HIGHLAND TECHNOLOGY

V460

VME ANALOG SCANNER MODULE

Technical Manual

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1 Introduction

The V460 is a VME-based versatile source/measurement unit. It includes a programmable constant-current source, a precision programmable gain 16-bit analog-to-digital converter, and a 4-wire, 16-channel analog multiplexer. An internal microprocessor supervises channel scanning according to user loaded parameters, reporting sensor voltage drops or, for selected sensor types, engineering-unit data.

The V460 is ideal for precision temperature measurement, using mixed resistive and diode sensor types. The programmable current sources and low duty-cycle scanning assure low sensor self-heating. Programmable digital filtering allows selectable rejection of AC line hum and other noise sources.

The V460 can measure resistances from 5.12 Megohms full scale (with 78-ohm resolution) to 80 ohms full scale (with 1.22 milliohm resolution); voltages from 5.12 volts full scale to 80 mV full scale may be measured, with resolution to 1.22 microvolts. Extensive internal self-tests help assure accurate measurements.

The V460 is a register-based VME module conforming to the IEEE 1014-1987 specification. The module is also compliant with the IEEE P-1155 interim VXI specification for "B" format register-based VXI modules.

Features include:

- Includes 16-channel, multiplexed, programmable constant-current source and precision analog-to-digital converter
- Capable of measuring nearly any mixture of resistive-, bridge- or semiconductor-type sensors, using 4-wire connections
- Ideal for cryogenic applications using mixed sensor types
- Ultrastable programmable constant current source: 1 μA, 10 μA, 100 μA, 1 mA source currents
- 16-bit ADC includes programmable gain differential amplifier, autozeroing, and programmable digital noise filtering
- All parameters are fully programmable for each channel
- Fully self-scanning without processor intervention: conditioned data is presented in transparent dual-port memory registers
- Reads sensor voltage drop directly; includes engineering unit conversion for common silicon diode and RTD type temperature sensors

2 Specifications

FUNCTION	16 channel VME current source and analog measurement module
DEVICE TYPE	16-bit VME register-based slave: A16:D16:D08(EO) Implements 64 16-bit registers at switch selectable addresses in the VME 16 bit addressing spaces
CHANNELS	16 channels, 4-wire sensor connections
INPUTS	Less than 1000 MΩ DC leakage current less than 200 pA Inputs are not isolated from circuit common
ADC	16 bits, programmable 0/+5.12 volts or ±5.12 volts full scale; programmable preamplifier gains of 1, 4, 16, and 64 magnify full-scale span to 80 mV (LSB resolution 1.22 µV) Accuracy ±0.01% ±25 PPM/K The ADC is monotonic to 16 bits
RESISTANCE	Resistance measurements are accurate to ±0.01% ±30 PPM/K for ISRC >1 µA, with preamplifier gains of 1, 4 and 16
SCAN RATE	Typically 20 ms per channel; full scan of 16 channels requires less than 400 ms Certain programmable options may increase scan times
CURRENT SOURCE	Per-channel programmable to 0, 1 µA, 10 µA, 100 µA and 1 mA Accuracy ±0.01% ±25 PPM/K, except 1 µA current is ±0.04% ±50 PPM/K
LINEARIZATION	Includes engineering units conversion for Lakeshore cryo-diode sensors and ISO 385 curve platinum RTDs (100Ω or 1000Ω)
FILTERING	Per-channel programmable digital lowpass filtering provides selectable time constants up to 128 samples Sample timing and filtering are optimized for 50/60 Hz hum rejection
OPERATING TEMPERATURE	-20 to +70° C; extended MIL/COTS ranges available
CALIBRATION INTERVAL	One year

POWER	Standard VME supplies: +5 volts, 1.5 A nominal +12 volts, 50 mA nominal (plus load current) -12 volts, 50 mA nominal (plus load current)
CONNECTORS	Two front panel female D37 connectors
INDICATORS	Three LEDs, VME access, sensor SCAN performed and PASS/FAIL self-test
PACKAGING	6U single-wide VME module
CONFORMANCE	ANSI/VITA 1-1994 (R2002) VMEbus spec

3 Theory of Operation

3.1 Microprocessor and VME Interface

The V460 module includes a microprocessor/VME interface section which includes the following elements:

- The microprocessor, a Motorola MC68B03
- Program read-only memory; a 27128 (16k bytes) is standard.
- Program RAM (CPU-resident 128 bytes)
- A dual-port memory, accessible by both the microprocessor and the VME bus. The DPM is physically a 2k by 16 bit array, but, for this application, is mapped such that it appears to be a contiguous block of 64 16-bit registers.
- Associated clock, decode logic, DPM arbitration logic, and watchdog timer/reset circuits.

