INSTRUCTION MANUAL

Model AS500A

Microseismic Data Logger

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1.0 Introduction

The AS500A Microseismic Data Logger system consists of the Microseismic Data Logger (MDL) unit and a number of transmitters. The system provides real-time monitoring of microseismic events within a mine. High-level, low-noise signals are ensured by use of a pre-amplifier and balanced line driver circuit in each transmitter. Geophones can be located up to 3 kilometers from the MDL. With the addition of an inline repeater, located midway between the MDL and the transmitter, the geophone can be located up to 5 kilometers from the MDL.

Systems are available for monitoring either 8 or 16 channels of data (note: 8-channel systems can be upgraded to 16 channels). Any channel can be connected to a passive geophone, a closure meter or many types of voltage output and 4-20 mA output sensors such as pressure transducers. A different type of transmitter is used for each of the different sensors. The MDL is normally located within the mine at a central location where power is available. A transmitter is located close to each of the sensors to be monitored. Two pair twisted, 22 AWG, shielded wires connect each transmitter to the MDL. One pair in the cable is used for the power and the other for the signal.

The MDL contains a low power PC, an IOTech Daqboard 2000 data acquisition card, one or two 8-channel receivers, power supplies and thermo-electric coolers. Terminal block connections on the front panel of the MDL allow easy connection of the sensor cables from the transmitters. Connections are also provided on the bottom panel for input power, Ethernet, video, USB, keyboard and a mouse.

2.0 Installation and Operation

1. The Microseismic Data Logger (MDL) should be mounted vertically on a wall in a dry location.

2. With the power switch, located on the front panel, in the OFF position plug the instrument into an appropriate AC source using the attached line cord. The unit requires a single-phase, 120VAC, 60 Hz power source with at least 5 amperes of current capacity. Ideally an uninterruptible power supply (UPS) should be installed to provide clean power to the logger.

3. Run wire from the MDL to the location of each sensor to be included in the monitoring system. We recommend using 22 AWG, 2-pair, twisted, and shielded wire.

4. Open the front Plexiglas dust cover on the MDL and connect the wires to the terminal blocks marked "Transmitter". We suggest that crimp-on fork terminals be used. A standard colour convention should be adopted for the connections. Assuming the cable contains a red and black pair, a white and green pair and a shield wire, then connect the red wire to **Pwr+**, the black wire to **Pwr-**, the white wire to **Sig+**, the green wire to **Sig-** and the shield wire to **Shield**. The wires can be routed to the terminal blocks through the wire ducts located on the front of the MDL.

5. Mount the appropriate type of transmitter close to the sensor to be monitored. We suggest fastening the Transmitter to a piece of wood using the two holes provided in the Transmitter base plate. The wood can then be mounted at a convenient location near the sensor. Care should be taken to ensure that the case of the Transmitter is electrically isolated from the mine walls. (This prevents a ground loop from being created back to the MDL). Connect the wires from the MDL to the terminal block on the transmitter that is marked "To Microseismic Data Logger". Use the colour convention listed in step (4). Note: connect the shield wire at both the MDL and at the transmitter. The shield at the transmitter is only connected to the transmitter case and not to the electronics within the transmitter.

6. Connect the wires from the sensor to the terminal block on the transmitter that is labeled "To Geophone", "To Closure Meter", "To 4-20 mA Sensor" or "To Voltage Sensor" depending on the type of sensor used.

   Passive Geophone - connect one lead from the geophone to the terminal marked **Geo+** and the other to **Geo-**. If the geophone has a shield wire then connect it to **Shield**.

Closure Meter - connect one end of the meter to **Vref** and the other end to **Com**. Connect the wiper to the terminal marked **Vsig**. If the closure meter has a shield wire then connect it to the terminal marked **Shield**.
4-20 mA Sensor Powered by Transmitter - the transmitter supplies power to the sensor and measures the 4-20 mA output. The sensor typically only has two wires; an example of this type of sensor is an Ashcroft K1-type 4-20 mA pressure transducer. Connect the power wire (usually red) from the transducer to the terminal labeled **Pwr+** and the white or black wire (the colour is dependent on the transducer model) to the terminal labeled **Out**. If a shield wire is present then connect it to the **Shield** terminal.

