 7.3: Pneumatics of a Differential PCU

Appendix D

PCU / PSU Coefficients and Equations

Unlike input units that provide raw data only, PCUs and PSUs have data conversion equations, coefficients, and operating parameters stored directly in the unit. These are used for Temperature Compensation and Engineering Unit, EU, data conversion. They are stored internally because the corrected EU pressure values are offered directly to the host as a data stream and are also used by the PCU pressure control algorithm. It is necessary to periodically calibrate PCUs and PSUs with all operating parameters in place. They are then used as secondary pressure standards for calibrating ESP scanners and primary measurements such as Pstatic and Ptotal; used to calculate air velocity in wind tunnel applications.

After a system RESET or Power Cycle, the PCU and PSU firmware copies the Pressure Standard coefficients and operating parameters from non-volatile storage into working memory; the Coefficient Table. During a PCU or PSU calibration the process is reversed, the coefficients are written to the Coefficient Table and then the entire table is copied back to non-volatile memory.

PCU and PSU coefficients are accessed by their Calibration Table Index, a positive integer parameter used in commands such as PC3, PS3, and OP6 or by their Feature Number, a negative integer parameter used in commands such as LA3 or DP2. Table 8.1 documents the coefficients and operating parameters available within each PCU and PSU, organized by the type of pressure standard installed within the instrument.

The values found within the Coefficient Table are either static or dynamic. Those identified as dynamic are primary data, the output of the sensor, or calculated values. Static values include the type of pressure standard and the Full Scale Range of the pressure standard. These two parameters are determined by hardware selection switches located on the circuit boards within the PCU or PSU. These switches are not changed outside of the factory. The remaining static values are operating parameters: the pressure conversion coefficients for the pressure standard, averaging window or integration interval, and the frequency of the clock and counter circuits.

PCU and PSU EU Coefficient Tables				
Coefficient Index (-) Feature	Resonant Quartz		Quartz Bourdon Tube	HASS
	Non-Temperature Compensated	Temperature Compensated		
(-) 1	C (A)	C [2]	A	P_{max} [6]
(-) 2	D (B)	D [2]	B	
(-) 3	T_0	T_0 [2]	C	
(-) 4		(Def. 1)		A_0
(-) 5		C_1		A_1
(-) 6		C_2		A_2
(-) 7		C_3		A_3
(-) 8		D_1		A_4
(-) 9		D_2		B_0
(-) 10		T_1		B_1
(-) 11		T_2		B_2
(-) 12		T_3		B_3
(-) 13		T_4		B_4
(-) 14		T_5		C_0
(-) 15		Y_1		C_1
(-) 16		Y_2		C_2
(-) 17		Y_3		C_3
(-) 18		X_0 [8]		C_4
(-) 19	Z_p [1]	Z_p [1]		Z_p [1]
(-) 20		T_{t_0} [2, 9]		T_t [2, 9]
(-) 21		X [2, 7]		C_r [2, 3]
(-) 22		C_t [2, 3]		C_t [2, 3]
(-) 23	C_p [2, 3]	C_p [2, 3]		C_p [2, 3]
(-) 24		N_t [5]		C_z [2, 3]
(-) 25	F_c [4] (Def. 20)	F_c [4] (Def. 20)	F_c [4] (Def. 20)	X_2 (Def. 0.0)
(-) 26	N_p [5] (Def. 2000)	N_p [5] (Def. 2000)	N_p [5] (Def. 2000)	N [5] (Def. 500)
(-) 27	Type Number	Type Number	Type Number	Type Number
(-) 28	Range [6]	Range [6]	Range [6]	Range [6]
(-) 29	Z_c [2, 6]	Z_c [2, 6]		Z_c [2, 6]
(-) 30	T [2, 7]	T [2, 7]		X_0
(-) 31				X_1
(-) 32				D_0
(-) 33				D_1
(-) 34				D_2
(-) 35				D_3
(-) 36				D_4
(-) 37				T_0
(-) 38				T_1
(-) 39				T_2
(-) 40				T_3
(-) 41				A [1]
(-) 42				B [1]
(-) 43				C [1]
(-) 44				D [1]
(-) 45				E [1, 10]
(-) 46				E_0 [10]
(-) 47				E_1 [10]
(-) 48				E_2 [10]
(-) 49				E_3 [10]
(-) 50				E_4 [10]
(-) 51				J_0 [10]
(-) 52				J_1 [10]
(-) 53				J_2 [10]

1 **Present in FRS PSUs Only**
2 **Dynamic Value**
3 **Counts**
4 **Frequency, MHz**
5 **Number of Samples**
6 **PSIA or PSID, dependent on TYPE**
7 **uSec**
8 **May be identified as U_0 in Legacy Documents**
9 **°C**
10 **4th Order HASS**

Table 8.1

Appendix D: Continued

The Primary Standard Type number, read via Coefficient Index 27, is used by the system directly and is also used during periodic calibration, in order to assure proper configuration.

The Calibration Document that comes with each PCU and PSU records the values of each coefficient at time of manufacture and / or factory calibration.

PCU and PSU Primary Standard Type: Index 27	
Type	Description
0	Absolute Resonant Quartz, NO Temperature Compensation
1	Differential Resonant Quartz, NO Temperature Compensation
2	Absolute Resonant Quartz, WITH Temperature Compensation
3	Differential Resonant Quartz, WITH Temperature Compensation
6	Low Pressure; Solatron
7	High Pressure; Solatron
8	Absolute Quartz Bourdon tube; Mensor
9	Differential Quartz Bourdon tube; Mensor
11	Absolute HASS, with Temperature Compensation
12	Differential HASS with Temperature Compensation; 3rd Order
13	Differential HASS with Temperature Compensation; 4th Order

Table 8.2

Raw Data from PCUs and PSUs

Although PCUs and PSUs normally return fully converted and temperature compensated pressure data to the OSP and to the host application, it is possible to read raw data from these units as well. Increased throughput may be possible, but the OSP and / or host application must then convert the data into engineering units and adjust it for temperature before it can be used. Uploading all of the coefficients and performing the equations locally is possible, and some legacy systems do exactly that.

PCUs and PSUs return raw data as 32 bit long integers. Each integer is in big Endian order. In some cases the values are the partial sum of several raw A/D count values, a function of the internal averaging set by the operating parameters. In other cases they are the derived average, having already been divided by the number of samples. Do not presume that every PCU or PSU behaves in the same manner or returns data formatted in the same way.

Appendix D: Continued

Resonant Quartz:

Within a Resonant Quartz transducer, a bellows or bourdon tube converts input pressure to mechanical force which is then applied to a crystal resonator. If the transducer is of the temperature compensated type a second resonator is present that is not subjected to the applied force. The resonators define the period, T, of independent pressure and temperature oscillator circuits. Measurement of the pressure and temperature oscillator period is performed using a counter and precision oscillator.

The Pressure Period, T_p, is a function of applied pressure and the sensor temperature while the Temperature Period, T_t, is a function of temperature only. The output of the pressure oscillator, and also of the temperature oscillator if present, is used to gate the reference oscillator signal to the counter circuit. The counters' registers increment at the reference oscillator rate for one or more periods of the pressure and / or temperature signals. When the desired number of pressure and / or temperature periods has elapsed the counter gate is closed and the counters' register sums are used to determine the period for the Temperature and Pressure oscillators via the following equation:

$$T_x = C_x/(F_c N_p)$$

Where:

C_x = the Counter Register value; the sum of the Reference Oscillator periods which elapsed during N_p periods of the Pressure or Temperature Oscillator.

F_C = The Frequency of the Reference Oscillator, in Megahertz.

N_p = The Number of Pressure or Temperature oscillator periods for which the Reference Oscillator periods are counted.

T_X = The average Pressure or Temperature oscillator period in micro seconds.

If the transducer is a temperature compensated unit, the temperature correction coefficients are used to derive the pressure coefficients C, D, and τ_0 using the following equations:

$$\Delta T_t = T_t - T_{t_0}$$

Where:

T_t = The Normalized Temperature period in microseconds.

T_{t0} = The Temperature period at 0.0 ºC in microseconds.

ΔT_t = The difference between the current Temperature period and the Temperature period at 0.0 ˚C in microseconds.

