MillScan

DSP2000

STATE-OF-THE-ART DIGITAL INSTRUMENTATION

**DIGITAL
CONTROL
LAB**

MillScan

DSP2000

Installation Manual

DIGITAL
CONTROL
LAB

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Introduction   Chapter 1

1.1. Product overview

MillScan DSP2000 is based on the latest floating point digital signal processing (DSP) microprocessor technology. It takes into account the mill shell vibration intensity, its frequency spectrum distribution and several important phase measurements. A combination of these parameters computed through a proprietary complex algorithm yields a considerable improvement in system accuracy.

MillScan DSP2000 is based on highly accurate vibration transducers with extremely flat frequency response curves for vibration analysis. By means of digital signal processing techniques, the shell vibration signals are transformed into digital format and the material fill level can be estimated accurately without interference from adjacent mills by analyzing the energy/frequency/phase content using numerous 'state of the art' DSP techniques.

Software for controlling the system consists of an easy-to-use graphical interface that aids in setting up the system configuration, instrument calibration, real-time operation and data trending. These form the essential steps towards generating a mill system that operates very efficiently. The graphical interface provides all the data required by an operator in a clear concise manner and is constantly updated in real-time.

MillScan DSP2000 allows you to store frequency spectrum measurements for future reference and detailed analysis in order to fine-tune the specifics of each mill.

MillScan DSP2000 offers such precise measurement of the level of material that it can be used not only for the material flow estimates but also for direct control of the mill feed. You can also setup an instrument network using a central monitoring personal computer.

For further information about how MillScan DSP2000 works and comparative product information, see Appendix A.

1.2. Contact information

If you have any technical questions or need to reach a sales representative, contact:

Digital Control Lab, LLC   +1.352.692.0800
3739 W. University Ave.   +1.352.692.0900 Fax
Gainesville, FL 32607   1.866.499.7651 Toll-free
                                            Support@digitalcontrollab.com
                                            Sales@digitalcontrollab.com

1.3. Package contents

Your MillScan DSP2000 package includes the following items:

- MillScan Base unit
- MillScan Remote unit
- Powering unit which includes Heat Sinks and a Connection board
- JB weld for securing Heat Sink magnets to mill shell (including brushes and stirring sticks)
- Two Vibration Sensors that connect to the Remote unit
- Antenna and Cable for Base unit
- Extra magnets to hold Vibration Sensor cables and Power cables to mill
- RS232 cable to connect from the PC to the Base unit for initial configuration and calibration
- Installation software CD which includes manual.

Installation   Chapter 2

2.1 Installing the base unit

The base unit must be installed on a wall free of vibrations, usually in the electrical room.
The most important component of the base unit is the antenna system. The antenna must
be installed outside the electrical room, and have a line of sight to the remote unit
installed on the mill shell. The maximum RF system communications range is 150 meters
in open ground and does not require an FCC license to operate.

Wiring the power cable

1. Wire your power cable to the AC Power In on the Base Unit as shown:

AC Power In

X = AC Line L
Y = Ground
Z = AC Line N
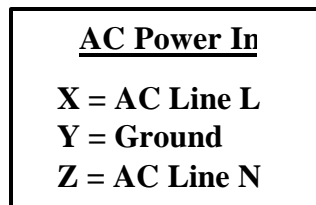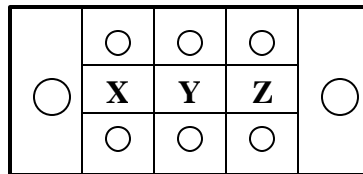
The supplied base antenna and coaxial cable <u>MUST NOT</u> be cut or extended because its length
is determined by the RF link frequency (418 MHz.) wavelength, RF Connectors must be tighten
carefully to avoid any damage.

Your system comes fully wired. However, a detailed wiring diagram showing analog
outputs, digital inputs and digital outputs is included in Chapter 4, Section 4.2 on page
23, for your reference.

The MillScan DSP2000 Windows^{TM} monitoring and configuration software is designed to configure, calibrate and monitor the DSP2000 system. The software runs on Windows 95, 98, NT 4.0, and 2000 and requires a RS232 serial communication port.

3.1 Installing the software

1. Exit all Windows programs.
2. Run SETUP.EXE on the installation software CD.
3. You can install the software on any directory of your choice. System configuration defaults are set for a complete DSP2000 system configuration using four nodes with all data channels enabled.

If you receive an access violation error for a file that is already on your PC, simply skip installing that file.

4. Connect serial cable from your PC serial port to the base unit RS232 port.
5. Start the MillScan DSP2000 software from Start/Programs/DSP2000.

If you get an RS232 serial communication error:
1. Make sure that the serial cable is plugged into the base from the PC.
2. Make sure that the power is on the base. You should see the base unit's LED display cycle through 0, 1, 2, 3….
3. If you get the error again after checking the above, you will need to configure the DSP2000 software to use a different serial port following the steps in this next section.

Configuring the serial port

To configure the serial port, you will need to modify a parameter on the file DSP2000.INI located under the software installation directory.

1. Close MillScan DSP2000 software
2. Open any text editor such as notepad.exe
3. Open DSP2000.INI in the install directory (C:\Program Files\DSP2000)
4. You will see the following: *default is port=1 (COM1)*

    [commport]
    port=1

5. Change port number to 2 as follows:
   [commport]

   port=2

6. Save file and exit editor.

7. Reopen MillScan DSP2000 software from Start/Program/DSP2000

8. if you continue to receive a port error, redo steps 1 through 7 above and change port number to Port=3, port=4, etc. until software runs without error message.

All serial communication parameters (Baud rate, data bits, parity, etc) are automatically configured by the software.

⚠ Please be sure to save the file as a text file ONLY. DO NOT save it using a word processing software (WORD, etc.) default format (.DOC). Those software packages include text formatting data into the file that might destroy system configuration data.

3.2 Configuring the system

1. Start the software package and the PC will establish a communication link to the DSP2000 base unit. The *Base DSP Unit* LED located on the bottom status line will turn green indicating serial communications are OK. See Figure 3.1

2. Start the system configuration tool by clicking on the **wrench tool** on the tool bar or *System Setup* from the main menu.
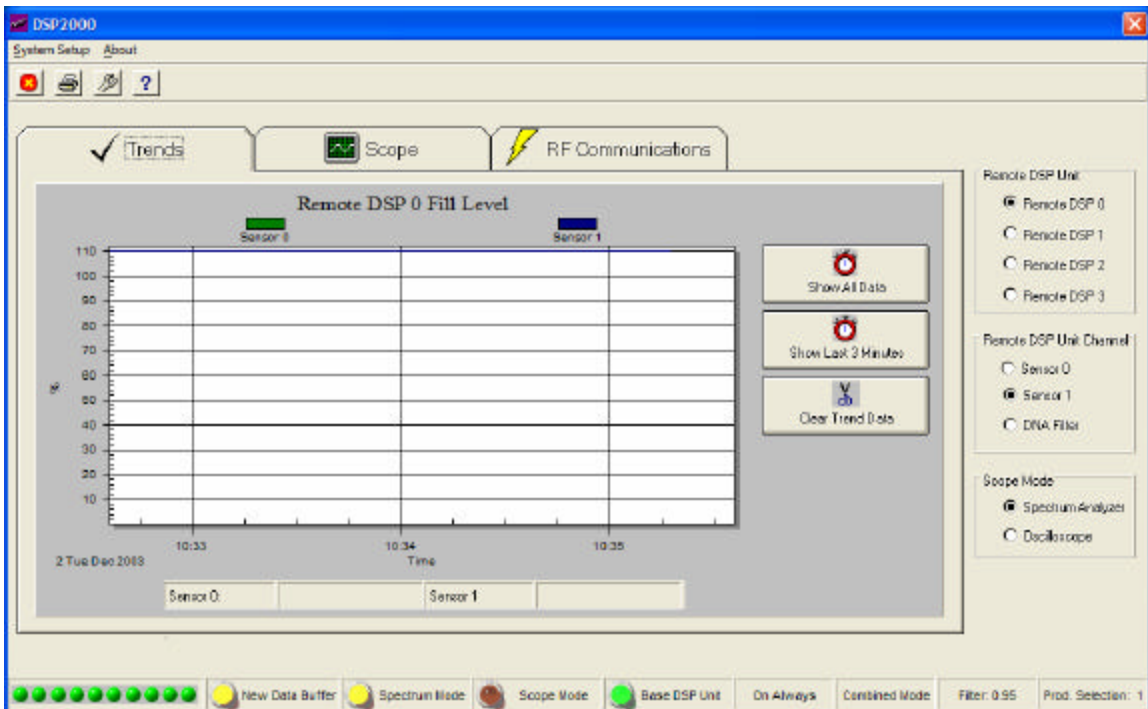
Main system setup

Figure 3.1 Software Startup Main Screen

Figure 3.2 shows the main system setup screen. Follow these steps.

