Innovations in Spectroscopy and Optical Sensing

Ocean Optics, Inc.
380 Main St.
Dunedin, FL 34698
(727) 733-2447 (727) 733-3962 FAX
http//www.OceanOptics.com

SAD500 Serial Port Interface Communications and Control Information

Overview

The SAD500 Serial Port Interface is a microcontroller-based analog-to-digital converter that interfaces to Ocean Optics' S2000 and S1024DW Miniature Fiber Optic Spectrometers and other stackable modules. When using an RS-232 serial communications protocol, the SAD500 can control all functions of the S2000 and S1024DW spectrometers and implement standard spectral processing. The SAD500 contains non-volatile flash memory to store spectra and operating parameters. Upon power-up, the SAD500 reads a set of operating parameters from flash memory. Users can tailor these parameters to satisfy their data acquisition and processing needs.

Hardware Description

The SAD500 utilizes a 16MHz Motorola 68HC16 microcontroller to control all functions. Digital communications utilizes RS-232 serial communications with 8 data bits, no parity, and a 1 data bit (8-N-1). While the majority of the general-purpose I/O pins control the S2000 and S1024DW spectrometers, there are headers for expansion modules. The available signals are the 7-bit through 10-bit A/D lines, 7 general purpose digital I/O lines, and the 3 wire Serial Peripheral Interface (SPI) bus with 14 chip selects. Consult Ocean Optics for custom software to drive these expansion signals.

Upon power-up, the SAD500 transmits the string "Ocean Optics Serial A/D – x", where x, the error code, should be 0. It transmits at the baud rate (default 9600 baud) defined in flash memory. The SAD500 operates with three segments of memory: program memory and SRAM and flash memory for data storage. The user cannot modify the 64KB of program memory. The following describes each data memory section.

SRAM (Fast) Memory

There are 64KB of SRAM memory used to store data as it is acquired by the SAD500. This section holds up to 15 full spectral acquisitions consisting of 2048 pixels. Only full spectra are stored in SRAM memory. Spectra are organized in a stack formation (i.e. LIFO).

Flash (Slow) Memory

There are 4MB of flash memory for non-volatile data storage. Data is transferred from fast memory to slow memory by the appropriate command or data storage mode parameter. When data is written to this section, the pixel mode parameter determines which pixels are written. Pixel modes can be mixed in the section. Two pointers determine where in this section data is written and read. The user cannot modify the write pointer but can adjust the read pointer (E command). For best results, view this memory as a FIFO buffer for scans. Due to several limitations, the user can only erase the entire contents of slow memory (L command) and not individual spectra. The first block of this memory contains the operating parameters that are recalled upon power-up. These parameters include the read and write pointers. To insure proper storage of data, issue the close session command (C command) prior to the interruption of power so that these pointers are accurately stored; otherwise, data can be overwritten, misinterpreted, and lost. The flash memory is rated for 1 million write cycles; therefore, the close session command should not be issued after every write cycle but only before loss of power.

Instruction Set

Command Syntax

The table on page 3 lists all of the commands and the microcode version number with which they were introduced. All commands consist of an ASCII character passed over the serial port, followed by some data. The length of the data depends on the command. The format for the data is either ASCII or binary (default). The ASCII mode is set with the "a" command and the binary mode with the "b" command. To insure accurate communications, all commands respond with an ACK (ASCII 6) for an acceptable command or a NAK (ASCII 21) for an unacceptable command (i.e. data value specified out of range).

In the ASCII data value mode, the SAD500 "echos" the command through the RS-232 port. In the binary mode, all data, except where noted, is passed as 16-bit unsigned integers (WORDs) with the MSB followed by the LSB. By issuing the "v" command (Version number query), the data mode can be determined by viewing the response (ASCII or binary).

In a typical data acquisition session, the user sends commands to implement the desired spectral acquisition parameters (integration time, A/D rate, pixel mode, pixel boxcar smoothing, adding scans, etc.). Then the user sends commands to acquire spectra (S command) with the previously set parameters. If slow memory is not being used, then close session (C command) does not need to be issued. If necessary, the baud rate can be changed at the beginning of this sequence to speed up the data transmission process.