Appendix D: Continued

Followed by calculation of the Temperature corrected Pressure Coefficients:

$$C=C_1+C_2\Delta T_t+C_3\Delta T_t^2$$
$$D=D_1+D_2\Delta T_t^2$$
$$T_0=T_1+T_2\Delta T_t+T_3\Delta T_t^2+T_4\Delta T_t^3+T_5\Delta T_t^4$$

> **Note:** The results of the equations above are temperature compensated pressure coefficients. If the unit being used is not a temperature compensated quartz transducer then the constant pressure coefficients C, D, and T_0 are used directly and the temperature compensation is skipped.

Where:

C_1, C_2, C_3 = The '**C**' Term Temperature Compensation Coefficients.

D_1, D_2 = The '**D**' Term Temperature Compensation Coefficients.

T_1, T_2, T_3, T_4, T_5 = The '**T_0**' Term Temperature Compensation Coefficients.

ΔT_t = The difference between the current Temperature period and the Temperature period at 0.0 ˚C in microseconds.

And finally, the EU pressure value is calculated.

$$P=C(1-T_0^2/T_p^2)(1-D(1-T_0^2/T_p^2))-[Z_c+\{Z_p(P_x-14.7)\}]$$

Where:

C = The static or temperature compensated dynamic '**C**' Coefficient.

D = The static or temperature compensated dynamic '**D**' Coefficient.

T_0 = The static or temperature compensated dynamic '**T_0**' Coefficient; The pressure period with 0.0 psi applied.

> **Note:** The portions of the function in [Brackets] and {Braces} are optional; used when the pressure sensor is a PSU or a Differential PCU to compensate for operating conditions. They are included here for reference purposes and the result will generally be 0.0:

Z_c = The Dynamic zero offset correction term. This term is used in differential quartz sensors and will generally be 0.0.

Z_p = The Offset correction for line pressure applications. This term is used in PSUs for FRS, the legacy Flow Reference System, only.

P_x = An External Pressure read via a separate PSU. This term is used in PSUs for FRS, the legacy Flow Reference System, only.

Appendix D: Continued

Temperature Equation:

Although the sensor Temperature in degrees is not used to compensate the sensor pressure, it can be determined using additional coefficients:

$$°C = Y_1 T_t + Y_2 T_t^2 + Y_3 T_t^3$$

Where:

°C = The sensor temperature.

Y_1, Y_2, Y_3 = The sensor temperature period to temperature coefficients.

T_t = The Normalized Temperature period in microseconds.

The sensor pressure, C_p, and temperature, C_t, sums can be read at real time using the LA3 command as can some of the intermediate calculated values. All values required for calibration and verification of the PCU or PSU performance are accessible through the LA3 command.

Periodic calibration is recommended to check and potentially adjust PCU or PSU offset and span. The Resonant Quartz transducer measures a force generated by external pressure and is also sensitive to force transmitted to the sensing element via acceleration or vibration. Calibration laboratories should be aware of this sensitivity and account for it using appropriate process and procedure. Temperature correction coefficients do not require adjustment and are valid for the life of the sensor.

HASS, High Accuracy Silicon Standard:

HASS Transducers contain a piezoresistive silicon sensor encapsulated within a temperature controlled housing. The sensor measures a true differential pressure applied between its positive and negative inputs and is typically ranged fifty (50) psid or less. Many HASS PCUs and PSUs were designed to operate at a “high line” condition; a condition or application characterized by a having a common mode pressure greater than one (1) Bar. HASS pressure standards have been rated for operation at 1, 4.5, or 10 Bar which can be determined by the model number of the PCU or PSU.

The output of the HASS sensor is a differential voltage proportional to the pressure applied and a single ended voltage proportional to sensor temperature. The pressure and temperature voltages output by the sensor are digitized using an A/D converter within the PCU or PSU. The excitation and A/D converter offset reading are also measured directly and used to ratiometrically correct the raw pressure and temperature voltages. The temperature and pressure ratios are then used to calculate the final pressure Engineering Unit measurement of the sensor.

The Pressure, Temperature, Excitation, and Zero values are A/D converter Counts, returned as 32 bit long integer values; the digital representation of the requested parameter. The Pressure counts are a function of the Pressure applied, the sensor Temperature, the sensor Excitation, and the A/D converter Offset. All four values are required to correctly calculate the Engineering Unit value for the pressure applied to the sensor.

> **Note:** It is not necessary to read the Excitation, A/D converter Offset, and Temperature signal every time a new pressure value is calculated. The A/D converter Offset and Excitation are only required on the first access of a PCU or PSU during a given data acquisition interval. They may change over relatively long periods measured in hours but reading these values on short intervals simply wastes bandwidth. The Temperature voltage must be read for each of the first two measurements of Pressure voltage to ensure closure of the Pressure Effect on Temperature calculation. The Temperature voltage must also be sampled at short intervals while the sensor is stabilizing to its operating temperature. Once the sensor temperature has achieved stability, the sample rate of the Temperature voltage can be reduced.

Appendix D: Continued

The first step in the process of calculating a new value is to normalize the Pressure and Temperature raw A/D counts for the current excitation and A/D offset.

$$C_{Tn} = (C_t - C_z)/(C_r - C_z)$$
$$C_{Pn} = (C_p - C_z)/(C_r - C_z)$$

Where:

C_r = sensor Excitation Counts

C_z = A/D converter Zero Counts

C_p = sensor Pressure Counts

C_{Pn} = sensor Normalized Pressure Counts

C_t = sensor Temperature Counts

C_{Tn} = sensor Normalized Temperature Counts

The next step in the process is to adjust the Normalized Temperature Counts for the applied pressure. The applied pressure is in psi units and should ideally be the pressure calculated previously.

If this is the first iteration of a calculated value for this sensor, then the value used for psi, **P_{prev}**, is set equal to 0.0, resulting in the application of just the offset term of the Pressure Effect on Temperature coefficients.

$$C_{Tc} = C_{Tn} - (X_0 + X_1 P_{prev} + X_2 P_{prev}^2)$$

Note: It is critical that the Pressure correction on Temperature be calculated twice when first accessing the sensor. This is done to assure that the temperature correction has converged to a stabile solution.

Where:

P_{prev} = 0.0 or the pressure in psi calculated in a previous iteration of this process.

X_0, X_1, X_2 = sensor Pressure Effect on Temperature **C_{Tn} =** sensor Normalized Temperature Counts

C_{Tc} = sensor Temperature Counts corrected for current pressure

Appendix D: Continued

Having calculated the pressure corrected temperature counts, the corrected pressure coefficients can now be calculated.

$$A=A_0+A_1C_{Tc}+A^2C_{Tc}{}^2+A^3C_{Tc}{}^3+A^4C_{Tc}{}^4$$
$$B=B_0+B_1C_{Tc}+B_2C_{Tc}{}^2+B_3C_{Tc}{}^3+B_4C_{Tc}{}^4$$
$$C=C_0+C_1C_{Tc}+C^2C_{Tc}{}^2+C_3C_{Tc}{}^3+C_4C_{Tc}{}^4$$
$$D=D_0+D_1C_{Tc}+D_2C_{Tc}{}^2+D_3C_{Tc}{}^3+D_4C_{Tc}{}^4$$
$$E=E_0+E_1C_{Tc}+E_2C_{Tc}{}^2+E_3C_{Tc}{}^3+E_4C_{Tc}{}^4$$

Note: The E group coefficients are used for a 4th order HASS sensor. The E group should be set to 0.0 for a 3rd order HASS sensor.

Where:

A_X, B_X, C_X, D_X, E_X = sensor Temperature Effect on Pressure coefficients

C_{Tc} = sensor Temperature Counts corrected for current pressure

A, B, C, D, E, = sensor Pressure coefficients corrected for Temperature

The Engineering Unit pressure can now be calculated.

$$P=A+BC_{Pn}+CC_{Pn}{}^2+DC_{Pn}{}^3+EC_{Pn}{}^4$$

Note: The E coefficient is used for a 4th order HASS sensor. The E coefficient should be set to 0.0 for a 3rd order HASS sensor.