4-20 mA Sensor Powered by an External Device - the transmitter is connected in line with the 4-20 mA line. Split the 4-20 mA wire and connect one end to the terminal labeled **Out** and the other wire to the terminal labeled **NC**. If a shield wire is present then connect it to the **Shield** terminal.

Voltage Sensor - sensors with a voltage output of up to +/-5 volts DC can be connected to voltage transmitter. Connect the voltage output signal to the terminal labeled **Out+**. Connect the ground signal to the terminal labeled **GND**. If the sensor requires power from the transmitter then connect the sensor's power line to the terminal labeled **+15V**. If a shield wire is present then connect it to the **Shield** terminal.

7. If the wire length from the MDL to a transmitter is greater than 3 km a Repeater should be used. The Repeater boosts the signal for long wire lengths. Mount the Repeater in a convenient location half way between the MDL and the sensor. Connect the wires from the MDL to the terminal block on the Repeater that is marked "To Microseismic Data Logger". Use the colour convention listed in step (4). Connect the wires from the Geophone Transmitter to the terminal block on the Repeater that is marked “To Transmitter”. Use the colour convention listed in step (4). Sensors can be located up to 5 km from the MDL when a Transmitter Repeater is used.

8. After all connections are made return to the MDL and ensure that the power switches for each channel are switched OFF. Turn the main power switch located on the front cover to ON. Then turn the power switch for each channel to the ON position. The red LED next to each switch should illuminate. If the LED doesn't illuminate then refer to the troubleshooting procedure shown in chapter 4.0.

9. The data logger software will automatically start after the Data Logger is powered. Normally the Microseismic Data Logger is connected to a data analysis computer using a LAN, Ethernet, connection. A waterproof connector is provided on the bottom panel of the Data Logger for the Ethernet line connection. A mating Ethernet connector is included with the MDL and instructions for terminating the Ethernet line are included with the connector.

10. The MISER (MIcroSeismic Event Recorder) software that is part of the CANSEIS software package (available from Kosteniuk Consulting Ltd.) has been installed on the Microseismic Data Logger computer. Use CANSEIS to communicate with the Microseismic Data Logger and setup the data logger. Once setup, record some data and inspect it to ensure that the system is operating correctly. Refer to the CANSEIS operating manual for instructions on the proper use of the software.

3.0 Design Details

3.1 Transmitter

The transmitter contains a low-noise, precision pre-amplifier, a balanced line-driver and a power supply. The transmitter amplifies the low-level signals from sensors to a ±2.5-volt signal that is transmitted back to the Microseismic Data Logger (MDL). Transmitters are available for monitoring passive geophones, closure meters, 4-20 mA sensors and voltage output sensors. A Repeater is also available and should be used when the distance between the sensor and the MDL is greater than 3 km. All transmitters use the same water-resistant aluminum case that measures 4.5" long x 2.5" wide x 1.25" high. A 2.5" wide x 6" long x 0.125" thick aluminum mounting plate with two 3/16" diameter-mounting holes is attached to the case. Transmitters are normally attached, using wood screws, to a piece of wood which is in-turn attached to the mineshaft as close as possible to the location of the sensor.

Connections to the transmitter are provided through two sets of terminal blocks located on the top cover of the transmitter. A five-contact terminal block labeled "To Microseismic Data Logger" connects the transmitter to the MDL. The other terminal block (4 contacts) connects the transmitter to the sensor and is labeled with the type of sensor ("To Geophone", "To Closure Meter", "To 4-20 mA Sensor", "To Voltage Sensor" or, in the case of the Repeater, "To Transmitter"). The "To Microseismic Data Logger" terminal block connections are **Pwr+**, **Pwr-**, **Shield**, **Sig+** and **Sig-**. The sensor terminal block connections are based on the type of sensor to be used.

Geophone terminals are labeled **NC** (no connection), **Shield**, **Geo+** and **Geo-**. Closure Meter terminals are labeled **Vref**, **Shield**, **Vsig** and **Com**. 4-20 mA Sensor terminals are labeled **+15V**, **Shield**, **Out** and **NC**. Note: for externally powered loops connect the loop between Out and NC. Voltage Sensor terminals are labeled **+15V**, **Shield**, **Out+** and **GND**. Transmitter Repeater terminals are labeled **Pwr+**, **Pwr-**, **Shield**, **Sig+** and **Sig-**.