1. Enter the plant name.
2. Mark the appropriate check boxes for each remote unit nodes available on your system.
3. Before clicking any Nodes configuration tab: Click **Save to Disk** under the **Nodes Configuration** frame located on the upper right part of screen.
4. Click **Yes** to Overwrite current system configuration file.
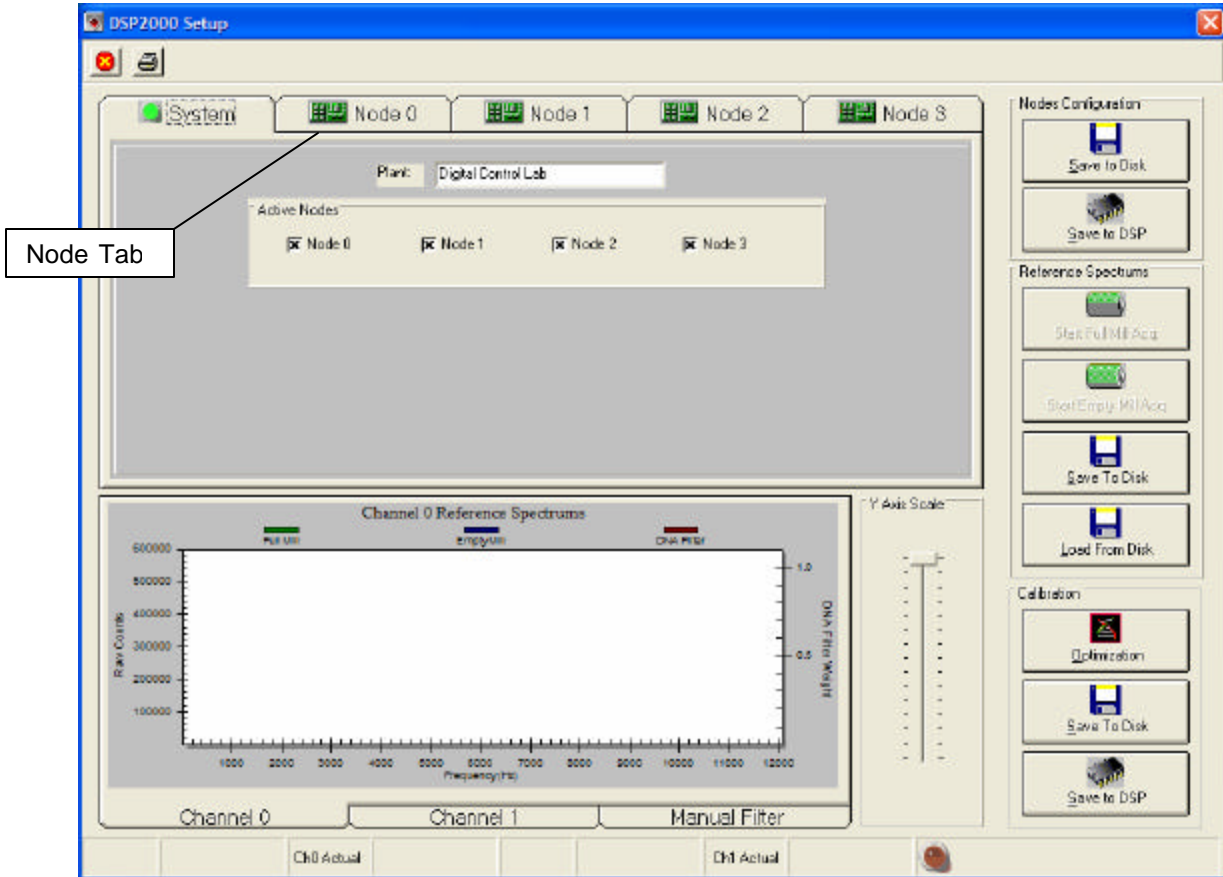

Figure 3.2 Main Setup Screen

Node setup

Click on the Node tab, Figure 3.3, to select the remote unit node you want to configure and follow these steps.

1. Enter node name.
2. Enter description.
3. Choose a product from the drop down menu under the **Select Product** frame
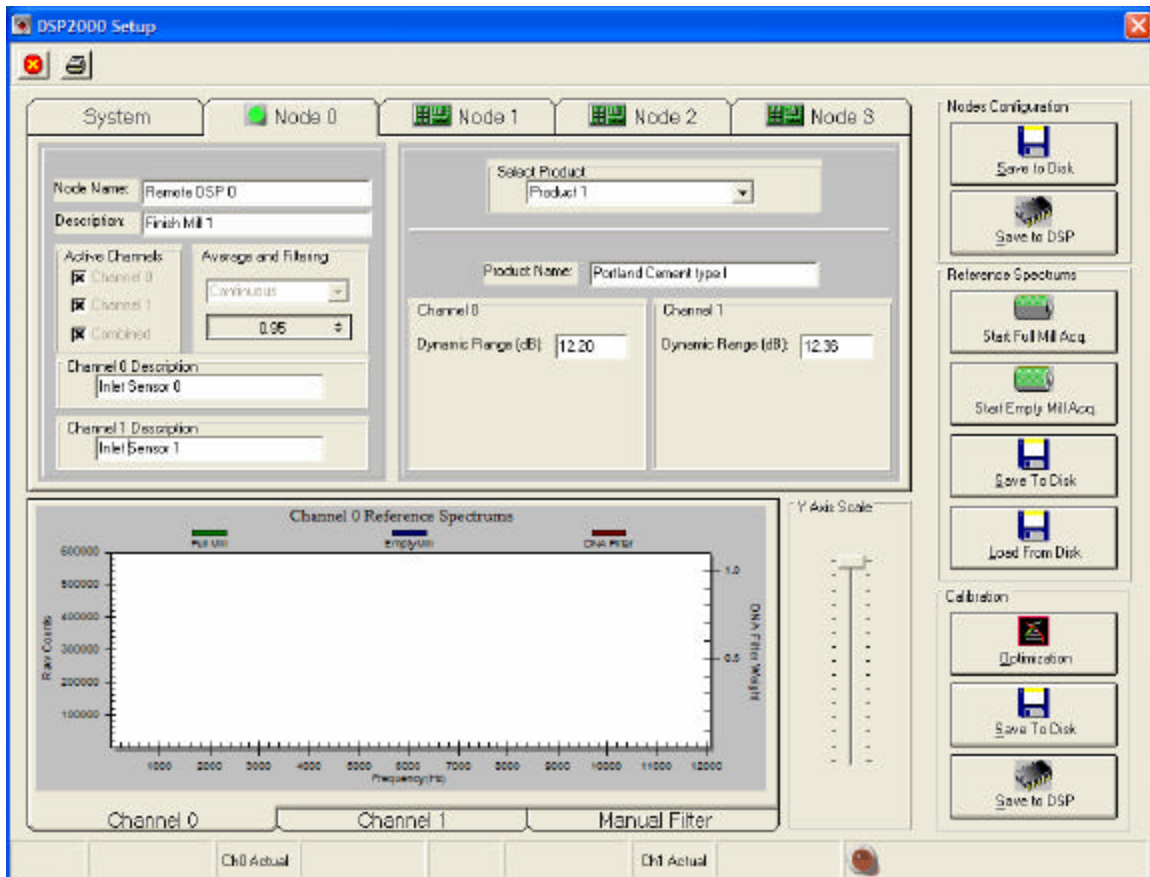
Figure 3.3 Main Setup Screen – Node Tab

The DSP2000 system allows five different product calibration curves per remote unit. These calibration curves can be used if the mill produces different products, and are selected via the base unit's digital inputs.