Where:

A, B, C, D, E = sensor Pressure coefficients corrected for Temperature

C_{Pn} = sensor Normalized Pressure Counts

P = Engineering Unit output: Pressure in psi

Appendix D: Continued

Standards Laboratory correction values, are only applied to 4th order HASS sensors. They are stored as **J** group coefficients which must be set to nominal values for 3rd order HASS sensors.

$$P' = J_0 + J_1 P + J_2 P^2$$

Note: For 3rd order HASS sensors, the values of the **J** group coefficients are set to: $J_0 = 0$, $J_1 = 1$, $J_3 = 0$

Where:

P = sensor Temperature Corrected Pressure value

J_X **=** sensor Standards Laboratory Correction coefficients

P' = sensor Engineering Unit Pressure

The sensor pressure C_p, temperature C_t, excitation C_r, A/D converter offset C_z, can be read in real time using the LA3 command as can some of the intermediate calculated values. All values required for calibration and verification of the PCU or PSU performance are accessible through the LA3 command.

Periodic calibration is recommended to check and potentially adjust PCU or PSU offset and span. Temperature correction coefficients do not require adjustment and are valid for the life of the sensor.

Temperature Compensated Quartz Bourdon Tube Standard

For Quartz Bourdon Tube PCUs and PSUs, the applied pressure is calculated from the following simple equations. Temperature compensation is performed electronically internal to the Bourdon Tube sensor and not mathematically.

$$P=C+BC_p+AC_p^2$$

Where:

C_p = sensor Pressure Counts

P = sensor Pressure in psi

Quartz Bourdon units have no useful dynamic data. Raw data Cp must be obtained with Feature 4 of the LA3 command since a copy of it is not stored in the Coefficient Table.

Periodic calibration is recommended to check and potentially adjust PCU or PSU offset and span. The Quartz Bourdon Tube transducer measures a force generated by external pressure and is also sensitive to force transmitted to the sensing element via acceleration or vibration. Calibration laboratories should be aware of this sensitivity and account for it using appropriate process and procedure. Temperature correction does not require adjustment and is valid for the life of the sensor.

Appendix E

PCU and PSU Calibration Procedure

PCUs must have a minimum Firmware revision of 3.50.

PSUs must have a minimum Firmware revision of 8.00.

Note: Meas recommends that the performance of the Secondary Pressure Standard within each PCU and PSU be validated using a Primary Pressure Standard at six (6) month intervals.

Warning: Optimus PCUs and PSUs are designed for and compatible with Dry Gas. Do not use any medium other than Dry Gas for calibration of Optimus PCUs and PSUs.

This document describes the equipment and procedure necessary for calibrating Optimus PCUs and PSUs. The reader is advised to consult other resources to become familiar with the details of operating a traceable calibration laboratory having a certified quality control system. Suggested reading includes but is not limited to: ANSI Z540.3 and the ISO “Guide to the Expression of Uncertainty in Measurement”.

Measurement Specialties offers calibration services for the secondary standards used by Optimus. Measurement Specialties customer service department, regional sales managers, or distributors may be contacted directly for a quotation.

An Optimus PCU is a digitally controlled pressure generator in which a highly accurate Secondary Pressure Standard measures the pressure produced by the control mechanism. The Optimus PSU is a similar highly accurate pressure measuring device that does not incorporate the pressure generation mechanism of the PCU. Measurement Specialties calibrates each PCU and PSU at the factory, storing the coefficients within the units’ non-volatile storage. The instruments are usable directly upon receipt however it is common practice to calibrate them after they are delivered to the end user facility.

Specifications and Limits:

Absolute PCUs and PSUs are always evaluated based on the absolute error relative to the primary pressure calibration standard. No preliminary adjustment is made to the state of the instrument prior to performing the “As Found” pressure loading.

Differential PCUs and PSUs are expected to have been adjusted for offset, prior to performing the “As Found” pressure loading and also prior to recording of calibration data points. The Optimus System forces all differential PCUs and PSUs to perform internal Offset corrections prior to their use. This being the case, the Offset terms of Differential PCUs and PSUs should be monitored as an indicator of the health of the instrument. Intermittently or dramatically varying Offset errors must be evaluated, and their root cause eliminated even if the variation period is sufficiently long that it does not impact immediate operation.

Appendix E: Continued

A PCU or PSU is considered to be within tolerance if the “As Found” error is less than or equal to the accuracy limit summed with the product of the stability limit and the number of stability intervals since the last adjustment.

A_c = The Accuracy limit.
S_t = The Stability limit.
N_i = The number of Stability Intervals since last adjustment.
Tol = The Tolerance limit, “As Found”

$$Tol = A_c + (S_t \times N_i)$$

The instrument is permitted to be at the limit of its tolerance after adjustment, and is permitted to change by the stability limit over the course of the stability interval.

For Example:

An instrument having an accuracy specification of 0.01% of its Full Scale Range and a stability specification of 0.01% of its Full Scale Range for a six (6) month interval is within specification, “As Found”, if the absolute error at any calibration point before adjustment is less than or equal to the sum of 0.01% of the Full Scale Range for accuracy and 0.01% of the Full Scale Range for stability.

In this example, the maximum “As Found” error before adjustment after a single six month interval has elapsed is 0.02% of the Full Scale Range of the instrument.

An instrument having an accuracy specification of 0.01% of its Full Scale Range and a stability specification of 0.01% of its Full Scale Range for a six (6) month interval is within specification, “As Left”, if the absolute value of the residual errors of all calibration data points, after adjustment, are less than or equal to 0.01% of the Full Scale Range of the instrument.

In this example, the maximum “As Left” error after adjustment is 0.01% of the Full Scale Range of the instrument.

A PCU or PSU is considered out of tolerance if either the “As Found” or “As Left” condition exceeds the limits described above. Instruments which exhibit such errors should be evaluated to determine the root cause of the error and repaired or replaced as necessary.

Materials and Equipment:

A supply of dry gas

Bottled N2 or compressed air may be used interchangeably.

ISO 1873.1; A2, B2, C4 is to be used as a reference guideline for the limits of water content, oil content, and Dew point.

The recommendations of the primary calibration standard manufacturer may differ from the limits noted above. If so, the more stringent requirements take precedence.

A precise, stabile, pressure generation device.

For example a manual pressure controller consisting of a variable volume and regulator may be used to generate the calibration pressures.

An accurate Pressure Standard.

Measurement Specialties maintains several air piston gauges at our facility calibration laboratory.

A computer and software capable of communicating with and controlling the PCU and PSU via the Optimus System Processor.

Measurement Specialties does not provide software used to calibrate the PCU and or PSU. The commands and procedures used to perform this task are the subject of this document.

An Ethernet Switch through which the computer is connected to the Optimus System Processor.

An Optimus System Processor.

The System Processor provides communication to the calibration laboratory computer and calibration software.

An Optimus Remote Processor.

The Remote Processor:

Supplies power for the PCU and PSU

Provides a communication interface to the Optimus System Processor.

Provides a pneumatic interface to the PCU and PSU.

Blanking units are necessary to seal the unoccupied slots within the pneumatic interface rack of the Remote Processor.

Interconnection pneumatic assemblies, tubing, and fittings appropriate for the pressures being generated and applied to the PCU and PSU.

Appendix E: Continued

Calibration Procedure:

The process of calibrating Optimus PCUs and PSUs is not computationally intensive it does however require a meticulous and deliberate nature. The instruments themselves are influenced by the manner in which the operator handles them and a casual attitude and demeanor will generally produce marginal or deficient results.

The following is a description of the sequence of operations with some details included for clarity. The specific sequence of commands depends on the version of the PCU and PSU firmware and also the pressure standard that is within the PCU or PSU. The list of commands to be executed will be documented later in this appendix.

Start with power to the Remote Processor, RP, and Optimus System Processor, OSP, turned off.

Verify that:

The OSP is attached to the Network Switch.

The RP is connected to the OSP.

The PCU or PSU is installed within the rack of the RP.

The unused slots in the RP rack are filled with Blanking Units.

The Calibration Pressure generator is pneumatically connected to the appropriate port on the RP.

The Calibration Pressure Standard is connected to the Calibration Pressure generator.