The MDL provides ±28 VDC to power the transmitter. If necessary the transmitter then provides power to the sensor. No ground (common) connection is provided between the MDL and the transmitter. This means that a voltmeter placed across Pwr+ and Pwr- on the transmitter will read 56 volts. Actually the voltage at the transmitter will be lower than 56 volts since there will be a voltage drop in the line connecting the MDL to the transmitter. The amount of voltage drop will depend on the current consumption of the transmitter and the resistance of the wire connection. Using Ohm's law the maximum theoretical distance between the MDL and the transmitter can be determined to be about 9 km (the transmitter requires a minimum of 36 volts across the power terminals, the transmitter current consumption is 22 mA and the loop resistance of 22 AWG wire is 14.74Ω/1000'). Note: 4-20 mA transmitters that are powering the loop must supply an additional 20 mA to the sensor so their total current consumption is about 42 mA. This means that the maximum theoretical

distance from the MDL to a 4-20 mA transmitter that is powering the loop is about 4.75 km. These distances are calculated based solely on the capability of the power supply to deliver the required voltage to the transmitter. In practice these distances may not be obtained due to limitations with the balanced line driver in the transmitter. Both resistance and capacitance increase as the line length increases and eventually reach a level that limits the performance of the line driver. Normally distances of 3 to 5 km can be handled without any problems. We recommend that a Repeater by installed in any line with a wire length greater than 3 km.

The Shield terminals on the transmitter are connected together and to the transmitter case. There is no electrical connection between the Shield terminals and the circuitry in the transmitter.

Figure AS005D is a schematic of the geophone transmitter circuit. Examination of the schematic shows that the transmitter can be divided into four sections: power supply, pre-amplifier, line driver and voltage reference.

The power supply section shows that a virtual ground is created using op-amp SU3B while positive and negative voltage regulators provide a ±15-volt, dual supply. Diodes D1 and D2 provide protection against reverse polarity connections.

The pre-amplifier (Analog Devices AD797) is a very low noise, low distortion operational amplifier. The noise output of the op-amp is rated at 0.9nV (root) Hz while total harmonic distortion is -120 dB at audio bandwidths. For Geophone transmitters the pre-amp gain is set to 100. For all other types of transmitters the pre-amp gain is set to 1.

The line driver section of the transmitter uses an Analog Devices SSM2142 balanced line driver IC. This IC is an integrated differential-output buffer amplifier that converts a single-ended input signal to a balanced output signal pair with high output drive. By utilizing low-noise thermally matched thin film resistors and high slew rate amplifiers, the SSM2142 eliminates power line interference, RF interference, voltage drops and other externally generated noise commonly encountered with long audio cable runs. The SSM2142 in tandem with the SSM2141 differential receiver establishes a complete, reliable solution for driving and receiving audio signals over long cables. The SSM2141 features an Input Common-Mode Rejection Ratio of 100 dB at 60 Hz.

The final section, the voltage reference, is only used with Closure Meter transmitters. A precision 2.5-volt reference is provided to power the closure meter. Other changes required for Closure Meter transmitters include the removal of resistor SR1 and changing resistor SR2 to 0 ohms. The following changes are made to the transmitter when using it with 4-20 mA pressure transducers. A 121-ohm resistor is placed across terminals TCON1-3 and TCON1-4, a connection is made from the +15 volt supply to TP5, SR1 is removed and SR2 is made 0 ohms.

Figure AS009A is a schematic of the Repeater circuit. Examination of the schematic shows that the transmitter can be divided into three sections: power supply, receiver, and line driver.

The power supply and line driver sections of the Repeater are identical to those of the transmitters. The receiver section is identical to that used in the MDL receivers. Thus the Repeater consists of a differential receiver/transmitter and a power supply. All other connections on the terminal blocks (Pwr+, Pwr- and Shield) are simply carried through from the input to the output terminal blocks.

3.2 Microseismic Data Logger

The Microseismic Data Logger contains a receiver circuit board, an interface circuit board, a low power computer (PC), power supplies, and a Thermo-Electric Cooler (TEC). Note: there are two receiver circuit boards and two interface circuit boards in the 16-channel version of the MDL.