Command Summary

Letter	Description	Version
A	Adds scans	1.00.0
B	Sets pixel boxcar width	1.00.0
C	Closes session and stores operating parameters	1.00.0
D	Dumps fast memory to slow memory	1.00.0
E	Changes slow memory read pointer	1.00.0
F	Sets A/D rate	1.00.0
G	Sets compressed data transfer	1.02.0
H	Sets spectrometer channel	1.00.0
I	Sets integration time	1.00.0
J	Sets strobe enable (S0) line	1.00.0
K	Changes baud rate	1.00.0
L	Erases memory	1.00.0
M	Sets storage mode parameter	1.00.0
N	Sets number of scans to store	1.00.0
O	Communicates if scan received is OK	1.00.0
P	Sets pixel mode	1.00.0
Q	Initializes SAD500	1.00.0
R	Reads all stored data	1.00.0
S	Starts spectral acquisition with previously set parameters	1.00.0
T	Sets external trigger mode	1.00.0
U	Communicates the slow memory available	1.00.0
W	Communicates the number of scans in memory	1.00.0
X	Communicates the fast memory available	1.00.0
Z	Reads one spectrum from memory	1.00.0
a	Sets ASCII mode for data values	1.01.0
b	Sets binary mode for data values	1.01.0
h	Sets correlated double sampling mode for S1024DW	1.02.0
k	Sets transmission of 16-bit checksum of spectral data	1.02.0
l	Finds maximum value of scan	1.01.0
q	Queries error code	1.00.0
t	Reads integration counter	1.00.0
v	Provides microcode version #	1.00.0
?	Queries parameter values	1.00.0

Command Descriptions

A detailed description of all SAD500 commands follows. The {} indicates a data value which is interpreted as either ASCII or binary (default). The default value indicates the value of the parameter setting when the Initialize command (Q) is executed.

Add Scans

Description: Sets the number of discrete spectra to be summed together. Since this routine can add up to 15 spectra, each with a maximum intensity of 4096, the maximum returned spectral intensity is 65535.

Command Syntax:	A{DATA WORD}
Response:	ACK or NAK
Range:	1-15
Default value:	1

Pixel Boxcar Width

Description: Sets the number of pixels to be averaged together. A value of *n* specifies the averaging of *n* pixels to the right and *n* pixels to the left. This routine uses 32-bit integers so that overflow cannot occur; however, the result is truncated to a 16-bit integer prior to transmission of the data.

Command Syntax:	B{DATA WORD}
Response:	ACK or NAK
Range:	0-500
Default value:	0

Close Session

Description: Sets the operating parameters to the non-volatile flash memory and controls the baud rate the next time the SAD500 powers up. This command stores the current slow memory read and write pointers, which control where data is written to and read from. If this command is not executed at the end of the session, an invalid write pointer would be recalled and previously written data would be overwritten.

Command Syntax:	C{DATA WORD}
Value:	0 = Do not store parameters 1 = Store all parameters except baud rate 2 = Store all parameters including the current baud rate 3 = Store all parameters except set baud rate to its default value
Response:	ACK or NAK. A NAK value can be generated if an error occurs in the flash memory writing operation. See error codes to explanation.
Default value:	N/A

! If the user issues the C3 command, the current baud rate remains unchanged; the default baud rate is not used until the next power-up.

! During sessions where the SAD500 has written data to slow memory, failure to issue this command prior to the interruption of power will result in unretrieved data.

Dump Fast Memory to Slow Memory

Description: Moves spectral data from fast memory to slow memory. The current pixel mode parameters are used to determine which pixel values are to be written to slow memory.

Command Syntax:	D
Response:	ACK or NAK. Generate a NAK value if an error occurs in the flash memory writing operation. See error codes for explanation.
Default value:	None

Move Slow Memory Read Pointer

Description: Moves the slow memory read pointer

Command Syntax:	E{DATA WORD}
Value:	0 – Move read pointer to the beginning of slow memory 65535 – Move read pointer to the current write pointer location (end of valid memory)
Response:	ACK or NAK. A NAK value can be generated if an error occurs while reading the flash memory. See error codes for explanation.
Default value:	None

! This command should be used with caution. Use this command to repeat the read out of slow memory or skip over previously read out data.

A/D Rate

Description: Sets the A/D rate in kHz to the value specified.

Command Syntax:	F{DATA WORD}
Response:	ACK or NAK
Range:	1-500
Default value:	500

Compressed Mode

Description: Specifies whether the data transmitted from the SAD500 should be compressed to speed data transfer rates. For more information on SAD500 Data Compression, see Technical Note 1.