4. Enter product descriptions under **product name** for each **Selected Product**.
5. Click **Save to Disk** under the **Nodes Configuration** frame located on the upper right part of the screen before clicking any other nodes configuration tab. This stores the current node configuration to disk.
6. Repeat Steps 1-7 for each Node on your system.

7. Once all nodes have been configured, click **Save to DSP** under the **Nodes Configuration** frame located on the upper right part of the screen.

8. The software will ask for confirmation, hit **Yes** and the new system configuration will be stored on the base unit's EEPROM memory. During the EEPROM storing operation, you will see an Ex indication on the base unit's LED display, where $x=0$ to 3 corresponding to the node-number data is being stored for.

9. Verify that the base unit's LED display cycles through node 00, 01, 02, 03.

10. Repeat for additional nodes and then close the System Setup window.

This completes the system setup operation.

3.3 Installing the remote unit, power source and vibration sensors

Before installing the remote unit on the mill shell, we recommend to first test the RF communication subsystem. This is done by placing the remote unit on the floor near the mill shell and ensuring the following.

Testing the RF communication subsystem

1. Connect remote unit to power source with supplied power cable.

2. In the Main window, click RF Communications tab.

3. Verify that the node LEDs are "on" for all nodes you have configured on your system.
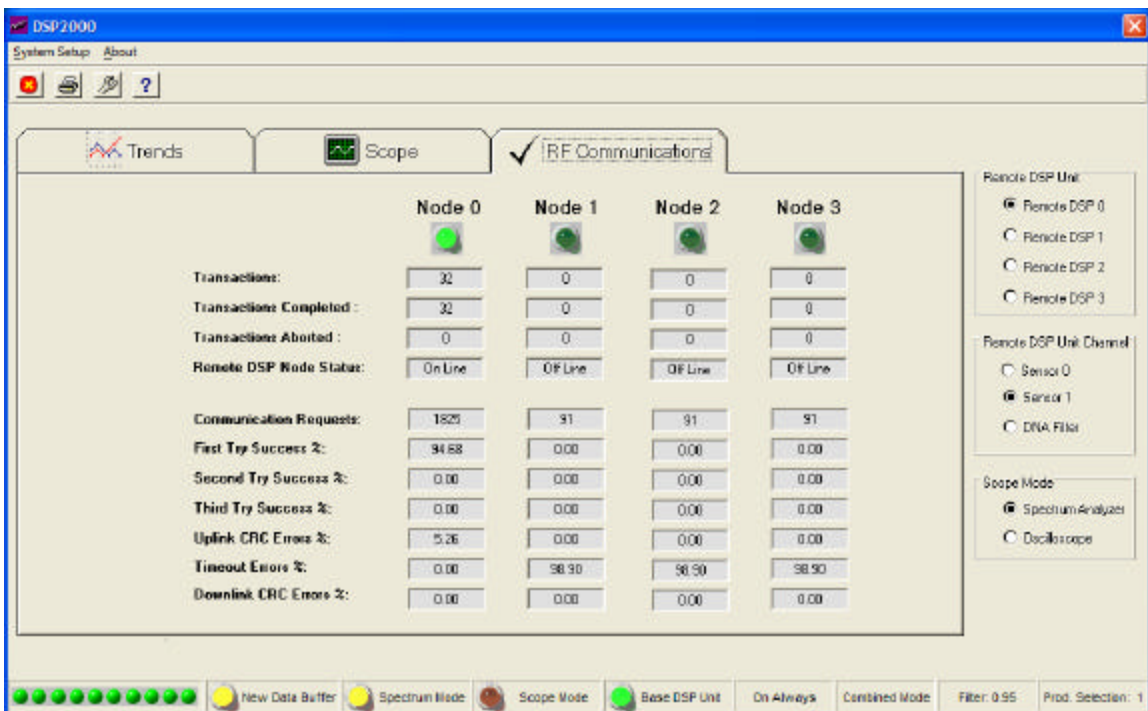
Figure 3.4 RF Communications Screen

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Mounting the remote unit and power source onto the mill

The remote unit, power source and vibration sensors come equipped with high weight capacity magnets for easy installation. Follow these instructions.

1. First magnetically mount remote unit onto inlet chamber of the mill shell.

2. Next mount heat sinks on warmest part of mill shell. **Apply a bead of JB Weld around magnet for extra security.**

3. Connect each heat sink to the connection board as shown in picture on page 13.

4. Connect power cable from connection board to Remote Unit. Use extra magnets to keep cable in place across mill.

5. Connect sensors to remote and position them equal distances from each other so that they are 180 degrees apart.

6. Once unit is secured on mill shell, check the RF Communication subsystem once again.
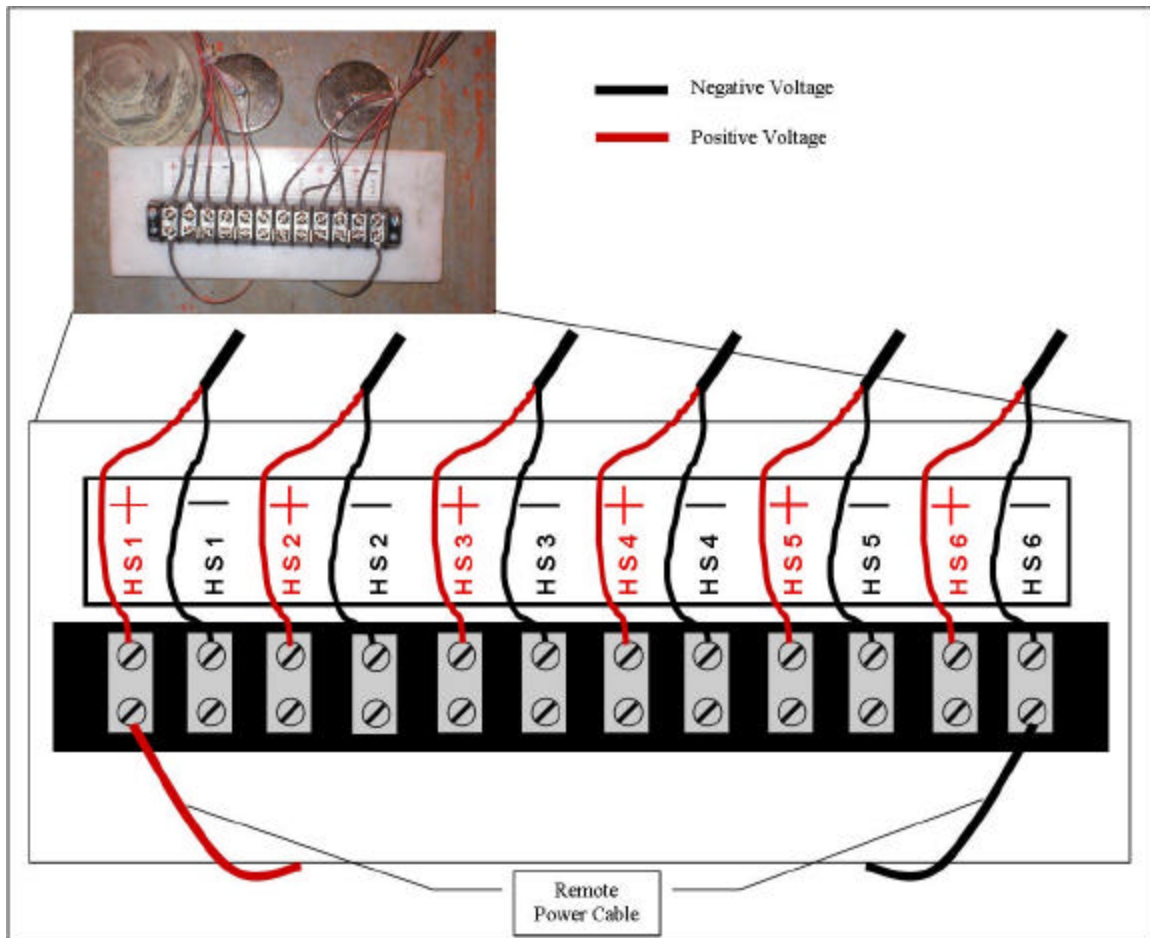
3.4 Calibrating the System

System calibration is an operation that tailors the instrument to the physical frequency characteristics of every single mill. The instrument calibration is performed on the system setup screen (which was used earlier to configure the nodes).