3.2 Analog Acquisition Section

The analog front-end includes the following elements:

- A low-leakage, 16-channel, 4-wire analog multiplexer.
- A programmable constant-current source, settable to 1µA, 10µA, 100µA, 1mA, or "off".
- An input differential amplifier, with programmable gains of 1, 4, 16, and 64.
- An active low-pass filter which removes high-frequency noise from the amplified signal.
- A 16-bit bipolar analog-to-digital converter.
- A separate self-test multiplexer section.

3.3 Microprocessor Program Function

3.3.1 Powerup Initialization

Following powerup, SYSRESET, or reset by the internal watchdog timer, the V460 examines the onboard OPTIONS DIPswitch to determine if it is to operate in normal scan mode, or if it should run one of several self-test diagnostics. If self-test is not selected, the DIPswitch pattern is used to set the default sensor types and operating conditions for all sixteen inputs, and normal scanning is begun. Once the scan is in progress, users may write to the channel parameter registers to modify individual channel scan parameters; refer to Section 4.3 for details of OPTIONS switch settings, and Section 5.6 for parameter register usage. Details regarding the self-test diagnostics may be found in Section 6.4.

A more detailed description of the startup sequence is given in Section 6.5.

3.3.2 Sensor Scan Cycle and Timing

The V460 scans all sixteen sensors sequentially (in channel order 0... 15) and then performs a number of internal autozeroing and self-test functions before beginning the next scan. Typical scan time is 400 ms for all sixteen channels.

Several user-selectable parameters affect scan timing. They include:

- **Sensor pre-charge time.** Users can program sensor settling time on a per-channel basis. This parameter determines a wait period between applying sensor constant-current excitation and the beginning of digitization; it is used with high-impedance sensors to allow cable capacitance to charge prior to taking measurements.

- **Scan delay**. A single SCAN DELAY may be programmed to include a pause between scans. This delay is generally used to reduce sensor self-heating in situations where reduced update rate is acceptable.

- **Filtering**. Per-channel digital lowpass filtering may be user selected. This parameter does not change the physical scan rate but, by slowing the time response of sensor signals, it does reduce the effective scan rate of selected channels.

- **EMF cancellation.** Measurement of resistive-type sensors may be disturbed by the presence of thermal EMF errors in the sensor or associated wiring. The V460 can be programmed to measure and cancel such errors, with a moderate increase in scan time.

3.3.3 Sensor Linearization

The V460 is capable of measuring the voltage drop across the external input sensors and reporting the sensor voltage drop directly. It is also capable of converting the observed voltage into scaled engineering units. The procedure is as follows:

- Each channel is selected at its appropriate position in the scan. The input is gated into the A/D converter, digitized, and auto-zero corrected.

- The voltage data from the channel is checked against appropriate limits for the selected sensor type; if the signal is out of range, low or high, the reported temperature is forced to zero or the "error max" value respectively. If the voltage is in range, it is applied to a lookup table, using linear interpolation between table points, and the voltage value is converted into degrees Kelvin, with resolution dependent on sensor type.

The temperature lookup tables are derived from the published sensor voltage versus temperature data. A typical table contains about 1000 lookup entries, and the linear interpolation will generally be accurate to 0.01 Kelvins.

The standard V460 is capable of linearizing Lakeshore "Curve 10" silicon cryo-diode sensors, 100 ohm ISO-curve ("385") platinum RTDs, and 1000 ohm RTDs. The V460-3 linearizes the Lakeshore DT-670 silicon cryo-diode in place of the "Curve 10" sensors. Users of special or custom-calibrated sensors should use the V460 as a current source/voltmeter and provide linearization routines external to the V460.

3.3.4 Digital Filtering

Each of the sixteen sensor channels may be selected to apply digital smoothing of sampled temperature or millivolt inputs. Eight smoothing factors may be selected; they are referred to as filter factors "0" through "7", with 0 specifying no filtering action, and 7 requesting maximum filtering; refer to Section 5.6 for programming details.

The filtering algorithm operates as follows: an internal value variable Tn is maintained for each channel. When a fresh measurement sample S is acquired every scan, the following is done:

```
Tn = Tn + (S-Tn)/K
```

where the filter constant K is equal to 2^FF, where FF is the filter factor in the range of 1 to 7. The effect of this algorithm is nearly equivalent to filtering the data by a first-order lowpass filter having a time constant equivalent to K scan times. If the module is scanning at the usual rate of about 400 ms per scan, and filter factor 5 were selected, corresponding channel data would appear to be filtered by a time constant of 12.8 seconds (400 mS *

32). Note that since the filtering is based on actual scans and not real time, options that increase scan time will also increase effective filter time constants.

Digital signal filtering is useful in suppressing noise caused by both internal sources (amplifier noise, ADC noise, etc.) and external sources (electrical hum and spike pickup, actual temperature fluctuations, etc).