Command Syntax:	G{DATA WORD}
Value:	0 = do not use data compression 1 = use data compression
Response:	ACK or NAK
Default value:	0

Spectrometer Channel

Description: Sets the spectrometer channel to be digitized.

Command Syntax:	H{DATA WORD}
Response:	ACK or NAK
Range:	0-7
Default value:	0

Integration Time

Description: Sets the S2000's and S1024DW's integration time, in milliseconds, to the value specified.

Command Syntax:	I{DATA WORD}
Response:	ACK or NAK
Range:	5 - 65535
Default value:	100

Strobe Enable

Description: Sets the S2000's and S1024DW's S0 (Strobe enable) line to the value specified. This command only has an effect in trigger modes 0 and 1.

Command Syntax:	J{DATA WORD}
Value:	0 = Light source/strobe off--S0 low 1 = Light source/strobe on--S0 high
Response:	ACK or NAK
Default value:	1

Baud Rate

Description: Sets the SAD500's baud rate.

Command Syntax:	K{DATA WORD}
Value:	0=2400 1=4800 2=9600 3=19200 4=38400 5=57600 6=115200
Response:	See below
Default value:	2

When changing baud rates, the following sequence must be followed:

1. Controlling program sends K with desired baud rate, communicating at the old baud rate
2. A/D responds with ACK at old baud rate, otherwise it responds with NAK and the process is aborted
3. Controlling program waits longer than 50 milliseconds
4. Controlling program sends K with desired baud rate, communicating at the new baud rate
5. A/D responds with ACK at new baud rate, otherwise it responds with NAK and old baud rate is used

! If a deviation occurs at any step, the previous baud rate is utilized.

! The SAD500 has a one byte input buffer. When communicating at 115,200 baud, we strongly recommend implementing a 1 millisecond delay between the transfer of each byte. The 1 millisecond delay ensures that this one byte buffer is not overrun.

Clear Memory

Description: Clears memory based upon the value specified. If slow memory is cleared, the current operating parameters are written back to flash memory since the read and write pointers need to be reinitialized. This process takes ~7 seconds. Clearing fast memory is immediate (<50us).

Command Syntax:	L{DATA WORD}
Value:	0 = Both fast and slow memory 1 = Fast memory 2 = Slow memory
Response:	ACK or NAK
Default value:	N/A

! CAUTION: All stored spectra are lost when the clear memory command is executed.

Data Storage Mode

Description: Sets the data storage mode for future spectral acquisitions.

Command Syntax:	M{DATA WORD}
Value:	0 = Scans transmitted through the serial port 1 = Scans stored in fast memory 2 = Scans stored in slow memory
Response:	ACK or NAK
Default value:	0

Number of Scans to Store

Description: Sets the number of scans to be acquired and stored. If the Data Storage Mode (M) value is 0 (transmits the data immediately) then this parameter must be 1. If this condition is not true when the Spectral Acquisition command (S) is sent, then an ETX is returned.

Command Syntax:	N{DATA WORD}
Response:	ACK or NAK
Range:	1 - 65535
Default value:	1

Scan Received OK

Description: Communicates whether or not the entire set of scan data was received successfully. If an O1 command is executed, the entire set of spectral data is re-transmitted. This optional feature can be utilized only if no other command is issued between the Scan (S) command and this command.

Command Syntax:	O{DATA WORD}
Value:	0 = Data received OK – No action taken 1 = Data transmission in error – re-transmit the previous scan
Response:	ACK or NAK
Default value:	N/A

Pixel Mode

Description: Specifies which pixels are transmitted or stored in slow memory. While all pixels are acquired on every scan, this parameter determines which pixels will be transmitted or stored.