Overview

The mill concerned is first run full in order to acquire the (quiet) full state reference spectrum (corresponding to 100% fill level), and is then run empty in order to acquire the (loud) empty state reference spectrum (corresponding to 0% fill level).
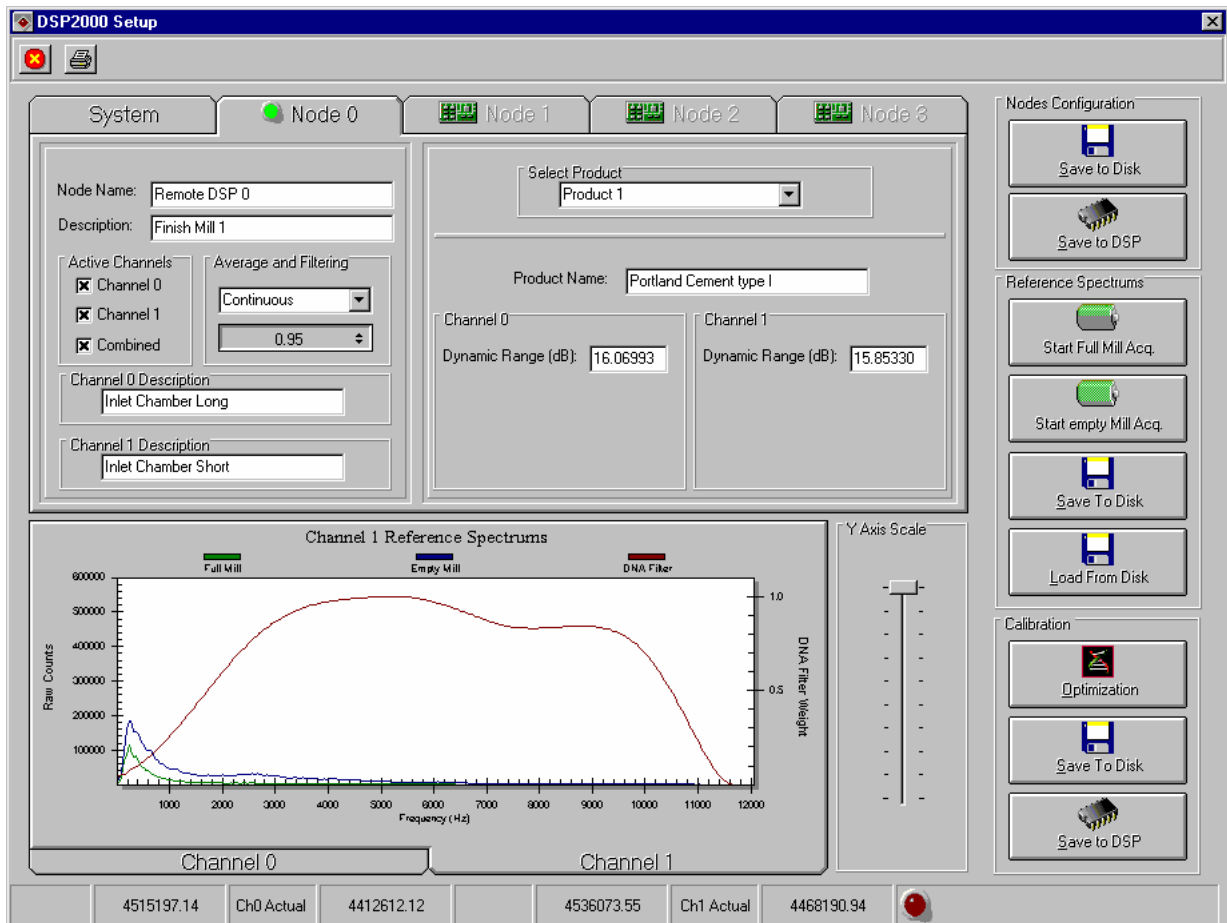

Figure 3.5 Main Setup Screen – Node Tab

100% Full reference spectrum acquisition

The system's calibration procedure is performed as follows:

1. Open the system configuration software tool by clicking the **wrench tool** on the tool bar or **System Setup** from the main menu.
2. Click on the appropriate tab to select the remote unit node to be calibrated.

3. Select the product number or calibration curve you want to calibrate by selecting it from the drop down list in the **Select Product** frame.

4. The mill should now be filled to the highest level possible as determined by an operator.

⚠ It is important that your mill be filled to optimum capacity before you continue with step 5.

5. Once mill is full, click **Start Full Mill Acq.** under the **Reference Spectrums** frame located on the middle right part of screen.

When you are setting the 100% full reference spectrum, the DSP2000 system calibration algorithm adaptively searches for the lowest energy spectrums.

The energy values are shown on the configuration screen status line at the bottom of the window. **Ch0 Prev, Ch1 Prev** are the minimum spectrum energy values found during the full calibration. **Ch0 Actual, Ch1 Actual** are the present spectrum energy values.

⚠ During the full calibration, you are interested in the lowest spectrum energy measurement. When you observe that **Ch0 Prev, Ch1 Prev** no longer change, you have found the minimum spectrum values and can now proceed to step 6.

6. Click **Stop Full Mill Acq.** under the **Reference Spectrums** frame located on the middle right part of screen.

7. Click **Save To Disk** under the **Reference Spectrums** frame located in the middle right part of screen.

8. The software will ask for confirmation, hit **Yes** and the new 100% full mill reference spectrum will be stored to disk.

The reference spectrums for the mill in 100% full state have been properly acquired. We can now proceed to acquire and store the 0% empty reference spectrum.

0% Empty reference spectrum acquisition

1. The mill should now be emptied to the lowest level possible as determined by an operator.

2. Click **Start Empty Mill Acq.** under the **Reference Spectrums** frame located on the middle right part of the screen.

When you are setting the 0% reference spectrum, the DSP2000 system calibration algorithm adaptively searches for the maximum energy spectrums.

The energy values are shown on the configuration screen status line at the bottom of the window. **Ch0 Prev, Ch1 Prev** are the maximum spectrum energy values found during the empty calibration. **Ch0 Actual, Ch1 Actual** are the present spectrum energy values.

	During the empty calibration, you are interested in the highest spectrum energy measurement. When you observe that **Ch0 Prev, Ch1 Prev** no longer change, you have found the maximum spectrum values and can now proceed to step 3.

3. Click **Stop Empty Mill Acq.** under the **Reference Spectrums** frame located on the middle right part of screen.

4. Click **Save To Disk** under the **Reference Spectrums** frame located on the middle right part of screen.

5. The software will ask for confirmation, hit **Yes** and the new empty mill reference spectrum will be stored to disk.

	Load From Disk allows a user at a future date to see what the calibration spectrums were.

Optimizing the calibration

Once the full and empty reference spectrum have been acquired, we need to calculate the calibration curve that maximizes the instrument's performance. The DSP2000 uses a **D**ynamic **N**eural **A**lgorithm to determine an optimal solution to this optimization problem.

1. Click **Optimization** under the **Calibration** frame located in the lower right part of screen.

2. The software will ask for confirmation, hit **Yes.**

	Depending on the computer's processor speed, this may take up to 5 minutes. The optimization process shows the resulting instrument's dynamic range in decibels for both data acquisition channels.

3. Click **Save To Disk** under the **Calibration** frame located on the lower right part of screen.

4. The software will ask for confirmation, hit *Yes* and the new optimized calibration curve will be stored to disk.

5. To finish the calibration procedure, hit **Save to DSP** under the **Calibration** frame located on the lower right part of screen.