For PCUs having a full scale pressure range equal to or greater than 200 PSIA. A special manual ball valve is present in the case to bypass the solenoid valves when calibrating. It must be set before the PCU is installed in the Remote Processor Rack. Verify that the valve is set to the 'RUN' position after the calibration process is completed.

Turn on the RP power followed by the OSP power.

Wait for the system to indicate ready on the front panel LEDs.

Establish a TCP/IP connection using the calibration software

Configure the item under test

A PCU requires a valid PC1 command

In addition, valves K3, K4, and K5 must be set properly.

A PSU requires a valid PS1 command

In addition, valve K1 must be set properly.

Change the integration time or number of samples to average; dependent on the PCU or PSU pressure standard type, Reference Coefficient Term (-26) in Appendix D, Table 1.

HASS and Mensor; Set Term (-26) = 2000 sample average

Vibrating Quartz beam; Set term (-26) = 12000 sample integration

Wait for a minimum two (2) hours for the instrument to warm up under this condition.

While the instruments are warming up, create a pressure loading table; a list of the pressure points that will be applied to the instrument and, if an air piston gauge is being used, the weights that will be loaded onto the piston to determine the set pressure.

Measurement Specialties typically uses:

A minimum of 11 pressure points.

All pressure points are Approached from the same direction; below with no overshoot.

Pressure points are spread evenly across the span of the instrument.

For Absolute standards, vibrating quartz beam type, the zero (0) intercept is always calculated. The lowest pressure point must be greater than or equal to 1% of instrument Full Scale Range.

For absolute standards with full scale ranges 100 psia and greater, the largest calibration pressure point shall be 15 psia above full scale. e.g. for a 100 psia PCU the largest calibration point will be 115 psia.

Example pressure tables for selected PCUs and PSUs are located at the end of this appendix.

Sequentially apply the pressures from the loading table to the PCU or PSU standard.

Read the value from the PCU or PSU continuously at a one (1) Hz rate while the pressure is being applied. The maximum Read rate of a PCU or PSU configured for calibration is one (1) Hz.

Calculate the standard deviation of the last ten (10) consecutive readings to qualify the stability of the system.

Standard Deviation for Vibrating Quartz beam PCU and PSU shall be less than 0.0003.

Standard Deviation for HASS or Mensor PCU and PSU shall be less than 0.003.

If the Standard deviation is within the required limits, use the mean for the "Indicated" pressure.

Record the “True” pressure of the Calibration Standard and the “Indicated” pressure from the PCU or PSU.

Set the next pressure point.

After applying the calibration pressure sequence and recording the output of the PCU or PSU, determine the “As Found” status of the instrument.

Calculate the error for each calibration point.

Evaluate the error of each point relative to the specified limits.

Return the integration time or number of samples to average to the default value; dependent on the PCU or PSU pressure standard type, Reference Coefficient Term (-26) in Appendix D, Table 1.

HASS and Mensor; Set Term (-26) = 500 sample average

Vibrating Quartz beam; Set term (-26) = 2000 sample integration

After verifying that the Unit is in tolerance, “As Found”, determine the “As Left” status of the instrument.

Calculate the new coefficients.

Evaluate the residual error at each calibration point relative to the specified limits.

Application Development:

The calibration application must perform each of the tasks listed in the flow chart to the right.

Discover:

Commands Used: “psi9000”, “LA4”

Either prompt the user to enter the IP Address of the system and the CRS of the installed instruments or perform an Automatic discovery using the UDP broadcast discovery command and probe for Remote Processors and the instruments installed. The UDP broadcast command “psi9000” will return the system IP Address and status. After establishing a TCP/IP socket connection, the “LA4” command is used to probe for the presence of an RP and the instruments installed within the slots of the RP.

Configure:

Commands Used: “PC1”, “PS1”, “PC3”, “PS3”, “LA3”, “CV0”

Once the system components, PCUs and PSUs, have been identified they must be configured for operation. The “PC1”, for a PCU, or “PS1”, for a PSU, command is sent to each discovered instrument; even if it is not going to be calibrated immediately.

The discovered instruments are then queried to determine their standard type and pressure range. The “LA3” command is used to read features -27, for Pressure Standard Type, and -28, for Full Scale Pressure Range. The PCU and PSU coefficient table documenting the features of the instruments is located in Appendix D.

The PCU or PSU internal valves must be placed in the correct state in order to apply pressure to the internal standard via the calibration port on the back of the Remote Processor chassis. The “CV0” command is used for this purpose. Review the pneumatic drawings of the PCU and PSU for the default state of the internal valves. The pressure standard must be isolated from the pressure generation circuitry; Valve K3 must be “open” i.e. not permitting passage of gas. Also, the reference port of the unit must be isolated from the measurement port; Valve K4 must be “open” i.e. not permitting passage of gas.

Note: “High Range” PCUs incorporate a manually operated ball valve in order to “by pass” the K4 and K5 valves during calibration. For consistency the K4 and K5 state should still be set by the application.

Appendix E: Continued

Once the physical configuration of the pneumatics is accomplished the instruments integration period or number of samples to average must be increased to achieve the necessary resolution and stability for calibration. The “LA3” command is used to read the current value via feature -26, typically 500 for HASS standards and 2000 for Quartz standards. The “PC3” or “PS3” command changes the value of the integration period or number of samples to average via term 26. Reference the PCU and PSU coefficients in Appendix D for the default values for the integration period or number of samples to average.

Note: The sign of the Term used in the “PC3” and “PS3” command is positive and that the sign of the Feature used in the “LA3” command is negative.

Reminder: The value for integration and averaging must be returned to the default operating value before returning the unit to service. If the calibration settings remain in effect, the unit will be slow to respond in service and will likely be identified as faulty.

Once the PCU or PSU is configured, the unit must be allowed to achieve a stabile temperature. Temperature stability is critical even if the pressure standard is temperature compensated. For HASS or temperature compensated quartz transducers, the temperature can be read directly from the PCU allowing the application to determine stability. A temperature stability of 0.01 C per minute is required, with the temperature of the pressure standard limited to 0.1 C over the period of the calibration. The temperature of the pressure standard is accessible using the “LA3” command with Feature -20.

Acquire Data:

Commands Used: “LA3”

Data acquisition during calibration is accomplished using the “LA3” command. A minimum of ten (10) measurements is required at each calibration data point. Calculate the arithmetic Mean and the Standard Deviation of the Error for the ten (10) values. The Standard Deviation must not exceed 0.0003 for quartz vibrating beam standards or 0.003 for HASS and Mensor standards.

“LA3” Feature:

HASS uses “LA3” Feature 1, units PSI

Temperature Compensated Quartz uses “LA3” Feature 1, units PSI

Un-Compensated Quartz uses “LA3” Feature 2, units Counts

Mensor uses “LA3” Feature 2, units Counts

Acquire one temperature reading using the “LA3” command Feature (-20) at each pressure point to verify that the standard temperature does not change by more than 0.01 ˚C per minute and 0.1 ˚C over the calibration duration.

Note: If a data point continually exceeds either the Standard Deviation limit or Temperature rate of change limit, stop the calibration and determine the root cause of the issue.

Appendix E: Continued

Process and Evaluate Data:

The absolute error at each calibration point is evaluated relative to the accuracy and drift specifications for the instrument. If the initial evaluation finds that the instrument is in tolerance, new coefficients are calculated that correct the instrument to the calibration laboratory standard.

Evaluate the initial, “As Found”, condition of the instrument:

Reference the data sheet for the accuracy and stability specifications for the unit.

For every calibration data point, calculate the difference of the instruments Indicated Pressure and the Calibration Laboratory Standards True Pressure. The absolute value of that error must be less than or equal to the accuracy limit summed with the product of the stability limit and the number of stability intervals since the last adjustment.

P_{meas} = The Pressure Measured by the instrument under test.

P_{true} = The Pressure Measured by the Laboratory Pressure Standard.

A_C = The Accuracy limit.

S_t = The Stability limit.

N_i = The number of Stability Intervals since last adjustment.

Tol = The Tolerance limit, “As Found”

$$Tol = A_c + (S_t \times N_i)$$

$$Tol \geq |P_{meas} - P_{true}|$$

Perform a regression of the data to derive the coefficients as described below.