Command Syntax:	P{DATA WORD}	
Value:	Description	Example
	0 = all 2048 pixels	P 0 (spaces for clarity only)
	1 = every n^{th} pixel with no averaging	P 1 n
	2 = every n^{th} pixel with averaging (effective boxcar width of *n*)	P 2 n
	3 = pixel x through y every n pixels	P 3 x y n
	4 = up to 81 randomly selected pixels between 0 and 2047 (denoted p1, p2, … p81)	P 4 n p1 p2 p3…p81
	256 = all 2048 pixels, compressed	
	257 = every nth pixel with no averaging, compressed	
	258 = every nth pixel with averaging, compressed	
	259 = pixel x through y every n, compressed	
	260 = up to 81 selected pixels, compressed	
	512 = all 2048 pixels, with CDS	
	513 = every nth pixel with no averaging, with CDS	
	514 = every nth pixel with averaging, with CDS	
	515 = pixel x through y every n, with CDS	
	516 = up to 81 selected pixels, with CDS	
	768 = all 2048 pixels, compressed, with CDS	
	769 = every nth pixel with no averaging, compressed, with CDS	
	770 = every nth pixel with averaging, compressed, with CDS	
	771 = pixel x through y every n, compressed, with CDS	
	772 = up to 81 selected pixels, compressed, with CDS	
Response:	ACK or NAK	
Default value:	0	

All pixel modes involving correlated double sampling can only be used with the S1024DW spectrometer.

Since most applications only require a subset of the spectrum, using the Pixel Mode command can greatly reduce the amount of time required to transmit a spectrum while still providing all of the desired data.

Initialize

Description: Sets all operating parameters to their default value.

Command Syntax:	Q
Response:	ACK or NAK

This command resets operating parameters to the parameters that were read from flash memory at power-up.

Read All Data

Description: Transmits all data from either fast or slow memory. For fast memory, the current pixel mode is utilized. For slow memory, the pixel mode in effect when that scan was stored is utilized. After transmitting each scan, the user must send the Scan Received OK command (O) before transmitting the next scan.

Command Syntax:	R{DATA WORD}
Value:	1 = Read data from fast memory 2 = Read data from slow memory
Response:	ACK or NAK
Default value:	N/A

! Consider issuing the Read Out 1 Scan from Memory command (see page 8) rather than issuing this command. Once initiated, this command continues to execute until all data is transmitted.

Spectral Acquisition

Description: Acquires spectra with the current set of operating parameters. When executed, this command determines the amount of memory required. If sufficient memory does not exist, an ETX (ASCII 3) is immediately returned and no spectra are acquired. An STX (ASCII 2) is sent once the data is acquired and stored. If the Data Storage Mode value is 0, then the data is transmitted immediately.

Command Syntax:	S
Response:	If successful, STX followed by data If unsuccessful, ETX

The format of returned spectra includes a header to indicate scan number, channel number, pixel mode, etc. The format is as follows:

WORD 0xFFFF – start of spectrum
WORD channel number
WORD scan number
WORD scans in memory
WORD integration time in milliseconds
WORD integration time counter -- see the Read Integration Counter command (t) for details
WORD pixel mode
WORDs if pixel mode not 0, indicates parameters passed to the Pixel Mode command (P)
WORDs spectral data
WORD 0xFFFD – end of spectrum
WORD checksum (optional)

Trigger Mode

Description: Sets the S2000's and S1024DW's external trigger mode to the value specified by driving the appropriate TTL signals onto the S0 and S1 lines.

Command Syntax:	T{DATA WORD}
Value:	0 = Normal – Continuously scanning 1 = Software trigger 2 = External synchronization 3 = External hardware trigger
Response:	ACK or NAK
Default value:	0

! When using external trigger modes (Values 1 through 3), the SAD500 and spectrometer require a trigger event after the Spectral Acquisition command (S) is issued.

Slow Memory Available

Description: Returns the amount of available slow memory in KBytes.

Command Syntax:	U
Response:	ACK followed by {DATA WORD}
Default value:	N/A

Number of Scans in Memory

Description: Returns the number of scans in the memory.

Command Syntax:	W{DATA WORD}
Value:	1 = Return number of scans in fast memory 2 = Return number of scans in slow memory
Response:	ACK followed by {DATA WORD}
Default value	N/A

Fast Memory Available

Description: Returns the number of full spectra that can be stored in fast memory.

Command Syntax:	X
Response:	ACK followed by {DATA WORD}
Default value:	N/A

Read Out One Scan from Memory

Description: Reads out one scan from the type of memory specified. The data is returned with the header information as described in the Spectral Acquisition command (S). To insure error free communications, follow this command with the Scan Received OK command (O).