6. The software will ask for confirmation, hit *Yes* and the new calibration curve will be stored on the base unit's EEPROM memory, during the EEPROM store operation you will see an "Ex" indication on the base unit's LED display, where $x = 0$ to 3 corresponding to the node.

7. The LED display will then indicate the version number of the software showing that the system has rebooted.

	The Y Axis scale changes the graphics Y axis scale so the user can easily compare signal magnitudes between both data acquisition channels.

8. Close Setup Window software.
9. Check that the base unit's LED display is running through the nodes acquisition. On the LED display, "Ax" stands for acquiring on a particular node, where $x = 0$ to 3 corresponding to a node. When the base is reset, "dx" is shown on the display to indicate the base is loading configuration information for each node from the EEPROM; where $x = 0$ to 3 corresponding to the node.

Repeat Section 3.4 for each of your different nodes and products.

Monitoring   Chapter 4

For process monitoring, you can use MillScan DSP2000 software or a 4-20mA device.

4.1 Using the software

The software includes two options for viewing instrument data, **Trend Mode** and **Scope Mode**, and one option for monitoring the **RF Communications** statistics.

The bottom status line shows instrument's specific information:

- **- New Data Buffer**: LED turns Yellow when a new data buffer exists on the base unit memory and is waiting to be downloaded and plotted on scope mode.
- **- Spectrum Mode**: LED turns Yellow when data acquisition is in Spectrum analyzer mode.
- **- Scope Mode**: LED turns Yellow when data acquisition is in oscilloscope mode.
- **- Base DSP Unit**: LED turns green when valid RS232 data link has been established.
- **- On Always**: Indicates the sampling is continuous
- **- Combined Mode**: Indicates both sensors are being used.
- **- Filter**: Shows level of filtering used
- **- Product Selection**: product type being run. Very important to verify with what was calibrated.
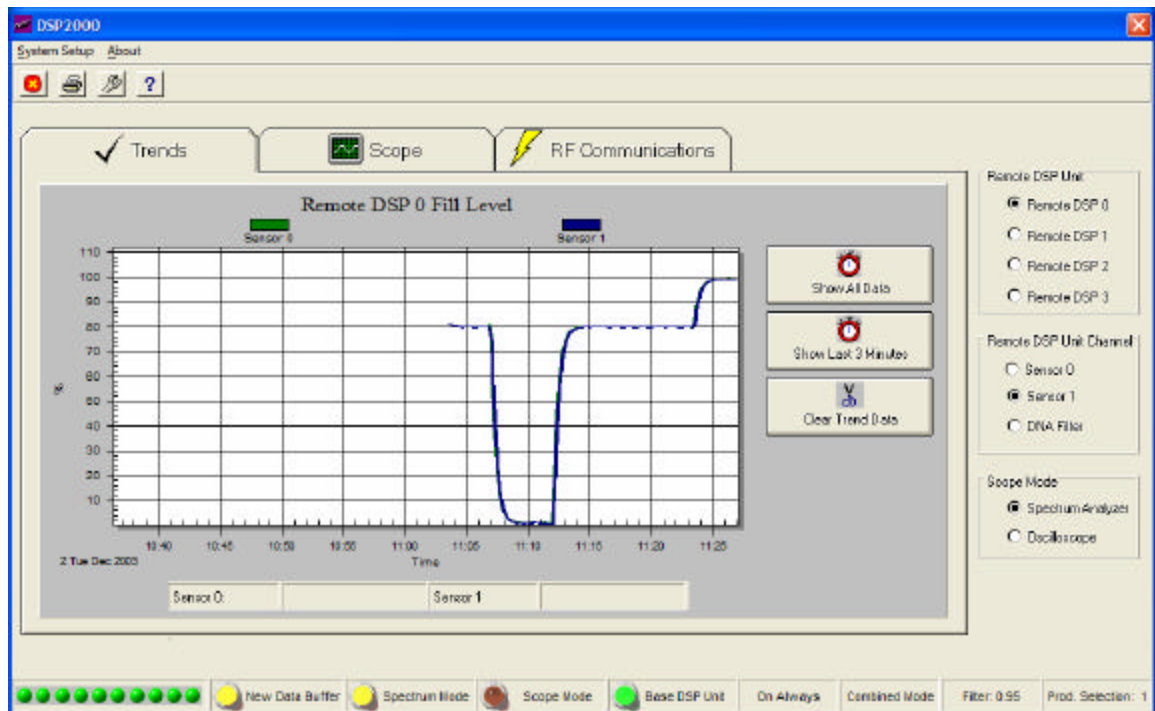
Figure 4.1 Trends Screen

Trend mode

Figure 4.1 also shows the fill ratio trend display for the selected node.

The **Remote DSP Unit** frame selects the remote unit for which the fill ratio trend display will be updated. If you select a different node while the display is being updated, the graph will be cleared and a new trend plot will be displayed. Clicking the mouse over a trend line will update the fill ratio values on the **Trends** tab.

Clicking **Show all Data** will display data contained on the graphic's internal buffer (600 samples).

Clicking **Show last 3 Minutes** will display only the last 3 minutes samples contained on the graphic's internal buffer.

If you want to reset the information on the trends window, close and reopen software.

Scope mode

This shows the spectrum for the selected node and data acquisition channel.

Figure 4.2 Scope Screen

Clicking **Signal Snapshot** will download and display the current data frame on the base unit memory, clearing the new data buffer flag. Clicking the mouse over a spectrum line will update the data values on the scope tab.
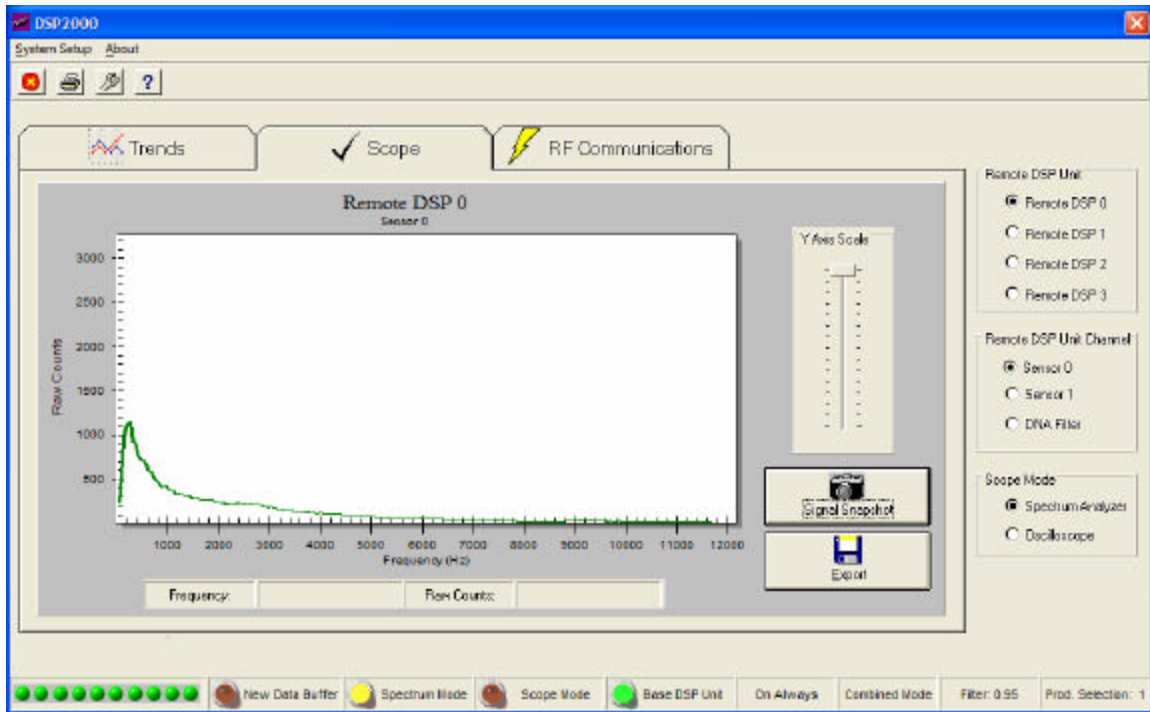
The Y Axis scale slider changes the graphics Y axis scale so you can easily compare signal magnitudes between both data acquisition channels.