Appendix E: Continued

HASS: Third order correction

Use the true pressure and measured pressure values to derive a first order fit for the data.

$$P=Cal_1X+Cal_0$$

Where:

Cal_0 = The Offset Term

Cal_1 = The Span Term

Referencing the table in Appendix D, use the “OP6” command to retrieve the twenty (20) following HASS coefficients:

A_0 through **A_4** = Indices four (4) through eight (8)

B_0 through **B_4** = Indices nine (9) through thirteen (13)

C_0 through **C_4** = Indices fourteen (14) through eighteen (18)

D_0 through **D_4** = Indices thirty-two (32) through thirty-six (36)

Apply the corrections to the coefficients.

Add the offset adjustment to HASS coefficient A0.

$$A_0=A_0+(-Cal_0)$$

Multiply the remaining coefficients by the Span Adjustment.

$$Coef_n=Coef_n\times 1/Cal_1$$

Write the HASS coefficients back to their respective memory locations using the “PC3” command.

Appendix E: Continued

HASS: Fourth Order correction

Use the true pressure and measured pressure values to derive a first order fit for the data.

$$P=Cal_1X+Cal_0$$

Where:

Cal_0 = The Offset Term
Cal_1 = The Span Term

Referencing the table in Appendix D, use the “OP6” command to retrieve the three (3) following HASS coefficients:

J_0 through **J_3** = Indices fifty-four (54) through fifty-six (56)

Note: J2 and J3, indices fifty-five (55) and fifty-six (56) are set to zero (0) and are reserved for future expansion.

Apply the correction to the coefficients

Add the Product of the Offset and Span adjustments to the J0 term.

$$J_0=(-Cal_0/Cal_1\times 1/Cal_1)+J_0$$

Multiply the J1 term by the Span adjustment

$$J_1=1/Cal_1 \times J_1$$

Write the HASS coefficients back to their respective memory locations using the “PC3” command.

Appendix E: Continued

Quartz bourdon Tube:

Use the true pressure and A/D Counts values to derive a second order fit for the data.

$$P = X^2 Cal_2 + X Cal_1 + Cal_0$$

Where:

Cal_0 = The C Term

Cal_1 = The B Term

Cal_2 = The A Term

Referencing the table in Appendix D, use the “OP6” command to retrieve the three (3) following Mensor coefficients:

A, B, and C = Indices one (1) through three (3)

Write the Mensor coefficients back to their respective memory locations using the “PC3” command.

Appendix E: Continued

Non-Temperature Compensated Quartz:

Use the true pressure and the inverse resonator period values to derive a second order fit for the data.

$$P=X^2Cal_2+XCal_1+Cal_0$$

Where:

Cal_0 = The Offset Term

Cal_1 = The Span Term

Cal_2 = The Squared Term

Calculate an initial value for the intercept; τ_Z.

$$\tau_z=(-(p_{min}-\tau_{min}(\Delta p/\Delta\tau)))/(\Delta p/\Delta\tau)$$

Where:

p_{min} = Min(TruePressure)
τ_{min} = Min(Tau)
Δ**p** = Max(TruePressure)-Min(TruePressure)
Δ**τ** = Max(Tau)-Min(Tau)

Calculate the two solutions, t_A and t_B, for the quadratic equation below using coefficients Cal_0, Cal_1, and Cal_2. Select t_A or t_B as the true value for t_0 based on the minimum absolute value of the differences; $\tau_A-\tau_Z, \tau_B-\tau_Z$.

$$\tau_0=(-Cal_1\pm\sqrt{(Cal_1^2-4Cal_2Cal_0)})/(2Cal_0)$$

If $|\tau_B-\tau_Z|<|\tau_A-\tau_Z|$ then $\tau_0=\tau_B$ else $\tau_0=\tau_A$

Calculate Beta and Alpha using Tau and the Coefficients Cal2, Cal0

$$\beta=(-Cal_2)/\tau_0^2$$
$$\alpha=\beta+Cal_0$$

Referencing the table in Appendix D, use the “OP6” command to retrieve the two (2) following Quartz coefficients:

α, ß, and **τ_0** = Indices one (1) through three (3)

Write the Quartz coefficients back to their respective memory locations using the “PC3” command.

Appendix E: Continued

Temperature Compensated Quartz:

Use the true pressure and measured pressure values to derive a first order fit for the data.

$$P=Cal_1X+Cal_0$$

Where:

Cal_0 = The Offset Term

Cal_1 = The Span Term

Referencing the table in Appendix D, use the “OP6” command to retrieve the three (3) following Quartz coefficients:

C_1 = Index five (5)

D_1 = Index eight (8)

T_1 = Index ten (10)

Calculate new values for C_1 and T_1 using the old values for C_1, D_1, T_1, and the coefficients Cal_0 and Cal_1.

$$T_1=T_1-(-Cal_0T_1/(2C_1))$$
$$C_1=(C_1+(-Cal_0\ )(1+1.6D_1)/(1-0.2D_1))/Cal_1$$

Write the Quartz coefficients back to their respective memory locations using the “PC3” command.

Appendix E: Continued

Appendix F

System Error Codes

2	Command Parse / Verify	-- Empty Line --
3	Command Parse / Verify	Illegal Command ID
4	Command Parse / Verify	Bad Data Type
5	Command Parse / Verify	Parameter is Missing
6	Command Parse / Verify	Value Too Low
7	Command Parse / Verify	Value Too High
8	Command Parse / Verify	Upper Range Too Low
9	Command Parse / Verify	Upper Range Too High
10	Command Parse / Verify	Upper Val < Low Val
11	Command Parse / Verify	Bad Name for Parameter
12	Command Parse / Verify	Need Integer Number
13	Command Parse / Verify	Need Floating Point
14	Command Parse / Verify	Illegal CRS
15	Command Parse / Verify	CRS Defined Different
16	Command Parse / Verify	CRS Should Be Odd #
18	Command Parse / Verify	Bad Sensor Port #
19	Command Parse / Verify	Bad Upper Port #
20	Command Parse / Verify	Upper Port # < Lower Port #
21	Command Parse / Verify	Bad Scanner #
22	Command Parse / Verify	Bad ESP #
23	Command Parse / Verify	0nly ESP Are Allowed
25	Command Parse / Verify	Bad Upper Scanner #
27	Command Parse / Verify	Bad Logical Range
29	Command Parse / Verify	Legal Values = 0 - 1
30	Command Parse / Verify	Legal Values = 0 - 2
31	Command Parse / Verify	Illegal Voltage Defined
32	Command Parse / Verify	To Many Parameters
37	Command Parse / Verify	Non-Volatile Memory Empty
39	Command Parse / Verify	Non-Volatile Memory Error
44	Command Parse / Verify	Use OD3/OD4 Command
53	Command Execute	No Modu1e this CRS
54	Command Execute	Module Defined Different
55	Command Execute	CRS Not OFIU
57	Command Execute	CRS Not PCU
58	Command Execute	No Module to Initialize
59	Command Execute	Module Not Initialized
60	Command Execute	SD1 or SD2 Not Executed
62	Command Execute	PC1 Not Executed
66	Command Execute	Too Many Sensors
67	Command Execute	Sensor Not Defined

Appendix F: Continued

68	Command Execute	Ports (Limit l024)
69	Command Execute	Port Not Defined
71	Command Execute	PCU LRN Undefined
72	Command Execute	Bad Property Type
74	Command Execute	Data Table Not Defined
75	Command Execute	SDU Table Not Defined
78	Command Execute	No CONTINUOUS Acquisition
80	Command Execute	DATA Not Acquired
81	Command Execute	Too Many DATA Packets
82	Command Execute	Data Acquisition Aborted
84	Command Execute	Calibration Running
85	Command Execute	Pressure Not Reached
86	Command Execute	CAL Pressure Undefined
87	Command Execute	No Calibration Data
88	Command Execute	Bad Data Some Ports
89	Command Execute	No Calibration Coefficients
90	Command Execute	Calibration Aborted
91	Command Execute	Calibration Not Running
107	Command Execute	Command w/o Effect
108	Command Execute	Bad Output Format
109	Command Execute	Exe. Not Implemented
112	Host IO	Bad Message to Host
113	Host IO	DMA Output Error
114	Host IO	Low Memory
115	Host IO	Input Line Too Long
162	BP/LS/RP Communication	Did Not Find ZLEAD
163	BP/LS/RP Communication	BP Transmission Short
165	BP/LS/RP Communication	Module Fail Line ON
166	BP/LS/RP Communication	BP Upload Timeout
167	BP/LS/RP Communication	BP Upload DMA Fai1
168	BP/LS/RP Communication	Module Fail Line ON
169	BP/LS/RP Communication	BP Download Timeout
170	BP/LS/RP Communication	BP Down DMA Fai1
175	BP/LS/RP Communication	LS Transmission Wrong
176	BP/LS/RP Communication	LS Output Timeout
177	BP/LS/RP Communication	LS DMA Error
178	BP/LS/RP Communication	LS Input Timeout
180	BP/LS/RP Communication	LS Checksum Error