Command Syntax:	Z{DATA WORD}
Value:	1 = Read scan from fast memory 2 = Read scan from slow memory
Response:	If successful, ACK followed by data (See Spectral Acquisition [S] for header information). If unsuccessful, NAK. NAK results if an error occurs in the flash memory reading operation or if no data is in fast memory. See error codes for explanation.
Default value:	N/A

ASCII Data Mode

Description: Sets the mode in which data values are interpreted to be ASCII. Only unsigned integer strings (0 – 65535) are allowed in this mode. Data values are terminated with a carriage return (ASCII 13) or linefeed (ASCII 10). In this mode, the SAD500 “echos” the command and data values back to the RS-232 port.

Command Syntax:	aA
Response:	ACK or NAK
Default value:	N/A

! This command requires that the string “aA” be sent without any CR or LF to insure that this mode is not entered inadvertently.

! A legible response to the Version number query (“v” command) indicates the SAD500 is in the ASCII data mode.

Binary Data Mode

Description: Sets the mode in which data values are interpreted as binary. In this mode, only 16 bit unsigned integer values (0 – 65535) -- with the MSB followed by the LSB -- are allowed.

Command Syntax:	bB
Response:	ACK or NAK
Default value:	Default at power up – not changed by Q command

! This command requires that the string "bB" be sent without any CR or LF to insure that this mode is not entered inadvertently.

Correlated Double Sampling (CDS) Mode

Description: Specifies whether the data transmitted by the SAD500 is assumed to be correlated double sampled data when using the S1024DW. When in the CDS mode, the data pixels are transferred first, followed by the dark pixels. For example, when in pixel mode 512 (all pixels transferred) 1024 data pixels will be followed by 1024 dark pixels. For more information on Correlated Double Sampling, see Technical Note 2.

Command Syntax:	H{DATA WORD}
Value:	0 = do not use correlated double sampling 1 = use correlated double sampling
Response:	ACK or NAK
Default value:	0

! This mode can only be used with the S1024DW spectrometer

Checksum Mode

Description: Specifies whether the SAD500 will generate and transmit a 16-bit checksum of the specstral data. This checksum can be used to test the validity of the spectral data, and its use is recommended when communicating at 115,200 baud. For more information on the SAD5000 Checksum Calculation, see Technical Note 3.

Command Syntax:	k{DATA WORD}
Value:	0 = do not transmit the checksum 1 = use correlated double sampling
Response:	ACK or NAK
Default value:	0

Find Maximum Spectral Reading

Description: Returns the maximum value of the last spectra acquired.

Command Syntax:	l (lower case letter l)
Response:	ACK or NAK followed by {Data Word}
Default value:	N/A

! Immediately after power up, this command will return a non-zero value that is due to the Fast memory data segment being at some undefined state.

Query Error Code

Description: Returns and clears the current error code.

Command Syntax:	q
Response:	ACK followed by {DATA WORD}
Default value:	N/A

The following table describes the specific error condition for a specific bit being set. An error code of zero indicates normal operation.

Bit	**Description**
15 (0x8000)	Error while loading boot table from slow memory
14 (0x4000)	Slow memory is full
13 (0x2000)	Can't create boot table in slow memory
12 (0x1000)	Must move boot table -- clear slow memory first
11 (0x0800)	Error while reading previously written block of slow memory
10 (0x0400)	Can't find start of next scan in slow memory
9 (0x0200)	Bad format in slow memory -- mainly pixel mode value
8 (0x0100)	Can't write to previously good block of slow memory
7 (0x0080)	Reserved
6 (0x0040)	Reserved
5 (0x0020)	Reserved
4 (0x0010)	Reserved
3 (0x0008)	Reserved
2 (0x0004)	Reserved
1 (0x0002)	Reserved
0 (0x0001)	Reserved

Read Integration Counter

Description: Returns the value of the current integration time counter. This value is the number of integration cycles used since power-up. This 16-bit counter wraps around from 65535 to 0.

Command Syntax:	t
Response:	ACK followed by {DATA WORD}
Default value:	N/A

Version Number Query

Description: Returns the version number of the code running on the microcontroller. A returned value of 1020 is interpreted as 1.02.0.

Command Syntax:	v
Response:	ACK followed by {DATA WORD}
Default value	N/A

Query Variable

Description: Returns the current value of the parameter specified. The syntax of this command requires two ASCII characters. The second ASCII character corresponds to the command character which sets the parameter of interest (acceptable values are P, B, M, A, N, I, H, F, K, T, J, h, k, G). A special case of this command is ?p (lower case) which returns the complete parameters of the Pixel Mode command. The returned format starts with an ACK, then the pixel mode value, and finally the data required to specify pixel mode (see Pixel Mode command for details).