For those applications which need maximum speed of temperature signal acquisition, digital filtering may be disabled, as noted in Section 5.6.

3.3.5 Internal Integrity Tests

The V460 performs a number of internal integrity tests to help assure the quality of acquired data. Two types of tests are included: A group of powerup-reset tests are performed to verify the basic functionality of the microprocessor system, and a number of background-level consistency check tests are run continuously during normal scanning to verify the integrity of the analog front-end circuitry.

Section 4.5 discusses startup LED indications, and Section 6.5 discusses the actual startup sequence in detail.

4 Setup and Installation

4.1 Physical Installation

The V460 may be installed in any VME crate which conforms to the IEEE 1014 specification. Only mandatory (+5 V, ±12 V) power supplies are required. The module does not use interrupts, but does provide internal bus grant jumpers so as to not break system interrupt paths.

⚠ **CAUTION: Always switch off crate power before inserting or removing any modules**

⚠ **CAUTION: Please observe handling precautions described in manual section 6.2**

4.2 Address DIPswitch

Two DIPswitches are provided on the V460 module. The ADDRESS switch selects the base address at which the VME bus master can address the V460's 64 16-bit registers. The V460 is always addressed in the 'VXI' register range, namely in the hex address range C000 - FF80 of the VME 16-bit address space, responding to hex address modifiers 29 and 2D.

The ADDRESS switch is labeled SW1. Sections 1 through 8 of this switch correspond to VME address bits 13 through 6 respectively. Setting all switch sections OFF selects the lowest address, C000 hex. Specific switch weightings are as follows:

SECTION	VME ADDRESS BIT	HEX VALUE
8	13	2000
7	12	1000
6	11	800
5	10	400
4	9	200
3	8	100
2	7	80
1	-	-- (ignored)

Note that the module responds only to those addresses which have bits 14 and 15 high; thus the actual bus address is C000 plus the "hex value" contributed by all ON DIPswitch positions. Although the V460 will operate normally at hex address FF80 (e.g., all switches

ON), this address is reserved by the VXI specification for use by dynamically configurable modules and should not be used for V460s.

4.3 Options DIPswitch

Although the V460 may be programmed by the host computer system to allow various per-channel sensor types and signal processing options, many installations will perform properly with all sensors set up to be the same type, and with optional signal processing functions disabled. For these 'standard' installations, it is possible to set the on-board OPTIONS (SW 2) DIPswitch to initialize the V460 inputs such that no computer setup actions are required, and such that the module will acquire the desired data automatically.

The options DIPswitch can select the default sensor type, current source level, amplifier gain, and data format.

Switch sections 1, 2, 3, and 4 select the default sensor type. Selections are as follows:

S4	S3	S2	S1	CODE	SENSOR/MEASUREMENT TYPE
-	-	-	-	0	Skip Channel
-	-	-	ON	1	Bipolar Voltage Input (Current Source OFF)
-	-	ON	-	2	Resistance
-	-	ON	ON	3	Resistance with EMF Cancellation
-	ON	-	-	4	100Ω Din-Standard Platinum RTD
-	ON	-	ON	5	1000Ω Din RTD
-	ON	ON	-	6	V460-1: Lakeshore DT-470 Series Diode V460-3: Lakeshore DT-670 Series Diode
-	ON	ON	ON	7	Unipolar Voltage Input (Current Source OFF)
X	x	x	x		Codes 8-14 are reserved for future use
ON	ON	ON	ON	15	Run Self-test Diagnostics (see Section 6.4)

If codes 4, 5, or 6 are selected, the module automatically selects the appropriate excitation current and amplifier gain to acquire the selected sensor type, and the remaining four DIPswitch sections are ignored. For sensor codes 2 and 3, users must select the desired excitation current and amplifier gain, using DIPswitch Sections 5 through 8.

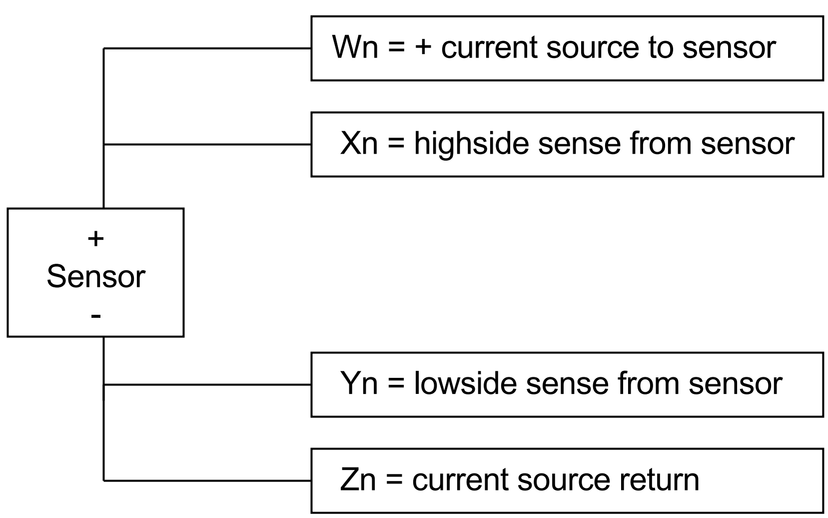
Amplifier gain is selected by OPTION switch Sections 5 and 6, and current source level is selected by sections 7 and 8 as follows:

S6	S5	GAIN
-	-	1
-	ON	4
ON	-	16
ON	ON	64

S8	S7	CURRENT
-	-	1 μA
-	ON	10 μA
ON	-	100 μA
ON	ON	1 mA

4.4 Input Connections

The V460 is equipped with two female D37 connectors mounted on its front panel. Each connector connects to eight 4-wire sensor inputs; sensor inputs are named Wn, Xn, Yn, and Zn, where "n" signifies a channel number (0 ... 15). See diagram below:



4-Wire sensor Diagram

Connector pinouts are as follows:

PIN	FUNCTION	PIN	FUNCTION	COMMENT
J1-2	W0	J2-2	W8	Sensor Positive Drive
J1-3	X0	J2-3	X8	Sensor Positive Sense
J1-21	Y0	J2-21	Y8	Sensor Negative Sense
J1-22	Z0	J2-22	Z8	Sensor Drive Return
J1-4	W1	J2-4	W9	
J1-5	X1	J2-5	X9	
J1-23	Y1	J2-23	Y9	
J1-24	Z1	J2-24	Z9	
J1-6	W2	J2-6	W10	
J1-7	X2	J2-7	X10	
J1-25	Y2	J2-25	Y10	
J1-26	Z2	J2-26	Z10	
J1-8	W3	J2-8	W11	
J1-9	X3	J2-9	X11	
J1-27	Y3	J2-27	Y11	
J1-28	Z3	J2-28	Z11	
J1-10	W4	J2-10	W12	
J1-11	X4	J2-11	X12	
J1-29	Y4	J2-29	Y12	
J1-30	Z4	J2-30	Z12	
J1-12	W5	J2-12	W13	Sensor Positive Drive
J1-13	X5	J2-13	X 13	Sensor Positive Senses
J1-31	Y5	J2-31	Y13	Sensor Negative Sense
J1-32	Z5	J2-32	Z13	Sensor Drive Return
J1-14	W6	J2-14	W14	
J1-15	X6	J2-15	X14	
J1-33	Y6	J2-33	Y14	
J1-34	Z6	J2-34	Z14	
J1-16	W7	J2-16	W15	
J1-17	X7	J2-17	X15	
J1-35	Y7	J2-35	Y15	
J1-36	Z7	J2-36	Z15	
J1-1	COMMON	J2-1	COMMON	VME Circuit Common
J1-18	COMMON	J2-18	COMMON	
J1-20	COMMON	J2-20	COMMON	
J1-37	COMMON	J2-37	COMMON	
J1-19	+12 Volts	J2-19	+12 Volts	Fused VME +12 Volts Supply

The COMMON pins are connected to the V460 ground plane, which is connected to VME bus ground, which itself should be connected to earth ground at some point in the system grounding scheme. It is recommended that these COMMON pins not be earth grounded externally, as this may disturb the existing VME grounding scheme.

The +12-volt outputs may be used for powering external devices. A fuse socket is located on the PC board to allow the insertion of an axial-lead picofuse to activate the +12-volt outputs. The fuse should be rated at no more than 0.5 amps. This fuse is NOT factory installed.

Note that the V460 front panel is NOT connected to VME GROUND or the connector COMMON pins. The panel is electrically conductive and will be grounded to the VME cage frame through the metallic module hold-down screws. The D-sub connector shells are in electrical contact with the module front panel; cable shields should be bonded to the metallic shells of the mating D-sub connectors.

4.5 LED Indicators

The blue VME LED will flash whenever the V460 is addressed from the VME bus.

The PASS/FAIL LED will go red whenever the module is asserting the VME SYSFAIL* line, and go green when it is not.

The amber SCAN LED will flash bright when a sensor scan is performed. During a programmed scan pause, the SCAN LED will glow dimly, flash briefly once a second, and make a longer flash whenever a sensor scan is done.

The SCAN LED also indicates startup tests, as noted in Section 6.5.