Appendix F: Continued

181	BP/LS/RP Communication	LS No Module At CRS
185	BP/LS/RP Communication	RP Lost Command
186	BP/LS/RP Communication	RP No Response
187	BP/LS/RP Communication	RP No Module At CRS
188	BP/LS/RP Communication	RP Bad Synchronize
189	BP/LS/RP Communication	RP Bad or No Data
190	BP/LS/RP Communication	RR Bad DOWN Checksum
191	BP/LS/RP Communication	RP Bad or No Data
203	BP/LS/RP Communication	Bad Module Packet Header
221	Memory Management	Empty Message Pool
222	Memory Management	No Contiguous Memory
225	Memory Management	Bad Packet Type

Appendix G

System Drawings

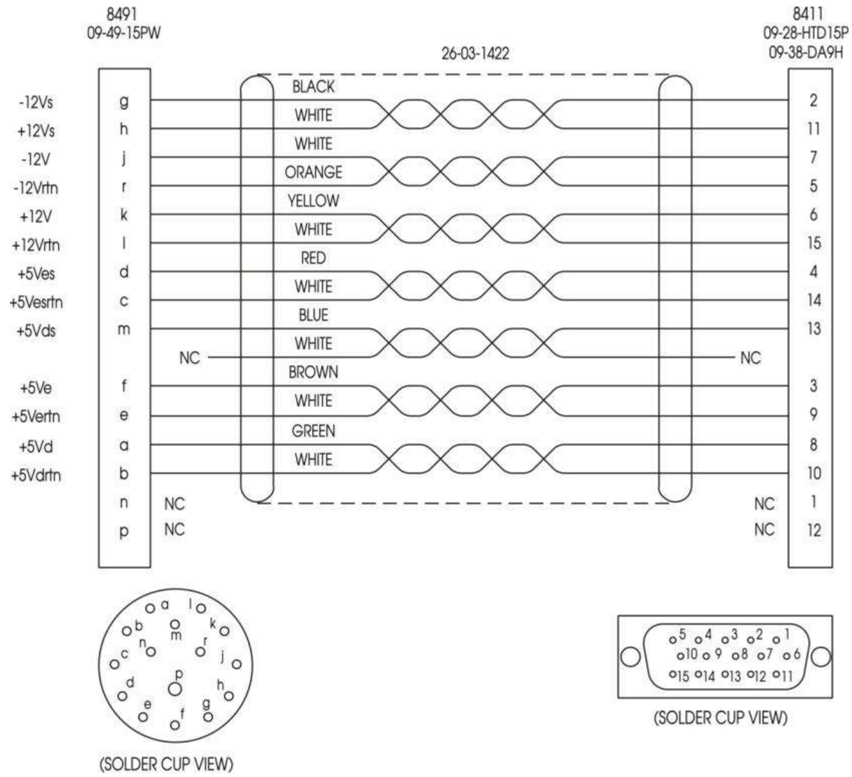