Command Syntax:	?{ASCII character}
Response:	ACK followed by {DATA WORD}
Default value:	N/A

Examples

Below are examples on how to use some of the commands. Commands are in **BOLD** and descriptions are in parenthesis. For clarity, the commands are shown in the ASCII mode (“aA” command) instead of the default binary mode.

Example 1

The desired operating conditions are: acquire spectra from spectrometer channel 0 (master) with a 200ms integration time, set pixel boxcar width to 5

aA	(Set ASCII Data Mode)
Q	(Reset SAD500 to default conditions)
I200	(Set integration time to 200ms)
B5	(Set boxcar width to 5)
S	(Acquire spectra)
…	Repeat as necessary

Example 2

The desired operating conditions are: acquire spectra from spectrometer channels 0 and 1 with a 50ms integration time on channel 0 and 10ms integration time on channel 1; add 5 scans on each channel; transmit pixels 500, 600 and 700 on each channel

aA	(Set ASCII Data Mode)
Q	(Reset SAD500 to default conditions)
A5	(Add 5 spectra)
P4 3 500 600 700	(Set pixel mode -- spaces shown for clarity)
I50	(Set integration time to 50ms)
H0	(Set active channel to 0)
S	(Acquire spectra)
I10	(Set integration time to 10ms)
H1	(Set active channel to 1)
S	(Acquire spectra)
	Loop back to I50 command and repeat for additional data sets.

Example 3

Store these operating conditions in flash memory so they are recalled for subsequent power-ups: acquire spectra from channel 0 with 50ms integration time, set software trigger mode, set baud rate at 57600

aA	(Set ASCII Data Mode)
Q	(Reset SAD500 to default conditions)
I50	(Set integration time to 50ms)
T1	(Set trigger mode to software trigger)
K5	(Start baud rate change to 57,600)
	Wait for ACK, change to 57600, wait for 50ms
K5	(Verify command, communicate at 57600)
C2	(Store all operating parameters in flash memory)
	Cycle power
S	(Acquire spectra)
…	Repeat as necessary

Example 4

Store 50 spectra with every 4th pixel in slow memory, read them out

aA	(Set ASCII Data Mode)
M2	(Set storage mode to slow memory)
P1 4	(Set pixel mode to transmit/store every 4th pixel)
N50	(Set # of scans to 50)
S	(Acquire spectra)
C1	(Close session storing read and write pointers in memory)
	Cycle power if desired
Z2	(Read one scan from slow memory)
Z2	Repeat 50 times
C1	(Store pointers so previously read out data will not be reread)

Application Tips

- During the software development phase of a project, the operating parameters of the SAD500 may become out-of-synch with the controlling program. It is good practice to cycle power on the SAD500 when errors occur.

- If you question the state of the SAD500, you can transmit a space (or another non-command) using a terminal emulator. If you receive a NAK, the SAD500 is awaiting a command; otherwise, it is still completing the previous command.

- For Windows 95 users, use HyperTerminal as a terminal emulator after selecting the following:
  1. Select **File | Properties**.
  2. Under **Connect using**, select **Direct to Com x**.
  3. Click **Configure** and match the following **Port Settings**:
     Bits per second (Baud rate): Set to desired rate
     Data bits: 8
     Parity: None
     Stop bits: 1
     Flow control: None
  4. Click the **Advanced** button and slide the **Receive Buffer** and **Transmit Buffer** arrows to the Low 1 value. Click **OK**.
  5. Click **OK** in **Port Settings** and in **Properties** dialog boxes.

- Determine the power-up baud rate by using a terminal emulator and observing the baud rate that displays the power-up message “Ocean Optics Serial A/D – x”.

- On some computers, the virus protection software and advanced power management must be disabled to insure timely and complete transfer of the data at 115.2Kbaud.

- When communicating at 115,200 baud, it is possible to overrun the SAD500’s one byte receive buffer. To prevent this from occurring, we recommend that a 1-millisecond delay be implemented between the transfer of each byte.