3.2.1 Receiver Circuit Board

The receiver circuit board contains eight receiver channels on a single circuit board. Each receiver channel has a balanced line receiver and an 8-pole Bessel low-pass filter with a cutoff frequency of 250 Hz. Drawing AS004B is a schematic of the receiver circuit board. This schematic shows the receiver and Bessel filter sections for one channel. The receiver (Analog Devices SSM2141) is an integrated differential amplifier intended to receive balanced line inputs in audio applications requiring a high level of noise immunity and optimum common-mode rejection. The SSM2141 typically achieves 100 dB of common-mode rejection (CMR). The 8-pole, low-pass Bessel filter was chosen as the anti-aliasing filter for geophone signals because of its constant phase delay and overshoot-free step response. The filter section has unity gain while there is a gain of 2 between the transmitter and receiver. Transmitter signals enter on JP1 and output signals leave through JP3. These connectors mate the receiver board to the interface board discussed in section 3.2.2.

Power for the receiver boards is supplied by a linear ±15 VDC power supply.

3.2.2 Interface Circuit Board

The interface circuit board provides the connections between each receiver channel and its associated terminal strip. The board also includes a power switch for each transmitter, an LED power indicator for each channel, fuse protection for each transmitter power line and connections to the PC-based data acquisition card. For each channel a switch, an LED and a terminal block are mounted on the front panel of the MDL enclosure. The interface circuit

board is soldered to these components and is thus attached to the inside of the door on the MDL enclosure. Board-to-board connectors allow the receiver circuit board to be plugged onto the back of the interface board. Power (±28 VDC and ±15 VDC) connects to the interface board and then through board-to-board connectors to the receiver board.

Drawing AS006C is a schematic for the interface board. Sheets 1 and 2 present the interface connections for each of the 8 receiver channels. These connections can be divided into 2 sections, power and signal.

Power originates on the interface board and passes through a double-pole switch before it is connected to the terminal strips on the front of the MDL. Present in each power line is a Polyswitch. This device is a thermal fuse that opens when the current through the device exceeds its rating (100 mA) and then resets when the current returns to normal. The Polyswitches protect the system in the event of a short in the power lines to any particular transmitter. Shorts often are caused when cables are damaged by mining equipment. The behaviour of the system is dependent on where the short occurs and whether it is across the two power lines or from one power line to the shield or to the signal lines. The troubleshooting chart in chapter 4.0 provides further details. It must be recognized that Polyswitches are thermal devices. When the current through the device exceeds its rating the device starts to warm up and its resistance increases thereby limiting the current able to flow through the device. Once the device has "tripped" it still conducts a small amount of current (about 10 mA) which is used to keep it warm and in the "tripped" condition. In order to reset the device the power switch, for the affected channel, must be turned off for several seconds (we recommend 30 seconds). This period of time allows the device to cool down so that when power is resumed it does not "trip" again on the normal operating current of the transmitters (about 25 mA).

Also shown on the schematic is an LED that provides visual indication that power to the transmitters is switched on. In the event of a short circuit the LED will either go out or glow dimly. Typically the LED will only go out completely if there is a short between the Pwr+ and Pwr- lines. Other types of shorts usually cause the LED to glow dimly. The schematic also shows the signal connections between each receiver and the terminal block mounted on the front panel of the MDL enclosure.

Sheet 3 shows the connections from the interface board to the PC-based data acquisition card. TCON8 provides a connection path to a second interface/receiver pair (this is used in 16 channel systems). A low-pass RC filter is included in each output data line to reduce A/D noise. The filter consists of a 100 pF ceramic capacitor and a 10kΩ resistor that together yield a cutoff frequency of about 160 kHz.

3.2.3 Computer

The PC type computer uses a low power EPIC motherboard with a Via 400 MHz processor, 256 MB of RAM, 40 GB hard drive, CD ROM drive, 1 COM port, 1 LPT port, 2

USB ports, a video port and a 100 Mbit Ethernet port. The PC also includes an IOTech Daqboard 2000 data acquisition card that is described in greater detail below. The computer is housed in a mini case that is fastened to the MDL enclosure with a mounting bar. A fan is included in the case to improve cooling. The PC automatically powers on and the MISER program starts upon application of power.