5 Programming Considerations

5.1 Dual-port Memory Considerations

The primary data interchange and control mechanism between the V460 and the VME bus is the 64-word-by-16-bit dual-port memory located on the module. Because both the VME bus and the microprocessor have full read/write access to all DPM locations, an "anti-collision" mechanism is needed to prevent data usage conflicts and interlock problems. In the V460 this interlocking is accomplished by the simple means of assigning, by convention, certain locations in DPM as being written into only by VME, and other locations reserved for writing only by the microprocessor. Although normal operation of the V460 assumes that the VME port will adhere to the documented conventions of register read/write use, system design is such that no unusual events will occur should the VME port write to a module "read only" DPM location. If the VME-side computer were to alter a "module output data" location, the V460 will restore that data in the next scan.

5.2 Default Operating Mode

Although the V460 has many operating modes and optional features, in many applications the module may be used in its default startup mode. On powerup, or following a hardware SYSRESET, the microprocessor will read the onboard OPTIONS switch and set all sensors to be the selected type.

If this setup is adequate, then the VME system may read the sensor voltages or temperatures and channel error flags as desired, with no setup actions required. DIPswitch positions are discussed in Section 4.3.

5.3 VME Register Addresses

The V460 interfaces to the VME bus through a group of 16-bit data registers. The registers are a contiguous block of 16-bit registers with beginning address selected by the ADDRESS DIPswitch as noted in Section 4.2.   Register functions are listed below, assuming that the first register ("VXID") is located at the module base address:

REG NAME	BYTE OFFSET	WORD INDEX	REGISTER FUNCTION
VXID	00h	0h	VXI ID/Logical Address Register
VTYPE	02	1	VXI Device Type
VCSR	04	2	VXI Status/Control Register
PGID	06	3	Firmware Program ID
PREV	08	4	Program Revision
STAT	0A	5	Module Status Flags
OPTS	0C	6	DIPswitch and other options
SCAN	0E	7	Scan Counter
PAUSE	10h	8h	Scan Pause Delay
PTIMER	12	9	Pause Timer
CHAN	14	A	Channel Currently Being Scanned
CRASH	16	B	Hard Reset Control Word
Z1	18	C	Autozero Value for Gain = 1
Z4	1A	D	Autozero Value for Gain = 4
Z16	1C	E	Autozero Value for Gain = 16
Z64	1E	F	Autozero Value for Gain = 64
CHEKA	20	10	Self-Check
CHEKB	22	11	Self-Check
CHEKC	24	12	Self-Check
CHEKD	26	13	Self-Check
CHEKE	28	14	Self-Check
CHEKF	2A	15	Self-Check
CHEKG	2C	16	Self-Check
LEAK	2E	17	Leakage Test
T0	30h	18h	Sensor Data 0
T1	32	19	Sensor Data 1
T2	34	1A	Sensor Data 2
T3	36	1B	Sensor Data 3
T4	38	1C	Sensor Data 4
T5	3A	1D	Sensor Data 5
T6	3C	1E	Sensor Data 6

T7	3E	1F	Sensor Data 7
T8	40h	20h	Sensor Data 8
T9	42	21	Sensor Data 9
T10	44	22	Sensor Data 10

REG NAME	BYTE OFFSET	WORD INDEX	REGISTER FUNCTION
T11	46	23	Sensor Data 11
T12	48	24	Sensor Data 12
T13	4A	25	Sensor Data 13
T14	4C	26	Sensor Data 14
T15	4E	27	Sensor Data 15
PAR0	50h	28h	Parameters, Sensor 0
PAR1	52	29	Parameters, Sensor 1
PAR2	54	2A	Parameters, Sensor 2
PAR3	56	2B	Parameters, Sensor 3
PAR4	58	2C	Parameters, Sensor 4
PAR5	5A	2D	Parameters, Sensor 5
PAR6	5C	2E	Parameters, Sensor 6
PAR7	5E	2F	Parameters, Sensor 7
PAR8	60h	30h	Parameters, Sensor 8
PAR9	62	31	Parameters, Sensor 9
PAR10	64	32	Parameters, Sensor 10
PAR11	66	33	Parameters, Sensor 11
PAR12	68	34	Parameters, Sensor 12
PAR13	6A	35	Parameters, Sensor 13
PAR14	6C	36	Parameters, Sensor 14
PAR15	6E	37	Parameters, Sensor 15

5.4 Module Overhead Registers

The VXID register is the VXI-compatible ID/LOGICAL ADDRESS register. It contains the value FEEE hex, the digit F denoting a register based, 16-bit VME/VXI device, and the hex digits EEE being the registered identification of Highland Technology as the manufacturer.

The VTYPE register contains the hex value 57BC, equivalent to the number 22460 decimal; this is the VXI-standard module type.

The VCSR register is the VXI-compatible control/status register. After initial powerup tests, this register will display the hex value C (decimal 12), corresponding to the "PASSED" and "READY" VXI flags.

The PGID register identifies the microprocessor program version; it generally contains the hex value 57BC, equivalent to 22460 decimal; special versions may contain other values (e.g., the V460-3 contains a value of 22463 decimal).