RF communications mode

This shows the RF communication mode detailed statistics display. This display allows you to easily monitor and diagnose the RF communication system performance.
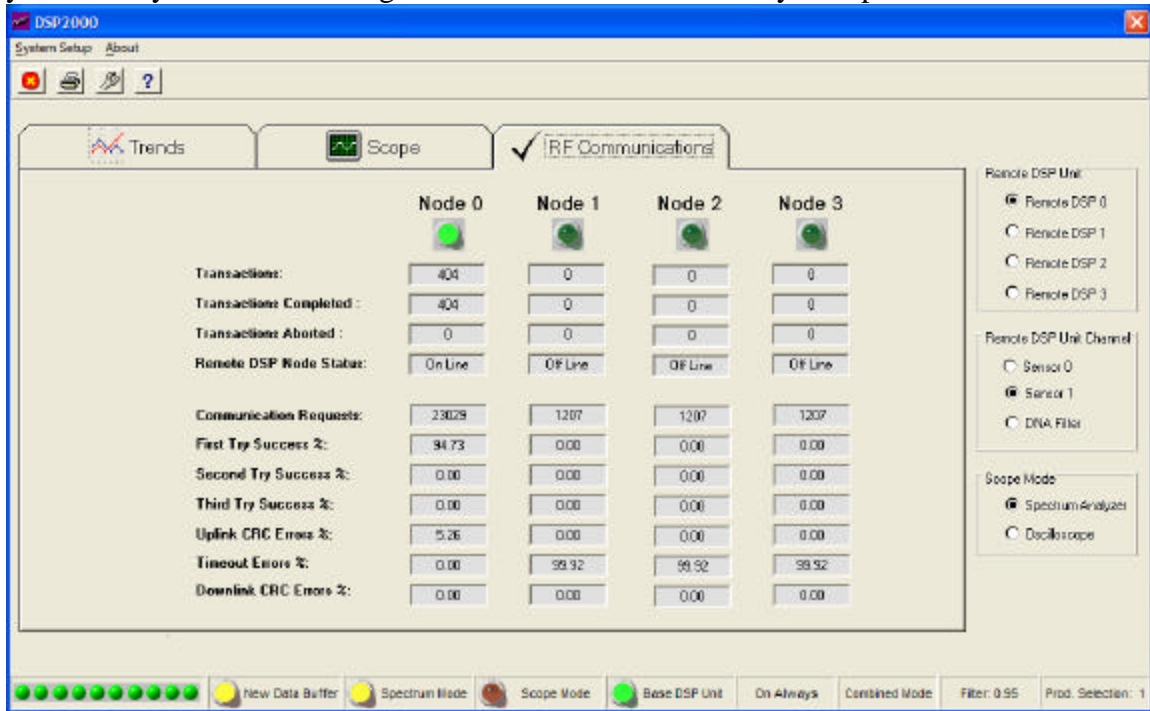
Figure 4.3 RF Communication Screen

- **Transactions** : This is the amount of complete data downloads tries per remote unit.

- **Transactions Completed**: This is the amount of completed data downloads per remote unit. This number should be as close as possible to Transactions field as it indicates a healthy RF subsystem.

- **Transactions Aborted**: This is the amount of aborted data downloads per remote unit.

- **Remote DSP Node Status** : This field indicates if remote unit is On line or Off line.

- **Communications requests**: This is the amount of data packets transmitted to a remote unit.

- **First Try Success %:** Successful data packet exchange at first try.

- **Second Try Success %:** Successful data packet exchange at second try.

- **Third Try Success %:** Successful data packet exchange at third try.

- **Uplink CRC Errors %:** CRC data communication error on the base unit to remote unit path.

- **Downlink CRC Errors %:** CRC data communication error on the remote unit to base unit path.

4.2 Using 4-20mA monitoring, product selection and loss of communication warnings

See diagram for the location of the 4-20mA signals.

Figure 4.4 RF Communication Screen

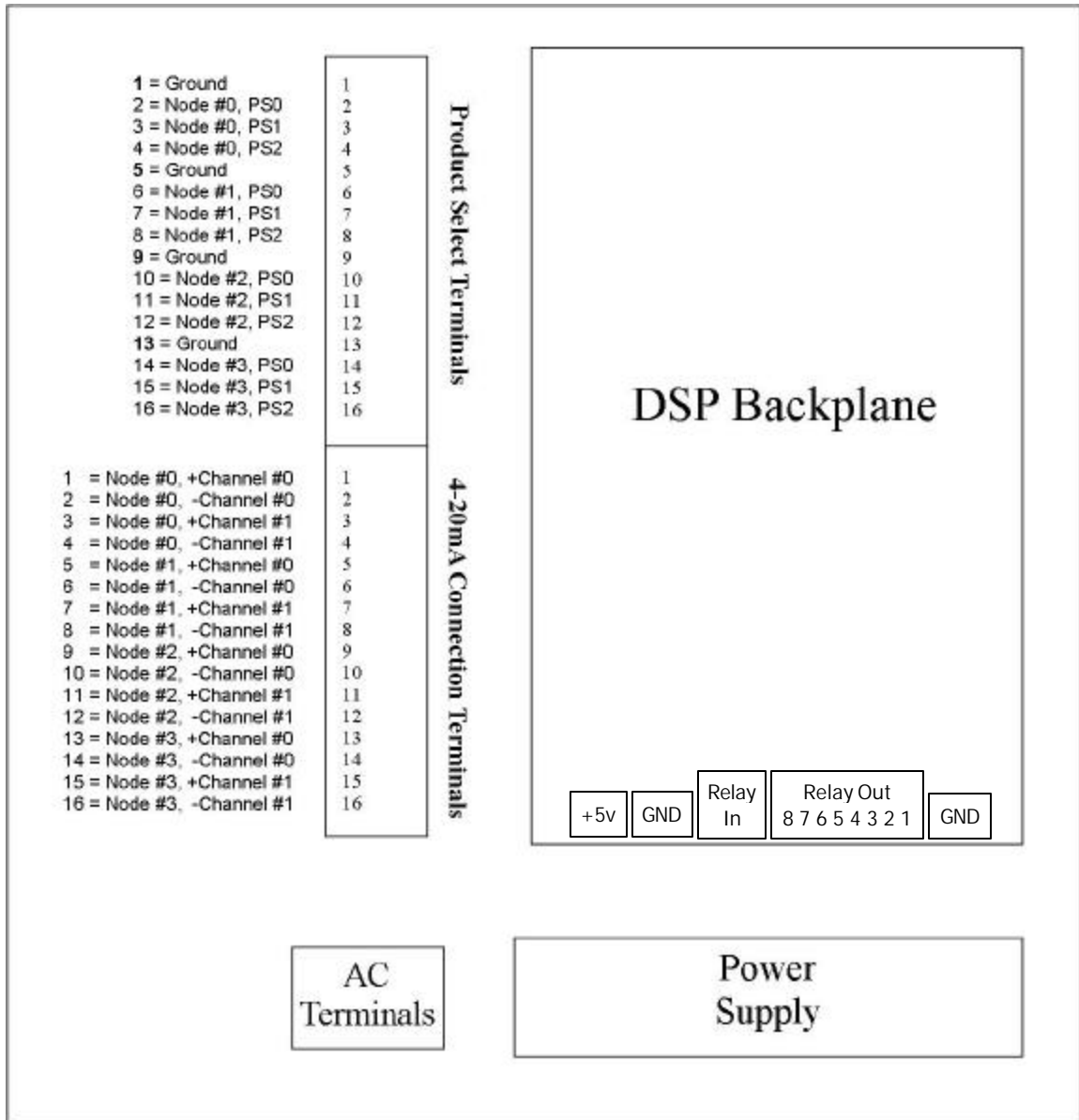A 4-20mA pair can be connected to pins 1 and 2 of the **4-20mA Connection Terminals** for transmitting information from the base to the control room. This would allow users to see Node 0, Channel 0 real-time fill ratio data on the control console. Similarly, other 4-20mA pairs can be added to track information from other active Node Channels.