Several computer connections are brought out to the bottom panel of the MDL enclosure. A DB-15 connector to the video port, a USB connector, and two mini-DIN-6 connectors for the keyboard and a mouse are all mounted within a waterproof, flip-top cover. An Ethernet line can be connected to a separate waterproof connector located on the bottom panel. This connector is connected to the internal Ethernet port on the PC.

The data acquisition card used in the PC is an IOTech Daqboard 2000 that features 16 channels of 16-bit analog input. The card is capable of digitizing signals at a maximum rate of 100,000 samples per second. The PC runs a real-time Linux operating system which ensures that data acquisition timing is maintained to within 100 microseconds. The board is configured to operate in bipolar mode with an input voltage range of ±10 volts on 16 single-ended channels.

3.2.4 Power Supplies

Two 28-volt DC linear power supplies and a ±15-volt linear power supply are enclosed in the MDL. The 28 volt power supplies provide power for the transmitters. The supplies are connected together to form a ±28 volt supply with a floating ground. The current rating of each supply is 2.0 amperes, sufficient to power 16 transmitters. The ±15-volt power supply provides power to the receiver circuitry. The main power switch on the MDL switches on the power supplies along with the PC and the TEC.

3.2.5 Thermo-Electric Cooler

Two thermo-electric coolers (TEC) are included in the MDL to minimize heating within the enclosure. Each TEC consists of an internal cool heat sink with an air circulating fan, a TEC chip and an external hot heat sink with an external fan and a protective cover over it. A 120 VAC powered switching power supply provides 12-volt DC power to the TEC. The TEC will maintain the internal temperature of the MDL at 35°C when operating with 16 transmitters in a 20°C ambient environment.

3.2.6 Input Power

CAUTION: LETHAL VOLTAGES ARE PRESENT WITHIN THE MDL. DISCONNECT INPUT POWER BEFORE OPENING THE CABINET.

The MDL requires 120 VAC, single-phase, power with a current rating of at least 5 amperes. A 6-foot long power cord with a standard NEMA 5-15P plug is attached to the MDL. Drawing AS500A-E001 is an interconnection diagram for the MDL. Within the MDL the input line connects to a 5A circuit breaker and then to the main power switch mounted on the front panel. The output from the switch is then brought to a terminal block that distributes AC power to the various devices within the MDL. The AC neutral wire connects to a similar terminal block. The AC ground is connected to the MDL case, front cover and to the computer's power supply.

The MDL should be connected to an Un-interruptible Power Supply (UPS) to ensure clean, reliable power. AC power sources in mines are notoriously noisy and because the MDL is a precision, low-noise data acquisition system, noise on the power lines will degrade MDL performance. Previous installations have demonstrated that the use of a commercially available UPS will eliminate problems associated with poor power lines. Another advantage of using a UPS is that the system will continue to log data in the event of a power outage.

4.0 Trouble Shooting

The following troubleshooting information can be used to solve most common problems encountered with the AS500A Microseismic Data Logger.