The PREV register contains, in its low byte, an ASCII code identifying the revision of the microprocessor program. The typical value is 41 hex, corresponding to the character A.

The STAT register displays a number of overall flags which indicate module states or errors. The register will be all zeroes in normal operation, and individual bits will be asserted if internal self checks do not pass. Bits 0-3 tag excessive Z1-Z4 autozero offsets respectively, and bits 8-15 tag out-of-range CHEKA-LEAK registers. If any of the powerup self-tests fail, the STAT register will be
set to all 1s.

The OPTS register contains, in its low byte, the value expressed in the OPTIONS DIPswitch. The presented value is a snapshot of the switch value taken at powerup reset time. The high byte of the OPTS register is reserved to flag future options.

The 16-bit SCAN COUNTER register increments once each time that all sixteen sensors are scanned and their values updated. It is a good indicator that the module is "alive" and scanning normally.

The PAUSE DELAY register contains a value which indicates the time, in seconds, which the module will wait between sensor scans. This value is set to zero at powerup, and may be altered by the user at any time.

The PTIMER register counts up, in one second increments, during a scan pause. When the PTIMER value hits or exceeds the user-loaded PAUSE DELAY value, a sensor scan will be performed and PTIMER reset to zero. This is a "read only" register from the VME port.

The CHAN register indicates the channel currently being scanned. During a scan pause, CHAN will be zero.

The CRASH register can be used to force a hard reset of the V460 module. If the VME master writes the number 54321 decimal (D431 hex) to this register, the microprocessor program will hang, causing the internal watchdog timer to force a hard reset.

The Z1-Z4 registers display the autozero offsets of the GAIN=1 through GAIN=64 preamp ranges respectively. These registers nominally contain the value 32768d (e.g., zero in offset binary), and may be expected to vary by as much as 26, 65, 220, and 840 counts respectively.

Eight self-test registers are provided. During normal scanning (or during an extended PAUSE) several internal test resistors are used to verify the operation of the current sources and amplifier. The check register functions are as follows:

REGISTER	TEST R	TEST I	GAIN	EXPECTED VALUE
CHEKA	5 K	1 mA	1	64000 ± 32
CHEKB	50 K	100 µA	1	64000 ± 32
CHEKC	500 K	10 µA	1	64000 ± 32
CHEKD	500 K	1 µA	4	25600 ± 13
CHEKE	5 K	100 µA	4	25600 ± 13
CHEKF	5 K	10 µA	16	10240 ± 6
CHEKG	5 k	10 µA	64	40960 ± 100
LEAK	500 k	0	64	32768 ± 205

The LEAK register indicates the magnitude of leakage current in the front-end multiplexer. Nominal value should be 32768d (e.g., zero in offset binary) with an allowable range of ± 205 LSB's from nominal. Each LSB corresponds to about 4.88 picoamperes of leakage.

5.5 Sensor Data Registers

The T0 through T15 registers report the measured value of channels 0 through 15 respectively. The scaling of the binary data in each channel depends on the type of sensor selected, the amplifier gain, and the current source setting for that channel.

For bipolar (code type 1) voltage inputs, data is presented in offset binary, representing signed voltage inputs. With an amplifier gain of one, negative full scale (hex data pattern 0000h) represents an input of -5.12 volts, and full scale (FFFFh) would be equivalent to +5.11984 volts. For programmed gains of 4, 16, or 64, the full- scale voltages are respectively 1.28, 0.32, and 0.08.

For unipolar voltage inputs (codetype 7), data is presented as unsigned binary. With gain=1, hex code 0000 corresponds to zero volts in, and code FFFFh corresponds to +5.11992 volts.

When resistances are measured, data is reported identically to unipolar voltage, but the constant-current source is turned on during the voltage measurement. If a 5-K resistor were measured with the 1-mA current source and a gain of 1, the corresponding hex data would be FA00 (decimal 64000), equivalent to 5.000 volts IR drop.

Temperature sensor values are reported as unsigned integers, in units of Kelvins * 100. Absolute zero temperature thus scales to hex code 0000h, and code FFFFh would correspond to +655.35 K.

Note that the unique hex code FFFFh is not normally presented as a measured sensor value, but is reserved as an error flag. This value will be reported if a sensor output exceeds the upper limit of an associated linearization table, or if a measured EMF compensation value is unreasonable.

5.6 Channel Parameter Registers

Each input channel has an associated PARAMETERS register.
Register
bit assignments are as follows:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	HZ	P1	P0	EMF	F2	F1	F0	I1	I2	G1	G0	T3	T2	T1	T0

The T3-T0 bits select the sensor type, with bits weighted in a binary sequence 8-4-2-1 respectively. Sensor codes are noted in Section 4.3.