The product select terminals are used to identify what product is presently being run in the mill. To configure a particular product for a given node, we use the following table:

Product Select Signals

PS0	PS1	PS2	Action
0	0	0	Mill Off
G	0	0	Product #1
0	G	0	Product #2
G	G	0	Product #3
0	0	G	Product #4
G	0	G	Product #5

where 0 = Open, G = Grounded

Note: Product is shipped with all Nodes set for Product #1.

When you select a particular product, the base unit loads the calibration information created for that product and node. The specific product is then selected by placing a jumper between the ground terminal and one or more of the PS2:0 signals. For example, if you want to select product 1, simply ground PS0 only.

It is important to calibrate the mill for every new product you plan to use in the mill.

At the bottom of the base in Figure 4.4, there is a common relay connection (relay in) that will be open or shorted to eight relay channels (relay out). Relay channels 1-4 are used to indicate if there is a loss of communication between a particular remote and the base. Channel 1-4 therefore corresponds to remote nodes 0-3 where, if communication is lost, the corresponding relay channel will short with Relay In or remain open if communication is functional.

These relays should be used to drive other relays feeding signals back to the control room. Maximum voltage is 24 VAC and current is 0.5 Amps.

Specifications   Chapter 5

General Specifications

Power supply   230/115 VAC, 50/60 Hz
Enclosures   Nema 12 (base unit) and Nema 4 (remote unit)
Dimensions (Base Unit)   6"D x 14"L x 16"W
Dimensions (Remote Unit)   6"D x 9"L x 8"W
Dimensions (Heat Sink)   4"D x 6"L x 6"W
Analog inputs   Up to eight accelerometers
Analog outputs   Up to eight 4-20 mA into 750 Ohms max.
Digital inputs   16 TTL level
Digital outputs   8 dry contact reed relay **24VAC@5A.max**.
Digital outputs   12 TTL level
Mills   Up to 4 mills
Software   Windows 95, 98, NT, 2000 and XP monitoring and configuration
                             software
Resolution   At least three times higher than traditional instruments

Sensors Technology

Type   High resolution accelerometers
Frequency response +/- 0.25 dB   20 to 20,000 Hz
Temperature conditions   -40° to 85° centigrade
Sensitivity   100 mV/G

CODECS (ADC,DAC converters):

Type   Sigma-Delta 64X over-sampling
ADC resolution   16 Bits
Dynamic range   95 dB
Total harmonic distortion   0.006%
Interchannel isolation   80 dB
DAC resolution   12 Bits
Analog outputs   4-20 mA current sink mode

Digital Signal Processor (DSP)

Type   TMS320C3X Floating point CPU
Bus width   32 Bits
Instruction cycle   33 nanoseconds
Processor speed   60 MFLOPS
Serial EEPROM   8K words
Static RAM   128K words @15 nSec
Communication Interfaces   Parallel port and RS232 serial port RF Digital Communications link

Embedded software

- High performance uC/OS real time multitasking MicroKernel
- DSPACKET-RF digital communications RF network protocol
- DSPACKET-S Serial interface network protocol
- DSP and Artificial intelligence algorithms for optimal frequency response determination

MillScan applications

- Raw meal ball mills
- Finish mills
- Mechanical equipment vibration monitoring
- Vertical mills vibration analysis

Appendix A

I. Introduction

It is a well-established fact that the majority of electrical energy consumed in a cement plant and/or related industry is spent during the ball mill process. The raw material and finish mill grinding energy efficiency is very low in this process since most of the electrical energy is converted into heat and only less than 12% of the energy expended in the milling operation itself is applied to increasing Blaine size to the desired value.

This fact strongly underscores the importance of making mill efficiency a top priority for all modern milling plants. Considering the scale of the economics involved, even a modest improvement in mill efficiency represents a substantial economic gain.

High mill efficiency translates to operating at the lowest possible power consumption per produced ton. Since, as mentioned above, about 90% of the power consumed by mills is expended whether or not the mill is producing material, optimal mill efficiency is attained only when the mill is operating at maximum throughput without overloading. At points less than this maximum throughput, the mill is subject to increased wear on the grinding media, liners and chamber baffles. This degradation in the equipment further adds to the inefficiency of the mill.

Extensive research has tackled the problem of process optimization by sampling various critical process variables through time. From this information, improvements in mechanical equipment design and system control algorithms have resulted. Examples are monitoring and regulating several process variables such as: fresh feed rate, vessels fill levels, circulating load, separator power, bucket elevator power and mill power. The results of operating at maximum throughput are increased productivity, minimized per-ton power consumption, reduced wear of the grinding media and improved product quality consistency.

An area of production optimization that can reap the benefits of new technologies emerging from digital signal processing is the grinding vessels material fill level, which is the variable directly responsible for the mill efficiency. The following is a short description of the traditional measurement technique and details of how this has been greatly improved using new 'state of the art' signal processing technology.

History

The traditional instrumentation method estimates the material fill level in the mill by measuring the noise intensity emitted from each grinding vessel using acoustic transducers (mics). The idea being that the noise generated by a mill is inversely related to material level. For example, a fully loaded mill is not as loud as when it is less loaded because the energy of the grinding media is absorbed or dampened by the additional material.

These instruments offer only an indication of the relative intensity of the noise without any special consideration to its frequency distribution. Some manufacturers approach this problem by including crude hardware selectable fixed response analog filters. However, the frequency distribution characteristics are different for every mill and thus these instruments do not provide a method to match the optimal filter to the unique frequency characteristics or signature of the specific mill under test and its surroundings.

In addition to this shortcoming, on installations where there are several mills operating close to one another, an instrumentation based on acoustic transducers will produce erroneous results due to cross talk noise between mills. It is relatively impossible to arrange the acoustic transducers so that they can pick up only the grinding noise from one individual mill. The resulting interference or acoustic crosstalk noise then affects the fill level measurement of each individual mill whereby operators have to make manual adjustments to compensate for the differences. This then leads to more variations and non-optimal results.

To compensate for this cross talk interference, some instrument manufacturers include crosstalk compensation circuits. This circuit is calibrated by sending a signal to the adjacent mill instrumentation from another remote mill. The information read from the remote site is then filtered using a constant coefficient filter. The problem is that this method assumes the acoustical coupling between mills is constant throughout time. However, it is a well known that the acoustical coupling is actually a highly non-linear function that is dependent upon factors like building construction materials, reflection paths, reverberation, and the grinding noise machinery itself.   All of these items can change over time and thus dilute any initial compensation performed early on in the instrument's life cycle. This again detracts from the optimal reading one can obtain from a given mill.

In the past, veteran operators would listen directly to a given mill acoustic output or sound. From the loudness and character of the sound, human perception could point out different frequencies in addition to changes in the noise intensity. This aural information was used to determine whether the feed rate should be increased or decreased, whether the ball charge was wearing out and whether or not there was plugging or blockage in the mill. An operator's trained ear served as passable instrument in the early days of cement manufacturing. However, our present boom in digital signal processing (DSP) technology can produce a far more sensitive and reliable instrument.

Process Operating Conditions

In the past, numerous control rooms were located in close proximity to the actual mills. This allowed the operators to listen and manually control/optimize the grinding process from a control room closest to the mill being optimized. However modern plants now use centralized process control and automation systems such that an entire plant can now be controlled by a single operator from a single centralized control room. This operating approach therefore depends on highly reliable, automated and dependable measurement signals coming from the field instrumentation.

Without doubt, the ball mill material fill level measurements have a direct affect on the ability of an operator to efficiently control production. Field instrumentation that can provide accurate and reliable information will allow an operator to reduce the safety margin usually applied to a given process. This results in increasing the operational efficiency of a mill and most importantly: It **significantly increases** the **overall production** of the mill system in general.

II. Operation Theory

System Overview

MillScan DSP2000 is based on the latest floating point digital signal processing (DSP) microprocessor technology. It takes into account the mill shell vibration intensity, its frequency spectrum distribution and several important phase measurements. A combination of these parameters computed through a proprietary complex algorithm yields a considerable improvement in system accuracy.