Technical Note 1: SAD500 Data Compression

Transmission of spectral data over the serial port is a relatively slow process. Even at 115,200 baud, the transmission of a complete 2048 point spectrum takes around 400 msec. The SAD500 implements a data compression routine that minimizes the amount of data that needs to be transferred over the RS-232 connection. Using the "G" command (Compressed Mode) and passing it a parameter of 1 enables the data compression. Every scan transmitted by the SAD500 will then be compressed. The compression algorithm is as follows:

1. The first pixel (a 16-bit unsigned integer) is always transmitted uncompressed.
2. The next byte is compared to 0x80.
   - If the byte is equal to 0x80, the next two bytes are taken as the pixel value (16-bit **unsigned** integer).
   - If the byte is not equal to 0x80, the value of this byte is taken as the difference in intensity from the previous pixel. This difference is interpreted as an 8-bit **signed** integer.
3. Repeat step 2 until all pixels have been read.

Using this data compression algorithm greatly increases the data transfer speed of the SAD500. The table below shows the data transfer speed, in milliseconds, for various light sources and baud rates. Keep in mind that these rates are for demonstration purposes only, and the speed of your computer may impact the data transfer rates.

	Comp	115 kb	% faster	57.6 kb	% faster	38.4 kb	% faster	19.2 kb	% faster	9.6 kb	% faster
dark	on	290	32.9%	426	45.2%	624	46.7%	1148	47.5%	2247	48.8%
	off	432		778		1170		2188		4391	
LS-1	on	290	32.9%	429	44.9%	624	46.6%	1141	49.6%	2192	50.1%
	off	432		779		1169		2266		4390	
HG-1	on	303	29.9%	465	40.2%	679	41.9%	1238	43.5%	2424	44.8%
	off	432		777		1169		2193		4391	

The following shows a section of a spectral line source spectrum and the results of the data compression algorithm.

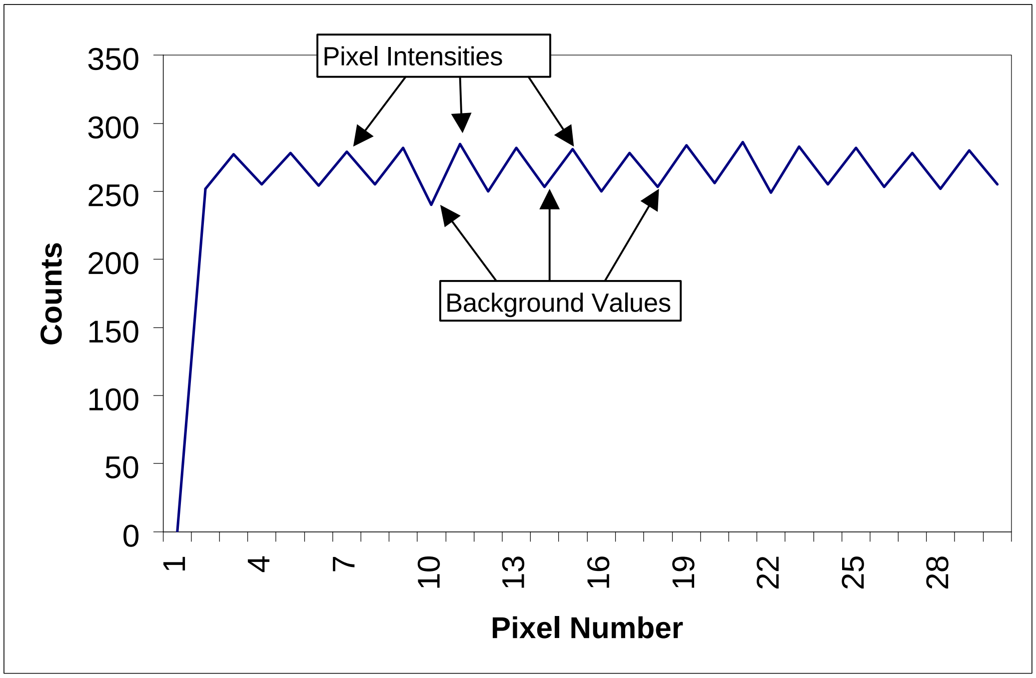
Pixel Value	Value Difference	Transmitted Bytes
185	0	0x80 0x00 0xB9
2151	1966	0x80 0x08 0x67
836	-1315	0x80 0x03 0x44
453	-383	0x80 0x01 0xC5
210	-243	0x80 0x00 0xD2
118	-92	0xA4
90	-28	0xE4
89	-1	0xFF
87	-2	0xFE
89	2	0x02
86	-3	0xFD
88	2	0x02
98	10	0x0A
121	23	0x17
383	262	0x80 0x01 0x7F
1162	779	0x80 0x04 0x8A
634	-528	0x80 0x02 0x7A
356	-278	0x80 0x01 0x64
211	-145	0x80 0x00 0xD3
132	-79	0xB1