The G1:G0 bits select amplifier gain. The pattern is as follows:

G1	G0	GAIN
0	0	1
0	1	4
1	0	16
1	1	64

The I1:I0 bits select current source level is as follows:

I1	I0	CURRENT
0	0	1 µA
0	1	10 µA
1	0	100 µA
1	1	1 mA

Note that, for voltage-only channels, the current source is held off and the I1:I0 bits are ignored.

For temperature channels (code type 4, 5, and 6) both the gain and current source programming bits are ignored. 100 ohm RTDs use 1 mA excitation; 1K RTDs use 100 µA;

and diode sensors always use 10 µA current drive.

The F2:F0 bits select the digital filtering factor, from 0 to 7. Filtering is discussed in Section 3.3.4. If all F bits are off, filtering is disabled.

If the EMF bit is set, the module will autozero on the external EMF of resistive-type sensors (sensor codes 2, 3, 4, and 5). In this mode, the module will first read the sensor voltage with the cur-rent source turned off; this zero offset is subtracted from normal resistance measurements, eliminating any constant potentials in the measurement loop. The EMF function cannot be used with voltage or diode inputs, and the EMF bit is ignored for those sensor types. This technique of EMF compensation provides identical results to the common polarity reversal technique, but does not incur the double precharge time penalty required of the reversal scheme.

The P1:P0 bits allow a precharge delay to be programmed prior to making channel measurements. The current source is turned on and a pause allows cable capacitance to charge up before a measurement is made. Bit functions are as follows:

P1	P0	PRECHARGE DELAY
0	0	2 ms
0	1	8 ms
1	0	32 ms
1	1	28 ms

As an example, if a sensor had a maximum resistance of 1 MOhm and a cable run of 100 feet, and assuming 15 pF per foot cable capacitance, the sensor:cable time constant would be 1.5 milliseconds, so selection of the 32 ms precharge would assure ample (21 time constants) settling time before measurement. The minimum precharge (2 ms) is always used for 100 ohm and 1 K RTDs.

In digitizing an input channel, the V460 samples the signal a number of times over a 16.66 millisecond interval, and averages the sample values. This technique reduces internal and external noise sources and averages out induced 60 Hz powerline-frequency hum. If the HZ bit is set, the sampling rate is modified to optimize for rejection of 50 Hz hum.

At powerup, the OPTIONS switch is read and a default channel setup is loaded into all sixteen PARAMETER registers. The sensor types, gain, and current source levels are loaded from the switch. The filter factor is set OFF, precharge to 8 ms, and the HZ bit is set OFF. The EMF bit is set only if sensor type 3 is selected. Users may, of course, overwrite these default PARAMETER settings at any time

6 Calibration and Maintenance

6.1 Handling Precautions

The V460 makes precision measurements to better than 100 PPM accuracy, with applied currents down to one microampere. The performance of the unit may be impaired by improper handling.

The V460 should not be exposed to severe shocks or vibration. If the unit is dropped or otherwise shocked, its calibration should be checked.

The V460 is very sensitive to electrical surface leakage, especially when using high gains and low current sources. The board must not be exposed to excess dust, and should always be used with a filtered air supply. The unit must not be exposed to water or condensation. If the parts-side cover is removed, do NOT touch the board surface or components with fingers; wear clean cotton gloves when handling the exposed board.

Make sure that mating connectors, cables, and field wiring are clean and dry and demonstrate leakage resistances compatible with desired measurement accuracy.

The solder side of the V460 board is coated with a polyurethane conformal coating to avoid conductive contamination. Do not handle the module such as to scrape the coating from component leads or from the board surface.

If the board is suspected to be contaminated with conductive residues, wash it thoroughly in clean isopropyl alcohol, then, while still wet with alcohol, spray thoroughly with hot tap water, shake dry, and re-rinse in clean distilled water. Bake dry at 175 F for at least four hours.

6.2 Calibration Procedures

The V460 does not require periodic maintenance. The internal self-checks will generally insure that the unit is within specifications; for critical applications, annual verification and calibration is recommended.

The calibration sequence is as follows:

1. Remove the cover and locate the T1/T2 test point cluster near the lower-left corner of the board. Remove adjacent multiplexer chips U36 and U38. Using a high-precision digital multimeter (30 PPM or better, Kiethley Model 2001 or

equivalent), measure the resistance at the 500K, 50K, and 5K test points, making sure to subtract any test lead resistance. Adjust the marked trimpots for exactly the proper resistance at each test point.