Figure 11.1 RPS to mSDI Power Cable; Type A wiring diagram

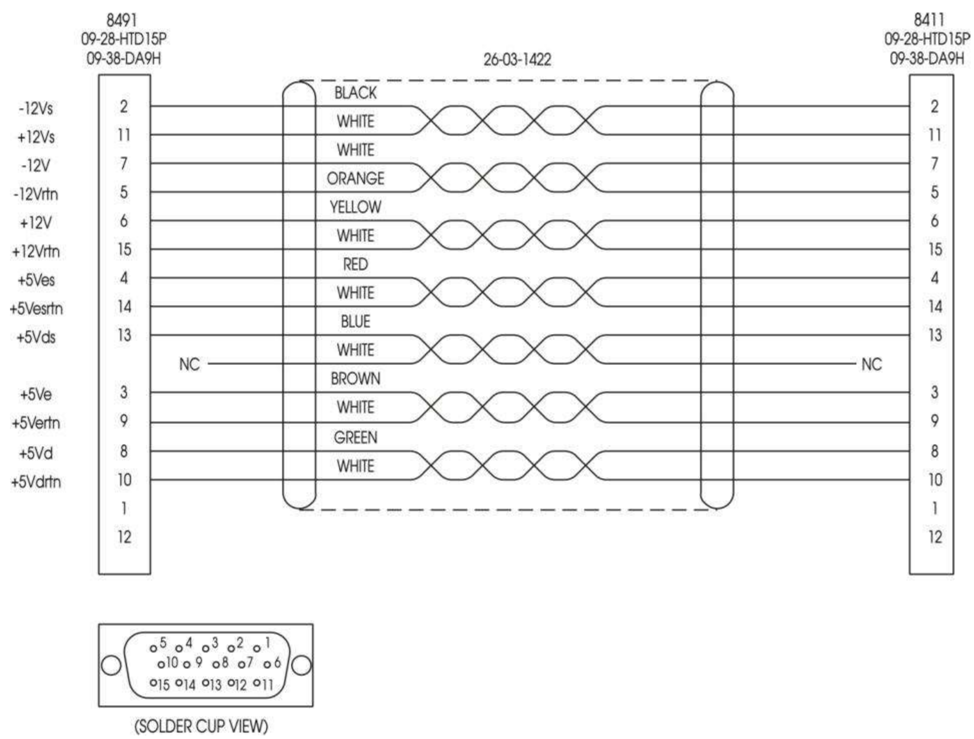


Figure 11.2 RPS to mSDI Power Cable; Type B wiring diagram

Appendix G: Continued

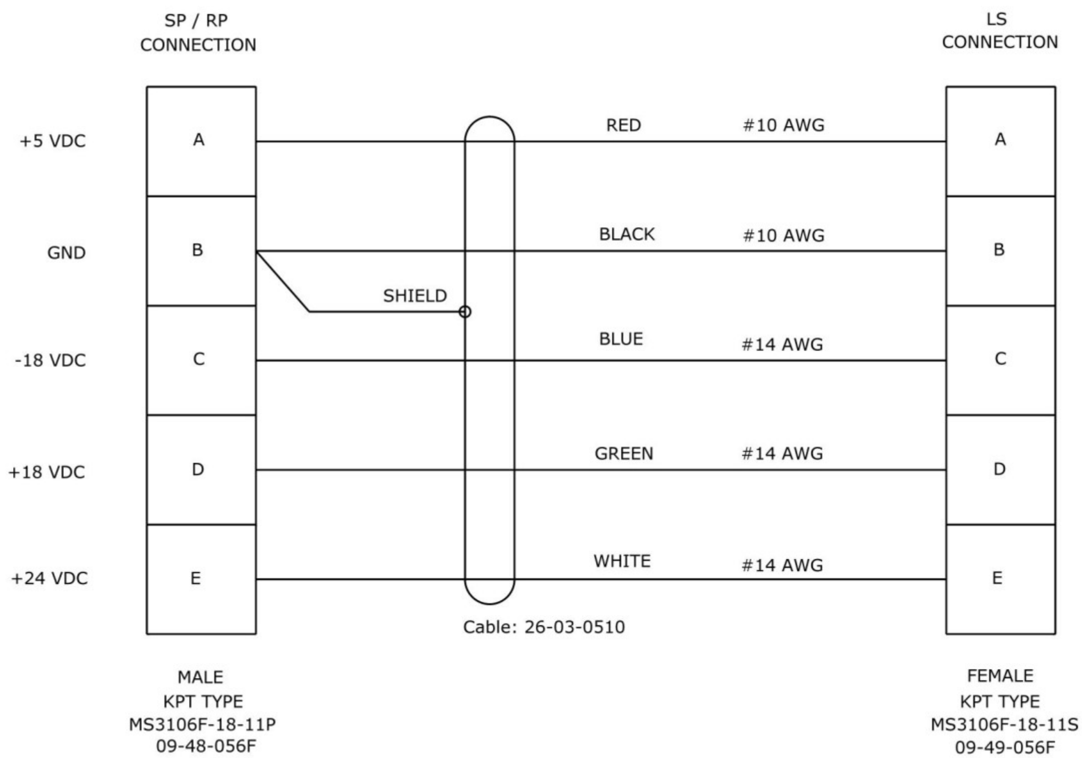


Figure 11.3 RP to LS Power Cable wiring diagram

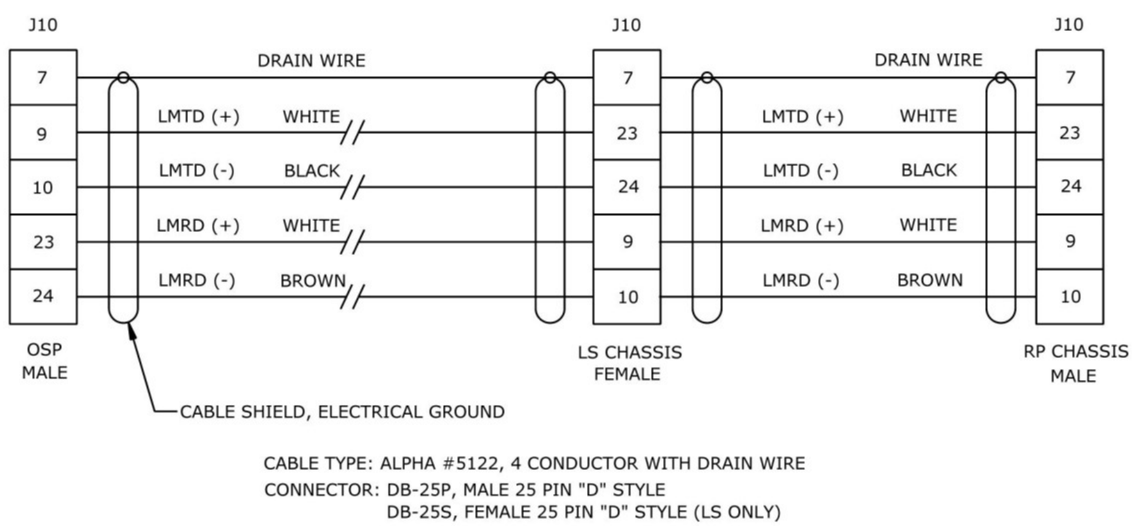


Figure 11.4 OSP to RP Communication Cable wiring diagram

Appendix G: Continued

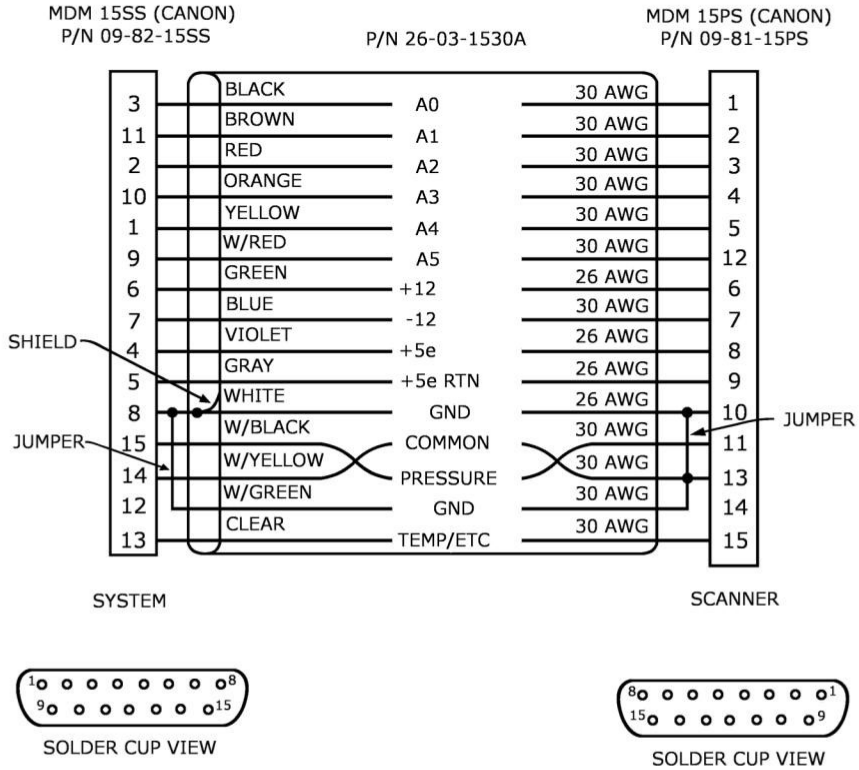


Figure 11.5, mSDI to ESP scanner; the OSCB Cable wiring diagram

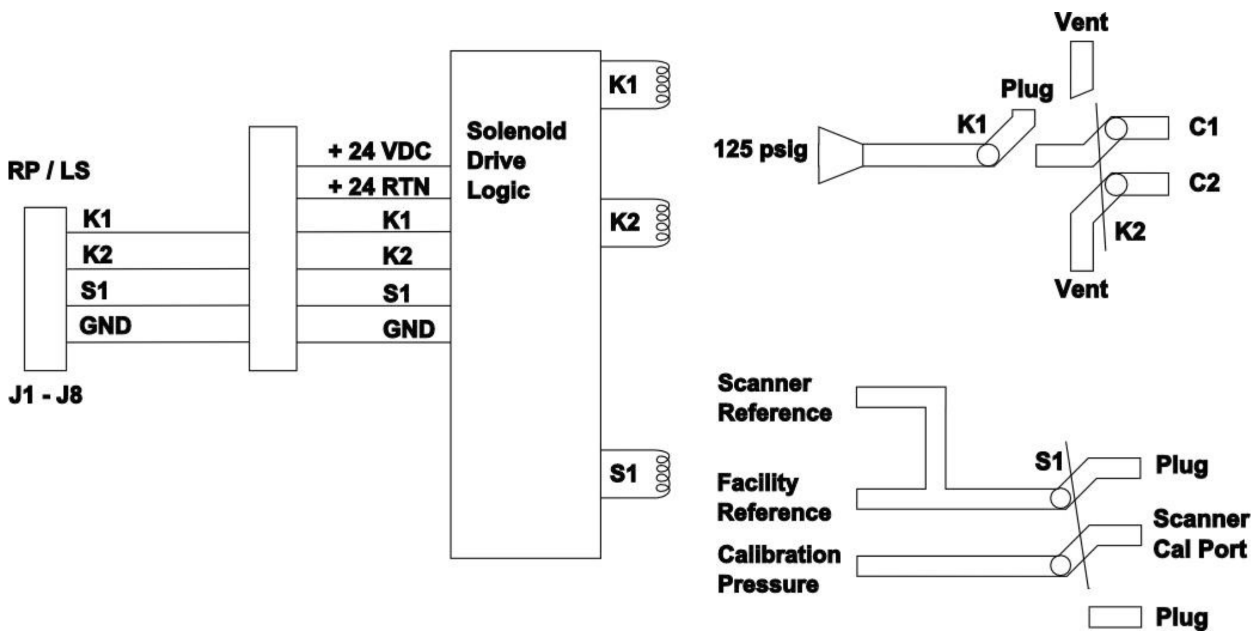
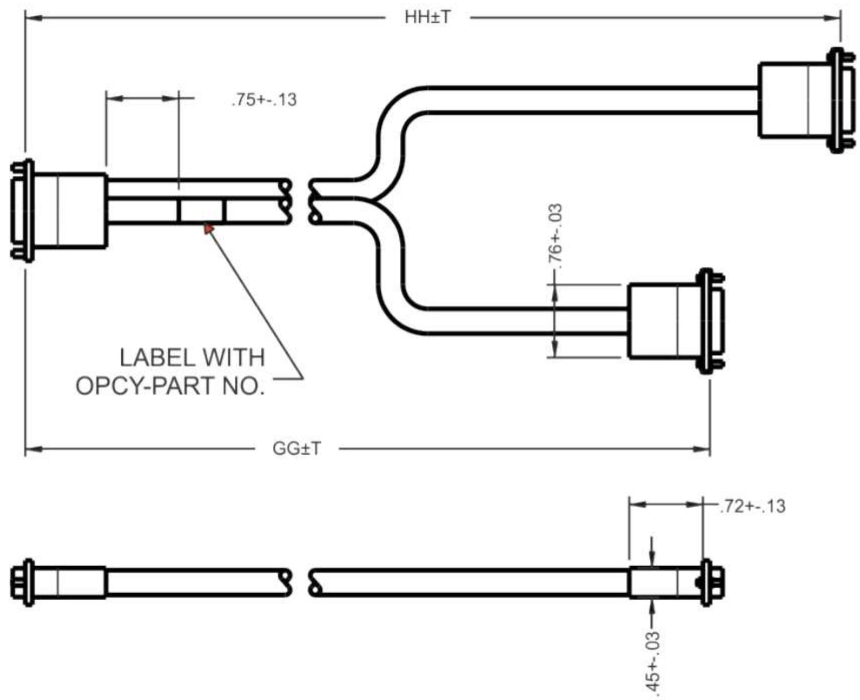