88	-44	0xD4
83	-5	0xFB
86	3	0x03
82	-4	0xFC
91	9	0x09
92	1	0x01
81	-11	0xF5
80	-1	0xFF
84	4	0x04
84	0	0x00
85	1	0x01
83	-2	0xFE
80	-3	0xFD
80	0	0x00
88	8	0x08
94	6	0x06
90	-4	0xFC
103	13	0x0D
111	8	0x08
138	27	0x1B

In this example, spectral data for 40 pixels is transmitted using only 60 bytes. If the same data set were transmitted using uncompressed data, it would required 80 bytes.

Technical Note 2: Correlated Double Sampling

The S1024DW and S1024DWX can be configured to utilize a data sampling technique called correlated double sampling (CDS). In this mode, each data point consists of a sampled pixel value and a sampled background value. The resulting spectral intensity is the difference between the pixel intensity and the background intensity. The figure below shows the raw output of an S1024DW.



When using the S1024DW with the SAD500, the microcontroller in the SAD500 rearranges these values so that the pixel values are transmitted first, and then the corresponding dark values.

Technical Note 3: SAD500 Checksum Calculation

For all uncompressed pixel modes, the checksum is simply the unsigned 16-bit sum (ignoring overflows) of all transmitted spectral points. For example, if the following 10 pixels are transferred, the calculation of the checksum would be as follows:

Pixel Number	Data (decimal)	Data (hex)
0	15	0x000F
1	23	0x0017
2	46	0x002E
3	98	0x0062
4	231	0x00E7
5	509	0x01FD
6	1023	0x03FF
7	2432	0x0980
8	3245	0x0CAD
9	1984	0x07C0

Checksum value: 0x2586

When using a data compression mode, the checksum becomes a bit more complicated. A compressed pixel is treated as a 16-bit **unsigned** integer, with the most significant byte set to 0. Using the same data set used in Technical Note 1, the following shows a section of a spectral line source spectrum and the results of the data compression algorithm.

Data Value	Value Difference	Transmitted Bytes	Value added to Checksum
185	0	0x80 0x00 0xB9	0x0139
2151	1966	0x80 0x08 0x67	0x08E7
836	-1315	0x80 0x03 0x44	0x03C4
453	-383	0x80 0x01 0xC5	0x0245
210	-243	0x80 0x00 0xD2	0x0152
118	-92	0xA4	0x00A4
90	-28	0xE4	0x00E4
89	-1	0xFF	0x00FF
87	-2	0xFE	0x00FE
89	2	0x02	0x0002
86	-3	0xFD	0x00FD
88	2	0x02	0x0002
98	10	0x0A	0x000A
121	23	0x17	0x0017
383	262	0x80 0x01 0x7F	0x01FF
1162	779	0x80 0x04 0x8A	0x050A
634	-528	0x80 0x02 0x7A	0x02FA
356	-278	0x80 0x01 0x64	0x01E4
211	-145	0x80 0x00 0xD3	0x0153
132	-79	0xB1	0x00B1
88	-44	0xD4	0x00D4
83	-5	0xFB	0x00FB
86	3	0x03	0x0003
82	-4	0xFC	0x00FC
91	9	0x09	0x0009
92	1	0x01	0x0001
81	-11	0xF5	0x00F5
80	-1	0xFF	0x00FF
84	4	0x04	0x0004

84	0	0x00	0x0000
85	1	0x01	0x0001
83	-2	0xFE	0x00FE
80	-3	0xFD	0x00FD
80	0	0x00	0x0000
88	8	0x08	0x0008
94	6	0x06	0x0006
90	-4	0xFC	0x00FC
103	13	0x0D	0x000D
111	8	0x08	0x0008
138	27	0x1B	0x001B

The checksum value is simply the sum of all entries in the last column, and evaluates to 0x2C13.