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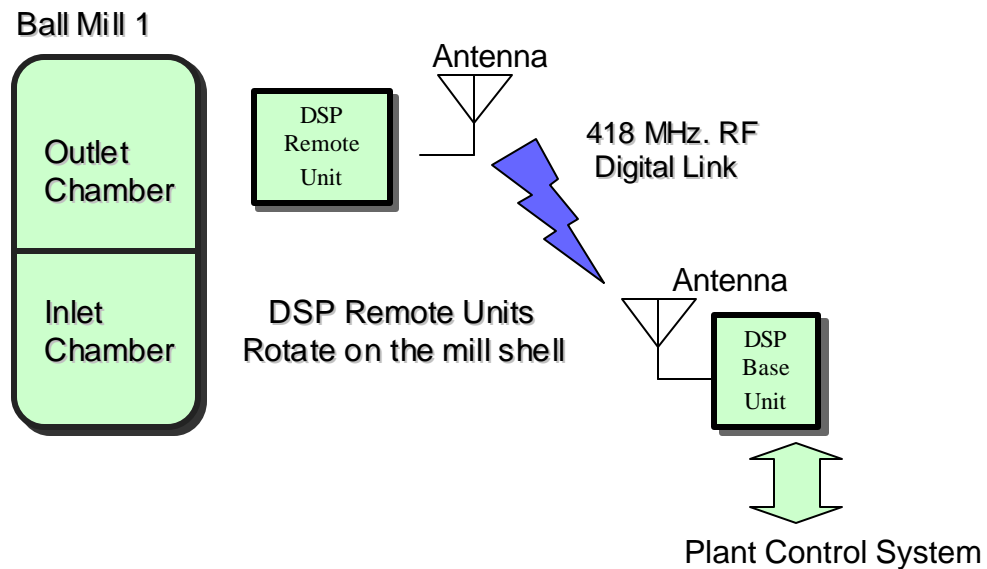
MillScan DSP2000 offers such precise measurement of the level of material that it can be used not only for the material flow estimates but also for direct control of the mill feed. The user can also setup an instrument network using a central monitoring personal computer.

Technical Features – A Comparative Analysis

Technical Features

Characteristic	ITECA	FLS	HASLER	DSP2000
Adjacent mills crosstalk canceling	Partial	no	Partial	*Total*
Number of channels per mill	1	1	1	*2*
Total Number of channels per instrument	1	1	1	*8*
All Digital electronics	no	no	no	*Yes*
Instrument networking	no	no	no	*Yes*
Frequency Spectrum analyzer	no	no	no	*Yes*
Optimal Calibration Curve Configuration	no	no	no	*Yes*
Monitoring and Configuration software	no	no	no	*Yes*
System diagnostics	no	no	no	*Yes*

System Block Diagram

Ball Mill 1

Outlet Chamber

Inlet Chamber

DSP Remote Unit

Antenna

418 MHz. RF Digital Link

DSP Remote Units Rotate on the mill shell

Antenna

DSP Base Unit

Plant Control System

Base Unit

The base unit is a 32 bit floating point DSP processor equipped with 128 K words SRAM, RF network Radio Packet Controller, antenna assembly, Analog Outputs board, etc.

The base unit continuously scans the remote units transmitting a "PING" command every 4 seconds; if a remote unit is powered up, the base unit will get a reply, will establish a valid data link and wait until the remote unit configuration data averaging period ends. When the data averaging period ends, the base unit downloads the vibration spectrum signature. If no complete data transaction is achieved, the current data transaction is aborted and is retried in the next scan cycle.

When a complete data transaction is achieved, the base unit transmits a shutdown command to the remote unit and processes the new vibration spectrum signatures to calculate the current fill-level measurement.

When booting, the base unit will show an "E1" indication on the LED display. This code indicates the base unit is initializing all its internal data tables and system configuration parameters.

Next, the LED display will show the remote unit nodes scanning sequence 00-01-02-03 as it scans through nodes 0 to 3. When a remote node is detected for the very first time or when the user has changed the current calibration curve using the base unit digital inputs, the base unit will show an "E5" indication. This code indicates the base unit is initializing the calibration curves for that node.

If a remote unit is powered up, the base unit will get a reply, and wait until the remote unit configured data averaging period ends. When the data averaging period ends, the base unit will download the vibration spectrum signature showing an "A0", "A1", "A2", "A3" indication depending on which remote unit data is being acquired.

Remote Units

The remote unit is a 32 bits floating point DSP processor equipped with 16 bits two channels CODEC, 32 K words SRAM, RF network Radio Packet Controller, antenna assembly and auto start timing circuitry.

Once the remote unit powers on, the DSP embedded software will immediately start gathering vibration data, the CODEC digitizes the vibration signals coming from the vibration transducers, the DMA (Direct Memory Access) IRQ interrupt service routine software fills a dual buffer memory structure.

When the data buffer is full, the IRQ signals the DSP to process the vibration data. The DSP calculates the FFT data spectrum, convolves the data spectrum with the weighing window spectrum and averages the current data spectrum frame with previous frames using a single pole IIR filter bank, keeping track on the amount of averaged frames.

The remote unit is queried continuously by the base unit for the amount of averaged frames. Once the data averaging period ends, the remote unit transmits the two channels vibration spectrum signature to the base unit using the DSPACKET-RF RF network protocol. Once the data download is complete, the remote unit shuts down.

When booting, the remote unit will remain in OFF state for about 3 minutes, after that period, the remote unit will power ON and start data acquisition and processing cycle, the green LED on the Remote Packet Radio unit should be ON.

Power Generator Unit

MillScan uses peltiers cooled by heat sinks to continually provide power to the remote. No change of batteries is necessary.

RF Digital Communications Network

The remote units communicate with the base unit via a highly reliable RF digital communications network protocol. Every remote unit has a unique network node number. The network protocol implements double error checking strategies, Checksum and CRC16. Stop-and-wait ARQ (Automatic Repeat Request) techniques are used for controlling transmission errors in the data transmission subsystem. These features ensure 100% data transmission reliability even on a harsh RF environment like the one existing in cement production plants.

RF communications Statistics and Diagnostics

The system's monitoring software maintains highly detailed RF communications reliability statistics that can be used to detect and diagnose any RF communications problems. Based on our application experience, the RF link reliability is over 99% on the very first try, the remaining 1% is obtained on the second or third communication try.

Scan Operation

The base unit is continuously scanning the remote units transmitting a "PING" command every second. If a remote unit is powered up, the base unit will get a reply, will establish a valid data link and wait until the remote unit configured data averaging period ends. When the data averaging period ends, the base unit downloads the vibration spectrum

signature, showing an "AX" indication on the LED display, where X corresponds to current remote unit node number being processed. If no complete data transaction is achieved, the current data transaction is aborted and will be retried the next scan cycle.

When a complete data transaction is achieved, the base unit will transmit a shutdown command to the remote unit and starts processing the new vibration spectrum signatures to calculate current fill level measurement.

RF Radio Digital Data link Processing

The Remote Packet Controller (RPC) Radio Unit continuously searches the radio noise for a valid packet preamble. On detection of preamble, the RPC Synchronizes to the incoming data stream, decodes the data and validates the check sum. The DSP processor is then signaled that a valid packet has arrived and is waiting to be downloaded.

The DSP processor downloads the packet and performs a double data integrity test using a Cyclic Redundancy Check CRC16. If the data is valid, the remote unit sends an ACK message to the base unit to acknowledge correct data reception. When data is invalid, the remote unit sends a NACK message to the base unit requesting an ARQ (Automatic Repeat Request). If an unsuccessful link is obtained after three tries, the current data transfer is aborted and retried in the next scan cycle.

On receipt of a packet uploaded by the DSP processor, the RPC will append to the packet: preamble, start byte and checksum error codes. The packet is then coded for security and mark: space balance by Trellis coding and transmitted over the RF link at a speed of 40 Kbit per second synchronous stream, Collision avoidance (Listen Before Transmit LBT) are enabled to prevent loss of packets.