Figure 11.6, 84sa External Valve Control assembly

Appendix G: Continued



OPCY P/N	UNITS	UNITS LABEL	MIN LENGTH GG	MAX LENGTH GG	MIN LENGTH HH	MAX LENGTH HH	LENGTH TOLERANCE "T"
OPCY-00000GGHH	FEET	f	01	03	01	03	0.5"
OPCY-010000101	METERS	m	01	01	01	01	02cm
OPCY-02000GGHH	INCHES	"	06	39	06	39	0.5"
OPCY-03000GGHH	CENTIMETER	cm	15	99	15	99	02cm

Figure 11.7, Optimus 'Y' Cable OPCY

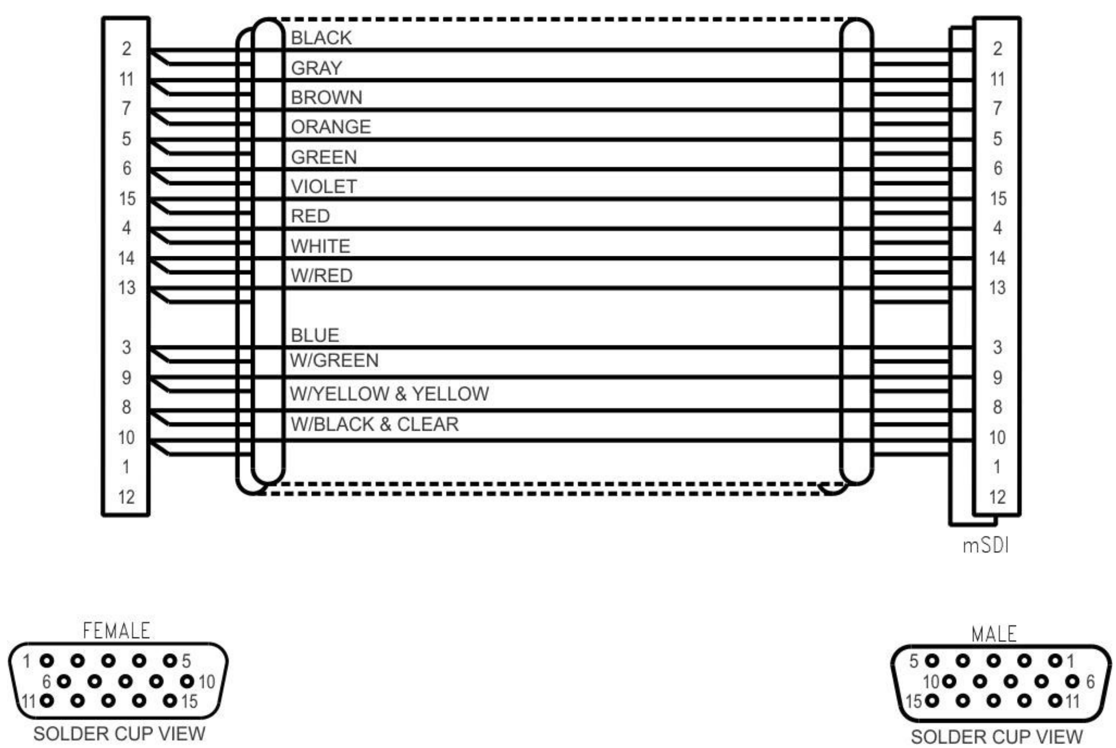


Figure 11.8, Optimus 'Y' Cable wiring diagram

Appendix G: Continued

Appendix H:

Revision History

Revision 0.0: August 2014, Prerelease

Revision 1.0: February 2015

Removed reference to Acquire and Store Data (AD1)

Removed reference to Clear All Acquired Data (OD0)

Removed reference to Output Selected Stored Data (OD1)

Removed reference to Output SP Storage Capacity (OD3)

Revision 1.1: March 2015

Added Appendix Y to document CE Compliance Requirements

Documented the Inclusion of Appendix H: The Revision History

Documented Appendix Z: The Open Source statement.

Revision 1.2: August 2015

Modified the documentation of the SP5 command.

Changed the description of the "Date" field from four (4) digits to two (2) digits, making it conform to the 8400 structure.

Revision 1.3: July 2016

Changed Font and Graphics to conform with new requirements.

Added the SP6 command to support NTP synchronization.

Added the SP7 command to support OFIU timing configuration.

Added the SP8 command to support DHCP.

Added the SP9 command to support PTP synchronization.

Added the AD1 command to Acquire and Store Data.

Added the OD0 command to Clear All Acquired Data.

Added the OD1 command to Output Selected Stored Data.

Added the OD3 command to Output SP Storage Capacity.

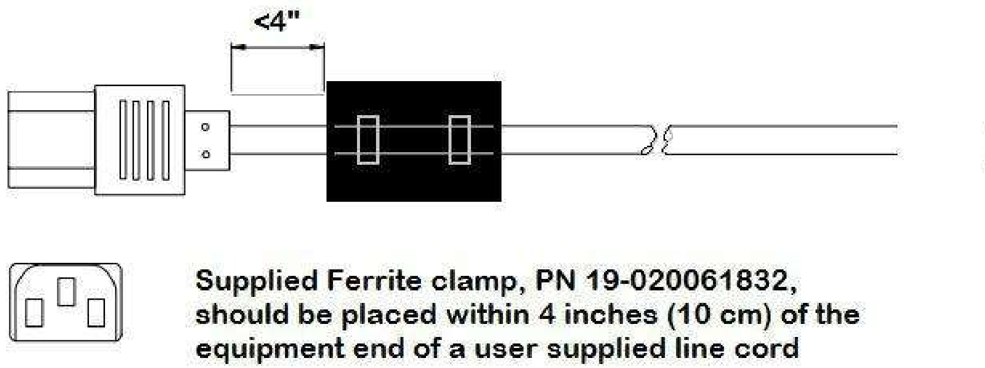
Revision 1.4: June 2021

Removed SP9 command.

Added the SP10 command to support OFIU synchronization.

Appendix Y:

Optimus is shipped with a power cord suitable for (Mains) AC Power connection in North America. A Ferrite clamp, which is necessary for CE compliance, has been attached to the supplied power cord. A second, spare, clamp is included with the Optimus packaging in order that the end user can apply this required component to a power cord suitable for use outside of North America. Attach the Ferrite clamp to the AC power cord as illustrated below.



Appendix Z

Optimus, as an application and system, is built upon dedicated hardware which utilizes the features and benefits of the Linux operating system and all of the attendant packages included within a typical installation or distribution. The Aerodynamic Research Group freely distributes all source code and configuration files according to the applicable License Agreements. If a copy of these documents is not found on the company web site, contact the Aerodynamic Research Group directly for the latest version.