Table 4.1 Troubleshooting

PROBLEM	RECOMMENDED ACTION
(A) MDL does not switch ON.	1. Ensure AC power cord is firmly plugged into an AC wall receptacle or UPS. 2. If plugged into a UPS then ensure the UPS is switched on and plugged into an AC wall receptacle. 3. Ensure the 5-amp circuit breaker inside the MDL is not tripped. 4. Ensure the power switch is in the ON position. 5. Ensure the line voltage is between 100 and 125 VAC.
(B) MDL ON but the power LEDs are off.	1. Ensure the power switches for each channel are ON. 2. Switch off all channels and then disconnect the wires to the terminal block of one channel. Switch that channel back on. If the LED lights then there is a short circuit in the transmitter wires. If the LED doesn't light then there is a problem with the main AC power. Refer to problem (A).
(C) Power switch for a channel is ON but LED is off, other channels work correctly.	1. A short between the Pwr+ and Pwr- wires leading to the transmitter causes this condition. This short can occur anywhere in the line. Switch off the affected channel and remove the wires from the terminal block on the MDL. Switch the power back on to that channel and the LED should light. If so then check the cable for shorts. Repair or replace the cable as necessary. 2. Note: a short loss of power may be seen on all channels (duration about 1 second) when the short occurs. This may be seen as a loss of data on all channels. Once the Polyswitch for the shorted channel "trips" full power is restored to all non-shorted channels.
(D) All LEDs on the MDL are dim or one LED is dim and the rest are bright.	1. A short between either Pwr+ or Pwr- and the cable Shield wire causes this condition. This short can occur anywhere in the line. Switch off the affected channel and remove the wires from the terminal block on the MDL. Switch the power back on to that channel and the LED should light. All other LEDs should also be bright. If so then check the cable for shorts. Repair or replace the cable as necessary. 2. Note: a loss of power may be seen on all channels (duration about 20 seconds) when the short occurs. This may be seen as a loss of data on all channels. Once the Polyswitch for the shorted channel "trips" full power is restored to all non-shorted channels and their LEDs get brighter.
(E) Wiring to transmitter is okay, power LED is ON, but data from affected channel shows no signal.	1. Wiring may be connected incorrectly. Check polarity of power wires and signal wires. Note: signal wires must be connected with correct polarity. Pwr+ on MDL should connect to Pwr+ on transmitter; likewise Pwr- connects to Pwr-, Sig+ to Sig+ and Sig- to Sig-. 2. Check that the voltage measured between the Pwr+ and Pwr- terminals on the transmitter is at least 36 volts. If voltage is less then the distance from the MDL to the transmitter is too great causing too high a voltage drop.

	Shorten the distance or use heavier gauge wire. 3. Balanced Line Driver (SSM2142) IC in transmitter may be damaged. Replace and try again. IC can be damaged by incorrectly connecting the signal wires. 4. The wrong type of transmitter is being used for the type of sensor being monitored. Ensure that the transmitter is the correct type for the sensor. 5. Sensor is wired incorrectly to the transmitter. Make the connections as indicated on the transmitter label. 6. Faulty sensor, replace.
(F) Data from affected channel is offscale.	1. The wrong type of transmitter is being used for the type of sensor being monitored. Ensure that the transmitter is the correct type for the sensor. 2. Sensor is wired incorrectly to the transmitter. Make the connections as indicated on the transmitter label. 3. For geophones the resistance of the geophone may be significantly different from that for normal geophones. Open the Geophone Transmitter and adjust P1 (the 20-turn potentiometer) to minimize the voltage across terminals SIG+ and SIG-. If this doesn't help then replace the geophone.
(G) No communications can be established with the PC using the Ethernet connection.	1. Check the Ethernet wire and ensure that it is intact. 2. Check the connection of the Ethernet wire to the MDL and ensure that the wires are connected correctly. 3. Check that the PC is operating correctly. Connect a keyboard, mouse and monitor to the KEYBD, MOUSE and VIDEO connections and then check for correct operation of the PC.
(H) Software problems with the CANSEIS or MISER programs.	1. Refer to software manuals. 2. Contact Kosteniuk Consulting Ltd. (Tel: 306-343-1557).
(I) Other hardware problem.	1. Contact Aurora Scientific Inc.; see contact information in section 4.1.

4.1 Technical Assistance

Technical assistance is available by regular mail, email, phone, or fax. Use the information below to contact Aurora Scientific Inc.

Address: Aurora Scientific Inc.
AS500A Technical Assistance
P.O. Box 2724
Richmond Hill, Ontario, CANADA
L4E 1A7
Phone: 1 905 727-5161
Toll Free: 1 877 878-4784
FAX: 1 905 713-6882
Email: info@aurorascientific.com
Web site: www.aurorascientific.com

5.0 Warranty

The AS500A Microseismic Data Logger is warranted to be free of defects in materials and workmanship for one year from the date of shipment. Aurora Scientific Inc. will repair or replace, at our option, any part of the AS500A system which, upon our examination, is found to be defective while under warranty. Obligations under this warranty are limited to repair or replacement of the instrument.

Drawings

This section consists of the following drawings:

Title	Drawing No
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2. Schematic, AS004B Receiver PCB	AS004B
3. Schematic, AS005D Transmitter PCB	AS005D
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