2. Replace the mux chips in their original locations, insert the module in a VME rack, and power it up; warm up for at least 30 minutes. Connect a precision voltage source to the Channel 0 input. Program Channel 0 to be a unipolar voltage input with gain of one. Apply +5.000 volts ± 30 PPM to the input and read and display the channel zero (T0) data. Adjust the G1 trimpot for a T0 register reading of 5.000 volts (64000d, FA00h). Repeat for gain 4, using 1.25 volts input, adjusting the G4 pot. Repeat for gain 16, using 0.3125 volts input, adjusting the G16 pot. Finally calibrate at gain = 64, using an input of 0.078125 volts and adjusting the G64 trimmer.

3. Observe the self-check registers and adjust the current sources:

   - Adjust the "1m" trimpot until CHEKA reads 64000d, FA00h;
   - Adjust the "100u" trimpot until CHEKB reads 64000d;
   - Adjust the "10u" trimpot until CHEKC reads 64000d;
   - Adjust the "1u" trimpot until CHEKD reads 25600d, 6400h.

6.3 Online Integrity Tests

During normal scan operation, a number of internal integrity tests are performed. These tests either perform range or reasonableness tests on internal variables or cross-check various analog signals. A failure of any of these tests will result in an associated error flag being set in the system status word.

6.4 Hardware Diagnostics

If the V460 is reset with sections 1, 2, 3, and 4 of the OPTIONS switch ON, the module will enter self-test mode. The high four positions of the OPTIONS switch will then be read to determine one of sixteen possible tests to be run.

The detailed self-test mode powerup sequence is as follows:

1. Steps 1-3 of the normal powerup sequence are followed, as noted in Section 6.5.

2. The OPTIONS DIPswitch sections 1-4 are sensed ON; SYSFAIL is cleared and the

PASS/FAIL LED goes green.

3. The high four DIPswitch positions are read and one of sixteen possible test routines is executed. If the routine passes, the SCAN LED will blink twice; if the test fails, SCAN will display one long blink, the PASS/FAIL LED will go (and remain) red, and SYSFAIL will be asserted.
4. If switch positions 1-4 are still ON, the program loops back to step C above. If not, a normal powerup/operate sequence is initiated.

The self-tests are as follows:

S8	S7	S6	S5	TEST
--	--	--	--	Ignore DPM; allows DPM tests from VME bus.
--	--	--	ON	Test Low PM; tests first 32 registers
--	--	ON	--	Test High DPM ; tests last 32 registers
--	--	ON	ON	Test All DPM ; tests all 64 registers
--	ON	--	--	Write Pattern to DPM ; pattern = FF00h + reg index
--	ON	--	ON	Park on Ch 0, Voltage Mode
--	ON	ON	--	Park on Ch 0, I = 1 µA
--	ON	ON	ON	Park on Ch 0, I = 10 µA
ON	--	--	--	Park on Ch 0, I = 100 µA
ON	--	--	ON	Park on Ch 0, I = 1 mA
ON	--	ON	--	Wiggle SYSFAIL; exercises SYSFAIL driver

6.5 Startup Sequence Details

Following a powerup, SYSRESET, or soft restart, the following sequence is executed:

The PASS/FAIL LED will powerup red, and the VME bus SYSFAIL signal will be asserted.

Four basic integrity tests are run: basic processor functionality, EPROM checksum, CPU

RAM test, and dual-port memory (VME registers) test. At the end of each of the first three tests, the SCAN LED will blink twice; after the last test, the PASS/FAIL LED will go green, SYSFAIL will be released, and normal scanning will begin. The VME CSR will then show the PASSED (B2) and READY (B3) bits up.

If any self-tests fail, the processor will loop; The CSR will be clear and the STATUS register will be set to all 1s. The VXID and VTYPE registers will be loaded, but all other VME registers will be uninitialized. The microprocessor will attempt to observe and respond to its VME CSR register. If the SYSFAIL INHIBIT bit (B1) is asserted by the VME master, the V460 will cease to assert the SYSFAIL line, and its PASS/FAIL LED will go green. If the master asserts the SOFT RESET (B0) bit, the V460 will enter its soft reset state and, when the master clears SOFT RESET, the V460 program will restart. SOFT RESET must be held true for at least 50 microseconds to ensure recognition by the V460.

7 Versions

V460-1: 16-channel VME current source and analog measurement module

8 Customization

Consult factory for information about additional custom versions.

9 Hardware and Firmware Revision History

9.1 Hardware Revision History

Revision A	December 1992
Revision B	December 2001
Revision C	December 2003

9.2 Firmware Revision History

Program 22460A is the original firmware release for the V460 module (version 1), and it comprises the linearization table for Lakeshore diode DT-470.

Program 22460B, V460 module version 1 was modified from revision 2246A to implement an ADC change from offset binary to two's complement. January 2002

Program 22463A, V460 module version 3 is for use with the Lakeshore DT-670 diode. October 2002

Program 22463B, V460 module version 3 was modified from revision 22463A to implement an ADC change from offset binary to two's complement. January 2002